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The 2015 IEEE Policy on Standard Essential Patents –The Empirical Record

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ABSTRACT

This study evaluates the effect of the 2015 IEEE patent policy shift on the willingness of Standard Essential Patent ("SEP") holders to pledge licensing Letters of Assurance ("LOAs") for IEEE standards under the new patent policy. By the use of non-parametric and Poisson models, a detailed statistical analysis of the IEEE LOA submission data reveals an overall statistically-significant decline in propensity to contribute LOAs, although the changes in LOA contributions from the Semiconductor/Chip industry segment are not statistically significant. The analysis further reveals that there was a statistically highly significant increase by a factor of 20 in the submission rate of express refusals to license under the new terms of the 2015 patent policy ("Negative LOAs"). A significant decline in the number of submitted LOAs per Project Authorization Requests is reported, indicating higher potential future hazard of unapproved standards.

Keywords: Standards Development Organization, Standard Essential Patent, FRAND, IEEE-SA, Letter of Assurance, Patent Policy, Mann-Whitney non-parametric statistical test, Poisson model for a counting process.

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1 Introduction

Technical standards promulgated by standard development organizations ("SDO"s) often incorporate technology contributed by innovators who hold patent claims on the technology, and the use of that patented technology may be essential to a compliant implementation of the standard. A patent on such technology is called "standard-essential patent" ("SEP"). In order to ensure that implementers of a proposed standard can use any patented technology that may be essential for implementing the standard, SDOs solicit prior to adoption of the standard voluntary commitments from holders of potential SEPs, to license the SEPs to all standard implementers under Fair, Reasonable and Non-Discriminatory ("FRAND") licensing terms.[2] Such voluntary commitments to license under FRAND terms are typically pledged by a Letter of Assurance ("LOA") to the SDO. Consequently, FRAND commitments in the last decades have assured standard implementers that SEP holders would not engage in opportunistic conduct in licensing their SEPs, and have generally facilitated robust technology-rich standards development.

The Institute of Electrical and Electronics Engineers ("IEEE") through its SDO affiliate, the IEEE Standards Association ("IEEE-SA"), adopted a new patent policy effective March 15, 2015 which sought to further define specific obligations a SEP holder must assume by pledging to license under FRAND for an IEEE standard. Whereas other SDO's patent policies uniformly refrain from formally defining the meaning of FRAND licensing terms (as did IEEE's prior patent policy), the new 2015 IEEE patent policy requires further specific concessions from the SEP holder. The key changes include the additional elements of: (a) recommending royalties based on "smallest salable" unit implementing any portion of the standard, (b) SEP holder must waive seeking injunction against non-cooperative implementers until it has successfully litigated claims against the unlicensed implementer to conclusion in a court of appeals (c) licenses qualified as "comparable licenses" for determining what constitutes FRAND royalties are only those negotiated under conditions under which the SEP holder had relinquished the right to seek, enforce, or even threaten, an injunction.[3] The requirement for these new commitments was unacceptable to certain SEP holder participants in the IEEE standards development process, who therefore protested and resisted the changes. [*** Cite]

This study is aimed at evaluating the effect of the 2015 IEEE patent policy shift on the willingness of SEP holders in two categories of the product supply chain to pledge LOAs to IEEE standards under the new patent policy. Using non-

[2] The term FRAND in this paper refers both to "reasonable and non-discriminatory" terms, as well as to "fair, reasonable and non-discriminatory" terms, two formulations having no substantive difference. *See, e.g.*, U.S. Dep't of Justice & U.S. Patent & Trademark Office, "Policy Statement on Remedies for Standards-Essential Patents Subject to Voluntary F/RAND Commitments," (2013), p1 n.2 ("Commentators frequently use the terms [RAND and FRAND] interchangeably to denote the same substantive type of commitment.") www.justice.gov/atr/public/guidelines/290994.pdf.

[3] IEEE SASB Bylaws, §6.2.

parametric and Poisson models, a detailed statistical analysis reveals an overall decline in propensity to contribute LOAs, although the changes in LOA contributions from the Semiconductor/Chip industry segment are not statistically significant. The analysis further reveals that the policy change also resulted in an increase by a factor of 20 in the submission rate of express *refusals* to license under the new terms of the 2015 patent policy ("Negative LOAs").

2 IEEE Standard Development Waypoints

The development of a new standard is typically triggered by a formal request, submitted to the IEEE Standards Association ("IEEE-SA") Standards Board ("SASB") by a Sponsoring Body (individual or entity, such as an industry society) for review and evaluation. The IEEE-SA's resources, expertise, standard development infrastructure, and consensus governance procedures help facilitate the process for the standards development.

A standards project begins by the submission of a Project Authorization Request ("PAR") to the SASB for approval. A PAR is a short, structured, and highly detailed document that essentially states the reason for the project, its scope and purpose, and any prior standards which the project may incorporate. An approved PAR constitutes a permission to move forward with the standard development and promulgation process using IEEE-SA's resources. Such PAR approval is given for a period not exceeding 4 years and any extension or modification of a PAR must be approved by the SASB.

Once the SASB approves the PAR, the sponsor follows the IEEE-SA rules and processes to recruit and assemble a collaborative team or "Working Group" to engage in active standards development. Working Groups are comprised of individuals and/or entities (people, companies, organizations, non-profits, government agencies) that may have expertise in the field and volunteer to support the development of standards. Members or employees of entities that may hold patent claims potentially essential to the standard may be among the participants of the Working Groups. If the new standard is an amendment for an existing standard for which a Working Group has already been established, a Task Group within the Working Group may be established for developing the amendment to the standard.

Thereafter, the IEEE-SA issues several types of standards documents: [4]

(a). ***New***. A document that does not replace or modify another standard.
(b). ***Revision***. A document that updates and replaces (i.e., supersedes) an existing IEEE standard in its entirety.
(c). ***Amendment***. A document that adds to, removes from, or alters material in a portion of an existing IEEE standard and may make editorial or technical

[4] IEEE SASB Operations Manual, §1.2.

> corrections to that standard. An amendment to a standard may be prepared to maintain the state-of-the-art within the standard due to advancing technology or techniques. An amendment facilitates the timely change of an existing IEEE standard prior to its complete revision.

In maintaining its standards, IEEE-SA often incorporates multiple amendments for a given standard accumulated over a period, "rolling" them into the new revision of that standard. For example, when the 802.11-2007 WiFi standard was revised into 802.11-2012, the revision was based on 802.11-2007 and cumulatively incorporated the interim standard amendments 802.11k-2008, 802.11r-2008, 802.11y-2008, 802.11w-2009, 802.11n-2009, 802.11p-2010, 802.11z-2010, 802.11v-2011, 802.11u-2011, and 802.11s-2011.[5] A compliant implementation of the 802.11-2012 standard is therefore required to implement all features included in the 2007 base standard, *and* in these 10 amendments from 2008 through 2011.

3 Data and methods

3.1 Types of LOAs

As technical approaches for the standard are proposed and decided in various standard drafts, it may become apparent to some that essential patent claims may be required to implement the draft standard. Working Group chairs are required to make periodic "calls for patents," asking all participants to identify and disclose any known patents, patent applications, or the holders thereof, that may be essential for the implementation of the draft standard.[6] When such patent holder is identified, the Working Group chair must send a formal request to that patent holder with information on the (proposed) standard and a request that the holder voluntarily submit an LOA subject the IEEE patent policy.[7]

If the IEEE-SA receives an LOA that meets its patent policy, IEEE-SA accepts the LOA, essentially as a contractual *acceptance* of the patent holder's *offer* in the LOA – an "Accepted LOA." An LOA "is irrevocable once submitted and accepted and shall apply, at a minimum, from the date of the standard's approval to the date of the standard's transfer to inactive status."[8] Under contract law, an Accepted LOA is binding on the IEEE and the patent holder or its successor of interest in the patent.[9] We call a "Positive LOA" an Accepted LOA in which the patent holder

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[5] IEEE 802.11-2012, *Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications*, at ix (March 2012).
[6] IEEE SASB Operations Manual, §§6.3.2, 6.3.5.
[7] *Id*., §6.3.2
[8] IEEE SASB Bylaws, §6.2.
[9] *See* Sidak J.G., "The FRAND Contract," 3 *Criterion J. on Innovation* 1 (2018); Sidak J.G., "A FRAND Contract's Intended Third-Party Beneficiary," 1 *Criterion J. on Innovation* 1001 (2016); Brooks & Geradin (2010); *see also*, *Apple, Inc. v. Motorola Mobility, Inc.*, 886 F. Supp. 2d 1061, 1083 (W.D. Wis. 2012) ("In this case, the combination of the policies and bylaws of the standard-setting organizations, Motorola's membership in those organizations and Motorola's assurances that it would license its essential patents on fair, reasonable and nondiscriminatory terms constitute contractual agreements."); *Microsoft Corp. v. Motorola, Inc.*, 854 F. Supp. 2d 993, 999

affirmatively commits to licensing under FRAND (or royalty free) terms pursuant to the IEEE patent policy.

