Australian Government
Australian Communications and Media Authority

Australia's regulator for broadcasting, the internet, radiocommunications and telecommunications www.acma.gov.au

Opportunity Cost Pricing of Spectrum

Public consultation on administrative pricing for spectrum based on opportunity cost

April 09

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Summary

In this paper ACMA examines administrative incentive pricing using opportunity cost as a preferred method for administratively allocated spectrum, which is expected to result in more efficient allocation of spectrum.

ACMA is inviting comment on:

- its proposal to use opportunity cost pricing in setting prices for administratively allocated spectrum to address congestion issues in the 400 MHz band; and
- other priority areas where opportunity cost pricing offers benefits in spectrum allocation.

To date, ACMA has not explicitly priced spectrum based on opportunity cost. Rather, administrative prices (annual taxes) have been based on a number of mixed policy goals, principally incentive pricing and cost recovery. This paper has been developed to illustrate the implications of ACMA's Principles for Spectrum Management,[1] especially Principle 1 ('*spectrum should be allocated to the highest value use or uses*') and Principle 2 ('*enable and encourage spectrum to move to its highest value use or uses'*) in relation to the administrative pricing of spectrum. Pricing based on these principles is expected to promote productive, allocative and dynamic efficiencies in spectrum markets and related downstream markets.

The opportunity cost of a part of the radiofrequency spectrum is the value of the spectrum in the highest value alternative use that is denied by granting access to one party rather than to the alternative. Efficient prices should be set in such a way that they create the right incentives for high-value spectrum licensees to provide their services at least cost. When the market sets spectrum prices (as in allocation by auction) this occurs automatically. A regulator setting spectrum prices (as in administrative allocation) should mimic the efficient and incentive effects of market based pricing. Such market-mimicking prices are based on the economic principle of opportunity cost.

Opportunity cost pricing is also consistent with the Total Welfare Standard ACMA uses to assess the impact of regulatory decisions, since opportunity cost pricing, by definition, is intended to achieve efficiencies that maximise consumer, producer and government welfare collectively.

There are a range of methods to determine opportunity cost. These include using market information and/or direct calculation methods, which are explored further in the paper. This

[1] ACMA consultation, IFC 05/2009, Principles for spectrum management, http://www.acma.gov.au/WEB/STANDARD/pc=PC_311683

work draws on advice from UK consulting firms Plum Consulting Ltd and Aegis Systems Ltd who were commissioned by ACMA in 2008 to recommend a specific method of calculating opportunity cost.

Opportunity cost pricing has different implications in different circumstances. In cases where demand exceeds supply, there are alternative uses of spectrum, and so pricing should be based on the highest value alternative uses. In cases where supply exceeds demand, there is unlikely to be alternative productive alternative uses of spectrum, and thus opportunity cost is expected to be zero or negligible.

One of the issues identified in ACMA's *Five–year Spectrum Outlook 2009–2013* (the Outlook)[2] is addressing congestion occurring in the 400 MHz band in specific geographic locations. Consequently, ACMA has developed price estimations based on opportunity cost principles for the 400 MHz case study band, to test the value of this approach in allocating spectrum to the highest value use or uses.

In high-density (congested) areas, users in the 400 MHz band currently pay $90 per kHz per assignment. Using the opportunity cost pricing methods outlined in this paper, an estimate of $180 per kHz per assignment was calculated. This paper outlines a proposal for price changes in high-density areas in the 400 MHz band to be phased in gradually in equal annual increments to a target of $180 per kHz per assignment after five years. Prices in lower density areas (where supply exceeds demand) are proposed to remain unchanged. The price levels that these opportunity cost calculations yield would form the basis for taxes paid by individual licensees, which are determined by the apparatus licence tax formula.

ACMA proposes to adopt opportunity cost pricing for the 400 MHz spectrum band, but is also interested in views on the priority uses of opportunity cost pricing in the other spectrum bands identified for progressive review and allocation, as outlined in the *Five–year Spectrum Outlook 2009–2013*.

ACMA invites comment on the following issues:

- **The instances where administrative pricing is preferable to auctions**
- **The use of opportunity cost pricing as the preferred pricing method for administratively allocated spectrum.**
- **General comments on the opportunity cost estimation methods outlined in this paper**
- **The potential for a wider application of opportunity cost pricing to government and community users of spectrum**
- **Comments about the opportunity cost pricing case studies presented in this paper**

[2] ACMA consultation, IFC 06/2009, ACMA's spectrum demand analysis and indicative work programs for the next five years, http://www.acma.gov.au/WEB/STANDARD/pc=PC_311686.

- **The 400 MHz band case study proposes increases in apparatus licences tax in high density areas (Sydney/Wollongong, Melbourne/Geelong, Brisbane/Gold Coast) over five years. Other changes to the tax in medium, low and remote density areas are not proposed at the current time.**

- **Comments on the bands where the application of opportunity cost pricing should be considered as a priority.**

- **Comments on the appropriate timeframe for the introduction of any price changes based on opportunity cost pricing and how frequently prices should be reviewed.**

Outline

This paper begins by providing the background and context to this review of administrative pricing of spectrum, before discussing the theoretical concept of opportunity cost and its efficiency properties (Chapter 2). In Chapter 3, the decision to implement opportunity cost pricing versus other allocation methods is discussed. The paper then focuses on the methods available for calculating opportunity cost, and constraints to the methods and practical pricing considerations (Chapters 4, 5 and 5.4). The paper then provides an example of this framework by developing opportunity cost pricing estimations/calculations for the 400 MHz band (Chapter 6). The price levels that are derived from opportunity cost calculations form the basis for taxes paid by individual licensees. Chapter 7 examines the apparatus licence tax formula that takes price levels and calculates individual licence taxes.

Consultation

ACMA invites comments on its proposal to set administrative prices for spectrum allocation according to the principle of opportunity cost outlined in this paper.

The outcome of this consultation may influence ACMA's approach to administrative pricing. It may change how we think about pricing and the way in which we intend to set prices.

ACMA is interested in hearing the views of all relevant parties on any issues raised in this paper. A number of proposals and questions are raised in it, and a summary of them is given in the conclusion.

The consultation strategy outlined here is in line with ACMA's approach to consultation on spectrum matters, announced earlier this year.[3]

WRITTEN SUBMISSIONS

Submissions on the issues raised in this discussion paper may be made to ACMA as follows:

By email: **economicresearch@acma.gov.au**

By mail: **Economic Research Section**
Australian Communications and Media Authority
PO Box 13112 Law Courts
Melbourne VIC 8010

The closing date for submissions is COB Friday 5 June 2009.

Electronic submissions in Microsoft Word or Rich Text Format are preferred. Please direct any questions about this discussion paper to Richard Scheelings by telephone on 03 9963 6828 or by email to richard.scheelings@acma.gov.au.

[3] ACMA media release 7/2008, A new approach to consultation on spectrum matters, 30 January, 2008, http://www.acma.gov.au/WEB/STANDARD/pc=PC_310939.

PUBLICATION OF SUBMISSIONS

In general, ACMA publishes all submissions it receives. However, ACMA will not publish submissions that it considers contain defamatory or irrelevant material.

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If information is accepted by ACMA as confidential, ACMA will seek to consult with the submitter of the information where ACMA intends to share that information.

Contents

List of figures and tables

List of abbreviations and terms

ACMA	Australian Communications and Media Authority
AIP	administrative incentive pricing
ALFS	Apparatus Licence Fee Schedule
the ACMA Act	*Australian Communications and Media Authority Act 2005*
BLF	Broadcasting Licence Fees Regime
BSA	*Broadcasting Service Act (1992)*
BSB	broadcast services bands
BWA	Broadband wireless access
CPI	Consumer price index
Defence	Department of Defence
DTT	digital terrestrial TV
FCC	Federal communications commission (US)
the Outlook	*Five-year Spectrum Outlook 2009–2013*
FOI Act	*Freedom of Information Act 1982* (Cth)
GDP	Gross domestic product
GHz	Gigahertz
IMT	international mobile telephony
ITU	International telecommunications union
kHz	kilohertz
MHz	Megahertz
NPV	net present value
ODV	optimal deprival value
PAMR	Public access mobile radio
PMR	Private mobile radio
PC	Productivity Commission

RC Act	*Radiocommunications Act 1992*
TETRA	Terrestrial Trunked Radio
TWS	Total Welfare Standard
UHF	Ultra high frequency
WRC-07	ITU world radiocommunications conference 2007

1 Introduction

Under the *Australian Communications and Media Authority Act 2005* (the ACMA Act), ACMA is responsible for managing the radiofrequency spectrum in accordance with the *Radiocommunications Act 1992* (the RC Act). One responsibility under the RC Act is the efficient allocation of spectrum. The RC Act permits ACMA to use a variety of primary allocation mechanisms, including administrative allocation at posted prices and auctions.

This consultation paper reviews current prices for administrative allocation and examines opportunity cost as a basis for setting and reviewing prices.

1.1 Context of the review

Administrative prices for spectrum in Australia generally aim to encourage the efficient use of spectrum. ACMA must have regard to the objects of the acts it administers, as well as ACMA's Principles for Spectrum Management.

