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TITLE: ITU-D HANDBOOK
NATIONAL SPECTRUM MANAGEMENT SYSTEM
ECONOMIC, ORGANIZATIONAL AND REGULATORY ASPECTS

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Please find hereafter the Handbook on national spectrum management system including the last comments of the Radiocommunication Sector for your consideration.

ITU-D HANDBOOK
NATIONAL SPECTRUM MANAGEMENT SYSTEM
ECONOMIC, ORGANIZATIONAL AND REGULATORY ASPECTS[1]

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SPECTRUM MANAGEMENT, INCLUDING MONITORING - INTRODUCTION

CHAPTER 2

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1 Source: Document 2/159-E (Rev-1), January 1996

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CHAPTER 1

SPECTRUM MANAGEMENT, INCLUDING MONITORING - INTRODUCTION

1.1 International Framework

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The purpose of this handbook is to assist Administrations in their efforts aimed at organising and/or improving their national spectrum management[2].

In the past, in many countries there was no need for any sophisticated spectrum management structure. Due to the limited number of users of the radio frequency spectrum it was possible to providea frequency band to each user over a given geographic area for his/her exclusive use. This situation has changed in many regions due to the tremendous development of radio communication systems and the social and economic role of wireless telecommunications. Radio frequency spectrum has become a precious and scarce resource[3]. Its careful use and management has become crucial to avoid congestion and mutual interference that nullifies all possible benefits drawn from the applications of wireless technologies. Such a situation would have negative impact on the overall economy, national and international..

1.1 International Framework

The International Telecommunication Union (ITU), a Specialised Agency of United Nations, provides an international framework for the usage and management of radio frequency spectrum resources. The ITU Constitution and Convention with accompanying Radio Regulations is an International Treaty to which all Countries - Signatories of the Treaty have committed themselves.

The ITU Constitution state that the Union, among others, shall

"... effect allocation[4] of bands of the radio-frequency spectrum, the allotment[5] of radio frequencies and registration of radio-frequency assignments[6] [and] *any associated orbital positions in the*

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2 This Handbook drafted by ITU-D Study Group 2, presents views of ITU members active in that Group and complements the documents issued by ITU-R on the same topics. There may be some difference between these texts as they were produced by separate Groups of Experts representing different expertise. In the future, it might be useful to integrate the ITU-R and ITU-D texts on spectrum management and monitoring into one ITU handbook. An early version of this Handbook was reviewed by ITU-R Study Group 1 and then edited. The Editor made every effort to follow the Study Group 1 comments (Doc. 1/14, Santa Rosa Oct. 1996) and - at the same time - to keep the text as close to the original as possible.

3 It has generally been accepted that the spectrum resources have dimensions of frequency, geometrical space and time, and that they include also satellite orbits.

4 The ITU Radio Regulations define allocation as entry in the Table of Frequency Allocations of a given frequency band for the purpose of its use by one or more terrestrial or space radiocommunication services or the radio astronomy service under specified conditions. This term is also applied to the frequency band concerned.

geostationary-satellite orbit in order to avoid harmful interference between radio stations of different countries[7] and *co-ordinate efforts to eliminate harmful interference between radio stations of different countries*[8] *and to improve the use made of the radio-frequency spectrum and of the geostationary-satellite orbit for radiocommunication services*[9]*"*

These tasks are to be fulfilled *"by ensuring the rational, equitable, efficient and economical use of the radio-frequency spectrum by all radiocommunication services, including those using the geostationary-satellite orbit*[10]*...."* Moreover, *"Members shall endeavour to limit the number of frequencies and the spectrum used to the minimum essential to provide in a satisfactory manner the necessary services. To that end, they shall endeavour to apply the latest technical advances as soon as possible*[11]*".*

Further, the Constitution determines that *"In using frequency bands for radio services, Members shall bear in mind that radio frequencies and the geostationary satellite orbit are limited natural resources and that they must be used rationally, efficiently and economically, in conformity with the provisions of the Radio Regulations, so that countries or groups of countries may have equitable access to both, taking into account the special needs of the developing countries and the geographical situation of particular countries*[12]*."*

It also declares that *"All stations, whatever their purpose, must be established and operated in such a manner as not to cause harmful interference to the radio services or communications of other Members or of recognised operating agencies, or of other duly authorised operating agencies which carry on a radio service, and which operate in accordance with the provisions of the Radio Regulations*[13]*"* and that "*Each Member undertakes to require the operating agencies which it recognises and the other operating agencies duly authorised for this purpose to observe the provision [...] above*[14]*."*

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5 Allotment is defined in the Radio Regulations as entry of a designated frequency channel in an agreed plan, adopted by a competent conference, for use by one or more administrations for a terrestrial or space radiocommunication service in one or more identified countries or geographical areas and under specified conditions.

6 Assignment is defined in the Radio Regulations as authorisation given by an administration for a radio station to use a radio frequency or radio frequency channel under specified conditions.

7 CS11 where "CS" stands for the Constitution and the number indicates its paragraph.

8 The Constitution mentions only the interference between stations of different countries, because interference cases between the stations of the same country can be solved internally, by a national spectrum management authority, without the need to engage any international body.

9 CS12

10 CS78

11 CS195

12 CS196

13 CS197

14 CS198

1.2 National Spectrum Management

Within this general framework, created by common decisions of all Countries-Members of ITU, each country has the sovereign right to regulate its telecommunications following its own needs and its own policy goals[15].

In most countries, it has now become necessary to operate a specialised agency - Spectrum Management Authority, with general objectives to manage, monitor and optimise the uses of the radio spectrum, following the ITU Convention, Constitution, Radio Regulations and other relevant international treaties. This implies that the National Laws, Rules, and Regulations imposed on national Radiocommunications should reflect the provisions of these international agreements. However, no Law, Rule or Regulation could be implemented in practice without efficient spectrum management.

The spectrum resources exploited by radiocommunications represent a high potential and their efficient use is required to assure harmonious development of all activities in the country that depend on radiocommunications:

Spectrum management contributes to building the national economy by providing and managing the resource necessary for radio communication use in a timely and efficient manner.

This statement reflects the fact that spectrum management is not only the mere husbandry of frequencies, but has an immense effect on the country's telecommunications and thus on its life, economy, safety and security. Spectrum managers now act as nation-builders that, in their decisions, take into account a general context of nation's activities. This aspect is central to the modern concept of spectrum management.

In the past, spectrum management was mainly representing exclusive frequency uses by governments, and governmental policy, nationally and internationally. Now, in the development of policies and procedures, successful governments include consultations with industry, which increasingly is taking more and more important role.

In view of the nature of the physical communication medium, an optimum use of the spectrum resources requires a clear and comprehensive policy enabling appropriate spectrum management and monitoring. As mentioned in the previous section, this policy should comply with the ITU Convention and Constitution and the ITU Radio Regulations that complements them.

It should also take into account the current Recommendations of ITU-R (formerly: CCIR) and other relevant ITU Publications. [16]

Of special interest are in this regards the ITU-R Handbook on National Spectrum Management (1995) and Spectrum Monitoring (1995) as well as ITU RAS/94/013 publication "Study on spectrum pricing" (1994) and Report ITU-R SM.2012 on Economic Aspects of Spectrum Management.

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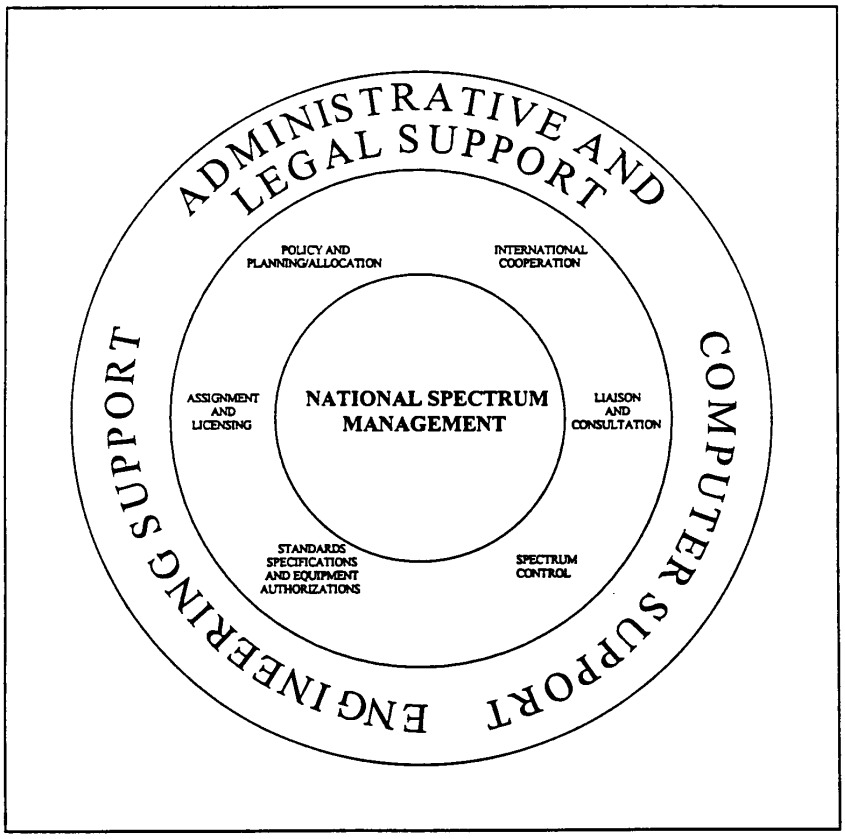
15 Preamble to the Constitution.

16 The list of current ITU Publications is available free of charge from ITU, Place des Nations, CH-1211 Geneva 20, Tel. (+41 22) 7306141, Telefax (+41 22) 7305194, E-mail sales@itu.int, or via Internet at http://www.itu.int/publications. These Recommendations are available as paper-based publications, CD-ROMs, diskettes, and also are available on-line.

1.3 Functional Responsibilities

Although no two administrations manage the spectrum resources in exactly the same way, there are some basic elements that are essential to all approaches. Figure 1 shows an example of national spectrum management structure based on functional responsibilities.

Figure 1: Spectrum management organisation based on functional responsibilities
(Source: ITU-R Handbook on National Spectrum Management).

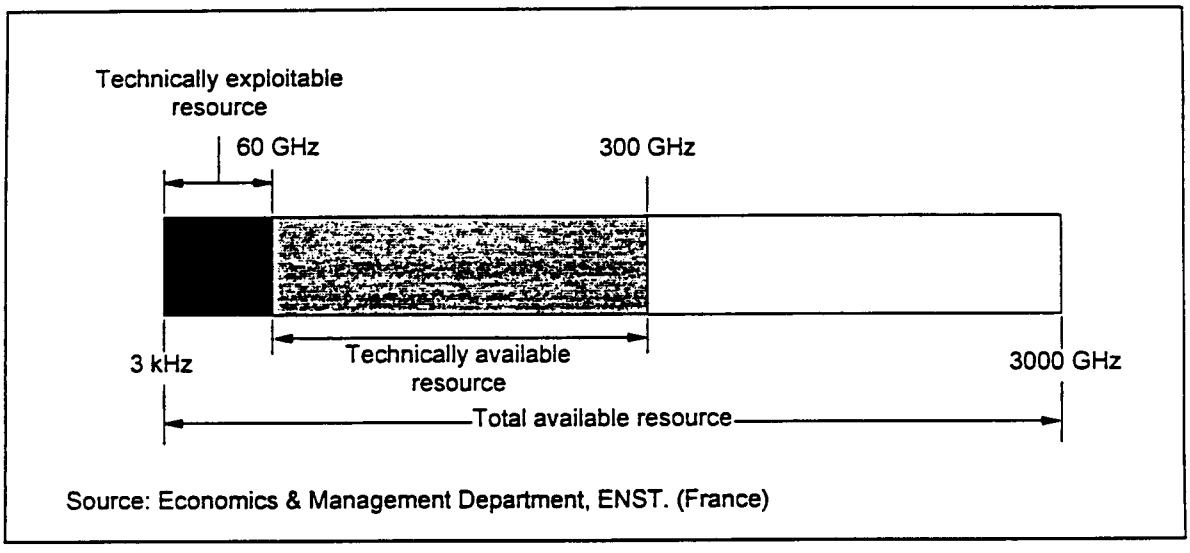


CHAPTER 2

ECONOMIC ASPECTS OF SPECTRUM MANAGEMENT

The radio frequency spectrum is a natural resource that exists independently of human activity. It is an intrinsically scarce resource since it is limited. In fact, only frequencies between 3 kHz and 3000 GHz are usable for information transmission via radio (Figure 2). This range is theoretical; spectrum above 300 GHz cannot be used at present, because currently available techniques are not sufficiently advanced. Thus, the practically available resource ranges between 3 kHz and 300 GHz. However, since making equipment that can operate above 60-100 GHz results in high prices for services supplied, only frequencies between 3 kHz and say 60 or 100 GHz are likely to be used by the end of the 20th century.

Figure 2: The Limits of the Radio Spectrum



Source: Economics & Management Department, ENST. (France)

Thus:

- The total spectrum resources are limited by natural and physical constraints.
- The available resources are determined by the evolution of technical and economic factors (in particular the evolution of relative costs).
- The useable resources are determined by technical and economic conditions.

As early as the 1950s, American economists noticed that the radio frequency spectrum and land have similar characteristics. They:

- are naturally available in the physical environment,
- are intrinsically scarce since their physical quantity is not extensible and man cannot reproduce them,
- constitute a fixed stock able to supply a production flow indefinitely, provided it is managed effectively,
- can be used in both extensive and intensive ways, and
- are heterogeneous.

2.1 Interference, Scarcity, Exclusivity Of Use

If two transmitters with the same characteristics covering the same area would transmit on the same frequency at the same time, they may generate mutually harmful interference. This would waste the spectrum because no meaningful communication could take place.

Thus, the scarcity of the spectrum lies not only in its quantitative limitation, but also in this necessary exclusivity in its use at a given time and geographic area. The situation is similar for land, where one cannot use a given piece of land simultaneously for two different purposes (e.g., housing and farming). In most cases effective use of the radio spectrum, like that of land, requires granting transmitters exclusive rights of use to a specific portion of the spectrum, area and time.

Implementing these exclusive rights involves appropriate means or authorisations whether in the framework of public concessions for a fixed or unlimited term, or through freely transferable private property rights on a spectrum market.

2.2 Differential Rent

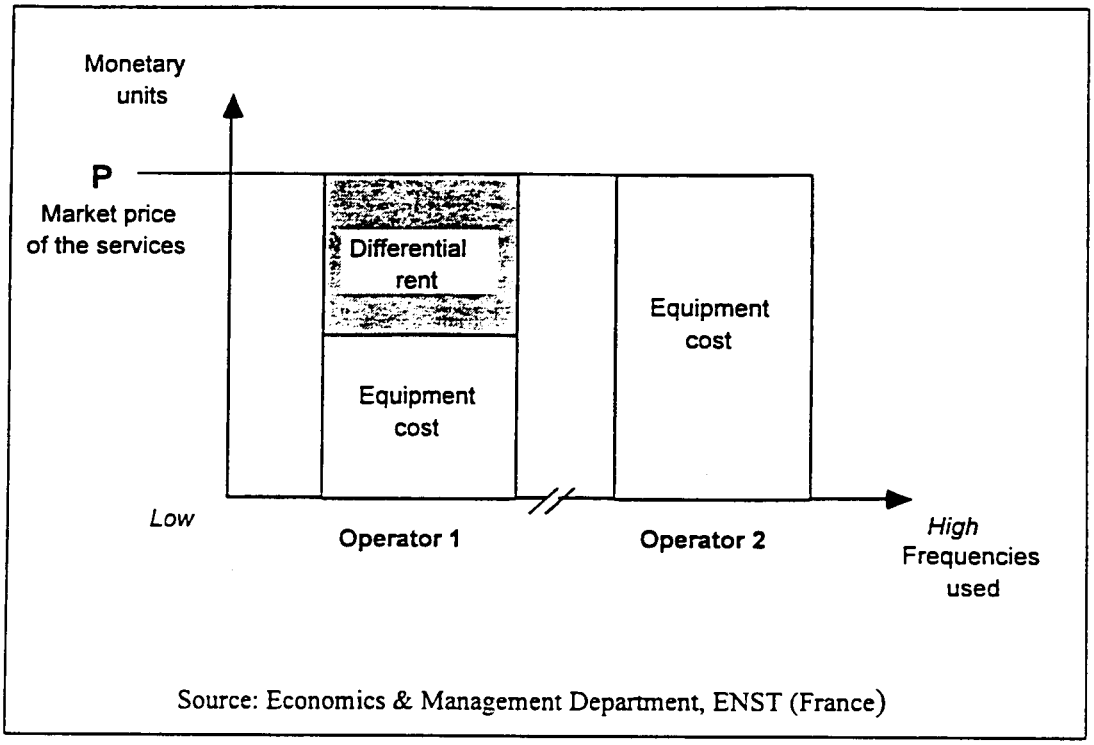
Various radio frequency bands have specific physical propagation characteristics that make them suitable for various information transmission purposes. Generally, the higher the frequency (shorter wavelengths), the less the signal is able to propagate beyond obstacles, either natural or man-made.

In addition, the higher the frequency band the greater the available bandwidth. For optimum exploiting of the radio spectrum the low frequencies should be used where the required channel widths are narrow (e.g., narrow band data or voice); higher frequencies should be used for wider bandwidth signals (e.g., television, broad band multiplexed signals). Pursuing the analogy with land, flat land and broad open spaces are better suited to cereal crops while hilly country and land dotted with trees are better suited to stock farming.

Technical means cannot overcome these two types of heterogeneity of the resource, as is the case for the fertility of the land. Having access to the most suitable frequency band thus makes it possible to minimise the investment cost of the equipment associated with the use of the radio spectrum resource. The natural heterogeneity of frequencies thus appears as a source of differential rent, the appropriation of which will be, explicitly or implicitly, an economic, political and social issue.

In the simplest case, the differential rent is immediately perceptible. For example, assume that two competing cellular radiotelephone systems use greatly different bands, both capable of handling the same volume of traffic with the same quality (Figure 3). The first uses 800 MHz frequencies, while the second has higher frequencies and assume as an example higher equipment cost for higher frequencies. Since the market imposes a single price for cellular radio communications (P), the operator using the lower frequencies with lower equipment costs has a higher profit level than his competitor. The origin and amount of this element of profit have nothing to do with his qualities as an entrepreneur, but relate solely to the properties of the assigned frequency band.

Figure 3: Principles Underlying the Emergence of Differential Rent



Source: Economics & Management Department, ENST (France)

This is a typical case of a differential rent. In the schematic example (Figure 3), the unit rate of the differential rent directly links to the difference in cost induced by the heterogeneity of the radio spectrum resource used by each of the two operators.