Because submissions of LOAs are voluntary, not all requests of patent holders to pledge LOAs for FRAND licensing are fulfilled. We call a "Negative LOA," numerically represented herein by "-1," an Accepted LOA in which the patent holder expressly declines to license pursuant to the IEEE patent policy prevailing at the time. The patent holder may also respond by disclaiming awareness of any patent claims it holds that may be essential for implementing the standard at issue – a "statement of non-awareness."[10] However, if no such disclaimer is made and no LOA is furnished in response to the request to submit the LOA, an LOA is said to be "missing," which we represent numerically by "-1." As used herein, a "Missing LOA" means a disclosed potential essential patent claim holder from whom IEEE sought, but did not receive, an Accepted LOA for a particular standard as of March 15, 2018.

A "Specific LOA" identifies a specific patent or patent application by serial number and binds the patent holder as to any patent claim in the patent and any patent claim that *may be issued based* on the patent application. By contrast, a "Blanket LOA" is an LOA "that applies to all Essential Patent Claims for which a Submitter may currently or in the future … have the ability to license."[11] Thus, unlike a Specific LOA, submission of a Blanket LOA for a particular standard covers that standard and encumbers all essential patent claims issued even on patent application claiming an invention that is yet to be made or disclosed.

To protect standard implementers, once a particular standard is identified in an Accepted LOA, the irrevocable FRAND commitment therein applies throughout the standards' maintained life. The SASB Operations Manual provides in §6.3.5: "[a]n Accepted Letter of Assurance referencing an existing standard, amendment, corrigendum, edition, or revision will remain in force for the application of the Essential Patent Claim(s) to the technology specified in another amendment, corrigendum, edition, or revision of the same IEEE Standard but only if (a) the application of the technology required by the amendment, corrigendum, edition, or revision of the same IEEE Standard has not changed from its previous usage and (b) the same Essential Patent Claims covered by the prior Accepted Letter of Assurance remain Essential Patent Claims in the same IEEE Standard or revision thereof."

(W.D. Wash. 2012) ("[T]hrough Motorola's letters to both the IEEE and ITU, Motorola has entered into binding contractual commitments to license its essential patents on RAND terms."); see also *Microsoft Corp. v. Motorola, Inc.*, 696 F.3d 872, 884 (9th Cir. 2012) (upholding the district court's conclusion that Motorola's RAND declarations to the ITU created a contract enforceable by third-party beneficiaries).

[10] IEEE SASB Bylaws, §6.2.

[11] IEEE SASB Bylaws, §6.1.

3.2 Unique and Duplicate LOAs

All LOAs pledged as of March 15, 2018 for all IEEE standards were tabulated as extracted from the *IEEE-SA Records Of IEEE Standards-Related Patent Letters Of Assurance* available online.[12] The list of all LOAs so identified establishes the set of what we call "Unique LOAs." The tabulated list includes (a) Specific LOAs identifying a single patent or application, (b) Specific LOAs identifying multiple patents or applications, and (c) Blanket LOAs that do not identify any patent claims. Because of the unknown number of patents pledged in Blanket LOAs, our analysis cannot rely on patents as the countable unit of analysis. Rather, of necessity, we use the LOA count as the unit of analysis, regardless of whether the LOA identifies a single patent, a group of patents, or merely a blanket assurance for unknown number of patents. Nevertheless, if a single LOA specifies multiple *standards*, we count the pledge for each standard as a separate LOA. Subject to appropriate controls, the LOA submission count over time thus serves as a reasonable proxy for the *relative* rate of patent holder's willingness to license under the different patent policies.

Using the LOA count, however, requires a procedure to ensure that actual LOA pledges of the same essential claims are not double-counted by Unique LOAs. To determine the non-duplicate licensing assurance pledges from any given patent holder, we apply a criteria that any standard implementer would reasonably apply to determine whether the patent holder submitting an LOA is actually repeating commitments that it has already made. In other words, we define "Duplicate LOAs" as repeat LOA pledges or restatements submitted for standards, amendments, or revisions for which a specific or blanket LOA commitment to license the same essential patent claims under FRAND terms was previously accepted from the same patent holder.

3.2.1 Examples of Duplicate LOAs

For example, on May 20, 2013, the Mentor Graphics Corporation pledged a Specific LOA for IEEE Standard 1838 on its U.S. provisional patent application Ser. No. 61/698,482 (the `482 application). This LOA was binding on Mentor Graphics as to *any* patent claims that were to issue based on this application. On January 31, 2017, Mentor Graphics filed another LOA for the *same* standard on U.S. Patent Nos. 9,389,944 and 9,389,945. Because both of these patents are based on the `482 application (as shown on the front-page of these patents), FRAND licenses under these two patents have been pledged already by the original LOA for Standard 1838; the January 31, 2017 Specific LOA is therefore considered "Duplicate" because it makes no commitments beyond those that were already pledged in the May 20, 2013 LOA. In this example, however, the submission of the Duplicate LOA was of significant merit, as it provided further notice to the public of the *issuance* of essential patent claims that were previously pledged under a FRAND licensing commitment.

[12] *See* http://standards.ieee.org/about/sasb/patcom/patents.html

Other examples of Duplicate LOAs are readily available from the Intel Corporation's mass filing of troves of LOAs shortly after the new IEEE patent policy was adopted in March 15 2015. On March 27, 2015, Intel filed a Blanket LOA for "802.11n" and on the same date, on March 27, 2015, a Blanket LOA for "802.11n-2009." But these are Duplicate LOAs because they were made for the *identical* standard – the amendment to 802.11 that was promulgated in 2009. Indeed, the use of different names for the same standard resulted in other superfluous LOAs: on March 27, 2015, Intel filed a Blanket LOA for 802.11-2012 and filed again on July 6, 2015 a Blanket LOA for "P802.11 (Revision PAR Approval Date 20 Aug 2012)," which is directed to the same standard and is therefore a Duplicate LOA.[13]

The pervasive scope of superfluous filing of LOAs is manifested by the filings of LOAs for standards *after* they have been superseded by another standard for which an LOA was also filed. For example, as discussed above, on March 27, 2015, Intel filed a Blanket LOA for 802.11-2012, which we regard as non-duplicate standing alone. At that time, this standard has long superseded all the amendments that were rolled into it in March 2012, namely: 802.11r-2008, 802.11y-2008, 802.11w-2009, 802.11n-2009, 802.11p-2010, 802.11z-2010, 802.11v-2011, 802.11u-2011, and 802.11s-2011.[14] Therefore, Intel's March 27, 2015 Blanket LOA for 802.11-2012 already fully covered *all* essential patent claims required to implement *all* these amendments – the amendments were an integral part of 802.11-2012. Yet, on the same day, about 3 years after these standard amendments were superseded and were no longer active, Intel filed separate Blanket LOAs for all of them:

Standard	Patent Owner	Patent/Type	LOA
802.11k	Intel Corp.	Blanket	27-Mar-15
802.11n	Intel Corp.	Blanket	27-Mar-15
802.11n-2009	Intel Corp.	Blanket	27-Mar-15
802.11r	Intel Corp.	Blanket	27-Mar-15
802.11s	Intel Corp.	Blanket	27-Mar-15
802.11u	Intel Corp.	Blanket	27-Mar-15
802.11v	Intel Corp.	Blanket	27-Mar-15
802.11w	Intel Corp.	Blanket	27-Mar-15
802.11y	Intel Corp.	Blanket	27-Mar-15
802.11z	Intel Corp.	Blanket	27-Mar-15

Table 1. Example of Duplicate LOAs for superseded amendments

[13] The SASB minutes show that the P802.11 Revision PAR Approval of August 30, 2012 was not an approval of a draft *standard* but merely an extension of the 802.11 PAR to December 2016. *See* http://web.archive.org/web/20150401114729/http://standards.ieee.org/about/sasb/0812sasbmin.pdf. Although the PAR Revision identified certain amendments that would be rolled into 802.11, per Section 3.2.2, we already count as Non-Duplicate the Blanket LOAs that Intel separately filed on March 27, 2015 for these rolled-in amendments: 802.11aa, 802.11ac, 802.11ad, and 802.11af.

[14] IEEE 802.11-2012, *Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications*, at ix (March 31, 2012).

We therefore treat all these as Duplicate LOAs. According to the IEEE Patent Policy, these Duplicate LOAs were contractually unenforceable and worthless from the very day they were filed because Accepted LOAs have no force beyond "the date of the standard's transfer to inactive status."[15] The submission of these Duplicate LOAs was gratuitous and apparently served no legitimate purpose. IEEE-SA's acceptance of these meaningless LOAs was apparently intended to create the impression of industry acceptance of the new patent policy.

