Cambridge University Press
978-0-521-87669-8 - Essentials of Modern Spectrum Management
Martin Cave, Chris Doyle and William Webb
Excerpt
More information

1 Emerging problems with the current spectrum management approach

1 Current spectrum management methods and their shortcomings

1.1 Why spectrum needs to be managed

A large and growing part of the world's output relies upon use of spectrum.[1] Frequencies are used both commercially, notably for mobile communications and broadcasting, and by public sector bodies to support national defence, aviation, the emergency services and so on. As demand grows spectrum needs to be managed to avoid the interference between different users becoming excessive. If users transmit at the same time, on the same frequency and sufficiently close to each other they will typically cause interference that might render both of their systems unusable. In some cases, "sufficiently close" might be tens or hundreds of miles apart. Even if users transmit on neighbouring frequencies, they can still interfere since with practical transmitters signals transmitted on one channel "leak" into adjacent channels, and with practical receivers signals in adjacent channels cannot be completely removed from the wanted signal. The key purpose of spectrum management is to maximise the value that society gains from the radio spectrum by allowing as many efficient users as possible while ensuring that the interference between different users remains manageable.

To fulfil this role, the spectrum manager provides each user with the right to transmit on a particular frequency over a particular area, typically in the form of a licence. Clearly, the spectrum manager must

[1] Spectrum is a term to describe a band of electro-magnetic frequencies. It is often used to refer to the radio spectrum, which extends from approximately 10 kHz to 300 GHz. This band is then subdivided with different parts being used for different applications. A licence will typically give a user the right to access or transmit on part of this spectrum, e.g. 800 MHz–820 MHz.

ensure that the licences that they distribute do not lead to excessive interference. In practice, this can be a highly challenging task.

This book is about how best the spectrum manager can accomplish this task, and in particular how the use of market mechanisms can assist them.

1.2 The current management mechanisms

Historically, the approach adopted by spectrum managers around the world to managing the radio spectrum has been highly prescriptive. Regulators often decide on both the use of a particular band and in some cases which users are allowed to transmit in the band.[2] Keeping a tight regulatory control over the use of the spectrum makes it easier for the regulator to ensure that excessive interference does not occur because the regulator is able to carefully model the interaction between neighbouring services and tailor the licence conditions appropriately. It also allows for other regulatory goals to be achieved – for example, ensuring that a service is available on a pan-European basis, or imposing coverage requirements to achieve ubiquity of services. Finally, it can result in high technical efficiency of spectrum use – that is to say in packing a large number of users into the spectrum. This is because like services in neighbouring bands tend to interfere less than unlike services and so can be allocated more closely together. If the regulator collects together like services and places them adjacent to each other it can increase the capacity of the spectrum (although maximising the capacity, or technical efficiency, is not always the same as maximising the benefits that society can gain from the spectrum, or economic efficiency, since the spectrum can be completely used but by a low value application).

As well as licensing users, the spectrum manager typically exempts other users from licensing. These exempted users are often assigned a band of spectrum sometimes known as unlicensed spectrum, or spectrum

[2] In the spectrum world, deciding the use of a band is called “allocation”; deciding which organisation can use it is called “assignment”.

commons. The decision to exempt users is made on the basis that they will not interfere significantly with each other if they use the spectrum in an uncoordinated manner. In practice, this is likely only if they transmit at a relatively low power level such that the distance over which they can cause interference is small and hence the probability of there being another user within this small "coverage" area is low. Typical services that are exempt include cordless phones and wireless LANs such as WiFi. It is up to the regulator to decide which equipment to exempt, what the rules for its operation should be, how much spectrum should be set aside for its operation and where in the frequency band this should be.

The current spectrum allocation process operates at both a national and international level. International coordination is essential in some cases because the zones of possible interference extend beyond national geographical boundaries and in other cases because users are inherently international, e.g. aviation. Broadly, international bodies tend to set out high level guidance which national bodies adhere to in setting more detailed policy.

At the highest level of management sits the International Telecommunication Union (ITU), a specialised agency of the United Nations. The ITU's International Radio Regulations allocate the spectrum from 9 kHz to over 275 GHz to a range of different uses. In some cases these are quite prescriptive, e.g. "satellite". In other cases they allow substantial variation, e.g. "fixed or mobile". The Radio Regulations also set out how countries should coordinate with each other and in the case of global services, such as satellite, provides a mechanism for the assignment of rights to individual users. The ITU conducts the key parts of its business through World Radio Conferences which are typically held every three to four years. These are events attended by thousands of delegates from spectrum managers and users around the globe where potential changes to the Radio Regulations are considered. In some cases the ITU may seek international spectrum allocations for particular uses, for example in previous years it has allocated spectrum to global low Earth orbit satellite systems (of which Iridium is an example) and in its 2007 conference is intending to discuss whether there should be a global allocation for 4G cellular systems. Nothing in the Radio Regulations can constrain each country's freedom to manage spectrum as it wishes, as long as the impact on other countries is minimal and it is willing to accept the risk of interference.

