INFRASTRUCTURE

Guidelines for the Review

OF SPECTRUM PRICING METHODOLOGIES AND THE PREPARATION OF SPECTRUM FEES SCHEDULES

Report

Telecommunication Development Sector

ITU

Guidelines for the review of spectrum pricing methodologies and the preparation of spectrum fee schedules

These guidelines focus on the review of spectrum pricing methodologies and the preparation of spectrum fee schedules. In addition, a brief overview of market-based and administrative methodologies is provided. These guidelines also address the need for spectrum revenue and pricing policies and an understanding of the future demand for spectrum. This report was prepared by ITU expert Adrian Foster, under the supervision of the ITU Telecommunication Development Bureau (BDT) Spectrum Management and Broadcasting Division and with the co-operation of the ITU Radiocommunication Bureau (BR).

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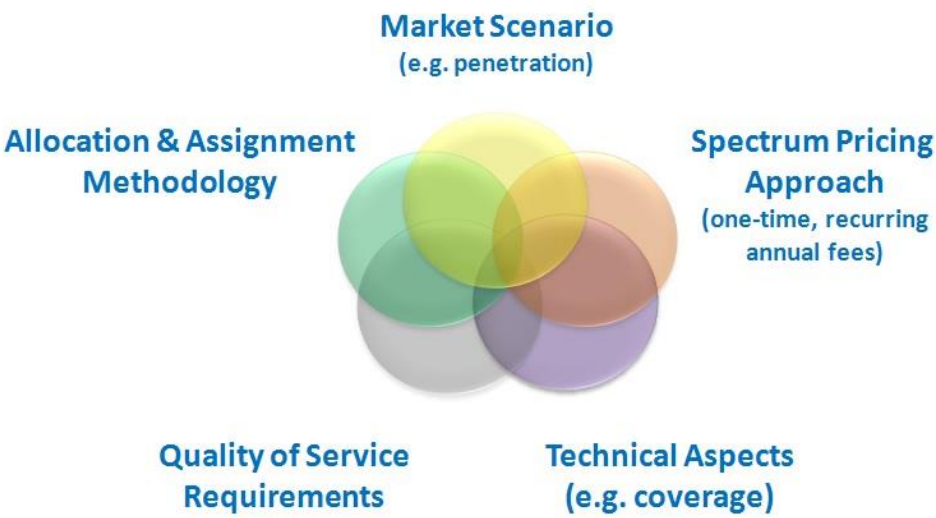
1 Introduction

These guidelines provide regulators and radio spectrum users with a better understanding of the purpose, objectives, principles, methods and strategies to determine spectrum prices and to prepare spectrum fee schedules. These guidelines will also sets out the advantages and disadvantages of modern spectrum price methods that achieve the primary goals of best practice spectrum management, which will ensure that radio frequencies are used efficiently – both technically and economically.

From the outset, it is important to understand that the determination of spectrum prices and establishment of spectrum fees are closely linked to economic and market conditions, technical factors such as which technologies and services are being used or deployed, the efficiency and quality of those technologies and services, and how spectrum is assigned to spectrum users.

Figure 1: Spectrum price interlinkages



As a result, spectrum pricing methods have evolved alongside more market-based methods for assigning and authorizing spectrum use such as spectrum auctions and spectrum trading. However, not all radio frequencies are suitable for applying spectrum auctions as the means for assigning and establishing neither spectrum prices nor are the conditions always present to support the effective use of auctions or other market-based methods such as administered incentive prices (AIP).

These guidelines begin by providing useful definitions and terms and by providing background on common types of spectrum fees used in current practice by national regulatory authorities and spectrum managers. The next sections of these guidelines will identify and describe the objectives, principles and methods used to determine spectrum prices and set spectrum fees, and are organized as follows:

- Section 2 – Spectrum price principles and objectives
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2 Spectrum price principles and objectives

Spectrum management includes activities such as planning spectrum use, allocating and assigning spectrum licences, coordinating shared spectrum use, harmonizing regional and global spectrum standards and monitoring and control its actual use. High-level economic, technical and social objectives (mainly related to universal access/service) associated with spectrum use have evolved with the spectrum management reform trend prevalent in the past ten years with less focus on the traditional command and control approach and greater emphasis on market-based systems[1]. High-level policy objectives require consistency in government approaches to matters such as access, competition, non-discrimination, user protection, equity and fairness in the manner spectrum is allocated and assigned to users

Spectrum price principles

Principles have emerged with the spectrum reform efforts of countries such as Australia, European Union, New Zealand, Singapore United Kingdom, and United States of America, when modernizing their approaches to spectrum management and are now reflected in key framework documents on how to govern spectrum management in the future. These national spectrum management principles reflect economic and behavioural aspects:[2,3]

- Spectrum should be allocated to the highest value use or uses to ensure maximum benefits to society are realized.
- Mechanisms should be put in place to enable and encourage spectrum to move to its highest value use.
- Greater access to spectrum will be facilitated when the least cost and least restrictive approach is chosen in achieving spectrum management goals and objectives.
- To the extent possible, regulators and spectrum managers need to promote both regulatory certainty and flexibility in how spectrum is used.
- Balance should be achieved between the cost of interference and the benefits obtainable from greater spectrum utilization.
- Fairness and objectivity require that fees are based on objective factors and all licence holders in a given frequency band should be treated on an equitable basis. This would preclude, for example, different treatment of different users in a given frequency band.
- Transparency requires that the basis on which fees are calculated should be made clear in a published document resulting from consultation with stakeholders and that all fees should be set based on a published schedule.
- Administrative costs will be lower if the fee schedule is simple to administer. The simplest fee schedule would be one involving a flat fee payment; however this may not promote efficient spectrum use.
- Administrative simplicity needs to be balanced against the requirement to encourage efficiency of spectrum use if fees are set taking account of parameters such as bandwidth, frequency band or coverage.

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1 As early as 2000, increased emphasis on economic aspects to govern spectrum management decisions was being recommended, "*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*" (ITU-SM 2012-4, revised 2014).

2 Australia Communications and Media Regulator: Principles for Spectrum Management, 2009

3 EU Authorization Directive 2002/20/EC and Framework Directive 2002/21/EC require the national regulatory authority when allocating and assigning spectrum in setting administrative spectrum fees to ensure that practices are based on criteria that are objective, transparent, non-discriminatory and proportionate to users.

In addition to the principles outlined in policy and directive documents, the following warrant consideration as additional principles:

- Spectrum fees should be reviewed at suitable intervals in order to cater for changes in economic KPIs (key performance indicators) or advancement in technologies resulting in increased demand of a particular band.
- Mechanisms should be in place to avoid, detect and where necessary prevent spectrum hoarding, which will deter competition.
- A balance should be established between financial approach and other key facets- regulatory (competition), social (universal service).

Spectrum price objectives

There are broad spectrum management objectives associated with spectrum prices and spectrum fees[4]:

- Spectrum prices should *promote efficient use of spectrum*. As a vital natural resource, the price of spectrum should be sufficient to ensure that it is valued and used wisely. Use of spectrum provides considerable benefits to the economy and benefits from spectrum should be maximized.
- The costs associated with managing and regulating radio frequencies (including monitor and control) should be *recovered from those who benefit from spectrum management activities*. This should apply to all users of spectrum – both public and private.
- Important social and cultural objectives can be advanced by use of the spectrum and *spectrum pricing should facilitate the achievement of government social and cultural objectives*.

Notwithstanding these objectives, the revenue goals and requirements of government influence the setting of spectrum fees by the regulator. As best as possible these revenue targets should align with the objectives of (i) optimal spectrum efficiency, (ii) achieving economic and social development goals, (iii) spectrum users paying for spectrum resource usage, and (iv) recovering spectrum management costs.

3 Determining spectrum prices: Administrative and market-based mechanisms

Spectrum prices for radio frequencies are established using either an administrative method, a market-based method, or by using a combination of both administrative and market-based mechanisms.

- ***Administrative*** mechanisms include administrative incentive pricing (AIP) and spectrum fee formulas that recover regulator costs of spectrum management.
- ***Market-based*** mechanisms for setting spectrum prices typically involve a market exchange such as spectrum auctions and (in the secondary market) spectrum trading.

Administrative mechanisms: Cost based

The administrative assignment of spectrum usually includes the imposition of fees associated with the frequency assignment process such as processing of applications for receipt and renewal of licences, as well as charges imposed on spectrum users for spectrum use. These fees can take the form of simple charges that are set at a level sufficient to recover the costs of spectrum management, and that can guide users in making decisions to use spectrum more efficiently. They can also take the form of more complex formulae such as the universal price performance model (described in section 5) that combine components intended to recover spectrum management costs and incorporate spectrum usage fees that reflect the amount of spectrum assigned and efficiently utilized.

[4] ITU ICT Regulation Toolkit Module 5 Chapter 5 Spectrum Pricing

The activities of each licensee impose direct costs on the spectrum management organization. These include the costs of issuing, maintaining data, spectrum monitoring and enforcing its individual licences. Some costs are common to a band or to a radio service (such as band planning); whereas others are common to a group of bands and some, such as management overheads, will straddle all licensees.

Regulators can tackle the issue of setting prices to recover costs in several ways:

- Some regulators create detailed costing models to establish licences that have imposed allocated costs. There are few examples of operating systems like these. The principal reason is the complexity involved in establishing and maintaining such ultimately arbitrary cost allocation systems.
- Most regulators establish rules that set charges on the basis of calculations based on the number of devices or that charge a percentage of licensee turnover. In these circumstances, a simple model of direct costs can be developed and related to revenues derived from fees. In addition, some method of allocating indirect or common costs will be needed, for example, based on the number of licensees in proportion to the direct costs that they impose. Or they can be allocated in accordance with the amount of spectrum (e.g. in MHz) allocated to the various services.

Administratively calculated market values: Administered incentive pricing

Administered incentive pricing (AIP) refers to prices that are set by the regulator to reflect the opportunity cost of spectrum while incorporating incentives. Prices are set at a level to encourage efficient use and that reflect spectrum scarcity. Administrative incentive prices used to set spectrum fees are intended to reflect the economic value calculated pursuant to an administrative method. It will typically estimate the opportunity cost of spectrum in a particular use, but may also include monopoly rents and options value. AIP is used extensively in the UK, where more than half of the spectrum is priced by AIP methods, as well as various other jurisdictions.

The methods for applying AIP are discussed in more detail in section 5.

Market-based economic value

In the case of auctions and spectrum trading, participants in a competitive auction or engaged in a spectrum trade will determine the price at which spectrum rights will be obtained by licence from the regulator or transferred between parties:

- In an auction, the economic value is reflected in the price paid by the successful bidder, which will meet or exceed the reserve price established for the auction. It will be composed of bidding deposits paid at the outset and the applicable winning price (see section 5).
- In the case of spectrum trading, the economic value is reflected in spectrum trading prices and the spectrum fee will include any transaction costs imposed on the participants in the trade.
- When spectrum prices are determined through market mechanisms, price levels at a given time may be influenced by a number of factors such as geography, competition amongst potential users, advances in technology, the present value of cash flows derived from a particular service over time, the general economic climate, and particular conditions and obligations to licensees.

