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Spectrum Pricing – Theoretical Approaches and Practical Implementation

SBR-White Paper 4

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1 Introduction

1.1 Deutsch

Die Nachfrage nach Frequenzspektrum steigt unaufhörlich. Vor allem mobiles Breitband und, in weitaus geringeren Ausmaß durch die Einführung von HD-TV, auch Satellitenverbindungen verstärken die Nachfrage. Diese erhöhte Nachfrage weckt bei Regulierungsbehörden Bedenken betreffend der optimalen Bepreisung der knappen Ressource Frequenzen. Weiters beschäftigen sich die Behörden mit der Frage, wie Knappheit in bestimmten Frequenzbändern überwunden werden kann indem man Anreize schafft, die die Nutzung von Frequenzen zu optimieren.

Dieses Weißbuch analysiert die derzeitigen Trends im Bereich der Bepreisung von Funkfrequenzen sowie der damit verbundenen Rahmenbedingungen (z.B. Frequenzhandel und gemeinsame Nutzung von Frequenzen) im Kontext nationaler Frequenzpolitiken. Es basiert auf einem extensiven internationalen Benchmark von 15 Ländern in Europa, Amerika, Afrika, Asien, Australien und im Naher Osten. Folgende Länder sind im Benchmark enthalten: Deutschland, Frankreich, Großbritannien, Schweiz, USA, Kanada, Marokko, Nigeria, Südafrika, Australien, Saudi-Arabien, Bahrain, Oman, vereinigte Arabische Emirate und Jordanien. Das Kapitel 2 untersucht die unterschiedlichen Methoden zur Bepreisung von Funkfrequenzen, die in den jeweiligen Benchmark-Ländern angewendet werden und beschreibt die theoretischen Konzepte um das Ziel einer effizienten Nutzung der Frequenzressourcen zu erreichen. Wir verwenden den Begriff „Tool-Box“ um diese unterschiedlichen Methoden zu umfassen, welche die einzelnen Regulierungsbehörden verwenden um ihre Frequenzpolitik umzusetzen. Kapitel 3 wirft ein Licht auf die internationale Umsetzung dieser theoretischen Konzepte sowie der einzelnen Politiken und Rahmenbedingungen. Dieses Kapitel enthält auch einen Überblick darüber, wie die jeweiligen Preismethoden hinsichtlich der drei essentiellen Diensteklassen (Breitband, Festnetz, Mobilnetz, Satellit und Forschungsdienste) in den einzelnen Benchmark-Ländern angewendet werden. In Kapitel 4 werden die Schlussfolgerungen der Analyse dargestellt.

1.2 English

The demand for radio spectrum is steadily increasing. Primarily mobile broadband and to a lesser degree due to HDTV in some continents also satellite communications are driving demand. This raises concerns of regulatory authorities about the optimal pricing mechanisms for spectrum usage. Further, authorities question how scarcity in a frequency

band can be overcome by the creation of incentives to foster optimal use of radio frequencies.

This white paper characterizes the current trends in radio frequency pricing and associated framework conditions (i.e. trading and sharing) in the context of national radio spectrum policies. It is based on an extensive international benchmark of 15 countries in Europe, the Americas, Africa, Asia, Australia, and the Middle East. Countries included in the research are Germany, France, UK, Switzerland, United States of America, Canada, Morocco, Nigeria, South Africa, Australia, Saudi Arabia, Bahrain, Oman, United Arab Emirates, and Jordan.

Chapter 2 examines the charging methodologies for radio frequencies, which are currently used and outlines the theoretical concepts to achieve the efficient use of spectrum resources. We call these methodologies the "toolbox" from which regulatory authorities may choose the appropriate tools to support their policy. Chapter 3 sheds light on the international implementation of these concepts, including the policies and framework conditions. Further, chapter 3 provides an overview on how pricing methodologies are applied in the benchmark countries with regard to five essential service classes (broadcast, fixed, mobile, satellite, and scientific services). In chapter 4 we derive conclusions from the analysis.

This white paper is published in SBR's series of white papers. It invites to debate and opens up for discussions amongst interested stakeholders. SBR regularly publishes white papers in German or English language on its homepage (www.sbr-net.com) on current national or international topics in regulated network industries with respect to technical, economic, legal, and regulatory issues.

2 Spectrum Pricing – the Toolbox

Pricing of spectrum is an important aspect of spectrum management. There are various strategies for setting the appropriate fees for spectrum users. Common practices are:

(i) to derive the license fees from the associated costs of spectrum management,
(ii) to consider license fees as a contribution to the national budget, or
(iii) to apply market mechanisms like incentive pricing or auctions.

An optimal pricing mechanism shall support the spectrum policy goals. These goals are national matter and are examined in chapter 3.1. Efficient use of spectrum is generally regarded as high priority but public and social benefits are also important policy goals.

