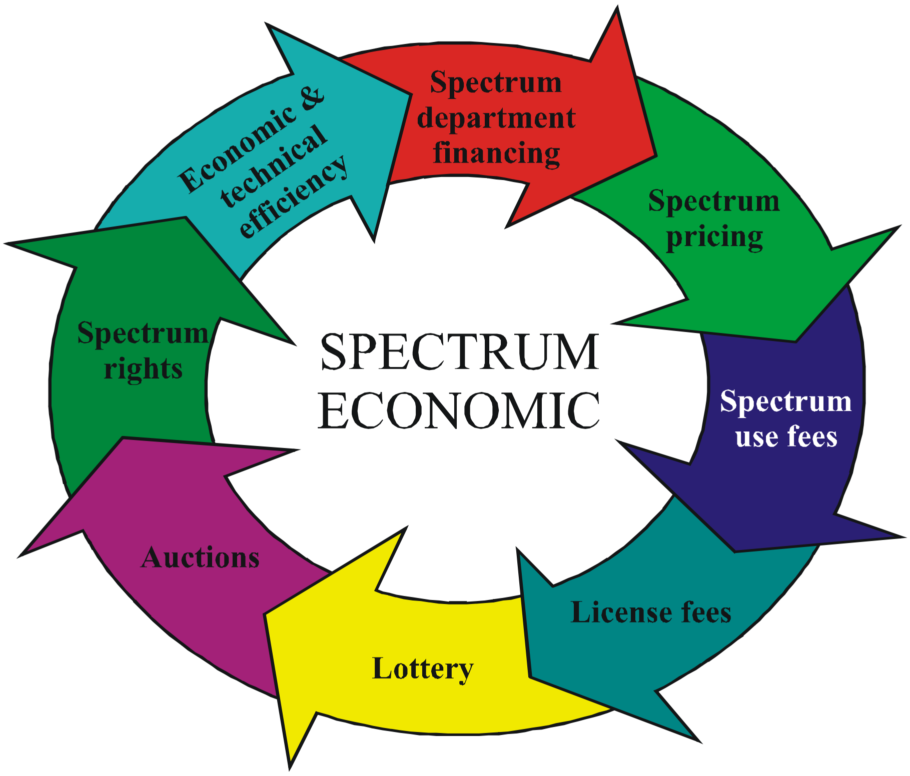
REPORT ITU-R SM.2012-2

ECONOMIC ASPECTS OF SPECTRUM MANAGEMENT



PREFACE

The initial version of Report ITU-R SM. 2012 – Economic aspects of spectrum management, was issued in 1998. In January 2001, the Report was updated to include summaries of additional experience obtained by a number of administrations.

This revised version of the Report consists of five Chapters which describe the different economic approaches for spectrum management activities. The Chapters contain detailed explanations and references that can be consulted for additional information. New Chapter 5 provides information on administrations' experience regarding the economic aspects of spectrum management.

Further contributions have been submitted to Study Group 1 and are compiled in Annex 1 (Parts 1 to 4) for use by administrations in developing and developed countries in view to establish effective strategies for national radio-frequency spectrum management.

Part 1 – Experience with Spectrum Fees – Republic of Korea

Part 2 – Observations of 3G and IMT2000/UMTS Networks and Services in Europe (Thales)

Part 3 – An Application of Spectrum Pricing – United Kingdom

Part 4 – An analytical model for calculating license fees on the basis of specified incentives that are designed to promote efficient spectrum use

The Report is intended for the use by administrations of both developing and developed countries in their development of strategies on economic approaches to national spectrum management and to the financing of this activity. In addition, the Report presents an analysis of the benefits of strategic development and the methods of technical support for national spectrum management. These approaches not only promote economic efficiency but can also promote technical and administrative efficiency.

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FOREWORD

Radiocommunications have become an increasingly vital part of the telecommunications infrastructure and economy of a country. In order to have effective radiocommunications, a country must have an effective spectrum management system. A number of technical and regulatory procedures need to be implemented for the spectrum management system to be effective. These procedures are described in the ITU Handbook on “National spectrum management” and, although complex, can be implemented with adequate financial resources, technical expertise and time. The key or starting point for this implementation is to obtain adequate financial resources for the spectrum management system. These financial resources can be obtained from the administration or from fees obtained from the use of the radio spectrum. The collection of fees varies from the fee for the processing of a radio licence to the auctioning of a portion of the radio spectrum.

The 1995 Radiocommunication Assembly recommended that Radiocommunication Study Group 1 study on a urgent basis “Economic aspects of spectrum management” and accelerate the development of a report. This Report answers many of the questions that were asked by the Radiocommunication Assembly and describes economic approaches that promote economic, technical, and administration efficiency and can also help fund a national spectrum system.

The main purpose of the economics Report is to describe to developing countries methods of obtaining adequate financial resources to implement an effective national spectrum management system. The development of this Report was primarily for the ITU-D sector and was accomplished in cooperation with ITU-D members. The Report should be distributed to ITU-D members and comments sought on aspects of this subject that may need further clarification.

The completion of this Report on a urgent basis was primarily due to the extra effort of a Rapporteurs group chaired by David Barrett (United Kingdom), Rodney Small and Karl Nebbia (United States of America), and Ian Munro (Canada). Special appreciation should also go to Alexander Pavliouk (Russian Federation), who organized the completion of the Report.

Robert J. Mayher

Chairman, Radiocommunication Study Group 1

REPORT ITU-R SM.2012-2

ECONOMIC ASPECTS OF SPECTRUM MANAGEMENT

(1997-2000-2004)

TABLE OF CONTENTS

Scope

The objective of this economic study is to respond to the following issues which are divided into three categories:

Category 1: Strategies for economic approaches to national spectrum management and their financing

1 What are the underlying principles that have been taken into consideration by various administrations in their approaches to financing the maintenance and development of national spectrum management?

2 What economic approaches have been, or are intended to be used to promote efficient national spectrum management in different frequency bands?

3 What are the advantages and disadvantages of these various economic approaches to national spectrum management?

4 What are the factors (e.g. geographical, topographical, infrastructural, social, legal) that could affect these approaches and how would they vary with the use of radio in a country and the level of that country's development?

Category 2: Assessment, for spectrum planning and strategic development purposes, of the benefits arising from the use of the radio spectrum

1 What are the benefits that accrue to an administration from the use of radio within its country and how can they be quantified, allowing them to be represented in an economic form so as to enable a comparison of the benefits and costs of particular spectrum management options (e.g. in terms of employment or Gross Domestic Product)?

2 What models can be used to represent these benefits in an economic form and how can they be validated?

3 What factors could affect the benefits accruing to an administration from the use of the radio-frequency spectrum, including by national safety services?

4 How would the factors in § 3 vary from country to country?

Category 3: Alternative methods of national spectrum management

1 What are alternative spectrum management approaches including the use of non-profit making user groups and private sector spectrum management organizations?

2 How can these approaches be categorized?

3 Which of these alternative spectrum management approaches would be responsive to the needs of the developing countries as well as for the least developed ones?

4 What measures, of a technical, operational and regulatory nature, would it be necessary for an administration to consider implementing when adopting one or more of these spectrum management approaches in the context of:

– the country's infrastructure;

– national spectrum management;

– regional and international aspects (e.g. notification, coordination, monitoring)?

Further information is likely to be submitted that is relevant to this Report and that information will be included in future revisions as appropriate.

CHAPTER 1

INTRODUCTION TO ECONOMIC CONSIDERATIONS

1.1 Need for spectrum economic approach

The increasing use of new technologies has produced tremendous opportunities for improving the communications infrastructure of a country and the country's economy. Further, the ongoing technological developments have opened the door to a variety of new spectrum applications. These developments, though often making spectrum use more efficient, have spurred greater interest and demand for the limited spectrum resource. Thus, the efficient and effective management of the spectrum, while crucial to making the most of the opportunities that the spectrum resource represents, grows more complex. Improved data handling capabilities and engineering analysis methods are key to accommodating the number and variety of users seeking access to the spectrum resource. If the spectrum resource is to be used efficiently and effectively, the sharing of the available spectrum has to be coordinated among users in accordance with national regulations within national boundaries and in accordance with the Radio Regulations (RR) of the International Telecommunication Union (ITU) for international use. The ability of each nation to take full advantage of the spectrum resource depends heavily on spectrum managers facilitating the implementation of radio systems, and ensuring their compatible operation. Furthermore, the imbalance between the demand for radio frequencies and the availability of spectrum keeps growing, especially in urban areas. According to economic theory, when demand exceeds supply, a price system should be implemented. As the frequency spectrum is a scarce resource, decisions concerning spectrum management should also consider the economic point of view. Therefore, to improve national spectrum management all available means including economic methods are needed.

This Report has been developed to assist administrations in the development of strategies on economic approaches to national spectrum management and their financing. In addition, the Report presents a discussion of the benefits of spectrum planning and strategic development and the methods of technical support for national spectrum management. These approaches not only promote economic efficiency but can also promote technical and administrative efficiency.

Before the economic approaches can be discussed it is first necessary to consider what is an effective spectrum management system and what areas of spectrum management can be appropriately supported by other means.

1.2 Requirements for national spectrum management

Effective management of the spectrum resource depends on a number of fundamental elements. Although no two administrations are likely to manage the spectrum in exactly the same manner, and the relative importance of these fundamental elements may be dependent on an administration's use of the spectrum, they are essential to all approaches. For further information on spectrum management functions see the ITU Handbook on National spectrum management.

1.3 Goals and objectives

In general, the goals and objectives of the spectrum management system are to facilitate the use of the radio spectrum within the ITU Radio Regulations and in the national interest. The spectrum management system must ensure that adequate spectrum is provided over both the short and long term for public service organizations to fulfil their missions for public correspondence, for private sector business communications, and for broadcasting information to the public. Many administrations also place high priorities on spectrum for research and amateur activities.

In order to accomplish these goals, the spectrum management system must provide an orderly method for allocating frequency bands, authorizing and recording frequency use, establishing regulations and standards to govern spectrum use, resolving spectrum conflicts, and representing national interests in international fora.

1.3.1 Radiocommunications law

The use and regulation of radiocommunications must be covered within each nation's laws. In areas where radiocommunications use is not extensive, and where the need for management of the spectrum may not yet be crucial, national governments must still anticipate the increase of radio use and ensure that an adequate legal structure is in place.

1.3.2 National allocation tables

A national table of frequency allocations provides a foundation for an effective spectrum management process. It provides a general plan for spectrum use and the basic structure to ensure efficient use of the spectrum and the prevention of RF interference between services nationally and internationally.

1.4 Structure and coordination

Spectrum management activities may be performed by a government body or by a combination of government bodies and private sector organizations. Which government bodies or organizations are given the authority to manage the spectrum, will however, depend upon the structure of the national government itself and will vary from country to country.

1.5 Decision-making process

The processes developed to allocate spectrum, assign frequencies to specific licensees, and monitor compliance with license terms are essential tools for implementing national goals and objectives. Administrative bodies responsible for developing rules and regulations governing the spectrum should develop an organized decision-making process to ensure an orderly and timely spectrum management process. The process should be set up to allow decisions that serve the public interest while reflecting national policies and plans relating to the spectrum, developments in technology, and economic realities. Often such processes will depend on the use of consultative bodies to make appropriate decisions.

1.6 Functional responsibilities

The spectrum management structure is naturally formed around the functions that it must perform. The basic functions are:

– spectrum management policy and planning/allocation of spectrum;
– frequency assignment and licensing;
– standards, specifications, and equipment authorization;
– spectrum control (enforcement and monitoring);
– international cooperation;
– liaison and consultation;
– spectrum engineering support;
– computer support;
– administrative and legal support.

Administrative and legal support functions will necessarily be a part of the spectrum management organization, but they are common to all organizations and thus it is not necessary to discuss these in relation to spectrum management.

1.6.1 Spectrum management policy and planning/allocation of spectrum

The national spectrum management organization should develop and implement policies and plans relating to the use of the radio spectrum, taking into account advances in technology as well as social, economic and political realities. National radiocommunications policy is commonly associated with regulation development because the regulations generally follow the establishment of policies and plans. Accordingly, it is often a primary function of the policy and planning unit to conduct studies to determine existing and future radiocommunications needs of the country and to develop policies to ensure the best combination of radio and wireline communications systems employed in meeting the identified needs.

The primary result of the planning and policy-making effort is the allocation of frequency bands to the various radio services. The designation of frequency bands for specific uses serves as the first step to promoting spectrum use. From allocation decisions follow further considerations such as standards, sharing criteria, channelling plans and others.

1.6.2 Frequency assignment and licensing

Providing or assigning frequencies represents the heart of the daily operation of the spectrum management organization. The frequency assignment unit performs, or coordinates the performance of, whatever analysis is required to select the most appropriate frequencies for radiocommunications systems. It also coordinates all proposed assignments with regard to existing assignments.

1.6.3 Standards specification, and equipment authorization

Standards provide the basis for equipments to work together and limit the impact of radio use to that which is intended. In many cases, such as aircraft navigation and communications systems, equipment must be capable of operating in conjunction with equipment operated by other users and often other countries. Standards can be used to require design characteristics that will ensure that such operation is possible. The second aspect of standards is their use to ensure electromagnetic compatibility (EMC) of a system with its environment and generally involves limiting transmitted signals to a specified bandwidth or maintaining a specified level of stability in order to prevent interference to other systems. In some cases an administration may choose to set standards for receivers, requiring a certain level of immunity to undesired signals. The establishment of an adequate program of national standards forms a basis for preventing harmful interference and, in some cases, for ensuring desired communications system performance.

1.6.4 Spectrum control (enforcement inspections and monitoring)

Effective management of the spectrum depends on the spectrum manager's ability to control use of the spectrum through enforcement of spectrum regulations. This control is built primarily on enforcement inspections and monitoring. See the ITU-R Handbook – Spectrum monitoring.

1.6.4.1 Enforcement inspections

Spectrum managers must be granted the authority to enforce regulation of spectrum use and set appropriate penalties. For instance, spectrum managers may be granted the authority to identify a source of interference and to require that it be turned off or to confiscate the equipment under appropriate legal mechanisms. However, the limits of that authority must also be specified.

1.6.4.2 Monitoring

Monitoring is closely associated with inspection and compliance in that it enables the identification and measurement of interference sources, the verification of proper technical and operational characteristics of radiated signals, and detection and identification of illegal transmitters. Monitoring further supports the overall spectrum management effort by providing general measurement of channel usage and band usage, including channel availability statistics and the effectiveness of spectrum management procedures. It obtains statistical information of a technical and operational nature on spectrum occupancy. Monitoring is also useful for planning, in that it can assist spectrum managers in understanding the level of spectrum use as compared to the assignments that are recorded on paper or in data files. Some administrations have chosen to use monitoring in place of licence records.

1.6.5 International cooperation

Radiocommunications have a significance that goes beyond the borders of each nation. Navigation equipment is standardized to allow movement throughout the world. Satellite system transmissions facilitate worldwide communications. Radio wave propagation is unhindered by political boundaries. Communications system manufacturers produce equipment for many markets, and the more the markets encourage commonality the simpler and less expensive the production process will be. For each of these reasons, the national spectrum manager’s ability to participate in international fora becomes significant. International activities include those within the ITU, those within other international bodies, and bilateral discussions between neighbouring countries concerned with ITU Radio Regulations.

1.6.6 Liaison and consultation

In order to be effective, the spectrum management organization must communicate with and consult its constituents, i.e. the radio users composed of businesses, the communications industry, government users and the general public. This includes dissemination of information on the policies, rules and practices of the administration and provides mechanisms for feedback to evaluate the results of these policies, rules and practices.

1.6.7 Spectrum engineering support

Since spectrum management involves decisions pertaining to a field of technology, engineering support is required to adequately evaluate the information, capabilities and choices involved. Engineering support can assist the spectrum manager in many ways. For example, interference situations can often be prevented or resolved through technical analysis. The equipment specifications and standards necessary to ensure compatibility between systems can be determined. Frequencies can be assigned using models or methods developed through engineering support. Also, the resolution of many spectrum allocation issues can be facilitated by analysis of spectrum use and future requirements.

1.6.8 Computer support

The extent to which computer support facilities are available to be used and are used by the spectrum management authority depends on the resources, priorities, and particular requirements of the country concerned. Computer support may cover licensing records to complex engineering calculations and may include the development, provision, and maintenance of support facilities for nearly all spectrum management activities, including record keeping, forecasting and financial management related to licensing.

1.7 Performance of spectrum management functions

The previously described spectrum management functions need to be established in order to have an effective spectrum management system. However not every aspect of each function needs to be performed by the national spectrum management organization. The policy or overall management authority must, however, remain with the national spectrum management organizations. The following Chapters discuss the means by which spectrum management may be funded and the means by which economic approaches may improve the efficiency of spectrum use, methods of assessing the benefits of spectrum use and the use of other organizations to support and/or provide part, or all, of specific spectrum management functions.

CHAPTER 2

STRATEGIES FOR ECONOMIC APPROACHES TO NATIONAL SPECTRUM MANAGEMENT AND THEIR FINANCING

2.1 Background

There is increasing interest in economic approaches to national spectrum management. This Chapter of the Report addresses issues pertaining both to the impact of these approaches on financing a national spectrum management program and their impact on economic, technical, and administrative efficiency. While economic approaches are commonly regarded as a means to increase revenues, the objective of economic approaches must be consistent with an administration's spectrum management goals and objectives. When implementing an economic approach, using and managing spectrum efficiently and effectively should be a top priority.

The ITU World Telecommunication Development Conference (Valetta, 1998), by Resolution COMA-3 Financial Support for National Spectrum Management Programmes (WTDC-98, Document 237) invited national and international finance organizations to pay more attention to giving substantial financial support, including through favourable credit arrangements, to national spectrum management. The Resolution invited such support, including support for radiomonitoring programmes, as a prerequisite for efficient spectrum utilization, the successful development of radio services, and the implementation of new and promising applications, including global ones, at both the national and the international levels.

The following material describes the economic approaches to financing national spectrum management. Furthermore, it describes the use of economic approaches to promote efficient national spectrum management. The approaches promoting efficient national spectrum management are subdivided into spectrum assignment methods, both market based and non-market based, and transferable property rights. Finally the economic aspects of various fee mechanisms are discussed.

2.2 Underlying approaches with respect to financing national spectrum management

Each administration must find a way to ensure sufficient revenues to cover the costs of maintaining an effective spectrum management programme to meet the national spectrum management requirements presented in Chapter 1. Adequate funding of spectrum management can be critical to implementing new spectrum-using services (see Note 1) and permitting those services to operate on an acceptable interference-free basis. Further, an adequately-funded spectrum management programme creates opportunities for service providers and equipment manufacturers and contributes greatly to the growth of the economy. Inadequate funding of spectrum management, on the other hand, can result in a failure to implement valuable radio services, or delays in implementing such services. In fact, service providers may choose not to serve a country that has an ineffective spectrum management programme in order to seek more hospitable spectrum regulatory environments in other countries.

It should be recognized that regardless of which of the following approaches is followed, the use of spectrum and spectrum management have associated costs borne by the population. Even where an administration issues licences without fees, the general population indirectly bears the cost burden for spectrum management through taxation. In that case, the share of spectrum management costs paid through the taxes of individuals that seldom use spectrum services will represent a greater amount than the benefits these individuals receive from spectrum services, while those that use spectrum services receive benefits that are greater than their share of the spectrum management cost burden. The use of licence fees and auctions for the purpose of covering the costs of the spectrum management system does not represent a new tax, but a potentially more appropriate method of distributing the costs of spectrum management to those who actually receive benefits.

NOTE 1 – In this Report the use of the word "service" with a non-capitalized "s" means an end-user service (e.g. cellular radio) and not a Radiocommunication Service.

2.2.1 Approaches

2.2.1.1 Traditional national budget financing

Until recently, virtually all countries have funded their spectrum management programmes through a centralized national budget process. This approach simply involves allocating a portion of the administration's annual budget to spectrum management. Generally the amount provided depends on the priorities of the national government. In many cases, the national spectrum manager provides estimates of its funding needs. The national government response, however, is limited by its total tax resources.

2.2.1.2 Spectrum use fees

This approach involves charging some or all licensees for their use of the spectrum. Some countries are now funding their spectrum management programmes in whole or in part through fees. In some cases this includes financing a phased implementation of a national spectrum management programme. These fees are based either directly on spectrum use or indirectly through general administrative or regulatory charges. Fees can be established on a variety of bases and formulas for fee calculation can range from the simple to the complex.

2.2.1.3 Auctions

Another way of funding spectrum management is by using a percentage of the money raised through auctions. While no country has directly funded spectrum management through auction revenues, such revenues in the United States of America have vastly exceeded spectrum management costs in recent years.

2.2.2 Advantages and disadvantages of these approaches

The national budget financing approach has been used successfully in some countries for a number of years. However, it depends heavily on the administration's recognition of the importance of radiocommunications and spectrum management. National governing bodies dealing with a host of national issues are often unfamiliar with spectrum issues or the impact of radio on the national economy. Furthermore, the national budget financing approach does not impose any immediate costs on those who directly benefit from spectrum use, but rather imposes an indirect tax on all citizens. Funding for spectrum management under this approach has often been difficult in developed countries, but may be a particular problem in developing countries, where budgetary resources are limited and where the importance of spectrum-using services to the economy may not be as evident as in developed countries.

The fee approach has also been used successfully in a number of countries, and it has the advantages of pre-determining revenues to be used for spectrum management and imposing costs on at least some entities that benefit from spectrum use. However, because fee levels can be based on a variety of considerations, such as policy direction or payment of administrative costs, determination of the levels for each type of radio use may represent a complex undertaking. Further, the use of fees to cover the cost of administrative processing may prove insufficient by itself to cover the costs of an adequate spectrum management programme. However, fee approaches that cover additional spectrum regulatory costs can be developed to fully fund spectrum management. It should be noted that in addition to fees charged to spectrum users, application fees could be charged for the right to participate in comparative processes, lotteries, or auctions.

Advantages of the auction approach are that it holds potential for an accurate reflection of the value of the spectrum and it imposes costs on those who directly benefit from spectrum use. However, the use of auctions may be viewed as a significant departure from normal practice. Furthermore, a disadvantage of this approach is that revenues are uncertain, (see Note 1) and may exceed or fall short of what is needed to adequately fund spectrum management. If revenues exceed what is necessary, a portion of the revenues could be returned to the treasury, which would need to determine how this revenue will be distributed; whereas if revenues fall short, supplementary national budget or licence fee funding would have to be used to maintain all necessary spectrum management functions. Spectrum managers could attempt to ensure that revenues would be sufficient by establishing minimum bid amounts; however, if these amounts were set too high, no bids would be received. Auctions may not be suitable under certain circumstances and may need to be supplemented by other means. Auctions would not be suitable, for example, if there are no competing applicants, if a spectrum right cannot be properly defined, or if the anticipated costs of the auction exceed the anticipated revenues.

NOTE 1 – In the United States of America, auctions held during 1994-1996 exceeded estimates, whereas recent auctions have generally fallen short of estimates.

2.3 Economic approaches used to promote efficient national spectrum management

Economic (market-based) approaches can be used to improve national spectrum management in a variety of ways. As the term implies, these approaches promote economic efficiency; they also promote technical and administrative efficiency.

For any resource, including the spectrum, the primary economic objective is to maximize the net benefits to society that can be generated from that resource; this is what economists refer to as an economically efficient distribution of the resource. Resources are said to be efficiently distributed, and the overall benefits to society maximized, when it is impossible to redistribute so as to make at least one individual better off without making another worse off. Such a distribution of resources is referred to as the "Pareto Optimality Criterion", in honour of its developer, Italian economist Vilfredo Pareto (1848-1923). Strict adherence to this criterion in decision-making, however, greatly restricts the options available to spectrum managers because there will always be at least one person made worse off by any decision, hence, the less restrictive "Potential Pareto Optimality Criterion" is far more feasible. This criterion states that a redistribution of resources leads to an increase in overall social welfare and therefore should take place if those that are made better off by that redistribution could, in principle, fully compensate those that are made worse off and still receive greater benefits than was the case prior to the redistribution.

A second economic objective relevant to spectrum management is resource rent capture. Economists categorize the value of a resource, be it spectrum, oil, or timber, as a "rent". Rights or privileges to extract oil from the ground have value to companies who can sell that oil to consumers or use it to fuel their vehicles, so too does a right or privilege to use radio spectrum have value to a spectrum user who can sell wireless services (a paging company, for example) or use wireless technologies in the provision of other goods or services (a taxi company, for example). The rent accruing to a resource, including a spectrum licence, can be quantified by the price that the resource would bring in an open market. If a spectrum licensee receives for free a licence that has economic value, the licensee has captured the rent accruing to that licence.

The value of spectrum is reflected in two inherent rents: scarcity rent and differential rent. Scarcity rent exists because demand for spectrum, at least in certain bands and at certain times, exceeds supply at zero price. Differential rent exists because each frequency band possesses specific propagation characteristics that make it suitable for specific services. Having access to the most suitable frequency band could minimize the cost of implementation and optimize the performance of a radio system. Bands that are suitable for many different services using inexpensive equipment are more valuable than bands that are suitable for only one type of service using costly equipment. However, even for the former bands, their non-exclusive use in a particular geographic area may dramatically reduce their value. While some shared use of spectrum may be efficient, where transmitters operate at the same time in the same area and on the same frequency, they may cause mutual harmful interference, thus reducing the band's value in that area at that time.

In theory, both the goals of Pareto Optimality and resource rent capture can be promoted by creating a free market in spectrum. In such a market, all spectrum assignments would consist of well-defined, legal rights of possession that could be transferred, aggregated and sub-divided, and used for any purpose the owner saw fit, so long as this use did not interfere with the possession rights of other spectrum users. However, preventing interference among technically different services (for example, broadcast, mobile, fixed, and satellite) in a spectrum market would require extremely complex engineering analysis, and could lead to litigation among spectrum users. Further, most spectrum managers believe that there are other reasons for imposing some limitations on a spectrum market. These include the following:

– Critical government, scientific research, and other socially desirable requirements may not be adequately satisfied.
– Limits on spectrum aggregation by individual users may be desirable to preclude anti-competitive market dominance by rich users.
– By allocating certain bands to certain uses, whether on a unilateral, national basis or a multilateral, international basis, economies of scale in equipment production may be facilitated.
– Internationally allocated bands for globally mobile spectrum users such as mobile users aboard ships and aircraft help to ensure that multiple transmitters and receivers for the same communications function are not needed on board.

Accordingly, national spectrum managers worldwide have usually chosen to forego an unfettered spectrum market and have allocated frequency bands to particular uses, with varying technical restrictions. However, in the absence of a property rights system, spectrum managers may wish to consider spectrum valuations of competing groups of users – broadcasters versus mobile telecommunications service providers, for example. Without a spectrum market, such valuations can be done only imperfectly, but using market proxies such as estimation of service revenues and impact of the service on gross domestic product and employment can be helpful in generating data for use in making allocation and other spectrum management decisions.

2.3.1 Spectrum assignment methods

After spectrum is allocated to a particular use, it must be assigned to individual users. If demand for a particular frequency band in a particular geographic area is limited, there will be no necessity to resolve mutually exclusive (competing) requests for that band. Accordingly, licences may simply be assigned to applicants upon request, provided that applicants adhere to certain technical standards and regulations. However, if mutually exclusive spectrum requests exist, an assignment method must be used to choose from among competing applicants. Three methods of doing this are comparative processes (such as comparative hearings), lotteries, and auctions.

2.3.1.1 Non-market-based assignment approaches: comparative processes and lotteries

In a comparative process, the qualifications of each of the competing spectrum applicants are formally compared based on established and published national criteria. (Typically, these criteria might include population to be served, quality of service, and speed of service implementation.) The spectrum management authority determines who is the best qualified applicant to use the spectrum and awards the licence. However, comparative processes can be very time-consuming and resource-intensive, may not assign spectrum to those who value it most highly, and may not generate any revenues unless licence fees and/or application fees are charged. Additionally, comparative processes are often decided on the basis of minor differences among applicants, and may cause the decision to be contested by unsuccessful applicants.

In a lottery, licensees are selected at random from among all competing spectrum applicants. Lotteries can decrease some aspects of the administrative burden entailed in comparative hearings, such as legal expenses, but may create a different kind of administrative burden by encouraging more applications to be filed. Additionally, lotteries do not assign spectrum to those who value it most highly, except by chance, lead to significant transaction costs, and again generate no revenues, unless fees are attached to the licence assigned by lottery or an entry fee to participate in the lottery is charged. Rather, lottery winners in many cases transfer their spectrum rights to other parties, thus capturing the resource rents for themselves. Thus lotteries, without significant application fees or other measures that guarantee the applicants' intent to provide radio services, tend to encourage speculation.

While comparative processes and lotteries are not market-based assignment methods, market forces can be brought to bear after the spectrum has been assigned through the establishment of a secondary market (see § 2.3.2).

2.3.1.2 Market-based assignment approach: auctions

In an auction, licences are awarded by bidding among competing spectrum applicants. Auctions award licences to those who value them most highly while simultaneously generating revenues for the spectrum authority. However, as is the case with an unrestricted spectrum market, auctions may raise competitive concerns if not combined with an active competition policy and limits on how much spectrum an entity may purchase. Market forces do not ensure economic efficiency or maximize consumer welfare in markets that are not competitive because a dominant service provider or group of providers have market power. Additionally, auctions may fail to adequately provide certain socially desirable services or distribute licences to certain groups, such as small businesses (if that is an objective). However, "bidding credits" (discounts) and installment payments to selected entities may alleviate these problems. In fact, entities that would have little chance to win in a comparative process or a lottery may be successful in an auction if bidding credits are significant and if installment payments permit licence costs to be paid over a number of years.

Auctions and lotteries may significantly decrease the administrative costs and time associated with the spectrum assignment process and therefore improve overall administrative efficiency in contrast to comparative processes.

2.3.2 Transferable and flexible spectrum rights

While auctions are the assignment mechanism best suited to providing an initial economically efficient distribution of the spectrum resource, they will not ensure that spectrum continues to be used in an economically efficient manner in the future. As with other resources, economists recommend that spectrum users be allowed to transfer their spectrum rights (whether assigned by auction or some other assignment mechanism) and that spectrum users have a high degree of flexibility in the choice of the consumer services that they provide with their spectrum.

The least restrictive form of transferable property rights permits unlimited technical flexibility without regard to an allocation structure, provided that harmful interference is not caused outside the assigned band. This system, if applied to all frequency bands, would result in an unfettered spectrum market. However, as discussed in § 2.3, a totally free market spectrum approach has not been implemented by any country.

The most restrictive form of property rights permits transferability only within the confines of a given allocation and only within strictly defined technical parameters. This system has the advantages of ensuring that the entity within the allocated service who values a particular frequency assignment the most will be able to use that assignment, while minimizing the possibility of interference. However, by restricting technical flexibility to ensure interference control, economic efficiency may also be significantly reduced. Further, if property rights are simply vested in incumbent licensees, any resource rent accruing to a particular frequency assignment is captured by the incumbent, rather than the spectrum management authority, unless the rents have been captured initially via an auction or through licence fees.

The middle course with respect to property rights, and the approach used in some bands by New Zealand, the United States of America, and Australia, is to specify emission rights within a given allocation, which may be broadly defined, for example, broadcasting or mobile radio. This approach can lead to an increase in economic efficiency both because licensees are allowed to adjust their use of inputs in accordance with cost and demand considerations; e.g. a mobile radio provider may be able to satisfy increased demand by using a different modulation technique, and because licensees may freely transfer their frequency rights in whole or in part to entities that value those rights more highly. Hence a tradable spectrum rights system provides licensees with the full incentive to use their spectrum in a technically efficient manner. However, a disadvantage of this approach is that it may increase the potential for harmful interference among licensees because technical inputs are not specified. Specifying licensees' emission rights rather than specifying what inputs licensees must use places a heavier interference control burden on licensees. However, licensees can be allowed to negotiate their emission rights; e.g., one licensee may agree to accept additional interference in exchange for monetary compensation. Dependent upon how often disputes requiring resolution by the spectrum management authority or the courts arise, permitting such negotiations may prove advantageous or disadvantageous.

2.3.3 Advantages and disadvantages of auctions and transferable spectrum rights

Auctions have the advantages of awarding licences to those who value them most highly, while simultaneously generating revenues. When auctions are used to assign licences within a given allocation structure, licences are awarded to those who value them the most only within the confines of the allocation structure. For example, if a particular block of spectrum in a particular area is valued most highly by broadcasters but is allocated to mobile radio, revenues and the economic benefits generated from that spectrum will be less than if broadcasters were allowed to participate in the auction. Broadening the range of uses permitted under an auctioned licence also allows spectrum to be used for those services most in demand. However, broadly defining services has the potential disadvantage of increasing the cost of interference coordination between licensees in adjacent spectrum and areas. These arguments regarding allocation structure apply equally to a system of transferable spectrum rights after the initial spectrum assignment.

Other expected benefits associated with auctions may be fairness, transparency, objectiveness, and the speed with which licenses can be awarded. Auctions can reduce the opportunities for favoritism and corruption in the competition for spectrum, promote investment, and promote technological advancement.

However, in order to promote competition, it may be necessary to impose additional safeguards, for auctioned services. For example, in some situations some or all of the potential bidders may be dominant service providers who are endeavouring to strengthen their monopoly or oligopoly (limited number of competitors) positions. Restrictions on eligibility to participate in an auction or limits on the amount of spectrum that any entity may win can alleviate this problem, although this may limit the number of participants.

Finally, auctions may be inefficient or impractical for certain services or situations. One case is where there is no competition for spectrum. This could occur, for example, with fixed microwave systems where there are many individual links with narrow beamwidths and very exact locations. A second case is where, providers of socially desirable spectrum-using services such as national defence or scientific research may have difficulties in placing a financial value on spectrum which could lead to those services being under-provided to society if all providers of spectrum-using services faced auctions. While ideally these services could be funded to allow participation in spectrum auctions, the prospect of this happening in any country in the near future appears to be remote. Finally, if auctions to license global or regional satellite systems were held in multiple countries, it is likely that potential service providers would have to expend significant resources simply to participate in each auction, and such a cumbersome process could lead to delays in implementing new and innovative services. In addition, sequential auctions would create significant uncertainty for potential service providers because such providers would be unsure that they would win auctions in all countries in which they wish to provide service. If this uncertainty were sufficiently severe, it could impede the provision and the development of international satellite systems under current ITU Radio Regulations.

2.3.4 Licence fees

Licence fees represent another way which can be used to achieve some of the spectrum manager's goals and objectives.

Revenues may be generated and at least some of the resource rent that may exist for use of a particular frequency band in a particular area may be captured by establishing licence fees. (In some administrations fees may cover concessions, authorizations or permissions.) Further, a simple fee structure, such as charging for the direct cost of processing licence applications or charging for the amount of spectrum used, may receive public support because it appears equitable. In addition to auctions, licence fees can also encourage radiocommunications users to make an economically rational choice regarding spectrum use.

Licence fees range in complexity from a simple table by service, to a charge per frequency per station for each service, to complex formulas involving a number of variables. Most countries do not charge government entities for spectrum use, and many also do not charge for other public interest uses, such as by non-profit organizations; however, Australia, Canada, and the United Kingdom, among other countries, do charge government entities.

Licence fees can be efficiently implemented using the following principles:

– Decisions and changes related to fee collection should be undertaken in an open manner through consultation with users and industry.
– Fees should take into consideration, to the maximum extent possible, the value of the spectrum.
– Fee mechanisms should be easy to understand and implement.
– Fees should not be an impediment to innovation and use of new radio technologies, or to competition.
– Fees should support the attainment of the spectrum manager's national goals and objectives.

The basic types of fees are those based on the spectrum management costs for processing licence applications, revenues derived from licensees' use of the frequency spectrum, and incentive fee formulas. Spectrum management fees are based on direct costs incurred by spectrum managers in processing applications, and may also reflect indirect spectrum management costs; i.e., overhead costs. In order for national spectrum management to be conducted, resources are needed to cover the full range of spectrum management functions (see Chapter 1). As stated in § 2.2.1.2, fees may be a source or the source of this funding. With this intent, fees can be linked to specific spectrum management activity, the overall annual funding requirement or to other spectrum management objectives. These fees can be charged for the initial application and for application renewals. Fees can also be charged annually in order to maintain the spectrum management activity since spectrum users continue to benefit from the activity of the national spectrum manager through monitoring, database maintenance, ITU representation, etc. even after their applications have been approved. Individual licensees are generally grouped into licence categories for the purpose of setting fees. Revenue-based fees are proportional to the gross income the licensees generate from use of the spectrum. Incentive fee formulas take into account the value of the spectrum.

Another option is to charge fees based on the "opportunity cost" of spectrum use. In an auction, the bidder with the highest willingness to pay will 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 best alternative use, or opportunity cost, of the auctioned item. Therefore, in a situation in which the spectrum management authority must set spectrum fees administratively, an economically efficient distribution can be ensured if the fee is set equal to this opportunity cost/market value. However, to calculate the opportunity cost accurately, a market must be simulated to determine spectrum users' willingness to pay. To do this with absolute precision is extremely difficult, nonetheless an approximation can be obtained which may make this a practical option.

It should also be noted that in some instances administrations may charge fees on the basis of individual equipment or frequencies, while in other cases a single fee for the use of a block of frequencies will be charged. The latter approach may provide improvements in administrative efficiency.

2.3.4.1 Fees based on spectrum management costs

Fees based on spectrum management costs depend on two separate elements: the range of spectrum management authority's functions included in the overall costs and the method used to determine the fees for an individual licensee. A spectrum management authority's costs can be broadly divided into two areas: direct and indirect costs. The specific spectrum management functions associated with each category may vary according to the administration.

2.3.4.1.1 Direct costs

The immediate and identifiable cost of issuing licences for specific applications. For example, they include: the cost of staff time in the frequency assignment process, site clearance, interference analysis when it can be directly associated with a particular class of service – keeping the public news and entertainment channels clear, ITU and regional international consultation that is specific to an identifiable group of users. In some frequency bands and for some services, or if the equipment is located near neighbouring countries, the direct costs will include the cost of relevant international consultation.

2.3.4.1.2 Indirect costs

The cost of the spectrum management functions (see Note 1) used to support the administration's frequency assignment process and the overhead of operating the administration's spectrum management procedures. They represent costs that cannot be identified as attributable to specific services or licensees such as general international consultation, for example with the ITU and regional groups, propagation research covering many frequency bands and services, general spectrum monitoring, interference investigations arising from the complaints of rightful users and the cost of support staff and equipment.

In some administrations the definition of direct costs is very restrictive and is limited to the costs incurred for each individual licence applicant. Some administrations may not make any charge for indirect costs.

The methods used to determine fees from spectrum management costs range from the simplistic method of dividing the total costs by the number of licensees to the more complex "cost recovery". Cost recovery is used to apportion the costs of spectrum management functions to the licensee according to the costs incurred in issuing the licence and the associated frequency assignment process (for example: frequency assignment, site clearance, coordination) including any other necessary spectrum management functions. The licence fees are usually structured on the principle of recovering the costs directly and indirectly attributable to a specific licence category. In some countries the accounts are audited, by a national auditor, to ensure the costs, on which the licence fees are based, are appropriate and justifiable.

The exact definition and operation of "cost recovery" varies according to national spectrum management, legislative and constitutional requirements. These requirements may have an impact on the implementation of cost recovery in each country and affect how the costs and fees are justified. There are several reasons for these differences:

a) In some countries a distinction is made between the administration's total income matching or simply approximating its costs. In the former case the administration is not permitted to subsidize or overcharge the licensee, with any excess having to be repaid. In the latter case it is recognized that fees are based on an estimate of the expected costs, and therefore the income may exceed or not reach the administration's actual costs. Note: in those countries operating the latter system, strict audit control may still be applied.

b) The fees set for cost recovery may be based on the work performed on an individual licence or the average for that licence category.

c) The complexity of the frequency assignment process and the number of spectrum management functions that need to be performed to issue a licence may vary due to:

   – national characteristics – for example the number of users, geographic features requiring the use of a detailed topographic database;

   – international requirements – for example bilateral or multilateral treaties, footnotes in the Radio Regulations.

d) How the costs of the individual spectrum management functions are attributed to a particular licence category may be different due to:

   – the government's interpretation of whether the cost should be the responsibility of the licensee, should attract a fixed fee or should be the responsibility of the State (paid from the national budget) – for example, some administrations consider monitoring is the responsibility of the state;

   – their allocation between direct and indirect costs.

All of these factors will affect the composition of the licence fee and the mechanisms an administration puts in place to monitor its income and costs.

NOTE 1 – There are activities associated with the management of the spectrum that some administrations consider to be separate from their licensing costs. These activities typically relate to approval processes not directly related to frequency assignment. In these cases the administrations tend to make a separate charge and this is usually based on a simple fee that does not recover the cost of the function. These miscellaneous spectrum management fees may include a type approval, test laboratory accreditation, EMC fees and charges, installation inspection, examination certificates (radio amateurs, maritime examinations, etc.).

2.3.4.2 Fees based on users' gross income

A fee can be charged based on a percentage of the gross income of a company. The value of the gross income used in the fee calculation must be directly related to the company's use of the spectrum to avoid difficulty in the accounting and auditing processes.

2.3.4.3 Incentive fees

An incentive fee attempts to use price to achieve spectrum management objectives and hence to provide some incentive to use the spectrum efficiently. Various elements of spectrum usage may be taken into consideration in the development of an approach or a formula (e.g. population density, bandwidth, frequency band, coverage area, exclusivity, power) and different formulae may be required for different frequency bands and services. Developing an incentive fee formula may not be a simple task if it is to accurately reflect the variation in spectrum usage across a country. Incentive fees may not be suitable for all services.

2.3.4.4 Opportunity cost fees

An opportunity cost fee tries to simulate the market value of the spectrum. This process may require financial analysis, estimations of demand or market studies to achieve a valuation, and considerable expertise.

2.3.4.5 Fee calculation examples

Fees based on spectrum management costs may be represented by the general functional forms:

$$F = Di \quad (1)$$

$$F = f(Di, LiI) \quad (2)$$

where:

F: fee charged to licensee

Di: direct administrative costs of processing licensee's application

Li: licensee's proportion of indirect administrative costs

I: total indirect administrative costs.

Fees based on user revenues may be represented by the general functional form:

$$F = f(a, G) \quad (3)$$

where:

F: fee charged to user

a: proportionate fee established by regulatory agency

G: user gross income

Incentive fee formulas may be represented by the general functional form:

$$F = f(B, C, S, E, F_R, F_C) \quad (4)$$

where:

F: fee charged to licensee

B: bandwidth

C: coverage area

S: site location

E: exclusivity of use

F_R: frequency

F_C: administration's financial coefficient

Opportunity cost fee formulas may also be used. Such fee formulas will resemble incentive fee formulas. However, in this case the administration's financial coefficient (F_C) will be set so as to make the fee approximate the market value of the spectrum.

A number of the above formulas and those presented in other ITU documents contain an arbitrary factor which is set by the administration. Use of this arbitrary factor means the resultant fee is itself an arbitrary value. A number of countries have implemented or are considering the implementation of fee models based on the various general functional forms described above. In countries developing incentive fee or opportunity cost fee models, it has been recognized that this is a complex and difficult undertaking and some administrations are holding public consultations prior to implementation.

2.3.5 Advantages and disadvantages of fee approaches

In terms of their effect on economic efficiency, spectrum fees are an improvement on awarding licences at no charge, provided that fees are not set higher than the market value. If they are set higher, spectrum will not be fully utilized. In fact, if fees are set above the willingness to pay of all potential users, spectrum will go unused and generate no benefits to society. On the other hand, if fees are set lower than the market value, economic efficiency will be improved even though excess demand will remain for the spectrum, and revenues to the spectrum management authority will be below the market valuation. Detrimental consequences of setting fees too low are that spectrum potentially could be used wastefully and that spectrum congestion may increase.

For example, assume that there is a service provider who uses two blocks of spectrum and pays a below-market value fee of $100 per block, or $200 in total. Assume also that by purchasing more spectrally efficient equipment for $150, the same service could be provided using only one spectrum block. The rational service provider will see that the second alternative has a higher total cost of $250 ($150 for the new equipment and $100 for the single spectrum block) and thus will not choose it. If, however, the true market value of the spectrum of, say, $175 per block is now charged, then the service provider will choose to buy the new equipment and keep one spectrum block for a total cost of $325, as opposed to a total cost of $350 for keeping the old equipment and both spectrum blocks. Now that this spectrum block has been released, another party can use it, meaning that the public is now receiving the benefits of two services via the same amount of spectrum that used to provide only one service.

A similar problem created by fees that are below market value is the potential for services to wastefully use spectrum. For example, some services, such as the delivery of television programming, can be provided by either wired or wireless means. Other services, such as mobile telephony, can be provided only via the radio spectrum. When all resources (spectrum, fibre-optic cable, copper wire, etc.) are priced at market rates, service providers will choose the combination of these inputs that is consistent with an economically efficient distribution. However, if spectrum is priced at a level below its market value, then service providers (such as the distributors of television programming) who have the option of using either wired or wireless infrastructure in their activities will be inclined to use more spectrum and less of the various available spectrum alternatives. The greater amount of spectrum used by television results in less being available for other services, such as mobile telephony, meaning that the total number of services available to the public has decreased – obviously, an inefficient outcome.

Formulae can be useful in setting licence fees, but must be tailored to the individual circumstances of the country. Development of formulae requires considerable effort on the part of the administration and spectrum users. In order to operate correctly, a formula must be designed to achieve a specific purpose within an explicit set of operational conditions. These conditions depend on particular aspects of the country including its geographical structure (e.g. terrain, size, latitude), its radiocommunications infrastructure, the potential demand for services, and the degree of coordination required with neighbours. Hence the applicability of any formulae, other than the most basic, is often limited to a specific administration, a particular service and even a limited number of frequency bands. Existing formula can be reused, but will invariably require modification. This process requires an understanding of the purpose and conditions behind the formula's original development as well as the details of its proposed implementation.

2.3.5.1 Fees based on spectrum management costs

This approach has the advantages of raising revenues for the spectrum management authority and ensuring that licensees will pay at least some nominal amount for their spectrum use, while eliminating those would-be licensees who place insufficient value on their use to pay even those nominal fees. However, a major disadvantage of this approach is that there is a disconnection between the level of the fee and the value of the spectrum used. For example, one licensee may use a spectrum band in a relatively unpopulated area and pay the same fee as a second user who uses the identical band in a heavily populated area, even though the latter band has far greater value. Because of this disconnection between fees and spectrum value, such fees do little to promote the efficient use of the spectrum. In some areas and frequency bands in which the spectrum has little value, fees can inhibit any use of the spectrum, producing an inefficient outcome. More typically, however, cost based fees are far less than the value of the spectrum, and therefore promote efficient use of the spectrum to only a minimal extent. Low fees can be a particular problem in countries that have a high inflation rate because fees generally are updated only every few years, and therefore may lag well behind the general price level. However, this problem can be alleviated if the political authority conveys to spectrum managers the ability to update fees as often as needed to reflect general price trends in the economy.

2.3.5.2 Fees based on users' gross income

Establishing a fee based on a certain percentage of gross income related to spectrum use can generate significant revenues for the spectrum management authority for certain services. For example, a television broadcaster with annual revenues of $500 million would pay an annual fee of $500 000 if the fee were just 0.1% of revenues. Further, this type of fee generates more revenue for the spectrum management authority as the licensee's gross income increases, which could be viewed as both efficient and equitable. However, there are three major problems with this type of fee.

First, it can apply only to users having a gross income directly linked to spectrum use and not to those users whose gross income results only indirectly from spectrum exploitation – as determining gross income may be difficult due to the complexity of company accounting and in addition determining how much of a users gross income is directly linked to spectrum use is virtually impossible, e.g., how much of a public utilities or telephone companies' gross income can be attributed to their use of microwave links in portions of their fixed network.

Second, such a fee does not necessarily promote efficient spectrum use or equitable treatment of licensees because a user's gross income is not directly related to the value of the spectrum. For example, two broadcasters may have an identical gross incomes, but one may be reaping substantial profits, while the second may be reaping no such profits, and indeed may even be operating at a loss.

Third, it may suppress spectrum usage, reduce the growth in services, impair innovation and spectrum efficiency, and have an adverse effect on international competitiveness.

2.3.5.3 Incentive fee formulas

Incentive fee formulas have the advantage of representing to some extent the scarcity and differential rents of the spectrum. By taking into account factors such as population, area, bandwidth used, and the frequency band such formulas may approximate the market value. However, the disadvantage of such fees is that no formula, however complex, can take into account all the variations of the market-place. This requires that considerable care is exercised in setting licence fees in order to avoid a large discrepancy between the fee and the market value. For this reason an incentive fee formula may need to be linked to a market valuation in order to be used effectively.

For some services, technical factors preclude a reduction in bandwidth and therefore incentive fees based on bandwidth would be inappropriate; for example, radar services.

2.3.5.4 Opportunity cost fee formulas

Opportunity cost fee formulas have the advantage of being directly targeted at the desirable goal of simulating the market value, – thus encouraging consideration of alternative means of communication and the return, by existing users, of surplus spectrum. However, just as it is extremely difficult to establish an incentive fee formula that accounts for all relevant variables that influence the price of spectrum in a particular location, so too it is extremely difficult to accurately simulate an auction and the effort required to complete the analysis may exceed the costs of an auction. Such a simulation depends upon evaluating individual consumer decisions and somehow integrating this information into a usable model. Financial studies or extrapolations based on prior secondary market transactions may be useful to some extent, but simulating the market will always remain very much an imperfect exercise, e.g., the three US broadband PCS auctions produced results strikingly different than what had been forecast by almost all analysts. Nonetheless, such methods may have advantages over cost-based alternatives in terms of managing the spectrum to balance supply and demand and maximizing economic welfare where an auction is impracticable or illegal.

2.4 Factors that could affect various economic approaches

There are a number of factors which could affect both the need and the ability of different administrations to implement the economic approaches to spectrum management discussed above. Various legal, socio-economic, and technical infrastructure considerations will all have an impact with respect to spectrum auctions, transferable property rights, and licence fee regimes.

2.4.1 Auctions

2.4.1.1 Applicability of auctions

As discussed previously, there are several 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, licence conditions, standards, etc.) which are fully compatible with spectrum auctioning, but 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. On a related note, administrations could choose to restrict spectrum supply, which would generally 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.

While it may seem obvious, it is also worth noting that auctions by definition 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 speaking, the higher the level of economic and communications infrastructure development, the more favourable 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 licence, etc.) as well as the accompanying responsibilities (licence conditions, service restrictions, 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 licence 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. They will also wish to be assured that the government will enforce this interference protection regime.

The quality of an administration's licence/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.

2.4.1.2 Pre-auction requirements

It is desirable that all the rights and responsibilities accompanying the spectrum to be auctioned are 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 licence 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 growing body of literature on this subject and to review the experiences of spectrum auction "pioneers" such as New Zealand, the United States of America, and Australia, to learn both from their successes and from some of 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, certain 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".

2.4.1.3 Competition policy

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

2.4.2 Transferable property rights

As with spectrum auctioning, the legal framework which underlies the ability of markets to function effectively, the clear specification by spectrum managers of rules and policies, and the legal and policy stance with respect to competition are all critical to how well a transferable spectrum property rights regime will work.

