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Spectrum Policy Reform and the Next Frontier of Property Rights

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SPECTRUM POLICY REFORM AND THE NEXT FRONTIER OF PROPERTY RIGHTS

Philip J. Weiser and Dale Hatfield[*]

INTRODUCTION

Wireless spectrum is hot property. In early 2008, a number of firms bid almost $20 billion for the right to use 62 megahertz of spectrum in the 700 MHz band (which will be vacated by TV broadcasters after the transition to digital broadcasting).[1] During the debate over the rules for auctioning off this swath of spectrum, policymakers regularly emphasized that this auction represented a unique opportunity for firms to gain access to spectrum. As the *Washington Post* reported, the spectrum licenses up for auction, "which are ideal for carrying wireless signals, are particularly valuable because they will be the last up for auction for decades."[2]

The scarcity of wireless spectrum reflects a costly failure of regulation. In practice, large swaths of spectrum are vastly underused or used for low value activities, but the regulatory system prevents innovative users from gaining access to such spectrum.[3] In principle, therefore, the auction for spectrum licenses in the 700 MHz band need not be the "final opportunity" for enterprising firms to gain access to valuable spectrum. As a practical matter, however, making spectrum available for more efficient uses requires that Congress or the Federal Communications Commission ("FCC") reform the system for managing rights to use the spectrum. Since the estab-

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1 *See 700MHz: 19.1B and Counting*, DAILYWIRELESS.ORG, Feb. 27, 2008, http://www.dailywireless.org/2008/02/07/700mhz-191b-and-counting/.

2 Kim Hart, *FCC to Rule on Wireless Auction*, WASH. POST, July 30, 2007, at A1.

3 *See* GAO, STRONG SUPPORT FOR EXTENDING FCC'S AUCTION AUTHORITY EXISTS, BUT LITTLE AGREEMENT ON OTHER OPTIONS TO IMPROVE EFFICIENT USE OF SPECTRUM 13 (2005) ("[D]uring a four-day period in New York City, only 13% of spectrum between 30 MHz and 2.9 GHz was occupied at one time or another." (quoting MARK MCHENRY & DAN MCCLOSKEY, NEW YORK CITY SPECTRUM OCCUPANCY MEASUREMENTS SEPTEMBER 2004 (2004))).

lishment of that system during the New Deal, it has remained resistant to reform.[4]

Commentators have recognized the need for reform, but the policy debate has often gotten mired down in whether a "property rights"[5] or a "commons" model[6] is the preferable regulatory strategy for managing access to the radio spectrum.[7] This debate, which is largely resolved in the policy world in favor of a hybrid model (albeit with an emphasis on property rights),[8] has obscured the fact that advocates of property rights have failed to articulate just how such a regime would work in practice. Rather, they have largely concluded that since property rights work well for land, they can work well for spectrum rights as well.[9] But as we explain, spectrum is not the same as land, and a poorly designed property rights regime

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4 *See, e.g.*, Thomas W. Hazlett, *Assigning Property Rights to Radio Spectrum Users: Why Did FCC License Auctions Take 67 Years?*, 41 J.L. & ECON. 529, 530-31 (1998) [hereinafter Hazlett, *Assigning Property Rights*]; Thomas W. Hazlett, *The Wireless Craze, the Unlimited Bandwidth Myth, the Spectrum Auction Faux Pas, and the Punchline to Ronald Coase's "Big Joke": An Essay on Airwave Allocation Policy*, 14 HARV. J.L. & TECH. 335, 336 (2001) [hereinafter Hazlett, *Wireless Craze*].

5 Technically speaking, the Communications Act does not allow any individual or firm to possess a property right in radio spectrum. *See* 47 U.S.C. § 301 (2006); *see also* Note, *Federal Control of Radio Broadcasting*, 39 YALE L.J. 244, 250 (1929) (stating that the premise that the "the government 'owns the ether' . . . was an idée fixe in the debates of Congress" over the Radio Act of 1927). Nonetheless, at least in a few frequency bands, the FCC has moved to a "property rights-like" treatment of spectrum licensees. *See infra* Part III.A. Although we will sometimes use the more precise phrase "property-like" rights, we will often follow the precedent of using the less precise terms of "property rights," "property rights advocates," or "property rights model."

6 Under the commons model, the FCC does not license access to the radio spectrum at all; instead, it allows all comers to use spectrum subject to some technical requirements. In an earlier article, we explained both the virtues of the commons model and what model of regulation was necessary to ensure its effectiveness. *See* Philip J. Weiser & Dale Hatfield, *Policing the Spectrum Commons*, 74 FORDHAM L. REV. 663, 671 (2005).

7 *Compare, e.g.*, Stuart Minor Benjamin, *Spectrum Abundance and the Choice Between Private and Public Control*, 78 N.Y.U. L. REV. 2007 (2003) (challenging the case for using commons spectrum and advocating for private property model), *with* Yochai Benkler, *Some Economics of Wireless Communications*, 16 HARV. J.L. & TECH. 25 (2002) (making the case for commons spectrum). For an outstanding overview of the competing reform proposals, see Ellen P. Goodman, *Spectrum Rights in the Telecosm to Come*, 41 SAN DIEGO L. REV. 269 (2004).

8 FCC, SPECTRUM POLICY TASK FORCE REPORT 3, ET Docket No. 02-135 (2002) [hereinafter SPECTRUM POLICY TASK FORCE REPORT], *available at* http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-228542A1.doc (noting consensus of task force that the optimal strategy is a "balanced spectrum policy that includes both the granting of exclusive spectrum usage rights through market-based mechanisms and creating open access to spectrum 'commons,' with command-and-control regulation used in limited circumstances").

9 *E.g.*, Lawrence J. White, *"Propertyzing" the Electromagnetic Spectrum: Why It's Important, and How to Begin*, 9 MEDIA L. & POL'Y 19, 22 (2000) ("The real estate analogy, as well as the pre-regulation experience, points strongly to the conclusion that a system of property rights in the radio spectrum could resolve interference problems satisfactorily (in the same way that the owners of real estate resolve their potential interference problems) while providing a far more flexible and responsive mechanism for allocating spectrum to its most efficient uses.").

for spectrum might even be worse than the legacy model of spectrum regulation.

Under the legacy model of spectrum regulation, the FCC administers a command-and-control model of regulation rooted in the Communications Act of 1934. The essence of that model is that extensive regulation of the "airwaves," or the radio spectrum ("spectrum"), is necessary to avoid interference between competing users.[10] As Justice Frankfurter concluded when upholding the wide authority that the FCC has claimed in this area, "[t]he facilities of radio [spectrum] are limited and therefore precious; they cannot be left to wasteful use without detriment to the public interest."[11] Armed with a broad mandate to regulate a "scarce resource," the FCC has largely maintained the legacy model of regulation. As one 2002 FCC report put it, "[u]ntil recently, spectrum policy at the administrative agency level, especially at the FCC, was generally formulated on a band-by-band, service-by-service basis, typically in response to specific requests for particular service allocations or station assignments."[12]

Over the last fifty years, beginning with Nobel Laureate Ronald Coase's landmark criticism of spectrum regulation and call for tradable property rights, commentators have increasingly criticized the legacy command-and-control model of regulation.[13] Thirty years after Coase's landmark work, the FCC took a notable step away from the legacy model by experimenting with auctions for spectrum licenses (for "cellular"[14] telephone service).[15] Ten years after those auctions, the FCC's Spectrum Policy Task Force concluded that this model of regulation needed to be largely replaced.[16] Nonetheless, the FCC largely continues to adhere to the legacy model of regulation and in 2007 closed a proceeding designed to create property-like rights in spectrum.[17] By so doing without acknowledging the

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10 *See* JONATHAN E. NUECHTERLEIN & PHILIP J. WEISER, DIGITAL CROSSROADS: AMERICAN TELECOMMUNICATIONS POLICY IN THE INTERNET AGE 232 (2005).

11 NBC v. United States, 319 U.S. 190, 216 (1943).

12 *See* SPECTRUM POLICY TASK FORCE REPORT, *supra* note 8, at 8.

13 *See* R. H. Coase, *The Federal Communications Commission*, 2 J.L. & ECON. 1, 17-40 (1959).

14 The term "cellular" is a popular term and the one we will use in this paper. More precisely, however, federal law categorizes cellular—as well as other bands used for cellular-like services (e.g., PCS, SMR)—as "commercial mobile services" ("CMS"). *See* 47 U.S.C. § 332(d) (2006). For simplicity purposes, however, we use the familiar (and less technically precise) term.

15 The 1993 experiments with auctions became mandatory policy in 1997. *See* 47 U.S.C § 309(j) (2006) (delineating exceptions to auction requirement); Report and Order, Implementation of Sections 309(j) and 337 of the Communications Act of 1934 as Amended, 15 F.C.C.R. 22,709 (Nov. 20, 2000). For an explanation of the move to auctions, see NUECHTERLEIN & WEISER *supra* note 10, at 242-51.

16 *See* SPECTRUM POLICY TASK FORCE REPORT, *supra* note 8, at 3 ("In many bands, spectrum access is a more significant problem than physical scarcity of spectrum, in large part due to legacy command-and-control regulation that limits the ability of potential spectrum users to obtain such access.").

17 *See* Order, Establishment of an Interference Temperature Metric to Quantify and Manage Interference and to Expand Available Unlicensed Operation in Certain Fixed, Mobile, and Satellite

need for reform in this area, the agency effectively ignored the "increasing dissatisfaction with the current approach to spectrum management which suppresses competitive entry, blocks efficient transfer of spectrum to higher value use, and insulates old technologies from innovative challenge."[18]

The lack of an active policy debate on how to design property rights in spectrum is matched by a lack of debate in the scholarly literature. In the scholarly arena, the lack of debate reflects both the preoccupation with the merits or demerits of alternative models (i.e., command-and-control and commons) as well as a consensus that developing and enforcing property rights should be a reasonably simple task. After all, many commentators argue, the legal system can enforce property rights in land—generally by providing an injunction to remedy trespass—and should thus be capable of enforcing property rights in spectrum using doctrines and institutions developed for that context.[19] This conventional wisdom, as we explain, glosses over the challenges of creating use rights for spectrum.[20] Like applying the rules of real property to intellectual property, applying traditional property rules to spectrum can lead to unfortunate results.[21] Thus, like the case for defining property rights to use water, policymakers should embrace a property rights system for spectrum more complex than the classic model of trespass law developed for and employed in the context of real property.[22]

Frequency Bands, ET Docket No. 03-237 (May 4, 2007) [hereinafter Interference Temperature Metric], *available at* http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-07-78A1.pdf.

18 Patrick Xavier, Org. for Econ. Cooperation & Dev., *Secondary Markets For Spectrum: Policy Issues* 4 (2005), http://www.oecd.org/dataoecd/59/2/34758854.pdf.

19 Gerry Faulhaber, for example, concluded that:

> While courts may have their own inefficiencies, the rest of the economy seems to work quite well against the backdrop of the courts. If the property rights are written clearly and carefully, then the courts likely will be able to interpret them successfully, and furthermore, most cases would be settled by negotiations if the rules are clear.

Gerald R. Faulhaber, *Wireless Telecommunications: Spectrum as a Critical Resource*, 79 S. CAL. L. REV. 537, 558 (2006). To his credit, Professor Faulhaber noted in a footnote that:

> Establishing clear, easy-to-verify-and-measure property rights is a very substantial task that must be undertaken before a property regime is put into place. Current technical license limitations are a starting point, but only that. Great care must be taken when casting rules that are easy to interpret, measure, and enforce.

Id. at 558 n.123.

20 Another dissenting view from the conventional wisdom is presented in John W. Berresford & Wayne Leighton, *The Law of Property and the Law of Spectrum: A Critical Comparison*, 13 COMMLAW CONSPECTUS 35, 37 (2004) ("[M]uch as defining rights to land has not been simple, clarifying the rights to spectrum will be a complex task.").

21 *Cf.* Richard A. Posner, *Do We Have Too Many Intellectual Property Rights?*, 9 MARQ. INTELL. PROP. L. REV. 173, 174 (2005) ("One error that the courts and Congress can fall into is moving too quickly from the principles of physical property to those of intellectual property.").

22 For a discussion of the evolution of water rights, see Eric T. Freyfogle, *Context and Accommodation in Modern Property Law*, 41 STAN. L. REV. 1529 (1989). Notably, even the development of the rules for real property reflect more nuance than the seemingly straightforward rules of trespass law would suggest. Not only does the law of nuisance provide an alternate model for protecting property—

The challenge of developing a model of property rights for spectrum centers around three central questions. First, policymakers must develop a set of rights and remedies around spectrum property rights that reflect the fact that radio signals defy boundaries and can propagate in unpredictable ways. In particular, if policymakers simply created rights in spectrum and enforced them like rights in land (i.e., with injunctions for trespass),[23] they would invite strategic behavior: spectrum speculators would buy licenses for the sole purpose of suing other licensees when their transmission systems created interference outside the permissible boundary (i.e., act as "spectrum trolls").[24] To avoid this result, policymakers should develop a property system that fits the technological realities of the radio spectrum and should avoid providing a broad right to injunctive relief as traditionally afforded by trespass law.[25]

The second principal question is whether to establish a unitary property right for spectrum or whether to "zone" the spectrum by establishing different levels of protection against interference (i.e., an ability to transmit signals with more or less latitude) in different frequency bands. Despite the considerable success of the use right established for cellular providers,[26] we do not embrace the selection of that model of interference protection for all

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and a model more attuned to the nature of spectrum—but even real property law recognizes the need to adapt to technological and market realities. *See* Richard A. Epstein, *The Property Rights Movement and Intellectual Property*, REGULATION, Winter 2008, at 58, 60 (explaining that the traditional rules of trespass "subject[] th[e] initial presumption [of absolute ownership and the right to an injunction] to scrutiny in order to find those situations where the reconfiguration of rights [as in the case of water rights, among others] will lead to overall social improvements, typically by increasing in high transaction cost settings the value of property entitlements through the forced transformation of property rights."); *see also infra* note 25.

23 Henry Smith, *Property and Property Rules*, 79 N.Y.U. L. REV. 1719, 1732 (2004) ("In the law of real property, trespassers face injunctions and often punitive damages as well.").

24 Spectrum trolls would be, in effect, a counterpart to the much-reviled "patent trolls" that do not invent or market technology, but simply purchase patents to threaten or pursue litigation with the aim of extracting royalty payments. *See infra* notes 194-199 and accompanying text.

25 Notably, the traditional model of Blackacre (with an unmitigated right to exclude) is more of a fiction than a reality—a point explained by Henry Smith with respect to the concept that "governance rules" traditionally limit property law's "exclusion rules." As he explained:

> Governance rules are used to loosen and moderate the exclusion rules in these contexts. Special rules for airplane overflights, riparian rights to water, and parts of nuisance law are use rules that serve to modify but not replace the basic exclusionary regime. As a result, the common metaphor of property as a bundle of sticks is only partially apt: property is not built up use by use, stick by stick. Building up packages of rights use by use is the election of an expensive governance regime for all use conflicts. Rather, much property comes "pre-bundled" so that many use conflicts can be decided based on who invaded whose rights, in accord with the traditional lay view—an exclusion regime. As a matter of clear line-drawing and information costs, some reliance on this approach is almost inevitable.

Henry Smith, *Governing the Tele-Semicommons*, 22 YALE J. ON REG. 289, 299 (2005) (citations omitted). Along these lines, a pure exclusion regime is modified by innovations such as zoning codes, safe harbors for particular conduct, and refined criteria for obtaining an injunction.

26 *See infra* Part III.A.

frequency bands. Rather, we believe that multiple models of permissible spectrum use will better serve society by both preserving socially valuable uses of spectrum (such as AM radio) and allowing experimentation with different types of technologies (e.g., higher powered versus lower powered uses). Thus, under our proposed system, there would be a number of different models for allowable spectrum use (applying in different bands) to provide a predictable basis for spectrum licensees to enjoy rights against interference and guide their operations to avoid causing harmful interference.

The final question for managing a system of spectrum property rights is what institutional strategy will best facilitate the development of the property right and its enforcement.[27] As noted above, the FCC's record in managing the spectrum is less-than-inspiring. Nonetheless, we conclude that an administrative agency—be it a new one or a reformed FCC—is better positioned than a court to develop and enforce the rules governing the use of spectrum so as to facilitate technological progress and prevent parties with antiquated equipment from objecting to more efficient uses of spectrum.

This Article proceeds in four Parts. Part I explains the basics of radio technology, describes how spectrum policy has traditionally guarded against interference between rival users of the radio spectrum, and highlights the principal weaknesses of the legacy model of regulation. In Part II, we discuss the current debate on developing property rights for spectrum, highlighting how it largely fails to consider the realities of how radio waves operate. In particular, we use the case of AM radio to illustrate this point. Based on this discussion, Part II demonstrates how predictive models—that estimate interference statistically and probabilistically—will need to be the starting point (and act as a safe harbor, at least for some time) for any system of property rights in spectrum. Part III evaluates the challenges of developing an effective system for property rights in spectrum, including how an after-the-fact enforcement process would complement a before-the-fact zoning-like regime. Finally, Part IV addresses a number of critical premises for our regime, including why property rights in spectrum (as opposed to a sole reliance on commons access) make sense, what institutional reforms are necessary for an administrative agency like the FCC to implement an effective spectrum management system, and what strategies can such an agency use to encourage technological and economic progress.

27 To be clear, the three sets of issues noted above—those related to defining the use right, providing for different types of use rights, and adjudicating disputes between users—are not the only relevant issues in managing property rights in spectrum. Notably, there are significant challenges in transitioning from the current system to a new one, such as whether a windfall tax should be imposed on those firms gaining additional flexibility under a property rights system and how to address government uses of spectrum, which are managed under a command-and-control system. This Article, however, focuses on the three questions outlined above, leaving those two sets of (and other spectrum policy) issues for another day.

I. THE RADIO SPECTRUM AND ITS REGULATION

Despite its economic significance, part of why spectrum regulation remains an unfamiliar topic to most policymakers is that it is intangible and difficult to conceptualize. The relative mystery of how wireless technology operates, the general lack of awareness of how the current regulatory system gives rise to long and costly delays in deploying new wireless technologies, and the challenges inherent in overcoming the inertia of a long established policy largely explain the continuing dominance of the command-and-control model of spectrum management.[28] Notably, these delays and their associated constraints on technological dynamism harm consumers—and often not today's incumbents—who generally do not realize what they are missing. In the case of wireless telephone services, for example, the loss from delays in the rollout of more and better services occasioned by the legacy model of spectrum regulation was estimated in 1994 to be as high as $33.5 billion dollars.[29]

To appreciate the imperative of spectrum policy reform, policymakers (as well as scholars) must understand that radio spectrum is not mystical. When radio technology is demystified, the FCC's role clearly does not match the "wise man" vision of the New Deal; instead, its actions come closer to those of many federal agencies skewered by the 1970s public choice critique for protecting incumbents from competition.[30] This protectionism takes the form of a policy that purportedly guards against any possible interference to incumbent users by employing a command-and-control system that places a series of critical decisions in the hands of the regulator.[31]

This Part will explain the legacy model of spectrum regulation and highlight its fundamental flaws. In short, the legacy model of spectrum regulation stands as a major obstacle to technical and economic progress in three basic ways. First, as we explain in Part I.A, the traditional model of spectrum management is premised on avoiding interference between different users of spectrum at all costs, creating *technical inefficiencies*. Second, as we explain in Part I.B, the traditional model of spectrum regulation re-

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28 For an example of the type of delay typical under today's regime, see *infra* notes 92-97 (discussing Qualcomm's twenty month wait for a more flexible set of rules governing its licenses used for broadcasting TV shows to cell phones).

29 Jerry Hausman, *Valuing the Effect of Regulation on New Services in Telecommunications*, *in* BROOKINGS PAPERS ON ECONOMIC ACTIVITY, MICROECONOMICS: 1997, at 1, 24 (1998).

30 Public choice theory is the modeling of politics as a strategic game in which all actors pursue their economic objectives. On this theory, companies can be expected to pursue (or oppose) regulations to protect (or garner) "rents" for themselves. For a classic explanation of this theory and its implications, see Daniel A. Farber & Philip P. Frickey, *The Jurisprudence of Public Choice*, 65 TEX. L. REV. 873 (1987).

31 *See infra* Part I.B.

stricts spectrum trading, resulting in *economic inefficiencies*. Third, as we explain in Part I.B with reference to a recent decision involving Qualcomm, the traditional model of spectrum regulation enables incumbent firms skilled in the art of spectrum lobbying to use the system to their advantage, creating *political inefficiencies (increased lobbying costs) and inequities.*

A. *Spectrum Technology 101*

For most Americans, the radio spectrum is an elusive concept. For many years, scientists could not believe that "air" could conduct electricity—think of Benjamin Franklin's experiments with lightning—and accordingly assumed that a substance called "the ether" resided in the atmosphere.[32] During the later years of the 1800s, scientists concluded otherwise, defining some of the essential characteristics of how radio technology works.[33] In honor of one of these scientists, Heinrich Hertz, the defining unit of the radio spectrum—the frequency of radio waves—is measured in "Hertz" (or "Hz" for short).

