ICT Regulation Toolkit

ICT Regulation Toolkit / 5. Radio Spectrum Management /

5.1

Spectrum Management Overview

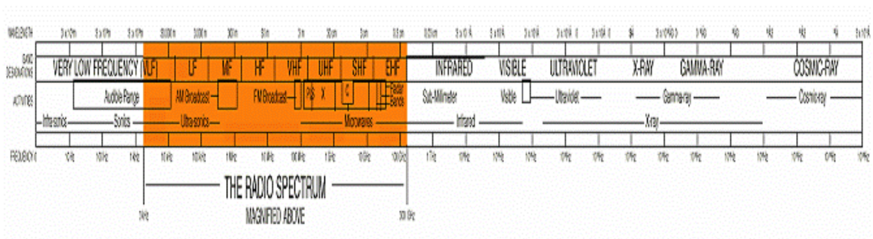
This section is an introduction to the management of the radio spectrum including the planning of current and future uses of spectrum; ensuring engineering compatibility of various uses and equipment; and authorization, licensing and monitoring of spectrum usage.

Reference Documents

- **Telecommunications Research Project, Spectrum Management**

5.1.1 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.

Reference Documents

- A Comparative Analysis of Spectrum Management Regimes
- Access to Spectrum/Orbit Resources and Principles of Spectrum Management
- Radiocommunications Inquiry Report, Productivity Commission, Australia, 2002 especially Chapter 2 and 4
- Review of Radio Spectrum Management- an independent review
- Value-focused thinking - strategic management of radio spectrum for mobile communications in Korea

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.

Reference Documents

- Mobile Telecommunications and Economic Growth: London Business School, John Cabot U, and U of T, May 2005
- Telecommunications Research Project, Spectrum Management

5.1.2.1 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 the Table below), as it exemplifies its similarities to other exhaustible resources within modern economies.

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

	Spectrum	Land	Oil Reserves	Water
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:

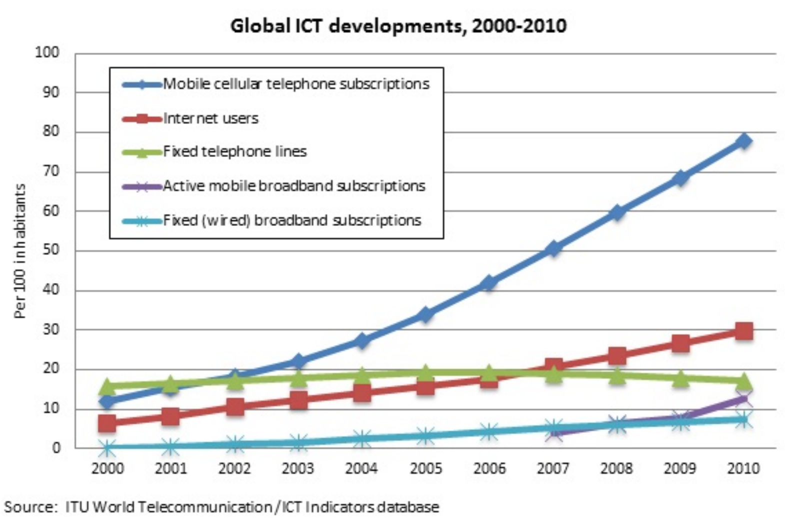
- Firstly, although investment in ICT represented a significant share of total fixed business investment in the United States (where most of the early research focused), it still represented only a small share of the total capital stock and, ICT-producing sectors, a small share of total GDP. [*]
- Secondly, measuring ICT inputs is notoriously difficult, in part, because of the very rapid pace of innovation and continuously declining prices. This phenomenom is known popularly as *Moore's Law*, where it isit 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 economics 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) [*] 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) [*] 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) * analyzed data for 24 Latin American and Carribean 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) * 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) * 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) * 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).

