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Risk-informed interference assessment: A quantitative basis for spectrum allocation decisions☆

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1. Introduction

Lottery billboards proclaim the huge amounts that punters could win, but they do not reveal the infinitesimal chance of actually winning. Most harmful interference claims work the same way: incumbent services fearing harm from new entrants emphasize the sensational consequences of extreme interference events, but not their low likelihood.

Making a trade-off between the benefits of a new service and the risks to incumbents is at the heart of spectrum policy (see Section 2.1). It has, to date, frequently been qualitative and often based on worst-case scenarios. This paper makes a case for quantitative risk assessments that broaden regulatory analysis from “What's the worst that can happen?” to “What can happen, how likely is it, and what are the consequences?” and can thus provide a stronger evidence base for policy judgments.

Quantitative risk assessment (QRA) is a well-established technique, with an extensive literature and regulatory uses, in industries from finance to food safety, spanning many decades. The method was not explicitly used in spectrum analysis until the work of FCC TAC (2015a) and De Vries (2015), although wider use of stochastic modeling and acceptable interference statistics was advocated in IEEE-USA (2012). The literature and some non-spectrum applications are briefly reviewed in Section 2.2.2.

As illustrated Section 3, QRA complements the customary and well-established practice of worst-case analysis, which is an assessment of interference potential that focuses on a single, high impact scenario where most if not all parameters take extreme values.

QRA has many benefits, such as providing a more complete and nuanced analysis than worst-case assessment; providing a common currency for comparing different hazard types; and providing an objective basis for decision making. Of course, it is also limited in various ways: it requires more data and computation than traditional methods; it challenges the regulatory community to think in new ways, e.g. in using statistics; and it needs complementary perspectives from economics (e.g. cost-benefit analysis) and the humanities (e.g. cultural and psychological perspectives) to augment engineering analysis. The benefits and limitations of QRA are discussed in Section 4.

Spectrum policy makers and managers can begin to incorporate quantitative risk assessment into their procedures immediately—

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no new rules are needed. Recommendations for policy action by regulators and legislators are given in Section 5.

The scope of this paper is limited to regulatory activities, in particular the upfront assessment of harmful interference during rulemaking, not post-allocation activities such as adjudication and enforcement. It also leaves aside important topics such as risk communication, ongoing risk management, and the use of risk analysis in interference disputes and enforcement.

1.1. The MetSat case study

Section 3 will frequently refer to a meteorological satellite ("MetSat") case study. It was developed in a set of closely related papers that will be referred to as the "MetSat Risk Studies": De Vries (2015), FCC TAC (2015b), and De Vries, Livnat, and Tonkin (2016). We will illustrate our method by frequent reference to De Vries et al. (2016).

The case study deals with the reception of signals from Polar-orbiting Operational Environmental Satellites (POES); geostationary satellite services (GOES) in the same band are less vulnerable to interference. MetSat receiving earth stations in the 1675–1710 MHz band need to be protected from harmful interference from cellular mobile devices in the 1695–1710 MHz band, which were assigned U.S. licenses through the AWS-3 auction. Polar satellites are in a low earth orbit and make a usable pass over a given earth station about once a day. Since the received signal is very weak, a satellite is tracked by a large, fixed, high gain dish antenna. The aggregate of all the signals transmitted by cellular mobiles close to the receiver can cause interference. The key regulatory question in the U.S. was: How far away should co-channel cellular mobiles sharing the band be kept from MetSat earth stations to ensure that data used in weather forecasting is successfully received? The exclusion distance was a key element of the resulting band sharing rules.

The exclusion zones proposed in the original NTIA assessment were calculated for co-channel interference using the maximum transmit power of cellular mobiles (NTIA, 2010, referred to for convenience as the "Fast Track Report"). The subsequent report by a working group of the Commerce Spectrum Management Advisory Committee assumed a more realistic range of mobile transmit power which resulted in protection zones reduced by 21–89% (CSMAC, 2013, "WG-1 Report"). Both studies took a worst-case approach that used extreme values for most parameters, and focused only on long-term, co-channel interference. The MetSat Risk Studies, summarized in Section 3, provided a more comprehensive hazards analysis, such as looking at both short- and long-term interference scenarios, and including adjacent band as well as co-channel interference. That results in even smaller co-channel protection zones.

2. Risk assessment and spectrum policy

2.1. The policy context

The insatiable and growing demand for spectrum use rights (so well known that it will not be rehearsed here) leads to a continual process of spectrum re-allocation. More and more applications and devices—of increasing variety, that require ever more spectrum capacity—must be squeezed into ever-more crowded spectrum. This leads to closer packing in time, space, and frequency.

Greater proximity increases the cost of mistakes in allocation or assignment of spectrum use rights, and increases the risk of service breakdowns due to harmful interference. This leads to a tussle between incumbents and new entrants. Incumbents fear that new allocations will harm their services, and aspiring entrants fear that exaggerated forecasts of harm will stymie their plans. At the same time, growing demand means that wide guard bands and protection zones are increasingly hard to justify.

The question of whether a spectrum regulator should allow a new radio service is usually informed by engineering analysis oriented around the worst-case, followed by a qualitative rather than quantitative judgment of risk (De Vries & Littman, 2014). This paper argues for a more rigorous approach: quantitative risk-informed interference assessment.[1]

2.2. Risk assessment defined

Engineering risk assessment sets out to inventory possible hazards and calculate their severity and likelihood. For example, when considering whether to install a burglar alarm system one might consider the various circumstances under which unwanted people might enter your house; how likely each possibility might be; and what harm might befall you in each case, from pranks and petty larceny to assault.

2.2.1. Deterministic methods and worst-case analysis

Before turning to the definition of risk assessment, it is instructive to examine *deterministic methods*. These evaluate risk in terms of scenarios characterized by single-valued parameters. A deterministic approach does not necessarily entail using extreme values, but usually does. A "worst-case" analysis—perhaps more accurately described as a deterministic extreme value analysis, since for any "worst" case one can almost always construct an even worse one—considers the single scenario with the most severe

[1] Interference is not necessarily harmful. The ITU-R definitions, incorporated in national regulation such as 47C.F.R. 2.1 in the U.S., characterize *interference* as "[t]he effect of unwanted energy due to one or a combination of emissions, radiations, or inductions upon reception in a radiocommunication system, manifested by any performance degradation, misinterpretation, or loss of information which could be extracted in the absence of such unwanted energy", and *harmful interference* as interference that "endangers the functioning of a radionavigation service or of other safety services or seriously degrades, obstructs, or repeatedly interrupts a radiocommunication service".