Section 9 of the ACMA Act sets out the spectrum management functions of ACMA, including:

- to manage the radiofrequency spectrum in accordance with the RC Act
- to advise and assist the radiocommunications community.

In managing the radiofrequency spectrum, ACMA is guided by the object set out in section 3 of the RC Act. Section 3 of the RC Act is reproduced below.

3 The object of this Act

The object of this Act is to provide for management of the radiofrequency spectrum in order to:

(a) maximise, by ensuring the efficient allocation and use of the spectrum, the overall public benefit derived from using the radiofrequency spectrum;

(b) make adequate provision of the spectrum:

(i) for use by agencies involved in the defence or national security of Australia, law enforcement or the provision of emergency services; and

(ii) for use by other public or community services;

(c) provide a responsive and flexible approach to meeting the needs of users of the spectrum;

(d) encourage the use of efficient radiocommunication technologies so that a wide range of services of an adequate quality can be provided;

(e) provide an efficient, equitable and transparent system of charging for the use of spectrum, taking account of the value of both commercial and non-commercial use of spectrum;

(f) support the communications policy objectives of the Commonwealth Government;

(g) provide a regulatory environment that maximises opportunities for the Australian communications industry in domestic and international markets;

(h) promote Australia's interests concerning international agreements, treaties and conventions relating to radiocommunications or the radiofrequency spectrum.

In addition to this legislative object, ACMA manages and prices spectrum according to its Principles for Spectrum Management, Principle 1 of which states, 'Spectrum should be allocated to the highest value use or uses.'[4]

Administrative allocations based on opportunity cost pricing are consistent with the object of the RC Act (especially section 3(a) and 3(e)) and with ACMA's Principles for Spectrum Management by ensuring that administrative allocations are efficient. If prices are not set according to the principle of opportunity cost pricing, then spectrum may be left idle, or be used at the expense of a higher value use to society.

In considering opportunity cost pricing ACMA has also been mindful of its general approach to the Total Welfare Standard in assessing the impacts of regulatory decisions, since opportunity cost pricing by definition is intended to achieve efficiencies that maximise consumer, producer and government welfare collectively.[5]

[4] See ACMA consultation, IFC 05/2009, Principles for spectrum management, http://www.acma.gov.au/WEB/STANDARD/pc=PC_311683

[5] Speech by Rebecca Burdon (Principal Economist, ACMA) at ACE Telecommunications Summit, 27–28 August 2008, Sydney, 'Regulating in the public interest', http://www.acma.gov.au/webwr/_assets/main/lib310654/regulating_in_the_public_interest.pdf

In addition to this regulatory context, a 2002 review by the Productivity Commission (the *Review of Radiocommunications*) [6] recommended a number of changes to spectrum management. In particular Recommendation 8.4 stated that:

> To achieve efficient outcomes, spectrum charges should be based on opportunity cost, that is, on the value of the best forgone alternative use of that spectrum.

1.2 Purpose of the review

This paper explicitly examines opportunity cost pricing as a way to achieve more efficient use of spectrum in the context of the proposals for future arrangements in the 400 MHz band. This paper should be read in concert with the ACMA's discussion paper on Spectrum Proposals: 403–520 MHz.[7]

Under the RC Act, ACMA can issue three types of licences: spectrum licences, apparatus licences, and class licences.[8] In practice, spectrum licences (which are technology-flexible, and potentially applicable to a large geographic area) have tended to be auctioned, and apparatus licences (which relate to a specific device) have tended to be administratively allocated.[9] As a result of this general practice, throughout this paper we focus on and refer to apparatus licences and the fees applicable to their use.[10] Those fees are set out in ACMA's Apparatus Licence Fee Schedule (April 2008) (the ALFS).[11]

To date, ACMA has not explicitly priced spectrum based on opportunity cost. Rather, administrative prices (annual taxes) have been based on a number of mixed policy goals, principally incentive pricing and cost recovery.

The Australian Communications Authority (ACMA's predecessor organisation) examined opportunity cost pricing in 2004, and has used opportunity cost pricing principles where appropriate (mostly limited to market benchmarks). However, developments in new opportunity cost direct calculation methods warrant further review of opportunity cost pricing practices.

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[6] Productivity Commission 2002, *Radiocommunications Inquiry Report*, Report no. 22, AusInfo, Canberra ('Productivity Commission Report'). Available at http://www.pc.gov.au/projects/inquiry/radiocomms

[7] ACMA consultation, IFC 08/2009, Spectrum Proposals: 403–520 MHz - Proposals for future arrangements in the 400 MHz band, http://www.acma.gov.au/WEB/STANDARD/pc=PC_311684

[8] With class licences, users do not have to apply to ACMA to operate in class licensed bands or pay any fees (although they must operate within their technical specifications). Examples of devices operated under class licences are baby monitors, garage door remotes, and wi-fi.

[9] Section 60 of the RC Act specifies a number of ways *spectrum* licences can be allocated. Section 100 of the RC Act leaves it to ACMA's discretion whether and how it will allocate *apparatus* licences. An example of auctioned apparatus licences are the Low Power Open Narrowcasting (LPON) apparatus licences which are auctioned when there is expected to be competing demand for a licence. LPONs allow for the provision of niche radio broadcasting services, such as tourist and racing information, or ethnic and religious programming. They are offered on a rolling quarterly program and while most are allocated with no contest, there are typically three or four auctions each year.
Whatever the licence, administrative allocation is but one way of allocating spectrum, and, in policy terms allocation by auction is the primary allocational competitor to administrative allocation.

[10] Although the general conclusions are applicable to administrative allocation of spectrum licences. Conversely, spectrum licences can be administratively allocated and priced. The 2.3, 20 and 30 GHz bands were converted to spectrum licences.

[11] The Apparatus Licence Fee Schedule and the underpinning legislation is available at http://www.acma.gov.au/web/STANDARD/pc%3DPC_1614

It is also timely to review opportunity cost pricing practices in light of the increasing demand for spectrum that ACMA's *Five-year Spectrum Outlook 2009–2013* highlights.

At present there are two types of fees applicable to apparatus licenses:

1. administrative charges to recover the direct costs of service provided by ACMA such as licence issue and renewal. These include fees levied for services such as assignments carried out by ACMA
2. annual taxes[12] to recover the indirect costs of spectrum management and to provide incentives for efficient use of the spectrum. In this report we also refer to the annual taxes as administrative prices, or prices for administratively allocated spectrum.

This paper focuses on the annual taxes and does not consider the fee-for-service charges other than to note that fee requirement on AMCA associated with cost recovery is a separate legislative obligation than can affect opportunity cost strategies, particularly in situations where demand is low.

[12] The term 'apparatus licence tax' is defined in the *Radiocommunications Act 1992* as a tax imposed under the *Radiocommunications (Receiver Licence Tax) Act 1983* or the *Radiocommunications (Transmitter Licence Tax) Act 1983*.

2 The principle of opportunity cost pricing

Historically, apparatus licence taxes have been based on a number of mixed-policy goals rarely based on direct estimates of opportunity cost. Taxes (or prices) that encourage efficient use of spectrum are called administrative incentive prices (AIP). Opportunity cost pricing is one form of AIP.

Prices should be set in such a way that they create incentives for radiocommunications licensees providing high-value services to provide those services at least cost (productive and allocative efficiency) which addresses the efficiency aspect of the object from the *Radiocommunications Act 1992*. When the market sets spectrum prices (as in allocation by auction) this occurs automatically. A government regulator setting spectrum prices (as in administrative allocation) should aim to mimic the efficiency and incentive effects of market-based pricing as far as practicable. Such market-mimicking prices are based on the economic principle of opportunity cost.

2.1 Markets and efficiency

In markets, prices are determined by the interaction of supply and demand. Firms supply a good and customers demand it. In a well-functioning market, the price at which the market clears (that is, where supply = demand) automatically provides market participants with the right incentives to behave efficiently. When all market participants are behaving efficiently, then the economy as a whole will be efficient. Efficiency for the economy as a whole can be assessed along three dimensions: allocative, productive and dynamic.[13]

> **Allocative**: The mix of goods and services that are produced in the economy is such that no other mix can increase the wellbeing of society.
> In terms of spectrum, users of spectrum should be such that the right final mix of spectrum-related products is being made available.

> **Productive**: Production of goods and services ought to be undertaken at the lowest possible cost (cost is measured in terms of inputs).
> In terms of spectrum, users of radio spectrum should choose inputs (capital, labour

[13] Doyle, Chris, *The Pricing of Radio Spectrum: Using Incentive Mechanisms to Achieve Efficiency*, Centre for Management under Regulation, Warwick Business School, January 2007.

and spectrum) in order that production of services is at the lowest overall cost.

Dynamic: Resources are deployed in a way that encourages the most desirable level of research, development and innovation. In terms of spectrum, the right amount of innovation in spectrum use and spectrum-related products should be encouraged to enable substantial supply and demand to interact over time to optimise allocation and technical outcomes.

Well-functioning markets typically exhibit all three dimensions of efficiency. Demand in the spectrum market is comprised of firms, community groups and government agencies providing telecommunications and broadcasting services to end-customers; agencies using spectrum for telemetry, radiodetermination, earth exploration, meteorology or astronomy; or individuals utilising spectrum to engage in recreation/amateur radio activity. Supply in the spectrum market is simply the government-regulated natural resource of the radiofrequency spectrum. Because this supply-side of the spectrum market is managed by the government rather than left to the market, government decisions can affect all three dimensions of efficiency listed above.

