Chapter 11

Managing the Radio Spectrum in the New Environment

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1.0 Introduction

1.1 A New Policy Environment

Government's role in controlling the national economy is visibly changing. During most of the 20th century, the *distribution* of welfare across society and – somewhat later – the *stabilisation* of the national economy (e.g., by maximising employment or by controlling inflation and balance of payments) tended to overshadow the classical financial function of government, namely, *allocation* of limited public resources. Over the last two decades, however, this balance appears to be changing back towards classical economic thinking. This neo-classical trend is seen by some observers as a conservative tendency in Western politics. Be that as it may, the increasing demand, even in the economically most developed countries, for further expenditure on better services and new public activities has forced all governments to give priority to the issue of optimum allocation. Which tasks can government do better than the private sector, and how should it find the necessary means to execute such tasks?

In telecom, the present policy trend of privatisation of national public operators (PTOs) clearly illustrates the ongoing reappraisal of the allocative function by governments. Typical questions asked are now: (a) Is there still a need to allocate public financial assets to PTOs? (b) Is the state better able to operate in the communications service sector than – appropriately regulated – private firms, given the necessity to introduce increasingly capital-intensive information and communication technologies?

A similar development of this nature is the changing view upon the allocation of scarce radio frequencies, until recently considered both a public asset and a matter for decision-making by government experts. But in granting the Nobel Prize in Economic Science to Ronald Coase in 1991, the Royal Swedish Academy of Sciences cited his "pioneering ... study of how property rights are distributed among individuals by law, contract, and regulations, showing that this determines how economic decisions are made and whether they will succeed." Notably, one of Coase's research subjects some 30 years earlier had been the concept of spectrum rights, transferable and valuable on a market(Coase 1959). In the early 1960s, Coase developed this concept further in joint (largely unpublished) studies with economists and policy analysts of the RAND Corporation. Still, it was not until the early 1990s that such thoughts attracted more

widespread interest outside the USA. Thus, the OECD put the "Economics of Frequency Allocation" on the agenda of its Committee for Information, Computer and Communications Policy; in April 1992, the author had the privilege of chairing the first meeting on that subject at OECD (OECD 1992). Within the last few years, several countries have decided to auction wireless network licences and/or to create markets in spectrum rights; a much larger number of countries have introduced administrative licence fees related to various national notions of the operational value or efficiency of frequency usage.

1.2 Transition Cases: Related to Geography and Culture?

This chapter cannot attempt to survey the rapidly emerging new practices and problems in spectrum management. Suffice it here to say that the Federal Communication Commission (FCC) in the USA has, since 1994, managed to transfer several billion USD annually to the federal government by auctioning licences to operate wireless networks for Personal Communications Services (PCS) (Bykowsky et al, 1995) and Direct Broadcasting Satellites (DBS). In fact, the auctioning methods used and the number of licenses awarded by the FCC in the USA now develop so fast that they are better followed on the *World Wide Web* (http://www.fcc.gov). Some other countries such as New Zealand (Fountain 1978) and Australia, with a common-law tradition and few significant border problems of radio interference to or from neighbouring countries, also created more market-driven instruments for spectrum allocation in the last few years.

In the European Union, on the other hand, given its land-locked character and the firm legal codes of continental Europe, only a pair of countries have yet developed any experience or even plans in the area of dynamic market valuation of frequency bands. In Belgium, the successful bid of the winning contender for the second GSM-mobile licence was used retroactively to determine a market value of the GSM licence previously granted to the incumbent PTO, Belgacom, under its general telecom licence. In compliance with European Common Market principles of fair competition, Belgacom was subsequently forced to pay the "shadow" price to the Belgian government in 1996.

The Netherlands government intends to auction the national licence(s) for the European PCS-system, DCS1800, from 1997 on. In this case, the auction value determined in the 1800-MHz band will serve as the shadow price to be paid by both the two competing Dutch operators of GSM and the analogue mobile operator, all three with frequencies assigned in the (lower) 900 MHz band several years earlier. This approach raises the important issue of how to determine fair and equitable shadow prices for the right to use of *different* radio technologies and frequencies for competing in *similar* markets. Opponents of auctions have argued that the Dutch approach is clear evidence of the arbitrariness of market mechanisms. The rebuttal by proponents of auctions is that simultaneous bidding for all Dutch wireless licences (not only one of them) would have avoided any problems of market distortion. In that event, all bidders would have been offered the possibility to value their own use of alternative technologies and frequencies on the same market. Clearly, this discussion can be broadened to the more general universal-service objectives of connecting telephone subscribers with minimum individual network costs to them. If compliance with such public objectives is financed by a Universal Service Fund, this could be financed, in part, from the revenues of spectrum auctions.