An administration considering the implementation of such a regime will wish to ensure that it has the wherewithal to continue to enforce applicable licence conditions, standards, and regulations once spectrum has been transferred from an original licensee to another party. The ability of an administration to maintain an accurate licence/licensee database is important in this regard, so a certain degree of administrative and/or technical infrastructure would appear necessary for a transferable property rights regime to be successfully implemented. This need is amplified if the administration intends to allow licensees to transfer their licences not only in whole, but also in part, that is to say, to allow licence divisibility.

2.4.3 Licence fees

The applicability of various licence fee regimes may vary among different countries. Countries with more developed economies and communications infrastructures may, for example, be more inclined to pursue such goals as:

– ensuring that the total payments made by spectrum users, through fees and/or auction proceeds, are greater than or equal to the total costs of spectrum management so as to avoid the subsidization of spectrum users from the general treasury;
– having fees approximate the market value of the spectrum resource to promote efficient use; and/or,
– capturing any economic rents that the spectrum resource may generate.

Countries with less developed economies may choose to pursue these same goals, or alternatively they might see fit to implicitly subsidize spectrum users through low licence fees if they feel that this will further other policy objectives.

With reference to the different types of licence fee regimes discussed previously, incentive and/or opportunity cost-based fees have certain requirements for successful implementation. These types of fees are generally based on notions such as "spectrum consumed" or "the economic value of spectrum", which are not always easy to practically define or estimate. Reliable automated licence/licensee databases and other informatics tools such as geographic information software may be necessary to perform the calculations imbedded in the fee model. Administrations wishing to reflect market values in their licence fees will need to consider to what extent the licences they grant resemble "market properties". Any attempt to extract fees which in actuality are beyond the value of the associated spectrum may have negative economic consequences such as stifling investment, limiting service penetration, or raising consumer prices.

Finally, in countries that have not previously charged fees, it is essential that spectrum managers have the legal authority in their communications law to charge for spectrum use.

2.5 Managing a change in spectrum management funding

Use of radio has been identified as providing a number of benefits (see Chapter 3). Whether the level of economic benefits from the use of radio grows or diminishes depends on the spectrum being used efficiently and managed effectively. As implementation of spectrum pricing, or spectrum rights, can have a significant impact on spectrum management processes it is advisable that change should be managed due to the potential implications for the economy, the licensing process, industry and radio users.

The issues that a spectrum management authority needs to consider related to these changes are likely to vary from administration to administration and the precise spectrum pricing procedure will differ, but they can be grouped into a small number of categories.

2.5.1 Legal

Whether or not an administration needs to develop new legislation to introduce spectrum pricing, it is essential that the administration ensures that its existing legislation is effective. If the administration plans to introduce auctions, transferable spectrum rights, or a secondary market, it is also essential that the administration has appropriate competition legislation in place. If effective competition legislation and any organizations required to implement it have not been created prior to the launch of spectrum pricing, this could inhibit its operation.

2.5.2 International obligations

Where an administration introduces spectrum pricing and particularly transferable spectrum rights, it is important that it should retain responsibility for the country's international obligations. However, the administration may need to consider establishing a mechanism for representing the users' views in the relevant international fora, especially if the user is permitted to take on any of the management responsibilities for their spectrum that normally may be associated with the administration (see Chapter 4). In most countries these mechanisms may already exist, whether they would need modification to reflect different levels of spectrum management responsibility between users may depend on the national spectrum management process structure and organization.

2.5.3 Formula development

Pricing requires the development of formulae to operate effectively. In developing these formulae it is advisable that the administration should consult the radio industry on the appropriate technical parameters and definition of the criteria to be used; for example, highly congested geographic areas and frequency bands. The spectrum pricing formulae need to be fair, objective, transparent and simple. Simplicity is important, otherwise there could be difficulty in operating and maintaining the formulae. Consultation can also help to ensure the parameters are appropriate for the service and any disputes on the definition of areas of high usage are resolved. The consultation process is also important for users as it provides transparency to the development of the spectrum pricing procedures.

If the introduction of spectrum pricing requires the development of new software, this may need to be tested and staff trained in its use. This is particularly important if the administration has previously never charged for a spectrum licence. The setting of the fee level is critical to the operation of spectrum pricing and it is necessary to have a suitable differentiation, in terms of the fee value, between areas with high and low levels of spectrum usage.

2.5.4 Funding implications

Administrations that have previously operated a "cost-recovery" system, or been dependent on fees for funding their spectrum management operations, need to consider the implications for their overall income arising from a change in spectrum management funding mechanisms, such as:

– auctions may be held only periodically, since at certain times there may not be suitable spectrum to be auctioned;

– incentive pricing is intended to relieve congestion, not to increase the levels of the administration's funding.

In the short term funding levels may increase, but as the spectrum pricing mechanisms take effect the levels of funding may fluctuate with time and adjustments to the level of supply and demand.

2.6 Summary

In view of increasing worldwide demand for radio services, economic approaches to national spectrum management are becoming essential. These approaches promote economic, technical, and administrative efficiency, and can also help fund national spectrum management programmes that can ensure that radio services are able to operate on a non-interference basis. While a free market in spectrum does not appear feasible due to technical, economic, and social considerations; auctions, transferable and flexible spectrum rights, and well-designed fees can enable a number of the benefits of a market approach to be realized. Auctions appear best-designed to promote efficient use of spectrum when there are competing applicants for the same frequency assignment, and transferable and flexible spectrum rights ensure that an assignment will continue to be used efficiently after the auction has taken place. However, auctions may not be appropriate for services in which there is limited competition for spectrum assignments, for socially desirable services such as national defence, and for international services such as satellite services. For some of these services, fees may be appropriate. Fees can promote efficient use of the spectrum provided that they incorporate the correct economic incentives and are not set so low as to be negligible in the eyes of spectrum users or so high as to exceed what a market would set, in which case spectrum will sit idle and generate no benefits.

Through spectrum pricing national spectrum managers can develop a variety of economic tools to promote more efficient spectrum use. If properly applied, these tools can help encourage investment in radio services, leading to growth of the telecommunications sector and benefiting the entire economy.

CHAPTER 3

ASSESSMENT OF THE BENEFITS OF USING THE RADIO SPECTRUM

3.1 Background

Effective management of the radio spectrum is required to ensure spectrum access for new services (see Note 1) and technologies, growth in existing services and avoidance of interference between users. Funding for this task will be dependent on the competing claims of all government activities. The extent of radio usage within a country will influence the particular functions performed by the spectrum management authority. As radio usage increases, so does the requirement for spectrum management. Assessment of the economic benefits (see Note 2) arising from the use of the radio spectrum are useful in making spectrum planning decisions. If quantification of these benefits is required for spectrum planning and strategic development then suitable methodologies must be identified. This Chapter, which is based on a report from the UK, provides a comparison of two methods to quantify the economic benefits and examines the factors that may affect this value.

NOTE 1 – In this Report the use of the word "service" with a non-capitalized "s" means an end-user service (e.g. cellular radio) and not a Radiocommunication Service.

NOTE 2 – Here the term benefits is not used in its standard economic sense.

3.2 Methods of assessing the spectrum's economic benefits

Economic benefits are generally recognized to accrue from the expansion of manufacturing capability, or the creation of new radio industries and services. They also arise from the impact radio services have on generating improvements in the performance of a business. These improvements may include: increased productivity, increased exports, reduced operating costs and increased employment. Improvements in the performance of a business are not only found where radio forms part of the core business (e.g. a telecommunications service provider, radio equipment manufacturer), but also where it is used as a way to support the core business (e.g. a water supply company using telemetry and telecommand to remote reservoirs, a taxi company using mobile radio to pass passenger details to taxis).

Two methods used for quantifying economic benefits have been identified in the Report "The Economic impact of the Use of Radio in the UK"[1] published in 1995. The methods calculate the contribution of radio use to the economy using:

– gross domestic product (GDP) and employment;
– consumer and producer surplus.

These methods may be used to estimate the economic benefits arising from the provision of a single end-user service, or each service's economic benefits can be added together to provide the total economic benefits arising from radio in a country. Both methods and their relative merits are presented in the following sections. Although in this Report measurement of employment is linked

[1] Produced by National Economic Research Associates (NERA) and Smith System Engineering Limited in 1995, commissioned by the Radiocommunications Agency (RA) and the Office of Telecommunications (Oftel).

to the measurement of GDP, it is really a complementary measurement that could be equally applied to the measurement of consumer surplus.

3.2.1 GDP and employment

The use of the GDP method to estimate the economic benefits is based on the contribution radio makes to all business activity within a country. The contribution to GDP will be equal to the product of the price of a good or service, and the number that are sold. The expenditure of the resulting wages and profits provides a further increase (multiplier effects, see § 2.1.1) in both GDP and employment which can be added to these figures.

In practice GDP and employment contributions may enter the economy at a number of different points that are determined by the operation of the particular service. Typically for a service which is sold to an end user (e.g. broadcasting), contributions will occur in:

– the business providing the radio service (company A). This contribution to the economy is known as the direct effect of the use of radio. When the whole of the business of "company A" is based on the radio service (e.g. broadcasting), determining the required information is relatively straightforward. When the radio service provides only part of the business (e.g. private mobile radio (PMR)) it can be more difficult;
– businesses manufacturing equipment purchased by "company A", or supplying other services (e.g. cleaning services, recruitment services, information technology support, market research) in support of "company A's" operations, these indirect contributions to the economy are called backward linkages;
– businesses manufacturing equipment for users of "company A's" service, or distributing and retailing "company A's" services, these indirect contributions to the economy are called forward linkages. These services need not be related to radio, e.g. airlines use aeronautical mobile but their services that are retailed relate to passenger and freight traffic.

In the case of a radio service provided by the end user, as in PMR, the direct effect and backward linkage would be the same. However, there is no forward linkage because the contributing elements are incorporated within the direct effect.

The contribution to GDP and employment from the service or services will be equal to the sum of the direct effect, the forward and backward linkages. This value will depend on the amount of capital equipment and materials originating within, and the level of profits retained in, a country. In practice all countries will import some of the capital equipment and materials used and this will reduce the GDP contribution. However, even in the worst-case scenario where all capital equipment and materials are imported (unlikely because of the impracticalities of importing all raw materials and the increase in overhead costs) there will still be a positive contribution to GDP and employment through salaries, supplies to users of the equipment, distribution and retailing.

3.2.1.1 Factors modifying the combined GDP and employment values

In all cases, the combined GDP and employment figures resulting from radio's contribution towards the economy has to be revised downwards because of the impact of "displacement effects". These are based on the principle there will always be an alternative to the existing use, e.g. if aircraft did not exist, then the shipping and railway industries would expand. These effects equate to the following scenarios:

– radio may be a substitute for another non-radio service, e.g. cable;
– if radio did not exist the resources used in its development would be employed in other parts of the economy.

Allowance can be made in the calculations for the impact of relative changes in GDP and employment arising from a substitute service. However, the latter case for the wider economic displacement is more of a problem. Although the theory that all resources are completely mobile has some validity, there are disagreements on the limitations to this theory and validation is hampered by a lack of substantive information.

Once the GDP and employment figures have been adjusted to take into account the displacement effects, the impact of "multiplier effects" can be considered. Multiplier effects arise from the impact of wages and profits, generated in all businesses associated with the use of radio, as they spread through the rest of a country's economy and in the process create further income and employment. They are a function of a country's economic structure and may be different values for assessment of GDP and employment. In the United Kingdom, the Report "The Economic impact of the Use of Radio in the UK" estimated that the "multiplier effect" allowing for imports was approximately 1.4 times for income and slightly more for employment.

Hence the total contribution to GDP and employment for a service = $(DE + FL + BL - DPE) \times MPE$.

Where: DE = direct effect; FL = forward linkage; BL = backward linkage; DPE = displacement effects; MPE = multiplier effects.

The total economic benefits arising from radio in a country would be equal to the summation of all of the total contributions arising from each service.

3.2.2 Consumer and producer surplus

Consumer surplus is a measure of the difference between what a customer is willing to pay and the actual price of the product. To determine the consumer surplus for a service it is necessary to estimate its demand curve – a plot of the item price (y-axis) against the quantity sold (x-axis). The consumer surplus is then equal to the area between a horizontal line at the item price from zero to the quantity purchased and the demand curve. To estimate the demand curve it is important to have historical information on the service that covers several years. This information is not always available. If the service is new then there will be no historical information. Without sufficient data it is extremely difficult to estimate the demand curve and if the demand curve cannot be estimated then the consumer surplus cannot be calculated.

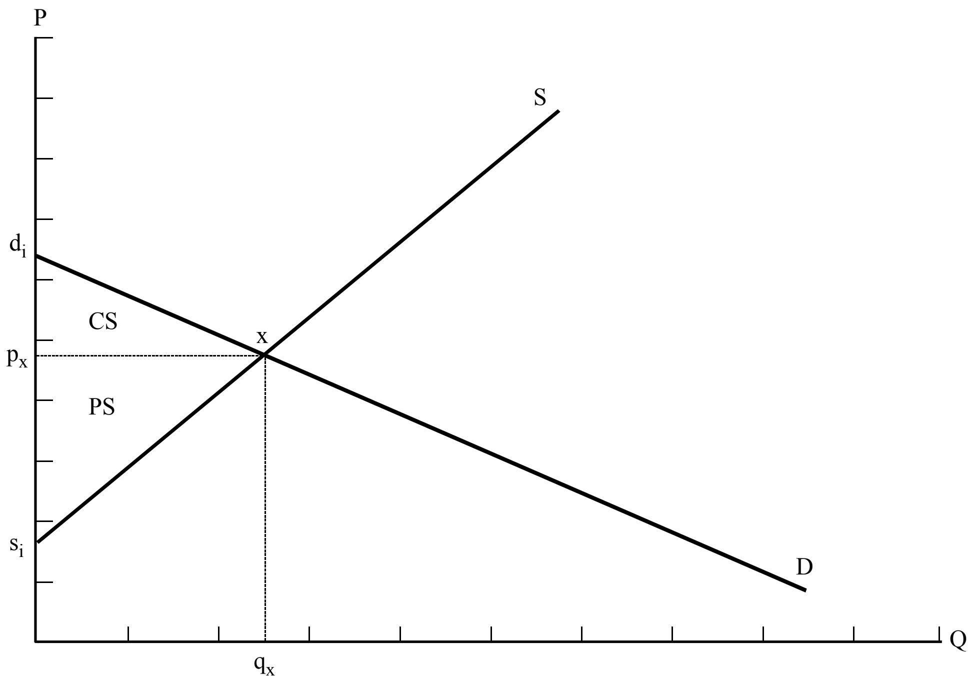
Producer surplus is the difference between what a producer actually earns and the amount it needs to earn to continue in business. To determine the correct value of producer surplus, the performance of the business needs to be monitored over a substantial part of its lifetime. In practice this is difficult to achieve as it requires consistent historical data for established businesses and accurate estimates of future performance for new businesses.

The total surplus arising from the use of radio would be equal to the summation of the consumer and producer surplus for each service.

Consumer and producer surplus are presented graphically in the Fig. 1. The price of the item (p_x) and the quantity (q_x) of the item sold at price p_x are shown on their respective axes. Consumer surplus (CS) is shown as the area between the demand curve and the price level (triangle p_x-x-d_i). Producer surplus (PS) is shown as the area between the supply curve and the price level (triangle p_x-x-s_i).

FIGURE 1

Consumer and producer surplus



P: price axis
Q: quantity axis
D: demand curve
S: supply curve
d_i: demand curve intercept
s_i: supply curve intercept
x: point of intersection between supply curve and demand curve
p_x: price of item
q_x: quantity sold at price p_x
CS: consumer surplus (triangle p_x-x-d_i)
PS: producer surplus (triangle p_x-x-s_i)

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3.2.3 The link between economic and social benefits

Some uses of the radio spectrum generate economic benefits but do not directly generate revenues. The economic benefits that the use of spectrum generates in such activities however, are not readily apparent. No clear or easily measurable financial values generally exist to directly quantify the magnitude of these benefits. Hence it may be assumed that economic analysis cannot account for these social benefits and can only account for such factors as the revenues and profits received by firms. This is not the case. A proper economic analysis considers benefits that do not directly generate revenues.

Examples of services providing social benefits include:

– broadcasting – providing education, training, news and recreation;
– emergency services – providing a link to the police, accident and rescue services including disaster control facilities;
– personal services – home health care/nursing, home security for the elderly;
– research – meteorology, radio astronomy.

3.2.4 Comparison of the methods for quantifying economic benefits

Both methods produce an estimate of the contribution of radio to the economy of a country, but are based on different assumptions for treatment of the wider economic displacement. GDP and employment do not take account of the wider economic displacement. Consumer and producer surplus take full account of wider economic displacement. In addition, the two methods measure different aspects of the impact of radio usage on the economy of a country. GDP measures what has been paid and consumer surplus measures what consumers would be willing to pay. Both methods include producer surplus. Accordingly, the results cannot be added together.

Although both methods can be used, and are used in the United Kingdom, for showing the spectrum's overall value to a country, it may be appropriate to select a method based on the application. GDP is better for assessing the value of multiple uses of radio within a country, or for comparison between individual uses/services, whereas consumer surplus provides more detailed information that may be used, for example, in determining licence fees or reserve auction prices. Comparison of the methods usually centres on the theoretical validity of the arguments and assumptions on which the particular methodology is based. However, it may be more realistic to review the methods based on the difficulty in obtaining data for analysis and the ease of comparison of the results with other economic data.

3.2.4.1 Advantages and disadvantages of the GDP method

The advantage of the GDP method is that it shows the collective impact of those involved in the radio using sector and provision of intermediate goods to that sector (e.g. in the United Kingdom[2] it equates to approximately 2% of GDP or £13 000m and 410 000 jobs). The information required for the calculations is available in companies' financial reports and is easy to understand and compare with other areas of the economy which are represented in the same form. This enables funding (or investment) decisions to be compared using the same measures.

The disadvantage of the GDP method is that it does not take proper account of the wider displacement effects and these may be considerable in a diverse and flexible economy. In the extreme, if all displacement effects are taken into consideration, the net benefit of the use of radio to the economy would simply equal the improvement in efficiency that radio provides. However, this approach assumes that the resources currently provided for radio can be easily diverted into other areas of the economy. This is not necessarily correct. Furthermore, the estimated contribution in GDP and employment may not include consequential improvements in associated businesses arising from improvements in their efficiency (e.g. cellular telephone users' improved access to their business and clients) and may therefore lead to a more conservative estimate of GDP. The extent to which this occurs will be dependent on the relationship between the use of radio and the original business (e.g. is it a manufacturer of radio equipment, a service provider, a business using radio) and the type of service (e.g. broadcasting, fixed links, PMR).

3.2.4.2 Advantages and disadvantages of consumer and producer surplus method

The advantage of the consumer and producer surplus method is that it accounts for the impact of the wider displacement effects, indicating the benefits of providing a service by radio against the best non-radio alternative to be shown. In addition, the demand and supply curves can be useful for displaying the costs and benefits of a particular use of radio.

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[2] From "A study to evaluate the economic impact of the use of radio in the UK" by NERA/Smith System Engineering Limited in 1997, commissioned by the Radiocommunications Agency (RA) – estimates based on the 1995/1996 Financial Year.

The disadvantage of the consumer and producer surplus method is that the demand curve can be difficult and time consuming to determine. A separate demand curve has to be produced for each service studied and this can be onerous if the aim is to measure the consumer and producer surplus for all radio services across the entire economy. If the demand curve cannot be produced, then alternative methods based on different assumptions have to be used and these may distort the results. Finally, consumer surplus is not easily comparable with GDP.

3.3 Potential uses for economic assessment

In recent years changes in radiocommunications technology together with the increasing tendency for shorter development cycles, have increased the pressure on spectrum managers for quicker decisions on who and which technology should have access to the spectrum. In addition to these changes in radiocommunications technology, further pressure has been added by the liberalization of telecommunications which has resulted in a growing demand for radio spectrum access. The increasing demand for spectrum access, combined with spectrum managers' difficulty in predicting which of several competing technologies and uses, will be successful and should therefore have access to the spectrum, is making the spectrum management process increasingly complex and time consuming. This can discourage investment, which can be especially detrimental when delays in providing spectrum access can make the difference between the success or failure of a new service. In addition, as demand has increased, the recurring spectrum management issues of achieving efficient spectral use and finding spectrum for the new services needed by society are becoming increasingly difficult to resolve for a number of countries. At the same time, governments' awareness of the overall burden of rising public spending on the economy has tightened control on funding for all government activities.

Management of the radio spectrum has traditionally been based on regulation of this finite resource. However, due to the pressures on spectrum management and particularly where difficulty in providing sufficient spectrum is limiting or distorting competition, or where it is inhibiting development of the radio spectrum resource, several administrations have moved away from a strict regulatory approach and are either using, or are considering using, economic factors as part of their approach to spectrum management.

3.3.1 Applications for funding spectrum management activities

Assessment of the economic benefits arising from the use of radio enables spectrum managers to demonstrate to the government that radiocommunications is not a self-contained industry, but is interwoven with other areas of a country's economy. Representation in economic form allows radio's contribution to the economy to be put in context with other areas of the economy. It also helps show the connection between spectrum management and radio's benefit to the economy.

3.3.2 National frequency assignment decisions

Knowledge of the economic and social benefits that competing uses and the manner in which they are provided give spectrum managers information, in addition to the standard technical and operational assessments, that could be used to help make assignment decisions and maximize the economic benefits from the utilization of the radio spectrum.

Economic benefits analysis can be used in a number of ways. It can show the impact of delays in introducing a new service, the relative benefits of different types of service, the economic benefits of introducing more spectrally efficient technology and the benefits from reassigning a frequency band to a new service or technology.

Technical and operational factors are obviously essential in any assignment decision, for without efficient use of the spectrum, economic benefits cannot be maximized. For some assignment decisions cultural/social aspects may be another factor. However, economic benefits analysis also has a role to play in determining assignment decisions, as failure to give due weight to economic benefits in spectrum management decisions could impose substantial costs on the economy. For example, it has been estimated that a two-year delay in providing spectrum for personal communications network (PCN) services in the United Kingdom would have cost the economy £410 million GDP or £2.5 billion consumer surplus a year and 7 600 jobs. The main advantage therefore of applying economic benefits analysis to assignment decisions, whether nationally or possibly internationally, is that it provides an analytical tool for optimizing the economic contribution made by radio. At present, perceptions of methodological difficulties may have meant that less emphasis is placed on benefits analysis than is warranted. As this Report shows, techniques are now available to estimate the economic benefits so that they can be taken into account.

3.3.3 Changes in spectrum management national legislation

For most administrations the provision of spectrum management is defined by legislation. This may limit changes in the way spectrum management can be provided, the way licences are issued and the type of support the spectrum management authority can receive from non-government organizations. Providing governments with justification for a change to legislation frequently requires assessment of the cost of implementation and the benefits the users and government will receive.

Economic analysis enables the economic benefits from using radio to be put in context with other areas of the economy and possibly an estimate of the consequential change in economic benefits arising from the proposed change in legislation to be provided. This information can provide governments with more information on the impact of the proposed legislation and the importance of the legislative changes relative to both spectrum management and the wider economy. Hence it can be used in the determination of timescales for introduction of the proposed changes to the legislature.

3.3.4 Support to the spectrum manager on the operation of auctions

Auctions are widely acknowledged to be the best method for determining the value of the spectrum (see Chapter 2 for a full explanation of auctions). However, the success of auctions can be affected by a number of different parameters. These include administrative limitations on auctions, administrative limitations on the operation of the new service or frequency assignment, and technical limitations imposed on the new service or frequency assignment. This last case may include issues of interference from another national or international radio source, coverage area, etc.

Economic analysis can be used to provide an initial assessment of the value of the frequency assignment. This may be used to determine if there will be sufficient competition for the spectrum, to support spectrum managers in their evaluation of bidders business plans, or to provide a reserve price for the auction.

A reserve price is a threshold value placed on a commodity by the owner that if not exceeded during the bidding process prevents the highest bidder winning the auction without the owner’s further consent. The reserve price is usually based on a percentage of the valuation of the item and is provided by either the auction house, or an expert in the field. Reserve prices are commonly used in many forms of auction, especially antiques and art.

3.3.5 Using economic assessment to monitor economic performance over time

Assessment at periodic intervals of the economic benefits from the use of radio can be used to provide information on the economic performance of radio usage over of time. Monitoring this performance provides a better picture of the radio spectrum’s condition than a single assessment and can be used with licensing data to show trends and developments in spectrum use. This information may be linked to spectrum management decisions, (e.g. frequency assignments, changes in licensing conditions, introduction of new services) so that the impact of spectrum management decisions may be evaluated and their application modified as necessary. In this way any detrimental impact on users can be rectified, and ineffective decisions reviewed or revoked.

For example, in the United Kingdom a follow-up study to the 1993/1994 economic Report has shown that radio's contribution to GDP has increased by 11% per annum compared to the 3% for the rest of the economy and employment increased over the two-year period by 1 000 jobs a week. Employment (see Note 1) due to the use of radio has increased by 110 000 to 410 000 an approximate increase of 36%. Although this increase is perhaps exaggerated by an underestimation of the employment figures in the previous study, it compares favourably with an increase of 485 000 for the total economy over the same period. This study of economic performance will in future be repeated bi-annually.

NOTE 1 – Employment due to the use of radio includes industries, or services, which use radio, but in which radio is not the primary product, e.g. taxi companies.

3.4 Factors affecting benefits

This section examines a series of factors affecting the economic benefits that arise from the use of radio. It does not seek to quantify their impact, rather its purpose is to explain how these factors impact the national radiocommunication infrastructure, which in turn affects the value of economic benefits.

The radiocommunications infrastructure is the combination of all existing radio systems operating in a country, the frequency allocations, individual frequency assignments, any necessary coordination agreements and the spare capacity in the spectrum that can be used by the existing radio technology.

The benefits arising from the use of radio increase with the level of investment, increased usage and the introduction of new services and technologies. However the larger the investments and the more heavily developed the spectrum becomes, the less flexibility exists for introducing new services in the same band. Providing a balance between the contradictory requirements of increasing the use of the spectrum and retaining sufficient spectrum to meet future demand is an increasingly difficult problem, particularly in the lower frequency bands, and becomes more difficult as demand for spectrum access increases. The following sections review some of the information that characterizes the infrastructure. It should be noted that they apply equally to the entire country and its regions.

3.4.1 Frequency availability

The ability of administrations to make frequencies available for use is a major factor in determining the economic benefits they can achieve. Availability of specific frequencies or frequency bands may affect the cost of implementing new radio systems, radio system viability and the number of users that can be accommodated. The more users that a frequency can accommodate, within agreed performance limits, the greater the potential economic benefits.

Frequency availability is closely linked with coverage area and required bandwidth. The larger the coverage area the lower the frequency reuse in a given area. The wider the required channel bandwidth, the fewer channels can be fitted into a particular frequency band and the more spectrum denied to other users or uses. Coverage area is determined by many factors, e.g. transmitter power, antenna height, antenna pattern. Reducing the coverage area with improved antenna patterns or site shielding, will increase frequency availability. By reducing the coverage area, the area denied to other users by those transmissions is also reduced.

NOTE 1 – The area denied to other users is normally larger than the coverage area.

3.4.1.1 Suitability

Providing spectrum for a new service is not necessarily a question of finding a vacant block of frequencies. Apart from the variation in cost of equipment between different frequency bands, and the impact of propagation considerations, both of which may determine whether it is economically viable to operate a particular service, there are some services and applications that have a requirement for a particular frequency band. For example: temperature profiling and climatic monitoring have a specific need for the oxygen absorption lines around 60 GHz, whilst international broadcasting needs HF; neither of these services could make use of the other's frequencies. In addition, the frequency band selected for a service may affect the structure of the system, cost of implementation and operation. Selecting the right frequency band will therefore determine the viability and hence the benefits the new service can provide.

3.4.2 Demand

A country's population and industry provide the demand for radio services. The viability of introducing services on a commercial basis (i.e. not State funded) throughout a country will depend on the level of that demand, unless there are specific requirements placed on the service provider (e.g. in the United Kingdom, some broadcasters and telephone service providers are obliged to provide universal coverage for certain services). The level of demand in a country is therefore probably the most important element in determining radio usage and together with the country's geography, determine the shape of the radiocommunications infrastructure.

A large population will normally provide the demand for the introduction of a wide variety of radio services, although it may not guarantee their viability. Although most communications are based on population centres, or areas of employment, that demand can also occur in relatively uninhabited areas e.g. major transport routes are not necessarily in major population centres. However it can normally be assumed that the greatest demand will occur in areas with the greatest population density and/or the highest economic activity. Conversely the lower the population density the lower the level of demand and the less competition the market will be able to support. This may lead to less variety and consequently higher costs for a particular service.

3.4.3 The country's geography

The geography of the country covers a number of separate items that can affect the benefits arising from the use of radio. These include the country's size, its geographic shape, terrain structure, the number of countries within coordination distance and their radiocommunications infrastructure.

Broadly this translates into: countries with many close neighbours are more likely to have to coordinate the majority of their radio systems and may therefore be more likely to fit their radiocommunications infrastructure around that of their neighbours. The more developed the neighbouring countries' infrastructure the greater the difficulty there is likely to be in introducing new services. This may not be a big problem as countries with low population densities generally have smaller populations and hence make less demands on the spectrum. At the other end of the scale large countries have greater freedom to plan services above certain frequency bands without the need to resort to coordination. This freedom is increased if they have few neighbours. Those countries with no neighbours within the coordination distance for a specific frequency benefit from the fact that they have unrestricted access to this frequency everywhere within their borders.

For the purpose of this Report, terrain structure includes mountain regions, dense woodland and desert. When combined with the other elements of the country's geography and the population characteristics the terrain structure helps to determine which frequency bands may be the most appropriate for a particular service.

3.4.3.1 Regional variations and spectrum congestion

A country's geography and demand distribution can combine to provide a variation in the level of frequency availability across a country. The distribution of a country's population equally across a country is extremely unlikely and the population tends to group in a number of population centres of varying sizes. In practice this grouping is beneficial to the provision of radio services; however, there comes a point where the level of demand can be disproportionate to the area in which it arises and this can cause frequency availability problems and eventually spectrum congestion. Spectrum congestion is a major problem for spectrum managers and cited by many administrations as one of the major factors in their consideration of moving to a spectrum pricing structure. The following example shows the impact of regional variations on spectrum demand.

In the United Kingdom some 25% of the population live in about 7% of the total land area, an area that includes two of the world's busiest airports and is bounded by the world's busiest shipping lane. This concentration of the population and industry creates high demand for all types of service (e.g. mobile, fixed, broadcasting, satellite, radionavigation) whilst at the same time placing considerable restraints on frequency reuse because of the short distance separation. In addition, despite being an island, the United Kingdom's close proximity to neighbouring countries requires coordination in many frequency bands and places further limits on frequency availability. Public mobile telephone services have increased dramatically with increasing competition from new telecommunication operators, but the roll out of services is based on major centres of population and the prime road and rail links that connect them. Consequently there is a shortage of spectrum in some parts of the United Kingdom whilst in other areas this is not a problem. In areas like the South East of England there is congestion in many bands and a general shortage of available spectrum below 25 GHz. In particular below 3 GHz there is a problem with spectrum availability for mobile services. The United Kingdom is therefore putting considerable effort into opening up the frequency bands above 30 GHz.

3.4.4 Variation from country to country

The variation between countries is similar to the variation within a country except that it is generally on a larger scale but with some modifications and additional factors.

3.4.4.1 Frequency allocation

Probably the most fundamental difference between countries will be in the allocation of frequencies to services. This may arise through different allocations to countries between ITU Regions, footnotes in RR Article 5 and individual differences from RR Article 5 that have been coordinated between countries. These differences between countries may affect both Primary and Secondary allocations. These changes will primarily affect frequency availability and be subject to coordination agreements between individual countries.

3.4.4.2 Regulatory approach and planning criteria

The spectrum management authorities may be subject to different legislative requirements and as a consequence have a different regulatory approach. In addition there are a number of factors that would normally be expected to vary between countries. These are spectrum management objectives, aims, frequency planning criteria, and operational requirements.

3.5 Summary

The value that the use of radiocommunications and the development of new services can provide to a country's economy is indicated by the economic benefits identified in the two United Kingdom studies. In the past, failure to recognize radiocommunications' economic contribution to a country, perhaps coupled with uncertainty over the methodology, may have meant that benefits analysis was not considered to provide information relevant to spectrum management. This Report shows that techniques are now available to quantify the economic benefits and are capable of providing information, previously unavailable to spectrum managers, that can be taken into consideration when making decisions on frequency assignments and for evaluating the effectiveness of spectrum management decisions. In addition, economic benefit analysis may be used to support justification for spectrum management funding. Effective spectrum management is essential for maintaining access to the radio spectrum and hence the benefits radio can provide to a country.

CHAPTER 4

ALTERNATIVE SUPPORT FOR NATIONAL SPECTRUM MANAGEMENT

4.1 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 or least developed 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, administrations need to consider alternatives to the traditional, centralized, government-operated and funded national spectrum management systems particularly when they are shown to be less expensive or less resource-consuming. 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 can enhance the efficiency and effectiveness of the national effort.

A number of administrations have 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 organizations, and quasi-governmental associations;

– frequency coordinators (and coordination groups) and designated spectrum managers; and

– spectrum management consultants, and support contractors.

These alternatives can be used to support the national spectrum manager in performing the nine spectrum management functions listed in Chapter 1. Which approach is used may vary with frequency band, radio service, and/or specific radio application, the capability resident within the national spectrum management organization, 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 reside within the national spectrum management organization. On the other hand, new technologies such as cellular mobile systems, low-orbiting satellites, and stratospheric systems, may present a complex spectrum management problem beyond the existing capabilities of the national spectrum management office. In some cases, particularly with bands used for single applications such as public broadcasting associated with well-defined groups, private organizations may offer to manage the spectrum and deal with related spectrum management issues in a way advantageous to all concerned. Furthermore, the national spectrum manager can determine the limits of responsibility and authority granted 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.

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;

– to increase the efficiency of spectrum use;
– to improve the efficiency of the frequency assignment and coordination processes; or
– to rationally supplement the expertise of the national spectrum manager.

4.2 Approaches

4.2.1 Communications groups with a direct interest in spectrum

Interested communications groups include organizations established by communications professionals, radio users, and manufacturing or trade associations having an interest in the use of the spectrum. In most cases, these organizations develop by themselves around their shared interests, but the government may need to establish a group, such as a formalized 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 coordination, 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 usually 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 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 bodies such as the ITU Radiocommunication Sector (ITU-R) and International Electrotechnical Commission (IEC), and regional bodies such as the American National Standards Institute (ANSI) and European Telecommunications Standards Institute (ETSI).

4.2.2 Frequency coordinators, designated spectrum managers and system licence holders

4.2.2.1 Frequency coordinators and coordination groups

Frequency coordinators are spectrum management resources outside the national government given the authority to coordinate the selection of frequency assignments within specific parts of the spectrum. This does not necessarily include final authority for the assignment of frequencies. Coordination groups are often created around users with like interests, recognizing that each band is allocated for specific use in which a limited number of parties are interested or permitted.

The frequency coordinator 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 coordinator presents the coordinated request for final approval by the national authority. Having gone through this process, the prospective user can practically be guaranteed access to the spectrum on the frequency coordinated.

The use of frequency coordinators may require financial resources from the government in exchange for the technical expertise provided. More often, however, the national authority grants the coordinator the authority to collect fees for its services from spectrum users. Coordination groups, created by the interested parties to coordinate their spectrum use, can be recognized by the national authority and granted the responsibility to coordinate 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 coordination group.

4.2.2.2 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 coordination, 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.

4.2.2.3 System licence holders

Many 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 and frequency range can be turned over to the licence holder, assuming that the particular spectrum is not shared with other users. 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.

4.2.3 Spectrum management consultants and support contractors

Consultants are individuals 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 legal analysis, training, and engineering analysis, select frequencies, develop policies, or participate for the government in spectrum management fora. No authority is conveyed to the consultant other than to perform studies and 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 organization, 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 organizational component or components of the national spectrum management office through the use of staff support contractors. These contractors may provide various forms of technical support, such as database entry, computer operation and software development or engineering support (see § 4.5.1). Under this type of approach, government staff are used to oversee the overall operation or to review contracted results.

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

In considering the use of consultants or contractors, administrations should keep in mind that such individuals may also represent private companies, other administrations or international organizations, thereby causing conflicts of interest. Administrations should be aware of the other obligations of these individuals and ensure that they do not perform tasks related to their other interests.

4.2.4 Costs and benefits of the approaches

While these approaches can assist the national spectrum manager in managing the growing 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 organizational inefficiencies.

4.2.4.1 Financial

Where their services are provided free of charge to the national spectrum manager, interested communications groups, frequency coordinators and designated spectrum managers provide a 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.

4.2.4.2 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.

4.2.4.3 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 coordinators 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 coordinator or manager. These groups often emphasize the need for government control of the national resource, demanding appeal procedures or government review of decisions.

Government oversight of coordinator 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 coordination process fair would be to have more than one certified coordinator for each sub-band. This "marketplace" approach to coordination raises the problem of database management. For coordination to be equitable, each coordinator 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.

4.2.4.4 Process efficiency

Frequency coordination groups are highly familiar with the specialized spectrum needs of the user groups they represent. Because of this familiarity, they can provide fast, efficient, conflict-free assignments to users. Because of their unique status, private sector coordination groups are in a position to provide a highly efficient and rapid method of frequency coordination 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. Licencing systems in an area and over a range of frequencies speeds the licencing process by granting one licence to what amounts to many transmitters, locations and frequencies.

4.2.4.5 Spectrum use efficiency

Because private sector spectrum managers and coordinators 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 maximize the number of assignments and thereby maximize their profit. Coordinators representing user groups work to the benefit of all those within the user group. Maximizing assignments maximizes benefit to the user group. Though designated spectrum managers, coordinators 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 coordinators 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.

4.2.4.6 Flexibility and sharing

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

4.2.4.7 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 coordination 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 to tasks.

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

4.3 Application in developing countries

The spectrum management organizations 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 minimize 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 are highly motivated to use their resources to establish and support a sound spectrum management process.

These resources can be drawn together in organized bodies to provide advice or in many cases voluntary support to include everything from frequency coordination, to site inspection, regulation drafting, and research. Coordination groups can be established to coordinate frequencies for some services. Groups for broadcasting, fixed, and mobile are often a good starting point. Coordination 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.

4.4 Legal and administrative implementation measures

The approaches described above are intended to decrease the national spectrum manager's work-load without necessarily decreasing the spectrum manager's level of authority or effectiveness. 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, centralized approaches to spectrum management, some legal authorization may be required to implement any of these alternative approaches. Actual delegation of government authority, for example licensing authority, to groups outside the national spectrum manager will require 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 Report.

A legal basis, including rules of conduct, may have to be created for the establishment of government-recognized advisory bodies. Because providing advice within government decision processes means gaining access to the government decision-makers rules might have to be established regarding methods for determining who participates in advisory bodies. For frequency coordinators 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. To avoid conflict of interests, 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.

To use individuals outside the government for international activities, national authorities would have to accredit individuals that participate on their behalf. However, ultimately administrations must be represented at treaty conferences by those authorized 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 coordinators 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.

4.4.1 Contracting/privatization options

Depending on the availability of government staff and the cost-effectiveness of using resources outside the government, each administration determines the best approach to fulfilling the spectrum management functions. While contracting may be a form of privatization, a distinction is made here between the two. Contracting is the payment of an individual or company to perform a specific service or task. Privatization, on the other hand, is the release of a function or component of a function by the government and the empowerment of a private entity to perform that function. For example, the national spectrum manager may choose to perform all functions related to interference resolution, including interference location. On the other hand, the national spectrum authority may choose to hire a contractor to perform the interference location activity. Under this scenario, the contractor may provide staff and equipment or just staff (using government equipment). However, as another option, the spectrum authority may determine that interference location as a subtask can be privatized. For example, complainants might have to pay a company to locate interference before the spectrum authority would get involved in interference resolution. Given these definitions, many aspects of national spectrum management can be performed by contractors with oversight of their activities or validation of results by the government. However, due to the policy and regulatory implications of spectrum management, only a few of the spectrum management functions or components of the functions can actually be privatized.

The State can consider privatization of some spectrum management activities, recognizing the following principles:

– 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 second party.

– Responsibility for radiocommunications regulation should not be privatized. The regulations and the international agreement negotiation should not be performed by a private company as this concerns direct exercise of an activity having a nature of national sovereignty.

– A private company directly participating in spectrum management activities should not have any connection with any of the companies or persons managed or monitored in the course of fulfilling the spectrum management role. The potential for collusion resulting from this is evident.

– A function implying use of enforcement power should not be privatized. This concerns exercise of an activity belonging to the State.

4.4.2 Contractable/privatizable functions

Regulation of radio use is primarily a State function since it involves the oversight of a national resource, determination of national policy, and negotiation of international treaty agreements. However, nothing prevents administrations from using individuals or private companies for a variety of spectrum management support functions such as drafting standards and regulations, and participating in international discussions likely to concern their national industries. Recognizing that the regulatory decision-making and policy-making authority, and the ultimate responsibility for international negotiation-authority must remain in the hands of government officials, each administration decides what roles can be given to private companies or individuals outside the government and which of these roles can be performed under contract to the government, or can be privatized. Within each spectrum management function an administration may choose that private companies may perform certain components but not others. For example, on-site monitoring of radiocommunication networks is an activity which could be contracted; however, the setting of penalty levels may need to be performed by the administration. The authority to grant frequency assignments and issue licences and authorizations ultimately belongs to the State. However, contractors can be used to perform licence processing and database maintenance. As noted earlier, some administrations have turned over primary responsibility for licensing in a particular band to private sector groups. In international activities, State-to-State discussion cannot be privatized, although private experts and advisors can support these activities. Many monitoring functions can be performed by contractors as long as the administration validates their operation and maintains the enforcement authority. Therefore, for each of the spectrum management functions, the issue for each administration becomes where to draw the line between administration responsibility and delegation to private entities, whether contracted or privatized. This decision may be based on the staff resources available to the administration or on the cost effectiveness of using outside resources. Where staff resources are not resident within the administration greater use of outside resources will have to be made. However, when an activity is performed by resources outside the government, the administration tends to lose its direct expertise in those areas, performing primarily an oversight role. Thus, the use of resources outside the government may be difficult to reverse once implemented. While this may not be a concern in administrations trying to determine where to find resources not available within its staff, other administrations could find the loss of expertise to limit their management choices and their ability to exercise the oversight role. Therefore, each administration needs to make decisions related to the use of contracting/privatization carefully with clear definition of activity to be contracted or privatized and in full knowledge of the long-term implications.

Recognizing that the activities contracted or privatized can be determined only on an administration-by-administration basis, and that each activity would need analysis of tasks from processing information up through policy formulation, Table 1 provides a general breakdown and guidance by spectrum management function.

Contracts that bind a company to the administration, should assure an agreed and documented workflow for the company. This means that any change in contract requirements should form the subject of an additional clause to the initial contract. Therefore use of contracting may limit the administration's management options. The company's remuneration could comprise a fixed sum related to deployment of equipment and staff, and a variable sum, that increases as a function of the amount of activity. Bonus mechanisms can also be added based on performance. Remuneration for some activities, such as the processing of licenses, could be linked to fees charged for those activities.

4.5 Summary

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 coordination, and supplementing the expertise of the national spectrum manager. Therefore, in seeking ways to provide an effective national spectrum management system, administrations should consider these approaches.

TABLE 1

General breakdown and guidance by spectrum management function*

Function	Activity	Contracting	Reason	Privatization	Reason	Notas
Regulation, policy, planning and allocation	Policy	Limited to developing of policy. Policy decisions restricted to the government	National policy a government matter	No	National policy a government matter	
	Planning	Limited to developing of plans. Planning decisions restricted to the government	National plans a government matter	No	National plans a government matter	At least one administration has chosen to sell pieces of spectrum, thereby yielding part of their spectrum management authority for those bands
	Allocation (national and international)	Limited to development of advice on allocations. Allocation decisions restricted to the government	Spectrum allocation a government matter	No	Spectrum allocation a government matter	At least one administration has chosen to sell pieces of spectrum, thereby yielding part of their spectrum management authority for those bands
Frequency assignment and licensing		Limited to staff support	Frequency assignment a government matter	Yes, limited to frequency coordination	Frequency authorization remains a government matter	
Standards, specifications and equipment authorization	Standards and specifications	Staff support	Can be used to support government activity	Many standards can be set by the user community		
	Equipment authorization	Staff support	Can be used to support government activity	Some forms of equipment authorization could be handled by the users	Some equipment authorizations could be set by the user community	

TABLE 1 (*continued*)

Function	Activity	Contracting	Reason	Privatization	Reason	Notas
Spectrum control	Enforcement	Limited to staff support	Regulatory authority needs to remain with the government	No	Regulatory authority needs to remain with the government	
	Monitoring	Yes, if overseen or verified by the government		Yes, if overseen or verified by the government		Teams performing this activity could be overseen by a person from the administration but staffed in general by a private company. Vehicles and other equipment could belong to the company. The overall deployment and operation of the monitoring system could be the responsibility of the private company under contract. *Specific monitoring activity* – Define the equipment capability to be installed for the teams in charge of interference resolution/mobile or fixed direction finding, etc., as well as availability of personnel from the private company assigned to this task – Define and lead the tasks of these teams – Define the monitoring coverage requirements of the territory by mobile or 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 specialized maintenance function remaining contracted – Define the monitoring system – general function and database interface – Define and execute monitoring procedures – Define the penalties in the event of non-observance of the contract by one or the other parties
	On-site monitoring	Yes, if overseen or verified by the government		Yes, if overseen or verified by the government		
	Resolution of interference	Yes, if overseen or verified by the government		No	Authority to determine responsibility lies with the government	

TABLE 1 (*end*)

Function	**Activity**	**Contracting**	**Reason**	**Privatization**	**Reason**	**Notes**
Spectrum control (*cont.*)	Interference location	Yes, if overseen or verified by the government		Yes		
International cooperation	International organization participation	Yes, with government involvement		No	Inter-governmental responsibility	
	Assignment coordination	Limited to staff support		No	Inter-governmental responsibility	
Liaison and consultation		No	The purpose of performing these functions is for the government to contact those outside the government. No benefit is gained by doing it through a third party	No	The purpose of performing these functions is for the government to contact those outside the government. No benefit is gained by doing it through a third party	
Spectrum engineering support		Yes		No	Directly linked to other government responsibilities	
Computer support		Yes		No	Directly linked to other government responsibilities	
Administrative and legal support	Administrative	Yes for many administrative functions such as invoicing, budgeting		No	Directly linked to other government responsibilities	
	Legal	No	Government legal personnel must be independent of outside interests	No	Government legal personnel must be independent of outside interests	

* The terminology used here with respect to spectrum management functions is consistent with the presentation given in the Handbook of National Spectrum Management, Radiocommunication Bureau, Geneva 1995.

CHAPTER 5

ADMINISTRATIONS' EXPERIENCE REGARDING THE ECONOMIC ASPECTS OF SPECTRUM MANAGEMENT

5.1 Experience with auctions and transferable property rights

During the 1990s, some countries have used auctions to assign licences. (For a discussion of auction types and design, see [McMillan, 1994].) Additionally, a few of these countries have recently introduced limited systems of transferable property rights, wherein licences to use spectrum may be sold to other parties.

5.1.1 Australia

In Australia, the Spectrum Management Agency (SMA) in its role of managing the spectrum is pursuing objectives which include promoting economic efficiency, encouraging technological change and expanding freedom of choice. It has sought to develop an efficient, equitable and transparent system of charging for the use of spectrum, and to ensure an acceptable return to the community. To balance these potentially conflicting objectives, the SMA has had to adopt a number of innovative approaches to managing spectrum. Its auctions and transferable property rights approaches are outlined below.

5.1.1.1 Making use of price as a tool in assigning licences

The radio frequency spectrum represents a scarce community resource, and in some frequencies, especially those capable of producing high future revenue for licensees, the possibility exists for high economic rents to be gained by the initial licensees. In attempting to capture these economic rents for the general community the SMA has successfully conducted three price-based assignments using an "open-cry" (English) auction style process. The auctions were used to assign multipoint distribution station (MDS) apparatus licences, which are capable of being used for pay TV, in the major population areas of the country. The licences, situated in the 2 GHz band, recouped in excess of A$100 million for the government and the bid prices paid reflect the future revenue gains that the market considered were capable of being achieved by the successful bidders.

5.1.1.2 Introducing a new form of licensing: the spectrum licence

The market system is based on the principle that direct marketing of spectrum will result in more efficient spectrum use. Under the market system, users of spectrum will make decisions on their spectrum access recognizing the pressures of demand and supply. To facilitate a more market-oriented approach to spectrum allocation and management, the SMA is introducing a new type of licence, analogous to a property right, called a spectrum licence. Spectrum licensing, instead of focusing on equipment and its uses (which in turn defines the area covered and the frequency bandwidth used), authorizes the use of spectrum within specified limits of frequency bandwidth and coverage area. Under spectrum licensing, licensees will have the flexibility to change their equipment, antenna, siting, in fact any aspect of their use of spectrum, provided they comply with the core technical conditions of the licence, and any coordination requirements. A spectrum licence is tradeable and provides explicit rights for a fixed period up to ten years. Users will be able to adjust the amount of spectrum they wish to use and the type of use they make of that spectrum in response to commercial incentives brought about by the price of spectrum access.

This new licence type, which complements rather than replaces traditional apparatus licensing, is to be allocated using price-based allocation methods. The SMA recently completed its first simultaneous multiple round auction for spectrum licences in the 500 MHz band.

Together with licence fees, the reforms being implemented by the SMA represent a fundamental shift in spectrum management in Australia. Market forces have been given a much greater role in spectrum assignment and use, and so far the initiatives taken have proven to be successful in promoting the SMA's primary objective of facilitating access to, and use of, the radio-frequency spectrum.

5.1.2 Canada

The Canadian Radiocommunication Act was amended in June 1996 to provide the explicit authority for the use of spectrum assignment auctions in appropriate circumstances. In June 1998, Industry Canada announced that spectrum in the 24 GHz and 38 GHz bands would be the subject of Canada's first spectrum auction. The policy and rules were published in May 1999. A simultaneous multiple round auction of 354 licences (one 400 MHz licence in the 24 GHz band, one 400 MHz licence in the 38 GHz band, and four 100 MHz licences in the 38 GHz band in each of 59 geographic areas across Canada) will commence in October 1999. The auction will be run remotely over the Internet.

The licences will be transferrable to eligible third parties after the auction and will have ten-year terms with a high expectation of renewal after the initial ten-year term.

5.1.3 The Russian Federation's experience with auctions

With a view to improving the mechanism for charging for use of the spectrum, in February 1999 the Government of the Russian Federation adopted a decree stipulating that "after the entry into force of this decree, in respect of organizations applying for a licence or other authorization to use the radio-frequency spectrum for the provision of cellular telephone services in bands above 1 800 MHz and television programme distribution services using MMDS, LMDS and MVDS type systems, charges for use of the spectrum will be determined on the basis of the results of competitions for such licences or authorizations conducted under the procedure set by the Government of the Russian Federation" (see Note 1).

NOTE 1 – MMDS: multichannel multipoint distribution system, LMDS: local multipoint distribution system, MVDS: multipoint video distribution system.

In order to define the mechanism for competitive bidding, regulations were also adopted on the competitive award of licences for activities associated with the provision of these types of service. These regulations set forth the competitive procedure, conditions governing participation in the competition, financial arrangements and specifications for the issuing of licences on the basis of the results of the competition.

