The Spectrum Regulator's Dilemma in a Dynamic World: Limiting Interference without Stifling Innovation

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We propose that FCC consider revisiting the general policy of providing incumbents protection against any interference resulting from subsequent rule changes. It is well known that limiting spectrum licensees to providing specific services using specific technologies ("command and control") can seriously retard the adoption of new highly valuable technologies, such as cellular telephones. The FCC has recognized this and since the early 1990s has been providing for service and technological flexibility for most newly allocated bands.

What is less well known is that the FCC's sequential approach to accommodating change coupled with its interference protection policy toward incumbent uses can also be detrimental to putting spectrum to its highest value uses. When bands are newly licensed, or when the rules within a band change, the FCC attempts to protect incumbents (those licensed first) against any actual interference resulting from those changes. Protecting incumbents against any actual interference can greatly reduce the potential value of adjacent bands and gives incumbents no incentive to implement efficient mitigation prior to licensing of a new service. Bargaining by licensees of a new service to reduce incumbent protections in adjacent bands is also generally ineffective due to high transaction costs.

To provide licensees better incentives to efficiently mitigate interference in a dynamic world, we propose that the FCC (1) structure all future allocations, flexible or otherwise, on the assumption that such allocations must internally self-protect against potential interference from adjacent bands based on the assumption that those bands, regardless of current use, will be flexibly licensed for dense deployments of base, mobile and fixed transmitters operating at fully functional in-band power levels; (2) gradually apply the same self-protection assumption to all bands as mitigation technology improves and equipment is replaced ; (3) apply a generic out-of-band emission limit to all new allocations, flexible or otherwise, that is low enough to be non-interfering on the assumption that adjacent bands, regardless of current use, will be flexibly licensed for dense deployments of base, mobile and fixed stations; and (4) gradually apply the same generic OOBE limit to all bands and incumbent uses as equipment is replaced.

Managing Interference Efficiently

The goal of efficiently managing interference can be stated as finding the set of rules that minimize the total cost of interference, where:

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Total cost of interference = cost of mitigation + cost of interference that occurs despite mitigation.

Mitigation costs include the opportunity cost of guard bands or guard areas, cost of mitigating technology such as filters in transmitters and receivers, loss from constraints on service and technological flexibility, and cost of coordination with other licensees. Interference costs are the value of lost services due to interference that occurs despite mitigation.

Regulators do not have sufficient information to formally minimize the total cost of interference. But the formula does help structure thinking about least-cost solutions to the interference problem. Among the insights that can be inferred under reasonable assumptions about costs are: (1) there is a tradeoff between mitigation and interference costs, (2) there is a tradeoff between mitigation by transmitters and receivers, (3) the optimal amount of interference is likely to fall over time because technology reduces the costs of certain mitigation measures such as filtering, and the cost of lost wireless services from remaining interference is likely to rise with increasing population and new wireless products, and (4) zero interference is probably never optimal because the cost of eliminating all interference is very high and the cost of tolerating very small amounts of interference is generally low.

Traditional Licenses

The traditional command-and-control approach to spectrum management limits spectrum licensee to providing a specific service, using specific technology, at specific locations. In broadcasting, satellite and other traditional services, the FCC engineers a grid of locations and frequency assignments that packs licensees together with only the minimum necessary amount of spectrum per licensee and the minimum necessary spacing in frequency and geography between licensees needed to prevent unacceptable interference, given technology assumptions. The Commission also specifies the technology such as antenna height and design at the specified site, radio modulation, and maximum power. Any system changes must be approved by the FCC and are closely scrutinized. The system is highly effective at preventing harmful interference for existing uses at the expense of limiting flexibility to put spectrum to more valuable new uses as technology and consumer demands change over time.