Currently, the existence of these rents may not be clearly manifested because the spectrum in most countries is not sold on a market and thus has no price. What is more, many uses of the spectrum are totally outside any market value logic as they involve achieving some other goals not directly related to economy (e.g., military uses, amateur radio).

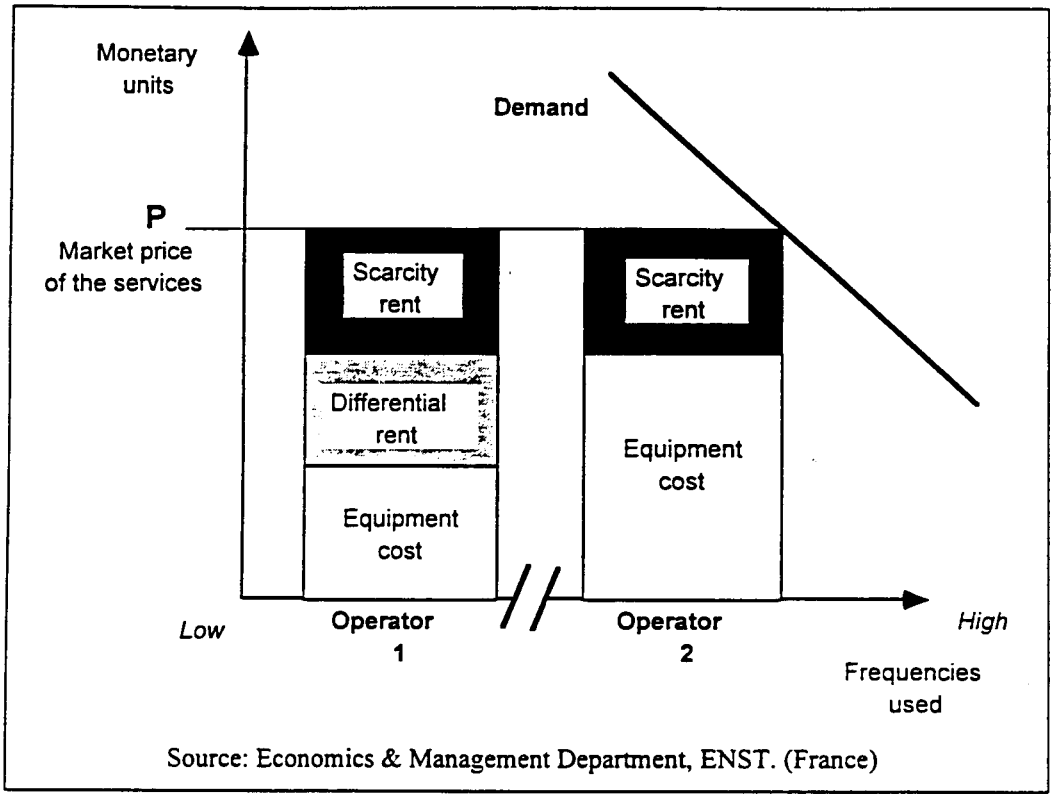
The fact remains that these differential rents exist for physical and technical reasons, independently of their form or mode of appropriation. In the present context, they benefit certain parties (e.g., operators, consumers, equipment suppliers) even if they do not have a monetary value put on them or are not subject to an explicit appropriation strategy.

2.3 Scarcity Rent

When demand for a good exceeds its supply, then scarcity gives rise to the emergence of a scarcity rent. This rent occurs because of the impossibility of increasing supply in the short term, while demand continues to grow. As with differential rent, scarcity rent is not readily apparent since the radio spectrum is not priced with this in mind. This rent links directly to the scarcity of the resource, not its heterogeneous quality, as in the case of differential rent, and one of the parties will appropriate it.

Figure 4 is a schematic representation of the situation that prevails in the case of a shortage of spectrum. Assume that two cellular radio operators (1 and 2) compete in a market. The demand for their services exceeds their supply capacity, which is limited by the amount of spectrum available to them. They raise the market price (P) for their services above costs. This increase is the emergence of a scarcity rent (shaded part of figure 4). In doing so, they reduce the waiting list of customers and avoid overloading their network. In the case where operator also has a more appropriate frequency, then the scarcity rent adds to his profits, as was the case with the differential rent.

Figure 4: Mechanisms Creating Scarcity Rent



Source: Economics & Management Department, ENST. (France)

One can clearly see the phenomenon of rent creation in countries where the tariff structure of cellular telephone networks distinguishes between high-density urban areas, and low or medium density areas. For example, a private company competing with a national telecommunication operator, charges twice the price in a major city and the closer suburbs than in the provinces. Since the investment cost per subscriber due to the greater density of network equipment in urban areas cannot justify doubling the price, one must conclude that this private company appropriates a scarcity rent.

As the company's public competitor adopts the same pricing policy, the two firms benefit from the scarcity rent. This situation tends to arise in cases of duopolies, when the good in demand is scarce.

This raises the question:

Should the differential and scarcity rent not go to the owner of this resource, the State?

In other words, should the State not legitimately include in its fees an amount to recover this rent, since in the end the consumer bears the cost of the scarcity?

2.4 The "Spectrum Paradox"

Technical progress in the field of electronics and information technologies has multiplied the number of users of radio spectrum.

While technical progress also has permitted a more intensive use of the spectrum, the imbalance between the demand for radio frequencies and the available supply keeps growing, especially in urban areas. This imbalance tends to be structural, at least in the industrialised countries. Consequently, there is rivalry for the use of the spectrum, which is typical in situations where the supply cannot satisfy the demand.

Economists suggest that, when demand for a scarce resource exceeds supply, a price system should be implemented, to balance supply and demand. Since the spectrum is a scarce resource, the rules of national frequency provision should consider economic aspects.

However, in the case of spectrum, although demand often exceeds supply, the price of the resource to many users remains nil in many countries. This atypical situation is called by some economists the *spectrum paradox*. This paradox results from the methods of allocation and regulation of the spectrum, that often consider only technical (i.e., interference control) and legal aspects, and fail to take into account the economic value of the resource.

The spectrum paradox initiated a body of important economic literature dealing with the nature and the mechanisms for the allocation of the resource. Given the current scarcity of the spectrum, some countries are investigating the possibility of introducing economic incentives into spectrum management procedures. A number of countries initiated studies on this subject and have set up commissions or expert working parties to study proposals in this area but no consensus on a common recommendation applicable to all countries has been reached on the issue till now. A review of the status of these studies can be found in ITU-R Report SM.2012 on economic aspects of spectrum management.

It is, however, universally recognized that the spectrum has economic value. This value could therefore be taken into account in spectrum management decisions and revealed to the users of the resource, irrespective of whether they are private or public entities. In terms of general principles, all countries acknowledge the need for greater flexibility in the current allocation procedures so that the frequency bands can be reallocated relatively speedily when necessary without jeopardizing long-term planning objectives. No final conclusion has been reached yet as concerns the recommended methods and ways on how to implement these principles in practice.

2.5 Spectrum provision approaches

It is important to note that providing spectrum can be tied to economic concepts and the setting of spectrum fees. In some cases, such as auctioning, the provision of spectrum inherently involves the fee system. In others, such as first-come, first-served licensing, the process and the fee are independent matters.

The following four major parties are involved in the development and operation of radio services:

- The **Administration**, who determines access, conditions to radio resources and equitable procedures for their use;
- The **Manufacturer**, who builds and distributes the equipment;
- The **Operator**, who operates the services making total or partial use of the equipment and assigned portion of spectrum resources ; and
- The **End user**, who may or may not know that the equipment he/she is using works on radio frequencies. Generally, all of the previous three groups claim to speak in the end user's interest.

The following three sections will consider the roles of these parties according to three general approaches to spectrum management. They are the:

- **Traditional**, characterized by little or no price being attached to spectrum access. Most often, this is combined with significant state control of telecommunication, including operating monopoly service providers.
- **Liberal**, characterized by a market approach that includes the possibility of spectrum pricing at all levels, including the allocation of spectrum.
- **Mixed**, a blend of traditional and liberal.

The first two approaches are the extreme positions; no administration takes either approach universally at this time. The third approach is the general practice throughout the world, with administrations operating at different points between traditional and liberal. In this case, portions of the spectrum are allocated to some entities (i.e., usually the Government) essentially at no charge, and more recently, others are allocated at a market price, established e.g. by means of auction. The balance is allocated to the public by licence, under various procedures, usually on a first-come first-served basis, at prices set arbitrarily by the Administration.

2.5.1 Traditional Approach to Spectrum Management

In legal terms, the radio spectrum is an international resource, analogous to international waters whose use requires international agreement. This is a historic classification that stems from the use of HF at the beginning of the 20th century. Propagation characteristics are such that a HF signal can go around the world across national borders. In order to avoid interference and respect national sovereignty it was therefore necessary to regulate their use at the international level.

As mentioned in Chapter 1, the International Telecommunication Union (ITU) has established general rules and regulations regarding international spectrum allocation and spectrum management. These are contained in the Radio Regulations (RR) published by the ITU. Taking into account these international regulations, each member nation creates its own legislation and relevant rules and regulations to accommodate its national radiocommunication infrastructure and goals. The intent of these rules is to provide a necessary structure for the spectrum management process.

The progressive use of higher frequencies that propagate over shorter distances, often remaining within national borders, means that there are now substantial, exclusively national spectrum uses. However, recognition of the international regulations by all countries results in similar national allocations to services and national regulatory structures. These are of the centralized administrative type, with the State playing the role of the General Spectrum Manager.

Under the present approach to spectrum regulation most frequency bands are subject to some restrictions that may be classified into six regulatory decision levels:

(1) International (ITU) restriction of type of use (e.g., fixed, mobile, broadcasting)

(2) National restriction of class of user (e.g., government or non-government)

(3) National restriction of type of use (e.g., fixed, land mobile, television broadcasting)

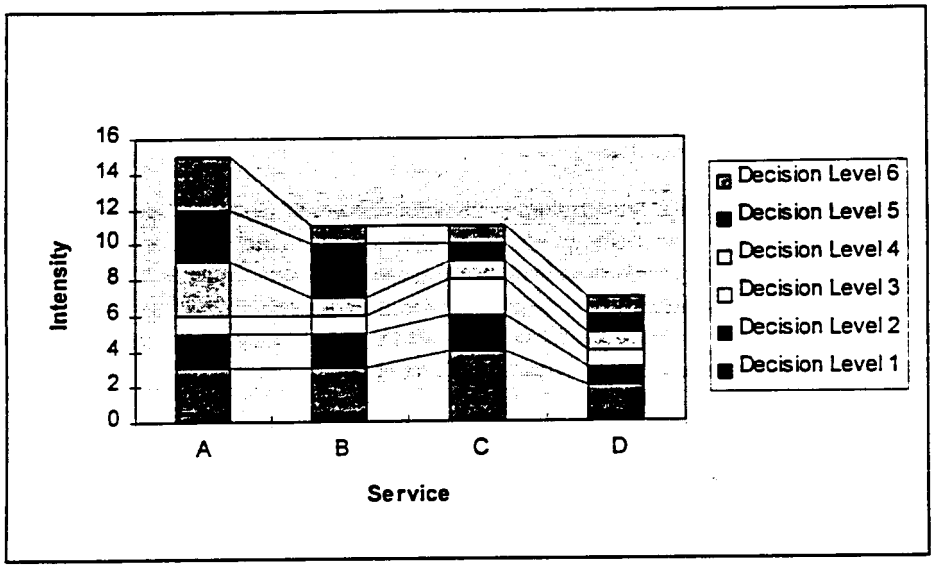
(4) National restriction of class of user (e.g., taxicabs, railroads, utilities)

(5) National restriction of system design technical details (e.g., modulation, power, antenna height)

(6) National restriction of spectrum use (e.g., No. of mobiles per channel, No. of channels per megahertz, co-channel distance spacing)

At each of these regulatory decision levels there may be a considerable difference in the intensity or details of the regulation imposed in one band or service, versus another.

Figure 5: Regulatory Intensity by Band



Thus, graphically, the present spectrum regulatory structure would appear as a series of bars representing the different services and bands (see figure 5). For example, consider two hypothetical adjacent bands, one allocated to private land mobile (bar A), the other to common carrier land mobile (bar B). As drawn, the bars representing the regulatory structures of these two bands coincide through decision levels 1, 2 and 3. This indicates that they both have the same ITU allocation (Mobile), both serve non-government users and the Administration has allocated both to land mobile. At levels 4, 5 and 6 however, the two bars differ, indicating the different degrees of the regulation applied. At level 4 the private band is sub-allocated into several smaller bands with each band restricted to a narrowly defined group of users (e.g., business, police), while the common carrier band is hardly user restricted at all (any citizen may use the facilities). At level 5, the technical constraints applied to the two bands are again similar (power limit, modulation type, antenna height, etc.). At level 6, the private band is more heavily regulated through the imposition of mandatory channel loading standards, whereas licensees in the common carrier band are given the freedom to provide various grades of service to meet a wide range of market needs.

In the traditional approach, the interplay among the four major parties (i.e., administration, manufacturer, operator, user) is complex and critically dependent on the regulatory environment. Hence, if we consider the radio frequency spectrum being owned by a public entity, the Administration is the only judge of the need and timeliness of using particular frequencies, and only

the general interest "as represented by the State" is taken into account[17]. Administration makes sole decisions as to the price of supplying a frequency band. These could include supplying it above its cost (i.e., creating a revenue for the State treasury), or below its cost (i.e., an industrial policy to indirectly subsidize the manufacturer or as a public service to the end user).

Until now, in many cases account was taken principally (if not exclusively) of technical parameters such as transmitter power, coverage area, transmission characteristics, bandwidth, and protection ratios that defined any sharing between different systems. Historic constraints also were taken into account (e.g., when a certain frequency is given to a particular use, that frequency is in principle inaccessible for another service)[18]. In this context, the efficiency of providing radio frequencies was measured essentially on the basis of technical indicators. Indeed, the major declared objective of most national administrations remained "until recently" the avoidance of interference and the guarantee of service quality. On the basis of this founding principle, allocation to services and assignment were accomplished on the basis of planning and first-come, first-served.

Planning depends on the availability of radio equipment.As the development of this equipment is long and costly, manufacturers and operators prefer to ensure the availability of suitable frequencies before making the necessary investment.

2.5.2 Liberal Approach to Spectrum Management

All countries of the world treat the frequency spectrum as a public good. As mentioned above, central government agencies manage the spectrum, often giving it out virtually free of charge, except for certain uses. In some countries, most notably in the US, a large number of users have been private enterprises; in other countries they have been public sector organizations.

In the 1950s, American economists questionned the windfall profits of private broadcasting companies, due to their free use of the radio spectrum. According to American authors, free access to this scarce resource has led to a situation where profits were greater than normal profits on competitive markets. The extent of such profits, in capital gains, could clearly be seen upon the sale of broadcasting stations between private operators.

From the standpoint of liberal analysis, competitive mechanisms should be implemented; and, in order to do so the radio spectrum should become a *private good.* According to economic theory, a commodity in order to be individually or privately owned must have the following attributes:

- **Exclusivity**, divisibility and rivalry between types of use; the use of a quantity of the item by one individual prohibiting the consumption of that same quantity by any other individual; and
- **Transferability**, possibility of allocation of exclusive and transferable property rights providing price-mediated exclusiveness, so that any economic agent not paying the required price is excluded from consumption.

In reality, many goods and services do not possess the above-mentioned characteristics. These are public or collective goods. Indivisibility and the impossibility of exclusion would thus seem to be a

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17 Governments/Administrations act for public interest, that is the interest of all groups, including manufacturers, operators, and end users in a balanced manner as approved by the parliamentary majority, and the parliament continuously controls its activities. Some social or national goals, such as e.g. defence development of poor regions, building information infrastructure in remote areas, may require departure from the marked-oriented decisions.

18 Such decisions may result from the necessity to protect the investments in the equipment installed.

central element in the definition of a pure public good or service. Clearly, from the point of view of competing uses (e.g., television, mobile services), frequency bands are divisible and the possibility of exclusion is a real one. In this respect, the spectrum would not in essence fall into the public domain.

The radio spectrum nevertheless is a physical thing whose consumption by an individual does not entail any destruction consequent upon its use, although a number of operators generally cannot simultaneously transmit similar signals at the same time over the same area without creating harmful interference. The impossibility of exclusion is to a certain extent characteristic of some of the uses of radio (e.g., broadcasting); but as will be seen later, it is possible to define exclusive and transferable rights to frequency bands.

The American economic analysis is essentially based on the theory of property rights. It advocates the setting up of legal property rights (exclusivity) and a market for the exchange of these rights (transferability). If the right is exclusive, its owner bears all profits and the negative consequences from the advantages attached thereto. The individual is able to make optimal decisions between competing uses only if he/she can transfer his rights at any time; the transferability presupposes the existence of efficient markets.

A market requires the existence of a decreasing demand curve (i.e., the higher the prices, the lower the demand) and a reduction in the extent of unsatisfied demand by means of changes in prices. The existence of transferable property rights, individual interests and the low cost of price adjustments ensure that there is a fall in demand as a result of price increases.

According to this theory, private property in the resources would ensure their optimum allocation, as they would always be attributed to the most profitable uses (i.e., to operators ready to pay the highest amounts for them). Competition between alternative uses would reduce uncertainty and tend to promote an efficient allocation and use of resources from the economic point of view. Hence, the allocation of frequencies could be dependent on market mechanisms, where prices play the role of an indicator, not requiring any administrative intervention. Furthermore, users of the spectrum generally buy intermediary items of consumption (e.g., equipment, land) on the market in competition with numbers of buyers.

If a market system can operate satisfactorily with the institution of property rights guaranteed by law, the definition of such rights over frequency bands requires taking into account problems of interference, as the quality of the signal received partly determines the value of the frequency bands. In order to avoid interference and achieve a degree of flexibility in the use of frequencies, entitlements to ownership should include precise clauses relating to the geographic limits of the area of transmission and the *usable* frequency bands. Also, the owner could be able to:

- Negotiate changes in his transmission boundaries and in the limits on his transmission power;
- Sell his emission right for a part or his entire geographic area and frequency band;
- Grant the right to transmit to a third party for a given period of time; and
- Predetermine the power of transmission, the location and the height of its antennas.

The existence of property rights and of a market system, it is thought, would promote the intensive and extensive development of the spectrum, and of any substitutes to it. It would do this by making cost comparisons and the appraisal of economic rates of return among various technologies possible.

The value of the transmission being dependent on the quality of reception, owners of frequency bands would have every interest in maintaining a certain quality of service. Hence the frequency market would act as a protector of the public reception rights. In a market system, the modernization of equipment and the substitution of one use by another would occur only if they led to an increase in

the value of the property rights. In this case it is likely that the operators would subsidize the necessary changes to receivers.

According to the liberal approach, private property rights can assure the optimal use of the spectrum, although these rights do not appear to be absolutely necessary from the point of view of economic efficiency. The State could rent the spectrum resource to the highest bidder instead of selling it. Hence there would be competition for concessions, and not for purchasing property rights.