In the years after the work of Hertz and others, inventors began to exploit the fact that, by modulating or changing the characteristics of a radio wave of a given frequency, individuals could communicate information over distances without wires or other physical media.[34] In the case of analog cellular services, for example, a frequency range (often called a "channel" or, for larger ranges, a "band") of 30,000 Hz (or 30 kHz) can provide sufficient bandwidth to establish a reliable communications link.[35] Significantly, one can use a particular 30 kHz channel to provide analog cellular service on one day and then still have the same amount of radio spectrum available for use on the next, meaning that spectrum is infinitely renewable.[36] Nonetheless, spectrum is still a scarce resource in the sense that two individuals

32 NUECHTERLEIN & WEISER, *supra* note 10, at 227.

33 HUGH G. J. AITKEN, SYNTONY AND SPARK: THE ORIGINS OF RADIO (1976).

34 NUECHTERLEIN & WEISER, *supra* note 10, at 228-29.

35 One kHz is one thousand Hz, one MHz is one million Hz, and one GHz is one billion Hz. *Id.* at 228.

36 Like air or water, however, the radio spectrum resource can be "polluted" by interference generated by natural sources of electromagnetic waves (e.g., lightning strikes) or by spurious emissions from radio transmitters or other man-made devices (e.g., florescent lights). For a discussion of issues surrounding viewing radio interference as pollution, see Goodman, *supra* note 7, at 398-401; *see also* J. Pierre de Vries, *Imagining Radio: Mental Models of Wireless Communication*, *in* 2ND IEEE INTERNATIONAL SYMPOSIUM ON NEW FRONTIERS IN DYNAMIC SPECTRUM ACCESS NETWORKS 372 (2007), *available at* http://www.pierredevries.com/docs/ImaginingRadioPID365685.pdf (exploring the policy implications of the different mental models used in understanding spectrum, signals, and radios).

cannot use the same frequency at the same time in the same place without canceling out—or at least interfering with—both transmissions.[37]

The possibility of interference between two users operating at the same frequency at the same time requires a little explanation about emerging technologies and the sophistication (or lack thereof) of radio receivers, which is where interference occurs. At first blush, the nature of interference may seem self-evident. But an unstated and sometimes inaccurate premise is that the users of the same frequency band at the same time are using reasonably cheap and dumb equipment.[38] With the aid of a number of emerging "smart radio" technologies, users can avoid interference by, for example, changing frequencies on a dynamic basis (in response to what frequencies are being used at a particular time).[39] The limitation of such technologies, however, is that they are often expensive or unproven.[40] Consequently, for services such as AM radio (and its installed base of inexpensive equipment), competing stations broadcasting at the same frequency at the same time in the same location will cause interference insofar as the average receiver will be unable to decipher the two transmissions and will leave the listener unable to listen to the programming of either station.[41] As we discuss in Part IV, however, self-help measures may enable receivers to avoid or minimize the threat of interference.

The term "the radio spectrum," while suggestive of radio broadcasting, actually refers to the entire set of frequencies that are suitable for technically feasible uses of wireless communications. Such uses, and thus the radio spectrum, have expanded over time. Because different bands within the radio spectrum have different technical characteristics, some bands are

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37 Goodman, *supra* note 7, at 285 ("Spectrum is simultaneously finite and renewable, everlasting and degradable.").

38 As one observer explained:

> The real culprits [for interference] are the speaker, car stereo, PC and other consumer electronics manufacturers for not designing their products to fend out this interference. With proper metal enclosures for motherboards and for wires that connect into these electronic components, the device can be shielded from picking up and amplifying stray radio frequency.
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> The problem, of course, is that many of the components and the products themselves are manufactured on the cheap overseas in places such as China and South Korea. And over the past couple of decades consumers have grown accustomed to getting PCs and other consumer electronics devices for bargain basement prices.

Marguerite Reardon, *FAQ: The 411 on Radio Frequency Interference*, CNET NEWS.COM, July 27, 2007, http://news.com.com/FAQ+The+411+on+radio+frequency+interference/2100-1033_3-6199149.html.

39 SPECTRUM POLICY TASK FORCE REPORT, *supra* note 8, at 14 ("[T]echnologies such as software-defined radios are called 'smart' or 'opportunistic' technologies because, due to their operational flexibility, software-defined radios can search the radio spectrum, sense the environment, and operate in spectrum not in use by others.").

40 Goodman, *supra* note 7, at 382-83; *see also, e.g.*, U.K. OFFICE OF COMMC'NS, OPEN SPECTRUM UK RESPONSE TO OFCOM'S "SPECTRUM FRAMEWORK REVIEW" CONSULTATION 9 (2005), *available at* http://www.ofcom.org.uk/consult/condocs/sfr/responses/openspectrum.pdf (calling such technologies "high-risk/high-reward").

41 *See* NUECHTERLEIN & WEISER, *supra* note 10, at 240.

more attractive for particular purposes than others. The most notable uses of spectrum (TV broadcasting, cellular telephone service, air-to-ground communications) rely on the frequencies between 30 MHz and 3 GHz because the physical dimensions of the antennas required for such transmissions are reasonably sized, transmitting and receiving devices are low in cost, and most fundamentally, the radio waves in such frequencies are less susceptible to being blocked or weakened by natural or manmade obstacles such as hilly terrain or tall buildings.[42]

B. *The Legacy Model of Regulation and Its Critics*

The traditional command-and-control model of spectrum management operates based on the "wise man" theory of regulation. Under this model, the government (1) allocates spectrum for particular uses or services (such as cellular telephone service, TV broadcasting, and air navigation systems); (2) allots spectrum resources (e.g., channels) to particular localities and/or particular types or classes of users within the particular allocations; (3) establishes technical and other service rules that apply to the service (e.g., maximum transmitter power limits); (4) grants licenses that assign users to particular channels or groups of channels (e.g., through comparative hearings or auctions); and (5) enforces usage rules through monitoring and other enforcement activities.[43] In short, this approach generally presumes that regulatory decisions, and not market forces, are "capable of deciding what [uses of spectrum are] *best* for the public."[44]

The FCC's initial conception of interference between rival users justified its highly conservative system of allocating and assigning rights to use spectrum.[45] That conception predates the FCC's creation when a "chaos of broadcasting" reportedly resulted from an absence of government oversight of spectrum users.[46] In essence, the FCC's early concern about interference in the radio spectrum was that, without close government supervision, eve-

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42 The range from 30 MHz to 3 GHz is a "sweet spot" that combines good propagation characteristics, little interference from lightning and other atmospheric phenomena, and the ability to build low-cost equipment. *See generally* LUCIEN BOITHIAS, RADIO WAVE PROPAGATION 310-11 (David Beeson trans., McGraw-Hill 1987) (1984); JOSEPH J. CARR, PRACTICAL ANTENNA HANDBOOK 479 (2001); FCC OFFICE OF ENG'G & TECH., BULL. NO. 70, MILLIMETER WAVE PROPAGATION: SPECTRUM MANAGEMENT IMPLICATIONS 1 (1997); JERRY C. WHITAKER, THE RESOURCE HANDBOOK OF ELECTRONICS 30 (2001).

43 NUECHTERLEIN & WEISER, *supra* note 10, at 232-39.

44 Douglas W. Webbink, *Frequency Spectrum Deregulation Alternatives* 10 (Fed. Commc'ns Comm'n, Working Paper, 1980), *available at* http:/www.fcc.gov/Bureaus/OPP/working_papers/oppwp2.pdf.

45 NUECHTERLEIN & WEISER, *supra* note 10, at 240.

46 For a discussion of both the incidence of amateur uses and widespread entry of radio stations, see Coase, *supra* note 13, at 1-6.

ryone would use the identical frequency at the same time in the same place and no one would be heard as a result.[47] Based on this fear, the FCC viewed interference like a virus to be avoided—as opposed to a fact of life (like different sources of light) that can be managed (say, by wearing sunglasses). As we will discuss below, this view continues to distort spectrum policy decisions, leading to the underuse of a valuable resource.[48]

The FCC's initial spectrum management regime adopted two basic strategies for safeguarding against interference. First, it required a certain amount of physical distance between stations operating at the same channel (co-channels). Second, it relied on the use of "guard bands" between adjacent channels to prevent any possible interference.[49] With respect to both strategies, the FCC adopted a very conservative view about the actual service area that should be within the scope of the license so as to protect against co-channel interference.[50] In particular, the FCC generally authorized blocks of spectrum—and assured against harmful interference—within a *predicted* signal area.[51] In the case of radio and later television broadcasting, for example, the FCC licensed Grade B signal contours based on its judgment about how signals would propagate in particular areas.[52] To make this judgment, the FCC used a predictive mathematical model and relied on a set of planning factors, such as the receiving antenna height and the ratio of the signal strength from the desired (or primary) licensee to undesirable ones (i.e., other transmissions).[53]

Even today, the contours of a licensed Grade B signal are based on a statistical judgment about the likely propagation of the relevant radio transmissions.[54] The FCC defines the relevant boundary based on a statistical judgment about whether, *in theory*, the signal would reach 50% of the locations at least 50% of the time.[55] But rather than allow other licensees to border the relevant contour (which would create the likelihood of interference created by overlapping signals), the FCC leaves significant space (the so-called "white space") between neighboring authorized users where spec-

47 NUECHTERLEIN & WEISER, *supra* note 10, at 232.

48 To give some credit to early U.S. policymakers, they did wisely reject the military's claim that the only means of managing interference on the "airwaves" was to authorize a government monopoly on spectrum. *See* Coase, *supra* note 13, at 3-4.

49 Hazlett, *Wireless Craze*, *supra* note 4, at 429.

50 *Id.*

51 *See, e.g.*, CBS Inc. v. Primetime 24 Joint Venture, 245 F.3d 1217 (11th Cir. 2001).

52 Steven J. Horvitz, *Rate Regulation and Video Competition*, 674 PLI/PAT 155, 230-31 (2001).

53 *Id.*

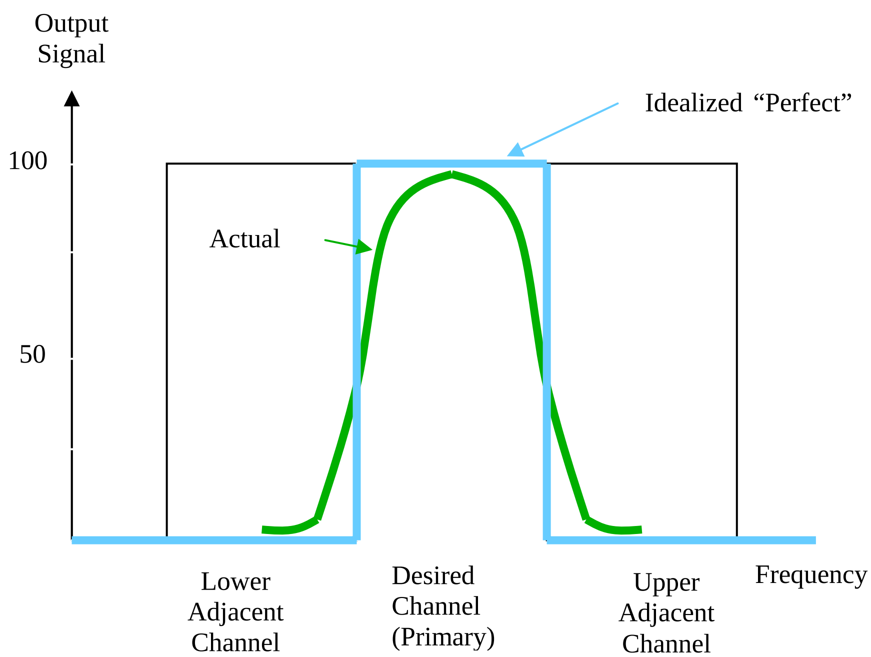
54 *See generally* Robert A. O'Connor, *Understanding Television's Grade A and Grade B Service Contours*, 47 IEEE TRANSACTIONS ON BROADCASTING 309 (2001).

55 Horvitz, *supra* note 52.

trum remains unused to avoid any possible interference between neighboring licensees.[56]

To appreciate how the "virus view" of interference has impacted the issue of adjacent channel inference, consider Figure 1 below:

Figure 1: Actual Signal Fit within a Single Channel



In general, the FCC has evaluated how to authorize adjacent transmitters for different radio channels based on the actual filters used by radio *transmitters*.[57] Reflecting this approach, the FCC has typically followed the conservative virus view of interference meant to ensure that none of the signal—even at a fairly low power—of the undesired transmission would bleed into the adjacent channel.[58] Moreover, the FCC has traditionally added an additional measure of conservatism when it develops its predictive models using planning factors that assume technologically limited receivers

56 Over the years, the FCC has investigated opportunities to enable this spectrum to be used without creating undue interference. In one famous case involving the authorization of low power FM stations, the incumbent broadcasters undermined the FCC's initiative. NUECHTERLEIN & WEISER, *supra* note 10, 240-42. In another, which the FCC recently acted on, the agency suggested that wireless broadband operators would be permitted to use the spectrum authorized to TV broadcasters that is left unused. Report and Order, Unlicensed Operation in the TV Broadcast Bands, 21 F.C.C.R. 12,266, 12,272, 12,277 (Oct. 18, 2006).

57 *See* NUECHTERLEIN & WEISER, *supra* note 10, at 240.

58 *Id.*

(and filters).[59] In short, on account of both of these considerations (i.e., protecting worst case transmitters and worst case receivers), along with the political clout of incumbent broadcasters, the FCC has adhered to an "allocations table" that widely spaces out authorized frequencies (i.e., both geographically and between channels in the same area).[60] For example, channel 21 would not be authorized in both Philadelphia and Baltimore, and channels 20 and 22 would not be authorized in Philadelphia if channel 21 was authorized for use in Philadelphia.[61]

In short, a principal weakness of the traditional spectrum policy regime is that it relies upon overly conservative and generally unrealistic predictive models of how radio waves propagate and how radio receiving systems operate (or could operate if proper incentives were applied), thereby unduly restricting the development of new services and new entry. In particular, the legacy system is technically inefficient because it models the transmission and reception of radio signals based on a set of unrealistic planning factors. It ignores, for example, a number of limitations of the primary licensee's service, including the level of sophistication and complexity of the signal itself, the type of transmission equipment, and the relevant receivers.[62] Again, these conservative estimates of the predicted signal strength are in addition to spaced out allocations that protect incumbents against the possibility of interference.[63]

In fairness to the traditional approach, some powerful reasons originally justified the conservative (and technically inefficient) model of spectrum management that characterizes the legacy command-and-control system. First, unlike today when policymakers can model interference in very sophisticated ways using computers, the early regulators had no such tools. Second, to the extent that the FCC's primary goal was to prevent interference at all costs, its approach made perfect sense, even if it sacrificed other possible uses of spectrum. Third, the traditional willingness to sacrifice more efficient uses of spectrum was far more tolerable when spectrum was less valuable. Fourth, the scientific understanding of how radio signals propagate and are measured has improved dramatically over the years. Fifth, signal processing technology in receivers, which mitigates interference and facilitates new uses of spectrum, is a relatively recent invention and continues to become more economical. Finally, and given the aforementioned reasons, the traditional emphasis on simplicity and front-end

59 *Id.*

60 *Id.* at 239-40.

61 *Cf.* Randy Hoffner, *White Space Devices: Threat to Broadcast TV?*, TV TECH., Dec. 5, 2007, http://www.tvtechnology.com/pages/s.0079/t.10086.html ("As television engineers, most of us are well familiar with the reasons that, for example, there is no NTSC television signal on Channel 4 in Philadelphia or in Hartford, Conn. The reason is these markets are too close to New York, Boston and Washington to avoid interfering with Channel 4 signals in those cities.").

62 *See* NUECHTERLEIN & WEISER, *supra* note 10, at 240-41.

63 *Id.* at 239-41.

protections over any back-end evaluation was a sound approach. But in light of the increased demand for spectrum, particularly during the 1990s once cellular telephony rose in popularity, policymakers began to realize that they could no longer responsibly rely on the traditional approach and needed to look for a more technically efficient model of spectrum regulation.

From an economic perspective, the traditional approach always appeared questionable. As noted above, Ronald Coase criticized the FCC's legacy system of regulation, suggesting that it artificially restricted the possible uses of spectrum and invited the use of the regulatory process—through claims about interference—to protect incumbents against entry (i.e., rent-seeking).[64] Although Coase emphasized the economic inefficiencies inherent in this system, its political dynamics are also very problematic. In particular, this system relies on arcane distinctions and an opaque lobbying process mastered by incumbents and bewildering to entrants.[65] Consequently, a transparent and across-the-board property rights model not only provides greater economic efficiency, but also a fairer process of acquiring rights to spectrum (i.e., one where all comers—and not exclusively politically sophisticated parties—can succeed).[66]

Coase's critique of the legacy model of regulation anticipated and outlined the basic elements of what has since become known as the "Coase Theorem" (i.e., that well-defined property rights and low transaction costs allow parties to bargain to reach efficient outcomes).[67] Based on this framework, Coase highlighted that the FCC left property rights (i.e., the rules on interference) murky and created significant transaction costs for the trading of spectrum rights, thereby undermining economic efficiency goals.[68] In particular, he explained that the FCC's regulatory system ensured that certain lower value uses of spectrum (such as today's UHF television

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64 *See* Coase, *supra* note 13, at 17-40.

65 As Thomas Hazlett has emphasized, this dynamic emerged not long after the command-and-control regulatory regime was put in place. *See* Hazlett, *Wireless Craze*, *supra* note 4, at 372 ("Probably no quasi-judicial body was ever subject to so much Congressional pressure as the Federal Radio Commission." (quoting LAURENCE F. SCHMECKEBIER, THE FEDERAL RADIO COMMISSION 55 (Brookings Institution 1932))).

66 Jim Snider explained this point:

> The complexity of the current system militates against public involvement. . . . The result is that band-by-band rulemaking is synonymous with special interest politics, with politically powerful incumbent licensees making out like bandits. By creating fewer different types of bands, changes to any one band are more important and thus can draw the interest of a larger fraction of the public.

J.H. Snider, *The Art of Spectrum Lobbying* 37 (New America Foundation, Working Paper No. 19, 2007), *available at* http://www.newamerica.net/files/WorkingPaper19_SpectrumGiveaway_Snider.pdf.

67 R. H. Coase, *The Problem of Social Cost*, 3 J.L. & ECON. 1, 19 (1960).

68 Coase, *supra* note 13, at 27 n.54.

broadcasting) could not give way to other higher value uses (such as today's cellular telephone service).[69]

Coase's fundamental premise was that the FCC should define property rights in spectrum licenses and allow for the free trading of those rights.[70] Under such a system, Coase explained, the equilibrium would not likely be one with no threat of interference, directly challenging the FCC's virus view of interference.[71] Rather, in Coase's view, spectrum regulation should seek to ensure that "the gain from [allowing additional] interference more than offsets the harm it produces."[72] As Coase concluded, in an undeniable understatement, "[t]here is no reason to support that the optimum situation is one in which there is no interference."[73] To further underscore this basic point, Coase later commented about pollution: "I am sure that pollution exists, I know that much; what I do not know is whether we have enough of it."[74] In short, Coase highlighted that interference (like pollution) is a byproduct of a socially valuable endeavor (radio communications) that should be tolerated except insofar as reasonable mitigation measures are available (but not being used) or the costs of the harmful activity outstrip the social benefits occasioned by the valuable endeavor.[75]

Despite Coase's and other economists' withering criticism of the FCC's legacy model of spectrum regulation, the FCC rarely departed from its traditional command-and-control approach to spectrum management before the 1990s.[76] In part, its traditional regulatory strategy reflected mis-

69 *Id*. This is hardly a hypothetical trade. Not only do the bands now used for UHF broadcasting represent spectrum that could be used effectively for other forms of wireless communications, a 1992 study suggested that lifting the use restriction that prevents TV stations from selling their spectrum for use in wireless communications would have produced a net social gain—in the Los Angeles market alone—of over $1 billion from 1992 to 2000. *See* Evan R. Kwerel & John R. Williams, *Changing Channels: Voluntary Reallocation of the UHF Telecommunications Spectrum* vii, 100 (Fed. Commc'ns Comm'n, Office of Plans and Policy, Working Paper No. 27, 1992), *available at* http://www.fcc.gov/Bureaus/OPP/working_papers/oppwp27.pdf. The actual amount of social gain that would have emerged from such a trade is lower than the $1 billion figure because the FCC authorized a number of other entrants into the cellular telephone market whereas the calculations of the 1992 study assumed no additional entry. *Id.* at vii.