In administrative allocations there are three main areas where inefficiency can arise. They include:

Low-value use: Spectrum might be allocated to a low-value use, thus leading to *allocative* inefficiency, in that the final mix of goods and services that exist in the economy does not match the preferences of end-customers or in extreme cases result in spectrum being allocated and unused.

Low-value users: Even when the highest value use is allocated, spectrum might be assigned to low-value users (for example, a higher cost provider rather than a lower cost provider), thus leading to *productive* inefficiency, in that the right mix of goods and services is not being provided at the least cost.

Inefficient price: Even when the highest value use is allocated spectrum, the price may be set arbitrarily or based on revenue-raising or other ad hoc policies, thus leading to *productive* and *dynamic* inefficiency.

In most cases administrative allocations do not involve the government explicitly choosing use or users, but rather involves the government implicitly choosing use or users via its designation of applications and services in the spectrum plan, and choice of administrative prices.[14] Spectrum users then self-select for spectrum-purchase, spectrum-use, and product-design/innovation at the administrative price. Consequently, price-setting is an important aspect of administrative allocation, and affects all three dimensions of efficiency, as well as indirectly impacting the choice of use and user (and thus influencing the total welfare to society).

2.2 The definition of opportunity cost

Market allocation usually avoids the potential efficiency pitfalls described above, and typically exhibit better efficiency than administrative allocations. The efficient prices that markets demonstrate give market participants the right incentives to behave efficiently and to

[14] Some command and control allocation is still in practices e.g. Defence, maritime use.

keep their costs low. This is not just good for the buying firm, but also for society, since it means that the efficient amount of the input is being used, leaving resources to be used for other societal purposes (for example, in other industries, or to make other products).

The efficient market-clearing price is equal to the opportunity cost of the marginal unit of the good or service in that market. ***Opportunity cost is defined as the highest value alternative forgone.*** Where governments seek to mimic the efficiency of markets in allocations, it follows that administrative allocations should price according to opportunity cost.

Since spectrum is a business input into the production of telecommunications and broadcasting services, such prices by default affect the decisions the spectrum users makes about use and innovation for those services. In the language of a 2002 review of spectrum management policy commissioned by the government of the United Kingdom:[15]

> [U]sers [should] face continuing incentives towards more productive use of this resource [i.e., spectrum] … [T]hese incentives should be financial and based on *opportunity cost* of spectrum use. In this way, spectrum would be costed as any other input into the production process. Price signals about the cost of using spectrum would be disseminated throughout the economy. This information should enable dispersed economic agents to make their own judgments about their use of spectrum and the alternatives open to them to meet their organisational goals.

2.3 Opportunity cost pricing and excess demand/excess supply

The underlying principle of opportunity cost pricing is that spectrum should be priced according to the amount of spectrum denied. That implies that opportunity cost pricing differs according to the circumstances. In cases where demand exceeds supply there are alternative uses of spectrum, and as such prices should be based on the highest-value alternative uses.

In cases where supply exceeds demand, there is unlikely to be alternative productive uses of spectrum and therefore the opportunity cost of that spectrum would be zero or negligible suggesting that price reductions may help to increase spectrum use.[16]

Many bands, especially the highest frequency bands, have historically low demand (regardless of geographic location) and this is not expected to change in the foreseeable future. Opportunity in these bands are likely to be zero or negligible. Similarly, opportunity cost pricing should only be positive in parts of Australia where there is excess demand, such as high-density areas. Remote density areas are unlikely to ever be congested.

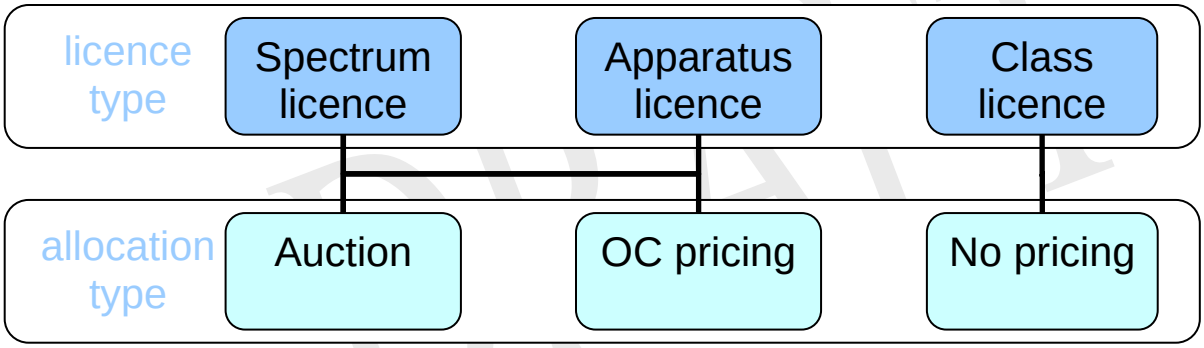
[15] Cave, M. , Doyle, C. , Webb, W., *Essentials of Modern Spectrum Management*, Cambridge University Press, 2007, p. 168.

[16] While the tax component of administrative licence fees could be zero, however administrative cost recovery fees may be charged.

3 When to use opportunity cost pricing

Before implementing opportunity cost, there is the threshold decision of whether to apply opportunity cost pricing or not. Figure 1 shows that for spectrum licences and apparatus licences opportunity cost pricing is an option. The decision to auction or administratively price is discussed below.

Figure 1: Licence types and the relationship with allocation types



3.1 Auctions versus administrative pricing

The *Radiocommunications Act 1992* permits ACMA to issue a number of types of licence, and permits ACMA to allocate these licences in a number of ways (primarily by auction or administratively).

The fact that opportunity cost pricing attempts to mimic the price which would be obtained in an auction acknowledges that markets generally produce more efficient outcomes than central planners. This reinforces a principle of allocation theory that in cases of excess demand, ***Auctions should always be used in allocation unless there is a good reason not to use them***.[17] Well-designed auctions ensure efficient outcomes, without the need for ACMA to have knowledge of private spectrum valuations.

[17] This is a simplified rule. For Greenfield (unencumbered) allocations, auctions are likely to be preferred. For brownfield (encumbered) spectrum (re)allocation, it is less clear how often auctions will be preferred, due to timing considerations, optimal licence duration, and incentives for incumbents to vacate. ACMA will address these issues in separate paper.

While ACMA should seek to auction whenever possible, there will be occasions when that is not possible, even for cases of very high excess demand. For example, fixed point-to-point services (numbering more than twenty five thousand assignments) often require careful spectrum frequency assignment and coordination (that is, separated in frequency and geographic distance). These are circumstances in which holding an auction is potentially unwieldy.[18] In such a case, apparatus licences may still be the preferred spectrum management approach, as specific device registration and device licensing can serve to coordinate services thus ensuring service integrity.

ACMA invites comment on:

- **The instances where administrative pricing is preferable to auctions.**

[18] ACMA is exploring the idea of outsourcing large parts of the spectrum (possibly by auction) to private band managers. Private band managers could then handle coordination and network integrity issues. Until such a reform happens, however, ACMA-administered AIP will need to play the lead role in spectrum management in situations where it is not possible to hold an auction.

4 Methods for estimating opportunity cost

In 2008 ACMA commissioned UK consulting firms Plum Consulting Ltd and Aegis Systems Ltd (Plum) to recommend a specific method of implementation when calculating the opportunity cost price for a band, and to then apply that method to the 400 MHz case study band (discussed in Chapter 6 and Plum's report to ACMA [Appendix A.1]).

Plum advised that there is no one method (no 'magic bullet') for implementing opportunity cost pricing within a band:

> The choice of approach to deriving opportunity cost estimates for a band 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.[19]

This chapter describes the different opportunity cost pricing methods available and the factors to consider when selecting the appropriate method.

4.1 Market versus direct methods

As discussed in the previous chapters, opportunity cost pricing attempts to simulate the efficiency properties of competitive markets (auctions). Bidders in auctions incorporate information about current and future states of the market which a regulator cannot be expected to know (and in allocation by auction, does not need to know). In the absence of an auction, a regulator must attempt to derive opportunity cost by other means; using market information and/or direct calculation methods.

4.1.1 MARKET VALUATION METHODS

ACMA may use the following market data to derive opportunity cost, including:

- spectrum market transactions, such as past auction results from the same or similar bands, nationally or internationally, and spectrum trades in the secondary market
- company values of spectrum-owning companies

[19] Plum Consulting and Aegis Systems, *Administrative Incentive Pricing of Radiofrequency Spectrum*, report for ACMA, October 2008, p. 35.

- capacity sales of spectrum-utilising services.

These are summarised in Table 1.

