

Before the
Federal Communications Commission
Washington, D.C. 20554

In the Matter of:)
)
Promoting Efficient Use of Spectrum) ET Docket No. 22-137
through Improved Receiver)
Interference Immunity Performance)

Reply Comments of JP de Vries

via electronic filing
July 26th, 2022

JP (Pierre) de Vries*
Distinguished Advisor, Silicon Flatirons
Center
University of Colorado Law School
Boulder, CO 80309
jp.devries@colorado.edu

* I thank Prof. Dale Hatfield, Dr. Susan Tonkin, Prasanth Prahlanan, and Dr. Janne Riihijärvi for their help in preparing these comments.

Summary

- In the *NOI*, the Commission seeks input on the role of interference immunity in the use of radio systems. There is striking agreement on several topics, including support for a policy statement, dislike of receiver mandates, and support for voluntary approaches. There is solid support in the record for further exploration of interference limits and harm claim thresholds (HCTs).
- The way forward is clear:
 1. The Commission should issue a policy statement that documents its assumptions and expectations about coexistence between radio systems. This guidance should lay out how staff should assess the compatibility of, and develop recommendations for, future spectrum allocations.
 2. The Commission should then pilot interference limits in a limited-scope reallocation or ad hoc rule change. A quantitative interference limit can be used to negotiate trade-offs between transmitter and receiver concerns.
 3. Once it has developed expertise and confidence in RF environment methods by using interference limits, the Commission can move on to using HCTs in technical rules.
- Several recommendations in the record would advance this work. CTIA proposes discussion about a framework for probabilistic analysis techniques and simulation. Bykowsky & Sharkey recommend that the Commission use an emulation testbed to examine the efficiency-enhancing effects of an interference limit. Stacey Weber puts forward negotiated rulemaking as a formal and accountable multi-stakeholder context for using interference limits. NCTA and Public Knowledge/OTI's proposals for "reasonable" and "standard" receiver approaches, respectively, could test key ideas of the interference limits approach without using statistics.

- Most of the fears and reservations about interference limits and HCTs can be filed under “Don’t shoot the messenger.” These concerns apply just as much to conventional Commission rulemaking as to this new approach.
 - Involving all stakeholders may be contentious and time consuming, but it always is.
 - Developing interference limits may require anticipating the future interference environment, but current rulemaking approaches do so, too.
 - It may sometimes be difficult to differentiate between simultaneous potential interferers when pursuing harm claims, but the same is true of interference resolution today.
 - Setting numerical values may be challenging in some cases, but making such determinations is a staple of Commission rulemaking.
 - Defining and interpreting probabilities may be daunting to some, but they reflect the inherent variability of the RF environment. Interference limits and HCTs merely highlight a reality that has been there all along.
 - Rules that use HCTs could lead to costly harmful interference claims, but so could any other approach to making technical rules, including current methods.
- HCTs do introduce some new challenges, but they can be overcome. Field strength measurement is a well-known and widely used technique in some industries. The Commission could allow modeling rather than, or in addition to, measurement. Some parties oppose placing the burden of pleading on the party claiming harmful interference. While plaintiffs typically bear this burden, it could be spread if necessary.
- A few comments in the record misunderstand or misconstrue harm claim thresholds. HCTs are not intended to identify “poor-performing” receivers and are not receiver mandates. They will not discourage innovation and do not have to be set retroactively for all bands.

Table of Contents

I. Introduction.....	1
II. There are several areas of broad agreement, including support for a policy statement, dislike of receiver mandates, and support for voluntary approaches.....	1
III. There is solid support for further exploration of interference limits policy, sometimes with reservations.....	3
IV. Don't shoot the messenger: Many reservations and fears about the interference limit/HCT approach apply to Commission rulemaking generally.....	5
A. Involving all stakeholders may be contentious and time consuming—it usually is.....	6
B. Developing interference limits may require anticipating the future interference environment—just as current rulemaking does.....	7
C. RF measurements may not be able to identify the responsible party if there are several possibilities—but this is not new.....	8
D. The interference limit/HCT approach requires setting numerical values for parameters—but this is a staple of Commission rulemaking.....	9
E. Concerns about defining and interpreting statistics are not valid—and the variability they capture is inherent in the RF environment.....	10
F. Rules that use HCTs could lead to costly harmful interference claims—but so could any other technical rules.....	11
V. Using HCTs for interference resolution poses challenges, but they can be overcome ..	12
A. Making HCT claims may require making field measurements, but modeling is also an option.....	12
B. HCTs as proposed place the burden of pleading on the party claiming harmful interference, but the burden could be spread.....	13
VI. Some comments misunderstand the intent and uses interference limits and harm claim thresholds.....	14
VII. The way forward.....	16
A. The Commission should issue a policy statement that describes how it will assess radio system compatibility.....	16
B. The Commission should pilot interference limits in a limited-scope reallocation or rule change.....	16
C. Other proposals in the record can support the use of interference limits.....	18
VIII. Conclusions	21

Reply comments of JP de Vries

I. Introduction

I submit these reply comments in response to the Federal Communications Commission's (FCC or Commission) Notice of Inquiry in ET Docket No. 22-137.¹ In the *NOI*, the Commission takes a fresh look at the role of interference immunity, including receiver performance, in radio system coexistence.

The way forward is clear. There is broad support in the record for the Commission to issue a policy statement that lays out how it will assess compatibility between radio systems. It should then pilot interference limits (but not harm claim thresholds) in a limited-scope reallocation proceeding or ad hoc rule change.

II. There are several areas of broad agreement, including support for a policy statement, dislike of receiver mandates, and support for voluntary approaches

I am heartened by the consensus in the comments that the interference immunity of radio systems is a critical issue that should be addressed explicitly. There is support for a policy statement that describes how the Commission would assess compatibility between radio systems, although sometimes with reservations, exceptions, and suggested alternatives.²

There is almost universal condemnation of receiver mandates and widespread support for voluntary approaches, although the problem of how industry standards would reflect the interests of all disparate neighbors across a band boundary is scarcely addressed. Nokia, however,

¹ *Promoting Efficient Use of Spectrum through Improved Receiver Interference Immunity Performance*, ET Docket No. 22-137, FCC 22-29, 87 FR 29248 (2022) (*NOI*). The views expressed here are mine alone and do not necessarily reflect the opinions of any institution with which I am affiliated. All references to comments are to those received in this proceeding on June 26 and 27, 2022, unless otherwise specified.

