5.4 Spectrum Sharing

This section is adapted from discussion paper on Spectrum Sharing prepared in 2008 for the 8th Annual Global Symposium for Regulators.

5.4.1 INTRODUCTION

This chapter reviews various trends in spectrum sharing methods used by spectrum managers who are responding to increasing demands for spectrum resulting from the unstoppable surge in new services and technologies. In the sections which follow, access to spectrum, international trends, and implementation issues are discussed.

Spectrum sharing is not a universal trend for all regulators nor are the approaches taken similar for all regulators:

- approaches by regulators for managing the unlicensed but regulated spectrum commons range from imposing license and permit constraints to few if any constraints at all beyond technical specifications. The allocation of ISM bands for unlicensed use by low power devices such as Wi-Fi has been encouraged by the ITU across all regions;
- Making changes to encourage spectrum sharing by different services such as fixed and mobile have shown many countries continue to reserve significant amounts of spectrum for exclusive (government use). The WRC-07 has made significant strides increasing the amount of spectrum available to broadband services.

Spectrum sharing encompasses several techniques – some administrative, technical and market-based. Sharing can be accomplished through licensing and/or commercial arrangements involving spectrum leases and spectrum trading. Spectrum can also be shared in several dimensions; time, space and geography. Limiting transmit power is also a factor which can be utilized to permit sharing. Low power devices in the spectrum commons operate on the basis of that principal characteristic: signal propagation which takes advantage of power and interference reduction techniques. Spectrum sharing can be achieved through technical means using evolving (not yet commercially available) advanced technologies such as cognitive radio. These technologies and related concepts are reviewed. Several prominent examples of spectrum trading experience are reviewed.

A common issue for both innovative technologies and market-based methods is arriving at the right balance. Resolving interference issues inherent in methods based on the principle of technological neutrality is an issue of great importance. Interference cannot be eliminated and so identifying interference management models which support spectrum sharing under either administrative, market-based or spectrum commons, remain as an ongoing requirement and challenge for spectrum managers. These issues are discussed and examples of possible solutions are given. The section ends with a review of some of the best practices used to encouraging spectrum sharing and implementation issues.

Related Materials

Module 2, Section 6.5, Mobile Network Sharing

5.4.2 ACCESS TO SPECTRUM

As the demand for spectrum increases and frequency bands become more congested, especially in densely populated urban centres, spectrum managers are following diverse approaches to sharing frequencies: using administrative methods including in band sharing, licensing such as leasing and spectrum trading, and the unlicensed spectrum commons combined with the use of low power radios or advanced radio technologies including ultra-wideband and multi-modal radios.

Spectrum sharing typically involves more than one user sharing the same piece of spectrum for different applications or using different technologies. When a band already licensed to an operator is shared with others it is known as overlay spectrum sharing. For example a spectrum band used for TV distribution in one geographical area could be used for an application such as broadband wireless access in another area without any risk of interference, despite being allocated on a national basis.

Spectrum sharing is required when sufficient demand exists for spectrum, causing congestion, and the technical means exist to permit different users to coincide; and other means for adjusting spectrum use and assignment have become burdensome and costly undermining the goals of economic and technical efficiency. The implications for spectrum managers are that spectrum management policies are evolving towards more flexible and market oriented models to increase opportunities for efficient spectrum use.

Reference Documents

- **Administrative Fees and Spectrum Charges: Report to the European Commission, Directorate General Information Society**

5.4.2.1 FORMS OF SPECTRUM SHARING

There are generally several ways to share spectrum and achieve the goal of improving access to spectrum by giving more users greater flexibility in its use by implementing:

- Liberalized methods for assigning spectrum rights such as leasing, trading (see section **1.5.2 Market methods**) and the spectrum commons (see section **1.5.3 Unlicensed spectrum**);
- A new paradigm for interference protection taking into account new technologies such as dynamic spectrum access where underlay technologies are used based on power limits, for example UWB, mesh networks, software defined radio (SDR), smart antennae and cognitive radios (see section **4.2.5 Technically-enabled sharing**).

RELATED INFORMATION

The ITU conducted a New Initiatives workshop on the subject of "Radio Spectrum Management for a Converging World". The workshop was held at ITU Headquarters, Geneva from 16 to 18 February 2004. Presentations and papers from the workshop can be obtained by going to the ITU website. Go to **www.itu.int/osg/spu/ni/spectrum**.

5.4.2.2 WHICH BANDS CAN BE SHARED?

Some frequency bands are shared by some users by maintaining geographic separation and ensuring strict adherence to operational constraints preventing interference between services. One good example is spectrum shared by satellite and fixed links where the microwave links transmit horizontally and interaction between systems is limited. As well, fixed and mobile services share bands and do so by maintaining geographic separation and limits on power.

Potentially all bands can be shared and many bands remain under-utilized, i.e. although sharing does not yet occur in under-utilized bands, it is technically possible to share these bands using combinations of administrative means (assignment – time, geographic, and interference management constraints) and technical solutions (filters, smart antenna, smart transmitters such SDR, and cognitive radio, along with transmit power limitations combined with a relaxation of interference constraints). An important exception exists where there has been a spectrum policy decision to maintain exclusive band and assignments for public safety and security services.

Not all bands are equal, however, and so there can be increasing pressure to release new bands or share bands for certain services. For BWA, bands need not necessarily be contiguous, but must have sufficient bandwidth (i.e., 2.5 MHz) to support broadband applications such as video and should be located where good propagation characteristics exist (i.e., below 1 GHz) and where there is wide geographic coverage. Bands with low occupancy and utilization could also be of interest (i.e. above 15 GHz).

The question of sharing Public Use Spectrum bands also arises given the extensive amount of spectrum held by governments for their exclusive use. The arguments for special arrangements for spectrum for the public sector are as follows:

- it is indispensable to the provision of service such as defence radar;
- the service itself (such as an ambulance service) has a very high priority; and
- under past spectrum management practices, the only way to acquire spectrum was by administrative methods.

Even so, spectrum is much like any other input to government services obtained in structured markets. For a more detailed discussion of issues related to public use spectrum see **Section 2.3.7 – Public Use Spectrum**.

