HARM CLAIM THRESHOLDS: FACILITATING MORE INTENSIVE SPECTRUM USE THROUGH MORE EXPLICIT INTERFERENCE PROTECTION RIGHTS

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I. INTRODUCTION

Wireless technology has become a cornerstone of economic growth and social well-being. It is a heavily regulated industry, and government institutions such as the FCC make the ground rules that determine what can be done, when, how and by whom. It is therefore crucial that spectrum regulation be effective.

This paper provides an introduction to harm claim thresholds, a regulatory tool that adds clarity to the rights and responsibilities of radio

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system operators seeking protection against harmful interference from other systems.

This section provides an introduction to key concepts in spectrum regulation, including economic externalities such as inter-system interference, the role of regulators in the management of such externalities, the value of clear default operating rights, and key concept of harmful interference. Section II explains the importance of receivers in spectrum regulation. Section III discusses the definition, benefits, implementation, and enforcement of harm claim thresholds.

A. Interference

Since two radio systems operating at the same time, place, and frequency—i.e., that use the same spectrum—tend to degrade each other's performance, setting operating rules that ensure efficient coordination of radio operations has traditionally been the province of government regulators.[1] In the U.S., the National Telecommunications and Information Administration ("NTIA") authorizes federal government operations,[2] and the Federal Communications Commission ("FCC" or "Commission") authorizes everyone else, including commercial as well as state and local government operations.[3] In some cases, such as aviation, governance is shared between the FCC and NTIA.

When one system degrades another's performance, harmful interference is said to occur.[4] "Interference" is defined as "unwanted energy."[5] However, "harmful interference" only occurs when an unwanted signal "seriously degrades, obstructs, or repeatedly interrupts" a service.[6] The amount of service degradation a receiver experiences is thus a combination of the strength of the unwanted signals delivered by the adjacent service and the receiver's ability to pick out its desired signal from the surrounding unwanted signals. Responsibility for harmful interference is therefore shared between transmitters and receivers. There are distinct connotations of the term "interference" in legal and

1. The term "spectrum" has multiple meanings; depending on the context in which the term is used, it can mean: the radio frequency range a service's signals are found in; the combination of frequencies, geographic area, time, and signal strength that a service may use; or the operating permissions, including licenses and license-exemption, issued to an operator or class of operators. Unless otherwise evident from the context, the term is used in this paper to denote a frequency range over which radio operation takes place.

2. The NTIA is an agency of the United States Department of Commerce that serves as the President's principal adviser on telecommunications policies. *See generally* 47 U.S.C §§ 901-904 (2013).

3. *See* 47 U.S.C. § 151 (1996).

4. *See* 47 C.F.R. § 2.1(c) (2013).

5. *Id.*

6. *Id.*

engineering parlance; engineering usage refers to an energy level,[7] while legal usage refers to the impact on system performance of that energy.[8]

Since the strength of radio signals generally decreases with distance, two wireless systems can operate simultaneously at the same frequencies if they are well separated. This leads to geographical operating assignments, where licenses are assigned to non-interfering areas. Combined with operating rules that limit either transmission power and/or the amount of signal that a licensee is allowed to deliver outside its operating area, this limits the effect one operation has on another in an adjacent area.

Two wireless systems can operate simultaneously in the same area by using different frequencies. Each transmitter broadcasts on its designated frequencies, and their respective receivers tune to those frequencies, filtering out signals on other frequencies. If the filtering does not reject signals and other frequencies sufficiently well, the receiver will admit a mixture of desired and undesired signals and may be unable to extract its own desired signal from the mix.

The further away unwanted signals are from the desired frequency, the easier it is for receivers to tune them out. Filtering out close-by signals, on the other hand, makes receivers more expensive. In the past, when more spectrum was available and filtering was expensive, the preferred solution was to spread services out widely in frequency, and so economize on receiver cost. Now that spectrum is more crowded, this solution seems increasingly questionable. It may be more cost-effective to increase the cost of receivers by requiring better filters while reaping greater benefit from being able to deploy more services.

B. Externalities and Regulators

Since radio systems interfere with each other, they contend for permission to operate. Since filters are imperfect, operation in one frequency band or area can degrade operations in an adjacent one. In economic terms this is a negative externality: a cost resulting from one party's activity incurred by another party against their will.

A service's *operating entitlements* consist of rights to exclude other operations by claiming that such operations cause harmful interference,[9] and rights that permit operation under certain constraints. Some of these constraints limit negative externalities, such as transmission power,

7. *See* GEN. SERVS. ADMIN., FEDERAL STANDARD 1037C (1996), http://www.its.bldrdoc.gov/fs-1037/fs-1037c.htm.

