Australian Communications Authority

MICROWAVE RADIO SPECTRUM TRENDS: ACCOMMODATING THE DEMANDS OF GROWTH, NEW TECHNOLOGIES AND RELOCATION

- an ACA Information Paper

Radiofrequency Planning Group

February 2000

FOREWORD

Technology and product developments within a largely deregulated market environment continue to present new and ongoing challenges for all stakeholders in the rapidly evolving communications industry. Consistent with the Government's policy of open competition in telecommunications, the ACA facilitates spectrum allocation that takes account of market demand and international developments.

As witnessed by the outcomes of recent price-based spectrum allocation activities, much of the microwave radio spectrum is subject to high demand, with consequent implications for the spectrum manager and user alike. With much of the microwave region of the spectrum already serving a variety of uses, in particular the fixed services, it is timely to consider in detail the clearly interrelated issues of growth demand, new technologies and relocation.

This information paper, prepared by the ACA Radiofrequency Planning Group discusses spectrum management issues relating to the (1-60 GHz) terrestrial fixed services. The paper presents:

- a detailed background to the current fixed service arrangements in the microwave bands;
- a description of the main propagation and operational characteristics of various fixed service bands;
- statistical analyses of current band usage and trends;
- identification of the principal demand drivers likely to affect current usage arrangements;
- discussion of options available to incumbents in bands likely to be displaced, including suitable transition bands and estimates of typical relocation costs;
- identification of additional ACA regulatory tools and enhancements to existing RADCOM database facilities considered important for effective management;
- discussion of spectrum denial approaches to licence fees; and
- recommendations dealing with particular issues.

The paper is intended to provide fixed service incumbents an overview of the ACA's current and possible future approaches to planning the microwave bands, as well as to provide interested parties with an opportunity to contribute to future policy development in this area.

The paper draws on other ACA work in making its considerations, including the 1998 report of the RCC's Working Group on Spectrum Demands for New Telecommunications Requirements, a number of RALIs and on recent studies into antenna performance as a key factor in determining spectrum denial.

A significant amount of detailed statistical information[1] is also provided, principally derived from the licensing assignment data of the ACA's RADCOM database.

Comments are invited on the detailed content of the paper and, in particular, the actions and recommendations consolidated at Section 5 "*Conclusions and Recommendations*" of the report. Enquiries and comments concerning the paper should be directed to:

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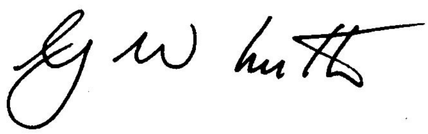
Note: The actions and recommendations detailed in this document are subject to further consideration by the ACA, with any final decisions taking account of all comments received by the due date of 30 April 2000.



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16 February 2000

[1] *Whilst every care has been take to check and verify the statistical data, no liability is or will be accepted by the ACA or it's officers, servants or agents for any loss suffered, whether arising directly or indirectly, due to the reliance on the accuracy of the information provided.*

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1. INTRODUCTION

1.1 Acronyms

The acronyms used in this paper are defined in the Glossary at Attachment 1.

1.2 Purpose of this Paper

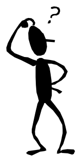
Considering:

1. *The demand for access to the radiofrequency spectrum both here in Australia and internationally has increased dramatically in recent years and continues to increase at a rapid rate;*

2. *The principal driving forces for spectrum demand are global telecommunications deregulation and the ongoing evolution and deployment of new radio based communications and broadcasting technologies; and*

3. *Many of the new services seek to be accommodated within frequency spectrum already occupied by other radiocommunications services, principally the terrestrial fixed service. The spectrum demands of the new services and the ongoing growth of terrestrial fixed networks place heavy pressures on the ever diminishing resources of suitably allocated and available radio spectrum.*

The purpose of this paper is to provide an overview of the spectrum management issues relevant to the utilisation of microwave frequency bands between about 1 GHz and 60 GHz. The principal focus is on spectrum access, sharing and displacement issues between the terrestrial fixed service and a range of new and emerging fixed and mobile communication and broadcasting technologies.



This paper considers a number of broad questions and issues including:

1. *What are terrestrial microwave fixed services, who is using them and where?*

2. *Is demand for terrestrial fixed services growing or declining and at what rate(s)?*

3. *What are the market drivers to spectrum demand in the microwave bands?*

4. *What types of services are being displaced, why and to what extent?*

5. *What options exist to meet the spectrum demand for incumbent microwave fixed services? Can they be replaced with cable or satellite based services?*

6. *Are there any differences in infrastructure costs between the different microwave bands? What factors contribute to infrastructure costs?*

7. *How much capacity remains in the existing microwave bands and what regulatory tools and approaches (eg. fees, planning rules) are available to optimise their utilisation?*

8. *Are there any new bands that can be put to use? What about 're-farming' existing microwave bands?*

9. *What legal, market and technical issues need to be considered in terms of the relocation of incumbents? Should relocated services be afforded priority? How?*

10. *What are the relevant technical, standards and allocation issues (eg. equipment product, RF channelling, re-farming options) relevant to meeting future demand?*

11. *Which licensing mechanisms are the most appropriate for microwave fixed services? What about where demand exceeds supply? and*

12. *Are there any other regulatory policy/spectrum management initiatives, which should be considered?*

The paper is primarily intended as providing information and advice relevant to current and envisaged ACA policies and planning activities concerned with the terrestrial fixed services. While it does not seek to promote any particular positions related to new developments, where appropriate, some recommendations on these matters are given.

1.3 Outline

Part 1 (this part) provides a brief introduction, detailing the purpose and scope of the report document.

Part 2 "*Background*" identifies those parts of the spectrum currently utilised wholly or significantly by the terrestrial fixed services and some technical and general planning matters relevant to their deployment and operation. An overview of the currently supported and emerging (network & wireless access) terrestrial fixed service applications is given. A brief outline of microwave fixed service infrastructure issues is provided, including matters of particular significance to network planners and operators. Radiowave propagation is briefly discussed so as to clarify the relationships between fundamental parameters of bandwidth, path length and relative location within the radiofrequency spectrum.

Part 3 "*Spectrum Demand for New Services*", looks at statistical growth trends for fixed networks, the role of liberalisation of the telecommunication market, competition issues and technology trends. Displacement issues are explored in detail, considering the bandwidth demands and spectrum access implications due to emerging fixed, mobile terrestrial and satellite based communication and broadcasting services.

Part 4 "*Accommodating Demand*", considers planning and regulatory infrastructure issues, with a view to accommodating the spectrum needs of new and relocated terrestrial fixed services. The capacity of existing bands is considered along with specific options for re-farming and/or opening up new bands. Issues relevant to dealing with displaced fixed services are discussed, including matters of timing, relocation costs and priority of access. This section also reviews the regulatory policy tools relevant to managing spectrum access by terrestrial fixed services.

Part 5 "*Conclusions and Recommendations*", consolidates the key issues and outcomes from the considerations discussed in parts 2.5 of the paper, with a view to contributing to current and ongoing planning activities for accommodating the demand for new and changing services. Various approaches to facilitating and regulating spectrum access for these services are also discussed.

2. BACKGROUND

2.1 General Spectrum Planning Considerations

The development of allocation policies and technical requirements for the introduction of new services in an orderly way is conducted on a national and international basis by the ACA, in consultation with Australian industry under the framework of the Radiocommunications Act 1992 (the Act). The spectrum planning framework is discussed more generally at Appendix 1.

The characteristics of the radiofrequency spectrum are frequency dependent and often dictate where a service may develop. The propagation characteristics of various spectrum bands are a key factor. For example, the lower end of the microwave spectrum at 1-3 GHz is excellent for long distance propagation whereas the higher bands above about 10 GHz are more suited to short range "line of sight" communication. These engineering characteristics substantially prescribe spectrum use. In general, equipment costs also tend to increase with frequency. Some general consequences of these influences are:

- the bands between 1 GHz and 3 GHz are the most in demand, principally for terrestrial and satellite based GMPCS[2] mobile services;
- the demand for mobile services has put pressure on existing 1-3 GHz microwave fixed services to move to bands above 3 GHz; and
- The bands above 3 GHz are also in high demand, for a range of new satellite based and terrestrial communication services, further restricting opportunities for the deployment of microwave fixed services.

More significantly in Australia we find ourselves subject to the pressures of developments in technology overseas and the decisions of spectrum management authorities in those regions which then flow into our environment. This is particularly the case for telecommunications services where we are users, or potential users of technologies developed in the USA, Europe or Japan. The reader will note this factor a number of times as this paper covers current and future telecommunications infrastructure issues.

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[2] *Global Mobile Personal Communications by Satellite* (GMPCS), as defined in the ITU *GMPCS Memorandum of Understanding* (GMPCS MoU), 18 February 1997, to which Australia is a signatory.

As noted in §1.2, another factor of increasing significance is the need for spectrum to be shared between services. This trend to sharing implies that the days of claiming "exclusive" access to spectrum are increasingly being challenged. Most ITU deliberations these days concerning the allocation of spectrum for new or changed requirements presume that spectrum should be shared by different services whenever possible. Increasingly the allocations being settled internationally at World Radiocommunication Conferences and in domestic planning include sharing. This results in the need for detailed technical study of the conditions under which such sharing may be possible, and the development of coordination rules for effective sharing.

2.2 Microwave Fixed Service Spectrum Allocations

The *Australian Radiofrequency Spectrum Plan*, January 1999 (The Spectrum Plan) allocates radiofrequency bandwidth to the various radiocommunication and broadcasting services, including the fixed service.

This section looks at the nature of microwave fixed services in terms of spectrum allocations, applications and users. Spectrum suitability, band planning and current Australian bands are discussed.

2.2.1 Spectrum Suitability

Given the basic transmission capacity requirements of modern communication networks and the nature of the radiofrequency spectrum, fixed links generally operate in the microwave region of the spectrum between about 1 to 60 GHz. The spectrum below about 1 GHz is generally not used for fixed links because of the bandwidth demand imposed by the transmission requirement, and in any case this spectrum is already devoted for use by various other radiocommunication services, in particular the broadcasting and mobile services. The upper bound for microwave fixed services is currently considered to be about 60 GHz, limited by inherent propagation limitations and cost factors associated with millimeterwave radio technology.

The lower microwave bands, between about 1 to 10 GHz, have traditionally been preferred for long haul and regional radio-relay applications due to their favourable propagation characteristics. Consequently, these bands are well utilised and congested at many locations, including the major telecommunications trunk routes and the larger metropolitan population centres. These lower microwave bands also accommodate the bulk of the population of the older analogue links still in service.

The bands above about 10 GHz are subject to significant rainfall and atmospheric attenuation, generally increasing with frequency. In practice, this equates to decreasing achievable hop lengths and consequent increase in network infrastructure costs. Hence the higher microwave bands, especially those above about 18 GHz, have not been extensively utilised in the past. However, they are ideal for high bandwidth urban networks and local access (ie. broadband wireless) applications. Channel re-use distances also become significantly smaller in these higher bands, increasing their utility for service delivery in the high-density urban environment.

For a more detailed discussion on propagation issues see § 3.8.

2.2.2 Fixed Link Allocations and Band Planning

Australian fixed service frequency allocations are specified in the Spectrum Plan, and generally conform to the ITU Radio Regulations fixed service allocations for Region 3, as also detailed in the same document.

As outlined in the Spectrum Plan, all of the fixed service allocations between 1 GHz and 60 GHz are also allocated to one or more other services. Not all fixed allocations can be implemented in all countries, nor would this be sensible; national policies generally determine the use to which each band is put. Some bands are reserved for the exclusive use of one service allocation whilst others may be available on a shared basis to one or more of the allocated services. The specific utilisation of each band is subject to particular implementation arrangements, including relevant intra and inter-service sharing and coordination considerations, generally derived from ITU agreed criteria.

About 62% of the radiofrequency spectrum between 1 and 60 GHz is allocated to the fixed service in the current Spectrum Plan. In practice only 21% of the potentially accessible primary spectrum is actually available for use by fixed services, as most of the allocations are shared with other primary services whose operation may not be compatible with the fixed service. In other cases, especially higher up in the spectrum range, technology is still maturing and market planning options under consideration.

Fixed service microwave bands are usually planned to align with well defined ITU recommendations or other credible regional standards, and to accommodate readily available products. Accordingly, most of the Australian Radio Frequency (RF) Channel Arrangements (as detailed in RALI-FX3[3]) are closely aligned with the appropriate ITU-R Recommendations.

Internationally, fixed service recommendations are developed by ITU-R Study Group 9, which is tasked with the study of the technical and operational aspects of fixed services. Australian participation in the work of Study Group 9 is coordinated by the ACA, on advice from the Australian Radiocommunication Study Group 9 (ARSG9). ARSG9 members meet regularly to consider international fixed service developments and proposals and contribute to the work of the ITU Radiocommunication Sector. Membership is open to all parties interested in the fixed services - current members include private and public sector organisations (eg. the telecommunication carriers and other major fixed link users including defence and broadcasters, equipment manufacturers, the ACA and other industry bodies).

2.2.3 Current Australian Microwave Fixed Service Bands

Terrestrial fixed services facilitate communication between specified fixed locations on the earth's surface. They may operate in either a point-to-point or a point-to-multipoint configuration, depending on the nature of the service requirement.

Point-to-multipoint fixed services are commonly employed in wireless access networks, current examples being the Fixed Wireless Access (FWA) arrangements at

[3] Radiocommunication Assignment and Licensing Instruction (RALI) FX 3 - "*Fixed Microwave Services - Frequency Coordination*".

3.4 GHz, used for the provision of regional and urban PSTN and Telstra's 500/1500 MHz Digital Radio Concentrator System (DRCS), providing basic telephony services in rural and remote areas of Australia. However, most fixed services currently operating in Australia are of the point-to-point configuration, providing transmission capacity for a range of common carrier and private network applications. Examples of network applications are detailed in the next section. Table 2.1 lists the current Australian microwave (1.5 – 58 GHz) fixed service bands, together with their designated use, transmission capacity and principal applications.

Australian Microwave Fixed Service Bands

Band	Freq Range	Designated Use	Typical Use	Capacity	Relevant Standard
1.5 GHz	1427 - 1535 MHz	*Low Capacity point-to-point*	*Radio Relay*	*2 Mb/s*	*ITU-R Rec. F701*
1.5 GHz DRCS	1427 - 1535 MHz	*Fixed Radio Access*	*Rural & Remote area USO services*	*0.7..2 Mb/s*	*ITU-R Rec. F701*
1.8 GHz	1700 - 1900 MHz	*Low Capacity point-to-point*	*Radio Relay*	*8/17 Mb/s*	*ITU-R Rec. F.283-5*
2.1 GHz	1900 - 2300 MHz	*Low & Medium Capacity point-to-point*	*Radio Relay*	*34 Mb/s*	*ITU-R Rec. F.382-6*
MDS A	2076 - 2111 MHz	*Access*	*Video Entertainment*	*Not specif.*	-
MDS B	2300 - 2400 MHz	*Access*	*Video Entertainment*	*Not specif.*	-
2.5 GHz	2450 - 2690 MHz	*ENG (TOB)*	*Itinerant use video links*	*FM Video*	-
3.4 GHz	3425 - 3492.5 MHz	*Fixed Wireless Access*	*Surburban Access Networks*	*Voice & Data*	*ETSI EN301 021 1997*
3.8 GHz	3580 - 4200 MHz	*High Capacity*	*Long Haul (Intercapital) Radio Relay*	*140 Mb/s*	*ITU-R Rec.F.635-2*
6 GHz	5925 - 6425 MHz	*Medium & High Capacity point-to-point*	*Medium Haul Radio Relay*	*34/155 MB/s*	*ITU-R Rec. F.383-5*
6.7 GHz	6425 - 7110 MHz	*High Capacity*	*Long Haul (Intercapital) Radio Relay*	*140 Mb/s*	*ITU-R Rec. F.384-5*
7.2 GHz	7100 - 7425 MHz	*TV Outside Broadcast*	*Itinerant use video links*	*FM Video*	-
7.5 GHz	7425 - 7725 MHz	*Low & Medium Capacity point-to-point*	*Medium Haul Radio Relay*	*2-17 Mb/s*	*ITU-R Rec. F.385-6*
8 GHz	7725 - 8275 MHz	*Medium & High Capacity point-to-point*	*Medium Haul Radio Relay*	*34/155 MB/s*	*ITU-R Rec. F.386-4*
8.3 GHz	8275 - 8400 MHz	*TV Outside Broadcast*	*Itinerant use video links*	*FM Video*	-
10.5 GHz	10.55 - 10.68 GHz	*Low Capacity point-to-point*	*Urban networks*	*2 Mb/s & FM Video*	*ITU-R Rec. F.747*
11 GHz	10.7 - 11.7 GHz	*High Capacity*	*Medium Haul Radio Relay & Urban Networks*	*155 Mb/s*	*ITU-R Rec. F.397-6*
13 GHz	12.75 - 13.25 GHz	*Medium capacity point-to-point & TV Outside Broadcast*	*video links in urban areas*	*FM Video & 34 Mb/s*	*ITU-R Rec. F.497-4*
15 GHz	14.5 - 15.35 GHz	*Low & Medium Capacity point-to-point*	*Urban networks*	*2-34 Mb/s*	*ITU-R F.636-3*
18 GHz	17.7 - 19.7 GHz	*Low to High Capacity point-to-point*	*Urban networks*	*2-155 Mb/s*	*ITU-R F.595-4*
22 GHz	21.2 - 23.6 GHz	*Low Capacity point-to-point & TV Outside Broadcast*	*Urban fixed networks & itinerant FM video links*	*2-8 Mb/s, FM Video*	*ITU-R F.637-2*
38 GHz	37 - 39.5 GHz	*Low & Medium Capacity point-to-point*	*Urban networks*	*2-8 Mb/s*	*ITU-R F.749-1*
49 GHz	49.2 - 49.95 GHz	*Itinerant point-to-point*	*Temporary links*	*Not specif.*	-
50 GHz	50.4 - 51.15 GHz	*Low Capacity point-to-point*	*Urban networks*	*Not specif.*	-
58 GHz	57.2 - 58.2 GHz	*Low Capacity point-to-point*	*Urban & MTS backhaul*	*Not specif.*	*ITU-R F.1100*

Point-to-Multipoint (Access Network)

Television Outside Broadcast or Electronic Newsgathering (2.5 GHz), itinerant point-to-point.

Television Outside Broadcast & Point-to-Point Fixed (shared use)

Table 2.1 Australian (1.5-58 GHz) Microwave Fixed Service bands.

Detailed information on the utilisation of the individual bands listed in the table is given in Appendix 3.

2.3 Fixed Applications: Transport Networks

A large proportion of microwave fixed services support digital communication network applications, with gross data rates between 2 Mb/s up to N $\times$ 155 Mb/s for broadband telecommunication trunk networks. Analogue fixed links are generally limited to the outside broadcast and television distribution type applications (FM video) and a dwindling population of FDM telephony links.

Most current terrestrial microwave fixed services are used as part of point-to-point telecommunication transport networks, with most operators holding telecommunication carrier licences. Transport network applications may be further subdivided into three basic types, categorised as trunk, regional and urban. The graphic at Appendix 7 "*The Geographic Distribution of Microwave Fixed Services*", serves to demonstrate the nature of these geographic definitions. The following sub-sections discuss these main categories and further sub-categories in more detail.

2.3.1 Trunk

Terrestrial trunk or 'long haul' radio-relay[4] systems provide high speed ($N \times 140/155$ Mb/s) backbone transmission capacity over intercapital (eg. Sydney to Melbourne) and major regional trunk routes , supplementing and providing physical diversity for high speed common carrier optic fibre networks. Considering:

- *the transmission performance requirements of high speed long haul networks;*
- *the long end-to-end communication distances spanned by such networks;*
- *the cost of establishing and maintaining long haul radio-relay routes;*
- *that hop lengths of about 25 to 40 km are preferred for economic reasons; and*
- *that rainfall related outage severely limits the utility of higher frequency bands*;

long haul trunk networks are accommodated in the frequency bands below 10 GHz.

Telstra's high capacity long haul networks are well established in the 'standard' 3.8 GHz and 6.7 GHz long haul frequency bands, accounting for 97% and 92% respectively of the usage of these bands.

Figure 2.1 shows the geographic distribution (the red lines of the figure) of links in the 6.7 GHz band, from which the locations of intercapital and regional trunk route corridors is clearly evident. For smaller capacity long haul networks other bands below 10 GHz are used (eg. the 2, 6, 8 or 7.5 GHz bands).

[4] 'Radio-relay' refers a type of point-to-point network whose end-to-end communication distance extends over multiple radio hops incorporating repeater stations.

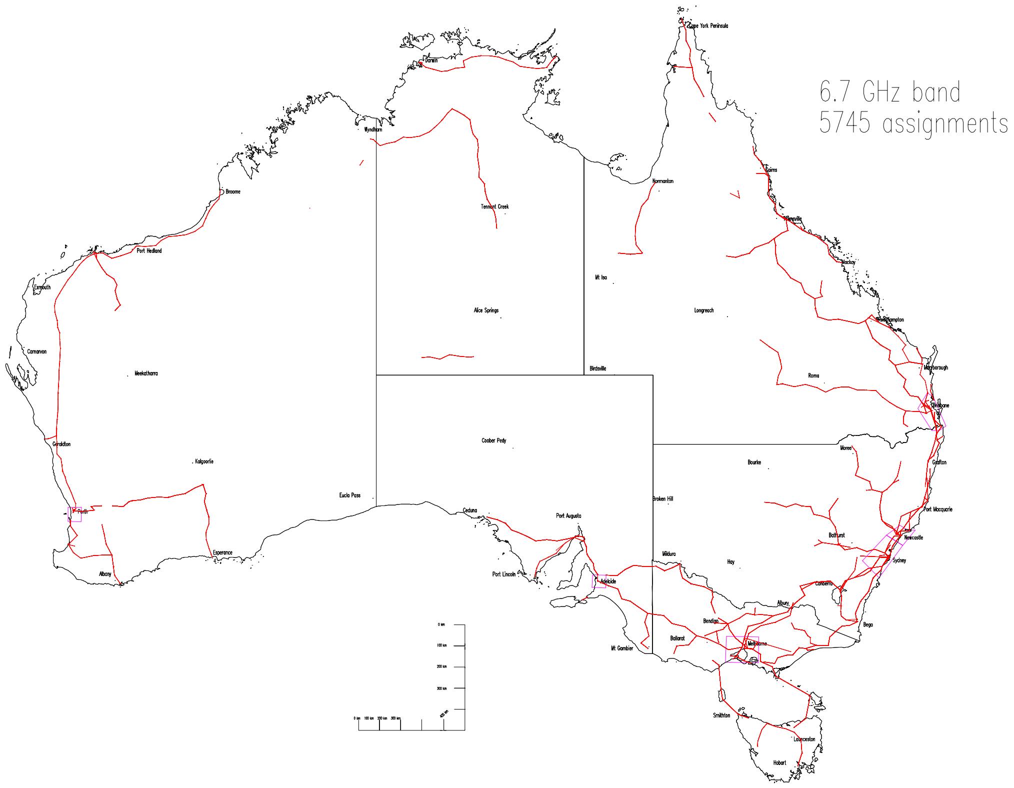

Figure 2.1 Trunk (long-haul) networks in the 6.7 GHz band[5]

Radio-based long-haul networks are attractive to new carriers, particularly where seeking to quickly establish an interest in the high volume intercapital route traffic market. However, on many trunk routes, suitable long haul spectrum is in short supply – refer to §3.1.1 for a detailed discussion.

2.3.2 Regional

Regional fixed networks include radio-relay systems and point-to-point fixed links servicing public and private communication requirements in regional, rural and remote areas. End-to-end network distances and communication link capacities are consequently smaller than on the trunk routes, typically being between 2- 34 Mb/s.

In addition to feeding common carrier cable and radio-based local access (including cellular backhaul) telecommunication services, medium-haul radio-relay applications include in-house regional networks operated by a variety of government and non-government utilities, with organisations such as Defence, gas, railway and electricity service providers. Television broadcasting feeder networks and studio-to-transmitter links (principally analogue to date) are also a significant spectrum user.

Radio-relay systems and other point-to-point applications servicing regional, rural and remote areas principally utilise the bands below about 10 GHz for reasons similar to those described in the previous section for trunk networks – ie. communication path lengths normally exceed that achievable in the higher bands due to rainfall related outage considerations. The principal bands used for regional infrastructure include:

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5 As recorded in the ACA RADCOM database @August 1999.

- The 1.5 GHz, 1.8 GHz, and 7.5 GHz bands are heavily utilised for small capacity (2-8 Mb/s) regional radio-relay networks and other point-to-point uses; and

- The 2 GHz, 6 GHz and 8 GHz are the traditional bands for medium capacity (16-34 Mb/s) medium-haul radio-relay applications, although higher capacity (155Mb/s) equipment is now emerging for these bands as well.

Communication distance and infrastructure factors permitting, the bands above 10 GHz are also used to meet particular regional communication requirements.

As an example of regional terrestrial fixed service deployment, Figure 2.2 demonstrates the geographic distribution of 8 GHz point-to-point links in Australia.

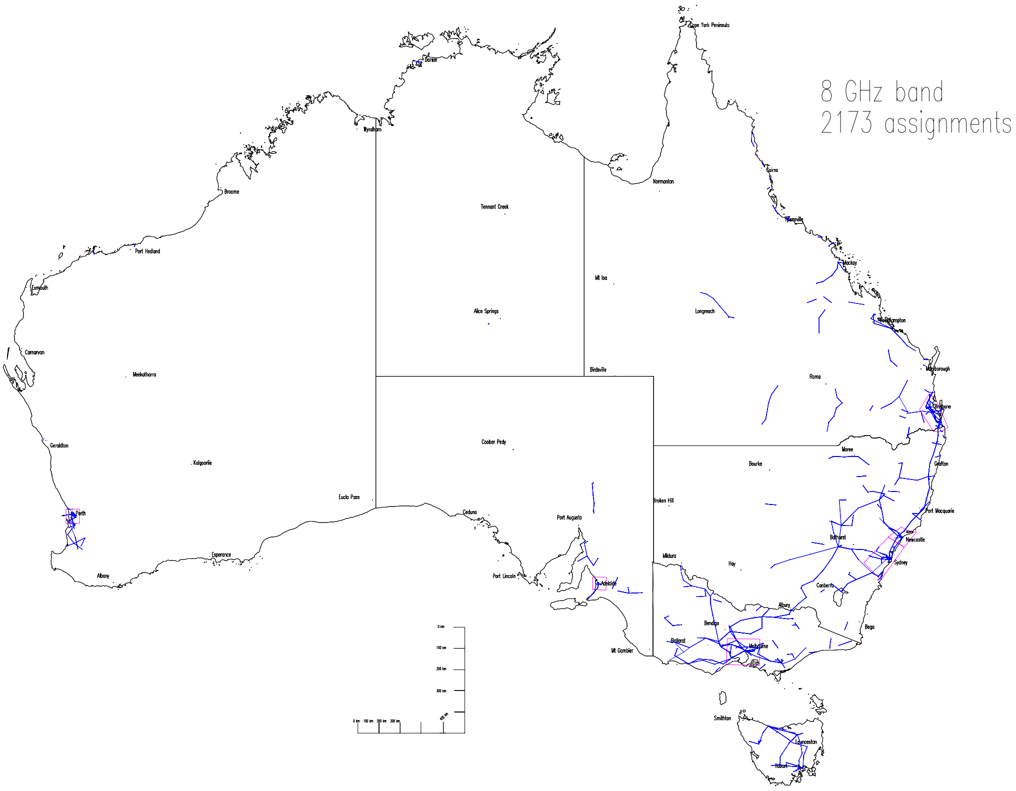
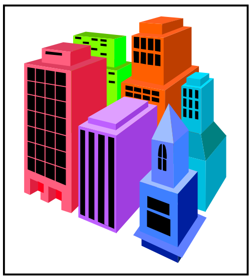


Figure 2.2 Regional (medium-haul) networks in the 8 GHz band[6].

Further discussion on spectrum demand and planning issues relevant to regional infrastructure networks is detailed in §3.1.2.

6 As recorded in the ACA RADCOM database @August 1999.

2.3.3 Urban



As demonstrated by Figures 2.1 & 2.2, trunk and regional radio-relay system infrastructure originates/terminates at locations within the urban environment, often within or close to the CBD where the trunk switches, corporate business centres and other urban communication infrastructure is consolidated.

A further class of fixed infrastructure extends throughout the urban environment. In cities and large regional centres fixed radio and cable networks service the most diverse range of public and private communication requirements. Business communications dominate the often congested urban radiofrequency environment, especially in CBD areas. Point-to-point cellular backbone and urban ring networks aggregate mobile telephone traffic between service segment base stations and switching nodes. Other common carrier and private networks interconnect corporate headquarters with their outlying operations. Private point-to-point links provide in-house voice and data communications, usually over relatively short distances as found at university campuses and large manufacturing plants.

End-to-end network and individual hop distances are relatively small, but link capacities vary widely, depending on the end user application. Figure 2.3 shows the Australia wide distribution of point-to-point fixed links in the 15 GHz band, demonstrating the urban nature of the frequency bands above 10 GHz.

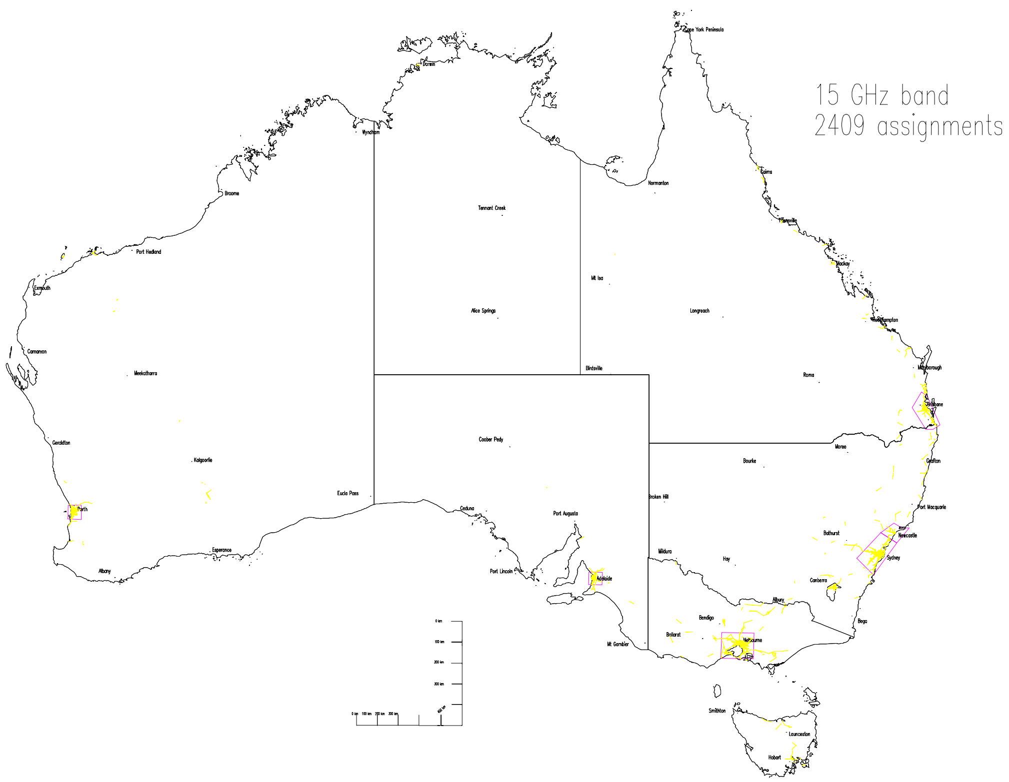


Figure 2.3 Urban (short-haul) networks in the 15 GHz band[7]

[7] As recorded in the ACA RADCOM database @August 1999.

Further discussion on spectrum demand and planning issues relevant to urban infrastructure networks is detailed in § 3.1.3.

2.4 Fixed Applications: Wireless Access

The term "*wireless access*" (sometimes referred to as Wireless Local Loop (WLL)) is defined by the ITU as an "*End-user radio connection to a core network*". A 'core network' in this context may be PSTN, ISDN, Internet, LAN/WAN. The 'end user' may be a single user or a user accessing services on behalf of multiple users. Numerous other terms exist for wireless access, with many relating to particular technologies (eg. LMDS, MDS, MVDS...). It may be useful to consider here the following generic terms and their standardised[8] definitions:

- Fixed Wireless Access (FWA) – a *wireless access* application where the location of the *end-user termination* and network access point to be connected to the end-user are fixed;

- Mobile Wireless Access (MWA) – *wireless access* application in which the location of the *end-user termination* is mobile;

- Nomadic Wireless Access (NWA) – *wireless access* application in which the location of the *end-user termination* may be in different places but it must be stationary when in use; and

- Broadband Wireless Access (BWA) – *wireless access* in which the connection capabilities are higher than the primary rate (ie. > 2 Mb/s).

Cellular mobile systems are an example of MWA/NWA access system, since they do not discriminate between fixed and mobile customers and are to an extent displacing growth in the wireline PSTN[9]. In fact, some digital switches have the capability to serve simultaneously as the mobile switching centre (MSC) of a cellular mobile system and as the local exchange for wireline and/or FWA system[10]. However, the principal focus in this information paper is the fixed or FWA type access networks. FWA networks may be provided using point-to-point links, but they are more commonly associated with point-to-multipoint networks. FWA systems may require a separate backhaul (radio or wireline) segment or it may be integrated into the service segment of the radio network.

The following sub-sections define and discuss the types of wireless access systems currently operating/deploying in Australia.

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[8] ITU-R Recommendation F.1399 "*Vocabulary of terms for Wireless Access*", 1999.

[9] "*Public Switched Telephone Network*" or traditional analogue common carrier access network.

[10] "*Europe's Wireless Futures*", Stephen McClelland, *Microwave Journal*, 9 September 1999, p.95.

2.4.1 Rural and Remote Area Telecommunication Services

Section 149(1) of the *Telecommunications Act 1997* defines the Universal Service Obligation (USO) as the obligation "*to ensure that the standard telephone service is reasonably accessible to all people in Australia on an equitable basis, wherever they reside or carry on business...*".

Much of the current rural and remote area USO requirement is delivered through the Telstra Digital Radio Concentrator System (DRCS), a type of FWA technology. This type of cellular FWA is characterised by large cells with relatively low traffic densities, ideal for sparsely populated regions and developing countries with limited communication infrastructure. DRCS fixed networks have been operating in Australia since the early 1980's, providing basic (low traffic density) telephony services and low speed data and currently servicing approximately 19000 rural and remote area customers.

A basic DRCS comprises of a switching node and parent hub station connected to a feeder network of point-to-multipoint hub stations, each with its own population of individual telephone customers. As shown in Figure 2.4, the system combines a hybrid point-to-point and point-to-multipoint architecture, effectively integrating service and backhaul network elements.

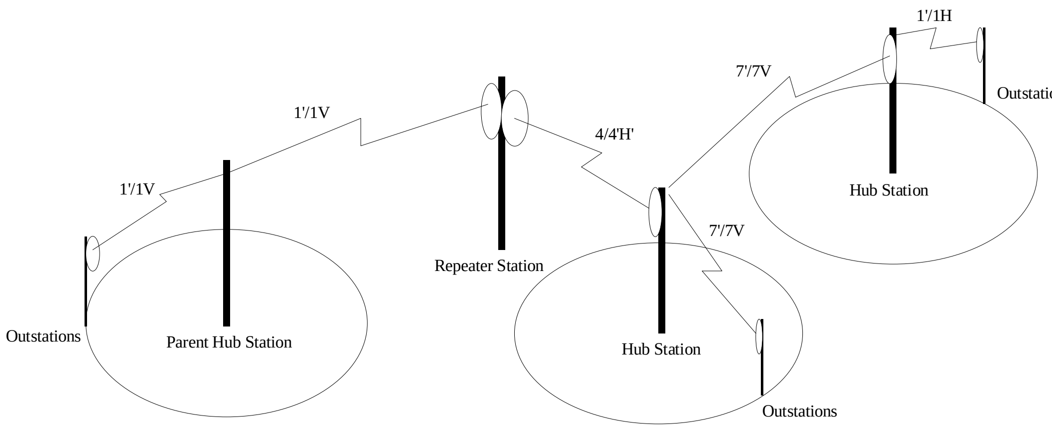

Figure 2.4 The network topology of an arbitrary DRCS network.

The 'daisy-chaining' of hub stations in this manner enables a service area of hundreds of square kilometres to originate from each parent switching centre, at which the system interconnects into the PSTN. The outstations are located adjacent to the customers premises, typically consisting of a small control unit/transceiver connecting to a telephone handset inside the customers premises. A low cost directional (eg. yagi or grid) antenna on a small antenna structure points to the respective serving hubstation, completing the connection to the point-to-multipoint DRCS network.

As shown in Figure 2.5, 500 and 1500 MHz DRCS services (shown in blue and green respectively) are extensively deployed throughout the rural and remote regions of Australia, including hybrid 500/1500MHz networks but with most systems operating in the 1.5 GHz band. Frequencies are selected on the basis of a cellular band plan, with pre-determined channel frequency re-use distance criteria to avoid interference.

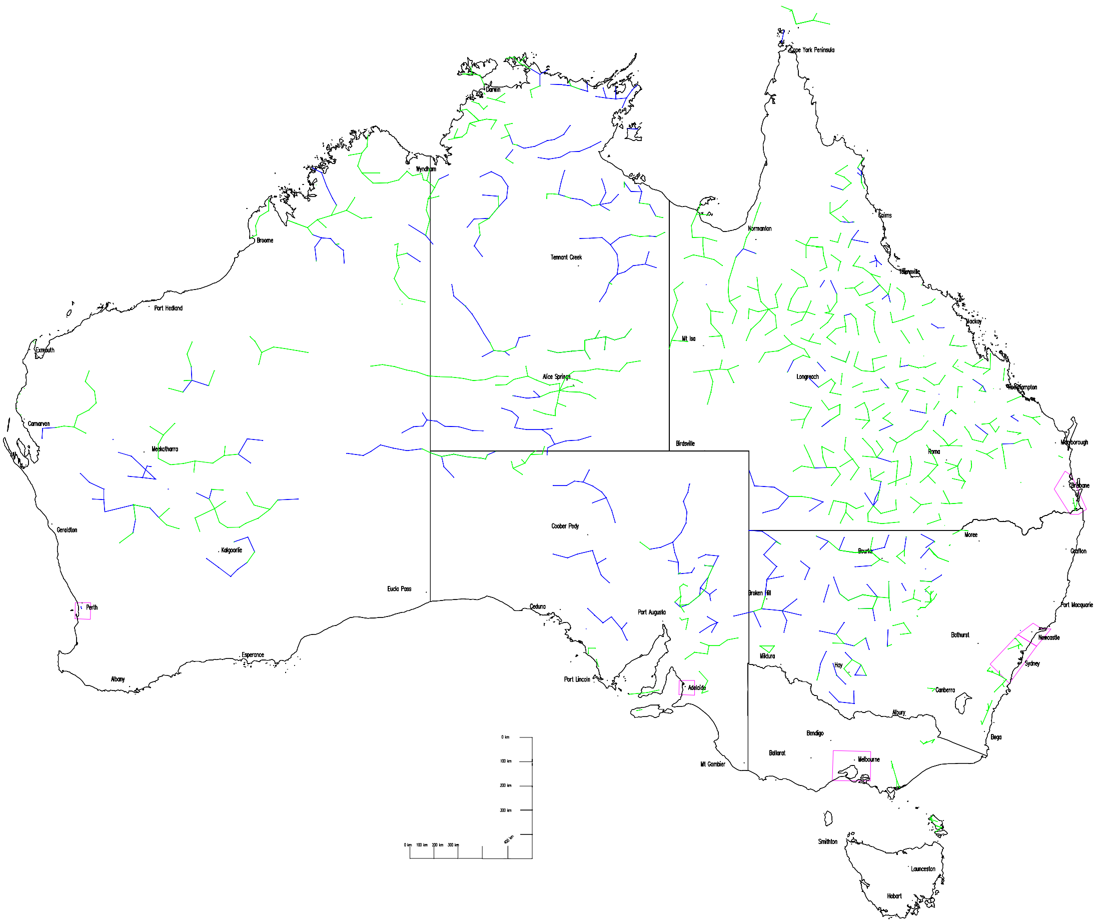

Figure 2.5 Geographic distribution of 500/1500 MHz DRCS networks[11]

The DRCS is a good example of a mature FWA technology that has allowed telephony provision in areas where it was either poor or non-existent. However, given that the DRCS transmission and switching technology is dimensioned to and optimised for rural service delivery (ie. large cells, low traffic density), this type of access system is not suitable for the urban environment.

In addition to the DRCS, the 1.8 and 2.1 GHz point-to-point bands are extensively used for carrying DRCS and other rural and remote backbone traffic. Further discussion on the 1.8 and 2.1 GHz bands is detailed in § 3.1.2 and § 3.6.2 and Appendices 3 & 4. Further discussion on spectrum demand and planning issues relevant to DRCS networks is detailed at § 3.1.5.

[11] Excludes customer outstations, the details of which are not included in the ACA database, for operational reasons.

2.4.2 3.4 GHz Fixed Wireless Access Services

In 1996, arrangements[12] were put in place for the deployment of FWA services in parts of the 3.4 GHz (3425-3492.5 MHz) band, aligned with European arrangements[13], for apparatus licensed operation in the frequency range 3425-3442.5 MHz and 3475-3492.5 MHz (ie. 2×17.5 MHz, with a 50 MHz duplex frequency spacing). Following the rapid deployment of services, the ACA placed an embargo on the issue of new licences in these frequency bands in specified geographic areas.

Figure 2.6 shows the (August 1999) geographic distribution of apparatus licensed FWA base stations in the bands 3425-3442.5 MHz and 3475-3492.5 MHz.

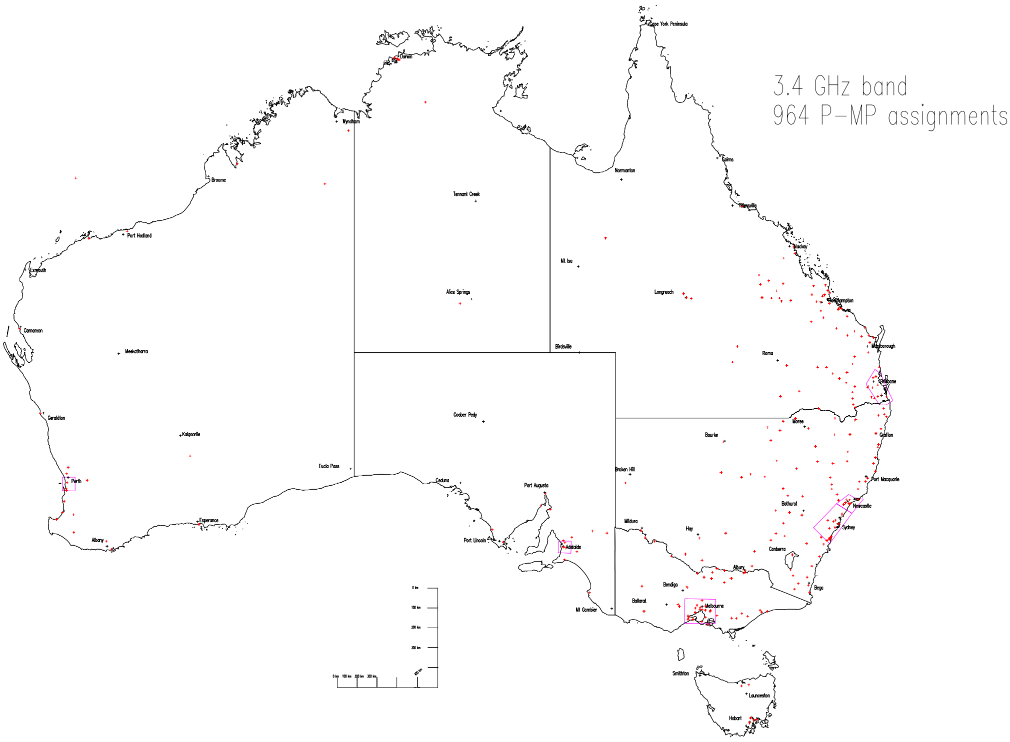

Figure 2.6 Distribution of apparatus licensed 3.4 GHz FWA Services.