General framework conditions, e.g. spectrum sharing and spectrum trading, are described in chapter 2.1. In addition to these general framework conditions, in chapter 2.2 different pricing methodologies are outlined. We use the term "toolbox" to describe the pricing methodologies and the framework conditions. This toolbox is embedded in the national spectrum policy. The whole ecosystem is shown in Figure 1below:

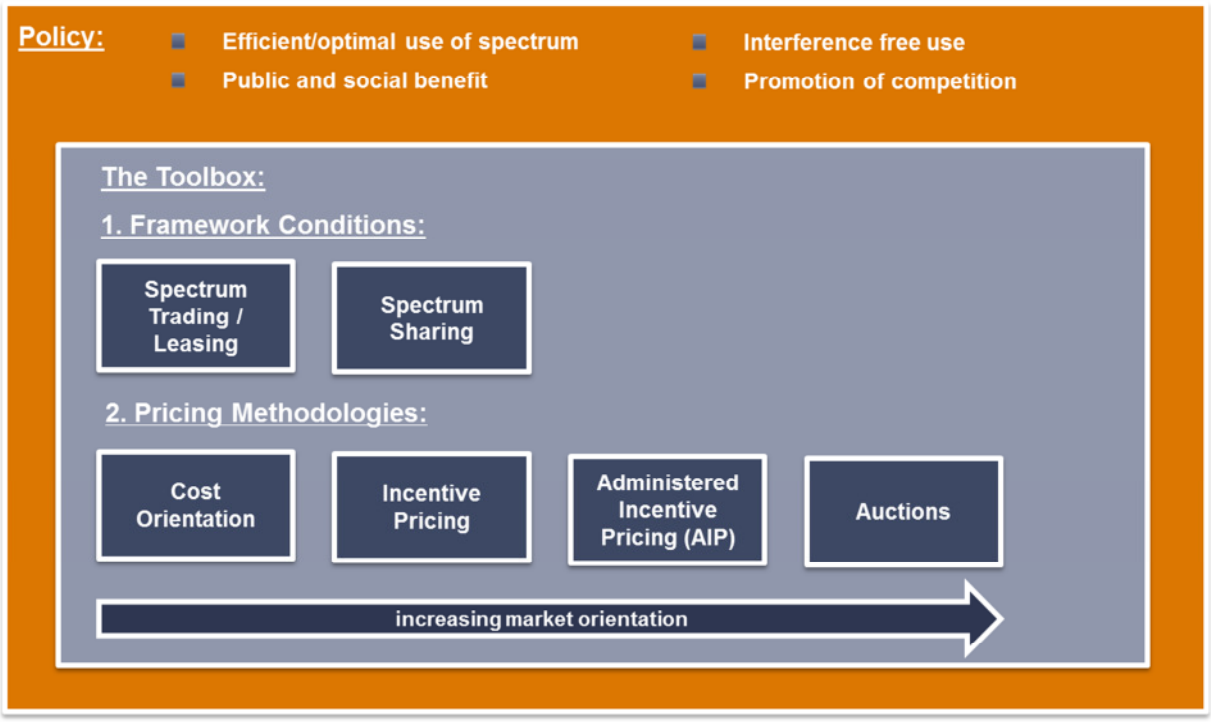

Figure 1: Toolbox (pricing methodologies, framework conditions) and policy in context

The policy is usually laid down in the legislation. The challenge for authorities responsible for spectrum management is to choose the right instruments from the toolbox to optimally

support the given policy goals. In this white paper we examine the current practice of applying these toolbox elements. [1]

2.1 Framework Conditions for Spectrum Usage

International bodies allocate spectrum for different purposes like fixed, mobile or satellite communications. National authorities assign frequencies to specific stakeholders. In addition to the applied pricing methodology, the actual price of spectrum also depends on the usage conditions, including usage rights.

The administration usually specifies a framework which separately determines the management of usage rights for each frequency band. In case of exclusive assignment of spectrum to one licensee, there is the possibility for the administration to allow for trading or sharing, leaving the option to the licensee whether to partly or fully transfer usage rights to a secondary user, or to use it on its own.

These usage conditions have considerable impact on the economic value of spectrum. Regardless of the actual pricing method, the willingness to pay by different users may alter considerably, e.g. when trading is allowed.

In this chapter we focus on current aspects of spectrum trading and spectrum sharing (white space and license exempt use). Other aspects of the framework like determination of scarcity in a frequency band, the impact of international standardization and the treatment of military and public use of spectrum are not the focus of this paper – but may also significantly influence the price of a certain frequency.

2.1.1 Spectrum Trading / Leasing

Trading allows spectrum users to trade their exclusively assigned usage rights in the market. Thereby, a secondary market for spectrum is created. The flexibility of this approach allows the strengthening of market forces in order to enable an efficient allocation of the available spectrum. Provided competitive market for usage rights exist, i.e. transparent offers and a sufficient degree of demand for spectrum, a transfer of rights towards the secondary users, who would benefit most from additional transmission capacities, can be expected to ensue.[2] However, it must be ensured that spectrum is not

[1] For an overview on spectrum management see: Cave M., Doyle C., Webb W. (2007).
[2] Cave et al. (2007)

acquired for strategic purposes only, e.g. to keep market entrants away from essential resources (“hoarding”). Thus, competition aspects have to be looked at closely.

Spectrum leasing has been introduced in the United States and recently in the UK. Leasing has the potential to further improve the secondary market for spectrum and is encouraged by the European Union.

2.1.2 Spectrum Sharing

Spectrum sharing is a tool which might remedy the outcome of inefficient usage. It has been demonstrated that in many cases, most of the allocated spectrum is unused most of the time in most of the locations.[3] Although sharing spectrum by using different frequencies and using different locations is quite well developed, sharing in time provides an opportunity but is still technically challenging.

