

Module 5. Radio Spectrum Management

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Module 5. Radio Spectrum Management

[Spectrum Management Overview](#)

An introduction to spectrum management including best practices and considerations involved in the use and regulation of radio frequency spectrum.

[Spectrum Policy and Planning](#)

An outline of policy and planning considerations including technical standards and the allocation of spectrum.

[Authorization](#)

An overview of the processes by which users gain access to the spectrum resource.

[Spectrum Sharing](#)

A review of administrative, market-based and technically-based spectrum sharing techniques.

[Spectrum Pricing](#)

A review of the role of spectrum pricing as it relates to the method of spectrum authorization being employed.

[Spectrum Monitoring and Compliance](#)

An overview of how spectrum monitoring and compliance can help users by avoiding incompatible frequency usage through identification of sources of harmful interference.

[International Affairs](#)

An overview of international harmonization of spectrum utilization.

[Developing Spectrum Management Capacity](#)

An overview of the strategies for organization, function, process development, staffing, staff retention and training for spectrum regulators.

THIS MODULE IN OTHER LANGUAGES:

 [Versión Española \(PDF\)](#)

 [Version française \(PDF\)](#)

RELATED MATERIALS:

[Regulating Spectrum Management: Overview and Trends](#)

[Background Resources on Spectrum Management \(ITU\)](#)



Executive Summaries

Module 5. Radio Spectrum Management

 [Executive Summary](#)

1 Spectrum Management Overview

CHAPTER 1 TRANSLATIONS

 [Version française \(PDF\)](#)

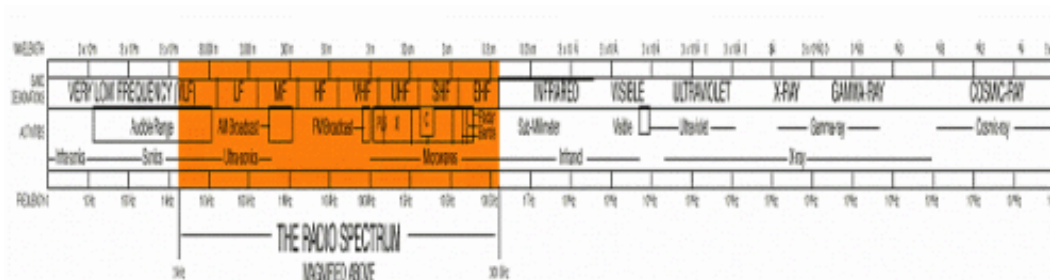
 [Versión Española \(PDF\)](#)

This section is an introduction to the management of the radio spectrum including the planning of current and future uses of spectrum; ensuring engineering compatibility of various uses and equipment; and authorization, licensing and monitoring of spectrum usage.

1.1 Introduction to Spectrum Management Overview

The radio spectrum is a subset of the electromagnetic waves lying between the frequencies from 9 kilohertz (kHz - thousands of cycles per second) to 30 gigahertz (GHz - billions of cycles per second) (see Figure 1). These support a wide range of business, personal, industrial, scientific, medical research and cultural activities, both public and private. Communications are foremost among those activities and, together with other radio services, are increasingly important to economic and social development.

Figure 1: Radio Spectrum



Historically, access to and use of radio spectrum has been highly regulated in order to prevent interference among users of adjacent frequencies or from neighbouring geographic areas, particularly for reasons of defence and security. In the past decade there have been significant innovations in the theory of spectrum management along with gradual changes in practice of spectrum management and regulation. This gradual change follows a growing consensus that past and current regulatory practices originally intended to promote the public interest have in fact delayed, in some cases, the introduction and growth of a variety of beneficial technologies and services, or increased the cost of the same through an artificial scarcity. In addition to these delays, the demand for spectrum has grown significantly highlighting the need for efficient use of all available spectrum in order to avoid scarcity.

Those factors are making policy-makers and regulators worldwide focus anew on spectrum regulation with an increasing emphasis on striking the best possible balance between the certainty required to ensure stable roll-out of services and flexibility (or light-handed regulation) leading to improvements in cost, services and the use of innovative technologies. In developing countries in particular, where mobile communications users now greatly outnumber those using fixed line telecommunication services, it is widely recognised that the spectrum is a highly valuable resource for future economic development.

The Radio Spectrum Toolkit is intended to canvass those policy and standards issues as they touch on a broad range of spectrum management areas including basic principles of spectrum regulation, spectrum sharing and trading, spectrum pricing, monitoring and international coordination.

The international framework for the use of the radio frequency spectrum is set out in a treaty – the *Radio Regulations* - ratified by the Member States of the International Telecommunication Union (ITU), a specialized UN agency. Within that international framework, countries manage their national use of the spectrum. At the highest level, countries do this through establishing a National Frequency Allocation Table which sets out what radio services can use which frequency bands and under what conditions. Conditions of use vary widely, from inflexibly reserving particular frequencies for uses which are specified in detail, to considerable freedom in spectrum use for particular bands or services. For a more in depth discussion of International Affairs see [Section 7](#).

Decisions are made at the international and national levels on the purpose or purposes to which particular frequencies will be put. This is known as making spectrum allocations on either an exclusive, shared, primary or secondary basis. These decisions are reflected in the International and National Tables of Frequency Allocations.

Assigning particular frequencies to specified users is the next stage in spectrum management. Because such methods of assignment rely on administrative decisions, such procedures are sometimes described as 'administrative methods'. The alternative is a process in which applicants bid for licences, for instance in an auction, or when spectrum licences change hands via the normal process of buying and selling assets. Here the spectrum regulator does not select the licensee, but the market does: hence the description of them as 'market-based methods'.

Additionally, some spectrum may be reserved for unlicensed use (a "spectrum commons"). All users satisfying certain restrictions, for example on power levels and geographic range, might have access to unlicensed bands.

For a more in-depth discussion of allocation and assignment see Authorization: [Section 3](#). As well, existing and new methods for improving spectrum sharing are discussed in [Section 4: Spectrum Sharing](#). Spectrums pricing using administrative and market-based methods such as auction are discussed in [Section 5](#).

1.2 Spectrum as a Resource

Effective use of spectrum can make a big difference to a country's prosperity, especially where communications are heavily reliant upon wireless technologies such as mobile phones. Spectrum scarcity whether it is real or artificial can have an adverse impact upon prosperity. This section considers spectrum as an economic and technical resource, and spectrum scarcity.

1.2.1 Spectrum as an Economic Resource

The production of goods and services involves the creation of output for end users (households and firms) from a combination of inputs. Traditionally those inputs are listed as labour, capital equipment and land. Clearly each of these can take on various uses; compare, for example, the use of land in city centres and for agricultural purposes.

Similarly, spectrum is one of these types of resources and can be used as an input in a multitude of services, whether for communications or other applications. Communications services encompass a wide range of forms, including narrow or broadband mobile telecommunications, broadcasting, aeronautical and marine communications, as well as communications for public bodies--such as defence or emergency services. Non-communication uses include military and civilian radar and scientific applications such as radio, astronomy and so on. It interesting to compare spectrum to other natural resources used in the economy such as land, oil and water (illustrated in Table 2), as it exemplifies its similarities to other exhaustible resources within modern economies.

Table 2 Spectrum as an Economic Resource

	Spectrum	Land	Oil Reserves	Water
Is the resource varied?	Yes	Yes	Not very	Not very
Is it scarce?	Yes	Yes	Yes	Yes
Can it be made more productive?	Yes	Yes	Yes	No
Is it renewable?	Yes	Partially	No	Yes
Can it be stored for later use?	No	No	Yes	Yes
Can it be exported?	No	No	Yes	Yes
Can it be traded?	Yes	Yes	Yes	Yes

What flows from these characteristics of spectrum?

- Because frequencies differ in what they can do, there can be problems of matching them to particular uses. Land has similar characteristics. The task of allocating and assigning spectrum noted above are intended to accomplish efficient matching.
- Spectrum can be in short supply because there may be more potential users of particular frequencies than available spectrum. There is, therefore, a need for rationing its use and giving priority to more important applications. Nevertheless, a country can respond to a

shortage of spectrum in particular frequencies by moving to other less favoured frequencies, or by developing the techniques, such as compression, which allow spectrum to be used more productively. These two responses is analogous to bringing less fertile land into cultivation and applying fertilizer to make existing cultivated areas more productive within the agricultural sector.

- Because spectrum is renewable and cannot be stored, there is no reason to hoard it for later use, as a country might save oil reserves for use or sale later.
- Because spectrum is locationally specific (specifically located?), it can only be used to provide services in a given territory. However, it can be traded, in the sense that property rights can be assigned to it.

The importance of basic telecommunications services - fixed and mobile - for economic growth and development has long been recognized in the international community. Telephone penetration (traditionally measured in terms of fixed or mobile voice equivalents per 100 population) is a standard metric for evaluating the quality of basic infrastructure, and the positive correlation between telephone penetration and economic activity (usually measured as GDP per capita) is well known,

Today, access to telephony services, while remaining essential, is no longer enough. Internet access--and this increasingly means broadband Internet access -- is now generally regarded as part of the essential basic infrastructure for society and the economy. Equally important is the centre of gravity for infrastructure growth in developing countries, which is clearly wireless. Chart 2 illustrates the recent rapid rise of wireless broadband subscriptions while Chart 3 illustrates the predominance of growth in mobile connections in developing countries.

Measuring and quantifying the economic impact of ICT's on the economy and spectrum as an input in its application in mobile telephone, while important to policy makers, is very challenging for three reasons:

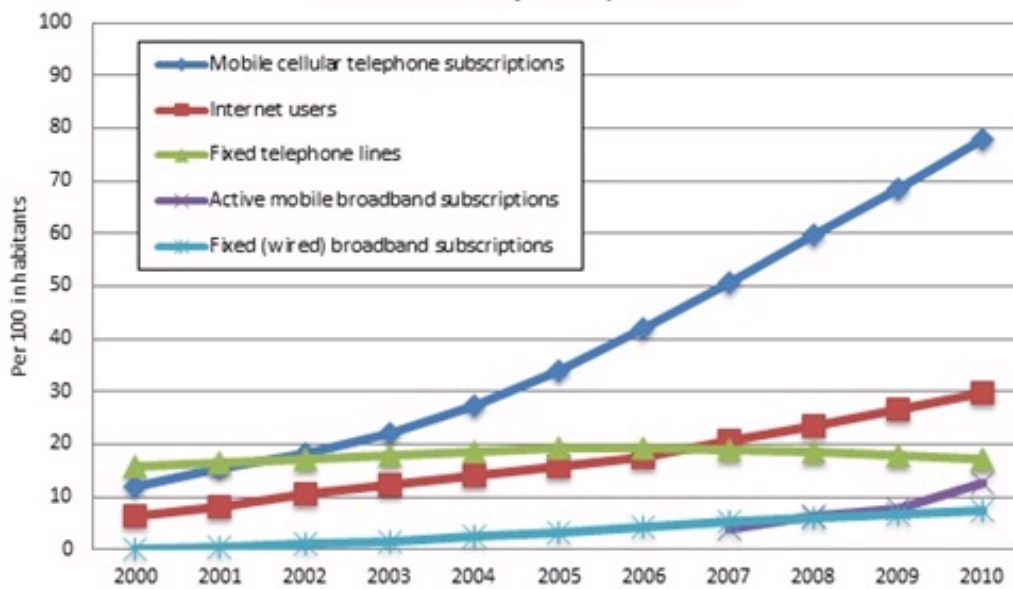
- Firstly, although investment in ICT represented a significant share of total fixed business investment in the United States (where most of the early research focused), it still represented only a small share of the total capital stock and, ICT-producing sectors, a small share of total GDP.[\[1\]](#)
- Secondly, measuring ICT inputs is notoriously difficult, in part, because of the very rapid pace of innovation and continuously declining prices. This phenomenon is known popularly as *Moore's Law*, where it is becoming increasingly difficult to measure the quantity and value of ICT inputs (and outputs) in appropriate quality-adjusted terms. For example, although more expensive the technological capabilities of a new Smartphone in 2012 are significantly greater than even in 2009.
- Finally mobile broadband can be viewed as a general-purpose technology, which is enabling companies-- especially service companies-- to introduce new products as well as change business processes such as supply chains. Capturing data and measuring outputs, similar to measuring inputs, are notoriously difficult.

Still, with these challenges being present several groups of economists have attempted to measure the impact of mobile telecommunications in general and mobile broadband specifically. A selection of these results are summarized below:

- Czernich et al. (2009)[\[2\]](#) used panel data for OECD countries from 1996-2007, and found that a 1% increase in broadband penetration raised GDP per capita growth by 0.09 to 0.15%.
- Franklin, Stam & Clayton (2009)[\[3\]](#) looked at a panel of 13 European countries on firm-level productivity from 2001-2005 and found that broadband enhanced employee productivity, but that this impact varied with the level of adoption, suggesting that critical mass is required to realize significant benefits.
- Katz and Avila (2010)[\[4\]](#) analyzed data for 24 Latin American and Caribbean countries from 2004-2008 and found that a 1% increase in broadband penetration resulted in a 0.0178% increase in GDP. They also estimated that the same 1% increase in broadband penetration would increase employment by 0.18%.
- Koutroimpis (2009)[\[5\]](#) examined a panel for 15 European countries from 2003-2006 and concluded that a 1% increase in broadband resulted in a 0.038% higher GDP growth.
- The OECD (2011)[\[6\]](#) looked at a number of OECD countries and found that 1% higher broadband penetration resulted in 0.109% faster GDP growth. This study also looked at the relationship between IPv4 address growth and GDP and found a similar positive impact. This is interesting because it provides additional support for the view that broadband causes (rather than follows) economic growth.
- Waverman (2009)[\[7\]](#) used data for the United States and 14 European countries from 1998-2007 to conclude that a 1% higher broadband penetration raised productivity by 0.0013% in markets with medium to high levels of broadband penetration, but resulted in no significant measured impact for countries with low broadband penetration (providing further support for the notion that critical mass is important in order to realize significant benefits from broadband).

Chart 1 shows the buoyant growth in the ICT sector over the past decade, clearly illustrating the tremendous expansion in the penetration of mobile services with 5.4 billion mobile subscribers, which is enough to reach 78 per cent of the world's population. In addition to this, by the end of 2010, growth in fixed lines stagnated at nearly 1.4 billion fixed line subscribers.

Global ICT developments, 2000-2010



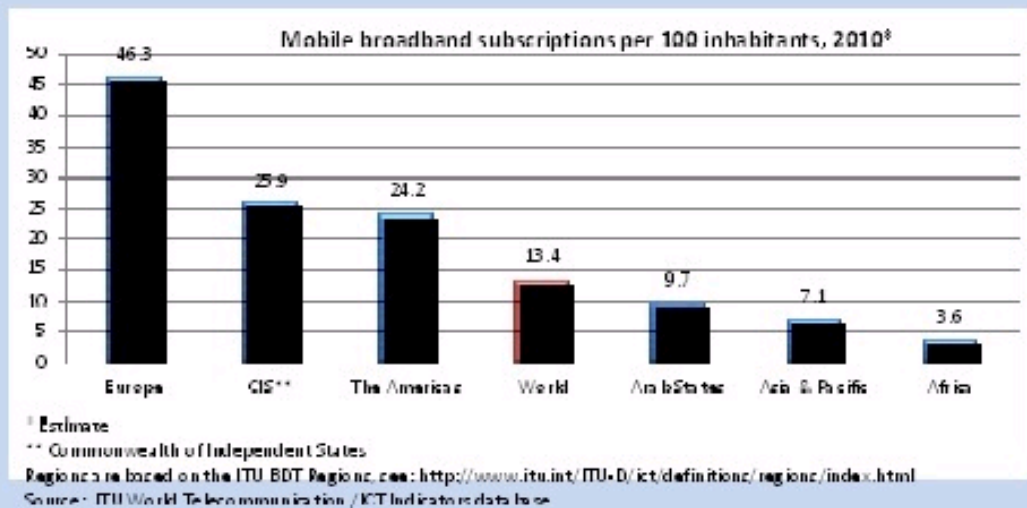
Source: ITU World Telecommunication/ICT Indicators database

Photo: ITU World Telecommunications Indicators Database

Chart 1 Growth in penetration per 100 inhabitants of fixed lines, mobile cellular subscriptions, and subscribers to mobile and fixed broadband networks 2000-2010

Penetration varies significantly between rich and poorer countries although the significant trend is for rapid growth in mobile usage in emerging and developing economies.

Chart 2 Mobile Broadband Subscriptions



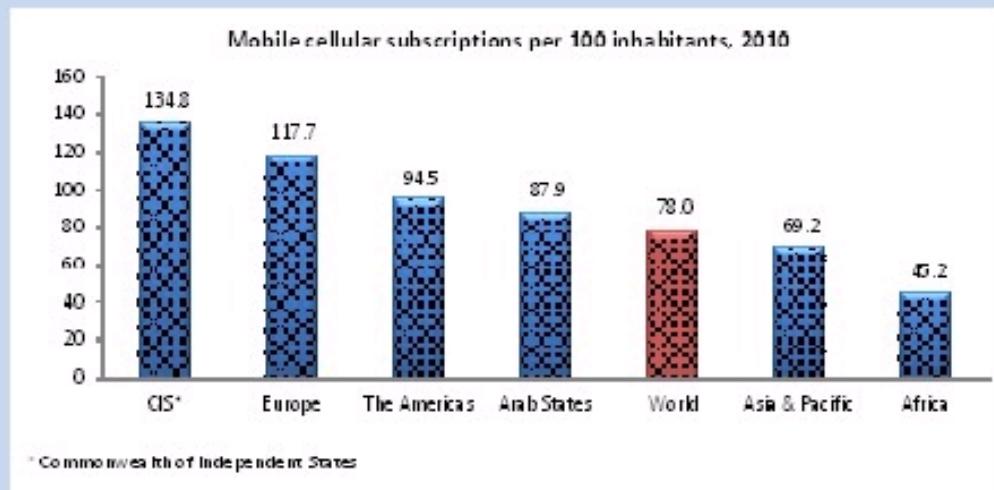
Source: ITU World Telecommunication Indicators Database

Photo: ITU World Telecommunications Database

Chart 2 Mobile broadband subscriptions per 100 inhabitants

Mobile penetration in developing countries in Africa and Asia has reached approximately 45 and 62 % respectively with mobile penetration growing at a phenomenal compound annual growth rate over 22 % globally in 10 years. Indeed, amongst the least developed economies, mobile cellular subscribers outnumber fixed lines by more than nine to one. The balance has shifted between developed and developing countries with most of the growth mobile subscriptions occurring in developing countries.

Chart 3 Mobile subscribers by region 2010.

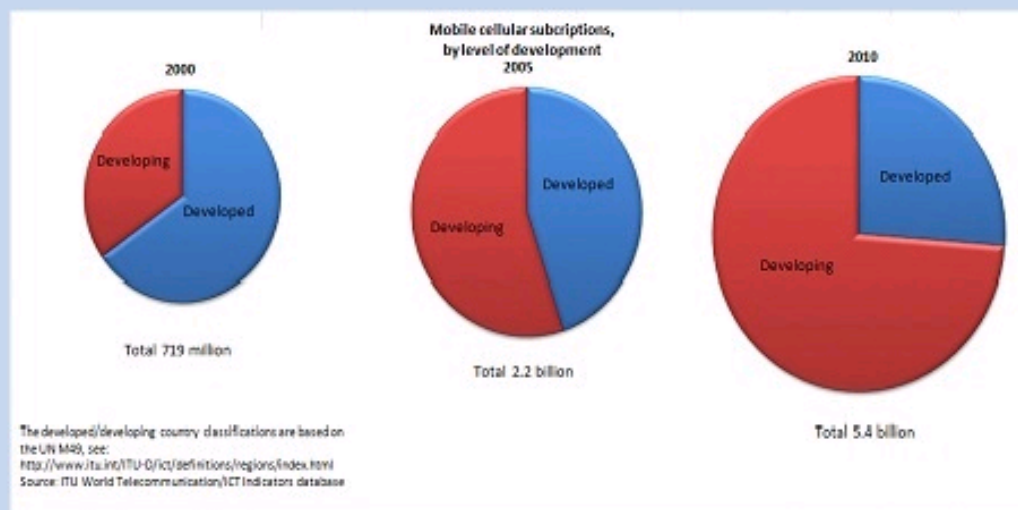


Source: ITU World Telecommunication Indicators Database

Photo: ITU World Telecommunications Database

Mobile cellular subscriptions per 100 inhabitants

Chart 4 Mobile subscribers worldwide by level of development 2000, 2005, 2010.



Source: ITU World Telecommunication Indicators Database

Photo: ITU World Telecommunications Database

[1] Oliner, S. and D. Sichel (1994), "Computers and output growth revisited: How big is the puzzle?" *Brookings Papers on Economic Activity* (2): 273-317).

[2] See Czernich, N., O. Falck, T. Kretschmer and L. Woessmann (2009), "Broadband Infrastructure and Economic Growth," CESifo Working Paper No. 2861, University of Munich, December 2009.

[3] See Franklin, M., P. Stam, and T. Clayton (2009) "ICT Impact Assessment by Linking Data," *Economic and Labour Market Review*, 3(10), 18-27.

[4] See Katz, R. and J. Avila (2010) "Estimating Broadband Demand and Its Economic Impact in Latin America," *Proceedings of the 4th*

[5] See Koutroumpis, P. (2009), "The economic impact of broadband on growth: A simultaneous approach" *Telecommunications Policy*, 33.

[6] See OECD (2011) "Economic Impact of Internet/Broadband Technologies," DSTI/ICCP/IE(2011)1/REV1, Working Party on the Information Economy, Directorate for Science, Technology and Industry, OECD, Paris, 30 May 2011.

[7] See Waverman, L. (2009) "Economic Impact of Broadband: An Empirical Study," LECG, a study prepared for Nokia-Siemens Networks as part of the *Connectivity Scorecard 2009*."

1.2.2 Spectrum as a Technical Resource

Electromagnetic radiation is the propagation of energy that travels through space in the form of waves. It includes the visible spectrum (light), as well as infrared, ultraviolet and x-rays. The radio frequency spectrum is the portion of electromagnetic spectrum that carries radio waves. The boundaries of radio spectrum are defined by the frequencies of the transmitted signals, and are usually considered to range from 9 kilohertz (kHz - thousand cycles per second) up to 300 gigahertz (GHz - billion cycles per second). However, technical change is making use of even high frequencies viable. Table 2.0 depicts the some of the many uses of radio spectrum associated with various bands derived from their inherent propagation characteristics.

Table 2 Radio Frequency Propagation

Band	Frequency	Range	Use	Bandwidth	Interference
VLF	3-30 kHz	1000's km	Long range radio-navigation	Very narrow	Wide Spread
LF	30-300 kHz	1000's km	Same as VLF strategic communications	Very Narrow	Wide Spread
MF	.3-3 MHz	2-3000 km	Same as VLF strategic communications	Moderate	Wide Spread
HF	3-30 MHz	up to 1000 km	Global broadcast and Point to Point	Wide	Wide Spread
VHF	30-300 MHz	2-300 km	Broadcast, PCS, Mobile, Wan	Very Wide	Confined
UHF	.3-3 GHz	< 100 km	Broadcast, PCS, Mobile, Wan	Very wide	Confined
SHF	3-30 GHz	Varies 30 km to 2000 km	Broadcast, PCS, Mobile, Wan, Satellite Communication	Very Wide up to 1 GHz	Confined
EHF	30-300 GHz	Varies 20 km to 2000 km	Microcell, Point to Point, ,PCS and Satellite	Very Wide up to 10 GHz	Confined

The key characteristics of spectrum are the propagation features and the amount of information which signals can carry. In general, signals sent using the higher frequencies have lower propagation distances but a higher data-carrying capacity. These physical characteristics of the spectrum limit the currently identified range of applications for which any particular band is suitable. Some spectrum (such as in the UHF band 300-3000 MHz) is known to be suitable for a wide variety of services and is thus in great demand.

Presentations delivered at the 2008 ITU World Radiocommunication Seminar, 8-12 December 2008, available at: www.itu.int/ITU-R/index.asp?category=conferences&link=seminar-program&seminar=geneva-2008&lang=en

1.2.3 Spectrum Scarcity

The demand for spectrum is increasing and many frequency bands are becoming more congested especially in densely populated urban centres. Spectrum managers are taking various approaches to improve efficiency; using administrative methods including inband sharing, changes to licensing such as spectrum leasing and spectrum trading, and use of unlicensed spectrum (the spectrum commons) combined with the use of low power radios or advanced radio technologies including ultra-wideband and multi-modal radios.

It is important to remember that where spectrum scarcity exists, shortages can be met in part by existing users through the use of more advanced radiocommunications equipment, for instance in the shift from analogue to digital television. However, as discussed in [Section 1.3.1](#), sufficient incentives are needed to ensure frequencies will be used efficiently by existing users or as in the case of license-exempt spectrum reduction in the number restrictions and barriers on use.

Scarcity is not one-dimensional, since there can be differences between urban and rural areas with spectrum most likely being highly congested in urban areas. As well, scarcity can result from the types of services allocated in certain geographic areas such as maritime services in coastal areas.

1.2.4 Spectrum Access

The past twenty years have given us dramatic improvements in telecommunications access and services accompanied by relentless and rapid changes including particularly:

- the development of nearly ubiquitous (and usually competitive) mobile voice networks now accounting for nearly six billion lines, as opposed to 1.2 billion fixed lines;
- the emergence of broadband as a general purpose technology affecting all aspects of economic and social activity – whether related to consumption, production or the delivery of government services – which could very likely match the spread of voice services in the next 10-15 years. In almost every part of the world, wireless data traffic is expected to double each year for the next five years. [\[1\]](#)

In emerging and developed economies, the key to continued development in telecommunications especially broadband over the foreseeable future will be access to spectrum, and a country's national broadband plan will depend crucially upon it. Abundant spectrum will be essential to promoting competition and innovation in telecommunications markets. In an opposite scenario, where spectrum access is inadequate the result will likely be higher prices for consumers, limited market entry, and constrained innovation. Successful national broadband plans will be almost inconceivable without strenuous efforts to add to available communications spectrum by all available means, including digital dividend, refarming and a willingness to be a 'fast follower' of new spectrum technologies associated with sharing frequencies.

As discussed further in Section 2.3: Spectrum Policies and Principles, it will be necessary to ensure that spectrum policies and principles connected with allocation and assignment procedures support both technical and economic efficiency while being properly balanced. Additionally, as discussed in Section 2.4.3: Planning for Future Use, the publication and adherence to a national spectrum use plan, the result of broad consultative process, and the incorporation of spectrum user views will help achieve efficient and effective uses for the spectrum resource. It is implicit that we know how spectrum is being used and by whom. Spectrum audits and spectrum supply and demand studies covering all spectrum users, especially government users, lead to steps which can result in new allocations and adjustments between users. These procedures are discussed in Section 2.4.2: Knowledge of Current Spectrum Use.

[\[1\] Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2010–2015, available at \[http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.html\]\(http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.html\)](http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.html)

1.2.4.1 SPECTRUM ACCESS - THE DIGITAL DIVIDEND

Generally speaking, the Digital Dividend resides in the ranges of broadcast spectrum – VHF (30 MHz – 300 MHz) and UHF (300 MHz – 3.0 GHz). The most common definition of the Digital Dividend is: the amount of spectrum in the VHF and UHF bands that is above that amount nominally required to accommodate existing analogue TV programmes and that might be potentially freed up in the switchover from analogue to digital television. Spectrum is becoming available since digitally transmitted broadcast services (principally, television) now require a smaller amount of spectrum than the amount needed to accommodate existing analogue transmissions.

Digital compression systems (DTV) allow six and even eight standard digital television channels (depending on the coding and modulation techniques) to be transmitted in the radio-frequency spectrum previously used by a single analogue channel. More content can now be carried for a given amount of spectrum. New technologies are likely to continue to increase the capacity of the current DTT multiplexes and hence allow more services to be provided without using additional spectrum that is in high demand for other uses.

Estimates of the size and value of the digital dividend vary by ITU region and national circumstances.

Table 1.2.1 The Digital Dividend by ITU Region

Band	Region 1	Region 2	Region 3
698 - 806 MHz		698 - 806 MHz	
806 - 862 MHz		806 - 862 MHz	
698 - 790 MHz			698 - 790 MHz
790 - 862 MHz	790 - 862 MHz		790 - 862 MHz
Digital Dividend Spectrum	72 MHz	164 MHz	164 MHz

Source: McLean Foster & Co., based on the ITU Radio Regulations 2007.

Notes:

(1) Identified for IMT services on a primary basis past 17 June 2015.

(2) Identified for IMT services on a co-primary basis. Effective now with various dates set for DSO (USA, 2009; Canada, 2011; Mexico, 2022).

(3) Brazil has opted to allocate 698 - 806 MHz for IMT on a secondary basis.

(4) The USA had decided earlier in 2003 to vacate broadcast services from the 700 MHz band.

(5) China, India, Japan, New Zealand and Singapore opted to identify the 698-790 MHz band, in addition to the 790-862 MHz band, which was accepted by all countries in the region.

(6) The European Commission adopted the policy of analogue shut-off for 790-862 MHz to take place 1

Significant estimates of the economic value of the Digital Dividend in the EU have been made and are provided in the Table below.

Table 1.2.2 : Estimates in Value for the Digital Dividend

Use	Assumptions	Valuation
Digital Terrestrial Television	Six DTT multiplexes in each Member State requiring 48 MHz when using National SFN's (8 MHz channels per SFN) and 384 MHz when using MFN's (64 MHz spectrum channels per multiplex).	Between EUR 130 Billion and EUR 370 Billion discounted over 15 yrs
Mobile Television	One multiplex using either 8 MHz per SFN or approximately 48 MHz for an MFN.	Between EUR 2.5 Billion and EUR 25 Billion discounted over 15 yrs.
Wireless Broadband	Use of a 72 MHz sub-band within the 470-862 MHz band for wireless broadband services.	Between EUR 50 Billion and EUR 190 Billion discounted over 15 yrs.
Total		Between EUR 182.5 Billion and EUR 585 Billion discounted over 15 yrs.

Source: Exploiting the Digital Dividend – a European Approach, Analysis Mason, DotEcon, Hogan & Hartson, 2009.

Decision-making processes for digital switchover and potential uses of the Digital Dividend, along with spectrum re-allocation decisions, have been driven essentially by political considerations. In some cases, these decision-making processes have pitted one set of interests (telecommunication operators and service providers) against other influential and powerful interests, such as consumers who primarily bear the cost of replacing in-home equipment and stakeholders, such as government departments and broadcasters (e.g., the European Broadcast Union).