The deployment principally represents medium density urban and regional local access infill. Hub station service area cell radius distance is about 20 km.

Apparatus licensees in the band include Telstra (89%) and Semaphore Telecommunications (11%), with deployment consisting mainly of Nortel 'Proximity' I-series proprietary 'copper replacement' PSTN local access systems[14]. However, equipment products are emerging for a range of other 3.4 GHz access applications.

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12 Detailed in the ACA RALI FX-14 "*Point-to-Multipoint Fixed Services in Specified Parts of the 3.4-3.59 GHz Band*".

13 CEPT Recommendation 14-03 "*Harmonised Radiofrequency Channel Arrangements and Block Allocations for Low and Medium Capacity Systems in the Band 3400 MHz to 3600 MHz*".

14 Annex 5, "*Wireless Access Local Loop*", volume 1, ITU-R, 6 November 1996, provides a detailed system description.

The band is now subject to re-allocation under spectrum licensing, with:

1. 2 × 17.5 MHz (ie. the bands 3425-3442.5/3475-3492.5 MHz) to be made available for price based allocation in city areas (Adelaide, Albury, Brisbane, Cairns, Canberra, Hobart, Launceston, Melbourne, Perth, Rockhampton, Sydney, Townsville); and

2. a further 2 × 32.5 MHz (in the bands 3442.5-3475/3542.5-3575 MHz) to be allocated in city and extensive regional areas.

The anticipated spectrum licence areas are shown in Figure 2.7. Auctions are anticipated[15] to take place later this year.

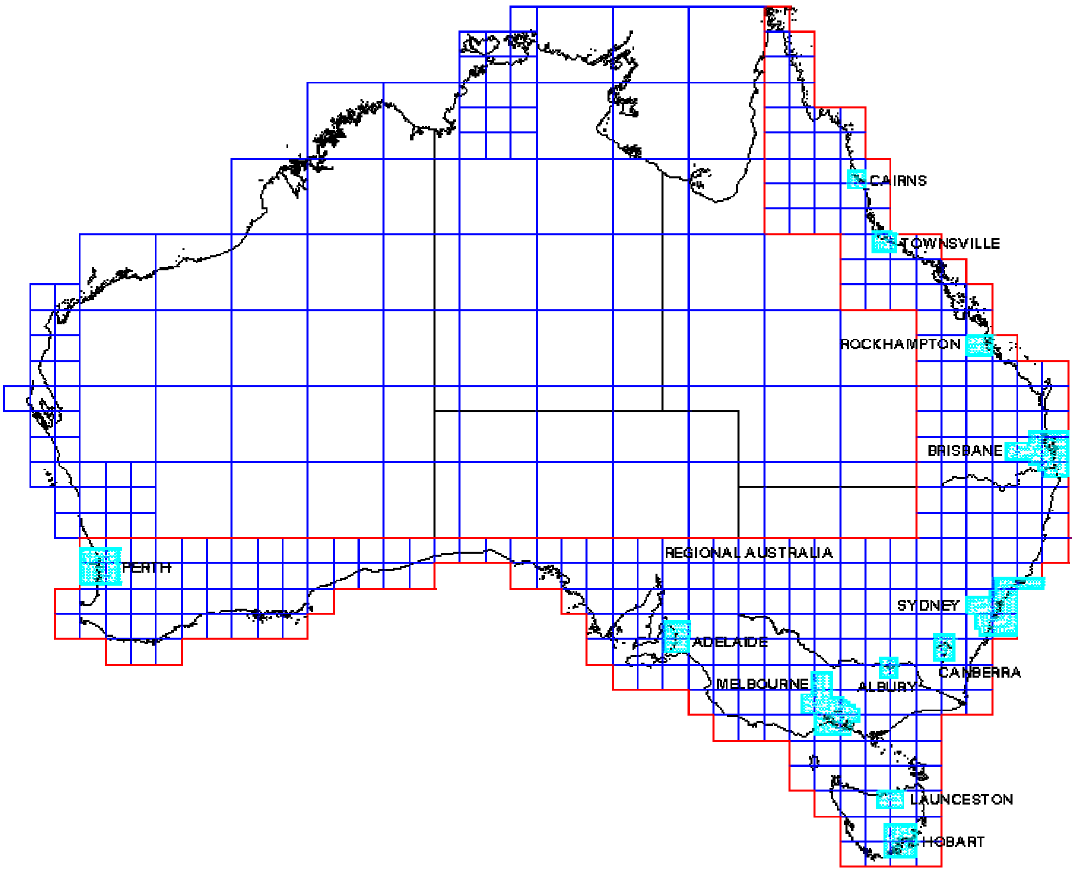
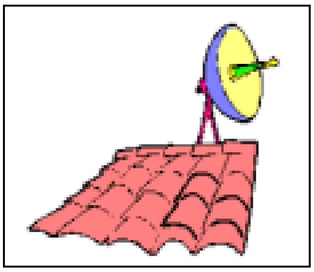


Figure 2.7 3.4 GHz Spectrum Licensing Areas

Whilst the existing utilisation of the 3.4 GHz band principally involves regional PSTN infill, future applications under the spectrum licensed arrangements are most likely to include high speed Internet delivery in urban and regional areas.

[15] See http://203.37.2.230/3_4GHz/3point4ghz.htm for the latest on the upcoming 3.4 GHz auction.

2.4.3 Broadband Wireless Access



Broadband Wireless Access (BWA) is defined[16] as a wireless service delivering services at 2 Mb/s or higher rates. Australian 2 GHz MDS services may be considered as a type of (unidirectional) analogue BWA system – the future of the existing MDS services are further discussed at §4.1.3.

Contemporary BWA technologies provide multiple bidirectional high-speed digital access services using a cellular point-to-multipoint radio architecture. Hub stations connected to high speed backbone networks service multiple customer outstations located within each cell. A mixture of voice, video and data services may be provided, making use of virtual circuit (eg. ATM) and wholly connectionless (eg. Internet) protocols. Particular BWA technologies include the Local Multipoint Distribution System (LMDS), originating in the USA and also deployed in the 28/31 GHz bands in many other countries.

Australian LMDS deployment in the 28/31 GHz bands is imminent, following the price-based allocation of spectrum in February 1999 to AAPT LMDS Pty Ltd, who secured Australia wide access to the 1.3 GHz of spectrum for $66.2 m. AAPT plans to use LMDS to target corporate, government and small to medium business enterprises, with commercial service anticipated[17] to commence by the first quarter 2000, delivering high speed data, voice and internet services. Twenty out of a total of 120 planned LMDS nodes are anticipated to be operating across Australia by December 2001, including all capital city & CBD areas and selected regional centres.

Further market demand is demonstrated for broadband wireless spectrum, including the operators excluded from the 28/31 GHz auctions through competition rules. Further discussion on BWA and related spectrum issues is detailed at §3.1.4 .

2.4.4 RLANs and ubiquitous wireless products

Radio Local Area Networks (RLANs) and other ubiquitous wireless devices operating within the 1 to 60 GHz frequency range can also be classified as terrestrial fixed services, consistent with the broad range of the definition of fixed services. They typically operate over short range with relatively low radiated power levels and, in Australia, their operation currently normally falls within the categories of devices permitted under the ACA's "Class Licence" arrangements – see http://www.aca.gov.au/legal/licence/class/index.htm.

Nevertheless, new applications and bandwidth demand for these types of applications continues to grow and spectrum access and sharing matters are likely to evolve to a more significant future issue. The ACA, in response to industry requests, is currently preparing planning proposals for the introduction in Australia of RLAN arrangements in the 5 GHz band, taking account of the USA NII arrangements, European ETSI Hiperlans standards/ERC decisions and relevant ongoing ITU-R studies. It is

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16 In ITU-R Recommendation F.1399.

17 'Attachment', AAPT's Response to the (DCITA) *National Bandwidth Enquiry* – see http://www.noie.gov.au/bandtask/submit/submit.htm .

envisaged that the proposed Australian arrangements will include a class-licensing framework. An ACA discussion paper on this matter is being prepared for release for public comment early in 2000.

2.5 Fixed Applications: Television Outside Broadcast

Television Outside Broadcast (TOB) services provide temporary wideband point-to-point links, principally in support of television broadcast events. Such events are normally of a short term nature, ranging from a few minutes (Electronic News Gathering or ENG) up to several days or longer (eg. the special case of the 2000 Olympics). Accordingly, although TOB services are classified as fixed services, their nomadic operational characteristics set them apart from other point-to-point fixed applications. Australian TOB bands are summarised in Table 2.2.

Band GHz	Total Channels*	Channel Bandwidth	User vs Channel Availability 7/9/10	ABC	Other	p-p FS	Comment
2.5	*8*	*28 MHz*	*8*	*8*	*0*	*0*	*Networks 7, 9, 10 & ABC TOB only*
7.2	*18*	*30 MHz*	*18*	*18*	*2*	*0*	*Networks 7, 9, 10 & ABC+ 2 channels for others*
8.3	*8*	*28 MHz*	*0*	*3*	*5*	*0*	*ABC+others*
13	*32*	*28 MHz*	*16*	*16*	*4*	*12*	*Segregated (p-p FS vs TOB) channels*
22	*14*	*50 MHz*	*6*	*6*	*6*	*8*	*Segregated (p-p FS vs TOB) channels*
49	*10*	*40 MHz*	*10*	*10*	*10*	*10*	*Unrestricted, uncoordinated*

** Note: Unpaired Channels - divide by 2 for bidirectional links*

Table 2.2 TOB band utilisation @ September 1999.

TOB links may involve single or multiple hops, linking temporary event broadcast sites with studios or into an access point of a regular fixed broadband transmission network. Multiple hop TOB operations may be carried out using a number of mobile ‘OB van’ vehicles parked and operating at temporary fixed locations, akin to regular radio-relay system repeater stations.

Some short term television broadcasting related operations may involve TOB transmissions from mobile platforms such as helicopters and other vehicles (eg. ENG and some sports events).

TOB services are normally licensed on an area-wide basis, either as individual apparatus licences authorised to operate within a certain distance of a defined location as a ‘TOB System Licence’ for a specified location(s) or a ‘TOB Network Licence’ providing for the use of unspecified number of apparatus Australia wide. As detailed in the *Radiocommunications Licence Conditions (Fixed Service) Determination of 1997*, Network licences are currently limited to the commercial free-to-air television operators (networks ‘Seven’, ‘Nine’ and ‘Ten’) and their affiliated regional operators.

TOB and ENG services are discussed further at §4.1.4, §4.1.6 & §4.1.7

2.6 Fixed Service Infrastructure, Planning and Standards

This section looks at terrestrial network infrastructure, planning criteria and applicable standards. Comments are made concerning infrastructure and planning matters particularly relevant to network operators.

2.6.1 RF Channel Arrangements and Block Allocations

Radio-frequency (RF) Channel Arrangements detail the allotment of radiofrequency channels within each particular fixed service frequency band. The details include channel designations corresponding to centre frequencies, channel bandwidth and transmit to receive frequency channel separation – see example of Figure 2.8.

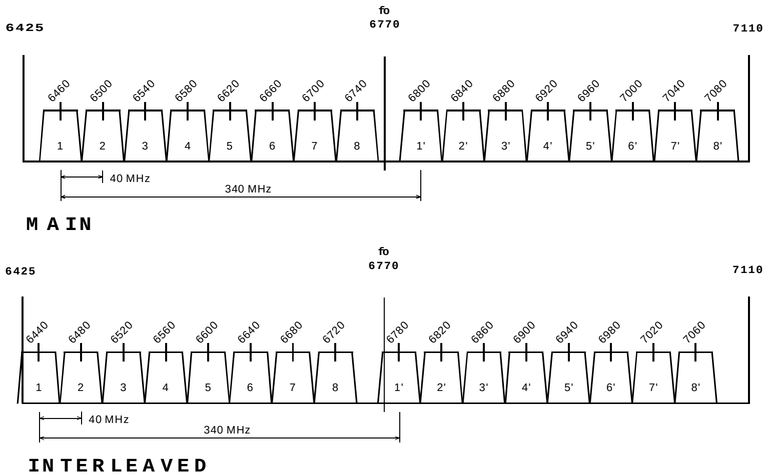

Figure 2.8 RF Channel Arrangements 6.7 GHz Band[18].

The Australian (RALI FX-3) RF channel arrangements, and those of most other countries, are aligned with well established ITU-R Recommendations[19] in order to accommodate readily available (world market) products. However, the ITU-R arrangements normally accommodate a range of options, facilitating differences in regional allocations, local market demand and applications. It is up to individual countries to choose which ITU-R recommended options are supported.

Block allocations are an alternative to discrete RF channel arrangements and current ITU-R studies anticipate the development of a new recommendation[20] dealing with their application. Rather than specifying arrangements based on groupings of discrete channelwidths, whole blocks of fixed spectrum are allotted to operators, facilitating the expedient deployment of new radio infrastructure, at least in cases where a relatively small number of operators need to be accommodated in a given area. Block allocations are particularly amenable to point-to-multipoint (FWA/BWA) and other

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18 Appendix 1, RALI FX-3 "*Microwave Fixed Services Frequency Coordination*".

19 The principal reference standard being Recommendation ITU-R F.746 "*Radio-frequency Channel Arrangements for Radio Relay Systems*".

20 ITU-R [F.YY] "*Frequency Arrangements Based on Frequency Blocks for Systems in the Fixed Services*", Doc. 9B/TEMP/98 (19 April 1999).

(eg. TOB) fixed systems used in a geographically contiguous area wide or cellular deployment. As an example, CEPT Recommendation 14-03[21] specifies (European harmonised) block allocations for point-to-multipoint (FWA) and ENG (TOB) services within the band 3400-3600 MHz. Block allocations are also discussed at §4.3.3 in conjunction with licensing matters.

2.6.2 System Performance Standards

The performance of digital terrestrial fixed services is generally associated with the criteria of error performance and availability. Simple definitions for these criteria are:

1. Availability refers to the probability of a long term outage where the service is unavailable to carry traffic. For example, an annual unavailability objective of 0.01% means that a link can be out of service for an aggregate period of up to 3153.6 seconds or just under1 hour per year without exceeding design performance objectives.

2. Error performance refers to short term disturbances where the link performance may be degraded but not to the extent of causing loss of traffic and contributions to unavailability.

For modern digital common carrier transport networks, performance and availability objectives are typically aligned with media independent ITU-T Recommendations[22] – ie. global standards applicable to both cable and wireless telecommunication transport networks. For analogue systems, noise performance and availability form the relevant reference criteria.

For many fixed services, in particular those operated by non-telecommunication carriers, system performance objectives may or may not be aligned to ITU-T telecommunication standards. As a rule, high link performance is associated with increased installation and maintenance costs, with high speed common carrier links representing the upper end of the market.

For radio based networks, error performance and availability are dependent upon factors such as equipment reliability (MTBF), interference and, in particular, propagation constraints (refer to § 2.8 "*Microwave Propagation*").

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[21] CEPT Recommendation 14-03 "*Harmonised Radiofrequency Channel Arrangements and Block Allocations for Low and Medium Capacity Systems in the Band 3400-3600 MHz*", Turku, 1996, Podebrady 1997.

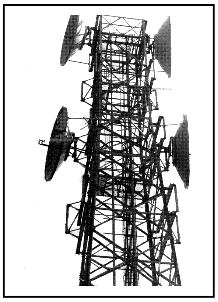
[22] ITU-T Recommendations G.821, G.826, G.827 and G.828.

2.6.3 Equipment Products

Equipment products for the Australian market are mainly sourced from other regions, although some local manufacturing and exporting takes place. European, North American and Japanese manufacturers, servicing global markets, dominate the range of available terrestrial fixed service equipment product. The capital cost of fixed service terminal equipment and other infrastructure hardware depends upon a range of factors, including frequency band and transmission capacity, with further differentiation in terms of reliability and network management options. In general, terminal equipment costs continue to fall, consistent with ongoing microwave hardware development and competition between global manufacturers. Further key cost factors include antennas and site infrastructure, discussed in the next section.

Note: For economic reasons, considering the size of the Australian market for radiocommunication products, it is generally desirable to align national fixed service arrangements with world market allocations and products.

2.6.4 Antennas, Support Structures and Other Plant



Microwave fixed network infrastructure costs are to a large degree influenced by the types of antennas and antenna support structures used. Parabolic ‘dish’ type antennas, between about 0.3 to 4 metres in diameter are prevalent. A physically large dish antenna has a higher gain and better interference characteristics than an otherwise equivalent smaller dish.

A significant infrastructure advantage, for fixed service systems operating below 3 GHz (ie. the 1.5, 1.8 and 2.1 GHz bands), is that economic ‘grid’ type parabolic antennas and coaxial feedline can be utilised.

For wavelength related physical reasons, options in the fixed bands above 3 GHz are confined to the (more expensive) solid dish antennas and waveguide feedline. By virtue of construction, a solid dish antenna is subject to much greater mechanical stress, due to wind pressure or ‘windloading’, requiring the use of support structures with greater strength and rigidity than that necessary with the open grid types.

<u>Trunk and regional</u> radio-relay systems generally employ dish antennas between about 1.8 to 4 metres diameter. In order to optimise system performance and in-band spectrum availability, the larger 3 and 4 metre antennas are more often deployed on high capacity intercapital routes. The mechanical stress on an antenna support structure is proportional to the antennas physical size (ie. diameter), the principal concern being wind loading (Figure 2.9).

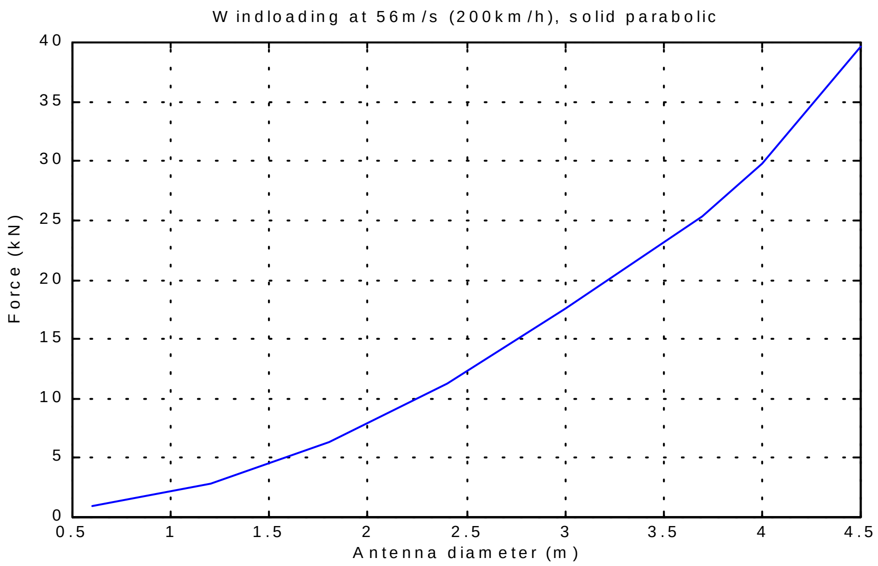


Figure 2.9 Antenna diameter vs estimated[23] windloading (solid parabolic)

Thus the need for rigid metal 'lattice' type towers at radio-relay system repeater stations with multiple antennas. The repeater stations, spaced (on average) between about 30-45 km apart[24] represent a major long term infrastructure investment commitment requiring something of the order of 20-25 stations per 1000km. Each station needs road access, mains power, security, building and standby diesel generator in addition to antennas, tower and radiocommunication equipment, not to mention emergency and ongoing routine maintenance arrangements commensurate with the availability requirements of the traffic being carried. In other words a significant infrastructure investment, comparable to the cost of fibre in cases where new sites need to be established.

Urban radio networks typically make use of smaller 0.3 to 1.2 metre antennas, depending upon the frequency band, the application and other case dependent constraints. The use of physically smaller antennas means that support structure demands are much more modest and less visually intrusive – an environmental consideration, especially important when dealing with councils, landlords and the general community. In the higher microwave bands used for short-hop links, modular radiocommunication equipment with integral antennas are a cost effective solution for many communication requirements, obviating the need for lossy RF feeder cables and separate transceiver/multiplexer arrangements. Metal lattice radio towers are also used in urban areas, particularly at major network nodes. Reinforced concrete poles of up to 25 metres in height are popular for cellular infrastructure networks and, quite often in CBD areas, antennas may be mounted on the roof or the side of a building. Other infrastructure requirements for urban point-to-point links are usually less problematic and modest in comparison to radio-relay systems, at least in terms of access, power availability and security.

[23]Fig. 3, §2.4, Design Studies in Engineering Report "*Analysing Fixed Service Antenna Performance Using Probabilistic Methods*", Erik S. Lensson, University of Canberra, November 1999.
[24] In the 3.8/6.7 GHz bands.

2.6.5 Planning Risks

Besides the purely economic business risks associated with all types of communication network planning, the radio network planner/operator also needs to deal with the following radiocommunication specific risk factors:

- *Spectrum access risk* – the risk that insufficient spectrum is available to meet the communication requirement. This risk is highly location dependent and in some cases may go unquantified until well into the planning phase when detailed system/network coordination takes place;

- *Environmental risks* – the establishment of most radiocommunication facilities involves the need to negotiate with landlords and to comply with town planning rules and guidelines. Furthermore, many people in the community hold strong concerns about the perceived health effects of electromagnetic radiation and the visual impact of radiocommunication facilities including antennas and antenna support structures.

These risks can have a crucial impact on an operator's ability to meet system commissioning commitments, involve a potential project cost blow-out or even totally jeopardise the success of a project. Accordingly, experienced planners endeavour to quantify spectrum availability and site constraints early in the planning process.

For designated telecommunication carriers and subject to certain conditions, the *Telecommunications (Low-Impact Facilities) Determination 1997* provides an expedient means to the deployment of telecommunication facilities. For example, designated carrier's point-to-point fixed links making use of small (1.2 metre or less in diameter) antennas qualify as 'low-impact' facilities and are exempted from the town planning process. This provision reduces risk and expedites the network rollout of designated carriers. However, the determination does not apply to the many non-carrier microwave fixed service users.

2.6.6 Regulatory Overhead

'Regulatory overhead', in the context of this document, refers to constraints placed on spectrum users by the need to conform with relevant regulatory standards and planning rules. Examples include the minimum performance antenna and path length criteria detailed in the RALI FX-3 for microwave fixed services operating in specific bands.

The ACA acknowledges that in some cases the rules may be inconvenient and that compliance can place additional costs on individual operators. However, as generally acknowledged by the spectrum user community, the rules are established as a reasonable balance between unnecessary spectrum denial and the cost of implementing services. Reviews are undertaken from time to time, normally in consultation with industry, to ensure that the rules remain in step with technology, spectrum sharing and other relevant requirements.

Further discussion on planning and coordination rules is detailed in §4.3.

2.6.7 Globalisation and 'Spectrum Vision'

The recent massive growth in telecommunications, the liberalisation of national and global telecommunication markets and the evolution of electronic communication technologies has prompted a renewed surge of interest in standardisation and radio/telecommunication standards activities. Although some individual economies have the scale to support arrangements geared to their own national interest, the global economy is largely driven by multinational and national companies whose business is increasingly aimed at global markets. Global or at least 'regional' standardisation is commensurate with market access and economies of scale in terms of the design, production and distribution of communication infrastructure and consumer equipment.

The recently adopted ITU-R Question (ITU-R 221/9*) "Spectrum Vision for the Fixed Service*" acknowledges the need for strategic guidance in anticipating the spectrum requirements of evolving point-to-point and wireless access fixed services and anticipates the development of a Recommendation addressing the following issues:

- *What are the spectrum requirements which permit the future evolution of the fixed service?;*
- *What methodologies are needed to identify the spectrum requirements, taking into account traffic-based calculations for FS applications, deployment scenarios, propagation considerations and sharing possibilities with other services?; and*
- *What are the appropriate time-frames that might be suitable for these spectrum requirements?.*

Such considerations are clearly relevant within the context of this paper and it should be noted that Australia is a participant in these current ITU studies. However, in order to respond with informed comment and to qualify any predictions, it is necessary to take stock of the current situation through a detailed review of Australia's own national microwave spectrum usage trends.

2.7 The Users of Fixed Services

As shown in Figure 2.11, the telecommunication carriers Telstra, C&W Optus and Vodafone are by far the largest operators of terrestrial (1.5-50 GHz) point-to-point radio networks, representing 53%, 11% and 9% of the population of current microwave fixed service licences.

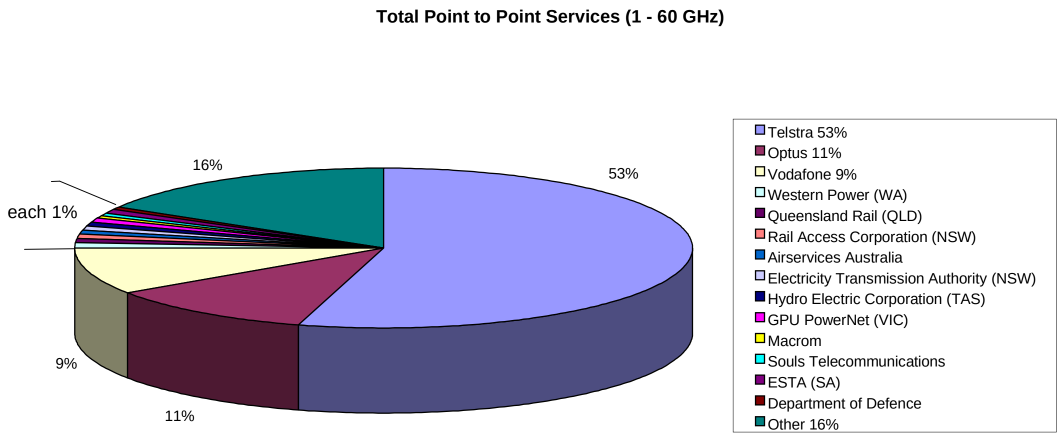


Figure 2.11 Users of fixed services (1.5-50 GHz) at August 1999[25]).

A further 11% represents new carriers and a range of government and non-government utilities, each with about 1% each of the total population of microwave fixed services. The remaining 16% include the remaining broad range of users.

2.8 Microwave Propagation

Microwave fixed services are sometimes referred to as ‘near’ Line-of-Sight (LOS) links in reference to the close relationship between microwave radio transmission and rayline optics (ie. light travels in a straight line). As any radiowave travels or ‘propagates’ its amplitude decreases as the distance from origin and the frequency of the signal increases (ie. greater loss equates to longer path and higher frequency). Furthermore, terrestrial transmissions, over distances of more than a few kilometres, are substantially affected by the presence of the earth, terrain and the (variable) geoclimatic conditions over the transmission path.

These propagation constraints are key factors in determining the single hop distances and transmission performance (see §2.6.2) that can be supported in the various frequency bands. Figure 2.12 provides a qualitative demonstration of the relationship between frequency and link path distances, based on the statistics of actual Australian fixed links.

[25] Based on RADCOM data, August 1999.

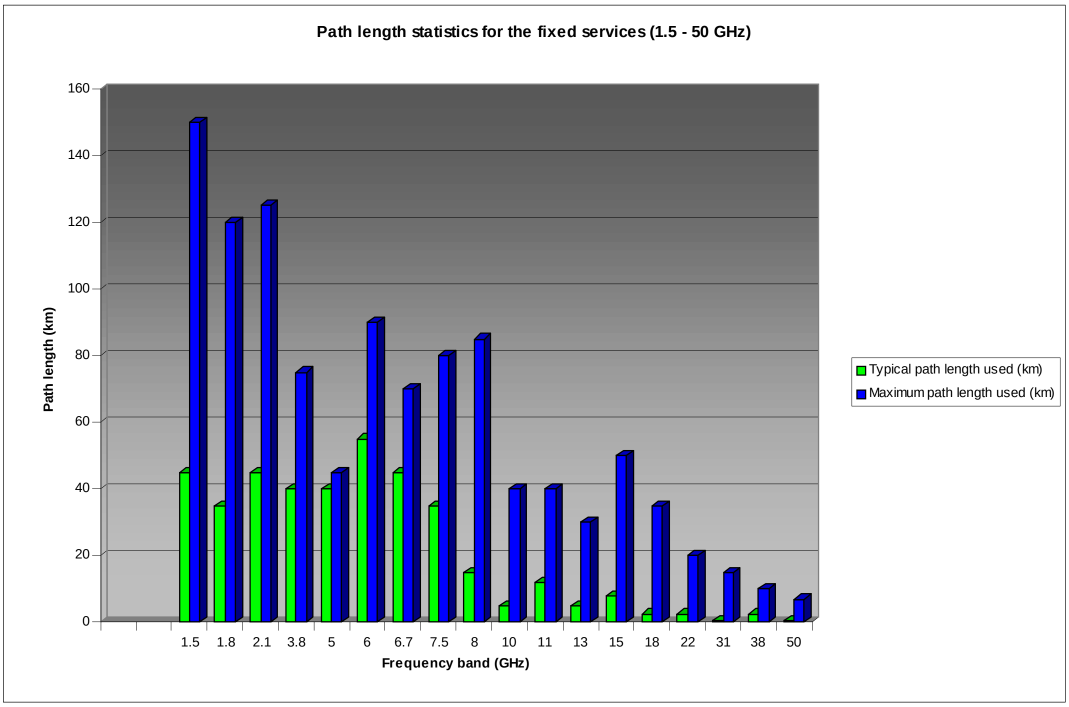


Figure 2.12 Microwave link path distance statistics[26] .

The bargraph shows the maximum (blue bars) and the typical (green bars) single hop path lengths for each frequency band. As expected, the maximum path length used decreases with frequency, with a significant discontinuity above vs below 10 GHz[27]. However, in considering individual links, the above frequency/distance statistics should not be considered in isolation of the range of other important limiting factors, including transmission bandwidth, link reliability and geographically unique terrain propagation and environmental variables – ie. requiring case-by-case consideration.

All radiocommunication systems incorporate a 'fade margin', to guard against signal loss and to minimise degradations due to time-varying transmission path disturbances. The fade margin represents the difference between normal received signal levels and the reduced level at which service quality begins to be significantly degraded. Given the performance requirements of fixed transport networks (see §2.6.2) and the relatively disturbance prone terrestrial propagation environment, fixed service fade margins are typically of the order of 30-50 dB, or more for links with particularly stringent performance requirements. In comparison, the necessary minimum fade margins of other radiocommunication services are orders of magnitude smaller – eg. 10-25 dB for satellite based services, which by their very nature avoid most of the disturbance prone lower atmosphere propagation environment.

The following subsections summarise the nature of terrestrial propagation in the microwave fixed bands, outlining the relationship between physical principles and their impact on fixed service communications.

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[26] Based on ACA RADCOM data for the 1.5 to 50 GHz bands, August 1999.

[27] The apparent anomaly at 5 GHz does not signify any particular problem at this frequency and is simply due to the small number of links operating in this band.

2.8.1 Frequency Bands 1 to 10 GHz

The lower microwave bands, between about 1 to 10 GHz, are preferred for many radiocommunication applications and they are well utilised for intercapital and regional transport networks. Further to the propagation advantage demonstrated by Figure 2.12, the radio technologies used in the lower bands are mature and relatively inexpensive, especially in the bands below 3 GHz and for which a wide variety of equipment product is available.

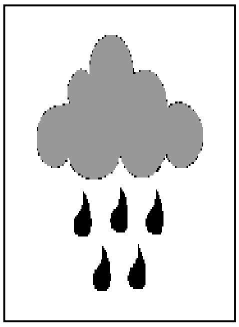
As demonstrated by Figure 2.12, the typical single hop communication distances in the 1.5 to 7.5 GHz bands are statistically of a similar order at around 40 km, suggesting this as the typical distance between stations of Australian trunk and regional radio-relay systems. As further demonstrated by Figure 2.12, the maximum path lengths are generally frequency dependent, but there are other constraints that must be taken into account in considering individual cases.

The principal propagation constraint at the lower end of the microwave spectrum is multipath fading, a complex time varying constructive/destructive self interference propagation mechanism that degrades link performance, especially over long paths and particular types of terrain (eg. bodies of water). The self interference is caused by reflection and refraction effects over the transmission paths, causing the wanted signal to be received via multiple paths, each arriving at slightly different times. Multipath fading is an important factor in determining link performance and achievable path length and to which the higher capacity wideband systems are particularly sensitive. For link planning purposes, fading probabilities are modelled using mathematical models, including ITU-R Recommendations[28] and other standard models.

From a network planning perspective, the achievable link path distance is a complex matter requiring consideration of the required communication distance, reliability performance objectives vs the probability of fading and system cost. In considering the relocation of terrestrial fixed services from the lower microwave bands, and particularly in the context of the 1.5, 1.8 and 2.1 GHz bands, the considerations of link path length, propagation and system performance are the crucial factors that set the limits for the range of possible options.

[28] An example of a commonly used model is ITU-R Recommendation P.530 “*Propagation Data and Prediction Methods Required for the Design of Terrestrial Line-of-Sight Systems*”.

2.8.2 Bands 10 to 40 GHz



As with the lower bands, the bands above 10 GHz are also subject to multipath fading. However, with increasing frequency, attenuation due to rainfall becomes a more important limiting factor, especially in areas of intense rainfall. Rain cells with high precipitation rates entering a propagation path cause a large increase in transmission loss for the duration of the passage of the cell, affecting link availability (see §2.6.2).

The net effect is smaller achievable hop length for a given link performance in comparison to the lower microwave bands. Thus the higher bands are unattractive for the communication needs requiring particularly long individual link paths, eg trunk and regional radio-relay systems and networks serving rural and remote areas. However, they are ideal for high bandwidth urban transport network and local access (ie. broadband wireless) applications . Channel re-use distances are significantly smaller in the higher bands, increasing their utility for service delivery in the high-density urban environment.

As with the multipath case, link performance is related to fading probabilities, which may be estimated using mathematical tools, including ITU-R standard models. For example, assuming that the 'per-hop' annual system outage due to adverse propagation lies within the range 0.01% (average system) to 0.001% (high grade system), we can estimate[29] whether a particular frequency band can reliably support communication over a particular link path distance (§2.13 & §2.14).

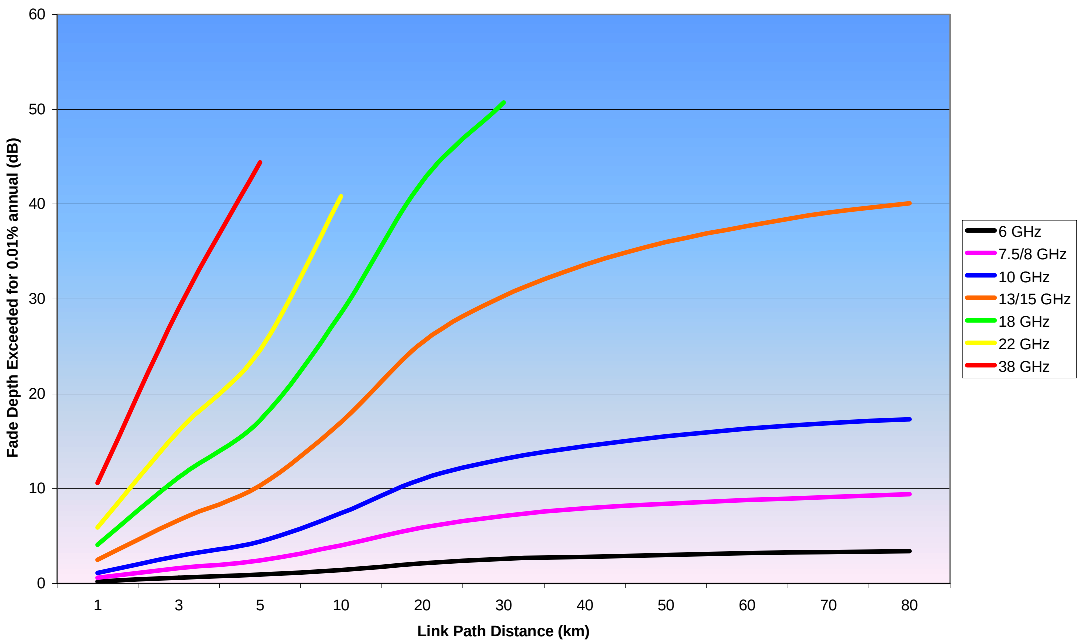


Figure 2.13 Fade depths exceeded for 0.01% annually, Sydney region.

[29]By applying the methods of ITU-R Recommendation P.530 "*Propagation Data and Prediction Methods Required for the Design of Terrestrial Line-of-Sight Systems*".

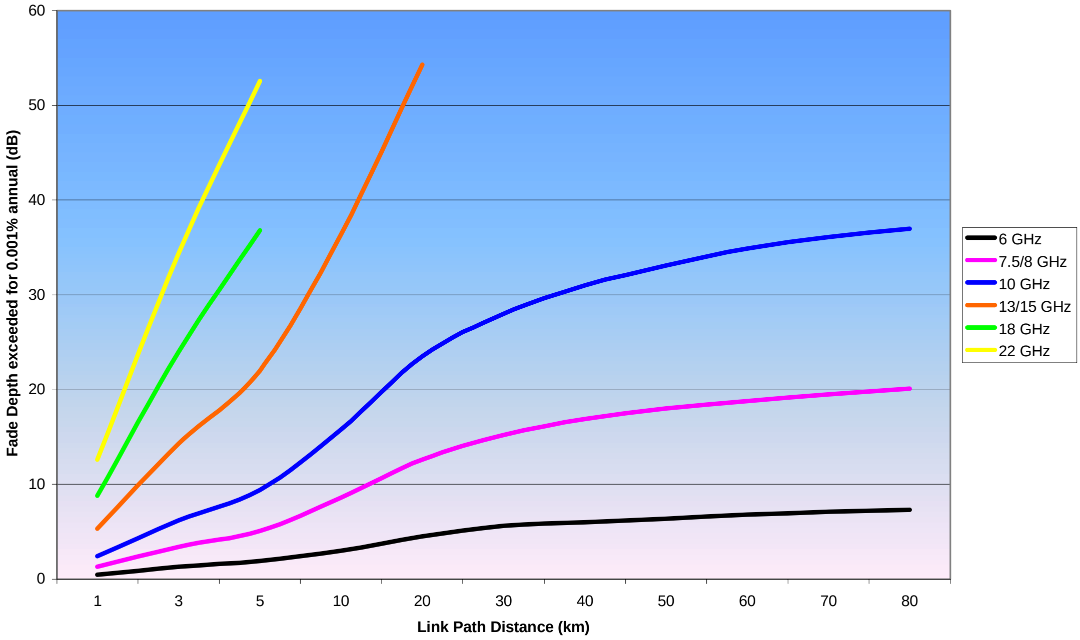


Figure 2.14 Fade depths exceeded for 0.001% annually, Sydney region.

Both statistical predictions are based on the use of horizontal polarisation (worst case) and a path inclination of 0° (the physical shape of raindrops means that vertically polarised signals are not affected as much as horizontal). The examples are for the Sydney region, with rain intensity of 40 mm/hr exceeded for 0.01% of the time annually[30]. Different sets of possibilities exist for other regions of Australia, with maximum rainfall intensities in the range 20-100$^+$ mm/hr.

A significant problem for link operators/planners and frequency assigners alike in using these rainfall attenuation prediction models is the lack of sufficiently accurate input data for rainfall intensities and Australian 'microclimates' in particular. Australia is a geographically large and climatically variable country and the generic contour data of Recommendation ITU-R P.837 (and current RALI FX-3) are too coarse for reliable link planning and optimum frequency coordination. The problem is exposed mainly as a consequence of the recent massive increase in demand for the use of the rain limited bands. Network carriers have worked around this problem by commissioning their own rainfall intensity studies and detailed geoclimatic information, but are understandably reluctant to share the information with competitors. The other operators, without access to microclimate data, are often averse to using the bands above 10 GHz or tend to adopt very conservative planning models in order to avoid what to them is at best a poorly quantified risk factor.

Consistent with recent discussions in Australian Radiocommunication Study Group 3 (ARSG3) on Radiowave Propagation, the development of a set of standardised geoclimatic and rainfall statistical information for Australian microclimates would remove many of the conservative anxieties associated with relocating fixed services and making better use of the spectrum in the bands above 10 GHz.

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[30] Rain intensity rates based on ITU-R Doc. 3/43(18 March 1999), Revision of ITU-R Recommendation P.837-1 "*Characteristics of Precipitation for Propagation Modelling*".

2.8.3 Above 40 GHz

The frequency bands above about 40 GHz represent a kind of 'frontier' in terrestrial fixed communications. At this time, only the 50 and the recently opened 58 GHz bands are being used in Australia. However, technology product development is well under way to further exploit these bands, including for high density, high bandwidth fixed service applications.

In addition to rainfall, these bands are subject to gaseous absorption which further reduces achievable communication path distances. In practice, maximum reliable communication distances range from several hundred metres up to a few kilometres. Nevertheless, this may be considered an advantage for some types of high density 'microcellular' applications, since potential interference signals are also quickly attenuated.

The relevant ITU-R propagation prediction models are given in Recommendations P.530 (point-to-point links), P.452 (interference paths) and P.1410[31] (broadband wireless access systems).

[31] *"Propagation Data and Prediction Methods Required for the Design of Terrestrial Broadband Millimetric Radio Access Systems Operating in a Frequency Range of about 20-50 GHz"*.

3. Spectrum Demand For New Services

This chapter looks at growth trends in existing fixed bands based on ACA licensing database statistics, the effects of the liberalisation of the telecommunication markets, competition issues and technology trends. Displacement issues in the 1-3 GHz bands are explored in detail, considering the bandwidth demands and spectrum access implications due to emerging fixed, mobile terrestrial and satellite based communication and broadcasting services.

3.1 Growth Trends in Existing FS Bands

Appendix 3 provides detailed statistics for each of the 1-60 GHz microwave fixed service bands currently supported in Australia, for the period 1993 through 1999. The statistics are based on assignment activity in the ACA's RADCOM database, reflecting spectrum usage trends and a 'snapshot' of usage at August 1999. A summary of the average growth rates (1994-1999) is provided in Figure 3.1.