The market system would eliminate most national regulatory restrictions . The initial distribution of rights could be realized by auctions or lotteries[19]; rights could also be given to existing users. Compared to the two other methods, auctions have the advantage to assigning the rights to users who value them the most. If the initial distribution of property rights does not lead to an optimal allocation of the spectrums, transactions would take place on the market until all viable services are implemented in acceptable conditions. Market forces could even replace the central administration in its allocation and interference control functions.

The interplay among the parties (i.e., administration, manufacturer, operator, user) would be quite different from that outlined for the traditional approach. The State's involvement would move away from technical aspects almost entirely. Although, the State might retain a part of the spectrum for services requiring broad frequency bands and for those considered to be in the public interest but not particularly profitable. Manufacturer's dependency would change from the State to the operators of the services. However, it might be more closely aligned with a new party, the venture capitalist, who could emerge from a secondary to a primary role. The user would have a broader range of services. However, if the State did not retain spectrum for public interest, or did not retain enough, some less profitable but socially desirable uses might come into shorter supply.

2.5.3 Spectrum Management in a Mixed Economy System

Regulation offers undeniable advantages:

- Answers the needs of national defence;
- Helps to maintain a certain quality of service;
- Helps to prevent abuses and speculative behaviors;
- Guarantees a certain degree of harmonization at the international level, allowing economies of scale in equipment production.

While pure market (i.e. liberal approach) and the centralized allocation (i.e. traditional approach) are the extremes of allocation, it is possible to mix the two methods that may create an effective mechanism. Several methods of allocation or assignment could be implemented, governed by different rationales.

From the Administration's perspective, this is desirable as optimum selection of method can take into account the administrative burdens and political concerns. So, for some bands, an approach towards liberalizing would reduce effort. For others, where the State requires more control, the price paid is to run some form of data base system with the inherent human and monetary costs involved.

The operators usually have two views, one for those that are state owned and often monopolies, and one for the private operators, many of whom at this time wish to break into the carrier market. A mixed system permits this to proceed in a controlled manner, with the Administration factoring in the socio-economic and political decisions on a service by service basis, usually during major changes or when it opens new bands.

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19 For more details on lotteries and auctions please refer to ITU-R Report SM.2012.

The manufacturers and operators generally play a major role in a mixed economy system. Often, the Administration has so many choices from which to pick, both technically and from a regulatory point of view, that it is desirable to make the manufacturers and operators into stakeholders. This is usually done through an extensive consultation mechanism, such as consultative committees, public tabling of government policy proposals for comment, or through acceptance of unsolicited policy inputs from industry.

The hybrid approaches increase users' freedom, to a lesser extent than the market, while allowing the State to keep overall control on the resource. It also allows the State to recover, at least in part, rents from awarding access to spectrum.

CHAPTER 3

SPECTRUM MANAGEMENT RULES

The national radiocommunications law should delegate the authority and responsibility to manage spectrum use to a government body or bodies. Which agency or agencies are given the authority to manage the spectrum will depend upon the structure of the national government itself and will vary from country to country. Spectrum management can be carried out by one or more agencies; a single authority may be better.

3.1 A clear-cut distribution of frequency bands and responsibilities

Frequency management is often shared between several entities. For instance, for various reasons, radio frequency spectrum used by armed forces is managed separately in many countries. Without appropriate co-ordination, it may lead to conflicts with non-military users. It is necessary to limit such conflicts by clearly distinguishing the "incompatible" users and avoid structures oriented towards defending their own particular interests only.

3.2 Management requirements

The frequency spectrum is limited. As long as each user can have a frequency assignment for his exclusive use, to keep order, it is sufficient to record the users only. However, this has now evolved in view of the insufficient number of frequency assignments available to satisfy the needs of an increasing number of potential users. Thus, the available frequency assignments must be shared, that is used by two or more users. This may lead to chaos and consequential blocking of radiocommunications if not managed and monitored adequately.

When the number of transmitters increases, selection of the spectrum management policy becomes more and more difficult. The RF spectrum is treated as a public resource in most countries. All this means that, without an effective management system, all possibilities offered by sharing and multiple usage of the radio frequency spectrum would be greatly diminished and the economy of a country striving to effectively develop its radiocommunication means would greatly suffer.

3.3 Planning spectrum management activities

Spectrum management is currently less developed in many countries, since most countries have only recently been confronted with spectrum congestion, creating the necessity for efficient utilisation of frequencies.

The spectrum management mechanisms can be planned over a short term, long term, or on a strategic basis[20]. Each of these implementation mechanisms requires a commitment to regular activity. Planning ceases to be planning when it is driven by immediate crisis or consequence. Therefore, the first step in implementing successful planning is to create a recognised process for considering issues and updating plans. This process should include specific means for conducting short term, long term, and strategic planning. Short term and strategic planning, in that they deal with specific or focused issues, will not fit prescribed outlines or formulas. However, they should always delineate requirements, resource availability, policy decisions, and plan implementation. A long-term plan, on the other hand, will generally fit a standardised pattern and cover certain areas as a minimum. Each administration must consider the impact of plans on its constituents, its neighbours, equipment manufacturers, service providers, and spectrum users. Decisions must be made based on the national priorities. Therefore, simple rules specifying how the individual factors must be considered cannot be applied.

3.3.1 Spectrum monitoring and complaint processing

Spectrum monitoring activities support spectrum management decision making by supplying information that can be used to:[21]

- Determine actual channel usage, channel availability;
- Locate and resolve interference problems;
- Verify compliance with spectrum management rules and regulations through measurements of technical and operational characteristics of transmitted signals and the selection and identification of unauthorised transmitters;
- Supplement and verify information contained in spectrum management registers;
- Determine the efficiency of the spectrum management process.

In several countries, monitoring means are limited often to isolated monitoring stations that can provide only listening possibilities, without localisation capabilities, and a few mobile auxiliary vehicles. Such equipment enables only direct localisation of transmitters, provides a weak assistance in localising illegal (clandestine) transmitters and is often inadequate to collect data on channel occupation and on utilisation of transmitters.

3.3.2 Registration and issuing of authorisations

In several countries, the criteria and administrative rules for issuing licenses and the policy used are often unclear and the whole process is not sufficiently transparent which makes it prone to corruption. Dispersion of spectrum management responsibilities masks private interests, which poorly accommodate transparency in issuing authorisations.

To counter such a lack of objective criteria and rules for providing authorisation, in some countries auctioning mechanism has been introduced for some frequency bands and services[22].

This approach encourages more profitable spectrum uses, whereas other uses that may be useful according to different non-for-profit-oriented criteria, are discouraged, since each actor seeks the

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20 See Chapter 3.3.2, ITU Handbook on National Spectrum Management

21 See Chapter 7, ITU Handbook on National Spectrum Management

22 For more details on that topic, see e.g. Report ITU SM.2012.

most profitable openings, the only ones implemented even if they only correspond little to the specific user requirements.

Only transparent published regulations can protect against unjustified attribution of privileges to certain users, and allow for rational management and use of the spectrum.

3.4 Structure for Radio Spectrum Management

Each country has to maintain a specialised spectrum management authority that fits best to the country's administrative structure and available resources. Generally, that authority should deal with all spectrum management issues, and be separated from institutions that create legislation. For spectrum management issues that do not fall within the scope of this agency, for example the frequencies for armed forces, it is necessary to set a negotiation/arbitration mechanism.

The spectrum management authority has to co-ordinate its activities with telecommunication authority in the following areas: Networks comprising (wired) telecommunication and ratio components (e.g. wireless rural telephone networks). The telecommunication authority controls the interface with the public telecommunication network and general telecommunication requirements, whereas the spectrum management authority the wireless part of the system.

CHAPTER 4

SPECTRUM MANAGEMENT CONCEPTS

4.1 Efficient Use of Spectrum

4.2 Spectrum Management Principles

4.3 Licence Fee Structure Principles

A - All spectrum users should pay a fee

B - The fees should cover the costs of spectrum management

C - The fees for exclusive or shared spectrum uses

D - The fees should not be treated as a source of revenues for the State

4.4 Licence Fees

4.4.1 Fees based on spectrum management costs

4.4.2 Incentive fee formulas

4.4.3 Fees based on users' revenues

4.4.4 Fees based on the opportunity cost

4.4.5 Fees based on the shadow price

4.5 Auctions

4.5.1 Applicability of auctions

4.5.2 Pre-auction requirements

4.6 Mission of the Agency

A - Assign frequencies

B Recommend technical/operational characteristics of radio systems

C - Control/manage of radio networks

E - Ensure collection of fees related to radio spectrum utilisation

D - Ensure representation abroad

Annex. Spectrum Fee Formulas

Discussion

Comparison of Fee Formulas

4.1 Efficient Use of Spectrum

Usually, a regulatory system for telecommunications at the national level comprises four main elements:

- The legal instrument(s) establishing the regulatory body or bodies; defining the regulator's powers, rights and obligations; and defining the rights and obligations of the regulated

Recognized Operating Agency (ROA) and other entities subject to telecommunication regulation.

- The regulatory organisation itself.
- The linkages of the regulatory organisation to other members of the governmental structure, including ministers or equivalent office-holders, the legislature, the courts, etc.
- The working methods of the regulatory organisation.

In many countries, policy makers have come to appreciate the critical importance of telecommunications as an "enabling technology". Telecommunications make it possible for a wide range of industries to reach high level of productivity, which is especially vital in global competition; and also serve important non-economic needs for information and communication. Experience of developed countries suggests that certain forms of regulation are necessary if the potential benefits of telecommunications are to be fully realised.

Any effective regulatory system must be charged with one or more clear fundamental "missions" that define the results that regulatory decision-making and intervention are intended to achieve. A statement of "mission" for the telecommunications regulator may include one or more of the following elements:

- **Achieving progress towards social goals concerning e.g. "universal service".** Such goals are generally designed to ensure that, as far as possible, no geographic area or social group is deprived of access to telecommunications service on reasonable terms. They figure, for example, prominently in the "concession" policy setting the regulatory ground rules for the recently-privatised monopolies. The "mission" may also include goals concerning the availability of service to limited-income households, or the disabled.
- **Protecting user interests and considering user complaints.** In addition to the "universal service" goals, the regulator may have a general obligation to protect the interests of telecom users, and to consider their complaints.
- **Changing the industry structure,** for example to ensure that competitive entrants become established in specified segments of the telecommunication services industry.
- **Moving towards a "no discrimination policy".** Where competitive entry is allowed, policy may call for a transition towards non-discriminatory conditions of participation in the market between different national carriers, including the major established carrier (the "incumbent ROA"). (Establishing such conditions may not be feasible in the early stages of a transition to full competition).
- **Supervising the dominant ROA.** Where the incumbent ROA retains either a monopoly or a dominant market share, supervising it may be a major mission, or even the major mission, required from the regulator to maintain non-discriminatory business environment.
- **Stimulating innovation.** The regulator may be required to identify opportunities for service innovations, and act to remove obstacles to them (as in the case of the recent strong growth of VSAT satellite communications in Mexico, or in the case of frequency allocations/assignments for Personal Communications Networks –PNC– in the UK and France). The regulator may also be required to actively promote such innovations.
- **Assuring technical preconditions for effective operation, e.g.**, controlling and updating the telephone numbering plan, or defining technical and financial conditions for interconnection of different carriers' networks to the public network.

- **Managing common resources effectively**. Use of certain physical resources and related rights and obligations, such as the RF spectrum or public rights-of ways.
- **Stimulating investment in the public network.** In some countries (especially the developing countries) a pressing need to accelerate investment in expanding and upgrading the public network infrastructure may mean that creating favourable conditions for this is a key responsibility required from the regulator. Where the network has been or is being privatised, for example, this may be crucial in establishing, and subsequently administering, license conditions for ROAs.

A national regulatory policy may also provide for the regulator to:

- Set technical standards;
- Licence carriers;
- Regulate carriers' prices (tariffs) for service;
- Monitor the quality of service provided by carrier and initiate corrective action if necessary;
- Approve carriers' programmes of construction and capital investment;
- Set the terms (financial, administrative and technical) for the interconnection of different carriers' networks;
- Control the type-approval of customer premise equipment (CPE) and its connection to the public network;
- Consider complaints from telecommunications users and take corrective action if necessary.

The list of regulatory functions given above represents the principal functions that a radiocommunication agency (in a narrow definition of the term) may undertake. The agency responsibilities may be more wide-ranging, and may include:

- Control/monitoring of the use of radio frequencies;
- Licensing and/or otherwise regulating broadcasters;
- Licensing cable TV operators and control their prices or service offerings.

The Agency's purpose is to enable an optimum utilisation of the RF spectrum, considering the frequencies available and means implemented, for all users of radiocommunication means.

This resource management can be optimised by applying the principles described hereafter in 4.3 and 4.4 sub-sections.

4.2 Spectrum Management Principles

Spectrum management is the combination of administrative and technical activities necessary to ensure the efficient operation of radiocommunication equipment and services without causing harmful interference. Simply stated, spectrum management is the overall process of regulating and administering the use of the ratio frequency spectrum taking into account the current and expected future applications of wireless technologies. The goal of spectrum management is to maximise spectrum efficiency and minimise interference. Rules and regulations based on relevant legislation, form a regulatory and legal basis for the spectrum management process. Databases of information, including details of all authorised users of the spectrum provide the administrative and technical basis for the process. Analysis of the information in these databases facilitates the spectrum management process resulting in decisions for spectrum allocations, frequency assignments and licensing.

Spectrum monitoring provides the inspection, verification and enforcement necessary to maintain the integrity of the spectrum management process.

The reader should refer to the lTU-R, 1995, Handbook on National Spectrum Management and Handbook on Spectrum Monitoring for more detailed information.

The planned organisation could be based on simple ideas, as follows:

a) It is illusory to control and manage the radio frequency spectrum without knowing the existing radio equipment.

Monitoring is impossible if we do not know what to monitor, and there can only be management when knowing what is effectively authorised. All that is outside that standard frame cannot be discernible and therefore checked. In particular, it is impossible to efficiently monitor the authorised uses of radio frequency spectrum if the reference databases are not complete and up to date: spectrum monitoring can only be effective by comparing the results of measurements with the existing data, to identify the differences. Without updated data, it is blind.

General information indicating that a frequency is used by a given user over an area is insufficient for management/monitoring the spectrum: it is necessary to know all the transmitters' data, especially fixed transmitters.

Experience gained in some countries indicates that the monitoring operators may not be motivated to check information on transmitters that are exempted from licensing process (not taxed), whose users do not declare the technical parameters of a network, for instance.

b) In order to use spectrum fees as an instrument of spectrum management, information about the existing equipment should be known.

To make the users pay their fees, the address where to send the bill should be known and who to prosecute if necessary. Similarly, if the technical descriptions of the equipment used are insufficiently known, then it is impossible to use financial means as a spectrum management instrument.

c) Armed forces have specific requirements.

Several factors may require special treating of the military networks. The fact that they under-utilise the frequencies reserved for them is not necessarily the sign of bad management. Such under-utilisation results often from the necessity of preserving the frequencies in reserve or for secrecy reasons..

d) Enforcement of laws and regulations can be implemented when the RF spectrum emitted by equipment is known.

Once spectrum management databases are updated, it becomes possible to monitor illegal uses (declared or not), since they can be compared with the authentic registers of legal uses. To practically implement enforcement, monitoring facilities should be available (equipment, access to installations, etc.), and appropriate execution means at hand. Sometimes the use of police powers may be necessary and technical monitoring facilities should correspond to sophistication level of the equipment to be controlled.

4.3 Licence Fee Structure Principles

At this point, there are questions of semantics that must be settled because terms such as fee, licence fee, royalty fee, value-added fee, and tariff may mean something different in each country. Also, some governments levy a simple once-per-year fee on each radio station, while others have multiple charges such as:

- Application fees,
- Construction permit fees,
- Import permit fees,
- Fees related to revenues.

To further complicate the issue, the applicant or licensee sometimes must pay fees to more than one government body.

This Handbook will generally use the term licence fee to include all payments by the applicant and licensee to the Government directly related to owning, establishing, and operating radio stations. It will not include such other charges as value-added tax, sales tax and customs duties. However, when the need occurs to go beyond this convenient definition, the specific nature of the payment will be specified.

Given the mission statement for spectrum management (section 4.2), a logical next step is to define the goal or objective of having a licence fee structure. For example in Asia, there is a wide diversity of national priorities, generally linked to the relative emergence of each nation from an economic perspective. Thus, the licence fee structure varies generally between countries.

A nation having a developed telecommunication infrastructure might have an objective to maximise government revenues from the use of radio frequency spectrum. Another nation might decide to collect licence fees at a level to simply recover the cost of managing the radio frequency spectrum. Nations with little underdeveloped infrastructure might have as a strategy, massive development of infrastructure to close the gap. This might include incentives, low or no duties on equipment and commensurably low licence fees.

Consequently, the prime objective for establishing a licence fee structure could range from: " *providing total revenues that cover the cost of managing the radio frequency spectrum and which provide a reasonable return to the "owners" of the radio frequency spectrum, that is the citizens of the country"* to: *Maintaining total revenues at as low a level as possible, while recovering essential costs, in support of the national goal to rapidly develop communication infrastructure.*

Fees for use of the RF spectrum is one of the factors taking part in optimising spectrum management, by inciting its good and economic usage. Whatever the precise fee rules adopted, especially the fee rates applied, the following principles should be applied:

A - Most spectrum users should pay a fee.

The fee should correspond to their actual spectrum use.

This principle is a minimum to partake in a healthy management, according to the management principles defined in 4.2. A user who does not have to pay for using the RF spectrum is no way incited to declare the reality of his radio frequency installations, nor in economising the resource.

Since use of these frequencies is not known if it is not controlled/monitored, the user has a possibility to request additional channels, without having to justify their use, which is evidently not the sign of a healthy management. This notably concerns institutions that have a natural tendency in believing to be owners of frequencies assigned to them.

B - The fees should cover the costs of spectrum management.

The radio spectrum use fees should cover the total costs of spectrum management. These costs should include all direct and indirect costs, including those related to the necessary research and development work and enforcement costs.

They may differentiate between

– Number of channels used,

– Channel utilisation coverage area,

– Channel utilisation duration,

– If necessary, channel utilisation timing.

Spectrum fees may effectively incite economizing the spectrum. Three main parameters listed below account for spectrum management.

The first parameter accounts for the frequency bandwidth used (it answers to the question "What?"): as a function of a reference channel (12.5 or 25 kHz for private user networks, for example) and modulation type.

The second parameter accounts for the area over which the frequency used would be impeding for other users. The surface area or situation of this coverage area can be introduced in the fees.

The third parameter accounts for effective utilisation of the assigned channels over the geographic area. Generally, a network with a low number of transmitters over a given area is much less impeding for future assignments than that comprising a large number of transmitters. The latter case makes it difficult to insert new transmitters over the geographic area.