Two important considerations for politicians concerning the Digital Dividend are measuring the public value of broadcast services and reserving spectrum for future use.

When choosing how much spectrum to allocate and for whom, regulators also place emphasis on social, development and cultural goals. Market mechanisms do not necessarily take public policy priorities into account, and so in the case of broadcast, governments often intervene in allocation decisions to ensure that public-value broadcast content is available. Public values are often strongly defended and yet they are hard to quantify because it is difficult to measure in terms of incremental spectrum assignments.

In answering the question: Should some of the Digital Dividend be reserved for future use, it is necessary to consider two central issues:

- the uncertainty over the best use of the reserved spectrum both now and in the future and the lack of information available,
- the potential for regulatory decisions to have undesirable effects on the incentives for spectrum efficiency.

Ofcom in the UK conducted an assessment of the potential significance of a decision concerning the future which is portrayed in the following practice note.

Practice Note : Reserving the Digital Dividend for potential future uses: the view of the UK regulator

In Ofcom's view, a market-led approach to determining the uses for the Digital Dividend is superior because:

- Where considerable uncertainty exists over the highest value future use, market mechanisms can help to ensure that the spectrum is used by those who value it the most. Markets allow the superior information held by participants to be revealed and combined in order to identify those who have the highest value.
- Market mechanisms also help to resolve uncertainty because markets help to reveal information about how much a resource is worth to others.

Finally information about value and flexibility of use give users strong incentives to get the most out of the spectrum they own and hence to ensure efficient use in the longer term and promote innovation. The ability to make these changes and to be flexible in responding to unforeseen changes quickly is particularly important for promoting efficient spectrum use in the longer term.

Source: Ofcom UK, Digital Dividend Review 2007

1.3 Objectives of Spectrum Management

Spectrum management reflects many separate activities, including planning spectrum use, allocating and assigning spectrum licences, enforcing licence conditions, interacting with a regional and international organisations and so on assignments and so on. Each of these will have its own key performance indicators. For example, an enforcement unit may have monitoring targets or a licensing department's performance may be measured by the number of licences granted or the average amount of time taken to issue a license. Such specific indicators can be separated from broader objectives relating to the key spectrum management role, which is deciding which frequencies should be put to use for what purposes.

Economic objectives relate to ensuring that spectrum is used in ways which meet the country's goals covering the efficient allocation of resources – that spectrum is employed by both private and public sector organisations in ways which meet the countries economic growth and other objectives. Technical efficiency objectives relate to the more specific goal of ensuring that service frequencies are used in ways which allow the maximum utilisation of the resource, avoiding, for example, both interference and unnecessarily large gaps ('guard bands') between adjoining users. High-level policy objectives relate to consistency in government policy on matters such as access, competition, non-discrimination, and equity and fairness in the manner spectrum is allocated and assigned to various users.

RELATED INFORMATION

[New Technologies and Impacts on Regulation Module: Section 2.7.1 Objectives for Spectrum Management](#)

1.3.1 High-Level Economic Efficiency Objectives

The goal of economic activity is to provide goods and services to end users – whether they are bought in the market place or provided to citizens by governments. In defining high-level objectives for spectrum policy, it is thus sensible to take as a starting point the maximisation of value of outputs produced by the spectrum available, including the valuation of public outputs provided by the government or other public authorities.

Some important conclusions follow from this objective. Suppose a given quantity of spectrum is available for use in only two sectors, mobile communications and commercial broadcasting. How should it be divided between the two uses? Because end-users derive benefit from both services, allocating the entire spectrum exclusively to one or the other use may create an artificial shortage of spectrum. Some kind of compromise is required which reflects the value end-users place on both services, the cost of providing them and the amount of spectrum they require. In turn, relating use to value pressures all users, private and public, to make more efficient use of their allocated spectrum,

thereby freeing up more spectrum for use generally. This is set out more formally in the accompanying practice note: Allocating Spectrum Efficiently.

Unfortunately, the problem of finding the most efficient allocation of spectrum is made harder by the complex interrelations among frequencies and their different uses. It requires the spectrum manager to have knowledge, or access to knowledge, about the relationship between providing an additional MHz of spectrum to a service and the net economic benefit of doing so. There are additional considerations to be taken into account including the following:

- In practice, many frequencies (subject to international agreement) can be used for more than two specific uses; hence using traditional approaches the spectrum manager will be making three or four - way splits, not just dividing particular frequencies between two uses;
- Uniform allocations of spectrum on a global basis benefits users since manufacturers of radiocommunications equipment are able to realize economies of scale sooner;
- Conversely, most services can be provided using a variety of frequencies, even if some are more accessible than others. This introduces more flexibility in spectrum management, but varying margins of substitution complicate the problem;
- It is often possible to replace spectrum in the provision of a service by other inputs – e.g. replacing spectrum base stations in a mobile telephony network. The technologies which use spectrum to provide services, the nature of these services, and their costs, are in many ways difficult to accurately predict.

This might be taken as implying that a spectrum manager must be omniscient to maximise the economic benefits (public and private) of spectrum use. Yet this is not necessarily so, for two contrasting reasons:

On one hand, means are available to harness the knowledge and opinions of all spectrum users (as well as those of the spectrum manager), and find a reasonably good solution to the problem. This involves the use of market pricing and information mechanisms to refer allocation issues to those with the best knowledge of the potential of spectrum to meet consumers' needs for service. These means are discussed in [Section 1.6](#).

On the other hand, if the manager chooses to rely on administrative methods to allocate spectrum, the considerations set out above offer useful pointers:

In allocating spectrum, priority should initially be given to services which are highly valued by end-users, with end-users expressing the value to them directly by making individual purchasing decisions. In some cases, the government might express that value on citizens' behalf by providing the service publicly;

- However, this does *not* mean that certain services should be deprived of spectrum altogether. The aim is to equalise the benefit of an *additional* MHz in each competing use;
- As demand for services changes, it may be desirable (for example) to switch some services to higher frequencies and reform the spectrum for better-suited new services; and
- Adopting these principles can improve spectrum allocation considerably. Even if imperfectly done on the basis of incomplete information, the benefit can be considerable.
- A final implication follows from the approach of maximising economic benefits from an inexhaustible resource. Where spectrum is available, it should be put to use in the most productive way possible. Deliberately withholding spectrum in order to raise its price, or licensing a single monopolist to provide a service where that monopolist will withhold services to end-users in order to raise their price, deprives those end-users of the benefits which they would otherwise receive. The harm they will suffer will always exceed the extra revenue the government can derive from spectrum allocation or the extra profit the monopolist will make.

There is thus a strong case that spectrum should be made available to those firms prepared to use it efficiently.

1.3.2 High-Level Technical Efficiency Objectives

At first glance, technical efficiency in spectrum use appears to be a self-explanatory benefit. Indeed, technical efficiency of frequencies suitable for a given purpose – whether it is the spectrum regulator's choice, or by firms - may rationally count as a leading factor in spectrum allocation decisions. Applying the matter in practice can, however, bring competing policy goals into play.

At the basic level, technical efficiency implies the fullest possible use of spectrum. For example, time is a component of several measures of technical efficiency, both in the sense of how constant or heavy usage is over a given period of time, and the speed in terms of bits per second that information is transmitted for a given spectrum capacity.

In practice, however, both of these measures have problems. Some uses are crucial, yet only occasional. In the absence of procedures for sharing spectrum with other users, which are very costly to implement, spectrum capacity, which is often left unused, may be essential for such uses.

Equally, the capacity measure fails to take account of the value of the information (signal or data) carried. A meaningless jumble might be sent very efficiently, but it would still be a meaningless jumble. This suggests that such measures make little sense, as they abstract from

the key element of economic calculation described in [Section 1.2.1.](#) above concerning the value of the service which the spectrum is being used to produce.

It is clear that digital TV transmission is technically more efficient than analogue signaling leading to the Digital Dividend.. Based on studies done by ITU-D covering the 2006-2010 timeframe, digital compression systems for digital television allow the transmission of several (up to six, depending on the coding and modulation techniques) standard digital television channels of acceptable quality in the radio-frequency spectrum previously used by a single analogue channel. Simply put, more content can be carried for a given amount of spectrum, and this trend is expected to continue. New technologies will continue to increase the capacity of the current DTT multiplexes (more than 20 per cent is probable) and will allow more services to be provided without using additional spectrum that is in high demand for other uses. It will be difficult to measure the value of spectrum due to increases in technical efficiency alone without comparing spectrum use to the demand for services and alternate uses.

Resolving these issues clearly depends on a number of considerations including the value of scarce spectrum – expressed as the potential demand for alternative service provided with the spectrum, which would be released along with considerations, such as social, political or industrial development, international agreements, etc.

Digital efficiency is very important, but is not the sole goal in itself. Because spectrum is increasingly scarce, there is every reason to strive for technical efficiency in most circumstances. And of course, where spectrum is truly scarce (e.g. below 1 GHz), there are clear benefits from increasing utilisation, while also planning for future use of spectrum using all technical means to achieve this end in the interest of maximizing economic effects and welfare.

Practice Note: Digital Dividend European Broadcast Union

During the Digital Dividend debate in the EU, the European Broadcast Union strongly argued (with some success) at the political level for preserving digital dividend spectrum for digital terrestrial broadcast using non-technical arguments. The European Broadcast Union promoted the idea that preservation of TV channel provisioning was needed to support DTT becoming a viable competing platform:

The terrestrial broadcasting platform represents a unique combination of elements such as technical excellence and efficiency, favourable coverage and service characteristics, flexibility, market success and wide support across the industry as well as by the public in most European countries. It serves equally well public service broadcasters and commercial broadcasters as well as many other players in the value chain. As a result the terrestrial broadcasting platform generates significant social and economic benefits. It would be very difficult to replicate such a powerful mixture on another platform (European Broadcast Union, 2009).

1.3.3 High-Level Policy Objectives

Governments design, implement and measure the effectiveness of policies to encourage economic, technical, and social development. This includes initiatives to promote competition and create preferences to rebalance opportunities for certain disadvantaged groups in society, and, in the case of radio spectrum, ensuring that sufficient amounts of spectrum are available and accessible for current and future needs, while meeting public safety and security requirements: including national defence, fire and security.

Policy design involves multiple dimensions and distinctions: current vs. future; absolute vs. relative, directional vs. influential; and public and private. As there are numerous trade-offs a central goal is achieving policy effectiveness. A central economic concept borrowed to guide the design of effective policy is Pareto Optimality, which is simply stated as follows:

- A change in policy should not provide an advantage to one individual or set of individuals and put others at a disadvantage.

Measuring and analyzing the impact of policy on individuals and the public is crucially important in determining effectiveness and yet it is both a complex and difficult process. Ofcom, the UK Regulator, in conducting its Digital Dividend Review developed the Total Value Framework to help resolve the analysis and measurement problems. See Figure 1.0 Total Value Framework for the complete model.

Setting policies does not occur in a vacuum either. Efforts to improve competition and ensure access to spectrum will be frustrated by reality, as in the case of competing interests between various stakeholders, such as existing users and new entrants (for more on market entry and new entrants see related sub-sections in [Module 2, Competition and Price Regulation](#)). Measuring the achievement of policy objectives

Picture 1 to add

General guidance on the framework for developing effective spectrum policy, its features and attributes and the steps needed has evolved to include the following:

- Integration with other dimensions of government goals, objectives and institutions;
- Founded on a realistic assessment of actual circumstances;
- Priorities are set (what comes first, what is most important);

- Establishes strategies and aims to meet clear objectives;
- Integration of policy, planning and implementation;
- Includes the full range of stakeholders (and expertise) in the development of policy;
- Measures and performance are based on outcomes not inputs.

Figure 2.0 depicts the policy formulation process in terms of a hierarchy beginning with guiding principles, policies and strategies.

through specific spectrum management initiatives can be less precise than setting prices using market mechanisms or in establishing technical efficient parameters. It follows, then, that some adjustment may be required overtime.

Digital Switchover is a good example where the economic and technical efficiency goals are balanced by government's concern for social cohesion. Market mechanisms do not necessarily or easily take public policy priorities into account, and so in the case of broadcast, governments often intervene in allocation decisions to ensure that public-value broadcast content is available.

Picture 2 to add

Furthermore, effective policy statements are characterized by the following features and should be considered:

1. Clear statement of goals and objectives;
2. Description of strategies and implementation steps;
3. Accountability framework;
4. Tangible outcomes and measureable targets;
5. Timeframe and milestones for achieving goals and outcomes.

1.4 Stakeholders

Spectrum management has an impact on almost everyone in society, since almost all of us consume or benefit from spectrum-using services. These services include marketed ones such as broadcasting or mobile communications, and non-marketed ones, such as national defence. Other firms and public bodies are more directly involved as direct users of spectrum.

These latter groups have knowledge and expertise about spectrum-using technologies and their potential. Services provided by private companies depend on people investing the capital necessary. For this reason alone, their views deserve consideration. However, the interests of service providers and end-users do not always coincide and regulators will continue to be involved in arbitrating between occasionally competing interests.

The overall universe of stakeholders includes:

- **End-users.** The interests of end-users, as purchasers of services and beneficiaries of public services, are pervasive. However, it may be hard to get them to participate in consultations. For one thing, most end-users have a small stake in spectrum-using services as consumers only, so their willingness to marshal their resources and make their interest heard may be small. Contrast this with the incentive for a firm such as a mobile operator which derives its livelihood from spectrum and thus from spectrum management. This is feature common to all regulation: concentrated sectional interests can outweigh dispersed consumers and the public interest.
- **Equipment manufacturers.** Traditional spectrum management has involved the assignment of spectrum to individual firms to provide services based on a specified technology and using specified apparatus. This clearly gives equipment manufacturers an incentive to promote proprietary technologies. For example, proponents of various versions of Wi-Max or mobile communications standard might provide information supporting the view that their equipment should be specified for a given spectrum allocation. Such information is valuable to regulators if they are adopting administrative methods of spectrum allocation and assignment, but they should recognize that it is not provided in a disinterested way. In a more flexible regime, where the spectrum regulator does not specify the technology to be employed, this issue does not arise.
- **Providers of commercial services.** Commercial licensees will quite properly pursue their own profits. This will involve seeking access to spectrum for their own use and preventing commercial rivals from gaining access to it and are thus likely to oppose awards to competitors. Also, when spectrum licences are auctioned licensees will argue to have limits placed on later awards of spectrum. They are thus likely to oppose awards to competitors. Also, when spectrum licences are auctioned, they will encourage the regulator to place a limit on later awards of spectrum. This may increase expected profits from the licences, and hence – to some degree – expected auction proceeds, but the cost falls on consumers, if in the later periods will have less access to competitive suppliers in the

market place for services.

- **Providers of public services.** Much spectrum – about a third or more in many countries – is assigned to providers of public services such as emergency services or national defence. Regulators typically grant requests for spectrum from such bodies free of charge, or subject to an administrative charge only. This creates an incentive for public bodies to ask for spectrum which they may not strictly need, or may not need at the time of asking. Such requests can be justified as a precautionary measure – to accumulate spectrum for future use, or retain it in case it is needed later, but this arrangement does not encourage spectrum efficiency in either the economic or the technical sense (see [Section 1.3.2](#)). Audits or special incentives may be necessary to encourage efficiency in the use of public spectrum or better still, since public users pay market prices for other inputs should public spectrum use not be subject to the same spectrum usage fees as equivalent private user.

It is thus clear that a spectrum regulator will have multiple interactions with parties seeking to influence its decisions. The regulator's goal should be to engage with the stakeholders, understand what they want from the spectrum management regime, and gain as much accurate knowledge from them as they can, but maintain independence in making final decisions in the public interest.

There are numerous examples of industry fora where the needs of providers of public services put forward arguments for additional spectrum resources and in some cases explore both existing and predicted technical issues and problems such as interference to existing services resulting from changes to frequency allocations.

1.5 Fundamental Management Approach

Historically, regulators have assigned frequencies by issuing licences to specific users for specific purposes – an administrative approach. The administrative approach can also be more or less prescriptive on the details of spectrum use. Often it has involved specifying what equipment a licensee can use and where, and at what power levels it can be used.

This is a good way to control interference yet such methods are often slow and unresponsive to new technological opportunities. They also assume a level of knowledge and foresight on the part of the spectrum regulator which it may not possess. Attention has recently been focused on creating genuine markets for spectrum and spectrum licences under which both the ownership and use of spectrum can change in the course of a licensee's operation. This is a major step beyond the auctioning of licences which are not subject to trading and change of use. It does, however, require the full specification of what 'property rights' to spectrum can be traded and utilized.

Some spectrum, especially for short-range use (Bluetooth, Radio Frequency Identification Device (RFID), microwave ovens, various remote control devices, wireless security systems, etc.) need not be licensed at all. This might be the case where users do not interfere with one another, or because new technologies can be employed which are capable of dealing with interference as it happens. If such coexistence can be achieved, the spectrum commons approach is desirable.

Regulators should look for the right balance among the three methods of administrative assignment, use of markets and commons. The choice will be based on such things as the general scarcity of spectrum in various parts of the country and in various portions of the spectrum, the human and financial resources available to the regulator; the various types of use – commercial or public service; and opportunities for innovation and commerce. The growing recognition that spectrum regulators may not be able to collect and process the information needed to make efficient administrative assignments is one of the factors promoting spectrum reform throughout the world.

As an illustration of the changing balance among methods of spectrum management the United Kingdom spectrum regulator, Ofcom, has decided upon a radical shift from administrative methods to a market-based approach, and a smaller expansion of the commons, over the period up to 2010, as shown in Table 3 below. An example of spectrum trading in Guatemala is given in the practice note below.

Table 3 Ofcom Market Based Allocations

Spectrum management method	% of Spectrum allocated in:	
	Year 2000	Year 2010
Administrative	96%	22%
Market	0%	71%
Commons	4%	7%

Note: Table 3.0 is based on a particular method of weighting spectrum in different frequencies, described in the source document.

The three methods are reviewed, and some general observations made on the balance among them, in the following sections.

1.5.4 Regulating Cellular and Mobile Broadband Services

The centre of gravity of the telecommunications sector in emerging countries is profoundly becoming wireless instead of fixed. This is

shown vividly in Table 1.5.4 which follows the number of mobile lines to the number of fixed lines, countries like India are 14 to 1; in Jordan it is 12 to 1; and in Vietnam the ratio is 6 to 1. Whereas, in developed countries such as the UK and USA the ratio is 2 to 1.

Country	Population (2)	# of Households (000) (3)	GDP/Capita/PPP/USD (2)	Mobiles per 100 Inhabitants (1)	Wirelines per 100 Inhabitants (1)
India	1,189 M	222,000	3,400	43.83	3.09
Indonesia	245.6 M	65,000	4,300	69.25	14.77
Jordan	6.5 M	1,193	5,300	95.22	7.94
Malaysia	28.7 M	6,270	14,700	109.74	15.70
Thailand	66.7 M	18,660*	8,700	97.33	10.63
Viet Nam	90.5 M	22,628	3,100	111.53	19.79

Sources: (1) ITU ICTeye 2009 and (2) CIA Fact Book, 2011. (3) Census data for each country originating with national offices for statistics. * Estimate extrapolated to 2009. Available statistic based on 2000 Census. Compiled by McLean Foster & Co.

In these six emerging countries, the fixed network is for all intents and purposes a monopoly, whereas mobile networks are more numerous, ranging from two/three in number in some countries to a dozen in some regions ('circles') in India. The main reason for this is that mobile networks are much less capital intensive, at least in the radio access network. A mobile network is more scalable, in the sense that when demand is low, service can be provided with a relatively inexpensive 'coverage network,' the cost of which depends upon the frequencies which have been assigned. A mobile network can then be furnished with more base stations in a given area when traffic volumes increase. For this reasons, and for others competition in the wireless arena is not subject to the same structural barriers of entry that afflict fixed networks. Moreover, by certain measures of competition the mobile sector is highly concentrated which might create barriers to competition and lead to low levels of penetration. This has proven not to be the case. In this respect, emerging countries show a combination of high concentration and of high take-up or penetration.

The implications of these observations for regulators and spectrum managers are significant. For emerging economies, as well as developed economies, the availability of spectrum is key to telecommunications development over the next decade. In almost every part of the world, wireless data traffic can be expected to increase, even double by some estimates, year over year for the next five years.^[1] Developing broadband will crucially depend upon spectrum availability. Abundant spectrum is essential in promoting competition and innovation in telecommunications markets. The opposite case, in which spectrum availability is inadequate will lead to higher prices, limit market entry for competitors, and constrain innovation.

Most successful efforts to improve availability begin with knowing how spectrum is being used and by whom. Spectrum audits and spectrum demand and supply studies which cover all spectrum users, especially government users, lead to steps which can result in new allocations and adjustments between users. See Section 2.4.3 Planning for Future Use.

It will likely be necessary to look at policies/principles connected with allocation and assignment procedures to ensure that both technical and economic efficiency are considered and properly balanced.

[1] Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2010–2015, available at http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.html

1.5.1 The Administrative Method

The administrative method (or traditional method) is the overwhelmingly dominant form of spectrum management at the present time and has been over the past one hundred years, since spectrum first began to be licensed. It is practised by all spectrum management authorities.

In the administrative spectrum management method, a spectrum manager specifies detailed rules and constraints affecting how, where and when spectrum can be used and who has access to spectrum. Minimizing harmful interference lies at the heart of the traditional model which places an emphasis on the technical management of radio spectrum. As a consequence, different services are sometimes allocated to different frequency bands, although in most frequency bands, more than one radio service is allocated, and sharing between services takes place under specified technical criteria.

In the administrative method there are two stages involved in authorizing spectrum use:

- The allocation stage; and
- The assignment stage.

At the allocation stage, as described in [Section 7: International Affairs](#), broad decisions on spectrum use are made on global and regional ITU radiocommunication conferences. National spectrum regulators prepare their own allocation tables on this basis, which usually impose further restrictions on spectrum use. The decisions are formalised in a National Frequency Allocation Table.

At the allocation stage, a key feature of the administrative method is that any restrictions on allowable uses of spectrum are made by the spectrum manager. Potential users of spectrum can make proposals for allocations - for example for new communication technologies, but without the allocation being made, matters cannot progress further.

Once an allocation has been determined, spectrum use is authorized at the assignment stage with the issuance of a license(s) which is assigned to particular user(s). Historically, assignments were made by methods such as first-come, first-served basis or by way of comparative evaluation (also known as 'beauty contests') sometimes involving public hearings and/or consultation rather than by market-based methods.

1.5.2 Market Methods

Market methods are being employed both at the initial issuance of a spectrum licence, when auctions are used (for a detailed discussion of Auctions see [Section 5.5](#)), 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. Trading only involves the change of ownership of licences, whereas liberalisation involves giving greater flexibility in how spectrum is used to the user. We use term 'trading' to cover both change of ownership and flexibility.

Spectrum Trading

Spectrum trading is introduced here in this section and for a more detailed discussion of Market-based Sharing see [Section 4.2.4](#) of this module.

Spectrum trading is a mechanism whereby rights and any associated obligations to use spectrum can be transferred from one party to another by way of a market-based exchange for a certain price. In contrast to [spectrum re-assignment](#), in a spectrum trade, the right to use the spectrum is transferred voluntarily by the present user, and a sum is paid by the new user of the spectrum which is retained, either in full or in part, by the present (transferring) user. For example, in February 2010, Optus Mobile, an Australian mobile network operator, announced that it had entered into an agreement to purchase 3G spectrum licences from 3G Investments, a subsidiary of Qualcomm.^[1] The spectrum licences are for 10MHz of paired spectrum in the 2100MHz band in eight regional capital cities in Australia.

Spectrum trading contributes to a more efficient use of frequencies 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 the acquired spectrum. These efficiency gains will not be realized, however, if transaction costs are too high and one of the aims of any spectrum trading regime should be to keep down transaction costs. After all, the goal is to facilitate transfers by establishing a swift and inexpensive mechanism. If neither the buyer nor the seller behave irrationally or misjudge the transaction, and if the trade does not cause external effects (e.g., anti-competitive behaviour or intolerable interference), then it can be assumed that spectrum trading contributes to greater economic efficiency and boosts transparency by revealing the true opportunity cost of the spectrum.

Furthermore, trading has other relevant indirect effects:

- it enables licensees to expand more quickly than would otherwise be the case;
- it makes it easier for prospective new market entrants to acquire spectrum;
- if spectrum trading were combined with an extensive liberalization of spectrum usage rights, there would be a considerable incentive 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, would boost market competition.

Forms of Spectrum Trading

The European Commission identifies the following methods for transferring rights of use:

- Sale – Ownership of the usage right is transferred to another party;
- Buy-back – A usage right is sold to another party with an agreement that the seller will buy back the usage right at a fixed point in the future;
- Leasing – The right to exploit the usage right is transferred to another party for a defined period of time but ownership, including the obligations this imposes, remains with the original rights holder.
- Mortgage – The usage right is used as collateral for a loan, analogous to taking out a mortgage on an apartment or house.

In terms of the trade itself, there are a variety of mechanisms that can be used. These include:

- Bilateral negotiation: The seller and (prospective) buyer directly negotiate the terms of the sale and are not subject to any particular constraints set by the regulator;
- Auctions: Once a type of auction has been chosen and the rules have been decided by primarily the seller, prospective buyers have the opportunity to acquire the spectrum usage rights by bidding in the auction;
- Brokerage: Buyers and sellers employ a broker to negotiate, with their consent, the contractual terms under which the transfer of usage rights can take place;
- Exchange: This refers to the establishment of a commercial trading platform, similar to a stock market, where transfers take place according to specific rules established by the members.

These mechanisms are most likely to be used in combination. In the first instance an auction will be used as the primary means of assignment, tradable spectrum is listed on an exchange and either direct negotiation or brokerage facilitate the transfer of spectrum user rights. As we have discussed earlier band managers may be delegated responsibility for managing certain bands on behalf of the regulator.

Endnotes

[1] At the time of writing (February 2010), this transaction remains subject to approval from the Foreign Investment Review Board and the Australian Competition and Consumer Commission.

1.5.3 Unlicensed Spectrum

License-exempt or unlicensed spectrum is free from centralized control in which anyone can transmit without a license while complying with rules that are designed to limit/avoid interference. The spectrum commons involves unlicensed spectrum although 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.

A detailed history of the development of unlicensed spectrum in the United States is provided in an FCC paper by Carter, Cahouji and McNeil (summarized below and also see the paper by Ken Carter). Broadly, the same history is true in other countries. In the 1920s, essentially all spectrum was unlicensed. The confusion and interference this caused, especially among broadcast stations, led to a licensed approach being adopted in the 1930s, although some spectrum was still set aside for unlicensed use.

Over time, the main unlicensed bands were those designated as industrial, scientific and medical (ISM). These were bands where there was non-communications use of spectrum, for example, for heating purposes, etc. Because this use generated interference, the ISM bands were generally not licensed. Hence, they were often made available for unlicensed usage. ISM bands under ITU Radio Regulation 5.150 pertaining to Region 2 include the following bands: 902-928 MHz (centre frequency 915 MHz), 2400-2500 MHz (centre frequency 2450 MHz), 5725-5875 MHz (centre frequency 5800 MHz), and 24-24.25 GHz (centre frequency 24.125 GHz).

In the past ten or so years interest in greater use of unlicensed spectrum has grown sharply. This is the result of the following developments;

- Deployments of new technologies in the 2.4GHz band, particularly W-LANs have been commercially successful, leading many to ask whether further unlicensed allocations would result in more innovation and deployments.
- The development of ultra wide band (UWB) and the promise of software defined radio (SDR) have led some to question whether these technologies can overcome historical problems with unlicensed spectrum.
- Continuing development of low power devices and new applications.

Low power device frequencies refer to a whole range of frequencies from 160 KHz. to 10.55 GHz. which are used for a variety of radio communication and non-communication purposes. The ISM bands include low power devices, and some of these are listed below:

- 902-902.1 / 927.9 – 928 MHz. (rural radiophones);
- 902-928, 2400-2483.5 and 5725-5875 MHz. Note: specific technical standards around field strength and harmonics apply (> 50 millivolts/m);
- 902-928, 2435-2465 and 5785-5815 MHz. (Field Strength Disturbance Sensors);
- 5150-5350 and 5725-5825 MHz. (local area network devices).

Other commonly used bands for low power devices include:

- 174-217 and 608-614 MHz. (medical telemetry);
- 2900-3260, 3267-3332, 3339-3345, 3358-3600 MHz. (vehicle identification).

Used of unlicensed devices is expected to rise dramatically in the next 5 years and is illustrated in Chart 1. Around 1 percent of the total

value from the radio spectrum comes from the use of unlicensed bands. This claim can be traced to a study undertaken by Europe Economics for Ofcom in 2006.

Chart 1 Global Sales of Unlicensed Devices

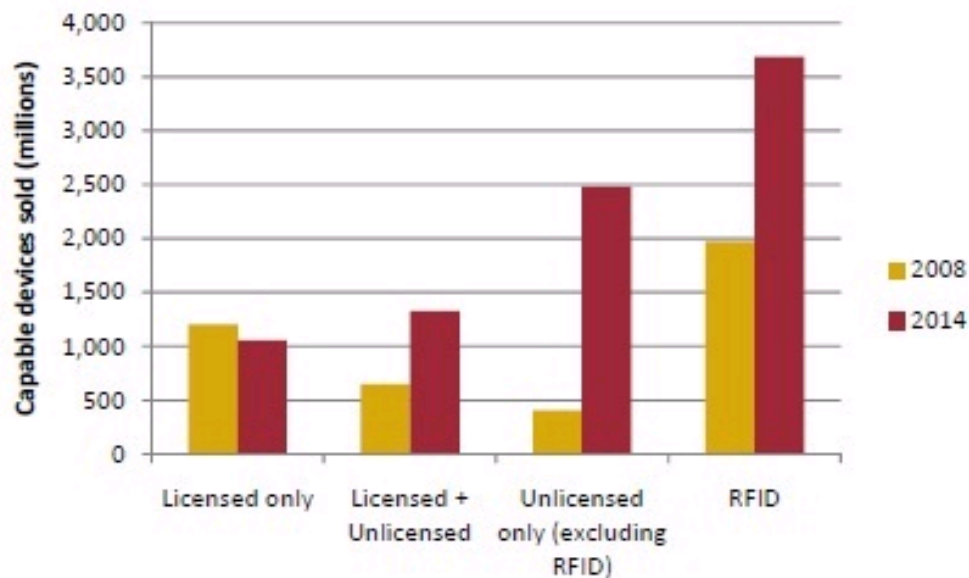


Photo: Perspective Associated 2009

In the USA the estimated yearly benefits derived by consumers and producers, in the form of consumer and producer surplus, for use of spectrum in a number of industry sectors was estimated at \$277 Billion per year. The uses for spectrum reflect a range of public and private uses of spectrum:

- Public mobile – including cellular mobile, paging, public mobile data networks, and public access mobile radio;
- Broadcasting – including analogue and digital TV, and analogue and digital radio;
- Satellite links – meaning the operation of satellite links, such as VSATs and permanent earth stations;
- Fixed links – meaning the operation of radio fixed links, for example to substitute for or supplement cable links in telecommunications infrastructure;
- Wireless broadband – meaning the provision of Wi-Fi and other wireless access services;
- Private mobile radio – meaning mobile radio communications services provided for non-public use, such as by emergency services, taxi companies and transport companies,

The study results for the USA for an estimate of the value of unlicensed spectrum use for three main applications appear below in Table 1.

