Administrative Incentive Pricing of Radiofrequency Spectrum

Final Report for ACMA

23 October 2008

Plum Consulting, 17-19 Bedford Street, Covent Garden, London, WC2E 9HP

T: +44(20) 7868 5340, **www.plumconsulting.co.uk**

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Executive Summary

This is the Final Report for a study for ACMA on the derivation of opportunity cost pricing for apparatus licences. The report presents a discussion of the components of spectrum value and a review of approaches used in other countries in setting AIP (administrative incentive prices) using opportunity cost principles, and develops a recommended approach for measuring opportunity cost in different frequency bands. This approach is then applied to two frequency bands: the 400 MHz band used mainly for land mobile applications and the 7.5/8 GHz bands used for fixed services.

Spectrum value and congestion

A rational firm can be expected to value access to spectrum based on the expected net present value (NPV) of future returns[1] where these are calculated valuing all other inputs (including capital) at their market price plus the option value from the flexibility offered by spectrum access. The expected net present value of returns will comprise the returns from using the spectrum – what we call the project value – and the defensive value of the spectrum which derives from desire to protect profits by limiting competition or raising competitors' costs (i.e. is value derived from anti-competitive behaviour). The option value does not require the spectrum to be used – it is the value of flexibility offered by having the option to use the resource or trade it in future should the value to others be higher than the value to the user.

We conclude that in the case of apparatus licences the project based value is the most tractable aspect of value to measure. Option and defence values are either zero or positive and hence project based values represent a lower bound on opportunity cost. However market benchmarks obtained from auctions (and possibly also trades) of spectrum licences could well include an element of option value and defence value in which case market values could exceed opportunity cost estimates based on project value.

Prices for spectrum in a given band might be expected to vary by geographic location and frequency according to the degree of congestion, much as land prices vary by strength of demand. For example, if a band is moderately congested prices might be expected to lie between those in heavily congested and uncongested areas or frequencies. While AIP should clearly be charged in bands deemed to be congested there is a case for applying above cost fees that are less than AIP in moderately congested bands to reflect both the market expectation that these bands could become congested in future and that users will value the flexibility having spectrum access (i.e. the option value of the spectrum).

In the context of this study, this means setting an above zero AIP in bands in Perth which are at present moderately congested i.e. cannot be said to be "full" by any objective measure. Judgment needs to be exercised in setting these values with higher values set if the band might become full in the next 3-5 years (based on expected demand growth).

[1] That is the discounted cash flows in a commercial context or discounted net benefits in a non-commercial context where the discount rate is the "normal" rate of return. This is the value from use of the spectrum or from trading the spectrum. In the long term the value of trades will be determined in part by returns from spectrum use.

International experience

The value of spectrum comprises two elements: the expected net present value (NPV) of future returns[2] plus the option value from the flexibility offered by spectrum access. The expected net present value of returns will comprise the returns from using the spectrum – what we call the project value – and the defence (or strategic) value of the spectrum. In the case of apparatus licences the project based value is likely to be of prime importance. Option and defence values are either zero or positive and hence project based values represent a lower bound on opportunity cost. In general it is only practical to estimate project values, because the information needed to estimate option and defence values is not available.

Administratively determined spectrum prices have been set by numerous regulators with a view to promoting efficient spectrum use. This is generally achieved by relating the prices to the key value drivers: bandwidth and area sterilised; frequency band; type of service and location of use. With the exception of New Zealand and the UK, the levels of the key parameters in these spectrum pricing formulae are not related to opportunity cost. Rather values are set judgmentally and are heavily influenced by historical precedent partly because of the political difficulties of making major changes to fees paid by users.

The key lessons from the UK and New Zealand experience in deriving opportunity cost estimates are that:

- Depending on the frequency band under consideration opportunity cost estimates can be derived from valuing the cost savings from access to additional spectrum (the “least cost alternative” approach) or from the net revenues that additional spectrum may generate.
- Values based on cost savings rather then net revenues are much easier to implement, because less information on the future development of services is required. Uncertainty over future market developments is a major problem when estimating opportunity cost for many communications services.
- Estimates of opportunity cost are necessarily approximate, and as adjustments to administratively determined prices can only be made periodically, it is necessary to consider the direction of “bias” in estimates that is likely to minimise potential economic losses.

There has been relatively little use of market benchmarks to derive opportunity cost estimates. This is because of the difficulty in making convincing like for like comparisons. There are relatively few comparators and national markets and the timing of spectrum releases differ considerably. Furthermore, in the one case where there has been considerable market information, namely auctions of spectrum for 3G mobile services, the volatility in market values meant that prices based on the early values were a very unreliable indicator of opportunity cost at a later date.

Recommended approach

Our appraisal of the possible options for estimating opportunity cost indicates that there is no one preferred approach. The relative merits of each approach depend importantly on the frequency band and potential uses of the band, and the quality of the information available. In some circumstances multiple approaches may need to be used and reconciled.

We recommend an approach based on the following multi-step process:

[2] That is the discounted cash flows in a commercial context or discounted net benefits in a non-commercial context.

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1. What services or applications could potentially use the frequency band? Are they to provide a service offering (i.e. public) or to support internal business processes (i.e. private)?
2. If they are to provide a service offering (i.e. public services) then for each use derive the value of spectrum as follows:
    a. Are there market values derived from spectrum transactions in comparable market and spectrum use situations? If yes, then use these data to provide an estimate of value for the service in question.
    b. If there are some uncertainties over the reliability of the value derived from market data or such values cannot be derived, then directly calculate the value as follows.
        i. Generally calculate value based on the NPV of future cash flows with all inputs (including capital) valued at their market price.
        ii. But if in some circumstances it is reasonable to assume that spectrum holdings change to achieve cost reductions while service output and revenues are constant, then estimate value based on the least cost alternative approach.
    c. Where market and directly calculated spectrum values are obtained, make choice of value based on the direction of bias that seems likely to best promote welfare.
3. If they support internal business processes (i.e. private services) then for each service derive estimate the opportunity cost of spectrum based on the least cost alternative approach
4. If there is a use with an estimated value greater than that for the current use then set the AIP between the two values – generally towards the bottom end of the range but depending on the shape of spectrum demand curves there may be circumstances where a value towards the middle of the range will be appropriate.
5. If there is no use with a spectrum value higher than the current use of the band then set the AIP at the spectrum value for the current use.

This report applies the AIP principles outlined above by way of two case studies. The two cases relate to land mobile (and to a lesser extent fixed link) usage in the 400 MHz band and fixed link usage in the 7.5 / 8 GHz bands in Sydney (congested) and Perth (moderately congested).

The 400 MHz band (403-420 MHz and 450-520 MHz)

This band refers to spectrum between 403-520 MHz. It consists of the two blocks 403 – 420 MHz and 450 – 520 MHz for mobile and fixed services with the spectrum in between these two blocks supporting various defence / government applications. Frequencies towards the upper end of the 450-520 MHz block are less attractive than others because there is less equipment available.[3]

The band is used for narrowband land mobile and fixed services as well as wideband rural services. These latter services are not relevant to the case studies, as use of the band is dominated by narrowband land mobile services which can be single frequency, two frequency or two frequency trunked. Similarly, the narrowband fixed services can be single frequency, two frequency point-to-point or two frequency point-to-multi-point. Historically 25 kHz channelisation has been used but 12.5 kHz systems are increasingly deployed.

[3] Frequencies from 490-520 MHz are used for broadcasting elsewhere in the region.

The band is reported to be congested and previous analysis[4] by ACMA of two of the segments in the band plan suggests that (for those segments at least) Sydney is heavily congested (tending towards 100% usage) but Perth is less so (around 50% usage). Land mobile comprises the main use of the band and is the application which is growing and so

if the band is congested in a particular location then land mobile users would be denied access to the band. These users face few other communications options. There is spare capacity at VHF but these frequencies are less attractive because the equipment is less compact and the bands are noisier. ACMA reduced fees in the VHF band to encourage migration but we understand that this has had little effect on demand at 400 MHz. There is an alternative band at 820-825 MHz/865-870 MHz but this is also congested in Sydney.

This means that if a user with its own system is denied access to spectrum in the 400 MHz band the practical alternative communications choices available are move to narrowband technology, use of cellular telephony or move to a trunked system. Cellular telephony is unlikely to give the functionality required by land mobile users (i.e. group calling, cost control) and so this leaves the two choices of narrow bandwidth technology and public trunked systems. The costs of moving to these two alternatives are estimated and we derive values from two market benchmarks: spectrum auctions and the value of capacity sold by public trunked network operators. We obtain the following values:

- More efficient technology (12.5 kHz v. 25 kHz) - $269 per kHz per year based on an averagely loaded system. Range of $77 to $988 for lightly / heavily loaded systems.
- Move to public trunked networks – positive values are only obtained for systems with at least 25 mobiles per base station. Values range from around zero to $369 per kHz per year for a system with 100 mobiles per base station.
- Inferred from capacity sales - $68 to $136 per kHz per year based on average loading across whole trunk network.
- International auction values – $2.3 to $14.4 per kHz per year but highest value considered an aberration

These values can be compared to the current Sydney spectrum tax in this band of $90 per kHz per year. Our calculations suggest that the tax applied is Sydney is too low to encourage migration to narrowband technology or public trunked systems as a way of relieving congestion and hence values should rise – possible doubling or trebling in value. As congestion occurs in both blocks and we anticipate there would also be demand for the block allocated to defence use, the higher values should apply to the entire 403-520 MHz block. As the defence allocation blocks the entire use of the band by land mobile, they should in principle pay for the entire exclusion and not on the basis of their actual use of the band (as is currently the case under their apparatus licences).

In Perth the level of congestion is much less acute and this together with the general uncertainty and about the rate of future demand growth given the moves to mobile data communications suggests the values here should not be changed.

[4] Quantifying Spectrum Use in the 400 MHz Land Mobile Band. SP 4/05, 1st December 2005.
Spectrum Options:403-520 MHz. Initial consultation on future arrangements for the 400 MHz band. April 2008.

The 7.5 / 8 GHz bands

The 7.5 GHz band plan supports low/medium capacity (2 – 17 Mbps) point-to-point medium haul (> 20 km) fixed links. The band plan is based on sets of 7 and 14 MHz channels offset with respect to one another, with new assignments also having to be coordinated with some legacy 3.5 and 18 MHz channels.

Assignments countrywide in the band have increased by nearly half over the last 10 years. ACMA consider[5] that the band is approximately half loaded at present and that it will be fully loaded by 2020 where this includes the East Coast of Australia Low Density Area.

The 8 GHz band plan supports medium/high capacity (34 Mbps, FM video) point-to-point medium haul (> 10 km) fixed links. The band plan is based on two sets of 29.65 MHz channels, main and interleaved.

Assignments countrywide in the band have nearly doubled over the last 10 years. ACMA consider that the band is currently 25% - 50% full on regional trunk routes and 50% - 80% full on most sites associated with major trunk routes (especially close to cities), with some sites close to or have reached 100% on particular azimuths. In this situation there are two potential sources of scarcity – spectrum and site capacity – and hence two sources of economic rent. If spectrum prices are set below opportunity cost then in principle the price of site capacity could rise to reflect both the scarcity value of spectrum and the scarcity value of site capacity. However, we consider that it is preferable for spectrum to be priced at its opportunity cost because 1) site capacity will not be constrained in all locations where there is spectrum scarcity and 2) the government should receive a fair return on spectrum access.

There are no practical alternative uses of the band and so we have estimated opportunity cost assuming use of the band by fixed links. We are not aware of any relevant market benchmarks from either Australia or other countries.

We have considered the incremental costs to a user denied access to the band of:

- using more efficient technology
- moving to a higher frequency band
- using alternative services – satellite and leased lines.

The following estimates are obtained:

- More efficient technology – information not available to quantify impact. But we note the current fees provide an incentive for adoption of higher order modulation.
- Higher frequency band - $42 to $179 per MHz per year
- Satellite substitute - $5,257 to 6,971 per MHz per year assuming a 20 hop trunk route has been substituted
- Leased line substitute - $268 per MHz per year assuming a 20 hop trunk route has been substituted.

These values can be compared to the current Sydney spectrum tax in these bands of $148 per MHz per year. Our calculations suggest that the current level of the spectrum tax in Sydney is a

[5] Band loading and assignment trend analysis of fixed link bands in Australia. SPP 9/07 September 2007.

reasonable reflection of opportunity cost. However, the tax in the 8.5-14.5 GHz band in Sydney of $127 looks high given the bands in this range are not congested. A useful first step could be to reduce these charges to levels comparable to those in Perth in order to encourage greater use of these bands as compared to the 7.5/8 GHz bands.

1 Introduction

Efficient resource use is promoted when prices reflect opportunity cost.[6] In the case of spectrum the opportunity cost is the value of the opportunity forgone by current spectrum use i.e. it is the value to the next best alternative use or user of the spectrum. This is the price at which supply and demand for spectrum are balanced.

Spectrum licences are assigned by auction and the auction determines the price paid for the licence. Apparatus licences are assigned on a first come first served basis and incur an annual transmitter or receiver licence fee based on a fee formula approach. They are set so as to contribute to the efficient allocation of spectrum, and to promote an equitable and consistent fee regime. Nevertheless there is no clear connection between the charges derived from the apparatus fees formula and the opportunity cost of the spectrum. The purpose of this study is to address this deficiency by recommending a particular opportunity cost pricing method that is efficient, practical and transparent. The study has three main elements

- A review of approaches used in other countries in setting AIP (administered incentive prices) using opportunity cost principles
- The development of recommendations for a particular opportunity cost pricing method
- The application of the recommended pricing method to two case study frequency bands namely, 403-520 MHz and 7425-8275 MHz for a high density (Sydney) and a medium density (Perth) location.

This draft Final Report addresses all three elements of the work. The report is structured as follows:

- Section 2 provides a general discussion of spectrum value and opportunity cost.
- Section 3 describes approaches to deriving opportunity cost developed in other countries.
- Section 4 gives our recommendations on a general approach to estimating opportunity cost for different frequency bands.
- Section 5 applies the recommended approach to the 400 MHz mobile band in Sydney and Perth.
- Section 6 applies the recommended approach to the 7.5/8 GHz fixed services band in Sydney and Perth.

The Annex provides an analysis of the current use of the bands examined, based on the RRL (Radiocommunication Record of Licences) database (as of 1st June 2008) and relevant analyses undertaken by ACMA over the past few years.

[6] Spectrum is an input to production and if it is underpriced there is a de facto subsidy on an input. It can be shown that subsidising inputs is inefficient and that policy should be focussed on outputs. This is discussed in "An Economic Study to Review Spectrum Pricing", Indepen, Aegis Systems and Warwick Business School, Ofcom, February 2004. http://www.ofcom.org.uk/research/radiocomms/reports/independent_review/spectrum_pricing.pdf Peter Diamond and James Mirrlees (1971) "Optimal taxation and public production 1: Production efficiency and 2: Tax rules", *American Economic Review*, vol. 61

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2 Spectrum Value

A rational firm can be expected to value access to spectrum based on the expected net present value (NPV) of future returns[7] where these are calculated valuing all other inputs (including capital) at their market price plus the option value from the flexibility offered by spectrum access. The expected net present value of returns will comprise the returns from using the spectrum – what we call the project value – and the defensive value of the spectrum which derives from desire to protect profits by limiting competition or raising competitors' costs (i.e. is value derived from anti-competitive behaviour). These elements of value are described below. The option value does not require the spectrum to be used – it is the value of flexibility offered by having the option to use the resource or trade it in future should the value to others be higher than the value to the user.

In this section we conclude that in the case of apparatus licences the project based value is the most tractable aspect of value to measure. Option and defence values are either zero or positive and hence project based values represent a lower bound on opportunity cost. However market benchmarks obtained from auctions (and possibly also trades) of spectrum licences could well include an element of option value and defence value in which case market values could exceed opportunity cost estimates based on project value. We conclude with a discussion of how value might be expected to vary with the degree of congestion in a band and/or at a specific geographic location.

2.1 Project based value

Spectrum may be acquired either to enhance an existing service or to start a new service.

In the case of service enhancement, the project based value of the spectrum will depend on the extent to which it allows the licensee to earn additional net returns (i.e. profits/or non-monetised benefits) or in a competitive market to maintain profits. Such profits may arise from:

- Additional revenues/benefits: For an existing service additional revenues/benefits may arise from being able to support increased demand or provide higher service quality.
- Cost savings: The total costs of providing a given service may be reduced if spectrum rather than some other input (e.g. infrastructure, another service) is used.

Alternatively a new service may be launched with the spectrum and this may offer the opportunity to earn above normal returns. Only if above normal returns can be made is the project worth undertaking[8] and the scale of these above normal returns sets an upper bound on the spectrum value.

Project based value is more easily measured than defence or option values, and so tends to be the focus of approaches used elsewhere to measure opportunity cost (see Section 3).

[7] That is the discounted cash flows in a commercial context or discounted net benefits in a non-commercial context where the discount rate is the "normal" rate of return. This is the value from use of the spectrum or from trading the spectrum. In the long term the value of trades will be determined in part by returns from spectrum use.

[8] Otherwise the money could as well be invested in other activities offering an expectation of above normal returns.

2.2 Defensive values

Defensive valuations are concerned with acquiring spectrum to protect market share and so profits in the same or other related markets by seeking to restrict entry and/or raise competitors' costs. If such markets were competitive there would be no value to defend as it would be eroded by competition regardless of the amount of spectrum the firm owned. The application of competition law and/or explicit regulatory controls on spectrum holdings should in principle mean that the scale of defence values is not high, and so could be largely ignored in measuring opportunity cost. If these controls are ineffective this may not be the case, but for the purposes of regulators deriving opportunity cost based prices it does not seem appropriate to set prices based on a speculative view of regulatory failure.

