COSTS AND BENEFITS OF RELAXING INTERNATIONAL FREQUENCY HARMONISATION AND RADIO STANDARDS

FINAL REPORT

INDEPEN AND AEGIS SYSTEMS

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1 Introduction

1.1 Background

International frequency harmonisation is undertaken at a global level by the International Telecommunications Union (ITU) and at a European level by the European Conference of Postal and Telecommunications Administrations (CEPT) and the European Union (EU). ITU decisions on spectrum use at a global level are made every 2-3 years at World Radio Conferences (WRCs) and are formalised in the ITU Radio Regulations which have international treaty status. CEPT decisions are agreed by consensus, take the form of Decisions or Recommendations and individual countries have discretion over whether they sign up to these measures. European Community (EC) decisions may take the form of Directives, Decisions, Recommendations or Communications. Directives must be transposed into national law. The European harmonisation measures referred to in this report comprise EC Directives and CEPT Decisions or Recommendations.

Standardisation is undertaken at an international level at the ITU and at a European level though the European Telecommunications Standards Institute (ETSI). Adoption of ETSI standards is voluntary though the standards are sometimes written into harmonisation measures, in which case they may become mandatory.

In the last twenty years there has been a move towards increased international and European harmonisation and standardisation of services using radio. Factors driving these changes have included:

- Increasing fixed costs associated with the development of new technologies, equipment and infrastructure for service provision (i.e. economies of scale). Large, sometimes global, markets are required by manufacturers and service providers to recoup these fixed costs;
- International mobility in service use as a result of the growth in mobile and transportable communication devices and greater personal mobility;
- Recognition of the increased competition in equipment and service provision that standards may provide;
- The political desire for a single market in Europe.

In parallel with these developments there have been moves towards the adoption of a technology neutral approach in standards and frequency harmonisation measures. The World Trade Organisation (WTO) requires that governments take a technology neutral approach to specifying equipment or interface standards. In addition, the Radio and Telecommunications Terminal Equipment (R&TTE) Directive supports the introduction of new technologies and refers to the use of frequency bands and not a specific technology. CEPT frequency harmonisation measures have moved from specifying particular technologies/standards for a given band to listing a range of possible technologies.

It is against this background that the Independent Spectrum Review[1] suggested there may be opportunities for the UK to take a more flexible and market-driven approach to spectrum management, while continuing to benefit from international harmonisation. The Review was concerned that harmonisation and standardisation measures could create inflexibilities in spectrum use that would have the effect of increasing the scarcity of spectrum, raising prices and limiting competition. The Review made a number of recommendations aimed at avoiding these costs by achieving the minimum harmonisation necessary to achieve any associated benefits of economic and technical efficiency. It recommended that harmonisation should be time limited and subject to periodic review and that the economic costs and benefits of EU harmonisation proposals should be assessed. The UK Government agreed with the general thrust of these recommendations.[2]

1.2 Scope of study

This is the final report for a study for Ofcom, to assess the costs and benefits of relaxing European measures for harmonised frequency allocations and radio equipment standards. The study does not address whether standardisation and harmonisation measures are in general good or bad.

The study is based on a number of case studies illustrating situations where frequency use in the UK is harmonised with the rest of Europe and/or European standards have been adopted and others where this is not the case. This study is related to the following Ofcom initiatives:

- The Autonomy Study[3]: this study assesses the extent to which the use of spectrum in the UK is constrained by interference to or from neighbouring countries. The results of this study are used in our analysis.
- The Ofcom initiative on Spectrum Trading[4]: harmonisation and standardisation measures are fundamental to the definition of property rights and may constrain the potential for trading. They may therefore have a fundamental impact on the economic value which can flow from spectrum trading.
- A study for the Radiocommunications Agency (RA) of administered incentive pricing for radio spectrum[5]: relaxation of harmonisation and standardisation could give more opportunities to change the use of spectrum in response to pricing and could change calculated administered incentive prices if the set of potential alternative uses of spectrum changes.

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[1] *Independent Spectrum Review* by Professor Martin Cave, for Department of Trade and Industry and HM Treasury, 2002.

[2] *Government's Response to the Independent Spectrum Review*. Department of Trade and Industry and HM Treasury, 2002.

[3] National Autonomy in the Use of Spectrum in the UK - Part 2: Inputs to the Harmonisation Study, Quotient/ATDI for Ofcom, March 2004

[4] *Spectrum Trading Consultation*, Ofcom, November 2003.

[5] *An Economic Study to Review Spectrum Pricing: Final Report,* Indepen, Aegis Systems and Warwick Business School, February 2004.

1.2.1 Key issues

Harmonisation and standardisation requirements constrain the way spectrum may be used and so reduce flexibility in spectrum use. This loss of flexibility may have a cost, in terms of foreclosing activities that yield greater economic welfare than the harmonised/standardised use of the spectrum. It may also yield benefits in terms of greater technical efficiency, international mobility, increased economic activity, increased competition and lower equipment costs. This study addresses the trade-off between these costs and benefits and, based on the case studies, seeks to identify factors that determine costs and benefits and so may allow more general conclusions about the desirability or otherwise of the adoption European harmonisation measures and standards.

The key issues addressed are:

- What are the potential economic benefits and costs of European harmonisation and standardisation measures?
- What factors affect the scale of costs and benefits of relaxing European harmonisation and standardisation measures?
- What are the interference effects of relaxing radio standards and frequency harmonisation?
- How might the costs and benefits of relaxing European harmonisation and standardisation measures be quantified?

The first two issues are addressed in Section 2 of this report. The second issue is also considered in the case studies. The third issue is addressed by the Autonomy Study undertaken by Quotient/ADTI and their results are taken into account in our analysis.[6] The final issue is considered in principle in Section 2 and then addressed in practice in the case studies.

1.2.2 Case studies

Initial work on the study involved detailed investigation of possible case studies and the issues they would help to illustrate. It is important to note that the case studies are hypothetical and do not indicate Ofcom's current, or possible future, policy on the frequency bands considered. The case studies have been considered in isolation, independent of the interaction with other frequency bands, international developments and possible new technologies. They have been developed solely for the purposes of this study and in no way reflect the views, plans or expectations of Ofcom. No inferences should be drawn from their inclusion in this study.

The following case studies were agreed:

- GSM 900 and 1800;
- TETRA allocations in the 854-960 MHz band;

[6] It should be noted that the interference effects related to services in adjacent spectrum were not taken into account in this or the Autonomy Study. In some cases it might be necessary to use guard bands and depending on their size this could result in less utilisation of the spectrum.

- Broadband fixed wireless access (BFWA) services at 2 GHz;
- 32 GHz fixed services band;
- Private mobile radio (PMR) services in the 450-470 MHz band;
- UHF TV frequencies released on analogue to digital switchover;
- Short range devices (SRDs) – specifically radio car keys at 418 MHz and telemetry and telecommand at 458 MHz;
- Wireless microphones and video links in bands allocated to programme making and special events (PMSE).

The case studies include historic and/or future looking analyses. Qualitative assessment of costs and benefits is undertaken for all case studies and where suitable data has been obtained the costs and benefits are quantified. Information and data was collected from published sources, from Ofcom and through industry interviews. We would like to thank all those who provided us with assistance in this work.

1.2.3 Definitions

In this document the following definitions of harmonisation and standardisation are used.

- Harmonisation refers to the services as defined in ITU-R, and CEPT or EC regulations that are permitted in a band, e.g. fixed, mobile, broadcasting, fixed satellite. Harmonisation addresses issues such as band sharing (on a primary or secondary basis) and common designation of bands for particular services in different countries.
- Standardisation refers to the level of specification of each of these services. Standardisation addresses issues such as minimum requirements to avoid the potential for harmful interference (e.g. transmitter power), channelisation (e.g. channel spacings and co-existence parameters such as transmitter power and receiver sensitivity), spectral efficiency (e.g. modulation schemes) and interoperability through the specification of protocols.

Standardisation and harmonisation as used in this report are therefore distinct and independent of each other. The terms can easily be confused because harmonisation measures produced by CEPT sometimes include conditions relating to standards (e.g. transmitter power and channelisation) and ETSI standards may include reference to harmonised frequency bands. [7]

1.3 Report Structure

The structure of the report is as follows. Section 2 discusses the economic costs and benefits of harmonisation and standardisation and how these might be measured. Section 3 presents the results of our cost benefit analyses. Details are given in Annexes 1-8. Section 4 provides our conclusions. Annexes 1-8 provide technical background on the spectrum bands considered and details of relevant results from the Autonomy Study.

[7] Standards under the R&TTE Directive, refer to "harmonised standards" compliance with which involves conformance to specified essential requirements, including avoidance of harmful interference. Radio and Telecommunications Terminal Equipment Directive, Directive 1999/5/EC.

2 Costs and Benefits of Standards and Harmonisation Measures

2.1 Introduction

Standards have become of increasing importance over the last twenty years because of their impact on innovation and technology diffusion in "high tech" sectors of the economy.[8] There is now an extensive literature on the economics of standards which was reviewed by Professor Peter Swann for the Department of Trade and Industry in 2000.[9] This literature addresses both *de facto* and *de jure* standards.[10]

The discussion in this Section is based on this review and relevant literature that we have found published since 2000. It should be noted that most of the literature is theoretical rather than empirical. Little of the empirical literature deals with the services to be addressed in this study's case studies, though we have found several papers that discuss the impact of standards on the development of cellular telephony.

The economics literature addresses two main issues:

- what is the economic role of standards and, in particular, what are their costs and benefits as compared with the situation of no standards?
- should standards be determined by the market or is there a role for government intervention in standards processes?

The literature addressing the first question provides a framework for identifying costs and benefits and this is reported in Section 2.2.

The literature concerned with the second question is less relevant though we have found one study that examines this question for the mobile sector and so provides some useful background for the GSM case study.[11]

Frequency harmonisation is not dealt with explicitly in the economics literature, however, it can be thought of as a form of standardisation affecting the radio frequency aspects of radio equipment.

In Sections 2.3 and 2.4, the costs and benefits of harmonisation and standardisation in the context of radio-based services are discussed. Section 2.5 considers issues in measuring these costs and benefits and Section 2.6 discusses the impact of technology change on their value. In Section 2.7 we summarise our proposed approach to assessing costs and benefits.

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[8] For discussions of the issues raised by standards in the context of high tech industries and the policy implications see: G Tassey (2000), *Standardisation in technology-based markets*, Research Policy 29 (2000) and Institute for Prospective Technological Studies, *Future Bottlenecks in the Information Society*, Report to the European Parliament, June 2001.

[9] *The Economics of Standardisation, Final report for Standards and Technical Regulations Directorate*, Peter Swann, Manchester Business School, Report prepared for the Department of Trade and Industry, December 2000.

[10] Standards derived through informal processes are referred to as *de facto* standards. These may often be proprietary technical solutions that gain acceptance in the marketplace. Standards which have received recognition through a formal process carried out by an official body are normally referred to as *de jure* standards.

[11] *Market and committee-based mechanisms in the creation and diffusion of global industry standards: the case of mobile communication*, J Funk and D Methe, Research Policy, 30 (2001).

2.2 Economics of Standards

Standards have been classified according to the economic problems they solve.[12] Swann (2000) reports the following four categories:

- Compatibility/interface standards: These standards promote network effects (or network externalities) that derive from being part of a large network of users (e.g. international mobility, ability to communicate with many others, low cost ancillary and support services). These standards reduce the costs to consumers and producers of switching between different interfaces and thereby promote competition.
- Minimum quality/safety standards: These standards are valuable in circumstances where consumers cannot easily discriminate between low and high quality goods (as may often be the case with radio-using equipment). The standards reduce consumers' search and transaction costs and ensure low quality producers do not drive out high quality producers. Technical barriers to trade may be reduced by providing reference points for quality. In the context of radio services, the requirement for radio equipment to conform with the R&TTE Directive and be CE marked should provide minimum levels of protection for users.
- Variety reduction/focussing standards: Standards that reduce the variety of technologies developed allow economies of scale in equipment manufacture and service provision to be exploited and so lead to lower costs to consumers. Producers' risks of sponsoring an unsuccessful variant are also reduced as the likelihood the market will achieve critical mass is increased (compared with the situation where there is no standard), even if there may be increased competition between producers of the standardised product or service.
- Information/measurement standards: Standards of information and product description give consumers assurance of compatibility between complementary products, reduce producer and consumer transaction costs and thereby promote trade and accelerate the take-up or diffusion of new technologies.[13] The CE marker is an example of an information standard.

In addition, when associated with intellectual property rights or patents the adoption of standards can also provide an incentive to innovate by helping secure a first mover advantage in the marketplace. However, this advantage also enables lock-in of consumers to particular technologies, because of the network externalities arising from the adoption of standards, and thereby reduces potential competition from rivals.[14]

This suggests the potential economic benefits of standardisation are:

- Economies of scale in equipment manufacture and service provision;

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[12] A distinction between reference and technical compatibility standards was introduced in the literature in David, P. A. and S. Greenstein (1990). "The Economics of Compatibility Standards: An Introduction to Recent Research," *Economics of Innovation and New Technology* **1** (1): 3-41. This analysis also provides an analysis of the standards making process distinguishing *de facto* or market-led process from *de jure* or deliberative standards making by voluntary standards organizations.

[13] Blind (2001) shows that Switzerland's stocks of standards have a positive impact on imports from and exports to Germany, France and the UK. Both international and national standards are found to have a positive impact on trade. K Blind, *The impacts of innovations and standards on trade of measurement and testing products: empirical results of Switzerland's bi-lateral trade flows with Germany, France and the UK*, Information Economics and Policy,13, 2001.

[14] This is discussed in *Future Bottlenecks in the Information Society*, Institute for Prospective Technological Studies, Report to the European Parliament, June 2001.

- Increased competition in equipment production and between service providers arising from reduced consumer switching costs and improved interoperability of terminal equipment and networks;
- Increased trade flows and the competitive benefits this yields;
- Reduced transaction costs between producers and consumers and between producers;
- Network effects leading to faster take-up and greater willingness to pay for services than would otherwise occur;
- Reduced risk for producers and consumers;
- Accelerated take-up and diffusion of new technologies;
- A stimulus to innovation in certain circumstances.

There are however a number of potential economic costs of standardisation. These include:

- Regulatory capture, in which the regulator is persuaded to adopt standards that benefit producers rather than consumers or some groups of producers at the expense of others;
- Reduced innovation and consumer choice because of variety reduction and exclusion of alternative uses;
- A possible reduction in competition in service/product provision arising from network effects. This is double edged because, while monopolisation means there are no 'orphaned' users as network effects take hold, at the beginning of the process one wishes to avoid lock-in to inferior standards due to a lack of competition;
- Delays in service introduction as the standardisation process itself takes time;
- Increased administrative costs associated with the processes for agreeing standards in circumstances where standards are developed collectively (either by industry or through government bodies).

The net effect of standards on competition, innovation, quality and costs is ambiguous and will depend on the economic and technical characteristics of the product or service in question including its market demand. Swann (2000) also notes that the ability of standards to achieve these results depends on the process by which they were prepared and, in particular, whether they are produced by a process that takes account of quality and that includes those at the technology frontier.

Econometric research on the impact of standards provides indirect evidence of a positive correlation between standards and macro-economic performance (as measured by economic growth, technology diffusion and trade). Swann (2000) reports that these findings are supported by case studies analysing the impact of standards on competition.

In summary, the economic literature provides an analytical framework in which to assess the costs and benefits of European harmonisation and standardisation. In the next two sections we apply this framework to radio frequency harmonisation and radio equipment standardisation respectively. The economic literature does not give any conclusive theoretical or empirical evidence on whether the economic impact of standards is positive or negative. However, studies of standards in mobile telephony indicate that a single standard applied at a national level has had a positive impact on technology diffusion, particularly in the case of analogue systems. Gruber and Verboven (2001) find a much weaker effect for digital standards and note that this may be because competition allowed innovative CDMA systems to develop. By contrast, Kauffman and Techatassanasoontorn (2003) find that the number of digital standards has a negative effect on the adoption of mobile services.[15]

2.3 Costs and Benefits of Harmonisation

Harmonisation is concerned with the allocation of services to specific frequency bands. European harmonisation measures seek to allocate particular frequency bands to one or a limited number of services throughout Europe. The main reasons for doing this are:

- to reduce the likelihood of harmful interference between services operating in different countries, particularly in border areas, and thereby increase the available spectrum for each country. The scale of this benefit will depend in part on whether spectrum in the bands in question is scarce or not;
- to create a European-wide market for equipment and services thereby reducing manufacturers' risks and allowing them to take advantage of scale economies;[16]
- to reduce equipment costs by limiting the number of frequency bands for which equipment must be made;
- to create the possibility for international roaming;[17]
- to provide certainty (protection) to users of spectrum that the spectrum will not be reallocated to other potential uses.

The main costs of European frequency harmonisation are those associated with the loss of flexibility at a national level in matching spectrum supply to demand and in allowing spectrum to be refarmed or traded so that high value uses replace low value uses. Service demands will differ between countries for many reasons, including income, geography, demographics and the provision of competing wired services (e.g. cable TV). Frequency harmonisation could mean that for any given service spectrum will remain idle in some countries while insufficient spectrum will be allocated in others resulting in higher prices and reduced consumer benefits.

Band sharing between different services is often permitted so that countries have some flexibility in matching band use to demand. An example might be sharing satellite links in rural areas with fixed links in urban areas. The cost of band sharing, however, can be a loss in potential capacity due to guard bands and interference, and depending on how the band is organised, an increase in the costs of management.

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[15] See *The evolution of markets under entry and standards regulation – the case of global mobile telecommunications*, H Gruber and F Verboven, International Journal of Industrial Organisation 19 (2001); *International Diffusion of Digital Mobile Technology: A Coupled-Hazard Approach*, R Kauffman and A Techatassanasoontorn mimeo University of Minnesota and forthcoming in Information Technology and Management, 2003

[16] In this regard there are thought to be significant benefits from trading with "nearby" countries, where distance is measured in cultural, administrative, geographic and economic terms. See *Distance Still Matters*, P Ghemawat, Harvard Business Review, 79(8), September 2001.

[17] This will also require standardisation for interoperability between consumer equipment and different networks.

Table 2.1 summarises the costs and benefits of frequency harmonisation. This is used as the basis for the case study analyses reported in Section 3.

Table 2.1 Benefits and costs of European frequency harmonisation

Benefits	**Costs**
Avoid harmful interference and thereby promote efficient use of spectrum and so increase spectrum use and competition	Restrictions on use (or trade) of underused or unused spectrum for alternative uses
Promote international mobility (of terminals)	Restrictions on ability to refarm spectrum for new services
Reduce equipment costs by reducing number of bands equipment needs to operate in	Insufficient spectrum allocated to some uses
Create large equipment markets	Delays caused by time to agree harmonisation measures
Promote competition between equipment suppliers	

Source: Indepen and Aegis analysis

2.4 Costs and Benefits of Standardisation

Standardisation is related to a particular application or service. From the perspective of this study, there are two key levels of standardisation to be considered.[18]

- Standardisation of the radio characteristics that goes hand in hand with the use of a channel plan for a band. The objective is to increase the potential capacity of a band by reducing the likelihood of harmful interference. We refer to this type of standardisation as "channelisation".
- Standardisation of the air interfaces so that equipment from one manufacturer will work with equipment from another manufacturer. We refer to this type of standardisation as interoperability. Such standardisation encompasses both the radio characteristics and the protocols used over the air interface. The objectives of interoperability standards are to:
  - increase the effective market size and hence reduce manufacturers' risks (and so costs) and reduce equipment costs through economies of scale;
  - reduce prices through increased competition in equipment supply;
  - increase competition between network operators by enabling users to change network without having to buy a new terminal;
  - increase the utility of equipment by introducing greater operational flexibility (e.g. allowing international mobility of terminals) and hence increase the potential demand.

Manufacturers often recognise these benefits of standards by publishing or making available their specifications to others and allowing third party manufacture under licence with royalty payments.

[18] Standardisation to reduce interference so as to meet the requirements of the R&TTE Directive is taken as a given, since the R&TTE Directive is not optional.

2.4.1 Benefits

The merits of channelisation depend on whether the spectrum under consideration is congested or not. Channelisation allows more efficient use of the spectrum which is of much greater value when the spectrum is congested. To the extent that standardisation sets power limits to appropriate levels then greater re-use may be possible and co-existence with other systems sharing the same frequency band may be facilitated.

