Efficient Interference Management: Regulation, Receivers, and Right Enforcement

A report on a Silicon Flatirons Summit, held 18 October 2011

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Highlights

- The group reached a rough consensus that receiver interference protection limits are preferable to receiver standards in regulating receiver-dependent radio interference
- A number of technologists noted that any receiver standards regime imposed by regulators is liable to become overly complicated. Some participants proposed minimal receiver standards as an interim measure on the way to implementing protection limits.
- There was support for the proposal that systems engineers should be incentivized to build systems, including receivers, with an eye towards future uses in adjacent bands
- Several alternatives to rulemaking and traditional adjudication were proposed for resolving interference disputes, including: (1) a "rocket docket"; (2) baseball-style arbitration; (3) non-FCC solutions; and (4) using smart devices to support enforcement.

1 Executive Summary

The management of interference between operators is at the heart of wireless regulation. To date, national regulators have borne most of this burden, attempting to manage interference by setting transmitter parameters and limiting the services that are allowed in a particular band. However, the increasing intensity of radio use is leading to more conflicts, particularly between different service allocations. The resolution of cross-allocation interference problems will have to be streamlined if the promise of wireless technology is to be realized.

On October 18, 2011 the Silicon Flatirons Center convened a group of legal, economic, and engineering experts from government, industry, academia, and civil society to explore improving the management of radio interference. It is the latest step in a multi-year program on this topic organized by the Silicon Flatirons Center that began in September 2009 with a summit in Boulder on Defining Inter-Channel Operating Rules, and was followed by a conference in Washington, DC in November 2010 on New Approaches to Handling Wireless Interference (proceedings published in 9 J. on Telecomm. and High Tech. L. 501).

The previous meetings indicated that ambiguous rights definition and ineffective adjudication contributed to difficulties in resolving cross-allocation interference conflicts, leading to delay, uncertainty, and political gamesmanship. The goal of this roundtable was to develop proposals for improved receiver management, more effective enforcement, and to seek consensus recommendations for changes in the regulatory framework that could achieve this.

The role of receivers

Receiver performance dramatically affects the coexistence of adjacent services. However, while transmitters are required to control out-of-band and spurious emissions to minimize interference with other services, the same does not apply to receivers. In the *receiver standards* approach, the regulator specifies minimum receiver performance characteristics, e.g. sensitivity and front-end performance. An alternative approach is *receiver protection limits*, in which the regulator specifies the in- and out-of-band interference environment that receivers can expect to operate in.

Consideration of case studies[1] highlighted several recurring problems: (1) operators of wireless systems rely on quiet neighbors, and don't account for changes in the radio environment; (2) operators don't always realize that the receivers are the problem, but rather assume that a neighboring transmitter is operating outside of its band; (3) information is lost when problems are resolved on a case-by-case basis, and other operators with similar problems have no access to the resolution of an individual case. The group agreed that when considering solutions to these problems, it is important to ensure that operators, licensees, and other users have proper notice when the FCC is considering making changes to current allocations.

There was consensus by the end of the discussion that protection limits are preferable to receiver standards. The group also agreed that any incremental step towards receiver management would be better than the current hands-off approach. A few participants suggested that some minimal receiver standards could be implemented as a short-term solution, but there was no consensus in this regard; there was concern that any receiver management regime, no matter how simple at the beginning, would quickly become overly complicated.

Enforcement

It is essential that parties can obtain efficient redress of their grievances about harm to their wireless operations, both current and foreseen. While like-to-like co-channel conflicts seem to be handled well, and are often resolved without FCC involvement, cross-allocation conflicts appear to be more time-consuming and contentious.

After considering a series of cases, the participants discussed several alternatives to rule making and traditional adjudication for resolving interference disputes, including: (1) a "rocket docket"; (2) baseball-style arbitration; (3) non-FCC solutions; and (4) using smart devices to aid in enforcement. There was no consensus on changes that might substantially improve matters.

[1] Briefing materials available at http://www.silicon-flatirons.org/documents/Roundtables/2011.10.18-1021/EfficientInterferenceManagement2011.pdf.

2 Introduction

The management of interference between operators is at the heart of wireless regulation. To date, national regulators have borne most of this burden, attempting to manage interference by setting transmitter parameters and limiting the services that are allowed in a particular band. However, the increasing intensity of radio use is leading to more conflicts, particularly between different service allocations. The resolution of cross-allocation interference problems will have to be streamlined if the promise of wireless technology is to be realized.

2.1 Prior meetings

On October 18, 2011 the Silicon Flatirons Center convened a group of legal, economic, and engineering experts from government, industry, academia, and civil society to explore improving the management of radio interference. It is the latest step in a multi-year program on this topic organized by the Silicon Flatirons Center that began in September 2009 with a summit in Boulder on Defining Inter-Channel Operating Rules, and was followed by a conference in Washington, DC in November 2010 on New Approaches to Handling Wireless Interference (proceedings published in 9 J. on Telecomm. and High Tech. L. 501).

This series of discussions began in 2009 with a meeting[2] on defining inter-channel[3] interference rules where three case studies were considered: 800 MHz rebanding, WCS/SDARS, and AWS-3. The 2009 roundtable discussion produced agreement regarding the need for better definition of rights and the importance of receiver performance. However, there was little agreement about approaches to a solution: is it a problem of governance, poorly defined rights, or commercial self-interest? What should be done about the way that institutions are structured?

In 2010, a public conference[4] in Washington, D.C. addressed how radio operating rights should be defined, assigned, and enforced in order to obtain the maximum benefit from wireless operations. There was no grand consensus from the 2010 conference. There was some agreement about the need for private negotiation but there was a wide range of views on how to deal with harmful interference. Ellen Goodman argued that harmful interference should be a yield sign and not a stop sign;[5] Gregory Rosston and Scott Wallsten advanced the importance of a regulatory framework that starts with clear rules and allows parties to negotiate efficiency-enhancing changes to those rules;[6] Michael Calabrese proposed access rights that would be more definite, more transparent, and more intensive;[7] Even Kwerel and John Williams proposed

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[2] Reading list and report available at http://www.silicon-flatirons.org/events.php?id=761.