2.3 Option values

The value of spectrum could greatly exceed its expected value calculated as the NPV of future cash flows if there is uncertainty over future applications and their value and there are sunk (or irreversible) costs associated with making investments.[9] The reason for this is that access to spectrum creates the opportunity, but not the obligation, to invest in the network and other infrastructure required to provide a wireless service at the time when expected returns are highest. Note this assumes that spectrum rights do not include binding coverage/service roll-out obligations. The option value will be enhanced if spectrum rights are flexibly defined (e.g. there are minimal or no restrictions on the technology used or the type of service offered) so the rights holder can readily take actions to maximise returns in response to new information and opportunities.

The existence of option value means the spectrum has economic value even if it is unused, because of the flexibility it gives the owner to respond to changing circumstances and to avoid the mistake of investing when there is a risk of poor returns from premature investment. The existence of option value may also imply a positive overall price for an asset even when supply exceeds demand. In New Zealand positive auction values have been observed for cellular spectrum in circumstances where supply clearly exceeds demand.[10]

If there was a well functioning spectrum market then it might be argued that option values would be lower than otherwise, because users could acquire the spectrum they needed at the time it was optimal to invest. However, if all firms in the sector were subject to the same event then prices may be high and/or there may not be willing sellers. In addition, there will be transaction costs and delays associated with acquiring the spectrum through bi-lateral trading. Efficient trades may fail to occur when buyers and sellers base their respective valuations on different views of non-privately available information on value (i.e. there is asymmetry of information)[11] or if trading requires revelation by the

[9] Sunk costs might include costs of marketing a service or infrastructure costs that may have to be written off if a service fails e.g. because the second hand market in infrastructure works imperfectly or because equipment costs are falling.

[10] Renewal of Spectrum Rights for Cellular Services pricing methodology, Discussion paper, July 2006, PriceWaterhouseCoopers and NZIER, Ministry for Economic Development, http://www.med.govt.nz/templates/MultipageDocumentTOC____20766.aspx

[11] There is an economics literature that discusses circumstances in which asymmetric information may cause markets to perform badly (when problems of adverse selection or moral hazard can occur) and potential mechanisms for addressing the situation (through signalling and screening) remedies to this situation. See for example "Market for lemons: quality uncertainty and the market mechanism", G Akerlof, Quarterly Journal of Economics, 1970, 84

buyer of its spectrum use plans (e.g. so that the seller is assured that it will not suffer an increased risk of harmful interference).

Option values will however be lower when 1) the duration of the spectrum right is reduced, 2) the use of spectrum is constrained, and 3) when there are use it or lose it conditions. All of these aspects reduce the benefits of flexibility that the option to use the spectrum offers.

A real life example of the potentially large size of option values is given by the case of undeveloped oil fields which may have a negative value if costs of production are compared with expected revenues given current oil prices (which equal expected future oil prices since oil prices, to a first approximation, follow a random walk). Nevertheless undeveloped oil fields trade for values that significantly exceed expected value which may be negative.[12] The reason for this is that the oil price may go up or down, and one would only invest in developing the field if the price went up. The option value of the undeveloped oil field is therefore positive.

Calculating option values is difficult because information on the uncertainty faced by firms may be very limited, and the option value depends on complex considerations including the nature of the underlying uncertainty (is it a random walk or mean reverting?), what the uncertainty applies to (output prices, input costs or technology?) and the regulatory-political environment (to what extent can investors exercise different options?). Nevertheless such values can be large in some circumstances e.g. when uncertainty and sunk costs are large.

Turning to the situation of spectrum and apparatus licences in Australia, both types of licence are tradable but differ in terms of their duration and flexibility. Apparatus licences must be used for a particular service whereas spectrum licences are service neutral which suggests option values should be relatively higher for spectrum licences. Spectrum licences are nominally of longer duration than apparatus licences (typically 15 years versus 1-5 years respectively) but apparatus licensees arguably have greater security of tenure in the sense that apparatus licences are renewed unless the spectrum is re-planned[13], whereas there is no presumption that spectrum licences will be renewed at the end of their fixed term (although this has not yet been tested in practice). These practical differences in licence duration could mean that option values for apparatus licences are higher than for spectrum licences, particularly towards the end of the term of spectrum licences.

The relative scale of the impact of licence conditions on the values of option values for apparatus and spectrum licences is unfortunately ambiguous. There is a risk that errors from omitting option values in estimating opportunity costs for apparatus licences could be significant. While auction values for spectrum licences may not give an appropriate guide to the value of apparatus licences for similar or even the same frequency bands they may provide a better guide than project based valuation alone. This suggests that estimates of opportunity cost may need to be derived using several different approaches.

2.4 Congestion

Prices for spectrum in a given band might be expected to vary by geographic location and frequency according to the degree of congestion, much as land prices vary by strength of demand. For

[12] Dixit and Pindyck. 2004. Investment under uncertainty. Page 403.

[13] 3-5 years notice is given for major re-planning of a band.

example, if a band is moderately congested prices might be expected to lie between those in heavily congested and uncongested areas or frequencies.

While a market in spectrum would seem likely to deliver such a result it is much more difficult to determine a precise estimate of the way prices should vary with congestion administratively, because there is no absolute measure of congestion and because value in bands that are not full but might be in future depends on expectations about future demand growth. Possible proxies for the degree of congestion include density of assignments, probability of blocked communications and ease of making new assignments. Inevitably some judgement is required when determining the severity of congestion and the implications for the level of prices.

While AIP should clearly be charged in bands deemed to be congested there is a case for applying above cost fees that are less than AIP in moderately congested bands to reflect both the market expectation that these bands could become congested in future and that users will value the flexibility having spectrum access (i.e. the option value of the spectrum).

In the context of this study, this means setting an above zero AIP in bands in Perth which are at present moderately congested i.e. cannot be said to be “full” by any objective measure. Judgment needs to be exercised in setting these values with higher values set if the band might become full in the next 3-5 years (based on expected demand growth).

3 International Review

3.1 Introduction

Administratively determined spectrum prices have been set by numerous regulators with a view to promoting efficient spectrum use. This is generally achieved by relating the prices to the key value drivers namely:

- the amount of spectrum used (bandwidth and area sterilised)
- the type of service supplied (often with higher fees for public mobile as compared with other services)
- the frequency band (with higher values in bands that are internationally harmonised, that offer better propagation characteristics and that are more likely to be congested)
- the location of use with higher values in more congested areas e.g. higher values in urban versus rural areas.

Examples of spectrum pricing approaches used or proposed for a selection of countries are shown in Table 3-1. For comparison we have also included the approach currently used in Australia for apparatus licences. With the exception of New Zealand and the UK, in the examples we have reviewed the levels of the key parameters in the formulae are not related to opportunity cost. Rather values are set judgmentally and are heavily influenced by historical precedent partly because of the political difficulties of making major changes in fees paid by users.

New Zealand and the UK are the only countries we know of where the regulator has sought to estimate opportunity cost directly.[14] We have advised the Singapore and the Portuguese regulators on applying the UK approach in some bands but these recommendations have not yet been implemented. The rest of this Section discusses the approaches adopted in New Zealand and the UK and issues encountered in deriving estimates of opportunity cost.

[14] We understand from e-mail contact with the US National Telecommunications and Information Administration that they are undertaking some work in this area but so far there is no publicly available output from this activity.

Table 3-1 Examples of spectrum pricing approaches

Country	Parameters in pricing formula	Derivation of levels
Australia	Scaling constant; spectrum band; geographic location; bandwidth; power; adjustment factors that depend on the service e.g. there are adjustments for frequency reuse for point to point links and for the band used by land mobile	Historic precedence; CPI inflation
Bahrain[15]	Constant based on local conditions and costs; frequency band; geography; bandwidth; power.	Not applied yet
Canada[16,17]	Fees are a function of bandwidth, population in geographic area covered in areas where there is scarcity	Judgemental
France[18]	Bandwidth and location for PMR, PAMR, fixed links and wireless local loop licensees. Number of base stations/links and whether the spectrum is shared or not also affects the level of fees. Market benchmark used for 3G licences.	Judgemental
Ireland[19]	For PMR and fixed links – frequency band; bandwidth; coverage area (for PMR); geographic location; degree of sharing	Cost recovery for PMR; rationing congestion for fixed links. Changes from historic fees governed by what was thought to be to politically acceptable
Japan[20]	Frequency bandwidth; frequency band; geographic location.	A target sum to be raised. 3:1 ratio of costs borne by users under 3GHz relative to those in 3-6 GHz. Over 6 GHz fees reflect spectrum management costs.
New Zealand	For broadcasting licences: auction value increased by a compound growth factor; regional licence values are set pro-rata to the share of national population. For cellular licences: the price/MHz is based on the incremental cost of being deprived divided by the amount of spectrum	Both approaches seek to estimate opportunity cost
Spain[21]	Coverage area; bandwidth; occupancy and demand for service; public vs private services; exclusive or shared use; efficiency of technology used; social and economic benefit from the service. Market benchmark used for 3G licences.	Judgemental
UK	Opportunity cost/MHz calculated on a national basis and then price adjusted to take account of bandwidth, area/population over which use sterilised or degree or reuse, location of use (i.e. degree of congestion)	Opportunity cost estimated using "least cost alternative" approach. AIP set at 50% of opportunity cost.

Source: Plum and Aegis analysis

[15] This approach has been proposed in Bahrain and is reportedly used in France, Greece, Italy and Malaysia. See p45 of http://www.tra.org.bh/en/pdf/spectrum_policy_consultation.pdf

[16] http://www.ntia.doc.gov/forums/2006/specman/ntia_connolly.pdf

[17] See chapter 4 in http://www.bundesnetzagentur.de/media/archive/4745.pdf

[18] There are proposals to have a given fee/MHz (A) for all use below 960 MHz and above 960 MHz set fees equal to A*960/F This proposal was included in a May 1997 Decree which has never been signed.

[19] http://www.comreg.ie/_fileupload/publications/ComReg0558.pdf

[20] The approach to policy development has been described in "Spectrum Policy in Transition", Phillipa Marks and Kiyotaka Yuguchi, Keio Communications Review, No 26, 2004.

[21] http://www.mityc.es/NR/rdonlyres/EA1520D2-6F18-4FA7-A01C-9FF82EA22D96/0/TASAS_2008.pdf

3.2 UK approach

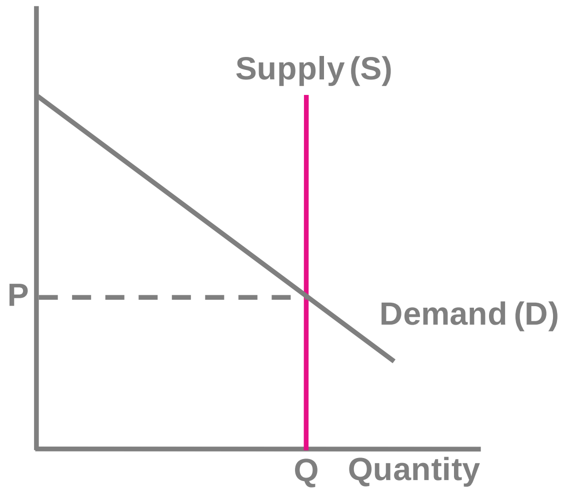
The approach to calculating the opportunity cost of spectrum in the UK has been developed over the last decade. We describe each of the main changes in methodology and discuss some implementation issues.

3.2.1 Opportunity cost – fixed allocations

Smith-NERA (1996) proposed a method for evaluating AIP based on opportunity costs calculated at the margin.[22] The approach focused primarily on assignment within frequency bands. It sought to answer the question: what should be the price of spectrum to ensure an efficient assignment amongst potential users assuming the allocated use of spectrum remains constant?

The high level answer to this question was: an efficient assignment would result from a price set equal to the opportunity cost of spectrum. The assumed situation is as shown in Figure 3-1 where the demand for spectrum is given by the grey downward sloping line, the supply is given by the vertical (pink) line and the opportunity cost of spectrum equals the market clearing price (P).

Figure 3-1 Supply and demand for spectrum



Opportunity costs were estimated by calculating the impact of a hypothetical marginal change in spectrum on the costs of an "average firm" in the sector assuming the level of output and service quality were kept constant. For example, suppose the average firm was denied a unit of spectrum then the marginal cost would equal the minimum additional costs the firm would incur. These additional costs were calculated by examining the least cost alternative action an "average firm" might take when denied access to a small amount of spectrum.[23] The options examined included one or more of:

- Investing in more network infrastructure to achieve the same quantity and quality of output with less spectrum.

[22] Study into the Use of Spectrum Pricing, NERA and Smith System Engineering, Radiocommunications Agency, April 1996.

[23] Usually the smallest change in spectrum use that is technically feasible.

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- Adopting narrower bandwidth equipment.
- Switching to an alternative frequency band.
- Switching to an alternative service (e.g. a public service rather than private communications) or technology (e.g. fibre or leased line rather than a fixed radio link).

In principle the approach can also be applied by assuming the firm is granted access to an additional unit of spectrum and calculating the cost saving to the firm. This approach overstates the opportunity cost of spectrum for reductions in spectrum and understates the opportunity cost for increases in spectrum.[24] An average of the values obtained from an increase and a decrease in spectrum would give a reasonable approximation to the value. In practice, it is not always feasible to estimate values for increases and decreases in spectrum and so one or other is used.

This approach to estimating opportunity cost makes the following assumptions:

- The private value of spectrum is a good proxy for social value (and so prices based on private value give socially efficient outcomes).
- Demand exceeds supply in the current use.
- Output and service quality are both fixed – so revenue effects and other non-cost aspects of value (e.g. convenience) do not need to be considered.
- Value is based on choices faced by users in the near term – either currently or in the next few years
- Increases/decreases in spectrum are roughly symmetric – so only one set of calculations is required.
- Changes in allocations are not feasible – so only values for the current use need to be considered.
- Defence and option values of marginal changes in spectrum access are zero.
- The user is able to afford the additional costs imposed by being denied spectrum access i.e. in the case of a private firm it does not go out of business and in the case of a public sector user there is sufficient budget to cover the additional costs.

Opportunity costs were calculated by Smith-NERA (1996) for mobile services (i.e. PMR, PAMR and cellular services) and fixed links and were intended to result in a more efficient assignment of spectrum to these services. Opportunity cost estimates for mobile services were over 10 times those for fixed links.

Smith-NERA(1996) suggested that mobile and fixed link prices could in principle be used to set benchmark prices for other spectrum that could be used by either mobile or fixed link services respectively. As a general rule mobile prices were applied by the UK Government below 3GHz while fixed link prices were applied above 3 GHz. The level of actual prices (i.e. AIP) charged were set conservatively, with increases phased in over 4 years up to a maximum of 50% of the calculated opportunity cost estimate.

[24] The difference arises because faced with a change in the quantity of spectrum, a profit maximising firm would change its output. Output would be expanded in the case of additional spectrum and so higher returns would be earned than calculated. Alternatively if the firm has less spectrum output would be reduced and lower returns made.

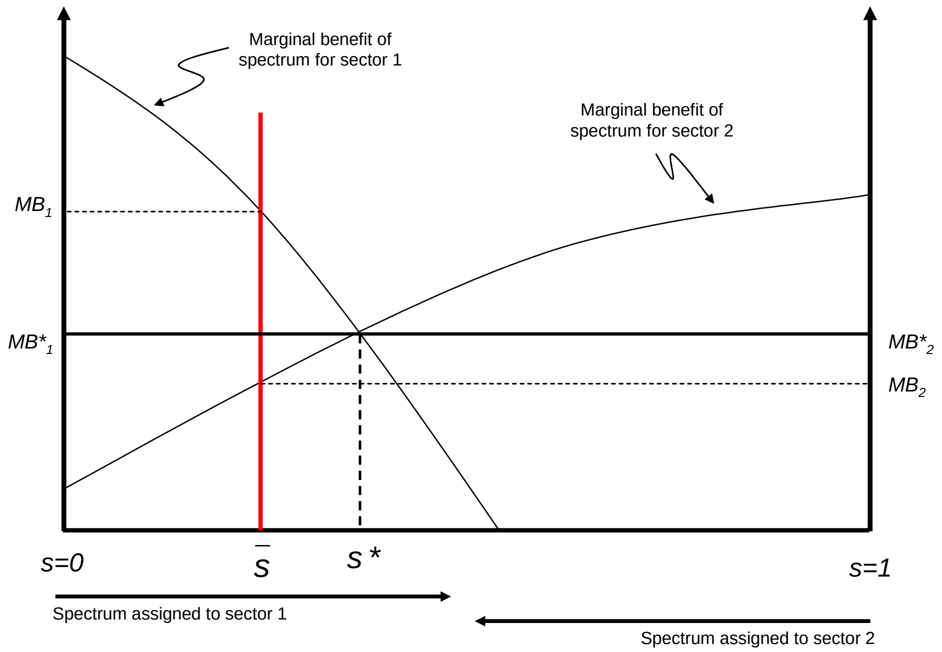
3.2.2 Opportunity costs – varying allocations

The approach just described was reviewed in 2004[25] and extended to cover the situation in which changes in spectrum allocations might occur as a result of the incentives provided by spectrum pricing. The methodological issue this raises is that it can no longer be assumed that one is looking at an equilibrium situation as drawn in Figure 3-1. Rather the situation shown in Figure 3-2 applies.

What this figure shows is a situation in which the split of the current division of a block of spectrum between two uses (shown by the vertical red line) is not at the market equilibrium (S*, MB*)– defined as the point at which marginal benefits to users are equalised between the two uses.[26] The reason for this is that allocations have historically been determined by a political process (at national and international levels) that has not been guided directly by information on the economic and social benefits of spectrum use. It would therefore only be by chance that allocations were in any sense optimal.

The marginal benefits calculated (MB_1 and MB_2) will not give an optimal price i.e. will not give the opportunity cost of spectrum with flexible allocations. However, a price set between MB_1 and MB_2 will provide users with incentives to move from the current disequilibrium towards the more efficient equilibrium. Taking an intermediate opportunity cost estimate reduces discontinuities in value as one moves from one frequency band to another and arguably better represents a longer term view of the value of different bands, as allocation constraints get relaxed.