5.4.2.3 ADMINISTRATIVE SHARING

Administrative management of spectrum sharing generally involves the regulator's processes to establish where sharing should take place and what rules should apply. It also includes defining the sharing rules for radio system performance and applicable technical standards, equipment specifications and equipment type approval. There are several steps which can be taken by the regulator to improve spectrum sharing:

- Establish policies to make spectrum allocation and licensing assignments that are based on marketplace demands and adopt fair, efficient and transparent processes for awarding licences. This may mean beginning a process to evaluate existing allocations and determine how much spectrum can be allocated on a shared or non-exclusive basis.
- Conduct an independent audit of spectrum holdings to identify bands where immediate changes can take place.
- Conduct consultations with stakeholders to obtain necessary information to support decisions on sharing and technical standards.
- Encourage solutions based on negotiations between affected parties including the payment of compensation.
- Establish specifications which encourage the utilization of spectrum efficient technologies and put mechanisms in place such as through use of spectrum fee incentives to begin to transition allocations and assignments to commercial allocations, assignments and users.
- Consider the use of band managers to manage and to resolve issues on the part of licensees within the band. There are several models for the delegation by the regulator of spectrum management activity to a band manager, both on a non-exclusive and an exclusive basis.

RELATED INFORMATION

For more on Band Managers see **Section 1.6.2** of this Module: Management Rights Systems and Band Managers

Practice Notes

- **Types of band managers**

5.4.2.4 MARKET-BASED SHARING

As a starting point, economically efficient use of spectrum means the maximization of the value of outputs produced from available spectrum, including the valuation of public outputs provided by the government or other public authorities. From an economic efficiency viewpoint, spectrum should be divided in such a way that the benefits to the overall economy are the same from different uses of spectrum for an equivalent incremental amount of spectrum assigned to either use. Market-based approaches such as auctions and spectrum trading are viewed as superior ways of achieving economic efficiency over administered methods.

Market methods are being employed both at the primary issue of spectrum licences, when auctions are used, and, more significantly, by allowing spectrum rights to be bought and sold in the lifetime of a licence and allowing a change of use of the relevant spectrum.

In cases where spectrum is a scarce resource, and like all scarce resources in a competitive market, efficient allocation decisions are premised on prices. Well designed and properly managed auctions are appealing since they ensure that frequencies go to the firm which bids the most, and that may, in certain conditions, be the most efficient firm. Efficiency is further enhanced if the successful licensee chooses what services to provide and technologies to use.

Spectrum trading

Spectrum trading contributes to a more economically efficient use of frequencies. This is because a trade will only take place if the spectrum is worth more to the new user than it was to the old user, reflecting the greater economic benefit the new user expects to derive from its use. In the absence of misjudgements or irrational behaviour on the part of the buyer or seller, and if the trade does not cause external effects, then it can be assumed that spectrum trading contributes to greater economic efficiency.

As well as this direct effect, which at the same time boosts transparency by revealing the true opportunity cost of the spectrum, secondary trading also results in a series of indirect positive effects. Spectrum trading makes it possible for companies to expand more quickly than would otherwise be the case. It also makes it easier for prospective new market entrants to acquire spectrum in order to enter the market.

Greater flexibly in spectrum use also provides considerable incentives for incumbents to invest in new technology in order

to ward off the threat of new entrants in the absence of other barriers to entry (i.e. the unavailability of spectrum). This in turn will boost market competition. These economic efficiency gains will not be realised, however, if transaction costs are too high or if external effects intervene (particularly, anti-competitive behaviour and interference).

It is important to ensure that the transaction or administrative costs for spectrum users are as low as possible. This implies, for example, that there should be few bureaucratic obstacles to the transfer of spectrum. At the same time, there should be a source of clear information that allows prospective spectrum users to find out which frequencies are available, what they can be used for, who is currently using them and what needs to be done in order to obtain a right of use.

In order for spectrum trading to be both transparent and efficient, it makes sense to give all interested parties direct access to information on current spectrum usage. To this end, it is advisable to set up a central database, which, for practical purposes, should be the direct responsibility of the spectrum regulator.

These criteria constitute the framework for a whole raft of institutional arrangements that determine the precise form of spectrum trading and set forth exactly how rights of use can be transferred. Institutional arrangements stipulate precisely who can make what decisions, when they can do so, and under what conditions. They also set forth the implications this will have for the parties involved. Ideally, such a system will include full details pertaining to all aspects of spectrum transfers and trading. At the same time, one of the aims of any spectrum trading regime should be to keep transaction costs down. Actually, the vast quantity of important details means that both primary legislation and secondary legal texts are limited in terms of how far they can specify actual arrangements.

To see more on Spectrum Trading go to **Section 1.6.4** Spectrum Trading Systems and also **Section 5 Spectrum Pricing**.

Licence duration

The introduction of spectrum trading diminishes the need to set a fixed expiry date for usage rights. Under a system of spectrum trading, rights are transferred to users who have identified an alternate use that promises greater economic returns. The choice of an expiry date, be it five, ten or twenty years hence, is always somewhat arbitrary. An argument in favour of granting spectrum usage rights in perpetuity is that users make complementary investments in stages and each investment has a different payback period. Indeed, one goal of spectrum regulation should be to encourage investment and innovation.

Economists who place their trust in unfettered market forces therefore advocate that spectrum usage rights be granted in perpetuity. This implies that, after the primary assignment of spectrum, the regulator would only have to intervene if users wished to return spectrum, or if their right of use were withdrawn owing to a breach of the conditions of use.

Nevertheless, since there are significant imperfections in the market, it may make sense to give the national regulatory authority the option of withdrawing spectrum usage rights. Alternatively, a certain period of time could be specified at the end of which the regulator decides whether or not the spectrum usage right shall be extended.

Competition issues associated with trading

Regulatory policy seeks to create a market in which prices are as close to costs as possible and where consumers can choose from a wide range of services. Sustainable competition is usually only possible where there are competing infrastructures, yet the scarcity of radio spectrum creates restrictions which often mean that an oligopoly is the only possible outcome. Frequencies should therefore be distributed in such a way as to create a market structure that ensures the maximum possible degree of competition for the available spectrum.

The *ex post* mechanisms of competition law plus regulatory oversight by the competition authority are, on their own, inadequate for policing markets, especially those that exhibit the above features. This means that *ex ante* regulation is required, particularly when it comes to distributing the scarce resource of spectrum. The design of the assignment mechanism, and of the associated licence conditions or conditions of use, is therefore crucial to the establishment of infrastructure-based competition. The assignment mechanism chosen by the regulatory authority shapes the market structure by dividing up the spectrum and limiting the maximum amount of spectrum any one user may acquire.