The merits of interoperability standardisation depend very much on the application. There are two main factors that affect the benefits of interoperable standards:

- Potential market size
- Number of parties procuring and using equipment

The effects of standardisation in reducing costs are likely to be disproportionately larger for equipment with a large potential market, especially in the case of consumer equipment. The reasons are that standardisation leads to a critical mass effect in consumer awareness and education about the use and potential of products.[19] It also facilitates the development of a large common market in critical components. For example, in electronics production critical features of the technology are introduced into the design of integrated circuits (IC) that can provide the basis for a variety of different implementations. 'Getting to silicon' more quickly is desirable as competition (actual or potential) from other IC producers will drive down the price of the related IC. The price will also fall as demand from a variety of different system producers engages economies of scale in IC production. If, however, a single supplier can under-price rivals and achieve a monopoly the price declines stop (disregarding cost) and 'wealth creation' sets in (at the expense of users).

The nature of the operation of equipment also affects the value of standardisation. Where the communicating equipment is likely to be procured and used by one party or organisation, then standardisation does not affect operation. Where, however, different parties need to communicate with each other, as in public broadcasting and public mobile networks, standardisation offers many benefits. These include the benefits of competition in equipment supply, service provision (because users with one type of terminal can choose between different service providers) and applications development and reduced consumer risks of purchasing incompatible equipment. For example, the GSM standards not only give the user a choice of terminal supplier for a given service (competition in the supply of equipment) but also give the user who already has a terminal a potential choice of service provider.[20]

All complex systems involving protocols require extensive testing, and in the process of testing problems are discovered with the standards that are tested against. There is therefore an iterative process. The extent of testing needed with an open standard where interoperability is required between equipment made by different manufacturers will be slightly greater than if all the equipment was made by the same manufacturer. However, the increased costs of doing this are likely to be more than compensated for by the increased competition resulting from multiple manufacturers. Overall the scale of testing costs for

[19] See Gruber and Verboven (2002) op. cit. for evidence of this effect in the case of analogue cellular systems.

[20] SIM locking and long duration contracts can block these benefits.

European standards as opposed to any others that might be adopted by the UK are likely to be similar and so we do not consider these costs any further.

Standardisation in channelisation and interoperation is not uniquely linked to specific frequency bands i.e. the same channel scheme and the same interoperation protocols can be used to advantage in different bands. This effect is seen especially with GSM where the benefits of interoperation standardisation and the protocols apply across different bands such as 900MHz, 1800 MHz, 1900 MHz and even some of the trunked PMR bands. The reason for this is that the proportion of the costs of terminals that is associated with the frequency dependent radio frequency (RF) aspects is much lower that the proportion associated with the frequency independent parts of the air interface such as the channel arrangements, TDM/TDMA scheme and interoperation protocols.

2.4.2 Costs

There are a number of costs associated with radio standardisation. Standardisation processes take time and it is possible that in waiting for a standard to be developed market opportunities will be lost with possible economic costs (e.g. reduced output, higher production costs and less service innovation). Although these costs may not arise if other services fill the gap in the market.

Standards can reduce the scope for innovation since they preclude the use of other competing technologies or systems, some of which may be superior to the standardised system, and the standardised system will inevitably exclude developments and features of value to some users. In addition, the adoption of a particular standard means that opportunities to use equipment made to other standards (which could be cheaper or otherwise more desirable) are forgone. If market demand for the standard does not materialise then the spectrum may be left idle unnecessarily. An example is the ERMES paging standard whose inclusion in a European Directive denied opportunities to the Motorola Flex designs and resulted in the allocated spectrum being left idle in many countries.

In developing standards and technical specifications within ETSI access to relevant intellectual property rights (IPRs) is an issue. It is important to ensure that the preparation, adoption and application of standards is not delayed or blocked by access to essential IPRs not being available. To minimise problems ETSI has developed a policy to ensure that they are informed of essential IPRs and the owners are requested to give an undertaking that they will grant irrevocable licences on fair, reasonable and non-discriminatory terms and conditions. Where an owner is not willing to license an IPR then work on the technical standard is ceased.[21]

2.4.3 Summary

Many of the costs and benefits of standards just discussed are not dependent on the adoption of European standards. They could rise if national standards, standards developed by bodies outside Europe or *de facto* standards were applied. Some of the benefits are however enhanced if the same standards are adopted across Europe, particularly those concerned

[21] This was the case with the standard that was being developed for “Digital Information Interchange Signalling” (DIIS).

with limiting interference, promoting international mobility and creating a large market. The costs however may also be increased if alternative superior standards are available in shorter timescales from elsewhere.

In Table 2.2 we summarise the benefits and costs of European radio equipment standardisation.

Table 2.2 Benefits and costs of European radio equipment standardisation

Benefits	Costs
Avoid harmful interference and promote spectrum efficiency and so increase spectrum use and competition	Restrictions on use of equipment developed elsewhere, which may be cheaper or have greater functionality
Promote international mobility (of terminals)	Less innovation and potential lock-in to an inferior standard
Create large equipment markets	Delays in the introduction of new services and equipment caused by the time to agree standards
Promote competition between equipment suppliers	
Promote interoperability between terminals and public networks (thereby reducing consumer risks)	
Promote competition between service and application suppliers	

Source: Indepen and Aegis analysis

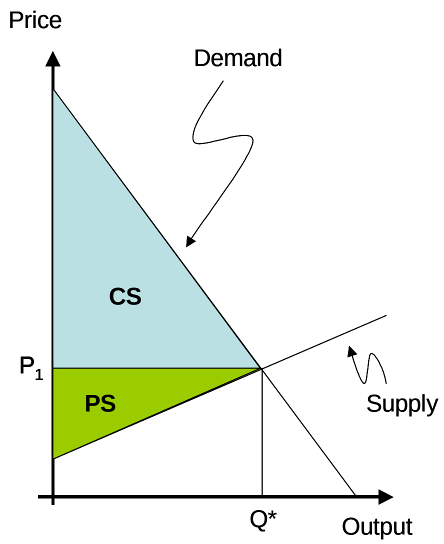
2.5 Measuring Costs and Benefits

This section sets out the conceptual basis for the measurement and appraisal of the costs and benefits described above. Conventional economic analysis uses the concept of welfare to capture the economic and other benefits of resources or goods and services, such as spectrum based services. The concept of economic welfare measures overall net benefits or ‘surplus’ to society as a whole and allows the change in welfare, or net benefits, of a policy change to be calculated.

The concept of economic surplus as a measure of welfare can be explained by introducing the concepts of supply and demand for a final good or service produced using spectrum. Supply and demand are equal in equilibrium and the equilibrium is characterised by a price (P) and quantity (Q) where the two are equated. Surplus has two components: consumer surplus (CS) and producer surplus (PS).

Figure 2.1 introduces these concepts, where output refers to the final good or service produced (rather than the quantity of spectrum used as an input). The economic welfare associated with the market for the final good or service is shown in Figure 2.1 as the sum of the consumer and producer surpluses (the total shaded area).

Figure 2.1 Economic welfare measured in terms of consumer surplus (CS) and producer surplus (PS) of a final good or service where spectrum is used as an input to production



Consumer surplus (CS) is the cumulative sum of the differences between the willingness to pay for a good and its price. Intuitively it is the value consumers collectively place on the good or service in excess of the market clearing price they are required to pay. In price-quantity space consumers' (marginal) willingness to pay is represented by the demand curve. For the final marginal unit of consumption willingness to pay just equals price.[22]

Producer surplus (PS) is the cumulative sum of the differences between the price of a good or service and the minimum firms are willing to be paid to produce a given level of output of the good or service. Intuitively producer surplus is any profit in excess of that required to recompense all costs including the cost of capital invested. In price-quantity space the minimum schedule of what firms are willing to be paid to produce their output is known as the supply curve.

In competitive markets where firms are "price takers" (i.e. no single firm can influence the price in the market) each firm will adjust their production capacity so that marginal cost is equal to price, and firms may enter or exit the market depending on overall demand for the good or service at the market price. If firms share a common productive technology then in this case the supply curve will be horizontal and there will be no producer surplus. If these circumstances apply then producer surplus does not need to be considered in appraising the welfare impact of changes in harmonisation and standardisation.

[22] In some markets firms may be able to price discriminate between different classes of customers in an attempt to capture some of the consumer surplus that a single market clearing price would leave with consumers. Mobile tariff schedules and airline pricing are examples of price discrimination. Consumers themselves may also benefit from price discrimination if consumers who would not have been willing to purchase a good or service at a single market clearing price are able to do so with price discrimination.

For generality Figure 2.1 shows an upward sloping supply curve. The upward sloping supply curve illustrated might apply if resources used in production such as land or spectrum were constrained and economies of scale across the entire range of market output did not offset the impact of such constraints on production costs. The supply curve would not necessarily become vertical once an input constraint becomes binding since firms may be able to substitute other inputs for the input that is constrained (though at a cost). For example, cellular operators can add base stations in a cellular network as spectrum becomes congested. The industry supply curve may therefore slope upwards, and possible changes in producer surplus should then be considered in analysing the costs and benefits of harmonisation and standardisation.

We also note that supply in Figure 2.1 is illustrated for a single homogenous good. In practice, producers may differentiate their products. It may then be possible for all producers to enjoy economies of scale if the market as a whole grows, without any single producer monopolising the entire market. If costs fall with increasing output across the entire range of market demand, then it will be economic for a single monopoly supplier to supply the market (a case we consider later in this section).

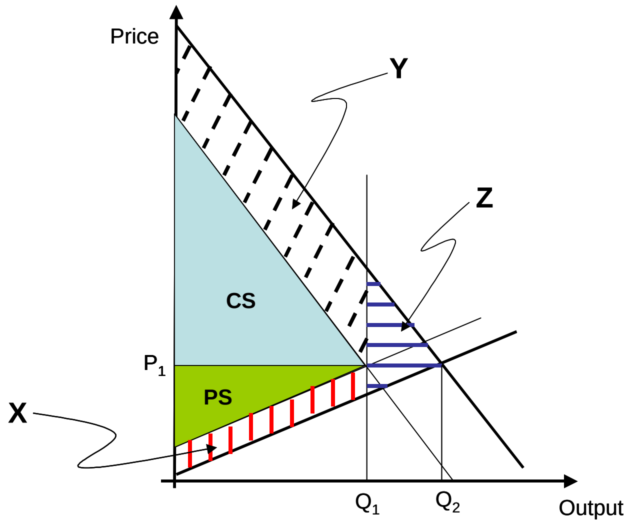
Using the concepts developed in Figure 2.1 we can consider how harmonisation and standardisation could lead to a change in economic welfare in the following ways:

- Shifting the demand curve outwards, for example, by allowing customers to roam through harmonisation and standardisation, thereby increasing their willingness to pay for cellular services.
- Shifting the supply curve downwards, for example, through harmonisation which increases the final market size and allows increased economies of scale, thereby reducing the cost of providing services.
- Flattening the supply curve, for example, via standardisation that results in more efficient use of existing spectrum, thereby allowing firms to economise on other inputs.

In Figure 2.2 we illustrate the total effect on welfare due to an increase in the effective use of spectrum due to possible changes in harmonisation and standardisation. In the figure we delineate the change in welfare along three lines. Two effects change existing (impact infra-marginal) consumption, through a reduction in production costs and an increase in values held by consumers already in the market (X and Y respectively). The third effect stems from a change in the market equilibrium, resulting in additional consumption (Z). These effects are shown as the three shaded lined areas X, Y and Z respectively in Figure 2.2.[23]

[23] In general the equilibrium price may change due to a variation in harmonisation and standardisation, but for expositional clarity the equilibrium price does not change in Figure 2.2 as demand and supply shifts are assumed to offset one another.

Figure 2.2 Total surplus change



In practice, if small changes in Q are considered cost benefit analysis may ignore the magnitude of Z as illustrated in Figure 2.2. For example, if production (supply) costs were reduced the change in overall surplus might be approximated by X, assuming output remains constant at Q_1.

As stated earlier producer surplus will be irrelevant if the supply industry supply curve is horizontal which simplifies quantification of the welfare impacts of policy alternatives. A further simplification is that we are often interested only in changes in welfare associated with existing goods and services. For example, if production costs were reduced with a horizontal supply curve then prices would fall and consumer surplus would increase (there is no change in producer surplus since both prices and costs have fallen by the same amount). We can then approximate the increase consumer surplus by simply multiplying the change in costs by the existing output level and need not estimate CS with and without the policy change.

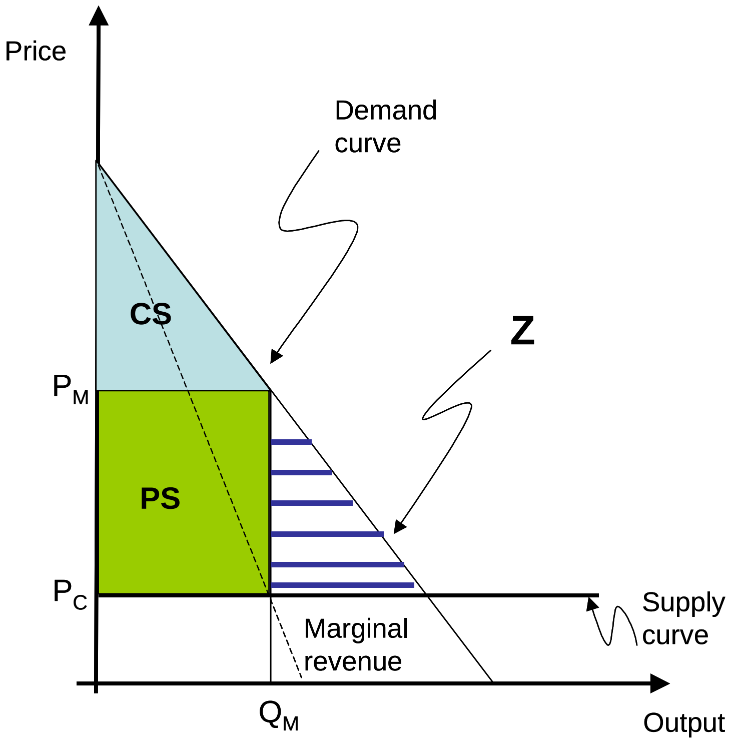
One of the core principles of cost benefit analysis is that one is interested in net changes in welfare, not 'transfers' between one group and another *per se*.[24] In Figure 2.2 the price P_1 remained unchanged and therefore no transfer from consumers to producers or visa versa was involved. If the price had fallen then some of the producer surplus would have been redistributed to consumers and the transfer itself would not constitute a net welfare gain.

2.5.1 Monopoly

An illustrative example of a transfer of surplus is the case where a price reduction occurs through increased competition rather than via a reduction in costs *per se.* There will then be a transfer from the formerly monopolistic producers who were able to mark prices up above costs to consumers. Figure 2.3 illustrates this case.

[24] Increased competition may spur a reduction in costs in addition to a reduction in prices.

Figure 2.3 Surplus change due to increase in competition



It is profit maximising for an unconstrained monopolist to set price (at P_M) such that marginal revenue equals marginal cost (at Q_M). At this point the firm earns economic rent or producer surplus. If changes in harmonisation or standardisation made the market competitive, then prices would fall to marginal cost (P_C).

The value of this price change at the prior level of output does not constitute a welfare change (the increase in CS is exactly offset by a reduction in PS). However, there will also be an associated increase in output and a change in welfare represented by Z in Figure 2.3. Z, rather than changes in X or Y, is therefore the focus of interest in this case.

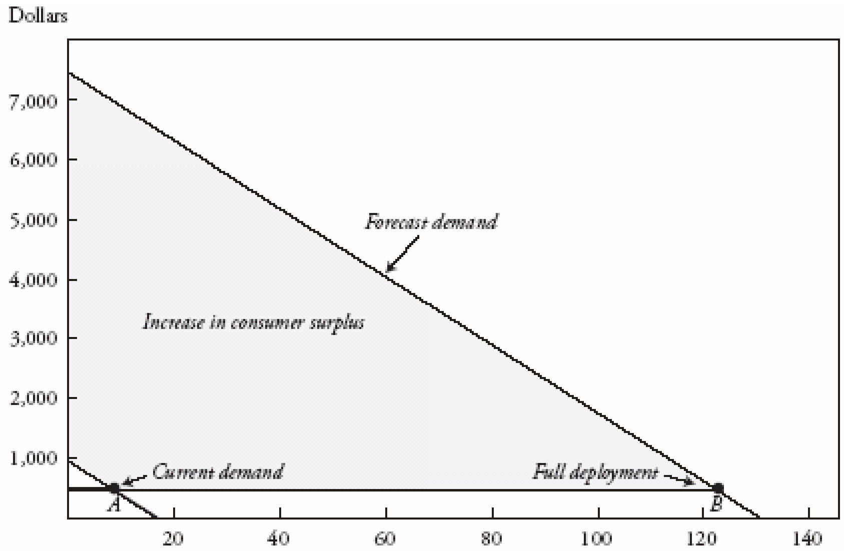
An increase in competition may in turn spur an increase in the productivity growth rate over time leading to a further increase in consumer and potentially producer surplus.

2.5.2 New goods and services

A relaxation in harmonisation or standardisation may free up spectrum to allow a wholly new service to be introduced, rather than a change in demand or supply for an existing service. We are then interested in the entire consumer and producer surplus generated by the new service rather than a change in consumer or producer surplus. In this case of consumer surplus an estimate of the demand curve and price of the new service is required to estimate the value of the new service.[25] For simplicity we have not considered producer surplus.

A related approach, relevant to a large increase in demand for a new service, is set out in Crandall, Hahn and Tardiff (2002).[26] If demand is linear with an elasticity of –1 at current demand, and demand is assumed to shift in a parallel fashion as demand grows, then consumer welfare increases with the square of demand – see Figure 2.4 from Crandall *et al*.[27] Crandall *et al* show that the result is sensitive to the shape of the assumed demand curve, with consumer surplus increasing in proportion to the quantity demand for a constant elasticity of demand curve (Figure 2.5 from Crandall *et al*).[28] The two demand curve assumptions therefore allow approximate bounds to be placed on benefits in circumstances where no other approach to estimation may be feasible.

Figure 2.4 Change in consumer surplus for demand growth with linear demand



a. Assumptions are that elasticity = –1 at the current price and demand; that the current price of broadband access is $40 a month; and that the current demand for broadband is 8 percent of 105 million households.

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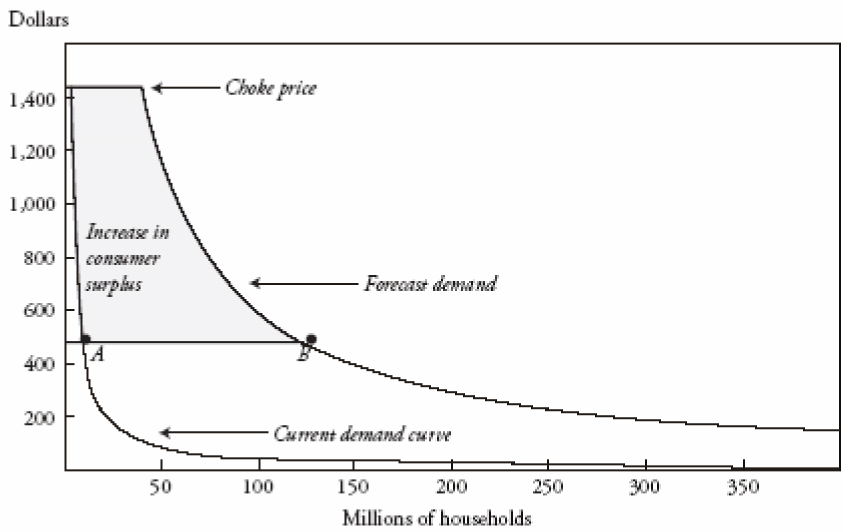
[25] Hausman first set out an empirical application of this approach in the telecommunications sector. *Valuing the Effects of Regulation on New Services in Telecommunications*. J Hausman, Brookings Papers: Microeconomics 1997.

[26] Crandall, Hahn, Tardiff. December 2002. *The Benefits of Broadband and the Effect of Regulation*. In Crandall and Alleman (eds). "Broadband: Should we Regulate High-speed Internet Access?". AEI-Brookings Joint Centre.