Figure 3-2 Marginal benefits from spectrum use



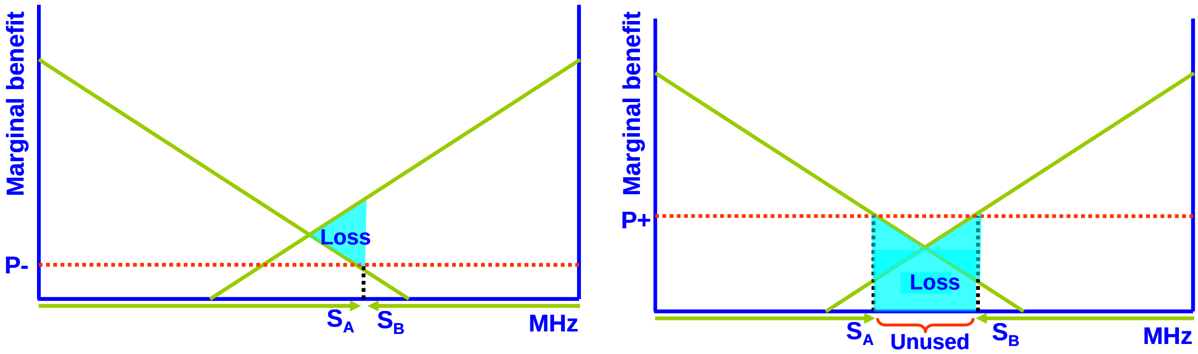
So what is the best estimate of opportunity cost in the range MB_2 to MB_1? The 2004 review of spectrum pricing in the UK suggested that it is more efficient to err on the side of caution to ensure

[25] "An Economic Study to Review Spectrum Pricing", Indepen, Aegis Systems and Warwick Business School, Ofcom, February 2004.

[26] Note that it is assumed that each use has exclusive use of its spectrum block.

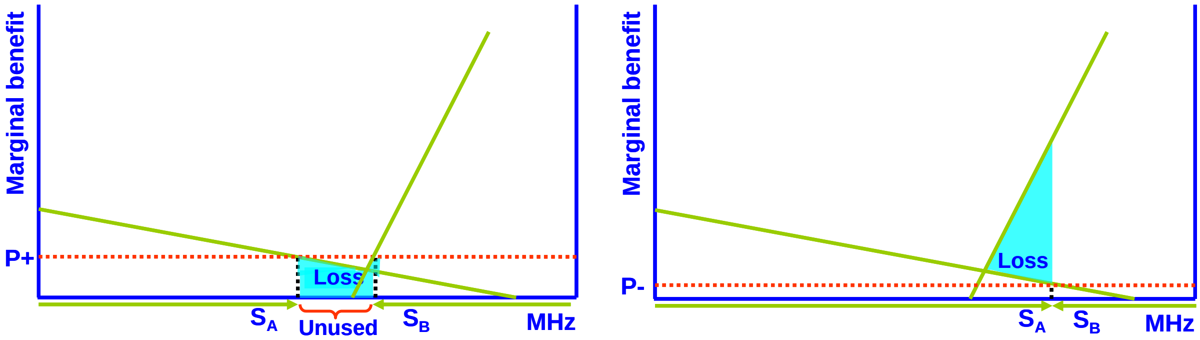
that spectrum is not left idle. This can be seen for the case of identical demand curves in Figure 3-3 which shows that the economic loss (the shaded area) is smaller if prices are set on the low side.

Figure 3-3 Economic losses from setting prices below/above the market clearing price with identical demand curves



If the assumption of identical demand curves is relaxed it is possible to construct situations where it is better from a welfare perspective to set the opportunity cost on the high side, as is shown by comparison of the size of the welfare losses in Figure 3-4.[27] We note these welfare effects matter in the context of prices that are set administratively because price adjustments will only happen at relatively long intervals (of years) as compared with a market situation in which prices may adjust immediately to a supply/demand imbalance. This means that one needs information on (or an assumption about) the slope of spectrum demand curves when deciding whether to set prices on the high or the low side in the range of estimated marginal benefits.

Figure 3-4 Economic losses from setting prices below/above the market clearing price with different demand curves



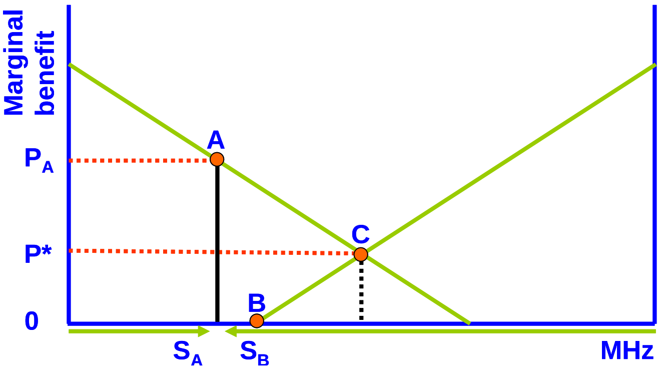
An additional consideration in relation to the longer term response is how one should think about opportunity costs when there are significant existing constraints on reassigning spectrum between alternative uses (e.g. international constraints). The situation is illustrated in Figure 3-5 for the simple example of two uses of a given spectrum band, and where there is scarcity in respect of use A and no scarcity of spectrum in relation to use B.[28] The constraint is given by the vertical line S_A, A. The

[27] This discussion is taken from the following report for Ofcom on applying AIP to the aeronautical and maritime sectors. http://www.ofcom.org.uk/research/radiocomms/reports/spectrumaip/

[28] Note that the results shown also apply for cases where there is scarcity of spectrum in use B.

optimum allocation of spectrum without the constraint is at point C. The optimal price in the absence of the constraint would be P*. If the constraint is taken as given, then one might set prices corresponding to A ($P=P_A$) and B (P=0) for the two uses, but this provides weak incentives to shift the constraint, in particular there is no incentive for the existing use S_B to propose a reduction in their allocation.

Figure 3-5 Opportunity costs with excess supply



However, from a social perspective, it may be appropriate for use B to face the opportunity cost of their current allocation without the constraint, and for use A to face the same constraint free opportunity cost. The reason for this is that it provides incentives to shift the constraint i.e. to allocate more spectrum to use A and less for use B. Potential inefficiencies with this approach are that use A may face too low an opportunity cost, though trade between users within use A may alleviate any such inefficiency if trading is permitted[29] and use B may face too high a charge with the risk of leaving spectrum unused. The timeframe over which these inefficiencies persist depends very much on how easy it is to change allocations – allocations made at a national level generally take less time to change than those agreed internationally through the ITU (which can take a decade or more).

In summary, the extension of the original Smith-NERA (1996) approach involved

- Marginal benefit calculations for all potential uses of a given block of spectrum using the least cost-alternative method.
- A judgement about the direction of bias when setting prices using information about the likely shape of the demand curves for spectrum and the potential for relaxing constraints on allocations between different uses.
- Taking the status quo as a starting point for calculating opportunity cost, and then relying on iteration to achieve a closer approximation to the social optimum over time as direct estimation of the social optimum is thought to be infeasible.

This extension of the original UK approach more closely approximates the real world situation where allocations have the potential to change. However, it requires more information and judgement. In particular information on current and potential future uses of the band and their respective least cost alternative actions are required. The derivation of a range of values and the need for judgement

[29] Trading is permitted for most commercial uses of spectrum but a decision on whether spectrum used by aeronautical and maritime users can be traded is expected to be made in 2007.Ofcom, 2004 “Statement on Spectrum Trading”

about the level to choose can mean that the chosen levels are sometimes perceived (by users) as somewhat arbitrary.

3.2.3 Opportunity costs – challenges to the method

The following criticisms have been made of the method described above for calculating opportunity cost:

- It ignores externalities created by the final service delivered.
- The smallest increment/decrement in spectrum may be large for some services in which case the assumption of constant output is unrealistic as this may not be the approach that maximises returns and furthermore viability issues may arise.
- It ignores market information which gives a more reliable indicator of value.

Externalities

There are two kinds of externality that need to be considered

- Market externalities involving financial impacts in secondary markets which are downstream or upstream from the market subject to primary or initial impacts (sometimes termed pecuniary externalities)
- Non-market externalities such as greenhouse gas emissions, acoustic noise and radio interference which impact on consumer wellbeing and production, but not directly via market prices.

Starting with market externalities, all economic activities have impacts on other parts of the economy since they involve inputs that might be used by, and outputs that may support, other economic activities. There is academic literature[30] that shows that such external economic impacts do not have any implications for optimal pricing since they involve secondary market impacts that occur through changes in quantities and prices in the market place, rather than via 'real' externalities (such as greenhouse gas emissions) that impact on production outside of market mechanisms. Only externalities involving impacts that are not priced (like that from pollution for example), might justify a departure from opportunity cost based pricing.

Some services that use spectrum create non-market externalities. For example, aeronautical and maritime activities creative negative externalities such as air and noise pollution while broadcasting is often argued to create positive externalities such as promoting social cohesion and democracy. These effects have impacts on other economic activity and welfare that are not mediated by market prices because of the absence of markets for these outputs. In general the most efficient way of dealing with material non-market externalities is to address them directly via regulation, taxes/subsidies and/or tradable permits targeted at the externality itself and not to adjust the price of an input such as spectrum.[31]

[30] Baumol and Oates. 1988. "The theory of environmental policy." Cambridge; Boardman, Greenberg, Vining and Weimer. 2006. "Cost-benefit analysis – concepts and practice." Third Edition. Pearson Prentice Hall.

[31] This position was supported by reference to the Diamond and Mirrlees (1971) result that in setting policy to maximise welfare in a second-best situation it is not desirable to tax (or subsidise) the use of inputs. Peter Diamond and James Mirrlees. 1971. "Optimal taxation and public production 1: Production efficiency and 2: tax rules". *American Economic Review*, Volume 61.

The essence of the argument is that whilst it would in principle be possible to take account of (i.e. internalise) externalities for spectrum using services (such as aeronautical and maritime communications and broadcasting) by adjusting input prices, potentially all input prices including spectrum prices would need to be adjusted with different adjustments for each source. [32] This is not practical. This result provides a powerful general argument against adjusting spectrum prices to take account of negative or positive externalities. This was further developed in Indepen-Aegis (2005) in relation to the application of AIP to broadcasting[33] and in Indepen-Aegis (2007)[34] in relation to the aeronautical and maritime sectors.

Finally it is important to note that when there are policies already in place to address externalities, such as coverage and content controls in broadcasting, then marginal opportunity cost will include social value. Figure 3-6 illustrates the derived demand for spectrum for broadcasting on the left and a competing use on the right – with the x-axis showing a finite quantity of available spectrum. On the left two declining marginal benefit curves are shown, one with private benefits to the industry in the absence of any broadcasting regulation, and the other showing private benefits once policies are in place to promote production of external social benefits e.g. coverage and programme content obligations. It is important to note that the broadcasting industry output produced differs between the two curves, with unregulated output levels associated with the curve labelled "MB_1" and regulated output levels associated with the curve labelled "MB_1 with policy constraints". When social benefits are taken into account more spectrum is now demanded by broadcasting in order to meet the social objective (assignment S_1* versus S_0*), and the implied price of spectrum that is consistent with this outcome is higher (MB_1^1 versus MB_1^0).

Provided spectrum prices are calculated using the opportunity cost methodology in the presence of policies, such as coverage and content requirements and public funding of broadcasting, that are designed to achieve an efficient outcome in terms of broadcasting output, then the calculated opportunity costs and so prices will be the correct (higher) ones. No further adjustment is required, provided output is held at current levels.

It is important to reiterate that Figure 3-6 illustrates derived demand for spectrum in the presence of other policies targeted at broadcasting policy objectives. It would, for example, be incorrect to infer from Figure 3-6 that an increase in spectrum alone from S_0* to S_1* would result in a corresponding increase in output to the socially optimal level. Or similarly, that a lower price of spectrum for broadcasting – and higher price for other sectors – would achieve socially desired levels of

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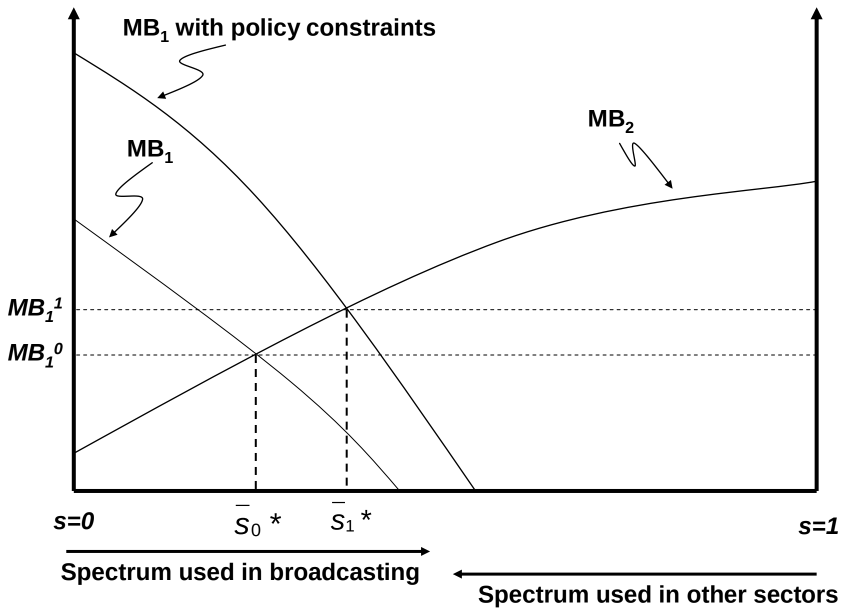
[32] Strictly, it is in principle possible to address an externality by modifying the price of all inputs in an appropriate way. In particular, Holtermann (1976) found that "Where it is impossible to tax an externality directly, Pareto optimality can nevertheless be achieved by a set of taxes (subsidies) imposed on all of the other inputs and outputs of the agent creating the externality." Sally Holtermann. February 1976. "Alternative tax systems to correct for externalities, and the efficiency of paying compensation." *Economica*, Volume 43169. However, this is in practice infeasible given the information and practical constraints on achieving efficient outcomes via the modification of input prices. Holtermann notes that "*in general it is likely to be preferable on practical grounds to tax the externality directly whenever possible."* This conclusion is reinforced by more recent literature. For example, Helfand (1999) concluded "*The problems in distinguishing instruments among sources, combined with lack of information about firms' production functions (and thus how firms will respond to input instruments), make it difficult to calculate the level of pollution reduction, if any, which can be achieved from applying suboptimal input instruments.*"; and that "*separate input taxes need to be developed for all inputs that influence pollution and for each source of pollution".* Gloria Helfand. November 1999. "Controlling inputs to control pollution: when will it work?" *Association of Environmental and Resource Economists Newsletter*, Volume 19(2). Page 17. http://www.aere.org/newsletter/Newsletter_Nov99.pdf

[33] Indepen and Aegis. October 2005. "Study into the potential application of Administered Incentive Pricing to spectrum used for Terrestrial TV & Radio Broadcasting."

[34] http://www.ofcom.org.uk/research/radiocomms/reports/spectrumaip/

broadcasting outputs. The reason for this is that other inputs would have to be increased at the same time to achieve the social optimum (S_1*, MB_1^1).

Figure 3-6: Marginal benefit functions with allowance for social value



Size of change in spectrum

Issues concerning the size of the increment/decrement in spectrum are well illustrated by attempts to apply the least cost alternative method to value spectrum used for analogue broadcasting. In this instance small changes in the amount of spectrum used are not generally possible because of one or more of international spectrum planning constraints and environmental planning constraints fix the location and sometimes frequency used by high power transmitters. In addition, coverage obligations or the nature of the technology mean a fixed amount of spectrum is used per transmission. Migration to another platform e.g. satellite or cable is sometimes the only alternative available to the radio or TV broadcaster denied access to spectrum. The problem is that these options may not be profit maximising or indeed viable and so the returns forgone from not being able to access the spectrum are what gives it value i.e. the entire business needs to be modelled.

The relaxation of the assumption that output is kept constant and the integration of the viability constraint in the framework gives the decision tree reported in Indepen et al (2005)[35] and reproduced below as Figure 3-7. This is used to calculate marginal benefits and then opportunity cost is derived using judgement over where in the range of values opportunity cost should be set.

Using market information

The issue of how to use market information has not yet been addressed directly in the development of AIP in the UK, though we note that for digital radio and TV values have been inferred from market information on the traded value of multiplex capacity.[36]

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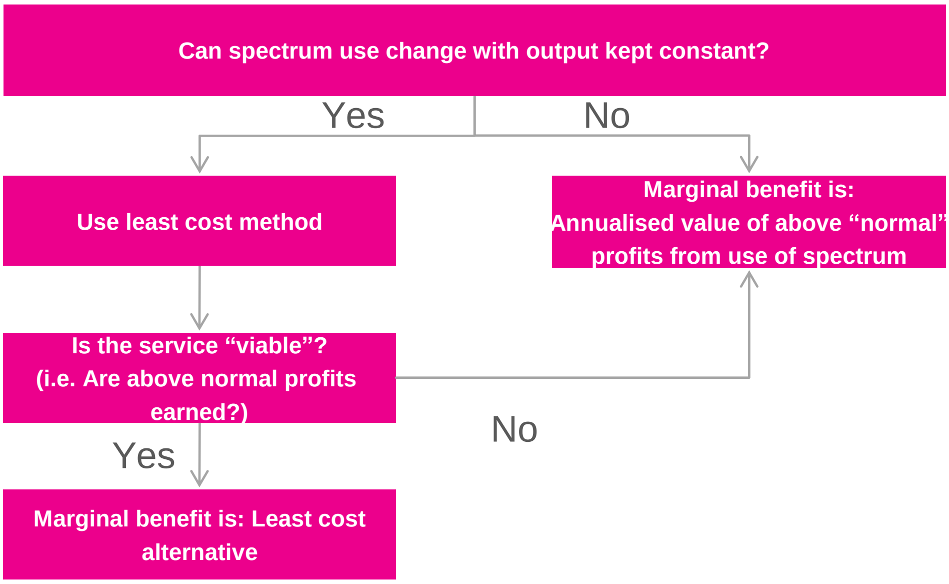
[35] http://www.ofcom.org.uk/consult/condocs/futurepricing/aipstudy.pdf

[36] Op cit.