Fixed Band	Average Growth Rates (% p.a.)		
	1 yr growth Jan99-Dec99	3 yr growth Jan97-Dec99	5 yr growth Jan95-Dec99
1.5 GHz	-5.08%	-0.24%	no data
1.5 DRCS	7.81%	2.99%	no data
1.8 GHz	-5.33%	-1.68%	0.77%
2.1 GHz	-0.87%	1.09%	2.29%
3.8 GHz	-0.62%	-4.63%	-4.74%
6 GHz	17.42%	1.61%	1.24%
6.7 GHz	5.39%	2.28%	-0.49%
7.5 GHz	8.99%	12.03%	16.92%
8 GHz	3.50%	2.65%	2.86%
10 GHz	12.77%	12.84%	25.56%
11 GHz	11.43%	8.26%	4.73%
13 GHz	41.97%	14.99%	10.14%
15 GHz	5.65%	5.68%	23.21%
18 GHz	27.89%	33.98%	39.29%
22 GHz	41.49%	27.12%	37.28%
50 GHz	0.00%	-16.47%	-12.23%
38 GHz	52.02%	65.92%	147.30%
5 GHz	-2.33%	88.15%	no data

Figure 3.1 Average annual assignment growth rates (1994-1998)[32]

The following subsections relate the growth trends to particular types of microwave fixed service applications.

[32] Note: Although the RADCOM statistics are generally indicative of growth in spectrum use and the number of links, they are based on assignment activity so care must be taken in interpreting the figures. Also, the 5 year growth figures for some bands (ie. < 10 GHz) may not be entirely reliable, due to SMIS/RADCOM database translation and (1995) consolidation of radiocommunication licence types.

3.1.1 Trunk

As discussed at § 2.3.1, radio-based long-haul transport networks are attractive to new carriers, particularly where seeking to quickly establish an interest in the high volume intercapital route traffic market. However, on many trunk routes and particularly over the high traffic volume intercapital routes, suitable long haul spectrum is in short supply – principally due to existing extensive utilisation (by Telstra) of the 'premium' 3.8 GHz (96%) and 6.7 GHz (92%) high capacity telecommunication bands. Existing trunk radio systems in these bands comprise mainly (N x 140Mb/s) PDH 'legacy' systems with new growth in (N x 155 Mb/s) SDH, though the importance of radio for high capacity intercapital transmission is likely to diminish (see § 3.2).

Given the high traffic volume and establishment costs of long haul radio infrastructure (see 2.7.3), spectrum utilisation over a high capacity trunk route implies that all the channels in a given frequency band are likely to be fully used. For example, the spectrum access records of any site on the Telstra Sydney-Melbourne trunk route will confirm that every go/return channel at 3.8 and 6.7 GHz is used – ie. on the high capacity trunk routes most in demand there is little likelihood of 'spare' channels being available in these bands. The two main options available to aspiring new high capacity trunk radio operators are:

i. *Establish a new trunk route, with sufficient geographic separation from the existing carriers trunk corridors to allow full re-use of 3.8 GHz and 6.7 GHz frequencies*; or

ii. *Seek bandwidth in alternative frequency bands over the existing trunk corridors and the use of established radiocommunication sites. This is an economically and operationally attractive option, since the route pioneering costs have already been absorbed by the existing operator(s) onto which equipment, antennas and new support structures (where needed) can be quickly deployed.*

Pioneering new trunk routes and radio-relay infrastructure is expensive and is likely to be dismissed by most prospective operators as uneconomic in comparison to the economics of laying optic fibre cable, with its massive transmission bandwidth advantage (§ 3.2). Supporting this view, entry into the trunk radio network market for the last few years since deregulation has been consistent with (ii), although in some cases existing alternative (ie. non-Telstra) sites and radio paths have been utilised, particularly at 6.7 GHz. Nevertheless, for most operators the remaining option is to seek alternative spectrum for use over the existing well utilised trunk radio transmission paths. Examples of bands suited for this purpose include:

1. The 5 GHz (4400-5000 MHz) band, a high capacity (40 MHz channelling) trunk band in use in many parts of the world, but allocated for defence purposes in the Australian Spectrum Plan. An arrangement with the Department of Defence, implemented in 1995, allowed non-defence users to access this band for long-haul radio relay systems, subject to certain conditions. However, due to escalation of demand (see Fig.3.1) and Defence concerns about meeting their own spectrum requirements the arrangement was discontinued in July 1998. Existing non-defence 5 GHz fixed services may continue to operate under the conditional

arrangement, but no new applications will be accepted – ie. this band is no longer an available option;

2. The arrangements in the 6.0 and 8.0 GHz bands. These arrangements, with 29 MHz channelling, were originally planned to accommodate medium capacity analogue and digital systems up to 34 Mb/s. However, following technological advances (eg. Trellis coding and higher order modulation schemes) digital radio products capable of supporting high capacity operation up to 155 Mb/s are now available and used in these bands. The principal drawback is that link performance will not be as robust as with an equivalent link using a simpler (ie. wider bandwidth) modulation scheme. A further limitation to using the 6 and 8 GHz bands for high capacity trunk networks is that the bands are already utilised for regional medium capacity systems, including analogue FDM FM systems for television aggregation, in many cases sharing infrastructure over parts of the existing high capacity trunk corridors. So trunk route corridor spectrum congestion exists in these bands as well, though not as widely as with the 3.8/6.7 GHz bands;

3. The 11 GHz band supports high capacity 40 MHz channelling and suitable radio equipment products are readily available from a range of major manufacturers. Some trunk route utilisation is evident as well as deployments of urban SDH ring networks. The principal limitation to trunk use in Australia is propagation, particularly in high rainfall regions (see § 2.8.2). In practice this means that, over the longer link path hops in high rainfall areas, the network availability performance typical of the 3.8 and 6.7 GHz bands are not realisable at 11 GHz without additional repeaters (ie. additional cost).

The statistics in Figure 3.1 indicate a negative growth rate for the 3.8 GHz high capacity band. The decline appears to result principally from Telstra's ongoing rationalisation of older analogue FDM FM legacy services, with analogue systems now accounting for 49% of services (was 62% in 1995).

The 6.7 GHz band population (now 85% digital, was 81% in 1995) continues to grow and consistent with ongoing interest from new carriers, Telstra usage now accounts for 92% (down from 99% in 1995) of all services in the band.

The 11 GHz band is experiencing strong recent growth, mainly by new Vodafone urban ring networks, but also other new operators. Telstra still accounts for 77% of all services (down from 92% in 1995).

The 3.8, 6.7 and 11 GHz bands, based on ITU-R standards, are the principal high capacity bands used in national and international long and medium haul high capacity networks worldwide. Other bands below 10 GHz can also be used for long-haul networks, but the arrangements in the 1.5, 1.8 and 7.5 GHz bands are optimised for small capacity regional and access network systems (discussed in the next section).

3.1.2 Regional

The recent DCITA discussion paper "*The National Bandwidth Inquiry*"[33], September 1999, concludes that many regional areas of Australia are poorly served for bandwidth, with most telecommunication bandwidth and service delivery competition concentrated around the low-risk, high volume urban markets. The fixed service assignment growth statistics of Figure 3.1 and Appendix 3 generally support this conclusion. Nevertheless, terrestrial radio based transport networks are an important element of service delivery to regional, rural and remote areas and are likely to remain so for the foreseeable future, in tandem with fibre transmission and satellite based solutions.

In the medium term, higher backbone bandwidth requirements are inevitable in regional and rural areas and for this purpose the upgrading and overlay extension of existing radio infrastructure is likely to remain an economically viable option for operators. Market demand is likely to be stimulated by the introduction of digital television and other regional broadcasting services. Nevertheless, in comparison to city and intercapital markets, current trunk backbone capacity demand in regional areas away from the high volume eastern seaboard intercapital routes is relatively modest. Accordingly, spectrum availability for regional high speed transport networks (ie. using the 3.8/6.7 & 11 GHz bands) is unlikely to be a significant development constraint, at least in the short to medium term.

The situation is different for medium and small capacity point-to-point radio services, due in part to the growth in cellular mobile and associated backhaul networks and particularly the developments and uncertainties now associated with the 1.5, 1.8 and 2.1 GHz frequency bands – see § 3.6.2 and the Appendices 4, 5 & 6. These bands have a longstanding association with regional and rural communication infrastructure, supporting a diverse range of telecommunication and non-telecommunication users. The bands support analogue and 0.7 – 34 Mb/s digital services with potentially long single hop (eg. 60 – 80 km without the need for special techniques[34]) and relatively cheap infrastructure in comparison to the bands above 3 GHz where infrastructure hardware costs are typically much higher (see § 2.7.3). For example, even at 7.5 GHz, comparable hop lengths are not achievable or require expensive special measures.

In addition to accommodating extended populations of existing point-to-point services and growing demand for regional cellular backhaul and other telecommunication network applications, the 6.0, 7.5 and 8.0 GHz bands are under pressure from the need to relocate small and medium capacity links from the 1-3 GHz bands. Although many of the anticipated relocations may be accommodated in the higher frequency fixed bands, a proportion will not be viable in the bands above 10 GHz. Further discussion on the matters relating to relocation is provided at § 4.2.

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33 A Department of Communications, Information Technology and the Arts (DCITA) study into the likely availability and price of bandwidth in Australia over the next five years – see http://www.noie.gov.au/bandtask/bandwidt.htm.

34 Eg. Frequency and/or Space Diversity, requiring extra RF hardware at significant additional cost.

3.1.3 Urban

As evident from ACA RADCOM licensing database statistics (Appendix 3), the growth and demand for urban fixed radio transport networks continues. The principal driver is telecommunication liberalisation, with many existing and new operators building and upgrading fixed transport networks in the commercially attractive urban markets. Microwave fixed point-to-point applications include cellular system backhaul, hybrid fibre/radio architecture ring networks and general transport network infrastructure.

The demand for urban fixed services will undoubtedly continue, driven by telecommunication competition and in support of the quest for the diverse range of emerging value-added communication products. Consistent with the trend towards higher transmission speeds and emergence of demand for higher capacities in the local loop (with end delivery by wire or wireless means), it is reasonable to conclude that the trend will be reflected in the demand patterns for microwave fixed services – ie. in order to provide more user bandwidth in the local loop, higher transmission capacities will be needed for all manner of feeder network links.

Whilst fibre has an unrivalled bandwidth advantage, radio transmission will remain an important transmission network element, especially at the ‘thinner’ end of transport networks where economic and other practical difficulties preclude the use of fibre.

Considering the statistics (Figure 3.1 and Appendix 3) for urban microwave fixed services, double-digit growth rates in most of the (>10 GHz) urban bands confirm the demand for and importance of microwave radio in delivering services and facilitating competition. In contrast to the lower microwave bands, where Telstra is by far the dominant fixed link spectrum user, most of the growth in the higher microwave bands reflects the activities of new carriers in mainly the urban markets. The following comments provide a brief background to the bands principally used in urban areas[35].

1. The 7.5 GHz band was restructured in 1992 in anticipation of demand resulting from changes in the 1-3 GHz bands and the introduction of telecommunication competition. It provides a number of channel rasters suitable for low to medium capacity (2-34 Mb/s) digital links. With hop lengths comparable to those achievable in the 1-3 GHz bands, it is effectively the first choice for replacing the services being displaced from the lower 1-3 GHz bands. Although experiencing strong growth over many years and with some operators claiming that the band is ‘full’, it is evident that further scope remains to accommodate new and relocated services – (see §4.1.5).

2. The 10 GHz band accommodates small capacity digital (2-8 Mb/s) and analogue (principally FM video) link services, used for a range of telecommunication and non telecommunication purposes. Vodafone is the largest single user at 43%, followed by Telstra (7%). Scope remains for further assignment growth, though some congestion is evident at major CBD locations.

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[35] The 31 GHz band is no longer available for apparatus licensed fixed services, since it was auctioned for LMDS applications in early 1999.

3. The 11 GHz band supports channelling suitable for high capacity trunk and urban network applications. Due to susceptibility to rain outage, trunk usage in Australia is limited and operators prefer the lower frequency high capacity bands at 3.8 and 6.7 GHz for long haul applications. Nevertheless, the band is well suited to high capacity applications in the urban environment and scope exists to accommodate urban and regional links with achievable link paths up to about 40 km. Some uncertainties exists with respect to sharing with (itinerant) NGSO earth stations - (see §3.6.3.1).

4. The 13 GHz band arrangements are shared between point-to-point fixed and itinerant TOB services. The sharing and access arrangements are sub-optimal for point-to-point applications and this is reflected in the usage & growth statistics. Only two of the eight channels are available for point-to-point use in urban areas. The remaining channels are used by the network broadcasters for TOB services. Scope exist for rationalising the use of the band with a view to improved utilisation (see §4.1.7).

5. The 15 GHz band provides multiple channel rasters, accommodating small to medium capacity digital link services up to 34 Mb/s. Assignment growth is tapering off and capacity to support new services is demonstrably limited at some high density locations (eg. some areas of Sydney). The principal users include Optus (46%) and Vodafone (22%), mainly for GSM backhaul applications.

6. The 18 GHz band was restructured in 1996, to take account of (WRC-95) allocations and ITU sharing studies between fixed vs NGSO fixed satellite services. Interim arrangements based on ITU-R Recommendation F.595 provide multiple channelling options accommodating the range of system capacities between 2 to 155 Mb/s. The band is experiencing strong assignment growth, but at this time uncertainties remain concerning the future access to large parts of the band due to potential interference from fixed services into itinerant NGSO earth stations (see §3.6.3.1).

7. The 22 GHz band provides a range of channellings suitable for 2-34 Mb/s digital and analogue TOB services in 50 MHz channels. Assignment growth indicates strong ongoing demand for capacity in this band. The 50 MHz channels are shared between point-to-point fixed and itinerant TOB services and they are also subject to uncertainties associated with the (WARC-92) allocation to the broadcasting-satellite service (BSS) - (see §3.6.3.2).

8. The 38 GHz band provides channelling up to 28 MHz and is extensively utilised by new carrier backbone networks in urban areas (eg. GSM backhaul). As shown in Figure 3.1, assignment growth exceeds 50% per annum, even though link path lengths are limited by propagation to something less than about 3-5km. Allocations to NGSO FSS may require consideration of the potential for interference from fixed service stations into itinerant (future) NGSO earth stations -(see §3.6.3.1).

9. The 58 GHz band was introduced in May 1999, with channelling based on ITU-R Recommendation F.1100. The arrangements provide for ten channels employing

time-division duplexing (TDD) and self coordination by users. The licensing arrangements allow operation on any of the ten channels on a no interference/no protection basis. Given that the arrangements have only just been implemented, no statistical information is available for this report.

3.1.4 Fixed Wireless Access

As outlined in §2.4, there are many types of fixed wireless access (local loop) systems, ranging from low density rural telephony systems operating over individual subscriber path lengths in excess of 60 km (in the 500/1500 MHz bands), through to high density broadband access systems providing voice, high speed data and video, limited by propagation (in the 20 to 40 GHz bands) to paths of the order of 3 to 5 km. The market demand for FWA spectrum is ultimately decided by the economic viability of FWA services, in turn determined by a balance of technical constraints and population demographics.

Fixed wireless access is characterised by the cellular nature of the point-to-multipoint systems used, sharing many similarities with mobile technologies. A key difference is that the network & MSC overhead necessary to maintain location, handovers and roaming is eliminated. FWA cell sizes are to a large degree determined by achievable grade of service vs propagation constraints. Technically, the principal parameters are system gain[36] vs distance, frequency and bandwidth and of course traffic density is also an important consideration. The parameters set an approximate upper limit to the achievable cell sizes in each particular frequency band. Practical cell sizes depend on the detailed choice of service reliability, the equipment and antennas used (ie. practical limits of system gain). Indicative cell sizes for several current technologies are shown in Table 3.1.

Band (GHz)	Cell Radius (km)	Area (km^2)	Use	Data speed
1.5	*60*	*11309.7*	*Rural & Remote PSTN access*	*2.4..28kb/s*
3.4	*20*	*1256.6*	*Urban/Regional PSTN access*	*64kb/s*
28/31	*5*	*78.5*	*Broadband Access*	*10-155Mb/s*

Table 3.1 Comparison of current FWA systems

The figures in Table 3.1 are approximate and based on particular technologies. Nevertheless, they are indicative of the practical tradeoff between cell radius distances vs deployment density/achievable access speeds. In order to gain access to large transmission speeds and bandwidth, high frequencies must be used. Because the use of high frequencies limits transmission distance, it is necessary to cellularise. This obligation imposes infrastructure costs that in turn requires a threshold customer density to be exceeded before deployment becomes economically viable. The identification of those density threshold values is something that the operator needs to take into account and will not be considered further here.

As mentioned at § 2.4.3, a current issue for the ACA is the identification and allocation of further spectrum for broadband wireless services in response to further market demand following the sale of the 28/31 GHz bands to AAPT in early 1999.

[36] ie. System transmit power, antenna gain and receiver sensitivity.

The bands above about 20 GHz provide the bandwidths necessary for high density BWA deployment, but the critical limiting factor on cell size is rain attenuation (§2.8.2). As demonstrated by Figure 3.2, comparing fade margins in the 26, 31 and 40 GHz bands against path distance (ie. cell radius), achievable cell sizes in the higher microwave bands are sensitive to both frequency and antenna polarisation.

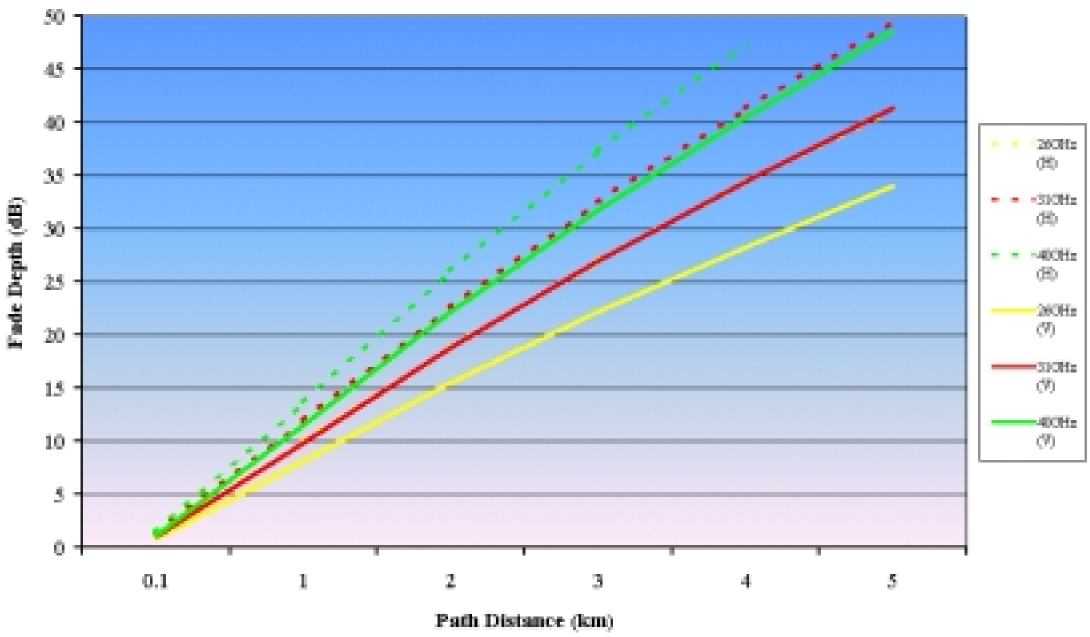

Figure 3.2 Distance vs likely fade depth due to rain attenuation (Target availability = 99.995%, R=40 mm/hr[37])

The graph compares the approximate path (cell radius) distances achievable in the 26 to 40 GHz BWA candidate bands for an assumed annual service reliability (limited by rain attenuation) of 99.995% and a maximum rainfall intensity of 40 mm/hr (ie. the Sydney region)[38]. Typical BWA systems have margins of the order of 20 to 40 dB (perhaps more using ATPC[39]). The Figure 3.2 single path approximation confirms that cell radius distances at 40 GHz will be about 20% shorter than at 26 GHz, equating to an effective service area differential of about 35%. Accordingly, it is easy to understand prospective BWA operator's preference for allocations around 26 GHz vs the higher (up to 40 GHz) bands. Nevertheless, infrastructure costs are likely to fall significantly as markets mature and >30 GHz BWA products appear from the volume markets of Europe and North America. European harmonisation (§3.1.4.3) and the large (3.5 GHz contiguous) amount of potentially available spectrum at 40 GHz should attract market attention.

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[37] A one-dimensional approximation derived using ITU-R Recommendation P.530-7 "*Propagation Data and Prediction Methods Required for the Design of Terrestrial Line-of-Sight Systems*".

[38] Other Australian climatic regions with different rainfall rates (eg. Melbourne 30 mm/hr, Brisbane 50 mm/hr) will have slightly different constraints. 40 mm/hr is a representative average for most of the capital cities, excluding Darwin at 100 mm/hr+. Similarly, less stringent availability criteria will extend the achievable cell radius distances, but 99.995% may be considered representative 'average'.

[39] Adaptive Transmit Power Control, boosting transmit power during periods of heavy fading.

As detailed at § 2.4, the price-based allocation of 3.4 GHz FWA spectrum is anticipated during 2000. BWA auctions are also likely to take place during the year 2000. In accordance with a recent ACA discussion paper[40], three mutually exclusive options are under consideration for BWA services through spectrum licensing:

3.1.4.1 "The 24/26 GHz bands"

The ACA's first preference is to designate the bands 24.25-24.5 and 26.5-27.5 GHz ("the 24/26 GHz") bands for spectrum licensing. As well as satisfying market demand for BWA spectrum, this option provides for the proposed (see §4.1.9) implementation in Australia of the European harmonised 26 GHz point-to-point arrangements, facilitating the ready availability of a range of suitable radio products for the fixed services.

However, the band 25.25-27.5 GHz is also allocated to the INTER-SATELLITE service (ISS) on a co-primary basis and ITU-R sharing studies between the ISS and (LMDS type) BWA services by the Joint Rapporteur Group 7D-9D (JRG 7D-9D) are still pending finalisation. Nevertheless, proponents of the fixed service (LMDS) and space science services (ISS) have completed the joint studies and there is agreement on the levels of interference from LMDS systems. As detailed in a draft new recommendation[41] developed by the Jan/Feb 2000 (Orlando, Florida) meeting of the JRG, the preferred regulatory approach is to limit the e.i.r.p. spectral density of each (LMDS) hub station.

For emissions in the direction of specified (ISS satellite) GSO locations the JRG agreed e.i.r.p. limits are:

a) *+8* *dBW per MHz, for elevation angles* $0° < \theta \le 20°$;
b) *+14-10log(θ/5)* *dBW per MHz, for elevation angles* $20° < \theta \le 90°$.

Otherwise (ie. for emissions away from the ISS satellite locations), the limits are:

c) *+14* *dBW per MHz, for elevation angles* $0° < \theta \le 5°$;
d) *+14-10log(θ/5)* *dBW per MHz, for elevation angles* $5° < \theta \le 90°$.

For elevation angles below the local horizon, the limits default to Article S.21 of the ITU Radio Regulations.

In addition, during rain induced fade conditions, the hub stations may use adaptive transmit power control to increase transmit power as long as the e.i.r.p. spectral density in the direction of the specified ISS satellite GSO locations does not exceed +17 dBW per MHz.

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40 "*Proposal for Allocating Radiofrequency Spectrum for Broadband Wireless Access (BWA) above 20 GHz – Invitation to Comment*", 7 December 1999, see http://203.37.2.230/Broadband/discpaper.pdf .

41 Doc 7D-9D/TEMP/18(Rev.1, 2 February 2000) "*Technical and Operational Requirements that Facilitate Sharing Between Point-to-Multipoint Systems in the Fixed Service and the Inter-satellite Service in the Band 25.25-27.5 GHz*".

As far as the LMDS outstations are concerned, Recommendation ITU-R F.1249[42] defines the relevant e.i.r.p. limits and GSO orbit avoidance criteria (see also §2.1 of Appendix 5 "*Geostationary Satellite Orbit Avoidance*", RALI FX-3).

The ACA is of the view that the e.i.r.p. limits and orbit avoidance criteria developed by the JRG 7D-9D are reasonable and manageable through the application of sectoral LMDS hub station antennas and sensible planning. Although the draft recommendation is yet to be approved by the relevant (SG9/SG7) ITU-R study groups and member administrations, it is likely to be endorsed and approved in its current form later this (2000) year. The ACA invites comment on the proposed sharing arrangements between the FS and ISS in the 25.25-27.5 GHz band.

3.1.4.2 "The 24 GHz band"

An alternative option for BWA spectrum is the band 24.25 - 25.25 GHz, outside of the 25.25 - 27.5 GHz band associated with ISS sharing uncertainties. However, as outlined in the discussion paper, the ACA would only pursue this option if it was fully satisfied that the adoption of this option would not jeopardise the feasibility of introducing an apparatus licensed point-to-point channel plan in the adjacent band (see §4.1.9).

3.1.4.3 "The 40 GHz band"

A further option is the use of the band 40-43.5 GHz, consistent with the European harmonised allocation detailed in ERC Decision (CEPT/ERC/DEC(99)15)[43], "*Designation of the harmonised frequency band 40.5 to 43.5 GHz for the introduction of Multimedia Wireless Systems (MWS) including Multipoint Video Distribution Systems (MVDS)*", Dublin, 1 June 1999. As discussed above (§3.1.4), the 40 GHz option requires denser infrastructure due to increased rain outage in comparison to the 26 & 28 GHz bands. However, the relatively large (3.5 GHz) amount of contiguous spectrum, anticipated mass market in suitable radio products and the avoidance of the likely hub station e.i.r.p. constraints of the 24/26 GHz option (due to the need to share with ISS – see §3.1.4.1) are the attractive features of this option.

For the latest on the proposed BWA spectrum auction, see http://203.37.2.230/Broadband/future.htm . For general information on spectrum auctions and further bands likely subject to future price based allocation, refer to §3.3.

3.1.5 Rural and Remote Area Access Services

At this time, rural and remote area telecommunication customers continue to be at a significant disadvantage in comparison to those living in urban areas. As outlined at §2.4.1, terrestrial delivery by way of the Telstra DRCS operating in the 500 and 1500 MHz bands is the principal current access network delivery method over large areas of Australia. The early 1980's "first generation" DRCS was dimensioned for telephony

[42] ITU-R Recommendation F.1249 "*Maximum Equivalent Isotropically Radiated Power of Transmitting Stations in the Fixed Service Operating in the Frequency Band 25.25-27.5 GHz Shared with the Inter-Satellite Service*".

[43] See http://www.ero.dk .

only traffic and did not anticipate the escalation of demand for data bandwidth and in particular the emergence of the Internet.

As mentioned in "*Telstra's Universal Service Plan*"[44], a traffic capacity and service quality upgrade of the Telstra DRCS network is currently underway, with the first generation DRCS equipment being replaced with newer High Capacity Radio Concentrator (HCRC) equipment. The network upgrade provides for significantly improved trunking capacity for voice, with support for much higher data speeds (see Table 3.2) - though still short of the speeds available to most urban PSTN users. Third generation (HCRC+) equipment is also under consideration, providing further improvements in data capability.

Type	Trunks	Voice	Data
DRCS	*16*	*yes*	*2.4 kb/s*
HCRC	*30*	*yes*	*19.2 kb/s*
HCRC+	*30*	*yes*	*28.8 kb/s*

Table 3.2. Comparison of Rural & Remote Area FRA technologies

Satellite-based communication systems are becoming a viable consumer bandwidth delivery method, with significant implications in terms of the future supply of broadband telecommunication services to rural and remote areas. Some GSO satellite operators are already providing satellite based one way (service provider to customer) high speed internet services, potentially available on an Australia wide basis. The return channel is provided through a normal low speed PSTN line. At this time, user costs for satellite internet services are relatively high and considered a premium service. The planned future introduction of LEO & MEO telecommunication satellite networks is likely to stimulate competition, with consequent effect on tariffs. Nevertheless, terrestrial (ie. existing 500 MHz & 1500 MHz FWA) services are likely to continue to dominate rural and remote access delivery for some time.

In considering the relevant spectrum issues, it is noted that the existing DRCS deployment (see Fig. 2.5) represents for the most part a mature fixed network. The current (HCRC) upgrading is consistent with the existing allocations and DRCS channelling and no further significant network growth or additional spectrum demand is anticipated for these services. However, (as detailed at §3.6.2) part of the 1427-1535 MHz DRCS band is affected by the WARC-92 allocations to the Broadcasting and Broadcasting Satellite Service (Sound) – ie. L-band (1452-1492 MHz) Digital Radio Broadcasting (DRB).

Nevertheless, given the inherent geographic separation between (the principally) rural and remote area DRCS and anticipated primary DRB service areas, it is likely that most DRCS services will remain largely unaffected, at least in the medium term.

DRB and 1.5 GHz spectrum issues are further discussed under §3.6.2 and Appendix 6.

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[44] See http://www.telstra.com.au/corporate/docs/uso/new/ (@September 1999).

3.2 Transport Network Technology Trends

Beyond market liberalisation, undoubtedly the single most influential driver for telecommunication services is the ongoing development of digital technology. As well as the introduction of new cellular mobile and satellite based communication technologies, a range of new and evolving terrestrial microwave fixed applications are emerging. This section looks at the new and existing fixed service applications, summarising emerging trends as they appear at this time.

'Transport networks' include trunk and regional and urban telecommunication transmission networks providing bulk transmission on a point-to-point basis, comprising cable, optic fibre and radio infrastructure. The current Australian radio based transport network infrastructure is based on a mixture of digital PDH and analogue 'legacy system' technologies, but with an increasing proportion of new digital systems using SDH/SONET standard protocols. This new generation of fixed service radio equipment provides for standardised vendor independent interfaces, integrated network management (TMN) and simplified connectivity between the high speed backbone and lower speed tributary streams.

Regardless of the type of transmission media (ie. cable or radio), there is no doubt that the overall system capacities of all transport networks are heading upward. As detailed in the DCITA "*The National Bandwidth Inquiry*" discussion paper, the driving forces are voice communications, Internet access, corporate networking, business communications, e-commerce, collaborative working and video services.

For long-haul high capacity applications, optic fibre enjoys a strategic advantage over radio network solutions in terms of available bandwidth. For example, a current 6.7 GHz Australian intercapital trunk radio route when fully loaded (assuming 8×140 Mb/s) has a gross transmission capacity of just over 1 Gb/s. Even if state-of-the-art high order transmission equipment and optimisation techniques (eg. 8×155 Mb/s SDH systems, using 1024 TCM, CCCP & ATPC[45]) were able to be deployed over the whole route, gross transport capacity could not exceed about 5 Gb/s. By contrast, a single mode fibre carries 2.5 Gb/s (STM-16) or with current Wave Division Multiplexing[46] (WDM) technology 40 Gb/s (16*STM-16). In the medium term, 'dense' WDM technologies are anticipated to extend the gross capacity of a fibre to beyond 1000 Gb/s. In accordance with the preliminary findings of the DCITA National Bandwidth Inquiry discussion paper:

- *"Oversupply of capacity is a characteristic of the backbone network within Australia. There is significant surplus of spare, or potential capacity terminating in all the population centres reviewed in this report which could be commissioned at relatively low marginal cost...";*

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45 Trellis Code Modulation (TCM), Co-channel Cross Polar (CCCP) and Adaptive Transmit Power Control (ATPC) techniques.

46 "*Reconstructing Transmission Networks Using ATM and DWDM*", Andrew G. Malis, IEEE Communications, June 1999, pp140.145 and "*The Evolution of a Reliable Transport Network*", Dave Johnson, Nigel Hayman and Paul Veitch, British Telecom Laboratories, IEEE Communications, August 1999, pp 52..57.

- *"The potential capacity exceeds the installed capacity by between 100 and 100000 times...*"; and
- "*Unit prices of bandwidth in the wholesale market will continue to decline by up to 30 to 50 % per annum over the study period* (ie. 5 years) *in capital city and thick route markets, but by less in regional and rural markets*".

So for high capacity intercapital and many other trunk applications requiring transmission capacities exceeding about STM-1 (155 Mb/s), the use of fibre is likely to be more cost effective. In essence, we can conclude that the overall emphasis for radio is moving away from trunk capacity towards the local network and the thinner transport networks where the deployment of radio remains competitive.

Consistent with the demand for higher capacities in the local loop, we can anticipate higher transmission rates and demand for more bandwidth in the telecommunication cell based mobile and fixed local network, other point-to-point local and regional feeder transport networks. In many cases, the local loop (eg. WLL/BWA) will be wireless as well as the thinner portions of backhaul and service networks.
These trends are already clearly evident in the demand for SDH radio in urban areas, in Australia and overseas[47].

3.3 ACA's Program of Future Spectrum Auctions

In April 1998 the ACA released a discussion paper, setting out preliminary views on possible bands for future spectrum auctions. The ACA received a range of responses to the paper, concerning issues such as the role of auctioning as an allocation method, the criteria which should be used to determine whether or not to auction a particular band and the desirability or otherwise of auctioning specific bands.

The document "*Program of Future Spectrum Auctions*"[48], March 1999 (updated annually), outlines the ACA's program of future spectrum auctions, providing a useful information about frequency bands likely to be subject to price-based allocation and the rationale used to determine which parts of the spectrum should be subject to price-based allocation. The document does not replace the detailed consultative processes under the Radiocommunications Act, as stakeholders and interested parties must be consulted before any final decisions are made to auction a band.

3.4 Telecommunication Competition

In addition to the displacement of fixed services from several frequency bands and the need to find suitable spectrum for the displaced incumbents, telecommunication competition and consequent infrastructure duplication places additional demands on the availability of spectrum for microwave fixed services.

As anticipated by the 1996 SMA information paper "*Spectrum Management Issues Relevant to Telecommunications*", the demand for new services and at least the initial

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47 "*SDH Radio Relay in Access Networks*", Ingvar Henne NERA, Global Communications Asia 1999.
48 Up-to-date copy obtainable from http://203.37.2.230/Future/future_plans.htm.

operations of new telecommunication carriers are, for commercial reasons, concentrated around the areas where spectrum availability for new fixed link services is already a concern. The growth figures (Appendix 3) for CBD and urban point-to-point fixed services confirm the role of microwave radio as an economically competitive (rapid roll-out, low cost deployment in the range 2-155 Mb/s) network element, complementing optic fibre and satellite based communication infrastructure. Wireless access delivery is also an area anticipated to make significant contributions to the competitive delivery of services such as high speed internet, video-on-demand and other broadband value added services (§3.1.4).

Whilst optic fibre promises virtually unlimited bandwidth, it requires the establishment of a 'right-of-way' with physical security. High deployment costs means that its economic competitiveness is not established until the required transmission capacity exceeds about STM-1 (155 Mb/s). In terms of telecommunication competition, the ownership of extensive broadband fibre networks in Australia is limited to a few large players (§3.2). Demand exists for access to trunk radio spectrum, but principally involving infrastructure duplication over existing high-volume trunk routes, hence spectrum availability is a problem (§3.1.1). In the medium to long term, demand for intercapital trunk radio spectrum is likely to diminish in line with anticipated tariff reductions on backbone routes. However, capacity demand over regional trunk and rural distribution networks is likely to require access to high capacity spectrum.

Satellite based transmission offers the unique advantage of ubiquitous coverage, but end-user bandwidth is generally limited[49] to about 2-10 Mb/s. Frequency channel re-use on a geographic basis is also limited by antenna directivity.

In contrast to urban areas, the growth figures for regional radio infrastructure indicate relatively static spectrum demand. This should not be overly surprising, given that most of the competition for telecommunication services is concentrated around low risk, high volume CBD and capital city areas. Terrestrial radio is likely to remain an important element of service delivery in regional, rural and remote areas (§3.1.2), although broadband (NGSO FSS in particular) platforms are anticipated to expand options, particularly for high speed access.

In conclusion, telecommunication competition places significant demands on the radiofrequency spectrum, demonstrated through recent growth, but principally confined to city areas. By contrast, evidence on the effects of telecommunication competition in regional areas is modest. Some growth is evident for radio-based intercapital trunk capacity, but anticipated tariff reductions are likely to reduce demand over the high volume routes.

3.5 GMPCS Satellite Based Access Technologies

Global Mobile Personal Communications by Satellite (GMPCS) is defined by the GMPCS MoU[50] as "*Any satellite system (that is, fixed or mobile, broadband or*

[49]"*Fixed Service Trends – Post 1998*", May 1998, European Radiocommunications Office, p.14.

narrow-band, global or regional, geostationary or non-geostationary, existing or planned) providing telecommunication services directly to end users from a constellation of satellites". In effect the MoU applies to any satellite system providing direct local loop access and provides for customers to be able to roam between countries with their terminals/handsets without having to produce a licence or to get a specific licence or type approval for each country.

Many existing GMPCS telecommunication services utilise frequencies within the 1-3 GHz range and more are planned higher in the microwave region of the spectrum, including broadband LEO (NGSO FSS) systems at 11, 18 and 38 GHz. Due to their itinerant nature and the high risk of mutual interference, many GMPCS services are unable to share spectrum with existing fixed services. In practice this means the potential displacement of existing fixed services and/or constraints on their future deployment. Displacement issues, including the implications of particular GMPCS allocations are discussed in the next section.

3.6 Displacement Issues

As discussed in §3.1, at the same time as demand for fixed services is accelerating, new services are being introduced that require access to spectrum already in use for microwave fixed services. In some cases, the new services may successfully share spectrum with the existing service, perhaps with some constraints, but in other cases sharing is not feasible and it is necessary to make a value judgement about which service is to be supported in the longer term. This leads to the problem of what to do about the incumbent services, usually terrestrial fixed services.

This section looks at the GMPCS, mobile and other new services in frequency bands where fixed services are being displaced.

3.6.1 Asymmetry of allocations

The great majority of fixed services are full-duplex, with discrete frequencies used for each direction of communication. As shown in §2.6.1, frequencies are normally channellised into mated channel pairs from two separate blocks of ‘go’ and ‘return’ channels.

The allocations to new services (whether homogenous or paired blocks) rarely (so far never) align with the channel pair blocks of the existing fixed services. So we end up with situations where the new service allocation impacts unequally on the spectrum blocks used by the existing fixed services. Figure 3.3 in the next section demonstrates the asymmetric relationships between new PCS and existing 1.8 GHz (ITU Rec. 283) & 2.1 GHz (ITU Rec.382) fixed service allocations.

Accordingly, although the impact of a new allocation may only extend to parts of an existing fixed service band, the (generally) duplex nature of fixed services means that spectrum in the paired channel block also becomes unusable – ie. a 100 MHz

[50] GMPCS Memorandum of Understanding, an international agreement, to which Australia is a signatory – see http://www.itu.int/GMPCS/gmpcs-mou/ .

allocation out of the channel block of an existing fixed band effectively precludes access for up to 200 MHz of valuable spectrum. These spectrum blocks effectively become the 'off-cuts' of the re-allocation process. Examples of such cases are illustrated in the subsequent sections.

3.6.2 The Lower (1 to 3 GHz) Bands

The lower (1.5, 1.8 and 2.1 GHz) microwave bands have been utilised for a variety of long haul, low to medium capacity analogue and digital link applications for many years, with relatively low infrastructure costs. However, the use of these lower bands is affected by the spectrum demand for other new services; including the allocations made in recent years in support of:

- broadcasting and broadcasting-satellite services (ie., DRB and BSS);
- GMPCS and other mobile satellite services (MSS); and
- personal communication services (PCS) such as DECT and DCS1800, and the designation of spectrum from the year 2000 for IMT-2000.

The 1-3 GHz bands have been affected to the extent that, globally, these bands are now no longer readily available for fixed services. Figure 3.3 illustrates the relationship between the current, new and emerging fixed vs PCS spectrum utilisations in the 1.7 to 2.3 GHz range.

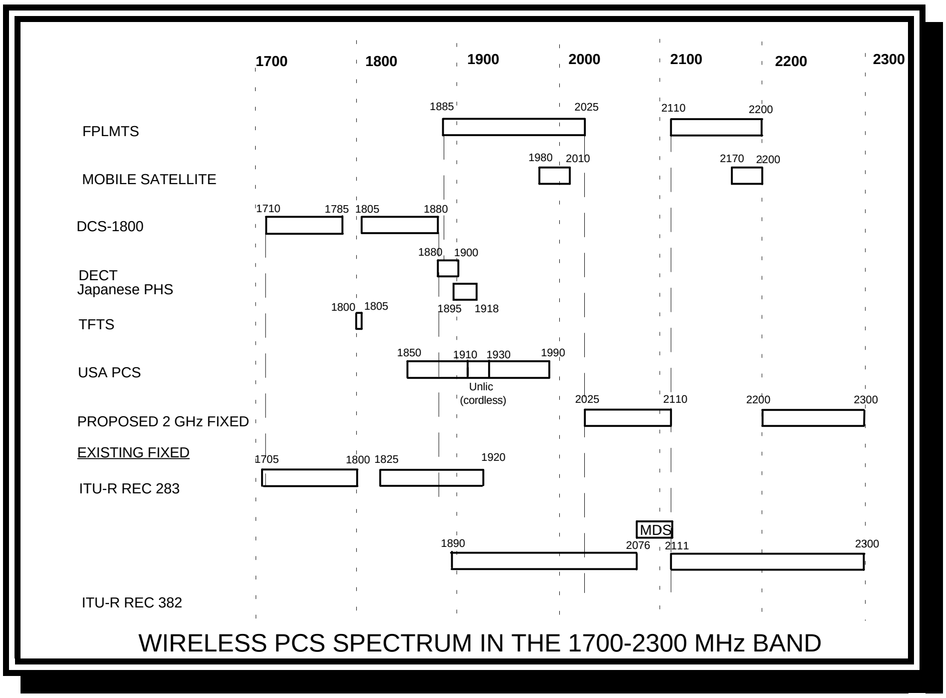


Figure 3.3 Wireless PCS Spectrum in the 1.7 - 2.3 GHz Band

Given the global nature of, and Australian support for facilitating spectrum access for many of these new and emerging technologies, a number of spectrum embargoes[51] and, in some cases, formal band plans (ie., 1.5 and 1.9 GHz Band Plans) are implemented in the 1-3 GHz bands, placing restrictions on existing uses during the planning and policy developments activities of the ACA and industry. As a consequence, access to these bands for terrestrial fixed link applications has been markedly affected and, in some cases, the relocation of existing fixed links is currently under way.

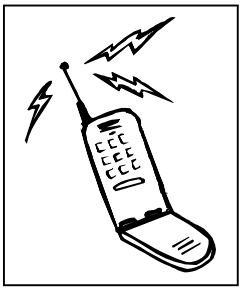
In order to preserve spectrum options for the possible introduction of these PCS in Australia, the (then) SMA took the following steps:

- in January 1993, an embargo on new fixed link assignments within 150 km of all capital cities was imposed on those fixed service channels in 1-3 GHz band affected by emerging PCS technologies; and

- since January 1993, all new and renewed fixed link licences in designated PCS bands (ie. 1.8 and 2 GHz) are required to contain advice that the frequency assigned is under review to accommodate possible changes in technology, and such review may lead to a requirement to change frequency or cease transmission.

In addition to the embargo arrangements and advisory notices on licences about the impending changes, the SMA in 1992 replanned the 7.5 GHz band to provide an alternative band to accommodate the types of links operating in the 1-3 GHz frequency range.

3.6.2.1 DCS1800



The process of review of the 1.8 GHz band has been in train for some years now as part of the wider planning process for the introduction of new telecommunications services in Australia. The planning has been conducted in consultation with industry groups representing current and prospective new users of the affected bands, principally through the RCC. Users of the band have also been informed of changes to the bands by way of advice included in renewed licences.

Spectrum in the 1.8 GHz band is suitable for new telecommunications services, including but not limited to DCS1800 cellular mobile technology[52] and in 1997, parts of the band were re-allocated through spectrum auction. 2x15 MHz blocks were auctioned for use in designated city and regional areas, with a further 2 x 30 MHz blocks made available for use in city areas only. The auction of a further 2 x 30 MHz of the band is currently under way – see http://203.37.2.230/PCS2000/PCS2000.htm for auction results and announcements.