[3] This term refers to a variety of frequency-dependent interference modes that are described in a variety of ways including cross-channel, adjacent channel, out-of-band, and intermodulation interference, as well as desensitization and overload. In this document the term "cross-allocation interference" to denote this set of topics.

[4] Reports and video available at http://www.silicon-flatirons.org/events.php?id=862.

[5] See Ellen P. Goodman, *Progress Toward Rational Spectrum Rights: Are We Getting Anywhere?*, 9 J. on Telecomm. And High Tech. L. 501, 505 (2011), available at http://jthtl.org/content/articles/V9I2/JTHTLv9i2_DeVries.PDF.

[6] See Gregory Rosston & Scott Wallsten, *Economic Principles for* Ex Ante *Rules for Radio*, 9 J. on Telecomm. And High Tech. L. 501, 509 (2011), available at http://jthtl.org/content/articles/V9I2/JTHTLv9i2_DeVries.PDF.

[7] See Michael Calabrese, *The Need for Well-Defined Yet Non-Exclusive Radio Operating Rights*, 9 J. on Telecomm. And High Tech. L. 501, 512 (2011), available at http://jthtl.org/content/articles/V9I2/JTHTLv9i2_DeVries.PDF.

that future allocations should self-protect against projected adjacent band interference, and that protections should be reduced over time;[8] Pierre De Vries and Kaleb Sieh proposed that operating rights be defined using probabilistic resulting-energy transmission permissions and reception protections, with remedies (i.e. injunctions or damages) defined when entitlements are issued;[9] Harold Feld pointed out that difficulties similar to adverse possession can occur even when rights are well defined;[10] Bruce Jacobs emphasized the difficulty of defining clear radio operating rights;[11] and Charla Rath argued that any theoretical framework for radio operating rights should be informed by the experience licensees have gained resolving interference issues in the marketplace.[12]

The issue of enforcement was not fully developed at the 2010 conference, and one of the goals of this workshop was to further consider that topic in some depth.

The previous meetings indicated that ambiguous rights definition and ineffective adjudication contributed to difficulties in resolving cross-allocation interference conflicts, leading to delay, uncertainty, and political gamesmanship. The goal of this roundtable was to develop proposals for improved receiver management and more effective enforcement, and to seek consensus recommendations for changes in the regulatory framework that could achieve this.

2.2 Framework for Discussion

The moderator framed the discussion in terms of three lessons from previous meetings: First, define the asset, radio operating rights, more clearly; this meeting would focus on receiver performance aspects of rights definitions. Second, make rights enforcement more efficient. Third, facilitate transactions; this would not be an explicit topic, but an underlying consideration.

The role of receivers. Receiver performance dramatically affects the coexistence of adjacent services. However, while transmitters are required to control out-of-band and spurious emissions to minimize interference with other services, the same does not apply to receivers. In the *receiver standards* approach, the regulator specifies minimum receiver performance characteristics, e.g. sensitivity and front-end performance. An alternative approach is *receiver protection limits*, in which the regulator specifies the in- and out-of-band interference environment that receivers can expect to operate in.

Enforcement. It is essential that parties can obtain efficient redress of their grievances about harm to their operations, both current and foreseen. While like-to-like co-channel conflicts seem to be handled well, and are often resolved without FCC involvement, cross-allocation conflicts appear to be more time-consuming and contentious. The meeting set out to develop a framework for thinking about enforcement issues, including their relationship to rights definition.

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[8] See Even Kwerel & John Williams, *Forward-Looking Interference Regulation*, 9 J. on Telecomm. And High. Tech. L 501, 516 (2011) available at http://jthtl.org/content/articles/V9I2/JTHTLv9i2_DeVries.PDF.

[9] See J. Pierre de Vries & Kaleb A. Sieh, *The Three Ps: A Resulting Energy Approach to Radio Operating Rights*, 9 J. on Telecomm. And High Tech. L. 501, 519 (2011), available at http://jthtl.org/content/articles/V9I2/JTHTLv9i2_DeVries.PDF.

[10] See Harold Feld, *Spectrum "Property Rights" and the Doctrine of Adverse Possession*, 9 J. Telecomm. And High Tech. L. 501, 523 (2011), available at http://jthtl.org/content/articles/V9I2/JTHTLv9i2_DeVries.PDF.

[11] See Bruce Jacobs, *How Should Radio Operating Rights be Defined, Assigned, and Enforced in Order to Obtain the Maximum Benefit from Wireless Operations?*, 9 J. on Telecomm. And High. Tech. L. 501, 526 (2011), available at http://jthtl.org/content/articles/V9I2/JTHTLv9i2_DeVries.PDF.

[12] See Charla M. Rath, *Defining Radio Rights: Theory and Practice*, 9 J. on Telecomm. And High Tech. L. 501, 528 (2011), available at http://jthtl.org/content/articles/V9I2/JTHTLv9i2_DeVries.PDF.

A list of attendees is given in Section 6. Participants were invited to speak as individuals, and to express views that may not be those of their organizations. In order to give the reader some context for a participant's comments while protecting confidentiality, we have used the terms "technologist" for those with an engineering or scientific background, "economist" for those with an economics background, and "practitioner" for those with legal training working in the legal profession, academia, or for an organization.

A web page with links to resources prepared for the meeting is available on the Silicon Flatirons site: http://www.silicon-flatirons.org/events.php?id=1021. It includes a reading list and links to the material presented at the meeting. Readers seeking a bibliography are referred to the reading list provided on the web site for this meeting.[13]

This report consists of five main parts: this introduction (Section 2); a summary of the discussion regarding the role of receivers (Section 3); a summary of the discussion regarding enforcement (Section 4); and a concluding section that characterizes areas of consensus and identifies remaining questions and areas where more research is needed (Section 5). The document closes with a list of attendees (Section 6) and a table of acronyms and abbreviations (Section 7).

2.3 *Participants' Expectations*

Expectations for the workshop were quite varied but common themes emerged. There was a general desire to understand the differences between how policy changes and new technology can address receiver and enforcement issues. Many participants hoped to come away from the conversation understanding what technology can and cannot do to help these problems, and what policy can contribute. Many hoped to get a clearer picture of how regulation should be tailored to these specific problems, and how experiences from the past can inform best practices going forward. One practitioner hoped to hear ideas that moved away from the traditional command-and-control model of spectrum management, and how to establish an environment that changes predictably over time. Many looked forward to discussion about how incentives could inform the process, and how manufacturers and operators could be incentivized to build more resilient systems. All expressed a strong desire for solutions to the many recent examples of interference problems where receivers played a key role, and hoped to develop next steps in the process. There was a strong desire to find workable short-term solutions that would also be sustainable over the long-term.