Usually, usage rights are assigned exclusively to stakeholders. This allows authorities to secure interference free use but it is an inflexible process, which leads to inefficient use of spectrum. Other forms of usage rights, which involve sharing of access, are emerging. [4] Spectrum sharing is a broad term that encompasses many aspects. Sharing allows to reuse spectrum in three dimensions: frequency, time and location. Spectrum is e.g. shared by users in cellular systems. Frequency reuse is an example of spatial spectrum sharing.

- The coexistence of several service providers in the same licensed frequency band can be allowed (also called "lite licensing"). In this case, the co-ordination of access has to be handled by the radio systems.
- It is also possible to define a primary system, having the highest priority for accessing the resource, coexisting with a lower-priority secondary system that can access the spectrum only by complying with the primary's requirements. This is known as white space or dynamic spectrum management.
- A further possibility is the allocation of specific chunks of spectrum for license exempt access, in which case all systems have the same right to access the band without implied spectrum ownership. A successful example of license exempt bands are the ISM (Industrial, scientific Medical) bands (e.g. 2.4 GHz used for WLAN). Also in this case the coordination is performed by the radio systems themselves.

A recent study for the German Federal Ministry of Economics and Technology[5] promotes that spectrum usage should not be analyzed only in a static sense (as defined by service

[3] FCC (2002) and Valenta (2010)
[4] See Wyglinski, Alexander M. et al (2010)
[5] Technical University of Braunschweig (2013)

and allocation) but also dynamically. Research and development should focus on co-operative and co-primary usage of spectrum. Although sharing of usage rights has the potential to alleviate scarcity, it is still technically challenging. According to Rysavy Research (2012) *"(t)he spectrum sharing implementation timeline is going to be long and involved. Other than sharing on a geographic basis, there is no sharing technology "magic bullet" already developed or even in the pipeline to adequately address short-term spectrum-shortage challenges."*

One way is to allow for secondary use of assigned spectrum in case it is not used. Technology advances enable the temporary use of spectrum for secondary purposes without impacting the licensee, e.g. when the primary usage is idle. For example, in UK and the United States, such approach is being followed for unused terrestrial TV spectrum, which can be accessed by so called White Space Devices (WSD)[6]. WSDs detect the usage by the primary service and become active on that frequency only in case and as long as the frequencies are not used by that service. For the primary services, this implies a certain risk that WSDs do not de-allocate frequencies sufficiently fast, in case capacities are needed.

Other examples for spectrum sharing in license exempt bands are Wireless LAN according to IEEE Standard 802.11 and Bluetooth which led to innovation and a flourishing market in appliances. Interference coordination is managed by the end user or by the devices themselves, respectively. License exempt spectrum use is usually restricted to low power transmission equipment and hence it qualifies for short range transmission applications.

While spectrum trading is contributing to market oriented pricing, the impact of spectrum sharing methods on pricing is more ambiguous. A price plays an important role in spectrum sharing since it indicates the value of spectrum supply and cost of spectrum sharing. The cost of spectrum sharing can be higher than the value of the spectrum as the competition among the secondary users for spectrum usage to maximize their utilities might be too low and the opportunity costs for sharing of the spectrum too high.

[6] OFCOM (2012) and FCC (2010)

2.2 Pricing Methodologies

The four main generic pricing methodologies for radio spectrum are cost orientation, incentive pricing, administered incentive pricing, and auctions. These are described below.

2.2.1 Cost Orientation

The main purpose of spectrum pricing based on cost orientation is to recover the costs caused by the administrations in charge of radio spectrum management. Two specific goals are linked to this method:

- The national budget shall not subsidize spectrum management and therefore total spectrum fees shall cover the costs of administering this national resource.
- The licensees shall not be overcharged with respect to the related costs.

For the purpose of cost recovery the fees for radio frequency licenses are set according to the costs associated with the management and administration of all related processes. This may involve the cost of several administrative bodies, i.e., ministries and agencies, when the administration is shared between multiple entities. The related processes are, amongst others, application and assignment of frequencies, handling, site preparation, national and international co-ordination, as well as interference management. Such an approach in theory guarantees that license fees are appropriate, justifiable, and transparent.

In practice, the exact implementation, definition, and operation of cost recovery may vary according to national policy. RSPG (2009-a) notes that charges can be based on the costs of the related administrative work performed directly or indirectly for individual licenses or the average for a license category. Indirect costs shall be allocated in addition, but this may be a very complicated and expensive process. Thus, creating several license categories for calculating average charges can therefore be a cost effective approximation.

As a consequence different license fees are determined for different processes. The related fees may be recovered directly or indirectly and may differ according to license categories. Thus, even cost oriented pricing leaves considerable room for varying prices and preferential treatment of specific frequency categories.

2.2.2 Incentive Pricing

Incentive pricing aims at promoting particular aspects of a regulatory policy.[7] In the context of spectrum pricing, incentive pricing is mainly related to extract the rent arising from the (public or private) use of a scarce common good.[8] In pure incentive formulas one of the overall goals is to promote (technical) efficiency and other socio-economic policy goals. Therefore, most commonly a mixture of parameters addressing technical aspects[9] and others reflecting the economic value of spectrum (e.g. spectrum may be more valuable in densely populated areas) is applied.

Typically there are the following main objectives behind incentive fees:

- Extraction of a rent arising from the public or private use of a scarce common good.
- Fostering and ensuring efficient use of spectrum.
- Incentive fee formulas consist of relatively few and easily measurable elements. The fee is deemed to be an indirect approximation of the market value. The fee tries to impact spectrum users in the following ways:
    - Preventing users from stockpiling spectrum that they do not really need,
    - Encouraging users to utilize spectrum in an optimal way,
    - Providing incentives to move to alternative (less congested) frequency bands (i.e. improve allocation efficiency), and
    - Encouraging users to move to more spectrally efficient equipment.