Table 1: Types of market information that might be used to derive opportunity cost values

Market method	Description	Pro	Con
Spectrum market transactions	The price of spectrum in auctions or trades in secondary markets may be used directly.	Simplest approach Transparent Objective Does not require potentially uncertain values of non-spectrum inputs/assets	Difficulty in making meaningful comparison between frequency bands and market values revealed in different countries and from different points in time. If auction values are used (and bidders in the auctions are also subject to AIP) then there is further incentive to keep auction values low (through collusion). May discourage (transparent) trade.
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 and apportioning value to spectrum.		Requires potentially uncertain values of non-spectrum inputs/assets Volatility of share price
Capacity sales	Information on the sale price of capacity for services which spectrum is an input. This price provides a valuation of the spectrum plus the value of the other inputs. Spectrum value can be estimated by deducting the value of other inputs from the capacity price.		Requires potentially uncertain values of non-spectrum inputs/assets.

Source: ACMA/Plum.

Using information from past spectrum market transactions is the simplest, most objective and transparent market approach; however, it is sometimes difficult to make meaningful comparison between frequency bands and market vales revealed in different countries and from different points in time. These differences can sometimes be adjusted for factors such as geography, demographics and GDP.[20]

Caution and judgment must be used when using past spectrum market transaction information. For example, the Spanish regulator used prices from UK and German auctions to set prices for 3G licences. Prices were later readjusted because they were not representative of the market after the dotcom crash.[21] Additionally there may be some adverse incentive effects when linking past auction prices to administrative prices. In the case of using auction results, if auction participants also face administrative incentive pricing (AIP) based on auction results, there is an increased incentive to keep auction prices down (by collusion). Similarly, linking AIP to spectrum trades may discourage spectrum trading (or at least discourage future trades from being transparent).

In theory, company values of firms holding spectrum rights represent the value of all assets within the company. By subtracting the value of non-spectrum inputs from the price of capacity sales, the value of spectrum can be inferred.

Similarly, the price of capacity sales of services using spectrum (for example, sale of digital terrestrial TV multiplex capacity or sale of wholesale capacity on a mobile network) expresses the value of spectrum in combination with other inputs. By subtracting the value of non-spectrum inputs from the price of capacity sales, the value of spectrum can be inferred.

Inference of spectrum prices from company values and capacity sales require the use of uncertain values of non-spectrum inputs, including factoring share market volatility on valuations. These values should only be considered in absence of more reliable information sources.

4.1.2 DIRECT CALCULATION METHODS

Direct calculation involves the regulator attempting to calculate what the bid of predicted bidders might be in the counterfactual of the auction actually being held. ACMA may conduct standard net present value (NPV) modeling that firms conduct; however, this is an onerous information-gathering task for a regulator to undertake, so when this was attempted for the first time overseas a method called the 'least cost alternative' (in the United Kingdom) or 'optimal deprival value' method (ODV) (in New Zealand) was developed which focused instead on what the bid of an *average* bidder (or bidders for multiple-use bands) might be, and only requires the use of cost information, that is, uncertain revenue projections are not required.[22]

[20] Plum Consulting and Aegis Systems, *Administrative Incentive Pricing of Radiofrequency Spectrum*, report for ACMA, October 2008, p. 27.

[21] Plum Consulting and Aegis Systems, *Administrative Incentive Pricing of Radiofrequency Spectrum*, report for ACMA, October 2008, p. 30.

[22] Overseas experience is described in greater details in Chapter 3 of the Plum report reproduced in Appendix A.1.

The selection of the representative firm therefore needs to be done carefully because in practice there are many different firms operating within a single use within a given frequency band. For some firms the single marginal benefit estimate obtained will be too high, and for others too low.

4.1.2.1 NPV methods

In an auction, firms bid according to their estimation of the value for access to the spectrum. Spectrum may be acquired either to enhance an existing service or to start a new service. To calculate its value, a bidding firm would model the cost and revenue advantages of acquiring the spectrum (or—which is the same thing from the converse perspective—the forgone revenues/costs of being denied access to the spectrum). This requires forecasts of traffic, costs and revenues, in both the situation that the firm wins the auction (and so obtains access to the spectrum) and the situation in which it does not win the auction.

Firms will value that access according to standard financing principles of the expected NPV of future returns resulting from that increased access. Future cash flows are 'discounted' to present values to reflect the time value of money. That is, in an environment with positive interest rates (and an expectation of positive interest rates in the future) a dollar today is worth more than a dollar tomorrow or sometime in the future.

For example, if a person can borrow or lend at six per cent interest per year, $1 now is equivalent to $1.06 in one year. Or in the context of project valuation, if we can expect revenues of $1.06 next year, it can be 'discounted' at six per cent to its present value of $1.[23]

The NPV of the project is calculated as the sum of future cash flows (revenues) discounted to present values, minus the market values of other inputs, expressed mathematically as follows:

$$NPV = \sum_{t=1}^{n} \frac{C_1}{(1+r)^t} - I_0, \quad \text{where}$$

C = cash flows/revenues

r = discount rate

I = market value of non-spectrum inputs

The NPV would then be apportioned to spectrum and non-spectrum inputs/assets. The way in which value is apportioned between these inputs is subjective.

NPV valuations require the use of revenue and cost information; however, the optimal deprival method discussed next requires only the use of cost information.

4.1.2.2 The ODV method: Constant output/quality

The ODV method (referred to by Plum as the 'least cost alternative') calculates the impact of a hypothetical marginal change in spectrum[24] on the costs of an 'average firm' in the sector,

[23] An appropriate discount rate generally depends on the prevailing cash rate (risk-free rate) plus factors such as inflation and the riskiness of spectrum as an investment

assuming the level of output and service quality were kept constant.[25] If a marginal unit of spectrum is denied (that is, unavailable due to congestion) to a cellular operator, how many base stations (and other inputs) would need to be erected and what are the associated costs that would need to be incurred to maintain output quantity and quality if spectrum was available?[26] (and other inputs) would need to be erected and what are the associated costs that would need to be incurred to maintain output quantity and quality if spectrum was available? These extra costs are considered the opportunity cost (next best alternative) of the marginal unit of spectrum because it is the cost that the incumbent will incur if that unit of spectrum is denied and effectively represents a 'willingness to pay' for a marginal unit of spectrum. 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 method assumes that output and quality are constant so that revenue effects and other non-cost aspects of value (for example, convenience) do not need to be considered. Consequently, ODV is informationally less onerous than NPV methods.

There may be a number of ways to maintain output. For example:

- investing in more network infrastructure to achieve the same quantity and quality of output with less spectrum
- adopting narrower bandwidth equipment (more spectrally efficient) could be used, so that less spectrum is required for the same output/quality
- switching to an alternative frequency band
- switching to an alternative service (for example, a public service rather than private communications) or technology (for example, fibre or leased line rather than a fixed radio link).

The costs for each approach are calculated and compared. The lowest cost approach is considered the opportunity cost of spectrum, that is, the value of spectrum in the highest-value alternative use that is denied by granting access to one party rather than to the alternative.

If ODV is conducted for potential high-value uses (in addition to incumbent uses), then ACMA will have information that helps to set prices that will encourage allocation of spectrum to the highest value uses (which satisfies allocative efficiency discussed in Section 2.1).

Assumptions

The implicit assumptions in the incremental ODV approach are as follows:[27]

---

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

[25] This is equivalent to the 'marginal rate of technical substitution' and thus can be considered to be the 'willingness to pay' for a marginal unit of spectrum.

[26] This assumes that there is some degree in flexibility of network configuration, where one input may be substitutable with other inputs, for example, base stations and spectrum.

[27] ODV is based on the premise that competition in a market will ensure that prices will not exceed the amount needed to cover efficient operating costs and provide a return of and return on capital invested in an optimally configured system of modern equivalent, efficient assets. Assuming no barriers to entry, prices for services will be set by the operator with the most efficient costs (operating and capital). ODV is an approach to quantifying efficient capital costs.

- Cost and quality are maintained so that there are no relevant revenue implications to consider in the valuation of spectrum.
- Costs should be based on 'modern equivalent assets'.[28]
- Assets should be configured in the most efficient way possible.
- Spectrum rights are freely tradeable and usable in small units.
- No entry barriers to alternative means of maintaining output, and no exit barriers to spectrum markets.
- The market has many profit-maximising participants, who are willing, non-anxious buyers and sellers, with no market power and no information asymmetries.
- Above a minimum amount of spectrum, network configuration and spectrum are substitutable.