3 The Role of Receivers

3.1 *Introduction*

Receiver performance dramatically affects the coexistence of adjacent services. However, while transmitters are required to control out-of-band and spurious emissions to minimize interference with other services, the same does not apply to receivers. In the *receiver standards* approach, the regulator specifies minimum receiver performance characteristics, e.g. sensitivity and front-end performance. An alternative approach is *receiver protection limits*, in which the regulator specifies the in- and out-of-band interference environment that receivers can expect to operate in.[14]

[13] Reading list available at http://www.silicon-flatirons.org/documents/Roundtables/2011.10.18-1021/ReadingList.pdf.

[14] See J. Pierre de Vries, *Receiver Standards v. Protection Limits* (Sept. 29, 2011), available at http://www.silicon-flatirons.org/documents/Roundtables/2011.10.18-1021/ReceiverStandardsvsProtectionLimits.pdf.

3.2 *Case Studies*

The briefing materials covered several case studies: (1) satellite-terrestrial: WCS/SDARS, C-band satellite earth stations and 3650-3700 MHz; (2) terrestrial: TDD/FDD, e.g. AWS-1/AWS-3, AWS-1/BAS; (3) TV Receivers: taboos, whitespace; and (4) Nextel/public safety in 800 MHz.[15] Participants discussed lessons learned from some of these and other case studies.

3.2.1 Military Radar/Satellite Earth stations

A technologist related a story about military radar systems causing satellite earth stations to fail. The airborne transmitters were operating within their assigned band 100 MHz away from the satellite frequency, but the earth stations' receiver front ends were being overloaded due to poor filtering. The earth station operators did not believe that filters were necessary because they thought their receivers were accurately tuned and functioning properly. However, they were persuaded to insert filters, and immediately found that the problem was fixed. Further, once operators understood the problem, they promptly told other operators with similar issues that the solution was simple and cost effective. In the end, a few earth stations were equipped with filters, but there was no widespread adoption of filters or standards as the problem was rare. The technologist felt that given the cost of filters, insertion loss, and the fact that only a very small percentage of earth stations were experiencing interference from the airborne radar systems, a post hoc solution was better than requiring filters or receiver standards for all earth stations; such issues are probably best resolved on a case-by-case or system-by-system basis.

3.2.2 SDARS/WCS

The SDARS/WCS case study illustrates the problems that can arise when the FCC tries to create opportunities for new services near an incumbent with many subscribers.

A technologist explained that the U.S. was unable to allocate SDARS at 1.4 GHz, in step with the rest of the world, due to a aeronautical telemetry allocation in the band. The FCC therefore engaged in a long struggle to clear and re-allocate 2.3 GHz. Given its strong desire to make sure the service was well protected, the Commission crafted out-of-band limits on the adjacent WCS band that ensured that mobile services were infeasible, even though WCS licenses nominally allowed both fixed and mobile service. After several failed attempts at operating as a fixed-only service, the WCS licensees decided to petition for a change in operating rules that would allow mobile operation. SDARS had not limited their receivers' front-end bandwidths on the reasonable assumption, they argued, that the adjacent band was going to be "quiet" forever. The other consideration in the SDARS/WCS case was the 30 million subscribers of the satellite service. Interestingly, the FCC was never able to reproduce claims of interference from WCS into SDARS. It came down to balancing what technology can do, and allocating costs. The FCC could have prevented the problem by putting a 5 MHz guard band on either side of SDARS. A practitioner commented that the other side of the story was SDARS' deployment of an operational network of terrestrial repeaters on the basis of a mere experimental license, and the failure of the Commission to rule on the impermissibility of this action.

The technologist drew two important lessons from the SDARS/WCS case study. First, if operators design equipment without any thought about what might happen in the band in the future, it sets up major problems down the road. Second, there is a constant tension between the investment in incumbent services and the opportunity costs for newcomers; it falls to the FCC to balance those interests. In this case, the question might be: could one allow for more power for WCS which would mean a more robust and

[15] See J. Pierre de Vries, *Receiver Protection Limits: A Better Way to Manage Interference Than Receiver Standards*, DEEP FREEZE 9 (June 22, 2011), http://www.silicon-flatirons.org/documents/Roundtables/2011.10.18-1021/EfficientInterferenceManagement2011.pdf.

competitive service and less costly infrastructure on the WCS side, but at the price of some quality of service issues for the incumbent SDARS. The Commission needs to define a boundary, but allow the parties to then negotiate to a different line if they wish.

One practitioner noted that it is important to impose some structure or timeline on the parties to reach a deal. In the SDARS/WCS case, the parties were allowed to negotiate a solution but were unable to reach a solution and the problem lingered on for years. The technologist conceded that it was a mistake in this case, but noted that there were counter-examples where allowing the parties to negotiate a solution did work out. He highlighted the case where the operators of the medical body area networks wanted to operate in an aeronautical telemetry band. The aeronautical telemetry interests were afraid that the interference would have disastrous results for them.[16] In any event, the parties were able to negotiate a solution.

In the case of WCS/SDARS, it was worth allowing the parties to try to negotiate a solution, but it was not a good idea to allow them to negotiate for so long. The practitioner mentioned that in the WCS/SDARS case, there was an incentive for the WCS licensees to drag on the negotiation because they hadn't started building yet. The WCS licensees had an incentive to allow the negotiations to drag on because the longer the negotiations, the longer they did not have to build.

An economist observed that how a negotiation turns out is a function of a threat point, i.e. the value the players can expect to receive if negotiations break down. He claimed that the parties in the WCS/SDARS case were negotiating without a threat point. There must be some stipulation up front about what will happen if the parties are incapable of reaching a solution. He suggested that rulemaking is about deciding the threat point and adjudication is about interpreting those threat points.