70 Coase, *supra* note 13, at 30.

71 *Id.* at 25, 27.

72 *Id.* at 27.

73 *Id.*

74 This quote comes from Professor Bruce Lehman, a former student of Ronald Coase and currently a professor at the University of California, San Diego. He quoted Coase as making this statement in a presentation at the Business Method Patents and Financial Services conference organized by the Federal Reserve Bank of Atlanta in April of 2003. The conference program is available at http://www.frbatlanta.org/invoke.cfm?objectid=A6BDAC9C-384A-4C59-9096A079D324A9B7&method=display. We thank Gideon Parchomovsky for bringing this quote to our attention.

75 *See* Coase, *supra* note 13, at 28-29.

76 For an exemplary critique of the FCC's traditional approach, see Gerald R. Faulhaber & David J. Farber, *Spectrum Management: Property Rights, Spectrum, and the Commons* (AEI-Brookings Joint

taken and often ultraconservative views about the nature of interference between different users (and uses) of spectrum. More often than not, however, these restrictions simply reflected the confluence of interests between regulators—who valued their role as wise men (or wise women)—and the ability of politically powerful incumbent licensees to use the regulatory process to limit competition.[77] Unfortunately, the FCC's deference to incumbents undoubtedly left consumers worse off, because even though "entry that generates interference damage exceeding consumer gains is inefficient, established interests reliably oppose both inefficient *and* efficient entry."[78]

With the explosion of wireless services in the 1990s and the increased demand for spectrum, policymakers began to face what some have called a "spectrum drought."[79] As policymakers have realized, however, this drought is solvable. To do so, the FCC has begun to question the virus view of interference, to evaluate how technology had upended some of its policies, and to reform some of its policies accordingly.[80] Consequently, policymakers are growing increasingly skeptical of the classic "wise man" restrictions on spectrum use.[81]

As the Spectrum Policy Task Force Report ("Report") explained, the key failing of spectrum policy is not the scarcity of available spectrum per se, but rather that administrative rigidities prevent more efficient use of this unique resource.[82] In its Report, the Task Force concluded that "[t]o increase opportunities for technologically innovative and economically efficient spectrum use, spectrum policy must evolve towards more flexible and market-oriented regulatory models."[83] As Chairman Powell explained upon

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Ctr. for Regulatory Studies, Working Paper No. 02-12, 2002), *available at* http://100x100network.org/papers/faulhaber-brookings2002.pdf.

77 For the classic explanation of this dynamic, see Richard A. Posner, *Taxation by Regulation*, 2 BELL J. ECON. & MGMT. SCI. 22 (1971).

78 Thomas W. Hazlett, *Liberalizing US Spectrum Allocation*, 27 TELECOMMS. POL'Y 485, 487 (2003).

79 *See* Policy Statement, Principles for Reallocation of Spectrum to Encourage the Development of Telecommunications Technologies for the New Millennium, 14 F.C.C.R. 19,868, para. 2 (Nov. 22, 1999) (recognizing "increased demand for a finite supply of spectrum").

80 In one proceeding, for example, the FCC concluded that "the benefits of adding new services or capabilities to a frequency band" outweighed "the relatively small" possible harms to the incumbent service. Report and Order, Amendment of Part 2 and 25 of the Commission's Rules to Permit Operation of NGSO FSS Systems Co-Frequency with GSO and Terrestrial Systems in the Ku-Band Frequency Range, 17 F.C.C.R. 9614, para. 32 (May 23, 2002) .

81 Consider, for example, Commissioner Adelstein's call for regulators to use "a light touch and a sense of humility" in developing rules that restrict uses of the spectrum. Jonathan S. Adelstein, Comm'r, Fed. Commc'ns. Comm'n, New Frontiers in Wireless Policy: A Framework for Innovation, Remarks to the Silicon Flatirons Telecommunications Program, University of Colorado at Boulder 3 (Apr. 9, 2003) (transcript available at http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-233139A1.pdf).

82 SPECTRUM POLICY TASK FORCE REPORT, *supra* note 8, at 3, 14-15.

83 *Id.* at 3.

releasing the report, innovative services are often "inhibited by the 'mother may I' phenomenon—businesses must go to the FCC for permission before they can modify their spectrum plans to respond to consumer demand."[84] In short, the FCC's expansive authority over spectrum is increasingly problematic; after all, "[a]s the variety of spectrum uses and associated technologies change and spectrum demand expands, the difficulties [in effectively managing such a system] compound."[85]

Since the Report, the FCC has shown little initiative in confronting some of the more challenging aspects of creating property rights in spectrum.[86] In particular, the Report's effort to define the contours of "harmful interference"[87] through a measurement-based system—which it styled as an "interference temperature"[88]—fell into a regulatory abyss.[89] Consequently, firms developing new wireless technologies must continue to ask the FCC for permission to modify the existing heavily prescribed limitations set forth in the relevant service rules.[90] Moreover, the FCC continues to pre-

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84 Michael K. Powell, Chairman, Fed. Commc'ns Comm'n, Broadband Migration III: New Directions in Wireless Policy 4-5 (Oct. 30, 2002) (transcript available at http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-227944A1.pdf).

85 *See* Xavier, *supra* note 18, at 11.

86 The notable exception is its secondary markets initiative. *See* Report and Order, Promoting Efficient Use of Spectrum Through Elimination of Barriers to the Development of Secondary Markets, 18 F.C.C.R. 20,604, 20,607 (Oct. 6, 2003).

87 *See* SPECTRUM POLICY TASK FORCE REPORT, *supra* note 8, at 27-30. The FCC defines "harmful interference" as "[i]nterference which endangers the functioning of a radionavigation service or of other safety services or seriously degrades, obstructs, or repeatedly interrupts a radiocommunication service operating in accordance with [international] Radio Regulations." 47 C.F.R. § 2.1 (2006). This standard leaves the FCC with significant discretion, and the FCC has yet to develop a more precise definition of the concept. For an excellent discussion of the importance of and challenges inherent in doing so, see R. Paul Margie, *Can You Hear Me Now? Getting Better Reception from the FCC's Spectrum Policy*, 2003 STAN. TECH. L. REV. 5, http://stlr.stanford.edu/STLR/Articles/03_ STLR_5/article_pdf.pdf.

88 *See* SPECTRUM POLICY TASK FORCE REPORT, *supra* note 8, at 27; *see also* Notice of Inquiry and Proposed Rulemaking, Establishment of an Interference Temperature Metric to Quantify and Manage Interference and to Expand Available Unlicensed Operation in Certain Fixed, Mobile and Satellite Frequency Bands, 18 F.C.C.R. 25,309 (Nov. 28, 2003).

89 In 2007, the FCC acknowledged as much, terminating the proceeding. *See* Interference Temperature Metric, *supra* note 17.

90 As the GAO reported:

> [F]or most frequency bands [the] FCC allocates, the agency issues service rules to define the terms and conditions for spectrum use within the given bands. These rules typically specify eligibility standards as well as limitations on the services that the relevant entities may offer and the technologies and power levels they may use. These decisions can constrain users' ability to offer services and equipment of their choosing.

JAYETTA Z. HECKER, GOV'T ACCOUNTABILITY OFFICE, OPTIONS FOR AND BARRIERS TO SPECTRUM REFORM 7. (2006), *available at* http://www.gao.gov/new.items/d06526t.pdf.

scribe command-and-control measures that specify technologies (as opposed to focusing on outcomes).[91]

To appreciate the state of spectrum regulation and its attendant economic effects, consider the case of Qualcomm's MediaFLO product. MediaFLO, as planned by Qualcomm, will provide mobile video delivery to cellular phones via spectrum that Qualcomm purchased at an auction.[92] When evaluating its new service, Qualcomm determined that the service might create interference with adjacent services,[93] but, on account of the legacy treatment of interference management, it had no clear guidance as to what principles would govern such interference. To address this issue, it petitioned the FCC for guidance.[94]

Over twenty months after filing its initial petition, Qualcomm—with its army of lawyers and lobbyists—finally received a decision detailing the basic rules governing the permissible uses of its license.[95] In its decision, the FCC considered embracing a more systematic (and less ad hoc) standard for interference management on similar issues as well as instituting a streamlined procedure for determining issues like that raised by Qualcomm.[96] Ultimately, however, the FCC declined to do either, instead adhering to its usual public interest, case-by-case determination system[97] that invites rent-seeking (i.e., delay-inducing) behavior by competitors.[98] By so doing, the FCC left in place its process of public interest balancing and wide discretionary judgments that creates, as Thomas Hazlett put it, "a moral hazard for incumbents who are rewarded for raising interference complaints simply to block competition."[99] In his earlier call for a funda-

91 Consider, for example, the FCC's Notice of Proposed Rulemaking for the 2155-2175 MHz band where it suggests that the agency might specify particular types of technological limitations for that band—that is, how uplink and downlink transmissions could be used. *See* Notice of Proposed Rulemaking, Service Rules for Advanced Wireless Services in the 2155-2175 MHz Band, 22 F.C.C.R. 17,035, 17,042-48 (Sept. 19, 2007).

92 Qualcomm Incorporated Petition for Declaratory Ruling, 21 F.C.C.R. 11,683, 11,684 (Oct. 13, 2006) (report & order). Qualcomm planned to offer between 50 and 100 local and national channels either in real time or in clip-casting for later viewing. *Id.*

93 *See id.* at 11,685.

94 *See id.* at 11,683.

95 *See id.*

96 *Id.* at 11,696-97, 11,699.

97 *Id.* at 11,696, 11,700-01.

98 *See* Hazlett, *Wireless Craze*, *supra* note 4, at 386-91.

99 Hazlett, *supra* note 78, at 486 (2003); *see also* note 56, *supra* (discussing the low power FM saga). Hazlett takes his argument one step further, arguing not only that FCC decision-making gates new entry, but also that it serves as a disciplining force so that all existing incumbents abide by an agreement not to create more competition against one another (say, by leasing available spectrum). Hazlett, *supra* note 78, at 488. In effect, Hazlett maintains that the FCC's implicit protection of an incumbents' cartel continues what, less than twenty years ago, was explicit policy. *See* Carroll Broad. Co. v. FCC, 258 F.2d 440, 443 (D.C. Cir. 1958) (holding that additional stations should not be assigned if they could endanger the vitality of current ones); Report and Order, Policies Regarding Detrimental Effects of Proposed New

mental reform of the FCC's spectrum management process, Chairman Powell recognized this very point, underscoring the need for the agency to move away from interference management approaches that constitute "barriers to entry, that assume a particular proponent's business model or technology, and that take the place of marketplace or technical solutions."[100]

At present, the regulatory strategy for guarding against interference is notoriously undefined, moves too slowly to offer effective guidance, raises transaction costs (as well as entry barriers), and leads to the underuse of spectrum. The logjam that the current system creates on the front end (in terms of the need for requests like that filed by Qualcomm) relates closely to the fact that the system provides insufficient back-end regulatory oversight or attention to actual consequences. To be sure, the FCC has encouraged more flexible uses of spectrum,[101] but most firms are not as well-heeled or politically effective as Qualcomm in pressing their case to reform the front-end protections.

In fairness to the FCC, the agency may view itself in a catch-22 scenario insofar as it is ill equipped to handle the increasing number of disputes over spectrum usage that would arise should it allow increased flexibility and address complaints after actual reports of interference.[102] This limitation, however, only underscores the need to make fundamental reforms as part of implementing a more flexible spectrum policy. After all, the legacy model of spectrum regulation was designed in a world where minimizing the hint of interference was the paramount policy goal. Not surprisingly, this model disserves today's goal of creating more opportunities to use spectrum—even though achieving that goal also means creating a greater likelihood of interference and a need to deal with it.

II. PROPERTY RIGHTS IN SPECTRUM

Under the classic notion of property, an owner possesses "a bundle of distinctive rights,"[103] the essence of which is the right to exclude others.[104]

Broadcasting Stations on Existing Stations, 3 F.C.C.R. 638, 638 (Feb. 11, 1988) (abolishing *Carroll* doctrine).

100 Powell, *supra* note 84, at 8.

101 NUECHTERLEIN & WEISER, *supra* note 10, at 244-45.

102 For another example of an interference dispute related to ill-defined and administered rules, see Jeffrey Silva, *Sirius Operating out of Bounds*, RCR WIRELESS NEWS (Oct. 30, 2006), http://www.rcrnews.com/apps/pbcs.dll/article?AID=/20061030/SUB/610300736/1005/FREE.

103 Glen O. Robinson, *Spectrum Property Law 101*, 41 J.L. & ECON. 609, 609 (1998).

104 *E.g.*, Kaiser Aetna v. United States, 444 U.S. 164, 179-80 (1979) ("In this case, we hold that the 'right to exclude,' so universally held to be a fundamental element of the property right, falls within this category of interests that the Government cannot take without compensation."); Richard A. Epstein, *Takings, Exclusivity and Speech: The Legacy of* PruneYard v Robins, 64 U. CHI. L. REV. 21, 22 (1997) ("[I]t is difficult to conceive of any property as private if the right to exclude is rejected.").

Following from this principle, the quintessential protection of both real property and intellectual property law is an action for trespass (or infringement in the case of intellectual property) to prevent or redress the use of property without the owner's consent. Along with damages, the remedy for trespass or infringement is generally an injunction to prevent the illegal conduct from occurring or reoccurring.[105]

In the wake of Coase's landmark work, a number of commentators sought to develop the particulars of how to "propertize" the radio spectrum. One notable early such effort was led by Arthur De Vany, who worked with an interdisciplinary team in the late 1960s.[106] More recently, others have amplified and reinforced the argument for property rights in spectrum.[107] In much of this work, as Part II.A explains, commentators have often suggested that spectrum can be subject to property rights along the lines used for real estate.[108] In so doing, as Part II.B explains, they have ignored, downplayed, or deferred addressing the realities of radio propagation and how they relate to the definition and enforcement of property rights in spectrum. As Part II.C illustrates with respect to AM radio, any realistic regime for managing property rights in spectrum must (as Part II.D underscores) recognize the critical role played by predictive models in regulating spectrum use.

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105 In the intellectual property context, injunctive relief is generally the available and appropriate remedy, but the state of the law in this area remains controversial. *Compare* eBay v. MercExchange, 126 S. Ct. 1837, 1841 (2006) (Roberts, C.J., concurring) (suggesting that injunctions are the traditional remedy in patent cases because of valuation concerns), *with id.* at 1842 (Kennedy, J., concurring) (suggesting that certain cases are not well-suited to injunctive relief).

106 Arthur S. De Vany et al., *A Property System for Market Allocation of the Electromagnetic Spectrum: A Legal-Economic-Engineering Study*, 21 STAN. L. REV. 1499 (1969).

107 *See, e.g.*, Hazlett, *Assigning Property Rights*, *supra* note 4; Hazlett, *Wireless Craze*, *supra* note 4; Jora R. Minasian, *Property Rights in Radiation: An Alternative Approach to Radio Frequency Allocation*, 18 J.L. & ECON. 221 (1975); Gregory L. Rosston & Jeffrey Steinberg, *Using Market-Based Spectrum Policy to Promote the Public Interest*, 50 FED. COMM. L. J. 87 (1997); Howard A. Shelanski & Peter W. Huber, *Administrative Creation of Property Rights to Radio Spectrum*, 41 J.L. & ECON. 581 (1998); Douglas W. Webbink, *Radio Licenses and Frequency Spectrum Use Property Rights*, 9 COMM. & L. 3 (1987); Faulhaber & Farber, *supra* note 76; Milton Mueller, *Property Rights in Radio Communication: The Key to the Reform of Telecommunications Regulation* (Cato Policy Analysis No. 11, 1982), http://www.cato.org/pubs/pas/pa011.html.

108 *See, e.g.*, White, *supra* note 9, at 22 ("The real estate analogy, as well as the pre-regulation experience, points strongly to the conclusion that a system of property rights in the radio spectrum could resolve interference problems satisfactorily (in the same way that the owners of real estate resolve their potential interference problems) while providing a far more flexible and responsive mechanism for allocating spectrum to its most efficient uses.").

A. *Academic Proposals for Spectrum Property Rights*

In their classic 1969 work, De Vany and his coauthors recognized the importance of—and the formidable technical obstacles to—establishing unambiguous and enforceable rights in the radio spectrum. Ultimately, the De Vany study proposed a multidimensional set of rights based upon time, geographic area, and spectrum (band) ("TAS" for short).[109] As they saw it, the owner of the TAS-based rights would have the exclusive right to produce (information-bearing) radio waves for a specified period of time (T), over a specified geographic area (A) and in a specified range of frequencies (S).[110] Moreover, they maintained, this system would enable spectrum licensees to trade their licenses and to use them however they chose, thereby giving rise to the more efficient uses of spectrum advocated by Coase in his landmark paper.[111]

The De Vany study recognized that the exclusive possession of spectrum along the TAS dimensions would pose notable technical challenges. Fundamentally, De Vany and his coauthors recognized that radio signals do not respect the time, area, and spectrum boundaries related to the TAS-based spectrum-use rights.[112] In particular, as discussed below, preventing a radio signal from "trespassing" into a neighboring geographic area or adjacent band is much harder than keeping a person or object from entering onto a particular piece of real property. To be sure, it is physically possible for noise and pollution to trespass onto real property, but that possibility does not complicate the effort to set the actual boundaries of such property (as is the case with defining property rights in spectrum). We shall discuss each in turn.

1. Geographic Spillover Issues

The basic problem with geographic boundaries is easy to understand because it stems from the simple and easily observable fact that radio waves propagate in an unpredictable manner. Notably, radio waves emanate from a transmitter antenna and, while they get steadily weaker with distance, they do not respect or automatically stop at preset borders.[113] Consequently, at the border between one defined geographic area and another, one spectrum licensee's signal inevitably encroaches on another's. The traditional

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109 De Vany, *supra* note 106, at 1501.

110 *Id.* at 1512-17. The terms frequency and spectrum are sometimes used interchangeably. Here "S" refers to the frequency dimension of the spectrum resource, not the resource more generally. *Id*. at 1501.

111 *See id.* at 1517.

112 *Id.* at 1519-27.

113 *Id.* at 1503.

response to this phenomenon (still widely used today) is for the FCC to control the characteristics and locations of the transmitter systems so that the weakening of radio waves over a particular distance guards against (or at least limits) the interference within the respective service areas of the two transmitters.[114] Such command-and-control restrictions on the placement or types of transmitters are, however, antithetical to a flexible, market-based approach.

To address the wide variability associated with radio propagation, the De Vany study proposed rules that would limit the maximum strength of the signal at the geographic boundary.[115] Under this approach, the owners of the spectrum-use rights in neighboring regions would be protected against interfering signals from surrounding areas at a level greater than the defined limit.[116] The De Vany approach also called for similar constraints as to the time and spectrum/frequency dimensions.[117]

When outlining his proposal, De Vany called for a fundamental reorientation of spectrum policy. In particular, De Vany called for a shift from prescribing how firms can operate (e.g., individual transmitter locations, power levels, and antenna heights) to focusing only on the desired result (e.g., a limited signal strength at the boundary). For example, as long as the out-of-area emission restriction is obeyed, the holder of the spectrum-use right under De Vany's framework could choose, without FCC oversight (or permission), to deploy a high power, wide coverage system; a low power, "cellularized" system with multiple transmitters and low antenna heights; or an "infrastructureless" system employing mesh network technology.

By developing a thoughtful proposal for spectrum property rights, the De Vany team transformed the debate over spectrum policy reform. Consider, for example, how Lawrence White outlined the parameters of an ideal system of property rights in spectrum:

> The property right to use the spectrum should be defined in terms of a specified spectrum frequency band, a specified geographic area, and a specified time period. The property right (in perpetuity) would be expressed as the right to transmit over the specified spectrum [frequency] band, so long as the signals do not exceed a specified strength (expressed in volts/meter) beyond the specified geographic boundaries during the specified time period (which would be the full 8,760 hours in a year or any sub-division of those 8,760 hours).[118]

114 Note that, as we will describe below, the signal strength in the real world does not always drop off monotonically.

115 De Vany, *supra* note 106, at 1513-14.

116 *Id.* at 1513.

117 *Id.* at 1512, 1515-16.

118 White, *supra* note 9, at 29-30. Notably, White uses the phrase "propertyzed" as opposed to "privatized" because, as he explains, the government may still own substantial amounts of spectrum for their own internal uses (e.g., national defense and homeland security) under a property rights regime. *Id.* at 31.