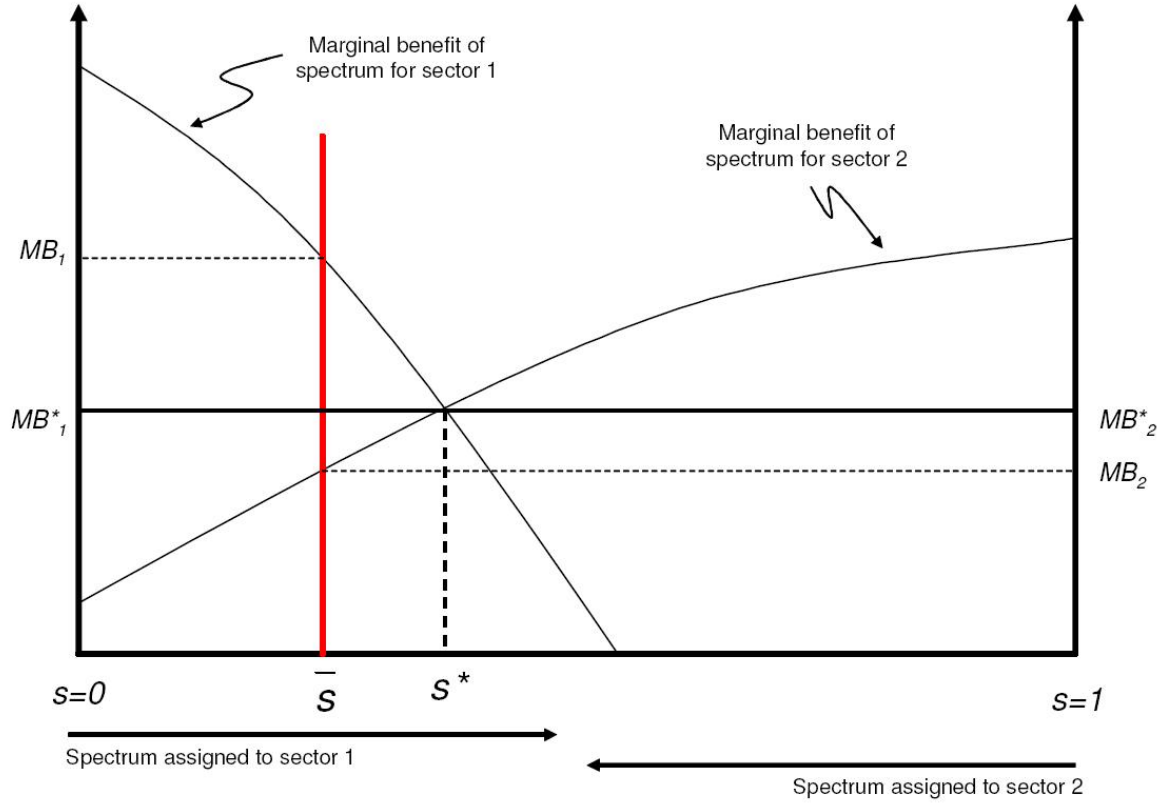
The values derived from the ODV method are estimates of marginal benefit (that is, MB_1 and MB_2 in Figure 2) that are then used to infer the market clearing price (to approximate MB* in Figure 2).

ACMA invites comment on:

- **The use of opportunity cost pricing as the preferred pricing method for administratively allocated spectrum.**
- **General comments on the opportunity cost estimation methods outlined in this paper**

[28] A modern equivalent asset replicates an asset with the most cost-effective asset that performs the same level of service.

Figure 2: Marginal value or opportunity cost for spectrum, by competing uses



4.2 Additional components of spectrum value to private bidders

The direct calculation methods described above represent the 'project value' that access to spectrum yields. It represents the additional net returns derived directly from increased access to spectrum. Project value represents only one component of the value of spectrum that a rational firm would consider. In addition to project value, a firm bidding in an actual auction would also incorporate two other types of value: market power value and option value.[29]

The first is the benefit to a firm with upstream market power (a necessary condition) of access to additional spectrum for the purpose of behavior such as monopolising an essential upstream input.

The second is the common commercial practice of acquiring an asset for future use rather than immediate use, either for speculative reasons (if the price goes up then the asset can be resold on the secondary market) or for productive reasons (the firm may need it in its future plans, and so holds the asset to keep such options open).

These sources of value may be low for the following reasons:

- Option value will tend to be low for license tenures with short durations, if uses within bands are restricted, and if there are use-it-or-lose-it conditions.

[29] Plum Consulting and Aegis Systems, *Administrative Incentive Pricing of Radiofrequency Spectrum*, report for ACMA, October 2008, p. 9.

- Any potential market-power value of holding spectrum may be negated by effective competition regimes.

Consequently, project-based values are substantive components of spectrum value and form lower bounds on estimates of opportunity cost. Consequently any prices that government set based on direct calculation methods are likely to be conservative estimates of actual value, as they will not encompass all possible types of value which a private sector bidder would incorporate.

4.3 Which method?

The appropriate calculation method depends on the spectrum in question, the likely uses of the spectrum and the available data. For example, an NPV method is likely to be appropriate when there are no viable spectrum or non-spectrum substitutes for the spectrum currently used to deliver the service. A range of methods might be used for robustness.

Table 2 summarises different options for frequency bands used by particular applications.

Table 2: Suitability of options for different bands/services

Options	Bands/services where most applicable
Market value ('Benchmarking' or 'Shadow Pricing')	
Spectrum transactions	Bands in similar frequency range and with similar licence duration and other conditions
Capacity sales	Public mobile, Broadband Wireless Access (BWA), third part supply of land-mobile services and digital broadcasting
Company value	Public mobile, BWA and broadcasting
Directly calculated values	
ODV	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.
NPV	Bands where spectrum is used by publicly provided services and changes in spectrum use are non-marginal.

Source: Plum report, p. 32

4.3.1 SERVICES TO EXTERNAL VERSUS INTERNAL CLIENTS

Whether a service is provided to the external clients (providing a service offering to the public) or to internal clients (supporting internal business processes) is the first consideration when determining the appropriate opportunity cost pricing method. Market valuation methods are generally only possible for frequency bands that are used to deliver services aimed at the general public (external clients), because there is likely to be more readily available market information such as capacity sale, company value and market transaction information (see Table 1).

From the range of available market valuation methods, values derived from spectrum transactions are preferable because they are generally more efficient, objective and transparent. If this is not feasible (because suitable like-for-like information is not available) then either capacity sales[30] (where feasible) or directly calculated values must be used.[31]

For frequency bands only used to provide services to internal clients, such as internal fixed and mobile communications, direct calculation of values is likely to be required. In these cases ODV 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. Similarly market information is unlikely to be available.

ODV is likely to be appropriate when the downstream services could be supplied using a non-spectrum alternative, an alternative part of the spectrum, or with a change in spectrum allocation. For example in the case of cellular mobile services, there is generally a trade-off between spectrum and network configuration: a more optimal allocation of spectrum reduces the network infrastructure costs required to deliver a given quantity and quality of service.

4.3.2 MARGINAL VERSUS NON-MARGINAL CHANGE IN SPECTRUM

ODV is typically appropriate with marginal changes in spectrum because we can assume that there is some degree of substitutability between spectrum and non-spectrum inputs (for example, substitute spectrum with base stations in the context of mobile applications). Thus we can assume that output/quality is constant and that revenue implications can be ignored, and only consider cost changes.

The NPV method would be more appropriate in instances where it was difficult to assume non-marginal changes in spectrum. For example ODV does not apply to spectrum used for analog broadcasting. In this instance small changes in the amount of spectrum used are not generally possible because coverage obligations or the nature of the technology mean a fixed amount of spectrum is used per transmission. Denial of spectrum means that next best alternative is a migration to another delivery platform, for example, satellite or cable. The entire business needs to be modelled.

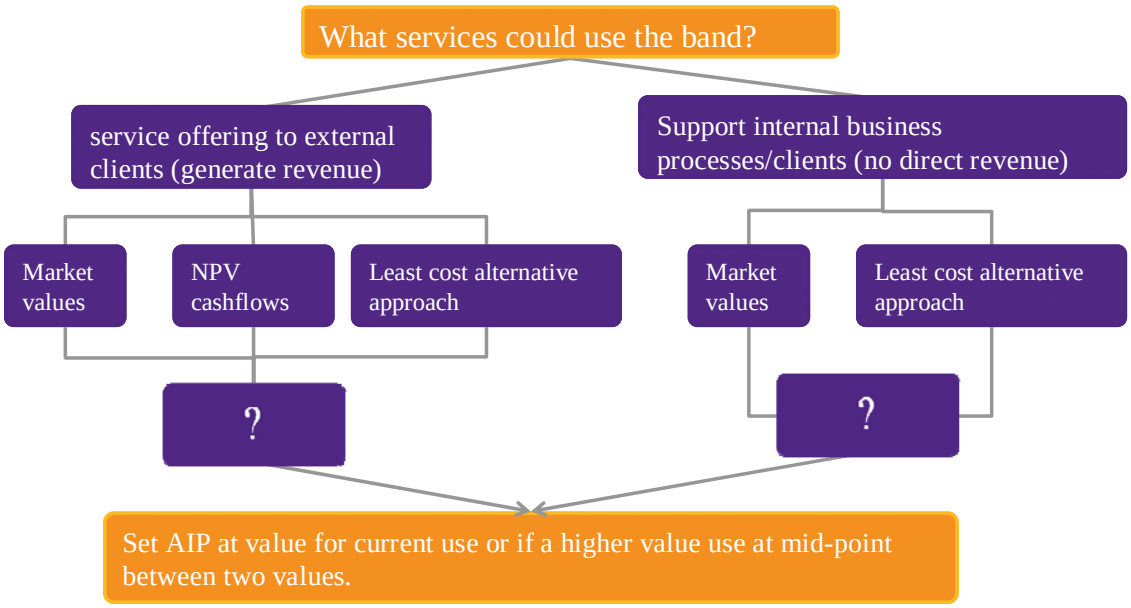
[30] Information on the sale price of capacity for services which spectrum is an input of. This price provides a valuation of the spectrum plus the value of the other inputs.

[31] Plum Consulting and Aegis Systems, *Administrative Incentive Pricing of Radiofrequency Spectrum*, report for ACMA, October 2008, p. 33.