8. *Id.*

9. 47 C.F.R. § 2.102(f) (2013) ("The stations of a service shall use frequencies so separated from the limits of a band allocated to that service as not to cause harmful interference to allocated services in immediately adjoining frequency bands.").

resulting field strength, and geographic area, that are intended to avoid harmful interference to other services. In the section on harm claim thresholds I propose adding a complementary right to receive signals, with a constraint on the ability to claim harm is being caused by others. There are also constraints, typically associated with command and control allocations, that are intended to create positive externalities, such as requirements that a license may only be used to offer a specific service, that a specific technology should be used to offer that service (e.g., the requirement to use ATSC for digital television, or in the European case, to use GSM for cellular service), or that services should be offered under specific terms (e.g., the "open access" condition on the 700 MHz C block).[10]

The operating permissions that the FCC assigns to a party provide benefits to that party, and impose costs on neighbors. An operator who is allowed greater signal strength will have better service, but a neighbor will incur greater cost in building a system that will be able to operate in the presence of that signal. Operating permissions therefore entail a negative externality.

It is possible that this externality leads to maximum social welfare: the combined costs and benefits of the two parties given this externality may be the greatest possible. However, it is also possible that an adjustment could lead to an improvement. For example, perhaps the incremental gain from increasing the allowed transmitted signal strength—leading to faster data transfers, say—would be greater than the incremental loss to the other party from degradation to their service, or the cost of improving their receivers to tolerate increased interference. Conversely, the loss from reduced transmission power might be smaller than the benefit to the neighbor, so that the optimum transmission ceiling should be reduced.

If parties are able to negotiate such an adjustment between themselves, government intervention (e.g., an FCC rule-making) may not be required.[11] Given the well-known frailties of any regulatory process,[12] this route is preferred.

However, this option is not available when there are impediments to successfully concluding a negotiation, such as the inability of parties to act to adjust their rights, or collective action problems when it proves to be impossible to coordinate the interests of a large number of parties.

10. 47 C.F.R. § 27.16 (2013).

11. Ronald H. Coase, *The Federal Communications Commission*, 2 J.L. & ECON. 25 (1959).

12. *See, e.g.*, Thomas W. Hazlett, *The Wireless Craze, the Unlimited Bandwidth Myth, the Spectrum Auction Faux Pas, and the Punchline to Ronald Coase's "Big Joke": An Essay on Airwave Allocation Policy*, 14 HARV. J.L. & TECH. 335 (2001).

Regulatory action is then required to frame rights appropriately, and address collective action problems where they cannot be avoided. The regulator can also provide an adjudication venue that backstops negotiations and provides a forum for dispute resolution.

Traditional methods of spectrum management need to adapt to the demands of the rapidly evolving wireless spectrum landscape, including a faster rate of technical and commercial innovation, increasing demand leading to more pressure to crunch services together, and the greater value of radio operations leading to greater losses when there is inefficiency.

C. The Importance of Clear Default Entitlements

There is a robust consensus in the economic literature that "bargainers are more likely to cooperate when their rights are clear and less likely to agree when their rights are ambiguous."[13]

Negotiations are therefore more likely to succeed when parties can proceed from a pre-defined default rule.[14] A pre-defined default rule offers a focal point for negotiations, preempts parties from focusing on getting the default rule to be their favored one, and provides a reasonable outcome when parties cannot agree. In a bilateral monopoly situation, one party may hold out for a better deal. Complete clarity—the absence of any ambiguity—is not possible.[15] However, the government has the responsibility to design an initial package of rights, along with a process for fine-tuning it.

The starting point does not need to be exhaustively defined; adding detail adds cost, but it also adds benefit. The challenge for policy makers, as always, is to complicate matters as much as necessary, but no more.[16]

It can be argued that where parties can negotiate effectively, clarity

13. ROBERT COOTER & THOMAS ULEN, LAW & ECONOMICS 89 (6th ed. 2011).

14. While the absence of clarity may lead to inefficient delay in a bargain, under certain conditions it may speed up the completion of an efficient bargain. *See* Rachel Croson & Jason Scott Johnston, *Experimental Results on Bargaining Under Alternative Property Rights Regimes*, 16 J.L. ECON. & ORG. 50, 69 (2000). In the latter case, the risk that that one party may take advantage of the absence of clarity may induce the other party to come to an agreement that either he/she would not have agreed to or may have increased the speed with which an efficient agreement is made.

15. "Property borders are always subject to some degree of fuzziness . . . . Contracts, in which property is reconfigured and rights traded, are likewise incomplete, reflecting efficiencies internalized by the parties to the contract." Thomas W. Hazlett & Sarah Oh, *Exactitude in Defining Rights: Radio Spectrum and the "Harmful Interference" Conundrum*, 28 BERKELEY TECH. L.J. 227, 294 (2013). Hazlett and Oh argue that "exclusive spectrum rights should not be over-defined. . . . [T]he goal of rights definition is . . . to simplify the process wherein rights are transferred to parties who can best maximize social value—a rule that also applies when seeking the parties in the best position to design the packages." *Id.* at 299.

16. With apologies to Albert Einstein, who is reputed to have said that things should be as simple as possible, but no simpler.

about entitlements is not necessary.[17] Allocating flexible use rights in ways that facilitate negotiation by reducing the fragmentation of allocations may well reduce the need to increase the clarity of rights definitions.[18] However, it is not a matter of either/or. Transaction costs in spectrum remain high; spectrum is not a simple commodity.[19] Improving clarity must therefore remain as an important part of effective spectrum policy, at least until I reach the point when spectrum markets are tolerably efficient. If nothing else, more clarity will be important for bands where fragmentation and/or lack of rights hamper effective renegotiation of default assignments. Such bands are likely to remain a feature of the regulatory landscape for a long time to come.