3.2.3 FCC Enforcement

A practitioner explained that many of the problems that FCC field agents encounter are adjacent channel interference problems where both parties are authorized to operate, but their systems are not designed to be sensitive to the actual radio environment. Honeywell, USCG, and public safety licensees have all experienced interference problems due to poor system design. Field agents have also received many complaints from cellular carriers. Because cellular carriers are not properly filtered at the cell site, and because they are operating at the noise floor, many cellular carriers experience interference from light bulbs and TV antennas.

3.3 Lessons Learned

Discussion of the case studies highlighted several recurring problems: (1) operators of wireless systems rely on quiet neighbors, and don't account for changes in the radio environment; (2) operators don't always realize that the receivers are the problem, but rather assume that a neighboring transmitter is operating outside of its band, and; (3) there is poor knowledge transfer regarding interference problems and their resolution.

[16] See Amendment of the Commission's Rules to Provide Spectrum for the Operation of Medical Body Area Networks, *Notice of Proposed Rulemaking* in ET Docket No. 08-59 (June, 29, 2009), available at http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-09-57A1.pdf. See also Lucas Mearian, FCC Urged to Approve Body Area Network Plan, COMPUTERWORLD (January 20, 2011 11:33 AM ET), http://www.computerworld.com/s/article/9205631/FCC_urged_to_approve_body_area_network_plan.

3.3.1 The assumption of quiet neighbors

Engineers and entrepreneurs that design, develop, manufacture and deploy spectrum dependent systems rarely consider the future RF environment. If changes are to be made to the spectrum, it will be important for the FCC to declare who has the responsibility to anticipate, and cover the costs of, changes. It is also important for the FCC to give proper notice of anticipated changes.

A technologist agreed that it is hard to incentivize the receiver operators to spend more on receivers when it isn't necessary because the current neighbors are quiet. He also explained that it is hard to know whether something is not being done because the operators didn't feel like spending an extra dollar, or because they are at the limits of what technology can do today. He described the problem that occurred in 3650 MHz band where the C-band satellite receivers go 40 MHz into the neighboring band because the neighbors were always quiet.

Evan Kwerel suggested that the FCC should establish expectations for more intensive future use of bands adjacent to new licensees.[17] He argued that even if those expectations were wrong, they would still be better than the current assumption that the adjacent band will be unoccupied. This would allow system operators to figure out the optimal way to deal with adjacent bands. Another technologist, however, argued that sometimes anticipating "noisy" neighbors would create unnecessary costs. He highlighted the example of garage door openers, and asked whether that would be considered a success or failure. He argued that while it may make for more interference problems now because of cheap receiver design, it was actually a success because we got to use very cheap receivers for 40 years. He reminded the group that we don't want to put a lot of extra costs into a system when we are trying to get to the highest value use.

Another technologist agreed and argued that you wouldn't want to require incumbents to improve their receivers unless change in the neighboring band is certain (and that the change will create a higher value use). He also argued that it would impose unnecessary costs to design the standard around the worst-case scenario.

3.3.2 Recognizing that receiver performance is the problem

Operators don't often realize that the interference problem is a result of their own receiver. One technologist explained that a receiver operator usually thinks that someone is operating in the receiver's frequency when interference occurs, even though this is true only about half of the time; for the rest, it is a receiver problem. He suggested that a practical solution to this problem would be to educate operators on both their receiver's performance and inexpensive filtering solutions.

3.3.3 Poor knowledge transfer

The final lesson drawn from the case studies is that there is poor knowledge transfer among all the actors in the receiver space. A technologist explained that it is not just operators that need an education, but rather that knowledge needs to be conveyed to all the various parties who interact with receivers, including spectrum licensees, equipment manufacturers, and equipment operators. The attendees learned that because the FCC field enforcement agents are generally focused on resolving an interference problem rather than assigning blame, sanctions are rare and cases are not published. Because problems are resolved on a case-by-case basis, other operators with similar problems have no access to the resolution of an individual case, and important knowledge may be lost.

[17] See Even Kwerel & John Williams, *Forward-Looking Interference Regulation*, 9 J. on Telecomm. And High Tech. L. 501, 516 (2011), available at http://jthtl.org/content/articles/V9I2/JTHTLv9i2_DeVries.PDF.

3.4 *Addressing Receiver Problems*

3.4.1 Authority to Regulate Receivers

In order for any receiver-related interference solutions to be implemented, the FCC requires the appropriate authority. There is some question about whether or not the FCC has the proper authority in the Communications Act to regulate receivers.[18]

One practitioner argued that there is a difference between standards that deal with immunity and standards that deal with performance,[19] and that there may be a stronger legal case for FCC authority to regulate immunity standards. Another practitioner suggested getting explicit Congressional authority would make it much easier to proceed. A practitioner suggested that now might be an ideal time to push for legislation giving the FCC more explicit authority to regulate receiver standards or protection limits. He suggested that current proceedings are highlighting the problem and making lawmakers sympathetic to the need for a solution, and that the legislation required for the UHF band incentive auctions provide an opening.

3.4.2 Setting Expectations

One technologist suggested that if regulators could anticipate the needs at the band edges and put people on notice that in ten years their neighbors would not be so quiet as now, it would go a long way to ensuring that system operators were given proper notice of impending changes. He warned that we will be in the same situation we face now in ten years' time if the FCC does not get started soon, given the need for development and upgrade time. The default assumption should not be that everything is going to stay the way it is today.

3.4.3 Managing Costs

Asking operators to change their receivers may imply additional costs, and the risk that they are asked to spend money to prepare for a future that never comes about. A technologist suggested that one way to mitigate the costs would be to phase in receiver regulation. There was concern, however, that the FCC has not always been able to commit to phase-in plans and stick to them. However, a technologist cited the experience with critical care telemetry and the DTV transition as examples of when the FCC was able to implement successful phase-in plans, and a practitioner added the PCS/microwave relocation case. Success in these cases was due to strong incentives for all the parties, and very tight FCC enforcement; the Commission pushed back on any problems and adopted rules for sharing the costs.

When considering a phase-in plan, it is important to be mindful of the following factors: (1) the time needed to build new equipment; (2) the cost of new systems; (3) the cost of moving systems; (4) the need, if any, for public education, and; (5) the need to help mitigate the costs of the phase-in (sometimes using rebate programs). A technologist suggested that an alternative approach to mitigating costs, especially if there is not time to take the phase-in approach, would be to take money out of an auction and give it to incumbents to cover the costs of transition.