Table 1 Economic Values Generated by Unlicensed Applications in the US

Scenarios (2009-2025) \$Billion per Year	Low	Medium	High
Home Wi-Fi	4.3	8.4	12.6
Hospital Wi-Fi	9.6	12.9	16.1
Clothing RFID	2.0	4.1	8.1
Total	15.9	25.4	36.8
As a % of Total Estimated Value from the Use of Spectrum	5.7%	9.2%	13.3%

Source: The Economic Value Generated by Unlicensed Usage of Spectrum, Perspective Associates 2009 and McLean Foster & Co.

Table 2 shows the currently unlicensed bands in the United Kingdom.

Table 2: UK Unlicensed Bands

Generic Frequency Band	Application

9 kHz to 30 MHz	Short Range Inductive Applications
27 MHz	Telemetry, Telecommand and Model Control
40 MHz	Telemetry, Telecommand and Model Control
49 MHz	General Purpose Low Power Devices
173 MHz	Alarms, Telemetry, Telecommand and Medical Applications
405 MHz	Ultra Low Power Medical Implants Devices
418 MHz	General Purpose Telemetry and Telecommand Applications
458 MHz	Alarms, Telemetry, Telecommand and Medical Applications
864 MHz	Cordless Audio Applications
868 MHz	Alarms, Telemetry and Telecommand Applications
2400 MHz	General Purpose Short Range Applications, including CCTV and RFID. Also used for WLANs including Bluetooth Applications
5.8 GHz	HyperLANs, General Purpose Short Range Applications, including Road Traffic and Transport Telematics
10.5 GHz	Movement Detection
24 GHz	Movement Detection
63 GHz	2 nd Phase Road Traffic and Transport Telematics
76 GHz	Vehicle Radar Systems

1.5.5 Striking a balance

Spectrum regulators have to exert judgement over how to combine the three methods described here. It may be sensible to start with defining the area for the commons by focussing upon the expected scope for relatively low-power, non-conflicting uses likely to emerge.

The major decision is where to settle between administrative and market methods in spectrum licensing.

- Arguments in favour of the former are:

- it gives a high level of control
- it is 'safer' in terms of avoiding interference.
- it makes re-allocation of spectrum among radio services easier

- Arguments in favour of the latter include:

- it is more flexible;
- it delegates decisions to those with the best knowledge;
- it can work speedily to make adjustments in spectrum use within defined criteria.

1.6 Governance and Outsourcing

High-level spectrum objectives have been discussed in [Section 1.3](#). Here we discuss how best to position the regulator to achieve those objectives, and how outsourcing and delegation can assist.

The fundamental issue here is how to divide up spectrum management responsibilities amongst the government, an independent spectrum regulator, and private sector organisations to which some of these tasks can be subcontracted by outsourcing, and the licensees themselves, which can be asked to undertake some 'self-regulation', possibly on a co-operative basis.

This raises broad questions over what type of body should exercise power over spectrum management decisions, as well as narrower ones about how particular functions can most efficiently be performed.

The broader question over how power to regulate spectrum should be exercised depends upon a country's constitutional circumstance, its political and legal systems and possibly its stage of development and the nature of the demand for spectrum- in particular whether spectrum is a scarce and highly valuable resource, or whether it be made available to at least the bulk of demands placed upon it.

It is clear that strategic decisions about the regulation of spectrum should not be undertaken by operators themselves, which would naturally pursue their own special interests. This same principle is set out in the WTO's Reference Paper on Basic Telecommunications, which, in relation to regulation of telecommunications more generally requires that;

"The regulatory body is separate from, and not accountable to, any supplier of telecommunications services. The decisions of and the procedures used by regulator shall be impartial with respect to all market participants."

The regulator's independence from government is a separate matter. There are arguments that a democratically accountable government is entitled to exercise key responsibilities over the development of a major sector of the economy, such as wireless communications, and there are concerns that there is a risk that such decisions will become politicised and that this will introduce uncertainty about regulation on the part of investors, which might in consequence fail to put up the necessary capital to build the networks.

The issue of the location of regulatory power is discussed in [1.6.1](#); alternative approaches to spectrum management such as New Zealand's Management Rights system and Band Managers are discussed in [1.6.2](#), and the more technical issues of outsourcing and the example of spectrum trading systems are discussed in [1.6.3](#) and [1.6.4](#).

1.6.1 Institutional arrangements

A spectrum regulator is buffeted by representatives of private sector stakeholders, some of whose interests are not fully aligned with the public interest. It has to retain the capacity for independent decision-making. This clearly requires the necessary authority and access information necessary to make that authority effective.

Secondly, it is something desirable to make the spectrum regulator independent of government in its day-to-day operations. This has the effect of making spectrum regulation free from political interference. As a result, operators may be more willing to invest in spectrum-using activities if they are to some degree protected from political pressure.

In practice, the institutional arrangements for spectrum regulators differ throughout the world, but broadly fall into two categories:

- The regulator is an independent agency, normally established by statute, with specified powers and responsibilities, and
- The regulator is part of a government ministry.

In the former case, the regulator regime may combine responsibility for spectrum regulation with regulation of broadcasting and/or regulation of the telecommunication sector (converged regulator). In the United Kingdom, for example, the task of regulating all spectrum was transferred in 2003 from the Department of Trade and Industry (part of Government) to Ofcom. In the United States, the Federal Communications Commission is responsible for regulating broadcasting and telecommunications and for those spectrum frequencies which are *not* used by the federal government. In Canada, spectrum regulation is the responsibility of the Industry Canada, a government ministry, while the telecommunications and broadcasting sectors are independently regulated by the Canadian Radio-television and Telecommunications Commission.

Two remarks can be made about the efficiency in these arrangements:

- First, there is a good case for unified regulation of all spectrum by the same body to ensure a consistent and logical approach to all frequencies. This is shown by the adverse consequence of the bifurcated system in the United States, where there are two spectrum agencies, the FCC and the NTIA. The FCC is responsible for managing private sector spectrum including broadcasting and spectrum used by state governments; the NTIA is part of the Department of Commerce which is responsible for managing the US government's use of spectrum. The involvement of both the FCC and the NTIA in the use and management of spectrum has resulted in major problems of co-ordination.
- Second, combining spectrum regulation with broadcasting and telecommunications regulation creates a better basis for providing analysis of both sets of problems – for example – ensuring that spectrum is available simultaneously to support opportunities for new competitive broadcasting and telecommunication services. There is, however, the risk that the regulator of these two industries (broadcasting and telecommunications) may become captured by these two large groups of spectrum users to the detriment of other users of the spectrum with less contact with the regulator.

It must also be recognised that there are many gradations of independence from government. An independent spectrum regulator might be created, but it might be granted little authority over major allocation and assignment decisions, being instructed instead to focus, for example, on licence enforcement or monitoring. Equally, the staffing of an 'independent' agency might in effect make it an instrument of government.

Whether an independent agency or a government body is better for spectrum regulation is likely to depend on particular circumstances. In some countries, agencies may be more subject to capture by special interests, and regulation by government may be preferable while in

other countries, government may be prove to interfere in regulatory decisions, for political or other reasons and in this may make it desirable to have an agency independent from governments, but operating within government policies guidelines making decisions.

RELATED MATERIALS

[Module 6, section 5.1, "What constitutes an effective regulator?"](#)

1.6.2 Management Rights Systems and Band Managers

New Zealand's Radiocommunications Act 1989 was pioneering and radically changed the landscape of spectrum management. New Zealand was the first country to create a management rights system whereby owners of blocks of "management rights spectrum" are free to issue spectrum licences for the specified part of the spectrum according to their own policies. In New Zealand's case, there are 209 management rights blocks with 70 reserved for the government covering services like broadcast. The other 139 blocks are reserved for essentially commercial services like fixed and mobile services.

Spectrum Licences granted by a manager of a block of management rights spectrum usually have the following characteristics:

- assigned for a defined period of time;
- non-specific to equipment or transmission methods; and
- define an envelope within which the licence holder is free to operate at his or her discretion.

Band Managers

A band manager will typically have assignment rights over, or be the licensee of, a block of spectrum, which it will then subdivide among many users. In many respects, a band manager can be thought of as a 'wholesaler' of spectrum, which it then 'retails' to individual users.

Use of a band manager may simply be a means of reducing transaction costs, if competitive tendering produces a manager which is more efficient in the relevant business process than the regulator itself. Band managers can also permit more efficient use of spectrum by pooling demand. Such policy is effective if:

- individual users have insufficient spectrum to achieve efficient usage, and
- different users of spectrum have demand patterns that peak at different periods.

New technological developments such as 'agile' technologies which allow transmitters and receivers to 'hop' across frequencies increase the potential role of band management.

On the other hand, band managers can become possessive of the spectrum which they have been awarded to manage, and this can thwart spectrum policy objectives, for example, when the spectrum regulator wishes to re-allocate the spectrum managed by the band manager to another purpose.

1.6.3 Outsourcing

Wherever a spectrum regulator is positioned, questions will arise – as with any activity – as to whether the organisation should perform functions in-house, or outsource them to others. In practice, almost all regulators outsource some activities. We are thus talking about choosing a point on a continuum, not making a single choice over whether to outsource. The decision criterion in each case should be efficiency: what arrangement yields the best outcome in terms of cost, quality and the independence of decision-taking?

In ascending order of significance, outsourcing may involve:

- i) Hiring consultants with specialised skills to perform discrete tasks, such as planning a particular band (see Practice Notes for an example of a tender for such a contract);
- ii) Using outside resources for certain support functions such as software development and operation or maintenance of computer systems;
- iii) Using outside resources to cope with short workload peaks;
- iv) Assigning a function, such as monitoring emissions in a particular region or interference investigations, to an outside organisation, which reports the results directly to the regulator;
- v) Assigning a client-facing function, such as enforcement of licence conditions to an outside body;
- vi) Assigning certain administrative responsibilities such as issuance of radio operator certificates to an outside body;
- vii) Assigning responsibility for a range of frequencies to a band manager, which will make assignments to individual users;
- viii) Delegating broader policy responsibilities.

1.6.4 Spectrum Trading Systems

The ability of regulators and licensees to keep track of current licences is an important component of market-based systems and can be 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 database should:

- 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;
- 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. See the following practice note.

2 Spectrum Policy and Planning

CHAPTER 2 TRANSLATIONS

 [Version française \(PDF\)](#)

 [Versión Española \(PDF\)](#)

Spectrum regulators will have to make decisions about the uses of spectrum and on who should be allowed to use it (i.e., uses and users). The international framework for the utilization of the radio frequency spectrum is set out in the ITU's Radio Regulations. There is, however, considerable flexibility for the establishment of national policies following recommendations contained within the framework. The mechanism for determining who may use spectrum within a given country involves some planning. How much planning depends on the extent to which the regulator wishes to rely on the market. The greater the reliance on the market, the less planning will be required.

2.1 Introduction

In this section you find a discussion on the related topics of Spectrum Policy and Planning followed by Technical Standards and Allocating Spectrum:

[2.2 Policy](#)

[2.3 Spectrum Planning](#)

[2.4 Technical Standards](#)

[2.5 Allocating Spectrum](#)

For more information on these topics, please click the appropriate heading in the Table of Contents in the left navigation pane on this page.

Regulators of the spectrum have to make decisions about how it can be used and who should be allowed to use it (i.e., uses and users). While the international framework for the utilization of the radio frequency spectrum is set out in the ITU's Radio Regulations, there is considerable flexibility for the establishment of national policies within this framework.

Determining who may use the spectrum within a given country requires a certain degree of planning, the extent of which depends on how much the regulator wishes to rely on the market. The greater the reliance on the market, the less planning is required.

This difference is revealed if we contrast the emphasis on planning under administrative and market based spectrum management approaches. Four phases of planning are described in the ITU-R Report SM.2015 on Long-Range Planning referenced below. The four planning steps are:

1. Determining spectrum requirements;
2. Determining spectrum availability;
3. Considering spectrum planning options;
4. Spectrum planning implementation.

Under a market based approach and with the caveat that sufficient spectrum has initially been made available for the market to properly function, the regulator can be less active in leading the determination of spectrum requirements and availability since these adjustments will take place between users. Also with the advent of advanced technologies and the use of the spectrum commons, the requirement for band planning could be curtailed. For more a detailed discussion on market mechanisms and spectrum sharing see Section 5: Spectrum Sharing.

2.2 Institutional Framework for Spectrum Management

International, regional and national regulatory frameworks significantly influence spectrum policy formulation, harmonization and implementation.

As reviewed in more detail in Section 7 - International Affairs, the ITU harmonizes the efficient use of the spectrum resource on a global

basis on behalf of governments. Ultimately, the implementation – how and when recommendations and regulations are implemented – rests with national governments. Allocations of radio spectrum are agreed upon at the ITU World Radiocommunication Conferences (WRC) for each ITU Region, and the Radio Regulations are then revised. Agreements on changes to allocations made at WRCs have treaty status, and international harmonization and coordination of spectrum allocation are essential for many public sector services, such as transport.

Practices across regions vary and decisions made about spectrum allocation vary across the three ITU regions. Region 1 has multiple sovereign markets and attempts a unified approach. Region 2 is dominated by the US and often reflects a single market approach whereas there multiple sovereign markets and no real unified approach across Region 3 encompassing Asia-Pacific and Oceania.

In Europe, common positions in relation to WRC agenda items are developed by the European Conference of Postal and Telecommunications Administrations (CEPT); the CEPT includes 48 European member states. The European Union presents a particularly unique situation with broad policy in terms of goals, direction and timelines set on a pan-national basis, while the detailed implementation of policy is left to individual member countries. Much like North and South America, there is no formal process for setting a common agenda in Asia to coordinate and harmonize policy or spectrum use.

One of the hurdles in establishing coordinated policy at the national level is diverse regulatory framework for broadcast and telecommunications:

- in some cases, there is one regulator for both broadcast and telecommunications, and;
- in other cases, the regulation of these services is divided between separate regulators.

At the beginning of 2011, separate regulators had been established in more than 80 per cent of countries, totaling 158 regulators worldwide, up from 106 regulators a decade ago. Africa has the highest percentage of regulators (relative to the total number of countries in each region) with 93 per cent, followed by the Americas and Europe with 91 and 88 per cent, respectively. Moreover, Asia-Pacific has 73 per cent, Arab States have 71 per cent, and the CIS has the lowest with 50 per cent.

Figure 1 Countries with Separate Regulators. 2010

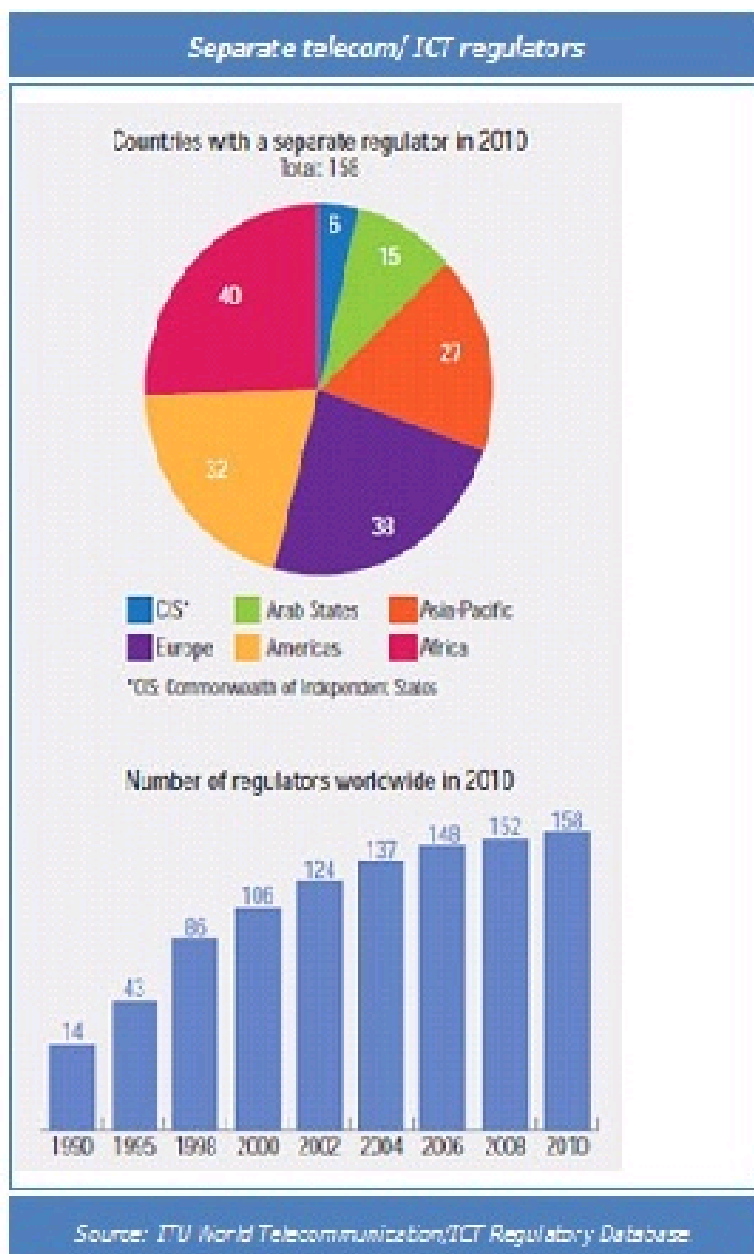
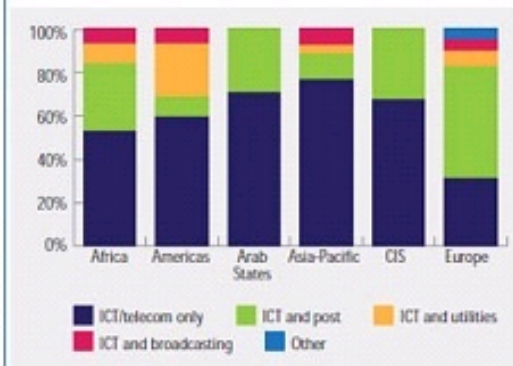


Photo: ITU World Telecommunication/ICT Regulatory Database

Countries with separate regulators have adopted different institutional and organizational frameworks to adapt to the fast-changing ICT environment. While the main trend in most regions has been to establish a sector-specific regulator, some countries have moved towards merging pre-existing separate regulatory authorities into a converged regulator, while others have expanded the mandate of the regulator to include posts, information technology, broadcasting content, or spectrum management. Figure 2.2 illustrates this issue by illustrating that there is no consistent pattern in regulatory mandate and function across the various regions of the globe.

Figure 2 Mandate of the Regulator 2010

Mandate of the regulator in 2010



Source: ITU World Telecommunication/ICT Regulatory Database.

Photo: ITU World Telecommunication/ICT Regulatory Database

Several countries in the Americas, Europe and Africa have established multi-sector agencies, either when sector reforms were initiated or after their markets reached a certain level of maturity. In these cases, countries have merged pre-existing separate regulators of public utilities to oversee, for example, the telecommunications, postal, electricity, gas and railway sectors.

In several jurisdictions regulators are now responsible for regulation beyond their traditional core activities. These traditional functions consist of: regulating access to telecommunication/ICT infrastructure and services through licensing; managing scarce resources such as spectrum and numbering resources; dealing with interconnection issues; setting and enforcing quality of service standards; and managing universal access support programmes.

In 2010, 16 per cent of regulators had responsibility for broadcasting content, sometimes sharing that responsibility with another ministry. While Internet content is unregulated in more than 44 per cent of countries worldwide, it is around 13 per cent of telecommunication/ICT regulators' mandates. Information technology is included in the mandate of 30 per cent of regulators, a responsibility that is shared in 12 per cent of cases.

At the policy and standards level, the same diversity is evident. For example, for television systems different standards apply to various regions around the world where there are three dominant analogue television standards: NTSC, PAL and SECAM. There have been some intensive efforts made to achieve cooperation at the regional and trans-regional level to smooth out the process and simplify the inherent diversity. The Geneva Frequency Plan referred to as GE06 is a prime example of such an initiative.

2.3 Spectrum Policies and Principles

At the national level, there are a number of important policy questions to be reviewed and resolved affecting the regulation of spectrum. These policy questions include the government's own use of spectrum with the underlying concern that government departments can under utilize the spectrum assigned to them. Other policy matters include the extent to which market mechanisms should be used to assign spectrum and used set the price for spectrum; and, what are the permanent or temporary property rights of licensed and unlicensed users. These and other policy questions are raised in the balance of this Section.

The typical important policy questions addressed by regulators can be summarized as follows:

- How much of the spectrum should be used and how is it regulated?
- Which commercial entities can use spectrum and at what cost to them?
- How to provide sufficient spectrum for government use?

2.4 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 both 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, channelling plan techniques, and tools should also be planned and developed.

The various aspects of planning at both the international, regional, national and local level are discussed in this toolkit. Information on planning at the international and regional levels may be found in [Section 7 on International Affairs](#).

2.4.1 Planning Timeframes

Planning is usually undertaken for long-term, medium-term and short-term timeframes. Long range (strategic) planning (10 to 20 years) is required to foresee spectrum requirements far into the future. Such long-term planning must take into account the need to accommodate uses that may not have been predictable at the time of inception. Determining those needs is best done by involving both spectrum managers and stakeholders, as the future needs of a given radio service and the various spectrum management approaches that might be applied are of interest to both of them. Medium-term planning (5 to 10 years) is needed to determine what changes should be made to regional, sub-regional, national and local spectrum policies to meet the changing needs of users and evolving technology that have already been identified. Finally, short-term planning (anything under 5 years) is important where, depending on the nature of spectrum governance in place, changes to spectrum policies can be made to adjust earlier decisions.

2.4.2 Knowledge of Current Spectrum Use

It is critically important to know what the current use of spectrum is before one can plan for the future. This can be ascertained from existing records of frequency use across the entire radio spectrum. This information may be held by various organizations and where national records are incomplete or unreliable, public consultation between regulators, service providers and users can help retrieve a fuller picture. A single national frequency register should be created if one does not already exist. Spectrum analyzers and computer-aided tools can be very helpful in conducting spectrum audits of selected bands to confirm occupancy and operating parameters.

2.4.3 Planning for Future Spectrum Use

Planning and forecasting future spectrum use are critically important if future spectrum needs are to be met. Forecasting spectrum use is, however, a challenge but one that can be overcome by employing various techniques. Projections based on historical growth of, for example, the number of land mobile systems is one method of forecasting growth. Monitoring new technologies and noting their spectrum requirements is another method. It is critically important to consult with spectrum users since they are usually in the best position to forecast growth in their sector. One must temper such forecasts, however, as there may be a tendency to overestimate future needs.

An important planning capability exists at the international and regional level through the ITU World and Regional Radio Conferences which consider the impact of growing demand for various radio services and technological innovation on existing and planned changes in allocations. The objective being to ensure that adequate spectrum is available for future use. For a more detailed discussion of ITU planning activities and recent World and Regional Radio Conferences see [Section 7.2.1 ITU Related Project Activities](#), and Section [7.2.2 Recent ITU World Radio \(WRC\) and Regional Radio Conferences \(RRC\)](#).

The following example from illustrates how consultation and discussion papers dealing with forecasts of future spectrum requirements affecting the reallocation of commercial spectrum rights in New Zealand

Reallocation of Commercial Spectrum Rights – New Zealand

Since 1989, the Government of New Zealand has progressively created and allocated tradable rights to spectrum under the Radiocommunications Act 1989 ("the Act"). Generally speaking spectrum rights have been allocated as:

1. Nationwide "management rights" over frequency bands used for telecommunications services; and,
2. Site and frequency specific "spectrum licences" under Crown-owned management rights in frequency bands used for television and radio broadcasting.

Spectrum rights for commercial use are usually allocated by competitive tender or auction. The Government reserves and allocates spectrum rights to meet specific government objectives contained in non-commercial broadcasting policy and to meet Treaty of Waitangi obligations. All spectrum rights are subject to the fees set out in the Radiocommunications Regulations. Under the Act, spectrum rights have a maximum term of 20 years. The first rights created, for UHF television, expire in 2010. Rights for AM and FM sound broadcasting expire in

2011 and VHF television rights (TV1, TV2, TV3 and C4) in 2015. Expiry dates for mobile telephone services vary, with the first rights expiring in 2011.

The Act provides that rights revert to the Crown at expiry, but is silent as to how they should be allocated or reallocated. An amendment to the Act in 2000 allows the Crown to create a "succeeding" management right ahead of expiry, to ensure a seamless transition from one term to another.

Several reasons are included in the discussion paper for not issuing new spectrum rights.

A case-by-case review is required to ensure consistency with New Zealand's international radio obligations and the general objective of maximizing the value of the spectrum to society as a whole.

The Ministry will consider the current and likely future use of the particular spectrum, based on available market and technical information, and whether reallocation of the rights in the current form will maximize the value of the spectrum.

<http://www.rsm.govt.nz/cms>

2.4.4 Spectrum in Transition

2.4.5 The Radio Regulations

The ITU Radio Regulations incorporate the decisions of the World Radiocommunication Conferences (see [Section 2.3.3 Planning for Future Spectrum Use](#)), including all Appendices, Resolutions, Recommendations and ITU-R Recommendations incorporated by reference.

2.4.6 National Frequency Allocation Table

For an explanation of spectrum allocations, spectrum designations and radio services, see [Section 2.5](#) of this module of the toolkit. Developing a national frequency allocation table is one of the first steps in long and medium-term planning. A national frequency allocation table should be developed within the framework of the ITU's Radio Regulations; Article 5 of those regulations sets out the international frequency allocation table for all three Regions of the world. The national frequency allocation table should be consistent with that country's regional allocations. That being said, the ITU allocation table will often contain more radio services than may be required or desired in a national setting and some aspects of the international regulatory provisions may not apply in the given country. Once a national frequency allocation table is developed, further sub-allocations or designations of use are often made in order to group like technologies or like users in a given frequency band. It is preferable to make sub-allocations or designations to uses rather than to users since users can sometimes view portions of spectrum as their bands. Generally speaking, greater spectrum efficiencies are obtained when uses with similar technical parameters share the same frequency band, for instance lumping high power applications with other high power applications. Further information on allocating spectrum can also be found in [Section 2.5](#) of this module.

2.4.7 National Legislation and Regulations Governing Spectrum Use

The legal basis for the regulation of the spectrum must be set out in legislation and detailed in regulations made pursuant to the legislation. Legislation should set out such things as definitions, powers of the Minister or head of the spectrum regulatory authority, the powers of others involved in spectrum regulation, offences and punishments and the organizational structure and framework for regulation of the spectrum, a discussion of which may be found in the spectrum overview of [Section 1.6 Governance and Outsourcing](#). In addition to the legislation and regulations, there may be other publications issued by the spectrum regulator which provide guidance to a specific group or groups of users of the spectrum.

Something to consider when establishing the legal framework is the use of incorporation by reference. Since legislation or even regulations are usually not frequently amended, often incorporation by reference is used to give legal effect to subservient text or documents. Under incorporation by reference, texts in one document having a certain legal status, such as the legislation or regulations, may cite other documents which normally would not have the same legal status and depending on the nature of such reference, such incorporation may confer the same legal status on these other documents. For example, regulations may state that a certain standard, perhaps developed by an international body, shall apply in a given situation. Such incorporation by reference of texts can be of two types: static incorporation or dynamic incorporation. In the former, a specific document issued at a specific date is referred to in the legal text. In the case of dynamic incorporation by reference, the reference in the legal text is to a specific document but with a phrase like "as amended from time to time" which allows for changes without going through the entire legislation or regulation approval process.

In order to preserve clarity and authority in rule-making, such delegation should be clearly defined. Legislation and/or regulations must make clear who has authority to designate changing sources of external reference when these are not already specified in existing regulation. Such delegation should be set out in a delegation instrument approved by that institution. The development of legislation and regulations and all subservient documentation should be developed in a transparent way with full consultation of spectrum users.

ITU-D has a web site (<http://www.itu.int/ITU-D/ICTEYE/Regulators/Regulators.aspx>) where the legislation of many countries can be found.

2.4.8 Public Use Spectrum

Achieving public policy economic and social development goes beyond the existence of an applicable and compliant national allocation table. Doing so may require a change in the balance between government spectrum and spectrum allocated to commercial and private uses.

In a market economy, inputs such as land, labour and capital equipment are distributed throughout the economy via market processes: the provider of capital or employee moves to whichever activity offers the best rewards. Spectrum is one input among many others (e.g., water and electricity) in a variety of production processes. Market systems when workably competitive promote economic efficiency, as inputs are put to use where they yield the highest returns.

At first glance, it may seem incongruous to require a public sector body such as a fire service or a defence force to compete in a market place for spectrum with commercial providers of services such as mobile broadcasting. However, this is exactly how public sector organizations acquire other inputs – such as employees, vehicles, land, and office space.

The arguments for special arrangements for spectrum for the public sector seem to be that:

- 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 practice, the only way to acquire spectrum was by administrative methods.

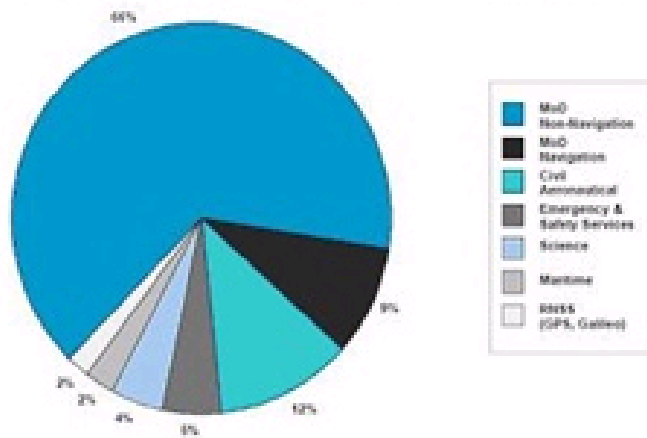
The use of markets to allocate other equally indispensable inputs into vital public services appears to negate the first two, and the third could be resolved by the development of a spectrum market place.