² *See, e.g.*, 5G Americas comments, 3; AT&T comments, 3; Cisco comments, 11–13; CTA comments, 13–15; De Vries comments, 47–49; Ericsson comments, 12–13; Intel comments, 3–8; Lumen comments, 4–7; NCTA comments, 6–13; Verizon comments, 9–11. *Cf.* CORF comments, 17–23; Longman comments, 2–7. *But see* Boeing comments, 8.

observes that “stakeholders have little incentive to evolve their technologies to benefit a different industry” and that for this and other reasons, “a voluntary approach may not lead to cross-industry solution [sic] agreeable to all parties.”³ Industry-developed standards are unlikely to be a viable, general solution for preventing conflicts over interference immunity performance.⁴

There is broad consensus that arrangements need to be band(edge) specific. Many commenters mention and support multi-stakeholder processes, including in the development of interference limits or harm claim thresholds.⁵

“One size fits all” is widely rejected, and rightly so.⁶ There will never be a universal interference limit, let alone HCT, for all bands. However, all the systems in a band, including ones operating under different radio services and using different receivers, operate in the same RF environment. It is therefore reasonable to have a single interference limit defined over a band, in the same way that a single, uniform out-of-band emission (OOBE) limit for transmitters takes into account the vulnerabilities of all receivers in adjacent bands.⁷ While different radio service types may have different susceptibilities to interference, one of them—the most vulnerable—will be the binding constraint on setting an interference limit.⁸ We do not all wear

³ Nokia comments, 8, 9.

⁴ De Vries comments, 40–41.

⁵ *See, e.g.*, Alliance for Automotive Automation comments; Cisco comments; CommScope comments; CTIA comments; De Vries comments; Deere comments; Echostar/Hughes comments; Ericsson comments; Garmin comments; Lockheed Martin comments; Motorola comments; Nokia comments; NPSTC comments; Peha comments; Qualcomm comments; Robert Bosch comments; T-Mobile comments; TechFreedom comments; Verizon comments; Weber comments; WinnForum comments; WISPA comments.

⁶ *See, e.g.*, AT&T comments; Boeing comments; Cisco comments; CTIA comments; Deere comments; EWA comments; Garmin comments; Intelsat comments; NPSTC comments; Robert Bosch comments; TechFreedom comments; Qualcomm comments.

⁷ *Contra* Cisco comments, 7 (“Even receivers that are designed to function in the same band may have different characteristics and vulnerabilities, because they originate from different manufacturers, or at different points in time. An all-purpose one-size-fits-all HCT would likely not be feasible or effective for all such receivers”)

⁸ *Contra* Nokia comments, 9–10 (“The interference thresholds may be different from one service to another, thus making it nearly impossible to define a common set of parameters and their values”).

same-size clothes, and some people feel the cold more than others—but in a particular place, we all live in the same climate. The government does not tell us what to wear but does help us understand the weather. Thus, a single interference limit for a given band (i.e., its RF climate) is not only desirable and necessary but practicable.

III. There is solid support for further exploration of interference limits policy, sometimes with reservations

There is support, some of it qualified, for the interference limit/HCT approach from a wide range of stakeholders, including industry (both operators and manufacturers), academics, and trade associations.⁹ The Commission should act on this support by piloting interference limits in a limited-scope reallocation or rule change (see subsection VII.B below, p. 16).

⁹ AT&T comments, ii (“[A]ppropriate ‘harm claim thresholds’ . . . would add needed predictability and incentivize users . . .”), 3 (“But there are pragmatic ways to implement this principle, such as implementing ‘harm claim threshold’ concepts . . .”), 8 (“[A] harm claim threshold can be tailored to provide greater operational certainty for all users, while improving overall spectrum efficiency.”); Bykowsky & Sharkey comments, 3 (“If parameters are set to the right levels, a harm claim threshold would create strong incentives to build systems that can withstand significant interference from neighbors . . .”); CTA comments, 3 n.9 (referring to its comments in ET Docket No. 13-101, filed July 22, 2013, 1 “CEA . . . specifically supports the TAC white paper’s proposal to establish harm claim thresholds as one option . . .”); CTIA comments, 8 (“CTIA supports Commission action to review and study mechanisms (including harm claim thresholds) that could potentially be applied to new or currently inefficient spectrum allocations going forward.”); De Vries comments, iv (“[T]he Commission can use interference limits in general policy statements and specific rulemakings, and use harm claim thresholds in equipment regulation.”); Ericsson comments, 14 (“[I]t could afford equipment manufacturers and operators flexibility to determine how best to respond to in-band and out-of-band signal levels deemed acceptable. . . . Implementing a harm claim threshold would involve multiple challenges, however.”); EWA comments, 4 (“[T]he Commission also may need to adopt harm-claim thresholds or similar standards that define, not how a receiver must be designed, but its ability to reject interference before it is permitted to claim interference protection.”); FiRA comments, 5 (“The FCC is encouraged to adopt such ‘interference limits’ or ‘risk informed interference assessment’ or principles of a similar effect . . .”); McKay comments, 7 (“[T]he FCC should consider adopting minimum interference thresholds.”), 9 (“The Commission can gauge operational challenges in a band by setting receiver harm claim thresholds that must be exceeded before an operator can file an interference complaint with the FCC.”); Nokia comments, 9 (“While interference limit policies are desirable, they pose several challenges.”); Peha comments, 3 (“[H]arm claim threshold is a promising approach If parameters are set to the right levels, a harm claim threshold would create strong incentives to build systems that can withstand significant interference from neighbors”); T-Mobile comments, 7 (“T-Mobile previously supported, and continues to support . . . ‘interference limits policy,’ including ‘harm claim thresholds’”);