In setting forth his proposal, White develops a number of useful recommendations for the future role of the federal government under a reformed spectrum policy regime, including acting as a registrar of spectrum holdings, an owner of some of the rights, and the administrative agency responsible for resolving widespread instances of interference where private enforcement is impractical because of transaction costs.[119] White does not, however, grapple with any of the implications of the often highly variable nature of radio propagation and radio system performance discussed in Part II.A.2. Most fundamentally, White assumes that, without questioning whether, the dimensions used by De Vany (and set forth in his proposal) will be reliable in the same sense as those used by real property law.[120]

In another important study on spectrum property rights, Kwerel and Williams also adopt the essential elements of the De Vany framework, but they discuss in some detail the interference issues in both the space and frequency dimensions.[121] With regard to these dimensions and to allow maximum flexibility, Kwerel and Williams follow the De Vany precedent of proposing objective limits on the amount of signal power that can spillover into adjacent frequency bands and into adjacent geographic areas. More specifically, they suggest that this proposal follows from the success of the regulatory strategy used for controlling out-of-area and out-of-band emissions in the bands reserved for the cellular services.[122]

2. Adjacent Channel Spillover

In their paper, Kwerel and Williams acknowledge not only the possibility of interference between services operating in the same band in adjacent geographic areas, but also between adjacent channels in the same geographic area.[123] This adjacent band problem underscores that interference is not a natural phenomenon—radio waves do not collide in a destructive fashion—but rather one that manifests itself in receivers.[124] Thus, interference can result from: (1) a transmitter emitting radio energy outside the licensee's assigned bandwidth and into an adjacent band; (2) a receiver that inadequately filters out the energy in an adjacent band even when the transmitter in that adjacent band emits without spilling over; or (3) a combination of the two.[125] Depending upon the characteristics of transmitters

119 *Id.* at 32.

120 *See id.* at 29-30.

121 *See* Evan Kwerel & John Williams, *A Proposal for a Rapid Transition to Market Allocation of Spectrum* iv-v (Fed. Commc'ns Comm'n, OSP Working Paper Series, Working Paper No. 38, 2002), *available at* http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-228552A1.pdf.

122 *See infra* notes 123-33 and accompanying text.

123 Kwerel & Williams, *supra* note 121, at 44.

124 *See id.* at 45-46.

125 *Id.* at 44.

and receivers, adjacent channel interference can even extend beyond immediately adjacent channels.[126]

Adjacent channel spillover problems are pervasive in spectrum use and, unlike the typical approach in real property, part of the solution may be for the "victim" of a "trespass" to change his or her use of the property.[127] Consider a scenario in which a receiver attempts to receive a very weak (e.g., very distant) in-band signal. In that case, a high-powered use (e.g., broadcast television) in an adjacent band is likely to create a spillover problem.[128] Interference in the frequency dimension can be controlled either by controlling the power of the transmitter or by requiring better filters and other techniques on the part of the receiver in the adjacent band.[129] Notably, an important benefit that emerges as a result of using more selective receivers (and a lower powered transmitter) in lieu of previously used ineffective receivers is that users of adjacent bands have greater protection against interference resulting from the use of a higher powered transmitter. The challenges of addressing this issue are that any solution will impose real costs on the parties—particularly when very high powered or small, portable devices are involved[130]—and that, unlike the case of land, no natural demarcation exists where one spectrum user's transmission power "trespasses" on the adjacent channel user's receiver sensitivity.

As Kwerel and Williams see it, the adjacent channel issue warrants a regulatory safeguard. In particular, they suggest the need for rules that would "rule out extreme power levels [that exacerbate the problem receivers have with rejecting very strong adjacent signals at reasonable cost] that have little practical benefit but, which, if left unchecked, could lead to excessive interference risk and harmful strategic behavior."[131] Despite the appearance of embracing a command-and-control-type rule (like the service rules generally eschewed by property rights advocates), Kwerel and Williams suggest (apropos of the Coase Theorem) that such a default rule can

126 Szu-wei Wang & Stephen S. Rappaport, *Balanced Channel Assignment Patterns for Cellular Communications Systems*, 1 IEEE INT'L. CONF. ON COMM. 452, 455-56 (1988) (distinguishing between immediately adjacent and not immediately adjacent channel interference).

127 We say "typical" because there are exceptions where the law withholds protection from property owners under certain conditions, in effect requiring them to protect themselves. *See, e.g.*, LeRoy Fibre Co. v. Chicago, Milwaukee & St. Paul Ry., 232 U.S. 340, 353 (1914) (Holmes, J., concurring) (suggesting a rule of tort law that, although recognizing the right of a farmer "to put his flax where he liked upon his own land, the liability of the railroad for a fire [should be] absolutely conditioned upon the stacks being at a reasonably safe distance from the train").

128 Kwerel & Williams, *supra* note 121, at 46.

129 *Id.*

130 The impact of receivers is particularly noteworthy with respect to the decisions made related to the UHF band, where the presence of inexpensive and relatively unsophisticated receivers are used to justify wide spacing requirements between the different channels.

131 Kwerel & Williams, *supra* note 121, at 46. By "strategic behavior," the authors are referring to actions designed to optimize results favorable to a particular party even if those actions risk hurting others and may well undermine overall social welfare.

be relatively crude because different licensees can successfully renegotiate the applicable limits.[132] Reflecting their faith that such Coasian bargains will take place, Kwerel and Williams conclude that the government need not recommend minimum receiver performance standards except in exceptional circumstances.[133]

The final, and most significant, development since the De Vany-led study is a 2005 paper by Robert Matheson. This paper presents the most complete analysis of property rights in radio spectrum as well as the fullest discussion of the practical challenges and limitations of actually employing such rights in the management of the resource.[134] Whereas De Vany et al. set forth a proposal based upon four dimensions (time, two dimensions of geographic location (latitude and longitude), and frequency), Matheson proposes a regime based upon seven dimensions.[135] To minimize confusion with the term "spectrum" (which normally only refers to the frequency dimension), Matheson calls his seven dimension model "electrospace."[136]

Under Matheson's proposal, the seven dimensions of electrospace include frequency, the three dimensions of location (latitude, longitude, and elevation), time, and the two possible directions of arrival (azimuth and elevation angles).[137] By adding altitude as a dimension, Matheson envisions that a holder of spectrum-use rights might choose to sell or lease "air rights" above a ground-based system.[138] As for the addition of direction of arrival, Matheson premises that dimension on the fact that a receiver can discriminate between radio waves arriving from different directions.[139] By using directive antennas, a receiving system can gather a greater amount of energy from a signal arriving from one direction while minimizing or

132 *Id.* at 47.

133 *Id.* 46-47. In Coase's classic article, and in anticipation of the insights of his later Nobel Prize-winning work, he suggested that a "nuisance" was a legal construct and that, except if transaction costs were significant, neighbors—such as a doctor and confectioner—should be able to agree on safeguards to optimize both of their uses of their property. Coase, *supra* note 13, at 27, 29. In the case of a doctor and a confectioner case operating next to one another, for example, it might be efficient for the confectioner to pay for insulation so as to protect the doctor from any noise made by the confectioner. *Id.* at 26-27. Similarly, there may well be a number of cases where neighboring spectrum owners can agree on such win-win agreements. *Id.* at 27-28. In other cases, however, the coordination and possible relocation costs—or other transaction costs (such as developing clear legal entitlements)—may be too formidable to be addressed through private market arrangements. *See id.* at 29. For a recent case where the FCC stepped in to coordinate a relocation of a set of incumbent licensees to avoid adjacent channel interference, see Report and Order, Improving Public Safety in the 800 MHz Band, 19 F.C.C.R. 21,818 (Oct. 29, 2004).

134 *See* Robert J. Matheson, *Principles of Flexible Spectrum Use Rights*, 8 J. COMMC'NS & NETWORKS 144 (2006).

135 *Id.* at 145.

136 *Id.* at 144.

137 *Id.* at 145.

138 *See id.* at 147.

139 *Id.*

"nulling out" the energy of an otherwise interfering signal arriving from a different direction.[140]

Like other proponents of spectrum property rights, Matheson emphasizes the importance of allowing technological flexibility in, and the free trading of, spectrum rights. Matheson suggests that the holders of spectrum-use rights should be free to divide or aggregate spectrum along any of the electrospace dimensions.[141] By adding complexity, however, Matheson develops a more sophisticated and realistic model that also raises new difficulties. Building antennas that focus all of the transmitted energy in a single direction is just as effective as building transmitters that confine all of the transmitted energy to one frequency range or channel. Consequently, by recognizing rights against (and in protection of) the direction of arrival, Matheson begs the question of how that measure could be enforced effectively.

As to the adjacent channel interference issue, Matheson refines Kwerel and Williams' approach of specifying a maximum power level to avoid adjacent channel interference. In his view, the power impinging upon the receiving system is the critical issue; thus, he suggests, regulating the actual power level received at ground level or a specified location (as opposed to at the transmitter) is the better approach.[142] As he explains, this method would regulate results and not how firms operate, thereby giving the spectrum licensee greater flexibility in how to meet the relevant constraint while still offering protection to the receivers at risk of interference.[143]

Unlike earlier proponents of the property rights approach, Matheson appreciates many of the difficulties and implications of defining exactly how the rights are to be specified. Notably, Matheson realizes that setting limits on the spillover outside each of the electrospace dimensions and on the maximum power levels that can be used inside those dimensions is much more difficult and costly than policing trespass to land. He explains, for example, that a very stringent limit on the spillover effects into an adjacent geographic area may force the rights-holder to reduce power such that significant "holes" in coverage are produced near the boundary.[144] To be sure, as we discuss below, a stringent limit may force the rights-holder to select a cellular architecture with multiple low-powered, low antenna-height sites to control the spillover and still provide the necessary coverage.[145] By contrast, a very generous limit on spillover into adjacent geographic areas would impose costs on the rights-holder across the boundary

140 *See* Matheson, *supra* note 134, at 147.

141 *Id.* at 148.

142 *Id.*

143 *Id.*

144 *See id.* at 146 (discussing the need to reduce signal strength in certain areas).

145 *See infra* pp. 592-93.

and would require it to adopt more expensive interference mitigation techniques.[146]

Of all commentators since De Vany, Matheson makes a particularly important contribution by highlighting how choices about maximum power levels do not lend themselves to easy answers and may well dictate the use of particular technologies (even if not otherwise cost effective). Moreover, as Matheson notes, there are important enforcement questions that are only beginning to be examined—such as whether a licensee could "game" the system by using multiple transmitters and spillover limits.[147] Unfortunately, Matheson does not analyze the nature of radio propagation and the implications of its wide variations for establishing clear and enforceable property-like rights in the radio resource. Part II.B addresses this very challenge.

B. *Radio Wave Propagation and Spectrum Rights*

As we discussed earlier, radio waves weaken as they travel away from the transmitter. In theoretical free space, radio waves steadily weaken in a very uniform, predictable way and at a rate that depends upon the frequency.[148] The higher the frequency, the faster the waves weaken.[149] In the real world, the situation is much more complicated and radio waves are affected by the shape of the earth, the atmosphere, the intervening topography, and natural and manmade objects such as foliage and buildings.[150] The magnitude of these effects depends heavily upon the relevant frequency (again, with the higher frequencies generally affected more).[151]

At the lowest radio frequencies, below 100 kHz or so, radio signals travel in a reliable way between the earth and a portion of the atmosphere known as the ionosphere.[152] Thus, using very high power transmitters,

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146 *See infra* p. 593.

147 Matheson, *supra* note 134, at 148-49 (concluding that because a region owner may potentially increase his allowed spillover by arbitrarily subdividing his territory, such subdivisions should not be allowed).

148 ASRAR U.H. SHEIKH, WIRELESS COMMUNICATIONS: THEORY AND TECHNIQUES 22-24 (2004).

149 *Id.* at 22-23.

150 *See generally* HENRY L. BERTONI, RADIO PROPAGATION FOR MODERN WIRELESS SYSTEMS 171-251 (2000) (describing the effects of buildings, trees, and terrain features on radio propagation).

151 Notably, at higher frequencies, the size of efficient antennas is smaller and it is correspondingly easier to focus the radio waves in a particular direction (and thus to utilize the direction-of-arrival dimension discussed earlier). *See* KENT SMITH, RF MONOLITHICS, INC., ANTENNAS FOR LOW POWER APPLICATIONS 1 (2000), http://www.rfm.com/support/apnotes/antenna.pdf (2000) (stating that wavelength is "[i]mportant for determination of antenna length"); *see also* Radiall/Larsen Antenna Technologies, Basic Antenna Concepts, http://www.radialllarsen.com/technicalreference_basicantennaconcepts.htm (last visited Feb. 26, 2008) (introducing the relationship between antenna size and wavelength).

152 *See* Ham-Shack.com, Radio-Wave Propagation, http://ham-shack.com/propagation.html (last visited Feb. 26, 2008). The ionosphere is "part of the earth's atmosphere extending from about 70 to 500 kilometers [above the earth], in which ions and free electrons exist in sufficient quantities to reflect

guided signals sent at this frequency can travel over great distances and penetrate into the ocean.[153] At higher frequencies, in roughly the 300 kHz to 3 MHz range, radio technology relies on two basic modes of propagation: ground waves and sky waves.[154] Ground waves, as the name suggests, travel close to the earth's surface (and thus cover limited distances unless repeated) whereas sky waves travel into the earth's atmosphere and are reflected or bounced back (often over a very long distance) by the ionosphere.[155]

Transmissions using the lowest frequencies are likely to be unpredictable. For example, the strength of the signal from traditional AM broadcasting stations (and the interference between and among them) is likely to vary significantly from daytime to nighttime, from location to location and from season to season.[156] In the daytime, ground waves provide coverage and the service is comparatively reliable to that of radio transmissions using higher bands but relatively limited in range.[157] In the nighttime, however, reflections from the ionosphere carry the radio signals in this range beyond the horizon, permitting coverage over much greater distances but with less stability because of the ionosphere's highly variable conditions.[158]

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and/or refract electromagnetic waves." NAT'L COMMC'NS SYS. TECH. & STANDARD DIV., INST. FOR TELECOMM. SCIS., FEDERAL STANDARD 1037C, TELECOMMUNICATIONS: GLOSSARY OF TELECOMMUNICATION TERMS (1996) [hereinafter FEDERAL STANDARD 1037C], *available at* http://www.its.bldrdoc.gov/fs-1037 (defining "ionosphere"). The ionization is produced by radiation from the sun and hence varies with the position of the sun and with solar activity. BOITHIAS, *supra* note 42, at 218-19.

153 BOITHIAS, *supra* note 42, at 309.

154 Some radio waves travel along the earth's curve, rather than in a straight line into space. BOITHIAS, *supra* note 42, at 52-78. Other kinds of radio waves are more influenced by atmospheric conditions. *See generally id.* at 79-143, 218-55 (discussing the influence of troposphere and ionosphere on radio wave propagation).

155 Ham-Shack.com, *supra* note 152.

156 In the daytime, AM radio signals primarily use ground wave propagation. At night, however, they also propagate through reflection off the ionosphere. Robert A. Anthony, *Towards Simplicity and Rationality in Comparative Broadcast Licensing Proceedings*, 24 STAN. L. REV. 1, 10 (1971) ("The propagation characteristics of signals in the lower AM frequency range are much more complex, and are more generative of distant interference. The longer AM waves tend to follow the curvature of the earth; also, at night, they bounce back from the ionosphere in "skywave" effect and return to the surface at considerable distances."); FCC, Why AM Radio Stations Must Reduce Power, Change Operations, or Cease Operations at Night, http://www.fcc.gov/mb/audio/bickel/daytime.html (last visited Jan. 11, 2008); s*ee also* BOITHIAS, *supra* note 42, at 309 (stating that low frequency waves "suffer significant absorption during the day"); Ham-Shack.com, *supra* note 152 (stating that AM signals are ground waves during the day, and describing the effects of solar conditions and weather on the ionosphere, and the consequent effects on radio propagation).

157 Ham-Shack.com, *supra* note 152 ("Ground wave propagation . . . means relatively short-range communications.")

158 *See id.*

The next highest range of the spectrum, the 3 MHz to 30 MHz range, is traditionally referred to as the shortwave region.[159] In this region, the ground wave component becomes less important and reflections from the ionosphere or even serial reflections between the earth and the ionosphere carry the signals over vast distances.[160] Before the advent of communications satellites and high capacity undersea fiber optic cables, this portion of the spectrum was particularly prized for long haul, intercontinental communications in military, governmental, and commercial applications.[161] Propagation conditions in this region of the spectrum vary widely with the condition of the ionosphere (including the maximum frequency that will be successfully reflected) and those conditions depend upon location, season of the year, time of day, and level of solar activity.[162] Because of this high variability, the relatively limited bandwidth available, and the size of the antennas required, this portion of the spectrum is no longer as highly desirable.[163]

The region of the spectrum between 30 MHz and 300 MHz is known as the very high frequency ("VHF") region and it is home to a number of popular services including VHF television, FM radio broadcasting, and a number of mobile services.[164] The lower portions of the VHF range exhibit some of the negative characteristics of the shortwave region because very long distance ionospheric propagation and associated interference occur in certain seasons, efficient antennas are still somewhat unwieldy for mobile/portable applications, and building penetration is often difficult.[165]

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159 FEDERAL STANDARD 1037C, *supra* note 152 (definition of "shortwave").

160 BOITHIAS, *supra* note 42, at 309-10.

161 The shortwave bands were initially thought to be of little value, and were relegated to amateur use. Amateurs soon, however, were using these frequencies to carry out intercontinental communications. National Radio Astronomy Observatory, Early Radio Astronomy: The Ham Radio Connection, http://www.nrao.edu/whatisra/hist_ham.shtml (last visited Jan. 9, 2008). Commercial use of shortwave bands for long-distance and even international broadcasting followed. *See generally* JEROME S. BERG, ON THE SHORT WAVES, 1923-1945 (1999). Some military use of shortwave frequencies continues to this day. Top 100 Military Shortwave Frequencies, http://w6yra.bol.ucla.edu/hfmil.htm (last visited Feb. 26, 2008).

162 BOITHIAS, *supra* note 42, at 310 ("[T]he use of [short waves] depends crucially on choosing . . . a specific time of day . . . . The major difficulty is due to . . . fluctuations in the ionosphere . . . ."); *see also* Ham-Shack.com, *supra* note 152.

163 Shortwave radio broadcasting is commonly viewed as an outdated technology. For instance, Kenneth Y. Tomlinson, then-chairman of the Broadcasting Board of Governors, when justifying budget cuts that would eliminate much shortwave Voice of America programming wrote that "satellite television is to the future what shortwave radio was to the past." Kenneth Y. Tomlinson, *Liberty TV*, WALL ST. J., May 6, 2006, at A8; *see also* David Folkenflik, *Budget Proposal Cuts English-Language Broadcasts*, NPR, Feb. 13, 2006, http://www.npr.org/templates/story/story.php?storyId=5204369.

164 Nat'l Telecomms. & Info. Admin., United States Frequency Allocations, http://www.ntia.doc.gov/osmhome/allochrt.pdf (last visited Feb. 26, 2008).

165 NAT'L ACADS. OF EMERGENCY DISPATCH, EMERGENCY TELECOMMUNICATOR 137 (2001).

The ultra high frequency ("UHF") portion of the radio spectrum—the portion between 300 MHz and 3,000 MHz (3 GHz)—is widely regarded as the most desirable range for a variety of applications, especially those involving communications with mobile/portable devices.[166] For this reason, some UHF bands—such as those used for television broadcasting (in the 700 MHz band)—are called "beachfront property."[167] Users of these bands can transmit with reasonably-sized directive antennas, easily generate adequate power levels, and readily transmit into and around buildings. In so doing, they could also avoid undesirable ionospheric reflections and worry less about natural and man-made sources of unintended interference (e.g., from florescent lights or digital computers).[168] Consequently, this region is home to UHF television broadcasting, cellular telephony, and a host of other important services.[169]

Despite its desirable, more stable characteristics, radio signals in this portion of the spectrum are still subject to vagaries that cause the strength of signals to vary widely. The signals are subject to being: (1) refracted (bent) by the earth's atmosphere; (2) diffracted (turned) by edges of obstructions such as buildings; and (3) reflected (bounced) off of natural and man-made obstacles such as mountains and buildings.[170] Unlike higher regions of the radio spectrum, frequencies in this range are not affected significantly by rain, snow, and fog, but the signals are absorbed to varying degrees by foliage and other clutter.[171]

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166 Press Release, UMTS Forum, UHF Spectrum Needed to Secure Latin America's Mobile Broadband Future, Says UMTS Forum (Jul. 2, 2007), http://www.umts-forum.org/content/view/2138/110 ("These frequencies . . . are ideally suited to providing wide-area coverage for broadband mobile services . . . .").

167 The use of the term "beachfront property" to describe UHF bands is widespread. *See, e.g.*, *On the Same Wavelength*, ECONOMIST, Aug. 14, 2004, at 61, 63. To appreciate the favorable characteristics of these bands, consider that "one access point in a 700 MHz network can cover the same area as four access points in a 2.4 GHz network or 10 access points in a 4.9 GHz network." Donny Jackson, *All or Nothing*, MRT MAG., Jan. 1, 2005, *available at* http://mrtmag.com/mag/radio_nothing.