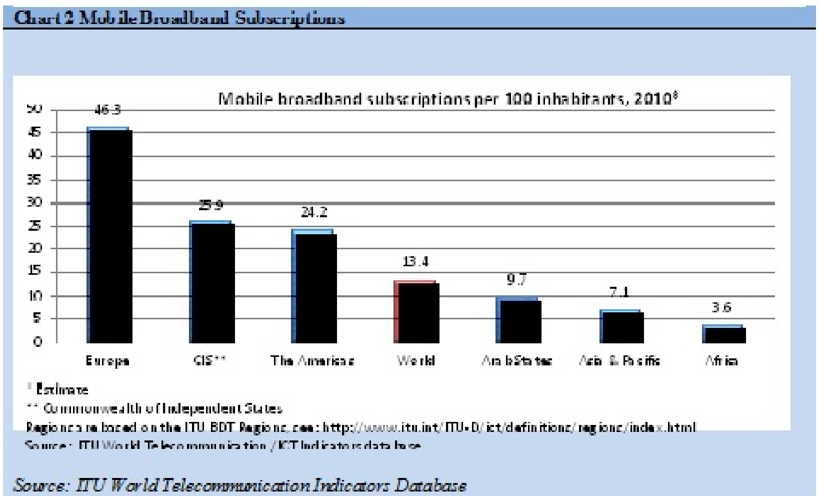
Chart 1 shows the buoyant growth in the ICT sector over the past decade, clearly illustrating the tremendous expansion in the penetration of mobile services with 5.4 billion mobile subscribers, which is enough to reach 78 per cent of the world's population. In addition to this, by the end of 2010, growth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



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

Photo: ITU World Telecommunications Indicators Database

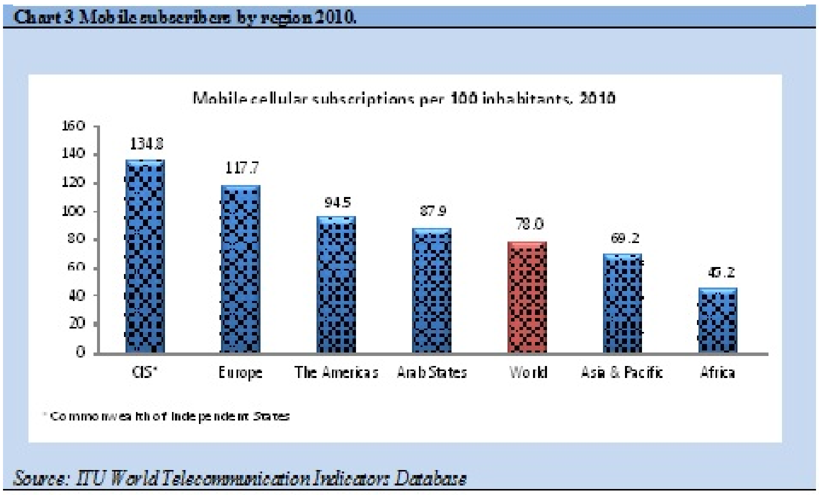
Penetration varies significantly between rich and poorer countries although the significant trend is for rapid growth in mobile usage in emerging and developing economies.

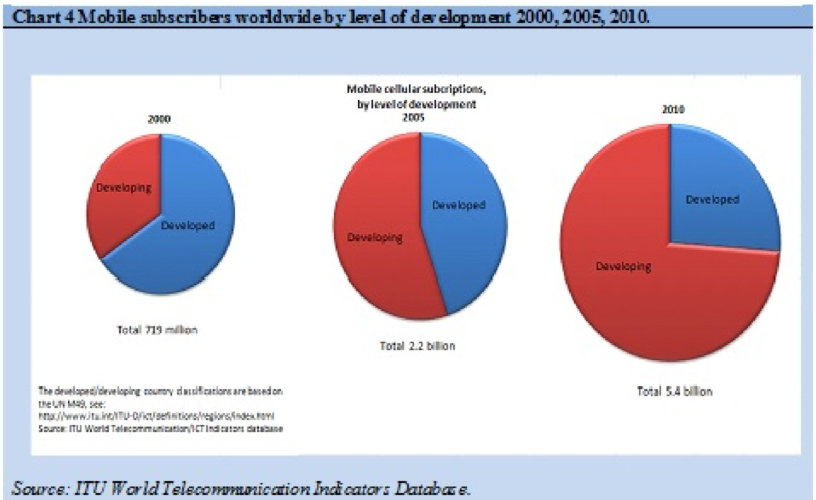


◄ **Chart 2 Mobile broadband subscriptions per 100 inhabitants**

Photo: ITU World Telecommunications Database

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.





