2014-1492

United States Court of Appeals for the Federal Circuit

CARNEGIE MELLON UNIVERSITY,
Plaintiff-Appellee,

v.

MARVELL TECHNOLOGY GROUP, LTD.,
and MARVELL SEMICONDUCTOR, INC.,
Defendants-Appellants.

Appeal from the United States District Court for the Western District of Pennsylvania in No. 2:09-CV-00290-NBF, Judge Nora Barry Fischer

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CERTIFICATE OF INTEREST

Counsel for Defendants-Appellants certifies the following:

1. The full name of every party or amicus represented by me is:

Marvell Technology Group, Ltd. and Marvell Semiconductor, Inc.

2. The name of the real party in interest (if the party named in the caption is not the real party in interest) represented by me is:

N/A

3. All parent corporations and any publicly held companies that own 10 percent or more of the stock of the party or amicus curiae represented by me are:

Marvell Technology Group, Ltd. is a publicly traded company. No publicly held company owns 10 percent or more of Marvell Technology Group, Ltd.'s stock. Marvell Semiconductor, Inc. is a subsidiary of Marvell Technology, Inc. and Marvell Israel (M.I.S.L.) Ltd., and is an indirect subsidiary of Marvell Technology Group, Ltd.

4. The names of all law firms and the partners or associates that appeared for the party or amicus now represented by me in the trial court or are expected to appear in this court are:

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STATEMENT OF RELATED CASES

No appeal from this civil action has previously been before this Court or any other appellate court. There is no case pending in this Court or any other court that will directly affect or be directly affected by the Court's decision here. There are no other cases related to this dispute.

PRELIMINARY STATEMENT

No patent infringement judgment for more than a billion dollars has ever received this Court's imprimatur,[1] and the $1.535 billion judgment here should not be the first. That judgment, entered by the Western District of Pennsylvania (Fischer, J.) in favor of Plaintiff-Appellee Carnegie Mellon University ("CMU") and against Defendants-Appellants Marvell Technology Group, Ltd. ("MTGL") and Marvell Semiconductor, Inc. ("MSI") (collectively, "Marvell"), involves two method-patent claims relating to microchips used to improve the accuracy of data read from hard-disk drives. But CMU's patents were incapable of commercial implementation in a semiconductor chip. Thus, when CMU sent letters in 2003 to ten companies inquiring about interest in licensing its patents, not one nibbled. And in 2005, when CMU offered to license one of the two patents as part of a group of patents to Intel for a flat fee of $200,000, Intel declined. Yet upon finding that Marvell's commercially-successful chips infringed CMU's patent on a theoretical algorithm, the district court awarded a ***running royalty of fifty cents per chip*** on the more than 2 billion chips that Marvell sold ***worldwide*** over nearly a decade. In short, the largest extant judgment in patent history, resting on

[1] *See Centocor Ortho Biotech, Inc. v. Abbott Laboratories*, 636 F.3d 1341 (Fed. Cir. 2011) (vacating judgment of $1.7 billion); *Lucent Techs., Inc. v. Gateway, Inc.*, 543 F.3d 710 (Fed. Cir. 2008) (affirming judgment for defendant following jury verdict exceeding $1 billion); *Litton Sys., Inc. v. Honeywell Inc.*, 238 F.3d 1376 (Fed. Cir. 2001) (same).

hypothetical per-unit royalties on worldwide sales, was awarded for infringement of two patents that no one has ever paid a penny in per-unit royalties to license in the commercial marketplace.

How did this happen? The district court itself doubted that this could be a billion-dollar case. *See* A42659:2-3 (doubting that "there's going to be a billion dollar judgment myself"). The answer turns on a series of legal errors by the district court that require this Court's reversal:

To begin with, the CMU patents should have been found invalid as anticipated by the prior art. The two claims that went to trial both disclose precisely the same elements as the Worstell patent.[2]

The district court likewise erred in denying JMOL of noninfringement. Because CMU did not assert infringement under the doctrine of equivalents, every element of the asserted claims must read exactly onto an accused device. But they do not. Marvell's NLD chips use a pre-filter circuit, *outside* the Viterbi "trellis," to determine a *single* signal sample. CMU's claims, by contrast, require a branch-metric function to be performed on a *plurality* of signal samples, *inside* the trellis. Likewise, Marvell's MNP chips use a

[2] In pending reexamination proceedings, the PTO has initially rejected as invalid both claim 4 of CMU's '839 patent, Office Action in Ex Parte Reexamination, 90/013,125 (June 4, 2014), and claim 2 of the '180 patent, Office Action in Ex Parte Reexamination, 90/013,124 (July 31, 2014), over prior art not at issue in this appeal.

conventional Viterbi detector and a post-processor where the output of the Viterbi is compared to two alternative sequences to correct errors. By contrast, according to the inventor, CMU's invention addresses media noise "in a trellis and NOT in post-processor." Finally, CMU's claims are directed to the use of detectors, and Marvell's simulations are not detectors.

Even if the judgment of liability could stand, the jury's damages award of $1.17 billion cannot. The court improperly admitted expert testimony conjuring a hypothetical-license royalty of $.50 per chip on worldwide sales despite uncontroverted evidence that the only licenses CMU had ever granted were modest flat fees. Nor was there any legal basis for the award of some $900 million based on Marvell's sale of ***foreign chips***—chips that were manufactured, sold, and used abroad, without ever entering the United States. This extraterritorial application of U.S. patent law, if affirmed, would lead global companies to locate their research, development, and customer-relations activities outside the United States, harming not only U.S. companies and workers, but also the U.S. universities with whom they partner.

In any event, the $.50-per-chip rate is unsupported by any evidence that any similar patents command such a figure in the real world, and cannot be sustained by (i) an "excess profits" theory that uses Marvell's business-wide profit goal as its benchmark or an (ii) "operating profit premium" theory that rests on a tiny amount of unrepresentative sample chips, both conjured for this litigation by CMU's damages expert.

The award of $287 million in enhanced damages for willfulness should also be vacated, for Marvell had objectively reasonable invalidity and non-infringement defenses.

And once the district court found that CMU had "inexcusably" and "unreasonably" delayed for more than six years before bringing suit, to Marvell's prejudice, it should have excluded $620 million in pre-suit damages as barred by laches.

JURISDICTIONAL STATEMENT

The district court had jurisdiction over this patent case pursuant to 28 U.S.C. §§ 1331 & 1338. This Court has jurisdiction over Marvell's appeal of the district court's May 7, 2014 final judgment pursuant to 28 U.S.C. § 1295(a)(1). Marvell filed a timely notice of appeal on May 14, 2014. A40460-61.

STATEMENT OF THE ISSUES

1. Whether the judgment should be reversed on the ground that CMU's two patent claims are invalid as anticipated and/or obvious in light of the Worstell patent.

2. Whether the judgment should be reversed on the ground that claim 4 of CMU's '839 patent and claim 2 of CMU's '180 patent are not infringed by Marvell's MNP/EMNP or NLD chips or simulations.

3. Whether the award of $1.17 billion in hypothetical-license reasonable-royalty damages should be reversed because it is erroneously based upon (a) a per-chip running royalty rather than a flat-fee license; (b) a royalty base consisting overwhelmingly of chips manufactured, sold, and used only outside of the United States; and/or (c) a royalty rate of $.50 per chip that exceeds any comparable real-world rate and is not properly apportioned to the technology covered by CMU's patent claims.

4. Whether the award of $287 million in enhanced damages should be vacated for lack of willfulness because Marvell had objectively reasonable invalidity and noninfringement defenses.

5. Whether the $620 million in damages accrued prior to suit should be vacated based on laches given that CMU inexcusably and unreasonably delayed nearly six years in bringing its claim, to Marvell's prejudice.

STATEMENT OF THE CASE

This is an appeal from a final judgment to CMU of ***$1.535 billion*** for supposed infringement of two claims of CMU patents directed to improving the accuracy of data read from a hard disk drive ("HDD"): U.S. Patent Nos. 6,201,839 (the "'839 patent"), and 6,438,180 (the "'180 patent"). A1-3. The judgment comprises $1.17 billion in reasonable-royalty damages awarded by the jury, plus supplemental damages of $79.5 million and a willfulness enhancement of $287.2 million (A2); in addition, the court ordered Marvell to pay CMU an ongoing royalty calculated at $.50 per chip. (A3).

A. The Parties

MSI is a leading designer of semiconductor microchips headquartered in Santa Clara, California. A161; A43650-51; A43742-43. It designs a wide range of chips that are manufactured by third-party manufacturers in Asia and then incorporated by downstream customers into their own larger products (*e.g.*, HDDs installed in laptop computers) sold throughout the world. A166-67. MTGL, MSI's indirect parent, is a Bermuda corporation. A161.

CMU is a research university located in Pittsburgh, Pennsylvania. It neither manufactures nor sells semiconductor chips or HDDs. A42; A41313:15-17.[3]

B. The Technology And The Prior Art

This case involves sequence detectors designed to account for errors when bits of data (1s and 0s) are read from an HDD.[4] A450. Data is stored on an HDD in long sequences of tiny magnetic "domains," each with a north and a south

[3] CMU inventors Aleksandar Kavcic and José Moura stand to obtain 50% of any award to CMU in this case. A42521:2-3.

[4] A more detailed background on sequence detection technology can be found at Marvell's April 7, 2010 Technology Tutorial (A2557-63).

pole. A41227. The domains create magnetic fields, which a "read head" measures and sends to a read channel to translate into a series of 1s and 0s. A150. At increased data densities, "media noise" can cause errors in the measurements, causing signals that should be read as 0s to be interpreted instead as 1s. A41229-30. Media noise takes two principal forms: "signal-dependent noise," which refers to noise attributable to a specific sequence of bits, and "correlated noise," which refers to the tendency of noise associated with adjacent bits to vary together. A45462-63. Unless addressed, media noise impairs the accuracy with which data can be read from an HDD. A41229-30. And because the problem becomes increasingly acute as data is stored more densely, accounting for media noise facilitates higher-density data storage. A41352-53.

Conventional detectors named for Qualcomm co-founder Andrew Viterbi ("Viterbi detectors") identify the most likely sequence of data through an iterative process involving the calculation of "branch metric values" for each branch in a "trellis"[5] representing every possible sequence of bits. A442; A45463-64.[6] One

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[5] A "branch" means "a potential transition between two states (nodes) immediately adjacent in time ***in a 'trellis.'***" A45463 (emphasis added). A "trellis" is "a graphical representation of the progression of states of a communications channel in time, wherein states are depicted as nodes and potential transitions between states are depicted as lines or arrows. An example of a trellis is illustrated in Figure 4 of the 839 patent." A45464.

such Viterbi detector uses a "Euclidean" branch-metric function (a simple squaring of the difference between the measured signal (r_i) and the expected signal (m_i) at each instant) to determine branch-metric values (M_i): $M_i = (r_i - m_i)^2$. A452 at 6:10-14. This Euclidean branch-metric function does not account for media noise. A41359.

In the last two decades, companies and researchers have developed sequence detectors that do account for media noise by using modified versions of the Viterbi branch-metric function. For example, in 1992, teams led by Dr. Weining Zeng (now a Marvell engineer) and Dr. Inkyu Lee independently developed modified Viterbi detectors that account for signal-dependent noise by using a noise statistic called a variance (σ^2) in their branch-metric functions. A450 at 1:38-56; A452 at 6:15-35; A53634-40. In early 1995, a Seagate engineer named Glen Worstell developed a modified Viterbi detector that accounted for *both* signal-dependent noise *and* correlated noise. A7082-83. Worstell's invention accounted for *signal-dependent* noise by using a statistic called transition noise standard deviation (σ), which is the square root of the variance (σ^2) that Zeng and Lee had used. A53697 at 9:45-10:67. Worstell also accounted for *correlated* noise by applying his branch metrics not only to the signal sample being measured at a given moment, but also

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[6] At a basic level, branch metrics represent a measure of the difference between actual signal reading (r_i) and ideal reading (m_i) associated with a branch of the trellis. A452 at 6:10-14.

to *previous* signal samples. A53693 at 2:1-7. The Patent & Trademark Office ("PTO") granted Worstell a patent on his invention (U.S. Patent No. 6,282,251) in August 2001. A53686.

C. CMU's '839 And '180 Patents

In late 1995, a CMU graduate student, Aleksandar Kavcic, working on his thesis with his professor Dr. José Moura, developed an "optimal," theoretical sequence-detection algorithm to account for both signal-dependent and correlated noise using complex statistics called covariance matrices. A41583. As Kavcic acknowledged in his thesis prospectus, his optimal approach was "too complicated for implementation in a detector" because it involves "computing correlation matrices and vectors from sample data and storing them in memory, which in a real-time application needs to be done adaptively on the fly." A53673; *see* A53677 ("The optimal receiver … implementation is difficult since the metric computations are too intense.").

In March 1997, Kavcic and Moura submitted an invention disclosure to CMU's Office of Technology Transfer, titling their invention "Correlation-Sensitive Adaptive Sequence Detector." A46086-96. The first sentence of the disclosure acknowledged that Viterbi-like detectors had *already* become the industry standard in magnetic recording. A46088. Kavcic and Moura claimed, however, that "[t]he current detectors ignore correlation between noise samples" (*id.*; A46092) while their invention uses "correlation matrices." A46089-90. Kavcic and Moura acknowledged that their theoretical work was "embryonic" and needed "substantial work to bring to market." A46093.

Shortly after Kavcic and Moura submitted their invention disclosure, CMU forwarded it to Worstell, the Seagate engineer. A46099. In an email dated April 15, 1997, Worstell informed CMU of his earlier work in the same area**:**

> A couple of years ago I did some work on a ***Viterbi detector modification to account for noise correlation***. This invention is related but goes beyond my work and is probably more interesting. I also know of work at UCSD and IBM which is related, but again as far as I know [Kavcic's] work is different enough to warrant investigation. An important issue is the circuit complexity required. I'll try to look at that, too.

Id. (emphasis added). Worstell thus acknowledged that CMU's optimal detector using correlation matrices went beyond his work but noted that his own work had been correlation-sensitive. *Id*.

CMU filed a provisional patent application on May 9, 1997. A439. Notwithstanding Worstell's e-mail, CMU's patent application did not disclose Worstell's work on a correlation-sensitive detector. *Id.* The application acknowledged the prior-art Zeng and Lee Viterbi detectors that account for *signal-dependent noise* by modifying the Euclidean branch metrics, but claimed that "[t]hese references ***ignore the correlation*** between noise samples." A450 at 1:38-56 (emphasis added). On April 3, 1998, CMU filed a non-provisional application, claiming priority to the provisional application. A439. On March 1, 1999, CMU filed a continuation-in-part application claiming priority to the same provisional application. A460. Neither of these applications remedied CMU's prior failure to disclose Worstell's prior art. A439; A460. The PTO granted the non-provisional applications on March 13, 2001 (the '839 patent), and August 20, 2002 (the '180 patent). *Id.*

Almost a decade later, on March 6, 2009, CMU sued Marvell, accusing it of infringing both the '839 patent and the '180 patent. A483-88. As narrowed for trial, only two claims remained at issue. Claim 4 of the '839 patent asserts:

> A method of determining branch metric values for branches of a trellis for a Viterbi-like detector, comprising:
>
> ***selecting*** a branch metric function for each of the branches at a certain time index from a set of signal-dependent branch metric functions; and
>
> ***applying*** each of said selected functions to a plurality of signal samples to determine the metric value corresponding to the branch for which the applied branch metric function was selected, wherein each sample corresponds to a different sampling time instant.

A456 (emphasis added).

Claim 2 of the '180 patent (dependent on claim 1) asserts:

> 1. A method of determining branch metric values in a detector, comprising:
>
> receiving a plurality of time variant signal samples, the signal samples having one of signal-dependent noise, correlated noise, and both signal dependent and correlated noise associated therewith;

> ***selecting*** a branch metric function at a certain time index; and
>
> ***applying*** the selected function to the signal samples to determine the metric values.
>
> 2. The method of claim 1, wherein the branch metric function is selected from a set of signal-dependent branch metric functions.

A481 (emphasis added). As in Worstell's work, each claim accounts for *correlated* noise through a modified Viterbi detector using a branch metric based on a *plurality* of signal samples, and each accounts for *signal-dependent* noise by using a set of signal-dependent branch-metric functions.

In May 2001, just three months after the '839 patent issued and nearly eight years before CMU filed suit, CMU realized that, while its "patent [was] optimal," others in the industry were "working on suboptimal" solutions to either "get around" the patent or provide a "simpler solution," because the "optimal implementation is complex." A54316; A80-81. Moura testified at trial that, although he did not have "concrete proof," he "suspect[ed]" that Marvell was infringing CMU's patents as early as 2001. A41271:12-272:4.

D. Marvell's Media-Noise Post Processor And '585 Patent

Marvell developed a post-processor architecture in 1998, and began developing a media-noise post processor ("MNP") in 2001. A43905. The MNP uses a conventional Viterbi detector followed by post-processor circuitry to identify and correct likely errors in the sequence emerging from the Viterbi detector. A48203. Marvell chose this approach largely because (as Kavcic and

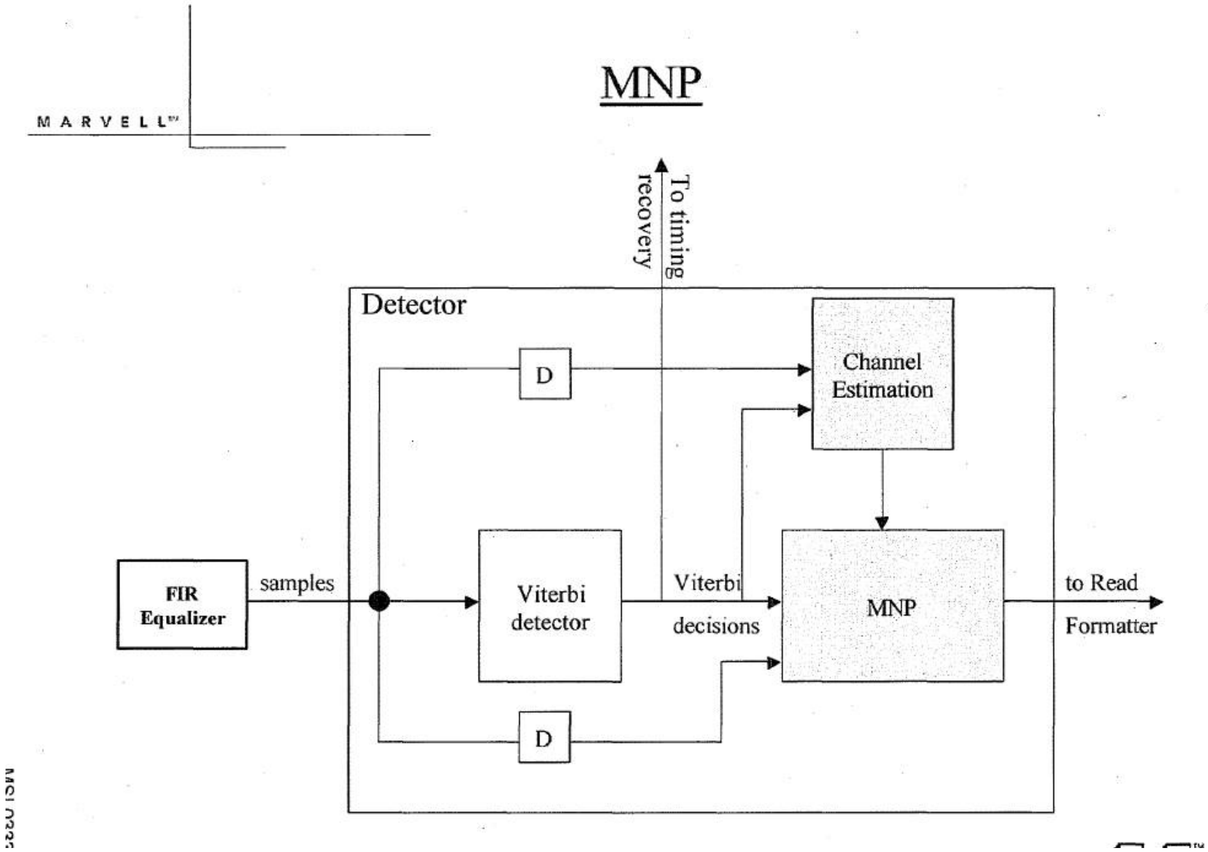
Moura had recognized) modifying a Viterbi trellis to achieve a theoretically optimal detector would require too much computational complexity to implement in a real-world chip. A42080-82; A43905-06; A43920-21; A44716-20. Indeed, Marvell engineer Greg Burd (using a software simulation that he had developed in March 2001 and named "KavcicViterbi") determined in December 2001 that Marvell "can not implement" the Kavcic detector, because it is "too large." A46140; *see* A44716-17. In view of this conclusion, Marvell set about developing a different kind of media-noise ***post processor*** that would be suboptimal but operationally practicable, naming its simulation of the detector "KavcicPP" (Kavcic post processor) in homage to Kavcic and his optimal detector. A44716-20.

On January 3, 2002, Marvell filed a provisional patent application for its post processor (A54259-67) in which it disclosed Kavcic's work as prior art, explaining that, "[e]ven though Kavcic's detector provides significant gains over conventional Viterbi detector in the presence of media noise, it is not very appealing due to implementation complexity" (A54264; *see* A43945:11-15; A53793). The provisional application included the results of simulations comparing the optimal Kavcic approach with the KavcicPP. A54267. Marvell filed a non-provisional application in July 2002 (A53793), and its patent (No. 6,931,585, the "'585 patent") issued in August 2005 (A53793-804). Both

CMU's '839 and '180 patents are identified on the face of Marvell's '585 patent as "References Cited." A53793.

Marvell thereafter invested substantial resources into developing, producing, and marketing its chips. A234; A31979-80; A43752-53; A46232. Marvell's chips are manufactured in Asia and sold to HDD manufacturers, which incorporate the chips into laptops and other devices sold around the world. A166-67; A43449-50. Marvell shipped its first MNP chips in late 2002. A42252-53; A42262:5-17; A42268:16-25. Marvell has continually improved its chips, introducing "enhanced" MNP chips ("EMNP") and Non-Linear Detector ("NLD") chips between 2003 and 2009. A97; A36191-92. CMU's suit accuses both Marvell's MNP/EMNP chips and its NLD chips, as well as detector simulations that Marvell used during its design process. A182.

Marvell's MNP/EMNP Chips—Marvell's MNP/EMNP chips apply a conventional Viterbi branch-metric function to a *single* signal sample, rather than to a plurality of samples. A48194. A post processor then compares the sequence output by the Viterbi detector to two alternative error sequences to correct errors caused by media noise. A41977:14-20. The parties prepared a stipulation on Marvell's chip technology called the "Chip Stipulation" and agreed that the details set forth therein are true and accurate depictions of the circuits within Marvell's products. A168. The stipulation includes the following MNP design document, which shows that Marvell's MNP uses a simple Viterbi detector whose output sequence is then processed by a media-noise post processor (MNP):



A48203.

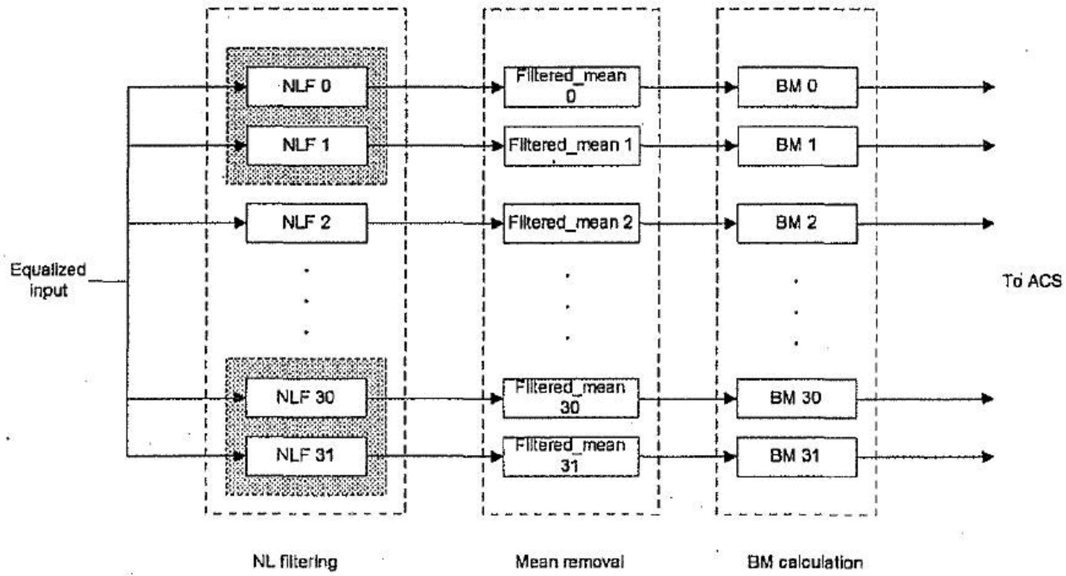
Marvell's design document also shows that the Viterbi detector uses a conventional branch-metric function of the form $BM_i = (r_i - m_i)$.[2] A48194. The design document next explains that the MNP computes, through its "non-linear error filter," the difference between two metrics—the Viterbi path and an error path:

- Just as linear counterpart, Non-Linear Error Filter computes $\sum_{\substack{\text{all branches effected} \\ \text{by an error event}}} [\text{BM(viterbi+ error path)} - \text{BM(viterbi path)}]$

A48207. Marvell's provisional application shows that this equals the difference between two path metrics. A54266.

Determining such a difference between two ***path metrics*** is not the same as determining the values for the potential transitions (branches) in a trellis. As Marvell's expert Dr. Richard Blahut testified at trial, Kavcic himself admitted that "the difference between two path metrics" is not a branch metric. A44522-24. Kavcic explained as much in an October 2001 email exchange with Seagate: asked whether CMU's "claim specif[ies] that the data dependent (DD) part happen[s] in the trellis or in a post processor" (A53701), Kavcic explained that CMU's patent claims "address the 'data dependent' nature of the algorithm … ***in the trellis and NOT in the post processor***," and admitted that "the [patent] examiner had us write extra material to ***make sure that we do not use a post processor***, which is a patent by Kelly Fitzpatrick" (A53700-04 (emphases added)).

Marvell's NLD Chips—Marvell's NLD chips use a non-linear filter ("NLF") to generate a *single* signal sample, which serves as an input into a simple Euclidean squaring metric. A41994-96; A48240; A48271; A48249. The following block diagram from the Chip Stipulation shows that the NLFs ***precede*** the branch metric calculation (see labels at bottom of diagram):



A48240. Thus, as CMU's expert admitted at trial, in Marvell's NLD chips the result of the "application step" is a "single signal sample" (f_y), not a branch-metric value. A41994-96. This is consistent with Marvell's design specifications in the Chip Stipulation, which identify Marvell's branch-metric function as $BM = (f_y - f_m)^2$ (A48271). As the diagram below shows, Marvell's NLD circuitry first pre-processes signals using an FIR filter (shown below on the left as receiving a signal, y, into a series of delay blocks, tap weights and a summation). The output of the FIR filter is a single signal sample f_y (highlighted here). A simple Euclidean squaring metric is then applied to the single sample, f_y, minus the ideal filtered mean f_m:

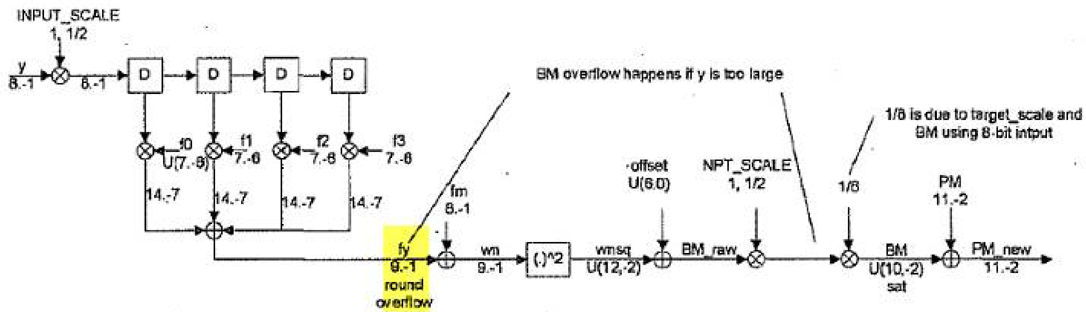


Figure 7. BM and PM calculation

A48249.

Marvell's Simulations—Marvell uses detector simulations during the design process. A190-91; A43666-67. Simulations are computer programs that simulate a detector (for purposes of research, study, or benchmarking) by processing synthetic sequences of symbols, or data files containing copies of wave forms recorded from HDDs. *Id.*; A43943; A43990; A41756:20-22; A41745:16-746:7. Marvell's simulations of detectors are not actually detectors. *Id.*

E. CMU's Unsuccessful Licensing Efforts

CMU never licensed the patents-in-suit on a per-unit royalty basis. CMU allowed any company to become an Associate of CMU's Data Storage Systems Center ("DSSC"), and thereby to obtain a royalty-free license to any CMU patent conceived during the term of its membership in exchange for a mere ***$250,000 annual fee***. A42361:13-18; A43429:7-23. In May 2001, CMU contacted two such Associates, Seagate and IBM, encouraging them to exercise their royalty-free licenses and to adopt CMU's methods in their HDDs. A53683-84; A53685. But neither Seagate nor IBM ever made a chip using the CMU patents. A43588:3-13; A53744-46.

In August 2003, CMU wrote to HDD manufacturers and chip suppliers soliciting them to license CMU's patents. A42461-67. Although CMU sent at least fourteen letters, not a single recipient expressed interest. A46980; A46981; A53751; A53752; A53753; A53754; A53756; A53757; A53758; A53759; A53761; A53762; A53763. Most of the companies (including Marvell) did not respond (A160), and CMU never followed up (A42470-72).[7]

In 2005, CMU offered Intel the chance to license *any* patent in a specified group of patents (including the '180 patent) for ***a flat $200,000 per-patent fee***. A53765-A53781. CMU's internal communications described this amount as "reasonable." A53783; *see* A42506-07. Kavcic and Moura requested that the '839 patent also be added to the group, at the same $200,000 rate. A53785-91. Intel never licensed the patents. A160-61; A42418:20-22.

In January 2006, CMU prepared a spreadsheet labeled "Highly Speculative Income Streams" identifying potential future royalty sources "over and above [CMU's] conservative" estimates. A53806. This "speculative" document

[7] Marvell's customer Fujitsu inquired about Marvell's opinion on the CMU patents, but by the time CMU filed suit years later, there was no record of any correspondence or follow-up by Fujitsu on the issue. A25.

projected that CMU might be able to obtain, at most, ***a $2 million annual license fee*** from Marvell for the patents-in-suit, starting in 2007. *Id*.

F. The Proceedings Below

CMU filed its complaint (A483-88) on March 6, 2009, nearly eight years after Moura and CMU "suspected" Marvell's infringement. A84-85; A41268-73.[8]

1. The Summary Judgment Orders

Marvell moved for summary judgment of invalidity on the ground that CMU's patents were anticipated by the Worstell patent. The district court denied the motion (A7064-88), ruling that Worstell did not disclose the "selecting" step of CMU's claims because it did not disclose a "set" of functions (A7078-79). To reach that conclusion, the district court construed the term "function" to mean "a mathematical relation that uniquely associates members of a first set with members of a second set," and then reasoned that "adding another variable into a function … does not operate to convert that single function into multiple functions." A7079. Because the district court found that the Worstell patent used variables in its equations, the court concluded that it did not disclose a *set* of branch metric functions from which one function is selected. *Id.* Because it lacked a set of functions to select from, the court concluded Worstell did not anticipate. *Id.*

[8] CMU asserted 12 claims against Marvell (A38562), the court granted summary judgment of noninfringement as to 5 claims (A17384-96), and CMU dropped 5 more claims on the eve of trial (*compare* A19326 *with* A30525).

In the course of its decision on anticipation, the court observed that its "reasoning would seem to render the CMU claims invalid under 35 U.S.C. § 112" for lack of written description, because under the court's definition, the equation on which CMU's claims rest (the '839 patent's equation 13), which also uses variables, would likely "also be[] considered a *single* function" and not "a set of functions from which one function may be selected." A7079-80. But because Marvell's initial motion had been based on anticipation alone, the court did not decide the written-description issue. A7080.

Marvell then moved for summary judgment of invalidity for lack of written description. The court denied this motion too (A8108-27), reasoning that while CMU's equation did contain variables, they were *parameter* variables representing multiple functions rather than *input* variables as in Worstell (A8119-20; A8122; A8126).[9]

2. The Trial

The district court held an eighteen-day jury trial in November and December 2012. A399-412. With respect to validity, the undisputed trial evidence was that the Worstell patent discloses a modified Viterbi detector that accounts for both correlated and signal-dependent noise; its very *title* is a "Modified Viterbi Detector

[9] Two other summary-judgment decisions, reported at 888 F. Supp. 2d 637 (W.D. Pa. 2012); 890 F. Supp. 2d 602 (W.D. Pa. 2012), and the district court's ruling on Marvell's motion in limine, reported at 906 F. Supp. 2d 399 (W.D. Pa. 2012), are not at issue on appeal.

Which Accounts For *Correlated* Noise" (A53686 (emphasis added)), and CMU's expert *admitted* that Worstell's patent also accounts for *signal-dependent* noise in the form of "transition" noise (A44968).

As to whether Marvell's MNP chips infringe, it was undisputed that CMU's claims address media noise "in a trellis and NOT in [a] post processor," as Kavcic confirmed in contemporaneous correspondence with Seagate (A53700-04). In contrast, the MNP chips use a "linear [conventional] Viterbi" component to determine the best path through the Viterbi trellis and *only then* invoke post-processor circuitry "to see if either [of two] alternate paths is better than the best path," as CMU's expert admitted. A41977:14-20. As to whether Marvell's NLD chips infringe, while CMU's claims require that the branch-metric value be determined by applying a branch-metric function to a *plurality* of signal samples, CMU's expert admitted that Marvell's pre-filter puts out a "*single* signal sample" (f_y) as the result of the application step in Marvell's NLD chips. A41995-96. With respect to Marvell's simulations, it was undisputed that CMU's patents cover only detectors (A41939:10-13), that simulations are computer programs that simulate detectors (A41756:14-22), and that, as CMU's expert put it, the "[d]etector is in the chip" (A41745:16-746:7).

As to willfulness, the evidence showed that Marvell was aware of CMU's patents, disclosed them as prior art in its own patent applications (A53793), and attempted to work around them by developing a "suboptimal" post processor that would eliminate the "implementation complexity" inherent in Kavcic's approach (A54264). But the district court allowed the jury to infer that Marvell had not sought an opinion of counsel on this issue (A25-26; A285-89), despite Marvell's assertion of attorney-client privilege over conversations between Marvell engineer Zining Wu and in-house attorney Eric Janofsky concerning CMU's patents (A43944:9-22; A281).

CMU's damages case rested entirely on the testimony of its damages expert, Catherine Lawton (admitted over Marvell's repeated objections, *see, e.g.*, A17367-81; A24637-44; A31957-62; A33398-425; A33893-94; 286 F.R.D. 266 (W.D. Pa. 2012)). Lawton is a career litigation consultant with no background in economics, accounting, microchips, or intellectual-property licensing. A42811-12; A33404; A43414-16; A42786-88; A42793-94; A43476:7-21.

It was undisputed that the sole real-world evidence concerning CMU's efforts to license the asserted patents involved flat fees rather than per-unit royalties: CMU issued licenses to the patents to IBM, Seagate, and 3M based on their payment of $250,000 flat fees, along with all CMU patents conceived during the term of their memberships. A42440-41; A53614-23, A53641-47, A53648-56. CMU offered to license the '180 patent to Intel for a $200,000 per-patent flat fee. A53765-81; A42498:10-17, A42502:2-9. And CMU made an internal estimate that it could license the '839 and '180 patents to Marvell for at most a $2,000,000 annual fee. A53806; A53828-29. Lawton testified nonetheless that the parties would have entered into a hypothetical per-unit license (A43412-13; A43439-40), reasoning that CMU had previously entered into one such license and Marvell had entered into three (A43353-54). None of those licenses concerned the patents-in-suit, and it was undisputed that they are not comparable licenses. A44237.

Lawton used Marvell's *worldwide* sales as the base for calculating hypothetical-license royalties (A5; A31961-62, A43439-40), and used a $.50-per-chip royalty rate (A43412:5-9). She derived that rate as intermediate between the numbers yielded by each of two supposed economic theories: Under a supposed "excess profits" theory, she hypothesized that, if Marvell aimed at a minimum profit margin of 50% (A43312-13; A43500), then Marvell's earnings of $.42 in "excess profits" per chip represented a premium from infringement (A43312:12-18; A43326-28). Under a supposed "operating profit premium" theory, she hypothesized that Marvell had earned an "operating profit premium" of up to $.72 on those chips that contained MNP as a "key" or "principal" feature. A43328-32; A43335-40; A32800. She based that analysis on a sample set of 9,855 chips, amounting to 0.0004% of Marvell's total chips at issue (A43487-88), that Marvell had offered to Maxtor, its smallest customer (A43484-85). Lawton admitted that no other customer had paid a comparable premium. A43486-87. The $.50 per-chip rate represented 23% of Marvell's average per-chip profit and 11% of its per-chip price (A43325-26).

On December 26, 2012, the jury returned a verdict finding CMU's patents both valid and infringed. A45544-47. The jury also found that the infringement was willful. A45547-48. The jury awarded damages of $1,169,140,271.00: fifty cents for each of the 2.34 billion chips Marvell had sold around the world between March 6, 2003 and July 28, 2012. A45547; A43412-13; A5-6.

3. The Post-Trial Orders

In an Order entered September 23, 2013, the district court denied Marvell's motions for JMOL or new trial on invalidity, non-infringement or damages. A149-274; 986 F. Supp. 2d 574 (W.D. Pa. 2013). With respect to invalidity, the district court ruled that CMU's expert's "conclusions were left to the jury to accept or reject as it was for them to determine credibility and the weight given to such evidence." A212. With respect to infringement, the court concluded that the "jury was free to accept either expert's opinions or reject them, as the 'credibility of the parties' competing experts is an issue for the jury to resolve, not the Court.'" A194 (citation omitted).

With respect to damages, the court concluded that Lawton's testimony was sufficient to support the jury's determination to award a royalty based on per-chip fees rather than a flat-fee license, reasoning that "there is *no* established royalty for the patents-in-suit in this case." A258. With respect to the royalty base, the district court upheld the inclusion of Marvell's worldwide sales, regardless of whether the chips were manufactured, sold, or used abroad. A255-56. And the district court upheld Lawton's use of a $.50-per-chip royalty rate (A263-64), despite Marvell's challenges to Lawton's qualifications, methodology, and data and even though that rate was out of all proportion to any real-world chip sales (A264-66).

The district court also upheld the jury's finding that Marvell's infringement was willful (A214-32), deferring to the jury's willfulness finding (A221; A227) despite its earlier acknowledgement that Marvell's invalidity defense was a "close call" on a summary judgment motion that would have disposed of both claims (A226-27). The district court also denied Marvell's post-trial motion to preclude $620 million in pre-suit damage on grounds of laches (A76-148), despite its holding that "CMU ***unreasonably and inexcusably delayed*** filing this lawsuit for a period of five years and eleven months, and that Marvell sustained evidentiary prejudice as a result" (A143-44 (emphasis added)), concluding that Marvell's willfulness tilted the equities in favor of CMU (A145).

Based on the award of a $.50-per-chip running royalty on each infringing chip, the district court awarded CMU $79.55 million in supplemental damages, accounting for chips sold between the close of the damages period considered by the jury (July 29, 2013) and the date the court entered judgment on the jury's verdict (January 14, 2014). A74. Based on that same finding, the court ordered Marvell to pay an ongoing $.50-per-chip royalty on its worldwide post-judgment sales. *Id.* The court denied CMU's motion for a permanent injunction. *Id.*

Based on the jury's finding that Marvell had willfully infringed, the district court enhanced the damages award (including the supplemental damages) by a factor of 23%—yielding a penalty of $287,198,828.60. A74.

The district court entered its Final Judgment on May 7, 2014, awarding a total of $1.535 billion in damages, plus the ongoing $.50-per-chip royalty for the life of CMU's patents. A1-3.

SUMMARY OF ARGUMENT

This is a case that should never have gone to trial, much less produced a record-breaking judgment.

First, the modified Viterbi detector claimed by CMU sets forth precisely the same elements as the Worstell patent, rendering it invalid as anticipated by prior art. The specific steps involving covariance matrices that might have distinguished Worstell were dismissed from the case at summary judgment because they clearly were not infringed; what was left was just as clearly anticipated by Worstell. The district court erred in denying summary judgment by creating an artificial distinction between inputs and parameters to distinguish Worstell from the patent claims, and then by denying JMOL without identifying a single element that distinguished CMU's claims from Worstell.

Second, the accused chips and simulations do not infringe because infringement here requires that every element of the claims must read exactly onto an accused device. In the words of Kavcic himself, there were key differences between what CMU theorized (but could never realize in silicon in the real world) and what Marvell incorporated into its chips. The NLD chips use a pre-filter circuit to determine a *single* signal sample f_y which is then used as an input to a branch- metric computation: BM = $(f_y - f_m)^2$. CMU's claims require that a branch-metric function be applied to a *plurality* of signal samples to determine branch-metric values for branches in a trellis. The MNP chips use a conventional Viterbi detector followed by a post processor, which compares the output of the Viterbi to two alternative error sequences. But as Kavcic explained, his invention addresses media noise "in a trellis and NOT in post-processor." And the simulation is just that: a simulation, not a detector. The district court denied JMOL without even addressing the undisputed differences between the claims and the accused products.

Third, the judgment as to damages fails on multiple grounds. CMU's damages expert should not have been permitted to testify in the first instance, for she lacked relevant expertise and used unreliable methodologies to select the wrong measure, the wrong base, and the wrong rate. Where, as here, all the real-world evidence supports a flat-fee license, which is all CMU ever offered, received, or contemplated for these patents, a court is not free to impose a per-unit royalty instead. The district court compounded that error by adopting what it termed CMU's "novel" theory that the royalty base should include chips that were made, sold, and used abroad, even though doing so amounts to extraterritorial application of U.S. patent law—exposing Marvell and its end users to double recovery in every country where these chips are used and encouraging global companies to do their research and development anywhere but here. And to make a perfect storm, the court's $.50-per-chip rate is based on made-up theories and is contrary to all real-world evidence: an "excess profits" theory that actually showed that Marvell's supposed "excess profits" from infringement were *higher* on chips that didn't have MNP; and an "operating profit premium" theory based on a quote for a tiny batch of high-priced sample chips and then applied to the billions of chips accused, virtually every one of which was sold to larger customers at much lower production prices.

Fourth, enhancing the damages by $287 million in a case where Marvell had reasonable invalidity and noninfringement defenses (and the district court even acknowledged that Marvell's invalidity defense was a "close call") violates this Court's precedent that enhancement requires both objective and subjective willfulness.

And *fifth*, pre-suit damages in the amount of $620 million should have been barred by laches, as the district court agreed but for its view that Marvell's conduct blocked the application of laches. But that was error, for Marvell was entirely open in its conduct, for example citing the CMU patents as prior art, and thus committed no inequity linked to CMU's delay.

STANDARDS OF REVIEW

Under applicable Third Circuit law, the denial of a motion for JMOL is reviewed *de novo*, "viewing the evidence in the light most favorable to the nonmovant." *Seachange Int'l, Inc. v. C-COR, Inc.*, 413 F.3d 1361, 1367-68 (Fed. Cir. 2005) (quoting *Rinehimer v. Cemcolift, Inc.*, 292 F.3d 375, 383 (3d Cir. 2002)). The district court's claim construction is a question of law reviewed *de novo*. *Id.* at 1367.

An award of enhanced damages for willful infringement is reviewed for abuse of discretion. *Powell v. Home Depot U.S.A., Inc.*, 663 F.3d 1221, 1228-29 (Fed. Cir. 2011). "Subjective" willfulness is a question of fact, but "objective" willfulness is an issue of law reviewed *de novo*. *Bard Peripheral Vascular, Inc. v. W.L. Gore & Assocs., Inc.*, 682 F.3d 1003, 1006 (Fed. Cir. 2012); *see In re Seagate Tech., LLC*, 497 F.3d 1360, 1371 (Fed. Cir. 2007) (*en banc*).

The court's admission of expert testimony is reviewed for abuse of discretion. *Pineda v. Ford Motor Co.*, 520 F.3d 237, 243 (3d Cir. 2008).

Instructional error is reviewed *de novo*, and where a "district court's instruction on damages was erroneous … a new trial on damages is required." *Tigg Corp. v. Dow Corning Corp.*, 962 F.2d 1119, 1131 (3d Cir. 1992).

The district court's laches determination is reviewed for abuse of discretion, and should be overturned if it rests on a "clearly erroneous factual underpinnings," "an unreasonable judgment in weighing relevant factors," or "an erroneous interpretation of the law." *Serdarevic v. Advanced Med. Optics, Inc.*, 532 F.3d 1352, 1358 (Fed. Cir. 2008).

The district court's denial of a motion for new trial because the verdict is against the weight of the evidence is reviewed for abuse of discretion. *Seachange*, 413 F.3d at 1368. In the Third Circuit, a court "exercises its own judgment in assessing" the weight of the evidence when considering a motion for a new trial. *Marra v. Phila. Hous. Auth.*, 497 F.3d 286, 309 n.18 (3d Cir. 2007).

ARGUMENT

I. THE DISTRICT COURT ERRED IN DENYING JMOL THAT CLAIM 4 OF THE '839 PATENT AND CLAIM 2 OF THE '180 PATENT ARE ANTICIPATED BY THE WORSTELL PATENT

In denying Marvell's motion for JMOL on invalidity (A210-14), the court did not identify a single element of the CMU claims not anticipated by the Worstell patent, saying only that the jury was free to credit CMU's expert over Marvell's (A212). Expert opinion is not a substitute for an assessment of the

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actual evidence. In assessing invalidity, the jury is not "free to discard probative admissions and undisputed facts," *Newell Cos. v. Kenney Mfg. Co.*, 864 F.2d 757, 767 (Fed. Cir. 1988), which here establish the invalidity of the asserted claims.

CMU's claims address correlated and signal-dependent noise by determining branch-metric values for branches of a trellis in a detector (or Viterbi-like detector) by using a two-step process. A456; A481. Specifically, claim 4 of the '839 patent is directed to a "method of determining branch metric values for branches of a trellis for a Viterbi-like detector" comprising: (1) "*selecting* a branch metric function for each of the branches at a certain time index from a set of signal dependent branch metric functions"; and (2) "*applying* each of said selected functions to a plurality of signal samples to determine the metric value corresponding to the branch." A456. Claim 2 of the '180 patent is similarly directed to a "method of determining branch metric values in a detector" comprising (1) "*selecting* a branch metric function at a certain time index" from a set of signal-dependent branch metric functions; and (2) "*applying* the selected function to [a plurality of time variant signal samples] to determine the metric values." A481. In both claims, the claimed "selecting" step requires the selection of a mathematical function for determining branch-metric values in a trellis (defined as a progression of "potential transitions") from a set of multiple signal-dependent mathematical functions, and the "applying" step requires the application of the selected functions to a *plurality* of signal samples to determine branch-metric values for branches in a trellis. *Id.*; A45462-64.

The Worstell patent ("Worstell, or the "Seagate patent"), is directed to a modified Viterbi detector that accounts for *both* correlated noise and signal-dependent noise:

> To this Court, it is clear that the Seagate Patent discloses a detector that receives correlated noise samples. Not only is the Seagate Patent entitled '[m]odified viterbi detector which accounts for correlated noise,' but it repeatedly refers to correlated noise…
>
> …The Seagate Patent also accounts for signal-dependent noise. The Court construed the term 'signal-dependent noise' to mean 'media noise ... whose noise structure is attributable to a specific sequence of symbols.' [A7083]. Transition noise is a type of media noise which is attributable to the sequence of symbols recorded on the recording media. Transition noise is, therefore, a form of signal-dependent noise.

A7082-83. Worstell addresses the media noise in the same way as the asserted claims:

First, Worstell's branch-metric functions are applied to a "plurality" of signal samples. Worstell explains that "***the present invention*** uses a branch metric in a Viterbi detector which is based on a current signal sample, as well as one or more previous signal samples. In this way, the Viterbi detector according to the present invention accounts for ***correlated noise*** in the system." A53693 at 2:3-7 (emphasis added).

Second, Worstell discloses the selection of a branch-metric function from a set of signal-dependent branch-metric functions. Specifically, Worstell discloses methods by which its modified metric (*see* Eq. 20 at 9:50) can be "further modified" to account for transition noise using a transition noise standard deviation (σ), which is simply the square root of the variance (σ^2) (A53697 at 10:48-67):

> The ***modified metric*** used in accordance with the ***present invention can be further modified to take into account transition noise as well.*** If it is assumed that ***the standard deviation of the noise component of each sample is greater where there is a transition in the signal written to the disc than where there is no transition, then each branch metric can be modified by multiplying the metrics which correspond to transitions by a fraction which depends on the transition noise standard deviation***. Implementing this in a fairly straightforward way would require 8 multipliers, one for each 'one' branch leading to each state in the appropriate trellis diagram.

A53697 at 10:48-59 (emphasis added). As recounted by Marvell's expert at trial, when asked about this passage at deposition, CMU's expert conceded that the transition noise differs depending on whether there is a transition or not, and thus the standard deviation of the noise for a transition (σ_1) differs from the standard deviation associated with noise for *no* transition (σ_2). A44648-49. Thus, Worstell's detector selects one branch-metric function for branches corresponding to a transition and a different function for branches corresponding to no transition.

Even under the court's construction of the elements of a function (where only a parameter variable as opposed to an input variable can produce a set of functions), Worstell's use of a fraction dependent on the transition-noise standard deviation (σ) (a parameter that varies depending on whether there is a transition or not) explicitly discloses a "set" of signal-dependent branch-metric functions. A7079; A8119-22. As a standard deviation (σ) is simply the square root of the variance (σ^2), Worstell's "further modified metric" constitutes a set of variance-dependent branch-metric functions in the same way as the variance-dependent branch-metric functions disclosed (σ^2) in the Zeng and Lee papers. A44635-36; A53634-40. As Marvell's expert recounted at trial, both CMU's expert and inventor, Dr. Moura, agreed that the use of a variance (σ^2), as in Zeng and Lee, represents a set of functions because the variance (σ^2) depends on whether there is a 1 or 0 written on the disk (A44635:13-24; A44636:6-19). These admissions confirm the disclosure of the selecting step—in the Worstell patent.

Moreover, even if, as CMU's expert opined at trial, the fraction dependent on the transition-noise standard deviation (σ) were a constant (A44956-57), Worstell *still* would disclose a "set" of signal-dependent branch metric functions. In what Worstell describes as a "fairly straightforward" embodiment, a fraction that depends on the transition-noise standard deviation (σ) can be multiplied by the function only for each "one" branch. A53697 at 10:48-59. That is, a first branch-metric function (multiplied by a transition-noise fraction) is applied only to the branches corresponding to a transition (the "one" branches). *Id.* And a second branch-metric function (not multiplied by a transition-noise fraction) is applied only to the branches corresponding to no transition (the "zero" branches). *Id.* Both functions must be used to account for signal-dependent noise, together constituting a "***set***" of signal-dependent branch metric functions. *Id.*

Thus, even assuming the standard deviation were constant, the Worstell patent by its terms *still* discloses *at least* two functions that must together be used to account for signal-dependent noise—one to be selected for use on branches with a transition and the other to be selected for use on branches without a transition. If there were any doubt as to whether Worstell discloses a "set" of functions or only a single function, it would have been obvious, in view of Worstell's disclosure, or in view of the work of Zeng and Lee, to provide a set of signal-dependent branch-metric functions. A44654-56. As described in the background of the CMU patents, Zeng and Lee "derived a branch metric computation method for combating the signal-dependent character of media noise" but "ignore[d] the correlation between noise samples." A450 at 1:45-52. Worstell extended their work to account for correlation by applying his branch metrics to a plurality of signal samples. Indeed, the asserted claims are directed to nothing more than the teaching of the prior art. Notably, the evidence at trial shows an absence of secondary considerations—as the prior art already accounted for media noise, and there is no evidence of anyone seeking to license or commercialize the asserted claims. A53744 ("[W]e are not aware of anyone utilizing the claims in the Kavcic-Moura patent."); A42496:2-13; A42450:6-12; A160-61; A17392-93; A53634-37; A53638-40; A53686-99.

CMU first accused Marvell of infringement on 12 claims (A38562; A17384-96), including a set of claims directed to an optimal detector using an "adaptively updated" set of "covariance matrices" (A17385)—the optimal detector that Worstell said went "beyond my work" and was "probably more interesting" (A46099) and that Marvell found too complex to implement (A43905-06; A43920-21; A44716-20; A46140). The court found no basis for infringement of those claims before trial (A17384-96), leaving CMU to assert only a very broad method of determining branch-metric values in a trellis using two steps that were disclosed in Worstell.

II. THE DISTRICT COURT ERRED IN DENYING JMOL THAT CLAIM 4 OF THE '839 PATENT AND CLAIM 2 OF THE '180 PATENT ARE NOT INFRINGED

As with invalidity, the court denied Marvell JMOL of noninfringement. (A182-94) based simply on the argument that the "jury was free to accept either expert's opinions or reject them, as the 'credibility of the parties' competing experts is an issue for the jury to resolve, not the Court'" (A194). That was error. In order to infringe, each and every element set forth in the claims must read on an accused device or method ***exactly***[10] and when carefully assessed against Marvell's

[10] CMU did not assert infringement under the doctrine of equivalents.

pre- and post-processing circuitry, no reasonable jury could find that Marvell infringed.[11]

According to the claims, the branch-metric function must be applied to a ***plurality*** of signal samples to ***determine*** branch metric values for the potential transitions in a trellis. A456; A481 A45462-64. But in Marvell's NLD chips, it is undisputed that the application of the NLD filter generates a ***single*** signal sample (f_y) as its output, and thus the branch-metric function is applied to a ***single*** sample output by the NLD filter (A41994-96; A48249).

According to the claims, as Dr. Kavcic himself conceded was critical (A53700-04), media noise is accounted for ***in the trellis and NOT in a post-processor***. But in Marvell's MNP chips, media noise is accounted for in a post-processor, not in the trellis. A48203; A48194. And the claimed ***detectors*** must operate on ***signal samples*** at a certain time instant. A456; A481. But Marvell's simulations are not "detectors" but rather ***simulations*** of detectors (A43943; A43990; A41756:20-22), and they operate not on signal samples but on synthetic sequences or data files of wave forms copied from HDDs (A192-93). As CMU's expert put it, the "[d]etector is in the chip." A41745:16-746:7.

[11] As a rational jury could not find the predicate direct infringement, neither could it find indirect infringement.

A. The NLD Chips Do Not Infringe

CMU's claims require the application of the selected branch-metric function to a ***plurality*** of signal samples ***to determine*** branch metric values for branches ***in a trellis***. A456; A481; A45462-64. That is, CMU's asserted claims require a branch-metric function to be applied to a ***plurality*** of signal samples to ***determine*** branch-metric values for the potential transitions (branches) in a trellis. *Id.*

The problem Marvell identified in Kavcic's approach is a speed bottleneck, and the undisputed evidence shows that Marvell avoided the bottleneck by moving its filter out of the Viterbi trellis—so that a pre-filter circuit (NLF), using tap weights that can be shared by more than one branch, first generates a ***single*** signal sample (f_y) which can then be used as an input to a simple branch-metric function ($BM_1 = (f_y - f_m)^2$). A41994-96; A48240; A48249; A48271.

At trial, CMU's expert admitted that the output of the NLF, and the result of the "application step" in Marvell's chips, is a ***single*** signal sample (f_y) which indisputably is *not* a branch metric value:

> Q So it's fair to say that the signal that's labeled F-sub-Y that we're discussing, that is a single signal sample, isn't it true, sir?
>
> A ***It's a single signal sample*** that's—that's the output, ***the result of the application, the application step.***

A41996:6-10. CMU's claims, however, require that the determination of a branch-metric value result specifically from the "application step." A456 at 14:15-16; A481 at 15:47-48.

Rather than addressing these specific defects, the district court repeatedly relied upon a Marvell document recognizing that Dr. Kavcic's branch metric uses FIR filters *within* the Viterbi trellis. A24; A196; A218; A224. In that January 10, 2003 email, Marvell's engineer Zining Wu stated that he had "discussed the approach of using a different noise whitening filter in each branch. It turns out to be the original structure that Kavcic proposed in his paper." A46779. But in the very next sentence, Wu explains that "We also found a way to move the noise whitening filter ***out of the Viterbi***," thus reducing "the speed bottleneck … in the branch metric calculation." *Id.* (emphasis added). Moving the filter out of the trellis reduces the computations—such that only one difference need be computed for each branch ($BM = (f_y - f_m)^2$), as shown in this figure highlighting the single signal sample (f_y) output by the NLF filter:

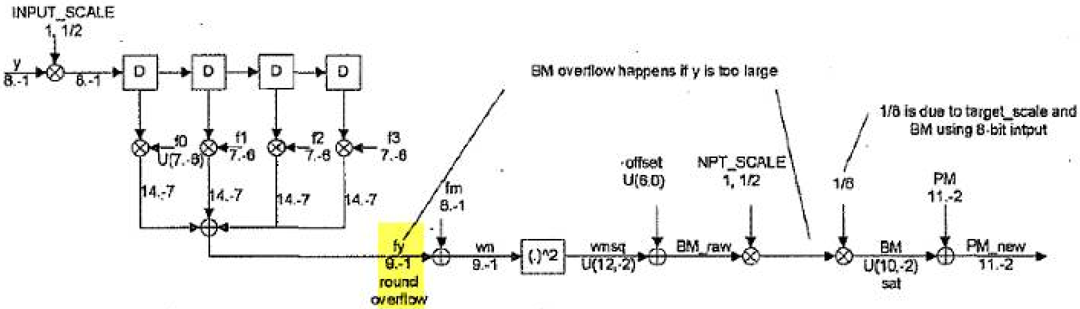
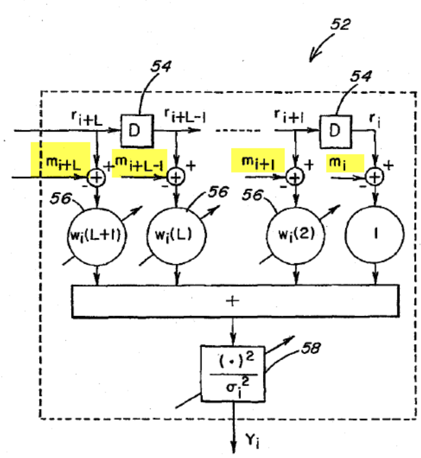


Figure 7. BM and PM calculation

A48249 (Marvell's NLD Specifications).

In contrast, CMU's claimed FIR filter resides in a trellis and requires numerous computations of differences between each of a plurality of signal samples (r_{i+L}, r_{i+L-1}, r_{i+1}, r_i) and their respective expected values (m_{i+L}, m_{i+L-1}, m_{i+1}, m_i) in the trellis, as shown highlighted below:

FIG. 3B



A443 (Fig. 3B of the CMU Patents). Given these differences, Marvell's NLD chips cannot infringe the asserted claims.

B. The MNP/EMNP Chips Do Not Infringe

CMU's claims require that the application of the selected branch-metric function to a plurality of signal samples result in the determination of a branch-metric value for the potential transitions (branches) "***in a trellis***." A456; A481; A45462-64. As Dr. Kavcic's own October 2001 email about his invention to Gregory Silvus of Seagate confirms, his invention addresses media noise "***in a trellis and NOT in [a] post processor***." A53700-04 (emphasis added). *See*

Gemalto S.A. v. HTC Corp., 2014 WL 2766195, *6 (Fed. Cir. June 19, 2014) (inventor testimony confirmed he had invented a microcontroller—not a microprocessor as used in the accused product).

In contrast, Marvell's MNP/EMNP chips use a conventional Euclidean Viterbi detector and then use ***a post-processor***, where the sequence output by the Viterbi detector is compared to two alternative error sequences. A48203; A48194; A41977:14-20. At trial, CMU's expert acknowledged that Marvell's MNP chips use a "linear Viterbi" that determines the best path through the trellis and *then* uses post-processor circuitry where "an evaluation is done to see if either [of two] alternate paths is better than the best path." A41977:14-20. By accounting for media noise in a post-processor rather than in the Viterbi trellis, Marvell's invention is capable of commercial implementation, for it uses a conventional Viterbi detector to compute branch-metric values and then outputs an actual sequence for comparison with two alternative error sequences, rather than computing potential transitions in a trellis using a complex branch metric function.

As Marvell's expert, Dr. Blahut, recounted at trial, Dr. Kavcic himself admitted that "the difference between two path metrics" is not a branch metric. A44522-24. To be sure, Marvell documents include references to computing path metrics in the MNP post-processor and refer to branch metrics in the context of discussing the post processor, and Marvell named its post-processing simulation

"KavcicPP" before changing its name to MNP—a fact the lay jury may have deemed suspect without appreciating the distinctions in the technology. But the undisputed evidence of Marvell's actual MNP implementation in circuitry shows that Marvell's post-processor operates outside of the Viterbi detector (A48203) and compares the difference between two metrics of actual sequences, and does not compute branch-metric values for the potential transitions (branches) in a trellis (A54266).

No Marvell documents refer to the use of a "trellis" in the post-processor—and the references in Marvell's patents to path-metric computations for the error metrics are not referring to branch-metric computations for the transitions (branches) in a trellis. *See Monsanto Co. v. Bayer Bioscience N.V.,* 363 F.3d 1235, 1244 (Fed. Cir. 2004) ("similar terms can have different meanings in different patents depending on the specifics of each patent"). The only document CMU pointed to in arguing that the MNP uses a "pruned" trellis (*see* A47923; A41817) was a high-level document intended for a sales audience (A41817), which should have been given no weight. *Scantibodies Lab., Inc. v. Immutopics, Inc.,* 374 Fed. App'x. 968, 971 (Fed. Cir. 2010) ("The use of language in [even a patentee's own] marketing materials often means something quite different from the language used in a patent."); *Aspex Eyewear, Inc. v. Altair Eyewear, Inc.*, 288 F. App'x 697, 704

(Fed. Cir. 2008) (according no weight to accused infringer's marketing materials in infringement analysis).

No reasonable jury could have found infringement in view of this evidence.

C. Marvell's Simulations Do Not Infringe

Claim 4 of the '839 patent is directed to a "method of determining branch metric values for branches of a trellis for a Viterbi-like ***detector***." A456 (emphasis added). Similarly, claim 2 of the '180 patent is directed to a "method of determining branch metric values ***in a detector***." A481 (emphasis added). But as CMU's expert rightly put it, the "[d]etector is in the chip" (A41745:16-746:7), and a *simulation* of a detector is not itself a detector.

The asserted claims also require "applying" selected functions to a "plurality of signal samples" (claim 4) or "signal samples" (claim 2). A456; A481. Yet Marvell's simulators are incapable of detecting actual signal samples. All they do is process artificially created (simulated) data or data files (copies of actual wave forms). A43943; A43990; A41756:20-22; A41745:16-746:7.

If running a simulation program could infringe claimed methods for processing signal samples in a detector, then the claims would cover an abstract idea not otherwise subject to patenting. This Court already rejected such an effort in *Harris Corp. v. Ericsson Inc.*, 417 F.3d 1241 (Fed. Cir. 2005), holding that use of simulation programs for testing algorithms did not infringe a method of using a signal-processing communication system, because the claimed method was not "actually carried out, rather than simulated" when the program for testing its algorithms is run. *Id.* at 1256.

The same reasoning and result should hold here—as CMU's expert conceded that Marvell's accused simulators are just computer programs, and the claims are not directed to simulation programs.[12] A41756:20-22 ("Q. And the accused simulators, that's the Marvell computer programs? A. That's correct."); A41939:10-13 ("Right. There's—the word 'simulator' is not in either one of the claims."). Accordingly, no reasonable jury could have found that Marvell's MNP and NLD simulation programs infringe.[13]

III. THE $1.17 BILLION DAMAGES AWARD CANNOT BE SUSTAINED

A. CMU's Expert Damages Testimony Should Have Been Excluded

The award of $1.17 billion in damages rested entirely on the testimony of CMU's damages expert Ms. Lawton, but she lacks relevant expertise and her testimony "finds no support in the facts in the record." *LaserDynamics, Inc. v. Quanta Computer, Inc.*, 694 F.3d 51, 81 (Fed. Cir. 2012). The district court thus

[12] Marvell's simulations of MNP and NLD chips also do not infringe for the same reasons set forth *supra* in Part II.A-B.

[13] Because the jury's verdict draws no distinction between the accused technologies, any reversal on liability would necessitate retrial as to all damages. *See Verizon Servs. Corp. v. Vonage Holdings Corp.*, 503 F.3d 1295, 1309-10 (Fed. Cir. 2007).

erred in rejecting Marvell's motions to exclude her testimony. A17433-44; A17445; A33398-425; A42691-99; A42714-15; A42978-79.

First, by her own admissions, Ms. Lawton lacks any qualifications entitling her to opine on the value of a hypothetical license to CMU's claims: she has never negotiated a patent license, and has no experience setting or negotiating chip pricing. A42811-12; A43414-16. She also disavows any experience with "technical matters concerning Marvell's business, the semiconductor industry [or] the market for computer chips and the patented technology." A33422. She does not have a technical degree, graduate degree or CPA. A42786-88; A42793. Instead, her "entire career since college has essentially been as a consultant or professional witness." A42788; A42794. Such lack of experience should have at least weighed against the admissibility of her testimony. *See Uniloc USA, Inc. v. Microsoft Corp.*, 632 F.3d 1292, 1318 (Fed. Cir. 2011) (finding damages expert testimony unreliable, in part because he had limited negotiation experience); *see also State Contracting & Eng'g Corp. v. Condotte Am., Inc.*, 346 F.3d 1057, 1073 (Fed. Cir. 2003); *Elcock v. Kmart Corp.*, 233 F.3d 734, 749 (3d Cir. 2000) .

Second, Ms. Lawton's theories "lack the hallmarks of genuinely useful expert testimony" because they rest on unreliable methodologies. *Power Integrations, Inc. v. Fairchild Semiconductor Int'l, Inc.*, 711 F.3d 1348, 1374 (Fed. Cir. 2013); *see id.* at 1372-74; *see also Uniloc*, 632 F.3d at 1315. Specifically, Ms.

Lawton disregarded evidence that CMU's patents were actually valued and licensed on a flat-fee rather than per-unit basis (A43431-33), dismissing contemporaneous examples (A53614-23, A53641-47; A53648-56; A53765-81) as "special agreements" (A43086-87); took no meaningful account of CMU's actual offers to license one of the patents-in-suit for $200,000 (A43420-21; A43114) or CMU's own projections valuing the patents-in-suit at $2 million annually, purporting to consider those real-world data points only to posit calculations altogether divorced from them based on irrelevant differences in timing (A43115); and based her opinion instead on isolated instances of Marvell paying running royalties for technologies that are not comparable to the patents-in-suit (A43353-56). Her failure to account for "[a]ctual licenses to the patented technology," which "most clearly reflect the economic value of the patented technology in the marketplace," *LaserDynamics*, 694 F.3d at 79, and her reliance instead upon "license agreements that were 'radically different from the hypothetical agreement under consideration' to determine a reasonable royalty," *Uniloc*, 632 F.3d at 1316 (citations omitted), rendered her testimony inadmissibly unreliable.

Ms. Lawton's use of a global, 556,812,091-chip royalty base was similarly speculative and unreliable, for it was based on industry reports for PC products further downstream. A246; A43405-06. This number was extrapolated without explanation, without reference to data specific to Marvell's chips, and without benefit of any technical or industry expertise. *See Power Integrations*, 711 F.3d at 1374 (excluding expert damages testimony that extrapolated on worldwide industry import data without providing evidence that the specific infringing circuits were present in the imports).

Moreover, Ms. Lawton's failure to properly apportion the relative contributions of the asserted claims to the accused products independently renders her opinion unreliable. *See Uniloc*, 632 F.3d at 1318 (excluding expert damages testimony for failure to apportion correctly, and granting new trial on damages). Ms. Lawton testified that she did not "value the other patents within Marvell's read channel" because she instead undertook "***a different approach to apportionment***, which is what I referred to as my excess profits analysis." A42790 (emphasis added). But as she herself explained it, her "excess profits" calculation bears no relationship to the value of CMU's patented methods. A43483 ("excess profits" are "not necessarily attributable to the patented technology"); A43475 (agreeing that "excess profits is [not] attributable to the technology of the patents in suit"); A43500 ("excess profits analysis goes to the issue of what does Marvell say is adequate profit for its business"). Indeed, her method indicated *negative* value for the accused MNP feature. A43481-82; A54443. Likewise, she acknowledged that her "operating profit premium" analysis accounts neither for Marvell's actual implementation of the MNP and NLD circuits in silicon separate and apart from

CMU's claimed invention (A43471-72; A43609-10), nor for features *other than* MNP and NLD that varied among the chips she was comparing (A43472-73). Such failure to apportion the infringement damages here should have foreclosed admission of her testimony.

Finally, Ms. Lawton used unreliable methodology in extrapolating a key part of her per-chip royalty-rate analysis from a highly unrepresentative mini-sample of sample chips sold to Marvell's smallest customer (A43486-87; *see infra* Part III.D.2). When asked on redirect to explain why she extrapolated as she did, Ms. Lawton answered that the data available "was very, very limited." A43498. But that neither immunizes expert analysis from the need to use relevant data nor renders valid what amounts to an unrepresentative, cherry-picked sample. *See, e.g.*, *E.E.O.C. v. Kaplan Higher Educ. Corp.*, 748 F.3d 749, 754 (6th Cir. 2014); *Espenscheid v. DirectSat USA, LLC*, 705 F.3d 770, 775 (7th Cir. 2013) (Posner, J.); *Dick's Sporting Goods, Inc. v. Dick's Clothing & Sporting Goods, Inc.*, 188 F.3d 501 (4th Cir. 1999); *United States v. Washington*, 157 F.3d 630, 654 (9th Cir. 1998). Notably, Ms. Lawton (or an expert with the requisite qualifications) could have sought to determine the value of the patented method to Marvell's chips by collecting data on that subject directly from Marvell's customers via third-party discovery or survey analysis, but CMU elected not to pursue that route.

Even if Ms. Lawton's testimony were admissible, however, the damages award is erroneous as a matter of law for the reasons that follow.

B. The District Court Erred In Allowing A Hypothetical License To Be Measured By A Per-Unit Royalty Rather Than A Flat Fee

Actual licenses are the most probative evidence of "the proper form of the royalty structure," *LaserDynamics*, 694 F.3d at 79-80, and this Court has not hesitated to vacate damages judgments that exceed the benchmarks set by actual licenses to a claimed invention, *see ResQNet v. Lansa*, 594 F.3d 860, 869-72 (Fed. Cir. 2010); *Riles v. Shell Exploration & Prod. Co.*, 298 F.3d 1302, 1313 (Fed. Cir. 2002); *Unisplay, S.A. v. Am. Elec. Sign Co.*, 69 F.3d 512, 519 (Fed. Cir. 1995). Here, the only evidence of any contemporaneous, actual licensing showed that CMU contemplated and received flat-fee sums rather than per-unit royalties, and contained no comparable license involving a per-chip royalty. The district court erred in denying Marvell JMOL on damages (or new trial or remittitur) for this reason alone.

Specifically, the record contains three "DSSC Agreements" whereby CMU issued lump-sum licenses encompassing the patents-in-suit to IBM, Seagate and 3M. A53614-23; A53641-47; A53648-56; A42361-62.[14] In a fourth "Subscription Agreement" (A53765-81), CMU provided Intel with an option to license one of the

[14] Notably, these DSSC agreements allowed licensing of *all* patents CMU conceived during a membership period in exchange for an annual $250,000 membership fee. A53615-17; A42439-42; A42226-27.

patents-in-suit—while omitting the second, related patent, which the inventors sought to include on the same terms (A53785-90)—for a single lump-sum payment of $200,000 (A53768; A42501-02). Even CMU's best-case, speculative licensing projection for 2006 and 2007 contemplated only a *flat*, annual rate of $2 million. A53805-06; A53827-31; A42529-30; A42536:8-15.

In denying JMOL on damages, the district court held (A273) that such flat-fee licensing evidence was not dispositive because, as Ms. Lawton noted, the DSSC Agreements were executed "well before the date of the hypothetical negotiation," "were special," and involved extra-contractual collaboration with CMU (A265; A43085-87; A43429-30; A265-66), and that the Intel Subscription Agreement took place "three-and-a-half years after the date of the hypothetical negotiation" (A265; A265-66; A43420-21). That was error, for if CMU was willing to license the patents-in-suit at flat rates both *before* and *after* the hypothetical negotiation, then the only rational inference is that it would have done so *during* negotiations. The record contains no explanation why, in the hypothetical world where Marvell and CMU were negotiating a license, Marvell would not have obtained a $250,000 lump-sum license to the patents-in-suit rather than agreeing to pay running royalties amounting to $1.17 billion. *See, e.g.*, *Gaylord v. United States*, 678 F.3d 1339, 1343 (Fed. Cir. 2012) ("It is incorrect in a hypothetical negotiation inquiry for a court to limit its analysis to only one side of the negotiating table[.]")

In denying JMOL, the district court also found sufficient Ms. Lawton's reliance on certain actual per-unit royalty agreements (A246; A259), but that too was error because those examples involved licenses unrelated and not comparable to the CMU claims here. Specifically, Ms. Lawton testified that CMU had (in 1998, years *before* the hypothetical negotiation) entered into one running-royalty license agreement and that Marvell had (between April 2000 and April 2001) entered into three running-royalty license agreements. A43353-54; A171; A258-17. Apart from that mere reference to a running royalty, the record contains no analysis of the terms and substance of those licenses, much less how they compare to any hypothetical patent license here.

C. The District Court Erred In Including Foreign Chips In The Royalty Base

The district court also erred in denying JMOL (and new trial or remittitur) striking the portion of the damages award that rested on sales of foreign chips that were manufactured, sold, and used abroad without ever entering the United States. While the district court correctly acknowledged that CMU may not recover direct or indirect infringement damages "in connection with sales of chips that are never used in the United States" (A17380), it nonetheless reasoned that damages from a supposed initial infringing use in the United States (here, during research, design, and customer-relations activities) may sweep in all ensuing sales, including those of *foreign* chips manufactured, sold, and used exclusively abroad (A239-48; A31957-62; A17380). This purportedly "novel" circumvention of the territorial limits of U.S. patent laws cannot be squared with this Court's decision in *Power Integrations*, 711 F.3d at 1371-72.[15]

1. *Power Integrations* Forecloses Inclusion Of Foreign Chips In The Royalty Base

The Patent Act, 35 U.S.C. § 284, makes no provision for any award for foreign sales, and it is well-established that the presumption against the extraterritorial application of U.S. law "applies with particular force in patent law," *Microsoft Corp. v. AT&T Corp.*, 550 U.S. 437, 454-55 (2007); *see Pellegrini v. Analog Devices, Inc.*, 375 F.3d 1113, 1118 (Fed. Cir. 2004); *Deepsouth Packing Co. v. Laitram Corp.*, 406 U.S. 518, 531 (1972); *Brown v. Duchesne*, 60 U.S. 183, 195 (1856). The presumption may be overcome only by "a clear congressional indication of intent," *Microsoft*, 550 U.S. at 444 (citation omitted), and Congress has made no such statement here.

This Court reaffirmed the rule against extraterritoriality in *Power Integrations*, upholding invalidation of a patent damages award to the extent it was "based on worldwide sales." 711 F.3d at 1372. The Court rejected the plaintiffs'

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[15] At minimum, the court below erred by instructing jury that it could include Marvell's global chip sales in determining a reasonable royalty. This error independently warrants a new trial, as explained in Part III.C.2, *infra*.

argument in that case that, because "it was foreseeable that [the defendant's] infringement in the United States would cause [the plaintiff] to lose sales in foreign markets," those sales could be included in a lost profits analysis. The Court stated that "the entirely ***extraterritorial production, use, or sale*** of an invention patented in the United States is an ***independent, intervening act*** that, under almost all circumstances, cuts off the chain of causation initiated by an act of domestic infringement." *Id*. at 1371-72 (emphases added).

That holding forecloses a damages theory that, as here, reaches extraterritorial sales based upon a supposed "chain of causation initiated by an act of domestic infringement." *Id*. *Power Integrations* cannot be distinguished, as the court below attempted (A240-41), on the ground that the *infringing activity* here was supposedly domestic use that foreseeably resulted in foreign sales, rather than the foreign sales themselves. For *Power Integrations* expressly rejected such an attenuated chain of causation:

> Power Integrations is incorrect that, having established one or more acts of direct infringement in the United States, it may recover damages for Fairchild's worldwide sales of the patented invention because those foreign sales were the direct, foreseeable result of Fairchild's domestic infringement.

711 F.3d at 1371. The fact that the chips at issue here are produced, sold and used abroad presents an "independent, intervening act" that should "cut[] off the chain

of causation initiated by an act of domestic infringement" no less than was true in *Power Integrations*. A166-67; A44204-05.

Nor can *Power Integrations* be distinguished on the ground that it involved an apparatus claim (infringed by sales) rather than a method claim (infringed by use), and that here, Marvell's global sales serve only as a supposed proxy for the value of infringing domestic use (*see* A37464-65 A43439-40; A43442:1-10). For this Court requires that damages for a method claim correlate with "the extent the infringing method is used," *Lucent Techs. v. Gateway, Inc.*, 580 F.3d 1301, 1334 (Fed. Cir. 2009), and to the extent that Marvell's sales may be considered an estimated measure of ***use***, total sales are an impermissible measure of damages because they correlate with the number of chips ***used worldwide***, and thus do ***not*** estimate use of the patented method ***in the United States***.[16] Indeed, *Power Integrations* speaks to territorial limits on both "use" and "sale" of any "invention patented in the United States." *Power Integrations*, 711 F.3d at 1371. And, as the Supreme Court has explained, the presumption against extraterritorial application of U.S. law is not overcome merely because "*some* domestic activity is involved in the case." *Morrison v. Nat'l Austrl. Bank Ltd.*, 561 U.S. 247, 266 (2010); *accord Power Integrations*, 711 F.3d at 1371.

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[16] *See, e.g.*, *Sutton v. Gulf Smokeless Co.*, 77 F.2d 439, 441 (4th Cir. 1934).

If affirmed, the district court's novel theory that foreign chip sales may be included in a royalty base for determining consequential damages for an infringing domestic use would have numerous adverse practical consequences for U.S. patent policy. *First*, such an approach would create potential conflicts with foreign law by imposing liability based on sales that do not violate the patent laws applicable where they occur. *See, e.g.*, *Microsoft*, 550 U.S. at 454-55 (noting that "foreign law may embody different policy judgments about the relative rights of inventors, competitors, and the public in patented inventions") (citation omitted).

Second, where a foreign sale does violate a foreign nation's patent laws, a U.S. defendant might be subject under the district court's approach to double recovery for sales that both infringe foreign patents and have some attenuated connection to an allegedly infringing use of a U.S. patent in the United States.

Third, inclusion of foreign sales in the measure of damages from domestic use would invite an end-run around well-established limitations on liability for indirect infringement. To establish liability for a third party's domestic acts of direct infringement, a patentee must prove not only the underlying direct infringement but also the additional elements of a claim for inducement or contributory infringement under 35 U.S.C. §§ 271(b) and (c).[17] But the trial

[17] *See Global-Tech Appliances, Inc. v. SEB S.A.*, 131 S.Ct. 2060, 2068 (2011); *Commil USA, LLC v. Cisco Sys., Inc.,* 720 F.3d 1361, 1368-69 (Fed. Cir.

court's approach opens the door for a patentee to recover damages for third-party use or sales without satisfying any of these liability requirements so long as the third party's use or sales are the "result of" even a single infringing use by the defendant. And permitting damages for third-party ***sales*** to flow from the defendant's ***use*** of the patented technology, however limited, would also enable a patentee to avoid establishing the requisite correlation between the amount of the damages sought and the extent of actual third-party use.[18]

Finally, if a hypothetical negotiation to pay for U.S.-based patent rights is construed to encompass an obligation to take a license with respect to foreign sales, companies with a U.S. presence will predictably have every incentive to move overseas for fear that any alleged infringing use in the United States would expose them to U.S.-based claims for recovery on their global operations. Reversal or vacatur of the judgment below is necessary to avoid these consequences.

2013) ; *DSU Med. Corp. v. JMS Co.*, 471 F.3d 1293, 1305 (Fed. Cir. 2006) (*en banc*) .

[18] *See Lucent*, 580 F.3d at 1334-35; *Dynacore Holdings Corp. v. U.S. Philips Corp.*, 363 F.3d 1263, 1274 (Fed. Cir. 2004) ("A defendant's liability for indirect infringement must relate to the identified instances of direct infringement.").

2. The District Court Erred In Instructing The Jury To Use A Worldwide Royalty Base

The court instructed the jury that, although "Marvell cannot be found to have directly or indirectly infringed in connection with chips that are never used in the United States," it was proper to consider *all* of Marvell's "sales resulting from Marvell's alleged infringing use [in the United States] during the sales cycle … in determining the value of the infringing use"—including sales of chips manufactured and sold abroad without entering the United States. A45456; *see* A237; A253-58. Marvell categorically objected to that instruction as soon as it was proposed. *See* A45143-48; *see also* A17367-81; A31957-62.

That instruction was error for the reasons set forth *supra* in Part III.C.1, warranting at a minimum a new trial on damages. Even assuming *arguendo* that inclusion of foreign chips in the royalty base is not altogether foreclosed, the instruction is further erroneous because it permitted the jury to consider any and all "sales resulting from Marvell's alleged infringing use during the sales cycle" without requiring the jury to find, as Marvell proposed (A45145; A45148), that such foreign sales were "solely" the result of Marvell's supposed infringing use of CMU's algorithm, and indeed without imposing any causal-nexus requirement whatsoever. The instruction thus fell well short of the "full and complete instructions" that are required to relate "the law to the relevant evidence in the case" for the jury's benefit. *Smith v. Borough of Wilkinsburg*, 147 F.3d 272, 279-

80 (3d Cir. 1997); *Dressler v. Busch Entm't Corp*, 143 F.3d 778, 783 (3d Cir. 1998) (instruction must advise "jury of concepts it needs to know to properly discharge its duties").

3. Marvell Preserved Its Objection To The Royalty Base

Contrary to the district court's suggestion (A248-50), Marvell never waived its contention that CMU's attempt to recover on foreign chips is foreclosed as a matter of law.[19] Nor can Marvell be faulted, as the district court erroneously suggested, for failing to present evidence at trial "that any aspect of its sales took place outside the United States" (A248). Once the court endorsed CMU's novel legal theory for recovering on "non-infringing foreign sales," because "use of these chips in this, quote, sales cycle, end quote, ultimately is the issue" (A42714-15), any such proof was beside the point. Moreover, it was CMU's burden to prove infringement and damages, and CMU's own damages testimony shows that most of Marvell's chips included in the royalty base are in fact manufactured and used exclusively outside the United States. *Compare* A43406-07 (testimony extrapolating supposed global sales of 556,812,091 chips) *with* A43449 (testimony

[19] As the court noted in denying Marvell's post-trial motions, Marvell's concerns surrounding extraterritoriality were "addressed numerous times in this case, from the earliest days of discovery disputes (Docket No 195), to summary judgment (Docket No. 441), in motions *in limine* (Docket No. 493) and 'emergency' motions (Docket No. 656), during trial (Docket No. 713), and now again post trial." A234; *see also* A239 ("The Court first ruled on the inclusion of extraterritorial conduct at summary judgment. (Docket No. 441)." Marvell also timely objected to the erroneous instruction on this point. *See supra* Part III.C.2.

tracing to actual customer data 329,297,798 chips, thus indicating possible U.S. sales); A43440-41. While the district court suggested post-trial that there was "sufficient evidence for a jury to find that [all relevant] sales occurred inside the United States" (A250), any such suggestion lacks foundation in the record and cannot be reconciled with the court's own jury instruction.

D. The District Court Erred In Imposing A $.50-Per-Chip Royalty Rate

Separate and apart from the legal error as to the royalty base, the district court erred in denying JMOL as to the $.50-per-chip royalty rate on which judgment was entered (A261-68; A73).

1. The "Excess Profits" Theory Fails To Support The Royalty Rate

The district court first erred in crediting (A261; A17442-44) Ms. Lawton's "excess profits" analysis despite its failure to identify what value the patented technology adds to the chips. There is no support in the record for the assumption (A43326-28; A43474-75; A43483:7-17) that a "target" 50% gross profit margin for a business unit, let alone the entire company, accounts for Marvell's contributions to the specific chips at issue here or that any "excess" profits are attributable solely to the patented feature. To the contrary, Ms. Lawton's own analysis shows that Marvell's chips *without* the patented technology had *greater or equal* "excess profits" than chips *with* the accused circuits. A43481-82; A54443 (showing that the gross margin of "Accused Infringing SOCs" is equal to or less than the gross margin of "All SOCs").

The district court brushed this problem aside by citing testimony from Ms. Lawton that "non-infringing products" included a "non-read channel chip for Seagate that sells at a premium" as well as "a chip that Marvell indicated had an MNP but CMU could not absolutely confirm" had an MNP. A267. Far from rehabilitating Ms. Lawton's "excess profit" analysis, however, those observations only indicate that Marvell makes *less* on chips that specifically embed the accused technology. At best, therefore, a rational jury would conclude that a variety of factors contribute to Marvell's total margins on chips ***with and without*** the accused circuits, such that the mere happenstance that Marvell's *gross* margins (as distinct from actual operating margins) may exceed an abstract target of 50% for a particular chip is not attributable to the accused technology.

Moreover, this Court's precedents require proper apportionment of patent damages "between the patented feature and the unpatented features," *Uniloc*, 632 F.3d at 1318; *see LaserDynamics*, 694 F.3d at 67, 81 (disapproving a royalty rate "untethered from the patented technology at issue"), and the "excess profits" analysis approved below fails to reflect the requisite apportionment. To the contrary, Ms. Lawton disavowed any such apportionment. *See* A43483:7-17 (acknowledging that "excess profits" are "not necessarily attributable to the patented technology"); A43500:12-13 ("excess profits analysis goes to the issue of what does Marvell say is adequate profit for its business"); A43474-75 (agreeing that she made "no determination" that excess profits are "attributable to the technology in the asserted claims in the patents in suit"). What Marvell estimates is an "adequate profit" obviously has nothing to do with the value the patented method adds relative to other features of Marvell's products, especially considering that Marvell's chips contain dozens of valuable features quite apart from any that are accused. *See* A54231-33; A43844-47; 43904.

In all events, the 50% target reflects a mere goal. As Ms. Lawton testified, the 50%-margin target simply represents Marvell's estimate of an "adequate profit for its business," not an actual or expected margin tied to any particular product or combination of technologies. A43500:12-13; A43327:9-25; A43483:7-17.[20] Such aspirations, quite removed from actual, operating margins,[21] illuminate nothing

[20] While this Court has suggested that the value of a patented feature may, in an appropriate case, be determined with reference to *actual, empirical operating* margins associated with products that lack the accused feature, *see Energy Transp. Grp., Inc. v. William Demant Holding*, 697 F.3d 1342, 1356-57 (Fed. Cir. 2012); *Lucent*, 580 F.3d at 1324; *TWM Mfg. Co. v. Dura Corp.*, 789 F.2d 895, 899 (Fed. Cir. 1986), Marvell's goals here were merely *aspirational* and concerned an *entire business unit*.

[21] Ms. Lawton further purported to measure excess gross profit rather than excess operating or net profit (A43326-28) and thus by her own acknowledgement neglected to account for research and development, sales and marketing and general and administrative costs surrounding the accused chips in calculating excess profits (A42996-99).

about whether or to what extent a particular line of chips is helping or hurting Marvell's actual operations.

2. The "Operating Profit Premium" Analysis Fails To Support The Royalty Rate

It was similarly error for the district court to credit Ms. Lawton's use of her supposed global "operating profit premium" theory as a basis for deriving the royalty rate. With this analysis, Ms. Lawton purported to calculate the "difference between the sale price of [a] chip that had the MNP minus the price of [a] chip that didn't have the MNP" and thereby to determine the "operating profit premium" that was "associated with the MNP." A43337-38; A32800.[22] Based on that theory, Ms. Lawton extrapolated a per-chip "premium" of up to $.72. A43338-39.

That calculation relied on far too small and unrepresentative a sample to support a $.50-per-chip royalty on all 2,338,280,542 chips in the royalty base. Ms. Lawton reached the upper bound of her $0.72 premium only by cherry-picking a tiny sample of merely 9,855 sample chips that Marvell offered to Maxtor—Marvell's smallest customer—from 2003-04, a one-year slice that post-dated the hypothetical negotiation. A43345-46; A43484-88. Assuming that Ms. Lawton's calculations were correct, Maxtor paid what she relied upon as the upper bound of

[22] Ms. Lawton is not an expert in "Marvell's business, the semiconductor industry [or] the market for computer chips and the patented technology," (A33422), and admitted that she has no relevant expertise when it comes to pricing the relevant chips (A42811-12)—all further reasons why her testimony should have been excluded (*see supra* Part III.A).

her price premium only for those less than 10,000 sample chips—less than 0.0005% of the total number of accused chips. A43345-46. In fact, Ms. Lawton's analysis shows that when *total* 2003-04 sales of the chips she compared to arrive at the Maxtor $1.00 price premium and $.72 profit premium are examined, both price per chip and gross margin per chip are *higher* for chips *without* MNP than for chips with MNP. A32796; A43330-32.

The Maxtor sample is not only trivial but unrepresentative. The Maxtor chips were *sample* chips. A43484:3-12; A43486:14-24. It was undisputed that low-volume sample chips are priced significantly higher than high-volume production chips. A43603-05; A44398:17-99:11. And Ms. Lawton was unable to show that Marvell's major customers like Western Digital, Samsung, Fujitsu, Hitachi, or Seagate ever paid *any* premium for the MNP. A43484-87; *see* A43486:6-13 (Western Digital "wanted a price reduction because the MNP was in it"); A44413-14; A44417-18; A44451-52 (Western Digital was not "willing to pay even one penny per chip" for MNP). To the contrary, the same "premium" analysis, once applied to Toshiba—a much larger and more representative purchaser at the relevant times (purchasing more than 46 times the number of chips Maxtor did)— yielded an alleged profit premium of at most only ***$.06*** per chip judged by Ms. Lawton's analysis. A32800; A43334-39; A43484-87; A44374-76; A39227.

Thus, no rational jury could extrapolate up-to-$.72 global "operating profit premiums" from certain "sample" chips offered to Maxtor alone, especially in light of Ms. Lawton's acknowledgements that that chip "price will [] vary by customer," "varies from chip to chip" and "will vary based on time" (A43329:3-15), particularly because, "in this industry, the price is always going down" (A43347:25-48:4).[23] For all these reasons, even if a rational jury might credit a $.72 "premium" as to 9,855 sample chips offered to Maxtor in 2003-04, it could not leap to the same conclusion as to the 99.9996% of the remaining chips in the royalty base over the entire time period at issue.

Finally, even if a rational jury could extrapolate from such a tiny sample at one point in time to the entire universe of Marvell's chips and sales across the entire period, the "premium" calculated by Ms. Lawton contravenes this Court's settled apportionment requirement. *See supra* Part III.A. Ms. Lawton did not differentiate the value of the *asserted algorithm* from the value of *Marvell's implementation in silicon*, nor credit Marvell with so much as a penny for the undisputed value of its own contributions—even though it was undisputed that

[23] At trial, Ms. Lawton testified that Marvell's margins on the accused chips increased over time even though "the price is always going down" (A43347-48), but no evidence supports any margin increase relative to non-accused chips that would offset the drop in price. To the contrary, margins for non-accused chips were the same as or higher than margins for accused chips during the relevant time period. A43481-82; A54443.

making a commercially viable circuit to implement the patented method "require[d] effort by Marvell's engineers" (A43471-72; *see* A46093).

Indeed, the record fails to support the inference that the "operating profit premium" was even attributable *to MNP* (*i.e.*, the CMU-patented method *plus* Marvell-designed hardware), much less to its allegedly patented aspects. Ms. Lawton testified that she understood MNP to be a "key" or "principal" difference between the Maxtor chips she compared in calculating the "premium" (A43334:2-13; A43339-40),[24] but she failed to analyze, much less account for, the value attributable to additional features apart from the MNP (A43471-73) like Marvell's "flagship" ten-bit error-correction code, which was introduced into Marvell's chips at the same time as the MNP (A44807-08; A42243:15-18; A44449-50). In contrast, when comparing theToshiba chips that yielded a $.06 "premium" (Part Nos. 88C5575 and 88C5575M), Ms. Lawton testified that MNP was the "only" difference. A43334-40; A32800. Thus, far from setting the lower bound of the range of any price "premiums" for the patented method, the $.06 Toshiba "premium" should have set the upper limit. On this record, any valuation of the MNP (or NLD) in excess of $.06 "encompass[es] components not covered by the patent." *LaserDynamics*, 694 F.3d at 70.

[24] Given her own lack of expertise, *see supra* Part III.A, Ms. Lawton could only cite testimony from Marvell's VP of Marketing, Dr. Armstrong, about comparable criteria (A43328-29; A43335-37) for this proposition.

E. Alternatively, The Damages Award Should Be Vacated And Remanded For New Trial Or Remittitur

For all the above reasons, this Court should reverse and direct entry of judgment for Marvell, or at a minimum direct entry of judgment based on a base that excludes foreign chips and a rate that does not exceed $.06. Alternatively, this Court should vacate and remand for a new trial as to damages or remittitur. The district court erred in instructing the jury to include foreign sales in the royalty base (*see supra* Part III.C.2). And the great weight of the evidence shows that the royalty base is improperly inflated by foreign sales (*see supra* Part III.C); and that the $.50-per-chip royalty rate is orders of magnitude removed from any real-world license values actually obtained or contemplated by CMU for its patents and untethered from any proportional value the claims added to Marvell's chips (*see supra* Parts III.B & D). Moreover, the district court abused its discretion in admitting Ms. Lawton's unreliable testimony (*see supra* Part III.A) and in failing (A261-68; A73) to weigh the evidence for itself in deciding Marvell's new-trial motion.

IV. THE DISTRICT COURT'S $287 MILLION WILLFULNESS ENHANCEMENT SHOULD BE VACATED

The district court's separate enhancement of $287 million (A2) should be vacated, for Marvell had objectively reasonable invalidity and noninfringement defenses that preclude a finding of willfulness and the record fails to support the

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jury's finding of subjective willfulness to which the district court deferred. To adjudge Marvell a willful infringer, the court needed to identify "clear and convincing evidence" that the infringement was both objectively and subjectively willful. *See Seagate*, 497 F.3d at 1371. This requires proof that Marvell "acted despite an objectively high likelihood that its actions constituted infringement of a valid patent," and that "this objectively-defined risk … was either known or so obvious that it should have been known to" Marvell. *Id.* The court decides objective willfulness, as a matter of law, from the vantage point of a reasonable defendant. *Bard*, 682 F.3d at 1006-07; *iLOR, LLC v. Google, Inc.*, 631 F.3d 1372, 1377 (Fed. Cir. 2011). "[W]here an accused infringer relies on a reasonable defense to a charge of infringement," objective willfulness rarely exists. *Spine Solutions, Inc. v. Medtronic Sofamor Danek USA, Inc.*, 620 F.3d 1305, 1319 (Fed. Cir. 2010).

A. Marvell Had Objectively Reasonable Invalidity And Noninfringement Defenses

First, Marvell had an objectively reasonable invalidity defense (*see supra* Part I), particularly in light of the court's own acknowledgement that Marvell's invalidity defense made for a "close call" on summary judgment (A7064; A8111 ("[I]t was a close case" on anticipation.)).[25] An invalidity defense that presented a

[25] The court below discounted the importance of the "close call" it confronted by saying: "A defense may be unreasonable even if the Court had

"close call" on anticipation cannot be "objectively baseless." *See, e.g.*, *DePuy Spine, Inc. v. Medtronic Solamor Danek*, Inc., 567 F.3d 1314, 1336-37 (Fed. Cir. 2009); *Cohesive Techs., Inc. v. Waters Corp*., 543 F.3d 1351, 1374 n.4 (Fed. Cir. 2008); *Apple, Inc. v. Samsung Elecs. Co.*, 920 F. Supp. 2d 1079, 1109-10 (N.D. Cal. 2013); *see also Spine Solutions*, 620 F.3d at 1319-20. The district court erred by nonetheless deferring *to the jury* on objective willfulness, first sending the question to the jury and then treating "the reasonableness of [Marvell's] reliance on [its] invalidity defense [as] the prerogative of the jury." A227. This Court has reserved the question of objective reasonableness for the judge, not the jury, to decide. *See Power Integrations*, 711 F.3d at 1356-57; *Bard*, 682 F.3d at 1007.

This Court has instructed further that, "[u]nder … *Seagate*, objective baselessness 'does not depend on the plaintiff's state of mind at the time the action was commenced, but rather requires an objective assessment of the merits.' State of mind is irrelevant to the objective [willfulness] inquiry." *iLOR*, 631 F.3d at 1377 (citation omitted); *see also Bard,* 682 F.3d at 1008; *DePuy Spine,* 567 F.3d at 1336. The district court thus further erred in demanding proof that Marvell had *subjectively* envisioned its objectively reasonable defense when it infringed (A227),

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earlier found there to be genuine dispute of materials facts." A226. But that elides the critical point, which is *not* that the court found (as is typical) a "genuine dispute of material facts" but that it nearly found Marvell's invalidity defense so strong as to *foreclose* any such dispute.

faulting Marvell for maintaining attorney-client privilege rather than "raising advice of counsel as a defense to the willfulness claims" (A222). Defendants may not be penalized on an objective willfulness analysis for invoking a legitimate privilege and declining to present proof of the specific defenses their counsel may have identified for them. *See Knorr-Bremse Systeme Fuer Nutzfahrzeuge GmbH v. Dana Corp.*, 383 F.3d 1337, 1341 (Fed. Cir. 2004) (*en banc*) (jury is not permitted to draw adverse inference from "failure to obtain or produce an exculpatory opinion of counsel"); *Insituform Technologies, Inc. v. CAT Contracting, Inc.*, 385 F.3d 1360, 1377 (Fed. Cir. 2004).

In addition, the district court erred (A228) in faulting Marvell for not presenting certain aspects of its invalidity defense to the jury at trial, including the one she had characterized pre-trial as making for a "close call."[26] But that is irrelevant: Objective willfulness is a question for the court, not the jury, and the district court should not have flip-flopped on the *legal* merits of Marvell's invalidity defense solely because the jury did not pass on that defense *factually*. *See, e.g.*, *Lee v. Mike's Novelties, Inc.*, 543 F. App'x 1010, 1017 (Fed. Cir. 2013) ("Because the objective inquiry is a question of law, if the court decides that 'the infringer's reliance on a defense was not objectively reckless, it cannot send the

[26] Marvell sought summary judgment of anticipation based on Worstell's "further modified" disclosure, as discussed herein, but the court declined to address the argument, focusing instead on a separate tap weight argument.

question of willfulness to the jury.'") (quoting *Powell*, 663 F.3d at 1236); *Spine Solutions*, 620 F.3d at 1319-20 (reversing denial of JMOL on willfulness given finding elsewhere that defendant's "obviousness arguments were 'reasonable'").

Second, Marvell's noninfringement defenses are at the very least reasonable, thereby independently defeating objective willfulness. *See Uniloc,* 632 F.3d at 1310 ("If the accused infringer's position is susceptible to a reasonable conclusion of no infringement, the first prong of *Seagate* cannot be met."). Objective willfulness is negated by CMU's own inventors' pre-suit admissions about what they invented. *See* A53700-01; A41541-46; *see also* A53846; A53851; A54316.

B. The Record Fails To Support Subjective Willfulness

Although the Court need not separately reach the issue of subjective willfulness in order to reverse, there is insufficient evidence to support the judgment below on this point. The record demonstrates that Marvell took care to work around Kavcic's algorithm en route to its own patentable solution. To be sure, Marvell evaluated Dr. Kavcic's algorithm when designing the MNP, determining that the algorithm was too complex and not commercially viable. A54259-67; A42080-82; A43905-06; A43920-21; A44716-20; A46140. That is why Marvell then diverged in its approach, developed what it believed to be a distinct technology, sought a patent for it, and in its provisional application expressly acknowledged and distinguished Kavcic's detector. A54264-67. Indeed, Marvell's patent references Kavcic's patents and papers on the first page. A53793.

Marvell's open approach to pursuing and patenting its own invention over that of CMU (A53793; A54259-67; A44054) is incompatible with any finding of willful infringement. Even assuming *arguendo* that Marvell was somehow mistaken as a technical matter that its post-processor implementation in silicon diverged from what Kavcic described and CMU patented, it cannot follow that it was subjectively willful.

