Testimony of

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hearing on

"The Role of Receivers in a Spectrum Scarce World"

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Chairman Walden, Ranking Member Eshoo and members of the Subcommittee on Communications and Technology, I am very pleased and honored to appear before you today to testify about the role of receivers in a spectrum scarce world. My name is Pierre de Vries and I am a Senior Adjunct Fellow at the Silicon Flatirons Center for Law, Technology and Entrepreneurship at the University of Colorado in Boulder.

I am a physicist by training and I have been involved in spectrum issues for about a decade, first managing technology incubations and technology policy projects at Microsoft and then as a policy researcher. As co-director the Silicon Flatirons Center's Spectrum Policy Initiative, I have organized, and participated in, a series of public conferences and expert working groups over the last four years that have brought together industry, policy makers, academics and civil society to develop solutions for the increasingly costly radio interference problems that we face, and that are the focus of today's hearing.

While my testimony today is based on my experience and my current academic research interests, it reflects solely my own views. I am testifying today entirely on my own behalf as a private citizen.

This testimony makes the following points:

- *First*, the "spectrum crunch" that really matters is the need to squeeze ever more services into increasingly crowded spectrum, and that requires improving the ability of radio systems to tolerate reasonable signals in adjacent frequency bands.

- *Second*, receivers are key. However, it's not just a matter of "better receivers," but rather of creating the right incentives so that receiving systems, the combination of transmitters and receivers, can better tolerate interference.

- *Third*, setting harm claim thresholds, i.e. explicit limits on the interference that systems have to tolerate without being able to claim harmful interference, would allow the FCC to incentivize improved system performance without mandating receiver performance standards.

- *Fourth*, Congress can help by continuing to focus on this issue; by making clear that the FCC can use approaches that do not mandate receiver standards, like the one outlined here; and by allocating funding to the FCC for engineering studies.

1. The "spectrum crunch" that really matters is the need to squeeze ever more services into increasingly crowded spectrum, and that requires improving the ability of radio systems to tolerate reasonable signals in adjacent frequency bands

Radio services are recognized, more than ever before, as vital to creating jobs and building a better society. The key challenge is to squeeze more and more services, of increasing variety, into ever more crowded spectrum. However, greater proximity increases the risk of service breakdowns due to harmful interference, caused both by poor interference tolerance in receivers and by inappropriate signals radiated by transmitters. Inadequate receiving systems can impose costs on neighboring transmitters, just as much as transmitters can harm receivers.

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

Interference is defined as "unwanted energy" in 47 CFR § 2.1(c); however, *harmful* interference only occurs when an unwanted signal "seriously degrades, obstructs, or repeatedly interrupts" a service. 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. The responsibility for harmful interference is therefore shared between transmitters and receivers.

The ability of receivers to tune out unwanted signals improves the further those signals are away from the desired frequency. Filtering out close-by signals adds cost. 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 questionable in an increasing number of cases.

The policy challenge is to ensure that services that are affected by each other's signals have the appropriate information and incentives to find the appropriate levels of interference and mitigation. The old strategy, which was to avoid any possibility of interference, is increasingly problematic as we need to crunch ever more services ever more closely together. A better approach is to maximize the value of wireless services, taking into account the costs and benefits of interference, rather than simply minimizing interference as an end in itself.

It has therefore become increasingly important to incentive receivers to tolerate reasonable signals outside their authorized bands. I believe the most effective way the FCC can do this is by drawing boundary lines more clearly, that is, by clarifying radio services' rights to be protected from harm, and their responsibilities to tolerate interference.

While this is a key ingredient, it is of course not the whole story; we also need to make economically efficient assignments that facilitate the adjustment of rights where necessary, and we need more effective enforcement of rights disputes. However, I will focus only on rights definitions today.

2. Receivers are key. However, it's not just a matter of "better receivers," but rather of creating the right incentives so that receiving systems, the combination of transmitters and receivers, can better tolerate interference.

Poor receiver performance has limited the introduction of valuable new services, and 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 AWS-1 cellular service, the recent GPS/LightSquared matter, and the unexpected interference from AWS-1 cell towers into broadcasters' electronic newsgathering receive stations.

This problem has been well understood for quite some time. For example, in its comments on the 2003 Receivers NOI ("Interference Immunity Performance Specifications for Radio Receivers" ET Docket No. 03-65) the NTIA enumerated examples of "a number of instances of reported interference that could have been avoided if appropriate receiver standards had been applied." 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."

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, 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 a 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 receiving system and the transmitting system play a role. The receiving 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 (aka internal guard bands).

An analogy can illustrate some of the issues. 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 I live in a tent, I'm going to be very sensitive to noise from next door. One response, and a typical one in spectrum policy, is to make the neighbors keep their voices down, i.e. limit the allowed transmit power in the adjacent band or perhaps even prohibit transmission altogether. However, it seems unreasonable for me to demand that my neighbors always whisper when they're in their own garden. I could also take some responsibility myself, for example by moving indoors; in radio terms, that's analogous to adding receiver filters to exclude signals in the adjacent band. I could ask the person I'm talking with to speak more loudly or come into the same room so that I can hear them better, or I could go to a room on the other side of the house. The radio analogy would be to increase the 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 (Sturges v. Bridgman 1897) cited by Ronald Coase in his 1959 paper "The Federal Communications Commission." In both cases, harm is reciprocal: avoiding disturbance to me by silencing my neighbors causes harm to them, and allowing them to make noise disturbs me. 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.