In some countries, there are multi-national bodies coordinating across a region. For example, this is very much the case within Europe where the European Union (EU) and the Confederation of European Post and Telecommunication Agencies (CEPT) provide further harmonisation. Broadly, these bodies can be seen as local versions of the ITU, providing further coordination. Often their coordination is more specific, for example rather than simply designating a band as "mobile", they might designate it to a specific standard such as "GSM". Different bodies have differing levels of power. For the CEPT their decisions, like those of the ITU, are non-binding but if a country deviates from them it is expected not to cause interference to its neighbours as a result. However, the EU has legal powers and is able to require national spectrum managers under its jurisdiction to enact decisions. For example, EU Law requires national regulators in all member states to set aside spectrum in particular bands for GSM, although there is currently much discussion as to whether this decision should be repealed.

1.3 Shortcomings of the current system

The current approach "works" in so much as it licenses spectrum to particular users and ensures that excessive interference is avoided. This allows a range of uses of the spectrum in a stable and predictable environment. However, it is unlikely that it achieves the full objective of a spectrum manager of maximising the economic value derived from the spectrum. To do this, the regulator would need to make sure that spectrum was appropriately divided up between all the different possible uses and users in a way which maximised benefits to end users of spectrum using services.[3] Since it is almost impossible to predict the

[3] These services can be either commercial ones, purchased by firms and households, or public services such as national defence which governments "provide" on behalf of their citizens.

value that each different service provides under any given spectrum allocation it is difficult to see how a "command-and-control" approach to managing the radio spectrum could maximise value. However, it is possible that an extremely astute regulator might distribute spectrum in a manner that approaches this objective, at least in some bands.

In times where supply of spectrum exceeded demand, or where there were a relatively small number of services, it was more plausible that the regulator might achieve this goal. However, increasingly, demand for the spectrum has grown as has the number of spectrum-using services. There have been many pieces of evidence that suggest that regulators are failing to maximise value under such circumstances. Some examples are as follows.

- Some regulatory decisions, such as the allocation of spectrum to the ERMES paging system or the TFTS in-flight phone system in Europe, have resulted in spectrum being unused for over a decade. Clearly, it could have been put to an alternative use which would have resulted in some value.
- Widely differing valuations for the spectrum at auction, for example, the 3G auctions as opposed to spectrum auctions at 3.4 GHz suggest that the balance between different uses is incorrect. In this example, the much higher valuation of 3G suggests that there should be more spectrum made available for cellular, with perhaps less for fixed wireless or other applications.
- Many new applications or technologies have had great difficulty in gaining access to spectrum – for example the iBurst cellular technology or more recently Mobile TV systems. While it is not certain that these would increase the value of the spectrum, their difficultly in entering the market may be a symptom of an excessively rigid system.
- Some applications which have been granted spectrum free, such as aviation radar, have not modernised their radar systems for many decades despite the availability of much more efficient technologies, suggesting there are insufficient incentives for some users to optimise their use of the spectrum.

The current system is also becoming increasingly difficult for the spectrum manager to operate. They may receive frequent requests for new spectrum or to allow existing users to change application. They may also suffer complaints of unfairness as convergence of communications services allows some users who have accessed the spectrum for free to compete with other users who have paid for it.

All of this suggests that the current approach to spectrum management, whereby the regulator selects the use of the spectrum and in some cases the user, is probably not maximising the value of the spectrum and is becoming increasingly difficult for the regulator to administer.

1.4 Alternative management approaches

Economists have long argued that market mechanisms should be applied to radio spectrum. Seminal papers in this area start with Coase in 1959 [1]. The essential idea here is to allow pricing mechanisms to act as an incentive for holders of spectrum to optimise their use – buying more if their business case can justify it, selling spectrum if they have excess, and adopting new technologies that can use spectrum more efficiently where economically viable. Economic theory suggests that in a market which is performing well, this will lead to a division of spectrum that maximises economic value. Under such an approach the regulator sets out rules that enable markets to function while ensuring that interference is controlled and then takes a back seat, leaving it to the market to determine the use and users of the spectrum. However, the development of such rules is complex, as we will be discussing in this book.

The simplest of the market instruments to adopt is probably the use of auctions as a mechanism to distribute spectrum. Auctions are now used as the preferred mechanism for assigning spectrum in many countries and they solve the most pressing problems for many of the regulators by allowing spectrum to be assigned where demand significantly exceeds supply in a transparent and fair manner. But auctions on their own still "freeze" the assignment of spectrum. They need to be accompanied by mechanisms to trade and change the use of spectrum as market conditions change and new services become available.