For the purpose of organizing and conducting competitions, the State Committee for Telecommunications of the Russian Federation (Gostelekom):

– forms a commission, decides on its composition and, where necessary, attaches to it the necessary independent experts;
– sets the amount of the minimum bid, based on the average annual income and profitability of cellular communication networks. The minimum bid will constitute the minimum annual charge for operations associated with the provision of cellular telephone services using radio frequencies;
– organizes the preparation and publication of an information note on the holding of competitions;

– receives applications from persons intending to take part in the competitions (hereinafter referred to as “candidates”), entering them in the register of applications in the order of receipt, with a corresponding registration number and an indication of when the documents were tendered (date, month, time in hours and minutes);
– verifies that the documents submitted by candidates are in due and proper form;
– organizes the receipt of deposits (in the amount of the designated minimum bid) from candidates.

The commission fulfils the following functions:
– examines the information transmitted by Gostelekom (or its representative) on applications received;
– examines the information transmitted by Gostelekom (or its representative) on the payment of deposits received from candidates and other documents and verifies their conformity with the requirements of Russian law;
– upon expiration of the deadline for receipt of applications, on the basis of the information on applications received transmitted by Gostelekom (or its representative), draws up the official list of applications received;
– makes a decision on whether or not to allow candidates to take part in the competition and draws up the official list of participants in the competition;
– draws up the official record of the results of the competition.

Participation in the competition is open to businesses and individuals who have submitted an application to participate in the competition by the deadline, have submitted in due and proper form the requisite documents listed in the information note published concerning the holding of the competition, and have deposited the requisite sum of money within the specified time-limit.

An application to participate in the competition from a candidate is deemed to constitute an expression of intent to take part in the competition under the conditions set in the regulations and published in the information note on the holding of the competition. The application form is endorsed by Gostelekom.

The deposit indicated in the information note pertaining to the competition will be transferred to one of the accounts indicated in the information note after submission of the application form. The number of the application will be indicated on the payment order.

Confirmation of receipt of deposits in the accounts opened with participating banks: Confirmation of the deposit must be provided to the commission before candidates are recognized as participants in the competition. A candidate assumes the status of participant when the members of the commission sign the official list of participants in the competition.

In order to determine the winner of the competition, the chairperman of the commission opens the bid envelopes in the presence of the members of the commission and representatives of the candidates and announces the proposed amounts of the annual payment. The highest bidder wins. In the event of identical bids, the winner shall be the candidate that submitted its bid earlier.

The deposits of participants who do not win the competition are returned to them within 15 days after identification of the winner of the competition.

Upon receipt of the transfer of the full annual payment (equal to the winning bid) from the winner to the account indicated in the information note, the State Committee for Telecommunications of the Russian Federation grants the licence under the established procedure.

The annual charge payable by the winner of the competition is distributed as follows:

– 80% as income to the federal budget, to be used in equal proportions to finance the Ministry of Defence of the Russian Federation (to cover expenses associated with releasing frequency bands) and the Russian Space Agency.

– 10% as income to the budget of the unit of the Russian Federation in whose territory the licence is valid (if the licence covers the territory of several units of the Russian Federation, the amount is divided among them proportionate to their populations).

– 10% to Gostelekom to cover expenses incurred for licensing and the holding of competitions, for registration of radio frequencies and for monitoring services.

5.1.3.1 A method for determining the minimum bid based on an evaluation of the "shadow price" of the radio-frequency spectrum

While the Russian Federation has not actually conducted an auction the administration has developed a method for determining the minimum bid [Bykhovsky *et al.*, 1998]. The proposed method hinges on an evaluation of the income index of the mobile communication network as a function of the system bandwidth. This income index provides a gauge of the annual effect of investment in the project with regard to a particular monetary unit, in this case USD 1.

The basic data required to carry out the analysis may be divided into three groups:

– data pertaining to the network's frequency plan;

– parameters defining the required volume of investment to set up the network;

– parameters defining income from operation of the network.

In the following example the technical parameters of a GSM cellular network are used. Nevertheless, the method can be applied to other cellular and trunking network standards.

a) *Number of base stations (BS) in the mobile network as a function of the bandwidth*

The first group of basic data includes the parameters shown in Table 2, which are used to determine the following key parameters of the mobile communication network:

N: cluster size

C: number of BS that have to be installed in a town

n_c: number of telephone channels.

TABLE 2

Symbol	Parameter	Calculated value
F	Bandwidth for the mobile network in the service area	2-25 MHz
F_k	Channel bandwidth of the mobile network system (for NMT, AMPS-D and GSM systems, F_k = 25, 300 and 200 kHz, respectively)	0.2 MHz
M	Number of sectors served in one cell (M = 1 for θ = 360°; M = 3 for θ = 120°; M = 6 for θ = 60°, where θ is the width of the BS antenna radiation pattern)	1-6
n_α	Number of subscribers that can use one frequency channel at the same time (for NMT, AMPS-D and GSM systems, n_α = 1, 3 and 8, respectively)	8
N_α	Number of subscribers to be served by the cellular mobile network in a town	10 000-150 000 people
β	Activity of one subscriber at peak traffic times	0.025 E
P_α	Permissible probability of call blocking in the mobile network	0.1
ρ_0	Required protection ratio for mobile network receivers (for NMT, AMPS-D and GSM systems, ρ_0 = 18.9 and 9 dB, respectively)	9 dB
P_t	Percentage of time during which the signal/interference ratio at the input to the transmitter in the mobile network is allowed to fall below the protection ratio, ρ_0	10%
σ	Parameter determining the range of random variations in the received signal level at the place of reception (for mobile network systems, σ = 4-10 dB)	6 dB

A procedure [Bykhovsky, 1993] for determining the basic parameters of a cellular mobile network is as follows:

– Total number of frequency channels in a cellular mobile network in a town:

$$n_k = \text{int}(F/F_k)$$

where int(x) is the integer part of the number x.

– Required cluster size for given values of ρ_0 and P_T:

$$p(N) = 100 \int_{\frac{(10\ \log(1/\beta_e) - \rho_0}{\sigma_p}}^{\infty} e^{\frac{t^2}{2}} \frac{\mathrm{d}t}{\sqrt{2\pi}}$$

where $p(N)$ is the percentage of time during which the signal/interference ratio at the mobile station receiver input falls below the protection ratio ρ_0. The values β_e and σ_p depend on the parameters $q = \sqrt{3N}$, σ and M. The value of $p(N)$ decreases as N increases. For given values of ρ_0, σ and M = 1, 3 and 6, values of $p(N)$ are calculated for a number of values of N (i.e.: q). The value of N for which the condition $p(N) \leq P_t$ is fulfilled is taken as the cluster size for the mobile network.

The parameters β_e and σ_p used in the equation for $p(N)$ are determined using the following expressions:

$$\sigma_p^2 = \sigma^2 + \sigma_e^2$$

$$\sigma_e^2 = \frac{1}{\lambda^2} \ln \left[1 + (e^{\lambda^2 \sigma^2} - 1) \frac{\sum_{i=1}^{\lambda} \beta_i^2}{\left(\sum_{i=1}^{\lambda} \beta_i \right)^2} \right]$$

$$\beta_e = \left(\sum_{i=1}^{\lambda} \beta_i \right) \exp \left[\frac{\lambda^2}{2} (\sigma^2 - \sigma_e^2) \right]$$

Here, λ = (0,1 ln(10)) and the values λ and β_i depend on M and may be found using the following formulae:

$$\left. \begin{array}{lll} \text{if } M = 1, \text{ then } \lambda = 6 & \beta_1 = \beta_2 = (q-1)^{-4}; \ \beta_3 = \beta_4 = q^{-4}; \ \beta_5 = \beta_6 = (q+1)^{-4} \\ \text{if } M = 3, \text{ then } \lambda = 2 & \beta_1 = (q+0.7)^{-4}; \ \beta_2 = q^{-4} \\ \text{if } M = 6, \text{ then } \lambda = 1 & \beta_1 = (q+1)^{-4} \end{array} \right\}$$

where:

$$q = \sqrt{3N}$$

– Number of frequency, n_s, and telephone, n_c, channels used to serve subscribers in one sector of one cell:

$$n_s = \text{int}(n_k / MN)$$
$$n_c = n_s \cdot n_\alpha$$

– Admissible telephone traffic in one sector of one cell (E):

$$A = \begin{cases} n_c \left[1 - \sqrt{1 - \left(p_a \sqrt{\pi \, n_c / 2} \right)^{1/n_c}} \right] & \text{for } p_a \le \sqrt{2 / \pi \, n_c} \\ n_c + \sqrt{p/2 + 2 n_c \ln\left(p_a \sqrt{\pi \, n_c / 2} \right)} - \sqrt{p/2} & \text{for } p_a > \sqrt{2 / \pi \, n_c} \end{cases}$$

– Number of subscribers served by one BS for a given value of blocking probability:

$$N_{BS} = M \cdot \text{int}(A / \beta)$$

– The number of BS in the cellular network is determined as follows:

$$C = \text{int}(N_\alpha / N_{BS}) + 1$$

Thus, the proposed method enables the calculation of the required number of base stations and number of channels for a given network's performance parameters and a given projected number of subscribers.

b) *Determination of expenditures for establishment of a mobile network*

The basic data in the second group are shown in Table 3.

TABLE 3

Symbol	Parameter	Calculation value
K_h	Average hourly rate of an installer	3 (USD/h)
K_{BS}	Price of a typical single-channel BS installation	USD 230 000
K_E	Cost of one receiving/transmitting unit	USD 11 000
 A_1 A_2	Fixed portion of cost of connection links, independent of link length	For digital radio-relay USD 351/channel USD 176/channel
 B_1 B_2	Variable portion of cost of connection links dependent on link length	For digital radio-relay USD 23/channel km USD 12/channel km

Expenditures comprise five components and are determined as follows:

$$K_\Sigma = K_1 + K_2 + K_3 + K_4 + K_5$$

where:

K_1: cost of construction and assembly work

K_2: cost of BS equipment

K_3: cost of establishing a switching centre (SC)

K_4: expenditure for purchasing software and technical facilities for billing systems

K_5: cost of establishing communication links between BS and SC.

Construction and assembly costs, K_1, are determined on the basis of statistical data [Boucher, 1992 and 1995] on the labour consumption of the various stages of work. These costs are proportional to C, which is the number of BS in the mobile network, and may be determined by the equation:

$$K_1 = K_h \begin{cases} 4\,900 + 1\,040\,C & \text{for} \quad 1 < C < 5 \\ 3\,900 + 1\,640\,C & \text{for} \quad 5 < C < 15 \\ 3\,900 + 1\,740\,C & \text{for} \quad 15 < C \end{cases}$$

Capital costs for BS equipment are determined by the equation:

$$K_2 = C\,[K_{BS} + (M \times n_s) \times K_E]$$

where $(M \times n_s)$ is the number of frequency channels in one cell.

The cost, K_3, of establishing the SC of a mobile network is determined from the data in Table 4 on the basis of the number of subscribers in the network.

TABLE 4

Required number of telephone channels in the network	Switching centre costs K_3 (USD)	
	Analogue	Digital
$N_a \leq 500$	300 000	3 500 000
$N_a \leq 2\,000$	500 000	3 600 000
$N_a \leq 10\,000$	1 300 000	4 000 000
$N_a \leq 50\,000$	3 000 000	5 000 000

The cost K_4 is determined from the data in Table 5. Calculations are made for the case in which the mobile network uses a very simple billing system for 10 000 subscribers that can be expanded as required as the number of subscribers increases.

TABLE 5

Type of system	Cost K_4 (USD)
Simple system for 5 000 subscribers	130 000
Simple billing system for 10 000 subscribers	240 000
System with additional capabilities up to 10 000 subscribers	750 000
System with additional capabilities up to 100 000 subscribers	1 400 000

For determining the costs of establishing communication links between the BS and SC, the number of communication links, N_{ck}, needed to connect one BS to the SC can be calculated. In cellular mobile networks, two types of communication links can be used, with a capacity of 60 or 30 telephone channels (with a transmission speed of 2 or 4 Mbit/s). The required number of communication links with a capacity of 30 telephone channels is as follows:

$$N_2 = \text{int}((M \times n_c)/30) + 1$$

In order to reduce the capital outlay for BS-SC connections, communication links of type 1 should be used as much as possible. The number of such links will be:

$$N_1 = \text{int}(N_{30}/2)$$

If N_{30} is an even number, then the given number of type 1 communication links is sufficient for BS-SC connections. If it is an odd number, one more communication link with a capacity of 30 telephone channels is required. Thus, for BS-SC connections, N_1 communication links of type 1 and N_2 communication links of type 2 are required.

Unit costs for one telephone channel with type 1 or type 2 links of length L_i are determined by the equation:

$$T_{1i} = A_1 + B_1 \times L_i$$

$$T_{2i} = A_2 + B_2 \times L_i$$

where A_1, B_1, A_2 and B_2 for cable, optical and radio-relay links may be determined on the basis of statistical data.

The cost of establishing communication links between the *i*-th BS and the SC is:

$$K_{5i} = 60 \times N_1 \times T_{1i} + 30 \times N_2 \times T_{2i} = A + B \times L_i$$

where:

$$A = 60 \times N_1 \times A_1 + 30 \times N_2 \times A_2 \qquad B = 60 \times N_1 \times B_1 + 30 \times N_2 \times B_2$$

The total cost of establishing communication links to connect all base stations to the switching centre may be determined by the following equation:

$$K_5 = \sum_{1}^{c} K_{5i} = C\,[A + B \times L_m]$$

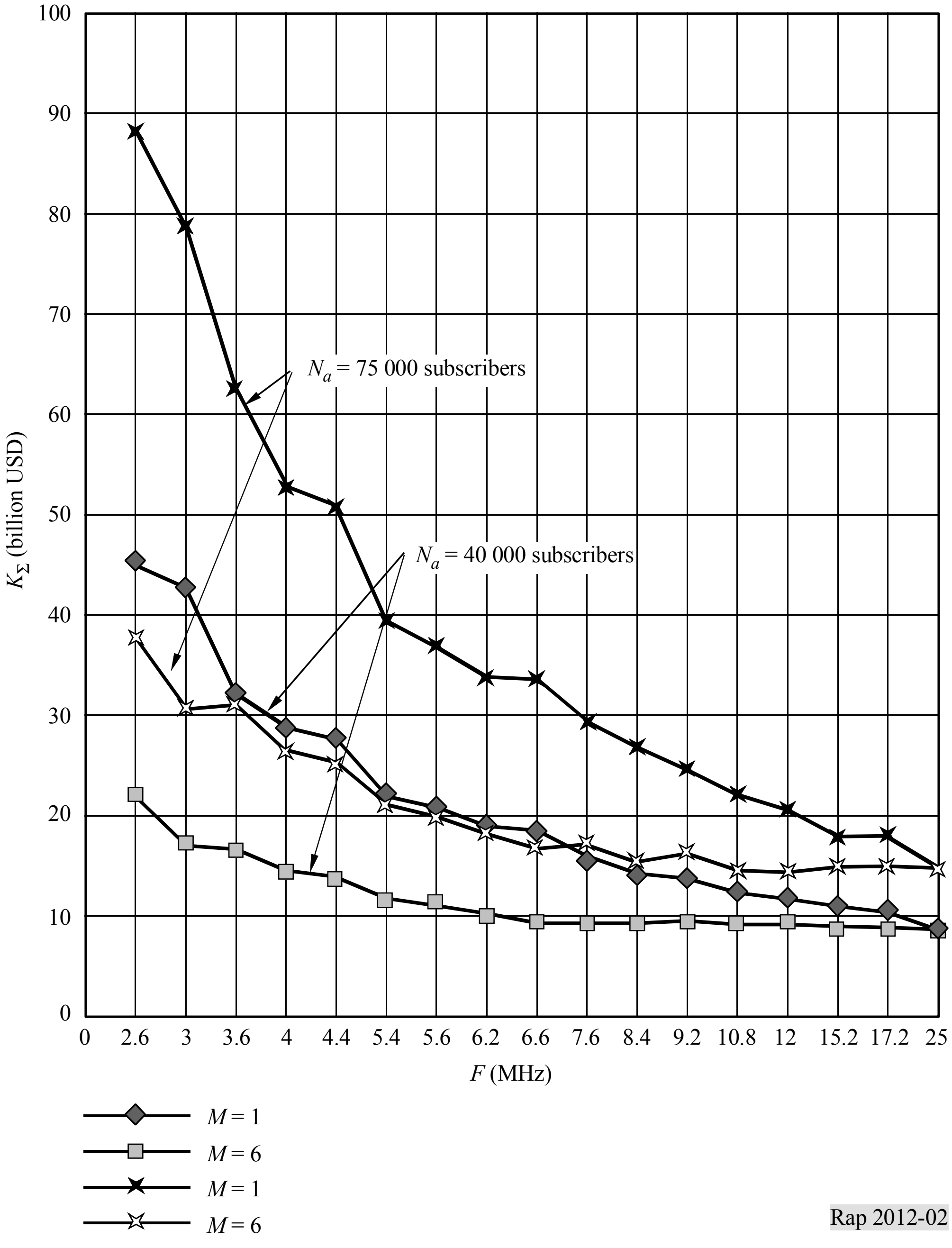
where $L_m = \left[\sum_{1}^{c} L_i\right]/C$ is the average length of all BS-SC connection links. The length of these links may vary from 5 to 25 km. If the mobile network's coverage area is assumed to be a circle and base stations are uniformly distributed throughout this area, then:

$$L_m = 2\,[25^3 - 5^3]/3 \times 25^2 \cong 16.6\ \text{km}$$

Figure 2 shows capital expenditure K_Σ as a function of the bandwidth, *F*, and the number of subscribers to be served, N_a. It reveals that the operator can reduce the necessary expenditure for the establishment of a network quite significantly by using a wider bandwidth, i.e. making less efficient use of the spectrum.

FIGURE 2

Capital investment vs. bandwidth



Rap 2012-02

c) *Determination of the discounted income index of a mobile network project*

Table 6 shows a set of calculation parameters based on statistical data and standards used in the Russian Federation:

TABLE 6

Symbol	Parameter	Calculation value
N_0	Initial number of subscribers in the mobile network	300 subscribers
T_1	Tariff per minute for the lease of a channel in the public network	USD 0.05/min
X	Coefficient characterizing the proportion of calls entering the public network	0.7
K_{PH}	Traffic concentration coefficient characterizing the proportion of average daily traffic occurring during the busy hour; this is the ratio of busy-hour call time and mean daily call time	0.18
β	Activity of the subscriber during the busy hour	0.025
P_1	Mean one-time payment for connection to the network	USD 200
P_2	Mean monthly subscription fee	USD 50/month
P_3	Mean call rate	USD 0.35/min
n	Licence period	10 years
δ	Rate of national profit tax	0.38
E_n	Discount rate, equal to the average annual bank rate	0.1

When determining the operator's income and annual expenditure, it must be borne in mind that the number of network subscribers constantly varies through time according to a specific equation, $N_a(t)$, which may be calculated based on statistical data on the development of mobile networks. For cellular mobile networks being developed in the Russian Federation, this may be expressed as follows:

$$N_a(t) = \max\{N_0 \times \exp(\nu_k \times t)\} \qquad \text{where } (k-1) < t < k;\ N_\alpha$$

Table 7 gives data on the evolution in the number of subscribers to GSM standard networks in the Russian Federation, together with the correspondingly calculated values of ν_k:

TABLE 7

Year	1994	1995	1996	1997	1998-2005
k	0	1	2	3	4-11
$N_{ak} = N_a(k)$	2×10^3	13×10^3	53×10^3	132×10^3	$N_{a11} = 2 \times 10^6$
ν_k	0	1.87	1.48	0.92	0.34

Current annual expenditure, $Z_{\Sigma k}$, comprises three components:

$$Z_{\Sigma k} = Z_{1k} + Z_{2k} + Z_{3k}$$

where:

Z_{1k}: annual expenditure for operation, amortization, equipment maintenance, administrative costs, salaries, share dividends or interest on loans, payments for public utilities, land rental. On the basis of statistical data, the following approximation may be used:

$$Z_{1k} = 805 \times N_{aki}$$

Z_{2k}: annual expenditure for maintenance of the billing system, which may be taken as:

$$Z_2 = \text{USD } 30\,000$$

Z_{3k}: annual expenditure for the lease of public network channels for one year (12 months):

$$Z_{3k} = 12 \times N_{ak} \times Y_M \times X \times T_1$$

The value of Y_M, the monthly traffic for one subscriber, is the number of minutes per month during which a subscriber occupies a communication channel, and is determined by the equation:

$$Y_M = 30.4 \times \beta / K_{PH}$$

Income from operation of a mobile network varies with the number of subscribers using the network's services. It is calculated by the following equation for k years of operation:

$$D_{\Sigma k} = D_{1k} + D_{2k} + D_{3k}$$

where

D_{1k}: income from one-time payments for connection to the mobile network for k years of operation, which directly includes: connection fee, guarantee deposit, access number, use of local public network operator's line, sales mark-up for subscriber equipment, as follows:

$$D_{1k} = N_{ak} \times P_1$$

It should be noted that the operator receives income, D_{1k}, from network subscribers in a single payment.

D_{2k}: income from monthly subscription fees

D_{3k}: income from monthly call fees.

Using the above relationship, $N_a(t)$, we determine D_{2k} and D_{3k} as follows:

$$D_{2k} = 12 \times P_2 \times \int_0^k N_{ak}(t)\,\mathrm{d}t = 12 \times P_2 \times \{N_0 + \sum_1^k N_{ak} \times [1 - \exp(-v_k)]/v_k\}$$

$$D_{3k} = 12 \times P_3 \times Y_m \times \{N_0 + \sum_1^k N_{ak}\ [1 - \exp(-v_k)]/v_k\}$$

In order to evaluate the economic efficiency of the operation of a mobile network, the discounted income index, I_D, is calculated as the ratio of the sum of discounted net profit of the project to overall capital expenditure.

The current worth of future income is determined using the discounting index $(1 + E_n)$, where the value of E_n is taken as the mean annual bank rate. Thus:

$$I_D = \frac{1}{K_\Sigma} \sum_{k=0}^{n} [(1-\delta)\,(D_{\Sigma K} - Z_{\Sigma K})]\ \frac{1}{(1+E_n)^k}$$

On the basis of the results obtained, the discount rate for the project may be calculated:

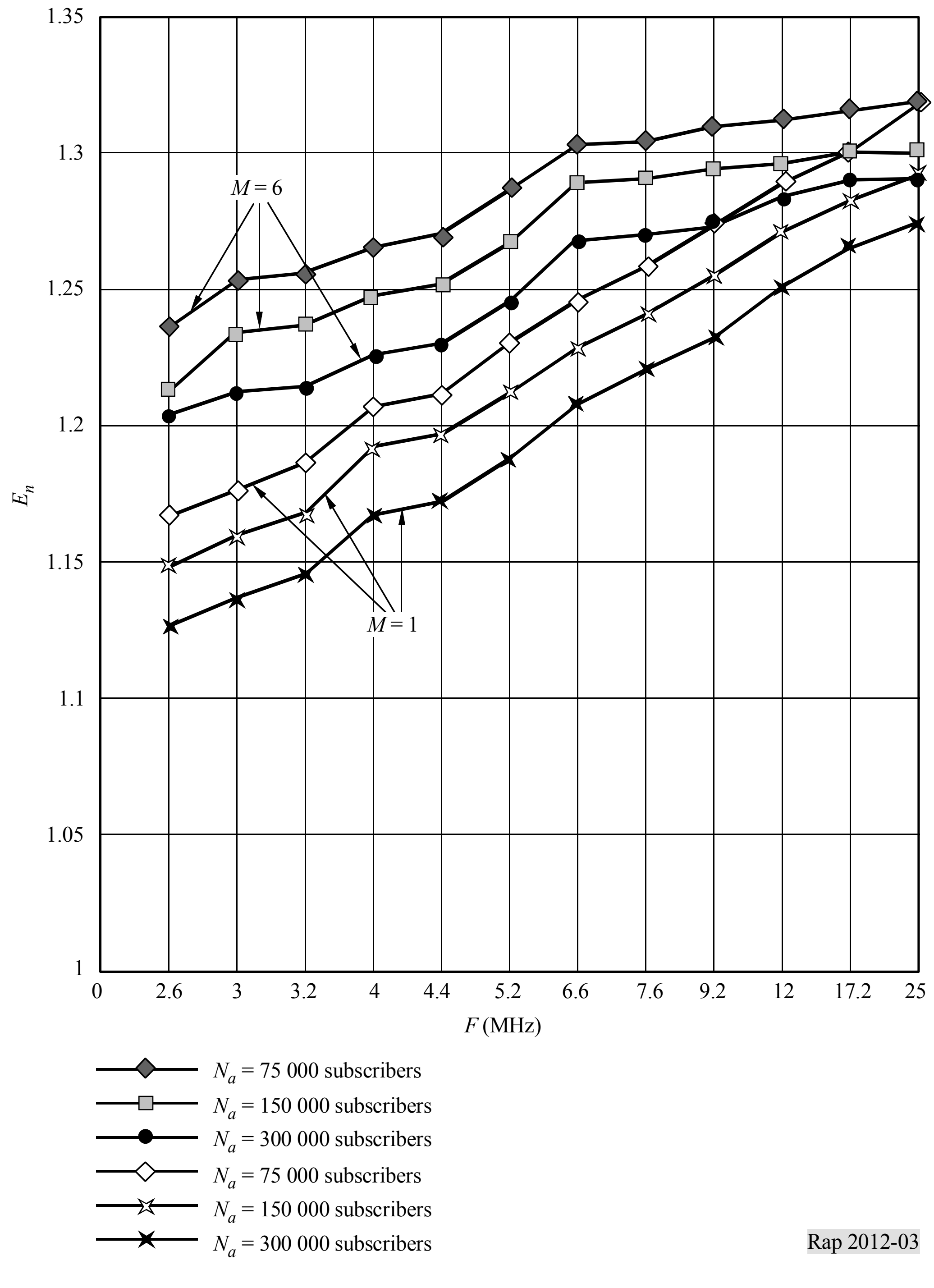
$$E_p = p\sqrt{I_D}$$

Discounted income is calculated as an annual amount relative to one dollar of investment in the project.

The relationship between a cellular mobile network operator's discounted standard profit and bandwidth F, the number of subscribers served, N_a, and the number of sectors served, M, is shown in Fig. 3. The graph reveals that an operator can make additional profit by using additional bandwidth. When determining the minimum bid, one fundamental principle must be to give operators an incentive to make more efficient use of the radio-frequency spectrum.

FIGURE 3

Profitability index vs. bandwidth



d) *Calculation of the minimum bid*

Table 8 gives values of minimum bids for GSM cellular mobile network operators calculated according to the described method. It should be pointed out that this example is given as an illustration. In the calculations, the profit standard for an operator set by the State for mobile communication enterprises is $E_r = 1.25$; and six sector antennas are used in each network. It is assumed that operators are allocated a bandwidth of 5 or 10 MHz.

The minimum bid is calculated by the equation:

$$T = (E_n - E_r) \times D_{pr}/n$$

where D_{pr} is the net profit of the operator during the licence term.

TABLE 8

Number of subscribers in network, N_a (persons)	75 000		150 000		300 000	
Bandwidth (MHz)	5	10	5	10	5	10
T (millions of USD)	1.08	1.68	0.93	2.1	0	1.73

NOTE 1 – The values of minimum bids should be refined on the basis of a market analysis for each specific case.

5.1.4 New Zealand

Most administrations that have begun applying market-based approaches continue to allocate spectrum based on consideration of national priorities, and have applied market approaches only to licensing within an agreed allocation. New Zealand, however, has applied a broader market-based approach to use of some frequency bands where the impact is limited to a national, rather than an international, scale.

In 1990, New Zealand introduced legislation to establish a regime of spectrum property rights. A "management right" to a frequency band enables the owner of that right to create licences to use frequencies within the band. The key differences introduced by this new procedure are that a licence is given a legal status in respect to transmission and interference, it has a tenure up to 20 years, and the licence becomes legally tradeable. Though a specific application is not required, the technical limitations of the licence provide inherent limitations on the nature of use. This concept has been applied in the following bands:

526.5-1 606.5 kHz	Management rights retained by the Government and MF-AM broadcast licences created and tendered International coordination based on ITU Region 1/3 LF/MF plan
88-100 MHz	Management rights retained and VHF-FM broadcast licences created and tendered
518-582 MHz and 646-806 MHz	Management rights retained and UHF-TV broadcast licences created and tendered
825-835 MHz and 870-880 MHz	Management rights tendered suitable for cellular telephony or other services
835-845 MHz and 880-890 MHz	Management rights transferred under transitional provisions of the legislation

890-960 MHz	Management rights tendered in form suitable for two cellular operators or other services
2 300-2 396 MHz	Management rights tendered in 12 bands of 8 MHz.

Work is underway to create management rights for Band I and Band III (television). A review of the band 1.7-2.3 GHz is being undertaken, with a view to establishing suitable spectrum blocks for personal communications services (PCS) development. Concurrent with this will be a move to define this spectrum for ultimate transfer to "management rights", using the tendering/auctioning process.

New Zealand has held a number of spectrum auctions, including simultaneous multiple round auctions. In its experience, the auctioning/tendering process requires careful consideration and planning. It should not be seen as the panacea for all spectrum issues and indeed much spectrum cannot be considered for this process. Consideration should also be given to the need to ensure actual use of spectrum after it has been auctioned by some sort of "use or lose legislation", which might be required to ensure that spectrum is not hoarded to prevent competition taking place.

When developing a suitable auctioning regime, early consideration needs to be given to the extent of possible participants. For example, will it be open to overseas companies/organizations? This decision may impinge on strategic planning, and any exclusion of such entities needs to be clearly stated up front.

5.1.5 United States of America

5.1.5.1 Authority

In the United States of America, spectrum management functions are divided between the Federal Communications Commission (FCC) and the National Telecommunications and Information Administration (NTIA). The FCC is tasked with managing non-Federal Government use of spectrum, including use by the private sector and local and state governments. The NTIA is authorized to manage Federal Government agencies' spectrum use, including the military. The U.S. Congress gave the FCC authority to issue licences via auctions in 1993. This authority is limited to using competitive bidding in instances where mutually exclusive applications have been received and where the principal use of the spectrum is reasonably likely to involve the receipt by the licensee of fees from subscribers in return for enabling those subscribers to receive or transmit communications signals. In granting the FCC auction authority the U.S. Congress sought to promote the following objectives:

"(1) the development and rapid deployment of new technologies, products, and services for the benefit of the public, including those residing in rural areas, without administrative or judicial delays;

(2) promoting economic opportunity and competition and ensuring that new and innovative technologies are readily accessible to the American people by avoiding excessive concentration of licences and by disseminating licences among a wide variety of applicants, including small businesses, rural telephone companies, and businesses owned by members of minority groups and women;

(3) recovery for the public of a portion of the value of the public spectrum resource made available for commercial use and avoidance of unjust enrichment through the methods employed to award uses of that resource; and

(4) efficient and intensive use of the electromagnetic spectrum."

In granting authority to use competitive bidding, the U.S. Congress also specified that the use of competitive bidding:

"(1) shall not alter spectrum allocation criteria and procedures;

(2) shall not be construed to relieve the FCC of the obligation in the public interest to continue to use engineering solutions, negotiation, threshold qualifications, service regulations, and other means in order to avoid mutual exclusivity in application and licensing proceedings."

The U.S. Congress further specified that the FCC cannot make allocation or service decisions based on the expectation of public revenue from auctions.

The majority of the proceeds from auctions conducted by the FCC are deposited in the general U.S. treasury. The FCC is permitted to retain only that portion of the auction proceeds necessary to pay for the cost of holding the auctions. This portion is well under 1% of the revenues generated by auctions. Generally, the licences that have been issued pursuant to auction are for a ten-year period, and it is intended that after this period the licence would be renewed if the licensee has complied with applicable FCC rules and has provided substantial service.

The following are services that have been licenced in the United States of America pursuant to auctions.

5.1.5.2 Personal communications services (PCS)

PCS providers are expected to give the public new communications capabilities by providing a variety of mobile services to compete with existing cellular, paging and other land mobile services. These services will be provided via a new generation of communications devices with two-way voice, data and/or message capabilities. These devices include small, lightweight, multi-function wireless phones, portable facsimiles and other devices. PCS is composed of several distinct categories, two of which are narrow-band PCS and broadband PCS.

The FCC held its first auction in July 1994, auctioning 11 nationwide licences to provide narrow-band PCS in the 900 MHz band. Narrow-band PCS can be used to provide new services such as voice message paging, two-way acknowledgment paging in which a subscriber can receive a message and transmit a response back to the sender, and other data services. Licences for narrow-band PCS may cover the entire nation (nationwide licence), large regions (regional licence), or smaller areas. Of the nationwide licences, five are 50/50 kHz paired, three are 50/12.5 kHz paired, and three are 50 kHz unpaired.

From 26 October through 8 November, 1994, the FCC auctioned 30 regional narrow-band PCS licences: six licences in each of five regions of the United States of America. Two licences in each region are 50/50 kHz paired and the remaining four are 50/12.5 kHz paired.

In December 1994, the FCC held its first auction of licences to provide broadband PCS in the 2 GHz (1 850-1 990 MHz) band. Broadband PCS encompasses a variety of mobile and/or portable radio services, using such devices as small lightweight, multifunction portable phones, portable facsimile machines, and advanced devices with two-way data capabilities, that are expected to compete with existing cellular, paging and other land mobile services.

The 1 850-1 990 MHz band was divided into six licence blocks. Licence blocks A, B, and C are each for 30 MHz of spectrum (two paired 15 MHz-wide segments). Licence blocks D, E, and F are each for 10 MHz of spectrum (two paired 5 MHz-wide segments). (Note that all six blocks combined contain 120 MHz of spectrum. The other 20 MHz (1 910-1 930 MHz) in the 1 850-1 990 MHz band is used by unlicensed PCS services.)

Licences for blocks A and B cover regional major trading areas (MTAs). There are 51 MTAs that, combined, cover the entire United States of America and its territories. Licences for blocks C, D, E, and F cover basic trading areas (BTAs). BTAs are components of MTAs, and there are 493 BTAs that combine to cover the entire United States of America and its territories. MTAs and BTAs are economic trading areas based on designations contained in the Rand McNally Commercial Atlas and Marketing Guide.

In the auction beginning in December 1994, the FCC auctioned licences in both frequency blocks A and B in 48 MTAs. In the other three MTAs, only the block B licence was auctioned. In those three MTAs (New York, Los Angeles, and Washington-Baltimore), the block A licence was previously awarded under the FCC's pioneer's preference rules. Thus, a total of 99 licences were auctioned. Thirty bidders qualified to bid in the auction and the auction lasted more than 112 rounds before concluding in March 1995.

The FCC began auctioning licences for broadband PCS block C in the 493 BTAs in December 1995. Unlike the MTA auction, bidding credits and installment payment plans were available to small entities for Block C. The auction concluded in May 1996 after 184 rounds. Auctioning for broadband PCS blocks D, E and F began in August 1996 for 153 bidders who qualified to participate for 1 479 different licences. Bidding credits and installment payment plans were available for block F only. The auction concluded in January 1997 after 276 rounds.

Although PCS is a new service, the spectrum that it occupies was previously allocated and licenced to a variety of fixed service (point-to-point) microwave users, including public safety services. Therefore, it is necessary either to move the incumbent microwave systems to another frequency band or to provide for their communications needs through some alternative means, such as cable. In establishing the PCS service, the FCC determined that the fastest and fairest way to make this transition was to have the new PCS licensees pay to move the microwave users out of the band. The FCC therefore established a procedure whereby the new PCS licensees and the incumbent microwave users have a certain period to negotiate the terms of the reaccommodation. In any event, however, the microwave users must vacate the band as of a certain date and cannot therefore prevent implementation of the new services.

5.1.5.3 Interactive video data service

The FCC held its second auction, for 594 interactive video data service (IVDS) licences, during July 1994. IVDS is a two-way communications service in the 218-219 MHz band. Licences are for a ten-year period, and consist of two 500 kHz licences in each of 297 metropolitan statistical areas (MSAs), which are essentially the urbanized areas of the United States of America. In each market, both licences were available for auction at the same time, with the highest bidder given a choice between the two available licences and the second highest bidder winning the remaining licence. The FCC auctioned all 594 licences within two days.

5.1.5.4 Specialized mobile radio (SMR) service

The SMR service is a land mobile radio service that provides dispatch, voice, and data services to commercial businesses and specialized users, although licensees are also permitted to provide service to the general public. The SMR service operates in both the 800 MHz and 900 MHz bands.

The FCC established the SMR service in the 800 MHz band in 1974 as a private land mobile radio service intended as a spectrally efficient method to provide dispatch radio service to businesses and other users that qualified as private radio users. Originally, applicants were limited to a relatively small number of channels to be located at a single base station. Coverage and service options were therefore limited. These licences were issued on a first-come, first-served basis, with a lottery used to resolve instances of mutual exclusivity. Over the years, however, the demand for this service increased and the rules limiting eligibility and licensing were gradually reduced. SMR providers today offer a range of services from traditional radio dispatch for local customers to more sophisticated voice and data transmissions for customers over large geographic areas. SMR licensees, in recent years, have been authorized to expand the geographic scope of their services and aggregate large numbers of channels to provide service more directly comparable to cellular radio and PCS. In October 1994, the FCC proposed to issue 800 MHz SMR licences based on FCC-defined service areas and subject to competitive bidding. The 800 MHz band will be the subject of a future auction.

The 900 MHz SMR service consists of 5 MHz of spectrum divided into twenty 10-channel blocks in each MTA. Assignments in the 900 MHz SMR service offer the potential for such competitive services as wireless data, specialized dispatch, two-way paging, and interconnected voice transmission. Licences for this service were initially issued for single transmitter sites in the 50 largest cities in the United States of America with licensees selected by lottery. Licensing, however, was suspended for a number of years, and the FCC recently restructured the service to issue area-wide licences pursuant to competitive bidding. Original licensees are protected from interference from new licensees; however, they can expand their operations only by obtaining a new licence.

5.1.5.5 Multichannel multipoint distribution system (MMDS)

MMDS is often referred to as "wireless cable". It offers delivery of video programming to subscribers using MMDS and/or instructional television fixed service (ITFS) channels. Only MMDS channels at 2 150-2 160 MHz and 2 596-2 680 MHz have been auctioned. MMDS resembles cable television, but instead of coaxial cable, "wireless cable" uses microwave transmission and signals. In the past, MMDS licences have been issued for specific coordinates at which the central transmitter was located. However, the FCC recently revised the MMDS licensing procedures so that all licensees will be authorized to operate throughout particular BTAs. New licensees will be required to avoid interference within the protected area of existing MMDS operations (a 35-mile radius). The FCC stated that mutually exclusive applications that are filed for a particular BTA will be processed using competitive bidding.

5.1.5.6 Direct broadcast satellite (DBS)

The DBS service is a radiocommunication service in which signals transmitted or retransmitted by space stations are intended for direct reception by the general public. This includes direct reception by both individuals and the community. The FCC held a very limited DBS auction for two orbital slots in January 1996. In adopting auction procedures, the FCC noted that there are characteristics of a national broadcast satellite service, such as the footprint of the satellite falling within the United States of America, that make DBS different from many other satellite services. One winning bidder received a construction permit for 28 channels and the second winning bidder received a construction permit for use of 24 channels.

5.1.5.7 Satellite digital audio radio (DAR)

The satellite DAR service is a broadcasting-satellite (sound) radiocommunication service located in the 2 320-2 345 MHz band, in which high-quality audio signals are transmitted to the Earth by satellite, either to subscribers or to the general public. The FCC held a satellite DAR service auction for two 12.5 MHz licences in April 1997. Both winning bidders plan to offer subscription-based services. Licences are for an eight-year period.

5.1.5.8 Wireless communications

The wireless communications service (WCS) is a radiocommunication service located in the 2 305-2 320 MHz and 2 345-2 360 MHz bands. WCS licensees have the flexibility to offer a variety of fixed, mobile, radiolocation, and broadcasting-satellite (sound) services, except that broadcasting-satellite (sound) and aeronautical mobile services may not be offered at 2 305-2 310 MHz. The FCC held a WCS auction for two 10 MHz licences for each of 52 major economic areas (MEAs) and two 5 MHz licences for each of 12 regional economic area groupings (REAGs) in April 1997. MEAs and REAGs consist of groupings of smaller economic areas, as defined by the U.S. Department of Commerce. There are 176 economic areas that cover the United States of America and its territories. A large variety of companies won licences in the WCS auction. Licences are for a ten-year period.

5.2 Experience with fees

5.2.1 Australia's experience with licence fees

In addition to conducting spectrum auctions and implementing a limited system of property rights, the Spectrum Management Agency (SMA) has attempted to improve the efficiency of the traditional system of licensing. Underpinning the SMA's approach has been a fundamental restructuring of radiocommunications apparatus licence fees. In April 1995, the SMA, in consultation with industry, moved from a traditional, service-based methodology of charging for spectrum usage, to a system which charges on the basis of the amount of spectrum that a particular service denies to other users. Thus, licence fees are calculated in a more consistent and transparent manner, as opposed to the somewhat arbitrary approach that focused predominantly on the characteristics of the radiocommunications service being licenced.

Under the new apparatus licence fee structure, each licence fee generally consists of three identifiable components:

– an issue or renewal component, reflecting the cost of issuing or renewing the licence;

– a spectrum maintenance component, reflecting the ongoing cost of managing the spectrum, including protection from interference (a fixed percentage of the spectrum access tax (SAT) described below); and

– a SAT, which represents a return to the government for use of a community resource, and is based on a formula involving spectrum location, geographic location, channel bandwidth, and communications coverage area.

The calculation of the SAT represents a market demand based pricing strategy in so far as services operating in higher demand areas of the spectrum (i.e., UHF/VHF) or more densely populated geographic areas (i.e., major capital cities) attract a higher licence fee than those operating in lower spectrum demand or geographic demand areas. Furthermore, in accordance with the spectrum denial methodology, services with larger operating bandwidths attract a higher licence fee than more spectrum efficient services, thereby encouraging users to seek more technically advanced equipment that utilizes narrower operating bandwidths, or alternatively encouraging users to operate in segments of the spectrum that are in greater supply.

The SMA has also introduced measures which allow greater flexibility and certainty for users in the radiocommunications market. Flexibility has been achieved by allowing licensees to transfer their apparatus licences to third parties, while greater certainty has been accomplished by permitting licensees to acquire licences for periods of up to five years.

5.2.2 Canada's experience with licence fees

Industry Canada is in the process of overhauling its spectrum licence fee model. The existing fee regime suffers from a number of economic "disconnects" and the goal of a current review exercise is to produce a new system in which fees are equitable among users and contribute to the objectives of economic efficiency and resource rent capture.

The model is based on measuring spectrum consumption in three dimensions: bandwidth, geographic coverage, and exclusivity of use. Larger bandwidths, greater geographic coverage, and exclusive use of a spectrum assignment will all result in higher fees, whereas smaller bandwidths, lesser geographic coverage, and a willingness to share the use of a spectrum assignment will all result in lower fees. Hence, spectrum users will face an incentive to conserve on their spectrum use, consistent with the objective of economic efficiency.

Of course, two licences identical in these three dimensions may have widely divergent real values because of geographic location (see Note 1), spectrum in a major city presumably being more valuable than spectrum in the high Arctic, for example. To account for these differences, and given the difficulties inherent in trying to determine true market values in the absence of a functioning market, the concept of spectrum scarcity has been applied as a sort of proxy variable. A grid/cell pattern has been overlaid on the geography of Canada, and in each cell, the volume of spectrum consumed by all users in a given band is divided by the total volume of spectrum existing in that band. It is this ratio that will determine the relative levels of fees across the country. In areas where spectrum use is high, such as major cities, the spectrum scarcity measure, and as a result the licence fee, will also be high. Conversely, where spectrum use is low, such as in the high Arctic, fees will be low. Geographic information software is used to operate the model in a quick, efficient, and user-friendly manner.

NOTE 1 – Similarly, the value of spectrum will vary across frequency bands due to differences in propagation characteristics, among other things.

5.2.3 China's experience with licence fees

In 1989, the Radio Regulatory Department (the former Office of State Radio Regulatory Commission) of China began collecting licence fees, most of which were spent on spectrum management facilities. This spending has improved spectrum management and has contributed to the deployment of radio services. In 1998, the fee mechanism was adjusted to make fee collection formulas simpler, in order to avoid ambiguity and reduce the cost of fee collecting.

Fee collecting in China is not only regarded as a source of revenue but also an effective means of increasing the efficiency of spectrum management. The following factors are taken into consideration when setting fee levels:

– *Bandwidth used*: Setting the fee level according to the amount of spectrum a user receives encourages the applicant to apply for only the necessary amount of spectrum, thus reducing hoarding.
– *Coverage area*: The coverage area may be a city, a province or more than one province. For each type of coverage area, there is a different fee level.
– *Frequency*: For the same service, different fees are charged, depending on the frequency band. For example, the fee per MHz for a microwave station operating above 10 GHz is only half as much as for a station operating below 10 GHz. Thus, the fee structure encourages service operators to introduce new services in less congested parts of the spectrum.

5.2.4 Germany's experience with spectrum usage fees

The telecommunications sector in Germany is subject to the new Telecommunications Act of 1 August 1996. The purpose of the Act is, through regulation of the telecommunications sector, to promote competition, to guarantee appropriate and adequate services throughout the country, and to provide for frequency regulation.

The Regulatory Authority for Telecommunications and Posts (Reg. TP) was established as a higher federal authority within the scope of business of the Federal Ministry of Economics in order to ensure fair competition in the postal and the telecommunications market.

Frequency regulation is based on a national table of frequency band allocations, frequency usage plans and frequency assignment procedures.

The performance of spectrum management functions, including the charging of licence fees, frequency assignment fees and frequency usage contributions, is regulated by ordinances having the force of law.

In terms of the Act, frequency management means ensuring effective, interference-free use of frequencies, with regard also to broadcasting requirements.

The spectrum usage fees comprise license fees, frequency assignment fees and frequency range contributions. The fees shown in § 5.2.4 are calculated for the year 2000 and are revised on an annual basis.

5.2.4.1 Licence fees

When the network monopoly ended with the new Act the legislator's aim was to regulate the German telecommunications market from this time onwards through licensing.

It is stated in the Act that a licence is required by anyone:

– operating transmission paths going beyond the limits of a property and used for public telecommunications offerings, and/or

– offering voice telephony over his own telecommunications network.

Licences are granted in writing by the Regulatory Authority upon request.

There are four licence classes in Germany. These licences can be termed "public licences", as opposed to "licences for frequency assignments". For the sake of simplification, this contribution focuses on Licence Classes 1 and 2 only:

Licence Class 1: operation – by the licence holder – of transmission paths for public mobile radio services (mobile radio licence)

Licence Class 2: operation – by the licence holder – of transmission paths for public satellite services (satellite licence).

The number of licences may be limited only if the frequencies designated in the frequency usage plan for Germany are not adequate for licensing needs.

Application procedure for Class 1 and 2 Licences

Applications for licences to operate transmission paths extending beyond the limits of a property and used to provide telecommunications services for the public must be made in writing, in the German language. These licences are issued by the Regulierungsbehörde für Telekommunikation und Post, Postfach 8001, 55003 Mainz, Germany.

Applicants must fulfil a number of prerequisites in order to qualify for a licence.

The information to be submitted by applicants includes the applicant's name and address, legal status of the applicant/company, licence class requested, details of the nature of the planned telecommunications service, proof of reliability, proof of efficiency, and proof of specialist knowledge.

Licence Classes 1 and 2

Licence Class 1: Mobile radio licences for digital cellular mobile radio, trunked radio, mobile data, paging

The Posts and Telecommunications Reorganization Act, which took effect on 1 July 1989, set a new regulatory framework for promoting competition in the telecommunications sector in particular, freeing the way to liberalize the mobile and satellite radio markets. The overlap between the new mobile operators and the State monopoly created the need for special authorizations, or licences.

Digital cellular mobile radio

Two licences (D1 and D2) were issued to build and operate a nationwide mobile network to the European GSM 900 standard.

Key licence elements

– Frequency band: 890-960 MHz.

– Coverage obligation: between 75% and 94% of the German population.

– Both licences valid until 31 December 2009.

Two licences (E1 and E2) were also issued to build and operate a digital national mobile network to the GSM 1800 standard.

Key licence elements

– Frequency band: 1 710-1 880 MHz.

– Coverage obligation: between 75% and 98% of the German population.

– Both licences valid until 2016.

Trunked radio

Holders of these licences are entitled to build and operate regional trunked land mobile networks within a defined geographical area (licence area), and to offer mobile services to mainly closed user groups. Trunked networks – modern-day private business radio networks with their own special features – are a useful supplement to the general public mobile networks.

Key licence elements

– Frequency band: 410-430 MHz.

– Coverage obligation: minimum field strength of 25 dB(µV/m) within the licence area.

– Licences valid for 15 years.

Mobile data

The licence holder is entitled to build and operate a mobile data network.

Key licence elements

– Frequency band: 416.6375-417.3625 MHz.

– Coverage obligation: 65% population coverage in the licence area with a minimum field strength of 20 dB(µV/m) and 50% time and location probability, three years after licence grant.

– Licence valid until 31 December 2012.

Paging

Two national licences have been issued to build and operate a terrestrial paging network at 448 MHz in Germany.

Key licence elements

– Frequencies: 448.425 MHz and 448.475 MHz.

– Coverage obligations: between 60% and 75% population coverage with a minimum field strength of 30 dB(µV/m) and 50% time and location probability, four years after licence grant.

– Licences valid until 31 December 2001.

Licence Class 2

Satellite licences

Holders are entitled to operate transmission paths for public satellite services in Germany. This does not include the right to offer voice telephony or to operate transmission paths for mobile radio services or transmission paths for which sound or TV broadcasting frequencies need to be assigned (Section 47(3) of the TKG).

Satellite licences cover the ground segment only, in other words not the space segment, or satellite capacity. Holders without their own satellite capacity need to lease from a space segment provider. Satellite licences are granted for an unlimited period of time.

Satellite Personal Communications Services (S-PCS)

S-PCS licence holders are entitled to operate transmission paths for public S-PCS in Germany. An S-PCS licence is basically a combination of a satellite licence and a mobile radio licence, but the holder does not have the right to offer voice telephony as referred to in the TKG. S-PCS licences are valid for 20 years.

Licence fees for Classes 1 and 2

The licence fees are specified in the Ordinance concerning telecommunications licence fees.

The Reg. TP charges fees for official acts for granting licences. The fees for Class 1 and 2 licences are calculated on the basis of the administrative expenditure occurred, in accordance with the prescribed rates.

The fees for Class 1 licences range from DM 15 000 to DM 5 million, and for Class 2 licences from DM 15 000 to DM 30 000.

5.2.4.2 Frequency assignment and fees

Each frequency usage requires prior assignment by the Regulatory Authority. Frequencies are assigned in accordance with the frequency usage plan in a non-discriminatory manner on the basis of comprehensible and objective procedures.

Fees are payable for frequency assignments within the framework of an administrative act and also for measures to counteract violations of the conditions of the licence issued under the Telecommunications Act.

Frequency assignment fees are non-recurring fees.

Assignment of a frequency may be revoked provided that use for the intended purpose of the assigned frequency is not commenced within one year of the assignment or if the assigned frequency has not been used for its intended purpose for more than a year.