168 BOITHIAS, *supra* note 42, at 310-11.

169 Nat'l Telecomms. & Info. Admin., *supra* note 164.

170 BERTONI, *supra* note 150.

171 In yet another complication, frequencies in the UHF range are subject to multipath fading. As the name implies, multipath fading is produced when multiple copies of the same signal arrive at a receiver via different paths. This might include a direct or "line of sight path" from the transmitting antenna to the receiving antenna and one or more indirect paths created by reflections from buildings, nearby vehicles, water, or other terrain features such as mountains. (In over-the-air television, multipath is what sometimes produces a "ghost" image on a television screen. The ghost is an image that arrives later due to the presence of multipath.) Because the reflected signals travel over a longer distance than the direct signal, they arrive at slightly later times or, to use the more technical term, with different phases. In some cases, when the different signals are "in-phase," they will add together in the receiver and increase the strength of the received signals. In other cases, when the signals arrive "out-of-phase," they will tend to cancel each other out, producing sometimes very deep fades in the signal power received.

The above description of radio propagation in the 300 MHz to 3 GHz range implies rather static conditions but, of course, the actual situation is typically much more dynamic. For example, the amount of atmospheric refraction is not constant; rather, it changes with weather conditions.[172] Atmospheric refraction of radio waves is useful because it normally extends the transmission range somewhat beyond the physical horizon.[173] As the refractive index changes with weather patterns, however, it changes signal strengths at a particular location.[174] In certain summertime conditions and over bodies of water, the radio signal may be carried over great distances (hundreds of kilometers) due to a phenomenon known as "ducting."[175] This may produce much stronger signals (and, hence, greater interference) in distant receivers than normal.[176] Longer term variations in received signal strength can also be produced by seasonal variations in the amount of signal absorbing foliage.[177]

In addition to time variations in received signal strength at a particular location, even slight changes in location can produce wide variations as well. For example, where a transmission may involve multiple transmission paths, a slight change in location (a few tens of centimeters) may mean that signals which formerly combined to produce a stronger signal subtract from or cancel one another to produce a much weaker signal.[178] In addition, once a person using a cellular radio handset in the radio "shadow" of a tall building moves around the corner, the signal may increase significantly.[179] Similarly, the strength of the received signal can vary significantly with altitude.[180] For example, a receiver located at ground level may receive a very weak signal from a transmitter while a receiver located in the upper stories of a nearby building and with a line of sight to the transmitter may receive a very strong signal. In short, even the signal strength using the most valued spectrum varies significantly with time, small location changes, and altitude changes.[181]

Because UHF signals travel different paths, the strength of the desired signal and interfering signals will often vary independently so that interfer-

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172 BOITHIAS, *supra* note 42, at 123.

173 *Id.* at 310-11.

174 *See id.*

175 STAN GIBILISCO, PHYSICS DEMYSTIFED 481 (2002).

176 PAUL BEDELL, WIRELESS CRASH COURSE 52 (2005).

177 BERTONI, *supra* note 150, at 201.

178 *Id.* at 36 (describing the phenomenon of "fast fading" which is often the result of multipath propagation).

179 *See generally id.* at 141-76.

180 Some of the issues involved in considerations of antenna height are discussed in R. DEAN STRAW & GERALD L. HALL, ANTENNA HEIGHT AND COMMUNICATIONS EFFECTIVENESS (2d ed. 1999), http://www2.arrl.org/FandES/field/regulations/local/antplnr.pdf.

181 *See* Bernard H. Fleury & Peter E. Leuthold, *Radiowave Propagation in Mobile Communications: An Overview of European Research*, IEEE COMMNS. MAG., Feb. 1996, at 70, 71-72.

ence may manifest itself one moment and virtually disappear the next.[182] The variability that inheres in such transmissions means that (1) the desired and interfering signal strengths at particular locations can, as a practical matter, *only be predicted in a statistical sense* and (2) field measurements of signal strengths (e.g., to detect "trespass") must take into account these same variations to the extent that the signal strength limit at the boundary is defined statistically. To date, however, commentators have largely glossed over this critical point, proceeding as if the signal strength at the boundary is constant and thus can create an enforceable boundary.[183]

C. *The Case of AM Radio*

To underscore the underappreciated challenges of defining property rights in spectrum, consider the case of AM radio. As a valued social use of the radio spectrum as well as one of its earliest uses, AM radio provides an instructive case study. For our purposes, the bands used for AM radio are significant because they exhibit some of the widest variability in propagation conditions and make defining appropriate property rights in spectrum particularly challenging.

In the AM broadcast band between 550 kHz and 1.71 MHz, the propagation conditions change dramatically due to the influence of the ionosphere. During the daytime, the lower layers of ionosphere absorb radio waves in this range, making it difficult (and rare) for signals to travel very long distances. Thus, during the day, the transmission ranges are limited to ground wave distances. During the nighttime hours, however, the lower layers of the ionosphere disappear, and the upper layers reflect the waves far beyond the horizon.[184] During the transition hours between daytime and nighttime, the signal levels are particularly volatile.[185]

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182 *See* FEDERAL STANDARD 1037C, *supra* note 152 (defining the term "multipath" and stating that its effects include "constructive and destructive interference").

183 The United Kingdom's spectrum regulator (Ofcom), which is further along the path of spectrum reform than the United States, has recognized this point: "As signal levels can vary due to propagation effects, it is appropriate to define the [relevant power levels] for an associated percentage of time. While often this is based upon [a statistically defined] median level (to assist in measurement) this can result in the risk of levels of interference above the threshold [in practice]." ÆGIS SPECTRUM ENG'G, SPECTRUM USAGE RIGHTS: OFCOM, FINAL REPORT 37 (2006), *available at* http://www.aegis-systems.co.uk/download/1721/casestudies.pdf.

184 *See supra* note 156 and accompanying text.

185 *See* FCC, Local Sunrise / Sunset Calculations, http://www.fcc.gov/mb/audio/bickel/srsstime.html (last visited Jan. 11, 2008). Of course, sunrise and sunset times vary daily, and by latitude and longitude. *See id.* Furthermore, changes in the ionosphere do not occur instantly. *Id.* Indeed, the FCC's regulatory practice takes note of this. Because the propagation characteristics of AM radio are so different at night, many AM radio stations are required to broadcast at a lower power during nighttime hours. *Id.* However, "in recognition that changes in the ionosphere . . . do not occur instantly at nightfall or at sunrise," the FCC grants special pre-sunrise and post-sunrise authority to certain stations. *Id.*

The conditions of the upper layers of the ionosphere not only vary widely at night and during transition hours, they vary from hour to hour, with the season of the year, the level of solar activity, and the location (e.g., latitude) of the transmission path.[186] Moreover, this portion of the spectrum is particularly susceptible to natural interference (i.e., static) produced by lightning strikes from both local and distant thunderstorms.[187] During the summer months this static may effectively mask interference from distant stations while, during the quiet winter months, signals from thousands of kilometers away produce noticeable interference to local stations.[188] Finally, the interference between the ground wave and sky wave signals can, at certain distances, cause severe multipath fading effects, making the desired signal more or less susceptible to interference from one moment to the next.

For bands like the one traditionally used for AM broadcasting, providing licensees with clearly defined interference protection—at least using the classic property law trespass concept—seems impractical, if not impossible. If, for example, a station in another geographic area could prosecute a trespass claim against a transmitter that created interference, it could seek relief based upon a series of natural conditions that happen only infrequently. Stated in terms used by the De Vany study, the question is: under what conditions do you measure signal strength at the boundary? Unfortunately, no easy answers to this question exist because the realities of radio wave propagation in this spectrum region simply do not lend themselves to clear and enforceable boundaries for the geographic area dimension of the spectrum resource.

Charles Jackson recognized the long-range interference issues associated with the AM broadcasting band and argued that the pervasive interference in the band "creates multiple interlocking externalities that cannot be properly taken into account in simple market transactions."[189] He concluded, as we do, that "a spectrum management system for the AM band using property rights based on station licenses would face enormous difficulties."[190] Moreover, Jackson concluded, as we noted above and discuss below, that the cellular bands are more amenable to a property right regime because of "limited signal range, systems operating over large blocks of

186 BOITHIAS, *supra* note 42, at 244-45.

187 Charles Jackson, Raymond Pickholtz & Dale Hatfield, *Spread Spectrum Is Good–But It Does Not Obsolete* NBC v. U.S.*!*, 58 FED. COMM. L.J. 245, 260 (2006) ("In the AM band, the primary source of radio noise is either distant lightning . . . or nearby electrical equipment . . . .").

188 In engineering circles, the effect of lightning on radio signals is known as "atmospherics." For an introduction to atmospherics, as well as a chart illustrating the varying levels of atmospherics by season, time of day, and latitude/longitude, *see* BOITHIAS, *supra* note 172, at 290-91.

189 Charles Jackson, *Limits to Decentralization: The Example of AM Radio Broadcasting or Was a Common Law Solution to Chaos in the Radio Waves Reasonable in 1927?* 1 (Aug. 29, 2005), http://web.si.umich.edu/tprc/papers/2005/454/Limits%20to%20Distributed%20Decisionmaking%20TPRC%202005.pdf.

190 *Id.* at 1.

bandwidth and over large geographic regions, and control of both transmitters and receivers by the system operator."[191]

Were licensees conferred property rights in spectrum along the lines available for landowners, they might bring trespass claims as a means of extracting payments from unlucky transmitters. In particular, Firm A could acquire a license for an area reached, even very intermittently, from Firm B, which is already in operation and does not possess the right to transmit to that location at that signal strength. Firm A could bring a trespass action against Firm B and gain enormous leverage over Firm B, which would fear an injunction stopping its service or forcing it to pay to avoid causing the trespass.[192] To prevent this outcome, Firm B might agree to a costly and oppressive "licensing" or "easement" arrangement that provides great rewards to Firm A regardless of whether Firm A is using or intends to use its spectrum at all. In our view, this scenario might well be worse than the current system's reliance on "muddy entitlements" (i.e., ill-defined rules that are enforced only to a limited degree,[193] as in the case of AM radio).

The above discussion of an entity acquiring a property right and opportunistically enforcing it is hardly speculative. Rather, it parallels the intellectual property rights phenomenon of the "patent troll."[194] In the case of patent trolls, firms buy up patent rights—which provide a complete right to exclude others from using an invention without permission[195]—knowing that other firms are using an infringing invention unaware of the patent. Then, without providing a product itself, the patent troll threatens to enforce its patent rights (and obtain an injunction) against the allegedly infringing party.[196] Because the invention user has made irreversible investments, the

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191 *Id.* at 32.

192 In theory, this situation could occur in land where a firm purchased a property right next to a would-be nuisance. The rules of nuisance law, however, require an actual harm to the property owner, whereas "trespass" law requires merely a violation of the relevant boundary. RESTATEMENT (SECOND) OF TORTS § 821D cmt. D (1979).

193 The concept of "muddy entitlements" is often identified with Carol Rose. *See* Carol M. Rose, *Crystals and Mud in Property Law*, 40 STAN. L. REV. 577, 590, 592 (1988).

194 For illustrative uses of the term "patent troll," including several early uses, s*ee* Word Spy, Patent Troll (Aug. 13, 2003), http://www.wordspy.com/words/patenttroll.asp. For a balanced look at someone accused of being a patent troll, see Nicholas Varchaver, *Who's Afraid of Nathan Myhrvold?*, FORTUNE, Jul. 10, 2006, at 110.

195 U.S. PATENT & TRADMARK OFFICE, GENERAL INFORMATION CONCERNING PATENTS, http://www.uspto.gov/go/pac/doc/general/ (2005) ("The right conferred by the patent grant is, in the language of the statute and of the grant itself, 'the right to exclude others from making, using, offering for sale, or selling' the invention in the United States or 'importing' the invention into the United States. What is granted is not the right to make, use, offer for sale, sell or import, but the right to exclude others from making, using, offering for sale, selling or importing the invention.").

196 In its report evaluating the competition policy case for patent law reform, the Federal Trade Commission explained that "non-practicing entities" can "obtain and enforce patents against other firms, but either have no product or do not create or sell a product that is vulnerable to infringement countersuit by the company against which the patent is being enforced." Consequently, such firms can threaten

patent troll can use its leverage to extract a significant licensing fee.[197] In the famous case brought by NTP, Inc. against Research In Motion Ltd. ("RIM"), NTP threatened to enjoin the use of technology underlying the popular BlackBerry product to secure an over $600 million settlement, even though the Patent and Trademark Office was reexamining these patents.[198] To be sure, the facts of that case as well as the actual extent of the patent troll problem are debatable (as is the proper definition of what is a patent troll),[199] but our point is that the development of rights in spectrum should be devised to avoid a similar problem.

D. *Establishing Rights by Using Predictive Models*

To design radio systems that utilize the 300 MHz to 3 GHz range of the spectrum, engineers make extensive use of predictive models to estimate the performance of radio transmissions. In basic terms, these models are used to compute what is known as "transmission loss" (i.e., the change in signal power from the output of the transmitter to the input of the receiver).[200] By knowing the transmitter output power and the predicted transmission loss for a particular path, an engineer can estimate the strength of the signal received by the receiver.[201] Moreover, the same models can also predict the level of interference caused by other, distant transmitters that operate on the same or adjacent channels.[202] Calculating the desired signal level and the undesired signal(s) level while considering the assumed or measured characteristics of the receiver, the engineer can estimate the

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"patent infringement [suits] and an injunction, which, if granted, could inflict substantial losses." FTC, TO PROMOTE INNOVATION: THE PROPER BALANCE OF COMPETITION AND PATENT LAW AND POLICY 38 (2003).

197 *See* WENDY H. SCHACHT & JOHN R. THOMAS, CONG. RESEARCH SERVE., PATENT REFORM: INNOVATION ISSUES 33 (2005) ("In the view of some observers, [the threat of an injunction] has encouraged strategic behavior by [patent] speculators."); Alex V. Chachkes, EBay Inc. v. MercExchange LLC*: A New Landscape for Patent Litigation*, 72 PAT. TRADEMARK & COPYRIGHT J. 130, 130 (2006) ("Wielding the threat of the almost-mandatory permanent injunction, patent owners have been filing more suits, law firms have been more willing to take the risk of a patent contingent-fee case, and the industry of the patent troll has flourished.").

198 Mark Heinzl & Amol Shama, *Getting the Message: RIM to Pay NTP $612.5 Million to Settle BlackBerry Patent Suit—With Pact, Tech Firm Avoids Court-Ordered Shutdown of Popular Wireless Device*, WALL ST. J., Mar. 4, 2006, at A1.

199 *See, e.g.*, Mark A. Lemley, *Are Universities Patent Trolls?* (Stanford Pub. Law Working Paper No. 980776, 2007), *available at* http://papers.ssrn.com/sol3/papers.cfm?abstract_id=980776.

200 *See, e.g.*, Joram Walfisch & Henry L. Bertoni, *A Theoretical Model of UHF Propagation in Urban Environments*, 36 IEEE TRANSACTIONS ON ANTENNAS & PROPAGATION 1788 (1988).

201 *Id.* at 1793-94.

202 *See, e.g.*, Theodore S. Rappaport & Sandip Sandhu, *Radio-Wave Propagation for Emerging Wireless Personal-Communications Systems*, IEEE ANTENNAS AND PROPAGATION MAG., Oct. 1994, at 14-15.

end-to-end performance of the radio transmission in terms of, say, availability and audio quality (e.g., bit error rate).[203] Consequently, the engineer can conduct cost and performance tradeoffs (e.g., among an increase in signal power at the transmitter, a more focused, directive antenna, or improved sensitivity of the receiver).

As the existing regulatory regime recognizes, any effective regulation of spectrum must rely, at least to some degree, on predictions of signal strength (and likely interference). Predictive models range from relatively simple ones ("back of the envelope calculations") to very complex software programs.[204] Complex models are typically based upon electromagnetic wave theory, empirical results from extensive field measurements in different environments, or, quite often, a combination of the two.

In addition to their complexity, models also differ in how they deal with site specific factors. In some cases, the relevant information (e.g., the locations of both end user devices and the intervening terrain) will not be known in any detail, leading engineers to rely on "site general" models.[205] A site general model is likely to yield predictions of signal strength along a line from the transmitter site that decreases at a consistent rate with increased distance from the site.[206] By adopting the simplifying assumption that signal strength drops off consistently with increased distance from the transmitter, site general models produce smooth coverage contours around the transmitter and produce neat maps of where a signal can supposedly be detected.[207]

To some property rights commentators, a site general model (as illustrated below in Figure 2 with respect to a TV station in Denver, Colorado) provides a picture of spectrum rights that is deceptively similar to real property. In reality, the actual terrain and the presence of buildings and other urban clutter can strengthen or weaken the actual signal strength. Buildings, for example, can cause a signal to drop significantly in an area that they "shadow" from the transmitter and then the signal can recover beyond that area.[208] For users of cellular telephones, this phenomenon is the explanation for some of the frustrating "holes" or gaps in coverage within a service area. Similarly, a hilltop or other favorable location that permits a

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203 *See, e.g.*, *id.* at 15, 18.

204 Simple models may be useful to roughly determine broadcast coverage, for example, or for predicting communications abilities between, say, two earth orbiting satellites with only open space between them. Complex models are more appropriate where the intervening terrain is hilly or mountainous, substantial urban clutter exists, or heavy foliage or in-building coverage is involved.

205 HARRY R. ANDERSON, FIXED BROADBAND WIRELESS SYSTEM DESIGN 78 (2003).

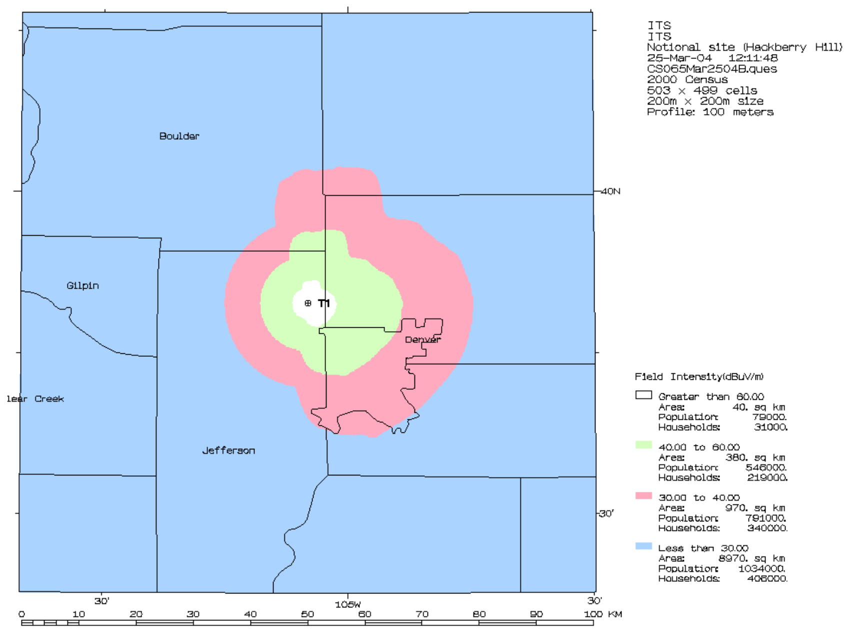
206 Jan Doeven, *Terrestrial Service Area Planning*, *in* BROADCAST ENGINEER'S REFERENCE BOOK 767, 773-75 (E.P.J. Tozer ed., 2004).

207 *Id.* at 775.