[27] An estimate of the initial consumer surplus is required to estimate the change.

[28] It is also assumed that the choke price, the price at which demand would be driven to zero, is a constant multiple of the current price.

Figure 2.5 Change in consumer surplus for demand growth with constant elasticity of demand



a. Assumptions are that elasticity = −1 at the current price and demand; that the current price of broadband access is $40 a month; and that the current demand for broadband is 8 percent of 105 million households.

2.5.3 Impacts in other markets including the spectrum "market"

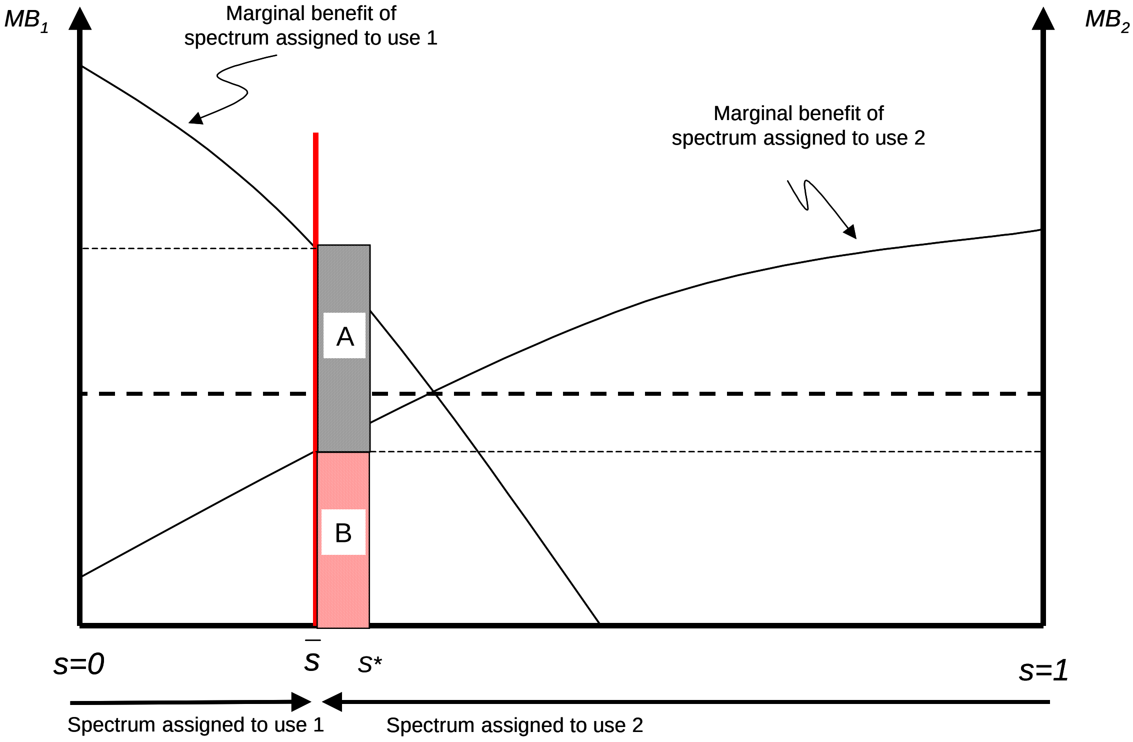
So far we have focussed on direct welfare changes associated with the final goods market. However, changes in harmonisation and standardisation may involve costs and benefits in secondary markets, and/or alter the value of scarce spectrum itself. Should these impacts be taken into account in our analysis?

In general cost benefit analysis should ignore impacts in secondary markets. The reason for this is that in the absence of price adjustments in secondary markets in response to price changes in primary markets, impacts are typically fully measured as consumer and producer surplus changes in primary markets.[29] However, since radio spectrum is not necessarily currently efficiently assigned or efficiently priced, and is in general not currently traded, secondary impacts in the spectrum "market" may be additional and material.

If the value of the spectrum in question differs in alternative uses then the quantity of spectrum which may be reallocated as a result of changes to harmonisation and standardisation should be considered. Figure 2.6 illustrates this possibility.

[29] See Boardman, Greenberg, Vining and Weimer (Section 5) for a fuller discussion of this point. *Cost-Benefit Analysis – Concepts and Practice*. Prentice Hall, 2001.

Figure 2.6 Potential Value from Reallocation of Spectrum



In Figure 2.6 a reallocation of spectrum from use 2 to use 1 (a move to the right) would result in additional value approximated by area A. Marginal values of spectrum in alternative uses calculated for the purpose of spectrum pricing would potentially provide a basis for calculating A. Changes to standardisation may also allow spectrum to be freed up for alternative uses without reducing the amount of usable spectrum in the existing use, for example, if the need for guard bands to manage interference were reduced. In that case the overall gain would be the sum of areas A and B. Finally, alternative standards might result in a loss of useable spectrum to use 1 without any gains to use 2, in which case the net loss would be approximated by area B.

2.5.4 Time, delay and discounting

Estimates of costs and benefits will extend over time and may also vary over time. Changes in harmonisation and standardisation may also advance or retard potential welfare gains. We therefore need to add these up and express them in net present value terms in order to evaluate alternative policies.

The standard approach is to express all estimates in constant value or real terms, and then to 'discount' future costs and benefits at an appropriate discount rate. The official Government source of guidance on the appropriate discount rate to use is the HM-Treasury "Green Book" last updated in 2003.[30]

[30] *The Green Book, Appraisal and Evaluation in Central* Government, HM Treasury, 2003.

The Green Book proposes using a discount rate equal to the social rate of time preference which is estimated to be 3.5 per cent. This is the discount rate we shall use in calculating the net present value of costs and benefits.

2.5.5 Option values

The option to use a resource at some point in the future can have value, even if the resource is unused at present. It is not therefore necessarily correct to assume that non-use of radio spectrum is inefficient, since option values may exceed alternative the value in currently feasible uses. Options values can be zero or positive, they can never be negative. In addition, option values increase in value with uncertainty over returns to future options since in the event of outcomes that would increase returns the option can still proceed, while in the event of outcomes that would decrease returns the option need not be exercised and no loss is involved.

We do not value any options in our appraisal. Instead, we use expected values (or central forecasts) of key parameters to estimate present values. Option values could however be important in some instances. For example, a use of spectrum now that precluded broadband fixed wireless access could prove costly if willingness to pay for broadband services grows substantially over time. Consideration of option values also has qualitative implications for policy. For example, use it or lose it provisions in relation to radio spectrum may eliminate valuable option values if users chose not to use the spectrum today because there are greater expected benefits from having the option to use the spectrum in future once certain market or technology uncertainties have been resolved.

2.6 Impact of Technology Developments on Costs and Benefits

Radio equipment technology is changing rapidly as a result of the advances in digital technology and integrated circuits. Most new equipment at frequencies up to a few GHz consists of:

- radio frequency (RF) components, namely a solid state wideband power amplifier and an antenna
- digital signal processors and integrated circuits with their software
- a power supply

All three elements are affected by technology change.

The replacement of expensive and difficult to manufacture frequency specific RF and intermediate frequency (IF) components with integrated circuits and software (the software radio) has changed the economics significantly by increasing the development costs, primarily in writing software, and reducing the production costs. It has also greatly increased the reliability and flexibility of equipment. The developments in digitalisation that shift the costs from low development/high production to high development/low production are creating increasing economies of scale. This potentially increases the benefits from standardisation and harmonisation.

There is also an increasing economy of scope as hardware and software routines become increasingly multi-purpose, in the sense that they are capable of being used in different applications (e.g. both TETRA and GSM) and in different frequency bands. The nature of mobile terminals and palm top devices is also changing as viewed from the perspective of the application. Terminals are becoming more like miniature PCs and general purpose communications platforms. This means it has become easier for equipment to support multiple standards, thereby increasing the costs of prescribing a single standard.

Power supplies an increasingly important part of equipment, especially mobile radios that are dependent on batteries. The increasing complexity of the digital circuitry, and the software processing, requires increased current drain and therefore much research is going into battery technology and management. For example, in the case of mobile phones, battery packs are designed to be specific to the phone and replacements are only available for a short period. Hence the determinant of the lifetime of the phone has become the battery.

Battery developments are similar in many ways to integrated circuits in that they involve high levels of investment in the technology and manufacturing plants but the recurring manufacturing costs are relatively low, although the fixed investment costs are not as high a proportion of total costs for batteries as for integrated circuits.[31] These trends again may increase the benefits from standardisation and harmonisation.

By contrast with these hardware trends, the trend in new services and applications is to allow for increasing customisation and differentiation and so less standardisation at the higher protocol levels, especially for new public communications services. This is partly the result of the growth of the Internet, where services are created at the edge of the network and the network is no longer "service specific", and partly the result of uncertainty amongst the operators about the development of new services. This means that service specific software is downloaded to general purpose terminals to operate the service. An example is the various Instant Messenger solutions. The result is growing fragmentation of the services market and loss of any-to-any capability.

Software Defined Radio (SDR) is now being implemented in some products and other wireless sub-systems are under development. For example, some mobile terminals download updates to code that affect operating parameters. SDR technology facilitates the implementation of some of the functional modules (modulation, demodulation, signal generation, coding and link-layer protocols) in software. It promises to solve problems such as limited equipment use, constant evolution of link-layer protocol standards and incompatible network technologies as the radio functionality is implemented through software modules running on a generic hardware platform. So where currently operators have to decide on a single air interface technology SDR will allow them to have a single device / equipment that will support a number of air interfaces.

Application and implementation of SDR can range from complex multi-mode and multi-band devices, to simple radio terminal implementations where product enhancements, "bug" (defect) fixes and simple upgrades can be supported by downloads "over the air". For example, a mobile terminal software reconfiguration requires a platform that can be fixed via software download and has to cover for example modulation, frequency and filter

[31] Concerns about the environment and the disposal of the electrolytes used in batteries are an important constraint in further battery development and are governed by European Directives (91/157/EEC and subsequent amendments) that will soon be updated to include newer battery technologies in their scope. The updated Directive is expected to restrict the types of battery placed on the market and to set targets for the recovery of batteries.

characteristics. The use of software reconfiguration in mobile terminals and base stations requires standards to be in place and this could potentially happen over another couple of years as work has started on standards. It is also necessary for there to be a commercial need and for vendors to use programmability as a differentiator to provide the necessary encouragement for mass usage.

The advantage of the software approach is that it allows operators the flexibility to reallocate traffic between different standards automatically depending on demand. The challenge will be to deliver general-purpose “chips” that are small, cheap, have sufficient power and do not place further demands on batteries if they are to be used in terminals. At this stage it is not clear when suitable SDR radio products will be come universally available in the market place.

The Federal Communications Commission (FCC) [32] considers that intelligent[33] radios can provide efficiencies in spectrum use within users own networks and also support the development of secondary markets by facilitating sharing of spectrum on “a negotiated or an opportunistic basis”. The necessary technologies include the ability of devices to determine their location, sense spectrum use by neighbouring devices, change frequency, adjust output power, and even alter transmission parameters and characteristics. These technologies are already used in wireless local area and mobile networks. As they are used in more products they will allow more flexibility in the use of the spectrum and it will become possible to undertake real-time frequency co-ordination between different radio systems.

In summary, the main trends are:

- A shift from a cost mix of low development/high production costs to high development/low production costs.
- Increasing economies of scale and scope and so concentration in the supply chain.
- The migration of terminals from dedicated equipments to multi-purpose platforms that can support multiple standards and that can be used in a number of frequency bands.
- The shift for new services from standardised public services to customised applications and services run by software that is downloaded onto terminals.
- The increasing availability of software defined radios that can switch from one wireless standard to another and from one frequency band to another by the addition of software.
- The increasing availability of products that deploy technologies that facilitate real-time frequency co-ordination between different radio systems.

These developments mean that equipment is now more flexible than was the case. It may be able to support different standards and may be adapted to operate in different frequency bands (that are in similar frequency ranges) at a reasonable cost.[34] Although increasing fixed (i.e. development) production costs might argue for greater harmonisation/standardisation so

[32] *Notice of Proposed Rule Making and Order on SMART radios*, 17 December 2003, FCC 03-322.

[33] The FCC uses the term “cognitive radio technology” which emerged from the application of advanced software techniques to radio processing.

[34] The extent to which this is likely to happen in practice depends on whether special-purpose devices are more cost effective than general-purpose devices and thus steal market share and hence economies of scale from the general-purpose device.

as to create large equipment markets, the other trends seem likely to reduce the costs of relaxing harmonisation and standardisation measures and to allow European countries to choose from a range of standards rather than having a single standard prescribed. This suggests that answers will be case specific depending on the nature of the application and equipment production economics.

2.7 Conclusions

The Swann review for DTI (2000) concluded that standardisation and harmonisation can result in significant benefits via increased willingness to pay where there are strong network effects, and can result in increased potential switching and competition. However, there are no generally applicable theoretical and empirical conclusions from the literature.

The literature on the economics of standardisation provides a framework for assessing the costs and benefits of harmonisation and standardisation. The costs and benefits considered in the case studies are those listed in Tables 2.1 and 2.2. These costs and benefits should in principle be measured with respect to their impact on consumer and producer surplus over a number of years.

The measure to be estimated is the net present value (i.e. discounted sum) over n years of the net benefits of a liberalised scenario less the net benefits of a scenario in which harmonisation/standardisation applies. In algebraic terms this is given by the sum over all years 1 to n of:

$$[(B_{Ai} - C_{Ai}) - (B_{Bi} - C_{Bi})]/(1+r)^{i}$$

where

B_{Ai}, C_{Ai} = benefits, costs of liberalised scenario A, year i

B_{Bi}, C_{Bi}= benefits, costs of a harmonisation/standardisation scenario B, year i

r = discount rate

Where there is sufficient data we have measured costs and benefits in terms of changes in consumer and producer surplus. In situations where the sectors involved can be assumed to be competitive and/or the supply curve is horizontal, producer surplus is zero and so the focus is only on consumer surplus. In cases where surplus cannot be measured because of a lack of suitable data we were sometimes able to estimate the impact of harmonisation/standardisation on users' costs as a proxy for the impact on welfare.

For case studies involving the diffusion of public services, in particular the GSM case study, we examined the impact of two different diffusion models – one in which diffusion rates are a function of the number of users of the service (viral diffusion and network externality) and another where diffusion rates are determined exogenously (e.g. by technology advances).

In situations where there is more/less spectrum available as a result of a change in harmonisation or standardisation this benefit/cost is estimated by multiplying the change in spectrum by an estimate of the opportunity cost of the spectrum derived in the spectrum pricing study undertaken by Indepen et al (2004). If changes in spectrum availability are large then this approach could either over/under estimate values.

We have not taken account of the benefits or costs arising if government receives more/less licence fee revenue under the scenarios explored.

The discount rate we have used is the recommended Treasury rate of discount for policy evaluation of 3.5 per cent. The timeframe over which costs and benefits are estimated depends on the case study. We note that because the Treasury discount rate is relatively low future benefits will have relatively high weight in the calculations.

Finally, as will be seen in the next section, in all of the case studies it was not possible to measure some of the effects listed in Tables 2.1 and 2.2. Reasons for this varied, including absence of suitable historical or current market data on spectrum use and willingness to pay for that use, absence of any firm basis on which to undertake technical and market analysis for services which are not currently provided in the UK and the scale of the work involved was beyond the scope of this study. We return to this issue in Section 4.4 where we discuss the role of regulator versus the market in making decisions about whether to adopt European harmonisation and standardisation measures.

3 Case studies

3.1 Introduction

This section presents the case studies. It is important to note that the case studies are hypothetical and do not indicate Ofcom's current, or possible future, policy on the frequency bands considered. The case studies have been considered in isolation, independent of the interaction with other frequency bands, international developments and possible new technologies. They have been developed solely for the purposes of this study and in no way reflect the views, plans or expectations of Ofcom. No inferences should be drawn from their inclusion in this study.

The case studies describe a baseline and a hypothetical alternative situation. The base line assumes what actually happened in the case of historic scenarios and a continuation of the current situation in future scenarios. Base line situations include situations with and without European harmonisation and standardisation. Numerous assumptions have been made to develop the alternative situations. In all cases we considered a number of options and chose the option which we considered was most likely to have happened in the absence of the harmonisation measure. We have tried to make assumptions about what might have happened in the alternative case as realistic as possible, based on discussion with Ofcom, industry and our understanding of the relevant market and regulatory background.

A description of the cases is given in Table 3.1. Some case studies consider the effects of relaxing European measures (cases 1-4 and 6 in Table 3.1) while others consider the effects of introducing measures where none currently apply (cases 5, 7 and 8 in Table 3.1). Some case studies address harmonisation issues, others address standardisation issues and others both (see Table 3.2). In the case studies we have sought to identify whether the key issue is harmonisation or standardisation, although when changes in both are going on it is generally not possible to separate the effects of liberalising or tightening each aspect. Detailed descriptions of the historical development of the relevant harmonisation and standardisation measures, the alternative situations and our quantitative analysis are given in Annexes 1-8.

Table 3.1 Summary of Case Studies

	Historic case	Future case
1. GSM 900 &1800 MHz	**Base line** Actual situation **Alternative** Assume spectrum is allocated to mobile at WARC 1979. Assume CEPT recommendations and EC Directives were not put in place. The UK decided to use band for GSM before other countries.	**Base line** Continuation of present situation **Alternative** Assume CEPT and EC measures lapse. The UK seeks to refarm 2G spectrum for 3G in advance of neighbouring countries.
2. TETRA in 854-960 MHz	**Base line** Actual situation **Alternative** Assume CEPT measures are relaxed to allow other standards (e.g. TETRAPOL). Assume CEPT decision on frequency bands for digital trunked services was not implemented.	**Base line** Continuation of present situation **Alternative** Assume CEPT Decision removed. Assume no further standardisation activities on TETRA and both wideband and narrowband systems can be deployed in the available spectrum.
3. BFWA at 2 GHz	Not applicable	**Base line** Band is allocated for use by 3G licence exempt or licensed services **Alternative** Allow use of band for broadband fixed wireless access (BFWA).
4. 32 GHz fixed band	Not applicable	**Base line** Assume the UK follows channel arrangements in the ERC Recommendation and other countries implement the Recommendation. **Alternative** Assume the UK implements the ERC Recommendation in part of the band. In the rest of the band assume the UK allows non-compliant systems.
5. PMR at 450-470 MHz	**Base line** Actual situation of non-standard use prevails **Alternative** The UK harmonised the use of the 450-470 MHz band with the rest of Europe in 1980.	**Base line** Assume band only used for narrowband technologies but the band has been realigned with the rest of Europe. **Alternative** Assume the UK allowed the band to be used for wideband as well as narrowband technologies as indicated in ECC Report 25.

	Historic case	Future case
6. UHF TV band	Not applicable	**Base line** The UK only allows use of DVB-T technology **Alternative** Assume the UK allows use of non-DVB-T mobile technologies in band and rest of Europe uses DVB-T.
7. Short range devices: radio car keys and telemetry and telecommand systems	**Base line** Non-harmonised use by radio car keys at 418 MHz and telemetry and telecommand systems at 458 MHz. **Alternative** UK followed European harmonisation of bands for radio car keys and telemetery and telecommand systems.	Not applicable
8. PMSE - Video links and wireless microphones	**Base line** Actual situation –applies i.e. bands not harmonised **Alternative** There were harmonised bands (specifying tuning ranges).	**Base line** Assume current situation where the equipment generally deployed is not defined by standards. **Alternative** Assume digital standards based on harmonised frequency bands for wireless microphones and video links.

Source: Indepen and Aegis analysis

Table 3.2 Issues addressed by case studies

	Historic case - frequency harmonisation	Historic case- Equipment standardisation	Future case – Frequency harmonisation	Future case - equipment standardisation
1. GSM 900 &1800	✔	✔	✔	✔
2. TETRA in 854-960 MHz		✔		✔
3. BFWA at 2GHz			✔	✔
4. 32 GHz fixed band			✔	✔
5. PMR at 450-470 MHz		✔		✔
6. UHF TV band			✔	✔
7. SRDs	✔	✔		
8. Video links and wireless microphones	✔			✔

Source: Indepen and Aegis analysis

3.2 GSM at 900 and 1800 MHz

This case study examines the impact of removing European harmonisation and standardisation measures for GSM services. The main focus of both the historic and the future scenarios is on the impact of removing requirements to use the GSM 900/1800 standard.