FCC operating rules are merely the starting point in a ceaseless process of finding the most productive way to operate radio systems that affect each other. They are not the end of the story. They are the defaults that should, wherever possible, be adjusted by radio operators among themselves. Only where refinement by private law is impractical should the regulator step in. Thus, I believe that operators should for the most part find the optimal configuration of their interacting systems through private negotiation to refine and adapt the defaults set by the FCC, both within an allocation and in neighboring allocations that affect each other.

The regulatory context should be designed to make such private optimization as easy and prevalent as possible. The proposals outlined in this paper would contribute to such private agreements by providing a valuable increment in the clarity of the rights and responsibilities regarding harmful interference.

D. Protection From Harmful Interference

Claims of harmful interference between systems are at the heart of spectrum disputes. For example, 47 C.F.R. § 2.102(f) requires that

17. Hazlett & Oh, *supra* note 15, at 241.

18. *Id.* at 243.

19. John W. Mayo & Scott Wallsten, *Enabling Efficient Wireless Communications: The Role of Secondary Spectrum Markets,* GEORGETOWN CTR. FOR BUSINESS & PUB. POLICY 11 (June 2009), http://www.gcbpp.org/files/Academic_Papers/EnablingWirelessCommunicationsJuly2009.pdf ("[T]he multidimensional nature of secondary market transactions introduces more complexity into potential transactions than are commonly appreciated."); Scott Wallsten, *Is There Really a Spectrum Crisis? Quantifying the Factors Affecting Spectrum License Value*, TECH. POLICY INST. (Jan. 23, 2013), https://techpolicyinstitute.org/files/wallsten_is_there_really_a_spectrum_crisis.pdf ("A spectrum "crisis," presumably, would therefore be reflected in rapidly rising prices. However, as Peter Cramton once remarked, "spectrum isn't like pork bellies. Pork bellies are nice." That is, spectrum is not a homogenous good, and its value depends on a myriad of factors, ranging from the physical characteristics of the spectrum, to the rules governing its use, to the behavior of users of neighboring bands.") (citations omitted).

"stations of a service shall use frequencies so separated from the limits of a band allocated to that service as not to cause harmful interference to allocated services in immediately adjoining frequency bands."[20] This is an explicit recognition of the possibility of interaction, i.e., interference between services in adjoining bands.[21]

Conflict resolution and avoidance can therefore be facilitated by a more technically verifiable definition of harmful interference that does not rely on case-by-case elucidation by the FCC.[22] I refer to such approaches in general as *interference limits*. I will describe a particular implementation, harm claim thresholds, below.

Rules and statutes as they stand are not very helpful. The definitions provided in 47 § C.F.R. 2.1 are very general and require case-by-case interpretation.[23] FCC precedent has not provided much if any clarity on the general meaning of "harmful interference." Its actions in particular cases are explicitly limited.[24] Since spectrum negotiations frequently hinge on responsibilities to mitigate interference, guidelines about what counts as harmful interference that do not require recourse to FCC rulemaking would be helpful.

Even if more explicit statements about harmful interference were not necessary in negotiation, they would provide more reliable guidelines for both incumbents and new entrants about the rules for new allocations. The LightSquared case illustrates how differently parties can interpret their responsibilities regarding harmful interference in the current regime.[25] Similar disagreements about responsibilities to prevent

20. 47 C.F.R. § 2.102(f) (2013).

21. Some advocates (i.e. LightSquared, Inc.) like to think of this as only applying to signals that are emitted outside a transmitter's assigned frequencies, referred to as out-of-band emissions (OOBE); if OOBE is limited, they have no further obligations. However, signal strength inside assigned frequencies also causes interference, and there is nothing in the language of the rule that limits interference only to OOBE. In fact, the limits on in-band transmit power are a recognition that such signals have the potential to cause harmful interference.

22. R. Paul Margie, *Can You Hear Me Now? Getting Better Reception from the FCC's Spectrum Policy*, STAN. TECH. L. REV. (Dec. 29, 2003), http://stlr.stanford.edu/pdf/margie-fcc.pdf.; Ellen P. Goodman, *Spectrum Rights in the Telecosm to Come*, 41 SAN DIEGO L. REV. 269 (2004); Mitchell Lazarus, *Finding the Harm in "Harmful Interference,"* COMMLAWBLOG (Jan. 30, 2009), http://www.commlawblog.com/2009/01/articles/broadcast/finding-the-harm-in-harmful-interference; Michael Marcus, *Harmful Interference: The Definitional Challenge*, SPECTRUMTALK (Dec. 18, 2008), http://spectrumtalk.blogspot.com/2008/12/harmful-interference-definitional.html.

23. 47 C.F.R. § 2.1 (2013).