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[18] See Madelaine Maior, *Statutory Basis for Receiver Regulation Memorandum*, available at http://www.silicon-flatirons.org/documents/Roundtables/2011.10.18-1021/FCCAuthorityMemo.pdf

[19] See CEA Comments to the Interference Immunity Specifications for Radio Receivers, *Notice of Inquiry*, ET Docket No. 03-65 and MM Docket No. 0-39, 18 FCC Rcd 6039 (2003), available at http://fjallfoss.fcc.gov/ecfs/document/view?id=6514682605.

A technologist asked if it was expensive to tighten up receivers. He submitted that we lack facts on how much it will cost to implement receiver standards. Another technologist, citing an Ofcom report,[20] said that the cost could be significant and it is hard to get consumers to understand that there is a benefit. One practitioner voiced concern that it can be a costly and time-consuming process to bring new devices to market, and difficult for operators to influence manufacturers. However, a technologist replied that there is plenty of technology available that lowers the cost of making more resilient receivers.[21] He argued that filters are not the only option and that any cost to insert new technology into receivers to make them more resilient may be worth the large amount of spectrum that could be liberated as a result.

A practitioner compared the spectrum situation to equipment compliance. He explained that one sets up a compliance system so that everyone knows what their responsibilities are, and one can jump in and mitigate problems when they arise. However, there is a probability curve because one can't capture all contingencies. With spectrum, there is a 100% probability of a problem and the factor that you can control for is the receiver performance. Because of this, it is a question of the expected damage and practical risks if done incorrectly. In order to predict risk, there must be a willingness to enforce the rights of the other licensees. Another practitioner replied that clearer rules are easier to enforce but that looking at the whole environment is going to be complicated to enforce.

Due to the significant costs associated with implementing receiver changes, one practitioner argued that it would be better for standards setting industry bodies, rather than regulators, to devise the requirement. Implementing any new regime will be highly complex and technical, therefore, expensive and regulatory bodies do not have the resources to manage the process successfully. The standards should then not necessarily be used for compliance so much as shifting the burden of responsibility. He also argued the compliance should be optional. However, a technologist was concerned that if you leave the standard setting for protection limits to industry, you are going to end up with very high standards for interference into their bands.

3.4.4 Receiver Standards v. Protection Limits

As described above, there are at least two possible approaches that regulators can use to influence receiver performance: receiver standards and receiver protection limits. The group discussed the relative merits of each, and came to a consensus that protection limits are preferable to receiver standards.

There are benefits and drawbacks to each approach.[22] Receiver standards are prescriptive, detailed, and may stifle innovation in business models and engineering. However, compliance with a standard is easily verifiable with bench testing. Receiver protection limits[23] require fewer parameter choices and offer more flexibility to operators, but validating compliance requires modeling and/or measurement of signals in the field, and it may be difficult to apportion blame if multiple transmitters combine to exceed a reception protection limit.

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[20] L. Davies and P. Winter, *Study of Current and Future Receiver Performance: Final Report to Ofcom*, Ofcom, Tech. Rep., 2010. [Online]. Available: http://www.ofcom.org.uk/research/technology/research/

[21] See J. Pierre de Vries, *Radio Regulation Summit: Defining Inter-Channel Operating Rules Report*, at pg. 30 (2009), available at http://www.silicon-flatirons.org/documents/misc/OOBSummit/Inter-channelSummitReportv1.0.1.pdf, where the opposite position was tendered: "Declining receiver quality due to CMOS integration of front-ends created a particular challenge…"

[22] See de Vries *supra* note 14, available at http://www.silicon-flatirons.org/documents/Roundtables/2011.10.18-1021/ReceiverStandardsvsProtectionLimits.pdf.

[23] See de Vries *supra* note 15, available at http://www.silicon-flatirons.org/documents/Roundtables/2011.10.18-1021/EfficientInterferenceManagement2011.pdf.

One practitioner raised the issue that receiver standards could have an adverse impact on industry, and worried that receiver standards may create a stratification of society where some people have access to good receivers and some are stuck with bad receivers. An economist argued that implementing a regime of protection limits gives manufacturers and consumers a choice about how sensitive they want their receivers to be. That choice will prevent a stratification of haves and have-nots.

In order to mitigate the concern over industry harm from receiver standards, one technologist suggested that regulation could start with some minimal standard just to get people used to the idea, while working towards protection limits as the long-term solution. He gave the 43 + 10 log(P) standard[24] for out-of-band transmission as an illustration of a minimal standard that is not too onerous on operators. Another technologist noted that while minimal receiver standards might seem like an easy fix, as soon as engineers start working on the details it will rapidly become complicated. He also observed that standards are often hard to enforce because powerful incumbents have political influence at the FCC and can often get the standard changed rather than be forced to comply. A technologist observed receiver standards tend to be very detailed and specific, and impose significant burdens on manufacturers and operators who have successfully opposed their introduction on multiple occasions. He observed that under the protection limits approach, manufacturers are not required to build the receiver in a certain way but they are foreclosed from complaining about interference if they don't build their receivers to be resilient enough to avoid the protection limit.

The NTIA's review of interference protection criteria[25] could inform receiver protection limits. A technologist explained that the criteria used to protect incumbent radio service(s) operating in the band. The interference protection criteria are typically specified in terms of general categories of interfering signals: noise-like, continuous wave, and pulsed. He was concerned, however, that the criteria are too conservative and in many cases inconsistent. Being too conservative with the interference protection criteria will make it hard to open opportunities for new use and potential spectrum sharing.

The moderator polled the room; there was a consensus (i.e. no objections were raised) in favor of protection limits over receiver standards. The group favored protection limits as the long-term solution but did not take a position on whether receiver standards should be used in the short-term.

3.4.5 Receiver Licensing

A technologist noted the problem of decoupled receivers, i.e. receivers that are not controlled by the license holder. In such cases, there is no one for a neighboring transmitter licensee to negotiate with when there are interference problems. He proposed that this could be addressed by granting a limited number of permissions (e.g. licenses) to manufacture receivers. This would both identify and limit the number of parties to an interference negotiation with a neighbor.