Flexible Use Licenses

Flexible use licenses provide licensees the exclusive right of use of specific spectrum within a specific geographic area. Exclusivity is not absolute because limiting externalities (interference) to zero is too costly. Licensees are provided flexible choice of services and technology. Spectrum rights are transferable, divisible and aggregatable. Markets determine spectrum use and users. Interference between licensees can be caused by electrical noise from the out-of-band emissions (OOBEs) from transmitters in adjacent frequency bands and from co-channel signals in adjacent geographic areas. Even in the absence of any out-of-band emissions, receivers may experience blocking by strong signals in adjacent frequency bands.

The FCC establishes one system of interference rules that applies among all the flexible use licensees within a given flexible use band (e.g., cellular to cellular) and another set of rules that applies between new flexible use licensees and incumbents in another service (e.g., 700 MHz to TV, WCS to SDARS).

The basic approach the FCC uses for managing interference among flexible use licensees in the same band is as follows:

- Define a *band plan* of licensable spectrum blocks based on "expected" use assumptions, *e.g*., cellular architecture, minimum efficient block size, FDD paring. Because FDD is the "expected" duplexing methodology in the U.S., band pairing is provided whenever possible (*i.e*., each license is given a separate band for base and mobile transmission with a certain amount of spacing between them). If pairing is not possible, then unpaired licenses are created in which both base and mobile are permitted (TDD assumption) or one or the other is permitted for one-way use. The FCC does not provide external guard bands between adjacent FDD licenses, although a large "guard band" is provided between up/down bands. In contrast, the FCC may provide for external guard bands or additional mitigation by licensees (*e.g.*, internal guard bands or synchronization of up/down transmission between adjacent licensees) between adjacent TDD and between adjacent TDD and FDD licenses.
- For each permissible transmitter class (*e.g*., base, mobile and fixed), specify an *in-band power limit* set high enough for full functionality while avoiding interference from excessive power. Transmitter classes such as satellites, high power broadcasting and radar are generally not permitted in flexible use bands.
- Specify generic *out-of-band emission (OOBE) limit* applicable at the edge of the licensed spectrum block. The same limit is generally applicable to all transmitter classes. It is an absolute limit regardless of in-band power and chosen to be achievable at low cost with available technology. Compliance is determined by measurements at the transmitter output.
- Specify generic *out-of-area field strength (radiated power) limit*. Compliance is determined through calculation using transmitter parameters and a *standard propagation model*. The same limit applies to all transmitter types regardless of power or antenna height. Cumulative field strength is not limited, with the resulting uncertainty addressed by bi-lateral coordination among licensees and unilateral actions to mitigate interference *e.g.*, increase the *"desired"* signal strength by strategic placement of base stations with directional antennas along the geographic boundary.

Based on a long tradition in spectrum management that incumbents have the right to absolute protection from interference from new users, interference rules between new flexible use licensees and incumbents in other services are designed to prevent actual interference to incumbents' systems. Power and OOBE limits on the licensees in the flexible use bands are based on an interference model using the incumbent's system parameters and parameters of "expected" use for the flexible licensees. Incumbents are not expected to improve filtering or implement other additional mitigation measures.

The Good, the Bad and the Ugly

The current approach to managing interference among licensees within bands allocated for flexible use has worked well. The rules do not limit actual interference (which depends on the specific characteristics of individual systems, especially receivers) but instead rely on separating licensees by frequency and geography and limiting transmitter externalities (permissible classes and power limits) based on assumptions about expected use. The approach yields large reductions in interference potential at low cost while providing licensees great flexibility in system design and certainty about what they are permitted to do. Within this regime, licensees appear to have managed remaining interference potential efficiently, taking into account the continued improvement of technology and increasing value of spectrum.

The FCC's approach to interference management has not worked so well for spectrum with traditional licenses, and adjacent bands licensed at different times. A unifying theme underlying the difficulties is adaption to change. As discussed above, the traditional method of defining license rules removes nearly all possibility of interference above a defined level as long as nothing changes. The assumption is that even small changes will require FCC approval providing great certainty, but often stifling innovation.

When bands are newly licensed, or when the rules within a band change, the FCC attempts to protect incumbents (those licensed first) against any actual interference resulting from those changes. Protecting incumbents against any actual interference can impose major constraints on the potential value of adjacent bands and gives incumbents no incentive to implement efficient mitigation prior to licensing of the new service.