Detailed analysis of the impact of spectrum reallocation in the 1.8 GHz band, including relocation options and indicative costings are provided in Appendix 3 "*1.8*

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[51] Refer to RALI MS 3 "Spectrum Embargoes" and the 1.9 GHz Band Plan for details.

[52] A derivative of the 900 MHz GSM digital mobile service operating in Australia and worldwide

GHz Relocation Strategies". Generally, all 1.8 GHz fixed services operating within the designated city areas must be relocated, with regional areas significantly less impacted. For the affected 1.8 GHz fixed service incumbents, relocation options include the higher (>10 GHz for short distance links) bands but options in the lower microwave bands are generally limited to the 6/7.5/8 GHz bands, already under pressure from demand competition. However, in contrast to some claims, opportunities in these bands are not necessarily exhausted.

3.6.2.2 1.9 GHz Cordless Telephone Services

The *1.9 GHz Band Plan*[53], 8 March 1996, facilitates the introduction and deployment of cordless telecommunication services (CTS) in the band 1880-1900 MHz. Specific CTS applications include, but are not limited to, telecommunication systems such as DECT (Digital European Cordless Telecommunication system) and PHS (the Japanese "Personal Handyphone System"). For an overview of (CTS see http://www.aca.gov.au/publications/info/1_9%20CTS_overview.htm .

Under the provision of the plan (and since 1990 under the pre-existing embargo) no new fixed services are permitted in the band 1880-1900 MHz, Australian wide. The plan effectively precludes the use of several channels of the 1.8 GHz band, as detailed under §1.0 of the 1.8 GHz (RALI FX-3) assignment instructions, though existing fixed services operating on these channels are permitted to continue[54].

Following the implementation of the 1.9 GHz Band Plan and the emergence of growing consumer and business interest in residential and small business applications, the ACA has reviewed, in consultation with industry groups representing both fixed and CTS interests, the spectrum access and coordination arrangements for fixed and CTS services. The revised arrangements include provisions:

1. for a digital CTS system licence (still subject to licence fees and frequency coordination) to be established to simplify access to the band prior to 1 July 2001;

2. that, as of July 2001, fixed service receivers will no longer be afforded protection from interference caused by the operation of CTS transmitters. From that date, CTS devices will not be required to coordinate with fixed services but will still not be able to claim protection from interference caused by fixed service transmitters; and

3. that, as of 1 July 2001, the operation of private (residential and business) digital CTS systems be authorised by a class licence which relieves individuals from the need to take out an individual apparatus licence.

Accordingly, from 1 July 2001, all fixed services operating within the 1880-1900 MHz band will be required to accept any interference caused by the operation of 1.9

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53 http://www.aca.gov.au/legal/bandplan/1-9.htm .

54 The detailed sharing arrangements are detailed in the RALI MS25 "Frequency Coordination and Licensing Arrangements for Cordless Telecommunication Services Sharing the 1.9 GHz Band with Fixed Links", - see http://www.aca.gov.au/frequency/frqassrq.htm .

GHz CTS devices. Whilst there is no legal obligation for fixed services operating within this frequency range to change frequency, operators need to consider the implications of the effective reduction of interference protection status and the consequent impact on their own operations. Generally, the likelihood of interference from CTS service will clearly be higher in urban rather than regional areas.

For discussion on relocation strategies, refer to Appendix 3 "*1.8 GHz Relocation Strategies*".

3.6.2.3 IMT-2000

International Mobile Telecommunications 2000 (IMT-2000)[55] defines ITU standards for third generation mobile systems, including terrestrial and satellite based (GMPCS) access systems. The standards aim to consolidate the diverse range of existing (2nd generation) digital mobile wireless access systems into a flexible radio infrastructure (3rd generation) capable of delivering a wide range of multimedia services, with appropriate quality levels within a range of different radio environments.

In May 1999, the RCC established the 3rd Generation Mobile Telecommunications Working Group to consider and report on spectrum planning issues associated with the proposed deployment of IMT-2000 in Australia. Consideration is being given to the allocation of the ITU designated IMT-2000 core bands of 1885-2025 & 2110-2200 MHz, over parts of Australia for the terrestrial segment of IMT.

The (co-primary with fixed and mobile services) MSS allocations at 1980-2010 (Earth-to-space) and 2170-2200 MHz (space-to-Earth) already provide for the deployment of satellite based IMT-2000 services and spectrum embargoes[56] have been in place since April 1996, preserving options for the introduction of the GMPCS segment of IMT-2000.

The RCC working group report[57] and up to date information concerning 3rd generation mobile service allocation is available at http://203.37.2.230/3GWG/3rdGenWG.htm . Relocation and incumbency issues are detailed in sections 1.3 and 10 of the RCC WG report, but decisions on spectrum auctions and clearance issues are still pending further consideration. However, auctions could take place some time towards the latter half of 2000. Appendix 4 "*2.1 GHz Relocation Strategies*" details preliminary work on relocation issues, including the identification of potentially affected fixed services, relocation options and indicative comments on the availability of suitable alternate spectrum for relocation.

In accordance with WRC-2000 Agenda Item 1.6, further international allocations are under consideration for terrestrial and satellite based IMT-2000 services, some of the options being considered could impact on the fixed service or available re-farming options (see §4.1.4).

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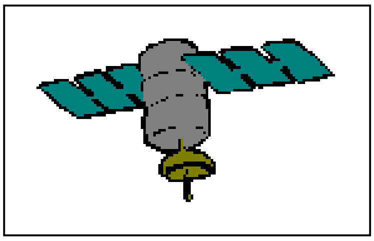
55 See http://www.itu.int/imt/ for background.

56 RALI MS-3 Embargo 23 – http://www.aca.gov.au/frequency/embargo.htm .

57 *Report of the Radiocommunications Consultative Council's Working Group on IMT-2000*, 24 December 1999.

3.6.2.4 MSS/BSS(S)



In addition to the 2.1 GHz MSS allocations in support of IMT-2000, (WARC-92) allocations within the 1.5 GHz (1427-1535 MHz) band in favour of MSS (1525-1530 MHz) and Broadcasting Satellite Service Sound (1452-1492 MHz) impact on the relatively large population of fixed services in the band.

The 1.5 GHz Band Plan[58], December 1996, preserves spectrum options for the introduction of MSS, BSS(S) and terrestrial digital radio broadcasting (see the next sub-section) services, by placing restrictions on the further assignment of frequencies to other services in certain parts of the band. The plan provides for the ongoing operation of existing fixed services until such time as decisions are made concerning the introduction of the new services. The plan also permits the upgrading of existing fixed services, including specific provisions covering point-to-multipoint systems used for the delivery of rural and remote area public telecommunication services.

An Australian '*DBSTAR*' satellite ITU filing[59] anticipates the delivery of Eureka 147 based digital radio broadcasting within Australia. However, planning is still at a preliminary stage. The relatively high power-flux-density required of a broadcasting service could have a significant effect on some 1.5 GHz terrestrial fixed services. The plan also makes provision for the delivery of terrestrial digital radio broadcasting services, discussed in the next sub-section and Appendix 6 "*1.5 GHz Relocation Strategies*".

3.6.2.5 DRB

As mentioned in §3.6.2.4, the 1.5 GHz Band Plan also anticipates the introduction of terrestrial Digital Radio Broadcasting (DRB) services. The Government has endorsed[60] the introduction of DRB and established the Digital Radio Planning and Steering Committee tasked with the planning issues and legislative proposals that will facilitate the introduction of DRB. However, no firm decisions have emerged, though planning is continuing. For further information on the planning process, refer to the DCITA website at http://www.dca.gov.au/ .

As detailed in Appendix 5 "*1.5 GHz Relocation Strategies*" the introduction of DRB services has potentially extensive implications to fixed services currently operating within the band 1452-1492 MHz. However, the deployment of terrestrial DRB may be anticipated to proceed in stages and by confining initial DRB operations to the mid-band gap (1475-1490 MHz) of the 1.5 GHz fixed service band, significant DRB rollout may be achieved with minimal disruption.

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[58] See http://www.aca.gov.au/frequency/bands.htm .

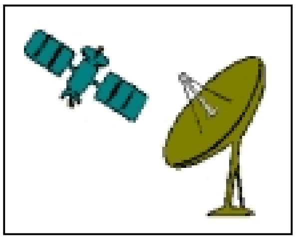
[59] GSO at 151.5° East, ITU-R Special Section API/A/787, WIC2392/24.08.1999.

[60] Minister for Communications, Information Technology and The Arts Media Release 35/98 "*Digital Radio Services Available by 2001*", 24 March 1998.

3.6.3 Above 3 GHz

Displacement and asymmetry of allocations issues are also relevant in the higher microwave bands. Competing uses and technologies are emerging in a number of bands currently accommodating or potentially accommodating fixed services.

3.6.3.1 NGSO FSS (11/18/38 GHz)



WRC-95 allocated 400 MHz of spectrum in the band 18.9-19.3 GHz to non-geostationary fixed satellite services (NGSO FSS) working in the space-to-earth direction. WRC-97 extended the allocation to cover the band 18.8-19.3 GHz, with urgent sharing studies to be undertaken by the ITU (Resolution 131).

In response to the new co-primary allocation and pending the outcome of ITU-R sharing studies between the NGSO FSS and terrestrial FS, an embargo[61] was placed on the issue of new fixed service licences in the band. In November 1996, revised RF channel arrangements were released for the 18 GHz (17.7-19.7 GHz) fixed service band, as an interim measure pending the resolution of the sharing issues in the 18.8-19.3 band. By virtue of the bidirectional nature of fixed services (ie. two channel blocks, separated by 1010 MHz in this case), the 18.8-19.3 GHz NGSO (space-to-Earth) allocation also potentially denies the fixed service access to a further 500 MHz of paired spectrum at 17.7-18.3 GHz.

Whilst the ITU-R sharing studies indicate that NGSO FSS interference into the fixed service is manageable through the application of appropriate power flux density limits[62], the principal problem for administrations is interference from fixed services into the itinerant NGSO earth terminal receivers.

ITU-R sharing studies anticipate the development of a Recommendation on the interference potential between ubiquitous NGSO earth stations and fixed service receivers operating in the 18.8-19.3 GHz band. The current status of studies is detailed in the ITU-R Working Party 4-9S Report[63] "*Working Document for the Development of a Recommendation for the Determination of the Interference Potential Between Earth Stations in the Fixed-Satellite Service Operating With Non-Geostationary Satellites and Stations in the Fixed Service in the 17.7-19.3 GHz Band*". The results to date are inconclusive and studies will continue into at least the next (post WRC-2000) ITU-R Study Period. Some satellite operators are presenting cases which argue that co-frequency sharing is not possible, concluding on the need for exclusive NGSO FSS access in the 18.8-19.3 GHz band. Other participants, in particular European interests with over 30000 18 GHz fixed service links already deployed, have put forward studies that show that co-frequency sharing is possible through the application of various mitigation techniques including the use of:

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[61] RALI MS-3 Embargo 25 - see http://www.aca.gov.au/frequency/embargo.htm .

[62] Doc. 4-9S/AC Draft New Recommendation "*Maximum Allowable Power Flux-density Produced at the Earth's Surface by Non-Geostationary Satellite in the Fixed-Satellite Service Operating in the 10.7-12.75 GHz and the 17.7-19.3 GHz Band*".

[63]Doc4-9S/178 (26 July 1999) "*Report on the Meeting of Working Party 4-9S*", Geneva, 21-28 April 1999, Chairman Working Party 4-9S, pp 144..160.

- Adaptive Transmit Power Control (ATPC) and/or the specification of high performance antennas for fixed services;

- Dynamic Channel Assignment (DCA) and/or site shielding and positioning of NGSO FSS earth terminals; and

- coordination of NGSO FSS terminals with fixed services.

However, at this time there are no consistent views on the effectiveness and practicality of the proposed mitigation techniques. In the event that the further studies conclude that co-frequency sharing is not feasible, the development of a new 18 GHz ITU-R channel plan, avoiding the 18.8-19.3 GHz band, may be anticipated.

Whilst the above discussions are in the context of the 18.8-19.3 GHz band, similar principles apply to other bands where sharing between point-to-point fixed services and ubiquitous NGSO FSS (space-to-earth) terminals is proposed – ie. the 38 GHz (37-39.5 GHz) and 11 GHz[64] (10.7-11.7 GHz) bands. The potential incompatibility is primarily confined to the geographic areas with large deployments of fixed services – ie. CBD and urban locations. Generally there is no problem in rural and remote areas.

For further discussion concerning the 18 GHz band see §4.1.8 and the next sub-section dealing with proposed (WRC-2000) allocation to the Earth Exploration Satellite Service in the band 18.6-18.8 GHz, for the 38 GHz band see §4.1.10.

3.6.3.2 Proposed (WRC-2000) EESS Allocation

WRC-2000 Agenda Item 1.17 considers a proposed worldwide allocation to the Earth Exploration Satellite (passive) and Space Research (passive) services in the band 18.6-18.8 GHz – ie. within the 17.7-19.7 GHz fixed service band. As detailed in IRAC WRC-2000 Sub-committee document No: 173 (rev.2, 3 December 1999), the proposal includes power limit constraints on 18 GHz FSS and terrestrial fixed services operating in the 18.6-18.8 GHz band.

The effect of WRC-2000 Agenda Item 1.17 may be to reduce the maximum allowable transmit power of fixed services in the 18.6-18.8 GHz sub-band to 1 Watt, a 10 dB reduction from the limit (10 Watts) set by the current Radio Regulation S21.5(3) for the 18 GHz (17.7-19.7 GHz) and adjacent fixed service bands. Although only a small number of existing fixed services utilise transmit powers in excess of the proposed 1 Watt limit (most systems operate with transmit powers of around ¼ Watt), ATPC is becoming more popular in overcoming rainfall induced unavailability and the cost of producing RF power at these frequencies is falling due to microwave semiconductor development. Accordingly the proposed new power limit does place a significant constraint on fixed services operating in the 18 GHz band, already subject to constraints due to the allocations in favour of NGSO FSS.

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[64] At this stage, ubiquitous NGSO FSS in the band 10.7-11.7 GHz is limited to ITU Region 1.

3.6.3.3 22 GHz BSS

The 22 GHz (21.2-23.6 GHz) band supports fixed services, with multiple channelling of 3.5/7/14/28 and 50 MHz[65]. As shown in Figure §3.1, the band sustains high average assignment growth rates, with the 7 MHz channels being by far the most popular channels.

The 50 MHz wide channels are shared between regular point-to-point and TOB services. All licences[66] issued for these channels are endorsed with Advisory Note BL, resulting from the (WARC-92) allocation of the 21.4-22.0 GHz to the broadcasting-satellite service (BSS), with effective date 1 April 2007. From that date (consistent with the provisions of Resolution 525) the fixed services operating in the 21.4-22 GHz band *"... shall neither cause harmful interference to BSS (HDTV) systems nor be entitled to claim protection from such systems..."*

Although the effective date is some time away and the introduction of satellite based HDTV in the band cannot yet be considered a certainty, some fixed service operators are now known to be avoiding the use of the 50 MHz channels due to the uncertainty of tenure in the longer term. Due to the asymmetry of many new service allocations (see § 3.6.1) and the bidirectional nature of fixed services, the 600 MHz (21.4-22 GHz) block allocation to BSS potentially denies future access to 2×350 MHz of fixed point-to-point spectrum.

3.6.3.4 28 GHz LMDS

Annex 2 of ITU-R Recommendation F.748-1[67] details CEPT harmonised arrangements for point-to-point fixed services with carrier spacings of 112 MHz, 56 MHz, 28 MHz, 14 MHz, 7 MHz and 3.5 MHz in the band 27.5-29.5 GHz. The arrangements are well established in Europe, with equipment product available from major global manufacturers. Although the 28 GHz band (and indeed also the 26 GHz band –see §4.1.10) has not been used for Australian point-to-point arrangements in the past, strong demand is evident for urban point-to-point medium to high capacity applications.

In Australia the band 27.5-28.35 GHz is subject to spectrum licensing and, as detailed in §2.4.3, the band was sold to AAPT LMDS Pty Ltd in February 1999. Whilst AAPT primarily plan to use the spectrum for the delivery of broadband wireless access (LMDS) services, there is no impediment to AAPT (or by others through secondary trading with AAPT) using the band for point-to-point fixed services. However, at this time, the rollout of LMDS networks is clearly the highest market priority and the effectiveness of secondary trading for point-to-point services is unknown.

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[65] Consistent with ITU-R Recommendation F.637-2 "*Radio-frequency Channel Arrangements for Radio-relay Systems Operating in the 23 GHz Band*."

[66] 230 assignments Australia wide, but with over 50% in the larger capital cities of Sydney, Melbourne and Brisbane (RADCOM August 1999).

[67] Recommendation F.748-1 "*Radio-frequency Channel Arrangements for Radio-relay Systems Operating in the 25, 26 and 28 GHz Bands*",

4. Accommodating Demand

This section considers planning and regulatory infrastructure issues, with a view to accommodating the spectrum needs of new and relocated terrestrial fixed services. The capacity of existing bands is considered along with specific options for re-farming and/or opening up new bands. Issues relevant to dealing with displaced fixed services are discussed, including matters of timing, relocation costs and priority of access. This section also reviews the regulatory policy tools relevant to managing spectrum access by terrestrial fixed services.

4.1 Availability of New Bands vs 'Re-farming'

Overall, there are limited opportunities for opening up new microwave fixed service bands, especially below 10 GHz. Options in this lower microwave range are thus limited to the need to consider the re-farming and optimisation of existing FS frequency band arrangements. The 1996 SMA telecommunications paper[68] anticipated the consideration of new ITU-R arrangements at 1.4, 2.1 and 2.5 GHz, to relieve pressures resulting from new demand and relocation. These options were further considered by the RCC SDNTS Working Group[69] and are still on the table, due to the uncertainties associated with the requirements of the new services at 1.5 GHz (DRB & BSS(S)), 2.1 GHz (IMT-2000) and strong opposition by the broadcasting industry to the proposed spectrum sharing arrangements at 2.5 GHz.

Although experiencing strong growth (principally in urban & metropolitan areas) the higher (> 10 GHz) microwave bands offer somewhat more scope for supporting new (short hop) point-to-point fixed arrangements and refarming options. However, there is competition also for this spectrum for other types of fixed (ie. LMDS) and satellite based (ie. NGSO FSS) radiocommunication services.

The capacity of existing fixed bands, opportunities for the introduction of new bands/ re-farming and optimisation of current arrangements to meet demand are discussed in the following sub-sections.

4.1.1 Capacity of Existing FS Bands

Capacity to service new link requirements is potentially available in most of the existing fixed microwave link bands not subject to restructuring. However, the utilisation patterns for fixed services are such that capacity in many bands may be depleted at a particular location, yet at a relatively short distance away bandwidth may be available in a number of bands.

Spectrum congestion can be particularly severe in situations where competition leads to service infrastructure duplication - eg. in metropolitan CBD areas and intercapital trunk routes. Congestion is further exacerbated by the consolidation of infrastructure at 'prime' nodal sites, often comprising several adjacent tower structures sharing a location with relatively high elevation. The use of common radiocommunication sites

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[68] "*Spectrum Management Issues Relevant to Telecommunications*" SMA, August 1996, §2.7.

[69] "*Spectrum Demand for New Telecommunication Services*", Final Report, RCC Working Group Report, March 1998.

is attractive to users for economic reasons and to allay the environmental concerns of the general community. However, such consolidation has a direct impact on interference management and spectrum availability – ie. the question of whether a particular band is 'full' is highly location dependent.

Therefore, the band occupancy statistics of Appendix 3 cannot provide us with definite answers about whether a particular band is full or predict how much capacity remains. It is possible to model theoretically achievable microwave link densities by making certain assumptions and probabilistic simulation (see §4.3.5), but even then the results need to be tempered with subjective judgement.

Overall, the ongoing relocation of services from the lower (1-3 GHz) bands and the consolidation of many of these services into the 6.0, 7.5 and 8.0 GHz bands puts considerable pressure on the capacity of these bands (refer to appendices 4, 5 & 6). There are also significant constraints in the higher microwave bands, due to escalating demand in urban areas and the introduction of services competing for the same spectrum space.

4.1.2 The 1.4 GHz (1350-1517 MHz) Band

The ITU-R Recommendation F.1242 channel arrangement[70] developed for the band 1350-1530 MHz (the 1.4 GHz band) provides for a range of small capacity channelling options, with different channel spacings and transmit / receive separations. It is intended as an alternative band suitable for services that could be displaced from the 1.5 GHz (1427-1535 MHz) band, with the introduction of digital sound broadcasting services in the band 1452-1492 MHz. The plan was sponsored primarily by ITU Region 1 countries (mainly Europe) where the fixed service is allocated on a primary basis. Although the fixed service is secondary in this region (Region 3), Australia supported its development in order to have as many options as possible available for additional fixed service bands. The band could be used in Australia, but planning for such use would involve consultation with incumbents, mainly Radiolocation system users, with a view to agreeing reasonable access arrangements. In particular, the ACA is aware of new requirements in this band for planned defence systems that could reduce its availability for fixed services.

In addition the new band would be overlaid partly within the existing 1.5 GHz plan, so new services would need to work around the many existing links. As this is now a widely accepted ITU-R channel arrangement, suitable equipment products are readily available.

The ACA invites comment on the suitability of arrangements based on ITU-R Recommendation F.1242 as a re-farming option for the 1.5 GHz (1427-1535 MHz) point-to-point band, including the issue of sharing with radiolocation services.

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70 ITU-R Recommendation F.1242 "*Radio-frequency Channel Arrangements for Digital Radio Systems Operating in the Range 1350 MHz to 1530 MHz*".

4.1.3 The 2.1 GHz (1900-2300 MHz) Band

As detailed in Appendix 4, the utility of the current 2.1 GHz RALI FX-3 medium capacity (29 MHz channel) arrangements, based on ITU-R Recommendation F.382[71], are now severely constrained by allocations to other services.

In recognition of the need to optimise fixed service arrangements around the new allocations (ie. IMT-2000, MSS) between 1900 and 2300 MHz, Australia proposed at the WARC-92 Conference that the ITU develop a new channel plan, now ITU-R Recommendation F.1098[72]. The F.1098 arrangements provide for a number of channelling options, based on 2.5 or 3.5 MHz rasters, with channel spacing of up to 14 MHz. In Australia a significant part of this new band is not available to fixed services due to the operation of MDS 'A' at 2076-2110 MHz. However, in accordance with the *Multipoint Distribution System Frequency Band Plan 2000*[73], MDS licences in the A band are being renewed only up to 25 July 2002, opening up prospects for the future introduction of the new F.1098 channel arrangements with up to 14 MHz wide RF channels.

Based on the deliberations of the RCC SDNTS Working Group and subsequent discussions with stakeholders, it is anticipated that industry will support the introduction of new arrangements based on Recommendation F.1098. However, it will be some time before the arrangements can be put in place, so there is no immediate benefit in terms of relocation of current incumbents. As this is a widely accepted ITU-R channel arrangement, suitable equipment products are readily available.

The ACA invites comment on the suitability of the arrangements based on ITU-R Recommendation F.1098 as a re-farming option for the 2.1 GHz point-to-point band.

4.1.4 The 2.5 GHz (2520-2670 MHz) Band

The 1996 "*Spectrum Management Issues Relevant to Telecommunications*" SMA information paper included options for the adoption of ITU-R Recommendation F.1243[74] fixed point-to-point arrangements in the band 2520-2670 MHz.

The arrangement provides for small capacity channelling suitable for services displaced from the 2.1, 1.8 and particularly the 1.5 GHz band. In Australia and a number of other countries, the band 2450-2690 MHz is used by the broadcast industry for television electronic news gathering (ENG) links.

The *Final Report* (17 March 1998) of the *RCC SNDTS Working Group* recommended the further investigation of the use of the proposed 2.5 GHz band, noting objections raised by FACTS concerning the existing use of the band for ENG.

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[71] Recommendation ITU-R F.382-6 "*Radio-frequency Channel Arrangements for Radio-relay Systems Operating in the 2 and 4 GHz Bands*".

[72] Recommendation ITU-R F.1098, "*Radio-frequency Channel Arrangements for Radio-relay Systems in the 1900-2300 MHz Band*".

[73] http://www.aca.gov.au/legal/bandplan/mds-bp.pdf

[74] Recommends 2 of ITU-R Recommendation F.1243 "*Radio-frequency Channel Arrangements for Digital Radio Systems Operating in the Range 2290-2670 MHz*".

Whilst acknowledging that the ENG services are constantly and extensively used in main city areas, the ACA believes that scope exists for both services to co-exist in this band on a shared basis in country areas, particularly on main microwave trunk routes, where ENG use would be expected to be low. Further, there would appear to be good scope for current ENG equipments, which have generally been in use for many years, to be upgraded or modified to more effectively utilise the spectrum provided for ENG. As the proposed 2.5 GHz (2520-2670 MHz) band is now a widely accepted ITU-R channel arrangement, suitable equipment products are readily available. However, as mentioned at §3.6.2.3, WRC-2000 (Agenda Item 1.6) seeks to allocate further spectrum to terrestrial and satellite based IMT-2000 mobile services. The band 2520-2670 MHz is identified (in the CPM-99 Report[75]) as an option for the extension of the terrestrial segment of IMT-2000 and parts of the band are further identified as potential candidates for further (IMT-2000) MSS allocation.

Pending the outcomes of WRC-2000, the ACA invites comment on the 2.5 GHz (2520-2670 MHz) arrangements detailed in ITU-R Recommendation F.1242 and the feasibility of sharing between the largely city-based ENG and regional, rural and remote area point-to-point fixed services.

4.1.5 The 7.5 GHz (7425-7725 MHz) Band

As discussed at (§3.1.3(1)), the 7.5 GHz band was restructured in 1992 in anticipation of demand resulting from changes in the 1-3 GHz bands and the introduction of telecommunication competition. The arrangements provide RF channel bandwidths of 14/7/3.5/1.75 MHz, being of a similar order to the services subject to relocation from the 1.5 and 1.8 GHz bands. Despite relatively high assignment growth (see Fig. 3.1) and suggestions[76] that the band is 'full' at many high demand locations, current RADCOM statistics confirm that some channels remain underutilised (3.5 MHz channels) or are not used at all (the 1.75 MHz channels).

The lack of any assignments on the 1.75 MHz channels implies the absence of suitable equipment products. The few assignments that utilise the 3.5 MHz channelling are principally in regional areas, indicating that little demand exists for their use. Accordingly, a strong case exists for re-farming the essentially unused but valuable spectrum in favour of more desirable channelwidths.

- Taking account of the demand pattern, it appears sensible to replace the eight 3.5 MHz and eight 1.75 MHz channel pairs in the bands 7522.5-7564.5 MHz/ 7683.5-7725 MHz with 7 and 14 MHz channels, providing for a further six 7 MHz and three 14 MHz new channel pairs to the band.

To assist in the relocation of important incumbent (small capacity) services subject to formal relocation requirements, access to the 'new' 7 and 14 MHz channels could be

[75] Also identified by the UMTS Forum, in "*Report on Candidate Extension Bands for UMTS/IMT-2000 Terrestrial Component*" (March 1999) as a 'prime candidate' for the (global) terrestrial segment of IMT-2000 - see http:// www.umts-forum.org

[76] The *1.8 GHz Microwave Users Forum* RCC SDNTS Working Group Final Report, 17 March 1998.

limited to the services formally subject to relocation, until the expiration of the current 1.8 GHz relocation period (1 January 2002) and subject to further ACA review.

The ACA invites comment on the proposed re-farming of channels in the (7.5 GHz) sub-bands 7522.5-7564.5/7683.5-7725 MHz.

4.1.6 The 7.2 GHz (7100-7425 MHz) and 8.3 GHz (8275-8400 MHz) Bands

The arrangements in these bands support TOB services and were last reviewed in July 1995[77]. A part (7250-7375 MHz) of the 7.2 GHz band is subject to footnotes AUS1 and AUS36[78] in the Australian Radiofrequency Spectrum Plan, January 1999. Accordingly, the arrangements in the 7.2 GHz are currently under review by the ACA, in conjunction with the network broadcasters and Department of Defence.

The 7.2 GHz band currently supports 30 MHz and the 8.3 GHz band 28 MHz channelling. However, video link products are now available for these bands with occupied bandwidths of the order of 15 MHz, opening up the opportunity, anticipated in SPP3/95, to make more efficient use of the available spectrum.

The ACA invites comment on channelling options and the future use of the 7.2 GHz and 8.3 GHz bands.

4.1.7 The 13 GHz (12.75-13.25 GHz) Band

As mentioned in 3.1.3, the (RALI FX-3) Australian 13 GHz arrangements are shared between point-to-point fixed and TOB (ie. transportable fixed) services. The sharing arrangements are sub-optimal and this is reflected in the growth and utilisation statistics. There is scope to rationalise the use of the band, with a view to improved utilisation. Specifically, the ACA proposes that the access arrangements for both TOB and point-to-point services in the 12.75-13.25 GHz be comprehensively reviewed, taking account of channel utilisation, including the future use of the channels previously designated ‘SBS’ (ie. channels marked 2/2’ in the RALI FX-3 arrangement). However, no changes are to the arrangements are anticipated until the after the Sydney 2000 Olympics.

The ACA invites comment on the 13 GHz fixed point-to-point and TOB arrangements, including suggestions for the rationalisation of channel usage and demand patterns for point-to-point vs TOB usage.

4.1.8 The 18 GHz (17.7-19.7 GHz) Band

As discussed in §3.6.3.1, NGSO FSS allocation and ITU-R sharing studies in the band 18.8-19.3 GHz have limited spectrum access opportunities for fixed services for some years now, with an embargo in place since 1996. The band (7.5 MHz channels) is

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[77] Spectrum Planning Report SPP3/95 “*Television Outside Broadcast Service – 7.2 GHz and 8.3 GHz RF Channel Arrangements*”, Spectrum Management Agency, July 1995.

[78] Footnote AUS36 states “*Existing civil systems operating in the band 7250-7375 MHz are to cease operation by 31 December 2000*”.

also potentially affected by proposed (WRC-2000) allocations to the EESS in the band 18.6-18.8 GHz, as detailed at §3.6.3.2 .

Considering the effects of telecommunication competition and consequent demand for fixed services (§3.1.3(6)), the ACA has reviewed the need for the embargo (RALI MS-3, embargo 25) placed on fixed services in the band 18.8-19.3 GHz. In view of the inconclusive status of sharing studies, the ACA proposes to maintain the embargo, pending the resolution of the ITU-R studies discussed at §3.6.3.1.

The ACA, among other administrations, considers that equitable sharing conditions should be encouraged and studies into potential interference mitigation techniques need to be conclusively finalised before making binding decisions about the use of the 18.8-19.3 GHz band.

Pending the resolution of ITU-R studies, the ACA invites comment on the issues related to the use of the band 18.8-19.3 GHz.

4.1.9 The 26 GHz (24.5-26.5 GHz) Band

This band is used in many countries for fixed point-to-point services with a number of channelling schemes in place, consistent with Annex 1 to Recommendation ITU-R F.748[79]. Although the band is not currently used in Australia, strong demand is evident, particularly in urban areas, to support cellular, PCS backhaul, private and common carrier short haul network applications. Further demand is anticipated to emerge in urban areas with the further deployment of cellular mobile systems, including IMT-2000 backhaul and other imminent requirements such as digital television distribution. A diverse range of suitable small, medium and high capacity equipment products is readily available.

In order to meet the demonstrated demand for urban mobile backhaul and new carrier network infrastructure, the ACA proposes the introduction of apparatus licensed point-to-point arrangements consistent with the (24.5-26.5 GHz) CEPT harmonised[80] arrangements shown in Annex 1 of Recommendation F.748, with channelling up to 56 MHz. Though the recommendation includes a further channelling option with 112 MHz wide channels, the ACA believes that demand for and equipment product for such channels may be limited. However, the introduction of the point-to-point fixed channel plan is predicated upon the outcomes of current considerations (see §3.1.4.1) concerning spectrum arrangements for broadband wireless access services.

Subject to the current BWA planning process (see §3.1.4), the ACA invites comment on the proposed introduction of 26 GHz fixed point-to-point arrangements.

4.1.10 The 38 GHz (37-39.5 GHz) Band

As shown in §3.1 and discussed in §3.1.3, the 38 GHz band is extensively utilised for new carrier backhaul networks in urban areas and assignment growth in the band is

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[79] Recommendation F.748-1 "*Radio-frequency Channel Arrangements for Radio-relay Systems Operating in the 25, 26 and 28 GHz Bands*".
[80] Annex B, CEPT Recommendation T/R13-02, Montreaux 1993.

currently running at over 60% p.a. The current (RALI FX-3) 38 GHz arrangements[81] provide a large band (over 2 GHz contiguous) with channelling options of 7, 14 and 28 MHz. However, consistent demand has emerged for channelling to support high capacity (ie. STM-1) urban backbone traffic and suitable high capacity equipment products are readily available.

Accordingly, the ACA proposes to extend the current arrangements (based on Annex 1 of Recommendation F.749-1) by including an overlaid arrangement with 56 MHz RF channels. A further option under the ITU arrangement includes 140 MHz channel spacing, though the need for and equipment support for such large channels may be limited.

The ACA invites comment on the proposed addition of an overlaid 56 MHz channel raster in the 38 GHz band.

4.1.11 Refarming Other Bands

Other microwave frequency bands have also been considered for re-farming – eg. the Final Report (17 March 1998) of the RCC's *Spectrum Demand for New Telecommunication Services* Working Group, recommended that the arrangements in the 6.0 GHz (5925-6425 MHz) and 8.0 GHz (7725-8275 MHz) bands be reviewed to assess suitability for new carriers services or to support the relocation of fixed services from below 3 GHz.

Another candidate band is the 3.8 GHz (3580-4200 MHz) band, currently supporting high capacity (40 MHz) long haul services, but where RADCOM assignment growth statistics indicate a consistent net decline (see §3.1) in usage. However, channelling and equipment options for the above bands are limited and the ACA is of the view that changes to the arrangements in the 3.8, 6.0 and 8.0 GHz bands are not warranted at this time.

In general, consistent with the considerations detailed at §2.6.1 & §2.6.3, for any new fixed bands and/or refarming options to be viable it is necessary to have reasonably widespread manufacturing and industry support. In practice this usually means consistency with ITU-R recommendations and/or other recognised regional standards.

4.2 Relocation and Treatment of Incumbents

The scope for new telecommunications services in the radiofrequency spectrum might be significantly inhibited by existing incumbent licences (especially in metropolitan areas) in some frequency bands. The relocation of incumbent fixed services from the frequency bands below 3 GHz is a matter of considerable current interest and a principal reason for the development of this paper. The driver for relocation is the need to clear spectrum for new radiocommunication services, including those described in Part 3 of this document.

The ACA recognises that clearance of spectrum, where it arises, could involve significant problems for incumbent apparatus licensees. Consultation with individual

[81] Recommendation ITU-R F.749-1 "*Radio-frequency Channel Arrangements for Radio-relay Systems Operating in the 38 GHz Band*".

licensees about options for re-location of affected services may be necessary to alleviate the impact of such problems.

The decision to introduce new services within a band wholly or partly occupied by fixed services has significant implications for the fixed link operators. In the initial stages of planning the incumbent operators are placed within an environment of ongoing uncertainty, until such time as the planning of the incoming service matures and is formally ratified with a decision. The natural questions arising out of this process include:

- Which particular existing services are affected?;
- Where can affected services be relocated?;
- What is the timescale for relocation?; and
- Who pays?

The following sub-sections discuss these concerns and other considerations relevant to determining strategies for the relocation of affected fixed services.

4.2.1 General Relocation Considerations

The Government's objective is that spectrum be made available more quickly in some circumstances to promote its objectives for the development of the communication industry. The Government's policies therefore allow the sale of spectrum licences in specified instances to go ahead with incumbents in place, with clearance of the spectrum to take place at a later date. In most cases, incumbents can bid for the spectrum they currently occupy in competition with other potential users. Alternatively, incumbents may be able to negotiate with the successful bidders to continue as 'tenants' in the spectrum. This would be entirely a matter for commercial negotiation between the incumbent and the new owner, without the involvement of the ACA.

Determining whether or not a particular microwave fixed service link is affected by spectrum clearance action involves deciding whether or not the frequencies used by the link fall within the reallocated spectrum frequency limits and the geographic location of the link in relation to the proposed areas of operation of the incoming service. In most cases specified geographic boundaries apply – e.g as defined in *Spectrum Reallocation Declaration No.4 of 1997* for frequencies in the 1.8 GHz band designated for reallocation in 'regional' areas. However, in some cases the details of the deployment of the new service may not be so well defined for some time and may, in the interim, be subject to change due to developments in the market environment.

Assuming that the incumbent fixed services need to move out of a band and that particular links need to be cleared, the question of alternative delivery options for the affected services needs to be considered. Generally, each incumbent service corresponds with a unique set of technical, environmental and economic parameters which must be evaluated against the range of available options. For such case-by-case considerations, potentially viable options could include:

1. diverting the communication traffic of the affected fixed link through the operator's own network, or through the leasing capacity from third parties;

2. the replacement of the fixed service with a wireline solution (ie. underground or overhead cable) or optic fibre;

3. the migration of the fixed service out of the affected spectrum into alternative channels within the same band or to another frequency band; or

4. the purchase of a spectrum licence covering the operation of the affected fixed service or an arrangement with the successful purchaser of the relevant spectrum.

It is up to the affected link operators to decide which of these options will be pursued, though the ACA may provide advice to affected licensees. The following discussion outlines the considerations that may be taken into account in deciding how to proceed.

For urban areas, well served with common carrier and private transmission infrastructure, alternative routing or leasing capacity from other operators may well be the most economic alternative. In some cases a wireline solution may also be viable, though the laying of optic fibre is expensive and unlikely to be warranted in most situations where only small capacity radio traffic is involved.

The third relocation option involves finding alternative available fixed service spectrum, usually in higher frequency bands. The viability of this option involves further detailed analysis of the relevant technical, environmental and economic constraints. These aspects are detailed in the next sub-section.

4.2.2 Relocating into Another Band

Relocation of a fixed service from one frequency band into another frequency band requires detailed consideration of the characteristics of the service being relocated against the accommodation potentially available in the alternative band. Considering a service subject to relocation is to be replaced with an equivalent service in another band, then the relocation options are limited to those bands supporting arrangements for similar services. Alternatively an operator may take the opportunity to upgrade the affected service, usually to a higher capacity system.

In an ideal situation, where a simple relocation into another band is feasible, much of the existing radio infrastructure can be reused, as the extent of the replacement is principally limited to RF equipment, feedline and antennas. In this case the relocation process may be relatively expedient and cost effective, with minimal disruption to the service being provided. However, in many cases the simple 'one for one' replacement option is not viable or additional measures, listed below in order of increasing cost, may be necessary to allow operation in the higher frequency band:

1. additional infrastructure (eg. diversity antennas) to overcome the inherent propagation constraints (§2.8.1) and to meet system performance requirements at the higher frequency of operation;

2. antenna structure (ie. tower) strengthening, extension or replacement, taking account of the higher windloading (§2.6.4) of the solid parabolic antennas necessary in the bands above 3 GHz;

3. additional repeaters, where the single hop performance in the higher frequency band cannot meet the minimum performance requirements (see of the service subject to relocation. In this case, relocation costs and lead times are invariably an order of magnitude greater, given that new sites need to be found, leases negotiated and new site infrastructure procured, installed and commissioned.

The availability of spectrum in the target higher frequency band(s) is a further factor that defines options for relocation, particularly at some locations within the more populous areas of Australia. At some locations, microwave spectrum congestion extends over many frequency bands, so the feasibility of relocation is predicated upon the availability of compatible spectrum arrangements in the alternative bands.

4.2.3 Costs

The magnitude of the costs of relocating fixed services are highly variable, depending upon the detailed technical, geographic and environmental constraints as applicable to each particular incumbent.

Under the present relocation policy arrangements, incumbents are protected by legislation for a certain period. There is no provision for compensation by the Government for the clearance requirement. However, commercial arrangements between incumbents and new owners may result in earlier clearances.

4.2.4 Timing

Once the decision to relocate services is made and the frequency and geographic extent of the necessary relocation exercise is defined, a reasonable period should be set aside for its planning, design and execution. It should be self evident that some relocations will happen more quickly than others, depending upon the individual circumstances. In considering timing issues, it is necessary to take account of the cyclical nature of business planning and to allow for equipment product provisioning delays in cases where a relatively large number of services are involved. As a rule, a reasonable planning and provisioning cycle should be not less than twelve to eighteen months from the date of the formal decision (ie. reallocation declaration).

The ACA acknowledges the need for lead time and endeavours to provide reasonable notice to incumbents.

4.2.5 Priority of Access – Displaced Services

In examining alternative spectrum access arrangements for terrestrial fixed services subject to relocation and to facilitate the timely relocation of incumbents consideration could be given to provide for some form of priority of spectrum access for important services subject to relocation. Nevertheless, it is also desirable to avoid unnecessary disruption to network rollout plans and general market activity in existing microwave bands. Accordingly, the ACA proposes that the implementation of any priority of access principles should:

- be principally confined to new bands and/or ‘re-farmed’ arrangements; and
- take account of the nature of the services being relocated (ie. potentially accommodating ‘like’ services, in terms of transmission capacity).

As an example, a potential candidate for relocation priority-of-access is the proposed (§4.1.5) revision of channelling in the 7.5 GHz band, potentially accommodating high priority 1.8 GHz incumbents.

4.3 Regulatory Policy and Management Issues

This sub-section outlines some current regulatory policy issues relevant to microwave fixed services and the ACA’s views on how these should be managed. Comments are invited on each of the issues discussed in this section.

4.3.1 Radio and Telecommunication Standards

The ACA’s objectives in managing the microwave fixed service spectrum includes alignment, wherever possible, with relevant ITU and/or other recognised regional standards (see §2.6). An important further objective is, where possible, to minimise the amount of regulation. As part of achieving this objective, the ACA conducts an ongoing program of review and revision of spectrum access arrangements, including for the fixed services. Overall, the Australian regulatory arrangements for microwave fixed services seek to maintain a strategic balance and compare favourably with those of other OECD countries.

4.3.2 Licensing

As detailed in Appendix 2, the *Radiocommunications Act 1992* provides three approaches to licensing access to the radiofrequency spectrum:

- class licensing;
- apparatus licensing; and
- spectrum licensing.

Some fixed services operate under a class license (eg. 10 GHz point-to-point) and the LMDS (broadband wireless access) services being deployed in the 28/31 GHz bands are spectrum licensed. However, for point-to-point and indeed most microwave fixed service applications, apparatus licensing is the most common.

4.3.3 Licensing – Spectrum vs Apparatus Licensing of Fixed Services

Whilst class licensing offers great flexibility, it is normally restricted to relatively low power levels and no mechanisms are in place to provide users with protection from interference. Apparatus licensing facilitates interference protection for individually licensed and coordinated services, but with inherent restrictions on the deployment and operation of each piece of apparatus (ie. defined location, transmit power, radiation pattern). Spectrum licensing provides flexibility to change equipment, location and antenna characteristics as long as the service in use complies with core conditions, taking account of bandwidth, area and time.