Similarly, a frequency which should be protected from other transmissions over an area (non-shared frequency) blocks any other utilisation and reassignment of the resource. Its payment may then be greater than that for users whose frequency can be shared. Including this parameter into fee considerations may lead to increased spectrum use efficiency over crowded areas.

It may also be judicious to consider the frequency utilisation timings, so as to apply different tariff rates for the use of frequencies according to timings, as for telephone call charging. This could enable multiple assignments by distinguishing, for example, between networks that operate during the day-time and those operating at night, or still between those operating on certain days of the week, to share the frequency.

C - The fees for exclusive spectrum use should not be smaller than the fees for shared use of the spectrum.

It may be necessary to assign specific frequency bands for exclusive use by certain users, e.g. broadcasting or "safety" networks. This situation may lead to abusive use of the spectrum. For that reason it may be preferable to discourage assignments of exclusive frequencies in unjustified situations. TDMA or CDMA techniques are promising techniques allowing utilisation of a common frequency channel by a number of transmitters. Systems able to share a common frequency channel and spectrum efficient systems should enjoy privileged fees with respect to exclusive uses.

D - The fees should not be treated as a source of revenues for the State.

The initial task of the agency is to achieve effective spectrum management. In many countries the monitoring and enforcement functions are considered as the best way to achieve that goal, whereas in others other mechanisms such as market mechanism are believed to be appropriate.

Though the agency and its government may naturally be interested in obtaining as much money as possible from the users, an over-charging with respect to the operating and investment costs of the agency should be avoided. One way is to limit license fee collection to the amount that covers the agency's budget (which should be monitored independently).

This limitation consisting in repayment to the State could however be cleared as a function of other national priorities, notably in the field of telecommunications or for specific development programs, if these actions are limited in time. The suspension of this obligation should occur only once the spectrum management system has been developed.

Conclusions

As noted in section 4.2, the principles of spectrum management are probably similar in all countries. However, as one might imagine from the discussion of the diversity of national economics and consequent differences in the national policies, the universal principles for setting spectrum fees are likely not so easy to articulate. They will vary depending on social, economic and political differences between the countries. Some of the spectrum management fee principles that could be applicable to most countries are:

- Users should pay at least for spectrum management and the fees should benefit all spectrum users.
- Fees should be as equitable as practicable - identical use should attract identical fees.
- Fees may be a function of the amount of the resource used - use more, pay more; use less, pay less.
- Fees may be a function of the value of the spectrum to the user, especially for public service licences.
- Fee collection should not be a burden on government resources.
- Fee changes should be made in consultation with the users and the industry.
- Fees should not be an impediment to spectrum access and, therefore, radiocommunication infrastructure development.
- Fee structure should be transparent and as simple as possible, for ease of comprehension and to avoid any delay in authorising the stations.
- Fees may be related to scarcity of spectrum due to congestion
- Sound technical and operational reasons should take precedence over revenue considerations.

4.4 Licence Fees

Licence fees, as used in this section, are usually annual fees related to the ongoing use of the spectrum. Fees may range in complexity from a simple table by service, to a charge per frequency per station for each service, to complex formulae involving a dozen variables. The following discussion provides some practical examples that respect the stated principles and policies underlying fee setting.

Simple licensing with licence fees is often overused, as it is the most common and best-understood means of extracting spectrum rent. In most country's fee schedules, the possibility of using other sources of revenue, either to simplify operations or to optimise revenues, is not very evident. For example, there are cases where no licence is necessary, since maintaining a detailed record for each station is not required. Consistent with the policy to minimise burden on the taxpayer, the Administration can choose from alternate licensing methods to save administrative burden.

The main licence options are:

- **Conventional:** A separate licence is issued for each station. This approach is recommended only where it is necessary to keep full details in a database for technical reasons.
- **Fleet:** A single licence is issued to cover all stations of a specified category, e.g. mobiles in a fleet. In this option, the base stations and repeaters, if any, are licensed using another method, usually a form of traditional licensing.
- **System:** A single licence is issued to cover all stations in a network. An example would be a single fee for established cellular operators, giving them the right to use their range of frequencies throughout the approved territory. The fee usually includes all the subscriber stations, in which case the subscribers would be exempt from licensing.

Previous sections put emphasis on reducing needless effort while maintaining fairness or equity. Similarly, it is recommended that administrations move to licensing multiple stations on single licences wherever justified. In other words, licence by system, fleet, or conventional means, in that order.

In a user-charge spectrum management system, administratively determined charges, fees, or taxes are applied to users. Simplicity and transparency is an important virtue of license fees since they reduce uncertainties and suspicions with regard to sums to be paid. Furthermore, they can be used without necessarily challenging the existing allocation/assignment of spectrum between uses and users. User fees, like auctions, could eliminate some regulatory restrictions. If they were employed only in the assignment process, none of the restrictions would necessarily be affected. If they were employed in the allocation to services process, some restrictions could be affected (i.e., a user charge could be specified for a given band and allocated on an unrestricted or a restricted basis to any service willing to pay that charge). User fees are not suitable for selection between applicants; they constitute a method for assigning some value to the spectrum.

The main purpose of license fees is to assign a *value* to the spectrum and thus oblige users to arbitrate between frequencies and the other inputs they use. In practice, many administrations do not charge fees to some users (i.e., government, military and state-owned telecom companies). The Administration may define by formula several types of fees. The advantages and disadvantages of each follow.

4.4.1 Fees based on spectrum management

With this approach fees only cover the spectrum management cost of spectrum management. The allocation of total costs between users could be based on several criteria (e.g., individual cost of spectrum regulation per user or user category, amount of spectrum occupied). The main disadvantage of this method is a total disconnection between the level of the fee and the real value of frequencies. Because of this disconnection such fees fail to promote the efficient use of the spectrum. Administrations choosing this basis for charging fees should consider other means such as licence conditions to obviate this problem.

4.4.2 Incentive fee formulas

A second, relatively simple method is to set a fee to encourage efficient use of frequencies. Most of the envisaged formulas contain factors proportional to the population or area served by the radio station, the attributed bandwidth, etc. The fee should cover at least the administrative cost of spectrum management and take into account the scarcity value of the spectrum (i.e., demand in the geographical area concerned) and alternative media to spectrum when they exist.

The Administration would have to determine the constituents of the formula, the way they influence the level of the fee as well as the cost of the reference spectrum unit (i.e., constant "a" in the formulas, see Annex). Since its choices will necessarily be arbitrary to a certain extent, the resulting fee will be arbitrary also.

The problem with these formulas is that efficient spectrum management based on economic considerations requires the determination of a price, equal to marginal willingness to pay for every assignment. There is no reason for these prices to be the same for each assignment, or for the correct price to vary according to the proposed fee schedules. Thus, one defect of the incentive fee formula approach is that one must find a reasonably correct formula to promote efficiency. Another defect of the incentive formula system is that the value of the constant (i.e., "a" in the formulas) has to be determined by an administrative process. There seems to be no way to establish the value of this constant, other than to satisfy some external goal defined by the Government, such as, for instance, raising revenue.

4.4.3 Fees based on users' revenues

Establishing a fee representative of a certain percentage of revenues generated by spectrum use is another simple solution. The problem with this type of fee is that it can apply only to users having revenues directly linked to spectrum utilisation (e.g., broadcasts, mobile communications operators). It can apply neither to those users whose revenues result only indirectly from spectrum exploitation (e.g., public utilities, telcos using microwave links in certain parts of their fixed network), nor to non-commercial services (e.g., defence, national parks).

Furthermore, such a tax does not promote using specimen efficiently, since revenues are not necessarily proportional to the quantity of frequencies used. If the improvement of spectral efficiency induces an increase of users' revenues, it induces an increase of the fee also. In order to avoid the latter, operators could try to under-utilise their frequencies. Nonetheless, if the fee represents only a small percentage of users' revenues such incentives remain weak. The advantage of such fees is that they connect the price of spectrum to the value of commercial activities using frequencies. They are also relatively easy to implement.

4.4.4 Fees based on the opportunity cost

A more complicated solution is to define fees according to the opportunity cost of spectrum utilization. *"Opportunity cost is the evaluation placed on the most highly valued of the rejected alternatives or opportunities"*. In the case of spectrum, the opportunity cost depends upon:

- the number and the variety of users excluded from access to frequencies,
- the value the users place on frequencies, and
- losses resulting from the impossibility to get access to spectrum.

Since calculating the two latter variables would require a huge quantity of information, it seems impossible to avoid approximations. Three methods, advocated by the FCC, are presented below. These are based on:

- the number of frequencies used,
- the average production/MHz, and
- the extra cost of alternative media for spectrum for some services.

A 1967 report considers a certain number of alternative uses for UHF TV channels and in particular the possibility of a reallocation to land mobile communications. Single UHF TV channels can accommodate several thousands of land mobiles. To compare quantities of spectrum used by these two services, account is taken of:

- the surface of the service area,
- the occupied bandwidth, and
- a factor measuring the amount of radiated energy per frequency unit .

The latter (x) is defined as follows:

$x = (r^2)\ (b)\ (P)/100$, where:

r = radius in miles of the effective coverage of the signal (r^2 is proportional to the coverage area of a given signal),

b = bandwidth assigned to an operator (in MHz), and

P = power density factor that measures the effective radiated energy per cycle for a given system compared to a reference system.

By applying this formula one can show that one television channel uses 5700 times more spectrum than a land mobile system (PMR) with one base station and 10 mobile units. If an agency were to introduce a $ 10 fee per spectrum or "X" unit, the PMR would pay an annual fee of $ 20 and the TV station $ 114 000. The tax paid by the PMR is so low that it could not possibly affect its profitability, while the one paid by the TV station is large enough that, for some stations, it could decrease profitability.

Such a fee system could induce a decrease in the number of TV stations and discourage entry in the industry. If we assume that this reasoning is correct, that would mean that there are too many TV stations and not enough PMRs.

The main disadvantage of this formula is that it takes into account only the amount of spectrum used by a given service or user, it does not give any idea about the value they place on frequencies. Furthermore, the same formula applies to all geographic areas and all frequency bands, when the values of spectrum remain heterogeneous, according to location.

Another method is to compare the revenue per frequency unit generated by various uses in order to measure the average product/MHz. In absence of data on operators' revenues, the comparison is based on their expenses (i.e., the two variables are assumed to be correlative).

According to Buchanan (See Bibliography), in 1965, expenses per MHz came up to $ 122,8 million for FM and AM radios, $ 37,3 million for PMRs and $ 8,6 million for TV. The disadvantage of this method is that it points out the *average product* and not the *marginal product* per MHz. The latter, or revenue loss resulting from the loss of one MHz, seems to be a more suitable selection criteria.

Finally, the same report evaluates the extra cost of the best alternative media to frequencies: $ 8 to 13 billion for mobile communications (more cars, more drivers, more phone calls) and $ 3,6 billion for TV (cable).

4.4.5 Fees based on the shadow price

An even more complicated solution is to calculate a fee based on the shadow price of the spectrum. From a theoretical standpoint, this method is certainly the most rigorous; but from a practical and empirical standpoint, it suffers from lack of information needed for its application. Furthermore, it is static, which means that it does not take into account the effects of future decisions, e.g. those resulting from the implementation of new technologies.

To calculate the shadow price, the Administration has to simulate a market from which to determine spectrum users' willingness to pay. To do so one must define an optimal objective and a method of allocation that permits attaining it. Furthermore, the Administration must determine the market price or shadow price based on information supplied by economic agents and taking into account global constraints. Thus, the efficiency of the system depends on the Administration's ability to reproduce users' individual decisions and to centralise information needed for the market simulation.

In the case of spectrum, the shadow price could refer to variables such as savings in investment costs resulting from the use of an extra frequency unit, estimated auction prices or the estimated optimal price of a frequency unit when used by the service that values it the most.

Macauley considers that mis-allocations resulting from an inefficient regulation of the spectrum involve high shadow prices (i.e., savings in investment costs) for frequencies used by satellite systems. According to this author, the shadow price of frequencies (e.g., equipment and R&D expenses) resulting from relaxed regulatory constraints is much higher than their opportunity cost (i.e., value of frequencies for alternative users). Because of the existing regulation, the ratio investment costs/occupied bandwidth is 27% higher than it would be with an efficient spectrum pricing. This distortion involves a 25% increase of satellite production costs compared to costs incurred in a lax regulatory environment with regard to spectrum access.

Shadow prices may be estimated with technical models also. Dunn and Eric compared the costs of various satellite networks with models taking into account variables such as the height of antennas, power and range of transponders and size of earth stations. Such studies allow estimation of the marginal cost of a frequency unit or satellite power unit. The problem with these approaches lies in the difficulty to define a widely accepted technical model. In fact, a deep knowledge of existing and future systems is needed in order to build up a benchmark model giving a correct evaluation of their costs and performances.

Furthermore, data required for these models is not always available. Besides, technical models generally fail to take into account sales, maintenance ant marketing costs. Thus, it seems desirable to combine technical and econometric approaches.

In 1972, a technical proposal submitted to the Office of Telecommunications Policy (predecessor of the NTIA) concluded: *"Although shadow pricing is conceptually popular among economists, there is almost no practical experience with it as a management tool."*

The market simulation project was cancelled because of the unavailability and the large quantity of information required for its operation.

4.5 Auctions

Some countries introduced recently auction mechanisms into their management of selected frequency bands and specific applications. This section is extracted for information purposes from the ITU-R Report SM.2012.

4.5.1 Applicability of auctions

There are potential advantages to using auctions as a method of spectrum assignment. However, different countries will likely also have a number of spectrum management objectives which auctions by themselves may not adequately address. Often such objectives can be met through the use of other policy instruments: regulations, license conditions, standards, etc. Each administration will have to consider its priorities and decide on the overall appropriateness of auctions in light of the various objectives it wishes to achieve. Should an administration decide to utilize auctions, it should be aware that, generally, the greater the number of regulations, conditions, or restrictions put on the use of spectrum to be auctioned, the lower will be the auction revenue, hence, administrations may wish to consider the trade-offs involved, depending on their priorities. For instance, administrations could choose to restrict spectrum supply, which could lead to higher auction revenues. However, there is a trade-off here as well in that a restricted supply of spectrum will lead to a narrower range of consumer services, higher consumer prices, and an overall decrease in economic efficiency.

It should be noted that auctions are applicable only in those circumstances where the demand for spectrum exceeds the available supply. Depending on any particular country's level of economic development, the level of its communications infrastructure development, its investment climate, and any foreign ownership or trade restrictions it may impose with regard to the provision of spectrum-based services (among other factors), the possibility exists that an administration may receive insufficient interest to make an auction necessary for some spectrum.

Generally, the higher the level of economic and communications infrastructure development, the more favorable the investment climate; and the lower the foreign ownership barriers and trade barriers, the greater will be the demand for access to spectrum, leading to more vigorous competition in an auction and presumably higher revenues for the government.

Auctions are a market-based mechanism and a fundamental requirement for the proper functioning of any market is a solid legal underpinning. This means, first of all, that the political authority must authorize the use of auctions for specified services. Second, for an auction to perform optimally, the nature of the right being auctioned (geographic coverage, available bandwidth, tenure of license, etc.) as well as the accompanying responsibilities (license conditions, service restrictions, interference limitations, equipment standards, etc.) should be specified as precisely as possible. As well, there should be certainty that the government is both willing and able to act as necessary to ensure that licensees are able to exercise the rights or privileges granted to them while at the same time meeting the responsibilities required of them. Any uncertainty surrounding such factors as the length of tenure of the license being auctioned will create confusion and may result in lower bids.

Before entering a spectrum auction, for example, bidders will wish to know what degree of protection from harmful interference they can expect with the spectrum to be auctioned, as well as the steps they will be expected to take to avoid causing harmful interference to others or suffer such interference. They will also wish to be assured that the government will enforce this interference protection regime.

The quality of an administration's license/licensee database, its spectrum monitoring capability, and its ability to impose meaningful penalties on those who cause harmful interference to others all impact the government's ability to protect the rights or privileges of spectrum users and hence have an impact on the ability to conduct successful spectrum auctions.

4.5.2 Pre-auction requirements

All the rights and responsibilities accompanying the spectrum to be auctioned should be specified prior to the auction. Otherwise, bidders will face high degrees of uncertainty, which will significantly

compromise their abilities to bid rationally, greatly increasing the chances of an unsuccessful auction. This means, of course, that administrations seeking to use auctions must be able, both legally and politically, to establish license definitions, terms, conditions, and policies before knowing who the licensees will be.

Similarly, the rules and procedures of an auction should be known and clearly understood by all participants prior to the auction's commencement. Great advances in auction theory, and in its practical application, have been made in recent years. Any administration planning to implement spectrum auctions would be well-advised to consult the literature on this subject and to review the experiences of spectrum auction "pioneers" such as New Zealand, the United States, and Australia, to learn both from their successes and from the problems that have been encountered with respect to auction design and operation.

Depending on the complexity of the auction in question, an automated auction system may be desirable. Thus, a technical infrastructure may be required to hold an auction. As well, education and training for both spectrum managers and potential bidders may be required to ensure a sufficient level of "auction literacy".

Depending on a given administration's stance towards competition in spectrum-based services, it may be important that the possibility of market dominance is considered. Existing competition policies, as well as proposed license conditions and auction rules and procedures should be reviewed to ensure that unacceptable auction outcomes are avoided.

4.6 Mission of the Agency

The suggested activities of the Agency are listed below.

A - Assign frequencies

Frequency assignments may be made by one entity, and a National Frequency Allocation Plan (or Table) may be a practical management aid. This guarantees that information on spectrum usage, as complete as possible, is easily available when deciding on frequency assignments. The assignment criteria and rules should be objective, acceptable by the majority, transparent, clearly defined, published and applied to all without discrimination. Due consideration should be given to shared use of the spectrum resources which should be encouraged. Frequency assignment activity should not be influenced by arguments of political nature, even in the politically sensitive area of radio and television broadcasting.

B - Recommend technical/operational characteristics of radio systems

In order to assure an effective use of radio spectrum, the Agency may define recommended technical/operational characteristics to be observed by all radio systems and equipment operating, or intended to operate, in the country. For that purpose it may set up formal type approval or homologation procedures. These should follow the relevant international agreements, standards and recommendations, especially those issued by ITU.

The Agency may designate national laboratories authorised to make type approval or homologation tests, may recognise results of such tests performed abroad, or may simply accept the manufacturer's declaration concerning the compliance with the recommendations in force. The approval procedures should be objective, acceptable by the majority, transparent, clearly defined, published, applied without discrimination and not influenced by non-technical arguments. For that purpose special legal/regulatory provisions may be needed.

C - Control/manage of radio networks

This activity usually requires maintenance of national spectrum management database, monitoring/inspection system. It implies also the existence of an enforcement structure and repressive means.