3.2.1 Historic case

3.2.1.1 Base line

The base line is the actual situation in which various CEPT measures identifying relevant frequency bands for GSM services, the GSM Directive and the Mobile Directive apply. The latter required the licensing of competing operators which stimulated growth in the market and helped drive down terminal prices.

3.2.1.2 Alternative

This case assumes that harmonisation and standardisation measures were not put in place by CEPT and the EC, but that allocations to mobile services at 900 MHz and at 1800 MHz were made at various WRCs. The latter allowed the bands to be used by any mobile service and standard (and also applies in the base line). It is assumed that the standardisation effort in Europe behind GSM happened in the same timescales that occurred in practice, because of the significant effort many countries put in to establish a digital mobile standard. It is also assumed that all countries in Europe would have adopted the GSM standard in preference to

US standards because the former were ready first, the benefits of roaming were recognised and almost all countries participated in the standardisation process.

It is assumed the UK cleared spectrum and licensed services at the same times as it did in the baseline, but that neighbouring countries' implementations were delayed by 5 years.

3.2.1.3 Analysis of costs and benefits

The absence of standardisation and harmonisation measures (for GSM 900 and 1800) in the alternative situation is assumed to have had the effect of:

- Delaying the clearing of spectrum for these services in some countries (though not in the UK)
- Delaying the licensing of services particularly in the case of DCS1800 services, though not in the UK as the UK government licensed services in advance of European measures mandating this.

These delays could have had the following impacts:

- The initial potential market size for GSM 900/1800 services across Europe would have been less than otherwise, and so equipment costs could have been higher and this in turn would have slowed market expansion.
- There would have been limitations on the use of spectrum for mobile services caused by the continued use of the spectrum for other services in neighbouring countries. This would have further reduced the potential market in the short term. In practice GSM 1800 deployment was significantly affected by French military use even with the harmonisation measures being in place.[35]
- Competition between mobile operators would be reduced both because of delays in licensing and the lack of available spectrum. This effect would have been negligible in the UK as DCS1800 operators were licensed before the relevant measures were put in place. Competition could also be affected because less spectrum was available for some operators, though this was not an issue in practice.
- Limited roaming capability, at least initially, which would have reduced the usefulness of the service and so demand.

These effects are all negative i.e. there would appear to be an unambiguous benefit from the standardisation and harmonisation measures. In this case it was the combined effect of the harmonisation measures (CEPT Decisions, the GSM directive and the Mobile Directive) and the associated standards that lead to the timely clearing of spectrum for GSM services (i.e. harmonisation) and the availability of affordable equipment that allowed international roaming (i.e. standardisation).

It is assumed that the combined impact of the effects listed above would be to delay the rate of take-up of GSM services in the UK. This means delaying consumer and producer surplus enjoyed. In quantifying the cost of delay we consider two cases:

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[35] At 900 MHz co-ordination arrangements for continued use of the analogue network (TACS) had to be negotiated in any event because of interference caused to French military systems by the UK TACS network.

- *Permanent delay*: The entire uptake profile for mobile delayed by 2 years. This alternative reflects an assumption that network effects, in terms of both word of mouth and the value to new users of a growing base of users, drive uptake.

- *Temporary delay*: The initial uptake profile is reduced by 50 per cent for 3 years, followed by instantaneous catch-up. This alternative reflects an assumption that underlying technological progress (Moore's law etc) delivers handsets of a particular functionality and battery life at a set point in time and that this drives uptake beyond the period of initial delay.

To estimate overall benefits from mobile we consider information on the growth in subscriber numbers over time under the two alternative cases above. In addition, information on the following is required:

- Estimates of consumer surplus for business and private customers.

- The mix of business and private customers.

- Estimates of producer surplus.

Producer surplus would be zero if the industry supply curve were horizontal and the industry were sufficiently competitive to ensure the market prices corresponded to the marginal costs of supply. Estimates of producer surplus published by the RA for 2G operators are however positive.[36] We use these estimates to form a judgement about the level of producer surplus over time.

Estimates of consumer surplus are also available in the same study for the RA. This gives estimates of average consumer surplus of £47 per month for business and £16 per month for private customers respectively. In the best fit models respondent's time as a mobile phone user was an explanatory factor for willingness to pay, while income was not. However, we assume for simplicity that business and private consumer surplus is not time dependent.

Net present values (at 2003 prices) were calculated for the period 1990-2003 using the HM-Treasury discount rate of 3.5%. Table 3.3 summarises the results.

Table 3.3 Total surplus estimates (£million 2003 prices) in net present value terms

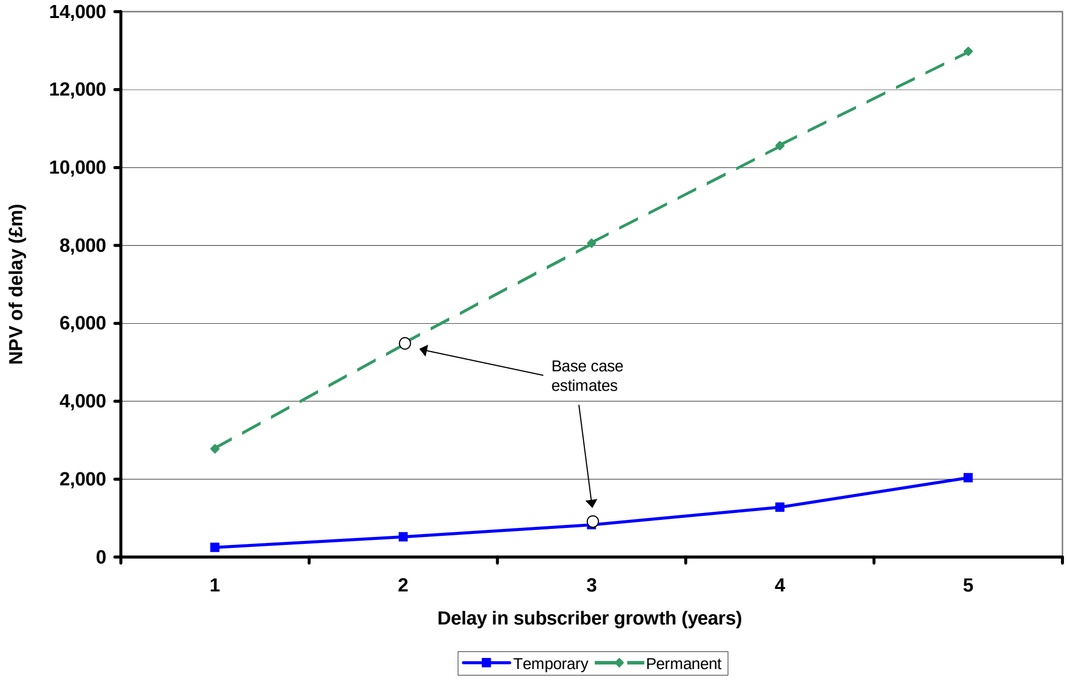
	Permanent delay	Temporary delay
Consumer surplus	5,466	829
Producer surplus	309	47
Total surplus	5,774	876

Source: Indepen and Aegis analysis

[36] *Consumer surplus to cellular mobile and pager users*, Hague Consulting Group and Accent Marketing and Research. February 2001. http://www.radio.gov.uk/topics/economic/surveys/cellular.pdfPositive producer surplus could reflect a number of underlying factors. Spectrum is constrained and therefore the industry supply curve may be upward sloping. In addition, in new industries involving initially risky investments returns are likely to be above "normal" if the industry is successful to compensate for the *ex ante* risk that the industry would have proved unsuccessful.

These estimates highlight the very high cost of delay, and the substantial benefits of harmonisation and standardisation for GSM mobile. The reason delay is so costly, particularly for the permanent delay case, is that all of the consumer and producer surplus is delayed and discounting reduces the present value. In contrast, changes that impact on the price of a service may have only a marginal impact on total surplus. Figure 3.1 shows the sensitivity of the estimates to variations in the delay period.

Figure 3.1 Impact of delays on NPV estimates



Source: Indepen and Aegis analysis

3.2.2 Future case

3.2.2.1 Base line

The existing CEPT/EC measures for GSM and DCS1800 continue in force thereby blocking refarming of spectrum to 3G and other uses.[37]

3.2.2.2 Alternative

CEPT/EC measures lapse and the UK seeks to refarm 2G spectrum to 3G services in advance of other countries in Europe. It is assumed this happens once operators require

[37] The CEPT measures refer specifically to the GSM standard although the GSM Directive only refers to a digital mobile system. It is possible that this might allow 3G though this would depend on a legal interpretation of the Directive. Also not all the currently available spectrum is referred to in the GSM Directive.

additional spectrum for 3G or must invest in additional infrastructure to exploit their existing spectrum.[38]

3.2.2.3 *Analysis of costs and benefits*

The potential costs of removing the standardisation and harmonisation measures are the costs of any interference between 3G networks and the existing GSM networks in this band. The Autonomy Study results show interference issues, arising from the UK moving to 3G use while neighbouring countries continue to use the spectrum for 2G services, are not a concern. The costs (in terms of additional base stations) of co-ordinating with 3G use are higher than with 2G use, though in both cases the costs are likely to be small (less than around £10m) relative to the costs of 3G deployment (see Annex 1).

The mature state of the GSM market means that other effects listed in Tables 2.1 and 2.2 (i.e. the benefits of harmonisation and standardisation) do not apply. This is because with penetration rates of over 70% the benefits of interoperability, low cost equipment, competition and international mobility have already been realised.

The potential benefits of refarming the 2G spectrum to 3G are:

- Reduced costs for operators who could expand capacity by using the current 2G spectrum more efficiently rather than investing in smaller cells. We assume refarming would only occur once existing 3G spectrum (including extension bands) becomes congested.[39]
- Reduced costs for operators from running only one network.
- Increased spectral efficiency as 3G is more spectrally efficient than 2G and in most cases 2.5G. Our simple analysis suggests that 3G services could be up to three times as efficient as 2G.[40]
- A stimulus to competition if the spectrum is assigned to all five 3G operators thereby putting the 3G only operator on a more equal footing with the four 2G operators in terms of its spectrum allocation. We are uncertain as to the extent of this benefit as it depends on how the extension spectrum for 3G is assigned between the 5 operators and the number of cell sites required to provide coverage at 900 or 1800 MHz rather than in the extension spectrum.[41] The scale of the cost differential also depends on whether the additional spectrum is used to extend coverage or provide additional network capacity in hotspots.

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[38] It is assumed that 3G services are the highest alternative use of the spectrum.

[39] *Consideration of possible frequency plans for the 3G expansion spectrum, 2500 to 2690 MHz - a consultation document* and *Use of the 2010 to 2025 MHz Band for the provision of 3G telecommunications services - a consultation document*. Radiocommunications Agency, October 2003.

[40] The following table illustrates how the technical efficiency of typical cellular networks, expressed in terms of erlangs/MHz/km2 has evolved from first to third generation systems

Speech channels/ MHz	TACS 40	GSM 40	UMTS 32
Cell repeat factor	TACS 7	GSM 4	UMTS 1
Average cell area (sq km)	TACS 3.14	GSM 0.79	UMTS .79
Speech chan/MHz/sq km	TACS 1.82	GSM 12.66	UMTS 40.51

[41] It could require more than 5 times as many cell sites to provide coverage in the extension bands as compared with 900 and 1800 MHz.

These benefits have not been quantified because of the many market and policy uncertainties concerning the future roll-out of 3G services. However, these benefits would have to exceed the costs that operators may incur in migrating mobile users from 2G to multi-band 3G terminals for refarming to be worthwhile.

The costs of migrating mobile users from 2G to multi-band 3G terminals would be partially offset by the benefits users may gain from migration, even though these benefits were insufficient to promote voluntary migration. These costs will depend on the residual pool of 2G handset owners at the time operators switch to 3G only networks and the costs of providing them with an equivalent 3G handset. Operators may do this on a progressive basis where congestion arises by progressively moving spectrum from 2G to 3G, or all at once. Operators would be expected to promote switchover only after other lower cost alternatives are exhausted, potentially including increasing the density of 3G base stations and using other available spectrum (extension bands etc).

As our base case we assume that the proportion of the population owning 2G handsets halves every 36 months from a level of 100% in 2003 (in other words 50% of replacement phones are 3G phones with a replacement cycle of 36 months).[42] By 2010 the percentage of adults with 2G phones would then be around 20%. Based on the Annual Abstract of Statistics (2001) there will be 49.5 million adults (over the age of 16) in the UK in 2010. Based on the population and estimated percentage of 2G handsets we therefore estimate that there would be 10 million 2G handsets left in the UK in 2010.

Assuming handset terminals are replaced at a cost to operators of £200-300[43] per handset, and half of the 2G phones are new and half are 36 months old and so due for replacement in 2010, the estimated cost of replacing the handsets is £645-968m (in 2003 prices).

In addition, allowance should be made for the fact that those who are upgraded to 3G handsets are likely to obtain some benefit from the upgrade, even though they had chosen not to upgrade when they faced the costs of upgrade. Assuming a 3G upgrade involves a margin of £50 to the customer over a replacement 2G handset, and a uniform distribution of valuations for the margin of 3G over 2G service below this threshold for those who do not upgrade, there would be an average benefit of £25 for those who are upgraded. This gives an estimated benefit of £96 million from the transition to 3G. The net social cost is therefore £645-968m, less £96 million, or £549-872 million (in 2003 prices).

The residual number of 2G handsets, and therefore the cost of transition, is sensitive to the number of customers who are assumed to switch from 2G to 3G every 36 months. This sensitivity is illustrated in Figure 3.2. By 2010 the proportion of customers with 2G handsets ranges from 4% to 51% for customer switching rates of 75% and 25% respectively.

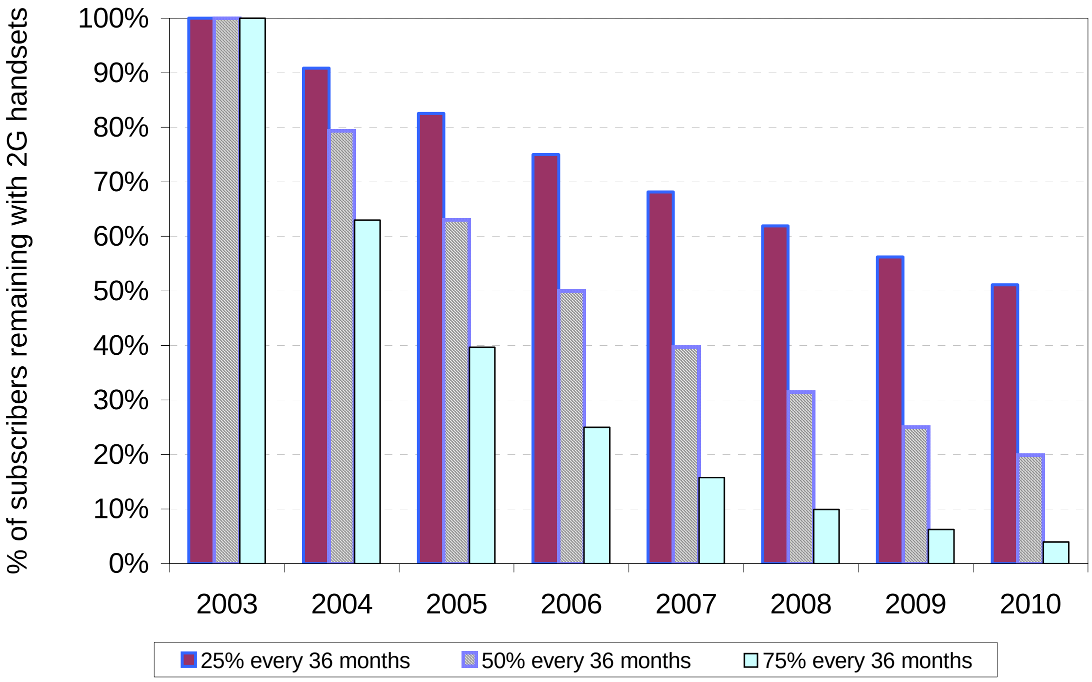
For 3G refarming to be economic for operators the net costs must be lower than those of feasible alternatives sources of spectrum/capacity, including expenditure on additional base stations. Given the potential scale of the handset replacement costs in 2010 it is far from

[42] *Enders Analysis Global Mobile Trends* August 2003 reports the average handset life for 2002 in Western Europe as 3.1 years. The Orange Social and Environmental Report states that Orange customers upgrade their handsets every 22 months on average.

[43] This is the difference between the cost of obtaining a 3G handset from “3” with and without a contract. www.three.co.uk

clear that this would be the case, unless the voluntary rate of switching to 3G handsets is much faster than we have assumed.

Figure 3.2 Proportion of customers with 2G handsets as a function of the proportion switching from 2G to 3G every 36 months



Source: Indepen and Aegis analysis

For 2G to 3G refarming to be feasible there would be a requirement for multi-mode and multi-band user terminals to support roaming. From our discussions with some of the major manufacturers we understand that demand in the UK alone would probably be insufficient to support the development and manufacture of such terminals.[44] The manufacturers would want at least the other major European countries to have the same policy. If a product was to be manufactured for the UK only it would be very expensive. The operators would have to subsidise this cost because users would not see any difference in the service they receive and there would be no incentive for them to purchase handsets that support 3G in the 900 and/or 1800 MHz bands.

3.2.3 Comments

GSM services are subject to European harmonisation and standardisation measures promulgated by CEPT, the EU and ETSI. The measures are generally regarded as having contributed to the success of GSM technology.[45] The academic literature is more mixed, for

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[44] At one stage, about the mid 90's, there were proposals to develop a GSM 1800/DECT handset. No such handsets became available and this could have been because:

- the potential size of the market was estimated to be less than a tenth of the tri-band terminal market or
- there was little incentive for the operators to subsidise such a terminal that did not provide them additional revenue.

[45] For example, Haug (2002) concludes that the GSM's success can be attributed to its fortunate timing (coinciding with growth in market demand), the possibility of international roaming and scale economies that arose from the fact

example Gruber and Verboven (2002) find that adoption of a single analogue mobile standard (by a country) increased speed of uptake, while a single digital GSM standard did not significantly affect the rate of diffusion (since the advantages from competing emerging systems e.g. CDMA compensate for the advantages from a single standard).

Other equally prescriptive European harmonisation and standardisation efforts have been notably unsuccessful, namely those for the ERMES paging system and the TFTS service, neither of which has had a successful commercial service launched. This raises the question of whether GSM was successful because it met market demand and there was competition which drove down prices or whether harmonisation and standardisation measures also played a significant role in its success. Our analysis suggests that the harmonisation and standardisation measures helped to clear spectrum faster than would have occurred otherwise and so delivered significant benefits in terms of consumer and producer surplus that would otherwise have been lost. However these gains represent only a small fraction of the total welfare gain from the introduction of the GSM service.

Looking to the future the harmonisation/standardisation measures potentially block reallocation of the GSM frequency bands to other services. The removal of these measures would allow the Ofcom to reconfigure the use of the spectrum in the 900 and 1800 MHz frequency bands. Based on discussions with manufacturers there could be little advantage in doing this in advance of other major countries in Europe as handsets are unlikely to be made at a reasonable price. However there is also little cost.

3.3 TETRA in 854-960 MHz

This case study addresses the implications of requirements to adopt the European TETRA standard in the 854-960 MHz frequency band. The potential consequences of relaxing the standards requirement are considered.

3.3.1 Base line – historic and future

There are two bands allocated to TETRA in the UK in the selected frequency range: one is 872 – 876 MHz paired with 917 – 921 MHz for civil use and the other is 871 – 872 MHz paired with 916 – 917 MHz for private use. ERC Decision(96) identifies the band 870-876 MHz paired with 915-921 MHz for TETRA but does not specify whether it is to be used for private or civil purposes. The base line is the situation in which this ERC Decision applies.

In the UK, following the closure of the analogue cellular service in 2001, 2x4 MHz of spectrum (872-876 MHz and 917-921 MHz) was allocated to Dolphin for TETRA Release 2 in 2002.[46] Going forward it is assumed that this situation continues.