24. *See, e.g.*, Improving Pub. Safety Commc'ns in the 800 MHz Band, *Report & Order*, 19 FCC Rcd. 14,969, 14,976 (2004) ("We adopt a new, objective definition of "unacceptable interference," for purposes of this proceeding only.").

25. *See* Petition for Declaratory Ruling, LightSquared Inc., FCC 11-109, i (Jan. 30, 2012), *available at* http://apps.fcc.gov/ecfs/document/view?id=7021857391 ("The commercial GPS industry claims, without justification, that these GPS receivers somehow are entitled to "protection" from the LightSquared authorized operations that occur entirely within the MSS

or mitigate interference occurred in the M2Z case.[26] I therefore believe that interference limits will be a cost effective part of the default rules, and will be beneficial not just in cases where private law is not expected to be effective.

If interference limits are promulgated, the default operating rules will not only place constraints on what transmitters can do, but will also make explicit the currently implicit limits on the extent to which operators can constrain the transmissions of other operators by claiming that they cause harmful interference. In other words, interference limits will make the rights and responsibilities of receiver operators explicit. However, as I will explain, I do not propose that the FCC defines the performance of individual receivers; I are not proposing mandated receiver standards.

II. THE IMPORTANCE OF RECEIVERS

The long history of cross-allocation receiver issues shows that more attention to receivers' role in harmful interference would be beneficial.[27] Poor receiver performance has precluded or delayed the introduction of valuable new services, or has led to costly instances of avoidable harmful interference. Many examples come to mind, including the dispute over M2Z's proposed operation in the AWS-3 band adjacent to existing

band."); Opposition of Deere & Company to LightSquared Inc. Petition for Declaratory Ruling, LightSquared Inc., FCC 11-109, 2 (Feb. 27, 2012), *available at* http://apps.fcc.gov/ecfs/document/view?id=7021869323 ("The Commission should reject LightSquared's Petition as another attempt to run roughshod over the legitimate and significant concerns of the GPS community regarding severe widespread interference harm that will result if LightSquared is permitted to proceed."); Opposition of the U.S. GPS Industry Council To LightSquared, Inc. Petition for Declaratory Ruling, LightSquared, Inc., FCC 11-109 at iii (Feb. 27, 2012), *available at* http://apps.fcc.gov/ecfs/document/view?id=7021869290 ("LightSquared's Petition is simply an effort to alter its manifest obligations as a non-conforming spectrum user to protect other L-band services from harmful interference.").

26. *See, e.g.*, Serv. Rules for Advanced Wireless Servs. in the 2155-2175 MHz Band, *Notice of Proposed Rulemaking*, 22 FCC Rcd. 17,035, 17,042 (2007) ("We may, however, determine that the interference protection measures necessary to protect mobiles receiving in the designated AWS-1 and proposed AWS-2 base-transmit bands adjacent to the AWS-3 spectrum and mobiles receiving in co-channel and adjacent channel AWS-3 bands would limit the ability of transmitting AWS-3 mobiles to operate effectively. We may also determine that the need to protect base stations receiving in the AWS-3 band would significantly limit the performance of base-transmit operations in the AWS-3 band.").

27. *See* J. Pierre de Vries & Kaleb August Sieh, *The Three Ps: Increasing Concurrent Operation by Unambiguously Defining and Delegating Radio Rights*, 2011 IEEE SYMPOSIUM ON NEW FRONTIERS IN DYNAMIC SPECTRUM ACCESS NETWORKS 56 (2010), *available at* http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1704194; Pierre de Vries, *Radio Regulation Summit: Defining Inter-channel Operating Rules: A Report on a Silicon Flatirons Summit on Information Policy, held 8/9 September 2009*, SILICON FLATIRONS CENTER 8-13 (Dec. 2, 2009), http://siliconflatirons.com/documents/misc/OOBSummit/Inter-channelSummitReportv1.0.1.pdf.

AWS-1 cellular service,[28] the unexpected interference from AWS-1 cell towers into broadcasters' electronic newsgathering receive stations,[29] as well as the recent GPS/LightSquared matter.[30]

This problem has been well understood for quite some time. For example, in its comments on the 2003 Receivers NOI,[31] the NTIA enumerated examples of "a number of instances of reported interference that could have been avoided if appropriate receiver standards had been applied."[32] Similarly, the Spectrum Working Group of the FCC Technological Advisory Council summarized in its December 2011 white paper "a number of examples of situations where receiver performance was a significant issue affecting access to the spectrum for new services."[33]

The ability of radio systems to tolerate interference is an important part of spectrum management, whether in the formulation of regulation or in negotiations between operators. This ability depends not only on the design of the receiver, but also the relative strength of desired and undesired signal transmissions. The received signal strength depends not only on the power of the signal at the transmitting antenna, but also the distance between the transmitter and the receiver, and intervening obstacles. A low power transmitter near to a receiver may deliver a much stronger signal than a high power transmitter that is far away.