The Agency should keep the information on existing networks updated at national level, according to information supplied by users. If other entities develop parallel management facilities, these should be limited to the equipment that they actually operate, to avoid unnecessary duplications and competence conflicts.

The National Spectrum Management Agency should be the sole agency responsible for the control, management and monitoring of the radio frequency use in the country and authorised to represent the country's interests in international contacts. The observance of this preponderance results in avoiding the development of competing parallel systems performing the same tasks, that may lead to conflicts of interests and organisational chaos, that could weaken the position and effectiveness of the Administration. As any rule without enforcement generally remains a dead letter, it is recommended to provide in the regulatory texts, for sanctions against infringements. That activity may be exercised by an external entity, co-operating closely with the Agency.

D - Ensure collection of fees related to radio spectrum utilisation

In order for the spectrum management activity to develop and continue, the Agency should have the power of ensuring that the payments related to spectrum utilisation are actually paid and are at the Agency's disposal. When the payments go to the general budget of the State it may be difficult to assure adequate financing the Agency's activities for various reasons, often purely bureaucratic.

E - Ensure representation abroad

The Agency should co-ordinate activities related to radio frequency spectrum in all sectors in the country, including armed forces. In spite of possible differences of opinions within a country, the latter should speak out with a single voice at international fora.

Annex. Spectrum Fee Formulas

This Annex gives main formulas that may be used to calculate spectrum fees. The formulas assign a spectrum value in accordance with the occupied bandwidth and the users receiving a given signal or receive excluding of others signals emitted in the same band.

Some countries use other models as fee formula.

	Formula
1	F = aBN
2	F = aBNT
3	F = aBATP
4	F = Abntp
5	F = aI
6	F = a(B/M)NT
7	0,25% of gross revenues < 1 M $ + 2,5% of gross revenues between 1 and 10 M $ + 25% of gross revenues > 10 M $ + cost of licenses processing (1)
8	F = 20 (Highest one minute spot radio announcement rate) (2)
9	F = aP*
10	F = aBA
11	$F = aB/f_{moy}$ if $f_{max}>f_{ref}$ (4) $F = aB/_{fref}$ if $f_{max}<f_{ref}$
12	F = a(B/R)(N/Ntot)
13	F = a(1/R)(N/Ntot)Log(fmax/fmin)

(1) Applied only to broadcasters. A PMR would pay a fee = 1/360 * minimum tax paid by a UHF TV located in the same service are.

(2) For full time radio. For day time radio, fee is one-half of this value.

$B= f_{max}-f_{min}$ and $f_{moy}=(f_{max}+f_{min})/2$

a = constant different in each formula

A = service area or area excluded from the reception of other signals. It is assumes that transmitting power required for a given quality of reception is a priori specifies.

Ai = weighting for area

B = bandwidth in MHz (includes interference on adjacent channels)

Bi = weighting for bandwidth

Ci = share of SMA overhead costs

F = fee in currency units

fmax = high limit of the band in MHz

fmin = low limit of the band in MHz

fmoy = average frequency in MHz

fref = reference frequency (500 MHz in the DRG proposal)

Gi = geographic location

H = number of homes possessing a TV set in the area concerned

I = transmitting capacity of the channel in bits

Li = licensees sharing

M = carrier frequency in MHz

N = population in millions receiving the signal or excluded from the reception of other signals transmitted on the same frequency. It is assumed that the reception power is a priori defined

Ntot = population in million of the reference area (generally the total population of a country)

P = power density factor (in radiated energy per cycle)

P* = power density > specified level in a given area and frequency band

R = average reuse ratio of the channel in the service area concerned (number of installed channels/number of assigned channels)

Si = spectrum location

T = fraction of the day when the frequency is used

Ti = spectrum scarcity tax component

U = number of UHF TV signals in the service area

V = number of VHF TV signals in the service area

Discussion

The first formula F = aBN, the simplest, takes into account only two factors; a is a constant defined a priori and identical for all uses and users. The cost of access to spectrum increases proportionally to the population covered (N) ant the used bandwidth (B). This type of formula bears upon services utilising large amounts of spectrum, such as TV broadcasting or fixed services for example, and should incite operators to reduce their spectrum consumption or to use their frequencies more intensively. Connection between the level of the fee and the population covered seems logical since this population is excluded from the consumption of other services (transmitted on the same frequency at the same time and a potential consumer of the service concerned). Such a fee takes partially into account the scarcity rent resulting from spectrum shortage. Spectrum supply is the same everywhere in the world but shortage and congestion exist only in areas with a high density of population and a high GNP/capita. Thus, shortage and the value of the spectrum are not the same in the Sahara and in Western Europe. Nonetheless, in order to render an account of scarcity resulting from the number potential customers of services using the spectrum, the formula should also contain the density of population and the GNP/capita of the service are concerned.

The second formula, F = aBNT, introduces a time sharing factor (T) and should favour time sharing of frequencies. Each user would pay a fee proportional to the fraction of the day when he effectively uses the channels assigned to him.

In the third formula, F = aBATP, the service area (in km^2), instead of the population covered, determines the cost of access to the spectrum. The service area depends only on technical and geographic data, such as the characteristics of the transmitter (transmitting power, type of antenna used, etc.) and of the ground (undulation, nature, etc.). It does not take into account the "geographic scarcity" of frequencies when it stands to reason that 100 km^2 in the Outback of Australia do not have the same value as 100 km^2 around Tokyo. Furthermore, in this formula the level of the fee varies according to a power density factor (P), which determines, at least partly, the service area. Thus, to some extent P is a useless repetition of A.

The fourth formula, F = aBNTP, which contains the power density (P) (which determines the surface of the service area) as well as the population covered (N) reveals fairly well the scarcity rent. In fact, the combination of these two factors allows to take into account implicitly the density of population of the service area.

In the fifth formula, F = aI, the cost of access to the spectrum varies according to the transmitting capacity of the channel (I, in bits). Since the quantity of information transmitted by channel does not seem suitable to give a fair idea of the utility, the quaky and the social and market values of a service and as this indicator is not suitable for analogue uses (the bit measures digital information), this formula does not favour economic efficiency of spectrum utilisation.

The sixth formula, F = a(B/M)NT, where the level of the fee varies in inverse ratio to the carrier frequency (1/M) constitutes the first attempt to take into account the differential rent and the heterogeneous quality of frequency bands. As the higher the frequency the lower the level of the fee, the formula favours extensive development of the spectrum and the clearing of fully loaded frequency bands. As a matter of fact, in most cases lower frequencies (below 3 GHz) are the most heavily congested.

Formulas 7 &: 8: formula 7, F = 0 25 % of gross revenues < 1 M $ +2,5 % of gross revenues between 1 and 10 M $ + 25 % of gross revenues > 10 M $ + cost of licenses processing, and formula 8, F = 20 (Highest one minute spot radio announcement rate), make the level of the fee vary with operators' revenues. Such formulas do not favour efficient spectrum use since the latter is not necessarily correlative to users' revenues. Furthermore, it seems too much limiting since it cannot be applied to non-commercial users. Besides, these two formulas have been proposed for commercial broadcasting services only.

The 9^{th} formula, F = aP*, seems more technical than economic, since it bears only upon users whose transmitting power exceeds the authorised limit. Thus, its sole function is to avoid interference and minimise interference levels.

In the 10^{th} formula, the author starts with a very wide formula taking into account a great number of factors likely to influence the value of spectrum. The price of the Hertz would thus depend on bandwidth, carrier frequency, service area (location and surface), time of use, type of service, type of modulation used, density of the service area compared to the average density world-wide and GNP/inhabitant compared to the average GNP/inhabitant world-wide.The author proposes an extremely simple "operational" formula, F = aBA. The price of the Hertz, in currency units/KHz/km^2, varies according to the bandwidth (B) and the surface covered (A) only. The constant a should be determined by auction (mobile communications) or based on the cost of an alternative media (microwave links, satellites).

The 11^{th} formula, F = aB/fmoy if fmax>fref and F = aB/fref if fmax<fref, contains incentives to intensive (fee proportional to the bandwidth) as well as extensive development of spectrum (the higher the frequency the lower the fee), but fails to take into account the geographic scarcity of frequencies.

The constant a should be revised periodically (perhaps annually) in accordance with the estimated cost of replacing networks over the next 10 years (this cost reflects the share of investments that has not yet been written off). fref represents the limit below which the tax per MHz should be constant and reflect a subjective economic value. By setting fref at 500 MHz, TV networks in bands I and III would be encouraged to migrate to bands IV and V and the planning of these bands would thus be improved.

In the 12th formula, F = a(B/R)(N/Ntot), the fee varies in direct ratio to the bandwidth (B) and in inverse ratio to the frequency reuse ratio (1/R). Such a fee promotes intensive development of spectrum and reveals the intensive differential rent. In order to encourage extensive development of spectrum and recover the extensive differential rent (resulting from the heterogeneous quality of frequencies), the constant a should decrease gradually as higher frequencies are used. The constant takes a different value in each of the spectrum allocations defined in Article S5 of ITU Radio Regulations (30-470 MHz, 470-960 MHz, 960-3400 MHz, 3,4-31 GHz). Taking into account N/Ntot (population covered/population of the country concerned) should encourage geographic sharing of frequencies. As we have already pointed out, in order to reveal the scarcity rent resulting from the geographic scarcity of spectrum, the formula should contain the density and the GNP/capita of the service area. Nonetheless, the frequency reuse ratio reflects to a certain extent the density of population. In principal and for some uses (mobile communications in particular) the two variables vary in direct ratio. The scarcity rent exists if there is a demand for the channel when its price is positive. In case of time sharing, the fee should decrease in direct ratio to the "intensity" of sharing.

The 13th formula, F = a(1/R)(N/Ntot)Log(fmax/fmin), is pretty much the same as the previous one. The only difference is that a sole value of the constant a applies to all frequencies. Nevertheless, since the formula contains a variable Logfmax/fmin, the cost of the reference spectrum unit falls continuously instead of decreasing gradually. Thus, the formula renders an account of the heterogeneous quality of frequencies between 960 and 3400 MHz for example.

Comparison of Fee Formulas

The following table presents the positive and negative aspects of formula approaches.

TABLE 1 - COMPARISON OF SPECTRUM FEE FORMULAS

Methods	Advantages	Disadvantages	Examples
Fee formulas	Generally can be applied to most users Easy to implement because they do not call into question existing allocation and assignment systems Assign a positive price to spectrum Provide for registering existing users	Generally, the level of the fee does not reflect the value assigned by users to frequencies Does not constitute a selection method	PNG Canada
Fee based on administrative costs	Easy to calculate Logical link to budget needs of Administration	Promotes neither technical nor economic efficiency of spectrum utilisation	Radiocommunications-UK FCC - USA
Incentive fee	Promotes efficient use of spectrum		Radiocom Australia PMR-France
Fee based on users' revenues	Connects the price of the spectrum to the value of commercial activities which use it	Does not promote spectral efficiency if revenues not proportional to quantity of spectrum used Apply only to users whose revenues are directly linked to spectrum utilisation	Broadcasting-Australia
Fee based on Opportunity cost	Good approximation of the *true* value of spectrum Promotes economic efficiency	Only partial and not general equilibrium (account is taken only of users and uses competing for a given frequency band) Requires a huge amount of data	
Fee based on Shadow price	Optimal method from the standpoint of economic theory Promotes economic efficiency Fee = users' willingness to pay	Requires even more data than the previous method, thus unrealisable Static, does not take into account technical progress	

CHAPTER 5

ORGANIZATIONAL ASPECTS

5.1 Powers for mission achievement

As indicated in previous sections, the following principles contribute to efficient spectrum management:

a) The Agency has revenues from the spectrum fees

Direct transfer of fees for spectrum utilisation into the general budget of the State often impedes spectrum management/monitoring programs, since it disrupts the economic link between the spectrum management cost and the necessary instigation on the spectrum users. Furthermore, temptation is inevitably great to use the product of these fees for other purposes that may be seen as having higher priority.

Therefore, whatever the approach taken, the link between fees and the budget for the spectrum management authority should be made firm.

A practical method to deploy an effective spectrum management system and to assure its smooth operation (provisioning of equipment, station consumables or software etc.) consists in maintaining a direct link between spectrum utilisation fees (but not the product of fines) and the costs of spectrum management and supporting activities such as monitoring, inspection, or research work.

b) The Agency decides on its budget

The Agency sets up is annual (or multi-annual) plan of activities and associated budget on the basis of spectrum management needs and expected expenses and fees. Once the spectrum fees are collected, the Agency should decide on their assignment, on its budget and on its future programs, since it alone knows its requirements (within the limit of missions deemed for it by the Law on Radiocommunications, and under control). A possible surplus or shortcoming should be arranged within the framework of the general budget of the State.

c) The Agency has means to identify and sanction non-authorised transmissions

The Agency has means to sanction (fine) for non-authorised transmissions and for non-conformities with the laws, rules and regulations in force. Non-authorised transmission is any transmission not declared to the Agency or not authorised by it.

d) The Agency has the authority and means to recruit qualified personnel

For Agency to operate, it is necessary to recruit personnel with the required qualifications. In particular, the Agency should have the authority and possibility to recruit personnel with required qualifications in radiocommunication and computer techniques. Should recruitment be decided outside the Agency, this would mean that its possibilities of action are limited.

e) The Agency co-operates with the police and customs

To achieve the Agency's mission goals, the Agency can request co-operation and assistance of police and customs. That assistance may be required during checks and inspections of sites and equipment. Moreover, they may have an important preventive impact.

f) The fees are determined by the Agency

The Agency proposes the fee structure, following the principles discussed in previous sections. The utilisation of these funds is controlled/monitored by external financial inspectors. This element assures flexibility and almost automatic adapting the payments to the actual spectrum management cost. The Agency is thus financed by the users.

The following elements form part of the powers likely to be exercised by the Agency:

A) The Agency manages installation of radio sites, for which it defines the rules.

B) The Agency manages international co-ordination activities and negotiates the corresponding agreements.

C) The Agency allocates the spectrum between the various national users.

D) The Agency issues authorisations for setting up and operation of radio stations.

E) The Agency issues fines for non-observance of the relevant laws and regulations and can carry out confiscation of non-authorized equipment.

In some countries the question of attachment of Agency is of importance as it co-ordinates activities that have influence on various sectors of national activities. In such cases it should be attached high in the governmental structure.

5.2 Organisational Structure

The organisational structure of the Agency should match the actual and foreseen needs of the country. To some degree, these needs are proportional to the number of existing and planned

radiocommunication networks in the region. It should also follow the country's governmental structure and national practices, taking into account the financial, technical and personal limitations. These elements vary from country to country so that it is difficult to recommend one structure universally applicable in each country. It should also be noted that the efficiency of the Agency depends more on the qualifications of the staff than on its number. An example of organisational structure based on functional responsibilities is shown in Chapter 2; more details can be found in the relevant ITU texts listed at the end of this handbook and in the Bibliography.

Use of computers and remote communications and automated monitoring stations simplifies many of the duties and responsibilities of the Agency. Office automation through personal or business computers, word processors, spreadsheets, databases and dedicated software can speed-up and facilitate many management and administrative functions of the Agency. Computerised equipment provides a means to perform mundane repetitive tasks rapidly and accurately, freeing service personnel for more demanding tasks. The use of databases and computer modelling streamlines spectrum management functions and can eliminate potential sources of interference before a user begins transmitting. Automating the technical procedures of management and monitoring operations facilitates rapid decision making for effective spectrum management as called for in Resolution ITU-R 21. ITU-R Handbooks on Spectrum Management and Computer-Aided Techniques and on Spectrum Monitoring contain more detailed discussion of the issue.

Below is given an example of possible organisation of an Agency.[23]

5.2.1 Department of Radio Regulations and International Co-ordination

A) This department contributes to the representation of the country abroad in all issues concerning utilisation of the radio frequency spectrum, including the co-ordination with the neighbouring countries and ITU Radiocommunication Sector activities.

International representation, notably in the ITU Conferences and Study Groups, should evidently be ensured. As mentioned earlier, a single national position should be presented at such occasions, and the Agency should co-ordinate preparations of such a common position nation-wide. This usually requires wide consultations among all those interested and a research work.[24] To fulfil that task, the Agency may request assistance of external consultants and specialised advisors.

B) The Department also drafts the necessary regulatory texts for publication after approval by competent bodies. Since the Agency has also enforcement functions, it should not be allowed to decide about its own powers. The powers (as well as amount and reason of fines, confiscation procedures, conditions for initiating legal prosecution) should be defined at an appropriate level, and approved in accordance with the national Law.

The Agency defines National Radio Regulations, as well as technical and operational requirement imposed on radio frequency equipment. These will define also the scope of monitoring and should be

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[23] This example is given for information purposes. It is unlikely that every country would follow it exactly. A different organisation may be required, depending on the needs, workload and conditions of the country, which differ from country to country. In some cases additional departments may be needed (e.g. those of Legal Affairs, Policy, Planning, Public Relations, etc.), in others tasks of few departments may be done by a single department.

[24] The research work may require very high professional qualifications, not always available in the Agency, in view of continuous emerging of new technologies. In such cases the Agency may contract research reports, technical analyses, measurement campaigns, or draft position documents from external experts, e.g. from local universities or from abroad.

published. Only the compliance with these requirements can then be controlled, which limits the temptation for issuing customised authorisations to privileged users: it is only possible to authorise, and therefore prevent, that what is indicated in the license, the form of which is general and the same for all users in the same situation (and all distinctions are the subject of a publication).

In particular, if a license is nominative by nature, it complies with the strictly defined rules and the scope of the control is framed by a general definition, construing the required conditions for equity of authorisations issued.

The overall legal frame deeming the limits of management and monitoring action, by defining the "rules of the game", is of crucial importance in the definition and organisation of means implemented for their enforcement. These should not be changed too often as it can induce substantial and costly modifications in the monitoring and information system.

That radio frequency regulation part of the Agency is designed to define the general rules for management and monitoring.

C) The Agency organises issuing of radio frequency equipment approvals (type approval). The scope is to check, in compliance with national regulations, that the equipment is compatible with the approved standards. In no case this should be used as a mechanism to block the market. It is intended to protect the user from equipment likely to impede him and incompatible with the existing or planned systems.

Issuing and control of approvals can be organised as follows :

C1) Approval control

This may involve four aspects:[25]

- Interdiction to import non-approved equipment. This interdiction is to be controlled by the customs that can prevent entry of non-approved equipment into the national territory, and impose a fine for any infringement.
- Interdiction to sell non-approved radio frequency equipment. This interdiction is controlled by the inspectors of the Agency carrying out "Legal actions". These actions may result in confiscation and fines to vendors of such equipment as defined by law. It may be required that the approved equipment has an easily recognisable label enabling a simple and fast check. These operations will rapidly become less frequent since the impact produced by making them publicly known renders them very efficient.
- Interdiction to possess non-approved radio frequency equipment. This interdiction is enforced by the inspectors of the Agency. It is difficult to control and can result in confiscation of equipment and issuing of a fine, if allowed by law.
- Interdiction to use non-approved equipment. This interdiction is difficult to control; it should give rise to penalties. Illegal utilisation can be proved by spectrum monitoring.