A technologist noted that such a regime could easily get overly complicated. There are many examples of systems with the decoupled receiver problem and when the license holders do go shop for receivers, they are not often interested in receiver sensitivity. A technologist and a practitioner both argued that markets are expanding, and it would be inadvisable to limit the number of permissions to design and build equipment. One practitioner wondered if it might be better to implement certification rather than licensing.

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[24] See 47 C.F.R. § 27.53 (2010).

[25] NTIA Report 05-432, Interference Protection Criteria: Phase 1 - Compilation from Existing Sources Technical report (Oct. 2005), available at http://www.ntia.doc.gov/osmhome/reports/ntia05-432/IPC_Phase_1_Report.pdf.

3.4.6 Incentives

Incentives were a recurring theme. There were several suggestions about the best ways to incentivize operators to adopt receiver standards or protection limits, and to engage in private negotiation. An economist was concerned that it would be difficult to align incentives for Federal users because they are not motivated by the same incentives as commercial licensees. A technologist questioned the ability of a private party to negotiate with the Department of Defense or public safety. Another technologist expressed concern that we don't know how the incentives process will work. He argued that in order for the incentives to work properly, regulators need credibility. Another technologist chimed in that these ideas need to be brought to the device and system manufacturers. The problem of decoupled receivers also makes it difficult to align incentives. Finally, there was a concern about negative incentives for system operators to build their systems to be so fragile as to not look like a good candidate for sharing or protection limits. However, increasing demand on the spectrum will mean that a solution must be found, so operators are incentivized to find a solution that works for them before they are forced into a solution they don't like.

4 Enforcement

4.1 Introduction

It is essential that parties can obtain efficient redress of their grievances about harm to their wireless operations, both current and foreseen. While like-to-like co-channel conflicts seem to be handled well, and are often resolved without FCC involvement, cross-allocation conflicts appear to be more time-consuming and contentious. Enforcement is also important because it influences private negotiations. In order to frame the discussion, Peter Tenhula began with a series of questions: How does one obtain rights in spectrum and how does one protect those rights? Is resolution of rights disputes fair, open, and expedient? What happens if negotiations fail? How does one prove harmful interference? What are the elements of a claim for harmful interference? What are the defenses to those elements? Who has the burden and should we consider alternative venues?

In order to address these questions, Tenhula proposed a taxonomy of enforcement mechanisms.[26] He broke disputes into three categories: (1) establishment of new rights (*ex ante*); (2) modification of existing rights (a mix of *ex ante* and *ex post*), and; (3) enforcing existing rights (*ex post*). He proposed that cases should be examined to see if an identifiable process had been followed. He felt that too much attention has been given to the need for clearly defined spectrum usage rights, and that enforcement was more important. One economist suggested that there may be useful examples of enforcement regimes in other markets.

4.2 Case Studies and Current Practices

The briefing materials covered the following case studies: (1) DARS Terrestrial Repeater STAs; (2) 5GHz U-NII/TDWR; (3) Puerto Rico WISPS: Islanet v. Neptuno; (4) Qualcomm/MediaFlo Petition for

[26] Peter Tenhula, *A Prototype "Taxonomy" for Enforcement of Spectrum Usage Rights* (Sept. 2011), available at https://docs.google.com/document/d/1OgbVgCi42a91F1hng7x9BYxUfUl9p1vTiMTTWnUc9gw/edit?hl=en_US

Declaratory Ruling.[27] Participants discussed the case studies, as well as current practices, to explore how enforcement mechanisms currently function.

4.2.1 Venue

The Neptuno/Islanet case illustrates that venue matters when attempting to enforce spectrum rights. One technologist argued that because the parties in that dispute could only go to the FCC, the injured parties were never made whole. A practitioner wondered if the injured party could bring an action in state court for tortious interference of its business. Another practitioner explained that the FCC has exclusive jurisdiction over interference claims and the party would be barred from bringing a state tort claim based on interference.[28] A practitioner explained that there are both civil and criminal avenues to pursue in most legal disputes; if you have to rely solely on criminal enforcement, often there is not redress for the victim.

4.2.2 FCC Enforcement Practice

Under the current regime, an FCC field agent investigating a complaint of interference assumes that the consumer is innocent and tries to trace the problem back to the manufacturer, especially where unlicensed devices are involved. If the manufacturer disputes that its devices are causing interference, the field agents will do a test and show the manufacturer the results. A technologist explained that such illustrative tests are highly effective.[29] He claimed to never have seen anyone dispute one of these tests.

FCC field agents currently rely on direction finding vehicles (72 in the fleet) to find the sources of interference. They will triangulate the signal and find the transmitter causing the interference. The agents do not have the authority to search, seize, or arrest; they are public safety officers who enforce the Communications Act. The agents can inspect but can't trespass. If needed, the agents can get a warrant and enforcement assistance from the US Marshalls. However, this is a long, minimally effective process; any equipment seized is usually low value and can easily be replaced. NTIA does investigate interference to and from federal systems, but does not have enforcement authority.

A technologist noted that the FCC avoided taking enforcement action in the SDARS terrestrial repeater case until a merger application provided a way to impose fines. A practitioner explained that it was an unusual case since no one was being harmed by the interference; the WCS licensees had not built out their systems yet. This may not be a useful reference case because of such peculiarities, and it is questionable whether the FCC should have become involved given its limited resources. It is important to remember that the FCC has the discretion to decide whether or not to take enforcement action, and that the decision to enforce or not is not judicially reviewable.[30] One practitioner expressed concern that the process was too political and needed to be depoliticized.

4.2.3 Private negotiation

Spectrum usage rights can be enforced through negotiations between private companies. One technologist noted that companies are allowed to negotiate with their neighbors in some cases. A

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[27] Briefing materials available at http://www.silicon-flatirons.org/documents/Roundtables/2011.10.18-1021/EfficientInterferenceManagement2011.pdf.

[28] See 1982 U.S. Code Cong. & Ad. News 2237, 2277, where the Conference Report explains that the amendments made to 47 U.S.C. §302a were "intended to clarify the reservation of exclusive jurisdiction to the Federal Communications Commission over matters involving RFI [radio frequency interference]." Cited in Broyde v. Gotham Tower, Inc. 13 F.3d 994, 998 (6th Cir. 1994).