It is generally believed that the greater the number of spectrum users, the more competitive the market and the less need there is for regulating end users. Imagine for a moment that all the frequencies available for GSM mobile applications were auctioned in small parcels with no restriction on the maximum amount of spectrum that any one bidder may acquire. It is conceivable that one company might acquire all the parcels of spectrum, resulting in a monopoly of the mobile communications market. Without undertaking an exact analysis as to the likelihood of such an outcome occurring under different types of auctions, it is nevertheless true that, according to economic theory, an unregulated monopolist is in a position to make the highest profit and will therefore be willing to pay the most for the spectrum.

Efforts to establish a competitive market structure do not stop at spectrum assignment. Unrestricted spectrum trading

could be exploited by users acting in concert to create a monopoly or at least a more concentrated oligopoly. Spectrum regulators should be alive to this possibility.

Anti-competitive behaviour, in the form of acquisition of "excessive" spectrum, can be prevented in different ways by the regulatory authority, which is in a position to set spectrum caps, to establish rules that specify how spectrum trading should take place, including prior approval of trades or transfers of spectrum.

The above remarks clearly show that, even under a more flexible regulatory regime, issues of market power will continue to be important. This, however, is not a reason to reject such a regime. In fact, a more flexible approach to spectrum regulation, which not only allows multiple transfers of spectrum but, moreover, is also accompanied by a far-reaching liberalisation of usage rights, would actually tend to diminish rather than amplify potential problems of market power.

Practice Notes

- **Spectrum Trading - GSR notes**
- **Windfall profits as a problem of transition to markets**

Reference Documents

- **A Proposal for a Rapid Transition to Market Allocation of Spectrum**
- **Designing property rights for the operation of spectrum markets, 2003**
- **Guatemala: The Guatemalan Experience, 2005**
- **Spectrum Management: Property Rights, Markets and the Commons**

5.4.2.5 TECHNICALLY ENABLED SHARING

Technically efficient use of spectrum, at a basic level, implies the fullest possible use of all available spectrum. Two measures of technical efficiency are occupancy and data rate. Time, for example, can be used as a measure of technical efficiency; in the sense of how constant or heavy the usage of spectrum is over time. Data rate means how much data and information can be transmitted for a given amount of spectrum capacity. Spectrum sharing technologies including spread spectrum, dynamic access, Ultra-wideband (UWB) are introduced and described in the next paragraphs.

Underlay Technologies – Ultra-wideband and Spread Spectrum

Spectrum underlay technique is a spectrum management principle by which signals with a very low spectral power density can coexist, as a secondary user, with the primary users of the frequency band(s). The primary users deploy systems with a much higher power density level. The underlay leads to a modest increase of the noise floor for these primary users.

Due to the extremely low emission levels currently allowed by regulatory agencies, UWB systems tend to be short-range and indoor applications. However, due to the short duration of the UWB pulses, it is easier to engineer extremely high data rates, and the data rate can be readily traded for range by simply aggregating pulse energy per data bit using either simple integration or by coding techniques.

Spread spectrum is a technique of spreading a signal out over a very wide bandwidth, often over 200 times the bandwidth of the original signal. CDMA (Code Division Multiple Access) is a digital cellular standard that uses wideband spread spectrum techniques for signal transmission.

Overlay Technologies and Dynamic Spectrum Access

Active overlay technologies are beginning to emerge and be trialed. A major trial is currently taking place in Ireland involving several major manufacturers of equipment and devices. There are several possible approaches being studied.

Dynamic Spectrum Access

Dynamic spectrum access, which is in its early stages of development, is an advanced approach to spectrum management that is closely related to other management techniques such as flexible spectrum management and spectrum trading. It involves unitising spectrum in terms of time slots and/or geographically. This allows users to access a particular piece of spectrum for a defined time period or in a defined area which they cannot exceed without re applying for the resource.

It permits communications to work by:

- Monitoring to detect unused frequencies;

- Agreeing with similar devices on which frequencies will be used;
- Monitoring frequency use by others;
- Changing frequency bands and adjusting power as needed.

Benefits of increased access to spectrum and better efficiency need to overcome several hurdles including:

- Potential for increased interference, effects on quality of service, and compliance with regulations;
- Technical issues related to unseen devices competing for similar frequencies (the hidden node problem) and development of complex equipment.

Dynamic spectrum access is often associated with, although not exclusively dependent on, technologies and concepts such as Software Defined Radio (SDR) and Cognitive Radio which are described in the next paragraphs.

Passive overlay

The other form of overlay is the passive overlay such as the Amateur radio service that has shared spectrum with various government users using passive overlay technologies that require the user to look for a CB radio channel that is free. A passive overlay technology is different from an active overlay technology.

Practice Notes

- **FCC and ITU Regulations Concerning UWB**
- **Spread Spectrum Techniques**

5.4.2.6 EMERGING TECHNOLOGY ENABLERS

In addition to the spectrum sharing techniques described in the previous paragraphs there are emerging technologies which are important in enabling these techniques, as well as fostering potential new methods for spectrum sharing. The most prominent enabling technologies are described in the next few paragraphs

Software-defined Radio (SDR) and Cognitive Radio (CR)

Software defined radio are radio systems implemented on general purpose hardware where specific operational characteristics are implemented in software – different radio systems and standards are essentially loaded as software programmes (e.g. a GSM program or a Wi-Fi program). A radio increases its flexibility as more of its functionality is software based.

SDR technologies are slowly making their way into commercial radio systems as technology developments make it economical for manufacturers to do so.

SDR enables more flexible spectrum allocation since these radio systems potentially use spectrum more intensively and are more tolerant of interference.

A cognitive radio is a radio that is to some degree aware of the environment by monitoring transmissions across a wide bandwidth, noting areas of unused spectrum and is able to modify its transmission using appropriate modulation and coding methods. From a user standpoint the certainty of finding unused spectrum in congested areas may fall low enough to impair its usefulness as a mainstay communications device.

See 'Dynamic Spectrum Access pp 12-13 and Reports ITU-R M.2063 and ITU-R M.2064. Issues on the agenda of WRC-12.

Smart Antennas and Other Technologies

Smart Antenna applications and technology have emerged in the past 10 years and are interesting because of their ability to significantly increase the performance of various wireless systems, such as 2.5 generation (GSM-EDGE), third generation (IMT 2000) mobile cellular networks and BWA. Smart Antenna technologies exploits multiple antennas in transmit and receive mode with associated coding, modulation and signal processing to enhance the performance of wireless systems in terms of capacity, coverage and throughput. Smart Antenna is not a new idea but a more cost effective one with the advent of digital signal processors and general purpose processors with application specific integrated circuits (ASICs).