All these types of interdiction should be provided for by law.

C2) Issuing approvals

Approvals are issued according to the published principles and standards, usually for a type of equipment and not for each individual piece of the equipment which would be impossible in practice.

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25 This should not be used to create administrative barriers to cross-border exchange of goods and services, which may be detrimental for the country's economy. There are international agreements, mostly in the framework of World Trade Organisation, that regulate such activities.

The approval specifications are drafted and published by the Administration. The interested manufacturers then send to the Agency their equipment documentation as defined in the approval specification to make evident that their equipment complies with the approval requirements. This is usually against payment.

The Agency may, after verification of qualifications and references, select a number of laboratories to serve as recognised type approval laboratories. These may be national or foreign and can be authorised to issue approvals for certain equipment types on behalf of the Agency. The list of these laboratories should be published, as well as the equipment types for which they are likely to verify an approval specification.

If a foreign approval specification is directly applicable and the equipment approved in the foreign country, the foreign authorisation can be recognised and the equipment can automatically be approved.

The Agency is not obliged to accept approval tests protocols from a laboratory depending on the manufacturer, even indirectly and accept them from selected laboratories only. If justified, the Agency may require the selected laboratory to not enter into direct contact with the manufacturer; in such a case the manufacturer contacts the testing laboratory via the Agency and the laboratory is not known by him until the end of approval process.

The advantage of this procedure consists in avoiding any collusion between the laboratory checking the approvals, whose selection is left free for the Agency, and above all having approval specifications available to all and known by all, which is an equitable competition condition between manufacturers and operators by avoiding abuse of a well established industrial manufacturer, and protecting the user at the same time.

The main administrative work consists in drafting the approval specifications themselves, work for which the Agency should seek the assistance of equipment manufacturers and users for their advice.

5.2.2 Personnel and Budget

The purpose of the Personnel and Budget Department is to:

A) Organise and manage human resources of the Agency

B) Prepare and follow up the Agency's budget evolution.

These are conventional management functions of human, accounting and financial resources of any administrative entity. Another of its mission is to co-ordinate training and public relations activities of the Agency, especially organisation of information meetings for spectrum users, equipment suppliers, operators, governmental agencies, etc.

The Head

The Agency is headed by a President appointed by the Minister[26] in charge of radiocommunications, for a mandate that can be renewed once.

It appears desirable to limit, not only the duration of the President's mandate, but also the possibility for its renewal. In this respect, this function has real powers and the appointment will certainly be a very sensitive issue. The candidate for the post should not change too often which could have a negative effect on the operating efficiency of the Agency.

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[26] This depends on the governmental structure of the country. In some cases the Head of Agency may be nominated by and responsible to Prime Minister, or President, or Parliament, or be part of another governmental structure.

By limiting renewal of the mandates by the same person, situations are also avoided where the activities of the Head are concentrated no longer on efficiency, but on being re-appointed for the next mandate. Furthermore, if the appointment is considered as political, it is preferable to offset the Agency's President's mandate for renewal by the State's Authorities by elections. Finally, the mandate period should be sufficiently long: four or five years seem to be an acceptable period.

Staff

The number of persons assigned to each function varies according to the situation of the country, e.g. the available budget, the number of assignements.

5.2.3 Spectrum Management Department

This department includes:

- A National Management Centre.
- Regional Centres.
- A Monitoring Centre for terrestrial and space radiocommunication services, including HF services.

Its organisation depends on the country's needs, on daily tasks to be performed in the achievement of its mission and on the spectrum management and monitoring programs to be deployed (refer to chapter 2.2 Organisation of Monitoring of ITU-R 1995 Handbook on Spectrum Monitoring).

A radio frequency can be managed and monitored as follows:

A) Preventive resolution of interference and spectrum policy enforcement:

- Examination of requests (demand), frequency planning and frequency assignment.
- On-site after-installation inspection.
- Monitoring on request and monitoring remotely (by fixed monitoring stations).
- Approval control.

B) Corrective processing:

- Resolution of interference by using fixed and mobile monitoring stations.

C) Instigation to economise the spectrum:

- Invoicing.

The management staff's main tasks consist in defining and setting up management means, both for the spectrum monitoring programs and for the information system, as well as definition of service action rules in order to standardise the monitoring procedures in the various regional centres to guarantee equitable processing to users according to the category to which they belong. The computer support has a great importance. Mobile direction finding vehicles are intended to intervene in certain cases.

Management Centre

Frequency assignment (including co-ordination) and issuing of licenses, as well as the studies prior to issuing an authorisation for important licenses, can be performed at a national or local level (See chapter 8 - Automation for Spectrum Management Activities of ITU-R Handbook National Spectrum Management 1995).

The invoicing follow-up operations can be decentralised but this implies a much more stringent central control in order to check processing correctness and equality between users. In practice, the difficulty in performing this check under satisfactory conditions most often implies a central management of this function at a national level.

Regional Centres and Stations

These centres achieve the on-site monitoring, remote monitoring and resolution of interference tasks, the Regional Centres can comprise sections dedicated to these activities (refer to the lTU-R Spectrum Monitoring Handbook 1995).

The purpose of on-site monitoring is to check that a new or a modified installation or network was installed according to the rules of the art and to the authorisation issued. It checks if all the criteria and requirements defined in the authorisation issued are fulfilled and verifies or measures the technical parameters (position of transmitters, amplifier output power, antenna type, conformity of equipment approval, etc.).

Remote monitoring is performed from fixed monitoring stations covering the territory, if necessary completed punctually by the use of mobile means for resolution of interference problems. Its purpose is to remotely detect installations not corresponding to the authorisation given (and also compliance of the network deployment schedule if necessary), or to obtain statistical information on the authorised transmitters, necessary for frequency assignment or for invoicing purposes. This function requires equipment facilities linked to the information system, forming an entire system operating together as one unit.

Approval controls are performed by the on-site monitoring teams both when checking a declared network and during punctual actions with equipment suppliers. The import control is left to the customs forces.

These three control types can give rise to legal prosecution. Interference complaint processing is initially performed using fixed means, providing, after consulting the assignment data (check of computed coverage and interference areas and inter-modulation products), elements determining the source of the problem and in certain cases, solving the problem without displacement. The studies carried out following complaints require mobile means. These facilities are also used to check the coverage (and interference) areas for a licensed station or system.

These control functions and complaint processing function consist in actions that involve the users and depend on the data on a dedicated geographic area. It is preferable for them to be implemented in the regional centres.

Note that a single centre with HF direction finding facilities is sufficient in most of the countries if the distance to a HF station remains below 2000 km. Otherwise, one HF centre may be needed for every 4 million km^2 within the national frontiers, taking account of the country's geography (See chapter 2 Siting, Building and Facilities of ITU-R Handbook on Spectrum Monitoring 1995).

5.3 Alternative Support for National Spectrum Management[27]

5.3.1 Introduction

Increasing requests for use of the radio spectrum, the need for more efficient and effective frequency assignment strategies, and ever changing radio technologies place an increasing burden on national spectrum managers. Administrations, particularly those in the developing countries, often have limited financial and human resources that can be applied to spectrum management. In some cases, these limitations can delay or restrict the implementation of communications vital to the national economy, services, and security. Therefore, a number of administrations[28] consider alternatives to the traditional centralised, government operated and funded national spectrum management systems. Though national spectrum management remains a primarily governmental effort, alternative approaches using resources outside the national spectrum manager to perform or fund certain spectrum management functions could enhance the efficiency and effectiveness of the national effort.

Some administrations have already made use of spectrum management resources outside the national spectrum manager including:

◊ communication groups with a direct interest in spectrum such as advisory committees, trade associations, professional organisations, and quasi-governmental associations;

◊ frequency co-ordinators (and co-ordination groups) and designated spectrum managers; and

◊ spectrum management consultants, and support contractors.

The objectives of using groups outside the national spectrum manager to assist in the spectrum management process are:

◊ to save government financial or human resources;

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[27] Sections 5.3.1 through 5.3.9 have been extracted from Report ITU-R SM.2012 sections 4.1, 4.2 and 4.4 through 4.6

[28] Especially those in developed countries with liberal approach to spectrum use and management.

◊ to increase the efficiency of spectrum use;

◊ to improve the efficiency of the frequency assignment and co-ordination processes; or

◊ to supplement the expertise of the national spectrum manager.

These alternatives can be used to support the national spectrum manager in performing spectrum management functions discussed in previous sections. Which approach is used may vary with frequency band, radio service, and/or specific radio application, the capability resident within the national spectrum management organisation, and the expertise available from other resources. For example, the national spectrum manager may find that sufficient technical expertise and experience to deal with traditional radio applications such as HF radio or FM broadcasting already resides within the national spectrum management organisation. On the other hand, new cellular mobile systems[29] may present a complex spectrum management problem beyond the existing capabilities of the national spectrum management office. Furthermore, the national spectrum manager can determine the limits of responsibility and authority granted to these groups based on the function to be supported. For example, while consultants can be used to study policy and planning options or support radio conference activities, they cannot be used to make policy and planning decisions or ratify conference agreements. Administrations may also find that a combination of approaches may be required to perform the overall spectrum management function.

Below discussed are possible approaches.

A number of administrations have implemented and gained experience with various forms of support to the national spectrum managers. These methods have potential for saving government financial or human resources, increasing the efficiency of spectrum use, improving the efficiency of the frequency assignment and co-ordination, and supplementing the expertise of the national spectrum manager. Therefore, in seeking ways to provide an effective national spectrum management system, administrations may wish to consider these approaches.

5.3.2 Communications Groups with direct interest in spectrum

Interested communications groups include organisations established by communications professionals, radio users, and manufacturing or trade associations having an interest in the use of the spectrum. In most cases, these organisations develop by themselves around their shared interests, but the government may need to establish a group, such as a formalised advisory committee, to perform some spectrum management activity. These groups have detailed knowledge of the technical capabilities of their equipment and of their members' needs. They have a good understanding of practical concerns associated with system operations and manufacturing.

Due to the benefit that their members derive from their involvement in standards development, frequency co-ordination, engineering capability development and research, they are often willing to participate in spectrum management related activities, frequently at no cost to the government. Though administrations often view inputs from these groups as advisory in nature, the work provided can be invaluable in relieving the national spectrum manager of the need to prepare such

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29 Other examples include new low-orbiting satellite systems, stratospheric systems etc.

advice internally. In some cases, the input of these groups may help to establish a level of voluntary self-regulation among spectrum users.

There may not always be adequate manufacturing or user interest within a single country to justify the establishment of national groups. In these cases, the work of multinational, regional or international bodies may be used to support the national spectrum manager. For example, many countries adopt as national regulations, standards developed within international standards bodies[30].

5.3.3 Frequency co-ordinators and co-ordination groups

Frequency co-ordinators are spectrum management resources outside the national government given the authority to co-ordinate the selection of frequency assignments within specific parts of the spectrum[31]. This does not necessarily include final authority for the assignment of frequencies. Co-ordination groups are often created around users with like interests, recognising that each band is allocated for specific use in which a limited number of parties are interested or permitted.

The frequency co-ordinator brings together spectrum users concerned with spectrum use in specific bands, performing analysis, selecting frequencies, and in some cases maintaining necessary frequency assignment databases. After selecting a frequency or frequencies the co-ordinator presents the co-ordinated request for final approval by the national authority. Having gone through this process, the user can expect official approval of the access to the spectrum on the frequency co-ordinated.

The use of frequency co-ordinators may require financial resources from the government in exchange for the technical expertise provided. More often, however, the national authority grants the co-ordinator the authority to collect fees for its services from spectrum users. Co-ordination groups, created by the interested parties to co-ordinate their spectrum use, can be recognised by the national authority and granted the responsibility to co-ordinate use in specific bands. In such cases, payment for services is jointly agreed by the members of the group, and generally covers the costs of operating the co-ordination group.

5.3.4 Designated spectrum managers outside the national spectrum manager

Designated spectrum managers are spectrum management resources outside the national government given the authority to manage the spectrum or parts of the spectrum by the national spectrum management authority. This includes the authority to grant frequency assignments and, in some instances, to establish limitations on the operations or technical characteristics of radio stations. Designated spectrum managers can perform functions including engineering analysis, frequency co-ordination, monitoring and licensing.

The use of designated spectrum managers requires financial resources from the government or the authority for the spectrum manager to collect fees from spectrum users. In cases where the national spectrum management authority chooses to allow market influence to have its maximum impact, private sector spectrum managers may be charged for the opportunity to perform the management function particularly if they are able to seek profits in providing their service to spectrum users.

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30 Such as, for instance, the International Telecommunication Union Standardisation Sector (ITU-T) or International Electrotechnical Commission (IEC).

31 Or within specific parts of the spectrum and within a given geographical region.

5.3.5 System licence holders

A number of administrations have found that, by providing licences that cover an area and a range of frequencies, the responsibility for managing the spectrum in that geographic area[32] can be turned over to the licence holder. This approach is particularly applicable to cellular, point-to-multipoint and other high-density operations. The licence holder can determine the specific channelization, site locations, and other system characteristics. This provides significant relief to the national spectrum manager.

5.3.6 Spectrum management consultants and support contractors

Consultants are individuals[33] that provide various types of service support. They can provide advice to national spectrum managers or in some cases represent the national authority and carry out its policies. Consultants provide services directly to the national spectrum manager or other spectrum users. The consultant may perform engineering analysis, select frequencies, develop policies, or participate for the government in spectrum management fora[34]. No authority is conveyed to the consultant other than to represent the views or policies of the national spectrum manager. Financial support for the private sector consultant comes from the national spectrum manager.

Consultants can support a temporary need of the spectrum management organisation, or their use may represent a long-term strategy of limiting government staff and increasing staffing flexibility. If the intent is temporary support, these resources may need to be used in part to train the staff of the national spectrum manager. Where they are viewed as a more permanent approach, sufficient expertise must be maintained by the national spectrum manager to select qualified contractors and oversee contracted activities.

In some cases, the national government may find it necessary or advantageous to staff some organisational component or components of the national spectrum management office through the use of staff support contractors. For the most part, these contractors provide various forms of technical support, such as computer or engineering support. Under this type of approach, government staff is used to oversee the overall operation.

While most consultant and support contractors are provided through private sector companies, many administrations have used government technical organisations to support spectrum management. Though this approach does not directly result in net financial savings, it can lead to efficiencies through the focusing of technical expertise.

5.3.7 Costs and benefits of the approaches

While these approaches can assist the national spectrum manager in managing the workload or technical complexity of the work, the government may lose some of its control. Although some of this loss of control may in fact be positive and result in greater initiative from interested parties, the national spectrum manager will need to ensure against undesired losses. Furthermore, the use of groups outside the national spectrum manager may result in some administrative or organisational inefficiencies.

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32 And that frequency band.

33 These individuals may represent private companies, other administrations, or international organisations as well.

34 The consultant can also perform legal analyses or perform training activities for the Agency staff.

5.3.7.1 Financial

Where their services are provided free of charge to the national spectrum manager, interested communications groups, frequency co-ordinators and designated spectrum managers provide direct savings to the administration. Financial benefit derived from the national spectrum manager paying consultants is not clear since such payments represent a full cost or near full cost replacement for government staffing. Similarly, the government contracting a private sector spectrum management support contractor, as a replacement for government staff will not necessarily result in cost savings. The financial benefit gained from these support resources depends on the manner in which the service is funded. Instability in consultant or contractor groups and the ongoing need to develop, review and monitor contracts may often result in significant additional costs. Consultants and support contractors can provide short-term support that is terminated when an assignment ends. However, the overall spectrum management effort may be affected by a lack of cohesiveness. These potential negative aspects may be able to be overcome by giving adequate attention to their transition plans.

5.3.7.2 Staff

When there is a lack of qualified personnel available to perform spectrum management tasks, saving money may not be as crucial as identifying sources of staff support. In some administrations, government policy stipulates limits on government staffing levels. Each of the support approaches provides assistance to alleviate the staff requirements of the national spectrum manager.

5.3.7.3 Control

Anytime the national spectrum manager delegates responsibilities to an outside group some of its control is lost. The use of private sector resources having their own interests and often a profit motive can create a conflict of interest. Thus the government spectrum manager must remain close to any private sector activities to ensure that biases do not have a negative impact. Care must be taken in the use of these resources to protect non-profit, public-interest services. A number of specific problems with such a system may be anticipated. Interested communications groups may create compatibility standards, for example that give greater consideration to their own costs than to the requirements of other spectrum users. In such a case, all of the users dealt with by frequency co-ordinators and managers might not agree with decisions that are made. Some may object to the fees involved. Others may feel that they are not adequately represented. Others may believe that their investment is put at risk by the judgement of a co-ordinator or manager. These groups often emphasise the need for government control of the national resource, demanding appeal procedures or government review of decisions.

Government oversight of co-ordinator or manager activities to ensure that treatment of the users is fair and equitable represents a management burden derived from turning over control to another group. A potential method of keeping the co-ordination process fair would be to have more than one certified co-ordinator for each sub-band. This "marketplace" approach to co-ordination raises the problem of database management. For co-ordination to be equitable, each co-ordinator must have equal access to an up-to-date database of licensees. They must share a single database or have simultaneously updated databases. This may necessitate operation of the database by the government or an agreed third party.

5.3.7.4 Process efficiency

Frequency co-ordination groups are highly familiar with the specialised spectrum needs of the user groups they represent. Because of this familiarity, they can provide fast, efficient, conflict-free[35] assignments to users. Because of their unique status, private sector co-ordination groups are in a position to provide a highly efficient and rapid method of frequency co-ordination that is not usually available to either the end user or the national spectrum manager. Private sector spectrum managers are likely to employ market techniques in selecting between prospective users. Such a process can speed the process of approval, eliminating the debate associated with an administrative process (often referred to as "comparative hearings") to compare user requirements. Licensing systems in an area and over a range of frequencies speeds the licensing process by granting one licence to what amounts to many transmitters, locations and frequencies.

5.3.7.5 Spectrum use efficiency

Because private sector spectrum managers and co-ordinators and system licence holders have a vested financial interest in the bands they oversee, increased efficiency in the use of those bands may result as compared to oversight by a government regulator. Private sector spectrum managers and system licence holders may be motivated financially to develop techniques to maximise the number of assignments and thereby maximise their profit. Co-ordinators representing user groups work to the benefit of all those within the user group. Maximising assignments maximises benefit to the user group. Though designated spectrum managers, co-ordinators or system licence holders may increase the efficiency of the bands that they oversee, they have no motivation to decrease the total amount of bandwidth that their users occupy. If a user group has more than enough spectrum for its use, there is no motivation to move toward more efficient technology or assignment procedures. Thus, having entrenched frequency co-ordinators or designated spectrum managers may make it more difficult for the national spectrum manager to make larger scale allocation or allotment changes. The use of these groups may decrease the national spectrum manager's overall flexibility, possibly leading to a decrease in spectrum efficiency.