Price-based allocation (either apparatus or spectrum licensed) is the ACA's preferred method of allocating spectrum in cases where market demand for spectrum exceeds supply. The traditional 'over-the-counter' apparatus licensing is preferred in situations where market demand does not warrant price-based allocation and where users do not require the flexibility afforded through spectrum licensing.
In cases where price-based allocation is being considered, apparatus licensed block allocations (discussed at §2.6.1) could be considered as an alternative to spectrum licensing, particularly in bands where the deployment of area-wide (eg. FWA/BWA or ENG/TOB) services is anticipated.

Although Telstra and other telecommunication carriers are the largest users of fixed point-to-point services (§2.7), there are many government, GBE & private utilities and business users who operate and require access to point-to-point services to address a range of in-house and other business communication requirements. These requirements emerge over time and new link requirements often evolve in a somewhat sporadic manner. In other words, the market for point-to-point microwave services is fragmented (both temporally and geographically) and for many users 'over-the-counter' apparatus licensing suits their requirements, with protection afforded through the coordination arrangements implicit to this form of licensing.

Whilst there is no impediment to operating point-to-point services under a spectrum licence, including under secondary trading arrangements, the point-to-point nature of fixed services makes it awkward to re-allocate radio spectrum into efficiently marketable parcels suitable for point-to-point use, without the 'offcuts' resulting through the allocation process. The situation does not arise under 'over-the-counter' apparatus licensing, since new services continue to be licensed as long as they can be successfully coordinated.

By contrast, area-based radiocommunication services (ie. cellular mobile, fixed wireless access and broadband wireless) are amenable to spectrum licensing (or block allocation under apparatus licensing) and packaging into marketable parcels, more suitable for price-based allocation to a (usually) relatively small number of competitive bidders.

4.3.4 Apparatus Licence Fees

In April 1995 the SMA established a new pricing framework for apparatus licensing, after having conducted a public enquiry into this matter during 1993/1994. As detailed in the current ACA licence fee schedule[82], the fees now comprise a spectrum

[82] *Apparatus Licence Fee Schedule*, Australian Communications Authority, 10 May 1999.

maintenance component to cover ACA overheads, an administrative licence transaction component and a spectrum access tax. The tax is based on the amount of spectrum denied to other users and is derived from a formula that takes into account four parameters:

- the frequency used;
- the geographic location;
- the channel bandwidth; and
- the area of coverage.

In general, the changes have led to more effective use of the fixed bands, confirming the role of fees as an important regulatory instrument. Operators demonstrate increasing familiarity with the principles of 'spectrum denial' and the need to consider the economic trade-offs between RF bandwidth, frequency, location and the use of technically spectrum efficient equipment. As confirmed by licensing statistics (§3.1) there has also been a massive increase in the use of the higher microwave bands, principally within urban areas subject to telecommunication competition.

Nevertheless, anomalies remain within the existing fee structures and there is scope for the further improvement of the current licence fee arrangements, based on the principles of demand, spectrum denial and user transparency. For example recent computer simulation studies[83] confirm that antenna performance is a key factor in determining spectrum denial and re-use relationships for microwave fixed services and further studies are anticipated to establish baseline criteria for licence fees and other regulatory criteria.

As confirmed by licensing statistics (§3.1) and consistent with the findings of the National Bandwidth Inquiry (§3.1.2), telecommunication competition using terrestrial means has (to date) mainly taken place in the urban markets.

The ACA will consider any comments on apparatus licence fee related issues.

4.3.5 Accreditation and Microwave Fixed Services

Section 263 of the *Radiocommunications Act 1992* provides for the ACA to accredit persons to perform certain activities related to the use of the radiofrequency spectrum. Such activities include the frequency coordination of microwave fixed and other radiocommunication services, as detailed in the ACA document "*The Role of Accredited Persons in Radiocommunications*"[84]. Accreditation has been in operation for a number of years and at this time 31 persons[85] are registered as being accredited by the ACA. Frequency assignment work may be performed by ACA staff or by an accredited person and, though not without some problems, accreditation is operating successfully, as attested to by the proportion of fixed link assignments made by

[83] "*Determining Terrestrial Fixed Service Antenna Performance Using Probabilistic Methods*", Erik S. Lensson, University of Canberra, November 1999.

[84] See http://www.aca.gov.au/licence/accredit/role.htm for details.

[85] http://www.aca.gov.au/licence/accredit/list.htm

accredited persons in the past 12 months – ie. of the 5503 apparatus licence (point-to-point) microwave (1.5-50 GHz) fixed service spectrum accesses made during the year ending 1 Dec 1999, 77% were made through accredited assigners (Figure 4.1).

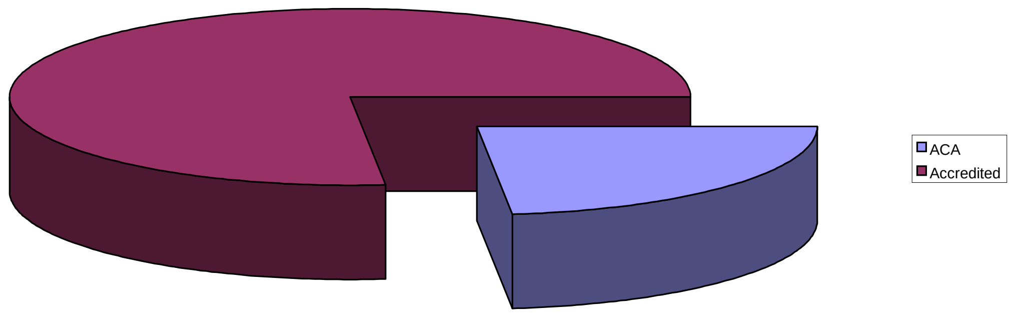

Figure 4.1 Apparatus licensed fixed services, ACA vs Accredited Assigners[86]

The obligations of the accredited persons are essentially the same as that of ACA assigners, in that the assignment work must be consistent with the Act, the Spectrum Plan and other relevant rules, including the RALI FX-3 in the case of microwave fixed services. In the absence of detailed guidance, assignments must have regard to the relevant ITU Recommendations and the International Radio Regulations.

4.3.6 RADCOM Fields Update

In recognition of the increasingly complex frequency coordination requirements with homogeneous fixed and other (eg. satellite based) radiocommunication services, the 1998 and subsequent revisions of the RALI FX-3 provide policy mechanisms and procedures for the use of more efficient detailed coordination methods. However, the application of such methods is predicated upon the availability of somewhat more detailed coordination than that supported by the current RADCOM assignment database.

The land mobile biased RADCOM assignment data model and poor support for terrestrial fixed service data issues were recognised by the RCC's SDNTS Working Group as well as being a recurring matter of concern to clients and frequency assigners, including accredited persons. Recommendation 2.6 of the SDNTS Final Report states *"... the need for improvement in the spectrum efficiency of fixed bands with particular attention to the following:*

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[86] Based on ACA Customer Services Group's "*Tactical Management Reports*" (TMR3), for the period 1 December 1998 through 1 December 1999.

- *the requirement for more detailed data in RADCOM, for example antennas and antenna/site elevation height and equipment bit error rate threshold;*
- *consideration of the systematic updating of the ACA database and ongoing process to ensure that more detailed data is required to be provided to users in order to facilitate the application of more efficient assignment coordination practices*".

In essence, the proposal amounts to the inclusion of a small number of additional fields in the RADCOM/RRL database, with data fields including:

1. Site elevation (*metres*);
2. Antenna elevation angle (*degrees*);
3. Fixed (feeder & branching) losses (*dB*);.
4. Antenna compliance (*TRUE/FALSE*); { ie. sub-notional antenna flag }
5. Protection criteria (*digital or analogue*);
6. Protection threshold (*BER or noise threshold*);
7. Adaptive Transmit Power Control (TRUE/FALSE); and {ie. ATPC flag }
8. Equipment make & model. { a key field link to external (non ACA) databases }

The provision of the additional information will facilitate much more efficient assignment practices than possible with current RADCOM/RRL data, with:

- significantly reduced levels of uncertainty and risk in intra and interservice frequency coordination;
- information essential to the coordination of major satellite gateway and coordinated VSAT terminals (including NGSO FSS); and
- the means for the further automation of routine microwave coordination practices.

The proposed approach is consistent with the aims of accreditation, though there may be some initial and ongoing resource requirements on the ACA in terms of implementing and maintaining the additional fields. However, the risk of not incorporating the proposed data fields is outweighed by the demonstrated need to facilitate consistent and confident coordination by ACA and accredited persons.

The ACA invites comments on the proposed additional RADCOM/RRL database fields and their implementation.

4.3.7 Assignment and Planning Rules (per RALI FX-3)

The Radiocommunications Assignment and Licensing Instruction (RALI) FX 3 "*Microwave Fixed Services Frequency Coordination*" provides important radiocommunication technical policy, guidelines and useful information for the coordination and licensing of microwave fixed services, including the channel arrangements and assignment instructions for each microwave frequency band and the regulatory rules for system planning relevant to frequency coordination.

The RALI is intended primarily for the use of ACA and accredited frequency assigners in optimising spectrum use for microwave fixed services. However, it also provides essential information and useful guidance for microwave system planners, operators and equipment product vendors.

In July 1998, the ACA completed a comprehensive review of the RALI. The review process concluded with an industry consultation period, comments from which contributed to the significant content and editorial changes to the RALI. A number of issues that were raised during the review were identified as requiring further work:

1. A review of the overall approach to minimum performance (notional) antennas. This work is now pending the outcome of the simulation studies mentioned at §4.3.4;

2. Review of the geoclimatic data (rainfall intensity & refractivity) necessary for coordination purposes, discussed at §2.8.2;

3. Consideration of the inclusion of additional data fields in the ACA's licensing and assignment database to facilitate more efficient coordination of fixed services and the detailed coordination of earth stations (GSO & NGSO) in shared bands (§4.3.6);

4. Consideration of the use of Adaptive Transmit Power Control (ATPC). Rules for the use of ATPC are now in place and included as Appendix 9 "*Adaptive Transmit Power Control*" in RALI FX-3 – http://www.aca.gov.au/frequency/recent.htm ;

5. Review of microwave fixed service emission criteria, taking into account ITU-R Recommendation F.1191-1 "*Bandwidths and Unwanted Emissions of Digital Radio-relay Systems*"; and

6. Review of interference mechanisms and protection criteria, with a view to the revision of protection ratios and interference evaluation of homogenous fixed services, taking into account new and revised ITU-T (G.821/826/827/828) criteria and relevant ITU-R Recommendations.

Each of the remaining issues is identified for further action, to be addressed in line with ACA workplan priorities and resource allocation needs.

Any comments concerning the RALI FX-3 and the above listed issues will be considered in the further development of the RALI.

4.3.8 High Spectrum Density Areas (HSDA)

Part 3.3.2 of the RALI FX-3 designates High Spectrum Density Areas (HSDA) for locations where microwave link usage density is high and where demand mandates a tightly managed assignment strategy, including strict compliance with spectrum productivity related assignment and system planning rules. High and medium density areas are also defined in the ACA's *Apparatus Licence Fee Schedule*, 10 May 1999 for fee purposes (covering all radiocommunication services). The purpose of the RALI FX-3 defined areas and the licence fee schedule areas may be considered complementary, with the common objective of encouraging the efficient use of the radiofrequency spectrum.

Although the RALI FX-3 HSDA and Fee Schedule areas are not identical, the respective defined areas do overlap to the extent that consideration could be given to consolidating to the areas defined in the licence fee schedule. The proposed alignment of area definitions is consistent with the common objective and would simplify the arrangements for microwave fixed services.

The ACA invites comments on the proposed consolidation of RALI FX-3 HSDA definitions to align with the HD/MD/LD definitions shown in Appendix E "Geographic locations and maps" of the ACA licence fee schedule.

5. Conclusion and Recommendations

This Part consolidates the key issues and outcomes from the considerations discussed in parts 2 through 4 of the paper, with a view to contributing to current and ongoing planning activities for accommodating the demand for new and changing services. The various approaches to facilitating and regulating spectrum access for these services are also discussed.

5.1 Conclusion

Microwave fixed services are an important element of cost effective electronic communication infrastructure and, consistent with global trends, demand is set to continue for the foreseeable future – despite the bandwidth advantage of optic fibre and the ubiquitous coverage offered by satellite based service alternatives. Each of these services has its place in the communication infrastructure of the new millenium.

Consistent with the global trend and technology developments, strong demand is evident in most fixed service bands, especially in urban areas subject to the effects of telecommunication competition. Some competition effects are also evident in regional areas, including demand for access network backhaul and for spectrum over particular (existing) high capacity trunk routes. Unsurprisingly, little competition and demand for fixed (other than for some already mature) services is evident in rural and remote areas.

Also consistent with global communication trends, many new radiocommunication services seek to be accommodated within frequency bands already occupied by microwave fixed services, placing heavy pressures on the ever diminishing resources of suitably allocated and available microwave radio spectrum. An issue of particular concern is the loss of access and restrictions applied to the fixed services in the 1-3

GHz range and the consolidation (through relocation) of the many services from these bands into fewer suitable (ie. with arrangements for like services) alternative bands.

In this paper we have explored spectrum management issues relevant to the utilisation of microwave frequency bands between about 1 GHz and 60 GHz, primarily in relation to spectrum access, sharing and displacement issues between the terrestrial fixed service and the range of new and emerging fixed and mobile communication and broadcasting technologies. In response to the questions detailed at §1.2, the following conclusions are made:

1. What are terrestrial microwave fixed services, who is using them and where?;

Terrestrial microwave fixed services comprise a range of (increasingly digital) point-to-point and point-to-multipoint applications, covering telecommunications and non-telecommunication network and local access applications (§2.3-§2.5). Microwave fixed services are extensively deployed in urban, regional and rural and remote areas of Australia. Users of (1.5 – 58 GHz) microwave fixed services include Telstra (53%), Optus (11%), Vodafone (9%) and an increasing number of new carriers and non-carrier operators (§2.7).

2. Is demand for terrestrial fixed services growing or declining and at what rate(s)?;

The demand for microwave fixed services is growing in most bands, especially in the >10 GHz bands, with consistent growth rates of most 'urban' frequency bands within the range 10-50% per annum. In the lower microwave bands, the 6.0, 6.7, 7.5 and 8.0 GHz bands demonstrate consistent growth, whilst in the 1.5, 1.8 and 2.1 GHz bands assignment growth is negative, consistent with current and anticipated future reallocation pressures (§3.1 and Appendix 3). A net downward trend is also evident for the 3.8 GHz long haul band, consistent with the amortisation of older (Telstra) analogue FDM links. However, strong new carrier interest is now evident at 6.7 GHz, with increasing demand for intercapital trunk capacity also demonstrated by the growth figures for the (now closed) 5 GHz trunk band (§3.1.1(1)).

3. What are the market drivers to spectrum demand in the microwave bands?;

Telecommunication competition is a strong market driver, contributing to the demand for cellular mobile backhaul networks and other small, medium and high capacity links, supplementing and integrated with wireline and optic fibre transport networks (§3.4). Access network demand is demonstrated by the recent (§2.4.3) and upcoming (§3.1.4) spectrum auctions for fixed wireless access, including broadband wireless services. Significant demand is also generated by the ongoing need to relocate incumbent services from the 1-3 GHz bands and the consolidation of these services into fewer alternative bands (§3.6.2).

4. What types of services are being displaced, why and to what extent?

At the moment, the 1-3 GHz bands are the most affected by displacement (3.6.2), with the particularly extensive relocations in the 1.8 GHz band putting pressure on alternative bands capable of supporting small-medium capacity links. In practice all 1.8 GHz services operating in city areas are subject to relocation, with regional areas *also affected but not to the same extent (Appendix 4). No decisions have yet been finalised on spectrum auctions or clearance issues in the 2.1 GHz band. However, allocations to MSS and IMT-2000 demands are likely to necessitate relocation and further changes to 2.1 GHz fixed service access arrangements (Appendix 5). Likewise, no decisions have yet been finalised on the allocations to L-band (1452-1492 MHz) digital radio broadcasting (DRB) and broadcasting satellite service, but preliminary studies indicate the existence of a potentially extensive displacement issue in 1427-1535 MHz fixed band (Appendix 6).*

5. What options exist to meet the spectrum demand for relocated microwave fixed services? Why not replace with cable, fibre or satellite based services?

Relocation options for incumbents include leasing capacity on third party networks, replacement of services with wireline or fibre solutions, the migration of affected services into alternative channels or frequency bands or the purchase of a spectrum licence or an arrangement with a spectrum licensee under secondary trading provisions. It is up to licensees to decide which option to pursue, although the ACA may provide assistance to incumbents considering options for relocation (§4.2). Wireline, optic fibre or even satellite based alternatives may be feasible in some cases. However, in many cases these alternatives are not economically competitive or even technically feasible. In practice, each re-location option needs to be considered on a case-by-case basis for each incumbent, to assess which options are feasible and cost effective (§4.2.1).

6. Are there any differences in infrastructure costs between the different microwave bands? What factors contribute to infrastructure costs?

There is wide variation in the infrastructure costs between different microwave bands and the types of services used. Overall, long haul trunk radio-relay systems in the 3.8 and 6.7 GHz bands may be considered by far as having the highest infrastructure costs, followed by regional radio relay systems (typically using the 6.0, 7.5 and 8.0 GHz bands). Infrastructure costs for urban links in the higher >10 GHz bands are (on average) much lower than radio-relay, particularly for small unobtrusive terminals with integral antennas, mounted on existing buildings or tower structures. Small capacity system infrastructure costs in the 1-3 GHz bands are also relatively low, due to the ready availability of low cost equipment and particularly through the use of cost-effective grid type antennas, facilitating the use of relatively light support structures (§2.6.4).

The most influential infrastructure cost determinants include antenna type (solid vs grid) & structure type, site access, security, power and standby plant requirements, transmission capacity, network reliability objectives, site establishment costs.

7. How much capacity remains in the existing microwave bands and what regulatory tools and approaches (eg. fees, planning rules) are available to optimise their utilisation?

Most microwave bands have significant capacity to support new services, but at some high density use locations and trunk route nodes congestion can make it difficult to use a particular frequency band (§4.1.1). Although statistical methods may be used to *estimate the maximum theoretical capacities in microwave frequency bands, in practice the issue of maximum capacity is highly location dependent and subject to many variables, including antenna radiation performance. Radiocommunication licence fees are an important regulatory tool and the ACA seeks to optimise the fee structures based on the principles of demand, spectrum denial and user transparency (§4.3.4). Similar ongoing review of other important regulatory tools includes the (RALI FX-3) planning & assignment rules and channel plans (§4.3.7). Further ACA regulatory initiatives under consideration include a proposed upgrade of ACA database information (§4.3.6) and the development of a set of standardised geoclimatic (rainfall & refractivity) statistical information for Australian (§4.3.7(2)) microclimates (see also §2.8.2), to facilitate more efficient frequency coordination and radio system planning.*

8. Are there any new bands that can be put to use? What about 're-farming' existing microwave bands?

Generally, there are few 'new' bands that can be opened up within the 1-60 GHz range. Fixed service allocations in the bands below 10 GHz are already extensively used by fixed services and many bands affected by allocations to other services. Somewhat greater opportunities exist for new in the bands above 10 GHz, but competing uses by other services are also limiting opportunities in these previously 'frontier' frequency bands (§4.1). Accordingly, options are for the most parts limited to 're-farming' of existing fixed bands. The ACA is committed to the ongoing review and revision of fixed service spectrum access arrangements, with a view to maintaining their currency and compatibility with market demand (§4.1).

9. What legal, market and technical issues need to be considered in terms of the relocation of incumbents? Should relocated services be afforded priority? How?

The rights of incumbents are a legal issue, including the concept of a 'reasonable expectation of renewal' of (generally annually renewable) apparatus licences. However, in the cases where spectrum is reallocated, planning processes (often extending over a number of years) and administrative embargoes on new assignments are a general precursor to formal reallocation. Formal reallocation instruments provide for a further period of grace (§4.2.4). In general there are no dominant single options when considering relocation – a range of options need to be considered, including radio and non radio options (§4.2.1). If relocating into another band, it is necessary to find alternatives with 'like' arrangements capable of supporting communication over the existing communication path distance(s), otherwise significant additional costs are likely to be incurred for antenna structure and site infrastructure (§4.2.2). Arrangements could be put in place to give some important incumbent services priority of access in any current microwave band. However, in order to avoid disruption of existing network rollout plans and other market activities, any priority rules would be best applied to 're-farmed' arrangements providing for services similar to those being displaced (§4.2.5).

10. What are the relevant technical, standards and allocation issues (eg. equipment product, RF channelling, re-farming options) relevant to meeting future demand?

ACA policy is to align with international technical standards and allocations, to the extent possible, including fixed service allocations and arrangements (§2.6.1) & (§4.3.1). Considering the small domestic market, alignment with global standards and mass market products makes good sense. The development of 'Australia only' arrangements for new or re-farmed spectrum would restrict market options and competitive pricing (§2.6.3).

11. Which licensing mechanisms are the most appropriate for microwave fixed services? What about where demand exceeds supply?

Most microwave fixed services are currently apparatus licensed. Because the market for point-to-point services is generally fragmented (temporally and geographically), 'over-the-counter' apparatus licensing suits the needs of most government, business and other private users, at least in situations where no singular market demand is evident. On the other hand, point-to-multipoint and other area-based fixed services are more amenable to being divided up into 'marketable parcels' and price-based allocation either through spectrum licensing or apparatus licensed block allocation (§4.3.3).

12. Are there any other regulatory policy/spectrum management initiatives which should be considered?

As discussed in Section 4.3, there is a range of regulatory policy and spectrum management initiatives which may be considered in the context of improving opportunities for the better use microwave radiofrequency spectrum. Important regulatory tools include licence fees (§4.3.4), ongoing ACA commitment to accreditation (§4.3.5), improvements in data management (§4.3.6) and technical planning policy (§4.3.7).

5.2 Recommendations

This section consolidates the material and conclusions developed in the discussion paper into a set of proposals concerning issues relevant to the ongoing management of microwave fixed service spectrum access arrangements. The following proposals are subject to further consideration based on the response to the matters detailed in this discussion paper.

All responses received by the due date will be considered by the ACA in the further development of preferred outcomes.

1. Meeting competition demand in the higher bands.

Considering:

- *the strong ongoing demand for short-haul point-to-point services in urban areas and the anticipated demand for IMT-2000 backhaul links;*
- *the trend towards higher transmission capacities up to 155 MB/s (SDH STM-1) for telecommunication transport and some access backhaul radio applications;*
- *the high usage densities and congestion beginning to affect spectrum availability in some urban bands (eg. 15 & 18 GHz);*
- *the (currently) inconclusive sharing studies into interference between fixed service transmitters and the receivers of proposed ubiquitous NGSO FSS earth stations in the band 18.8-19.3 GHz; and*
- *the restrictions imposed by further allocations to other services (eg. to BSS at 21.4-22 GHz (ie. proposed HDTV) and EESS at 18.6-18.8 GHz); and*

the ACA proposes,

- *the implementation of a new point-to-point band at 26 GHz (24.5-27.5 GHz), with arrangements catering for low/medium/high capacity systems between 2 and 155 Mb/s, based on Annex 1 to ITU-R Recommendation F.748, subject to the outcome of considerations outlined at §3.1.4, concerning access arrangements for BWA services; and*
- *the implementation of (overlaid) 56 MHz channels in the 38 GHz (37-39.5 GHz) band, consistent with Annex 1 of ITU-R Recommendation F.749.*

the ACA further proposes,

- *the ongoing application of RALI MS-3 Embargo 25 (17.7-19.7 GHz), preventing the assignment of fixed services in the band 18.8-19.3 GHz, pending the finalisation of ITU-R sharing studies into interference between fixed services and ubiquitous NGSO FSS earth terminals.*

2. Relocation and growth demand in the lower bands.

Considering:

- *the need to find suitable alternative spectrum for services displaced from the lower (1-3 GHz) microwave bands;*
- *the particular need to accommodate some displaced links with relatively long path lengths and the desirability of access to alternative spectrum with 'like' arrangements;*
- *the low utilisation of the 1.75 & 3.5 MHz channels in the 7.5 GHz band;*
- *that the need to relocate services from the 1.8 GHz, 2.1 GHz and 1.5 GHz bands can be anticipated to continue for some time;*
- *that an ongoing requirement remains for a small capacity point-to-point band (in the 1-3 GHz range, permitting the use of 'grid' type antennas), to facilitate the economic deployment of long hop links, particularly in rural areas; and*
- *the suitability of the 1-3 GHz bands for economic rural infrastructure and the availability of equipment products and grid antennas within this frequency range.*

the ACA proposes,

- *the expedited re-farming of the spectrum occupied by the current (7.5 GHz) eight 1.75 MHz & eight 3.5 MHz channels to support the more popular 7 and 14 MHz channelling; and*
- *the adoption of ITU-R Recommendation F.1098 arrangements in the 2 GHz band as a medium term option for accommodating long-hop small capacity point-to-point services, including future clearances from the 1452-1492 MHz DRB allocation;*

the ACA further proposes,

- *that in considering the implementation of new and/or re-farmed (eg. 7.5 GHz) fixed service arrangements, priority of access could be considered for particular fixed services subject to formal relocation requirements;*
- *the further consideration of ITU-R Recommendation F.1242 (1350-1517 MHz) arrangements as a longer term option, following decisions on the future of L-band DRB and BSS services; and*
- *the further consideration of sharing arrangements with 2.5 GHz (2450-2690 MHz) ENG services and the adoption of the 2.5 GHz (2520-2670 MHz) band for point-to-point use in rural and remote areas, taking account of WRC-2000 decisions on the proposed IMT-2000 extension bands.*

3. Review of spectrum used by TOB services.

<u>Considering:</u>

- *that there is considerable scope to rationalise the existing 28/30 MHz wide channels of the 2.5 GHz ENG, 7.2 GHz and 8.3 GHz TOB bands, with a view to more efficient utilisation;*
- *that a part (7250-7375 MHz) of the 7.2 GHz (7100-7425 MHz) band, used by the network broadcasters for TOB applications is subject to the footnote AUS36[87] in the Australian Spectrum Plan;*
- *that the use of the 8.3 GHz band for TOB is limited to date, but that the ABC has committed to relocating to this band (from the 7.2 GHz band) by end 2000;*
- *that there is also scope for better FS vs TOB channel allocations in the 13 GHz (12.75-13.25 GHz) band; and*
- *that TOB/ENG service operations are principally concentrated within major city areas.*

<u>the ACA proposes</u>,

- *the formal review of TOB requirements, with a view to re-farming the existing 28/30 MHz TOB channelling to something of the order of 15-18 MHz[88], providing more channels and better utilisation of available bandwidth;*
- *that in addition to channel bandwidths, channel allocations and sharing arrangements should also be reviewed; and*
- *that shared use of the 2.5 GHz bands by ENG and point-to-point fixed services should be considered in rural and remote areas.*

4. Geoclimatic data for coordination and planning purposes.

<u>Considering:</u>

- *the importance of geoclimatic factors (rainfall, refractivity) in both link planning and interference management of microwave fixed services;*
- *that the coarseness of the geoclimatic information currently provided by the ACA in the RALI FX-3[89] precludes the efficient use of rain limited bands – ie. lack of*

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[87] Footnote AUS36 states "*Existing civil systems operating in the band 7250-7375 MHz are to cease operation by 31 December 2000*".
[88] Eg. Consistent with FCC Part 74.6 Broadcast Auxiliary Service (BAS), see also FCC NPRM (ET Docket 95-18, December 1998), proposing 15 MHz BAS (ie. US TOB) channels.
[89] Based on ITU-R Recommendation P.837.

knowledge of 'microclimates' means that overly conservative planning and inefficient assignment practices are followed;

- *the many comments provided to the ACA in this matter over a number of years by carriers and other network operators and accredited assigners;*
- *the ever increasing growth in the number and types of services using the bands affected by rainfall outage (point-to-point fixed and broadband wireless access);*
- *that the necessary source (raw) data is available for purchase (BoM) and ARSG3 (Propagation) expertise could be drawn on to assist in processing the data to the right form for radiocommunication users and frequency assigners;*
- *that many of the network carriers already have much of this information for their own areas of operation, but may be reluctant to share the information with competitors; and*
- *that the microclimate data for local rainfall intensities is most critically needed for the areas with high spectrum usage – ie. city and coastal urban areas.*

<u>the ACA proposes</u>,

- *that the network carriers and other interested parties consider making available and pooling, through the ACA, relevant geoclimatic information in the form of rainfall intensity rates and refractivity gradient data for use in sharing and coordination studies.*

5. Regulatory Policy Rules and Management Issues

<u>Considering:</u>

- *that some technical planning rules are necessary for facilitating efficient spectrum use and re-use;*
- *that the growing use of the radiofrequency spectrum for fixed and other new (especially satellite based) radiocommunication systems requires the application of increasingly complex sharing studies;*
- *that confident coordination and effective spectrum re-use by ACA and Accredited Assigners is strongly predicated upon the availability of sufficiently accurate coordination information; and*
- *that the limitations of the current ACA RADCOM/RRL data model places significant constraints on the efficient coordination of terrestrial stations of the microwave fixed and space services.*

<u>the ACA proposes</u>,

- *to review*[90] *the level of support provided by the ACA's RADCOM/RRL for microwave fixed services and terrestrial stations of space based radiocommunication and broadcasting services, with a view to facilitating better support for detailed intra and inter-service coordination; and*

- *to continue the further work identified under §4.3.7 concerned with detailed coordination and planning rules for the RALI FX-3.*

6. Apparatus Licence Fee Issues

Considering:

- *That effective regulatory schemes involve the appropriate integration of market, technical and social policy issues; and*

- *that apparatus licence fees are an important regulatory tool and they should be aligned, as closely as possible, with the principles of demand, spectrum denial and transparency.*

the ACA proposes,

- *the further review of the apparatus licence fees applicable to microwave services, with a view to closer integration with fundamental concepts of spectrum denial and user transparency.*

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90 Consistent with Recommendation 2.6 of the *Final Report of the RCC's Spectrum Demand for New Telecommunication Services*, March 1998 – refer to §4.3.6 for details.

ATTACHMENT 1:

GLOSSARY OF TERMS

ACA	Australian Communications Authority
ACCC	Australian Competition and Consumer Commission
AMPS	Advanced Mobile Phone System
ARSG	Australian Radiocommunication Study Group
ATM	Asynchronous Transfer Mode
ATPC	Adaptive Transmit Power Control
BoM	Bureau of Meteorology
BSS(S)	Broadcasting Satellite Service (Sound)
BWA	Broadband Wireless Access
CBD	Central Business District
CDMA	Code Division Multiple Access
CCCP	Co-channel Cross-Polar
CEPT	Committee of European Posts and Telegraphy
CPM	Conference Preparatory Meeting
CTS	Cordless Telephone Service
CMTS	Cellular Mobile Telecommunications Service
DCITA	Department of Communications, Information Technology and The Arts
DCA	Dynamic Channel Assignment
DCS1800	Digital Cellular System at 1800 MHz
DECT	Digital European (*or Enhanced*) Cordless Telecommunications
DRB	Digital Radio Broadcasting
DRCS	Digital Radio Concentrator Service
DSB	Digital Sound Broadcasting (see DRB)
EESS	Earth Exploration Satellite Service
ENG	Electronic News Gathering
ERC	European Radiocommunication Committee
ETSI	European Telecommunications Standards Institute
FCC	(US) Federal Communications Commission
FDM	Frequency Division Multiplexed
FDMA	Frequency Division Multiple Access
FM	Frequency Modulation
FRA	Fixed Radio Access (see FWA)
FSS	Fixed Satellite Service
FWA	Fixed Wireless Access
GBE	Government Business Enterprise
GMPCS	Global Mobile Personal Communication by Satellite
GSM	Global System for Mobiles
GSO	Geostationary Synchronous Orbit
GST	Goods and Services Tax
HCRC	High Capacity Radio Concentrator
HDTV	High Definition Television
HEO	Highly Elliptical Orbit

HSDA	High Spectrum Density Area
IMT-2000	(International Mobile Telecommunications 2000 (See FPLMTS)
IP	Internet Protocol
ISDN	Integrated Services Digital Network
ISS	Inter-Satellite Service
ITU-R	International Telecommunication Union – Radiocommunication Sector
ITU-T	International Telecommunication Union – Telecommunication Sector
LAN	Local Area Network
LEO	Low Earth Orbit
LMDS	Local Multipoint Distribution Service
LOS	Line-of-Sight
MDS	Multipoint Distribution Station
MEO	Medium Earth Orbit
MoU	Memorandum of Understanding
MSC	Mobile Switching Centre
MSS	Mobile Satellite Service
MTBF	Mean Time Between Failure
NII	National Information Infrastructure
NGSO	Non-Geostationary Satellite Orbit
OECD	Organisation for Economic Cooperation and Development
PCS	Personal Communications Services
PDH	Plesiochronous Digital Hierarchy
PHS	Personal Handyphone System
PSTN	Public Switched Telecommunications Network
RADCOM	ACA Licensing computer database system
RALI	Radiocommunications Assignment and Licensing Instruction
RCC	Radiocommunications Consultative Council
RF	Radiofrequency
RLAN	Radio Local Area Network
RSC	(ACA) Radiocommunication Steering Committee
SDH	Synchronous Digital Hierarchy
SMA	Spectrum Management Agency
STM	(SDH/SONET) Synchronous Transport Module
TCP	Transmission Control Protocol
TDD	Time Division Duplex
TDMA	Time Division Multiple Access
TMN	Transmission Management Network
TOB	Television Outside Broadcast
USO	Universal Service Obligation
WAN	Wide Area Network
WLL	Wireless Local Loop
WRC	World Radiocommunication Conference

ATTACHMENT 2:

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[27]	ACA RALI MS-3 "*Spectrum Embargoes*".
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APPENDIX 1.

AUSTRALIAN RADIOCOMMUNICATIONS SPECTRUM PLANNING

The spectrum is a public resource with a finite capacity to support many and varied uses.

Spectrum planning is undertaken as a basis for:

- allocating a limited resource effectively to meet the needs of government, business and the community across a diverse range of uses; and
- containing interference between users.

Planning is undertaken only to the extent and detail necessary to achieve the above objectives. The philosophy underpinning the Radiocommunications Act 1992 is to give greater freedom to users and place greater reliance on market determination of spectrum usage.

International Obligations

The ITU provides the framework for international co-operation for the use of the spectrum. This:

- assists standardisation in equipment and internationally used services such as maritime and aeronautical services;
- allocates limited resources between countries such as satellite orbital positions; and
- contains interference between countries, eg., HF frequencies.

Australia as a member of the ITU has treaty obligations to ensure that there is not interference to other countries' services operating in accordance with the International Radio Regulations, in particular the table of frequency allocations. Conversely, services not operating in accordance with the international table are not entitled to protection from services in other countries operating in compliance with the table.For further information on the ITU and Australian involvement in international radiocommunication matters, refer to http://www.aca.gov.au/international/index.htm .

The Australian Radiofrequency Spectrum Plan

The Spectrum Plan is the broadest level planning document. It aligns generally with the ITU spectrum allocations. This allocates blocks of spectrum to broad types of services such as fixed, mobile, radionavigation and broadcasting.

The present Spectrum Plan is regularly updated to incorporate decisions of the World Radiocommunication Conferences and changes of a domestic nature. The current version of the Spectrum Plan is dated January 1999. For further details about the Spectrum Plan, refer to http://www.aca.gov.au/frequency/spectrum.htm .

Frequency Band Plans

Band plans are developed for particular bands as and when necessary. They do not necessarily cover the whole Spectrum Plan.

Frequency band plans show the level of planning below the Spectrum Plan. They further sub-divide the broad allocations made in the Spectrum Plan to specific service types. For example, a block of spectrum may be allocated to the broad category of FIXED services in the Spectrum Plan and be allotted to the specific category of Point-to-Multipoint Services in a band plan.

Frequency band plans may be applied to both the market and administrative planning regimes although the level of detail required to support apparatus licensing may be higher than for spectrum licensing (see Appendix 2 for explanation of different forms of licensing available under the Radiocommunications Act). For apparatus licensing, frequency band plans are used as the basis upon which spectrum is reclaimed and re-allocated. Formal band plans are employed to authorise the administration of this process.

Formal band plans have been developed:

- to specify the spectrum arrangements for Multipoint Distribution Services;
- to establish provision of spectrum at 900 MHz for additional Public Mobile Telephone Services;
- to restructure the VHF bands to provide for future growth and for new types of services;
- to establish provisions for the use of the 1880-1900 MHz (1.9 GHz) band by new cordless telecommunications devices, on a shared basis with fixed link services; and
- to put a "hold" on the assignment of any services in parts of the 1.5 GHz band, until decisions are made on the method and extent of providing spectrum for new digital sound broadcasting services in Australia.

Planning and management of the broadcasting spectrum rests with the ABA[1]. Management of all other types of services rests with the ACA. For further information on band plans, see http://www.aca.gov.au/frequency/bands.htm .

Frequency Assignment Guidelines

Frequency assignment guidelines serve as the basis for the co-ordination of specific frequencies so as to contain interference between users and to maximise spectrum efficiency. These guidelines are usually issued in the form of a Radiocommunications Assignment and Licensing Instruction (RALI).

For further information concerning frequency assignment guidelines, including RALI's, refer to http://www.aca.gov.au/frequency/frqassrq.htm .

[1] Australian Broadcasting Authority.

APPENDIX 2

ACCESS TO SPECTRUM UNDER THE RADIOCOMMUNICATIONS ACT

1. Licensing Radiofrequency Spectrum

Access to the Radiofrequency Spectrum can be facilitated by legally authorising a licensee to operate a piece of radiocommunication apparatus, a radiocommunication system or the actual spectrum involved. Also, depending on the particular service or the extent of demand, the method of allocation may vary. This part of the paper describes briefly the licensing and allocation framework.

The *Radiocommunications Act 1992*[1] provides three approaches to licensing access to the radiofrequency spectrum:

- class licensing;
- apparatus licensing; and
- spectrum licensing.

Until 1992, all licensing for radiocommunications followed the apparatus licence model. After July 1993, a number of class licences have been implemented and spectrum licensing with price based allocation has taken place in a number of frequency bands, including at 500 MHz, 1.8 GHz and 28/31 GHz.

The main differences between the three approaches to licensing are briefly described in the following sections.

1.1 Class licensing

Class licensing provides what is essentially an open warrant for any person to operate devices of a particular *class*, without a specific and individually issued licence from the ACA. A class licence is an instrument, approved by the ACA, which sets standard conditions for operating equipment of the specified class.

Class licensing is appropriate for low power, mass consumer market devices that, because of their low power and expected mode of operation, do not need to be individually coordinated to minimise the potential for unacceptable interference to either their services or other people's services. Some examples of current class licences are the licence for low power remote control devices and for "citizen's band" two way radiocommunications. Cellular mobile handsets are also class licensed.

Details of class licensing are given at http://www.aca.gov.au/licence/class/index.htm

[1] Links to the *Radiocommunications Act 1992* and other relevant communication legislation can be found at http://www.aca.gov.au/legal/index.htm .

1.2 Apparatus licensing

Apparatus licensing coordinates spectrum use by prescribing the operation of radiocommunications equipment according to a particular frequency, geographic location and purpose. Typically, the licensee is authorised to operate transmitters (and in some cases receivers) at a specific site, utilising a specific frequency with technical conditions attaching to the licence which govern transmitter power, antenna height and radiation pattern and thus area of coverage. The nature of the licensees apparatus determines the type of licence. There are many types of apparatus licence, and the type definition constrains the type of operation and service which is authorised.

Under apparatus licensing, parts of the spectrum are planned to support the operation of particular types of devices. The interference management framework is therefore linked directly to the sorts of devices used, which in turn facilitates concentrated use of the spectrum.

Apparatus licensing is particularly appropriate in spectrum where there are long range propagation characteristics (where devices operating in Australia could create interference over very long distances, including in other countries), or where there are international agreements relating to use of spectrum (for example, for satellite communications). Apparatus licensing is also preferred in situations where market demand does not warrant price-based allocation and where users prefer an ‘over the counter’ approach for the provision of services to often geographically and temporally fragmented communication requirements. But apparatus licensing is less able to cope with situations of rapid technological change and where more flexible use of the spectrum is required due to competition reasons.

Apparatus licences can be issued for any period up to a maximum of five years. Apparatus licences can be transferred, but must be transferred as they stand - that is, location of transmitter, power level, licence type etc. must remain unchanged.

For further details on apparatus licensing, refer to http://www.aca.gov.au/licence/apparatus/index.htm .

1.3 Spectrum Licensing

A spectrum licence authorises a licensee, or a person authorised by the licensee, to operate radiocommunications devices within specified boundaries of frequency bandwidth, area and time. Under spectrum licensing, there is flexibility to change equipment, antenna, device siting, or any other aspects of spectrum use, provided a license complies with the conditions of the licence, written determinations and any other rules or obligations applied by the ACA. A spectrum licence does not otherwise constrain the type of service the licensee wishes to operate.

Spectrum licensing confers a form of spectrum access right, described in terms of area and frequency bandwidth in which emissions may be created. The main goal of spectrum licensing is to allow market mechanisms to be much more influential in *allocating* spectrum between users, and determining how spectrum is used. Unlike apparatus licensing, it operates independently of devices and is therefore more technology transparent.

Licensees may trade licences, or parts of licences, provided they follow any rules about trading made by the ACA. Licensees are able to acquire licences or parts of licences from each other in the market place and aggregate them to form licences covering larger areas or licences permitting use of a wider frequency bandwidth, or both. Licensees may also divide their licences into smaller parts and market surplus spectrum as licences covering narrower bandwidth, or licences covering smaller areas, or both.

Spectrum licensees are free to change the technology they use in response to changing market conditions, or in response to the emergence of new technology . They do this by buying or selling spectrum space in the market in order to accommodate their preferred use. The concept of access rights, combined with an appropriate allocation system, allows market factors to resolve preferred aggregations, preferred technologies and preferred licensees.

For further details on spectrum licensing, refer to http://www.aca.gov.au/licence/spectrum/index.htm .

APPENDIX 3

UTILISATION AND GROWTH IN MICROWAVE FIXED SERVICES BANDS

This appendix details statistical information concerning the spectrum utilised by apparatus licensed microwave fixed services in the frequency range 1.5-50 GHz. The statistical information was assembled using the ACA's RADCOM and the earlier SMIS assignment and licensing databases[1].

Table A3.1 lists the number of apparatus licensed assignments (ie. spectrum accesses) for the period 31 December 1993 through 31 December 1999 and the corresponding 1, 3 and 5 year growth trends.

Further detailed statistical information is provided for:

- long term growth trends in each band, with a line chart showing the number of (one way) spectrum access in each band from 1993 through August1999;
- the identification of spectrum users in each band (current at August 1999), with a pie chart showing the breakup of the major users of the band and a listing of the primary spectrum users; and
- the proportion of analogue vs digital services at August 1999, as a pie chart.

The statistics take account of all apparatus licensed point-to-point fixed services including the (now closed) 5 GHz high capacity as well as DRCS point-to-multipoint services. No data is included for television outside broadcast (TOB) services, since the network licensing arrangements for these services preclude the availability of meaningful information concerning their numbers and geographic deployment.

Further discussion on the detailed content of this appendix is given in §3.1 of the main report.