V. THE DISTRICT COURT'S AWARD OF $620 MILLION IN PRE-SUIT DAMAGES SHOULD BE VACATED AS FORECLOSED BY LACHES

In an order entered January 14, 2014 (A76-148), the district court expressly found that CMU had engaged in "unreasonable and inexcusable delay" (A129-30; *see* A119) by waiting to sue for nearly six years after it had notice of possible infringement; as the court noted, CMU "did not conduct a reasonable investigation" in 2003,[27] and even when it received "additional information concerning Marvell's potential infringement, it "did not change its position in any meaningful way" (A114-16). The court also found that Marvell was prejudiced by that delay. A130-36. CMU's inventors "purged" evidence that could have

[27] In fact, because CMU suspected Marvell of infringement in 2001 (A41271:12-72:4; A54315-16), its delay properly dates back even earlier to more than six years before it filed suit.

bolstered Marvell's defenses (A79; A132-34), and Marvell invested millions in R&D related to the accused products (A137-38). Those developments might have been obviated had CMU made timely infringement allegations. While conceding that laches would otherwise attach under the traditional factors (A143-44), the court below nonetheless found laches foreclosed (A144-48) on the supposed ground that "the equities clearly favor CMU, which acted negligently in delaying to enforce its patents against Marvell, rather than Marvell, which copied CMU's patents consciously and deliberately for an entire decade" (A145).

That was legal error. As explained above, far from undertaking "particularly "particularly egregious conduct" (A144-45), Marvell submitted its own different, practical solution in a publicly filed patent. But even accepting the district court's erroneous conclusion *arguendo*, laches should *still* bar pre-suit damages as a matter of law, for Marvell's alleged misconduct had nothing to do with CMU's delay in filing suit.

The court's reliance on Marvell's supposed inequitable conduct in respects *wholly divorced* from CMU's relevant delay contravenes this Court's ruling in *Serdarevic*, which held that "a plaintiff relying on the unclean hands doctrine to defeat a defense of laches must show not only that the defendant engaged in misconduct, but moreover that ***the defendant's misconduct was responsible for***

the plaintiff's delay in bringing suit." 532 F.3d at 1361 (emphasis added).[28] In this case, there is no evidence that Marvell behaved surreptitiously in an effort to deceive CMU, to lull it into complacency, or to capitalize on its trust. A144-48. To the contrary, Marvell openly patented its own technology (A53793-804; A53807-26), and, in doing so, even disclosed its references to Kavcic, without making any misrepresentations or frustrating any inquiries by CMU. As the district court acknowledged, "CMU did not conduct an actual investigation which was thwarted by Marvell's policies and was never misled by Marvell." A122. Thus, CMU's delay was a far cry from being the predictable or desired result of Marvell's alleged misconduct; the two had nothing to do with each other. In such a case, a district court does not have discretion to suspend laches as a defense.

Similarly, this Court has held that, where an accused infringer was openly infringing, even the allegedly "willful nature of the defendants' alleged infringement" will not excuse untimely suit. *Hall v. Aqua Queen Mfg., Inc.*, 93 F.3d 1548, 1554-55 (Fed. Cir. 1996) (affirming grant of summary judgment on laches where willful infringement contentions remained outstanding). Accepting CMU's theory as ultimately advanced, it had ample basis to complain of infringement long before it sued. It follows that CMU has only itself to blame for

[28] Although *Serdarevic*'s laches ruling arose in the context of an inventorship dispute, its reasoning as to the doctrine applies with equal force here.

its delay, just as the court below found. *See Gossen Corp. v. Marley Mouldings, Inc.*, 977 F. Supp. 1346, 1352 (E.D. Wis. 1997) ("[E]gregious copying … should have been an impetus for Gossen to file a timely suit rather than an excuse for delay.").

To suspend laches in a case like this would effectively reward gamesmanship and invite calculated delay by patent-holders that may prefer to sit silent about infringement allegations (while accruing claims for astronomical royalties) instead of promptly pressing suspected infringers to license their patents on actually prevailing market terms. In these circumstances, the district court was obliged to hold that laches limits CMU's recovery to post-suit damages, and this Court should at a minimum direct entry of judgment reducing the award by $620 million.[29]

CONCLUSION

The judgment should be reversed. In the alternative, the judgment should be vacated and the case remanded for a new trial.

[29] If this Court reverses the district court's willfulness finding (see Part IV, *supra*), it should likewise reverse the district court's laches ruling (which depends on the conclusion that Marvell engaged in "particularly egregious conduct" through "conscious and deliberate copying" (A144-45)), thereby tilting the equities back in Marvell's favor even by the district court's reasoning.

Dated: August 4, 2014

Respectfully submitted,

By: /s/ Kathleen M. Sullivan

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ADDENDUM

ADDENDUM

Final Judgment (A1-3)	Final Judgment of May 7, 2014
Opinion (Liability, Damages & Willfulness) (A149-274)	Opinion denying Marvell's Motion for Judgment as a Matter of Law, or in the Alternative, Motion for New Trial On Non-Damages Issues; Marvell's Motion for Judgment as a Matter of Law, New Trial And/Or Remittitur With Respect To Damages; and granting, in part, CMU's Motion for a Finding of Willful Infringement and Enhanced Damages, and reserving ruling on enhancement
Opinion (Enhancement) (A4-75)	Opinion granting-in-part and denying-in-part CMU's Motion for a Finding of Willful Infringement and Enhanced Damages
Opinion (Laches) (A76-148)	Opinion denying Marvell's Motion for Judgment of Laches
839 Patent (A439-59)	U.S. Patent No. 6,201,839
180 Patent (A460-82)	U.S. Patent No. 6,438,180

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Final Judgment of May 7, 2014

(A1-3)

IN THE UNITED STATES DISTRICT COURT
FOR THE WESTERN DISTRICT OF PENNSYLVANIA

CARNEGIE MELLON UNIVERSITY, Plaintiff, v. MARVELL TECHNOLOGY GROUP, LTD., and MARVELL SEMICONDUCTOR, INC., Defendants.	)))))))))	Civil Action No. 2:09-cv-00290-NBF

<u>FINAL JUDGMENT</u>

AND NOW, this 7th day of May, 2014, pursuant to Rules 54 and 58 of the Federal Rules of Civil Procedure, and in accordance with the Court's pre-trial and post-trial Orders awarding judgment on certain claims and defenses, (Docket Nos. 420, 443, 444, 901, 902, 920, 921, 933, 934), and the jury's verdict, (Docket Nos. 762, 769), the Court **ORDERS AND ENTERS FINAL JUDGMENT** as follows:

1. For Plaintiff Carnegie Mellon University and against Defendants Marvell Technology Group, Ltd. and Marvell Semiconductor, Inc. (collectively, "Defendants" or "Marvell") for infringement of claim 4 of U.S. Patent No. 6,201,839 B1 ("'839 Patent") and claim 2 of U.S. Patent No. 6,438,180 B1 ("'180 Patent"), (collectively, the "Patents") under 35 U.S.C. §§ 271 (a), (b) and (c), upon the jury's verdict of December 26, 2012. (Docket Nos. 762, 769).

2. For Marvell and against Carnegie Mellon University for non-infringement of claims 11, 16, 19 and 23 of the '839 Patent and claim 6 of the '180 Patent, the Court having granted summary judgment in favor of Marvell as to same on August 24, 2012. (Docket Nos. 443, 444).

3. For Carnegie Mellon University and against Marvell on Carnegie Mellon University's claim for willful infringement of claim 4 of the '839 Patent and claim 2 of the '180 Patent, the

Court having granted same in Memorandum Opinions and Orders issued on September 23, 2013 and March 31, 2014, after considering the jury's advisory verdict finding willful infringement on December 26, 2102. (Docket Nos. 762, 769, 901, 902, 933, 934).

4. For Carnegie Mellon University and against Marvell on its affirmative defense of laches, the Court having denied same in a Memorandum Opinion and Order issued on January 14, 2014. (Docket Nos. 920, 921).

5. For Carnegie Mellon University and against Marvell on its remaining counterclaims for declaratory judgment of non-infringement and invalidity of the Patents, upon the Court's Order of June 7, 2012, (Docket No. 420), granting Carnegie Mellon's motion for partial summary judgment as to Marvell's sixth affirmative defense and its fifth and sixth counterclaims, and the jury's verdict of December 26, 2012, (Docket Nos. 762, 769). Those counterclaims and affirmative defenses shall be and hereby are dismissed, with prejudice.

6. For Marvell and against Carnegie Mellon University on the remaining claims of the Patents which were alleged to be infringed in its Complaint (Docket No. 1), but were not tried before the jury. Such claims shall be and hereby are dismissed, with prejudice.

IT IS FURTHER ORDERED that Plaintiff shall have and recover from Defendants the total sum of $1,535,889,387.60, which includes: the jury's verdict of $1,169,140,271; supplemental damages of $79,550,288.00 for the period from July 29, 2012 through and including January 14, 2013; enhanced damages of $287,198,828.60 (calculated using an enhanced damages factor of 1.23 applied to the sum of the jury's verdict and the supplemental damages); together with post-judgment interest on the $1,248,690,559.00 reflected by the jury's verdict plus supplemental damages calculated at the rate of 0.14% compounded annually from and after January 14, 2013. (Docket Nos. 762, 769, 901, 902, 933, 934).

IT IS FURTHER ORDERED that, for any continuing infringement during the time period commencing on January 15, 2013 until the expiration of the Patents, an ongoing royalty shall be awarded and calculated at the rate of $0.50 for each MNP-type chip or NLD-type chip sold by Marvell. To this end, the parties shall meet and confer and provide the Court with a joint status report regarding any continuing infringement by **5:00 p.m. on August 1, 2014**, detailing all of Marvell's U.S. and overseas (worldwide) sales for the period of April 16, 2014 until as close to August 1, 2014, as possible. The parties shall then proceed to file quarterly joint status reports containing the same information for subsequent periods as set forth in the Court's March 31, 2014 Order. (Docket No. 934). To the extent that the parties agree to more comprehensive or convenient terms, they shall promptly notify the Court of any such agreement. To the extent that this process engenders disputes, a Special Master shall be appointed after consultation with the parties.

All relief not specifically granted herein is **DENIED**. This is a Final Judgment. The Court retains jurisdiction to enforce this Final Judgment.

BY THE COURT:

s/Nora Barry Fischer
Nora Barry Fischer
United States District Judge

cc/ecf: All counsel of record.

Opinion (Liability, Damages & Willfulness)

(A149-274)

IN THE UNITED STATES DISTRICT COURT
FOR THE WESTERN DISTRICT OF PENNSYLVANIA

CARNEGIE MELLON UNIVERSITY, Plaintiff, vs. MARVELL TECHNOLOGY GROUP, LTD. et al., Defendants.	))))))))))	Civil Action No. 09-290 Judge Nora Barry Fischer

OPINION

I. INTRODUCTION

This is a patent infringement case brought by Plaintiff, Carnegie Mellon University ("CMU"), against Defendants Marvell Technology Group, Ltd. and Marvell Semiconductor, Inc. (collectively "Marvell"), alleging that Marvell has infringed two of its patents, U.S. Patent Nos. 6,201,839 (the "'839 Patent") and 6,438,180 (the "'180 Patent") (collectively, the "CMU Patents"). CMU contends that Marvell's infringement was willful. (Docket No. 461). Marvell counters that the CMU Patents are invalid. (Docket No. 465). This matter was tried before a jury for four weeks, with jury selection starting on November 26, 2012. (Docket No. 760). A number of motions for Judgment as a Matter of Law ("JMOL") were made before the verdict was rendered. (Docket Nos. 699; 701; 703; 731; 738; 740; 742; 747). The Court denied these motions on the record[1] on December 21, 2012. (Docket No. 759). The case was then presented to the jury. After deliberations, the jury entered a verdict on December 26, 2012 in favor of CMU on infringement, validity, and willfulness, awarding damages in the amount of $1,169,140,271.00. (Docket No. 762).

[1] Rather than state its reasons on the record, the parties requested the Court articulate its denial in a written opinion. (Docket No. 764 at 99).

Following the trial, the Court entertained post-trial motions, wherein the parties: (1) renewed their earlier JMOL contentions; (2) moved for a new trial on several grounds; (3) argued the equitable defense of laches; and (4) requested a permanent injunction, post-judgment royalties, supplemental damages, interest, enhanced damages, as well as attorney fees.[2] (Docket Nos. 786-811). These matters have been completely briefed (Docket Nos. 823-829; 832-837; 849-855; 857-863), and the Court heard argument on same from May 1 through May 2, 2013. (Docket No. 873).[3] The Court writes now to explain its reasoning for denying the pre-verdict motions for JMOL, and to rule on the renewed JMOLs, the Motions for New Trial, and Motion for a Remittitur.

II. FACTUAL BACKGROUND[4]

A. Technology in Suit

The patents-in-suit are generally directed to the method of sequence detection in high density magnetic recording sequence detectors. *See* '839 Patent col.16 ll.20-23.

1. Hard Disk Drive Data Recordings

Hard disk drives ("HDD") contain a platter or disk that holds data on concentric tracks. (Docket No. 673 at 154). The device bears a visual resemblance to the classic record player. (*Id.*). Just as a record player has a needle attached to the tip of the arm, an HDD has a "read head" that reads and writes data onto these tracks. (*Id.*). Each track is made up of a track width, and this track width is broken into millions of bit regions. (*Id.*). The track is made of magnetic

2 The Court has denied CMU's request for Attorney Fees, without prejudice. (Docket No. 884).

3 The parties had also filed their hearing slides. (Docket Nos. 874; 875). The transcript of these proceedings was then filed on May 15, 2013. (Docket Nos. 880; 881). In August, they provided a joint status report with an update on pertinent technology and financial information as well as a notice of related case authority. (Docket Nos. 889; 891; 893; 896; 897).

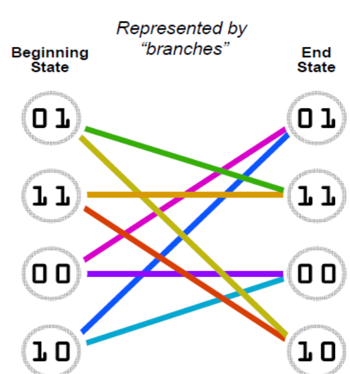
4 The Court now sets forth the pertinent facts for a general understanding of the case. Later in this Opinion, the Court will discuss additional evidence as it relates to a particular issue. The Court is mindful that in deciding a motion for judgment as a matter of law, the Court must view the evidence in the light most favorable to the non-moving party. *Galena v. Leone*, 638 F.3d 186, 196 (3d Cir. 2011).

material. (*Id.*). The bit regions are magnetized to store data in the form of "zeros" and "ones." (*Id.*). As the track moves underneath the read head, the read head picks up the fields emanated from these magnetic regions on the track and turns the fields into read back signal samples. (*Id.* at 155). However, the read back signal samples are not exactly equal to what is actually written on the disk. (*Id.* at 156). For instance, the read back signal may read "0.3" when a "zero" was written on the track. (*Id.*). These discrepancies occurring during the read back process are referred to as "noise." (*Id.*).

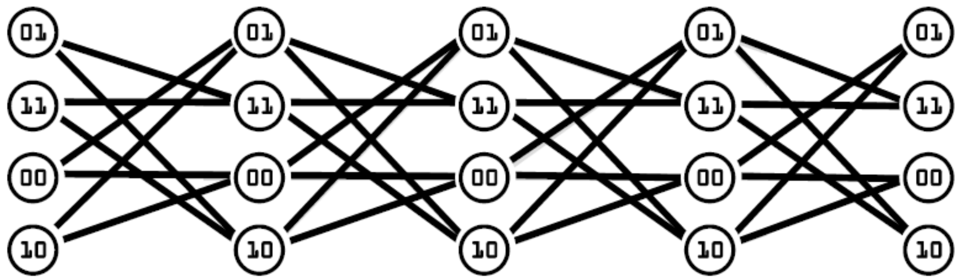
2. Viterbi-Like Detector and the Trellis Concept

A Viterbi-like read channel detector found in the HDD takes the read back signal samples and determines the sequence of symbols written on the disk using a trellis. (*Id.* at 157-158). This process is called "sequence detection." (*Id.* at 158). A trellis section is used to represent a string of bits sitting on a medium. (*Id.*). There are four potential sequences of two bits, called states: 01, 11, 00, 10; and they can be connected by branches. (*Id.* at 162-163).

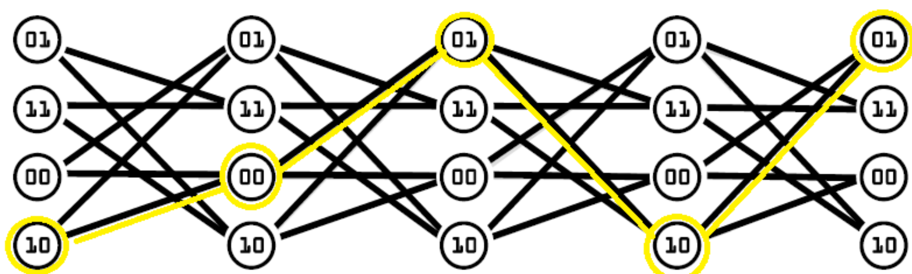
A trellis is used to represent a string of these bits; for example, a three-bit string of 011, would be represented by a "01" connected by a branch to "11." (*Id.*). One trellis section includes all possible bit sequences. (*Id.*). In this instance, a single trellis section of 011, 010, 111, 110, 001, 000, 101, 100 is represented as follows:



(Docket No. 771 at Ex. C at14). A trellis can then be created to represent a sequence of any length. For example, a six bit sequence is represented as follows:



(*Id.* at 18). Through this trellis, one can trace a path that is equivalent to a specific sequence of symbols. (*Id.*). For example 100101, is shown below:



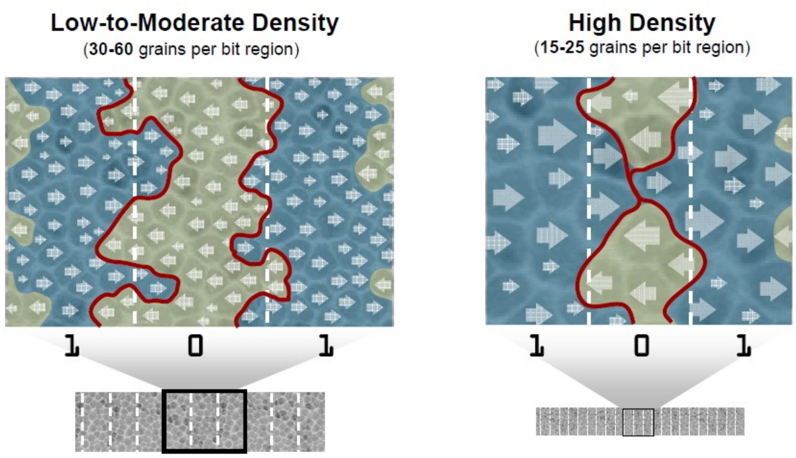
(*Id.* at 17).

The detector determines the "best path" through the trellis, meaning the best or most likely written sequence on the disk, using branch metric values. (Docket No. 673 at 169). The read back signal samples are taken by the detector to compute the branch metric.[5] (*Id.* at 170). The path with the lowest branch metric values becomes the detected sequence. (*Id.*). Thus, the detector calculates the path with the lowest cumulative branch metric value to determine the detected sequence of zeros and ones written on the disk. (*Id.* at 172).

[5] One form of computation uses Euclidean branch metrics, which would be = (r – (the bit value of either zero or one at the point in the trellis))^2. (Docket No. 673 at 171). A read back signal of .3 would result in $(.3 - 0)^2 = .09$ or $(.3 - 1)^2 = .49$. (*Id.*). Whichever option gives a value closest to "zero" represents the best guess. In this example, the read back signal most likely represents a "zero" on the drive. (*Id.*). If the "r" value was .9, the branch metric would be $(.9 - 0)^2 = .81$ or $(.9 - 1)^2 = .01$, and the likely signal on the disk is a "one." As indicated at trial, the magnetic recording disk drive industry no longer uses Euclidean branch metrics. (*Id.*).

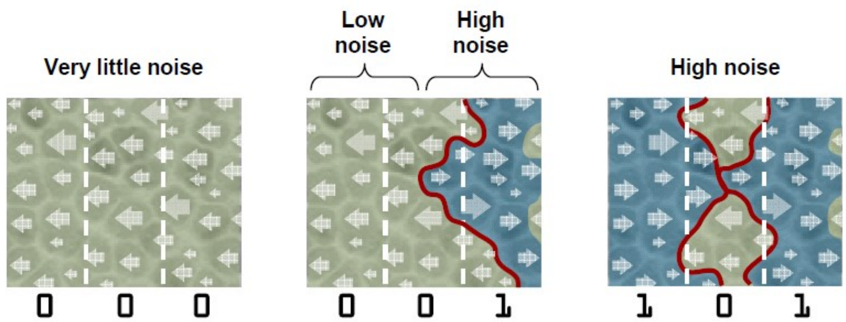
3. Noise

Bit regions are not homogenous. (*Id.* at 175). Rather, they are made up of small tiles or magnetic grains that create regions of magnetization that do not fall within straight bit regions on the track. (*Id.*). As the bit regions become narrower in high density recording and more bits are packed onto a smaller area, there will be fewer grains per bit region. (*Id.* at 176). With fewer grains, islands of grains may develop in which the detector cannot accurately read the data. (*Id.* at 176-177). This is shown below in a diagram in which green represents "zeros," and blue represents "ones."[6]



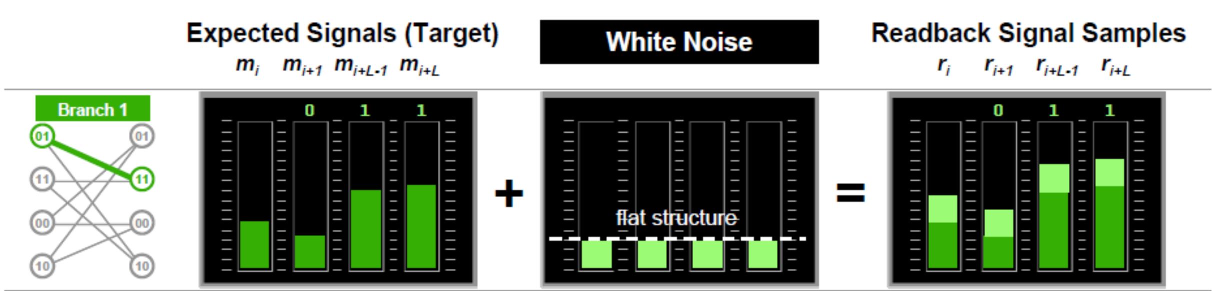
(Docket No. 771 at Ex. C at 24). So, as the density of the recording increases, the amount of noise or uncertainty in the signal also increases. (Docket No. 673 at 179). As seen below, the amount of noise is also affected by the specific sequence of bits written on the track.

[6] The Court notes that these figures represent how the technology was presented to the jury in teaching this difficult area of technology. Accordingly, they are simplified explanations. The technology tutorial materials contain more in-depth explanations of the technology. *See* (Docket Nos. 108; 109).

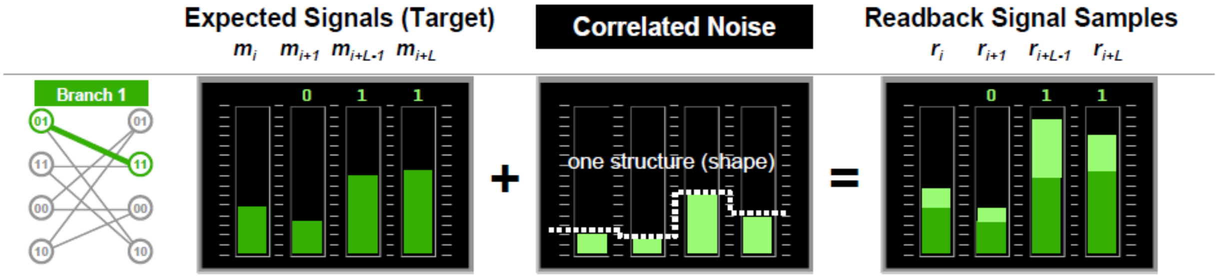


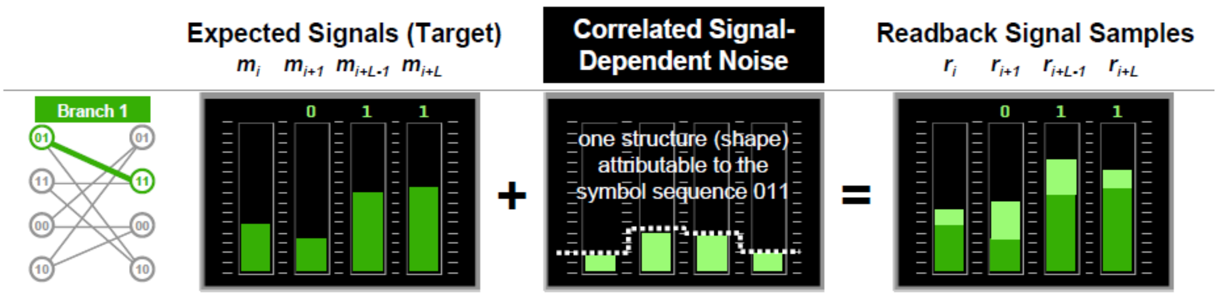
(Docket No. 771 at Ex. C at 25). This is correlated signal-dependent noise, because the noise signals from one boundary to the other move together, either attracting or moving away from each other. (Docket No. 673 at 179).

Noise was previously assumed to be white, or flat, at all time instances and in all branches.[7] (*Id.* at 183-184). Using this noise assumption in determining disk signals worked in the low density environment of the 1970s and 1980s. (*Id.* at 184). A Viterbi-like detector computed Euclidean branch metric values based on the assumption that the noise was white. (*Id.*). Next, the industry used another assumption, that of correlated noise, where the noise had structure but the structure was the same regardless of the symbol sequence (i.e., written symbols). (*Id.* at 186). The current assumption is that of correlated signal-dependent noise. (*Id.* at 193). This is media noise in the read back signal, whose noise structure is attributable to a specific sequence of symbols. (*Id.*). Below is a comparison of the three forms:



[7] This is referred to as a white Gaussian noise assumption. (Docket No. 673 at 184).





(Docket No. 771 at Ex. C).

4. The CMU Patents

With the last model of signal-dependent noise, the detected sequence is obtained by maximizing the likelihood function. (Docket No. 673 at 206-207). The CMU Patents start by showing that such a likelihood function is dependent on all the read back signals and all written symbols from the entire disk. (Docket No. 673 at 206-207). This is expressed as:

$$\{\hat{a}_1, \ldots, \hat{a}_N\} = \arg\left[\max_{all\ a_i} f(r_1, \ldots, r_N \mid a_1, \ldots, a_N)\right].$$

‘839 Patent Eq. 1.

As there are billions of symbols on the disk, the likelihood function is broken up into smaller per sample functions. (Docket No. 673 at 208). The CMU Patents derived a function based on the observed signal samples; postulated a sequence of written symbols; then applied certain mathematical manipulations to turn the function into a quotient of a likelihood function, as seen below. (*Id.* at 214-215).

$$\{\hat{a}_1, \ldots, \hat{a}_N\} = \arg\left[\max_{all\ a_i} \prod_{i=1}^{N} f(r_i \mid r_{i+1}, \ldots, r_{i+L}, a_{i-K_l}, \ldots, a_{i+L+K_t})\right]$$

$$\{\hat{a}_1, \ldots, \hat{a}_N\} = \arg\left[\max_{all\ a_i} \prod_{i=1}^{N} \frac{f(r_i, r_{i+1}, \ldots, r_{i+L} | a_{i-K_l}, \ldots, a_{i+L+K_t})}{f(r_{i+1}, \ldots, r_{i+L} | a_{i-K_l}, \ldots, a_{i+L+K_t})}\right]$$

$$\{\hat{a}_1, \ldots, \hat{a}_N\} = \arg\left[\min_{all\ a_i} \log \prod_{i=1}^{N} \frac{f(r_{i+1}, \ldots, r_{i+L} | a_{i-K_l}, \ldots, a_{i+L+K_t})}{f(r_i, r_{i+1}, \ldots, r_{i+L} | a_{i-K_l}, \ldots, a_{i+L+K_t})}\right]$$

$$\{\hat{a}_1, \ldots, \hat{a}_N\} = \arg\left[\min_{all\ a_i} \sum_{i=1}^{N} \log \frac{f(r_{i+1}, \ldots, r_{i+L} | a_{i-K_l}, \ldots, a_{i+L+K_t})}{f(r_i, r_{i+1}, \ldots, r_{i+L} | a_{i-K_l}, \ldots, a_{i+L+K_t})}\right]$$

$$\{\hat{a}_1, \ldots, \hat{a}_N\} = \arg\left[\min_{all\ a_i} \sum_{i=1}^{N} M_i (r_i, r_{i+1}, \ldots, r_{i+L}, a_{i-K_l}, \ldots, a_{i+L+K_t})\right]$$

'839 Patent Eq. 4-6. The resulting function can be used to create different embodiments, as disclosed in the CMU Patents. (Docket No. 673 at 220). One embodiment is called the correlation matrices embodiment, expressed in Equation 13 of the '839 Patent:

$$M_i = \log\frac{\det\ C_i}{\det\ c_i} + \underline{N}_i^T C_i^{-1} \underline{N}_i - \underline{n}_i^T c_i^{-1} \underline{n}_i$$

'839 Patent Eq. 13; (Docket No. 673 at 221).

Another form of embodiment is the Finite Impulse Response ("FIR") embodiment. The FIR filter coefficients operate on a plurality of signal samples and are different for each specific sequence of written symbols. (Docket No. 673 at 225-226). When applied to the FIR embodiment, the coefficients account for the structure of signal dependent noise attributable to that specific sequence. (*Id.* at 227). Once the FIR has been applied to all of the sequences to account for the noise of a specific sequence, a Viterbi-like detector can work on the result. (*Id.* at 228).

As the recording density increases, such detectors become better compared to signal insensitive detectors. (*Id.* at 234). There is little benefit to increasing the amount of data on a disk if it cannot be accurately read. (*Id.* at 90). The patents' solution constitutes the "optimal" detector, such that when the media noise is the dominant factor there is no better solution. (*Id.* at 70-71; Docket No. 677 at 170).

Media noise became increasingly significant as the industry moved from longitudinal to perpendicular recording around 2005. (Docket No. 678 at 53-53, 114, 226).[8] Media noise has become the main limiting factor in accurately reading bits from the disk, with 90% of the noise in read channels coming from media noise. (Docket No. 673 at 54). Consequently, academic institutions and private industry undertook research to address this media noise problem at both a theoretical level and product implementation level. (*Id.* at 40-41, 141; Docket No. 707 at 233).

B. CMU/DSSC Background

Carnegie Mellon University is a leading research university located in Pittsburgh, Pennsylvania, with highly ranked engineering, information technology, and computer science programs. (Docket No. 671 at 187). (*Id.*). Dr. Jared Cohon had been the President of the University since 1997.[9] (*Id.*). In response to the storage industry's decreasing presence in the

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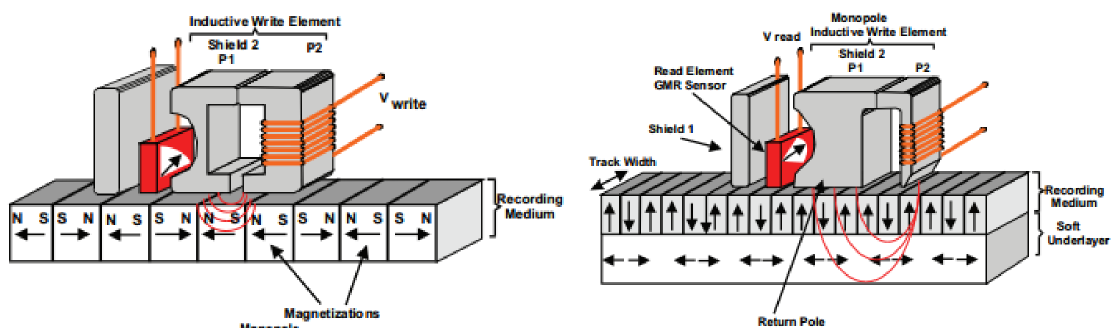
[8] One of CMU's experts, Dr. Bajorek "worked at Komag, between '96 and 2005, [ ] and led the team that developed the perpendicular magnetic recording disk that became standard in the whole industry." (Docket No. 678 at 553-54). Perpendicular recording is where "the information is stored vertically above the surface of the disk, instead of horizontally. And by storing it vertically, you can pack more bits, you can store more data by having denser data on that disk," but the "the price [ ] paid in that transition was to also see a dramatic increase in media noise." (*Id* at 55-56.). Below is picture depicting longitudinal versus perpendicular recording:



See HITACHI GLOBAL STORAGE TECHNOLOGIES, HITACHI RESEARCH AND TECHNOLOGY, available at http://www.hgst.com/tech/techlib.nsf/techdocs/F47BF010A4D29DFD8625716C005B7F34/$file/PMR_white_paper_final.pdf.

[9] Dr. Cohon stepped down from his position as President on July 1, 2013. His successor is Dr. Subra Suresh, former director of the National Science Foundation. *See* CMU WELCOMES PRESIDENT ELECT, at http://www.cmu.edu/homepage/society/2013/winter/cmu-welcomes-president-elect.shtml (last visited September 20, 2013).

United States, CMU created the Magnetics Technology Center (MTC) in 1983 with the support of industrial funding. (Docket No. 682 at 27). In collaboration with the National Science Foundation, the MTC became the Data Storage Systems Center ("DSSC") in 1990. (*Id.*). The DSSC is an interdisciplinary center at CMU, funding long-term research and development through federal grants, university investments, and corporate sponsorship. (Docket No. 682). Since 1983, business partners have become "associate members" of the DSSC, by paying a yearly $250,000 fee, sponsoring faculty chair positions, hiring students and making other investments in the University. (Docket No. 682 at 41-42). DSSC Members at one point or another have included IBM, Seagate, 3M, Hitachi, and Western Digital. (*Id.* at 43-44).

Dr. Mark Kryder[10] testified at trial regarding the history and nature of the DSSC. (*Id.*). Dr. Kryder was the cofounder and director of the DSSC until 1998, when he left to join Seagate where he eventually became the Chief Technology Officer ("CTO"). (*Id.* at 25). Upon retiring from Seagate, he returned to CMU and the DSSC. (*Id.*). According to Dr. Kryder, associate members of the DSSC received disclosures of inventions created in the DSSC and enjoyed a royalty-free license to same. (*Id.* at 43-44). The patents-in-suit were invented within the DSSC. (*Id.* at 43-44). As such, the parties agree that the DSSC members at the relevant time had a royalty-free license to the patents.[11] (*Id.*). However, Marvell was never a DSSC Member. (*Id.* at 42).

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[10] Dr. Kryder is a professor of electrical and computer engineering at CMU. He has a B.S. in electrical engineering and Ph.D. in electrical engineering and physics from the California Institute of Technology ("Cal Tech"). (Docket No. 682 at 25-26). He taught at the University of Regensburg and worked at the IBM TJ Watson Research Center before joining CMU. (*Id.*). His expertise is in magnetic recording heads and media. (*Id.*at 83). He is knowledgeable about signal processing on a high level, but is not an expert in the field. (*Id.*).

[11] The parties debate the relevant time period of the inventions as well as the rights in effect at different points in time. The parties further contest which DSSC companies use (or used) the patents pursuant to their DSSC licenses. (Docket No. 673 at 203-204, 253-257, 268; Docket No. 682 at 161-162, 234-236; 244; Docket No. 726 at 235).

C. Development and Acquisition of CMU Patents

From 1995 to1998, Professor Jose Moura[12] of the Department of Electrical and Computer Engineering and doctoral student Aleksandar Kavcic[13] worked to develop a method for addressing problems in high density and media noise problems related to new generation sequence detectors. (Docket No. 673 at 42). On March 10, 1997, they submitted an invention disclosure form to CMU's technology transfer office regarding same. (Pl. Ex. 156). The provisional patent application was filed in May 1997, with the final patent application being filed on April 3, 1998. (Pl. Ex. 1). This patent which was granted on March 13, 2001 is referred to as the '839 Patent. (*Id.*). On March 1, 1999, they filed for a second patent as a continuation in part of the first. (Pl. Ex. 2). It was granted on August 20, 2002, and it is referred to as the '180 Patent. (*Id.*). In 1998 and 2000, the pair published papers: "Correlation-Sensitive Adaptive Sequence Detection" in IEEE Transactions on Magnetics and "The Viterbi Algorithm and Markov Noise Memory" in IEEE Transactions on Information Theory, describing their work. (Pl. Ex. 169, 183).

In 1998, Aleksandar Kavcic received his Ph.D. and left CMU to join the faculty at Harvard University. (Docket No. 673 at 149). He is currently a professor of electrical engineering at the University of Hawaii. (Docket No. 673 at 149). Dr. Moura remains a professor of electrical engineering at CMU. (*Id.* at 37). Pursuant to CMU's policy, half of any proceeds that CMU realizes on these patents, including from this lawsuit, are split between the inventors, Dr. Kavcic and Dr. Moura. (Docket No. 671 at 194-195).

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[12] Dr. Moura is originally from Mozambique. (Docket No. 673 at 36). He obtained his undergraduate degree in electrical engineering from the Technical University of Lisbon, Portugal, and his Ph.D. from Massachusetts Institute of Technology ("MIT"). (*Id.* at 36-37). He was a professor at the Technical University of Lisbon and MIT, before becoming a professor at CMU in 1986. (*Id.*).

[13] Dr. Kavcic is originally from Yugoslavia and obtained a B.S. in electrical engineering from a university in Germany before receiving his Ph.D. in electrical and computer engineering from CMU. (Docket No. 673 at 149-150).

D. CMU's Marketing of the CMU Patents

CMU's Center for Technology Transfer and Enterprise Creation, currently headed by Robert Wooldridge,[14] is tasked with managing the University's intellectual property. (Docket No. 682 at 96). In August 2003, Carl Mahler, Esq.,[15] a subordinate of Robert Wooldridge, sent fourteen letters to several companies, including Marvell, Toshiba, Western Digital, Fujitsu, Samsung, Hitachi, and Maxtor, asking if they would be interested in licensing the '180 and '839 Patents. (Pl. Ex. 422, 431; Def. Exs. 225; 226; 227; 229; 230; 231; 232; 233; 234; 1573). Not all of these companies make read channel or system-on-a-chip ("SOC") products. (Docket No. 682 at 149-153). Two companies contacted CMU declining to license the technology; the rest never responded. (*Id.*).

CMU entered into a subscription agreement with its long-time corporate partner Intel in September 2004. (Def. Ex. 255). For a yearly administration fee of $75,000, Intel would have the option to license patents from a rotating pool.[16] (Docket No. 682 at 185). If the inventors approved the licensing, Intel could license a patent for a one-time fee of $200,000. (Def. Ex. 255; Docket No. 682 at 183). In early 2005, it was proposed that the '180 Patent join the pool and in an email regarding same, the inventors also expressed interest in having said patent be part of the

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14 Robert Wooldridge is the Director of the Center for Technology Transfer and Enterprise Creation at CMU since 2001 and has been with the Center for approximately fifteen years. (Docket No. 682 at 96).

15 Mr. Mahler was not called as a witness for either party.

16 CMU's relationship with Intel went beyond this subscription agreement. (Docket No. 682 at 97-100). CMU calculated that its partnership with Intel included investment in research, sponsorships, grants, fellowships, and the creation of the Intel Science and Technology Centers on campus. (*Id.*). All of these investments totaled approximately $150 million of funding for the University. (*Id.*).

pool.[17] (Def. Ex. 263). Regardless of the inventors' recommendation, the Patent was not licensed by Intel. (Docket No. 682 at 100).

E. Marvell and Pertinent Staff

A leading fabless semiconductor company, Marvell was founded in 1995 by Dr. Sehat Sutardja,[18] along with his wife, Weili Dai, and brother, Dr. Pantas Sutarjda. (Docket No. 707 at 35). Defendants, Marvell Semiconductor Inc., a California corporation, and Marvell Technology Group, Ltd., a Bermuda corporation, both have their primary place of business in Santa Clara, California. (*Id.* at 29-34). Marvell designs and develops a wide variety of integrated circuit devices, including read channel and SOC devices, used in storage products such as hard disk drives. (*Id.*). Marvell researches, designs, and develops its read channel and SOC products, including the accused products in this case, in Santa Clara. (*Id.*). The company has grown from seven employees to nearly 7,000 employees, and is now a publicly traded company. (*Id.* at 53).

Dr. Sehat Sutardja is the current President and CEO; Ms. Dai is the Vice President and General Manager of Communications and Consumer Business; and Dr. Pantas Sutardja is the Director, Vice President, CTO, and Chief R&D Officer. *See* (Docket No. 707); *see also* MARVELL COMPANY – GLOBAL SEMICONDUCTOR LEADERSHIP, http://investor.marvell.com/ phoenix.zhtml?c=120802&p=irol-govmanage (last visited September 20, 2013). Together these three individuals own 19% of Marvell. (Docket No. 707 at 146). Dr. Alan Armstrong is the Vice President of Marketing, Storage Business Group and was the company's Rule 30(b)(6)

[17] The email from Dr. Moura to the Intel Program Manager states in relevant part "any reason you did not include in this deal the other patent # 6,201,839 … the inventors are the same (Kavcic and Moura) and we both would like this included." (Def. Ex. 263).

[18] Dr. Sutardja is originally from Indonesia. (Docket No. 707 at 36-37). He received his Bachelors in electrical engineering and computer science from Iowa State University, and he obtained his Masters and Ph.D. in electrical engineering and computer science from the University of California, Berkley. (*Id.*). Dr. Sutardja is a member of IEEE, and before starting Marvell, he had worked at Micro Linear and Integrated Information Technology, focusing on chips, digital circuits, and digital signal processors. (*Id.* at 41). He is named the inventor on approximately 300 patents. (*Id.* at 54).

deposition witness regarding same. (Docket No. 707 at 31). Bill Brennan is the former Vice President of Sales, Storage Business Group. (Docket No. 707 at 31). Mr. Michael O'Dell is the worldwide director of field application engineering at Marvell and worked for Mr. Brennan in the early 2000s. (Docket No. 726 at 233).

Relevant engineering employees include Dr. Zining Wu, Gregory Burd, and Toai Doan. Dr. Wu joined Marvell in 1999 after receiving his Ph.D. in Electrical Engineering from Stanford University. (Docket No. 707 at 217-219). Mr. Burd[19] joined Marvell in the same year. (Docket No. 726 at 129). Mr. Doan, was a manager and principal engineer of signal processing and later Vice President of read channel development. (Docket No. 761 at Jt. Ex. D-1 at 1). Mr. Doan left Marvell in October 2009. (*Id.*). Last, Dr. Nersi Nazari was Mr. Burd's acting manager in the early 2000s.[20] (Pl. Exs. 280; 283; 285). Of note, he was also Dr. Kavcic's contact within Marvell. (Def. Ex. 1023). In fact, Dr. Kavcic emailed him in early March 1998, inquiring about Marvell's work on detectors, sending him a link to his recent publications, resume and work, and seeking information on job openings at Marvell. (Def. Ex. 1023).[21]

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19 Mr. Burd is originally from Moscow, Russia, and came to the U.S. at age 18. (Docket No. 726 at 125-130). He obtained a B.S. in mathematics and statistics from the University of Wisconsin, a Masters in mathematics from Oregon State University, and completed some Ph.D. work at the University of Washington before joining Marvell in 1999. (*Id.*).

20 Dr. Nazari was not deposed and he did not appear at trial. Interestingly, he now works at a health care company called Vital Connect, with Mr. Doan and Mr. Brennan. *See* EXECUTIVE TEAM, VITAL CONNECT http://www.vitalconnect.com/executive-team (last visited September 20, 2013).

21 The email reads:

> Hi Nersi, Somebody told me last week at our annual DSSC review here at Carnegie Mellon that Marvell has a detector that implements some of the approaches I suggested in my talk here. It is also in GLOBECOM 98 paper I sent you. Is there a write-up regarding this detector. Also I am going to graduate soon (May) and am on the look for jobs. [*sic*] Is Marvell hiring by any chance. Please let me know. My resume and downloadable publications are on my web page. The URL is …. Thanks, Alex.

(Def. Ex. 1023). The URL is no longer active. (last visited September 20, 2013). This Globecom Paper addresses some of the ideas expressed in the patents, but it is not the IEEE paper later referenced by Burd. (Docket No. 674 at

F. Marvell's Development of Read Channel Products

Both Dr. Wu and Mr. Burd worked to develop new technologies for digital signal processing and read channel technologies. (Docket No. 707 at 221). As discussed, a read channel is situated between a drive's controller and the analog recording head, providing an interface so that digital data can be read from the disk. (*Id.* at 30). As data is packed more tightly onto the disk, errors arise from adjacent data tracks. (*Id.* at 96). The extent to which the error can be corrected limits how much data can be stored on the disk. (Docket No. 707 at 231). Hence, the team at Marvell worked to increase the signal-to-noise ratio ("SNR") in its read channel chips, addressing media noise and other sources of noise, such as asymmetric noise, baseline wander, and thermal noise. (*Id.* at 230-234). One of their earlier projects from around 1999 to 2001 was implementing iterative coding, a different method of improving SNR on chips. (Docket No. 678 at 119). This form of coding was also the basis of Dr. Wu's Ph.D. thesis at Stanford. (Docket No. 707 at 255). However, iterative coding was not initially successful for Marvell.[22] (Docket No. 687 at 119-124). In fact, Mr. Doan called these chips a "lost cause" and Mr. Brennan said many referred to them as "coffee warmer" chips because they used so much power. (*Id.*).

G. MNP/NLD Chip Development

Because iterative coding was not initially successful, the team at Marvell continued to work on other potential solutions to the noise problem. (Docket No. 687 at 119-124). In 2001,

118). In this Court's estimation, it could be inferred that Dr. Nazari gave Dr. Kavcic's work to the Marvell team working in this arena. *Caver v. City of Trenton*, 420 F.3d 243, 262 (3d Cir. 2005) (a Court must view all reasonable inferences in light most favorable to non-moving party when determining the facts on JMOL). The response to this email was not proffered at trial and as such the Court cannot consider the response in deciding the present motion. *See Goodman v. Pennsylvania Tpk. Comm'n*, 293 F.3d 655, 665 (3d Cir. 2002) (on Rule 50 motions the court can only consider properly admitted evidence). Yet, in the hearing on post-trial motions, Marvell presented Dr. Nazari's response, which stated in relevant part that "as far as I know our [*sic*] we do not have a product in line of your work, yet. Yes, we are hiring and I'll read your resume on the web…" (Def. Ex. 1611).

[22] Marvell was not able to install iterative coding on chips until the 2007-2008 time period. (Docket No. 707 at 105-106).

Mr. Burd read the papers by Dr. Kavcic and Dr. Moura explaining their invented method and he began working on developing a "solution" for Marvell based on same. (Docket No. 726 at 137). CMU asserts that Marvell "copied" Dr. Kavcic's method as described in said articles and claimed in the '180 and '839 Patents. (Docket No. 677 at 54-55). In response, Marvell maintained throughout trial that Mr. Burd had developed his own sub-optimal "solution," using Dr. Kavcic's scheme only as a launching pad, as later expressed in Marvell's U.S. Patent Number 6,931,585, which listed the '180 Patent as prior art. (Docket No. 726 at 125-135). The method Mr. Burd developed, originally named KavcicPP, was renamed "MNP" in January 2003 and later incorporated into Marvell's EMNP and NLD technology, all of which are used on read channel chips and SOC chips (collectively, the "Accused Chips"). (Pl. Exs. 368; 823). In connection with same, simulators were developed by Marvell engineers to mimic chips, so that Marvell engineers could run and test the chip systems before producing the chips in silicon. (Docket No. 707 at 113-114). Marvell also ran all of its chips against what it considered the optimal benchmark simulator, called KavcicViterbi. (Docket No. 677 at 171-172; Docket No. 761 at Jt. Ex. D at 137-138). The KavcicPP, MNP, EMNP, and NLD type simulators and the KavcicViterbi simulator are collectively the "Accused Simulators" in this litigation. (Pl. Exs. 89; 99; 106; 108; 110). The Accused Chips and Accused Simulators are collectively referred to as the "Accused Technology."

H. Marvell's Sales of Accused Chips

Read channel chips were dominant until around 2004, when the industry transitioned to SOC-type chips. (Docket No. 707 at 309-311). SOC chips integrated several different blocks,[23]

[23] Other blocks on SOC chips include the central processing unit, the hard drive controller, a servo block controlling the mechanics in the HDD, and the chip level circuit, among others. (Docket No. 707 at 224).

including the read channel block, onto one chip to improve speed, power, and cost. (*Id.* at 226). Today, Marvell has about 800 employees involved in the development of SOC chips. (*Id.*).

CMU alleged infringement by Marvell's MNP, EMNP-type and NLD type chips, encompassing both read channel and SOC chips. (Docket No. 671). All of the Accused Chips were custom made to the exact specifications requested by the customer. (Docket No. 678 at 50-142). As noted, the custom designs and sample engineering chips are developed and tested by using them with the Accused Simulators. Sample engineering chips are produced in Asia and sent back to the United States to be tested by both Marvell and its customers. (Docket No. 678 at 105-106; Docket No. 707 at 164). Once the customer places an order, the chips are put into production at Taiwan Semiconductor Manufacturing Company's ("TSMC") foundry in Taiwan.[24] (Docket No. 707 at 164). Marvell field application engineers then assist the hard drive company to install chips into their product and instruct them on how to use the chips. (Docket No. 677 at 178-179).

As stipulated by the parties, Marvell sells its chips through a lengthy sales cycle, in which Marvell must invest significantly in each customer without the assurance of sales. (Docket No. 707 at 32-35). There is first a 3-6 month period of rigorous evaluation and reliability testing by the customer in a stage called "qualification." (*Id.*). This is followed by a 12-18 month development period and then a 3-6 month period before Marvell commences volume production (i.e. until 1 million units are produced). (*Id.*). Throughout this entire cycle, there is a significant risk the customer will change its mind before the design is selected and the time and expense incurred by Marvell will generate no revenue. (*Id.*). Since a customer usually uses a selected

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[24] A "foundry" is a business that operates a semiconductor fabrication plant (commonly called a "fab") for the purpose of fabricating the designs of other companies. PCMAG ENCYCLOPEDIA, http://www.pcmag.com/encyclopedia/term/43433/foundry (last visited September 20, 2013).

design for a full generation, the loss of a sales win cannot be remedied until the customer develops a new product or new generation. (*Id.*).

During this sales cycle, Marvell engineers assist the customer in implementing the Marvell solutions into its product. (*Id.*). Almost all of this activity, including sales,[25] marketing, evaluation, testing, and development occurs in Santa Clara, California. (*Id.*). The Accused Simulators are used at various points throughout this sales cycle to formulate product concepts and to design, refine and evaluate chip designs. (*Id.* at 45). As CMU's expert witness Dr. Steven McLaughlin testified, the simulators are used for research and development to verify the hardware design for the chip. (Docket No. 677 at 158). Marvell provides the simulation code to its customers so they can evaluate the functionality and performance of a chip design. (*Id.*). Marvell's major customers are Fujitsu, Hitachi/IBM, Maxtor,[26] Samsung, Seagate, Toshiba, and Western Digital.[27] (Docket No. 710 at 243-244). All of these customers go through this process with Marvell at its Santa Clara location. Once the customer is satisfied that the design and testing have met its specifications, the chip designs and engineering samples are sent back to TSMC to begin volume production. (Docket No. 678 at 92).

According to Marvell sales data, between March 6, 2003 and July 28, 2012, Marvell sold 2.34 billion Accused Chips. (Docket No. 686 at 61). The average revenue per accused chip is $4.42, with an average operating profit of $2.16. (*Id.* at 53-54). As noted, the chips are manufactured by TSMC foundry in Taiwan, and then sent to the customers' manufacturing sites in Asia to be put into their HDDs. (Docket No. 710 at 360-361). These HDDs are then sold

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[25] Until his departure from Marvell, Vice President of Sales Mr. Brennan signed off on all deals. (Docket No. 761 at Jt. Ex. C at 7).

[26] Maxtor was bought by Seagate in 2006. (Docket No. 673 at 268).

[27] Teik Ee Yeo and Iftiqar Baqai testified at trial on behalf of Western Digital. (Docket No. 671 at Jt. Ex. B; Docket No. 711).

primarily to laptop manufacturers, which incorporate the HDDs into their products at their own factories. (*Id.*). A portion of the laptops are then imported back into the United States. (*Id.* at 164-165). The locations of the chips' end users are unknown, but CMU presented estimates based on import data calculated by its damages expert that 329,297,799 or 556,812,092 of the 2.34 billion Accused Chips were imported in to the United States. (*Id.* at 165; Docket No. 770-11 at 7).

I. Correspondence Regarding CMU Patents

In January 2002, Mr. Burd sent two emails to Mr. Doan, who was then his boss at Marvell, stating that the Kavcic method was patented and assigned to CMU.[28] (Pl. Exs. 280; 283). The following year, Carl Mahler of the CMU Technology Transfer Office sent out fourteen letters to various technology companies, including two addressed to Marvell personnel Dr. Pantas Sutardja and then-General Counsel Matthew Gloss, encouraging these companies to contact CMU if they were interested in licensing the '180 and the '839 Patents. (Pl. Exs. 422; 431). There was no known response by Marvell to these letters from Mr. Mahler. In 2004, Fujitsu, a read channel customer, wrote a letter to Marvell, stating that it had become aware of the '839 Patent and asked for Marvell's position regarding the relationship between these patents and its own technology. (Pl. Ex. 477). There is no known response to this letter. (Docket No. 761 at Ex. C at 531-535).

J. Parties' Evidence as to Infringement

At trial, CMU maintained that Marvell makes, uses, offers to sell, or sells chips and uses simulators that infringe Claim 4 of the '839 Patent and Claim 2 of the '180 Patent.

Claim 4 of the '839 Patent provides:

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[28] These facts are admitted by both parties and supported by the evidence presented at trial, but the motivations and effect of these points were greatly debated.

> [a] method of determining branch metric values for branches of a trellis for a Viterbi-like detector, comprising:
> selecting a branch metric function for each of the branches at a certain time index from a set of signal-dependent branch metric functions; and
> applying each of said selected functions to a plurality of signal samples to determine the metric value corresponding to the branch for which the applied branch metric was selected wherein each sample corresponds to a different sampling time instant.

'839 Patent col.14 ll.10-19.

Claim 2 of the '180 Patent, incorporates Claim 1. Claims 1 and 2 of the '180 Patent state:

> 1. A method of determining branch metric values in a detector, comprising:
> receiving a plurality of time variant signal samples, the signal samples having one of signal-dependent noise, correlated noise, and both signal dependent and correlated noise associated therewith;
> selecting a branch metric function at a certain time index; and
> applying the selected function to the signal samples to determine the metric values.
> 2. The method claim 1, wherein the branch metric function is selected from a set of signal-dependent branch metric functions.

'180 Patent col.15 ll.39-51.

CMU argued that Marvell's MNP and NLD Chips infringed these claims. CMU also asserted that Marvell's KavcicPP Simulator, MNP Simulator, EMNP Simulator (these three collectively the MNP-Type Simulators), NLD Simulator, and KavcicViterbi Simulator infringed Claim 4 of the '839 Patent and Claim 2 of the '180 Patent.

Counsel for the parties prepared a stipulation on the chip technology, affectionately called the "Chip Stip." (Pl. Ex. 823). The parties agreed that the circuits set forth therein are true and accurate depiction of the circuits within Marvell's products. (*Id.*) The stipulation identified which Marvell read channel and SOC models correspond to each of the stipulated circuits.[29] (*Id.*) CMU submitted the stipulation as evidence of infringement to the jury. (Pl. Ex. 823). Marvell's code for the KavcicPP Simulator (Pl. Ex. 110), MNP Simulator (Pl. Ex. 99), EMNP Simulator (Pl. Ex. 89) (these three collectively, the "MNP-Type Simulators"), NLD Simulator (Pl. Ex. 106), and KavcicViterbi Simulator (Pl. Ex. 108) was also admitted as evidence of infringement.

Further, the parties presented competing expert opinions on infringement. For CMU, Dr. Steven McLaughlin[30] opined that Marvell's chips and simulators infringed CMU's patents. (Docket No. 677). Dr. McLaughlin testified over two days using a PowerPoint presentation with over 130 slides to help demonstrate his infringement analysis.[31] (Docket No. 677-678). In doing so, Dr. McLaughlin analyzed the Chip Stip, Simulator Code, Marvell's technical documents, and relevant deposition testimony from Marvell's engineers in reaching his conclusions. At trial, he broke down both claims into elements and demonstrated to the jury how the circuitry of the MNP Chips and NLD Chips, in addition to the code of the Accused Simulators, infringed each and every step of the two patents. (Docket No. 771). He was clear that as these are method claims, infringement only occurs when the method is actually run on the chips or simulators. (*Id.).*

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29 There are approximately 206 accused Models of chips. *See* (Pl. Ex. 1912; P-Demo at 39; Docket No. 771 at Ex. 19 at 6).

30 Dr. McLaughlin has a Ph.D. in electrical engineering and is currently the chair of the School of Electrical and Computer Engineering at the Georgia Institute of Technology. (Docket No. 677 at 30-31). Dr. McLaughlin's ability to testify as an expert based on his knowledge, skill, experience, training, and education was not challenged by Marvell. (Docket No. 677 at 36). Given the small community focused on this technology, Dr. McLaughlin knows, professionally, Dr. Kavcic, Marvell's Dr. Wu, and both of Marvell's experts Dr. Blahut and Dr. Proakis. (*Id.* at 34). He was previously retained as a Technical Expert by Judge Posner in *Apple v. Motorola*. Civ. No. 11-8540 (N.D. IL). (Docket No. 677 at 35). His experience in this field of art spans from basic research, writing papers, and teaching, to implementation on chips in a commercial setting. (Docket No. 456 at 1). Dr. McLaughlin provided an expert report on his infringement opinions in accord with Rule 26(a) and a deposition on same. *See* (Docket No. 456). The Court accepted him as an expert in signal processing. (Docket No. 677 at 36).

31 The Court acknowledges that the transcript may not always be clear on what parts of a diagram are being described by witnesses, as much testimony included pointing out with a laser pointer certain spots on circuit diagrams that corresponded with elements of the claim. To aid in this endeavor, the Court required the parties to file all demonstratives used during the trial. Dr. McLaughlin's presentation is P-Demo 7. (Docket No. 771 at Ex. H).

Marvell countered with Dr. Richard Blahut,[32] who opined that there was no infringement of the CMU Patents. (Docket No. 711). Dr. Blahut believes that in the Marvell products, the Viterbi algorithm uses a simple branch metric function that uses the same branch metric function on every branch of the trellis, so there is no selecting step as required in the patents. (*Id.* at 244). He also opined that there was no selecting function in the Viterbi detector or post processor; hence, there was no applying step as required by the CMU Patents. (*Id.* at 246).

K. Parties' Evidence as to Invalidity

During trial, Marvell maintained that CMU's Patents were invalid because they were both anticipated[33] and obvious.[34] To this end, Marvell submitted U.S. Patent No. 6,282,251 (the "Worstell Patent") as prior art for purposes of its anticipation defense. (Def. Ex. 187). This patent was filed on March 21, 1995, three years before the CMU Patents were filed. (*Id.*). As further evidence of invalidity, Marvell also presented a 1992 IEEE article by Inkyu Lee and John Cioffi titled "Performance Analysis of the Modified Maximum Likelihood Sequence Detector in the Presence of Data-dependent Noise" and a 1992 IEEE Transactions on Magnetics article by Weining Zeng and Jaekyun Moon titled "Modified Viterbi Algorithm for a Jitter-dominant 1-D2 Channel" (Def. Exs. 37; 38).

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[32] Dr. Blahut is a professor of electrical and computer engineering at the University of Illinois and has received many awards throughout his career. (Docket No. 771 at 207). He has experience with signal processing and read channels, both as an academic and during his time at IBM. (*Id.* at 207-216). Dr. Blahut's opinions went through a *Daubert* challenge prior to trial, after which the Court accepted him as an expert in signal processing and read channel technology. (Docket No. 447).

[33] A patent claim is "invalid for anticipation if a single prior art reference discloses each and every limitation" of the claim. *Schering Corp. v. Geneva Pharm.*, 339 F.3d 1373, 1377 (Fed. Cir. 2003) (emphasis added).

[34] An obviousness analysis measures the difference between the claimed invention and the prior art to determine whether "the subject matter as a whole would have been obvious at the time the invention was made" to a person having ordinary skill in the art. *Alza Corp. v. Mylan Labs., Inc.*, 464 F.3d 1286, 1289 (Fed. Cir. 2006) (citations omitted).

Again, the parties had dueling expert witnesses appear. Dr. John Proakis[35] testified for Marvell, and opined that the CMU Patents were invalid based on the aforementioned prior art. (Docket No. 726). CMU called Dr. McLaughlin in rebuttal to testify on the subject of invalidity. (Docket No. 736). Dr. McLaughlin countered Dr. Proakis' testimony and concluded that the CMU Patents were not invalid based upon the two IEEE articles and/or the Worstell Patent. (*Id.* at 73). CMU also submitted a critical 1997 email from Glen Worstell, stating in relevant part that he:

> had reviewed the 'Correlation Sensitive Adaptive Sequence Detector' patent proposal (i.e. the proposal of the CMU Patents) ... A couple of years ago I did some work on a Viterbi detector modification to account for noise correlation. This invention is related, but goes beyond my work and is probably more interesting.

(Pl. Ex. 161).

L. Damages Evidence

CMU sought money damages from Marvell for infringement, in the form of a $0.50 per chip royalty on all Accused Chips sold by Marvell from March 2003 to the present. CMU proffered evidence that the Accused Technology was "must have" for Marvell and thus the parties would have agreed to this running royalty at a hypothetical negotiation in March 2003.[36] In support of its position, CMU first called Dr. Christopher Bajorek[37] as an industry expert.

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[35] Dr. Proakis is an adjunct professor of U.C. San Diego, and former professor and Chairman of the Department of Electrical and Computer Engineering at Northeastern University. (Docket No. 726 at 53). He has written several textbooks on electrical engineering and signal processing, and consulted for Quantum Corporation and Digital Equipment Corporation designing read channel systems. (*Id.*) The Court accepted him as an expert in digital signal processing and read channel technologies. (*Id.* at 54). CMU did not make any *Daubert* challenges to Dr. Proakis's opinion.

[36] The parties agreed that the hypothetical negotiation would have occurred on March 6, 2003. (Docket No. 686 at 60).

[37] Dr. Bajorek obtained his Ph.D. in electrical engineering from Cal Tech. (Docket No. 678 at 51). He has worked in the HDD industry for 40 years, including at IBM where he worked to commercialize the first Viterbi channel and at Komag as CTO and Vice President. (*Id.* at 52-53). The Court accepted Dr. Bajorek as an expert

(Docket No. 678 at 72-73). Dr. Bajorek opined that Marvell and its customers used the MNP and NLD technologies during the sales cycle; the sales cycle essentially took place in the US; that the MNP and NLD technology had become industry standard;[38] and that the same technology was "must have" for Marvell. (*Id.*). Dr. Bajorek testified that Seagate, IBM, HDST, Samsung, Western Digital, and Toshiba use or previously used the patented technology. (*Id.* at 163-165). Marvell did not counter Dr. Bajorek with a competing expert in his area of expertise.

CMU next called Catherine Lawton[39] as its damages expert. (Docket No. 686 at 29). She stated that Marvell sales data showed sales of 2.34 billion Accused Chips between March 6, 2003 and July 28, 2012. (Docket No. 686 at 61). She then analyzed sales data provided by Marvell to calculate an "excess profits" benchmark of $0.42 per chip and "operating profit premium" benchmark of $0.06 to $0.72 per chip, which she used along with other pertinent facts to arrive at a reasonable royalty of $0.50 per chip. (Docket No. 710 at 170-171). Her analysis is examined in more detail later herein.[40]

CMU also submitted supporting evidence in the form of internal Marvell communications and presentations, including Marvell presentations to customers, deposition testimony from Marvell sales and marketing executives such as Mr. Brennan and Dr. Armstrong,

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witness in the areas of the hard disk drive industry, industry standards, and the use of Marvell's technology as elucidated in his report. (*Id.* at 63). Marvell filed a *Daubert* challenge to Dr. Bajorek which the Court granted, in part, and denied, in part. (Docket No. 445).

[38] A technology becomes "industry standard" when it is adopted by the majority of drive makers for two or more generations of drives. (Docket No. 678 at 108-109).

[39] Ms. Lawton is a damages consultant with Berkeley Research Group. She has a degree in finance and has been working in the field of damages calculation for 27 years, testifying and working on a variety of cases. Marvell filed a *Daubert* challenge to Ms. Lawton which the Court granted, in part, and denied, in part. (Docket No. 451). After a full day of examination on her credentials and experience both before the jury and *in camera*, she was accepted by the Court as an expert in IP damages. (Docket No. 713).

[40] *See* discussion *infra* at Section V.D.4.

as well as the joint stipulation regarding Marvell's sales cycle. (Pl. Exs. 220; 240; 244; 297; 331; 333; 651; 938).

Marvell rebutted this damages calculation by presenting its own damages expert, Creighton Hoffman.[41] (Docket Nos. 709; 710). Mr. Hoffman based his opinion primarily on the DSSC Agreements (Def. Exs. 17; 39; 40), the Intel offer to license (Def. Ex. 255), and his perception of a lack of marketing and licensing of the patents by CMU or their Inventors.[42] (Docket No. 709). His ultimate opinion was that a reasonable royalty in this case would be a one-time royalty payment of $250,000.00. (*Id.* at 242-245). Marvell did not submit any evidence on other licensing agreements or alternative pricing opinions.

M. Evidence of Alleged Willfulness

CMU argued that Marvell's infringement had been willful by submitting evidence of Marvell's internal communication about the patents, including the aforementioned emails from Mr. Burd (Pl. Ex. 280, 283), the letters received from CMU (Pl. Exs. 422; 431), the letter from Fujitsu (Pl. Ex. 477), and deposition testimony of Dr. Wu, Mr. Doan, Dr. Armstrong, and Mr. Burd. *See* (Docket No. 677 at 53-55; Docket No. 761 at Jt. Ex. C, D). CMU also submitted Dr. McLaughlin's expert testimony to the extent that he opined that the MNP was "copied" from the CMU Patents. (Docket No. 677 at 82).

Marvell presented evidence to show that it had not willfully infringed, relying on internal Marvell correspondence and presentations on the Accused Technologies and proof of Marvell's own patents, some of which cite the CMU Patents. (Def. Ex. 266). Marvell also offered portions

41 Mr. Hoffman is a CPA previously employed at Price Waterhouse, now with Hoffman-Alvary, where he primarily deals with intellectual property negotiations and damages consulting. (Docket No. 709 at 105-172). CMU filed a *Daubert* challenge to Mr. Hoffman which the Court granted, in part, and denied, in part. (Docket No. 450). The Court accepted him as a damages expert in the realm of intellectual property damages. (*Id.* at 172).

42 *See* discussion *supra* at Section II.D "CMU's Marketing of the CMU Patents," and the August 5, 2003 CMU letters to which Wooldridge testified that no company expressed any interest in taking a license. (Pl. Exs. 422; 431; Def. Exs. 225; 235; 1573).

of Dr. McLaughlin's deposition testimony to disprove copying from Dr. Kavcic and Dr. Moura, as well as testimony at trial, such as that of Mr. Burd, (Docket No. 726 at 125-126), and Dr. Wu, (Docket No. 707 at 326), who stated they did not copy the CMU Patents. As Dr. Sehat Sutardja testified, Marvell's people "are not stealers." (Docket No. 707 at 92, 326).

N. Jury Verdict

On December 21, 2012 the jury was charged to decide issues of infringement, validity, damages, and willfulness given all of the evidence before it. The jury deliberated for nearly two days to render its verdict, returning on December 26, 2012. (Docket No. 762).

With respect to infringement, the jury found that CMU had proven by a preponderance of the evidence that Marvell's MNP-Type chips, MNP-Type simulators, NLD-Type chips, NLD-Type simulators, and Kavcic-Viterbi simulator literally infringe Claim 4 of the '839 Patent and Claim 2 of the '180 Patent. (*Id.* at Q. 1-10). The jury held that CMU had proven by a preponderance of the evidence that Marvell had induced at least one of its customers or an end user to infringe Claim 4 of the '839 and Claim 2 of the '180 Patent in the United States with both the MNP-Type and NLD-Type Chips. (*Id.* at Q. 11, 13). It additionally found that CMU had proven by a preponderance of the evidence that Marvell contributed to the infringement of Claim 4 of the '839 and Claim 2 of the '180 Patent in the United States by at least one of its customers or an end user with both the MNP-Type and NLD-Type Chips. (*Id.* at Q. 12, 14).

On invalidity, the jury found that Marvell had not proven by clear and convincing evidence that Claim 4 of the '839 and Claim 2 of the '180 were invalid on the grounds that they were anticipated by prior art or because they would have been obvious at the time the invention was made. (*Id.* at Q. 15, 16). After finding that the claims infringed and are not invalid, the jury awarded $1,169,140,271.00 to CMU for the use of the patented methods. (*Id.* at Q. 17).

Regarding willfulness, the jury found that Marvell had actual knowledge of the '180 and '839 Patents prior to commencement of the lawsuit on March 6, 2009. (*Id.* at Q. 19, 22). It determined that Marvell did not have an objectively reasonable defense to CMU's claim of infringement on either the '180 or '839 Patent. (*Id.* at Q. 20, 23). Finally, the jury found that once Marvell learned of the '180 and '839 Patent, there was clear and convincing evidence that Marvell actually knew or should have known that its actions would infringe both Claim 2 of the '180 Patent and Claim 4 of the '839 Patent. (Docket No. 21, 24).

III. PROCEDURAL HISTORY

CMU filed its complaint in this case on March 6, 2009. (Docket No. 1). Since then this case had gone through extensive discovery and motions practice, including a Motion to Transfer[43] (Docket No. 55), Claim Construction[44] (Docket No. 143), and several rounds of Summary Judgment proceedings.[45]

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[43] On July 7, 2009 Marvell filed a Motion to Transfer the case to the Northern District of California, which, after briefing and oral argument, was denied on September 21, 2009. (Docket Nos. 25; 26; 31; 33; 36; 45; 50; 54; 55). Marvell then filed its Amended Answer on April 29, 2010, and CMU filed its Answer and Affirmative Defenses to same on May 28, 2010. (Docket Nos. 116; 127).

[44] The Court held a seven hour Technology Tutorial with the parties' experts Dr. McLaughlin and Dr. Proakis, in preparation for claims construction. (Docket Nos. 104; 143). The Court then held a two day *Markman* hearing. (Docket Nos. 104-106). Upon consideration of the parties' arguments, briefs, and materials submitted in support, as well as with the aid of the Court's Technical Advisor, Dr. Daniel Costello, the Court issued an order on the meaning of the disputed claims. (Docket Nos. 175; 176); *see also Markman v. Westview Instruments, Inc.*, 517 U.S. 370, 377-90 (1996). The Court entered its Pretrial Order on October 10, 2011, scheduling jury selection and trial and setting other pretrial hearings and deadlines. (Docket No. 315); *see also* (Docket Nos. 78; 79; 80; 81; 82; 83; 84; 89; 90; 91; 93; 94; 95; 105; 106; 108; 109; 110; 118; 119; 120; 128; 129; 142; 146).

[45] This Court denied Marvell's First Motion for Partial Summary Judgment of Invalidity of U.S. Patent Nos. 6,201,839 and 6,438,180, its Second Motion for Partial Summary Judgment of Invalidity and subsequent Motion for Reconsideration of said denial of the Second Motion for Partial Summary Judgment upon consideration of the parties' briefs, declarations and oral argument. (Docket Nos. 218; 306; 307; 318; 337; 339; 423). The parties filed their Summary Judgment Motions and *Daubert* Motions, along with briefs, declarations, and statements of facts in support and opposition in the spring of 2012. The Court heard argument on these motions from July 10 through July 11, 2012. (Docket Nos. 433; 438-440). The Court granted, in part, and denied, in part, Marvell's Motions for Partial Summary Judgment of No Infringement and No Damages with Respect to Extraterritorial Conduct and for Partial Summary Judgment of No Infringement and No Damages with Respect to Licensed Use. (Docket Nos. 356; 360; 441; 442). The Court granted Marvell's Motion for Partial Summary Judgment of non-infringement with respect to Claims 11, 16, 19 and 23 of U.S. Patent No. 6,201,839 and Claim 6 of U.S. Patent No. 6,438,180. (Docket Nos. 352; 443; 444). Further, the Court granted, in part, and denied, in part, Marvell's Motion to Exclude the Testimony of

Following the Court's Summary Judgment and *Daubert* rulings, and upon consideration of the parties' pretrial proffers,[46] the Court convened a two-day hearing on October 17 and October 18, 2012 to address nineteen Motions *in limine* (five by CMU and fourteen by Marvell). (Docket Nos. 578; 579; 590; 591). The Court issued rulings shortly thereafter.[47] (Docket Nos. 595; 596; 601; 602; 604; 605; 607-614).

On November 9, 2012, the parties filed their responses to objections to exhibits, responses to objections to deposition designations,[48] joint stipulations, proposed jury instructions, proposed limiting instructions, proposed *voir dire*, and proposed verdict slips.[49] *See* (Docket Nos. 615-626; 640-644). The Court held a lengthy two-day Pretrial Conference on November 14 and 15, 2012, during which objections to exhibits were ruled upon and arguments on trial issues were heard. (Docket Nos. 636; 638; 645; 648; 650; 653). The parties subsequently

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Christopher Bajorek. (Docket Nos. 364; 445; 446). The Court denied CMU's Motion to Exclude Opinion Testimony Regarding Purported Acceptable, Non-Infringing Alternatives. (Docket Nos. 373; 447; 448). CMU's Motion to Exclude Certain Opinion Testimony of Creighton G. Hoffman was granted, in part, and denied, in part. (Docket Nos. 370; 449; 450). Finally, Marvell's Motion to Exclude the Opinions of Catherine M. Lawton was granted, in part, and denied, in part. (Docket Nos. 367; 451; 452).

[46] CMU filed its Pretrial Statement on September 12, 2012, and Marvell filed its modified Pretrial Statement on September 24, 2012. (Docket Nos. 461; 481). Witness Lists and Offers of Proof were filed on October 8, 2012 and October 15, 2012, by CMU and Marvell, respectively. (Docket Nos. 538; 575).

[47] In accordance with the Pretrial Order, on September 24, 2012, the parties filed their Motions *in Limine* with briefs in support, and both filed responses to same on October 9, 2012. (Docket Nos. 483-525; 555-571).

[48] Exhibits, Objections to Exhibits, Reponses to Objections to Exhibits, Deposition Designations, Objections to Deposition Designations, and Responses to Objections to Deposition Designations had been previously submitted but were stricken by the Court's October 24, 2012 Order. (Docket No. 586). The parties had presented the Court with more than 2,700 exhibits and hundreds of deposition designations and counter depositions which they claimed they might use at trial. Through the series of filings, the parties objected to nearly every exhibit, deposition designation, and counter designation of their opponent in some fashion. Accordingly, the Court struck these submissions and ordered the parties to meet and confer to resolve disputes. (Docket No. 586). By November 9, 2012, the parties had narrowed their disputes to 335 exhibits and reserved deposition disputes until the deposition's confirmed use at trial. (Docket Nos. 615-620; 631; 632; 640; 644).

[49] The Court struck the parties proposed final jury instructions and verdict slip for violating the Court's directive to submit joint proposals, as the parties offered only twelve, out of a total thirty-seven, agreed upon proposed jury instructions, few relating to the substantive law in the case, and two completely separate verdict forms. (Docket Nos. 623; 626; 627). The parties were ordered to meet and confer to resolve disputes. On December 19, 2012, the parties submitted joint instructions and verdict slips to the Court by email, and the Court ruled on disputes on the record during the Charge Conference. (Docket No. 764).

submitted trial briefs on the issues of law that would need to be addressed by the Court during trial. (Docket Nos. 647; 652).

Jury selection proceeded as scheduled on November 26, 2012, and trial began on November 28, 2012. (Docket Nos. 666; 669; 671). The Court heard argument, accepted briefing, and ruled on a number of motions made during trial regarding witnesses, exhibits, and points of law.[50] The parties agreed that the Plaintiff, CMU would not rest its case until the conclusion of testimony by three defense witnesses.[51] Once CMU rested its case, Marvell moved for judgment as a matter of law on "Non-infringement," "No Damages," and "No Willful Infringement." (Docket Nos. 703; 701; 699). At the end of Marvell's evidence, CMU moved for "Judgment As a Matter of Law on Marvell's Invalidity Defenses." (Docket No. 731). Following CMU's rebuttal, Marvell filed a Motion for Judgment as a Matter of Law on Invalidity, and renewed its earlier Motions for Judgment as a Matter of Law on Non-Infringement, No Damages, and No Willful Infringement. (Docket Nos. 738; 740; 742; 747). The Court denied these motions on the record

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[50] The Court will not discuss in depth the substance of these motions. *See* (Docket Nos. 656; 672; 679-681; 683-685; 687-698; 705; 712-720; 722-724; 727; 728; 730; 733; 735; 737; 744-746; 751; 753; 755-757) (denying Marvell's request for the Court to submit the issue of laches to the jury on an advisory basis; denying Marvell's Emergency Motion to Strike CMU's Attempt to Include Non-infringing Sales of Chips that Are Never Used in the U.S. in the Damages Case It Intends to Present to the Jury; granting Marvell's Motion for Extension of Time for trial; denying CMU's Motion For Leave to Recall Dr. Kryder; granting in part and denying in part Marvell's Motion to Exclude the Testimony of Catherine Lawton; granting Marvell's Motion for Reconsideration re: Court's Order Sustaining CMU's Objections to Disputed Defendants' Exhibit DX-189; denying Marvell's Oral Motion to "Strike Slide 19 of Plaintiff's Demonstrative and Associated Testimony"; granting in part and denying in part CMU's Rebuttal Witness List/Offers of Proof; denying CMU's Motion to Strike Testimony of Marvell Expert Creighton Hoffman; Plaintiff's Motion to Strike Testimony of Marvell Expert Richard Blahut and Enter Judgment of Infringement for Accused MNP Chips and Simulators; denying Marvell's Motion to Strike Certain Testimony of Catharine M. Lawton; granting in part and denying in part CMU's "Motion in Limine to Strike Testimony and to Preclude Argument Relating to Marvell's Pre-Suit Communications with Counsel"; and denying without prejudice Marvell's Motion for Mistrial).

[51] In accordance with the Court's October 20, 2011 Pretrial Order (Docket No. 315), counsel were limited to twenty hours per side to present their case to the jury. Despite having proposed said time limit, Marvell moved for an extension of trial time. (Docket No. 687). The Court granted said motion, allowing twenty-five hours per side including opening statements, direct examination, cross examinations, and closing arguments. (Docket No. 710). Since the parties were "on the clock," they had a "gentlemen's agreement" that certain witnesses that would have been called by both parties, in the interest of saving time, would only be called once, with cross examination allowed to go beyond the scope of the direct examination. The Court was not privy to this agreement but was told that this agreement applied to the testimony of Marvell engineers: Mr. Doan, Dr. Wu, and Mr. Burd.

(Docket No. 759 at 52-53), with the parties requesting the Court to explain its rulings in written opinions. (Docket No. 764 at 99). The Court then charged the jury on December 21, 2102, and it returned its verdict on December 26, 2012. (Docket No. 762). As noted, the jury found for CMU on infringement, validity, and willfulness, and awarded damages to CMU in the amount of $1,169,140,271.00. (*Id.*). The Court entered the parties' joint proposed form of judgment on January 14, 2013. (Docket No. 769).

Pursuant to the Court's scheduling order, (Docket No. 763), on February 11, 2013, Marvell filed a Motion for Judgment as a Matter of Law or in the Alternative, Motion for New Trial on Non-Damages Issues, specifically for Non-Infringement, Invalidity, No-Willfulness, and CMU Misconduct (Docket Nos. 805; 806), Motion for Judgment as a Matter of Law, Motion for New Trial And/Or Motion for Remittitur with Respect to Damages, (Docket Nos. 807; 808), and Motion for Judgment on Laches. (Docket Nos. 802-04).

CMU moved for "Permanent Injunction, Post Judgment Royalties, and Supplemental Damages" (Docket Nos. 786; 787), "Prejudgment Interest" (Docket Nos. 788; 789), "A Finding of Willful Infringement and Enhanced Damages" (Docket Nos. 790; 793), and "Attorneys' Fees Pursuant to 35 U.S.C. Section 285" (Docket Nos. 794; 810; 811).

These matters have been completely briefed (Docket Nos. 823-829; 832-837; 849-855; 857-863), and the Court heard oral argument on same from May 1 to May 2, 2013. (Docket Nos. 872-874). In earlier opinions, the Court had denied, without prejudice, CMU's Request for Attorneys' Fees (Docket No. 884), and denied Marvell's Motion for a New Trial on the Grounds of CMU Misconduct. (Docket No. 900). The Court now turns to the parties' Motions for JMOL, Motions for a New Trial, and Motion for Remittitur. (Docket Nos. 805; 807).

IV. LEGAL STANDARD[52]

A. Judgment as a Matter of Law

It is well-established that a motion for judgment as a matter of law "should be granted only if, viewing the evidence in the light most favorable to the non-moving party, there is no question of material fact for the jury and any verdict other than the one directed would be erroneous under the governing law." *Galena v. Leone*, 638 F.3d 186, 196 (3d Cir. 2011) (quoting *Beck v. City of Pittsburgh*, 89 F.3d 966, 971 (3d Cir. 1996)).[53] Accordingly, the Court must determine "'whether there are any genuine issues of material fact such that a reasonable jury could return a verdict for [the non-moving party].'" *McGreevy v. Stroup*, 413 F.3d 359, 364 (3d Cir. 2005) (quoting *Debiec v. Cabot Corp.*, 352 F.3d 117, 128 n.3 (3d Cir. 2003)) (alteration in original); *see also Trueman v. City of Upper Chichester*, 289 F. App'x. 529, 540 (3d Cir. 2008) (affirming denial of Rule 50(a) motion because "the jury could not reasonably have found in [the non-movant's] favor on his claim against the [movant]").

In ruling on a Rule 50(a) motion, the Court "must refrain from weighing the evidence, determining the credibility of witnesses, or substituting our own version of the facts for that of the jury." *Eschelman v. Agere Sys.*, 554 F.3d 426, 433 (3d Cir. 2009) (citing *Marra*, 497 F.3d at 300). "Although judgment as a matter of law should be granted sparingly," it should be granted where "the record is critically deficient of the minimum quantum of evidence" necessary to support a verdict in favor of the non-moving party. *Id.* (quoting *Gomez v. Allegheny Health*

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[52] While this is a patent case, Third Circuit law governs the Court's analysis of the parties' motions for judgment as a matter of law and motions for a new trial. *See Leader Technologies, Inc. v. Facebook, Inc.*, 678 F.3d 1300, 1305 (Fed. Cir. 2012), *cert. denied*, 133 S. Ct. 889 (2013).

[53] Courts apply the same standard to motions pursuant to Rule 50(a) and Rule 50(b) of the Federal Rules of Civil Procedure. *See Galena*, 638 F.3d at 196 (reviewing Rule 50(b) motion by using standard articulated in *Beck*, 89 F.3d at 971, which articulated the Rule 50(a) standard); *McDaniels v. Flick*, 59 F.3d 446 (3d Cir. 1995) (applying the same standard to the review of both Rule 50(a) and Rule 50(b) motions); *Foradori v. Harris*, 523 F.3d 477, 485 n.8 (5th Cir. 2008) ("We apply this same 50(a) standard when we review a renewed motion for judgment as a matter of law under 50(b).").

Servs., Inc., 71 F.3d 1079, 1083 (3d Cir. 1995)). To that end, "a scintilla of evidence is not enough" to survive a Rule 50 motion at trial. *Johnson v. Campbell*, 332 F.3d 199, 204 (citing *Goodman v. Pa. Turnpike Comm'n.*, 293 F.3d 655, 664-65 (3d Cir. 2002)). The question is not whether there is literally no evidence supporting the unsuccessful party, but whether there is evidence upon which a reasonable jury could properly find a verdict in favor of the non-moving party. *Gomez*, 71 F.3d at 1083. In other words, "a directed verdict is mandated where the facts and the law will reasonably support only one conclusion." *McDermott Int'l, Inc. v. Wilander*, 498 U.S. 337, 356 (1991) (citation omitted).

B. Motion for New Trial

A motion for a new trial pursuant to Federal Rule of Civil Procedure 59 can be granted "to all or any of the parties and on all or part of the issues in an action in which there has been a trial by jury." FED. R. CIV. P. 59(a). The Court is also "empowered to order a new trial on its own initiative 'for any reason that would justify granting one on a party's motion.'" *Pryer v. C.O. 3 Slavic*, 251 F.3d 448, 453 (3d Cir. 2001) (quoting FED. R. CIV. P. 59(d)). A new trial is most commonly granted in select situations, including: (1) when the jury's verdict is against the clear weight of the evidence; (2) when new evidence surfaces that would have altered the outcome of the trial; (3) when improper conduct on the part of an attorney or the court unfairly influenced the verdict; or (4) where the jury's verdict was facially inconsistent. *Davis v. Mountaire Farms, Inc.*, 598 F. Supp. 2d 582, 587 (D. Del. 2009).

The Court's level of discretion varies, depending on the type of error alleged. *Moussa v. Commonwealth of Pennsylvania Dep't of Pub. Welfare*, 289 F. Supp. 2d 639, 648 (W.D. Pa. 2003) (citing *Klein v. Hollings*, 992 F.2d 1285, 1289-90 (3d Cir. 1993)). When the motion for a new trial is based on the claim that the verdict is against the clear weight of the evidence, the

Court's discretion is limited—the verdict must be "contrary to the great weight of the evidence; that is, where a miscarriage of justice would result if the verdict were to stand." *Pryer*, 251 F.3d at 453. A verdict may not be set aside when there is a plausible or rational basis for the decision. *Moussa*, 289 F. Supp. 2d at 648. The Court must not substitute its own judgment of the facts and assessment of the witnesses' credibility for the jury's. *Davis*, 598 F. Supp. 2d at 587. When the basis for the motion is an alleged error on the part of the court, such as an error in jury instructions or evidentiary rulings, a district court must first determine whether an error was made, i.e., "whether, taken as a whole, the instruction properly apprised the jury of the issues and the applicable law." *Donlin v. Philips Lighting N. Am. Corp.*, 581 F.3d 73, 78 (3d Cir. 2009). If there was an error, the court must then determine "whether that error was so prejudicial that refusal to grant a new trial would be 'inconsistent with substantial justice.'" *Bhaya v. Westinghouse Elec. Corp.*, 709 F. Supp. 600, 601 (E.D. Pa. 1989) (quoting FED. R. CIV. P. 61). "Generally, a party is not entitled to receive a new trial for objections to evidence that he did not make at or prior to the initial trial, even if they may have been successful." *Ashford v. Bartz*, Civ. No. 04-642, 2010 WL 272009, at *4 (M.D. Pa. 2010) (citations omitted); *see also Kiewit Eastern Co., Inc. v. L & R Constr. Co., Inc.*, 44 F.3d 1194, 1204 (3d Cir. 1995) ("Courts often take a dim view of issues raised for the first time in post-judgment motions. Generally, this is a decision within the sound discretion of the district court.").

V. DISCUSSION

With these standards in mind, the Court discerns substantial evidence upon which a reasonable jury could have found in favor of the non-movants for each of the filed Motions challenging the evidence.

A. Infringement

CMU had the burden of proving its claims of direct and indirect infringement pursuant to 35 U.S.C. §§ 271(a), (b) and (c). It alleged that Marvell's chips and simulators infringe Claim 4 of the '839 Patent and Claim 2 of the '180 Patent. To that end, it produced the opinion testimony of Dr. McLaughlin, who testified over the course of two days. (Docket Nos. 677; 678). Against same, Marvell moved for JMOL on the grounds that CMU had not presented sufficient evidence that a reasonable jury could find infringement by Marvell, or, in the alternative, for a new trial. (Docket Nos. 703; 805).

1. Legal Standard

Direct infringement of a U.S. patent occurs when a party, "without authority makes, uses, offers to sell, or sells any patented invention, within the United States." 35 U.S.C. § 271(a). Method claims are not infringed simply by the sale of an apparatus that is capable of infringing use. *Ormco Corp. v. Align Tech., Inc*., 463 F.3d 1299, 1311 (Fed. Cir. 2006); *Standard Havens Products, Inc. v. Gencor Industries, Inc.*, 953 F.2d 1360, 1374 (Fed. Cir. 1991). "Because a process is nothing more than the sequence of actions of which it is comprised, the use of a process necessarily involves doing or performing each of the steps recited." *NTP, Inc. v. Research in Motion, Ltd.*, 418 F.3d 1282, 1318 (Fed. Cir. 2005). Thus, direct infringement of a method claim only occurs if each step of the claimed method is actually performed. *See Muniauction, Inc. v. Thomson Corp*., 532 F.3d 1318, 1328 (Fed. Cir. 2008).

In this case, the only form of direct infringement at issue is literal infringement. Marvell literally infringes if Marvell's chips and simulators use a method that includes each and every method step in Claim 4 of the '839 Patent or Claim 2 of the '180 Patent. *Akamai Techs., Inc. v. Limelight Networks, Inc.*, 692 F.3d 1301, 1307 (Fed. Cir. 2012). If Marvell's methods as employed by its chips and simulators do not contain one or more method steps in that patent claim, Marvell does not directly infringe that claim. *Id.* Accordingly, literal infringement must be determined with respect to each patent claim, individually.

There are also two forms of indirect infringement: inducing infringement and contributory infringement. These modes of infringement are governed, respectively, by 35 U.S.C. § 271(b) and (c).

To prove inducement of infringement and contributory infringement, CMU must first prove there is direct infringement. *Akamai Techs.*, 692 F.3d at 1308. Second, "inducement requires that the alleged infringer knowingly induced infringement and possessed specific intent to encourage another's infringement." *DSU Med. Corp. v. JMS Co.*, 471 F.3d 1293, 1306 (Fed. Cir. 2006) (en banc) (internal quotation marks omitted); *see also Global–Tech Appliances, Inc. v. SEB S.A.*, __ U.S. __, 131 S. Ct. 2060, 2068 (2011). It is enough that the inducer "cause[s], urge[s], <u>encourage</u>[s], or <u>aid</u>[s]" the infringing conduct and that the induced conduct is carried out. *Akamai Techs.*, 692 F.3d at 1308 (internal citations omitted, emphasis added). A defendant must "actively induce" infringement which "require[s] knowledge of the existence of the patent that is infringed" or taking "deliberate actions to avoid confirming a high probability of wrongdoing." *Global-Tech*, 131 S. Ct. at 2068-2070. Thus, induced infringement occurs if Marvell actively induces someone else, such as one of Marvell's customers, to use a method that is covered by Claim 4 of the '839 Patent or Claim 2 of the '180 Patent. *Id.*

To prevail on a claim for contributory infringement, it must be shown that an infringer sold, offered to sell, or imported into the United States a component of an infringing product "knowing [the component] to be especially made or especially adapted for use in an infringement of such patent, and not a staple article or commodity of commerce suitable for substantial non infringing use." 35 U.S.C. § 271(c); *see Lucent Techs. v. Gateway, Inc.*, 580 F.3d 1301, 1320 (Fed. Cir. 2009). Thus, in this instance, contributory infringement occurs if Marvell sold or offered for sale a material component of the patented invention that was not a staple article of commerce, and which Marvell knew was specifically made for use in practicing the claimed methods of either Claim 4 of the '839 Patent or Claim 2 of the '180 Patent. As with induced infringement, a claim for contributory infringement must contain allegations of the requisite knowledge of the patent-in-suit at the time of infringement. *Mallinckrodt*, 670 F. Supp. 2d at 355; *see also Global–Tech*, 131 S. Ct. at 2068. In addition, the patentee bears the burden of proving that the accused products have no substantial non-infringing uses. *See Golden Blount, Inc. v. Robert H. Peterson Co.*, 438 F.3d 1354, 1363 (Fed. Cir. 2006).

Before delving into its analysis, the Court notes that expert testimony is not necessary to prove infringement. In a case involving complex technology, however, the Federal Circuit has "repeatedly approved the use of expert testimony to establish infringement" and indeed "where the accused infringer offers expert testimony negating infringement, the patentee cannot satisfy its burden of proof by relying only on testimony from those who are admittedly not experts in the field." *Centricut, LLC v. Esab Grp., Inc.*, 390 F.3d 1361, 1370 (Fed. Cir. 2004).

In reaching its decision, the Court has considered all of the parties' arguments raised in their briefs and at trial, arguments made at the motion hearing held on May 1 and May 2, 2013, the transcript thereof, and the entire trial record along with the parties' latest submissions. (Docket Nos. 703; 704; 729; 742; 743; 805; 806; 827; 851; 857; 880; 881).

2. Direct Infringement

As the party alleging infringement of the method claims at issue, CMU must demonstrate that Marvell practices every step of the claimed method. *See Muniauction*, 532 F.3d at 1328. At trial, CMU called Dr. Steven McLaughlin to provide expert technical testimony about CMU's patents and whether they are infringed by Marvell's MNP-type chips, NLD type chips, and related simulators. Dr. McLaughlin analyzed the documents produced by Marvell concerning the MNP, EMNP, NLD, and Simulator Technology and the Chip Stip. (Pl. Ex. 823).

a. MNP/EMNP Chips

To begin, Marvell asserts that no reasonable jury could find that the accused MNP/EMNP Chips infringe because: (1) they do not select a branch metric function for each of the branches of the trellis at a certain time index; (2) they do not apply each of said branch metric functions to a plurality of signal samples; and (3) the MNP/EMNP module does not determine branch metric values for branches of a trellis. (Docket No. 743). CMU counters that its expert Dr. McLaughlin has demonstrated otherwise through his mapping of the claims onto the Accused Technology. (Docket Nos. 704; 743).

CMU asserted that Marvell's MNP Chips first infringed Claim 4 of the '839 Patent. Claim 4 of the '839 Patent provides:

> [a] method of determining branch metric values for branches of a trellis for a Viterbi-like detector, comprising:
> selecting a branch metric function for each of the branches at a certain time index from a set of signal-dependent branch metric functions; and
> applying each of said selected functions to a plurality of signal samples to determine the metric value corresponding to the branch for which the applied branch metric was selected wherein each sample corresponds to a different sampling time instant.

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'839 Patent col.14 ll.10-19.

In order to show infringement of the '839 Patent, Dr. McLaughlin broke this claim into three "elements." First, he mapped "a method of determining branch metric values for branches of a trellis for a Viterbi-like detector" onto the MNP technology via the circuits of the Chip Stip by showing how the MNP: (1) is a detector; (2) computes branch metric values for branches of a trellis; and (3) is a Viterbi-like detector. (Docket No. 677 at 86-120). On this point, CMU also proffered supporting internal Marvell documents, such as the 88c7500M Specification from August 2004, which stated the "MNP is an advanced post processing adaptive detector," and Mr. Burd's "Media Noise Processor" write up, which stated the "MNP is used to properly take media noise into account during the detection processor." (Pl. Exs. 472; 408) In addition, the "DSP Technical Presentation 5: Data Detection" by Dr. Hongxin Song from 2009 stated "Media noise post-processor is a partial nonlinear detector in data dependent noise channel." (Pl. Ex. 770). This exhibit also contained circuit drawings of the MNP, trellis models, and detailed the "steps to calculate nonlinear branch metric." (*Id.*).

Second, Dr. McLaughlin pointed out where the MNP technology contained a method for "selecting a branch metric function for each of the branches at a certain time index from a set of signal-dependent branch metric functions" on the circuits from Exhibit A of the Chip Stip. (Docket No. 677 at 108-117). Third, Dr. McLaughlin used Exhibit A of the Chip Stip to demonstrate how the MNP used a method "applying each of said selected functions to a plurality of signal samples to determine the metric value corresponding to the branch for which the applied branch metric was selected wherein each sample corresponds to a different sampling time instant." (*Id.* at 118-119). He explained that the FIR filter implements the function and applies it to the plurality of signal samples which then computes the metric value, wherein each sample corresponds to a different time instant, referred to as "D." (*Id.*). After finding that each of the elements of Claim 4 of the '839 Patent was used by the MNP technology, Dr. McLaughlin opined that the MNP infringed Claim 4 of the '839 Patent. (*Id.* at 120).

Likewise, CMU claimed Marvell's MNP technology infringed Claim 2 of the '180 Patents, which incorporates Claim 1. Claims 1 and 2 of the '180 Patent claim:

> 1. A method of determining branch metric values in a detector, comprising:
>
> receiving a plurality of time variant signal samples, the signal samples having one of signal-dependent noise, correlated noise, and both signal dependent and correlated noise associated therewith;
>
> selecting a branch metric function at a certain time index; and
>
> applying the selected function to the signal samples to determine the metric values.
>
> 2. The method claim 1, wherein the branch metric function is selected from a set of signal-dependent branch metric functions.

'180 Patent col.15 ll.39-51.

Given same, Dr. McLaughlin divided these claims into five "elements" and walked the jury through how each was mapped on to the accused MNP circuits. He showed how some of the language of the '180 Patent was the same as the '839 Patent and explained that there was no need to go through the circuit schematics again since the methods were being applied to the same circuit. (Docket No. 677 at 120-125). He "checked off" that he had already demonstrated that the MNP technology involved: (1) "a method of determining branch metric values in a detector, comprising"; (2) "selecting a branch metric function at a certain time index;" and (3) "applying the selected function to the signal samples to determine the metric values;" and (4) "the method claim 1, wherein the branch metric function is selected from a set of signal-dependent branch metric functions." (*Id.*).

On the remaining element, Dr. McLaughlin explained how the MNP technology used a method of "receiving a plurality of time variant signal samples, the signal samples having one of signal-dependent noise, correlated noise, and both signal dependent and correlated noise associated therewith," which was consistent with the second element of Claim 1 of the '180

Patent. (Docket No. 677 at 122). Based on his knowledge and expertise in the field, as well the Marvell DSP Technical Presentation slides titled "Data Dependent Noise" and "Noise Correlation," he showed that the MNP technology used this last element. (Pl. Ex. 770). He also noted that there was no requirement in the '180 Patent that the detector be a Viterbi-like detector. (Docket No. 677 at 121). In light of his prior conclusion that each of the elements of Claim 2 of the '180 Patent, through which the elements of Claim 1 are incorporated, was used in the MNP technology, he concluded that the MNP infringed Claim 2 of the '180 Patent. (*Id.* at 123).

b. NLD Chips

Marvell next argues that no reasonable jury could find that Accused NLD Chips infringe because, again: (1) the chips do not select a branch metric function for each of the branches of the trellis at a certain time index; (2) the chips do not apply each of said branch metric functions to a plurality of signal samples; and (3) the NLDs do not determine branch metric values for branches of a trellis. (Docket No. 743).

As with the MNP and EMNP chips, Dr. McLaughlin started with the '839 Patent and mapped the first element, "a method of determining branch metric values for branches of a trellis for a Viterbi-like detector" onto the NLD circuits from Exhibit D of the Chip Stip. (Docket No. 677 at 140-142). Dr. McLaughlin broke this down further, and showed how the NLD: (1) is a detector; (2) computes branch metric values for branches of a trellis; and (3) is a Viterbi-like detector. (*Id.* at 140-143). Dr. McLaughlin based his conclusions on his analysis, using his personal knowledge and expertise in this area, and he also explicitly relied on Marvell documents, such as the presentation titled "Nonlinear Viterbi Detector Application Note – C8830R1.0" by Dr. Hongxin Song. (Pl. Ex. 596).

In light of the Chip Stip, Dr. McLaughlin opined that the NLD technology contained a method for "selecting a branch metric function for each of the branches at a certain time index from a set of signal-dependent branch metric functions." (Docket No. 677 at 142-144). He demonstrated this on the circuit drawing and referenced supporting testimony from Marvell engineer Mr. Burd.[54] (*Id.* at 145-146).

Last, for the '839 Patent, Dr. McLaughlin relied on Exhibit D of the Chip Stip to conclude that the NLD used a method "applying each of said selected functions to a plurality of signal samples to determine the metric value corresponding to the branch for which the applied branch metric was selected wherein each sample corresponds to a different sampling time instant." (Docket No. 677 at 146-149). He highlighted the location on the circuit diagrams of the plurality of signal samples, the application of the branch metric function, and the branch metric value. (*Id.*). CMU also offered deposition testimony from Mr. Burd, who stated that "[a]nd so in fact noise whitening filter is a parameter of the branch metric function," as well as Dr. Song's Application Note, to further support Dr. McLaughlin's conclusion. (*Id.* at 149; Pl. Ex. 596). Given that Dr. McLaughlin demonstrated how each of the elements of Claim 4 of the '839 Patent was found to be used in the NLD technology, he opined that the NLD infringed Claim 4 of the '839 Patent. (Docket No. 677 at 149-150).

Moving on to Claim 2 of the '180 Patent, Dr. McLaughlin stated that his analysis showed that the NLD technology involved: (1) a method of determining branch metric values in a

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[54] As Marvell's Rule 30(b)(6) deposition witness on the technology-in-suit, Mr. Burd stated:

> Q: And it is possible that for a different branch of the Viterbi trellis that the f0, f1, f2, and f3 valued can be different.
> A: Yes it is possible. So basically we're using a branch metric function that is parameterized in terms of --….Parameterized in terms of branch—branch metric, branch—sorry—branch index, and so for different branches you would choose different set of parameters.