Several commenters recognize the importance of making explicit the costs of interference immunity.¹⁰ Interference limits and HCTs are an observable, objective, neutral coupling between the concerns of receiving systems and transmitting systems that will facilitate negotiations about who bears such costs. The Commission’s determination of the trade-off may not be optimal, or the trade-off point may change after rules are written. HCTs enable parties to adjust it.¹¹

While HCT adjustments would occur after rulemaking, an interference limit can facilitate bargaining before and during rulemaking since it is a simple but quantitative metric that (1) represents the RF environment that is expected to result from transmitter technical rules, and (2) can be used to assess the overall effects of a new allocation on receiving systems. It is a meeting point half-way across the long span of assumptions that bridges from the radiated power of a single transmitter to the interference immunity of a single receiver: actual transmit power, transmitter antenna gain, transmitter deployment pattern, receiver deployment and thus path length from undesired transmitter to the receiver, path loss assumptions, receiver antenna—not to mention the deployment of transmitters in a receiver’s own system and thus the desired/undesired signal ratio at that receiver.

Verizon comments, 12 (“An approach that develops band-specific expectations, identifies a level of interference below which an operator may not claim harmful interference, and provides for flexibility rather than mandating specific receiver characteristics, would go far in promoting more efficient use of spectrum.”); WISPA comments, 3–4 (“[A] two-phase process that considers and includes voluntary best practices and recommendations from a multi-stakeholder group . . . followed by rules that set harm claim thresholds to define interference protection.”).

¹⁰ AT&T comments, Summary (“[T]he licensee . . . may inflict the costs of poor performance on unrelated parties”); Bykowsky/Sharkey comments, 7 n.11 (“[T]he goal is to ‘internalize the externality’”); Boeing comments, 20 (“[O]ne of the major encumbrances to the widespread adoption of more efficient receivers is the externalities of their benefits”); Ericsson comments, 7 (“[T]he operator incurring the cost of improved receiver performance does not reap the benefits of such improvements.”); NCTA comments, 10 (“[T]he Commission should [not permit] users in particular bands to externalize costs onto others by under-investing in reasonable receivers.”); PK/OTI comments, 14 (“[R]ather than encouraging incumbents to create negative externalities for future services.”).

¹¹ Bykowsky/Sharkey comments 10–11 (efficiency enhancing effects); De Vries comments, 27 (bargaining).

Some commenters express reservations, concerns, qualifications, and outright criticism of the interference limit/HCT approach. I am grateful that they took these proposals seriously enough to contribute such thoughtful responses to the record. All their comments are important. I will tackle a few key ones below.

To distinguish concerns, it is useful to separate two contexts where the RF environment approach could be used by the Commission:¹²

1. In non-binding ways to communicate expectations and balance the interests of competing parties, for example, in policy statements and during the rulemaking process (“guidance” mode).
2. In binding ways that define rights and responsibilities, for example, in regulation (“rules” mode).

My use of the terms interference limits and HCTs aligns with these two categories and with the TAC’s definitions: interference limits are non-binding guidance and HCTs are binding rules.¹³

IV. Don’t shoot the messenger: Many reservations and fears about the interference limit/HCT approach apply to Commission rulemaking generally

Many of the concerns about the interference limit/HCT approach seem to be projecting fears and dissatisfactions with current spectrum policymaking onto this method. While I understand

¹² De Vries comments, 9.

¹³ De Vries comments, 1; *cf.* TAC Spectrum / Receiver Performance Working Group, *Interference Limits Policy and Harm Claim Thresholds: An Introduction* (2014) (*TAC IL/HCT Introduction*), Section 1, found at <https://transition.fcc.gov/oet/tac/tacdocs/reports/TACInterferenceLimitsIntro1.0.pdf>. Note that the NOI discusses “Interference limits policy, including harm claim thresholds” under the heading of “Commission Policy and Guidance” (*NOI* paras. 119-136), but HCTs are intended to be used in rules and thus do not fall under “policy and guidance.”; *cf.* NCTA comments, 15 (“While TAC harm claim threshold papers focus on ex post interference disputes, a notice of proposed rulemaking should seek comment on how to use interference limits policy in the many important rulemakings where the Commission considers introducing a new service adjacent to (and potentially co-channel with) an incumbent.”).

and respect these reservations, the RF environment approach will be no worse than the current equipment-oriented approach. It is important to separate institutional and technical problems inherent in spectrum policymaking from their recurrence in new approaches.

A. Involving all stakeholders may be contentious and time consuming—it usually is

There is unanimity in the record, as one would expect, that all stakeholders should be involved in rulemaking that could affect their interests. However, the participation of many stakeholders can generate contention that can be time consuming, and this may also be the case for interference limits as it is for current proceedings.¹⁴ The Commission’s rulemakings often consider numerous adjacent bands when it decides on reallocations or changes conditions, and it successfully balances competing claims.¹⁵ For example, there is frequently contention about the impact of in-band transmitter power and OOB limits on services in adjacent bands. In the end, the Commission resolves differences. The interference limit/HCT approach would not be any more contentious or time consuming than traditional processes. In fact, using interference limits could make developing rules not only more transparent but also more efficient by making assumptions explicit and quantitative.

¹⁴ Cisco comments, 7 (“Development [of HCTs] would be contentious and time consuming.”); Ericsson comments, 15 (“The process to set an acceptable interference limit is expected to be a contested one . . .”); Garmin comments, 15 (“It is highly unlikely that various disjointed parties will agree on the many assumptions required to structure HCTs.”).

¹⁵ Peha comments, 4 ([W]e cannot expect a typical adversarial debate among competing stakeholders to yield consensus for the harm claim threshold. The impetus to seriously consider the harm claim threshold should come from the entity whose job it is to promote efficient and valuable use of spectrum in the long term: the [FCC].”).