Figure 3-7 Generalised approach to estimating marginal benefits



3.2.4 Where next?

Ofcom has commissioned Plum and Aegis to undertake a research project to develop a generalised approach to modelling spectrum value derived from engineering and commercial models. The intention is to:

- Provide an analytical framework that establishes the variables that drive the value of spectrum.
- Construct a generic formula for estimation of spectrum value based on parameterisation of frequency band and service characteristics.
- Develop a model of spectrum value that implements the generic formula and assigns values to each of its coefficients.
- Refine the scope of the work in terms of bands, technologies and services to be assessed. As much of the spectrum should be included as is practical.
- Use the model to estimate spectrum value across the bands.
- Consider the future use of the model in terms of its accuracy, updateability and appropriateness for use in areas of spectrum management.

The overall aim of the project is to investigate the estimation of market clearing prices with a view to providing information to the market for trading and not to determine levels of AIP except incidentally. As this is a research project there is some uncertainty as to the actual final outputs. This work is on-going and will conclude at the end of 2008.

3.2.5 Implementation issues

AIP should in principle apply to all spectrum where opportunity costs are non-zero. In other words there is no economic reason to give priority to one band over another, though there may be practical reasons to do so. A clear transition path to a final set of values should mean users still have appropriate incentives for efficient use of spectrum. In the UK when AIP was introduced it was phased in over a 4 year period and the final AIP values were around 50% of the calculated opportunity cost of spectrum. As a practical matter the scale of the increase in fees may affect decisions about the speed of transition to new fees levels.

The approach to setting AIP in the UK is intended to move spectrum use towards a more efficient outcome but is unlikely to deliver the optimal outcome at any one point in time. It assumes that iterations will be made towards the optimum, recognising that the optimum itself is also moving over time as consumer demands and technology change. This raises the question of how frequently AIP should be reviewed. Factors affecting the choice are:

- The time taken to undertake a pricing review;
- The time taken to collect a useful time series of data about changes in spectrum use;
- The volatility of demand for spectrum;
- The need to give licensees some certainty concerning the charges they will pay.

A pricing review can take up to one year, i.e. three to six months to do the work and the same again for public consultation. This suggests a minimum of two years between reviews. We would expect that at least three to four years' data would be required to see any impact from a change in pricing, given users' behaviour is likely to be slow to change because of their existing investments. A pricing review would have to start at least a year in advance of implementing new prices and so this suggests there should be at least five years between reviews. This would also give users a reasonable degree of certainty around which to plan.

There has been one review of AIP levels in the UK and this addressed whether the level of prices was still appropriate and the frequency bands for which AIP should be introduced or discontinued.

3.3 New Zealand approach

Spectrum licences used to supply radio, TV and cellular mobile services will expire from 2010 onwards. The New Zealand Government plans to offer the incumbent users the opportunity to renew these licences (which were originally bought at auction) for a fee that will be administratively determined. If the incumbents reject the government's offer the licences will be auctioned. [37] The approach to setting administratively determined fees is intended to provide a proxy for the market value of the rights. It was initially decided that the best way to do this was to model the licensee's business in a way that is simple and transparent but gives a reasonable approximation to market value. [38]

[37] All relevant documents can be found at http://www.med.govt.nz/templates/ContentTopicSummary____9326.aspx

[38] Development of Price setting Formulae for Commercial Spectrum rights at Expiry, Covec, October 2003. http://www.med.govt.nz/templates/MultipageDocumentTOC____9629.aspx

3.3.1 Radio and TV

The approach recommended by the Government's consultants and adopted for radio and TV licence fees involves using the original auction price as a base price and then applying a growth factor that equals the average of past and future growth in revenues. In the case of regional licences an adjustment was made for the ratio of regional to national population.

This approach makes the following assumptions:

- Revenue growth is a good proxy for net cash flow growth – this requires an assumption of constant profit margin.
- The growth factor is stable over time.
- The original auction was efficient.
- The growth factor is that which is relevant to the highest losing bidder – as this (usually) gives the market clearing price in an efficiently designed auction.

Of these assumptions the first two are arguably the most difficult to defend – particularly for TV. The market environment for advertiser financed and pay TV could change significantly in the next 20 years as mobile TV and TV delivered over broadband networks are introduced and as audiences fragment further with more choice offered. In addition to increasing competition for audience viewing time from new TV channels and on-demand content, TV advertising as a whole is not expected to grow in most markets (and may decline) partly as a result of the loss of young audiences and partly as a result of advertising budgets moving to the internet and other more directly measurable forms of marketing. In the UK for example, TV advertising revenues are not expected to grow in the real terms in future and may well decline, despite expanding numbers of channels.[39] We note the outlook in this respect has changed considerably since the methodology was initially developed and applied to broadcasting licences in 2003/2004.

3.3.2 Cellular

The formula developed for broadcast licences was not applied to cellular licences as in the latter case projections of future revenue growth based on historic data were judged to be unreliable because of uncertainty concerning future technology and market developments.

A further consultancy study re-examining options for estimating market value was then commissioned. This study considered approaches based on 1) benchmarking, 2) earnings or project value and 3) avoided costs or deprival value. [40] Benchmarking was rejected on the grounds that there are few, if any, like-for-like comparators. Earnings based approaches suffer from the uncertainties about future revenue growth and service/technology change and so the consultants recommended an approach based on avoided costs/deprival.

The incremental optimal deprival approach adopted involves valuing spectrum as the difference in network roll-out and operating costs arising from deprival of a given quantity of spectrum for the life of

[39] See Section 5 of Annex 7 of Ofcom's Second Public service Broadcasting Review, 14 April 2008. http://www.ofcom.org.uk/consult/condocs/psb2_1/annex7.pdf

[40] Renewal of Spectrum Rights for Cellular Services pricing methodology, Discussion paper, July 2006, PriceWaterhouseCoopers and NZIER, Ministry for Economic Development, http://www.med.govt.nz/templates/MultipageDocumentTOC____20766.aspx;

a cellular licence for a generic operator.[41] This is similar to the least cost alternative approach adopted in the UK. A key advantage of this approach is that the information requirements are not unduly onerous. It requires assumptions concerning:

- Traffic forecasts.
- The technology deployed in future.
- Network configuration with/without the marginal spectrum.
- Network capital and operators costs with/without the marginal spectrum.

Values have been calculated and the incumbent cellular operators now need to decide whether to accept the implied prices or to refuse and buy spectrum at auction.

3.4 Conclusions

There appears to be an international consensus that the price of spectrum should be related to "quantity "of spectrum occupied (defined in terms of bandwidth, area sterilised and duration of use). The degree of congestion, the regulatory and physical characteristics of the particular frequency band and the services that can use it will be reflected in opportunity cost estimates.

Economic analysis suggests that externalities produced by spectrum using services should not be taken into account in setting spectrum prices. Rather instruments targeted on the externality should be used. Where such instruments are applied, opportunity cost estimates will take account of the social value of the service.

Market benchmarks have not typically been used to set spectrum prices. Rather these have been found to be too unreliable and values have been calculated directly using either the least cost alternative approach or by estimating project value.

The main issues in deriving estimates of the opportunity cost of a given block of spectrum are:

- How to suitably characterise the alternative uses of a given block of spectrum and the choices facing users if denied /given access to an increment of spectrum.
- What assumptions should be made about future choices that face users and their costs and future traffic levels that will need to be supported by radio networks. In particular, should current values be used or future changes anticipated? In principle, there should be some attempt to anticipate future changes as this is what users will do when valuing spectrum, not least because spectrum used in conjunction with other long lived infrastructure and users typically plan their needs over the equipment or service lifecycle.
- The uncertainty over revenue forecasts for the licence period where an earnings based model is applied.

The annual opportunity cost values calculated in the UK are essentially static based on a snapshot of current traffic, costs and technologies. The New Zealand approach had to be forward looking, as the opportunity cost of a 20 year licence had to be valued. Uncertainty over future services, technology

[41] Renewal of management Rights for cellular Services (800/900 MHz), Network Strategies, Ministry of Economic Development, October 2007 http://www.med.govt.nz/templates/MultipageDocumentTOC____32548.aspx.

and revenues made this difficult for cellular spectrum and had the analysis for TV been done today and not in 2003 similar conclusions might have been reached.

The least cost alternative approach developed for the UK was applied in New Zealand to derive values of spectrum used by cellular operators. Such an approach is however more difficult to apply in the case of TV and radio services, because the infrastructure/spectrum trade-offs are difficult to quantify because they are likely to involve re-planning the entire VHF/UHF frequency bands used for TV broadcasting.

4 Estimating Opportunity Cost

4.1 Introduction

In this Section we describe a range of approaches to deriving opportunity cost estimates that are based on either

1 market information, or

2 direct calculation

and assess these options against the following criteria:

- Incentives for efficient spectrum use – both static and dynamic efficiency aspects need to be addressed here and the approach adopted may differ depending on the relative importance placed on these two aspects of efficiency. Whether appropriate incentives are given in each case depends on the accuracy of the opportunity cost estimates, the upside and downside risks of welfare losses from having poor estimates which in turn depend on the extent to which the modelling approximates real life choices by spectrum users.
- Objectivity – this depends on the extent to which judgement as opposed to calculations and objectively derived information are used to derive values.
- Simplicity – this is determined by the simplicity of the analysis and the number of assumptions that are required to derive values. Simplicity can aid transparency.
- Transparency – this is indicated by the replicability of the analysis and the extent to which publicly available information is used. If the pricing approach is not transparent then it will be difficult to demonstrate that it is objective.

Our recommendations for the approach to adopt in general for different frequency bands are given.

In practice there are administrative costs associated with spectrum management and these apply whether there is congestion or not. The opportunity cost estimates derived for a congested situation should apply in addition to any charges intended to cover administrative costs.

4.2 Market valuation approaches

Market determined prices contain information about the expectations of market players regarding spectrum value that the regulator will not know (e.g. expectations about future uses of the spectrum, changes in allocations etc). Market prices are therefore thought likely to give a more reliable indication of opportunity cost than prices calculated by regulators.

The types of market information that might be used to derive opportunity cost values include:

- <u>Spectrum market transactions</u>: The price of spectrum in auctions or trades could be used directly.
- <u>Capacity sales</u>: Information on the sale price of capacity for which spectrum is an input (e.g. sale of digital terrestrial TV (DTT) multiplex capacity or sale of wholesale capacity on a mobile network) provides a valuation of the spectrum plus the value of the other inputs. The spectrum value can be estimated by deducting the value of other inputs from the capacity price.

- Company value: Information on the market value of companies holding spectrum rights reflects the value spectrum plus the value of other assets the company owns. The spectrum value can in principle be estimated by subtracting the value of other assets from the company value.

The first of these options is in principle the simplest, and most objective and transparent as it does not require the potentially uncertain value of other inputs/assets to be subtracted from the revealed market price in order to provide an estimate of the spectrum value. The errors introduced by uncertainty about the value of non-spectrum assets could be large in the case of company valuations especially if spectrum is only a minor input to the company's main activities, as will be the case for example for private applications such as fixed links and PMR.

Even using values obtained from spectrum market transactions is not straightforward. The difficulties of making like for like comparisons between frequency bands and between market values revealed in different countries and different points in time are well known. Some differences can be reconciled by using econometric analysis to adjust for factors such as geography, demographics and GDP (as a proxy for revenue/user). Other factors relating to the local competitive environment may require deeper consideration of a licensee's business case to obtain tighter reconciliation.

In addition, the timeframe over which users assess opportunity cost, the size of spectrum blocks, volatility in market values, and circularity between AIP and market values can all affect the interpretation of market benchmarks. These issues are discussed below and affect the extent to which we regard market values as providing a good proxy for opportunity cost. The discussion below suggests that market values may provide overestimates of current opportunity cost values.

4.2.1 Timeframe for opportunity cost

The opportunity cost for annual or fixed duration licences will depend on future returns to the extent that licensees expect their licences to be renewed. Whether the timeframe is the same as that implicit in traded and auction values will not necessarily be clear. It is quite possible that the latter will reflect value over a longer time period than for shorter duration (e.g. annual) licences.

The opportunity cost of spectrum could change significantly over time as a result of a wide range of factors including:

- Real income growth which drives consumer preferences for convenience and time savings, and increases in the relative cost of labour which will tend to favour commercial experiments which involve relatively more capital versus labour.
- Changes in other economic parameters such as inflation and interest rates.
- Expanding technological possibilities which might include next generation broadband that could allow more efficient use of spectrum via dense cellular networks.[42]
- Changes to regulation, for example changes to the potential uses of different frequency bands.
- Commercial experiments could include use of spectrum to provide converged fixed/mobile services.

If the value of spectrum were, for example, expected to rise over time then annualised auction values could overstate the opportunity cost. Of course if users expected these licences to be renewed each

[42] Webb. 2007. "Wireless Communications: The Future." John Wiley. Page 209.

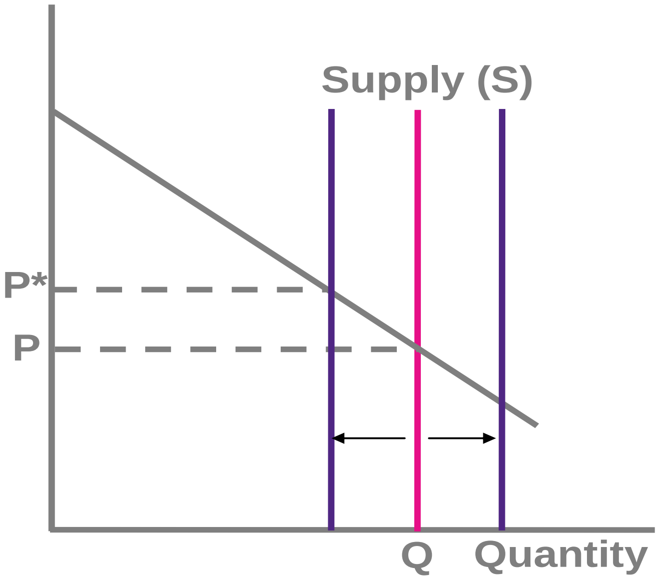
year, subject to a given notice period, then they would have the same opportunity cost as perpetual licences (with the same notice period).

4.2.2 Amount of spectrum

A further distinction between opportunity cost and auction/traded values concerns the unit of spectrum that is being valued. The market clearing price is the opportunity cost value at the margin (whether based on a static or dynamic view of the network/market) which is typically calculated using the minimum amount of spectrum that can practically be used to deliver an application or expand a network.

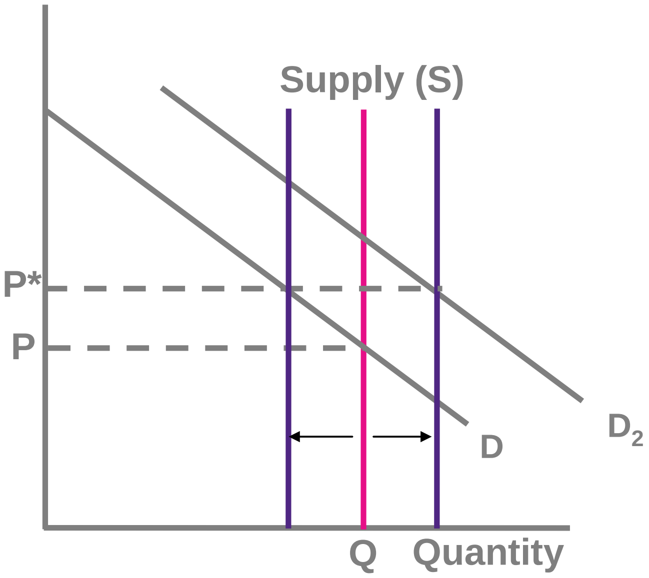
Trades and auctions in particular generally involve larger blocks of spectrum shown in a stylised way by the vertical purple lines in Figure 4-1. The average value per MHz for a block of spectrum could be higher or lower than the opportunity cost at the margin. First, taking a static view in which the demand curve is unaffected by changes in the blocks of spectrum made available, removal of a block of spectrum will give a higher average value per MHz, because it includes the value of infra-marginal units to the left of point (P,Q) in Figure 4-1 as well as marginal units, while an additional large block would have a lower average value per MHz .

Figure 4-1 Prices with large changes in spectrum supply and demand unchanged



Second, if additional large blocks of spectrum support the introduction of new services (or removal of large blocks means existing services go out of business) then average values may be higher (lower) than for marginal units as indicated by the higher price P* resulting from the outward movement of the demand curve as shown below in Figure 4-2.

Figure 4-2 Prices with large changes in spectrum supply and demand changed



4.2.3 Volatility in market values

While spectrum prices should be adjusted periodically to reflect market changes, care needs to be taken in not over reacting to what may be large short term market fluctuations. An example of this is given by the European 3G auctions, where the Spanish Government set a price for 3G licences (which were awarded by beauty contest) many times higher than existing GSM fees, based on the results of the UK and German auctions. The Government then had to reduce these values substantially when it became apparent that the UK and German auction results were not representative of the market more generally after the "dot-com" crash. The reason for this is unclear – for example it might have been caused by myopia concerning the "dot-com" crash, differences in the value of licences in the UK and German markets versus others or collusion between bidders to reduce prices in later auctions.[43] .