1.5 How this book addresses the new approaches

This book analyses the key new approaches proposed for managing spectrum. It is structured as follows.

- Chapters 2 and 3 consider new spectrum-using technologies and the implications that they might have for the manner in which spectrum is managed.
- Chapters 4 through to 10 look at the application of market mechanisms to radio spectrum. Chapter 4 provides an overview as to how markets can be used, and then subsequent chapters consider particular economic tools; namely auctions and property rights. This part of the book concludes with a look at the possibilities for competition concerns to emerge and an assessment as to whether market intermediaries in the form of "band managers" might be beneficial.
- Chapters 11 and 12 consider how economic methods can be applied in those areas where market forces, for whatever reason, may not be appropriate. The main tool for achieving this is administratively calculated incentive based spectrum pricing.
- Chapters 13 and 14 look at the commons as an alternative approach to managing spectrum, considering how commons work and setting out guidelines as to where they might be used.
- Chapters 15 and 16 discuss how the analysis set out above needs to be adapted for public sector users and developing countries, respectively.
- Chapter 17 provides brief conclusions.

Reference

[1] R. H. Coase, "The Federal Communications Commission", *Journal of Law and Economics*, **2**, 1–40, 1959.

2 How changing technology is impacting spectrum management

2.1 Technology used to lend itself to discrete allocations

Until recently all technologies used a relatively narrow bandwidth and assumed that they were the sole users of that frequency. For example, the GSM mobile phone system transmitted signals with a 200 kHz bandwidth, which at 900 MHz is less than a thousandth of the carrier frequency. The systems were designed assuming that there would be little interference, and where there was it would be carefully controlled by the operator.

The result of the use of these technologies has been to regulate the spectrum by frequency. That is, the spectrum is divided up into discrete parcels of frequency, for example 915–925 MHz, and assigned to a particular user. That user then expects that they will be given exclusive use of the band.[1] This is shown diagrammatically in Figure 2.1, and has been the system on which spectrum management has been based for almost 100 years.

This approach facilitates the same use of spectrum in multiple countries, often known as harmonisation. By aligning the decision as to what the spectrum is to be used for across multiple countries, the same technology, such as GSM, can be deployed. This brings a range of benefits including economies of scale, international roaming and reduced interference. However, it also brings some disadvantages including the need for the regulator to predict the optimum service and technology and tying many countries to the same frequency plan regardless of whether the need differs from country to country.

[1] In practice, there are other emissions in the band, often from devices such as hairdryers or computers. These are allowed so long as they fall below recognised levels. Hence, the term "exclusive use" is not precise. We will return to this issue in much more detail at a later stage when we discuss ultra-wideband.

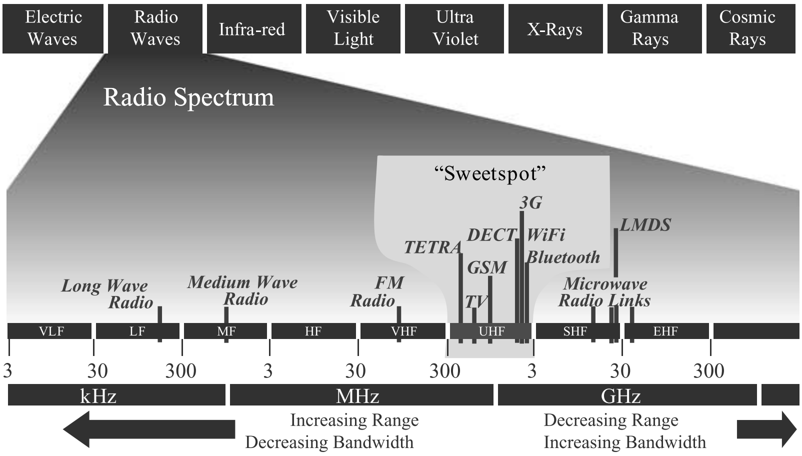

Figure 2.1. Schematic representation of the division of radio spectrum.

After over 100 years of radio spectrum management, the technology underlying the traditional approach to spectrum management is slowly changing. Two new technologies offer the potential for spectrum access under different conditions from today – these are cognitive radio and ultra-wideband. Other similar technologies might be expected to emerge. In addition, the ability to build multi-modal radios reduces the need for international harmonisation, changing some of the drivers for conventional spectrum management. These are discussed in more detail in the following sections

2.2 Multi-modal radios

A multi-modal radio is one capable of working across multiple bands and multiple technologies. To some degree multi-modal devices have existed for many years. A classic example is the AM/FM radio receiver, capable of working across both the medium wave (MW) and very high frequency (VHF) bands and capable of decoding signals with amplitude modulation (AM) and frequency modulation (FM). The increasing trend to multi-modality has been particularly noticeable with mobile phones. Early GSM phones worked only in the 900 MHz band. By the