208 Neal H. Shepherd, *Radio Wave Loss Deviation and Shadow Loss at 900 MHz*, 26 IEEE TRANS. ON VEHICULAR TECH. 309 (1977).

greater line of sight path to the transmitter site may actually increase a signal significantly more than a simple, general model might predict.[209]

Figure 2: Predicted Coverage for Denver TV Station



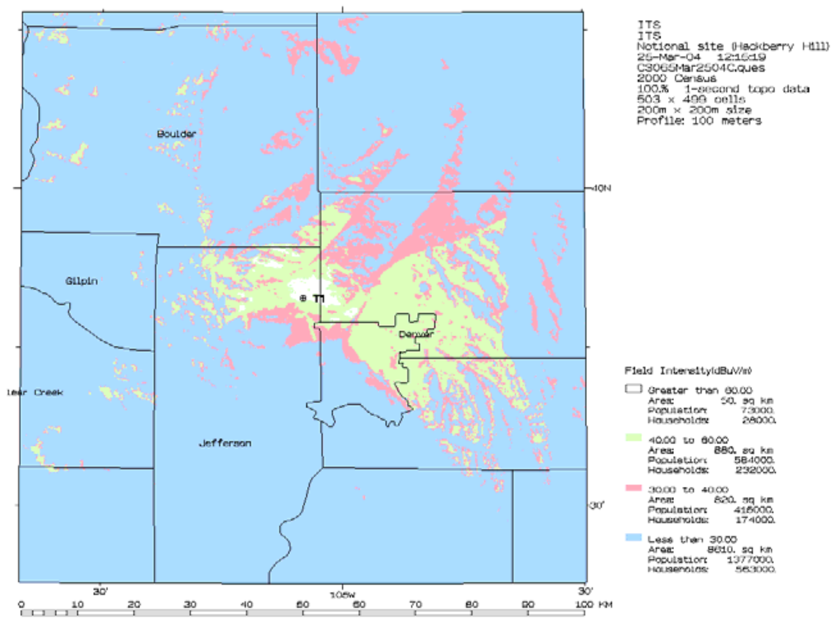
In some cases, a predicted model of signal coverage and its real-world counterpart will look nothing alike. In reality, islands of coverage may exist well beyond the predicted contour (as indicated in Figure 3 below). Moreover, gaps and islands of coverage so numerous and complex in shape (on account of hilly or mountainous terrain or areas with tall buildings or other obstructions) may render meaningless a predicted boundary. Television broadcasters, for example, often have predicated signal strength curves (the so called "Grade B contour") that bear little resemblance to the actual presence of the signal.[210] To appreciate this point, compare Figure 3's actual

209 BERTONI, *supra* note 150, at 187-201 (modeling terrain effects).

210 Notably, the scope of the theoretical range of a Grade B coverage contour versus its reality became controversial because the theoretical availability of local television signals—and not the practical reality—determined whether satellite providers could deliver distant network programming to "unserved" households (i.e., those unable to receive local television broadcasts). *See* CBS Inc. v. PrimeTime 24 Joint Venture, 245 F.3d 1217, 1219-20 (11th Cir. 2001). Ultimately, Congress settled this controversy—and prevented an injunction from taking effect that would have deprived a large number of satellite subscribers of their access to network television—by enacting the Satellite Home Viewers Improvement Act. *See* 17 U.S.C. § 122(a), (f), (j)(2) (2006); *see also* NUECHTERLEIN & WEISER, *supra* note 10, at 367-69.

signal strength to the site general model of the same area as depicted in Figure 2.

Figure 3: Actual Coverage for Denver TV Station



To make matters more complicated, even a site specific statistical predictive model will not produce a clear map of where signal strength will be detectable 100% of the time.[211] Rather, it predicts that the signal level in a given vicinity exceeds some value *x* percentage of the time and at *y* percent of the locations within that vicinity.[212] Consequently, the Grade B coverage contour for a television broadcast station means that a signal above a specified strength can be detected 50% of the time and at 50% of the locations along the contour.[213] The predicted strength of interfering signals at a par-

211 *See* BERTONI, *supra* note 150, at 248 (describing the difference between predictions and measurements in a site specific model); Leonard Piazzi & Henry L. Bertoni, *Achievable Accuracy of Site-Specific Path-Loss Predictions in Residential Environments*, 48 IEEE TRANSACTIONS ON VEHICULAR TECH. 922 (1999).

212 For a treatment of site-specific prediction of signal propagation, see BERTONI, *supra* note 150, at 217-48.

213 Notice of Inquiry, Technical Standards for Determining Eligibility For Satellite-Delivered Network Signals Pursuant to the Satellite Home Viewer Extension and Reauthorization Act, 20 F.C.C.R. 9349, para. 4 (May 3, 2005).

ticular point will thus have similar statistical characteristics.[214] In short, the contours of a coverage area are not sharply defined boundaries like the metes and bounds of real property.[215]

A number of reasons account for the deviation between predicted models and reality, including the use of certain assumptions and planning factors. For example, when establishing allotments and assignments in television broadcasting, regulators make assumptions about the receiving antenna's height and directivity, the reduction in signal strength in the cable going from the receiving antenna to the receiver, and the required desired-to-undesired signal ratio for acceptable receiver performance.[216] If the systems do not actually conform to these assumptions, the possibility of interference becomes much more (or less) likely than the prediction.

The ability to generate different outcomes based on planning factors is a considerable wild card in any predictive model. As noted above, a transmitting antenna located at ground level (or, even worse, inside a building) will produce a much weaker signal than one mounted on a rooftop above the surrounding obstructions. Moreover, the receiver might also vary from model to model or manufacturer to manufacturer.

The final challenge, which presents complications in cases like TV broadcasting, is that the licensee may only control the transmission equipment and not the receivers. The consumer may buy equipment with capabilities different from those assumed in the model, making the predictions of any model less likely to be accurate. The unpredictability as to such services would grow considerably under a true property rights system where particular bands could be used for any type of service or technology, thereby making the relevant measurements and assessments of receiver performance much more complex and uncertain insofar as it would be more challenging to develop a benchmark case where a variety of different devices were being used. We shall return to such complications in Part IV, but first, Part III explains the reasons for the often touted successful property rights approach used in the cellular bands as well as what lessons policymakers should draw from this history.

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214 Wayne Bretl et al., *ATSC RF, Modulation, and Transmission*, 94 PROC. IEEE 44, 45-46 (describing statistical interference models).

215 FCC, FM AND TV CONTOUR DATA POINTS, http://www.fcc.gov/mb/audio/bickel/contour-data.html (last visited Feb. 26, 2007) ("FM and TV service contours usually do not define the outer limit of service. In most cases, a radio or television station may be received at locations outside . . . the service contours . . . . Within the service contour, reception is generally protected from interference caused by other stations on the same channel or adjacent channels or frequencies. Outside of that contour, interference may occur from other stations. It simply is not possible . . . to protect each station [from interference from other stations outside of their contours.]").

216 *See* O'Connor, *supra* note 54.

III. GUIDELINES FOR ESTABLISHING PROPERTY RIGHTS IN SPECTRUM

In Part II, we explained why radio propagation makes the establishment of property rights in spectrum a complicated endeavor. This argument challenges the conventional wisdom that establishing spectrum property rights is a fairly straightforward issue and can be managed along the lines outlined in the De Vany study. In championing the De Vany view, modern adherents such as Kwerel and Williams routinely point to the vibrant trading and management of property-like rights in the cellular bands to bolster their claim that spectrum property rights are easily manageable. As we discuss in Part III.A, however, this claim overlooks some particular conditions that make the cellular bands an exceptional case. Rather, as Part III.B explains, more elaborate before-the-fact and after-the-fact procedures are necessary to ensure that property rights in spectrum work effectively.

A. *The Cellular Bands: Precursor or Anomaly?*

Despite the difficulties associated with establishing property rights in the space and frequency dimensions, the cases of television broadcasting and cellular telephone service provide powerful precedents that when the FCC has established property rights in certain services, interference issues at the associated boundaries can be successfully resolved.[217] Notably, valuable transactions involving the transfer of those rights take place on a routine basis, and affected parties work together to minimize interference. In cellular services, for example, the geographic spillover limit is the maximum signal strength permitted at the boundary and disputes over interference there are routinely resolved without the involvement of the FCC.[218]

To understand the successful management of property rights in the cellular context, policy observers must appreciate two distinct aspects of these services. First, the technical characteristics of cellular services make them less prone to interference. In particular, not only do the large geographic areas associated with cellular bands[219] make geographic spillover problematic only in a relatively small percentage of the total area, but the fact that

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217 Kwerel & Williams, *supra* note 121, at 6.

218 E-Mail from James D. Young, President, U.S. Tower Operations, Crown Castle Int'l Corp., to Dale Hatfield (Feb. 20, 2008) (on file with author) ("RF interference issues between wireless carriers are always resolved in the field without FCC intervention.").

219 Our reference to the "cellular bands" here does not mean to discuss only those bands originally used for cellular, but to include all subsequent bands that were authorized for flexible uses, including, but not limited to, the PCS, SMR, and AWS bands. *See* NUECHTERLEIN & WEISER, *supra* note 10, at 267 (discussing technical definition of "commercial mobile radio service").

such systems are "cellularized"[220] (i.e., the transmission systems operate in distinct areas) creates a greater opportunity to carefully tailor coverage to limit interference among a limited number of firms. Second, providers of cellular services are stable and "repeat players"[221] creating considerable incentives for cooperative behavior and against engaging in strategic behavior along the lines of patent trolls.

Like other environments where industry norms are effective regulators, cellular providers appreciate that each party possesses a mutual threat of interference and that all providers are better off as a result of cooperating with one another.[222] Moreover, such negotiations continue over time and often involve engineers who may adhere to a professional ethic to act in good faith (i.e., honestly report technical capabilities and limits).[223] Significantly, because of repeated transactions among a relatively small group of firms, this environment is uniquely suited to cooperative behavior—even if the entitlements themselves are not clearly defined or enforced by the FCC. Along the lines of Stewart Macaulay's landmark study of how businesses that dealt with one another regularly behave, cellular providers realize that "'[y]ou don't read legalistic contract clauses at each other if you ever want to do business again.'"[224] Consequently, even though the reality of the spectrum property right is "muddy," the affected parties can still agree on mutually beneficial accommodations, thereby providing a potentially misleading case upon which to build an entire regulatory regime.

Given the unique technology, professional ethos, and market conditions prevailing in the cellular bands, the optimism that Kwerel and Williams take from the cellular context is potentially misplaced. As a theoretical matter, transaction costs between identifiable neighboring users of spectrum will be low and mutually beneficial arrangements will be the rule. As a practical matter, however, we are skeptical that this confidence will be borne out in numerous other contexts and think the uncertainty (or "muddiness") of geographic boundary rights caused by signal strength variations will make agreeing on reasonable arrangements to avoid interference diffi-

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220 By cellularized, we refer to the use of the technology of transmitting radio signals within relatively small "cells." *See id.* at 263.

221 "Repeat playing" refers to the game theory concept of when firms are involved in the same "game" over and over. This type of game, in contrast to a "single shot game," is far more likely to elicit a cooperative outcome. For the classic discussion of this game theory concept, see ROBERT M. AXELROD, EVOLUTION OF COOPERATION (1984).

222 *See* ROBERT C. ELLICKSON, ORDER WITHOUT LAW: HOW NEIGHBORS SETTLE DISPUTES (1991).

223 The Institute of Electrical and Electronics Engineers (IEEE) is the professional organization for radio engineers. It requires its members "to be honest and realistic in stating claims or estimates based on available data." IEEE Code of Ethics (2006), http://www.ieee.org/portal/pages/iportals/aboutus/ethics/code.html.

224 Stewart Macaulay, *Non-Contractual Relations in Business: A Preliminary Study*, 28 AM. SOC. REV. 55, 61 (1963).

cult. Instead, we believe that regular or occasional islands of interference across geographic boundaries that are tolerated today will become the subject of litigation seeking to define more clearly spectrum rights (and obtain injunctive relief to enforce those rights). In the worst possible case, such litigation will be strategic and brought by the spectrum equivalents of patent trolls.

The economics literature explaining the success of cooperative arrangements like those developed to minimize interference in the cellular bands underscores that close-knit business environments can reinforce cooperation. In other environments, by contrast, the social norms that underpin such commitments may break down. As Jason Johnson has explained, "[w]ithin suitably dense and homogenous communities, the harm to the breacher's reputation and lost future dealings with third parties that she will suffer when the aggrieved party tells others in the community about her breach may supplant the 'second party' sanction of relationship termination."[225] If, however, the firms are not engaged in repeat-playing games—as would be the case for spectrum trolls or even some firms which were not established incumbents—they would need to resort to a third party for enforcement of their property rights.[226] In today's environment, the FCC can simply withhold or delay such enforcement—deliberately or not—as a means of encouraging cellular providers to agree on cooperative arrangements designed to minimize interference.[227] But in a more diverse environ-

225 Jason Scott Johnston, *The Statute of Frauds and Business Norms: A Testable Game-Theoretic Model*, 144 U. PA. L. REV. 1859, 1874-75 (1996); *see also* Lewis A. Kornhauser, *Reliance, Reputation, and Breach of Contract*, 26 J.L. & ECON. 691, 699 (1983) ("[I]n simple worlds with reputations, the rule of law does not matter."). Indeed, even the claim that extra-legal enforcement (i.e., reputation sanctions) can operate effectively in close-knit communities is open to question, as an increase in the number of relevant parties creates challenging enforcement issues. *See* Paul G. Mahoney & Chris William Sanchirico, *Norms, Repeated Games, and the Role of Law*, 91 CAL. L. REV. 1281, 1294-95 (2003) (discussing enforcement problems that occur when more than two actors are involved).

226 Robert E. Scott, *A Theory of Self-Enforcing Indefinite Agreements*, 103 COLUM. L. REV. 1641, 1644, 1647 (2003) (noting that conditions of repeat-playing games and significant reputation effects are "stringent," and that when those conditions are not met, "legal enforcement is necessary"). One example of this problem emerges from the context of standard-setting organizations, where commitments to fair dealing and reasonable patent policies must be enforced by external legal mechanisms insofar as firms exit from the collective enterprise of dealing and participating in the standard-setting body's mission. *See* Rambus, Inc., No. 9203, 2006 FTC LEXIS 60 (Fed. Trade Comm'n Aug. 2, 2006); *see also* Rambus Inc. v. Infineon Techs. AG, 318 F.3d 1081 (Fed. Cir. 2003).

227 In terms of the FCC's enforcement apparatus, its regular practice is to delay any dispute resolution to facilitate a mediated settlement. For instance, when the FCC created the Accelerated Docket for complaint resolution, it required that "parties seeking to place their disputes on the Accelerated Docket first meet for pre-filing settlement discussions supervised by Commission staff . . . . [The complaint] will not be accepted onto the Accelerated Docket if the complainant has not made an adequate effort to settle the matter through staff-supervised discussions." Report and Order, Implementation of the Telecommunications Act of 1996, 13 F.C.C.R. 17,018, para. 4 (July 14, 1998); *see also* Josh Long, *Heavy-Handed or Hollow?*, PHONE+, Mar. 1, 2003, *available at* http://www.phoneplusmag.com/arti-

ment (both in a technological and a business sense), the FCC's inability to enforce property rights could (1) effectively undermine investment incentives and the development of new services, and (2) encourage self-help behavior whereby parties seek to make life difficult for one another to achieve a business advantage.[228]

B. *Toward a New Regime for Spectrum Rights*

The success of property rights in the cellular bands is a notable accomplishment. As explained above, this success rests on a particular set of circumstances that is unlikely to exist across the board. After all, many firms acquire licenses in other bands without an ongoing connection to existing incumbents and would be, under a liberalized regime, in a position to use technology that might cause interference to neighboring licensees. Moreover, as noted above, some firms might take advantage of a property rights regime by acquiring licenses for the strategic purpose of claiming interference and extracting fees from existing licensees to avoid suit. Thus, policymakers should devise a system for managing property rights that provides a basis for making investments, ensures against harmful interference, and avoids strategic abuses of the legal system. To do so, policymakers must develop the right combination of front-end assurances (in the form of a safe harbor based on a predictive model) and back-end oversight.

The overall goal of our proposed reforms is to replace the existing command-and-control regulatory system with a more flexible system that will facilitate marketplace arrangements and ensure that spectrum licenses are used in an optimal fashion. As an initial matter, however, it is critical that our proposed system reassures spectrum licensees that the new framework will competently define and enforce their rights against interference. At the same time, this new system should enable firms to effectively use and trade the rights to use spectrum, ensuring that remedies are calibrated to address only actual harms and not to deter more efficient uses of spectrum.

1. The Use of Predictive Models in Spectrum Property Rights

By building upon current practice in many services (e.g., television broadcasting), we believe that spectrum-use rights can be developed upon

cles/351FEAT3.html ("[In fiscal year 2002 the] bureau also settled through mediation about 40 of 60 cases over wholesale provisioning and other competitive issues such as special access and OSS . . . .").

228 One context where this issue becomes particularly problematic is where users of spectrum are actually governmental agencies and not commercial providers. For such cases, as in the interference disputes that arose between Nextel and public safety agencies, the role of the FCC in overseeing the relevant interference rights is likely to be particularly important in resolving disputes. *See* Report and Order, Improving Public Safety in the 800 MHz Band, 19 F.C.C.R. 14,969 (Aug. 6, 2004).

predicted signal strengths that are also subject to some after-the-fact oversight. As an initial matter, we believe geographical boundaries could be established and the owner of a block of spectrum in the frequency dimension should have the right to spill energy over into the adjacent geographic areas up to some maximum amount. Conversely, the same owner would have the obligation to accept spillover at the boundary up to the same maximum amount. Rather than measured at the boundary, however, the spillover amount or level would be computed using an accepted model for how radio signals propagate.

The premise of a strategy that relies on a predicted rather than measured level at the geographic boundary has two major advantages. First, this approach is relatively simple, although regulators may well opt for some degree of complexity to provide adjacent licensees with a greater level of assurance against actual interference. Second, this approach can potentially lower enforcement costs because regulators would use computer modeling rather than expensive field measurements. In the case of television broadcasting and to a certain extent cellular services, such models are already used and, at least in a "muddy entitlements" sense, work reasonably well; that is, firms are willing to buy TV stations and cellular systems based on the existing legal protections against interference. Thus, as an initial approximation, even an imperfect, but reasonably well defined, property rights regime can offer an initial basis for firms to make investment decisions and deploy new services.

When arguing for spectrum regulation that provides a safe harbor defined by a predictive model for each relevant band (at least for some transition period), we recognize that such a system would raise a number of challenges, including difficulties in establishing the initial maximum signal power levels and the receiver antenna height as well as predicting the actual level that would be transmitted. Nonetheless, to devise an effective legal regime for spectrum rights, we believe that a predictive model must be developed to define the relevant right—a challenge not confronted by real property rights. This model need not (and will not) be perfect; rather, it merely needs to be good enough to allow subsequent refinements by bargaining and adjudication. In any event, regulators must use the selected model to limit expected interference to a reasonable amount (say, less than 10% of the locations 10% of the time at the boundary) and not to avoid interference entirely. By so doing, the FCC can, as Paul Margie put it, seek to "maximize total utility in each band rather than to minimize interference to any individual spectrum user."[229]

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229 Margie, *supra* note 87, ¶ 67. The FCC recognized this point in its order addressing interference issues related to broadband over powerline systems. *See* Report and Order, Amendment of Part 15 Regarding New Requirements and Measurement Guidelines for Access, Broadband over Power Line Systems, ET Docket No. 03-104, 2004 WL 2411391, paras. 22-24 (Oct. 28, 2004) [hereinafter BPL Order] (noting that ham radio operators have worked in tandem with other users, no interference would

We also recognize that the government agency that selects the model and defines the safe-harbor level of allowable expected interference will play a critical coordination function along the lines of the role played by zoning authorities. Just like zoning codes specify a vision for an aesthetic expected of buildings (say, their height or even exterior configuration), safe harbor decisions would greatly influence technology decisions. If, for example, regulators authorized very little interference close to a designated boundary, that would encourage low power uses as well as a cellularized architecture. Similarly, the amount of authorized interference will greatly influence the design of receivers and their susceptibility to interference. Thus, we recommend that regulators adopt a set of different models for different frequency bands, approximating to some degree the current uses of wireless spectrum.

Unless the relevant parties can bargain to reach alternative arrangements, the safe harbor's default rules could drive technology decisions related to the geographic spillover between neighbors using the same frequencies (co-channel interference) and spillover in the frequency dimension in the same geographic area (adjacent channel interference).[230] On one hand, setting a limit that is too stringent could force the rights-holder to reduce power to the point of creating coverage holes near the boundary, adopt a cellular architecture that may not be optimal for a particular service, or deploy additional cell sites to provide adequate coverage while meeting the spillover limit. On the other hand, setting limits that are too lenient may impose excessive costs on the rights-holder across the geographic or frequency boundary, including costs associated with increasing transmitter power to overcome the interference or abandoning service in areas where the interference is excessive.

Like zoning regulators' recognition that different neighborhoods serve different needs, we believe that the best strategy for "zoning the spectrum" is to recognize that certain bands are more conducive to some services (e.g., low powered, cellularized ones) and other bands are more conducive to other ones.[231] In this sense, zoning the spectrum performs a similar role to

result unless an amateur user was on top of a BPL extractor, the benefits of BPL warrant a small degree of interference risk, and these risks can be managed through protective measures).

230 Notably, other interference mechanisms are not addressed in this paper, including: spurious emissions from transmitters (as opposed to adjacent channel spillover in the frequency dimension), transmitter and receiver intermodulation, and receiver desensitization due to strong out-of-band signals. Although we do not suggest that these factors are unimportant or that a property-rights regime will not need to account for and address them, we believe that these are secondary considerations and that the principal challenge is developing an effective framework to govern geographic spillovers and adjacent channel interference.