5.2.4.2.1 Example: private mobile radio (PMR)

A common frequency is used, for example, to exchange intra-company messages within a private company.

Network configuration: 1 base station and 5 mobile stations.

No licence fees are payable because it is not a public but a non-public service.

Frequency assignment fee

In accordance with the Frequency Fee Ordinance concerning the frequency assignment fees, the fee for frequency assignment is composed of the following elements:

– frequency assignment fee of DM 125.00:

– additional fee per transmitter of DM 30.00: DM 30.00 × 6 transmitters = DM 180.00.

The total frequency assignment fee payable is:

DM 125.00 + DM 180.00 = DM 305.00

5.2.4.2.2 Example: very small aperture terminals (VSATs)

Frequency assignment fee

A satellite network (satellite service for the public) is operated, for example, with 1 hub station and 20 VSATs. Each VSAT uses one frequency that is subject to coordination.

Chargeable act: assignment of a frequency subject to coordination for the operation of a satellite earth station.

In accordance with the Frequency Fee Ordinance, the fee for frequency assignment is composed of the following:

– fee per transmitter of DM 72.00 (number of transmitting stations: 21).

The total frequency assignment fee payable is:

DM 72.00 × 21 transmitters = DM 1 512.00

5.2.4.3 Frequency usage contributions

The parties (e.g. user groups) which have been assigned frequencies must make an annual contribution towards the cost of maintaining spectrum management activities. For example, expenditure on the planning and updating of frequency usages, including the necessary measurements, tests and compatibility studies to ensure effective, interference-free frequency usage.

Contribution rates are such that staff costs and other expenditure associated with official acts are covered. The shares in the overall costs are allocated, as far as possible on a market-related basis, to the individual frequency allocation user groups that have been assigned frequencies. Within these groups the contribution is divided in consideration of the number and, if applicable, the bandwidth of the frequencies used, as well as the number of items of transmitting equipment operated.

5.2.4.3.1 Example: private mobile radio (PMR)

Radio service: Non-public land mobile service (PMR)

User groups: Private companies: exchange of intra-company messages

Unit: Item of transmitting equipment (number of transmitters in this case: 6)

Annual contribution in accordance with the Ordinance concerning the contributions for frequency usage: DM 27.00.

The total contribution payable is:

DM 27.00 × 6 items of transmitting equipment = DM 162.00

5.2.4.3.2 Example: VSATs

A satellite network (satellite service for the public) is operated, for example, with 1 hub station and 20 VSATs. Each VSAT uses one frequency subject to coordination.

Radio service: Fixed service

User groups: Point-to-point links (e.g. banks)

Unit: Item of transmitting equipment (number of transmitters in this case: 21)

Annual contribution in accordance with the Ordinance concerning the contributions for frequency usage: DM 174.00

The total contribution payable is:

DM 174.00 × 21 items of transmitting equipment = DM 3 654.00

5.2.4.4 Current procedure for calculation of frequency assignment fees and frequency usage contributions

In 1996 the Reg. TP introduced a performance and accounting system (known by the acronym LKR) with the intention of establishing a recording system and a controlling instrument for the calculation of frequency assignment fees and contribution-related costs (staff costs and other expenditure).

The idea – based on the new German telecommunication legislation – was to develop a tool which offers the possibility to carry out real calculations instead of estimations in terms of fees and contributions.

With the introduction of the LKR a step was made towards the development of performance and cost transparency within the Reg. TP.

Public administrations normally have a "monopoly" in the tasks they carry out but must maintain public accountability by achieving performance transparency, cost transparency and cost efficiency. This requires the development and introduction of a performance and accounting system as a modern tool to ensure economic-based work in a public administration. In this relation it is the goal in the Reg. TP to assign and to allocate costs totally to the corresponding cost causer.

The definition of cost units (e.g. user groups) as the smallest unit in the performance structure of the Reg. TP is the basic element of the whole LKR concept.

A module called "expense record" was developed which allows the direct assignment of upcoming costs with regard to the most important categories of staff costs, costs for measurement equipment as well as costs for cars for individual transport and for vans of the monitoring service.

The expense record is carried out by using a worksheet which has to be filled in by the employees who worked in the relevant performance range.

The expense record contains on a daily basis precisely (accuracy-limit of time is equal to half an hour) the duration of the period needed for the accomplishment of the specified tasks in the framework of a monthly evaluation

The figures given in the above-mentioned examples have been calculated by means of the LKR system.

The Telecommunications Act forms the basis for the calculation and stipulation of frequency assignment fees and frequency usage contributions.

A distinction must be made between frequency assignment fees and frequency usage contributions (and licence fees).

5.2.4.4.1 Calculation of frequency assignment fees

Frequency assignment fees are calculated on the basis of firstly the costs according to the cost accounting data and secondly statistical data (e.g. number of new frequency assignment applications, changes in frequency assignments, frequency assignment waivers).

Under the cost accounting method, all fee-related costs (staff costs and other expenditure) are recorded and allocated according to service and user group on a daily basis.

A number of spectrum management functions carried out by the Reg. TP do not lead to an income. For this reason the cost coverage cannot be 100%. However, the record and the evaluation of the free-cost spectrum management functions (specified in the Ordinance of frequency usage contributions) and for other authorities (e.g. Ministry of Defence) provides the necessary transparency of the fee and the reasons for not being able to achieve full cost recovery.

5.2.4.4.2 Calculation of frequency usage contributions

Frequency usage contributions are also calculated on the basis of all the contribution-related costs according to the cost accounting data. As with the fee-related costs, the contribution-related costs (staff costs and other expenditure) are recorded and allocated according to service and user group on a daily basis. The contribution per user group is calculated taking account of the number of frequencies assigned to each user group. The principle of solidarity applies within each user group, i.e. all user groups under the same service group pay, although one individual user group may have a financial advantage.

The annual contribution must be recalculated annually on a cost-recovery basis in relation to each user group.

The underlying principle in the calculation of frequency assignment fees and frequency usage contributions is that the fees and contributions must cover the staff costs and other expenditure associated with the activity in question. However, the cost-accounting method applied in Germany forms the basis for calculation.

5.2.5 Israel's experience with licence fees

The Ministry of Communications of the State of Israel has established a few licence mechanisms:

– one time payment for submittal of application for telecommunication service providing;

– annual fee for usage of the frequency spectrum;

– annual royalties, which are a percentage of the income, for telecommunications service provider;

– one time payment, payed by a winner of an auction.

Annual spectrum fees

As an amendment to the Wireless Telegraph Order, the Administration of Israel started annual spectrum fees in January 1995, in order to persuade operators and private users to pursue more efficient spectrum use. The Ministry of Communications may modify, once a year, the structure or the value of a specific fee. This is done through the Financial Committee of the Kneset (The Israeli Parliament), and any service provider or a private user of the spectrum who may be affected by those modifications, has the right to present his case to the Committee.

Because the fee decreases with frequencies above 960 MHz, the use of a higher frequency is encouraged. Below 960 MHz, the spectrum fee is about USD 170 000 per 1 MHz. This approach has been taken to encourage the use of less occupied bands and to encourage spectrum users to take advantage of the higher frequency reuse associated with high attenuation and lower antenna side-lobes at higher frequencies.

The frequencies spectrum fees are categorized to different services, such as:

– Private mobile radio

– Trunking mobile radio service providers

– Cellular service providers

– TV and radio broadcasting

– Microwave point-to-point link

– Fixed wireless access

– Satellite communication (private and commercial users)

– Radio amateurs

– Aeronautical and maritime services
– Temporary licences for tests or demonstrations.

The fee system has some measures to encourage better and higher reuse of frequencies. Some examples are:

– Lower fee for lower transmission power, for TV and radio broadcasters
– Discount for TV broadcasters which reuse the same frequency in different locations
– No charge for radio broadcasters that reuse the same frequency in additional locations
– Discount for telecom service providers which reuse the same frequency for multiple point-to-point microwave links.

Some examples from Israel's short experience of the last few years, utilizing incentive fees:

– Within two years all point-to-point links on frequencies below 960 MHz (about 100), were relocated to higher frequencies.
– An agreement with TV broadcasters to modify frequencies, to obtain more efficient use of the spectrum.
– Migration of different systems from frequencies below 1 GHz, to clear bandwidth for a third cellular operator in the GSM band.
– Some of the operators have been paid to move their systems, and the cost of this migration was covered by the licence fee advanced payment paid by the new entrant to the Government (not directly to the existing user of that spectrum).

5.2.6 Experience of the Kyrgyz Republic on application of licence fees

In 1997 in the Kyrgyz Republic, the independent regulating body of communications, the National Communications Agency (NCA), was established. According to the Law of the Kyrgyz Republic on "Postal and Telecommunications", accepted in 1998, spectrum management began.

In 1998 the NCA created a licence fee model. The purpose of this model was to increase spectrum efficiency, introduce a non-discriminatory approach to various categories of users, stimulate the use of unused frequency ranges, develop radiocommunication services throughout the Republic, and cover the cost of spectrum management.

The model determines the value of annual payment for the spectrum and contains the following basic elements:

– radio-frequency resource, used in the Republic, representing all frequency assignments stored in the national database, is determined on an annual basis. For each frequency assignment this resource is determined in view of the band used and the coordination area;
– the annual cost of spectrum management;
– the average price for the unit of the frequency resource used is determined from the above values;
– the annual payment of a specific user is determined from the value of the frequency resource used.

A number of incentive factors are entered in the formula, so the payment depends not only on the bandwidth used and coverage area, but also on geographical location of the station, population density in the coverage area, social factors, exclusivity, type of radiocomminication service, spectrum employment, and spectrum monitoring complexity.

The developed software allows the user at any moment to determine the value of the annual payment for the spectrum and also renders the model transparent and accessible to all users.

Thus, for the user the greater the bandwidth and the more populated the geographical area, the larger the payment. This encourages the use of more modern equipment, new frequency ranges and expansion of coverage to rural and remote areas.

The NCA has adopted licence terms of up to 7 years. Determination of the spectrum payment algorithm includes the determination of:

– the annual expenditures of the State on management of radio-frequency resource use and determination on this basis of the common value of the annual payment for all radio-frequency resources;
– the value of the radio-frequency resource;
– the price for a unit of the radio-frequency resource;
– the annual payment for a specific user on a differential and non-discriminatory basis, determined from the value of the frequency resource and the unit price of this resource.

5.2.6.1 Expenditures and income of the State on spectrum management

The total amount of the annual payments for spectrum, C_{ann}, collected from all users, can be submitted as:

$$C_{ann} = C_1 + C_2 \tag{5}$$

where:

C_{ann}: total annual cost of the users for the spectrum

C_1: share of resources that is necessary for covering of costs of the State on spectrum use management

C_2: net income of the State.

It is possible to separate the terms C_1 and C_2 into additional components:

$$C_1 = C_{11} + C_{12} + C_{13} \tag{6}$$

where:

C_{11}: means necessary for purchase and operation of a spectrum management system, including radiomonitoring station equipment, direction finders, computers, software, materials, amortization of buildings, etc.

C_{12}: means necessary for carrying out scientific research, purchase of scientific literature and recommendations, electromagnetic compatibility analysis, frequency assignment, coordination, etc.

C_{13}: spectrum management staff salaries.

Taxes are not included in the amounts C_{11}, C_{12}, C_{13}.

C_2 can be separated into the following components:

$$C_2 = C_{21} + C_{22} \tag{7}$$

where:

C_{21}: taxes imposed by State spectrum management agency on telecommunications equipment, software, materials etc.

C_{22}: payments for spectrum use. At present in Kyrgyzstan, to encourage development of radiocommunication services $C_{22} = 0$.

Formulas (5) and (7) do not take into account the indirect income of the State taxes on the incomes of telecommunication operators whose activity is connected with radio-frequency resource use (for example, taxes from the income of cellular communication operators). This component of the income of the State is essential and exceeds component C_{22}.

In essence C_{22} is an initial payment for spectrum. However, no telecommunication operator, especially in the developing countries, will immediately be able to make a large payment and this would be an obstacle to development. A good way to provide an economic incentive is reducing to a minimum the C_{22} component, so that the telecommunication operator may begin to provide service with no initial spectrum payment. The loss, C_{22}, will be compensated for the State by the taxes from the telecommunication operator's activity.

Thus, for the purposes of rapid development of telecommunication and information services in the country and the provision of economic incentives to the telecommunication operators, it is essential to hold spectrum payments to the minimum necessary for covering the costs of spectrum management.

5.2.6.2 Determination of the value of the radio spectrum

Proceeding from formulas (5), (6), and (7) it is possible to determine C_{ann}, representing annual payment for all radio-frequency resource, used in the country. Further this amount is necessary for collecting from all telecommunication operators using radio-frequency spectrum on a fair and non-discriminatory basis. To accomplish this, according to this Report and the ITU World Telecommunication Development Conference (Valetta, 1998), it is necessary to determine the value of the spectrum used by each operator.

Limitations regarding use of frequency assignments are given to users by the NCA. These limitations concern installation and operation of their radio equipment. The necessary information on all frequency assignments (frequency bands, transmitter capacity, geographical coordinates, antenna type and height of its installation, etc.) is stored in the national database. Total frequency assignments are designated as "*n*".

The method used is as follows.

For any *i*-th user on the basis of its frequency assignment characteristic incorporated in the national database, it is possible to determine a three-dimensional value of the spectrum used, as follows:

$$Z_i = F_i \cdot S_i \cdot t \quad (8)$$

where:

- Z_i: frequency resource used for *i*-th frequency assignment
- F_i: radio frequency band used for *i*-th frequency assignment
- S_i: area of the territory used for *i*-th frequency assignment
- t: time.

Each component may be considered in more detail:

a) The time t for all users is equal to one year ($t = 1$).

b) The population density of the territory is not uniform. The high population density area is more attractive to the telecommunication service operator. Therefore, the whole territory of the republic is divided into, m, territories according to its administrative structure and for each j-th territory, $1 \le j \le m$, the population density coefficient (according to the data of the census) is K_j (see Table 9). $K_j = 1$ for the area with the lowest population density.

TABLE 9

Population density coefficient for various territories of the Kyrgyz Republic

Designation – Province (oblast)	B_j
Naryn	1
Talas	3.7
Issyk-Kul	3.5
Jalal-Abad	5.6
Osh	5
Chuy	8
Cities and settlement of an urban type	
With a population of 10 000 to 50 000 inhabitants	16
With a population of 50 000 to 100 000 inhabitants	32
With a population of 100 000 to 500 000 inhabitants	64
With a population over 500 000 inhabitants	128

The population density coefficient permits a fair annual payment for users. Then, if the coordination area of *i*-th frequency assignment covers, q, sites in different territories, the area is determined as follows:

$$S_i = \sum_{j=1}^{q} K_j \lambda_j \qquad \text{km}^2 \tag{9}$$

where:

S_i: area of the territory used by the *i*-th frequency assignment

q: overall number of territories covered by coordination area of *i*-th frequency assignment ($q \leq m$)

K_j: population density coefficient in *j*-th territory (from Table 9)

λ_j: area of coordination area site located in *j*-th territory.

c) For each *i*-th frequency assignment, frequency band Δf_i is used. But different ranges are used by various radiocommunication services. Therefore there is a number of the coefficients, which are necessary to take into account, as they influence are the price of the frequency band used. In the general case it is possible to determine the value of the used frequency band for *i*-th frequency assignment, as follows:

$$F_i = \alpha_i \cdot \beta_i \cdot \Delta f_i \qquad \text{kHz} \tag{10}$$

where:

F_i: theoretical frequency band used by i-th frequency assignment

Δf_i: actual frequency band used by i-th frequency assignment

α_i: coefficient which takes into account a number of the factors, given below in equation (11)

β_i: coefficient which determines exclusiveness of use. If the given site of the spectrum is used on an exclusive basis then $\beta_i = 1$. With sharing β varies within the limits of $0 < \beta_i < 1$ depending on conditions of sharing.

It is possible to examine the coefficient α_i in more detail. A number of factors influence the value of α_i factor and it can be presented as product:

$$\alpha_i = \alpha_1 \cdot \alpha_2 \cdot \alpha_3 \cdot \alpha_4 \tag{11}$$

where:

α_i: general coefficient taking into account the various factors of spectrum use

α_1: commercial value of the spectrum range used

α_2: social factor

α_3: takes into account features of transmitter location

α_4: takes into account the complexity of spectrum management functions.

The values of coefficients α_1, α_2, α_3 and α_4.are given in Table 10.

Coefficient α_1 varies in limits from 0 up to 100 and, basically, is determined by two factors:

– the commercial value of radio services; this factor increases with value;

– many radio services may be moved to higher frequencies as experience is gained, thus, decreasing the loading of lower frequency bands. This is the economic level which encourages use of higher bands. For example, for the purposes of encouraging transition of stations at frequencies below 1 GHz to frequencies above 1 GHz, the value of the coefficient α_1 in the range above 1 GHz is less than the value used for stations below 1 GHz. Currently frequencies below 1 GHz are used by several radio services at the same site and hence there is also a question of their electromagnetic compatibility. The range above 1 GHz is poorly mastered in the Republic, but at the same time in the world the newest technologies are used which, allow effective use of the spectrum.

Coefficient α_2 varies in limits from 0 up to 10 and takes into account a social factor. For those radio services whose existence is vital for all sections of the population, including the most needy, this coefficient has a low value. For example, for stations above 1 GHz in which long-distance communications are organized, as well as for television broadcasting, the coefficient α_2 has a low value. However, for cellular communication, coefficient α_2 has a higher value.

TABLE 10

Values of coefficients α_1, α_2, α_3, α_4

Service \ α	α_1	α_2	α_3		α_4
			City	**Village**	
Radio-relay line in a range above 1 GHz	0.5	0.30	1	0.1	1
Radio-relay line in a range below 1 GHz	1	4.00	1	0.1	1
Television in meter range (MW TV)	5	0.30	1	0.1	5
Television in meter range (DMW TV)	5	0.40	1	0.1	5
USW broadcasting	12	5.00	1	0.1	5
SW broadcasting	5	5.00	1	0.1	4
SW radiocommunication	13	6.00	1	0.1	4
Trunking	12	6.00	1	0.1	5
Cellular communication	13	6.00	1	0.1	5
Paging	60	6.00	1	0.1	5
Mobile communication	10	6.00	1	0.1	5
Radiocommunication in CB range	0.12	1.00	1	0.1	1
Radiolocation	0.15	0.10	1	0.1	1
The security radio signal system	6	1.0	1	0.1	2
Earth station for fixed-satellite service	40	1.00 0.30*	1	0.1	1
Feeder link for broadcasting-satellite service	7	0.30	1	0.1	1

NOTE 1 – α_2* – Value taking into account a social factor is entered for international organizations working in the territory of the Kyrgyz Republic, not representing commercial communication services and whose activity is directed towards stability of economy, development of a science, or culture.

Coefficient α_3 takes into account features of site location in urban and rural areas. In rural areas, where the density of the population and the level of incomes is low, the commercial value of communication services is also low and the technological costs of providing these services is high. Therefore with the purpose of support of these telecommunication operators and services, as well as for encouraging development of radiocommunication services, there is a reduction coefficient $\alpha_3 = 0.1$ (in urban district $\alpha_3 = 1$).

Coefficient α_4 varies in limits from 0 up to 10 and is determined by the complexity of spectrum management functions performed. This coefficient is the highest for mobile services, as here it is required to carry out the function of radiodetermination of mobile objects, and for television broadcasting, where it is required to determine with high accuracy a number of parameters.

Thus, with the help of weighting coefficients K_j, α_i, and β_i in formulas (9) and (10), according to formula (8) it is possible to determine the given (in view of the various factors) frequency resource Z_i for each frequency assignment. Then it is possible to determine the general frequency resource used in the Kyrgyz Republic, according to formula (12):

$$Z = L \sum_{i=1}^{n} Z_i \qquad \text{kHz} \cdot \text{km}^2 \cdot 1 \text{ year} \qquad (12)$$

where:

Z: general frequency resource used in the Republic

Z_i: frequency resource used with i-th frequency assignment

n: overall number of frequency assignments registered in the national database

L: estimated expansion coefficient for the spectrum used. The introduction of this coefficient permits prices for spectrum to be determined in advance for the next fiscal year.

5.2.6.3 Price for the unit of the frequency resource used

On the basis of formula (5) and in view of formulas (6) and (7) the total amount of annual payments is determined.

On the basis of formula (12) the value of the spectrum annually used in the Republic is determined.

Then it is possible to determine the price of ΔC_{ann} for a conventional unit of the frequency resource:

$$\Delta C_{ann} = \frac{C_{ann}}{Z} \left(\frac{Som^*}{\text{kHz} \cdot \text{km}^2 \cdot \text{year}} \right) \tag{13}$$

Som^*: name of the national currency.

5.2.6.4 Annual fees for a particular frequency assignment

According to formula (13) the price ΔC_{ann} for the conventional unit of the frequency resource is determined.

According to formula (8) the frequency resource Z_i used for a particular frequency assignment is determined. Then the amount of the annual payment C_i from a specific user of the spectrum for a specific i-th frequency assignment is determined by formula (14):

$$C_i = \Delta C_{ann} \cdot Z_i \tag{14}$$

If any telecommunication operator has more than one frequency assignment, the payment for each assignment is determined and then they are summated.

5.2.6.5 Application of the method

This method is authorized by the NCA in a text on determination of the annual payment for all the spectrum used in the Republic. Its application is coordinated with the National Commission of the Kyrgyz Republic on Protection and Development of Competition.

There is software for the national database on frequency assignments, and calculation of the payment for a specific user does not present difficulties.

Seminars for telecommunication operators regarding this method were conducted. Because the method is known for practically all users, transparency is provided.

5.2.6.6 Funding the monitoring system

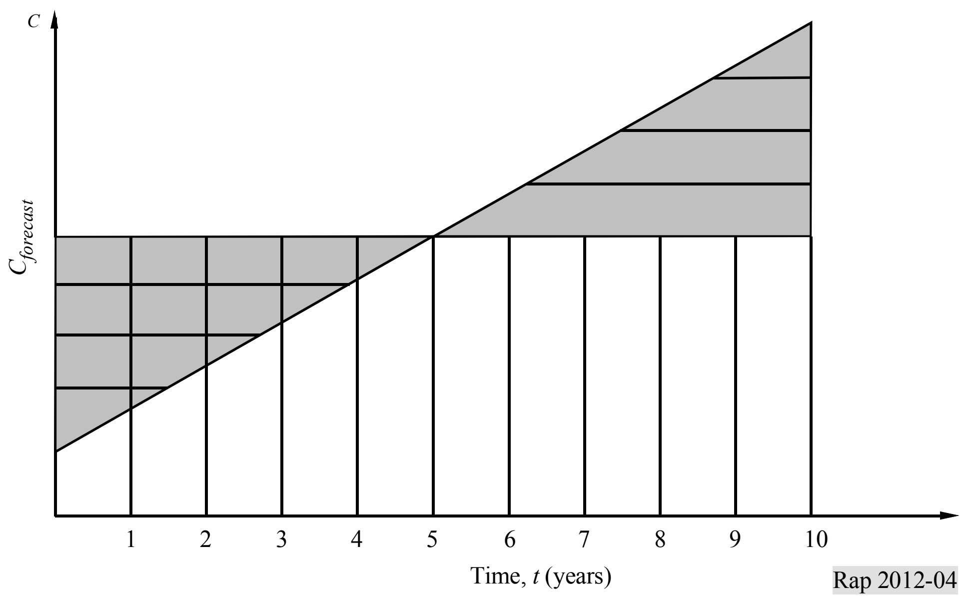
The Kyrgyz Republic, like the majority of new and developing countries, experienced difficulties in funding a modern system of spectrum management. The greatest difficulty was the funding of the national automated radio monitoring system, which can ensure effective spectrum management. Such a system is necessary, but its cost is high. The condition of the State budget does not allow funding of such a system.

One of the ways to fund such a system is a loan on preferential terms from international financial organizations or from other countries. The principal could be included in the amount of the annual payment and gradually returned to the creditor. The mechanism of return of the principal is shown in Fig. 4. It is possible to return the principal in equal payments each year. However, the payment (principal and interest) would be very high in the first years of return of the principal.

Such payments would result in substantial growth of expenses of the telecommunication operators and a rise in price of their services. Accordingly development would be impaired and in some cases operators would fail. The delay of expansion of telecommunication services would cause not only reduction of tax receipts, but a recession, as has happened in the past.

FIGURE 4

Mechanism of return of the principal



A different approach is possible. Based on the experience of other countries, the number of the spectrum users will grow. Therefore, it is possible within reasonable limits to increase the price for the unit of the spectrum and to support it in hard currency until the annual total fee has reached the forecast size, $C_{forecast}$, n the middle of an amortization period (for example, 5 years after installation of the equipment, assuming the loan is for 10 years).

The total amount of the taxes for 10 years (including the principal, which it is necessary to return within 10 years) is equivalent to the area shaded by vertical lines. For the first 5 years there would be a shortage, equivalent to the area shaded with vertical and horizontal lines, whereas in the next 5 years there would be a surplus (area shaded with horizontal lines). The main advantage of such policy would be price stability, which would allow the telecommunication operators to plan their incomes, expenditures and development of services.

Of course, the above would be only the initial approach to price policy. If it will possible to forecast more accurately and to determine more precisely the price policy based on actual conditions, it would be possible to make faster payments.

The above technique would allow to determine the Republic tariff policy regarding spectrum use in view of conditions of loan repayments, thus keeping a non-discriminatory approach to the various spectrum users.

5.2.7 The Russian Federation's experience with licence fees

With a view to ensuring more efficient use of the radio-frequency spectrum, the Government of the Russian Federation adopted a decree in June 1998 on the "Introduction of charges for use of the radio-frequency spectrum". Under this decree, with effect from September 1998, businesses, individual entrepreneurs and other persons using the radio-frequency spectrum in the Russian Federation for the provision of telecommunication services to commercial ends are charged for such use, pursuant to the "List of telecommunication services for whose provision use of the radio-frequency spectrum shall be on a paid basis" set forth in the decree.

Operators providing the following types of service are required to pay for use of the spectrum:

– mobile telephony
– cellular telephony
– radio paging
– radio paging with VHF FM channel multiplexing
– global mobile personal communications by satellite
– distribution of television programmes using MMDS, LMDS and MVDS type systems.

For implementation of the fees for use of the spectrum, regulations were also adopted on "Payment for use of the radio-frequency spectrum in the Russian Federation". The regulations set out the basic principles and general conditions for payment for the use of radio channels by all organizations – irrespective of their type of ownership – and individual entrepreneurs that use the radio-frequency spectrum in the territory of the Russian Federation for the provision of commercial telecommunication services. Charges for use of the spectrum are set separately for each category of service, depending on the service area, number of channels used and the bandwidth used.

The amount of the charge levied for use of the spectrum is set annually. Annual charges for use of the spectrum are payable to Russia's national frequency management authority, in equal quarterly instalments, not later than the fifth day of the first month of each quarter.

The payment is distributed as follows:

– 50% to cover the expenses of the national spectrum management authorities;
– 50% as income to the federal budget.

Failure to respect the procedures for payment for use of the spectrum constitutes grounds for withdrawal of the licence for provision of the telecommunication services for which the spectrum is used.

5.2.8 The United Kingdom's experience with licence fees

In the United Kingdom, the Radiocommunications Agency (RA), which is an "executive agency" of the United Kingdom Department of Trade and Industry, is responsible for non-military radio spectrum and for representing both civil and military users in international discussions on radio matters.

For many years the United Kingdom has operated a cost-recovery system based on the direct and indirect costs of spectrum management. Fees have been charged on an annual basis although, to improve the cash flow payments for users with a large number of licences, payments could be made in 3 or 6 month instalments. Since the early 1990s the demand for spectrum access has dramatically increased, especially in bands suitable for mobile communications, and new types of service have required access to spectrum. In part this increase in demand is due to deregulation of telecommunications provision and a subsequent increase in competition as new services were introduced. At the same time, technical and market developments, such as convergence, have accelerated in often unpredictable ways. This has led to areas of high spectrum congestion and in parts of the country there is virtually no spectrum available below 25 GHz – due to the high population density (approximately 20 million in the south east of England) and the communications infrastructure needed to support their requirements, the requirements of major users (including five international airports and the world's busiest shipping lane) and international sharing constraints. Despite this limitation in spectrum availability, demand for access in the United Kingdom is continuing to grow and in some cases the rate of growth in demand is increasing.

The Government was concerned that unless spectrum could be made available for new services and users, there was a real danger that spectrum congestion and shortages would hold back growth and slow down innovation. Further having pioneered studies into the economic benefits arising from the use of radio (see Chapter 3) it was aware that failure to make the best possible use of the spectrum resource could impose substantial costs on users, including loss of international competitiveness and there could be a consequential impact on other areas of the United Kingdom economy. A combined impact on the United Kingdom economy in the order of 1 000s of millions of pounds.

The RA recognized that the existing frequency allocation and assignment processes could not cope with the rising level of demand for spectrum. Specific problems identified were:

– the existing frequency assignment/licensing process could control only frequency acquisition, and did not have the flexibility to regulate demand or make more spectrum available in congested areas without adversely affecting users in others areas of the country;
– users had little incentive to give up unused or under-utilized spectrum or to invest in more spectrum-efficient technology or services;
– the administrative procedures for changing spectrum allocations and assignments were too slow in responding to changes in users requirements and technological development, thus retarding technical progress and innovation.

Hence new spectrum management tools were needed to deliver a faster and more responsive service to users. It was understood that individual radio services have different characteristics and may require different approaches. Thus a change to the frequency assignment/licensing process would have to recognize the requirements of the differing services and therefore may not be applicable to all services and frequency bands.

The solution adopted was the introduction of spectrum pricing which would be selectively applied in congested frequency bands as a complement to the existing licensing process. Thus a combination of administrative incentive pricing (taking into consideration opportunity costs) and regulatory pricing is being used to manage spectrum for most mobile radio and point-to-point fixed links, while a regulatory pricing continues to be sufficient for some other licence classes.

5.2.8.1 Legislative changes

The Wireless Telegraphy Act 1998, which entered into force in June 1998, substituted spectrum pricing for cost recovery as the basis for setting radio spectrum licence fees in the United Kingdom. In accordance with Article 11.2 of the EU Licensing Directive (see Note 1), it is a cardinal principle in the United Kingdom that spectrum pricing should be used to achieve spectrum management objectives, not to maximize licence revenue. Since other EU Member States are also subject to Article 11.2, the transposition of this provision into United Kingdom law and its mode of application may have wider interest.

The Act introduced two forms of spectrum pricing:

– auctions, in which fees are set directly by the market; and
– "administrative incentive pricing", in which fees are set on the basis of spectrum management criteria by the spectrum manager as a surrogate for market forces.

The legislation was preceded by widespread public consultation, including a consultative document [RA,1994], White Paper [HMSO, 1996] and a study of the application of spectrum pricing [RA, 1996]. This consultation demonstrated widespread support for spectrum pricing in principle and helped construct consensus for reform. There has since been further extensive consultation on detailed implementation [RA, 1997 and 1998]. The majority of licence fees are set by a combination of administrative incentive pricing and the opportunity costs arising from the nearest alternative, or regulatory pricing rather than auctions which are only considered to be applicable in specific circumstances and have still to be implemented in the United Kingdom.

The 1998 Act requires the Secretary of State, in setting spectrum licence fees, to have regard in particular to various spectrum management factors. These are:

– the balance between spectrum availability and current and expected future demand; and
– the desirability of promoting:
  – efficient spectrum use and management;
  – economic benefits;
  – development of innovative services; and
  – competition.

The legislation therefore ensures that spectrum pricing cannot be used as a form of taxation. Indeed, the Act ended the statutory requirement for licence fee regulations to be approved by the Treasury. Under proposals for administrative incentive pricing in the United Kingdom, although some users with exclusive national channels or assignments in parts of the country affected by congestion will pay higher fees, tens of thousands of smaller business users will pay no more than previously or will benefit from fee reductions. Even where fees are increased, they will be no higher than necessary for spectrum management purposes.

NOTE 1 – Directive 97/13/EC. Article 11.2 states, “Member States may, where scarce resources are to be used, allow their national regulatory authorities to impose charges which reflect the need to ensure the optimal use of these resources. Those charges shall be non-discriminatory and take into particular account the need to foster the development of innovative services and competition.”

5.2.8.2 Setting licence fees in practice

The United Kingdom methodology may be summarized as follows.

– *Define alternatives to the current assignment*. For example, in the case of private business radio used by taxi firms, couriers etc. the use of narrow-band technology, trunked systems, more efficient sharing and reuse and moving to a different frequency band.
– *Cost the alternatives over the lifetime of the equipment*. The additional cost of the cheapest alternative compared to current radio costs (in the example quoted above this was a move to trunked systems) provides a measure of the marginal value of the spectrum for the specific application. In the case of mobile radio, the marginal values differed between services and it was decided to apply an average “spectrum tariff unit” to all mobile radio in the interests of fair competition. This amounts to about £1.65/MHz/km^2.
– *Derive licence fees from the marginal value of spectrum* on the basis of pre-selected parameters. In the example of private business radio, those proposed are bandwidth, coverage area and the degree of sharing as indicated by the number of mobiles as a proxy for traffic generated. Location is also taken into account with higher fees in congested areas. Congestion is quantified on the basis of a formula for each cell in a grid of 10 km × 10 km squares covering the whole country, leading to the definition for mobile radio of three charging regions:
  – central London, which is heavily congested;

  – Birmingham, Manchester and Liverpool, which are congested; and
  – the rest of the country, which is uncongested.

  Fees for exclusive regional and national channels can also be derived.

– *Apply "modifiers"*, i.e. numerical factors to take account of various spectrum management factors, such as competition, choice and diversity, quality of service and spectrum usage constraints. For example, in the case of mobile radio, spectrum above 1 GHz is considered less valuable than spectrum below that frequency because of its propagation characteristics.

5.2.8.3 Phased implementation of administrative incentive pricing

The new regime is being implemented in three waves, each phased in over 4 years so that users have an opportunity to adjust.

– The first wave of incentive pricing, which began in July 1998, tackled the worst distortions of the previous cost-based regime by increasing fees for mobile telecommunications networks and reducing them for thousands of users of on-site private business radio.
– The second wave, which began in July 1999, will extend spectrum pricing principles to other mobile radio and point-to-point fixed links. Fees for national telecommunications networks will continue to increase, but smaller private business radio users will continue to benefit from fee reductions outside congested areas.
– The third wave, due to commence in July 2000, will cover other licence classes, including broadcasting, which raises special issues on some broadcasting franchises, as opposed to spectrum licences.

This will also enable the effects to be monitored and licence fees to be modified if necessary to achieve the desired spectrum management objectives.

5.2.8.4 Affordability

The Agency has published detailed Regulatory Impact Assessments for the first and second waves of administrative pricing. These documents analyse the business sectors affected and the costs and benefits of the new policy with particular reference to small businesses. For the second wave, the Agency estimates that:

– over 60% of the current 57 000 private business radio licensees will pay no more than at present or enjoy fee reductions of up to 65%;
– the fee increases for a small private business radio user, such as a taxi company, that will pay more would be no more than 8p per taxi per week;
– the increase for a mobile telecommunications network would amount to just 5p per subscriber per week and even this modest amount may not be passed on to subscribers in view of fierce market competition;
– the potential economic benefits from the greater spectrum efficiency spectrum pricing should promote would far exceed the costs to business of the additional licence revenue.

As can be seen, planned fee increases are modest. The figures convincingly demonstrate that spectrum pricing in the United Kingdom will not make radio too expensive for businesses to afford.

5.2.8.5 Spectrum pricing in the public sector

It has been a consistent feature of United Kingdom policy that the public sector, including the armed forces and emergency services, should be charged for spectrum on a comparable basis to the private sector. The public sector is a major user of spectrum. For example, the armed forces occupy more than 30% of the spectrum between 9 kHz and 30 GHz. It is seen as important that the public sector should also have incentives to use spectrum more efficiently and this has been a key factor in securing general acceptance of spectrum pricing.

Comparability is being achieved through the application of spectrum pricing principles to public sector users, including the armed forces. The details of how public sector spectrum will be valued are under negotiation with the other departments concerned, but the principle is established as an essential component of the new regime.

5.2.9 United States of America's experience with licence fees

The FCC regulates both spectrum and wired services for the civilian sector and charges application fees (also known as filing fees) and regulatory fees (information is included here for wired services only for background and completeness). The FCC process of imposing and collecting fees is mandated by statute of the U.S. Congress solely as a means to reimburse costs of issuing licences and of associated regulatory services.

In 1987, the FCC began collecting application fees that are charged for all FCC-licensed radio services and are intended to cover the direct administrative costs of processing a licence application. They are paid when a licence is obtained or renewed. Local and state governments and non-profit entities are generally exempt from application fees. Application fees vary from service to service.

The authority to impose and collect application fees was not assumed independently by the FCC, but was established by the U.S. Congress and is contained in Title III, Section 3001 of the Omnibus Budget Reconciliation Act of 1989 (Public Law 101-239), Section 8, revising 47 U.S.C. 158, which directs the FCC to prescribe charges for certain types of application processing or authorization services it provides to communications entities over which it has jurisdiction. Funds collected as application or filing fees pursuant to Section 8 of the Act are deposited into the General Fund of the U.S. Treasury as reimbursement to the United States of America Federal Government. They do not offset funds appropriated to the FCC (47 U.S.C. 158(a)). Section 8(b) of the Communications Act, as amended, requires that the FCC review and adjust its application fees every two years after 1 October 1991 (47 U.S.C. Section 158(b)). The adjusted or increased fees reflect the net change in the Consumer Price Index for all Urban Consumers (CPI-U).

Since 1990, the FCC has collected application fees averaging about USD 39 million annually. The programme encompasses over 300 different fees with the vast majority collected at the time an original licence application, renewal or request for licence modification is filed with the FCC.

Most fees are assessed as a one-time charge on a per-application basis, although there are certain exceptions. Local (state, county, city, etc.) government, non-profit, non-commercial broadcast and amateur licence applicants are exempt from the fees.

The schedule of charges is exactly as reviewed and approved by Congress. The charges represent the best estimate of the FCC's actual direct administrative costs of processing a licence application.

In 1993, Congress mandated that the FCC must collect regulatory fees to cover its enforcement activities, policy and rule-making activities, user information services, and international activities. Consequently, regulatory-related fees were implemented in 1994.

The requirement to collect annual regulatory fees is contained in Public Law 103-66 "The Omnibus Budget Reconciliation Act of 1993". These regulatory fees, which may change yearly, are used to offset costs associated with the FCC's enforcement, public service, international, policy and rulemaking activities. These fees are in addition to any application processing fees associated with obtaining a licence or other authorization from the FCC.

Without regulatory fees to offset the FCC's costs, the agency would have required a Congressional appropriation of USD 189 million for fiscal year 1997 (1 October 1996 to 30 September 1998).

When offsetting regulatory fees (USD 152 million) were taken into consideration, only USD 37 million had to be appropriated from the U.S. Treasury to fund the FCC.

By statute, the total fees collected should cover, but cannot exceed, the amount of money appropriated by Congress to the FCC for these activities. Regulatory fees collected are deposited into an account providing appropriations to the FCC.

Some of the activities included in the regulatory fees are considered below.

5.2.9.1 Policy and rulemaking

Formal inquiries, rulemaking proceedings to establish or amend the FCC's rules and regulations, action on petitions for rulemaking, and requests for rule interpretations or waivers; economic studies and analyses; spectrum planning, modelling, propagation-interference analyses, and allocation; and development of equipment standards. This also includes policy direction, programme development, legal services, and executive direction, as well as support services associated with policy and rulemaking activities.

5.2.9.2 Enforcement

Enforcement of the FCC's rules, regulations and authorizations, including investigations, inspections, compliance monitoring, and sanctions of all types. This also includes the receipt and disposition of formal and informal complaints regarding common carrier rates and services, the review and acceptance/rejection of carrier tariffs, and the review, prescription and audit of carrier accounting practices. It also includes policy direction, programme development, legal services, and executive direction, as well as support services associated with enforcement activities.

5.2.9.3 Public information services

The publication and dissemination of FCC decisions and actions, and related activities; public reference and library services; the duplication and dissemination of FCC records and databases; the receipt and disposition of public inquiries; consumer, small business, and public assistance; and public affairs and media relations. This activity also includes policy direction, programme development, legal services, and executive direction, as well as support services associated with public information activities.

The following licensees and other entities regulated by the FCC must pay regulatory fees:

Common carrier regulatees: inter-exchange carriers (long-distance companies), local exchange carriers (local telephone operating companies), competitive access providers (companies other than the traditional local telephone companies that provide interstate access services to long-distance carriers and other companies), operator service providers (carriers that enable customers to make away from home calls and to place calls with alternative billing arrangements), pay telephone operators (owners of pay telephones), resellers (companies that obtain lines from facilities-based carriers and sell service to others, but does not include mobile resellers governed by the commercial wireless radio services), and other interstate providers (e.g., calling card providers).

Commercial mobile radio services (CMRS) regulatees: specialized mobile radio services (Part 90); public coast stations (Part 80); public mobile radio, cellular, 800 MHz air-ground radiotelephone, and offshore radio services (Part 22); and PCS broadband services (Part 24). The CMRS messaging services category includes all one-way paging (Parts 22 and 90), two-way paging, qualifying interconnected business radio services, 220-222 MHz land mobile systems (Part 90), and PCS narrow-band services (Part 24). All other private wireless regulatory fees are paid in advance for the full licence term and submitted along with the appropriate application fee.

Mass media licensees: commercial AM and FM radio stations, commercial TV stations, low power television and television translator and booster licensees, broadcast auxiliary, FM translator and FM booster licensees, and multipoint distribution service licensees (includes multichannel multipoint distribution service). Non-commercial educational licensees are exempt from regulatory fees as are licensees of auxiliary broadcast services such as low power auxiliary stations, television auxiliary service stations, remote pickup stations and aural broadcast auxiliary stations where such licences are used in conjunction with commonly owned non-commercial educational stations. Emergency alert system (EAS) licences for auxiliary service facilities are also exempt as are instructional television fixed service (ITFS) licensees. In the event that there has been a change in ownership of a system after the effective date, but before the date payment is due, responsibility for payment of the regulatory fees rests with the owner of record on the effective date noted.

Cable television systems: cable television systems operating on 31 December 1996, were requested to pay regulatory fees per subscriber in the fiscal year 1997. All cable television systems were requested to pay regulatory fees of USD 0.54 per subscriber for each community unit in which they operate. Additionally, each system operating on 1 October 1996, was requested to pay a USD 65.00 fee for each community antenna relay service licence held and, if applicable, a USD 25.00 fee for each broadcast auxiliary service licence held. In the event that there had been a change in ownership of a system after the effective dates above, but before the date payment was due, responsibility for payment of the regulatory fees rested with the owner of record on the appropriate effective date noted above.

International public fixed licensees (Part 23), international (HF) broadcast licensees (Part 73), providers of international bearer circuits, earth station regulatees (Part 25), geosynchronous space station regulatees (Part 25) and direct broadcast satellite licensees (Part 100), and low-Earth orbit system licensees (Part 25).

Local governments and non-profit entities are not required to pay regulatory fees. However, the FCC is considering a proposal which would require that each exempt entity submit, or have on file with the FCC, a current internal revenue service determination letter documenting its non-profit status, a certification of local governmental authority, or certification from a local governmental authority attesting to its exempt status. Under the proposal, a regulatee would be relieved of its fee payment requirement if its total fee due, including all categories of fees, amounts to less than USD 10.

For the fiscal year 1997, the FCC adjusted the estimated regulatory payment units for each service from the fiscal year 1996 fees. The FCC obtained its estimated payment units through a variety of means, including its licensee databases, actual prior-year payment records, and industry and trade group projections. Whenever possible, the FCC verified these estimates from multiple sources to ensure their accuracy.

The FCC multiplied the revised payment units for each service by its fiscal year 1996 fee amounts in each fee category to estimate how much revenue the FCC would collect in the fiscal year 1997 without any change to the existing schedule of regulatory fees. The amount of revenue the FCC would have collected was approximately USD 137.3 million. This amount was approximately USD 15.2 million less than the amount the FCC was required to collect in the fiscal year 1997. The FCC therefore adjusted the revenue requirements for each fee category on a proportional basis, consistent with Section 9(b)(2) of the Act, to obtain an estimate of revenue requirements for each fee category necessary to collect the USD 152 million required by Congress for the fiscal year 1997.

On 1 October 1995, the FCC implemented, in accordance with 47 U.S.C. § 159(i), a cost accounting system designed, in part, to provide the FCC with useful data, in combination with other information, to help ensure that fees closely reflected the FCC's actual costs of regulation.

In order to utilize actual costs derived from the FCC's cost accounting system for fee development purposes, indirect support costs contained in the cost accounting system had to be added to direct costs (see Note 1) and the results adjusted further to approximate the amount of revenue that Congress required the FCC to collect in the fiscal year 1997 (USD 152 million) (see Note 2). Thus, the FCC proportionally adjusted the actual cost data related to regulatory fee activities recorded for the period 1 October 1995, through 30 September 1996, among the fee categories so that total costs approximated the USD 152 million.

The FCC's next step was to determine whether reliance on actual costs to develop fiscal year 1997 regulatory fees would result in fees which were too disparate from the corresponding fiscal year 1996 fees. As a result of this analysis, the FCC proposed establishing a ceiling of 25% on the increase in the revenue requirement of any service over and above the Congressionally mandated overall increase in the revenue requirement and after taking into consideration changes in payment unit counts (see Note 3).

Because Congress, for the fiscal year 1997, increased the FCC's overall fee collection requirement, the FCC was required to collect substantially more than it collected in the fiscal year 1996. Nevertheless, capping each service's revenue requirement at no more than a 25% increase enabled the FCC to begin the process of realigning fees to account for differences in regulatory costs. The 25% increase was over and above the revenue which was required after adjusting for the projected fiscal year 1997 payment units and the proportional share of the 21% increased in the amount that Congress requires the FCC to collect. Thus, the fiscal year 1997 fees increased by more than 25% over the fiscal year 1996 fees. Under this methodology, fees actually increased by as much as 40%.

An important consideration in establishing a revenue ceiling is the impact on other fee payers. Because the FCC was required to collect USD 152 million in the fiscal year 1997 regulatory fees, the additional revenue that would have been collected from classes of licensees subject to a revenue ceiling, instead needs to be collected from licensees not subject to the ceiling. This results in a certain amount of cross-subsidization between fee payer classes (see Note 4). The FCC asserted, however, that the public interest would best be served by adopting a revenue ceiling because, otherwise, several entities would be subjected to unexpected, substantial increases which could severely impact the economic well being of these licensees.

Regulation of interstate telephone service providers accounts for approximately 36% of all FCC costs. Therefore, any methodology which employs a subsidization feature, such as the FCC's proposed revenue ceiling, will impact these regulatees to a greater extent than others, at least in the short term. As other fee payers' fees approach amounts that bring their revenues closer to their actual costs, as the FCC's phased-in revenue ceiling technique would do, the amount of subsidization required of fee payers below their revenue ceilings (such as those common carriers providing interstate telephone service) will steadily decrease. Thus, in the long term, cross-subsidization will decrease and revenue requirements for all services will approach actual costs (assuming other factors, such as the total amount that Congress requires the FCC to collect, remain constant).

The FCC adopted the 25% revenue ceiling as proposed. Application of the 25% ceiling was accomplished by choosing a "target" fee revenue requirement for each individual fee category. This "target" was either the actual calculated revenue requirement (for those categories at or below the 25% ceiling) or, in cases where the calculated revenue exceeded the ceiling, an amount equal to the ceiling. The shortfall created by reducing the revenue requirement of those whose revenue requirement exceeded the revenue ceiling was proportionately spread among those fee categories whose revenue requirements were below the ceiling. This computation required more than one round of adjustment because the allocation of this revenue, in a few instances, caused the new revenue requirement amount to exceed the 25% ceiling. After two iterations (rounds), all the revenue requirements were at or below the revenue ceiling.

Once the FCC determined the amount of fee revenue needed to be collected from each class of licensee, the FCC divided the individual revenue requirements by the number of associated payment units (and by the licence term, if applicable, for "small" fees) to obtain actual fee amounts for each fee category. These calculated fee amounts were then rounded to an even amount.

NOTE 1 – One feature of the cost accounting system is that it separately identifies direct and indirect costs. Direct costs include salary and expenses for

a) staff directly assigned to the FCC's operating Bureaus and performing regulatory activities and

b) staff assigned outside the operating Bureaus to the extent that their time is spent performing regulatory activities pertinent to an operating Bureau.

These costs include rent, utilities and contractual costs attributable to such personnel. Indirect costs include support personnel assigned to overhead functions such as field and laboratory staff and certain staff assigned to the Office of the Managing Director. The combining of direct and indirect costs is accomplished on a proportional basis among all fee categories.

NOTE 2 – Congress' estimate of costs to be recovered through regulatory fees is generally determined at least twelve months before the end of the fiscal year to which the fees actually apply. As such, year-end actual activity costs will not equal exactly the amount Congress designates for collection in a particular fiscal year.

NOTE 3 – For example, the regulatory cost associated with the Aviation (Aircraft) service is USD 934 905. If no change were made to this service's fiscal year 1996 regulatory fee (USD 3 per year), the total revenue collected from licensees in this service would have been only USD 70 634 in the fiscal year 1997, a shortfall of USD 864 271. Application of the proposed 25% revenue ceiling to this service resulted in a capped revenue ceiling of USD 88 293 (USD 70 634 × 125%).

NOTE 4 – Revenues from current fee payers already offset significant costs attributable to regulatees exempt from payment of a fee or otherwise not subject to a fee pursuant to Section 9(h) of the Act or the Commission's rules. For example, CB and ship radio station users, amateur radio licensees, governmental entities, licensees in the public safety radio services, and all non-profit groups are not required to pay a fee. The costs of regulating these entities are borne by those regulatees subject to a fee requirement.

5.2.10 Brazil's experience with spectrum fees

The Brazilian General Telecommunication Law, issued in 1997, established that the use of radio frequency for any service would always be charged. The value of the charge should alternatively be:

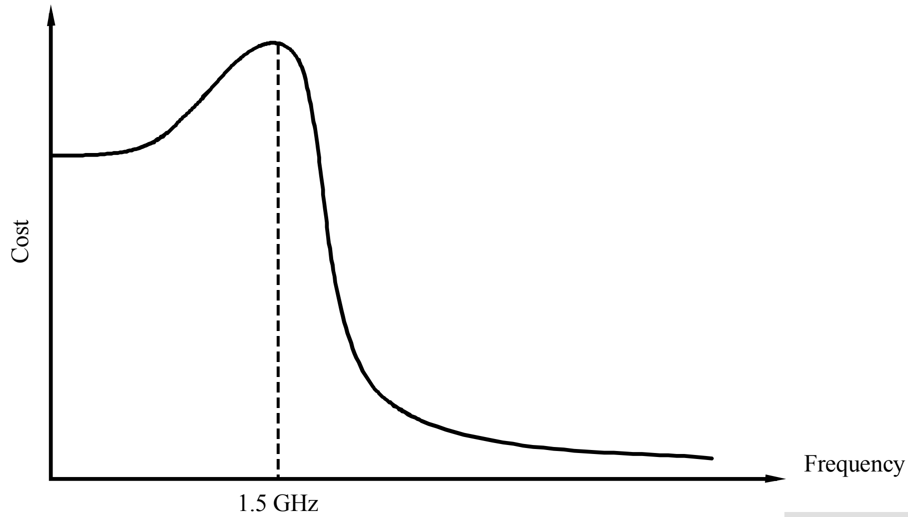
– determined by the regulations or the tender invitation document; or

– established as per the winning proposal, when it becomes a judgement item or established in the concession contract or license act, in the cases where bidding is not required.