Multi-modal radios are capable of operating across multiple bands and technologies. The tri-band and world mobile phone are examples of multi-modal radios. Frequencies continue to be divided in discrete elements although the need to harmonize frequency allotments and technical standards on a regional or global basis is not as critical.

Digital Terrestrial Television

Broadcast mobile TV is a very efficient multicast service that allows users with a mobile device to watch multiple TV channels in ways similar to DTT. Broadcast mobile TV services are available in several countries including Austria, Finland, Italy, the Netherlands and the USA. They use several technologies based on standards such as:

- Digital Video Broadcast – Terrestrial (DVB-T);
- Digital Video Broadcast – Handhelds (DVB-H);
- Digital Multimedia Broadcast (DMB);
- Advanced Television System Committee – Mobile/Handheld (ATSC M/H);
- Integrated Services Digital Broadcasting – Terrestrial 1 seg (ISDB-T 1seg); and
- China Mobile Multimedia Broadcast (CMMB).

The 470-862 MHz band is preferred by mobile operators for simultaneous use of broadcast mobile TV and GSM/3G services. Yet, other bands could be used for broadcast mobile TV such as the VHF television band.

Reference Documents

- **Digital dividend: cognitive access**
- **Digital Dividend: Geolocation for Cognitive Access**
- **RSPG Report on cognitive technologies**
- **The Path to Market Success for Dynamic Spectrum Access Technology**
- **The Path towards Efficient Coexistence in Unlicensed Spectrum, Cargenie Mellon University, IEEE 802.16 Broadband Wireless Access Working Group, 30 April 2000**

5.4.3 INTERNATIONAL TRENDS IN SPECTRUM SHARING

International trends in spectrum management are discussed under sections 4.3.1 to 4.3.4. These sections examine the recent trends in spectrum management policy and regulation, property rights in spectrum licences, interference, best practices on spectrum sharing techniques and country case studies implementing such practices.

5.4.3.1 TRENDS IN REFORM

In recent years, spectrum management policy and regulation have evolved greatly to better reflect the demand and supply requirements new services and uses. There has been a shift from relying predominantly on the traditional model, most notably in countries where demand for radio spectrum use is rising fast. The main principles underpinning the spectrum management reform agenda are:

- Liberalization and flexibility;
- Technology and service neutrality; and
- Licensing reform including spectrum transfers and the spectrum commons.

For a more detailed discussion of these concepts see **Section 3.2.3 Liberalization and the Impact on Authorization and Section 3.1 Introduction to Authorization.**

In this section, we review several of the most important trends in spectrum management including:

- Growing Importance of Spectrum Use and Spectrum Management
- Convergence and Reform of the Institutional Framework
- Spectrum Trading and Transfers
- Increased value and use of Unlicensed Spectrum
- Spectrum Planning - Spectrum Demand and Supply Studies

Growing Importance of Spectrum Use and Spectrum Management

In establishing the European Union's first policy on the Spectrum Management Programme in 2010, telecommunication professionals recognized that radio spectrum is a key resource for essential sectors and services, including mobile, wireless

broadband and satellite communications, television and radio broadcasting, transport, radiolocation, and applications such as alarm, remote controls, hearing aids, microphones, and medical equipment. Spectrum also supports public services such as security and safety services, including civil protection, and scientific activities, such as meteorology, Earth observation, radio astronomy and space research. Regulatory measures on spectrum therefore have economic, safety, health, public interest, cultural, scientific, social, environmental and technical implications.

The total volume of services which depend on radio spectrum availability is estimated to be worth at least €200 billion annually in Europe.

http://ec.europa.eu/information_society/policy/ecomm/radio_spectrum/index.

Convergence and Reform of the Institutional Framework

Regulatory institutional reform leading to the combination of telecommunications, broadcasting and spectrum regulators can help facilitate spectrum sharing. There are several examples of where this has occurred or is being considered:

- In Australia the Spectrum Management Agency, Australian Communications Authority and the Australian Broadcasting Authority were merged in several steps beginning in 1997 to create the Australian Communications and Media Authority;
- The Canadian Telecommunications Policy Review Panel Report recommended to the government that Industry Canada transfer its spectrum regulatory functions to the CRTC;
- The UK has recently set up such a combined regulator (Ofcom) which regulates broadcasting, (wireline and wireless) telecommunications and spectrum;
- In Germany, regulation of spectrum is combined with regulation of telecommunications (and of other infrastructures), but separate from regulation of broadcasting.

Spectrum Trading and Transfers

Spectrum transfers are generally understood to mean some form of lease or sublease arrangement, including features such as frequency assignment transferability or divisibility:

- Transferability - licences maybe transferred (disaggregated);
- Divisibility or divided (partitioned), subject to either approval or notification to the appropriate authority subject to service and technical restrictions. Since spectrum can be assigned nationally or on a regional/local basis, a given assignment can be partitioned and shared by users in different locations.

Increased value and use of Unlicensed Spectrum

Spectrum commons

A spectrum commons is part of the spectrum that is free from centralized control where anyone can transmit without a license. For this reason it is sometimes referred to as license-exempt or unlicensed spectrum.

In practice what is referred to as a spectrum commons can have varying degrees of management. Licence-exempt bands (e.g. the ISM bands) are an example of a spectrum commons with some management in terms of power restrictions on individual users as applied in the US under the FCC Part 15 rules. In Europe there is a further degree of control in that devices used for communication in these bands must conform to certain technology standards (e.g. ETSI approval). So far this approach has only been used in limited bands for short range applications. However, significant innovation has emerged in these bands (e.g. Wi-Fi), which have led some to call for more spectrum to be managed similarly.

Spectrum white spaces

Most radio and TV broadcast channels are separated by small amounts of unused channels called white space, which are used to limit interference between active channels. Technology companies and consumer advocates believe the use of this underutilized and unassigned spectrum could be used for new services such as BWA. Not surprisingly, TV broadcasters oppose allowing any unlicensed device to use white-space spectrum because, they argue, these devices would interfere with television broadcasts, potentially harming the federally mandated transition from analogue to digital TV service.

A very active debate is taking place in the US between the broadcasters and Internet content companies such as Google, who argue the white spaces can be used to extend the reach of broadband services to rural communities. On October 15, 2008, the Chairman of the FCC indicated that he supports the idea based on extensive field tests conducted by the FCC to establish the veracity of either claim and on November 4th - the FCC approved the development of wireless devices that can use "white space".