(Docket No. 726).

detector; (2) a detector selecting branch metric functions; (3) application of the selected function; (4) wherein the branch metric function is selected from the set of signal dependent branch functions; and finally (5) that it received a plurality of time variant signal samples, those having one of signal dependent noise and correlated noise. (Docket No. 677 at 154-156). He did not walk through the circuits again as he had already demonstrated his analysis in those respects. Because Dr. McLaughlin gave expert opinion testimony that each of the elements of Claim 2 of the '180 Patent, through which the elements of Claim 1 are incorporated, used the NLD technology, he concluded that the NLD infringed Claim 2 of the '180 Patent. (*Id.*).

c. Simulators

Marvell also contends that the Accused Simulators do not infringe as a matter of law. (Docket No. 743 at 5-7). It alleges that the '839 Patent is directed to a method of determining branch metric values for branches of a trellis for a Viterbi-like "***detector***." (*Id.* at 5) (emphasis in original). Similarly, it claims that the '180 Patent is directed to a "method of determining branch metric values in a ***detector***." (*Id.* at 5-6) (emphasis in original). Because Marvell's simulators are not detectors and do not process actual signal samples, they are not implicated by either patent. (*Id.* at 6-7).

In support, Marvell cites to *Harris Corp. v. Ericsson Inc.* for the proposition that "as a matter of law, running a simulator program does not constitute actually performing the claimed methods in a detector for processing signal samples." 417 F.3d 1241, 1256 (Fed. Cir. 2005). The *Harris* case involved a method of using a communication system which could "be directly infringed only by one who uses the system, not by one who makes or sells the components of the system." *Id.* at 1256. In *Harris*, the Federal Circuit focused on the fact that the plaintiff had submitted only a flow chart describing a "simulation program" and had not shown that the "claimed method <u>is actually carried out</u>, rather than simulated, when Ericsson runs this program." *Id.* (emphasis added). Accordingly, the plaintiff had failed to present evidence of the method being carried out by the program. *Id.* Nevertheless, the Federal Circuit did not create a bright line rule about simulation programs. As described herein, CMU has presented enough evidence to persuade the trier of fact that the claimed method in this case is actually carried out on the challenged simulators.

Upon examination of the Accused Simulators, Dr. McLaughlin opined at trial "that Marvell's simulators infringed the asserted claims." (Docket No. 677 at 83). In reaching this conclusion, he studied the code of five simulators provided by Marvell in discovery: (1) the KavcicPP Simulator; (2) the MNP Simulator; (3) the EMNP Simulator; (4) the NLD Simulator; and (5) the KavcicViterbi Simulator. (*Id.* at 156-166). The first four simulators correspond to particular chips and the last is used as a benchmark. (*Id.* at 169). Dr. McLaughlin described the simulators' use by Marvell: (1) to research and develop the chips; (2) to verify the chips' hardware design; and (3) to provide simulation code to customers so that they may, in turn, evaluate the performance and functionality of Marvell's chips. (*Id.* at 158). This testimony was supported by the deposition testimony of the Marvell corporate designee on this technology, Greg Burd, in which he stated "C Code which is used in our simulation. So we provide a version of the same C code to the designers to be used to serve as a golden source of test vectors to verify the design against." (*Id.* at 169-170).

Dr. McLaughlin analyzed the simulator code (Pl. Ex. 106), and he compared lines of code to the circuits of the chip. (Docket No. 677 at 156-166). He demonstrated how the simulators mimic the chips and how the different elements of the claims were covered by the code. (*Id.*). Further, Dr. McLaughlin determined that there was a one-to-one match between what was in the computer code and what was being calculated in the circuitry. (*Id.*). Dr. McLaughlin showed this for each of the first four simulators. (*Id.*). Based on his conclusion that the chips infringed each and every claim, he determined the simulators also infringed. (*Id.*).

For the KavcicViterbi Simulator, Dr. McLaughlin similarly analyzed the code in question. (*Id.* at 166-173). In doing so, Dr. McLaughlin looked at testimony by Marvell on how it uses this particular simulator. For example, Mr. Doan, then a Marvell engineer, stated that the KavcicViterbi Simulator was used as the benchmark and that they "continuously run Kavcic algorithm to benchmark any subsequent algorithm we develop at Marvell." (*Id.* at 171-172; Docket No. 761 at Jt. Ex. D at 137-138). Some of his analysis was also based on the testimony of Marvell engineer Mr. Burd, who stated in relevant part:

> The way I do my research which might be different from other people, I first try to understand what's available out there. So maybe look at some ideas which people came up with before me. … To make sure that I do, in fact, understand what Professor Kavcic is trying to do and at the same time just to see kind of what's out there. Right? And then I can use this code for benchmarking later. Right? For performance benchmarking later. So this was a launching pad for our research.

(Docket No. 677 at 170-173).

> This (Plaintiff Ex. 93) is KavcicViterbi.cpp class, written by engineers in Marvell, and I do believe it contains the implementation, as understood by our architecture team of the IP which is taught in Professor Kavcic's papers, and consequently in his patent.

(Docket No. 677 at 170-171; Pl. Ex. 93).

Although Marvell insists that its simulators do not process actual signal samples, Dr. McLaughlin maintained that the simulators do process both synthetic as well as real samples from a hard drive or hard drive disk. (Docket No. 677 at 174-178). To this end, he referred to two Marvell documents to support his conclusion, the first being an "Analysis and Design of

Viterbi Detector" which showed test results for a Toshiba wave form. The second document he used was an email from Marvell's Mike Madden[55] to Hitachi, showing test results for wave form captured from the spin stand that were resampled, scaled, and fed into Marvell's simulators. (Pl. Exs. 527; 341).

In sum, Dr. McLaughlin opined that: (1) the computer code directly mimics the chip; (2) the chip infringes each and every element of the claims of the CMU patent; and (3) the computer code and the simulator also infringe each and every element of the claims. While Marvell vigorously disagreed with all these opinions, both parties had an opportunity to make their opposing arguments on the nature of simulators to the jury. *See, e.g.*, (Docket No. 759 at 64-65) ("And [CMU] say yeah, simulated data; simulations, simulator. They know full well that when you sit down at a computer and you put in code and you simulate a formula, that's not the detector. You're not infringing anybody's work when you do that. Everybody does it. They did it."). The determination was purely factual and one which the jury alone would have to decide by weighing the offered evidence and the credibility of witnesses who testified to same. *Walker v. Gordon*, 46 F. App'x 691, 695 (3d Cir. 2002).

d. Direct Infringement in Sum

CMU presented sufficient evidence, through Dr. McLaughlin as well as supporting Marvell documents, that the MNP, EMNP, and NLD chip technology and the Accused Simulator technology use a method that includes each and every method step of Claim 4 of the '839 Patent and Claim 2 of the '180 Patent. Whether Dr. McLaughlin's conclusions were persuasive or otherwise worthy of credence goes to the core of his credibility as a witness, and such

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[55] The parties did not provide information to the jury about Michael Madden, but provided his deposition to the Court in the fall as part of possible depositions designations at trial. *See* (Docket No. 535). Therein, he stated he went with Marvell as a design engineer in 2000, and then rose up the ranks to be a senior design manager. *See* November 3, 2010 depo. at 19-23. He reports to Mr. Burd. *Id.*

"[d]eterminations regarding the weight to be accorded, and the sufficiency of, the evidence relied upon by the proffered expert are within the sole province of the jury." *Walker*, 46 F. App'x at 695. Indeed, Marvell took advantage of the opportunity to rebut Dr. McLaughlin's conclusions by offering opinion evidence through its own non-infringement expert Dr. Blahut that its products did not infringe CMU's patents. (Docket No. 711 at 204-308). The jury was free to accept either expert's opinions or reject them, as the "credibility of the parties' competing experts is an issue for the jury to resolve, not the Court." *Miller ex rel. Miller v. Evenflo Co., Inc.*, Civ. No. 09-108, 2011 WL 7037127, at *3 n.3 (W.D. Pa. Dec. 15, 2011); s*ee also Walker*, 46 F. App'x at 695.

Considering the evidence in the light most favorable to the nonmoving party, and giving it the advantage of every fair and reasonable inference in light of the undisputed facts, the Court finds there was adequate evidence upon which a reasonable jury could properly find a verdict in favor of CMU. Therefore, Marvell's motion for JMOL and motion for a new trial on this issue is denied. The question of whether there was direct infringement by the Accused Chips and Accused Simulators was properly submitted to and decided by the jury.

3. Indirect Infringement

a. Inducement

Marvell asserts that it was entitled to a judgment as a matter of law or a new trial on CMU's claims of indirect infringement for actively inducing infringement. (Docket No. 743, 805). It argues that CMU has not proven: (1) direct infringement; (2) that Marvell had actual knowledge of the patents-in-suit; and (3) that it specifically intended for others to perform acts that directly infringe one or more of the asserted claims. (*Id.*).

First, the Chip Stip lists the models of chips that correspond to the agreed-upon circuits that Dr. McLaughlin analyzed. (Pl. Ex. 823). These chips are sold to Marvell's customers to be used in hard disk drives, and they are also used by Marvell in research and development phases. (Docket No. 677 at 103-104, 178). As part of his testimony, Dr. McLaughlin analyzed the hardware and firmware settings of Marvell's customers such as Western Digital, Samsung, and Toshiba. (Pl. Exs. 1914; 1915; 1918; 1919). Once again, Dr. McLaughlin put forth expert testimony to prove direct infringement of Marvell's chips, thereby allowing CMU to advance a theory of induced infringement.[56]

Second, in order to achieve success on induced infringement, CMU was required to show that Marvell had "knowledge of the existence of the patent" or took "deliberate actions to avoid confirming a high probability of wrongdoing." *Global-Tech*, 131 S. Ct. at 2068-70. To that end, CMU presented significant amounts of evidence to show Marvell's knowledge of the patents. Much of this evidence also supported CMU's claim of willful infringement, which is addressed later herein.[57]

CMU proffered the following evidence of Marvell's knowledge of the patents-in-suit. First, is the email from Dr. Kavcic sent to Dr. Nazari at Marvell in 1998, providing a link to his publications, resume, and recent work. (Def. Ex. 1023). Second, is the January 3, 2002 email from Greg Burd to Toai Doan and Nersi Nazari, attaching a write up on the KavcicPP and stating "1. Kavcic's detection scheme is patented (assignee: Carnegie Mellon Univ. 2001)." (Pl. Ex. 280). Third, there is the January 4, 2002 weekly status report email from Mr. Burd to Mr. Doan,

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[56] *See* discussion *supra* at Section V.A.2.

[57] *See* discussion *infra* at Section V.C.

Dr. Nazari, and Ke Han,[58] describing his work and stating "[a]nd of course as I mentioned earlier, Kavcic detector is also patented." (Pl. Ex. 283). Such evidence indicated that Marvell knew of both the patents and the high likelihood that the Accused Technology infringed, especially given that the very people who designed the Accused Technology, i.e., the engineers, knew of the patents. (*Id.*).

In fact, Marvell hardly argued that it did not know of the CMU Patents; its theme throughout trial was that Dr. Kavcic's work was its launching point only, and its technology was a "sub-optimal" version of Kavcic's algorithm. (Docket No. 756). CMU replied that the MNP/NLD used the Kavcic algorithm, and optimality had no bearing on whether the claims of the Kavcic patented method were infringed. (*Id.*) In support, CMU proffered one of Dr. Wu's weekly emails from January 10, 2003 that stated "1. MNP enhancement: Greg and I discussed the approach of using a different noise whitening filter for each branch. It turns out to be the original structure that Kavcic proposed in his paper." (Pl. Ex. 366).[59] Thus, even if, as Marvell insists, it did not know the accused technologies infringed the patents-in-suit, CMU put forth sufficient evidence that a jury could find that Marvell was willfully blind in light of the high probability of infringement. *Global-Tech*, 131 S. Ct. at 2072. Once presented with the patents, Mr. Doan testified that he never looked at the patents, never directed others to look at them, and never contacted Marvell's legal department about them. (Docket No. 761 Jt. Ex. D at 125, 130).

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[58] Mr. Han was not deposed or called as a witness by either party. Based on his email address, he was a Marvell employee at the time said email was transmitted. (Pl. Ex. 283).

[59] As detailed later herein, Mr. Burd admits that at least the KavcicViterbi simulator used by Marvell during testing, was designed to encapsulate Dr. Kavcic's work:

> This (Plaintiff Ex. 93) is KavcicViterbi.cpp class, written by engineers in Marvell, and I do believe it contains the implementation, as understood by our architecture team of the IP which is taught in Professor Kavcic's papers, and consequently in his patent.

(Docket No. 677 at 170-171; Pl. Ex. 93).

Despite same, he reported to Nersi Nazari on his January 14, 2002 status report that they would "continue work on non-linear detector based upon Kavcic's model." (Pl. Ex. 285).

Additionally, as to Marvell's knowledge of the patents, CMU's Technology Transfer representative Carl Mahler sent a letter in August 2003 to Marvell's CTO Dr. Pantas Sutardja and Matthew Gloss, who was Marvell's then General Counsel, stating that CMU held patents in the area of correlation-sensitive adaptive sequence detectors, "namely US Patent number 6,201,839 B1 and US Patent number 6,438,180 B1." (Pl. Ex. 422, Pl. Ex. 431). Mr. Mahler attached the patents to the letter and encouraged Marvell to contact him if they found the patents to be of interest. (*Id.*). There was no response to these letters. (Docket No. 682 at 150). Similarly, Junya Suwanai of Fujitsu, "a customer for Marvell's read channel i.e. 5575M, 7500M," corresponded with Marvell in November 2004, stating that Fujitsu had received a license offer for the CMU Patents-in-suit. (Pl. Ex. 477). He wrote that "since it seems that these patents might be related to read channel, we would like to know, by the end of November, your opinion regarding relationship between CMU's Patents and the above Marvell lead [*sic*] channel and the specific grounds/reasons for such opinion." (*Id.*). No documents were found in relation to this letter, and Marvell's corporate designee testified that he did not know of any response to this letter. (Docket No. 761 at Jt. Ex. C. at 534-535).

CMU had to prove that Marvell had the specific intent to encourage another's infringement, which can be demonstrated if Marvell caused, urged, encouraged, or aided the infringing conduct. *DSU*, 471 F.3d at 1306; *Akamai Techs.*, 692 F.3d at 1308. On this point, CMU showed that Marvell aided its customers' infringement by producing chips that used the accused methods and instructed its customers to use the chips in infringing modes. (Docket No. 677 at 180-183; Docket No. 678 at 91; Pl. Exs. 1913; 1918; 1919). Specifically, CMU entered into evidence emails, firmware, as well as programming instructions for hardware showing that Marvell directed its customers, including Western Digital, Samsung, and Toshiba, to use the chips in infringing modes. (Pl. Exs. 730; 932; 1914; 1915; 1918; 1919).

Likewise, Dr. McLaughlin testified about Marvell field application engineers who are deployed to Marvell's customers to assist them in putting Marvell's chips into their products and instruct them on how to use the chips. (Docket No. 677 at 178-179). To that end, Teik Ee Yeo, Western Digital's corporate designee, testified that the chips it buys from Marvell have the technology enabled, i.e., set to "infringing modes," and that Western Digital tended to follow the suggestions of Marvell engineers regarding these settings on the chips. (Docket No. 761 at Jt. Ex. B 146).[60] This knowledge of customer use was buttressed by the testimony of CMU industry expert, Dr. Bajorek, who opined that the Accused Technology became industry standard. (Docket No. 678 at 108-112).

Accepting the evidence in the light most favorable to CMU, the nonmoving party, and giving it the advantage of every fair and reasonable inference based on the facts of record, there was sufficient evidence presented at trial to support CMU's theory that Marvell created technology that employed the accused methods with either actual knowledge or willful blindness to the possibility that its devices infringed the patents-in-suit, and that Marvell sold same to its customers. CMU produced sufficient evidence that Marvell actively induced at least one of Marvell's customers to use a method that is covered by Claim 4 of the '839 Patent or Claim 2 of the '180 Patent. Thus, Defendants' JMOL on this issue was denied, and the question of whether

[60] As noted, two representatives from Western Digital testified at trial, corporate designee Teik Ee Yeo, (Docket No. 761 at Jt. Ex. B), and Iftiqar Baqai. (Docket No. 711). From 1997 to 2005, Mr. Baqai worked at Western Digital in selection and development of read channel chips and their subsequent integration. (Docket No. 711 at 145-147). His testimony did not touch on the enablement of the chips in certain modes. (*Id.*). After 2005, he no longer worked in the read channel area at Western Digital. (*Id.* at 175).

there was induced infringement properly proceeded to the jury. Considering the record as a whole, the jury's verdict of induced infringement is not against the weight of evidence, and the motion for a new trial on this issue is denied.

b. Contributory Infringement

Marvell argues that it was entitled to either a judgment as a matter of law or a new trial on CMU's claims of contributory infringement for actively contributing to infringement. (Docket Nos. 743; 805). It argues that CMU has not proven: (1) direct infringement; (2) that Marvell possessed the requisite intent for contributory infringement, i.e., that it knew the Accused Chips were infringing on CMU's patents; and (3) that Marvell's components had no substantial non-infringing uses. (Docket No. 743 at 3-4).

As previously stated, however, the record shows that CMU put forth ample evidence to prove direct infringement by Marvell's customers, thereby allowing CMU to advance a theory of induced infringement.[61] The Court has also observed that CMU presented sufficient evidence to show that Marvell possessed the requisite knowledge of the patents-in-suit at the time of infringement. (Pl. Ex. 280; Pl. Ex. 283)

Moving forward, the Court finds that CMU has produced sufficient evidence that the Accused Chips were made specifically to use the Accused Technology with no other non-infringing use. For example, Dr. Bajorek testified that all the chips are designed through the described sales cycle and that the final chips are custom made for each customer, with the Accused Technology specifications in mind. (Docket No. 678 at 70). Each customer then received programming instructions to use the chips in infringing modes. (Pl. Ex. 730; Pl. Ex. 1913). Dr. McLaughlin also testified that the MNP and NLD chips do not have any use besides

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[61] *See* discussion *supra* at Section V.A.2.

detecting data in hard drive disks and that they do not have any substantial uses beyond the enabled, infringing modes. (Docket No. 677 at 188).

Accepting the evidence in the light most favorable to Plaintiff, the nonmoving party, and giving it the advantage of every fair and reasonable inference based on the undisputed facts, it is clear that there was sufficient evidence upon which a reasonable jury could properly find that Marvell contributorily infringed Claim 4 of the '839 Patent and/or Claim 2 of the '180 Patent. Accordingly, Marvell's JMOL as to this issue was denied, and the question of whether there was contributory infringement was properly presented to the jury. The jury's finding that Marvell had engaged in contributory infringement was not against the weight of the evidence, and the Court likewise denies Marvell's motion for a new trial on these grounds.

B. Validity

The parties filed cross-motions for JMOL on the patents' validity. The Court was initially presented with CMU's Motion for Judgment As a Matter of Law on Marvell's Invalidity Defenses" as well as its "Brief in Support of its Motion. (Docket Nos. 731; 732). Marvell opposed this motion. (Docket No. 749). Marvell, in turn, submitted its own Motion for Judgment as a Matter of Law on Invalidity with a supporting brief. (Docket Nos. 747; 748). CMU similarly opposed this cross-motion. (Docket No. 750). The Court denied both of these Motions on the record. (Docket No. 759). Following trial, Marvell renewed its JMOL on invalidity and requests, in the alternative, a new trial. (Docket No. 805). CMU did not renew its JMOL on validity given the jury's favorable verdict. (Docket No. 762).

1. Legal Standard

a. Anticipation Legal Standard

An issued patent enjoys a presumption of validity. *See* 35 U.S.C. § 282; *SRAM Corp. v. AD-II Engineering, Inc.*, 465 F.3d 1351, 1357 (Fed. Cir. 2006). Due to this presumption, invalidity must be proven by clear and convincing evidence. *Microsoft Corp. v. i4i Ltd. Partnership* (hereinafter "*i4i*"), __ U.S. __, 131 S. Ct. 2238, 2242 (2011). "The burden of establishing invalidity of a patent or any claim thereof shall rest on the party asserting such invalidity." 35 U.S.C. 282. Even in instances where the allegedly anticipatory reference was not before the Patent and Trademark Office ("PTO"), the clear and convincing standard remains. *See i4i*, 131 S. Ct. at 2244; *see also Uniroyal, Inc. v. Rudkin-Wiley Corp.*, 837 F.2d 1044, 1050 (Fed. Cir. 1988). Given that "[c]redibility determinations, the weighing of evidence, and the drawing of legitimate inferences from the facts are jury functions, not those of a judge," this Court should not, at this late stage, consider the possible additional weight carried by a piece of prior art not considered by the PTO. *Reeves v. Sanderson Plumbing Prods., Inc.*, 530 U.S. 133, 150 (2000) (citations omitted).

A patent claim is "invalid for anticipation if a single prior art reference discloses each and every limitation" of the claim. *Schering Corp. v. Geneva Pharm.*, 339 F.3d 1373, 1377 (Fed. Cir. 2003) (emphasis added); s*ee also Zenith Elecs. Corp. v. PDI Commc'ns Sys., Inc.*, 522 F.3d 1348, 1363 (Fed. Cir. 2008). Each element, and the "arrangement or combination" of those elements, must be present in the prior art reference. *See Net MoneyIN, Inc. v. VeriSign, Inc.*, 545 F.3d 1359, 1371 (Fed. Cir. 2008). The key is that, within "the four corners of a single, prior art document … every element of the claimed invention [must be described], either expressly or inherently, such that a person of ordinary skill in the art could practice the invention without undue experimentation." *Advanced Display Sys., Inc. v. Kent State Univ.*, 212 F.3d 1272, 1282 (Fed. Cir. 2000).

b. Obviousness Legal Standard

Obviousness under 35 U.S.C. § 103(a) is a legal question based on underlying factual determinations. *Unigene Labs., Inc. v. Apotex, Inc.*, 655 F.3d 1352, 1360 (Fed. Cir. 2011), *cert. denied*, 132 S. Ct. 1755 (2012). An obviousness analysis measures the difference between the claimed invention and the prior art to determine whether "the subject matter as a whole would have been obvious at the time the invention was made" to a person having ordinary skill in the art. *Alza Corp. v. Mylan Labs., Inc.*, 464 F.3d 1286, 1289 (Fed. Cir. 2006) (citations omitted).

The factual underpinnings of the obviousness analysis, often referred to as the *Graham* factors, include: 1) the scope and content of the prior art; 2) the level of ordinary skill in the art; 3) the differences between the claimed invention and the prior art; and 4) evidence of secondary factors, also known as objective indicia of non-obviousness. *Graham v. John Deere Co.*, 383 U.S. 1, 17-18 (1966). "Evidence rising out of the so-called 'secondary considerations' must always, when present, be considered en route to a determination of obviousness." *Transocean Offshore Deepwater Drilling, Inc. v. Maersk Drilling USA, Inc.*, 699 F.3d 1340, 1349 (Fed. Cir. 2012).

Obviousness requires more than a mere showing that the prior art includes separate references covering each limitation in a claim under examination. *KSR Int'l Co. v. Teleflex Inc.*, 550 U.S. 398, 418 (2007). Rather, obviousness requires the additional component that a person of ordinary skill at the time of the invention would have selected and combined those prior art elements in the normal course of research and development to yield the claimed invention. *Id.* at 421.

As the parties alleging invalidity of the patents at issue, Marvell was required to prove its invalidity defenses by clear and convincing evidence. *i4i*, 131 S. Ct. at 2242. At trial, Marvell called Dr. John Proakis to provide expert technical testimony. (Docket No. 726). In rebuttal, CMU recalled Dr. Steven McLaughlin to provide expert technical testimony about CMU's patents and the prior art in this field. (Docket No. 736).

2. CMU's Motion on Marvell's Invalidity Defenses

While not raised post-trial, the Court will first address CMU's earlier Motion for Judgment as a Matter of Law on Marvell's Invalidity Defenses (Docket No. 731), which was denied on the record on December 21, 2012 without further exposition given the time constraints of trial. (Docket No. 764 at 99).

a. Anticipation

CMU moved for judgment as a matter of law, asserting that Marvell had failed to put forth sufficient evidence on its invalidity defense of anticipation because: (1) Dr. Proakis admitted that the Worstell Patent does not disclose all elements of the CMU Patents; and (2) Dr. Proakis relied upon an incorrect claim construction making his opinion both incorrect and inadmissible, as a new opinion not disclosed in his expert report. (Docket No. 732).

Marvell had presented Dr. Proakis's testimony to show that all of the elements of the claims-in suit were found in prior art. At the outset, Dr. Proakis opined that the Weining Zeng and Inkyu Lee articles, as well as Dr. McLaughlin's statements on same, proved that Dr. Kavcic and Dr. Moura were not the first to disclose a method selecting a branch metric function from a set of functions for each of the branches at a certain time index. (Def. Exs. 37; 38). Dr. Proakis continued explaining that one of the equations in the '839 Patent expressing the same equation as

Weining Zeng, was, in fact, a set of functions and referenced Dr. Moura's testimony.[62] (Docket No. 726 at 57). Dr. Proakis also stated that Dr. Kavcic was not the first person to propose a Viterbi detector that took correlated noise into account and recounted that Dr. McLaughlin had said the same thing at his deposition. (*Id.* at 58).

Next, Marvell proffered U.S. Patent No. 6,282,251 (the "Worstell Patent") as prior art for purposes of its anticipation defense. (Def. Ex. 187). This patent was filed on March 21, 1995, three years before the CMU Patents were filed. (*Id.*). Dr. Proakis stated that equation 20 of the Worstell Patent took into account signal dependent noise by scaling the branch metrics that have a signal dependent noise with a fraction that depends on the transition noise standard deviation. (Docket No. 726 at 60). He stated that because transition noise is another term for signal dependent noise, Worstell teaches that whenever there is a transition, the corresponding branch metric function is scaled by one over sigma squared, as disclosed by Inkyu Lee and Weining Zeng. (*Id.*). Dr. Proakis also said that the Worstell Patent disclosed a modified Viterbi detector which accounts for correlated noise, claimed by the first element of Claim 4 of the '839 Patent. (Docket No. 726 at 63). Dr. Proakis then opined that the selecting and applying limitations of the '839 Patent are found in the Worstell Patent by highlighting the parts of relevant equations derived from the Worstell Patent and the corresponding elements of Claim 4. (*Id.* at 68). Marvell

[62] Dr. Moura's referenced deposition testimony is as follows:

> Q: Okay. So, in your mind, branch metric equation 10 at the bottom of column 6 of the '180 Patent is a set of branch metric functions; is that correct?
> A: I guess we could say so.
> Q: Why?
> A: I told you, because the variance depends on the AIs, signal dependent.

(D Demo 12-10).

supported its position with proffered deposition testimony from Dr. McLaughlin.[63] Thus, Dr. Proakis concluded that Claim 4 of the '839 Patent was anticipated by the Worstell Patent.

Dr. Proakis then moved to Claim 2 of the '180 Patent, and as four of the elements were previously determined to be present in the Worstell Patent through his '839 analysis, he discussed the receiving step of Claim 2. (Docket No. 726 at 68-71). Dr. Proakis highlighted the relevant portions of the Worstell Patent and stated that the Worstell branch metric equation covers both correlated noise and signal dependent noise. (*Id.*). With this, Dr. Proakis concluded that Claim 2 of the '180 Patent was anticipated by the Worstell Patent. (*Id.*).

CMU countered that Dr. Proakis' opinions rested on an incorrect claim construction of the terms "function" and "signal dependent branch metric function" and that such contradictory testimony is therefore insufficient for a finding of validity as a matter of law. (Docket No. 732). Having considered his testimony, the Court held that the record was not entirely clear that Dr. Proakis offered a contradictory construction at trial, thereby violating the expert disclosure requirements of Rule 26. (Docket No. 726 at 110-111); *see Pritchard v. Dow Agro Scis*, 263 F.R.D. 277, 284-85 (W.D. Pa. 2009) ("[c]aselaw establishes that a declaration should be stricken if it contains new opinions or information which is contradictory to that set forth in the expert report, but it need not be stricken if it contains merely an elaboration of and is consistent with an

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[63] Dr. McLaughlin testified:

> Q: The paragraph refers to a further modified metric at Line 49 and Column 10; right?
> A: Okay. Yes.
> Q: And you agree that the paragraph describes modifying a metric to take transition noise into account?
> A: That is what -- that is what the sentence says.
> Q: And you agree that the transition noise can depend on the type of the transition; is that correct?
> A: The noise -- the value of the noise is going to be different -- is going to be different whether there is a transition or whether there is no transition.

(D Demo 12-16).

opinion/issue previously addressed in the expert report"). While the Court has clarified the legal meaning of certain terms for this case, Dr. Proakis' use of the challenged terms throughout his long career has not been guided by this Court's claim construction. Similarly, his prior use of the word "function" came before the Court offered clarification as to the meaning of this term for this case. (Docket No. 337).[64] To find that he has changed his entire opinion based on these statements alone is an unwarranted conclusion for the Court to make. Even if Dr. Proakis had offered a "new opinion" for the first time at trial, the striking of such evidence for a discovery violation is an "extreme sanction" normally reserved for a "showing of willful deception or 'flagrant disregard' of a court order by the proponent of evidence," which is not the case here. *Konstantopoulos v. Westvaco Corp.*, 112 F.3d 710, 719 (3d Cir. 1997) (quoting *Meyers v. Pennypack Woods Home Ownership Ass'n*, 559 F.2d 894, 905 (3d Cir. 1977)).

To the extent that CMU continues to claim that Dr. Proakis used the incorrect meaning of the term "signal dependent branch metric function," its argument seems to be one of semantics and not an issue of law upon which the Court need rule. Throughout the trial of this case, the jury had the Court's claim constructions,[65] and counsel as well as witnesses displayed portions in parts of their slides. (Docket No. 770 at Ex. M; Docket No. 771 at Ex. H). Any alleged discrepancies between his use of the term "signal dependent branch metric function" in his expert report and trial testimony were addressed during cross-examination, and, as such, went towards the ultimate weight of his opinion, as determined by the jury. *See i4i Ltd. P'ship v.*

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64 The Court is also mindful in June 2012, after its decision on the construction of the term "function," the Court denied Marvell's Motion for Leave to Supplement Expert Reports to Take Into Account the Court's Summary Judgment Ruling. (Docket No. 425). In so holding, the Court noted that expert discovery was to have been completed by April 6, 2012, (Docket No. 315), and that as Marvell had been aware of CMU's position "well before its expert reports were due, [ ] it should have anticipated the possibility that the Court would adopt CMU's position." (Docket No. 425).

65 Each of the jurors had a notebook throughout trial that contained a copy of the patents, claims construction, and a glossary of useful terms.

Microsoft Corp., 598 F.3d 831, 856 (Fed. Cir. 2010) ("'[v]igorous cross-examination, presentation of contrary evidence, and careful instruction on the burden of proof are the traditional and appropriate means of attacking shaky but admissible evidence.'") (citing *Daubert v. Merrell Dow Pharm., Inc.*, 509 U.S. 579, 596 (1993)).

CMU claims that during cross-examination, Dr. Proakis admitted that the Worstell Patent did not disclose all elements of the CMU Patents. (Docket No. 732). Dr. Proakis stated that the Worstell Patent spoke of "zero" branches and "one" branches. (Docket No. 726 at 92-94). During cross, he agreed that the Worstell Patent never put any multiplier on the "zero" branches but stated it would be "totally obvious to a person skilled in the art." (Docket No. 726 at 94). The key to anticipation is that every element of the claimed invention must be described in the piece of prior art. *Advanced Display Sys., Inc.*, 212 F.3d at 1282. However, the prior art can describe the elements <u>inherently</u>, such that a person of ordinary skill in the art could still practice the invention without undue experimentation. *Advanced Display Sys., Inc.*, 212 F.3d at 1282.

The Court is mindful that Dr. Proakis is a technical expert, not a legal expert, and his statement, as CMU interprets it, is not dispositive on its own. Resolving all reasonable inferences in favor of the non-movant, the Court determined that a jury could find that his statement that the multiplier would be "totally obvious to a person skilled in the art" was made to show that the prior art inherently described the claimed invention. (Docket No. 726 at 94). Whether his position is credible is the province of the jury. *Collins v. Signetics Corp.*, 605 F.2d 110, 115 (3d Cir. 1979) ("Neither a trial nor an appellate court has the authority to substitute its judgment for that of the jury and thus usurp the jury's function as the principal finder of fact."). Given the stage of trial, the Court did not find Dr. Proakis's statement to be an admission that the Worstell Patent does not anticipate the patents-in-suit as a matter of law. The Court reiterates that the making of credibility determinations, weighing of evidence, and the drawing of reasonable inferences from the facts are jury functions—they are not to be usurped by the Court as a matter of law. *Eschelman*, 554 F.3d at 433.

Having considered the evidence in the light most favorable to the nonmoving party, Marvell, and giving it the advantage of every fair and reasonable inference in light of the undisputed facts, this Court concluded that Marvell had presented enough evidence for a reasonable jury to find that Claim 4 of the '839 Patent and Claim 2 of the '180 Patent were anticipated. Therefore, CMU's motion for judgment as a matter of law on this basis was denied, and the question of whether there was invalidity by anticipation was presented to the jury.

b. Obviousness

CMU argued that it was entitled to judgment as a matter of law on invalidity because Marvell had failed to provide sufficient evidence that the asserted claims were obvious because: (1) Dr. Proakis again admitted that the Worstell Patent does not disclose all elements of the CMU Patents; (2) Dr. Proakis once more relied upon an incorrect claim construction making his opinion both incorrect and inadmissible, as a new opinion not disclosed in his expert report;[66] and (3) Dr. Proakis's opinion was simply conclusory. (Docket No. 732).

Dr. Proakis opined that even if the Worstell Patent did not anticipate the asserted claims, the Worstell Patent proves that the claims would have been obvious to a person of ordinary skill in the art. (Docket No. 726 at 94). He stated that he believed a person of ordinary skill in the art, reading the Worstell Patent claims and Column 10, would know that sigma squared has to vary from branch to branch. (*Id.*). This, he urged, would make Claim 2 of the '180 Patent and Claim 4 of the '839 Patent obvious to a person of ordinary skill in the art. (Docket No. 726 at 77). His

[66] The Court has just addressed CMU's arguments on the admissibility of Dr. Proakis's "new" opinion and need not address the issue again. *See* discussion *supra* at Section V.B.2.a.

analysis was based primarily on his examination of the Worstell Patent. However, Marvell had provided enough evidence to show that Dr. Proakis's testimony was not conclusory and that he considered secondary indicia of non-obviousness, such as statements by Dr. McLaughlin, Dr. Moura, and Dr. Kavcic regarding the novelty of aspects of their invention. (Docket No. 726 at 58-59).

He and Dr. McLaughlin disputed what a person of the ordinary skill in the art would find to be obvious and the nature of secondary considerations. (Docket No. 726 at 75-77; Docket No. 736 at 80-81). To this end, Dr. Proakis stated the reasons for his view (Docket No. 726 at 75-77), and the Court does not find that they were conclusory as a matter of law. Obviousness, in the end, is a question that must be determined based on the weight of the evidence presented and on credibility determinations. *See Unigene*, 655 F.3d at 1360.

After considering the evidence in the light most favorable to the nonmoving party, Marvell, and giving it the advantage of every fair and reasonable inference in light of the undisputed facts, the Court concluded at trial that Marvell had presented enough evidence for a reasonable jury to find that Claim 4 of the '839 Patent and Claim 2 of the '180 Patent were obvious. Therefore, CMU's motion for judgment as a matter of law on this basis was denied, and the question of invalidity by obviousness was properly given to the jury to decide.

c. Written Description, Indefiniteness, and Enablement

At trial, CMU contended that Marvell had adduced no evidence in support of its written description, indefiniteness, and enablement defenses. Marvell acknowledges such in its Brief in Opposition, stating "Marvell acknowledges that it has not pursued its Section 112 defenses (written description, enablement, and indefiniteness) at trial." (Docket No. 749). Accordingly, these defenses are waived. Moreover, as there was no evidence presented on Marvell's invalidity defenses of written description, indefiniteness, and enablement, no reasonable jury could properly find a verdict in favor of Marvell on these defenses. (Docket No. 726). Therefore, CMU's motion for judgment as a matter of law on these three defenses was denied as moot. (Docket No. 764 at 99).

3. Marvell's Motion for Invalidity

a. Anticipation

Marvell argues that it is entitled to judgment as a matter of law or, in the alternative, a new trial on the issue of invalidity by anticipation because: (1) the PTO did not consider the Worstell Patent (Def. Ex. 187); (2) the Worstell Patent discloses every limitation of Claim 4 of the '839 Patent; and (3) that Worstell discloses every limitation of Claim 2 of the '180 Patent. (Docket Nos. 748; 805).

On the first point, Marvell has given the Court no authority as to why the fact that the Worstell Patent was not disclosed to the Patent Office is relevant to the JMOL anticipation analysis. Marvell argues that such a circumstance may ease the burden of clear and convincing evidence (Docket No. 748 at 2); yet, the Court is mindful that the jury is tasked with weighing the evidence. *Eschelman*, 554 F.3d at 433. The fact that the allegedly anticipatory reference was not before the PTO does not change the clear and convincing standard for invalidity defenses, and it is therefore irrelevant to the Court's decision on anticipation. *i4i*, 131 S. Ct. at 2244. Despite same, the jury was free to consider this fact in its determination on invalidity.[67]

[67] The jury as the fact finder is tasked also with determining expert credibility. *Miller*, 2011 WL 7037127, at *3 n.3. The Court notes several factors that could have had an impact on the jury's analysis of the facts, including length of the testimony, demonstratives, the thoroughness of presentation, and ease of understanding the expert's testimony, all of which, in the Court's estimation, weighed in CMU's favor throughout the trial. For each of his conclusions, Dr. McLaughlin methodically laid out his opinions, cited the underlying factual support, explained his reasoning with drawings and demonstratives, and then reiterated his opinion again. (Docket No. 677). His approach was extremely thorough, complete, and clear. Dr. Blahut and Dr. Proakis, on the other hand, were forced to testify in a hurried, sometimes disjointed fashion due to the time spent on other witnesses by Marvell's trial team.

At trial, CMU called Dr. McLaughlin, as a rebuttal validity expert, to show that the Worstell Patent did not invalidate the asserted claims. Dr. McLaughlin first testified that CMU's patents were novel in that they claimed a method using a set of signal dependent branch metric functions and applied those signal dependent branch metric functions to a plurality of signal samples. (Docket No. 736 at 54). Dr. McLaughlin contrasted the CMU Patents from the Inkyu Lee and Weining Zeng articles by explaining that those articles referred to a single signal sample, directed just towards transition noise, while CMU's invention is oriented towards multiple signal samples and intended to address noise associated with a specified sequence of symbols, not just one transition. (*Id*. at 54).

In regards to the Worstell Patent, Dr. McLaughlin stated that both Claim 4 of the '839 Patent and Claim 2 of the '180 Patent require a set of signal-dependent branch metric functions while the Worstell Patent only contemplates one. (*Id*. at 55). Dr. McLaughlin explained that Equation 20 of the Worstell Patent shows just this single FIR filter. (*Id*. at 65). Given Dr. Kavcic's prior testimony and related demonstratives, Dr. McLaughlin showed how Dr. Kavcic had originally only contemplated one FIR filter, which was the same as the Worstell Patent invention, but then moved on from this idea to develop the invention in suit. (*Id.* at 64). Next, Dr. McLaughlin opined that Worstell's patent takes transition noise into account by modifying the branch metrics by a fraction, but that this modification only happens on the "one" branches, not the "zero" branches, and thus not on all branches. (*Id.* at 67). He further explained that the fraction is a constant for all the branches, meaning that the method taught in the Worstell Patent is different from that discussed in the patents-in-suit, where that modification is variable. (*Id.* at

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Unsurprisingly, they were not able to elucidate their opinions as clearly as Dr. McLaughlin, who was by far the best of the technical witnesses. (Docket Nos. 711; 726).

67-68). Finally, Dr. McLaughlin concluded that the Worstell Patent did not apply the transition noise adjustment to a plurality of signal samples. (*Id.* at 70).

Dr. McLaughlin disagreed with Dr. Proakis's opinions on invalidity, considering them to be incorrect. (*Id.*) Instead, he testified that Dr. Proakis had described the Worstell method in the opposite order of how the patent described it and referred to a further modified branch metric equation that did not appear in the Worstell Patent. (*Id.* at 67-68). Given all of this, Dr. McLaughlin stated that the Worstell Patent did not contain each of the elements of Claim 4 of the '839 Patent or each of the elements of Claim 2 of the '180 Patent. (*Id.* at 73) In his opinion, the asserted claims of the '839 Patent and the '180 Patent were not anticipated. (*Id.*).

The factual disputes regarding invalidity that underlie the experts' opinions in this case were for the jury to decide. *See In re Montgomery*, 677 F.3d 1375, 1379 (Fed. Cir. 2012), *cert. denied*, 133 S. Ct. 788 (2012). Once again, Dr. McLaughlin's conclusions were left to the jury to accept or reject as it was for them to determine credibility and the weight given to such evidence. *Id.* Considering the evidence in the light most favorable to the nonmoving party CMU, and giving it the advantage of every fair and reasonable inference in light of the undisputed facts, the Court concluded that CMU had presented enough evidence upon which a reasonable jury could properly find that Claim 4 of the '839 Patent and Claim 2 of the '180 Patent were not anticipated. Therefore, Defendants' motion for JMOL on the basis of invalidity is denied. Similarly, the jury's finding that the patents were not invalidated due to anticipation is not against the weight of the evidence, and Marvell's motion for a new trial on these grounds is thus denied.

b. Obviousness

Marvell further contends that it is entitled to judgment as a matter of law or a new trial on the issue of invalidity because the asserted claims are obvious. To prove otherwise, once again, CMU proffered the testimony of its expert, Dr. McLaughlin. In his analysis, Dr. McLaughlin considered all of the pieces of prior art that Dr. Proakis relied upon in his opinion of invalidity, such as the Inkyu Lee and Weining Zeng articles, as well as the Worstell Patent, in addition to other pieces of prior art that Dr. Proakis did not discuss. (Docket Nos. 726; 737). Dr. McLaughlin then concluded that the asserted claims were not obvious. (Docket No. 737 at 73).

Dr. McLaughlin also considered the secondary indicia of non-obviousness presented throughout the trial such as praise for the invention by the industry in general and by Marvell employees and the fact that the invention solved a long-perceived problem. (*Id.* at 71-72).[68] Additionally, CMU and Dr. McLaughlin proffered an email from Glen Worstell as secondary indicia of non-obviousness. (Pl. Ex. 161). In his email, Dr. Worstell wrote that the Kavcic/Moura invention "is related but goes beyond my work and is probably more interesting." (*Id.*).

Based on his analysis, the factors of non-obviousness, and his knowledge of the field, Dr. McLaughlin concluded that neither Claim 4 of the '839 Patent nor Claim 2 of the '180 Patent were obvious to a person of ordinary skill in the art. (Docket No. 736 at 73). Given Dr. McLaughlin's opinion and the underlying factual predicates, the Court found that the question of obviousness was rightly sent to the jury to resolve. *See Walker*, 46 F. App'x at 695; *Miller*, 2011 WL 7037127, at *3 n.3. Considering the evidence in the light most favorable to the nonmoving party, CMU, and giving it the advantage of every fair and reasonable inference in light of the undisputed facts, the Court found that CMU had sufficiently presented enough evidence upon which a reasonable jury could properly find that Claim 4 of the '839 Patent and Claim 2 of the '180 Patent were not obvious. Therefore, Marvell's motion for judgment as a matter of law on this issue was denied. The question of invalidity by obviousness was properly decided by the

[68] While, Dr. McLaughlin explicitly listed examples of indicia to show non-obviousness, (Docket No. 737 at 71-72), Dr. Proakis did not rebut Dr. McLaughlin's considerations on this indicia or provide any contrary evidence. (Docket No. 726).

jury, which found that the patents were not rendered invalid for being obvious. (Docket No. 762). Considering the evidence proffered by CMU, this verdict was not against the clear weight of the evidence and a new trial is not warranted as to this defense.

C. Willfulness

The Court turns to CMU's claims of willfulness. At trial, Marvell filed a Motion for Judgment as a Matter of Law on Willful Infringement and a Renewed Motion for Judgment as a Matter of Law on Willful Infringement (Docket No. 740), both of which were fully briefed. (Docket No. 700, 721, 740, 741). The Court denied these motions on the record, following arguments by counsel, letting the relevant issues of willfulness go to the jury. (Docket No. 759 at 52-53).

After trial, CMU filed a Motion for a Finding of Willful Infringement and Enhanced Damages. (Docket No. 790). Marvell also filed a Motion for Judgment as Matter of Law, or in the Alternative, New Trial on Non-Damages Issues, wherein it requests a JMOL or new trial on the issue of willfulness. (Docket No. 805).

The Court will now address the specific matters raised by these motions, considering all of the parties' arguments and the entire trial record, to explain its earlier and current decision.

1. Legal Standard

It is undisputed that CMU must establish willful infringement by proving, with clear and convincing evidence that (1) Marvell acted despite an objectively high likelihood that its actions constituted infringement of a valid patent, and (2) that this objectively-defined risk of infringement was either known or so obvious that it should have been known to the accused infringer. *Bard Peripheral Vascular Inc. v. W.L. Gore & Assocs., Inc.*, 682 F.3d 1003, 1005 (Fed. Cir. 2012), *cert. denied*, 133 S. Ct. 932 (2013); *In re Seagate Tech. LLC*, 497 F.3d 1360, 1371 (Fed. Cir. 2007) (en banc). The Court's determination should be "based on the record ultimately made in the infringement proceedings." *Bard*, 682 F.3d at 1008.

a. Objective Reasonableness

Marvell first argues that CMU has not proven objective unreasonableness. (Docket No. 700 at 6, Docket No. 741 at 7). To the contrary, the Court believes CMU has presented sufficient evidence to conclude that Marvell's actions were such that a reasonable person would have considered there to be a high likelihood that infringement of CMU's patents would result.

i. Marvell's Knowledge of the Patents and Awareness of an Objectively High Likelihood of Infringement

The evidence at trial clearly and convincingly shows that Marvell had knowledge of the patents-in-suit at the time of infringement by 2002 and that the very people who designed the Accused Technology knew of the patents. To the extent a question of fact remained, the jury found as part of its December 26, 2012 verdict that Marvell had "actual knowledge of the '180 and '839 Patent prior to commencement of this lawsuit (in other words, prior to March 6, 2009)." (Docket No. 762 at 6-7). This jury determination is supported by substantial evidence.

Marvell first should have been aware of Kavcic's work through an email on March 8, 1998 from Aleksandar Kavcic to Nersi Nazari at Marvell, in which Dr. Kavcic inquired about Marvell's detectors and sought information about the possibility of getting a job at Marvell. (Def. Ex. 1023). In that email, Kavcic states that he had sent Dr. Nazari his Globecom paper and referred Dr. Nazari to his other publications online. (*Id.*) This Globecom Paper addresses some of the ideas expressed in the patents, but it is not the IEEE paper later referenced by Burd.[69]

[69] On these facts the Court believes the jury could have made a number of legitimate inferences, including the possible conclusion Dr. Nazari may have shared Dr. Kavcic's work with Marvell's team. The jury was instructed that :

(Docket No. 674 at 118). In sending this email, Dr. Kavcic did not grant Marvell any rights to use the ideas in the paper.[70] (*Id.*). The response to this email was not proffered at trial, and Dr. Nazari did not testify at trial.[71]

Next, Marvell engineer Gregory Burd, the developer of the Accused Technology, stated that he read Dr. Kavcic's published papers and learned about his Viterbi detector. (Docket No. 726 at 137). He told his supervisor, Toai Doan, about his work on "Kavcic's model" in 2001, (Docket No. 677 at 53:14-54:17; Pl. Ex. 227), and stated he was able to develop a sub-optimal media noise detector based on the Kavcic model from Kavcic's IEEE Paper. (Pl. Ex. 279). Mr. Burd then informed his superiors twice via email about the CMU Patents in January 2002. (Pl. Ex. 280; Docket No. 677 at 73:13-74:11; Pl. Ex. 283) ("And of course as I mentioned earlier, Kavcic detector is also patented."). Mr. Burd testified that he used Dr. Kavcic's model to create a simulation program at Marvell. (Docket No. 726 at 137) ("Q. Did you or someone else at Marvell create a simulation in the computer of what Professor Kavcic was describing? A. Yes, I did."). Mr. Burd named his model KavcicPP, and he named his optimal simulator KavcicViterbi.

> While you may consider only the evidence in the case in arriving at your verdict, you are permitted to draw such reasonable inferences from the testimony and the exhibits you feel are justified in light of your own common experience, reason, and common sense.

(Docket No. 764 at 55).

70 At trial Dr. Kavcic was asked,

> Q: And you understood if you sent the paper to Marvell, they were free to use the information that was in the paper in their business. Right?
> Kavcic: No, sir. No. No, not. Because this was already filed for a patent, and nobody is free to use something that is without a license if it's filed and then ultimately patented.
> Q: And --
> Kavcic: But I was sending this to Dr. Nersi Nazari because I wanted him to know what I was working on as a lead-in to providing me an interview, because I was looking for a job.

(Docket No. 674 at 118-119).

71 *See supra* note 21.

In 2003, the KavcicPP was renamed to MNP. (Pl. Ex. 368). Both Dr. Wu and Mr. Doan, who were engineers at Marvell at that time, testified that they became aware of the patents in early 2002 when applying for Marvell's patent related to MNP technology, when they listed CMU's patents as prior art. (Docket No. 707 at 322; Docket No. 761 at Jt. Ex. D at 124:22-125:19; U.S. Patent No. 6,931,585). Yet, all three claimed they had not read the patents at the time. (*Id.*).

In addition to internal notification on the patents, CMU also sent two letters to Marvell's CTO Dr. Pantas Sutardja and Matthew Gloss, then General Counsel, enclosing copies of the patents and inquiring if there was an interest in the patents. (Pl. Ex. 422; Pl. Ex. 431). Marvell did not respond to these letters because, as CEO Dr. Sehat Sutardja alleges, they were "not interested in using the technology in our chip." (Docket No. 707 at 91). In addition, Fujitsu, "a customer of Marvell's read channel i.e. 5575M, 7500M," wrote to Marvell in November 2004, that it had received a license offer for the CMU Patents-in suit. (Pl. Ex. 477). Fujitsu wrote that "since it seems that these patents might be related to read channel, we would like to know, by the end of November, your opinion regarding relationship between CMU's Patents and the above Marvell lead [*sic*] channel and the specific grounds/reasons for such opinion." (*Id.*). No documents were found in relation to this letter, and Marvell's corporate designee testified that he did not know of any response to this letter. (Docket No. 761 at Jt. Ex. C at 534-535).

Despite knowing about the patents-in-suit, the evidence presented at trial reveals that Marvell made little effort to determine whether it was infringing these patents. Dr. Wu, Mr. Burd, and Mr. Doan all state that they decided not to read the patent claims, even though email correspondence indicates that both were aware that Dr. Kavcic had patented his algorithm. (Pl. Ex. 280; Pl. Ex. 283). If believed, this behavior is a clear sign they disregarded a high likelihood of infringement. Once presented with the patents, Mr. Doan did not conduct further investigations on his own, tell others to investigate or send the patents to Marvell's legal team.[72] (Docket No. 761 at Jt. Ex. C at 125-130). Instead, he directed his employees to continue working to capture the realized gain and reported that his employees would continue to work on the "Kavcic model." (*Id*. at Ex. D at 190-191; Pl. Ex. 285). This occurred around the time that he was promoted from his position as principal engineer of the signal processing group to Vice President of read channel development. (Docket No. 761 at Jt. Ex. C at 16-17). While Marvell alleges that the MNP is a suboptimal version of Dr. Kavcic's work, Dr. Wu's 2003 email to Doan stated that he and Burd were implementing an approach that "turns out to be the original structure that Kavcic proposed in his paper." (Pl. Ex. 366; Docket No. 677 at 134-135).

These failed opportunities to investigate engendered a great deal of risk that Marvell's engineers infringed CMU's patents. Moreover, the lack of action by Marvell's employees does not conform to Marvell's own purported IP policy, which according to the testimony of Dr. Armstrong, Marvell's Vice President of Marketing, requires that any such information about patents be forwarded to the legal department for analysis. (Docket No. 761 at Jt. Ex. C at 294-295). Despite this, Dr. Armstrong stated that he did not know whether the CMU Patents were ever submitted to the legal department according to this policy. (*Id.* at 295, 299). He further testified that he was not aware of any internal discussion about licensing the patents from CMU given Fujitsu's letter request. (*Id.*).

Marvell's lack of inquiry about the possibility of infringement also meant that it took no effort to avoid infringement of the subject patents. This fact was specifically corroborated by Mr. Burd, who stated that he was not aware of any measures being taken to stop using the CMU Patents. (Docket No. 678 at 101). Marvell is a sophisticated entity with nearly 3,000 patents.

[72] Mr. Doan testified by way of deposition designations. (Docket No. 761 at Jt. Ex. C). Mr. Doan left Marvell in October of 2009. (*Id.*). As a former employee, he may not have been perceived with any bias towards Marvell, compared to other witnesses who were still current employees. (*Id.*).

(Docket No. 707 at 53). Yet, it took absolutely no steps to investigate these patents before producing 2.3 billion chips, despite the fact that the technology was *named* after Dr. Kavcic, one of the inventors of the CMU Patents.[73] To this day, Marvell continues to use the Accused Technology. In fact, at trial Mr. Burd testified that Marvell had no plans to discontinue using the technology. (Docket No. 678 at 101). Only as of July 2013—seven months after the verdict—is it beginning to design around the technology. (Docket Nos. 889; 898).

Succinctly put, Burd presented his superiors at Marvell with a product named "KavcicPP" and noted that Dr. Kavcic held a patent on such a detection scheme, yet nothing was apparently done to investigate infringement, reach out to Dr. Kavcic or CMU, or respond to CMU and Fujitsu's inquiries on same. Accordingly, CMU has shown that Marvell's behavior created an objectively high risk of infringement. *See Spectralytics, Inc. v. Cordis Corp.*, 649 F.3d 1336, 1348 (Fed. Cir. 2011) (failure to investigate the patent situation is a consideration that tends to establish willful infringement).

ii. "Reasonable" Defenses

In response to CMU's claim of willfulness, Marvell urges that the "'objective' prong of [willfulness] tends not to be met where an accused infringer relies on a reasonable defense to a charge of infringement." *Bard.*, 682 F.3d at 1005. Given its stance, the Court will review Marvell's defenses, how they evolved and were used at trial, if at all.

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73 As shown at trial, Mr. Burd stated at his deposition:

> Q: And why use the Kavcic approach, as the yardstick?
> A: …just because his name, kind of became a yardstick. I don't know why. I mean, people use it. It's like when you say-you know there are certain people which get associated with – some event…. Ronald Reagan is credited with breaking down the wall. Well, I didn't see him break any bricks. Right? But yet, he is the one. So same thing.

(Docket No. 771 at Ex. H at 110).

Marvell had several overarching defenses to the willful infringement claim, the first being that Marvell believed its own technology covered the MNP. To this end, Marvell was allowed to present, at trial, patent U.S. Patent Number 6,931,585 (the "'585 Patent")[74] filed in July 2002, with Dr. Wu and Mr. Burd listed as inventors, and which related to MNP technology.[75] (Def. Ex. 266). These patents may be relevant to the state of mind of the infringer, but infringement is determined by mapping the claims of the <u>patents-in-suit</u> onto the Accused Technology. *See Akamai Techs.*, 692 F.3d at 1307 ("Because patent infringement is a strict liability offense, the nature of the offense is only relevant in determining whether enhanced damages are warranted."). Marvell argued that since the PTO had granted Marvell the '585

[74] The '585 patent is owned by Marvell International Ltd, based in Hamilton, Bermuda. *See* '585 Patent. Marvell International Ltd., is not a party to this case, and, as such, CMU argues these patents are irrelevant. (Docket No. 726 at 4). CMU contends that the admission of these patents opened the door to inquiry of Marvell's corporate structure, such that this patent and hundreds of others offered as exhibits at trial

> are owned by Marvell International, Limited as part of the tax structure -- tax favorable structure I'll call it. So, you know, if they would want to go there with respect to those patents, we ought to be entitled to talk about, you know, why that works and how it works and what's going on there. The fact that Marvell has to pay royalties to itself -- although, frankly, they did not give us discovery on that issue and so they can't talk about a number, but, you know, they've introduced that patent and want to introduce evidence of about 200 more that are owned by some other entity.

(Docket No. 710 at 4-5). In its order on Marvell's motion *in limine*, the Court precluded CMU from introducing evidence or argument at trial that Marvell's tax strategy was illegal or inappropriate. (Docket No. 605). Thus, evidence on this subject was not introduced by the parties during trial.

[75] The Court reminded the jury throughout the trial that owning one or more patents in and of itself is not a defense against the charge of infringement. The following instruction was taken from the parties' proposed limiting instructions (Docket No. 625 at Ex. 4), and was repeatedly used during trial:

> You have heard testimony about Marvell and whether Marvell does or does not own a patent. Marvell may claim that some of its patents cover some of the accused chips or simulators in this case. It may also claim that it improved on the CMU patents. While this evidence may be relevant to some issues you will decide, owning one or more patents in and of itself is not a defense against the charges of infringement of the CMU patents.

(Docket No. 707 at 90, 294).

Patent, Marvell believed it did not infringe.[76] The reasonableness of this position, given its factual nature, was left for the jury to decide. *Bard*, 682 F.3d at 1008. Indeed, Marvell's argument on this point is completely factual, as it has not argued any legal theory to support its defense that its later patents in some way invalidate earlier ones, or that owning a patent on Accused Technology is a *per se* sign of reasonableness and non-infringement. To the extent that this defense is factual in nature, it was presented to the jury, as instructed by *Bard*,[77] and the jury found that Marvell had no "objectively reasonable defense." (Docket No. 762). The Court likewise agrees.

A novel and non-obvious after-issued patent may be valid over a prior-issued patent, but that does not mean that, if practiced, the technology disclosed in the after-issued patent would not infringe the prior-issued patent. *Bio-Tech. Gen. Corp. v. Genentech, Inc.*, 80 F.3d 1553, 1559 (Fed. Cir. 1996) ("The existence of one's own patent does not constitute a defense to infringement of someone else's patent.") (internal citation omitted). Therefore, Marvell's over-reliance on its own patents is misplaced. Rather than focusing on its patents, which have absolutely no bearing on the reasonableness of its defense, the inquiry should center on the Accused Technology and CMU's patents. Marvell's assertions that its patents form a valid defense are not at all reasonable, either legally or, according to the jury, factually, as the Court will now explain.

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[76] Of course, a patent issued by the PTO may later be declared invalid. *See* 35 U.S.C. § 282. Indeed, Marvell has sought to invalidate CMU's patents in this case. (Docket Nos. 747; 748)

[77] "[T]he judge may when the defense is a question of fact or a mixed question of law and fact allow the jury to determine the underlying facts relevant to the defense." *Bard*, 682 F.3d at 1008. Trial courts have adopted this practice in similar patent cases. *See, e.g.*, *Grant St. Grp., Inc. v. Realauction.com, LLC*, Civ. No. 09-1407, 2013 WL 2404074, at *4-5 (W.D. Pa. May 31, 2013) ("The Court concludes that there are likely mixed questions of law and fact with regard to Realauction's defenses, insofar as the jury should be presented the evidence to determine the underlying facts relevant to the defenses before this Court rules on the objective prong of willful infringement") (internal citations omitted).

To the extent that Dr. Wu has suggested that he consulted with Marvell's legal counsel about the patent, the Court notes that this testimony is hotly contested, was not significantly developed at trial, and was shrouded by the attorney-client privilege. Dr. Wu testified that the "prior art," i.e., the '180 Patent and the '839 Patent, was given to Marvell's patent counsel and that he later obtained his own patents (owned by a Marvell-entity).[78] (Docket No. 707 at 323; Docket No. 709 at 90). Marvell, however, has expressly stated throughout this litigation that it is not raising advice of counsel as a defense to the willfulness claims. (Docket No. 174-1 at 77-78). To that end, the Court on December 20, 2012 ruled that Marvell could not at trial – "without putting the actual communications from counsel at issue – argue that its receipt of a patent implies or suggests that Marvell's counsel returned a favorable opinion that Marvell's NLD-type and MNP-type chips and simulators and the Kavcic-Viterbi simulator do not practice the patented methods of the asserted claims." (Docket No. 753). Despite this, Marvell's counsel attempted to imply at closing that its engineers had vetted this patent with counsel based on snippets of Dr. Wu's testimony. (Docket No. 759 at 79-80). The Court has doubts about the credibility of certain testimony[79] regarding this consultation and the reasonableness of this defense, given its years of involvement with this matter.[80]

[78] CMU contends that Dr. Wu was clear in his deposition that such communications with a lawyer regarding the patents were made only for his prior art search for his own patent filed in 2002. (Docket No. 709 at 91-92).

[79] As the Court recounted in its opinion on Marvell's Motion for a Mistrial, (Docket No. 900), Dr. Wu during his testimony clenched his jaw, drank an entire pitcher of water, generally appeared uncomfortable, and continuously looked at Dr. Sutardja in the back of the courtroom throughout his appearance as a witness. In this Court's estimation, the jury could have easily found Dr. Wu was not credible given his demeanor on the stand. On this and all other areas of inquiry, the jury was charged to weigh witness testimony and give it the appropriate weight it deserved or discredit the testimony completely. *See, e.g.*, *Barber v. CSX Distribution Servs.*, 68 F.3d 694, 700 (3d Cir. 1995).

[80] Upon consideration of CMU's "Motion in Limine Strike Testimony and to Preclude Argument Relating to Marvell's Pre-suit Communications with Counsel about the Patents-in-Suit" (Docket No. 722), the Court ordered Marvell to produce any and all documents that involve or reference Mr. Gregory Burd, Dr. Zining Wu, Eric Janofsky, Esq., CMU, Kavcic, or Seagate between the years of 2001 to 2003, and any and all documents involving Fujitsu between the years of 2003 to 2005 to the Court for an *in camera* review. (Docket No. 737). The Court

Next, Marvell argued that it did not infringe the patents-in-suit in its chips and chip simulators because the patents-in-suit are too "complex." (Docket No. 741 at 9, 10, 15, 18). This defense does not address Marvell's KavcicViterbi Simulator, which it acknowledges embodies the "complex" solution of the patents.[81] Marvell claims that even the inventors of the patents admitted that their method was too complex to implement in an actual chip, suggesting that Marvell could not have willfully infringed on a patent with its "simpler, sub-optimal" solutions. (Docket No. 759). But, optimality is not relevant to whether Marvell used a method that includes each and every method step of the asserted claims in the patents-in-suit. *Akamai Techs.*, 692 F.3d at 1307. As Dr. McLaughlin explained at trial, the difference between an optimal and sub-optimal media detector relates to performance as measured by SNR gain rather than infringement. (Pl. Ex. 279; Docket No. 677 at 64-65). In fact, he specifically stated that the sub-optimal detector "would be using the same method" as the optimal noise detector, (Docket No. 677 at 65), and he has testified that the sub-optimal versions do infringe on CMU's patents. (*Id.*). Marvell's infringement expert, Dr. Proakis, similarly agreed that sub-optimality is not part of the infringement analysis.[82] Furthermore, Marvell cites no legal authority to support its asserted

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reviewed these documents on December 19, 2012. The Court took said documents under advisement in reaching its decision on willfulness, but did not base its analysis herein on any document produced under this order. (Docket No. 759 at 186-187) ("It was only the Court which asked for the documents in camera so that [it] could address this issue and the opinion that I looked at…. [T]he Court is also well aware that you can't draw an inference one way or the other.").

[81] Marvell's 30(b)(6) designee on the technology stated,

> This (Plaintiff Ex. 93) is KavcicViterbi.cpp class, written by engineers in Marvell, and I do believe it contains the implementation, as understood by our architecture team of the IP which is taught in Professor Kavcic's papers, and consequently in his patent.

(Docket No. 677 at 170-171; Pl. Ex. 93).

[82] To this end, Dr. Proakis testified that:

> A. I don't believe suboptimality -- optimality or suboptimality is mentioned in any claims of the patent.

position that complexity constitutes a defense to infringement, and this Court's research efforts have uncovered no such authority.

Once again, Marvell's defense is fact-intensive. Whether it was reasonable to believe that the MNP, merely by being "sub-optimal," did not use the method of the CMU Patents goes to the defendants' state of mind regarding the alleged infringement. The jury was presented with the convincing testimony of Dr. McLaughlin explaining how the MNP used the methods as well as the 2003 email from Dr. Wu to Mr. Doan stating that he and Mr. Burd were implementing an approach that "turns out to be the original structure that Kavcic proposed in his paper." (Pl. Ex. 366; Docket No. 677 at 134-135). Ultimately, the jury had to decide what was reasonable based on the credibility of witnesses and the weight to be given to the evidence. *Eschelman v. Agere Sys.*, 554 F.3d 426, 433 (3d Cir. 2009). They found that this was not a reasonable defense (Docket No. 762), and the Court takes this jury verdict on a question of fact as advisory to its overall holding on willfulness. *See Bard*, 682 F.3d at 1008.

Specifically addressing the KavcicViterbi Simulator, Marvell has presented little to rebut CMU's position that this simulator infringes the patents-in-suit. Mr. Burd outright states that this simulator contained the implementation of the "IP which is taught in Professor Kavcic's papers and consequently in his patent." (Docket No. 677 at 167). Marvell's only argument supporting non-infringement on the KavcicViterbi Simulator appears to be that the patents-in-suit do not cover simulators. (Docket No. 671). To the extent that this is a "reasonable defense," a jury had to decide this question based on the weight of the evidence and the credibility of same. *See*

> Q. So a suboptimal version of an invention that's covered by a claim can still infringe; right?
> A. It may or it may not. It depends on the circumstance.
> Q. Right. But sub-optimality doesn't enter into the analysis at all; does it?
> A. No.

(Docket No. 711 at 281-282).

Eschelman, 554 F.3d at 433. Marvell, however, presented no evidence showing that its employees believed the patents-in-suit did not cover simulators at the time of infringement.[83] Indeed, Marvell employees considered the Kavcic algorithm the "gold standard" against which they continuously run tests. (Docket No. 677 at 55). And, no evidence was ever presented as to why Marvell believes using the patented technology for comparison and testing purposes negated the need for a license on said technology.

Marvell further argues that CMU's delay in initiating this lawsuit suggests that the case for infringement is not sufficiently obvious to support a finding of willful infringement. (Docket No. 741 at 8). Given that the willful infringement inquiry depends on the alleged infringer's conduct rather than the litigation strategy of the patentee, *In re Seagate*, 497 F.3d at 1374, the Court fails to see how CMU's timing with respect to the litigation is relevant on this issue. Moreover, Dr. Wu testified during trial that it was not possible for anyone outside of Marvell to determine the technology used on the chips without Marvell's engineers explaining how its chips worked. (Docket No. 709 at 61-64) ("Just like Coca-Cola keeps its formula as a secret…For you to understand how the circuits implemented, the implementation detail, yes, you do need to talk to our people."). He also stated that he would not have explained to CMU how its chip circuitry was implemented and had never told Dr. Kavcic about the use of his algorithm at Marvell despite meeting him several times.[84] (*Id.* at. 63:19-63:24). These facts may well have delayed CMU from

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83 Certain witness (such Dr. Wu, Mr. Burd, Dr. McLaughlin, and Dr. Blahut) testified to the nature of simulators and whether in their opinion simulators process real or simulated data. (Docket No. 677 at 167-175; Docket No. 707 at 309-311, 322; Docket No. 711 at 261-266; Docket No. 726 at 131-136). However, none spoke to how their beliefs about the nature of simulators affected Marvell's decision to use the patents-in-suit.

84 During trial, Dr. Wu discussed the significance of naming active projects after Dr. Kavcic:

> Q. Did you tell Dr. Kavcic you had files named after him?
> A No.
> Q Why not?

making a determination as to whether it could bring a lawsuit in good faith.[85] But again, it is the infringer's actions, not the patentee's, that prove willful infringement. *See In re Seagate*, 497 F.3d at 1374.

Marvell asserts again that the Court's comment that Marvell's invalidity defense was a "close call" in its opinion denying summary judgment forecloses a finding of willfulness as a matter of law. (Docket No. 741 at 11). The Court has already indicated that its prior summary judgment rulings do not amount to a finding that an objectively reasonable defense has been presented.[86] (Docket No. 601, at 4); *Monsanto Co. v. E.I. Dupont de Nemours and Co.*, Civ. No. 09-686, 2012 WL 2979080, at *2 (E.D. Mo. July 20, 2012); *Grant St. Grp., Inc. v. Realauction.com, LLC*, Civ. No. 09-1407, 2013 WL 2404074, at *3 (W.D. Pa. May 31, 2013).

> A Why should I? It's just -- it's like Dr. Viterbi, right? I think I bump into Dr. Viterbi at the conference, should I just approach him and say: Dr. Viterbi, we implemented your algorithm named after you?

(Docket No. 709 at 64). In addition, Mr. Burd and Dr. Wu testified that their references to Dr. Kavcic's name were meant to reference the media noise problem that Dr. Kavcic identified in his paper. (*Id*. at 22).

85 The Court is cognizant of Rule 11 of the Federal Rules of Civil Procedure, which establishes the standards that counsel must follow when making written representations to the court. Rule Rule11(b) of the Federal Rules of Civil Procedure provides in pertinent part:

> [b]y presenting to the court a pleading, written motion, or other paper—whether by signing, filing, submitting, or later advocating it—an attorney or unrepresented party certifies that to the best of the person's knowledge, information, and belief, formed after an inquiry reasonable under the circumstances:
> ...
> (3) the factual contentions have evidentiary support or, if specifically so identified, will likely have evidentiary support after a reasonable opportunity for further investigation or discovery[.]

FED. R. CIV. P. 11(b)(3). Generally, Rule 11 "'imposes on counsel a duty to look before leaping and may be seen as a litigation version of the familiar railroad crossing admonition to 'stop, look, and listen.'" *Oswell v. Morgan Stanley Dean Witter & Co.*, 507 F. Supp. 2d 484, 488 (D.N.J. 2007) (quoting *Lieb v. Topstone Indus.*, 788 F.2d 151, 157 (3d Cir. 1986)).

86 Under Rule 56, the Court may only grant summary judgment if the "movant shows that there is no genuine dispute as to any material fact." FED. R. CIV. P. 56. A defense may be unreasonable even if the Court had earlier found there to be genuine dispute of material facts. *See, e.g.*, *Grant St. Grp*, 2013 WL 2404074 at *3. Moreover, in considering a motion for a judgment as a matter of law after trial or a motion for a new trial, under Rule 50, the Court looks at the evidence, actually presented at trial, in the light most favorable to the non-movant. *Galena*, 638 F.3d at 196. These standards of review are not one and the same.

Having now examined the trial record as a whole, the Court declines to hold that Marvell's failed invalidity defense affords shelter against a finding of willful infringement. It is clear to the Court that in order for Marvell to have a "reasonable defense" to infringement for the time period of 2001-2009, there needs to be some proof that the basis for such invalidity defense was known to the infringers or even the person having ordinary skill in the art.[87] In this regard, Marvell's claims at trial rested on the Worstell Patent, U.S. Patent No. 6,282,251, alone. (Def. Ex. 187). Despite same, Marvell proffered no evidence that anyone at Marvell knew of the Worstell Patent from 2001 until this litigation began in 2009. Therefore, Marvell did not have any basis to believe that it could reasonably invoke such a defense to infringement prior to this infringement. Instead, Marvell pursued a course of conduct that was without regard to the potential legal ramifications of infringement. Even if the Court concluded that Marvell has now put forth a reasonable defense to infringement that has been developed during litigation, such a determination would not be dispositive. Rather, the full weight of Marvell's actions as documented in the record and presented at trial precludes the Court from finding that a reasonable person would believe its actions did not involve a high risk of infringement. Further, invalidity of the patents-in-suit was a factual determination to be made in this case.[88] As such, the reasonableness of reliance on such invalidity defense was also the prerogative of the jury.

[87] The idea that outside counsel discovering prior art that may invalidate the patent-in-suit, eight years after the start of infringing activity, defeats willful infringement, seems contrary to the spirit of the law. Just because a defendant is able to hire a lawyer to develop a defense to a patent suit, cannot mean that its prior actions no longer ran an "objectively high likelihood of patent infringement." *In re Seagate*, 497 F.3d at 1374 ("in ordinary circumstances, willfulness will depend on an infringer's prelitigation conduct.").

[88] It would clearly be in error for the Court to have determined that no reasonable defense to infringement exists before the jury even decided the factual underpinnings of invalidity and infringement. To do so would mean the Court's finding of objective willfulness necessitates judgments as a matter of law on validity and infringement, or the Court could be left stating that "no reasonable litigant could realistically expect those defenses to succeed" with the jury possibly finding for the defendant on same. Similarly, it would mean that allowing any defense to go to the jury necessitates a finding of no willful infringement. See *i4i Ltd. P'ship v. Microsoft Corp.*, 598 F.3d 831, 860 (Fed. Cir. 2010) ("The fact that Microsoft presented several defenses at trial, including non-infringement and invalidity, does not mean the jury's willfulness finding lacks a sufficient evidentiary basis.").

Marvell has trotted out a number of different non-infringement or invalidity defenses throughout its four years litigating before the Court. Nevertheless, the Court has consistently found that the issues of infringement and invalidity are to be decided by the jury. To the extent that Marvell again believes the Court should deny a finding of willfulness on the basis that the earlier defenses that were not presented to the jury were reasonable, the Court disagrees. If Marvell thought that any of those "other" defenses were reasonable, it should have presented them to the ultimate finder of fact, the jury.

iii. Conclusion: Objective Willfulness

After taking into account the totality of this litigation, the Court finds the question of whether Marvell acted despite an objectively high likelihood that its actions constituted infringement of a valid patent to be, in part, a question of fact. The Federal Circuit sitting *en banc* held "when the resolution of a particular issue or defense is a factual matter, however, whether reliance on that issue or defense was reasonable under the objective prong is properly considered by the jury." *Powell v. Home Depot U.S.A., Inc.*, 663 F.3d 1221, 1236-37 (Fed. Cir. 2011). This Court recognizes that the Federal Circuit's decision in *Bard* holds that this objective recklessness determination is, however, "decided as a matter of law by the judge." 682 F.3d at 1008. Given the lack of further guidance by the Federal Circuit on how to reconcile these principles in a practical manner for trial, and the Circuit's own debate on the precedential value of *Bard*,[89] the Court sent the question of willfulness to the jury for factual findings on an

[89] In the Federal Circuit's *en banc* decision in *Highmark, Inc. v. Allcare Health Management Systems., Inc.*, the five-member dissent opinion written by Judge Moore stated "*Bard*'s holding that the objective prong '*should always* be decided as a matter of law by the judge' cannot be reconciled with *Powell* ... For reasons similar to those discussed below, this court should also revisit *Bard* en banc." 701 F.3d 1351, 1357 n.1 (Fed. Cir. 2012) (emphasis in original). Judge Reyna, in another minority dissent, agreed that *Bard* was "a puzzling conclusion ... that we can transform a question of fact into a mixed question of law and fact in order to exclude a jury from deciding what conduct is reasonable." *Id.* at 1366. Similarly, in Judge Mayer's original panel dissent in the *Highmark* case, he concluded "that because *Bard* usurps the fact-finding role of the trial courts and is plainly inconsistent with our precedent it is an outlier and of no precedential value." *Highmark*, 687 F.3d 1300, 1320-21 (Fed. Cir. 2012).

advisory basis. This, the Court believes, is in accord with *Bard*, which affirms that underlying fact questions should be sent to a jury.[90]

In makings its ultimate finding, the Court has considered the whole record, including all of the evidence; the jury's verdict on infringement and invalidity; Marvell's knowledge of the patents; and the reasonableness of their defenses; along with the jury's advisory verdict on objective reasonableness.[91] In doing so, the Court, as the final arbiter, finds that CMU has shown by clear and convincing evidence that Marvell acted in disregard of an objectively high likelihood that its actions constituted infringement of a valid patent. Thus, CMU's Motion for a Finding of Objective Willfulness is granted (Docket No. 790), and Marvell's JMOL and/or Motion for New Trial as to Objective Willfulness, (Docket No. 805), is denied.

b. Subjective Prong

Under the subjective prong of willful infringement, "the patentee must also demonstrate that this objectively-defined risk (determined by the record developed in the infringement proceeding) was either known or so obvious that it should have been known to the accused infringer." *Powell*, 663 F.3d at 1236. The jury ultimately determines whether this subjective prong is met. *Id.* Notwithstanding a finding of objective willfulness, Marvell further maintains

[90] Initially, the Court had contemplated sending interrogatories to the jury on the factual issues underlying the objective prong of willfulness, but it became apparent that this was not feasible given the number of claims, disputed facts, and defenses presented. For example, in considering Marvell's belief that its invention was "less complex," a jury needed to weigh the "complexity" of the patents-in-suit, the Accused Technology, the Marvell patents, the relationship between same, and the credibility of the witnesses who claimed to believe they were not infringing due to this factor, balanced against all of Marvell's infringing activity. Further, this is not a case in which the defenses were tried in prior proceedings. With the parties' agreement, infringement, validity, damages, and willfulness were all presented to the jury in one trial.

[91] The jury verdict addressed objective reasonableness as follows: "Did Marvell have actual knowledge of the [patents] prior to commencement of this lawsuit (in other words, prior to March 6, 2009)?"; and "If Marvell learned of the [patents] and prior to commencement of this lawsuit, did Marvell have an objectively reasonable defense to CMU's claim of infringement?" (Docket No. 762 at 6-7). On subjective willfulness, the jury was asked "If Marvell learned of the [patents], do you find clear and convincing evidence that Marvell actually knew or should have known that its action would infringe the [claims of the patents]." (*Id.*).

that no reasonable jury could find that Marvell possessed the requisite subjective intent for willful infringement. (Docket No. 741 at 13).

Again, the evidence presented at trial belies Marvell's assertions. CMU has presented sufficient evidence that would permit the jury to find that Marvell's engineers worked on multiple projects bearing Kavcic's name, clearly indicating that those engineers were aware that Dr. Kavcic had a hand in creating this technology. Moreover, Marvell's failure to investigate the patents despite the high likelihood of infringement militates against a finding that it had a subjectively reasonable basis for believing that it was not infringing or that the patents were invalid.

In addition, as the Court has already explained, the conduct of Marvell's engineers in copying Dr. Kavcic and Dr. Moura's work as described in their papers is relevant to finding that Marvell had a subjective intent to infringe. CMU presented evidence at trial showing that Marvell's engineers duplicated the technology described in Dr. Kavcic and Dr. Moura's papers in their chips and simulators, as testified to by Dr. McLaughlin. (Docket No. 677 at 54-55). The evidence shows that shortly after beginning work on the Kavcic model, Mr. Burd prepared a preliminary write-up of the KavcicPP detector which referenced the work of Dr. Kavcic and Dr. Moura. (Pl. Ex. 280). Again, Dr. McLaughlin testified that this KavcicPP write-up became the MNP circuit. (Docket No. 677 at 66-67). Although Mr. Burd stated that he was "generally following the papers," not the patents, and that he "left it at that," (*Id.* at 77), Dr. McLaughlin testified that the papers are virtually identical to what is described in the patents. (*Id.* at 66-67).

The evidence also showed that when Kavcic's name was disassociated with the project, there was no functional difference between the old and new computer codes. (Pl. Ex. 368; Docket No. 677 at 81). Dr. Wu informed Mr. Doan that he and Mr. Burd were working on a model that ended up being the original structure that Kavcic proposed in his paper. (Pl. Ex. 366; Docket No. 677 at 134-135). Dr. McLaughlin confirmed that the NLD used the original structure proposed in Dr. Kavcic's paper, and subsequently in the CMU Patents. (Docket No. 677 at 136-137). This evidence of copying contributes to the Court's finding that Marvell acted in a subjectively reckless manner with respect to the risk of infringing the subject patents.

In arguing that it lacked knowledge about the underlying infringement, Marvell points out that CMU acknowledged its reputation as a technology innovator. The Court fails to see how this pertains to whether Marvell knew or should have known that its actions ran an objectively high risk of infringing the patents-in-suit. The Court also finds unavailing Marvell's alternative argument that CMU's failure to follow-up on its 2003 licensing letters lulled it into a false sense of security. Nothing disclosed at trial even indicated that any person at Marvell considered the implications of these licensing letters. Nor was there testimony from Marvell employees stating that they were aware CMU failed to follow up with other inquiries. Rather, when presented with potential warnings about the risk of infringement, Marvell ignored them and proceeded ahead in developing read channel technology based on Dr. Kavcic and Dr. Moura's work.

For all of these reasons, after considering all of the evidence in this case in the light most favorable to CMU, and drawing all reasonable inferences in its favor on subjective willfulness, the Court denied Marvell's original and renewed Motion for Judgment as a Matter of Law on Willful Infringement, (Docket Nos. 699; 740), and denies Marvell's JMOL now. (Docket No. 805). Likewise, the Court finds CMU presented sufficient evidence on which a jury could have found that Marvell knew or should have known about the substantial risk of infringement. Thus, the verdict on subjective willfulness is not against the great weight of evidence and Marvell's request for a new trial is not justified. As such, the Court grants CMU's Motion for a Finding of Willful Infringement. (Docket No. 790).

D. Damages

The Court also considers Marvell's Motion for Judgment as a Matter of Law, New Trial and/or Remittitur with Respect to Damages, along with related briefing. (Docket Nos. 807; 808; 829; 855; 857). In these motions, Marvell renews arguments from its at-trial JMOL. (Docket Nos. 701; 702; 725; 738; 739). In sum, Marvell maintains that the jury award of $1.169 billion is legally unsound and factually unsupported. (Docket No. 808). CMU counters that the award is in accord with the governing statute and Federal Circuit precedent, and supported by the facts of record. (Docket No. 829).

1. Legal Standard

As the Court has set forth in a number of prior decisions, in a patent infringement action, a successful plaintiff is entitled to "damages adequate to compensate for the infringement, but in no event less than a reasonable royalty for the use made of the invention by the infringer, together with interest and costs as fixed by the court." 35 U.S.C. § 284. Two forms of compensation are authorized by § 284: lost profits and reasonable royalty damages. *Lucent Techs., Inc. v. Gateway, Inc.*, 580 F.3d 1301, 1324 (Fed. Cir. 2009). Because CMU does not manufacture or sell products that practice the claimed methods, it is not entitled to lost profits. CMU thus bears the burden of proof to establish its damages at trial through a reasonable royalty. *See Lucent*, 580 F.3d at 1324 (citation omitted) ("The burden of proving damages falls on the patentee.").

"A reasonable royalty contemplates a hypothetical negotiation between the patentee and the infringer at a time before the infringement began." *Red Hat*, 705 F. Supp. 2d at 689 (citing

Hanson v. Alpine Valley Ski Area, Inc., 718 F.2d 1075, 1078 (Fed. Cir. 1983)). The hypothetical negotiation assumes two preconditions are met: (1) that both the patentee and the accused infringer are willing parties to the negotiation, and (2) that the patent was valid, enforceable, and infringed. *Georgia-Pacific Corp. v. U.S. Plywood Corp.*, 318 F. Supp. 1116, 1120 (S.D.N.Y. 1970). The *Georgia-Pacific* case sets out a series of factors that may be relevant to the analysis of a reasonable royalty. *Id.* "Although some approximation is permitted in calculating the reasonable royalty, the Federal Circuit requires 'sound economic and factual predicates' for that analysis." *Red Hat, Inc.*, 705 F. Supp. 2d at 689 (quoting *Riles v. Shell Exploration & Production Co.*, 298 F.3d 1302, 1311 (Fed. Cir. 2002) (citation omitted)); *see also i4i*, 598 F.3d at 857-58 (citing *Lucent*, 580 F.3d at 1325) ("any reasonable royalty analysis necessarily involves an element of approximation, and uncertainty").

In general, the determination of compensatory damages is within the province of the jury and is entitled to great deference." *Dee v. Borough of Dunmore*, 474 F. App'x 85, 87 (3d Cir. 2012). The United States Court of Appeals for the Third Circuit[92] has held that a remittitur is appropriate if the trial judge concludes that a jury verdict is "clearly unsupported and/or excessive." *Cortez v. Trans Union, LLC*, 617 F.3d 688, 715 (3d Cir. 2010). The reduction may not be less than the maximum amount that does not "shock the judicial conscience." *Evans v. Port Auth. of N.Y. & N.J.*, 273 F.3d 346, 355 (3d Cir. 2001). If remittitur is granted, the party against whom it is entered can accept it or can proceed to a new trial on the issue of damages. *Martik Bros., Inc. v. Huntington Nat'l Bank*, Civ. No. 08-83, 2010 WL 2041065, at *1 (W.D. Pa. May 20, 2010).

[92] While the substantive law of patent damages is reviewed under Federal Circuit precedent, the "decision to grant or withhold a remittitur [is decided] under the law of the regional circuit." *Power Integrations, Inc. v. Fairchild Semiconductor Int'l, Inc.*, 711 F.3d 1348, 1356 (Fed. Cir. 2013).

2. Background

The issues surrounding CMU's damages claim have been addressed numerous times in this case, from the early days of discovery disputes (Docket No. 195), to summary judgment (Docket No. 441), in motions *in limine* (Docket No. 493), and "emergency" motions (Docket No. 656), during trial (Docket No. 713), and now again post trial. At the earlier stages, the Court ruled based upon the evidence submitted by the parties and what it expected to hear at trial. (*Id.*). Unsurprisingly, a significant portion of the trial focused on determining damages.

CMU's liability theories against Marvell are critical to understanding the jury's damages award. At trial, CMU argued that that Marvell directly infringed the CMU Patents by using the method of the patents during its sales cycle as well as indirectly infringed by inducing and contributing to the infringement by its customers in the United States. As already discussed, the evidence presented through the testimony of Dr. Bajorek, CMU's industry expert, Marvell's SEC filings (Pl. Ex. 198), and the joint stipulation by the parties (Pl. Ex. 938), established that Marvell sells its chips through a lengthy, expensive sales cycle during which Marvell "invest[s] significant resources with each potential customer without any assurance of sales to that customer." (Docket No. 707 at 32-35). At the end of a given sales cycle, Marvell achieves a "design win" if "the customer decides to go into production" with Marvell and actually does so. (*Id.*). Such a design win is generally a winner-take-all affair in the HDD industry, which typically results in the winner becoming the exclusive supplier for the customer's specific hard drive or generation of hard drives. (*Id.*). Simulation programs are used throughout the sales cycle to formulate the concepts and basic designs, research and develop new products, refine and evaluate chip designs before incurring the cost of setting the chips in silicon, among other ways. (*Id.*). Once the simulation programs have satisfactory results, an engineering sample chip is created in Asia and sent back to domestic offices for continued refinement, testing, and evaluation with Marvell engineers and its customers. (Docket No. 678 at 105-106; Docket No. 707 at 164). If the customer is satisfied and places an order, the chips are put into volume production and manufactured in Asia. (Docket No. 707 at 164). Following Marvell's "design win," it would become the exclusive supplier for a customer's specific hard drive or generation of hard drives. (*Id.* at 32-35). A portion of these chips comes back to the United States through the chain of commerce in hard drives and/or laptops. (Docket No. 710 at 360-361). As Dr. Bajorek testified, the "sales cycle sequence" takes "three or four years to complete" and "with the exception of the chip making, which is made by a foundry in Taiwan, all the activities related to designing, simulating, designing [*sic*], testing, evaluating, qualifying the chips by Marvell as well as by its customers occurs in the United States." (Docket No. 678 at 105).

Much of this sales cycle activity uses the methods claimed in the CMU Patents. Through evidence regarding this sales cycle, CMU proved Marvell's direct infringement by: (1) use of the method in the KavcicViterbi simulator, which all chips are tested against to evaluate their performance and used to develop greater SNR gain; (2) use of the method by the Chip Simulators (KavcicPP, MNP, EMNP, and NLD Simulators) during the research, development, design, qualification and testing phases for the corresponding chips; and (3) use of the method in Accused Chips as engineering samples, sometimes called "golden chips," that Marvell uses during the sales cycle. (Docket No. 678 at 78-82; Docket No. 673 at 156-178). CMU demonstrated that these three scenarios of direct infringement all arise in the United States during Marvell's sales cycle. CMU also successfully argued contributory infringement and induced infringement through Marvell's customers' use of the patented method in the Accused Chips in the United States. (Docket No. 759). CMU has never asserted infringement against

Marvell for any use of its patented methods which did not occur in the United States, nor does it seek damages for instances of foreign infringement.

With these theories of infringement in mind, the Court turns to the problem of quantifying the volume or the value of the "use" of the patented methods during the sales cycles. This issue has been hotly contested by the parties throughout this litigation, and, as the case progressed towards trial, it became clear that there were only a limited number of options to value "use." First, calculating a reasonable royalty on the simulators and/or engineering samples was not promising as they are not products in the market place. Thus, such a hypothetical negotiation led back to the initial question of how to quantify use of patented methods during such a sales cycle. The second potential solution was to quantify a fee per use of the patented method. *See Sinclair Ref. Co. v. Jenkins Petroleum Process Co.*, 289 U.S. 689, 697 (1933) ("[t]he use that has been made of the patented device is a legitimate aid to the appraisal of the value of the patent at the time of the breach."). However, quantifying a per use fee in this case is nearly impossible, as the patented method is literally run hundreds of millions of times per second. (Docket No. 677 at 38). By the Court's rough calculation, assuming an eight hour work day, and 100 million runs per second, there are a minimum of 2.88 trillion infringing uses, per single chip or simulator, per day. Given same, if Marvell would rather negotiate a fee based on such use, the Court is certain CMU would be more than willing, but such astronomical numbers make this method extremely impractical. *See, e.g.*, *Lucent*, 580 F.3d at 1334 ("A company licensing a patented method often has strong reasons not to tie the royalty amount strictly to usage. The administrative cost of monitoring usage can be prohibitively expensive.").

The third option quantifies the use of the patented methods during this sales cycle based on a reasonable royalty for the sales that arose from the sales cycle. CMU proffered this theory and the Court ruled on several occasions that Marvell's sales could be an appropriate metric for assessing the value of the use of the patented methods in the U.S. by Marvell and its customers. (Docket Nos. 441; 672). Accordingly, CMU was permitted to present this theory to the jury, and Marvell was given a full opportunity to rebut this valuation method.

To support this theory, CMU called Catherine Lawton as its damages expert and she opined that the value of the patented method would be a royalty of $0.50 on all chips sold by Marvell as a result of the sales cycle. (Docket No. 686 at 29). Her calculations resulted in her opinion that CMU's damages are $1.169 billion. (*Id.*). Marvell rebutted this damages calculation by presenting its own damages expert, Creighton Hoffman, who opined that a reasonable royalty in this case would be a one-time royalty payment of $250,000.00. (Docket No. 709 at 242-245). At the conclusion of trial, the Court instructed the jury:

> Marvell cannot be found to have directly or indirectly infringed in connection with chips that are never used in the United States. To the extent, however, that Marvell achieved sales resulting from Marvell's alleged infringing use during the sales cycle, you may consider them in determining the value of the infringing use…
>
> The damages you award must be adequate to compensate CMU for the infringement. Damages are not meant to punish an infringer. Your damages award, if you reach this issue, should put CMU in approximately the same financial position that it would have been in had the infringement not occurred, but in no event may the damages award be less than what CMU would have received had it been paid by Marvell a reasonable royalty. CMU has the burden to establish the amount of its damages by a preponderance of the evidence. In other words, you should award only those damages that CMU establishes that it more likely than not suffered. In this case CMU seeks a reasonable royalty. A reasonable royalty is defined as the monetary amount CMU and Marvell would have agreed upon as a fee for use of the invention in the United States at the time prior to when the infringement began.

(Docket No. 764 at 62-63, 80-81). Against this backdrop, the jury returned a verdict in favor of CMU on all forms of direct and indirect infringement, validity, and willfulness, ultimately assessing $1.169 billion in damages for CMU. (Docket No. 762).

Having considered the applicable legal standard against the facts of record, the Court finds that CMU had presented sufficient evidence from which the jury could have found that CMU is entitled to damages authorized by 35 U.S.C. § 284, as expressed by the expert opinion of Ms. Lawton, i.e., CMU is entitled to a reasonable royalty of $0.50 per chip sold by Marvell. Of course, the jury could have found that Ms. Lawton's testimony was not credible, or it could have favored the expert testimony of Mr. Hoffman and awarded any figure he believed was appropriate. *See Micro Chem.*, 317 F.3d at 1394. The jury also could have reached a different verdict altogether from any amount that was suggested by either expert and awarded a greater or lesser sum. It is not the Court's role to weigh the factual disputes presented by the parties at trial. *Eschelman*, 554 F.3d at 433. Likewise, it is not the Court's duty to usurp the jury's fact finding role when it reached a verdict on damages that was within the calculations proffered by the competing experts. Both parties came into trial knowing that $1.169 billion was within the range of possible compensatory verdicts. This is not a punitive award. It is the exact award sought by CMU. (Docket No. 671 at 132). As such, the jury's verdict is not against the great weight of evidence as to mandate a new trial on damages. Nor is the verdict clearly unsupported such that remittitur is warranted. For completeness, the Court now briefly addresses the bevy of arguments advanced by Marvell to limit damages in this case, which can be categorized as either challenges to the royalty base or the royalty rate.

3. Challenges to the Royalty Base

a. Argument Based on *Power Integrations*

Marvell has repeatedly challenged the Court's decision to allow CMU to value Marvell's use of the CMU Patents by considering all the chips that were sold under the aforementioned sales cycle. (Docket Nos. 356; 656; 808). The Court first ruled on the inclusion of extraterritorial conduct at summary judgment. (Docket No. 441). Motions *in limine* were due September 24, 2012. (Docket No. 315). Marvell did not raise this issue in a motion *in limine*; instead, it waited until the last minute to file an "Emergency Motion to Strike CMU's Attempt to Include Noninfringing Sales of Chips that Are Never Used in the US in its Damages Case It Intends to Present to the Jury" on the Saturday after Thanksgiving, two days before the start of trial.[93] (Docket No. 656) (emphasis added). Consequently, the Court reiterated, in response to this "emergency" motion:

> CMU intends to prove that the alleged infringing method is used during Marvell's sales cycle, which is performed here in the United States, where both its engineers and customers are located. (Docket No. 665). CMU seeks damages for this sales cycle infringement by claiming a reasonably royalty rate on all of the chips that are produced during this sales cycle and purchased based on the result of said cycle.
>
> To be clear, CMU does not seek damages from alleged infringement of the Accused Chips that are never used in the United States, because the Court has held the extra-territorial sales are not infringing (Docket No. 441), it seeks damages on the infringement from the U.S. based sales cycle, and has chosen to quantify these damages by applying a per chip royalty rate on all Accused Chips produced under the sales cycle. (*Id.*). Marvell will have a full opportunity at trial to argue that this quantification is unreasonable.

(Docket No. 672 at 5-6).

[93] The Court notes that in October and November of 2012, eight new attorneys entered their appearances to take the lead at trial for Marvell. (Docket Nos. 550-554; 599; 600; 630). The Court is not sure why this strategy was employed. In any event it resulted in a complete changeover of lead counsel for Marvell from all prior proceedings.

During this post-trial stage, Marvell's now claims that the Federal Circuit's holding in *Power Integrations, Inc. v. Fairchild Semiconductor Int'l, Inc.*, 711 F.3d 1348 (Fed. Cir. 2013), precludes consideration of all of Marvell's chips in computing a reasonable royalty.[94] (Docket No. 855). Having fully considered the law, the arguments of the parties, and the evidence presented at trial, the Court does not believe that *Power Integrations* overrules this Court's earlier decisions.[95]

In *Power Integrations*, the plaintiff argued for an award of damages on the lost profits from foreign sales which it would have made but for the defendant's domestic infringement. *Power Integrations, Inc.*, 711 F.3d at 1371. In holding that such foreign lost profits were not cognizable damages, the Circuit held that the question presented in the end was whether the plaintiff was "entitled to compensatory damages for injury caused by infringing activity that occurred outside the territory of the United States." *Id.* at 1371. The Circuit panel held that "the entirely extraterritorial production, use, or sale of an invention patented in the United States is an independent, intervening act that, under almost all circumstances, cuts off the chain of causation initiated by an act of domestic infringement." *Id.* at 1371-1372 (finding that the damages expert's "estimate of $30 million in damages was not rooted in [the defendant's] activity in the United States").

The *Power Integrations* fact pattern is quite distinct from the facts at hand. First, this case has nothing to do with lost profits. Second, unlike the situation in *Power Integrations*, CMU does not seek "damages for injury caused *by infringing activity that occurred outside the territory of*

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94 New counsel have only recently, post trial, joined the cause, (Docket Nos. 776; 777), and bring with them new issues for the Court to address.