4.3.3 DECISION FRAMEWORK FOR DETERMINING APPROPRIATE PRICING METHOD

Plum summarises the considerations for determining an appropriate pricing method in Figure 3.

Figure 3: Plum decision tree framework



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 approach is given by the following multi-step process:

1. What services or applications could potentially use the frequency band? Are they private or public?
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 of the opportunity cost of spectrum based on the least cost alternative approach (ODV).
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.

Source: Plum report to ACMA, *Administrative Incentive Pricing of Radiofrequency Spectrum*, 4 July 2008. See Appendix A.1.

5 Constraints to opportunity cost pricing

This chapter examines some of the regulatory, technical and practical constraints in applying and estimating opportunity cost. As a general principle, all services should be considered in the process to ensure that allocative efficiency is addressed; however there are some important constraints that apply in a spectrum management context.

5.1 Regulatory constraints: International

Following on from Spectrum Management Principle 1—*Allocate spectrum to the highest value use or uses*—ideally all potential applications/services should be considered when deciding band allocation. However, the nature of radiocommunications interference has led to a global management regime where the spectrum is highly segmented by regulation (for example, radio regulations, band plans) designed to harmonise frequency use and mitigate interference. Technical characteristics of adjacent bands may be similar, but spectrum substitution possibilities may be constrained by these planning rigidities, and the lack of readily available radio equipment.

Consequently, spectrum allocation in Australia is influenced by trends in the wider international radiocommunications community. The International Telecommunication Union (ITU) make Radio Regulations which define allocation of different frequency bands to different radio uses. It can prohibit the use of spectrum, or oblige operators to use certain spectrum bands. Sovereign states have the flexibility to deviate from these allocations, to the extent that harmful interference is not caused to any member state which is using the spectrum in accordance with the Radio Regulations. ACMA contributes to international fora to achieve suitable outcomes for Australia, consistent with the object of the *Radiocommunications Act 1992*. In most cases, Australia's interests are enhanced by working towards globally harmonised bands in order to promote competition and economies of scale in the provision of equipment.

Australia's relatively isolated geographical location gives it some flexibility. For example, Australia may allow an application to operate in a band that is not allocated by ITU, having deemed the risk of interference to be negligible. However, radio equipment manufacturers typically produce equipment for bands with large international markets (which in most cases are bands allocated by ITU regulation). Australia is an 'equipment taker' rather than an 'equipment maker', consequently Australia's band planning arrangements often reflect Radio Regulation.

The opportunity cost pricing framework promotes the consideration of multiple potential uses within bands. If the ITU restricts uses within a band it potentially restricts the high-value uses from accessing spectrum. If the inclusion/allocation of these uses (and pricing to encourage its use) is not officially sanctioned by the ITU, then any potential increased benefit to Australia must be balanced with the costs of any potential international interference, and considerations of low or zero equipment availability.

5.2 Regulatory constraints: Australia

5.2.1 REGULATION OUTSIDE THE JURISDICTION OF ADMINISTRATIVE INCENTIVE PRICING

Regulation may preclude the application of opportunity cost pricing to administratively allocated spectrum in some instances. For example Part 3 of the *Broadcasting Services Act (1992)* specifies criteria for planning of broadcasting services bands (BSB). Access to the band is restricted primarily for broadcasting services, and is paid for under the Broadcasting Licence Fees Regime (BLF) (which is based on income rather than opportunity cost).[32] Broadcasters pay some apparatus licence taxes in addition to the BLF, which may encourage broadcasters to ration spectrum; however, the influence of administrative incentive pricing (AIP) on band allocation changes in BSBs is weak.

5.2.1.1 Defence and government users of spectrum

Government users of spectrum currently pay the same apparatus licence taxes as other private operators.

In accordance with views expressed in the *Independent Review of Government Spectrum Holdings*, ACMA as a general rule believes that government users continue to face the same apparatus licence taxes that private operators face, so that there is an incentive to relinquish unused or unnecessary spectrum and or use the spectrum more efficiently.[33] An example of this is the 400 MHz band (see case study in Section 6.1). The 380–400 MHz and the 430–450 MHz blocks are allocated exclusively to the Department of Defence (Defence). They sit within and around the 400 MHz band which is experiencing considerable congestion. The application of opportunity cost pricing across the entire 400 MHz band (including the Defence segment) will encourage spectrum users to surrender unused or low-value spectrum holdings to ACMA, and potentially allow it to allocate spectrum to other uses/users.

However, the harmonised government band 403–430 MHz proposed in the 400 MHz band consultation paper[34] may have different pricing arrangement in place to encourage swifter movement to the band.

[32] Senator Ian Campbell is quoted, "The legislative/policy intent is for the BLF to provide a method of recompensing the nation for access by broadcasters to the BSBs and for the benefits granted to licensees who operate in a closed market created by legislative restrictions on the number of licences made available" in his second reading speech, Television Licence Fees Amendment Bill 1997, 15 May 1997.

[33] SpectrumWise Radiocommunications Consulting, *Independent Review of Government Spectrum Holdings*, report to ACMA, April 2007. Available at http://www.spectrumwise.net/IRGSH.html.

[34] ACMA consultation, IFC 08/2009, Spectrum Proposals: 403–520 MHz - Proposals for future arrangements in the 400 MHz band, http://www.acma.gov.au/WEB/STANDARD/pc=PC_311684

ACMA invites comment on:

- **The potential for a wider application of opportunity cost pricing to government and community users of spectrum**

5.3 Technological constraints

Different parts of the spectrum exhibit different propagation characteristics which are suitable for particular spectrum applications. This creates a natural set of uses to consider and to factor into any consideration of pricing, including opportunity costing. For example, the UHF is sometimes referred to as the 'sweet spot' of the radio spectrum because it tends to offer a good mix of propagation distance, bandwidth and the ability to penetrate walls and can support many important applications. As such it is often in high demand for wide-scale high bandwidth applications such as broadband and mobile services. Other parts of the band are typically demanded by niche services and are unlikely to exhibit the same demand levels.

5.4 Practical estimation issues

In applying opportunity cost, there are a range of practical implementation issues that also need to be addressed in deriving price estimates.

5.4.1 JUDGMENT IS REQUIRED IN SETTING PRICE LEVELS

The pricing methods described in Chapter 4 will often yield a range of values (sometimes derived from different methods/information sources) within which a price level must be selected. The decision framework in Section 4.3.3 specifies an algorithm for selecting the appropriate method and price level.

With regards to selecting the appropriate method, issues of data reliability and applicability of the method to the current environment are important. Of the applicable methods, the least cost option should be selected.

If there is a price range within which to set price, setting prices too high will result in under-use of spectrum. Where there is doubt it is generally better for spectrum to be slightly underpriced. This will at least mean that the completely renewable resource will be used and contribute to welfare, rather than not being used at all.[35] Pricing in this fashion requires judgment because it is difficult to know the exact shape of the marginal benefits curves of the competing uses, and thus it is difficult to know the equilibrium prices for the competing uses. When trying to set a market-clearing price, setting a conservative price is recommended.

[35] Cave, M. , Doyle, C. , Webb, W., *Essentials of Modern Spectrum Management*, Cambridge University Press, 2007, page 180.

5.4.2 PRICE REVIEWS/ITERATIONS

There are a number of reasons why prices may need to be reviewed. The market is dynamic and opportunity cost pricing exercises represent a snapshot in time. Over time prices in other bands may be adjusted, and incentives in the related band may change. Technological development and changes in demand for downstream services will also alter the value of the spectrum. Even holding demand and all other prices constant, it may be that finding efficient prices is an iterative process, with response to changes in prices understood only after first-round changes have been made. Triggers for a review may be the emergence of new technologies, or evidence of excess demand or underuse in the band.

The frequency of price iterations will depend on a number of factors, such as:

- the time required for spectrum users to adjust to new price incentives
- the degree of desired investment certainty for parties that invest in spectrum and spectrum equipment.
- the administrative cost of reassessing prices.

Regular pricing reviews *within and across* bands is an iterative process that will help capture knock-on effects of prices changes in related bands (as described in step 7 of the pricing algorithm), plus factor in any significant technological progress in the telecommunications market and help to achieve dynamic efficiency over time.

6 Case study: Setting price levels in the 400 MHz band

In the previous chapter the different methods available to a manager of spectrum were described. This chapter considers the practical application of opportunity cost pricing in the case study 400 MHz band, exploring market values and direct calculation methods as an adjunct to planning and allocation reform more broadly.

The case study focuses on the two urban areas of Sydney (a high-density area) and Perth (a medium-density area). The 400 MHz band was selected as a case study because ACMA is currently exploring ways to better manage high demand within this band.[36]

The calculated values discussed in the case study form the baseline price level. The price level can then be translated into taxes for individual licensees using a generalised tax formula. This issue of how opportunity cost prices translate into ACMA's license tax formula is considered in Chapter 7.

6.1 400 MHz band synopsis

This band refers to spectrum between 403–520 MHz, including the segment 420–450 MHz that supports various Department of 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.

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 since we focus on Sydney and Perth. 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-multipoint. Historically 25 kHz channelisation has been used, but 12.5 kHz systems are increasingly deployed.[37]

In the high-density area of Sydney, this band is experiencing excess demand and ACMA is examining a number of strategies to address it.[38] Excess demand suggests that positive prices in some form would serve to ration the demand.