Care has to be taken that fees are set to sound values as both too low and too high incentive fees would reduce efficiency. If fees are too low, the incentive to use spectrum efficiently is weak and inefficient use might result in a shortage of spectrum for additional users. If fees are set too high, spectrum may remain unused and will provide no benefits to society at all.

The list below shows parameters typically used for the calculation of incentive fees. It builds on the comprehensive international survey provided by the authors as well as on the findings of a recent ITU report[10] and a comprehensive survey on European countries provided by RSPG[11]:

- Amount of spectrum (bandwidth)

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7 Campell D. (2008)
8 Marelli M. (2007)
9 E.g. higher microwave frequencies incur a lower charge because more bandwidth is available and these bands are less crowded although the reuse distances are smaller.
10 ITU (2010)
11 RSPG (2009-b)

- Geographic area (also known as area sterilized)
- Type of frequency band (modeled by a band factor)
- Population covered/population density
- Level of exclusivity
- Technology
- Number of terminals
- Financial coefficient

Incentive fees are often used to prevent congestion of frequency bands. Ad hoc changes have been made over time as demand for certain frequency bands increases and so a higher fee as under pure cost recovery conditions is justified. Often there is one basic financial coefficient that may be used to adjust the relative level of the respective fees.

2.2.3 Administered Incentive Pricing (AIP)

Economic theory suggests that spectrum fees shall be set at their monetary value, especially for spectrum that brings commercial benefits to the licensees.[12] The application of opportunity cost principles for deriving spectrum fees is termed "administered incentive pricing" and intends to promote efficient use of radio spectrum.

Opportunity cost shall be set at the value of an asset or resource in the next best alternative that is foregone by virtue of its actual use.

> *"The opportunity cost fee is a calculated value that tries to simulate the market value of the spectrum. It is directly targeting the final goal of value based fee systems: what amount an alternative user would pay. The calculation of opportunity cost requires complicated financial analysis, estimation of demand etc. The opportunity cost fee can be seen as a more sophisticated method to calculate incentive fee."*[13]

The UK is a forerunner in using administered incentive pricing. The policy of UK regulator OFCOM is to base administered incentive pricing on the actual market value of spectrum. AIP has been introduced in the UK for most services gradually since the beginning of 2000. Until now, only very few other countries are using opportunity pricing principles for specific services (e.g. Australia).

It is generally recommended that AIP and incentive fees on top of cost based fees should only be introduced if there is excess demand, i.e. competition for access or at least the

[12] Ure J. (2008)
[13] Doyle C. (2006)

risk of scarcity in the foreseeable future, or to create awareness that spectrum is scarce and incentives to return (excess) spectrum (e.g. government use, broadcast).[14]

On the other hand, a basic point is that cost covering fees and prices set primarily based on economic efficiency coincide when there is excess supply.[15]

The main drawback of AIP is that the calculation of opportunity cost values for certain frequency bands is extremely challenging. In practice, the calculation ends up with a wide range of estimates.[16] When looking at practical applications of the method[17], this is not surprising: A multitude of scenarios, decisions, and economic as well as technical parameter estimates, e.g. related to prices for alternative infrastructure and services, have to be made in an increasingly dynamic environment. Thus, despite the effort and costs associated with a thorough economic approach necessary in applying the opportunity cost method, the burden of determining the optimal level of fees is often put upon the administrations' shoulders.

2.2.4 Auctions

Although the opportunity cost method also relies on estimating market prices, only auctions are considered as full market approach for determining the economic value of spectrum.[18]

Auctions, being a sale of property to the highest bidder, are commonly used for commodities, government bonds or for sales on internet platforms such as eBay, etc.[19] But even here, a wide range of results can be obtained at the same place and time for the same good only by changes in auction design.[20] With regard to auctioning radio spectrum, the problem is that the decision of the administration, in this case on auction design (and other regulatory conditions related to the auction), may strongly influence the resulting price level.[21]

There is another interesting aspect with respect to spectrum valuation in auctions. As known from financial markets, the value of companies expressed as value of shares at the stock exchange is not only based on facts such as current turnover and profit margins but

[14] Wellenius B. (2008)
[15] Marelli M. (2007)
[16] Doyle C. (2010)
[17] Plum (2009)
[18] Krishna V. (2002)
[19] McMillan J. (1995)
[20] Wolfstetter (2001)
[21] Cramton P. (2002), and Cramton P. (2012)

is strongly influenced by the expectations of investors related to future potential and performance of that company. The same is also true for market value of spectrum resulting from auctions. When UMTS spectrum was first auctioned a few years after the liberalization of telecommunications in Europe in 1998, expectations were skyrocketing, leading to spectacularly high results in the first UMTS auctions in the year 2000 in the UK and in Germany. But as likewise known from financial markets: "the higher the expectations ("bubbles") the more dynamically they may be subject to change". In general, a change of expectations and increasing uncertainty may lead to significantly different auction prices for the same spectrum at distinct points in time not far apart. This is impressively illustrated by the timeline of European UMTS auctions results (in EUR per inhabitant) presented in the table below (see columns "When" and "€/Pop"):

Where?	When?	# Bidders	# Licenses	# Incumbents	€/Pop
UK	March/April 2000	13	5	4	630
Netherlands	July 2000	9/6	5	5	170
Germany	July/Aug. 2000	12/7	4-6	4	615
Italy	Oct. 2000	8/6	5	4	210
Austria	Oct. 2000	6	4-6	4	103
Switzerland	Nov./Dec. 2000	10/4	4	3	19

Table 1: UMTS Auctions in Europe in the Year 2000[22]

Market dynamics as observed in UMTS auctions determine the methods applied for spectrum pricing. There hardly seems to be a way for Administered Incentive Pricing to timely cope with these market dynamics (as this would imply very short cycles of opportunity costs re-evaluations).