4.2.4 Circularity

A further source of complexity in interpreting traded values arises if AIP is related to the traded value, either in the same market or in an adjacent market with ownership overlaps. Traded values will then be lower by an amount corresponding to the anticipated impact of the traded price on future values of AIP. Incomplete adjustment of the AIP for changes in traded prices and lags in making changes to AIP could reduce the impact so long as it was transparent to buyers/sellers how the regulator intended to adjust AIP based on traded prices. Assuming instantaneous partial pass through a stable relationship between value and traded value can be worked out. If the value is V*, the observed traded value is V and the fraction of V reflected in AIP is α, the V*=V/(1- α) i.e. if pass through is 50 per cent the spectrum value will be double the observed traded value.

Alternatively if auction values are used to set AIP and the bidders in the auction are also subject to AIP then incentives to keep auction values low (e.g. through collusion) are increased.

[43] This idea is advanced in "Auctions: Theory and Practice", Paul Klemperer, 2004.

4.3 Directly calculated approaches

The direct calculation of opportunity cost involves numerous assumptions about the situation being modelled. First the size of the change in spectrum holdings needs to be assumed depending on the choices that users face in practice. If large changes in spectrum holdings are considered then the project valuation may need to take account of revenue as well as cost changes – though for some applications only cost changes will be relevant. If small changes in spectrum use are feasible then changes in cost alone may give a reasonable estimate of marginal benefit. Next it is necessary to consider whether opportunity cost estimates are to be derived assuming changes in the allocated use of the spectrum are possible in addition to changes in assignments. If changes in allocations are possible then multiple marginal benefit estimates need to be produced. If the current use has the highest marginal benefit then it is this value that should be used to estimate opportunity cost i.e. this gives the same result as a single service calculation.

Taken together these aspects give the following options:

- Single service, change in costs: least cost alternative approach, no change in allocations, value based on current use
- Multiple service, change in costs: least cost alternative, change in allocations possible, value at least as high as in current use
- Single service, change in net revenues: NPV of cash flows, no change in allocations, value based on current use
- Multiple service, change in net revenues: NPV of cash flows, change in allocations, value at least as high as in current use.

The option that is most appropriate depends in part on the situation being considered. Once this has been decided the main difference between the options concerns the amount of information that is required to calculate marginal benefits and so opportunity cost values.

4.4 Appraisal

The desirability and workability of the different options depends on

- The purpose of the valuation exercise. If the purpose is to promote dynamic efficiency and achieve significant changes in allocations/the possible launch of new services/networks then non-marginal changes in spectrum use may need to be modelled. If prices are to be set to motivate changes at the margin in spectrum use (static efficiency and more modest dynamic efficiency gains) then some of the directly calculated approaches may be most relevant.
- The frequency bands under consideration, particularly the type of service that currently use or could in future use the frequencies. Values derived from market information are generally only possible for frequency bands that are used to deliver services aimed at the general public, as these frequency bands are more likely to be auctioned (because they are of high value) and spectrum is a key (and sometimes an essential) input required for service delivery. For frequency

bands only used to provide private applications used by firms, such as internal fixed and mobile communications, direct calculation of values is likely to be required. In these cases the least cost alternative approach tends to be most relevant as there is no revenue directly associated with the use of the spectrum and so the NPV of net revenues is not relevant. Approaches based on the NPV of net revenues are also easiest to apply in frequency bands where the applications are relatively mature and so revenues can be forecast with some confidence.

Table 4-1 summarises our views on the suitability of different options for frequency bands used by particular applications. What this says is that the choice of approach depends importantly on the characteristics of the frequency band under consideration. In particular we distinguish between bands used to mainly deliver public versus private services, identify the feasible set of options for each of these two categories of bands and then appraise the options against the criteria listed in the introduction to this section.

Table 4-1 Suitability of options for different bands/services

Options	Bands/services where most applicable
Directly calculated values	
Single service, change in costs	Bands where change of use is highly unlikely because of international or regulatory constraints or where it is clear current use is highest value application. Bands where spectrum is used for private applications. But possible for bands used for public services where demand difficult to forecast and/or marginal changes in spectrum use are practical.
Multiple service, change in costs	Bands where there are few constraints on change of use or where change of use may be desirable. Bands where spectrum is used for private applications. But possible for bands used for public services where demand difficult to forecast and/or marginal changes in spectrum use are practical.
Single service, change in net revenues	Bands where change of use is highly unlikely because of international or regulatory constraints or where it is clear current use is highest value application. Bands where spectrum is used by publicly provided services and changes in spectrum use are non-marginal.
Multiple service, change in net revenues	Bands with few constraints on change of use or where change of use may be desirable. Bands where spectrum is used by publicly provided services and changes in spectrum use are non-marginal.
Market values	
Spectrum transactions	Bands in similar frequency range and with similar licence duration and other conditions
Capacity sales	Public mobile, BWA, third part supply of land mobile services and digital broadcasting
Company value	Public mobile, BWA and broadcasting

4.4.1 Public services

The appraisal of approaches for frequency bands used mainly to deliver publicly facing services is given in Table 4-2. The more plusses the better the performance against the criterion and the more minuses the worse. The appraisal assumes the following:

- Spectrum transactions are likely to require considerable adjustment to achieve a reasonable like for like comparison. If this is not the case then spectrum transactions are likely to provide the best estimates of opportunity cost.
- More complex calculated values are likely to give a more accurate estimate despite the need for additional information and assumptions however they are less transparent and objective.
- For the directly calculated options multiple service options are more efficient than single service options, on the grounds that changes in the long run changes in allocations are likely to be possible. Also marginal benefits for different uses need to be calculated to be sure that the current use is the highest value use of the band.
- Options based on the change in net revenues are in principle highly desirable however the considerable information demands and the uncertainty over future revenues mean that the additional accuracy they give is sometimes questionable. However calculation of the NPV of cash flows may be necessary to check the viability of the least cost alternatives examined.

Table 4-2 Appraisal of options for estimating opportunity cost – bands used by public services

Options	Dynamic Efficiency	Static Efficiency	Objectivity	Simplicity	Transparency
Directly calculated values					
Single service, change in costs	0	+	+	+	+
Multiple service, change in costs	++	+	++	-	-
Single service, change in net revenues	0	+	+	+	+
Multiple service, change in net revenues	++	+	++	-	-
Market values					
Spectrum transactions	+++	+	++	-	-
Capacity sales	++	+	+	-	-
Company value	-	-	-	--	---

The conclusions that can be drawn from Table 4-2 are as follows:

- For approaches based on market information, values derived from spectrum transactions are preferable. If this is not feasible (because suitable like for like information is not available) then either capacity sales (where feasible) or directly calculated values must be used.
- For approaches based on direct calculation, approaches that take account of alternative uses of the band are generally preferable as they provide more information and should better promote

efficiency than approaches based on a single value. However some judgement is required to set values as compared with the situation where a single value is calculated and so some transparency and simplicity is forgone.

- For direct calculation, whether based on changes in net revenues or just costs the approach used depends on the assumed change in spectrum value that is most relevant to the situation being considered. For example, for some applications there is no direct revenue associated with the use of spectrum and there are a number of substitute technologies that can be used (e.g. for fixed links bands) whereas in others there are few if any substitutes and value is driven by net revenues (e.g. FM radio).

The choice between market values and direct calculation depends on the extent to which the market information provides a good comparison, possibly with some adjustments to normalise for differences in key value drivers such as population and population density, income levels, licence duration, degree of competition and amount of spectrum sold,

For example a normalised spectrum value index *in (USD/pop/MHz/year)* might be calculated as

$$\frac{Actual\,Price(USD) * Operators * 10{,}000}{AddressablePopulation * Bandwidth(MHz) * Duration(Yrs) * GDP / capita(USD)}$$

We can expect considerable variability in the indices calculated in this way since the calculation does not take account of more complex country specific aspects such as market dominance by incumbent operators, ARPU and level of urbanisation.

If there are sufficient data points from different countries and/or frequency bands, it may be possible to undertake econometric analysis to estimate the impact of variables such as population, income, amount of spectrum, number of competitors, timing of the auction etc and then use the estimated parameters to calculate a value for the situation in Australia using Australian parameter values. This is likely to be most feasible for auctions of spectrum to deliver 3G services as many countries have conducted such auctions (over 40) since 2000. However, the predictive accuracy of models derived from such data has been questioned as values obtained in different auctions were to degree interdependent and changed significantly over time in response to changes in market sentiment.[44]

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4.4.2 Private services

Table 4-3 appraises options for bands used by private services. In this case market values have limited or no applicability because such frequency bands tend not to be auctioned, capacity is not traded and spectrum forms a small part of the company value. Amongst the directly calculated options, only those based on the cost of using alternative technologies, frequency bands or services are relevant and multiple service approaches should give greater efficiency but require more judgement and assumptions and so tend to score less well on other criteria.

[44] Such a model was produced in the course of a current inquiry into mobile termination rates being conducted by the UK Competition Commission.

Table 4-3 Appraisal of options for estimating opportunity cost – bands used by private services

Options	Dynamic Efficiency	Static efficiency	Objectivity	Simplicity	Transparency
Directly calculated values					
Single service, change in costs	-	+	++	++	+
Multiple service, change in costs	+	+	-	-	-
Single service, change in net revenues	n.a.	n.a.	n.a.	n.a.	n.a.
Multiple service, change in net revenues	n.a.	n.a.	n.a.	n.a.	n.a.
Market values					
Spectrum transactions – limited applicability	++	+	+	-	-
Capacity sales – limited applicability	+	+	+	-	-
Company value – not applicable	n.a.	n.a.	n.a.	n.a.	n.a.

4.5 Recommendations

The discussion above indicates is that the choice of approach to deriving opportunity cost estimates is contingent on the objectives the regulator is seeking to achieve, the frequency band being considered and the quality of the information available. In some circumstances multiple approaches may need to be used and reconciled.

The recommended approach is given by the following multi-step process:

1. What services or applications could potentially use the frequency band? Are they to provide a service offering (i.e. public) or to support internal business processes (i.e. private)?
2. If they are to provide a service offering (i.e. public services) then for each use derive the value of spectrum as follows:
    a. Are there market values derived from spectrum transactions in comparable market and spectrum use situations? If yes, then use these data to provide an estimate of value for the service in question.
    b. If there are some uncertainties over the reliability of the value derived from market data or such values cannot be derived, then directly calculate the value as follows.
        i. Generally calculate value based on the NPV of future cash flows with all inputs (including capital) valued at their market price.
        ii. But if in some circumstances it is reasonable to assume that spectrum holdings change to achieve cost reductions while service output and

revenues are constant, then estimate value based on the least cost alternative approach.

c. Where market and directly calculated spectrum values are obtained, make choice of value based on the direction of bias that seems likely to best promote welfare.

3. If they support internal business processes (i.e. private services) then for each service derive estimate the opportunity cost of spectrum based on the least cost alternative approach

4. If there is a use with an estimated value greater than that for the current use then set the AIP between the two values – generally towards the bottom end of the range but depending on the shape of spectrum demand curves there may be circumstances where a value towards the middle of the range will be appropriate.

5. If there is no use with a spectrum value higher than the current use of the band then set the AIP at the spectrum value for the current use.

5 Application to the 400 MHz band

5.1 Current use of the band

This band refers to spectrum between 403-520 MHz. It consists of the two blocks 403 – 420 MHz and 450 – 520 MHz with the spectrum in between these two blocks supporting various defence / government applications. Frequencies towards the upper end of the 450-520 MHz block are less attractive than others because there is less equipment available.[45]

The band is used for narrowband land mobile and fixed services as well as wideband rural services. These latter services are not relevant to the case studies. Use of the band is dominated by narrowband land mobile services which can be single frequency, two frequency or two frequency trunked. Similarly, the narrowband fixed services can be single frequency, two frequency point-to-point or two frequency point-to-multi-point. Historically 25 kHz channelisation has been used but 12.5 kHz systems are increasingly deployed.

In order to support this range of services the band is split into a number (46) of paired and unpaired segments each of which is identified for a particular type of service and channelisation. This band is not completely rigid – flexibility is available in terms of 12.5 kHz channels being allowed in the land mobile segments designated for 25 kHz use, and point-to-multipoint fixed systems may use some of the segments designated for the land mobile service if assignments in their own segments are unavailable.

The band is reported to be congested and previous analysis[46] by ACMA of two of the segments in the band plan suggests that (for those segments at least) Sydney is heavily congested (tending towards 100% usage) but Perth is less so (around 50% usage). In Sydney the block above 450 MHz is marginally less congested than that below 430 MHz (probably because of reduced equipment availability). There is still congestion however in both blocks and this suggests that there would be interest from industry in the block allocated to defence (i.e. 430 - 450 MHz).

We assume that if the band is congested in a particular location then land mobile users would be denied access to the band. They face few other communications options. There is spare capacity at VHF but these frequencies are less attractive because the equipment is less compact and the bands are noisier. ACMA reduced fees in the VHF band to encourage migration but we understand that this has had little effect on demand at 400 MHz. There is an alternative band at 820-825 MHz/865-870 MHz but this is also congested in Sydney. This means that if a user with its own system is denied access to spectrum in the 400 MHz band the practical alternative communications choices available are move to narrowband technology, use of cellular telephony or move to a trunked system. Cellular telephony is unlikely to give the functionality required by land mobile users (i.e. group calling, cost control) and so this leaves the two choices of narrow bandwidth technology and public trunked systems. The costs of moving to these two alternatives are estimated below. In addition we derive values from two market benchmarks: spectrum auctions and the value of capacity sold by public trunked network operators.

[45] Frequencies from 490-520 MHz are used for broadcasting elsewhere in the region.

[46] Quantifying Spectrum Use in the 400 MHz Land Mobile Band. SP 4/05, 1st December 2005.

Spectrum Options:403-520 MHz. Initial consultation on future arrangements for the 400 MHz band. April 2008.

First however we consider whether there are any alternative uses of the band that need to be considered in deriving the opportunity cost.

5.2 Potential other uses

Applying the general approach summarised in the introductory section we first need to determine potential uses of the band. In addition to the current use possible alternatives include BWA (e.g. using WIMAX), FWA and TV broadcasting. We understand from ACMA that TV broadcasting is not likely.

Earlier work[47] undertaken by Ovum and Aegis for ACMA estimated the spectrum demand for wireless access and cellular services up to 2022. That work noted that the bands 410 – 430 MHz, 450 – 470 MHz and 470 – 862 MHz were candidate frequency bands for IMT expansion at WRC-07. At the same time the report suggested that there was a low probability of the lower two bands meeting future spectrum demand because of the small amount of bandwidth and the limited opportunities for global harmonisation. The report identified the higher band as having a greater possibility for meeting future spectrum demand but noted the difficulties in agreeing harmonised channel arrangements due to the different timescales in each country regarding analogue to digital switch over.

In the event, WRC-07 identified the band 450 – 470 MHz 'worldwide' for IMT – this is only part of the upper 400 MHz band (450 – 520 MHz) used for land mobile / fixed services in Australia. Although most CITEL countries support this identification, the USA and Canada will not implement it for IMT since they have some reservations. In Europe, the band is already licensed where available, and some CEPT countries are implementing IMT in the band[48].

It is not clear the extent to which this band might be used across the world but it is more than likely that if it is used it will be for wide area coverage in developing and/or sparsely populated countries (or parts of countries) and therefore not much deployed in dense urban centres that we are considering here except perhaps as a coincidental overlay. In any event, there are several other frequency bands that have been designated for IMT2000 (i.e.2.5 GHz and the top part of the UHF TV band) which are more likely to be used operationally and sooner.

We conclude therefore that there are no other serious candidate uses of the band.

5.3 More efficient technology

For the private land mobile services we can estimate spectrum value to a "typical "user based on the cost to such a user of moving from 25 kHz to 12.5 kHz channels. In order to do this we have to make a number of assumptions regarding system usage as follows:

- For each duplex channel (i.e. frequency pair) we will assume that there are on average 25 mobile users[49]

[47] "Estimation of Spectrum Demand for Wireless Access Service and Cellular Service", Report v6.1 dated 26 July 2007.

[48] Denmark, Sweden, Norway, Portugal, Czech Republic, Poland, Romania, Latvia and other easterly CEPT countries. From CDMA Development Group at http://www.cdg.org/worldwide/print_records.asp?fontsize=2

[49] Based on information provided by Motorola.

- Assume that all mobiles and the base station transceiver are not capable of being reconfigured to use 12.5 kHz channelization and therefore have to be replaced
- It is further assumed that the cost of 12.5 kHz equipment is the same as 25 kHz equipment. As there is no difference in cost the only costs that need to be considered concern the scrapping of existing equipment (see bullet below)
- Consider that the scrapping of the old 25 kHz system occurs half way through its useful life of 10 years

The costs[50] that have to be considered are therefore as follows:

Basic base station transceiver cost = $3000

$1500 is therefore written off = $360 annualised (10% / 5 years)

Radios reportedly cost between $700 and $1500 depending on functionality, or from another source, around $800 - 1000 and $2,800 for high end equipment. For the purposes of this costing we will assume $1,000.

The loading on a channel can be expected to vary widely. We will assume that a lightly loaded channel will support 5 users, an averagely loaded channel 25 users and a heavily loaded channel 100 users.

In the averagely loaded case we therefore have:

25 mobiles ($1000 each), $12,500 written off = $2,998 annualised (10% / 5 years)

Total = $3,358 p.a. = $269 p.a. per kHz

Repeating the calculation for the lightly loaded and heavily loaded cases gives values of $77 p.a. per kHz and $988 p.a. per kHz respectively.

5.4 Use of public trunked services

In this section we consider the situation in which a user faces the choice of self providing its communications or using a service provided by a public trunked network.

We assume a system life of 10 years and a base station cost consisting of a $3,000 transceiver and $1,000 antenna (including installation). We will take a range of loading from 5 mobiles to 25 mobiles and 100 mobiles representing lightly, averagely and heavily loaded channels. In addition assume a 15% overhead for operations and maintenance.