[36] ACMA consultation, IFC 08/2009, Spectrum Proposals: 403–520 MHz - Proposals for future arrangements in the 400 MHz band, http://www.acma.gov.au/WEB/STANDARD/pc=PC_311684

[37] There may even be a case for accommodation of 6.25 kHz channelling.

[38] Other management methods may serve to promote great use of spectrum despite there being licence demand. For a full discussion of these strategies see ACMA consultation, IFC 08/2009, Spectrum Proposals: 403–520

In Perth, this band exhibits about half the spectrum density as Sydney.

6.1.1 ESTIMATION OF OPPORTUNITY COST

Opportunity cost was estimated only for land-mobile services, which is the predominant use in this band (also assumed to be the highest value use and the marginal use). The ITC World Radiocommunications Conference 2007 (WRC-07) identified the band 450–470 MHz 'worldwide' for international mobile telephony (IMT); however, this was not considered a potential high-value use for this exercise because it was not clear whether these services would be deployed in dense urban areas in the near future.[39]

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

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

Plum Consulting Ltd (Plum) estimated that the least cost alternative for land-mobile services is to move to narrowband (more spectrally efficient) equipment, if a marginal unit of spectrum is denied.[40] Figure 4 below shows that using the ODV method Plum Consulting estimated that the opportunity costs of a marginal unit of spectrum for a 'typical' system is approximately $269 (per kHz per assignment).[41] In other words it would cost $269 per kHz per to switch to more efficient equipment and maintain their existing output. Estimation of opportunity cost found that lightly loaded systems valued spectrum at approximately $77 and heavily loaded systems valued the marginal unit of spectrum at approximately $989.[42]

Setting the price at opportunity cost for a 'typical' system will encourage:

- high value users (with heavily loaded systems) to maintain spectrum since they value the spectrum highly,
- low value users (with lightly loaded systems) to relinquish spectrum since it would be economical to invest in more spectrally efficient equipment.

Over time as equipment becomes older and operating lifecycles come to an end, the decision to switch to more spectrally efficient equipment becomes more viable.

A worked example of the opportunity cost estimation for the 400 MHz band is outlined in Figure 4.

MHz - Proposals for future arrangements in the 400 MHz band, http://www.acma.gov.au/WEB/STANDARD/pc=PC_311684

[39] If it becomes clear that IMT is likely to be used in the band, an iterated opportunity cost exercise is likely to account for this.

[40] For calculations and a discussion on the other alternatives for maintaining output/quality refer to the Plum report in Appendix A.1.

[41] A typical marginal land mobile system was assumed to be have 25 mobiles and equipment is half way through its useful life of 10 years.

[42] Lightly loaded systems assumed the use of 5 mobiles, and heavily loaded systems assumed the use of 100 mobiles.

Figure 4: Plum Consulting calculations for the cost of moving to more efficient equipment

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[43]
- 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[44] 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.

Source: see Appendix A1: Plum report, page 38 for more detail.

6.1.2 IMPLICATIONS FOR PRICING IN THE 400 MHZ BAND (SYDNEY: HIGH-DENSITY AREAS)

Plum's calculations suggest that the current tax applied in Sydney is too low to encourage optimal levels of migration to narrowband technology or public trunked systems as a way of relieving congestion (productive efficiency and dynamic efficiency); hence values should rise in the vicinity of two or three times its current price.

As congestion is experienced across the entire 400 MHz band, the higher prices should apply across the entire 400 MHz band. Consistent with the *Independent Review of Government Spectrum Holdings*,[45] these prices should apply to the 380–400 MHz and 420–450 MHz Department of Defence blocks. If Department of Defence surrender spectrum after

[43] Based on information provided by Motorola.
[44] Costs provided by Motorola and Vertel.
[45] SpectrumWise Radiocommunications Consulting, *Independent Review of Government Spectrum Holdings*, report to ACMA, April 2007. Available at www.spectrumwise.net/IRGSH.html.

reconsideration of its spectrum use, there may be a case for allowing non-Defence users access to unused spectrum.[46]

However, the proposed harmonised government band 403–430 MHz (See the 400 MHz band consultation paper[47]) is a unique situation where different pricing arrangement may have to be put in place to encourage swifter movement to the band.

Consistent with the UK approach and the approach suggested by Plum, ACMA should price conservatively (see Section 5.4.1) to mitigate the risk of overpricing (which is typically more costly to society than underpricing). Using Plum's estimate for the 'typical' user ($269) as an upper bound and the existing price, $90, as a lower bound, the mid-point ($180) is considered a prudent price target to encourage a movement to higher value use/users. Price increases in high-density areas (Sydney, Melbourne and Brisbane) are proposed to be implemented gradually in equal annual increments to a target of $180 per kHz per assignment after five years. If it was observed that demand was equalising with supply at one of the interim increments, the price would be kept at that level—until demand once again started to outstrip supply.

A number of other measures to address congestion in the 400 MHz band such as the accommodation of smaller channelling arrangements (that is, 12.5 kHz and 6.25 kHz) will also assist with gradual movement to more efficient use/users and help alleviate congestion.

Future price reviews will provide ACMA with an opportunity to assess the effectiveness of the price change and adjust prices accordingly. Secondary trading may also assist in achieving more efficient outcomes.

6.1.2.1 Timing of opportunity cost pricing

The introduction of opportunity cost prices is unlikely to have an immediate impact. Some spectrum users may be constrained and be unable to alter their spectrum consumption in the short term, variously by contractual and investment commitments, business plans and the market environment, and sector regulation.

However, to mitigate any adverse effects of a price change, early notice of price increases will help with private investment decisions. For this reason, the introduction of pricing changes may need to be phased in over a number of years or at least signalled to industry as early as possible so that industry can factor in the cost of spectrum.[48]

6.1.3 IMPLICATIONS FOR PRICING IN THE 400 MHZ BAND (PERTH: MEDIUM-DENSITY AREAS AND REMOTE DENSITY)

6.1.3.1 Congestion and pricing

In Chapter 2 the concept of opportunity cost implied that when demand exceeds supply the price of spectrum should be positive in the magnitude of its next best alternative use.

[46] Unlike the US and Europe, Australia uses the 420–450 MHz block for defence, suggesting that there will be available equipment for land-mobile services. Similarly, there is ample TETRA (Terrestrial Trunked Radio) equipment available in the 380–400 MHz band.

[47] ACMA consultation, IFC 08/2009, Spectrum Proposals: 403–520 MHz - Proposals for future arrangements in the 400 MHz band, http://www.acma.gov.au/WEB/STANDARD/pc=PC_311684

[48] Ofcom has used a phased approach to introduce AIP to the maritime and aeronautical sectors in the UK. *Applying Spectrum Pricing to the Maritime and Aeronautical Sectors*, Ofcom consultation document, 30 July 2008.

Conversely, when supply exceeds demand the price of spectrum should be zero since there is no or negligible opportunity cost.

This strict binary interpretation is unlikely to be practical because there is unlikely to be a clear distinction between a state of no congestion and absolute congestion. There will be a grey area where the decision to apply a zero price or a positive price will be unclear. In practice there are degrees of congestion. The 400 MHz band in Perth is one such case.

Rather than take a binary approach to the application of opportunity cost pricing, a more practical approach would be to vary prices according to varying degrees of demand. For example, heavily congested bands may bear full opportunity cost prices (for example, Sydney), uncongested bands bear zero prices (for example, remote areas), and moderately congested bands bear prices somewhere in between.

Markets are forward-looking and thus ACMA needs to take a view on future demand based on:

- past assignment trends
- current ease of making assignments
- view of future technology and market developments.

A case for pricing in between clear cases of spectrum congestion and surplus is Perth, where congestion is much less acute than in Sydney (exhibiting only half the spectrum density). Although there is spectrum capacity in Perth (implying a need to reduce prices) there is potential for future high-value uses such as IMT mobile data communications to enter the band (which may require an increase in price in the future). It would be imprudent for ACMA to reduce prices now, only to discover the need to raise them in the near future, after industry have made infrastructure investment decisions based on reduced licence fees. Consequently, there is some uncertainty about the rate of future demand growth and no clear case to increase or decrease prices and so prices should not be changed.

If there were a clear need to reduce the price in Perth, ACMA may need to conduct further opportunity cost pricing calculations For example, in the calculations for the 400 MHz in Sydney, the average user was assumed to be a land-mobile user with 25 mobiles. In the less dense region of Perth the average user may be assumed to be a land-mobile user with a need for less than 25 mobiles.[49] The opportunity cost is likely to be less in Perth and a pricing exercise may give ACMA an indication of an appropriate magnitude for a price reduction.

6.1.4 IMPLICATIONS FOR PRICING IN THE BROADER 399.9–960 MHZ BAND

The price level for the 400 MHz band (set in Section 6.1.1) will not apply to the remaining segments of the 399.9–960 MHz band. In other words, the 400 MHz band will be priced differently to the remainder of the 399.9–960 MHz band. The 400 MHz band is treated separately because of different demand characteristics, largely because other parts of the 399.9–960 MHz band are not good substitutes for the 400 MHz band.