Wireless systems in one band that cannot tolerate reasonable signal levels in an adjacent band unfairly impose costs on others, notably the operators in those adjacent bands, while reaping the benefits themselves,

28. *E.g.*, de Vries & Sieh, *supra* note 27, at 58-59; Receivers & Spectrum Working Grp.: FCC Tech. Advisory Council, Interference Limits Policy: The Use of Harm Claim Thresholds to Improve the Interference Tolerance of Wireless Systems (Feb. 6, 2013) (white paper), *available at* http://transition.fcc.gov/bureaus/oet/tac/tacdocs/WhitePaperTACInterferenceLimitsv1.0.pdf [hereinafter TAC RECEIVERS & SPECTRUM WORKING GROUP (2013)].

29. Serv. Rules for Advanced Wireless Servs. in the 1.7 GHz and 2.1 GHz Bands, *Report & Order*, 18 FCC Rcd. 25,162 (2003).

30. Letter from Lawrence E. Strickling, Assistant Sec'y for Commc'n & Info., to Julius Genachowski, Chairman of the FCC 7 (Feb. 14, 2012), http://www.ntia.doc.gov/files/ntia/publications/lightsquared_letter_to_chairman_genachowski_-_feb_14_2012.pdf ("NTIA urges the FCC, working with all stakeholders, to explore appropriate actions to mitigate against the impact GPS and other receivers may have to prevent the full utilization of spectrum to meet the nation's broadband needs.").

31. Interference Immunity Performance Specifications for Radio Receivers, 68 Fed. Reg. 23,677 (proposed May 5, 2003) (to be codified at 47 C.F.R. pt. 15).

32. NAT'L TELECOMM. & INFO. ADMIN., COMMENTS: STANDARDS FOR NON-GOVERNMENT RADIO RECEIVERS Section IV, http://www.ntia.doc.gov/federal-register-notice/2003/comments-standards-non-government-radio-receivers (last visited Jan. 7, 2014).

33. Technological Advisory Council Sharing Work Group, Spectrum Efficiency Metrics 24, (Sept. 25, 2011) (white paper), *available at* http://transition.fcc.gov/oet/tac/tacdocs/meeting92711/Spectrum_Efficiency_Metrics_White_Paper_by_TAC_Sharing_Working_Group_25Sep2011.doc.

for example by using cheaper receivers. This is not only unfair, but prevents the addition new wireless services that could foster innovation, improve public safety, and create jobs. Government has a legitimate role in seeking to limit such an unfair economic externality where one service stands to gain while their neighbor bears the cost.

So far, the FCC has handled such interference to an affected receiver due to signals from inside an adjacent band almost entirely by placing the burden on the neighbor, e.g., by reducing their transmit power, moving neighbors away from the band boundary, or requiring transmitters to provide additional filters for receivers.

However, it takes two to tango: both the affected system and the influencing system play a role.[34] The affected system that is being protected also needs to bear some responsibility. While this is often framed as a matter of "better receivers," it is actually a system issue: in addition to using more robust receivers, an operator might also improve interference tolerance by increasing the strength of the desired signal at the receiver, and/or by moving their service away from the frequency boundary (a.k.a. internal guard bands).

Where the resulting signal strengths at receivers and the ability of receivers to process such signals is known to all parties, as is the case if they are in the same industry, then they both can be factored into system designs and border negotiations.[35] However, this is often not the case at boundaries between spectrum allocations, particularly when receiver performance specifications are proprietary. In such cases, statements by the regulator about the interference environment in which a receiver must be operate—called *interference limits* in TAC Receivers & Spectrum Working Group (2013)—could facilitate negotiations.[36]

This baseline information is particularly important in cases where there are many kinds of receivers in the same band with different abilities to tolerate interference. A receiver-independent statement of the interference that needs to be tolerated provides clarity for operators in adjacent bands.

34. I use the terms "affected" and "influencing" to avoid the implied judgments of the more common terms "victim" and "transmitter." The latter terminology implies that the transmitter is always at fault, and the receiver always the victim. The consensus that receivers also have a role to play in avoiding harmful interference is relatively recent. For example, a 1987 Report and Order stated that "[s]ub-standard receivers do not cause system interference." Dev. & Implementation of a Pub. Safety Nat'l Plan and Amendment of Part 90 to Establish Serv. Rules and Technical Standards for Use of the 821-824/866-869 MHz Bands by the Pub. Safety Servs., *Report & Order*, 3 FCC Rcd. 905, 908 (1987).

35. However, just because adjacent operators have congruent interests does not guarantee that this situation will persist.

36. TAC RECEIVERS & SPECTRUM WORKING GROUP (2013), *supra* note 28.

A. The Tent Analogy

An analogy might help to clarify the radio system design factors that influence the trade-offs between transmitter and receiver performance. Imagine the property line between a two adjacent lots—in the radio case, it would be a boundary between two frequency bands, not two geographic areas. Everyone has to take some responsibility for tolerating sounds that come from their neighbors. If Bob lives in a tent, he is going to be very sensitive to noise from Alice next door.