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that the system was an accepted standard. (*A commentary on standardisation practices: lessons from the NMT and GSM mobile telephone standards histories*, T Haug, Telecommunications Policy 26 (2002). Methe and Funk (op. cit.) also note that if "Europe in mass had not decided to adopt a single digital standard, there probably would have been a great deal of confusion in Europe over mobile technologies and Europe would probably have moved more slowly to digital systems; perhaps as slowly as the US".

[46] The RA considered whether to allocate the spectrum to GSM services but decided against this on the grounds that the TETRA operator did not have sufficient spectrum to operate a mature network and there would be no GSM handsets that could operate in the band. See *Spectrum for TETRA Mobile Services in the 872-876 MHz and 917-921 MHz bands*, RA Consultative Document August 2001.

We note that the requirement to use TETRA Release 2 is not mandatory under ERC Decisions (i.e. this is a UK requirement) but that the data capabilities of Release 2 are likely to be required to meet market demand for increased data rates. TETRA Release 2 still requires a test specification and therefore there is no equipment available for this service. The spectrum is currently sitting idle.

3.3.2 Alternative – historic and future

The alternative case is the situation in which standardisation requirements are relaxed thereby allowing other standards to use the band. It is assumed the band continues to be used for a civil mobile application.

3.3.3 Analysis of costs and benefits

Deployment of TETRA systems at 400 MHz has been slow although it has grown considerably over the last year,[47] and there has been no deployment at 900 MHz. This can be attributed to a number of factors including:

- *Slow standards development*: TETRA standards have taken 13 years to be produced (see Annex 2).
- *Competition from other services*: Market demand has been weak because, in the time taken to develop standards, GSM has taken the high-value end of the market and PMR446 (i.e. unlicensed PMR services) has taken the low value end.
- *Multiplicity of services*: The TETRA standard defined around 28 telephony services (e.g. follow me services, ambient listening) and each vendor has implemented a limited number of these. This has resulted in the vendors being out of phase with each other.
- *Internal interfaces are not specified*: This means it is not possible for an operator to purchase the base stations, switches or other network elements from different manufacturers to increase competition between equipment vendors as is the case with GSM.
- *Lack of roaming capability*: It had not been anticipated that there would be a need for roaming on to other networks. SIM cards were added late in the development of the standard and are not generally implemented.
- *Cost of terminals*: TETRA terminals are at least 2 to 2 ½ times the cost of GSM terminals and no doubt this is a function of the small market size and its fragmentation between emergency service and civil applications.
- *Size of terminals*: Initially TETRA terminals were large relative to GSM terminals and therefore not as attractive to end users.

[47] In 2003 the number of contracts for TETRA systems increased by 84%. Most systems were for public safety and transport applications. See *Turning Point*, Richard Lambley, Land Mobile, 2003.

- *Slow release of spectrum*: In the initial phases of the roll-out of the Dolphin network access to spectrum was very constrained by military use of the 410-430 MHz band. This made it difficult to plan to avoid interference. In addition, Dolphin had to take measures to try and limit interference to SRDs (radio car keys) mainly in the 418 MHz band.

A more liberal approach to equipment standards in the 900 MHz bands could have resulted in a better outcome, in the sense that there would be a better prospect of the spectrum being used rather than remaining idle.

At the time of the UK's decision to licence the 900 MHz band for TETRA2 there were a number of other standards that could have been used, namely[48]: Tetrapol, if there had been sufficient interest to develop a variant that would operate in the 900 MHz band; PMR; GSM or 3G. There are also now standards available in the US for digital PAMR (namely TIA-97-E and TIA-98-E). The air interface is already in use as it is the same as that for IMT 2000 and equipment is available for use in the 900 MHz band for PAMR.[49]

The main cost therefore of requiring standardised equipment compliant with TETRA release 2 is the risk that spectrum sits idle and that the time taken to complete the standard again loses the market opportunity for the service. The key candidates for alternative use of the spectrum are PMR or US digital PAMR services.[50] Demand for wide area PMR has been static or declining in recent years so it seems unlikely there would be demand from this source. Demand for digital PAMR services is uncertain but the advantages of CDMA PAMR as compared with TETRA[51] and its ready availability could stimulate demand. The opportunity cost of spectrum for PAMR was estimated to be £1.27m/2x1 MHz in the spectrum pricing study for Ofcom. These values are likely to overestimate the value of additional spectrum as the marginal value can be expected to decline as the supply of spectrum increases. Nevertheless this suggests that the value of the idle spectrum could be as much as £5m per annum.

If any PAMR standard could have been deployed there might have been interference issues to deal with – both within the UK and between UK and neighbouring countries. However it would be expected that adjacent band compatibility studies would be undertaken by CEPT before deploying any systems. CEPT has completed compatibility studies for both 200 kHz and 1.25 MHz[52] wideband systems. Furthermore we note that the spectrum is not used in neighbouring countries so interference issues at least initially would be minimal.

3.3.4 Comments

This case study illustrates the costs of harmonisation measures which prescribe a single standard that takes many years to be developed, contains too many options and compromises and does not specify interfaces sufficiently to allow interworking between

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[48] In addition, the DSI III suggested that the bands might also be used for fixed wireless access (on a co-primary basis in rural areas), short range devices (spread spectrum devices, RFIDS) and military tactical radio relay.

[49] It is specified as band class 12 equipment for European PAMR.

[50] It is assumed there is currently sufficient harmonised spectrum for 3G for the immediate future.

[51] CDMA PAMR is more spectrally efficient. It can support more voice channels than TETRA and also can deliver around 30-60% more data capacity.

[52] There is a draft ECC Decision covering 1.25 MHz CDMA-PAMR wideband systems which is expected to be approved in March 2004.

different manufacturers products. The main constraint in this case study is the standards requirement. The case study demonstrates the important role played by vendors in developing the standards and that if they are not supportive the standards will either be delayed or not completed. In these circumstances the market may be lost to another service and this is what has happened here with the potential market for digital PAMR being eroded by both PMR 446 and GSM. It is possible that if use of the 900 MHz band for civil PAMR had been permitted and standards were not prescribed there would have been the opportunity to start the roll-out of digital PAMR systems in 2004. In the event, the spectrum will remain idle until manufacturers are prepared to make equipment for the 900 MHz band or another technology is permitted in the band.

3.4 Broadband Fixed Wireless Access at 2GHz

The 2010-2025 MHz band is currently allocated to licence exempt (i.e. self-co-ordinated) 3G services. ERC Decision (99)25 states “that subject to market demand, Administrations make provision to allow the operation of UMTS self provided applications in a self co-ordinated mode in the frequency band identified in Annex 1” i.e. the 2010 – 2020 MHz band. The Decision also says, “However, the ERC may review this “Decision” within two years after the date of entry into force” (31 January 2000). Twenty six administrations have signed up to the Decision including the UK.

At present there is no standard and hence no equipment for self-co-ordinated use of the band and so the spectrum is sitting idle. It is widely expected that it will be at least 2-3 years before a standard is produced and equipment becomes available for use in the band on a licence exempt basis.

The ERC Decision does not limit use of the band to self-provided 3G systems, as requirements are subject to market demand i.e. whether equipment is available. Hence licensed 3G services could in principle also use the band and 3G operators have indicated they may be interested in having access to the band for licensed services at the time the expansion spectrum (2500-2690 MHz) is released.[53] This suggests that we should compare use of the band for any 3G services with use by other services. In discussion with Ofcom it was agreed that BFWA would provide a reasonable alternative comparison for the purposes of the case study.

3.4.1 Base line

The UK reserves the spectrum for use by licence exempt or licensed 3G systems. Note this represents a change in current UK policy under which only licence exempt systems are currently allowed.

3.4.2 Alternative

The UK relaxes the constraint imposed by ERC measures and so allows systems other than 3G services in the band, in particular broadband fixed wireless access services (BFWA). Use of the band is assumed to be constrained by the need to not interfere with services operating

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[53] See responses the *Consultation document use of the 2010-2025 MHz band for the provision of 3G telecommunications services*, RA, 9 December 2003.

in adjacent frequency bands (e.g. space operation, Tactical Radio Relay, and PMSE). It is assumed no standardisation requirements or channel plans are imposed.

3.4.3 Analysis

The potential costs/benefits of standardisation and harmonisation in this case study are the costs/benefits of the spectrum delivering less/more welfare when used for 3G services as compared with BFWA. In considering the welfare benefits associated with use of spectrum for BFWA we need to take account of any interference between these systems and 3G systems that may be deployed elsewhere in Europe.

Our estimates of the consumer surplus that may be derived from use of the spectrum in different applications are as follows:

3.4.3.1 3G licence exempt

Given the current absence of equipment and demand for services we consider the value for 3G licence exempt use of the band is likely to be small or zero. Industry views differ. It is thought by some industry participants that the market for licence exempt services has largely been taken by other systems at 2.4 GHz and 5 GHz. However, in response to the RA consultation on the use of the 2010 to 2025 MHz band a number of the respondents felt that the band should be retained for self-provided use and considered that delays in use of this spectrum were due to delays in the use of licensed 3G TDD networks.[54]

3.4.3.2 BFWA

We have modelled the potential cost and take-up of BFWA in order to derive estimates of consumer surplus for households and businesses. The cost of the service is based on costs of services deployed in other countries and take-up is based on the assumption of a logistic take-up curve, technical coverage constraints and assumptions concerning the relative cost of BFWA and DSL. The details are given in Annex 3. The NPV of consumer surplus for three scenarios in which BFWA is assumed to have respectively the same, a higher and a lower cost than DSL are shown in Table 3.3. As can be seen there is a wide range in the estimates.

Table 3.4 NPV of consumer surplus (£million2003 prices)

	Scenario 1 Cost of BFWA = DSL	Scenario 2 Cost of BFWA > DSL	Scenario 3 Cost of BFWA < DSL
Households	2,323	744	3,902
Businesses	321	140	502
Total	2,644	884	4,404

Source: Indepen and Aegis analysis

It has been suggested to us that these estimates may be overly optimistic given that FWA services have not been particularly successful so far in the UK. One counter argument is that

[54] Also one reply to the RA's consultation expressed the view that "short term or frequent term reviews of band allocation create an environment of regulatory uncertainty. Such an environment discourages research, development and investment". It was proposed that there should be at least 10 years before this band was re-examined.

the 2GHz frequency band is more attractive than others so far allocated to the service (at 3.5 GHz, 10 GHz and 28 GHz) because of the availability of cheaper equipment and the greater range of transmissions.

We agree there is a risk that the service could fail but we note that the chances of BFWA failing will rise the longer the decision concerning spectrum access is delayed, as cable and DSL will take much of its potential market.

3.4.3.3 3G licensed

The spectrum could in principle be used for 3G licensed services, either as expansion spectrum or to provide an additional network. We have estimated that if one operator had access to all 15 MHz of spectrum then each base station could support 2,000-4,000 users in a busy hour (see Annex 3 for details). Given a network may have many thousands of base stations it is clear that a considerable number of users could be supported by this spectrum. However, it would not be correct to assume that these users would not otherwise have access to 3G services. Rather it could be expected that the spectrum will be used to support both growth in the number of users and growth in traffic levels or to provide an improved grade of service to users. In any event it is possible the spectrum could be of value to 3G operators.

The consumer surplus benefits from use of the spectrum for 3G services cannot be estimated reliably as we do not know how the spectrum will be used in practice. We observe however that the benefits could be considerable, if estimates of the consumer surplus from 3G services produced in research for the RA are used.[55] These estimates give a value per user of £500-720/annum. Given the spectrum could in principle support millions of users the implied consumer surplus could be in excess of £1bn.

The inter-dependencies between alternative 3G expansion options, and potential competition between use for 3G and use for BFWA, suggest that consideration should be given to auctioning the 2010-2025 MHz band for licensed use in a technology neutral way i.e. that would allow either 3G or BFWA or some other use of the spectrum. This would entail some risk for the UK if at some point in future there is a harmonisation measure that pairs the spectrum with some other frequency band, in which case the latter might be left underused.

3.4.3.4 Interference Issues

Considering lastly interference issues, the Autonomy Study has considered the use of BFWA in this spectrum with neighbouring countries deploying self-provided 3G systems both indoors and outdoors with a maximum EIRP of 25 W to avoid excessive cross border interference. The study found that serious restrictions on output powers in parts of South East England that comprise about 1.4% of the UK geographic area although the area over which interference would have some effect would be 35,000 km^2 (14% of UK geographic area). In Northern Ireland the increase in the number of sites required is likely to make the provision of BFWA uneconomic. Overall we conclude that the impact of interference constraints on the deployment of BFWA is likely to be small.

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[55] *Cellular Mobile/Fixed Services: RP/SP survey main results*, Rand Europe, for the Radiocommunications Agency, 28 January 2002.

3.4.4 Comments

This case study has assumed Ofcom requires that the 2010-2025 band is used for either 3G or BFWA services. The estimated net benefits of BFWA are substantial. Licensed 3G use may also offer substantial benefits. However, a less prescriptive approach could be adopted in which the band is designated for fixed and mobile services and requirements that ensure services do not interfere with services operating in adjacent bands imposed. The key issue then is whether services are licensed or not. Improved estimates of the value of and possible demand for licence exempt versus licensed services are required in order to make this trade-off.

3.5 32 GHz Fixed Band

Harmonised CEPT channel arrangements have been developed for this band with the same channel spacings as in the fixed service bands below and above this band. This provides opportunities to use similar equipment and systems. The RA allocated one-third of the band to fixed links and the rest to general fixed services.[56] The policy issue to be addressed is: should the UK depart from European standards (i.e. channel spacing) when deciding the constraints on use of that part of the band allocated to general fixed services?

There is no historic use of the band and so the focus is on possible future scenarios.

3.5.1 Base line

The base case assumes that the UK and other countries implement the channel arrangements proposed in the relevant ERC Recommendation in the entire band.

3.5.2 Alternative

Other countries implement the ERC Recommendation but the UK allows non-compliant systems anywhere in the band.

3.5.3 Analysis

The potential costs of standardisation in this case are that high valued uses of the band are not given access to the spectrum, while the potential benefits are that harmonised channel arrangements allow more efficient use of spectrum. In analysing these costs and benefits a key question is whether the 32 GHz band is likely to be congested.

The first consideration is that the 32 GHz band is not used and there is apparently no market demand currently. A possible future source of demand is for fixed links for 3G operators. We have analysed demand from these operators using the information provided by the RA on fixed link requirements to support 3rd generation mobile infrastructure (see Annex 4).[57]

[56] The RA has not specified the nature of these services but rather has asked for suggestions from industry.

[57] *Fixed Link Requirements to Support Third Generation Mobile Infrastructure*, FLCC (02-01)/005, Radiocommunications Agency.

This analysis suggests that if these demands materialise then in the worst case all the available spectrum at 32 GHz [58] would be required for fixed links.

Even if the 32 GHz band was to become congested there are other millimetric bands that could be used, that are currently not congested (e.g. 23 GHz, 26 GHz, 38 GHz and, for shorter links, 52 and 55GHz) and for which equipment costs, at least up to 38 GHz are the same as for the 32 GHz band. We understand that it is feasible to produce a new product in between 3 and 6 months. Manufacturers have indicated that the existence of ERC Decisions / Recommendations does not influence their decision to develop and manufacture equipment for new frequency bands although they see benefits in harmonisation and standardisation as it provides a potentially larger market for their products. The decision is market driven and there needs to be sufficient demand ideally from a number of operators in a number of countries.[59] This factor suggests that were congestion to appear in the 32 GHz band users could readily make use of other vacant millimetric bands.

Of course fixed links may not be the highest value use of the band. The alternative case allows for this possibility by permitting other uses such as FWA, high altitude platform services (HAPS) and wireless cameras for studios. Demand from HAPS and FWA services seems even less likely than from fixed links, as there are still licences available at 28 GHz and as far as the study team is aware there are currently no initiatives to deploy HAPs. Millimetric bands are not suitable for ENG/OB applications, because of the short range of the frequencies, however, they might be attractive to programme makers for cable-free High Definition studio cameras perhaps operating at 100 – 200 Mbit/s in 50 – 100 MHz bandwidth channels. A big studio might use 10 cameras, which would require up to 1GHz of spectrum, although frequency re-use between studios would be very high. However, at the moment we are not aware of any research on use of the millimetric bands by studio cameras. The alternative case also allows use of non-compliant equipment that may better suit users requirements. For example, it may allow the entry of lower cost equipment that does not meet the ETSI transmitter mask for a specific type of modulation. The disadvantage is that this approach is likely to be less spectrally efficient because there may be parts of the band that cannot be used because of a mix of different channel plans or the equipment itself is less spectrally efficient.[60] This is becoming less of an issue as there is now fixed link equipment available that has the flexibility to operate over a range of duplex spacings and that can be re-tuned without taking it out of service.[61] This tends to indicate that there is the potential for other manufacturers to meet such requirements.

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[58] This is very much a worst case scenario as the assumption has been that links with lengths between 2 and 10 kms will be assigned in the 32 GHz band. Based on assignments in other frequency bands link lengths of between 2 and 4 kms are more likely to be assigned in this band. For the purposes of this study a re-use figure of 300 has been used based on historic re-use figures in other fixed link bands. This re-use figure could be even higher if it is assumed that automatic transmitter power control will be used on all the links.

[59] In certain circumstances it is understood that a request from a single operator in a single country with a minimum requirement for 50-100 links could be sufficient volume to justify development and manufacture.

[60] For example, if the spectrum was to be used for FWA on a regional basis there would be less efficient use of spectrum. Based on information available in a draft IEEE Coexistence Recommended Practice document then for there to be no requirement to co-ordinate there needs to be:

- A separation distance of greater than 80 km between the point-to-point station and the service area boundary of the point-to-multipoint system, in the direction of the link if they are to operate on the same channel.
- A frequency separation of two guard channels to allow the operation in the same geographic area.

[61] There are technologies now being implemented in some equipment that allow the duplex spacing of the equipment to be altered within the frequency range of the diplexer. In this case it would be feasible to define the transmit and

The Autonomy Study concluded that for Southern England there would be a need to co-ordinate with France on a site by site basis for a small percentage of cases. The situation would be unchanged with or without the same channel plan / equipment standards. In Northern Ireland, based on the Berlin Agreement 2001[62], a coordination distance of 50km will apply from any border for frequencies between 30 and 43.5 GHz. Therefore, an estimate of the potential loss of usable spectrum is that, within approximately 50 km of the border:

- Half the spectrum would be denied to UK assignments, and this would be the same with and without a relaxation of the technical standards[63];
- A maximum of 4.8% of this (preferred) spectrum, but likely less, could be denied to the UK in the case of relaxed standards.

However actual assignments in other frequency bands indicate that operators tend to request frequencies for fixed links with lengths that are closer to the minimum allowed value in the band rather than the maximum. It is therefore unlikely there will be many links with lengths longer than 4 / 5 kms and so the assumption in the Autonomy Study of link lengths between 2 and 10 kms is a worst case. The potential for interference will be less than that estimated as the transmitter powers will be lower than assumed. It is also noted that in adjoining bands the RA have only registered the assignments with the ITU. The reduction in available spectrum to the UK of 4.8% in Northern Ireland is considered to be well within the margin of error in our estimates of demand for the band.

3.5.4 Comments

In summary, the expected costs and benefits of relaxing the harmonisation measure specifying channel plans for the 32 GHz band (i.e. standardisation) are both small. There is potential for upside in the benefits if new applications that could use the 32 GHz band are developed as a result of relaxing the harmonisation measure and there is a small potential downside risk of congestion arising from less efficient use of the spectrum.

3.6 Private Mobile Radio 450-470 MHz

This case study is concerned with the timing of UK efforts to standardise frequency use (namely base station and user terminal frequencies) in the UK so that it aligns with that elsewhere in Europe. Should it have been done earlier, when there were relatively few users and so the costs of change were low but there was no obvious benefit, or postponed to later, when there may be greater disruption costs but also a greater need to harmonise use because of interference issues?

The current costs and benefits of realigning base station and transmitter frequencies with those that apply in Europe (estimated by the RA) are compared with the costs and benefits

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receive frequencies independently and there is no need to define a specific duplex spacing. If at a later date the duplex spacing required modifying then it would be possible to re-tune the equipment in the field using software.

[62] The Berlin Agreement 2001, Annex 11. Note, the UK is not party to this agreement.