4 Issues with setting spectrum fees

The spectrum manager will need to review and consider various issues when deciding upon the method, the financial basis, amounts and the timing for payment of fees in respect of a particular spectrum band, type of use or type of user. The issues include:

- fiscal context;
- relevant principles and objectives for certain types of spectrum fees;

- funding regulator operations;
- demand and supply for spectrum;
- technological change;
- type and duration of the spectrum authorization and renewal options.

Fiscal context

The regulator should consider the impact that current and changing levels of fees will have on the viability of particular segments of the radiocommunications sector. It is accepted that the mobile telecommunication sector significantly contributes to GDP growth.[5] Similarly there is wide consensus on the importance of broadband development in regard to both the economic health and social interaction of a country's inhabitants. Access to rich and varied data content and services is now a prerequisite for global trade and is becoming an essential component of the interaction between the inhabitants of a country and between the people and their government. Consequently, broadband has acquired a special status and is recognized by the United Nations as an essential convenience (or even a new human right[6]), and has consequences for all aspects of the economy and development of society and a large portion of these broadband accesses is provided through mobile networks (>80% in developing countries).

Spectrum fees set too high combined with income taxes, VAT, excise, regulatory fees, and other charges can negatively impact growth opportunities and attractiveness, sector valuations, investment levels, and compliance with authorisations.

Particular objectives of the relevant spectrum fee

The regulator should take into account the intended purposes for applying spectrum fees, such as collecting revenues to cover spectrum management and other regulatory costs, and in the case of scarce spectrum, promoting economic and technical efficiency, extracting excess rents and reducing windfall gains for licensees. Although both administrative and market-based methods can be used to achieve the objectives of spectrum fees, the regulator should plan for the introduction of market-based methods that better match the goals of economic and technical efficiency for those bands and services to which the approach best fits.

However, there may be situations where an auction will not produce the result sought even though spectrum scarcity exists in the band or bands. For instance, in some cases, if offering regional spectrum licences in order to increase rural connectivity, an auction might not identify the applicant best qualified and committed to serving the region in question. Where bids are expected to be very low, the differences between bids may not provide meaningful information about the best applicant. Thus in some situations, a price may be set administratively and selection made on the basis of comparative review of applicant proposals.

Funding regulator operations

The regulator spectrum management activities depend upon a financially stable and sustainable operating model where sufficient spectrum fees cover both direct and indirect costs. It will set fees in a manner that ensures that its operations will be adequately funded.

Figure 2 below shows annual spectrum management costs by service as reported by the Office of Communications (Ofcom) in the United Kingdom for 2014-2015. It also illustrates the Ofcom transparent reporting of spectrum management costs by radio service.

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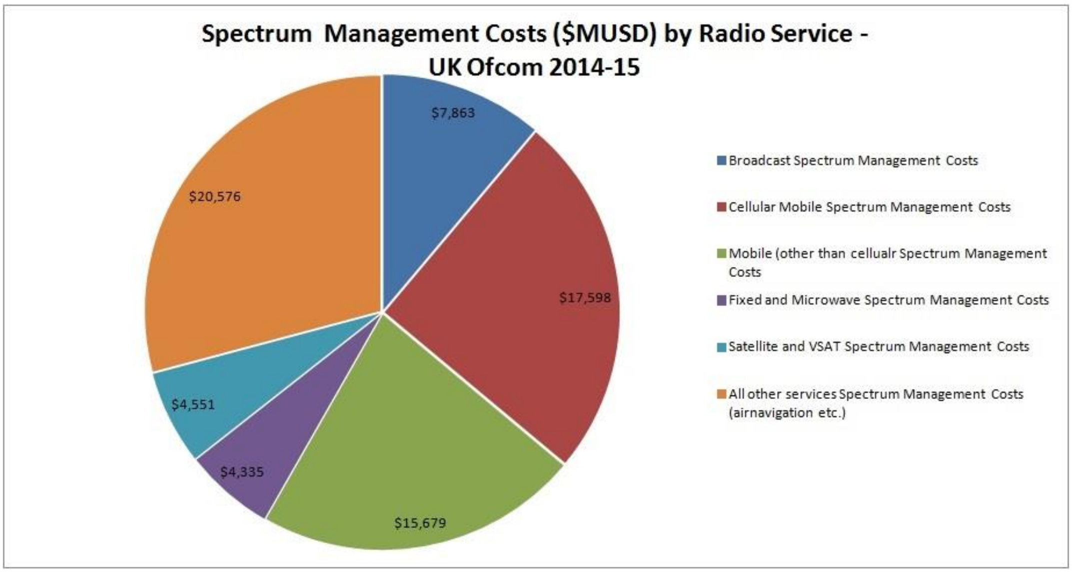
[5] Data covering 96 countries (2008-2011) found that for a given level of mobile penetration a 10 per cent increase in 3G penetration resulted in an average annual increase in GDP of 0.15. The Economic Impact of Next Generation Mobile Services, Chapter 1.6, World Economic Forum, 2013.

[6] www.broadbandcommission.org/Documents/Broadband_Challenge.pdf

Figure 2: Spectrum management costs by service



Source: Ofcom

Scarcity of and demand for the spectrum

The regulator should consider the scarcity of spectrum - excess of demand over its supply - when choosing a method appropriate for setting spectrum fees taking into account the level of existing congestion under current use of the band, and likely congestion if artificial constraints such as licence restrictions are removed, or if the spectrum were made available for an alternative use.

Two contrasting situations illustrate the different pricing approaches depending on whether there is scarcity or no scarcity:

- **Scarcity**: For example, in the bands below 1 GHz where various technologies are available to provide services for which there is high demand. Several methods may be appropriate for setting spectrum fees:
  - market-based pricing through auctions;
  - AIP where, despite the excess demand, an auction is not feasible, combined with comparative review of applicants; and
  - comparative review of applicant qualifications (beauty contest), which might include comparing financial offers for the spectrum or alternatively price the spectrum according to administrative costs.
- **Non-scarcity:** Often where there are few users, services and data requirements are tolerant to interference and lower power devices are commonly used in a non-interference/non-protection basis. The services and applications associated with non-demand situations include industrial, scientific and medical (ISM) applications, (see provision No. 1.15 of the ITU Radio Regulations) and typically bands above 15 GHz.

  In such cases (assuming the spectrum is not licence-exempt), the regulator should usually assign the spectrum, setting prices administratively with a view to recovering administrative costs, publish the prices in a fee schedule, and assign the spectrum on a first-come, first-served basis.

Ensuring the highest value use of spectrum

Where demand for radio spectrum in a given band exceeds the available supply, fees for the right to use the band can be used to encourage the highest valued use of the band. Higher fees that weed out the less valuable uses of spectrum will curtail demand to the point where it no longer exceeds supply. The highest value use will create the highest consumer surplus and therefore result in the licensee being willing to pay the most for a frequency licence. Thus, in theory, the best ideas for how radio spectrum can be used should attract the highest amount of investment capital, and so for example the winner of an auction will be the bidder that can convince the market that it has the most profitable project.

Allocating spectrum fairly and transparently

Methods of charging fees for the right to use radio spectrum can also act as a transparent allocation protocol where demand for spectrum in a given frequency band might otherwise exceed the available supply. For example, auctioning spectrum can achieve the goal of ensuring a fair and transparent allocation among rival bidders. Alternatively, if radio spectrum prices are set at or near the level of economic rent, demand for the band may diminish to the point that supply exceeds demand so that spectrum assignments can simply be made on a first-come, first-served basis. If prices are set too low, demand may exceed supply, requiring regulators to select among competing applicants which places responsibility on the regulator rather than market forces. One of the reasons for using spectrum auctions is to avoid the risks associated with weak or corrupt assignment practices by following fair and transparent assignment methods

Technologies, standards and market developments

Changing technologies, international and national decisions on spectrum allocations and harmonisation, consumer demand, and the commercial availability and cost of radiocommunications equipment, all affect the value of radio spectrum. These factors may greatly affect both demand and supply:

- Demand for radio spectrum may increase as consumer demand rises for the applications that use it (e.g., social media). Technologies that shift demand to other bands, such as digitalisation of television, may reduce demand for previously heavily utilized spectrum.
- Supply may increase as it becomes possible to use a technology platform on radio spectrum previously used for less valuable means (e.g., digital switchover). Technologies, such as multiplexing that increase the throughput over the same bandwidth, and technologies that allow greater reuse of spectrum on a shared basis may also increase supply.

Technologies and standards may affect the mechanism for spectrum pricing. For instance, they may influence the conditions of spectrum auctions (e.g. licence durations, block-size and channeling arrangements of bands auctioned).

Type and duration of the spectrum licence

Numerous different types of spectrum licence are available or in force in every country. For example, some allow private companies to operate national networks to provide telecommunications services to the public, some allow public bodies to provide public services, some permit amateur spectrum use. Some spectrum use is exempt from licence requirements, although regulations and standards may govern the types of devices, use and power levels that are permitted.

Where spectrum is to be licensed, the licences have different durations, with some being renewed annually and others having terms of 10 years, 15 years or another lengthy duration. The regulator should typically set fees for one-year spectrum licences administratively with a view to recovering costs, and will not charge separate application and renewal fees. No fees will apply in respect of licence-exempt spectrum.

Where a lengthy licence for scarce spectrum expires, the regulator may auction the spectrum or renew the licence for an administratively calculated fee. Where it does the latter, it will typically seek to price the spectrum to economic value using AIP based on opportunity cost or, to avoid windfalls to licensees, priced at a full market value taking into account business modelling and/or benchmarking.

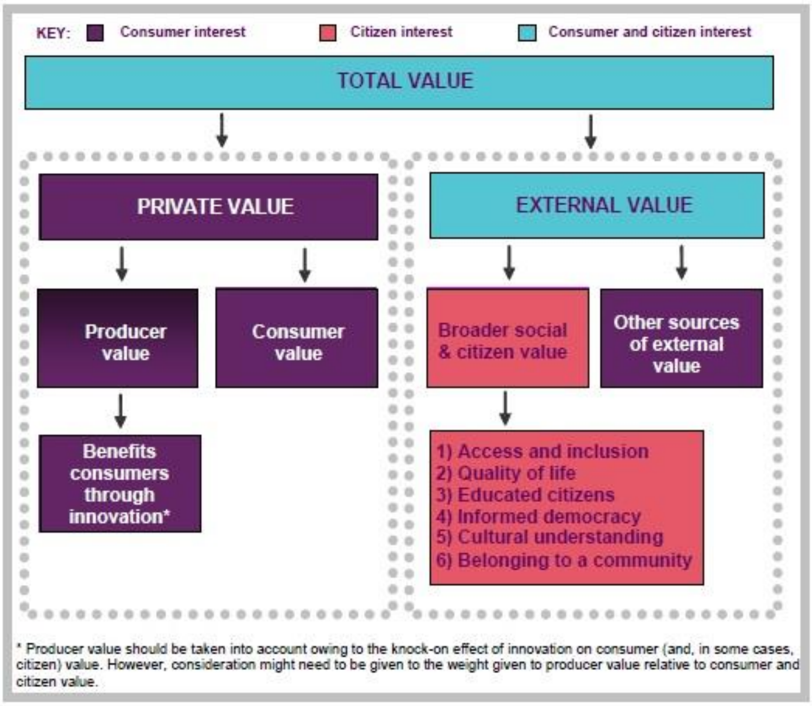
Considering social values

The primary economic objective (and many will argue the primary social objective) is to maximize the net benefits generated from the resource, enabling an efficient distribution with maximum benefits to society. While the importance of social values is widely accepted, few attempts have been made at actually measuring social value in connection with spectrum use. Ofcom in 2007 developed its framework in connection with the digital dividend to understand better how the different uses might generate broader social values and hence make better-informed decisions concerning allocations and spectrum valuation. The following elements of social value were identified:

- access and inclusion (e.g. value derived from universal access and facilitating access to public services);
- quality of life (e.g. value derived from providing access to services that improve quality of life by promoting work/life balance or family life);
- belonging to a community (e.g. value derived from allowing people with similar interests to communicate and/or participate in the local community);
- educated citizens (e.g. value derived from services with educational content or child oriented services);
- cultural understanding (strengthened cultural identities or promote diversity and understanding of other cultures);
- better informed democracy (e.g. value derived from services that provide information facilitating democratic debate).
- negative value derived from any of the elements above.