If spectrum is auctioned, secondary trading could be an appropriate tool to cope with market dynamics. Nevertheless competition issues have to be considered in this case. As of today, practical experience with spectrum trading is limited (see chapter 2.1 and 3.2). It has to be noted, that the approach of trading depends to a large extent on the usage of the frequency band. While mobile data shows high market dynamics and thus higher demand patters for secondary trading, other frequency bands like those for fixed services are more stable with less market dynamics.

[22] Wolfstetter (2001)

3 Current Spectrum Pricing – Practical Implementation

This chapter covers the practical implementation of spectrum pricing in several benchmark countries. The evaluation is based on an extensive research on the spectrum policy and pricing documents issued by the responsible authorities in the benchmark countries and provides a broad picture of the current pricing regimes and the accompanying frameworks.

3.1 National Radio Spectrum Policies

The policy applied by the different states governs the usage and pricing of spectrum. The policy is supplemented by the legal basis for spectrum pricing and applied methodologies. It is worthwhile to examine the spectrum pricing policies of the benchmark countries, since the pricing methodologies and framework conditions are instruments to achieve the policy goals.

Policy approaches for spectrum pricing show a significant variety. In most countries the optimal utilization and efficient usage of spectrum has been defined as the primary goal. Nevertheless, other aspects, such as economic and social benefits, competition or public interest, are considered.

We have identified six major methodological approaches to spectrum pricing: cost orientation, incentive pricing, AIP, auctions, trading/leasing und spectrum sharing. These approaches are mapped against the goals defined in national policies:

The general trends are:

- The efficient/optimal use of the spectrum is one of the major goals to be fulfilled. Public or social benefits are also prime policy goals.
- From the three methodologies cost recovery, incentive pricing, opportunity costs (AIP) most countries employ one or two of these methodologies, while a few apply all three approaches (Bahrain and Australia). With the exception of three countries, cost recovery is applied in all countries as one of the methodological principles. Incentive pricing is employed in 10 countries whereas opportunity cost approaches are only to be found in 4 countries.
- The application of auctions is handled quite differently. It was found that auctions are not used in the legislation in at least three countries. Additionally, it needs to be mentioned that even countries where auctions are a basic form of a methodological approach to spectrum management and spectrum pricing, not all countries that foresee auctions in their legislation also have deployed it in practice.
- License exempt regulations can be found in all but two from the researched international benchmark countries.

- Spectrum trading is a less developed methodology. It can be found especially in Western countries (Europe, United States, and Australia) in the legislation. Spectrum trading in the Arab countries is implemented in Bahrain and Jordan. Nevertheless, it seems that spectrum trading is not a common tool in practice.

The following table summarizes our findings regarding the policy approach:

Country	Main policy approach	Methodologies					
		Cost recovery	Incentive pricing	Opportunity costs (AIP)	Spectrum Sharing	Auctions	Trading
Saudi Arabia	optimum utilization of spectrum; competition and innovative services	●	●	-	●	●	-
Bahrain	efficient use, promotion of competition	●	●	●	●	●	●
Oman	optimal use	●	●	-	●	●	-
United Arab Emirates	efficient and proper use	●	●	-	●	●	-
Jordan	effective and efficient management of radio spectrum	-	●	-	-	●	●
Morocco	network deployment, optimal an effective use, non-discrimination	●	●	-	-	-	-
Nigeria	efficient use, competition	●	-	-	●	●	-
South Africa	efficient and effective use, transparency	●	-	●	●	●	-
Germany	optimal and efficient use	●	●	-	●	●	●
France	promotion of competition, development and employment	-	●	-	●	●	●
United Kingdom	optimal use	●	-	●	●	●	●
Switzerland	efficient and interference free use, balance the requirements of commercial and non-commercial users	●	●	-	●	●	-
Canada	maximize economic and social benefits	●	-	-	●	●	●
USA	public interest	●	-	-	●	●	●
Australia	public benefit	●	●	●	●	●	●

Table 2: Policy goals and application of the toolbox in the benchmark countries

An international comparison of the respective fees for spectrum has to be undertaken with care as the general policy approach of a country may heavily influence the pricing.

Regarding the way fees are calculated, there is no clear international methodology and no harmonized approach (e.g. formulas), although it can be stated that the international trend

is to price spectrum according to the amount of bandwidth used – the more spectrum is used the more a user has to pay.

The application of the framework conditions (trading and sharing) is analyzed in chapter 3.2. The application of the pricing methodologies (cost orientation, incentive pricing, AIP, and auctions) in different service classes is analyzed in chapter 3.3.

3.2 Application of Framework Conditions

In many of the researched countries, methodologies applied for calculating spectrum fees are complemented by framework conditions, such as spectrum trading or sharing.