95 The Court notes that Power Integrations' request for rehearing and rehearing *en banc* has been denied, but it has indicated it intends to seek Supreme Court review on the damages issue. *See Power Integrations v. Fairchild*, Civ. No. 04-1371 (D. Del.) at (Docket No. 812).

the United States." *Id.* at 1371 (emphasis added). The Court reiterates that CMU has always sought damages for domestic infringement resulting from Marvell's use of the patented methods during research, development, chip design, qualification, use of engineering samples, continuous evaluation and indirect infringement by end users in the United States. (Docket No. 860 at 5; Docket No. 678 at 70-162). There was ample evidence presented at trial to establish that these infringing activities occur in the United States. Dr. McLaughlin testified at length to establish that the MNP and NLD chips and KavcicPP, MNP, EMNP, NLD, and Kavcic Viterbi Simulators infringed the methods. (Docket No. 673 at 156-178). Dr. Bajorek then, in turn, explained how these chips and simulators are used during the sales cycle. (Docket No. 678 at 76-90). He next testified that all steps of the sales cycle, other than physical production of the chips, occur in the United States, adding that he had personally been to each of the customer's design centers in the United States. (Docket No. 678 at 105) ("Hitachi, San Jose. Samsung in San Jose. Toshiba in San Jose. And Western Digital in San Jose, in Lake Forest, which is southern California. In Longmont and Fremont, several design centers by Seagate."). He provided the following demonstrative for the jury, which tabulated some of the infringing sales cycle activities, the participants, the place of the activity, and the pinpoint reference citation supporting his conclusion:

Where Marvell's "Sales Cycle" Activities Takes Place

Activity	Specific Activity	Who Participates?	Activity Occur in the US?	Where in the US Does This Activity Occur?	Exhibit or Testimony
Tapeout	Accused Chip design development and finalization	Marvell Semiconductor, Inc.	Yes	Santa Clara, CA	Armstrong Vol. 3 (Dec. 16, 2010) at 151:9-152:9
		Marvell Semiconductor, Inc.	Yes	Santa Clara, CA	A. Armstrong Vol. 3 (Dec. 16, 2010) at 152:4-157:10
	Transfer final Accused Chip design to overseas foundry for fabrication of engineering samplers	Marvell Semiconductor, Inc.	Yes	Santa Clara, CA	T. Doan at 82:22 – 83:6
	Engineering samples are shipped from the overseas foundry to Marvell Semiconductor, Inc. Santa Clara prior to distribution to customers	Marvell Semiconductor, Inc.	Yes	Santa Clara, CA	P. Patel at 60:2 -61:21
		Marvell Semiconductor, Inc.	Yes	Santa Clara, CA	P. Patel at 113:2 – 114:22
	Engineering samples supplied to customers	Marvell Semiconductor, Inc.	Yes	Santa Clara, CA	A. Armstrong Vol. 3 (Dec 16, 2010) at 157:13 - 161:1
		Western Digital Marvell Semiconductor, Inc.	Yes	Lake Forest, CA	Brennan at 328:20 – 329:7
Validation / Qualification of Samples	ATE Test Program Development and ATE Hardware Design	Marvell Semiconductor, Inc.	Yes	Santa Clara, CA	Armstrong Ex. 114 (Decl. of A. Wu)
		Marvell Semiconductor, Inc.	Yes	Santa Clara, CA	A. Wu at 46:17 – 47:8
		Marvell Semiconductor, Inc.	Yes	Santa Clara, CA	A. Armstrong Vol. 1 (June 23, 2010) at 86:14 -87:10; 88:22 – 25
		Marvell Semiconductor, Inc.	Yes	Santa Clara, CA	A. Armstrong Vol. 1 (June 23, 2010) at 91:3 – 94:8
		Marvell Semiconductor, Inc.	Yes	Santa Clara, CA	A. Wu at 46:17 – 47:7
	ATE Testing	Marvell Semiconductor, Inc. MAPL	Yes, but not exclusively	Santa Clara, CA	A. Wu at pp 44:4 – 46:2
		Marvell Semiconductor, Inc.	Yes, but not exclusively	Santa Clara, CA	A. Wu at pp 45:9 – 46:2
		Marvell Semiconductor, Inc. MAPL	Yes, but not exclusively	Santa Clara, CA	A. Armstrong Vol. 1 (June 23, 2010) at 91:3 – 94:8

Where Marvell's "Sales Cycle" Activities Takes Place

Activity	Specific Activity	Who Participates?	Activity Occur in the US?	Where in the US Does This Activity Occur?	Exhibit or Testimony
Validation / Qualification of Samples *(continued)*	Testing and Evaluation of Samples	Marvell Semiconductor, Inc.	Yes	Santa Clara, CA	Armsrong Ex. 114 (Decl. of A. Wu)
		Marvell Semiconductor, Inc.	Yes, but not exclusively	Santa Clara, CA	S. Huang at pp. 26:15-27:1
		Marvell Semiconductor, Inc.	Yes	Santa Clara, CA	A. Armstrong Vol. 3 (Dec. 16, 2010) at pp 159:10–162:4
		Marvell Semiconductor, Inc.	Yes	Santa Clara, CA	A. Nazari at 32:3–33:20
		Marvell Semiconductor, Inc.	Yes	Santa Clara, CA	A. Nazari at 30:7–31:20
		Marvell Semiconductor, Inc.	Yes	Santa Clara, CA Lake Forest CA (WD) San Jose, CA (TAIS)	R. Pai at 42:23–43:8; 44:23–45:21
		Marvell Semiconductor, Inc.	Yes	Santa Clara, CA	A. Wu at pp 37:13–38:2; 40:9–40:20; 44:4–46:2 A. Wu Ex. 27 at Marvell Semiconductor, Inc. 2137382
		Marvell Semiconductor, Inc.	Yes, but not exclusively	Santa Clara, CA	S. Huang at 232:18–233:10
		Marvell Semiconductor, Inc.	Yes	Santa Clara, CA	A. Armstrong Vol. 1 (June 23, 2010) at 83:9–84:14
		Marvell Semiconductor, Inc.	Yes, but not exclusively	Santa Clara, CA Colorado	Z. Wu at pp 249:1–250:9
	Validation of Accused Chips (including validation of MNP, EMNP, NLD)	Marvell Semiconductor, Inc.	Yes, but not exclusively	California	V. Khanzode at pp 153:22–154:12
		Marvell Semiconductor, Inc.	Yes, but not exclusively	Santa Clara, CA Colorado	V. Khanzode at pp 30:15–31:10
		Marvell Semiconductor, Inc.	Yes, but not exclusively	Santa Clara, CA	A. Nazari at 104:18–104:20
		Marvell Semiconductor, Inc.	Yes, but not exclusively	Santa Clara, CA	V. Khanzode at pp 59:21 60:20; 140:18 143:16
		Marvell Semiconductor, Inc.	Yes	Santa Clara, CA	S. Huang at 39:14–19;
		Marvell Semiconductor, Inc.	Yes	Santa Clara, CA	S. Huang at pp. 90:24–91:11
	MNP, EMNP, and NLD optimization	Marvell Semiconductor, Inc.	Yes	Santa Clara, CA	S. Huang at 44:3–45:4
		Marvell Semiconductor, Inc.	Yes	Santa Clara, CA	S. Huang at 46:2–46:21
		Marvell Semiconductor, Inc.	Yes	Santa Clara, CA	S. Huang at 122: 10–18
		Marvell Semiconductor, Inc.	Yes	Santa Clara, CA	S. Huang at 32:18–39:25
	Customer testing and optimization of Accused Chips	Western Digital	Yes	Lake Forest, California	Khanzode Ex. 46
		Maxtor	Yes	California	Khanzode Ex. 10
		SISA (Samsung)	Yes	San Jose, CA	A. Nazari at 19:19–20:9
		SISA (Samsung)	Yes	San Jose, CA	A. Nazari at 29:25–30:22
		SISA (Samsung)	Yes	San Jose, CA	A. Nazari at 33:12–33:20
		TAIS (Toshika)	Yes	San Jose, CA	S. Huang at 30:15–30:20
		TAIS (Toshika)	Yes	San Jose, CA	S. Huang at 23:15–25:10

Where Marvell's "Sales Cycle" Activities Takes Place

Activity	Specific Activity	Who Participates?	Activity Occur in the US?	Where in the US Does This Activity Occur?	Exhibit or Testimony
Marvell Customer Support	Direct assistance of customers for training, evaluation and optimization of the Accused Chips	SISA (Samsung)	Yes	San Jose, CA	A. Nazari at 33:15–33:20
		SISA (Samsung)	Yes	San Jose, CA	A. Nazari at 30:7–31:20
		SISA (Samsung)	Yes	San Jose, CA	A. Nazari at pp 19:3–20:9
		HGST (Hitachi) Marvell Semiconductor, Inc.	Yes	San Jose, CA	S. Huang at pp 126:7–127:17
		HGST (Hitachi) Marvell Semiconductor, Inc.	Yes	San Jose, CA	Huang Ex. 4 at Marvell Semiconductor, Inc. 2482540, -543
		Western Digital Marvell Semiconductor, Inc.	Yes	Lake Forest, CA	Khanzode Ex. 46
		Western Digital Marvell Semiconductor, Inc.	Yes	Irvine, CA	T. Tran at pp 19:9–20:2
		Marvell Semiconductor, Inc. Western Digital Seagate Hitachi Samsung	Yes	Lake Forest, CA (WD) San Jose, CA (Samsung) Rochester, MN (Hitachi) Twin Cities, MN (Seagate)	M. Madden at pp. 21:24–26:6
		TAIS (Toshiba)	Yes	San Jose, CA	S. Huang at pp. 23:13–25:13
		TAIS (Toshiba)	Yes	San Jose, CA	S. Huang at pp. 26:24–27:15
	Create and supply reference firmware for Accused Chips to customers	Marvell Semiconductor, Inc.	Yes	Santa Clara, CA	A. Nazari at 194:2–21
		Marvell Semiconductor, Inc.	Yes	Santa Clara, CA	A. Nazari at pp. 163:1–164:21
		SISA (Samsung) Marvell Semiconductor, Inc.	Yes	San Jose, CA	Pai Ex. 31
Failure Analysis	Failure analysis testing	Marvell Semiconductor, Inc.	Yes, but not exclusively	Santa Clara, CA	P. Patel at 112:5–114:22
	Development of ATE tests for failure analysis	Marvell Semiconductor, Inc.	Yes	Santa Clara, CA	P. Patel at 227:7–20
	Failure analysis reports prepared	Marvell Semiconductor, Inc.	Yes, but not exclusively	Santa Clara, CA	P. Patel at 38:16–39:4

(Docket No. 771 at Ex. I). Dr. Sutardja, likewise, testified that the sales cycle process occurs in the United States for its largest customers such as Seagate, Western Digital, Samsung, Quantum, Maxtor, Toshiba, and possibly Hitachi. (Docket No. 707 at 132-133; Docket No. 868 at Ex. 1). Mr. Yeo, Western Digital's corporate designee also testified that the MNP and NLD technology was tested as part of drive development in the United States. (Docket No. 761 at Jt. Ex. B at 41-43). Additionally, the parties entered into a stipulation which reads in part:

> Eight, the headquarters and principal place of business of Marvell Semiconductor, Inc., also known as MSI, is located at 5488 Marvell Lane, Santa Clara, California.
>
> Nine, the management and strategic decision-making of MSI as well as most of its business activities are conducted at MSI Headquarters in Santa Clara, California.
>
> ....
>
> Eleven, the accused read channel and SOC products in this case were researched, designed, and developed in MSI's headquarters in Santa Clara, California.
>
> Twelve, as of June of 2009, MSI's system and design teams for the read channel R&D organization consisted of approximately 133 employees, of whom approximately 131 were located at MSI's facility in Santa Clara, California.

> Thirteen, Dr. Zining Wu, vice-president of data storage technology, Toai Doan, former vice-president for signal processing technology and read channel product development, and Greg Burd, senior manager of engineering, are knowledgeable about the design, operation, and features of the accused read channel products, particularly as related to the technology area of the patents asserted in this litigation. All three of them work or worked in northern California, and the managerial functions that they carried out on a daily basis are essential to MSI's ongoing data storage business operations.
>
> Fourteen, almost all of the design and development documents from MSI's read channel R&D organization are located in Santa Clara, California.
>
> ....
>
> Eighteen, MSI's manufacturing operations group generally supports read channel research and development rather than commercial production activities. MSI's manufacturing operations group supports MSI's read channel R&D through, for example, ATE test development, product characterization, qualification, and oversight of product transfer during read channel product development. These activities are conducted in Santa Clara, California.
>
> Nineteen, as of June, 2009, approximately fifty employees from Marvell's manufacturing operations group who support read channel research and development work at Marvell's facilities in Santa Clara, California.
>
> Twenty, Albert Wu, vice-president of manufacturing operations, works in northern California, managed those fifty employees in June of 2009; and the managerial functions that he carries out on a daily basis are essential to MSI's ongoing operations support for research and development.
>
> Twenty-one, MSI's operations documents concerning the accused read channel products are located in Santa Clara, California.

(Docket No. 764 at 49-56; Pl. Ex. 938).

Upon review of the record, the Court can find no evidence regarding whether any step of the sales cycle process occurred anywhere other than in the United States. Indeed, Marvell proffered almost no evidence regarding its business operations to rebut CMU's arguments on infringement, sales, or damages.[96] Accordingly, CMU has shown that the infringement for which it seeks damages occurred within the United States, clearly distinct from the *Power Integrations* foreign exploitation of a patented invention.[97] 711 F.3d at 1371.

Even after *Power Integrations*, the Court must still confront the question of how to quantify damages for Marvell's use of the method patents at issue. As the Court discussed, a fee per use is unrealistic. Moreover, no established fee exists. At trial, Marvell argued that a one-time fee of $250,000 was the appropriate measure of damages, (Docket No. 809), while CMU countered that a reasonable fee should be a $0.50 royalty per chip on all chips created through this sales cycle. (Docket No. 829). The Court has never endorsed either side's position, only ruling that CMU's theory could presented to the jury. Based on the evidence before it, the Court found CMU's theory just as reasonable as Marvell's. Accordingly, the jury considered both positions. Furthermore, the Court properly instructed the jury that Marvell could not infringe "with chips that are never used in the United States" but "[t]o the extent, however, that Marvell achieved sales resulting from Marvell's alleged infringing use during the sales cycle, you may consider them in determining the value of the infringing use."

In requesting the Court to follow *Power Integrations*, Marvell asks the Court to limit CMU's royalty to an estimate of chips that came back into the United States in the stream of commerce. This proposition, however is lacking in evidentiary support and common sense. Marvell did not submit evidence at trial that it or any company has ever licensed patented

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96 This is not to say that Marvell had the burden of proof on damages, s*ee Lucent*, 580 F.3d at 1324, but only that CMU has presented unchallenged direct and circumstantial evidence to establish the sales cycle occurred in the United States.

97 As part of her damages evaluation, Ms. Lawton considered whether Marvell, in order to avoid infringement, could move its design and sales centers overseas. (Docket No. 686 at 223-224). She determined, however, based on Dr. Bajorek's testimony, that it was key to Marvell's business success to be in California where the majority of its customers were based and where there was the largest pool of talent. (*Id.*). As such, moving the research, design, testing, sales and marketing centers overseas was not a potential option. (*Id.*).

technology on a per United States imported chip basis. The *only* Marvell license submitted into evidence at trial (by CMU no less), was between Marvell Technology Group and DSPG signed in April 2000. (Pl. Ex. 197). According to the licensing arrangement, Marvell was to pay a $2.1 million fee plus a running royalty between $0.10 to $0.40 per unit, after 35 million units are produced.[98] (*Id.* at 79). The royalties paid to DSPG are not linked to the units' location in any particular country.[99] (*Id.*). Likewise, Dr. Sutardja, Dr. Armstrong, and Mr. Brennan did not testify that Marvell would have, or had ever, entered into an agreement which limited royalties to chips in the United States, only. Dr. Armstrong did testify, however, that Marvell had entered into running royalty agreements on chips, referring for instance to the aforementioned DSPG contract. (Docket No. 761 at Ex. C at 15-16). The major concern with limiting a royalty for sales cycle infringement to chips in the United States is that no one, including Marvell, tracks how many chips come back into the country. (Docket No. 356-1; Docket No. 710 at 361).[100] For the purposes of this trial, Ms. Lawton projected two estimates: the first, 556,812,092 chips, based on adjusted industry analytics of HDDs imported into the United States; and the second, 329,297,799 chips, based on the import records of Marvell's four largest customers, i.e., Samsung, Hitachi, Western Digital, and Toshiba. (Docket No. 356-1 at 488-489; Docket No. 710 at 165, 200, 207-210).

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98 One of the *Georgia Pacific* factors, is the "rates paid by the licenses for the use of other patents comparable to the patent in suit." 318 F. Supp. at 1120. While the Court does not suggest that the DSPG technology is necessarily comparable, it does offer a glimpse at standard contract terms of Marvell and the industry in general. This exhibit was admitted in connection with Dr. Armstrong's testimony, in part, to show that Marvell has entered into running royalty arrangements in the past. (Docket No. 682 at 252).

99 CMU's DSSC licenses, equally, show that CMU licensed its patents on a worldwide basis, without reference to use in or outside the United States. (Def. Exs. 17; 39; 40).

100 Mr. Hoffman stated "Nobody really knows is the bottom line. Okay? Because you just can't tell. You just -- you lose it. It goes through too many hands in commerce before I get a laptop here on my -- here in Pittsburgh or somebody else gets a laptop in Paris or Buenos Aires. It's -- you just don't know where those things are going." (Docket No. 710 at 361).

All relevant information on the estimate of chips used in the United States and the total number of chips produced worldwide was presented to the jury. Marvell argued to the jurors that they should consider only the number of chips that are ever used in the United States in valuing Marvell's use of the patented method, while CMU urged the jurors to consider all chips produced during the sales cycle regardless of whether they come back into the country. (Docket No. 759 at 96, 113). The factual record was such that the jury had substantial evidence on which to find in favor of CMU's theory.

The Court also believes that in envisioning a hypothetical negotiation, the jury could have properly considered as illogical an agreement to a per chip royalty predicated on an analytic neither party knows or tracks, and, depending on estimates, could vary by millions. It seems unrealistic that for one license agreement, Marvell and CMU would undergo extensive accounting review each and every year of import and export data of Marvell's customers (if even available). Moreover, such calculation would not include the number of simulators being used by Marvell. The Federal Circuit counsels that "where it is impossible to make a mathematical or approximate apportionment between infringing and noninfringing items, the infringer must bear the burden and the entire risk." *Nickson Indus., Inc. v. Rol Mfg. Co., Ltd.*, 847 F.2d 795, 799 (Fed. Cir. 1988); *see also TWM Mfg. Co., Inc. v. Dura Corp.*, 789 F.2d 895, 900 (Fed. Cir. 1986) (where infringer's failure to keep accurate records causes difficulty in ascertaining damages, infringer must bear adverse consequences).[101]

The Court also reminds counsel that CMU's damages request incorporates the damages for Marvell's indirect infringement, which if segregated from sales cycle infringement would have created an even larger award for CMU. The Court had to remind Marvell of this as one of

[101] Under this precedent, any remittitur based on the location of end products would be based on Ms. Lawton's 556,812,092 million chip estimate. (Docket No. 710 at 165).

the verdict forms it proposed included separate lines for damages on each set of chips and simulators, which could have inadvertently led to an award far in excess of $1.169 billion. (Docket No. 759 at 39).

b. Location of Sales

As previously discussed, CMU seeks damages based on the sales that are created because of Marvell's infringement during the sales cycle. Marvell argues for the first time in its reply brief on its Rule 50(b) Motion that CMU has not entered enough evidence to show that sales took place in the United States in light of the *Power Integrations* decision. (Docket No. 855 at 6).

First and foremost, Marvell seems to conflate several issues in maintaining that CMU must prove that the sales were made in the United States. Marvell's liability is not predicated on "sales," but rather on "use" under 35 U.S.C. § 271(a). Under CMU's theory, as proffered, it would seem that sales would not necessarily need to be made in the United States because as long as the sales were a direct result of Marvell's infringement in the United States during the United States sales cycle, the foreign sales would remain an appropriate component to value domestic infringement. Second, Marvell introduced **no** evidence at trial that any aspect of its sales took place outside the United States. Third, *Power Integrations*' damages theory was predicated on lost profits, while this matter focuses on finding a reasonable royalty or negotiated fee for the use of CMU's methods.

Next, there is the issue of waiver. Marvell contends that there is no evidence that sales took place in the United States, because there was no evidence of the location of delivery, location of the buyer, the passage of legal title, location of contracting, or execution of a sales contract. (Docket No. 855 at 6-8). It also argues that the jury was not instructed on the law relevant to determining the location of sales. (*Id.*). CMU objects to this argument because it was never raised in either of Marvell's two Rule 50(a) Motions during trial or even the initial post-trial Rule 50(b) Motion. (Docket No. 860).

A "defendant's failure to raise an issue in a Rule 50(a)(2) motion with sufficient specificity to put the plaintiffs on notice waives the defendant's right to raise the issue in [his] Rule 50(b) motion." *State Farm Mut. Auto. Ins. Co. v. Lincow*, 444 F. App'x 617, 620 (3d Cir. 2011); *see also Lightning Lube, Inc. v. Witco Corp.*, 4 F.3d 1153, 1173 (3d Cir. 1993) (stating that Rule 50(b) motion "must be preceded by a Rule 50(a) motion *sufficiently specific* to afford the party against whom the motion is directed with an opportunity to cure possible defects in proof which otherwise might make [his] case legally insufficient") (emphasis in original). Marvell did not raise this argument until its most recent *reply* brief. Throughout the trial, there was no argument on the sufficiency of showing, where legal title was passed or even argument on the sufficiency of the evidence regarding sales in general. This highlights why the Court of Appeals for the Third Circuit directs that such arguments must be raised in a sufficiently specific Rule 50(a) motion—if properly noticed, CMU could have submitted more evidence to rebut Marvell's current assertions.[102] Further, Marvell cannot argue that it only raised such argument because of *Power Integrations*, because the Court made it clear that the site of sales was not settled during discovery (Docket No. 195), at Summary Judgment (Docket No. 441), and in its order on the emergency motion on the fourth day of trial. (Docket No. 672).

To the extent that Marvell argues the jury should have been instructed on the legal definition of sales, including any of the aforementioned factors, that argument has been waived as such point for charge was neither suggested in proposed jury instructions nor preserved as an

[102] For example, the Court notes that at summary judgment, CMU submitted the executed supply agreement between Western Digital and Marvell, signed in California, as an exhibit to rebut Marvell's Motion for Summary Judgment of No Damage on Extraterritorial Conduct. (Docket No. 403 at Exhibit 68). However, in deciding a JMOL the Court relies only on the properly admitted evidence. *See Goodman*, 293 F.3d at 665 (3d Cir. 2002).

objection during the charge conference. (Docket Nos. 623; 761; 764). Indeed, the Court has reviewed the parties' proposed jury instructions, the numerous versions of draft final instructions, objections submitted via email and the transcript of the charge conference that spanned three days, and it can find no requests by Marvell for the Court to include such instructions. (*Id.*). The Court's instruction on contributory infringement required CMU to prove that Marvell "sold or offered to sell" infringing chips in the United States. (Docket No. 764 at 75). There was no request for an instruction defining sales in connection with this claim as well. If a party does not preserve its objection to the final instructions it cannot challenge them later. *Brooks v. City of Summit*, 138 F. App'x 390, 393 (3d Cir. 2005). Verdicts based on faulty instructions are only reversed where there is error that is "fundamental and highly prejudicial or if the instructions are such that the jury is without adequate guidance on a fundamental question and ... failure to consider the error would result in a miscarriage of justice." *Id.*

Even if Marvell has not waived this argument, which the Court believes it has, there is more than sufficient evidence for a jury to find that the sales occurred in the United States. First, in an effort to prevent CMU from entering numerous of Marvell's SEC filings into evidence, the parties stipulated that:

> Eight, the headquarters and principal place of business of Marvell Semiconductor, Inc., also known as MSI, is located at 5488 Marvell Lane, Santa Clara, California.
>
> Nine, the management and strategic decision-making of MSI as well as most of its business activities are conducted at MSI Headquarters in Santa Clara, California.
>
> ....
>
> Fourteen, almost all of the design and development documents from MSI's read channel R&D organization are located in Santa Carla, California.
>
> Fifteen, almost all of MSI's sales and marketing management personnel for read channel products are located in Santa Clara, California. MSI's sales and marketing decision-

> making for read channel products is conducted in Santa Clara, California.
>
> Sixteen, Alan Armstrong, vice-president of marketing, storage business group, and Bill Brennan, former vice-president of sales, storage business group, are knowledgeable about MSI's sales and marketing of the accused read channel products. Both of them work or worked in northern California, and the managerial functions that they carried out on a daily basis are essential to MSI's ongoing sales and marketing on data storage products.
>
> Seventeen, almost all of MSI's sales and marketing documents concerning the accused read channel products are located in Santa Clara, California.

(Docket No. 764 at 49-56). Secondly, Dr. Armstrong testified that Mr. Brennan, based in California, signed off on the sales. (Docket No. 761 at Ex. C at 213). Then, Dr. Bajorek gave uncontradicted testimony that Marvell's sales "essentially take place in the United States" and identified the domestic office of each of Marvell's major customers.[103] (Docket No. 678 at 72, 105-106). In deciding a discovery dispute as to the scope of relevant discovery, nearly three years ago, this Court wrote that some factors in determining sales in the context of 35 U.S.C. § 271 could include:

> (1) the location of the contemplated future sale, (2) the location of delivery, (3) the location of performance, (4) the location of the buyer; (5) the location of the passage of legal title; (6) the location of contracting; (7) the location of the negotiation of the sales contract, and (8) the location of the execution of the sales contract

(Docket No. 195 at 3-4). While these factors are not exhaustive or necessarily determinative, with the above-described stipulation in evidence, along with one of Marvell's SEC filings (Pl. Ex. 198), testimony from Dr. Armstrong, and expert testimony from Dr. Bajorek, there is

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[103] Dr. Bajorek testified:

> Hitachi, San Jose. Samsung in San Jose. Toshiba in San Jose. And Western Digital in San Jose, in Lake Forest, which is Southern California. In Longmont and Fremont, several design centers by Seagate.
> Q Have you personally been in these design centers, sir?
> A Yes, I have.

(Docket No. 678 at 106).

sufficient direct and circumstantial evidence to support the proposition that sales resulting from Marvell's sales cycles were made in the United States. *See, e.g.*, *Snyder v. Bazargani*, 241 F. App'x 20, 23 (3d Cir. 2007) (juries can rely on direct and circumstantial evidence).

Again, there is no contrary evidence in the record showing that any activity beyond the manufacture of the chips occurred anywhere outside the United States. Marvell allowed CMU to present all of the evidence about Marvell's business structure, organization and sales cycle. Marvell presented no evidence to suggest that sales occurred in any other country.[104] Counsel did not argue to the jury that sales occurred in any other location than the United States. (Docket No. 759 at 96) (at closings arguing only that some chips are not *used* in the United States). Based on the testimony and exhibits of record presented at trial, a finding that the chips were sold outside the United States would have been without any evidentiary support. By withholding all evidence on its operations and sales, Marvell undermined its ability to counter CMU's proposition that the sales, in fact, occurred in the United States.[105]

Marvell asks the Court to follow Judge Gilstrap's decision in *Lake Cherokee v. Marvell Semiconductor, Inc.*, wherein Marvell's evidence of foreign sales of chips was excluded as a basis for damages.[106] (Docket No. 890). However, in that case, not only was the court analyzing what constitutes a "sale" under 35 U.S.C. § 271(a),[107] but it was presented with undisputed facts regarding Marvell's foreign activities. (*Id.*). Based on the record before him, Judge Gilstrap was

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[104] The only evidence in the record of any foreign activity came from CMU's expert, Dr. Bajorek who testified that Marvell chips are made in a Taiwanese foundry. (Docket No. 678 at 105).

[105] The Court ruled that if Marvell introduced evidence at trial, such as tax invoices, to try and establish the location of sales, CMU may be able to use certain evidence pertaining to Marvell's tax strategy, tax payments, effective tax rates, or corporate structure to rebut said argument. (Docket No. 605). Possibly as a preventive measure, Marvell did not submit any evidence or elicit any testimony that the Court could find "opened this door."

[106] The Court notes that Defendant Marvell Technology Group Ltd, the parent company of Marvell Semiconductor, and Marvell's Asian subsidiary MAPL, were not party to the Texas lawsuit. (Docket No. 890).

[107] CMU does not argue liability for Marvell's sales or offers to sell under § 271(a). Rather, CMU's theory of liability is based on Marvell's use of the patented method. (Docket No. 860).

able to conclude that there was "no dispute that companies abroad submit purchase orders to MAPL in Singapore and that, pursuant to such purchase orders, certain accused products are manufactured abroad, delivered abroad, and never cross United States borders physically or by legal title" and that "no revenues enter the United States." (Docket No. 890-1 at 4-5). This Court is in no place to make any similar conclusions. Not a single purchase order, nor delivery receipt, nor any revenue data was introduced by Marvell. No Marvell witness testified that activities such as sales, orders, deliveries, or accounting occurred overseas. Marvell's strategy was "all or nothing" in this case. By choosing to allow CMU to present *all* of the evidence regarding Marvell and its business, Marvell was not able to control the message given to the jury, nor was it able to establish convincing contrasting arguments.

In finding Marvell liable for contributory damages, the jury necessarily had to find that Marvell sold or offered to sell the Accused Chips in the United States. Considering all the evidence of record, the Court finds that there was sufficient evidence to support this finding, and accordingly no JMOL, new trial, nor remittitur is warranted.

c. "But For" Standard

Marvell next contends that CMU has failed to meet its burden on damages under the "but for" standard because it cannot prove that the sales of the Accused Chips arose due only to Marvell's infringement. (Docket No. 739 at 16; Docket No. 809 at 16). Marvell asserts that: (a) no reasonable jury could conclude that the claimed methods in the patents-in-suit were "must have" for Marvell's customers; (b) CMU has no evidence that the claimed methods were "must have" for Western Digital; (c) that non-infringing components made Marvell successful in the storage hard drive business; (d) that incremental SNR gains are achieved with multiple non-infringing components; (e) that no reasonable jury could conclude that Marvell would have gone out of business but for the claimed methods used in the read channel; and (f) the location of Marvell's sales cycle is irrelevant. (Docket No. 739 at 16-26). CMU counters that it has presented sufficient evidence at trial from which a reasonable jury could find that Marvell's use of the claimed methods in the patents-in-suit was the "but for" cause of Marvell's sales of the Accused Chips. (Docket No. 725 at 9).

The Court finds that based on the evidence of record, viewed in the light most favorable to the non-movant CMU and drawing all inferences in its favor, a reasonable jury could determine that the alleged infringement in this case was the "but for" cause of the sales. Marvell has made a "mountain out of a molehill" in arguing the requirements of "but for" causation, maintaining that CMU must prove a certain level of customer demand or sole causation. (Docket No. 855 at 8). The Court ruled at the Summary Judgment stage that CMU's theory was reasonable given that Marvell's sales are the "but for" result of Marvell's infringement during the sales cycle. (Docket No. 441). The "but for" language on which Marvell relies does not arise from case law or statute in this instance, but from the parties' agreed-upon findings of fact. (Docket No. 402 at ¶ 8; Docket No. 415 at ¶ 8) ("Marvell would not make volume sales of the Accused Chips but for the use of Accused Chips in infringing modes in the U.S. during the sales cycle."). Thus, in stating in its summary judgment opinion that Marvell's sales were a "but for result of Marvell's infringement," the Court recognized that sales could be an indicator of the value of Marvell's use of the patents as long as there was a causal link between the infringement and the sales. (Docket Nos. 441; 672). The Court was not speaking to whether there could be only one cause or many. Regardless, the Court believes that CMU has met or exceeded its burden of proof as to same.

To this end, the parties' stipulation that was read into the record at trial on December 11, 2012, and again as part of the final instructions, provides that Marvell's lengthy (eighteen to thirty-month) sales cycle is a very important component of its business operations and is completed almost entirely within the United States by its engineers, marketing and sales executives as well as other members of Marvell's staff at its Santa Clara offices. (Docket No. 676; Pl. Ex. 938). Nearly all of Marvell's research and development, as well as its testing of chips and multiple interactions with customers, occur there. (*Id.*). If a customer selects Marvell to produce chips, Marvell achieves a "design win" whereby the customer orders a particular integrated circuit for a full generation of its product line. (Docket No. 707 at 29-34). As already recounted in addressing the JMOL motion on infringement, Dr. McLaughlin offered his expert opinions, which the jury was free to credit, that the simulators run by Marvell and the NLD and MNP-type chips sold by Marvell infringe CMU's patents as Marvell uses the methods claimed in this case.[108] This opinion was bolstered by evidence adduced at trial that showed Marvell's product simulators are operated during the sales cycle and that infringing engineering sample chips are used throughout the sales cycle. (Docket No. 707 at 45; Docket No. 678 at 70-162). It was also shown that all of Marvell's products and sales are the result of this lengthy sales cycle and that "deals" are ultimately made by the Marvell sales team based in California. (Docket No. 761 at Jt. Ex C at 251-252). In addition, Dr. Bajorek gave his expert opinion, which the jury was able to accept, that all of Marvell's sales of the NLD and MNP-type chips are the result of this United States sales cycle, and the MNP and NLD technology was the critical driver of the sale of these chips. (Docket No. 678 at 66-75).

The sales data upon which Ms. Lawton relied in her opinion showing the number of NLD and MNP-type chips sold by Marvell was provided by Marvell to CMU and not disputed at trial.

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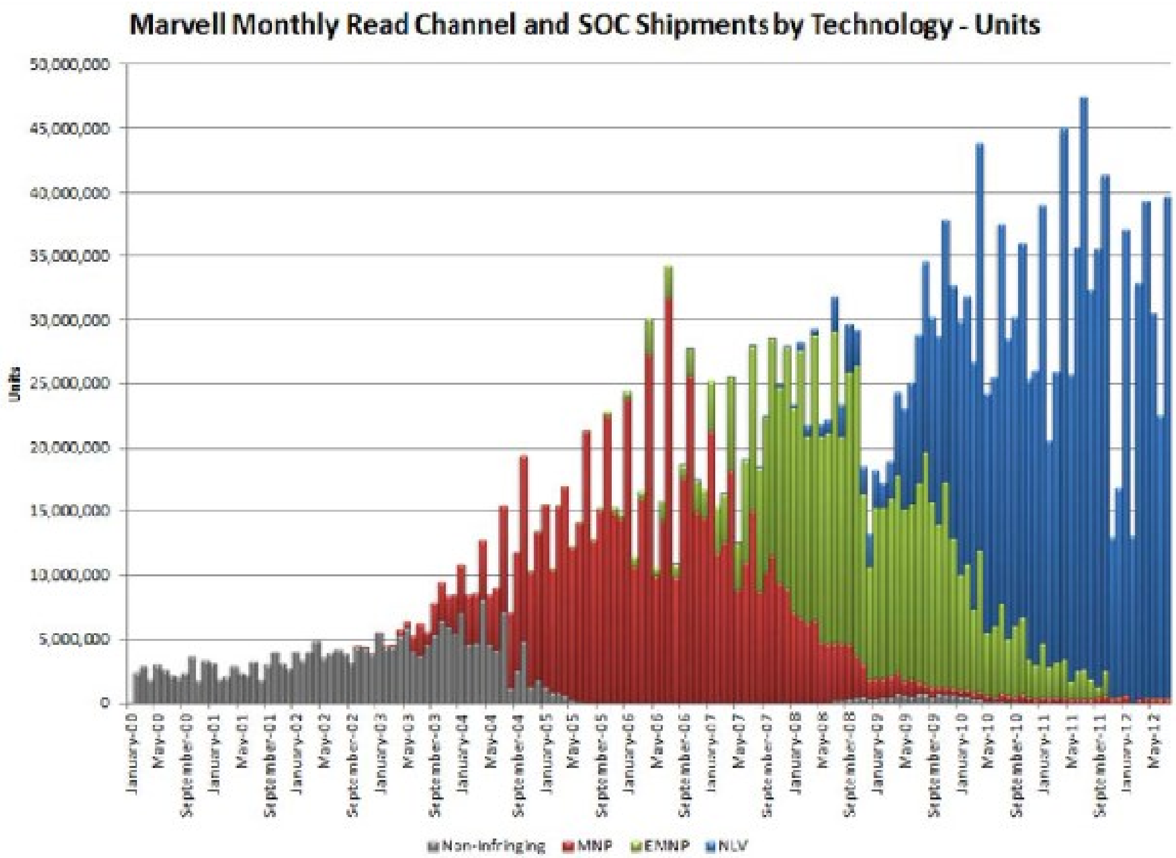
[108] *See* Docket No. 673 at 156-178; *see also* discussion *supra* at Section V.A.2.c.

(Docket Nos. 315; 686). She testified that between March 6, 2003 and July 28, 2012, Marvell sold 2,338,280,543 chips, (Docket No. 686 at 61), as illustrated by the following chart:



(Docket No. 868-16 at 6). A reasonable jury could conclude from this, and the other evidence of record, that Marvell's use of the claimed methods in the United States was the "but for" cause of Marvell's sales of the NLD and MNP-type chips.

The other matters that Marvell has raised, including whether the technology was "must have" for its customers like Western Digital, whether the other components in the NLD and MNP-type chip drove sales, the success of its other product lines at achieving SNR gains, and whether Marvell would have gone out of business without the use of the claimed methods, challenges the credibility and weight to be given to CMU's damages evidence and presents factual issues the jury had to consider and decide. Marvell proclaims it is "undisputed" that customers did not want the MNP. (Docket No. 885 at 9). The Court, however, does not agree. Marvell heavily relies on Iftiqar Baqai of Western Digital and Marvell's Michael O'Dell to argue that customers did not want the MNP. Mr. Baqai testified that when he worked in the relevant division, Western Digital wanted to pull the MNP. (Docket No. 711 at 164). However, Mr. Baqai was only involved in read channel activities until 2005.[109] (*Id.* at 175). Moreover, Western Digital went on to buy one billion infringing chips with the technology enabled. (Docket No. 868 at Ex. 1; Pl. Ex. 1922). Mr. O'Dell, a late additional witness for Marvell, likewise stated that when he was with Marvell, customers wanted to remove the MNP; however, he did not work at Marvell in the critical time period between 2004 to 2010. (Docket No. 726 at 229).

On the other hand, CMU presented: (1) the expert testimony of Dr. Bajorek that the technology was "must have"; (2) internal Marvell communications showing failed predecessors to the MNP, requests to include the MNP as a "critical requirement," as well as references that the MNP was a key feature in Marvell's products; (3) testimony of Western Digital's original corporate designee, Teik Ee Yeo, stating that Western Digital used the technology and saw gains from it; and (4) relevant data on Marvell's sales of infringing products. (Docket No. 829 at 913). Even if the Court ignores all of the arguments by counsel, statements from witnesses, and opinions from experts, the data shows that a majority of all chips sold by Marvell contained the infringing technology. (Docket No. 686 at 117-126). Therefore, Marvell's contentions of what is purportedly "undisputed" evidence do not hold weight. At most, the parties' evidence created factual disputes for the jury, which were resolved in favor of CMU. *See, e.g.*, *Curley v. Klem*, 499 F.3d 199, 208 (3d Cir. 2007) (factual disputes must be resolved by a jury). The Court finds

[109] Marvell avers that Mr. Baqai was present due to a subpoena. (Docket No. 711 at 144). CMU argued that Mr. Baqai, a California resident, was not technically compelled to appear by way of a subpoena from the Western District of Pennsylvania. *See* FED. R. CIV. P. 45(b)(2)(b). It is true that Mr. Baqai could not have been actually compelled by this subpoena, but he may have thought he was compelled to appear.

that there is sufficient evidence on which a jury could find that Marvell's infringement through the sales cycle was the cause of its sales.

d. Running Royalty

Marvell contends that CMU has adduced no evidence in support of a running royalty tied to product sales, allegedly undermining its damages case. (Docket Nos. 738; 805). As CMU points out in its response, there is sufficient evidence in the record from which the jury could have found the parties to the hypothetical negotiation determined that a running royalty was appropriate in this case. (Docket No. 725). As the Court held at the *Daubert* stage of these proceedings in the opinions addressing both the motion to exclude the testimony of Ms. Lawton and Mr. Hoffman, there is no established royalty for the patents-in-suit in this case. (Docket No. 449). To this end, as the Court recounted in one of the memorandum orders denying CMU's motions *in limine* to exclude the evidence of the Intel Subscription Agreement, (Def. Ex. 255), and the "Highly Speculative Forecast," (Def. Ex. 272), the parties to the hypothetical negotiation in this case would have to negotiate both the financial aspect of any license for the patents-in-suit as well as the framework or structure of the deal, including whether it was a running royalty or a lump sum payment. (Docket No. 609 at 5-6 (citing *Lucent Technologies, Inc. v. Gateway, Inc.*, 580 F.3d 1301, 1326 (Fed. Cir. 2009)).

In this Court's opinion, CMU presented sufficient evidence showing that both parties have used the running royalty structure in past license agreements. (Pl. Ex. 197; Def. Ex. 272). In the absence of an established royalty, a reasonable jury could conclude that the parties to the hypothetical negotiation would have agreed to a running royalty in accordance with Ms. Lawton's expert opinion.

As CMU recounts (Docket No. 725 at 7-8), the trial record contains evidence that Marvell has been a party to running royalty licenses in the past. Indeed, Dr. Armstrong has represented that Marvell entered into both lump sum and running royalty agreements in the past. (Docket No. 761 at Jt. Ex. C at 251-252). Ms. Lawton also relied on three license agreements for a running royalty into which Marvell had entered: (1) Hitachi; (2) DSP group (Pl. Ex. 197); and (3) ARM, during her testimony, to which there was no objection by Marvell. (Docket No. 710 at 112-113).

The trial record also contains evidence that CMU has been a party to both running royalty and lump sum licenses in the past. First, Ms. Lawton testified that she relied on a Showa Denko license agreement wherein CMU had agreed to a running royalty for a set number of cents per disk and Marvell did not object to such testimony. (Docket No. 710 at 112-113). Second, the "Highly Speculative Forecast" was entered in evidence over CMU's objection. It contains a list of license agreements to which CMU has been a party and reflects that CMU was a party to running royalty agreements at that time.[110] (Def. Ex. 272). Third, Dr. Wooldridge also testified that CMU had been a party to running royalty agreements in general and as set forth in the "Highly Speculative Forecast." (Docket No. 682 at 102, 110).

For these reasons, the Court finds that CMU adduced sufficient evidence from which a reasonable jury could conclude that the parties to the hypothetical negotiation may have agreed to a running royalty in this case. Once again, the parties' competing evidence on this issue was left for the jury to decide.

[110] These include running royalties for ATRP with PPG, Ciba, Kaneka, and Dolonex; for Smartcube with Psychogenics; and for Microvelcro with Alza. (Def. Ex. 272).

e. Licensed Sales

Marvell's final argument in its initial Rule 50(a) motion was that CMU improperly included licensed sales to non-party Seagate Technologies in the royalty base, relying on this Court's Summary Judgment opinion dated August 24, 2012. (Docket No. 441). However, Marvell misconstrues the Court's earlier decision. At that point in the litigation, the Court also found that Marvell's use of the claimed methods during its sales cycle could support a verdict against it because there was no evidence of record that Seagate had exercised its "have made" rights under the license and solicited Marvell to build the patented technology for it.[111] (Docket No. 441 at 10-11). Without such evidence, the Court further found that Marvell's use of the patented methods in this manner could support a claim for damages.[112] (Docket No. 441 at 12-14). As before, Marvell did not introduce any evidence at trial demonstrating that Seagate exercised its "have made" rights under its DSSC license such that the Court's prior decision no longer stands. Nor have they convinced this Court that its prior decision was incorrect.

[111] Seagate, as a member of the DSSC, has a right to the patents-in-suit under the Associates Agreement. To this end, that agreement gives Seagate a right to have the Inventions made, i.e., "have made" rights. (Def. Exs. 39; 1003; 1008). However, it is not clear to the Court that the appropriate Seagate Associates Agreement covering these patents was entered into evidence, as at trial, Marvell only proffered unsigned copies of Seagate DSSC Associates Agreements. (Def. Exs. 39; 1003; 1008). These three versions of the agreement have conflicting terms for the period of 1992-1997. *Id.* The agreement in place in 1995-1997 would be controlling regarding Seagate's "have made" rights for the patents-in-suit. Thus at trial, Marvell did not present uncontroverted evidence that Seagate had a license to the patents. Regardless, Marvell likewise did not proffer any contract, communication, testimony or document showing Seagate exercised any DSSC rights in conjunction with its dealings with Marvell.

[112] The Court's reasoning was that had Seagate exercised its "have made" rights before Marvell undertook the sales cycle, it would not be liable for infringement. (Docket No. 411). If Marvell, however, did not secure such a grant of rights it would have infringed the patents in order to make a non-infringing sale. (*Id.*). Hence, the sales to Seagate could still demonstrate the value to Marvell of infringing CMU's patents. (*Id.*).

4. Challenges to the Royalty Rate

a. Challenges to Ms. Lawton's Methodology

Marvell contends that a royalty of $0.50 per chip is unsupported by the record because Ms. Lawton's opinion is speculative. (Docket No. 809 at 10-17). Marvell's first line of attack is on Ms. Lawton's use of excess profits analysis and operating profit premium analysis.

Because of Marvell's numerous challenges to Ms. Lawton, the Court held two *Daubert* hearings regarding Ms. Lawton's opinion at Marvell's request. (Docket Nos. 438-440; 706). In addressing these same arguments, the Court has now written over forty pages analyzing Ms. Lawton's qualifications and methods, ultimately holding that she was qualified to testify as an expert in this case and that she applied a reliable methodology in reaching her damages opinion. (Docket Nos. 451; 713). The Court incorporates both opinions herein and denies the Motion for Judgment as a Matter of Law, the Motion for a New Trial, and Motion for Remittitur to the extent that Marvell argues Ms. Lawton is not qualified to render her damages opinion, that her opinions were unreliable, or that they did not fit this case.

Going through these *Daubert* challenges, the Court put Ms. Lawton to the test, requiring her to first give her testimony *in camera* for all counsel and the Court before addressing the jury. Additionally, ten minutes before her testimony, the Court excluded Ms. Lawton's prepared slides, given numerous and time consuming arguments over them and what the Court determined to be a summary presentation that should not be permitted in a trial. (Docket No. 686 at 29).[113]

[113] Despite these last minute changes and extra scrutiny, Ms. Lawton, in this Court's estimation, was remarkable as a witness. In the Court's thirty years of private trial practice and over six years on the bench, there have not been many witnesses (fact or expert) who have had such a grasp on all the facts and figures of a case, possessed the ability to answer thoroughly, succinctly, and convincingly, as well as communicate in a direct yet amicable manner.

With respect to her computations,[114] Ms. Lawton initially arrived at a price-per-chip of \$4.42 and operating profit-per-chip of \$2.16 based on Marvell's internal sales data. (Docket No. 686 at 53-54). She then relied on comments from Marvell's CEO, Dr. Sutardja, and deposition testimony of Marvell's marketing executive, Dr. Armstrong, both of which suggest that Marvell's target gross margin for all of its products was 50%. (Docket No. 710 at 232-233). She next looked at Marvell's gross margin, operating income and excess profits from 2000 to 2013 of MNP and NLD chips and found that Marvell made approximately 59.6% profit on its gross margins. (*Id.* at 82-86; Lawton Chart 27). Based on this analysis, Ms. Lawton concluded that Marvell received \$0.42 of "excess profits" from its sales of the read channel and SOC chips, i.e., profit in excess of the 50% target margin. (*Id.* at 85-86). She then conducted an operating profit premium analysis in which she compared the sales of Marvell's chips to certain customers (Maxtor and Toshiba) for which she had information from the same time period (2003) where products were sold with and without the addition of the allegedly infringing MNP detector.[115] (*Id.* at 95-100). From this data, Ms. Lawton calculated that Marvell had an operating profit delta[116] between \$0.06 and \$0.72 on the chips containing the MNP/NLD compared to those that did not have an MNP/NLD. (*Id.*). She refers to this \$0.06 to \$0.72 range as the "operating profit premium" and suggests that this range would also have been the range of negotiations between

[114] The full data and her calculations are detailed in her expert report which is over 500 pages with 3,000 footnotes. (Docket No. 356-1).

[115] Marvell maintained that this comparison was not appropriate and cross-examined Ms. Lawton on same. (Docket No. 710 at 242-245). Ms. Lawton stated she compared these customers' chips because Dr. Armstrong advised that to analyze prices with respect to the chips that Marvell was selling, one would need to establish comparability of the chips. (*Id.* at 95-96). In order to establish comparability, she stated the chips would have to have: the same data rate; the same packaging; been sold to the same customer; and been sold in the same quarter. (*Id.*). Ms. Lawton also looked at the price deltas of Fujitsu, Hitachi, and Seagate, but stated they did not meet her comparability standard given that for Fujitsu the sales were not in the same quarter and for Hitachi the comparison chips had different data rates. (*Id.*). The prices for Seagate were listed in a price quote and Ms. Lawton stated she was not able to see the prices actually paid. (*Id.*).

[116] An operating profit delta is the price delta minus the cost associated with the MNP. (Docket No. 710 at 97).

the parties during the hypothetical negotiation. *Id.* at 172. Ultimately, relying in part on her calculations of the excess profits benchmark of $0.42 per unit, and the operating profit premium benchmark of $0.06 to $0.72 per unit, and considering all the other factors as laid out in *Georgia-Pacific*,[117] Ms. Lawton opined that a reasonable royalty in this case was $0.50. (Docket No. 710 at 170-171). After applying this figure to the 2,338,280,543 Accused Chips sold over the past ten years since March 6, 2003, she concluded that CMU's damages were $1.169 billion. (Docket No. 686 at 61).

This analysis and testimony was in stark contrast to Marvell's damages expert, who did not do any financial analysis of Marvell's sales data. He only opined that CMU and Marvell would have agreed to a one time lump sum payment of $250,000. (Docket No. 709 at 242-245). His opinion was based on the DSSC licenses and CMU-Intel Subscription Agreement. (Docket No. 709, 710). While he tried to discredit Ms. Lawton's in-depth analysis, he did not offer any analysis of his own of any sales data. Unlike Ms. Lawton, Mr. Hoffman appeared unfocused at times and repeatedly lost track of his points during his brief "expert" testimony. His expert opinion bordered on mere regurgitation of the facts related to the DSSC and Intel licenses, rather than any analysis based on his knowledge, education or expertise. His ultimate opinion was $250,000 one-time lump sum, despite the fact that the Intel agreement was for a lump sum of $200,000 and the DSSC agreement required annual $250,000 payments. (Def. Exs. 17; 39; 40; 255). In the Court's estimation, it is not hard to see why the jury chose to credit Ms. Lawton over Mr. Hoffman. To that end, the jurors took their task in analyzing the expert opinions very seriously. Indeed, they asked the Court during deliberations if they could be provided with the

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117 The factors she considered include: the advantages of the patented invention; the market and industry background; the date of the hypothetical negotiation; acceptable available non-infringing alternatives; consideration of the parties to the negotiation; projection sales; norms in the relevant industry; the structure of the agreement; royalties received by CMU; rates paid by Marvell; the commercial relationship between the two; the duration of the patents; and the use of the patents by Marvell, among many others. (Docket No. 761 at P. Demo 12).

full expert reports and demonstratives for both Ms. Lawton and Mr. Hoffman. (Docket No. 761 at Ct . Ex. 3).[118]

As the Court held at the summary judgment stage, whether Ms. Lawton's testimony would be accepted or not is a "[d]eterminations regarding the weight to be accorded, and the sufficiency of, the evidence relied upon by the proffered expert…within the sole province of the jury." (Docket No. 451 at 10) (citing *Walker v. Gordon*, 46 F. App'x 691, 695 (3d Cir. 2002)). The Court does not find any of the data points utilized by Ms. Lawton improper. Thus, the JMOL is denied to this extent, and a new trial and/or a remittitur is not warranted on this basis.

b. Damages Are "Out of Proportion"

Marvell next argues in its motion for JMOL that "CMU's claim for $1.169 billion is wildly out of proportion to its own pre-litigation assessments of value." (Docket No. 739 at 12). It maintains that judgment as a matter of law is warranted as a result of Ms. Lawton's failure to rely on the following evidence: (1) the DSSC membership licenses (Def. Exs. 17; 39; 40); (2) the August 5, 2003 letters to which Wooldridge testified that no company expressed any interest in taking a license (Pl. Exs. 422; 431; Def. Exs. 225; 235; 1573); (3) the 2004 Intel Subscription Agreement through which an offer was made to Intel for the patents-in-suit for a lump sum of $200,000 (Def. Ex. 255); (4) the evidence that CMU had not entered into a single license arising out of engineering or computer science let alone a single, upfront licensing fee greater than $100,000; and (5) the "highly speculative" projection spreadsheet and emails wherein Wooldridge stated that an estimate for the patents-in-suit was $2,000,000.00 per year. (Def. Ex. 299).

As the Court noted in the Memorandum Order denying CMU's Motion to Strike Mr. Hoffman's testimony filed on December 18, 2012, all of this evidence underpins Mr. Hoffman's

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118 After consulting with counsel and hearing argument on same, the Court instructed the jury that neither the slide presentation nor any expert reports were admitted into evidence and could not be used in their deliberations. (Docket No. 765 at 12-13).

opinion that the reasonable royalty in this case would be a one-time, lump-sum payment by Marvell to CMU of $250,000.00. (Docket No. 733). As the Court has recounted, Mr. Hoffman relied heavily upon this figure in both his expert report and opinion testimony.

Based on this Court's review of the record, Ms. Lawton did not disregard any of this evidence. She convincingly explained her consideration of the DSSC and Intel agreements and how those agreements affected her opinion. (Docket No. 686 at 138-166). [119] Ms. Lawton identified the special nature of the agreements as well as the other forms of compensation the University received in connection with said agreements, such as research grants, funding, scholarships, sponsored fellowships, etc. (*Id.*). She did the same with respect to CMU's marketing efforts, discussing how this evidence did or did not affect her calculation of the reasonable royalty through her use of the hypothetical negotiation framework.[120] (*Id.*). The

[119] On the DSSC agreements, Ms. Lawton testified:

> Q: Did you consider these DSSC agreements and the fact that they provided for a 250,000-dollar annual fee?
> A: Yes, I did.
> Q: And did you have a view as to whether that was an appropriate measure of the -- of a royalty in this case?
> A: Yes, I did.
> Q: And what was your conclusion?
> A: My conclusion is that that is not an appropriate measure in this case, because those were special agreements.

(Docket No. 686 at 138). In regards to the Intel agreement she testified:

> Q: Okay. Now, we saw testimony in this case yesterday, at some length, about a subscription agreement between CMU and Intel. Do you recall the date of that subscription agreement?
> A: September of 2004.
> Q: And how does that compare to the date of the hypothetical negotiation?
> A: That's about three-and-a-half years after the date of the hypothetical negotiation.
> Q: And did you consider the existence of this Intel agreement in connection with your analysis?
> A: I did, yes…

(*Id.* at 165-166).

[120] In considering the "highly speculative" spreadsheet Ms. Lawton noted:

record clearly shows she was cross-examined extensively by Marvell's counsel on these very points. (Docket No. 710 at 179-191). Obviously, Marvell disagrees with Ms. Lawton's opinions regarding the importance of this evidence, but that does not mean such facts were not considered.

The jury was presented with all of the evidence that Marvell avers was not considered by Ms. Lawton. Further, CMU's witnesses including Dr. Kavcic, Dr. Kryder, and Mr. Wooldridge were cross-examined on these facts. (Docket Nos. 673; 674; 682). Accordingly, the weight of these facts that underlie the experts' opinions was for the jury to decide. *See Micro Chem., Inc. v. Lextron, Inc.*, 317 F.3d 1387, 1394 (Fed. Cir. 2003). Whether Ms. Lawton's testimony would be accepted or not is a "[d]etermination[ ] regarding the weight to be accorded, and the sufficiency of, the evidence relied upon by the proffered expert…within the sole province of the jury." *Walker v. Gordon*, 46 F. App'x 691, 695 (3d Cir. 2002). As such, Marvell's motions for judgment as a matter of law are denied to the extent that it argues that the damages which were sought are "out of proportion" with reality.

c. Patented and Unpatented Features

Marvell claims that: (1) CMU has no evidence that the claimed algorithm drives customer demand; (2) CMU did not apportion the value of the claimed algorithm to the accused MNP chips; (3) the calculated price premium for one of Marvell's smallest customers is

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> Q: And we spent some time talking about what we at least fondly call the highly speculative memo at CMU that Mr. Wooldridge talked about yesterday. What -- how does the date of that -- do you know what the date of that memo was?
> A: January of 2006.
> Q: And how does the date of that memo compare to the date of the hypothetical negotiation?
> A: Almost five years later -- four -- four years and ten months later.
> Q: And how do all those dates compare to the dates of the events that you studied at Marvell?
> A: They're well after the dates that surround the hypothetical negotiation on March 13th of 2001.

(Docket No. 686 at 166).

inapplicable to all accused sales;[121] and (4) CMU's excess profits analysis is completely divorced from any measure of value for the claimed algorithm. (Docket No. 739 at 27-36). The Court finds that these arguments go to the weight rather than the admissibility of Ms. Lawton's testimony. *See Micro Chem., Inc. v. Lextron, Inc.*, 317 F.3d 1387, 1394 (Fed. Cir. 2003). She addressed each and every one of these arguments and was cross-examined by Marvell on same. (Docket No. 710 at 173-266). The Court has already reviewed her testimony at length here and in its opinion on Marvell's Motion to Exclude Catherine Lawton's testimony.[122]

Similarly, the Court has already discussed the propriety of Ms. Lawton's price premium and excess profits analysis. Again, she based her reasonable royalty opinion on the opinion of Dr. Bajorek that the technology became "industry standard" and was "must have" for Marvell's survival and his other opinions regarding the value of the Accused Technology to Marvell's customers in order to establish liability. (Docket No. 686 at 68); *see, e.g.*, *Member Services, Inc. v. Sec. Mut. Life Ins. Co. of New York*, Civ No. 06-1164, 2010 WL 3907489, at *27 (N.D.N.Y. Sept. 30, 2010) (an "expert may rely upon another expert to form an opinion under Rule 703" as long as the expert does not "merely recite another expert's opinion as his own"). Ms. Lawton also relied on Dr. McLaughlin's opinions on the infringement of the claimed algorithm on the MNP and NLD chips again in order to assume liability. *See, e.g.*, *Sys. Dev. Integration, LLC v. Computer Scis. Corp.*, 886 F. Supp. 2d 873, 882 (N.D. Ill. 2012) ("It is entirely appropriate for a damages expert to assume liability for the purposes of his or her opinion. To hold otherwise would be illogical."); *Sancom v. Quest Commc'ns Corp.*, 683 F. Supp. 2d 1043, 1068 (D.S.D.

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121 At trial and post-trial hearings, Marvell's counsel claims it was able to show that the average margin of non-infringing storage products is higher than its margin of infringing products. (Docket No. 880 at 65-66). However, Ms. Lawton explained that those non-infringing products include a non-read channel chip for Seagate that sells at a premium, and a chip that Marvell indicated had an MNP but CMU could not absolutely confirm this and out of an abundance of caution, she did not include this chip in its list of Accused Products. (Docket No. 710 at 257-258).

122 *See supra* at Section V.D.4.a.; *see also* (Docket No. 713).

2010) ("it is well-settled that a damages expert ... can testify as to damages while assuming the underlying liability"). The specific challenges to the factual underpinnings of these expert opinions go to the weight to be afforded to their respective testimonies. *See Miller*, 2011 WL 7037127, at *3 n.3.

The Court is guided by the Federal Circuit's decision in *Micro Chemical, Inc.*, which aptly stated:

> [t]his case is a classic example of competing experts. Each side had the opportunity to present its damages theory. Each party's expert supported his reasonable royalty determination with an analysis of relevant factors based on his client's view of the disputed facts. The outcome of the case depended to a large extent upon which predicate facts the jury believed, and then on which expert's analysis they believed. Upon reviewing the record, we cannot say that [plaintiff's] damages theory and the jury's ultimate damages award were unsupported by substantial evidence. The defendants may not like the jury verdict, but it was the result of a fair trial, fairly fought.

317 F.3d at 1394. Likewise in this case, all of the evidence Marvell cites, along with their expert testimony, as well as their arguments, were presented to the jury, who had ample opportunity to consider same in their calculation of damages. Ms. Lawton's opinion is not rendered unreliable simply because she reached a conclusion adverse to Marvell's arguments on the facts. The jury was tasked with evaluating the credibility of all of the witnesses and the weight of the evidence in order to reach its ultimate decision on damages. They did just that and found for CMU. Accordingly, Marvell's motion is denied on these grounds.

5. Conclusion on Damages

Marvell is in its current predicament because it deliberately undertook a series of strategic risks. It took the risk of incorporating technology into its products that it knew might have been covered by CMU's Patents. It took the risk of continuing its use of this technology even after this litigation was initiated. It bore the risk of failing to keep or to demonstrate it kept records pertaining to sales and use of its chips.[123] Its trial team took the risk of taking this case to trial, despite repeated efforts to mediate this case (Docket No. 236),[124] and knowing full well the size of the possible award. Indeed, Marvell has known CMU's position on damages since January 2012, when Catherine Lawton's expert report was produced. (Docket No. 315). Now, Marvell looks to the courts to relieve it from the damages award it faces from taking those risks. This Court, however, remains unconvinced by Marvell's arguments. Perhaps, in foreseeing such a result, Marvell has vowed to march forward on the chance that the Federal Circuit may favor its position, as Marvell has made it clear that it believes the Court's rulings were in error and against the great weight of Federal Circuit precedent. While Marvell may believe the Court's purportedly flawed legal analysis precipitated its defeat, it is the undersigned's impression as a Judge and former trial lawyer that Marvell's bad facts and even worse litigation strategy were fatal to its cause.

Marvell's strategy was always "all or nothing." At trial, Marvell argued that the parties would have agreed to a one-time payment of $250,000. It took the risk that the jury would reject this argument.[125] In making this argument, Marvell intentionally declined to present evidence of a lower running royalty amount, upon which a jury could have awarded CMU substantially reduced damages. Marvell did not offer <u>any</u> evidence about its sales cycle, business strategy, technology, pricing or products, in relation to determining damages. It took the risk of not

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123 *See* discussion *supra* at Section V.D.3.b.

124 Magistrate Judge Infante attempted to mediate this case twice, (Docket Nos. 236; 315), the Court held a settlement conference immediately before trial, (Docket No. 641), and the Court ordered the parties to Court-annexed mediation twice, once during trial, before the verdict and once before the hearing on post-trial motions. (Docket Nos. 734; 872). Despite same, this case is obviously still ongoing.

125 It likely would have been difficult for the jury to believe the technology at issue was only worth a one-time payment of $250,000 once they observed the number of lawyers in the Courtroom at any given time during this trial. Just the sight of these armies of attorneys would suggest to any casual observer that this case was about valuable technology and important for both sides.

presenting this evidence in order to keep its technology, products, and sales information secret. This was Marvell's choice. It should thus not come as a shock that the jury did not find in its favor, as it proffered no solid evidence about its business and its products.

CMU's damages expert Ms. Lawton was the only person in the trial to present evidence concerning Marvell's sales of the Accused Technology.[126] (Docket Nos. 868; 710). She was thus able to define Marvell's sales, characterize its actions in her favor, and support CMU's theory of the case. Opposing her was Mr. Hoffman, whose testimony appeared disjointed and did not demonstrate a comparably firm grasp of the facts and data as Ms. Lawton. Although he was dismissive of Ms. Lawton's opinion, he did not provide any other contrary calculations or well-considered alternatives. In effect, Marvell let CMU create a one-sided expert exposition, because it did not argue for any per chip royalty. This left the jury in a tough spot, with no reasonable options for a damages award other than $250,000 or $1.169 billion.[127] While the Court cannot even begin to calculate the hours it spent on arguments, objections at over 130 sidebars, and motions regarding minutiae,[128] Marvell's proper focus should have been on persuading the jury, if liability were found, that a lower royalty existed.[129]

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[126] Ironically, when Marvell wished to seal Ms. Lawton's trial slides months later, CFO Brad Feller provided an affidavit as to the importance of this information. (Docket No. 773).

[127] During deliberations on December 21, 2012, the jury requested a calculator. (Docket No. 761 at Ct. Ex. 2). Marvell objected to this request. (Docket No. 764 at 106-120, 131-132). As a result, the parties and the Court could not come to a resolution until the jury resumed deliberations on December 26, 2012. (Docket No. 765). The Court eventually advised the jury that a calculator could be made available upon request. (*Id.* at 13). The jury never again requested to use a calculator, and none was provided. In this Court's estimation, a calculator may have been in the best interest of Marvell because it could have allowed the jury to consider per chip royalties below $0.50 per chip.

[128] *See* (Docket No. 72) (Marvell's Oral Motion to Strike Slide 19 of Plaintiff's Demonstrative); (Docket No. 660) ("Motion for Reconsideration Regarding Order Sustaining CMU's Objections to Disputed Defendants' Exhibit DX-189").

[129] Given the attitude of Marvell's counsel and its actions, the Court felt at times that Marvell was treating this trial as a dress rehearsal for the new trial that it hopes to gain from the Federal Circuit.

John Adams has observed that "[f]acts are stubborn things; and whatever may be our wishes, our inclinations, or the dictates of our passion, they cannot alter the state of facts and evidence."[130] Such was the case for Marvell. CMU presented three extremely qualified and competent experts, each of whom did an excellent job explaining their opinions and pointing the jury to the factual proof underlying their opinions.[131] On the other hand, Marvell focused on attacking CMU's witnesses instead of presenting a cohesive defense based on its witnesses. While CMU had numerous fact witnesses, such as Dr. Cohon and Dr. Kryder, who apparently garnered credibility with the jury, Marvell's employee testimony may not have been as convincing, especially when they had to struggle against facts tending to show infringement (naming the Accused Technology after Dr. Kavcic),[132] and patent validity (email from the inventor of the Worstell patent). (Pl. Ex. 161).[133] Moreover, given the nature of the invention, everyone agreed that Dr. Kavcic's method is the optimal solution. (Docket No. 677 at 170; 759 at 133). As Dr. Burd said in his displayed deposition testimony [Dr. Kavcic] "is kind of VIP which everybody tries to cite and everybody is citing, even in the papers… so it's a natural thing

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130 John Adams, Argument in Defense of the Soldiers in the Boston Massacre Trials (December 1770), *available at* http://www.bostonmassacre.net/trial/acct-adams3.htm.

131 In contrast, at one point in trial, the Court observed two of out of Marvell's three experts sound asleep for a period of time. In all likelihood, the jury made the same observation.

132 The Court particularly recalls the deposition testimony of Mr. Burd:

> Q. And why use the Kavcic approach, as the yardstick?
> A. …just because his name, kind of became a yardstick. I don't know why. I mean, people use it. It's like when you say-you know there are certain people which get associated with – some event….Ronald Reagan is credited with breaking down the wall. Well, I didn't see him break any bricks. Right? But yet, he is the one. So same thing.

(Docket No. 771 at Ex. H at 110).

133 Three former Marvell employees Mr. Doan, Dr. Armstrong, and Mr. Brennan did not appear in person, opting to testify by deposition designations, and offered testimony helpful to CMU's cause. (Docket No. 761 at Jt. Exs. A, C, D). For example, Mr. Doan testified that he never looked at the patents, never directed others to look at them, and never contacted Marvell's legal department about them. (Docket No. 761 Jt. Ex. D at 125, 130).

to compare yourself to, you know, people whose work considered to be, you know, on a leading edge or on the cutting edge of a field." (Docket No. 771 at Ex. H at 110). While these facts may not be dispositive on the issues of infringement, invalidity, and willfulness, they were nevertheless very difficult to overcome.

As to damages, there is likewise telling sales data that shows that a majority of all chips sold by Marvell used the Accused Technology for a ten-year period. (Docket No. 686 at 117-126; P-Demo 13). Marvell's revenue on the Accused Technology was $10.34 billion, with a total operating profit of $5.05 billion.[134] (Docket No. 868 at P Demo 9-Lawton Chart 4). Over the past decade, Marvell has grown to become the dominant market leader, holding 60% of the market. (Docket No. 707 at 122). If a new trial is warranted, Marvell will have to proceed to trial with these same facts and the same experts.[135] The Court is not sure how different the outcome would be.

While the Court acknowledges this award is large, the facts show that the infringement was long and sustained. Marvell often ridiculed CMU's request for a billion dollars; however, just because a damages award is large[136] does not mean the Court's standard of review changes.

[134] In an abundance of caution, the Court did not permit Ms. Lawton to discuss the total figures of revenue and profit, but only offer average revenue and profit per chip. However, it was within the jurors' prerogative to "do the math," as both the average values and the volume of chips (2.34 billion) were proffered.

[135] Expert discovery closed in this matter on April 16, 2012, and it will not be reopened if a new trial is ordered. (Docket No. 335). Thus, Marvell would be limited to Mr. Hoffman's expert damages opinion of $250,000 in any future proceedings.

[136] The size of the award is in part of Marvell's own making. Since this matter was filed in March 2009, Marvell has not made any efforts to remove the Accused Technology from its products and sold a number of infringing products, thereby incurring a substantial amount of additional damages of around $535 million based on information regarding sales dating to July 29, 2012. (Docket No. 569; Docket No. 889-2 at 2). According to the latest joint submissions regarding sales data, Marvell has sold 363,752,585 infringing chips from July 29, 2012 to August 3, 2013, (Docket No. 889 at 3; Docket No. 898 at 2), thereby yielding $181,876,292.50 in added damages. This combined sum of more than $716 million in damages accrued (and likely attorney fees as well as costs approaching $20 million) since the initiation of this litigation could have easily been avoided if the parties came to a reasonable and mutually beneficial licensing agreement or settlement agreement—such as the Marvell Hall of Engineering at CMU—back in 2009.

At this stage of the case, the Court is only an "umpire,"[137] checking to make sure there is sufficient evidence upon which a reasonable jury could have returned their verdict. *Galena*, 638 F.3d at 196. The nature and scope of the damages to be awarded was properly left to the jury.

For all of these reasons and after considering all of the evidence in this case, in the light most favorable to CMU, and drawing all reasonable inferences in its favor, the Court denies Marvell's Motion for Judgment as a Matter of Law on Damages, its Motion for a New Trial, as well as its Motion for Remittitur.

VI. CONCLUSION

Given the above findings and analysis, the Court denied the parties' motions for JMOL before giving the case to the jury for deliberations. (Docket Nos. 699; 701; 703; 731; 738; 740; 742; 747). For these and other reasons discussed herein, the Court denies Marvell's Motion for Judgment as a Matter of Law, or in the Alternative, New Trial on Non-Damages Issues (Docket No. 805), and Marvell's Motion for Judgment as a Matter of Law, New Trial And/Or Remittitur With Respect To Damages. (Docket No. 807). The Court grants CMU's Motion for a Finding of Willful Infringement and Enhanced Damages (Docket No. 790), in part, on willfulness, and reserves its ruling on enhanced damages for a forthcoming opinion. The Court also reserves its rulings on Marvell's Motion for Judgment on Laches, (Docket No. 802), CMU's Motion for Permanent Injunction, Post-Judgment Royalties, and Supplemental Damages (Docket No. 786),

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[137] As Chief Justice Roberts said in his opening statements before the Senate Judiciary Committee in 2005,

> Judges and justices are servants of the law, not the other way around. Judges are like umpires. Umpires don't make the rules; they apply them. The role of an umpire and a judge is critical. They make sure everybody plays by the rules. But it is a limited role. Nobody ever went to a ball game to see the umpire.

Confirmation Hearing on the Nomination of John G. Roberts, Jr. to be Chief Justice of the United States Before the S. Comm. on the Judiciary, 109TH CONG. 55 (2005).

and CMU's Motion for Prejudgment and Post-Judgment Interest (Docket No. 788), for a memorandum opinion that will be filed in due course.

s/Nora Barry Fischer
Nora Barry Fischer
United States District Judge

Date: September 23, 2013

cc/ecf: All counsel of record.

Opinion (Enhancement)

(A4-75)

IN THE UNITED STATES DISTRICT COURT
FOR THE WESTERN DISTRICT OF PENNSYLVANIA

CARNEGIE MELLON UNIVERSITY,	)	
	)	
Plaintiff,	)	
	)	
vs.	)	Civil Action No. 09-290
	)	Judge Nora Barry Fischer
MARVELL TECHNOLOGY GROUP, LTD. et al.,	)	
	)	
	)	
Defendants.	)	

MEMORANDUM OPINION

I. INTRODUCTION/BACKGROUND

This is a patent infringement case brought by Plaintiff Carnegie Mellon University ("CMU"), against Defendants Marvell Technology Group, Ltd. and Marvell Semiconductor, Inc. (collectively "Marvell"), alleging that Marvell has infringed two of its patents, U.S. Patent Nos. 6,201,839 (the "'839 Patent") and 6,438,180 (the "'180 Patent") (collectively, the "CMU Patents"), for which the Court conducted a four-week jury trial from November to December of 2012. (Docket No. 760). The jury rendered its verdict on December 26, 2012 in favor of CMU on infringement, validity and willfulness, and awarded damages in the amount of $1,169,140,271.00. (Docket No. 762).[1] The Court has continued to preside over hotly contested

[1] As the parties are well aware of the factual and procedural background of this case and the Court has already written extensively on the facts of this case, (*see* Docket Nos. 900, 901, 920), the Court will limit its discussion to the background necessary for the resolution of the current motions. For convenience, the Court cites to the docket numbers associated with these previously issued opinions on its own docket throughout this decision but notes that the opinions resolving post-trial motions are available at the following citations: (1) denying the mistrial, *see Carnegie Mellon Univ. v. Marvell Tech. Grp., Ltd.*, Civ. A. No. 09-290, 2013 WL 4511293 (W.D. Pa. Aug. 23, 2013); (2) resolving the parties' motions for judgment as a matter of law ("JMOLs"), *see Carnegie Mellon Univ. v. Marvell Tech. Grp., Ltd.*, Civ. A. No. 09-290, --- F. Supp. 2d ----, 2013 WL 5332108, at *41-42 (W.D. Pa. Sept. 23,

post-trial proceedings in this case, which has included extensive briefing and post-trial evidentiary submissions, a two-day motion hearing, supplemental briefing on disputed legal points and periodic joint status reports from the parties as to Marvell's continuing sales of the infringing technology. The Court has moved sequentially through the post-trial motions and issued a number of decisions, including: (1) denying Marvell's motion for a mistrial, (Docket No. 900); (2) resolving the parties' challenges to the sufficiency of the evidence supporting the jury's verdict on liability, damages and willfulness but reserving ruling on the financial penalty to be imposed as a result of Marvell's willful infringement, (Docket No. 901); and (3) denying Marvell's equitable defense of laches, which could have substantially reduced the jury's award, (Docket No. 920). All of those decisions are incorporated by reference herein. (Docket Nos. 900, 901, 920).

At this juncture, the jury's verdict of $1,169,140,271.00, which has been adopted as a judgment filed on January 14, 2013, has been sustained. (Docket Nos. 762, 769, 901). The jury's verdict represents one hundred percent (100%) of the compensatory damages sought by CMU at trial for Marvell's infringement of the patented methods. (*Id.*). It also signifies that the jury wholly adopted the testimony of CMU's damages expert, Catharine Lawton, who opined that a hypothetical negotiation between the parties would have resulted in a reasonable royalty of $0.50 per Accused Chip sold by Marvell during the relevant time period (the royalty base) and would result in the exact damages figure which was awarded by the jury. (Docket No. 686 at 61). Ms. Lawton's opinions have been heavily scrutinized by the Court in prior decisions (including *Daubert* challenges both before and during trial) and the decisions on those issues are

2013); and (3), denying the motion for judgment on laches, *see Carnegie Mellon Univ. v. Marvell Tech. Grp., Ltd.*, Civ. A. No. 09-290, 2014 WL 183212 (W.D. Pa. Jan. 14, 2014).

likewise incorporated by reference herein. (Docket Nos. 451, 713, 901). Relevant here, Ms. Lawton's testified to the following damages computations:

Damages Period	Royalty Base	Royalty Rate	Damages
3/6/03-3/5/09	1,109,100,006	\$0.50	\$554,550,003
3/6/09-7/28/12	1,229,180,536	\$0.50	\$614,590,268
3/6/03-7/28/12	**2,338,380,542**	**\$0.50**	**\$1,169,140,271**

(Docket No. 633-1 at 7). While the post-trial motions were pending, the Court ordered a number of post-trial accountings regarding Marvell's continuing sales of Accused Chips[2] and the parties filed status reports providing such information. (Docket Nos. 885, 886, 904). Through this process, the parties met and conferred and generally agreed[3] that Marvell has made the following sales of Accused Chips in the subsequent periods:

Period	**Sales**
7/29/12 – 1/14/13	159,100,576
1/15/13-8/3/13	204,652,009
8/4/13 – 11/2/13	94,390,559

(Docket Nos. 889, 907, 901 at n.136). The Court has not ordered additional status reports at this time because the same are unnecessary to the Court's present decisions. However, updated accountings will be ordered in conjunction with the Court's rulings set forth below.

[2] As noted in the Court's prior Opinions, "Accused Chips" refers to Marvell's read channel and SOC chips containing the infringing technology. (*See* Docket No. 901 at 16).

[3] In the latest status report dated November 2, 2013, the parties dispute the amount of revenue generated for this period of time and CMU objects to Marvell presenting the sales data in a form which breaks out international and domestic sales of Marvell's products. (Docket No. 907). These disputes have no bearing on the instant matters.

Turning back to the pending matters before the Court, all of the remaining post-trial motions involve CMU's efforts to seek to increase this substantial award and/or to seek a reasonable royalty for ongoing infringement by Marvell or enjoin it from same.[4] CMU seeks all of the following in addition to its billion dollar jury verdict:

- supplemental damages of $79,550,288;
- prejudgment interest of up to $326,144,393.25;
- enhanced damages of up to three times the jury's verdict and supplemental damages (i.e., for a total verdict of $3,746,071,677);
- 0.14% post-judgment interest on the jury's verdict, and any supplemental damages, attorneys' fees (the issue of attorneys' fees has been deferred by the Court until any appeals are resolved), and/or prejudgment interest which may be awarded, compounded annually;
- a permanent injunction preventing Marvell from further production of any products which infringe CMU's patented methods because Marvell is allegedly a "collection risk," and,
- an on-going running royalty of up to $1.50 per chip on all of Marvell's post-judgment sales of chips containing the infringing technology.

(Docket Nos. 786, 788, 790). Marvell essentially concedes that an award of supplemental damages and post-judgment interest are appropriate in light of the jury's verdict but opposes

[4] However, before the Court was able to finalize its rulings on these remaining matters, all of which potentially inure to CMU's benefit, including the outstanding motion to treble the damages award, CMU saw fit to bring a series of motions seeking to register the judgment, initiate execution of same, and sought guidance from the Court on how to proceed as negotiations over Marvell's acquisition of a supersedeas bond in advance of its appeal to the Federal Circuit have not progressed as quickly as CMU would like. (Docket Nos. 908, 909). CMU also put forth financial documents and other evidence which it claimed showed that Marvell was seeking to avoid its financial obligations under the jury's verdict, including an acquisition of approximately five percent (5%) of its common stock by an investment firm and turnover of key members of its management team and Board of Directors. Marvell countered with its own evidence showing that these were business decisions unconnected to the present litigation. (*Id.*). These motions were extensively briefed by the parties, all of which the Court considered prior to summarily denying such motions, holding that all of CMU's requests were premature in light of the outstanding matters. Undeterred by the Court's Orders, CMU then filed additional papers wherein it essentially asked the Court to supervise the parties' negotiations on the bond issues. (Docket No. 919). After even more briefing was submitted, and reviewed and considered, the Court appointed a Special Master to act in this capacity, so that the Court could focus on the tasks at hand rather than mediate the parties' ongoing negotiations. (Docket Nos. 928, 930).

CMU's requests for prejudgment interest, enhanced damages, a permanent injunction and/or a reasonable royalty on future sales of the Accused Chips. (Docket Nos. 824, 828, 833, 861-863).

CMU's requests are framed as its Motion for Prejudgment and Post-Judgment Interest, (Docket No. 788), Motion for a Permanent Injunction, Post-Judgment Royalties, and Supplemental Damages, (Docket No. 786), and Motion for a Finding of Willful Infringement and Enhanced Damages,[5] (Docket No. 790). These matters have been completely briefed, (Docket Nos. 787; 789; 790; 793; 834; 836; 837; 850; 852; 853; 861; 862; 863), and the Court heard argument on same on May 1 and May 2, 2013. (Docket No. 873). The transcripts of these proceedings were filed on May 15, 2013. (Docket Nos. 880; 881).[6] The parties have also submitted status reports and supplemental briefing on certain issues. (Docket No. 889, 891, 893, 896, 897, 898, 905, 906). Accordingly, these motions are now ripe for disposition. Upon careful consideration of all of the parties' submissions, oral argument, and for the following reasons, CMU's Motions [788], [786] and [790] are granted, in part, and denied, in part. More specifically,

- CMU's Motion for Prejudgment and Post-Judgment Interest [788] is granted to the extent that CMU seeks post-judgment interest under 18 U.S.C. § 1961 but denied to the extent that CMU seeks prejudgment interest under 35 U.S.C. § 284;

- CMU's Motion for a Permanent Injunction, Post-Judgment Royalties, and Supplemental Damages [786] is granted to the extent that CMU will be awarded supplemental damages in the amount of $79,550,288.00; denied to the extent that a permanent injunction is sought; and granted, in part, as the Court will order an on-going royalty of $0.50 per sale of Accused Chips by Marvell; and,

- CMU's Motion for a Finding of Willful Infringement and Enhanced Damages [790] is granted to the extent that the Court

[5] The Court has already made a finding of willful infringement. (Docket No. 901 at 67-81). The Court has also denied, without prejudice, CMU's request for Attorney Fees. (Docket No. 884).

[6] The parties likewise filed their hearing slides (Docket Nos. 874, 875).

> will award enhanced damages at a rate of 1.23 multiplied by the jury's award and supplemental damages, for a total enhancement of $287,198,828.60, but denied to the extent that CMU seeks enhanced damages at a higher rate.

II. MOTIONS SEEKING RELIEF UNDER 35 U.S.C. § 284

CMU's post-trial motions for supplemental damages, prejudgment interest and enhanced damages seek relief under the patent damages statute, 35 U.S.C. § 284, which provides that:

> [u]pon finding for the claimant the court shall award the claimant damages adequate to compensate for the infringement, but in no event less than a reasonable royalty for the use made of the invention by the infringer, together with interest and costs as fixed by the court.
>
> When the damages are not found by a jury, the court shall assess them. In either event the court may increase the damages up to three times the amount found or assessed. …
>
> The court may receive expert testimony as an aid to the determination of damages or of what royalty would be reasonable under the circumstances.

35 U.S.C. § 284. The decisions as to whether to award supplemental damages, prejudgment interest and enhanced damages are respectively committed to the sound discretion of the trial court, in light of the developing precedent of the Supreme Court and Federal Circuit on these issues. "'Although courts have broad discretion in determining appropriate relief for patent infringement ... damages must be tailored to the circumstances and be correlatively determined.'" *Finjan, Inc. v. Secure Computing Corp.*, 626 F.3d 1197, 1212-13 (Fed. Cir. 2010) (quoting *Carborundum Co. v. Molten Metal Equip. Innovations, Inc.*, 72 F.3d 872, 881 (Fed. Cir. 1995)). The Court will address these matters sequentially, starting with supplemental damages.

A. Supplemental Damages

CMU's request for supplemental damages for all infringing sales of Accused Chips that were not included in the jury's verdict and accrued until the judgment was entered on January

14, 2013 is rather uncontroversial. (Docket No. 787 at 19; Docket No. 837 at 26). The parties agree that the jury's verdict of $1,169,140,271.00 included damages sustained by CMU during the period of March 3, 2006 through July 29, 2012, a period which did not include the full damages period which ended as of January 14, 2013. (*Id.*). The parties have likewise stipulated that the accrued supplemental damages for this additional period (i.e., from July 29, 2012 to January 14, 2013) is $79,550,288.00. (Docket No. 889 at 3). Such figure was calculated by multiplying the reasonable royalty found by the jury of $0.50 per chip times the royalty base of 159,100,576 Accused Chips which Marvell sold during the supplemental damages period. (*Id.* at 3).

It is well settled that a prevailing patentee is due the damages for uncalculated pre-verdict sales through the date of the entry of judgment. *See Power Integrations, Inc. v. Fairchild Semiconductor Int'l, Inc.*, 711 F.3d 1348, 1380-81 (Fed. Cir. 2013); *see also Finjan*, 626 F.3d at 1213. The Court finds that supplemental damages are properly awarded to CMU for the period of July 29, 2012 through January 14, 2013 because the jury did not have the opportunity to assess them due to a lack of financial information regarding Marvell's ongoing sales of Accused Chips at the time of trial. *See* 35 U.S.C. § 284 ("When the damages are not found by a jury, the court shall assess them."). Further, the parties' stipulations are consistent with the jury's verdict, which awarded $0.50 per all of Marvell's infringing sales of Accused Chips, during the relevant period. *Id.* Accordingly, CMU's Motion [786] is granted to the extent that it seeks supplemental damages and CMU is awarded supplemental damages of $79,550,288.00. The Court will analyze CMU's companion requests for an ongoing royalty and periodic accountings resulting from Marvell's continuing post-judgment infringement in section IV.B., *infra*.[7]

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[7] The parties' status reports reflect that an additional 299,042,568 Accused Chips have been sold as of November 2, 2013, which consists of sales of 204,652,009 Accused Chips from January 15, 2013 to August 3, 2013

B. Prejudgment Interest

The Court next addresses CMU's motion for prejudgment interest, which remains hotly contested by Marvell. (Docket Nos. 788-89, 824, 852, 861). CMU has set forth three separate proposals in support of its request for an award of prejudgment interest on the entirety of the jury's verdict and supplemental damages by applying either: (1) the Pennsylvania state statutory rate of 6%, compounded quarterly, resulting in $326,144,393.25; (2) the rate of its investment returns, compounded quarterly, resulting in $285,054,096.75; or, (3) the prime rate, compounded quarterly, resulting in $211,538,112.38. (Docket Nos. 788; 898). Marvell contends that prejudgment interest should be denied in its entirety, or limited through the application of a lower interest rate or by compounding the figures annually rather than quarterly. (Docket Nos. 824, 861).

In large measure, the parties have set forth positions akin to those advocated in the context of Marvell's assertion of the defense of laches, with CMU touting that prejudgment interest is necessary to make it whole and provide compensation for its lost opportunity to invest the reasonable royalties it is owed and Marvell countering that CMU's delays in bringing this case caused it prejudice, undermining the request for prejudgment interest. (Docket Nos. 788-89, 824, 852, 861). As noted, the Court denied Marvell's motion for judgment on laches in a lengthy decision dated January 14, 2014. (Docket No. 920). There, the Court found that Marvell met its burden to demonstrate by a preponderance of the evidence both that: (1) CMU's delays in prosecuting this lawsuit were unreasonable and inexcusable; and (2) Marvell was prejudiced, in part, by the delays, because CMU did not take reasonable steps to preserve the full quantum of potential evidence during the laches period. (*Id.*). However, the Court denied Marvell's laches

($102,326,004.50) and 94,390,559 Accused Chips from August 4, 2013 to November 2, 2013 ($47,195,279.50). (Docket Nos. 901 at n. 136; 907).

defense after weighing the equities between the parties, finding that Marvell's willful infringement outweighed CMU's negligence in failing to reasonably protect its patent rights through enforcement activities against Marvell. (*Id.*). The ultimate effect of this decision was to sustain the jury's award of approximately $545 million in pre-suit damages for the period of March 6, 2003 through the date the lawsuit was filed March 6, 2009. (*Id.*).

The Court recognizes that the issue of prejudgment interest is analytically distinct from its earlier laches inquiry; however, the Court views the parties' arguments as to the appropriateness of an award of prejudgment interest through the prism of its analysis and factual findings on the laches defense and with due consideration of the financial impact of that decision. (Docket No. 920). The Court likewise understands that its prior rejection of the laches defense, on equitable grounds, is not dispositive on the issue of prejudgment interest. *See e.g., Enzo Biochem, Inc. v. Applera Corp.*, Civ. A. No. 3:04-cv-929, 2014 WL 29126, at *2 (D. Conn. Jan. 3, 2014); *Humanscale Corp. v. CompX Int'l Inc.*, Civ. A. No. 09-cv-86, 2010 WL 3397455, at *2 (E.D. Va. Aug. 23, 2010); *Church & Dwight Co., Inc. v. Abbott Labs.*, No. 05–2142(GEB)(LHG), 2009 WL 2230941, at *7 (D.N.J. 2009).

With that said, the parties do not dispute that the award of prejudgment interest under section 284, including the rate of prejudgment interest to be applied and whether to compound any prejudgment interest awarded, are discretionary matters for the Court. *See Uniroyal, Inc. v. Rudkin-Wiley Corp.*, 939 F.2d 1540, 1545 (Fed. Cir. 1991) (internal citations omitted) ("[a] trial court is afforded wide latitude in the selection of interest rates, and may award interest at or above the prime rate."). The Supreme Court has held that an award of prejudgment interest is ordinarily appropriate in patent cases, reasoning that:

> [i]n the typical case an award of prejudgment interest is necessary to ensure that the patent owner is placed in as good a position as he

> would have been in had the infringer entered into a reasonable royalty agreement. An award of interest from the time that the royalty payments would have been received merely serves to make the patent owner whole, since his damages consist not only of the value of the royalty payments but also of the foregone use of the money between the time of infringement and the date of the judgment.

Gen. Motors Corp. v. Devex Corp., 461 U.S. 648, 655-56 (1983). Despite its pronouncement that prejudgment interest is generally appropriate, the Supreme Court clarified that district courts retain discretion to limit or deny prejudgment interest in certain circumstances, such as where the patentee has been responsible for undue delays in prosecuting the lawsuit. *Gen. Motors*, 461 U.S. at 657. Yet, the Federal Circuit has emphasized that "absent prejudice to the defendants, any delay by [the patentee] does not support the denial of prejudgment interest." *Crystal Semiconductor Corp. v. TriTech Microelectronics Int'l, Inc.*, 246 F.3d 1336, 1361-62 (Fed. Cir. 2001) (internal citations omitted). Because the award of prejudgment interest is not unique to patent law, it is determined under the law of the regional circuit, prompting this Court to also look to precedent from the Court of Appeals for the Third Circuit in deciding these issues. *Transmatic, Inc. v. Gulton Indus., Inc.*, 180 F.3d 1343, 1347 (Fed. Cir. 1999). The Third Circuit advises that a district court should consider and balance the following factors before exercising its discretion to award prejudgment interest:

> (1) whether the claimant has been less than diligent in prosecuting the action;
>
> (2) whether the defendant has been unjustly enriched;
>
> (3) whether an award would be compensatory; and,
>
> (4) whether countervailing equitable considerations militate against a surcharge.

Feather v. United Mine Workers of Am., 711 F.2d 530, 540 (3d Cir. 1983).

Having fully considered the totality of the circumstances in this case, in light of the aforementioned precedent from the Supreme Court and Federal Circuit, demanding a showing of delays by the patentee and prejudice to the infringer, *see Gen. Motors Corp.*, 461 U.S. at 655-56 and *Crystal Semiconductor Corp.*, 246 F.3d at 1361-62, each of which were found satisfied in the context of the Court's laches decision, (*see* Docket No. 920), and after weighing the factors set forth by the Court of Appeals for the Third Circuit, *see Feather*, 711 F.2d at 540, the Court finds that CMU's exceptional delays in prosecuting this case and its corresponding failure to timely investigate the infringement allegations fully justify denying CMU's request for prejudgment interest.

In this Court's estimation, the first factor, which requires a showing of diligence in prosecution of the action, plainly favors Marvell. To this end, the Court reiterates its prior holding that CMU unreasonably and inexcusably delayed filing this litigation for a period of <u>five years and eleven months</u> because it failed to timely conduct a sufficient investigation into infringement allegations brought to its attention by the inventors, Drs. Aleksandar Kavcic and Jose Moura. (Docket No. 920 at 34-54). CMU's delays were also largely self-serving as the evidence shows that it did not take the inventors' initial allegations seriously and conducted only a cursory investigation of infringement by contacting its Data Storage Systems Center ("DSSC") partner, Seagate, for a free opinion on the matter, without disclosing that it was Marvell – Seagate's own chip vendor – which was allegedly infringing. *See id.*; *see also Crystal Semiconductor Corp.*, 246 F.3d at 1362 (holding that "self-serving" delays warranted denial of prejudgment interest). The record further demonstrates that until November of 2008, CMU chose not to invest the time and money it would take to investigate the alleged infringement, even after the inventors provided significant information about the infringement to CMU many years earlier, with continued updates throughout the laches period. For example,

- CMU was notified in April of 2003 that Marvell was producing chips "exactly" as the inventors set forth in their papers and claimed in the patents;

- CMU was told in July of 2004 that Marvell had a subroutine in its detector named after Dr. Kavcic and was marketing new chips designed to combat media noise and Dr. Kavcic demanded that a lawsuit be initiated; and,

- CMU was advised that Marvell had obtained its '585 Patent[8] citing CMU's Patents as prior art in early 2006.

(Docket No. 920 (citing, at various points, Def. Exs. 212, 246, 266; Docket Nos. 816-1 at 4; 816-4 at 10-12; 674 at 220-21)). Additionally, CMU never followed up with Seagate, which purchased millions of the Accused Chips from Marvell during this period of CMU's inaction and Seagate then incorporated the Accused Chips into its hard drives and sold them to third parties down the stream of commerce. (Docket No. 920; Def. Ex. 213, 214). Indeed, CMU's decision to commence a full investigation of Marvell's infringement only occurred in late 2008 *after* the inventors attempted to obtain the patents from CMU through a release in order to pursue a lawsuit without CMU and with financial support from Astro Teller of Cerebellum Capital and potentially a hedge fund. (*Id.* (citing Def. Ex. 306)). This lack of timely action cannot suffice to demonstrate diligence. *See Feather*, 711 F.2d at 540.

The Court believes that the second factor requiring unjust enrichment by Marvell is neutral, when viewed in the context of the Court's laches decision. Again, the Court determined that Marvell was prejudiced by CMU's delays because CMU failed to preserve all potentially relevant evidence (including, among other things, emails and notebooks previously maintained

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8 As noted in prior decisions, the '585 Patent refers to U.S. Patent Number 6,931,585, filed in 2002, with Dr. Zinning Wu and Mr. Gregory Burd listed as inventors, related to MNP technology. (Def. Ex. 266).

by the inventors) during the laches period. (Docket No. 920 at 54-61). The Court adds that although it found an insufficient nexus to demonstrate "economic prejudice" in the context of the laches defense, (*id.* at 61-68), it is undisputed that Marvell's sales of chips containing the infringing technology increased dramatically during the period of CMU's delays and thereafter, causing CMU's damages to escalate substantially into the billion dollar jury award.[9] *See id.* at 68 ("At most, Marvell has shown that its exposure to a judgment for its infringement has grown substantially (along with its sales and revenues from the infringing chips) during the laches period and that it simultaneously made significant capital expenditures in order to support its expanding business."); *see also Crystal Semiconductor Corp.*, 246 F.3d at 1362 ("Crystal's two year delay in initiating the present suit caused the damages owed by TriTech and OPTi to escalate. The record contains sufficient evidence for the district court to determine that Crystal's delay was self-serving and resulted in prejudice to the defendants."). Likewise, the requested prejudgment interest on this award has increased significantly because of the lengthy period of time wherein CMU took no affirmative action to protect its rights. *See id.* Despite these findings, the Court denied the laches defense due to Marvell's willful infringement of the patented methods, sustaining approximately $545 million of the jury's verdict and one hundred

[9] As noted in Table 2A to the Second Update to Expert Report of Catharine Lawton, the annual breakdown of royalties/damages is the following:

Year	**Amt ($$)**
2003	$8,263,072
2004	$41,515,659
2005	$91,265,925
2006	$117,234,916
2007	$131,913,050
2008	$145,030,763
2009	$155,954,794
2010	$181,314,415
2011	$189,142,443
2012 (1/1 – 7/28)	$107,505,236
Total	**$1,169,140,271**

(Docket No. 634-1 at 5).

percent (100%) of CMU's claimed damages during the laches period. (Docket No. 920). Accordingly, CMU has been sufficiently compensated for its losses of the reasonable royalties through the jury's verdict[10] and the award of supplemental damages, without the imposition of prejudgment interest as Marvell was prejudiced by CMU's delays, rendering this factor neutral. *See Feather*, 711 F.2d at 540.

The third factor examines whether the award would be compensatory in nature. The Court recognizes that it retains discretion to adjust the rate of prejudgment interest and to award same on all or part of the judgment award and to order that such interest be compounded or not. *See Uniroyal,* 939 F.2d at 1545. However, the potential size of any prejudgment interest award, e.g., those proffered by CMU, ranging from $211 million to $326 million, demonstrates that an award of prejudgment interest would represent an unearned windfall to CMU. (See Docket Nos. 788, 789, 852). In this Court's opinion, CMU's suggestion that it should be awarded "lost opportunity" damages it would have earned on royalties is undermined by evidence of its inactivity in response to allegations which should have caused it to investigate infringement, all of which the Court considered in the context of Marvell's laches defense. (*See* Docket No. 920). Again, CMU did not act like a reasonable patentee because it was unwilling to timely invest and pursue infringement allegations. The Court, thus, cannot conclude that it would have aggressively invested the royalties where the record overwhelmingly establishes that CMU had little interest in protecting the patents, despite repeated requests from the inventors. (*Id.* at 20-22). Further, although the approximately $545 million in pre-suit damages are classified as compensatory in nature; this award was sustained *only* because of Marvell's willful infringement. (*Id.* at 68-72). Otherwise, the well-supported laches defense would have barred

[10] The inventors will share in their portions of this award through their agreements with CMU wherein they are entitled to fifty percent (50%) of the damages obtained through this litigation, less costs and attorneys' fees. (Docket No. 671 at 194–195).

the claim for pre-suit damages. (*Id.*). Given same, any prejudgment interest added to that portion of the award (and the portion of prejudgment interest which is compounded against the escalating damages throughout the pendency of the lawsuit) would be, at least in part, punitive in nature. *See Humanscale Corp.*, 2010 WL 3397455, at *1 (citing *Gen. Motors Corp.*, 461 U.S. at 655). (Prejudgment interest is not punitive, thus "it must be applied only to the compensatory damages, not enhanced or other punitive damages."). Accordingly, this factor weighs against awarding prejudgment interest.

The final factor for the Court's consideration looks to the equities between the parties. But, the equities have already been fully examined by the Court in the context of the laches defense and such factors underlie the Court's holdings above. (Docket No. 920). On balance, the Court believes that the pre-suit damages of approximately $545 million should be awarded to CMU given Marvell's willful infringement for the laches period, but an additional award of prejudgment interest added to the judgment award of $1.249 billion, at any rate, compounded or not, is unwarranted due to CMU's inexcusable and unreasonable delays in prosecuting this case and the prejudice to Marvell attendant to such delays.

For these reasons, CMU's Motion [788] is denied to the extent that it seeks an award of prejudgment interest under 35 U.S.C. § 284.

C. Enhanced Damages

The Court now moves on to the issue of enhanced damages, which has become the "elephant in the room" between the parties. It remains contested on all fronts. (Docket Nos. 790, 793, 833, 850, 862). CMU seeks an unprecedented financial penalty against Marvell requesting that the Court impose a penalty of at least half a billion dollars and up to $2.5 billion. (Docket No. 793). To this end, CMU advocates that the willful infringement by Marvell is sufficient to justify a full trebling of damages in this case, (i.e., $3,746,071,677), but, recognizing the scope of the damages award exceeding one billion dollars, alternatively contends that the Court should award enhanced damages in any of the following amounts: (1) double damages, (i.e., $2,497,381,118); (2) double pre-suit damages, (i.e., $1,803,240,562); or (3) double post-suit damages, (i.e., $1,942,831,115).[11] (*Id.*). In opposition, Marvell initially maintains that enhanced damages are not appropriate but continues that if the Court should find its infringement willful and exercise its discretion to award enhanced damages, any enhancement should not exceed twenty percent (20%) of the damages award which would result in a total damages award of $1,498,428,671. (Docket No. 834 at 24-25). Marvell suggests that such an award would be more appropriately tied to its level of culpability in this case. (*Id.*).

Section 284 authorizes the Court to award up to treble damages to a prevailing patentee. *See* 35 U.S.C. § 284 ("the court may increase the damages up to three times the amount found or assessed."). An award of enhanced damages under section 284 is punitive in nature and awarded in the Court's discretion. *See Whitserve, LLC v. Computer Packages, Inc.*, 694 F.3d 10, 37 (Fed. Cir. 2012) *cert. denied*, 133 S. Ct. 1291 (U.S. 2013) ("enhanced damages, however, are punitive, not compensatory, and can be awarded only in the judge's discretion."). The Court has already determined that Marvell wilfully infringed CMU's patents in its prior decision of September 23, 2013, (*see* Docket No. 901), and this initial finding is sufficient to justify the imposition of a penalty of enhanced damages against Marvell, as the willful infringer. *See Whitserve,* 694 F.3d at 37 (quotation omitted) ("First, the fact-finder must determine whether an infringer is guilty of conduct upon which increased damages may be based. …, an act of willful infringement satisfies

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[11] The Court notes that the specific penalty sought by CMU under each theory is:

- Treble Damages = $2,497,381,118.00
- Double Damages = $1,248,690,559.00
- Double Pre-suit Damages = $545,550,003.00
- Double Post-suit Damages = $694,140,556.00

th[e] culpability requirement and is, without doubt, sufficient to meet the first requirement to increase a compensatory damages award."). The remaining decision for the Court requires the exercise of its sound discretion to determine "whether, and to what extent, to increase the damages award given the totality of the circumstances." *Id.* (quotation omitted). To be clear, a finding of willful infringement does not necessitate the imposition of enhanced damages; however, after such a finding is made, the Court must explain its reasons for declining to award enhanced damages. *See id.* ("Upon a finding of willful infringement, a trial court should provide reasons for *not* increasing a damages award." (emphasis added)).

The Federal Circuit has held that the *Read* factors, established in *Read Corp. v. Portec, Inc.*, 970 F.2d 816 (Fed. Cir. 1992), should be evaluated and weighed in determining whether damages should be enhanced under section 284. *Spectralytics, Inc. v. Cordis Corp.*, 649 F.3d 1336, 1348 (Fed. Cir. 2011). The *Read* factors are:

> (1) whether the infringer deliberately copied the ideas or design of another;
> (2) whether the infringer, when he knew of the other's patent, investigated the patent and formed a good faith belief that it was invalid or that it was not infringed;
> (3) the infringer's behavior in the litigation;
> (4) the infringer's size and financial condition;
> (5) the closeness of the case;
> (6) the duration of the misconduct;
> (7) the remedial action by the infringer;
> (8) the infringer's motivation for harm; and,
> (9) whether the infringer attempted to conceal its misconduct.

Id. Further, the "paramount determination in deciding to grant [an] enhancement and the amount thereof is the egregiousness of the defendant's conduct based on all the facts and circumstances." *Read*, 970 F.2d at 826. Both parties have extensively considered the *Read* factors in their submissions as well as during oral argument. (Docket Nos. 790, 793, 833, 850, 862). As the parties have, the Court will address each factor, in turn. *Whitserve*, 694 F.3d at 37.

1. Deliberate Copying

Although a patentee is not required to present evidence that an infringer deliberately copied its invention in order to establish that its patent has been infringed, the first *Read* factor counsels that evidence of deliberate or intentional copying is one of the primary factors which must be considered by the Court to determine if damages should be enhanced under section 284. *See DePuy Spine, Inc. v. Medtronic Sofamor Danek, Inc.*, 567 F.3d 1314, 1336 (Fed. Cir. 2009) (Although evidence of copying is "of no import on the question of whether the claims of an issued patent are infringed," it is a factor in determining enhanced damages). Evidence of deliberate copying by an infringer, among other factors, may justify an award of enhanced damages under section 284 because it demonstrates that the infringer had a culpable state of mind by acting wilfully and/or in bad faith toward the patentee's rights. *See Jurgens v. CBK, Ltd.*, 80 F.3d 1566, 1571 (Fed. Cir. 1996); *see also nCube Corp. v. Seachange Intern., Inc.*, 436 F.3d 1317, 1325 (Fed. Cir. 2006) (affirming award of enhanced damages due, in part, to copying of the invention). In meeting this burden to show deliberate copying, the patentee is not required to prove that the infringer engaged in "slavish copying" or produced an infringing product which is an "exact copy" of the patentee's product or used the patentee's product as a template. *See Stryker Corp. v. Intermedics Orthopedics, Inc.*, 96 F.3d 1409, 1414 (Fed. Cir. 1996).

The parties' positions as to whether the evidence presented at trial is sufficient to demonstrate conscious copying by Marvell were addressed by the Court in the context of its decision finding that the evidence supported a finding of willful infringement. (Docket No. 901 at 25-26, 66-83). To reiterate, CMU relies heavily on Dr. Stephen McLaughlin's opinions that the technology was copied by Marvell in its simulators and chips and the jury's finding that Marvell had the subjective intent to infringe without an objectively reasonable defense to infringement. (*Id.*). Marvell counters that its engineers merely used publicly available information (i.e., the papers produced by Drs. Moura and Kavcic and the patents) in order to develop a suboptimal version of the patented methods which were allegedly too complex to implement in a detector and also claims that the simulators did not infringe the patents. (*Id.*).