Figure 3 illustrates how to consider the potential value to society of different uses of the spectrum. While the framework is a useful conceptual model, measuring the dollars and cents of social value is subject to a degree of subjectivity and considerable disagreement. Most NRAs recognize the need to take social value into account although little effort is expended on measurement.

Figure 3: Social value and the potential value to society of difference uses of spectrum



Source: Ofcom Digital Dividend Review[7]

5 Closer look at spectrum price methodologies

Regulators worldwide predominantly use administrative methods for establishing spectrum fees for most bands and services with cellular, fixed and satellite-based telecom services being the exception. As spectrum management best practices migrate towards more liberalized market-based methods, spectrum auctions are becoming more commonplace. Spectrum auctions for cellular spectrum and some fixed and satellite-based telecom services spectrum have been held worldwide although concentrated in Western Europe, the Americas, and South East Asia. Over 70 have taken place in the United States of America. Developing countries in Africa, the Caribbean and Eastern Europe, have been less inclined to use auctions to assign cellular spectrum and determine spectrum prices. The reasons include lack of scarcity and capacity within regulators.

More detailed descriptions for establishing spectrum fees using administrative and market-based methods such as auctions and AIP is given in this section.

Administrative methods

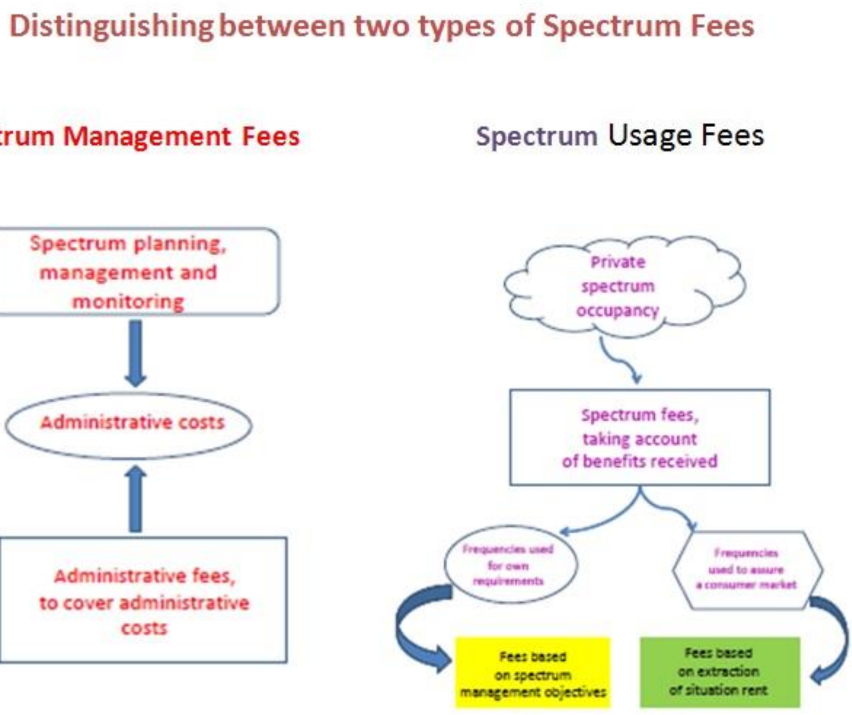
The administrative assignment of spectrum usually includes the imposition of spectrum management fees and spectrum usage fees. These fees can take the form of simple charges or more complex formulae. The two types of fees are described below and further illustrated with Figure 4:

- **Spectrum management fees**: These are funds that are collected from spectrum users on annual bases that are generally geared to recover direct and indirect costs of spectrum management activities of the national spectrum regulatory authority. Spectrum management fees are set, exclusively using administrative means.

7 http://stakeholders.ofcom.org.uk/binaries/consultations/ddr/statement/statement.pdf

- **Spectrum usage fees**: These fees are charged to recover a spectrum resource rent for the government and to ensure that users of spectrum utilize the resource on an efficient basis. Under a spectrum usage pricing framework users should move to a state where only assigned and utilized spectrum is paid for and unutilized spectrum is returned for reuse. How spectrum is used does vary considerably across regions due to economic, demographic, and technical realities. There is an argument for making spectrum usage charges consistent across a region to avoid investment disincentives. However, in looking at regional best practice several important factors including scarcity, quality, congestion and value in use need to be taken into account. Spectrum usage fees can be set either administratively, by market-based methods such as auctions, or by administrative means intended to reflect opportunity costs, a proxy for market prices.

Figure 4: Two types of spectrum fees – management and usage fees



Source: ITU Resolution 9 Guidelines for Coherent Spectrum Usage Fees

Where more than one type of authorization fee is charged, it is good practice to unbundle them, i.e. to calculate them separately. This improves transparency and makes it easier to determine that administrative charges related to cost recovery are indeed cost-based. Separating spectrum management fees related to spectrum management costs from other spectrum usage fees improves transparency and accountability. Equally important is the improvement in overall effectiveness of the fees. Efficient use of spectrum can only be achieved when spectrum users are able to respond to the incentive factors incorporated in spectrum usage fees (e.g. band and bandwidth, geography, time, coverage density, etc.).

Relevant costs

The activities of each authorized spectrum use impose direct costs on the spectrum management organization including the costs of issuing authorization, maintaining data, spectrum monitoring and enforcing licences. Some costs are common to a band or to a radio service (such as band planning), whereas others are common to a group of bands and some, such as management overheads, will straddle all.

With spectrum management fees related to specific administrative activities and processes, the regulator introduces fees with a view to aligning them the objective of cost recovery of associated spectrum management expenditures. These direct and indirect costs include:

- salaries for skilled professional (including monitoring and enforcement) and administrative spectrum management staff;
- investments in ICT's and databases including: spectrum management tools, national frequency allocation tables, spectrum users databases and monitoring system and equipment such as fixed and mobile monitoring stations and their upgrades/calibrations;
- Capex and Opex for automated spectrum management functions and their upgrades;
- office space and services for utilities;
- research activities and costs associated with consultations and publications;
- interference coordination/mitigation activities;
- participation in ITU and other international meetings;
- management overheads;
- legal fees of enforcement actions;
- refarming.

Some costs will be common to a band or to a radio service of a particular band planning (such as 700 MHz band plan). Others will be common to a group of bands and some, such as management overheads, will straddle all services and authorisations. A study conducted by the Australian Communications Media Regulator (ACMA) suggests that indirect costs predominate. Fees are usually imposed by the regulator when administratively assigning spectrum and processing applications. The types of fees include:

- application fees;
- type approval fees;
- radio operator examination fees;
- fees for radio operator certificates;
- interference complaint investigation fees.

The simplest general formula for setting administrative spectrum fees to recover costs using a simple model of direct and indirect costs is shown in Figure 5.

Figure 5: general formula for setting administrative spectrum fees

$$\text{Spectrum Fee} = \frac{\text{Spectrum Management Costs (Direct and Indirect)}}{\text{Amount of Spectrum Assigned to the User}}$$

Source: ACMA

Spectrum fees can also reflect the demand and supply conditions for spectrum use, and the degree to which spectrum use is liberalized. The regulator or ministry will choose from three levels of spectrum management cost recovery:

- partial costs recovery resulting in the regulator requiring revenue from government general revenues;
- full cost recovery that may mean the regulator is financially self-sufficient; or
- fee revenues exceed spectrum management costs and the surplus is contributed to other regulatory programmes or government general revenues.

Cost recovery leading practice: Authorisation Fees and the EU Authorisation Directive

The EU Authorisation Directive (Authorisation Directive) includes provisions related to levying fees on undertakings that provide electronic communications services or that operate electronic communications networks. The provisions of the Directive that relate to licensing fees are paragraphs 30 to 32 of the introductory section of the Directive and Article 12 of the Directive.

Pursuant to the provisions of the Directive, national regulatory authorities (NRAs) are permitted to impose administrative charges on undertakings for the sole purpose of recouping the cost of managing, controlling and enforcing the general authorisation regime and the costs associated with granting rights of use. Administrative charges that are imposed on undertakings must be limited to the actual administrative costs involved with these regulatory functions.

NRAs that opt to impose administrative charges are required to publish an annual report that sets out the total sum of charges collected and the total administrative expenditures incurred. NRAs are further required to make appropriate adjustments if there is a difference between the total sum of charges collected and the total amount of expenditures incurred.

The Authorisation Directive distinguishes between administrative charges and usage fees for radio frequencies and numbering resources. The Directive permits the levying of usage fees for scarce resources such as radio frequency and numbers as a means of promoting the optimal use of such resources. Usage fees must not, however, hinder the development of innovative services or act as a barrier to competition. The Directive also states that it is "without prejudice to the purpose for which fees for rights of use are employed." Thus, NRAs are free to determine the use to which these fees will be put.

NOTE – http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=URISERV%3Al24164

Universal system performance pricing model[8]

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

[8] ITU Resolution 9, Guidelines for the establishment of a coherent system of radio-frequency usage fees: ITU-D SG 2, provides further guidance and examples of how this model is applied.

When it comes to using administrative formulae for calculating spectrum usage fees several models have been developed. A universal model for spectrum price determination based on system performance has been developed and is described in more detail below[9].

$$P = \frac{V}{M} \times \frac{K_f K_S}{K_m} \times C_S \times K_P$$

Where:

P = the spectrum price

V = volume of space or geometric area occupied

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

K_f = coefficient reflecting specific characteristics of range used

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

K_m = coefficient reflecting the social benefit of radio system

C_s = annual spectrum management costs

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

On one hand, the application of this method is intended to stimulate more efficient use of spectrum, and on the other hand various problems with the practical use of formulae such as this arise. The main difficulty with this technique is in choosing factors that may vary in effectiveness on a case by case basis while taking into account the specific features of a service, the demand for spectrum, revenues potential from the service, etc.

Market based methods

Market-based methods include auctions, administered incentive prices, and spectrum trading and leasing.

