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Optimizing receiver performance using harm claim thresholds

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ABSTRACT

More and more systems need to be squeezed together in frequency, space and time in order to satisfy the growth in demand for radio services. However, greater proximity increases the risk of service breakdowns caused both by poor interference tolerance in receivers and by inappropriate signals radiated by transmitters.

In order to maximize the value of radio operation, a system view that facilitates trade-offs between receiver and transmitter performance is required. However, radio operation has traditionally been regulated using limits on transmitters, with few if any explicit constraints on receivers. This paper brings receivers into the regulatory picture by using harm claim thresholds, that is, interfering signal levels set by the regulator or spectrum manager that have to be exceeded before a receiving system operator can claim harmful interference; the specification of receiver performance (aka receiver standards) is left to manufacturers and operators.

The paper explains how harm claim thresholds would be defined from both radio engineering and regulatory perspectives, and outlines how parameter values can be derived for television service and for a new allocation with cellular service in the adjacent band.

Harm claim thresholds benefit both radio system operators and regulators by providing greater clarity about the entitlements that are entailed in assignments. They reduce business risk, and allow regulators to delegate both engineering design and boundary adjustment decisions to operators, thus allowing market forces to work more efficiently. These attributes will be particularly useful in bands with many, diverse and rapidly changing services and devices.

1. Introduction

To meet the rapidly increasing demand for wireless capacity, wireless systems must operate in ever closer proximity in frequency, space and time. However, greater proximity of potentially dissimilar services increases the risk of service interruptions. Such so-called harmful interference is caused as much by insufficient interference tolerance in receivers as by undesired energy radiated by other services' transmitters.[1] This paper proposes a regulatory approach that will allow regulators and operators to balance the responsibilities of receivers and transmitters when it comes to mitigating harmful interference.

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[1] There are two distinct uses of the term *interference*. Engineers typically use it to connote a signal level, whereas in regulatory use it refers to the impact of a signal level on a system's performance. The regulatory meaning derives from the definitions in Article 1 of the ITU radio regulations: “Interference. The effect of unwanted energy due to one or a combination of emissions, radiations, or inductions upon reception…”; “Harmful Interference. Interference which endangers the functioning… or seriously degrades, obstructs, or repeatedly interrupts a radiocommunication service…” (http://life.itu.ch/radioclub/rr/art01.htm). This paper will generally follow the engineering usage; thus, the term “interference limit” refers to a signal level, not the response of a system to the presence of interference at that level.

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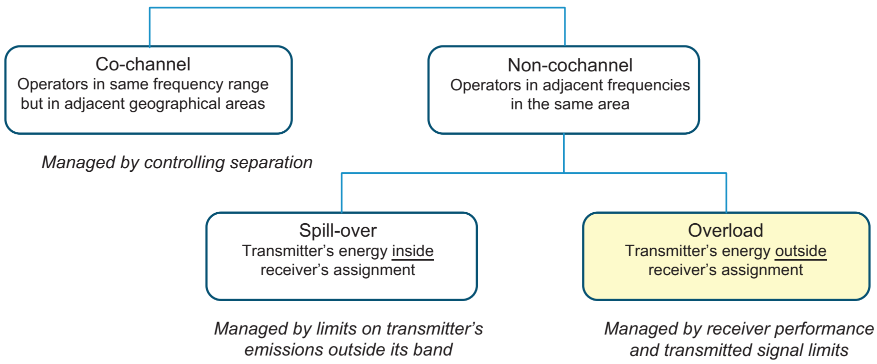

Fig. 1. A classification of interference types.

While the responsibility for harmful interference is shared between transmitters and receivers, and the existence of interfering energy does not determine who is responsible for its mitigation, radio regulation has traditionally placed the responsibility on transmitters, particularly those of new entrants. For example, the guiding principle in U.S. regulation – a large part of the context of this paper – is that new allocations, and particularly newly entering transmitters, should not cause harmful interference.[2] While the Federal Communications Commission (FCC) has the authority to make rules to govern the interference potential of any transmitter, it may only regulate receivers in the home.[3]

However, receivers that cannot reject moderate interfering signals transmitted outside their licensed frequencies can suffer service degradation, and may thus preclude new allocations in bands adjacent to them. Lists of cases where receiver performance was a significant issue limiting the regulator's ability to allocate spectrum for new services can be found in NTIA (2003, Section IV) and the FCC Technological Advisory Council (TAC) report on spectrum efficiency metrics (Spectrum Working Group, 2011, Appendix C); they include, among many others, fixed satellite service receiving earth stations, digital radio relay receivers, VHF Maritime receivers, cellular receivers in the AWS-1 F block, and the LightSquared/GPS case. The monetary scale of the problem is difficult to quantify since the impact is usually in gains foregone when new services cannot be deployed. However, it is large: for example, an economist retained by LightSquared estimated the consumer surplus of its proposed terrestrial cellular service at $120 billion (Bazelon, 2011, p. 1), while the Federal Aviation Authority (2011, p. 1) estimated the impact of a LightSquared deployment on the aviation community to be at least $70 billion. While these numbers are not strictly comparable, and both can be questioned as being self-interested, the large amounts cited provide an indication of the substantial financial implications of inter-service interference disputes.

This paper describes a way to increase the value of wireless services by bringing more clarity to operating rights, particularly to the degree of protection a service has against harmful interference. This will allow operators and their suppliers to create new solutions, optimize their deployments and resolve disputes among themselves in the ordinary course of business, without constant recourse to the regulator. It does this by bringing receivers into the regulatory calculus using *harm claim thresholds*, that is, interfering signal levels set by the regulator that have to be exceeded before a receiving system operator can claim harmful interference; the specification of receiver performance (aka receiver standards) is left to manufacturers and operators.

The rest of this introduction is devoted to a brief discussion of the role of receivers in interference disputes and a brief review of prior work. Section 2 discusses regulatory approaches to receiver management, outlining the regulatory context and describing the two main options, receiver mandates and interference limits. Section 3, the core of this proposal, focuses on the harm claim threshold approach to interference limits policy, describing the parameters required to define thresholds, how to choose parameter values, and regulatory roll-out. Section 4 discusses the benefits and limitations of this approach, and Section 5 sketches its application to cellular operations and television reception.

1.1. Receivers and interference

Interference, in the regulatory sense of a degradation in system performance (cf. the definition in Article 1 of the ITU radio regulations cited in footnote 1), arises from the interaction between transmitters and receivers. Both the energy delivered by the transmitter and the receiver's response affect the outcome: it takes two to tango.

The effect of a transmitter on a receiver generally decreases with larger separation between them in frequency and space.[4] Interference can be classified along these two dimensions: between operations using the same frequencies but in different (usually adjacent) geographic areas and operations using different (usually adjacent) frequencies in the same area (Fig. 1).

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[2] 47 U.S.C. § 303(y) (2) (C) (the FCC has the authority to allocate electromagnetic spectrum provided, among other things, that "such use would not result in harmful interference among users"); 47 C.F.R. § 2.102 (f) ("The stations of a service shall use frequencies so separated from the limits of a band allocated to that service as not to cause harmful interference to allocated services in immediately adjoining frequency bands.")

[3] 47 U.S.C. § 302 (a) (1) and (2), respectively.

[4] Exceptions to this generalization are not uncommon. For example, superheterodyne television receivers in North America are more sensitive to interference from so-called taboo channels, 14 and 15 channels away from the tuned channel, than to most channels closer in frequency (see e.g. Rhodes,