[63] It is our understanding that there is no denial of spectrum due to interference in lower frequency bands (23 and 26 GHz) where it would be expected that the potential for interference would be higher. So the effects may be less than those estimated.

that would have been incurred had the UK aligned with Europe in 1980, when the opportunity to realign was made possible by the migration of fixed links from the band.

3.6.1 Historic case

3.6.1.1 Base line

Use of the 450-470 MHz band does not conform to the relevant CEPT recommendations. In the UK the base station and user terminal frequencies are the reverse of those used elsewhere in Europe. This situation is expected to end in 2005 when Ofcom plans to start to realign the band to comply with the CEPT Recommendations. The realignment process is expected to be finished by 2010. The baseline assumes this situation applies.

3.6.1.2 Alternative

The alternative scenario assumes the UK adopted the CEPT channel arrangement in 1980 when the migration of fixed links from the band released spectrum that could have been used to facilitate band reversal.

3.6.1.3 Analysis

The main potential benefits from earlier re-alignment are:

- The earlier release of spectrum made possible by more efficient repackaging of assignments. Ofcom estimates that 2x2-2x3 MHz would have been released. The amount of spectrum and its value would have been less than it is today, because there were fewer users in the band and willingness to pay would have been less. We have assumed that the value of the spectrum in 1980 is the value in 2001 deflated by the growth in GDP.
- The avoidance of interference from systems in mainland Europe. It has been estimated by the RA that approximately 12% of all base stations could experience interference problems and would either have to be retuned or replaced. This has not been a problem so far as systems have not yet been deployed. It is possible that in future more systems will use the band in mainland Europe and so we assume that each year between 2005 and 2010 2-3% of base stations experience interference and half of these need retuning and half need to be replaced.

The costs from earlier re-alignment are those associated with retuning or replacing equipment, including equipment and staff costs.

Costs that we have not quantified are:

- The forgone opportunity of implementing NMT 450 technology for analogue mobile rather than TACs, so that users would have benefited from roaming opportunities.
- Lower cost equipment that might have been available if the UK had adopted the European plan. However, we understand from discussions with industry that there is little or no difference in equipment costs at least for on-site systems that are used in this band.

- The costs of replacing or retuning equipment for uses of the band other than PMR that may be affected by the realignment (e.g. scanning telemetry). This cost was not estimated because of lack of suitable data.

We have estimated the costs and benefits of re-alignment in 1980 and compared these with the costs of realignment in 2005. In doing this we have assumed a range of values for the additional spectrum released. We start with a value of £0.624/MHz based on the opportunity cost of spectrum calculated for Ofcom in the spectrum pricing study.[64] However there are reasons to believe that this value might increase in future, as we understand that new PMR users may not be permitted access to the 410-430 MHz band. We have therefore tested the effect of values at £1m/MHz and £1.3m/MHz in 2001.[65] These values have been adjusted by GDP growth to give values for other years. In addition we have taken the assumptions concerning the retuning, replacement and staff costs of days made in the RA's cost/benefit analysis.[66] The cumulative net benefits under the base case and the alternative are shown in Figure 3.3, assuming this range of spectrum values and that 3MHz is released by realigning the use of the band with that in the rest of Europe.

The results are sensitive to the assumptions concerning the value of spectrum released by the realignment (see Figure 3.3). We find that if a spectrum value of £0.624m/MHz is assumed then the NPV of the costs and benefits is positive under the base case and much larger under the alternative: £4m to £16m under the base case and £78m to £124m under the alternative case (assuming 2 and 3 MHz are released respectively). The NPV under the base more than doubles if the value of spectrum is increased to £1m/MHz which may be appropriate in future if expected increased constraints on PMR use of spectrum occur.

It is important to note that these estimates do not take account of the potential benefits from introducing digital technology, including wideband PAMR systems, that band realignment may offer. Digital PMR equipment could be available from 2006 on and it can be expected that this equipment will be made to match the European band alignment. It is not obvious that equipment will be made for the reverse alignment in the UK in which case users will have to use inferior (e.g. more costly or less appropriate) substitutes for digital PMR.

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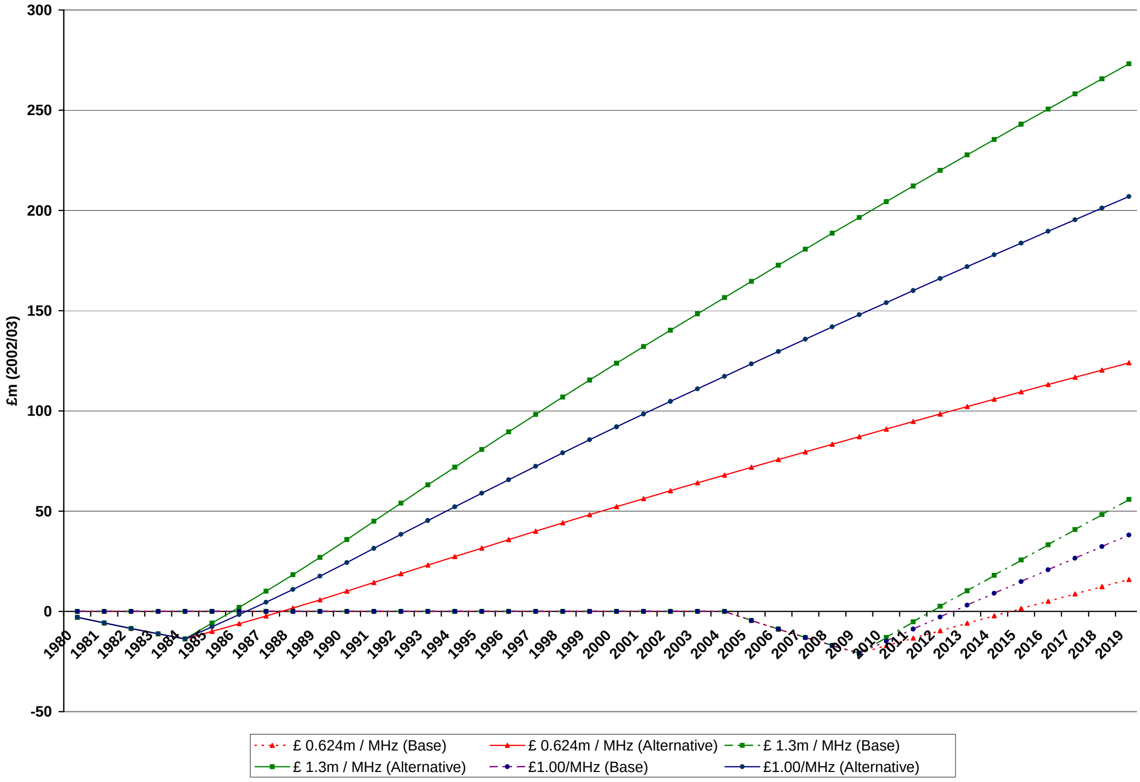
[64] See Indepen et al (2004) op. cit.

[65] The estimate of £1.3m/MHz value is an alternative estimate of the marginal value of PMR spectrum assuming the average value is £27m/MHz and that the demand curve is linear. The average value of £27m/MHz is derived from the RA's estimate of the consumer surplus associated with all use of the spectrum by PMR. Consumer surplus is proportional to the square of quantity with a linear demand function.

[66] *Quantifying the Costs and Benefits of the 450-470 MHz Band Alignment*, Radiocommunications Agency, April 2nd 2003

Figure 3.3 Cumulative Net Benefits from Band Realignment (£m 2003 prices)



Source: Indepen and Aegis analysis

3.6.2 Future

3.6.2.1 Base line

The UK continues to use the band for narrowband PMR analogue systems (and SRDs) in accordance with the current ERC Recommendation T/R 25-08. In practice users may also be able to deploy narrowband digital systems instead of analogue when replacing equipment as part of the band alignment process.

3.6.2.2 Alternative

It is assumed the UK allows the band to be refarmed according to market demands for wideband or broadband services as proposed in ECC Report 25. In this case the UK is following a European strategy that provides national flexibility in the use of the spectrum depending on the availability of equipment.

3.6.2.3 Analysis

A potential benefit of the base line relative to the alternative is that interference between narrowband and wideband or broadband PMR systems would be avoided. However, the results of the Autonomy Study show that the extent of the interference between wide band (200 kHz) PMR and narrowband digital PMR[67] is less than for narrowband into narrowband digital PMR. In particular, it is found that the limit on the cross border field strength has a bigger impact on the number of additional base stations required in the UK than interference from French narrow band systems. The number of additional base stations required for both narrowband and wide band are determined by the maximum field strengths that can be caused in France. The type of system deployed in France will therefore not impact on the decision on what system to deploy in the UK. UK users are likely to make their choice between the different systems based on availability of equipment and services, capacity, coverage and costs including any additional costs that might be incurred to meet the cross border emissions.

The potential costs of the base line relative to the alternative are that market demands for wideband and broadband systems (PMR or PAMR) may not be met and/or they will be accommodated in other bands where equipment costs may be higher. It is unlikely that wideband and broadband systems will be developed specifically for the UK market so that means alternative bands will need to be identified if band reversal is not implemented. Other bands that might be used are those identified in ECC/DEC/(03)01; 410 – 430 MHz and 870 – 876 /915 – 921 MHz. Whether these bands will be available and suitable is not clear. It is important to note that because of the band alignment exercise we are probably talking about demand in 2010 when the alignment process has been completed. We have not found a source of relevant demand forecasts and so have not quantified the benefits of allowing wideband systems.

3.6.2.4 Comments

The historic scenario shows that there would have been net benefits from earlier alignment with the European approach to use of the PMR 450-470 MHz band. However, under some assumptions the NPV of costs and benefits is negative under both scenarios.

In the future scenario adoption of a market led approach to determining use of the bands could yield benefits, allowing wideband systems to be introduced when there is a market requirement for these services. This approach could be made easier to implement if the spectrum was tradable, as users could then aggregate/disaggregate the spectrum as required. We note that users will take into account interference issues when making these decisions.

3.7 UHF TV

The UHF TV spectrum is harmonised for use by TV services in Europe and DVB standards have been set within ETSI. A European plan for terrestrial digital TV services based on the DVB standard is to be decided by the end of 2006. This case study considers the costs and benefits of using the spectrum released by digital switchover for 3G mobile services rather than digital TV.

[67] It should be noted that CEPT is to update Rec. 25-08, which deals with cross border co-ordination, to include wider band systems. There are only working documents currently available but the output of this work should also be taken into account when it becomes available.

3.7.1 Base line

The base line assumes that the UK only allows TV broadcasts using the DVB technology. The possibility of using the spectrum to provide mobile broadcast applications is not considered, as we do not have any data on the consumer surplus associated with these services.

3.7.2 Alternative

In this case it is assumed that

- Europe adopts a planning mechanism that allows national administrations to submit requirements for coverage and protection based on one or more of the many possible configurations of the DVB standard
- the UK allows the channels freed on switchover to be used for 3G TDD services and these services must operate on a no protection, no interference basis
- neighbouring countries use the spectrum for transmitting terrestrial TV – initially analogue TV and then later digital TV.

3.7.3 Analysis

The Government's work on the costs and benefits of digital switchover addresses the benefits from using the spectrum released by switchover for additional digital TV and mobile services.[68] It concludes that the benefits are greater if the spectrum is used by mobile rather than TV services.[69]

However the estimated benefits are subject to considerable uncertainty and could be significantly impacted by the following eventualities if they came about

- the interference impacts of the UK using the spectrum released for services that do not conform to the DVB-T standard could reduce the benefits from mobile use
- 3G equipment that could use the UHF bands might not be available
- there may not be any requirement from 3G operators for the UHF TV spectrum when it is released in 2010 or beyond.

3.7.3.1 Interference issues

The deployment of a different standard and service within the spectrum could potentially result in interference problems and hence reduce the available spectrum that can be used by either the mobile or the TV service. However, the Autonomy Study has found that

- it would be possible to operate a 3G TDD network on a DVB-T frequency anywhere within the corresponding DVB-T coverage area without exceeding acceptable interference levels

[68] *Cost Benefit Analysis (CBA) of Digital Switchover*, DCMS and the DTI, 2003
[69] Para 14 op. cit.

- in Southern England it was estimated that only one additional 3G TDD base station would be required. In Northern Ireland an additional 4 base stations would be required and there would also be a geographic area of 3,400 km² within which the stations would not be deployable.

3.7.3.2 Equipment

In the case of 3G equipment – terminals and base stations – the current vendor of TDD equipment has indicated that the development of products for the UHF band would depend on the size of the prospective market in the UK and whether there is blanket coverage in the band or it is only restricted to inner city locations. From our discussions with other manufacturers on terminal and base station developments, we understand that demand in the UK alone would probably be insufficient to support the development and manufacture of such terminals and the manufacturers would want at least the other major European countries to have the same policy. If a product was manufactured for the UK only it would be very expensive. Furthermore handsets and base station antenna systems made for the UHF band could be much larger than those made for higher frequency bands.

By contrast, we note that the departure of the UK from a harmonised position is unlikely to have an impact on the costs of digital TV receivers. This is because at switchover many (and possibly the majority of) UK households will have these receivers in order to view at least the six existing multiplexes on at least one set in the home.

3.7.3.3 Demand for the spectrum

Demand for 3G services in 2010 and beyond is uncertain. There is the possibility that demand will grow rapidly once services have been launched across Europe, as was the case with 2G services, but equally service demand may grow slowly. The UMTS Forum[70] clearly expects considerable demand growth and has stated that the spectrum requirement for 3G mobile services up to 2010 would be around 190 MHz beyond the already available 2G and 3G spectrum. The additional spectrum would be in the 2.6 GHz band along with the 806 – 960 MHz and 1710-1885 MHz bands. The 806-960 MHz band includes the upper seven channels in the UHF TV broadcast band.

There may be also demand for the spectrum from integrated DVB-T/3G services. There is considerable research and development effort in Japan and Europe devoted to developing integrated TV and mobile services using the DVB technology. The approach being adopted assumes that the DVB-T network is used to broadcast data and video services to 3G mobile terminals and that the return path is provided over the 3G network (which may use a different frequency band to that used to broadcast data and services).[71]

3.7.4 Comments

The market uncertainty concerning the demand for UHF spectrum from 3G services makes it difficult to come to a reliable view on either the costs or the benefits of allowing 3G services to

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[70] Joseph Huber at ANRT & ETSI Conference, Casablanca, April 2003

[71] See for example *Mobile Broadcast Services,* J Kamarainen, presented at the 11th CEPT conference, Nice, October 2003 (www.ero.dk)

use the UHF TV band although the benefits would be considerable if released spectrum was to be used by mobile services like 3G. However, given the uncertainties intrinsic in any estimate looking this far ahead and the scale of the potential benefits, we suggest that decisions about the service and technology to be provided are left to the market – say if 8 MHz blocks of tradable spectrum were auctioned.

3.8 Short Range Devices

This case study is concerned with two historic examples of non-harmonised use of spectrum by SRDs, namely radio car keys and telemetry and telecommand devices. In both cases we assess the net benefits/costs of moving to harmonised use of the spectrum.

3.8.1 Radio Car Keys

3.8.1.1 Base line

In 1986 the UK started using the non-harmonised 418 MHz band for car key fobs. The RA had agreed with the Ministry of Defence (MoD) that spectrum at 418 MHz would be released to provide a national allocation for very low power SRDs (less than 250 micro watts output power) and equipment deployed in this band had to meet the requirements of the UK specification MPT 1340.[72] The rest of Europe was using the 433 MHz band which was mentioned in various ERC Recommendations.

The UK used a non-harmonised frequency band for radio car keys because the band at 433 MHz was already assigned to the MoD and radio amateurs. All UK vehicles that had alarm systems requiring radio car keys were fitted with 418 MHz car fobs including those made in mainland Europe.

In 1992 the MoD agreed to release the 433 MHz spectrum[73] to facilitate harmonisation. Military use of the band comprised PMR type applications and a radar at Fylingdales. The former migrated but the latter is still present in the band. The reason for moving to the 433 MHz band was that the RA could not police the entry of 433 MHz key fobs into the UK. However the 418 MHz band continued to be used until 1997 and the installed base of equipment may continue to use the band until 2007.

The need to harmonise the frequency use was strengthened by the interference problems caused when TETRA services were rolled out by Dolphin Telecommunications in the 410 – 430 MHz band in 1998. Interference occurred because the radio car keys used in the UK had wide receiver bandwidths of 10 MHz[74] and this meant people could not open their cars. There can also be interference at 433 MHz, though the situation in the UK was aggravated by the use of a non-harmonised band. It is thought that work involved testing and realignment of TETRA sites to alleviate the interference problems and involved several hundred thousand pounds of effort by the Government and Dolphin Telecommunications. In addition, car

[72] MPT 1340 was first published in 1986 and covered the frequency band 417.9 – 418.1 MHz.

[73] In 1993 / 1994 the second edition of MPT 1340 was published and included the band 433.05 – 434.79 MHz with a maximum power of 10 milliwatts to allow the use of 433 MHz. There was also an EC Automotive Directive in 1995 that specified the use of the 433 MHz band for radio car keys.

[74] Wideband receivers allowed manufacturers to make key fobs for less than the target price of £1 each.

owners were expected to bear the cost (estimated to be about £100) of refitting their cars with 433 MHz car fobs.[75]

3.8.1.2 Alternative

The alternative scenario assumes that the UK adopted a harmonised approach to spectrum use and used the 433 MHz band for car key fobs. This would have meant that the military would have had to move earlier than in the base line, presumably at some cost, but that the costs of realignment would have been avoided.

3.8.1.3 Analysis

In this case the benefits of harmonisation would have been:

- Avoidance of the costs of re-equipping cars with new car fobs compliant with the harmonised frequencies (estimated to be £100/car). We assume that only cars at the top end of the market i.e. 2 litres or more were equipped with car fobs and that the number of cars affected lies between the number of new cars and total number of cars of 2 litres capacity or more in 1998. Assuming that problems arose for 10% of vehicles and each vehicle had two key fobs, implies a cost of £4-40m, not counting the value of the car owners' time.
- Avoidance of the costs of some of the interference cases with TETRA. These costs include the investigation and realignment costs incurred by Government and Dolphin and the costs to car owners unable to open their cars. Callout costs are estimated based on the Royal Automobile Club's costs for roadside assistance and assuming a 50% callout probability per member per year. This gives a cost estimate of £4-34 million.

The costs of harmonisation would have been the costs to the military having to vacate the band sooner than otherwise. This would have included the costs of having to retune equipment. We have not been able to obtain information required to quantify these costs.

The impact of harmonisation on SRD equipment costs is not material in this case. Most manufacturers are small (generally employing less than 20 people) suggesting that scale economies are small relative to the size of the market.

Our estimate that the benefits of harmonisation of around £8-74m is an overestimate as some interference problems would have occurred had the band been harmonised at 433 MHz and we have not been able to quantify the costs of harmonisation.

3.8.1.4 Comments

The case for harmonisation looks strong in principle, although we have not been able to estimate the costs of releasing spectrum for harmonised use. The case for harmonisation arises from the international mobility of the equipment and the risk that a non-harmonised allocation may finish up being in the middle of a band harmonised for another service. If the services cannot co-exist then the non-harmonised use may have to move. This case study

[75] Note the alarm system has to be replaced at the same time. It is of course possible that there are car owners who live and travel outside the TETRA coverage area and who still have the 418 MHz fobs.

also indicates that tighter minimum receive characteristics can be advantageous for mobile receivers, particularly in non-harmonised bands, although this is likely to result in increased equipment costs.

3.8.2 Telemetry and Telecommand Devices

3.8.2.1 Base line

There is 1 MHz in the 458 MHz band that was allocated for telemetry and telecommand use in the 1980's following representation from the water industry. It is still used by the water industry but there are also a number of other uses such as control of other utility networks (e.g. electricity and gas), building controls (e.g. fire and security systems) in hospitals and other large sites (e.g. airports, universities) and internal data communications in supermarkets and on other sites. Products were individually designed and developed for these applications.

Spectrum is also available at 173 MHz (again on a non-harmonised basis) but it is not greatly used because the long propagation distances at this frequency range increase the likelihood of interference. The 173 MHz band is mostly used for in-building systems.

3.8.2.2 Alternative

In the alternative case it is assumed that only the harmonised spectrum at 433 MHz and 868 MHz is available. The 433 MHz band would not have been suitable for most applications because of the power limits (10 mW), the inability to meet the requirement for many narrowband channels and the lack of sufficient frequency stability to give reliable transmissions. Some applications could have used the 433 MHz band and include, for example, control of sewer filter beds by water companies.