Auctions

Spectrum auctions are used around the world and are an important method for awarding licences and assigning spectrum authorizations for mobile services. The amount of revenues collected from spectrum auctions can be significant. Auctions best support the main regulatory objectives of technical and economic efficiency where market conditions permit competitive bidding. The typical indicators of auction success include some measure of participation (more is better), an absence of collusive bidding behaviour, and winning prices that reflect, more or less, the 'true' value of the spectrum to winning bidders. Auctions are particularly well suited for assigning high-value spectrum rights such as cellular and fixed links for various reasons:

- sound economic principles related to consumer welfare and investments are applied when spectrum is in the hands of those who value it most highly;
- prices set in spectrum auctions are comparatively free from political influence and collusion;
- auctions are a comparatively quick method of delivering a result;
- operators themselves rather than the regulator set the spectrum price (even if the regulator can influence prices through selecting the auction method and setting reserve prices);

[9] Spectrum Pricing, Vadim Nozdrin, delivered at the ITU Regional Radiocommunication Seminar, Lusaka, 2003.

- market prices can encourage rapid rollout of services by putting pressure on competing operators to extend coverage quickly to generate cash-flow to cover the investment in the auction price.

In addition to meeting the main objective of achieving an efficient, timely and dispute-free assignment of scarce spectrum when the demand for spectrum exceeds supply, spectrum auctions meet the other important objective of supporting competition. Because spectrum is an essential element of many high value commercial and public services for which there are not good wireline substitutes, the operator controlling the necessary spectrum can also control (or heavily influence) the downstream service sold to end-users. Hence, improving access to spectrum will reduce barriers to entry into existing and new markets. Some useful background for analysis has been gained because of the significant number of mobile licences granted by auction around the world. The most relevant and key variables include:

- the number of licences on offer;
- whether their geographic coverage is national or regional;
- the extent of coverage and roll-out obligations;
- the size of spectrum lots, including combinations of different bands;
- payment obligations such as licence fees and royalties;
- access to additional spectrum and existence of overall caps;
- features that might encourage smaller operators and new entrants;
- restrictions on foreign ownership; and
- the tradability of authorizations.

The regulator should take the following key steps when considering the approach to a band or bands available for assignment and then in implementing an auction. These keys steps usually include the following:

	Stage	Activity
1	*Consultation*	The regulator will generally seek to consult with stakeholders such as government ministries and the likely users of spectrum as to the factors described below, both before deciding to carry out an auction and while developing the elements of the auction itself. The regulator seeks to ensure that any auction is suited to the realities of demand in the market.
2	*Assessing the appropriateness of an auction*	The regulator will first review demand for and available supply of the relevant spectrum in order to determine whether it is subject to scarcity. It will consider also whether the benefits of assignment through an auction process outweigh the costs of such process as opposed to other assignment processes. Where there are few users or high geographic frequency reuse is possible or services and data requirements are tolerant to interference and lower power devices are commonly used (non-interference/non protection basis), an auction is unlikely to be appropriate. Also exclude radio services non oriented to general public, e.g., aeronautical, maritime, radio navigation, radio amateurs, etc.
3	*Defining the band or bands to be auctioned*	The regulator will consider the object of the auction, including whether the band should be auctioned in combination with another band. It may take into account for example linkages between business cases for the bands, timescales in which bands will be available for use, spectrum caps to be applied and timescales of availability of relevant equipment. When refarming is necessary, how to do it, and finance.

	Stage	Activity
4	*Selecting the auction method*	The regulator will determine the method of auction to employ, such as for example simultaneous multiple-round ascending (SMRA) auctions, simple clock auctions, combinatorial clock auctions (CCA) and sealed bid auction.
5	*Benchmarking*	While no two auctions are alike benchmarking of similar auctions situations (regions, economic status, bands and services) can provide valuable information and lessons learned to help ensure auction success
6	*Designing the auction*	The regulator will consider a number of issues in relation to auction design depending on the circumstances. Among others, these may include: • evaluate key end-state conditions and key performance indicators such as coverage and roll-out, subscriber penetration, service prices and options, and quality of service; • addressing bidder pre-qualification and participation, licensing and operating conditions including entry fees, bid deposits, license payment terms; • packaging the spectrum, including through setting the number of licences on offer in the relevant bands and the size of spectrum lots; • estimating spectrum values which will guide the determination of reserve prices and the determination of bid increments and aid in optimising competition through bidding rules; • addressing market power concerns, such as through use of spectrum caps; • promoting specific social goals, such as through coverage and roll-out obligations; • encouraging new entry and growth, such as through spectrum set asides; • limiting risk of collusion through transparent communication, publicity, activity rules, and severe penalties for collusive action by bidders and related parties (*) • sending appropriate price signals and securing a minimum economic rent through reserve prices; • Increasing the option value of the spectrum through the subsequent tradability of licences and clarity regarding renewal;
7	*Conducting the auction*	The regulator will tend, particularly in its early years, to engage specialist spectrum auction advisers to assist with preparation of the Auction Information Memorandum for and conduct of an auction.
8	*Reviewing the results*	The regulator will review auction results in order to draw lessons, including in particular to the degree to which and manner in which the auction was competitive.
*– www.globalmobileawards.com/awards-history/winners-2015/		

No two auctions are alike and as a result a generalization about the valuation of radio spectrum becomes too complex for numerous technical, market and other interrelated reasons.

Deciding to auction spectrum, or to authorize a tender process, is not a simple process. Market value for spectrum can fluctuate tremendously, and key decisions about timing, auction processes, regulatory rules, bidding thresholds and market structure can mean the difference between very low bids and irrational overbidding.

The key differences between auctions and comparative hearings or administrative decisions are that:

- An auction assigns the licence to the firm which bids the most, and that may in certain conditions be the most efficient firm;

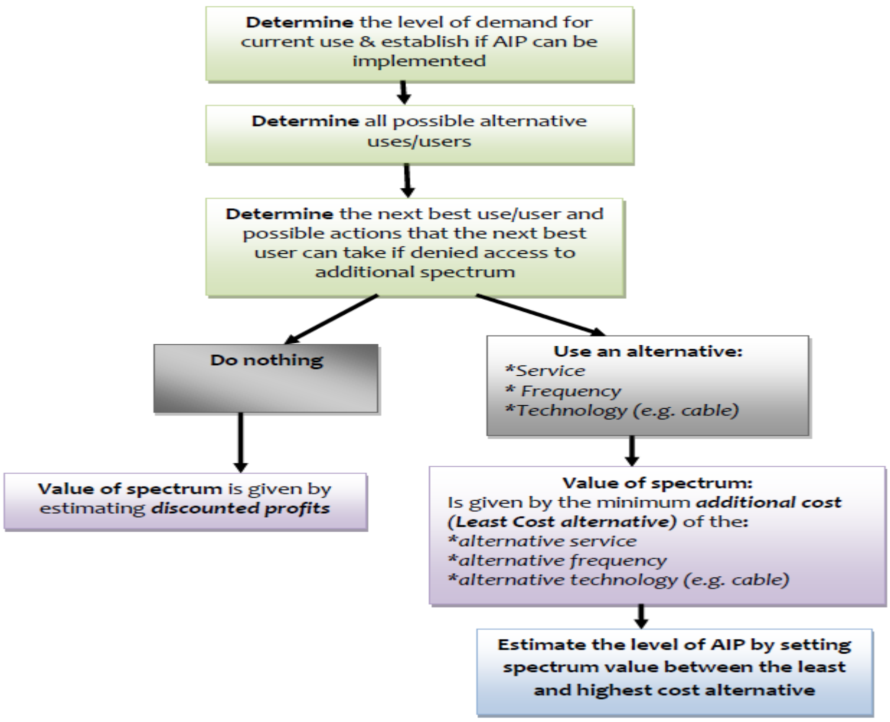
- A competitive auction, if it operates properly, will direct any expected excess profits from providing the service to go to the government, rather than the operator as would be the case if the operator were chosen via a competitive hearing. [10]

Administered incentive prices

Setting an administrative price for spectrum equal to its opportunity cost is predominantly used in the United Kingdom by Ofcom and by ACMA in Australia. A price is calculated by estimating what additional costs are incurred by a firm to produce the same services using incrementally less spectrum in a particular band or by having to utilize spectrum in the next cheapest band, or with a non-spectrum input (such as a fibre optic cable). Those extra costs measure the loss of opportunity to use the spectrum in question.

Figure 5 summarizes the decision steps applicable to AIP the method, while Table 1 summarizes the main steps in calculating AIPs using the cost-reduction approach.

Figure 5: AIP decision steps



[10] ITU report *Exploring the Value and Economic Valuation of Spectrum* www.itu.int/pub/D-PREF-BB.RPT3-2012

Table 1: Main steps in calculating AIP using the cost reduction approach

Step	Action	Comments
Step 1: Determine network and technology situation to be modelled	Make assumptions concerning future network coverage and technology	Transitions between technologies must be considered in a practical manner
Step 2: Determine 'typical operator characteristics'	Make assumptions concerning forecast traffic, number of base stations (actual or modelled based on link budget and propagation assumptions), and base line spectrum assignment	Traffic should be split between urban, suburban rural and remote areas and each of these locations separately modelled. This is crucial to ensure that the impact of spectrum supply on capacity constrained areas is isolated.
Step 3: Determine the spectrum increment or decrement	Make assumptions about amount of spectrum to add/take away from base line allocation. This is the minimum amount that can technically can be used to enhance/reduce capacity	Typically this could be the spectrum associated with removing a carrier from each sector. It depends on the carrier size and frequency re-use pattern
Step 4: Determine the number of base station sites and amount of network equipment to deliver traffic	Either model network or use data from operators to identify initial number of base stations affected that are capacity constrained initially. Model impact of traffic growth on network quantities in future.	Increases in base station numbers will typically be required in urban areas, though some suburban areas may also experience capacity constraints
Step 5: Estimate number of base stations required and network costs to support traffic forecasts with and without additional spectrum	Model network with and without spectrum in areas that are capacity constrained.	Where areas are capacity constrained, fewer base station sites will be required with additional spectrum.
Step 6: Estimate network costs to support traffic forecasts with and without additional spectrum	Change in the number of base stations will results in change in base station and backhaul costs.	The future deployment costs are discounted back to a net present value. Costs include both capital and operating costs such as site rental and maintenance, which may vary by area. With additional spectrum the costs of adding carriers must be taken into account.
Step 7: Estimate value of the spectrum increment or decrement	Calculate difference between network costs with and without spectrum.	

The input variables for steps 1-5 of the approach are described below and grouped into six categories:

1. **Economic and demographic**: Input parameters that relate to population (current and future projection), characterisation of area type by population density, and economic conditions/assumptions with impact on costs and return on investments.
2. **Market**: Input parameters relating to operator market share, which determine the amount of traffic expected for each operator for the modelling period.

3. **Technical network and deployment**: Input parameters defining the way the network carries traffic, which, in turn, determines the overall capacity of each base station and hence the rate at which new sites will be added.
4. **Network costs**: Input parameters that enable the translation of network elements into total network costs, given the technical network and deployment assumptions.
5. **Base station (BTS):** Input variables that relate to the distribution of base stations by operator across area types and the coverage limit of each individual base station for different area type and radiofrequency band.
6. **Radio spectrum:** Input variables that relate to the amount of spectrum in different radiofrequency bands that each operator expects to have access to during the modelling period.