◂ **Mobile cellular subscriptions per 100 inhabitants**

Photo: ITU World Telecommunications Database

Photo: ITU World Telecommunications Database

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

[*] 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.

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

[*] See Katz, R. and J. Avila (2010) "Estimating Broadband Demand and Its Economic Impact in Latin America," *Proceedings of the 4th ACORN-REDECOM Conference*, Brasillia, May 14-15, 2010

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

[*] 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.

[*] 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*."

Reference Documents

- Economic Versus Technical Approaches to Frequency Management Telecommunications Policy
- Mobile Telecommunications and Economic Growth

5.1.2.2 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 below depicts the some of the many uses of radio spectrum associated with various bands derived from their inherent propagation characteristics.

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 Communications	Very wide up to 1 GHz	Confined
EHF 30-300 GHz Varies 20 km to 2000 km	Microcell, Point to Point, PCS, 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&rlink=seminar-program&seminar=geneva-2008&lang=en

Reference Documents

- Wireless Technology for Non-engineers

5.1.2.3 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.

- Underutilized License Exempt Spectrum in the UK

5.1.2.4 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.*

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.*

5.1.2.4.1 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.

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

Table 1.2.1
The Digital Divident by ITU Region
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

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

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.

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.

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

5.1.3 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

Reference Documents

- **Facilitating Spectrum Management Reform via Callable/Interruptible Spectrum**
- **UK: Spectrum Framework Review - Ofcom's Views as to how Radio Spectrum should be managed, 2004**

5.1.3.1 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.

Reference Documents

- **India: Consultation Paper on: Efficient Utilization, Spectrum Allocation, and Spectrum Pricing, 2004**
- **India: TRAI Allocation and Pricing of 3G and BWA Spectrum - A consultation report, 2006**
- **United Kingdom - Independent Audit of Major Spectrum Holdings, 2005**

5.1.3.2 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.

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).

◂ **Box Practice Note: Digital Divident European Broadcast Union**

Source: European Broadcast Union, 2009

Reference Documents

- **USA: Spectrum Efficiency Working Group Report, 2002**

5.1.3.3 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:

- Clear statement of goals and objectives;
- Description of strategies and implementation steps;
- Accountability framework;
- Tangible outcomes and measureable targets;
- Timeframe and milestones for achieving goals and outcomes.

Practice Notes

- **Spectrum Set-Asides for New Entrants – AWS Auctions in Canada**

Reference Documents

- **Radio Resource Management in Highly Populated Developing Countries**

5.1.4 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.

Reference Documents

- **Cayman Islands - Information and Communications Technology Authority - The Public Consultation Process**
- **India: TRAI Allocation and Pricing of 3G and BWA Spectrum - A consultation report, 2006**
- **Lesotho- Proposal for Licensing Procedures: Consultation Document**

- Mauritius - Broadband Wireless Access Consultation
- United Kingdom - Independent Audit of Major Spectrum Holdings, 2005

5.1.5 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.

Reference Documents

- Group on Telecommunications Report - Mechanism of Spectrum Management
- Leadership and the Independent Regulator
- Marketplace Readiness of Narrowband/Broadband Wireless Access Systems in the 2.3 and 3.4 GHz Spectrum Bands
- Modelling the Efficiency Properties of Spectrum Management Regimes
- Review of Spectrum Management Practices
- Up the Revolution, 2005

5.1.5.1 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.

Reference Documents

- **CTU Workshop: Administrative and Market Methods for Assignment, 2006**
- **ITU/BDT: GREX Seminar on Spectrum Reform: Administrative Methods, Extract of Presentation given by Dale Hatfield, 2006**

5.1.5.2 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.[*] 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.