On the basis of a 25 kHz frequency pair which would incur a spectrum charge of $4,658 p.a. in Sydney (including administrative charges annualised over 10 years) the costs for a self provided system and the public trunked alternative would be as follows:

[50] Costs provided by Motorola and Vertel.

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No. of mobiles	5	25	100
Base station transceiver, antenna & installation ($)	4,000	4,000	4,000
Mobile equipment ($)	5,000	25,000	100,000
Operations & maintenance ($)	1,350	4,350	15,600
Sub-total ($)	**10,350**	**33,350**	**119,600**
Annualised - 10 years / 10% ($ p.a.)	1,531	4,934	17,695
Spectrum fee ($ p.a.)	4,658	4,658	4,658
Total ($ p.a.)	**6,189**	**9,592**	**22,353**
Equivalent Telstra single site trunk network tariff ($ p.a.)	2,112	10,560	42,240

On the basis of a single 12.5 kHz frequency which would incur a spectrum charge of $1,203 p.a. in Sydney (including administrative charges annualised over 10 years) the costs would be:

No. of mobiles	5	25	100
Base station transceiver, antenna & installation ($)	4,000	4,000	4,000
Mobile equipment ($)	5,000	25,000	100,000
Operations & maintenance ($)	1,350	4,350	15,600
Sub-total ($)	**10,350**	**33,350**	**119,600**
Annualised - 10 years / 10% ($ p.a.)	1,531	4,934	17,695
Spectrum fee ($ p.a.)	1,203	1,203	1,203
Total ($ p.a.)	**2,734**	**6,137**	**18,898**
Equivalent Telstra single site trunk network tariff ($ p.a.)	2,112	10,560	42,240

It can be seen by comparing the annualised costs in the tables above that there is only one instance where it is clearly more expensive to self-provide a network rather than use a trunk network and pay a tariff. That case is a system using a 25 kHz pair to support five mobiles. It is more likely that such a system would use a single 12.5 kHz frequency and it can then be seen (in the lower table) that the reduced spectrum fee means that self-provision and trunk costs are more comparable.

The biggest difference in cost between self-provision and use of a trunk network is for heavily loaded systems, irrespective of whether a single 12.5 kHz frequency or a pair of 25 kHz frequencies is being used as the spectrum fees are less significant in this situation. In order to encourage such users to move to a trunked network it would be necessary to charge $19,887 p.a. (2 x 25 kHz) or $23,342 p.a. (1 x 12.5 kHz). These values are equivalent to a range of $398 to $1867 per kHz p.a. We note that it is highly unlikely a large user would be using a simplex channel and so consider the lower value in this range as being more appropriate.

We note that in Australia there is no oversight by the regulator on how many mobiles share a channel (single frequency or frequency pair). Assignments are made to spectrum users to use as they wish in terms of how many mobiles are to be supported. It can be seen quite clearly from the earlier tables that spectrum fees are much more significant for lightly loaded systems but there is no more direct way that encouragement can be given to attaining higher levels of utilisation.

5.5 Inferred value from capacity sales

The value of spectrum might also be inferred from the price of capacity on land mobile networks offered to third parties.

Telstra's UHF Fleetcoms network has the following tariffs:

Plan	Price (inc GST)
Once only connection charge per mobile	$12.10
Voice and Data Monthly Access Charges This monthly access fee includes 140 minutes airtime and 400 Control Channel Data Units per mobile per month during business hours	
Single or any Two sites	$35.20
Region	$43.45
2 Regions	$52.25
State (all sites)	$60.50
Any 2 States	$78.65
National (entire network)	$96.80

There are additional tariffs covering items such as call diversion, number retention, change of number etc.

TeamTalk is Vertel's branded name for five MPT 1327 trunked radio networks they operate in both VHF and UHF frequency bands - they are based on Tait infrastructure. The fee structure is:

- $34.00 per mobile per month for metropolitan coverage (e.g. Sydney)
- $50.00 per mobile per month for state-wide coverage

These tariffs include 300 minutes airtime per mobile per month[51].

Radios cost between $700 and $1500 depending on functionality and can be rented for $12 - $15 per day for short term requirements (typically < 1 month) or $30 - $40 per month for long term requirements (e.g. 36 months).

Ideally, complete knowledge of the networks run by these two operators and their business results would enable the value of the spectrum to be determined. In the absence of this information, one can only make an approximate comparison based on a single site as follows.

If a single site supports 25 mobiles on average then the potential revenue from the Telstra tariffs (but excluding the once only connection charge) would be $10,560 per annum.

The annualised cost of a single site would be made up as follows[52]:

Base station cost = $16,000 = $2,367 (annualised at 10% over 10 years)

Site costs = $2,100 p.a.

Land line = $630 p.a.

Power = $630 p.a.

Total = $5,727 p.a.

In addition to these costs there will be operating costs of the order of 15% and an expected return of 10% giving total costs of $7,159.

The balance of potential revenue ($10,560 p.a.) against costs ($7,159 p.a.) giving a surplus of $3,401 p.a. appears favourable and suggests that the average loading of 25 mobiles per channel across the whole network may be optimistic.

However, if it is assumed the system is based on channel pairs, and using the 25 mobiles loading assumption, then the value per kHz will range from $68 to $136 per kHz depending on whether 25 or 12.5 kHz channels are used.

5.6 International auction values

Finally, there could be a limited number of international auction values for part of the band from those countries where it is used to deliver public trunked mobile services. The sale of residual spectrum in the 500 MHz band in 2007 for land mobile and earlier auctions of spectrum in the 400 MHz and 500 MHz bands in Australia and elsewhere might also provide useful benchmarks[53]. However, it should be noted that purchases of 500 MHz spectrum licences have to be able to plan the use of the spectrum with engineering models and this limited demand for these frequencies i.e. depressed the price.

[51] This amount is rarely exceeded. There is no charge for data as long as likely usage is known and the impact on the network's control channel can be assessed.

[52] The equipment cost was provided by Motorola and the recurring costs are based on figures used previously in the UK. On the basis that the site being costed is part of a trunk system, rather than a less sophisticated single site system, we have assumed the higher base station cost provided by Motorola.

[53] http://www.acma.gov.au/WEB/STANDARD/pc=PC_310637

Country	Auction	Bandwidth	Duration	Coverage	Equivalent annualised cost per kHz ($)	Equivalent annualised cost/million pop per kHz ($)
Australia	Residual 500 MHz (2007)	(2x12.5 kHz) + (2x25 kHz) + (2x37.5 kHz)	5 years	Sydney	14.4	3.34
Australia	Reallocated 500 MHz (2007)	12.5 kHz to 1 MHz	5 years	Sydney	2.3 to 16.3	0.53 – 3.79
UK	413 / 423 MHz	2 x 2 MHz	15 years	National	94.8	1.56
Ireland	413 / 423 MHz	2 x 2 MHz	10 years	National	13.3	3.24
Ireland	411 / 421 MHz	2 x 2 MHz	10 years	National	6.8	1.66
Sweden	454 / 464 MHz	2 x 1.8 MHz	15 years	National	510	56.7

We note that use of the UK spectrum is significantly constrained by the need to protect a military early warning radar at Fylingdales, and this will have depressed the UK values. We also understand that the winning Swedish bid was significantly higher than bids made by other participants in the auction and as such may not be a reliable indicator of value. We have excluded it from further consideration.

5.7 Conclusions

Comparison of the different means to arrive at the next best alternative cost is as follows:

Method	Annual cost per kHz ($) per assignment	Comment
Potential other uses	---	No credible other uses
More efficient technology	269	Based on an averagely loaded system. Lightly / heavily loaded systems provide a range of 77 – 988.
Public trunked network	0 – 369	Positive values only apply to users with more than 25 mobiles
Inferred value from capacity sales	68 – 136	Based on averagely loaded channels.
International auction values	2.3 – 14.4	The non Australian values are adjusted for differences in population and the Swedish outlier is excluded.

The least cost alternative is therefore to move to narrowband equipment, implying an opportunity cost in the range $77-$989, with a value of $269 for a "typical" system. The auction values are very low by comparison with the calculated values, and this is to be expected given that only companies with spectrum management expertise (i.e. not most users) are likely to bid. The value inferred from capacity sales is lower in the range $68-136 per kHz per assignment. However, we consider this inferred value range to be less reliable as it is based on a single base station and an assumed average channel loading rather than a complete trunk network and variations in channel loading that would occur across such a network. We should therefore rely more on the value associated with using more efficient technology.

By way of comparison the current fees (Division 4 of the Apparatus Licence Fee Schedule, 1 April 2008) in the 400 MHz band amount to:

Frequency band	Tax per kHz p.a. per assignment in Sydney (high density) - $	Tax per kHz p.a. per assignment in Perth (medium density) - $
>399.9 to 960 MHz	90.1236	41.2316

In addition to the spectrum tax identified in the table above each assignment is liable to an administrative charge when first issued and on renewal. Taking the initial charge and renewal, and annualising the charge over 10 years at 10%, this is equivalent to $76 p.a. per assignment. This would also apply if opportunity cost based taxes were applied.

Our calculations suggest that the tax applied is Sydney is too low to encourage migration to narrowband technology or public trunked systems as a way of relieving congestion and hence values should rise – possible doubling or trebling in value. As congestion applied across the entire band, the higher values should apply across the entire band including the portion allocated to defence. As the defence allocation blocks the entire use of the band by land mobile, they should in principle pay for the entire exclusion and not on the basis of their actual use of the band (as is currently the case under their apparatus licences).In Perth the level of congestion is much less acute and this together with the general uncertainty and about the rate of future demand growth given the moves to mobile data communications suggests the values here should not be changed.

6 Application to the 7425 – 8275 MHz band

6.1 Current use of the band

This band consists of two fixed link band plans operating adjacent to one another; 7425 – 7725 MHz (the 7.5 GHz band plan) and 7725 – 8275 MHz (the 8 GHz band plan).

The 7.5 GHz band plan supports low/medium capacity (2 – 17 Mbps) point-to-point medium haul (> 20 km) fixed links. The band plan is based on sets of 7 and 14 MHz channels offset with respect to one another, with new assignments also having to be coordinated with some legacy 3.5 and 18 MHz channels.

Assignments countrywide in the band have increased by nearly half over the last 10 years. ACMA consider[54] that the band is approximately half loaded at present and that it will be fully loaded by 2020 where this includes the East Coast of Australia Low Density Area.

The 8 GHz band plan supports medium/high capacity (34 Mbps, FM video) point-to-point medium haul (> 10 km) fixed links. The band plan is based on two sets of 29.65 MHz channels, main and interleaved.

Assignments countrywide in the band have nearly doubled over the last 10 years. ACMA consider that the band is currently 25% - 50% full on regional trunk routes and 50% - 80% full on most sites associated with major trunk routes (especially close to cities), with some sites close to or have reached 100% on particular azimuths. In this situation there are two potential sources of scarcity – spectrum and site capacity – and hence two sources of economic rent. If spectrum prices are set below opportunity cost then in principle the price of site capacity could rise to reflect both the scarcity value of spectrum and the scarcity value of site capacity. However, we consider that it is preferable for spectrum to be priced at its opportunity cost because 1) site capacity will not be constrained in all locations where there is spectrum scarcity and 2) the government should receive a fair return on spectrum access. We note that if site costs do capture some of the spectrum rent then this approach risks setting prices at levels than are higher than is socially optimal. This could be addressed by phasing in increases and observing whether significant amounts of resource are left idle or not. If they are left idle this suggests spectrum prices are too high.

In the next section we consider alternative potential uses of the band and then move on to derive opportunity cost estimates assuming use of the band by fixed links. In doing this we have considered the incremental costs to a user denied access to the band of:

- using more efficient technology
- moving to a higher frequency band
- using alternative services – satellite and leased lines.

We are not aware of any relevant market benchmarks from either Australia or other countries.

[54] Band loading and assignment trend analysis of fixed link bands in Australia. SPP 9/07 September 2007.

6.2 Potential other uses

Applying the general approach summarised in the introductory section we first need to determine potential uses of the band. In addition the current use possible alternatives could include FWA, satellite and low power devices (licence-exempt). However, we do not believe that these alternatives would be viable in an Australian context.

Insofar as satellite services are concerned this is not a mainstream commercial satellite band. In other parts of the world the band is designated for government / military use so it would not be expected that commercial demand will arise for satellite use of this band.

Although technically appropriate for Fixed Wireless Access it is not expected that there would be any commercial demand for this frequency band as lower bands (which are more appropriate to the coverage of urban areas) are available.

Licence-exempt low power devices can always be constructed to satisfy particular applications in most frequency bands. However, the effective use of a piece of spectrum by low power licence-exempt devices generally only occurs when international harmonisation of one sort or another gives rise to a global market and therefore cost effective devices. There is no evidence of this occurring with respect to this frequency band.

We conclude that there are no other serious candidate uses of the band.

6.3 More efficient technology

The possibility of using a more efficient technology (i.e. an alternative modulation scheme) has been identified as a possibility to consider.

In a given frequency band different equipment costs for different bitrates now largely reflect equipment vendor licence costs rather than any difference in hardware costs as the equipment is software reconfigurable. The table below gives some indication of how these costs change as the bit rate supported by a link increases, where the increase in bit rate is achieved through a combination of channel bandwidth and modulation level. While the first category below relates to 3.5 / 7 / 14 MHz channels and the middle three categories relate to 28 / 29.65 MHz channels, it is likely that the last category would require a larger RF channel bandwidth.

Bit rate (Mbps)	Equipment cost > 8GHz ($)	Equipment cost <8GHz ($)
2 – 34	12,375	16,000
>34 – 50	16,500	21,500
>50 – 100	23,100	30,000
>100 – 200	29,700	38,500
>200 – 400	34,650	45,000

Source: Equipment vendor

If it is assumed that the above costs are made up of a basic hardware cost (assumed to be the cost of the lowest category) and an equipment vendor licence cost reflecting the higher bitrates, it can be seen that moving from E3 (34 Mbps) to STM-1 (155 Mbps) would involve an equipment vendor licence fee cost of $22,500[55] (or possibly $38,500 if in the worst case no costs are associated with the hardware itself). This corresponds to an annualised cost (10% discount rate and 10 years, part way through 15 year life) of $3,329 p.a. (or $5,696 p.a. worst case). This compares with the annual licence cost of moving from two 14 MHz assignments (= $4,144 p.a. spectrum tax in Sydney) to two 28 MHz assignments (= $8,188 p.a. spectrum tax in Sydney). Without higher order modulation being available, albeit in a channel having twice the bandwidth, it would have been necessary to move from two to eight 14 MHz assignments (= $16,376 p.a. spectrum tax in Sydney).

Whether this situation is relevant to AIP is a moot point for two reasons. Firstly, there is already some incentive in fixed link channel pricing to encourage the use of higher modulation schemes if higher capacity is required as current fees are per MHz in channel increments. The requirement for capacity needing two assignments on a link is far from extensive based on an examination of the ACMA database. It is likely[56] that operators are already changing modulation schemes in order to achieve higher throughputs as required.

6.4 Higher frequency band

The possibility of moving links to a higher frequency band has been identified as one of the options to consider. The fixed link bands immediately above the 7.5 and 8 GHz bands are the 10 and 11 GHz bands.

The 10 GHz fixed link band, which supports 7 and 14 MHz channels, has a minimum path length of 5 km. The average path length in this band is 14.3 km and ranges up to 40 km. This band is classified by ACMA as being less than half loaded.

The 11 GHz fixed link band, which supports 40 MHz channels, also has a minimum path length of 5 km. The average path length in this band is 16.9 km and also ranges up to 40 km. This band is classified by ACMA as being under-utilised and having massive potential for growth.

It can therefore be seen from the above description of the two higher bands that there is real possibility for moving most[57] of the links in the 7.5 and 8 GHz bands into these higher bands without requiring an additional hop. In this case only new equipment and not additional sites would be required. There are some cases (i.e. links greater than 40 km) where an additional hop would be required and in this case an additional site would need to be used as well as new and additional equipment. The ACMA database indicates that links of up to 70 km exist in the Sydney area.

As for the 400 MHz case in moving from 25 kHz to 12.5 kHz equipment, the cost involved in moving from the 7.5 / 8 GHz bands to the 10 / 11 GHz bands mainly concerns the scrapping of equipment nominally half way through its expected life of 15 years.

[55] $38,500 (cost of STM-1 equipment operating in frequencies below 8 GHz) - $16,000 (basic hardware cost) = $22,500.

[56] There is no evidence however as the ACMA assignment database only holds ITU emission designations which do not provide sufficient detail to obtain a complete deployment picture.

[57] In Sydney approximately 80% of 7.5 GHz links and 95% of 8 GHz links are 40 km or less and in Perth the figures are 100% (7.5 GHz) and 97% (8 GHz).

The indicative cost of low capacity equipment, which is considered to cover the range 2 to 34 Mbps, is $12,375 per two way link without antennas operating at higher frequencies. For lower frequency links below around 8 GHz, which would include the 7.5 and 8 GHz bands being examined here, there is a premium of around 30% due to more expensive RF components. This leads to an equipment cost of $16,000 per two way link.

In addition to the radio equipment there is a need for antennas - large antennas in the range 3.0 – 3.7 m are likely to be used in the 7.5 and 8 GHz frequency bands. The approximate cost per antenna is $6000.

Radio equipment cost = $16,000

Depreciated cost of $8,000 therefore written off = $1,429 annualised (10% / 7.5 years)

Antenna costs = $12,000

Depreciated cost of $6,000 therefore written off = $1,071 annualised (10% / 7.5 years)

Total = $2,500 p.a.

Note that this cost is largely independent of the carrier size between 2 and 34 Mbps as the equipment is software configurable. These costs therefore relate to a pair (go and return) of 7, 14 or 29.65 MHz carriers therefore giving an annual cost of $42 to $179 per MHz.