Spectrum Planning - Spectrum Demand and Supply Studies

Spectrum Managers are increasingly conducting comprehensive reviews to quantify current the future demand and supply for spectrum. These studies typically include determining what is authorized and where, as well as identifying what is currently being used.

The timing and publication of the spectrum demand study varies by regulator with forecasts that can span from two to five (and even beyond) in years. The results of spectrum demand studies and comparisons with the spectrum database illustrate potential areas of surplus or deficit spectrum that should be investigated and made transparent to users..

The published report provides background information on the current state of the spectrum, what is driving spectrum demand (consumer, commercial, government demand, new technologies, new services) as well as future trends and projections that the regulator should consider when planning spectrum use.

Spectrum Demand and Supply Studies: UK, USA and Thailand.

United Kingdom

Ofcom and the UK Treasury Department obtain on a bi-annual basis from government departments independent studies of spectrum requirements - Supply and Demand Studies. The application of market prices using AIP has resulted in profound changes in the approach taken by departments, such as the Ministry of Defence (MOD), in the way spectrum is managed.

The MOD, as the single largest government user of spectrum in United Kingdom, has access to 30% of the spectrum between 100 MHz and 3.0 GHz. Its use is not exclusive – it administers civil applications and shares bands with other users

The most recent study was completed in early 2009 with the UK MOD conducting a forward view of spectrum demand covering 80% of its allocations (2010, 2015, 2027) in accordance with its agreement with Ofcom to perform such a review every 2 years. The study is both illustrative and instructive because:

- It shows the depth of analysis involved in assessing demand across a range of services and spectrum bands
- It demonstrates how spectrum prices based on AIP have resulted in two important changes which are noted in the report:
- Prior to AIP, the MOD did not factor in spectrum pricing as part of investment and operational decision making;
- Prices reveal surpluses in spectrum leading to another important change in which the MOD now sees itself managing spectrum needs and not existing allocations.

USA

The US Government published a National Broadband Plan and recommended that the FCC make available 500 megahertz (MHz) of new spectrum for wireless broadband, including 300 MHz for mobile flexible use within five years. In addition, the President directed in June 28, 2010, Executive Memorandum that 500 MHz of new spectrum for mobile and fixed broadband use. The drive to make available new spectrum for broadband is grounded in strong consumer demand for high-speed wireless Internet access. The FCC conducted a study of Broadband Spectrum requirements and published the results in the technical paper in 2010 - Mobile Broadband: The Benefits of Additional Spectrum, OBI Technical Paper Number 8.

Thailand

The National Broadcast and Telecommunication Commission (NBTC) of Thailand is the new legislated regulatory body combining the former National Broadcast and Telecommunication Commission into a multi-sector regulator. The NBTC is required to prepare a Master Plan for Telecommunications Services, a Master Plan for Spectrum Management and the National Table of Frequency Allocations. The Master Plan is to be published within one year from the outset of the new regulator being formed and will focus on spectrum demand and supply with particular attention given to cellular, broadband and broadcast requirements while addressing the issue of the Digital Divide

5.4.3.2 INTERFERENCE MANAGEMENT

Freedom from interference and restrictions of rights to interfere with others are two major related dimensions of property rights in spectrum licences. An exclusive use license defines the rights to occupy the spectrum volume for a user with the primary user has a presumptive right to exclude other users from occupying their electrospace while secondary users may have the right to occupy the electrospace if they can do so without causing interference to primary users, although they

have no interference protection rights of their own. By setting conditions for all licences in this way, using an interference model which simulated the impact of apparatus on neighbouring reception equipment, interference can be controlled.

Spectrum managers are fundamentally concerned with managing interference and in establishing the methods, techniques, information and processes needed to protect users and uses from harmful interference. Harmful interference arises in radio systems when a transmitter's ability to communicate with its intended receiver(s) is limited because of the transmissions of other transmitters. The problem may be thought of as arising from the limitations of the receiver: better receivers are more able to extract the desired signal from a noisy environment of background radiation and other transmitters.

There are three categories of interference that are of principal concern:

- In-band interference from adjacent areas;
- In-band interference from adjacent frequencies;
- Out-of-band interference.

Under a secondary trading regime, licensees can bargain with one another to make adjustments to specified boundary emission levels. If such deals benefit both sides, it is likely, but not inevitable, that they will be made. The type of control exhibited in the administrative model may no longer be feasible, as the nature and location of the apparatus to be employed are no longer given, since they are now up to the licensee.

This requires a redesign of the interference model, from one where calculating the impact of specific apparatus is done, to one which sets limits to the emissions the licensee can deliver at the geographical and frequency boundaries of the spectrum it is licensed to use.

By properly defining the electrospace along with the size of the volumes, it is possible theoretically to specify transmitter (Tx) and receiver (Rx) occupancy rights so that a Tx/Rx must operate in different and distinct electrospace volumes to ensure non-interfering operation. For more on Interference, see **Section 6.1.2 Emissions, Interference and Spectrum Use**.

Various approaches to specifying these limits have been applied in Australia, the United Kingdom, the United States and elsewhere, as described in the Related Practice Notes and Related Reference Documents.

Interference cannot be eliminated and so identifying interference management models which support spectrum sharing under either administrative, market-based and spectrum commons remain as an ongoing requirement and challenge for spectrum managers. The goal is to develop an appropriate regime which protects user rights and finds the right balance for flexibility and innovation, and service neutrality. Finding the balance and structuring the appropriate response continue to be debated.

Reference Documents

- **FCC - Staff Working Group Paper Report of the Interference Protection Working Group**

5.4.3.3 LEADING PRACTICES

In most countries, the use of radio spectrum has been, and in many cases remains, very closely managed and supervised, in accordance with an agreed international framework established by the Member States of the International Telecommunication Union (ITU). Such management is predicated on a need to minimize harmful interference and has resulted in the application of what is sometimes referred to as the “command and control” model. In recent years, there has been a shift away from relying predominantly on the traditional model, most notably in countries where demand for radio spectrum use is rising fast.

In this section best practices are described in a system of reformed spectrum management that incorporates a greater reliance on spectrum sharing techniques which increase flexibility and are forward-looking.

Spectrum planning

Spectrum planning processes provide direction and cohesion in support of policy formulation and support future steps to achieve optimal spectrum use. Major trends and developments in technology and the needs of current and future users of the frequency spectrum should be closely monitored and mapped. The types of user requirements for systems utilized to conduct frequency management activities like monitoring systems, channel plan techniques, and tools should also be planned and developed.

