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The technical basis for spectrum rights: Policies to enhance market efficiency[☆]

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ABSTRACT

This paper describes a conceptual framework to articulate clear rights of access to radio spectrum in a way that would foster an efficient market-based allocation of the resource. In this approach, regulators partition spectrum rights across the dimensions of space, time, frequency, and direction of propagation. They devolve each partition, called a licensed electrospace region (LER), to licensees who may buy, sell, aggregate, and subdivide their LERs at will. All signals outside an LER must have a power level of less than a regulated limit with de minimis exceptions. In addition, even within an LER, transmitter power or field strength must fall below a separate regulator-set level for the band. Licensees may deploy any devices and provide any services that do not violate these rules.

In this framework, regulators establish a few core parameters for each band, manage a rights database, and enforce compliance with signal strength rules. This approach includes no protection of, or constraints on, receivers. Rather, the simple signal strength limits allow licensees to optimize their transmitter and receiver characteristics based on engineering and economic factors. Negotiated LER boundaries between adjacent LER owners can further balance the costs and benefits of interference protection to each.

1. Introduction

In the United States, the federal government has traditionally regulated access to radio spectrum with command-and-control (C&C) licensing. Regulators have generally optimized the technical rules in each band for different radio services. However, rapidly evolving technology and increasing demands for new wireless services mean this rigid regulatory structure increasingly fails to accommodate new services and applications and fails to provide efficient incentives to develop and deploy new technology.

Many of the existing C&C bands were allocated 50 or more years ago for services that are now outdated or use technology ill-suited to the original allocation. For example, cell phones have supplanted mobile radios; optical fiber is replacing point-to-point microwave systems; broadcast TV is losing ground to cable, satellite, and wideband Internet; and GPS has replaced many radar services. Yet, the rigid regulatory regime leaves old allocations frozen in time and unable to meet the new requirements of today's expanding wireless systems. Regulators cannot easily adapt most old band allocations to new services. Rather, they

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must impose the costs of scrapping old systems to reallocate and repopulate a newly emptied band. Today, regulators can adjust band allocations, but the complex rulemaking proceedings can take years, depending on whether opponents attempt to delay or modify the changes. Although the FCC's Secondary Market Report and Order allows easier license transfers, it generally does not allow any changes in the services for which the licenses can be used. This discourages investment and innovation by increasing the risk that new services and technologies cannot find sufficient accommodation in the established band plans.

A number of alternative approaches could replace C&C, including a variety of flexible exclusive rights and non-licensed approaches. Here the specific design features of a flexible licensed rights regime are focused on. Although economists have designed efficient spectrum license auctions and some have advocated property rights approaches to spectrum management, they have given less attention to the structure and substance of that which is auctioned (one exception is by Hazlett & Munoz, 2009). This paper moves the ball forward by describing one conceptual framework to articulate clear rights of access to spectrum in a way that fosters a market-based, flexible-use allocation of the resource (an economic case for spectrum property rights appears in Hazlett, 2008). As Hazlett (2008) notes, "the policy goal is to initially define and package property rights so as to facilitate a pathway to efficient resource employments." A licensed spectrum rights regime that allows market forces to optimize dynamically the allocation of the resource would minimize the need for costly interventions by regulators, create efficient incentives for investment and innovation, and strengthen the contribution of wireless technologies to the country's economy. This would benefit consumers by allowing providers to more rapidly respond to their demands. The authors argue that the flexible-use property rights they described will obviate most wholesale reallocations by allowing bands to continuously accommodate changing technologies and services according to evolving markets. It would not necessarily be the only rights regime within the overall portfolio of spectrum management tools; as noted in Section 4 below, each approach has advantages and disadvantages in different bands and applications. However, it could offer one way to articulate an economically efficient set of rights.

This work seeks to find the minimal conditions necessary for market forces to balance the costs and benefits of controlling interference without unnecessarily constraining the evolution of wireless industries. Some other proposed flexible-use spectrum rights approaches are similar, but they require protecting existing receivers from interference. The protection of foreign receivers adds many complications, since users can be responsible for a potentially huge number of receivers over which they have little knowledge and no control. The approach proposed here requires users to be responsible only for keeping their transmitted signals within described license limits. Receiver users are responsible for handling signals that are within these prescribed limits.

Section 2 describes the seven-dimension electrospace approach to describing radio signals and the rights to emit them. It offers a way to express the rights to use spectrum that is not tied to any specific service or technology. Section 3 discusses how traditional regulatory approaches and flexible-use property rights approach differ in the way they manage interference. Section 4 describes implementation issues and potential solutions. Section 5 concludes.

2. The electrospace as a technical basis for spectrum rights

The term electrospace is used for the hyperspace that describes radio signals by their frequency, time, location, and direction (Matheson, 2003a). Table 1 shows the seven electrospace dimensions of radio signals, selected as sufficient for articulating a useful bundle of spectrum rights.

An electrospace volume is a subset of the electrospace that occupies a range in each dimension, including a three-dimensional physical space, a frequency band, a duration in time, and a set of angles through which the direction of propagation may lie. An electrospace volume is a straightforward, unique and complete technical basis that regulators could use to articulate the spectrum to which a licensee can hold rights of access. Such a set of rights is called a licensed electrospace region, or LER.

In the regulatory system proposed, licensees would acquire and use rights to access spectrum that are expressed as disjoint LERs. Much of the material to this topic is drawn from earlier papers by Matheson (Matheson, 2003b, 2006). The ideas here are also very consistent with Kwerel and Williams (2006).

In this approach, regulators govern interference and the allocation of the resource by the following fundamental rules:

1. Licensees must keep all signals within their respective licensed electrospace regions (LERs)—including frequency band, geographical area, authorized time of operation, and angle of arrival. Outside their LER, all signals must have a power level of less than a regulated value: E_0.
2. Licensees must keep all signals below $E_{\max}$ inside their LER. This limits the presence of strong signals that can cause out-of-band (OOB) interference to systems operating at other frequencies.

As long as these rules are obeyed, this flexible rights regime allows any services, technologies, architectures, transmitter powers, and modulations. In theory, this replaces nearly all of 47 CFR and the NTIA Manual. The major efficiency gains from the LER approach relative to C&C derive from the flexibility to design any spectrum-using system that fits within the LER rules and to change services or the rights allocation as market forces and technology evolve. The authors' contribution here is to offer one fairly specific way to introduce this flexibility.

Section 4 below explores the pragmatic details of designing an LER regime. The dimensions in Table 1 provide a flexible regulatory underpinning for an economically efficient, market-based allocation of spectrum across its possible applications. Polarization and modulation are also valuable electrospace dimensions in system design, but they do not appear in