After carefully considering the parties' arguments, the Court holds that the credible evidence presented at trial sufficiently establishes that Marvell deliberately copied CMU's Patents and such finding favors awarding enhanced damages to CMU. Again, the jury found that Marvell operated with the subjective intent to infringe CMU's Patents, had no objectively reasonable defense to the infringement, and as is explained in the following section, Marvell and its engineers were aware of CMU's Patents essentially upon their issuance. (Docket No. 762). Further, the Court has already determined that:

> CMU presented evidence at trial showing that Marvell's engineers duplicated the technology described in Dr. Kavcic and Dr. Moura's papers in their chips and simulators, as testified to by Dr. McLaughlin. (Docket No. 677 at 54–55). The evidence shows that shortly after beginning work on the Kavcic model, Mr. [Gregory] Burd prepared a preliminary write-up of the KavcicPP detector which referenced the work of Dr. Kavcic and Dr. Moura. (Pl. Ex. 280). Again, Dr. McLaughlin testified that this KavcicPP write-up became the MNP circuit. (Docket No. 677 at 66–67). Although Mr. Burd stated that he was "generally following the papers," not the patents, and that he "left it at that," (*Id.* at 77), Dr. McLaughlin testified that the papers are virtually identical to what is described in the patents. (*Id.* at 66–67).

(Docket No. 901 at 82-83). In fact, Dr. McLaughlin credibly testified that the drawing in Gregory Burd's lab notebook was a "cut and paste" of Figure 3B of CMU's Patents. (Docket No. 677 at 106, Pl. Ex. 295).[12]

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[12] The Court agrees with CMU's assessment that Dr. McLaughlin was not intensely cross examined on his technical opinions. (*See* Docket No. 793, n.20 (citing issues with Marvell's cross-examination of Dr. McLaughlin)).

> The evidence also showed that when Kavcic's name was disassociated with the project, there was no functional difference between the old and new computer codes. (Pl. Ex. 368; Docket No. 677 at 81). Dr. [Zinning] Wu informed Mr. [Toai] Doan that he and Mr. Burd were working on a model that ended up being the original structure that Kavcic proposed in his paper. (Pl. Ex. 366; Docket No. 677 at 134–135). Dr. McLaughlin confirmed that the NLD used the original structure proposed in Dr. Kavcic's paper, and subsequently in the CMU Patents. (Docket No. 677 at 136–137).

(Docket No. 901 at 82-3). Thus, the record fully supports a finding that Marvell copied the patented technology.

As to the simulators, Marvell acknowledged that the IP taught in CMU's Patents is implemented by its Kavcic Viterbi simulator, (Docket No. 677 at 167), and that its employees considered this simulator to be the "gold standard" against which they continuously run tests, (*id.* at 55). Dr. McLaughlin testified that the other simulators likewise infringed the patents. (*Id.*). Considering this evidence, the jury decided affirmatively that Marvell deliberately and willfully infringed the patents in all of its simulators (i.e., Kavcic Viterbi, Kavcicpp, MNP, EMNP and NLD). (Docket No. 762). Given this admission and the jury's findings, CMU has submitted more than enough evidence of copying of the patents as exhibited through the operation of the simulators.

Additionally, the Court has rejected Marvell's argument that the alleged "sub optimality" of its solution to the media-noise problem was relevant to the infringement inquiry. (Docket No. 901 at 70). For the same reasons, such defense is likewise of no help to Marvell to defend against the claims that it copied CMU's Patents. (*Id.*). To this end, both parties' technical experts testified that suboptimal detectors were capable of infringing the patented methods[13];

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[13] The Court previously recounted that:

> Dr. McLaughlin explained that the difference between an optimal and suboptimal media detector relates to performance as measured by SNR [signal-

therefore, copying the methods for use in a suboptimal detector offers no defense to the charge of copying. (*Id.* at 75-76, n.82). But, more importantly, the facts adduced at trial demonstrated that Marvell knew that its MNP detector was not a suboptimal version of the patented methods, which it had claimed in its provisional patent application in 2002 and its '585 Patent. Again, Dr. Zining Wu wrote a year later in January 2003, that he and Mr. Burd had discussed the structure of the MNP chip enhancement and concluded that it "**turns out to be the original structure that Kavcic proposed in his paper.**" (Pl. Ex. 366 (emphasis added)). As noted in prior decisions, the MNP chip enhancement referred to in this email was later incorporated into all 2.3 billion of the MNP-type and NLD-type chips which the jury determined were infringed throughout the sales cycle and the hundreds of millions of additional infringing chips it has produced since the verdict. (Docket Nos. 762, 901, 920). In light of these facts, the evidence clearly supports the finding that Marvell copied the patented methods and incorporated same into its simulators and chips. Accordingly, such findings favor enhancing damages. *See Read*, 970 F.2d at 826.

2. Knowledge/Good Faith Belief of Non-Infringement/Invalidity

The second *Read* factor directs the Court to consider whether the infringer had knowledge of the patents, investigated same and developed a good faith belief that its activities were not infringing and/or that the patents were invalid prior to proceeding with its own products. *See id*. This factor is directly relevant to the underlying issue of willfulness and was exhaustively discussed in the Court's September 2013 decision. (*See* Docket No. 901). For the

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to-noise ratio] gain rather than infringement. (Pl. Ex. 279; Docket No. 677 at 64–65). In fact, he specifically stated that the suboptimal detector "would be using the same method" as the optimal noise detector, (Docket No. 677 at 65), and he has testified that the sub-optimal versions do infringe on CMU's patents. (*Id.*). Marvell's infringement expert, Dr. Proakis, similarly agreed that sub-optimality is not part of the infringement analysis.

(Docket No. 901 at 75).

reasons that were fully expressed in that decision, (*id.*), and consistent with the jury's verdict, (*see* Docket No. 762), the Court finds that Marvell had actual knowledge of CMU's Patents since at least January of 2002, and such patents were brought to its attention at several different points in time by a number of independent sources. Specifically,

- In January 2002, Mr. Burd sent two separate emails to his then-boss, Toai Doan, advising him of his work on the Kavcic method and pointing out that this work was patented by CMU, (Pl. Exs. 280, 283);

- In August 2003, CMU sent its "friendly letters" to high level Marvell personnel, i.e., former Chief Technology Officer Pantas Sutardja and former General Counsel Matthew Gloss, advertising the patents and asking that Marvell contact CMU to investigate a licensing agreement, (Pl. Exs. 422, 431); and,

- In November 2004, Fujitsu sent a letter to Marvell requesting an opinion on the scope of CMU's patents as compared to the read channel chips it was buying from Marvell at the time, (Pl. Ex. 477).

There is no evidence in the record that anyone at Marvell investigated the scope of the patents vis-à-vis its simulators or production of Accused Chips, including the simulators and detector (at least for a period of time) bearing Kavcic's name, in response to any of these communications. (Docket No. 901 at 69-70). At most, the evidence shows that Marvell forwarded the patents to its patent prosecution counsel and that the patents were cited as prior art in the provisional patent application and the '585 Patent which later issued. (*Id.* at 74, n.80). Marvell did not raise advice of counsel as a defense to CMU's willful infringement. As such, it has presented no evidence as to the scope of the investigation, if any, which was conducted by its attorneys and/or engineers (including the inventors of the '585 Patent, Dr. Wu and Mr. Burd). (*Id.*). In this Court's estimation, Marvell's suggestion that this process – forwarding the patents to an internal prosecution attorney and then adding a citation to same in its patent application – represents a "public vetting" of the propriety of its activities is unreasonable and unsupported by the law. The record before the Court is undisputed that Marvell simply did not explore the scope of CMU's Patents; proceeded to run simulators and sell 2.3 billion Accused Chips (and counting) copying and/or closely modeling products after the inventors' work.

Marvell's inaction resulted in its failure to develop any infringement and/or invalidity defenses until after this litigation was commenced and its litigation defenses were only mildly successful. (*See* Docket Nos. 13, 116). It is true that the Court granted summary judgment in Marvell's favor on the Group II claims which were asserted by CMU, (Docket No. 443), and commented that it was a "close call" in denying summary judgment on the Group I claims, (Docket Nos. 306, 337), but two of the Group I claims were presented to the jury at trial, (i.e., claim 4 of the '839 Patent and claim 2 of '180 Patent), and the jury found in favor of CMU on <u>all</u> issues of infringement, invalidity and damages, (Docket No. 762). In light of the jury's verdict, particularly the damages award which, as supplemented, is now in excess of $1.248 billion, Marvell's partial summary judgment victory can hardly be characterized as truly successful.

To conclude, analysis of this second *Read* factor weighs strongly in favor of awarding enhanced damages to CMU.

3. <u>Infringer's Behavior in the Litigation</u>

The third *Read* factor involves an examination of whether the infringer engaged in "litigation misconduct" during the pendency of the case. *Read*, 970 F.3d at 827. The Federal Circuit has held that "[t]ypically, 'litigation misconduct' refers to bringing vexatious or unjustified suits, discovery abuses, failure to obey orders of the court, […] acts that unnecessarily prolong litigation," or direct violations of court orders by counsel. *i4i Ltd. Partnership v. Microsoft Corp.*, 598 F.3d 831, 859 (Fed. Cir. 2010) (citing *Jurgens*, 80 F.3d at

1570–71 & n. 3; *Va. Panel Corp. v. MAC Panel Co.*, 133 F.3d 860, 866 (Fed. Cir. 1997)). While "litigation misconduct" is properly considered as part of the analysis of the *Read* factors; such misconduct is not sufficient to provide an independent basis to enhance damages under section 284. *See i4i Ltd.*, 598 F.3d at 859.

CMU argues that Marvell has taken actions for the primary purpose of unnecessarily increasing the burden of this litigation, by, among other things, presenting defenses at trial based on contradictory testimony, disavowing its contemporaneous documents on its prior non-infringement and invalidity positions, and engaging in excessive motions practice on unmeritorious issues. (Docket Nos. 792-93, 850).[14] In opposition, Marvell counters CMU's individual arguments and points to instances of supposed litigation misconduct by CMU's counsel during the case. (Docket Nos. 832-33, 862). Marvell's counsel further suggests that their advocacy – like that provided by their opponents for CMU – was undertaken only in zealous representation of their clients' interests. (*Id.*).

Having presided over this matter from the outset, and after fully considering the conduct of the parties and their attorneys throughout this case, the Court finds that the third *Read* factor is neutral. It does not support an award of enhanced damages. This is "high stakes" litigation involving two sophisticated parties represented ably by highly capable and qualified counsel. The parties have steadfastly remained very far apart in their respective evaluations of the merits of this case as to both liability and damages,[15] (i.e., $250,000 v. in excess of $1 billion), causing

14 CMU makes similar arguments in support of its Motion for Attorney's Fees, (Docket No. 791), which the Court has denied, without prejudice, given Marvell's expressed intent to appeal this matter. (*See* Docket No. 884).

15 The Court has repeatedly noted the parties' inability to effectively mediate this case and the numerous methods and professionals (including the undersigned, former Magistrate Judge Infante and others) who were engaged in various attempts to have the parties bridge the gap and successfully negotiate the matter. (*See* Docket Nos. 901 at n.124; 920 at n.48). While these efforts were unsuccessful, there has never been a motion from an opposing party claiming bad faith mediation practices under § 2.4 of this Court's ADR Practices and Procedures. Hence, there has been no adjudication that either of the parties engaged in bad faith during this process. *See ADR Policies and Procedures of the United States District Court for the Western District of Pennsylvania*, § 2.4 (effective

the litigation to be very contentious at times. Certainly, this case required an inordinate amount of the Court's time umpiring discovery disputes, deciding numerous pretrial motions brought by both parties on dispositive and non-dispositive issues, refereeing countless evidentiary objections and motions during the trial and now finally resolving the balance of the post-trial motions.[16] (*See* Docket No. 901). But, neither the parties nor their counsel were sanctioned by the Court during the case, perhaps because of the Court's active case management and willingness to engage the parties and resolve all of their aforementioned disputes. (*See* Docket Report, Civ. A. No. 09-290). In any event, while the Court has questioned the methods of both sides on occasion, rightly or wrongly, neither side crossed the proverbial line between zealous advocacy and engaged in the types of litigation misconduct which the Federal Circuit counsels would be properly considered in support of an award of enhanced damages under section 284. Accordingly, the Court finds that this factor is neutral and does not serve as a basis for enhanced damages.

4. Infringer's Size and Financial Condition

The next issue for discussion given the fourth *Read* factor is whether the infringer's size and financial condition are sufficient to support an award of enhanced damages. *Read*, 970 F.3d at 827. While recognizing that enhanced damages are imposed to punish the infringer as well as to deter infringing behavior, courts examine the infringer's size and financial condition to determine if an award of treble damages would "severely prejudice" its business. *See Univ. of Pittsburgh of Com. Sys. of Higher Educ. v. Varian Med. Sys., Inc.,* Civ. A. No. 08-1307, 2012 WL 1436569, at *7 (W.D. Pa. Apr. 25, 2012) (Schwab, J.). In some instances, an infringer's

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Feb. 1, 2012), *available at:* https://www.pawd.uscourts.gov/Applications/pawd_adr/Documents/ADRPolicies.pdf (last visited 3/27/14).

[16] Here the Court would note it has been hampered by the loss of three active District Judges in the past year, resulting in a larger civil case load and the highest individual criminal case load in the Pittsburgh division.

financial condition is cited as a reason not to grant enhanced damages to the fullest extent if the infringer is in a weak financial position. *See, e.g.*, *Funai Elec. Co., Ltd. v. Daewoo Elecs. Corp.*, 593 F. Supp. 2d 1088, 1115 (N.D. Cal. 2009) (noting that infringer was in a weak financial position and did not support award of damages), *aff'd*, 616 F.3d 1357, 1376–77 (Fed. Cir. 2010). Other cases recognize that this factor supports the enhancement of damages against a financially strong infringer which is easily able to withstand an award of treble damages. *See e.g., i4i Ltd.*, 598 F.3d at 858 (noting that the infringer, Microsoft, was undisputedly the world leader in software business and computers, with more than $60 billion in revenues in 2008 and could easily withstand a penalty of up to $600 million in damages, if trebled).

At the outset, the Court points out that CMU has set forth seemingly contradictory positions vis-à-vis the strength of Marvell's financial condition, undermining its arguments that this factor supports an enhancement. As support for its requests for enhanced damages and an ongoing reasonably royalty of $1.50 per Accused Chip, CMU claims that Marvell has a strong financial position, as exhibited in financial statements which it has presented and the sales information submitted at trial and adds that Marvell has made certain public comments that its business will not be disrupted as a result of the verdict. (Docket No. 793 at 21). On the other hand, in CMU's pursuit of a preliminary injunction, and later motions to register and execute on the judgment, it suggests that Marvell is a "collection risk" due to its business structure and purported intentional dissipation of its liquid assets in order to avoid a judgment. (Docket Nos. 787, 853, 908-09). From its perspective, Marvell denies that it is a "collection risk" but also maintains that its financial condition, while sound, could not support an award of trebling the jury's substantial verdict in this case. (Docket Nos. 833, 862).

The Court agrees with Marvell that its business appears to be doing very well at present. The Court, however, does not believe that Marvell is sufficiently capitalized to withstand a penalty of treble or even double damages creating an additional penalty of $2,497,381,118 or $1,248,690,559, on top of the billion dollar award in this case. Marvell is a publicly traded company with its shares traded daily on the NASDAQ Global Select Market under the symbol "MRVL."[17] (*See* 10-K, Docket No. 909-3 at 52). One of the many ways to value a publicly traded company is to look to its market capitalization, which "is measured by multiplying its stock price by the total number of shares it has issued."[18] *Alco Ind., Inc. v. Wachovia Corp.*, 527 F. Supp. 2d 399, n.4 (E.D. Pa. Nov. 5, 2007) (citation omitted). Market capitalization is often used by courts to value businesses because, absent evidence to the contrary, the public markets generally produce an impartial and unbiased valuation of a company. *Cf. Iridium Operating LLC v. Motorola, Inc.*, 373 B.R. 283, 293 (Bankr. S.D.N.Y. 2007) (recognizing that "the public trading market constitutes an impartial gauge of investor confidence and remains the best and most unbiased measure of fair market value and, when available to the Court, is the preferred standard of valuation"). A company's market capitalization fluctuates daily because it is tied to the company's stock price, which changes based on a substantial number of different factors, including the financial performance of the business, trading volumes and prices, financial forecasts by analysts, litigation risks and other external market forces. *Id.*

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17 Like all publicly traded companies, Marvell is required to make periodic filings with the Securities and Exchange Commission ("SEC"), and several of these SEC filings have been submitted for the Court's review. (*See e.g.,* Docket No. 909-3).

18 The market valuation of a company is typically used to categorize it as a large-cap, mid-cap or small-cap company, although the precise values for each category varies considerably between funds and other sources. *See Alco, Ind., Inc.*, 527 F. Supp. 2d at n.4. NASDAQ defines large-cap stocks as those companies with a market capitalization of over $5 billion and mid-cap stocks as those companies with a market valuation between $1 billion and $5 billion. *See NASDAQ*, large-cap definition, *available at:* http://www.nasdaq.com/investing/glossary/l/large-cap and mid-cap definition, *available at:* http://www.nasdaq.com/investing/glossary/m/mid-cap (last visited 3/24/14). Other indexes and funds use different ranges to determine whether the companies are categorized as large-cap, mid-cap or small-cap. *See Alco, Ind., Inc.*, 527 F. Supp. 2d at n.4. As noted, during the pendency of this case, Marvell's market capitalization has fluctuated between the ranges for mid-cap and large-cap companies.

Here, the record evidence before the Court indicates that Marvell's market capitalization is presently in excess of seven billion dollars. (Docket No. 927 at 2). This valuation has, however, fluctuated greatly during the pendency of this litigation, most notably via an immediate decrease in value following the jury's verdict in this case. (*See* Docket No. 908-4 at 2-3 (Marvell's "[s]hares tumbled late in 2012, when a federal jury in Pittsburgh ordered the company to pay a $1.17 billion award for infringing Carnegie Mellon patents covering integrated circuits.")). After the jury's verdict on December 26, 2012, Marvell's stock price fell to a low of $6.98 per share at its lowest point resulting in an approximate market capitalization of around $3.4 billion dollars. (*See* Docket No. 912-2 at 2). By November 2013, the market capitalization had rebounded to approximately $5.9 billion. (Docket No. 908-4 at 2-3). On December 16, 2013, after the public announcement of a significant acquisition of Marvell stock by Kohlberg Kravis Roberts & Co., LP., the market capitalization became $6.8 billion. (Docket No. 912-2). Since then, Marvell's market capitalization has steadily increased to the present valuation of over seven billion dollars. (Docket No. 927 at 2).

The parties have additionally provided the Court with information concerning Marvell's liquid assets, including its cash, cash equivalents, restricted cash and short term investments, but such figures are likewise dynamic, changing over time. (*See* Docket No. 909-2, Table titled, "Marvell's Cash v. "But for" Cash without SPR & Div"). In February of 2013, around the time of the entry of judgment in this case, Marvell maintained approximately $2 billion in these liquid assets, causing CMU to proclaim that it was "flush with cash" and able to pay an ongoing running royalty of $1.50 per chip. (Docket No. 787 at 3). But, Marvell's liquid assets have changed over time due to its ongoing business operations, including a share repurchase program, through which Marvell has set out to repurchase up to $3 billion in stock over the past few years while the litigation was pending. (*See* Docket No. 909-3).[19] CMU roundly criticized Marvell's continuation of its share repurchase program after the verdict, but Marvell reports that such program was instituted years before the award and has now substantially concluded. (*See e.g.*, Docket No. 909). Even with these repurchases, the latest financial information provided to the Court indicates that Marvell maintains around $1.8 billion in liquid assets and CMU's own expert forecasts that it will maintain around $2 billion in same throughout this fiscal year. (*See* Docket No. 909-2 at 2).

The Court is also cognizant of the exceptional revenues generated by Marvell through its sales of Accused Chips containing the infringing methods. Before trial, this figure was approximately $10.3 billion and due to continuing sales, (Docket No. 634-1 at 3, 8), the total revenue figure now exceeds $12 billion, (Docket No. 907). Again, these figures grew because of CMU's failure to meaningfully investigate the infringement allegations asserted by the inventors during the period of time where Marvell's sales were not as robust.[20] (*See* Docket No. 920).

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19 Marvell's 10-K Report explains this program, as follows:

> In August 2010, our board of directors initially authorized our current share repurchase program to repurchase up to $500 million of our outstanding common shares. During fiscal 2012, our board of directors authorized an additional $1.5 billion to be used to repurchase our common shares under the share repurchase program. In May and December 2012, we announced additional increases of $500 million to the share repurchase program. This increases the total available under the repurchase program to $3.0 billion. We intend to effect the repurchase program in accordance with the conditions of Rule 10b-18 under the Exchange Act. The repurchase program will be subject to market conditions and other factors and does not obligate us to repurchase any dollar amount or number of our common shares. The repurchase program may be extended, modified, suspended or discontinued at any time. We may make repurchases in open market or privately negotiated transactions in order to effect our repurchases.

(Docket No. 909-3 at 54).

20 For example, through 2005, when CMU had already been told by Dr. Kavcic that Marvell was making chips "exactly" as claimed in the patents, had named a subroutine in the detector after him, and demanded that CMU file a lawsuit, and Marvell's '585 Patent, citing CMU's Patents as prior art, had already issued, Marvell had sold only 282 million chips resulting in $141 million in royalties. (*See* Docket Nos. 920; 634-1 at 5, Lawton, "Table 2A"; and n.9, *supra*).

CMU likewise points to Marvell's overall profits from the sales of the infringing chips, which it values at over $6 billion. (Docket No. 907). However, its expert on damages, Ms. Lawton valued the infringement in this case based on an "excess profits" analysis wherein she specifically opined as to the added financial value of the patented methods to the Accused Chips and priced the reasonable royalty at $0.50 per chip based on her belief that the parties would negotiate a reasonable royalty at that rate.[21] (*See* Docket No. 901 at 114-15). She also opined that the total "excess profits" attributable to Marvell's additions of the patented methods to its chips was the ultimate damages figure of $1.169 billion based on the $0.50 royalty rate because the patented methods were "must have" for Marvell and its customers. (Docket No. 634-1). So, the damages award reflects the fact that Marvell has already been disgorged of the percentage of profits that CMU's own expert attributed to the inclusion of the patents in Marvell's products.[22]

In all, the Court believes that a penalty of treble or double damages which would increase the judgment to approximately $3.7 billion or $2.5 billion would "severely prejudice" Marvell's business. *See Varian Med. Sys., Inc.*, 2012 WL 1436569, at *7. Such a significant penalty would effectively value the infringement at a rate of nearly fifty percent (50%) or one-third (33%) of the current market capitalization of the entire company. Based on the historical data of the stock price and the decline of same when the jury's verdict of $1.169 billion was announced, the Court can logically infer that the stock price and market capitalization would again decrease if such a significant penalty was imposed, and the judgment debt would then hold an even greater percentage of the total value of the company. Indeed, if the stock price returned to its low price in December 2012, trebling damages would exceed the market capitalization of the company, which was then at approximately $3.4 billion. (*See* Docket No. 912-2 at 2). Further,

[21] Again, Marvell did not specifically counter these opinions through a rebuttal expert.

[22] The Court also considers this factor in imposing an ongoing royalty for the continuing infringement. *See* § IV.B., *infra*.

the imposition of a penalty based on either trebling or doubling damages would place Marvell in a financial position where the judgment debt owed to CMU would likely exceed its current liquid assets of approximately $1.8 billion. (*See* Docket No. 909-2). While such an exceptional award may lend credence to CMU's "collection risk" theory, by possibly requiring Marvell to incur debt, issue additional equities or engage in some type of other financial maneuvers in order to satisfy the judgment, this type of penalty would likely "severely prejudice" Marvell's ongoing operations, including its many non-infringing business lines.

For these reasons, the Court finds that Marvell's financial condition does not support an enhancement and strongly counsels against enhancing damages to the degree requested by CMU.

5. Closeness of the Case

The next *Read* factor is whether the case was "close," on which of course the parties disagree. *Read*, 970 F.3d at 827. The Court's inquiry under this factor requires it to weigh the strength of the parties' evidence on the disputed issues in the case. *See Mentor H/S, Inc. v. Medical Device Alliance, Inc.*, 244 F.3d 1365, 1380 (Fed. Cir. 2001); *see also Spectralytics, Inc. v. Cordis Corp.*, 2011 WL 60003931, at *5-6 (D. Minn. 2011). In evaluating this factor, the Court looks to its prior rulings on dispositive motions, the strength of the evidence presented at trial and the jury's verdict. *See e.g, id; SSL Servs., LLC v. Citrix Sys., Inc.*, 2:08-CV-158-JRG, 2012 WL 4092449 (E.D. Tex. Sept. 17, 2012) (Court held that the case was not a close call as the jury had deliberated for 3 hours and awarded Plaintiffs the precise amount presented to the jury by SSL's damages expert and asked for by SSL in its closing arguments.); *Wordtech Sys., Inc. v. Integrated Network Solutions, Inc.*, 204-CV-01971-MCE-EFB, 2009 WL 113771 (E.D. Cal. Jan. 15, 2009) ("the evidence presented at trial overwhelmingly favored a finding for Plaintiff, as is evidenced by the relatively short deliberations required for the jury to reach a unanimous verdict on all causes of action.").

At the outset, the Court agrees generally with CMU's position that the jury's verdict is reflective of the jury's view that the case was not close. Indeed, the jury found in favor of CMU on every issue presented to it and awarded the precise amount of damages requested by CMU. *See id*.; (Docket No. 762). Yet, the Court must also look beyond the jury's verdict to determine whether, and to what extent, the case presented close issues.

For all of the reasons that have been previously expressed, the Court does not believe that the issues of infringement or willfulness were close as CMU's trial presentation on these issues was very strong and having addressed these matters at length, the Court will not belabor those points. (*See also* Docket No. 901). The Court acknowledges that it stated in ruling on the motion for summary judgment on invalidity issues that it was a "close call"; however, such ruling merely denied a summary judgment motion and permitted that aspect of the case to be decided by the jury. (Docket Nos. 306, 337). While the Court believes that the invalidity defense was likely Marvell's strongest, the jury disagreed and presumably found Dr. McLaughlin's opinions to be more credible than those put forth by the defense expert, Dr. John Proakis. Having presided over the trial, and heard all of the parties' evidence, the Court agrees with that assessment. (*See* Docket No. 901 at 52-66). Accordingly, the invalidity issue was not sufficiently close at trial to weigh in Marvell's favor in the Court's analysis of the *Read* factors.

On the other hand, Marvell's challenges to the admission of non-U.S. sales as part of the royalty base, its motions contesting pre-suit damages under both the marking statute and the doctrine of laches were all close. (Docket Nos. 595, 672, 920). The Court also heavily scrutinized the reasonable royalty opinion of CMU's damages expert, Lawton, as has been discussed at length above. (Docket Nos. 451, 713, 901).

Although the Court ruled in CMU's favor on the balance of these issues and continues to believe that those decisions are correct, the Court recognizes the significance of same on the damages evidence CMU was permitted to present to the jury and the ultimate jury verdict. To this end, the Court precluded CMU from recovering pre-suit damages as to the '839 Patent under the marking statute, 35 U.S.C. § 287. (Docket No. 595). The Court carefully examined the pre-suit conduct of both parties as to the '180 Patent but ultimately upheld the jury's award of $545 million in damages for this period of time. (Docket No. 920). The Court also acknowledged that CMU's "but for" causation theory permitting Marvell's use of the infringing simulators during the U.S.-based sales cycle to capture all of Marvell's sales was "novel," but permitted this theory to be presented to the jury. (Docket No. 672). A ruling for Marvell on this issue would have significantly lowered the royalty base presented to the jury (for the time period of March 6, 2003 to July 28, 2012) to 556,812,092 and consequently, reduced the recoverable damages available to CMU to only <u>$278,406,046</u>. (Docket No. 633-1 at 7). With that said, the Court emphasizes that its findings made in its September 2013 decision on the JMOLs that despite Marvell's pretrial posture, it did not factually prove <u>at trial</u> that its sales were made outside the United States. (Docket No. 901 at 96-105). Further, as noted, Marvell offered no real counter evidence to challenge Ms. Lawton's carefully crafted damages opinion on the reasonable royalty. (*Id.* at 89). Instead, Marvell put forth Creighton Hoffman and his rather cursory opinion that the royalty agreement would have been a one-time, lump sum payment of $250,000.00. (*Id.* at 89 (citing (Docket No. 709 at 242-245)). In light of all of these rulings, the jury was tasked with weighing a $1.169 billion valuation versus a $250,000.00 valuation. (*Id.*). Although it was certainly permitted to award an intermediate verdict, it chose not to do so.

To conclude, the evidence on liability strongly favored CMU's positions but the case certainly presented "close calls" for the Court on damages which appear to be ripe for decision by an appellate court. As the present discussion concerns the extent of a financial penalty to be imposed on top of the significant damages which have already been awarded, the Court does not believe that the fifth *Read* factor favors an enhancement.

6. Duration of the Misconduct

The sixth *Read* factor examines the duration of the misconduct by the infringer, which may be weighed against any delays in prosecution by the patentee. *Read*, 970 F.3d at 827. It is also well recognized that delays which are insufficient to demonstrate laches, may still be relevant to this factor. *Mass Engineered Design, Inc. v. Ergotron, Inc.*, 633 F. Supp. 2d 361, 391 (E.D. Tex. 2009). The Court has exhaustively discussed its evaluation of the evidence as to CMU's delays and Marvell's long and sustained willful infringement of the patented methods in the context of its laches decision, (Docket No. 920), and in § II above regarding the claim for prejudgment interest.

On balance, after again weighing these facts, the Court holds that the sixth *Read* factor does not support an enhancement to the extent advocated by CMU and further notes that an appropriate adjustment will be made to the overall award of enhanced damages due to the fact that CMU's pre-suit damages claim was sustained only as a result of Marvell's willfulness. Further explanation of these calculations is set forth in § II.C.10 below.

7. Remedial Action by the Infringer

The seventh *Read* factor requires the Court to evaluate the remedial action taken by the infringer, if any. *Read*, 970 F.3d at 827. Courts look to any remedial action by the infringer in determining whether to enhance damages because "patent infringement is a continuing tort, and an action even if innocently begun does not automatically retain its purity as circumstances change. The filing of a lawsuit does not stop the clock insofar as culpability may arise from continuing disregard of the legal rights of the patentee." *Pall Corp. v. Micron Separations, Inc.*, 66 F.3d 1211, 1221-22 (Fed. Cir. 1995). To this end, actions by the infringer to remediate the alleged infringement may undermine a claim for willfulness and/or counsel against awarding enhanced damages, through such activities as: discontinuation of product lines allegedly infringing; investing in a redesign of the allegedly infringing products; and/or negotiating with the patentee in good faith to avoid infringement. *See e.g., Trading Technologies Intern., Inc. v. eSpeed, Inc.*, 595 F.3d 1340, 1358 (Fed. Cir. 2010) ("Prompt redesign efforts and complete removal of infringing products in a span of a few months suggest that eSpeed was not objectively reckless."); *Amstar Corp. v. Envirotech Corp.*, 823 F.2d 1538, 1546-47 (Fed. Cir. 1987) (infringer obtained an opinion of counsel and attempted to design around the product and also negotiated with patentee in good faith during this process); *Pall Corp.*, 66 F.3d at 1221-22. In contrast, conduct by the infringer throughout the litigation which shows a disregard for the patentee's credible claims often is found to support enhancing damages, including: failing to obtain an opinion of counsel; ramping up production of new products despite the allegations; and continuing to infringe after a finding of willfulness. *See e.g., SynQor, Inc. v. Artesyn Tech., Inc.,* 709 F.3d 1365, 1385 (Fed Cir. 2013) (post-verdict infringing sales supported enhancement); *Power Intergrations, Inc. v. Fairchild Semiconductor Intern., Inc.*, 725 F. Supp. 2d 474, 480 (D. Del. 2010), *rev'd on other grounds*, 711 F.3d 1348 (Fed. Cir. 2013).

The parties once again dispute the import of this *Read* factor. (Docket Nos. 793, 833, 850, 862). CMU suggests that Marvell's lack of any remedial action to avoid infringement until months after the billion dollar verdict in this case fully supports enhancing damages. (Docket Nos. 793, 850). CMU further points out that Marvell not only continued to infringe during the pendency of this lawsuit through known product lines but actually introduced at least 17 new product lines containing the infringing technology. (*Id.*). Marvell challenges these assertions, trumpets that its actions were reasonable and maintains that as of July, 2013, it had moved to design around the patents. (Docket Nos. 833, 862).

After considering all of the evidence of record as well as the parties' arguments, the Court agrees with CMU that this seventh *Read* factor supports an award of enhanced damages because Marvell has acted with a complete disregard for CMU's patent rights throughout this case. The Court initially looks to the numerous opportunities which Marvell had to conduct a pre-suit investigation and evaluate whether its simulators and products infringed. Instead, Marvell simply ignored inquiries from CMU and its own customer, Fujitsu, to evaluate the claims in CMU's Patents. (Pl. Exs. 422, 431, 477). When CMU finally brought this suit in 2009, it affirmatively put Marvell on notice of its claims that Marvell was wilfully infringing its Patents. (Docket No. 1). Moreover, the Court made a number of rulings that put Marvell on notice of the potential scope of this case, when it construed the claims on October 1, 2010, (Docket No. 176), and in numerous decisions on summary judgment motions in 2012. (Docket Nos. 306, 337, 423, 441, 443, 445, 447, 449, 451). Yet, Marvell has continued to unabashedly infringe the patented methods through its existing chip lines. And, as noted above, it also added the challenged technology to new product lines which were not even created until after the lawsuit was filed. (*See* Docket No. 850 at 7). Marvell further points to its lengthy sales cycle and proffers that it was not cost effective to redesign the chips including the patented methods which were in process. (Docket Nos. 833, 862). However, the length of the sales cycle provides no explanation for the production of these additional lines of chips containing the infringing technology which were later introduced. So, these arguments are granted little weight.

The Court recognizes that Marvell has consistently taken a "no liability" position throughout this case but it also exhibited no interest in even attempting to design around the patented methods until very recently. It took this position despite arguing to the jury that the patents were essentially worthless and unnecessary to the success of the products.[23] (Docket No. 707 at 59-62). Pursuant to a joint status report from the parties, Marvell only actively started to attempt to design around the accused methods in July of 2013 – seven months after the verdict. (Docket No. 898). According to Marvell, its redesign (of its C11000 chips) will not include the NLD but will not be in volume production until the end of 2014, at the earliest. (Docket No. 833 at 23). It is, therefore, wholly unreasonable that Marvell took no remedial action until months after the billion dollar verdict in this case and the jury's finding of willful infringement. (Docket No. 793 at 22).

Marvell's complete disregard of CMU's patent rights is best exemplified through its post-trial affidavit of Dr. Wu, who stated that Marvell would discontinue its inclusion of the infringing technology in its MNP and NLD products but only after CMU obtained a judgment against Marvell. (Docket No. 802 at Ex. 2). As this Court has recognized, Marvell always knew what it was doing and deliberately took on both the business and legal risk to continue infringing until it was ordered by the Court to discontinue. (Docket No. 920). To Marvell, the

[23] At trial, Marvell claimed to have several other technologies that could offer the same benefits as the MNP and NLD (Docket No. 707 at 59-62), yet Marvell has not replaced the MNP or NLD with any of them in the past four years. In fact, CMU identified 17 Marvell infringing chips that were developed at least a year after the lawsuit was filed. (Docket No. 850 at 7).

risk was worth the reward of billions of dollars of revenues and profit obtained throughout this case and continuing through post-trial infringement. Marvell has also consistently maintained that it will appeal every adverse decision this Court has rendered, along with the jury's verdict and the judgment. But "the Court is 'not directed to evaluate defendant's appellate position. Instead, the Court is told to determine whether remedial actions have been taken.'" *Varian*, 2012 WL 1436569, at *7 (quoting *Muniauction, Inc. v. Thomson Corp. and i-Deal, LLC*, 502 F. Supp. 2d 477 (W.D.Pa.2007) (Lancaster, J.), *rev'd on other grounds*, 532 F.3d 1318 (Fed. Cir. 2008)). The remedial actions taken by Marvell here are simply "too little, too late" in order to avoid the penalty of enhanced damages.

For these reasons, the Court finds that Marvell's lack of any remedial action prior to July 2013 supports an enhancement under section 284.

8. <u>Infringer's Motivation for Harm</u>

The Court next looks to evidence of the infringer's motivation for harm toward the patentee. *Read*, 970 F.3d at 827. This eighth *Read* factor typically favors enhanced damages when the patentee is a direct competitor of the infringer and the infringement is used and designed to harm the competition. *See e.g., Odetics, Inc. v. Storage Tech. Corp.*, 14 F. Supp. 2d 800, 804 (E.D. Va. 1998) *aff'd,* 185 F.3d 1259 (Fed. Cir. 1999); *Parker-Hannifin Corp. v. Wix Filtration Corp.*, Civ. A. Nos. 1:07-cv-1374, 1:07-cv-1375, 2011 WL 976559, at *17 (N.D. Oh. Mar. 17, 2011) (noting that patentee and infringer were fierce competitors and each were vying for GM's business); *K-TEC v. Vita-Mix*, Civ. A. No. 2:06-cv-108-TC, 2011 WL 285699, at *4-6 (D. Utah Jan. 26, 2011) (patentee and infringer were direct competitors and infringer was seeking to prevent customers from purchasing products from patentee). Absent such direct competition between the parties, this eighth *Read* factor does not support enhancing damages. *Id.*; *see also Varian,* 2012 WL 1436569, at *7.

The evidence is uncontested that Marvell and CMU are not competitors as CMU is a university that does not practice the methods of the patents or manufacture any products while Marvell is arguably the market leader in its chip manufacturing business. *See Varian,* 2012 WL 1436569, at *7 ("The parties in this case were not direct business competitors, because Pitt, as an educational and research institution, has not made or marketed products resulting from its efforts."). Further, the evidence is clear that CMU has not entered into an affirmative license for the patents-in-suit with any of Marvell's competitors such that it could be reasonably argued that its willful infringement was designed to harm CMU's licensees. Indeed, at least one of Marvell's customers, Seagate, has a royalty-free license to use the patents through its DSSC partnership with CMU and it has purchased millions of infringing chips from Marvell. (*See* Docket No. 920). Additionally, Dr. Kavcic advised CMU that he was told that several other chip manufacturers (e.g., Hitachi, Agere, and ST Microelectronics) were likewise infringing the methods, yet CMU has not pursued those entities for patent infringement, to this Court's knowledge. (Def. Ex. 212). In all, the record demonstrates that Marvell's motivation for its willful infringement of the patented methods is the singular pursuit of profit rather than to directly harm CMU. *See Varian,* 2012 WL 1436569, at *7. Accordingly, this factor is neutral in regards to enhanced damages.

9. <u>Attempt to Conceal Misconduct</u>

The last *Read* factor for the Court's consideration is whether there is evidence that the infringer attempted to conceal its misconduct. *Read*, 970 F.3d at 827. In evaluating this factor, courts look to a number of facts, including: misleading communications to the patentee about the scope of the products; advertising or selling the products covertly; or concealing evidence of misconduct. *See e.g., Minks v. Polaris Industries, Inc.*, No. 6:05-cv-1894-Orl-31KRS, 2007 WL 788418, at *1 (M.D. Fl. Mar. 14, 2007), *aff'd, in part, rev'd in part, on other grounds*, 546 F.3d 1364 (Fed. Cir. 2008); *Varian*, 2012 WL 1436569, at *7; *PACT XPP Technologies, AG v. Xilinx, Inc.*, Civ. A. No. 2:07-CV-563-RSP, 2013 WL 4801885, at *3 (E.D. Tex. Aug. 30, 2013). In contrast, open activities by the infringer may counsel against the award of enhanced damages. *See Odetics, Inc.*, 185 F.3d at 1274 (noting that infringer did not attempt to conceal its activities).

The parties' disputes as to this factor raise similar points which have been addressed by the Court in other contexts. CMU suggests that this factor favors its position because of Marvell's "policy of secrecy" enveloping its confidential circuitry designs and failure to respond to communications about the patents from its Technology Transfer Office and Fujitsu. Marvell counters that confidentiality is necessary to protect its trade secrets and proprietary technology and once again, relies on its '585 Patent to demonstrate its claimed open and good faith actions.

In this Court's estimation, this factor slightly favors an enhancement because the evidence is somewhat mixed. To this end, although there is certainly evidence of Marvell's secrecy, CMU was aware of the willful infringement from very early on but failed to meaningfully investigate the inventors' allegations and despite its communications to Marvell in August of 2003, it never followed up on alleged infringement. (*See* Docket No. 920). It is true that there is robust evidence in the record demonstrating that Marvell is extremely secretive with both its business practices and chip circuitry designs and essentially sells all of its products in a manner to avoid them being reverse-engineered. (*See e.g.*, Docket No. 707 at 55 (Dr. Sutardja testifying that Marvell and its employees are "extremely paranoid people"); (Docket No. 709 at 61–64) (Dr. Wu testifying that "[j]ust like Coca–Cola keeps its formula as a secret ... For you to understand how the circuits implemented, the implementation detail, yes, you do need to talk to our people.")). But, there is no evidence that Marvell's policies kept CMU from learning of the infringing activities. (*See* Docket No. 920). Indeed, Dr. Kavcic learned in 2003 that Marvell was infringing the patented methods and in 2004, that Marvell had products named after him. (Def. Exs. 212, 246, 266; Docket Nos. 816-1 at 4; 816-4 at 10-12). He also became aware of Marvell's '585 Patent in early 2006. (Docket No. 674 at 220-21). He then promptly and timely provided all of the information he gathered to CMU. (*Id.* at 108-110). If anything, CMU was dissuaded from investigating infringement by Dr. Mark Kryder and Seagate and it never changed its position until 2008. (Def. Ex. 213).

The Court has also discussed the import of the "friendly letters" *ad naseum*. (Docket Nos. 901, 920, § II.B., *supra*). Again, there is no evidence that Marvell mislead CMU because it simply did not respond to the letters or the inquiry from Fujitsu. (Pl. Exs. 422, 431, 477). But, there is also no evidence that anyone at Marvell considered the import of the letters when its executive team, engineers and in-house counsel clearly should have read, considered and thoughtfully responded to the letters after investigating whether its products were infringing the patented methods or not.

Finally, while Marvell suggests that its '585 Patent citing CMU's Patents as prior art represents a "public vetting" of its activities, the Court disagrees. (Docket Nos. 833, 862). In this Court's view, Marvell's '585 Patent claiming a suboptimal method to CMU's patents was merely a "smoke screen" designed to mask its true infringing conduct from the outside world, i.e., its use of "the original structure that Kavcic proposed" in the MNP enhancement and all of its other infringing products. (Pl. Ex. 366; see also Docket No. 920 at 71). Marvell was fully aware of CMU's Patents at all times and proceeded to develop such technology, without changing its behavior in any way after being notified of the patented methods by Mr. Burd, CMU, and Fujitsu. (Pl. Exs. 280, 283, 368, 366, 422, 431, 477, 823; Def. Exs. 373, 1086). Marvell also named the products after Dr. Kavcic but "disassociated" his name with the project in favor of the MNP moniker around the same time (January of 2003) when Dr. Wu acknowledged that there was no functional difference between the MNP and Dr. Kavcic's detector. (Pl. Ex. 368; Docket No. 677 at 81). In light of same, the Court views the '585 Patent as an effort by Marvell to conceal its activities and this factor favors enhancement of damages.

10. Enhanced Damages Award

After carefully considering all of the parties' arguments and the evidence of record, the Court believes that four of the *Read* factors support an award of enhanced damages (factors 1, 2, 7 and 9), four of the factors are neutral (3, 5, 6, 8), and one of the factors weighs against an award of enhanced damages (4). Overall, the Court believes that a penalty of enhanced damages should be assessed against Marvell given its:

- known willful infringement through its deliberate and extensive copying of the patented methods;
- failure to investigate the scope of the patents vis-à-vis its products and simulators at any time prior to the suit;
- failure to respond to the inquiries by CMU and Fujitsu; continued production of infringing products containing the patented methods and lack of any remedial action until after the verdict in this case; and,
- its concealment of its activities through its internal policies and its '585 Patent which claimed that it was operating a "suboptimal" method while Marvell and its engineers knew that the MNP detector was functionally equivalent to CMU's patented methods.

But, even with these findings which strongly support an award of enhanced damages, the Court does not believe that the size of the unprecedented penalty sought by CMU is warranted upon weighing the other *Read* factors, particularly:

- the fact that CMU has been awarded one-hundred percent (100%) of the compensatory damages it sought at trial, which with the assessment of supplemental damages, is approximately $1.248 billion;
- Marvell's size and financial condition, which the Court does not believe could sustain a penalty doubling or tripling this outstanding award;
- CMU's inexcusable and unreasonable delays in prosecuting this case despite the credible allegations it received of Marvell's infringement;
- the evidentiary prejudice sustained by Marvell due to these delays;
- the exponential increase in sales during this time period; and,
- the "closeness" of the damages issues which strongly affect the calculation of any enhancement.

(*See* Docket No. 920). The amount of the penalty awarded under section 284 is committed to the discretion of the Court. *Read*, 970 F.3d at 826. Based on this Court's research, there is no consensus providing a precise calculation of how to arrive at an appropriate penalty. This lack of consensus exists simply because no two cases are alike and the inquiry is fact intensive, focusing on the egregiousness of the conduct of the infringer in light of the totality of the circumstances. *Id.* at 827. Indeed, some courts finding willful infringement have denied enhancements and others have awarded penalties in varying amounts:

- denied enhanced damages, *Crystal Semiconductor*, 246 F.3d at 1352;
- twenty-percent (20%) of damages, *Powell v. Home Depot U.S.A., Inc.*, 663 F.3d 1221, 1236-37 (Fed. Cir. 2011); *i4i*, 598 F.3d at 858-59;

- twenty-five percent (25%) of damages, *Applied Medical Resources Corp. v. U.S. Surgical Corp.*, 435 F.3d 1356, 1365 (Fed. Cir. 2006);
- fifty-percent (50%) of damages, *Acumed LLC v. Stryker*, 483 F.3d 800, 810-11 (Fed. Cir. 2007);
- seventy-five percent (75%) of damages, *SynQor*, 709 F.3d at 1385;
- double damages, *Metabolite Laboratories, Inc. v. Laboratory Corp. of America Holdings*, 370 F3d 1354, 1370-71 (Fed. Cir. 2004); *Varian*, 2012 WL 1436569, at *7; and,
- treble damages, *Golden Blount, Inc. v. Robert H. Peterson Co.*, 438 F.3d 1354, 1365-70 (Fed. Cir. 2006).

Other courts have awarded different amounts based on pre- and post-verdict activities of the infringer. *See e.g., Stryker Corp. v. Davol, Inc.*, 234 F.3d 1252, 1260 (Fed. Cir. 2000) (affirmed award of fifty percent (50%) award on pre-suit damages but double damages for post-verdict damages until entry of permanent injunction.). All told, this Court has considerable discretion in arriving at the appropriate figure. *Read*, 970 F.3d at 826.

After much deliberation, the Court will impose a penalty of 1.23 times the damages award (including the jury's verdict plus supplemental damages). In reaching this decision, the Court has considered all of the alternatives proposed by both parties, which range from no enhanced damages to twenty-percent of the verdict, as advocated by Marvell and CMU's suggested range of between $545 million to $2.48 billion, the latter figure which would treble damages. (Docket Nos. 793, 833, 850, 862). Having studied all of these proposals, the Court believes that each is flawed in some respect as they do not fully account for all of the circumstances which put the parties before the Court on these most contested issues. Therefore, the Court finds an intermediate sanction to be appropriate. This twenty-three percent (23%) award results in a penalty of $287,198,828.60 and increases the total damages figure to $1,535,889,387.60.

The Court believes that this award is sufficient to penalize Marvell for its egregious behavior and to deter future infringement activities. The Court also finds that this award is sufficiently tied to the level of culpability that Marvell exhibited throughout this case, appropriately accounts for all of the considerations set forth in *Read* and is consistent with the Court's prior decisions, (*see* Docket Nos. 900, 901, 920). The twenty-three percent (23%) penalty was not arrived at casually as the Court once again reviewed all of the damages evidence and set this amount with full consideration of its prior decision on the issue of laches, which upheld an award of approximately $545 million in pre-suit damages only because the equities substantially weighed in CMU's favor due to Marvell's willful infringement. (Docket No. 920).

As noted with reference to its discussion of the fourth *Read* factor above, the Court does not believe that Marvell is sufficiently capitalized to sustain an award of double or treble the current damages award of $1,248,690,559.00. The Court also believes that CMU's suggestion that the Court double either the portion of this award for pre-suit ($545 million) or post-suit ($694 million) infringement does not properly account for its prior findings on the issues of laches. (Docket No. 920). As a consequence, the Court has determined that any penalty could best be tied to Marvell's level of culpability and set an amount its business is able to sustain with its ongoing operations, by starting with the post-suit damages figure ($694 million), crediting the pre-suit damages figure ($545 million) which has been sustained only as a result of Marvell's willful infringement and doubling the result. The Court's initial calculations are as follows:

Total Post-Suit Damages	$694,140,556
Less Presuit Damages	$554,550,003
Subtotal *2	139,590,553
Total Enhanced Damages	$279,181,106.00
Percentage of Verdict	22.3579%

As a next step, the Court "rounded up" the percentage of the verdict to arrive at twenty-three (23%), which results in a penalty of $287,198,828.60 and increases the total damages figure to $1,535,889,387.60. In terms of the reasonable royalty calculation, this enhancement results in a total royalty of $0.615 per Accused Chip. Hence, the penalty assessed equates to $0.115 per chip in addition to the $0.50 per chip in compensatory damages awarded by the jury. The Court believes that this penalty is sufficiently supported by the record and warranted by the egregiousness of Marvell's conduct. *See Read*, 970 F.2d at 826 (the "paramount determination in deciding to grant [an] enhancement and the amount thereof is the egregiousness of the defendant's conduct based on all the facts and circumstances."). It is also within a range that Marvell can financially support without severely damaging its business. Accordingly, the Court will impose this penalty, as stated.

D. Conclusion

Based on the foregoing, CMU's motion for supplemental damages is granted; its motion for prejudgment interest is denied, and its motion for enhanced damages is granted, in part. In accordance with these rulings, the Court's damages calculations are, as follows:

	Type of Damages	**Amount**
1	Jury Verdict	$1,169,140,271.00
2	Supplemental Damages	$79,550,288.00
3	Prejudgment Interest	$0.00
4	Total Damages	$1,248,690,559.00
5	Enhanced Damages Factor	1.23
6	Total with Enhancement	$1,535,889,387.60

III. POST-JUDGMENT INTEREST UNDER 28 U.S.C. § 1961

The next request by CMU for an award of post-judgment interest under 28 U.S.C. § 1961 is rather straightforward and largely uncontested by Marvell. (Docket Nos. 789, 836, 852, 861). CMU requests annually compounded post-judgment interest on its entire money judgment at the statutory rate. (Docket No. 788). Marvell does not oppose, but maintains that such calculations are premature before the damage award is upheld. (Docket No. 836).

Unlike, prejudgment interest, post-judgment interest on a district court judgment is mandatory. *Air Separation, Inc. v. Underwriters at Lloyd's of London*, 45 F.3d 288, 290 (9th Cir. 1995). 28 U.S.C. § 1961 states that post-judgment interest "shall be allowed on any money judgment in a civil case recovered in a district court ....“ and that "[s]uch interest shall be calculated from the date of the entry of the judgment, at a rate equal to the weekly average 1–year constant maturity Treasury yield, as published by the Board of Governors of the Federal Reserve System, for the calendar week preceding the date of the judgment." 28 U.S.C. § 1961. The Supreme Court has stated that "[t]he purpose of post-judgment interest is to compensate the successful plaintiff for being deprived of compensation for the loss from the time between the ascertainment of the damage and the payment by the defendant." *Kaiser Aluminum & Chem. Corp. v. Bonjorno*, 494 U.S. 827, 835-36 (1990). The Third Circuit holds that post-judgment interest under 28 U.S.C. § 1961 applies to the prejudgment interest component of a monetary award. *Sun Ship, Inc. v. Matson Navigation Co.*, 785 F.2d 59, 63 (3d Cir.1986).

According to CMU, the applicable treasury rate was 0.14% for the week before the Court's judgment on January 14, 2013. (Docket No. 789 at 14). Given the clear law and the lack of true opposition, the Court finds that CMU is due post judgment interest on the total money judgment of $1,169,140,271.00 plus supplemental damages of $79,550,288.00 for a total of

$1,248,690,559.00. 28 U.S.C. § 1961. CMU's motion is thus granted and post judgment interest at the rate of 0.14% is awarded on $1,248,690,559.00, compounded annually.

IV. PERMANENT INJUNCTION/ONGOING ROYALTY

The Court's final deliberations focus on CMU's alternative requests for a permanent injunction barring Marvell's continued use of the patented methods and/or an ongoing royalty for any continued infringement by Marvell. (Docket Nos. 787, 853, 905). CMU's theory supporting the permanent injunction is that Marvell is allegedly a "collection risk" and it may be irreparably harmed by any continuing infringement because it will be unable to collect on the judgment, purportedly making money damages inadequate in this case. (*Id.*) In the event that an injunction is denied and/or delayed, CMU further requests that an ongoing royalty be imposed for any continuing infringement by Marvell at a rate of $1.50 or treble the jury's award (consistent with Ms. Lawton's testimony) of $0.50 per Accused Chip. (*Id.*). Marvell opposes the motion for a permanent injunction, strongly denying that it is a "collection risk" and further arguing that an injunction is inappropriate in light of *eBay Inc. v. MercExchange, L.L.C.*, 547 U.S. 388, 391 (2006) and more recent Federal Circuit precedent, primarily *Apple v. Samsung Electronics Co., Ltd., "Apple III"*, 735 F.3d 1352 (2013),[24] analyzing the propriety of permanent injunctions of multi-feature products such as the instant read channel and SOC chips. (Docket Nos. 828, 863, 906). Marvell also suggests that any ongoing royalty should be lower than the jury's allegedly excessive award of $0.50 per Accused Chip. (*Id.*).

Having fully considered these matters, and all of the pertinent evidence of record, the Court finds that CMU has not met its burden to demonstrate that the extraordinary relief of a

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[24] In deciding these issues, the Court has carefully considered the entire series of decisions by the Federal Circuit in the *Apple v. Samsung* litigation. *See e.g., Apple, Inc. v. Samsung Elecs. Co. ("Apple I")*, 678, F.3d 1314, 1423 (Fed. Cir. 2012); *Apple, Inc. v. Samsung Elecs. Co. ("Apple II")*, 695 F.3d 1370 (Fed. Cir. 2012). The Court also reviewed and considered the more recent decision by Judge Lucy H. Koh denying Apple's final request for permanent injunction after the case was remanded. *See Apple, Inc. v. Samsung Electronics Co., Ltd.*, Civ. A. No. 11-cv-01846, 2014 WL 976898 (N.D. Cal. Mar. 6, 2014).

permanent injunction is warranted and, as the parties' efforts at negotiating an ongoing royalty have failed, the Court will impose an ongoing royalty of $0.50 per chip sold by Marvell for its continuing infringement of the patented methods.

A. Permanent Injunction

CMU's request for a permanent injunction seeks relief under 35 U.S.C. § 283, which provides that courts "may grant injunctions in accordance with the principles of equity to prevent the violation of any right secured by patent, on such terms as the court deems reasonable." 35 U.S.C. § 283. For a permanent injunction to issue, CMU "must demonstrate that: (1) it has suffered an irreparable injury; (2) legal remedies, such as money damages, are inadequate compensation; (3) the balance of hardships warrants an injunction; and (4) the public interest would not be disserved by an injunction." *ActiveVideo Networks, Inc. v. Verizon Commn'cs., Inc.*, 694 F.3d 1312, 1337 (Fed. Cir. 2012) (citing *eBay Inc.*, 547 U.S. at 391).

> The Supreme Court has cautioned that "[a]n injunction is a drastic and extraordinary remedy, which should not be granted as a matter of course." *Monsanto Co. v. Geertson Seed Farms*, 561 U.S. 139, 130 S.Ct. 2743, 2761, 177 L.Ed.2d 461 (2010) (citing *Weinberger v. Romero–Barcelo*, 456 U.S. 305, 311–12, 102 S.Ct. 1798, 72 L.Ed.2d 91 (1982)). Rather, "[i]f a less drastic remedy ... [is] sufficient to redress [a plaintiff's] injury, no recourse to the additional and extraordinary relief of an injunction [is] warranted." *Id.*

Apple II, 735 F.3d at 1359. "The decision to grant or deny permanent injunctive relief is an act of equitable discretion, reviewable on appeal for abuse of discretion." *Id.* (quoting *eBay*, 547 U.S. at 391). The Court next considers the parties' arguments and the facts of record in light of each of the considerations set forth in *eBay Inc.*, 547 U.S. at 391, in turn.

1. Irreparable Injury

It is now well settled that "there is no presumption of irreparable harm upon a finding of patent infringement." *Apple III*, 735 F.3d at 1359 (citing *Robert Bosch LLC v. Pylon Mfg. Corp.*, 659 F. 3d 1142, 1148 (Fed. Cir. 2011)). "[T]o satisfy the irreparable harm factor in a patent infringement suit, a patentee must establish both of the following requirements: 1) that absent an injunction, it will suffer irreparable harm, and 2) that a sufficiently strong causal nexus relates the alleged harm to the alleged infringement." *Id.* (citing "*Apple II*", 695 F.3d at 1374). The Federal Circuit has clarified that:

> "the causal nexus inquiry is ... part of the irreparable harm calculus," and that "although the irreparable harm and the causal nexus inquiries may be separated for the ease of analysis, they are inextricably related concepts." *Apple II*, 695 F.3d at 1374–75. Put another way, the causal nexus requirement is simply a way of distinguishing between irreparable harm caused by patent infringement and irreparable harm caused by otherwise lawful competition—e.g., "sales [that] would be lost even if the offending feature were absent from the accused product." *Apple I*, 678 F.3d at 1324. The former type of harm may weigh in favor of an injunction, whereas the latter does not.

Apple III, 735 F.3d at 1359-60. A lack of commercial activity in the practicing patents does not by itself establish that the holder would not suffer irreparable harm if a permanent injunction is not issued. *eBay Inc.*, 547 U.S. 388. And even "without practicing the claimed invention, the patentee can suffer irreparable injury." *Presidio Components, Inc. v. Am. Technical Ceramics Corp.*, 702 F.3d 1351, 1363 (Fed. Cir. 2012). However, Courts have more commonly found irreparable injury warranting an injunction in cases between direct competitors. *See e.g. Praxair, Inc. v. ATMI, Inc.*, 479 F. Supp. 2d 440, 444 (D. Del. 2007); *LaserDynamics, Inc. v. Quanta Computer, Inc.*, No. 2:06-cv-348, 2010 WL 2574059, at *2 (E.D. Tex. June 22, 2010).

It is CMU's burden to demonstrate that it will sustain an irreparable injury absent the issuance of a permanent injunction barring continuing infringement of the patented methods by

Marvell. *See Apple III*, 735 F.3d at 1359. To meet its burden, CMU argues that it is likely to sustain irreparable injury because of "concerns" about its ability to collect the judgment against Marvell in light of *Robert Bosch LLC v. Pylon Mfg. Corp.*, 659 F.3d 1142, 1154-55 (Fed. Cir. 2011). CMU specifies that "[t]he factual predicate underlying [its] request for injunctive relief is the risk that [it] will not be able to collect monetary damages awarded against Marvell, and therefore CMU will be denied any remedy whatsoever for Marvell's future (and even its past) infringement." (Docket Nos. 787 at 2; 905 at 4). CMU supports its "collection risk" theory with all of the following: (1) Defendant Marvell Technology Group, Ltd. ("MTGL") is incorporated in Bermuda, such entity may hold the majority of Marvell's assets and its SEC filings state that a civil judgment "would not be automatically enforceable" in Bermuda courts; (2) Marvell has recently dissipated significant liquid assets through its share repurchase program and issuance of dividends; (3) Marvell's SEC filings state that it has not set aside any assets to satisfy the judgment; and (4) media reports in late 2013 suggested that Kohlberg, Kravis, Roberts & Co. ("KKR") may be considering a leveraged buyout of Marvell. (*Id.*).

Marvell objects to the entry of a permanent injunction on any of the bases set forth by CMU and maintains that the "collection risk" theory is both legally and factually unsupported. (Docket Nos. 828, 863, 906). Marvell counters CMU's evidence with declarations from its Chief Executive Officer affirming that Marvell will pay any judgment awarded in this case which is affirmed by the higher courts, (*see* Docket No. 828 at Ex. 2), and another from its current Chief Financial Officer that it is not engaged in any negotiations with any entity as to a leveraged buyout or other extraordinary corporation transaction, (*see* Docket No. 922-3 at ¶ 2). Marvell further advocates that the proposed injunction is legally unsound under the *Apple III* decision because CMU has failed to demonstrate a sufficient casual nexus between the alleged infringement and the asserted irreparable harm. (Docket Nos. 828, 863, 906).

The Court agrees with Marvell that CMU has failed to demonstrate irreparable harm in this case. CMU's "collection risk" theory relies heavily on the Federal Circuit's discussion of the financial instability of the defendant in *Robert Bosch LLC v. Pylon Mfg. Corp.*, 659 F.3d at 1153-56. Yet, a careful reading of that decision clearly demonstrates that it is distinguishable from the instant matter for a number of reasons. *Id.* First, unlike CMU, which is proceeding solely under the "collection risk" theory, Bosch claimed that it was irreparably harmed because it: practiced the infringed patents and was a direct competitor of Pylon; had lost market share and customers to Pylon as a result of the infringement; and Pylon lacked the financial ability to pay a judgment. *Id.* Second, the court found that irreparable harm was established as a result of the direct competition with the practicing patentee, lost market share and lost customers, none of which are present here. *Id.* Third, the evidence of Pylon's financial instability was uncontested and even its own attorneys could not provide any assurances to the court that a monetary judgment could be satisfied. *Id.* To this end, Bosch presented uncontested evidence of Pylon's financial instability including a financial report stating that it was a "moderate risk of severe financial stress, **such as bankruptcy**, over the next 12 months," and had a risk factor in the 49th percentile of all companies nationally and also presented evidence that its parent company which held 100% of the company's stock had "obtained a five million dollar loan at a rate of 8.46%." *Id.* (emphasis added). In reaching its decision to enter a permanent injunction, the Federal Circuit emphasized that Pylon did not contest such evidence and found it "troublesome" that it had "fail[ed] to submit rebuttal evidence regarding its ability to satisfy an award of money damages." *Id*. The Federal Circuit went so far as to point out that even during oral argument on appeal, Pylon's counsel could not "offer express assurances" that it was financially able to pay the judgment. *Id.* at n.6. In contrast, both Marvell and its counsel have stated, on the record, that it will pay the judgment in this case, rebutting the evidence presented by CMU.[25] (*See* Docket Nos. 828 at Ex. 2; 912 at 15).

The other cases relied upon by CMU for the proposition that a patentee may sustain irreparable injury based on an asserted inability of an infringer to pay a judgment are likewise distinguishable as each of the infringers in those cases faced severe financial distress, including: an infringer that could not afford to pay its former attorneys or hire new counsel to respond to a summary judgment motion, *see Custom Designs of Nashville, Inc. v. Alsa Corp.*, 727 F. Supp. 2d 719, 726-27 (M.D. Tenn. 2010); an infringer which admitted the infringement litigation was a "make or break event" for the company and two weeks after the jury's verdict entered into the Australian equivalent of bankruptcy, *see Retractable Technologies, Inc. v. Occupational & Med. Innovations, Ltd.*, 6:08-CV-120, 2010 WL 3199624, at *5 (E.D. Tex. Aug. 11, 2010); and an infringer which was deemed to be insolvent by the court, *see Sundance, Inc. v. Demonte Fabricating Ltd.*, 2007 WL 3053662, at *1 (E.D. Mich. 2007), *rev on other grounds*, 550 F.3d 1356 (Fed. Cir. 2008). Marvell simply does not face any of these types of dire financial circumstances as the company is doing well financially, remains able to pay its many attorneys and is neither insolvent nor a risk for bankruptcy.[26]

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[25] Specifically, Marvell's attorneys state, as officers of the court, that the evidence they has presented regarding Marvell's financial condition "confirms that Marvell is positioned to follow through" on Dr. Sutardja's "commitment to pay any final damages award that survives appeal." (Docket No. 912 at 15). Such statements are made by counsel pursuant to its obligations under Rule 11(b)(3), which requires a certification by the attorney that such "factual contentions have evidentiary support." FED. R. CIV. P. 11(b)(3).

[26] The Court notes that the above discussion concerning Marvell's size and ability to pay focused on whether it was sufficiently capitalized to withstand a penalty of treble or double damages without severely damaging its business. *See* § II.C.4., *supra*. That discussion does not undermine the Court's belief that Marvell is financially able to meet the current obligations to CMU, with the enhancement imposed by the Court, and the payment of any ongoing royalty.

CMU next argues that it will suffer irreparable harm without the entry of an injunction because MTGL is a foreign corporation registered in Bermuda and a civil judgment is not automatically enforceable against it in that country. (Docket No. 787 at 9). CMU relies on *O2 Micro Intern. Ltd. v. Beyond Innovation Tech. Co., Ltd.*, Civ. Action No. 2-04-CV-32 (TJW), 2007 WL 869576, at *2 (E.D. Tex. Marc. 21, 2007), *vacated and remanded on other grounds*, 521 F.3d 1351 (Fed. Cir. 2008), for the proposition that a permanent injunction should issue when a foreign infringer is unable to provide assurance to the patentee that it will be able to collect monetary damages. (Docket No. 787 at 9). But, the irreparable injury set forth by patentee in that case was the loss of market share to the directly competing patentee rather than the fact that the defendants were foreign corporations. *Id.* Also, the District Court pointed out that all three of the infringing entities were foreign corporations. *Id*. Thus, the facts of this case are very different from *O2 Micro* because: the instant parties do not compete; CMU does not practice the patents and has no portion of the market; the only irreparable harm claimed by CMU is based on the alleged "collection risk" of Marvell; and only MTGL is a foreign corporation while MSI is incorporated in the United States.

In this Court's estimation, Marvell has also sufficiently rebutted CMU's reliance on the passage from MTGL's 10-K reports and other SEC filings concerning the non-automatic enforceability of the judgment in Bermuda courts. CMU suggests that the situs of MTGL's incorporation is a "self-imposed obstacle to enforcement." (Docket No. 787 at 9). However, Marvell has presented an affidavit of Dr. Sehat Sutardja, the Chief Executive Officer of the Bermuda corporation, MTGL, which expressly states that it will pay any judgment awarded in this case which is upheld on appeal. (*See* Docket No. 828 at Ex. 2). Even if CMU is correct that it will have some difficulty collecting the judgment in Bermuda, because the courts in that country may not automatically reduce this Court's judgment in order to immediately effectuate collection, it has not demonstrated that it would be unable to enforce Dr. Sutardja's subsequent promise to pay the judgment in Bermuda. (Docket Nos. 787, 853, 905). In light of the uncontested affidavit, it appears that Marvell has largely removed any "self-imposed obstacle" to collection in Bermuda. At most, CMU has established that collection may not be "automatic" such that some legal proceedings may need to be initiated against MGTL in Bermuda in order to collect the entirety of the judgment. The potential need to initiate some type of legal proceedings in Bermuda is not sufficient to show that CMU may be irreparably harmed. *Apple III*, 735 F.3d at 1359 ("a patentee must establish … that absent an injunction, it will suffer irreparable harm").

Additionally, on this Court's record, CMU has not demonstrated that Marvell maintains insufficient assets in the United States to satisfy the judgment, possibly making the need to pursue MTGL in Bermuda unnecessary, if Dr. Sutardja does not own up to his promise. In fact, CMU has expressly argued that both MTGL and MSI own substantial assets in the Northern District of California which may be sufficient to satisfy all of the judgment, which, at the time, was "in excess of $1.16 billion." Specifically, CMU's counsel averred the following:

> **MTGL and MSI own substantial assets located in the Northern District of California that could satisfy a significant portion or all of the Judgment.** MTGL's U.S. headquarters, which houses research and design functions as well as substantially all of its sales, marketing, administration, and operations, is located in Santa Clara, California, which lies within the Northern District of California. *See* Ex. I. According to MTGL's SEC filings, it (likely through subsidiaries) owns the company's Santa Clara facility, which consists of approximately 993,000 square feet on 33.8 acres of land. *Id.* MSI, which is MTGL's operating subsidiary, maintains its headquarters and principal place of business at the Santa Clara facility. *See* Dkt. 25-7; Dkt. 26, at 4-7; Ex. J (Marvell website description of company). Given that both MTGL and MSI have a very significant presence in the Northern District of California, CMU states on information and belief that additional and

> substantial assets will likely be found in that judicial district and in other districts in California.

(Docket No. 909 at 8). CMU further points out in the same brief that MTGL "owns or leases real property in several U.S. states." (*Id.*). It also repeatedly references the amount of liquid assets held by Marvell but never describes where those assets are located. (*See* Docket No. 909-2). Accordingly, the Court dismisses CMU's "Bermuda incorporation theory" as speculative and sufficiently rebutted by the evidence advanced by Marvell.

The Court also disagrees with CMU's other theories making Marvell a "collection risk" including: the share repurchase program and issuance of dividends; the failure to set aside reserves for the judgment; and/or the supposed KKR leveraged buyout transaction. (Docket Nos. 787 at 2; 905 at 4). All of these claims are likewise rebutted by the affidavit of Dr. Sutardja. (*See* Docket No. 828 at Ex. 2). Further, each remains unproven for additional reasons. With respect to the share repurchase program and dividends, CMU has presented no evidence that such program was initiated in order to avoid judgment and its own expert continues to estimate that even with such program Marvell will have around $2 billion in liquid assets throughout fiscal 2014. (*See* Docket Nos. 909-2, 909-3). The Court fully expects that the asserted failure to set aside reserves to pay the judgment will be resolved in the context of the parties' ongoing bond negotiations which are being supervised by the Special Master.[27] In this regard, the prior filings related to the parties' bond disputes indicate that Marvell would likely be qualified for a bond in an amount of $1.5 billion, an amount which will cover the current judgment. (Docket No. 915-1 at ¶ 3). Finally, the supposed KKR deal was affirmatively countered by Marvell's statement that it was not involved in that type of an extraordinary corporate transaction

[27] The Court notes that, with the parties' consent, the Honorable Thomas T. Frampton has been appointed to serve as a Special Master in this case. (Docket No. 930). Judge Frampton is presently a shareholder at the law firm of Goehring Rutter & Boehm and previously served as a Judge for the Mercer County Court of Common Pleas.

demonstrating that the media reports relied upon by CMU were pure speculation. (Docket No. 922-3 at ¶ 2).

For all of these reasons, the Court finds that CMU's "collection risk" theories are unproven and do not support a finding that it will be irreparably harmed without the imposition of a permanent injunction. *See Robert Bosch*, 659 F.3d at 1153-56. CMU has presented no direct evidence that Marvell will not pay the judgment or that Marvell has a history of dilatoriness in paying its debts and the Court has already determined that it is sufficiently capitalized to withstand the current judgment (including the enhancement). The Court is likewise not persuaded that Marvell will be unable to meet its future obligations to pay an ongoing royalty such that CMU will be unable to collect additional monies stemming from the continuing infringement.[28] As such, CMU has therefore failed to meet its burden to demonstrate that it will be irreparably harmed without the imposition of a permanent injunction due to the alleged inability of Marvell to pay a money judgment. *Apple III*, 735 F.3d at 1359.

With this holding, the Court need not specifically address Marvell's well-taken arguments that an injunction should not issue to bar its continued production of its multi-feature read channel chips given *Apple III* and the other reasons proffered by Marvell. *Cf. Apple III*, 735 F.3d at 1363 ("[T]his argument seems to be premised on the mistaken notion that the causal nexus is a separate factor from irreparable harm. As we have explained, however, the causal nexus requirement is part of the irreparable harm factor. Without a showing of causal nexus, there is no relevant irreparable harm. In other words, there cannot be one without the other.").

[28] The Court notes that the ongoing post-judgment infringement, which is considered in the context of the ongoing royalty discussion in the following section, includes additional sales of 299,042,568 chips from January 15, 2013 until November 2, 2013. (Docket No. 907). Additional accountings have not yet been made but quarterly accountings will be required by the Court's corresponding Order to be issued with this Opinion. Commensurate sales of chips developed using the infringing simulators and containing the infringing technology are expected to continue until the proposed design around is completed and into the future. So, Marvell's continuing infringement will likely result in significant continuing royalties due to CMU.

The Court acknowledges that the parties have presented interesting arguments regarding the reach of *Apple III* and whether CMU should be able to avoid the import of its discussion of the nature of the products by couching its irreparable harm arguments to challenge only the alleged collection issues. (Docket Nos. 905, 906). The Court also notes that the nature of the read channel chips, when coupled with the other evidence that CMU does not practice the patents, has exhibited a willingness to license same to Marvell specifically, and has failed to demonstrate that Marvell is a "collection risk," certainly counsels against the issuance of a permanent injunction in this case.

Marvell's read channel chips are multi-feature products, covered by many patents owned by Marvell, and supplemented by numerous unpatented features. *Cf. Apple IV*, 2014 WL 976898 at *19 ("Smartphones and tablets are complex devices embodying hundreds of features, inventions, and components."). The infringed methods essentially operate within the read channel chips to reduce media noise and improve the performance of the chips. *Id.* The *Apple v. Samsung* line of cases has made clear that a patentee seeking an injunction of such a multi-feature product is required to "show that the infringing feature drives consumer demand for the accused product … [and] this inquiry should focus on the importance of the claimed invention in the context of the accused product, and not just the importance, in general, of features of the same type as the claimed invention." *Apple III*, 735 F.3d at 1364. The patentee must demonstrate:

> some connection between the patented feature and demand for [the infringer's] products. There might be a variety of ways to make this required showing, for example, with evidence that a patented feature is one of several features that cause consumers to make their purchasing decisions. It might also be shown with evidence that the inclusion of a patented feature makes a product significantly more desirable. Conversely, it might be shown with

> evidence that the absence of a patented feature would make a product significantly less desirable.

Id. Yet, the Federal Circuit has held that the weight and credibility of the evidence presented on these issues are discretionary for the Court such that a patentee presenting some evidence showing that the patented feature drives demand does not, by itself, demonstrate irreparable harm. *Id.* Again, this is just one of many factors which must be weighed by the Court. *Id.*

While CMU has continually and repeatedly touted its invention as "must have" for Marvell and its customers, the Court need not look much farther than the damages evidence to conclude that these are multi-feature products which have many valuable non-infringing aspects. On the other hand, as the Court recounted in its JMOL opinion, Marvell did not introduce evidence at trial valuing these other components of its read channel chips, for reasons unknown to the Court. (*See* Docket No. 901). In any event, Ms. Lawton engaged in an "excess profits" analysis to value the patented methods in this case, resulting in her opinion at trial that the infringement was worth $1.16 billion. (Docket No. 713 at 11). Her "excess profits" analysis started with calculating the price-per-chip ($4.42) and operating profit-per-chip ($2.16) based on Marvell's internal sales data. (*Id.*). She then compared the sales of Marvell's chips to certain customers (Maxtor and Toshiba) for which she had information from the same time period (2003) where products were sold with and without the addition of the allegedly infringing MNP detector, resulting in a range of between $0.06 and $0.72 per chip. (*Id.*). She ultimately opined that the reasonable royalty would be near the high end of this range, $0.50, based on the opinion of Dr. Christopher Bajorek that the patented methods were "must have" for Marvell and its customers because of the increased performance of the chips. (*Id.*). But, Ms. Lawton's opinions make clear that Marvell otherwise met its profit margin goal of fifty percent of the total revenue generated by the sales of the Accused Chips, even with paying its "excess profits" attributable solely to the inclusion of the patented methods to CMU. So, while there is evidence that the patented methods made the Accused Chips "more desirable," it cannot be said that there is no value to the numerous other features in the chips which are not addressed by the patented methods and those features have collectively generated more profit for Marvell, (i.e., $1.66 per chip), than the addition of the patented methods, (i.e., $0.50 per chip), even with the "must have" valuation of the patents by Ms. Lawton.

Based on the *Apple v. Samsung* line of cases, the sufficiency of the "casual nexus" evidence is a matter of degree to be determined by the District Court in its discretion. *See Apple III*, 735 F.3d at 1364. Given same, while CMU has presented evidence that the patented methods added value to the read channel chips, in the absence of a showing as to how customers and/or the market valued the other numerous features in the read channel chips vis-à-vis the features of the patented methods, the "must have" evidence is not as strong as CMU suggests. Indeed, the record is not sufficiently developed for the Court to conclude definitively that the patented methods outweighed the significance of the other features to customers given the obvious value of the Accused Chips, even without the patented methods. *Cf. Apple IV*, 2014 WL 976898 at *19 ("The various consumer surveys presented to the Court, including Dr. Hauser's survey, do no more than confound the Court's efforts to determine whether—of the many smartphone and tablet features such as the camera, screen quality, operating system, and screen size—the three patented features at issue here drive consumer demand. Put another way, the evidence shows that the three patented features may add to a device's appeal, but Apple has not shown that these specific features are among several that 'cause consumers to make their purchasing decisions' or otherwise drive consumer demand"). As a consequence, this Court would likely require a more specific showing from CMU prior to enjoining these types of products but further proceedings on these issues are unnecessary in light of the Court's determination that CMU has not demonstrated that it will be irreparably harmed by Marvell's financial condition and it has repeatedly asserted that this is the sole basis for the permanent injunction it seeks. (*See e.g.*, Docket Nos. 787, 905).

For these reasons, the Court concludes that CMU has failed to meet its burden to establish irreparable harm and such finding weighs strongly against the imposition of a permanent injunction.

2. Adequacy of Legal Remedies

"This factor requires a patentee to demonstrate that 'remedies available at law, such as monetary damages, are inadequate to compensate' the patentee for the irreparable harm it has suffered." *Apple III*, 735 F.3d at 1368 (citing *eBay*, 547 U.S. at 391). This Court is directed to "assess whether a damage remedy is a meaningful one in light of the financial condition of the infringer before the alternative of money damages can be deemed adequate." *Robert Bosch LLC*, 659 F.3d at 1155. Further, "unlike an infringer's inability to pay a judgment, which may demonstrate the inadequacy of damages, a defendant's ability to pay a judgment does not defeat a claim that an award of damages would be an inadequate remedy. Rather, a defendant's ability to pay merely indicates that a court should look to other considerations to determine whether a damages award will adequately compensate the patentee for the harm caused by continuing infringement." *Apple III*, 735 F.3d at 1369. Thus, the Court must decide if a damages remedy is adequate to compensate the patentee for the alleged irreparable harm rather than the underlying infringement. *Cf. id.*

In order to sustain its burden on this prong, CMU relies on the same evidence and reiterates it arguments that Marvell is financially unable to pay a judgment on both the past and continuing infringement and/or may seek to avoid same given the foreign incorporation of MTGL. (Docket Nos. 787, 905). As the Court has rejected this position, and found that CMU has not demonstrated irreparable harm, CMU has likewise failed to demonstrate that an award of money damages for the past and continuing infringement is inadequate as a matter of law. Accordingly, this factor counsels against entering a permanent injunction in this case.

3. Balance of Hardships

"The balance of hardships factor 'assesses the relative effect of granting or denying an injunction on the parties.'" *Apple III*, 735 F.3d at 1371 (quoting *i4i*, 598 F.3d at 862). Proper considerations under this factor include "the parties' sizes, products, and revenue sources." *I4i*, 598 F.3d at 862. Matters that are irrelevant to the inquiry include the consequences to the infringer as a result of its infringement, such as, the costs of product redesigns, lost future commercial successes, and sunk development costs. *Id.*

As CMU has failed to convince this Court that Marvell would be unable to pay the judgment, the Court finds that CMU has not articulated any appropriate reason as to how or why the proposed permanent injunction would benefit it. Again, CMU stands to be paid in excess of $1.5 billion for past infringement and will be due any additional royalties for continuing infringement, as is discussed in the following section of this Opinion. *See* § IV.B., *infra*. Any injunction barring future infringement of the patented methods would cut off continuing infringement and stop what could be a significant revenue stream to CMU. This revenue stream will likely exceed an additional $100 million annually on top of the already substantial judgment to be entered in this case. It is certainly well in excess of the "highly speculative forecast" of two million dollars annually which CMU's Technology Transfer Office forecasted in 2006. (Def. Ex. 272). Additionally, there is no competition between the parties; CMU does not practice the methods; and, it has no licensing arrangements for these patents outside of its DSSC program, under which its members such as Seagate have free "use" rights.[29] Therefore, CMU is presently in a position where it can either license the patents to Marvell for a handsome royalty or not license them at all.

In contrast, if an injunction were granted, there could plainly be harm to Marvell beyond the costs of redesigns, lost future commercial successes and sunk development costs, although Marvell has and will continue to incur such expenses as it proceeds with its redesign of future chip lines. *I4i*, 598 F.3d at 862. As has already been discussed, the Accused Chips are multi-feature products with many non-infringing features and any injunction would bar these non-infringing features as well as the infringing ones. The Court has also concluded that CMU's "must have" evidence alone is not sufficient to meet the clarified standards for obtaining a permanent injunction of these types of products under the *Apple v. Samsung* line of cases. Further, CMU cannot meaningfully contest that an immediate injunction would significantly impair Marvell's customers, as Marvell's lengthy sales cycle would preclude it from generating redesigned products for over a year, leaving its customers without chips to incorporate into their hard drives and other devices. (Docket No. 828 at 16, at Ex. 3). Moreover, the process of disenabling the infringing features of the more than 2 billion chips that have already been sold is basically impossible and the cost of disenabling the infringing features in existing chips that have yet to be sold would be significant. (*Id.*). Finally, based on CMU's infringement theory presented at trial, any injunction which would only bar the use of the simulators rather than the chips themselves would effectively stop production of all of Marvell's chips and cause the same type of harm that has already been discussed.

[29] Despite the verdict and the post-trial filings and proceedings, CMU has not identified any additional licensing agreements for this technology. (Docket Nos. 787, 853, 905).

For these reasons, the Court believes that this factor also favors Marvell but only slightly because the Court does not believe that CMU would be harmed by continuing infringement as such infringement would generate significant compensation.

4. Public Interest

The last factor that the Court must consider is whether "the public interest would be disserved by an injunction." *Apple III*, 735 F.3d at 1371 (citing *eBay*, 547 U.S. at 391). "[T]he touchstone of the public interest factor is whether an injunction, both in scope and effect, strikes a workable balance between protecting the patentee's rights and protecting the public from the injunction's adverse effects." *i4i*, 598 F.3d at 863 (citing *Broadcom Corp. v. Qualcomm, Inc.*, 543 F.3d 683, 703-04 (Fed. Cir. 2008)). The members of the public to be considered include the infringer's vendors, manufacturers, customers, end-user consumers, and other members of distribution channels for the infringing products. *Id.*

The Court recognizes that there is a strong public interest in enforcing CMU's patent rights because this technology was sponsored, in part, by public funding. *Precision Instrument Mfg. Co. v. Auto. Maint. Mach. Co.*, 324 U.S. 806, 815-16 (1945). However, the scope and effect of the proposed injunction in this case would in all likelihood cause significant harm to all of the companies which unwittingly participate in some fashion in the production and distribution of Marvell's read channel chips. Marvell is the dominant leader in the production of these types of chips and has approximately a sixty percent (60%) market share. (Docket No. 707 at 122). The downstream effects of any such injunction could be very significant, as increased prices set by the market leader would be passed down the stream of commerce to the ultimate end-purchaser of computers and like equipment containing the subject chips. Distribution delays would likewise have a dramatic effect on the hard drive manufacturers, like Seagate, computer manufacturers and the retailers of same. Ultimately, the imposition of an injunction may force semiconductor businesses like Marvell completely offshore which would not be in the best interest of the public. It would also undermine what Dr. Kryder explained was one of the primary purposes of the National Science Foundation's support of the establishment of the DSSC at CMU, i.e., to promote domestic research and production of this type of technology and to prevent such business from moving to other countries. (Docket No. 682 at 27-28).

Accordingly, the Court finds that the public interest would be disserved by the entry of a permanent injunction in this case.

5. Conclusion

Based on the foregoing, CMU's motion for a permanent injunction [787] is denied as CMU has failed to demonstrate that Marvell is unable to pay the past and future damages resulting from its infringement. However, such denial is without prejudice, to CMU renewing its motion in the event that credible and significant evidence well beyond that which has already been presented demonstrates that Marvell's financial condition has worsened to such an extent that it cannot pay future damages.

B. Ongoing Royalty

While the Court has declined to impose the requested permanent injunction, an ongoing royalty for continuing infringement of the patented methods will be assessed. The Federal Circuit has held that:

> [i]n most cases, where the district court determines that a permanent injunction is not warranted, the district court may wish to allow the parties to negotiate a license amongst themselves regarding future use of a patented invention before imposing an ongoing royalty. Should the parties fail to come to an agreement, the district court could step in to assess a reasonable royalty in light of the ongoing infringement.

Paice LLC v. Toyota Motor Corp., 504 F.3d 1293, 1315 (Fed. Cir. 2007). In undertaking this assessment, the Court weighs the traditional *Georgia-Pacific* factors[30] to arrive at a reasonable royalty which is adequate to compensate the patentee for the continued infringement. *Id.* The Court is not bound by the royalty rate that the jury determined was appropriate for prejudgment infringement because of the possible changed bargaining positions of the parties. *Varian*, 2012 WL 1436569, at *11 (citing *Amado v. Microsoft Corp.*, 517 F.3d 1353, 1361–62 (Fed. Cir. 2008)).

1. Failed Negotiations

Pursuant to the Federal Circuit's well-advised suggestion in *Paice* that the parties should be permitted to negotiate any future ongoing royalty payments amongst themselves, the Court ordered the parties to meet and confer to negotiate an ongoing royalty after the initial filing of post-trial motions. (Docket No. 865). The parties were unsuccessful and advised the Court that they "remain[ed] very far apart" at that point. (Docket No. 871). In an effort to bridge the gap between the parties, the Court ordered lead trial counsel and party representatives with full settlement authority to participate in Court-annexed mediation[31] the morning before oral argument on post-trial motions. (Docket No. 872). Unfortunately, they were unable to reach any resolution or agreement at that time and have not indicated any willingness to return to the negotiating table in the interim.[32]

2. Ongoing Royalty

As the parties have been unable to negotiate an ongoing royalty for the continuing infringement, the Court must step in to assess a reasonable royalty in light of the ongoing infringement. *Paice*, 504 F.3d at 1315. The parties' positions as advocated in their papers are

30 *See Georgia–Pacific Corp. v. United States Plywood Corp.*, 318 F. Supp. 1116 (S.D.N.Y. 1970).
31 *See* n.14, *supra*.
32 The parties are, however, negotiating the aforementioned bond at present.

consistent with their "very far apart" report as CMU argues that the ongoing royalty should be set at up to $1.50 per Accused Chip given the finding of willful infringement while Marvell suggests that the ongoing royalty should be set at a rate much less than the jury's allegedly excessive award of $0.50 per Accused Chip. (Docket Nos. 787, 837, 853, 863). Having fully considered the parties' positions in light of the jury's verdict, all of the Court's post-trial rulings and the relevant *Georgia-Pacific* factors, the Court believes that a reasonable royalty for the ongoing infringement is $0.50 per Accused Chip.

In reaching this decision, the Court recognizes that it is not bound by the jury's findings that $0.50 is a reasonable royalty and that "pre-suit and post-suit acts of infringement are distinct, and may warrant different royalty rates given the change in the parties' legal relationship and other factors." *Paice*, 504 F.3d at 1317 (Rader, J., concurring). However, the Court finds the jury's determination reasonable as CMU's trial presentation of this royalty rate was well-supported by Ms. Lawton's credible and comprehensive testimony. The Court believes that the parties at a hypothetical negotiation at this juncture of the case would likely reach the same figure, even with changes in the parties' legal relationship and considering any other changes in the parties' positions since the verdict.

At this point, CMU is a prevailing patentee which has been awarded one-hundred (100%) percent of the compensation it sought through a substantial award of compensatory damages, accounting for every $0.50 in Marvell's "excess profits" which its expert attributed to the inclusion of the patented methods in each chip. It has also received an additional twenty-three percent (23%) compensation on the pre-judgment royalties, which equates to an additional $0.115 per Accused Chip. *See* § II.C., *supra*. All told, CMU has received one hundred twenty-three percent (123%) compensation for the pre-judgment infringement, or \$0.615 per Accused Chip, for a judgment award totaling in excess of \$1.5 billion. *Id.*

While this award can be appropriately characterized as very significant, the return on investment by CMU is at best described as staggering. The record is uncontested that CMU developed these patents through its DSSC program with public grants and the support of corporate donors. (Docket No. 901 at 10). Its own financial investment in the research and development of the patents has never been quantified during these proceedings but under any measure would be considered extraordinarily insignificant when compared to the present award.

Given the valuation of these "must have" and "industry standard" patents, CMU's marketing efforts, or lack thereof, is stunning to the Court.[33] CMU then ignored repeated allegations of infringement from the inventors and took nearly six full years to decide whether to pursue litigation, never following up with Marvell during this time period. (Docket No. 920). It received similar allegations about other entities but to this Court's knowledge has not pursued them. (*Id.*). And, despite the verdict, CMU has not negotiated licenses with any other third parties.

From the Court's view, CMU appears largely satisfied with the exceptional returns on its minimal financial investments in these patents and only questions whether it will be able to collect the judgment against Marvell.[34] Accordingly, the Court believes that CMU would accept an ongoing royalty of \$0.50 per Accused Chip for the continuing infringement rather than the requested \$1.50 per Accused Chip or some rate between those two figures, including the

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[33] To this end, CMU: sent out initial correspondence to DSSC members Seagate and IBM in 2001 announcing the patents; sent its "friendly" licensing letters to fourteen companies, including Marvell, in 2003; and had some unsuccessful negotiations with Intel in 2004 which included a brief discussion of these patents. (See Docket No. 920 at 12-13 (citing Pl. Exs. 422; 431; Def. Exs. 182, 185; 225; 226; 227; 229; 230; 231; 232; 233; 234; 1573); 901 at 12 (citing Def. Exs. 255, 263; Docket No. 682 at 100, 183-85)).

[34] The Court acknowledges that CMU also seeks to recover its attorneys' fees in this litigation. The Court postponed its decision. (Docket No. 884). The Court does not consider same as part of its "investment" in the patents.

effective rate of $0.615 per Accused Chip which it has been awarded for the pre-judgment infringement and willfulness. CMU effectively seeks to have the Court impose a higher rate than the jury's assessment to punish Marvell for its willfulness rather than arriving at that figure after undertaking a comprehensive *Georgia-Pacific* analysis.[35]

Marvell stands before the Court as an adjudicated willful infringer which has been ordered to pay substantial compensatory and punitive damages to CMU in order to account for its unlawful conduct. While the award is very high due, in part, to CMU's inaction, it is a just award given the scale and scope of the infringement and its utter disregard for CMU's patent rights. Marvell remains in a position where it needs to continue to use its simulators and include the infringing methods in its read channel chips for the foreseeable future. But, Marvell has started to redesign certain of its read channel chips and avers that its redesign will be concluded by the end of this year. (Docket No. 833 at 23). If successful at developing non-infringing products, Marvell will have the ability to walk away from the patented technology.[36]

As Ms. Lawton discussed at trial, Marvell also has the option of moving a large portion of its operations to an overseas location in an effort to avoid incurring a significant portion of the expected future damages. (Docket Nos. 686, 710). This could be achieved by moving its simulators and testing programs offshore along with other significant aspects of its U.S. based sales cycle and these moves could limit the amount of ongoing royalties to only those resulting from its inducement of customers located in the United States to use the patented methods. But, this scenario is unlikely as Marvell is ingrained in its Silicon Valley headquarters having made significant investments in infrastructure and key personnel at that location and conducting nearly

[35] Indeed, while Lawton has submitted numerous post-trial declarations in support of CMU's various motions, CMU has not put forth her opinion on the results of a post-trial hypothetical negotiation between these parties.

[36] It is unknown whether Marvell's customers will accept these redesigned products.

all of its sales cycle activities from there. (Docket Nos. 802-2 at ¶ 20; 802-1 at ¶¶ 6-9). Further, as explained in the context of the Court's discussion responding to CMU's request for an injunction, Marvell's products contain numerous non-infringing features which undoubtedly provide significant value to its customers and end-users. *See* § IV.A., *supra*. Considering all of these factors, the Court believes that Marvell should be willing to pay an ongoing royalty of $0.50 for the continuing infringement, rather than the lesser amounts it has suggested.

3. Conclusion as to Ongoing Royalty

With these findings, and after weighing the relevant *Georgia-Pacific* factors, the Court holds that a post-trial hypothetical negotiation between CMU and Marvell would result in the parties agreeing to a reasonable ongoing royalty of $0.50 per Accused Chip. Accordingly, CMU's motion is granted to the extent that an ongoing royalty of that amount will be ordered for the ongoing infringement. The Court will further order that Marvell make periodic, quarterly accountings of its continuing sales to CMU; that the parties meet and confer to reach agreement on pertinent sales data and continuing damages from the ongoing royalty; and, provide the Court with status reports outlining same going forward.[37]

As a final point, considering the present status of the parties' bond negotiations, wherein the parties are actively meeting with a court-appointed Special Master to determine the appropriate level of financial security for Marvell's forthcoming appeal, (Docket No. 930), the Court will deny, without prejudice, CMU's requests that an escrow account be established and that Marvell deposit any ongoing royalties in same and refer such requests to the Special Master with the same direction as the initial referral of the bond issues, i.e., the parties should initially be granted the opportunity to negotiate these issues and, if necessary, present any contested matters

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[37] To the extent that the quarterly accountings process engenders disputes, the Court will appoint a Special Master to resolve same.

to the Special Master for resolution through a Report and Recommendation directed to the Court. *See* FED. R. CIV. P. 53. However, the immediate priorities for the parties and the Special Master remain to finalize the bond issues so that a final judgment can be entered and Marvell can take its appeal.

V. CONCLUSION

Based on the foregoing, CMU's Motions [788], [786] and [790] are granted, in part, and denied, in part. As explained herein, CMU's requests for prejudgment interest and a permanent injunction are denied and its requests for supplemental damages, enhanced damages, post-judgment interest and an ongoing royalty are granted. A summary of the damages award is, as follows:

	Type of Damages	**Amount**
1	Jury Verdict	$1,169,140,271.00
2	Supplemental Damages	$79,550,288.00
3	Prejudgment Interest	$0.00
4	Total Damages	$1,248,690,559.00
5	Enhanced Damages Factor	1.23
6	Total with Enhancement	$1,535,889,387.60
7	Post-Judgment Interest	0.14%
8	Ongoing Royalty	$0.50 per chip

As noted in the Court's prior Orders, the parties will be directed to meet and confer and present the Court with a proposed final judgment in light of these rulings and the prior rulings in this case. They are also to proceed to negotiate the bond issues with the court-appointed Special Master. An appropriate Order follows.

s/Nora Barry Fischer
Nora Barry Fischer
United States District Judge

Date: March 31, 2014

cc/ecf: All counsel of record

Opinion (Laches)

(A76-148)

IN THE UNITED STATES DISTRICT COURT
FOR THE WESTERN DISTRICT OF PENNSYLVANIA

CARNEGIE MELLON UNIVERSITY, Plaintiff, vs. MARVELL TECHNOLOGY GROUP, LTD. et al., Defendants.	)	Civil Action No. 09-290 Judge Nora Barry Fischer

MEMORANDUM OPINION

I. INTRODUCTION

This is a patent infringement case brought by Plaintiff Carnegie Mellon University ("CMU"), against Defendants Marvell Technology Group, Ltd. and Marvell Semiconductor, Inc. (collectively "Marvell"), alleging that Marvell has infringed two of its patents, for which the Court conducted a four-week jury trial from November to December of 2012. (Docket No. 760). The jury rendered its verdict on December 26, 2012 in favor of CMU on infringement, validity, and willfulness, and awarded damages in the amount of $1,169,140,271.00. (Docket No. 762).[1]

Presently pending is "Marvell's Motion for Judgment on Laches," which has been fully briefed by the parties. (Docket Nos. 802-804; 823-826; 854; 858). The Court heard argument regarding this Motion on May 2, 2013, (Docket No. 873), with the transcript of these proceedings filed on May 15, 2013. (Docket No. 881).[2] Before addressing the contested factual and legal issues raised by Marvell's laches defense, the Court was required to decide numerous

[1] As the parties are well aware of the factual and procedural background of this case and the Court has already written extensively on the facts of this case, *see* (Docket No. 901), the Court will limit its discussion to the background necessary for the resolution of the current motions.

[2] The parties likewise filed their hearing slides. (Docket Nos. 874; 875). Post-verdict, the parties have provided joint status reports with updates on pertinent technology, financial information and notices of related case authority. (Docket Nos. 889; 891; 893; 896; 897; 898; 905; 906; 907).

other contested post-trial motions filed by the parties which were potentially outcome determinative with respect to the laches defense. Therefore, after the hearing on post-trial motions, the Court proceeded to initially deny Marvell's motion seeking a mistrial in a decision dated August 23, 2013. (Docket No. 900). The Court then moved on to resolve the parties' challenges to the sufficiency of the evidence supporting the jury's verdict on liability, damages and willfulness and issued rulings resolving many of these matters on September 23, 2013. (Docket No. 901). In that same decision, the Court granted CMU's motion for a finding of willfulness and enhanced damages, but reserved ruling on the financial penalty to be imposed as a result of Marvell's willful infringement, an issue which will be determined in a later decision. (*Id.*). Now that the Court has resolved those related matters and sustained the jury's billion dollar verdict, the laches defense invoked by Marvell whereby it seeks to invoke the Court's equitable powers to reduce the jury's damages award by approximately $620 million is ripe for disposition. (Docket No. 802).

The Court has carefully considered all of the parties' arguments and the voluminous evidentiary record (consisting of the entire trial record, as supplemented by the parties' post-trial submissions), which has required the Court to pause and debate the appropriate weight to be afforded to certain of the evidence and its legal rulings. After weighing the equities between the parties in light of the totality of the circumstances, and for the following reasons, Marvell's Motion for Judgment on Laches [802] is denied.

II. FINDINGS OF FACT

As the defense of laches is an equitable defense for which there is no right to a trial by jury, the Court sits as the trier of fact tasked with resolving factual disputes, weighing the credibility of the evidence and deciding the disputed legal issues between the parties. *See I/P*

Engine, Inc. v. AOL, Inc., 915 F. Supp. 2d 736, 740 (E.D. Va. Nov. 20, 2012); *see also, EBC, Inc. v. Clark Bldg. Sys., Inc.*, Civ. A. No. 05-1549, 2008 WL 4922107, at *4 (W.D. Pa. Nov. 13, 2008), *aff'd*, 618 F.3d 253 (3d Cir. 2010) (The "court's task is to weigh the evidence, resolve any conflicts in it, and decide for itself where the preponderance lies… . The Court is also required to assess the credibility of witnesses to determine whether the movant has demonstrated a factual and legal right to relief by a preponderance of the evidence."). With this standard in mind, the Court now makes the following findings of fact and conclusions of law pursuant to Rule 52 of the Federal Rules of Civil Procedure.[3] *See* FED. R. CIV. P. 52.

A. Prior to Issuance of the Subject Patents (late 1990's to March 2001)

From 1995 to 1998, Dr. Jose Moura, a tenured professor of Electrical Engineering at CMU and then doctoral student, Aleksandar Kavcic worked to develop a method addressing high density and media noise problems in magnetic recording. (Docket No. 673 at 42). On March 10, 1997, they submitted an invention disclosure form to CMU. (Pl. Ex. 156). And, in May 1997, they filed a provisional patent application claiming this method. (Pl. Ex. 1).

On March 8, 1998, Kavcic wrote the following email to Dr. Nersi Nazari, Vice President of Signal Processing at Marvell:

> Hi Nersi, Somebody told me last week at our annual DSSC review here at Carnegie Mellon that Marvell has a detector that implements some of the approaches I suggested in my talk here. It is also in GLOBECOM 98 paper I sent you. Is there a write-up regarding this detector. Also I am going to graduate soon (May) and am on the look for jobs. [*sic*] Is Marvell hiring by any chance. Please let me know. My resume and downloadable publications are on my web page. The URL is …. Thanks, Alex.

[3] Because laches is a fact-specific defense that requires consideration of all the circumstances and equities, the Court considers all of the relevant evidence in the record, including the evidence presented at trial and the parties' post-trial submissions of affidavits and supplemental exhibits. *See* § III, *infra*.

(Def. Ex. 1023; Docket No. 674 at 113:12-114:25). Dr. Nazari replied, in relevant part, "as far as I know our [*sic*] we do not have a product in line of your work, yet. Yes, we are hiring and I'll read your resume on the web…" (Def. Ex. 1611). Kavcic replied discussing the different types of positions at Marvell in which he was interested and did not focus on any substantive points of the paper or the invention, or mention that he was seeking to patent his work. (*Id.*). The email included a link to his resume and collections of work. This link is no longer active.