3.2.1 Spectrum Trading / Leasing

The valuation of the beneficial effects, especially with respect to spectrum trading, however, is ambiguous: In the US, the argument is made that incentive pricing is not required because auctions and secondary markets suffice to determine market prices. In contrast to that, in the UK it has been argued that trading alone may not be sufficient to promote efficient use in certain spectrum markets and thus AIP might be an option, as it is seen as a helpful complement to market based transfer mechanisms for usage rights.

In fact, the example of UK shows that if there is no single spectrum market but rather a set of separate markets across the various frequency bands, trading volumes in individual markets may prove insufficient to attract those intermediaries that would enable markets to operate more efficiently. Due to the different technical usability of the different frequency ranges the development of different markets is enabled which is further promoted when licenses are issued for a large number of small geographic areas. Such an approach has been followed by Australia where licenses for small areas define the smallest tradable unit. In France, the Ministry of Industry (by order) defines a list of bands which are foreseen to become part of the so-called “secondary market”. Currently, these bands include those assigned to the wireless local loop, some bands of commercial mobile networks, fixed microwave links, and some for fixed and mobile satellite links.

Instead of purchasing and selling licenses for the use of frequencies, leasing is an upcoming option which has already been introduced in the US and UK but is also planned to be introduced in several European countries. With regard to the execution of control functions relating to the compliance with license obligations by the user, two options are possible: Either the initial licensee (lessor) remains responsible towards the license

granting authority and is therefore in charge of control functions, or the lessee becomes itself responsible towards the authority, after obtaining the approval by the latter (USA).

In the international context, however, spectrum trading is a less developed practice. It has been found in some Western countries (Europe, America, Australia), and only to a lesser degree elsewhere. The concept of spectrum trading in the legal framework of Arab benchmark countries has only been found in Jordan and Bahrain.

Summing up, a trend can be observed that spectrum trading, and therefore market based approaches to transfer spectrum usage rights, is gaining importance. New features such as spectrum leasing are being introduced in order to create additional flexibility in the markets. However, market based mechanisms alone may not always be sufficient in order to reach that purpose. The highly scattered nature of the spectrum market may require these measures to be complemented by an appropriate pricing regime.

3.2.2 Spectrum Sharing

Spectrum sharing between a primary user and secondary users is an emerging feature in some countries but only the US and the UK engage in measures which focus on the application secondary spectrum usage by enabling the use of white space devices (see chapter 2.1) in regionally or/and temporarily unused digital terrestrial TV bands.

License exempt use is a common feature for the ISM band and low power devices.

3.3 Application of Pricing Methodologies per Service Class

Spectrum pricing encompasses the whole spectrum range. In the national pricing regimes services are grouped into service classes.[23] The pricing depends on the service class.

Below, we examine in detail which of the pricing tools are used for in the different service classes. Furthermore, we examine the comparability of the different pricing schemes.

3.3.1 Broadcast

With respect to broadcasting, research shows that a number of countries do not request any fee for broadcasting spectrum at all. Thus, they follow an approach that is supporting the distribution of media information at lowest cost for the social benefit. For those

[23] The services are defined by the ITU-R in the radio regulations (ITU-R 2012). A distinction between broadcast, fixed, mobile, satellite and scientific service has been derived from the research and found useful for classification.

countries which have spectrum fees for broadcasting some charge per station and some charge per TV channel (thus: spectrum). The comparability between prices in case they are charged per station and per channel needs further assumptions about the network layout and therefore there seems to be no direct way to compare the different pricing approaches.

In general prices for spectrum allocated to broadcasting are considerably lower in comparison to other commercial services (e.g. mobile or fixed services). If charges are applied at all these are usually calculated to recover cost of regulation only. This holds also true for the UK where a discussion started that AIP should be introduced for broadcasting services too and that broadcasters have been able to receive a rent from too low prices for broadcasting frequencies.

In most countries, the social benefits or public interests aspects of media and information can be seen as primary leading indicator for pricing of frequencies for broadcasting services. Although this aspect is only rarely mentioned in the policy goals for spectrum pricing of the countries – but may be included in other legislation.

3.3.2 Fixed Services

Countries use a large number of different factors and parameters in their pricing formulas for fixed services. It seems that the higher the demand for a certain (fixed) service is the higher the prices are. This is reflected by a so called band factor that allows to weigh the prices for different frequency bands. The international comparison shows e.g. for point-to-point microwave services that these are generally priced with a considerable incentive. For frequencies with low demand, cost orientation is often applied. Only a few countries apply cost based pricing for all fixed frequencies (e.g. Switzerland and USA) and only UK is using AIP pricing.

3.3.3 Mobile Services

The spectrum demand for mobile telephony and recently mobile data services has risen dramatically in the last two decades. A basic distinction has to be made between private and public mobile services. Research results show that for public mobile services incentive pricing combined with auctions is the preferred method to allocate spectrum.