These difficulties are illustrated by the case of *WCS* (Wireless Communications Service) and *SDARS* (Satellite Digital Audio Radio Service). SDARS was licensed before WCS giving SDARS incumbent status. When WCS service rules were subsequently established, power limits (especially the out-of-band emission limit) were set at very low levels to protect incumbent SDARS receivers to a no-interference standard. The WCS band was rendered unusable for high valued uses because of the high cost of equipment capable of meeting such an extreme OOBE limit. WCS licenses were auctioned anyway and brought very low prices reflective of these costs. Since they were licensed first, SDARS licensees had no incentive to build receivers that would permit sufficient power in WCS band for WCS to have any value. Building better SDARS receivers would have cost more with all the benefits accruing to WCS. Thirty MHz of WCS spectrum at 2.3 GHz has been virtually idle since it was auctioned in 1997. Private negotiations were not able to resolve the difficulties. Finally, in 2010 the FCC changed the service rules for SDARS, raising the power limits for WCS spectrum not directly adjacent to SDARS.

Policies for a Changing World

The FCC should consider revisiting the general policy of providing incumbents absolute protection against any interference resulting from subsequent rule changes. What are the market failures that would justify such a policy change?

First, when not all rights have been assigned there is nobody to negotiate with. When an adjacent band is not licensed (*e.g.*, WCS band prior to licensing) or not all the rights are assigned (*e.g.,* bands with traditional services such as broadcasting where there is "white space") a new licensee in an adjacent band has no one to negotiate with to design a system that minimizes the total cost of interference. You can't negotiate with future licensees. The direct solution would be to assign all rights. But when most of the spectrum is occupied with traditionally licensed users this is difficult. Kwerel and Williams (2002) address this issue.

Second, even when most rights have been assigned (*e.g.*, WCS after licensing), but many licensees must agree to negotiate a change in the rules, holdout problems, free riding and generally high transactions costs may prevent achievement of a deal that potentially could make all parties better off.

Default assumed emission limits for adjacent bands

To address the problem that not all rights are assigned in adjacent bands at the time of licensing a new band, in all *future* allocations the FCC could require that licensees must self protect against interference exposure from adjacent band(s) *assuming* that those bands would be licensed under the flexible use model with base, mobile and fixed stations at fully functional power levels operating right up to the band edge. This would *internalize* the total spectrum cost of accommodating the new use rather than passing some or most of that cost off to someone else. It would thus provide better incentives to build more robust receivers and avoid disputes about interference. For example, suppose SDARS had been treated this way. They would have had to purchase enough WCS spectrum to create adequate guard bands to protect their highly sensitive receivers, make their receivers better, increase the power in their satellites, or taken other measures. They would have faced the opportunity cost of their system design, resulting in more efficient use of the spectrum.

Dynamic interference rules

To address the problem of high transactions costs in negotiating efficiency enhancing changes in interference rules as mitigation technology improves and spectrum value increases, the FCC should consider establishing dynamic interference rules. Over time, the level of potential interference that incumbents must tolerate might increase. This might include allowing in-band power to rise to fully functional levels where they are now set lower because of protections to incumbents in adjacent bands. This would recognize the increasing value of spectrum (increasing cost of lower-than-functional power levels) and create an incentive for incumbents to upgrade their receivers or adopt other mitigation over time (including internal guard bands) so as to tolerate functionally adequate power levels in adjacent bands. Similarly, the FCC should consider gradually tightening the generic out-of-band power limit to a non-interferring (or nearly so) level.

This would eliminate this mode of interference (an externality) in its entirety. To meet this limit licensees would have the incentive to make the lowest cost tradeoffs between better transmitter technology and internal guard bands as the relative costs of those choices changes dynamically over time.

Reference

Kwerel and Williams, 2002. “A Proposal for a Rapid Transition to Market Allocation of Spectrum” Working Paper 38, Office of Plans and Policy, Federal Communications Commission, November, 2002.