One response, and a typical one in spectrum policy, is to make the neighbors—such as Alice—keep their voices down, i.e., limit the allowed transmission power in the adjacent band or perhaps even prohibit transmission altogether. However, it seems unreasonable for Bob to demand that Alice always whispers when she is in her own garden. Bob could also take some responsibility, for example by moving indoors. In radio terms, that is analogous to adding receiver filters to exclude signals in the adjacent band. Bob could ask the people he is talking with to speak more loudly or come into the same room so that they can be heard better, or Bob could move to a room on the other side of the house.

The radio analogy would be to increase the Bob's desired radio signal level by increasing transmitter power or deploying more transmitters, or to move an operating channel away from the band boundary, respectively.

This example is a riff on the case of the doctor and the confectioner cited by Coase.[37] In both cases, harm is reciprocal: avoiding disturbance to Bob by silencing his neighbors causes harm to them, and allowing them to make noise disturbs Bob. Receiving systems with inadequate interference tolerance can harm the interests of neighboring transmitters, the converse of the conventional assumption that it is always transmitters that harm receivers. As Coase suggested, the ideal solution is to give the parties well-defined rights so that they can find the optimal balance among themselves.[38]

III. HARM CLAIM THRESHOLDS

A. Definition

Interference-limits policies describe the environment in which a receiver must operate without necessarily specifying receiver performance. There are many ways to implement interference limits. This paper advocates *harm claim thresholds*, a statement in a service's rules that defines the signal levels it needs to tolerate before being able to

37. *See* Ronald. H. Coase, *The Problem of Social Cost*, 3 J.L. & ECON. 1, 9-10 (1960).
38. *See* COOTER, *supra* note 13.

bring a harmful interference claim.[39]

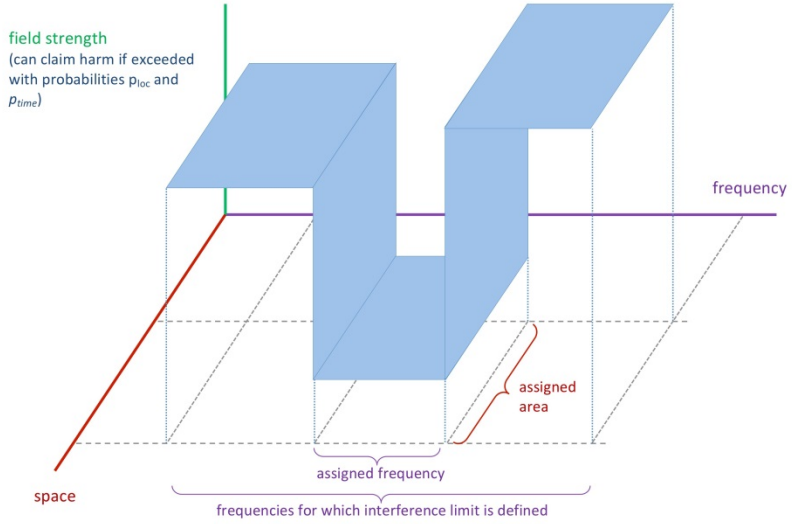

FIGURE 1. A GENERIC HARM CLAIM THRESHOLD. ONLY ONE SPATIAL DIMENSION IS SHOWN.

Harm claim thresholds are expressed as a field strength profile—both inside and outside an assigned service's designated frequencies—that must be exceeded at more than a specified, small percentage of locations and times in a measurement area before a user can claim that it is experiencing harmful interference.[40]

Interference-limits policies may or may not specify the performance of receivers; harm claim thresholds do not explicitly specify receiver performance. This is important, since receiver performance specifications are just one of many requirements needed to define a wireless system. Manufacturers and operators are left to determine whether and how to build receivers that can tolerate such interference, or even to determine that they will choose to ignore these limits. In other words, harm claim thresholds are not government receiver performance mandates, sometimes referred to as "receiver standards."

B. Benefits

Setting harm claim thresholds delegates decisions about system design, including receiver performance, to manufacturers and operators. This gives them more flexibility, and reduces the need for the FCC to

39. *See* TAC RECEIVERS & SPECTRUM WORKING GROUP (2013), *supra* note 28.
40. *See supra* Figure 1.

adjudicate interference disputes. Harm claim thresholds also give manufacturers and operators the information they need to figure out the best way to tolerate potentially interfering signals in adjacent bands, including by improving the performance of their receivers.[41] For example, they can invest in high performance receivers that tolerate high levels of adjacent band noise even when their own received signals are weak, or they can deploy more basic receivers, but invest in increasing the level of their own received signals by deploying more transmitters.

Harm claim thresholds can facilitate bargaining, allowing wireless system operators to find and adjust the optimum level of mutual interference. Depending on the economic/regulatory environment, a harm claim threshold should also improve clarity of entitlements.

Setting harm claim thresholds also allows the FCC to give notice to operators that an adjacent band that is currently radio quiet will not remain so, by setting a high harm claim threshold over that band. It also allows the Commission to incentivize improved system performance without imposing receiver performance mandates. It delegates decisions to the market place. If the FCC chooses, it can select threshold levels, or gradually increase levels over time, to incentivize better receivers without mandating them.