The 868 MHz band could have been used for in building fire and security detection devices but at four times the cost of 458 MHz equipment and with shorter life batteries and larger equipment. Furthermore, the 868 MHz band was not made available for telemetry and telecommand applications until 1998.[76] Now the 2.4 GHz band might also be used but it would be even more impractical for devices that must be battery powered.

For users with long range communications used to control critical elements of utility networks (e.g. electricity grid switches) the only real alternative would have been to install multiple point to point fixed links. PMR is not sufficiently reliable and the topology of scanning telemetry is not appropriate, though in the future digital mobile radio might offer an alternative.

3.8.2.3 Analysis

The potential benefits of harmonisation in this case are:

- The costs avoided from not having to move incumbent users in the 458 MHz band when it was first allocated to SRDs 15-20 years ago. We do not have any information on what that use might have been and so these costs are not estimated.

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[76] *New Frequency Allocations for Licence Exempt Low Power Devices*, RA Press Release, 30 September 1998.

- The benefits from having an additional 1 MHz spectrum available for PMR and other mobile radio use in the 450-470 MHz band.[77] If we apply the opportunity cost of spectrum derived in the spectrum pricing study of £0.624m/MHz then over a ten year period this gives a NPV of £5m.

We note that there is no evidence of significant scale economies in equipment production. There are a number of relatively small UK manufacturers making equipment for the UK and overseas markets at a cost of around £550 per unit in the 458 MHz band[78]. While this is much more expensive than equipment at 433 MHz, which costs around £5, the utilities are willing to pay considerably more for a product that meets their specific requirements.

The costs of harmonisation comprise the cost to existing users in the non-harmonised band of being denied access to the spectrum. There are a number of cases to consider:

- the costs of using fixed links instead of telemetry at 458 MHz for critical utility communications. Assuming the current installed base of 25,000 systems consisting of a master station and 5 outstations is replaced by 5 fixed links and that the existing equipment is half way through its economic life, the additional cost is around £4,100m.

- the costs of using 868 MHz equipment for in-building systems. We understand that there could be around 70-75,000[79] fire senders installed in the UK and the equipment made for the 868 MHz band is four times as expensive as that made for the 458 MHz band. This implies an additional cost of £135-144m.[80]

The NPV of the benefits/costs of harmonisation are estimated over a 10 year period. This gives a net cost of around £4,200m.

3.8.3 Comments

The two cases discussed above illustrate the following general points:

- The benefits of harmonisation are greater if the application is internationally mobile (e.g. car fobs, RFIDs).[81] This is a particular issue for SRDs where it is not feasible to police the movement of non-compliant equipment.
- Non-harmonised use offers the opportunity to tailor spectrum needs to local demands and features and this can yield considerable benefits. The 458 MHz band is a clear example of this though the benefit of non-harmonised use needs to be considered against the costs of denial of spectrum use to other services.

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[77] The RA has concluded that it would not be feasible to migrate users in the 458 MHz band because of their licence exempt status and so is planning the 450-470 MHz band realignment around this use. It is not known whether there will be more/less interference experienced post-band realignment.

[78] Equipment can be adapted to other bands at relatively low cost because only two components in the RF part of the equipment need to be changed.

[79] Source: Ken Schneider, EMS

[80] Before 1998 the only alternative would have been to use the 433 MHz band. The cost of using this band could have been four times that of the 868 MHz band, as duplicate paths would have been required when there were more than 32 devices that could have been affected by a break in communications.

[81] In the case of RFIDs, for example, additional RFID production costs and operational costs would be incurred if the UK adopted a non-harmonised band. This is important as the RFID market is very cost sensitive, as tags need to cost less than 1 cent to compete with bar codes.

3.9 Programme Making and Special Events (PMSE)

This case study considers two scenarios:

- Historic: where the base line assumes non-harmonised bands (as happened in practice) and compares this with a situation in which it is assumed the UK had followed European harmonisation measures.
- Future: where the base line assumes no standards and this is compared with the use of digital standards based on harmonised frequency bands.

The examples of radio microphones and video links are used.

3.9.1 Historic Case

3.9.1.1 Base line

The base line assumes the current non-harmonised situation applies. In the case of radio microphones the bands are mainly shared with TV and the MoD and for video links the bands are generally shared with the MoD.

3.9.1.2 Alternative

The alternative case assumes frequency bands are harmonised. The key assumptions are as follows:

- PMSE had harmonised frequency bands under a CEPT measure and this measure specified tuning ranges.
- These frequency bands are those specified in ERC Recommendation 25-10 (11th February 2003) – see Annex 8.
- Such a measure was adopted five years ago and CEPT countries implemented it.[82]

3.9.1.3 Analysis

The advent of harmonised frequency ranges compared with the base case of no harmonisation would have had the following potentially beneficial effects:[83]

- Interference management undertaken by Ofcom at major events might be reduced. However, it is more likely that there would be fewer instances where Ofcom would be requested to make specific frequencies available to users from outside the UK. We understand it is unlikely that harmonised spectrum would be sufficient to meet requirements for major events and if this was the case Ofcom would have to identify additional frequencies. So at most a fraction of Ofcom's costs of managing spectrum for major events would be saved i.e. ½ person year (assumed to have a cost of £50,000 per person year) per major event would be saved. On average there are 5 major events, giving a maximum value of £125,000.

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[82] If the UK adopted the harmonisation measure and other countries did not we would be in the same position as at present.

[83] Currently in the UK PMSE have allocations in all the harmonised tuning ranges as well as access to other non-harmonised spectrum and both are needed to meet demand.

- Equipment costs might be lower overall due to economies of scale, but it appears that market demand is the main driver for the development of equipment and not the identification of harmonised tuning ranges. An example of this is the harmonised band 1785 – 1800 MHz, which is intended for digital radio microphones and is not used. Manufacturers do not consider there is sufficient bandwidth and that equipment will not work well because of body absorption, different propagation characteristics and higher power consumption compared with spectrum at 800 MHz (the key bands currently for radio microphones are 766 – 862 MHz i.e. UHF TV channels 58 – 69).
- Touring shows would be able to use the same frequencies throughout the CEPT countries and thereby potentially make equipment cost savings. Event organisers told us that the main advantage would be the certainty they would have in being able to access spectrum (e.g. channels 68 and 69 which are generally used in the UK do not tend to be available in other European countries where they are used for military applications). However, the fact that the equipment has a tuning range spread across 4/5 TV channels means that it is normally feasible to find spectrum. Thus the cost savings to event organisers are likely to be small.
- Some instances where PMSE users have to modify equipment or even move bands to accommodate the primary user of the band might be avoided. However, given that most of the harmonised bands are currently used by PMSE in the UK and because it seems unlikely that Ofcom would designate PMSE the sole primary use of the band the extent to which this might happen in practice is doubtful. To give an indication of the magnitude of the costs that could be involved we consider the case of proposed changes in the 3-4-3.6 GHz band to allow FWA equipment, with a duplex spacing of 100 MHz, that will require video links to vacate some spectrum and move to nearby alternative spectrum within the same band. Although the existing equipment could be used in principle it is necessary to migrate to digital video links to avoid the necessity for large guard bands, and lost spectrum, to protect against interference. The costs to users could be in the range £1.75 m.[84]
- The lack of harmonised spectrum means that any frequency band being used by PMSE in the UK could be targeted for harmonisation within CEPT for another service. The likelihood of this happening is increased by the fact that use of PMSE in the UK is high relative to that in other European countries. However, the lesser status of PMSE use in shared bands means that the existence of the harmonisation measure seems unlikely to stop, for example, the loss of spectrum in the TV bands or reallocation of spectrum to FWA. Hence we do not consider that there are any benefits in this case.

The costs of moving to harmonised bands as compared with doing nothing would have been as follows:

- Users would have had to replace some of their equipment so they could use the harmonised bands and equipment for non-harmonised bands would potentially become obsolete. Video links have limited scope for reconfiguration, as their switching ranges are limited, and even operating on slightly different frequencies could necessitate new equipment. The implied costs could be considerable, but we have not been able to estimate these as industry was not able to supply us with estimates of the number of links

[84] This assumes 50 items of equipment need to be moved and the cost of digital equipment is about £35k/item. Source: Industry.

that might be affected. As the example given above for 3.5 GHz shows the costs can be considerable.

- Incumbent users in the harmonised bands may have to be moved to provide sufficient spectrum for PMSE. It seems unlikely this would happen in practice given that PMSE shares spectrum with other users and is typically fitted in around an existing use.
- There would be less spectrum available for PMSE and so the possibility of users being denied access to the spectrum. However, it is likely in practice that Ofcom would seek to obtain spectrum on a temporary basis from the MoD or Home Office rather than deny users licences, not least because they might go ahead and use spectrum illegally.

In summary the main benefits that seem likely to arise from harmonisation are those caused by the international mobility of equipment – lower costs for touring shows and fewer planning/interference management costs incurred by Ofcom. These are both likely to be small compared with the costs of moving existing PMSE users i.e. there would be a net cost to harmonisation.

3.9.2 Future Case

3.9.2.1 Base line

In the base line it is assumed that there continues to be no ETSI standardisation. Rather proprietary standards developed by major broadcasters and/or equipment vendors are used.

3.9.2.2 Alternative

The alternative case assumes that

- Digital standards for radio microphones apply from now on
- Digital standards for video links apply when digital systems are introduced over the next 5 years.

3.9.2.3 Analysis

Standards offer the potential advantages of spectrum efficiency, assuming that the standard is developed with this objective in mind, and lower cost equipment.

Concerning spectrum efficiency, digital standards for video links that have been developed in ETSI enable adjacent channel working at the same site whereas for analogue systems only every other 20 MHz channel can be used as the equipment requires 35 MHz channel spacings. The efficiency gains are significant: probably around a 2-3 fold increase in efficiency is achieved.[85] We are not aware of any estimates of the value of video links to users as measured by either consumer surplus or auction payments. However, given that

[85] This is based on 8MHz digital channels (on a 10 MHz raster) and using adjacent 10 MHz channels co-sited. This compares to 20 MHz analogue channels on a 20 MHz raster with no co-sited use of adjacent channels (i.e. minimum channel spacing of 40 MHz). Multi-channel co-sited analogue use requires 30 MHz per channel whereas 3 digital channels are expected to be achievable hence there is a 3:1 gain. Not all digital links are currently 8 MHz bandwidth. Some require 2 x 8 MHz so somewhat less than a 3: 1 ratio will be achieved.

spectrum used by PMSE is increasingly congested there is clearly considerable value gained from moving to digital standards.

By contrast, the standard for digital radio microphones in the harmonised band 1785 – 1800 MHz includes a range of curves for the transmitter spectrum depending on the bandwidth of the equipment. In reaching this compromise solution efficiency considerations were not taken into account meaning that that the standard does not support many users in a given area. In addition, manufacturers do not consider there is sufficient spectrum to justify developing equipment.[86] At present it seems more likely the spectrum will remain idle than be used more efficiently. There is therefore a cost to standardisation in this case, namely the potential value forgone as a result of the spectrum being idle. The spectrum could potentially be used for BFWA and, as indicated by the BFWA case study, there could be significant benefits from this application.

3.9.3 Comments

The two cases discussed above indicate that:

- Frequency harmonisation with Europe is unlikely to offer any benefits for UK PMSE users because it would reduce the spectrum they have available, not lead to lower equipment costs and the benefits of mobility are small. There could be benefits from harmonising with the US PMSE bands as most new equipment in this sector is developed in the US, presumably because of the scale of the US broadcast and film sectors. For example the only manufacturer providing digital radio microphones is based in the US.
- Without regulatory and/or user input the ETSI standards can end up being the lowest common denominator of all the manufacturers' inputs. This was the case for radio-microphones where adoption of a harmonised band using a European single standard seems unlikely to yield any benefits. By contrast the standard for video links offers significant technical and economic efficiency gains.

3.10 Conclusions

A summary of the findings from the case studies is given in Table 3.5. The conclusions from the case studies depend on the economic and technical characteristics of the services under consideration. However, the following general points can be made:

1. In mass consumer markets delay can be very costly since overall consumer and producer surplus is reduced in value for each year of delay by the discount rate. For example, in the 2G historical case, where there are significant economies of scale and international mobility is valued, harmonisation and standardisation were very valuable.

[86] ECC Report 2 says that the theoretical simulations for the use of this band identified that 27 digital microphones could be used simultaneously at one location but manufacturers assumed between 8 and 25. Within the same report it says that the indoor use of large multi-channel sets of radio microphones falls into two main categories:

- Large single studio / stage where more than 40 channels may be used
- Large numbers of microphones in adjacent halls or studios within a complex but with each hall or stage operating fewer channels than those in the first category.

In the London theatres on average 26 radio microphones are used with peaks up to 40 and the possibility of requiring up to 50 for some of the newer American musical productions. Hence it can be seen that the spectrum is likely to be insufficient to support major musical productions.

2. National relaxation of harmonisation and standardisation measures is not necessarily constrained by international measures since domestic requirements are the binding constraint in some instances. For example, European measures allow standardisation in the 900MHz TETRA band to be relaxed depending on market demand.

3. Cross border interference concerns are not necessarily a constraint on autonomous measures to relax harmonisation and standardisation since interference can be managed at a cost (by having more lower powered transmitters) or by foregoing benefits (for example, foregoing non-harmonised service in Northern Ireland and the South of England). For example, the UK could relax CEPT standardisation and harmonisation constraints and allow broadband fixed wireless access services in the 2010-2025 MHz band. While interference constraints would increase the costs of such services the benefits of greater flexibility are potentially large.

4. Economies of scale do not always predominate, and may be declining in importance for fixed link services in particular. Where spectrum is not expected to be congested, allowing non-compliant services into a band may offer benefits if manufacturers can modify equipment to use the band at low cost. For example, standardisation measures specifying channel plans for the 32 GHz band could be relaxed.

5. Standardisation measures can delay the introduction of services. In the case of TETRA the standardisation process itself took many years and the outcome contained too many options and compromises. As a result, the potential market for digital PAMR was eroded by unlicensed private mobile radio and cellular services.

6. Earlier standardisation could have been beneficial in relation to PMR since alignment would have avoided interference costs, fewer users would have been disrupted and valuable spectrum would have been released earlier.

7. Harmonisation would have been beneficial in relation to car key fobs since these devices may travel across national borders, and local interference problems were aggravated by use of non-harmonised spectrum.

8. Non-harmonised use in relation to telemetry in the 458 MHz band has allowed benefits that would have been denied otherwise, as equipment and technical solutions for harmonised spectrum are more expensive and less suitable than those for non-harmonised spectrum.

9. The PMSE case study illustrates that moving from non-harmonised to harmonised frequency allocations can be costly if this reduces the spectrum available for services, scale economies in equipment production are not significant and the benefits of mobility are small (e.g. because equipment has wide tuning ranges).

10. The PMSE case study also illustrates that harmonised use can impose costs where national patterns of demand are for historical or socio-economic reasons very different from those elsewhere in Europe.

Table 3.5 Summary of Case Study Findings

	Costs	Benefits	Conclusion
1a. GSM 900 &1800 – historic	Costs of delay in service roll-out: £876-5774m	None	Standardisation and harmonisation had a positive impact.
1b. GSM 900 & 1800 – future	None	Reduced network and operating costs for operators less cost of handset replacement (around £550-900m in 2003 prices), more efficient use of spectrum (a factor of 3) and possible competition stimulus.	Continued requirement for use of 2G standard has no positive effect and may have a negative effect.
2. TETRA	Forgone value from idle spectrum at 900 MHz – could be around £5m/annum.	None, spectrum idle	Standard has net negative effect. Spectrum might be used if other standards were permitted.
3. BFWA at 2 GHz	Forgone use by BFWA – £900-4,400m	Spectrum currently idle but harmonised use of this band could yield benefits for 3G licensed use. Benefits from 3G licence exempt use likely to be small.	Designation for licence exempt 3G use has a negative impact as no standard has been developed and other potential uses are not permitted.
4. 32 GHz fixed services band	Small	Small	Standardisation has a neutral impact.
5a. PMR at 450-470 MHz – historic	See benefits column	Benefits less costs: Earlier harmonisation results in a larger NPV. (Difference in NPVs is around £70-100m).	Harmonisation would have yielded greater benefits if undertaken earlier.
5b. PMR at 450-470 MHz – future	No interference costs relative to use of band for narrowband, though issue of guard bands in UK not addressed	Consumer gains from use of wideband	Benefits from allowing users to chose whether to use wideband or narrowband
6. UHF TV frequencies	Use denied to DTT. Interference impacts minimal.	Use of spectrum by 3G services. Demand is uncertain.	Benefits have small expected value but relaxing harmonisation and standardisation constraints has few

	Costs	Benefits	Conclusion
			costs, assuming services can compete on an equal basis for the spectrum. Hence should relax constraints.
7a. Radio car keys	Unquantified costs of moving incumbent users (the military)	£8m-74m – the costs of interference and equipping cars with new key fobs.	Appears to be a good case for harmonisation
7b. Telemetry and telecommand systems	Around £4,000m – costs of using alternative bands and technology	£5m – spectrum released for PMR	Harmonisation would have a substantial negative impact.
8a. PMSE – historic	Costs of moving existing users to harmonised allocation. Not quantified but could be considerable.	At least £2m - PMSE users have to move to another band to make way for the primary use of the band.	Harmonisation could have a negative impact because it would reduce the available spectrum, not lead to lower equipment costs and the benefits of mobility are small. Against this users might gain more security of tenure, though this seems unlikely in practice.
8b. PMSE – future	Inappropriate standard results in idle spectrum in the case of radio microphones	Spectral efficiency gains depend on the standard – positive for video links but not for radio microphones	Standardisation *per se* does not offer benefits.

Source: Indepen and Aegis analysis

4 Conclusions and Recommendations

Four sources inform our policy conclusions and recommendations: the general literature on the economic impacts of harmonisation and standardisation; first principles considerations; the in-depth case studies drawing on our qualitative and quantitative analysis; and the Autonomy Study.

Our conclusions are primarily concerned with identifying conditions under which European harmonisation or standardisation measures are likely to offer benefits and how these measures could be made more flexible whilst retaining their benefits. The impact of technology changes on these costs and benefits is also discussed. The focus is on greater flexibility because the main problem with standardisation and harmonisation measures is that they place constraints on market development that may result in a loss of economic benefits, particularly if spectrum is congested.

European harmonisation and standardisation measures may reduce risks for manufacturers and operators and this may offer wider economic benefits in terms of lower cost/better quality equipment and services (arising from economies of scale and increased competition), however, the measures preclude other uses of spectrum that could give economic benefits. The key issue is whether there are overall net economic benefits for countries that adopt such measures. Uncertainty means mistakes will happen, because with hindsight the costs, benefits and risks are found to be incorrectly forecast, and so flexibility to allow market adjustment or to change policies is required.

4.1 Factors impacting on costs and benefits

The case studies illustrate that the success or otherwise of European harmonisation and standardisation measures depends on a combination of factors, many of which are difficult to anticipate. Based on the literature review and the case studies we have undertaken, the following factors appear to be important in determining the success of European harmonisation and standardisation measures:

- Service demand
- Value of the service
- Spectrum congestion
- Timeliness and appropriateness of standards
- Mobility of equipment
- Economies of scale in equipment production

Our findings in respect of these aspects are as follows.

Service demand: If demand in the UK for a service that is subject to a European harmonisation measure is uncertain or weak then the UK should not adopt the measure or should ensure it can opt out later if demand for other higher valued uses emerges. In addition, if harmonised allocations do not meet the requirements of the UK market (for example it may be that insufficient spectrum is included in the harmonisation measures) then there can be advantages to adopting non-harmonised allocations.

Value of the service: The higher the value of the service using the spectrum the more likely it is that there will be net benefits from standardisation measures, when these result in more efficient use of the spectrum (e.g. historic PMR case study). Similarly, harmonisation is more likely to deliver net benefits if the harmonised service is of higher value than the non-harmonised service in the band.

Spectrum congestion: A primary objective of specifying a single European channel plan and modulation method (i.e. standardisation) is to maximise potential spectrum usage. This may also be an objective of harmonisation measures. This is advantageous where the spectrum is expected to be congested. However standards other than those included in European harmonisation measures may offer similar or greater benefits in terms of spectrum efficiency.

