Interference Limits Policy and Harm Claim Thresholds: An Introduction

Spectrum / Receiver Performance Working Group*

FCC Technological Advisory Council

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* Pierre De Vries (Principal Author), Lynn Claudy, Mark Gorenberg, Dave Gurney, Dale Hatfield, Greg Lapin, Brian Markwalter, Geoffrey Mendenhall, Dennis Roberson (Chair). FCC Liaisons: Matthew Hussey, Julius Knapp, Robert Pavlak.

1. Background

In order to meet the growing demand for wireless service, the number of wireless systems that operate in close proximity in frequency, space and time needs to increase dramatically. Closer packing brings many benefits, including increased access, new services, and device innovation. However, tighter proximity also increases the risk of service disruptions due to inter-system interference.

Increased density of wireless systems requires increased regulatory attention to the optimization of the interactions between transmitters and receivers on either side of band boundaries. Increased signal strength from transmitters may provide improved reception and / or coverage, but requires receivers in adjacent spectrum to be able to reject unwanted signals outside their allocated frequencies—and such interference tolerance comes at a cost. Further, as regulators strive for more intensive use, they seldom have the luxury of being able to place like services with like services; they increasingly need to place new services in bands not previously allocated to that category of service. Thus, receivers that cannot reject interfering signals transmitted outside their assigned frequencies can preclude or at least constrain new allocations in adjacent bands.

However, radio operation has traditionally been regulated solely based on using limits on transmitters, with few if any explicit constraints on receivers. This has led to a litany of interference conflicts and lost opportunities; for example, the NTIA's comment on the Receiver NOI (NTIA 2003) enumerated "a number of instances of reported interference that could have been avoided if appropriate receiver standards had been applied," and an FCC Technological Advisory Council working group listed nine cases "where receiver performance was a significant issue affecting access to the spectrum for new services" (FCC TAC Spectrum Working Group, 2011, Appendix C). A holistic system view is therefore needed that facilitates trade-offs between receiver and transmitter performance.

Interference limits policies
Ways to describe the environment in which a receiver must operate without necessarily specifying receiver performance.

Harm claim thresholds
In-band & out-of-band interfering signals that must be exceeded before a system can claim that it is experiencing harmful interference.

Such "receiver issues" usually result in calls for FCC receiver performance mandates. However, the FCC has been reluctant to use this option for a variety of reasons, and it has been imposed very rarely. There has been growing support in recent years for an alternative approach: quantitative statements by the regulator of the interference environments in which a variety of radio systems should expected to be able to operate. We refer to such approaches as *interference limit policies*.

The growing importance of database-coordinated spectrum sharing, such as that proposed for the 3.5 GHz band, adds urgency to the need for objectively defined interference criteria because such databases will need to compute interference-avoiding assignments in real time without recourse to case-by-case interpretation of the qualitative definitions of harmful interference by the Commission.

2. Harm Claim Thresholds

Building on work by the President's Council of Advisors on Science and Technology (PCAST, 2012, Section 3.2) and motivated by the receiver problems noted above, our TAC working group has been

exploring a particular kind of interference limit policy: *harm claim thresholds*, i.e. in-band and out-of-band interfering signal levels that must be exceeded before a radio system can claim that it is experiencing harmful interference. One goal of a harm claim threshold is to reduce the uncertainty among radio system operators regarding the level of interference that one operator is entitled to impose on another operator. A related goal has been to find ways the FCC could encourage more efficient radio service coexistence, including ways to encourage receiver performance improvement without mandating receiver performance specifications.

This committee described the use of harm claim thresholds in a 2013 white paper (FCC TAC Receivers and Spectrum Working Group, 2013; "White Paper" hereafter). The purpose of this note is to provide a concise introduction to the White Paper, where further detail may be found.

The FCC requested feedback on the White Paper through a public notice on April 22, 2013 (ET Docket No. 13-101). The Spectrum / Receiver Performance Working Group reported to the TAC at its meeting on September 23, 2013 (FCC TAC, 2013) that the comments submitted to the Commission indicated that there was broad support for defining the environment in which receivers need to operate, although many commenters also noted that details would need to be worked out; that there was broad support for using multi-stakeholder organizations to develop harm claim thresholds, but again, the details of the process would need to be developed; and finally, that there was support in the record for the FCC to encourage industry action in a pilot project. Consequently, the Working Group recommended that the FCC should encourage formation of a multi-stakeholder group to investigate interference limits and pilot the use of harm claim thresholds in the 3.5 GHz band.