[29] Cf. section 4.2.1 above.

[30] Heckler v. Chaney, 470 U.S. 821 (1985).

practitioner explained how commercial players engage with each other to solve disputes. Some larger companies engage in many private negotiations in the course of business, and are usually able to reach an agreement with a neighboring license holder. The parties generally have similar incentives to get an agreement worked out. Sometimes, if an agreement cannot be reached, the FCC will be called upon to facilitate the negotiation, or the company will just buy more spectrum to avoid the problem.

Another practitioner explained that satellite bands have similar coordination issues and the rights are often formally recognized and enforced by the governments of the ITU-R. However, the parties often find that the governments are unwilling or unable (due to forum selection) to help resolve disputes. The parties must rely on private negotiation to resolve these disputes. Another practitioner explained that sometimes having no reliable governmental process can be good for negotiations because the parties cannot fall back on the regulator to resolve the issue.

A practitioner observed that the Qualcomm example, the only case of conflict between unlike services, is not a good illustration of private negotiation because it was largely taken over by the Commission. The 902-928 MHz band, where inferior rights have effectively trumped superior rights, is another example where private negotiations would not be possible. He noted that Federal radar operations have superior rights to unlicensed ISM devices owned by millions of consumers, who can be difficult or impossible to negotiate with. As a result, the primary Federal systems have yielded to the unprotected, unlicensed systems.[31]

A technologist pointed out that it was incorrect to assume that interference problems were consistent and identifiable. He noted that one often does not know who is causing the interference, leaving no one to negotiate with. He claimed that this problem will only get worse in the future when there is more widespread adoption of dynamic devices and sharing, especially in unlicensed bands.

4.2.4 Rulemaking vs. Enforcement

On the topic of enforcement, a technologist submitted that there is not enough separation between rulemaking and adjudication. He cited Phil Weiser's argument in *The Future of Internet Regulation*[32] that the FCC focuses too heavily on rulemaking to the detriment of adjudication. A second problem with the current regime is that the FCC does not define the remedies up front when defining rights in the spectrum.[33] He noted that enforcement is currently taken to mean the enforcement of FCC rules, but as we change to a more flexible use model the focus may shift to enforcement of private parties' rights.

4.3 Alternative Enforcement Mechanisms

The participants were interested in exploring alternatives to traditional enforcement mechanisms. There was a sense that the case studies did not reveal any patterns in how enforcement mechanisms are implemented. The bureaus have broadly delegated authority to resolve disputes without employing rulemaking procedures, which can be invoked only by the full Commission, but those adjudicatory type actions are resource intensive, case-by-case, fact-specific processes. When considering alternatives to current enforcement practices, it is important to seek predictability and consistency. The participants

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[31] See Frank Sanders, ISART 2011 presentation slides at 9, 33-35, July 27, 2011, available at http://www.its.bldrdoc.gov/isart/art11/slides/InventoryBriefings.pdf. See also ISART 2011 panel discussion video archive at 30:48 – 34:41, available at http://www.ustream.tv/recorded/16278188.

[32] Phil Weiser, *The Future of Internet Regulation*, February 16, 2009, available at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1344757.

[33] See Ellen P. Goodman, *Spectrum rights in the Telecosm to Come*, 41 SAN DIEGO L. REV. 269 (2004), available at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=484922.

discussed several alternatives to rulemaking and traditional adjudication, including: (1) the rocket docket; (2) baseball-style arbitration; (3) non-FCC solutions; and (4) using smart devices to support enforcement.

4.3.1 Rocket Docket

One practitioner suggested that a "rocket docket"[34] may be a less process heavy enforcement mechanism. He worried, however that a "rocket docket" could undermine the development of a full record for future reference. Another practitioner explained that the FCC does have a rocket docket-like process in place for formal complaints against common carriers, but that it doesn't work; in the last 14 years only three cases were brought before the "rocket-docket." The problems that these parties have are not issues that can be resolved quickly. The first practitioner responded that there doesn't necessarily need to be so much pressure placed on getting the issue resolved quickly. Rather, there needs to be a process that is predictable and consistent because all issues cannot be addressed in *ex ante* rulemaking.

4.3.2 Baseball-style Arbitration

In baseball-style arbitration, if the parties can't come to a resolution after a period of mediation, they are each asked to give their best and final offer and the mediator then picks one of the two offers. This process drives both parties to put reasonable offers on the table and may be a more expeditious process. However, one technologist worried that this may cut engineers out of the conversation. One of the economists worried that because baseball-style arbitration is set up for commercial disputes, it may not apply in situations that seem more like rights disputes. He felt that forcing parties into baseball-style arbitration for rights disputes could run afoul of the Constitution. Finally, a practitioner argued that baseball style-arbitration might work best in a bilateral dispute, but not so well in a polycentric dispute.

4.3.3 Non-FCC Solutions

There were several suggestions made for the possibility of moving enforcement to some other body, either governmental or private. One suggestion was to allow state courts to adjudicate interference disputes. Some states are starting to enforce pirate radio claims and the FCC has largely ignored this practice because it lightens the FCC's load.

Another possibility would be to allow some other expert tribunal to be available for dispute resolution. One practitioner explained that these tribunals would enforce the substantive rights of the parties while giving them a fair process for doing so. It may be easier for the adjudicator if the issues were framed around particular "elements" of an actionable interference claim, and then the parties would have a clear understanding of who has the burden to prove a duty of care and breach of that duty.[35] The benefit of this type of adjudication procedure is that there is a record of the proceeding, and lessons can be gleaned from the process about ways to develop interference mitigation approaches and alternative remedies. Another practitioner explained that given the way the FCC is structured it might be possible to hand off a small number of disputes to a private mediator.

If there is to be a shift to alternative venues, there must be a structure for private negotiation. There was some concern that harmful interference is not a terribly useful standard as currently framed, and would be difficult to apply in the context of private mediation or state court. A practitioner agreed and

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[34] See Matt Montgomery, *Draft Petition for NOI on Spectrum Enforcement*, available at http://www.silicon-flatirons.org/documents/Roundtables/2011.10.18-1021/Montgomery.pdf.