Government use of spectrum utilized to provide services similar to those provided by the private sector should be, at a minimum, subject to prices reflecting the market price or opportunity cost of spectrum. Where market prices don't apply, some negotiation will be necessary between those holding allocations and those desiring them, along with incentives to ensure the opportunity costs of spectrum are reflected in decisions

Several studies of the amount of spectrum held by government agencies have been conducted in recent years. As an example of leading practice, the United Kingdom table of allocations has allocations for Government Use on an exclusive basis for Civil, Military, and Emergency Services. As reported in the Independent Audit of Spectrum Holdings reported in 2005 by Prof. Martin Cave to the UK Government (referred to here as the Cave Audit), government holdings of spectrum approximate 50% of the spectrum below 15GHz. The UK government reviewed and assessed requirements for all government spectrum holdings and made recommendations leading to improving access to and efficiency of use in spectrum

Figure 1 below, illustrates the relative share of spectrum between various government services in the United Kingdom.

Figure 1: Composition of public sector spectrum holdings below 15 GHz



To facilitate the process of shifting spectrum allocated to other non-government uses, the following steps could be taken:

- Issue a clear statement of government policy and direction, identifying and setting balanced targets, within sensible but aggressive timeframes for moving government spectrum allocations to commercial allocations;
- Conduct an independent audit of spectrum holdings to identify bands where immediate changes can take place; and
- Put mechanisms in place to begin transitioning allocations and assignments to new uses (commercial applications and assignments) and users. These will likely include:
 - Incentives – where all users pay for frequency assignments unless usage is unlicensed (spectrum commons and personal consumer products are two examples).
 - Compensation for affected users. There are various means to achieve compensation between parties. The overall process should be encouraged by government but the regulator should not become the payer of last resort between parties negotiating settlements for relinquishing licence rights or equipment under the administrative approach. More flexible licenses and spectrum trading accommodate results for these types of issues.

2.4.9 Re-allocating and Refarming Spectrum

One of the biggest challenges facing spectrum regulators is the reallocation of spectrum. When frequencies have been used for one purpose, perhaps for decades, it is often difficult to reallocate these frequencies for a different use. The need for reallocation – often known as re-farming - can arise in several ways. It may be that the international table of frequency allocations has changed and the national table of frequency allocations must be realigned to be consistent with it. Alternately, a radio service may not have developed as expected, while the spectrum available for another service operating in a nearby frequency band is insufficient to keep up with growing demand. Sometimes, new technologies become available which is more spectrum-efficient, allowing spectrum to be freed up either for the same use in that band or other uses. Whatever the reason, there will be times when spectrum users will have to make changes to their operations. The central issues that arise are then who decides, and who will pay for the costs incurred by these users in transitioning to new frequencies? One solution involves the regulator establishing a re-farming fund by setting aside a portion of spectrum revenues. A Fund for Refarming Spectrum has been established in France and is managed by the *Agence nationale des fréquences*.

Various approaches exist now for re-farming whereby regulators (administrative) address the issues and where users determine the timing and price (market-driven). Some simply require the user to absorb the cost. In other cases, the beneficiaries of the change are either invited or required to reimburse all or part of the transition costs of the incumbent user.

The essential difference between administrative and market-driven approaches is that under the administrative approach the regulator makes the decision while considering several criteria and possible competing objectives such as: logical market-structure, financial, socio-economic, and technical efficiency criteria. The regulator's analyses will include factors such as prices, costs, license conditions, withdrawal, and compensation. Under a market driven approach, the criteria used and analyses centre on financial and business factors with decisions resulting from an agreement between two or more parties.

Re-farming Definition

Generally speaking, refarming may be seen as process constituting any basic change in conditions of frequency usage in a given part of radio spectrum. Such basic changes might be:

1. Change of technical conditions for frequency assignments;

2. Change of application (particular radiocommunication system using the band);
3. Change of allocation to a different radiocommunication service.

2.4.10 Consultation with Stakeholders

Consultation with stakeholders is essential in virtually every aspect of spectrum management including the development of national legislation and regulations, spectrum policies, technical standards, etc. While it is seldom practical to consult with each individual spectrum user, effective consultations can take place by also allowing associations or bodies representing groups of users to contribute. In order to facilitate consultation on important spectrum management issues, it is important that the spectrum regulator's proposals be made public. In some countries, this is in any event required under broader national legislation governing all regulatory activities, perhaps by a requirement for setting out proposals in an official or widely-distributed publication. Sometimes, several options may be presented for public comment. It may also be helpful to allow for exchanges between interested parties. Often, meetings are held between the spectrum regulator and relevant stakeholders and the Internet has increasingly become a standard tool for such consultations. Regardless of the means for obtaining input, minimal guidelines allowing interested parties to contribute gainfully should be set, such as allowing for a given period of time, with a deadline by which comments must be submitted. In all consultations, transparency and fairness are paramount. While it deals with somewhat different subject matter, more information on the consultation process may be found in [Section 6.2 of Module 3 on Authorization of Telecommunication/ICT Services](#).

RELATED INFORMATION

[Authorization Module, Section 6.2.1: The Public Consultation Process](#)

2.4.11 Dispute Resolution

It is quite likely the increased use of spectrum utilizing either market-based or administrative approaches will raise issues which need to be resolved between parties. In the past, this has involved intervention on the part of the regulator which has proven to be difficult in terms of time and cost.

There are two trends at work:

- Rapid changes in the 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 mechanisms for resolving disputes requires resolution procedures which are not only fast and flexible – but also suited for the types of disputes that the global telecommunications industry produces. In turn, the dispute resolution field is increasingly offering new models that may be useful to the telecommunications sector's new needs.

While most regulators decide between the positions of disputing parties, typically after a formal process that involves the presentation of arguments by those parties, there is a trend towards more flexible and consensual methods – alternative dispute resolution (ADR) including: negotiation and arbitration (for more on dispute resolution see the ITU World Bank report on Dispute Resolution) . Most telecommunications licenses include guarantees of access to arbitration. Even so, it is helpful to have developed guidelines for managing ADR processes such as those issued by Ofcom governing ADR between public telecommunications operators and the public that are:

- Independent and impartial;
- Transparent, providing regular communication to the public through out the process;
- Effective with an expectation that the disputes will be resolved within a reasonable timeframe;
- Able to properly investigate disputes and make awards of appropriate compensation.

2.4.12 Financing of Spectrum Management

Funds for financing the cost of regulating the spectrum can come from either general taxation revenues, specific telecommunications charges such as licence fees or other spectrum-related fees or from a combination of these two. It is generally felt that those who benefit from having access to spectrum should pay for the cost of its regulation. Revenues can be obtained in relation to those parts of the spectrum for which access is payable, no such revenue is forthcoming from unlicensed (free) bands. The funding requirement of regulatory activity or change related to these latter cases is probably most efficiently met through general taxation revenue. Such regulatory costs are usually low.

Allowing a spectrum regulator to establish its own charging regime, collecting all spectrum-related revenues, and retaining them to fund

spectrum management activities can be a source of concern to policy-makers. In economic terms, the regulator is effectively a monopoly and has little incentive to contain its costs if it can increase its revenues by raising licence fees and other charges. Safeguards can be put in place to avoid such practices, such as putting limits on the growth of the regulator's expenditures.

In countries where spectrum revenues exceed the cost of spectrum management sometimes by a very large margin, governments view this as a spectrum dividend whereby the government, and hence all members of the public, reap the financial benefits of such royalties. However, attention must be paid to the broader legislation within a country, as spectrum revenues in excess of costs may be viewed as taxation. The power of taxation may be reserved by another government entity and the legislation dealing with spectrum management may or may not be constructed so as to allow revenues to exceed costs.

The cost of spectrum management immediately raises issues of cost accounting. For example, what costs should be included in the total cost of regulating the spectrum. What indirect costs or overheads should be included, etc.? For a more complete discussion of this, see [Section 5.2 Cost Recovery](#), in this module.

2.5 Technical Standards

Regulators, users of radiocommunication services and radio equipment, operators and suppliers rely on technical standards as a basis for preventing interference and in many cases ensuring that radio systems perform as designed. Technical standards involve radio standard specification documents, the approval process, as well as testing and certification of radio equipment such as transmitters, receivers and antennas to determine compliance with radio or manufacturer specifications.

From a planning standpoint, the regulator uses technical standards to determine how certain radio equipment will interfere with other equipment in either shared or adjacent frequency assignments. That determination can then be used to develop spectrum use plans. The mutual interaction of radio and electrical products is known as "electromagnetic compatibility" (EMC). Balanced standards frameworks try to minimize business compliance costs while providing effective protection of the radio spectrum resource.

There are two categories of radio system interaction which concern the regulator.

Electromagnetic Interference (EMI) can be viewed as radiocommunications pollution and is sometimes referred to as "radio frequency interference" (RFI). Reducing the level of EMI produced by electrical and electronic products is particularly important where public safety and security services are involved such as aircraft and ship navigation, fire, ambulance and police communications. Under Article 15 of the International Radio Regulations, regulators are required to "take all practicable and necessary steps" to ensure EMI does not cause harmful interference to radiocommunication services.

Radio transmissions can also cause other non-radio electrical and electronic products to malfunction, a phenomenon sometimes known as "immunity" or "electromagnetic susceptibility" (EMS). EMS can also be a safety of life issue, for example, when the use of cell phones interfere with hospital equipment.

This section begins with a discussion of the desired objectives, types of standards and concludes with certification processes and various options available to regulators.

2.5.1 Objectives of Technical Standards

Technical standards for radiocommunication and radio equipment help to achieve electromagnetic compatibility (EMC) between radio equipment and services such as broadcasting services, navigational aids for aeronautical and marine traffic control, and radiocommunication services including cellular, land mobile, microwave and satellite services. As well, technical standards help by allowing planners and users to minimize interference between radio apparatus and other equipment. The uses of radio frequencies in industrial and commercial applications are important to the economy, so that interference-free use can be an important factor in economic development. Finally, consumers are better served when the quality and reliability of equipment distributed in the country can be improved over time.

Technical standards form the basis for certification and testing of radio equipment. Equipment is said to be certified when it complies with applicable standards of the country. The ITU also has equipment standard regulations for reference by its members. Technical standards and certification processes for specific types of equipment are the same for all manufacturers and importers, ensuring consistent quality for consumers.

Finally, the regulator can require, through technical standards, manufacturers to produce equipment which provides for greater efficiency in spectrum use.

2.5.2 Spectrum Use Standards

The demand for spectrum is increasing and technology has developed so that radios can perform the same function at previously unused frequencies or require less spectrum capacity, or allow more frequency re-use for the same performance. In many countries and regions and especially in developing countries where growth in telecommunication services is primarily wireless, demand for spectrum continues to increase very rapidly. This increase is a result of expanded use of current services like cellular, radio and precision landing systems for improved aviation safety, and the development of new uses, such as Personal Communications Systems (PCS), digital audio broadcasting, advanced television, and satellite sound broadcasting. In the short term, technical advances needed to meet that demand may exceed the limits of practicality and increase the potential for spectrum congestion and interference. Increasing spectrum efficiency below 3 GHz is more and more difficult and affordable technology in higher bands for consumer wireless communications is not readily available. Spectrum use standards are thus important since they are used to minimize interference between users and systems sharing frequency bands. Spectrum use standards allow regulators to minimize interference regardless of the assignment or authorization method used – Service Based Licences, Spectrum Commons or Licence Exempt. Spectrum use standards and radio system plans refer to planning documents issued by the spectrum management authority which state the minimal technical requirements for the efficient use of a specified frequency band or bands. They are used in the design, specification and evaluation of technical applications for new radio facilities or modification to existing radio systems operating within the specified band in accordance with a spectrum use policy. A spectrum use standard typically specifies appropriate equipment characteristics relating to efficient spectrum use and not the design of equipment. Spectrum use standards can be designed to match ITU-R Recommendations developed by the Radiocommunication Sector of the ITU in conjunction with the International Table of Frequency Allocations or be developed to reflect unique channelling arrangements formulated to meet national requirements.

2.5.3 Coping with Congestion in Unlicensed Spectrum – No Standards?

In determining the most appropriate regulatory policy regarding unlicensed spectrum, it is necessary to determine:

- Whether there is spectrum which is currently uncongested or can be expected to remain uncongested and so could become unlicensed;
- Whether there is spectrum which is congested, but only because of inefficient usage and where changing the management policy of unlicensed usage would remove the congestion.

There are many factors that influence congestion. Some of these are caused by suboptimal allocation policies and can be expected to be gradually alleviated by the introduction of trading. Some are caused by allowing the use of equipment that is inefficient in its use of spectrum. Others are caused by the nature of the radio spectrum.

There is little that the regulator can do to affect the relative desirability of these bands. However, there are several things that the regulator can control. One of these, which has a significant effect on congestion, is the maximum transmit power.

For terrestrial uses of spectrum, the shorter the range of transmission, the lower the probability that there will be two users operating at the same frequency and in range of each other that might interfere. For example, the whole idea behind cellular telephony in major population centres is the use of low power cell sites so that the same frequencies can be re-used within a relatively short distance. Similarly in satellite communications, the use of spot beams as opposed to global or regional beams allows the re-use of frequencies. Obviously, while the regulator can control these factors to some extent, the radio system's service requirements and system economics are also important factors.

Therefore, if only short-range devices were allowed to use a particular piece of spectrum, the probability of congestion would be lower than for wider coverage applications. Broadly, this has been the regulatory policy to date, with unlicensed spectrum having a maximum transmit power that tended to limit the range to around 100m.

The other factor influencing congestion is the bandwidth and time of transmissions. These mostly depend on the usage. For example, a garage door opener only needs to transmit a short burst of narrowband data and only on a few occasions each day. A W-LAN base station might transmit broadband data almost continuously. The probability of congestion is proportional to this time-bandwidth product or information rate.

Historically, most short range devices have also had a low information rate, but more recently W-LANs and BlueTooth have changed this trend. If the unlicensed bands were restricted to products with a low information rate then congestion would be lower. However, it is quite difficult for the regulator to restrict the information rate in an unlicensed band.

The technical characteristics of receiving equipment (receivers and antennas) also play an important role in spectrum efficiency. If receiving equipment is allowed that cannot easily discriminate between wanted and unwanted signals, more spectrum will be consumed than is technically necessary. However, while some regulators do insist that receiving equipment meet certain standards, other regulators do not. Some others do not regulate receiving equipment explicitly but do so in a de facto manner i.e., specifying only transmitting characteristics and leaving it to users to decide how much interference they can tolerate.

Hence, the main tool at the disposal of the regulator in controlling the level of congestion and the suitability for unlicensed use, is the maximum transmit power, which equates to the range. By enforcing the lowest feasible maximum transmit power, the probability of interference is reduced. Further, the amount of usage will also likely be reduced as some applications will not be viable with short range transmissions. Regulators might have a number of different bands with different transmit power limits to offer users different levels of

range and congestion. Alternatively, as an unlicensed band becomes more heavily used, the transmit power might be progressively reduced to new entrants in order to keep the congestion at an acceptable level.

In the past, the number of applications and users of radio spectrum has grown faster than the ability of technology to accommodate them. Hence, congestion has increased over time. However, it has been argued that if a “spectrum commons” approach were widely adopted, then this would reduce the overall levels of congestion. This section considers whether this is likely.

Without regulatory intervention, the problem of dealing with congestion would not be resolved. Equipment will only be made efficient or polite to the extent that it is necessary for that piece of equipment to operate reliably and not for the greater good of all the users of the band.

In summary, many observers conclude that spectrum should be unlicensed if it were unlikely to be congested. It has been noted that:

- Congestion was most likely in the core bands of around 100MHz to 5GHz;
- There is insufficient evidence that taking bands currently considered to be congested and making them unlicensed would alleviate congestion, hence this approach cannot currently be advocated;
- The probability of congestion could be dramatically reduced by restricting the range of devices through controlling the maximum transmitted power or by requiring specific behaviour such as politeness protocols.

Still, there is no definitive way to predict congestion. A judgment needs to be made on the basis of the frequency band, likely use and range. The range in turn depends on the use. Hence, a key stage in predicting the congestion likely in the band is determining the most likely use.

This suggests that the regulator should first come to a conclusion as to the most likely use or uses for the band. The regulator does not need to impose these uses. For example, if the band is subsequently auctioned there is no need to restrict its use to that deemed most likely. However, this decision will be used in the process of deciding whether spectrum should be unlicensed.

Having decided on the most likely use, spectrum should be subject to licensing where any of the following hold true:

1. The band is likely to be congested. A way to approximate for this is to assume that congestion would occur if the use would entail a wide area service (i.e. one covering a contiguous area greater than $\sim 1\text{km}^2$) being offered. Examples of such services are cellular and broadcasting;
2. A guaranteed quality of service (QoS) is needed. This is the case, for example, with most public safety communications;
3. International treaty obligations provide restrictions that would be breached by operation on a licence-exempt basis either now or at some known point in the future;
4. Finally, the regulator will need to make a judgement as to the most appropriate level of restriction.

Essentially, the greater the perceived risk of congestion developing, the more restrictions should be imposed. However, the restrictions should also take into account the likely additional cost imposed on the devices compared to the benefit that might accrue.

Depending on the level of information, it might be possible to perform an economic assessment of the value of the different approaches. For example, where imposing politeness protocols will have minimal impact on the device cost then they might be used without hesitation. Where such protocols would significantly increase the cost and where congestion is unlikely, or has little impact, then they should not be imposed.

2.5.4 Radiocommunication Equipment Standards

Radio equipment standards are technical standards specifying the minimal acceptable technical specifications and performance characteristics of radio equipment in general use. Radio equipment standards exist for both licensed radiocommunication equipment or stations and licence-exempt radiocommunication equipment which include low-power devices such as garage-door openers, radio frequency identification devices (RFIDs) or equipment utilizing ISM or unlicensed bands such as WiFi and WiMAX. Regardless of the licensing and frequency authorization process, radiocommunication equipment standards are established by the spectrum management authority and used by manufacturers to create minimally acceptable technical parameters for radiocommunication equipment. Technical standards documents provide general information describing the equipment and the application; indication of licensing and certification requirements, channelling arrangements, modulation techniques used by the equipment, transmitter power and transmission limits for unwanted emissions.

For a more detailed discussion of radiocommunication equipment licensing and authorization go to [Section 3: Authorization](#). Certification of radiocommunication equipment is discussed in [Section 2.4.8](#). Channelling arrangements involve spectrum use and are explained in [Section 2.3.2](#). Modulation techniques and unwanted emissions are discussed in [Section 6: Monitoring](#).

2.5.5 Radiation Standards

Radiation standards refer to electromagnetic emissions which, at certain frequencies, may be harmful to life or some other concern to public safety. The spectrum manager is not typically responsible for conducting the research and determining the scientific basis for that concern. Other agencies of government such as the Ministry of Health and public and private research institutes conduct research to substantiate concerns. Once a decision by government on policy or regulation has been reached however, the spectrum management authority may need to take certain measures such as making modifications to radiocommunication equipment standards to ensure public safety.

The study of radiation effects on humans occurs at the national and international level. For instance, the World Health Organization studies radiation effects. The International Union of Radio Sciences in its Commission K addresses the effects of emissions on human health.

2.5.6 Other Standards

In connection with the deployment of radiocommunication system, other standards relating to the environment, construction and land use may apply. Although the spectrum manager may not be responsible for the development and enforcement of these types of standards, she or he will need to be aware of them and their implications in planning frequency use and licensing. This is particularly true where location with respect to essential facilities such as power transmission lines and airports is a factor.

2.5.7 Standards Development and Application

The development of radiocommunication equipment standards and spectrum use standards occurs at the national, regional and international levels. In some cases, due to the importance and size of the national economy, national standards acquire international importance. Smaller nations routinely adopt, either formally or informally, radiocommunication equipment standards developed by other standards organizations, which is a cost-effective manner of designing a set of standards. Indeed, countries within almost all regions, including Europe, the Caribbean, Africa and Asia have opted to recognize both European (ETSI) and North American standards (FCC and ANSI). There are standards bodies in most regions of the world and particularly in regions where high technology and telecommunication and radiocommunication equipment are manufactured.

The regional and national standards bodies include: American National Standards Institute (ANSI); European Telecommunications Standards Institute (ETSI), the Australian Communications Forum (ACF), the Association of Radio Industries and Businesses (ARIB), the Telecommunications Technology Association (TTA), etc.. International standards bodies include: The Institute of Electrical and Electronic Engineering (IEEE) and the International Telecommunication Union (ITU).

RELATED INFORMATION

[American National Standards Institute \(ANSI\):](#)

[Australian Involvement in International Standardization, Standardization Guide 2005.](#)

[European Telecommunications Standards Institute \(ETSI\):](#)

[The Australian Communications Industry Forum \(ACIF\)](#)

[The Association of Radio Industries and Businesses \(ARIB\)](#)

[The Telecommunications Technology Association \(TTA\)](#)

[The Institute of Electrical and Electronic Engineering \(IEEE\)](#)

2.5.8 Certification

Testing of radiocommunication equipment to establish compliance with national standards is performed by government-operated testing facilities or in private sector laboratories. In recognition of the dynamic nature of technological change and innovation and the high cost of test equipment, national governments are increasingly favoring private sector facilities. Due to the importance of testing and certification, the complexity involved and the reliance placed on results, policies and regulations have evolved around the harmonization of standards across regions and markets. Harmonization has also been promoted by the adoption of consistent approaches through the certification of Conformity Assessment Bodies (CAB's). CAB's are organizations recognized by the spectrum management authority to conduct testing and certification of radiocommunication equipment.

A CAB in one country can be recognized in another country by way of agreement. Mutual Recognition Agreements (MRA's) facilitate trade among countries. They are established on a bilateral or a regional basis, and streamline the conformity assessment procedures for a wide range of telecommunication and telecommunication-related equipment. One such example is the Asia-Pacific Economic Cooperation

Telecommunications MRA. These steps reduce the cost of supply of radiocommunication equipment and ensure both quality and conformity. An MRA provides for the mutual recognition by the importing parties of CAB's and mutual acceptance of the results of testing and equipment certification procedures undertaken by those bodies in assessing conformity of equipment to the importing parties' own technical regulations.

Conformity to radiocommunication equipment standards and certification are necessary conditions for interoperability of radio communications services and terminals such as handsets. It is not a guarantee, however. Across a region or within a country, a common technology or standard such as GSM or CDMA may be used by service providers with similar networks but operating at different frequencies, making it difficult for users to migrate between networks. The absence of roaming agreements may also prevent interoperability even when frequencies and the technologies are the same.

2.6 Allocating Spectrum

In establishing what use can be made of the spectrum, allocating ranges of frequencies in what are referred to as bands is a central concept, and is explored through the rest of this section.

2.6.1 Radio Services

Radiocommunication is a sub-set of telecommunication. Radiocommunication services are one of the main kinds of radio uses for which spectrum is allocated. Radiocommunication services have been the dominant focus of attention in attempting to match demand for spectrum with frequencies. It is important, however, for regulators to not overlook the other important uses and user of spectrum: navigation and public safety, for example.

In Article 1 of the ITU Radio Regulations, the term “radiocommunication service” is defined as “a service...involving the transmission, emission and/or reception of radio waves for specific telecommunication purposes”.

An example of radiocommunication service and related allocation issues follows in the next few paragraphs.

Mobile satellite services (MSS) refers to networks of communications satellites intended for use with mobile and portable wireless devices. The mobile-satellite service (MSS) includes maritime mobile-satellite service (MMSS), the land mobile-satellite service (LMSS) and aeronautical mobile-satellite service (AMSS). There are many important applications in the MSS including:

- Aeronautical Mobile Communications – global satellite phone service, distress and emergency services;
- Land Mobile Communications - global satellite phone service, distress and emergency services;
- And Ship borne or Maritime Mobile Communications – Inmarsat safety and communications services for maritime operations.

Telephone connections using MSS are similar to a cellular telephone link, except the repeaters are in orbit around the earth, rather than on the surface. MSS repeaters can be placed on geostationary, medium earth orbit (MEO), or low earth orbit (LEO) satellites, provided there are enough satellites in the system, and provided they are properly spaced around the globe, an MSS can link any two wireless telephone sets at any time, no matter where in the world they are located. MSS systems are interconnected with land-based cellular networks.

Services have proliferated and periodically allocations have been reviewed in an effort to harmonize allocations on both an international and regional basis. As well, several bands have been re-allocated to support the growth in terrestrial mobile services – IMT-2000.

One of problems facing MSSs is the relative success of terrestrial mobile services like GSM and Advanced Wireless Services in comparison to MSSs. There have been several significant attempts to bring widely based MSSs to consumers which have not lived up to the expectations of the business or consumer – (for example: Globalstar went into service in 1998 at a cost in excess of USD 4 billion and filed for bankruptcy in 2002 and the assets were ultimately purchased for USD 43 million). With these failures in the background, it has become a hot debate to reallocate spectrum to other expanding services. MSSs do have a fundamental advantage over terrestrial systems in that they can reach users practically anywhere. It is the prospect for advanced services to remote regions which continues to attract proponents for maintaining MSS allocations.

Recently, The European Parliament has approved a proposal that demands mobile satellite services reach at least 60 per cent of every country in Europe, and 50 per cent of their populations, in order to get operating spectrum. The ruling relates to a couple of chunks of spectrum which have been handed to the EU by member countries, for allocation to mobile satellite services on a pan-European basis. The spectrum is around 2GHz, specifically 1980-2010MHz for the up link and 2170-2200MHz for the down link, with no applicant being allowed to have more than 15MHz for each direction: thus specifying a minimum of two operators. To qualify for the spectrum those operators will have to reach every country in Europe, with reception possible in 60 per cent of each country's landmass, and by half of their populations.

The future of AMS(R)S primary allocations is on the agenda for WRC-11. WRC-07 agreed on a future Conference Agenda Item for WRC-11 to consider the results of ITU-R studies to ensure long term spectrum availability and access to spectrum necessary to meet the requirements for aeronautical mobile-satellite service in accordance with Resolution 222. For a more detailed look at the proposed WRC-11

2.6.2 Frequency Allocation Tables

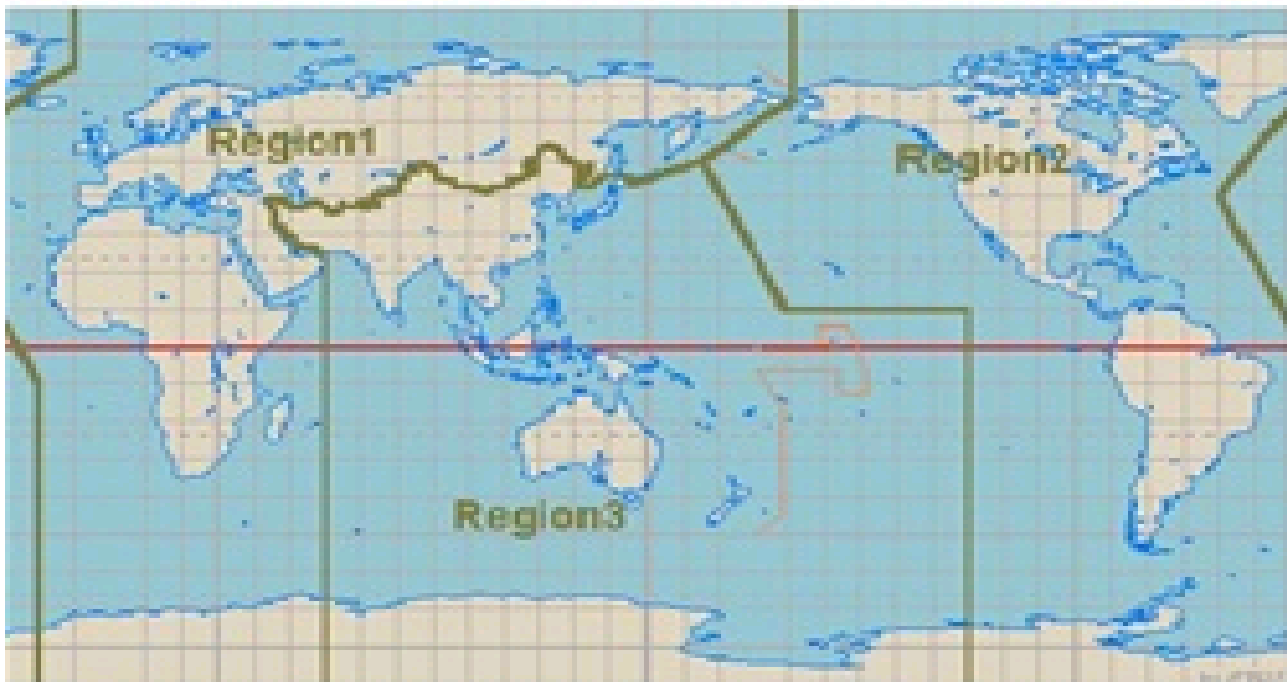
Before considering how the spectrum is allocated, it is perhaps best to clarify three terms: allocation, allotment and assignment.

An allocation is an entry in a table of frequency allocations which sets out the use of a given frequency band for use by one or more radiocommunication services. The term allocation is also applied to the frequency band concerned. An allocation then is a distribution of frequencies to radio services.

An allotment is an entry of a designated channel in a plan for use by one or more countries in those countries or within designated areas for a radiocommunication service under specified conditions. An allotment then is a distribution of frequencies to geographical areas or countries.

An assignment is an authorization given for a radio station to use a radio frequency or a radio frequency channel under specified conditions. An assignment then is a distribution of a frequency or frequencies to a given radio station.

For purposes of allocation, the world is divided into three Regions referred to as Regions 1, 2 and 3. A map indicating these Regions can be found below. A precise definition of the boundaries between Regions may be found in Article 5 of the ITU Radio Regulations.



Allocations are made on a primary or on a secondary basis. Stations of a secondary service cannot cause harmful interference to stations of primary services to which frequencies are already assigned or to which frequencies may be assigned at a later date. Stations of a secondary service cannot claim protection from harmful interference from stations of a primary service to which frequencies are already assigned or to which frequencies may be assigned at a later date. Stations of a secondary service can, however, claim protection from stations of the same or other secondary service(s) to which frequencies may be assigned at a later date. In a given band of the Table of Allocations, there are often footnotes which allocate the band in question (or a portion of a band) only in a specified geographic area. When a band (or portion of a band) is indicated in a footnote as allocated to a service on a secondary basis in an area smaller than a Region, or in a particular country, this is a secondary service. Where a band (or portion of a band) is indicated in a footnote as allocated to a service on a primary basis in an area smaller than a Region, or in a particular country, this is a primary service only in that area or country. The international Table of Frequency Allocations set out in the ITU Radio Regulations covers frequencies from 9 kHz to 275 GHz (or 1000 GHz, see footnote 5.565).