Pricing methods differ with regard to technologies used. We found different approaches for 2G/3G and 4G services:

- Initially spectrum for 2G - GSM was allocated to the incumbent carrier without formal bids. Subsequent licenses and extensions of spectrum were typically awarded by using auctions. It was found that utilization fees for GSM are best compared when these values are related to the population of the respective country. The benchmark shows that the average values countries charge for utilization of 1 MHz GSM spectrum per inhabitant is about 0.84 Euro Cent.
- 3G - UMTS has been introduced at the beginning of this millennium. Usually auctions were used and UK and Germany achieved the highest income from these auctions. The utilization fees have to be regarded together with the initial spectrum allocation process. In countries, that did not use auctions to award UMTS frequencies, the utilization fee is slightly higher than for GSM.
- The third major air interface technology is 4G - LTE. Recently spectrum in the digital dividend was auctioned and will be used for LTE technology which has a higher spectral efficiency. The trend is, however, to award spectrum technologically neutral and leave it to the licensee to apply to optimal technology. Therefore it can be expected that the spectrum prices will be aligned between different mobile technologies.

In order to address the increasing demand for mobile broadband new spectrum needs to be found. The digitization of broadcasting provided an opportunity to vacate spectrum for allocation to mobile services (i.e. the digital dividend). Some countries have already allocated spectrum in the 800 MHz band (e.g. Germany). Initiatives to allocate a second part of the digital dividend in the 700 MHz band have already been started by the ITU World Radio conference (WRC) in 2012 and it could happen that auctions will be used to allocate this spectrum to mobile services as well. The FCC intends to use a new form of auction called incentive auction which also provides incentives for broadcasting companies to vacate spectrum.

Due to the international globalization trend and increased transport volume, the demand for private mobile services (PMR) increases over time. This is also reflected in the rising incentives included in the pricing schemes of the benchmark countries.

3.3.4 Satellite Services

Satellite services are used for various purposes. Services like radio determination, space operation, and earth exploration require a limited amount of bandwidth and are generally priced with flat fees in the benchmark countries. In general it is not made transparent, whether these fees reflect costs only or also include an incentive fee. We assume that an incentive fee is included, which reflects the value of the service.

For satellite earth station hubs the fee depends generally on the amount of bandwidth used. The utilization fee per MHz varies and is about 4,000 Euro/year in the benchmark countries. Some countries charge a much lower fee, which seems to cover costs only.

3.3.5 Scientific Services

There is variety of scientific services, where spectrum demand is predictable and rather low. These are maritime and aeronautical services, radio astronomy, and similar. These services are generally priced at cost, although this is not made transparent in the pricing regulations.

3.3.6 Summary of pricing trends per service class

The figure below shows the international trend in the degree of pricing methodologies applied in the different service classes. Mobile services are the "hot spot", followed by fixed and satellite services. There are some variations found in the benchmark countries. However as countries develop their pricing regarding the usage of spectrum we expect pricing trends to develop as shown in Figure 2 below.

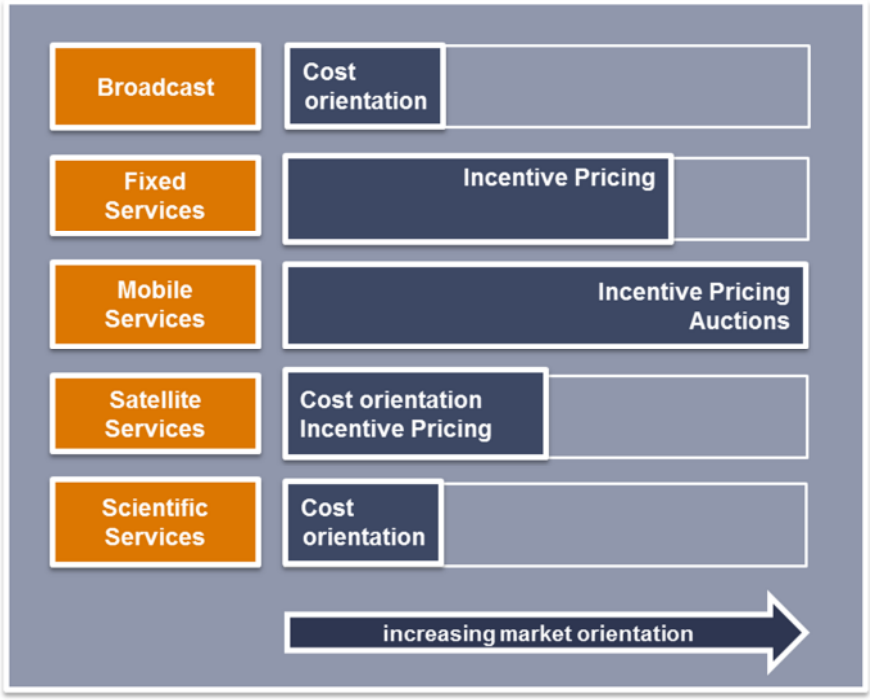

Figure 2: Pricing methodology dependent on the service class

The reasoning for our evaluation is given below.

- As long as broadcast is mainly public, spectrum fees are rather low or non-existent. As the market opens and private broadcasting is allowed we expect a move towards cost orientation. Incentive pricing does not seem appropriate unless there is access demand. However, the high social value of broadcasting seems to indicate that cost oriented pricing is the most appropriate approach.
- For fixed services the demand depends on the frequency band. Lower frequencies are more sought after since the propagation characteristics are superior. We deem inventive pricing as the appropriate approach for fixed

services. Since the reuse factor for fixed services is rather high, excess demand that justifies more market oriented methodologies seem not to be required.

- The demand for mobile services is currently very high. Pure market oriented measures like high incentives and auctions seem appropriate.
- Satellite services are mainly used for broadcast services. Digitization of transmission allows a more efficient use of spectrum. However, demand is increasing. We deem a mixture between cost orientation and incentive pricing as appropriate, depending on the demand situation.
- For scientific services demand is rather low and predictable. Cost orientation seems to be the appropriate methodology.