The final patent application was filed on April 3, 1998. (Pl. Ex. 1). Later that year, Aleksandar Kavcic received his Ph.D. and left CMU to join the faculty at Harvard University. (Docket No. 673 at 149). CMU purged Dr. Kavcic's email account sometime after he left the university. (Docket No. 858-1 at 28). CMU could not determine an exact date of when the email account was deleted but its technical witness estimated that the email account would likely have been purged "significantly under a year, most likely … three to six months" after his departure under CMU's email account maintenance policies. (*Id.*). CMU did not maintain a backup of Dr. Kavcic's emails and they could not be located on CMU's servers for purposes of this litigation. (*Id.*). Thus, CMU did not produce to Marvell any of Dr. Kavcic's emails from the period of 1996-1998. (Docket No. 803 at ¶ 6). Dr. Kavcic likewise was unable to produce any emails from his Harvard account from 1998-2000 or any personal emails from 1996-2000. (*Id.*).

CMU's '839 Patent was issued on March 13, 2001. (Pl. Ex. 1).

B. Marvell's Development of the Accused Technologies (March 2001 to March 2003) and CMU's Activities in the Same Time Period

On March 16, 2001, Gregory Burd at Marvell reported that he "started working on the Kavcic's [*sic*] model" and believed it would be "a good starting point to implement it into the simulator."[4] (Pl. Ex. 227; Docket No. 677 at 53-55). By March 23, 2001, the Kavcic detector was "running and debugged," but the team at Marvell continued to investigate other alternatives after experiencing mixed results. (Def. Ex. 1060).

Independently, Dr. Moura wrote an email to Dr. Kavcic on April 13, 2001, asking him to compile a list of possible companies which may have an interest in the '839 Patent and suggesting that they meet with the Executive Director of the DSSC, Horacio Mendez, to discuss the information. (Def. Ex. 180). Dr. Kavcic responded a few hours later, listing a number of companies he thought may be interested in the technology and providing contact information for individuals he knew at those companies, including Nersi Nazari at Marvell. (Docket No. 874 at Ex. H at 14). When Dr. Kavcic was asked if "as of April 2001, he believed that any of the companies listed [ ] may be infringing your '839 patent," he answered "I don't think I believed that." (*Id.*).

On May 16, 2001, Dr. Kavcic and Dr. Moura met with CMU's Casey Porto, Horacio Mendez, and Dr. Bob White to discuss future plans with respect to the '839 Patent.[5] (Def. Ex. 1522). Dr. Moura, a copious note taker, wrote during this meeting that they should identify companies that would be interested, "not disk manufacturers since they don't manufacture chips, except IBM, but buy from: Integr. Circuits, Marvel [*sic*], TI, Lucent, Infineon, EMC as well, and any other company that makes chips." (*Id.*). Dr. Moura further noted that "[c]hip manufacturers will make them (recording industry) [do] whatever they want them to do" and that "a viable strategy is to convince IBM and Seagate" to adopt the patented technology. (*Id.*). Dr. Moura also wrote that the CMU patent is an "optimal" solution, but "people are working on suboptimal" solutions, "adding little bells and whistles" and "people are trying to get around either because of

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4 Dr. McLaughlin testified that Mr. Burd's work on Dr. Kavcic's detection scheme eventually led to the development of the KavcicViterbi simulator. (Docket No. 677 at 53-55; Pl. Ex. 93).

5 At the time, only the '839 Patent had issued.

patent or simpler solution." (*Id.*). Following this meeting, Dr. White sent out two letters to Dr. Mark Kryder at Seagate and Thomas Albrecht at IBM Almaden in May 2001. (Def. Exs. 182; 185). The letters enclosed the '839 Patent and asked the companies to adopt the technology because CMU believed it offered advantages over current detection schemes. (*Id.*).

Dr. Kavcic later corresponded with Mr. Gregory Silvus of Seagate about the patents in October of 2001. (Def. Ex. 189). Mr. Silvus asked Dr. Kavcic if the patent claims specify whether the data dependent part happens in the trellis or in a post processor. (*Id.*). In response to this inquiry, Dr. Kavcic wrote:

> Our patent does not use the words 'noise prediction', but the circuits are the same as in Park's and Moon's 'noise prediction'. We derived the equations from the autoregressive model (it is a known fact that the autoregressive model equations and linear prediction equations are the same, so the two methods are the same). Yes, we address the 'data dependent' nature of the algorithm. We call it the 'signal dependent' nature. The data dependence is in the trellis and NOT in the post processor. Actually, the examiner had us write extra material to make sure that we do not use a post processor, which is a patent by Kelly Fitzpatrick.

(*Id.*).

By December 28, 2001, Mr. Burd had developed a media noise detector based on the "Kavcic model." (Pl. Exs. 196, 279). Less than a week later on January 3, 2002, he sent an email to Nersi Nazari and Toai Doan enclosing his "kavcicPP.pdf" write-up and informing them that "Kavcic's detection scheme is patented (assignee: Carnegie Mellon Univ., 2001)." (Pl. Ex. 280). The next day, Mr. Burd sent an email to Nersi Nazari, Toai Doan, and Ke Han again enclosing his "kavcicPP.pdf" write-up and reminding them "[a]nd of course as I mentioned earlier, Kavcic detector is also patented." (Pl. Ex. 283). Around the same time as these email communications, on January 3, 2002, Marvell filed a provisional patent application directed to its media noise processor. (Def. Ex. 1086). The provisional application referenced Kavcic's work and stated that "[e]ven though Kavcic's detector provides significant gains over conventional Viterbi detector in the presence of media noise, it is not very appealing due to implementation complexity." (Def Ex. 1086).

CMU's '180 Patent was issued on August 20, 2002. (Pl. Ex. 2). Marvell shipped its first sample chips integrating the KavcicPP method to Toshiba on August 30, 2002, to Fujitsu on October 7, 2002, and to Western Digital on October 8, 2002. (Docket No. 678 at 198, 208, 214). KavcicPP was later renamed "MNP" in January 2003 and years later the same was incorporated into Marvell's NLD technology, both of which are used on read channel chips and SOC chips (collectively, the "Accused Chips"). (Pl. Exs. 368; 823). In one of Dr. Wu's weekly emails from January 10, 2003, he stated "1. MNP enhancement: Greg and I discussed the approach of using a different noise whitening filter for each branch. **<u>It turns out to be the original structure that Kavcic proposed in his paper.</u>**" (Pl. Ex. 366 (emphasis added)). Marvell shipped sample chips containing MNP to Seagate on February 12, 2003. (Docket No. 868-14, *P-Demo 20*).

C. Evidence Regarding Potential Infringement by Marvell (Spring 2003 to August 2005)

The earliest evidence of CMU's knowledge of potential infringement of the patents-in-suit, is an entry on CMU's privilege logs from March 9, 2003, (a few days short of six years before the lawsuit was initiated), describing that Dr. Moura prepared "notes" concerning the potential infringement of the patents-in-suit at the direction of the Office of General Counsel for CMU. (Docket No. 812-1 at 5). The substance of these notes has been withheld by CMU under the attorney-client privilege; thus, there is no evidence presently before the Court that CMU had knowledge of <u>Marvell's</u> potential infringement as of that date. (*Id.*). Shortly thereafter, on April 5, 2003, Dr. Kavcic wrote to Dr. Moura:

> Today I got two more independent confirmations about what the industry is building in their next generation chips. Direct quotes:
>
> a) "They are now building chips to tackle media noise"
>
> b) "Alek, the chip vendors are building chips EXACTLY as you said in your autoregressive noise paper"
>
> I cannot tell you who told me because these people asked to remain anonymous. The companies who are building the chips are:
>
> 1) Hitachi (they may have inherited IBM's patents and license agreements, and IBM supported DSSC throughout)
> 2) Agere (they were previously Lucent, and I am not sure if they supported DSSC)
> **3) Marvell (they definitely did not support DSSC)**
> 4) ST Microelectronics (I am not sure if they are actually building signal dependent detectors, but we may have to check. However ST Microelectronics does not have a large market share anyhow)

(Def. Ex. 212 (emphasis added)). Dr. Moura responded "great" and that he would "pursue it from this end." (*Id.*). Dr. Moura then promptly engaged in privileged email communications with others at CMU regarding "possible infringement of patents-in-suit" on April 7, 9, 10, 11 and 12, 2003. (Docket No. 812-1 at 5-6).

At trial, Dr. Moura testified about his knowledge of Marvell's potentially infringing activity during the time period of 2001 until the April 5, 2003 emails:

> Q: After looking at this e-mail, Dr. Moura, you responded to Dr. Kavcic and you said that you would pursue the issue on your end. Do you see that?
> A: Yes.
> Q: Did CMU file a lawsuit against Marvell in 2003?
> A: Not in 2003, in 2009.
> Q: CMU waited six years from the date of this particular e-mail to file a lawsuit?
> A: No. I don't think so. CMU -- this is all speculation at this time, and CMU would not engage -- just look at this room -- not engage in these proceedings unless they did whatever they did to figure out that they needed to file a lawsuit. It's not something that CMU, as far as I know, takes lightly.

Q: So you're saying it was just -- you and Dr. Kavcic were just speculating that Marvell was using your patents back in 2003, is that it?
A: It's clear CMU doesn't know because we are the experts and we are talking to each other and we are figuring out what's going on. We don't have access to your documents or -- I mean Marvell's, Marvell's documents. So we hear or he hears or we hear; we speculate. And that's how you kind of start forming an opinion. It takes -- takes time; and this – these proceedings, I tell you, it's not in anyone's interest to be here. It takes time to make such a decision.
Q: So is it your opinion, sir, that back in 2003, in this e-mail, you were -- you and Dr. Kavcic were speculating that Marvell was using your patents back then?
A: We are not speculating. We are hearing rumors that these things are happening. Look at what it says: Today I got two more independent confirmations about what the industry is building in their next generation chips. Direct quotes. They are now building chips to tackle media noise. Alek, the chip vendors are building chips exactly as you said in your autoregressive noise paper. So this is people that are in the know, we assume, that are telling us. We didn't look at your circuits. You didn't -- actually, that's interesting, because more or less at this time or maybe sometime earlier we looked on the web. The web is already available at that time, as you know. And we figured there was a marketing document sometime on the web that mentioned exactly things like this and there was a paper. And then when we tried to recover those things, those things disappeared from the web.
Q: So you don't have those papers, do you?
A: Unfortunately not.
Q: So when you say here you're going to pursue it on your end, did you do any investigation of Marvell's technology back in 2003?
A: For example, this I just told you. We went looking back for your materials; they had disappeared from the web.

. . . .

Q: I'm asking you did you believe, sir, in 2003 that Marvell was using your patents?
A: Sir, in 2003 we had suspicions Marvell was -- we were hearing rumors that Marvell was using the technology.
Q: Did you believe, sir, in 2001 that Marvell was using your technology?
A: I think the rumors were much stronger in 2003 than in 2001.
Q: I'm -- did you believe in 2001 that Marvell was using your technology?
A: And I'm answering you, we heard rumors; the rumors became stronger as time went on.

Q: I'm not asking about rumors, sir. I'm asking you just for your view. Did -- did you believe in 2001 that Marvell was using your patent?
A: That's an answer that is not a yes or no. You are -- you hear things and you speculate. Is this true? Is it -- how do we know? I don't know, someone says. Do you -- do you have concrete proof? I don't. So I cannot answer to you no or yes. But I cannot say either way, yes or no. I suspect.
Q: You had a suspicion in 2001 that Marvell was using your technology.
MR. GREENSWAG: Objection, mischaracterizes his testimony.
THE WITNESS: This is nothing -- I'm hearing rumors. I have no idea what to do with the rumors. So the best thing to do is hope that they will come to their senses and license our patent that just came out.
Q: Did you -- did you believe in 2001 that anybody else was using your technology?
A: Well, to tell you the truth, I think in 2001 it may be too early because I think that's -- industry is very conservative. They kind of don't say, okay, let's switch gears. They had invested a lot in the Viterbis, so I don't think in 2001 that maybe industry jumped. I don't know. Maybe, maybe not. I have no idea.
Q: In 2001 did you do anything to investigate whether Marvell was using your technology -- strike that. In 2001 did you do anything to investigate whether Marvell was using your patent?
A: As I told you, we went -- somewhere in that time frame we approached Dr. White, and we also did a search on the web. We looked at some documents; the documents disappeared. We had -- we were -- we were trying to -- to see what's going on.
Q: And Dr. White then turned around and asked Dr. Kryder what his opinion was, and Dr. Kryder said: I don't think anybody's using the Kavcic/Moura patents; right?
A: And that was exactly because --
Q: Right, sir?
A: Can you refer back to the e-mail, please?
Q: It's Exhibit 214, sir.
A: Yeah. That's what I wanted to see. 2001. So this is exactly the point where I think industry is still not jumping into that, okay? Maybe even Marvell -- I don't know when you started copying the technology. I don't know, but maybe it's not 2001. I don't know.

(Docket No. 673 at 93-99). Dr. Kavcic explained at trial that he informed CMU of what he heard from the engineers at the Intermag conference.[6] (Docket No. 674 at 108-110).

As Dr. Moura testified, Dr. White contacted Dr. Kryder at Seagate by email and requested assistance in determining whether the patents were being utilized by anyone in the industry. (Def. Ex. 13). Dr. Kryder was seemingly contacted by CMU because he was the cofounder and former director of the DSSC, but had left to take a position at Seagate, which was a DSSC member and held a royalty-free license to CMU's patents. (Docket No. 682 at 43-44). To this end, Dr. White asked Dr. Kryder:

> You may recall a year or so ago I was trying to get our sponsors who make drives to consider pushing to Kavcic-Moura algorithm dealing with correlated media noise with their channel-chip vendors. At Intermag Alex heard rumors that several chip suppliers are in fact developing chips that employ this algorithm. Is there any way you could help us confirm these rumors? This is obviously IP that Seagate has funded and has rights to through the DSSC.

(Def. Ex. 213). Dr. Kryder testified that "what I did was to go to my expert in signal processing here in Pittsburgh, [Erozan Kurtas], and asked him to -- and, you know, give me feedback on that." (Docket No. 682 at 49). Dr. Kryder replied to Dr. White's email on April 11, 2003, stating:

> We are not aware of anyone utilizing the claims in the Kavcic-Moura patent although channel vendors may well be working in the area of designing detectors for signal dependent noise. Even before Kavcic and Moura filed their patent, there had been work by others on signal dependent noise. Hence their patent does not read on every implementation of channels that are designed for signal dependent noise. To really answer the question of whether their patent was being used or not, one would have to carefully look at the claims in their patent and then look, very carefully at how the channel chips being manufactured were implementing their detection algorithms. This is not easy to do.

[6] Dr. Kavcic also testified at trial as to the identity of the engineers, Rick Brandt, Brooks Wilson and Ara Patapoutian. (Docket No. 674 at 108).

> What you might want to do is send the patent to relevant people in each of the channel vendors making them aware of the patent and indicating that, if they are building channel chips that incorporate algorithms for signal dependent noise, they may be violating that patent, and if they are not, they may want to consider designing a chip based upon that patent. In either case, they may be interested in obtaining a license to that patent. If they are using something claimed by the patent, this may cause them to take a license, because, as I understand the law, they are liable for considerable higher damages if they knowingly use your patent after you have notified them of it.

(Def. Ex. 214). In stating that "[t]his is not easy to do," Dr. Kryder testified that he meant "[b]asically it's impossible to do because you cannot -- you cannot take apart a channel chip and understand what the algorithms are that are being processed through them." (Docket No. 682 at 50). But, there is no evidence that Dr. Kryder communicated the alleged "impossibility" of an investigation to CMU at the time of this email. Dr. White forwarded the original email from Dr. Kryder to Dr. Moura and others at CMU, opining that "this suggests we continue on the path we discussed at our meeting." (*Id.*). Dr. Moura, in turn, forwarded this email to Dr. Kavcic. (Def. Ex. 214).

Four months after Dr. Kryder's communication, CMU sent fourteen letters to several companies in August 2003, including Marvell (specifically, to Vice President Dr. Pantas Sutardja and General Counsel Matthew Gloss), Toshiba, Western Digital, Fujitsu, Samsung, Hitachi, Maxtor, Agere, Infineon, and others asking if they would be interested in licensing the '180 and '839 patents.[7] (Pl. Exs. 422; 431; Def. Exs. 225; 226; 227; 229; 230; 231; 232; 233; 234; 1573). Not all of these companies made read channel or SOC chips. (Docket No. 682 at 149-153). The "friendly letters" sent by CMU to the companies, including Marvell, stated that:

> It has come to the attention of Carnegie Mellon University ("CMU") that in recent months there has been an upsurge of

[7] By June 2003, however, Marvell had made its first volume shipment of its MNP chips to Samsung. (Docket No. 678 at 241).

> interest on the part of industry in correlation-sensitive adaptive sequence detection for signal-dependent noise and their application in data storage and retrieval using magnetic media. CMU is pleased to have been among the very first parties to have performed research in this area and has been awarded two United States patents, namely US Patent number 6,201,839 B1 and US Patent number 6,438,180 B1. I have taken the liberty of including copies of these patents along with this letter.
>
> CMU has a long history of working with industry in order to bring the benefits of its research to the public and I would be happy to work with you to negotiate a license to these patents if that would be of interest to you. It is CMU's intention to work with industrial partners such as [Marvell Semiconductor] to establish reasonable terms that allow these companies to manufacture products covered by our patents on clear and equitable terms that benefit all the parties involved.
>
> If you find the attached patents to be of interest, please feel free to contact me at the address given above so that together we can further investigate whether you would find it attractive to license CMU's proprietary technology.

(Pl. Exs. 422, 431). Agere and Infineon contacted CMU declining to license the technology; the rest, including Marvell, never responded. (*Id.*; Docket No. 826-1 at 45-48).

CMU's privilege logs[8] reflect that there were some additional communications between CMU representatives (including Mahler, Mendez, Wooldridge, Ross, and White) and the inventors during 2003 which were "prepared at the direction of CMU's Office of General Counsel in anticipation of litigation and reflecting legal advice from counsel [regarding] possible infringement of the patents-in-suit."[9] (Docket Nos. 812-1; 812-2; 812-3). As noted above, the earliest of these privileged communications is dated March 9, 2003 and is described as "notes"

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[8] The privilege logs presented by Marvell include those produced by CMU, Dr. Kavcic and K&L Gates. (Docket Nos. 812-1; 812-2; 812-3; 812-4).

[9] The substance of these communications is not before the Court because Marvell did not timely seek to compel disclosure of the communications during the discovery period and the Court denied Marvell's post-trial motion to compel and/or to conduct an *in camera* review of such documents, for reasons that are explained in this Court's February 28, 2013 Memorandum Order, which is fully incorporated herein. (Docket No. 819). The Court further notes that Marvell did not seek reconsideration of this Memorandum Order. (*See generally* Docket Report Civ. A. No. 09-290).

prepared by Dr. Moura under the direction of the Office of General Counsel.[10] (Docket No. 812-1 at 5). The other entries generally referencing communications concerning "possible infringement of the patents-in-suit" are dated in April, May, July and August of 2003. (Docket No. 812-1 at 5-8). None of the entries made during 2003 on the privilege logs reference Marvell specifically. (Docket Nos. 812-1; 812-2; 812-3; 812-4). But, Dr. Kavcic expressly stated that Marvell was potentially infringing in his April 5, 2003 email and the dates of the privileged communications between CMU representatives and the inventors certainly surround this disclosure. (Def. Ex. 212).

The following year, on July 6, 2004, Dr. Kavcic emailed Dr. Moura stating "[t]he patent – we need to put a law suit in process." (Def. Ex. 246). It appears that this email prompted a series of privileged communications between the inventors and CMU representatives about "possible infringement," but the log entries from this time period again do not mention Marvell specifically. (Docket No. 812-1 at 9-10). However, CMU admitted in its Answers to Interrogatories that "[b]y July 2004, CMU had been advised that Marvell had used a subroutine[11] named 'kavcic.c,' and that Marvell advertised to OEMs that a new Marvell chip (with an ID composed of several numbers and ending with 7500 and a letter) incorporated new technology to combat media noise, but did not include similar advertisements on its public web pages." (Docket No. 816-1 at 4). At his deposition, Dr. Kavcic testified that he learned from former Marvell employees (Peter Kou and another individual whose name he could not recall) in 2004

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[10] The Court notes that Marvell's summary of the privilege log references communications dated 1999. (Docket No. 812-1). In response, CMU has presented the affidavit of its counsel, Christopher Verdini, Esquire, which states that these entries contain typographical errors and should reflect that these communications were actually made in 2008. (Docket No. 826). Of course, the evidence appears undisputed that CMU's patents had yet to issue and Marvell did not begin to infringe or even attempt to replicate Kavcic's work until 2001.

[11] A "subroutine" is defined as "a set of computer instructions that performs a typical task, that is part of a larger computer program, and that can be used repeatedly." *See* "subroutine", Merriam-Webster, available at: http://www.merriam-webster.com/dictionary/subroutine (last visited 1/8/14).

"that Marvell has a routine in their detector with my name on it, kavcic.c."[12] (Docket No. 816-4 at 10-12; *Kavcic Depo Vol I., 7/13/10* at 213-18). Therefore, it is more than reasonable to infer that Dr. Kavcic was suggesting that CMU sue Marvell in his July 7, 2004 email. (Docket No. 246).

Around September 2004, Dr. Kavcic issued a memorandum to his review committee at Harvard discussing his research, teaching, and program building activities. In one section of his report he wrote:

> The work that characterized my Ph.D. thesis is the formulation of the optimal signal detector for the magnetic recording channel that is sensitive to intersymbol interference, the data-dependent character of the noise and signal nonlinearities. Of all my work so far, this has made the biggest impact in the magnetic recording industry. **All major read channel manufacturers (Agere, Marvell, ST-Microelectronics) utilize a form of the detector I proposed in their latest generations of read channel chips.**

(Def. Ex. 373, Docket No. 802-3 at 12 (emphasis added)). He also added that "[t]he industrial community recognizes the model to be a very valuable tool. Several researchers in industry and in academic institutions use this as the standard model for the magnetic recording channel when simulating detectors and decoders for these channels." (*Id.*). There is no evidence that this memorandum was published beyond transmission to the Harvard Review team. Nor is there any evidence that CMU or Dr. Moura ever saw this memorandum. Yet, it is of moment that Dr. Kavcic listed the same entities in this communication that he had earlier alleged were infringing his work in his April 5, 2003 email to Dr. Moura. (*See* Def. Ex. 212).

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12 Dr. Kavcic explained that he had approached these individuals in the hallway outside a meeting at Link-A-Media's Santa Clara Offices and asked them if they had any information about Marvell's read channel chip designs. (Docket No. 816-4 at 11-12; *Kavcic Depo Vol I., 7/13/10* at 212-13). He added that "one or both of the people said that they don't know much about what is going on at Marvell because Marvell keeps things compartmentalized, so that they won't reveal details of their chips to all the employees, but that only a few people got to know everything about chips." (*Id.* at 221). (Dr. Kavcic was working as a consultant at Link-A-Media at the time but concluded his consulting work with that entity by 2007. (*Id.* at 214)).

On November 11, 2004, Junya Suwanai of Fujitsu, "a customer for Marvell's read channel i.e. 5575M, 7500M," corresponded with Marvell, stating that Fujitsu had received a license offer for the CMU Patents. (Pl. Ex. 477). He wrote that "since it seems that these patents might be related to read channel, we would like to know, by the end of November, your opinion regarding relationship between CMU's Patents and the above Marvell lead [sic] channel and the specific grounds/reasons for such opinion." (*Id.*). Marvell did not respond to this communication. (Docket No. 761-5, Joint Ex. C at 12-13, *Armstrong Depo.* at 531-535). There is no evidence that CMU was involved with this communication which only appears to have come to light during discovery in this case.

CMU's privilege logs demonstrate that there were increased privileged communications among CMU representatives and the inventors during 2004 about "possible infringement of the patents-in-suit." (Docket Nos. 812-1; 812-2; 812-3; 812-4). Based on the entries contained in these records, CMU's general counsel, Mary Jo Dively, Esquire, was specifically included in this correspondence in July of 2004. (Docket No. 812-4 at 3). Further, CMU sought assistance regarding analysis of possible infringement of the patents-in-suit from outside counsel at K&L Gates, Holly Towle, Esquire,[13] in August of 2004. (*Id.*). Similar communications continued into 2005. (Docket No. 812-1 at 14-16). The first explicit reference in the privilege logs to potential infringement by Marvell is contained in an entry dated March 10, 2005, which states that Attorneys Dively and Towle engaged in an "[e]mail thread prepared in anticipation of litigation and for purposes of seeking and providing legal advice [regarding] **CMU/Marvell litigation**." (Docket No. 812-1 at 15 (emphasis added)). The privilege logs contain references to additional general communications about "possible infringement" in April, June, August and September of

[13] Ms. Towle is a partner at K&L Gates and works out of the Seattle Office.

2005 between CMU representatives, outside counsel and the inventors, but there are no additional references to Marvell in the privilege log entries in this timeframe. (*Id.* at 15-16).

D. After Issuance of Marvell's Patent (August 2005 to Filing of Complaint)

Marvell's '585 Patent, which cited the '180 and '839 Patents and Dr. Kavcic and Dr. Moura's paper as prior art, was issued on August 16, 2005. (Def. Ex. 266). At that time, Marvell's provisional patent application it had previously filed on January 3, 2002 became available for inspection at the Patent and Trademark Office. (Docket Nos. 803 at ¶ 42; 825 at ¶ 42). There is no evidence that Marvell marked its read channel chips with the '585 Patent.[14]

On January 16, 2006, the Director of CMU's Center for Technology Transfer and Enterprise Creation, Mr. Robert Wooldridge, prepared a spreadsheet titled "Highly Speculative Income Streams" listing a number of technologies owned by CMU and the speculative amounts of income which could be generated from same. (Def. Ex. 272). One entry reads "Technology: Hard Disk Head Noise Reduction; Company: Marvell; Royalties: $2,000,000; Key Hurdle: Possible Infringement; Status: We need to strategize and make a decision." (*Id.*). During trial, Mr. Wooldridge testified:

> Q: Did you write that, possible infringement?
> A: Yes.
> Q: What did you mean by that?
> A: It means that one of our researchers, one of our faculty members, at one-time had said to me, I think someone may be infringing on my patent. Nothing more.[15]

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[14] Dr. Kavcic testified that he first reviewed Marvell's '585 patent "sometime in 2006" in preparation for a publication that was written in 2007 and released in 2008. (Docket No. 674 at 220-21). Although Dr. Kavcic was no longer with CMU at the time, CMU's privilege logs reflect that he sent and received correspondence which was prepared "at the direction of CMU's Office of General Counsel in anticipation of litigation" throughout this general time period. (*See* Docket Nos. 812-1; 812-3).

[15] Despite his testimony that he was aware of "possible infringement" only from a one-time conversation with a "faculty member," the Court notes that Wooldridge was included on correspondence before the date of his spreadsheet (January 16, 2006) concerning "possible infringement of the patents-in-suit" which has been withheld as privileged in this case. (Docket No. 812-1). Of note, entries on January 3 and 4, 2006, reflect that he received emails from Carl Mahler which contained "legal advice from counsel (M. Dively, K&L Gates) re: possible infringement of patents-in-suit" and from Mary Jo Dively providing "legal advice re: potential IP suits." (Docket

(Docket No. 682 at 103). Mr. Wooldridge also testified that as of the date of his spreadsheet, CMU had not initiated any investigation to determine if Marvell was infringing or not, had not hired anyone (like Dr. McLaughlin) to conduct such investigation, and added that no one from CMU had advised Marvell of its infringement concerns. (*Id.* at 213-14). Two months later, Dr. Thomas Kailath nominated Dr. Moura for the National Academy of Engineering. (Docket No. 802-4). Of note, the nomination form lauded Dr. Moura's work in developing the Kavcic-Moura detector described in CMU's patents:

> [A]ll major read channel manufacturers are producing chips with versions of the detector. This represents the single most important invention in the development of magnetic recording read channel electronics in the 90's. Their AR media noise model is today the standard modeling tool adopted by the entire magnetic storage industry.

(*Id.*).

CMU generally claims that it performed an "evolving analysis" of the patents between 2006 and 2008, pointing to Mr. Wooldridge's deposition testimony for support. (Docket No. 826-1 at 59). But, Mr. Wooldridge clarified during his deposition that CMU had conducted only a "preliminary analysis as to whether there should be a longer conversation" about the potential infringement of the patents during this timeframe. (Docket No. 826-1 at 60, *Wooldridge Depo* at 111). Mr. Wooldridge testified as CMU's Rule 30(b)(6) designee on these issues. CMU has submitted no other evidence supporting a finding that anything more than a "preliminary analysis" was completed around this time, disclosing only in its privilege logs that there were

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No. 812-1 at 16). He was likewise involved in similar correspondence subsequent to the date of the spreadsheet. (*Id.* at 16-19). In any event, the fact that Wooldridge was copied on these emails does not wholly undermine his testimony about the extent of his knowledge of possible infringement by Marvell because he is not a lawyer and appeared to the Court that he did not seem to appreciate more complex aspects of this case as he testified. (*See* Docket No. 682). Given his demeanor and testimony, it is the Court's impression that, at the time, Wooldridge likely did not comprehend the significance of what Mahler and Dively, both lawyers, may have been telling him in their correspondence.

some continuing internal discussions among the inventors, CMU representatives and occasionally, outside counsel from K&L Gates regarding possible infringement of the patents-in-suit. (Docket No. 812-1).[16] During this same timeframe, Marvell made significant financial investments in the design and production of its NLD chips and made initial shipments of these chips to its customers in 2007. (Docket No. 678 at 242).

In 2008, Drs. Kavcic and Moura grew dissatisfied with the lack of any action taken by CMU to enforce the patents and they sought to obtain the patents from CMU through a release so that they could pursue enforcement activities against Marvell and possibly other entities believed to be infringing. (Def. Ex. 306). They contacted Astro Teller of Cerebellum Capital[17] to assist them in their pursuit of the patents. (*Id.*). In the context of these discussions, Dr. Kavcic told Mr. Teller that "[t]he reality is that CMU will be very reluctant to do anything with these patents in the future, so the only way out, in my opinion is to push for a release [to me and Dr. Moura]." (*Id.*). Subsequently, in May of 2008, Mr. Teller approached Ms. Tara Berstrand of CMU's Tech Transfer Office by email regarding the subject patents. (Def. Ex. 306). In this email, Mr. Teller recounted a conversation that he had with Dr. Moura:

> He mentioned to me recently that he and an old student of his (Alek Kavcic) filed two patents about 10 years ago that **they would like to see CMU be more active about and that it is clear CMU is not going to be more active about**. Particularly, it seems that the 6 year anniversary of putting some companies on notice that they think are the most likely infringers is coming up in about 1 year.

(*Id.* (emphasis added)). Accordingly, Mr. Teller sought a release of the patents back to the inventors in order to pursue an infringement lawsuit. (*Id.*). Ms. Berstrand replied that the

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[16] Carl Mahler was not deposed and was not called as a witness by either party. (*See* Docket No. 901 at 12, n.15).

[17] Mr. Teller knew Dr. Moura because his wife, Manuela Veloso, was his Ph.D. thesis advisor while he was a student at CMU. (Def. Ex. 306). Dr. Kavcic testified that he had no knowledge of Mr. Teller's business and only knew that he was a former student of Dr. Moura's wife. (Docket No. 673 at 103-105).

University would not permit a release because it would compromise the other licenses of the '180 and '839 Patents to DSSC members. (*Id.*). In response to this forwarded string of emails, Dr. Kavcic expressed on June 3, 2008 that he believed CMU was reluctant to do anything with these patents, affirming Mr. Teller's parallel statements to CMU in his letter. (*Id.*). Dr. Kavcic further wrote that Marvell and a number of other companies were potential infringers. (*Id.*). The inventors and Mr. Teller did not further pursue their efforts to obtain a release of the subject patents. Based on the privilege logs, Dr. Kavcic's concerns did eventually prompt CMU into increased activity concerning the potential infringement of the patents-in-suit and, on November 14, 2008, Dr. Kavcic was communicating directly with lead trial counsel, Mr. Douglas Greenswag, Esquire at K&L Gates, who was providing CMU with legal advice concerning what is described as the "CMU/Marvell Patent Litigation." (Docket No. 812-1 at 50).

E. Pre-Suit Investigation and Filing of Complaint to Present

On March 6, 2009, CMU filed this lawsuit. (Docket No. 1). In its Complaint, CMU accused Marvel of directly, indirectly, contributorily and/or by inducement infringing its '839 and '180 Patents in certain of its "read-channel integrated circuit devices" or

> products that incorporate read-channel integrated circuit devices, including but not limited to Marvell's 88c3000, 88C3100, 88C4200, 88C4300, 88C5500, 88C7500, 88C7500M, and 88i5520 series of products and/or any additional Marvell hardware and/or software components that incorporate or implement noise predictive detection including, but not limited to, pattern dependent noise prediction, signal dependent noise prediction, data dependent noise prediction, and/or branch label noise prediction, for detecting data stored on a hard-disk drive.

(Docket No. 1 at ¶¶ 15, 22). CMU admits that it was able to bring the lawsuit without having first gained access to Marvell's confidential chip designs and circuitry. (Docket No. 804 at 13). CMU has sought attorney's fees for services rendered by its counsel, K&L Gates, for the period of "late 2008 to March of 2009" in the amount of $350,000.00 under 35 U.S.C. § 284.[18] (Docket No. 811-1 at ¶ 12). K&L Gates asserts that its pre-filing investigation included the following tasks, a "detailed review of the patents in suit, file histories and related technical materials, interviews with the inventors and key CMU personnel, identification and analysis (to the extent possible) of Marvell read channel products, analysis of CMU's documents, analysis of infringement and validity issues, and preparation of and filing the Complaint." (*Id.*). This pre-filing investigation allegedly took 711.6 attorney hours to complete. (*Id.*).

The decision to file suit was made by individuals "at the top administration of the university." (Docket No. 826-1 at 60, *Wooldridge Depo* at 111-12). Then-President of CMU, Dr. Cohon, admitted that CMU never reached out to anyone at Marvell to discuss the alleged infringement of the patents before initiating this lawsuit. (Docket No. 671 at 208:10-15). In addition, Dr. Kavcic conceded at trial that he had numerous communications with Marvell representatives throughout the years but never mentioned any issues to them concerning Marvell's infringement of the patents. (Docket No. 674 at 102-03). Tellingly, Dr. Kavcic's only explanation for not discussing this matter with anyone at Marvell was that, "it's not my job to inform anything of anybody to anybody because this is property of CMU." (*Id.*). Later, he testified that it "was CMU's job to communicate [with Marvell] because CMU owned the

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[18] In support of the Motion for Attorneys' Fees, Attorney McElhiney avers as follows:

> (i) Pre-Filing Investigation and Complaint
> 10. Between late 2008 and March 2009, counsel for CMU conducted its pre-filing investigation, prepared its complaint, and performed other initial tasks.
> 11. During that phase, the time spent by certain of the timekeepers listed above was 711.6 hours. The tasks performed included detailed review of the patents in suit, file histories and related technical materials, interviews with the inventors and key CMU personnel, identification and analysis (to the extent possible) of Marvell read channel products, analysis of CMU's documents, analysis of infringement and validity issues, and preparation of and filing the Complaint.
> 12. The value of the work performed, at the rates then in effect, was approximately $350,000.

(Docket No. 811-1 at ¶¶ 10-12).

patents." (*Id.*). However, pursuant to CMU's policy, half of any proceeds that CMU realizes from the patents, including a portion of any net damages awarded to CMU in this lawsuit, are split between the inventors, Dr. Kavcic and Dr. Moura. (Docket No. 671 at 194–195).

The record is undisputed that between 2003 and 2009, Marvell made significant financial investments in its MNP technology, introduced additional lines of chips containing the MNP (including the EMNP and NLD/NLV series of chips) and sold 2.34 billion Accused Chips through July of 2012. The parties' status reports reflect that an additional 458,143,144 Accused Chips have been sold as of November 2, 2013, which consists of sales of 363,752,585 Accused Chips from July 29, 2012 to August 3, 2013 ($181,876,292.50) and 94,390,559 Accused Chips from August 4, 2013 to November 2, 2013 ($47,195,279.50). (Docket Nos. 901 at n. 136; 907). After the verdict, Marvell started to remove such technology from its chips but continues to sell products containing the patented methods because of the stage of the production of the chips in relation to Marvell's lengthy sales cycle; such infringing sales are expected to continue throughout 2014. (Docket No. 891).

F. Relevant Procedure as to Instant Motion for Judgment

Marvell raised the defense of laches in its Answer and Amended Answer, (Docket Nos. 13 at 6; 116 at ¶¶ 28, 29), but neither party filed a motion for summary judgment on the defense of laches nor a motion in limine directly challenging same. However, the Court granted a related motion in limine brought by Marvell and precluded CMU from recovering pre-suit damages for infringement of the '839 Patent based on CMU's failure to require its licensees (i.e., Seagate) to mark products containing the '839 Patent before selling hard drives containing such technology to third parties. *See Carnegie Mellon University v. Marvell Semiconductor, Ltd, et al.*, 906 F. Supp. 2d 399, 413 (W.D. Pa. 2012). Such ruling did not limit CMU from pursuing pre-suit damages as to the infringement of the '180 Patent. *Id.* Prior to trial, Marvell requested that the Court present the defense of laches to the jury on an advisory basis. The Court declined such invitation, for reasons stated in a Memorandum Order dated November 28, 2012 and deferred consideration of Marvell's laches defense until post-trial proceedings. (Docket No. 670). The jury rendered its verdict on December 26, 2012 in favor of CMU on infringement, validity, and willfulness, and awarded damages in the amount of $1,169,140,271.00. (Docket No. 762). This damages award includes pre-suit damages as to the '180 Patent only, as the Court's instructions to the jury and verdict slip expressly precluded any award of damages to CMU for pre-suit infringement of the '839 Patent. (*Id.*).

In post-trial proceedings, the parties litigated a number of issues related to the defense of laches and the Court's procedures for resolving such disputes. Of note, Marvell sought an evidentiary hearing, a request which CMU opposed and the Court denied. (Docket Nos. 778, 780, 781). The Court instead permitted the parties to present affidavits and to conduct depositions challenging the averments in same, although no depositions were conducted by the parties.[19] (Docket No. 781). Marvell also moved to compel CMU to disclose communications set forth in its privilege logs in an effort to demonstrate the date and level of CMU's knowledge of Marvell's infringement in this case. (Docket Nos. 800, 801). The Court agreed with CMU that Marvell's motion was untimely as filed outside the discovery period and denied this motion as well. (Docket Nos. 816, 819). However, as is noted above, the Court did consider the produced privilege logs in conjunction with all of the other evidence of record to determine *when* CMU had knowledge of Marvell's potential infringement and to assess the credibility of the

[19] In this regard, the Court denied Marvell's motion to file certain information under seal and a later motion for reconsideration of the initial order. (Docket Nos. 838, 856, 864).

evidence presented. The Court did not secure nor did it review the actual communications which were described in said logs.

The motion for judgment on laches has been exhaustively briefed by the parties, including their submissions of proposed findings of fact and conclusions of law and additional evidence beyond the trial record has been presented to and considered by the Court regarding this motion. (Docket Nos. 802-804; 823-826; 854; 858). Oral argument was heard on May 2, 2013. (Docket Nos. 873; 881). The Court has issued rulings resolving a number of other post-trial motions filed by the parties, (Docket No. 901), and after further reviewing all of the relevant materials before the Court and due consideration, is now prepared to address this hotly contested motion.

III. LEGAL STANDARD

It is well established that there is no explicit statute of limitations barring patent infringement claims. *A.C. Aukerman Co. v. R.L. Chaides Constr. Co*., 960 F.2d 1020, 1030 (Fed. Cir. 1992). However, 35 U.S.C. § 286 expressly limits the potential recovery of damages in a patent infringement case to a period of six years prior to the date that the infringement claim was filed. *See* 35 U.S.C. § 286 ("Except as otherwise provided by law, no recovery shall be had for any infringement committed more than six years prior to the filing of the complaint or counterclaim for infringement in the action."). Pursuant to 35 U.S.C. § 282, laches is a cognizable equitable defense to a claim of patent infringement. *Aukerman*, 960 F.2d at 1028. Under the doctrine of laches, federal courts "will not assist one who has slept upon his rights, and shows no excuse for his laches in asserting them." *Lane & Bodley Co. v. Locke*, 150 U.S. 193, 201 (1893). The laches defense is flexible in its application, and the Court must look at all of the particular facts and circumstances of each case and weigh the equities of the parties.

Aukerman, 960 F.2d at 1032 (citing *Bott v. Four Star Corp.*, 807 F.2d 1567, 1576 (Fed. Cir. 1986)). If successful, a laches defense effectively reduces the damages awarded by the jury at trial but "bars relief only for damages accrued *prior* to suit." *Gasser Chair Co., Inc. v. Infanti Chair Mfg. Corp.*, 60 F.3d 770, 773 (Fed. Cir. 1995) (emphasis added); *see also Univ. of Pittsburgh v. Varian Med. Sys., Inc.*, Civ. A. No. 08-1307, 2012 WL 952849, at *2 (W.D. Pa. Mar. 19, 2012) (Schwab, J.).

In order to prevail on the defense of laches, the defendant has the burden of proving two elements by a preponderance of the evidence: (1) unreasonable and inexcusable delay by the plaintiff in bringing suit, measured from the date the plaintiff knew or should have known of the infringement; and (2) material prejudice suffered by the defendant as a result, which may be evidentiary or economic in nature. *Gasser*, 60 F.3d at 773 (collecting cases). However, if the defendant is able to prove that the plaintiff knew or should have known of the infringement more than six years before the infringement suit was filed, these two elements are presumed and the burden shifts to plaintiff to disprove laches. *Ultimax Cement Mfg. Corp. v. CTS Cement Mfg. Corp.*, 587 F.3d 1339, 1349-50 (Fed. Cir. 2009). In either event, the application of the defense of laches "remains an equitable judgment of the trial court in light of all the circumstances." *Aukerman*, 960 F.2d at 1036. Thus, the ultimate determination of laches is committed to the sound discretion of the Court. *Id.* at 1028; *see also Wang Labs., Inc. v. Mitsubishi Elecs. Am., Inc.*, 103 F.3d 1571, 1576 (Fed. Cir. 1997).

IV. DISCUSSION

Marvell sets forth alternative arguments in support of its Motion for Judgment on Laches. (Docket Nos. 804, 854). Initially, Marvell contends that the presumption of laches applies in this case because the evidence it has presented demonstrates that CMU had constructive knowledge of its allegedly infringing actions before March 6, 2003, or more than six years prior to the filing of this lawsuit on March 6, 2009, and that CMU has failed to rebut the applicable presumption by proving that its delays in bringing the case were reasonable or that Marvell did not suffer economic or evidentiary prejudice resulting from the delays. (Docket No. 804 at 8). Alternatively, Marvell maintains that even if the presumption does not apply, it is entitled to judgment on laches because its evidence proves that CMU unreasonably delayed this litigation, causing it both economic and evidentiary prejudice. (*Id.* at 16-20). CMU opposes Marvell's Motion and argues that its damages should not be limited because laches has not been established as a matter of law. (Docket No. 823, 858). From CMU's perspective, the presumption of laches should not apply because Marvell has established that before the operative date (March 6, 2003) CMU had only, at most, heard "rumors" or "suspicions" of possible infringement of the patents by chip manufacturers and had identified Marvell as a potential licensing target. (*Id.*). CMU also argues that its delays in bringing suit, if any, were reasonable and that Marvell has suffered neither economic nor evidentiary prejudice with a sufficient causal nexus to the alleged delays. (*Id.*). Finally, CMU claims that a finding of laches in this case is inappropriate because a weighing of the equities between the parties favors its position. (*Id.*).

The Court will address the parties' arguments as to each of these issues, in turn.

A. The Presumption of Laches

The first issue in dispute between the parties is whether Marvell has demonstrated by a preponderance of the evidence that CMU had actual or constructive knowledge of Marvell's infringement of the patents prior to March 6, 2003, which would raise a presumption in favor of Marvell. (Docket Nos. 804, 823). Marvell points to various events which occurred in 1998, 2001 and 2002 in support of its efforts to invoke the presumption. (Docket No. 804). CMU contends that Marvell's evidence is both factually and legally insufficient. (Docket Nos. 823, 858).

Before directly addressing the parties' arguments on these issues, the Court notes that several general legal principles and its prior rulings in this case limit the scope of Marvell's laches defense to the extent that it seeks to invoke the presumption. To this end, the law is well-settled that the laches clock does not commence until the date that the patent in dispute issued. *See Aukerman*, 960 F.2d at 1032 ("the period does not begin prior to issuance of the patent."); *see also Pei-Herng Hor v. Ching-Wu Chu*, 699 F.3d 1331, 1335 (Fed. Cir. 2012) (citing *Aukerman*, 960 F.2d at 1032). Here, the laches clock could potentially commence at different times for the '839 and '180 Patents because they were issued on separate dates, i.e., the '839 Patent was issued on March 13, 2001 and the '180 Patent was issued on August 20, 2002. (Pl. Exs. 1; 2); *see also Meyers v. Brooks Shoe Inc.*, 912 F.2d 1459, 1462 (Fed. Cir. 1990) (holding that district court erred by "basing its decision on a single laches period for all three patents" when they were all issued at different times). However, a successful laches defense operates to bar a plaintiff from recovering pre-suit damages for infringement. *Gasser*, 60 F.3d at 773. Therefore, Marvell's laches defense can only possibly succeed with respect to claims for which CMU was awarded pre-suit damages at trial. *Id.*

At this stage of these proceedings, only the date of the issuance of the '180 Patent (August 20, 2002) is relevant because this Court previously held that CMU could not recover pre-suit damages as to the '839 Patent. *See CMU*, 906 F. Supp. 2d at 413.[20] In fact, at trial, the jury was instructed that it could not award pre-suit damages as to the '839 Patent; the verdict slip

20 In this decision, the Court held that pre-suit damages for the '839 Patent were barred because CMU failed to comply with 35 U.S.C. § 287(a) by requiring its licensees to mark the '839 Patent on products the licensees sold to third parties and *CMU*, 906 Supp. 2d at 413. As such, CMU was precluded from pursuing pre-suit damages for infringement of the '839 Patent. *Id.*

used by the jury explicitly stated that "CMU cannot collect damages from before its filing of this lawsuit on March 6, 2009 for the '839 Patent" and no such damages were awarded. (Docket No. 762). Instead, the jury ultimately determined that both the '839 Patent and '180 Patent were infringed by the accused chips and simulators, adopted CMU's damages theory which valued the infringement of both patents together, and awarded damages of $1,169,140,271.00 from Marvell's sales during the period of March 6, 2003 to July 28, 2012.[21] (*See* Docket Nos. 762; 901). All told, in order to successfully invoke the presumption, Marvell must demonstrate by a preponderance of the evidence that CMU knew or should have known of Marvell's infringement of the '180 Patent during the time period of August 20, 2002 to March 6, 2003 or a period of a little over six months. *See Aukerman*, 960 F.2d at 1037; *see also Univ. of Pittsburgh*, 2012 WL 952849, at *2 (citation omitted).

With this background, Marvell's arguments as to the applicability of the presumption are rejected by the Court because it has not pointed to any significant evidence of CMU's alleged knowledge of its infringement of the '180 Patent between August 20, 2002 and March 6, 2003. (*See* Docket No. 803). Marvell does not argue that CMU had actual knowledge of its infringement of either the '180 Patent or the '839 Patent (to the extent it remains relevant) but focuses on CMU's alleged constructive knowledge of infringement at that time. (*See* Docket No. 804 at 8). As to constructive knowledge, "[t]he plaintiff is chargeable with such knowledge as he might have obtained upon inquiry, provided the facts already known by him were such as to put upon a man of ordinary intelligence the duty of inquiry." *Advanced Cardiovascular Sys., Inc. v. Scimed Life Sys., Inc.*, 988 F.2d 1157, 1162 (Fed. Cir. 1993). On this point, the only evidence presented by Marvell during the relevant period (from August 20, 2002 to March 6, 2003)

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21 Again, the damages calculation starts on March 6, 2003 because CMU is precluded by 35 U.S.C. § 286 from claiming damages prior to that date. *See* 35 U.S.C. § 286.

consists of several entries contained in privilege logs dated in September and December of 2002. (*Id.* at ¶ 25). Upon review of same, the Court finds that none of the entries reference the '180 Patent or indicate that there was knowledge of possible infringement of the '180 Patent (or even the '839 Patent) at that time by any entity and there are no references to Marvell in any of the entries. (Docket No. 812-1 at 4-5). Indeed, the September 2002 entries reflect that CMU sought advice of outside counsel concerning possible infringement of the "B2 patent" which is not at issue in this litigation[22] and the December 2002 entries concern its receipt of legal advice about the "disk drive market" and "data storage industry." (*Id.* at 5). Accordingly, the Court holds that Marvell has failed to demonstrate by a preponderance of the evidence that the presumption of laches applies in this case. *See Aukerman*, 960 F.2d at 1032.

Before moving on, the Court alternatively recognizes that even if the pre-August 20, 2002 evidence upon which Marvell relies was deemed relevant to the defense of laches as to the infringement of the '180 Patent, it is likewise insufficient to warrant the invocation of the presumption of laches. First, the email Dr. Kavcic sent to Dr. Nazari in 1998, while he was still a graduate student at CMU and seeking potential job opportunities at Marvell, (Def. Ex. 1023), was sent <u>prior</u> to the issuance of either patent and is therefore largely immaterial to the laches inquiry. *See Aukerman*, 960 F.2d at 1032. Further, the content of that email is not sufficient to demonstrate any awareness by CMU (or Dr. Kavcic) that Marvell was developing a detector that copied his then-unpatented work. (*Id.*). Instead, the email states that Dr. Kavcic heard that "Marvell has a detector that implements some of the approaches" that he suggested during a speech and Dr. Nazari responded by denying that Marvell had "a product in line of your work,

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[22] The "B2" patent refers to U.S. Patent No. 5,693,426, titled "Magnetic recording medium with B2 structured underlayer and a cobalt magnetic layer," which was invented by Li-Lien Lee, David Lambeth and David Laughlin. (*See* Docket No. 816 at n.9). "This patent relates to magnetic storage media for use in disk drives." (*Id.*). CMU sued Fujitsu to enforce the B2 patent in 2002 and that case was resolved in 2004. *See CMU v. Fujitsu Ltd, et al.*, Civ. A. No. 02-1232 (W.D. Pa. 2002). K & L Gates represented CMU in that litigation as well. *Id.*

yet." (Def. Ex. 1611).[23] Additionally, Dr. Nazari's response was confirmed through the evidence presented at trial which demonstrated that Mr. Burd did not even begin working on the Kavcic model until March 16, 2001 and the first sample chips incorporating Kacvic's method were not delivered to Marvell's customers until August and October of 2002. (*See* Pl. Ex. 227; Docket No. 678 at 198, 208, 214). As such, CMU could not possibly have constructive knowledge of infringement which had yet to even occur. *See Aukerman*, 960 F.2d at 1032. For these reasons, the 1998 email cannot be construed as providing CMU actual or constructive knowledge of Marvell's infringement of either patent. *Id.*

Second, with respect to the evidence of CMU's asserted knowledge of potential infringement as early as May 16, 2001, following Mr. Burd's development of a detector based on Dr. Kavcic's work in March of that year, and the incorporation of same into Marvell's simulators, such evidence is likewise insufficient to trigger the presumption. To this end, the Court finds that both Dr. Moura and Dr. Kavcic credibly testified[24] that they did not know or believe Marvell was infringing in the 2001 timeframe. (Docket No. 874 at Ex. H at 14; Docket No. 673 at 93-99). As Dr. Moura convincingly explained, on May 16, 2001, CMU held a meeting to discuss licensing targets where CMU identified Marvell and commented that several

[23] The Court notes that Dr. Nazari is a former Marvell employee but he was neither called as a witness at trial nor put forth as a declarant in support of Marvell's present motion for judgment on laches. Although he was potentially subject to being used as a witness and/or declarant by both parties, the Court infers that any facts which would have been presented by Dr. Nazari on the issue of Dr. Kavcic's awareness of potential infringement around the time of these emails would not have been favorable to Marvell; otherwise, Marvell would have presented his version of these events during trial and/or post-trial proceedings. *See ID Security Systems Canada, Inc. v. Checkpoint Systems, Inc.*, 249 F. Supp. 2d 622, 678 (E.D. Pa. Mar. 28, 2003) (quoting *Grajales–Romero v. Am. Airlines, Inc.*, 194 F.3d 288, 298 (1st Cir. 1999)) ("A 'missing witness' instruction is permissible when a party fails to call a witness who is either (1) 'favorably disposed' to testify for that party, by virtue of status or relationship with the party or (2) 'peculiarly available' to that party, such as being within the party's 'exclusive control.'"); *see also Arch Ins. Co. v. Carol & Dave's Roadhouse, Inc.*, Civ. A. No. 11-801, 2013 WL 607829, at *4 (W.D. Pa. Feb. 19, 2013) (noting requirements to procure a missing witness instruction at trial of civil case). Indeed, such an adverse inference is appropriate here because Marvell had the opportunity to procure Dr. Nazari's declaration after a billion dollar judgment was entered against it but did not do so.

[24] Based on the verdict in CMU's favor, the jury obviously found Drs. Moura and Kavcic to be credible; the Court agrees that each were earnest, convincing witnesses throughout their respective testimony. *See EBC*, 2008 WL 4922107, at *4 (noting court's requirement to "assess the credibility of witnesses" under Rule 52).

companies were "trying to find ways to avoid licensing the patent" by claiming it was "complex," and by adding "bells and whistles" to suboptimal versions of detectors to try to "get around" the patent. (Def. Ex. 1522; Docket No. 673 at 92:22-24). Dr. Moura's testimony was corroborated by his notes of the meeting, which likewise reflected that the purpose of the meeting was to determine potential targets for licensing the technology and do not allege or imply that any chip manufacturer, including Marvell, was possibly infringing the '839 Patent at that time. (Def. Ex. 1522). Email correspondence between Drs. Kavcic and Moura prior to the meeting likewise reflects that the meeting focused on potential licensing targets. Further, the Court also believes that Dr. Moura credibly explained his attempt to search for web-based documents about Marvell's technology, which disappeared from cyberspace sometime after he briefly read them. (Docket No. 673 at 98). On this point, Dr. Moura clearly stated that the purpose of his Internet search was to determine how companies were developing ways to avoid licensing the '839 Patent and he was searching to find information about the products that were being developed so that they could attempt to market their "optimal solution" to these manufacturers. (*Id.*). In all, the Court holds that the awareness of the possibility that companies were trying to design around the technology in 2001 does not form a basis for constructive knowledge that Marvell was infringing the '839 Patent at that time (or the '180 Patent, which had yet to issue), because the very attempt to create a viable alternative to the patented technology likely constitutes, at most, an attempt to *avoid* infringement. *Cf. Muniauction, Inc. v. Thomson Corp.*, 532 F.3d 1318, 1328 (Fed. Cir. 2008) (direct infringement of a method claim only occurs if each step of the claimed method is actually performed).

To conclude, after carefully considering all of the parties' arguments and the evidence of record, the Court holds that Marvell has failed to carry its burden of proving that it is more likely than not that CMU knew or should have known of Marvell's infringement before March 6, 2003 or more than six years prior to the filing of this patent infringement action. *See Aukerman*, 960 F.2d at 1037. Accordingly, Marvell's Motion is denied to the extent that it requests that the presumption of laches be applied in this case and for the burden to be shifted to CMU to disprove laches.[25]

B. Laches

As the presumption of laches has not been established, in order for Marvell to succeed in its laches defense, it must affirmatively prove that CMU: (1) unreasonably delayed the filing of this litigation after becoming aware of Marvell's infringement; and (2) that such delays caused Marvell material prejudice. *See In re Katz Interactive Call Processing Patent Litigation*, 882 F. Supp. 2d 1123 (N.D. Cal. 2010) (citing *Hemstreet v. Computer Entry Sys. Corp.*, 972 F.2d 1290, 1293 (Fed. Cir. 1992), *which cited Aukerman*, 960 F.2d at 1032) ("once the presumption is burst, the defendant must affirmatively prove both elements of laches."). Naturally, the parties contest the sufficiency of Marvell's evidence as to both prongs of this test. (Docket Nos. 804, 823, 854, 858).

1. Delay

Like the disputes on the presumption, the Court's initial inquiry is to determine *when* CMU had actual or constructive knowledge of Marvell's infringement. From this date, the Court must calculate the length of the delays in bringing the suit and ultimately decide if such delays were reasonable in light of the proffered justifications for same by CMU. *See Univ. of*

[25] If the presumption of laches were to apply, CMU would then have to produce evidence sufficient to support a finding of the nonexistence of the presumed facts. In other words, the patentee must show that: (1) the delay was reasonable; (2) the defendant has suffered no material prejudice because of the delay; or (3) the defendant acted inequitably. *Univ. of Pittsburgh*, 2012 WL 952849, at *2, n.1 (citing *Aukerman*, 960 F.2d at 1029). If the patentee puts forth such evidence, the presumption evaporates and the alleged infringer must then satisfy its burden of persuasion with "actual evidence." *Aukerman*, 960 F.2d at 1037-38.

Pittsburgh, 2012 WL 952849, at *3 (citing *Wanlass v. Gen. Electric Co*., 148 F.3d 1334, 1337-38 (Fed. Cir. 1998)); *see also Aukerman*, 960 F.2d at 1037. As to the disputed date of CMU's knowledge, Marvell's position is that the evidence demonstrates that CMU had constructive knowledge of infringement in March of 2003, while CMU contends that it did not have "hard evidence" of infringement until after Marvell's '585 Patent was issued in 2005 and Dr. Kavcic (and CMU) became aware of it sometime in 2006. (Docket Nos. 804, 823).

There are no bright line rules delineating the level of constructive knowledge of an act of infringement required to trigger the laches clock because laches is an equitable defense requiring the Court to review the totality of the circumstances. *See Crown Packaging Tech., Inc. v. Rexam Bev. Can Co.*, 679 F. Supp. 2d 512, 520 (D. Del. 2010). To this end, courts have recognized that "[i]t is enough that the plaintiff has or should have 'more than a mere suspicion but less than absolute assurance of [the] alleged infringement in order to activate the laches clock." *Id.* (quoting *Rockwell Int'l Corp. v. SDL, Inc.*, 103 F. Supp. 2d 1192, 1197 (N. D. Cal. 2000)); *see also Intirtool, Ltd. v. Texar Corp.*, 369 F.3d 1289, 1297-98 (Fed. Cir. 2004) ("Although our precedent is clear that the patentee's constructive knowledge of an infringer's behavior can suffice to start the laches clock, it is equally clear that the patentee must have actual or constructive knowledge of an act of infringement that gives rise to a legal claim before that clock begins to run against the patentee."). While courts have concluded that "pervasive, open and notorious" infringement may be sufficient to demonstrate constructive knowledge, even in the absence of such widespread infringement, the law places an affirmative duty on patentees to police their rights and they are charged with a duty of inquiry when the facts known to the patentee "were such as to put upon a man of ordinary intelligence the duty of inquiry." *Wanlass* *v. General Elec. Co.*, 148 F. 3d 1334, 1338 (Fed. Cir. 1998) (citations omitted). Courts have further held that:

> If a patentee knows of the existence of a product or device that (i) embodies technology similar to that for which he holds a patent and (ii) uses that similar technology to accomplish a similar objective, he has a duty to examine the product or device more closely to ascertain whether it infringes his patent. If he shirks this duty, he does so on peril of triggering the laches period and perhaps ultimately losing his right to recover damages for the infringement.

I/P Engine, 915 F. Supp. 2d at 741-42 (quoting *Odetics, Inc. v. Storage Tech. Corp.*, 919 F. Supp. 911, 918 (E. D. Va. 1996), *on remand*, 14 F. Supp. 2d 800 (E.D. Va. 1998), *aff'd in part, rev'd in part*, 185 F.3d 1259 (Fed. Cir. 1999); *see also Crown Packaging*, 679 F. Supp. 2d at n.42 (quoting same); *St. Clair Intellectual Property Consultants*, *Inc. v. Acer, Inc.*, --- F. Supp. 2d ----, 2013 WL 3367319, at *3 (D. Del. Jul. 2, 2013). Accordingly, these cases teach that a patentee's reasonable suspicion that its patent is being infringed requires the patentee to conduct a prompt and reasonable investigation into the allegations, and the failure to timely conduct such an investigation may result in the commencement of the laches period. *See id.*

In light of the applicable standard and after carefully considering all of the evidence presented by the parties, the Court finds that Marvell has demonstrated by a preponderance of the evidence that CMU should have known about Marvell's potential infringement of the patents as of **April 5, 2003**. Because CMU initiated this lawsuit on March 6, 2009, the period of delay in this case is approximately **five years and eleven months**.

Before addressing the reasonableness (or unreasonableness) of such a lengthy delay, the Court comments on the evidence supporting its finding that CMU had reasonable suspicions of Marvell's infringement by April 5, 2003. As of that date, CMU already possessed the information from the 2001 meeting with Dr. Moura and others, which included the disclosures that Marvell was a licensing target for the '839 Patent and the inventors' beliefs that a number of companies were trying to design around the '839 Patent in order to avoid taking a license. (Def. Ex. 1522). Then, on the date in question, April 5, 2003, Dr. Kavcic emailed Dr. Moura that he received "two more independent confirmations" that their work was being infringed by chip manufacturers. (Def Ex. 212). Dr. Kavcic further explained that he was told by others that Marvell was among a number of "chip vendors [which were] building chips EXACTLY as you said in your autoregressive noise paper," which disclosed the inventions of the patents-in-suit.[26] (Def Ex. 212 (emphasis in original)). At trial, Dr. Kavcic repeatedly testified that he provided the information he received from such individuals to CMU. (Docket No. 674 at 108-110). The record further shows that after receiving this email communication, Dr. Moura, who remained at CMU, responded "great" and told Dr. Kavcic that he would "pursue it on this end." (Def. Ex. 212). Dr. Moura then passed on the information to CMU representatives (including the Technology Transfer Office and the Office of General Counsel) as is evidenced by the numerous

[26] The Court notes that the email reflects that Dr. Kavcic did not want to provide Dr. Moura with the names of the individuals who provided this information to him "because these people asked to remain anonymous." (Def. Ex. 212). During his trial testimony, however, Dr. Kavcic identified the individuals who provided the information to him as Rick Brandt, Brooks Wilson and Ara Patapoutian, but the record does not demonstrate whether Dr. Kavcic provided all of their names to CMU in 2003 or even at any time prior to his trial testimony. (Docket No. 647 at 108). CMU's Initial Disclosures, dated August 17, 2009, identify Dr. Ara Patapoutian as an individual with knowledge of "[e]arly disclosure of the inventions claimed in the patents-in-suit." (Docket No. 826-1 at 74). This document further identifies Dr. Patapoutian's address as Seagate Technology in Shrewsbury, MA. (*Id.*). Dr. Kavcic's 2004 memorandum to his Harvard Review committee notes that Patapoutian was then at Maxtor Corporation and that they had been involved in "collaborative activities" including "modeling the magnetic recording channel." (Docket No. 802-3 at 30). Dr. Kavcic and Dr. Patapoutian also co-authored an article about read channels in 2007, which was published in IEEE in 2008. (Docket No. 674 at 127-130). Neither of the other two individuals, Brandt and Wilson, were noted as potential witnesses in CMU's Initial Disclosures. (Docket No. 826-1 at 74). Further, Dr. Kavcic identified only Patapoutian during his deposition. (*See* Docket No. 858-1 at 8-9). Then, CMU mentions that he was the source of the rumors in its slide presentation in opposition to this motion, without referencing the other two individuals. (Docket Nos. 874-19 at 7 ("Dr. Patapoutian was a source of 'rumors' heard by Dr. Kavcic")). Accordingly, there is no evidence before the Court that CMU ever produced the names of all of these individuals to Marvell prior to Dr. Kavcic's disclosures at trial. However, despite Marvell's army of lawyers, it has not challenged CMU's untimely disclosure of these individuals in any fashion to this point. Nor did it seek to depose these individuals during trial or in the context of the post-trial laches proceedings. Therefore, the Court considers any objections to same by Marvell to be waived. *See* FED. R. EVID. 103(a)(1); *see also Government of The Virgin Islands v. Archibald*, 987 F.2d 180, 184 (3d Cir. 1993) ("If a party fails to object in a timely fashion, the objection is waived.").

privileged email communications in which he engaged with others at CMU regarding "possible infringement of patents-in-suit" in the following days, i.e., April 7, 9, 10, 11 and 12. (Docket No. 812-1 at 5-6).

While CMU claims that the information it possessed in April of 2003 was "speculative" and consisted only of "rumors" or "suspicions" and implies that such evidence was insufficient to establish a duty to investigate Marvell's possible infringement at that time, the Court believes that the evidence CMU and the inventors possessed as of April 5, 2003 was more than sufficient to trigger a duty requiring CMU to inquire and to investigate the potential infringement by Marvell. (Docket Nos. 823, 858). CMU's reference to "rumors," "speculation," and "suspicions" are largely reliant on Dr. White's subsequent characterization of the information he received from the inventors as "rumors" in his correspondence to Dr. Kryder, which is discussed in further detail below. (Def. Ex. 213). The inventors testified using similar terms at trial but Dr. Moura even admitted that the "rumors" of infringement were "much stronger" in 2003. (Docket No. 673 at 93-99). Additionally, CMU's privilege logs plainly establish that the inventors and CMU representatives immediately engaged in communications about "possible infringement of the patents in suit" in response to the information provided by Dr. Kavcic on April 5, 2003. (*See* Docket No. 812-1).

In any case, the applicable standard is not a subjective inquiry of how CMU perceived the information it possessed; rather, it is an objective, reasonableness standard, which looks at how a reasonably prudent patentee would act in response to the information. *Aukerman*, 960 F.2d at 1032. Here, the inventors acquired information from engineers working in the industry that Marvell was building chips "EXACTLY" as they had disclosed in their autoregressive noise paper and which was later claimed as their invention in the patents. The inventors then immediately forwarded this information to CMU, which was already aware from prior discussions in 2001 that Marvell was a potential licensing target for the technology and that chip manufacturers were trying to add "bells and whistles" to the technology in order to avoid licensing it as of that time. With this information, CMU was put on notice by the inventors, both of whom are well renowned experts in the field, that Marvell: (1) was producing computer chips that embodied technology similar to CMU's '180 and '839 Patents; and (2) that the computer chips used similar technology to accomplish a similar objective as is disclosed in the methods of the patents. *See e.g., I/P Engine,* 915 F. Supp. 2d at 741-42; *Odetics,* 919 F. Supp. at 918; *Crown Packaging*, 679 F. Supp. 2d at n.42. Because CMU had notice of these facts, the same triggered its "duty to examine the product or device more closely to ascertain whether it infringes [its] patent," and a failure to do so may result in a determination that it "should have known" of the infringement, triggering the running of the laches clock. *Id.*

The parties next dispute the reasonableness of CMU's investigation upon its receipt of this information. (Docket Nos. 804, 823, 854, 858). CMU asserts that its inquiry to Dr. Kryder at Seagate in 2003 and subsequent letters to Marvell were reasonable actions for it to take given all of the relevant facts at the time. (Docket Nos. 823, 858). CMU further contends that it could not have determined definitively whether Marvell was infringing without access to confidential source code and circuitry, which could not be reverse engineered given the nature of the technology and was maintained by Marvell in strict confidence under an asserted policy of secrecy. (*Id.*). Marvell argues that it has demonstrated by a preponderance of the evidence that CMU's investigation into this information was unreasonable because it should have asserted its infringement position directly to the company rather than resting solely on its "friendly letters." (Docket Nos. 804, 854). Marvell also adds that it would have made its chip designs and circuitry available to CMU had it requested such information and/or asserted its infringement position at the time. (*Id.*).

Based on all of the evidence of record, the Court holds that Marvell has proven by a preponderance of the evidence that CMU's cursory inquiry to Seagate in 2003 was not a reasonable investigation under the totality of the circumstances and that Marvell has demonstrated that CMU's failure to conduct a meaningful investigation at that time is sufficient to trigger the laches clock as of April 5, 2003. *See e.g., I/P Engine,* 915 F. Supp. 2d at 741-42; *Odetics,* 919 F. Supp. at 918; *Crown Packaging*, 679 F. Supp. 2d at n.42. In this regard, it is undisputed that CMU's response to the information provided by Dr. Kavcic was Dr. White's general inquiry to Dr. Kryder at Seagate on April 10, 2003 asking whether Seagate was aware if "anyone" in the industry (without mentioning Marvell specifically) was using the Kavcic/Moura algorithm. (Def. Ex. 213). Dr. Kryder responded to this inquiry the following day, on April 11, 2003, stating, among other things, that "[w]e are not aware of anyone utilizing the claims in the Kavcic-Moura patent although channel vendors may well be working in the area of designing detectors for signal dependent noise." (Def. Ex. 214). Dr. Kryder generally explained that the claims of the patent would have to be evaluated against the chips which were being manufactured to determine if the algorithm was being used and stated that this "was not easy to do." (*Id.*). He alternatively suggested that CMU send letters to companies in the industry to advise them of the patents, counsel them that they may be infringing if they are using the patented algorithm in their chip designs and to inquire if they would like to take a license on the technology. (*Id.*). Dr. Kryder also stated in this communication that his understanding of the law was such that a party put on notice of possible infringement may be liable for increased damages. (*Id.*). Of note, Dr. Kryder's response to this inquiry did not detail any analysis of whether Seagate believed that Marvell – which had already supplied Seagate samples of the Accused Chips to that point[27] – was infringing the patents, presumably because Dr. White did not identify Marvell specifically in his inquiry and downplayed the information provided by Dr. Kavcic as "rumors." (Def. Ex. 213).

Dr. Kryder's email to Dr. White was then circulated among representatives of CMU and the inventors. (Def. Ex. 214). Dr. White commented initially to the other individuals on the email chain that they should proceed as they had "previously discussed." (*Id.*). However, CMU did not act on any of Dr. Kryder's suggestions until four months later, in August of 2003, when Carl Mahler of the Technology Transfer Office sent what he termed "friendly letters" to manufacturers, including two to Marvell. (Pl. Exs. 422, 431). The "friendly letters" do not allege infringement of the patents and are best construed as marketing letters designed to notify targeted manufacturers of the patents in an apparent effort to initiate licensing negotiations regarding same. (*Id.*). It is undisputed that Marvell received such letters but did not respond to them in any fashion. Yet, Marvell's non-response is akin to the actions of the twelve (12) other companies that received these form letters from CMU and never responded to CMU. (Docket No. 826-1 at 45-48). It is likewise uncontested that CMU did not follow up with Marvell in regard to the letters. Nor did it assert that Marvell was infringing the patents until the instant lawsuit was filed on May 6, 2009, five years and eleven months after Dr. Kavcic's initial notification to CMU that the patents were being infringed by Marvell.

Looking objectively at all of the facts that CMU possessed on April 5, 2003, in sum, the Court believes that CMU did not conduct a reasonable investigation at that time because it did

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[27] Marvell sold Seagate 159,544,715 Accused Chips from March 6, 2003 to July 28, 2012. On February 12, 2003, Marvell shipped sample 88C7500M chips, which contained MNP, to Seagate; Seagate placed an MAPL Order for such chips with Marvell on August 12, 2003; and Marvell sold its one millionth unit, achieving its "design win" as to this order, in January of 2005. (Docket No. 868-14, P-Demo 20).

not investigate whether Marvell was manufacturing products which infringed the '180 Patent (or the '839 Patent), which is what the relevant caselaw teaches a reasonable patentee would do upon receipt of such information. *See e.g., I/P Engine,* 915 F. Supp. 2d at 741-42; *Odetics,* 919 F. Supp. at 918; *Crown Packaging*, 679 F. Supp. 2d at n.42. Rather, CMU largely ignored the significance of the information provided by the inventors that they believed that Marvell was manufacturing chips "EXACTLY" as claimed in the patents and then made a general inquiry to Seagate about whether it could confirm "rumors" that the technology was being used by "anyone" in the "industry." (Def. Ex. 212 (emphasis in original)). The record evidence before the Court further illustrates that CMU did not disclose to Seagate that it was Marvell that was potentially infringing; if it had, Seagate (a member of CMU's DSSC) could have potentially investigated whether any of the sample chips it was supplied by Marvell infringed the patents and would have then been put on notice to look for any such infringement in the millions of chips it later purchased from Marvell. (Def. Ex. 213). As Dr. White noted in his letter, because Seagate had funded the development of the patents through the DSSC and possessed rights to same, it would have had a strong incentive to conduct such an investigation of Marvell's chips. (*Id.*).

In addition, CMU did not even follow Dr. Kryder's sound advice, which was to notify the chip manufacturers that "if they are building channel chips that incorporate algorithms for signal dependent noise, they may be violating the patents." (Def. Ex. 214). Such an assertion would have likely provided more support for CMU's present position, but it was not made. Instead, armed with allegations of potential infringement, brought to its attention by the inventors, CMU waited approximately four months and then sent its form "friendly letters" to Marvell asking if it was interested in licensing the patents and made no assertion of an intent to enforce the patents through litigation or otherwise. (Pl. Exs. 422, 431). The use of letter communications to directly or indirectly assert infringement allegations against potential infringers or to warn entities of potential infringing activities is commonplace in intellectual property practice and often a cost effective and powerful tool to enforce patent rights. *See e.g., Matthews Int'l Corp. v. Biosafe Engineering, LLC*, Civ. A. No. 11-269, 2011 WL 4498935 (W.D. Pa. 2011), *aff'd*, 695 F.3d 1322 (Fed. Cir. 2012).

The record evidence also shows that over time, CMU continued to obtain additional information concerning Marvell's potential infringement from the inventors and other sources, but CMU did not change its position in any meaningful way vis-à-vis Marvell in response to this additional information. CMU also did not undertake a thorough and diligent investigation into the potential infringement until a few months before the lawsuit was filed, despite being a top-flight computer science and engineering University, with a Technology Transfer Office, (*see* Docket No. 901 at 9), and an active Office of General Counsel which had initiated patent litigation to enforce its patents against other potential infringers in the past.[28] (*See e.g., Carnegie Mellon University et al. v. Hoffmann-LaRoche, Inc. et al.*, 541 F. 3d 1115 (Fed. Cir. 2008); n.22, *supra* ('02 *Fujitsu* litigation); Docket No. 812-2 (describing confidential communications concerning other potential enforcement litigation against other entities)). The record also plainly demonstrates that the inventors believed that they had an infringement case against Marvell as early as April of 2003, (Def. Exs. 212, 246), and that they would periodically receive additional information confirming their beliefs and then promptly share such information with CMU, representatives of which would discuss the latest disclosures internally and with counsel but then

[28] The Court understands from presiding over these proceedings from the outset that General Counsel Mary Jo Dively, Esquire, has a background in intellectual property litigation and technology and engaged in such practice at Reed Smith prior to joining CMU in her present capacity. *See e.g.,* http://www.cmu.edu/ogc/attorneys_staff.html (last visited 1/9/14).

take no affirmative action to thoroughly investigate the alleged infringement by Marvell. (*See* Docket No. 674 at 110).

Specifically, by July of 2004, CMU had received another demand by Dr. Kavcic that a lawsuit be initiated, and was also aware from former Marvell employees that Marvell had named a "subroutine" "kavcic.c," after him and was marketing a new line of chips (7500 series) to its customers which incorporated new technology to combat media noise. (Def. Ex. 246; Docket Nos. 816-1 at 4; 816-4 at 10-12). Indeed, Dr. Kavcic was so confident in his position that his work was being used that he told his review board at Harvard that Marvell and other notable read chip manufacturers "utilize[d] a form of the detector I proposed in their latest generations of read channel chips," and noted that companies and research institutions were building simulators modeled after his work. (Def. Ex. 373). CMU intermittently consulted with K&L Gates as outside counsel around this time and the privilege logs plainly reflect that by March of 2005, it was discussing the "CMU/Marvell litigation" with K&L Gates. (Docket No. 812-1 at 15). Mavell's '585 Patent issued in 2005, citing the CMU Patents as prior art; Dr. Kavcic and CMU became aware of Marvell's '585 Patent shortly thereafter in 2006. (Def. Ex. 266; Docket Nos. 803 at ¶ 42; 825 at ¶ 42; 674 at 220-21). Later, in 2006, CMU internally estimated the potential value of Marvell's infringement of the patents at $2 million annually, although they apparently conducted this financial analysis without having first conducted any investigation of Marvell's infringement or engaging a consultant or an expert like Dr. McLaughlin to evaluate potential infringement. (Def. Ex. 272; Docket No. 682 at 103). In fact, that internal document expressly states that CMU still "need[ed] to strategize and make a decision" about whether to pursue litigation. (Def. Ex. 272).

CMU counters that it conducted an "evolving analysis of the patents" between 2006 and 2008, (Docket No. 823 at 14), but Mr. Wooldridge testified that the "evolving analysis" consisted of only "preliminary discussions" to determine if more substantive discussions should take place concerning enforcement of the patents, (Docket No. 826-1 at 60). CMU's inertia concerning the alleged infringement by Marvell continued into 2008, when the inventors attempted to obtain the patents from CMU through a release. But such efforts were rejected by CMU, prompting Dr. Kavcic[29] to comment that he did not believe that CMU was interested in enforcing the patents at all. (Def. Ex. 306). It was not until late 2008 that K&L Gates was more formally engaged to conduct the pre-suit investigation which culminated in the filing of this lawsuit in March of 2009.[30] (Docket No. 812-1 at 50; 811-1 at ¶¶ 10-12).

In this Court's opinion, CMU's failure to conduct anything more than a cursory investigation of infringement until late 2008 was unreasonable in light of all of the relevant facts and circumstances; particularly, the information known to CMU in April of 2003 that Marvell was building chips "EXACTLY" as Kavcic had disclosed in his paper and was claimed in CMU's patents and the additional information it obtained thereafter, all of which should have prompted CMU and its counsel to commence a thorough investigation of the alleged infringement at that time. (Def. Ex. 212). Further, by July 2004, CMU had more than sufficient information to conduct an investigation as to whether Marvell was *willfully infringing* the patents

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29 For his part, Dr. Kavcic testified that he and Dr. Patapoutian co-authored an article in 2007, which was published in 2008, and that in the article he "proved" how the operation of Marvell's '585 patent infringed the methods of CMU's patents. (Docket No. 674).

30 The filing of the lawsuit necessarily implies that CMU's counsel had conducted a sufficient pre-suit investigation of the facts to make the assertions contained therein in accordance with Rule 11 of the Federal Rules of Civil Procedure and that the allegations were sufficiently factually supported under the plausibility standards set forth in *Bell Atl. Corp. v. Twombly*, 550 U.S. 544 (2008) and *Ashcroft v. Iqbal*, 556 U.S. 662 (2009). The Court further discusses the Rule 11 obligations of CMU's counsel below. *See* p. 48-49, *infra*. The Court also notes that if CMU had filed its case closer in time to the commencement of the laches period in 2003, the heightened pleading standards of *Twombly* and *Iqbal* which did not become the law until 2009, would not have applied. In any event, Marvell filed an Answer to CMU's Complaint and did not challenge the sufficiency of the pleadings Rule 12(b)(6). (*See generally* Docket Report, Civ. A. No. 09-290).

because to that point it: had already put Marvell on notice of the patents through its "friendly letters"; was aware of allegations that Marvell was producing chips "EXACTLY" as claimed in the patents to combat media noise; knew how the new series of chips were named, i.e., with an ID composed of several numbers and ending with 7500 and a letter; and knew that Marvell had a subroutine in its detector named after Dr. Kavcic. (Def. Ex. 212; Docket Nos. 816-1 at 4; 816-4 at 10-12; Pl. Exs. 422, 431). Indeed, these are the core facts which serve as the basis for the willful infringement allegations CMU ultimately made in its Complaint filed against Marvell on March 6, 2009. (*See* Docket No. 1 at ¶¶ 15, 22).

Additionally, the Court finds that the delays by CMU are inexcusable, especially when considering that its own licensee and DSSC partner, Seagate, purchased in excess of 159 million chips from Marvell (between 2003 and 2012), which possessed the infringing technology, and incorporated same into hard drives which were then sold to third parties down the stream of commerce. (Docket No. 868-14, *P-Demo 20*). As the Court noted in its decision on the marking issue, CMU's license of the patents under the DSSC program required little of the licensees and did not meaningfully permit CMU to police the use of its patents by the licensees because it did not require the licensees to mark products or even advise CMU that the patents were being used. *CMU*, 906 F. Supp. 2d at 413. Under its licenses, Seagate was not affirmatively required to even inspect the chips it received from Marvell to determine if they were infringing the patents. *Id.* Accordingly, the Court believes that it was wholly unreasonable for CMU to rely on Dr. Kryder's general assertion that they were not aware of anyone using the algorithm, especially when CMU did not even advise Dr. Kryder of the entities that the inventors believed were infringing, including Marvell. (Def. Ex. 213).

Moreover, the breadth of CMU's infringement case presented at trial, which alleged that Marvell produced 2.34 billion infringing chips from 2001 until 2012 (a figure which has since been updated to include sales post-July 2012 and up to November of 2013, i.e., an additional 458,143,144 chips), is such that CMU should have known about Marvell's infringement much earlier than it contends in its papers. *See Comcast v. Finistar*, No. C-06-04206, 2008 WL 170672 at *4-6 (N.D. Cal. Jan. 17, 2008). CMU's position that the infringement was not as widespread in 2003 or 2004 and did not become "industry standard" until 2005, and "must have" for Marvell until[31] that time do not weigh in its favor because, again, CMU conducted no formal investigation into Marvell's infringement until late 2008, despite the inventors' reports of infringement in 2003 and 2004 and their various demands that a lawsuit be filed during the relevant time period. Admittedly, Marvell's sales increased exponentially over time, but the sales in 2003 and 2004 were not insignificant; rather millions of chips were sold even in this timeframe. (*See* Def. Ex. Q, *Affidavit of Dr. Sutardja* at ¶ 8, Docket No. 868 (noting Marvell's sales of 16,526,143 units in 2003; 83,031,317 units in 2004; 182,531,849 units in 2005)). In this Court's opinion, CMU had sufficient information that it should have conducted a prompt and thorough investigation of infringement much closer in time to Dr. Kavcic's reports of infringement.

[31] Dr. Bajorek testified the technology only became industry standard in 2005 and specifically denied that it was widespread in 2003. (Docket No. 678 at 113-115, 171, 226). Prior to that juncture, the SNR gains from using the infringing MNP technology were "deemed to be pretty small." (*Id.* at 114). It was after the industry moved to perpendicular recording in 2005 that "the value of MNP … really shined." (*Id.*). However, CMU had already been advised by Kavcic that Marvell was likely infringing prior to the exponential increase in sales that followed. In 2005, the hard disk drive industry moved to perpendicular recording and Marvell's infringing MNP chip was recognized as an effective tool for dealing with media noise. (*Id.* at 113-115, 171). Several Marvell emails related to the necessity of MNP/NLD technology including one on February 6, 2007, wherein Mr. Burd stated, "[w]e did not do comparison with linear Viterbi since now days [sic] the drives are dominated by media noise, and MNP or NLV is a must." (Pl. Ex. 607). Dr. Bajorek remarked that "once customers saw the gain, they enabled the technology and used it in that mode ever since." (Docket No. 678 at 114).

CMU suggests that it is improper for the Court to find constructive notice of infringement because of the complexity of Marvell's chips and the fact that Marvell kept its circuitry and chip designs confidential under an asserted policy of secrecy. (Docket Nos. 823, 854). Marvell responds with sworn affidavits by Dr. Sutarja and Dr. Wu, which state that they would have made the chip circuitry available to CMU had infringement allegations been made, as Marvell has shared such confidential information with competitors in the past and would have been more inclined to do so with a university. (Docket Nos. 802-1, 802-2). CMU claims that such evidence should be given little weight because such affidavits were submitted after a billion dollar verdict was won against Marvell at trial and the mammoth publicity the verdict received[32] that followed, and further believes that the evidence is contrary to the testimony of Dr. Wu and others, which allegedly demonstrates that Marvell would not have been so cooperative. (Docket Nos. 823, 854).

Turning first to the legal principles, the Court holds that the cases relied upon by CMU for the proposition that the inaccessibility of Marvell's chip circuitry and its asserted policy of secrecy preclude a finding of constructive notice are distinguishable from the present circumstances. (*Id.*). To this end, although there is certainly evidence that Marvell kept its designs confidential and secret to the outside world (which is a competitive advantage sought by most companies that manufacture products, e.g., Coca Cola's secret formula referenced by Dr. Wu, *see* Docket No. 709 at 61-62), CMU has not presented any evidence that the confidentiality and/or secrecy employed by Marvell actually prevented it from investigating whether Marvell was infringing, because there is no evidence that CMU undertook anything more than a cursory investigation of whether Marvell was infringing at all in the 2003 timeframe and CMU's DSSC

32 There are numerous references to the publicity of the verdict throughout the record. (*See e.g.*, Docket No. 828-4 (Marvell's Form 10-Q)).

partner and licensee Seagate had been supplied with millions of the infringing chips by Marvell at that time. (*Id.*). In contrast, the cited cases recognized that confidentiality and secrecy policies may prevent a finding of constructive notice in situations where other compelling factors are also present, including: when a private investigator was hired by the patentee and this individual was unable to determine if infringement was occurring, or not, because of the secrecy of infringement, *see Ultimax Cement Mfg. Corp. v. CTS Cement Mfg. Corp.*, 587 F.3d 1339, 1350 (Fed. Cir. 2009); and when a patentee makes direct inquiry to the infringer, which denies the infringement allegation but then continues to infringe in secret, *see Eastman Kodak Co. v. Goodyear Tire & Rubber Co.*, 114 F.3d 1547, 1559 (Fed. Cir. 1997) (noting that Goodyear denied that it was infringing upon a direct inquiry by the patentee and maintained a policy of secrecy); *see also Union Carbide Chems. & Plastics Tech. Corp.*, 2004 WL 1305849, at *19 (D. Del. Jun. 9, 2004) (noting that patentee made direct inquiry to alleged infringer, which denied any infringement at the time, and such facts coupled with secret nature of infringing activities showed objective reasonableness).

Here, CMU did not conduct an actual investigation which was thwarted by Marvell's policies and was never misled by Marvell because it simply did not respond to the "friendly" licensing letters.[33] Thus, CMU cannot validly claim that its investigation was hindered by such policies. *See Ronald A. Smith & Assocs. v. Hutchinson Tech. Inc.*, No. 01-03847, 2002 WL 34691677, at *9 (N.D. Cal. Aug. 16, 2002) ("Significantly, Smith Associates proffers no evidence to demonstrate that its investigative efforts were impeded or thwarted by Hutchinson's trade-secret policy… Smith Associates cannot now complain that it would have been denied

[33] The Court notes that the 1998 email exchange between Dr. Kavcic and Dr. Nazari at Marvell, wherein Dr. Nazari advised that Marvell was not working on his model, was not misleading because there is no evidence that Marvell was actually working on the Kavcic Model until Burd commenced same in 2001, after the '839 Patent had issued. (Def. Ex. 1023). CMU's counsel admitted as much at the motion hearing on May 2, 2013. (Docket No. 873).

confidential information or access to inspect Hutchinson's equipment since it, in fact, never attempted to secure either…"). Additionally, CMU has not presented any significant evidence that it was aware of Marvell's confidentiality and/or secrecy policies in 2003, and the trial testimony it relies on from Drs. Bajorek, McLaughlin and Kryder on these points included facts which were not known by CMU until after the lawsuit was filed. (*See* Docket No. 677 at 104-105 (Dr. McLaughlin testifying that he would "need Marvell's documents or engineers to describe – to tell you how it works, what's inside it."); *see also* Docket No. 678 at 58, 64-65 (Dr. Bajorek testifying that "it's impossible to tell from the chip what its internal wiring is. It's just no[t] humanly possible to do that in any practical or affordable way" … "[t]o really be able to understand what's inside a chip, you need to get a hold of the design documents for that chip and interview the engineers who worked on that chip. Something that cannot be done without a chip maker delivering that information to whoever wants to find out what is in the chip.")). For example, Dr. Kryder testified that it was "basically impossible" to conduct an investigation of infringement without some assistance from Marvell and its engineers, among other things. (Docket No. 682 at 50). Yet, there is no evidence that this was communicated to CMU at that time or even before the lawsuit was filed, as Dr. Kryder's letter merely advised Dr. White and CMU that "it was not easy" to conduct such an investigation. (Def. Ex. 214). Dr. Bajorek and Dr. McLaughlin testified similarly; but again, these were experts retained by CMU in the context of this litigation which was not initiated until 2009. (*See* Docket No. 677 at 104-05; *see also* Docket No. 678 at 58, 64-65).

The Court likewise agrees that CMU's admission that it filed the instant lawsuit without first obtaining access to the confidential circuitry and proprietary information undermines its position on these points. *See, e.g., Beam Laser Sys., Inc. v. Cox Commc'ns, Inc.*, 144 F. Supp. 2d

464, 470-71 (E.D. Va. 2001) (rejecting plaintiff's argument that it needed discovery of non-public information where plaintiff filed suit without such information); *I/P Engine,* 915 F. Supp. 2d at 747-48. Indeed, the pre-suit investigation conducted by its counsel from late 2008 through filing on March 6, 2009 allegedly took 711.8 attorney hours, cost $350,000.00 and was completed over a period of a few months. (Docket No. 811-1 at ¶¶ 10-12). The lawsuit was then filed by CMU's counsel alleging that Marvell was willfully infringing the patents without CMU or its attorneys having sought or gained access to Marvell's confidential and/or proprietary information. (*Id.*; *see also* Docket No. 804 at 13). By filing its Complaint, CMU's counsel was affirming that it had made the necessary pre-suit investigation to support not only its allegations of infringement but of willfulness as well and they were able to do so without reviewing any of the confidential and/or proprietary materials. *See Ultimax Cement Mfg. Co.*, 587 F.3d at 1339; *see also* FED. R. CIV. P. 11(b).[34] In any event, because CMU admits that it was able to conduct a pre-filing investigation of this magnitude, the real issue is whether CMU's decision to not commence this investigation until late 2008 was reasonable and whether the delays should be excused.

The parties also debate whether CMU was required to notify Marvell of its alleged infringement at any time prior to filing the instant lawsuit. (Docket Nos. 804, 823, 854, 858). CMU is correct that there has been no clearly established rule set forth by the Federal Circuit (or any other court) which absolutely requires a patentee to make an infringement allegation prior to bringing suit, as the Federal Circuit has emphasized "equitable flexibility" in evaluating all relevant facts of the situation. *See Hemstreet*, 972 F.2d at 1293 (quoting *Aukerman*) ("*Aukerman*

[34] By presenting a filing to the court, an attorney certifies that to the best of his or her knowledge, information, and belief formed after an inquiry reasonable under the circumstances, "the factual contentions have evidentiary support or, if specifically so identified, will likely have evidentiary support after a reasonable opportunity for further investigation or discovery." FED. R. CIV. P. 11(b)(3).

restores equitable flexibility: 'The equities may or may not require that the plaintiff communicate its reasons for delay to the defendant.'"); *see also Aukerman*, 960 F.2d at 1034 ("In the simplest or purest form of laches, there need be no direct contact between the plaintiff and the defendant from the time the plaintiff becomes aware of its claim until the suit."). As is discussed above, the proper test requires an objective inquiry into whether the patentee acted reasonably in light of all of the circumstances. *Id.* Here, it is undisputed that, despite all of the evidence of potential infringement it possessed, CMU never made such a direct inquiry of infringement to Marvell prior to filing suit. While such facts are not dispositive, they must still be considered by the Court among the totality of the circumstances to determine if CMU acted as a reasonable patentee. The failure to directly assert infringement does not weigh in CMU's favor.[35] *Id.*

Another point of contention between the parties is whether Marvell would have set aside its confidentiality and secrecy policies and granted CMU access to its chip circuitry and designs if its infringement allegations had been made directly to Marvell. (Docket Nos. 804, 823, 854, 858). Of course, this debate surrounds a completely hypothetical situation because CMU never approached Marvell with any such infringement allegations, but only sent its "friendly" letters in an effort to engage in licensing negotiations. (*See* Pl. Exs. 422; 431). Marvell has submitted the affidavit of Dr. Sehat Sutardja, wherein he states, under penalty of perjury, as follows:

> 13. If CMU had approached Marvell prior to initiating this lawsuit and requested information relevant to CMU's instant claims of infringement, Marvell would have provided sufficient information to allow CMU to evaluate its claims under a Non-Disclosure Agreement (NDA).

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[35] It would appear that CMU's strategy to forego allegations of infringement enabled it to avoid being sued for declaratory judgment in the Northern District of California, where Marvell is based and CMU operates a branch campus. *See e.g., Matthews Int'l Corp. v. Biosafe Engineering, LLC*, Civ. A. No. 11-269, 2011 WL 4498935 (W.D. Pa. 2011), *aff'd*, 695 F.3d 1322 (Fed. Cir. 2012). As a consequence, CMU was able to control the litigation by bringing the infringement suit here in its home forum and later successfully defended Marvell's motion to transfer the case to the Northern District of California, which was denied by the Court. (*See* Docket No. 54).

> 14. While engaging in licensing discussions with other companies, Marvell has presented information regarding the operation of Marvell's products. I have reviewed several sets of slide presentations that Marvell shared in 2009 with its competitor Freescale, labeled "Subject to Fed. R. Evid. 408" and "*CONTAINS CONFIDENTIAL MARVELL INFORMATION*," because the slides include confidential information regarding the operation of Marvell's products and the particular accused circuitry. Of course, Marvell would have been more inclined to share confidential information with a university, as opposed to a competitor. Because of this, I would have approved the sharing of confidential information regarding our circuitry with CMU under an appropriate NDA.

(Docket No. 802-1 at ¶¶ 13-14). CMU cites evidence from the trial record in an effort to undermine these statements, but has pointed to no evidence which directly counters the facts that Marvell actually shared its confidential circuit designs with a competitor under a pre-litigation non-disclosure agreement ("NDA") or the assertion that Marvell would be more willing to enter into such an NDA with a university rather than a competitor. (*See e.g.*, Docket No. 707 at 95-96 (Dr. Sutardja responding affirmatively that Marvell wants to keep its chip designs secrets and shields such designs from its customers); Docket No. 709 at 61-64 (Wu testifying); *Depo of Burd 6/10/10* at 428-429). CMU opposed Marvell's request for a hearing on its laches defense and also declined the Court's invitation to depose Dr. Sutardja and Dr. Wu concerning the facts set forth in their affidavits. (Docket Nos. 778, 780, 781). As such, CMU has not directly challenged the affiants on these facts, despite opportunities for cross-examination.

Overall, the Court agrees with CMU's general assertions that the post-trial affidavits should be viewed with some skepticism, but the Court does not believe that the credibility of Dr. Sutardja's statements in same have been fully undermined and finds that Marvell would have likely been amenable to entering into an NDA with CMU if it had been approached at some point between 2003 and 2009. (Docket No. 802-1 at ¶¶ 13-14). But, again, CMU did not make any direct infringement allegations or request that it be granted access to Marvell's confidential circuit designs prior to filing the lawsuit. *See Smith & Assoc.*, 2002 WL 34691677, at *9.

CMU further posits that the delays were reasonable because the decision to file suit needed to be made by individuals at the top of the university's administration and the same required careful deliberation about a matter outside of its core competencies. (Docket Nos. 823, 858). Nevertheless, courts have held that a corporate entity's strategic indecision of whether to file a lawsuit due to corporate bureaucracy and management changes is not sufficient to demonstrate that the entity acted as a reasonably prudent patentee, *see I/P Engine*, 915 F. Supp. 2d at 741-42 (strategic indecision by Lycos caused by ownership and management changes not sufficient), and the fact that an investigation is potentially expensive or complicated is likewise not sufficient to make lengthy delays reasonable, *see St. Clair Intellectual Property Consultants*, 2013 WL 3367319, at *3 (rejecting position that "efforts were made to conduct the analysis and the type of analysis was expensive, time-consuming, required particular expertise, and was heavily reliant upon the public availability of information on the design of computer components and the particular implementations of those components by computer manufacturers"). Given this precedent, the Court does not believe that CMU's status as a non-profit university engaged in matters outside the scope of its core competencies (i.e., educating students and conducting research) which was faced with a potential complex and expensive investigation of Marvell's infringement, suffices to demonstrate reasonableness here. *Id.* To the contrary, throughout this case CMU has touted its DSSC program, through which it partners with industry leaders such as Seagate, and within which Drs. Kavcic and Moura developed the instant technology, as an important part of its mission. (Docket No. 678 at 25, 27, 41-44). CMU operates a Technology Transfer Office and owns a substantial portfolio of patents. (Def. Ex. 272). Moreover, CMU has enforced its patent rights through litigation in the past, including the suit brought against Fujitsu in this jurisdiction to enforce the B2 Patent, using some of the same attorneys who appear in this litigation as counsel in that case. *See CMU v. Fujitsu Ltd, et al.*, Civ. A. No. 02-1232 (W.D. Pa. 2002).

In any event, having presided over this matter from the outset, and after considering all of the evidence on these issues, the Court believes that the delays in filing suit were more likely than not attributable to a strategy by CMU to: (1) send out the "friendly letters" in order to notify Marvell of the patents[36]; (2) avoid the front-end costs (financial and administrative) associated with investigating the possible infringement of the patents and litigation of same at that early juncture; and (3) "wait and see" how Marvell's chips performed in the marketplace prior to making the ultimate value judgment of whether pursuit of the instant lawsuit was economically viable.[37] The record also demonstrates that CMU was unwilling to invest the $350,000 it ultimately paid to K&L Gates for a pre-suit investigation until after Marvell's products became wildly successful between 2003 and 2008 and it had become the market leader, with approximately a 60% market share. (Docket Nos. 707 at 122; 811-1 at ¶¶ 10-12). Up to that point, CMU was "pennywise and pound foolish" because it was only willing to commit limited internal resources and seek free information from Seagate in response to its general inquiry. These sources provided CMU with inaccurate information concerning both whether the patents were being infringed (i.e., Dr. Kryder's assertion that he was not aware that "anyone" in the industry was using the patented methods in 2003) and the potential value of such infringement (i.e., Mr. Wooldridge's "highly speculative estimate" of the value of the infringement at $2

[36] As Dr. Kryder advised Dr. White in his letter, by notifying Marvell of the patents, CMU preserved a potential claim for willful infringement and possible treble damages. (Def. Ex. 213).

[37] As the Court has commented on several occasions, it also appears that CMU was perhaps more interested in Marvell supporting its DSSC and/or its efforts to expand its branch campus in Silicon Valley. In fact, at various stages the Court suggested such partnership in an effort to resolve this dispute.

million annually in 2006, a figure which pales in comparison to Ms. Lawton's later valuation and the jury's verdict). (Def. Exs. 213; 272). It was CMU's decision to pursue these avenues for information, and it relied on same to its own detriment. Simply put, CMU should have done more to timely investigate the infringement allegations, and its failure to act reasonably leaves its pre-suit damages award vulnerable to a well-supported laches defense.

CMU points out that certain courts have recognized that a four year delay between the patentee's receipt of actionable information and the filing of an infringement lawsuit is not *per se* unreasonable. *See e.g., IXYS Corp. v. Advanced Power Technology, Inc.*, 321 F. Supp. 2d 1156, 1163 (N.D. Ca. Jun 16, 2004) (citing cases). Marvell counters that other courts have found that laches bars damages for delays of even shorter time periods, such as two or three years. *See e.g., Altech Controls Corp. v. E.I.L. Instruments, Inc.*, 33 F. Supp. 2d 546, 554 (S.D. Tex. 1998) (delay of approximately two years and three months); *Odetics*, 919 F. Supp. at 923-24 (delay of three years). The Court acknowledges that other courts have reached various conclusions about the length of the delays needed to establish laches after analyzing the facts in individual cases but reiterates that the delay in this case of <u>five years and eleven months</u> was nearly long enough to invoke the presumption of laches, *cf. Altech Controls Corp. v. Eli Instruments, Inc.*, 8 F. App'x 941, 951 (Fed. Cir. 2001) (upholding the district court's grant of laches when "[t]he delay in filing suit was five years and ten months, only two months shy of the six-year presumptive period."), and its decision that CMU's delays during this time period were unreasonable and inexcusable was reached after conducting a fact intensive inquiry concerning CMU's failure to act in this case rather than the adoption of any *per se* rules.

In sum, after carefully considering all of the facts in the record, the Court holds that Marvell has proven by a preponderance of the evidence that CMU's delays in filing this lawsuit were unreasonable and inexcusable under the first prong of the laches analysis. *See Aukerman*, 960 F.2d at 1032.

2. Material Prejudice

The Court now turns to the contested issue of whether Marvell has proven by a preponderance of the evidence that it was materially prejudiced by such delays. (Docket Nos. 804, 823, 858, 858). Material prejudice may be shown on the grounds of economic or evidentiary prejudice. *Aukerman*, 960 F.2d at 1033. Marvell alleges that it has presented sufficient evidence as to both of these forms of prejudice, and the Court will evaluate the parties' positions as to each type of prejudice, in turn.

a. Evidentiary Prejudice

With respect to evidentiary prejudice, Marvell argues that CMU's delays caused the loss of potentially favorable documents from the inventors Dr. Moura and Dr. Kavcic, the fading of memories of witnesses, including the patent prosecution attorney, Jonathan Parks, Esquire, as well as the death of one of its experts, Dr. Jack Wolf, who would have testified as to his opinion that CMU's patents were invalid. (Docket No. 804 at 20-22). CMU counters that Marvell has not met its burden to demonstrate prejudice because the cited evidentiary losses are too general and concern immaterial matters. (Docket Nos. 823, 858). CMU further maintains that Marvell has failed to demonstrate a sufficient nexus between the unavailable evidence and the ability to defend, because Marvell could have further developed the record during discovery. (*Id.*).