In addition, a substantial number of LOAs filed after the change of the IEEE patent policy on March 15, 2015, pledged the same essential patent claims as pledged by the same patent holder in a previous LOA for the same standard under a previous IEEE patent policy. These were effectively repeat commitments that were previously made in an Accepted LOA from the same patent holder to license under FRAND terms the same essential patent claims. We therefore consider these as Duplicate LOAs.[16]

Examples of LOAs duplicating FRAND commitments made prior to the change in the IEEE patent policy are shown in Table 2. Because the Blanket LOA made in May 31, 2011 was for 5 standards, we count it as 5 Non-Duplicate Blanket LOAs. However, the subsequent Specific LOAs of 2015 listing European and US patents duplicate the Blanket FRAND commitment made in the 2011 LOA regardless of what specific patents are identified later because the Blanket LOA "applies to all Essential Patent Claims for which a Submitter may currently *or in the future* …

[15] IEEE SASB Bylaws, §6.2.

[16] Some commentators have argued that such LOAs should not be considered as duplicating prior FRAND commitments because those were made under a different patent policy. However, we decline to adopt this distinction for this study. This is because we assume that patent holders who actually made such new Duplicate LOA FRAND commitments do not regard the change a material deviation from *their* terms made in *their* actual prior bilateral licenses already made under the previous patent policy to *their* legacy licensees. Otherwise, a material deviation in favor of the new licensees *would be discriminating* against the legacy licensees, in violation of the patent holder's pledge under the *previous* legacy FRAND commitment to license under *nondiscriminatory terms*. That such material shift in FRAND commitment by a SEP owner would violate its "nondiscriminatory" obligations to licensees under a legacy LOA is confirmed by a court in India in the case of *Ericsson v. Intex Technologies, Ltd*. The court found that should a SEP holder set a royalty based on the chip value (as may be expected under the new IEEE policy on the "smallest salable" unit) after it had used the end-product value (as under the old IEEE policy, and the policy of other SDOs), it would be discriminating against prior licensees under the FRAND commitment in the legacy LOA. See *Ericsson v. Intex Technologies, Ltd.* The High Court of Delhi, Case CS(OS) No. 1045/2014, p.250, (March 13, 2015). To avoid such violations if disparities of actual terms are truly material, the patent holder would have to reopen the license contracts with all legacy implementers to reduce their royalty rates in conformance with the new policy. However, reasonable patent holders are unlikely to initiate such disruptive renegotiations and we assume that it was unnecessary here because the patent holders at issue were already licensing under terms that did not require material changes due to the new FRAND commitments – that they were previously already operating under terms which they lobbied IEEE to adopt in its new patent policy.

have the ability to license."[17] Similarly, Intel filed several dozen Blanket LOAs in 2015 that duplicated their 2013 Blanket LOAs.

Standard	Patent Owner	Patents/Type	LOA
802.11-2007 802.11n 802.11r 802.11ac 802.11ad	Samsung Electronics Co., Ltd.	Blanket	31-May-11
802.11n	Samsung Electronics Co., Ltd.	EP1681808; EP2040417; EP1626538; EP1681807; EP2224615; EP1847042; EP2224616; EP2224618; EP2224617; EP2224619; EP2224613; EP2224614; EP1946488	20-Jan-15
802.11n	Samsung Electronics Co., Ltd.	US7817614; US7859987; US7,944,874; US8107493; US8660140; EP1972102	15-Jul-15
802.11ac	Samsung Electronics Co., Ltd.	US13/590594	15-Jul-15
802.11ad	Samsung Electronics Co., Ltd.	US9026044	15-Jul-15

Table 2. Example of Duplicate LOAs filed in 2015, duplicating the Blanket LOA of 2011.

3.2.2 LOAs that are not considered Duplicate

Multiple patent-specific LOAs pledged by a patent holder for the same standard identifying *distinct* patents are *not* considered Duplicate LOAs because they are directed at distinct essential claims in different patents. Under patent law, which proscribes double-patenting, the claims in different patents do not cover the same invention – the respective essential claims are said to be *patentably distinct*.[18] In other words, because claims identified in any LOA are presumed *essential*, an implementer must obtain a license on *all specific* essential patent claims to comply with the standard and an LOA pledging to license only some essential patent claims not covered by a previous LOA does not duplicate any of the patent holder's *prior* commitments and is therefore a Non-Duplicate LOA.

Standard	Patent Owner	Patents/Type	LOA
1904.1	PMC-Sierra Inc.	US20090263127; US20100118753	10-May-10
1904.1	PMC-Sierra Inc.	Blanket	1-Nov-12
802.11ad	Nokia	US8706124; EP2342837	Negative, 15-Jul-15
802.11ad	Nokia	US8422961	Negative, 15-Jul-15

Table 3. Examples of Non-Duplicate positive and negative LOAs.

[17] IEEE SASB Bylaws, §6.1. (Emphasis added).

[18] 35 U.S.C. §121 ("If two or more independent and distinct inventions are claimed in one application, the Director may require the application to be restricted to one of the inventions."); 37 C.F.R. §1.141(a) ("Two or more independent and distinct inventions may not be claimed in one national application").

Two examples of Non-Duplicate LOA pairs are shown in Table 3. The two Nokia Specific LOAs of July 15, 2015 are directed to distinct patents and are therefore Non-Duplicate LOAs. In the PMC-Sierra LOA of 2010, the company pledged to license under FRAND terms only essential claims that may issue form the two specified published U.S. patent applications and no others. In its 2012 Blanket LOA for the same standard, PMC-Sierra expanded this pledge to *any* other essential patent claim for which it may "currently *or in the future* have the ability to license." Because this commitment to license *additional* essential patent claims under FRAND terms was not previously available to implementers of the 1904.1 standard, the 2012 LOA pledge is considered Non-Duplicate.

Standard	Patent Owner	Patent/Type	LOA
802.11-2012	Intel Corp.	Blanket	23-May-13
802.11aa	Intel Corp.	Blanket	23-May-13
802.11ac	Intel Corp.	Blanket	23-May-13
802.11ad	Intel Corp.	Blanket	23-May-13
802.11af	Intel Corp.	Blanket	23-May-13
802.11ah	Intel Corp.	Blanket	23-May-13
802.11ai	Intel Corp.	Blanket	23-May-13

Table 4. Example of Non Duplicate LOAs for new standard amendments

Notwithstanding the provision in §6.3.5 of the SASB Operations Manual discussed above that may require reading Blanket LOA commitments for a given standard as covering its amendments, we cautiously assume that an LOA submitted by a patent holder for an *active* amendment to an existing standard is presumed to cover new essential patent claims that are not covered by any LOA that the patent holder might have pledged for the existing standard. Otherwise, the patent holder would not need to file an LOA for that amendment, an avoidance that appears universally practiced for all amendments to IEEE standards. As such, we consider LOAs for *active* amendments Non-Duplicate LOAs. This is in contrast with LOAs submitted for an amendment *after* it had been superseded by a revision, a situation described in Section 3.2.1.

Examples of such non-duplication are shown in Table 4, where the existing base standard is 802.11-2012, for which an LOA was filed. Because the 6 subsequent amendments referred to in the table were new and not already part of the base standard, the 6 LOAs for these amendments are counted as Non-Duplicate LOAs.

3.2.3 Nonawareness statements

Occasionally, a party may "after Reasonable and Good Faith Inquiry, indicate it is not aware of any Patent Claims that the Submitter may own, control, or have the ability to license that might be or become Essential Patent Claims."[19] The statement to that effect is made in the IEEE LOA form. However, such statements

[19] IEEE SASB Bylaws, §6.2.

are not included in the LOA counts of this study because they pledge no commitments or refusals to license. An example of such nonawareness statement is that filed on October 23, 2013 by Lehman Electrical Resources, LLC for the 1264 standard.

3.3 PARs

In order to provide context to the rate of LOA submissions, a proxy for the *relative* rate of new standard initiations that may require licensing assurances is desirable, both as a driver for LOA submissions and a control for changes in LOA submission rates. For this purpose, the counts of PAR approvals in each semi-annual period were used because those events mark initiations of new projects intended to produce new, amended, or revised standards. The data is obtained from the periodic listings on the SASB approval website[20] wherein the number of New PARs and PARs for the Revision of Standards were combined. Modified PARs or Withdrawn PARs are not included in this PAR count. These are shown in semiannual bins in Appendix A, Table 6.

PAR approvals appear to be the best readily available indicator set for temporally predicting LOA submission events, although the latter appear with a time lag due to the standard development process. The time lag is because a determination that certain patent claims may be essential is made only after certain drafts of a standard are adopted. Thereafter, SEP holders are expected to disclose any potential SEPs they may hold by submitting an LOA as early as possible, but no later than the standard's approval.[21] The average time at IEEE from PAR approval to the standard's approval is 3 years and 3 months.[22] Nevertheless, SEP holders have a legal incentive for full and early disclosure of their SEPs in order to prevent potential loss of their patent enforcement rights.[23] It is therefore estimated that the lag of LOA submissions after PAR approvals is sufficiently less than 3 years on average, permitting the use of the PAR approval intensity as a reasonable control, particularly at the coarse granularity of aggregate counts over a 6-year period before, and a 3-year period after the change of the IEEE patent policy.