6.5 Satellite services

A satellite service could be used as a substitute for a fixed link. However, it is unreasonable to assume that this would be for a single hop as the cost would be prohibitive. Any assessment of a satellite link as an alternative should assume that it is replacing an end-to-end trunk route consisting of many fixed link hops.

Satellite link costs quoted to us by telephone by Optus and Telstra are summarised in the table below.

Satellite costs associated with a unidirectional 2 Mbps link

	Capacity rental	Equipment	Higher rates
Optus	AUS$ 15 – 16,000 per month (9 MHz transponder slot = AUS$ 500 per hour)	AUS$ 15 – 25,000 one-off payment	Pro rata
Telstra	AUS$ 15 – 20,000 per month	AUS$ 4,000 per month	Pro rata

If the Optus average equipment cost of AUS$ 20,000 is annualised over 5 years / 10% (giving AUS$ 4,800 p.a.), say, then the range across both Optus and Telstra tariffs for a unidirectional 2 Mbps links is AUS$ 184,000 – 244,000 per annum.

If this link were to replace a 20 hop trunk route (e.g. Sydney / Melbourne) this would equate to twenty 7 MHz bandwidth assignments (a total bandwidth of 140 MHz) and the cost equivalence would therefore be in the range AUS$ 1,314 – 1,743 per MHz per year. The use here of 7 MHz channels is based on the fact that they are the smallest assignments available in the fixed link bands being addressed by this study. It should however be noted that a 7 MHz fixed link channel is quite capable of carrying more that 2 Mbps. The modulation/coding technologies discussed in section 6.3 above would enable a capacity of 4E1 to be supported i.e. 8 Mbps. The cost equivalence should therefore be related to an 8 Mbps satellite link.

In general satellite costs can be pro-rated by data rate. An 8 Mbps satellite link will cost 4 times as much as a 2 Mbps satellite link. It would therefore be expected that the tariff for a unidirectional 8 Mbps satellite link would be AUS$ 736,000 – 976,000 per annum. This equates to twenty 7 MHz bandwidth assignments as before and the cost equivalence is AUS$ 5,257 – 6,971 per MHz per year.

6.6 Leased line

While the tariffs associated with satellite links as discussed above are distance independent, this is not the case when considering leased lines as an alternative.

Example leased line costs from Telstra are shown in the table below.

Telstra leased line tariffs (excluding initial connection charge and GST)

	39 km	Sydney / Melbourne	Notes
Megalink 2 Mbps bidirectional	AUS$ 48,048 per annum	AUS$ 75,000 per annum	39 km assumed because max distance in Large Megabit Bearer tariff table.
Large Megabit Bearer 34 Mbps bidirectional	AUS$ 204,204 per annum	AUS$ 318,762 per annum	Sydney / Melbourne not explicitly offered. Ratio for 2 Mbps link assumed in order to derive cost.

In the first instance the 39 km route is equivalent to a single fixed link hop using a single channel assignment in each direction; two 7 MHz channel assignments for the 2 Mbps link and two 29.65 MHz channel assignments for the 34 Mbps link. It has already been noted in the satellite services section that 7 MHz channels are the smallest assignments available in the fixed link bands being addressed by this study.

For the Sydney /Melbourne route it will be assumed that this will replace 20 fixed link hops as was assumed for the satellite services case. This means that 40 channel assignments will be involved when determining the cost equivalence.

The cost equivalence based on the four tariffs in the table above is shown in the table below.

	39 km route	Sydney / Melbourne route
2 Mbps link	AUS$ 3,432 per MHz per year	AUS$ 268 per MHz per year
34 Mbps link	AUS$ 3,444 per MHz per year	AUS$ 269 per MHz per year

It is interesting to observe that the ratio between the 2 Mbps and 34 Mbps tariffs on the 39 km route is almost exactly the same as the ratio between the two channel bandwidths assumed to support these two bitrates, namely 7 MHz and 29.65 MHz. This coincidence follows through to the Sydney / Melbourne route simply because an assumption was made about the 2 Mbps tariff ratio (relating to distance) also applying to the 34 Mbps case where no Sydney / Melbourne tariff is published.

6.7 Conclusions

Comparison of the different means to arrive at the next best alternative cost is as follows:

Method	Annual cost per MHz ($) per assignment	Comment
Potential other uses	---	No credible other uses
More efficient technology	---	Detailed assessment not possible because of lack of information on current usage. Use of more efficient technology already encouraged by existing fees structure.
Higher frequency band	42 to 179	Range due to software reconfigurability of equipment
Satellite services	5,257 – 6,971	Assuming a 20 hop trunk route.
Leased line	3,432 268	Based on short distance (39 km) tariff. Assuming a 20 hop trunk route.

As can be seen from the table the least cost alternative is to move to a higher frequency band. The values obtained bracket those already charged in Sydney and Perth under the spectrum tax. By way of comparison the current fees (Division 2 of the Apparatus Licence Fee Schedule, 1 April 2008) in the 7.5 and 8 GHz fixed link bands, as well as the bands immediately above, amount to:

Frequency band	Tax per MHz p.a. per assignment in Sydney (high density) - $	Tax per MHz p.a. per assignment in Perth (medium density) - $
5 to 8.5 GHz	148.00	68.90
8.5 to 14.5 GHz	127.00	30.00

In addition to the spectrum tax identified in the table above each assignment is liable to an administrative charge when first issued and on renewal. Taking the initial charge and renewal, and annualising the charge over 15 years at 10%, this is equivalent to $52 p.a. per assignment. These charges would also apply when the tax is based on opportunity cost.

Our calculations suggest that the current level of the spectrum tax in Sydney is a reasonable reflection of opportunity cost. However, the tax in the 8.5-14.5 GHz band in Sydney looks high given the bands in this range are not congested. A useful first step could be to reduce these charges to levels comparable to those in Perth in order to encourage greater use of these bands as compared to the 7.5/8 GHz bands.

Annex: Base line data for the case studies

400 MHz Band

The part of the spectrum collectively known as the 400 MHz band consists of two parts; 403 – 420 MHz and 450 – 520 MHz[58]. The band is used for narrowband services and wideband rural services. The latter are not of relevance to this study which focuses on Sydney as a high density area and Perth as a medium density area.

The narrowband services comprise:

- Land mobile – single / two frequency with 12.5 / 25 kHz channelling and two frequency trunked with 12.5 kHz channelling
- Fixed - single frequency with 12.5 / 25 kHz channelling, two frequency point-to-point with 25 kHz channelling and two frequency point-to-multipoint with 12.5 / 25 kHz channelling.

Segments of the plan allocated for 25 kHz land mobile use may be used by 12.5 kHz land mobile systems[59].

Stations in the fixed service (point-to-multipoint) may, if frequencies are not available in segments allocated to the fixed service (point-to-multipoint), use segments allocated for the land mobile service, except those allocated for the land mobile service (trunked). The principles specified in the plan for the land mobile service apply to the use of these segments by stations in the fixed service (point-to-multipoint).

There is an embargo (No. 45) on the topmost 2 MHz (i.e. 518 – 520 MHz) which relates to the possible future use of UHF channel 27 (519 – 526 MHz).

The band is reported[60] to be congested although in some cases it is not clear whether the congestion is due to licence congestion (i.e. due to administrative constraints) and/or spectrum congestion (i.e. due to technical constraints). An example is provided of the occupancy in Segment I relative to the 39 channels available in that segment. The map provided indicates that Sydney is heavily congested in that frequency segment (tending towards 100% usage on the basis of visual inspection of the map provided) whereas Perth is less so at something around 50% usage of available channels. A further example for Segment K also shows heavy congestion in Sydney based on the then (2005) mix of 25 and 12.5 kHz channels. The accompanying analysis provides evidence that a wholesale move to 12.5 kHz channels would reduce the congestion significantly.

An overall view of occupancy and type of usage in the various segments that make up the 400 MHz Plan is shown in the following table. The current occupancy for the 400 MHz band in Sydney and Perth is shown in subsequent tables.

[58] 420 – 450 MHz is used for Defence / Government (420 – 430 MHz) and Defence Radiolocation (430 – 450 MHz). Amateurs also have access on a secondary basis.

[59] Channel Splitting in Pursuit of Increased Spectrum Productivity in the 403 to 520 MHz band. SPP 13/92, September 1992.

[60] Quantifying Spectrum Use in the 400 MHz Land Mobile Band, SP 4/05, 1st December 2005 and Spectrum Options: 403 – 520 MHz. Initial consultation on future arrangements for the 400 MHz band. ACMA, April 2008.

Service	Ch BW (kHz)	Transmit segments	Degree and type of usage	Channelisation usage	Other usage	General comments
LMS (2 freq)	25	I, K, N, X, Z, BB, II, JJ, PP	Moderate. Largely high power.	Largely 25 kHz. Increasing 12.5 kHz / decreasing 25 kHz assignments.	Mainly analogue. Digital increase in a few segments.	Segments below 420 MHz have even 12.5 and 25 kHz assignments, segments above 450 MHz have higher proportion of 25 kHz assignments.
LMS (1 freq)	25	L, P, Y, AA, CC, HH, KK, QQ, VV	Moderate to high. L, QQ & VV fairly low. Small number of high power.	Largely 25 kHz with increasing 12.5 kHz services	Mainly analogue. Increase in digital.	Proportion of digital below 420 MHz higher than above 450 MHz.
FS P-P (2 freq)	25	B, J, Q, U	Very high. Almost entirely low power.	25 kHz. Minimal 12.5 kHz.	Mainly analogue. Small increase in digital.	---
FS	25	P, AA, VV	Very high. High number of low power services.	Largely 25 kHz with increasing 12.5 kHz services (rapid in VV).	Equal analogue and digital. Increase in digital.	---
LMS (2 freq)	12.5	W, MM, OO	Low. Largely high power.	Largely 12.5 kHz	Mainly analogue	MM predominantly used by Telstra. This segment experiencing significant decline in number of services
LMS (1 freq)	12.5	G*,H	Low but experiencing growth. Mainly low power.	Some 25 kHz but increasing numbers of 12.5 kHz	Mainly digital in G and analogue in H	---
CB	25	EE	Moderate to high	25 kHz	Analogue	---
FS	12.5	G*	Low	Some 25 kHz but increasing numbers of 12.5 kHz	Mainly digital	It is not entirely clear how the aggregated information for this segment is attributable to the Fixed and Land Mobile Services(see two rows above), both of which use the

						segment.
LMS (trunked)	?12.5?	M	High? Mostly high power.	25 kHz	Analogue	---
FS P-MP	25	V	High? Strong increase in demand. Mostly low power.	Almost even 25 and 12.5 kHz	Mainly digital	---
Spectrum licensing	---	NN, SS	Moderate? Mostly high power.	12.5 kHz	Mainly analogue in NN and digital in SS.	---

Derived from ACMA internal document "General Spectrum Usage in the 400 MHz band" – countrywide narrowband assignments March 2006.

7.5 GHz band[61]

This band is primarily used for low / medium capacity (2 – 17 Mbps) medium haul (20 km minimum path length) fixed point-to-point links.

There are two go / return channel arrangements based on 7 MHz and 14 MHz channels and derived from ITU-R Recommendation F.385-6. There is an offset of 3.5 MHz between the two channel plans.

14 MHz channels are assigned from the highest channel downwards and 7 MHz channels are assigned from the lowest channel upwards.

Assignments should not be made on the 7 MHz Channel 1 (7428 MHz) to avoid band edge interference.

Earlier arrangements accommodated 3.5 MHz and 18 MHz channels. New assignments have to be coordinated around these systems.

In 1996 there were around 1300 assignments countrywide and by 2007 this had increased to nearly 2500. ACMA consider[62] that the band is currently (as of September 2007) about half loaded and that it will be 100% loaded by 2020.

The current occupancy in Sydney and Perth is shown in subsequent tables.

8 GHz band[63]

[61] Microwave Fixed Services Frequency Coordination. RALI FX3 date of effect 26/08/1998, also dated January 2008.

[62] Band loading and assignment trend analysis of fixed link bands in Australia (ACMA – Internal use only). SPP 9/07, September 2007.

[63] Microwave Fixed Services Frequency Coordination. RALI FX3 date of effect 26/08/1998, also dated January 2008.

This band is primarily used for medium / high capacity (34 Mbps, FM video) medium haul (10 km minimum path length) fixed point-to-point links.

There are two go / return channel arrangements, main and interleaved, both based on 29.65 MHz channels and derived from ITU-R Recommendation F.386-4. There is an offset of 14.825 MHz between the two channel plans.

No assignments shall be made on Channels 7 and 8, main and interleaved (7910.775, 7925.60, 7940.425, 7955.25 MHz), except in cases where the availability of other channels in the band is precluded through unsuccessful coordination.

In 1996 there were just over 2000 assignments countrywide and by 2007 this had increased to around 2750. ACMA consider[64] that the band is currently (as of September 2007) 25% - 50% full on regional trunk routes and 50% - 80% full on most sites associated with major trunk routes (especially close to cities), with some sites close to or have reached 100% on particular azimuths.

The current occupancy in Sydney and Perth is shown in subsequent tables.

Summary data (site-specific assignments at 1/6/08)

400 MHz band

	Sydney	Perth
403 - 420 MHz	3,974	629
450 - 520 MHz	7,402	2,884

In addition to site-specific licences, ACMA issues are-wide licences that authorise operation anywhere in an area. In the land mobile bands, some channels are unofficially used for these area-wide licences for use on a "no interference / no protection basis", and assigners avoid assigning site-specific licences on these channels. More than one area wide licence is assigned on the same channel - users have to avoid each other or cope with the interference.

These 400 MHz band wide-area licences, which through assigners' actions effectively deny site-specific licences, are shown in the table below:

Licence area	Location	Assignments
Australia	Australia Wide	1546
High Density Area	New South Wales	876
High Density Area	Sydney/Wollongong HD	20
Medium Density Area	Perth MD	36
Medium Density Area	Western Australia	453

7.5 & 8 GHz bands

	Sydney	Perth
7425 - 7725 MHz	284 (0)	88 (0)
3.5 MHz	8	
7 MHz	108	32
7.5 MHz	2	12
8 MHz	18	

[64] Band loading and assignment trend analysis of fixed link bands in Australia (ACMA – Internal use only). SPP 9/07, September 2007.

14 MHz	148	44
7725 - 8275 MHz	569 (0)	192 (1)

Note: Numbers in brackets indicate assignments in the band gap.

The 7.5 GHz occupancy for both Sydney and Perth confirms the practice that 14 MHz channels are assigned from the highest channel downwards and 7 MHz channels are assigned from the lowest channel upwards, and that assignments should not be made on the 7 MHz Channel 1 (7428 MHz) to avoid band edge interference.

It has been noted that earlier arrangements accommodated 3.5 MHz and 18 MHz channels. While there is evidence of a few 3.5 MHz channels in Sydney there is no evidence of any 18 MHz channels in Sydney or Perth. There are, however, some 7.5 and 8 MHz channels.

The 8 GHz occupancy for Both Sydney and Perth suggests that the rule regarding assignments not being made on Channels 7 and 8 (main and interleaved), except in cases where the availability of other channels in the band is precluded through unsuccessful coordination, has to be overridden on a significant number of occasions.

It can also be noted that the interleaved channels are heavily used (particularly in Sydney) whereas use of the main channels is sparse.

400 MHz band (403 – 420 MHz and 450 – 520 MHz) - Sydney

Segment	Service allocation	Frequency limits (MHz)	Paired segment	Channels x bandwidth (kHz)	No. of assignments (1/6/08) (12.5/25 kHz split)
A	Land Mobile Service (two frequency, base receive)	403.0000 403.9875	I	39 x 25	107
B	Fixed Point-to-Point (two frequency)	403.9875 405.0125	J	41 x 25	237 (1 / 236)
C	Land Mobile Service (two frequency, base receive)	405.0125 406.0000	K	39 x 25	73
D	Mobile Satellite Service	406.0000 406.1000	-	-	
E	Land Mobile Service (trunked, base receive)	406.1000 408.6375	M	200 x 12.5	430
F	Land Mobile Service (two frequency, base receive)	408.6375 410.5375	N	76 x 25	1034
G	Land Mobile + Fixed Services (single frequency) (see note 1)	410.5375 410.96875	-	34 x 12.5 (see note 2)	76 (46 / 30)
H	Land Mobile Service (single frequency) (see note 1)	410.96875 412.4625	-	119 x 12.5	123 (121 / 2)
I	Land Mobile Service (two frequency, base transmit)	412.4625 413.4375	A	39 x 25	108 (81 / 27)
J	Fixed Point-to-Point (two frequency)	413.4375 414.4625	B	41 x 25	237 (1 / 236)
K	Land Mobile Service (two frequency, base transmit)	414.4625 415.4375	C	39 x 25	73 (33 / 40)
L	Land Mobile Service (single frequency) (see note 1)	415.4375 415.5625	-	5 x 25	1 (0 / 1)
M	Land Mobile Service (trunked, base transmit)	415.5625 418.0875	E	200 x 12.5	433 (432 / 1)
N	Land Mobile Service (two frequency, base transmit)	418.0875 420.0000	F	76 x 25	1042 (1023 / 19)