While it is possible to model cellular spectrum values using AIP, it is also clear that adequate capture of important spectrum value drivers, such as traffic, and maintaining data over time, will require developing complex models with a large number of input assumptions that are not likely to be constant over a large number of countries with differing economic conditions, service offerings, and usage patterns.

The example in Figure 6 depicts a hypothetical calculation of AIP for cellular spectrum using the cost reduction methodology using GSM spectrum assignments and also illustrates some of the difficulties associated with calculating AIPs.

Some assumptions can be made with reasonable confidence (e.g. unit equipment costs) while others are more difficult to develop:

- Some assumptions are reliant on the current assets and operations of the specific mobile network operator (MNO) such as the number of sites, subscribers and usage data for different categories of subscribers. There is not a single set of typical assumptions that are representative of all MNOs because of the variability in market share and the nature of their subscriber usage.
- Other assumptions require market forecasts for the mobile sector- ARPU (average revenue per user/unit) growth and traffic growth. Forecasting mobile services over long-life network assets is necessarily uncertain, and relative spectrum values will therefore depend upon the respective aspirations and market confidence of individual operators.

Equipment costs are investment or capital costs of constructing the site and the costs of operating the base stations for a network of specified capacity. In order to use these as a basis for spectrum prices, a conversion to an annual cost per MHz is required. This is done by:

- assuming a base station life of 20 years;
- estimating the cost of installing and operating the network for the first half of this period as a net present value in year one, using a real discount rate of 10 per cent.

The net present value is then re-expressed as a sequence of equal annual costs over the ten year period, and divided by the number of MHz deployed to yield a price or value in USD million per MHz per year. The residual values of any assets at the end of the ten year period count as a negative cost

The calculated opportunity cost of nearly USD 5 million per 1 MHz of GSM spectrum is very sensitive to variations in key cost inputs such as the cost of land for situating cell sites, the cost of radio equipment, and the discount rate. The example utilizes a very simplified traffic model which may not appropriate today given the increasing dominance of data traffic and declining voice traffic.

The cost reduction scenario used in Figure 5 shows the calculation for the value of the cost savings derived from deploying additional spectrum by an operator with existing spectrum assets. The methodology relies heavily on the ability of future traffic growth to be accommodated within the existing spectrum holdings (for a sensible *without additional spectrum* scenario). Another assumption that may underpin the use of this model is that reduced costs from the use of incremental or even alternative spectrum will not have a significant impact on the revenues.

Figure 6: Hypothetical calculation of AIP for cellular spectrum

AIP for Mobile

Key Assumptions:
1. Network traffic and traffic distribution are important and vary by situation.
2. Total Spectrum assigned will typically range between 2 * 9.6 - 15 MHz.
3. Additional spectrum can be added in high density areas or smaller cells can be used.
4. Additional spectrum blocks be needed at declining rate, i.e. 60 % then 30 % of sites.
5. Typical channelling plan is assumed: 3 by 4 cells or a cluster of 4 tri-sectored cells with 200 kHz of paired spectrum per sector.
6. Minimal spectrum assignment is therefore 200 kHz * 3 * 4 = 2.4 MHz per transceiver
7. If additional capacity is required to go from 3 to 4 transceivers per sector an additional 2.4 MHz is required → 7.2 to 9.6 MHz

Base Station Cost Assumptions: (Source: LRIC Cost Model/Author)
1. DCF: Annualized at 10% over 10 years (beginning of the period)
2. Cost per site acquisition = $100,000 or $33,000 per sector
3. Radio equipment = $39,000.00 per sector = $6,231.00 p.a.(10% discount rate, 10 years, 8% maintenance costs p.a. based on cost of capital)
4. Cost of additional radio equipment and maintenance for an existing sector (from 3 to 4 transceivers) = $1,822.00 per annum.

Traffic Assumptions: (Source: Ofcom/Oftel LRIC GSM Cost Model)
Spectrum Assigned: 2 * 7.2 MHz, 2 * 9.6 MHz, 2* 2.4 MHz
Sectors Required[2]: 1/3 * 42,000/Capacity = 968 - 661 = 307

Opportunity Cost Calculation:
1. Cost of Additional Radio equipment and maintenance from 3 → 4 transceivers: 307 * $1,822.00 = $559,354
2. Cost Reduction for Sectors (Sites): 307 * ($33,000 + $6,231) = $12,071,547.00
3. Difference in radio cost reduction versus increased maintenance: $12.071,547 - $559,354 = $11,512,193
4. Cost per 2 * 5 Mhz: $11,512,193/2.4*5 = $23,982,735

Source: ITU

Spectrum trading and leasing

Secondary markets may introduce price signals that lead to more efficient spectrum use because a spectrum licensee holding onto spectrum faces the opportunity cost of revenues foregone from not disposing of it. Secondary markets also allow for the fact that spectrum valuations can change over time as a result of changing technologies and patterns of demand.

Primary award mechanisms are never perfect. Secondary markets can help correct imperfections, allowing particularly in the case of spectrum that has been administratively assigned for it to move to those who value it more than those initially licensed. In the case of auctions, where the licensee acquires the right to use spectrum through a market mechanism, the ability to trade or lease the spectrum allows the licensee also to dispose of it through a market mechanism. Such possibilities of exit will increase the option value of the spectrum.

For these reasons, the regulator should, on a step-by-step basis, allow increasing levels of secondary markets through permitted spectrum trading and spectrum leasing by considering requests to trade spectrum rights and lease spectrum, taking into account factors including:

- proposed change in use of the spectrum, including whether any proposed change of technology may cause harmful interference;
- qualification requirements, including whether the transferee meets any qualification requirements that applied to the transferor;
- licence obligations, including how obligations associated with the spectrum rights to be transferred will be treated;
- the impact of the transfer on competition in the market;
- whether the transferor and transferee are in good standing under applicable laws and regulations; and
- national security.

When the spectrum manager is satisfied that a proposed trade or lease is not likely to lead to more harm than the benefit it should be allowed to proceed.

Other methods

Economic modelling and business based valuation provide useful information on sector performance and the impact spectrum fees may have on income growth, investment in the radiocommunications services and technology.

Economic modelling

The objective of economic modelling is to assess spectrum value from the perspective of its contribution to the national economy. This is important because governments are interested in increasing economic contributions from the telecommunications sector. Economic modelling also allows the NRA to consider how changes in the raising or lowering of economic activity such as economic downturns, changes in taxation, and new trade relationships will affect performance in the sector and what adjustments, if any, to market structure and regulation are needed. Economic valuation modelling does not easily translate into specific valuations for radio spectrum.

The basic model involves examining the economy at three levels of aggregation to get a picture of the stimulus to the overall economy on the assumption there are meaningful connections between individual, households and firms, industries and the macro-economy. Economic modelling gauges the increments in economic output and its effect in terms of employment and GDP per head. The essential steps in this modelling approach consist of:

- assessing demand using various take-up scenarios;
- constructing a quantitative model using regression analysis and carefully selecting parameters;
- applying historical data and projecting forward across the three levels of the economy.

The results can best be used to determine general trends and make several linkages between income growth, productivity growth and the increasing use of spectrum in the overall economy. Determining a quantified value of potential impact on the overall economy can only be determined after considerable effort. Most studies employing economic modelling of the telecommunication sector often focus on the impact that an investment in telecommunications network infrastructure will have on GDP. For example, economic modelling is used to estimate the increase in GDP resulting from investment in new services and infrastructure and repurposing of underutilized government allocated spectrum to be applied and used in a national broadband network. There are a number of general studies and country specific studies have been conducted in recent years with increasing emphasis on investment in broad band infrastructure,[11] [12] and while it is safe to conclude the use of spectrum in cellular services makes an important contribution to growing the economy, it is much more difficult to arrive at specific valuations for specific bands.

Economic modelling can be used by the communications regulator to shed light on the important issues of the economic contribution (or loss) of government spectrum holdings of commercial spectrum and what adjustments are necessary when the contribution from spectrum in a particular service begins to tail off.

Business based valuation

A business-based valuation model assesses the value of spectrum from a commercial user's perspective. The exercise will be highly relevant to operators. The objectives for both the regulator and operator will converge at the point when spectrum values and resulting spectrum prices are optimal. The NRA is interested in economic and technical efficiency whereas the operator is interested in exploiting the profit potential of assigned frequencies. The principles of the business-based valuation approach

[11] The Impact of Broadband on the Economy – Research to Date and Policy Issues, Dr. Raul Katz, Columbia University and ITU, 2010

[12] Socio-Economic Assessment of Broadband Development in Egypt, Dr. Matt Halfmann and Dr. William Lehr MIT, World Bank ICT Unit, 2010.

involve estimating the value of profits over the model period by understanding how much profit the spectrum in question will generate.

A base model case is needed where current and future aggregated growth in demand and revenues for the sector are compared to the costs of providing and delivering the service (Capex and Opex). The resulting discounted cash flows do not, at this point, reflect the value of spectrum to a business since there are multiple factors affecting profitability, not just the contribution of spectrum. Measuring the value of spectrum from the operator perspective also involves estimating the constraints on profit such as competition and regulation. The number of licensees in the market and potentially entering the market will potentially affect composite service demand model while the introduction of new services and technologies (either complements, substitutes, or disruptive technologies such as OTT (over-the-top)) have to be factored into measuring cash flows and the resulting value of spectrum value to that user.

The aim of this type of modelling is to generate an upper bound estimate of the operator's willingness to pay for the spectrum. The discounted cash flow (DCF), the net present value of revenue less cost over the licence term, which can be expected by an operator from the use of the spectrum to deliver service to subscribers, represents the limit of what the operator will be willing to pay. If it has to pay more than this limit, the operator will be better off not acquiring the spectrum, since the net benefit of the spectrum use is negative. A proportion of the DCF value is attributed to each frequency band – a simple way of doing this is to pro-rate the value by bandwidth.

Some of the important issues which will affect spectrum valuation utilizing a business-based model include:

- the level and growth in demand (subscribers and ARPU) given that certain regional markets may be considered as mature or reaching maturity;
- the level of competition and respective market shares of operators and how spectrum valuations will be affected;
- differences in the attractiveness of various IMT Bands such as 700- 900 MHz, 1700-2100 2300-2500, 3400-3600 MHz bands for the introduction of new services and technology;
- strength of competition from other services including fixed line and new services such as VoIP and broadband wireless system (BWA);
- assumptions about current and future costs of equipment and assumptions about operating costs of all operators and the timing of investments;
- assumptions about the business finances and its weighted average cost of capital (WACC).

Again as with AIP, a service neutral model cannot be practically constructed because the value for spectrum is a function of network structures and final communications markets, both of which are service specific.