As mentioned in [Section 2.3.5](#) of this module, a National Frequency Allocation Table is an important document in planning the use of the spectrum within a given country. The National Table of Frequency Allocations must, in general, be consistent with the ITU Table of Frequency Allocations but usually contains a sub-set of the allocations found in the International Table. In addition, it usually is far more detailed and gives additional conditions for the use of spectrum usually through national footnotes in the National Table.

A recent example of modifications to Article 5 of the Radio Regulations involving significant changes to allocations across all regions are the IMT Advanced Allocations for Broadband Wireless Access (BWA) which have implications for most if not all members. These resolutions affecting the changes in allocation were made at the World Radio Conference (WRC) in Geneva in 2007. For a more detailed

discussion of Recent World Radio Conferences see [Section 7.2.2](#).

In this section, we discuss some of the step by step approaches involved in changing national frequency allocations to reflect and accommodate the changes in the International Table resulting from the WRC decisions concerning BWA.

Introducing New Services such as BWA – a general approach

Changes to the National Table of Allocations will ultimately lead to assignments for services. Allocations and assignments are linked and will ultimately reflect local market structures and conditions.

Allocating and assigning spectrum for various uses and users by regulators is a powerful tool with significant implications. Imposing or limiting restrictions on uses and users has a direct impact on spectrum access and efficiency. Knowing where and where not to impose restrictions requires information, building consensus and where consensus is lacking, the means to smooth out differences by way of an adjustment process such as compensation or arbitration. Consultation is important at all stages. Some of the general practical steps taken by regulators include:

1. Acquiring the information needed to assess use, users and utilization. Spectrum audits can be performed to fill in the gaps in information;
2. Consulting with current and prospective users;
3. Creating channelling plans which compact spectrum assignments and increase the number of occupants through techniques such as re-use to ease congestion and interference;
4. Reinforce the application of technical standards and compliance to ensure interference is managed and manageable;
5. Clearing zones of spectrum through refarming incentives (user to user) or recapturing underutilized spectrum;
6. Examining ways to license or unlicense underutilized spectrum to increase use and sharing;
7. In bands where trading can take place and demand has been pooled, band managers can be tasked to manage use and users.

Specific practical steps include the following:

1. Identify the specific bands of interest and determine current use and utilization;
2. Consult with existing and potential users and assess demand and value for existing and potential services;
3. Conduct comparative analysis with relevant country experience and consider spectrum assignment, licensing and spectrum pricing issues and implications;
4. Conclude on affected bands and consider allocation methodology. For example will 2 X 5 or 10 MHz chaired spectrum be allocated and in which bands;
5. Consult and determine which allocation methodologies and authorization and assignment methodologies will be proposed or applied. The practice varies significantly across regions and methods include: administrative processes such as first-come first served, comparative review, auction methods. As well, concessions granted in the past may include unified service licenses (for more on authorisations see Module 3);
6. Prepare resulting policies, plans and processes required to support conclusions on methodology, reallocation implementation steps, and expected assignment and licensing (unlicensed) outcomes.

2.6.3 Spectrum Use Designations

In the international Table of Frequency Allocations as well as in national Tables, there are designations or identifications of spectrum use. These set out more specific types of frequency use than that foreseen in the allocation of a frequency or frequencies to a given radio service. For example, in the international Table, some bands allocated to the mobile service are designated for use by IMT-2000 systems. Such designations in the international Table do not preclude any use of the frequency band by the services to which it is allocated nor do they result in any priority for such use. At the national level, however, countries may choose to give such designations a priority or even use such indications to mandate an exclusive use within a given band. For example, a band allocated to the mobile or land mobile service may nationally be designated for a cellular mobile telephone service to the exclusion of all other mobile operations.

3 Authorization

Authorization is the process by which users gain access to the spectrum resource. This may involve assigning specific frequencies to users, allotting certain frequency bands or sub-bands to specific users who may or may not be able to transfer such spectrum rights to others or it may mean simply authorizing the use of specific equipment or categories of equipment. It is important to distinguish between methods for determining who will have access to spectrum versus determining the cost of such access (see also [Section 4](#) and [Section 5](#)).

3.1 Introduction to Authorization

Some authorization activities associated with spectrum management include licensing, examination, certification of radio operators, equipment, type approval, type acceptance and international notification and registration. In terms of licences, there are various types, including individual licences, system licences, class licences, general authorizations, etc. Some uses of spectrum are not licensed. It is important, however, to recognize that unlicensed does not necessarily mean unregulated since equipment may still need to meet certain technical standards.

Of particular importance given the expansion of mobile telecom services and liberalization of telecom markets in developing and emerging economies, is the authorization of spectrum in connection with licensing of the provision of telecommunications services. It is necessary, for instance, to authorize cellular service providers to use the required spectrum as well as authorizing them to operate the cellular networks.

It is important that the regulatory process facilitates granting, at virtually the same time, authorizations to operate a telecommunication service and to use the required radio spectrum. There should be no delays or risks of inconsistent regulatory requirements between the two types of authorizations. This is also the case for authorizing broadcasting undertakings. If two separate authorizations are issued, they should be issued simultaneously. For telecommunication services, these approaches are discussed in more detail in the Module 3 - Authorization of Telecommunication/ICT Services Module.

A number of administrative methods are used to manage processes by which access to spectrum may be granted. These include “a first come-first served basis”, a reserved basis for certain uses or users in a form of a-priori planning and so-called beauty contests which may be held to decide who will be assigned certain frequencies or bands of frequencies. Economic methods such as lotteries or auctions may also be employed. There are clear advantages and disadvantages for each method and these are explored in more detail below and in [Section 5.0 Spectrum Pricing](#).

Improved technology used in analyzing spectrum use ([See Spectrum Monitoring Activities Section 6.2.3](#)) and information systems are playing increasingly important roles in assigning and keeping track of spectrum use as well as administrative functions such as collection of licence fees and preparing submissions of various information to other countries or to the ITU where required. It is very important tailor systems and the application of such technologies to the real requirements and to the resources available. Maintenance of any such information systems must be ensured which underlines the need for competency in such systems.

No matter what method for assigning frequencies is adopted, some level of spectrum engineering support is required to ensure, inter alia, that the use of frequencies authorized will not result in interference or to resolve any cases of intra-national or international interference that might arise. Such capability is also required to assess, for example, some of the newer technologies such as software defined radio equipment.

The next sections discuss Assigning Frequencies and related sub-topics including Methods for Assigning Frequencies, Relation to Other Authorizations and the important subject of the Impact of Technological Innovation and the Impact on Authorization as well as providing an overview of several technical topics such as Certification of Radio Operators and Equipment Authorization.

RELATED INFORMATION

[Authorization of Telecommunications Services Module – Section 6.6 Spectrum Authorization](#)

3.2 Assigning Frequencies

For spectrum managers, spectrum authorization involves the licensing of radiocommunication equipment and the making of frequency assignments. The administration of licensing contributes to the proper functioning of spectrum management operations. Licensing places controls on the operation of radio stations and the use of assigned frequencies.

Spectrum authorization activities include analyzing requirements for proposed frequencies in accordance with national plans and policies for frequency allocation. They include actions to protect radiocommunication systems from harmful and obstructing interference. Spectrum authorization strategies are used to ensure proper use, facilitate reuse, and achieve spectrum efficiency.

For users and potential users of spectrum, it is important for them to know their rights and obligations with sufficient precision to allow them to make plans and avoid interfering with one another's activities. Except in the case of unlicensed spectrum, this is done at the stage of assignment of frequencies which thus becomes a key aspect of spectrum regulation especially if licences are granted for a long duration.

For example, the Comprehensive Free Trade Agreement being negotiated in 2009, between the EU and ASEAN includes Article 31 which ensures that the requirements for the attribution of frequencies by licensees are adequately specified in the terms of the licence. In the case of spectrum authorizations, this is particularly important when licensees have transfer, leasing or trading rights and the licensee is required to either seek approval from the regulator for the change or simply provide notice of the change.

Precisely what the spectrum manager has to do in order to achieve an effective assignment depends on the method chosen, and also upon linkages with other authorisations such as the issuing of broadcasting licences. New technological developments may change the methods used to issue authorisations and may require 'refarming' of spectrum. The process will require engineering and administrative support and, in some cases, financial support. These issues are discussed in the following sections.

3.2.1 Methods for Assigning Frequencies

Spectrum Overview - [Section 1.5](#) above provides an in depth discussion of the three major methods of granting users access to spectrum: by administrative methods, using market-based methods and by permitting access to unlicensed spectrum. For the purposes of the present discussion on spectrum authorization, only the first two are relevant, because the third does not involve assignment to, or licensing of, individual users.

In the case of administrative methods, a spectrum manager specifies detailed rules and constraints affecting how, where, and when spectrum can be used and who has access to spectrum. Minimizing harmful interference lies at the heart of the traditional model which places an emphasis on the technical management of radio spectrum.

Market methods are used at the initial issuance of a spectrum licence, when auctions are used, by allowing spectrum rights to be bought and sold (traded) over the lifetime of a licence, and allowing a change of use and transfer between users of the relevant spectrum.

Administrative methods of assignment and the use of market-based methods such as auctions have many elements in common. In both cases, utmost clarity is required about what rights and responsibilities are entailed by the licence. These must be specified in respect of technology, geography and time.

The most complex is technology. Under administrative assignment of licences to a particular user providing a particular service (a specified form of radar, GSM, etc.), the technological restrictions in the licence are normally defined in terms of the location, power and geographic coverage of the specified apparatus. The specifications are chosen to avoid interference with other users. Any departure by the licensee from these conditions is a breach of the licence. If, however, spectrum licenses are flexible and can be employed for any purpose – following a trade of the licence, for example – apparatus licensing of the kind described above does not work, as each possible use will be associated with different equipment. In these circumstances, licensees will have to face restrictions in what emissions their activities are allowed to make at the boundaries of the licence area – i.e. what spill over they can make into adjoining geographic areas and frequencies. This is considerably more complex.

The geographical scope of a licence is more easily specified once the interference issue noted above has been resolved. It may be the whole territory governed by the spectrum regulator, or a small subset needed for a radar or a local radio station.

The duration of the licence must also be specified. [Section 4.2.4](#) on Market-based Methods – Licence Duration of this module discusses the pros and cons of shorter or longer licence durations.

Following the stage of definition of licensee rights and obligations, the administrative and market (auction) methods diverge. If an administrative method is employed, then the regulator must decide how to make the assignment. If there is no excess demand for spectrum licences, the method chosen might be 'first come, first served': the regulator would announce the available licences and invite applications. Applicants might have to be qualified in specified ways but qualified applicants would then be granted licences until they were exhausted.

If excess demand is anticipated, use of a competitive assignment process is normally preferred. For this to be done fairly and transparently, the regulator must set out the various criteria to be employed, relating for example to the technical and financial qualifications of applicants, their access to capital, the scope and geographical range of their services, and so on. Each criterion should have a pre-

announced weight, and an objective method of measurement should be specified.

If an auction method is used to make an assignment, the procedures to be employed must be set out in fine detail to ensure that all competitors are on an equal footing. For example, if a sealed bid is employed, the date and place at which it must be lodged have to be clear. If an open auction process is utilised, in which bidders make offers for licences in successive rounds of bidding, a whole range of procedures relating to the frequency of rounds, increments in amounts bid, obligations to make new bids and so on must be specified. These points are discussed further in the Practice Note on auctions.

In all cases, it is vital that the regulatory body abide strictly by the conditions it has specified for the assignment. Any departure or evidence of partiality, prejudice or of conflict of interest will be damaging in several ways. First, legal challenges can delay the start of services of benefit to end users, possibly for many years. Secondly, doubts about the integrity of the process will deter companies from participating in competitive assignment processes. As a result, inferior candidates may be successful, leading to long term harm for consumers.

3.2.2 Relation to Other Authorizations

It should be noted that there are often other authorizations that are required in parallel with the spectrum authorization. In the case of telecommunication carriers, often telecom licensing is required (see the [Module 3. Authorization of Telecommunication/ICT Services](#)). The licensing of such telecom facilities can involve radio and non-radio based facilities, the former being subject to spectrum authorization as well as telecom licensing. In some countries, such licensing of telecom carriers is performed by the same regulatory body which regulates the use of spectrum whereas in other countries, telecom licensing is carried out by a separate regulatory authority. Similarly, in the case of broadcasting, often a broadcasting licence separate from a spectrum authorization is required. Again, in some countries it is the same regulatory body that issues broadcasting licences as issues spectrum authorizations whereas in other jurisdictions, it is a different regulatory body. In some countries, the regulation of spectrum, telecommunications and broadcasting is all carried out by a single regulatory body.

In addition to these authorizations, there are often additional authorizations required for a radiocommunication facility. For example, if an associated antenna structure is above a certain height and/or within a certain distance of an airport, painting and lighting requirements may enter into play. These requirements are usually set out by the government authority responsible for air navigation safety. Another type of authorization that may be required in some countries is what is often referred to as local planning permission. The siting of antennas may be subject to local land use policies and authorizations confirming conformity with such policies may be required.

RELATED INFORMATION

The following references give examples of regulators in selected jurisdictions who are responsible for multiple service authorizations (television, radio, telecommunications), singular authorizations, and regulations concerning deployment of infrastructure (antenna in municipalities).

Ofcom is the independent regulator and competition authority for the UK communications industries, with responsibilities across television, radio, telecommunications and wireless communications services.

<http://www.ofcom.org.uk>

The CRTC is an independent agency responsible for regulating Canada's broadcasting and telecommunications systems.

<http://www.crtc.gc.ca>

The Nepal Telecommunications Authority is responsible for The National Broadcasting Regulation, 2052 (1995) and the licensing of broadcast facilities.

http://www.nta.gov.np/national_broadcasting_regulation_2052.html

3.2.3 Liberalization and the Impact on Authorization

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. Two features of more reformed spectrum management policies are liberalization and flexibility:

- **Liberalization** is the extent to which spectrum usage rights can be managed through market-based mechanism - this covers competitive assignments (such as auctions) through to secondary trading. Within this environment, management is delegated as much as possible to participants within the spectrum arena. Spectrum management agencies in this setting perform the role of 'light-handed' regulation;
- **Flexibility** involves the relaxation of constraints on usage and technologies (either as a commons or in the form of managed shared use), as well as the possible expansion of licence-exempt frequencies. Very few countries have opened up large parts of the spectrum as a genuine commons. Most notably the United States has embarked on a path of considerable innovative activity. The use of WiFi, WiMAX and UWB in the US has emerged many years before its deployment in most other countries, partly due to the size of the

market and as a result of regulatory actions designed to promote flexibility and unlicensed use.

The benefits of liberalization are strengthened in the presence of greater flexibility and the benefits of flexibility are greater within a liberalized environment. Thus liberalization and flexibility are closely intertwined.

3.2.4 Technological Innovation and the Impact on Authorization

A major challenge for assignment procedures arises when technological innovation alters the optimal use to which a particular frequency should be put. In certain circumstances, this does not create a problem. Thus if, under an administrative procedure, a licence expires at the moment when a change of use is desirable, a new licence can be issued to provide the new service. If a market regime involving secondary trading and involving change of use is in place, then the purchase and sale of the relevant spectrum licence should allow the transition to take place without regulatory intervention. Indeed one of the arguments for the use of markets is that it takes the regulator out of the process of responding to technological change which is occurring at an increasing rate.

Technological innovation is improving the efficient use of spectrum, and at a basic level, this 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.

In the next several paragraphs several broad categories of innovative technologies are introduced which are altering the landscape. These are Underlay and Overlay technologies;

- **Spectrum Underlay** is a spectrum management technique 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;
- **Spectrum Overlay** involves either active or passive overlay. The Amateur radio service has shared spectrum with various government users using passive overlay technologies which require the user to look for a CB radio channel that is free. A passive overlay technology is different from an active overlay technology. 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.

In reality, however, things are usually a great deal messier. There may be uncertainty over what entitlement to spectrum a licensee has. This has been the case in the United Kingdom, for example, where licences have had a reasonable and legally enforceable expectation to receive a notice of an unspecified number of years before they are evicted. In a market regime where licences are of limited duration (e.g. twenty years), there may be a period of uncertainty, when a switch to a new use is desirable but no one is prepared to make the necessary investments to achieve it, because of uncertainty about future access to spectrum.

Refarming can be facilitated by public subsidies, or other sources of funding, which cushion the transfer by users to another frequency. In the UK, a Spectrum Efficiency Scheme, administered by the regulator, exists to finance such costs. In the USA, federal government users, such as the Department of Defense, may be willing to give up frequencies to commercial users if they are compensated. Legislation is in place which allows the auctioning of such spectrum, using as a 'rescue policy' the costs of relocation: in other words the process only goes ahead if the displaced party is compensated.

Another variant of re-assigning spectrum to allow new technologies involves the use of auctions. For example, a licensee has a license with a fixed term remaining and the regulator chooses, in advance, to auction the licence for the succeeding period simultaneously making the current licence tradable. The prospective licensee can then bargain with the current licensee to achieve early release of the spectrum, if it is in the parties' mutual commercial interest to agree such a transfer.

Successful re-assigning or 'refarming' of spectrum is a key element in achieving flexible use which responds to demands for new services.

RELATED INFORMATION

[Legal and Institutional Aspects of Regulation Module: Section 4.3.2, Impact of Convergence on Licensing, Spectrum](#)

3.2.5 Engineering Support

Software tools have been developed in house by spectrum management organizations and by the private sector. These tools are designed to support spectrum planning and frequency management in both head office and field applications. These tools assist frequency managers in establishing and maintaining the administrative and technical requirements of radio frequency management. The tools are very sophisticated and perform analyses which require the manipulation of large amounts of data in varying formats and structure. This poses several problems for regulators in both developed and developing countries. The capability to acquire and manage data and the development of innovative techniques have been developed for extracting and manipulating critical data elements and databases so as to

transform data into useful frequency management information.

Engineering support is also required to determine which radio services and applications can share the same frequency band. Complex engineering calculations are often required in order to pack as many users and uses as possible into a given portion of the radio frequency spectrum. Analysis of cases of national or international harmful interference and coordination of frequencies with other countries requires engineering expertise. Engineering support is important when making proposals to change bilateral or multilateral treaties and agreements (e.g. at ITU World Radiocommunication Conferences) and when analyzing the proposals of others.

RELATED INFORMATION

[SMS4DC Version 2.0 - Spectrum Management System for Developing Countries Edition 2008](#)

[ITU-D Regional Development Forum for the Arab Region: "Access to spectrum, including broadcasting services trends and technologies"](#)

3.2.6 Administrative Support

Substantive spectrum management tasks such as authorization involving planning, engineering, and authorization tasks cannot be effectively performed without support from other staff units with expertise in legal, finance, and information management, as well as various clerical and administrative activities. The table below lists several administrative functions and responsibilities in addition to the mainstream spectrum management activities of planning, engineering, etc.

Some of the administrative functions will be associated with some of the routine tasks and methods associated with licensing of radiocommunications, approval of radio equipment type, and routine monitoring. These routine tasks should be supported by well-defined administrative processes, which can be dramatically improved and made more cost-effective through the use of efficient information management systems. Quality of service can be improved by placing service points of presence close to clients and users.

Other will be associated with some of the more technical areas involved in planning and authorization. Legal, finance and economic expertise will be required to support planning activities and implementation of new practices. For example, preparation of band plans, spectrum fees, licensing processes, spectrum occupancy analysis and surveillance and competitive bid processes create new business processes. The analysis of business processes will lead to an understanding of needs in information, data, and application. At this point, planning can shift to a consideration of technical architecture and technology platforms.

Spectrum Management Functions

Spectrum Management Policy and Planning: Allocation of Spectrum
Frequency Assignment and Licensing
Standards, Specifications, and Equipment Authorization
Spectrum Control (enforcement and monitoring)
International Coordination
Liaison and Consultation
Spectrum-Engineering Support
Computer Support
Administrative and Legal Support

Source: ITU Spectrum Management Handbook

3.3 Certification of Radio Operators

The ITU Radio Regulations set out the need for certain operators of radio equipment to possess a radio operator's certificate. Chapter 8 of the Radio Regulations deals with the requirements within the aeronautical environment while Chapter 9 deals with requirements in the maritime environment. In addition, Article 25 of the Radio Regulations and ITU-R Recommendation M.1544 which is incorporated by reference deals with the requirements for amateur radio operators. Ensuring conformity with these and with any additional national radio operator requirements involves examinations and the issuance of radio operator certificates of various types. In most countries, the conducting of these examinations is delegated to a public or private sector entity closely associated with the respective field i.e., aeronautical, maritime and amateur. Often such bodies will also conduct courses covering the material required for operator certification. In some cases, the delegated authority also issues the operator certificate on behalf of the government regulator.

3.4 Equipment Authorization

Radiocommunication equipment (often referred to as radio apparatus) must be authorized for use even if the use of the specific equipment does not require a licence. Ensuring that equipment meets certain technical standards reduces the possibility of harmful interference.

3.4.1 Equipment Certification

Equipment certification and/or type approval provides assurance that, in terms of design, the licensed radio equipment will meet regulatory requirements and will enable radio equipment and radio stations to coexist within acceptable limits. These limits are considered in conjunction with practical economic considerations of efficient spectrum use. Accessible records of approved equipment and licensed equipment facilitate the licensing and assignment processes.

The spectrum management authority or a designated agent maintains a listing of equipment categories which require either certification or type approval. Acceptance, sometimes referred to as voluntary certification, allows listed telecommunication equipment to be either marketed or used without having to obtain an equipment certification (type approval certification). Certification requires that equipment intended for sale or use be certified as approved prior to either its use or sale within the country of jurisdiction.

3.4.2 Laboratory Certification

Testing of radiocommunication equipment to establish compliance with national standards is performed by government operated testing facilities or in private sector laboratories. In recognition of the dynamic nature of technological change and innovation and the high cost of test equipment, national governments are increasingly favouring private sector facilities. Due to the importance of testing and certification, the complexity involved and the reliance placed on results, policies and regulations have evolved around the harmonization of standards across regions and markets. Harmonization has also been promoted by the adoption of consistent approaches through the certification of Conformity Assessment Bodies (CAB's). CAB's are organizations recognized by the spectrum management authority to conduct testing and certification of radiocommunication equipment.

A CAB in one country can be recognized in another country by way of agreement. Mutual Recognition Agreements (MRA's) facilitate trade among countries. They are established on a bilateral or a regional basis, and streamline the conformity assessment procedures for a wide range of telecommunication and telecommunication-related equipment. One such example is the Asia-Pacific Economic Cooperation Telecommunications MRA. These steps reduce the cost of supply of radiocommunication equipment and ensure both quality and conformity. An MRA provides for the mutual recognition by the importing parties of CAB's and mutual acceptance of the results of testing and equipment certification procedures undertaken by those bodies in assessing conformity of equipment to the relevant technical regulations.

4 Spectrum Sharing

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

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](#)

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.

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.

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](#).

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

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 flexibility 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.

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.

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 to 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 of as a mainstay communications device.

See also Issues also on the agenda of WRC-11.

Smart Antennas and Other Technologies

Smart Antenna applications and technology have emerged in the past 10 years and are interesting for 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 new idea but a more cost effective one with the advent of digital signal processors and general purpose processor and 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.

See also Reports ITU-R M.2063 and ITU-R M.2064.

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.

4.3.1 Trends in reform

In recent years, spectrum management policy and regulation have evolved considerably by reflecting the changes in the demand and supply of services reliant upon radio spectrum. 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.

Some the concepts underpinning the reform agenda include:

- 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](#).

Spectrum 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 at different locations.

Spectrum commons

A spectrum commons is a 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 raging in the US between the broadcasters and Internet content companies such as Google which argues 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 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".

Regulatory structure

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.

It is debatable whether the duties of such an independent spectrum regulator should be combined with those of regulating competition and protecting consumers in downstream service markets.

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.

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^[1]. 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.

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 Telecommunication 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.

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.

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.

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.

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.

5 Spectrum Pricing

For any resource, including radio spectrum, the primary economic objective is to maximize the net benefits to society that can be generated from that resource such that there is an efficient distribution of resources resulting in maximum benefits to society. Prices are used as an important mechanism to ensure the spectrum resources are used efficiently by users.

The broad goals and objectives associated with spectrum pricing are:

- Covering the costs of spectrum management activity borne by the spectrum management authority or regulators;
- Ensuring the efficient use of the spectrum management resource by ensuring sufficient incentives are in place;
- Maximizing the economic benefits to the country obtained from use of the spectrum resource;
- Ensuring that users benefiting from the use of the spectrum resource pay for the cost of using spectrum;
- Providing revenue to the government or to the spectrum regulator.

Spectrum pricing refers to a range of spectrum management activities and tools including administrative fees, spectrum usage, and spectrum prices determined by way of market mechanisms. Developing spectrum pricing strategies invariably involves alignment with the government's and regulator's revenue goals and objectives, setting targets, and discussion with key stakeholders such as the Ministry of Finance and key sector groups – telecommunications service providers. Revenue targets and strategies relate directly back to the primary objectives; spectrum users pay for spectrum use, covering management costs, spectrum efficiency, and achieving economic and social development goals.

5.1 Introduction to Spectrum Pricing

In this section, we discuss various approaches taken by spectrum managers to both raise revenue and distribute the spectrum resource using spectrum pricing techniques and methods. We begin by describing and contrasting administratively determined and market-based spectrum prices and expand on revenue related spectrum management objectives.

Administrative fees and prices

The administrative assignment of spectrum (also discussed in the following section [1.5.1 Administrative methods](#)) is often supplemented by imposing charges for spectrum use. These charges can take the form of simply setting fees sufficient to recover the costs of spectrum management. Prices can also be used to guide users in making decisions to use spectrum more efficiently. One example, applicable within the framework of administrative assignment of spectrum, is to set a charge for spectrum equal to an estimate of what the spectrum might be worth in a market context. This is sometimes called 'administered incentive pricing'.

Market-based prices

Alternatively, prices can emerge through an authentic market transaction such as an auction or secondary trading. The general theory of prices involves assumptions regarding economic behaviour of consumers of resources concerning rationale preferences for outcomes, utility (maximizing efficiency and profit) and information availability and access. From these assumptions, economists developed a structure to help in understanding how the allocation of scarce resources among alternative ends occurs in markets. We employ these basic assumptions to begin our understanding of how market prices for spectrum are set.

Administered incentive prices

We also refer to a method where spectrum regulator attempts to approximate the prices (often flat rate charges) that might emerge in a market context. This method is referred to as 'administered incentive pricing': 'administered' because prices are set by the regulator reflecting the opportunity cost of spectrum while incorporating potential 'incentive' properties: prices are set at a level to encourage efficient use reflecting spectrum scarcity.

This section on spectrum pricing explains these possibilities in greater detail. We start with a discussion of prices or charges set to recover the cost of running a spectrum regulatory agency. We then discuss spectrum usage fees which are charged to recover a spectrum resource rent and ensure spectrum is utilized on an efficient basis.

Next, we discuss where spectrum is assigned by means of a lottery: a winning ticket chosen at random will carry with it a spectrum award. This is a 'non-pricing' method of assignment. However we note it here (and advise against it), as the lottery winner will often wish to turn the licence into cash (if is he or she is allowed to do so) by trading it on a markets.

We then consider in some detail how prices for spectrum licences can emerge through an auction process, reviewing different types of auction and their likely outcome. Auctions are a well-know means of using market-generated prices to assign spectrum at the time of its first issue by the spectrum regulator. Where subsequent or secondary trading of licences is allowed, procedures will emerge which set the prices for such trades, and these may also include auctions. We review the conditions for such trading successfully to emerge.

Finally, we give an account of how the spectrum regulator approximates spectrum prices that might emerge in a market context by setting spectrum charges which reflect the opportunity cost of spectrum.

An important issue can arise when the regulator uses both administrative and market-based systems for different spectrum segments, and this is the issue of price adjustment and alignment. For example, how spectrum prices should be adjusted in adjacent bands when auctions take place indicating a rise in the opportunity cost of spectrum and equally should prices fall along the lines of mark-to-market valuation adjustments.

5.2 Spectrum Valuation

5.3 Spectrum Pricing Objectives

5.4 Spectrum Management Cost Recovery

It takes money to run a spectrum regulatory agency. The resources the spectrum management agency requires include: skilled labour, IT resources, investment in technical monitoring equipment, and expenditures to pay for participation in ITU and other international meetings. As well, the normal inputs such as office space and utility services needed to be funded. Governments can remunerate such costs directly from general revenue and in certain circumstances they should do so (for example if full cost recovering would deter spectrum use). It is usually efficient, however, for licensees or groups of licensees to be liable for the direct regulatory costs which they impose, on the ground that such costs are 'caused' by each licensee. Each user should then expect a direct cost based licence charge when it seeks access to spectrum, just as it takes account of other costs which it incurs or imposes.

5.4.1 The Structure of Costs in a Spectrum Management Agency

The activities of each licensee impose direct costs on the regulator. These include the costs of issuing, maintaining data, spectrum monitoring and enforcing its individual licenses. Some costs will be common to a band or to a radio service (such as band planning); whereas others will be common to a group of bands and some, such as management overheads, will straddle all licensees. The Australian study referenced in the following practice note suggests that indirect costs predominate.

5.4.2 Setting Fees and Prices to Recover Costs in Practice

Fees are usually imposed by the regulator when administratively assigning spectrum and processing applications. The types of fees include:

- Application fees
- Type approval fees
- Radio operator examination fees
- Fees for radio operator certificates
- Interference complaint investigation fees

Setting fees schedules and prices to recover costs has been tackled by regulators in several ways. Some have used detailed costing models to establish which licenses have imposed which costs; others rules of thumb. Rules of thumb, such as setting charges on the basis of a percentage licensee's turnover, are likely to be subject to increasing criticism by those who think they are overcharged. In these circumstances, a simple model of direct costs can be developed. The model needs to be based on defined structure and business processes and associated management accounting data within the regulator – for example the amount of time spent issuing and enforcing particular licences. As well, a method of allocating indirect or common costs will be needed – for example, based on licensees in proportion to the direct costs which they impose. Or they can be allocated in accordance with the amount of spectrum (e.g., in MHz) with which a licence is associated.