In 1998, the National Telecommunication Agency issued a Regulation on the Collection of Public Fees for the Right to Use Radio Frequencies. The main premise of such rules was that the price should be based on how one precludes the use of a specific radio frequency to other users. So the following aspects were considered: time, space (geographic area), bandwidth and frequency band.

It was considered that the frequency bands around 1.5 GHz are, from the economic point of view, more important than any other, and so they should have a higher value. Consequently, two functions were defined to describe such idea, which is illustrated in the Fig. 5.

FIGURE 5



Rap 2012-05

For a centre frequency f (kHz) less than, or equal to, 1.5 GHz:

$$F(f) = 0.05 + 0.011 \times 10^{-6\left(\log\left(\frac{f}{1\,500\,000}\right)\right)^2}$$

For a centre frequency f (kHz) greater than 1.5 GHz:

$$F(f) = 0.001 + 0.06 \times 10^{-6\left(\log\left(\frac{f}{1\,500\,000}\right)\right)^2}$$

It is important to note that the procedure described for the calculation of the public fee applies to the authorization of use of any frequency within the entire radio frequency band.

The reference value, *P*

A reference value for the right to use radio frequencies is obtained by applying the following formula:

$$P = K \cdot B \cdot A^{0.1} \cdot T \cdot F(f)$$

where:

- B: bandwidth to be authorized (kHz)
- A: geographic area in which the frequency shall be used (km^2)
- T: factor related to the time period of use
- $F(f)$: frequency factor, according to the expression given above
- f: centre frequency of the operating frequency band (kHz)
- K: cost factor of radio frequency.

The value of frequency, *f*, to be utilized in the formula shall be the average value of the minimum and maximum authorized frequencies, and, in the case that a specific channel is used, such value shall be equal to that of the carrier frequency of the mentioned channel.

The bandwidth, *B*

As regards exclusive use, the value of bandwidth B to be used in the formula is that of the total authorized band, whereas as regards non-exclusive use, the value to be considered is that of the authorized bandwidth, according to the emission designation.

The area, *A*

As regards exclusive use, the value of area A to be used in the formula is that of the region for which the service was authorized, or the designated area covered by the station. Whereas as regards non-exclusive use, the value of area A shall be that which is indicated in the license. If no such indication exists, the value of the area shall be that of the surface defined by the circular sector of radius d and aperture α, that is:

$$A = \pi \cdot d^2 \cdot \frac{\alpha}{360°}$$

For point-to-point systems, d is the distance (km) between the stations involved and α is the half-power angle (degrees) of the radiating system. For point-area systems, the distance, d, to be considered is the farthest distance (km) covered by the nodal station.

Under any circumstances, the surface to be considered in the calculation of the area shall be limited to the national territory, including the Brazilian territorial waters.

The minimum value of the area shall be 1 km^2.

With respect to earth-space feeder links for satellite communications systems, the value of area A to be considered shall be that of the coordination area, determined in accordance with the procedures described in RR Appendix 7.

The Time, *T*

The factor T takes into consideration both the number of hours of use per day T_1 and the term T_2, in years, of the authorization to use the radio frequency, and shall be calculated by the following formula:

$$T = \left(\frac{T_1}{24}\right) \cdot \left(\frac{T_2}{20}\right)$$

For periods of use per day of less than one hour, the value of T_1 to be considered shall be 1 h.

For authorizations granted for a term of less than one year, the value of T_2 to be considered shall be one year.

The cost factor, *K*

The cost factor K is defined by taking into consideration the mode of use of the spectrum, whether exclusive or non-exclusive, and the nature of the interest in the service, whether collective or restricted, as shown in Table 11:

TABLE 11

Mode of use	Nature of interest	Cost factor *K*
Non-exclusive	Collective	20
	Restricted	25
Exclusive	Collective	50

The value to be paid, *V*

For the utilization of radio frequencies, V, shall be obtained by applying the following formula:

$$V = P \cdot C \cdot D \cdot E$$

where:

P: reference value for the right to use radio frequencies

C: 0.6 for stations of mass media services and stations of radio broadcasting services, and 1.0 for stations of other services

D: 0.3 for stations intended for services of a scientific nature, and 1.0 for stations intended for other services

E: 1 for point-to-point systems and, in accordance with Table 12, for point-area systems.

TABLE 12

Population (inhabitants)	Value of *E*
Up to 50 000	0.10
From 50 001 to 100 000	0.15
From 100 001 to 150 000	0.20
From 150 001 to 200 000	0.35
From 200 001 to 250 000	0.40
From 250 001 to 300 000	0.50
From 300 001 to 350 000	0.60
From 350 001 to 400 000	0.75
From 400 001 to 450 000	0.90
Above 450 000	1.00

The value to be paid for the utilization of radio frequencies, V, shall not be less than ($T_2 \times$ R$ 20.00).

For the following cases a fixed value of V is applicable: amateur radio and citizen band services; coastal stations, stations aboard ships, and port stations; stations aboard aircraft, and aeronautical stations; and stations of the community broadcasting services.

For purposes of the Regulation, the following systems shall be subject to the payment of the appropriate utilization charges:

– point-to-point – upon assignment of each transmit frequency;

– point-area – upon assignment of each radio frequency, whether receive or transmit, to nodal stations, base stations, or space stations.

The payments due shall be effected, whenever applicable, upon issuance or renewal of an authorization for the utilization of a radio frequency.

Besides the public fees for the right to use radio frequencies, there are inspection fees to be paid by all telecommunication service providers and those using radio frequencies:

– Installation inspection fee: fee due by the holder of concessions, permits and authorizations of telecommunication services for the use of radio frequencies, at the moment of the issuance of a license certificate for the operation of each station.
– Operations inspection fee: fee due by the holder of concessions, permits and authorizations of telecommunication services for the use of radio frequencies, to be paid on an annual basis in connection with the operations inspection of stations.

The following are exempt from inspection fees: National Telecommunications Agency, Armed Forces, Federal Police, Military Police, Federal Highway Police, Civil Police, and Military Fire Brigades.

The value of the operations inspection fee shall be equivalent to 50% of the value established for the installation inspection fee.

5.3 Experience with using alternative resources

Many administrations have used alternative resources to support national spectrum management for a number of years. The following information reviews some of this experience.

5.3.1 Canada

5.3.1.1 Consultation process

In Canada, the Radio Advisory Board of Canada (RABC) is the main body in the private sector that provides advice to the Canadian Administration on a wide variety of issues related to spectrum management. The RABC is basically an association of associations with a large number of members representing the service provider, equipment manufacturer and radio user sectors of Canada. The RABC is organized in a number of committees, such as the mobile and personal communications, the fixed wireless communications, broadcasting, electromagnetic compatibility, etc., committees. The administration participates in these meetings as observer. The Board advises the administration on matters related to policy, standards, technical and procedures development. Engineering analyses on channelling plans, interference calculations, sharing scenarios are often conducted in the RABC and have provided significant inputs to the Canadian spectrum management process. Once every two years, the RABC and the administration jointly organize a high-level conference, called the Spectrum 20/20 Symposium, bringing together industry and government officials to discuss long term as well as short-term issues of spectrum management including spectrum economics. The RABC has been recognized as a very successful cooperation between government and the private industry in Canada.

5.3.1.2 Frequency coordination process

The Canadian national spectrum management organization makes use of frequency coordinators in a number of cases.

In the case of fixed service and the fixed-satellite service frequency applications, while the Department of Industry is responsible for processing licence applications, including the examination of interference potential, international coordination, etc., domestic coordination is the responsibility of the applicant. The fixed service users maintain their own databases from which they coordinate with each other. The majority of the coordination is done within the Frequency Coordination System Association which is a non-profit Canadian corporation, with major telephone companies as its members. It operates and administers a computerized Microwave Information and Coordination System.

5.3.1.3 Licensing process

In the amateur service, while a licence is required to operate the radio equipment in the amateur bands, no interference analysis is conducted. However, an examination is required of the amateur operators, which has been delegated to amateur organizations.

5.3.1.4 Information dissemination

In order to facilitate the dissemination of information the assigned frequency records are made available to the general public through Internet access or on a CD-ROM format.

5.3.2 Germany

In Germany, user associations perform some limited spectrum management functions for private mobile radio (PMR) systems. These associations have been successfully involved in the frequency assignment procedure for more than 25 years.

The experts of these associations advise their members in all aspects of PMR use. They explain national regulations and support user planning of PMR networks. The association recommends to the regulatory authority characteristics of a PMR network such as frequency, coverage area, antenna height, call sign, etc. Normally, all relevant technical standards, rules for frequency planning and other licensing conditions are taken into account in the recommendation of the user association. The regulatory authority is able to follow these recommendations in almost all cases and grants a licence accordingly. In this way, national technical coordination is carried out de facto by the user association. International coordination is, however, always carried out by the regulatory authority.

The users associations are financed by contributions from their members and work for the benefit of the PMR users. Beside the day-to-day frequency coordination, they contribute to the medium and long-range planning process for the frequency spectrum representing the spectrum requirements of their members to the regulatory authority. They provide a valuable link between the regulatory authority and the users.

5.3.3 Israel

Israel takes advantage of private sector resources to perform some spectrum management functions.

In the past there were some operators who assisted the administration by assigning their own frequencies in a specified band. Today this is done only with trunking operators, cellular operators and in some cases for point-to-point microwave links.

The administration still receives support from operators and the industry in participating in ITU work, like world radiocommunication conferences and the Radiocommunication study groups (examples: TADIRAN in Radiocommunication Study Group 1, Motorola Israel in Radiocommunication Study Group 8).

5.3.4 Russian Federation

In the Russian Federation great support to governmental spectrum management activities is provided through various scientific, development and design organizations, which play the role of frequency coordinators and spectrum management consultants. While administratively these organizations may belong to different ministries and other governmental bodies, they are actually providing independent expertise in many fields of radiocommunications, and particularly of spectrum management, to the Russian Federation telecommunication administration, as well as to private radio operators and various commercial organizations supporting their activities. Due to close collaboration with the Russian Federation telecommunication administration on the one hand and with radio operators on the other hand, and through active participation in relevant regional and international activities, they are very familiar with what is needed for the development and improvement in different radio services and in spectrum management issues at the national, regional and international levels.

Such spectrum management organizations include research institutes, particularly the Radio Research and Development Institute (NIIR) together with its branches, type-approval testing laboratories, private operator associations and consulting firms operating on a commercial basis.

The main assistance to the telecommunication administration provided by these organizations are:

– conducting, at the request of the administration, systematic interference analysis for fixed (microwave) and fixed-satellite service frequency applications including issues of domestic and international coordination;
– conducting frequency-site planning of radio transmitters for sound and TV broadcasting services;
– conducting experimental investigations of the potential for allocating additional TV and sound broadcasting channels for areas with specific terrain problems. Based on conclusions provided, the administration issues relevant frequency permissions and licences for operational activities;
– developing various draft standards, specifications, recommendations, etc. concerning radiocommunication networks and equipment development, EMC analysis and frequency planning, frequency sharing criteria and conditions to be approved by the administration; recently these activities more and more concern relevant regulatory and legislative matters as well.

As far as it concerns assistance to radio operators, the main issues are the following:

– explanation of national, regional and international regulations in their implementation with respect to various radio services;
– assistance in user planning of relevant radio networks particularly cellular, trunking etc., using all relevant technical standards, rules for frequency planning and other licensing conditions;
– preliminary analysis of interference-free broadcasting channels for commercial sound and TV broadcasters, calculation of service areas, etc.;
– assistance in preparation of relevant licence application and bid documentation;
– assistance to various state and commercial enterprises in the field of industrial interference limitation.

5.3.5 United States of America

The United States of America makes wide use of frequency coordinators, interested communications groups, and private sector spectrum management consultants.

5.3.5.1 Use of interested communications groups

The United States of America spectrum management organizations also make significant use of advisory committees. The FCC for instance develops its radio conference proposals through an open advisory committee process. Furthermore, the National Telecommunications and Information Administration (NTIA), as the manager of United States of America government agency use of radio systems, relies heavily on the Inter-department Radio Advisory Committee (IRAC), its subcommittees (planning, technical, and radio conference), and ad hoc committees for advice on regulation and policy development. This committee is the longest standing advisory committee in the United States of America government. Though this is not a private sector body, it represents an excellent example of using advisory bodies or collections of experts. NTIA also seeks the advice, with regard to spectrum management policy, from a joint government/private sector group, the Frequency Management Advisory Committee (FMAC).

The FCC has also successfully employed a technique known as negotiated rulemakings whereby it has placed system developers and spectrum advocates in a position of jointly developing the very regulations and standards which will be used to regulate their activities.

5.3.5.2 United States of America use of frequency coordinators

Under FCC rules, prior to applying for a station licence for certain services, an applicant must provide technical coordination information or evidence of prior coordination of the station with existing stations. Private groups often perform this prior coordination function.

In the private land mobile radio services (PLMRS), the FCC has certified groups for specific sub-allocations (e.g., public safety, industrial, and land transportation services) to coordinate frequency assignments prior to their application for the actual licence. Under this system, applicants proposing new stations or modifying existing licences send their completed applications to the appropriate certified coordinator. The coordinator checks the application for completeness, accuracy, and compliance with the FCC's rules, recommends the most suitable frequency for the applicant, and forwards the completed application to the FCC, which issues the licence directly to the applicant upon approval. The FCC oversees the performance of these coordinating committees. Performance consistently below FCC standards could lead to an inquiry and eventual decertification of the coordinator. In cases of disagreement between the applicant and the coordinator, the FCC has final authority to resolve the problem.

Prior coordination takes place in other services, such as the FCC's point-to-point microwave radio service and the private operational fixed microwave service. Prior to obtaining a licence, applicants for these services are required to engineer their proposed systems to avoid interference and to coordinate with existing applicants and licensees who could potentially experience interference from these proposed systems. Coordination in these bands is typically done by the applicant or their private frequency coordination consultant and depends largely upon industry cooperation. There are no certified coordinators for these bands. The applicant must certify that the coordination process has been completed before the application is accepted for filing. Private frequency coordinators charge a fee for their services.

Through this requirement for prior coordination, the FCC attempts to ensure that interference conflicts are resolved through private negotiations before applications are filed. Successful coordination through this method lessens the need for federal government administrative processes to resolve conflicting private claims to the spectrum. Since the FCC established requirements for frequency coordination within the microwave bands in 1975 and implemented the certified frequency coordinator program for the PLMRS bands in 1986, the speed of service has improved and the FCC's licensing burden has been reduced. Further, the first recourse of action for licensees involved in interference problems is to seek the assistance of the coordinator. In most cases, the coordinator can find a solution to the problem without the FCC ever being involved.

5.3.5.3 United States of America use of spectrum management consultants

While NTIA and the FCC currently make limited use of spectrum management consultants, federal agencies with significant communications interests but limited staff resources make extensive use of technical consultants and functional support contractors. These groups play an active role in the wide array of advisory and ad hoc committees performing engineering analysis and preparing committee documents. In many cases, they represent government agency interests in delegations to international bodies.

5.4 Other experiences

5.4.1 Amateur services

Generally, amateur stations are not assigned specific frequencies by government spectrum managers but are free to select operating frequencies according to current band occupancy and propagation conditions. National, regional and local band plans are established by informal agreement to arrange compatible intra-service uses, principally by class of emission, such as telegraphy, data and voice.

The major exceptions to stations selecting frequencies in real-time are VHF/UHF voice repeaters, packet radio-relay stations and propagation research beacons, which use specific frequencies on a long-term basis. Some administrations have regulations that encourage the establishment of private sector frequency coordinators, particularly to maintain user databases and, by recommendation rather than assignment, coordinate the selection of voice repeater frequencies to minimize interference within their geographic areas.

Amateur-satellite frequencies are international in nature and are coordinated through amateur-satellite organizations known as Radio Amateur Satellite Corporation (USA) (AMSAT).

The three International Amateur Radio Union (IARU) regional organizations also establish informal band plans. The IARU and AMSAT organizations cooperate in matters concerning frequency usage.

5.4.2 Area and high density systems

Most administrations have experience with authorizing area systems to a range of frequencies. This has been done primarily for cellular, PCS and other area and high density systems.

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Glossary

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

Administrative pricing: A form of *spectrum pricing* 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 (FCC) in the United States of America. 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.

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 USD 1 000 000, it would pay only USD 750 000. Originally, bidding credits were also proposed for women and racial minorities; however, the FCC dropped this proposal after the United States of America Supreme Court's *Adarand* decision, which declared that such preferences were discriminatory, and therefore illegal.

Differential rent: Rent attributable to varying characteristics of a resource, e.g., more desirable propagation characteristics in one frequency band than another frequency band.

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.

Scarcity rent: Rent attributable to a resource demand exceeding supply at zero price.

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 denoting of 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 rights: 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 the 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 overestimate 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 minimize this effect. *Winner's curse* can be reduced or eliminated by careful design, particularly by using multiple round auctions (see *simultaneous multi-round auction*).

ANNEX 1

Part 1

Experience with Spectrum Fees – Republic of Korea

The Administration of the Republic of Korea implemented spectrum fees in 1993 in accordance with Korean Radio Law in order to create revenue for effective spectrum management and radio technology development programs. The assessment and collection of spectrum fees is prescribed in the Presidential Decree of the Radio Law. However, no fees are imposed on radio stations that are:

– used for emergency communications;
– used for experimental communications;
– used for amateur radiocommunications;
– used for standard radio frequency/time signalling;
– used by the Korean Red Cross Association;
– installed in tunnels and other underground areas and that are used for relaying subscriber-based communications and broadcasting services;
– used for the purpose of disaster prevention (such as flood warnings);
– used by common carriers for official use; and
– covered by the criteria in Table 13.

TABLE 13

Type of station	Frequency (MHz)	Bandwidth (MHz)	Maximum power supplied to antenna (W)
Ship	2 20	2.8 2.8	50 25
Aircraft	100	6	10
General purpose	146	8.5	5

Additionally, in fee Categories 2 and 3 below, no fees are imposed in cases in which the calculated fee would be less than 3 000 Won.

Spectrum fees for subscriber-based facilities (except for fixed wireless access (FWA) and microwave links) are based on the number of subscribers (Type 1 fees). Spectrum fees for subscriber-based FWA and microwave link facilities and for non-subscriber based facilities are based on the frequency band, bandwidth, power, etc., which are used, and fall into one of three additional fee categories:

Category 1: subscriber-based FWA and microwave link facilities and non-subscriber-based facilities of common carriers (Type 2 fees);

Category 2: private fixed and land mobile radio facilities (Type 3 fees);

Category 3: other mobile radio facilities (Type 4 fees).

NOTE 1 – All fees are imposed quarterly.

Assessment criteria of spectrum use fees

Type 1 fees: Subscriber-based facilities (except for FWA and microwave links):

Spectrum use fees (SUF) are imposed on the operator based on the following equation:

$$(SUF)_{operator} = N_s \times U_c \times \{1 - (C_f + R_f + E_f)\} \tag{15}$$

where:

- N_s: number of subscribers
- U_c: unit price
- C_f: common facilities factor
- R_f: roaming factor
- E_f: use efficiency factor.

Described as follows:

a) Number of subscribers

The average number of subscribers is calculated using the following equation:

{(the number of subscribers on the first day of a quarter (season)) + (the number of the subscribers on the last day of the quarter)}/2

b) Unit price

Services	Unit price (Won/subscriber/quarter)
Mobile phone service	2 000
Personal communication system (PCS)	2 000
Radio pager service	150
Trunked radio service	150
Narrow-band radio data service (900 MHz band)	30

c) Common facilities and roaming factors

Common facilities ratio and roaming ratio (%)	<10	10~20	20~30	30~40	40~50	>50
Common facilities factor	0.01	0.02	0.04	0.06	0.08	0.10
Roaming factor	0.05	0.10	0.15	0.20	0.25	0.30

Common facilities ratio: ratio of the number of stations served by an operator that use common radio facilities to the total number of stations served by that operator.

Roaming ratio: ratio of the number of stations served by an operator that use roaming technology to the total number of stations served by that operator.

d) Use efficiency factor

Frequency use efficiency (%)	<100	100~150	150~200	200~250	>250
Frequency use efficiency factor	0.01	0.02	0.03	0.04	0.05

Frequency use efficiency: ratio of the average number of subscribers per frequency assignment to the basic capacity of the number of subscribers (which is 500 000 subscribers per frequency assignment in the Republic of Korea for mobile phone and personal communication systems).

NOTE 1 – The frequency use efficiency factor does not apply to the radio pager, trunked, and narrow-band radio data services.

Type 2 Fees: Subscriber-based FWA and microwave link facilities and non-subscriber-based facilities of common carriers:

The SUF is imposed on the facility according to the equation:

$$(SUF)_{radio\,station} = C_B \times U_f \times S_f \times N \tag{16}$$

where:

- C_B: basic price
- U_f: designated spectrum amount
- S_f: service factor
- N: number of assigned frequencies.

Described as follows:

Basic price, C_B: 250 000 Won/station

The designated spectrum amount, U_f: the value in the cell at the intersection of the column amount of designated spectrum, and the row, frequency bands, in Table 14.

TABLE 14

Frequency bands \ Amount of designated spectrum (MHz)	<0.1	0.1 ~ 0.3	0.3 ~ 1.5	1.5 ~ 4	4 ~ 7	7 ~ 10	10 ~ 15	15 ~ 20	20 ~ 30	30 ~ 40	40 ~ 60	60 ~ 80	80 ~ 110	110 ~ 150	>150
<1 GHz	1	2	3	5	7	9	12	15	19	23	28	33	28	44	50
1~3 GHz	7	1.4	2.1	3.5	4.9	6.3	8.4	10.5	13.3	16.1	19.6	23.1	26.6	30.8	35
3~15.4 GHz	0.3	0.6	0.9	1.5	2.1	2.7	3.6	4.5	5.7	6.9	8.4	9.9	11.4	13.2	15
>15.4 GHz	0.2	0.4	0.6	1	1.4	1.8	2.4	3	3.8	4.6	5.6	6.6	7.6	8.8	10

NOTE 1 – If analogue technology is used, the fee is tripled.

Service factor, S_f

Radio stations	Factors
Fixed stations: – for microwave link – for local loop – for communications with islands – for other applications	 0.5 0.25 0.05 1
Other stations–	1

Type 3 Fees: Private fixed and land mobile radio facilities:

The SUF is imposed on each transmitter, according to the equation:

$$(SUF)_{other\,stations} = C_B \times \left(\sqrt{A_P + B_W}\right) \times P_f \times T_f \times O_f \qquad (17)$$

where:

C_B: basic price

A_P: antenna power

B_W: bandwidth

P_f: preference factor

T_f: frequency sharing factor

O_f: operating purpose factor.

Described as follows:

Basic price, C_B: 2 000 Won/designated frequency

Antenna power, A_p (W)

Bandwidth, B_W (kHz). The value of 1 kHz is used for a bandwidth of less than 1 kHz at a frequency of less than 960 MHz, and the value of 1 MHz is used for a bandwidth of less than 1 MHz at a frequency above 960 MHz.

Preference factor

Frequency bands		Factor
MF/HF	<28 MHz	1
VHF	28 ~ 300 MHz	1.3
UHF	300 ~ 960 MHz	1.5
Sub microwave	960 ~ 3 GHz	0.1
Microwave	3 ~ 15.4 GHz	0.03
	15.4 ~ 30 GHz	0.02
Millimeter wave	>30 GHz	0.01

Frequency sharing factor

Frequency type	Factor
Exclusive use	1
Common use	0.1

NOTE 1 – *Exclusive use* occurs when an operator uses a frequency exclusively over a country or region and *common use* occurs when an operator uses a frequency non-exclusively over a country or region.

Operating purpose factor

Operating purpose	Factor
Radionavigation services (radar, transponder, distance estimator, radio altimeter)	0.5
Radiotelemetry (including detection and beacon) services	0.1
Other services	1

Type 4 Fees: Other mobile radio facilities:

The SUF shall be imposed on each mobile station as follows:

Type of mobile stations	SUF (Won)
Stations installed on vehicles (such as ships and airplanes) and communicating through satellite relay.	20 000
Other stations	3 000

Part 2

Economic aspects of 3G and IMT-2000/UMTS Networks and Services – Thales

1 Background

The deployment and introduction of 3G mobile services has been a subject of intense public and political debate in Europe. 3G mobile services have been identified as key to competitiveness in Europe. Recently, the European Commission issued a "Communication on The Introduction of Third Generation Mobile Communications in the European Union: State of Play and the Way Forward". In this document, the Commission confirms its confidence in the potential which 3G communications have for the EU in terms of capitalizing on European technology strengths and securing jobs, growth and investment for the future.

It was the desire to leverage European leadership in GSM communications that prompted the UMTS Decision, issued in 1998. This Decision set up a requirement on Member States to facilitate introduction of 3G services by 1 January 2002. Following this Decision, licensing for IMT-2000/UMTS has now been concluded in 11 Member States with the rest soon to follow. Member States have chosen different methods to select licensees and assign the radio spectrum necessary to operate 3G services. Some have auctioned off spectrum and some have made use of administrative procedures. The amounts paid by licensees so far amount to over 130 billion Euro, according to Commission data. This is far above the framework of the reasonable administrative fees that have been so far associated to radio services licensing. The highest amounts were paid in auctions that were completed before the Internet stock market "bubble" burst in the autumn of 2000. Subsequent market developments have sent the entire communications sector, both manufacturers, operators, and many Internet-based companies, into a serious slowdown. This is in strong contrast to the extremely favorable conditions that prevailed earlier in 2000.

One of the consequences of the market downturn has been the reluctance of financial markets to fund expansion and investment in many ICT and Internet-related business ventures. For the telecom sector this has meant that many operators are burdened with extremely high debt and find it difficult to finance, among other things, build out of 3G networks. Further, many analysts have voiced concern that the 3G "killer application" was yet to be identified. The likely consequence is a delay in the launch of these services.

Given that early launch of 3G services has been identified as a political priority, policy makers now face the question whether the UMTS licensing process has contributed to the current difficulties of the sector and what policy action may be appropriate in this situation. This document seeks to provide European industrial views on what the correct lessons to be learned from the 3G experience are and what the correct policy response may be.

2 Issues and conclusions arising from the 3G experience

2.1 European market

One of the most important conclusions of the 3G process so far is the likely emergence of 15 different national markets for 3G services. The fragmented approach to licensing across the EU – the difference in timing and licensing methods – has provided the basis for a fragmented market for 3G services in Europe. Spectrum allocation is currently a Member State prerogative and there is no legal basis for imposing the European approach. It seems that the difference in licensing methods undermines the explicitly stated goals of creating a single market in electronic communications.

The experience of the 3G licensing process shows the necessity of a strongly coordinated approach of electronic communications regulation. It confirms the need to coordinate the selection processes for granting licenses for networks which cover the use of radio spectrum and to strengthen the harmonization of the partition of the allocated resource into frequency bands assigned to the operators.

2.2 Managing spectrum resources

The licensing situation for 3G systems in Europe is a result of two things: firstly, a major discrepancy between the amount of business opportunities for 3G services (based on spectrum availability) and industry's demand for it, and secondly, the use of licensing procedures that have resulted in very high spectrum fees. Therefore a fundamental task for governments should be to ensure that additional spectrum is made available, as appropriate, to support the growth of new services. Furthermore, a "technology" neutral approach is necessary.

Another important task is to ensure that all types of wireless services use the spectrum efficiently. For traditional services and for spectrum used by the State, governments should make sure that spectrum is used and managed efficiently, and take appropriate measures including financial support for spectrum redeployment to release spectrum when the situation demands it.

A large portion of the public and political debate has been focused on the methods being used for allocation of limited resources such as spectrum – spectrum auctions, beauty contests, and mixed models. All models have both advantages and drawbacks associated with them. However, what can be concluded is that when spectrum resources are allocated, the chosen licensing method should reflect a balance of legitimate policy objectives.

In the UMTS case, it should be noted that maximizing short term revenue for the State (whether through auction design or administrative pricing) should not be the main objective. Other objectives, such as innovation, competitiveness and service development are equally, if not more, important.

The net gain for the government and society as a whole is the growth, investment and employment which result from service deployment – not merely the licensing fees paid. It would be short-sighted and counter productive to consider allocation of scarce resources as merely a revenue opportunity for governments. In some cases, it may be argued that the proceeds from licensing of 3G radio spectrum vastly exceed the costs involved in managing the spectrum.

2.3 The difficulty in predicting technology and market developments

As mentioned, the financial markets have shown doubts about the 3G business case and analysts are asking themselves what the "killer application" may turn out to be. At the same time, it is likely that mobile Internet access will be made possible via other and cheaper means than 3G networks. These questions are yet to be clarified.

From a policymaking perspective, the important lesson may be the great difficulties involved in trying to predict market and technological developments. This inherent uncertainty should definitely be born in mind when considering future policy action. In general, policy objectives should not be linked to a particular technology. Rather, policy objectives should be broad enough to encompass a combination of different technologies. For example, while the rapid proliferation of infrastructures enabling broadband Internet access is and should be a key political priority, it should be recognized that there are several different infrastructure options (xDSL, cable modems, wireless local loop, fiber-to-the-home, satellite, and 3G mobile), each of which will be able to serve different market needs.

2.4 Addressing questions relating to roll-out of 3G networks

Most of these observations concern the longer term. The question is, whether there are policy actions that can be taken in the shorter term to address the current situation as regards 3G services. The recent Commission Communication on 3G summarizes some of the decisions to be made regarding infrastructure sharing, licensing requirements on infrastructure rollout and measures to facilitate site acquisition The need to secure a strong competition has of course over-riding importance, but certain forms of infrastructure sharing should be considered and could be a valuable tool in a transition phase to ensure a quick roll-out and a good coverage of suburban and rural areas.

These questions should be considered in a coordinated way in order to ensure similar operating conditions in the European market. In doing so, it is important to avoid market-distorting measures. As stated above, broadband services are likely to be provided over a variety of broadband infrastructures, and it is important to bear in mind that measures taken with regard to one infrastructure will inevitably have consequences for the entire sector.

2.5 Issues

Broadband services will be the prerequisite for 3G success. They shall therefore be encouraged. The uncertainty regarding the business models and applications for 3G is an important factor contributing to the current difficulties. Essentially, it is for the market to devise these services and applications and package them in a way that will spur demand. What government can do to address demand-side issues in a first step is to ensure that "e-government" services and content will be accessible for 3G users. On the research front, governments can support efforts to develop new services that take advantage of wireless mobility services.

With regard to these topics, studies can be done in the following ways:

– Create a framework for electronic communications regulation that ensures harmonization of market conditions throughout the world. The IMT-2000 licensing process showed the danger of a fragmented approach: Improve the harmonization of methods for granting licenses covering the assignment of relevant frequency hands.

– Avoid spectrum scarcity. Ensuring efficient mechanisms for allocating spectrum where it is needed is fundamentally important. It is therefore important that government services and agencies using spectrum do so efficiently and relinquish it for commercial use when possible.

– Bear in mind the difficulty of predicting market and technology developments. The overall policy objective of bringing affordable broadband should be considered in terms broad enough to encompass a variety of infrastructures.

– Address three IMT-2000 roll-out questions such as licensing requirements and facility-sharing in a coordinated fashion and avoid measures that would create market distortions.

– Develop e-government applications and content to support demand for IMT-2000 mobile services.

Part 3

An application of spectrum pricing – United Kingdom

The following text is drawn from a consultation document that was issued by the UK Radiocommunications Agency (RA) in January 2002. That consultation document is the fifth in a series of documents which provide the pricing schedules that are applicable to spectrum use in the United Kingdom. The pricing schedule presented here became effective in July 2002. Further detailed information is available from the RA website: http://www.radio.gov.uk/topics/spectrum-price/documents/eu-pricing.pdf

Throughout the following seven parts certain questions are presented which were included in the original source document for the purpose of focusing responses on the various proposals offered for spectrum pricing. For the convenience of the reader, these questions are all listed together on page 143. These questions as well as all the information in this part are offered only as examples of questions to be considered by an administration when developing a national pricing structure for using the radio-frequency spectrum.

CONTENTS

Page

1 Executive summary

1.1 This fifth year consultation document aims to outline the latest proposals of the Radiocommunications Agency (RA) for implementation of administrative spectrum pricing from July 2002 through regulations made under the powers of the Wireless Telegraphy Act 1998 (1998 Act).

1.2 This consultation document seeks views from licensees on the implication of the changes to fees and charging in each of the sectors identified in § 2 to 6, specifically:

– Fixed terrestrial links, scanning telemetry, uncoordinated links, permanent and transportable earth stations and satellite links (see § 2)
– Public telecommunications network services (see § 3)
– Programme making and special events (see § 4)
– UK general private business radio (PBR), IR2008 Data Protocol and Private Mobile Road Construction licence (see § 5)
– Ship radio licence (see § 6).

1.3 Section 7 of this consultation text summarizes previous work and consultation exercises and explains the principles of spectrum pricing. RA continues to work with the relevant industry and user working groups to develop proposals to tackle spectrum pricing issues in each relevant sector.

1.4 It is intended that when the proposals have been finalized following the conclusion of the consultation, these will be incorporated in new regulations under the 1998 Act which come into force in July 2002 and which will include a consolidation of existing fees regulations for clarity and ease of use (2002 Fees Regulations).

Making the most of the radio spectrum

1.5 These proposals are part of an ongoing programme to introduce spectrum pricing principles to all sectors of radio use. In the Autumn 2000 pre-budget Report, the Government drew attention to spectrum management and the need to make the most use of the radio spectrum. It announced that the Government would commission an independent review to advise on spectrum management principles. The consultation paper, "Independent Review of Radio Spectrum Management" by Professor Martin Cave, was published in June 2001. Individual responses to that consultation have been published on the RA website, and views were taken into account in finalising recommendations. The completed Review was presented to the Government in March 2002. The Government then considered its response. In as far as the recommendations concern spectrum pricing, the Agency will need to decide on future implementation, but this will be without prejudice to any changes proposed for 2002 in this document.

Statutory consultation

1.6 In accordance with the provisions of the 1998 Act RA will publish notices in the London, Edinburgh and Belfast Gazettes, detailing the substance of the proposed regulations. Shorter notices will be posted in equivalent publications in the Channel Islands and Isle of Man. For the 2002 Fees Regulations, publication of these notices allow a period of 28 days from the date of publication of the notices for the making of representations. It is also intended to place copies of these notices on the RA website. In addition, this consultation document "Spectrum Pricing: Year Five" is published on the RA website, UK Online Register of Consultations, and in hard copy.

2 Proposals for scanning telemetry, fixed links and satellite links

The following paragraphs outline specific proposals to take forward pricing proposals in these sectors for implementation in July 2002.

Scanning telemetry

2.1 The July 2001 Fees Regulations introduced administratively priced national channels as an alternative to the existing per station fee. Such channels are now priced in line with the fees introduced in 1999 for PBR, and the annual fee of £7 920 per national channel will remain unchanged in 2002.

2.2 All the water industry operators have now moved to this new pricing regime, and individual companies have seen their annual WT Act licence fees for scanning telemetry reduce as a result. Detailed discussions are under way with a view to extending this regime to the forty-eight scanning telemetry channels currently self-managed by the Joint Radio Company on behalf of the electricity and gas industries. Given the larger number of channels allocated to these utilities, and their less intensive use of the spectrum compared with the water industry, licence fees in this sector are expected to rise.

2.3 In the case of the eight channels (T73 to T80) reserved for non-utility operators it is proposed to replace the present £40 per station fee by an administratively priced fee of £410 for each channel used at a base station. This will fully implement administrative pricing for all operators of scanning telemetry systems, and introduce fees in line with those in the PBR area.

Uncoordinated links

2.4 Fixed links in this band are not planned or coordinated by RA. It is therefore planned that this band will be deregulated and made licence exempt, provided set technical parameters are observed when 58 GHz equipment is installed and operated. Further details will be published later on the RA website and all licence holders will be advised directly about the new arrangements. This step will, in practical terms, save operators the current £50 annual licence fee charged for each link registration.

Private point-to-multipoint

2.5 The fees set for CCTV at 31 GHz will remain at the July 2001 level, and therefore continue to match those for fixed point-to-point links in this band.

Fixed terrestrial links

2.6 The July 1999 Fees Regulations introduced the first step of administrative pricing for all coordinated terrestrial point-to-point links. RA plans to implement the fourth and final step of the initial phased implementation programme in July 2002. This will mean a further increase in license fees for links in congested areas, balanced by a reduction in fees for links in non-congested areas.

2.7 Fees for this fifth year are set out in detail in Table 15. The changes from 2001 range from £25 to £775 per link, with the highest increases applying to mature equipment and analogue links in congested areas. The changes are in line with the phased programme as originally set out in the September 1998 consultation document for the second stage of spectrum pricing entitled "Implementing Spectrum Pricing: The Second Stage", but RA has also proposed that there should be an increase in respect to licence fees for analogue links in congested areas. In the newly opened 50, 52 and 55 GHz bands RA is proposing to introduce a bandwidth related pricing structure in line with other fixed link frequency bands in place of the current flat fee of £220.

2.8 The demand for fixed link spectrum continues to increase, especially with the need for infrastructure for 3G mobile services. RA is therefore considering introducing pricing differentials to match the spectral efficiency of the equipment used, so that lower data rates within a given bandwidth will attract a surcharge. Additionally, since links requiring exceptionally high availability – in excess of 99.99% – make great demands on the available spectrum, it is proposed that some form of differential be developed to reflect this. Both these proposals have yet to be fully developed, and there will be continuing discussion with industry through the Fixed Links Consultative Committee and its supporting bodies.

2.9 No changes are proposed in the 2002 Fees regulations in respect to the frequency bands and regions considered to be congested. The effect of spectrum pricing will continue to be monitored to confirm emerging trends and level of demand, with any changes to the existing regime being implemented in 2003 and subsequent years.

Q1 These proposals for fixed links reiterate points raised in previous consultations. Do you have any further comments on these proposals?

TABLE 15

a) Fees payable in relation to congested areas

Frequency band	Limits of bandwidth per fixed link	Minimum data bit rate (Mbit/s)	Fee (£)
3.600-4.200 GHz	Not more than 15 MHz	51	950
	More than 15 MHz but not more than 30 MHz	51 140	1 900 1 225
	More than 30 MHz but not more than 90 MHz	140	3 675
5.925-6.425 GHz	Not more than 15 MHz	51	950
	More than 15 MHz but not more than 30 MHz	51 140	1 900 1 225
	More than 30 MHz but not more than 90 MHz	140	3 675
7.425-7.900 GHz	Not more than 3.5 MHz	8	460
	More than 3.5 MHz but not more than 7 MHz	8 16	920 615
	More than 7 MHz but not more than 14 MHz	16 34	1 230 950
	More than 14 MHz but not more than 28 MHz	34 140	1 900 1 225
	More than 28 MHz but not more than 56 MHz	140	2 450
12.750-13.250 GHz and 14.250-14.500 GHz	Not more than 1.75 MHz	2	305
	More than 1.75 MHz but not more than 3.5 MHz	4 8	610 460
	More than 3.5 MHz but not more than 7 MHz	8 16	920 615
	More than 7 MHz but not more than 14 MHz	16 34	1 230 950
	More than 14 MHz but not more than 28 MHz	34 140	1 900 1 225
	More than 28 MHz but not more than 56 MHz	140	2 450
All bands specified above	Any bandwidth in relation to an analogue link	As for 34 or 51 as appropriate	1 900

TABLE 15 (*end*)

b) Fixed links fees payable in relation to non-congested areas

Frequency band	Limits of bandwidth per fixed link	Fee (£)
1 350-1 690 MHz	Not more than 500 kHz More than 500 kHz but not more than 1 MHz More than 1 MHz but not more than 2 MHz	260 380 500
1.700-1.900 GHz	More than 50 kHz	380
3.600-4.200 GHz	Not more than 15 MHz More than 15 MHz but not more than 30 MHz More than 30 MHz but not more than 90 MHz	485 625 1 875
5.925-6.425 GHz	Not more than 15 MHz More than 15 MHz but not more than 30 MHz More than 30 MHz but not more than 90 MHz	485 625 1 875
6.425-7.125 GHz	Not more than 20 MHz More than 20 MHz but not more than 40 MHz	500 625
7.425-7.900 GHz, 12.750-13.250 GHz and 14.250-14.500 GHz	Not more than 3.5 MHz More than 3.5 MHz but not more than 7 MHz More than 7 MHz but not more than 14 MHz More than 14 MHz but not more than 28 MHz More than 28 MHz but not more than 56 MHz	235 315 485 625 940
17.300-17.700 GHz	Not more than 14 MHz More than 14 MHz but not more than 100 MHz More than 100 MHz but not more than 200 MHz More than 200 MHz but not more than 300 MHz More than 300 MHz	720 925 1 030 1 155 1 280
21.200-23.600 GHz, 24.500-26.500 GHz and 27.500-29.500 GHz	Not more than 3.5 MHz More than 3.5 MHz but not more 7 MHz More than 7 MHz but not more than 14 MHz More than 14 MHz but not more than 28 MHz More than 28 MHz but not more than 56 MHz	190 255 395 570 765
31.000-31.800 GHz	Not more than 56 MHz More than 56 MHz but not more than 140 MHz More than 140 MHz but not more than 250 MHz More than 250 MHz but not more than 280 MHz	720 885 1 030 1 155
37.000-39.500 GHz	Not more than 3.5 MHz More than 3.5 MHz but not more than 7 MHz More than 7 MHz but not more than 14 MHz More than 14 MHz but not more than 28 MHz More than 28 MHz but not more than 56 MHz	150 200 310 400 600
48.500-50.200 GHz 51.400-52.600 GHz 55.780-57.000 GHz	Not more than 3.5 MHz More than 3.5 MHz but not more than 7 MHz More than 7 MHz but not more than 14 MHz More than 14 MHz but not more than 28 MHz More than 28 MHz but not more than 56 MHz	100 135 205 265 400

Permanent earth stations (PESs)

2.10 The pricing regime introduced by the July 2001 Fees Regulations came into force on 30 October 2001 and the new site-based licensing arrangements are still bedding down. The only change to the existing pricing arrangements as from July 2002 will be the proposed introduction of a minimum fee of £175 per site. This fee will be applied in all cases where the algorithm calculation produces a fee lower than this threshold. This step will keep the fees structure more closely aligned with that applied to equivalent terrestrial fixed links in shared spectrum.

Transportable earth stations (TESs)

2.11 The July 2001 Fees Regulations implemented a spectrum pricing regime for TESs based on the PES pricing algorithm with suitable modifier values. With the agreement of the Satellite Consultative Committee membership, three categories of TES licence have been established. An annual licence fee for each category has been calculated using set operational maximum power and widest bandwidth parameters as explained below.

Category	OMP × WBW	OMP (W)(1)	WBW (MHz)(1)	Licence-fee per TES terminal: (Rounded after being calculated using the algorithm(2)) (£)
1	100.0	40.0	2.5	200
2	2 500	200.0	12.5	1 000
3	>2 500	>200.0	>12.5	3 000

OMP: operational maximum power

WBW: widest bandwidth

(1) The OMP × WBW figure determines the category; the separate OMP and WBW figures are typical values only.

(2) Using Transmit modifier (*Tx Mod*) = 0.75. This is an average value of the 2 *Tx Mods*; for 14.00-14.25 GHz, *Tx Mod* = 0.5, and for 14.25-14.50 GHz *Tx Mod* = 1.0.

Example:

A TES operator has 25 TES terminals/licences. Three are small, low power-bandwidth terminals (Category 1), 12 are medium power-bandwidth terminals (Category 2); and 10 are fully equipped high power-bandwidth TES trucks (Category 3).

Under the proposed scheme, this operator would hold 3 TES licences:

Category 1 licence with 3 terminals registered: Fees = 3 × £200 = £600

Category 2 licence with 12 terminals registered: Fees = 12 × £1 000 = £12 000

Category 3 licence with 10 terminals registered: Fees = 10 × £3 000 = £30 000

Total licence fees = £42 600

Q2 These proposals for satellite link reiterate points raised in previous consultations. Do you have any further comments on these proposals?

Interactive user terminal networks

Introduction

2.12 The RA proposes to introduce a new licensing product to facilitate a lighter touch administrative regime for networks using small interactive satellite earth station terminals. This has been endorsed by the appropriate industry consultation group.

In order to provide equal treatment of different spectrum users, there is a clear linkage between the pricing structure for Network Licenses and the existing permanent earth station (PES) fees and algorithm.

The structure of the proposed Network Licence relates only to terminals complying with the appropriate harmonized European standards (i.e. 2° and 3° orbital spacing and appropriate off-axis power density) and applies to UK FSS satellite exclusive (Earth-space) bands;

Pricing proposal

2.13 As noted above, the Network Licence proposed here only addresses the issue of Network Licences for terminals which operate to GSO satellites, and which transmit in the FSS satellite exclusive bands 14-14.25 GHz and 29.5-30 GHz.

2.14 The pricing structure is such that it should obviate the preference of some operators to individually license terminals in networks that consist of only a few terminals. The expectation is that an operator would apply for a Network Licence, and provide parameters for all classes of terminals operating in the network. Online registration of terminals under that Network Licence would then be available with a rapid decision on clearance status.

2.15 The licence fee will be set according to the number of terminals that the licensee expects to operate within the network. Depending on roll-out, pro rata adjustments to the fee will then be made at the licence renewal stage to reflect the actual situation.

2.16 It is proposed that the Network Licence charges for both the 14-14.25 GHz and 29.5-30 GHz bands be derived from a straightforward application of the PES algorithm. As a result of the licence fees for each network being based on the required access bandwidth and antenna flange power, it is proposed that a minimum fee be applied across the range of satellite earth station licence products. To achieve this for the Network Licence, it is proposed that for fee calculation purposes a minimum value for n (number of terminals in the network) be set at 50.

2.17 As with PESs, the two frequency bands concerned will be considered as being uncongested and the whole of the United Kingdom, Northern Ireland, Isle of Man and the Channel Islands will be considered as a single site for Network Licence purposes.

2.18 The process for calculating fees for individual networks is similar to that for PESs.

Methodology

2.19 The fee will be dependent on the number of terminals registered in the network. This is most readily achieved using the following adaptation of the established PES algorithm.

Algorithm for Network Licence:

$$\sqrt{433.4 \times \sum_{n} (P_n \times BW_n \times MOD_n)}$$

where:

- n : number of earth station terminals licensed in the network
- BW_n: network transmit assigned bandwidth (MHz)
- MOD_n: modifier value as specified in Statutory Instrument 2001 No. 2265 (for the cases under consideration, this is 0.5)
- P_n: transmit peak power (W) appearing at the flange of the network terminal antennas.