3.4 Temporal Scope of this Study

The LOAs included in this study are those submitted in the period starting 6 years before the IEEE patent policy change (March 15, 2009), and ending at the third anniversary (March 15, 2018). Semiannual counts beginning on March 16 or September 16 in each year of the study are shown in Appendix A, Table 6. LOAs

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[20] See http://standards.ieee.org/about/sba/ and its counterpart archives at www.archive.org .

[21] IEEE SASB Bylaws, §6.2 ("If the patent holder or patent applicant provides an LOA, it should do so as soon as reasonably feasible in the standards development process once the PAR is approved by the IEEE-SA Standards Board. This LOA should be provided prior to the Standards Board's approval of the standard.");

[22] IEEE-SA, *Elapsed Time for 2017 Approved Standards*, Board presentation (December 6, 2017).

[23] *See, e.g.*, *Rambus Inc. v. Infineon Technologies AG,* 318 F.3d 1081 (Fed. Cir. 2003); *In re Dell Corporation*, 121 F.T.C. 616 (1996), in which a consent agreement was reached.

submitted earlier than this period were also taken into consideration in order to determine that LOAs submitted in the study period are Non-Duplicates.

3.5 LOAs by Entity Types

We classify LOA submissions into two categories: those LOAs submitted by entities commercially engaged *predominantly* in developing and selling semiconductor devices, chips or designs for such components, and LOAs submitted by all other entities, which we categorize as Products and Systems companies. The determination of the category that best characterizes each entity was made based on the entities' description of its business, their products and services, as those appear on their respective main internet web site as well as in their press releases. The patent holders so classified in the classification Semiconductor/Chip Entities are listed in Appendix B.

4 Positive, Negative, and Missing LOAs

Standard	Technology	LOA	Patent Holder
802.11n	WiFi, Antenna Diversity Enhancements for Higher Throughput	Negative	Nokia
		Negative	Orange
		Missing	Texas A&M Univ.
802.11ac	WiFi, Enhancements for Operation in Bands below 6 GHz	Missing	Texas A&M Univ.
802.11ad	WiFi, Enhancements for Very High Throughput in the 60 GHz Band	Missing	Texas A&M Univ.
		Negative	Nokia
802.11af	WiFi, Television White Spaces (TVWS) Operation	Negative	Nokia
802.11ah	WiFi, Sub 1 GHz License Exempt Operation	Negative	Nokia
		Negative	Ericsson
		Submitted	Qualcomm*
802.11ai	WiFi, Fast Initial Link Setup (for mobility handoff)	Negative	Nokia
		Missing	Blackberry
		Missing	IBM
		Missing	HP
802.11ax	Enhancements for High Efficiency WLAN (dense deployment scenarios)	Negative	Ericsson
		Negative	InterDigital
		Negative	Panasonic
802.11ay	WiFi, 3650-3700 MHz Operation in USA	Negative	Panasonic
802.11ba	WiFi, Wake-up radio operation	Missing	Endioo
802.11z	WiFi, Extensions to Direct-Link Setup (DLS)	Negative	Nokia
802.15.4q	Ultra-Low Power Physical Layer	Missing	Freescale
		Missing	Elster
802.16	Wireless Metropolitan Area Networks	Negative	Nokia
802.16.1	Wireless MAN-Advanced Air Interface for Broadband Wireless Access Systems	Negative	Nokia
802.19.1	TV White Space Coexistence Methods for LAN and MAN	Negative	Nokia
1588	Precision Clock Synchronization Protocol for Networked Measurement & Control Systems	Negative	Alcatel Lucent
1901	Broadband over Power Line Networks, MAC and PHY Layer Specifications	Negative	Orange

Table 5. Negative and Missing LOAs for IEEE standards as of March 15, 2018. *Sources*: Negative LOAs – IEEE-SA PatCom record of Accepted LOAs[24]; Missing LOAs – IEEE 802.11 Register of LOA Request (March 5, 2018)[25]; IEEE 802.15 Minutes (Sep. 17, 2015).

[24] *See* http://standards.ieee.org/about/sasb/patcom/patents.html

The list of all Negative and known Missing LOAs is provided in Table 5. This table shows that several IEEE standards racked multiple Negative or Missing LOAs.

4.1 Statistical Analysis

The semiannual Non-Duplicate LOA submission rates for Semiconductor/Chip companies and Product/System companies are shown in Figure 1. Also included are Negative and Missing LOAs, shown as negative numbers. In order to obtain one scalar measure for analysis we "net out" the Negative and Missing LOAs to obtain a single "net" variable for each entity category. The result under such representation for all Non-Duplicate LOAs is shown in Figure 3.

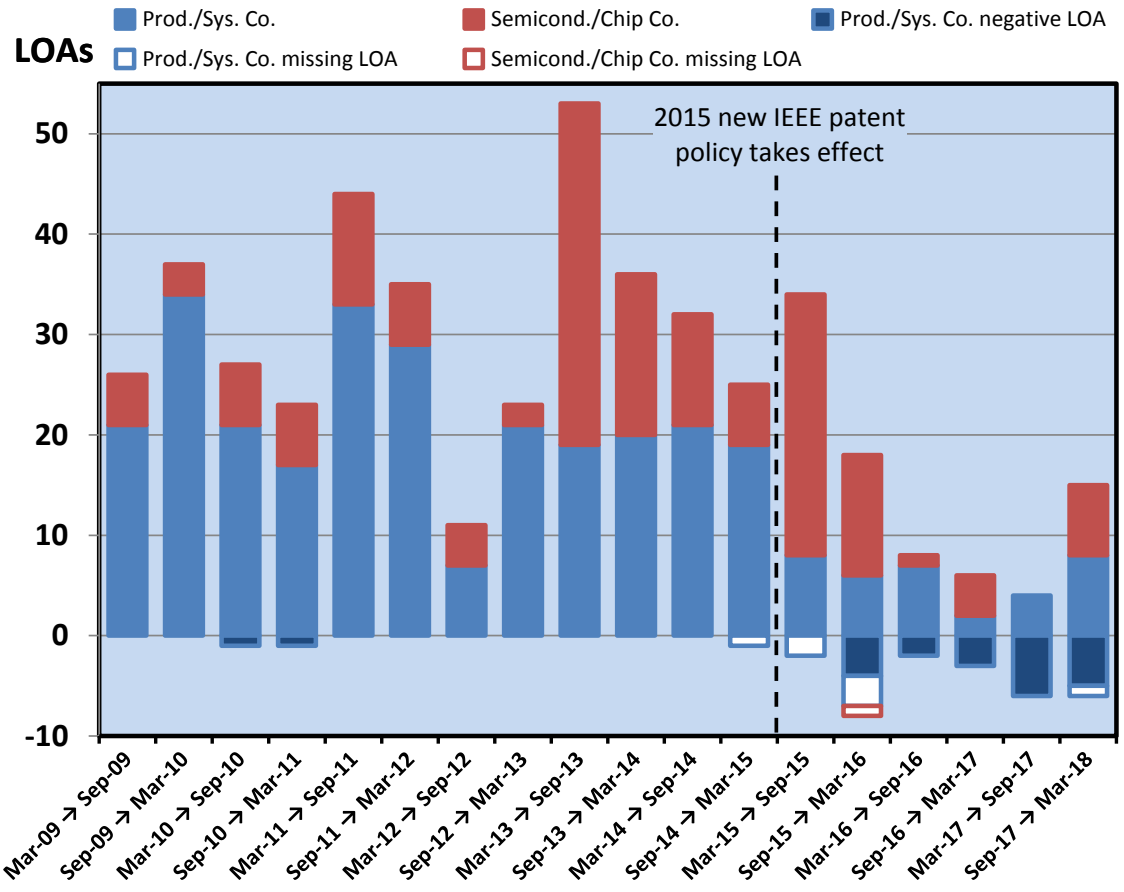

Figure 1. Semiannual submission rates of Non-Duplicate LOAs by Semiconductor/Chip companies and by Product/Systems companies. Sources: See Appendix A.

While the figures appear to show significant changes in the LOA submission rates after the change in the IEEE patent policy, we seek to test the hypothesis that, treated as random variables $\boldsymbol{x}$ and $\boldsymbol{y}$, the LOA submission rates $\boldsymbol{x}$ after the IEEE patent policy change are stochastically smaller than those rates $\boldsymbol{y}$ before the policy change. We formulate our hypothesis as follows:

[25] *See* https://mentor.ieee.org/802.11/dcn/15/11-15-1489-09-0000-register-of-loa-requests.docx

H_0: $\boldsymbol{x}$ and $\boldsymbol{y}$ have equal cumulative probability distribution functions.

H_1: $\boldsymbol{x}$ is stochastically smaller than $\boldsymbol{y}$.

In Appendix A we test these hypotheses in four separate $\boldsymbol{x}$ and $\boldsymbol{y}$ ensembles of LOA submission rates after and before the IEEE patent policy change: all Unique LOAs, all net Non-Duplicate LOAs, Semiconductor/Chip companies' net Non-Duplicate LOAs, and Product/Systems companies' net Non-Duplicate LOAs. The results for these four Mann-Whitney tests are shown in Table 7.