3. Benefits of using Harm Claim Thresholds

Harm claim thresholds provide added clarity about the rights and responsibilities of radio service operators regarding harmful interference. This will be particularly useful in, and at the boundaries of, bands with many diverse and frequently emerging new device types. This approach also continues to delegate decisions about system design, including receiver performance specifications and standards, to manufacturers and operators. It gives an operator the flexibility to decide how best to deal with the levels of interference it needs to tolerate, whether by improving receiver selectivity, deploying more base stations, using internal guard bands, or accepting occasional degradation given their choice of receiver design.

For systems at risk of harmful interference, harm claim thresholds provide a statement of the radio environment that a receiver will have to operate within. If a receiving system is designed to operate successfully in this environment, it can be sure that it has a readily enforceable claim of harmful interference if the interference limit is ever exceeded. Incumbent systems given harm claim thresholds would have the reassurance that new services operating above these limits could not be allocated in neighboring bands without their permission and/or compensation for their financial loss.

For systems at risk of claims that they are causing harmful interference, harm claim thresholds preclude unexpected claims from insufficiently selective receivers. Thresholds allow better estimates of deployment costs and benefits because interference risks are better known. If a transmitting system is designed to meet the assigned harm claim threshold criteria, it is known up-front that it will not be subject to valid subsequent harm claims. (Of course, it is still possible that a receiving system would suffer harmful interference and have a valid claim if a transmitting system were incorrectly configured.)

For example, if the FCC had defined harm claim thresholds for the AWS-1 F block, it would have been absolutely clear at the time of the auction whether or not TDD operation would have been permitted in the AWS-3 block, sparing both the new entrant M2Z and AWS-1 F-block licensees like T-Mobile considerable uncertainty, wasted investment, and lobbying costs. Similarly, promulgating harm claim thresholds in the early stages of the LightSquared ATC proceeding would have made the interference management responsibilities of all parties explicit at the beginning of the process, rather than being revealed ten years later.

Looking ahead to a future where harm claim thresholds are being used, one could expect they will be used as an objective and efficient way to establish the interference protection rights of incumbent services when new allocations, including sharing between diverse systems, are contemplated.

Harm claim thresholds state the interference at the antenna without making direct reference to receiver operating characteristics. Out-of-band harm claim threshold profiles[1] would provide a transparent way to calculate the guard bands and/or coordination zones required by incumbent services, such as satellite earth stations and radar systems.

Once the thresholds are in place, the operating permissions for new systems, either in adjacent bands or secondary sharers in the same band, could be calculated in a straightforward manner, including automatically by a spectrum access database such as that proposed for the 3.5 GHz shared band.

One can also expect that harm claim thresholds will facilitate interference resolution negotiations and/or enforcement actions. Disputes between parties about whether harmful interference has taken place would be a matter of (potentially challenging) measurement, rather than ad hoc interpretation of 47 C.F.R. 2.1 as is currently the practice.

4. Defining Harm Claim Thresholds

Harm claim thresholds are the in-band and out-of-band interfering signal levels that must be exceeded before a radio system can claim that it is experiencing harmful interference. They are deemed to be exceeded if the measured or modeled signal strength exceeds the stated value for more than some percentage of locations and times. Thresholds have a statistical basis in that they would also specify the confidence level at which signals exceeding the threshold would have to be demonstrated in order to justify a harmful interference claim.

In order to remove dependence in the rules on the particular device's antenna, we specify harm claim thresholds as field strengths, not power levels (e.g. dB(μV/m) not dBm).[2] The field strength can be specified in a standard reference bandwidth e.g. as "100 dB(μV/m) per MHz", a field strength spectral density, and/or as an aggregate value e.g. as "123 dB(μV/m) in the second 20 MHz adjacent band".

Limits represent threshold conditions for claims of harmful interference, and are not intended to capture specific interference situations.[3] Performance degradation as a result of interfering signals is system and scenario dependent; however, initial limits can be chosen to reflect incumbent needs e.g. to

[1] Or, in-band harm claim threshold profiles between sharers in the same band.
[2] The signal power at a receiver input depends on both the received signal field strength and the gain of the antenna attached to the receiver input.
[3] If appropriate, multiple thresholds could be defined to reflect the differing impact of different signal types on inter-system interference.

protect existing operations from claims of harmful interference, and to allow legacy receivers to continue to operate successfully.

Figure 1 shows the fundamental elements of a harm claim threshold: a field strength profile defined over a frequency range, associated with a percentage of locations and times where the field strength must be exceeded to qualify as harmful interference.