This chapter gives only a summary discussion of the thoughts behind the many ongoing policy reviews of instruments for spectrum allocation and valuation. Section 2 sketches the mounting critique of the – still prevailing – purely administrative international and national approaches to allocation and assignment of frequencies to users. Section 3 goes on to consider options for new spectrum management policies suitable for repairing the obvious economical paradox of present spectrum use, i.e., access to the spectrum is gratis, even where user demand greatly exceeds frequency supply! Section 4 contains some, necessarily tentative, conclusions on the very dynamic field of radio communications policy and regulatory procedures.

2.0 Frequency Management: The Classical View

2.1 The General Framework.

Classical frequency management is carried out by expert bodies, *allocating* spectrum resources to classes of users such as broadcasters, telecom operators, and the armed forces. Propagation of radio waves is governed only by Maxwell's laws of electromagnetics and by physical and environmental boundary conditions (local topography; meteorological conditions), and not by national boundaries and laws. So the (inter-)national interests have to be laid down under the auspices of the International Telecommunication Union (ITU), in terms of agreements on

- technical and operational criteria for (sufficiently) interference-free shared usage of frequencies
- tables of the frequency bands entrusted to certain (groups of) nations and users on given conditions
- an international frequency register of frequencies already assigned or in actual use.

Generally, broad international agreement in technical and administrative ITU-fora precedes and delimits all domestic procedures for *assigning* the limited national frequency resources to each individual actual users. The notion of a 'trust' of frequencies, to be managed equitably by a benevolent, highly specialised technical authority in accordance with [its] best perception of the public interest, prevails in most member states of the ITU. National access to the shared international trust of frequencies is periodically reviewed and updated at Regional and World Radio Conferences (RRC, WRC) of national representatives. These national 'trustees' mandate the subsequent domestic assignment and actual use of individual frequencies, in accordance with their treaty obligations as accepted at the international Radio Conferences.

2.2 National Spectrum Policy

The administrative procedures adopted by most national trustees have resulted in *first come, first served* assignments of frequencies to users in most ITU member states. This approach is now becoming exposed to a number of criticisms:

- Technological innovation constantly enables more efficient use of spectrum at less cost, and generally advances considerably faster than the – necessarily bureaucratic – procedures for international consultation and agreement about the national frequency tables.

- Limiting access of newcomers to frequencies may hinder competitive development and marketing of the many new, economically interesting wireless communication systems and services, such as cellular mobile radio, PCS and satellite services, which are in increasing demand in many nations and/or for international use.

- The present erosion of monopolistic rights to specialised PTOs and public broadcast networks reduces the acceptance of non-transparent or anti-competitive *first come, first served* frequency rules and regulations. Increasingly, these become exposed to annulment in litigation procedures lodged by new market entrants.

- Improved East-West relations cause claims that a 'peace dividend' could be reaped from release of some of the ample frequency bands frozen for military contingencies.

- Some government treasuries have discovered that rights of access to the radio spectrum may have sufficient commercial value to collect substantial public revenues, either to fund special projects in the telecom sector or simply as a general tax measure.

Discussion of some of these developments began during the last two decades, initially in academic circles (see, e.g., the references in Melody 1980), and was broadened in the early 1990s because of the visible trend towards technological convergence between broadcast and telecom networks governed by very dissimilar regulations. Nevertheless, most national policies are still concerned with the following three general classes of rights to spectrum usage,

- user rights, often granted to minor private users of a few frequencies, e.g. for taxi dispatch and other local business, or for Citizens' Band radio,

- management rights, e.g. those granted to major national users of entire frequency bands, such as telecom operators, government agencies or national TV broadcast networks,

- marketable rights, i.e., the right to buy, use and/or sell access to certain frequency bands.