The choice between these and other approaches has to be made by the regulator in the light of considerations of fairness, and the likely effect of the charges on spectrum use. If a high allocation of indirect costs makes a licence uneconomic, the matter may require reconsideration. We give two examples of alternative approaches in the following practice note and reference document.

RELATED INFORMATION

[ITU-D: Study Groups: Spectrum Fees Database - Spectrum Management](#)

5.5 Spectrum Usage Fees

Spectrum usage fees are charged to recover a spectrum resource rent for the government and to ensure that users of spectrum utilize the resource on an efficient basis. Under a spectrum usage pricing framework users should move to a state where only assigned and utilized spectrum is paid for. Unutilized spectrum is returned for reuse.

Specific targets for spectrum use do vary considerably across regions. There is an argument for making spectrum usage charges consistent across a region to avoid investment disincentives. However, in looking at regional best practice several important factors including scarcity, quality, congestions and value in use need to be taken into account.

It should be noted that spectrum usages charges should also apply to other main users of spectrum including microwave and satellite.

5.5.1 Spectrum Usage Fees in Practice

There are two methods for pricing described in the articles which are commonly adopted for concession and network pricing and for spectrum usage. These two systems are briefly described below

- Spectrum Use Management Value (Nurmatov); and
- System Performance Pricing (Nozdrin)

Spectrum Use Management Value

Fees can be calculated on the base of costs on spectrum management possibly to present in the total functional form:

$$F = D_i$$

$$F = f(D_i, L_i \times I)$$

where:

F = fee, imposed on the spectrum authorisation licensee

D_i = direct administrative costs on processing license applications;

L_i = share of in additional administrative costs;

I = total additional costs.

System Performance Pricing

A universal approach to spectrum price determination based on system performance has been developed where the price can be built up from a number of separate elements based on any or all of various criteria such as the amount of spectrum used, number of channels or links used, degree of congestion, efficiency of radio equipment, transmitter power/coverage area, geographical location and so forth. The basic principle of this approach is to identify various technical parameters in order to measure the spectrum volume used or define the "pollution area" of a radio system as a common basis for establishing spectrum fees.

For example, the following universal formula may be considered:

$$P = \frac{V}{M} \times \frac{K_f K_s}{K_m} \times C_s \times K_p$$

where:

P = spectrum price;

V = volume of space or geometric area occupied;

M = useful results obtained from the radio equipment considered, for example the number of channels to be provided or users to be served;

K_f = coefficient reflecting specific characteristics of range used;

K_s = coefficient taking into account the region of the radio station installation;

K_m = coefficient reflecting social benefit of radio system;

C_s = annual spectrum management costs;

K_p = coefficient reflecting the level of spectrum access demand in the band in question.

On one hand, the application of this method can stimulate more efficient spectrum utilization; on the other hand various problems with the practical use of such formulas remain to be resolved. One disadvantage of the above technique is the choice of coefficients designed to take into account specific features of service, spectrum demand, etc.

5.6 Spectrum Royalties and Lotteries

Spectrum royalties and lotteries are administrative methods for raising revenue which may bear no resemblance to either the economic value of spectrum or the cost of spectrum management. Historically, royalties and lotteries preceded what are now viewed in practice as more reliable market-based methods for setting prices – such as auctions.

Spectrum Royalties

Spectrum or licence charges can be assessed as a percentage of (or royalty on) revenues or profits, which has to be handed to the spectrum regulator under the terms of the licence received or profits earned by an operator. This can be a way to cover regulatory costs, or it can be designed to raise revenue for the government.

The amounts that royalties paid go up and down depends on the the prosperity of the firm and sector (e.g., mobile communications). This makes the regulator a kind of 'partner' of the operator, sharing a common interest in maximising revenue or profit. Because royalty payments depend upon operator's performance the income they generate is unpredictable, which may be a disadvantage. There also needs to be legislative clarity to ensure that what might be viewed as taxation is indeed legal.

Finally, the basis for calculating payments must be spelt out, to prevent an operator from using accounting devices to hide income or profit and thus reduce payment.

Lotteries

Revenues are raised by applicants paying entrance fees to gain spectrum rights. Although this procedure may seem attractive and equitable, it has many drawbacks and has fallen out of favour.

1. First, if there are many applicants, the cost of administration may be large, especially if applications are reviewed and vetted for suitability.
2. Second, if applicants are not vetted the lucky winner may not have the necessary qualifications to operate the service efficiently. If they are not allowed to sell the licence, this may be a recipe for disaster.
3. And if, thirdly, they are allowed to sell them to efficient operators, the winners will be appropriating auction proceeds which would otherwise go to the government.

5.7 Spectrum Auctions

In recent years regulators have relied heavily upon assigning some licences via a competitive process involving (normally) a monetary payment (which we call an auction) rather than relying on alternative procedures such as comparative hearings. In which applications are

judged on a range of criteria. A more complete discussion of the methods for selecting licensees can be found in [Section 3 of this Spectrum Management Module](#). This present Section focuses on the pricing aspects of the selection process.

In an auction, contestants for a licence make competitive bids and the licence goes to the highest bidder. It is normal for the bids to be made in monetary term, the competitor offering the largest monetary sum getting the licence. But the competition can be in some other variable. For example, competitors can bid against one another over which of them will offer service over the largest geographical area. Or the competition can be in terms of which operator will charge the lowest amount for service. Once the rules are established, however, the winner is determined by the operation of the competitive process, not by an administrative decision.

Switching from comparative hearings, followed by an administrative decision, to an auction does not in itself fundamentally change the spectrum regulatory regime. If licences specify in great detail the technological apparatus to be employed and services to be provided, the winner of an auction is as effectively tied down as a firm granted a licence by any other means. The key differences are that:

1. an auction assigns the licence to the firm which bids the most, and that may in certain conditions be the most efficient firm;
2. a competitive auction will, if it operates properly, cause any expected excess profits from providing the service to go to the Government, rather than the operator as would be the case if the operator were chosen via a competitive hearing.

The licence being auctioned is not always so prescriptive as assumed above, but may allow the successful licensee to choose what services to provide. We consider some of the resulting issues associated with change of use under the heading of 'secondary trading in practice'.

Although auctions have been used in many countries over the last 10-15 years, it still remains the case that most of the spectrum in use in all countries has been allocated by administrative methods. Auctions tend in practice to be confined to cases where:

- the spectrum available is in scarce supply;
- many firms want to acquire licence;
- the service to be provided with the spectrum can be precisely defined
- the monetary value of the licence is relatively high, justifying what can be a complex assignment procedure.

It is clear, however, that auctions can be used in a wider class of cases than these. A successful auction process relies upon clarity about the rights and obligations being auctioned, and also from clear rules for the conduct of the auction. If either of these is absent, firms will face uncertainty which will make them reluctant to participate or to submit high bids.

A more extensive discussion of the methods for selecting licensees can be found in [Section 3 of this module](#).

5.7.1 Types of Spectrum Auctions

There are several circumstances where an auction can be considered as a means of assigning licences:

1. The simplest case is one in which a single licence is offered for auction in a self-standing process.
2. When two or more identical or complementary licences are offered, they can be offered sequentially or simultaneously. Where each licence is local, a simultaneous auction can allow firms to piece together local licences to provide broader coverage.
3. The licence(s) can be assigned on the basis of a so-called 'open bidding' or public process, with bids visible to other parties, or on a 'sealed tender' system, under which each party marks a single private offer; there are numerous alternative variants of open auctioning, one of which is the so-called clock auction.
4. The auction can have a minimum acceptable bid or 'reserve price'.

Some examples are given below:

- A spectrum regulator proposes to assign a single licence for the provision of a national second generation mobile telephone service. The successful applicant must commit itself to providing coverage to 50% of the land area and 80% the population. Sealed bids must be submitted by a specified date, by firms which have pre-qualified (i.e. have shown their competence to become a licensee). The winner is the firm which bids the most.
- Two or more licences to provide national 3G mobile services are auctioned. Pre-qualified applicants bid against each other in an open bidding auction. They have the opportunity to submit new bids for the licences at pre-specified intervals. The auction ends when the winning bids for each licence are the same, in terms of bidder and sum bid, as they were in the previous round. To ensure completion of such an auction, firms must be made to bid at a specified frequency.
- This example is similar to the 3G example above, except that there is restriction as to the use to which the winning competitor can put the spectrum (provided that interference conditions are met). Such auctions are said to exhibit technology- and service-neutrality. A country's territory is divided into, for instance, twenty areas, and three (identical or similar) licences are auctioned in each area (sixty in all). The procedure is an open bidding one. At each round, a firm can bid for one licence in each region. This procedure makes it possible for firms to put together a national service by bidding in all areas simultaneously. At the opposite extreme a firm can bid to provide a local service in one area only.
- An ascending clock auction is a procedure for selling multiple identical licences which requires the auctioneer to announce prices to bidders that increase over time (ascend with the clock) and bidders choose whether to accept or reject the announced prices. The auction is over when the number of bids equals the number of licences. The winning bidders all pay the required bid amount and each of them is assigned an identical licence. Variants of the clock auction can accommodate differences among licences, via a separate

sequence of prices for each one. Clock auctions can also be combined with a subsequent phases to deal with bids for packages of complementary licences.

The choice of auction mode will vary with the nature of licences made available, the number and nature of firms with an interest in theirs and the regulator's or government's objectives. There are a number of trade-offs between, for example, the advantages which an open auctioning system has in spreading knowledge among firms about other firms' valuations, hence encouraging higher bidding, and the opportunities for collusion among bidders which the communication present in open auctioning may facilitate. As a result, each set of circumstances tends to require an individual solution.

5.7.2 Specifying Rights and Obligations

A successful auction requires a clear understanding by participants of what rights and obligations are available to the winner or will be imposed upon them. If there is uncertainty about this, it will discourage competitive bidding. Auctions differ in two main ways: in the number of lots (or licences) made available and the way the auction is conducted. There has been a significant number of mobile licenses grant by auction around the world and they form a good basis for analysis and understanding. In relation to these wireless communication licences, some the the key variables in designing the auction are:

1. The number of licences to be offered to the service and in which band: this decision is of fundamental importance, since it determines the structure of the services market. The objective of maximizing consumer welfare suggests the harnessing of competitive forces to the maximum – i.e., issuing, subject to spectrum availability, as many licences as the market will be able to support (plus one or two extras to permit freedom of entry into the market);
2. Any commitments made at the time of the auction relating to restrictions on the award of subsequent licences;
3. Whether national or local regional licences are issued; here the regulator may find it helpful to anticipate the kind of business plans (national or regional) firms are likely to have and make licences available, accordingly there is nothing to preclude a mixture of national and regional licences;
4. How long the licences will last: too short a period may discourage investment in the services, while too long a period may allow the spectrum in question to stagnate if it cannot be sold on for another purpose;
5. Any obligations a licensee may have to make periodic payments in the course of the licence;
6. Any network roll-out obligations or 'use it or lose it' clause;
7. Any foreign ownership restrictions.

All these aspects influence the expected revenues from the auction, and their expected impact on consumer welfare.

5.7.3 Rules and Procedures for Spectrum Auctions

Auctions only work properly when there are clear rules attached to them which all participants understand. These should be designed both to prevent collusion and to bring the proceedings to an efficient close. Regulators have to stipulate the rules in some detail in bidding documents.

The nature of the rules required varies from the very basic to the more sophisticated, depending on the form of auction chosen.

In the former category, basic housekeeping rules have to be established to ensure that scaled bid remain confidential until the 'official' opening date, and that competing bids in an 'open bidding' system are delivered simultaneously by all competitors.

To bring complex multiple round auctions to a close, it is necessary to force all participants to bid at regular intervals (according to so-called 'activity rules'), rather than make unexpected bids as the end of the process approaches, and to ensure that there is a minimum bid increment, to prevent bids rising endlessly by small amounts. Both the Canadian Advanced Wireless Services (AWS) and other spectrum in the 2GHz range auction and the Finnish 2500-2690 MHz spectrum auction featured activity rules, for example.

In one US PCS auction, it was discovered that participants were using the amounts they bid to signal to competitors – more precisely to 'warn them off' bidding for certain lots. As a result, a rule was introduced which required bids to be in round numbers, which could not send signals of this type.

RELATED MATERIALS

[Module 3, "Authorization of Telecommunication/ICT Services", Section 4.1.1, "Features of a Multiple Round Auction: The Canadian Example"](#)

5.7.4 Spectrum Auctions in Practice

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Literally hundreds of spectrum auctions have been conducted in the past ten years. Some have attracted great attention by generating billions of euros or dollars from bidders. Most have been on a much smaller scale. A range of methods have been employed and some have been judged successful, others found to have failed. Regulators can learn from this experience to choose a procedure which meets their circumstances.

Here we offer an account of a selection of spectrum auctions; it is not intended to be complete but to identify useful precedents.

Great experience has been accumulated in the USA, where the Federal Communication Commission (FCC) has run a series of auctions starting in July 1994, and continuing in 2007.

One commentator has drawn the following lessons from these auctions, which typically have involved the auctioning of multiple local licences which can be aggregated to provide regional or national services:

- Open bidding is better than a single sealed bid;
- Simultaneous open bidding is better than a sequential auction, in which licences are auctioned one after another;
- Allowing bidders to bid for packages (e.g. a group of local licences capable of providing wider area services) is desirable in principle but found (in 2001) to be too difficult in practice;
- Collusion is a major problem, which can be countered by concealing bidders' identities (i.e. publishing the bid, but not who made them), and setting high reserve prices, amongst other ways.

The most conspicuous recent auctions have probably been those for 3G (UMTS) licences in Europe. In 2000-2001 a sequence of auctions took place, beginning with the UK, where operators bid very large amounts (USD 35 billion for five 3G licences). Although revenues from the German auction several months later were also high, thereafter they declined on a per capita basis. Many analysts of these processes have now been published – among the best that by Paul Klemperer, to be found in the references below.

Where a small number of national licences are being auctioned, for example in a developing country, a simpler approach is possible. A good example of this is provided by the auction of three identical GSM licences in Nigeria in 2002. This was done with a carefully thought-out process which involved invitation and pre-qualification stages, as well as the auction itself. Recognising the problem of collusion, the designers made alternative plans which depended on the number of qualified bidders for the three licences. If they were five or more - i.e., if bidders exceeded the number of licences by more than one, an ascending clock auction would be held. If these were only four, a sealed bid process would be implemented.

RELATED MATERIALS

[Module 3, "Authorization of Telecommunication/ICT Services", Section 4.1.1, "Features of a Multiple Round Auction: The Canadian Example"](#)

5.8 Secondary Markets

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When licences for spectrum are being initially offered, auctions can create competition for spectrum however it is often the case that the successful licensee is precluded from trading the licence at anytime afterward. Continuous reselling of spectrum becomes possible when a secondary market operated in respect of either spectrum that has been auctioned or of spectrum allocated initially by administrative methods but which is now been cleared for trading. When a secondary market is combined with flexibility in spectrum use, licences can be deployed by the original licensee or, after a trade, by another firm in a new innovative use. Auctions alone merely introduce an initial market-based selection by organizations that will exercise highly specified spectrum usage rights, whereas secondary trading seeks to develop a primarily market-based solution both for spectrum assignment and for spectrum allocation, on the condition that flexibility in use is permitted.

For more details on market-based sharing see sections [4.2.4 Market-based sharing](#) and [4.3.4 Spectrum sharing in practice](#) of this module.

5.8.1 Defining Property Rights for Spectrum Trading

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Where trading occurs, it is desirable or even necessary that buyer and seller – as well as the regulator and the courts where appropriate – share the same understanding of this bundle of rights and obligations which is changing hands. This is true of land, for example, and also of a spectrum licence. Clearly defined property rights are thus a precondition for efficient spectrum markets.

The dimensions of rights and obligations in a spectrum licence include:

1. The band which is available for use;
2. The geographical area in which it can be used;
3. The period for which the licence is entitled;
4. The uses to which it can be put;

5. The licensee's degree of protection from other users;
6. The licensee's obligation not to interfere with other spectrum user's rights.

5.9 Administered Incentive Prices (AIP)

Administered Incentive Prices (AIP) is used by some regulators as an additional tool to promote efficiency in spectrum use within a framework of administrative spectrum management. Licences are issued by an administrative means but they carry with them an obligation to make a payment to the regulator or government which is designed to promote efficient spectrum use – not simply to recover spectrum management costs. The idea is that if a user has unused spectrum, it will choose to return it rather than pay the charge. Also, if a user can pay a lower fee by using spectrum more efficiently, that user may adopt more spectrum-efficient operations. The cost recovery prices noted above can also cause a user to return excess spectrum or to use spectrum more efficiently, but they may be too low to impose an appropriate level of discipline on licensees. This arises because often the value to a nation of its spectrum greatly exceeds the cost of running the spectrum regulator.

5.9.1 Introduction to Administered Incentive Prices

5.9.2 The Opportunity Cost of Spectrum

In the absence of a primary or secondary market for spectrum (or even in their presence), it may be desirable to give licensees an incentive to economise on spectrum use, in order to discourage extravagant use or hoarding. This applies both to private sector (or commercial) users and to public sector users.

There are various ways of doing this, including regular audits. By setting a charge for spectrum steady pressure is imposed on users to economise, just as appropriate electricity prices discourage waste of electricity.

To apply the right level of price pressure without forcing excessive economies which leave valuable spectrum unused, spectrum should be priced in any use at its opportunity cost. This can be found by estimating the other resources which would be saved if the same spectrum were redeployed to produce another service, or the extra costs which would be incurred if it were not available to provide the service for which it is currently employed, so service had to be produced with less spectrum.

As an example, spectrum used from mobile communications can have its opportunity cost computed in either of the above two ways. Either we can ask: "how much extra would it cost to provide mobile communications with less spectrum – i.e., with better spectrum re-use, hence lower power and use of more base stations?" Or we can ask: "if the spectrum were reallocated to another use, what costs would the new spectrum licensee save in the production of that service?" Both of these are possible measures of opportunity costs, but we should also take the higher of the two (or more) estimates provided because that measures the cost to society of keeping the spectrum in its current use.

Note that this approach only measures the potential of spectrum to reduce costs of services, not its role in generating excess profits from monopolisation of services. Hence the opportunity cost is not an estimate of the market price of leasing or buying spectrum, as this would include any 'monopoly profits'. If the regulatory body wants estimates of the market price of any spectrum, it might examine price levels in comparable commercial transactions, such as auction proceeds or secondary trading.

5.9.3 Administered Incentive Prices in Practice

When spectrum licences are assigned using an administered method or even sometimes by auction, regulators may wish to impose extra pressure to economise by charging an annual fee for spectrum use. Charges set by the regulator with this objective in mind are often called 'administered incentive prices' (AIP).

At first sight, cost recovery fees might seem to fall in this category, but the primary motivation for this method is to fund the spectrum regulator (and perhaps gain some additional revenue). As a consequence, such fees may not be calculated to promote efficient spectrum use. In practice however, there is no 'bright line' between the two pricing concepts, and both motives may be present in differing degrees, as illustrated by the Practice Note on cost recovery pricing in Australia (see [section 5.2.2](#)).

A good way of setting AIP is to make them equal the 'opportunity cost' of the frequency in question. As explained in [section 5.7.1](#) this can

be calculated by the increase in cost which would occur in producing the same service if the spectrum were replaced by another input – a different frequency or a non-spectrum input.

Doing this in practice will require the regulator to identify the relevant alternative or alternatives, and perform the necessary cost calculations. This will inevitably produce results which are only approximately accurate, but the regulator may conclude that it is better to apply incentives for cost efficiency via a price which is only approximately right, then not to charge any price at all.

If AIP's are based on opportunity cost, then it follows that they should be zero (and replaced, probably, by cost recovery prices based on direct cost only) if the spectrum has no alternative use. This might arise because:

- there is no shortage of spectrum in the relevant frequency, so that all users can be accommodated;
- there is a legal impediment to using the spectrum in question for other purposes; this might apply for instance, to spectrum used for the purposes of aeronautical communication under the auspices of the International Civil Aviation Organisation (ICAO).

An alternative way of setting AIP is to use prices observed in market transactions in the same or related frequencies. These could be taken from winning bids in auctions or from secondary trades of existing licences. These transaction prices will embody not only 'opportunity costs' – the cost-saving potential of the spectrum licence, but also any excess profits which the licence holder can derive through exclusivity or market power. As a result, they should be used with caution. For example, suppose that two mobile licences have been auctioned. Bids may well have been based on business plans which anticipated high mobile telephone charges, based on limited competition. If a subsequent entrant faced an administered price equal to these bids, it might find it uneconomic to enter the mobile market, as the profits achievable in a more competitive market might not be enough to cover so high a charge. This shows how an excessive administered price can leave spectrum underutilised.

In conclusion, AIP is another tool available to regulators to encourage spectrum efficiency. It is applicable in an administrative regime for spectrum assignments and can be applied to private and public sector users. But the regulator must be sure that the AIP are taking effect. For example, if a ministry paying AIP on spectrum simply has its budgetary allocation increased to allow it to pay, there is no incentive to economize and the regime is ineffectual.

5.9.4 Adjusting AIP spectrum prices

An important feature of the price for most objects is that it can change over time in response to scarcity, substitutes and changes in consumer tastes. To the extent prices change in well ordered markets, the prices of spectrum will change when prices are determined by market methods.

What of administered prices and AIP? Again, prices can change as allocations and availability are altered through international or national processes. If administrative scarcity is the dominant characteristic in certain bands improving availability and access should have downward pressure on spectrum prices. As regulators become more efficient in the management of radio spectrum, there is justification for a reduction in that portion of spectrum fees that are related to cost recovery.

As we have seen AIP's for a particular band or service are determined by estimating the opportunity cost of the existing service with the best alternative use. As opportunity costs change reflecting both technological improvements and changes in the service offering then we can expect AIP's to be adjusted lower. This is the case with the prices determined by Ofcom. Ofcom periodically re-calculates AIP for various services and adjusts some prices upwards and others downwards.

Should the price of spectrum in bands adjacent to bands reflecting either an opportunity cost or market-prices go up in price in some synchronous manner? The answer to this question depends on whether the bands in question are used for similar services. Market-based methods will resolve the price question quite readily whereas the spectrum manager will need to adjust the price through an administrative process and possibly run the potential for both delay and inaccuracy.

6 Spectrum Monitoring and Compliance

Spectrum monitoring is one of four key spectrum management functions which include spectrum planning, spectrum engineering and spectrum authorization. Spectrum monitoring helps spectrum managers to plan and use frequencies, avoid incompatible usage, and identify sources of harmful interference. Key spectrum monitoring activities explained in this section include data collection and compliance enforcement.

Properly designed and functioning spectrum management processes including planning, authorization and engineering activities require data derived from monitoring technical procedures and from components which are characterized by varying degrees of complexity and cost. Spectrum monitoring and compliance activities help users to avoid incompatible frequency usage through identification of sources of harmful interference.

Furthermore, spectrum use planning and resolution of spectrum scarcity issues can be accomplished through study and analysis of spectrum occupancy data. Maintaining interference free assignments includes the use of data and electro magnetic compatibility (EMC) verification activities, as well as monitoring and enforcement activities needed to ensure user compliance with licence conditions and technical standards.

In the next three parts of this section, we expand on the topic of Spectrum Monitoring and demonstrate its importance in supporting spectrum management activities. In [the first section](#), we provide more detailed explanations of spectrum monitoring objectives, activities and strategies. Spectrum monitoring technology is outlined in [the second section](#). The [last section](#) deals with compliance enforcement activities.

6.1 Spectrum Monitoring

Even though electromagnetic spectrum is theoretically boundless, the portion currently useful for key applications such as communications, while substantial, is finite. In practice, the properties of radio wave propagation and electronic equipment limit radio communications to frequencies allocated between 9 KHz and 30 GHz. These properties also constrain particular types of communications systems to certain portions of the allocated spectrum, limiting the spectrum available for specific uses.

The demand for interference-free frequency assignments is steadily increasing. This is a result of the worldwide liberalization of telecommunications, the subsequent appearance of new market entrants along existing operators of competitive wireless services, and users of frequencies for non-telecommunications applications. Making interference-free assignments requires the use of data and involves Electromagnetic Compatibility (EMC) verification activities. These monitoring and enforcement activities are also needed to ensure user compliance with licence conditions.

Accomplishing this involves several management and process models. Monitoring and enforcement of licence and technical standards has traditionally been a responsibility of spectrum regulators, whether within independent agencies, or attached to the Ministry of Telecommunications. Departments such as Defence and Transport also often have responsibility over frequencies allocated to governmental use. In addition to public sector agencies, private sector participants are sometimes involved in the monitoring and problem resolution processes. These include industry associations, advisory councils, etc. In some countries, band management organizations govern specified frequency ranges under government authorization.

Regulators in developing countries may not have access to a sufficient amount of monitoring capacity or expertise to engage in the full range of monitoring activities. Careful decisions are needed to determine what investments to make in equipment and development of processes or formalized activity. Administrators will also have to decide what use of which segments of spectrum are most important to monitor. Priorities will need to be set to make efficient use of existing equipment and capabilities, including outsourcing and utilizing existing industry sector resources.

In the next sections we discuss [spectrum monitoring objectives](#) and provide an overview of related technical topics including: [emissions and interference](#); a description of [spectrum monitoring activities](#), as well as a perspective on [how countries cooperate and coordinate monitoring activities](#).

6.1.1 Spectrum Monitoring Objectives

Spectrum Planning and Authorization are central functions supported by spectrum monitoring. Monitoring supplies information used in determining compliance with rules and regulation, such as license conditions, and in achieving compliance with technical and operational standards. It provides general measurements which are used by the spectrum manager to understand and plan channel and band usage as well as confirm the effectiveness of current planning and authorization activities. Understanding the level of spectrum use or occupancy in comparison to assignments is important for efficient use of the spectrum resource. Spectrum monitoring provides statistical information on the technical and operational nature of spectrum occupancy. Conversely, spectrum authorization and spectrum engineering functions support spectrum monitoring by providing accurate, complete and timely information on current assignments and licences.

The overall goal of spectrum monitoring activities is to support the proper functioning of the general process of spectrum management. Central objectives for spectrum managers include the following:

- Spectrum efficiency in determining planned and actual frequency usage and occupancy, assessing availability of spectrum for future uses;
- Compliance with national spectrum management regulations to shape and sustain radio environments and user behaviour, maximizing the benefit of the spectrum resource to society;
- Resolution of interference problems for existing and potential users.

One radiocommunication system is more "spectrum efficient" than another if it conveys the desired information using less of the spectrum resource. Spectrum efficiency also involves the arrangement of communication systems within the spectrum resource. In this broader sense, spectrum is used inefficiently when systems are not packed together as tightly as possible in frequency bands (as when excessive guard bands are used), or when portions of frequency bands are unused while other bands with similar physical characteristics are congested. The allocation of frequency bands, the development of channeling plans, and the assignment of frequencies to specific systems all affect spectrum efficiency.

In order to promote spectrum efficiency, spectrum managers must possess some means of quantifying spectrum use and evaluating various radio technologies and frequency selection techniques. Management decisions can then be based on the relative spectrum efficiency of the various technologies and techniques. Data is collected through spectrum monitoring measures of spectrum occupancy and utilization for purposes of making assignments including the effects of spectrum reuse and band clearing efforts. As well, as spectrum becomes scarcer in highly congested areas, monitoring data is used to support spectrum engineering activities including validation of tolerance levels, determining the probability of interference and development of band-sharing strategies.

In addition to supporting assignment and authorization activities, spectrum monitoring supports the second goal: compliance with licence conditions and regulations through determination of deviations from authorized parameters, identification of sources of interference and location of legal and illegal transmitters.

A radio system can deny the use of part of the spectrum resource to another system that would either cause interference to, or experience interference from, the first system. A radio system is said to "use" spectrum resources when it denies other systems the use of those resources. Spectrum use can be quantified, subject to certain assumptions, both for a single radiocommunication system and for a related group of systems.

The facilities, equipment and approach employed in achieving these objectives will depend heavily on current use and congestion, technical capacity of the spectrum management organization and funding of spectrum management operations.

6.1.2 Emissions, Interference and Spectrum Use

This section explains the differences in meaning between emissions and interference and conveys the importance of each to spectrum monitoring. It also provides an explanation for spectrum use and occupancy.

The International Telecommunication Union has created a system which classifies radio emissions according to the bandwidth, method of modulation, nature of the modulating signal, and type of information transmitted on the carrier signal. These form the technical basis for establishing equipment specifications for radio systems designed to operate within certain frequencies.

Emissions of a radio transmitter are authorized to an assigned frequency band within the necessary bandwidth and tolerance for the frequency band. Emissions which do not meet technical parameters are unwanted emissions consisting of spurious emissions and out-of-band emissions. These types of emissions can be generated accidentally or through distortions caused by various components of the radio system.

Transmission of radio signals emitted by a radio transmitter can therefore be in-band in accordance with technical parameters or unwanted and due to several causes including out-of-band emissions and spurious emissions.

Electromagnetic Interference (EMI) is a term applied to unwanted emissions from both intentional and unintentional radiators. EMI or interference is the negative effect on reception of radio signals by a radio receiver caused by emissions by radio transmitters or other sources of electromagnetic waves. The negative effect on reception can vary by degree from permissible, to acceptable to harmful interference resulting in partial degradation to complete loss of information. Other sources of electromagnetic waves causing interference

include devices such as radio receivers, electrical motors, and electronic devices. The need to turn off computers, video players, and CD players during take-off in an aircraft is due in part to the possibility of interference to navigational and communication aids.

Spectrum managers are therefore interested in both emissions and interference. Emissions by transmitters can become a source of interference. Planning to use frequencies requires that the spectrum manager understand how frequencies are being used and the technical characteristics and performance of the transmission devices operating within and adjacent to the frequency band(s). Interference causes problems and can ultimately impair radiocommunication services. Determining the nature and source of interference are important objectives for the spectrum manager.

6.1.3 Spectrum Monitoring Activities

This section outlines the monitoring activities associated with specific spectrum monitoring objectives reviewed in [Section 6.1.1: Spectrum Management Objectives](#).

Compliance with Rules and Regulations

Monitoring is done to obtain detailed information on the technical or operational characteristics of radio systems. Radio Equipment Standards are discussed in [Section 2.4.4](#). The spectrum manager will monitor radio equipment to determine conformity with applicable standards. This can be done as part of an equipment certification process where measurements can be taken and recorded and then used in analyzing the compatibility of radio systems - Electromagnetic Compatibility (EMC).