Spectrum user rights

When existing licences become tradable and are subject to a change of use, rights should be established consistent with current uses; this will avoid conflicts of rights and permit parties to renegotiate rights when circumstances change. Discussion of spectrum user rights is a very detailed topic dealing with questions such as:

- whether to allow easements for new technologies?
- whether vacant spectrum should be placed in the market place (subject to international agreements)?
- fall back or insurance policies such as compulsory purchase of spectrum when there are hold-out owners of spectrum - should they be confined to national security needs?
- should users pay a perpetual annual charge for spectrum licensees or will these charges discourage efficient trading?

What about the license database?

The ability of potential sellers and buyers (and regulators) to keep track of current licences is an important component of tradable markets facilitated by a publicly available database. Knowledge of the location of existing Tx's and Rx's (where feasible) will allow potential purchasers of rights to accurately model the existing interference environment they are seeking to enter and to enable them to properly assess the rights they seek to acquire.

The information should enable regulators if called upon to adjudicate spectrum disputes and to enable them to track and assess the usage of spectrum in differing bands.

Finally, the database should include additional tools to analyze data on spectrum historical occupancy/usage and to interpret alternative propagation models.

In the US a spectrum auction and trading system is operated by Cantor-Fitzgerald, the Wall Street brokerage, providing an example of the sorts of capabilities that are needed at a minimum[i]. Cantor Spectrum & Tower Exchange provides an open or closed transparent forum for both primary (auction) and secondary (post-auction) market spectrum transactions in both public and private marketplaces.

- Sellers/Lessees can review FCC licensee information obtained by the exchange and see a snapshot in real-time.
- Qualified licence sellers/lessors or public sector entities offer radio frequency spectrum and digital sub-channel capacity in a multi-dimensional format showing coverage area, population, frequency range, radio service rules, terms and conditions, channel, time slot, etc.
- Buyers/lessees search for specific assets (or receive electronic notification), and can easily evaluate and bid on them.

This type of system helps facilitate the critical matching function that liquid markets depend on.

Dispute resolution

It is quite likely that with the arrival of the spectrum commons and increased sharing of spectrum through transfers and trades effective means other than regulatory adjudicative intervention to resolve issues between parties will be required.

There are two trends at work:

- rapid changes in telecommunications sector; and
- changes in the realm of dispute resolution procedures.

The expansion of the global telecommunications market, with its emphasis on innovative and fast-changing technology may need to be accompanied by dispute resolution procedures which are fast, flexible, and suited to the types of disputes that the global telecommunications industry will produce. In turn, the dispute resolution field is increasingly offering new models that may be useful to the telecommunications sector's new needs.

For a more detailed discussion on the topic of dispute resolution see **Section 2.3.10 – Dispute Resolution**

[i] See **www.cantor.com/brokerage_services/spectrum_and_tower** for further information about their system.

Practice Notes

- **Ofcom - Spectrum Usage Rights: A guide for describing SURs**

- Ofcom Spectrum Usage Rights

Reference Documents

- Designing property rights for the operation of spectrum markets, 2003

5.4.3.4 SPECTRUM SHARING IN PRACTICE

The following country examples reflect many of best practices described in the preceding section. Some of them feature practices for spectrum trading and spectrum commons management. Given the recent focus at the international level on identifying bands for Broadband Wireless Access, we look at the leading practices of several developing and developed countries where BWA is being implemented.

Brazil – Broadband Wireless Access

In January 2008, ANATEL in Brazil issued 4 licences per licensed area for 3G wireless deployment in the whole country. Coverage obligations for all licensed operators will lead to coverage over the whole Brazilian territory (probably 8 years after the licences have been issued). Operators are allowed to share network components such as towers as well as spectrum in order to provide services in municipalities with less than 30,000 inhabitants. ANATEL will likely issue new regulations on the conditions for spectrum sharing and sharing of active elements of the network. Spectrum sharing arrangements must be authorized by ANATEL. The rules governing the 3G auction in Brazil refer expressly to spectrum sharing as a means of providing coverage in rural and remote areas (i.e. the municipalities with less than 30,000 inhabitants).

ANATEL issued a number of licences for WiMax in the 2.6 GHz and five licensees in the 3.5 GHz band bands. A new auction for additional 3.5 MHz spectrum is planned for 2008. Some of the licences have already started authorized trials.

Europe - Flexible User Rights and Spectrum Trading

The European Union (EU) does not manage radio spectrum. Instead the Member States supervise its management at the national level and in international coordination. However, the management of radio spectrum in EU Member States is influenced significantly and increasingly by European legislation. Legislation is aimed at facilitating harmonization of regulation and promoting competition through the liberalization of markets. The key legislation is contained in a number of directives and decisions passed in 2002.

The Radio Spectrum Decision laid the foundation for a general EU radio spectrum policy and is binding on all Member States. The objective of the Radio Spectrum Decision is to ensure coordination of radio spectrum policy approaches by facilitating harmonized conditions for the availability and efficient use of radio spectrum.

The Radio Spectrum Decision encourages the European Commission to organize consultations to take account of the views of Member States and all other stakeholders. To facilitate more effective consultations, the Radio Spectrum Policy Group (RSPG) was established by separate decision.

The RSPG launched a consultation on secondary trading of spectrum in February 2004 following a request received from the EC in 2003 for an opinion on secondary trading. In November 2004, the RSPG published its Opinion on secondary trading.

RSPG has adopted a cautious stance with regard to spectrum trading considering it to be “beneficial in certain parts of the spectrum” and that “European administrations should introduce secondary trading with due care”.

The EU now proposes that one-third of the spectrum below 3GHz could have flexible usage rights and be tradable by 2010.

RSPG is elaborating on the concept of Wireless Access Policy for Electronic Communications Services (WAPECS) to move away from too narrowly specified allocations and applications, for which specific spectrum is designated.

Guatemala – Spectrum Trading

Guatemala and El Salvador are two small Central American countries (with populations of 12,728,111 and 6,948,073 respectively) which decided in 1996/97 to adopt a simple but effective spectrum market which, in the case of non-public sector spectrum, gave private parties exclusive control over use of bandwidth and confined the regulator to defining, issuing and protecting spectrum rights. This note focuses on Guatemala; the regime in El Salvador is similar but not as well documented.

The frequency use title (TUF) created could be leased, sold, subdivided or aggregated at will and lasts for 15 years

(renewable on request); they are thus virtually private property. Regulation is restricted to setting aside bands for use by the state and adjudicating interference disputes which are not resolved by mediation.