Citizens benefit because more clarity about interference rights and better receivers will lead to valuable new commercial services being deployed in limited spectrum while protecting public safety and enhancing national security by improving resistance to both "friendly" interference and hostile jamming.

Explicit thresholds facilitate long-term planning by both the FCC and industry, thus encouraging investment in new services by more clearly stating the rights and responsibilities of services to tolerate interference from each other.

C. Implementation

I note some salient points regarding the implementation of harm claim thresholds.[42]

The harm claim threshold values for an assignment can be chosen to reflect the status quo. For example, if the receivers in an allocation are very susceptible to interfering signals in frequencies outside their band, the harm claim threshold can be set very low; thus, little or no operation will be permissible in the adjacent band. In this way, incumbents will not

41. *See supra* Part II.A.

42. *See* TAC RECEIVERS & SPECTRUM WORKING GROUP (2013), *supra* note 28; J. Pierre de Vries, *Optimizing Receiver Performance Using Harm Claim Thresholds*, 37 TELECOMM. POL'Y 757 (2013), http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2195330.

be required to replace existing receivers. However, if the FCC wishes to change the neighboring allocation in the future to allow a stronger signal there, it can stipulate that harm claim thresholds will increase at some future date. The time period can be chosen to give incumbent operators sufficient time to upgrade their receivers over time.

Conversely, if the status quo is that there is already strong signal operation in the adjacent band, the harm claim threshold for the new assignment can be set sufficiently high over the adjacent band that the incumbent strong signal operation will not be deemed to be causing harm.

The approach is not one-size-fits-all. As the preceding examples illustrate, an assignment's harm claim threshold can be customized to reflect the current and expected performance of systems in this assignment, and those next to it. Thus, different bands will have different harm claim thresholds.

A harm claim threshold is not a receiver performance mandate since it does not specify how a receiver should perform in the presence of interference. It merely defines the interfering signal levels that must be exceeded before a service can bring a harmful interference claim.

There may be cases where the initially assigned harm claim threshold is not economically efficient. For example, there might be net social gain if the threshold were increased, allowing increased transmit power and thus better service in the adjacent band. The FCC should allow parties to adjust the limit by negotiation among affected neighbors. If the Commission deems that there is no prospect of such negotiations being concluded successfully, it could put incumbents on notice that the harm claim threshold level will be increased step-wise over time.

Harm claim thresholds may not be sufficient in cases where receivers are not controlled by a license holder, for life-safety systems like aviation, or for unlicensed devices. For example, thresholds attached to a transmitter license may be ineffective as a means of encouraging optimum receiver performance when receivers are not controlled by a licensee, as in the so-called decoupled receiver.[43] Examples include television, GPS, FM radio, satellite weather receivers, and unlicensed cases.

Additional measures may be required to ensure that such receivers operate adequately in the presence of interference. One possible solution is to require that manufacturers self-certify that a receiver is fit for

43. *See* Madelaine Maior, *Efficient Interface Management: Regulation, Receivers, and Right Enforcement: A Report on a Silicon Flatirons Summit, held 18 October 2011*, SILICON FLATIRONS CENTER (Jan. 10, 2012), http://www.siliconflatirons.com/documents/publications/report/EfficientInterferenceManagement.pdf.

purpose in its envisaged use, e.g., that it will operate successfully given the prescribed harm claim thresholds. A self-certification could function as an express warranty, or the certification could be enforced by false advertising regulation. This could be done by individual companies, or collectively through an industry-certified seal of approval. The FCC could also require the manufacturer to submit a testing protocol that allows validation of the claim to be fit for purpose, as in the self-declaration approach of the R&TTE directive.[44]

I do not believe that government receiver performance mandates are necessary or desirable. Receiver performance specifications are just one of many requirements needed to define a wireless system. Others include transmitter performance, and the power, height and spacing of transmit antennas. These specifications result from trade-offs between many design requirements, including the nature of the service to be delivered, cost constraints, quality of service requirements, and the radio interference environment. Imposing receiver performance mandates requires the FCC to take a position on these trade-offs for every product and every allocation where they are required. A mandate necessarily embeds these design trade-offs in regulation. But, while industry-defined receiver standards can evolve quite rapidly as technology changes, regulation changes more slowly. Last but not least, there are questions about whether the FCC currently has sufficient statutory authority to impose receiver mandates. Mandating "better" receivers may be unavoidable in a few cases —such as where receivers are not controlled by a license holder, for life-safety systems, or for unlicensed devices—but should be a last resort. Receiver standards may be best used as a safe harbor where industry standards ensure that systems should operate satisfactorily as long as the harm claim threshold is not exceeded. The FCC could use performance degradation of a standards-compliant system as prima facie evidence that a harm claim threshold has been exceeded.

D. Enforcement

The use of harm claim thresholds would make it clearer when a radio system operator is entitled to seek protection from the FCC against harmful interference by another operator. Since the 47 C.F.R. 2.1 definition of harmful interference is qualitative, the basis for seeking enforcement is unclear.