To date, such rights are mostly granted using purely administrative and technical procedures, based on the ITU Radio Regulations. This approach tacitly implies that the administrative national frequency authority (the 'trustee') is fairer and better informed about user needs and technological progress than any private or corporate interested party, such as commercial operators, radio equipment manufacturers, or users of wireless services. In accordance with this classical view, a public authority is entitled to prescribe spectrum fees (if applicable), the technical standards and all other licence requirements deemed relevant for quality, coverage, content, etc., of the service offering. Moreover, most national authorities will monitor the actual use of the frequencies granted, in order to ascertain that all licence obligations imposed continue to be duly fulfilled.

The historical roots for this classical approach may be found in the infancy of radio techniques. Around World War I, use of radio frequencies was associated with a few important services that could not be provided through the private market, such as tactical communications in military battlefields and maritime emergency and navigation

services. (No one shipowner wished to finance the latter services, since once provided, they could also be used by all other shipowners at no cost.) The only practical way of rendering such risky wireless services was by collective action; hence they were considered a *public good,* including the necessary vital radio frequencies.

A different, but related economic concept is that of a *merit good.* Public policy deems it necessary to provide certain goods at an attractive cost to the public, with the purpose of encouraging their general consumption. A familiar example of a merit good is the publicly funded broadcast service in many countries, which is offered for cultural, educational and other national reasons. The subtle distinction between a merit good and a public good should be carefully noted. From an economic perspective, public broadcasting is *only* a public good to the extent that commercial operators would prove incapable of sustaining a similar service – an empirical test seldom accepted by public policy!

With the classical 'trustee' model rooted in these historical foundations of public and/or merit goods, pricing of wireless services has borne little, if any relationship to the scarcity of spectrum. This fact has engendered the so-called *spectrum paradox:* even if user demand greatly exceeds spectrum supply, no price has to be paid for access. Such an economic anomaly is a standard recipe for inefficient use of scarce resources; it raises the issue of how to create more effective and fairer procedures for (sharing) access to the limited spectrum by incumbent operators and new entrants. Ideally, such procedures should discourage inefficient occupation of spectrum by contingency (military) users, outdated (analogue) wireless technologies, or applications with satisfactory wired alternatives (cable television); they should also leave sufficient room for vital public/merit-good wireless services, as defined by public policy. In the following Section, various mechanisms for assigning a price for spectrum (use) are discussed.

3.0 New Spectrum Policies and Issues: An Agenda for Research

3.1 Determining the Transaction Costs of Present Administrative Procedures

By 1992, a common trend of charging administrative fees for spectrum use to recover the various costs of national frequency management and control had emerged in all but one OECD member state. However, a simple and reasonable way of deriving or even comparing the various user charges and, more generally, the underlying cost principles for spectrum management in different countries cannot be established. Should an international index be based on, e.g., the population density, the level of economic activity, the presence of adjacent or other neighbouring states, the legal tradition (e.g., common law or codified law) or a suitable combination of these and any other relevant factors for the activity of the frequency authorities in a given country?

More fundamentally, what will be the future role of public administration in frequency management? As a minimum, international agreements about frequency allocation and mutual co-ordination to avoid harmful interference have to negotiated and agreed by sovereign states in an ITU context. On the national level, some governments still hold a strong belief in the duties and capabilities of a benevolent spectrum authority. On the other hand, some national regulators are prepared to admit that they, by definition, are bound to be less well informed about the operational needs than the service providers. Hence, these regulators wish to play a more facilitating role, for instance in future

commercial negotiations about the fairest and most efficient (shared) use of the spectrum, especially where market mechanisms and competition are allowed: “A parent might try to cut the cake as equitably as possible, but the children will always try to choose the pieces they value most”.

3.2 Valuation of the Radio Spectrum

The analogy with real estate is useful for arguing how access to spectrum might be given an identifiable value on the market. Just like land, radio spectrum is only really useable in connected bands. Different bands have different physical characteristics which may permit or preclude certain applications. The value might therefore be better determined by a – technically and commercially informed – interested user on a free market, than by historical or administrative considerations by a disinterested public servant. Obviously, such a valuation of the radio spectrum by market demand would not preclude frequency planning as part of overall public policy, just like the zoning restrictions imposed in regional and urban planning, especially in the most crowded areas. Little-used spectrum, on the other hand, would bear more resemblance to the ‘commons’, the shared vacuum of property rights known in pre-industrialised societies.