In all but the Semiconductor/Chip companies' category, we reject the null hypothesis H_0 with high confidence in favor of H_1, i.e., $\boldsymbol{x}$ is stochastically smaller than $\boldsymbol{y}$**.** This conclusion is statistically significant even if one does not remove Duplicate LOAs from the analysis by using all Unique LOAs. As shown in Table 7, Product/Systems companies' net Non-Duplicate LOAs submission rate declined by 94% ($p \approx 7\times10^{-4}$); all net Non-Duplicate LOAs submission rate declined by 68% ($p < 6\times10^{-3}$); and all Unique LOA submission rate declined by 20% ($p < 4\times10^{-2}$). Thus, we find that only in the Semiconductor industry segment was there no statistically significant decline in the LOA submission rate after the change in the IEEE patent policy.

The aggregate mean rate of total LOA submissions per year before and after the change in the IEEE patent policy is shown in Figure 2. Motivated by this figure, we next explore in Appendix A whether certain explanatory variables (controls) could account for the changes in LOA submission counts aggregated over a 6-year period before, and a 3-year period after the change of the IEEE patent policy.

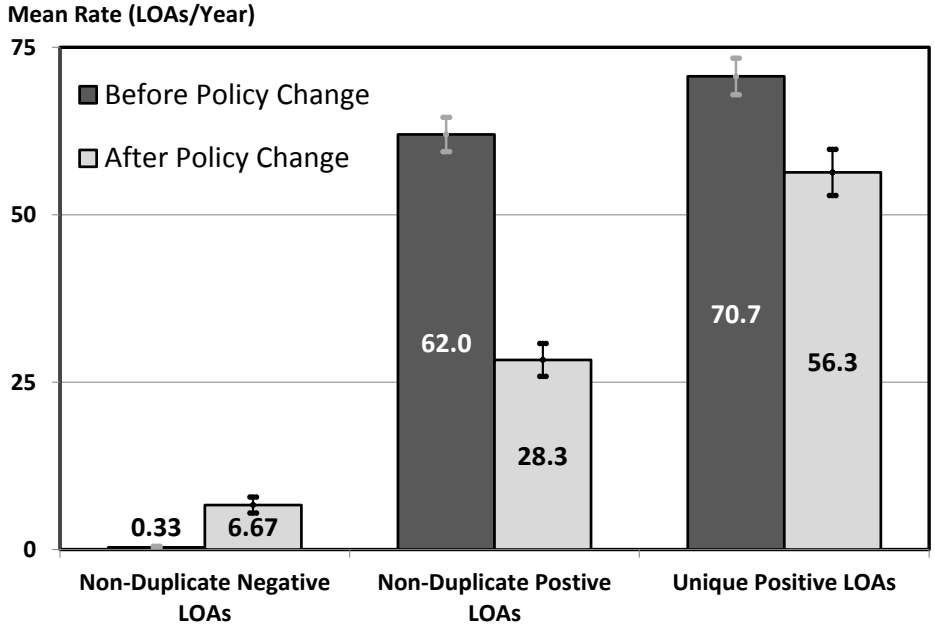

Figure 2. Mean rate of total LOA submissions per year before and after the change in the IEEE patent policy. Mean absolute deviations calculated as described in Appendix A.

We denote these periods by epoch 1 and epoch 2 respectively. For example, using a Poisson counting model, we test whether the increase in Negative LOAs from 2 (epoch 1) to 20 (epoch 2) is explainable by a proportional change in submission of all Unique Positive LOAs generally (control); we also test whether the reduction in count of Non-Duplicate LOAs from 372 (epoch 1) to 85 (epoch 2) is explainable by a proportional change in new standards initiations as measured by changes in the number of PAR approvals (control).

In all such statistical tests for which Table 8 in Appendix A shows the results, the changes in the control cannot explain the precipitous changes in LOA submission intensities. As Table 8 shows, these results are statistically extremely significant and the only reasonable inference is that the propensity to pledge Positive LOAs has declined precipitously after the change in the IEEE patent policy.

5 PARs as predictors and control

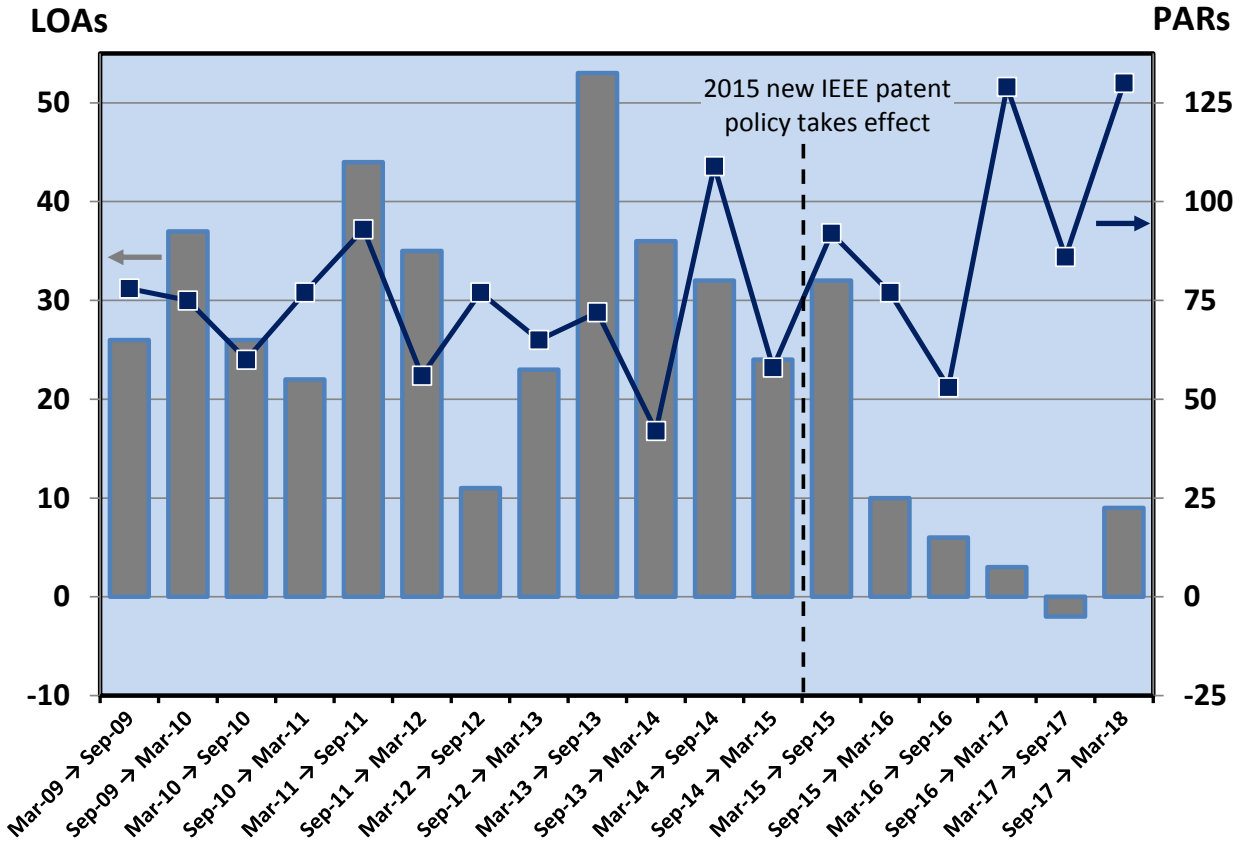

Figure 3. Semiannual submission rates of Non-Duplicate LOAs by all entities (netting out Negative and Missing LOAs). PAR approvals are superimposed in the line plot. Sources: see Appendix A.

Figure 3 demonstrates that while PAR approvals were in general growth through the change of the IEEE patent policy, net Non-Duplicate LOA submissions declined significantly. Contrary to commentators' remarks that the robust growth in PAR approval is a mark of success of the new patent policy, the fact that the number of

LOA submissions *per new project* is declining is far from a measure of success – it is troubling. It indicates two possible ominous outcomes or their combination: (1) IEEE standards will be promulgated under a growing cloud of uncertainty as to availability of FRAND licensing, resulting in either lower fraction of initiated standards that will get *approved* and/or (2) IEEE commenced promulgating standards for easily attainable technologies for which no patents are required, or for which participating patentees can obtain sufficient return on relatively small sunk investments in innovative activity. Regarding the second outcome, high quality pioneering advances in technology resulting from more substantial R&D investments require higher compensation to patent holders, which may not be made available to IEEE standards – IEEE may become an SDO for mere interoperability and connectivity standards. Neither outcome bodes well for IEEE and its brand.