5.3.7.6 Flexibility and sharing

When spectrum is turned over to frequency co-ordinators or co-ordination groups, sharing flexibility may be lost. Generally, each co-ordination group has one service with which it deals. Therefore, management or co-ordination by one group may prevent sharing a band with other services. However, in some cases, co-ordination groups have successfully been used to co-ordinate use by different radio services within shared spectrum.

5.3.7.7 Technical expertise

National spectrum managers sometimes find it difficult to focus available technical expertise on each of the myriad of services, bands, users, and technologies needing spectrum access in a country. System licence holders have direct experience from managing their own systems. Interested communications groups and frequency co-ordination groups generally originate from the groups they manage. Therefore, they have the expertise and information directly at hand to perform their tasks. The use of consultants allows the selection of individuals or groups with the skills matched

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35 Within the group; conflicts with external users cannot automatically be excluded in that arrangement.

to tasks. Designated spectrum managers carrying out general duties similar to the national spectrum manager experience the same difficulties in covering all spectrum issues.

Application in developing countries

The spectrum management organisations of developing countries frequently suffer from inadequate funding for spectrum management, insufficient training of spectrum management staff to perform technical engineering and computer tasks, unclear spectrum management procedures and mechanisms, and a lack of spectrum management experience. Though in most cases increased funding and staff are crucial to upgrading their spectrum management capability, short-term significant increases are not often possible and long-term increases via the normal national budget allotments may not be sufficient. Spectrum management approaches must be considered that minimise the need for government funding increases. Growth of the spectrum management unit should be incremental; however, funding increases alone will not provide results. As with the general national economy, free and secure capital investment is essential for the national telecommunications infrastructure and a portion of that capital investment may be needed to support the national spectrum management system.

Because spectrum users and service providers are often the most qualified to deal with technical issues and have a great deal of motivation for resolving issues, they represent the most readily available source of active support. In many cases, a significant difference in private and government salaries has caused many of the qualified experts to gravitate toward private enterprise. Because spectrum management is essential to the success of their enterprises, private companies should be highly motivated to use their resources to establish and support a sound spectrum management process.

These resources can be drawn together in organised bodies to provide advice or in many cases voluntary support to include everything from frequency co-ordination, to site inspection, regulation drafting and research. Co-ordination groups can be established to co-ordinate frequencies for some services. Groups for broadcasting, fixed, and mobile are often a good starting point. Co-ordination groups can perform tasks under government oversight but using primarily private sector participation. The members of these groups are motivated by the fact that they want to use the spectrum. Advisory committees can develop initial drafts for national regulations and spectrum management procedures as well as positions on international issues.

Where monetary resources from spectrum fees or market approaches to spectrum management have been used to increase funding but technical expertise is deficient in the government, the government spectrum manager can employ consultants or contractors to provide support. Such groups are excellent for providing database and engineering support. In some cases, they have been successfully used to support national representation in international bodies.

Whether by voluntary or contract support, government staff requirements can be lowered, but other considerations, such as security and government control, may impact government implementation of these approaches. However, most approaches discussed above can be used without relinquishing the government's primary leadership and oversight role.

5.3.8 Implementation measures

The approaches described above are intended to decrease the national spectrum manager's workload without necessarily decreasing the spectrum manager's level of authority. They also take advantage of the expertise of the spectrum users and service providers. However, the measures that are required to implement these approaches depend on the level of authority that is granted to groups outside the national spectrum manager. Because most administrations have used traditional

centralised approaches to spectrum management, some legal authorisation may be required to implement any of these approaches. Actual delegation of government authority, for example licensing authority, to groups outside the national spectrum manager will require additional legal provisions. As these approaches deal with spectrum management support in conjunction with the national spectrum management authority, as opposed to national government operation of radio services, implementation of these approaches requires no changes to the national industrial infrastructure. Many of the significant changes to national processes are legal or administrative. Others may involve shifts in the types of skills maintained by the national spectrum manager. Developing private sector support for the national spectrum manager can be accomplished regardless of the national position with regard to privatization of national phone companies. Separation of the national spectrum management role from that of a government run telecommunications operator is not dealt with in this text.

A legal basis, including rules of conduct, may have to be created for the establishment of government recognised advisory bodies. For frequency co-ordinators or designated spectrum managers to charge fees, their authority to do so may need to be established. In cases where a group outside the government is delegated authority to actually perform a spectrum management function, this authority must be clearly presented to the spectrum user community. Rules for conduct of such a group would have to be established. These rules would necessarily include provisions that prevent a group from exercising management authority in bands or services where it has a direct financial stake in those users under its authority. In dealing with contracted support, laws concerning contract bidding and award have to be developed and applied. For international activities, national authorities would have to accredit groups that participate on their behalf and ultimately, administrations must be represented by those authorised to make national treaty commitments.

Arranging a multitude of counsellors does not necessarily make decision-making easier. In some cases, the ideas of interested groups may be in conflict with one another. Therefore, while more detailed and expert advice may become available, the national spectrum manager will still have to sort out issues and make decisions.

Approaches where responsibilities are delegated through contracting or use of spectrum co-ordinators or managers require a new set of skills related to development and oversight of these resources. While there may be a specific need for contract processing or other administrative skills, the national spectrum manager must maintain a sufficient level of technical capability to select and oversee support resources. Furthermore, the national spectrum manager will need to develop and maintain methods to monitor and evaluate how well these approaches are working.

5.4 Privatisation options

The State can plan to privatise a part of the RF Management and Monitoring Functions, considering the following principles:

A) *All countries engage to comply with the ITU Radio Regulations. This obligation comes under the competence of the State, and cannot be conceded to a third party.*

B) *Activities dedicated to radiocommunications regulation should not be privatised.*

The regulations and the international agreement negotiation, in particular within the ITU, should not be performed by a private company that has no authorisation to issue recommendations as this concerns direct exercise of an activity having a nature of national sovereignty.

In compliance with these principles, it is possible to envisage privatization of certain of the functions provided for in the Agency in charge of radiocommunications.

C) *A private company directly participating in monitoring or management missions should not have any connection with any of the companies or persons monitored or managed.*

The collusion resulting from this is evident.

D) *The elements revealed during controls should not easily be contestable.*

This is a question of credibility; in this respect, the measurements performed should be of high quality and be exact (except proven otherwise), in order to serve as basis for a possible judgement.

E) *A function implying use of a strict police power (sanction or necessity to show proof) should not be privatised.*

This concerns exercise of an activity belonging to the State.

5.4.1 Privatisable Functions

1) The radio sectors should not be regulated by a private company, since this concerns exercising a sovereignty function, which only belongs to the country itself. However, nothing prevents associating private companies for drafting standards and regulations, and participating of national industrials in international discussions likely to concern them.

2) Management decisions (apart from operating functions) depend on the requirements of the Administration and should follow the radiocommunication policy of the country.

3) On-site monitoring of radiocommunication networks is an activity which could be subcontracted; however, it can result in issuing of penalties when a component not complying with the authorisation is discovered, requiring action by the Administration.

4) The legal follow-up, resulting from controls, consists in representing the Minister in charge of radiocommunications, as an expert or plaintiff in the court of justice. As for any legal procedure, if assistance is possible, this function should not be privatised.

5) Frequency assignment and issuing of licenses and authorisations are the reflection of the public nature of the RF spectrum. These are exerted by a power, which can only belong to the State.

6) Discussion or co-ordination with Administrations is the implementation of the final phase for negotiating an international agreement, which, under the circumstances, has a mission of being permanently reviewed on each new case. This State to State discussion should not be privatised, although private experts and advisors can be employed, but it is not treated as privatization.

7) Invoicing is a reflection of the public nature of the RF spectrum. If only the State has the mission of imposing fees on spectrum users for achieving a mission of general interest, it is possible to subcontract this function, while monitoring it closely. Here, this is not an actual privatization, however.

8) Resolution of interference intervention almost always gives rise to issuing of a fine for non-observance of authorisation characteristics. This police function is to be exerted by the Administration. Conversely, unlike on-site monitoring, more important facilities should be used. It is sufficient to have a member of the Administration to check out the subcontractors in view of validating the operation. This function can therefore be partially subcontracted.

9) Technical monitoring of the actual spectrum is a surveillance and information activity for the Administration, further away for the user. It is however necessary to have administrative action to certify the measurements performed. Since this function is performed within the Regional Centres, the Administration can be permanently present. This function, the heaviest in terms of investments, appears privatisable under the control of the Administration.

The functions that can be processed by a private company are given in the following table:

FUNCTION	SUB- CONTRACTING	PRIVATIZATION (OPERATION)	REASON
Radio regulations	NO	NO	Expression of sovereignty
International representation	Yes, limited	NO	Expression of sovereignty
Management	YES (production)	NO	Spectrum management policy
On-site monitoring	NO, except if done by a team with participation of Administration representative	NO	Enforcement power
Legal actions	Yes, limited to help by jurists	NO	Representation of State
International Co-ordinations	NO (except for expert assistance)	NO	Expression of sovereignty
Frequency assignment/ allocation	NO (except for expert assistance)	NO	RF spectrum belongs to public domain
Invoicing requirements	YES (execution and operation)	NO	RF spectrum belongs to public domain
Resolution of Interference	YES (with presence of Administration representative)	YES (with presence of Administration)	Technical/police power
Spectrum monitoring	YES (execution only)	YES (with presence of Administration representative)	Technical/enforcement power

In regards to the study of privitisable functions given above, below are the principles to be considered:

Resolution of Interference

The teams performing this function would comprise one person from the Administration per mobile control vehicle, the remainder of the personnel depending on the private company. The vehicles would also belong to the company.

Invoicing

Printing and sending out of invoices would be ensured by the private company, as well as cash collection operations. Processing of complaints and conflicts would be ensured by the Administration.

Technical monitoring of spectrum

The overall deployment and operation of the fixed monitoring system would be to the charge of the private company.

Specific functions

a) Define the equipment to be installed for the teams in charge of resolution interference, mobile direction finding (semi-fixed stations), etc., as well as availability of personnel from the private company assigned to this task.

b) Define and lead the tasks of these teams.

c) Define the surveillance coverage requirements of the territory by fixed stations and the measurements to be made. The fixed stations would remain the property of the company or could, in the long term, become the property of the Administration, the highly specialised maintenance functions remaining subcontracted.

d) Define the monitoring system - general function and database interface.

e) Define the functions to be fulfilled by the invoicing means.

f) Define the interfaces between the data output by the invoicing application, the printout means and the calculation centre.

g) Define and execute surveillance procedures of the company during resolution of interference operations (presence of a person from the Administration), spectrum monitoring and sending out of invoices.

h) Define the penalties in the event of non-observance of the contract by one or the other parties.

The company to which these functions would be assigned could be organised as follows, keeping in mind that the necessary surveillance of activities implies having Administration representatives and the private company personnel on the same location

The personnel of the private company will be subtracted from the administrative personnel, as indicated in sub-section 5.3.2.

Company control elements

The contract, which would bind this company to the Administration, should assure a constant workload for the company. This means that any change in regulations, modifying its tasks, should form the subject of an additional clause to the initial contract, which limits the change possibilities for the Administration. *The effect of Privatization consists in increasing the regulation's rigidity.*

The company's remuneration should comprise a fixed part related to deployment of the systems and their maintenance, and a variable part, that increases as a function of the number of networks to monitor and their type, and the number of on-site monitoring operations performed, along with a bonus mechanism for discovering non-authorised networks (according to their type), which is not connected to the size of the network, but to the difficulty to discover it (a low-power transmitter is more difficult to localise than a high-power transmission), even to its geographic location according to the situation cleaning up priorities desired by the Administration. This bonus could be calculated on a controlled basis knowing that the Administration permanency monitors the effective activities of the private company.

Since the Administration fixes the license fee rates, it is preferable to avoid directly remunerating the company according to "turnovers", i.e. the amount of fees collected, originating from a right for spectrum utilisation and having no direct relationship with the spectrum management/monitoring cost. A part of fees related to the work performed by this company (file creation tax, fixed tax for sending out invoice, spectrum monitoring tax, etc.) could directly be assigned to this company.

The Administration's experience for daily tasks will be reduced by Privatization, causing a loss of competencies and increasing dependence on external assistance. However, since the teams of the private company are accompanied by Administration members for accomplishing the required police tasks, this loss of competence and of information should become reduced.

With Privatization, the Agency's workload is increased. This should be compensated by the competencies and greater flexibility introduced by the private company. In this respect, the tasks of the latter should clearly be defined, and monitored closed; this does not form part of the Agency's missions.

CHAPTER 6

SPECTRUM MANAGEMENT INFORMATION SYSTEM

6.1 Computerised information system

As mentioned in Chapter 1, no spectrum management system can work properly without monitoring and enforcement. A crucial element in these activities is gathering, maintaining, processing and making available the necessary information. This is the aim of spectrum management information system. The main objective of this system is: *Knowledge of the radio frequency scene, complete and updated.*

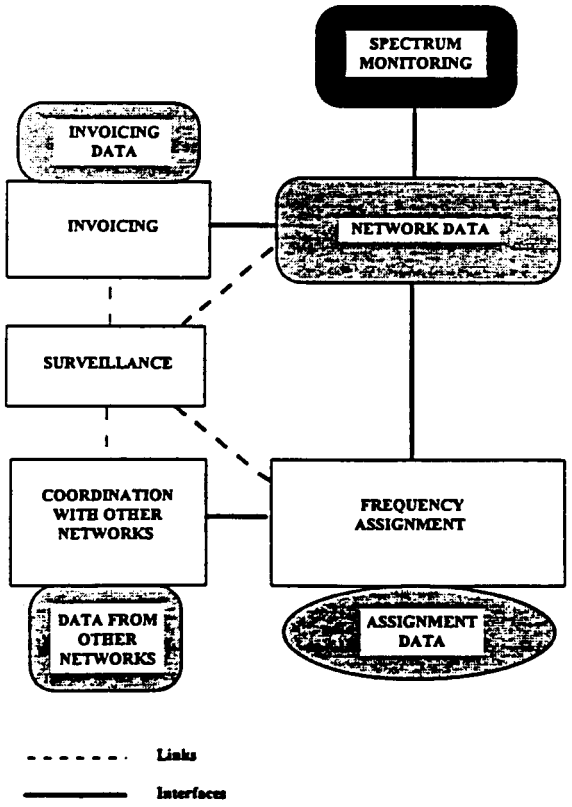
In order to carry out spectrum management, specialised management tools are needed. These tools are necessary to gather data relative to the authorisations issued and to perform operations needed to follow the changes. Administrative activities and monitoring activities should be limited

The different operations that should be considered are as follows:

A user of a radio frequency should obtain an authorisation to use that frequency so he can operate. It is the frequency assignment function implementing a specific spectrum policy. If necessary, additional authorisation may be required from another Administration of a foreign country. This information - result of the co-ordination - goes to the Assignment database. The authorisation is materialised in the form of a license, which contains all the relevant characteristics of the station and conditions of its operation. These data are to be included in the general database (Network Data). The user's activities are subject to inspection on site or are monitored remotely, often following the interference claim against him (or suffered by him). The results of the inspection/ monitoring are entered to the spectrum monitoring database. The user receives an invoice for his license, according to the authorisation issued and these data are entered to the invoicing database.

The target organisation that can be proposed corresponds to the principles given in the ITU-R Handbooks on National Spectrum Management and Spectrum Monitoring of 1995.

An example is shown in the following figure.



FUNCTIONAL STRUCTURE

6.2 Database

A single database can contain all data concerning the authorisations issued. Such a database is the only reference for what has been authorised. In principle, it should not contain duplicate data nor should it be broken down into separate databases, e.g. one "administrative" and another "technical". Such a database serves as the only reference for all spectrum management and monitoring activities. It should be safety protected and accessed (entirely or partially) only by an operator empowered to work with the data. For additional information see chapter 8 of the ITU-R Handbook on National Spectrum Management, issue 1995.

This general database on authorised users is designed to record all data concerning all authorisations issued. In particular, if a network is not registered in this database it is understood that it really does not exist, both for the Administration and for third parties. The database records all relevant information on radio stations and networks and on all operations that took place on them (controls, issuing of licenses, modifications, etc.). The main feature and primary scope of such an approach is that all data required for management purposes at all stages of operations on the networks are always available and updated. The data may be used by any authorised person to monitor network conformity, to issue operation authorisations, or to record operations performed to avoid radio interference affecting (or produced by) the network, for invoicing purposes, etc.

The extent to which database computer support facilities are available to and used by the spectrum management authority depends on the resources, priorities, and particular requirements of the country concerned. However, considering their low cost and variety of applications, the use of computers is essential to the effectiveness of any spectrum management effort no matter how small. In the early stages of its introduction, computer support may be limited to licensing records or complex engineering calculations. Ultimately the computer support group may assume responsibility for the development, provision and maintenance of support facilities for nearly all spectrum management activities, including record keeping, forecasting and financial management related to licensing.

It should be avoided to re-create one function with two separate databases, even with an interface ensuring data coherency between the two bases, since this could impede unintended tariff modifications.

6.3 Invoice Sub-system

An invoice system is an application, which computes, sends out invoices and follows them up, according to the program and data contained in the database. Its purpose is to retrieve the description or the networks from the central database in order to compute and print out the corresponding invoice according to the rules in force and to send out this invoice and then to follow it up by presenting the relevant data to the persons in charge of invoicing and payment collection.

This application comprises three major aspects that should not be dissociated:

- Computation of fees and printing of invoices
- Invoice follow-up (records of payments, claims, credits, etc.). It is not enough to compute an invoice; its follow-up is indispensable.
- The effective sending out of invoices, which implies enveloping the invoices and addressing the envelopes, etc.

6.4 Frequency Assignment Sub-system

An application starts the frequency assignment process, often involving a co-ordination with other national entities or with a foreign country if necessary. Data located in the general database are processed, in order to assist the operator in selection of optimum frequency for a new network or to modify operations of an existing network. The operations performed are stored in the assignment database. This assignment database contains all the data required for all existing networks.

It involves not only propagation computations, but also calculations of interference-free frequencies. The assignment database contains thus the results of specific computations necessary for knowing the status of the channels examined and the reason for their rejection or acceptance as proposed by the assignment.

An important part of this software concerns the interface with the general database, both data items (raw data in the general database and processed data in the assignment database) being always coherent, so that the data required for assignment reflect the reality of the existing radio frequency means found in the general database. In particular, the software can effectively be installed only once the implementation of the general database is completed.