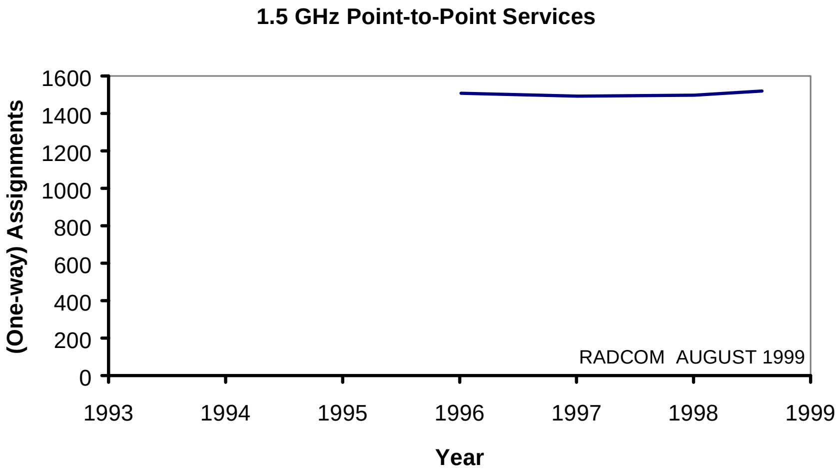
[1] *NOTE: Whilst every care has been taken to check and verify the information provided, no liability is or will be accepted by the ACA or it's officers, servants or agents for any loss suffered, whether arising directly or indirectly, due to the reliance on the accuracy of the information provided in this document.*

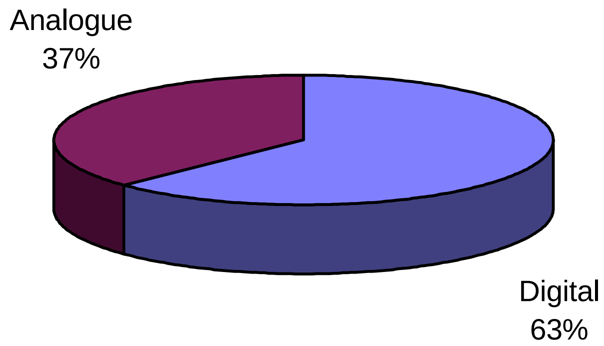
	SMIS data			RADCOM data				Average (p.a.) Assignment Growth		
Fixed Band	1993 31-Dec-93	1994 31-Dec-94	1995 31-Dec-95	1996 31-Dec-96	1997 31-Dec-97	1998 31-Dec-98	1999 31-Dec-99	1 yr growth Jan99-Dec99	3 yr growth Jan97-Dec99	5 yr growth Jan95-Dec99
1.5 GHz				1508	1492	1497	1421	-5.08%	-0.24%	no data
1.5 DRCS				2464	2528	2689	2899	7.81%	2.99%	no data
1.8 GHz	2142	2506	2644	2733	2745	2741	2595	-5.33%	-1.68%	0.77%
2.1 GHz	2038	1639	1607	1770	1805	1844	1828	-0.87%	1.09%	2.29%
3.8 GHz	2567	2647	2501	2393	2252	2086	2073	-0.62%	-4.63%	-4.74%
6 GHz	1126	1148	1144	1164	1094	1022	1200	17.42%	1.61%	1.24%
6.7 GHz	6070	6090	5535	5526	5530	5606	5908	5.39%	2.28%	-0.49%
7.5 GHz	793	854	947	1303	1517	1679	1830	8.99%	12.03%	16.92%
8 GHz	1865	1930	1901	2050	2115	2142	2217	3.50%	2.65%	2.86%
10 GHz	451	477	719	996	1124	1269	1431	12.77%	12.84%	25.56%
11 GHz	611	619	616	612	595	691	770	11.43%	8.26%	4.73%
13 GHz*	253	254	288	266	268	274	389	41.97%	14.99%	10.14%
15 GHz	634	960	1522	2138	2283	2388	2523	5.65%	5.68%	23.21%
18 GHz	463	560	752	1205	1717	2259	2889	27.89%	33.98%	39.29%
22 GHz	462	534	828	1242	1518	1786	2527	41.49%	27.12%	37.28%
50 GHz	205	192	186	170	170	86	86	0.00%	-16.47%	-12.23%
38 GHz	2	28	66	332	582	992	1508	52.02%	65.92%	147.30%
5 GHz				16	35	86	84	-2.33%	88.15%	no data

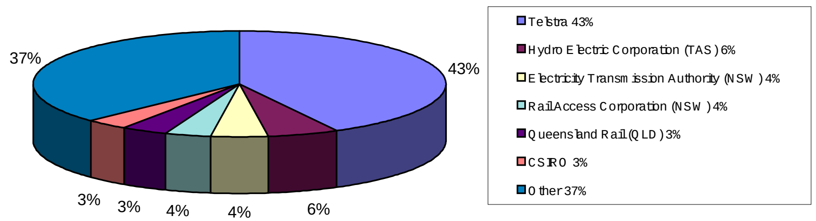
Table A3.1 Summary of apparatus licence statistics for microwave fixed services (1993-1999)

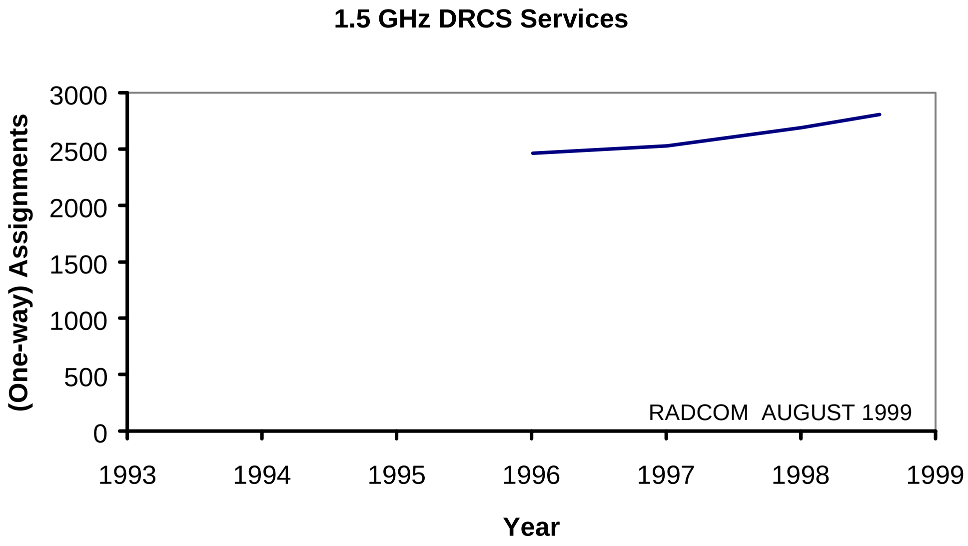
Note: The 5 year trend may not be entirely reliable due to the 1995 consolidation of apparatus licence types and changeover from SMIS (Spectrum Management Information System) to RADCOM.

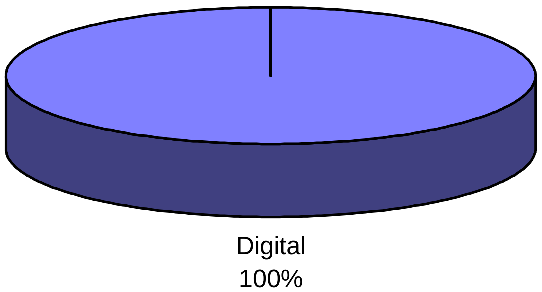
* The 13 GHz Band is shared with itinerant (TOB) Services - figures do not include TOB usages.

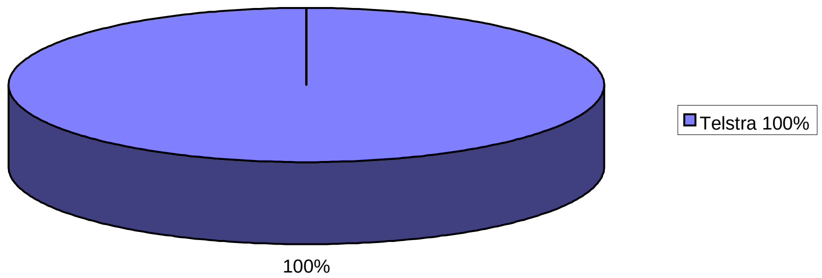

1.5 GHz Point-to-Point Services
(One-way) Assignments
1600
1400
1200
1000
800
600
400
200
0
1993
1994
1995
1996
1997
1998
1999
Year
RADCOM AUGUST 1999

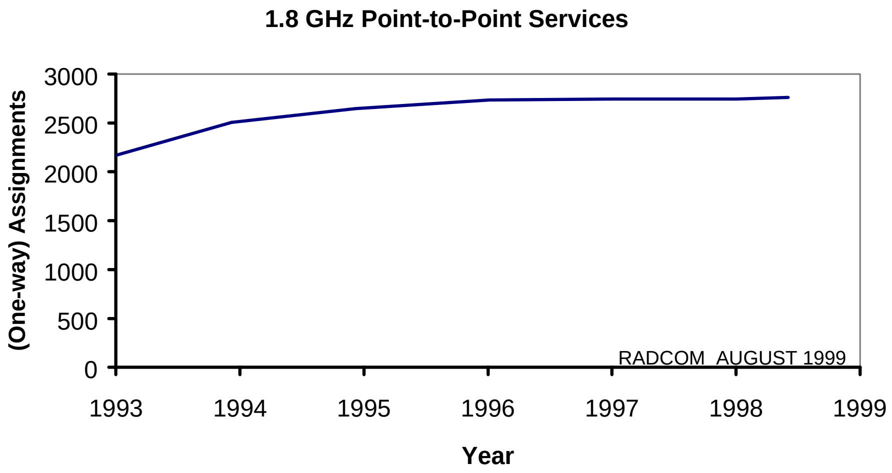

Analogue
37%
Digital
63%

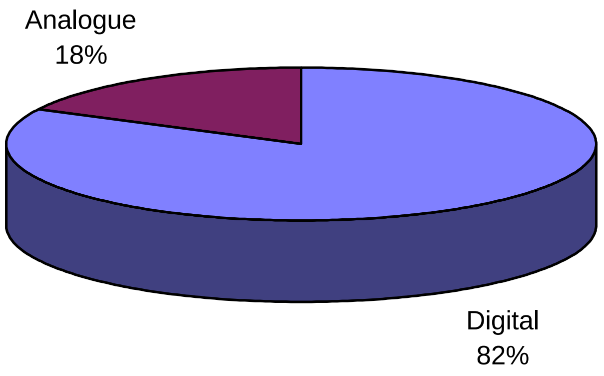

37%
43%
3%
3%
4%
4%
6%
Telstra 43%
Hydro Electric Corporation (TAS) 6%
Electricity Transmission Authority (NSW) 4%
Rail Access Corporation (NSW) 4%
Queensland Rail (QLD) 3%
CSIRO 3%
Other 37%


1.5 GHz DRCS Services
(One-way) Assignments
3000
2500
2000
1500
1000
500
0
1993
1994
1995
1996
1997
1998
1999
Year
RADCOM AUGUST 1999


Digital
100%


Telstra 100%
100%


1.8 GHz Point-to-Point Services
3000
2500
2000
1500
1000
500
0
(One-way) Assignments
RADCOM AUGUST 1999
1993
1994
1995
1996
1997
1998
1999
Year


Analogue
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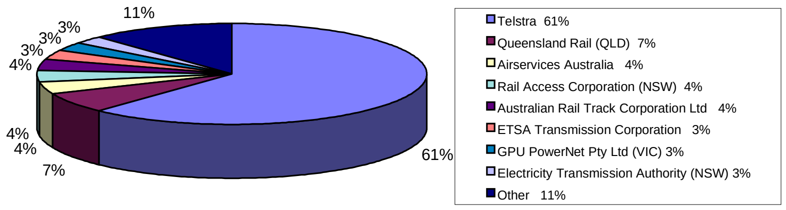
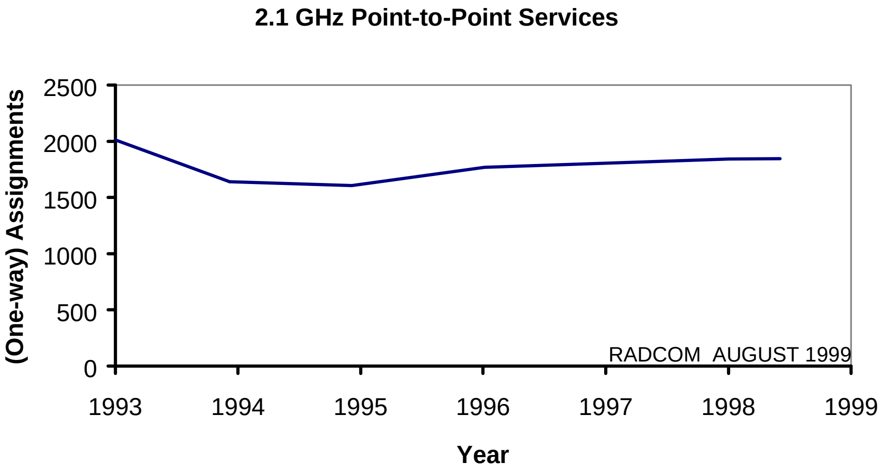
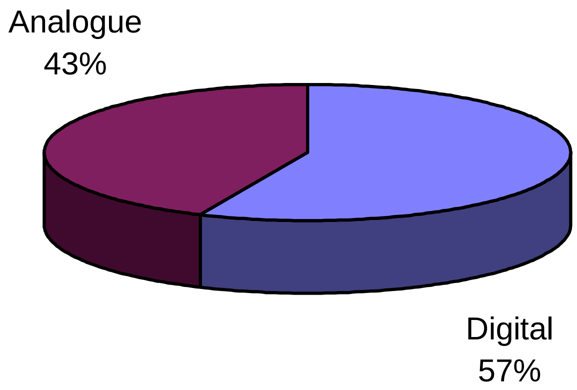
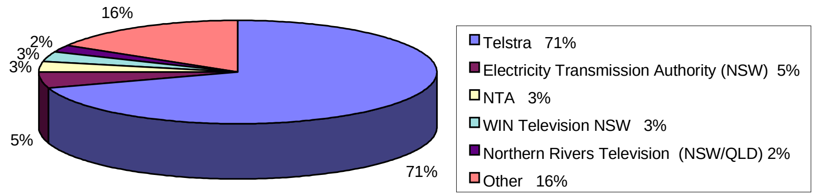
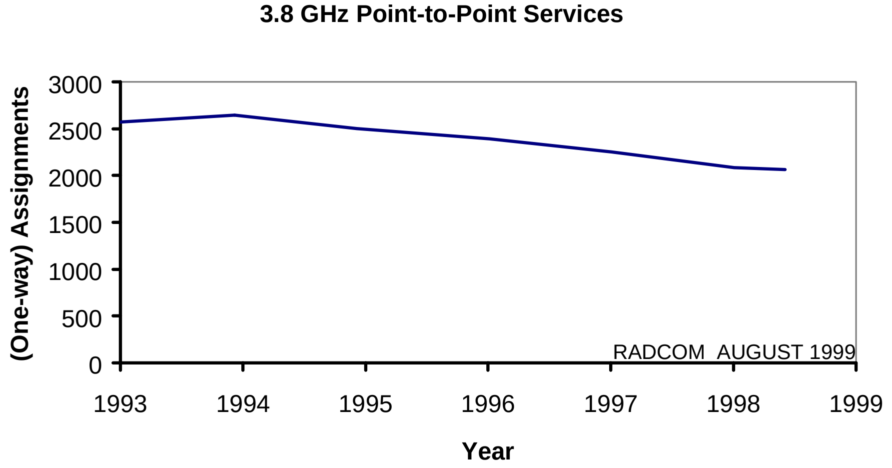
Digital
82%

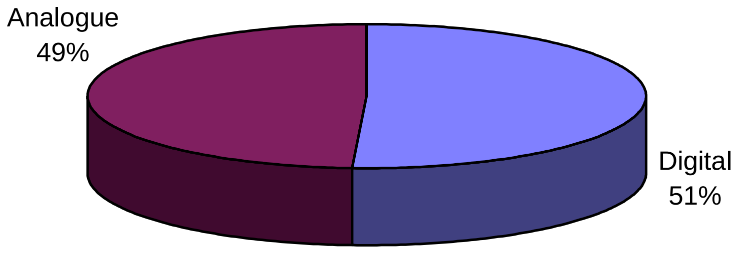

11%
3%
3%
3%
4%
4%
4%
7%
61%
Telstra 61%
Queensland Rail (QLD) 7%
Airservices Australia 4%
Rail Access Corporation (NSW) 4%
Australian Rail Track Corporation Ltd 4%
ETSA Transmission Corporation 3%
GPU PowerNet Pty Ltd (VIC) 3%
Electricity Transmission Authority (NSW) 3%
Other 11%

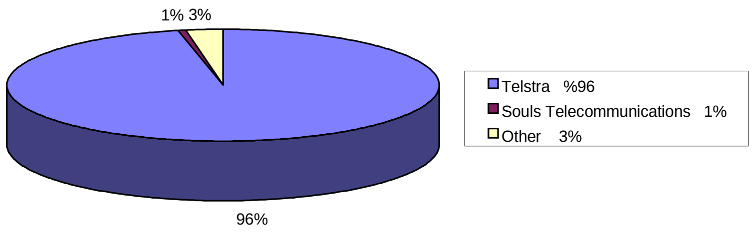

2.1 GHz Point-to-Point Services
(One-way) Assignments
2500
2000
1500
1000
500
0
RADCOM AUGUST 1999
1993
1994
1995
1996
1997
1998
1999
Year


Analogue
43%
Digital
57%

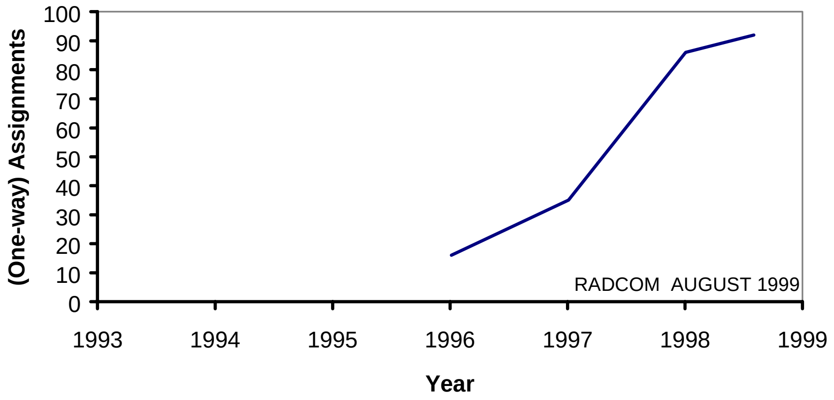

16%
2%
3%
3%
5%
71%
Telstra 71%
Electricity Transmission Authority (NSW) 5%
NTA 3%
WIN Television NSW 3%
Northern Rivers Television (NSW/QLD) 2%
Other 16%

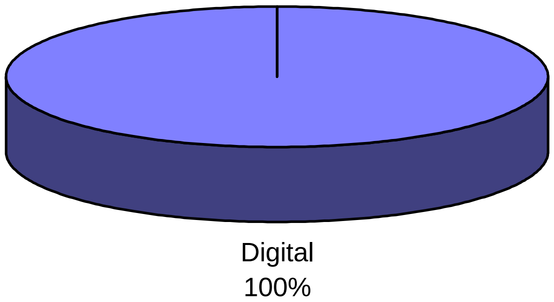

3.8 GHz Point-to-Point Services
(One-way) Assignments
3000
2500
2000
1500
1000
500
0
RADCOM AUGUST 1999
1993
1994
1995
1996
1997
1998
1999
Year

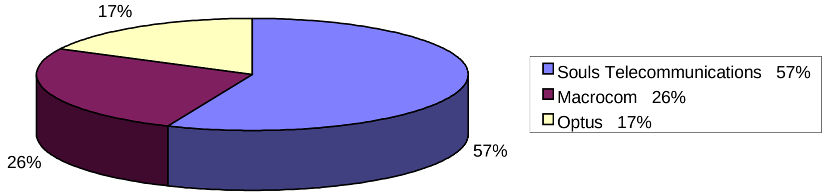

Analogue
49%
Digital
51%

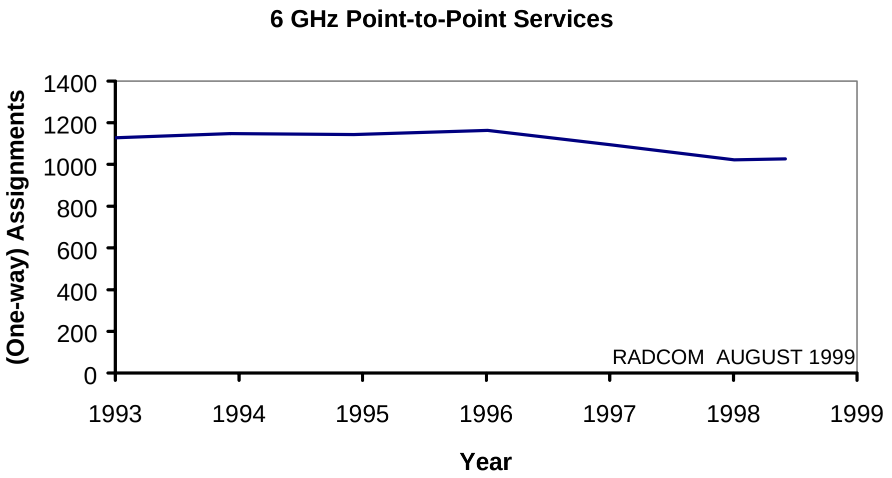

1% 3%
96%
Telstra %96
Souls Telecommunications 1%
Other 3%

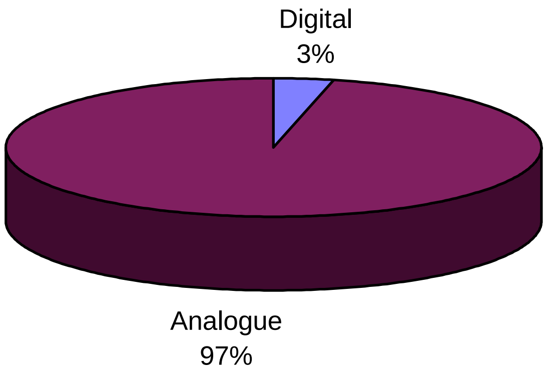
5 GHz Point-to-Point Services

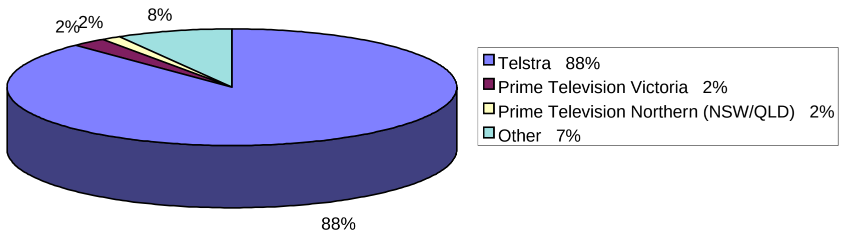


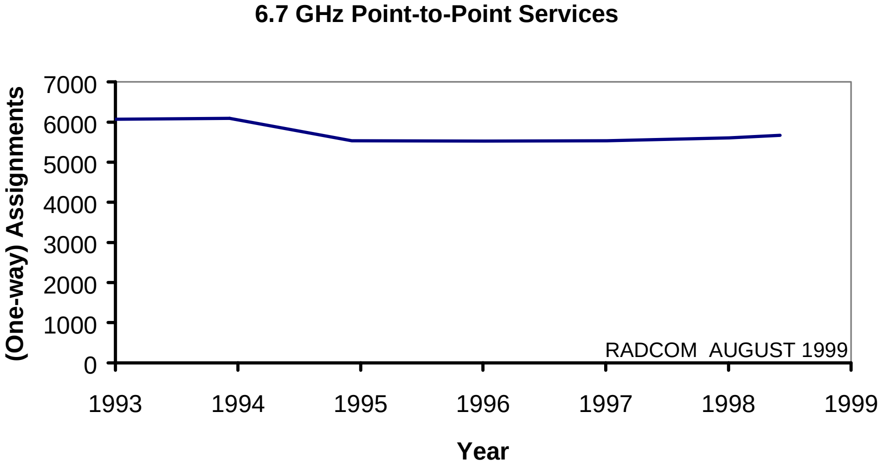


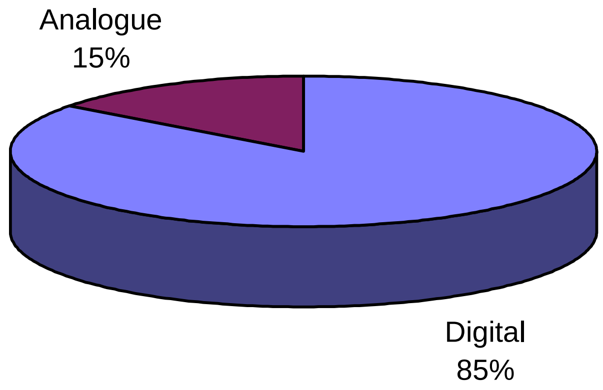


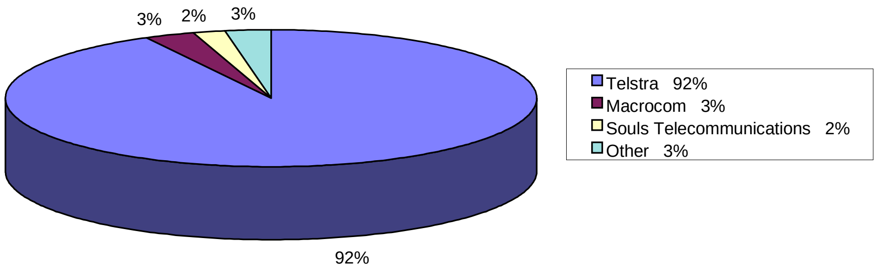

6 GHz Point-to-Point Services
(One-way) Assignments
1400
1200
1000
800
600
400
200
0
1993
1994
1995
1996
1997
1998
1999
Year
RADCOM AUGUST 1999

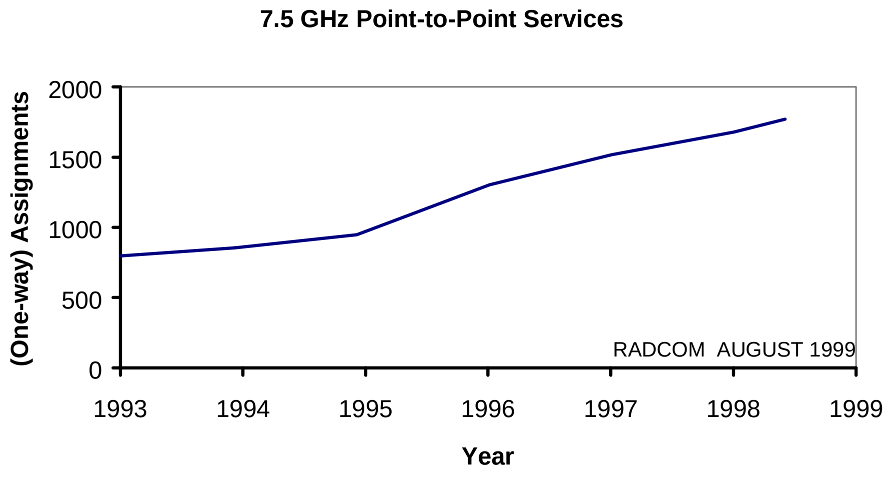

Digital
3%
Analogue
97%

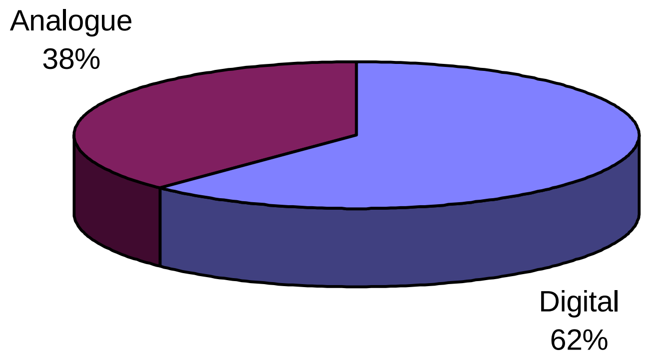

2%
2%
8%
88%
Telstra 88%
Prime Television Victoria 2%
Prime Television Northern (NSW/QLD) 2%
Other 7%

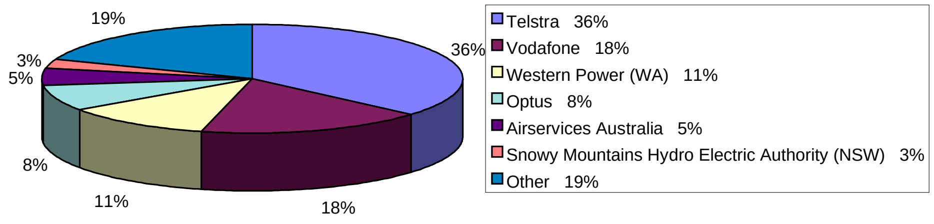

6.7 GHz Point-to-Point Services
(One-way) Assignments
7000
6000
5000
4000
3000
2000
1000
0
RADCOM AUGUST 1999
1993
1994
1995
1996
1997
1998
1999
Year

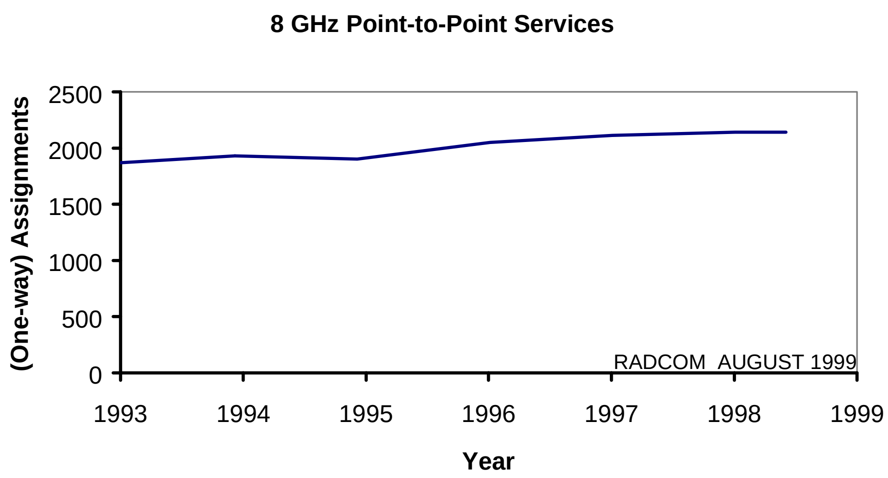

Analogue
15%
Digital
85%

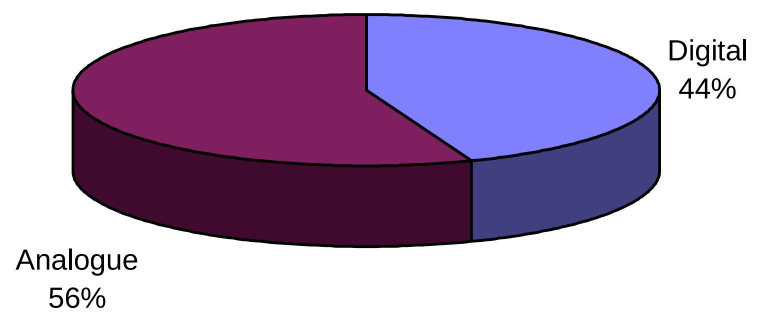

3%
2%
3%
92%
Telstra 92%
Macrocom 3%
Souls Telecommunications 2%
Other 3%

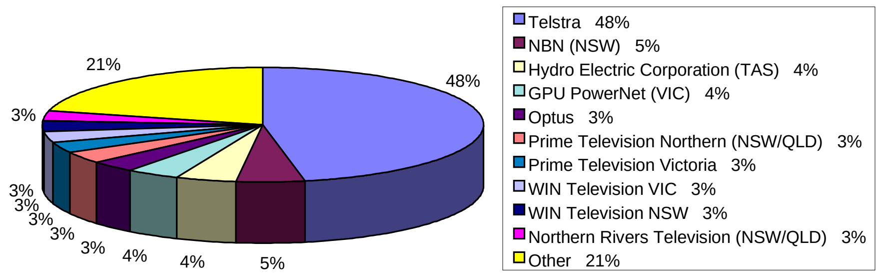

7.5 GHz Point-to-Point Services
(One-way) Assignments
2000
1500
1000
500
0
RADCOM AUGUST 1999
1993
1994
1995
1996
1997
1998
1999
Year

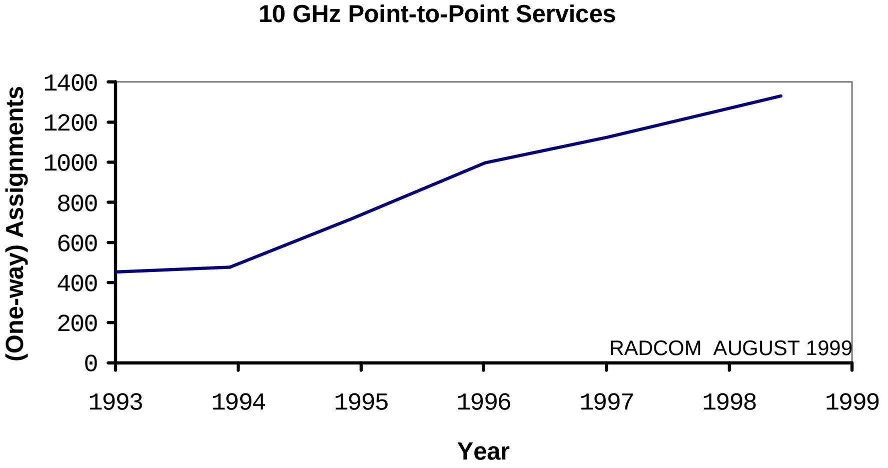

Analogue
38%
Digital
62%

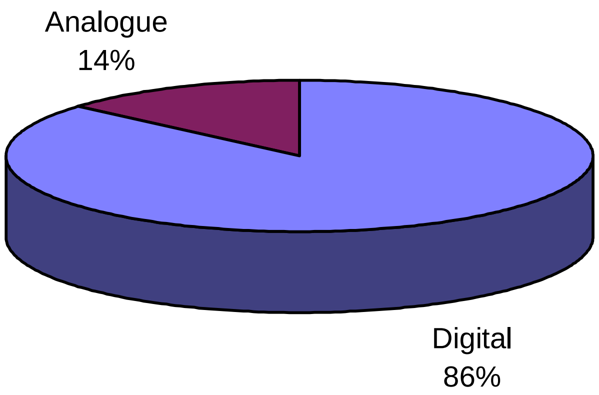

19%
36%
3%
5%
8%
11%
18%
Telstra 36%
Vodafone 18%
Western Power (WA) 11%
Optus 8%
Airservices Australia 5%
Snowy Mountains Hydro Electric Authority (NSW) 3%
Other 19%

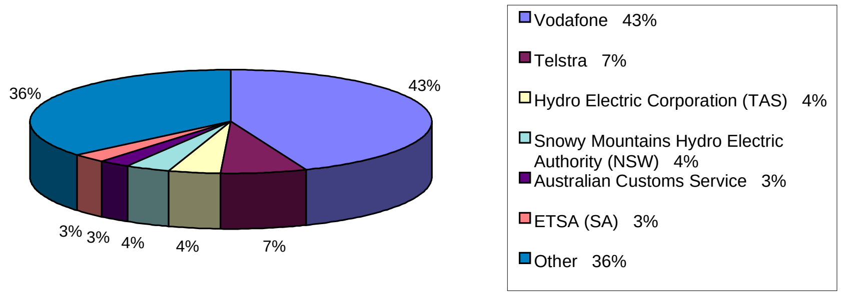

8 GHz Point-to-Point Services
(One-way) Assignments
2500
2000
1500
1000
500
0
1993
1994
1995
1996
1997
1998
1999
Year
RADCOM AUGUST 1999

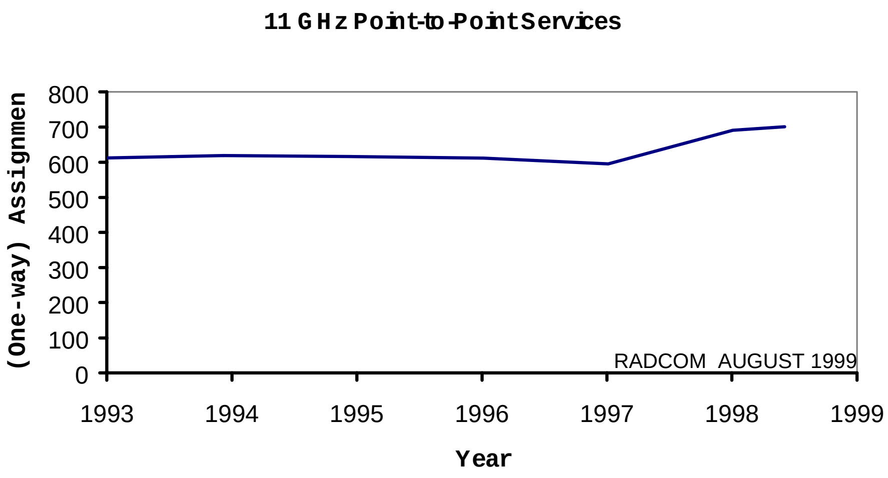

Digital
44%
Analogue
56%

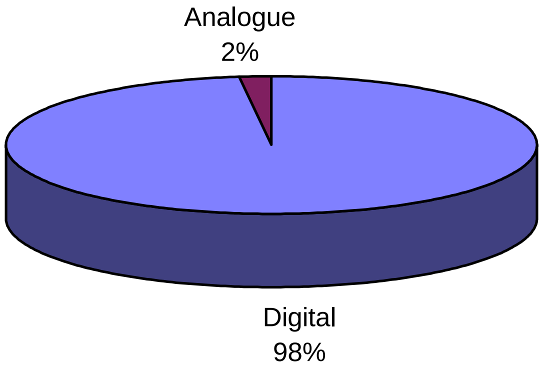

21%
48%
3%
3%
3%
3%
3%
3%
4%
4%
5%
Telstra 48%
NBN (NSW) 5%
Hydro Electric Corporation (TAS) 4%
GPU PowerNet (VIC) 4%
Optus 3%
Prime Television Northern (NSW/QLD) 3%
Prime Television Victoria 3%
WIN Television VIC 3%
WIN Television NSW 3%
Northern Rivers Television (NSW/QLD) 3%
Other 21%

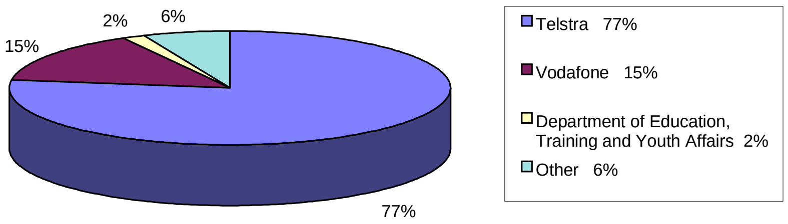

10 GHz Point-to-Point Services
(One-way) Assignments
1400
1200
1000
800
600
400
200
0
1993
1994
1995
1996
1997
1998
1999
Year
RADCOM AUGUST 1999

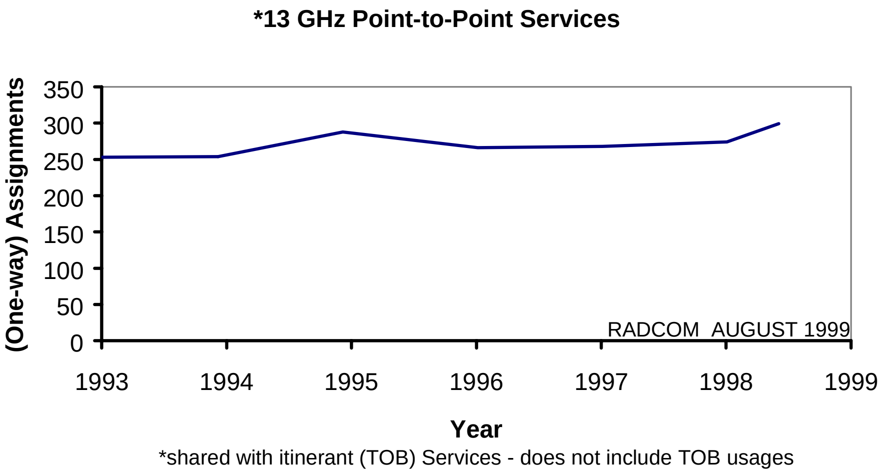

Analogue
14%
Digital
86%

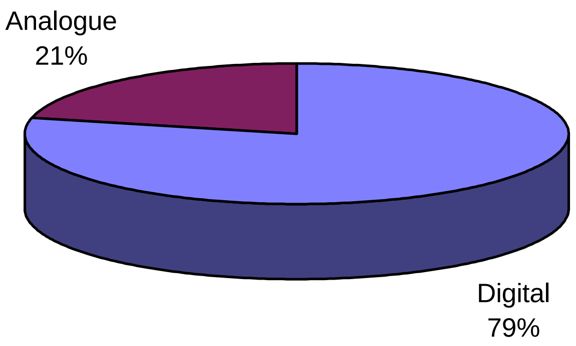

36%
43%
3%
3%
4%
4%
7%
Vodafone 43%
Telstra 7%
Hydro Electric Corporation (TAS) 4%
Snowy Mountains Hydro Electric Authority (NSW) 4%
Australian Customs Service 3%
ETSA (SA) 3%
Other 36%

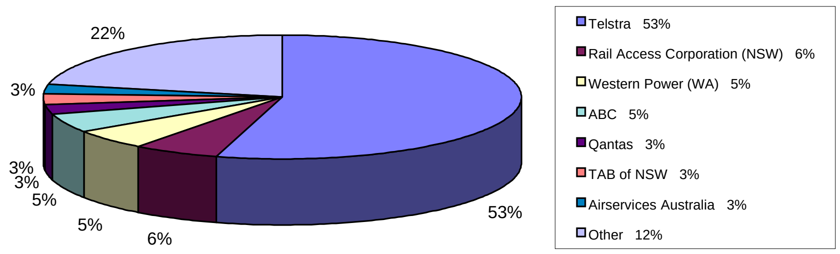

11 GHz Point-to-Point Services
(One-way) Assignmen
800
700
600
500
400
300
200
100
0
RADCOM AUGUST 1999
1993
1994
1995
1996
1997
1998
1999
Year