6 Conclusion

There is substantial evidence that overall propensity for contributing LOAs for IEEE standards has declined after the change in its patent policy. These results are statistically extremely significant. However, SEP holders in one industry segment – the Semiconductor/Chip companies – do not appear to have slowed down in submitting LOAs, indicating that they may have already operated under similar terms in their bilateral licenses and/or that they may perceive to be the ultimate beneficiaries of the new policy, not as SEP holders, but as implementers/licensees. The fact that more of the SEP holders categorized in the Product/Systems industry segment are reluctant to pledge positive LOAs under the new patent policy erodes consensus in promulgating new IEEE standards.

Appendix A – Statistical Analysis of LOA Submissions

The dataset for this study was assembled by tabulating all LOA posted on the IEEE PatCom web page.[26] After case-by-case determination of Non-Duplicate LOAs as described in 3.2, the semiannual LOA counts were summarized in Table 6 below.

Period	Unique Positive LOAs		Semicon/ Chip Co.	Product/ Sys. Co.	Semicon/ Chip Co.	Product/ Sys. Co.	Semicon/ Chip Co.	Product/ Sys. Co.	Semicon/ Chip Co.	Product/ Sys. Co.	Net ND LOAs; All Entities	ND Positive LOAs	Approved PARs	
			Non-Diplicate Positive LOAs		Non-Diplicate Negative LOAs		Missing LOAs		Net Non-Diplicate LOAs					
Mar-09 → Sep-09	27		5	21					5	21	26		78	
Sep-09 → Mar-10	37		3	34					3	34	37		75	
Mar-10 → Sep-10	29		6	21		-1			6	20	26		60	
Sep-10 → Mar-11	24		6	17		-1			6	16	22		77	
Mar-11 → Sep-11	44		11	33					11	33	44		93	
Sep-11 → Mar-12	43		6	29					6	29	35		56	
Mar-12 → Sep-12	12		4	7					4	7	11		77	
Sep-12 → Mar-13	29		2	21					2	21	23		65	
Mar-13 → Sep-13	80		34	19					34	19	53		72	
Sep-13 → Mar-14	37		16	20					16	20	36		42	
Mar-14 → Sep-14	32		11	21					11	21	32		109	
Sep-14 → Mar-15	30	**424**	6	19			-1		6	18	24	**372**	58	**862**
Mar-15 → Sep-15	114		26	8			-2		26	6	32		92	
Sep-15 → Mar-16	19		12	6		-4	-3	-1	11	-1	10		77	
Mar-16 → Sep-16	9		1	7		-2			1	5	6		53	
Sep-16 → Mar-17	7		4	2		-3			4	-1	3		129	
Mar-17 → Sep-17	4			4		-6				-2	-2		86	
Sep-17 → Mar-18	16	**169**	7	8		-5	-1		7	2	9	**85**	130	**567**
Totals		**593**	**160**	297		**-22**	**-7**	**-1**				**457**		**1429**

Table 6. Semiannual LOA submission rates by entity type from Mar-16-09 to Mar-15-18. Sources: LOA lists, IEEE-SA PatCom;[26] Missing LOAs in: 802.15 minutes, 17-Sep-2015; 802.11 LOA Requests Register, March 5, 2018.[27] PAR

Non Parametric Comparison of LOA Submission Rates

Because the statistical distribution of LOA submission rates cannot be adequately modeled by specific known probability distributions, we apply methods for unknown probability distributions – non-parametric tests. We test the null hypothesis that the sample of LOA submission rates before the change in the IEEE patent policy and the sample of LOA submission rates after that change are drawn from the same underlying probability distribution. If we can reject this null hypothesis, we may conclude that the change in LOA submission rates is statistically significant. We use the Mann-Whitney (Mann & Whitney 1947) non-parametric two-sample test also known as the Wilcoxon rank sum test for this purpose. Its statistical formulation is as follows:

Let $\boldsymbol{x}$ and $\boldsymbol{y}$ be two random variables having cumulative probability distribution functions F and G respectively. The variable $\boldsymbol{x}$ is called *stochastically smaller* than

[26] http://standards.ieee.org/about/sasb/patcom/patents.html .
[27] https://mentor.ieee.org/802.11/dcn/15/11-15-1489-09-0000-register-of-loa-requests.docx .

$\boldsymbol{y}$ if $F(a) > G(a)$ for every a. The Mann-Whitney non-parametric test uses samples x_i, $i = 1\ldots n$, and y_j, $j = 1\ldots m$, drawn from two such ensembles to test the null hypothesis $F = G$ against the alternative hypothesis that $\boldsymbol{x}$ is stochastically smaller than $\boldsymbol{y}$. Mann & Whitney showed in their seminal paper that their test is suited for large or small samples and they specifically provide tables for tests using sample sizes n and m from 1 to 8. This is particularly useful in our case wherein one of the two ensembles of LOA submissions is of 6 samples. Of course, we must accept that the statistical power of tests with such small samples may not always result in statistically significant p values when there is small disparity in the underlying distributions.

Lehmann subsequently showed in (Lehmann 1951) that the Mann-Whitney test is unbiased and holds for discontinuous cumulative distribution functions. This is particularly applicable in our application wherein the LOA submission rates are discrete valued integers, necessarily having cumulative distribution functions with discontinuities at integer values. Moreover, the Mann-Whitney test is robust, resulting in fewer wrongfully significant results in the presence of one or two extreme values in the sample under investigation (Siegel and Castellan, 1988).

We denote the semiannual LOA submission rates after the change in the IEEE patent policy by x_i, $i = 1\ldots 6$, and the rates before that change by y_j, $j = 1\ldots 12$. We assume that x_i and y_j are realizations of random variables $\boldsymbol{x}$ and $\boldsymbol{y}$ respectively. We formulate our hypothesis as follows:

$\boldsymbol{H}_0$: $\boldsymbol{x}$ and $\boldsymbol{y}$ have equal cumulative probability distribution functions.
$\boldsymbol{H}_1$: $\boldsymbol{x}$ is stochastically smaller than $\boldsymbol{y}$.

We test these hypotheses in four separate ensembles of LOA submission rates before and after the IEEE patent policy change: all Unique LOAs, all net Non-Duplicate LOAs, Semiconductor/Chip companies' net Non-Duplicate LOAs, and Product/Systems companies' net Non-Duplicate LOAs. As shown in Table 6, we obtain the net Non-Duplicate LOA counts by adding the Negative LOAs and Missing LOAs counts as negative numbers. The results for these four Mann-Whitney tests are shown in Table 7.

Entity Ensemble Category	All Unique LOAs		All Non-Duplicate LOAs		Semicond./Chip Co. Non-Duplicate LOAs		Product/System Co. Non-Duplicate LOAs	
Mann-Whitney Test for Two Independent Samples	**Sample 1**	**Sample 2**	**Sample 1**	**Sample 2**	**Sample 1**	**Sample 2**	**Sample 1**	**Sample 2**
Sample Period	Before Mar-15-2015	After Mar-15-2015	Before Mar-15-2015	After Mar-15-2015	Before Mar-15-2015	After Mar-15-2015	Before Mar-15-2015	After Mar-15-2015
count	12	6	12	6	12	6	12	6
sample mean	35.3	28.2	30.8	9.8	9.17	8.40	21.58	1.40
change in sample mean		**-20%**		**-68%**		**-8%**		**-94%**
median	31	12.5	29	7.5	6	5.5	20.5	0.5
rank sum	136	35	143.5	27.5	119.5	51.5	150	21
U	14.0	58.0	6.5	65.5	30.5	41.5	0	72.0
Rank Test Results	one tail	two tail	one tail	two tail	one tail	two tail	one tail	two tail
alpha	0.05		0.05		0.05		0.05	
U	14.0		6.5		30.5		0	
mean	36		36		36		36	
std dev	10.68		10.67		10.65		10.67	
z-score	-2.06049		-2.76435		-0.51646		-3.37345	
U-crit	17.94	14.57	17.95	14.58	17.98	14.63	17.95	14.58
p-value	**0.0197**	0.0394	**0.0029**	0.0057	**0.3028**	0.6055	**0.0004**	0.0007
Statistically significant	**yes**	**yes**	**yes**	**yes**	**no**	**no**	**yes**	**yes**

Table 7. Results of four non-parametric statistical tests comparing two sample distributions of LOA submission rates listed in Table 6.

First, note that even without removing Duplicate LOAs, i.e., when considering all Unique LOAs, the decline of 20% in their mean submission rate is statistically significant and we can reject the null hypothesis H_0 with confidence in favor of H_1, i.e., $\boldsymbol{x}$ is stochastically smaller than $\boldsymbol{y}$ (Mann–Whitney $U = 14$, $n = 12$, $m = 6$, $p < 2 \times 10^{-2}$ one-tailed). Only in the Semiconductor/Chip companies' category, the null hypothesis H_0 *cannot be rejected* (Mann–Whitney $U = 30.5$, $n = 12$, $m = 6$, $p = 3 \times 10^{-1} > 0.05$ one-tailed). This means that only in this industry segment there was no statistically significant change in the LOA submission rate probability distributions after the change in the IEEE patent policy.