Still, this suggestive analogy between the right(s) to own, use and trade frequency assignments on the one hand, and real estate on the other, is the subject of much discussion. For instance, it can be argued that the rights and borders of real estate are much better defined in property law and land registers, than the purely fictitious, administrative contours of transmitter coverage and interference areas. The latter are determined by the randomly fluctuating propagation conditions for the radio waves influenced, e.g., by weather conditions or sun spots. Therefore, the international co-ordination procedures must necessarily allow a measure of inadvertent ‘property trespassing’ (i.e. harmful interference inflicted on adjacent users of the same frequency bands), especially during extreme (unlikely) propagation conditions. It is questionable whether a civil court, even if formally competent within its (national) jurisdiction would be willing to judge on conflicting rights in such intangible and circumstantial, but economically important circumstances as the occasional harmful interference between licensed wireless operators. With this in mind, it is often held that interference *mitigation* as a technical remedy is preferable to interference *litigation* as a judicial remedy, and that associating permanent property rights with frequency assignments would sacrifice the immense proven flexibility and speed of technological progress in radio communications.

Assuming that spectrum valuation could indeed be done by the market, two economic anomalies arising from the limited spectrum must be noted. One anomaly is known as the *differential rent*, which affects a new spectrum entrant more than an incumbent user of frequencies. The latter’s costs have already been ‘sunk’, probably in a cheaper technology operating in a lower frequency band than available to the new entrant, whose higher investment need may form an effective barrier to market entry. Whether the differential rent should be collected by government or enjoyed as an extra profit by the incumbent, is a matter of public policy. This problem is indeed well-known in the real-estate market, where the availability of old or regulated apartments at low rents may hamper new building projects and create arbitrary social imbalances between different generations of tenants.

The other market anomaly, the *scarcity rent*, arises if the dearth of spectrum is such that the prices for use of wireless facilities or services can be raised greatly above the operational costs of a provider. The regulatory problem here appears to be whether abuse of the provider's privileged position, e.g. by reaping monopoly profits, can best be prevented by price regulation, fair-trading rules, or technological innovation to improve spectrum efficiencies.

The mere existence of such dynamic market issues and the ensuing regulatory attempts to resolve them may result in new or modified government policies from time to time. Such policy changes could be ground for grievance of commercial operators who have acquired spectrum rights at a time where it was impossible to predict the government's conduct in such circumstances. Generally, the private sector will emphasise the need for long-term planning stability, especially for equipment manufacturers and operators of public infrastructure, as a strict condition for accepting market valuation of spectrum. This particularly applies if a government plans to introduce auctions for radio licences. How could the present value of a future licence be assessed and a realistic bid made if taxation, price regulation, trade relations and/or industrial policy would be allowed to change significantly during the licence period? This question is seen by many as the strongest reason not to adopt/accept auctions, at least not without sufficient financial involvement or even guarantees from the government.

One reason for determining a realistic spectrum value and invoking a corresponding suitable operator charge for user rights would be the possibility to relocate an operator's service from one band of the spectrum to another band (or perhaps even to cable or optical transmission), if this would be more economically efficient. The financing of public – perhaps even international – infrastructure funds from such spectrum revenues could subsidise the costly replacement of wireless equipment held by incumbent operators, who have no other incentive to cooperate towards a more efficient overall use of the spectrum resources. This semi-public approach is strongly resisted by the more radical proponents of market mechanisms, who would prefer commercial negotiations between parties interested in or holding certain rights to spectrum use.

Another argument in favour of levying sufficiently effective charges (in excess of a mere administrative spectrum fee) is the stronger incentive to non-active holders of spectrum rights to vacate any historical assignments of small practical value to them. This mechanism is similar to raising the parking fees in city centres, resulting in more slots for car owners who value them more.

4.0 Conclusion: The Special Nature of a Spectrum Market

In microeconomic theory, a *perfect* market consists of many suppliers/producers and many users of certain goods. In principle, the market turnover is determined as the equilibrium between choices made by the users of their preferred mix of goods produced, with the offerings of the producers choosing the cheapest mix of inputs for their products. Can the radio spectrum be allocated to services and/or assigned to users, simply by being considered as an input to the economic production of services?