A physical TUF is a paper certificate listing the frequency band, hours of operation, maximum transmitted power, maximum power emitted at the border, geographic territory and duration of right.

International Telecomunication Union

ITU Resolution 951 (Rev. WRC.07) Enhancing the international spectrum regulatory framework. This resolution establishes guidelines used in evaluating and developing concepts related to four identified options for enhancing the spectrum regulatory framework and for preparing solutions to be discussed at WRC.11. The four options include: keeping current practices, revising current service definitions, creating new service definitions, and introducing composite definitions.

Mauritius – Broadband Wireless Access

In early 2005 with spectrum pollution occurring in the 2.4 GHz band, the Information and Communication Technologies Authority (ICTA) conducted public consultations to receive input on proposed BWA frequency band allocations, technical characteristics and regulatory requirements and issued its decisions within three months. Those decisions opened the 2.5 GHz band for Mobile and Nomadic BWA (IMT-2000) applications by 2010, the 3.5 GHz band immediately for Fixed BWA and the 5.1-5.3 GHz band for low power in-building applications. In 2006, ICTA additionally opened the 5.4 GHz and 5.8 GHz bands for BWA. Band plans and technical rules were established limiting allowable power levels, separation and channelisation.

As of 2007, there are two mobile licensees providing IMT-2000 and WiMax services on a national basis.

New Zealand – Spectrum Trading and Spectrum Commons

The Radiocommunications Act 1989 was pioneering and radically changed the landscape of spectrum management. New Zealand was the first country to redefine spectrum in terms of property rights and to assign it in a tradable form. New Zealand also pioneered the application of competitive assignments based on auctions for radio spectrum, with the first auction held in 1989.

There are three licensing systems that apply to spectrum in New Zealand:

- The Management Rights Regime (MRR) (applicable to spectrum used primarily for commercial purposes);
- The Radio Licence Regime (RLR), earlier known as apparatus licensing, (an administrative assignment process which applies to spectrum used for applications in the public interest); and
- General User Licences for devices such as low-powered devices: garage door openers and Wi-Fi).

United Kingdom – Flexible User Rights and Spectrum Trading

OFCOM is currently shifting U.K. spectrum policy towards a flexible system of spectrum management through the liberalization of spectrum usage rights and spectrum trading. A gradual approach is being adopted, embracing progressively more bands and greater flexibility in use but relying on competitive assignment methods. This progression is exemplified by OFCOM's intention to apply service and technological neutrality in a forthcoming spectrum assignment involving frequencies currently used to support terrestrial analogue TV broadcasting, the proposed use of spectrum user rights in a forthcoming auction of the L Band, and in other auctions.

The United Kingdom has also adopted the policy of extending market methods of spectrum management to public sector spectrum, giving public sector users the right to trade or lease their spectrum and the obligation to go into the market place to acquire additional spectrum. OFCOM is also extending the application of administrative incentive pricing.

- Administrative Incentive Prices (AIP): are intended to encourage licensees of non-auctioned spectrum to use their spectrum rights efficiently; legislation enables annual licence fees to be set above administrative cost to reflect a range of spectrum management objectives (efficient management and use, economic and other benefits, innovation and competition), having regard in particular to availability of present and expected future demand for spectrum. OFCOM has been using AIP since 1998 and revised the approach in 2004. There AIP is used to value spectrum at its marginal value as a proxy for the opportunity cost to the representative spectrum user in those bands where AIP fees were charged.

United States – Flexible Spectrum Use and Broadband Wireless Access

The United States has been a leader in regard to spectrum liberalization. Liberalized spectrum management primarily

relates to the non-government spectrum, whereas the usual framework for government spectrum continues to be traditional. Spectrum Policy Initiative – 2003 addressed several important components:

- Auctions: it was proposed that the FCC should be granted permanent authority to assign licences via auction (competitive bidding);
- Spectrum Licence User Fees - to ensure that licence holders pay the opportunity costs of their spectrum use.

The United States has also moved progressively in the direction of flexible use of spectrum, in conjunction with generally liberalized practices. The Communications Act specifically authorizes the FCC to permit flexible use where:

- such use is consistent with international agreements to which the United States is a party;
- the Commission finds, after notice and opportunity for public comment, that such an allocation would be in the public interest;
- such use would not deter investment in communications services and systems, or technology development; and
- such use would not result in harmful interference among users.

The FCC Spectrum Policy Task Force – 2002 advocated:

- increased reliance on both the exclusive use and commons models, and reduced use of traditional allocation mechanisms;
- maximum feasible flexibility for licensees, limited only by interference concerns;
- increased use of spectrum trading, including the ability to lease spectrum on a rapid or an overlay or underlay basis.

Practice Notes

- **Spectrum Trading in Practice - ECOWAS**

5.4.4 IMPLEMENTING SPECTRUM SHARING

Success in implementing spectrum sharing requires both vision and commitment for moving from current regulatory allocation and assignment practices based on a sound understanding of technology and systems operating under predictable circumstances.

Spectrum policies should address incentives for innovation, promote flexibility, establish spectrum users' rights, determine practical methods for compliance monitoring, compliance monitoring, and dispute resolution, whether spectrum is used in the spectrum commons or shared by some other means when implementation relies heavily on advanced radio technologies designed to facilitate spectrum sharing.

An additional step could be to follow the path being taken by the FCC and the NTIA in the United States to create Spectrum Sharing Innovative Test-Bed for studying spectrum sharing emerging radio systems such as software defined radio and methods and techniques such as dynamic spectrum access.

5.4.4.1 MARKET STRUCTURE

Analysis of current and future spectrum uses will be needed to help determine which bands should be included and how and when they should be released, for example by auction. Planning will involve consultation with various stakeholders and with industry fora. At a minimum, careful review and understanding of recent decisions at WRC and certain leading countries will be both helpful and necessary. A chief concern will be ensuring sufficient spectrum is available to satisfy demand and for proper market functioning. As we have seen earlier the extent to which spectrum is allocated for commercial or exclusive government use has an important bearing on improved access. Processes to review and understand government requirements and to shift spectrum away from exclusive use require both time and negotiation.

Demand and scarcity

Market-based methods work best when demand is sufficient and rules and rights are clear. For developing countries the real absence of scarcity and emerging demand for services might prove sufficient to cause delay in the introduction of spectrum sharing policies and assignment practices. The difficult question to answer is the impact of delay on the overall economy coming from investment and productivity. Favouring the creation of attractive markets for investors who can deploy or utilize advanced services and technologies should not to be ignored by spectrum policy makers.