LOA counts compared to Controls

In this section, we characterize parametrically the change in LOA submissions at the coarse granularity of aggregate counts over a 6-year period before, and a 3-year period after the change of the IEEE patent policy. We denote these periods as epoch 1 and epoch 2 respectively. We compare the relative change in this aggregate LOA count to the relative change in other aggregate count in the same epochs. We thus treat the other aggregate counts as the "Controls" for specific LOA submissions. For example, using PAR approvals as the control for all Non-Duplicate Positive LOAs, Table 6 shows that the aggregate count of 862 PAR approvals during epoch 1 changed to an aggregate count of 567. If no change occurred in propensity to submit LOAs for new standards between epochs 1 and 2, we would expect that the aggregate number of all Non-Duplicate Positive LOAs would change proportionately and track the PAR approvals. However, the aggregate count of Non-Duplicate

Positive LOAs changed disproportionately from 372 to 85. In the analysis below, we seek to ascertain whether this disproportionality is statistically significant.

As customary in modeling integer random counting processes, we model all aggregate counts as having a Poisson probability distribution (Hausman, Hall, & Griliches, 1984). Where, as here, the counts are small in some periods (as low as 2), the Poisson model is particularly appropriate for hypothesis testing.

We denote the aggregate accumulated count within epoch e (e = 1, 2) as random variable integers $\boldsymbol{n}_e$ and $\boldsymbol{m}_e$ for the counts of the measured quantity and the control respectively. We therefore allow for distinct intensities Λ_e and Γ_e for $\boldsymbol{n}_e$ and $\boldsymbol{m}_e$ respectively, each having the Poisson probability density:

$$(1) \qquad \begin{aligned} \Pr\{\boldsymbol{n}_e = n\} &= f_{\boldsymbol{n}}(n;e) = \frac{\Lambda_e^n}{n!}\exp(-\Lambda_e); \\ \Pr\{\boldsymbol{m}_e = m\} &= f_{\boldsymbol{m}}(m;e) = \frac{\Gamma_e^m}{m!}\exp(-\Gamma_e); \end{aligned} \qquad \text{where } e = 1,2.$$

For example, the quantity $f_{\boldsymbol{n}}(n;e)$ represents the probability that an underlying LOA submission intensity of Λ_e will produce $\boldsymbol{n}$ observed LOA submissions during the epoch e.

We limit our analysis to a model in which a possible coupling through simple proportionality may empirically exist between the "control" count and the measured count. This functional assumption of our model is the most basic way to capture the essence of the "control" aspect of $\boldsymbol{m}$ — it absorbs the "control" activity trend as accounting for common conditions affecting both. Such common factors may be slowing down of standardization activities and the like.

Although under this model, the intensities Λ_e and Γ_e, may be coupled, we shall assume that $\boldsymbol{n}_e$ and $\boldsymbol{m}_e$ are otherwise *conditionally* statistically independent, – i.e., that their joint probability density function conditioned on their intensities is the product of their individual marginal probability densities conditioned on their respective intensities. This assumption is no different than assuming that two random variables having the *same* mean values are statistically independent. Similarly, although there may be temporal coupling between the underlying intensities of $\boldsymbol{n}_e$ and $\boldsymbol{n}_{e-1}$ or $\boldsymbol{m}_e$ and $\boldsymbol{m}_{e-1}$ respectively the two epochs, we shall also assume joint conditional statistical independence therebetween such that their joint conditional probability density function is given by:

$$(2) \qquad f_{\boldsymbol{nm}}(n_{e-1}, m_{e-1}, n_e, m_e \mid \Lambda_{e-1}, \Gamma_{e-1}, \Lambda_e, \Gamma_e) = f_{\boldsymbol{n}}(n_{e-1} \mid \Lambda_{e-1}) f_{\boldsymbol{m}}(m_{e-1} \mid \Gamma_{e-1}) f_{\boldsymbol{n}}(n_e \mid \Lambda_e) f_{\boldsymbol{m}}(m_e \mid \Gamma_e)$$

In other words, even though their underlying intensities may be proportionately coupled temporally, we assume that the actual events of filing the LOAs or PAR

approvals within the distinct epochs result in realization counts $\boldsymbol{n}_e$, $\boldsymbol{n}_{e-1}$, $\boldsymbol{m}_e$, and $\boldsymbol{m}_{e-1}$ that are jointly statistically independent random variables.

We state our hypotheses as follows:

> $\boldsymbol{H}_0$: the change in the underlying LOA submission intensity Λ tracked the intensity of the control, Γ, meaning that within a coupling-scale-factor to be estimated from the ratio of the respective intensities during the previous epoch $e-1$, the underlying LOA submission intensity during epoch e followed the "control." This means: $\Lambda_e = \Gamma_e \Lambda_{e-1}/\Gamma_{e-1}$.
>
> $\boldsymbol{H}_1$: the underlying LOA submission intensity Λ changed between the consecutive epochs $e-1$ and e to a value other than that explained by $\boldsymbol{H}_0$.

Under conventional statistical hypothesis testing practice, we test hypotheses $\boldsymbol{H}_1$ against $\boldsymbol{H}_0$, by forming the likelihood ratio R from the respective conditional joint probability densities and comparing the respective prior probabilities Pr[$\boldsymbol{H}$] for each hypothesis and the probabilities that each hypothesis is correct given the observable data $\boldsymbol{n}_{e-1}$, $\boldsymbol{n}_e$, $\boldsymbol{m}_{e-1}$, and $\boldsymbol{m}_e$. The likelihood ratio tells us how much more probable $\boldsymbol{H}_1$ is relative to $\boldsymbol{H}_0$ given the observed data. Using Bayes theorem for conditional probabilities, we have:

$$R = \frac{\Pr[H_1 \mid \boldsymbol{n}_{e-1}, \boldsymbol{m}_{e-1}, \boldsymbol{n}_e, \boldsymbol{m}_e]}{\Pr[H_0 \mid \boldsymbol{n}_{e-1}, \boldsymbol{m}_{e-1}, \boldsymbol{n}_e, \boldsymbol{m}_e]} = \frac{\Pr[\boldsymbol{n}_{e-1}, \boldsymbol{m}_{e-1}, \boldsymbol{n}_e, \boldsymbol{m}_e \mid H_1]\Pr[H_1]}{\Pr[\boldsymbol{n}_{e-1}, \boldsymbol{m}_{e-1}, \boldsymbol{n}_e, \boldsymbol{m}_e \mid H_0]\Pr[H_0]} = \tag{3}$$
$$= \frac{f_{nm}\left[\boldsymbol{n}_{e-1}, \boldsymbol{m}_{e-1}, \boldsymbol{n}_e, \boldsymbol{m}_e \mid H_1\right]}{f_{nm}\left[\boldsymbol{n}_{e-1}, \boldsymbol{m}_{e-1}, \boldsymbol{n}_e, \boldsymbol{m}_e \mid H_0\right]} \times \frac{\Pr[H_1]}{\Pr[H_0]}$$

In our case, we take the ratio of the prior probabilities Pr[$\boldsymbol{H}_1$]/Pr[$\boldsymbol{H}_0$] as 1 because we have no prior reason to favor one hypothesis over the other. Given the formulation of the two hypotheses above and the joint density function of Equation 2, we have:

$$R = \frac{f_{nm}\left[\boldsymbol{n}_{e-1}, \boldsymbol{m}_{e-1}, \boldsymbol{n}_e, \boldsymbol{m}_e \mid H_1\right]}{f_{nm}\left[\boldsymbol{n}_{e-1}, \boldsymbol{m}_{e-1}, \boldsymbol{n}_e, \boldsymbol{m}_e \mid H_0\right]} = \frac{f_{nm}\left[\boldsymbol{n}_{e-1}, \boldsymbol{m}_{e-1}, \boldsymbol{n}_e, \boldsymbol{m}_e \mid \Lambda_{e-1}, \Gamma_{e-1}, \Lambda_e, \Gamma_e\right]}{f_{nm}\left[\boldsymbol{n}_{e-1}, \boldsymbol{m}_{e-1}, \boldsymbol{n}_e, \boldsymbol{m}_e \mid \Lambda_{e-1}, \Gamma_{e-1}, \Lambda_e = \Gamma_e\Lambda_{e-1}/\Gamma_{e-1}, \Gamma_e\right]}$$
$$= \frac{f_n\left[\boldsymbol{n}_{e-1} \mid \Lambda_{e-1}\right] f_m\left[\boldsymbol{m}_{e-1} \mid \Gamma_{e-1}\right] f_n\left[\boldsymbol{n}_e \mid \Lambda_e\right] f_m\left[\boldsymbol{m}_e \mid \Gamma_e\right]}{f_n\left[\boldsymbol{n}_{e-1} \mid \Lambda_{e-1}\right] f_m\left[\boldsymbol{m}_{e-1} \mid \Gamma_{e-1}\right] f_n\left[\boldsymbol{n}_e \mid \Lambda_e = \Gamma_e\Lambda_{e-1}/\Gamma_{e-1}\right] f_m\left[\boldsymbol{m}_e \mid \Gamma_e\right]}$$
$$= \frac{f_n\left[\boldsymbol{n}_e \mid \Lambda_e\right]}{f_n\left[\boldsymbol{n}_e \mid \Lambda_e = \Gamma_e\Lambda_{e-1}/\Gamma_{e-1}\right]} = \frac{\Lambda_e^{\boldsymbol{n}_e} \exp(-\Lambda_e)/\boldsymbol{n}_e!}{(\Gamma_e\Lambda_{e-1}/\Gamma_{e-1})^{\boldsymbol{n}_e} \exp(-\Gamma_e\Lambda_{e-1}/\Gamma_{e-1})/\boldsymbol{n}_e!} \tag{4}$$
$$= \left(\frac{\Lambda_e\Gamma_{e-1}}{\Lambda_{e-1}\Gamma_e}\right)^{\boldsymbol{n}_e} \exp(\Gamma_e\Lambda_{e-1}/\Gamma_{e-1} - \Lambda_e)$$

.