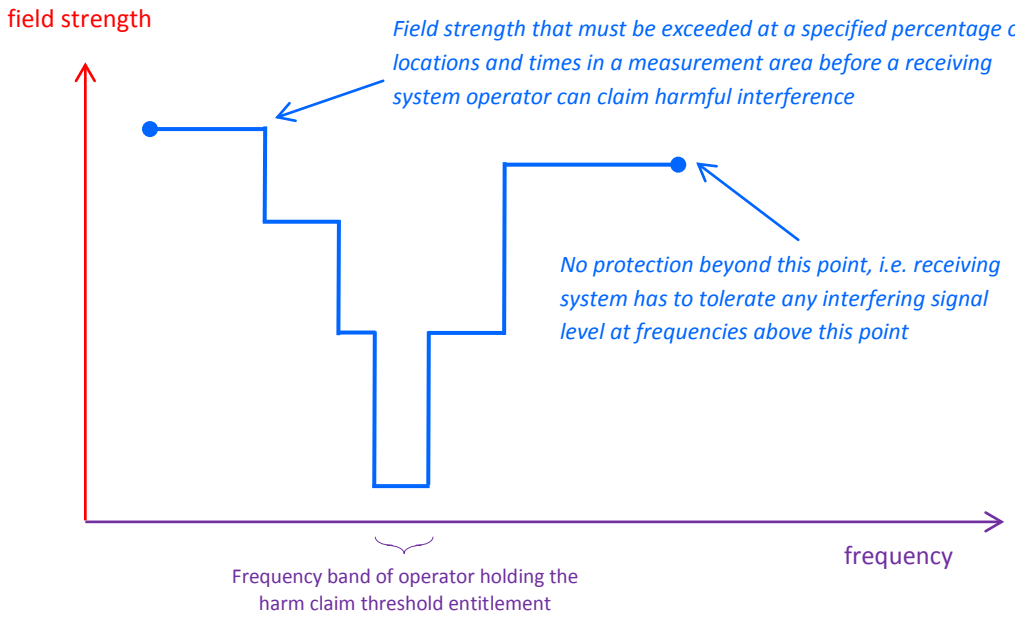

Figure 1. Elements of a harm claim threshold

Harm claim thresholds would be different from band to band; for example, the shape of the profile could depend on the service being protected by a harm claim threshold, and the neighboring services. Further, harm claim thresholds may be different on either side of the block to be allocated.

Since field strength varies with height, the measurement altitude should also be given; measurement heights might be 1.5 m above ground level for interference into hand held or fixed user equipment, and 10 m for fixed station antennas.

In its base formulation, a harm claim threshold specifies a field strength at a specified quantile, e.g. 100 dB(μV/m) per MHz must be exceeded in more than 10% of locations and times to demonstrate harm. As shown in Figure 2, as field strength increases, the likelihood of its occurrence decreases. The FCC may elect to specify field strength levels at more than one quantile to more accurately reflect the cumulative distribution function of field strength that underlies any interference environment.

A harm claim threshold informs a system designer about the radio interference environment that needs to be tolerated. However, many other factors, such as transmitted signal characteristics, desired quality of service, cost constraints, and transmitter deployment also factor into specifying the performance requirement of a receiver. The private sector will play a key role in developing receiver specifications and standards that ensure adequate performance given the harm claim thresholds of a particular allocation.