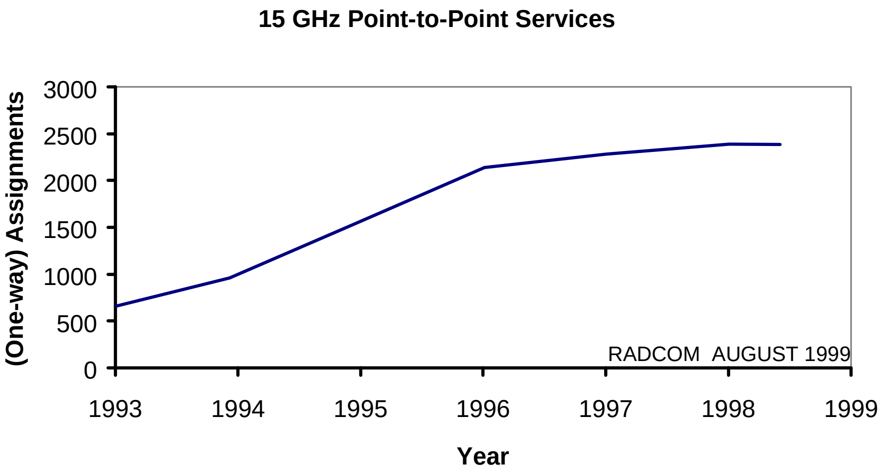

Analogue
2%
Digital
98%

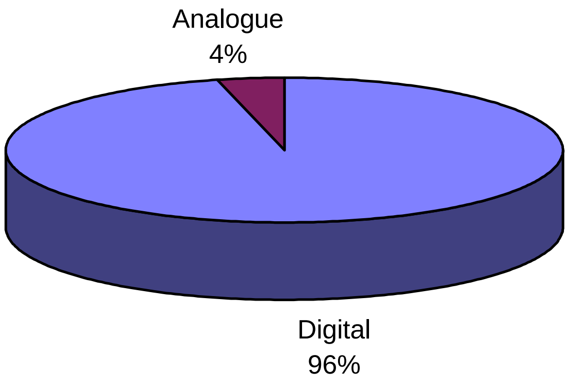

15%
2%
6%
77%
Telstra 77%
Vodafone 15%
Department of Education, Training and Youth Affairs 2%
Other 6%

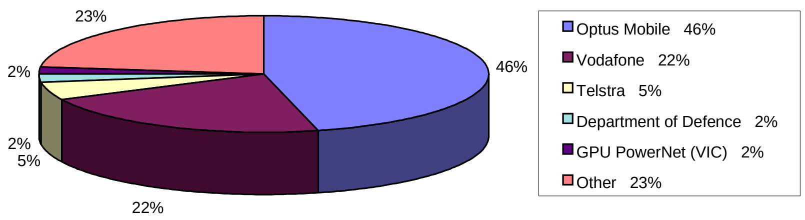

*13 GHz Point-to-Point Services
(One-way) Assignments
350
300
250
200
150
100
50
0
RADCOM AUGUST 1999
1993
1994
1995
1996
1997
1998
1999
Year
*shared with itinerant (TOB) Services - does not include TOB usages

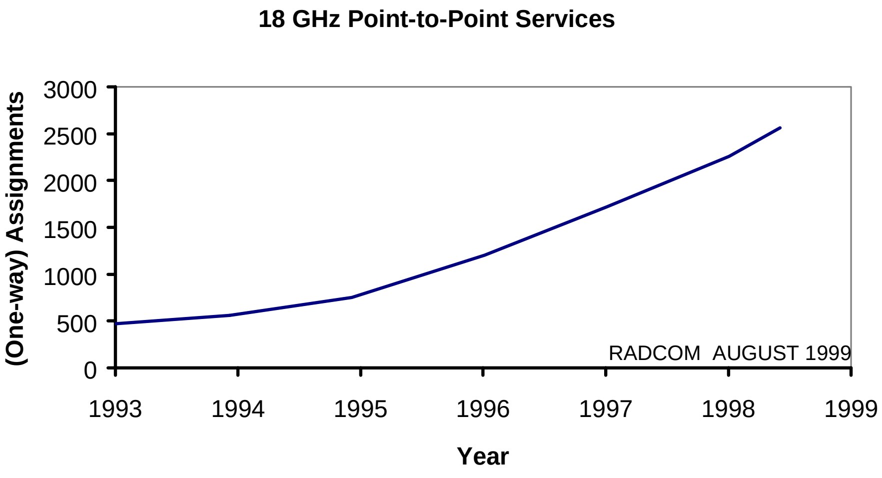

Analogue
21%
Digital
79%

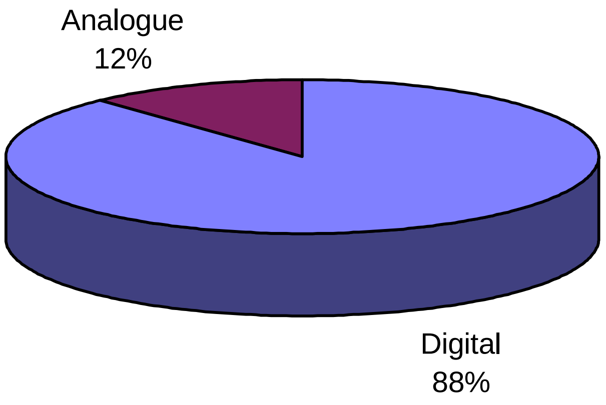

22%
3%
3%
3%
5%
5%
6%
53%
Telstra 53%
Rail Access Corporation (NSW) 6%
Western Power (WA) 5%
ABC 5%
Qantas 3%
TAB of NSW 3%
Airservices Australia 3%
Other 12%

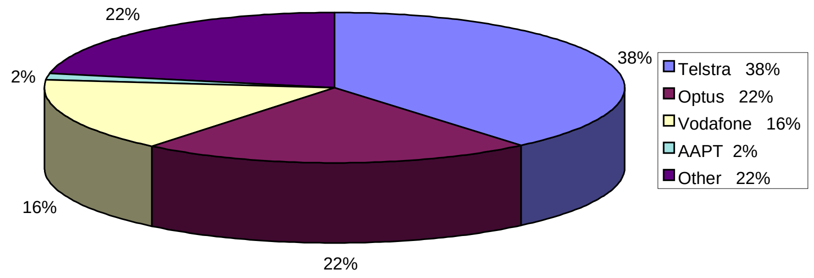

15 GHz Point-to-Point Services
(One-way) Assignments
3000
2500
2000
1500
1000
500
0
RADCOM AUGUST 1999
1993
1994
1995
1996
1997
1998
1999
Year

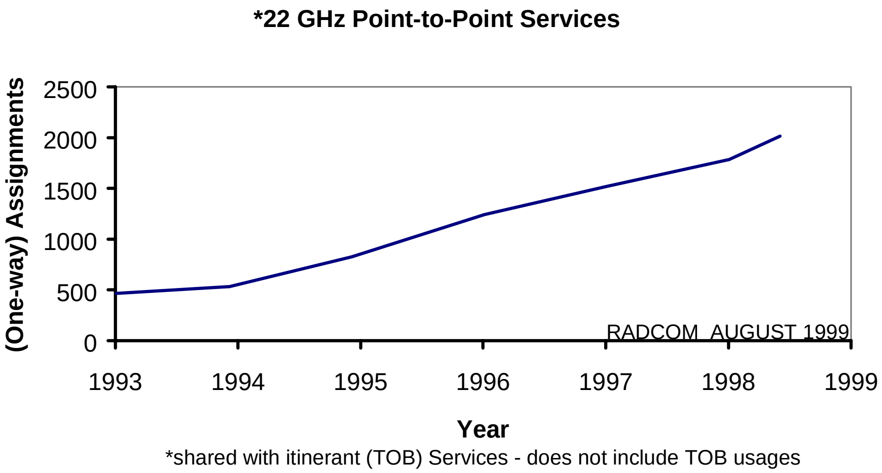

Analogue
4%
Digital
96%

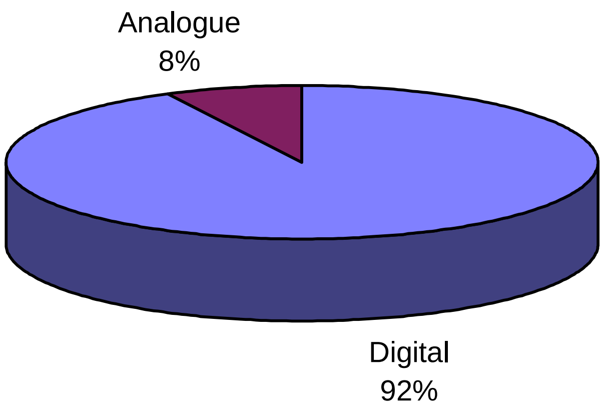

23%
2%
46%
2%
5%
22%
Optus Mobile 46%
Vodafone 22%
Telstra 5%
Department of Defence 2%
GPU PowerNet (VIC) 2%
Other 23%

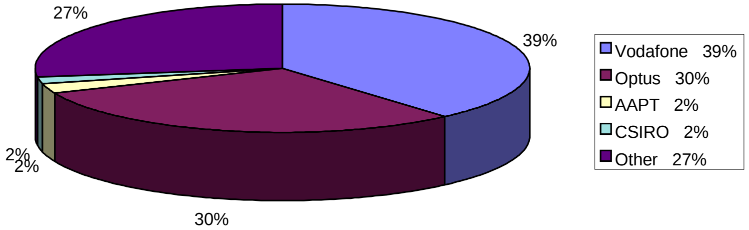

18 GHz Point-to-Point Services
(One-way) Assignments
3000
2500
2000
1500
1000
500
0
1993
1994
1995
1996
1997
1998
1999
Year
RADCOM AUGUST 1999


Analogue
12%
Digital
88%

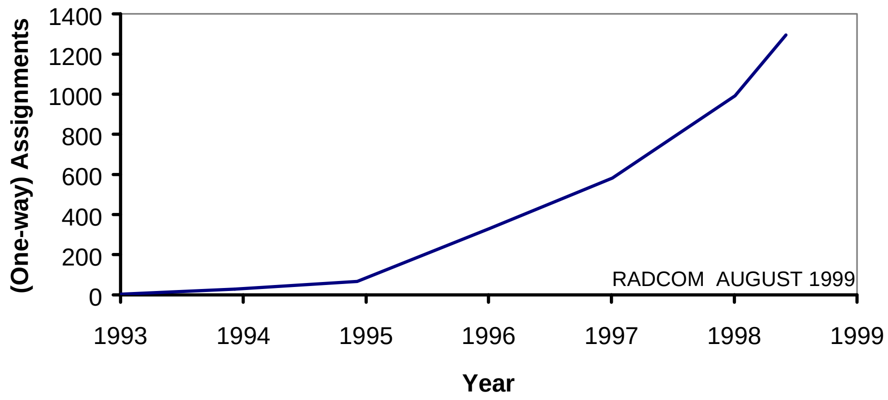

22%
2%
38%
16%
22%
Telstra 38%
Optus 22%
Vodafone 16%
AAPT 2%
Other 22%

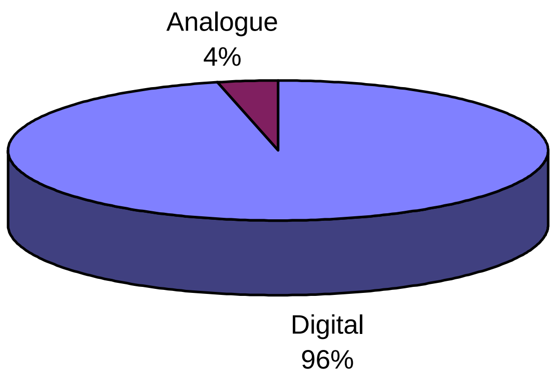

*22 GHz Point-to-Point Services
(One-way) Assignments
2500
2000
1500
1000
500
0
1993
1994
1995
1996
1997
1998
1999
Year
RADCOM AUGUST 1999
*shared with itinerant (TOB) Services - does not include TOB usages

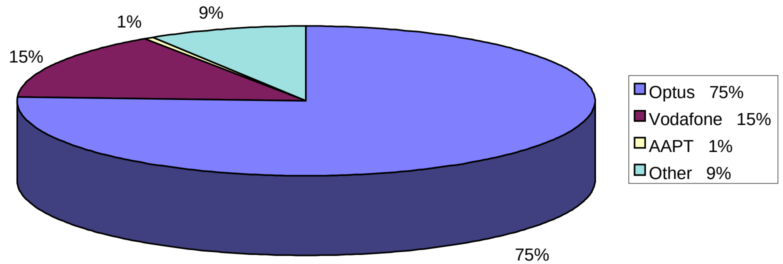

Analogue
8%
Digital
92%


27%
39%
2%
2%
30%
Vodafone 39%
Optus 30%
AAPT 2%
CSIRO 2%
Other 27%

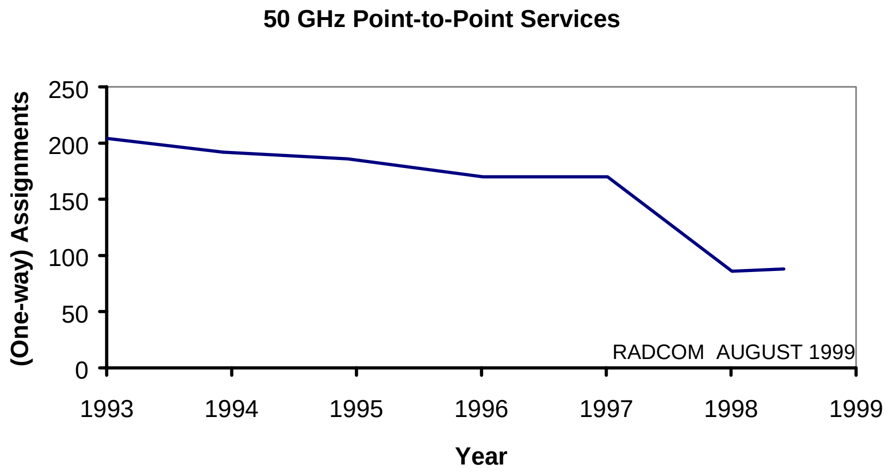
38 GHz Point-to-Point Services

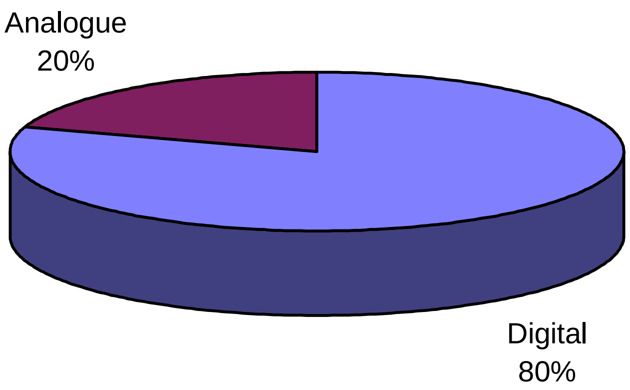


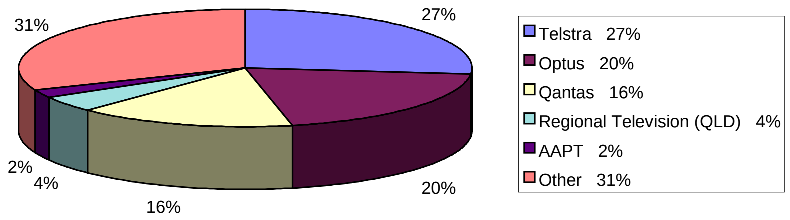




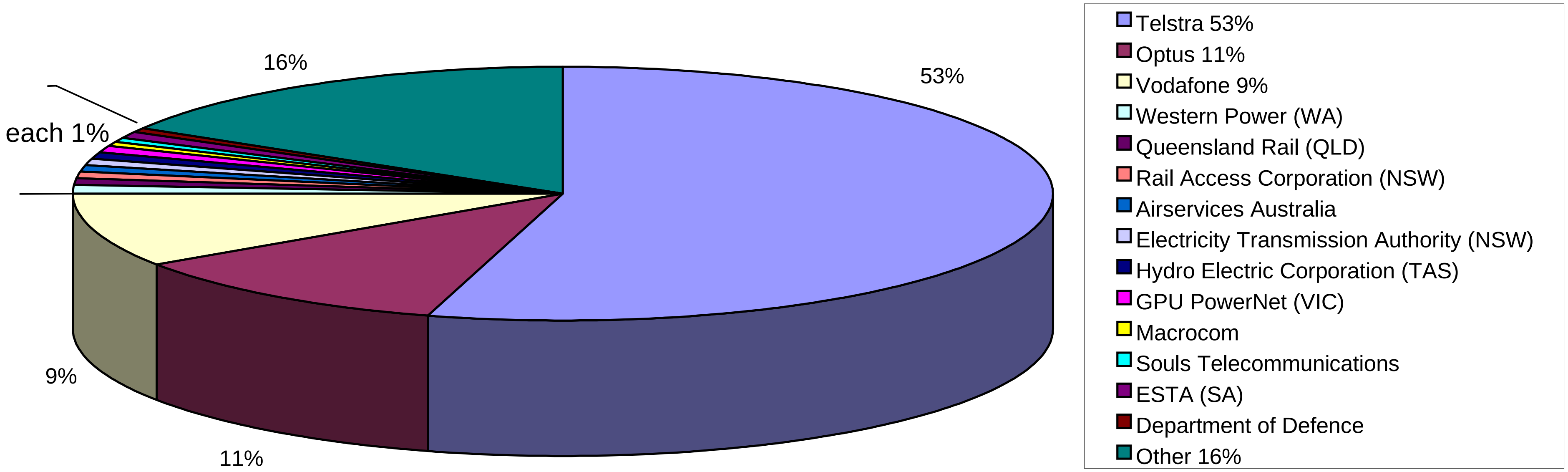
50 GHz Point-to-Point Services

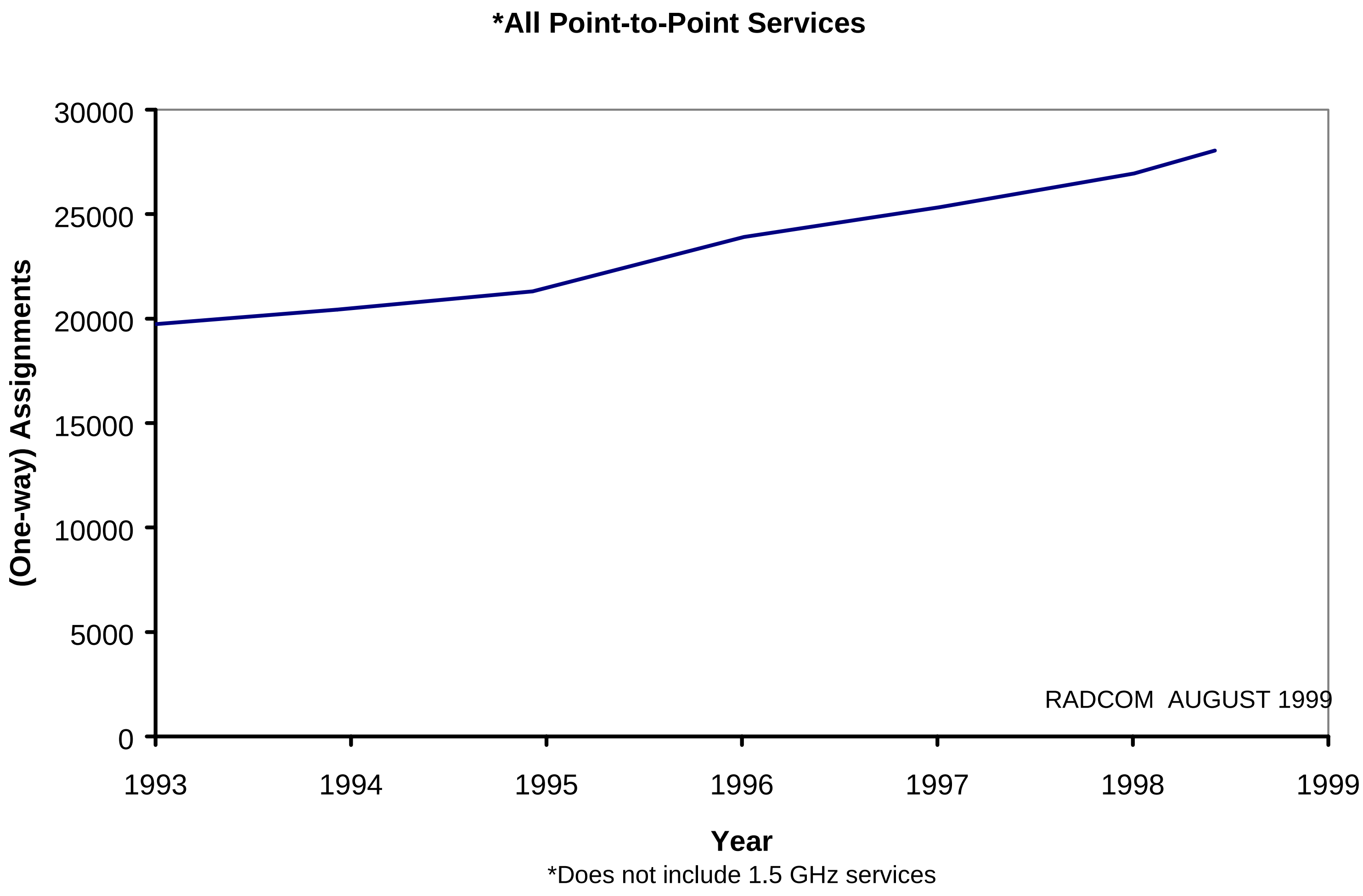






Total Point to Point Services (1 - 60 GHz)




*All Point-to-Point Services
(One-way) Assignments
30000
25000
20000
15000
10000
5000
0
1993
1994
1995
1996
1997
1998
1999
Year
RADCOM AUGUST 1999
*Does not include 1.5 GHz services

APPENDIX 4 – 1.8 GHz RELOCATION STRATEGIES

General relocation issues and strategies are discussed in §4.2 of the main report document. This appendix discusses relocation strategies and options for fixed services affected by the price based allocation of significant portions of the 1.8 GHz (1700-1900 MHz) band.

1. 1.8 GHz Fixed Services and Relocation Requirements

The 1.8 GHz band is a long established fixed service band, accommodating a range of analogue and digital (PDH) small capacity point-to-point links and thin-route radio relay applications. Based on ACA licensing information[1], the 1700-1900 MHz band accommodates a total of 2760 point-to-point spectrum accesses (equating to approximately 1380 bi-directional two-frequency links).

As demonstrated by Figure A4.1, the band is extensively utilised by Telstra, including a significant proportion of rural and remote area telecommunication feeder networks. Other major users include government and non-government utilities, using 1.8 GHz to support their own in-house operational communication and telemetry networks.

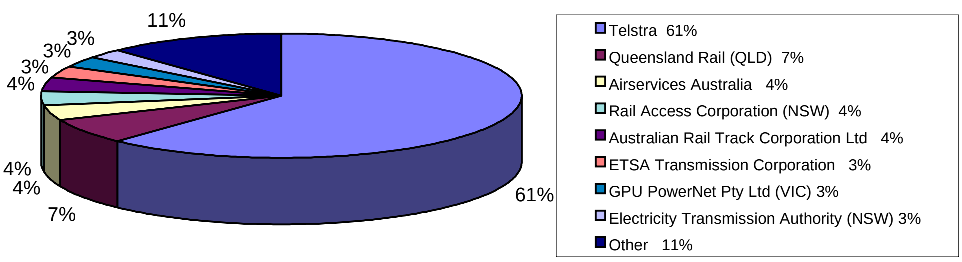


Figure A4.1. Users of the 1700-1900 MHz band.

As detailed under §2.6 of the main report, infrastructure for the 1.8 GHz band is relatively cheap due to mass market equipment availability and the relatively modest antenna support structures possible with the grid type parabolic antennas used in the bands below 3 GHz.

The majority (82%) of fixed links in the 1.8 GHz band are digital and of between about 2 to 17 Mb/s capacity, consistent with the 14 MHz channelling[2] of the band. Occupied bandwidths range from 1 MHz up to the full channel width of 14 MHz, but typically lie in the range 6 to 12 MHz.

[1] ACA RADCOM licensing database, August 1999.
[2] Aligned with ITU-R Recommendation F.283-5 "*Radio-frequency channel arrangements for low and medium capacity analogue or digital radio-relay systems in the 2 GHz band*".

1.1 Current Status of 1.8 GHz Re-allocation Arrangements

In 1997, parts of the 1.8 GHz band were re-allocated for spectrum licensing and subsequently auctioned:

1. the bands 1710-1755 and 1805-1850 MHz (ie. 2 x 45 MHz) in designated major city areas (Ref. *Spectrum Re-allocation Declaration No.3 of 1997*): and

2. the bands 1710-1725 and 1805-1820 MHz (2 x 15 MHz) in defined regional areas, (Ref. *Spectrum Re-allocation Declaration No.4 of 1997*).

In response to further demand for 1.8 GHz spectrum, the Government recently confirmed a decision to reallocate a further 2x30 MHz in metropolitan areas. Accordingly, a further price-based allocation is now taking place for:

3. the bands 1755-1785 and 1850-1880 MHz, in designated major city areas (Ref. *Spectrum Re-allocation Declaration 1999 (No.2).*

As with the earlier 1.8 GHz reallocations, spectrum is again be sold with incumbents (ie. fixed services) in place, but with a set relocation period. Under the arrangements put in place, incumbent fixed services in the band 1755-1785 and 1850-1880 MHz have until 1 January 2002 to relocate. Spectrum acquisition caps for the sale are defined in the *Radiocommunications (Spectrum Licence Limits-1.8 GHz Band) Direction No.1 of 1999*. Further details concerning the latest 1.8 GHz spectrum auction is provided at http://203.37.2.230/PCS2000/PCS2000.htm.

1.2 The 1.9 GHz Band Plan Provision for CTS

As discussed at §3.6.2.2 "*1.9 GHz Cordless Telephone Services*", the plan facilitates the deployment of cordless telecommunication services within the band 1880-1900 MHz and prevents the assignment of new 1.8 GHz services within this frequency range. As further detailed in the main report, from 1 July 2001, all fixed services operating within the 1880-1900 MHz band will be required to accept interference caused by the operation of 1.9 GHz CTS devices. Whilst there is no legal obligation for fixed services to change frequency or to relocate, operators need to consider the implications of the effective reduction in interference protection status and consequent impact on their own operations. The likelihood of interference will clearly be higher in urban rather than rural areas.

As any relocation/retuning action will be at the discretion of potentially affected operators, no detailed displacement estimates are provided in this document for the 1880-1900 MHz band. However, the available relocation options and likely costs are substantially the same as for the other 1.8 GHz services subject to reallocation and spectrum licensing.

1.3 Identifying Affected Services

Figure A4.2 shows the RF Channel Arrangements for the 1.8 GHz (1700-1900 MHz)[3] band, overlaid with the frequency blocks allocated to city and regional spectrum licensed and cordless (1880-1900 MHz) services.

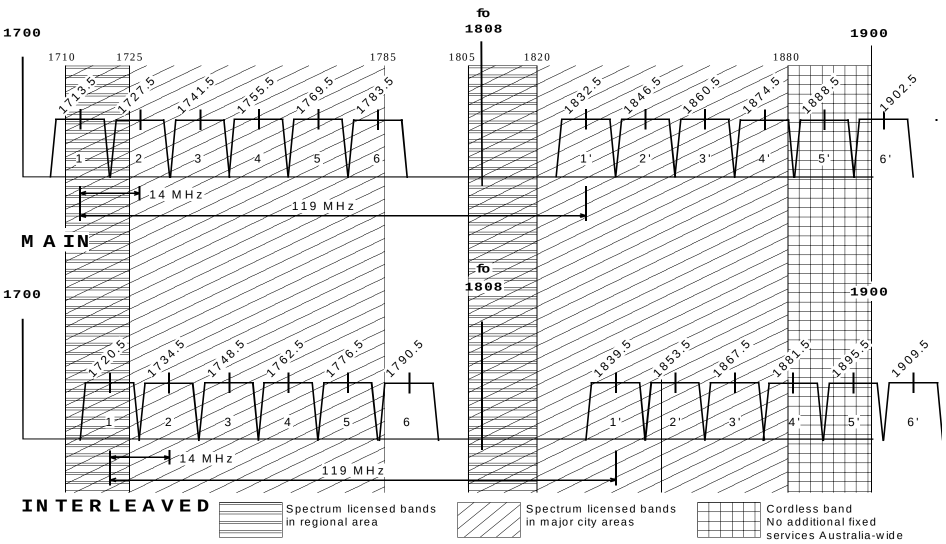


Figure A.4.2. 1.8 GHz fixed services RF channel arrangements.

Figure A.4.2 shows the distribution of all fixed services operating in the 1.8 GHz band, the Major City and regional Spectrum Licence Area boundaries (Ref. §A4.1.1).

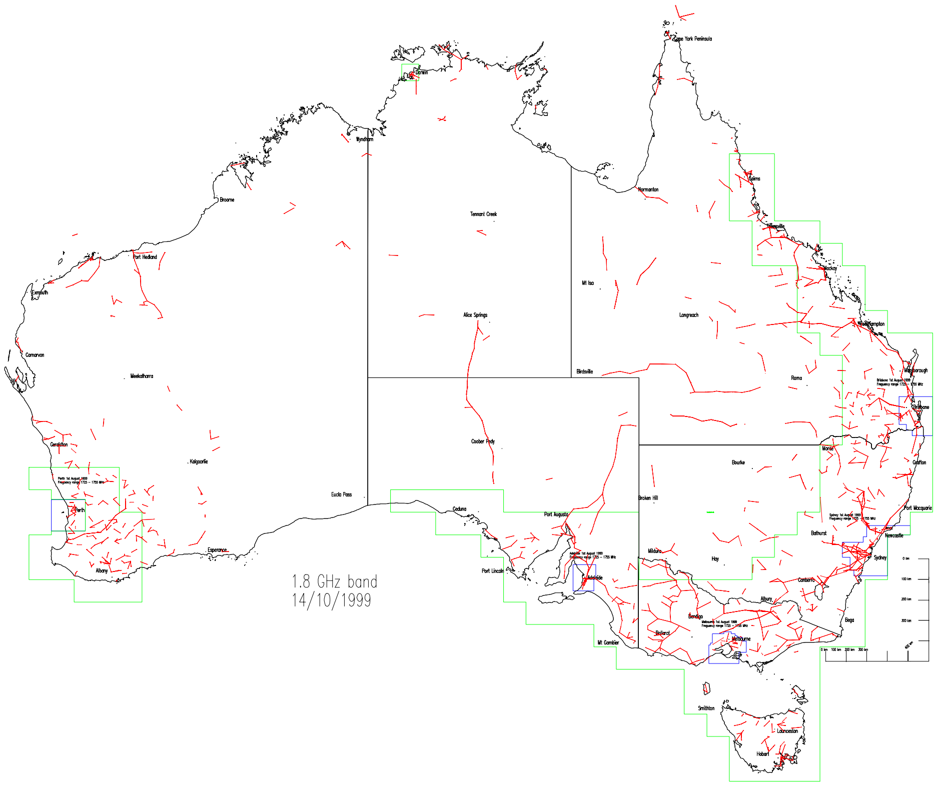


Figure A.4.3. Fixed Services in the 1700-1900 MHz Band[4].

[3] Based on ITU-R Recommendation F.283-5. "*Radio-frequency Channel Arrangements for low and Medium Capacity Analogue or Digital Radio-Relay Systems Operating in the 2 GHz Band*".

Clearly, not all of the fixed services operating in the 1.8 GHz (1700-1900 MHz) band are subject to relocation and, in order to determine if a particular link is potentially affected, it is necessary to check whether:

- one or more of the link operating frequencies fall within the frequency ranges identified for reallocation; and
- the link is operating within an area designated for reallocation (ie. if the location coordinates of one or both ends of the link fall within the areas defined in the relevant reallocation declaration).

In practice, the many 1.8 GHz fixed services operating outside of the declared spectrum licence areas are not affected and can continue to operate unhindered. However, the many services operating in major city and regional areas are affected.

1.3.1 Major City Areas

Due to spectrum demand for mobile services (see §3.6.2) and the nature of fixed service channel pairing, virtually all[5] of the 1.8 GHz fixed services operating in designated (A.4 §1.1(1 & 3)) major city areas are affected by relocation requirements.

As summarised in Annex A, 117 major city area fixed services are affected by the most recent re-allocation of the band 1755-1785 and 1850-1880 MHz, with relocation to be effected by January 2002.

1.3.2 Regional Areas

In the designated (A.4 §1.1(2))‘regional’ spectrum licensing areas, only those fixed services with emission overlapping the frequency range 1710-1725 and 1805-1820 MHz (ie. RALI FX-3 1.8 GHz Band channels 1 main/interleaf and channel 2 main) are subject to reallocation. Figure A.4.4 shows the geographic distribution of these links.

[4] Based on ACA RADCOM licensing data, at September 1999.
[5] With the possible exception of certain services operating on the interleaved channels 6/6’ with an occupied bandwidth less than about 10 MHz.

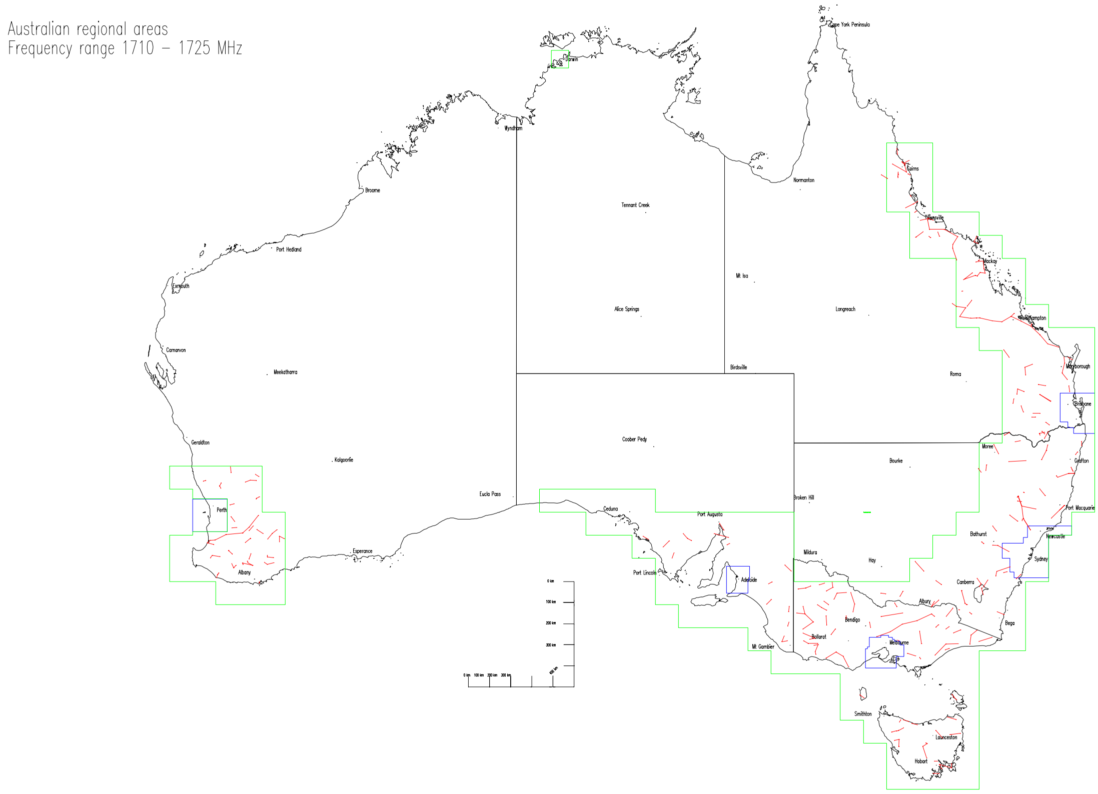


Figure A.4.4. Regional Fixed Services operating in the range 1710-1725 MHz.

Annex B lists the 271 apparatus licensed fixed services still operating within the frequency range 1710-1725 and 1805-1820 MHz and the designated regional areas.

2. Relocation Options

This section looks at the options available for the relocation of fixed services from the 1.8 GHz band. As discussed at §4.2.1, relocation into another (higher) frequency band is predicated upon the availability of alternative spectrum and a detailed analysis of the relevant technical, environmental and economic constraints.

In some cases, a non-radio solution may be required. The following sections explore the options for relocating into alternative frequency bands, taking account of the information available for the services identified for relocation.

2.1 Consideration of Alternative frequency bands

As outlined at A.4 §1.0, the majority of fixed services operating in the 1.8 GHz band are digital, of between E1 (2 Mb/s) to 8E1 (16 Mb/s) capacity. In considering alternative frequency bands for relocation, the 14 MHz (RF) channel bandwidth of the 1.8 GHz band does not mean that relocation options are confined to those bands with 14 MHz channelling. However, the channelwidth does set the upper bound for the traffic capacity of the RF channel and 16E1 is about the maximum transmission capacity that can be achieved within a 14 MHz channel using readily available radio products.

Many frequency bands offer arrangements compatible with the types of services being relocated from 1.8 GHz – potential candidate bands are listed in Table 1.

Capacity	*Frequency Band (GHz)*								
	6	**7.5**	**8**	**10**	**13**	**15**	**18**	**22**	**38**
1/2E1	-	✓	-	✓	-	✓		✓	✓
4/8/16E1	✓	✓	✓	✓	✓	✓	✓	✓	✓
FDM	✓	✓	✓	✓	✓	✓	✓	✓	✓

Table A.4.1. Candidate bands for relocation of 1.8 GHz fixed services

The table options do not include 3.8, 6.7 and 11 GHz as these bands are used for high capacity applications, functionally incompatible with the small capacity services accommodated at 1.8 GHz. Nevertheless, some licensees may choose to take relocation as an opportunity to replace a service with a high capacity system.

As discussed at §4.2.2, the relocation of a fixed service into another frequency band requires detailed planning, with the identification of the potential alternatives in Table A.4.1 representing only an initial step.

2.1.1 Path Lengths, Propagation & Link Performance

Key factors to take into account in considering viable options for relocation is the necessary performance and availability criteria vs multipath and rainfall induced outage (see §2.6.2 and §2.8 of the main report). Whilst the bands above 10 GHz are potentially available for the relocation of 1.8 GHz fixed services, their utility is particularly limited by inherent propagation related constraints (ie rainfall outage).

The severity of such propagation constraints are frequency, location and link path distance dependent and significantly more acute in the areas of high rainfall intensity.

A common feature of < 3 GHz bands is that good link performance is achievable even over relatively long single-hop path lengths. Nevertheless, as demonstrated in Figure A.4.5 (Distribution of 1.8 GHz link path lengths, Australia wide), a significant proportion of 1.8 GHz services do operate over relatively short link paths, with about 30% of all paths shorter than 20 km.

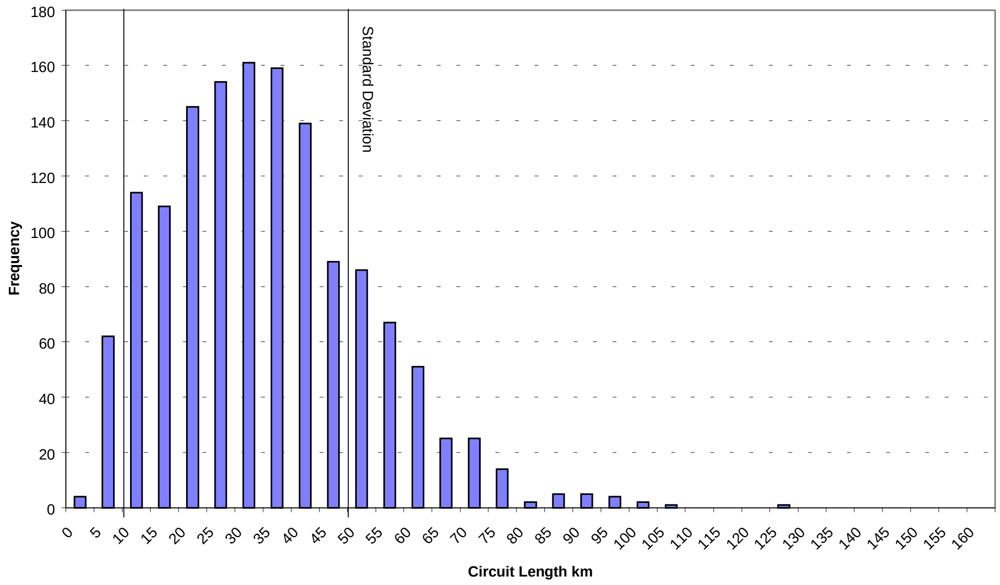


Figure A.4.5. Frequency Distribution of 1.8 GHz Path Lengths[6].

From the graph it is also readily apparent that 80% of the single hop path lengths lie within the range 10 to 50km, with the most common path length at about 33 km. However, these figures represent Australia wide statistics and regional differences are to be expected – see Figure A.4.6, which shows a major city area vs national comparison of the cumulative distribution of 1.8 GHz link path lengths.

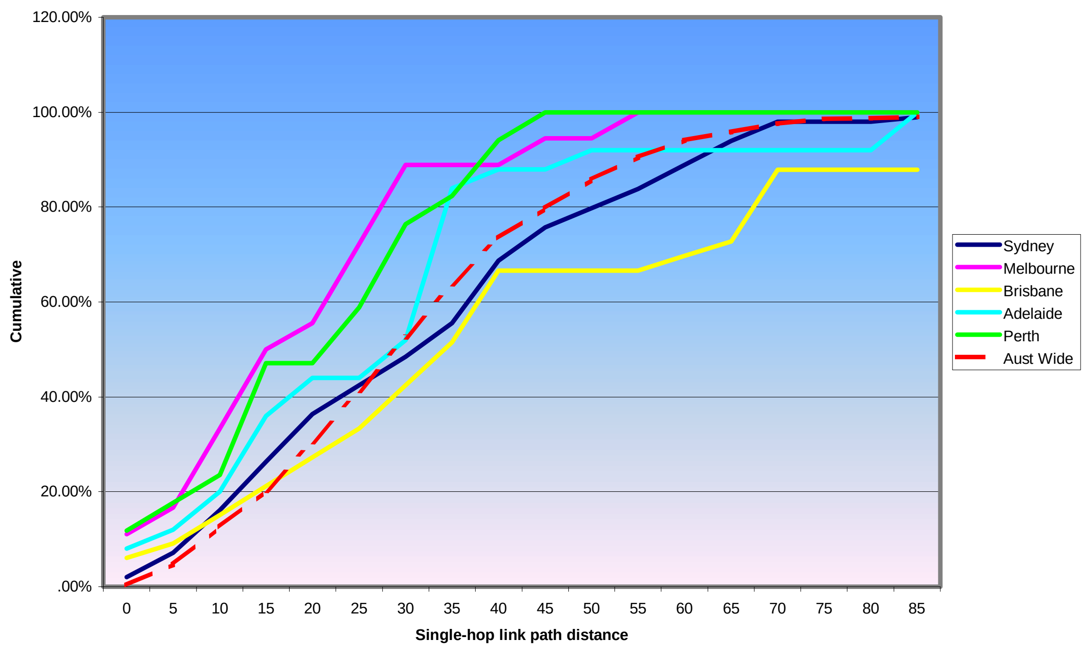


Figure A.4.6. Cumulative distribution of path lengths in the 1.8 GHz band.

[6] ACA RADCOM licensing database information for 1.8 GHz fixed services, September 1999.

Clearly, the links in the designated major city areas (with the single exception of Brisbane) tend to have link paths significantly shorter than in the regional, rural and remote areas. The RALI FX-3 1.8 GHz assignment instructions specify a minimum path length of 20 km, but many links with shorter path lengths were commissioned prior to the introduction of the rule. Based on RADCOM statistics, over 55% of the links in Melbourne that are subject to relocation have path distances of less than 20 km, followed by Perth (47%), Adelaide (44%), Sydney (36.4%) and finally Brisbane (27.3%), at slightly below the national figure (30.5%).

So the extent of the relocation issue in most of the designated major city areas is ameliorated by the fact that many links have relatively short path lengths (in comparison to regional, rural and remote areas where long single-hop paths are more prevalent). Accordingly, many 1.8 GHz city area links may be relocated into higher frequency bands, including the rainfall limited higher microwave bands.