B. Developing interference limits may require anticipating the future interference environment—just as current rulemaking does

Interference limits and harm claim thresholds should take expected changes in the RF environment into account, to the extent possible.¹⁶ This is done routinely in any reallocation. In addition, technological progress can change the RF environment even when allocations do not change. The interference limit/HCT approach does not require any more insight into future interference environments than existing approaches do.¹⁷

It is possible—and perhaps even likely, given the contentious nature of many proceedings—that using interference limits in policymaking and/or HCTs in technical rules will lead to outcomes that one party finds disappointing or even considers dangerous.¹⁸ Losing an argument is part of policymaking, not a new feature of interference limits or HCTs.

If the Commission expects the RF environment to change several times after rulemaking, it can quantify this expectation during rulemaking in a technology-neutral way by using interference limit ratchets.¹⁹ Interference limits are unlikely to change once the rulemaking is over unless the Commission reopens a proceeding or updates an Order.

On the other hand, HCTs might be updated occasionally, in the same way that other technical rules change to reflect new information. They would not be continually updated, just as

¹⁶ NCTA comments, 15 (“[A]ny interference limits policy should account for technological advancement.”). *Contra* Cisco comments, 2 (“Even if performance standards or harm-claim thresholds were feasible, they would likely deter innovation because they would reflect only the current spectrum environment . . .”).

¹⁷ *Contra* NCTA comments, 13 (“[T]heir practical implementation would require considerable insight into a future interference environment that is difficult to predict.”).

¹⁸ *See, e.g.*, NPSTC comments, 5 (“[I]f a harm claim thresholds policy were enacted, it would provide a mechanism for the Commission to authorize an incompatible service within or adjacent to a public safety band with a defined level of interference public safety must accept.”).

¹⁹ De Vries comments, 18–19 (ratchet); *cf.* NCTA comments, 15 (“By clarifying as a matter of policy that any interference limits policy should evolve over time, the Commission would incentivize operators to invest in technological developments and update their networks over time, rather than under-invest in a manner that undermines the overall value of the nation’s spectrum resources.”).

existing technical rules only change occasionally.²⁰ I do not expect that harm claim thresholds would be updated as types of devices change, since—unlike receiver performance requirements—they characterize the overall RF environment and not the characteristics of particular devices.

C. RF measurements may not be able to identify the responsible party if there are several possibilities—but this is not new

Shure points out the difficulty of dealing with transient interference.²¹ This is certainly a challenge, but it is neither new nor unique to the interference limits/HCT approach.²²

One of the most difficult problems for both harm claim thresholds and interference resolution under current rules is identifying the party responsible for harmful interference if there are several possibilities.²³ In the general case, as well as for harm claim thresholds, one could

²⁰ *Contra* Cisco comments, 7 (“[A]ny HCT would need to be continually updated as the environments and types of devices change over time.”), 9 (“[Th]e agency would have to update it regularly to reflect the dynamic environment in which receivers operate.”). Cisco appears to want things both ways, arguing to the contrary at 2 that “[e]ven if performance standards or harm-claim thresholds were feasible, they would likely deter innovation because they would reflect only the current spectrum environment.”

²¹ Shure comments, 8 (“[H]ow to prove harmful interference when the victim network is only temporarily deployed and the interference signal has a transient nature . . .”).

²² See, e.g., TAC Spectrum and Receiver Performance Working Group, *A Study to Develop the Next Generation Systems Architecture for Radio Spectrum Interference Resolution* (2016), 9, found at <https://transition.fcc.gov/oet/tac/tacdocs/reports/2016/A-Study-to-Develop-a-Next-Generation-System-Architecture-V1.0.pdf> (“The dynamic nature of the modern wireless systems, the normal variability [of] radio propagation conditions, and the increased mobility of end user devices results in interference being highly intermittent in terms of time, space and frequency . . .”).

²³ *Cf.* Cisco comments, 8 (“Receivers may record levels of interference that may exceed a given HCT for reasons unrelated to particular transmissions.”); Garmin comments, 12 (“[T]he origin of an increase that exceeds an HCT may not be clear – and, therefore, not identifiable.”); NPSTC comments, 9 (“A significant challenge for public safety is ghost interference, i.e., harmful interference where the source is not readily known.”); Peha comments, 4 (“[T]he harm claim threshold is more difficult to apply when there are multiple sources of interference . . .”).

disentangle “cross coupling” between the transmit and receive paths within a radio transceiver by using third party measurement equipment.²⁴ On/off testing may also work in some cases.²⁵

Garmin’s concerns that “the FCC, if it tries to implement an HCT approach, will likely be unable to determine which contributor is ‘responsible’ for a change in the noise floor” or that the adoption of an HCT approach could “[i]n the long run, [lead to] increases in the noise floor [that] could render the RNSS bands inoperable for navigation and location-based services, technologies, and systems” are not germane.²⁶ It is highly unlikely that an HCT would be used to characterize the RF environment in a noise limited band where Garmin equipment is operating. It would, rather, describe the more intense RF environment in a neighboring band that has been reallocated to an interference limited service. Thus, if they impinge on Radio Navigation Satellite Service (RNSS) at all, interference limits/HCTs would be used to limit the interference generated in adjacent bands that could endanger the functioning of safety services.

D. The interference limit/HCT approach requires setting numerical values for parameters—but this is a staple of Commission rulemaking

It may sometimes happen that “selecting the appropriate numerical value for the various parameters that define a harm claim threshold will not be easy.”²⁷ There may also be difficulty reaching consensus on the parameters even before deciding their values. However, setting technical parameters and their values is a contentious topic even under the current regime.²⁸

²⁴ *NOI*, para. 135.

²⁵ De Vries comments, 17, 23.

²⁶ Garmin comments, 12.

²⁷ Peha comments, 3.