Timeliness and appropriateness of standards: The critical issues for standardisation concern the timing and quality of standards and whether exclusive use of European measures excludes use of "better" specifications. Successful standards may take some time to be developed yet they need to be available at a time when market demand materialises. If standards are late and a more attractive competing specification becomes available then exclusive use of a European standard will deny valuable opportunities. (e.g. even though the GSM standards took some 10 years to develop fully, they were successful but other European attempts at creating a large harmonised and standardised market such as TETRA were not).

Competition: Standardisation can increase the number of vendors that will compete in a market, but the additional delay needed for the standardisation process can reduce the prospects for the whole market. The alternative to European standardisation would be a requirement to publish specifications, so that there can be competition in manufacture. (Many developers are willing to license competitive manufacture on a voluntary basis.)

Economies of scale in equipment production: Frequency harmonisation and equipment standardisation may offer benefits of economies of scale. If markets several times as large as that offered by the UK alone are required before manufacturers will develop equipment for a non-harmonised band, then the UK is likely to find it advantageous to adopt European harmonisation measures.

However it is not the case that all radio equipment is characterised by large economies of scale in production. Also for some equipment, such as fixed links, there is a standard product for all frequency bands with only the RF modules requiring modification to operate in different frequency bands. This reduces scale economies and makes it easier and quicker to develop equipment for new bands. It also potentially increases the degree of competition between equipment manufacturers.

International mobility of terminals: Harmonisation is most likely to be beneficial where equipment is mobile and users value the opportunity to use it in different countries e.g. mobile phones, car and their key fobs, radio and increasingly TV receivers as these become smaller/mobile, or where communications are cross border e.g. satellite broadcasts, VSATs. Where interoperability between user terminals and networks in different countries is also required by users, standardisation can also assist in promoting take-up of the service.

As may be evident from this discussion, the circumstances in which harmonisation and standardisation measures will be beneficial depend on the specific attributes of the service, technology and frequency bands under consideration. Our general conclusions are as follows.

1. Where spectrum is expected to remain uncongested there are unlikely to be benefits from European standardisation and harmonisation measures that increase the technical efficiency of spectrum use, and there may be costs in terms of foregone use of equipment using alternative specifications.

2. Where there are not expected to be supra-national economies of scale, international mobility has low value, and constraints or costs imposed by potential interference are low, European harmonisation measures are likely to offer small benefits and potentially significant costs if harmonisation results in foregone use by higher value services.

3. If a change is worthwhile do not wait. In general it is better to act immediately on policy options for which the net present value of the benefits is positive, so as to maximise the net present value of returns. This might not be the case, however, if the costs of change are expected to decrease so that the reduction in costs more than offsets the costs of delaying net benefits.

4. For the cases we considered, the existence of European harmonisation measures and the possibility of interference to non-harmonised use of the spectrum in the UK did not impose an unavoidable constraint on UK spectrum use. Harmful international interference can be avoided by limiting service availability in parts of the UK, and/or by altering network configurations, for example, using more base stations operating at lower power.

5. Decisions over whether to follow CEPT harmonisation measures can be separated from the decision of whether to participate in the development of these measures and the relevant standards in ETSI. Participation in these processes may have benefits in giving a better understanding of the technical issues, the potential of the technology and the views of industry players and should lead to a more informed decision about whether or not to subscribe to CEPT measures.

4.2 Technology flexibility

Technology is helping frequency management by making equipment more flexible and increasingly self-adaptive to fit into whatever frequency and interference environment the equipment senses. Economies of scale in relation to the development of flexible equipment may be increasing, because of the high initial costs of software development, however, the costs of adapting this equipment for use in a particular market using particular frequency bands or a particular standard are decreasing. The flexibility affects:

- Harmonisation in relation to multi-band equipment and flexible tuning ranges
- Standardisation in relation to software defined radio.

Equipment is becoming available where it is possible to alter the RF frequencies and also the duplex spacings via software either from a central control point or by downloading data on site. Developments such as software programmable radio, and radios that sense the radio environment and adapt to it are gradually reducing the need for harmonisation and creating more flexibility, especially for smaller scale applications. Thus for some spectrum bands the balance of costs and benefits is changing in favour of less harmonisation and standardisation.

The possibility of flexible equipment raises the question of whether users have incentives to use this equipment. Ofcom could introduce a requirement that licensees should be capable of changing frequency assignments in a relatively short period of time. As there is a risk that this degree of flexibility would be redundant, it may be preferable for Ofcom to indicate that continued use of the band is not guaranteed and that the costs of changing band would not be taken into account in any cost benefit analysis of such a change. This would give licensees an incentive to use flexible equipment. The costs and benefits of such an approach would need to be considered for the particular applications under consideration.

4.3 Increasing the flexibility of harmonisation and standardisation measures

A number of the case studies involved situations in which bands are currently unused because applications have not developed along the lines assumed when harmonisation and standardisation measures were adopted. Non-use can be costly if there are potential alternative uses of the spectrum, and option values associated with use consistent with existing harmonisation and standardisation requirements are low.[87] There are a number of ways in which harmonisation and standardisation measures could be made more flexible so that idle spectrum is more likely to be used more effectively.

4.3.1 Harmonisation

We recommend that Ofcom considers promoting the following approaches to relaxing harmonisation measures

- Harmonised bands should allow applications outside the scope of the harmonised service if the applications are expected to be compatible in technical terms and there is spare capacity (on a local or a national basis) in such harmonised bands. Within a trading environment this might occur through spectrum leasing.
- There should be a move away from exclusive harmonisation measures. Rather a half way position where countries would agree to allocate frequencies in a common band for a common purpose, but would also allow other applications to be considered where it can be demonstrated that other applications have a higher value than the harmonised use. Harmonisation might thereby provide sufficient focus and certainty for the achievement of economies of scale in manufacturing, without entirely precluding alternative uses in particular circumstances. Spectrum auctions and/or trading would assist in assigning spectrum to the highest value use under this policy.
- Harmonisation measures that have built-in milestones in relation to market development.[88] If the milestones are not met then signatories to CEPT and EC measures could have the option of derogating from the measure (i.e. removing their signature). In the box below we set out some possible milestones and some indicate timescales. We

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[87] The option value is the expected benefit of possible future use of the spectrum.

[88] A model for this is given in the *ERC Decision on the Harmonised Use of Spectrum for Satellite Personal Communications Services* (ERC/DEC/(97(03). ERC Decision (99)25 concerning the use of the 2010-2020 MHz band also has a review point after two years.

note that if these milestones had been applied in the case of say the 854-960 MHz band then the UK might have the option to use the spectrum for services/technologies other than those specified in the relevant ERC Decisions.

Possible Milestones for CEPT Decisions and EC Measures

Formulation of Decision

This will include technical work and a cost/benefit analysis

CEPT pass the Decision

Review at year X (say X=3)

This review would establish whether there is evidence of manufacturers producing test or commercial equipment. If this is not the case then countries could be permitted to abandon the Decision.

Review at year Y (say X=5)

This review would establish whether there is evidence of commercial systems in operation or soon to commence operation (e.g. as evidenced by spectrum licences being issued). If this is not the case then countries can abandon the Decision.

Review at year Z (say Z=7)

If there are no commercial systems operating in CEPT countries at year Z then the Decision falls.

Decision Rescinded Automatically at Year W (say W=10)

The measure should no longer be required by year W if the market is well established. If the market is not well established by this time then countries should have the opportunity to introduce other services and technologies into the band.

If harmonisation measures with milestones are not feasible, then we suggest there should be the possibility of time-limited support for European harmonisation and standardisation measures. This would allow countries to opt out of measures after a fixed period of time if the measure was not needed given their national circumstances.

4.3.2 Standardisation

We recommend that Ofcom considers relaxing standardisation measures in the following ways

- Adaptive frequency assignment technologies should be used wherever practicable, especially for applications that involve many unrelated users, because they eliminate the safety margin needed for a-priori planning and the expense of such planning. Use of a specific technology does not need to be required provided that the technologies are not grossly incompatible and that they meet some minimum level of spectral efficiency.

- If adaptive frequency assignment technologies are not appropriate then we recommend that
  - Where independent management is needed because there are many different unrelated users and where there is confidence in large scale demand and congestion is likely, then either a single channelisation and modulation scheme should be specified or a spectrum mask defined and acceptable in band interference.
  - Where users can manage their own frequencies in a sub-band, they should be able to choose their own channelisation scheme even if large scale demand and congestion are likely, because they will have sufficient incentives to use the spectrum efficiently.
  - Where independent management is needed because there are many different unrelated users but demand is uncertain and congestion unlikely, then there should be no or minimal constraints on channelisation and modulation within bands.

4.3.3 General changes

More generally we recommend that

- Sunset clauses are built in to European harmonisation and standardisation measures, such that they automatically lapse at some date. This would ensure that redundant regulation does not persist (e.g. measures for GSM) and would give countries the option to reallocate the spectrum in cases where the measure has not been successful (e.g. TETRA at 900 MHz).
- Harmonisation measures should be justified in advance of being adopted by CEPT by a cost/benefit analysis (undertaken by the CEPT). The cost/benefit analysis should demonstrate that the measure is likely to deliver net benefits to the CEPT countries, based on available information and forecasts.
- There is the possibility of time-limited support for European harmonisation and standardisation measures. This would allow countries to opt out of measures after a fixed period of time if the measure was not needed given their national circumstances or reviews establish there is no evidence of equipment production of actual commercial operations.
- There should be periodic reappraisal by the UK of the net benefits from supporting European harmonisation and standardisation measures, if the measures do not have milestones that allow the UK to remove its support for them.

4.4 Role of the regulator versus the market

In carrying out this study we have experienced considerable difficulty in obtaining the information required to determine the costs and benefits of harmonisation and standardisation measures. This suggests a number of courses of action for a regulator making decisions about whether to adopt European harmonisation and standardisation measures, including:

- Make decisions on the basis of available information, accept that there will be mistakes and build in some flexibility for dealing with mistakes.

- Collect more market data and information.
- Delegate more decisions to the market, with the regulator setting only basic parameters that define the interference/compatibility environment for the band and allowing considerable flexibility in the services that may be offered.

We have already discussed ways of adopting a more flexible approach to European harmonisation and standardisation measures.

If the regulator collected more market information this could in principle lead to better informed decisions on whether to sign up to European harmonisation measures. However, there are limits to the extent to which currently available information and analysis can anticipate future developments. In a number of the case studies (e.g. BFWA at 2GHz and UHF TV) we came to the conclusion that the use of the band should be decided by the market – either through trading or auctions that allowed different uses of the spectrum. Where possible we think it is preferable to delegate more decisions to the market.

Where costs and benefits are private (i.e. are all experienced by the spectrum user) there is a strong argument for allowing private choices to determine spectrum uses and technologies deployed. Where there are externalities (i.e. costs or benefits experienced by others) then delegation of decisions to the market may not be efficient. Examples of externalities that could be important are interference (though this was not a significant issue in our case studies), bandwagon effects and competition impacts of private decisions.[89] The choice depends on the scale of the externalities – an imperfect market solution may still be better than an imperfect regulatory decision.

One case where market approaches cannot be used to determine the future use of spectrum concerns the choice between allocating spectrum to licence exempt versus licensed uses of spectrum. This choice will need to be informed by market studies and the analysis of the costs and benefits of different uses of the spectrum.[90] To carry out such analyses information on users' willingness to pay for wireless services is required and we suggest that Ofcom undertakes research on this issue.

4.5 Categorising uses

Harmonisation and standardisation apply to the applications for which spectrum use is licensed. Consequently any evaluation of harmonisation and standardisation must include an evaluation of the way in which the applications are defined or categorised for the purpose of harmonisation and standardisation.

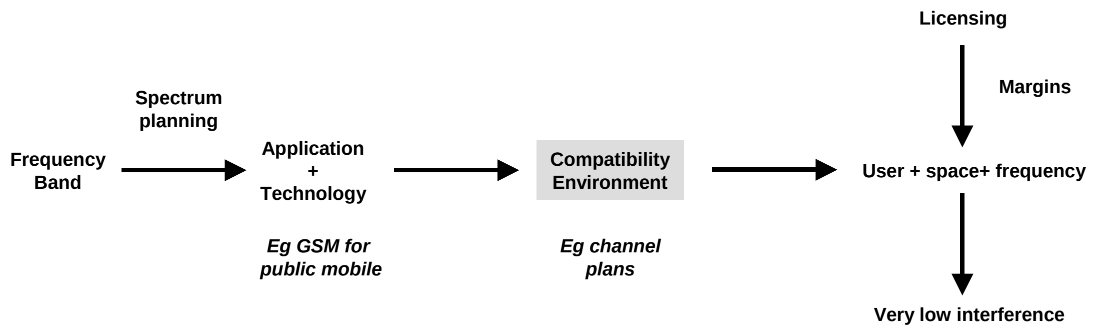
At this point there is a basic choice over how frequency use should be categorised. Traditionally bands have been organised according to combinations of application and

[89] For example, choices of technologies could have important impacts on competition in different markets so that incumbents may acquire spectrum and use technologies that limit the extent of competition. While in principle these issues could be dealt with through competition policy, it may be too late to reverse the situation once the spectrum has been assigned to incumbent users.

[90] Assuming that licence exempt users are sufficiently numerous or diverse that their interests are not readily represented by a "club", there does not appear to be a market based approach to deciding whether licensed or license exempt spectrum has the highest value. This issue is discussed in *Spectrum Licensing and spectrum commons- where to draw the line?*, William Webb and Martin Cave, Warwick Business School, September 2003.

technology (e.g. GSM for public mobile in one band and TETRA for private trunked mobile in another band). The combination of application and technology has created a "compatibility environment" for the band and licensing has been used to divide up the capacity of the band between different users according to different frequency and geographical arrangements (a combination of user, space and frequency). The licensing procedure has included *a priori* margins designed to give protection from interference. The arrangement is shown in Figure 4.1.

Figure 4.1 Traditional approach to categorising uses

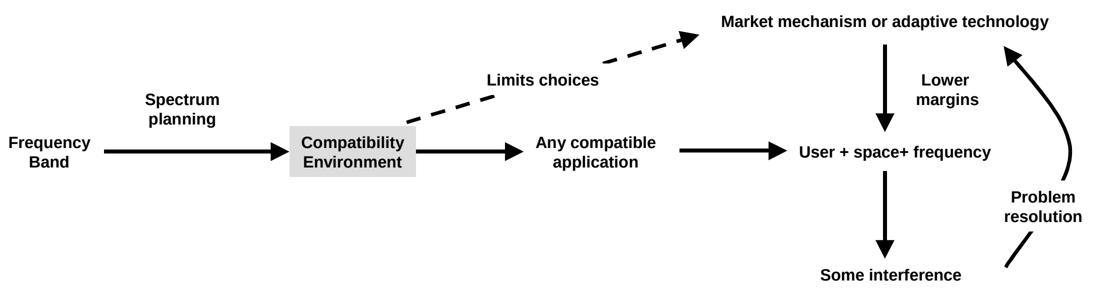


The definition of the compatibility environment would include a spectrum mask (which defines permitted power levels for emissions in and out of the band) and an assumed quality of service (e.g. probability of interference). Other parameters are also likely to be required.

The approach of greater involvement of the market implies allocating bands to create various different compatibility environments and then allowing any use that roughly fits within that environment provided that the necessary grade of service can be achieved. Rights of use can then be determined by adaptive technology (unlicensed bands) or market mechanisms (auctions and secondary trading) depending on the nature of the compatibility environment. Both adaptive technology and market mechanisms offer more flexibility than traditional licensing. The arrangements however generally allow greater risk of interference and require improved methods of resolving interference disputes.

The arrangement is shown in Figure 4.2. In this figure, the dotted line from the compatibility environment to the market mechanism shows that the market mechanism has to be constrained by the compatibility environment planned for the band. In other words, the market mechanism cannot allow any application but only those that fit within the compatibility environment, otherwise the whole approach to spectrum planning the grouping of technically compatible applications to achieve efficient use of the spectrum is put at risk.

Figure 4.2 Categorising uses



In this new approach, the focus is on the definition of the compatibility environment rather than a precise definition of the application. This appears to align with Ofcom's proposals that rights to use spectrum should be defined in terms of physical parameters rather than technology or usage dependent parameters.[91]

Some consequences of moving to a more broadly defined compatibility approach include:

- Applications that are currently treated quite differently but that have similar compatibility characteristics such as mobile and broadcasting (both require exclusive use of frequencies over a given area) would become more readily interchangeable by market means.
- Applications that are less likely to cause or suffer interference could be allowed in compatibility environments that have restrictive emission requirements, e.g. the use of short range devices in shared frequency bands.
- Geographic sharing by different applications that conform to the same compatibility requirements may be possible, e.g. mobile operators could use mobile spectrum for fixed applications if they do not need it for mobile (this would fit well with the needs to use radio for fixed links in rural areas where the demand for frequencies for mobile applications is less than in towns where leased lines can be used).

This approach would help facilitate spectrum trading and would involve a move away from the current approach used to harmonise frequency bands. It seems possible therefore that as spectrum trading develops there could be pressure from those users seeking to maximise the use of their spectrum to relax the constraints implied by European harmonisation and standardisation. We recommend that Ofcom studies further the relationship of frequency bands to applications to create more flexibility for different applications around the concept of "compatibility environments".

[91] Para 6.3.3. *Spectrum Trading Consultation*, Ofcom, November 2003.

Glossary

2G	Second generation mobile system
3G	Third generation mobile system
ADSL	Asymmetric Digital Subscriber Lines
AIP	Administered incentive pricing
Band III	Frequencies in range 174-230 MHz
CAA	Civil Aviation Authority (UK)
CBS	Common Base Station
CDMA	Code Division Multiple Access
CEPT	European Conference of Postal and Telecommunications Administrations
DAB	Digital Audio Broadcasting
dBW	Decibels relative to one Watt of power.
DCS1800	Digital Cellular System 1800
DSL	Digital subscriber line
DVB	Digital video broadcasting
DTI	Department of Trade and Industry
DTV	Digital Television
DVB-T	Digital Video Broadcasting - Terrestrial
E GSM	Extended GSM
EC	European Commission
ECC	Electronic Communications Committee
EIRP	Effective Isotropically Radiated Power
ENG	Electronic news gathering
ERC	European Radiocommunications Committee
ERMES	European Radio Messaging System

ERO	European Radiocommunications Office
ETSI	European Telecommunications Standards Institute
EU	European Union
FSS	Fixed Satellite Service
FWA	Fixed Wireless Access
GHz	Gigahertz
GSM	Global System for Mobile Communications Groupe Spécial Mobile. See ERC Decision ERC/DEC/(94)01.
GSM1800	GSM using 1800 MHz frequencies
GSM900	GSM using 900 MHz frequencies
HAPS	High altitude platform system
IMT 2000	International Mobile Telecommunications 2000
ITC	Independent Television Commission
ITU	International Telecommunications Union
ITU RR	ITU Radio Regulations
ITU-R	ITU-Radiocommunications Sector
kHz	kilo Hertz
MASTS	Mobile Assignment Technical System
MHz	Megahertz
MoD	Ministry of Defence
NATS	National Air Traffic Service.
Ofcom	Office of Communications
PAMR	Public Access Mobile Radio
PCN	Personal Communication Networks (at 1800 MHz)
PMR	Private Mobile Radio
PMSE	Programme Making and Special Events.
R&TTE	Radio and telecommunications terminal equipment

RA	Radiocommunications Agency (UK)
RF	Radio Frequency
RFID	Radio frequency identification systems
RR	Radio Regulations
SDR	Software defined radio
SRD	Short range device
TACS	Total access communication system
TDD	Time division duplex
TDMA	Time division multiple access
TETRA	Terrestrial Trunked Radio (ETSI digital trunked radio standard)
TETRAPOL	Proprietary digital trunked radio standard
TFTS	Terrestrial Flight Telecommunications system
TV	Television.
UHF	Ultra High Frequency (300 to 3000 MHz)
UMTS	Universal Mobile Telecommunications System (3G mobile standard)
VHF	Very High Frequency (30 to 300 MHz)
VSAT	Very Small Aperture Terminal
WARC/WRC	World Administrative Radio Conference/World Radiocommunications Conference
WTO	World trade organisation