Examples of fees

2.20 FSS Satellite Network pricing examples in Tables 16 to 20 are as follows:

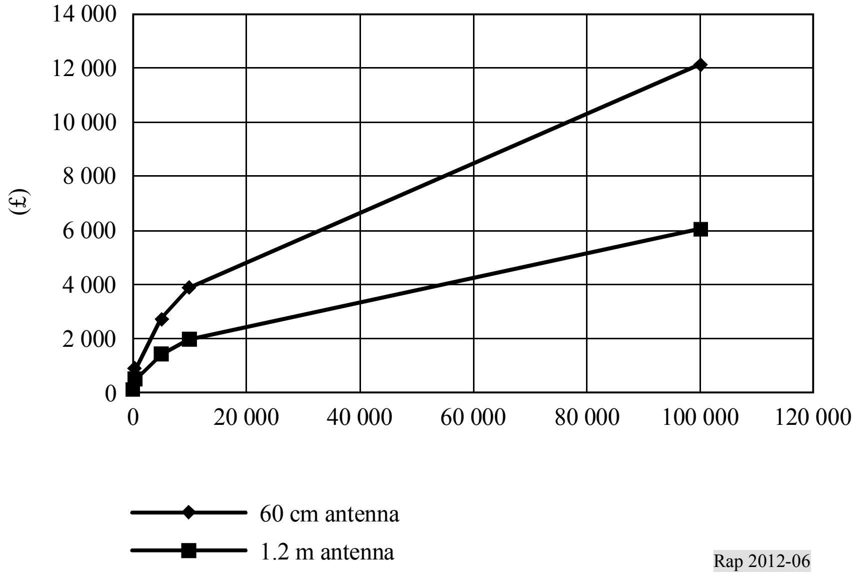
TABLE 16

Example 1: 14-14.25 GHz band: 45 dBW, 1 MHz cleared band, 0.6 or 1.2 m antennas

Number of terminals	Fee, 60 cm antenna (£)	Fee, 1.2 m antenna (£)	BW (MHz)
50	275	140	1.00
500	860	430	1.00
5 000	2 710	1 360	1.00
10 000	3 830	1 920	1.00
10 0000	12 105	6 070	100.00

FIGURE 6

1 MHz bandwidth, 45 dBW



Rap 2012-06

TABLE 17

Example 2: 14-14.25 GHz band: 45 dBW, 2 MHz cleared band, 0.6 or 1.2 m antennas

Number of terminals	Fee, 60 cm antenna (£)	Fee, 1.2 m antenna (£)	BW (MHz)
50	385	195	2.00
500	1 215	610	2.00
5 000	3 830	1 920	2.00
10 000	5 415	2 715	2.00
100 000	17 120	8 580	2.00

FIGURE 7

2 MHz bandwidth, 45 dBW

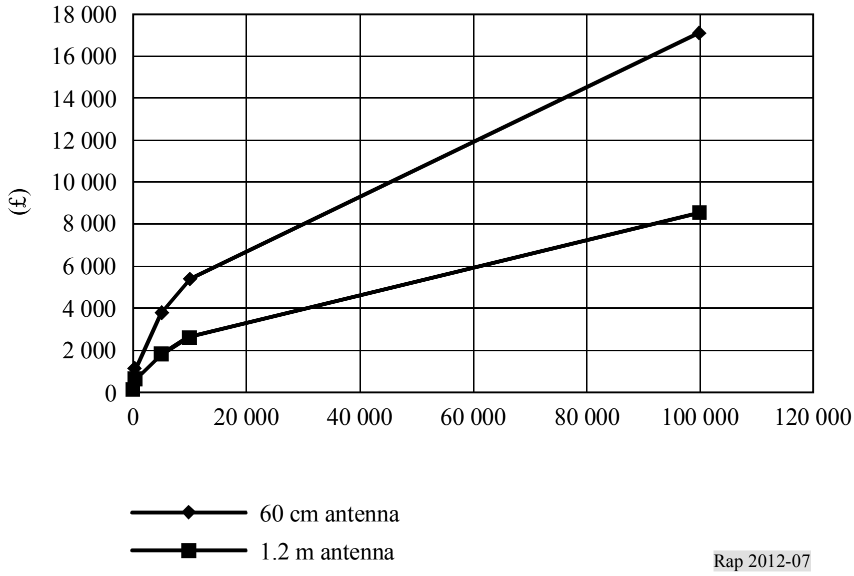


TABLE 18

Example 3: 14-14.25 GHz band: 45 dBW, 36 MHz cleared band, 0.6 or 1.2 m antennas

Number of terminals	Fee, 60 cm antenna (£)	Fee, 1.2 m antenna (£)	BW (MHz)
50	1 625	815	36.00
500	5 140	2 575	36.00
5 000	16 240	8 140	36.00
10 000	22 970	11 515	36.00
100 000	72 625	36 400	36.00

FIGURE 8

36 MHz bandwidth, 45 dBW

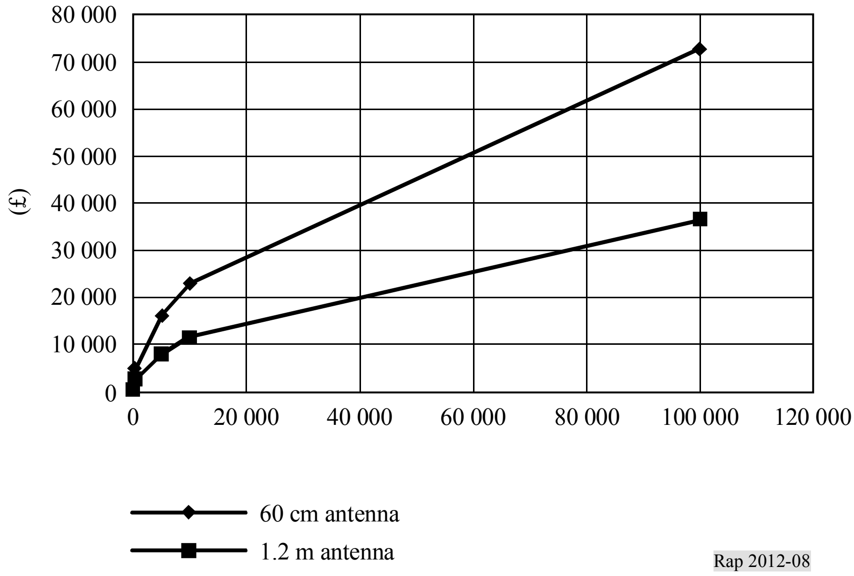


TABLE 19

Example 4: 29.5-30 GHz band. 48 dBW, 100 MHz cleared band, 0.6 or 1.2m antennas

Number of terminals	Fee, 60 cm antenna (£)	Fee, 1.2 m antenna (£)	BW (MHz)
50	1 820	910	100.00
500	5 755	2 880	100.00
5 000	18 195	9 100	100.00
10 000	25 730	12 870	100.00
100 000	81 365	40 685	100.00

FIGURE 9

100 MHz bandwidth, 48 dBW

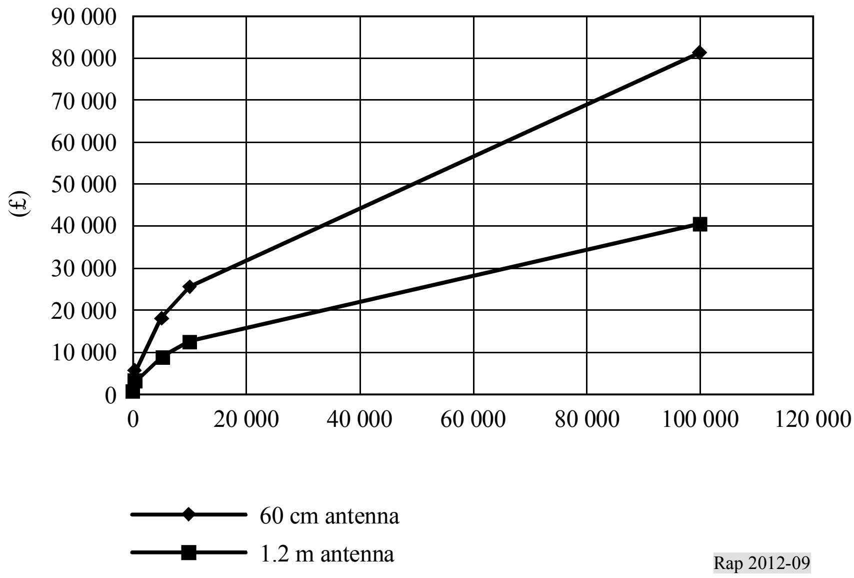


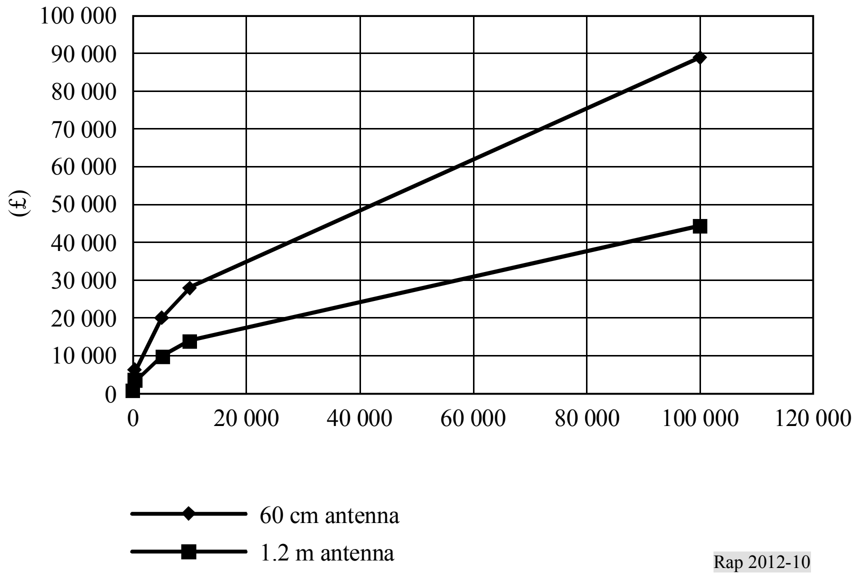
TABLE 20

Example 5: 29.5-30 GHz band: 48 dBW, 120 MHz cleared band, 0.6 or 1.2 m antennas

Number of terminals	**Fee, 60 cm antenna (£)**	**Fee, 1.2 m antenna (£)**	**BW (MHz)**
50	1 995	1 000	120.00
500	6 305	3 155	120.00
5 000	19 930	9 970	120.00
10 000	28 190	14 095	120.00
100 000	89 130	44 570	120.00

FIGURE 10

120 MHz bandwidth, 48 dBW



Future licence products

2.21 Since the above licence product is specifically aimed at ubiquitous user terminals, the RA intends to continue discussion of additional licence products within the industry consultation groups in order to facilitate other customer requirements in the non-exclusive bands.

Q3 The proposals for a new network licence continue the rollout of a consistent approach to pricing in the satellite sector. Do you have any comments on these proposals?

3 Proposals for public telecommunications network (PTN) services

3.1 The following paragraphs set out proposals for the continuing phased implementation of spectrum pricing to this sector. Tables 22 and 23 illustrate in detail the continuing phasing-in of spectrum pricing for PTN services, to take effect from July 2002 onwards.

3.2 These proposals are without prejudice to the announcement made in October 2000 (see press announcement dated 20 October 2000) that RA is proposing to make available spectrum for fixed wireless access (FWA) services. Further details can be found on the RA website (www.radio.gov.uk) on the public fixed wireless access pages.

3.3 It should be noted that no further prices are levied on any licences that are awarded by auction processes. The auction price covers the licence for the full period of the award.

Mobile operators

3.4 The objectives of spectrum pricing for mobile communications are:

– to promote spectrum efficiency;

– to encourage users to consider alternative services and frequency bands; and

– to promote the use of more spectrally efficient technologies (i.e. the ability to handle the same/more traffic within narrower bandwidths).

3.5 The primary aim of this document is to illustrate further the migration levels, for the pricing of the wide range of public telecommunications services, already addressed in the previous four phases towards:

– equivalent relative levels for the amount of spectrum utilized,
– adjusted by appropriate modifier scaling factors to address particular spectrum or sector issues.

3.6 Additionally, proposals are offered for the pricing of categories of cellular telephone services in the Channel Islands and the Isle of Man and remote meter reading services. FWA is covered as a separate topic.

3.7 As previously, RA2/PTN will hold discussions, both individually and collectively, with the PTN operators, to agree the application and value of appropriate modifiers. Discussions with the Mobile Services Committee will also be held to decide whether there is a need to review the existing modifiers as well as whether any new modifiers need to be introduced.

Licence classes

3.8 The classes to which it is proposed to continue to apply spectrum pricing principles for the year 2002/03, as detailed in the following paragraphs, include:

– Public mobile operator class, comprising:
  – cellular and PCN radiotelephones (but note no further changes this time);
  – public mobile data;
  – public paging;
  – public access mobile radio (PAMR) including Public TETRA.
– Common base stations (CBSs) licence class:
  – Existing CBS services including congestion factors;
  – CBS services in new spectrum such as Band I and Band III.
– FWA licence class:
  – services in the 3.6-4.2 and 10-11 GHz bands.
– Licence classes being considered for incentive pricing proposals:
  – FWA in the 2.0 GHz and 2.4 GHz bands.
– Other public telecommunications services:
  – remote meter reading.

Spectrum allocation for public services

3.9 Spectrum for public networks is allocated on an exclusive basis for a local area, or for regional, national or United Kingdom-wide coverage. With the exception of local area CBS services, the allocation procedure is normally through public open consultation/competition which is managed jointly by RA and the DTI. Spectrum for entirely new services, or for later generation technologies of existing services, may be (and has been) considered in future for possible auctioning of spectrum which is made possible by the provisions of the 1998 Act.

3.10 Once the initial allocation is made, further spectrum may be allocated (if available) only on demonstrable need and, if not specifically provisioned for call-off under the terms of the original consultation, may also be subject to open consultation/competition. The channels allocated are considered to be uniformly "congested" since, once allocated to meet the operators' traffic demand, there is no further spectrum available for these services. The use of "congestion" as a factor is therefore not appropriate in calculating fees for these services.

3.11 CBS assignments are made from a pool of spectrum allocated to the sector, with defined levels of traffic and customer loading required to retain existing channels or to justify additional allocations. The RA uses monitoring data (both routine and targeted) as well as customer-supplied information in order to assess the merits of applications and employs coverage-prediction software tools to make effective re-use of the spectrum. In the longer term, the RA intends to replace the current fees based on the BS location (i.e. within a non-, ordinary- or heavy- congested area) with a regime that calculates the fee according to the coverage area of the CBS, reflecting the percentage of congested/heavily congested coverage.

STU rate and phasing-in arrangements

3.12 Section 7 of this document summarizes the background to spectrum pricing and the development of the standard tariff unit (STU) as a means of equitable pricing.

3.13 The STU rate for mobile communications of £1.65 per MHz/km^2 (yielding a value of £9 900 per 2 × 12.5 kHz channel nationally) which was calculated and applied in the earlier stages, was based on the relative allocations of spectrum to the range of service sectors. As allocations have changed in recent years and since further spectrum will continue to be allocated, for example to 3G cellular, and to public (and in due course private) TETRA, the basic STU unit will in time need to be re-calculated. However STUs represent only half the recommended tariff rate suggested by the initial consultancy work[3]. The Government decided on a cautious approach, implementing the £1.65 rate as appropriate followed by a review to assess the effect of spectrum pricing on the radiocommunications market. It is therefore proposed that, in the initial implementation years, a stable basis of £1.65 should continue to apply and that there should be no increase until a further review at the end of the implementation phase.

3.14 Table 22 shows the steps taken so far and the remaining steps envisaged to phase in the £1.65 STU rate to current services. However, it is possible that amended or additional modifier rates may be applicable for particular licence categories or in particular bands.

Modifiers and congestion factors

3.15 The Modifiers Working Group of the original Spectrum Pricing Sub-Committee formulated the framework of the policy for applying a scaling factor or "modifier" in cases where there was demonstrable need. Five modifier types were agreed. (Appendix 1, reproduced from the second stage consultation document, gives further information on the modifiers).

Cellular/PCN radiotelephony

3.16 No further changes to fees are proposed in this stage. Cellular operators and PCN mobile telephony services started the process of migrating to spectrum priced fees in 1998 and which were completed in 2001.

Public data networks

3.17 The demand for public mobile data (PMD) has increased greatly due to the expansion of computer-based services and the popularity of mobile personalized communication. This sector uses prime mobile spectrum and, as such, the national standard value of £9 900 per 25 kHz of spectrum (2 × 12.5 kHz) continues to be applied. It is proposed to continue the progression toward implementing the full charge in 2002/2003 to reflect the market value of this spectrum. A response to the second stage consultation asked for consideration to be given to the fact that some national channels have geographic constraints on their usage. This has been accepted and where applicable the modifier of 0.8 continues to apply for spectrum constraints and coordination.

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3 Smith Nera Report.

Public paging

3.18 This is the final year for the phasing in of spectrum pricing for public paging. As the sector continues to develop, it is proposed to continue to the final progression towards implementing the full charge in 2002/2003. The full rate for national mobile spectrum of £9 900 per 25 kHz of spectrum (as shown in Table 22) will apply.

PAMR/TETRA

3.19 It is proposed that the modifier of value 0.7 for choice and diversity should continue to be applied for analogue PAMR services, so that the national standard rate of £9 900 is modified to £6 930 (regional £1 386 based on a reuse factor of 5) and the phased increments, detailed in the previous consultation, should remain unchanged. Following comments from the Agency's customers it has also been agreed to apply a 0.8 modifier to national and regional channels in Band III (174-208 MHz) as spectrum usage is constrained by coordination requirements.

3.20 It is also proposed that for digital public TETRA services a modifier of 0.7 is now included for fragmented spectrum and coordination. New services will still be entitled to a start-up escalator over 5 years, rising to the new proposed equivalent national standard value of £13 860 per channel of 50 kHz (2 × 25 kHz). Some channels may also have additional geographic restrictions and this factor will be reflected in the charge. Currently 1 MHz (duplex) has been awarded for civil TETRA, which will be charged on the same basis as 400 MHz TETRA.

3.21 It is also proposed, due to the rise in the fee of regional PAMR channels to £1 386 per channel, to mirror this increase in the capped ceiling figure, bringing it to £3 000.

CBS

3.22 The aim of administrative pricing for CBS is to encourage operators to use channels more effectively, including the use of trunking. Spectrum pricing will mean that CBS are assigned customized licences on a similar basis to that proposed for PBR wide-area. Congestion is therefore a suitable criterion for formulating the licence fee.

3.23 It is proposed that the modifier of value 0.7 for choice and diversity should continue to be applied for CBS services and that in bands where there is congestion, the PBR fee ratio of 1:2:4 for non-congested: congested: heavily congested should still hold, assuming a theoretical reuse factor of 10. In bands where there is no congestion, specifically those where new spectrum is now being made available for CBS services such as Band I and Band III, a non-congested rate should be adopted, again with an assumed reuse factor of 10. To encourage new services into the uncongested bands it has been agreed that services utilising these bands should be entitled to start-up escalators, rising to the proposed equivalent national standard value of £824 per channel. The incremental steps will be different for each escalator as they are dependent on the band used. Table 23 illustrates the relevant fee structures.

3.24 At present the revised fees for CBS vary according to congestion, defined by grid-references. This arrangement is currently being considered for review. For example, the pollution of CBS channels by historical PMR assignments may affect the congested state in some areas. It is therefore proposed that the pricing of CBS should be reviewed in the near future so that it is based on the actual coverage area, rather than on the initial band reuse factor of 10 regions (although this is expected to cause problems of administrative practicality). CBS assignments are made on the understanding that new licensees will establish a defined level of traffic loading within a given period. If the specified channel loading is not reached, the assignment may be revoked.

3.25 It is therefore proposed to implement the next and final step of differential spectrum pricing for CBS in 2002. However, following responses to the last round of spectrum pricing, the Agency proposes to introduce some revisions to address specific issues on a band-by-band basis for CBS assignments. The proposed changes are:

– low band to be now deemed as non-congested nationally;

– mid band, high band and UHF1 will remain the same as the grid references previously defined;

– CBS assignments on down-graded channels operating in VHF high band and mid band shared with wide area PBR systems will now qualify for a further 0.7 modifier due to non exclusive use. This will apply nationally;

Non-congested	Congested	Heavily Congested
£407	£815	£1 630
0.7 modifier = £285	0.7 modifier = £570	0.7 modifier = £1 141

– all CBS assignments in Northern Ireland and Isle of Man are to be re-defined as non-congested in their available bands due to specific coordination and spectrum allocation difficulties in these two areas.

FWA

3.26 The Agency consulted in September 1999 on proposals for Spectrum Pricing for FWA. The methodology was set out in the consultation document "Spectrum Pricing: Implementing the Third Stage and Beyond". Current charges are given in Table 21. These commenced in July 2000:

TABLE 21

FWA

(£ for each 1 MHz slot each year from issue of licence)

Frequency band (GHz)	On issue(1)	Y1(1)	Y2	Y3	Y4	Y5 and beyond
3.6-4.2(2)	4 218	8 436	12 654	16 872	25 308	33 744
3.6-4.2(3)	1 113	2 226	3 339	4 452	6 678	8 904
10-11(4)	3 375	6 750	10 125	13 500	20 250	27 000

(1) Already implemented.

(2) Where coordination is required with satellite earth stations.

(3) Where coordination is required with satellite earth stations and fixed links.

(4) Excluding those frequencies formerly licensed to Ionica which are in the process of being reallocated. Details may be obtained from the Public Fixed Wireless Access pages of the RA website www.radio.gov.uk.

3.27 Further proposals may be made in 2002 for spectrum pricing for FWA (including the 2 GHz and 2.4 GHz bands) depending on the outcome of economic studies and the award of spectrum for FWA.

3.4/10 GHz allocation proposals

3.28 Further to the announcement in October 2000 (see press announcement dated 20 October 2000) RA is proposing to make spectrum available for FWA services. Further details of the proposals and consultation can be found on the RA website www.radio.gov.uk on the Public Fixed Wireless Access pages.

Fees in the Channel Islands and Isle of Man

3.29 Spectrum pricing was introduced in the Channel Islands and Isle of Man in July 2000. In previous years, only an administrative fee for the ongoing maintenance of licences was levied. This was because at sector level, under a cost-recovery system of charging, the cellular telephone licence class was already fully funded by the mainland national operators and the Islands' contribution was negligible by comparison. However, on an individual basis the cost of the work of coordinating the Islands' local channels and services both nationally and internationally, as well as the overhead of work done towards development of technical standards, planning and policy would, in real terms, have far exceeded the fees actually levied.

3.30 The Agency planned that as soon as the development of fees policy and legislation permitted, a spectrally priced fee structure would be applied to the Islands in a similar way as for other services. This is now possible and the RA therefore proposes to continue with the final phasing in of spectrum pricing for cellular telephony, based on the relative proportion of the UK population resident in the Islands. The RA proposes that a value in the order of 0.2% of the national channel fee rate (based on the £1.65 STU) should be applied per channel and the introduction of this fee rate should be phased in over three years. This should encourage efficient use of spectrum resulting in fewer channels requiring coordination. It is also proposed that the same fee value should also be applied to 3G (UMTS) spectrum in these islands.

Remote meter reading

3.31 This class of licence, introduced in 1999, is already priced closely equivalent to the £1.65 STU rate and it is therefore proposed not to make any changes until the value of the STU rate has been reviewed. This is not likely to be earlier than 2003/04.

Actual values

3.32 Tables 22 and 23 summarize the headline fee rates proposed, and the corresponding values after the application of proposed modifiers.

Q4 These proposals for PTN services reiterate points raised in previous consultations. Do you have any further comments on these proposals?

TABLE 22

Headline tariffs		1997/98	1998/99	1999/2000	2000/01	2001/02	2002/03	2003/04		
No modifiers applied	kHz	£	£	£ (ex. mods.)	£ (ex. mods.)	£ (ex. mods.)	£ (ex. mods.)	£ (ex. mods.)		
		SP: Pre.	SP: Pre.	SP: Yr 1	SP: Yr 2	SP: Yr 3	SP: Yr 4	SP: Post		
Regional paging	1 × 25	3,600	3,600	1,980	1,980	1,980	1,980	1,980		
National paging	1 × 25	5,400	5,400	6,500	7,600	8,750	9,900	9,900		
Regional PAMR	2 × 12½	790	790	1,285	1,645	1,785	1,980	1,980		
National PAMR	2 × 12½	1,800	1,800	3,571	4,714	6,857	9,900	9,900		
National TETRA PAMR	2 × 25	–	–	4,950	7,425	9,900	14,850	19,800		
Data[(1)]	2 × 12½	1,800	1,800	4,500	6,000	7,500	9,900	9,900		
		SP: Pre.	SP: Yr 1	SP: Yr 2	SP: Yr 3	SP: Yr 4	SP: Post	SP: Post		
Cellular	2 × 25	1,800	3,960	6,875	12,500	19,800	19,800	19,800		
Cellular/PCN	2 × 200	14,400	31,680	55,000	100,000	158,400	158,400	158,400		

Actual tariffs		1997/8	1998/9	1999/2000	2000/01	2001/02	2002/03	2003/04		
With modifiers included	kHz	£	£	£ (inc. mods.)	£ (inc. mods.)	£ (inc. mods.)	£ (inc. mods.)	£ (inc. mods.)	Modifier	Rate
		SP: Pre.	SP: Pre.	SP: Yr 1	SP: Yr 2	SP: Yr 3	SP: Yr 4	SP: Post		
Regional paging	1 × 25	3,600	3,600	1,980	1,980	1,980	1,980	1,980		Unity
National paging	1 × 25	5,400	5,400	6,500	7,600	8,750	9,900	9,900		Unity
Regional PAMR[(1)]	2 × 12½	790	790	900	920	1,000	1,386 (1,109)[(1)]	1,386 (1,109)[(1)]	Choice and diversity	0.7 *(0.7 × 0.8)[(1)]
National PAMR[(1)]	2 × 12½	1,800	1,800	2,000	2,640	3,840	6,930 (5,544)[(1)]	6,930 (5,544)[(1)]	Choice and diversity	0.7 (0.7 × 0.8)[(1)]
National TETRA PAMR[(1), (2)]	2 × 25	–	–	4,950	5,200	6,930 (5,545)[(1)]	10,395 (8,315)[(1)]	13,860 (11,090)[(1)]		0.7 (0.7 × 0.8)[(1)]
National data[(1)]	2 × 12½	1,800	1,800	3,600	6,000 (4,800)[(1)]	7,500 (6,000)[(1)]	9,900 (7,920)[(1)]	9,900 (7,920)[(1)]		Unity (0.8)[(1)]
		SP: Pre.	SP: Yr 1	SP: Yr 2	SP: Yr 3	SP: Yr 4	SP: Post	SP: Post		
Cellular (900) [(2)]	2 × 25	1,800	3,960	5,500	10,000	17,820	17,820	17,820	Fragmentation	0.9
Cellular (GSM900)	2 × 200	14,400	31,680	44,000	80,000	142,560	142,560	142,560	Fragmentation	0.9
Cellular (GSM1800)	2 × 200	14,400	31,680	41,250	75,000	110,880	110,880	110,880	Propagation	0.7
PCN (1800)	2 × 200	14,400	31,680	38,500	70,000	110,880	110,880	110,880	Propagation	0.7
Channel Islands/IoM	2 × 25	–	–	–	25	32	40	40		-
Cellular (900/1800/UMTS)	2 × 200	–	–	–	200	260	320	320		-

(1) A modifier of 0.8 applies to national or regional channels in Band III (174-208 MHz) PAMR and designated channels in UHF1 (420-450 MHz), and for TETRA in the band (410-430 MHz) as spectrum usage is constrained by coordination requirements.

(2) 900 MHz TETRA (1 MHz available now unfragmented) other spectrum released with closure of TACS and subject to local restrictions for RAFSEE.

TABLE 23

Headline tariffs		1997/98	1998/99	1999/2000	2000/01	2001/02	2002/03	2003/04		
No modifiers applied	kHz	£	£	£ (ex. mods.)	£ (ex. mods.)	£ (ex. mods.)	£ (ex. mods.)	£ (ex. mods.)		
		SP: Pre.	SP: Pre.	SP: Yr 1	SP: Yr 2	SP: Yr 3	SP: Yr 4	SP: Post		
CBS – Channels with congestion areas	2 × 12½	675	675	1,285 (H/C) 800 (C) 582 (N/C)	1,714 (H/C) 964 (C) 582 (N/C)	2,000 (H/C) 1,071 (C) 582 (N/C)	2,328 (H/C) 1164 (C) 582 (N/C)	2,328 (H/C) 1164 (C) 582 (N/C)		
CBS – Uncongested band				–	825	825	825	825		

Actual tariffs		1997/98	1998/99	1999/2000	2000/01	2001/02	2002/03	2003/04		
With modifiers included	kHz	£	£	£ (inc. mods.)	£ (inc. mods.)	£ (inc. mods.)	£ (inc. mods.)	£ (inc. mods.)	Modifier	Rate
		SP: Pre.	SP: Pre.	SP: Yr 1	SP: Yr 2	SP: Yr 3	SP: Yr 4	SP: Post		
CBS – Channels with congestion areas[1]	2 × 12½	675	675	900 (H/C) 675 (C) 407 (N/C)	1,200 (H/C) 675 (C) 407 (N/C)	1,400 (H/C) 750 (C) 407 (N/C)	1,630 (H/C) (1141)[1] 815 (C) (570)[1] 407 (N/C) (285)[1]	1,630 (H/C) (1141)[1] 815 (C) (570)[1] 407 (N/C) (285)[1]	Choice and diversity	0.7 (0.7 × 0.7)[1] 0.7 (0.7 × 0.7)[1] 0.7 (0.7 × 0.7)[1]
CBS – Uncongested bands	2 × 12½	–	–	–						Unity
Band I and Sub-Band I of Band III										
On issue					103	103	103	103		
1st Anniversary					206	206	206	206		
2nd Anniversary					309	309	309	309		
3rd Anniversary					412	412	412	412		
4th Anniversary					618	618	618	618		
5th Anniversary					824	824	824	824		
Sub-Band III of Band III										
On issue					412	412	412	412		
1st Anniversary					516	516	516	516		
2nd Anniversary					618	618	618	618		
3rd Anniversary					722	722	722	722		
4th Anniversary					824	824	824	824		

(1) An additional 0.7 modifier due to non exclusive use has been applied nationally to CBS assignments on down graded channels operating in VHF high band and mid band sharing with wide area PBR systems.

4 Proposals for programme making and special event licences

Background

4.1 In 1999 The Smith Group, together with the Joint Frequency Management Group (JFMG), were commissioned by RA to study likely spectrum demand in the programme making sector over the forthcoming 10 years. The report concluded that there would be an increase in demand for spectrum from the Programme Making and Special Events sector over the coming years. The report "*The demand for programme making and special events spectrum*", published in November 1999 is available on the RA website and from the RA library.

Previous consultations

4.2 In December 2000 a consultation document was published by the RA, setting out proposals for changes to the Radio Microphones, Request Channels, News Reporting Tariff and the Premium Hours Charge licences. Seven responses were received by the closing date. These responses were mainly in favour of the proposed changes. Most of the proposed changes were implemented in July 2001; however it was decided to give further consideration to the proposals for Request Channels.

Request channels (season tickets)

4.3 Draft proposals were set out in the previous consultation "Spectrum Pricing: Third Stage Update and Consultation" published in December 2000. After taking into account some of the comments received RA now proposes the following approach.

4.4 It is proposed to introduce a carnet system, which will replace the current system of Request Channels (known as "Season Tickets"). It is proposed to charge a fixed fee for each assignment irrespective of an individual customer's operation profile, thereby ensuring that the customer's costs are always predictable. The proposed changes would also allow a proper audit trail of the number of tokens used out of the total number purchased. It is envisaged that the proposed system would be much simpler to understand than the existing system and would therefore be more attractive to a wider range of customers. Also it is considered that the implementation of the carnet system would create a closer link between the impact on spectrum and the fee paid.

4.5 To enable the customer to obtain optimum benefit from the introduction of the "carnet" system it is proposed to allow the licensee the opportunity to "offset" tokens that are unused on renewal of the licence, against further purchases of carnets. This would be subject to the licence being renewed annually on the specified renewal date.

Current and proposed fee structure

4.6 The current Occasional Use fee is based upon a charge per bandwidth unit per time unit. The charge and the size of the bandwidth unit vary according to which frequency range the assignment is in. The time unit is up to 48 h.

4.7 A current Request Channel (Season Tickets) is restricted to use for assignments within any one frequency range and the fee is 60 times the equivalent single Occasional Use fee. Each Season Ticket covers one bandwidth unit (of the same size as the equivalent Occasional Use fee) and may be re-used to cover any number of time units (provided that each Season Ticket is only in use once at any given time).

4.8 A carnet would also be restricted to use for assignments within any one frequency range. One carnet token would be used per bandwidth unit (of the same size as the equivalent Occasional Use fee) per time unit, and a token could not be re-used. Therefore the charging basis would be the same as for the Occasional Use fee. The fee for a carnet would be the equivalent single Occasional Use fee multiplied by the number of tokens in the carnet, less a discount depending on the number of tokens. It is proposed that carnets would be available in only two sizes: – 50 tokens at 10% discount from the equivalent Occasional Use fee and 500 tokens at 30% discount.

Proposed fees

For Permit Channels (known as carnets) and existing fees for Request Channels (known as season tickets) and for Occasional Use channels (also known as Pay-As-You-Go)

			Cost per channel			
			Pay-As-You-Go	Season Tickets	Carnet 60 tokens	Carnet 480 tokens
	Band	Bandwidth	Occasional use (£)	Request channels (£)	Multiple use (60) channel (£)	Multiple use (480) channel (£)
PMSE Link	26-65 MHz	12.5 kHz	2.00	120.00	108.00	672.00
	65-470 MHz	12.5 kHz	6.00	360.00	324.00	2 016.00
	470-1 000 MHz	12.5 kHz	2.00	120.00	108.00	672.00
	1-2 GHz	0.5 MHz	12.00	720.00	648.00	4 032.00
	2-5 GHz	5 MHz	20.00	1 200.00	1 080.00	6 720.00
	5-8 GHz	5 MHz	12.00	720.00	648.00	4 032.00
	8-20 GHz	5 MHz	6.00	360.00	324.00	2 016.00
	20-40 GHz	5 MHz	4.00	240.00	216.00	1 344.00
	40 GHz and above	5 MHz	2.00	120.00	108.00	672.00
PMSE low power	Single channel radio microphone		8.00	480.00	432.00	2 688.00
	Multichannel microphone or single wideband		40.00	2 400.00	2 160.00	13 440.00

Examples of comparisons

4.9 Below are four examples of comparisons between fees under the current system and under the carnet system, in the band 65-470 MHz.

Example 1 – A medium user who might use Season Tickets now and who would pay less with carnets:

60 jobs in year, with no concurrent jobs; each job uses two assignments (i.e. 120 assignments total); each assignment is in 65-470 MHz, for a bandwidth of 12.5 kHz (i.e. 1 bandwidth unit) and 18 h (i.e. within 1 time unit).

Occasional Rate fee

The fee per assignment is £6 (£6 × 1 bandwidth unit × 1 time unit). Thus the total fee for the year is £720 (£6 × 120).

Season Tickets

Two Season Tickets are bought to cover the two concurrent assignments and the fee per Season Ticket is £360. Thereby the total fee for the year is £720 (£360 × 2) and the average fee per assignment is £6 (£720/120).

Carnets

The 60-token Carnet fee is £324 and two of these Carnets are bought since there are 120 (120 × 1 × 1) bandwidth time units to cover. Thus the total fee for year is £648 (£324 × 2), with no tokens remaining unused (for the following year). The fee per assignment is £5.40 ((£324/60) × 1 token per assignment).

Summary

	Fee per assignment (£)	Total fee for year (£)
Occasional Rate fee	6	720
Season Tickets	6	720
Carnets	5.40	648

Example 2 – A heavy user who would use Season Tickets now to gain a large discount and who would pay more with carnets:

150 jobs in year, with no concurrent jobs; each job uses two assignments (i.e. 300 assignments total); each assignment is in 65-470 MHz, for a bandwidth of 12.5 kHz (i.e. 1 bandwidth unit) and 18 h (i.e. within 1 time unit).

Occasional Rate fee

The fee per assignment is £6 (£6 × 1 bandwidth unit × 1 time unit). Therefore the total fee for the year is £1 800 (£6 × 300).

Season Tickets

Two Season Tickets are bought to cover the two concurrent assignments and the fee per Season Ticket is £360. Therefore the total fee for the year is £720 (£360 × 2) and the average fee per assignment is £2.40 (£720/300).

Carnets

The 60-token Carnet fee is £324 and five of these carnets are bought since there are 300 (300 × 1 × 1) Bandwidthtime units to cover. Therefore the total fee for year is £1 620 (£324 × 5), with no tokens remaining unused (for the following year). The fee per assignment is £5.40 ((£324/60) × 1 token per assignment).

Alternatively a 480-token carnet is bought at £2 016. Thus the total fee for year is £2 016, with 180 tokens remaining unused (for the following year). The fee per assignment (excluding unused tokens) is £4.20 ((£2 016/480) × 1 token per assignment).

Summary

	Fee per assignment (£)	Total fee for year (£)
Occasional Rate fee	6	1 800
Season Tickets	2.40	720
Carnets (60 tokens)	5.40	1 620
Carnets (480 tokens)	4.20 (excluding unused tokens)	2 016 (with 180 tokens unused)

Example 3 – A medium user with peak demands who could use Season Tickets now to gain a discount and who would pay less (per assignment) with carnets:

35 concurrent pairs of jobs plus 60 non-concurrent jobs in year (i.e. 130 jobs total); each job uses two assignments (i.e. 260 assignments total); each assignment is in 65-470 MHz, for a bandwidth of 12.5 kHz (i.e. 1 bandwidth unit) and 18 h (i.e. within 1 time unit).

Occasional Rate fee

The fee per assignment is £6 (£6 × 1 bandwidth unit × 1 time unit). Therefore the total fee for the year is £1 560 (£6 × 260).

Season Tickets

Four Season Tickets are bought to cover the 2 × 2 concurrent assignments and the fee per Season Ticket is £360. Thus the total fee for year is £1 440 (£360 × 4) and the average fee per assignment is £5.54 (£1 440/260).

Carnets

The 60-token Carnet fee is £324 and five of these Carnets are bought since there are 260 (260 × 1 × 1) bandwidth time units to cover. The total fee for the year is £1 620 (£324 × 5), with 40 tokens remaining unused (for the following year). The fee per assignment (excluding unused tokens) is £5.40 ((£324/60) × 1 token per assignment).

Summary

	Fee per assignment (£)	**Total fee for year (£)**
Occasional Rate fee	6	1 560
Season Tickets	5.54	1 440
Carnets	5.40 (excluding unused tokens)	1 620 (with 40 tokens unused)

Example 4 – A light user who would not use Season Tickets now and who would pay less with carnets:

30 jobs in year, with no concurrent jobs; each job uses one assignment; each assignment is in 65-470 MHz, for a bandwidth of 0.5 MHz (i.e. 4 bandwidth units) and 48 h (i.e. one time unit).

Occasional Rate fee

The fee per assignment is £24 (£6 × 4 bandwidth unit × 1 time unit). Therefore the total fee for year is £720 (£24 × 30).

Season Tickets

One Season Ticket, for four bandwidth units, is bought and the fee per Season Ticket is £1 440 (£360 × 4). Therefore the total fee for the year is £1 440 and the average fee per assignment is £48 (£1 440/30).

Carnets

The 60-token Carnet fee is £324 and two of these Carnets are bought since there are 120 (30 × 4 × 1) bandwidth time units to cover. Therefore the total fee for the year is £648 (£324 × 2), with no tokens remaining unused (for the following year). The fee per assignment is £21.60 ((£324/60) × 4 token per assignment).

Summary

	Fee per assignment (£)	Total fee for year (£)
Occasional Rate fee	24	720
Season Tickets	48	1 440
Carnets (60 tokens)	21.60	648

The future

4.10 A number of spectrum pricing proposals have been implemented in the programme-making sector over the past few years while markets and technologies have been experiencing an unprecedented state of flux. The RA will need to consider the impact of past pricing proposals against a range of current developments in the sector, in particular:

– concerning the impact of the loss of bands to other services, such as 3G mobile;

– the development of spectrally-efficient technologies; and

– the trends in demand in each of the programme-making bands, and how these might influence future pricing proposals.

These considerations will, of course, be reflected in future consultation processes.

Q5 These proposals for programme making and special events reiterate points raised in previous consultations. Do you have any further comments on these proposals?

5 Proposals for private business radio (PBR)

Spectrum pricing consultation document

5.1 As described in previous Spectrum Pricing consultation documents, almost all classes of licence in the PBR sector are now subject to spectrum pricing. The result has been restructured and simplified licences, complemented (other than in heavily congested areas) by decreased licence fees, and the revised fee has become a more accurate indicator of value of spectrum allocated to the licence. The changes proposed in this consultation are therefore focused on bringing all licences into line with spectrum pricing principles. These are shown below:

PMR (Standard) UK general licence

5.2 This licence permits the use of a number of simplex channels anywhere in the UK. Following licensee consultation during September and October 2001 (see below) it is proposed to rationalise this licence class by introducing, with effect from mid July 2002, a new PBR UK General Licence and by requiring, where appropriate, certain licensees to migrate to PBR On-Site Licences. It is open to licensees to opt for a different type of licence if they deem it preferable, although any such migration will take place over a five year period. In keeping with the simplification of the PBR licensing regime, it is intended that the licence fee will be £60 for a licence with three years validity before renewal.

5.3 The proposed licence fee of £60 for three years' validity is based on the value of PBR spectrum allocated to the total number of licensees using the UK General facility.

5.4 The public consultation, "Private Business Systems PMR (Standard) licence for UK General Speech Systems", published in September 2001, produced approximately 30 responses, all of which, subject to certain requests for further information and clarification, broadly supported the

'RA's plans. The RA has placed a summary of these responses on its website www.radio.gov.uk and has responded individually where necessary to contributors.

5.5 In the light of consultation responses received, the RA intends to remove the one year fixed location restriction placed upon use of UK general frequencies as well as proceeding with the removal of the fourteen day advance frequency use notice period.

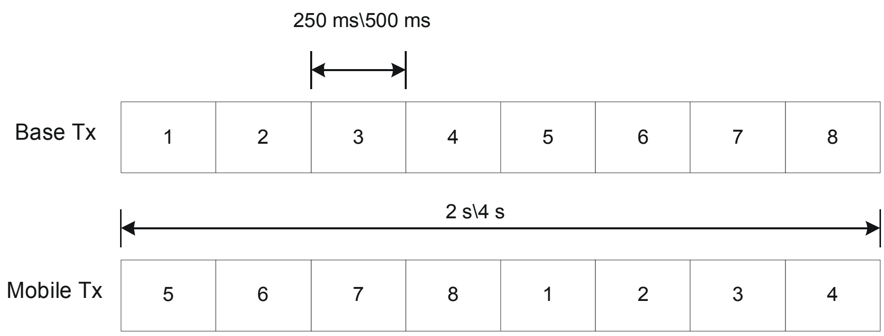
Private business radio channel access procedure for transmission of data messages. IR 2008.

5.6 The RA has recently embarked on wide ranging discussions with suppliers and manufacturers who have an interest in the development of data transmission using PBR. Discussion covered the structure and introduction of a new licensing regime to permit and encourage the use of data on specific data-only channels. It is intended that a new licensing regime will be introduced based upon "Interface Requirement: IR 2008. IR 2008" will, as soon as is practicable, replace existing arrangements based upon "MPT 1379 Code of Practice (1994)", which allowed the operation of data equipment on PBR channels.

5.7 The RA, together with industry, has reached a firm conclusion that for new data users, a clear break is needed with MPT 1379. The introduction of a new licensing regime will alleviate the problems currently being experienced and encourage the introduction and use of a more spectrum-efficient licensing environment. For details on this, please refer to the RA website www.radio.gov.uk under "Private Business Radio" and "Data Only" and/or "Interface Requirements" and "IR 2008".

5.8 The new IR 2008 channel access method will enable users, through access to systems incorporating GPS technology[4], to have the use of licensed "time slots", giving in effect users "exclusive" use of shared spectrum (see diagram below)

IR 2008/"Time-slot" channel access



5.9 The 13 channels (10 in VHF Low Band and 3 in VHF mid band) that will be made available have been designated as "data only". Compliance with the IR 2008 Interface Requirement will be a licence condition for their use.

5.10 The advantage of enabling PBR data transmissions in spectrum dedicated for such use is that the RA will be able to maintain specific grades of service through improved assignment methods and through the use of dedicated and synchronized "time-slots". This method of operation will ensure spectrum efficiency gains through the use of non-prescribed technology. The RA will ensure the integrity of the spectrum and its use, through a programme of planned inspection and enforcement to ensure compliance with IR 2008. Each new system will be inspected to ensure that

[4] Global-positioning Satellite Systems.

only the correct licensed "time-slots" are being used. The use of the new spectrum will ensure that no new data systems are required to share channels with voice transmissions.

5.11 The RA proposes that the introduction of the new data service will not affect the operating conditions which currently apply to systems licensed under MPT 1379. The migration path for moving the licensing of MPT 1379 systems to the new IR 2008 regime will be:

– IR 2008/data: only channels to be licensed with effect from mid July 2002.
– The cessation of licensing of MPT 1379 equipment one year after the introduction of IR 2008 data-only channels.
– All users of MPT 1379 equipment will be required to migrate to new channels by the end of 2006.

5.12 However, the RA anticipates that existing licensees may wish to take advantage of the improved operating conditions provided by IR 2008 and it will encourage licensees to migrate to the new spectrum as soon as possible, provided that they are able to meet the conditions of IR2008.

5.13 The RA intends that, with effect from mid July 2002, licences will be available at the rate of £25 for each single time slot with a maximum of two time slots permitted per licensee.

5.14 The proposed licence fee has been based on the value of a PBR Wide Area system operating in Low Band with effective exclusive use of the channel. The value of that spectrum has been further subdivided by a factor of 8 to reflect the number of synchronized time slots that can be used on a single channel.

PMR road construction licence

5.15 The PMR road construction licence authorizes the use of radio at road construction sites where contracts have been awarded by the Department for Transport, Local Government and the Regions, the Scottish Executive and the National Assembly for Wales.

5.16 As notified previously, the final increase in the fee for this licence will take effect from mid-July 2002, when the fee will become £2 000 per year.

Q6 These proposals for PBR reiterate points raised in previous consultations. Do you have any further comments on these proposals?

6 Proposals for maritime licensing

Five-year ship fixed radio licence

6.1 The RA intends to launch a five-year duration ship fixed radio licence during 2002. This licence will only be available to SOLAS convention and certain other categories of vessel which are subject to compulsory annual survey. The new licence will be introduced to reduce the administrative burdens on commercial vessels by bringing the ship radio licence cycle into line with other certification required by vessels and which is issued on a five-year cycle. It will replace the current annual licence.

6.2 It is not appropriate to apply the "economic value" philosophy of spectrum pricing to ship radio licences. The frequencies used are globally agreed. A vessel may only be licensed by the administration under which it is registered. That administration will issue a unique identifier to the vessel, called an IMSS number, and this is held on the MARS database of the International Telecommunication Union and helps in search and rescue operations.

6.3 The proposed fee will be £80 for the five-year period, and will be non-transferable.

Q7 This new proposal for ship fixed radio licence aims to bring a consistent approach with other maritime regulatory requirements. Do you have any comments on this proposal?

Summary of Questions

Q1 The proposals for fixed links reiterate points raised in previous consultations. Do you have any further comments on these proposals?

Q2 The proposals for satellite link reiterate points raised in previous consultations. Do you have any further comments on these proposals?

Q3 The proposals for a new network licence continue the rollout of a consistent approach to pricing in the satellite sector. Do you have any comments on these proposals?

Q4 The proposals for PTN services reiterate points raised in previous consultations. Do you have any further comments on these proposals?

Q5 The proposals for programme making and special events reiterate points raised in previous consultations. Do you have any further comments on these proposals?

Q6 The proposals for PBR reiterate points raised in previous consultations. Do you have any further comments on these proposals?

Q7 This new proposal for ship fixed radio licence aims to bring a consistent approach with other maritime regulatory requirements. Do you have any comments on this proposal?

7 Summary and background to spectrum pricing

The importance of radio spectrum and its management

7.1 The radio spectrum is a finite resource of considerable and fast-growing economic importance. A study by the RA indicates an estimated benefit of the radio industry, to the UK economy, amounted to some £20bn for the year 2000[5]. The recent European Commission Green Paper on spectrum policy[6] emphasized the strategic economic importance of spectrum to the EU as a whole.

7.2 Failure to make the best possible use of the spectrum resource can impose substantial costs, including loss of international competitiveness. Effective management of the spectrum resource is therefore of great importance in building the knowledge-driven economy.

The challenge for spectrum management in the 21st century

7.3 Although national circumstances differ, administrations worldwide face broadly similar spectrum management challenges. Demand for frequencies is increasing, especially in bands suitable for mobile communications. At the same time, technical and market developments, such as convergence, are accelerating in unpredictable ways and new types of service are constantly requiring access to spectrum. The challenge for spectrum managers in the 21st century is how to

[5] "Economic Impact of the Radio", published by the Radiocommunications Agency, February 2001.

[6] COM(1998)596 final, published by the Commission on 9 December 1998.

satisfy demand for spectrum that is simultaneously growing quantitatively and changing qualitatively. Unless that challenge can be met, there is a real danger that spectrum congestion and shortages will hold back growth and slow down innovation.

7.4 Spectrum managers have generally relied solely on regulation to manage spectrum and licence fees have tended to be set no higher than necessary to recover administrative costs. This worked reasonably well while spectrum was plentiful, technology relatively stable and demand could be met on a "first come-first served" basis. But, as demand grows and change accelerates, the RA has to make increasingly difficult spectrum management decisions at the allocation and assignment levels. Some or all of the following harmful consequences could result:

– Spectrum management decisions are imposed by administrations on the basis of incomplete information about future trends.

– Slow administrative procedures for changing spectrum allocations and assignments retard technical progress and innovation.

– Users have little incentive to give up unused or under-utilized spectrum or to invest in more spectrum-efficient technology or services. This creates a self-perpetuating circle of shortage and hoarding. If licence fees do not reflect the economic value of the spectrum, users have an incentive to retain surplus spectrum in case they need it later, which exacerbates the shortage. Hoarding can in principle be prevented by regulation but, in practice, this is difficult.

– Spectrum is not assigned to the highest value user or use and investment decisions are distorted leading to misallocation of resources. For example, a telecommunications operator may decide to retain high capacity radio fixed links in its trunk networks instead of installing cable. This might be cost-effective from the operator's point of view but may not represent the most beneficial use of the spectrum for the economy as a whole.

7.5 It has become apparent that, in some cases, regulation, despite its advantages, is no longer sufficient by itself and needs to be augmented.

New spectrum management tools were needed

7.6 The UK, like several other administrations, is making increasing use of market-based spectrum management tools, such as spectrum pricing. These work through the market and apply market-players' private information to help achieve the optimal outcome in terms of spectrum distribution and are capable of responding dynamically to changing circumstances. However, market forces are being used as a complement to regulation, not as substitute for it. It would not be desirable to allow market forces total freedom. Regulation will continue to play a central role in managing radio spectrum in order to:

– give effect to harmonization and frequency coordination within the ITU, CEPT and EU frameworks;

– deal with interference and unlicensed use;

– ensure effective competition and maintain diversity, including access to spectrum by small businesses;

– guarantee access to spectrum to meet the operational needs of essential public and safety-of-life services.

7.7 Regulation and market-based tools are being combined in the UK in a pragmatic manner. Different radio services have different characteristics and may require different approaches. Therefore a combination of administrative pricing and regulation is being used to manage spectrum for most mobile radio and point-to-point fixed links. Third Generation mobile telecommunications spectrum has been auctioned while regulation alone will continue to be sufficient for some other licence classes.

The introduction of spectrum pricing in the UK

7.8 Spectrum pricing can be defined as charging fees for access to spectrum that reflect the value of that spectrum. The 1998 Act, which entered into force in June 1998, substituted spectrum pricing for cost recovery as the basis for setting radio spectrum licence fees in the UK.

7.9 This approach is in line with standard economic theory that the distribution of a scarce resource, such as spectrum, will be optimized in terms of economic welfare if it is priced at its marginal value, thereby ensuring that it is assigned to those who can achieve most benefit from its use. If it is priced below this level, those who generate less benefit have little incentive to relinquish it in favour of those who can add more value; and businesses, consumers and jobs suffer. It is also likely that fees charged to recover costs will discriminate unfairly against small business users as the cost of administering a licence is unrelated to the amount or value of the spectrum occupied.

7.10 In accordance with Article 11.2 of the EU Licensing Directive[7], it is a cardinal principle in the UK that spectrum pricing should be used to achieve spectrum management objectives, not to maximize licence revenue. Since other EU Member States are also subject to Article 11.2, the transposition of this provision into UK law and its mode of application may be of wider interest.

7.11 The 1998 Act introduced two forms of spectrum pricing:

a) *administrative pricing*, in which fees are set by regulation on the basis of spectrum management criteria; and

b) *auctions*, in which fees are set directly by the market.

7.12 The legislation was preceded by widespread public consultation, including a consultative document[8], White Paper[9] and a study of the application of spectrum pricing[10]. This consultation demonstrated widespread support for spectrum pricing in principle and helped construct consensus for reform. There has since been further extensive consultation on detailed implementation[11].

Administrative pricing

7.13 Administrative pricing involves the spectrum manager setting the level of licence fees as a surrogate for market forces. Most licence fees are set by administrative pricing rather than by auctions. Administrative pricing may include such variants as:

– incentive pricing, where an attempt is made to set prices to promote particular aspects of efficient use;

– regulatory pricing (cost based pricing), where fees are set unrelated to market considerations, for example, to recover spectrum management costs.

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[7] Directive 97/13/EC. Article 11.2 states, "Member States may, where scarce resources are to be used, allow their national regulatory authorities to impose charges which reflect the need to ensure the optimal use of these resources. Those charges shall be non-discriminatory and take into particular account the need to foster the development of innovative services and competition."

[8] "The Future Management of the Radio Spectrum", Radiocommunications Agency, March 1994.

[9] "Spectrum Management: into the 21st Century", HMSO, June 1996 (Cm 3252).

[10] "Study into the Use of Spectrum Pricing", by National Economic Research Associates and Smith System Engineering Ltd, published by the Radiocommunications Agency, June 1996.

[11] See "Implementing Spectrum Pricing", May 1997, and "Spectrum Pricing: Implementing the Second Stage", September 1998 and "Spectrum pricing; Implementing the Third Stage and Beyond", September 1999 published by the Radiocommunications Agency.

7.14 The 1998 Act requires the Secretary of State, in setting spectrum licence fees, to have regard in particular to various spectrum management factors. These are:

– extent of spectrum availability
– rent and expected future demand for use if the spectrum
– the desirability of promoting:
  – efficient spectrum use and management;
  – economic benefits;
  – development of innovative services; and
  – competition.

7.15 The legislation therefore ensures that spectrum pricing cannot be used as a form of taxation. Indeed, the 1998 Act ended the statutory requirement for licence fee regulations to be approved by the Treasury. Under proposals for administrative pricing in the UK, although some users with exclusive national channels or assignments in parts of the country affected by congestion will pay higher fees, tens of thousands of smaller business users will pay no more than previously or will benefit from fee reductions. Even where fees are increased, they will be no higher than necessary for spectrum management purposes.

7.16 It also follows that spectrum pricing is being applied in a focused way. Spectrum pricing is not an appropriate tool in all circumstances. For example, the use of spectrum pricing is not normally indicated where spectrum is not congested or technical standards and parameters, such as bandwidth and frequency, are mandated by international regulation and users cannot respond to price signals by adopting alternative technology.