[49] Alternatively, the average user may be assumed to be operating a lower-value use than land-mobile services.

ACMA invites comment on:

- **Comments about the opportunity cost pricing case studies presented in this paper**
- **The 400 MHz band case study proposes increases in apparatus licences tax in high-density areas (Sydney/Wollongong, Melbourne/Geelong, Brisbane/Gold Coast) over five years. Other changes to the tax in medium, low and remote density areas are not proposed at the current time.**
- **Comments on the bands where the application of opportunity cost pricing should be considered as a priority.**

7 The apparatus licence tax formula

This paper up until now has focused on how to estimate opportunity cost as a way of determining price levels for spectrum bands experiencing excess demand. These price *levels* form the basis for calculating taxes for individual licensees (using a generalised tax formula, that is, the apparatus licence tax formula).

This chapter explains the tax formula and discusses possible changes to the formula.

7.1 Translation of the opportunity cost of a marginal unit of spectrum to the cost of an individual licence

7.1.1 EXISTING VALUE DRIVERS IN THE TAX FORMULA

The apparatus licence tax formula is used to translate the opportunity cost of a marginal unit of spectrum to the price of an individual licence by considering the following factors:

- **spectrum location**: what frequency range is being used
- **geographic location**: where is the transmitter located
- **bandwidth**: how much spectrum is used
- **power**: factor which is used to reduce fees for services that only deny spectrum to other users over a small area (0.1 for low power or 1 for non-low power)

plus:

- **an adjustment factor**: there are a number of adjustment factors for particular sets of licensing options (application specific) such as a premium to reflect the higher demand for mobile spectrum or a discount to reflect the frequency reuse possible with fixed links
- **a normalisation factor** (sometimes referred to as the scaling 'constant'): converts the relative spectrum values to a dollar figure and allows for overall levels of fees to be adjusted. This factor is adjusted for CPI.

Table 3 shows the parameters used in the pricing formula of overseas jurisdictions. Most of the countries surveyed use a formulaic approach and include similar parameters to derive licence taxes.

Table 3: International spectrum pricing approaches

Country	Derivation of price levels	Parameters in pricing formula
Australia	Historic precedence; CPI inflation	Scaling constant; spectrum band; geographic location; bandwidth; power; adjustment factors, e.g., for frequency reuse.
Bahrain[50]	Not applied yet.	Constant based on local conditions and costs; frequency band; geography; bandwidth; power.
Canada[51,52]	Judgmental	Fees are a function of bandwidth, population in geographic area covered in areas where there is scarcity.
France[53]	Judgmental	Bandwidth and location for Private Mobile Radio (PMR), Public Access Mobile Radio (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.
Ireland[54]	Cost recovery for PMR; rationing congestion for fixed links. Changes from historic fees governed by what was thought to be to politically acceptable.	For PMR and fixed links: frequency band; bandwidth; coverage area (for PMR); geographic location; degree of sharing.
Japan[55]	A target sum to be raised. 3:1 ratio of costs borne by users under 3 GHz relative to those in 3–6 GHz. Over 6 GHz fees reflect spectrum management costs.	Frequency bandwidth; frequency band; geographic location.
New Zealand	Both approaches seek to estimate opportunity cost.	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.
Spain	Judgmental	Coverage area; bandwidth; occupancy and demand for service; public versus private services; exclusive or shared use; efficiency of technology used; social and economic benefit from the service. Market benchmark used for 3G licences.
UK	Opportunity cost estimated using 'least cost alternative' approach. AIP set at 50% of opportunity cost.	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).

[50] This approach has been proposed in Bahrain and is reportedly used in France, Greece, Italy and Malaysia. See p. 45 of http://www.tra.org.bh/en/pdf/spectrum_policy_consultation.pdf.

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

[52] See Chapter 4 of http://www.bundesnetzagentur.de/media/archive/4745.pdf.

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

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

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

Country	Derivation of price levels	Parameters in pricing formula
USA	The Federal Communications Commission's (FCC) regulatory fees for spectrum users are applied toward the agency's broad range of enforcement, policy, rulemaking and international activities. By statute, the total fees collected must cover (but cannot exceed) the level of funding appropriated by the US Congress for these activities. These fees are assessed annually and vary from service to service. Intentionally, these fees are based only on the cost of regulating an entity that holds an FCC license, and cannot reasonably be seen as payment or compensation for 'spectrum access'. The National Telecommunications and Information Administration (NTIA) does not charge federal agencies for use of the spectrum	N/A
HK	Spectrum and licence fees have been designed to cover administrative costs of the studies and monitoring required in planning and managing the relevant part of the spectrum.	Fixed fee of $50/kHz Variable fees for the number of base stations built

Source: Plum.

Regardless of the nuanced differences in the pricing formulas of each country, or whether price levels have been derived from opportunity cost, most formulaic approaches aim to set individual licence prices based on relative value of spectrum and spectrum denial (consistent with opportunity cost principles). An apparatus licence will allow use of spectrum by one party often at the exclusion of other parties, and the licence price aims to reflect this spectrum denial.

The location weightings (Apparatus Licence Fee Schedule, p. 32) reflect relative congestion in various spectrum locations and geographic locations, and are currently based on outdated statistics. The proposed price changes to the 400 MHz band will effectively replace the location weighting for spectrum in the 400 MHz band with price levels based on opportunity cost (values derived from the opportunity cost pricing methods in chapter 4). These base price levels can then be varied by spectrum denial variables (i.e. bandwidth and power) to determine taxes for individual licensees.[56]

In the Australian context, the 2002 Review of Radiocommunications by the Productivity Commission (PC) noted that the tax formula suffered from a number of shortcomings, including inflexibility, lumpiness, failure to distinguish between users of scarce and non-scarce spectrum within the same broad bands, and the lack of transparency about the size of the normalisation factor.[57]

The tax formula is only inflexible up until the time that it is reviewed. If ACMA is to apply opportunity cost pricing in any particular band, then regular reviews should form part of the

[56] The bandwidth factor accounts for frequency spectrum denial. The power factor is a crude proxy for geographical spectrum denial.

[57] Productivity Commission 2002, *Radiocommunications Inquiry Report*, Report no. 22, AusInfo, Canberra. ('Productivity Commission Report'), Pp 191-196.
Available at: http://www.pc.gov.au/inquiry/radiocomms/docs/finalreport

administrative pricing regime, but not so frequent as to nullify determinability and transparency of licence fees.

In the past the normalization factor has been used to adjust prices each year by the Consumer Price Index (CPI). Renaming this to 'inflation factor' explicitly links and limits its function to the adjustment of prices in line with CPI.

ACMA invites comment on:

- **Comments on the appropriate timeframe for the introduction of any price changes based on opportunity cost pricing and how frequently prices should be reviewed.**

8 Conclusion

Opportunity cost pricing provides ACMA with an objective and practical tool to efficiently price spectrum in the absence of direct market mechanisms.

In the past ACMA has applied broad opportunity cost thinking but this has often been limited to use of market proxies. However, new developments in opportunity cost calculation techniques enable ACMA to consider a wider application of opportunity cost pricing to specific allocation decisions.

Opportunity cost pricing sometimes requires judgments on the part of the regulator and as such, decisions need to be transparent. On balance, the introduction of opportunity cost pricing will likely create immediate efficiencies from the status quo, and help ACMA better achieve the object of the Act and the Principles for Spectrum Management.

The application of opportunity cost pricing in the 400 MHz case study band (which may serve to complement other spectrum management strategies) demonstrated that current prices in high-density areas should increase over a five-year period to provide sufficient incentive to alleviate congestion in this band.

Wider implications of opportunity cost pricing suggests that prices in congested bands and geographies are likely to increase and prices in non-congested bands and geographies are likely to decrease and ACMA is interested in views on these implications.

ACMA is seeking comments on a proposal to adopt opportunity cost pricing for the 400 MHz spectrum band, and is interested in views on the potential of opportunity cost pricing to address demand in other spectrum bands, identified for review and allocation as outlined in the *Five–year Spectrum Outlook 2009–2013*.

ACMA intends to consult further on any detailed pricing proposals informed by feedback developed through this consultation process.

A list of all consultation questions is summarised below. ACMA welcomes comments on the issues raised in this paper.

ACMA invites comment on:

- **The instances where administrative pricing is preferable to auctions**
- **The use of opportunity cost pricing as the preferred pricing methodology for administratively allocated spectrum.**
- **General comments on the opportunity cost estimation methodologies outlined in this paper**
- **The potential for a wider application of opportunity cost pricing to government and community users of spectrum**
- **Comments about the opportunity cost pricing case studies presented in this paper**
- **The 400 MHz band case study proposes increases in apparatus licences tax in high density areas (Sydney/Wollongong, Melbourne/Geelong, Brisbane/Gold Coast) over five years. Other changes to the tax in medium, low and remote density areas are not proposed at the current time.**
- **Comments on the bands where the application of opportunity cost pricing should be considered as a priority.**
- **Comments on the appropriate timeframe for the introduction of any price changes based on opportunity cost pricing and how frequently prices should be reviewed.**

Appendixes

A.1 Plum report to ACMA: Administrative Incentive Pricing of Radiofrequency Spectrum

Download Plum report separately at www.acma.gov.au.