6.5 International Co-ordination Sub-system

During an assignment, it may he necessary to request the opinion of a foreign country before actually assigning a frequency that is potentially impeding for this country, in virtue of the ITU Regulations

and Recommendations and other international agreements in force. The procedures provided by the agreements should then be complied with; this is the role of the co-ordination. The co-ordination application will then imply taking into account old agreements, which may be not computerised.

The main functions of the co-ordination are as follows:

- Assessment of co-ordination requirement, based on computations performed and on international agreements in force.
- Assessment of success possibility (positive reply) for initiating co-ordination with a frequency, according to the characteristics of the transmitter considered.
- Co-ordination initiation, in compliance with the procedures in force for selected frequencies.
- Reply recording and its follow-up.

6.6 Supervision Sub-system

The software described above should be completed by a dedicated system supervision application, with a scope of monitoring correct operation of the whole system as well as simply executing the statistic operations for information on the progress statuses of the various operations being executed, and the flows between the various applications.

This application provides an overall view on the system, retrieves data for compiling statistics, checks the general system condition both as concerns data processing and physical architecture, has a scheduling chart for system status, etc. It should be flexible and easy to operate.

The application can only be completely developed once the system, from which it takes its data, is stabilised. To avoid being completely blind during system deployment, in an initial phase, the system administrator and statistic functions should be generated in each of the system applications, which will then become null and void when the supervision application is implemented.

6.7 Cost and Planning Aspects

Only one information system should be under operation. If the costs remain relatively moderate as compared to spectrum monitoring, the time for setting the system into operation can be long, mainly because the project cannot be stopped or slowed down.

Once a spectrum monitoring station or an associated monitoring centre has been acceptance tested, it becomes almost immediately operational. The set of computer applications will need to be specifically developed to enable, in all cases, take-over of the existing means, which is different for each application. This phase (long), which no longer concerns the supplier whose product has been accepted, is completely to the charge of the Administration that is the alone likely to successfully conduct the phase since it is the only entity possessing data to be taken in the new applications.

If the system is entirely modular, it is possible, without great difficulty, to move back or advance the deployment rhythm of the spectrum monitoring system (after installation of the first monitoring centre). Finally, the very high specificity of such systems (which has to fulfil specific Administration's requirements) implies, for its achievement, having an experienced supplier who is specialised in the radio frequency field.

CHAPTER 7

AGENCY PLANNING AND IMPLEMENTATION PRINCIPLES

7.1 Planning

Any program for deploying a spectrum management system greatly depends on legal and regulatory decisions and evidently on budget needed for creating such a system. Effective setting up of such a program depends on the political will and on its constancy in the long term.

In accordance with the chapter 3.3 of the ITU-R National Spectrum Management Handbook (1995), the following outline indicates many of the areas that should be covered in a long-term plan:

SPECTRUM USE PLAN	**SPECTRUM MANAGEMENT SYSTEM PLAN**
Spectrum Use Objectives - Objectives for meeting of requirements of users in accordance with national . policies, for example: • Safety and Law Enforcement • Commerce and Transportation • National Security • Broadcasting • Education Spectrum Resource • National Table of Frequency Allocations • Lightly or Unused Bands, and Shortages Spectrum Requirements • List of Frequencies in Use • Future Requirements • Emerging Technologies • Forecasts • International Trends Spectrum Availability • Government File Data • Measured Data • Monitoring Long Term Plan Schedule of Activity and Milestones	Authorities • Radiocommunications Law • Delegated Authority • Regulations and Procedures Spectrum Management Functions • Policy Development • Enforcement and Regulation • Licensing and Fee Collection Spectrum Engineering and Computer Support • Equipment Standards • Channeling Plans • EMC Models • Engineering Analysis Methods • Computer Hardware and Software International Activities • Strategies for Participation in ITU, other International Fora • International Agreements • Co-ordination Along Borders Resource Requirements • Source of Funding • Personnel Resources • Future Needs Schedule of Activity and Milestones

The main objective of the Law on Radiocommunications is to create an effective spectrum management.

It specifies in particular

- Responsibilities and powers of Spectrum Management Agency;
- Procedures for arbitration between the Agency, the Armed Forces and other entities;
- Distribution of responsibilities for international representation;
- Spectrum utilisation license fees and other payments required from radio frequency spectrum users;
- Principles of distributing revenues originating from these fees;
- Rules of co-operation with police and customs forces;
- Character of any authorisation without indemnity;
- Control procedures for issuing approvals and the corresponding interdictions;
- Limits of the agency's police powers, the amounts of fines and their issuing conditions;
- Privatisation rules, if any.

This Law should be completed by regulations providing for fixing the tariffs corresponding to spectrum utilisation fees and to the works performed by the Administration, in observance of the conditions provided for by the Law.

The recurrent regulatory tasks of the Agency shall then concern:

- Definition of technical utilisation rules of radio frequency equipment;
- Procedures and conditions for issuing licenses;
- Definition of radio spectrum policy and in particular of the assignment conditions;
- Approval specifications;
- Technical conditions for carrying out monitoring operations.

It is however possible to indicate the times (approximate) for realising the systems, while keeping in mind that the decision for realisation and availability of funds for creating these assemblies are always blocking points that are likely to challenge any forecast.

7.4

7.2 Project scheduling

The overall project should be scheduled over several years, by making an abstraction of its extreme dependence on implementation decisions: here, it only concerns time limitations caused by industrial production limits, all things being equal (see chapter 4 - Spectrum Engineering Practices of ITU-R Handbook on National Spectrum Management - 1995).

For the Administration, the first two years are the most intensive since it has to create an (almost) new field, and set up structures enabling it to operate as best as possible, before passing to more standardised phases requiring fewer new regulations and specifications, but more important in terms of volume.

Year 1

The first year mainly consists in defining the bases enabling the Agency to operate. And if necessary, the regulations for Privatization should be defined in parallel with those governing the powers and missions of the Agency. The creation of the Agency, including drafting of the related laws and regulations is the first of the priorities at the time of the spectrum management and monitoring program initiation (in particular, start of drafting of a new comprehensive and detailed national frequency distribution chart).

The most important work in time is to define the national database, and the elements given in chapter 6, to combine that data from all existing networks into a single source. This activity forms the basis of the overall system and it should be undertaken at the earliest. The first part of this first year is mainly aimed at setting up the structures and carrying out the required studies then enabling program development.

Another action to be undertaken consists in drafting the bases for specifications of the national spectrum monitoring system, within the frame of an initial system, mainly for specifying requirements. The aim of this system is to validate the spectrum monitoring concepts and to refine the expected results by the Agency.

Year 2

This second year is that of effective operability of the agency, associated to that of its privatised part if any. The main task consists in setting up the regulations adapted to the new structures; organisation of first regional centres and remote stations; setting up procedures for approval control; definition of assignment rules and frequency management; training of the staff. New invoicing application and an assignment and spectrum monitoring application will occur during this year. Here

again, the most time consuming activity is correction of data in the general database. Daily questions should also be managed, which can occur with the private company if any.

This year marks the end of take-over of existing means of the national database.

Year 3

This year mainly reveals the monitoring activities that are put forward. It is during this year, with the complete deployment of regional and remote controlled stations, that the results of the search for clandestine transmitters will become visible. This third year can in fact be used for catching up a delay on development of other applications, in particular that of assignment, since programming of management rules requires harmonisation of the customary habits, which is long and sometimes difficult.

NOTE - Creation of a HF and terrestrial and space radiocommunications services monitoring centre requires research work and a particular specification. Installation of HF direction finders satisfies requests (especially those, very few, from a foreign country) on these frequencies. Installation of the terrestrial and space radiocommunication services centre enables co-operation with neighbouring countries, which should be planned and co-ordinated earlier.

Year 4 and beyond

These years see the completion of the national territory coverage by monitoring system.

The system development criteria (monitoring and management activities) are assumed to be stable; it is probable that 4 or 5 years after the start of the program, with the radio networks having increased it may become necessary to review the whole spectrum management system and reinforce its monitoring capabilities in order to adapt them to the development of radiocommunications.

7.3 Deployment Program Principles

A few principles can contribute to correctly conduct an important program, in the field of radio frequency.

a) A single entity responsible for the complete spectrum management system

A single entity may be the prime contractor of the complete system. For the computer part as for that oriented to radio frequency spectrum monitoring, this is a true industrial type program. As such, there should be a single and alone prime contractor in charge of the overall system, the development of which requires taking concrete, precise and rapid decisions.

b) A single system deployment manager

In no case should a partial user have the responsibility of the overall system. The target of the overall system being radio frequency, radio frequency experts should have the full and exclusive prime contracting powers of this program, notably having budgets that are directly available to avoid fatal competence conflicts. They should be backed up by computer specialists, budget control specialists etc., but this only concerns backing up. For each part of the program, the future system users form an integrating part in the definition of applications.

c) Once a new system is operational, other systems cease to exist

Once an application is installed, and following the existing equipment means take-over phases, only existing data are those contained in the new application. In particular, no one should claim for "missing" data that could not be requested during the specification phases. The radio specialist, who

is the manager of the program, should then have the powers to close all the old applications and inhibit future application thereof.

d) The system forms an entity which should not be segmented

The overall system forms an entity, which should not be segmented: no independent design applications should be allowed to co-exist. The data entered for spectrum monitoring are used for frequency assignment in the case of shared frequencies (transmitter rate of occupation); they can also be used for tariffs (frequency utilisation duration and time); the processed data used for frequency assignment originate from those in the general database and are just a retranscription; co-ordination can only be performed for an assignment, as a function of the characteristics of the network or of the concerned transmitter, using the processing performed during assignment preparation. Finally, invoicing exclusively depends on effectively declared data, i.e. those recorded in the central database.

For all these reasons, it is necessary to globally design the system (and its evolutions); more particularly, an application, which is an element of this system, should always be installed with the interfaces and data exchanges that are needed for its operation.

The data exchange system should also be the subject of a special definition: the overall data should remain updated in the entire network, which connects the regional centres to the national management centre. It should ensure data coherency and integrity.

7.4 Example: Deployment of the Monitoring System

Areas with the highest network density have priority for being fitted out with the most complete spectrum monitoring means. The order of deployments should also closely follow the development of radiocommunication means and it could be necessary to modify this target during development.

Depending on the network density and the geographical configuration of the country, the monitoring system deployment can be forecast, with due care to the geographical location of stations to enable their efficient operation. Elements that should be taken into account are given in the ITU-R Handbook on Spectrum Monitoring. On average (weighted by the number of transmitters and the topography), a monitoring centre can cover a surface area of 60,000 km^2, and thus connects around fifteen remote controlled stations (having an average operation range of 60 km) with signal measurement and analysis capacities of up to 2.7 GHz and above if needed. Areas with crowded frequency bands should have greater capacity due to the increase multiplicity of tasks to be performed.

Installation of an isolated monitoring station has little meaning for direction finding since a single azimuth measurement does not enable localising a transmitter and thus prevents comparison with the general database, which contains all authorisations. Direction finding stations should be installed (on priority in areas with the greatest radio frequency density) in groups such that at least three stations cover at least a part of the same area.

Stations that are remotely controlled from the Regional Centre should provide all conventional signal measurement and analysis functions, as well as signal listening. The Regional Centre should be capable of comparing the measurements performed with the authorisation data in real time and authorise transmission into this database of statistical data collected by actual measurements. In particular, the monitoring system of the Regional Centre interfacing with the general database should form part of the contract of the monitoring centre.

Furthermore, monitoring stations should be protected against emissions produced in their vicinity by construction work, to avoid risks of their environment being downgraded, thus rendering the station unusable in certain cases. The towns selected for installing the regional centres should be located in

such a way as to facilitate displacements for on-site monitoring or for resolution of interference cases.

In regions with low network density, it is not necessary to have all the functions offered by a complete monitoring centre, but it is preferable to contend with a reduced and less expensive monitoring centre.

To be complete, the spectrum monitoring system should also comprise an HF monitoring centre equipped with direction finders, and a terrestrial and space radiocommunication services monitoring centre, also used during investigations of interference produced by RF networks (chapter 4 of ITU-R 1995 Spectrum Monitoring Handbook). The geographical location of the HF spectrum centre is relatively less important, given the propagation type of HF waves. Conversely, the terrestrial and space radiocommunication services centre should be located as a function of possible realisations of radio stations in the country and also in the neighbouring countries, in order to optimise its position when exchanging measurements between centres (a triangulation with satellite transmission monitoring centres in neighbouring countries for example). Only the downlink can easily be monitored with an acceptable cost. Although the action of regulator is rare, this function is nevertheless important for satellite link users since the controller intervenes as a last resort in these very few cases, but which become very impeding for the user (or the satellite operator). Specific analysis techniques enable fulfilling this function, which is rarely used, but which forms part of the spectrum monitoring missions.

GLOSSARY[36]

Administrative pricing A form of *spectrum pricing*[37] in which *equipment licence* fees or charges for *spectrum rights* are set by the spectrum manager. Administrative pricing may include such variants as:

- *shadow pricing* (see below);
- *incentive pricing*, where fees are set with the intention of promoting efficient spectrum use;
- *regulatory pricing*, where fees are set unrelated to market considerations, for example, to recover spectrum management costs.

Apparatus licence A permission to install and use radio equipment. This will specify the frequency or frequency band to be used and may also impose terms and conditions restricting matters such as the type of apparatus to be used, power, coverage area, geographical location or service to be provided. The extent and specificity of the restrictions will depend on circumstances and the characteristics of the service in question.

Auction A form of *spectrum pricing* - as well as a spectrum assignment mechanism - in which *apparatus licences* or *spectrum rights* are assigned to the winner(s) of a competitive process selected on the basis of price. (In some countries, other factors, such as quality of service, speed of roll-out and financial viability, may also be taken into account, either in the assessment of the bids or as pre-qualification criteria.) *Auctions* may take various forms, including:

- the *English auction*, where the auctioneer increases the price until a single bidder is left;
- the *first-price sealed bid auction*, where bidders submit sealed bids and the highest wins;
- the *second-price sealed bid auction*, where bidders submit sealed bids and the highest bidder wins but pays the second highest amount bid;
- the *Dutch auction*, where the auctioneer announces a high price and reduces it until a bidder shouts "mine";
- the *simultaneous multiple round auction*, as first practiced by the Federal Communications Commission in the USA. This involves multiple rounds of bidding for a number of lots that are offered simultaneously. The highest bid on each lot is revealed to all bidders before the next round when bids are again accepted on all lots. The identity of the high bidder may or may not be revealed after each round, but is revealed at the auction's close. The process continues until a round occurs in which no new bids are submitted on any lots. This variant is more complex than single-round auctions but offers bidders greater flexibility to combine lots in different ways, and, because it is more open than a sealed bid process, limits the impact of the *winner's curse*, allowing bidders to bid with more confidence.

Auctions are commonly considered to have advantages of economic efficiency, transparency and speed compared to alternative assignment methods and also capture the market value of spectrum rights for the administration holding the auction. They can give rise to anti-competitive outcomes if they result in large operators acquiring an undue concentration of the available spectrum but various safeguards against this can be introduced, for example restrictions on the amount of spectrum an individual bidder may win or 'use it or lose it' provisions to prevent hoarding.

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36 This glossary has been extracted from Report ITU-R SM.2012

37 Terms defined in this glossary are printed in *italics*.

Bidding credit A discount given to certain bidders to promote socially desirable goods. Bidding credits were given to smaller, entrepreneurial firms in some FCC auctions. For example, a 25% bidding credit would mean that if an entrepreneurial firm submitted a winning bid of $1,000,000, it would pay only $750,000. Originally, bidding credits were also proposed for women and racial minorities; however, the FCC dropped this proposal after the U.S. Supreme Court's *Adarand* decision, which declared that such preferences were discriminatory, and therefore illegal.

First-come, first-served An assignment procedure in which spectrum is assigned to applicants until it is exhausted, subject only to compliance with minimum technical or financial criteria. This procedure has tended to be used for small scale assignments, such as individual private business radio and fixed links licences. It works best where spectrum is not scarce.

Gross Domestic Product (GDP) The sum of the value of all final goods and services sold within the geographic borders of a country in a year.

Lottery A process for assigning *apparatus licences* or *spectrum rights* to applicants selected at random. *Lotteries* have the advantage of speed and simplicity but they are unlikely to lead to an economically optimum outcome and can give rise to speculative applications because of the prospect of windfall gains.

Mutual exclusivity A situation in which two or more applicants are competing for the same spectrum assignment.

Oligopoly A situation in which only a small number of firms are supplying a product or service. This situation may be contrasted with a monopoly situation, in which there is only one firm supplying a product or service.

Opportunity cost The benefits foregone by not putting a resource to its best alternative use. For example, the best alternative use of a frequency band currently used for a broadcast service might be for a mobile service. In an auction, the bidder with the highest willingness to pay will generally win, with a bid that is just above the valuation of the bidder with the second highest willingness to pay. This second highest valuation represents the opportunity cost.

Resource rents The term economists use to categorize the value of a resource. The rent accruing to a resource right, such as a spectrum right, can be quantified by the price that the right would sell for in an open market.

Secondary trading Buying and selling of *apparatus licences* or *spectrum rights* after initial assignment by the spectrum manager. Dealing may take place directly between the parties or through an intermediary.

Shadow pricing A form of administrative pricing in which the price is set according to a predetermined formula intended to mimic the effect of market forces. Parameters commonly used include bandwidth, frequency location, geographical location and coverage area.

Spectrum pricing A generic term currently used to denote the use of pricing as a spectrum management tool. It covers both *administrative incentive pricing* and *auctions* of either *apparatus licences* or *spectrum rights*. Under *spectrum pricing*, charges are not set by reference to the fully allocated costs of spectrum management attributable to particular user categories but are intended to balance supply of and demand for spectrum or to achieve other spectrum management policy objectives, such as facilitating the introduction of new services or promoting competition.

Spectrum right The right, analogous to a property right, to use a specified frequency or range of frequencies in a particular location or throughout a nation or region for a particular time period within ITU Radio Regulations. Where such rights have been introduced, restrictions on the type of

equipment to be used or service to be provided may be minimal apart from technical non-interference conditions in relation to adjacent *spectrum rights*. It may be possible to assemble *spectrum rights* to provide increased bandwidth or coverage area or both.

Threshold qualifications Qualifications that are a prerequisite to participate in some process, such as a lottery or auction. Threshold qualifications may include financial and technical viability, and a service plan that satisfies certain social goals.

Unjust enrichment An award, such as the award of a valuable frequency assignment, to a person or company that exceeds that person's or company's entitlement to the award.

Winner's curse A possible effect of an auction, most commonly a sealed-bid auction. Assuming that some bidders will over-estimate the value of the lot, the winner may be the most optimistic rather than the most skilful in assessing the value of the lot. In a sealed-bid auction, auction proceeds may be reduced as bidders attempt to minimise this effect. *Winner's curse* can be reduced or eliminated by careful design, particularly by using multiple round auctions (see *simultaneous multi-round auction*).

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