231 In principle, courts could adjust these rules by declaring such uses, at least in certain contexts, to be a public nuisance. But like the move from courts to zoning bodies to make such decisions, we believe that zoning the spectrum is sufficiently complex as to warrant agency—and not judicial—oversight. *Cf.* Green v. Castle Concrete Co., 509 P.2d 588, 590 (Colo. 1973) (noting that zoning deci-

nuisance law, which recognizes that a "nuisance may be merely a right thing in the wrong place, like a pig in the parlor instead of the barnyard."[232] As in nuisance law (and zoning), the relevant classifications may need to change over time, but the FCC must establish the relevant safe harbor based on the particular propagation characteristics of the band, realizing that such classifications can restrict the likely uses of the spectrum and may well create certain economic inefficiencies. In the case of the AM band, for example, parties should be given wide latitude whereas the cellular bands should be zoned to demand and expect (as is currently the case) that parties can control their interference levels carefully.

In developing a zoning code for the radio spectrum, the FCC should avoid specifying technology or service decisions. To be sure, specific rules will necessarily privilege certain uses, but regulators should not specify any particular services as technologies will change over time and services should succeed or fail in the marketplace. In short, such a code should merely regulate the total output (i.e., actual interference) or, where necessary, institute the least restrictive means of regulating inputs to guard against the possibility of interference. In particular, by moving away from regulating the inputs to a licensed service, the FCC would move towards the Spectrum Policy Task Force's Spectrum Rights and Responsibilities Working Group's recommendation to adopt "[i]nterference standards based on outputs" because they "provide desired flexibility while protecting the reasonable expectations of licensed and authorized service providers and the public."[233] By staying away from regulating inputs wherever possible, the FCC can leave it to the market to make such decisions.

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sions determine what, in effect, constitutes a "public nuisance" and that courts cannot enjoin a legislatively permitted public nuisance); *id.* at 591 ("Solutions for problems of the magnitude anticipated here may suggest legislative and not judicial action.").

232 Village of Euclid v. Ambler Realty Co., 272 U.S. 365, 388 (1926).

233 FCC SPECTRUM POLICY TASK FORCE, REPORT OF THE SPECTRUM RIGHTS AND RESPONSIBILITIES WORKING GROUP 29 (2002), *available at* http://www.fcc.gov/sptf/files/SRRWGFinalReport.pdf; *see also id.* at 27 ("Parameters based on [outputs] provide licensees with greater flexibility in determining their system architecture to meet customer density, geographic location and scope, and cost considerations, while maintaining what should be the Commission's most basic regulatory concern: the extent to which they impact the service of other licensees and operations.") Similarly, as one of us has explained on the issue of why regulators should focus, wherever possible, on regulating outputs and not inputs:

> Moreover, it is better (in terms of achieving more efficient outcomes) for regulators to focus on regulating the outputs or results they want to achieve rather than on the inputs that are utilized to achieve those outcomes. If network reliability is a concern, then the regulator can establish and enforce network reliability standards, leaving it to the operators to figure out how to meet them. For their part, operators must figure out the optimal network design that will maximize the productivity of their networks while minimizing costs. The operators, after all, have strong economic and competitive incentives to meet the regulators' standards using the most economical and efficient architecture and equipment.

Dale N. Hatfield & Eric Lie, *Why License?, in* TRENDS IN TELECOMMUNICATIONS REFORM 2004/2005, at 25, 30 (2004).

In calling for a zoning-like system, we are aware of criticisms leveled against zoning systems in the land use context—namely, that such a role invites rent-seeking behavior.[234] As one commentator put it, "[z]oning has particularly been criticized for procedural inadequacies: lax enforcement, favoritism, lack of consistency with planning, and excessive rigidity in some cases and undue flexibility in others."[235] Such problems might emerge in the spectrum context, but we nonetheless prefer this model to either the existing system or a unitary property rights model. In short, the problem with the existing system is that it restricts possible uses of spectrum by providing limited guidance; by contrast, if the FCC adopted a unitary property rights model, it would place a thumb on the scale that would bar certain types of services (like AM radio) from succeeding and would not allow for experimentation across bands (in the form of differently defined use rights).

The selection of a single form of property rights across the spectrum would undermine differentiated uses of spectrum and push toward particular technological architectures (i.e., low-powered and cellularized). Rather than embrace a single technology, the FCC can better serve society by defining different types of spectrum usage rights to enable different technologies. To be successful, such a framework must break away from the highly restrictive existing rules and must take account of technological realities through some form of ongoing, after-the-fact oversight that calls for regular reassessment.

2. The Role of After-The-Fact Oversight

Developing a zoned spectrum with safe harbor rights (at least for some period of time) and some predictability for spectrum licensees would be a salutary development. If, however, policymakers choose to rely solely on ex ante predictions—without any ex post evaluation of actual interference, they would make several notable sacrifices. First, any system that provides unconstrained discretion for the FCC to determine the specifics of a predictive model risks inviting rent-seeking behavior by incumbents.[236] Second, licensees would possess limited certainty of their rights under a predictive model, requiring them to adopt additional measures such as cooperative arrangements or technical contingency plans. Finally, a system based on predictions leaves open the question of how to enforce property rights when there is a significant discrepancy between predicted and measured levels at

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234 *See* Nicole Stelle Garnett, *Ordering (and Order in) the City*, 57 STAN. L. REV. 1, 39 n.192 (2004) (collecting sources).

235 RUTHERFORD H. PLATT, LAND USE AND SOCIETY 296 (1996).

236 *See supra* notes 30-31, 64-66, 96-99 and accompanying text.

the boundary.[237] In short, we believe that allowing some measure of a safe harbor is critical (at least for the near term), but we are also confident that unless the predicted contours are reasonably close to reality and checked against it, spectrum will be underutilized and licensees may resist making costly investments necessary to deliver a promised service.

The role of a reality check on spectrum property rights is a double-edged sword. On one hand, the use of predictive models that do not sufficiently match reality may allow more interference than intended and may thus need to be altered to protect a licensee's interest. On the other hand, as was the FCC's historic practice, the relevant models may be overly cautious to prevent any possible interference and thus leave significant amounts of spectrum underused. To address both issues, policymakers should allow licensees to request greater flexibility to create interference (i.e., the restrictions placed upon them are too great) and policymakers should be able to restrict the amount of tolerated interference because reality allows for more interference than anticipated in theory (i.e., the restrictions on neighboring users are too lenient).

The nature of the reality check that we propose is a dispute resolution forum whereby parties could bring either of the two types of challenges noted above. In one case, in essence, they would ask for a zoning variance based on a demonstration of the relevant technological realities—as opposed to the predictions of the model that gave rise to the governing restrictions.[238] In the other case, they would challenge a neighbor's (either a user of a co-channel or adjacent channel) spectrum use. In both cases, bargaining between the relevant neighbors should be expected and encouraged.[239]

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237 It is worth noting that there are two types of discrepancies—(1) enduring levels of nontrivial interference that, taken together, create material difficulties; or (2) transient interference levels that are significant even if intermittent. *See* Jackson, Pickholtz & Hatfield, *supra* note 187, at 255.

238 Of late, the FCC has begun to grant such requests with increasing regularity, implicitly recognizing the limitations of statistical models that predict interference, taking important strides to ground its spectrum policy in reality and moving towards a more consistent focus on "harmful interference." Consider, for example, the Wireless Telecommunications Bureau's waiver of some technical requirements to permit land mobile base stations to operate within a television broadcast radius. In that case, the Bureau recognized the hypothetical nature of the "Grade B contour" radius and explained that this hypothetical form of protection did not prevent the authorization of another use. In particular, the Bureau made clear that because: (1) any possible interference—as evaluated in real terms—was "very small"; and (2) there was no evidence that any receivers were in the affected area, the Bureau's bar against additional entry within the contour of the Grade B signal should be lifted. *See* Access Spectrum, LLC Request for Waiver of Section 27.60, 19 F.C.C.R. 15,545, para. 15 (Aug. 12, 2004); *see also* Report and Order, Second Periodic Review of the Commission's Rules and Policies Affecting the Conversion to Digital Television, 19 F.C.C.R. 18,279, para. 46 n.97 (Sept. 7, 2004) (setting channel allotment process to allow for additional interference for up to 0.1% of the population served by adjacent station).

239 *See infra* Part IV.

The dispute resolution forum, like a court hearing trespass claims, should be authorized to award damages and, in special cases, injunctions. Like the safe harbor model used in statutes like the Digital Millenium Copyright Act ("DMCA"), parties would be immunized from liability where they complied with the relevant safe harbor requirements.[240] The predictive model that gave rise to those requirements should not be inviolate; rather, it should only provide a starting point for the enforcement of property rights in spectrum. In particular, for cases where the model's predicted level of interference was off by a substantial degree, the injured party could provide notice to its interfering neighbor (or neighbors) that it was creating a nontrivial amount of impermissible interference. If the specified notice period passed without any correction of the illegal interference (or a negotiated solution), the injured party could bring a claim for relief. Alternatively, if a party—for whatever reason—did not comply with the relevant safe harbor requirements and the predictive model closely mimicked reality, no such notice would be required, and the affected party could immediately bring a claim for relief.

The rules governing a claim for spectrum trespass, as suggested above, should be designed to prevent strategic behavior and thus the available relief should be restricted accordingly. Notably, injunctions that would curtail a firm's ongoing operations should only be provided upon a showing that the illegal interference at issue created a material injury to the affected licensee's business.[241] As to damages, a party should be entitled not only to compensatory damages, but also some form of prescribed damages in cases where a party presented evidence of a substantial deviation from the interference authorized by the zoning code and the firm failed to take effective measures to correct the interference.[242] If firms fail to pay the required damages or comply with any relevant injunctive order within a reasonable period of time, they would also be subject to the sanction of forfeiting their license. Finally, in the event that a firm brought a bad faith

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240 *See* 17 U.S.C. § 512 (2000).

241 *See* Mark A. Lemley & Philip J. Weiser, *Should Property or Liability Rules Govern Information?*, 85 TEX. L. REV. 783, 798-800 (2007). In the spectrum context, some commentators have implicitly assumed the presence of only damages remedies, but have not explicitly discussed the potential availability—and potential abuses—of injunctions. *See* Hazlett, *Liberalizing US Spectrum*, *supra* note 78, at 490 ("[P]rivate users' liability for damage will yield efficient incentives to respect other transmissions."); *id.* at 493 ("Harmful interference could occur, but with full compensation.").

242 Such damages could be on the order of, but not at the high levels of, the statutory damages provided by copyright law. *See* 17 U.S.C. § 504(c)(1) (2000) (setting rate for presumed damages for copyright infringement at a minimum of $750 per infraction and a maximum of $30,000 per infraction). For non-willful infringement, the measure of damages can be reduced to $200 per infraction (and no less); for willful infringement, a court may increase the award to no more than $150,000. § 504(c)(2).

action for spectrum trespass, the licensee subject to the suit would be entitled to all costs and attorneys' fees as well as punitive damages.[243]

IV. THE CHALLENGES OF A NEW REGULATORY REGIME

Either adhering to the legacy command-and-control model or championing a property rights regime similar to the one for land dodges many of the most difficult issues related to developing a system of managing property rights for spectrum. In fact, the not-so-hidden secret of the FCC's traditional spectrum policy regime is that it avoids the very difficult tasks of: (1) defining property rights clearly enough to allow for marketplace transactions; and (2) instituting an effective enforcement regime. To advance its spectrum policy reform agenda, the FCC will have to define spectrum rights and protections against interference (and the correlative right to interfere) far more clearly than has historically been the case. The implementation of an improved regime—like the one we proposed in Part III—will raise a series of challenging questions. In this Part, we address a number of them, including why such a regime is worth pursuing (as opposed to, say, dedicating all spectrum to a commons model), what type of institution should superintend the regime we have in mind, and how to encourage Coasian bargaining in a property rights-based system.

A. *The Commons Model as an Alternative*

Since the outset of this Article, we have avoided discussing one popular alternative to a system of property rights: the commons model. Advocates of this model can view our basic point—that developing and enforcing property rights in spectrum is more difficult than appreciated by the conventional wisdom—as an argument to scrap the notion of property rights altogether. This argument, however, downplays the benefits of the property rights model and underestimates the challenges that the commons model faces.

Our view of the debate between property rights and commons approaches is that both approaches have different advantages and neither should be pursued to the exclusion of the other. The commons approach allows spectrum users to avoid gaining access to spectrum via a license (or a lease of licensed spectrum) and asking permission from the FCC to authorize a particular use.[244] As such, we believe that dedicating some swaths

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243 This measure parallels one along the lines of the DMCA's penalty for filing a notice and take-down request in bad faith. *See* Online Policy Group v. Diebold, Inc., 337 F. Supp. 2d 1195 (N.D. Cal. 2004) (concluding that such a penalty was warranted).

244 NUECHTERLEIN & WEISER, *supra* note 10, at 251-57.

of spectrum for unlicensed uses, as the FCC has done with some bands (including those used for Wi-Fi), is sound policy.

In evaluating the significance of the success of Wi-Fi and the promise of the commons model for facilitating new technologies, policymakers must appreciate the fundamental limitations of that approach. The commons model depends on the FCC's ability to play a critical coordination function to guard against "tragedy of the commons"-type behavior. To date, the FCC manages this concern by requiring all commons wireless devices to be low powered, which lessens the possibility of interference.[245] As we have explained in a prior article, this strategy depends on considerable ongoing FCC enforcement efforts to be successful and requires greater administrative oversight than is widely appreciated.[246]

A central virtue of the property rights model is that the recognition of property rights enables individual licensees to make judgments about what technologies (and power levels) to use. Moreover, insofar as individual licensees believe that a commons approach is viable, they are entitled to create private commons whereby they enforce compliance with whatever technical or power limitations they impose on the use of the relevant spectrum band. Additionally, if a licensee develops an application that is highly dependent on quality of service guarantees, the licensee—which possesses enforceable rights as to limitations on interference—is far more likely to provide reliable service than can be offered using unlicensed spectrum.

Many commons advocates justify their support of unlicensed spectrum by maintaining that new technologies, which allow dynamic avoidance of interference, can obviate the need for exclusive control of spectrum via licenses as a means of managing interference concerns.[247] Consequently, as Ellen Goodman has explained, "[t]he crux of the disagreement between the two schools [property rights and commons advocates] concerns an empirical question of whether technological innovation will effectively render spectrum so abundant that the costs of a private property regime cannot be defended."[248] In short, the relevant technology has not reached that point, as it is still in an early period of development without clear indications that it will successfully address the sorts of concerns that have traditionally created interference issues.[249]

The belief that technologies using commons spectrum likely will radically outperform those using privately managed spectrum represents a "Schumpeterian" argument that future innovation will deliver more effec-

245 *Id.* at 251-52.

246 Philip J. Weiser & Dale N. Hatfield, *Policing the Spectrum Commons*, 74 FORDHAM L. REV. 663 (2005).

247 *See* Benkler, *supra* note 7, at 28.

248 *See* Goodman, *supra* note 7, at 380.

249 For a relatively skeptical assessment as to whether these technologies will ever obviate interference concerns entirely, see Jackson, *supra* note 187.

tive services for consumers than an effective use of spectrum using today's technologies.[250] We disagree with this claim for two reasons. First, we believe technologies will not reach this point within the foreseeable future. Second, even if technologies using commons spectrum would provide far better uses of spectrum than their property rights counterparts, we are dubious that the government could manage this spectrum so that these benefits occur in a reasonably effective and timely manner.

In short, the commons model has much to commend it and we believe it should be implemented in conjunction with a property rights approach. In many respects, the two models complement each other and may be more effective in tandem than in isolation. As Pierre de Vries put it, the two models may well operate in the "same way that a public park enhances the market value of surrounding properties, and the use by surrounding residents increases the utility of the park."[251] Notably, commons spectrum provides a valuable testing ground for technologies that might ultimately be moved to licensed spectrum. In other cases, such as T-Mobile's new Wi-Fi/cellular hybrid phone, the two technologies can quite literally work in tandem.[252] We acknowledge the risk that the commons approach could outperform the private property model, but betting entirely on that model is unwise (and politically unrealistic).

B. *Back-End Oversight and Institutional Reform*

Given the FCC's history of solicitude for rent-seeking behavior by incumbents, an appealing alternative to any reliance on the FCC is to transfer oversight to courts of general jurisdiction. To that end, one might argue that generalist courts could have managed the spectrum resource more effectively through property rights developed by judges on a common law basis from the outset (rather than through a New Deal-chartered regulatory agency). This argument, however, envisions a far simpler version of spectrum property rights and their administration than we proposed in Part III.[253] Given the complex realities of spectrum management and the need for zoning the spectrum, we believe that some specialized administrative oversight

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250 This line of argument, named in honor of the late Joseph Schumpeter, places its faith in "creative destruction" that emerges from technological change and is skeptical of the relative value of "static" efficiencies that emerge from more efficient uses of existing resources. *See* JOSEPH SCHUMPETER, CAPITALISM, SOCIALISM AND DEMOCRACY 81-86 (1942).

251 Pierre de Vries, *Populating the Vacant Channels: The Case for Allocating Unused Spectrum in the Digital TV Bands to Unlicensed Use for Broadband and Wireless Innovation* 18 (New. Am. Found., Working Paper No. 14, 2006), *available at* http://www.newamerica.net/files/WorkingPaper14.DTVWhiteSpace.deVries.pdf.

252 *See* Marguerite Reardon, *Switching from Cell to Wi-Fi, Seamlessly*, CNET NEWS.COM, Sept. 7, 2006, http://www.news.com/Switching-from-cell-to-Wi-Fi%2C-seamlessly/2100-1039_36113223.html.

253 *Cf.* Jackson, *supra* note 189, at 2-9 (criticizing this argument).

is critical, even if a role for the FCC in spectrum regulation is like what Winston Churchill said about democracy—it is the worst form of government, except for all of the others.[254]

While administering a property rights system for spectrum, the FCC (or any oversight agency)[255] will face a number of critical challenges. The first challenge is to develop a sufficient set of models and a zoning-like framework to enable spectrum users to develop new technologies and trade spectrum licenses with the freedom to develop services without first obtaining expensive permission. The second challenge is for the FCC to develop the expertise to manage adjudications of the kind we describe in Part III.B.2.

The opportunity to shift the emphasis of spectrum policy from front-end modeling to back-end (or after-the-fact) oversight, which is an important and often overlooked aspect of spectrum policy reform, presents the FCC with a considerable challenge. As the FCC's Spectrum Policy Task Force explained, successful spectrum management requires that the "predictive models used by the Commission [to estimate and manage interference] be updated, and perhaps eventually replaced, by techniques that take into account and assess actual, rather than predicted, interference."[256] By using and refining such a regime, the FCC can focus on claims of actual interference—as opposed to relying entirely on a regime that addresses only the possibility of interference.

Most critically, the FCC must develop the institutional abilities to function as a "spectrum court"[257] to avoid employing a quasi-legislative approach to managing spectrum. When criticizing the slow pace of the transition to a new regulatory regime, commentators routinely downplay the relevant institutional challenges—often arguing, without any discussion, that courts can perform this function effectively.[258] In many respects, the proponents of generalist courts make an overly harsh judgment about the possibilities of the devil we know (the flaws of the FCC) versus the one we do not (the flaws of courts in complex and technical areas).[259]

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254 For a development of this point as to the role of the FCC more generally, see NUECHTERLEIN & WEISER, *supra* note 10, at 419-29.

255 As we note here and at the outset, we are agnostic (for present purposes at least) on whether the administrative agency charged with spectrum management should be a reformed FCC or newly established administrative agency. For ease of exposition, however, we will refer to such an agency as the FCC.

256 SPECTRUM POLICY TASK FORCE REPORT, *supra* note 8, at 14.

257 For example, the "spectrum court" could use administrative law judges to decide issues in a rule-of-law oriented fashion.

258 *See* PETER HUBER, LAW AND DISORDER IN CYBERSPACE: ABOLISH THE FCC AND LET COMMON LAW RULE THE TELECOSM (1997); Kevin Werbach, *Supercommons: Toward a Unified Theory of Wireless Communication*, 82 TEX. L. REV. 863 (2004).

259 *See* Pablo T. Spiller & Carlo Cardilli, *Toward a Property Rights Approach to Communications Spectrum*, 16 YALE J. ON REG. 53, 65 (1999) ("Implementing a property rights system would remove the

The often unexamined claim that judges should be authorized to evaluate interference claims between rival licensees overlooks the highly technical nature of wireless communications. In high technology areas more generally, commentators such as Judge Posner have highlighted the mismatch between ordinary judicial tribunals and the technical expertise necessary to judge rival claims; as Posner has explained, "[c]omputer science and communications technology are much more difficult areas than the average body of scientific or engineering knowledge that lay judges and jurors are asked to absorb en route to rendering a decision."[260] One alternative would be to rely on a system of special masters who could assist judges in such matters[261] and another would be to implement a specialized court system.[262] These are reasonable suggestions, but our preferred alternative is to empower a specialized tribunal—say, administrative law judges operating within the FCC—to consider such claims.[263] Stated simply, we believe that such a model could more effectively be able to integrate the necessary technological and policy expertise as well as keep abreast of technological change.