As discussed in Section 2.2 above, market failures will occur for *public goods.* When certain vital wireless services fall in this category, such as emergency communications, governments may need to reserve sufficient spectrum to meet the corresponding contingency demand. Traditional spectrum monitoring by a competent

authority may be invoked to give a reasonable guarantee of efficient use of resources that would have a substantial alternative value on a 'free' market. Alternatively, they may grant the extra funds to the provider of such (public-good type) wireless services, to ensure that this provider is able to procure the necessary frequency rights in straight competition with others. The funding should be sufficient to guarantee service, but should also provide incentives to use scarce spectrum efficiently, for instance by allowing the provider to buy innovative radio equipment or to lease his frequencies for commercial use when not required for the vital public services. Similar funding approaches may be useful to facilitate efficient wireless distribution of merit goods like public broadcasting.

On the other hand, for a commercial communication service offered on a more or less 'free' market, candidate providers may choose different technology mixes, including wireless options, to offer a service with a certain quality on the market. Also, consumers of services may select different wireless or wired options with a given level of satisfaction (such as data transport capacity, coverage area, service time and quality of service (bit error rate)). The assumption of classical market theory is that both providers and users would always choose the particular mix with lowest cost to them; the equilibrium state would represent the maximum utility to all parties on the (communication) market.

Consider now the simple production function for wireless capacity given by Shannon's formula for the maximum error-free transport capacity on a communications link

$$I = B \log (1 + S/N) \text{ bit/s},$$

where B, the available bandwidth (in hertz) and S, the received power (in watts), represent the production variables available to a service provider wishing to offer the capacity I to a *user* on a certain receiver on a desired market location. Note that for any required capacity, signal power can be traded for bandwidth; mixing these two inputs thus allows an operator many different systems solutions. The optimum depends on the relative costs to the operator of power and bandwidth. Note, however, the additional impact of the variable N, the noise level (in watts), on each particular receiver location. In practical terms, that noise level is determined by three contributions, namely

1. natural noise, e.g. environmental atmospherics, and internal receiver noise,
2. man-made noise, e.g. due to imperfect electrical equipment of other applications,
3. the interference from other (authorised) users of the same part of the radio spectrum.

Note that 1. and 2. can be reduced by the service provider by a suitable choice of technology and frequency band, albeit at certain costs. Again, such costs can be factored into his choice of design option and service offering. However, 3. represents a *negative* externality from other service providers, who may (or may not) choose to operate in the same market.

So far, this negative externality has provided the most convincing arguments for public management of frequencies, and against the use of market mechanisms. Clearly, a radio spectrum market is not merely a meeting place between pairs of producers and consumers of wireless services. It requires a substantial measure of control of potentially harmful disturbances of the producer-consumer relation from the links between any other

producers and consumers operating in the same (or an adjacent) frequency band and geographical area.

The key policy issue in the ongoing debate about spectrum allocation methods is how such mutually harmful relations can best be minimised: by recourse to classical administrative processes derived from principles and practices of international and national public law, or by private negotiations and dealings between interested/interfering parties, subject to suitable government regulation overview. To a certain extent, this is a political choice, determined by one's faith in optimum resource allocation by due process of expert government bodies.

However, as noted in the introduction, this balance is now clearly shifting towards more widespread use of economic criteria for access to frequencies. While some of the reasons for this may well be ideological, it should be borne in mind that technological progress has delivered new network options with strong incentives (see Arnbak, this volume) to more efficient joint use of the frequency spectrum, for instance by cellular mobile radio and digital audio broadcasting (DAB). Such modern wireless systems are standardised and designed to 'internalise' the negative externalities of radio interference between many users into one collective system; this allows system optimisation by a commercial system operator. In short, more effective overall frequency use can be made a private interest by entrusting resource-limited collective systems to commercial parties.

The challenge of future spectrum management will be to re-align, from time to time, the fluid borderline between those wireless applications which will continue to require traditional interventions in the public interest, and the – rapidly growing – number of wireless applications where public policy objectives may be satisfied by transferring the spectrum rights and the significant negative externalities to a single commercial operator.