²⁸ *See, e.g., Use of Spectrum Bands Above 24 GHz For Mobile Radio Services, et al*, Report and Order, FNPRM, FCC-16-89, 31 FCC Rcd 8014 (10) (2016), paras. 297–306 (use of conductive emission limits); U.S. Dept. of Transp., *Analysis of 2016 Proposed Changes to Existing Out of Band Emissions (OOBE) Rules: Adjacent Channel Interference from Unlicensed National Information Infrastructure (UNII) Transmissions into the 5.9 GHz*, (2018), found at <https://www.transportation.gov/research-and-technology/analysis-2016-proposed-changes-existing-out-band-emissions-oobe-rules> (new limits potentially increase interference to DSRC); *NTIA Comments Regarding 24 GHz Emission Limits* (2021),

E. Concerns about defining and interpreting statistics are not valid—and the variability they capture is inherent in the RF environment

A few commenters raise concerns about the use of probabilistic methods, and particularly their applicability to their services.²⁹ They seem to believe that probabilistic analysis is inapplicable to safety-of-life services, which is belied by its use in other safety-critical contexts like nuclear power and aviation.³⁰

Riihijärvi et al. describe how probability could be used in the design and use of HCTs.³¹ Concerns about the difficulties caused by varying assumptions are no different for probabilistic methods than for rulemaking generally, cf. subsection IV.B above (p. 7).³² Threats to communications due to variability in the RF environment occur in safety-of-life applications as they do in others. Systems are designed to cope with them.³³ The need to anticipate variability is a fact of life, not a consequence of the harm claim threshold approach.

found at <https://www.ntia.gov/fcc-filing/2021/ntia-comments-regarding-24-ghz-emission-limits> (NTIA urges the FCC to harmonize domestic 24 GHz OOB limits with those adopted at WRC-19).

²⁹ See, e.g., Garmin comments, 15 (“[P]robabilistic methods and models . . . are subject to varying assumptions and interpretations that diverge quickly for dissimilar services . . . Probabilistic risk analysis also has the potential to mask the magnitude of interference to safety-of-life services.”), 12 (“[F]undamental questions exist as to whether it would be practical to implement HCTs based on probabilistic models, for determining interference to navigation systems.”); NPSTC comments, 5 (“[H]arm claim thresholds [are not] viable in the real world with respect to public safety.”).

³⁰ Cf. Nuclear Regulatory Commission, *An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis*, Revision 3 to Regulatory Guide (RG) 1.174, 83 FR 4520 (2018), found at <https://www.federalregister.gov/documents/2018/01/31/2018-01901/an-approach-for-using-probabilistic-risk-assessment-in-risk-informed-decisions-on-plant-specific>; Federal Aviation Administration, *Safety Risk Management Policy* (2017), 14, found at https://www.faa.gov/documentLibrary/media/Order/FAA_Order_8040.4B.pdf (“When sufficient empirical data exists, statistical probabilities should be used.”).

³¹ Janne Riihijärvi, Petri Mähönen & J. Pierre De Vries, *Statistical Inference on Spectrum Data for Design and Enforcement of Harm Claim Thresholds*, 3 IEEE Trans. on Cognitive Comm. & Networking 520–533 (2017) (Riihijärvi et al.), found at <https://ieeexplore.ieee.org/document/8022976>.

³² *Contra* Garmin comments, 9 (“Probabilistic methods for projecting and predicting interference utilized with HCTs also raise special concerns since they are subject to varying assumptions and interpretations . . .”).

³³ Motorola comments, 4–5 (“Resiliency and survivability are the fundamental design criteria for every radio that MSI makes for mission critical services.”).

Shure believes that it is impractical to specify interference limits for wireless networks like those it provides.³⁴ It is difficult to understand why this is so, since an upper bound interference limit could be found for the RF environments created by local private networks, regardless of the RF technology used. However, the question is moot since interference limits (or harm claim thresholds, if they were used) would not be set over the bands in which PMSE equipment is operating, but rather over bands that were being reallocated to a more intensive use like cellular or unlicensed communications.

F. Rules that use HCTs could lead to costly harmful interference claims—but so could any other technical rules

Garmin contends that “an HCT approach would expose parties to significant harms, disruption, and confusion” by forcing parties to “rely[] on Commission complaint procedures to sort out widespread issues after the fact.”³⁵ It seems to assume that a rulemaking that led to harm claim thresholds—or perhaps even the use of interference limits in guidance—would be less likely to protect the functioning of safety of life services than a traditional one. This is equally unlikely under the interference limits/HCT approach as under traditional rulemaking. Likewise, Garmin seems to believe that harm claim thresholds will lead to “significant economic harm in the expense of identifying interference sources and pursuing resolution through protracted negotiations and interference complaint proceedings.”³⁶ This is no different in the interference limit/HCT approach than under the current regime.

³⁴ Shure comments, 8 (“[I]t is almost impossible to specify meaningful interference limits A virtually unlimited number of measurement campaigns would be required . . .”).

³⁵ Garmin comments, 10.

³⁶ Garmin comments, 9.

V. Using HCTs for interference resolution poses challenges, but they can be overcome

A few commenters raise concerns about the use of harm claim thresholds that are inherent to the approach, and not merely a routine trait of spectrum rulemaking like the ones discussed in the previous section. I have dealt with some concerns in my comments and will now address specific issues raised in the record.³⁷

A. Making HCT claims may require making field measurements, but modeling is also an option

A harm claim threshold defines the RF environment conditions under which an operator can claim harmful interference, for example by demonstrating that a field strength statistic has been exceeded.³⁸ This may require making measurements. Such effort provides a barrier to “frivolous claims.”³⁹

The measurement process may be contentious. The Commission can reduce contention by defining in advance what an acceptable measurement and analysis process would be.⁴⁰

There are many organizations with extensive experience of doing RF measurements in the field, including consultants offering field surveys and drive testing, government laboratories like NTIA’s Institute for Telecommunication Sciences, and several universities.⁴¹

³⁷ De Vries comments, 28–30.

³⁸ De Vries comments, 1; *see also TAC IL/HCT Introduction*, Section 1 (“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.”).

³⁹ *Contra* Intel comments, 14 (“We are concerned this could lead to frivolous claims and assertions of rights to impose remediation on another party.”); Cisco comments, 8 (“The Commission could be flooded with innumerable claims of HCT ‘violations,’ placing significant investigatory and ‘policing’ burdens on Commission spectrum enforcement staff.”).

⁴⁰ *See, e.g.,* Riihijärvi et al., Section VI.D. *But cf.* Peha comments, 4 (“Useful proposals have been made, but the work is not done.”).