Under the pertinent hypothesis, the LOA submission intensity parameters Λ_e and Γ_e of $\boldsymbol{n}_e$ and $\boldsymbol{m}_e$ respectively are unknown. Therefore, we follow the traditional method described in (Lehmann, 1959, 16) and evaluate the likelihood ratios R by using the maximum likelihood estimates of the unknown parameters. It is a common textbook exercise to show that the maximum likelihood estimate for the intensity parameter of a Poisson random variable given an observation of its count is simply the observed count, and this estimate is statistically unbiased:

$$\hat{\Lambda}_e = \boldsymbol{n}_e \;;\; \hat{\Gamma}_e = \boldsymbol{m}_e \;;\; E\left\{\hat{\Lambda}_e\right\} = E\left\{\boldsymbol{n}_e\right\} = \Lambda_e \;;\; E\left\{\hat{\Gamma}_e\right\} = E\left\{\boldsymbol{m}_e\right\} = \Gamma_e \,. \tag{5}$$

Using the likelihood ratio in Equation 4 above, and the estimated parameters from Equations 5, we obtain the following estimate for R:

$$\hat{R} = \left(\frac{\boldsymbol{n}_e \boldsymbol{m}_{e-1}}{\boldsymbol{n}_{e-1} \boldsymbol{m}_e}\right)^{\boldsymbol{n}_e} \exp(\boldsymbol{m}_e \boldsymbol{n}_{e-1} / \boldsymbol{m}_{e-1} - \boldsymbol{n}_e) \,. \tag{6}$$

In each respective epoch case, the likelihood ratio is the ratio of the probabilities of only two possible mutually exclusive event "answers" to a given question – "has the LOA submission intensity change proportionately with the "control" intensity or not?" Hence, we have $\Pr[\boldsymbol{H}_0 | \boldsymbol{n}_{e-1}, \boldsymbol{m}_{e-1}, \boldsymbol{n}_e, \boldsymbol{m}_e] + \Pr[\boldsymbol{H}_1 | \boldsymbol{n}_{e-1}, \boldsymbol{m}_{e-1}, \boldsymbol{n}_e, \boldsymbol{m}_e] = 1$, and the estimated significance level p of rejecting $\boldsymbol{H}_0$ in favor of $\boldsymbol{H}_1$ (the probability that the null hypothesis $\boldsymbol{H}_0$ is true given the observables) is therefore given by:

$$p = \Pr[H_0 \mid \boldsymbol{n}_{e-1}, \boldsymbol{m}_{e-1}, \boldsymbol{n}_e, \boldsymbol{m}_e] = \frac{1}{1 + \hat{R}} \,. \tag{7}$$

The results of the calculations of the likelihood ratios and significance levels for rejecting $\boldsymbol{H}_0$ in each test are shown in Table 8. Note that unlike traditional significance-level estimates that rely on the 'tail' of probability distributions that apply only for large populations, this result is unbiased and applies for any count number, including for epochs having only 2 counts. The only assumption relied upon here is that the underlying joint probability density of the observed LOA submissions and PAR approvals is that of jointly statistically independent Poisson-distributed random variables.

	epoch (e)	1	2	1	2	1	2
	Non Duplicate	Negative LOAs Prior to Policy Change	Negative LOAs After Policy Change	Negative LOAs Prior to Policy Change	Negative LOAs After Policy Change	Positive LOAs Prior to Policy Change	Postive LOAs After Policy Change
Time Period	Start Date	March 16, 2009	March 16, 2015	March 16, 2009	March 16, 2015	March 16, 2009	March 16, 2015
	End Date	March 15, 2015	March 15, 2018	March 15, 2015	March 15, 2018	March 15, 2015	March 15, 2018
	T_e (years)	6	3	6	3	6	3
LOA Count	n_e	2	20	2	20	372	85
	Avrg./Year	0.33 (0.18)	6.67 (1.18)	0.33 (0.18)	6.67 (1.18)	62 (2.56)	28.3 (2.45)
	Control	Non-Duplicate Positive		Unique Positive LOAs		PAR Authorizations	
Control Count	m_e	372	85	424	169	862	567
	Avrg./Year	62 (2.56)	28.33 (2.45)	70.7 (2.74)	56.3 (3.46)	143.7 (3.9)	189 (6.33)
Statistical Inferences		Test 1		Test 2		Test 3	
Likelihood Ratios R			2.16E+24		4.47E+19		2.09E+30
eject H_0 at significance p value of			**4.62E-25**		**2.24E-20**		**4.77E-31**

Table 8. Results of the statistical analysis and hypotheses tests covering 3 tests.

As Table 8 shows, we can reject the null hypothesis with extreme confidence for all three tests, which have *p*-values that are infinitesimally small.

The mean absolute deviation of a Poisson-distributed random variable $\boldsymbol{n}$ from its mean value Λ was derived by (Ramasubban 1958) and is given by:

$$E\{|\boldsymbol{n}-\Lambda|\} = 2\Lambda \Pr\{\boldsymbol{n} = \lfloor \Lambda \rfloor\} = 2\frac{\Lambda^{\lfloor \Lambda \rfloor+1}}{\lfloor \Lambda \rfloor!}\exp(-\Lambda) \tag{8}$$

where $\lfloor \Lambda \rfloor$ is the integer part of Λ. We use this expression for estimating the mean deviation of the observable counts in each epoch by substituting Λ with its respective estimates in Equations 5, from which we obtain (by dividing these by the respective epoch duration) the mean deviation of the average LOA submission rates shown in Figure 2 and in parentheses in Table 8.

Appendix B – Semiconductor/Chip Entities

The following SEP holders having LOAs considered in this study were categorized as Semiconductor/Chip companies based on criteria described in Section 3.5.

Altera Corp.
Analog Devices, Inc.
Aquantia Corp.
Atheros Communications, Inc.
Broadcom Corp.
Canova Tech Srl.
Celeno Communications
Green Plug, Inc.
IHP GmbH
Infineon Technologies AG
Intel Corp.
Inter-universitair Micro-Electronica Centrum vzw
Knowledge Development for POF SL
Lantiq BeteiligungsGmbH & Co. KG
Linear Technology Corp.
LSI Corp.
Marvell International Ltd.
Marvell Semiconductor
Maxim Integrated Products, Inc.
Microchip
Microsemi Corp.
NeoPhotonics Corp.
NXP B.V.
PMC-Sierra Inc.
Ralink Technology Corp.
Renesas Mobile Corp.
Silicon Laboratories Inc.
STMicroelectronics Inc.
Teranetics Inc.
Texas Instruments Inc.
Toumaz UK Ltd.

References

Brooks R.G. and D. Geradin, "Taking contracts seriously: The meaning of the voluntary commitment to license essential patents on 'Fair and Reasonable' terms," March 12, 2010. Available at SSRN: http://ssrn.com/abstract=1569498.

Hausman, J., Hall, B. H. and Griliches, Z. (1984), 'Econometric Models for Count Data with an Application to the Patents-R & D Relationship,' *Econometrica,* **52**(4), 909-938.

Lehmann, E. L. (1959), *Testing statistical hypotheses*. Wiley: New York.

Lehmann, E. L. (1951) Consistency and Unbiasedness of Certain Nonparametric Tests. *Annals of Mathematical Statistics,* **22**, no. 2, 165-179. http://projecteuclid.org/euclid.aoms/1177729639.

Mann, H. B., & Whitney D. R. (1947), On a test of whether one of 2 random variables is stochastically larger than the other. *Annals of Mathematical Statistics*, **18**, 50-60. http://projecteuclid.org/download/pdf_1/euclid.aoms/1177730491

Ramasubban, T. (1958), 'The Mean Difference and the Mean Deviation of Some Discontinuous Distributions,' *Biometrika,* **45**(3/4), 549-556.

Siegel, S. & Castellan, N.J. Jr. (1988), *Nonparametric statistics for the behavioral sciences*, 2nd Ed., McGraw-Hill.