4 Lessons Learnt and Conclusions

This white paper is based on an extensive research of spectrum pricing in America, Europe, Africa, and the Middle East. We have found that advanced theoretical concepts like AIP, trading and sharing are not widely implemented. Although most countries state in their policy the goal of efficient use of spectrum there is no clear indication which of the tools best supports this goal. Theoretical concepts like AIP and auctions are based on the fact that spectrum is or will be scarce. This might be the case for some countries and some applications, but there are many instances where scarcity is not foreseeable. Most countries simply apply a combination of cost recovery and incentive pricing. Such approach is easier to handle. Changes in spectrum pricing do occur carefully and slowly in order not to disrupt the market.

Based on the foregoing analysis, the theoretical approaches to spectrum regulation can be compared with reality and policy. The following key findings have been identified:

1) **A dynamic view on scarcity**
   It may be common sense to assume that spectrum is generally a scarce resource and therefore allocation and pricing mechanisms should focus on scarcity. However, this is not necessarily the case. In several frequency bands spectrum cannot be considered as scarce. Thus, a dynamic analyses should be conducted which takes into consideration that spectrum availability may depend on technologies, usage purposes, the geographic location, etc. and may change over time. This implies that the actual degree of scarcity might be even lower than reported on the basis of static analyses and thus there may exist a larger degree of flexibility for spectrum policy design.

2) **AIP is the exception, not the rule**
   Although administrative incentive pricing (AIP) is highly regarded for its theoretical qualities, it is the exception in practice. Opportunity cost approaches are only found in a very limited number of countries and thus cannot be assumed to be a trend in international comparison. In practice we usually find a mixed approach containing elements of cost recovery and incentive pricing.

3) **Pricing is determined by national or regional characteristics**
   Pricing of spectrum is to a high degree determined by national and regional characteristics. The factors which influence spectrum pricing can be manifold and countries apply them very differently. To mention a few factors that may be relevant for a spectrum pricing: bandwidth, frequency range, area covered, antenna height, power, exclusivity, technology, congestion, and population density. It seems that many countries regard a regional benchmark as the most important guideline for pricing of spectrum.

4) **Compare with care**
The application of completely different pricing methodologies in the respective countries combined with the local conditions with respect to supply and demand for spectrum require to regard results of spectrum price comparisons with care.

5) **Service classification is not harmonized**
The spectrum range encompasses a large differentiation of different technologies and services. Thereby, not all countries apply the same classification for services. There is no internationally completely and fully accepted service classification.

6) **Mobile broadband is "the hot topic"**
A very clear trend is that mobile broadband is a dominant aspect in discussions about spectrum allocation. The reason for this is that broadband in general is regarded as a highly sensitive issue and the most important service. By using mobile broadband many countries are able to leapfrog certain fixed technologies in order to bring broadband to the customers as quickly as possible via mobile solutions.

7) **Public use of spectrum is often license exempt**
A general experience that can be found is that certain usages (most prominently for public as well as for military use) are often exempted from licensing as well as from pricing.

8) **The transparency of pricing regimes is limited**
In many cases it is not made clear whether the utilization fee is cost based only or includes an incentive fee. A detailed cost analysis of the authorities' work is also not made transparent by most administrations and might not be unambiguous. The US, UK, and Switzerland are an exception.

9) **Spectrum trading and sharing is not yet widely applied**
Besides license exempt, spectrum trading, and thus market based approaches, are applied predominantly in western countries. New methodologies, such as spectrum sharing and leasing, shall theoretically create additional flexibility in the markets and help to reduce scarcity. Nevertheless, such measures can rarely be found and are rather academic in the application.

10) **Policy goals are imperfectly translated into pricing methodologies**
Although many countries have stated policy goals in their regulations these policy goals cannot be seen as directly implemented in the pricing regime. Only very few countries (UK, US, Switzerland) that apply a mere cost based approach reflect the policy directly in the pricing regime.

SBR wishes to highlight that spectrum pricing is an important aspect of regulation for the forthcoming years. The demand for spectrum will continue to increase and the various stakeholders will remain highly interested to get access to valuable spectrum to support their business goals. For stakeholders as well as for regulators, the definition of the right

pricing scheme to value the spectrum and to create fair conditions for competition remains an important task which requires regular analysis and review to integrate new international and technical developments.

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Bahrain: Telecommunications Regulatory Authority, http://www.tra.org.bh

Canada: Canadian Radio-television and Telecommunications Commission, http://www.crtc.gc.ca

France: Autorité de régulation des communications électroniques et des postes, http://www.arcep.fr

Germany: Bundesnetzagentur, http://www.bundesnetzagentur.de

Jordan: Telecommunications Regulatory Commission, http://trc.gov.jo

Morocco: Agence Nationale de Réglementation des Télécommunications (ANRT), http://anrt.net.ma

Nigeria: Nigerian Communications Commission, http://www.ncc.gov.ng

Oman: Telecommunications Regulatory Authority, http://www.tra.gov.om

Saudi Arabia: Communications and Information Technology Commission, http://www.citc.gov.sa

South Africa: Independent Communications Authority of South Africa, https://www.icasa.org.za/

Switzerland: Federal office for communications (OFCOM/BAKOM), http://www.bakom.admin.ch

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