⁴¹ *See, e.g.,* <https://duckduckgo.com/?q=interference+hunting>; <https://duckduckgo.com/?q=rf+drive+test>; Spectrum Monitoring, ITS: The Nation’s Spectrum and Communications Lab, <https://its.ntia.gov/research-topics/spectrum-management-r-d/spectrum-monitoring> (last visited Jul 20, 2022).

The Commission may also choose to allow modeling as an alternative to measurement. Ofcom considered both measurement and modeling to verify compliance with its spectrum usage rights (SURs).⁴² SURs are statistical transmitter license conditions that use similar parameters to HCTs but for different purposes.⁴³ After extensive discussion with a wide range of stakeholders, Ofcom concluded that there was a general preference for modeling.⁴⁴ However, it concluded that no final choice needed to be made since “[e]ither approach can be used to verify SURs” and the method used could even “be changed during the lifetime of the licence if the licence holders wish.”⁴⁵

B. HCTs as proposed place the burden of pleading on the party claiming harmful interference, but the burden could be spread

Cisco and Garmin are concerned that HCTs place the burden of demonstrating harmful interference on the party claiming harm.⁴⁶ This is little different from the current situation when a party seeks Enforcement Bureau action against harmful interference, other than clarifying what justification needs to be provided. There is no clear regulatory precedent about where the burden of proving, or disproving, harmful interference lies.⁴⁷

⁴² Ofcom, *Spectrum Usage Rights: A guide describing SURs* (2008) (*SURs Guide*), Section 6, found at <https://web.archive.org/web/20080728142003/http://www.ofcom.org.uk/radiocomms/isu/sursguide/sursguide.pdf>.

⁴³ *Contra* Intel comments, 12 (“UK Ofcom’s Version of HCT, Called SUR . . .”). A SUR is a transmission system license, while an HCT allows a receiving system to seek protection against harmful interference.

⁴⁴ *SURs Guide*, para. 6.16.

⁴⁵ *SURs Guide*, para. 6.15.

⁴⁶ Cisco comments, 8 (“HCTs would place the burden of proof on the “victim” of interference by requiring the receiver to record or otherwise capture the level of interference at a specific time.”); Garmin comments, 10 (“[U]se of HCTs breaks with regulatory precedents and reassigns the burden of proving interference on incumbents. The HCT approach also places the burden of policing interference on existing spectrum users . . .”).

⁴⁷ *Cf.* Peter A. Tenhula, *Enforcement of Spectrum Usage Rights: Fair and Expedient Resolution of “Interference” Disputes*, 2012 TRPC (2012), found at <https://papers.ssrn.com/abstract=2032312>.

However, the Commission may choose to spread the burden. For example, it might allow a party who has made a preliminary claim to obtain corroborating data from the transmitting operator if that operator can collect data more easily than the complainant.⁴⁸

VI. Some comments misunderstand the intent and uses interference limits and harm claim thresholds

A few comments in the record misunderstand or misconstrue interference limits and harm claim thresholds. Since the RF environment approach is not yet widely used, it may be useful to clarify some points.

Cisco seems to believe that HCTs only apply to new devices.⁴⁹ This leads it to worry that HCTs would discourage innovation.⁵⁰ This may be because it wrongly considers HCTs to be receiver mandates.⁵¹ The Consumer Technology Association (CTA) also seems to believe that interference thresholds could discourage technology improvement because it conflates equipment-based receiver mandates with environment-based interference limits.⁵² Quite the opposite. *First*, HCTs and interference limits are ways to characterize a band’s RF environment,

⁴⁸ Cf. Multi Cell - Measurement in LTE, ShareTechnote, https://www.sharetechnote.com/html/Handbook_LTE_MultiCell_Measurement_LTE.html (last visited Jul 20, 2022); Catherine Sbeglia Nin, *What is Minimization of Drive Tests (MDT) in 5G?*, RCR Wireless News (2022), found at <https://rcrwireless.com/20220504/5g/what-is-minimization-of-drive-tests-mdt-in-5g>.

⁴⁹ Cisco comments, 8 (“HCTs would be counterproductive were they to encourage operators to keep outdated devices to maintain their adjacent spectrum protections, rather than upgrade or replace those devices with new ones that are subject to an HCT.”).

⁵⁰ Cisco comments, 8 (“HCTs could discourage innovation by incentivizing the design and operation of inefficient equipment HCTs could build in a safe harbor for devices based on older technology . . .”).

⁵¹ Cisco comments, 9 (“[C]isco has serious concerns that HCTs or other mandatory receiver performance standards . . .”).

⁵² CTA comments, 3–4 (“The Commission should not adopt government-mandated receiver performance standards or interference thresholds. Mandated technical rules related to receiver performance would disincentivize improvements”); cf. De Vries comments, 7 (subsection on equipment vs. environment), 10–11 (subsection on combining the categories).

but they say nothing about the performance of receiver equipment. *Second*, interference limits or HCTs could be chosen to incentivize the deployment of more interference-immune systems.⁵³ However, it should be up to operators to decide whether they do so by improving receivers or by some other means.⁵⁴

Intel believes that HCT levels would have to be set retroactively for all existing bands.⁵⁵ I am not aware of any such proposals and indeed, papers on this topic have emphasized the use of interference limits and HCTs in new allocations.⁵⁶

Intel objects to the fact that HCTs do not solve problems they are not designed to solve.⁵⁷ HCTs or interference limits are not intended to identify “poor-performing receivers.”⁵⁸ They may prompt (but do not require) operators to change elements of their system architecture, which may include receivers. Existing receivers in bands near reallocations that will not be immune to interference at the planned new levels are not “poor-performing” as such. As I have argued, “[T]he Commission has an RF environment challenge, not a receiver equipment problem. ‘Poor receivers’ are the canaries not the carbon monoxide in a coal mine.”⁵⁹

⁵³ Peha comments, 3 (“If parameters are set to the right levels, a harm claim threshold would create strong incentives to build systems that can withstand significant interference from neighbors, even in cases where today’s FCC policies do not provide these incentives because current neighbors do not generate significant interference.”).