[35] See Tenhula *supra* note 25 at note 14, available at https://docs.google.com/document/d/1OgbVgCi42a91F1hng7x9BYxUfUl9p1vTiMTTWnUc9gw/edit?hl=en_US

observed that when FCC field agents deal with enforcement issues, it is much easier to pursue a rule violation than a claim of harmful interference. It is difficult to prove harmful interference because it is hard to identify the transmitter and it is a very fact specific inquiry. Another practitioner explained that it is hard to penalize someone for harmful interference unless it is clearly defined.

4.3.4 Smart Devices

Paul Kolodzy proposed that there is an opportunity to use smart devices to contribute to enforcement. New devices allow measurement of the radio environment in a way that was not previously possible. Such devices could make diagnosing interference problems easier. Also, devices could be required to report on their locations. A database of device locations and waveforms could keep track of their operation, and turn them off if they are not behaving properly. A technologist explained that Mobile Pulse[36] was measurement-enabling fleets of devices so that companies can enforce their cellular service agreements. He argued that one could easily see this extending to enforcement of spectrum rights.

Using devices in this way is not without problems. One technologist wondered if devices that were constantly measuring the RF environment would be measuring just in their own bands or in adjacent bands as well. Kolodzy responded that the devices measure just a bit out of their own band. One technologist wondered what was needed to ensure that the device is detecting a signal and not noise as waveforms become more noise-like. The proposer explained that the problem would be mitigated by the large number of devices deployed. He argued that the more devices deployed that were measuring, the more sensitive the system would be overall. The sensitivity of the system would ensure that the devices were measuring signal and not noise.

A technologist gave three cautionary notes. First, it may not be necessary to run a nationwide spectrum monitoring system to get the needed information. Second, people will be concerned about being surveilled. Third, a nationwide spectrum monitoring system is likely to encounter three main problems: too much information, bad data, and false alarms. Another engineer worried that in bands that are only intermittently used, no single measurement would be a good reflection of the use of the band.

There were also legal concerns about the idea of using devices for enforcement. The most prevalent concern was information privacy. Many worried that people would not like the idea of having their location constantly tracked. Kolodzy replied that many device users already consent to this kind of monitoring with their cell phones. A practitioner wondered what would motivate operators to build these devices into their systems. He thought that the devices enabled operators to engage in self-help rather than having to rely on regulators for interference resolution. Another practitioner noted that it was an open question as to who would administer such a system. Another liked the idea of using technology as a tool for enforcement, but argued that there are some very different functions under the heading of enforcement, such as policing functions and adjudicating functions, that technology may not be able to address.

[36] See http://www.mobilepulse.com/.

5 Conclusions

The conversation on receiver management was productive. The group reached consensus that protection limits were preferable to receiver standards, though it was unable to agree on the need for some limited receiver standards in the short-term. There was a sense that while there may not be a silver bullet for managing receivers, even a small step would be better than the absence of any receiver management. Incentives would be required, but there were difficulties in structuring them.

The group agreed that spectrum issues were only going to become more complex and that interference was a growing problem. There was general support for either starting a rulemaking process around receiver management, and/or enacting legislation to give the FCC more explicit authority to regulate receivers. The group agreed that the conversation needed to continue.

A technologist noted that the topic of intermodulation had been ignored in the discussion of receiver management. In order to properly assess the needs at the band edges, intermodulation will have to be taken into account. However, others felt that this topic was too difficult to address within the confines of this workshop.

The takeaways from the enforcement conversation were less clear. There was uncertainty about what enforcement actually meant, though the group recognized that enforcement could include investigating, adjudicating, rulemaking, and actual enforcement. This wide range of activities made it difficult to pin down a solution for how to engineer better enforcement mechanisms.

There were several areas where participants felt that further research would be helpful. One technologist would like to see some case studies reviewed with an eye on what is possible in terms of threshold values for protection limits. Another technologist suggested that some research on how to achieve the right balance on appropriate protection limits would be helpful.

Research needed in the enforcement realm included going through Peter Tenhula's taxonomy and finding cases that illustrate each category. Those cases should be analyzed to see if there are patterns in how enforcement processes have been implemented.

6 Attendees

Bob Matheson, NTIA/ITS (Retd.)
Brad Bernthal, Silicon Flatirons Center
Bryan Tramont, Wilkinson Barker Knauer, LLP
Charla Rath, Verizon
Coleman Bazelon, Brattle Group
Dale Hatfield, Silicon Flatirons Center
David Solomon, Wilkinson Barker Knauer, LLP
Ed Drocella, NTIA/OSM
Eric Nelson, NTIA/ITS
Evan Kwerel, FCC
Frank Sanders, NTIA/ITS
Henry Goldberg, Goldberg, Godles, Wiener & Wright
Jeff Carlisle, LightSquared
John Williams, FCC
Julie Knapp, FCC
Michael Calabrese, New America Foundation
Peter Tenhula, Shared Spectrum Company
Paul Kolodzy, Kolodzy Consulting
Preston Padden, Silicon Flatirons Center
Rebecca Dorch, FCC
Rich Lee, Greenwood Telecommunications Consultants
Tom Peters, FCC

Chair: Pierre de Vries, Silicon Flatirons Center

Rapporteuse: Madelaine Maior

7 Acronyms and Abbreviations

Acronym	Meaning
AWS	Advanced Wireless Service (FCC)
BAS	Broadcast Auxiliary Service (FCC)
CMOS	complementary metal–oxide–semiconductor
DARS	Digital Audio Radio Service (FCC)
DTV	Digital Television
FCBA	Federal Communications Bar Association
FCC	Federal Communications Commission
FDD	Frequency-Division Duplexing
ITS	Institute for Telecommunication Sciences (NTIA)
ITU-R	International Telecommunication Union – Radiocommunication Sector
MHz	Megahertz
NTIA	National Telecommunications and Information Administration
Ofcom	Office of Communications (United Kingdom)
OSM	Office of Spectrum Management (NTIA)
PCS	Personal Communications Services (FCC)
RF	radiofrequency
SDARS	Satellite Digital Audio Radio System (FCC)
TDD	Time-Division Duplexing
UHF	Ultra High Frequency
WCS	Wireless Communications Service (FCC)