As an initial matter, the FCC should make available a forum for incumbent users to contest actual interference.[264] By so doing, the FCC can move away from its sole reliance on front-end models and prophylactic safeguards. Notably, some recent FCC decisions, such as its Broadband over Power Line Order, have moved in this very direction, providing for an after-the-fact complaint procedure to deal with claims of interference that actually arise.[265]

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ability of politicians to use spectrum allocation for political benefits, and would put a large proportion of the regulatory staff, not to mention lobbyists and lawyers, out of work."); *id.* at 65 n.66 ("While it might increase the workload on judges, it is likely than [sic] many fewer lawyers would be needed to litigate [the resulting] cases than to navigate the FCC's Byzantine regulations.").

260 Richard A. Posner, *Antitrust in the New Economy*, 68 ANTITRUST L.J. 925, 937 (2001).

261 *See* Spiller & Cardilli, *supra* note 259, at 73; *see also* Posner, *supra* note 260, at 940; STEPHEN BREYER, ECONOMIC REASONING AND JUDICIAL REVIEW 11-13 (2003), *available at* http://www.aei.brookings.org/admin/authorpdfs/page.php?id=840 (embracing use of experts by judicial tribunals).

262 In the patent system, the Federal Circuit plays this role at the appellate level and Congress recently commissioned an experiment of training specialized patent judges in each district.

263 *See* Weiser & Hatfield, *supra* note 246, at 691-94 (discussing advantage of agencies in facilitating effective use of spectrum commons); Philip J. Weiser, *The Relationship of Antitrust and Regulation in a Deregulatory Era*, 50 ANTITRUST BULL. 549, 557-61 (2005) (discussing advantages of regulatory bodies over antitrust courts).

264 Commissioner Furchtgoff-Roth initially argued for such an approach in 2000. *See* Service Rules for the 746-764 and 776-794 MHz Bands, and Revisions to Part 27 of the Commission's Rules, 15 F.C.C.R. 476, 557 (Jan. 7, 2000) (separate statement of Furchtgoff-Roth, Comm'r) ("Rather than creation of so-called 'guard bands,' I would have been inclined to resolve our mandate by establishing strict interference limits with significant penalties for non-compliance.").

265 *See* BPL Order, *supra* note 229, para. 59.

C. *Promoting Technological Progress*

When designing property rights for spectrum, we (like other proponents of such a system) envision a baseline property rights system that will give rise to Coasian bargaining. Unlike many proposals, however, ours does not view the role of a regulatory authority as antithetical to such a regime. In particular, we believe that a regulatory authority must play a critical role because: (1) the system of property rights must rely on a before-the-fact zoning-like code (based on predictive models); and (2) the adjudication of after-the-fact judgments (to modify the before-the-fact safe harbor protection and address noncompliance) will require expertise in radio technology beyond the capacity of generalist courts. When developing a zoning code for spectrum, the relevant judgments involve both technical and political expertise. For example, appreciating that certain types of safe harbors would make AM radio uneconomical requires technical proficiency; however, deciding whether society should preserve AM radio is a political judgment. We caution that policymakers should not, without appreciating its impact, adopt a property rights system that would wipe out socially valuable uses of radio technology.

The after-the-fact dispute resolution system we envision would require the FCC to make two critical kinds of judgments. The first type of judgment, as alluded to above, is defining the baseline property right and safe harbor protection, presumably privileging certain applications as a result. Even under such a system, if particular applications (e.g., UHF TV broadcasting) were less socially valuable and other applications (e.g., wireless broadband) could produce greater social welfare benefits, the Coase Theorem suggests that such trades would take place. But because transaction costs (which can be shaped by the system of property rules) may prohibit effective trading, it is quite possible that the initial property right and its intended beneficiary (say, AM radio broadcasters) will remain in possession of the right despite its lower social welfare benefit. This is not necessarily an anti-Coasian result, but rather reflects the ability of society to place a thumb on the scale through the development of the entitlement in question.[266]

The ability of the FCC to set the initial conception of the property right and alter it over time via a dispute resolution process plays an important role in facilitating the emergence and adoption of interference management technologies.[267] To a large degree, firms will internalize the value of adopt-

266 *See* Pierre Schlag, *An Appreciative Comment on Coase's* The Problem of Social Cost*: A View from the Left*, 1986 WIS. L. REV. 919, 960-61.

267 *Cf.* Xavier, *supra* note 18, at 10 ("Interference management techniques are likely to evolve to accommodate and exploit emerging technologies that have the potential to reduce the impact of the interference environment. Low-density power technologies like spread spectrum and ultra wideband systems appear to hold considerable promise in allowing spectrum underlay to be exploited, while

ing such technologies and will seek to use such technologies to enhance the value of their spectrum. But, in many cases, the value of such technologies to a licensee will depend greatly on its neighbor's adoption of interference mitigation techniques. If, for whatever reason (say, transaction costs or strategic behavior), Firm A is unwilling to upgrade its interference mitigation system to benefit a neighbor, its neighbor will presumably be (at least without regulatory action) unable to deploy a more socially valuable product because the interference that it would produce would subject it to legal action.

As an initial strategy, the FCC should rely on private bargaining to allow licensees to subsidize the upgrade of their neighboring users' receivers (or interference mitigation systems). By so doing, the party gaining the benefit from the interference mitigation will be the one who will pay the relevant costs. Thus, as in the case of the sparks-producing train and the farmer's crops planted close to the tracks, the railroad can either pay the farmer not to plant (thereby authorizing its valuable use) or the farmer could pay the train to adopt more effective spark mitigation technology (thereby authorizing his valuable use).[268] In theory, as Coase explained with regard to that case, clear property rights should give rise to bargaining that will produce the efficient result.[269] Indeed, as to radio technology in particular, Coase explained that "[t]he reduction of interference on adjacent frequencies may require costly improvements in equipment, and operators on one frequency could hardly be expected to incur such costs for the benefit of others if the rights of those operating on adjacent frequencies have not been determined."[270]

Certain scenarios show that the transaction costs inherent in bargaining can prevent the parties from reaching a mutually beneficial agreement.[271] In the case of unlicensed spectrum, for example, the multitude of parties involved necessitates that the FCC play a more active role in overseeing the use of such spectrum (as it does through its equipment certification program).[272] Similarly, if the number of relevant licensees is large enough, co-

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frequency agility technologies and smart antenna technology offer potential in mitigating interference concerns.").

268 *See* Coase, *supra* note 67, at 15-16.

269 *Id.*

270 Coase, *supra* note 13, at 28. Similarly, as the Spectrum Policy Task Force Working Group on Spectrum Rights and Responsibilities noted "[n]ew entrants often complain that incumbents have no incentive to produce robust systems that are less affected by potential interference and, in fact, have a disincentive to do so if the Commission continues to protect legacy equipment that is not designed to operate in a spectrally efficient manner." FCC SPECTRUM POLICY TASK FORCE, REPORT OF THE SPECTRUM RIGHTS AND RESPONSIBILITIES WORKING GROUP 28 (2002), *available at* http://www.fcc.gov/sptf/files/SRRWGFinalReport.pdf.

271 *See* Coase, *supra* note 13, at 26-29.

272 Reflecting this rationale, the FCC took an active stance in its Broadband over Power Line Decision to facilitate coordination and cooperation between the amateur radio (ham) operators and those

ordinating their behavior effectively may be difficult. Indeed, it is just such coordination problems that justify the use of zoning codes in the first place.

In addition to the coordination (or collective action) problem, three other types of market failures might justify regulatory involvement through the development or refinement of a zoning code. First, incumbents may withhold their cooperation to engage in holdup-type behavior. Second, incumbents may refuse to cooperate when the benefiting party is developing a disruptive technology that will ultimately undermine the incumbent's core business. Third, governmental agencies that own rights to spectrum may not act rationally, because they are not motivated by economic incentives (i.e., they are not allowed to monetize their spectrum).

First, the law and economics literature has clearly established that the incentive for parties to withhold cooperation for strategic reasons can undermine socially beneficial transactions.[273] In the case of telecommunications regulation, this theory (among others) explains the need for mandatory interconnection with an incumbent's network and an open interface to facilitate competition in equipment manufacturing.[274] If all entrants in the telecommunications service or equipment manufacturing markets could be "held up" from deploying a new service or product until the incumbent voluntarily agreed to afford it access and interconnection to its network, those entrants would be placed at a formidable and likely insurmountable disadvantage.

The second form of a transaction cost is that incumbent providers will often fail to embrace the promise of "disruptive technologies"[275] and will seek to prevent their introduction into the marketplace. In the case of AT&T, for example, it initially refused to deploy fiber optic technology in its network, explaining that it intended to stick with its legacy infrastructure which it would be able to depreciate until the late 1990s. But once the government forced AT&T (or, more precisely, its divested Bell Operating Companies) to interconnect with rivals like MCI, it could not sit idly by while rivals embraced the disruptive technology.[276]

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deploying broadband over power lines systems. *See* BPL Order, *supra* note 229, para. 83 (imposing BPL notification and database requirements on BPL operators).

273 For the classic development of the legal responses to holdout and the development of the Coasian analysis, see Guido Calabresi & A. Douglas Melamed, *Property Rules, Liability Rules, and Inalienability: One View of the Cathedral*, 85 HARV. L. REV. 1089 (1972); *see also* Lemley & Weiser, *supra* note 241, at 784.

274 *See* Philip J. Weiser, *The Next Frontier In Network Neutrality*, 60 ADMIN L. REV. (forthcoming 2008).

275 This concept is developed in CLAYTON CHRISTENSEN, THE INNOVATOR'S DILEMMA (1997).

276 *See* Howard A. Shelanski, *Competition and Deployment of New Technologies in U.S. Telecommunications*, 2000 U. CHI. LEGAL F. 85, 107 (explaining that AT&T failed to deploy fiber optic technology in its long-haul network until Sprint and other upstarts did and began advertising a superior quality network). As an executive from Corning explained:

> AT&T, which owned most of the telephone lines in America at the time [of the invention of fiber optic technology], said it would be 30 years before its telephone system would be ready

In situations where holdup opportunities or the fear of disruptive technologies lead incumbents to withhold cooperation, the FCC should be willing to mandate an arrangement that would call for coordination between the affected parties. As Coase argued, the role of government in such situations is to identify and institute the solution that "would have been achieved if the institution of private property and the pricing mechanism were working well."[277] By calling for a notice and negotiation process before a party seeks FCC dispute resolution, our system of property rights would encourage private resolution. We recognize, however, that parties may fail to resolve such disputes and the FCC will need to redefine property rights to facilitate technological change.[278]

When exercising its power to modify the relevant zoning code, the FCC should recognize that it can mandate creative remedies to promote technological progress and the more efficient use of spectrum.[279] Consider the case of a service that relies on technologically antiquated equipment where the interference—or its likelihood given a requested change in the allowable levels of radio energy at the relevant boundary—could be substantially lessened with relative ease by upgrading equipment.[280] Reflecting this point, the FCC might determine that the old analog TV sets, which are

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> for optical fiber. And when it was, AT&T planned to make its own fiber. . . . [After AT&T entered into a consent decree,] MCI took the risk [of ordering fiber optic technology] and placed a 100,000 kilometer order for a new generation of fiber.

Willard K. Tom & Joshua A. Newberg, *Antitrust and Intellectual Property: From Separate Spheres to a Unified Field*, 66 ANTITRUST L.J. 167, 202 (1997) (quoting *Telecommunications: The Role of the Department of Justice: Hearing Before the H. Comm. on the Judiciary*, 104th Cong. 125-26 (1995) (statement of Timothy J. Regan, Division Vice President and Director of Public Policy, Corning, Inc.)).

277 Coase, *supra* note 13, at 29.

278 Notably, the courts have endorsed such measures, making clear that licensees are only entitled to protection from harmful interference and that speculative claims of interference do not suffice to challenge FCC decisions that purportedly impinge on a licensee's rights. AT&T Wireless Services, Inc. v. FCC, 270 F.3d 959, 963-64 (D.C. Cir. 2001) (affirming in relevant part AirCell, Inc., 15 F.C.C.R. 9622 (2000)); AMSC Subsidiary Corp. v. FCC, 216 F.3d 1154, 1160 (D.C. Cir. 2000).

279 This authority is one currently wielded by administrative bodies in the water rights context. *See* Freyfogle, *supra* note 22, at 1541-42.

280 This measure would be in line with the widely recognized point that receiver technology is a critical constraint on facilitating the more effective use of spectrum. *See* Notice of Inquiry, Interference Immunity Performance Specifications for Radio Receivers, 18 F.C.C.R. 6039, para. 10 (Mar. 24, 2003) (emphasizing the importance of receiver performance with reference to efficient use of spectrum); FCC SPECTRUM POLICY TASK FORCE, REPORT OF THE INTERFERENCE PROTECTION WORKING GROUP 25 (2002), *available at* http://www.fcc.gov/sptf/files/IPWGFinalReport.pdf ("The Working Group believes that receiver reception factors, including sensitivity, selectivity, and interference tolerance, need to play a prominent role in spectrum policy."); Powell, *supra* note 84, at 3 ("[I]nterference is often more a product of receivers; that is, receivers are too dumb or too sensitive or too cheap to filter out unwanted signals. Yet, our decades-old rules have generally ignored receivers."); *see also* FED. GOV'T SPECTRUM TASK FORCE, SPECTRUM POLICY FOR THE 21ST CENTURY 17 (2004), *available at* http://www.ntia.doc.gov/reports/specpolini/presspecpolini_report1_06242004.htm (suggesting appropriateness of considering whether incumbents should be obligated to "deploy more robust equipment as they replace existing equipment").

more sensitive to interference than their newer digital TV counterparts, are no longer the appropriate baseline against which to measure possible interference.[281] This step would both create more usable spectrum (i.e., by limiting the possibility of harmful interference caused by sensitive receivers and allowing removal of buffer areas) and pressure owners of analog TVs receiving over-the-air reception to upgrade to digital TVs.

The easiest case is the one where the parties can negotiate a mutually beneficial arrangement that allows new entry into the market based on equipment upgrades.[282] The FCC, however, is likely to face challenging cases where the parties fail to agree. In some cases, such as where transaction costs (or other obstacles) prevent such arrangements, the FCC should consider requiring the entrant to subsidize such upgrades.[283] Alternatively, if the agency believes that the use of ineffective receivers is unjustifiable (such as in the analog TV example noted above), it can raise the baseline of interference protection to require more robust receivers, therefore placing the burden on the party with poor equipment to pay for an upgrade.[284] Finally, in the case of government users, which may be particularly obstinate because they are not necessarily motivated by financial incentives, the FCC's role in brokering arrangements that facilitate more effective uses of spectrum is particularly important.

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281 Comments of New America Foundation Before FCC, Unlicensed Operation in the TV Broadcast Bands, ET Docket 04-186 (January 31, 2007), *available at* http://www.newamerica.net/publications/resources/2007/final_results_of_university_of_kansas_tv_white_space_interference_study (noting that analog TV receivers are more sensitive to interference than their digital TV counterparts).

282 For such cases, less than perfect FCC oversight, (as is likely to be the case given the considerable difficulties in creating and calibrating property rights in spectrum), may well encourage parties to bargain more effectively. *See* Ian Ayres & Eric Talley, *Solomonic Bargaining: Dividing a Legal Entitlement to Facilitate Coasean Trade*, 104 YALE L.J. 1027, 1095-96 (1995) (arguing that where each party has a probable claim to the same entitlement, muddy defaults facilitate bargaining when parties cannot predict ex ante which of them will win in litigation).

283 This form of relief, which in effect concludes that an incumbent licensee is preventing socially valuable uses of spectrum and should be subsidized to allow that new use, is a variant of Calabresi & Melamed's famous Rule 4. *See* Calabresi & Melamed, *supra* note 273, at 1115-24; *see also* Spur Indus., Inc. v. Del E. Webb Dev. Co., 494 P.2d 700, 708 (Ariz. 1972). It is also increasingly used in the water rights context. *See* Freyfogle, *supra* note 22, at 1542. In implementing such a program, however, the FCC should oversee it carefully so that the incumbent does not, among other things, unduly delay implementing the technological upgrade, overspend on such upgrades as a strategic step to raise the costs of a rival, or use the subsidy to support unrelated objectives.

284 A study commissioned by Ofcom, the UK regulator, explained the implications of this point:

> It is important to note that the minimum receiver performance is not meant to be mandated. It serves as a benchmark with which the interference environment can be assessed. If an operator chooses to use receivers having a performance in some way inferior to the minimum receiver performance, then they will not be protected from interference levels higher than those used for the assessment. They may however choose to negotiate with a neighbour to reduce the neighbour's emissions such that their inferior receivers operate satisfactorily.

ÆGIS SPECTRUM ENG'G, SPECTRUM USAGE RIGHTS: OFCOM, FINAL REPORT (2006), *available at* http://www.ofcom.org.uk/consult/condocs/sur/spectrum/summary.pdf.

CONCLUSION

The New Deal optimism about the effectiveness of command-and-control regulation has generally given way to market-based reforms. The legacy model of spectrum regulation, however, remains stubbornly in place. In part, entrenched interests and regulatory inertia explain this resistance to reform. But another critical factor is that instituting property rights in spectrum is not as simple as transposing existing real property rules for trespass onto spectrum licenses. To be sure, more effective uses of spectrum might emerge over time as judges defined property rules for spectrum in a common law-like fashion as they did for water rights (say, providing for a limited use of injunctions and money damages only after the relevant harm already occurred).[285] Such an approach, however, would be suboptimal because it would not prevent an avoidable harm (preventable interference and huge societal and economic disruptions) that could be managed through a zoning-like system and the transition to a property rights model envisioned by our proposal.

Both our proposal and ones calling for an increased role for courts in managing property rights in spectrum rely on Coase's vision of promoting a market for spectrum licenses. We criticize the conventional view of spectrum property rights, however, on the ground that defining rights to use spectrum is far more difficult than ordinarily suggested and allowing courts to manage the development and enforcement of such rights is a riskier proposition than generally appreciated by spectrum property rights advocates. In this regard, the case study of cellular services, which have unique characteristics, is misleading insofar as commentators have suggested that this precedent establishes that property rights in spectrum will be easy to manage. Thus, in lieu of a unitary property rights model based on the cellular precedent, we propose a zoned system of property rights that relies on both before-the-fact predictive models and after-the-fact oversight. To be sure, an essential predicate for this vision is the ability of a reformed FCC or a new administrative agency to manage a new system of spectrum regulation. On this point, we are well aware of and readily acknowledge the public choice risks that inhere in our proposal, but we are nonetheless skeptical that judges can manage a system of spectrum property rights more effectively than their administrative agency counterparts.

The conventional wisdom that the command-and-control system of spectrum management must be reformed to provide property rights in spectrum along the model used in the cellular bands has yet to give way to a

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285 Hazlett, for example, appears to assume that licensees violating tolerable interference limits would be free to cause such harm and pay the applicable damage remedy if that were an economically efficient choice. *See* Hazlett, *supra* note 78, at 490 ("[P]rivate users' liability for damage will yield efficient incentives to respect other transmissions.").

debate focused on the real challenges of developing and enforcing property rights in spectrum. As we explain, a careful appreciation for how such a system would operate in practice requires an understanding of the predictive nature of the models used to develop the relevant boundaries for spectrum rights and how levels of allowable interference could be incorporated—based on creating safe harbors from liability—into a property-based system. As we envision it, such a system calls for after-the-fact refinements that will require familiarity with the overall system, how radio technology operates, and the practical impact of the requested relief.

If implemented properly, a reformed system of spectrum regulation would create incentives for users to coordinate with each other to avoid interference and make any reasonable accommodations to ensure that each service continues to work effectively. Ultimately, however, such a system will also require the FCC to make judgments based on relevant technical and societal realities as to what types of spectrum rights should be protected. Significantly, by specifying such judgments in advance through predefined property rights (as opposed to defining them on a purely case-by-case basis), the FCC can end its traditional reliance on overly restrictive protections that "retards entry and innovation and favors incumbents."[286] We have no illusions that the transition to a new model of regulation will be easy, but we believe that the merits of this model are far superior to our current system, and that, sooner or later, some version of it will be adopted. After all, the alternative is that the recently auctioned off swaths in the 700 MHz band of spectrum—which were eagerly sought by a variety of firms—will truly be the last great opportunity to obtain new spectrum for higher value uses than many of today's incumbent services.

[286] Gregory L. Rosston, *The Long and Winding Road: The FCC Paves the Path with Good Intentions*, 27 TELECOMMS. POL'Y 501, 511 (2003), *available at* http://siepr.stanford.edu/papers/pdf/01-08.pdf (suggesting increased back end adjudication to guard against interference).