6 Preparing administrative spectrum fee schedules

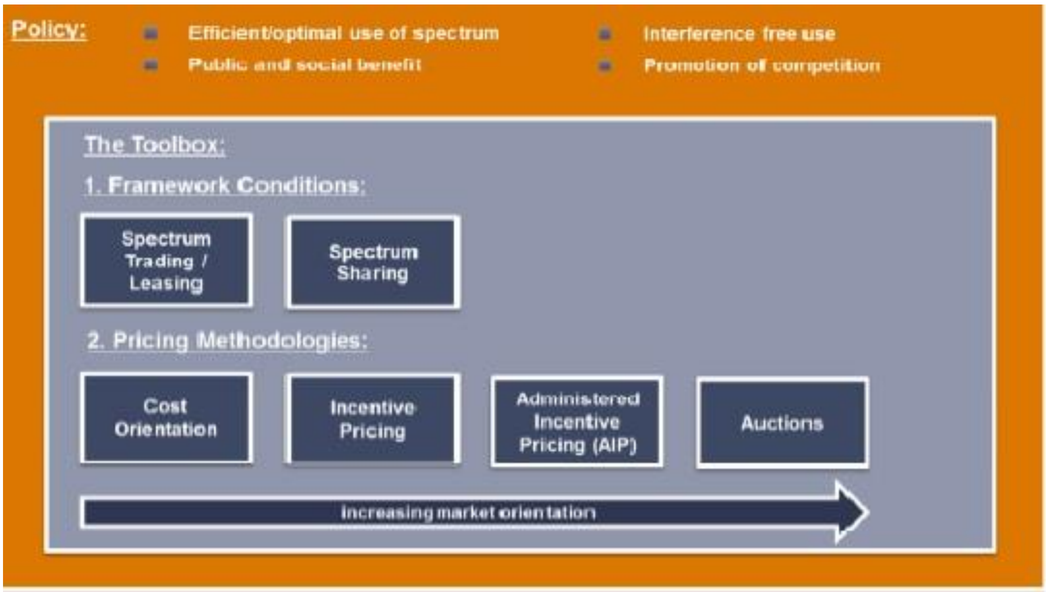
In this section, general guidelines for establishing administrative spectrum fees for multiple services such as broadcast, cellular, broadband, fixed and mobile services are provided.

Policy decisions

Spectrum management and spectrum fees policies, consisting of a preamble, spectrum policy and spectrum fees objectives and a set of principles and regulations provides the framework for the management of spectrum and establishing spectrum fees. The government stated spectrum policy objectives provide the fundamental basis for the regulator spectrum management programme whilst the principles provide guidance for achieving the objectives through management of the spectrum resource. Regulations derived from and consistent with policy provide the rules to be followed by those involved - the regulator and those authorized to use spectrum. Together, these framework components provide the direction for radiocommunications, wireless applications, services and uses, which range from national defence, security and public safety through to commercial, consumer, scientific and private radio.

For most developing countries the regulator will typically begin with spectrum fees based on simple administrative formulas to recover spectrum management costs and contribute to government revenues and at a later stage once spectrum becomes scarcer should commence processes for introducing spectrum prices reflecting economic value using methods such as AIP, spectrum auctions, and spectrum trading. Figure 7 presents the spectrum policy/spectrum price toolbox.[13]

Figure 7: Spectrum policy/spectrum price toolbox



Source: SBR Juconomiy Consulting AC

Practical considerations

Spectrum fees should not be introduced in cases where potential users are hard to identify individually (for example users of licence exempt spectrum), since the collection of spectrum fees would be uncertain and probably very limited in terms of completeness.

When choosing the parameters to be used as the basis for the spectrum fee calculation, difficult or impossible to verify values to be declared by the users in question (e.g. height of a station antenna or number of mobile stations in a private network) should be avoided. Likewise the regulation should be concerned with reducing the opportunities for data manipulation data in an attempt to reduce the amount payable.

The establishment of a fee system should be based on consultation and where possible consensus among all the players, since this makes for a healthy collection results.

Understanding the market sector: implications

As mentioned earlier, spectrum fees along with taxes, excise taxes and other payments to the regulator and government can have a significant negative impact on sector growth, penetration and use, and

13 Spectrum Pricing – Theoretical Approaches and Practical Implementation, SBR Juoconomy Consulting AC, 2013

investment. The regulator should be wary of significant increasing spectrum fees where they will be passed onto users since this will lower penetration and use. The regulator should develop economic modelling techniques to estimate the impact on users of spectrum resulting in changes in economic conditions, end user prices and spectrum fees.

Understanding the future demand for spectrum: implications

The demand for spectrum should be understood from the perspective of the demand for the service for end users. For example, aeronautical navigation systems may become more intensive users of spectrum, but if people stop flying the urgency of demand will change significantly. In the case of mobile and broadband services, the focus should be on cellular operators who presumably have a keen understanding of end-user demand and are intent on promoting demand for the services they offer.

Spectrum availability and spectrum fees do have a major impact on the demand for spectrum by operators. When spectrum is scarce, alternatives to spectrum use such as fibre back bone and fixed services will be sought after. If spectrum prices are high enough, operators can then make choices involving trade-offs- less spectrum or more radios.

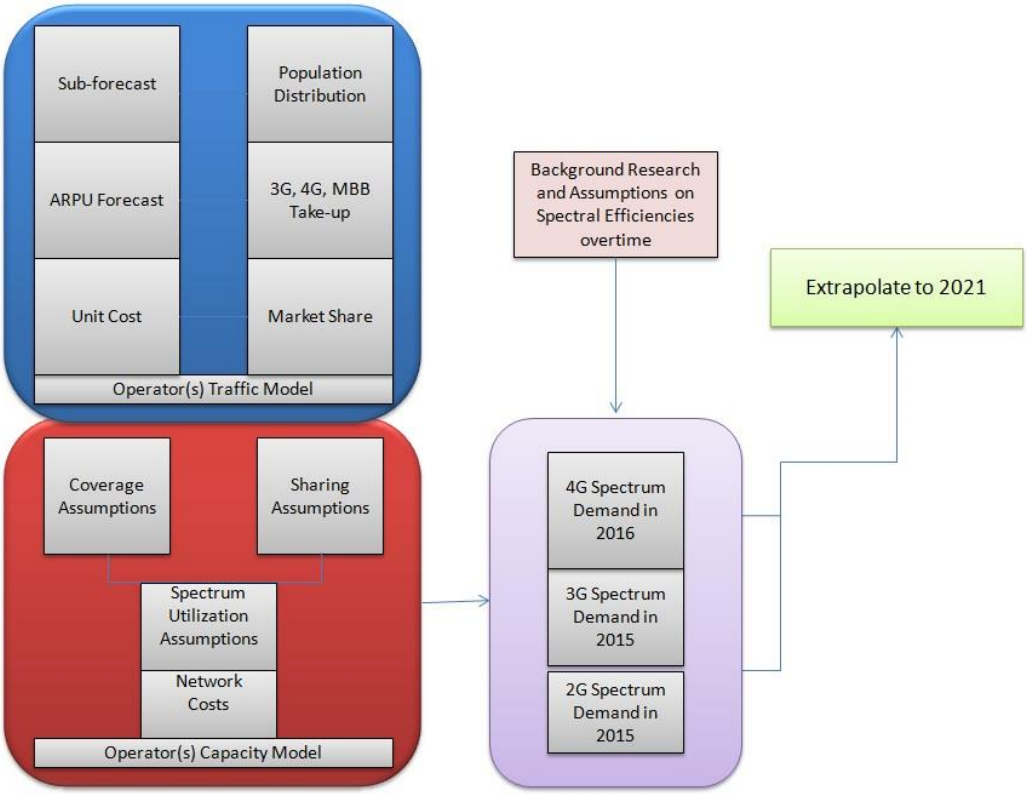
It shall consider also the international framework, in particular band allocations contained in ITU Radio Regulations; they are revised every four years during the world radio conferences (WRCs) every change in band allocation decided by a WRC has huge impact in affected sectors, as it could increase or reduce total amount of available spectrum for a given service.

Specific forecast models are unique to each service taking into account differences in demand in urban and rural areas. One implication of the difference is the possibility of making change to spectrum authorizations and spectrum fees allowing for regional and national license variants. Estimates of spectrum demand also take into account potential future improvements in the spectral efficiency of the technologies supporting the delivery of individual services. Similarly, as technologies become more efficient spectrum fees should allow for variants in price levels.

An operator cost model can be developed. When spectrum prices are high there is little encouragement for intensifying network design and adding new cell sites and base stations. Even so, an operator cost model will demonstrate how at a certain level of spectrum price the appropriate trade-off in opportunity cost can be reached. This is the fundamental assumption underlying administered incentive prices (AIP). Figure 8 illustrates a high level view of the steps taken in developing a forecast model for cellular services.

A spectrum audit can be conducted to examining particular bands used by the public sector in order to understand better the scale of current public sector use, potential alternative uses, the possibility of refarming, and the implicit policy choice of maintaining the status quo. Developing a forecast of cellular service spectrum demand will require a number of steps outlined in Figure 8.

Figure 8: Developing a forecast of spectrum demand for cellular services



Source: ITU

Collecting data and information: Assumptions and data requirements

Benchmarking

The regulator may also carry out benchmarking by drawing inferences from market prices in other jurisdictions for similar spectrum bands. Such prices will usually have been derived from spectrum auctions, but over time might potentially be derived from spectrum trading prices. Benchmarking will typically involve taking into account:

- prices on a 'per MHz per population' basis, adjusted for differences per capita;
- the price relationships across different bands in countries where auctions in higher and lower value bands have occurred;
- differences in licence durations;
- differences in timing of payments; and
- difference in coverage and other associated obligations.

Understanding spectrum management costs

A cost model should be developed and based on a defined structure, relevant business processes and associated management accounting data within the regulator – for example the amount of time spent issuing and enforcing particular authorisations. As well, a method of allocating indirect or common costs will be needed – for example, based on licensees in proportion to the direct costs which they impose. Or they can be allocated in accordance with the amount of spectrum (e.g., in MHz) with which an authorization is associated. In some cases detailed costing models are developed to establish which costs are to be imposed (operating expenses (Opex) and capital expenses (Capex)).

Direct and indirect costs are involved in the spectrum management functions, will likely include:

- ***Direct costs*** are likely to include the immediate and identifiable cost of specific regulatory procedures and events, such as issuing licences pursuant to applications for specific frequencies.[14] This would include the cost of staff time in the frequency assignment process, site clearance, interference analysis required to clear the band, international and regional coordination specific to a spectrum band among other costs. There may be particular monitoring costs associated with a given band for particular reasons, such as legacy overhang from refarming or proliferation of equipment in that band.
- ***Indirect costs*** are likely to include the overhead of operating the regulator spectrum management responsibilities. These will involve costs that are not directly attributable to specific spectrum licenses but are required for spectrum management. Examples of such costs include general international and regional cooperation, spectrum planning, spectrum monitoring, research, preparation of regulations and guidelines, interference investigations, as well as the cost of support staff, equipment and premises.

Preparation of a cost recovery spectrum fees schedule will require the following:

1. ***Internal accounting:*** Internal accounting systems to enable it to estimate direct and indirect costs attributable to spectrum management as opposed to its various other administrative activities. Where possible, attribution of such estimated costs to categories of various spectrum management activities. Such categories might include, for instance, spectrum licensing, spectrum monitoring and enforcement, spectrum policy programmes and projects, international coordination, ICT costs and common costs such as property, human resources and facilities.
2. ***Apportionment of costs:*** Apportioning estimated costs across the various types of spectrum licence, taking into account the relative administrative burdens of effort for different spectrum bands and spectrum uses.
2. ***Application to licence types:*** processes for introducing cost-based fees for spectrum to which the regulator has determined cost-based fees should apply.