-	*Defence / Government* *Defence Radiolocation*	*420 - 430* *430 - 450*	-	-	-
P	Land Mobile + Fixed Services (single frequency) (see note 1)	450.0000 450.4875	-	19 x 25	372 (65 / 307)
Q	Fixed Point-to-Point (two frequency)	450.4875 451.5125	U	41 x 25	270 (4 / 266)
R	Fixed Point-to-Multipoint (two frequency, base receive)	451.5125 452.5000	V	79 x 12.5 (see note 3)	95
S	Land Mobile Service (two frequency, base receive)	452.5000 453.5125	W	80 x 12.5	118
T	Land Mobile Service (see note 4) (two frequency, base receive)	453.5125 459.9875	X	259 x 25	795
U	Fixed Point-to-Point (two frequency)	459.9875 461.0125	Q	41 x 25	271 (3 / 268)
V	Fixed Point-to-Multipoint (two frequency, base transmit)	461.0125 462.0000	R	79 x 12.5	96 (77 / 19)
W	Land Mobile Service (two frequency, base transmit)	462.0000 463.0125	S	80 x 12.5	118 (111 / 7)
X	Land Mobile Service (see note 4) (two frequency, base transmit)	463.0125 469.4875	T	259 x 25	836 (360 / 476)
Y	Land Mobile Service (see note 5) (single frequency) (see note 1)	469.4875 469.9875	-	20 x 25	287 (34 / 253)
Z	Land Mobile Service (two frequency, base transmit)	469.9875 471.2125	DD	49 x 25	89 (24 / 65)
AA	Land Mobile + Fixed Services (single frequency) (see note 1)	471.2125 472.2125	-	40 x 25	434 (98 / 336)
BB	Land Mobile Service (two frequency, base transmit)	472.2125 474.7875	FF	103 x 25	176 (46 / 130)
CC	Land Mobile Service (see note 5) (single frequency) (see note 1)	474.7875 475.1875	-	16 x 25	167 (54 / 113)
DD	Land Mobile Service (two frequency, base receive)	475.1875 476.4125	Z	49 x 25	90
EE	Land Mobile Service (Citizen Band Radio, single frequency)	476.4125 477.4125	-	40 x 25	28 (0 / 28)

FF	Land Mobile Service (two frequency, base receive)	477.4125 479.9875	BB	103 x 25	178
GG	Land Mobile Service (two frequency, base receive)	479.9875 484.7875	II	192 x 25	319 (129 / 190)
HH	Land Mobile Service (single frequency) (see note 1)	484.7875 485.1875	-	16 x 25	156 (59 / 97)
II	Land Mobile Service (two frequency, base transmit)	485.1875 489.9875	GG	192 x 25	321 (130 / 191)
JJ	Land Mobile Service (two frequency, base transmit)	489.9875 494.7875	LL	192 x 25	297 (101 / 196)
KK	Land Mobile Service (single frequency) (see note 1)	494.7875 495.1875	-	16 x 25	125 (55 / 70)
LL	Land Mobile Service (two frequency, base receive)	495.1875 499.9875	JJ	192 x 25	294
MM	Land Mobile Service (two frequency, base transmit)	499.9875 500.99375	RR	80 x 12.5	48 (48 / 0)
NN	Designated for Spectrum Licensing (see note 6)	500.99375 504.99375	-	*4 MHz block* *Licence expires 2012*	248 (59 / 45) + other BWs
OO	Land Mobile Service (two frequency, base transmit)	504.99375 507.01250	TT	161 x 12.5	193 (192 / 1)
PP	Land Mobile Service (two frequency, base transmit)	507.0125 509.5375	UU	101 x 25	138 (44 / 94)
QQ	Land Mobile Service (single frequency) (see note 1)	509.5375 509.9875	-	18 x 25	116 (87 / 29)
RR	Land Mobile Service (two frequency, base receive	509.9875 510.99375	MM	80 x 12.5	49
SS	Designated for Spectrum Licensing (see note 6)	510.99375 514.99375	-	*4 MHz block* *Licence expires 2012*	245 (57 / 45) + other BWs
TT	Land Mobile Service (two frequency, base receive)	514.99375 517.01250	OO	161 x 12.5	193
UU	Land Mobile Service (two frequency, base receive)	517.01250 519.53750	PP	101 x 25	137
VV	Land Mobile + Fixed Services	519.5375	-	18 x 25	103

	(single frequency) (see note 1)	520.0000			(53 / 50)

Notes:

1. The land mobile service allocation in segments G, H, L, P, Y, AA, CC, HH, KK, QQ, and VV is intended primarily to support single frequency low power applications; assignments may be made to single frequency high power land mobile applications if required.
2. In segment G (410.5375 - 410.96875 MHz) channel bandwidths of 25 kHz may be used.
3. In segments R (451.5125 - 452.5 MHz) and V (461.0125 - 462.0 MHz) channel bandwidths of 25 kHz may be used provided the requirements of Spectrum Planning Report SP 2/90 '*400/900 MHz Point to Multipoint Assignment Guidelines'* are met.
4. The frequencies 457.525 MHz, 457.550 MHz, 457.575 MHz, 467.525 MHz, 467.550 MHz and 467.575 MHz may be used by on-board communication stations in the Maritime Mobile Service.
5. The segments Y (469.4875 - 469.9875 MHz) and CC (474.7875 - 475.1875 MHz) may be used by the fixed service outside of the areas defined as high spectrum demand areas (see Table 2).
6. On 16 May 1996, the Minister for Communications and the Arts designated that the bands 500.99375 - 501.39375 MHz and 510.99375 - 511.39375 MHz throughout Australia, and the bands 501.39375 - 504.99375 MHz and 511.39375 - 514.99375 MHz in parts of Australia, be allocated by issuing spectrum licences. No apparatus licences may be issued in the designated spectrum licensed bands and areas.

400 MHz band (403 – 420 MHz and 450 – 520 MHz) - Perth

Segment	Service allocation	Frequency limits (MHz)	Paired segment	Channels x bandwidth (kHz)	No. of assignments (1/6/08) (25/12.5 kHz split)
A	Land Mobile Service (two frequency, base receive)	403.0000 403.9875	I	39 x 25	23
B	Fixed Point-to-Point (two frequency)	403.9875 405.0125	J	41 x 25	38 (7 / 29)
C	Land Mobile Service (two frequency, base receive)	405.0125 406.0000	K	39 x 25	18
D	Mobile Satellite Service	406.0000 406.1000	-	-	
E	Land Mobile Service (trunked, base receive)	406.1000 408.6375	M	200 x 12.5	96
F	Land Mobile Service (two frequency, base receive)	408.6375 410.5375	N	76 x 25	100
G	Land Mobile + Fixed Services (single frequency) (see note 1)	410.5375 410.96875	-	34 x 12.5 (see note 2)	21 (2 / 19)
H	Land Mobile Service (single frequency) (see note 1)	410.96875 412.4625	-	119 x 12.5	65 (63 / 2)
I	Land Mobile Service (two frequency, base transmit)	412.4625 413.4375	A	39 x 25	25 (1 / 24)
J	Fixed Point-to-Point (two frequency)	413.4375 414.4625	B	41 x 25	36 (7 / 27) + other BWs
K	Land Mobile Service (two frequency, base transmit)	414.4625 415.4375	C	39 x 25	18 (0 / 18)
L	Land Mobile Service (single frequency) (see note 1)	415.4375 415.5625	-	5 x 25	1 (0/1)
M	Land Mobile Service (trunked, base transmit)	415.5625 418.0875	E	200 x 12.5	96 (96 / 0)
N	Land Mobile Service (two frequency, base transmit)	418.0875 420.0000	F	76 x 25	92 (0 / 92)

-	*Defence / Government* *Defence Radiolocation*	*420 - 430* *430 - 450*	-	-	-
P	Land Mobile + Fixed Services (single frequency) (see note 1)	450.0000 450.4875	-	19 x 25	160 (3 / 157)
Q	Fixed Point-to-Point (two frequency)	450.4875 451.5125	U	41 x 25	68 (2 / 66)
R	Fixed Point-to-Multipoint (two frequency, base receive)	451.5125 452.5000	V	79 x 12.5 (see note 3)	79
S	Land Mobile Service (two frequency, base receive)	452.5000 453.5125	W	80 x 12.5	44
T	Land Mobile Service (see note 4) (two frequency, base receive)	453.5125 459.9875	X	259 x 25	225
U	Fixed Point-to-Point (two frequency)	459.9875 461.0125	Q	41 x 25	65 (2 / 63)
V	Fixed Point-to-Multipoint (two frequency, base transmit)	461.0125 462.0000	R	79 x 12.5	79 (23 / 56)
W	Land Mobile Service (two frequency, base transmit)	462.0000 463.0125	S	80 x 12.5	44 (27 / 17)
X	Land Mobile Service (see note 4) (two frequency, base transmit)	463.0125 469.4875	T	259 x 25	227 (6 / 221)
Y	Land Mobile Service (see note 5) (single frequency) (see note 1)	469.4875 469.9875	-	20 x 25	208 (3 / 205)
Z	Land Mobile Service (two frequency, base transmit)	469.9875 471.2125	DD	49 x 25	35 (0 / 35)
AA	Land Mobile + Fixed Services (single frequency) (see note 1)	471.2125 472.2125	-	40 x 25	199 (3 / 196)
BB	Land Mobile Service (two frequency, base transmit)	472.2125 474.7875	FF	103 x 25	81 (1 / 80)
CC	Land Mobile Service (see note 5) (single frequency) (see note 1)	474.7875 475.1875	-	16 x 25	170 (6 / 164)
DD	Land Mobile Service (two frequency, base receive)	475.1875 476.4125	Z	49 x 25	35
EE	Land Mobile Service (Citizen Band Radio, single frequency)	476.4125 477.4125	-	40 x 25	10 (0 / 10)

FF	Land Mobile Service (two frequency, base receive)	477.4125 479.9875	BB	103 x 25	80
GG	Land Mobile Service (two frequency, base receive)	479.9875 484.7875	II	192 x 25	111
HH	Land Mobile Service (single frequency) (see note 1)	484.7875 485.1875	-	16 x 25	90 (2 / 88)
II	Land Mobile Service (two frequency, base transmit)	485.1875 489.9875	GG	192 x 25	111 (19 / 92)
JJ	Land Mobile Service (two frequency, base transmit)	489.9875 494.7875	LL	192 x 25	82 (4 / 78)
KK	Land Mobile Service (single frequency) (see note 1)	494.7875 495.1875	-	16 x 25	76 (1 / 75)
LL	Land Mobile Service (two frequency, base receive)	495.1875 499.9875	JJ	192 x 25	82
MM	Land Mobile Service (two frequency, base transmit)	499.9875 500.99375	RR	80 x 12.5	4 (4 / 0)
NN	Designated for Spectrum Licensing (see note 6)	500.99375 504.99375	-	*4 MHz block* *Licence expires 2012*	117 (107 / 0) + other BWs
OO	Land Mobile Service (two frequency, base transmit)	504.99375 507.01250	TT	161 x 12.5	15 (15 / 0)
PP	Land Mobile Service (two frequency, base transmit)	507.0125 509.5375	UU	101 x 25	31 (0 / 31)
QQ	Land Mobile Service (single frequency) (see note 1)	509.5375 509.9875	-	18 x 25	63 (4 / 59)
RR	Land Mobile Service (two frequency, base receive	509.9875 510.99375	MM	80 x 12.5	4
SS	Designated for Spectrum Licensing (see note 6)	510.99375 514.99375	-	*4 MHz block* *Licence expires 2012*	186 (176 / 0) + other BWs
TT	Land Mobile Service (two frequency, base receive)	514.99375 517.01250	OO	161 x 12.5	15
UU	Land Mobile Service (two frequency, base receive)	517.01250 519.53750	PP	101 x 25	26
VV	Land Mobile + Fixed Services	519.5375	-	18 x 25	62

	(single frequency) (see note 1)	520.0000			(7 / 55)

Notes:

1. The land mobile service allocation in segments G, H, L, P, Y, AA, CC, HH, KK, QQ, and VV is intended primarily to support single frequency low power applications; assignments may be made to single frequency high power land mobile applications if required.
2. In segment G (410.5375 - 410.96875 MHz) channel bandwidths of 25 kHz may be used.
3. In segments R (451.5125 - 452.5 MHz) and V (461.0125 - 462.0 MHz) channel bandwidths of 25 kHz may be used provided the requirements of Spectrum Planning Report SP 2/90 '*400/900 MHz Point to Multipoint Assignment Guidelines'* are met.
4. The frequencies 457.525 MHz, 457.550 MHz, 457.575 MHz, 467.525 MHz, 467.550 MHz and 467.575 MHz may be used by on-board communication stations in the Maritime Mobile Service.
5. The segments Y (469.4875 - 469.9875 MHz) and CC (474.7875 - 475.1875 MHz) may be used by the fixed service outside of the areas defined as high spectrum demand areas (see Table 2).
6. On 16 May 1996, the Minister for Communications and the Arts designated that the bands 500.99375 - 501.39375 MHz and 510.99375 - 511.39375 MHz throughout Australia, and the bands 501.39375 - 504.99375 MHz and 511.39375 - 514.99375 MHz in parts of Australia, be allocated by issuing spectrum licences. No apparatus licences may be issued in the designated spectrum licensed bands and area

7.5 GHz band (7425 – 7725 MHz) - Sydney

7 MHz channels

Channel designation	Frequency (MHz)	No. of assignments (1/6/08)
1	7428	
2	7435	17
3	7442	8
4	7449	9
5	7456	6
6	7463	4
7	7470	
8	7477	4
9	7484	2
10	7491	
11	7498	
12	7505	
13	7512	2
14	7519	
15	7526	2
16	7533	
17	7540	
18	7547	
19	7554	
20	7561	
Subtotal		54
1’	7589	
2’	7596	17
3’	7603	8
4’	7610	9
5’	7617	6
6’	7624	4
7’	7631	
8’	7638	4
9’	7645	2
10’	7652	
11’	7659	
12’	7666	
13’	7673	2
14’	7680	
15’	7687	2
16’	7694	
17’	7701	
18’	7708	

19’	7715	
20’	7722	
Subtotal		54
Total		108

<u>14 MHz channels</u>

Channel designation	Frequency (MHz)	No. of assignments (1/6/08)
1	7431.5	4
2	7445.5	2
3	7459.5	4
4	7473.5	4
5	7487.5	17
6	7501.5	6
7	7515.5	7
8	7529.5	9
9	7543.5	7
10	7557.5	14
Subtotal		74
1’	7592.5	4
2’	7606.5	2
3’	7620.5	4
4’	7634.5	4
5’	7648.5	17
6’	7662.5	6
7’	7676.5	7
8’	7690.5	9
9’	7704.5	7
10’	7718.5	14
Subtotal		74
Total		148

Total assignments in the band 7425 – 7725 MHz = 256 (of 284)

7.5 GHz band (7425 – 7725 MHz) - Perth

7 MHz channels

Channel designation	Frequency (MHz)	No. of assignments (1/6/08)
1	7428	
2	7435	7
3	7442	2
4	7449	5
5	7456	
6	7463	2
7	7470	
8	7477	
9	7484	
10	7491	
11	7498	
12	7505	
13	7512	
14	7519	
15	7526	
16	7533	
17	7540	
18	7547	
19	7554	
20	7561	
Subtotal		16
1’	7589	
2’	7596	7
3’	7603	2
4’	7610	5
5’	7617	
6’	7624	2
7’	7631	
8’	7638	
9’	7645	
10’	7652	
11’	7659	
12’	7666	
13’	7673	
14’	7680	
15’	7687	
16’	7694	
17’	7701	
18’	7708	

19’	7715	
20’	7722	
Subtotal		16
Total		32

14 MHz channels

Channel designation	Frequency (MHz)	No. of assignments (1/6/08)
1	7431.5	
2	7445.5	
3	7459.5	
4	7473.5	2
5	7487.5	
6	7501.5	6
7	7515.5	2
8	7529.5	4
9	7543.5	4
10	7557.5	4
Subtotal		22
1’	7592.5	
2’	7606.5	
3’	7620.5	
4’	7634.5	2
5’	7648.5	
6’	7662.5	6
7’	7676.5	2
8’	7690.5	4
9’	7704.5	4
10’	7718.5	4
Subtotal		22
Total		44

Total assignments in the band 7425 – 7725 MHz = 76 (of 88)

8 GHz band (7725 – 8275 MHz) - Sydney

Main 29.65 MHz channels

Channel designation	Frequency (MHz)	No. of assignments (1/6/08)
1	7747.70	4
2	7777.35	2
3	7807.00	
4	7836.65	
5	7866.30	2
6	7895.95	
7	7925.60	
8	7955.25	3
Subtotal		11
1’	8059.02	6
2’	8088.67	2
3’	8118.32	
4’	8147.97	
5’	8177.62	2
6’	8207.27	
7’	8236.92	
8’	8266.57	3
Subtotal		13
Total		24

Interleaved 29.65 MHz channels

Channel designation	Frequency (MHz)	No. of assignments (1/6/08)
1	7732.875	34
2	7762.525	51
3	7792.175	51
4	7821.825	37
5	7851.475	19
6	7881.125	40
7	7910.775	24
8	7940.425	16
Subtotal		272
1’	8044.195	35
2’	8073.845	53
3’	8103.495	51
4’	8133.145	36
5’	8162.795	20
6’	8192.445	37

7’	8222.095	24
8’	8251.745	17
Subtotal		273
Total		545

Total assignments in the band 7725 – 8275 MHz = 569 (of 569)

8 GHz band (7725 – 8275 MHz) - Perth

Main 29.65 MHz channels

Channel designation	Frequency (MHz)	No. of assignments (1/6/08)
1	7747.70	5
2	7777.35	
3	7807.00	
4	7836.65	
5	7866.30	
6	7895.95	
7	7925.60	
8	7955.25	
Subtotal		5
1’	8059.02	5
2’	8088.67	
3’	8118.32	
4’	8147.97	
5’	8177.62	
6’	8207.27	
7’	8236.92	
8’	8266.57	
Subtotal		5
Total		10

Interleaved 29.65 MHz channels

Channel designation	Frequency (MHz)	No. of assignments (1/6/08)
1	7732.875	16
2	7762.525	15
3	7792.175	17
4	7821.825	19
5	7851.475	6
6	7881.125	6
7	7910.775	5
8	7940.425	5
Subtotal		89
1’	8044.195	18
2’	8073.845	14
3’	8103.495	17
4’	8133.145	19
5’	8162.795	6
6’	8192.445	8

7’	8222.095	5
8’	8251.745	5
Subtotal		92
Total		181

Total assignments in the band 7725 – 8275 MHz = 191 (of 192)