It is well-settled that "[c]onclusory statements that there are missing witnesses, that witnesses' memories have lessened, and that there is missing documentary evidence, are not sufficient" to establish evidentiary prejudice. *Meyers v. Asics Corp.*, 974 F.2d 1304, 1308 (Fed. Cir. 1992). Instead, the infringer must point to specific evidence that was unavailable to it and demonstrate a nexus between such evidence and how its absence hindered its ability to defend the lawsuit or prove a separate claim. *Id.*; *see also Hearing Components, Inc. v. Shure Inc*., 600 F.3d 1357, 1376, 94 U.S.P.Q.2d 1385 (Fed. Cir. 2010) ("Regarding evidentiary prejudice, Shure asserts that because of the delay in suit, evidence of further delay to prove the laches defense itself was lost. … But evidentiary prejudice must consist of some separate disadvantage resulting from the delay, such as loss of records, unavailability of evidence, etc., that prevents a party from proving a separate claim or defense."). As noted in *Aukerman*, the infringer must show that the missing evidence prevented it from presenting a "full and fair defense on the merits," "thereby undermining the court's ability to judge the facts." *Aukerman*, 960 F.2d at 1033.

Here, Marvell has pointed to specific evidence that it was unable to present at trial to defend CMU's infringement claims and/or to submit in support of its invalidity defenses. Specifically, CMU did not produce Dr. Moura's notebooks from the time period between 1996 and 2000 and Dr. Moura admitted that these notebooks were either discarded due to the passage of time or were lost when he had moved offices. (Docket No. 673 at 121-122). Additionally, Dr. Kavcic did not produce any emails from his CMU/Harvard or personal accounts during 1996-2000 regarding his work on his media-noise detector as these materials could not be recovered. (Docket No. 803 at ¶ 6). Further, the prosecution attorney, Mr. Parks, could not recall basic facts about the patents by the time his deposition was taken during the pendency of this case.[38] (*Id.*). Finally, one of Marvell's invalidity expert witnesses, Dr. Jack K. Wolf, passed away following a battle with cancer on May 12, 2011 at the age of 76. (Docket No. 220 at Ex. 9).

[38] Marvell also argues that it was prejudiced because certain other witnesses, including Dr. Kryder and Mr. Wooldridge, were unable to recall certain facts, a position which CMU also contests. (Docket Nos. 804, 823, 854, 858). The Court need not address these issues given its finding that the other evidence cited by Marvell did cause it to be prejudiced.

In opposition, CMU cites the facts that Dr. Kavcic's 1998 email to Dr. Nazari at Marvell about his GLOBECOM 98 paper was included in the record (although not produced by Kavcic) and that several emails from Dr. Moura in the same time period were likewise included. (Docket No. 826-1, Pl. Exs. 3-6). CMU also avers that Dr. Kavcic's emails while he was at CMU would have been purged in the normal course a few months after he earned his Ph.D and that there is no evidence of record that any other emails on these issues existed. (Docket Nos. 823, 858). Nonetheless, CMU has not supported its assertions with any evidence such as affidavits from the inventors assuring the Court that there were no relevant emails, or notes in Dr. Moura's notebooks that could have been discovered. (*Id.*). CMU failed to even respond to Mr. Parks' inability to recall information about the prosecution of the patents. (*Id.*). CMU contests Marvell's claim of prejudice due to the death of Dr. Wolf because his opinions about the "tap weight theory" were rejected by the Court at summary judgment and it presented the testimony of well-qualified experts in the field at trial, such as Dr. Proakis and Dr. Blahut and its own Dr. Wu. (*Id.*). CMU also posits that Marvell could have cured any prejudice it may have encountered by taking depositions of additional potential witnesses who were disclosed by CMU during discovery.[39] (*Id.*).

In this Court's opinion, Marvell has demonstrated by a preponderance of the evidence that it was prejudiced by the lack of such evidence and that the absence of same hindered its ability to defend the case, particularly with respect to its affirmative defense of invalidity. *See Meyers*, 974 F.2d at 1308. At the outset, the Court agrees with Marvell that CMU overreaches in its position that Marvell must be able to absolutely demonstrate that the missing evidence would

[39] The Court generally agrees that there were more than a few individuals who should have been deposed by both sides, including, among others, Attorney Mahler and the informants who provided information to Dr. Kavcic. But it does not appear that deposing any of these potential witnesses could have filled the gaps in the missing evidence from Dr. Moura's notebooks or the inventors' emails.

have changed the outcome of this case. The Court does not believe that the relevant standard is so taxing, but requires that the infringer show that it was disadvantaged in proving its case by the lack of evidence, s*ee Hearing Components*, 600 F.3d at 1376, "thereby undermining the court's ability to judge the facts," *Aukerman*, 960 F.2d at 1033. Marvell has met this burden.

The Federal Circuit has recognized that evidence which is lost due to an *infringer's* operation of its own standard business practices to destroy materials after a certain period of time can be sufficient to demonstrate evidentiary prejudice. *See Wanlass*, 148 F.3d at 1340 (holding that infringer's destruction of evidence under its own standard business practices, among other things, helped to demonstrate evidentiary prejudice); *see also Altech Controls Corp. v. Eil Instruments, Inc.*, 8 F. App'x 941, 951 (Fed. Cir. 2001) ("EIL presented evidence of evidentiary prejudice because it has a policy of shredding invoices after five years."). Accordingly, it reasonably follows that a *patentee's* destruction of evidence under its own policies or otherwise which may have been relevant to the defense but is now unavailable can likewise support a finding of evidentiary prejudice. *Id.* Here, the inventors' missing documents from the 1996-2000 timeframe were never in Marvell's custody or control and it was CMU's duty to preserve[40] such evidence in its possession (and to instruct the inventors to retain and preserve such information in their possession) in the event that CMU sought to litigate its patents. Further, the inventors have a financial stake in the patents and this litigation. (Docket No. 671 at 194-195). They were aware of suspicions of companies "trying to design around" the patents in 2001 and were very much pushing CMU to pursue litigation of the patents as early as 2003. (Docket No. 673 at 93-99). Not only should CMU have done more to investigate the infringement allegations around that time, but it also should have taken affirmative steps to preserve evidence. *See*

[40] "The duty to preserve evidence begins when litigation is pending or reasonably foreseeable." *Micron Tech., Inc. v. Rambus, Inc.*, 645 F.3d 1311, 1320 (Fed. Cir. 2011) (quotation omitted). Litigation may be reasonably foreseeable if, among other facts, the patentee has "knowledge of likely infringing activity by particular parties." *Id.*

Micron Tech., Inc. v. Rambus, Inc., 645 F.3d 1311, 1320 (Fed. Cir. 2011). Further, despite Marvell's production of evidence in support of its claim of material prejudice, CMU has not presented *any* evidence of steps that were taken to preserve such evidence during the laches period of 2003 to 2009. (*See* Docket Nos. 823, 858).

It is also more than reasonable for the Court to infer that there were likely relevant emails from Dr. Kavcic and Dr. Moura that were never discovered or produced by CMU from the 1996-2000 timeframe. The record is replete with emails from both Dr. Moura and Dr. Kavcic after 2000 and up until trial, and they both obviously communicated by email quite often about the patents given their scientific backgrounds. (*See e.g.*, Def. Ex. 189 (the "Silvus" email)). Plus, the inventors have not disavowed the existence of any such relevant communications, despite the Court's invitation to both parties to present affidavits as to this Motion. (*See* Docket No. 781). Dr. Moura also admitted that his notebooks from that time period could have contained information about the methods which were ultimately patented. (Docket No. 673 at 121-122). CMU acknowledges that it purged Dr. Kavcic's emails after he moved on to Harvard, but could only estimate that they were likely destroyed within three to six months of his departure (in 1998 or 1999) and could not determine if backup files had been created and/or when any such backup files were destroyed.[41] *Cf. Artic Cat, Inc. v. Injection Research Specialists, Inc.*, 362 F. Supp. 2d 1113, 1122 (D. Minn. 2005) (finding an "inventor notebook" among missing evidence supporting determination of evidentiary prejudice). Likewise, Dr. Moura did not provide any evidence as to the timeframe in which he lost his notebooks. (Docket No. 673 at 121-122). Nor

[41] The Court seriously questions why CMU would treat Dr. Kavcic's email account under its standard policy requiring it to be purged in the manner that it does for any other student or staff member of the university. (Docket No. 858-1 at 28). Dr. Kavcic was not an undergraduate student or typical staff member; he was a Ph.D candidate conducting cutting-edge research under the DSSC and joined with Dr. Moura to create an invention about complex technology. (Docket No. 673 at 42, 149). In fact, CMU had filed patent applications in 1998 for the technology before Dr. Kavcic left CMU for Harvard. (Pl. Ex. 1; Docket No. 673 at 149). It certainly should have taken steps to preserve his emails, at least those with respect to this invention.

has CMU presented any evidence concerning when Dr. Kavcic's personal and/or Harvard emails from 1996-2000 were lost and/or destroyed. (Docket Nos. 823, 854). Thus, the precise content of the documents which were lost and/or destroyed by Drs. Kavcic and Moura is unknown, through no fault of Marvell, and it is more likely than not that the missing evidence could have been recovered during the laches period (from 2003 to 2009) had CMU more timely sought to enforce its rights in this case. *Aukerman*, 960 F.2d at 1033. Therefore, a sufficient nexus between the lost evidence and the delays has been established. *Id.*

The Court next finds that any emails from the inventors and Dr. Moura's notes during the period of the invention (1996-2000) may have been relevant to Marvell's invalidity defenses of obviousness and anticipation in light of the Worstell Patent. (Docket Nos. 13, 116). Likewise any evidence which could have been provided by Mr. Parks as the patent prosecution attorney and the expert testimony of Dr. Wolf may have been relevant to these defenses. As the Court recounted in its Memorandum Opinion of September 23, 2013, both parties presented expert testimony on such issues (Dr. McLaughlin on behalf of CMU and Dr. Proakis and Dr. Blahut on behalf of Marvell), and relied upon documents such as those that are described above as well as evidence from the prosecution of the patents. (Docket No. 901). While Dr. Proakis and Dr. Blahut ably substituted for Dr. Wolf,[42] making his absence less prejudicial, the other missing evidence could have been persuasive evidence that the jury may have considered during their deliberations.

Drs. Kavcic and Moura testified at length during trial about their creation of the patented methods and their credibility was squarely at issue such that any of these missing documents

[42] The Court also notes that Marvell could have made greater efforts to secure a trial deposition of Dr. Wolf prior to his unfortunate passing. *See* FED. R. CIV. P. 30(b)(3) ("testimony may be recorded by audio, audiovisual, or stenographic means."). However, Dr. Wolf's passing in May of 2011 was well before the close of expert discovery in April of 2012.

could have been used for cross-examination. *See Aukerman*, 960 F.2d at 1035 ("our experience, which appellant invokes, has been that testimonial evidence is frequently critical to invalidity defenses."). Mr. Parks was not even called as a witness at trial, presumably because of his inability to provide anything of substance during his deposition, which was taken on July 21, 2010, (*see* Docket No. 854-5), while courts have recognized that evidence from patent prosecution attorneys is typically highly relevant to invalidity defenses. *See Thomas v. Echostar Satellite L.L.C.*, 2006 WL 3751319 at *3-4 (W.D.N.C. Dec. 19, 2006). Here, the privilege logs produced by CMU disclose that Mr. Parks was with K&L Gates (and its predecessor) from at least 1997 until 2007. (Docket Nos. 812-2). In addition, CMU has withheld privileged communications between its representatives and Parks, who was allegedly providing legal advice to CMU concerning the maintenance of the '180 Patent during the laches period and as late as April, August and November of 2005. (*See* Docket No. 812-2 at 10-11). Obviously, had CMU proceeded with this litigation in a more timely fashion, Mr. Parks' testimony could have had an impact on this case, but like the missing emails and notebooks, this Court is unable to judge the substance of such unknowns. *See Aukerman*, 960 F.2d at 1033.

For these reasons, the Court holds that Marvell has sufficiently demonstrated by a preponderance of the evidence that CMU's delays in this case caused it evidentiary prejudice.

b. Economic Prejudice

With respect to economic prejudice, Marvell claims that CMU's delays in bringing this lawsuit have corresponded to its substantial monetary investments in its infringing MNP technology and the integration of same into its EMNP and NLD/NLV lines of chips, which were developed at later points in time during the laches period. (Docket Nos. 804, 854). Marvell also cites the significant capital investments which were made to support these very successful product lines, including an exponential increase in employees and the overall size of its operations. (*Id.*). CMU argues in opposition that Marvell's investments in the infringing technologies resulted from its own decisions to capitalize on business opportunities and that it has not demonstrated an appropriate nexus between the financial investments it made and CMU's delays in filing suit. (Docket Nos. 823, 858).

The Federal Circuit has held that economic prejudice "is likely to be a slippery issue to resolve" but it may exist "where a defendant and possibly others will suffer the loss of monetary investments or incur damages which likely would have been prevented by earlier suit." *Aukerman*, 960 F.2d at 1033. "It is not enough that the alleged infringer changed his position-i.e., invested in production of the allegedly infringing device." *Hemstreet*, 972 F.2d at 1294 (citing *Aukerman*, 960 F.2d at 1033). "A nexus must be shown between the patentee's delay in filing suit and the expenditures; the alleged infringer must change his position 'because of and as a result of the delay,'" *State Contracting & Eng'g Corp. v. Condotte Am., Inc.*, 346 F.3d 1057, 1066 (Fed. Cir. 2003) (quoting *Hemstreet*, 972 F.2d at 1294 and citing *Gasser Chair*, 60 F.3d at 775), and "not simply [make] a business decision to capitalize on a market opportunity," *Hemstreet*, 972 F.2d at 1294. To this end, "the infringer must prove that the change in economic position would not have occurred had the patentee sued earlier." *Gasser Chair*, 60 F.3d at 775. However, "[a]n alleged infringer need not show economic prejudice due to *reliance upon* the patentee's delay." *Crown Packaging*, 679 F. Supp. 2d at 526 (citing *Meyers*, 974 F.2d at 1308).

In this Court's estimation, Marvell has met its initial burden to demonstrate that it made significant capital investments in its MNP, EMNP and NLD/NLV lines of chips after CMU knew or should have known of Marvell's infringement in April of 2003. *Id.* Marvell has submitted uncontroverted evidence that it would not have invested so heavily in the post-MNP product lines or moved them into production if CMU had timely made infringement allegations or filed its lawsuit prior to 2007. (Docket No. 802-1 at ¶¶ 16-18). In this regard, the parties do not generally dispute that Marvell invested millions in research and development of its MNP technology starting before the laches period of 2003 and continuing into the laches period. Marvell then incorporated such technology into new product lines in later years, i.e., its EMNP and NLD/NLV lines of chips, the first of which were not shipped to customers until 2007. Overall, Marvell's revenues from the sale of infringing chips grew exponentially from 2001 to 2009. (Docket Nos. 802-2 at ¶ 20; 802-1 at ¶¶ 6-9). The uncontested evidence also shows that Marvell has invested considerably in human capital as it has expanded from only 735 employees in 2001 to 7,200 as of February 11, 2013, as well as incurred millions in expenses in research and development, marketing and general administrative expenses. (*Id.* at ¶¶ 7, 8). The record further demonstrates that Marvell's overall business aside from the sales of infringing chips has had significant revenue increases during this time period with exceptional financial gains which parallel the increases in chip revenues but are attributable to Marvell's other business units. (Docket No. 868-17, Def. Ex. Q at ¶ 10). Accordingly, there is sufficient evidence in the record to conclude that Marvell made capital investments in excess of the judgment in this case.

The main contested issue between the parties is whether Marvell has established a sufficient *nexus* between these capital expenditures and CMU's delays during the laches period. *See State Contracting*, 346 F.3d at 1066. Both parties have referred the Court to numerous decisions from the Federal Circuit and lower courts addressing the evaluation of economic prejudice in various factual circumstances, all of which the Court has reviewed and considered.[43]

[43] *See e.g., State Contracting*, 346 F.3d at 1066; *Hearing Components*, 600 F.3d at 1376; *Gasser*, 60 F.3d at 775; *Meyers*, 974 F.2d at 1308; *Humanscale Corp. v. CompX Int'l Inc.*, Civ. A. No. 09-cv-86, 2010 WL 3222411 at * 13 (E.D. Va. Aug. 16, 2010); *Aukerman*, 960 F.2d at 1033; *Lautzenhiser Techs., LLC v. Sunrise Med. HHG, Inc.*, 752 F. Supp. 2d 988, 1004 (S.D. Ind. 2010).

(*See* Docket Nos. 804, 823, 854, 858). Ultimately, the Court believes that there are no cases that are directly on all fours with the facts of the instant case, and after considering the totality of the circumstances, Marvell has not demonstrated a sufficient nexus between its capital expenditures and CMU's delays. *See State Contracting*, 346 F.3d at 1066.

The Federal Circuit has recognized a fine distinction between an infringer's burden to demonstrate prejudice which *resulted from the delays*, as is required to demonstrate laches, and its burden to demonstrate prejudice *in reliance upon the delays*, which is not required as to laches (but is necessary to prove a defense of equitable estoppel, which is not at issue here). *Meyers*, 974 F.2d at 1309, n.1. To this end, the Federal Circuit has noted that:

> An infringer can build a plant entirely unaware of the patent. As a result of infringement, the infringer may be unable to use the facility. Although harmed, the infringer could not show reliance on the patentee's conduct. To show reliance, the infringer must have had a relationship or communication with the plaintiff which lulls the infringer into a sense of security in going ahead with building the plant.

Id. (quoting *Aukerman*, 960 F.2d at 1043). "In this case, defendants need not show that they relied on [the patentee's] delay to establish laches. However, they must show that the prejudice they suffered resulted from the delay." *Id.* While specific proof of an infringer's reliance upon the delays is not required, several courts have found that an infringer's implied reliance on a patentee's silence after an initial threat of infringement, which is denied by the patentee, may be sufficient to prove a nexus, reasoning that the lack of any follow-up by the patentee essentially connoted an acceptance of the infringer's denials, creating a reasonable inference that the patentee had abandoned its infringement claims. *See e.g., Aukerman*, 960 F.2d at 1034 ("Where there has been contact or a relationship between the parties during the delay period which may give rise to an inference that the plaintiff has abandoned its claim against the defendant, the facts may lend themselves to analysis under … laches."). However, even in these instances, the evidence may be deemed insufficient if the infringer takes a non-infringement position which it maintains throughout the case. *See e.g., Hemstreet*, 972 F.2d at 1294 (holding that infringer "apparently made a deliberate business decision to ignore that warning, and to proceed as if nothing had occurred" undermining assertion of laches). It is also noteworthy that many of the other cases cited by the parties[44] similarly involve a period of either prior litigation between the parties and/or several communications concerning potential infringement of specific products among representatives of both sides.

In this case, the evidence demonstrates that the only pre-litigation communications between the parties were the "friendly" letters sent by CMU in August of 2003 which did not allege that Marvell was infringing. (Pl. Exs. 422, 431). Importantly, Marvell was already aware of the patents well before its C.T.O. and General Counsel received these communications and there is no evidence that anyone at Marvell (including the executives in charge of Marvell's technology and legal departments to whom the letters were addressed) ever read or considered these communications in any fashion, despite Mr. Burd's raising a red flag on at least two occasions. (Docket No. 901; *see also* Pl Exs. 280, 283). As such, Marvell did not evaluate the business and/or legal risk associated with its production of chips containing the infringing technology in response to the letters. (*Id.*). Marvell failed to do so despite its knowledge of the importance of patent rights as is exemplified in its corporate policy articulated by Alan Armstrong, Vice President of Marketing, Storage Business Group, which required infringement allegations to be reviewed by the Legal Department, (Docket No. 761 at Jt. Ex. C at 294-295), and its promotion of patent acquisitions by the firm with vigor. Because there is no evidence that

[44] *See e.g., Gasser*, 60 F.3d at 775 (prior negotiations between parties); *Ronald A. Smith & Assoc.*, 2002 WL 34691677 at *2-3 (prior infringement allegations); *Eastman Kodak*, 114 F. 3d at 1559 (pre-suit assertion of infringement by patentee and denial of same by alleged infringer).

anyone at Marvell even read the letters, there is likewise no evidence that Marvell changed its course as a result of the letters or did so later because of CMU's lack of any follow-up. Thus, the message from CMU remained the same throughout the laches period, i.e., if Marvell was interested in licensing the patents, on equitable terms to be negotiated between the parties, it should contact CMU's Technology Transfer Office.[45] (Pl. Exs. 422, 431).

There is likewise no evidence of any changes associated with Marvell's own position vis-à-vis the patents throughout this litigation. The record demonstrates that Marvell was essentially aware of the patents upon their issuance (in 2001 for the '839 Patent and in 2002 for the '180 Patent), as is plainly evident through internal email communications by Burd and others, and Marvell's references to the patents in its provisional patent application in January of 2003 and its later application and award of the '585 Patent. (Pl. Exs. 280, 283; Def. Exs. 266, 1086). Marvell stated in its provisional patent application that Dr. Kavcic's model was too complex to implement, and claimed a suboptimal version of same, facts which laid the groundwork for its non-infringement defense at trial, i.e., the patented methods were too complex. (Def. Ex. 1086). However, both this Court and the jury have found that this was not a reasonable defense (neither subjectively reasonable nor objectively reasonable) given Dr. Wu's later communications which plainly stated that the MNP "**turns out to be the original structure that Kavcic proposed in his paper**," (Pl. Ex. 366), and other significant evidence demonstrating that Marvell knowingly copied and infringed the technology, which the Court has outlined in its September 23, 2013 decision. (*See* Docket No. 901). Additionally, there is no evidence that Marvell even read or considered the letter from Fujitsu which requested an opinion as to how its chips operated with respect to CMU's patents. (Docket No. 901; Pl. Ex. 474). Again, even if it had, the most

45 In addition, even if Marvell had read and considered the letters, the only reasonable inference that could be implied by CMU's lack of follow-up would be that it was no longer interested in negotiating a license with Marvell.

reasonable inference from the evidence of record was that Marvell would have advised Fujitsu that it was not infringing because its products embodied a "suboptimal" solution to CMU's patents, as that was Marvell's theme at trial.

To be clear, Marvell has submitted some evidence which courts have recognized may be sufficient to lay the groundwork for a well-supported laches defense. (*See* Docket Nos. 802-1; 802-2). In this regard, the Court has considered the affidavits of Dr. Sutardja and Dr. Wu, who both affirm, under penalty of perjury, that the company would not have continued investing resources into developing the infringing technologies if CMU had filed suit between 2001 and 2007 or otherwise notified Marvell of its intent to enforce its patents against Marvell. (Docket Nos. 802-1 at ¶ 15; 802-2 at ¶ 20). Further, Dr. Sutardja and Dr. Wu each cite numerous possible alternative non-infringing products that Marvell allegedly would have invested in if CMU had raised its infringement concerns earlier during the laches period, and the Court does not dispute that Marvell could have changed its chips to implement one of these other technologies. (*Id.*). Even accepting these assertions at face value, the affidavits do not go far enough because neither Dr. Sutardja nor Dr. Wu make any real attempt to explain Marvell's decision to continue producing chips containing the infringing technology <u>after</u> the lawsuit was filed and up to the present. (*Id.*). At most, Dr. Wu avers that it was too expensive to remove the infringing technologies from the chips after they were embedded in Marvell's product lines because of its lengthy sales cycle, among other things. (Docket No. 802-2 at ¶ 26). Dr. Wu also states that the infringing technology is unnecessary to the performance of its NLD chips given its development of iterative coding, (*id.* at ¶ 21), but neither he nor Dr. Sutardja offer any evidence as to why Marvell decided to continue to include the infringing technology in the millions of

NLD chips that Marvell has sold from the date the lawsuit was filed until the present. (Docket Nos. 802-1; 802-2).

In short, Marvell's decision to continue production despite this infringement action demonstrates Marvell's apparent acceptance of the business and legal risks associated with same and further illustrates that it would not have changed its production schedule or declined to make the capital investments if the infringement lawsuit was initiated earlier. *See e.g., State Contracting*, 346 F.3d at 1067 (evidence that accused infringer would not have ceased infringing activities had the lawsuit been filed earlier counters the argument for economic prejudice); *Meyers*, 912 F.2d at 1463 (delay in filing suit does not result in prejudice when the evidence indicates that the accused infringer would have continued its activity regardless). At most, Marvell has shown that its exposure to a judgment for its infringement has grown substantially (along with its sales and revenues from the infringing chips) during the laches period and that it simultaneously made significant capital expenditures in order to support its expanding business. The same is not sufficient under Federal Circuit precedent to establish a nexus. *See Hemstreet*, 972 F.2d at 1294 ("The change must be because of and as a result of the delay, not simply a business decision to capitalize on a market opportunity.").

For these reasons, Marvell has not demonstrated a sufficient nexus between its capital expenditures and CMU's delays in this case. *Id.* Accordingly, the Court finds that Marvell has not met its burden to demonstrate economic prejudice.

3. Conclusion as to General Laches Elements

Based on the foregoing, the Court holds that Marvell has presented sufficient evidence to prove the necessary elements of its laches defense by a preponderance of the evidence, i.e., that CMU unreasonably and inexcusably delayed filing this lawsuit for a period of five years and eleven months and that Marvell sustained evidentiary prejudice as a result. *See Aukerman*, 960 F.2d at 1033. However, Marvell has not demonstrated that it has suffered economic prejudice as a result of CMU's delays. *See Hemstreet*, 972 F.2d at 1294.

C. Equitable Considerations

The last dispute for the Court to resolve is whether the Court should decline to exercise its discretion to find laches and bar pre-suit damages for the infringement of the '180 Patent after weighing all of the equities between the parties. (Docket Nos. 804, 823, 854, 858). CMU argues that a finding of laches would be improper in this case because of Marvell's unclean hands[46] resulting from its conscious and deliberate copying of the infringing technology for more than a decade. (Docket Nos. 823, 858). Marvell advocates that the finding of willful infringement in this case is insufficient to defeat its laches defense. (Docket No. 854).

"Ultimately, the establishment of the factors of undue delay and prejudice […] does not mandate recognition of a laches defense in every case. Laches remains an equitable judgment of the trial court in light of all circumstances." *Crown Packaging*, 679 F. Supp. 2d at 521 (citation omitted). "A patentee may […] defeat a laches defense if the infringer 'has engaged in *particularly egregious conduct* which would change the equities *significantly* in plaintiff's favor.'" *Aukerman*, 960 F.2d at 1033 (quoting *Bott*, 807 F.2d at 1576)) (emphases added). Courts have recognized that a finding of willful infringement is not, by itself, sufficiently egregious conduct to defeat a well-supported laches defense. *Odetics, Inv. v. Storage Technology Corp.*, 14 F. Supp. 2d 800, 806 (E.D. Va. 1998) ("A mere showing of inequitable conduct on the part of the infringer, however, does not suffice to negate the effect of laches.").

[46] In this context, the doctrine of unclean hands precludes application of laches if it is demonstrated that the defendant has engaged in "'particularly egregious conduct which would change the equities significantly in plaintiff's favor.'" *Serdarevic v. Advanced Medical Optics, Inc.*, 532 F.3d 1352, 1361 (Fed. Cir. 2008) (quoting *Aukerman*, 960 F.3d at 1038).

Further, "[c]onscious copying may be such a factor weighing against the defendant, whereas ignorance or a good faith belief in the merits of a defense may tilt matters in its favor." *Aukerman*, 960 F.2d at 1033. The Court may also look to other factors such as: (1) the defendant's pre-litigation conduct; (2) public policy considerations;[47] and, (3) the findings of the jury. *Univ. of Pittsburgh*, 2012 WL 952849, at *5-6.

After carefully considering all of the parties' arguments and the evidence of record, the Court finds that the equities clearly favor CMU, which acted negligently in delaying to enforce its patents against Marvell, rather than Marvell, which copied CMU's patents consciously and deliberately for an entire decade. *See Aukerman*, 960 F.2d at 1033. Indeed, Marvell's knowing infringement of CMU's patents is precisely the type of egregious misconduct which the Federal Circuit has recognized should significantly tip the scales of justice in favor of a patentee and defeat an otherwise well-supported laches defense. *See e.g., Gasser, 60 F.3d at 775; Bott*, 807 F.2d at 1576; *Aukerman*, 960 F.2d at 1044.

It is true that the Court has stated on the record numerous times that CMU's delays were not fair to Marvell in the general sense, and CMU is not without fault for its unreasonable and inexcusable delays. CMU certainly had the financial wherewithal to invest in an earlier investigation of the infringement allegations that Drs. Moura and Kavcic brought to its attention and should have done so, not only to protect its own patent rights, but to defend the millions of dollars of donations, public research grants and corporate awards which funded the DSSC and the research and development of these patents in the first instance. (Docket No. 901 at 10). However, this Court does not believe that the record demonstrates that CMU engaged in

[47] The Court notes that, as is discussed in its prior decision on the JMOLs, the DSSC was established as an interdisciplinary center at CMU, funding long-term research and development through federal grants derived from taxpayer dollars, university investments and corporate sponsorships. (*See* Docket No. 901 at 10). Marvell was never a member of the DSSC and, thus, made no contributions to the technology developed by Dr. Kavcic and Dr. Moura. (*Id.*). Rather, Marvell copied the technology for its own use and has profited greatly for over a decade.

predatory behavior by secretly "lying in wait" to build a billion dollar damages case, as Marvell suggests. *See Aukerman*, 960 F.2d at 1033 ("a patentee may [not] intentionally lie silently in wait watching damages escalate."). In fact, the evidence shows the opposite, i.e., that CMU did not fully appreciate either the value of the patented methods or the extent of Marvell's infringement because it did not conduct a timely and thorough investigation of the inventors' allegations against Marvell from the outset. *See* § IV.B., *supra*. CMU could be best described as naïve, timid or "gun shy" and apparently avoided raising the specter of litigation with Marvell in its initial correspondence and lack of follow-up, possibly because it viewed Marvell as a potential supporter of its research efforts or employer for its students rather than litigation target. The record also shows that CMU treated the potential infringement lawsuit against Marvell as a non-core function and focused its efforts on its core competencies of educating students, conducting research, soliciting donations and the like. But, CMU never misled Marvell nor has it engaged in any fraudulent or illegal conduct. *Id.* At most, CMU acted negligently by failing to diligently pursue its rights and by failing to retain and preserve all of the potential evidence in this case. *Id.*

For its part, Marvell seeks to invoke this Court's equitable power to set aside a portion of the jury's sizable damages award, but it comes before the Court with unclean hands after having engaged in deliberate and sustained copying of the patented methods throughout the entire laches period and up to the present. *See e.g., Gasser*, 60 F.3d at 775*; Bott*, 807 F.2d at 1576; *Aukerman*, 960 F.2d at 1044. In this Court's view, Marvell's '585 Patent claiming a suboptimal method to CMU's patents was merely a "smoke screen" designed to mask its true infringing conduct from the outside world, i.e., its use of "the original structure that Kavcic proposed" in the MNP enhancement and all of its other infringing products. (Pl. Ex. 366). Marvell was fully aware of

CMU's Patents at all times and proceeded to develop such technology, without changing its behavior in any way after being notified of the patented methods by Mr. Burd, CMU, and Fujitsu. (Pl. Exs. 280, 283, 368, 366, 422, 431, 477, 823; Def. Exs. 373, 1086). Further, the evidentiary prejudice to Marvell was not so significant as to outweigh its willful conduct. Nor was its claimed economic prejudice so severe as to justify finding laches. *See* § IV.C.b.2, *supra*. In all, the fundamental tenets of equity demand that Marvell should bear the risk of loss for its egregious and illegal behavior. *See Aukerman*, 960 F.2d at 1044.

Finally, the Court also finds that public policy considerations weigh against application of laches because granting the defense in this case would reward Marvell for its claimed ignorance of the notifications by CMU and the request for an opinion by Fujitsu, and its following silence. Such a decision would likely encourage infringers to avoid responding to these types of routine communications. Public policy (as exemplified in Rule 1 of the Federal Rules of Civil Procedure and this Court's ADR Practices and Procedures) promotes the parties' pre-litigation resolution of disputes through negotiations on equitable terms, as CMU suggested in its initial letters to Marvell.[48] At the same time, because the record does not support a finding that CMU deliberately sat on the sidelines in an effort to build a billion dollar damages case against Marvell, the Court does not believe that patentees will read this decision as promoting a lack of diligence in pursuing viable patent infringement claims. Instead, patentees should understand that their pre-suit conduct will be highly scrutinized by courts in light of *Aukerman* and related precedent, and that they are expected to act responsibly toward prospective infringers.

48 Indeed, nearly 97% of all civil cases settle at some point during litigation. Settlement efforts directed at this matter have been unsuccessful to date. With the parties' agreement, former Magistrate Judge Infante attempted to mediate this case twice, (Docket Nos. 236; 315); the Court held a lengthy settlement conference immediately before trial, (Docket No. 641); and the Court ordered the parties to Court-annexed mediation twice: once during trial, before the verdict and once before the hearing on post-trial motions. (Docket Nos. 734; 872).

Accordingly, the Court denies Marvell's defense of laches after weighing all of the evidence and the equities in this case.

V. CONCLUSION

"He who seeks equity must do equity." *Aukerman*, 960 F.2d at 1038 (citation omitted). Marvell has not acted equitably toward CMU and the Court declines to endorse its conscious copying of CMU's patented methods by sustaining its defense of laches and limiting the jury's pre-suit damages award for its infringement of the '180 Patent. Therefore, for the aforementioned reasons, Marvell's Motion for Judgment on Laches [802] is denied.

s/Nora Barry Fischer
Nora Barry Fischer
United States District Judge

Date: January 14, 2014

cc/ecf: All counsel of record

U.S. Patent No. 6,201,839

(A439-59)

US006201839B1

(12) **United States Patent**
Kavcic et al.

(10) **Patent No.: US 6,201,839 B1**
(45) **Date of Patent: Mar. 13, 2001**

(54) **METHOD AND APPARATUS FOR CORRELATION-SENSITIVE ADAPTIVE SEQUENCE DETECTION**

(75) Inventors: **Aleksandar Kavcic; Jose M. F. Moura**, both of Pittsburgh, PA (US)

(73) Assignee: **Carnegie Mellon University**, Pittsburgh, PA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/055,003**

(22) Filed: **Apr. 3, 1998**

Related U.S. Application Data

(60) Provisional application No. 60/046,006, filed on May 9, 1997.

(51) **Int. Cl.**[7] **H03D 1/00**

(52) **U.S. Cl.** **375/341**; 714/796

(58) **Field of Search** 375/262, 265, 375/285, 340, 341, 343, 348; 714/791, 792, 793, 794, 795, 796, 719, 716, 722

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,689,532 *	11/1997	Fitzpatrick	375/341
5,737,342 *	4/1998	Ziperovich	714/736
5,781,590 *	7/1998	Shiokawa et al.	375/341
5,784,415 *	7/1998	Chevillat et al.	375/341
5,844,946 *	12/1998	Nagayasu	375/341
5,856,983 *	1/1999	Okazaki	371/21.4
5,862,192 *	1/1999	Huszar et al.	375/347
5,914,988 *	6/1999	Hu et al.	375/341
5,920,599 *	7/1999	Igarashi	375/341
5,937,020 *	8/1999	Hase et al.	375/376
5,970,091 *	10/1999	Nishida et al.	375/231
5,978,426 *	11/1999	Glover et al.	375/376

OTHER PUBLICATIONS

Nakagawa et al., "A Study on Detection Methods of NRZ Recording", IEEE Trans. On Magnetics, vol. MAG–16, No. 1, pp. 104–10, Jan. 1980.

Chevillat et al., "Noise–Predictive Partial–Response Equalizers and Applications," IEEE ICC '92 Conference Record, pp. 942–47, Jun. 1992.

Zeng et al., "Modified Viterbi Algorithm for Jitter–dominant $1-D^2$ Channel," IEEE Trans. On Magnetics, vol. 28, No. 5, pp. 2895–97, Sep. 1992.

Lee et al., "Performance Analysis of the Modified Maximum Likelihood Sequence Detector in the Presence of Data–dependent Noise", Proceedings of the 26th Asilomar Conference, pp. 961–64, Oct. 1992.

Zayad et al., "Comparison of Equalization & Detection for Very High–Density Magnetic Recording," IEEE Intermag Conference, Apr. 1997.

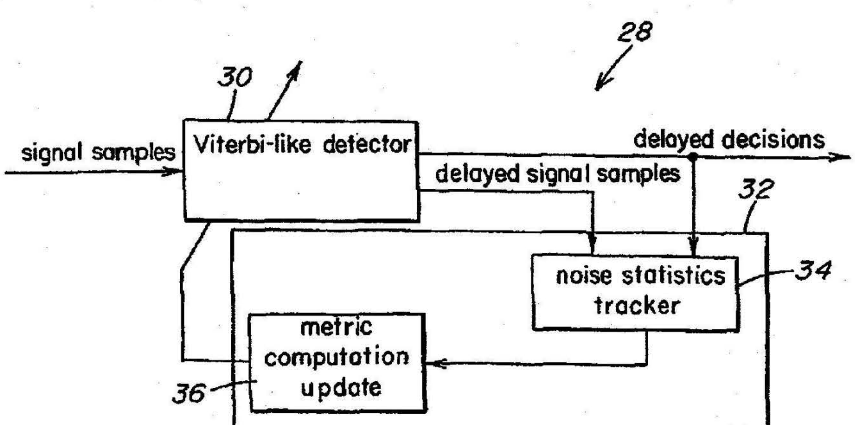
* cited by examiner

Primary Examiner—Chi H. Pham
Assistant Examiner—Emmanuel Bayard
(74) *Attorney, Agent, or Firm*—Kirkpatrick & Lockhart LLP

(57) **ABSTRACT**

The present invention is directed to a method of determining branch metric values for branches of a trellis for a Viterbi-like detector. The method includes the step of selecting a branch metric function for each of the branches at a certain time index. The method also includes the step of applying the selected function to a plurality of time variant signal samples to determine the metric values.

28 Claims, 10 Drawing Sheets



PLAINTIFF'S TRIAL EXHIBIT
P-1

Exhibit 5
Witness
Date
Rptr.
AKF

FIG. 1

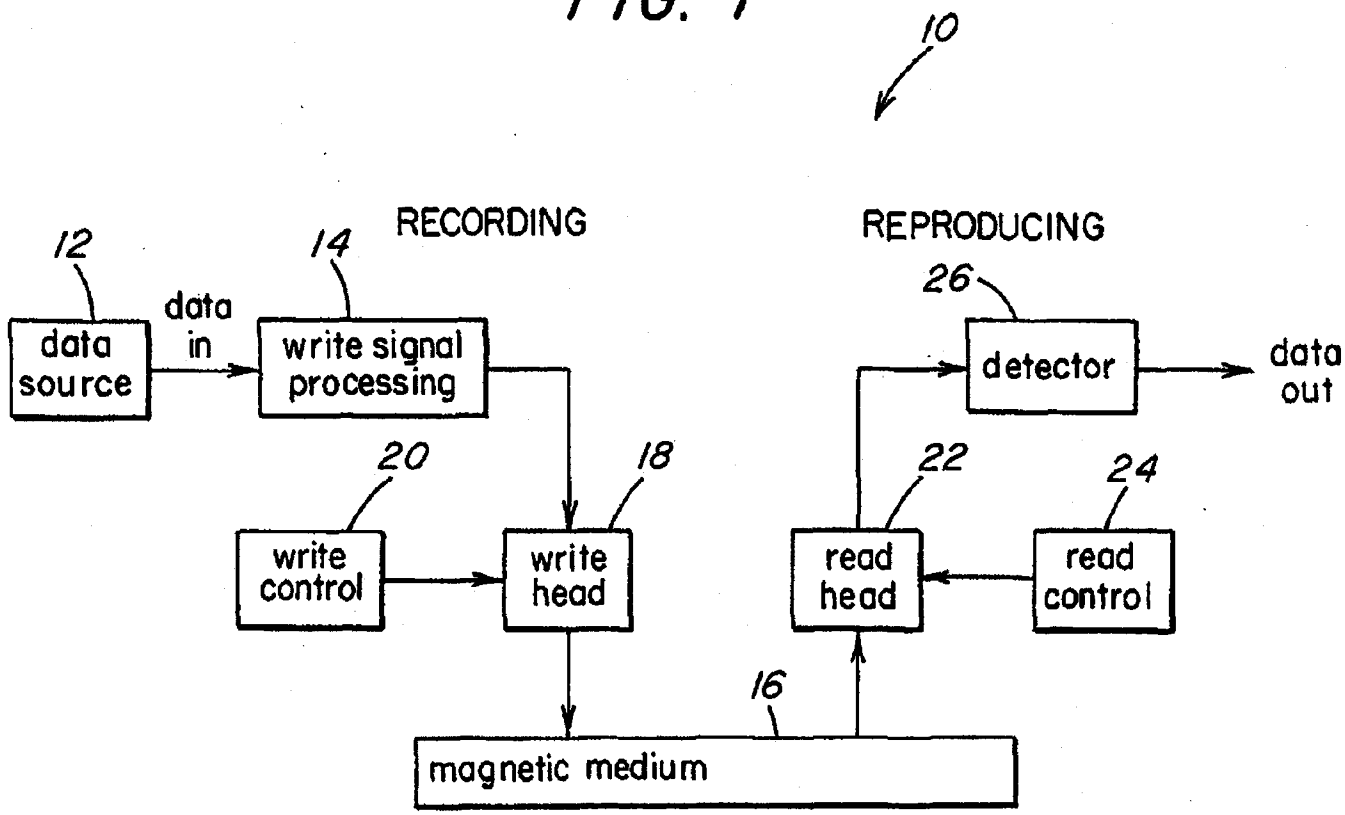

10
RECORDING
REPRODUCING
12
data source
data in
14
write signal processing
20
write control
18
write head
16
magnetic medium
22
read head
24
read control
26
detector
data out

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FIG. 2

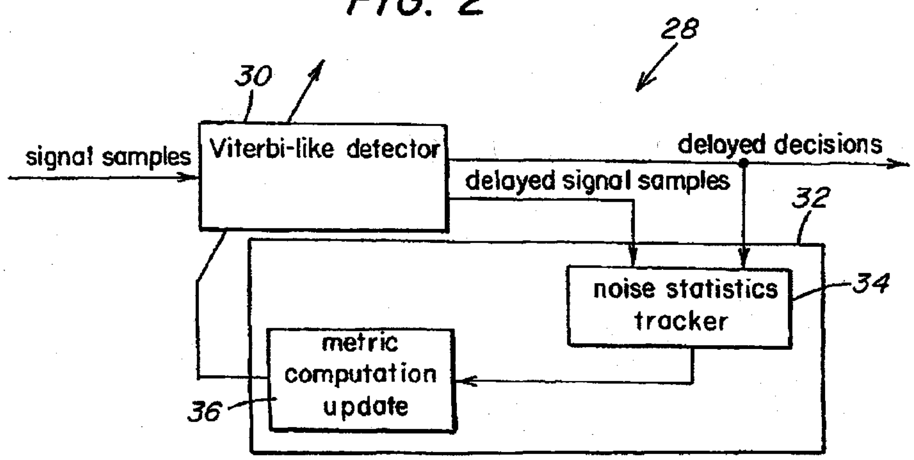


FIG. 3A

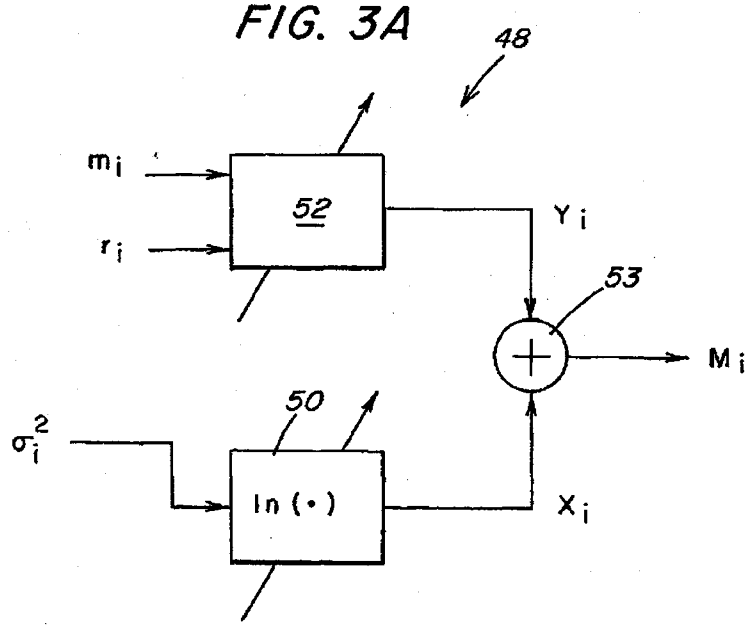


FIG. 3

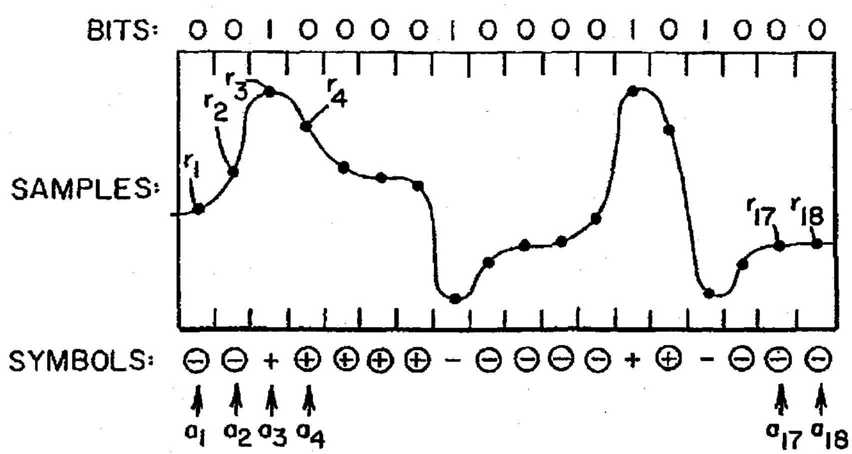

BITS: 0 0 1 0 0 0 0 1 0 0 0 0 1 0 1 0 0 0
SAMPLES:
r_1 r_2 r_3 r_4 r_{17} r_{18}
SYMBOLS: ⊖ ⊖ + ⊕ ⊕ ⊕ ⊕ − ⊖ ⊖ ⊖ ⊖ + ⊕ − ⊖ ⊖ ⊖
a_1 a_2 a_3 a_4 a_{17} a_{18}

FIG. 4

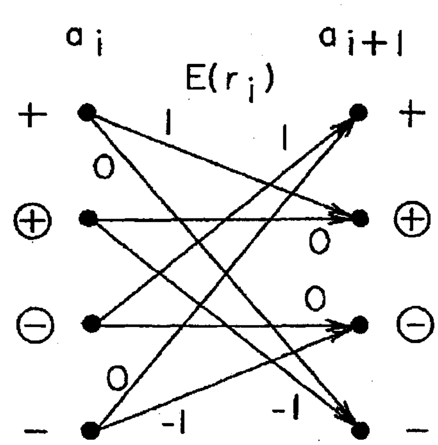
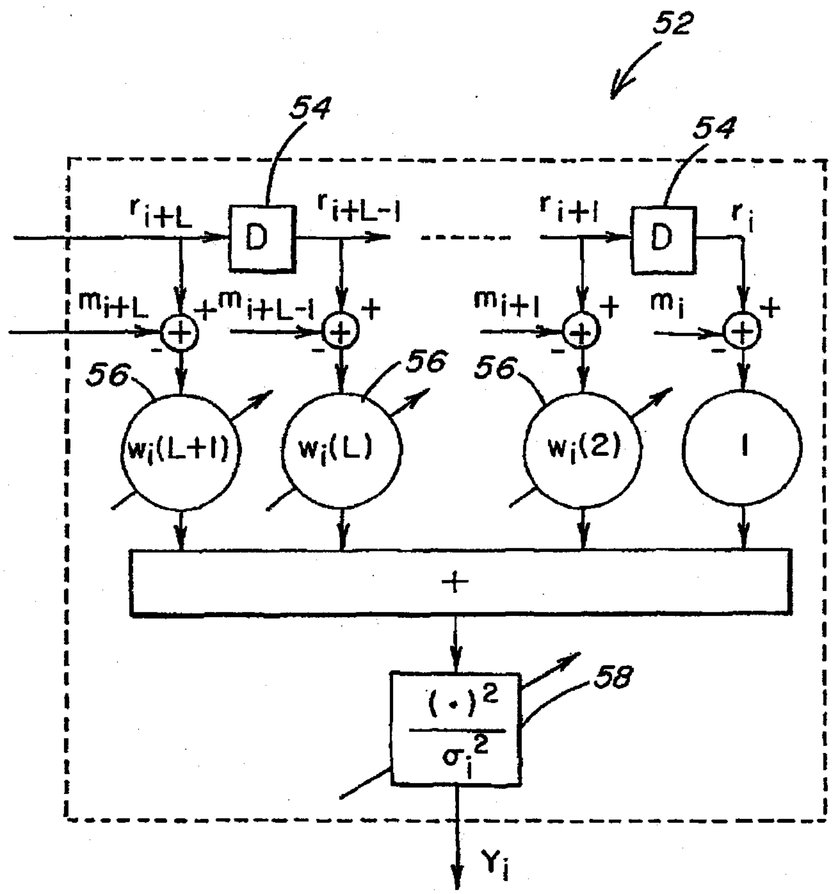

a_i
a_{i+1}
$E(r_i)$
+
⊕
⊖
−
1
1
0
0
0
0
-1
-1

FIG. 3B


52
54
54
r_{i+L}
D
r_{i+L-1}
r_{i+1}
D
r_i
m_{i+L}
m_{i+L-1}
m_{i+1}
m_i
56
56
56
$w_i(L+1)$
$w_i(L)$
$w_i(2)$
1
+
58
$\frac{(\cdot)^2}{\sigma_i^2}$
Y_i

Case: 14-1492 Document: 42 Page: 375 Filed: 08/05/2014

FIG. 5

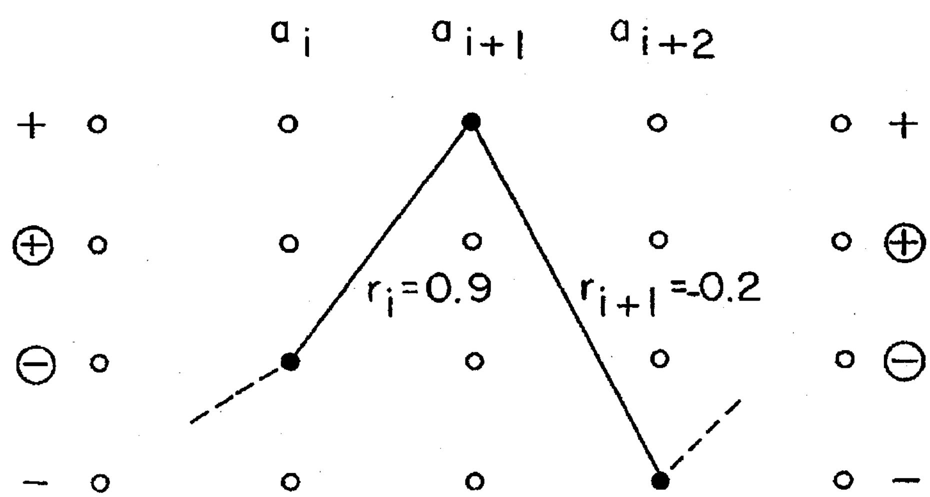


FIG. 6

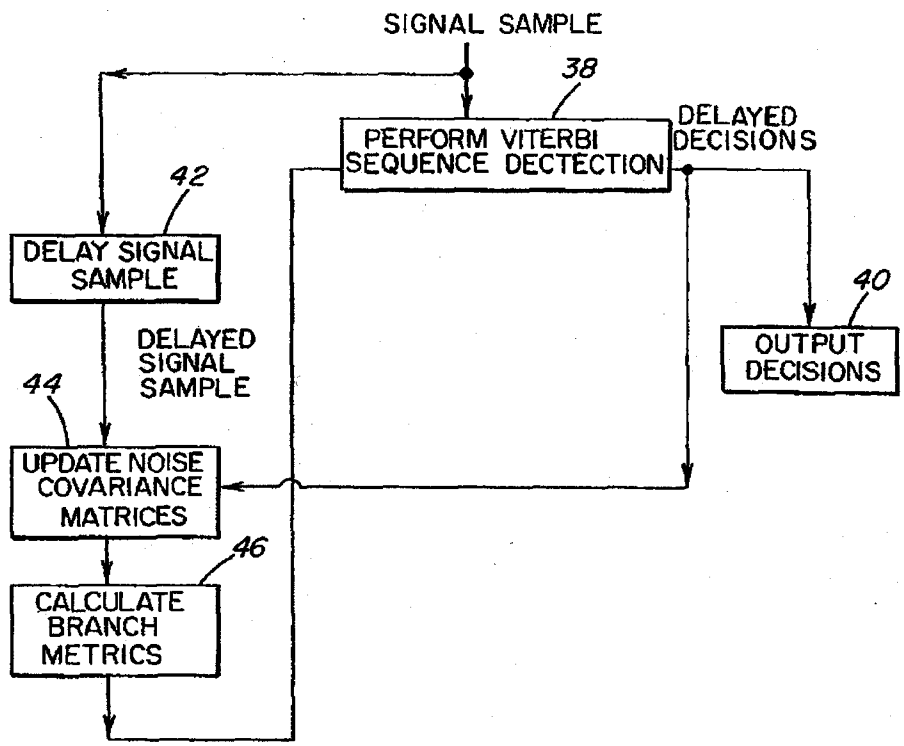

SIGNAL SAMPLE
38
PERFORM VITERBI SEQUENCE DECTECTION
DELAYED DECISIONS
42
DELAY SIGNAL SAMPLE
DELAYED SIGNAL SAMPLE
40
OUTPUT DECISIONS
44
UPDATE NOISE COVARIANCE MATRICES
46
CALCULATE BRANCH METRICS

FIG. 7

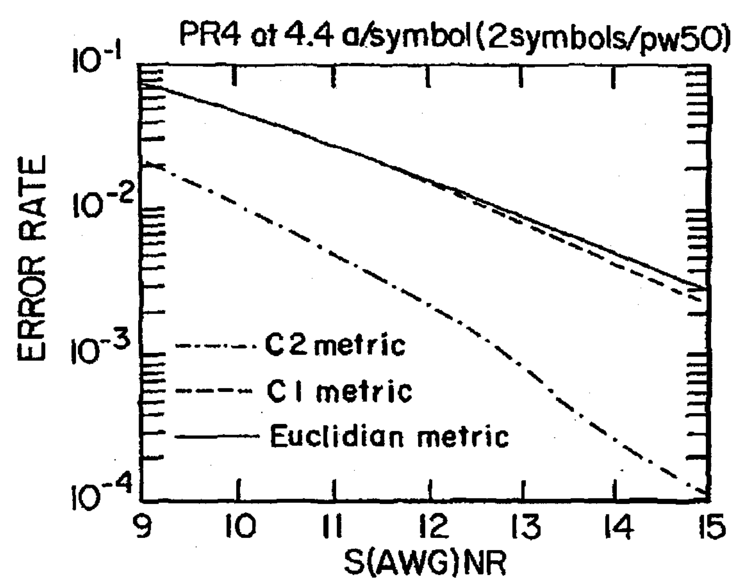

PR4 at 4.4 a/symbol (2symbols/pw50)
ERROR RATE
10^{-1}
10^{-2}
10^{-3}
10^{-4}
C2 metric
C1 metric
Euclidian metric
9
10
11
12
13
14
15
S(AWG)NR

FIG. 8

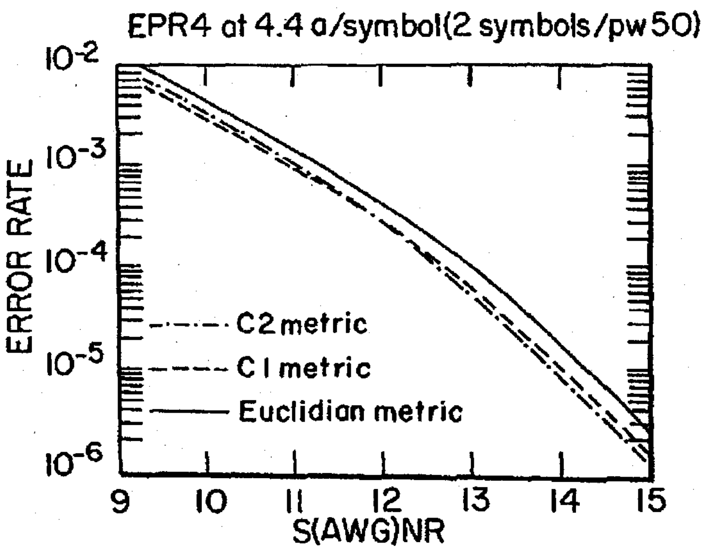

EPR4 at 4.4 a/symbol(2 symbols/pw50)
ERROR RATE
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
C2 metric
C1 metric
Euclidian metric
9
10
11
12
13
14
15
S(AWG)NR

FIG. 9

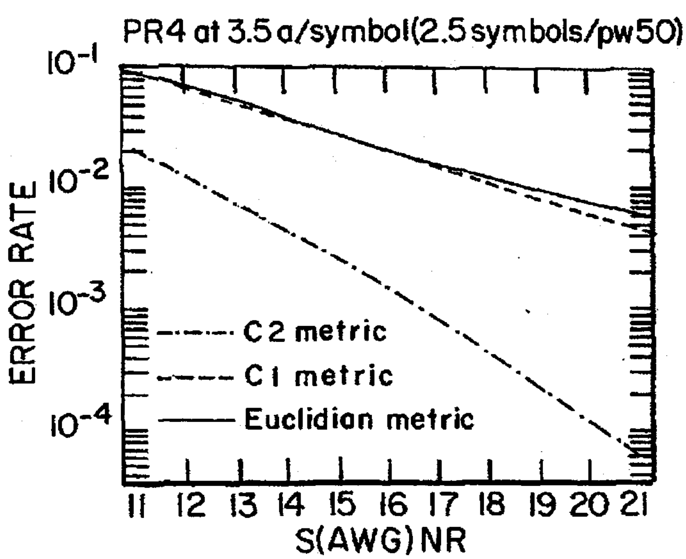

PR4 at 3.5 a/symbol(2.5 symbols/pw50)
ERROR RATE
10^{-1}
10^{-2}
10^{-3}
10^{-4}
C2 metric
C1 metric
Euclidian metric
11
12
13
14
15
16
17
18
19
20
21
S(AWG)NR

FIG. 10

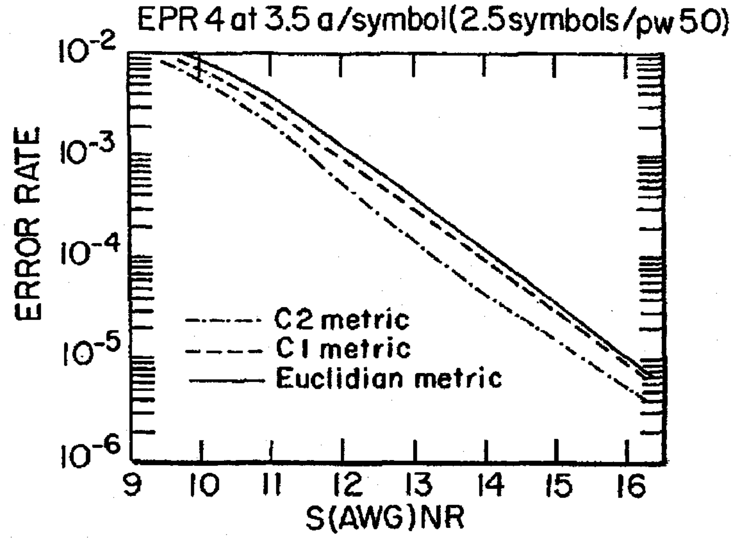

EPR 4 at 3.5 a/symbol(2.5symbols/pw 50)
ERROR RATE
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
C2 metric
C1 metric
Euclidian metric
9
10
11
12
13
14
15
16
S(AWG)NR

FIG. 11

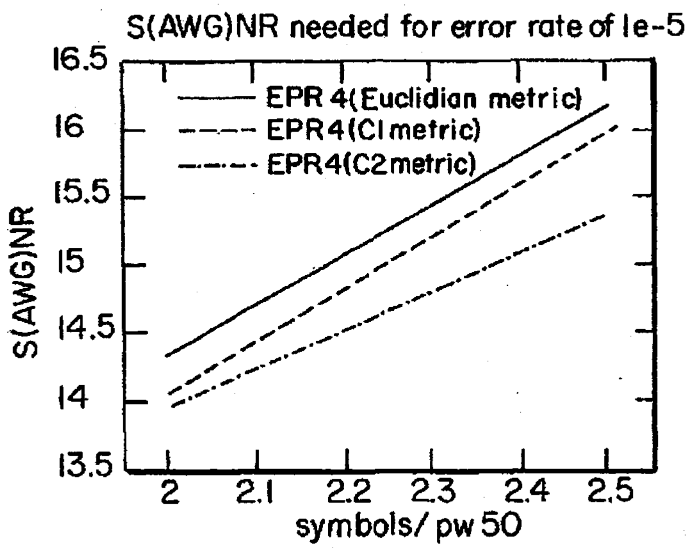

S(AWG)NR needed for error rate of 1e-5
S(AWG)NR
16.5
16
15.5
15
14.5
14
13.5
EPR 4(Euclidian metric)
EPR4(C1 metric)
EPR4(C2metric)
2
2.1
2.2
2.3
2.4
2.5
symbols/ pw 50

FIG. 12

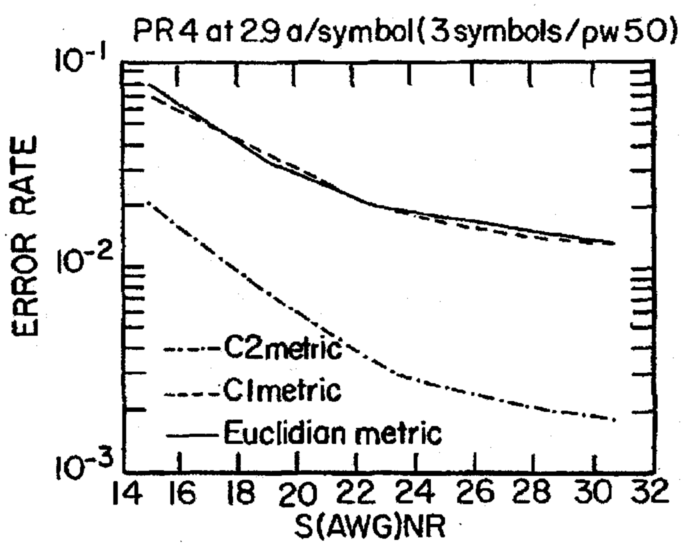
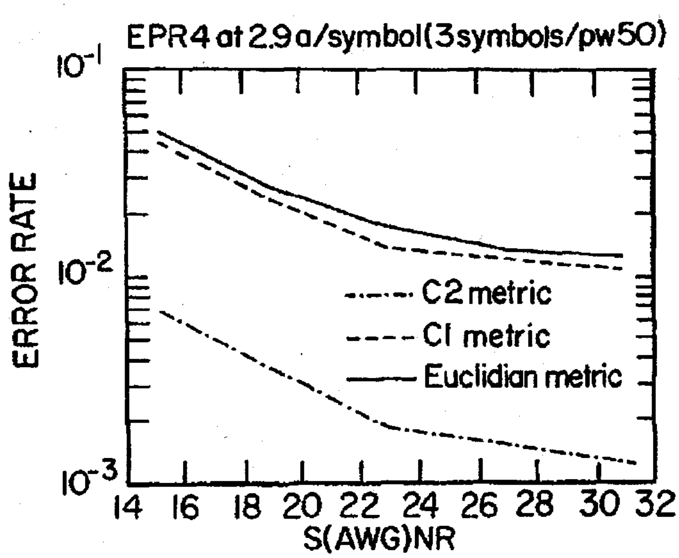

PR4 at 2.9 a/symbol(3symbols/pw50)
ERROR RATE
10^{-1}
10^{-2}
10^{-3}
C2metric
C1metric
Euclidian metric
14 16 18 20 22 24 26 28 30 32
S(AWG)NR

FIG. 13


EPR4 at 2.9 a/symbol(3symbols/pw50)
ERROR RATE
10^{-1}
10^{-2}
10^{-3}
C2 metric
C1 metric
Euclidian metric
14 16 18 20 22 24 26 28 30 32
S(AWG)NR

METHOD AND APPARATUS FOR CORRELATION-SENSITIVE ADAPTIVE SEQUENCE DETECTION

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims priority to Provisional Serial No. 60/046,006, filed May 9, 1997, under 35 U.S.C. Section 119(e).

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH

This invention was supported in part by the National Science Foundation under Grant No. ECD-8907068. The United States Government has certain rights in this invention.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention is directed generally to high density magnetic recording sequence detectors, and, more particularly, to correlation-sensitive sequence detectors.

2. Description of the Background

In recent years, there has been a major shift in the design of signal detectors in magnetic recording. Traditional peak detectors (PD), such as those described in Nakagawa et al., "A Study of Detection Methods of NRZ Recording", IEEE Trans. Magn., vol. 16, pp. 1041–110, Jan. 1980, have been replaced by Viterbi-like detectors in the form of partial response maximum likelihood (PRML) schemes or hybrids between tree/trellis detectors and decision feedback equalizers (DFE), such as FDTS/DF, MDFE and RAM-RSE. These methods were derived under the assumption that additive white Gausian noise (AWGN) is present in the system. The resulting trellis/tree branch metrics are then computed as Euclidian distances.

It has long been observed that the noise in magnetic recording systems is neither white nor stationary. The nonstationarity of the media noise results from its signal dependent nature. Combating media noise and its signal dependence has thus far been confined to modifying the Euclidian branch metric to account for these effects. Zeng, et al., "Modified Viterbi Algorithm for Jitter-Dominated 1-D^2 Channel," IEEE Trans. Magn., Vol. MAG-28, pp. 2895–97, Sept. 1992, and Lee et al., "Performance Analysis of the Modified maximum Likelihood Sequence Detector in the Presence of Data-Dependent Noise," Proceedings 26th Asilomar Conference, pp. 961–64, Oct. 1992 have derived a branch metric computation method for combating the signal-dependent character of media noise. These references ignore the correlation between noise samples. The effectiveness of this method has been demonstrated on real data in Zayad et al., "Comparison of Equalization and Detection for Very High-Density Magnetic Recording," IEEE INTERMAG Conference, New Orleans, April 1997.

These methods do not take into consideration the correlation between noise samples in the readback signal. These correlations arise due to noise coloring by front-end equalizers, media noise, media nonlinearities, and magnetoresistive (MR) head nonlinearities. This noise coloring causes significant performance degradation at high recording densities. Thus, there is a need for an adaptive correlation-sensitive maximum likelihood sequence detector which derives the maximum likelihood sequence detector (MLSD) without making the usual simplifying assumption that the noise samples are independent random variables.

SUMMARY OF THE INVENTION

In high density magnetic recording, noise samples corresponding to adjacent signal samples are heavily correlated as a result of front-end equalizers, media noise, and signal nonlinearities combined with nonlinear filters to cancel them. This correlation deteriorates significantly the performance of detectors at high densities.

The trellis/tree branch metric computation of the present invention is correlation-sensitive, being both signal-dependent and sensitive to correlations between noise samples. This method is termed the correlation-sensitive maximum likelihood sequence detector (CS-MLSD), or simply correlation-sensitive sequence detector (CS-SD).

Because the noise statistics are non-stationary, the noise sensitive branch metrics are adaptively computed by estimating the noise covariance matrices from the read-back data. These covariance matrices are different for each branch of the tree/trellis due to the signal dependent structure of the media noise. Because the channel characteristics in magnetic recording vary from track to track, these matrices are tracked on-the-fly, recursively using past samples and previously made detector decisions.

The present invention represents a substantial advance over prior sequence detectors. Because the present invention takes into account the correlation between noise samples in the readback signal, the detected data sequence is detected with a higher degree of accuracy. Those advantages and benefits of the present invention, and others, will become apparent from the Detailed Description of the Invention hereinbelow.

BRIEF DESCRIPTION OF THE DRAWINGS

For the present invention to be clearly understood and readily practiced, the present invention will be described in conjunction with the following figures wherein:

FIG. 1 is an illustration of a magnetic recording system;

FIG. 2 is an illustration of a CS-MLSD detector circuit of a preferred embodiment of the present invention;

FIG. 3 is an illustration of a sample signal waveform, its samples, and written symbols;

FIG. 3A is an illustration of a branch metric computation module;

FIG. 3B is an illustration of an implementation of a portion of the branch metric computation module of FIG. 3A;

FIG. 4 is an illustration of one cell of a PR4 trellis;

FIG. 5 is an illustration of a detected path in a PR4 trellis;

FIG. 6 is a block diagram of a preferred embodiment of a method for signal detection;

FIG. 7 is an illustration of PR4 detection results at a 4.4 a/symbol;

FIG. 8 is an illustration of EPR4 detection results at a 4.4 a/symbol;

FIG. 9 is an illustration of PR4 detection results at a 3.5 a/symbol;

FIG. 10 is an illustration of EPR4 detection results at a 3.5 a/symbol;

FIG. 11 is an illustration of S(AWG)NR margins needed for error rate of 10^{-5} with EPR4 detectors;

FIG. 12 is an illustration of PR4 detection results at a 2.9 a/symbol; and

FIG. 13 is an illustration of EPR 4 detection results at a 2.9 a/symbol.

DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 illustrates a magnetic recording system 10. A data source 12 supplies data to a write signal processing circuit 14. The signal processing circuit 14 converts the input data into signals with a format suitable for storage on a magnetic medium 16. The medium 16 is typically a rotating disk, a "floppy" disk, or a tape with magnetic coatings. A write head 18 stores the signals on the medium 16 as a series of variations in the magnetic flux of the medium 16. The write head 18 is controlled by a write control circuit 20, which supplies signals to the write head 18 to control its position with respect to the medium 16.

A read head 22 retrieves the variations in the magnetic flux that are stored on the medium 16. A read control circuit 24 supplies signals to the read head 22 to control its position with respect to the medium 16. The read head 22 provides a stream of data to a detector circuit 26. The detector circuit 26 detects the data from the data stream and outputs the data. The detector 26 must be able to detect the data in the presence of intersymbol interference ("ISI") noise. Prior art detector circuits have employed the maximum likelihood sequence ("MLS") estimation algorithm or peak detection techniques. The MLS algorithm analyzes a sequence of consecutive data and determines the output data based on the sequence. Peak detection techniques identify analog peaks in a sequence of data and determine the output data based on the peaks.

A block diagram of a CS-MLSD detector circuit 28 is shown in FIG. 2. The CS-MLSD detector circuit 28 is a part of the detector circuit 26 of FIG. 1. The detector circuit 28 has a feedback circuit 32 which feeds back into a Viterbi-like detector 30. The outputs of the detector 30 are decisions and delayed signal samples, which are used by the feedback circuit 32. A noise statistics tracker circuit 34 uses the delayed samples and detector decisions to update the noise statistics, i.e., to update the noise covariance matrices. A metric computation update circuit 36 uses the updated statistics to calculate the branch metrics needed in the Viterbi-like algorithm. The algorithm does not require replacing current detectors. It simply adds two new blocks in the feedback loop to adaptively estimate the branch metrics used in the Viterbi-like detector 30.

The Viterbi-like detector 30 typically has a delay associated with it. Until the detector circuit 28 is initialized, signals of known values may be input and delayed signals are not output until the detector circuit 28 is initialized. In other types of detectors, the detector may be initialized by having the necessary values set.

The correlation-sensitive maximum likelihood sequence detector (CS-MLSD) 28 is described hereinbelow. Assume that N>1 channel bits (symbols), $a_1, a_2, \ldots, a_N$, are written on a magnetic medium. The symbols a_i, $i=1, \ldots, N$, are drawn from an alphabet of four symbols, $a_i \in \{+, \oplus, -, \ominus\}$. The symbols '+' and '−' denote a positive and a negative transition, respectively. The symbol '⊕' denotes a written zero (no transition) whose nearest preceding non-zero symbol is a '+' while '⊖' denotes a written zero whose nearest preceding transition is a negative one, i.e., '−'. This notation is used because a simple treatment of transitions as '1's and no transitions as '0's is blind to signal asymmetries (MR head asymmetries and base line drifts), which is inappropriate for the present problem. In FIG. 3 a sample waveform is illustrated. The signal asymmetries and base line shifts are exaggerated in FIG. 3. FIG. 3 also shows the written symbols $a_1, \ldots, a_{18}$, as well as the samples $r_1, \ldots, r_{18}$ of the read-back waveform, sampled at the rate of one sample per symbol interval.

When the written sequence of symbols a_i, $i=1, \ldots, N$, is read, the readback waveform is passed through a pulse-shaping equalizer and sampled one sample per symbol, resulting in the sequence of samples r_i, $i=1, \ldots, N$. Due to the noise in the system, the samples r_i are realizations of random variables. The maximum likelihood detector determines the sequence of symbols a_i that has been written, by maximizing the likelihood function, i.e.:

$$\{\hat{a}_1, \ldots, \hat{a}_N\} = \arg\left[\max_{all\ a_i} f(r_1, \ldots, r_N \mid a_1, \ldots, a_N)\right]. \tag{1}$$

In (1), the likelihood function $f(r_1, \ldots, r_N|a_1, \ldots, a_N)$ is the joint probability density function (pdf) of the signal samples $r_1, \ldots, r_N$, conditioned on the written symbols $a, \ldots, a_N$. The maximization in (1) is done over all possible combinations of symbols in the sequence $\{a_1, \ldots, a_N\}$.

Due to the signal dependent nature of media noise in magnetic recording, the functional form of joint conditional pdf $f(r_1, \ldots, r_N|a_1, \ldots, a_N)$ in (1) is different for different symbol sequences $a_1, \ldots, a_N$. Rather than making this distinction with more complex but cluttered notation, the notation is kept to a minimum by using simply the same symbol f to denote these different functions.

By Bayes rule, the joint conditional pdf (likelihood function) is factored into a product of conditional pdfs:

$$f(r_1, \ldots, r_N \mid a_i, \ldots, a_N) = \prod_{i=1}^{N} f(r_i \mid r_{i+1}, \ldots, r_N, a_1, \ldots, a_N). \tag{2}$$

To proceed and obtain more concrete results, the nature of the noise and of the intersymbol interference in magnetic recording is exploited.

Finite correlation length. The conditional pdfs in Equation (2) are assumed to be independent of future samples after some length $L \geqq 0$. L is the correlation length of the noise. This independence leads to:

$$f(r_i|r_{i+1}, \ldots, r_N, a_1, \ldots, a_N) = f(r_i|r_{i+1}, \ldots, r_{i+L}, a_1, \ldots, a_N). \tag{3}$$

Finite intersymbol interference. The conditional pdf is assumed to be independent of symbols that are not in the K-neighborhood of $r_i, \ldots, r_{i+L}$. The value of $K \geqq 1$ is determined by the length of the intersymbol interference (ISI). For example, for PR4, K=2, while for EPR4, K=3. $K_1 \geqq 0$ is defined as the length of the leading (anticausal) ISI and $K_t \geqq 0$ is defined as the length of the trailing (causal) ISI, such that $K=K_l+K_t+1$. With this notation the conditional pdf in (3) can be written as:

$$f(r_i|r_{i+1}, \ldots, r_{i+L}, a_1, \ldots, a_N) = f(r_i|r_{i+1}, \ldots r_{i+L} a_{i-K_l}). \tag{4}$$

Substituting (4) into (2) and applying Bayes rule, the factored form of the likelihood function (conditional pdf) is obtained:

$$f(r_1, \ldots, r_N \mid a_i, \ldots, a_N) = \prod_{i=1}^{N} f(r_i \mid r_{i+1}, \ldots, r_N, a_1, \ldots, a_N) = \prod_{i=1}^{N} \frac{f(r_i, r_{i+1}, \ldots, r_{i+L} \mid a_{i-K_l}, \ldots, a_{i+L+K_t})}{f(r_{i+1}, \ldots, r_{i+L} \mid a_{i-K_l}, \ldots, a_{i+L+K_t})}. \tag{5}$$

The factored form of equation (5) is suitable for applying Viterbi-like dynamic programming detection techniques. Equation (5) assumes anticausal factorization, i.e., it is derived by taking into account the effect of the samples $r_{i+1}, \ldots, r_{i+L}$, on r_i. If only the causal effects are taken into account, the causal equivalent of (5) can be derived as $f(r_1, \ldots r_N | a_1, \ldots, a_N) =$

$$\prod_{i=1}^{N} \frac{f(r_i, r_{i+1}, \ldots, r_{i+L} \mid a_{i-K_l}, \ldots, a_{i+L+K_t})}{f(r_{i+1}, \ldots, r_{i+L-1} \mid a_{i-K_l}, \ldots, a_{i+L+K_t})}$$

The causal and anticausal factorization could be combined to find the geometric mean of the two to form a causal-anticausal factorization. Since this only complicates derivations and does not provide further insight, only the anticausal Equation (5) is considered.

Maximizing the likelihood function in (5) is equivalent to minimizing its negative logarithm. Thus, the maximum likelihood detector is now:

$$\begin{aligned}\{\hat{a}_1, \ldots, \hat{a}_N\} &= \arg\left[\min_{all\ a_i} \log \prod_{i=1}^{N} \frac{f(r_{i+1}, \ldots, r_{i+L} \mid a_{i-K_l}, \ldots, a_{i+L+K_t})}{f(r_i, r_{i+1}, \ldots, r_{i+L} \mid a_{i-K_l}, \ldots, a_{i+L+K_t})}\right] \\ &= \arg\left[\min_{all\ a_i} \sum_{i=1}^{N} \log \frac{f(r_{i+1}, \ldots, r_{i+L} \mid a_{i-K_l}, \ldots, a_{i+L+K_t})}{f(r_i, r_{i+1}, \ldots, r_{i+L} \mid a_{i-K_l}, \ldots, a_{i+L+K_t})}\right] \\ &= \arg\left[\min_{all\ a_i} \sum_{i=1}^{N} M_i(r_i, r_{i+1}, \ldots, r_{i+L}, a_{i-K_l}, \ldots, a_{i+L+K_t})\right]\end{aligned} \tag{6}$$

M_i represents the branch metric of the trellis/tree in the Viterbi-like algorithm. The metric is a function of the observed samples $r_i, r_{i+1}, \ldots, r_{i+L}$. It is also dependent on the postulated sequence of written symbols $a_i - K_1, \ldots, a_i + L + K_t$, which ensures the signal-dependence of the detector. As a consequence, the branch metrics for every branch in the tree/trellis is based on its corresponding signal/noise statistics.

Specific expressions for the branch metrics that result under different assumptions on the noise statistics are next considered.

Euclidian branch metric. In the simplest case, the noise samples are realizations of independent identically distributed Gaussian random variables with zero mean and variance σ^2. This is a white Gaussian noise assumption. This implies that the correlation distance is L=0 and that the noise pdf s have the same form for all noise samples. The total ISI length is assumed to be $K=K_l+K_t+1$, where K_l and K_t are the leading and trailing ISI lengths, respectively. The conditional signal pdfs are factored as

$$\frac{f(r_{i+1}, \ldots, r_{i+L} \mid a_{i-K_l}, \ldots, a_{i+L+K_t})}{f(r_i, r_{i+1}, \ldots, r_{i+L} \mid a_{i-K_l}, \ldots, a_{i+L-K_t})} = \sqrt{2\pi\sigma^2} \exp\left[\frac{(r_i - m_i)^2}{2\sigma^2}\right] \tag{7}$$

Here the mean signal m_i is dependent on the written sequence of symbols. For example, for a PR4 channel, $m_i \in \{-1,0,1\}$. The branch/tree metric is then the conventional Euclidian distance metric:

$$M_i = N_i^2 = (r_i - m_i)^2 \tag{8}$$

Variance dependent branch metric. It is again assumed that the noise samples are samples of independent Gaussian variables, but that their variance depends on the written sequence of symbols. The noise correlation length is still L=0, but the variance of the noise samples is no longer constant for all samples. The variance is σ^{2i}, where the index i denotes the dependence on the written symbol sequence. As for the Euclidian metric, it is assumed that the total ISI length is $K=K_l+K_t+1$. The conditional signal pdf is factored to give:

$$\frac{f(r_{i+1}, \ldots, r_{i+L} \mid a_{i-K_l}, \ldots, a_{i+L+K_t})}{f(r_i, r_{i+1}, \ldots, r_{i+L} \mid a_{i-K_l}, \ldots, a_{i+L+K_t})} = \sqrt{2\pi\sigma_i^2} \exp\left[\frac{(r_i - m_i)^2}{2\sigma_i^2}\right] \tag{9}$$

The corresponding branch metric is:

$$M_i = \log\sigma_i^2 + \frac{N_i^2}{\sigma_i^2} = \log\sigma_i^2 + \frac{(r_i - m_i)^2}{\sigma_i^2} \tag{10}$$

Correlation-sensitive branch metric. In the most general case, the correlation length is L>0. The leading and trailing ISI lengths are K_l and K_t, respectively. The noise is now considered to be both correlated and signal-dependent. Joint Gaussian noise pdfs are assumed. This assumption is well justified in magnetic recording because the experimental evidence shows that the dominant media noise modes have Gaussian-like histograms. The conditional pdfs do not factor out in this general case, so the general form for the pdf is:

$$\frac{f(r_{i+1}, \ldots, r_{i+L} \mid a_{i-K_l}, \ldots, a_{i+L+K_t})}{f(r_i, r_{i+1}, \ldots, r_{i+L} \mid a_{i-K_l}, \ldots, a_{i+L+K_t})} = \sqrt{\frac{(2\pi)^{L+1} \det C_i}{(2\pi)^L \det c_i}} \frac{\exp[\underline{N}_i^T C_i^{-1} \underline{N}_i]}{\exp[\underline{n}_i^T c_i^{-1} \underline{n}_i]} \tag{11}$$

The $(L+1)\times(L+1)$ matrix C_i is the covariance matrix of the data samples $r_i, r_{i+1}, \ldots, r_{i+L}$, when a sequence of symbols $a_{i-Kl}, \ldots a_{i+L+Kt}$ is written. The matrix c_i in the denominator of (11) is the L×L lower principal submatrix of $C_i=[c_i]$. The (L+1)-dimensional vector $\underline{N}_i$ is the vector of differences between the observed samples and their expected values when the sequence of symbols $a_{i-Kl}, \ldots, a_{i+L+Kt}$ is written, i.e.:

$$\underline{N}_i = [(r_i - m_i)(r_{i+1} - m_{i+1}) \ldots (r_{i+L} - m_{i+L})]^T \tag{12}$$

The vector $\underline{n}_i$ collects the last L elements of $\underline{N}_i$, $\underline{n}_i = [(r_{i+1} - m_{i+1}) \ldots (r_{i+L} - m_{i+L})]^T$.

With this notation, the general correlation-sensitive metric is:

$$M_i = \log det \frac{C_i}{det\ c_i} + \underline{N}_i^T C_i^{-1} \underline{N}_i - \underline{n}_i^T c_i^{-1} \underline{n}_i \tag{13}$$

In the derivations of the branch metrics (8), (10) and (13), no assumptions were made on the exact Viterbi-type architecture, that is, the metrics can be applied to any Viterbi-type algorithm such as PRML, FDTS/DF, RAM-RSE, or, MDFE.

FIG. 3A illustrates a block diagram of a branch metric computation circuit **48** that computes the metric M_i for a branch of a trellis, as in Equation (13). Each branch of the trellis requires a circuit **48** to compute the metric M_i.

A logarithmic circuit **50** computes the first term of the right hand side of (13)

$$\left(\text{i.e. } \log \frac{det\ C_i}{det\ c_i}\right)$$

and a quadratic circuit **52** computes the second terms of the right hand side of (13) (i.e. $\underline{N}_i^T C_i^{-1} \underline{N}_i - \underline{n}_i^T c_i^{-1} \underline{n}_i$). The arrows through the circuits **50** and **52** represent the adaptive nature of the Virterbi-like detector **30**. A sum circuit **53** computes the sum of the outputs of the circuits **50** and **52**.

As stated above, the covariance matrix is given as:

$$C_i = \begin{bmatrix} \alpha_i & \underline{c}_i \\ \underline{c}_i^T & c_i \end{bmatrix}. \tag{14}$$

Using standard techniques of signal processing, it can be shown that:

$$\frac{det\ C_i}{det\ c_i} = \alpha_i - \underline{c}_i^T c_i^{-1} \underline{c}_i. \tag{15}$$

This ratio of determinants is referred to as σ_i^2, i.e.:

$$\sigma_i^2 = \frac{det\ C_i}{det\ c_i} = \alpha_i - \underline{c}_i^T c_i^{-1} \underline{c}_i. \tag{16}$$

It can be shown by using standard techniques of signal processing that the sum of the last two terms of (13), i.e. the output of the circuit **52**, is:

$$Y_i = \underline{N}_i^T C_i^{-1} \underline{N}_i - \underline{n}_i^T c_i^{-1} \underline{n}_i \tag{17}$$

$$= \frac{(\underline{w}_i^T \underline{N}_i)^2}{\sigma_i^2}, \tag{18}$$

Where the vector $\underline{w}_i$ is (L+1)-dimensional and is given by:

$$\underline{w}_i^T = [1 \quad w_i(2) \quad w_i(3) \quad \ldots \quad (w_i(L+1)])^T \tag{19}$$

$$= \begin{bmatrix} 1 \\ -c_i^{-1} \underline{c}_i \end{bmatrix}. \tag{20}$$

Equations (17), (18) and (16) (the circuit **52**) can be implemented as a tapped-delay line as illustrated in FIG. 3B. The circuit **52** has L delay circuits **54**. The tapped-delay line implementation shown in FIGS. 3A and 3B is also referred to as a moving-average, feed-forward, or finite-impulse response filter. The circuit **48** can be implemented using any type of filter as appropriate.

The adaptation of the vector of weights $\underline{w}_i$ and the quantity σ_i^2 as new decisions are made is essentially an implementation of the recursive least squares algorithm. Alternatively, the adaptation may be made using the least mean squares algorithm.

The quantities m_i that are subtracted from the output of the delay circuits **54** are the target response values, or mean signal values of (12). The arrows across multipliers **56** and across square devices **58** indicate the adaptive nature, i.e., the data dependent nature, of the circuit **52**. The weights $\underline{w}_i$ and the value σ_i^2 can be adapted using three methods. First, $\underline{w}_i$ and σ_i^2 can be obtained directly from Equations (20) and (16), respectively, once an estimate of the signal-dependent covariance matrix C_i is available. Second, $\underline{w}_i$ and σ_i^2 can be calculated by performing a Cholesky factorization on the inverse of the covariance matrix C_i. For example, in the $L_i D_i^{-1} L_i^T$ Cholesky factorization, $\underline{w}_i$ is the first column of the Cholesky factor L_i and σ_i^2 is the first element of the diagonal matrix D_i. Third, $\underline{w}_i$ and σ_i^2 can be computed directly from the data using a recursive least squares-type algorithm. In the first two methods, an estimate of the covariance matrix is obtained by a recursive least squares algorithm.

Computing the branch metrics in (10) or (13) requires knowledge of the signal statistics. These statistics are the mean signal values m_i in (12) as well as the covariance matrices C_i in (13). In magnetic recording systems, these statistics will generally vary from track to track. For example, the statistics that apply to a track at a certain radius will differ from those for another track at a different radius due to different linear track velocities at those radii. Also, the signal and noise statistics will be different if a head is flying slightly off-track or if it is flying directly over the track. The head skew angle is another factor that contributes to different statistics from track to track. These factors suggest that the system that implements the metric in (13) needs to be flexible to these changes. Storing the statistics for each track separately is very difficult because of the memory span required to accomplish this. A reasonable alternative is to use adaptive filtering techniques to track the needed statistics.

Tracking the mean signal values m_i is generally done so that these values fall on prespecified targets. An adaptive front-end equalizer is employed to force the signal sample values to their targets. This is certainly the case with partial response targets used in algorithms like PR4, EPR4, or EEPR4 where the target is prespecified to one of the class-4 partial responses. For example, in a PR4 system, the signal samples, if there is no noise in the system, fall on one of the three target values 1, 0, or −1. Typically this is done with an LMS-class (least mean-squares) algorithm that ensures that the mean of the signal samples is close to these target values. In decision feedback equalization (DFE) based detectors or hybrids between fixed delay tree search and DFE, such as FDTS/DF or MDFE, the target response need not be prespecified. Instead, the target values are chosen on-the-fly by simultaneously updating the coefficients of the front-end and feed-back equalizers with an LMS-type algorithm.

When there are severe nonlinearities in the system (also referred to as nonlinear distortion or nonlinear ISI), a linear equalizer will generally not be able to place the signal samples right on target. Instead, the means of the signal samples will fall at a different value. For example, in a PR4 system, the response to a sequence of written symbols . . . , −,+, ⊕, . . . might result in mean sample target values . . . , 0, 1, 0.9, . . . , while a sequence of written symbols . . . , +, −, ⊖, . . . might result in a sequence of mean sample values . . . , 0.95, −1.05, 0, . . . Clearly, in this example, what should be a target value of 1 becomes either 1, 0.9, or 0.95 depending on the written sequence. Because mean values and not noisy samples are being considered, this deviation is due to nonlinearities in the system. There are two fixes for this problem. The first is to employ a nonlinear filter (neural network or Volterra series filter) that is capable of overcoming these nonlinear distortions. Although recently very popular, such a method introduces further correlation between noise samples due to the nonlinear character of the filter. The second fix is to track the nonlinearities in a feedback loop and use the tracked value in the metric computation. For example, let the response to a written symbol sequence . . . , ⊖, +, ⊕, . . . be consistently . . . , 0, 1, 0.9, . . . Then, rather than using the value 1 in the metric computation for the third target, this behavior can be tracked and the value m_i=0.9 can be used.

In the remainder of this discussion, for simplicity, it is assumed that the front-end equalizer is placing the signal samples right on the desired target values and that there is no need for further mean corrections. The focus is shifted to tracking the noise covariance matrices needed in the computation of the branch metrics (13).

Assume that the sequence of samples r_i, r_{i+1}, . . . , r_{i+L} is observed. Based on these and all other neighboring samples, after an appropriate delay of the Viterbi trellis, a decision is made that the most likely estimate for the sequence of symbols a_{i-K_l}, . . . , a_{i+L+K_t} is $\hat{a}_{i-K_l}$, . . . , $\hat{a}_{i+L+K_t}$. Here L is the noise correlation length and $K=K_l+K_t+1$ is the ISI length. Let the current estimate for the (L+1)×(L+1) covariance matrix corresponding to the sequence of symbols $\hat{a}_{i-K_l}$, . . . , $\hat{a}_{i+L+K_t}$ be $\hat{C}(\hat{a}_{i-K_l}, \ldots, \hat{a}_{i+L+K_t})$. This symbol is abbreviated with the shorter notation, $\hat{C}(\hat{a})$. If the estimate is unbiased, the expected value of the estimate is:

$$E\hat{C}(\hat{a})=E[\underline{N}_i\underline{N}_i^T] \tag{21}$$

where $\underline{N}_i$ is the vector of differences between the observed samples and their expected values, as defined in (12).

Note that once the samples r_i, r_{i+1}, . . . , r_{i+L} are observed, and once it is decided that most likely they resulted from a series of written symbols $\hat{a}_{i-K_l}$, . . . , $\hat{a}_{i+L+K_t}$, the sequence of target (mean) values m_i, m_{i+1}, . . . , m_{i+L} is known that correspond to these samples. They are used to compute the vector $\underline{N}_i$, with which the empirical rank-one covariance matrix $\underline{N}_i\underline{N}^T_i$ is formed. In the absence of prior information, this rank-one matrix is an estimate for the covariance matrix for the detected symbols. In a recursive adaptive scheme, this rank-one data covariance estimate is used to update the current estimate of the covariance matrix $\hat{C}(\hat{a})$. A simple way to achieve this is provided by the recursive least-squares (RLS) algorithm. The RLS computes the next covariance matrix estimate $\hat{C}'(\hat{a})$ as:

$$\hat{C}'(\hat{a})=\beta(t)\hat{C}(\hat{a})+[1-\beta(t)]\underline{N}_i\underline{N}_i^T \tag{22}$$

Here, β(t), 0<β(t)<1, is a forgetting factor. The dependence on t signifies that β is a function of time. Equation (22) can be viewed as a weighted averaging algorithm, where the data sample covariance $\underline{N}_i\underline{N}_i^T$ is weighted by the factor [1−β(t)], while the previous estimate is weighted by β(t). The choice of β(t) should reflect the nonstationarity degree of the noise. For example, if the nonstationarity is small, β(t) should be close to 1, while it should drop as the nonstationarity level increases. The forgetting factor is typically taken time-dependent to account for the start-up conditions of the RLS algorithm in (22). As more data is processed, a steady-state is expected to be achieved and β(t) is made to approach a constant value. Initially, β(t) is close to zero, to reflect the lack of a good prior estimate $\hat{C}(\hat{a})$, and to rely more on the data estimate. With time, β(t) is increased and settles around a value close to 1.

The impact of the initial conditions in (22) decays exponentially fast. Hence, the algorithm (22) can be started with an arbitrary initial guess for the covariance matrix $\hat{C}(\hat{a})$, with the only constraint being that the matrix be positive semidefinite, e.g, a zero matrix or an identity matrix.

The one-dimensional equivalent of equation (22) is

$$\hat{\sigma}_{new}^2=\beta\hat{\sigma}_{old}^2+[1-\beta]N_i^2. \tag{23}$$

This equation can be used in conjunction with the metric in (10).

It is important to point out that, due to the signal-dependent character of the media noise, there will be a different covariance matrix to track for each branch in the tree-trellis of the Viterebi-like detector. Practical considerations of memory requirements, however, limit the dimensions of the matrices to be tracked. Fortunately, simple 2×2 matrices are enough to show substantial improvement in error rate performance.

The following example illustrates how the algorithm in (22) works. Assume a PR4 target response with a simple trellis structure as shown in FIG. 4 Notice that for PR4, the symbols can be equated to the trellis states, as is illustrated in FIG. 4 The number next to each branch in FIG. 4 represents the target value (mean sample value) for the corresponding path between states. The target values in PR4 can be one of three values −1, 0, or 1.

In this example a noise correlation length of L=1 is assumed. It is also assumed that the leading and trailing ISI lengths are K_l=0 and K_t=1, respectively, to give the total ISI length $K=K_l+K_t+1=2$ for the PR4 response. Because L=1, signal covariance matrices of size (L+1)×(L+1)=2×2 need to be tracked. The number of these matrices equals the number of different combinations of two consecutive branches in the trellis. A simple count in FIG. 4 reveals that this number is 16, because there are 4 nodes in the trellis and 2 branches entering and leaving each node.

Assume that, using the branch metric in (13), the Viterbi-like detector decides that the most likely written symbols a_i, a_{i+1}, a_{i+2}, equal $\{\hat{a}_i, \hat{a}_{i+1}, \hat{a}_{i+2}\}$={⊖, +, −}. This is illustrated in FIG. 5, where the corresponding path through the trellis is highlighted. The noisy signal samples corresponding to the trellis branches are r_i=0.9 and r_{i+1}=−0.2, which deviate slightly from their ideal partial response target values of 1 and 0, respectively.

Suppose that, prior to making the decision $\{\hat{a}_i, \hat{a}_{i+1}, \hat{a}_{i+2}\}$={⊖, +, −}, the estimate for the covariance matrix associated with this sequence of three symbols is

$$\hat{C}(\ominus, +, -)=\begin{bmatrix} 0.5 & -0.2 \\ -0.2 & 0.8 \end{bmatrix} \tag{24}$$

Let the forgetting factor be B=0.95. To update the covariance matrix the vector is first formed:

$$\underline{N}=[(r_i-1)(r_{i+1}-0)]^T=[-0.1-0.2]^T \tag{25}$$

The rank-one sample covariance matrix $\underline{N}\,\underline{N}^T$ is used to find the covariance matrix update:

$$\hat{C}'(\Theta,+,-)=\beta\hat{C}(\Theta,+,-)+(1-\beta)\underline{N}\,\underline{N}^T \quad (26)$$

$$=\begin{bmatrix} 0.4755 & -0.189 \\ -0.189 & 0.7620 \end{bmatrix}$$

The matrix $\hat{C}'(\Theta, +, -)$ becomes our estimate for the covariance matrix corresponding to this particular symbol sequence (trellis path) and is used to compute the metrics (13) in the subsequent steps of the Viterbi-like algorithm.

FIG. 6 illustrates a flowchart of a method of detecting a sequence of adjacent signal samples stored on a high density magnetic recording device. Viterbi sequence detection is performed using a signal sample at step 38. The sequence detection produces decisions which are output at step 40. The signal sample is delayed at step 42. The past samples and detector decisions are used to update the noise statistics at step 44. Branch metrics, which are used in the sequence detection step 38, are calculated at step 46.

It can be understood by those skilled in the art that the method of FIG. 6 can be performed on a computer. The steps may be coded on the computer as a series of instructions, which, when executed, cause the computer to detect a sequence of adjacent signal samples stored on a high density magnetic recording device. The computer may be, for example, a personal computer, a workstation, or a mainframe computer. The computer may also have a storage device, such as a disk array, for storage of the series of instructions.

Simulation results using two partial response detection algorithms, namely PR4 and EPR4 are now presented. To create realistic waveforms, corrupted by media noise, an efficient stochastic zig-zag model, the TZ-ZT model was used. These waveforms are then passed through the detectors. A Lindholm inductive head is used for both writing and reading. Table 1 presents the recording parameters of the model. These recording parameters are chosen so that with a moderately low symbol density per PW50, a low number of transition widths a per symbol transition separation results. Namely, at 3 symbols/PW50 a transition separation of only 2.9a is present. The transition profile was modeled by an error function, where the transition width a denotes the distance from the transition center to the point where the magnetization equals $M_r/2$.

TABLE 1

Recording parameters used in simulations.

Parameter	Symbol	Value
media remanence	M_r	450kA/m
media coercivity	H_c	160kA/m
media thickness	δ	0.02 μm
media cross-track correlation width	s	200Å
head-media separation	d	15 nm
head field gradient factor	Q	0.8
had gap length	g	0.135 μm
track width	TW	2 μm
transition width parameter	α	0.019 μm
percolation length	$L = 1.4\alpha$	0.0266 μm
50% pulse width	PW50	0.167 μm

Table 1: Recording Parameters Used in Simulations

The symbols utilizing the (0,4) run length limited code are written. No error correction is applied, so the obtained error rates are not bit error rates, but (raw) symbol error rates.

Both the PR4 and EPR4 detectors were tested using the following three different metric computation methods: the Euclidian metric (8), the variance dependent metric (10), also referred to as the C1 metric, and the 2×2 correlation sensitive metric (13), named the C2 metric for short. For a PR4 target response, the total ISI length is $K=K_l+K_t+1=2$, where the leading and trailing ISI lengths are $K_l=0$ and $K_t=1$, respectively. The noise correlation length for the Euclidian and the C1 metrics is L=0, and for the C2 metric the noise correlation length is L=1. These three PR4 detectors are referred to as PR4(Euc), PR4(C1), and PR4(C2).

Similarly to the PR4 detectors, three EPR4 detectors were tested, EPR4(Euc), EPR4(C1) and EPR4(C2). The only difference between the PR4 detectors and the EPR4 detectors are the target response and the ISI length, which for the EPR4 target response equals $K=K_l+K_t+1=3$, with $K_l=1$ and $K_t=1$.

The signal obtained by the TZ-ZT model is already corrupted with media noise. To this signal white Gaussian noise was added to simulate the head and electronics noise in a real system. The power of the additive white Gaussian noise is quoted as the signal to additive white Gaussian noise ratio, S(AWG)NR, which is obtained as:

$$S(AWG)NR = 10\log\frac{A_{iso}^2}{\sigma_n^2} \quad (27)$$

where A_{iso} is the mean (media noise free) amplitude of an isolated pulse and σ^2_n is the variance of the additive white Gaussian noise. The noise distorted signal is first passed through a low-pass filter to clean out the noise outside the Nyquist band. The signal is then sampled at a rate of one sample per symbol and subsequently passed through a partial response shaping filter, either PR4 or EPR4. The partial response shaping filter is implemented as an adaptive FIR filter whose tap weights are adjusted using the LMS algorithm. Note that both filters add correlation to the noise. For the C1 and C2 metrics in (10) and (13), the RLS algorithms (22) and (23) are used to estimate the noise variances and covariance matrices for the branch metric computations. In both cases, the forgetting factor is set to $\beta=0.95$.

All six detection algorithms were tested at three different recording densities.