Deciding on a method

It is most likely that a regulator will chose from several methods to establish spectrum prices and fees. Before doing so, the regulator should review legislation, policy, and regulation. The level of competition, sector health and the demand and supply of spectrum are additional important considerations. The availability of reliable data, systems, adequately experienced and proficient staff will be necessary. Once the regulator has completed this assessment, the final decision rests with what spectrum management and spectrum pricing objectives are to be met. Table 2 summarizes the advantages and disadvantages of various spectrum price methods.

Preparation, review, consultation

Recalling the spectrum price principles discussed in section 3, the following principles apply to the preparation of spectrum fee schedules and their review and consultation with stakeholders.

- Fairness and objectivity require that fees are based on objective factors and all licence holders in a given frequency band should be treated on an equitable basis. This would preclude, for example, different treatment of different users in a given frequency band.

[14] The administration and management of radio spectrum incorporates four building blocks: allocation planning, technical rules, authorization of spectrum, and interference avoidance. Similarly, ITU recognizes four main spectrum management functions: Spectrum planning, authorization, engineering, and monitoring. See ITU Spectrum Management Handbook, 2007 revised 2015.

Table 2: Advantages and disadvantages of various price methods

Methods	Advantages	Disadvantages
Simple fees	Can be applied to all users of spectrum (public/private). Can be implemented without establishing a fee calculation model and fixing the level of the various fees based on various radiocommunication application. Easy to implement and recovers some or all of the cost of issuing a license.	The fee does not reflect the spectrum management costs of neither the regulator nor the value the user places on the spectrum. Applied alone it does not promote technical or economic efficiency in spectrum utilization.
Spectrum Management Cost Recovery	Spectrum users are assured that they pay only for the costs connected with the spectrum management authority. Taxes collected from the general tax payers are not employed to finance activities of the administration whose beneficiaries are clearly identifiable.	Applied alone it does not promote technical or economic efficiency in spectrum utilization. It can become very complicated process to distribute direct and indirect costs of the spectrum management authority by mean of fee calculation models and tariffs. Due to legal restrictions it may happen that not all activities of the spectrum management authority can be financed with cost recovery fees.
Incentive Factors	Promotes efficient use of spectrum. Recovers some or all of the cost of issuing a license, although it is not the objective of such a fee.	Can require considerable effort to approximate market values. May not be suitable for all services.
Fee based on opportunity cost	Good approximation of the market value of spectrum. Promotes efficient use of spectrum.	Requires a large amount of data and analysis. Only applicable to limited part of spectrum (account is taken only of users and uses competing for a given frequency band).
Fee based on users' gross income	Links the cost of spectrum to the value of the commercial activities that use it. Simple to calculate.	Can only be applied to users whose revenues are directly linked to spectrum utilization. Does not promote spectral efficiency if revenues not proportional to quantity of spectrum used. Can be seen as an extra tax.

- Transparency requires that the basis on which fees are calculated should be made clear in a published document resulting from consultation with stakeholders and that all fees should be set based on a published schedule.
- Administrative costs will be lower if the fee schedule is simple to administer. The simplest fee schedule would be one involving a flat fee payment; however this may not promote efficient spectrum use in many circumstances.

It is very important to ensure that the perspectives of those who use spectrum are taken into account in setting spectrum prices, particularly where market-based methods may be adopted or prices are to be set with a view to establishing incentives to use spectrum efficiently. Accordingly, the regulator should plan to consult with stakeholders and spectrum users at various junctures in the spectrum fee setting process.

7 Examples of administered price method: Spectrum fee schedule

In this section three examples of spectrum fees are described with the first two employing formulas similar to the universal system performance model and the third example illustrating how one regulator set new spectrum fees for spectrum licences now coming due for renewal and previously awarded using administrative means:

1. Lebanon: Telecommunication Regulatory Authority (TRA) draft consultation paper - www.tra.gov.lb/Spectrum-Right-To-Use-Fees – an advanced example of the system performance model with forecasts of spectrum costs and congestion factors.
2. South Africa: Independent Communications Regulator of South Africa (ICASA) – recently revised spectrum fee approach termed administered incentive pricing whereas Administered Prices with Incentives may be a more accurate way to describe the adopted methodology. www.icasa.org.za/LegislationRegulations/EngineeringTechnology/RadioFrequencySpectrumLicensing/SpectrumFees/tabid/357/Default.aspx
3. United Kingdom (Ofcom): Approach in dealing with the now frequent problem of setting new spectrum fees for spectrum licences previously awarded using administrative means and now coming due for renewal. www:stakeholders.ofcom.org.uk/binaries/consultations/annual-licence-fees-further-consultation/statement/statement.pdf

Lebanon: Telecom Regulatory Authority (TRA)

The TRA completed a study of spectrum administrative charges (SAC) and in draft consultation paper proposed changes in regulation to the Minister of Telecommunications. The purpose of this very advanced approach and informative study was to review the spectrum charging regime and ensure that it is non-discriminatory and transparent. SAC were to be applied to spectrum licensees and are intended to recover TRA administrative costs for spectrum management, control, and enforcement. One of the important goals was that fees should not in any way hinder the development of innovative services and competition in the market.

SACs are based on values that are directly proportional to the allocated band, occupancy and congestion. The cost of any band is derived by calculating the effective management and monitoring system cost that is based on the functions and activities that will be performed on such band in order to:

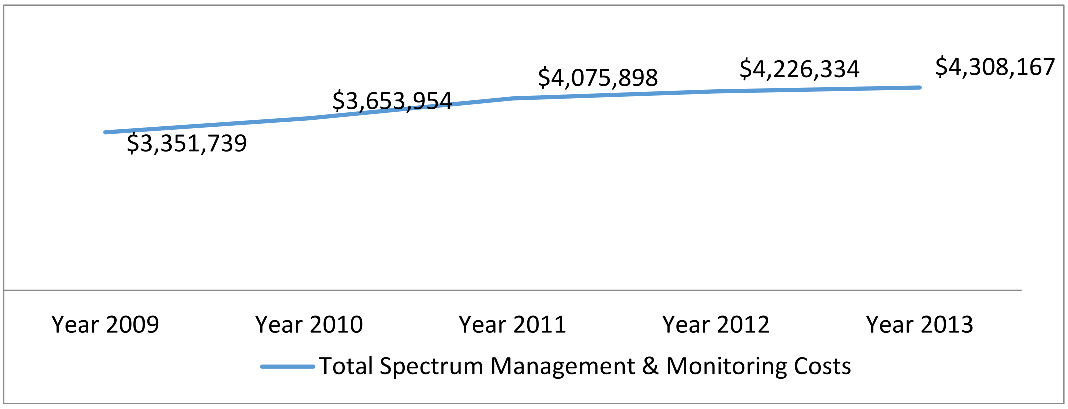
- manage spectrum efficiently;
- optimize spectrum usage;
- protect licensed spectrum;
- avoid harmful interference; and

- detection and location of unauthorized users.

Other parameters were introduced when finalizing SAC charges for each service including: power of transmission, number of sites and cells, and directivity. These variables have a direct impact on the nature and extent of spectrum management and monitoring activities. Hence resources needed to handle such activities and functions are determined accordingly. These factors are used in most countries in different ways to calculate spectrum fees and different methods are applied without any common base relation (different countries studies have different approaches). Furthermore, most of the countries do not differentiate between the right-to-use (RTU) fees and administrative charges.

The fees in a given year and over forecast period are based on the capital and operating costs incurred in managing spectrum. TRA developed a five-year forecast of these costs. Figure 9 illustrates the forecast of spectrum management costs.

Figure 9: Example of a forecast of spectrum management costs



An additional interesting aspect of the work done by TRA is the development of a set of congestion factors that are applied to different ranges of bands and change over time. The concept is straight forward – over time as demand in certain bands increases, the effort and costs required to make new non-interfering assignments increases. Figure 10 illustrates the congestion factor formula which is a multiplier factor and ranges from 0.5 to 4.5 based on the following formula:

Congestion factor = 0.5*EXP^ (2.2*X)

Where x = occupancy of the given frequency band

Figure 10: Calculations for the congestion factor over time

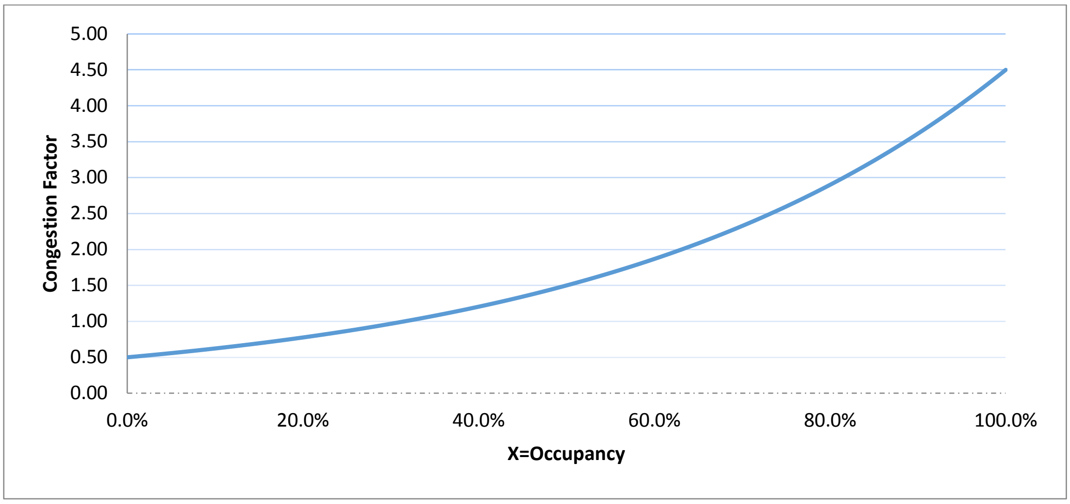


Table 3 shows the derived congestion factors to be applied over time to various bands.

Table 3: Congestion factors by band

	B1	B2	B3	B4
	30 kHz-3 GHz	**3 GHz-6 GHz**	**6 GHz-18 GHz**	**18 GHz-40 GHz**
2009	2.19	1.27	3.82	0.61
2010	2.26	1.29	3.98	0.61
2011	2.33	1.32	4.15	0.61
2012	2.40	1.34	4.33	0.62
2013	2.48	1.37	4.51	0.62

By analysing and consolidating methods used in different countries and using the data available for Lebanon, the general formula was deducted in such a way to serve the regulator approach to apply the proper SAC for each service (such as PMR, PMP, P2P, analogue and digital broadcast) and to reflect efforts required in managing and monitoring each service.

SAC(i)(n) = C(i)(n) × BW × Kp

Where SAC (i) (n) is the cost per band (i) in year (n), Band Width (BW) is the Occupied Bandwidth per service; K_p is a factor or multiple of factors that depend on the requested service. A list of K_p factors appear in Table 4.