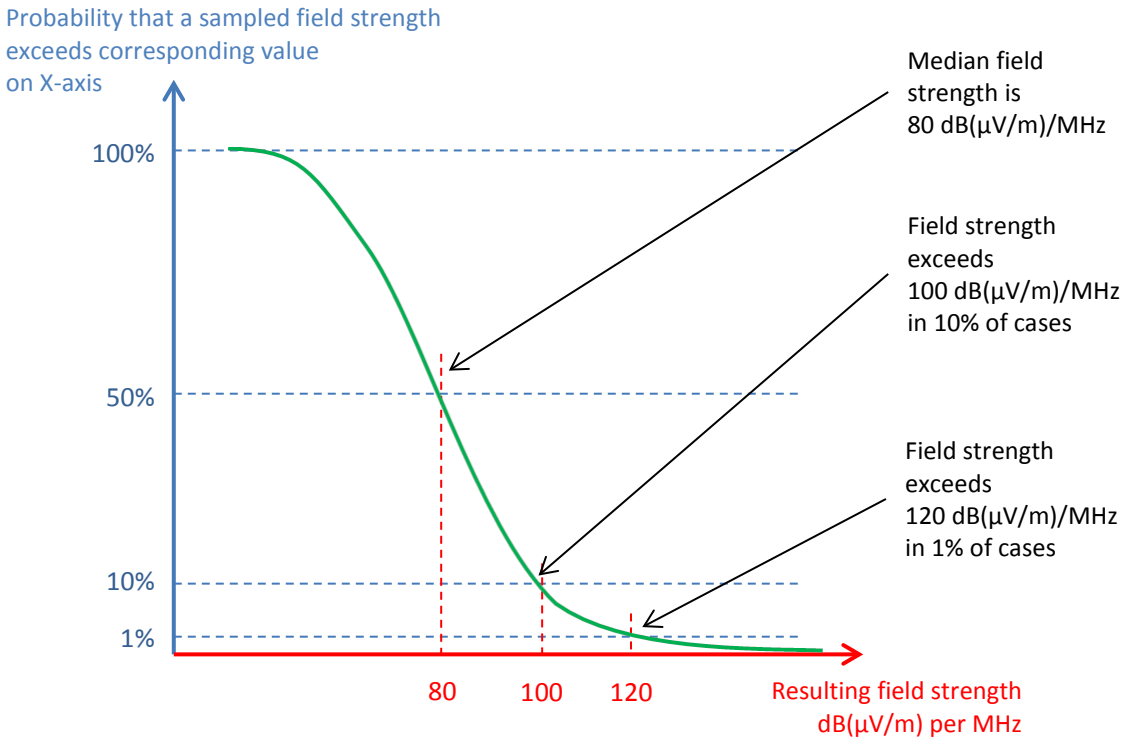

Figure 2. Cumulative distribution of resulting field strength for a hypothetical deployment of transmitters

The implementation of harm claim thresholds may require special consideration in cases where receivers are not controlled by a license holder or for life-safety systems like aviation and public safety. Additional measures may be required to ensure that devices sold at retail outlets outside the control of a licensee are operating within their prescribed harm claim thresholds, such as requiring vendors to certify that devices sold at retail can operate effectively in the specified interference environment.

5. Developing harm claim threshold values

In new allocations, harm claim thresholds would most likely represent the typical strongest signal levels generated by existing neighboring band operations; thus, transmissions by incumbent neighbors would not exceed the chosen harm claim threshold, and would not trigger harmful interference claims. Likewise, new transmission permissions would be chosen so that the resulting signals did not exceed the harm claim thresholds of incumbent neighbors.

If the band(s) next to a new allocation are currently unused or have low resulting field strength levels, the FCC could set harm claim thresholds that will allow more intensive use in the future. For example, by stipulating to a multi-stakeholder group that it should expect as a starting point that the adjacent band will be re-allocated for use as a cellular downlink, new licensees will be put on notice that they should not depend on quiet neighbors when designing their systems.

Interference limits could be added to existing rules in already-allocated bands, with values chosen to grandfather in existing devices and operations, i.e. to ensure that interfering signals from other operations

would not be deemed to cause harmful interference to incumbent services. The parties involved could modify these harm claim thresholds over time if mutually agreeable alternative limits that enhance the overall value of radio operation could be established, with appropriate compensating financial payments where necessary.

The roll-out of harm claim threshold policy-related rules and regulations might follow a three step process. The FCC could: (1) identify boundaries where defining harm claim thresholds would add significant value; (2) encourage a multi-stakeholder process to work out implementation details; and (3) engage in rulemaking as required.

First, the FCC would identify frequency allocation boundaries where harm claim thresholds would bring immediate value. Adjacent allocations with a prospect of intensified use are good candidates for early implementations of interference limits policy.

A second step would be to initiate a consultation process. Since harm claim thresholds span band boundaries, stakeholders in multiple services, bands and potentially industries will have to be involved. Such multi-stakeholder groups could work out boundary issues and implementation choices such as methods for determining harm claim thresholds, and enforcement and conflict adjudication mechanisms. A multi-stakeholder group could also develop guidelines, and perhaps standards, for receiver performance parameters such as receiver sensitivity, selectivity, intermodulation rejection, and dynamic range, that, together with the transmitter power, signal modulation and deployment assumptions applicable to a particular service, would ensure that conformant receivers would operate satisfactorily given interference up to the harm claim threshold.

In the best case, the participants in the multi-stakeholder process for affected allocations would agree on both parameters and their values that the FCC could then endorse. If this is not achieved, the group is likely to at least agree on relevant parameters and methods, if not the parameter values that establish a particular balance of costs and benefits between neighboring assignments. Finally, even if there was no agreement on the trade-off between transmitter and receiver interests, the multi-stakeholder process would assist the FCC in identifying critical issues and mapping out points of consensus vs. areas where the Commission itself would need to make the public interest trade-off.

Thirdly, the FCC would monitor the progress of the multi-stakeholder process. It would represent the interests of future licensees and other absent stakeholders, and ensure that the record developed provides a thorough basis for a Notice of Inquiry and/or Notice of Proposed Rulemaking, should that be required. If necessary, it would add interference protection entitlements to the rules for a new assignment.

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