⁵⁴ *Cf.* Cisco comments, 5 (“[T]here is no need for the Commission to . . . consider adopting federally mandated standards establishing minimum requirements for receiver performance.”).

⁵⁵ Intel comments, 10 (“[T]he vast majority of the time would be spent dealing with legacy/existing bands by re-opening rulemaking proceedings for all these established bands, in order to set HCT levels retroactively for each existing band.”).

⁵⁶ *Cf. e.g.* TAC Receivers and Spectrum Working Group, *Interference Limits Policy: The use of harm claim thresholds to improve the interference tolerance of wireless systems* (2013), found at <https://transition.fcc.gov/bureaus/oet/tac/tacdocs/WhitePaperTACInterferenceLimitsv1.0.pdf>; Riihijärvi et al.

⁵⁷ Intel comments, 11–12 (“The problem of determining criteria to draw the line between ‘good’ and ‘bad’ receivers in existing bands so that ‘bad’ receivers can be identified or otherwise incentivized to self-identify is a difficult problem that needs to be addressed, but HCT does not provide the solution.”).

⁵⁸ *Id.*

⁵⁹ De Vries comments, 5.

VII. The way forward

A. The Commission should issue a policy statement that describes how it will assess radio system compatibility

There is support in the record for the Commission to issue a policy statement that lays out how it will assess compatibility between radio systems.⁶⁰ The *TAC Basic Principles* white paper provides an excellent foundation for such guidance.⁶¹ The Commission should use the extensive and often detailed feedback in the record to develop *Basic Principles 2.0*. This statement of policy would guide staff on how to assess the compatibility of, and develop recommendations for, future spectrum allocations.

B. The Commission should pilot interference limits in a limited-scope reallocation or rule change

While a policy statement lays the groundwork for improved whole-system interference immunity, it will not be sufficient at band boundaries between disparate services and industries that have no common interests. Voluntary approaches like single-industry standards that represent interests only on one side of a band edge will not help here, either. Something like an interference limits approach is needed.

However, interference limits and harm claim thresholds—and RF environment approaches generally—are relatively unfamiliar. The Commission should develop its expertise and build confidence by piloting interference limits. It could use them to support developing rules in a new proceeding with limited scope, such as a 5 or 10 MHz band below 2 GHz that is being

⁶⁰ See, e.g., 5G Americas comments, 3; AT&T comments, 3; Cisco comments, 11–13; CTA comments, 13–15; De Vries comments, 47–49; Ericsson comments, 12–13; Intel comments, 3–8; Lumen comments, 4–7; NCTA comments, 6–13; Verizon comments, 9–11. Cf. CORF comments, 17–23; Longman comments, 2–7. *But see* Boeing comments, 8.

⁶¹ TAC Spectrum and Receiver Performance Working Group, *Basic Principles for Assessing Compatibility of New Spectrum Allocations : A White Paper (Release 1.1)* (2015) (*TAC Basic Principles*), found at <https://transition.fcc.gov/bureaus/oet/tac/tacdocs/meeting121015/Principles-White-Paper-Release-1.1.pdf>.

reallocated to terrestrial mobile service, with just a few stakeholders on either side of the band edge.⁶² The Commission can use interference limits (for example, a field strength level in the reallocated band exceeded at less than 5% of places and times) to balance interests between transmitters in one band and receiving systems in others. It can invite parties to propose and justify interference levels, or it can propose its own. The parties can bargain about the interference limit rather than falling into arguments about transmit powers and receiver vulnerabilities, disparate perspectives that are difficult to reconcile. The interference limit the Commission eventually chooses would encapsulate its expectations about the performance of transmitting and receiving systems.

Two parties seeking a mutually beneficial ad hoc adjustment of technical rules (perhaps with one compensating the other) would be an even more direct way to pilot the approach. The Commission could suggest that they use an interference limit as the commodity being traded. The parties can negotiate the price of an interference level without having to disclose sensitive or confidential information about their systems to each other.⁶³

The Commission could defer other possible uses of interference limits as well the use of harm claim thresholds until it has learned from this and perhaps subsequent pilots.⁶⁴ Pilots would lay the groundwork for more ambitious implementation of RF environment approaches, such as Prof. Peha's proposal that for five years, "any NPRM that contemplates a fundamental change in how spectrum will be used in a given band should proactively include a proposal to use a harm claim threshold in that band, and possibly adjacent bands as appropriate."⁶⁵

⁶² De Vries comments, 13–15 (Scenario A), 47; cf. Peha comments, 4 (“[I]t will be easiest to apply a harm claim threshold when the Commission is already making fundamental changes in how a band is to be used . . .”).

⁶³ Cf. Martin B. H. Weiss & Liu Cui, *Spectrum trading with interference rights*, in 2012 7th International ICST Conference on Cognitive Radio Oriented Wireless Networks and Communications (CROWNCOM) 135–140 (2012), found at <https://eudl.eu/doi/10.4108/icst.crowncom.2012.248690>.

⁶⁴ De Vries comments, 16–23 (Scenarios B–F).

⁶⁵ Peha comments, 4.

C. Other proposals in the record can support the use of interference limits

Proposals in the record that could contribute to the implementation and refinement of interference limits and harm claim thresholds include (1) establishing a framework for the use of probabilistic simulations, (2) using negotiated rulemaking to develop interference limits, (3) using an emulator to examine the market effects of using HCTs, and (4) a standard/reasonable receiver approach.

CTIA makes the important observation that “other Federal agencies . . . have instituted specific principles for how these types of probabilistic analysis techniques should be conducted,” and that “the Commission’s international counterparts routinely rely on these types of simulations.”⁶⁶ I support CTIA’s recommendation that “the Commission initiate a public discussion about the use of simulations and the framework that could be established to ensure they are utilized in a consistent and accurate manner.”⁶⁷

There is support in the record for involving all affected stakeholders in deliberations, and the use of interference limits should certainly follow this path.⁶⁸ A pilot of interference limits may be well suited to negotiated rulemaking, an enforceable collaborative approach that arose in the 1980s to address challenges similar to those facing the Commission today.⁶⁹ Negotiated rulemaking has more formality and accountability than many multi-stakeholder activities. This may be particularly attractive in developing interference limits and, eventually, setting HCTs.⁷⁰ A pilot of interference limits is likely to meet the statutory test that a negotiated rulemaking will

⁶⁶ CTIA comments, 12.