Symbol separation of 4.4a. This recording density corresponds to a symbol density of 2 symbols/PW50, see Table 1. FIG. 7 shows the symbol error rate performance of the PR4 detectors for different additive noise SNRs. The media noise is embedded in the system, which is why the x-axis on the graph is labeled as S(AWG)NR instead of simply SNR. At this density, the PR4(Euc) and PR4(C1) detectors perform just about the same and the PR4(C2) detector outperforms them both by about 3 dB. The reason for this is that the PR4 shaping filter averages noise samples from different symbols, which masks the signal dependent nature of the media noise. This is why there is not much to gain by using PR4(C1) instead of PR4(Euc). The PR4(C2) detector performs better because it partially removes the effects of noise correlation introduced by the PR4 shaping filter. FIG. 8 shows how the EPR4 detectors perform at this same density (symbol separation 4.4a). The PR4(C2) has the best performance and PR4(Euc) has the worst. The difference in performance at the error rate of 10^{-5} is only about 0.5 dB between PR4(Euc) and PR4(C2). This is because the media noise power at this density is low and the signal is well matched to the target so the EPR4 shaping filter does not introduce unnecessary noise correlation.

Symbol separation of 3.5a. This recording density corresponds to a symbol density of 2.5 symbols/PW50. FIG. 9

shows the performance of the PR4 detectors at this density. FIG. 9 is similar to FIG. 7, except that the error rates have increased. This is again due to a mismatch between the original signal and the PR4 target response, which is why the PR4 shaping filter introduces correlation in the noise. PR4 (C2) still outperforms the two other algorithms, showing the value of exploiting the correlation across signal samples.

FIG. 10 shows the error rates obtained when using the EPR4 detectors. Due to a higher density, the media noise is higher than in the previous example with symbol separations of 4.4a. This is why the graph in FIG. 10 has moved to the right by 2 dB in comparison to the graph in FIG. 8. While the required S(AWG)NR increased, the margin between the EPR4(Euc) and EPR4(C2) also increased from about 0.5 dB to about 1 dB, suggesting that the correlation-sensitive metric is more resilient to density increase. This is illustrated in FIG. 11 where the S(AWG)NR required for an error rate of 10^{-5} is plotted versus the linear density for the three EPR4 detectors. From FIG. 11 it can be seen that, for example, with an S(AWG)NR of 15 dB, the EPR(Euc) detector operates at a linear density of about 2.2 symbols/PW50 and the EPR4(C2) detector operates at 2.4 symbols/PW50, thus achieving a gain of about 10% of linear density.

Symbol separation of 2.9a. This recording density corresponds to a symbol density of 3 symbols/PW50. Due to a very low number of symbols per a, this is the density where the detectors significantly lose performance due to the percolation of magnetic domains, also referred to as nonlinear amplitude loss or partial signal erasure. FIGS. 12 and 13 show the performance of the PR4 and EPR4 families of detectors at this density. The detectors with the C2 metric outperform the other two metrics. The error rates are quite high in all cases. This is because at the symbol separations of 2.9a, nonlinear effects, such as partial erasure due to percolation of domains, start to dominate. These effects can only be undone with a nonlinear pulse shaping filter, which have not been employed here.

The experimental evidence shows that the correlation sensitive sequence detector outperforms the correlation insensitive detectors. It has also been demonstrated that the performance margin between the correlation sensitive and the correlation insensitive detectors grows with the recording density. In other words, the performance of the correlation insensitive detector deteriorates faster than the performance of the correlation sensitive detector. Quantitatively, this margin depends on the amount of correlation in the noise passed through the system. Qualitatively, the higher the correlation between the noise samples, the greater will be the margin between the CS-SD and its correlation insensitive counter part.

While the present invention has been described in conjunction with preferred embodiments thereof, many modifications and variations will be apparent to those of ordinary skill in the art. For example, the present invention may be used to detect a sequence that exploits the correlation between adjacent signal samples for adaptively detecting a sequence of symbols through a communications channel. The foregoing description and the following claims are intended to cover all such modifications and variations.

What is claimed is:

1. A method of determining branch metric values for branches of a trellis for a Virterbi-like detector, comprising:

selecting a branch metric function for each of the branches at a certain time index; and

applying each of said selected functions to a plurality of signal samples to determine the metric value corresponding to the branch for which the applied branch metric function was selected, wherein each sample corresponds to a different sampling time instant.

2. The method of claim 1 further comprising the step of receiving said signal samples, said signal samples having signal-dependent noise, correlated noise, or both signal-dependent and correlated noise associated therewith.

3. The method of claim 1 wherein said branch metric functions for each of the branches are selected from a set of signal-dependent branch metric functions.

4. A method of determining branch metric values for branches of a trellis for a Viterbi-like detector, comprising:

selecting a branch metric function for each of the branches at a certain time index from a set of signal-dependent branch metric functions; and

applying each of said selected functions to a plurality of signal samples to determine the metric value corresponding to the branch for which the applied branch metric function was selected, wherein each sample corresponds to a different sampling time instant.

5. The method of claim 4 further comprising the step of receiving said signal samples, said signal samples having signal-dependent noise, correlated noise, or both signal-dependent and correlated noise associated therewith.

6. A method of generating a signal-dependent branch weight for branches of a trellis for a Viterbi-like detector, comprising:

selecting a plurality of signal samples, wherein each sample corresponds to a different sampling time instant;

calculating a first value representing a branch-dependent joint probability density function of a subset of said signal samples;

calculating a second value representing a branch dependent joint probability density function of said signal samples;

calculating the branch weight from said first and second values; and

outputting the branch weight.

7. The method of claim 6 further comprising the step of correcting the branch weight by an additive term.

8. The method of claim 6 further comprising the step of correcting the branch weight by a multiplicative term.

9. The method of claim 7 wherein said correcting step includes the step of selecting a third value representing a prior branch probability for use as said additive term.

10. A method of generating a branch weight for branches of a trellis for a Viterbi-like detector, wherein the detector is used in a system having Gaussian noise, comprising:

selecting a plurality of signal samples, wherein each sample corresponds to a different sampling time instant;

calculating a first value representing a logarithm of a quotient of a determinant of a trellis branch dependent covariance matrix of said signal samples and a determinant of a trellis branch dependent covariance matrix of a subset of said signal samples;

calculating a second value representing a quadratic of said signal samples less a plurality of target values normalized by a trellis branch dependent covariance of said signal samples;

calculating a third value representing a quadratic of a subset of said signal samples less a plurality of channel target values normalized by a trellis branch dependent covariance of said subset of signal samples;

calculating the branch weight from said first, second, and third values; and outputting said branch weight.

11. A method for detecting a sequence that exploits the correlation between adjacent signal samples for adaptively detecting a sequence of symbols stored on a high density magnetic recording device, comprising the steps of:

(a) performing a Virterbi-like sequence detection on a plurality of signal samples using a plurality of correlation sensitive branch metrics;

(b) outputting a delayed decision on the recorded symbol;

(c) outputting a delayed signal sample;

(d) adaptively updating a plurality of noise covariance matrices in response to said delayed signal samples and said delayed decisions;

(e) recalculating said plurality of correlation-sensitive branch metrics from said noise covariance matrices using subsequent signal samples; and

(f) repeating steps (a)–(e) for every new signal sample.

12. The method of claim 11 wherein said Virterbi-like sequence detection is performed using a PRML algorithm.

13. The method of claim 11 wherein said Virterbi-like sequence detection is performed using an FDTS/DF algorithm.

14. The method of claim 11 wherein said Virterbi-like sequence detection is performed using an RAM-RSE algorithm.

15. The method of claim 11 wherein said Virterbi-like sequence detection is performed using an MDFE algorithm.

16. A method for detecting a sequence that exploits the correlation between adjacent signal samples for adaptively detecting a sequence of symbols through a communications channel having intersymbol interference, comprising the steps of:

(a) performing a Virterbi-like sequence detection on a plurality of signal samples using a plurality of correlation sensitive branch metrics;

(b) outputting a delayed decision on the transmitted symbol;

(c) outputting a delayed signal sample;

(d) adaptively updating a plurality of noise covariance matrices in response to said delayed signal samples and said delayed decisions;

(e) recalculating said plurality of correlation-sensitive branch metrics from said noise covariance matrices using subsequent signal samples; and

(f) repeating steps (a)–(e) for every new signal sample.

17. The method of claim 16 wherein said channel has nonstationary noise.

18. The method of claim 16 wherein said channel has nonstationary signal dependent noise.

19. A detector circuit for detecting a plurality of data from a plurality of signal samples read from a recording medium, comprising:

a Viterbi-like detector circuit, said Viterbi-like detector circuit for producing a plurality of delayed decisions and a plurality of delayed signal samples from a plurality of signal samples;

a noise statistics tracker circuit responsive to said Viterbi-like detector circuit for updating a plurality of noise covariance matrices in response to said delayed decisions and said delayed signal samples; and

a correlation-sensitive metric computation update circuit responsive to said noise statistics tracker circuit for recalculating a plurality of correlation-sensitive branch metrics from said noise covariance matrices, said branch metrics output to said Viterbi-like detector circuit.

20. A branch metric computation circuit for generating a branch weight for branches of a trellis for a Viterbi-like detector, wherein the detector is used in a system having Gaussian noise, comprising:

a logarithmic circuit having for each branch an input responsive to a branch address and an output;

a plurality of arithmetic circuits each having a first input responsive to a plurality of signal samples, a second input responsive to a plurality of target response values, and an output, wherein each of the arithmetic circuits corresponds to each of the branches;

a sum circuit having for each branch a first input responsive to said output of said logarithmic circuit, a second input responsive to said output of said arithmetic circuit, and an output.

21. The circuit of claim 20 wherein said branch metric computation circuit is a tapped-delay line circuit with adaptive weight.

22. The circuit of claim 20 wherein said branch metric computation circuit is an adaptive linear filter circuit.

23. A system for recording information on a magnetic medium, comprising:

a write signal processing circuit for processing a plurality of data from a data source;

a write control circuit;

a write head responsive to said write control circuit for receiving a plurality of signals from said write signal processing circuit, said write head for writing said signals to the recording medium;

a read control circuit;

a read head for reading said signals from the recording medium, said read head responsive to said read control circuit; and

a detector circuit for detecting a plurality of data from said read signals, said detector comprising:

a Viterbi-like detector circuit, said Viterbi-like detector circuit for producing a plurality of delayed decisions and a plurality of delayed signal samples from a plurality of signal samples;

a noise statistics tracker circuit responsive to said Viterbi-like detector circuit for updating a plurality of noise covariance matrices in response to said delayed decisions and said delayed signal samples; and

a correlation-sensitive metric computation update circuit responsive to said noise statistics tracker circuit for recalculating a plurality of correlation-sensitive branch metrics from said noise covariance matrices, said branch metrics output to said Viterbi-like detector circuit.

24. A system for recording information on a magnetic medium, comprising:

a write signal processing circuit for processing a plurality of data from a data source;

a write control circuit;

a write head responsive to said write control circuit for receiving a plurality of signals from said write signal processing circuit, said write head for writing said signals to the recording medium;

a read control circuit;

a read head for reading said signals from the recording medium, said read head responsive to said read control circuit; and

a detector circuit for detecting a plurality of data from said read signals, said detector circuit having a circuit for selecting a branch metric function for each branch of a trellis and for applying said metric function to a plurality of time variant signal samples to determine a plurality of branch metric values.

25. A system for recording information on a magnetic medium, comprising;

a write signal processing circuit for processing a plurality of data from a data source;

a write control circuit;

a write head responsive to said write control circuit for receiving a plurality of signals from said write signal processing circuit, said write head for writing said signals to the recording medium;

a read control circuit;

a read head for reading said signals from the recording medium, said read head responsive to said read control circuit; and

a detector circuit for detecting a plurality of data from said read signals, said detector circuit having a circuit for selecting a branch metric function for each branch of a trellis at a certain time index from a set of signal-dependent branch metric functions and for applying said selected function to a plurality of time variant signal samples to determine a plurality of branch metric values.

26. A system for recording information on a magnetic medium, comprising;

a write signal processing circuit for processing a plurality of data from a data source;

a write control circuit;

a write head responsive to said write control circuit for receiving a plurality of signals from said write signal processing circuit, said write head for writing said signals to the recording medium;

a read control circuit;

a read head for reading said signals from the recording medium, said read head responsive to said read control circuit; and

a detector circuit for detecting a plurality of data from said read signals, said detector circuit having a tapped-delay line branch metric computation circuit, the computation circuit including:

a logarithmic circuit having for each branch an input responsive to a branch address and an output;

a plurality of arithmetic circuits each having a first input responsive to a plurality of signal samples, a second input responsive to a plurality of target response values, and an output, wherein each of the arithmetic circuits corresponds to each of the branches;

a sum circuit having for each branch a first input responsive to said output of said logarithmic circuit, a second input responsive to said output of said arithmetic circuit, and an output.

27. A computer-readable medium having stored thereon instructions which, when executed by a processor, cause said processor to perform the steps of:

selecting a branch metric function for each branch of a trellis for a Viterbi-like detector at a certain time index; and

applying each of said selected functions to a plurality of time variant signal samples to determine a branch metric value corresponding to the branch for which the applied branch metric function was selected.

28. A computer-readable medium having stored thereon instructions which, when executed by a processor, cause said processor to perform the steps of:

selecting a branch metric function for each branch of a trellis for a Viterbi-like detector at a certain time index from a set of signal-dependent branch metric functions; and

applying each of said selected functions to a plurality of time variant signal samples to determine a branch metric value corresponding to the branch for which the applied branch metric function was selected.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 6,201,839 B1
DATED : March 13, 2001
INVENTOR(S) : Kavcic et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 5,
Line 64, should read "pdf's", missing a apostrophe.

Column 6,
Line 56, delete "submatrix of $C_j = [c_j]$ and replace with -- submatrix of $C_j = \left[\,\vdots \quad \dot{c}_j\right]$--.

Column 12,
Line 30, delete "band-" and replace therewith -- band. --.

Signed and Sealed this

Fifth Day of March, 2002

Attest:

JAMES E. ROGAN
Director of the United States Patent and Trademark Office

Attesting Officer

U.S. Patent No. 6,438,180

(A460-82)

US006438180B1

(12) **United States Patent**
Kavcic et al.

(10) **Patent No.: US 6,438,180 B1**
(45) **Date of Patent: *Aug. 20, 2002**

(54) **SOFT AND HARD SEQUENCE DETECTION IN ISI MEMORY CHANNELS**

(75) Inventors: **Aleksandar Kavcic**, Cambridge, MA (US); **Jose M. F. Moura**, Pittsburgh, PA (US)

(73) Assignee: **Carnegie Mellon University**, Pittsburgh, PA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **09/259,195**

(22) Filed: **Mar. 1, 1999**

Related U.S. Application Data

(63) Continuation-in-part of application No. 09/055,003, filed on Apr. 3, 1998.
(60) Provisional application No. 60/046,006, filed on May 9, 1997.

(51) **Int. Cl.**[7] **H03D 1/00**
(52) **U.S. Cl.** **375/341**; 714/796
(58) **Field of Search** 375/262, 265, 375/285, 340, 341, 343, 348; 714/791, 792, 793–796, 716, 719, 722

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,689,532 A		11/1997	Fitzpatrick	375/341
5,737,342 A		4/1998	Ziperovich	714/736
5,781,590 A		7/1998	Shiokawa et al.	375/341
5,784,415 A		7/1998	Chevillat et al.	375/341
5,844,946 A		12/1998	Nagayasu	375/341
5,856,983 A		1/1999	Okazaki	371/21.4
5,862,192 A		1/1999	Huszar et al.	375/347
5,914,988 A		6/1999	Hu et al.	375/341
5,920,599 A		7/1999	Igarashi	375/341
5,937,020 A		8/1999	Hase et al.	375/376
5,970,091 A		10/1999	Nishida et al.	375/231
5,978,426 A		11/1999	Glover et al.	375/376
6,005,731 A	*	12/1999	Foland, Jr. et al.	360/53
6,104,766 A	*	8/2000	Coker et al.	375/341
6,201,839 B1	*	3/2001	Kavcic et al.	375/341
6,215,831 B1	*	4/2001	Nowack et al.	375/340

OTHER PUBLICATIONS

Nakagawa et al., "A Study on Detection Methods of NRZ Recording", IEEE Trans. On Magnetics, vol. MAG-16, No. 1, pp. 104–10, Jan. 1980.

Chevillat et al., "Noise-Predictive Partial-Response Equalizers and Applications," IEEE CC '92 Conference Record, pp. 942–947, Jun. 1992.

(List continued on next page.)

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Assistant Examiner—Bayard Emmanuel
(74) *Attorney, Agent, or Firm*—Kirkpatrick & Lockhart LLP

(57) **ABSTRACT**

A method of determining branch metric values in a detector. The method includes receiving a plurality of time variant signal samples, the signal samples having one of signal-dependent noise, correlated noise, and both signal dependent and correlated noise associated therewith. The method also includes selecting a branch metric function at a certain time index and applying the selected function to the signal samples to determine the metric values.

27 Claims, 12 Drawing Sheets

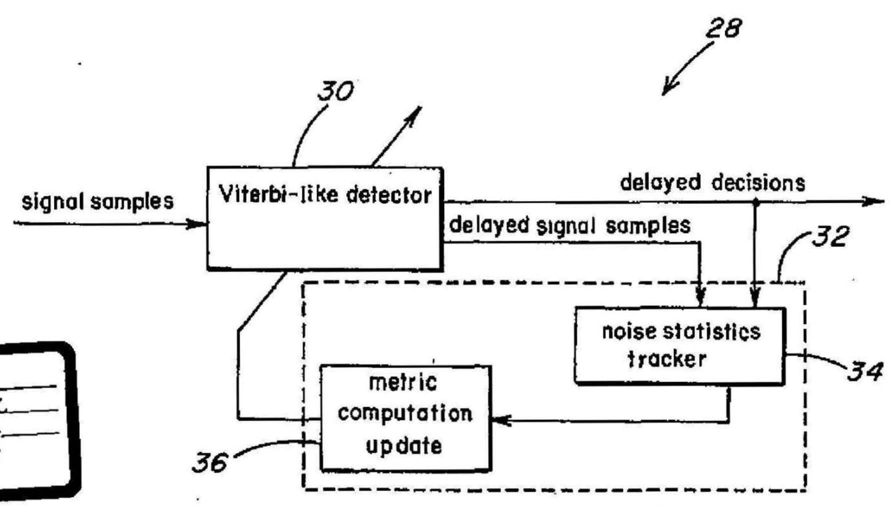


Exhibit 18
Witness Kavcic
Date ____ Rptr. ____
AKF

PLAINTIFF'S
TRIAL EXHIBIT
P-2

OTHER PUBLICATIONS

Zeng et al., "Modified Viterbi Algorithm for Jitter–dominant $1-D^2$ Channel," IEEE Trans. On Magnetics, vol. 28, No. 5, pp. 2895–2897, Sep. 1992.

Lee et al., "Performance Analysis of the Modified Maximum Likelihood Sequence Detector in the Presence of Data–dependent Noise", Proceedings of the 26th Asilomar Conference, pp. 961–964, Oct. 1992.

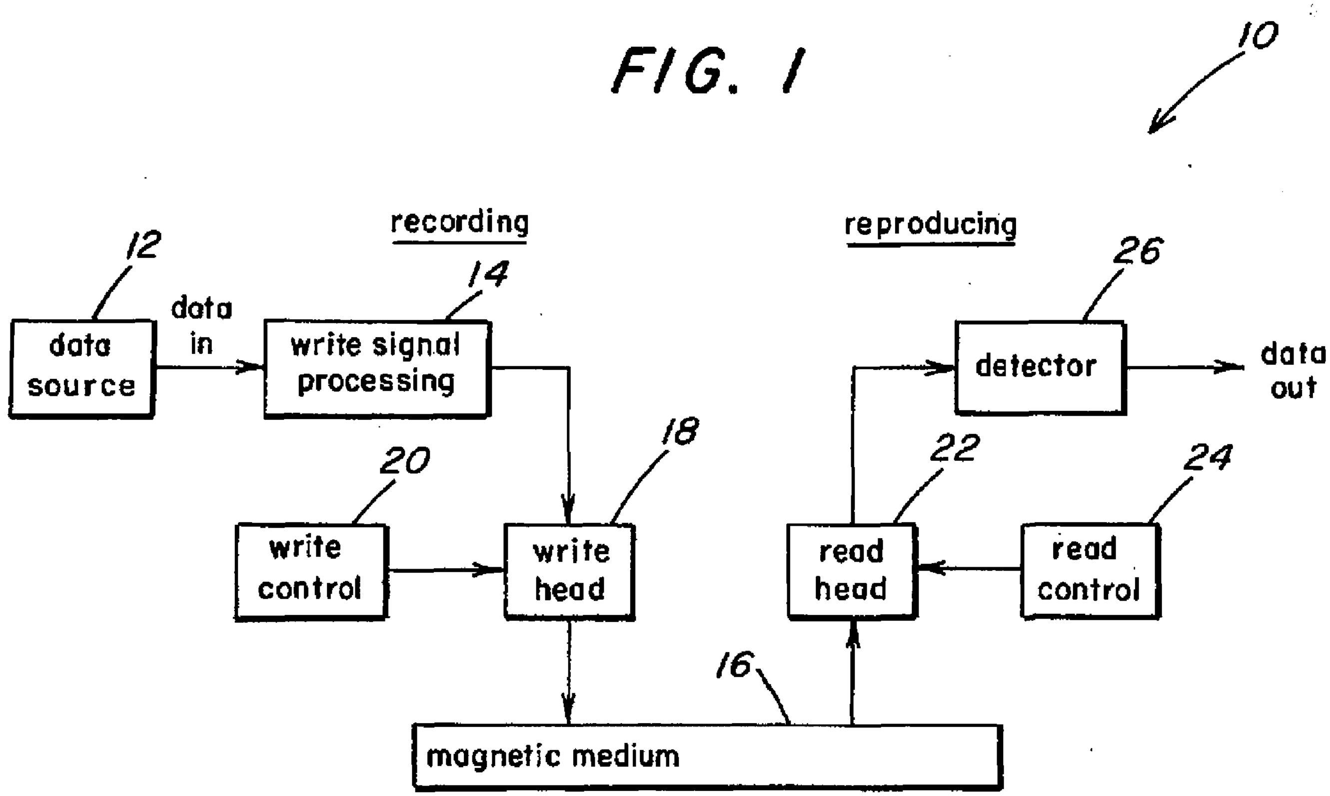
Zayad et al., "Comparison of Equalization & Detection for Very High–Density Magnetic Recording," IEEE Intermag Conference, Apr. 1997.

Bahl, et al., "Optimal Decoding of Linear Codes for Minimizng Symbol Error Rate," IEEE Transactions on Information Theory, pp. 284–287, Mar. 1974.

Heegard et al., Turbo Coding, 1999, Kluwer Academc Publishers, pp. 121–164.

* cited by examiner

FIG. 1


10
recording
reproducing
12
data source
data in
14
write signal processing
26
detector
data out
20
write control
18
write head
22
read head
24
read control
16
magnetic medium

Case: 14-1492 Document: 42 Page: 395 Filed: 08/05/2014

FIG. 2

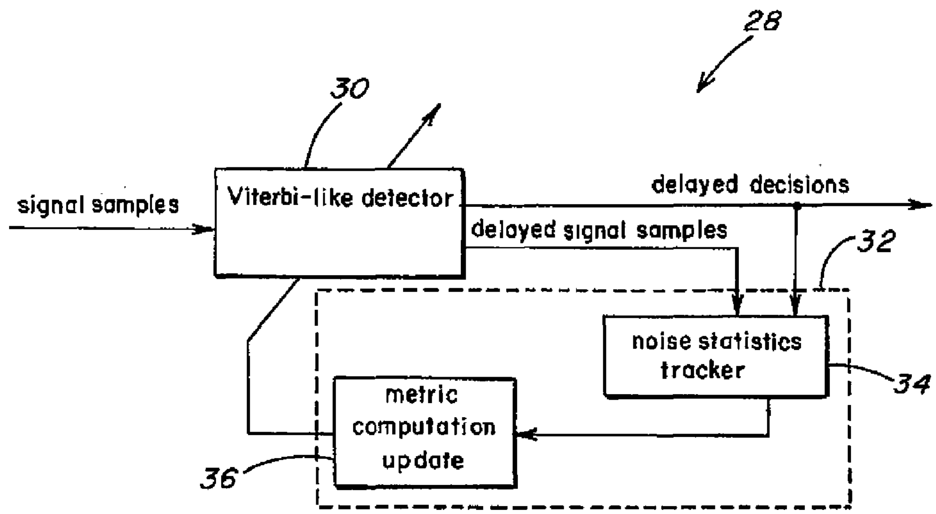


FIG. 3

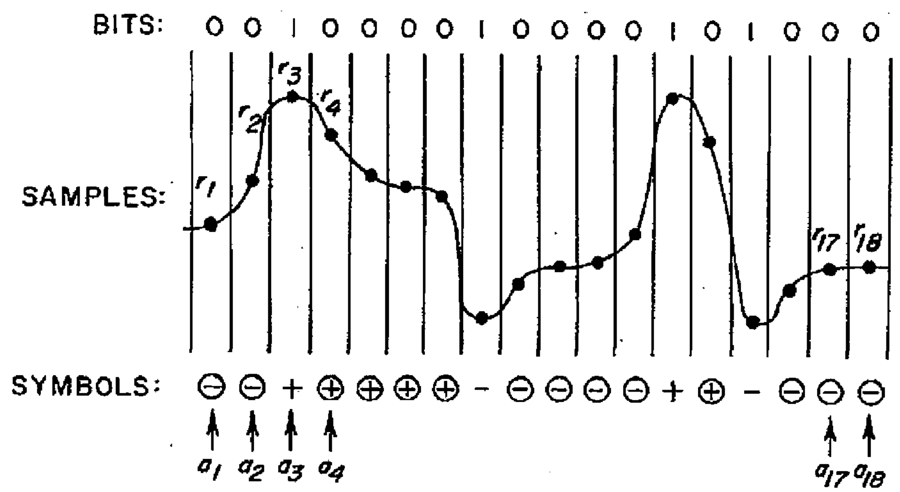

BITS: 0 0 1 0 0 0 0 1 0 0 0 0 1 0 1 0 0 0
SAMPLES:
r_1 r_2 r_3 r_4 r_{17} r_{18}
SYMBOLS: ⊖ ⊖ + ⊕ ⊕ ⊕ ⊕ - ⊖ ⊖ ⊖ ⊖ + ⊕ - ⊖ ⊖ ⊖
a_1 a_2 a_3 a_4 a_{17} a_{18}

FIG. 4

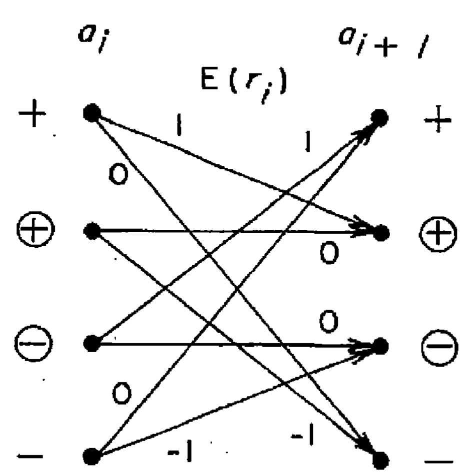

a_i
a_{i+1}
$E(r_i)$
+
⊕
⊖
−
1
1
0
0
0
0
-1
-1

FIG. 3A

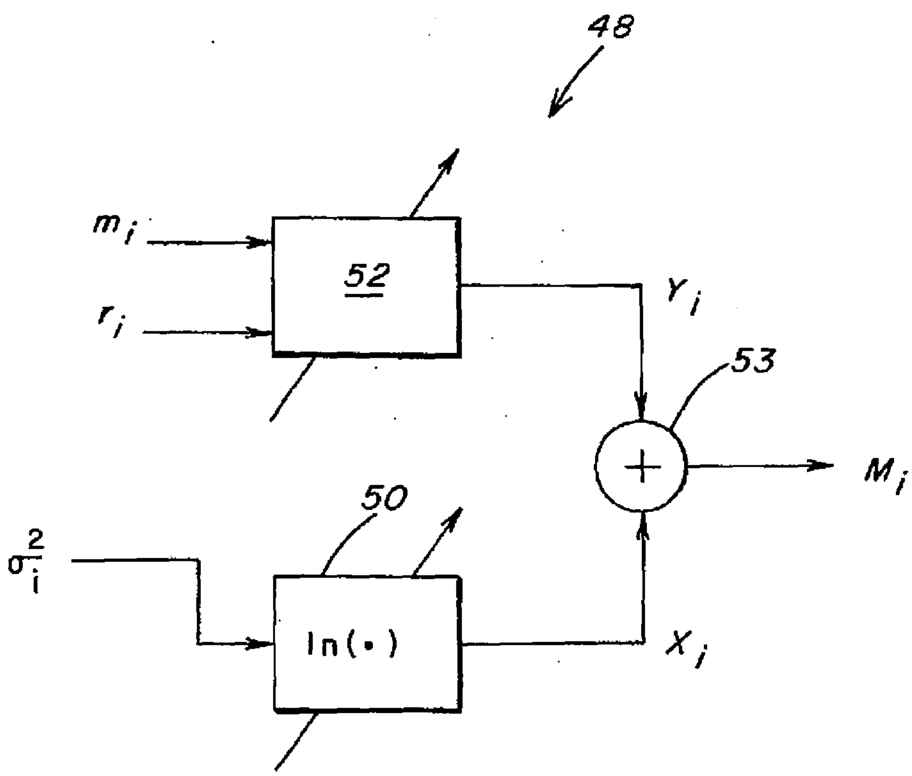


FIG. 3B

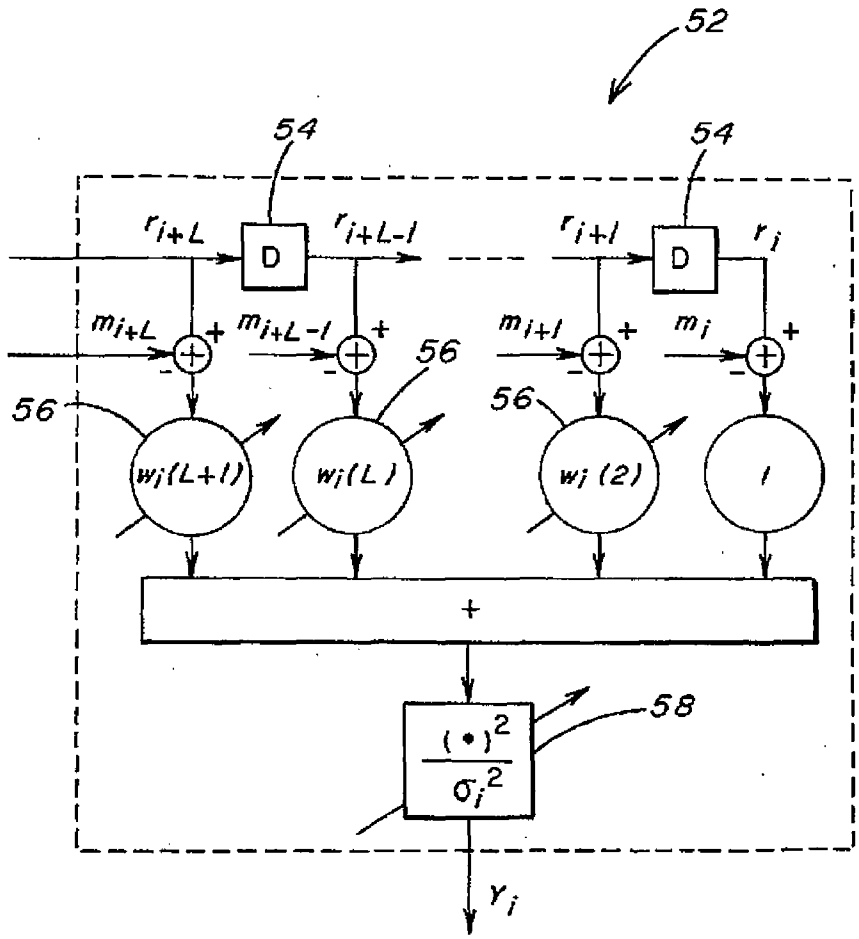

52
54
54
D
D
r_{i+L}
r_{i+L-1}
r_{i+1}
r_i
m_{i+L}
m_{i+L-1}
m_{i+1}
m_i
56
56
56
$w_i(L+1)$
$w_i(L)$
$w_i(2)$
1
+
58
$\frac{(\bullet)^2}{\sigma_i^2}$
Y_i

FIG. 5

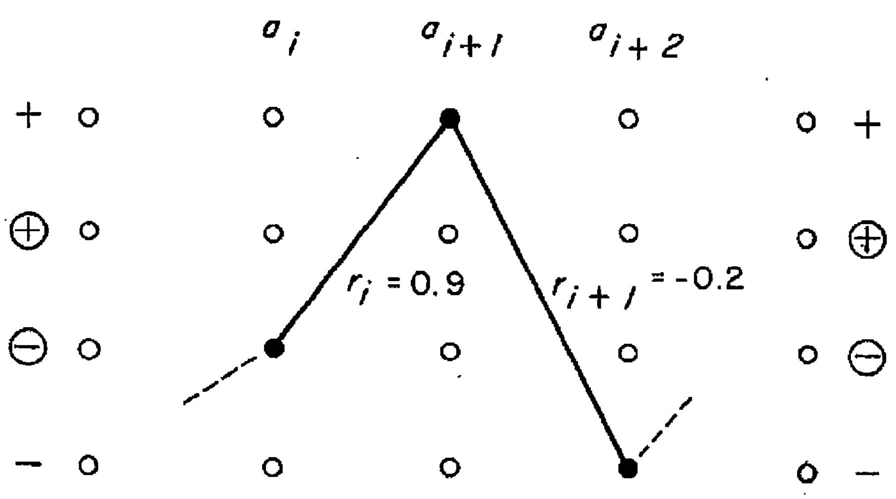
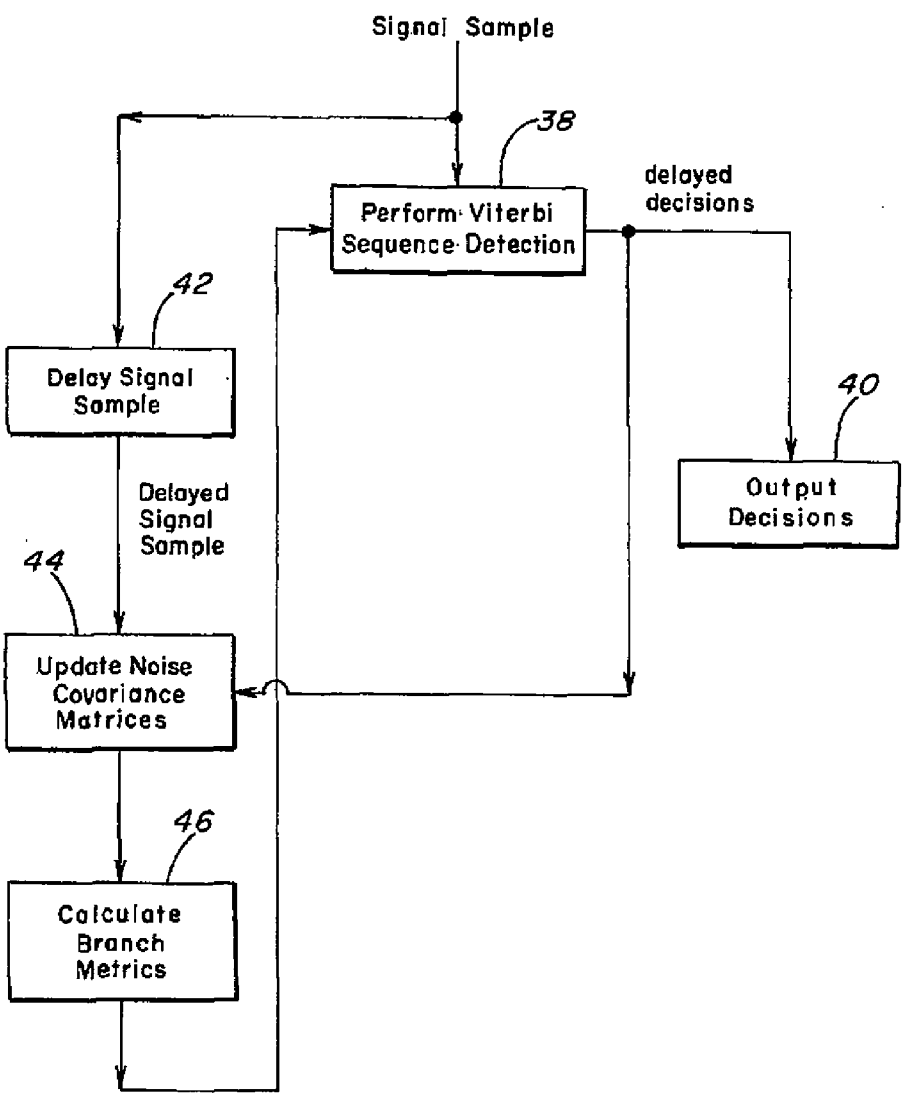


FIG. 6



Signal Sample
38
Perform Viterbi Sequence Detection
delayed decisions
42
Delay Signal Sample
40
Output Decisions
Delayed Signal Sample
44
Update Noise Covariance Matrices
46
Calculate Branch Metrics

FIG. 7

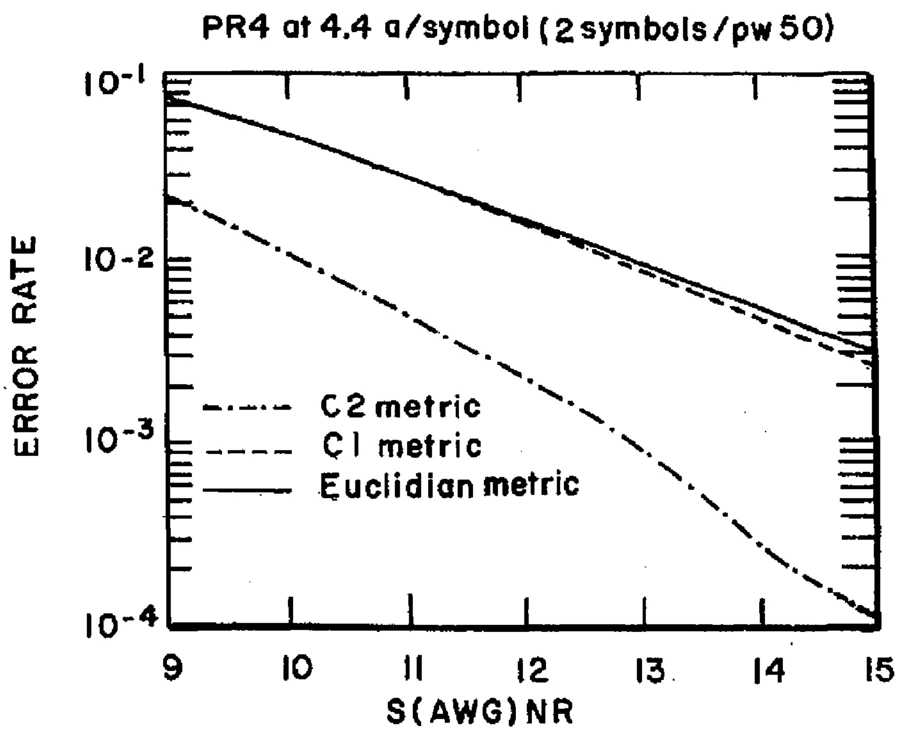

PR4 at 4.4 a/symbol (2 symbols/pw 50)
ERROR RATE
10^{-1}
10^{-2}
10^{-3}
10^{-4}
C2 metric
C1 metric
Euclidian metric
9
10
11
12
13
14
15
S(AWG)NR

FIG. 8

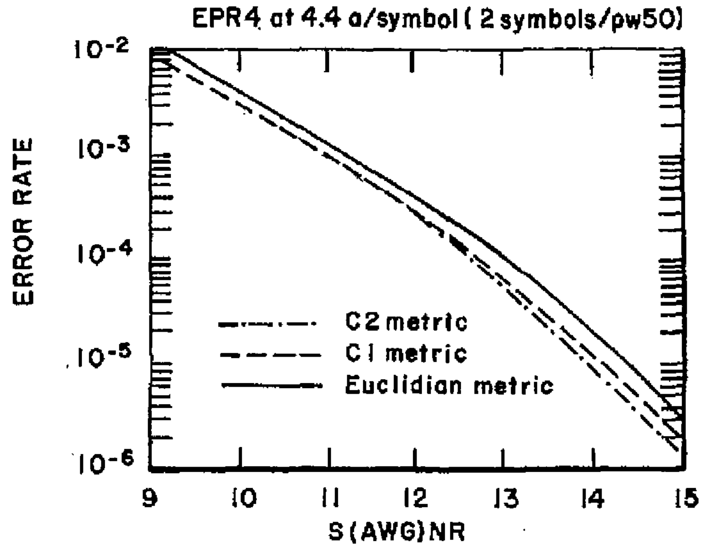

EPR4 at 4.4 a/symbol (2 symbols/pw50)
ERROR RATE
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
C2 metric
C1 metric
Euclidian metric
9 10 11 12 13 14 15
S(AWG)NR

FIG. 9

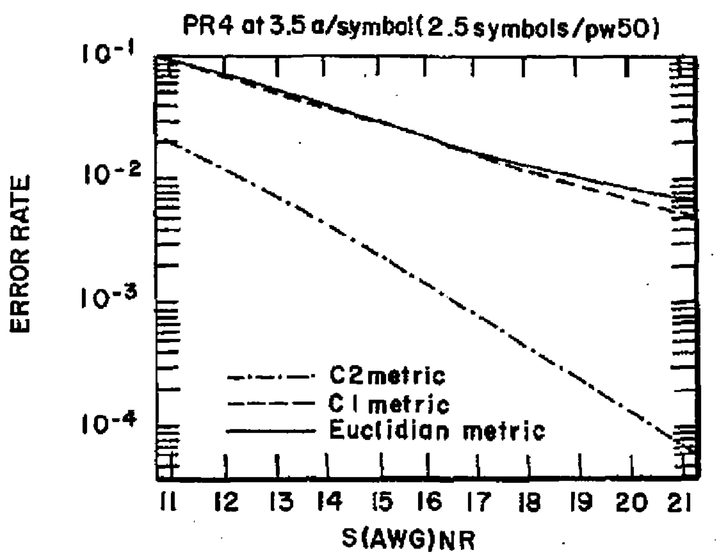

PR4 at 3.5 a/symbol(2.5 symbols/pw50)
ERROR RATE
10^{-1}
10^{-2}
10^{-3}
10^{-4}
C2 metric
C1 metric
Euclidian metric
11 12 13 14 15 16 17 18 19 20 21
S(AWG)NR

FIG. 10

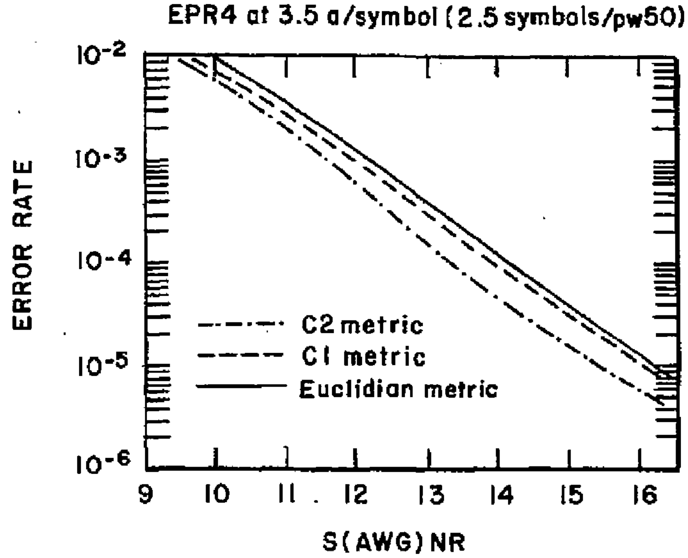

EPR4 at 3.5 a/symbol (2.5 symbols/pw50)
ERROR RATE
10-2
10-3
10-4
10-5
10-6
C2 metric
C1 metric
Euclidian metric
9
10
11
12
13
14
15
16
S(AWG)NR

FIG. 11

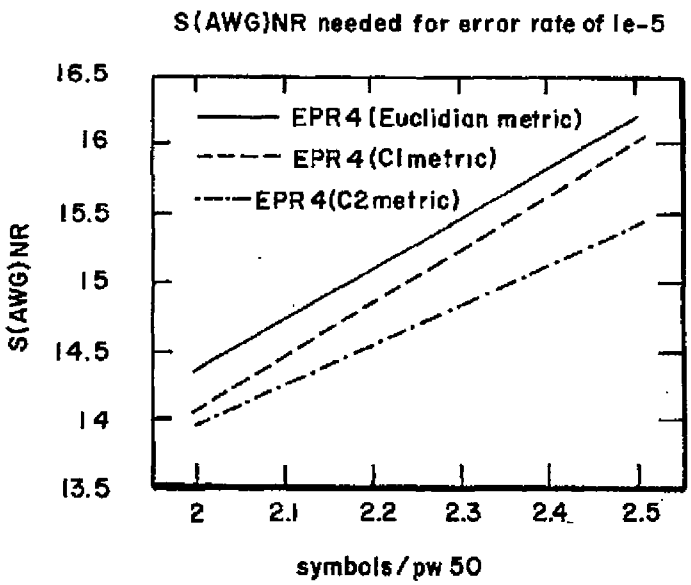

S(AWG)NR needed for error rate of 1e-5
S(AWG)NR
16.5
16
15.5
15
14.5
14
13.5
EPR4 (Euclidian metric)
EPR4 (C1 metric)
EPR4 (C2 metric)
2
2.1
2.2
2.3
2.4
2.5
symbols/pw 50

FIG. 12

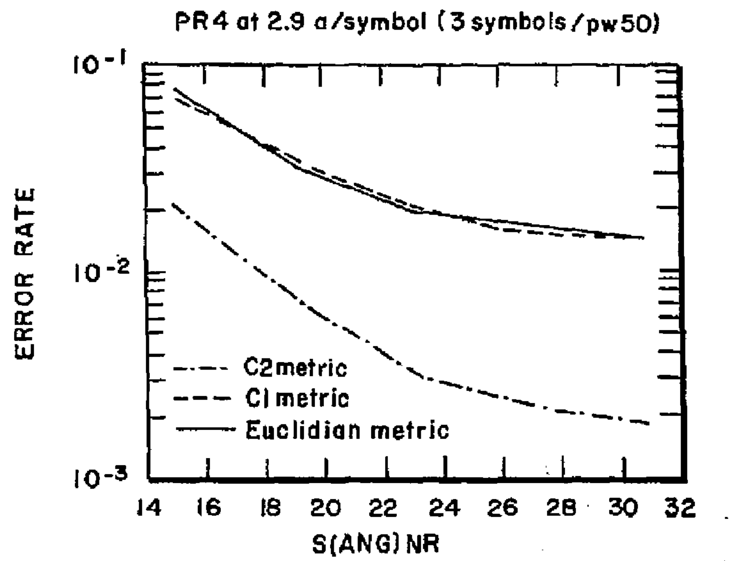
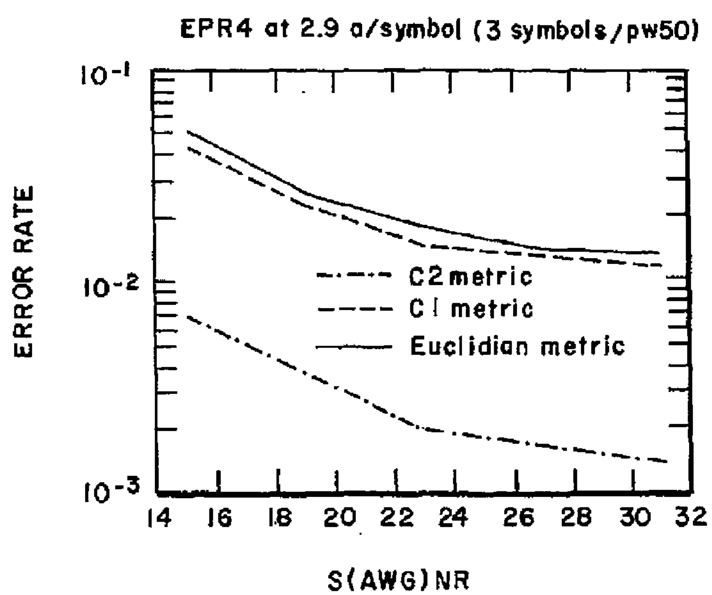

PR4 at 2.9 a/symbol (3 symbols/pw50)
ERROR RATE
10⁻¹
10⁻²
10⁻³
C2metric
C1 metric
Euclidian metric
14 16 18 20 22 24 26 28 30 32
S(ANG) NR

FIG. 13


EPR4 at 2.9 a/symbol (3 symbols/pw50)
ERROR RATE
10⁻¹
10⁻²
10⁻³
C2 metric
C1 metric
Euclidian metric
14 16 18 20 22 24 26 28 30 32
S(AWG) NR

Case: 14-1492 Document: 42 Page: 405 Filed: 08/05/2014

FIG. 14

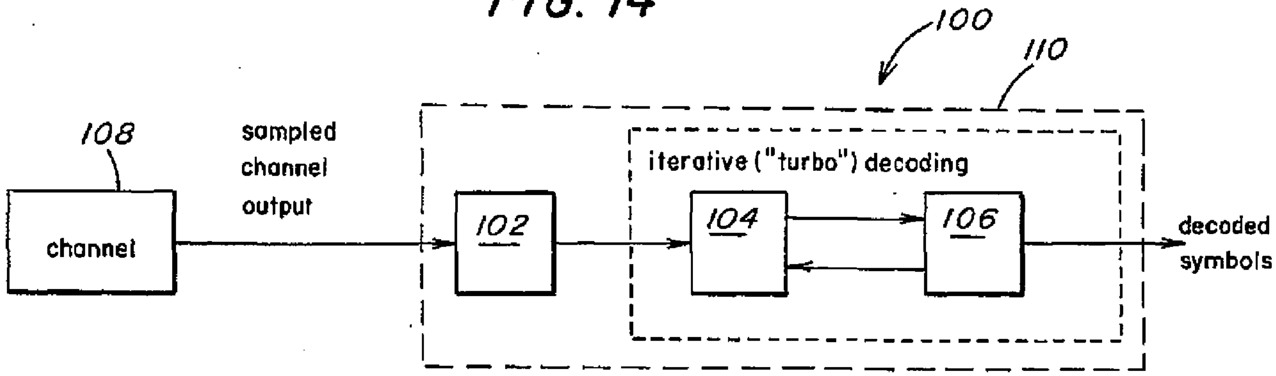
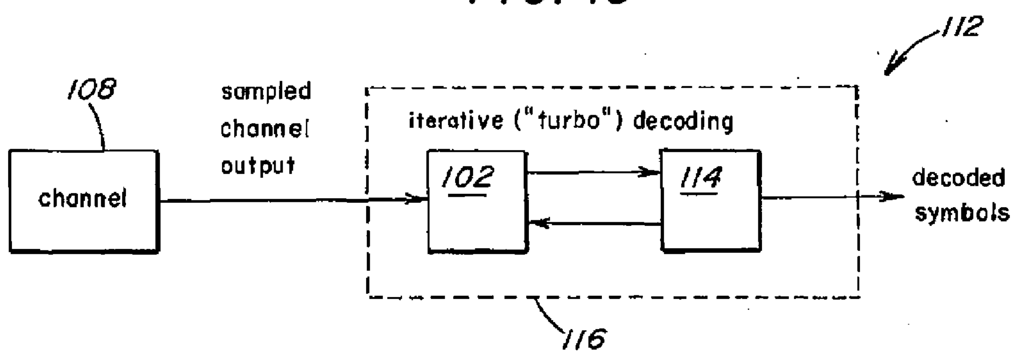


FIG. 15



SOFT AND HARD SEQUENCE DETECTION IN ISI MEMORY CHANNELS

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of U.S. patent application Ser. No. 09/055,003, filed Apr. 3, 1998, which claims priority to Provisional Ser. No. 60/046,006, filed May 9, 1997, under 35 U.S.C. Section 119(e).

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH

This invention was supported in part by the National Science Foundation under Grant No. ECD-8907068. The United States Government has certain rights in this invention.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention is directed generally to sequence detectors, and, more particularly, to sequence detectors in ISI memory channels.

2. Description of the Background

In recent years, there has been a major shift in the design of signal detectors in magnetic recording. Traditional peak detectors (PD), such as those described in Nakagawa et al., "A Study of Detection Methods of NRZ Recording", IEEE Trans. Magn., vol. 16, pp. 1041–110, January 1980, have been replaced by Viterbi-like detectors in the form of partial response maximum likelihood (PRML) schemes or hybrids between tree/trellis detectors and decision feedback equalizers (DFE), such as FDTS/DF, MDFE and RAM-RSE. These methods were derived under the assumption that additive white Gausian noise (AWGN) is present in the system. The resulting trellis/tree branch metrics are then computed as Euclidian distances.

It has long been observed that the noise in magnetic recording systems is neither white nor stationary. The nonstationarity of the media noise results from its signal dependent nature. Combating media noise and its signal dependence has thus far been confined to modifying the Euclidian branch metric to account for these effects. Zeng, et al., "Modified Viterbi Algorithm for Jitter-Dominated 1-D^2 Channel," IEEE Trans. Magn., Vol. MAG-28, pp. 2895–97, September, 1992, and Lee et al., "Performance Analysis of the Modified maximum Likelihood Sequence Detector in the Presence of Data-Dependent Noise," Proceedings 26th Asilomar Conference, pp. 961–64, October 1992 have derived a branch metric computation method for combating the signal-dependent character of media noise. These references ignore the correlation between noise samples. The effectiveness of this method has been demonstrated on real data in Zayad et al., "Comparison of Equalization and Detection for Very High-Density Magnetic Recording," IEEE INTERMAG Conference, New Orleans, April 1997.

These methods do not take into consideration the correlation between noise samples in the readback signal. These correlations arise due to noise coloring by front-end equalizers, media noise, media nonlinearities, and magnetoresistive (MR) head nonlinearities. This noise coloring causes significant performance degradation at high recording densities. Thus, there is a need for an adaptive correlation-sensitive maximum likelihood sequence detector which derives the maximum likelihood sequence detector (MLSD) without making the usual simplifying assumption that the noise samples are independent random variables.

Turbo codes were introduced in 1993 and hold the promise of substantial coding gains over current coding algorithms, and their performance is within a fraction of a dB of the Shannon theoretical limit for additive white Gaussian noise channels. The basic idea in turbo decoding and other iterative decoding strategies is to pass "soft" information between several components of the decoder and the detector. In this context, the detector is the first device that processes data which is observed at the output of the communications channel. Classically, the detector is a hard-detection device which provides zeroes and ones at its output. A Viterbi detector is a typical example of such a hard detector. When iterative decoding is used, however, the detector is often a soft detector in which the outputs of the detector are reliability measures for bits transmitted through the communications channel. Because the detector is the first device that processes the channel output, the detector should be tuned to the channel signal and noise statistics. However, existing soft output detectors are designed only for channels which are assumed to have white noise. Thus, there is a need for a soft detector which is designed for channels which have correlated and/or signal-dependent noise.

SUMMARY OF THE INVENTION

The present invention is directed to a method of determining branch metric values in a detector. The method includes receiving a plurality of time variant signal samples, the signal samples having one of signal-dependent noise, correlated noise, and both signal dependent and correlated noise associated therewith. The method also includes selecting a branch metric function at a certain time index and applying the selected function to the signal samples to determine the metric values.

The present invention represents a substantial advance over prior sequence detectors. Because the present invention takes into account the correlation between noise samples in the readback signal, the detected data sequence is detected with a higher degree of accuracy. Those advantages and benefits of the present invention, and others, will become apparent from the Detailed Description of the Invention hereinbelow.

BRIEF DESCRIPTION OF THE DRAWINGS

For the present invention to be clearly understood and readily practiced, the present invention will be described in conjunction with the following figures wherein:

FIG. 1 is an illustration of a magnetic recording system;

FIG. 2 is an illustration of a CS-MLSD detector circuit of a preferred embodiment of the present invention;

FIG. 3 is an illustration of a sample signal waveform, its samples, and written symbols;

FIG. 3A is an illustration of a branch metric computation module;

FIG. 3B is an illustration of an implementation of a portion of the branch metric computation module of FIG. 3A;

FIG. 4 is an illustration of one cell of a PR4 trellis;

FIG. 5 is an illustration of a detected path in a PR4 trellis;

FIG. 6 is a block diagram of a preferred embodiment of a method for signal detection;

FIG. 7 is an illustration of PR4 detection results at a 4.4a/symbol;

FIG. 8 is an illustration of EPR4 detection results at a 4.4a/symbol;

FIG. 9 is an illustration of PR4 detection results at a 3.5a/symbol;

FIG. 10 is an illustration of EPR4 detection results at a 3.5a/symbol;

FIG. 11 is an illustration of S(AWG)NR margins needed for error rate of 10^{-5} with EPR4 detectors;

FIG. 12 is an illustration of PR4 detection results at a 2.9a/symbol; and

FIG. 13 is an illustration of EPR 4 detection results at a 2.9a/symbol.

FIG. 14 is an illustration of a portion of a communications system having a detector with parallely concatenated decoders; and

FIG. 15 is an illustration of a portion of a communications system having a detector serially concatenated with a decoder.

DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 illustrates a magnetic recording system 10. A data source 12 supplies data to a write signal processing circuit 14. The signal processing circuit 14 converts the input data into signals with a format suitable for storage on a magnetic medium 16. The medium 16 is typically a rotating disk, a "floppy" disk, or a tape with magnetic coatings. A write head 18 stores the signals on the medium 16 as a series of variations in the magnetic flux of the medium 16. The write head 18 is controlled by a write control circuit 20, which supplies signals to the write head 18 to control its position with respect to the medium 16.

A read head 22 retrieves the variations in the magnetic flux that are stored on the medium 16. A read control circuit 24 supplies signals to the read head 22 to control its position with respect to the medium 16. The read head 22 provides a stream of data to a detector circuit 26. The detector circuit 26 detects the data from the data stream and outputs the data. The detector 26 must be able to detect the data in the presence of intersymbol interference ("ISI") noise. Prior art detector circuits have employed the maximum likelihood sequence ("MLS") estimation algorithm or peak detection techniques. The MLS algorithm analyzes a sequence of consecutive data and determines the output data based on the sequence. Peak detection techniques identify analog peaks in a sequence of data and determine the output data based on the peaks.

A block diagram of a CS-MLSD detector circuit 28 is shown in FIG. 2. The CS-MLSD detector circuit 28 is a part of the detector circuit 26 of FIG. 1. The detector circuit 28 has a feedback circuit 32 which feeds back into a Viterbi-like detector 30. The outputs of the detector 30 are decisions and delayed signal samples, which are used by the feedback circuit 32. A noise statistics tracker circuit 34 uses the delayed samples and detector decisions to update the noise statistics, i.e., to update the noise covariance matrices. A metric computation update circuit 36 uses the updated statistics to calculate the branch metrics needed in the Viterbi-like algorithm. The algorithm does not require replacing current detectors. It simply adds two new blocks in the feedback loop to adaptively estimate the branch metrics used in the Viterbi-like detector 30.

The Viterbi-like detector 30 typically has a delay associated with it. Until the detector circuit 28 is initialized, signals of known values may be input and delayed signals are not output until the detector circuit 28 is initialized. In other types of detectors, the detector may be initialized by having the necessary values set.

The correlation-sensitive maximum likelihood sequence detector (CS-MLSD) 28 is described hereinbelow. Assume that N>1 channel bits (symbols), $a_1, a_2, \ldots, a_N$, are written on a magnetic medium. The symbols a_i, $i=1, \ldots, N$, are drawn from an alphabet of four symbols, $a_i \in \{+, \oplus, -, \ominus\}$. The symbols '+' and '−' denote a positive and a negative transition, respectively. The symbol '$\oplus$' denotes a written zero (no transition) whose nearest preceding non-zero symbol is a '+', while '$\ominus$' denotes a written zero whose nearest preceding transition is a negative one, i.e., '−'. This notation is used because a simple treatment of transitions as '1's and no transitions as '0's is blind to signal asymmetries (MR head asymmetries and base line drifts), which is inappropriate for the present problem. In FIG. 3 a sample waveform is illustrated. The signal asymmetries and base line shifts are exaggerated in FIG. 3. FIG. 3 also shows the written symbols $a_1, \ldots, a_{18}$, as well as the samples $r_1, \ldots, r_{18}$ of the read-back waveform, sampled at the rate of one sample per symbol interval.

When the written sequence of symbols a_i, $i=1, \ldots, N$, is read, the readback waveform is passed through a pulse-shaping equalizer and sampled one sample per symbol, resulting in the sequence of samples r_i, $i=1, \ldots, N$. Due to the noise in the system, the samples r_i are realizations of random variables. The maximum likelihood detector determines the sequence of symbols a_i that has been written, by maximizing the likelihood function, i.e.:

$$\{\hat{a}_1, \ldots, \hat{a}_N\} = \arg\left[\max_{\text{all } a_i} f(r_1, \ldots, r_N | a_1, \ldots, a_N)\right]. \tag{1}$$

In (1), the likelihood function $f(r_1, \ldots, r_N|a_1, \ldots, a_N)$ is the joint probability density function (pdf) of the signal samples $r_1, \ldots, r_N$, conditioned on the written symbols $a_1, \ldots, a_N$. The maximization in (1) is done over all possible combinations of symbols in the sequence $\{a_1, \ldots, a_N\}$.

Due to the signal dependent nature of media noise in magnetic recording, the functional form of joint conditional pdf $f(r_1, \ldots, r_N|a_1, \ldots, a_N)$ in (1) is different for different symbol sequences $a_1, \ldots, a_N$. Rather than making this distinction with more complex but cluttered notation, the notation is kept to a minimum by using simply the same symbol f to denote these different functions.

By Bayes rule, the joint conditional pdf (likelihood function) is factored into a product of conditional pdfs:

$$f(r_1, \ldots, r_N | a_1, \ldots, a_N) = \prod_{i=1}^{N} f(r_i | r_{i+1}, \ldots, r_N, a_1, \ldots, a_N). \tag{2}$$

To proceed and obtain more concrete results, the nature of the noise and of the intersymbol interference in magnetic recording is exploited.

Finite correlation length. The conditional pdfs in Equation (2) are assumed to be independent of future samples after some length L≧0. L is the correlation length of the noise. This independence leads to:

$$f(r_i | r_{i+1}, \ldots, r_N, a_1, \ldots, a_N) = f(r_i | r_{i+1}, \ldots, r_{i+L}, a_1, \ldots, a_N). \tag{3}$$

Finite intersymbol interference. The conditional pdf is assumed to be independent of symbols that are not in the K-neighborhood of $r_i, \ldots, r_{i+L}$. The value of K≧1 is determined by the length of the intersymbol interference (ISI). For example, for PR4, K=2, while for EPR4, K=3. $K_l \geqq 0$ is defined as the length of the leading (anticausal) ISI and $K_t \geqq 0$ is defined as the length of the trailing (causal) ISI, such that $K=K_l+K_t+1$. With this notation the conditional pdf in (3) can be written as:

$$f(r_i|r_{i+1}, \ldots, r_{i+L}, a_1, \ldots, a_N) = f(r_i|r_{i+1}, \ldots, r_{i+L}, a_{i-K_l}, \ldots, a_{i+L+K_t}) \tag{4}$$

Substituting (4) into (2) and applying Bayes rule, the factored form of the likelihood function (conditional pdf) is obtained:

$$f(r_1, \ldots, r_N|a_1, \ldots, a_N) = \prod_{i=1}^{N} f(r_i|r_{i+1}, \ldots, r_N, a_1, \ldots, a_N) = \prod_{i=1}^{N} \frac{f(r_i, r_{i+1}, \ldots, r_{i+L}|a_{i-K_l}, \ldots, a_{i+L+K_t})}{f(r_{i+1}, \ldots, r_{i+L}|a_{i-K_l}, \ldots, a_{i+L+K_t})}. \tag{5}$$

The factored form of equation (5) is suitable for applying Viterbi-like dynamic programming detection techniques. Equation (5) assumes anticausal factorization, i.e. , it is derived by taking into account the effect of the samples $r_{i+1}, \ldots, r_{i+L}$, on r_i. If only the causal effects are taken into account, the causal equivalent of (5) can be derived as $f(r_1, \ldots, r_N|a_1, \ldots, a_N)=$

$$\prod_{i=1}^{N} \frac{f(r_i, r_{i+1}, \ldots, r_{i+L}|a_{i-K_l}, \ldots, a_{i+L+K_t})}{f(r_i, \ldots, r_{i-L-1}|a_{i-K_l}, \ldots, a_{i+L+K_t})}.$$

The causal and anticausal factorization could be combined to find the geometric mean of the two to form a causal-anticausal factorization. Since this only complicates derivations and does not provide further insight, only the anticausal Equation (5) is considered.

Maximizing the likelihood function in (5) is equivalent to minimizing its negative logarithm. Thus, the maximum-likelihood detector is now:

$$\begin{aligned} \{\hat{a}_1, \ldots, \hat{a}_N\} &= \arg\left[\min_{\text{all } a_i} \log \prod_{i=1}^{N} \frac{f(r_{i+1}, \ldots, r_{i+L}|a_{i-K_l}, \ldots, a_{i+L+K_t})}{f(r_i, r_{i+1}, \ldots, r_{i+L}|a_{i-K_l}, \ldots, a_{i+L+K_t})}\right] \\ &= \arg\left[\min_{\text{all } a_i} \prod_{i=1}^{N} \log \frac{f(r_{i+1}, \ldots, r_{i+L}|a_{i-K_l}, \ldots, a_{i+L+K_t})}{f(r_i, r_{i+1}, \ldots, r_{i+L}|a_{i-K_l}, \ldots, a_{i+L+K_t})}\right] \\ &= \arg\left[\min_{\text{all } a_i} \prod_{i=1}^{N} M_i(r_i, r_{i+1}, \ldots, r_{i+L}, a_{i-K_l}, \ldots, a_{i+L+K_t})\right] \end{aligned} \tag{6}$$

M_i represents the branch metric of the trellis/tree in the Viterbi-like algorithm. The metric is a function of the observed samples $r_i, r_{i+1}, \ldots, r_{i+L}$. It is also dependent on the postulated sequence of written symbols $a_{i-K_l}, \ldots, a_{i+L+K_t}$, which ensures the signal-dependence of the detector. As a consequence, the branch metrics for every branch in the tree/trellis is based on its corresponding signal/noise statistics. Although the above discussion focused on maximum likelihood sequence detectors, the discussion also applies to maximum a-posteriori (MAP) branch metrics by including prior probabilities. See J. Moura and A. Kavcic, "The Viterbi Algorithm and Markov Noise Memory", accepted for publication in IEEE Transactions on Information Theory. An example of MAP soft decision detection is give hereinbelow in connection with FIGS. 14 and 15.

Specific expressions for the branch metrics that result under different assumptions on the noise statistics are next considered.

Euclidian branch metric. In the simplest case, the noise samples are realizations of independent identically distributed Gaussian random variables with zero mean and variance σ^2 This is a white Gaussian noise assumption. This implies that the correlation distance is L=0 and that the noise pdfs have the same form for all noise samples. The total ISI length is assumed to be $K=K_l+K_t+1$, where K_l and K_t are the leading and trailing ISI lengths, respectively. The conditional signal pdfs are factored as

$$\frac{f(r_{i+1}, \ldots, r_{i+L}|a_{i-K_l}, \ldots, a_{i+L+K_t})}{f(r_i, r_{i+1}, \ldots, r_{i+L}|a_{i-K_l}, \ldots, a_{i+L+K_t})} = \sqrt{2\pi\sigma^2}\exp\left[\frac{(r_i-m_i)^2}{2\sigma^2}\right] \tag{7}$$

Here the mean signal mi is dependent on the written sequence of symbols. For example, for a PR4 channel, $m_i \in \{-1,0,1\}$. The branch/tree metric is then the conventional Euclidian distance metric:

$$M_i = N_i^2 = (r_i - m_i)^2 \tag{8}$$

Variance dependent branch metric. It is again assumed that the noise samples are samples of independent Gaussian variables, but that their variance depends on the written sequence of symbols. The noise correlation length is still L=0 but the variance of the noise samples is no longer constant for all samples. The variance is σ^{2i}, where the index i denotes the dependence on the written symbol sequence. As for the Euclidian metric, it is assumed that the total ISI length is $K=K_l+K_t+1$. The conditional signal pdf is factored to give:

$$\frac{f(r_{i+1}, \ldots, r_{i+L}|a_{i-K_l}, \ldots, a_{i+L+K_t})}{f(r_i, r_{i+1}, \ldots, r_{i+L}|a_{i-K_l}, \ldots, a_{i+L+K_t})} = \sqrt{2\pi\sigma_i^2}\exp\left[\frac{(r_i-m_i)^2}{2\sigma_i^2}\right] \tag{9}$$

The corresponding branch metric is:

$$M_i = \log\sigma_i^2 + \frac{N_i^2}{\sigma_i^2} = \log\sigma_i^2 + \frac{(r_i-m_i)^2}{\sigma_i^2} \tag{10}$$

Correlation-sensitive branch metric. In the most general case, the correlation length is L>0. The leading and trailing ISI lengths are K_l and K_t, respectively. The noise is now considered to be both correlated and signal-dependent. Joint Gaussian noise pdfs are assumed. This assumption is well justified in magnetic recording because the experimental evidence shows that the dominant media noise modes have Gaussian-like histograms. The conditional pdfs do not factor out in this general case, so the general form for the pdf is:

$$\frac{f(r_{i+1}, \ldots, r_{i+L} \mid a_{i-K_l}, \ldots, a_{i+L+K_t})}{f(r_i, r_{i+1}, \ldots, r_{i+L} \mid a_{i-K_l}, \ldots, a_{i+L+K_t})} = \sqrt{\frac{(2\pi)^{L+1} \det C_i}{(2\pi)^L \det c_i}} \frac{\exp[\underline{N}_i^T C_i^{-1} \underline{N}_i]}{\exp[\underline{n}_i^T c_i^{-1} \underline{n}_i]} \tag{11}$$

The (L+1)×(L+1) matric C_i is the covariance matrix of the data samples $r_i, r_{i+1}, \ldots, r_{i+L}$, when a sequence of symbols $a_{i-Kl}, \ldots, a_{i+L+Kt}$ is written. The matrix c_i in the denominator of (11) is the LxL lower principal submatrix of $C_i=[\,\cdot\, c_i]$. The (L+1)-dimensional vector $\underline{N}_i$ is the vector of differences between the observed samples and their expected values when the sequence of symbols $a_{i-Kl}, \ldots, a_{i+L+Kt}$ is written, i.e.:

$$\underline{N}_i=[(r_i-m_i)\ (r_{i+1}-m_{i+1}) \ldots (r_{i+L}-m_{i+L})]^T \tag{12}$$

The vector $\underline{n}_i$ collects the last L elements of $\underline{N}_i$, $\underline{n}_i=[(r_{i+1}-m_{i+1}) \ldots (r_{i+L}-m_{i+L})]^T$. With this notation, the general correlation-sensitive metric is:

$$M_i = \log\frac{\det C_i}{\det c_i} + \underline{N}_i^T C_i^{-1} \underline{N}_i - \underline{n}_i^T c_i^{-1} \underline{n}_i \tag{13}$$

In the derivations of the branch metrics (8), (10) and (13), no assumptions were made on the exact Viterbi-type architecture, that is, the metrics can be applied to any Viterbi-type algorithm such as PRML, FDTS/DF, RAM-RSE, or, MDFE.

FIG. 3A illustrates a block diagram of a branch metric computation circuit **48** that computes the metric M_i for a branch of a trellis, as in Equation (13). Each branch of the trellis requires a circuit **48** to compute the metric M_i.

A logarithmic circuit **50** computes the first term of the right hand side of (13) (i.e.

$$\log\frac{\det C_i}{\det c_i}$$

and a quadratic circuit **52** computes the second terms of the right hand side of (13) (i.e. $\underline{N}_i^T C_i^{-1}\underline{N}_i - \underline{n}_i^T c_i^{-1}\underline{n}_i$), The arrows through the circuits **50** and **52** represent the adaptive nature of the Virterbi-like detector **30**. A sum circuit **53** computes the sum of the outputs of the circuits **50** and **52**.

As stated above, the covariance matrix is given as:

$$C_i = \begin{bmatrix} \alpha_i & \underline{c}_i \\ \underline{c}_i^T & c_i \end{bmatrix}. \tag{14}$$

Using standard techniques of signal processing, it can be shown that:

$$\frac{\det C_i}{\det c_i} = \alpha_i - \underline{c}_i^T c_i^{-1} \underline{c}_i. \tag{15}$$

This ratio of determinants is referred to as σ_i^2, i.e.:

$$\sigma_i^2 = \frac{\det C_i}{\det c_i} = \alpha_i - \underline{c}_i^T c_i^{-1} \underline{c}_i. \tag{16}$$

It can be shown by using standard techniques of signal processing that the sum of the last two terms of (13), i.e. the output of the circuit **52**, is:

$$Y_i = \underline{N}_i^T C_i^{-1} \underline{N}_i - \underline{n}_i^T c_i^{-1} \underline{n}_i \tag{17}$$

$$= \frac{(\underline{w}_i^T \underline{N}_i)^2}{\sigma_i^2}, \tag{18}$$

Where the vector $\underline{w}_i$ is (L+1)-dimensional and is given by:

$$\underline{w}_i^T = [1\ w_i(2)\ w_i(3) \ldots w_i(L+1)]^T \tag{19}$$

$$= \begin{bmatrix} 1 \\ -c_i^{-1}\underline{c}_i \end{bmatrix}. \tag{20}$$

Equations (17), (18) and (16) (the circuit **52**) can be implemented as a tapped-delay line as illustrated in FIG. 3B. The circuit **52** has L delay circuits **54**. The tapped-delay line implementation shown in FIGS. 3A and 3B is also referred to as a moving-average, feed-forward, or finite-impulse response filter. The circuit **48** can be implemented using any type of filter as appropriate.

The adaptation of the vector of weights $\underline{w}_i$ and the quantity σ_i^2 as new decisions are made is essentially an implementation of the recursive least squares algorithm. Alternatively, the adaptation may be made using the least mean squares algorithm.

The quantities m_i that are subtracted from the output of the delay circuits **54** are the target response values, or mean signal values of (12). The arrows across multipliers **56** and across square devices **58** indicate the adaptive nature, i.e., the data dependent nature, of the circuit **52**. The weights $\underline{w}_i$ and the value σ_i^2 can be adapted using three methods. First, $\underline{w}_i$ and σ_i^2 can be obtained directly from Equations (20) and (16), respectively, once an estimate of the signal-dependent covariance matrix C_i is available. Second, $\underline{w}_i$ and σ_i^2 can be calculated by performing a Cholesky factorization on the inverse of the covariance matrix C_i. For example, in the $L_i D_i^{-1} L_i^T$ Cholesky factorization, $\underline{w}_i$ is the first column of the Cholesky factor L_i and σ_i^2 is the first element of the diagonal matrix D_i. Third, $\underline{w}_i$ and σ_i^2 can be computed directly from the data using a recursive least squares-type algorithm. In the first two methods, an estimate of the covariance matrix is obtained by a recursive least squares algorithm.

Computing the branch metrics in (10) or (13) requires knowledge of the signal statistics. These statistics are the mean signal values m_i in (12) as well as the covariance matrices C_i in (13). In magnetic recording systems, these statistics will generally vary from track to track. For example, the statistics that apply to a track at a certain radius will differ from those for another track at a different radius due to different linear track velocities at those radii. Also, the signal and noise statistics will be different if a head is flying slightly off-track or if it is flying directly over the track. The head skew angle is another factor that contributes to different statistics from track to track. These factors suggest that the system that implements the metric in (13) needs to be flexible to these changes. Storing the statistics for each track separately is very difficult because of the memory span required to accomplish this. A reasonable alternative is to use adaptive filtering techniques to track the needed statistics.

Tracking the mean signal values m_i is generally done so that these values fall on prespecified targets. An adaptive front-end equalizer is employed to force the signal sample values to their targets. This is certainly the case with partial response targets used in algorithms like PR4, EPR4, or EEPR4 where the target is prespecified to one of the class-4 partial responses. For example, in a PR4 system, the signal samples, if there is no noise in the system, fall on one of the three target values 1, 0, or −1. Typically this is done with an LMS-class (least mean-squares) algorithm that ensures that the mean of the signal samples is close to these target values. In decision feedback equalization (DFE) based detectors or hybrids between fixed delay tree search and DFE, such as FDTS/DF or MDFE, the target response need not be prespecified. Instead, the target values are chosen on-the-fly by simultaneously updating the coefficients of the front-end and feed-back equalizers with an LMS-type algorithm.

When there are severe nonlinearities in the system (also referred to as nonlinear distortion or nonlinear ISI), a linear equalizer will generally not be able to place the signal samples right on target. Instead, the means of the signal samples will fall at a different value. For example, in a PR4 system, the response to a sequence of written symbols . . . , −, +, ⊕, . . . might result in mean sample target values . . . , 0, 1, 0.9, . . . , while a sequence of written symbols . . . , +, −, ⊖, . . . might result in a sequence of mean sample values . . . , 0.95, −1.05, 0, ... Clearly, in this example, what should be a target value of 1 becomes either 1, 0.9, or 0.95 depending on the written sequence. Because mean values and not noisy samples are being considered, this deviation is due to nonlinearities in the system. There are two fixes for this problem. The first is to employ a nonlinear filter (neural network or Volterra series filter) that is capable of overcoming these nonlinear distortions. Although recently very popular, such a method introduces further correlation between noise samples due to the nonlinear character of the filter. The second fix is to track the nonlinearities in a feedback loop and use the tracked value in the metric computation. For example, let the response to a written symbol sequence . . . , ⊖, +, ⊕, . . . be consistently . . . , 0, 1, 0.9, . . . Then, rather than using the value 1 in the metric computation for the third target, this behavior can be tracked and the value m_i=0.9 can be used.

In the remainder of this discussion, for simplicity, it is assumed that the front-end equalizer is placing the signal samples right on the desired target values and that there is no need for further mean corrections. The focus is shifted to tracking the noise covariance matrices needed in the computation of the branch metrics (13).

Assume that the sequence of samples $r_i, r_{i+1}, \ldots, r_{i+L}$ is observed. Based on these and all other neighboring samples, after an appropriate delay of the Viterbi trellis, a decision is made that the most likely estimate for the sequence of symbols $a_{i-K_l}, \ldots, a_{i+L+K_t}$ is $\hat{a}_{i-K_l}, \ldots, \hat{a}_{i+L+K_t}$. Here L is the noise correlation length and $K=K_l+K_t+1$ is the ISI length. Let the current estimate for the (L+1)×(L+1) covariance

matrix corresponding to the sequence of symbols $\hat{a}_{i-K_l}, \ldots, \hat{a}_{i+L+K_t}$ be $\hat{C}(\hat{a}_{i-K_l}, \ldots, \hat{a}_{i+L+K_t})$. This symbol is abbreviated with the shorter notation, $\hat{C}(\hat{a})$. If the estimate is unbiased, the expected value of the estimate is:

$$E\hat{C}(\hat{a})=E\,[\underline{N}_i\underline{N}_i^T] \tag{21}$$

where $\underline{N}_i$ is the vector of differences between the observed samples and their expected values, as defined in (12).

Note that once the samples $r_i, r_{i+1}, \ldots, r_{i+L}$ are observed, and once it is decided that most likely they resulted from a series of written symbols $\hat{a}_{i-K_l}, \ldots, \hat{a}_{i+L+K_t}$, the sequence of target (mean) values $m_i, m_{i+1}, \ldots, m_{i+L}$ is known that correspond to these samples. They are used to compute the vector $\underline{N}_i$, with which the empirical rank-one covariance matrix $\underline{N}_i\underline{N}_i^T$ is formed. In the absence of prior information, this rank-one matrix is an estimate for the covariance matrix for the detected symbols. In a recursive adaptive scheme, this rank-one data covariance estimate is used to update the current estimate of the covariance matrix $\hat{C}(\hat{a})$. A simple way to achieve this is provided by the recursive least-squares (RLS) algorithm. The RLS computes the next covariance matrix estimate $\hat{C}'(\hat{a})$ as:

$$\hat{C}'(\hat{a})=\beta(t)\hat{C}(\hat{a})+[1-\beta(t)]\underline{N}_i\underline{N}_i^T \tag{22}$$

Here, β(t), 0<β(t)<1, is a forgetting factor. The dependence on t signifies that β is a function of time. Equation (22) can be viewed as a weighted averaging algorithm, where the data sample covariance $\underline{N}_i\underline{N}_i^T$ is weighted by the factor [1−β(t)], while the previous estimate is weighted by β(t). The choice of β(t) should reflect the nonstationarity degree of the noise. For example, if the nonstationarity is small, β(t) should be close to 1, while it should drop as the nonstationarity level increases. The forgetting factor is typically taken time-dependent to account for the start-up conditions of the RLS algorithm in (22). As more data is processed, a steady-state is expected to be achieved and β(t) is made to approach a constant value. Initially, β(t) is close to zero, to reflect the lack of a good prior estimate $\hat{C}(\hat{a})$, and to rely more on the data estimate. With time, β(t) is increased and settles around a value close to 1.

The impact of the initial conditions in (22) decays exponentially fast. Hence, the algorithm (22) can be started with an arbitrary initial guess for the covariance matrix $\hat{C}(\hat{a})$, with the only constraint being that the matrix be positive semidefinite, e.g, a zero matrix or an identity matrix.

The one-dimensional equivalent of equation (22) is

$$\hat{\sigma}_{new}^2=\beta\hat{\sigma}_{old}^2+[1-\beta]N_i^2. \tag{23}$$

This equation can be used in conjunction with the metric in (10).

It is important to point out that, due to the signal-dependent character of the media noise, there will be a different covariance matrix to track for each branch in the tree-trellis of the Viterebi-like detector. Practical considerations of memory requirements, however, limit the dimensions of the matrices to be tracked. Fortunately, simple 2×2 matrices are enough to show substantial improvement in error rate performance.

The following example illustrates how the algorithm in (22) works. Assume a PR4 target response with a simple trellis structure as shown in FIG. 4 Notice that for PR4, the symbols can be equated to the trellis states, as is illustrated in FIG. 4 The number next to each branch in FIG. 4 represents the target value (mean sample value) for the corresponding path between states. The target values in PR4 can be one of three values −1, 0, or 1.

In this example a noise correlation length of L=1 is assumed. It is also assumed that the leading and trailing ISI lengths are $K_l=0$ and $K_t=1$, respectively, to give the total ISI length $K=K_l+K_t+1=2$ for the PR4 response. Because L=1, signal covariance matrices of size $(L+1)\times(L+1)=2\times2$ need to be tracked. The number of these matrices equals the number of different combinations of two consecutive branches in the trellis. A simple count in FIG. 4 reveals that this number is 16, because there are 4 nodes in the trellis and 2 branches entering and leaving each node.

Assume that, using the branch metric in (13), the Viterbi-like detector decides that the most likely written symbols a_i, a_{i+1}, a_{i+2}, equal $\{\hat{a}_i, \hat{a}_{i+1}, \hat{a}_{i+2}\}=\{\oplus, +, -\}$. This is illustrated in FIG. 5, where the corresponding path through the trellis is highlighted. The noisy signal samples corresponding to the trellis branches are $r_i=0.9$ and $r_{i+1}=-0.2$, which deviate slightly from their ideal partial response target values of 1 and 0, respectively.

Suppose that, prior to making the decision $\{\hat{a}_i, \hat{a}_{i+1}, \hat{a}_{i+2}\}=\{\oplus, +, -\}$, the estimate for the a covariance matrix associated with this sequence of three symbols is

$$\hat{C}(\ominus, +, -)=\begin{bmatrix} 0.5 & -0.2 \\ -0.2 & 0.8 \end{bmatrix} \tag{24}$$

Let the forgetting factor be B=0.95. To update the covariance matrix the vector is first formed:

$$\underline{N}=[(r_i-1)(r_{i+1}-0)]^T=[-0.1\ -0.2]^T \tag{25}$$

The rank-one sample covariance matrix $\underline{N}\,\underline{N}^T$ is used to find the covariance matrix update:

$$\hat{C}'(\ominus, +, -)=\beta\hat{C}(\ominus, +, -)+(1-\beta)\underline{N}\underline{N}^T = \begin{bmatrix} 0.4755 & -0.189 \\ -0.189 & 0.7620 \end{bmatrix} \tag{26}$$

The matrix $\hat{C}'(\oplus, +, -)$ becomes our estimate for the covariance matrix corresponding to this particular symbol sequence (trellis path) and is used to compute the metrics (13) in the subsequent steps of the Viterbi-like algorithm.

FIG. 6 illustrates a flowchart of a method of detecting a sequence of adjacent signal samples stored on a high density magnetic recording device. Viterbi sequence detection is performed using a signal sample at step 38. The sequence detection produces decisions which are output at step 40. The signal sample is delayed at step 42. The past samples and detector decisions are used to update the noise statistics at step 44. Branch metrics, which are used in the sequence detection step 38, are calculated at step 46.

It can be understood by those skilled in the art that the method of FIG. 6 can be performed on a computer. The steps may be coded on the computer as a series of instructions, which, when executed, cause the computer to detect a sequence of adjacent signal samples stored on a high density magnetic recording device. The computer may be, for example, a personal computer, a workstation, or a mainframe computer. The computer may also have a storage device, such as a disk array, for storage of the series of instructions.

Simulation results using two partial response detection algorithms, namely PR4 and EPR4 are now presented. To create realistic waveforms, corrupted by media noise, an efficient stochastic zig-zag model, the TZ-ZT model was used. These waveforms are then passed through the detectors. A Lindholm inductive head is used for both writing and reading. Table 1 presents the recording parameters of the model. These recording parameters are chosen so that with a moderately low symbol density per PW50, a low number of transition widths a per symbol transition separation results. Namely, at 3 symbols/PW50 a transition separation of only 2.9 a is present. The transition profile was modeled by an error function, where the transition width a denotes the distance from the transition center to the point where the magnetization equals $M_r/2$.

TABLE 1

Recording parameters used in simulations.

Parameter	Symbol	Value
media remanence	M_r	450 kA/m
media coercivity	H_c	160 kA/m
media thickness	δ	0.02 μm
media cross-track correlation width	s	200 Å
head-media separation	d	15 nm
head field gradient factor	Q	0.8
had gap length	g	0.135 μm
track width	TW	2 μm
transition width parameter	α	0.019 μm
percolation length	$L = 1.4\alpha$	0.0266 μm
50% pulse width	PW50	0.167 μm

The symbols utilizing the (0,4) run length limited code are written. No error correction is applied, so the obtained error rates are not bit error rates, but (raw) symbol error rates.

Both the PR4 and EPR4 detectors were tested using the following three different metric computation methods: the Euclidian metric (8), the variance dependent metric (10), also referred to as the C1 metric, and the 2x2 correlation sensitive metric (13), named the C2 metric for short. For a PR4 target response, the total ISI length is $K=K_l+K_t+1=2$, where the leading and trailing ISI lengths are $K_l=0$ and $K_t=1$, respectively. The noise correlation length for the Euclidian and the C1 metrics is L=0, and for the C2 metric the noise correlation length is L=1. These three PR4 detectors are referred to as PR4(Euc), PR4(C1), and PR4(C2).

Similarly to the PR4 detectors, three EPR4 detectors were tested, EPR4(Euc), EPR4(C1) and EPR4(C2). The only difference between the PR4 detectors and the EPR4 detectors are the target response and the ISI length, which for the EPR4 target response equals $K=K_l+K_t+1=3$, with $K_l=1$ and $K_t=1$.

The signal obtained by the TZ-ZT model is already corrupted with media noise. To this signal white Gaussian noise was added to simulate the head and electronics noise in a real system. The power of the additive white Gaussian noise is quoted as the signal to additive white Gaussian noise ratio, S(AWG)NR, which is obtained as:

$$S(AWG)NR = 10\log\frac{A_{iso}^2}{\sigma_n^2} \tag{27}$$

where A_{iso} is the mean (media noise free) amplitude of an isolated pulse and σ_n^2 is the variance of the additive white Gaussian noise. The noise distorted signal is first passed through a low-pass filter to clean out the noise outside the Nyquist band. The signal is then sampled at a rate of one sample per symbol and subsequently passed through a partial response shaping filter, either PR4 or EPR4. The partial response shaping filter is implemented as an adaptive FIR filter whose tap weights are adjusted using the LMS algorithm. Note that both filters add correlation to the noise. For the C1 and C2 metrics in (10) and (13), the RLS algorithms (22) and (23) are used to estimate the noise variances and covariance matrices for the branch metric computations. In both cases, the forgetting factor is set to β=0.95.

All six detection algorithms were tested at three different recording densities.

Symbol separation of 4.4 a. This recording density corresponds to a symbol density of 2 symbols/PW50, see Table 1. FIG. 7 shows the symbol error rate performance of the PR4 detectors for different additive noise SNRs. The media noise is embedded in the system, which is why the x-axis on the graph is labeled as S(AWG)NR instead of simply SNR. At this density, the PR4(Euc) and PR4(C1) detectors perform just about the same and the PR4(C2) detector outperforms them both by about 3 dB. The reason for this is that the PR4 shaping filter averages noise samples from different symbols, which masks the signal dependent nature of the media noise. This is why there is not much to gain by using PR4(C1) instead of PR4(Euc). The PR4(C2) detector performs better because it partially removes the effects of noise correlation introduced by the PR4 shaping filter. FIG. 8 shows how the EPR4 detectors perform at this same density (symbol separation 4.4 a).: The PR4(C2) has the best performance and PR4(Euc) has the worst. The difference in performance at the error rate of 10^{-5} is only about 0.5 dB between PR4(Euc) and PR4(C2). This is because the media noise power at this density is low and the signal is well matched to the target so the EPR4 shaping filter does not introduce unnecessary noise correlation.

Symbol separation of 3.5 a. This recording density corresponds to a symbol density of 2.5 symbols/PW50. FIG. 9 shows the performance of the PR4 detectors at this density. FIG. 9 is similar to FIG. 7. except that the error rates have increased. This is again due to a mismatch between the original signal and the PR4 target response, which is why the PR4 shaping filter introduces correlation in the noise. PR4 (C2) still outperforms the two other algorithms, showing the value of exploiting the correlation across signal samples.

FIG. 10 shows the error rates obtained when using the EPR4 detectors. Due to a higher density; the media noise is higher than in the previous example with symbol separations of 4.4 a. This is why the graph in FIG. 10 has moved to the right by 2 dB in comparison to the graph in FIG. 8. While the required S(AWG)NR increased, the margin between the EPR4(Euc) and EPR4(C2) also increased from about 0.5 dB to about 1 dB,suggesting that the correlation-sensitive metric is more resilient to density increase. This is illustrated in FIG. 11 where the S(AWG)NR required for an error rate of 10^{-5} is plotted versus the linear density for the three EPR4 detectors. From FIG. 11 it can be seen that, for example, with an S(AWG)NR of 15 dB, the EPR(Euc) detector operates at a linear density of about 2.2 symbols/PW50 and the EPR4(C2) detector operates at 2.4 symbols/PW50, thus achieving a gain of about 10% of linear density. Symbol separation of 2.9 a. This recording density corresponds to a symbol density of 3 symbols/PW50. Due to a very low number of symbols per a, this is the density where the detectors significantly lose performance due to the percolation of magnetic domains, also referred to as nonlinear amplitude loss or partial signal erasure. FIGS. 12 and 13 show the performance of the PR4 and EPR4 families of detectors at this density. The detectors with the C2 metric outperform the other two metrics. The error rates are quite high in all cases. This is because at the symbol separations of 2.9 a, nonlinear effects, such as partial erasure due to percolation of domains , start to dominate. These effects can only be undone with a nonlinear pulse shaping filter, which have not been employed here.

The experimental evidence shows that the correlation sensitive sequence detector outperforms the correlation insensitive detectors. It has also been demonstrated that the performance margin between the correlation sensitive and the correlation insensitive detectors grows with the recording density. In other words, the performance of the correlation insensitive detector deteriorates faster than the performance of the correlation sensitive detector. Quantitatively, this margin depends on the amount of correlation in the noise passed through the system. Qualitatively, the higher the correlation between the noise samples, the greater will be the margin between the CS-SD and its correlation insensitive counter part.

The teachings of the present invention can be extended beyond Viterbi-like detectors to apply to turbo decoders, soft-decision detectors, and detectors utilizing the Viterbi algorithm, the BCJR algorithm, the Soft-Output Viterbi Algorithm (SOVA), and other similar algorithms. Traditionally, these algorithms and devices have been derived and designed assuming that the communication channel is memoryless, i.e. that the noise in the channel is white and uncorrelated. However, the teachings of the present invention, in which the branch metric computations are performed assuming the channel has memory, i.e. the noise is correlated and the noise statistical correlation is possibly signal dependent, can be applied to any device or algorithm in which branch metrics must be computed.

FIG. 14 is an illustration of a portion of a communications system 100 having a detector 102 with parallely concatenated decoders 104 and 106. The output of a communications channel 108 is connected to a receiver 110. The receiver includes the detector 102, a first decoder 104, and a second decoder 106. The detector 102 processes the output of the channel 108 and feeds decisions to the decoders 104 and 106. The decoders 104 and 106 can be, for example, turbo decoders or any other iterative decoders that use, for example, low density parity check codes, linear block coders, or convolutional codes.

FIG. 15 is an illustration of a portion of a communications system 112 having the detector 102 connected in a serially concatenated arrangement to a decoder 114. The detector 102 and the decoder 11 comprise a receiver/decoder 116.

The detector 102 can use any type of appropriate algorithm such as, for example, BCJR, Viterbi, SOVA, or any other instance of the Generalized Viterbi Algorithm (GVA). The detector 102 can work on a trellis, tree, finite-state machine, graph, or any other structure with branches for which the detector 102 has a component that must compute branch metrics. Because this component reflects the assumptions on the noise memory and statistics, the teachings of the present invention can be designed into this component such that the detector 102 is accurate when the channel 108 has memory, i.e. the channel 108 has intersymbol interference and correlated noise with signal dependent statistics.

As an example, the BCJR algorithm can be described for channels with memory. The following equations use standard notation to describe the BCJR algorithm, as described in L. R. Bahl et al., "Optimal Decoding of Linear Codes for Minimizing Symbol Error Rate", IEEE Transactions on Information Theory, IT-20:284–87, March 1974 and C. Heegard et al., Turbo Coding, 1999, Kluwer Academic Publishers, which are herein incorporated by reference.

BCJR soft-output algorithm for Markov noise with memory length L:

Initialization

$$\alpha_0(0)=1,\ \alpha_0(m)=0 \text{ for } m\neq 0 \tag{28}$$

$$\beta_K(0)=1,\ \beta_K(0)=0 \text{ for } m\neq 0 \tag{29}$$

$$z_0=0,\ z_{-1}=0,\ \ldots,\ z_{1-L}=0 \tag{30}$$

For $k = 1, 2, \ldots, K$

-continued

$$\gamma_k(m', m) = P(x_k = m \mid x_{k-1} = m') \cdot f(z_k \mid x_{k-1} = m', x_k = m, z_{k-1}, z_{k-2}, \ldots, z_{k-L}) \tag{31}$$

$$= P(x_k = m \mid x_{k-1} = m') \cdot (2\pi)^{-0.5} e^{-0.5 \cdot M_{ML}} \tag{32}$$

$$\alpha_k(m) = \sum\nolimits_{m=0 \text{ to } M-1} [\gamma_k(m', m)\, \alpha_{k-1}(m')] \tag{33}$$
For $k = K-1, K-2, \ldots, 0$

$$\beta_k(m) = \sum\nolimits_{m''=0 \text{ to } M-1} [\gamma_{k+1}(m, m'')\beta_{k+1}(m'')] \tag{34}$$
For $k = 0, 1, \ldots, K$

$$\lambda_k(m) = \alpha_k(m)\beta_k(m) \tag{35}$$

$$\delta_k(m', m) = \alpha_{k-1}(m')\gamma_k(m', m)\beta_k(m) \tag{36}$$

Thus, the branch metric, as denoted by the second half of Equation x, is computed exactly the same way as the branch metric of Equations 6, 9, 10, 11, and 13. When the noise process is Gaussian, the branch metric can be computed using Equation 13 and the arrangements described in FIGS. 3A and 3B.

The generalization of the case described above for the BCJR algorithm can be made for any other soft output or hard output algorithm defined on a trellis or a graph of any communications (or other dynamic) system. The place in the detector where the branch metric is computed can be substituted by the metric computation as described in Equations 6, 9, 10, 11, 13 and FIGS. 3A and 3B.

While the present invention has been described in conjunction with preferred embodiments thereof, many modifications and variations will be apparent to those of ordinary skill in the art. For example, the present invention may be used to detect a sequence that exploits the correlation between adjacent signal samples for adaptively detecting a sequence of symbols through a communications channel. The foregoing description and the following claims are intended to cover all such modifications and variations.

What is claimed is:

1. A method of determining branch metric values in a detector, comprising:

receiving a plurality of time variant signal samples, the signal samples having one of signal-dependent noise, correlated noise, and both signal dependent and correlated noise associated therewith;

selecting a branch metric function at a certain time index; and

applying the selected function to the signal samples to determine the metric values.

2. The method of claim 1, wherein the branch metric function is selected from a set of signal-dependent branch metric functions.

3. The method of claim 1, wherein the detector is a hard decision detector.

4. The method of claim 1, wherein the detector is a soft decision detector.

5. The method of claim 1, wherein the detector is selected from a group consisting of a Viterbi detector, a soft output Viterbi detector, a Generalized Viterbi detector, and a BCJR detector.

6. A method of detecting a sequence that exploits a correlation between adjacent signal samples for adaptively detecting a sequence of symbols through a communications channel having intersymbol interference, comprising:

(a) performing sequence detection on a plurality of signal samples using a plurality of correlation sensitive branch metrics;

(b) outputting a delayed decision on a transmitted symbol;

(c) outputting a delayed signal sample;

(d) adaptively updating a plurality of noise covariance matrices in response to the delayed signal samples and the delayed decisions;

(e) recalculating the plurality of correlation sensitive branch metrics from the noise covariance matrices using subsequent signal samples; and

(f) repeating steps (a)–(e) for every new signal sample.

7. The method of claim 6, wherein the channel has nonstationary noise.

8. The method of claim 6, wherein the channel has nonstationary signal dependent noise.

9. The method of claim 6, wherein performing a sequence detection includes performing a hard Viterbi sequence detection.

10. The method of claim 6, wherein performing a sequence detection includes performing a soft Viterbi algorithm sequence detection.

11. The method of claim 6, wherein performing a sequence detection includes performing a BCJR sequence detection.

12. The method of claim 6, wherein performing a sequence detection includes performing a generalized Viterbi algorithm sequence detection.

13. The method of claim 6, wherein performing a sequence detection includes performing a soft decision sequence detection.

14. The method of claim 6, wherein performing a sequence detection includes performing a hard decision sequence detection.

15. A receiver, comprising:

a sequence detector receiving communications signal samples wherein adjacent signal samples have a correlation and wherein the signal samples have intersymbol interference, the sequence detector for detecting a sequence in the communications signal samples by exploiting the correlation; and

at least one decoder connected to the sequence detector.

16. The receiver of claim 15, further comprising a second decoder parallely concatenated with the decoder.

17. The receiver of claim 15, wherein the sequence detector and the decoder are serially concatenated.

18. The receiver of claim 17, further comprising a second decoder serially concatenated with the decoder.

19. The receiver of claim 15, wherein the decoder is an iterative decoder.

20. The receiver of claim 16, wherein the decoder is an iterative decoder.

21. The receiver of claim 16, wherein the second decoder is an iterative decoder.

22. The receiver of claim 17, wherein the decoder is an iterative decoder.

23. The receiver of claim 20, wherein the decoder uses codes selected from the group consisting of low density parity check codes, linear block codes, and convolutional codes.

24. The receiver of claim 15, wherein the decoder is a turbo decoder.

25. The receiver of claim 15, wherein the sequence detector is a hard decision detector.

26. The receiver of claim 15, wherein the sequence detector is a soft decision detector.

27. The receiver of claim 15, wherein the sequence detector is selected from the group consisting of a soft output Viterbi detector, a generalized Viterbi detector, a BCJR detector, and a Viterbi detector.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 6,438,180 B1 Page 1 of 1
DATED : August 20, 2002
INVENTOR(S) : Kavcic et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 14,
Line 32, delete "coders" and replace therewith -- codes --.

Signed and Sealed this

First Day of April, 2003

JAMES E. ROGAN
Director of the United States Patent and Trademark Office

PROOF OF SERVICE

The undersigned hereby certifies that on August 5, 2014, I electronically filed the foregoing with the Clerk of the Court for the United States Court of Appeals for the Federal Circuit by using the appellate CM/ECF system. I certify that all participants in the case are registered CM/ECF users and that service will be accomplished by the CM/ECF system.

/s/ Kathleen M. Sullivan
Kathleen M. Sullivan

CERTIFICATE OF COMPLIANCE

Counsel for Defendants-Appellants hereby certifies that:

1. The brief complies with the type-volume limitation of this Court's July 18, 2014 Order permitting an opening brief of up to 17,000 words because exclusive of the exempted portions it contains 16,785 words as counted by the word processing program used to prepare the brief; and

2. The brief complies with the typeface requirements of Federal Rule of Appellate Procedure 32(a)(5) and the type-style requirements of Federal Rule of Appellate Procedure 32(a)(6) because it has been prepared using Microsoft Office Word 2007 in a proportionately spaced typeface: Times New Roman, font size 14.

Dated: August 4, 2014

/s/ Kathleen M. Sullivan
Kathleen M. Sullivan