One of the most important technical parameters to measure is the emission of radio transmitters. This is done to determine whether the transmitter is operating within specified limits.

The modulation techniques and types of systems employed and frequencies vary. The spectrum manager needs to choose the measuring system carefully and to ensure capabilities exist with the spectrum management agency to effectively monitor and analyze frequency bands. Circumstances will vary by country and monitoring solutions should be tailored to meet needs, budget and institutional capacity.

Interference Issues

Spectrum monitoring activities determine measurements of radio waves and radiation causing interference to authorized transmitters and receivers. Interference may be the result of authorized emissions causing unintended results such as spurious emissions. Interference may also be caused by unauthorized transmitters or devices operating beyond technical specifications. In either case, the spectrum manager will use a combination of engineering analysis and data obtained from spectrum measurements to resolve problems associated with interference problems.

The identification of unauthorized transmitters can be very difficult to achieve, especially in congested areas and where various services share the same frequencies. In some bands, where spectrum sharing is encouraged through the use of Class Licences or Radio Frequency Authorizations, no protection is provided from acceptable levels of interference. For more information on this topic, see [Section 3 Authorizations](#) and [Section 4 Spectrum Sharing](#).

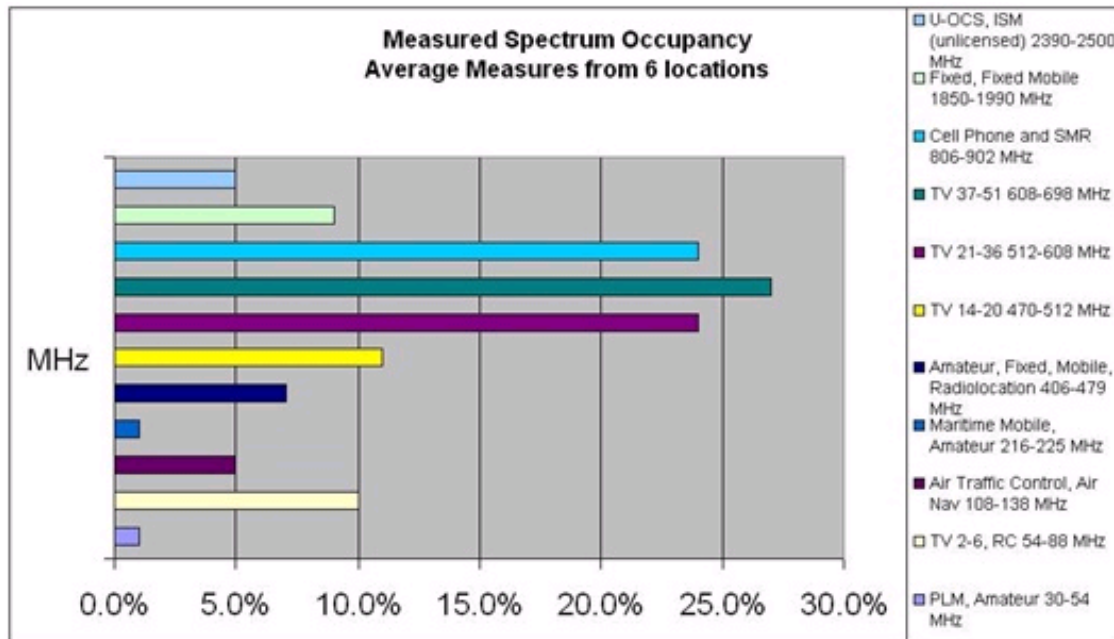
For a brief description of common types of interference see [Section 6.3.2: Solving Interference Problems](#).

Frequency Use and Occupancy

Access to radio spectrum is at a crossroads. More and more technological alternatives are becoming available and demand from both public and private sectors is increasing very rapidly, if not exponentially. There is increasing recognition that the root of the problem is that most of the spectrum is actually unused, and that the present system of spectral regulation is grossly inefficient. Current spectral regulation is based upon the premise that slices of the spectrum, representing uses within specified upper and lower frequency bounds, must be treated as exclusive domains of single entities: the recipients of exclusive licences to use specific frequency bands.

Spectrum measurements are critical to policy makers and researchers in the development of new spectrum access technologies. Specifically, spectrum occupancy studies identify what spectrum bands have low or no active utilization (and thus may be appropriate for spectrum sharing). They provide information on the signal characteristics within these bands, which is needed to design spectrum sharing algorithms.

Figure: Sample Spectrum Occupancy Report



Note: Each band averaged over six locations.

Source: National Science Foundation: M.A. McHenry Shared Spectrum Co.

6.1.4 International Spectrum Monitoring Cooperation

Member countries of the International Telecommunication Union typically operate monitoring facilities which aid spectrum managers in the prevention, detection, and control of (harmful) interference to radio transmitters. This is done to ensure that frequencies are used in accordance with the internationally planned spectrum framework. Since it is recognized that development and duplication of monitoring facilities is both uneconomical and operationally inefficient, cooperation exists among member countries in the operation of an international monitoring system. Article 16 of the Radio Regulations lays down the provisions governing the establishment and operation of the international monitoring system.

Stations comprising the international system check for transmissions that have effects beyond national boundaries, particularly for frequencies below 30 MHz, are in accordance with the internationally agreed conditions of operation. This includes checking frequency, bandwidth, emission type and usage. Where non-compliance with any prescribed condition is determined, the ITU provides for an infringement report to be sent via the Radiocommunication Bureau to the country responsible.

A good example of the far-reaching implications of interference is the international cooperation is demonstrated in the case of maritime coast stations and interference with maritime mobile services in New Zealand, Belgium and the United States.

Cooperation also occurs between countries on a bilateral basis and involves non-governmental organizations and industry associations who advise regulators on policy and technical matters. For example, broadcast and microwave propagation issues and solutions are identified and analyzed by associations and confirmed through spectrum monitoring tasks performed by the regulator.

6.2 Spectrum Monitoring Technology

Fixed, remote, unmanned and mobile monitoring stations can be combined to provide a network of integrated tools for verification of licensing compliance, channel occupancy, spectrum planning, and regulatory enforcement. Those can also provide greater flexibility in the design of national and regional monitoring systems. Monitoring equipment and integrated software tools are very complex and expensive and integrated monitoring systems can be very expensive as well. Fortunately, advances in computerization, monitoring technology, and security techniques have permitted greater use of remote unmanned monitoring techniques involving integrated spectrum observations. Alongside advances in technology, tactics and work practices are also changing. There is a reduced emphasis on continuous monitoring of all utilized spectrum to focus on areas of known problems and congestion. Memoranda of agreement can be used whereby an agency of government or non-governmental organizations (NGOs) assumes responsibility for essential monitoring activities and shares information on problems affecting civilian applications. Another example involves industry associations taking responsibility for monitoring and taking steps to resolve interference problems in fixed-link microwave services. Finally, the spectrum regulator concentrates its monitoring resources on public priority frequency bands affecting essential services, including air navigational aids, fire, safety, ambulance, police and areas of concentrated commercial activity such as is typically found in VHF/UHF.

Spectrum management policy decisions involve trade-offs: the desire and needs of the regulator and industry for complete and accurate

information; cost of implementation and maintenance; and accountability and technical capabilities.

6.2.1 Monitoring Equipment

The basic types of monitoring equipment include radio receivers, spectrum analyzers, direction-finding equipment and antenna. These basic types can be further categorized by frequency range (HF, VHF, UHF, etc.) and signal type – analogue or digital. With the advent of spread spectrum and computer-based radio technologies like Cognitive Radio, the sophistication, complexity and prices for monitoring equipment have risen. As well, the approaches to monitoring and the architecture of the spectrum manager's monitoring system have a bearing on the types of systems needed and the configuration of operations and resources. The approaches to system architecture are outlined in Monitoring System Architecture. Options and strategies for configuring and resourcing Spectrum Monitoring Operations are discussed in Monitoring Operations – Options and Strategies.

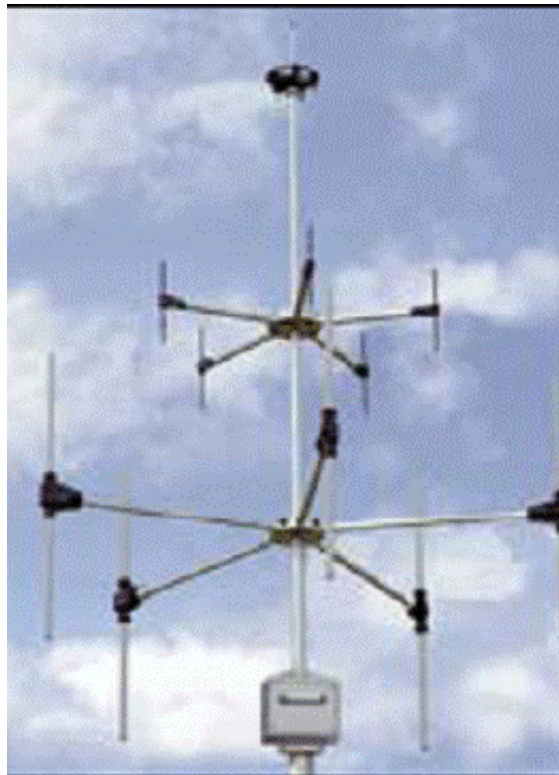
The regulator's monitoring capabilities depend on three types of equipment: antennas, spectrum analyzers, and radio direction-finding equipment.

Antennas

An antenna is simply an electronic component designed to radiate energy and transmit or receive radio waves. Antennas have practical use for the transmission and reception of radio frequency signals (broadcast radio, TV, etc.), which have different propagation characteristics and can transmit, in the case of low frequencies, over great distances. Different antenna types are used for different radio frequencies and for different coverages. All antennas radiate some energy in all directions but careful construction results in large directivity in certain directions and negligible power radiated in other directions. There are two fundamental types of antennas, which, with reference to a specific three-dimensional (usually horizontal or vertical) plane, are either omni-directional (radiate equally in the plane) or directional (radiate more in one direction than in the other).

Antennas are linked to either radio receivers or signal generators of direction-finding equipment. As mentioned in the previous paragraph, different antenna types are needed for each application. Antenna products encompass a wide range of highly sensitive active and passive antennas which can be applied in Mobile and Stationary Systems, providing complete coverage of the frequency range from 100 Hz to 30 GHz and beyond in the case of some manufacturers. Examples of different antenna types (HF or VHF) and application (stationary and mobile) are depicted below. Antennas are used often under extreme weather conditions and need to be designed to operate in those conditions.

Fixed VHF/UHF Station (Argus-Thales)



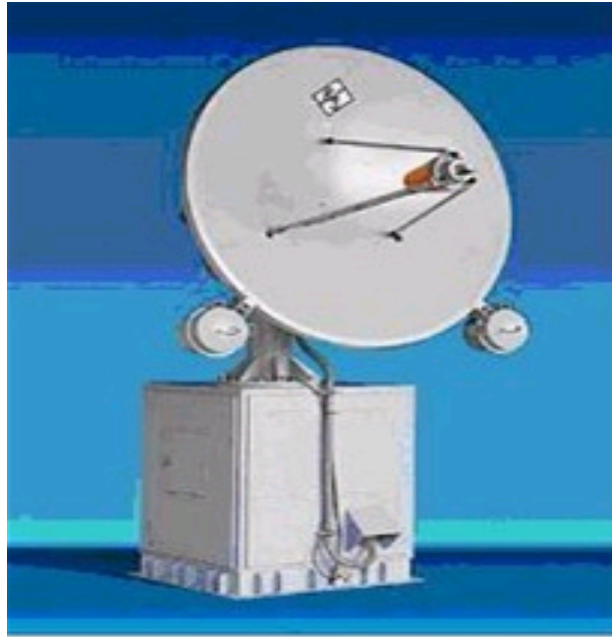
Mobile HF/VHF/UHF Antenna (Argus-Thales)



Fixed HF Antenna (Rohde & Schwarz)



Rotatable Microwave Antenna System - 1GHz to 40Ghz (Rohde & Schwarz)



Spectrum Analyzers

Since regulatory agencies allocate different frequencies for various radio services, it is critical that each service operate at the assigned frequency and within the allocated channel bandwidth. Due to scarcity, transmitters and other intentional radiators will be planned to operate at closely spaced adjacent frequencies. Power amplifiers and other components used in these systems are measured to determine the amount of signal energy that spills over into adjacent channels and causes interference. The concern is that these unwanted emissions, either radiated or conducted (through the power lines or other interconnecting wires), might impair the operation of other systems. The design or manufacture of electrical or electronic products also involves the testing for emission levels versus frequency according to Technical Standards set by various government agencies or industry standards bodies.

The common measurements taken by a spectrum analyzer include frequency, power, modulation, distortion, and noise. Understanding the spectral content of a signal is important, especially in systems with limited bandwidth. Transmitted power is another key measurement. Too little power may mean the signal cannot reach its intended destination. Too much power may drain batteries rapidly, create distortion, and cause excessively high operating temperatures. Measuring the quality of the modulation is important for making sure a system is working properly and that the information is being correctly transmitted by the system. Tests such as modulation degree, sideband amplitude, modulation quality and occupied bandwidth are examples of common analogue modulation measurements. It is important to note that for digital modulation techniques there are additional measurements which need to be taken, including: error vector magnitude (EVM) and phase error versus time, among other measurements.

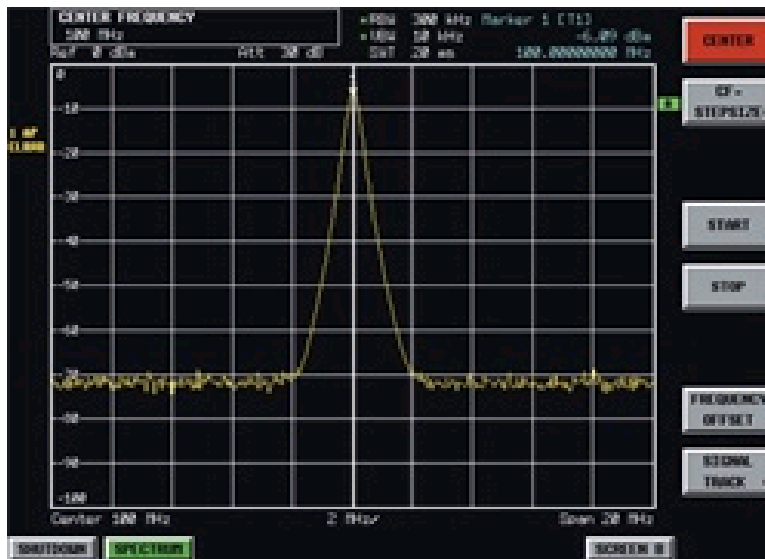
There are several basic types of spectrum analyzers. These are: Fourier, Vector Signal and Superheterodyne Analyzers. Each type is briefly described in the next few paragraphs.

Fourier signal analyzers measure the time-domain signal and then use digital signal processing (DSP) techniques to perform a fast Fourier transform (FFT) and display the signal in the frequency domain showing both phase as well as magnitude of the signal.

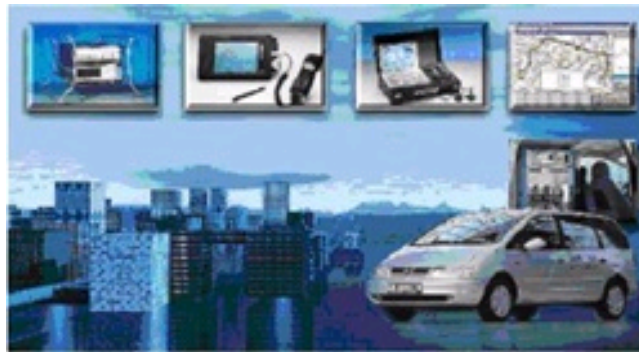
Like Fourier analyzers, Vector signal analyzers (VSA's) measure the time domain signal, but have the advantage of extending to the 5-6 GHz. RF frequency range. VSA's offer faster, higher-resolution spectrum measurements, demodulation, and advanced time-domain analysis. They are especially useful for characterizing complex signals such as burst, transient or modulated signals used in communications, video, broadcast, sonar, and ultrasound imaging applications.

Because the signals that people must analyze are becoming more complex, the latest generation of spectrum analyzers include many of the vector signal analysis capabilities previously found only in Fourier and Vector signal analyzers. Superheterodyne analyzers are able to mix; that is, to translate frequency at frequency ranges above the audio range.

Typical Spectrum Analyzer Display (Rohde & Schwarz)



Automated Field Strength Measurement Equipment (Rohde & Schwarz)



Radio Direction-Finding Equipment

Radio Direction-Finding, or RDF, is the technique for determining the direction of a radio transmission. Radio direction-finding using triangulation techniques can also be used to determine the location of a radio transmission. Radio direction-finding is used by spectrum managers to locate the source of radio frequency interference.

There are two common technical approaches to radio direction-finding. The first approach involves the use of directional antennas which are designed to be more sensitive to signals received in some directions rather than in others. As the antenna is turned in various directions, a signal being received will either increase or decrease in strength. All other things being equal, the direction in which the signal is strongest is the likely direction in which the radio transmitter is located. The movement of the antenna and the determination of the peak signal strength can be made by a human operator or can be done automatically by electronics.

The second approach exploits the effects of phase shift. Fixed antennas are deployed in a precise geometric pattern and an electronics system switches between the antennas very rapidly. By computing the amount of phase shift present on the signal from antenna to antenna, a direction to the signal source can be computed.

There are anomalies of radio propagation which at ground level can affect both of these techniques. Common potential problems include reflections or multi-path loss. In a multi-path situation, the radio signal may be arriving at the antenna or antennas from multiple directions, perhaps because the signal is reflecting off nearby buildings, hills, or metal structures such as fences. The strongest signal may, in fact, be coming from a reflection rather than the direct path, especially if the direct path includes terrain features that might attenuate the signal. This can result in false directional readings.

The preceding paragraphs provide a brief summary of the main types of equipment used in monitoring. The complexity and cost of equipment varies with the level of computer integration, number of functions and types of analysis performed and the speed at which a number of frequencies can be scanned and analyzed. Simple systems for VHF/UHF monitoring can be comprised of several fixed antennas, receivers and limited function spectrum analyzers. More complex systems can consist of multiple sites and mobile and fixed stations. Monitoring System Architecture is further explored in [Section 6.3.2](#).

RELATED INFORMATION

Recommended HF Receivers, Spectrum Monitoring Handbook, ITU, 2002: Chapter 2, Table 15, p. 135

Recommended VHF/UHF Receivers, Spectrum Monitoring Handbook, ITU, 2002: Chapter 2, Table 16, p. 136

6.2.2 Monitoring System Architecture

Design Considerations for Spectrum Monitoring Systems

Due to spectrum congestion and sophistication of wireless communication technologies, it is an ever-increasing challenge to monitor spectrum, particularly considering the rapid growth of wireless, satellite, and point-to-point communication devices. Regulators are asked to hunt for and resolve RF interference in this crowded and complex spectrum.

There are two likely scenarios. There is a-priori information on the emitters to be tracked or tested, e.g., approximate frequency and amplitude. Here, traditional spectrum analysis techniques and equipment will work extremely well. Alternately, there is no prior knowledge.

Without control of the RF/microwave airspace and with little information about the target signals, the RF spectrum-monitoring task is a discovery process. Signals of interest reveal themselves to spectrum monitoring because many wireless signals vary in power, duration, and bandwidth. Some of the complex interactions between systems may actually be harmonics of known emitters, translated into frequencies where they become unwanted interferers. There can be thousands, even tens of thousands of irrelevant signals that need to be ignored when capturing data on emissions of interest.

Key considerations in the design of spectrum monitoring systems include types of equipment, speed and sophistication of data capture and processing, degree of integration with software tools for analysis and comparison with other license and type approval data. Other considerations include proximity to active airspace, staff skills, and mobile versus fixed locations.

State-of-the-art spectrum monitoring equipment is highly integrated. Integration typically involves the use of graphical user interface (GUI) based spectrum management tools and systems which are specifically designed to operate multiple electronic components simultaneously and remotely over data protocols such as TCP/IP. This allows for an integrated network system for management of the radio spectrum using remote devices. These devices can be located at existing government sites and facilities on the outskirts of population centres. Remote devices permit access to monitoring equipment from anywhere through compatible computer, a modem and a telephone line or network connection (LAN or WAN). Remote devices can be controlled in several ways:

- Locally from the server;
- Remotely across a LAN;
- Modem over a WAN.

Architecture Components

There are equipment and organizational and functional aspects to architecting spectrum monitoring systems.

The key technical equipment components are described in [Section 6.3.1 Monitoring Equipment](#). Additional equipment components in a monitoring system include: buildings, power supplies, mobile vehicles and man portable components.

Organizational components include centralized, regional and remote locations for siting of monitoring equipment in stations and operational staffing or use of unmanned remote capabilities, where applicable.

In addition to technical equipment, functional components of spectrum monitoring systems include: central monitoring control; operational consoles for operation of equipment and analysis of data; and data networking and management systems for data communications and repository.

6.3 Enforcing Compliance

Spectrum management also requires that users comply with licence requirements and technical rules and regulations. Without effective regulations and enforcement procedures, the integrity of the spectrum management process can be compromised. The spectrum regulator needs an appropriate framework and process for responding to and managing complaints and for settling disputes. Consideration needs to be given to penalties, remedies, enforcement and alternative dispute resolution (ADR) mechanisms for industry disputes with the aim of ensuring rapid resolution.

6.3.1 Monitoring Compliance with Technical Standards

Monitoring is used to obtain detailed information on the technical and operational characteristics of radio systems which are in use or are being tested for future use. Measurements will typically include frequency, power and emission spectrum of a transmitter. Licence conditions can be verified against actual use of equipment aiding in the determination of electromagnetic compatibility (EMC). Because technical standards are associated with certain allocations and assignments, the spectrum manager can detect the existence of

unauthorized transmitters which affect other users by causing interference and by reducing the value of licensed spectrum.

6.3.2 Solving Interference Problems

Resolving interference problems is often a difficult task for spectrum managers since the source of interference is not necessarily known nor easily identified.

Coordination with the complainant is often needed, if only to know the frequency of the receiver operation. Direction finding equipment is often used to determine the source of interference. Deciding on what to use will depend on the range of the affected frequencies. Sources of interference can be from atmospheric effects such as precipitation, long-range HF and UHF frequencies from across national borders, or from intentional efforts to interfere with transmissions, a practice sometimes referred to as jamming.

Spectrum managers are particularly concerned with interference problems affecting public safety and security services such as ambulance, fire fighting, police, and navigational services at airports.

Other sources of offending interference can come from industrial applications of radio energy such as microwave dryers used in manufacturing. Understanding sources of emission, technical standards and the technical aspects of interference are the tools used by spectrum managers to resolve these types of interference problems.

6.3.3 Inspections

In the course of conducting exercises to resolve interference problems, the spectrum manager may be required to enter user premises and inspect radio equipment to determine compliance with licence conditions and technical standards.

An important aspect of fulfilling these tasks is the requirement under law and regulation to establish the powers, authorities, duties and obligations of the spectrum manager/inspector and protection of rights for the public under circumstances where inspection of property is necessary.

Equipment Seizure and other Enforcement Actions

There are (hopefully rare) occasions when the user of a transmitter causing harmful interference is endangering the public in a persistent and wilful manner and the reasonable course of action requires the spectrum manager to seize equipment to prevent such endangerment.

Again, it is necessary to provide the spectrum manager with the appropriate authority to seize equipment under carefully defined conditions to prevent abuses of power and ensure the user's right to due process.

When it is determined that harmful interference may be caused by any particular equipment, the spectrum manager may, by first informing the person in writing, direct the owner or user of that electrical, electronic or radiocommunication equipment to do, at their own expense, any one or more of the following:

- Take suitable measures to eliminate or reduce the interference or disturbance;
- Remedy a fault in or the improper operation of the equipment;
- Modify or alter the equipment; or
- Disconnect the equipment.

Otherwise, the owner or user risks having the equipment seized by the spectrum manager.

6.3.4 Equipment Seizure and other Enforcement Actions

There are (hopefully rare) occasions when the user of a transmitter causing harmful interference is endangering the public in a persistent and wilful manner and the reasonable course of action requires the spectrum manager to seize equipment preventing future endangerment.

Again, it is necessary to provide the spectrum manager with the appropriate authority to seize equipment under carefully defined conditions ensuring the user's right to due process and preventing abuses of power.

Typically, when the spectrum manager determines that harmful interference may be caused by any particular electrical, electronic or radiocommunication equipment, whether subject to licensing or not, the spectrum manager may, by first informing the person in writing, direct the owner or user of that electrical, electronic or radiocommunication equipment to do, at their own expense, any one or more of the following:

1. Take suitable measures to eliminate or reduce the interference or disturbance;
2. Remedy a fault in or the improper operation of the equipment;

3. Modify or alter the equipment; or
4. Disconnect the equipment.

Otherwise the owner or user risks having the equipment seized by the spectrum manager.

The Radio Regulations of Singapore, Trinidad and Tobago and Canada provide examples of the types of regulation used to define the actions of spectrum managers when it comes to enforcement action.

7 International Affairs

CHAPTER 7 TRANSLATIONS

 [Version française \(PDF\)](#)

 [Versión Española \(PDF\)](#)

Radio waves do not respect national borders and many uses of the radio frequency spectrum have an impact outside the territory of the country in which the operation occurs. International harmonization of spectrum utilization is important for many applications because of roaming users e.g., maritime, aeronautical, mobile telephony, etc. International harmonization can also reduce equipment costs through economies of scale and can reduce the possibility of harmful interference. There are two types of international activities, namely project activities and transactional activities.

7.1 Introduction to International Affairs

Radio waves do not respect national borders and many uses of the radio frequency spectrum have an impact outside the territory of the country in which the operation occurs. Sometimes this is deliberate as, for example, in short wave broadcasting or international satellite communications or sometimes it is simply unavoidable. International harmonization of spectrum utilization is also important for many applications because users of communications services are not stationary (roaming) e.g., maritime, aeronautical, mobile telephony, etc. International harmonization can also reduce equipment costs through economies of scale and can reduce the possibility of harmful interference.

The governance of spectrum use on a global basis is a core responsibility of the [International Telecommunication Union \(ITU\)](#) and, in particular, its [Radiocommunication Sector \(ITU-R\)](#). The ITU is a specialized agency of the United Nations with its headquarters located in Geneva, Switzerland. It is important to recognize that the ITU is not a global regulatory authority in the way that a national regulator is within its own jurisdiction since the rules for international regulation and cooperation are written by those governed by them, i.e., by the Member States of the ITU. These rules are administered by the ITU-R's Radiocommunication Bureau (BR) in Geneva and conformity with the rules is based on goodwill rather than on the kind of regulatory sanctions found at the national level. The mission of the ITU-R sector is, *inter alia*, to ensure rational, equitable, efficient and economical use of the radio frequency spectrum by all radiocommunication services, including those using satellite orbits and to carry out studies and adopt recommendations on radiocommunication matters.

The [ITU's Telecommunication Development Sector \(ITU-D\)](#) has well-established programmes of activities. These programmes are designed to facilitate telecommunication connectivity and access to information and communication services (ICTs), foster ICT policy as well as technology development, assist in regulatory and network readiness, expand human capacity through training programmes, formulate financing and cybersecurity strategies. Some of these programmes are also designed to address topics of interest to spectrum regulators. In addition to activities carried out within the ITU framework, there are often, of course, bilateral and multi-lateral agreements by which the use of spectrum is harmonized across national borders. There are two general categories of international activities, namely project activities and transactional activities.

7.2 Project Activities

International project activities are those which have a defined beginning and ending date. Like all types of project activities, tasks and sub-tasks can be defined and milestones established. Appropriate resources must be committed over the lifetime of the project.

The ITU World Radio Conference and related Regional Conferences and Study Groups are described [in the first of the four following sections](#). Projects undertaken by international bodies such as the World Trade Organization and the International Civil Aviation Organization are described [in Section 7.2.2](#). Project activities related to other global or regional inter-governmental organizations are highlighted [in Section 7.2.3](#). Bilateral and memoranda of agreement between countries are described [in the last section](#).

7.2.1 ITU Related Project Activities

Project activities of the ITU consist of, primarily, World Radio Conferences, Study Groups and Development Conferences. The general purpose and scope of each of these activities is described here in this section. A more detailed description of WRC [2003](#) and [2007](#) along with the agenda for [WRC 2011](#) can be found in the next section, [Recent World Radio Conferences](#).

[ITU radiocommunication conferences](#) are held every two to three years. One of the main jobs done at the radio conferences is the review, and, if necessary, revisions to the Radio Regulations (See [Section 2.3.4 Radio Regulations](#)), the international treaty governing the use of the radio-frequency spectrum and the geostationary-satellite and non-geostationary-satellite orbits.

ITU-R World and Regional Radiocommunication Conferences establish treaty level regulations, agreements and plans for the global use of the radio frequency spectrum. Revisions to treaties are made on the basis of an agenda determined by the [ITU Council](#), which takes into account recommendations made by previous world radiocommunication conferences.

The general scope of the agenda of world radiocommunication conferences is established four to six years in advance, with the final agenda set by the ITU Council two years before the conference, with the concurrence of a majority of Member States.

Under the terms of the ITU Constitution, a WRC can:

- revise the Radio Regulations and any associated frequency assignment and allotment plans;
- address any radiocommunication matter of worldwide character;
- instruct the Radio Regulations Board and the Radiocommunication Bureau, and review their activities;
- determine the questions to be studied by the Radiocommunication Assembly and related Study Groups in preparation for future Radiocommunication Conferences.

On the basis of contributions from administrations, the Special Committee, the Radiocommunication Study Groups, and other sources (see Article 19 of the Convention (Geneva, 1992)) concerning the regulatory, technical, operational and procedural matters to be considered by World and Regional Radiocommunication Conferences, the Conference Preparatory Meeting (CPM) shall prepare a consolidated report to be used in support of the work of such conferences.

[ITU-R Study Groups](#), in addition to advancing radiocommunication science, prepare the technical, regulatory and operational basis for the treaty level Radiocommunication Conferences. The work of the Study Groups is overseen by the Radiocommunication Assembly which normally takes place in association with a World Radiocommunication Conference. While other ITU-R Study Groups deal with specific radio services, ITU-R Study Group 1 focuses specifically on Spectrum Management and Study Group 3 addresses radiowave propagation. As part of its work, Study Group 1 has produced handbooks on national spectrum management, on spectrum monitoring and on computer-aided techniques for spectrum management.