Auctions

7.17 Compared to the alternative of comparative selection, auctions offer important advantages of:

– *economic efficiency*: A well-designed auction ensures that licences are awarded to operators that value them most and can generate greatest economic benefit;
– *fairness*: Selection by administrative criteria is more subjective and less transparent;
– *being less unfavourable to new market entrants*: Comparative selection tends to favour incumbents with established track records.

7.18 However, auctions are not suitable in all circumstances. For example, they would be impracticable for high volume-low value licences for PBR used by taxis or individual fixed links. The Government has made clear that auctions will be used selectively in the United Kingdom for new national or regional services where there are more applicants than can be accommodated in the available spectrum. Existing operators will not be required to enter a spectrum auction for the right to continue their existing services within existing allocations. Nor will broadcasters who have won their broadcasting franchizes in an auction under the broadcasting legislation be required to enter a spectrum auction.

Phased implementation of administrative pricing

7.19 The new spectrum pricing regime is being implemented in stages, each generally being phased in over four years so that users have an opportunity to adjust.

7.20 The first stage of administrative pricing, which began in July 1998, tackled the worst distortions of the previous cost-based regime by increasing fees for mobile telecommunications networks and reducing them for thousands of users of on-site PBR.

7.21 The second stage, which began in July 1999, extended spectrum pricing principles to other mobile radio and point-to-point fixed links. Fees for national telecommunications networks will continue to increase but smaller PBR users will continue to benefit from fee reductions outside congested areas. Full details of proposals for this stage were set out in the September 1998 Consultative Document, which have generally been followed in the July 1999 Fees Regulations.

7.22 The third stage, which started in July 2000, extended spectrum pricing to the whole of the PBR sector (apart from the United Kingdom General licence class). Fees for national telecommunications networks, CBS and point-to-point fixed links increased. Users of shared spectrum continued to benefit from fee reductions. In the maritime and aeronautical sectors the RA simplified licences classes to aid understanding and reflect other regulatory regimes. The RA also introduced three-year licences for the first time as a deregulatory measure. Full details of proposals for this stage were set out in the September 1999 Consultative Document, and were generally adopted in the July 2000 Fees Regulations.

7.23 The fourth stage, which started in July 2001, extended spectrum pricing principles to permanent and transportable earth stations, resulting in lower fees for most customers, and in some areas of the programme making and special events sector, bringing some rationalization and simplification of the current system. Fees for national telecommunications networks, CBS and, point-to-point links increased for congested or national channels, while fees in non-congested areas continued to decrease. A number of new licence classes were introduced in the maritime sector.

7.24 Full details of proposals for this stage were set out in the December 2000 Consultative Document, and were generally adopted in the July 2001 Fees Regulations. This current consultation document sets the ’RA’s proposals for implementation in July 2002.

Development of STUs

7.25 As a means of deriving equitable fees, STUs were evolved for the mobile bands. Details of the derivation of these units were set out in the May 1997 and September 1998 Consultative Documents on Implementing Spectrum Pricing. ’STUs aim to give a value for spectrum as a raw material from which individual product values can then be calculated. The Independent Spectrum Review will examine the STU and make recommendations as to whether it should be reviewed. The ’Review’s recommendations have yet to be published and we will look again at STUs in the light of its final report.

Licence exemption/deregulated services

7.26 Under the Wireless Telegraphy Act 1949 installation and use of radio equipment is permitted only under a licence or through licence exemption. Any other use is illegal and subject to enforcement action. Licence exemption is provided by the Wireless Telegraphy (Exemption) Regulations 1999 (SI 1999/930, as amended by SI 2000/1012 and SI 2001/730).

7.27 These Regulations cite categories of equipment (generally equipment in the domestic area) and state conditions which apply in order for the exemption to be effective. These conditions are much lighter and more general than those applying to licensed use of equipment. Examples of factors involved in determining whether or not equipment should be licence exempt are:

– the frequency allocated to the equipment
– power of transmission
– use to which equipment is put
– compliance of equipment with national or international standards
– the need for the equipment to be protected from interference from other authorized users.

7.28 Equipment which is currently licence-exempt includes: short range devices, PMR 446, and mobile (terrestrial and satellite) phone terminals. As part of the effort to enhance harmonization of regulatory practices in Europe, much of this equipment is also licence exempt in states that are members of the European Conference of Postaland Telecommunications Administrations (CEPT).

7.29 Please note the RA published in October 2001 a consultation document entitled, "Use of Licence-Exempt Spectrum for the provision of Public Telecommunication Services". This consultation document is seeking views concerning a proposal by the RA to relax, or remove where practical, the current prohibition on the use of licence-exempt spectrum for the provision of public telecommunication services by way of business.

7.30 It is in the nature of exemption that the RA does not have any record of how, when or where, licence exempt equipment is used. As there is no direct contact between the RA and users of these kinds of equipment, it would be impracticable to apply spectrum pricing to licence exempt services.

Regulatory impact assessments (RIAs)

7.31 The RA has published detailed RIAs for each stage in the implementation of administrative pricing and a draft RIA accompanies this consultation document. RIAs analyse the costs and benefits of the new policy to the business sectors affected, with particular reference to small businesses. The proposals for implementation in July 2002 will introduce a more effective licensing regime for some sectors and result in lower fees for small businesses. There will be price increases for some sectors, but these will be mainly for large national or regional companies using high value spectrum. The potential economic benefits from greater spectrum efficiency is expected to far exceed the costs to business of the additional licence revenue.

Spectrum pricing for the public sector

7.32 It has been a consistent feature of United Kingdom spectrum management policy that the public sector, including the armed forces and emergency services, should be charged for spectrum on a comparable basis to the private sector. The public sector is a major user of spectrum. For example, the armed forces occupy more than 30% of the spectrum between 9 kHz and 30 GHz. It is seen as important that the public sector should also have incentives to use spectrum more efficiently and this has been a key factor in securing general acceptance of spectrum pricing. There is currently a commitment by the Ministry of Defence to return 2 × 5 MHz of spectrum although not of all of this has been identified.

7.33 Comparability is being achieved through the application of administrative pricing principles to public sector users, including the armed forces. The details of how public sector spectrum will be valued are under negotiation with the Departments concerned.

Independent review of radio spectrum management

7.34 The consultation paper referred to in § 1.5 examines the impact of the spectrum pricing implemented so far, and raises a number of questions and proposals for making further use of pricing as a spectrum management tool. The review is expected to report to Government in early 2002 and further information about the Government's response is likely to be published before the RA makes any further proposals about spectrum pricing. Any further proposals will be without prejudice to what is being proposed in this Report for implementation in July 2002.

Part 4

An analytical model for calculating license fees on the basis of specified incentives that are designed to promote efficient spectrum use

TABLE OF CONTENTS

Page

Introduction

This model was developed in the framework of the BDT Asia and Pacific Project on Spectrum Validation and Licensing, Bangkok, 2000. The study focuses on a specific method of spectrum fee calculation. The model is derived from the conceptual base that there is a distinct need to price spectrum and that the pricing of spectrum resources should reflect more than administrative convenience. This has been reinforced by the views of administrations participating in the data collection and policy review of SE Asian countries under the above Project. Further detailed information is available from the ITU website:

http://www.itu.int/ITU-D/tech/spectrum-management_monitoring/MODEL-FULL.pdf

The importance of the model rests on it providing to administrations a functional tool which can be used to calculate spectrum fees on the basis of tangible criteria. In fact it falls within the category of administrative incentive pricing approaches that were documented in the Report ITU-R SM.2012-1. In the manner of most prevalent administrative incentive approaches it allows variations in not only the criteria used as inputs to the pricing but supports weighting those criteria to reflect the importance of certain spectrum utilization variables. This can also be used to vary the pricing between different spectrum uses whereby the underlying scarcity of spectrum can be considered.

The model, while rather complicated for manual calculations, is most effective for application to automated national spectrum management systems. Relevant software can be customised in accordance with the Model and all the rest calculations will be fulfilled automatically without any involvement of the system operators. Similar experience is described by the Administration of the Kyrgyz Republic in Report ITU-R SM.2012-1.

1 General purpose of the model

The purpose of this model is to increase spectrum utilization efficiency. It is designed to introduce non-discriminatory access to the spectrum for various categories of users, stimulate the use of less congested (particularly – higher) frequency bands, stimulate harmonized development of radio communication services throughout the country, and cover the cost of spectrum management. It includes the consideration of the phased development and/or maintenance of spectrum management and monitoring facilities and reimbursement of expenditures of a national telecommunication administration including its international activities within ITU.

The model was developed on the basis of materials (including those contributed by the authors of this Report) contained in the new version of Report ITU-R SM.2012 – Economic Aspects of Spectrum Management, which will be published soon as Report ITU-R SM.2012-1, and other available publications.

The model determines the value of annual payments to be made for the spectrum use of each transmitting radio station using a pricing formula based on the following basic elements:

– Three-dimensional radio frequency-spatial[12]-time resource, referred to as the *spectral resource*, used in the country and representing the common spectral value applicable to all frequency assignments, stored in the national spectrum management database and which is calculated on an annual basis.

– For each frequency assignment the spectral value is determined by the frequency band occupied by the emission, multiplied by an area, occupied by the emission (which is

[12] For reasons of simplicity and taking into account that spectrum sharing conditions are usually provided only by territory separation of stations, for purposes of the given Model a spatial (three-dimensional) resource is represented by a territorial (two-dimensional) one.

determined by the power of transmitter, height and direction of the antenna etc.), and multiplied by the fraction of time throughout which the transmitter operates with that emission in accordance with terms of relevant license. Relevant assumptions and criteria are presented below in § 5.

– The annual administration cost of spectrum management including the phased development and/or maintenance of spectrum management and monitoring facilities and the reimbursement of expenditures of a national telecommunication Administration.
– The average price for the spectral resource unit determined from the above values.
– The annual payment by a specific user determined from the actual value of used spectral resource.

A number of incentive weighting factors are entered in the formula. Thus the spectrum price or fee will depend not only on the relevant occupied bandwidth and coverage area values, but also on time-sharing conditions, geographical location of the station, economic development level or population density in the coverage area, social factors, exclusivity, type of radio service, spectrum employment, as well as some operational factors such as complexity of radio monitoring and imposing sanctions, etc.

The proposed Model allows the user at any moment to determine the value of his annual payment for the spectrum and also renders it to be transparent and accessible to all users. Thus, if the user employs greater bandwidth and service area, operates in more populated geographical area or the area is more economically developed and operates full time in more congested frequency bands, the larger will be the payment.

The approach thus encourages more efficient spectrum use and is an incentive for the user to implement more modern equipment and operate in new higher frequency bands. It should also encourage the use if possible of time-sharing regimes with other users, avoid using redundant margins for the power of a transmitter and height of antenna etc. and support expansion of its coverage to rural and remote areas.

2 Steps in the model formulation

The proposed spectrum payment algorithm includes the following steps:

– Determination of annual expenditures of the State on management of actually used spectral resource and determination of the common value of the annual payments for all spectral resources.
– Determination of the value of the spectral resource used by each radio station and, through their summation, by all stations registered in a national Spectrum Management Database.
– Determination of the price for a unit of the spectral resource.
– Determination of the annual payment for a specific user on a differential and non-discriminatory basis, determined from the actual value of used spectral resource.

Each of these steps is described in detail below.

3 General principles for the model development

It is necessary to underline that the number and values of all particular coefficients below are given only as illustrative examples. They are based on available data and the experts estimations in application to South-East Asia countries. Each national telecommunication administration can chose other values and add other coefficients reflecting its particular needs and experiences. All coefficient values, unless indicated specifically, can be integer or fractional numbers.

The model is intended to cover those cases (and they are the great majority of frequency assignments) for which simplified calculation methods of some important parameters (mainly – service or occupied areas) can be used.

This approach has been chosen also from the understanding that for purposes of fees calculation it is much more important to provide universal procedures to guarantee equal conditions for all users belonging to one group (by radio service or its particular application) rather than to obtain a high accuracy of technical parameter calculations. Different options in obtaining the data necessary for calculations are presented in Annex 1.

Based on a general principle that not only a transmitter but also a receiver occupies a particular spectral resource by denying operation of other transmitters (other than a communicating one) in a particular frequency band within the limits of a particular territory (Recommendation ITU-R SM.1046-1), the Model can be used for calculating fees for receivers as well in a case when a user requires protection of a receiver from interference and it is registered in a National Frequency Assignment Database. The procedures for the calculations are presented in Annex 1.

Annex 1 also presents some options to administrations on simplification of calculation procedures implying the decrease in calculation accuracy, or on their somewhat complication for increasing calculation accuracy.

For certain new radio systems for which the service area or occupied frequency band calculations are very complicated and when they have not been definitively fixed (spread-spectrum systems, satellite mobile communications using LEO, MEO, etc.), calculations can be postponed and fixed license fee regimes may continue to be used.

4 Expenditures and income of a state concerning spectrum management

This Section offers the framework on which the State or administration's costs for spectrum management may be considered.

The total amount of the annual payments for spectral resource C_{an}, to be collected from all users, can be presented as:

$$C_{an} = C_1 + C_2 - I_{an} \quad \text{(units of a national currency)} \tag{18}$$

where:

- C_1: share of the sum that is necessary for covering expenditures of the State on all national and international spectrum management activities
- C_2: net income of the State, if applied
- I_{an}: total amount of annual radio communication inspection charges, if applied.

The last term is applied if an administration uses separate additional tariffs for inspection and examination activities (examination of frequency assignment application forms, inspection of radio stations after installations before entering to operation, systematic inspection of radio installations on conformity to license terms, etc.). This value can be assumed for each current year based on previous year data.

It is possible to subdivide the terms C_1 and C_2 into additional components:

$$C_1 = C_{11} + C_{12} + C_{13} + C_{14} \tag{19}$$

where:

C_{11}: funds necessary for the purchase and efficient operations using spectrum management system facilities and equipment, including radio monitoring station equipment, direction finders, computers and software for monitoring stations and for a national Spectrum Management Database, equipment for inspection purposes, materials, amortisation of buildings, constructions, transport vehicles, etc.

C_{12}: funds necessary for carrying out supporting scientific research, purchase of the scientific and operational literature, international standards and recommendations, carrying out electromagnetic compatibility analysis for supporting frequency assignment process, etc.

C_{13}: funds necessary to provide efficient activities of a national telecommunication administration within ITU-R and to fulfil bilateral and multilateral frequency coordination obligations relating to terrestrial and satellite radio services etc.

C_{14}: spectrum management staff salaries.

Taxes are not included in the amounts $C_{11} – C_{14}$.

Coefficient C_2 can be presented as the following components:

$$C_2 = C_{21} + C_{22} \tag{20}$$

where:

C_{21}: taxes on the incomes of a national spectrum management body and taxes included in the cost of the equipment, software, materials etc., which are bought by this body from the market

C_{22}: additional payment for spectrum use coming directly to a State budget.

To encourage faster development of radio communication services to support economic development of a country some countries do not apply such additional charges (see Report ITU-R SM.2012-1). Equations (18) and (20) do not take into account any indirect income of the State from the used spectral resource in the form of taxes from the incomes of the telecommunication operators whose activity is connected with spectral resource use (for example, taxes from the incomes of the cellular communication operators). This component of the income of the State usually is collected and repeatedly exceeds reasonable values of C_{22}, if those would be collected. At the same time these taxes are also the State income from used spectral resource although an indirect one.

In essence C_{22} is some kind of advanced payment to the State for a spectrum and many telecommunication operators, especially in the developing countries, will not be immediately be able to make such large payments and furthermore this could be an obstacle to development.

A good measure of the provision of an economic incentive is to reduce to a minimum the C_{22} component, so that a telecommunication operator begins to provide service as quickly as possible. The loss of this C_{22} component can be easily compensated by a State from taxes from the telecommunication operator's activity.

Thus, for the purposes of rapid development of telecommunications and information services in a country and the creation of economic incentives to the telecommunication operators, it is essential to hold spectrum payments to the minimum necessary values to cover the costs of a national spectrum management. Administrations can gain further fees from the license for applications to which the spectrum is used and furthermore the taxes on operator revenues will compensate for the revenue foregone. This will be the case particularly where spectrum fees and licensing are treated separately.

5 Determination of the used spectral resource value

Proceeding from equations (18)-(20) it is possible to determine $C_{an.}$ representing the cumulative annual expenditures and income payment for all spectral resources, used in the country. The second step is to determine the spectral resource value used by each user and then – by all users. These are calculated on the basis of data regarding each frequency assignment contained in a national Spectrum Management Database.

The method proposed is as follows.

For any *i*-th frequency assignment (from their total amount *n* incorporated in the national database) the three-dimensional value of the spectral resource, denoted as W_i, is to be determined as follows:

$$W_i = \alpha_i \cdot \beta_i \cdot (F_i \cdot S_i \cdot T_i) \tag{21}$$

where for *i*-th frequency assignment:

- F_i: frequency resource
- S_i: territorial resource
- T_i: time resource
- α_i: aggregate coefficient which takes into account a number of weighting factors, such as commercial, social and operational ones as it is given below
- β_i: weighting coefficient which determines exclusiveness of the frequency assignment as it is given below.

Let us consider items of equation (21) in their reverse order.

5.1 Determination of a time resource used by an emission

A time resource T_i used by *i* -th emission is determined as:

$$T_i \leq 1 \text{ (year)} \tag{22}$$

and for each frequency assignment represents a fraction of time related to one year, determined in that or another way, during which the radio transmitter operates in accordance with terms set out in the relevant license. It can be a fraction of a day, which may be the case with broadcasting or PMR service, or a fraction of a year for seasonal operations such as expeditions, agricultural activities, etc.

For example, if particular TV transmitter in accordance with terms of its license is operating only 16 h per a day throughout the whole year, than: $T_i = 16/24 = 0.67$ year. If another transmitter (for example an HF one used for geological expedition), in accordance with terms of its license can operate totally only 3 months per year, then: $T_i = 3/12 = 0.35$ year.

It is obvious that for a transmitter which operates permanently, for example a microwave (RRL) one (short intervals of maintenance breaks usually do not taken into account if it is not especially stated in the license), $T_i = 1$ year. The last situation is usually typical for the majority of frequency assignments presented in any national Spectrum Management Database. Such a regime is the most commonly requested and licensed.

5.2 Determination of a territorial resource used by an emission

A territorial resource S_i used by *i* -th emission is determined as:

$$S_i = b_{ij} \cdot s_i \quad (\text{km}^2) \qquad 1 \leq j \leq m \tag{23}$$

where:

S_i: the territory actually occupied (covered) by the emission in accordance with certain criteria (km^2)

b_{ij}: weighting coefficient which depends on the j-th category of the territory actually occupied by the emission

m: number of categories.

The number of categories m and the relevant values of the weighting coefficients b_j should be set out by a national telecommunications administration. These categories can take into account density of population and/or level of economic (industrial and/or agricultural) development of various regions of a country. It represents a measure of attractiveness for radio communication and broadcasting operators. Categories may also distinguish urban and rural areas, inland and coastal areas, mainland and island areas. Additionally settlement type and number of permanent or transitory inhabitants could also be included.

Illustrative examples are presented in Table 24.

TABLE 24

Example of weighting coefficients taking into account a density of population (a level of economical development) in various regions of a country

	Designation	b_j
1	The less populated and/or the less economically developed regions (deserts, high mountains, deep jungles etc.) which are usually the less attractive for radiocommunication and broadcasting operators	0.1
2 – j – ...	Regions with several intermediate and increasing gradations of density of population and/or indicators of economical development	0.2-0.9
...	The most populated and/or the most economically developed regions (capital region, main industry and/or agricultural areas etc.) which are the most attractive for radiocommunication and broadcasting operators	1

Cities and settlements of an urban type		
…	With a population of 10 000 to 50 000 inhabitants	1.2
…	With a population of 50 000 to 100 000 inhabitants	1.5
m – 2	With a population of 100 000 to 500 000 inhabitants	2.0
m – 1	With a population of 500 000 to 1 000 000 inhabitants	3.0
m	With a population over 1 000 000 inhabitants	4.0

The territory actually occupied by the emission s_i is calculated individually for each i-th emission based on the relevant service area concept (and its equivalent for point-to-point communications) by criterion of nominal usable field strength E_n at its border. The procedures for calculations applicable to different radio services and relevant examples of the calculations are presented in Annex 1.

If the territory actually occupied by the i-th emission includes K regions belonging to different categories above, related territorial resource ΣS_i can be determined as:

$$\Sigma S_i = \sum_{k=1}^{K} b_{ik} \cdot \Delta s_{ik} \tag{24}$$

where:

b_{ik}: relevant weighting coefficient for q-th area category

s_{ik}: relevant proportion of the whole occupied region s_i

i.e.:

$$s_i = \sum_{k=1}^{K} \Delta s_{ik} \qquad 1 \le k \le 3 \text{ (usually)}$$

Examples for the calculation of proportional values s_{ik} for different cases are presented in Annex 1 (§ 1.2.1.1.3). If an administration has a digital administrative terrain database interrelated with relevant frequency assignment software, calculations of ΣS_i can be made automatically in accordance with a procedure presented in § 5.2.6 of Report ITU-R SM. 2012-1.

5.3 Determination of a frequency resource used by an emission

A frequency resource F_i used by i-th emission is determined as:

$$F_i = \chi\, B_{ni} \qquad \text{MHz} \tag{25}$$

where:

B_{ni}: necessary bandwidth of the emission (MHz), calculated in accordance with Recommendation ITU-R SM.1138 (see Radio Regulations, Geneva 1998, Volume 4), taking into account that an occupied bandwidth of an emission should be equal to its necessary bandwidth (Recommendation ITU-R SM.328-9)

χ: adjustment $(0 \le \chi \le 1)$ can be used in some cases, for example, to decrease somewhat a very great difference in fees between sound and TV broadcasting, under the same powers of transmitters, due to significant difference in the necessary bandwidths. It also can be used in cases of radar applications (see example of calculations below), etc.

5.4 Determination of weighting coefficients

General weighing coefficient α_i in equation (21) can be presented as a product of the following fractional coefficients:

$$\alpha_i = \alpha_1 \cdot \alpha_2 \cdot \alpha_3 \cdot \alpha_4 \cdot \alpha_5 \tag{26}$$

where:

α_1: takes into account commercial value of the spectrum range used

α_2: taking into account social factor

α_3: takes into account features of transmitter location

α_4: takes into account the complexity of spectrum management functions

α_5: other coefficient (coefficients) which can be introduced by an administration reflecting its specific needs.

Illustrative examples of these coefficient values are presented in Table 25.

TABLE 25

Table of service depended coefficients

Service \ α_I	α_1	α_2	α_3		α_4
			City	Village	
Radio relay line in a range above 1 GHz	0.1	0.1	1	0.1	0.2
Radio relay line in a range below 1 GHz	0.4	0.2	1	0.1	0.2
Television in metre range (MW TV)	1	0.1	1	0.1	1
Television in decimetre range (DMW TV)	1	0.2	1	0.1	1
VHF sound broadcasting	2.4	1	1	0.1	1
LF – HF broadcasting	1	1	1	0.1	0.8
HF radiocommunications	2.6	1.2	1	0.1	0.8
Trunking	2.4	1.2	1	0.1	1
Cellular	3	1.2	1	0.1	1
Paging	3.5	1.2	1	0.1	1
PMR communications	2	1.2	1	0.1	1
Radiocommunications in CB range	0.1	0.2	1	0.1	0.2
Radiolocation	0.1	0.02	1	0.1	0.2
Aeronautical radiocommunication and navigation	0.1	0.2	1	0.1	0.8
Maritime radiocommunication	1	0.2	1	0.1	1
Earth station for FSS	4	0.2	1	0.1	0.2
Earth stations for other satellite services including feeder links	1.4	0.1	1	0.1	0.2

Coefficient α_1 is basically determined by two factors:

– The commercial value of radio services. This factor is linked to the willingness of users and operators to pay for the right to provide services or use the services operated over a specific frequency.

– The necessity of using less congested (usually – higher) frequency bands. Some radio services may be moved to higher frequencies as experience is gained or technology changes. Thus, decreasing the loading of lower frequency bands. This is the economic lever which should encourage the usage of higher bands.

Coefficient α_2 takes into account a social factor. For those radio services, whose existence is vital for all groups of the population, including the most needy, this coefficient has a low value reflecting a truly social value or obligation on behalf of the administration.

For example, for stations above 1 GHz, through which long-distance communications are provided, as well as for television broadcasting, the coefficient α_2 has a low value and for cellular communication, coefficient α_2 has a higher value.

Coefficient α_3 takes into account features of site location in urban and village conditions. In village conditions, where the density of the population is low and the level of the incomes is also low, the commercial value of communication services will also be low, at the same time technological costs for providing these services will also be high. Therefore with the purpose of support of the telecommunication operators and services as well as for encouraging development of radio communication services this can be a lower coefficient α_3, while in urban districts it may be considerably higher.

Coefficient α_4 is determined by the complexity of spectrum management functions performed. This coefficient is usually the highest for mobile services. It is here that it is required to carry out the function of radio determination of mobile objects. Likewise for television broadcasting, it is required to determine with a high degree of accuracy a number of relevant parameters.

Another weighting coefficient in equation (21) is β_i. This coefficient determines exclusiveness of the frequency assignment. If, the given site of the spectrum is used on an exclusive basis, then $\beta_i = 1$. With sharing β_i varies within the limits from 0 up to 1 depending on conditions of sharing. Sharing may be on the basis of territorial separation that can result in reducing actual service area etc.

5.5 Determination of the whole value of the used spectral resource

Thus, with the help of weighting coefficients b_j, α_i and β_i, in accordance with equation (21), it is possible to determine (in view of the various factors) spectral resource W_i actually used for each frequency assignment. Then it is possible to determine the whole value of spectral resource W used in the country, according to the equation:

$$W = \sum_{j=1}^{n} W_j \qquad \text{(MHz} \cdot \text{km}^2 \cdot \text{1 year)} \qquad (27)$$

where:

W_i: spectral resource used by i-th frequency assignment

n: overall number of frequency assignments registered in the national Spectrum Management Database.

6 Price for the qualified unit of the used spectral resource

On the basis of the equations (18)-(20) the total amount of annual payment can be determined which should be received from all users of all or part of the spectral resource. This could be done for all users combined or for individual services such as mobile cellular or broadcasting. On the basis of the equations (21)-(27) the whole value of the annually used spectral resource in the country can be determined.

Then it is possible to determine the price of ΔC_{an} for a qualified unit of the spectral resource:

$$\Delta C_{an} = L(C_{an} / W) \qquad \text{units of a national currency/(MHz} \cdot \text{km}^2 \cdot \text{1 year)} \qquad (28)$$

where:

L: adjustment factor which takes into account possible changes in prices/costs in the country for the next fiscal year.

7 Annual fees for particular frequency assignment

According to equation (28) the price ΔC_{an} for the qualified unit of the spectral resource is determined. Equation (21) gives the value of the spectral resource W_i used for a particular i-th frequency assignment. Based on this, the amount of the annual payment C_i from the specific user of the spectrum for this frequency assignment will be determined as:

$$C_i = \Delta C_{an} \cdot W_i \qquad (29)$$

If the particular radiocommunication operator has several frequency assignments, the payment for each assignment is determined as above and then they are summated in relation to all operator's frequency assignments.

Annex 1
to Part 4

Procedures and examples of used spectral resource calculations in application to different radio services

1.1 General considerations

It is important to point out that calculation methods and procedures of service occupied areas, fixed radio link lengths, etc. for exact operational purposes are usually very complicated, time consuming and require special qualification of the personnel.

Their implementation for license fee calculation purposes could impose a great additional workload on a national spectrum management staff and not lead to significant increasing accuracy of such kind of calculations. Moreover, for the purposes of fee calculations it is much more important to provide universal procedures to guarantee equal conditions for all users belonging to one group (by radio service or its particular application) rather than to have a high accuracy of technical parameter calculations.

Taking this into account, for purposes of the given license fees calculation model, considerably simplified calculation methods are proposed. The main orientation is given on using pre-calculated graphs and tables rather than complicated formulas. For the most difficult cases (HF broadcasting, satellite communications etc.) particular calculations of service areas, fixed radio link lengths etc. can be replaced by values taken directly from relevant license application forms or received from operators by special requests.

Another common approach is to make estimation of service or occupied areas only within the national borders of a country. For maritime services national maritime economical border concept may be used (usually 200 miles, i.e. 360 km).

For cellular mobile radiocommunication systems, paging etc. which may contain numerous base stations including micro- and pico-cell ones for nearby and indoor operations, it may be too time-consuming to make calculations based on the determination of service areas of individual base stations. Therefore for this case the overall service area of the relevant cellular network and overall frequency bands assigned for base-mobile and mobile-base communications can be used for calculation of a spectral resource, used by the whole network.

Occupied areas of earth stations of satellite communication systems are proposed to be determined on the basis of coordination distances agreed during the process of coordination and notification of frequency and orbital assignments in the ITU-R. If they are not available, a universal coordination distance of 350 km for VSATs and 750 km for other stations is proposed to be used. In some cases the values as agreed between the administration and operator can also be used.

It was indicated in § 3 above that the model is also applicable to receivers for which users especially demand protection from interference. To calculate the relevant fees, in accordance with the principle of reciprocity of a receiver and transmitter, the receiver is substituted by a transmitter of typical power (or a power agreed with user) and antenna, which effective height, gain and direction correspond to the receiving one. For this set of parameters the relevant spectral resource and then radio license fees are calculated in accordance with procedures presented below for related radio services and their applications.

It is necessary to mention that an administration, depending on particular conditions and abilities, may decide on simplification of some of the proposed calculation procedures. Particularly it concerns eliminating of service/occupied area subdivisions to different zones belonging to different license fees categories (see § 1.2.1.1.3) and the only one category, corresponding to the largest service/occupied area, can be used. It also concerns eliminating of the effective antenna height determinations (see § 1.2.1.1.2), etc.

1.2 Radio broadcasting

1.2.1 VHF/UHF sound and TV radio broadcasting

1.2.1.1 Calculation procedures

1.2.1.1.1 Service area radius calculation

In the absence of digital terrain map facilities and computerized propagation and frequency planning models, which can provide exact automatic calculations, it is proposed to use the following simplified method of service area determination. The procedure is mainly based on provisions of Recommendation ITU-R P.1546, which presents propagation curves and procedures of their use for determining distances at which field strengths take specific values adopted as minimal usable by Recommendation ITU-R BT.417-4.

The propagation curves presented at Figs. 11 and 12 (Figs. 1 and 9 of Recommendation ITU-R P.1546 correspondingly) represent field-strength values in VHF and UHF bands in dB(µV/m) as a function of various parameters and refer to land paths. The propagation curves relate to transmitter power of 1 kW radiated from a half-wave dipole and represent the field-strength values exceeded at 50% of the locations for 50% of time. These field-strength values are usually used for service areas determination. They also correspond to different transmitting antenna heights and a receiving antenna height of 10 m. The curves are given for particular effective transmitting antenna heights between 10 m and 1 200 m as presented at Figs. 11 and 12. For different values of effective height, a linear interpolation between the two curves corresponding to effective heights immediately above and below the true value can be used.

The effective height of the transmitting antenna, h_{ef}, is determined as its height over the average level of the ground between distances of 3 km and 15 km from the transmitter in the direction of the receiver. Procedures of h_{ef} calculations, to be used under service area radius calculations, are presented in § 1.2.1.1.2.

Service areas are determined by values of minimal usable field strengths, E_{mu}, at their borders, which are usually utilized for frequency planning purposes. These are presented in Table 26.

Values of service area radius R taken from curves at Figs. 11 and 12 under different values of effective radiated power (e.r.p.) P_{ef}, and effective height of the transmitting antenna h_{ef}, for minimal usable field strength values, E_{mu}, indicated in Table 26, are presented in Tables 27-32. Interpolation and extrapolation of field strength as a function of frequency is made in accordance with Annex 5 to Recommendation ITU-R P.1546. Particular frequencies, f_c, for re-calculation are shown in table headings. Calculations are made for effective antenna heights typical for broadcasting.

TABLE 26

Minimal usable field strengths E_{mu} values

Frequency band	Below 76 MHz (TV)	76-108 MHz (TV)	108-230 MHz (TV)	230-582 MHz (TV)	Above 528 MHz (TV)	Below 108 MHz (Sound)
E_{mu} (dB(μV/m))	48	52	55	65	70	54

e.r.p. is given as:

$$P_{ef} = P + G_t + \eta \qquad \text{dBW} \tag{30}$$

where:

- P: transmitter power in dB against 1 W i.e. in dBW
- G_t: antenna gain against a half-wave dipole (dB)
- η: feeder losses (dB).

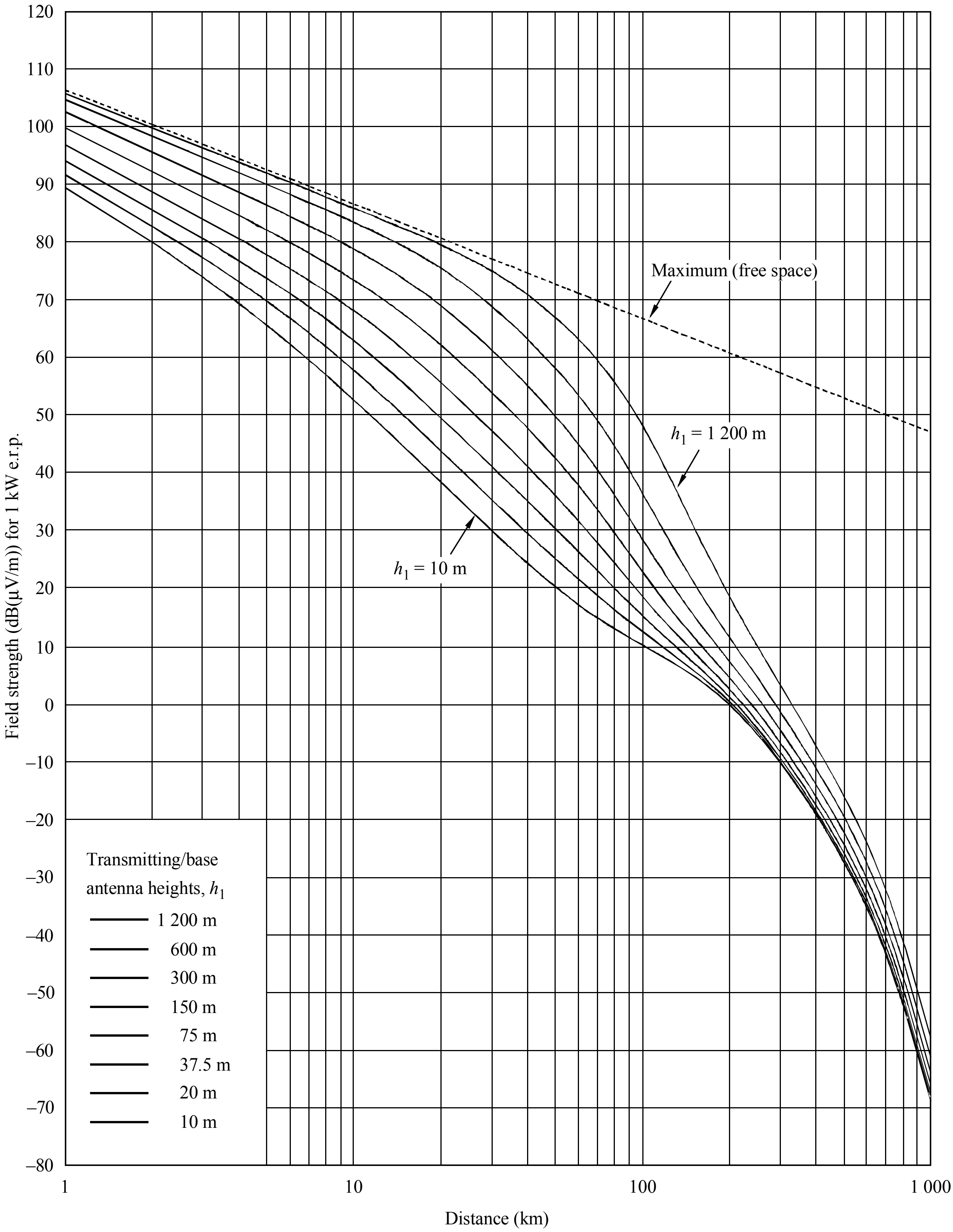
For purposes of the given licence fees calculation model it is proposed to accept $\eta = 0$ for all cases.

It is necessary to note, that under high power and low height antenna conditions and especially for lower frequencies, calculated service area radius exceeds the distance to radio horizon. As far as the quality of the service beyond the radio horizon is significantly decreases it means that excessive transmitter powers are used non-effectively. Relevant distances to radio horizon, when they are less than radiuses of service areas, are indicated by second figures in cells of Tables 27-29.

It can be mentioned that data of Figs. 11 and 12 without any re-scaling correspond to data of Tables 28 and 31 for rows belong to 30 dBW (as far as 1 kW equals 30 dBW). For example, distances which correspond to points indicated at curves of these Figures and can be read along the abscise axis, are highlighted in related rows of Tables 28 and 31.

FIGURE 11

Propagation curves for 30-300 MHz frequency band



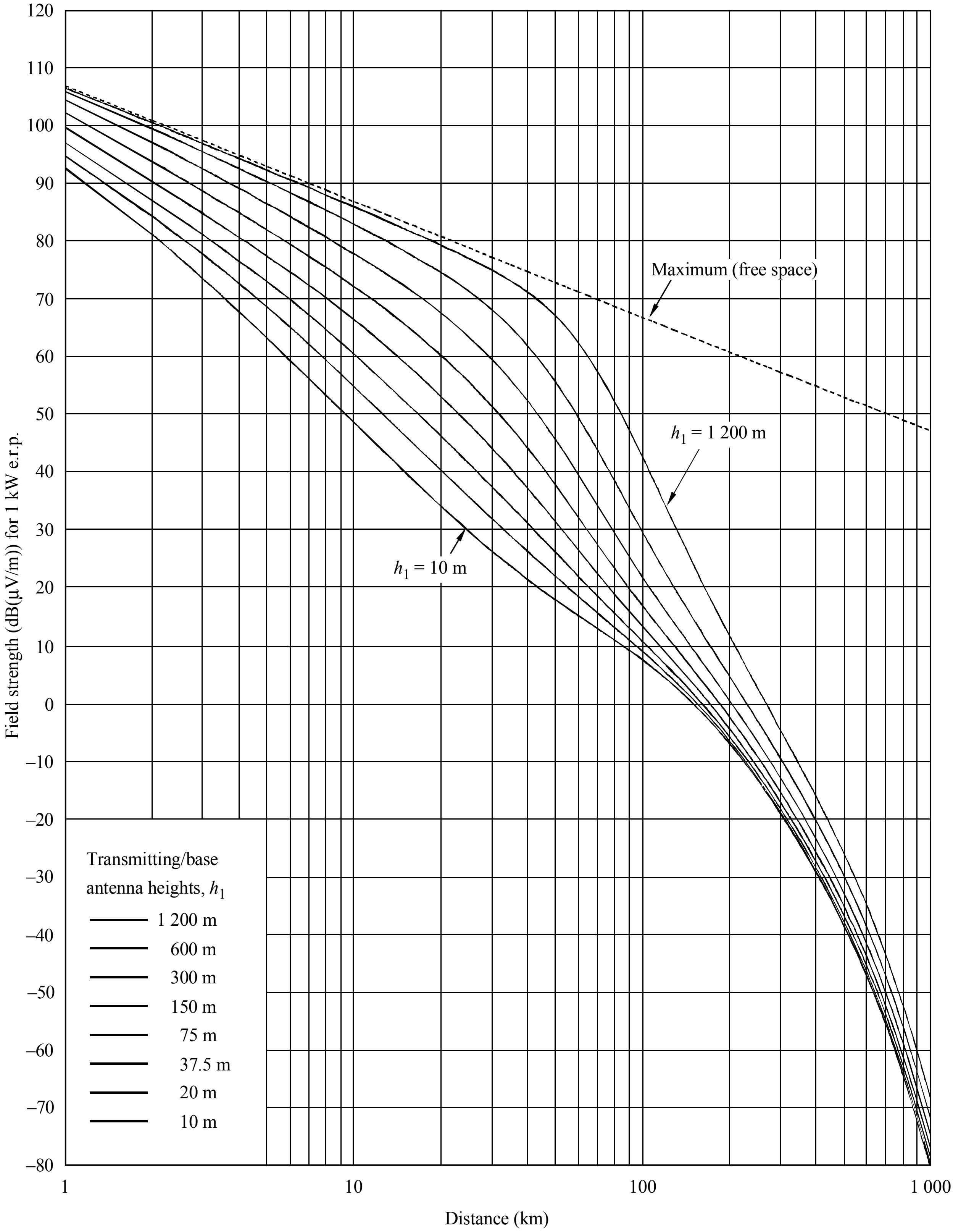
50% of locations

h_2: representative clutter height

Rap 2012-11

FIGURE 12

Propagation curves for 300-1 000 MHz frequency band



50% of locations

h_2: representative clutter height

Rap 2012-12

TABLE 27

Radius of service area (km) for TV below 76 MHz,
E_{mu} = 48 dB(μV/m), f_c = 70 MHz

h_{ef} (m) / P_{ef} (dBW)	30	50	75	100	150	200	250	300	350	400	500
15.0	9	12	14	16	20	23	26	28	31	33	37
20.0	12	15	18	21	25	29	33	36	39	42	47
25.0	16	20	24	27	33	37	42	45	49	53	58
30.0	20	25	30	34	41	47	52	56	60	64	70
35.0	26	32	38	43	51	58	63	68	72	76	82
40.0	33	41	48	54	63	70	75	79	84	88	95
43.0	38/36	47/42	55/49	61/54	70/63	77/71	83/78	87/84	92/90	96/95	103
46.0	44/36	54/42	63/49	69/54	78/63	85/71	91/78	95/84	100/90	104/95	112/105
50.0	54/36	65/42	73/49	80/54	89/63	97/71	102/78	107/84	112/90	117/95	124/105
55.0	69/36	80/42	89/49	96/54	105/63	113/71	119/78	124/84	130/90	135/95	143/105
60.0	88/36	100/42	108/49	115/54	125/63	134/71	140/78	145/84	152/90	157/95	166/105

TABLE 28

Radius of service area (km) for TV in 76-108 MHz,
E_{mu} = 52 dB(μV/m), f_c = 100 MHz

h_{ef} (m) / P_{ef} (dBW)	30	50	75	100	150	200	250	300	350	400	500
15.0	7	9	11	13	15	18	20	23	25	26	30
20.0	9	12	14	17	20	24	27	29	32	34	39
25.0	13	16	19	22	26	30	34	37	40	43	48
30.0	16	20	**24**	28	**33**	38	42	**46**	50	53	59
35.0	21	26	31	35	42	47	52	56	60	64	70
40.0	26.3	32.8	38.7	43.8	51.4	57.8	62.9	67.0	71.4	75.2	81.7
43.0	30	38	44	50	58	65	70	74	78	82	89
46.0	37/36	43/42	51/49	56/54	65/63	72/71	77	81	86	90	97
50.0	43/36	52/42	60/49	66/54	75/63	82/71	87/78	91/84	96/90	101/95	108/105
55.0	54/36	65/42	73/49	80/54	88/63	96/71	101/78	106/84	111/90	116/95	123/105
60.0	69/36	80/42	89/49	95/54	104/63	112/71	118/78	123/84	129/90	133/95	141/105

TABLE 29

Radius of service area (km) for TV in 108-230 MHz,
E_{mu} = 55 dB(μV/m), f_c = 150 MHz

h_{ef} (m) / P_{ef} (dBW)	30	50	75	100	150	200	250	300	350	400	500
15.0	6	7	9	10	13	15	17	19	20	22	25
20.0	8	10	12	14	17	20	22	25	27	29	33
25.0	10	13	16	18	22	25	29	31	34	37	41
30.0	13	17	20	23	28	32	36	39	43	45	51
35.0	17	21	26	29	35	40	45	48	52	55	61
40.0	22	27	32	37	44	49	54	58	62	65	72
43.0	25	31	37	42	49	55	60	64	68	72	78
46.0	29	36	42	48	55	62	67	71	75	79	85
50.0	36/36	43/42	50/49	56/54	64/63	71	76	80	85	89	95
55.0	50/36	54/42	62/49	68/54	76/63	83/71	88/78	93/84	97/90	102/95	109/105
60.0	57/36	67/42	75/49	81/54	90/63	97/71	103/78	107/84	113/90	117/95	125/105

TABLE 30

Radius of service area (km) for TV in 230-528 MHz,
E_{mu} = 65 dB(μV/m), f_c = 250 MHz

h_{ef} (m) / P_{ef} (dBW)	30	50	75	100	150	200	250	300	350	400	500
15.0	3	3	4	5	6	7	8	9	10	11	12
20.0	4	5	6	7	9	10	12	13	14	15	18
25.0	6	7	9	10	12	14	16	18	20	21	25
30.0	7	9	11	13	16	19	22	24	26	28	32
35.0	10	12	15	17	21	25	28	31	33	36	41
40.0	13	16	19	22	27	31	35	38	41	44	49
43.0	15	19	22	26	31	36	40	43	46	49	55
46.0	17	22	26	30	35	40	45	48	51	55	60
50.0	21	26	31	35	42	47	51	55	59	62	68
55.0	27	33	39	43	50	56	61	65	69	73	79
60.0	34	41	48	53	60	67	71	75	80	84	90

TABLE 31

Radius of service area (km) for TV above 528 MHz,
E_{mu} = 70 dB(μV/m), f_c = 550 MHz

h_{ef} (m) / P_{ef} (dBW)	30	50	75	100	150	200	250	300	350	400	500
15.0	2	3	3	3	4	5	5	6	6	7	7
20.0	3	4	4	5	6	7	8	9	9	10	11
25.0	4	5	6	7	8	10	11	12	14	15	17
30.0	5	7	**8**	9	**12**	14	15	**17**	19	21	24
35.0	7	9	11	13	16	18	21	23	25	27	31
40.0	9	12	14	17	20	24	27	30	32	35	39
43.0	11	14	17	19	23	27	31	34	37	39	44
46.0	13	16	19	22	27	31	35	38	41	44	49
50.0	15	19	23	27	32	37	41	44	47	50	55
55.0	19	24	29	33	39	44	48	51	55	58	64
60.0	25	31	36	41	47	52	57	60	64	67	73

TABLE 32

Radius of service area (km) for sound broadcasting below 108 MHz,
E_{mu} = 54 dB(μV/m), f_c = 550 MHz

h_{ef} (m) / P_{ef} (dBW)	30	50	75	100	150	200	250	300	350	400	500
15.0	6	8	9	11	14	16	18	20	22	24	27
20.0	9	11	13	15	18	21	24	26	29	31	35
25.0	11	14	17	19	24	27	31	34	37	39	44
30.0	15	18	22	25	30	35	39	42	46	49	54
35.0	19	23	28	32	38	43	48	52	56	59	65
40.0	24	30	35	40	47	53	59	63	67	71	77
43.0	28	34	41	46	53	60	65	69	74	78	84
46.0	33	39	46	52	60	67	72	76	81	85	92

1.2.1.1.2 Effective antenna height calculation

It was already mentioned that the effective height of the transmitting antenna, h_{ef}, is determined as its height over the average level of the ground between distances of 3 km and 15 km from the transmitter in the direction of the receiver (see Fig. 13), i.e.:

$$h_{ef} = h_s - h_{av} \tag{31}$$

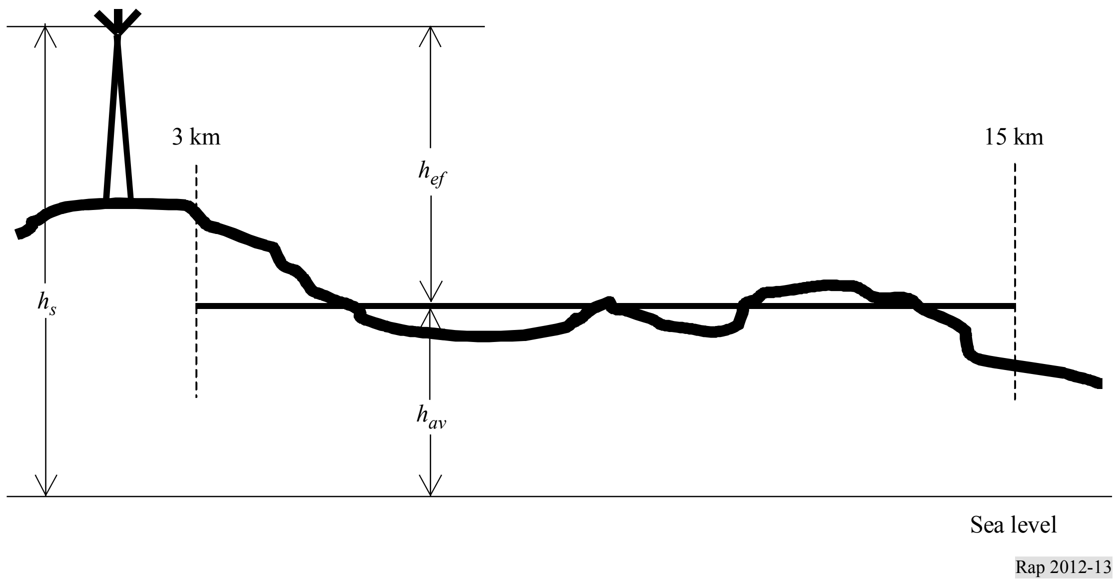
where:

- h_s: antenna height above the sea level (i.e. antenna mast height plus a height of the ground above the sea level at a place of installation)
- h_{av}: average level of the ground between distances of 3 km and 15 km from the transmitter.

It is essential to take into account not physical (mast height) but effective antenna height because antennas are frequently installed at tops of hills which heights can be comparable or even more than a mast height (see Fig. 13). Average level of the ground between distances of 3 km and 15 km from the transmitter is calculated with relevant terrain maps (preferably having scales 1:200 000 of 1:500 000). Using the map readouts of the ground height along some direction should be taken through each 1 or 2 km between distances of 3 km and 15 km from the transmitter and an average level is calculated as a sum of all readouts divided by their number.

FIGURE 13

Determination of antenna effective height



It is obvious that even for non-directional transmitting antenna used, a real service area usually will not be a circular one as far as average levels of the ground between distances of 3 km and 15 km from the transmitter in various directions will be different and, therefore, relevant antenna effective heights will be also different. Nevertheless, for the purposes of the given licence fees calculation model it is assumed to be a circular one based on antenna effective height calculation in one direction.

If an administration likes to increase accuracy of calculations in cases of a rather variable terrain profiles in different directions from antenna, an average value of antenna effective height can be calculates according to its four values in the North, East, South and West directions from the antenna. Example of calculations is presented in Table 33.

TABLE 33

Example of effective antenna height calculation for a case of non-regular terrain

No.	Distance of readout from antenna (km)	Readouts of ground heights (m)			
		North	South	East	West
1	3	250	240	300	240
2	4	240	220	300	220
3	5	220	180	290	200
4	6	230	180	280	170
5	7	240	160	270	160
6	8	260	140	260	180
7	9	260	120	250	200
8	10	280	120	230	250
9	11	280	110	220	250
10	12	280	100	210	240
11	13	290	100	200	200
12	14	300	80	200	180
13	15	320	60	200	140
	Readout sums, S_d (m)	3 450	1 810	3 210	2 630
	Effective heights, S_d /13 (m)	265	139	245	202
	Averaged effective height, h_{ef} (m)	213			

1.2.1.1.3 Service area calculation

Having calculated service area radius, R, (km) in accordance with procedures presented in § 1.2.1.1.1 and 1.2.1.1.2, a service area, s, is obviously calculated as:

$$s = \pi R^2 \qquad \text{km}^2 \tag{32}$$

It can happen that a service area contains two (see example at Fig. 14) or even three (see example at Fig. 15) zones belonging to different license fees categories, as it was mentioned in § 5.2 of the model. It can also happen at the border of a country with other ones. In these cases, and when an administration has not got an digital administrative terrain data base interrelated with relevant frequency assignment software, the following simplified procedures are applicable for calculation of parts of the service area belonging to different zones.