⁶⁷ *Id.*

⁶⁸ See *supra* note 5 on p. 2, e.g., Ericsson comments, 14 (“[C]onsideration of a harm claim threshold involve stakeholders representing all interests”); T-Mobile comments, 7 (“[H]arm claim thresholds could be adjusted through a multi-stakeholder forum”).

⁶⁹ Weber comments, iii, 2–6.

⁷⁰ Cf. Garmin comments, 11 n.27 (“The Commission’s *laissez-faire* approach proposed with HCTs is very like its hands-off approach to multi-stakeholder groups in the 3.7 to 4.2 GHz Band proceeding.”).

be in the public interest.⁷¹ Limited scope will limit the number of parties, increasing the likelihood that a representative committee can be convened and will reach a consensus.⁷² Even if the Commission does not choose to initiate a negotiated rulemaking, the best practices developed by the Administrative Conference of the United States (ACUS) could inform the formation of multi-stakeholder groups.⁷³

A pilot of interference limits would also provide a concrete test case for Drs. Bykowsky & Sharkey’s astute proposal that the Commission “allocate the necessary funds to scientifically examine, using advance [sic] engineering and economic techniques, the efficiency enhancing effects of an interference limit.”⁷⁴

The innovative proposals by Public Knowledge and the Open Technology Institute at New America (PK/OTI) and by NCTA about “standard” and “reasonable” receivers, respectively, resonate with the goals and philosophy underlying the interference limits/harm claim thresholds approach.⁷⁵ Both proposals seem intended for use in the guidance context rather than in rules, the same context as interference limits rather than harm claim thresholds. The difference is that they focus on radio equipment rather than the RF environment.⁷⁶

⁷¹ Weber comments, 5 n.29.

⁷² 5 USC § 565(b) (“[L]imit membership on a negotiated rulemaking committee to 25 members, unless the agency head determines that”); cf. Administrative Conference of the United States (ACUS), *Recommendation 82-4: Procedures for Negotiating Proposed Regulations* (adopted June 18, 1982), (*Recommendation 82-4*), 3–4, found at <https://www.acus.gov/sites/default/files/documents/82-4.pdf>, (factors bearing on decision to empanel a negotiating group); *id.* Recommendation 4(c) (“[N]egotiations should ordinarily involve no more than 15 participants.”).

⁷³ *Recommendation 82-4*; see also Philip J Harter, *Negotiating Regulations: A Cure for Malaise*, 71 *Geo. L.J.* 1, 46 (1982), found at <https://www.acus.gov/sites/default/files/documents/1982-04%20Procedures%20for%20Negotiating%20Proposed%20Regulations.pdf>.

⁷⁴ Bykowsky/Sharkey comments, 11–14.

⁷⁵ NCTA comments, 3 (“[T]he Commission would conduct interference analyses based on its determination of the receiver characteristics of a well-designed receiver using available technologies, rather than assuming hypothetical, worst-case scenario receivers.”); PK/OTI comments, 5 (“The Commission should state . . . that it assumes certain basic characteristics of any receiver potentially impacted by the Commission’s decision.”).

⁷⁶ Cf. De Vries comments, 10 (Table 1).

If adopted, such proposals could test key ideas of interference limits—notably, providing effective notice and delegating design/deployment decisions—without explicitly characterizing the RF environment in which receiving systems should operate. Just like the RF environment approach, both proposals provide effective notice of planned changes and leave decisions about receiver design to those who deploy systems.⁷⁷ Just like declaring an interference limit, declaring standard/reasonable receiver performance facilitates rulemaking by incentivizing affected parties to volunteer information.⁷⁸ And again in the same vein, these proposals encourage interference immunity without using mandates.⁷⁹

The standard/reasonable receiver approach faces its fair share of challenges, like any policy method. One is that there is no such thing as a standard receiver since different whole-system design trade-offs can lead to the same overall performance with different receiver specifications. Identifying one approach as “standard” or “reasonable” would require the Commission to choose between designs and business models.⁸⁰ Next, even if only one receiver type were designated as standard/reasonable, the Commission would still have to define many parameter values.⁸¹

⁷⁷ NCTA comments, 17–18 (“Likewise, as in the case of harm claim thresholds, some manufacturers and operators may decide that the cost of tolerating some level of interference is lower than the cost of investing in receivers that operate at industry standards.”); PK/OTI comments, 17 (“Manufacturers and licensees would have notice to the extent that their receivers are now ‘substandard.’”); 5 (“Licensees (or other relevant stakeholders) may then make the decision as to whether they wish to continue to offer ‘substandard’ receivers . . .”).

⁷⁸ PK/OTI comments, 16 (“[T]hey would have every incentive to come forward as quickly as possible with relevant information as to the nature of their receivers and what characteristics they believe typify the ‘standard’ receiver.”).

⁷⁹ NCTA comments, 17 (“[A] reasonable receiver approach would incentivize investment in receivers that advance overall spectrum utility and would require parties to internalize the costs of relying on substandard receivers.”).

⁸⁰ *Cf.* De Vries comments, 42 (“[D]ifferent vendors have different product strategies and different customers have different preferences.”), 35 (sixty values for the Department of Agriculture’s VHF High-Band Receiver mandate).

⁸¹ De Vries comments, 33–35.

Finally, this is an equipment approach and faces the challenge that relating receiver requirements to transmitter rules requires a long chain of assumptions.⁸²

VIII. Conclusions

The spectrum community has responded extensively and thoughtfully to the *NOI*. The Commission should now include receiving systems in the spectrum management calculus by issuing a policy statement that describes the principles it will use to assess spectrum coexistence. It should then pilot interference limits in a limited-scope rulemaking. I look forward to further progress on this important topic.

⁸² See *supra* p. 4 (span of assumptions). In the RF environment approach, an interference limit is a neutral coupling point between transmitting and receiving systems.