Project activities include preparing for and participating in these ITU conferences, assemblies and meetings. It is important for all spectrum regulators to keep abreast of the activities undertaken within the ITU's Radiocommunication Sector (ITU-R) since many of these activities have a direct impact on the national regulation of the radio frequency spectrum. For more information on the broad scope of the ITU-R's activities, see (www.itu.int/ITU-R/).

In addition to ITU-R activities, the [ITU's Development Sector \(ITU-D\)](#) is committed, among other things, to assisting spectrum regulators in carrying out their responsibilities. This occurs through workshops and other training opportunities, publications, virtual conferences, the [Global Symposium for Regulators](#), regional meetings of regulators, sharing of legislation and country experiences, etc. For more information, see www.itu.int/ITU-D/treg/.

[ITU-D Study Group 2](#) on the development and management of telecommunication services and networks also addresses several topics related to spectrum management including the development of a software based [Spectrum Management System for Developing Countries \(SMS4DC\)](#), information on the calculation of spectrum fees, etc.

The ITU Development Conference adopted Resolution 9 (Rev. Doha, 2006) on the participation of countries, particularly developing countries, in spectrum management. Cooperative work has been performed pursuant to this Resolution by experts participating in a joint group between ITU-R and ITU-D. The text of this resolution is available at: www.itu.int/ITU-D/conferences/wtdc/2006/pdf/dohaactionplan.pdf

To follow all ITU activities related to spectrum management is very resource intensive and priorities must be established so that the most critical activities are closely monitored. A cost effective way of involvement in ITU work is to participate in the ITU related activities of regional and sub-regional telecom organizations. These organizations can be an efficient and effective way by which countries can influence global decisions. A brief description of these organizations is given below along with their web sites where more information may be found.

A compilation of the legislation of different countries may be found at: www.itu.int/ITU-D/treg/profiles/LegislationSelect.asp?lang=en

A database related to the establishment of spectrum fees is available at: www.itu.int/ITU-D/study_groups/SGP_2002-2006/SF-Database/index.asp

A set of Best Practice Guidelines for Spectrum Management to Promote Broadband Access adopted at the Global Symposium for Regulators 2005 is available at: www.itu.int/ITU-D/treg/bestpractices.html

Founded in 1977 as a specialized agency of the Organization of African Unity (now the [African Union](#)) in the field of telecommunications, the African Telecommunications Union (ATU) is a partnership between public and private stakeholders in the information and communication technology (ICT) sector.

ATU provides a forum for stakeholders involved in ICT to formulate effective policies and strategies aimed at improving access to information infrastructure and services. In addition, the Union represents the interests of its members at global decision-making conferences and promotes initiatives aimed at integrating regional markets, attracting investment in ICT infrastructure and building institutional and human capacity. The mission of the Union is, in fact, to promote the rapid development of info-communications in Africa in order to achieve universal access and full inter-country connectivity.

For more detail, see: www.atu-uat.org

ASIA-PACIFIC TELECOMMUNITY

The Asia-Pacific Telecommunity was established in July 1979 by a joint initiative of the United Nations Economic and Social Commission for Asia & the Pacific – UN ESCAP and the International Telecommunication Union (ITU).

The APT is a unique organization of Governments, telecom service providers, manufacturers of communication equipment, research & development organizations and other stakeholders active in the field of communication and information technology. The APT has 33 Members, 4 Associate Members and 103 Affiliate Members. Through its various programmes and activities, APT makes a significant contribution to the growth of the information and communication (ICT) sector especially the telecommunication sector in the Asia Pacific region. APT assists its members in their preparations for global conferences such as various ITU meetings as well as promoting regional harmonization for these events.

For more detail, see: www.aptsec.org

CARIBBEAN TELECOMMUNICATIONS UNION

The Caribbean Telecommunications Union was established by the Heads of the CARICOM Governments. At the time of the establishment of the CTU, key roles were played by the Caribbean Association of National Telecommunication Organizations (CANTO) and by the International Telecommunication Union.

For more detail, see: [Caribbean Telecommunications Union](#).

CEPT EUROPEAN CONFERENCE OF POSTAL AND TELECOMMUNICATIONS ADMINISTRATIONS

CEPT is composed of policy-makers and regulators. With its 45 Member States, CEPT now covers almost the entire geographical area of Europe. The roles and purposes of CEPT include, inter alia:

- providing mutual assistance among members with regard to the settlement of sovereign/regulatory issues;
- exerting an influence on the goals and priorities in the field of European Post and Telecommunications through common positions;
- strengthening and fostering more intensively co-operation with Eastern and Central European countries;
- promoting and facilitating relations between European regulators (e.g., through personal contacts);
- influencing, through common positions, developments within ITU and UPU in accordance with European goals;
- settling common problems.

The CEPT deals exclusively with sovereign issues and regulatory matters. It has established three committees, one on postal matters, CERP (Comité Européen de Réglementation Postale) and two on telecommunications issues: ERC (European Radiocommunications Committee) and ECTRA (European Committee for Regulatory Telecommunications Affairs). The field of responsibility for each committee is decided by CEPT's Plenary Assembly, while each committee establishes its own rules of procedure and elects its chairman.

The committees handle harmonization activities within their respective fields of responsibility and adopt recommendations and decisions. These recommendations and decisions are normally prepared by their working groups and project teams.

For more detail, see: www.cept.org

CITEL - INTER-AMERICAN TELECOMMUNICATION COMMISSION

The Inter-American Telecommunication Commission was established under the auspices of the Organization of American States. It has 35 Member States and over 200 Associate Members. It has been entrusted by the Heads of State at the Summits of the Americas with specific

mandates. CITEL has technical autonomy to perform its functions within the limits prescribed by the OAS Charter, its statutes and the mandates of the General Assembly. Its objectives include facilitating and promoting the continuous development of telecommunications.

- CITEL has a [Permanent Executive Committee \(COM/CITEL\)](#) consisting of eleven members, three Permanent Consultative Committees and one working group. The Committees are:
- Permanent Consultative Committee I (PCC I) which deals with [telecommunication standardization](#);
- Permanent Consultative Committee II (PCC II) dealing with [radiocommunications including broadcasting](#);
- A [steering committee](#); and,
- A [conference preparatory](#) working group whose members are all Member States of the Organization, Associate Members that represent various private telecommunication associations or companies, and Permanent Observers and regional and international organizations.

For more detail, see: www.citel.oas.org/

GCC - COOPERATION COUNCIL FOR THE ARAB STATES OF THE GULF

The objectives of the GCC are, *inter alia*:

1. To effect coordination, integration and inter-connection between Member States in all fields in order to achieve unity between them;
2. To deepen and strengthen relations, links and areas of cooperation between their peoples in various fields; and,
3. To formulate similar regulations in various fields including the following:
 - Economic and financial affairs;
 - Commerce, customs and communications;
 - Education and culture.

For more detail, see: www.gccsg.org/eng/index.php

RCC - REGIONAL COMMONWEALTH IN THE FIELD OF COMMUNICATIONS

The Regional Commonwealth in the field of Communications (RCC) was established on December 17, 1991 in Moscow by the Heads of Communications Administrations (CA) of independent states. Its mission is to carry out cooperation among new independent states in the field of telecommunication and postal communication, including:

- harmonization of the development of communications networks and facilities;
- coordination in the field of scientific and technical policy;
- radio spectrum management;
- tariff policies for communication services and settlements;
- staff training;
- interaction with the international organizations in the field of communications and informatization;
- information interchange, etc.

The supreme organ of the RCC is the Board of the Heads of the Communications Administrations. The RCC Board and the Coordination Council direct the work of several Commissions including one on regulation of frequency spectrum use. The RCC also provides a forum for coordination of Member State's participation in ITU activities.

For more detail, see: www.rcc.org.ru/en/

7.2.2 Recent ITU World Radio (WRC) and Regional Radio Conferences (RRC)

ITU World Radiocommunication Conference – 2003: Important decisions were taken on a global allocation at 5 GHz. for mobile wireless access systems thus paving the way for the use of wireless devices that do not require individual licences that can be used to create broadband networks in homes, offices and schools. These networks are also used in public facilities in so-called hot spots such as airports, cafés, hotels, hospitals, train stations and conference sites to offer broadband access to the Internet. The use of these frequency bands is subject to provisions that provide for interference mitigation mechanisms and power emission limits to avoid interference into other radiocommunication services operating in the same spectrum range.

The 2003 conference also adopted a new Resolution which paves the way for the deployment of new technologies for wideband and broadband public protection and disaster relief applications. WRC-2003 opened the door for the commercial deployment of a new mobile

information service: two-way real-time broadband connectivity to aircraft passengers and crew. There were many other decisions dealing with other services such as; aeronautical services, future development of 3G mobile applications, earth stations on board vessels, the protection of radio astronomy, amateur radio regulations, the sound broadcasting satellite service, the radionavigation-satellite service, sharing criteria for VSAT applications and land, ship and airborne radars, etc.

ITU Regional Radiocommunication Conference – 2004: Inter Alia resolutions were adopted by the first session of the Regional Radiocommunication Conference held in Geneva for planning of the digital terrestrial broadcasting service in parts of Regions 1 and 3, in the frequency bands 174-230 MHz and 470-862 MHz (RRC-04).

ITU Regional Radiocommunication Conference – 2006: At RRC-06 A treaty agreement was signed at the conclusion of ITU's Regional Radiocommunication Conference (RRC-06) in Geneva, heralding the development of 'all-digital' terrestrial broadcast services for sound and television

ITU World Radiocommunication Conference – 2007: As discussed in WRC-07 Results and the Impact on Terrestrial Broadband Wireless Systems of the main issues at WRC-07 was the determination of new allocations and identification of spectrum for International Mobile Telecommunications (IMT-Advanced Wireless Broadband). One of the goals of the conference was to earmark spectrum at worldwide level to facilitate this development tapping into the higher frequencies beyond 1GHz increasing the capacity of new systems.

The ITU had commenced work on standardizing systems beyond IMT-2000 – now known as IMT-Advanced as early as 2000. Collectively, the IMT-2000 standards became the basis for what the industry and regulators came to refer to as "third-generation" or "3G" mobile systems, distinguishing them from the existing generations of analogue (1G) and digital (2G) mobile systems.² IMT-2000 envisioned transmission speeds ranging from 2 megabits per second (Mbit/s) on a stationary or nomadic basis, up to 348 kilobits per second (kbit/s) at vehicular speeds.

The actual standards as presented in the same GSR Discussion Paper referenced are:

- IMT-Direct-Sequence (IMT-DS) - Also known as Wideband-Code Division Multiple Access (W-CDMA) or UMTS Terrestrial Radio Access – Frequency Division Duplexing (UTRA-FDD), used in the Universal Mobile Telecommunications System (UMTS) 3G standard.
- IMT-Multi-Carrier (IMT-MC) - Also known as Code Division Multiple Access 2000 (CDMA2000), the successor to second-generation (2G) CDMA.
- IMT-Time-Division (IMT-TD) - This comprises: TD-CDMA (Time Division - Code Division Multiple Access) and TD-SCDMA (Time Division - Synchronous Code Division Multiple Access).
- IMT-Single Carrier (IMT-SC) - Also known as Enhanced Data rate for GSM Evolution or "EDGE" .
- IMT-Frequency Time (IMT-FT) also known as Digital Enhanced Cordless Telecommunications or "DECT".

While WiMAX and IMT-2000 developed along different paths, they really were evolving toward functional equivalency. Both provide broadband Internet access (roughly equivalent to a DSL line), as well as voice connectivity. WRC – 2007 ultimately adopted a resolution adding the WiMAX air interface specification as the 6th IMT-2000 technology and modified the general naming conventions for IMT technologies:

- 3G technologies will continue to be known as "IMT-2000";
- 4G technologies will be known as "IMT-Advanced", and;
- Collectively, all of the 3G and 4G technologies will be known as simply "IMT".

How to approach enhancing the international spectrum regulatory framework was an important issue discussed at WRC-07. Resolution 951 was agreed to and establishes guidelines for evaluating and developing concepts related to four options identified in the resolution for enhancing the 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.

ITU World Radiocommunication Conference – 2011. The agenda for WRC-11 can be viewed at www.itu.int/ITU-R/index.asp?category=study-groups&rlink=rcpm-wrc-11-studies&lang=en. There are over 35 agenda items with several examples listed below:

- 1.14 to consider requirements for new applications in the radiolocation service and review allocations or regulatory provisions for implementation of the radiolocation service in the range 30-300 MHz, in accordance with Resolution [COM6/14] (WRC-07);
- 1.19 to consider regulatory measures and their relevance, in order to enable the introduction of software-defined radio and cognitive radio systems, based on the results of ITU-R studies, in accordance with Resolution [COM6/18] (WRC-07);
- 1.20 to consider the results of ITU-R studies and spectrum identification for gateway links for high altitude platform stations (HAPS) in the range 5 850-7 075 MHz in order to support operations in the fixed and mobile services, in accordance with Resolution 734 (Rev.WRC-07).

7.2.3 Project Activities Related to Other Global Inter-governmental Organizations

It is important for countries to be aware of, and participate, as appropriate, in activities that touch on spectrum matters in other international bodies in addition to activities within the framework of the International Telecommunication Union. These organizations include, for example,

the World Trade Organization (WTO), the International Maritime Organization (IMO), the International Civil Aviation Organization (ICAO), the World Meteorological Organization (WMO), etc.

A reference is provided below to the West African Common Market (ECOWAS) approach which aims at developing common policies to achieve greater coordination and harmonization in the access, use and development of ICT technologies including wireless in support of development goals.

7.2.4 Other Bilateral and Multilateral Project Activities

In addition to activities in the ITU and other global, intergovernmental organizations, often bilateral and multilateral agreements for the use of the spectrum must be developed. Such agreements might, for example, set out how two or more countries will coordinate their use of certain frequency bands. Establishing such agreements requires negotiations between the spectrum authorities in the respective countries and possibly the involvement of foreign affairs ministries depending on the legal status of the resulting agreement which can take the form of a simple exchange of letters, a memorandum of understanding, a treaty, etc. Some multilateral agreements can also be established through participation in the regional and sub-regional telecommunication organizations (e.g., CITELE's Inter American Convention on an International Amateur Radio Permit, the agreement within the framework of CEPT between the Administrations of Austria, Belgium, the Czech Republic, Germany, France, Hungary, the Netherlands, Croatia, Italy, Liechtenstein, Lithuania, Luxembourg, Poland, Romania, the Slovak Republic, Slovenia and Switzerland on the coordination of frequencies between 29.7 MHz and 39.5 GHz for the fixed and land mobile services).

CEPT's HCM Agreement which is the unofficial designation of the Agreement between the Administrations of Austria, Belgium, the Czech Republic, Germany, France, Hungary, the Netherlands, Croatia, Italy, Liechtenstein, Lithuania, Luxembourg, Poland, Romania, the Slovak Republic, Slovenia and Switzerland on the Coordination of frequencies between 29.7 MHz and 39.5 GHz for fixed service and land mobile service.

7.3 Transactional Activities

Transactional international activities are those activities which are of an ongoing nature. Specific types of transactions are processed over an extended period of time. These types of activities lend themselves to process engineering and electronic data processing support.

7.3.1 ITU Related Transactional Activities

Under the [ITU Radio Regulations](#), there are requirements for the regular submission of spectrum related information such as details concerning frequency assignments to the [ITU's Radiocommunication Bureau](#) for purposes of coordination with other countries and for registration in the Master International Frequency Register (MIFR). This information is published every two weeks in an ITU-R publication known as the [Radiocommunication Bureau's International Frequency Information Circular \(BR IFIC\)](#). The BR IFIC contains details on the current and intended frequency usage by ITU Member States.

The BR IFIC is composed of two parts. The first part deals with space services. It contains information on the frequency assignments to space stations, earth stations and radioastronomy stations submitted by countries to the Radiocommunication Bureau for recording in the Master International Frequency Register, as well as those that are submitted under the relevant provisions of the Radio Regulations or which are subject to the Appendices 30 and 30A Plans for the Broadcasting Satellite Service and the Appendix 30B Plan for the Fixed Satellite Service Plan. The information published corresponds to the recorded assignments as well as the notifications still being processed.

The second part of the BR IFIC deals with terrestrial services. It contains a permanently updated edition of the International Frequency List with regard to terrestrial services, as well as permanently updated versions of the frequency allotment or assignment plans for terrestrial services that are drawn up under the auspices of the ITU. In addition, it contains information on the frequency assignments submitted by countries to the Radiocommunication Bureau for recording in the Master International Frequency Register and in the various regional or worldwide Plans/Agreements.

In order to protect a nation's sovereign rights, there is also a need to analyze on a regular basis the regulatory material published by the ITU in order to determine if there is a potential impact on the country's use of the spectrum and, if so, involvement in the relevant procedures set out in the Radio Regulations is required.

The BR International Frequency Information Circular is published on CD-ROM (for space services) and on DVD (for terrestrial services) every two weeks. One copy of the BR IFIC (consolidated package) is provided to the ITU Member States' Administrations responsible for radiocommunication matters.

There is also a need for submission of information for publication by the ITU in various service documents. Such documents include List IV – List of Coast Stations, List V – List of Ship Stations, List VI –List of Radio-determination and Special Service Stations, List VII A – List of Call Signs and Numerical Identities of Stations Used by the Maritime Mobile and Maritime Mobile-Satellite Services, List VIII – List of International Monitoring Stations and List VIII A – List of Stations in the Space Radiocommunication Services and in the Radio Astronomy Service (twice per year on DVD). Again, there is a need to review these publications on a regular and ongoing basis.

7.3.2 International Borderline Frequency Coordination

Coordination of frequency assignments and freedom from harmful interference form essential features of modern global radiocommunications networks. A lack of coordination is both economically and technically inefficient. For a discussion of economic and technical efficiency see [Section 1.3 - Objectives of Spectrum Management](#).

Article 4 of the ITU [Radio Regulations](#) – Assignment and use of radio frequencies states the member states shall:

- Endeavour to limit the number of frequencies and spectrum used;
- Undertake to make assignments which are in accordance with the Table of Frequency Allocations;
- Make changes to assignments will be made to avoid harmful interference; and,
- Not seek protection for frequencies not in accordance with the Table of Frequency Allocations.

Member states are required to notify the ITU-R and update the Master International Frequency Register (MIFR) in order to facilitate coordination. The Radio Regulations describe the four steps involved in the notification process which are: notification, publication using the [International Frequency Information Circular \(IFIC\)](#), examination and finally registration in the MIFR.

There are several examples where international frequency coordination has taken place on a regional basis using radio service specific coordination agreements. The HCM Agreement (Vilnius 2005) which superseded the previous “Berlin Agreement - 2003” amongst 17 European countries requires the participant countries to actively coordinate, register and resolve issues using harmonized calculation models for specified Fixed and Land Mobile Services.

7.3.3 Other Transactional Activities

In addition to transactions involving the ITU, there are transactional activities that need to be carried out on a bilateral or multilateral basis. For example, pursuant to bilateral or multilateral agreements, there may be a need for submission of frequency assignment information for purposes of frequency coordination with adjacent or nearby countries. Often such activities are automated to the extent feasible.

8 Developing Spectrum Management Capacity

Strategies for organization, function, process development, staffing, staff retention and training are important considerations for spectrum regulators. These capacity building strategies flow from legislation, policy and the regulatory framework including which other agencies are involved in certain aspects of spectrum management. Spectrum regulatory functions include:

- Spectrum planning of the future steps required to achieve optimal spectrum use by charting the major trends and developments in technology and considers the needs of current and future users of the radio spectrum.
- Spectrum engineering including the evaluating of information, capabilities and technology choices to support decisions affecting the allocation, allotment and assignment of radio spectrum. Identifying solutions to interference problems and technical compatibility among radio systems are key areas of focus.
- Spectrum authorization involves licensing of radiocommunication equipment and the making of frequency assignments.
- Spectrum monitoring and compliance activities help by avoiding incompatible frequency usage and through identification of sources of harmful interference.

8.1 Introduction to Developing Capacity

The contemporary view of capacity building goes beyond the conventional perception of training. The central concerns of spectrum management – to promote spectrum access and efficient use, to resolve conflicting demands, to manage change, to enhance coordination and avoid interference, to foster communication and consultation and to ensure that data and information are shared – require a broader view of capacity development. This definition covers both institutional and individual capacity building.

Spectrum regulators need to consider strategies for developing the spectrum management organization including human resource development, spectrum management functions, process development, staffing and staff retention, and training. These capacity building strategies flow from legislation, policies and the regulatory framework including which other agencies are involved in certain aspects of spectrum management.

The traditional spectrum management regulatory functions include:

- Spectrum planning of the future steps required to achieve optimal spectrum use by charting the major trends and developments in technology and considering the needs of current and future users of the radio spectrum.
- Spectrum engineering including the evaluation of information, capabilities and technology choices to support decisions affecting the allocation, allotment and assignment of radio spectrum. Identifying solutions to interference problems and technical compatibility among radio systems are key areas of focus.
- Spectrum authorization involves licensing of radiocommunication equipment and the making of frequency assignments.
- Spectrum monitoring and compliance activities help by avoiding incompatible frequency usage and through identification of sources of harmful interference.

How spectrum managers fulfill these requirements and meet strategic operational and organization goals represent formidable challenges made more difficult in an environment characterized by change and innovation. These types of capacity building problems are not new nor are they unique to spectrum management. Solutions do exist for developing planning and implementing processes that will improve organization structure, function and to develop necessary and required skills.

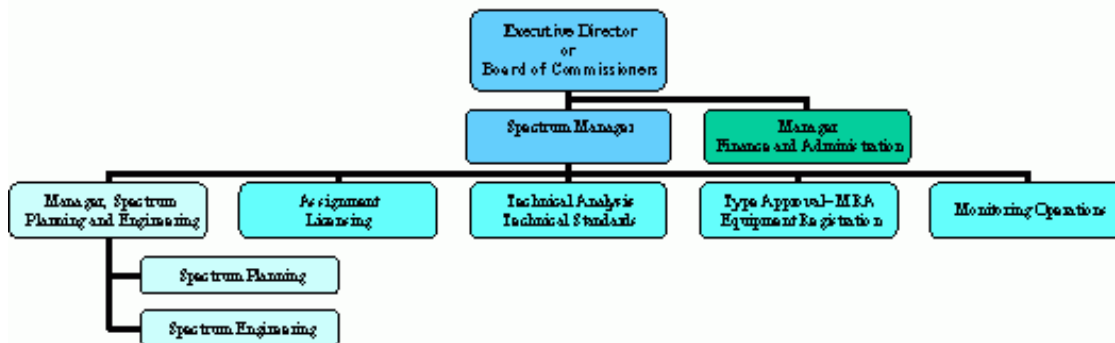
8.2 Organization

There is little point in developing strategies for spectrum management capacity building without a thorough understanding of the mandate under which the spectrum management organization operates. The country's legal and regulatory frameworks along with policies concerning governance provide the defining building blocks for the spectrum management organization. For example, as was described in Sections I and III, the spectrum management regulatory function is, in some cases, combined with telecoms and broadcasting regulation or it

can function separately as a stand alone organization. The implication here for capacity building is the need to develop and maintain human resource skills independently of other organizations or to find ways of sharing in the development and utilization of human resources through strategies such as matrix management or centres of excellence within the combined regulator.

No two spectrum management organizations will be organized in the same manner, yet there are some similarities in structures organized around the key functions of planning, engineering, and authorization and monitoring. Cost and resource availability put pressure on spectrum managers to create organization and design functions which ensure productivity is achieved through sharing and cross-fertilization of skills.

For purposes of illustration, a model organization chart and functional mapping of key responsibilities are presented below for purposes of clarifying the understanding of spectrum management functions and activities.



As pointed out earlier, one of the outcomes of the analysis of structure and function is the potential for sharing common resources such as engineering staff in both the planning and engineering functions. As well, it is possible for administrative staff to support spectrum management and telecommunications and/or broadcasting regulatory staff. Another important consideration is deciding to utilize outsourcing options for common services and infrastructure such as information systems and software applications, and human resource management staff. The determining the structure of the desired organization has a direct bearing on staff recruitment, training and capacity building.

8.3 Human Resources and Training Development

Human resource planning and development through training are essential components of the overall plan and strategy to build capacity within the spectrum management organization. In this section, we explore many of the themes and topics associated with the need to hire, train and retain skilled human resources.

8.3.1 Human Resources

Spectrum Management is knowledge-based requiring skilled and committed personnel who are able to keep pace with continuous progress in radio technologies along with increasing complexity and demands coming from improved data handling capabilities and engineering analysis methods used to accommodate the number and variety of users seeking access to the spectrum resource. Providing a challenging and rewarding experience for staff, trainees and new recruits means giving them the tools and support they need for learning and development throughout their careers.

Issues related to new technologies, dynamic market conditions and effective regulatory responses can easily overtake the attention and focus of the spectrum management organization. At the same time, human resource management is strategic to organization development and goal achievement but sometimes relegated to the tail-end of the agenda. The reasons for the lack of focus are often related to budgetary and salary constraints which prevent the recruitment of necessary skilled resources especially when the regulator is competing for the same resources with the private sector or when there is a general lack of sufficient talent or skilled numbers of recruits to draw upon.

There are many challenges for Spectrum Management Organizations to educate, to attract and to keep needed professionals and staff. Some of the trends creating the challenge include the following:

- A continuing shortage of funds and sustainable revenues to support regulatory activity.
- It is more than probable that governments will face significant shortages of qualified professionals over the next 5 to 10 years in both developed and developing countries for very different reasons. In developed countries, changing demographics and the impending shortage of skilled resources has been well documented. In developing countries, the challenge to educate sufficient numbers while the population and economies grow will continue.
- Hurdles exist to some sources of relief for looming shortages. The approach to licensing of foreign-trained experts creates problems as does emigration of locally and foreign educated nationals to richer countries.
- Spectrum managers and other government agencies will face stiff competition nationally and regionally to recruit and retain professional leaders in radiocommunication engineering, economics and finance and legal affairs.
- In addition to pay and benefits, the national and international reputation of the spectrum manager, the telecommunications sector, workload, support for professional development, and roles and responsibilities between professions will be among a number critical factors for professionals in deciding where they choose to pursue their careers.
- Competitive wages needed to attract appropriate personnel are constantly at odds with efforts to control government budgets and to divert more resources away from the telecoms and spectrum regulator to other government priorities.
- Roles and responsibilities among the related professions are changing due largely to innovation and change in the use of technology and changes in the telecoms marketplace. Multi-disciplinary teams are likely to become more common along with the emergence of new types of working arrangements (e.g., outsourcing).
- New regulatory requirements arising from new approaches to service will affect how spectrum management professionals work with each other and with stakeholders.

Strategies

Spectrum managers need to develop and maintain strategic human resource development plans which identify needs, gaps in capability and strategies to fill or compensate for deficiencies in human resource numbers and skills. Strategies need to be consistent with overall government policy and legislation governing public service employment yet responsive to changing requirements. Planning and development of strategies are essential.

Several helpful references to review are listed below:

- Robert L. Katz, Skills of an Effective Administrator, Harvard Business Review: Reprint 74509.
- Frederick Herzberg, One more time: How do you motivate employees? Harvard Business Review: Reprint 87507.

8.3.2 Training Development

Spectrum managers are responsible for ensuring their agency and staffs promote and ensure the efficient use of the radio frequency spectrum resource. To satisfy this responsibility, spectrum managers must not only understand current spectrum-dependent technologies, but also understand the likely interference interactions between the services provided by incumbent spectrum users and the services envisioned to be provided through the use of cutting edge technologies. Obtaining or developing effective training programs for spectrum managers, and making these programs available to private sector entities can help to ensure that all spectrum managers operate from a common frame of technical and analytical reference.

Spectrum managers should be able to use the latest spectrum management analysis tools. Spectrum managers should also be aware of the commercial services available that could satisfy their functional requirements for spectrum services.

There is also a need for additional spectrum management expertise. Spectrum management needs highly-trained staff capable of adapting to technological change, instituted engineering recruitment and training programs.

There is a similar need for such training throughout the spectrum management community. By building in-house expertise, non-government spectrum managers and spectrum users can make more informed choices on equipment purchases and on other spectrum management issues.

8.4 Business Processes

There are numerous complex tasks and processes within the spectrum management organization which need to be planned:

- Routine tasks and methods are associated with licensing of radiocommunications, type approval of radio equipment and routine monitoring. Routine tasks are supported by well defined administrative processes which can be dramatically improved and made more cost effective through the use of efficient information management systems. Quality of service can be improved by placing service points of presence close to clients and users.
- Technical tasks require staff with extensive formal and methods-based training and experience. Frequency assignment, technical standards, spectrum engineering, information systems and radio monitoring are tasks that require these levels of training. Core professionals/specialists work closely with clients.
- Conceptual and coordination tasks. These are associated with planning, coordination, consultation, and strategic initiatives associated with international consultation on spectrum planning matters.

Several techniques (Business Process Re-engineering, Process Improvement, Performance Management Framework, to cite a few), developed in the area of management science are available to the spectrum manager to assist in the design and evaluation of improved, more effective business processes. If a decision is made to re-engineer the processes of the organization to better align them with changing market dynamics, technology or regulation, it is important to stage the training and development of staff so that the training effort coincides with the creation of new processes and systems to support them.

8.5 Consultative Practices

The Spectrum Management Organization needs to communicate and consult with stakeholders to be effective. The spectrum manager needs to take effective measures to provide information on the policies, rules and practices of the administration and provide mechanisms for feedback to evaluate policies, rules and practices. Consultation is another means for building overall support for compliance by users. Another impetus for consultative mechanisms for stakeholders arises from the need for improved short term planning and assignment processes which reflect the economic value of spectrum to the public and improved transparency in decision-making. The discussion of consultative processes takes place within a broader discussion of the role, contribution and extent to which industry and stakeholder groups should participate in the implementation and monitoring of the broader agenda of planning and efficient usage of spectrum. Action based on partnerships and involvement of major groups opens up a wider political sphere for the participation of social and economic actors and constitutes a "bottom-up" source of strength.

Consultative processes occur at several levels including international and regional efforts and processes can be formalized, informal or *ad hoc*. Planning subjects range from policy and regulatory framework development and formulation through forecasting of demand and technology application to procedural such as channel planning for broadcasting frequencies.

Industry participants in various segments of the market – mobile, satellite, microwave and broadcasters should be encouraged to form associations which can formulate recommendations reflecting the common needs and interests of the sector. As well, the spectrum manager can request from the associations expert advice on contentious matters such as interference resolution solutions, band channeling plans and band clearing options. Individual licensees and users are not precluded from submitting formal briefs of their own in addition to the industry wide brief submitted to the regulator.