Table 4: K_p factors for various services

Service	Kp =
Mobile & DSP (PMP)	Cell Factor (F_{TX})
MVDS (digital transmission)	Power Factor (F_p) x Site Factor (F_{SF})
Broadcast (TV& FM-analogue transmission)	Weight Factor (*Wf*) x Power Factor (F_p)
MW Links (P2P)	Service Factor (F_S) x Direction Factor(F_D)
PMR (n is the number of Fixed Stations, *p* is the number of Mobile Stations; *q* is the number of Portable Handheld Stations	$[\sum_{k=0}^{n}\binom{n}{k}\mathrm{Fp} + \sum_{j=0}^{p}\binom{p}{j}\mathrm{Fp} + \sum_{l=0}^{q}\binom{q}{l}\mathrm{Fp}]$

South Africa: ICASA

ICASA proposed changes to its spectrum fee regulations in 2009 and conducted extensive consultations seeking input from various users and stakeholders throughout 2010 and provided several training sessions on the new fee schedule throughout 2012. The Radio Frequency Spectrum Licence Fee Regulations came into force in 2010 and are described as administrative incentive pricing (AIP) intended to provide for a new basis for calculating radio frequency spectrum licence fees in South Africa. As described in the regulations, AIP involves the use of a specific formula for the calculation of fees for four radiocommunication services:

- point-to-multipoint services;

- point-to-point services;
- satellite hub ground stations;
- satellite VSAT subordinate ground stations.

The policy rationale for these fees is that they should as a minimum serve to recover the administrative cost to ICASA of spectrum regulation and serve to promote greater efficiency the use of spectrum in South Africa. Although references are given to both Ofcom and AIP, upon examination both of the fee formulae incorporated in the new regulations are extensions of the universal system performance model.

Annual spectrum fees are calculated using one of two formulae:

Point-to-point

Fee=(UNIT*BW*FREQ*CG*GEO*SHR**HOPMINI**UNIBI)

Point-to-multi-point

Fee=(UNIT*BW*FREQ*CG*GEO*SHR**ASTER**UNIBI)

Where the fee for point-to-multipoint services equals the spectrum price determined by multiplying the unit price (UNIT) by the frequency factor (FREQ), the bandwidth in MHz, the congestion factor (CG), the geographic factor (GEO), the sharing factor (SHR), the area sterilized factor (ASTER), and the unidirectional factor.

- UNIT= is the unit price for spectrum (currently set at R2000 for paired spectrum)
- BW = is the amount of bandwidth (MHZ) expressed for paired spectrum;
- FREQ = coefficient taking into account the coverage area in km^2;
- CG= coefficient taking into account radiocommunication congestion;
- GEO= coefficient reflecting population density;
- SHR= coefficient taking into account exclusive or shared allocations and assignments;
- ASTER factor= coefficient taking into account the coverage area in km^2;
- UNIBI= coefficient taking into unidirectional or bidirectional signal transmission.

Fees for multi-year authorization can be determined using factors established in regulation. For example, a five year authorization is equal to 4.17 times the price of a one year authorization and a ten year authorization is equal to 6.76 times the price of a one year authorization.

ICASA received documented comments from various groups and operators that expressed concerns in two main areas: (i) lack of sufficient incentives and (ii) excluding certain services and users from paying fees.

Examples of the comments received

Existing spectrum fee structures do not give sufficient incentives to encourage efficient use of spectrum at a time when there is increasing pressure on limited spectrum resources. However, what does come through in the newly proposed formulae is the application of penalties for inefficient use more so than incentives for efficient use. Furthermore, there are no incentives given for employing higher modulation orders, the use of statistical multiplexing, the use of high performance antennas over standard performance antennas, the use of Automatic Transmit Power Control (ATPC), etc., all of which are real costs incurred by some spectrum users in an attempt to increase the bits per MHz and to enable earlier re-use of spectrum.

Under the new fee structure broadcasters continue to be exempt from paying for spectrum. However, broadcasters are like any other licensees who use any part of the spectrum and they should pay for their use of the broadcasting spectrum. In the converged environment, broadcasters will have the opportunity to provide converged services that will compete with ECS licensees.

The view was expressed that an increase in spectrum fees should have a reasonable relationship with the underlying regulatory cost of doing such regulatory work.

The trade-off between licence fees and other considerations must be analysed. All operator revenues are capped by demand factors in the countries where they operate. These factors include demographics such as the size of the potential customer base, per capita GDP and the price elasticity of demand. To the extent that regulators charge high licence fees, this affects the viability of an operator's business case by increasing the costs of supply. If the costs of supply exceed revenues, the viability of an operator business will be doubtful.[15]

United Kingdom: Ofcom

Ofcom notified licensees of 900 and 1800 MHz spectrum that license fees would be brought into line with *full-market value*. Ofcom issued the policy statement in 2010. The term of licences when issued and used for 2G services is "indefinite" with a five year notice period if revocation is to take place. Vodafone UK, Telefónica UK, EE and 3 UK payed a combined total of GBP 24.8 million per year for 900 MHz spectrum and GBP 39.7 million for 1800 MHz spectrum under their existing licences. Extensive consultations began in 2013 in addition to a special project conducted by DotEcon focussing on determining lump sum values akin to auction values. Recent 4G auctions of 900 and 1800 MHz spectrum in other jurisdictions in Europe were brought into the mix along with other benchmarks. Implementation was expected to take place immediately once the consultation period ended. The consultation did however result in some important changes:

- UK regulator Ofcom scaled back plans to increase fees for 2G and 3G spectrum use, a move that was previously described by analysts as a tax of GBP 4.5 billion (EUR 5.6 billion/USD 7.5 billion) on the United Kingdom mobile industry over 20 years.
- The regulator revealed that it has revised its proposal to GBP 109.3 million per year for 900 MHz spectrum and GBP 137.5 million for 1800 MHz spectrum. The previous proposal in January of 2015 had suggested GBP 138.5 million for 900 MHz spectrum and GBP 170.4 million for 1800 MHz spectrum.

Overall, the process was completed by September, 2015 nearly six years later with a proposal being developed over two years by Ofcom and with extensive consultations over a three year period.

[15] Licence Fee Practices: Historical Perspectives and New Trends, ITU Trends in Telecommunication Reform: 2004

Abbreviations

ACMA – Australia Communications and Media Authority

BWA – Broadband Wireless System

GDP – Gross Domestic Product

GHz – Gigahertz

GSM – Global System for Mobile (2G)

ICT – Information Communication Technology

MNO – Mobile Network Operator

NRA – National Regulatory Authority

Ofcom- The Office of Communications- UK

OTT – Over-the-Top (Technologies)

SOE – State owned enterprise

Glossary

Assignment: any authorization to use a frequency at a given site and under identified conditions. Such a frequency is referred to as an *assigned frequency.*

Administered incentive prices (AIP): administered because they are set by the regulator with potential incentive properties. AIP is used by some regulators such as the Office of Communications (Ofcom) in the UK and Australian Communications Media Regulator (ACMA) in Australia to promote efficiency in spectrum use within a framework of administrative spectrum management since AIP's are intended to be set at a level that reflects the scarcity of spectrum and encourages economy in its use.

Economic efficiency*:* relate to the way spectrum is used – employing an efficient allocation of spectrum by both private and public sector organisations to meet the economic growth objectives such as improving national income and the provision of government service.

Spectrum management fees: collected from spectrum users on annual bases that are geared to recover the cost of spectrum management activities of regulator.

Spectrum prices: are representative of spectrum value and can be set through an administrative process such as establishing a fee schedule where those willing to pay accept the price or, alternatively, spectrum prices can be established by way of a market mechanism such as an auction or some form of market-based method such as AIP.

Spectrum usage fees*:* collected from spectrum users as a resource rent and intended to encourage efficient use of assigned frequencies.

Spectrum values: reflect the benefits to be gained by society from the best use for spectrum and at a given point in time period can be influenced by a number of factors including: geography, competition amongst potential users, advances in technology, the present value of cash flows derived from a particular service over time, and the general economic climate.

Technical efficiency: relate to the specific goal of ensuring that frequencies are used efficiently allowing for the maximum utilisation of spectrum by avoiding, for example, interference and unnecessarily large gaps ('guard bands') between adjoining users and by encouraging the deployment and use of more advanced technologies.

Broadband – Traditionally, broadband has often been defined in terms of data transmission speed (i.e., the amount of data that can be transmitted across a network connection in a given period of time, typically one second, also known as the data transfer rate or throughput). Defining broadband in terms of speed has been an important element in understanding broadband, particularly since the data transfer rate determines whether users are able to access basic or more advanced types of content, services and applications over the Internet. Recommendation I.113 of the ITU Standardization Sector, defines broadband as "transmission capacity that is faster than at 1.5 or 2.0" Mbit/s.

Internet of everything (IoT) – is the interconnection of uniquely identifiable embedded computing devices within the existing Internet infrastructure[16]. Typically, IoT is expected to offer advanced connectivity of devices, systems, and services that goes beyond machine-to-machine communications (M2M) and covers a variety of protocols, domains, and applications. The interconnection of these embedded devices (including smart objects), is expected to usher in automation in nearly all fields. Estimates for the number of devices connected to Internet of Everything (Internet of Things) by 2020 range from 20 billion (Gartner) to 30 billion (ABI Research).

Machine-to-machine – The CTIA defines M2M as "applications or mobile units that use wireless networks to communicate with other machines. These applications may include telemetry and

[16] J. Höller, V. Tsiatsis, C. Mulligan, S. Karnouskos, S. Avesand, D. Boyle: From Machine-to-Machine to the Internet of Things: Introduction to a New Age of Intelligence. Elsevier, 2014.

telematic devices, remote monitoring systems (e.g. smart grid, healthcare, transportation, etc.) and other devices that provide status reports to businesses' centers.

Wireless broadband – Similar to the ITU definition, the IEEE 802.16-2004 standard defines broadband to mean instantaneous bandwidths greater than 1 MHz and supporting data rates greater than about 1.5 MBits/s. Wireless broadband involves radio access technologies to provide Broadband speed Internet access or computer networking access over a wide area.

4G – short for fourth generation is the fourth generation of mobile telecommunications technology, succeeding 3G and preceding 5G. A 4G system, in addition to the usual voice and other services of 3G, provides mobile broadband Internet access, for example to laptops with wireless modems, to smartphones, and to other mobile devices. Potential and current applications include amended mobile web access, IP telephony, gaming services, high-definition mobile TV, video conferencing, 3D television, and cloud computing.

5G – 5th generation wireless systems denote the next major phase of mobile telecommunications standards beyond the current 4G / IMT-Advanced standards. 5G does not describe any particular specification in any official document published by any telecommunication standardization body.

The Next Generation Mobile Networks Alliance (NGMNA) has expressed the view that 5G should begin rolling out by 2020 to meet business and consumer demands. In addition to providing simply faster speeds, NGMNA predicts that 5G networks also will need to meet the needs of new use cases, such as the IoT (network equipment in buildings or vehicles for web access) as well as broadcast-like services and lifeline communication in times of natural disaster

Annex 1 – ITU Guidelines for the establishment of a coherent system of radio-frequency usage fees: ITU-D SG

www.itu.int/pub/D-STG-SG02.FEES-1-2010

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