The procedure for seeking enforcement under a harm claim

44. *See* Directive 1999/5/EC, of the European Parliament and of the Council of 9 March 1999 on Radio Equipment and Telecommunications Terminal Equipment and the Mutual Recognition of Their Conformity, 1999 O.J. (L 91) 10, 17-18.

threshold regime[45] requires a plaintiff to make a quantitative showing that received interfering signal levels exceed their harm claim threshold.[46] If the plaintiff is suffering service degradation but the threshold is not being exceeded, it is responsible for finding a remedy, e.g., by improving its receivers or paying the interfering[47] neighbor, the influencing system, to reduce its transmitter levels.

If the harm claim threshold is exceeded the plaintiff may bring a harm claim to the FCC, and the Enforcement Bureau will determine whether the influencing system is operating outside its allowed transmitter parameters. If so, the FCC will conduct an enforcement proceeding. If the transmitter limits are not exceeded, there is a rule conflict: the affected system's harm claim threshold is exceeded, but not due to a fault of the influencing system. The FCC will then need to resolve this contradiction.

Showing actual harm (e.g., service degradation) is not necessary to show liability, but would affect the remedy. Even if liability is established, a greater or lesser showing of fault influences the consequences. For example, an affected system that has not yet started operating in a particular region will not suffer actual harm if a neighbor's signals exceed the harm claim threshold, but may be able to enjoin that operation in any case. There is also room for the defending influencing system to rebut the claim of harmful interference, for example if the circumstances that lead to the threshold being exceeded were very unusual.

The status quo enforcement procedure, i.e., without harm claim thresholds, is shown in Figure 2 by the blue shading. The use of harm claim thresholds makes it clear that an affected system bears some responsibility to mitigate the effects of interference, as shown by the unshaded boxes on the left-hand side.

45. *See infra* Figure 2.

46. *See* TAC RECEIVERS & SPECTRUM WORKING GROUP (2013), *supra* note 28 (noting this treatment differs from it in assigning more responsibilities to the FCC, and fewer to the affected system (called the target system there) and multi-stakeholder bodies).

47. GEN. SERVS. ADMIN., *supra* note 7 (noting interference refers here to energy that impedes reception of desired signals and does not presuppose that the interference is harmful).

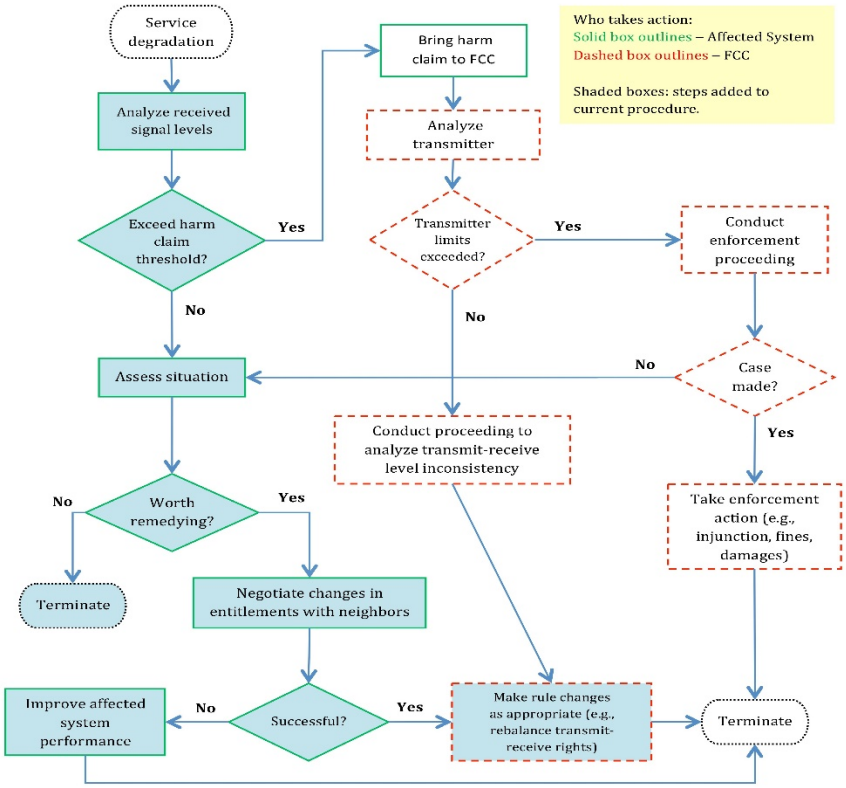

FIGURE 2. ENFORCEMENT PROCESS. A DECISION TREE FOR MAKING ENFORCEMENT DECISIONS AS DESCRIBED IN THE TEXT. STEPS ADDED TO THE CURRENT PROCEDURE ARE INDICATED BY SHADED BOXES.

IV. CONCLUSION

Setting harm claim thresholds is a minimally intrusive way to incentivize better receiver system performance by clearly stating the rights and responsibilities of systems to protect themselves against interference. If expectations about the interference tolerance of receiving systems had been set more clearly in the past, lost opportunities and economic harms could have been reduced or avoided.