Practice Notes

- **Check-list for implementing spectrum markets**
- **Review of the European Union Telecommunications Regulatory Framework, 2007**
- **Spectrum Trading in Practice - ECOWAS**

Reference Documents

- **A Proposal for a Rapid Transition to Market Allocation of Spectrum, Federal Communications Commission, November 2002**
- **Designing property rights for the operation of spectrum markets, 2003**
- **Guatemala - Spectrum Trading**
- **Guatemala: The Guatemalan Experience, 2005**
- **Solving Spectrum Gridlock: Reforms to Liberalize Radio Spectrum Management**
- **Spectrum Trading in Germany, Austria and the UK: The influence of regulatory regimes and evaluation of criteria**

on competition in the European Mobile Telecommunications Sector, August 2003

- Spectrum Trading Increasing Efficiency of Spectrum Usage
- Study on the conditions and options in introducing secondary trading of radio spectrum in the European Community
- USA: Assigning Property Rights to Radio Spectrum Users, 1998

5.1.5.3 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 year's 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.

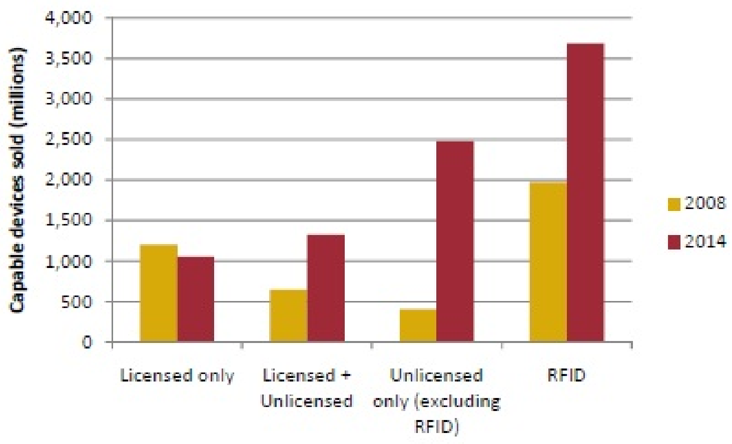
Low power device frequencies refer to a whole range of frequencies from 160 KHz. to 10.55 GHz. which are used for a variety of radio communication and non-communication purposes. The ISM bands include low power devices, and some of these are listed below:

- 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.



◂ **Figure 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 yeae. 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.

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%

◂ **Table 1 Economic Values Generated by Unlicensed Applications in the US shows the currently unlicensed bands in the United Kingdom.**
UK Unlicensed Bands

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

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	2nd Phase Road Traffic and Transport Telematics
76 GHz	Vehicle Radar Systems

Practice Notes

- **ITU Radio Regulation 5.150 - ISM Bands**

Reference Documents

- **Ireland: Use of Unlicensed Spectrum in Rural Applications**
- **RSPG Report on cognitive technologies**
- **Unlicensed and Unshackled: A Joint OSP-OET White Paper on Unlicensed Devices and their Regulatory Issues, Federal Communications Commission, May 2003**
- **USA: Spectrum Efficiency Working Group Report, 2002**
- **Wireless internet access 3G vs. Wi-Fi, Lehr, 2003**

5.1.5.4 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.

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.

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

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. [*] 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. [*]

5.1.5.5 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.

5.1.6 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.**

Reference Documents

- **De-regulating the spectrum - Implications for Technology**
- **Report of the Spectrum Rights and Responsibilities Working Group**
- **Utility Regulator's - The Independence Debate**

5.1.6.1 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?"

Reference Documents

- **Impact of the Regulator's Independence on the Telecommunications Industry**
- **Leadership and the Independent Regulator, Public Utilities Research Centre, University of Florida**
- **Traits of an Independent Communications Regulator: A Search for Indicators, FCC International Bureau Working Paper Series, June 2004**
- **Utility Regulators – The Independence Debate, The World Bank Group, Private Sector, Note. No. 127, October 1997**

5.1.6.2 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.

Practice Notes

- **New Zealand - Creation of Management Rights in the Broadcast and IMT Bands - 1999**
- **Types of band managers**

5.1.6.3 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.

Practice Notes

- **Types of band managers**

5.1.6.4 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.

Practice Notes

- Spectrum Trading Systems

Next: 5.2 Spectrum Policy and Planning ➡