The actual border curves are approximated by straight lines situated in such ways that areas between actual border curves and relevant approximating lines, at each sides of these lines, would be approximately equal (see Figs. 14 and 15). Approximating line between zones S_2' and S_3 at Fig. 15 should also go along a radius of a service area, as it is presented at that Figure.

FIGURE 14

Example with covering two different zones

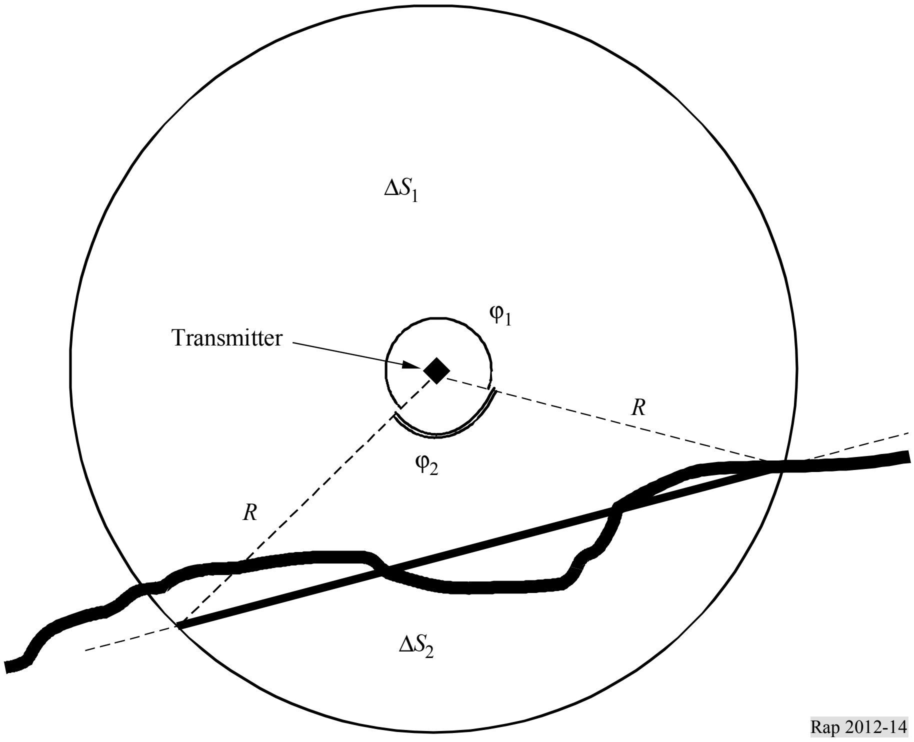
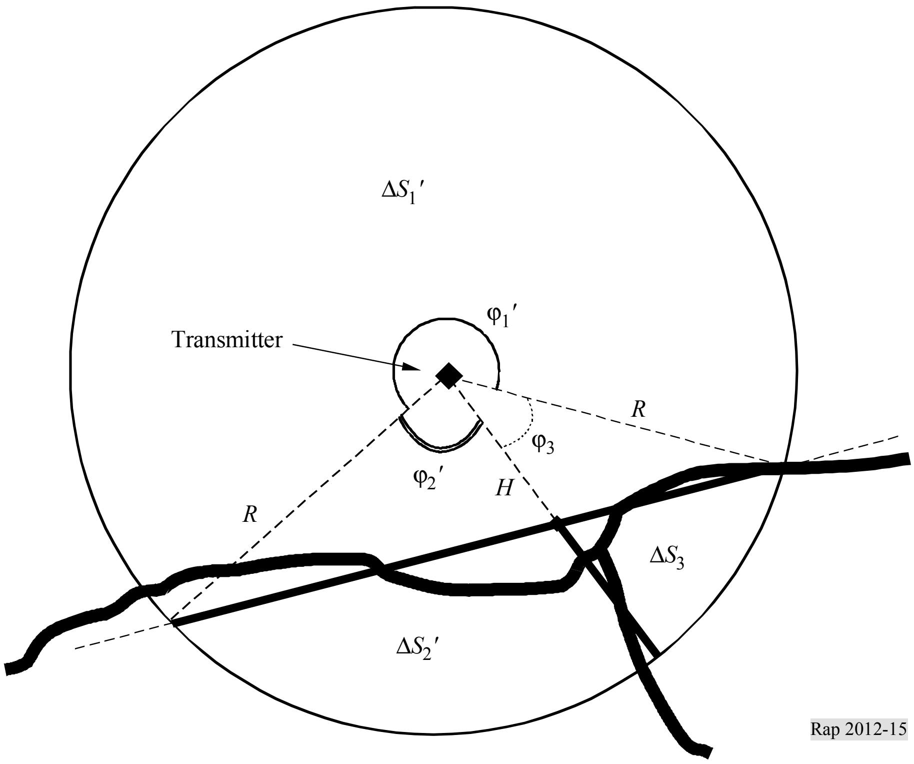


FIGURE 15

Example with covering three different zones



Segment S_2 area ΔS_2 for two-zone case (Fig. 14) is calculated as:

$$\Delta S_2 = \frac{R^2}{2}\left(\frac{\pi\varphi_2}{180} - \sin\varphi_2\right) \tag{33}$$

where:

φ_2: relevant sector angle (see Fig 14),

and segment S_1 area ΔS_1 is determined as:

$$\Delta S_1 = \pi R^2 - S_2 \tag{34}$$

In three-zone case (Fig. 15) parts S_2' and S_3 of common sector ($S_2' + S_3$) have correspondingly the following areas:

$$\Delta S_2' = \frac{R^2}{2}\left(\frac{\pi\varphi_2'}{180} - \Psi\sin\varphi_2'\right) \tag{35}$$

$$\Delta S_3 = \frac{R^2}{2}\left(\frac{\pi\varphi_3}{180} - \Psi\sin\varphi_3\right) \tag{36}$$

$$\Psi = \frac{H}{R}$$

where:

H: distance from a transmitter to the junction point of approximating lines (see Fig. 15) (km)

φ_2' and φ_3: relevant sector angles (see Fig. 15) (degrees).

Then:

$$\Delta S_1' = \pi R^2 - \Delta S_2' - \Delta S_3 \tag{37}$$

As an example, let us calculate relative areas for the three-zone case presented at Fig. 15. From the Figure we have: φ_2' = 88°, φ_3 = 39° and ψ = 0.51.

Then from equations (35), (36) and (37) it follows, correspondingly:

$$\Delta S_2' = \frac{R^2}{2}\left(\frac{\pi\cdot 88}{180} - 0.51\cdot 0.999\right) = 0.51\,R^2$$

$$\Delta S_3 = \frac{R^2}{2}\left(\frac{\pi\cdot 39}{180} - 0.51\cdot 0.63\right) = 0.18\,R^2$$

$$\Delta S_1' = (3.14 - 0.51 - 0.18)\,R^2 = 2.45\,R^2$$

1.2.1.2 Example of calculations

1.2.1.2.1 Incoming parameters

Let us calculate a spectral resource used by a FM sound broadcasting station working in an urban area 20 h per each day with a power 1.5 kW in exclusive regime (no sharing). Antenna, having mast height 100 m, situated at the top of a hill with ground height 360 m above the sea level. Terrain situation around the transmitter corresponds to example presented in § 1.2.1.1.2, i.e. average level of the ground between distances of 3 km and 15 km from the transmitter, h_{av}, in accordance with Table 33 is equal to 213 m. Antenna gain against a half-wave dipole equals 3 dB. Modulation conditions are standard ones: peak deviation is 75 kHz, maximum modulation frequency is 15 kHz.

1.2.1.2.2 Time and frequency resources used

In accordance with equation (22), used time resource is:

$$T = 20/24 \text{ (each day)} = 0.83 \text{ year}$$

According to Recommendation ITU-R SM.1138 (Radio Regulations, Geneva 1998, Volume 4) under Section III-A “Frequency modulation”, item 3 “Sound broadcasting” (class of emission F3E) the necessary bandwidth is 180 kHz, i.e., accepting $\chi = 1$, used frequency resource in accordance with equation (25) is:

$$F = 0.18 \text{ MHz}$$

1.2.1.2.3 Territorial resource used

Firstly, e.r.p. of the transmitter, effective antenna height and then service area radius should be calculated.

In accordance with data presented in § 1.2.1.2.1 and equation (30), e.r.p. of the transmitter is:

$$P_{ef} = 10 \log 1\,500 + 3 = 31.8 + 3 = 34.8 \cong 35 \text{ dBW}$$

In accordance with data given in § 1.2.1.2.1 and equation (31), it can be found:

$$h_s = 100 + 360 = 460 \text{ m}$$

$$h_{ef} = 460 - 213 = 247 \text{ m} \cong 250 \text{ m}$$

It is worth to indicate that in this particular case effective antenna height is 2.5 times greater than the mast height and this greatly influence on calculation results.

From Table 32 for P_{ef} = 35 dBW and h_{ef} = 250 m, it follows:

$$R = 47.8 \text{ km}; \; R^2 = 2\,285 \text{ km}^2$$

Let us assume that service area under consideration is subdivided by three zones of different categories (see § 5.2) in proportion presented in § 1.2.1.1.3 i.e.: $\Delta S'_1 = 2.45\ R^2$, $\Delta S'_2 = 0.51\ R^2$ and $\Delta S_3 = 0.18\ R^2$. Let us assume that relevant coefficients b_j from Table 24 are equal: $b_1 = 1$, $b_2 = 0.8$ and $b_3 = 0.6$. Then, in accordance with equation (24) it follows:

$$\sum S = 2285 \cdot (1 \cdot 2.45 + 0.8 \cdot 0.51 + 0.6 \cdot 0.18) = 6777 \text{ km}^2$$

It is instead of 7 179 km^2 when the whole service area lies within one zone having $b = 1$.

1.2.1.2.4 Spectral resource used

Substituting values calculated in § 1.2.1.2.2 and 1.2.1.2.3 to equation (21), using values of weighting coefficients presented in Table 25 (§ 5.4) and taking into account non-sharing conditions ($\beta = 1$), we get finally:

$$W = 2.4 \times 1 \times 1 \times 1 \times 1 \times 0.18 \times 6\,777 \times 0.83 = 2\,430 \qquad \text{MHz} \cdot \text{km}^2 \cdot 1 \text{ year.}$$

1.2.2 LF-HF sound broadcasting

For LF-HF sound broadcasting stations time and frequency resources used are determined similarly to § 1.2.1.2.2. Necessary bandwidths are calculated in accordance with Recommendation ITU-R SM.1138 (Radio Regulations, Geneva 1998, Volume 4) under Section II "Amplitude modulation", item 3 "Sound broadcasting", row "Sound broadcasting, double-sideband" (class of emission A3E). It should be noted that for this kind of broadcasting the Administrations usually use transmitters with different classes of quality, depending on highest modulating frequency which determines a necessary bandwidth value. Relevant data should be taken from a National Frequency Assignment Database.

As far as it concerns a territorial resource used, its calculation for this case meets some difficulties due to complexity of calculations, especially for HF broadcasting, which hardly to be significantly simplified without loosing a minimal necessary accuracy. For MF transmitters service area greatly differ for day-time and night-time operations. Taking account rather low number of LF-HF broadcasting stations in many countries, it is proposed that instead of complicated calculations the relevant data on service area from a National Frequency Assignment Database are used. If those are not available, they can be asked from operators. Operators usually have information on their service areas through calculations and/or monitoring.

On obtaining these data, related spectral resource used can be calculated similarly to the procedure presented in § 1.2.1.2.3. As far as for MF transmitters principally there are two considerable different values of service area for day-time and night-time operations, overall spectral resource used can be determined as a sum of two partial spectral resources which correspond to those different values of the service area.

It should also be noted that service areas of LF, MF (night-time) and HF broadcasting transmitters can be very large and may be extended beyond borders of countries which sizes are relatively small. In this case (determined in co-operation with relevant operators) the service area may be considered as a whole territory of the country, or its larger part. Areas of zones belonging to different categories (see § 3.2) are determined by relevant administrative documentation or estimated by maps.

In case of directional transmitting antennas application, a "service sector" concept, given by Recommendation ITU-R F.162-3, can be used (see details in § 1.4.1).

1.3 Mobile radio services

1.3.1 Land mobile radio service

1.3.1.1 Background of calculation procedures

The procedure generally follows radio wave propagation model known as modified Okamura-Hata one, some information on which is given in Annex 7 to Recommendation ITU-R P.1546. The model assumes existence of homogeneous urban development in limits of the service area, lack of direct visibility between the transmitter of the BS and mobile personal receiver, heights of transmitting and receiving antennas are in limits 20-200 m (but in the majority of cases they are 40-100 m) and 1.5-10 m correspondingly.

Considering, for purposes of the given model, that antenna feeder losses at transmitting and receiving sides are both equal zero, the power of a signal P_r (dBW) at an input of the receiver can be presented as:

$$P_r = P_t + G_t + G_r - L(R) \qquad \text{dBW} \tag{38}$$

where:

- P_t : transmitter power (dBW)
- G_t : transmitter antenna gain (dB)
- G_r : receiver antenna gain (dB)
- $L(R)$: transmission losses between transmitter and receiver (dB).

To provide the necessary quality of the received signal at a border of the service area the following condition should generally be met:

$$P_r = P_{min} + k_f\,\sigma$$

where:

- P_{min} : minimal power of a received signal which equals to a sensitivity of the receiver (dBW)
- k_f : fading allowance a signal for a given time of the signal quality deterioration
- σ : mean square value of a signal fluctuations (dB).

For 50% of time $k_f = 0$, for 95% of time $k_f = 1.65$. For conventional urban areas σ varies from 6 to 8 dB. Accepting, similarly to broadcasting, that a service area is determined by the criterion of 50% time i.e. $k_f = 0$, overall coefficient $k_f\,\sigma$ becomes equal to zero and:

$$P_r = P_{min} \tag{39}$$

Equating right parts of equations (38) and (39) to meet condition at the border of the service area, we get:

$$P_t + G_t + G_r - L(R) = P_{min}$$

where:

$$L(R) = P_t + G_t + G_r - P_{min} \tag{40}$$

In accordance with modified Okamura-Hata radio wave propagation model, accurate for a signal median value (i.e. for 50% of time):

$$L(R) = \vartheta + \xi \log R \tag{41}$$

where ϑ and ξ are coefficients in dB whose values depend on frequency and heights of a transmitter and receiver. For conventional urban areas:

$$\xi = 44.9 - 6.55 \log h_t \tag{42}$$

$$\vartheta = 65.55 - 6.16 \log f + 13.82 \log h_t + a_r(h_r) \qquad \text{for } f \leq 1 \text{ GHz} \tag{43}$$

$$\vartheta = 46.3 - 33.9 \log f + 13.82 \log h_t + a_r(h_r) \qquad \text{for } f \geq 1.5 \text{ GHz} \tag{44}$$

where:

f : working frequency (MHz)

h_t : effective height of transmitting antenna (m)

h_r : effective height of receiving antenna (m)

$a_r(h_r) = (1.1 \log f - 0.7)\, h_r - (1.56 \log f - 0.8)$ (dB).

Effective height of transmitting antenna is to be determined as it is presented in Recommendation ITU-R P.1546, i.e. by procedure demonstrated in § 1.2.1.1.2 and 1.2.1.2.3. However, taking into account that recently powers of base stations are not too high and, therefore, related service areas are relatively small, for great majority of urban areas situated at a plain terrain, effective height of transmitting antenna can be approximated by its height above ground at a place of its installation. The antenna height of a mobile or portable station is taken as its height above the ground. These assumptions are taken for purposes of the given licence fees calculation model.

Following equations (40) to (44), a service area radius R can be calculated as:

$$R = 10^{\left(\frac{z - \vartheta}{\zeta}\right)} \qquad (45)$$

where:

R : service area radius (km)

z : easily determined generalized power parameter (dB) calculated as:

$$z = P_t + G_t + G_r - P_{min} \qquad (46)$$

Graphs of relationships $R = \varphi(z)$, calculated in accordance with equations (45) and (46), for frequencies below 1 GHz and above 1.5 GHz are presented at Figs. 16-17 and 18-19 accordingly. Figures 16 and 18 correspond to transmitter antenna heights, h_t, equal to 40 m and Figs. 17 and 19 to 100 m. In all Figures line 1 corresponds to receiver antenna height, h_r, equal to 1.5 m and line 2 to 10 m. The last allows to use these graphs for calculations associated with VHF/UHF fixed communications and “point-multipoint” program distribution systems, when the collective reception antennas are placed on roofs of buildings. Line 3 indicates dependencies for free-space propagation conditions. It can be used for calculations associated with short distance VHF/UHF fixed communications with line-of-sight propagation conditions. For other antenna heights lying within above-mentioned limits, service area radius values can be obtained from Figs. 16-19 by interpolation.

Somewhat typical values of parameters appeared in equation (46), for a number of land mobile radio communication systems including equipment for digitally enhanced cordless telecommunications (DECT) and private mobile radio (PMR), are presented in Table 34.

TABLE 34

Values of equipment parameters

Parameter \ System	CDMA	GSM	AMPS	NMT	DECT	PMR
Transmitting antenna gain G_t (dB)	13	18	17	10-17	3	6-15
Receiving antenna gain G_r (dB)	0	0	0	6	3	3-6
Receiver sensitivity P_{min} (dBW)	–147	–138	–146	–115	–112	–110

This Table can be amended in future for new, more efficient, land mobile radiocommunication systems.

FIGURE 16

Service area radius calculation for frequencies below 1 000 MHz, h_t = 40 m
1: h_r = 1.5 m, 2: h_r = 10 m, 3: free space propagation

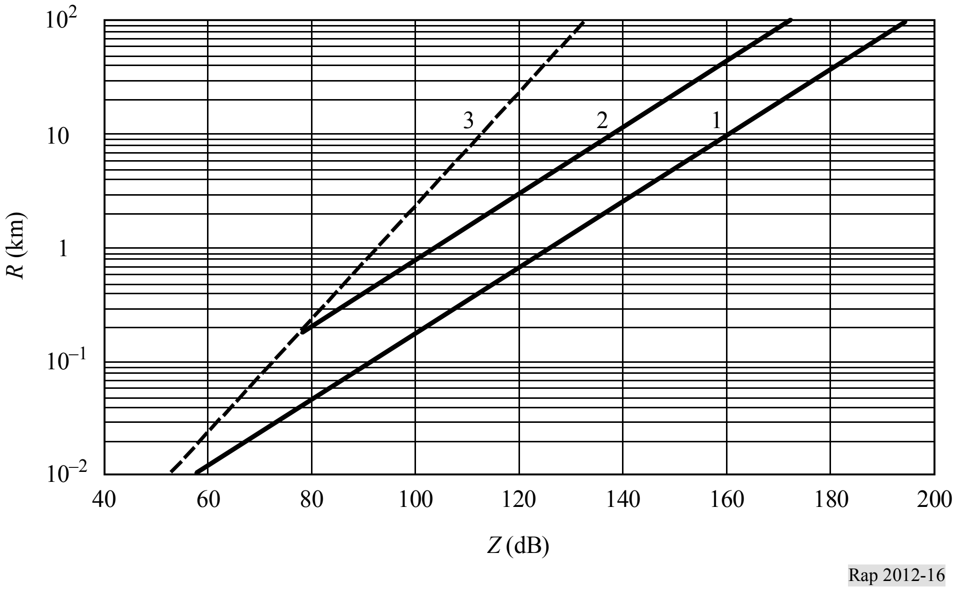


FIGURE 17

Service area radius calculation for frequencies below 1 000 MHz, h_t = 100 m
1: h_r = 1.5 m, 2: h_r = 10 m, 3: free space propagation

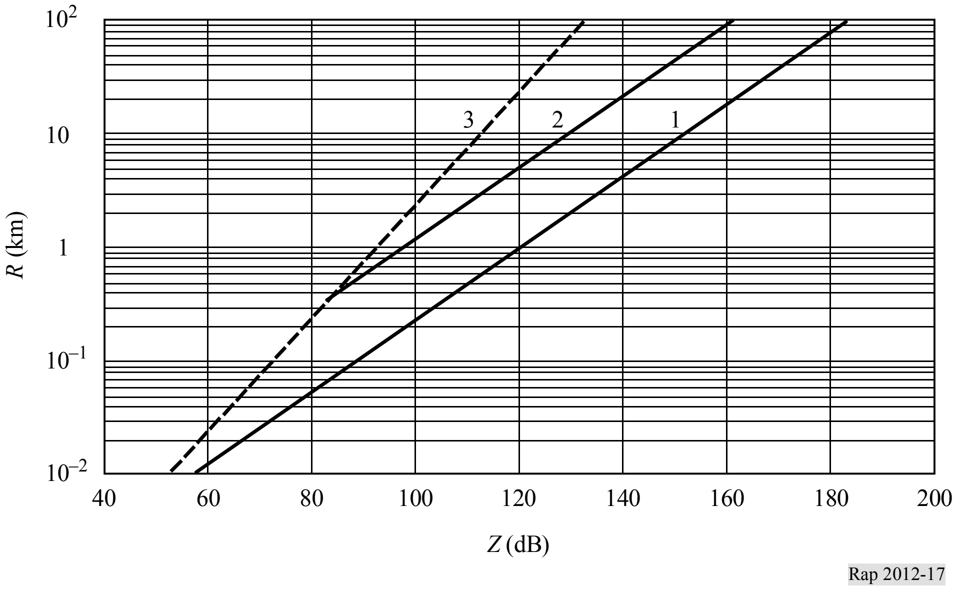


FIGURE 18

Service area radius calculation for frequencies below 1 500 MHz, h_t = 40 m
1: h_r = 1.5 m, 2: h_r = 10 m, 3: free space propagation

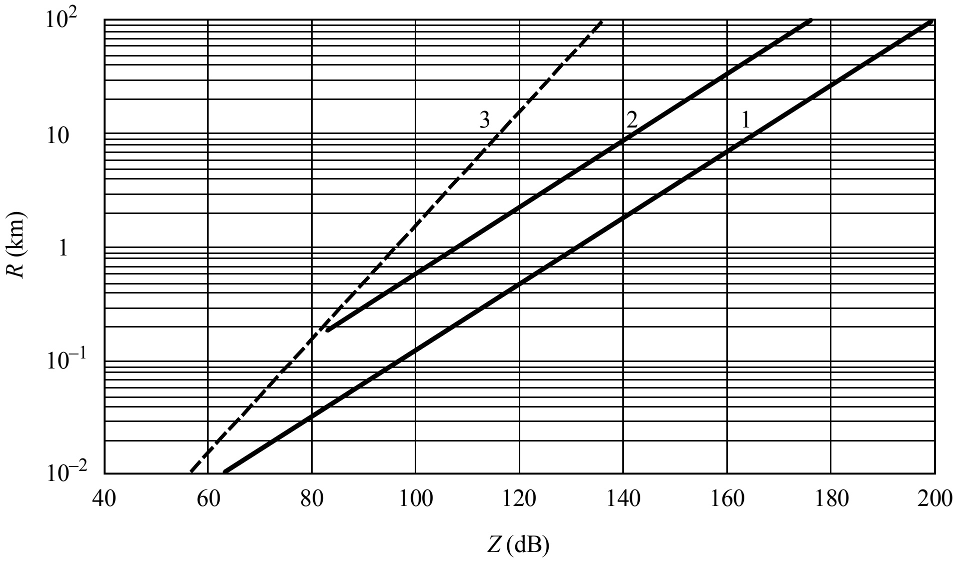


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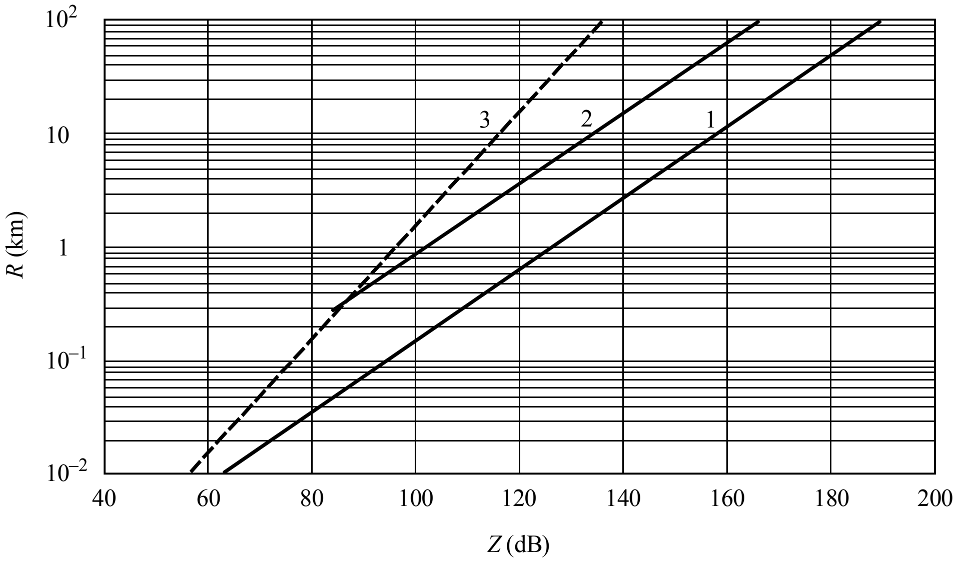
FIGURE 19

Service area radius calculation for frequencies below 1 500 MHz, h_t = 100 m
1: h_r = 1.5 m, 2: h_r = 10 m, 3: free space propagation



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1.3.1.2 Calculation procedures

Having got graphs presented at Figs. 16 to 19 calculation procedure becomes a quite simple one. It is only necessary to insert into equation (46) required parameters, taken from the national frequency assignment database (or, in their absence, from Table 34), and to read related service area radius R for calculated value of parameter z directly from Figs. 16 and 17, depending on working frequency and antenna heights. Due to the fact, that for land mobile service, and especially for cellular systems, service areas of individual base stations are rather small ones, they will usually lie within only one zone of license fees category. Thereby service areas usually can be calculated by simple equation (32).

After determining service area value, procedure of used spectral resource calculation follows the same one, which is presented in § 1.2.1.2.

1.3.1.3 Example of calculations

1.3.1.3.1 Incoming parameters

Let us calculate a spectral resource used by a base station of GSM 900 MHz cellular system working with power 2.5 W without interruption 24 h per each day, without sharing, in a city with population 40 000 inhabitants (i.e. according to Table 24, $b_j = 1.2$). Overall frequency bands used for base – mobile and mobile – base transmissions are equal 0.8 MHz each. Transmitting and receiving antenna heights are 40 m and 1.5 m correspondently. Let us assume that other parameters correspond to Table 34.

1.3.1.3.2 Time and frequency resources used

In accordance with equation (22), used time resource is:

$$T = 24/24 \text{ (each day)} = \text{year}$$

As far as the system within the same service area uses two sets of frequency bands, one for base – mobile and other for mobile – base transmissions, the overall used frequency resource, accepting in formula (25)$\chi = 1$, can be found as:

$$F = 2 \times 0.8 = 1.6 \text{ MHz}$$

1.3.1.3.3 Territorial resource used

Substituting relevant data from § 1.3.1.3.1 and Table 34 to equation (46) we get:

$$z = 10 \log 2.5 + 18 + 0 - (-138) = 160 \text{ dB}$$

For this z value from line 1 of Fig. 16 and formula (32) it follows:

$$R = 10 \text{ km}, \quad S = 314 \text{ km}^2$$

From equation (23), taking into account relevant data from Table 24, it follows:

$$S_i = 1.2 \times 314 = 377 \text{ km}^2$$

1.3.1.3.4 Spectral resource used

Substituting values calculated in § 1.3.1.3.2 and 1.3.1.2.3 to equation (21), using values of weighting coefficients presented in Table 25 (§ 5.4) and taking into account non-sharing conditions ($\beta = 1$), we get finally:

$$W = 3 \times 1.2 \times 1 \times 1 \times 1 \times 1.6 \times 377 \times 1 = 2\,172 \qquad \text{MHz} \cdot \text{km}^2 \cdot 1 \text{ year}$$

1.3.2 Maritime mobile radio service

1.3.2.1 Background of calculation procedures

For coast and ship stations of maritime mobile service working in VLF and HF frequency bands, proposed provisions for LF and HF broadcasting stations can be used (see § 1.2.2) taking into account limitations by national maritime economical border (usually 200 miles, i.e. 360 km). In cases of directional transmitting antennas applications, a “service sector” concept, given by Recommendation ITU-R F.162, can be used (see details in § 1.4.1).

Service areas of VHF coast and ship stations working in 156-174 MHz frequency bands (RR Appendix 18 are determined by propagation curves given in Annex 2 to Recommendation ITU-R P.1546, i.e. on the same basis as for broadcasting (see § 1.2.1). Technical characteristics of equipment are described in Recommendation ITU-R M.489.

For ship stations having omnidirectional antennas service areas, *s*, are calculated as:

$$S = \pi R_s^2 \qquad \text{km}^2 \qquad (47)$$

where:

R_s: radius of circular service area calculated from propagation curves of Recommendation ITU-R P.1546 for 30-300 MHz frequency band, sea, 50% of time and 50% of locations (Fig. 4 of Recommendation ITU-R P.1546).

It is necessary to note, that for this particular case the curves are the same for cold and warm seas. Transmitting antenna heights are actual antenna heights above the see level. For simplicity, receiving antenna heights for purposes of this particular calculation model are accepted as to be equal 10 m in all cases. However it should be noted that in reality, to provide equal communication conditions between coast and ship stations in both directions, receiving antennas of coast stations are usually have the same heights than their transmitting antennas.

For coast stations it is accepted that one half of an occupied area, being a service one, with a radius R_s lies at a surface of sea and the second half with a radius R_l, at a surface of land, i.e.:

$$S = 0.5\,\pi\,(R_s^2 + R_l^2) \qquad \text{km}^2 \qquad (48)$$

where:

R_l: radius of half-circular service area calculated from propagation curves of Recommendation ITU-R P.1546 for 30-300 MHz frequency band, land, 50% of time and 50% of locations (Fig. 1 of Recommendation ITU-R P.1546, see Fig. 11).

Effective antenna height calculations for land service area are provided similarly to broadcasting case (see § 1.2.1.1.2).

Taking into account that maritime mobile service belongs to safety services its reliability should be sufficiently high. Taking this into account, minimal usable field strength at the border of service area is accepted to be 30 dB above receiver reference sensitivity (2.0 µV in accordance with Recommendation ITU-R M.489), i.e. $E_{mu} = 36$ dB(µV/m).

Based on the above parameters and assumptions and accepting all antennas gains equal to 6 dB, relevant service/occupied areas radiuses were calculated for different transmitter powers from 10 W to 50 W (maximal carrier power of coast stations in accordance with Recommendation ITU-R M.489) and various effective antenna heights presented in Recommendation ITU-R P.1546. Results of calculations are presented in Table 35.

TABLE 35

Radiuses of occupied areas by see and by land (km)
for maritime radio communications in 156-174 MHz frequency band

		H_{ef} (m)					
***P*(W)**	**Paths**	**10**	**20**	**37.5**	**75**	**150**	**300**
10	Land	11	14	19	25	35	48
	Sea	24	28	35	43	53	68
20	Land	13	16	22	29	40	53
	Sea	27	31	39	47	59	74
30	Land	14	17	24	32	43	57
	Sea	29	34	42	51	62	77
40	Land	14	19	25	34	45	59
	Sea	30	36	44	53	64	80
50	Land	15	19	27	35	47	61
	Sea	32	37	45	55	66	82

It is necessary to note that a land half-circle area of a coast station is only occupied but not service one because there are no ship stations there. Therefore its subdivision to different zones belonging to different license fees categories (like it is presented in § 1.2.1.1.3) can be eliminated and the only one category, corresponding to the largest occupied area, can be used. Moreover, an Administration may decide not to include this land half-circle area to territorial resource used. In this case radius R_l in equation (48) should be equal zero.

For coast stations situated along rivers or and rather narrow lakes the whole circular service/ occupied are is calculated by land propagation paths radius, i.e.:

$$S = \pi R_l^2 \qquad \text{km}^2 \tag{49}$$

1.3.2.2 Calculation procedures

Using known transmitter power and its antenna height above the sea level, relevant service area radius by see can be determined directly from Table 35. The usual procedure of linear interpolation can be used for intermediate power and height values. Based on this radius service area for a ship station or see half-circle service area for a coast station can be calculated by equation (47) or (48). For determination of a land half-circle radius for the coast station, antenna effective height against the terrain should be firstly calculated in accordance with methodology, presented in § A1.2.1.1.2. For this particular application, the procedure can be simplified by calculation of effective terrain height only in one direction to be perpendicular to a generalised shoreline (see example below). After determination by Table 35 of relevant land half-circle radius, overall service/occupied area then can be calculated by equation (48).

1.3.2.3 Example of calculations

1.3.2.3.1 Incoming parameters

Let us calculate a spectral resource used by a VHF coast station situated in rural but highly developed area (let coefficient $b_j = 1$ in Table 24) near the shoreline generally stretched in East to West direction, see is southward. Let us assume that transmitting antenna, having mast height 30 m, situated at the top of a hill with ground height 270 m above the sea level. Terrain situation around the transmitter corresponds to example presented in § 1.2.1.1.2, i.e. effective height of the ground between distances of 3 and 15 km in the northern direction from the transmitter, calculated from column "North" of Table 33, equals to 265 m. In accordance with § 1.3.2.2 for this application it represents average level of the ground, h_{av}, in equation (31).

Let us further assume that the transmitter power is 50 W and it works around the clock. Modulation conditions correspond to Recommendation ITU-R M. 489: class of emission F3E, deviation ± 5 kHz, necessary bandwidth 16 kHz. That also corresponds to Recommendation ITU-R SM.1138 (Radio Regulations, Geneva 1998, Volume 4) under Section III-A "Frequency modulation", item 2 "Telephony (commercial quality)" (class of emission F3E).

1.3.2.3.2 Time and frequency resources used

In accordance with equation (22), used time resource is:

$$T = 24/24 \text{ (each day)} = 1 \text{ year}$$

Used frequency resource, accepting in equation (25) $\chi = 1$, can be found as:

$$F = 0.016 \text{ MHz}$$

1.3.2.3.3 Territorial resource used

Following approach and data presented in § A1.3.2.1 and 1.3.2.3.1 effective antenna height for sea propagation paths equals to sum of antenna mast and site ground heights, i.e. (see also § A1.2.1.1.2):

$$h_{ef} = h_s = 30 + 230 = 300 \text{ m}$$

From Table 35 for transmitter with power 50 W and antenna height 300 m, sea propagation paths, it follows: $R_s = 82$ km.

For land propagation paths in accordance with data of § 1.3.2.3.1 and equation (31):

$$h_{ef} = 300 \text{ m} - 265 \text{ m} = 35 \text{ m} \approx 37.5 \text{ m}$$

From Table 35 for transmitter with power 50 W and antenna height 37.5 m, land propagation paths, it follows: $R_l = 27$ km.

Substituting calculated radiuses to equation (48) we get:

$$S = 0.5\, \pi\, (82^2 + 27^2) = 11\,701 \text{ km}^2$$

and, taking into account that $b_j = 1$, from equation (23) it follows:

$$S = s = 11\,701 \text{ km}^2$$

1.3.2.3.4 Spectral resource used

Substituting values calculated in § 1.3.2.3.2 and 1.3.2.3.3 to equation (21), using values of weighting coefficients presented in Table 25 (§ 5.4) and taking into account non-sharing conditions ($\beta = 1$), we get finally:

$$W = 1 \times 0.2 \times 0.1 \times 1 \times 1 \times 0016 \times 11\,701 \times 1 = 3.7 \qquad \text{MHz} \cdot \text{km}^2 \cdot 1 \text{ year}$$

1.3.3 Aeronautical mobile, radionavigation and radiolocation services

1.3.3.1 Calculation procedures

Common feature of these services is the fact that they provide radio communication (or location) operations with highly flying aircrafts. It leads to large service areas which borders are determined by distances up to radio horizon. If refraction of radio waves in the Earth's atmosphere is taken into account, a distance up to a radio horizon, R_g, can be calculated by formula:

$$R_g = 4.14\left(\sqrt{h_t} + \sqrt{h_r}\right) \qquad \text{km} \qquad (50)$$

where:

h_t: height of transmitting antenna above the averaged ground surface (at the ground or at the aircraft) (m)

h_r: height of receiving antenna above the averaged ground surface (at the ground or at the aircraft) (m).

With height of the aircraft, 10 000 m and terrestrial antenna height, 15 m, equation (49) gives radio horizon distance equals 429 km. Beyond the radio horizon the field strength sharply drops, as it is clearly demonstrated by curves of Recommendation ITU-R P.528. Therefore, in the given particular case, service area radius is accepted as to be equal to the distance up to the radio horizon irrespective to transmitter power and receiver sensitivity. The last parameters mainly determine only reliability of radio communication in the vicinity of service area borders in real influence environment that is very important for these of services as to be safety ones. Omnidirectional antennas are widely used. In case of directional transmitting antennas applications (mainly in radionavigation and sectorial radiolocation), a "service sector" concept, given by Recommendation ITU-R F.162, can be used (see details in § 1.4.1).

Taking into account that spectral resource used for these services, as to be safety ones, will not be too high, for simplicity reasons subdivision of the service area to different zones belonging to different license fees categories (see § 1.2.1.1.3) can be eliminated and the only one category, corresponding to the largest occupied area, can be used.

Given approach to the determination of service areas for aeronautical mobile, radionavigation and radiolocation services is proposed to be use for purposes of this calculation Model. The same approach can be accepted and for maritime radionavigation and radiolocation applications by using in equation (50) a target height equals about 10 m.

1.3.3.2 Examples of calculations

1.3.3.2.1 Aeronautical radio communications

1.3.3.2.1.1 Incoming parameters

Let us calculate a spectral resource used by an aeronautical radiocommunication station working around the clock in 118-136 MHz band. Omnidirectional transmitting antenna height is 15 m and communications are provided with aircrafts flying at 10 000 m and higher, i.e in accordance with § 1.3.3.1, R_g = 429 km. Let the largest occupied area lies in rural zone categorized by Table 24 as 0.8. Usual double-side AM is used (class of emission A3E), commercial quality.

1.3.3.2.1.2 Time and frequency resources used

In accordance with equation (22), used time resource is:

$$T = 24/24 \text{ (each day)} = 1 \text{ year}$$

Following Recommendation ITU-R SM.1138 (Radio Regulations, Geneva 1998, Volume 4), Section II “Amplitude modulation”, item 2 “Telephony (commercial quality)”, double-sideband (class of emission A3E), related necessary bandwidth is 6 kHz. Therefore, used frequency resource, accepting in equation (25) $\chi = 1$, can be found as:

$$F = 0.006 \text{ MHz.}$$

1.3.3.2.1.3 Territorial resource used

Substituting $R_g = 429$ km into equation (32) we get:

$$s = \pi \cdot 429^2 = 578\,182 \text{ km}^2$$

and, taking into account that $b_j = 0.8$, from equation (23) it follows:

$$S = 0.8 \times 578\,182 = 462\,546 \text{ km}^2$$

1.3.3.2.1.4 Spectral resource used

Substituting values calculated in § 1.3.3.3.1.2 and 1.3.3.3.1.3 to equation (21), using values of weighting coefficients presented in Table 25 (§ 5.4) and taking into account non-sharing conditions ($\beta = 1$), we get finally:

$$W = 0.1 \times 0.2 \times 0.1 \times 0.8 \times 1 \times 0.006 \times 462\,546 \times 1 = 4.4 \qquad \text{MHz} \cdot \text{km}^2 \cdot 1 \text{ year}$$

1.3.3.2.2 Primary radars

1.3.3.2.2.1 Incoming parameters

Let us calculate a spectral resource used by an aeronautical primary radar working around the clock with circularly rotating antenna of 15 m height and set aside for locating aircrafts flying at 10 000 m and higher. It means that in accordance with § 1.3.3.1 $R_g = 429$ km. Let the largest occupied area lies in rural zone categorized by Table 24 as 0.5. Radar uses shaped radio pulses with a half-amplitude duration equals 1 μs.

1.3.3.2.2.2 Time and frequency resources used

In accordance with equation (22), used time resource is:

$$T = 24/24 \text{ (each day)} = 1 \text{ year}$$

Following Recommendation ITU-R SM.1138 (Radio Regulations, Geneva 1998, Volume 4), Section IV “Pulse modulation”, item 1 “Radar”, primary radar (class of emission P0N), related necessary bandwidth is 3 MHz. Therefore, used frequency resource, accepting in equation (25) $\chi = 0.1$, can be found as:

$$F = 0.1 \times 3 = 0.3 \text{ MHz}$$

1.3.3.2.2.3 Territorial resource used

Substituting $R_g = 429$ km to equation (32) we get:

$$s = \pi \cdot 429^2 = 578\,182 \text{ km}^2$$

and, taking into account that $b_j = 0.5$, from equation (23) it follows:

$$S = 0.5 \times 578\,182 = 289\,091 \text{ km}^2$$

1.3.3.2.2.4 Spectral resource used

Substituting values calculated in § 1.3.3.3.2.2 and 1.3.3.3.2.3 to equation (21), using values of weighting coefficients presented in Table 25 (§ 5.4) and taking into account non-sharing conditions ($\beta = 1$), we get finally:

$$W = 0.1 \times 0.02 \times 0.1 \times 0.2 \times 1 \times 0.3 \times 289\,091 \times 1 = 3.5 \qquad \text{MHz} \cdot \text{km}^2 \cdot 1 \text{ year}$$

1.4 Fixed radio services

1.4.1 Calculation procedures

All fixed radiocommunications, HF radio links and UHF/SHF radio relay links (RRL), nowadays use directional and highly directional antennas. Taking this into account, for calculation of area occupied by an emission a "service sector" concept, given by Recommendation ITU-R F.162, can be used. This Recommendation states that for HF fixed links the service sector is very close to twice the angular width of the main beam measured to the half-power (–3 dB) point. Taking into account the same physical background, for purposes of the given license fee calculation Model, this concept is accepted for RRL links and for all other radio applications when directional antennas are used.

Therefore, if relevant antenna beam-width is known (from the national frequency assignment database or, on special request, from the operator or user) relevant emission occupied area can be determined as

$$S_o = \frac{2\theta}{360} \cdot \pi \cdot L_c^2 = \frac{\theta}{180} \cdot \pi \cdot L_c^2 \qquad (51)$$

where:

S_o: area occupied by an emission (km^2)

θ: antenna beam-width (degrees)

L_c: length of the radio link (km).

Fixed radio links, especially RRL, usually are planned very carefully, planning methods are sophisticated and significant fading allowances are usually used. Taking this into account and aiming to avoid complicated calculations, for purposes of the given model it is proposed to use exact distance between relevant transmitter and receiver as the length of the radio link L_c. For RRL it will be one hop between two RRL stations.

On determination of S_o, related territorial resource can be calculated in accordance with equation (23). Provisions concerning coverage of several zones belonging to different license fees categories are the same as in § 1.2.1.1.3 although here influence of this factor is considerable smaller, especially for RRL, due to considerably smaller values of sector widths. Nevertheless, if an administration likes to increase calculation accuracy, the following equation is applicable for the case when a service sector crosses two areas in approximately perpendicular direction at a distance L_b from the transmitter:

$$s_1 = \frac{\theta}{180} \cdot \pi \cdot L_b^2$$

$$s_2 = \frac{\theta}{180} \cdot \pi \cdot \left(L_c^2 - L_b^2\right)$$

In accordance with the concept presented in § 1.1, for overseas HF communications L_c is determined by the distance from the transmitter to the country border in the direction of the transmission.

Frequency and time resources and, then, spectral resource are calculated similarly to other cases above. As far as multi-station RRL can carry different numbers of channels at different hops due to branching and hop-lengths are different, spectral resources are calculated separately for each hop and then all values are summed.

1.4.2 Example of calculations

1.4.2.1 Incoming parameters

Let us calculate a spectral resource used by one hop of a RRL in 2 GHz frequency band. Hop-length is 45 km, antenna beam-widths of both stations are 1.5° each (and it corresponds to $G \approx 40$ dB). This hop lies within one zone categorised by Table 24 as 0.4 and carries 960 telephone channels in both directions with parameters corresponding those indicated in Recommendation ITU-R SM.1138 (Radio Regulations, Geneva 1998, Volume 4), Section III-A "Frequency modulation", subsection 5 "Composite emissions", RRL with 960 channels.

1.4.2.2 Time and frequency resources used

Taking into account principally continuous mode of RRL operation, from equation (22) it follows:

$$T = 24/24 \text{ (each day)} = 1 \text{ year}$$

In accordance with data, presented in above mentioned subsection of Recommendation ITU-R SM.1138 (Radio Regulations, Geneva 1998, Volume 4), B_n = 16.32 MHz (for both transmission directions). Therefore the overall used frequency resource, accepting in equation (25) $\chi = 1$, can be found as:

$$F = 2 \times 16.3 = 32.6 \text{ MHz}$$

1.4.2.3 Territorial resource used

Substituting relevant data from § 1.4.2.1 to equation (51) we get:

$$s_o = (1.5/180) \times 3.14 \times 45^2 = 53 \text{ km}^2$$

From equation (23), taking into account the zone category, it follows:

$$S = 0.4 \times 53 = 21 \text{ km}^2$$

1.4.2.4 Spectral resource used

Substituting values calculated in § 1.4.2.2 and 1.4.2.3 to equation (21), using values of weighting coefficients presented in Table 25 (§ 5.4) and taking into account non-sharing conditions ($\beta = 1$), we get finally:

$$W = 0.1 \times 0.1 \times 1 \times 0.2 \times 1 \times 32.6 \times 21 \times 1 = 1.4 \qquad \text{MHz} \cdot \text{km}^2 \cdot 1 \text{ year}$$

1.5 Earth stations of satellite communications

1.5.1 Calculation procedures

Similarly to the case of fixed radio communication services presented in § 1.4.1, for the calculation of occupied areas a "service sector" concept, given by Recommendation ITU-R F.162 is proposed to be used.

As it was already indicated in § 1.1, due to great difficulties in exact calculation of occupied areas of Earth stations of satellite communication systems, it is proposed to determine them on the basis of coordination distances agreed during the process of coordination and notification of frequency and orbital assignments in the ITU-R. If these are not available universal coordination distances of 350 km for VSATs and 750 km for other stations are proposed to be used. In some cases values agreed between administration and operator can also be used.

Occupied (necessary) bandwidth of an emission, or a bandwidth of a received signal, due to their absence in Recommendation ITU-R SM.1138, should be taken from related frequency assignment data, stored in a national spectrum management database or received from an operator on a special request.

1.5.2 Examples of calculations

1.5.2.1 Transmitting earth station

1.5.2.1.1 Incoming parameters

Let us calculate a spectral resource used by an earth station providing feeder link for non-GSO satellites operating in the mobile-satellite service. Due to absence of more detailed data, coordination distance is accepted as to be 750 km. The station is situated in rural area and its antenna beam-widths is 0.5^{o}. Occupied area of the emission lies within one zone categorized by Table 24 as 0.2. Let us assume that, in accordance with relevant frequency assignment recorded in the national spectrum management database, the bandwidth of the emission is 200 MHz.

1.5.2.1.2 Time and frequency resources used

Taking into account principally continuous mode of feeder link operation, from equation (22) it follows:

$$T = 24/24 \text{ (each day)} = 1 \text{ year}$$

In accordance with data presented in § 1.5.2.1.1 used frequency resource, accepting in equation (25) $\chi = 1$, can be found as:

$$F = 200 \text{ MHz}$$

1.5.2.1.3 Territorial resource used

Substituting related data from § 1.5.2.1.1 to equation (51), where L_c represents coordination distance, we get:

$$s_o = (0.5/180) \times \pi \times 750^2 = 4\,909 \text{ km}^2$$

From equation (23), taking into account the zone category, it follows:

$$S = 0.2 \times 4\,909 = 982 \text{ km}^2$$

1.5.2.1.4 Spectral resource used

Substituting values calculated in § 1.5.2.1.2 and 1.5.2.1.3 to equation (21), using values of weighting coefficients presented in Table 25 (§ 5.4) and taking into account non-sharing conditions ($\beta = 1$), we get finally:

$$W = 1.4 \times 0.1 \times 0.1 \times 0.2 \times 1 \times 200 \times 982 \times 1 = 550 \qquad \text{MHz} \cdot \text{km}^2 \cdot 1 \text{ year}$$

1.5.2.2 Receiving earth station

1.5.2.2.1 Incoming parameters

Let us calculate a spectral resource used by a receiving VSAT earth station working around the clock. Due to absence more detailed data, coordination distance is taken as 350 km. The station is situated in rural area and its antenna beam-widths is 1°. Occupied area of the emission lies within one zone categorised by Table 24 as 0.3. Let us assume that, in accordance with relevant frequency assignment recorded in the national spectrum management database, the bandwidth of the received signal is 30 MHz.

1.5.2.2.2 Time and frequency resources used

Assuming continuous mode of the station operation, from equation (22) it follows:

$$T = 24/24 \text{ (each day)} = 1 \text{ year}$$

In accordance with data presented in § 1.5.2.2.1 used frequency resource, accepting in equation (25) $\chi = 1$, can be found as:

$$F = 30 \text{ MHz}$$

1.5.2.2.3 Territorial resource used

Substituting related data from § 1.5.2.2.1 to equation (51), where L_c represents coordination distance, we get:

$$s_o = (1/180) \times \pi \times 350^2 = 2\,138 \text{ km}^2$$

From equation (23), taking into account the zone category, it follows:

$$S = 0.3 \times 2\,138 = 641 \text{ km}^2$$

1.5.2.2.4 Spectral resource used

Substituting values calculated in § 1.5.2.1.2 and 1.5.2.1.3 to equation (21), using values of weighting coefficients presented in Table 25 (§ 5.4) and taking into account non-sharing conditions ($\beta = 1$), we get finally:

$$W = 14 \times 0.1 \times 0.1 \times 0.2 \times 1 \times 30 \times 641 \times 1 = 54 \qquad \text{MHz} \cdot \text{km}^2 \cdot 1 \text{ year}$$

1.6 Summary of calculation results

Summary of calculation results for the purpose of comparison and for general orientation is presented in Table 36.

TABLE 36

Summary of calculation results

Section	Radio service, transmitter power or radio link characteristic	Spectral resource used (MHz · km^2 · 1 year)
1.2.1.2	FM sound broadcasting, 1.5 kW	2 430
1.3.1.3	Land mobile service, GSM base station, 2.5 W	2 172
1.3.2.3	Maritime mobile service, coast station, 50 W	3.7
1.3.3.2.1	Aeronautical radiocommunication aircraft height 10 000 m	4.4
1.3.3.2.2	Primary radar, aircraft height 10 000 m	3.5
1.4.2	Fixed service, microwave link, hop-length 45 km	1.4
1.5.2.1	Transmitting earth station, MSS feeder link	550
1.5.2.2	Receiving VSAT earth station	54