Monopolization

Under administrative methods of licence assignments, the regulator plays a major role in determining the structure of the downstream services market. If two GSM licences are available, the GSM market place will have two suppliers, and so on. Indeed regulators have often deliberately chosen the number of licences to maximise competition or – less respectably – to limit competition in order to capture monopoly profits for themselves through an auction process for the licences.

Once secondary trading is allowed, industry structure can be affected by mergers of companies or the direct transfer of spectrum ownership. There is a risk of a structure emerging which contains a monopoly or, more generally, a dominant firm or firms, which can set excessive prices. If spectrum markets lead to the monopolization of the supply of downstream services (i.e., if a single firm could corner the entire spectrum capable of producing such a service), and there are no other competing or substitute technologies or services, then a spectrum market could easily produce worse results than an administrative system which led to competition among downstream suppliers of services.

Are these problems likely? It depends upon the degree of flexibility the regulator allows the market to exhibit. If there are no prior allocation restrictions (limiting certain services to certain bands) and if the arena in which the market operated is extensive, building a spectrum monopoly leading to dominance in downstream markets is not likely to succeed. For major services such as mobile voice or data, or mobile broadcasting, the required spectrum holdings would be very large. The danger does increase if either there are allocation restrictions or if the scope of the market is small (and other barriers to entry are high).

These problems can also be combated by ordinary competition law where the law exists; for example a dominant position might be broken up or a merger disallowed. But it may also be necessary for the regulator to have the power to scrutinize and, if appropriate, prohibit certain spectrum trades. For example, special procedures may be needed to limit the acquisition of spectrum licences or requiring prior approval of transfers or the application of merger-control procedures which vet a proposed concentration of spectrum for its impact on the relevant anti-trust market.

Finally, spectrum regulators can construct auction rules for the release of new spectrum in ways that promote competition. There are several examples:

- the 700 MHz auction rules in the USA include a requirement that some spectrum should be auctioned subject to an open access obligation;
- the AWS auctions in Canada completed in the summer of 2008 where the regulator included spectrum "set asides" to ensure access to spectrum for new entrants.

Market liquidity

Another key requirement for an effective market is that it have sufficient liquidity (i.e., volume of trades) to provide participants with a reliable method of transacting. Illiquid financial markets notoriously exhibit high spreads or differences between the buy and sell price, to compensate the intermediary for the cost of holding stock.

International experience in spectrum trading was highlighted in the sections above and the following similarities and differences were exhibited:

- there were few , if any, signs of intermediaries being active in the market;
- there were no signs of speculators entering the market;
- several countries exhibited significant levels of trade (Guatemala and El Salvador) or a number of significant ($ hundred million) trades (the United States);
- in Australia and New Zealand, levels of trade have been fairly low (roughly equal to the turnover of commercial property) reflecting an orderly turnover in spectrum through trades;
- in the United Kingdom, trades in the limited bands available have been infrequent, but the number of traded bands has been small and the spectrum regulator is in the middle of a large programme of spectrum awards which may provide an alternative source of spectrum to those who want it.

Liquidity of spectrum markets remains a real issue, and the design of liberalization measures should be in the foreground.

5.4.4.2 PRACTICAL STEPS

The regulator in exercising its primary responsibilities related to spectrum management goals and objectives should decide on what the appropriate balance and mix of administrative and market-based techniques is. It is a matter of reliance on methods that will ensure access and protection from interference. The current balance favours administrative approaches

and it is the view of this author that a shift towards market-based methods should be acknowledged and encouraged by regulators. The practical steps involved in this shift in stance include:

- Spectrum legislation and regulation creating expanded authorities by the regulator to manage, assign, and license, while permitting spectrum use flexibility, technology neutrality, and sharing;
- Creating the necessary mechanisms, tools and processes to capture and include the needs and expertise of both current and future spectrum users.

These may seem like obvious steps to take. Making the decision to increase access and improve sharing requires a very strong commitment from the regulator for change and includes stakeholders and users as integral partners in the process of determining which approaches, methods and spectrum should be made more accessible. It is the commitment to change and inclusion which is often lacking and so the process sputters to a stalemate.

Advocating the use of innovative technologies is also a key role of regulators. Providing the means to test and trial new technologies by making spectrum available and using test licenses are two very practical steps that can be taken. ComReg in Ireland has indicated that it is keen to encourage innovative developments and more efficient ways to use spectrum. They wish to encourage development in these technologies through their test and trial licence scheme.

As discussed throughout the document, regulators have a powerful tool in allocating spectrum for various uses and users. Are there bands which by and large should always be allocated to BWA and so simplify the process for regulators?

The answer is most likely no. As we know, each region and country within a region differ and as we saw in the previous **sections 4.3.4** and **4.4.1** approaches vary. We can say with confidence that by limiting the restrictions on uses and users, access is improved. Knowing how to go about limiting restrictions requires information, some consensus and where this lacking, the means to smooth an adjustment. What can be done?

The regulator should consider:

- acquiring the information needed to assess use, users, and utilization. Spectrum audits can be performed to fill in the gaps of information;
- consulting with current and prospective users;
- planning for and clearing zones of spectrum through incentives and adjustments like refarming;
- examining ways to license or unlicense underutilized spectrum to increase use and sharing;
- reinforcing the application of technical standards and compliance to ensure interference is managed and manageable;
- utilizing band managers to manage use and users in bands where demand has been pooled and where trading can now take place.

5.4.4.3 INFORMATION AND ADMINISTRATIVE PROCEDURES FOR SPECTRUM TRANSFER

If spectrum markets are to work properly, participants must have basic information about spectrum holdings adjacent to where they are considering buying licences. Otherwise buyers will not appreciate the constraints relating to interference to which they will be subject. This raises problems of confidentiality – both commercial confidentiality and the need for secrecy where spectrum is used for security or defence purposes. For a variety of reasons concerned with the policing of interferences as well as the policing of competition, the regulator will have to keep a register of spectrum use and licence holdings. Much of this can be published, and its existence will be of great help to potential licensees seeking to find out who their spectrum neighbours would be if they offered a particular service in a particular frequency in a particular area.

Practice Notes

- **Online Spectrum Registers: Canada and New Zealand**
- **Sharing Mobile Network Infrastructure in India**
- **Spectrum Trading: Implementing Secondary Markets in the European Union**

Next: 5.5 Spectrum Pricing ➔

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