3. Setting harm claim thresholds, a statement in the service rules that defines the signal levels a service needs to tolerate without being able to bring a harmful interference claim, would allow the FCC to incentivize improved system performance without mandating receiver performance standards.

There are a variety of ways one can include the receiving systems into the interference trade-off. In addition to industry acting in its own interest, government agencies can, for example: improve designers' knowledge of the interfering systems on the other side of a band boundary by making information about the standards used in adjacent bands readily available; encourage manufacturers to use more advanced technology through information dissemination, procurement rules, and stating the interference they need to tolerate; make interference claims contingent on meeting certain receiver performance standards; and mandate receiver performance levels in FCC rules and government procurement contracts.

A key tool, I believe, is for the FCC to state the interfering signal levels in adjacent frequencies that a service needs to tolerate without being able to bring a harmful interference claim; the NTIA

could use the same approach when managing federal spectrum assignments. This is the key to the proposal I am putting forward today.

It is useful to define terms when discussing receiver performance, since the expression "receiver standard" is used with many different meanings. I will use the term *receiver specification* to refer to any description of receiver performance requirements. Receiver specifications can be developed by any party, including individual manufacturers, customers, standard-setting organizations or government. The term *receiver standard* will refer to a receiver specification developed by a standard-setting organization, and the term *receiver mandate* will refer to refer to a receiver specification (which may or may not be a receiver standard, i.e. a specification developed by a standard-setting organization) that is required by rule or statute.

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 performance specifications are just one of many requirements needed to define a wireless system; others include specifications of 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.

A better base-line solution is to set harm claim thresholds in service rules:

> A *harm claim threshold* defines the interfering signal levels that must be exceeded before a service can bring a harmful interference claim.

This gives 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. 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.

In other words: Setting harm claim thresholds allows the FCC to incentivize improved system performance without imposing receiver performance mandates. A judicious choice of thresholds will incentivize better receivers without mandating them.

Setting harm claim thresholds has many benefits:

> *First*, 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.

> *Second*, 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 adjudicate interference disputes.

Third, explicit thresholds enable better planning and thus encourage investment in new services by more clearly stating the rights and responsibilities of services to tolerate interference from each other.

The implementation details of a harm claim threshold approach have been discussed elsewhere, e.g. in my paper "Optimizing Receiver Performance Using Interference Limits" delivered at the TPRC conference this year (http://ssrn.com/abstract=2018080). I note a few key points here:

First, 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.

Second, the approach is not one-size-fits-all. 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.

Third, multi-stakeholder groups that include engineers from all affected parties at a band boundary can play an important role in developing the technical parameters and enforcement protocols for harm claim thresholds. The FCC's role may be limited to encouraging the creation of such a group, and protecting the interests of future licensees and other absent stakeholders. The work of a multi-stakeholder group can be the basis for a rulemaking, should that be required.

Fourth, 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.

Fifth, 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. 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 purpose in its envisaged use, e.g. that it will operate successfully given the prescribed harm claim thresholds. This could be done by individual companies, or collectively through an industry-certified "Seal of Approval." Alternatively, the FCC may *condition* full interference protection on receivers meeting certain performance criteria, as it did in the 800 MHz Public Safety proceeding (2004 Report and Order in WT Docket 02-55). Finally, it may choose to *mandate* receiver performance levels in the same way that the Federal Aviation Administration requires that aviation radio receivers meet certain industry standards.

In conclusion: setting harm claim thresholds is a minimally intrusive way to incentivize better receiver system performance. If expectations about the interference tolerance of receiving systems had been set more clearly in the past, the lost opportunities and economic harms I cited above could have been reduced or avoided.

4. Congress can help by continuing to focus on this issue; by making clear that the FCC can use approaches that do not mandate receiver standards, like the one outlined here; and by allocating funding to the FCC for engineering studies.

Congress plays an important role in ensuring that government creates the right incentives for the public and private sectors to make the most of our limited resources. Smart regulation will maintain and advance American leadership in spectrum innovation. It can do so in at least three ways:

First, this Committee can keep attention focused on the problem through oversight hearings like these. Spectrum players face many concurrent challenges. It is always tempting to defer difficult strategic problems such as improving the interference tolerance of radio systems. Congressional oversight provides essential reminders that we cannot realize the full potential of wireless services without dealing with this problem now.

Second, it can make clear that the FCC can use the harm claim threshold approach, or others like it, without new statutory authority. Some doubt exists whether the FCC has the authority to regulate receivers under current rules. Setting harm claim thresholds avoids this difficulty by simply clarifying the definition of harmful interference definition already on the books (47 CFR § 2.1(c)), and leaving it up to industry players, individually or collectively, to decide on the receiver performance level that would meet these needs. Since harm claim thresholds do not regulate receivers, no additional authority is needed.

Third, Congress can provide the FCC with the resources to fund the engineering studies that can accelerate the development of such smart regulation. It is vital that the FCC develop its own expertise on such a key topic, and not rely entirely on partial, tendentious submissions by warring

parties. With additional funding, the FCC could commission technical consultants to develop harm claim thresholds for critical cases, such as terrestrial cellular next to satellite service, or adjacent services in the shared 3.5 GHz band. It could also address fundamental issues that underpin wise regulation: for example, how much more spectrum value can be achieved, at what cost, given various kinds and degrees of improvement in system design?

Mr. Chairman that concludes my testimony and once again I want to express my appreciation for being invited to testify here today on this important topic. I would be happy to respond to any questions that you might have.