2.1.2 Potential of Rain Limited (>10 GHz) Bands

In order to make definite statements about the various band options identified in A.4 §2.1 and Table A.4.1, it is necessary to consider each incumbent link on a case-by-case basis. In the absence of such information, and for the purpose of gauging the useability of rain limited bands, it is necessary to make assumptions about the performance criteria of incumbent 1.8 GHz systems.

Typical 1.8 GHz small capacity links have fade margins of the order of 30 to 40 dB and performance commensurate with multipath propagation dominated worst month outage probability. Translating link availability and fade margin requirements into the higher bands where rainfade is the dominant limiting factor, we can assume that fade margins of a similar order (30-40 dB) and annual per-hop link outage probabilities in the range 0.01% to 0.001% (for an average up to a high grade system). Achievable link path distances vs frequency bands are shown at §2.8.2 of the main report. The examples (Figures 2.13, 2.14) are for the Sydney region (rainfall intensity of 40 mm/hr exceeded for 0.01% annually).

Different sets of possibilities exist for other regions of Australia, with rainfall intensities within the range 20-100+ mm/hr. However, as shown in Table A.4.2, most of the designated city areas subject to 1.8 GHz fixed link relocations have maximum rain intensities of less than 40 mm/hr.

Location	**Path Length* (km)**			**Rain Intensity****
	typical	**80%**	**max.**	**max (mm/hr)**
Australia Wide	*33*	*50*	*125*	*20..100+*
Sydney/Wollongong	*42*	*55*	*95*	*40*
Melbourne/Geelong	*20*	*35*	*60*	*30*
Brisbane	*40*	*70*	*100*	*50*
Perth	*18*	*40*	*50*	*30*
Adelaide	*38*	*40*	*88*	*25*

* From ACA RADCOM statistics Sep 1999 ** From ITU-R Doc. 3/43 (18 March 1999)

Table A.4.2. Path length (1.8 GHz) vs rainfall intensity statistics

Accordingly, taking account of the path length statistics established in §2.1.1 and regional variation, between 25 to 50% of the major city area 1.8 GHz incumbents may be accommodated in the bands above 10 GHz. In order to derive more accurate figures it is necessary to apply case-by-case consideration and detailed knowledge of individual link design performance objectives, terrain and local microclimates.

The remaining 50-75% of city area 1.8 GHz links with longer path lengths require relocation strategies making use of the fixed service bands in the range 3-10 GHz and the establishment of additional repeaters where link path hops exceed about 55 km.

2.1.3 Potential in the 3 to 10 GHz Bands

The dominant limiting factor in the lower microwave bands is multipath fading (§ 2.8.1 of main report), typically of high intensity but of short duration, hence the impact on availability is diminished in comparison to the dominant events in rain limited bands.

In the 3 to 10 GHz frequency range, relocation opportunities for 1.8 GHz fixed services are primarily limited to the 6.0/7.5/8.0 and 10 GHz bands, since the requirement is to find alternative bands with arrangements supporting 'like' point-to-point services. The 3.8 and 6.7 GHz arrangements accommodate homogenous high capacity (68/155 Mb/s) services and are therefore inconsistent with the types of small to medium capacity (2-16 Mb/s & FDM) links requiring relocation. Nevertheless, there is no reason why some relocations could not take advantage of the high capacity arrangements, in situations where the high capacity replacement fulfils an operators business plan requirement.

As outlined in §4.2.2 "*Relocating into another band*", the relocation of a link from the 1-3 GHz frequency range requires at least the replacement of equipment terminals, up to 30 metres of waveguide and solid parabolic dish antennas to replace existing1.8 GHz grid parabolics. Some of the relocated links are likely to require additional countermeasures against multipath fading (eg. space diversity antennas), with consequent further loading of existing antenna structures and possibly requiring the strengthening or replacement of an antenna mast or tower. Depending on the required link performance and local geoclimatic factors, additional repeaters may be needed where link path hop distance greater than about 55 km are needed.

Gaining access to spectrum in the potential alternative bands is another risk factor that needs to be addressed. Gauging the risk accurately requires detailed case-by-case consideration, since spectrum availability is highly location and orientation (ie. subject to detailed coordination) dependent.

2.1.4 Spectrum Availability in the Alternative Bands

In the previous sub-sections, we have established that the principal bands for relocation of 1.8 GHz fixed services are the 6.0, 7.5, 8.0 and 10 GHz bands and the rain limited bands at 13, 15, 18, 23 & 38 GHz. The ultimate choice depends not only on individual assessment of technical and economic factors, but also spectrum availability in the alternative bands at the link location.

1. Short Path (< 20 km), small to medium capacity services. About 35% of the incumbent links have link paths shorter than 20 km and these should be readily accommodated in > 10 GHz bands, at least in areas of low to moderate rainfall intensity. Although the use of the higher microwave bands has increased dramatically in recent years, channelling and readily available radio equipment products are available to accommodate the whole range of short-hop small to medium capacity (2-34 Mb/s & analogue) relocated services;

2. Long Path (>20 km), medium capacity services. Due to the reasons outlined in the previous sections, practical relocation options for long path medium capacity links are principally limited to the 6.0 and 8.0 GHz bands, both with 29.65 MHz channel spacing. The 7.5 GHz band can also be used, but with some loss in system gain due to the need to deploy equipment with higher order modulation. As confirmed by Appendix 3 "*Utilisation and Growth Statistics: Australian Microwave Fixed Service Bands*", September 1999, regional fixed networks in the 6.0 and 8.0 GHz bands are relatively mature. Nevertheless, the potential remains for relocating substantial numbers of medium capacity (8-34 Mbs/ digital and analogue 1.8 GHz incumbent fixed services with path lengths in excess of 20 km;

3. Long Path (>20 km), small capacity services. RADCOM assignment statistics for the 7.5 GHz band reflect an ongoing demand for small to medium capacity (2-8 Mb/s) digital links with path lengths exceeding 20 km. Whilst the 10 GHz and higher rain limited bands can potentially accommodate displaced small capacity links, achievable path distances are affected in areas of high rainfall intensity.

Overall, the most critical aspect to the relocation of services from the 1.8 GHz band (and all < 3 GHz bands for that matter) is the need to find spectrum for small to medium capacity digital services of between 2 to 34 Mb/s in capacity and able to support single-hop path lengths of 20-50km with acceptable reliability.

In practice this equates to the 7.5 GHz band for small capacity and the 6, 7.5 and 8 GHz bands for medium capacity services. Assignment statistics for the larger capital cities (Sydney, Melbourne & Brisbane, Fig. A.4.7) show that the 8 GHz band is well utilised in these areas but also indicates that the opportunities in the 6 and 7.5 GHz bands are not exhausted.

In fact, considering the (lack of) utilisation of the 3.5 & 1.75 MHz channel rasters in the 7.5 GHz band suggests that there is further scope to improve utilisation in this band. The lack of any assignments on the 1.75 MHz channels suggests the absence of suitable equipment product and if this is the case, then the bandwidth allocated to these channels could be consolidated to the more desirable 7/14 MHz channels.

In conclusion, alternative spectrum opportunities remain for the relocation of 1.8 GHz links even in the high density city areas of Sydney, Melbourne and Brisbane. However, given that more services are being consolidated into fewer frequency bands, inevitably there will be situations where suitable channels may not be available at particular locations or they may be difficult to find. This risk is particularly relevant at high density nodal sites.

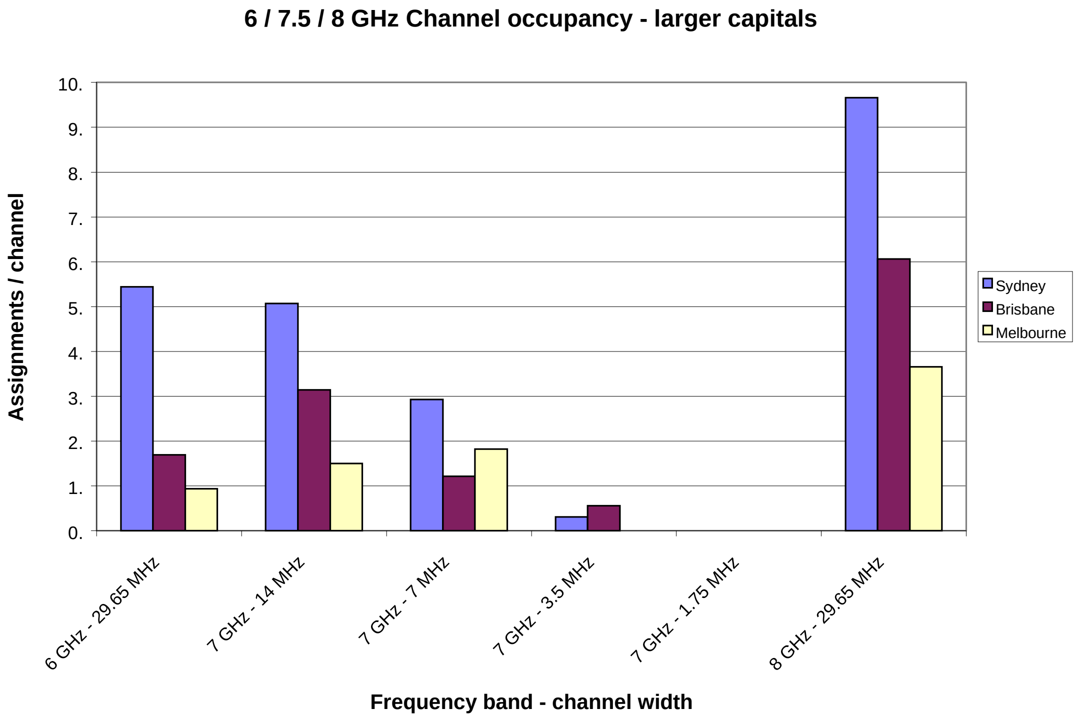


Figure A.4.7 Channel occupancy 6/7.5/8 GHz, Sydney, Melbourne & Brisbane

3. Relocation Costs

Relocation costs are highly variable, depending upon system capacity, path length, performance criteria and their relationship to propagation and local geoclimatic conditions. This section provides an approximate statistical estimate of the likely relocation costs for the 117 links identified (Annex A(1) as incumbents in the bands 1755-1785/1850-1880 MHz and designated for spectrum licensing. The estimates (Tables A4.3 to 4.6) are based on city area links, includes equipment and installation labour costs, but not including planning, design, administrative costs and the GST.

Estimated Equipment Costs[7]

30 metre freestanding tower	$50000
6.0/7.5/8.0 GHz, **16E1** (34Mb/s) RF terminal equipment	$35000
1.8/2.4 metre solid parabolic dish antenna	$5000
35 metres of waveguide	$3000
Auxiliary equipment & building	$6000

Table A.4.3 Assumed equipment & plant costs (34Mb/s, 6.0/7.5/8.0 GHz)

Estimated Labour Costs

Establishment of a new radio site	$50000
Modifications at an existing site	$25000
Tower strengthening/extension	$25000

Table A.4.4 Assumed labour costs for site & structure works.

[7] Assumptions based on SMA Report SPP2/96, May 1996.

Relocation Cost per 1.8 GHz Link

	Antenna Structure		*Equipment & Antennas*				*Labour*		*Total per*
	Tower	**Ext/Str.**	**RF Eqpt.**	**Antennas**	**Waveguide**	**Aux Eqpt**	**Ex. Site**	**New Site**	**2 way link**
Simple Replacement	-	-	$70,000	$10,000	$6,000	$12,000	$50,000	-	$148,000
With Extension/Strengthening	-	$50,000	$70,000	$10,000	$6,000	$12,000	$50,000	-	$198,000
With two new Towers	$100,000	-	$70,000	$10,000	$6,000	$12,000	$50,000	-	$248,000
With new Repeater Station	$50,000	-	$140,000	$20,000	$12,000	$24,000	$50,000	$50,000	$346,000

Table A.4.5 Estimated relocation cost per 1.8 GHz link

Relocation Cost per Link vs Path Length

Link Path Distance	% of links	Cost
<20 km	100%	$148,000
>20 & < 50km	25%	$148,000
>20 & <50km (ext/strengthening)	50%	$198,000
>20 & < 50km (new tower)	25%	$248,000
>50 km (new site & tower)	100%	$346,000

Table A.4.6 Estimated relocation cost vs link path length

The figures established in Tables A.4.3 to 4.6 are indicative statistical estimates, intended only for establishing the order of costing. Actual costs may exceed or fall short of the estimates. In any case, individual costs will vary substantially from the given figures and accurate costing for particular links must be evaluated on a case-by-case basis. Taking account of the statistical information established in Section 2, Annex A(1) "*Extra 2 x 30 MHz in City Areas (1755-1785MHz/1850-1880 MHz)*" and assuming that 1.8 GHz incumbents with path lengths of:

- up to 20 km can be accommodated in higher (>10 GHz) bands utilising 0.6 metre solid parabolic dishes, but do not require antenna structure upgrading;

- up to 50 km can be accommodated in the 6.0, 7.5 and 8.0 GHz bands, but 50% of them require tower strengthening/extension to meet additional structural loading due to the need to replace grid parabolics with solid parabolic dish antennas with much higher windloading. A further 25% are assumed to require the replacement of the existing antenna structure with a new 30 metre freestanding tower; and

- exceeding 50 km require the establishment of one additional repeater, including a new 30 metre freestanding tower, a 2.4 metre (standard) solid parabolic antenna, back-to-back RF terminal equipment, 2×35 metres of waveguide and a simple equipment enclosure.

we can gauge the overall cost of relocating the 117 city area 1.8 GHz city area links subject to the *Spectrum Re-allocation Declaration 1999 (No. 2)* – See Table A.4.7.

Area	% of links	# of links	$ per link	sub-total
Sydney				
<20km	36.40%	21	148000	*$3,108,000*
>20km & < 50km	43.40%	25	198000	*$4,950,000*
>50km	20.20%	12	346000	*$4,152,000*
Total	100%	58		*$12,210,000*
Melbourne				
<20km	55.6	7	148000	*$1,036,000*
>20 & <50km	38.9	5	198000	*$990,000*
>50km	5.5	1	346000	*$346,000*
Total	100	13		*$2,372,000*
Brisbane				
<20km	27.3	6	148000	*$888,000*
>20 & <50km	39.4	9	198000	*$1,782,000*
>50km	33.3	7	346000	*$2,422,000*
Total	100	22		*$5,092,000*
Adelaide				
<20km	44	7	148000	*$1,036,000*
>20 & < 50km	48	7	198000	*$1,386,000*
>50km	8	1	346000	*$346,000*
	100	15		*$2,768,000*
Perth				
<20km	47.1	4	148000	*$592,000*
>20 & < 50km	52.9	5	198000	*$990,000*
>50km	0	0	346000	*$0*
	100	9		*$1,582,000*

Table A.4.7 Relocation cost estimate ("Extra" 2 x 30 MHz in City Areas)

So the total cost of relocating designated city area fixed links from the bands 1755-1785/1850-1880 MHz comes to about $24 million, at an overall average cost for the 117 affected links of about (24024k/117) $205.3 k.

Estimates for the 1.8 GHz incumbents subject to the earlier reallocations (ie. the original 1997 2 x 45 MHz city area and 2 x 15 MHz regional) may be approximated using similar methods. The average relocation costs of regional 1.8 GHz incumbent links may be somewhat higher, since regional areas have (A.4 §2.1.1 & Figure A.4.6) more links using long paths and infrastructure costs are higher due to the likely need for more extensive site works.

Note: The Table A.4.7 estimates are based on city area requirements and exclude the need for extensive site works – eg. access road, mains power, additional multiplexers, remote monitoring equipment, airconditioning and waveguide desiccating & pressurisation plant.

3.1.1 Timing

Clearly some relocations will happen more quickly than others, depending upon individual circumstances. From the estimates of the previous section, it is self evident that relocation involves a significant planning and provisioning cycle – ie. it takes some time to order, manufacture and deliver the estimated requirement for 276 RF terminals, antennas, the 10km of waveguide and other materials and services.

In Australia, and in other parts of the world affected by similar considerations, the radiocommunication industry has become increasingly responsive to relocation requirements. Extensive industry consultation also takes place before final decisions are formalised into spectrum re-allocation declarations. Nevertheless, a reasonable timeframe is required to allow for the cyclical nature of business planning, equipment product provisioning and installation delays since relocation exercises invariably involve a relatively large number of services.

For relocations involving 1.8 GHz incumbent fixed services, the timing of relocations are subject to the relevant (A.4 §1.1) reallocation declarations and the time limits summarised in Table A.4.8:

Frequency Range		**Area**	**Reallocation Period**	
(MHz)	(MHz)		Start Date	End Date
1710	*1755*	*Major City*	*21-Jul-97*	*31-Dec-99*
1805	*1850*	*Major City*	*21-Jul-97*	*31-Dec-99*
1710	*1725*	*Regional*	*21-Jul-97*	*31-Dec-00*
1805	*1820*	*Regional*	*21-Jul-97*	*31-Dec-00*
1755	*1785*	*Major City*	*28-Sep-99*	*1-Jan-02*
1850	*1880*	*Major City*	*28-Sep-99*	*1-Jan-02*

Table A.4.8 1.8 GHz reallocation periods.

Although fixed service incumbents are expected to vacate the spectrum by the end dates shown, services may continue to operate provided that the incumbent operator either holds a spectrum licence covering the operation of the link or has made arrangements with the spectrum licensee holding rights to the spectrum.

3.1.2 Conclusion

- The 1.8 GHz (1700-1900MHz) band accommodates 1380 two-way fixed services, with the majority (82%) being digital and links between 2-17 Mb/s capacity and a smaller proportion of analogue links;
- Telstra is the main user of the band at 61%, with many smaller private and government agencies and utilities making up the remaining usage for their in-house operational communications and telemetry networks;
- Parts of the band were reallocated (2x45 MHz in designated major city areas, 2x15 MHz in regional areas) and auctioned in 1997 to satisfy demand for mobile services;

- In response to further demand for 1.8 GHz spectrum, the Government decided to reallocate a further 2x30 MHz in designated metropolitan areas, with spectrum auctions currently underway;
- The further sale is proceeding with incumbents allowed to continue until the 1 Jan 2002;
- In city areas, virtually all 1.8 GHz fixed services must be cleared;
- In regional areas, only channels 1 main/interleaf and channel 2 main are affected. Of the affected regional services, 271 are still shown as operating at August 1999;
- Many city links have short paths in comparison to links in regional areas and the national average and there is scope to relocate them into the bands above 10 GHz;
- The utility of the above 10 GHz bands is somewhat constrained by lack of detailed propagation data (microclimates). The lack of detailed planning data discourages at least some operators from making more effective use of these bands;
- For the links with longer (20-50km) paths, cost effective options are limited to the 6.0/7.5 and 8.0 GHz bands, already well utilised and crowded at some high density node locations;
- The 7.5 GHz band is under a lot of pressure due to existing demand but scope exists to make better use of the available spectrum through consolidation of the smaller (3.5 & 1.75 MHz) channel rasters; and
- Relocation costs are highly variable, for example from about $148k to $346k+ per (two-way) link, depending upon path length, performance criteria and local geoclimatic conditions.

Annex A to Appendix 4 "1.8 GHz Relocations in Major City Areas".

1. Services affected by the *Spectrum Re-allocation Declaration 1999 (No.2)*.

1.8 GHz REALLOCATION: 1999 EXTRA 2 x 30 MHz IN CITY AREAS

(Incumbents in the (2 x 30 MHz) bands 1755-1785/1850-1880 MHz **@ August 1999)***

	Adelaide	Brisbane	Melbourne	Perth	Sydney	All
ETSA Utilities Ltd	*7*					7
ETSA Transmission Corporation	*8*					8
ACA Southern Qld. Area Office		*2*				2
Airservices Australia		*2*			*7*	9
Queensland Rail Telecommunications		*4*				4
TNT Australia					*1*	1
Northern Rivers Television		*2*				2
Telstra Corporation		*10*	*7*	*2*	*14*	33
Rail Access Corporation					*21*	21
Metropolitan Ambulance Service			*2*			2
Metropolitan Fire & Emergency Serv			*2*			2
Energy Australia					*2*	2
Electricity Transmission Authority					*9*	9
Department of Defence		*2*		*2*	*1*	5
NSW Police					*3*	3
Public Transport Corporation			*2*			2
Western Power				*2*		2
West Australian Govt Railways				3		3
Total (by Area)	**15**	**22**	**13**	**9**	**58**	**117**

* Total number of two-way fixed links and licensees affected by each designated area
Based on Australian Communication Authority RADCOM RRL CD-ROM data @ August 1999.
Spectrum Licensing Areas as defined in the *Spectrum Reallocation Declaration 1999 (No.2)* .

Annex B to Appendix 4 "1.8 GHz Relocations in Regional Areas".

1. Services affected by the *Spectrum Re-allocation Declaration No. 4 of 1997.*

1.8 GHz REALLOCATION: 1997 IN REGIONAL AREAS

(Incumbents in the (2 x 15 MHz) bands 1710-1725/1805-1820 MHz ***@ August 1999)****

	NSW/ACT	VIC	QLD	SA	WA	TAS	All
ETSA Transmission Corporation				*1*			1
Airservices Australia	*2*	*4*	*4*				10
Queensland Rail Telecommunications			*36*				36
Queensland Electricity Transmission			*1*				1
NBN Limited	*1*						1
Northern Rivers Television	*2*						2
Optus Mobile	*2*						2
GPU PowerNet		*2*					2
Telstra Corporation	*25*	*45*	*41*	*14*	*39*	*22*	186
Rail Access Corporation	*11*						11
Energy Australia	*1*						1
Electricity Transmission Authority	*4*						4
SMHE Authority	*6*						6
Hydro Electric Corporation						*2*	2
Western Power					*6*		6
Total (by Area)	**54**	**51**	**82**	**15**	**45**		**271**

* Total number of two-way fixed links and licensees affected by each designated area
Based on Australian Communication Authority RADCOM RRL CD-ROM data @ August 1999.
Spectrum Licensing Areas as defined in the *Spectrum Reallocation Declaration No. 4 of 1997*.

APPENDIX 5 – 2.1 GHz RELOCATION STRATEGIES

General relocation issues and strategies are discussed in §4.2 of the main report document. As with Appendix 4, this appendix discusses relocation strategies and options for fixed services which may be affected by the possible re-allocation of spectrum in the 2.1 GHz (1900-2300 MHz) band for 3rd Generation Mobile phone services, both terrestrial and satellite.

1. 2.1 GHz FIXED SERVICES AND POSSIBLE RELOCATION

The 2.1 GHz band is a long established fixed service band, accommodating a range of analogue and digital (PDH) medium capacity point-to-point links and FM Video applications. Based on ACA licensing information[1], the 2.1 GHz band (1900-2300 MHz) accommodates a total of 1877 point-to-point spectrum accesses (equating to 1094 links, mostly bi-directional, some one-directional).

As demonstrated by Figure A5.1, the 2.1 GHz band is extensively utilised by Telstra, including a significant proportion of rural and remote area telecommunication feeder networks. Other major users include television broadcasters (using FM Video) and public utilities, using 2.1 GHz to support their own in-house operational communication and telemetry networks.

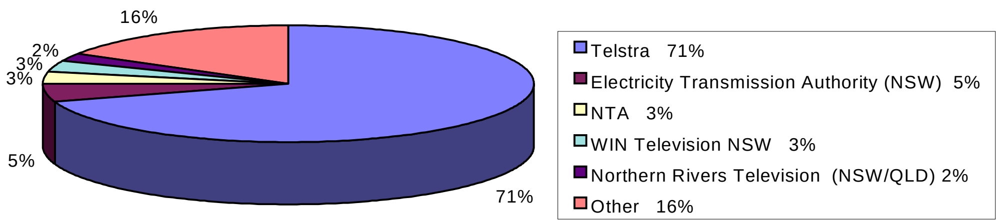


Figure A5.1: Fixed Service Users of the 1900-2300 MHz band.

As mentioned in Appendix 4, infrastructure for the bands below 3 GHz is relatively cheap due to mass market equipment availability and the relatively modest antenna support structures possible.

Fixed links in the 2.1 GHz band are a mix of digital (57%) and analogue, up to 34 Mb/s capacity, consistent with the 29 MHz channelling[2] of the band. Occupied

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[1] ACA RADCOM licensing database, August 1999. This figure for number of links includes links which fall on the 1.8 GHz channels 1902.5 and 1909.5 MHz.

[2] Aligned with ITU-R Recommendation F.382-6 "*Radio-frequency channel arrangements for radio-relay systems operating in the 2 and 4 GHz bands*".

bandwidths range from 2 MHz up to the full channel width of 29 MHz, but typically lie in the range 8 to 24 MHz. In the major cities, bandwidths are predominantly (65%) 18 MHz.

1.1 Current Status of 2.1 GHz Re-allocation Arrangements

As discussed at §3.6.2.3 of the main report, the ITU has designated a 'core band' for IMT-2000 (to accommodate 3rd Generation {3G} Mobile Phone services), the bands 1885-2025 and 2110-2200 MHz. This core band is subdivided into two parts:

- a band for IMT-2000 terrestrial services, 1885-1980, 2010-2025 and 2110-2170 MHz; and
- a band for IMT-2000 satellite (MSS) services, 1980-2110 and 2170-2200 MHz.

To illustrate the overlap between the IMT-2000 band, the current fixed service bands in Australia and other important overseas allocations, a chart is attached at Annex C to this appendix.

The Government is seriously considering allocating the terrestrial 'IMT-2000' band by spectrum auction, for use in certain areas of Australia for 3rd Generation Mobile services. In 1999 the Radiocommunications Consultative Council (RCC) set up a Working Group on IMT-2000. The Working Group report and up-to-date information concerning 3rd generation mobile service allocation is available at http://203.37.230/3GWG/3rdGenWG.htm and auctions in support of terrestrial IMT-2000 may take place as early as late 2000. A multi-tier strategy (most spectrum required in Sydney and Melbourne CBDs, lesser amounts in other metropolitan areas and even less in regional areas) is likely to be recommended.

The IMT-2000 satellite band (1980-2110 and 2170-2200 MHz) is already allocated on a co-primary basis to fixed, mobile and mobile-satellite services (MSS) in Australia. Options for re-allocation of fixed services in these bands so that IMT-2000 satellite services can commence are currently being considered by the ACA.

1.2 Potentially Affected Services

Auctioning the terrestrial IMT-2000 band (1885-1980, 2010-2025 and 2110-2170 MHz) would have a major effect on fixed links operating in the 2.1 GHz band, as 4 out of 6 main channels and 4 out of 6 interleaved channels would be affected in the areas where spectrum licences are issued.

Four groups of fixed services have been identified as being 'potentially affected' by future re-allocation:

> ***Group A***: Links in Sydney or Melbourne city areas[3] operating in the frequency bands for terrestrial IMT-2000;

[3] The boundaries for these areas are the ACA's 1.8 GHz Spectrum Licence Area boundaries. These boundaries were chosen as the 1.8 GHz spectrum has already been allocated for auction for mobile phone services

Group B: Links in other major city areas[3] (Brisbane, Perth and Adelaide) operating within the frequency bands for terrestrial IMT-2000;

Group C: Links in regional areas[3] operating within the frequency bands for terrestrial IMT-2000 (including some links in the 1.8 GHz Band[4]); and

Group D: Links within the IMT-2000 satellite band (Australia-wide).

These four groups have a varying likelihood of needing to relocate.

Figure A5.2 shows the RF Channel Arrangements for the 2.1 GHz (1900-2300 MHz)[5] band, overlaid with the IMT-2000 band (as designated by the ITU).

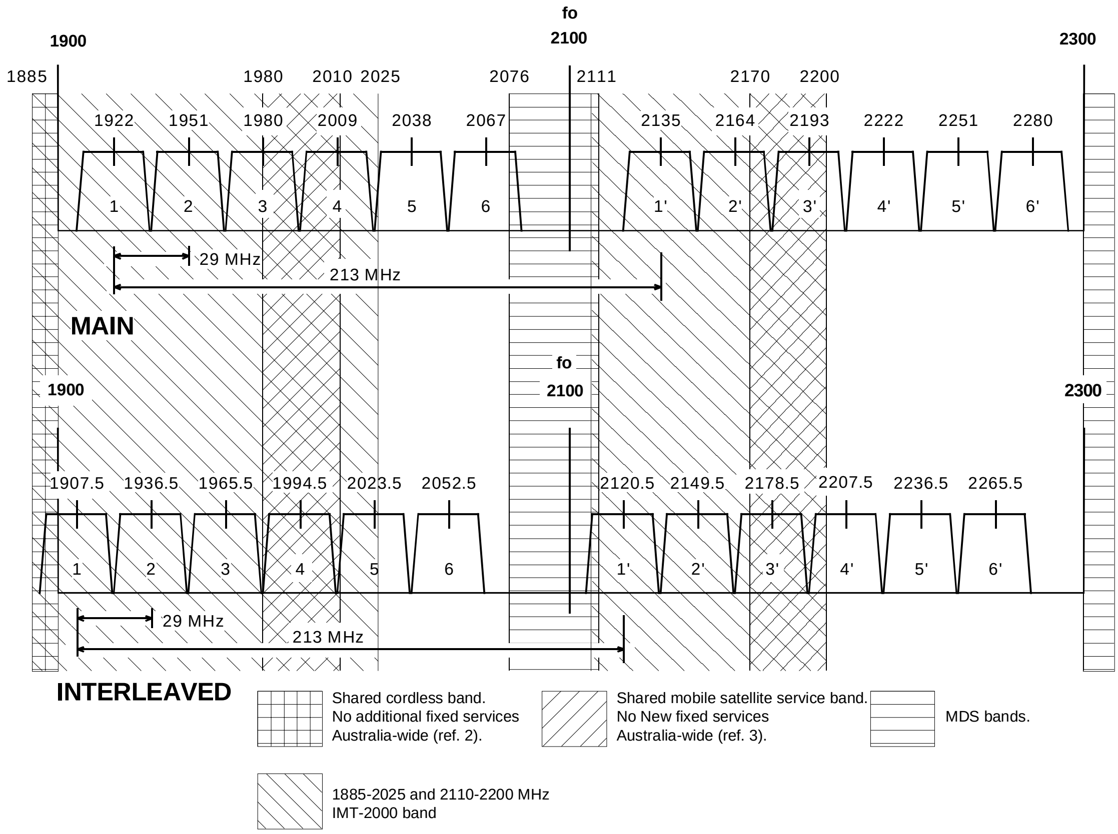


Figure A.5.2: 2.1 GHz fixed services RF channel arrangements.

Figure A.5.3 shows the geographic distribution of all fixed services operating in the 2.1 GHz band (1094 links - mostly bi-directional, some one-way). Also shown for comparison are the major city and regional Spectrum Licence Area boundaries for the 1.8 GHz band (Ref. §A4.1.1).

[4] Some channels in the 1.8 GHz band overlap with the terrestrial IMT-2000 band. In regional areas (only) these links are typically not required to relocate due to 1.8 GHz spectrum re-allocation, but they may be affected by future IMT-2000 arrangements.

[5] Based on ITU-R Recommendation F.382-6. "*Radio-frequency channel arrangements for radio-relay systems operating in the 2 and 4 GHz bands*".

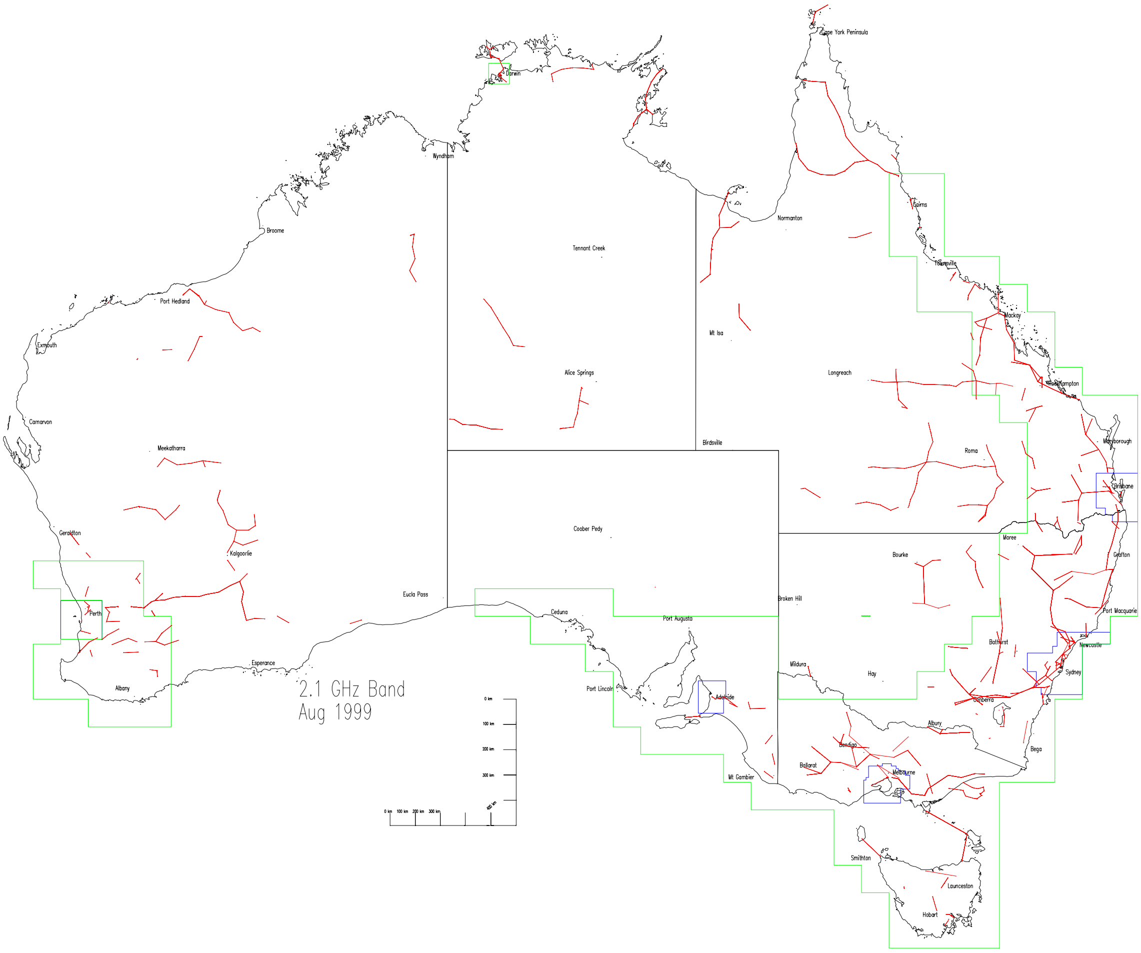


Figure A.5.3: Fixed Services in the 2.1 GHz Band (1900-2300 MHz).

1.2.1 Group A: Links in Sydney & Melbourne city areas in the terrestrial IMT-2000 band

The main demand driver for 3rd Generation mobile services, at least initially, is in the Sydney and Melbourne CBD areas. This is likely to result in a city-wide spectrum licence area in Sydney and Melbourne. The **53 links** in this area which are potentially affected are shown in Figure A5.4. Links in this Group are listed in Annex A. It is highly likely that the Group A links will require relocation.

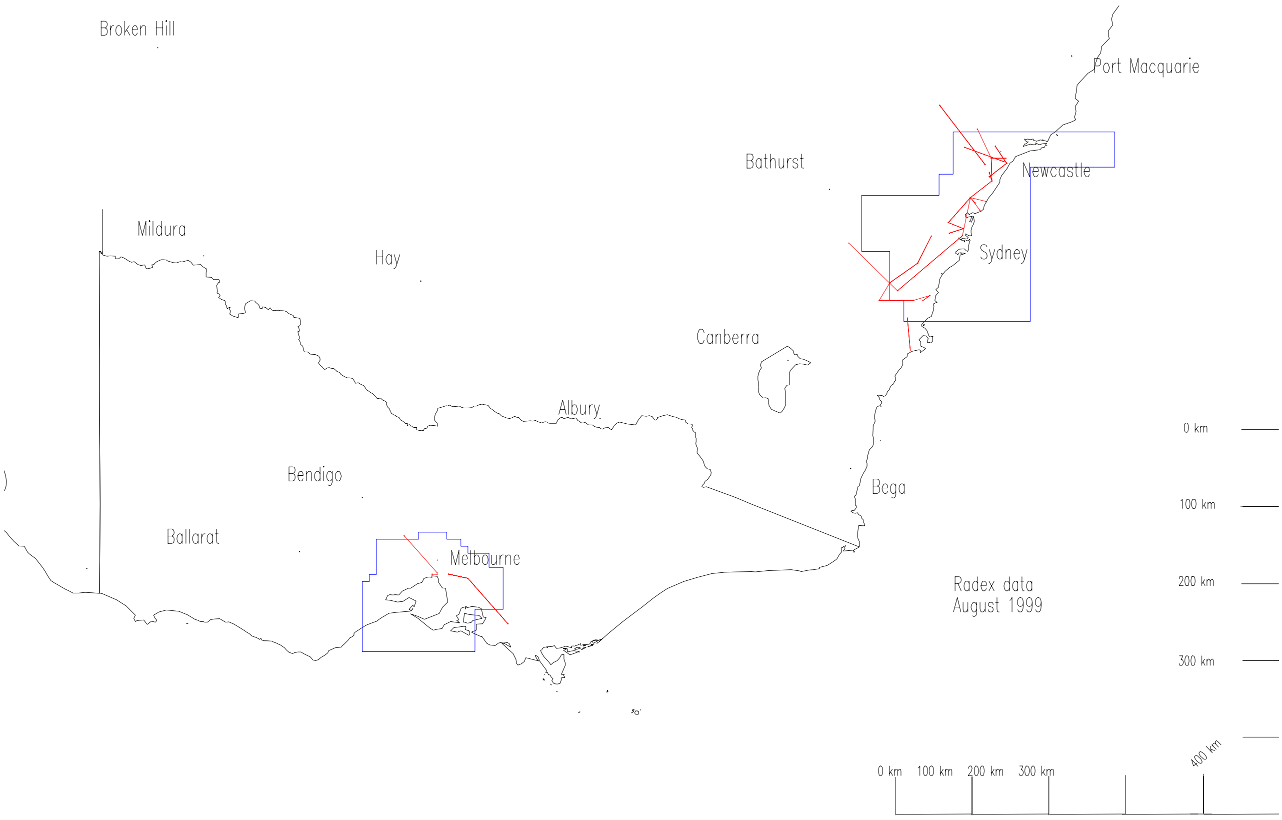


Figure A.5.4: Links in Sydney & Melbourne city areas in the terrestrial IMT-2000 band (Group A)

1.2.2 Group B: Links in other major city areas (Brisbane, Perth and Adelaide) in the terrestrial IMT-2000 band

Due to the predicted future spectrum demand for 3rd Generation mobile services in these other major capital cities, it is not clear yet whether a significant part of the terrestrial IMT-2000 band will be sold in these major cities.

If the entire ITU terrestrial IMT-2000 band was sold in the other major cities, this would affect **16 fixed links**, as shown in Figure A5.5 below. The links shown have a reasonable potential of being affected and are listed in Annex A.

Figure A.5.5: Links in other major city areas (Brisbane, Perth and Adelaide) in the terrestrial IMT-2000 band (Group B)

1.2.3 Group C: Links in regional areas in the terrestrial IMT-2000 band.

The boundary area for Group C is the 'Regional Areas', as designated by the 1.8 GHz Spectrum Licence areas. This boundary area does not include major city areas (Groups A & B). The regional areas are likely to require much less (if any) spectrum in the terrestrial IMT-2000 band for 3rd Generation Mobile Phone services.

If at a later time, access to a portion of the terrestrial IMT-2000 band was required for regional areas, some of the **484 links** that fall in this band (1885-1980, 2010-2025 and 2110-2170 MHz) in these areas would be affected. The links in regional areas are shown in Figure A.5.6 below. These links have a low potential of being affected and are also listed in Annex A.

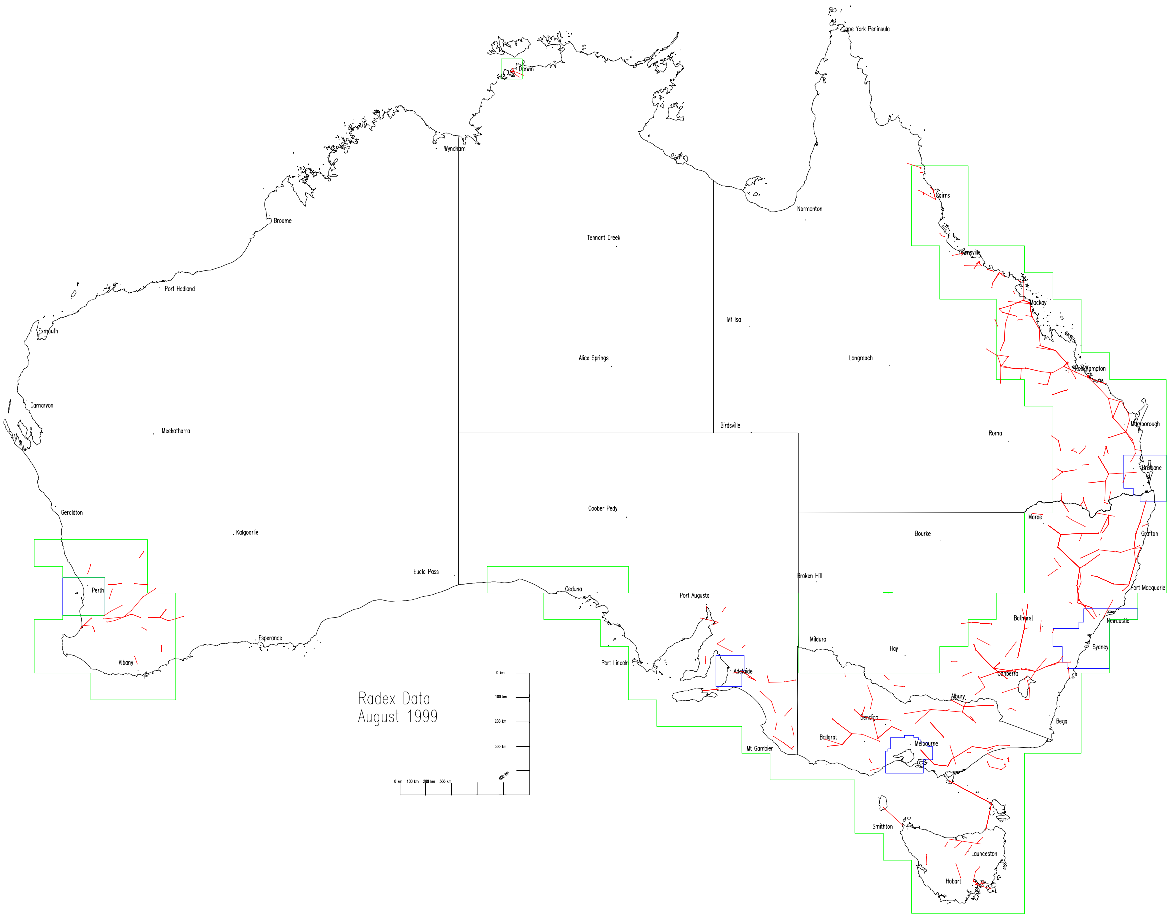


Figure A.5.6: Links in regional areas in the terrestrial IMT-2000 band (Group C).

1.2.4 Group D: Links within the IMT-2000 satellite band (Australia-wide).

Group D includes links Australia-wide in the IMT-2000 satellite band (1980-2010 and 2170-2200 MHz). There are **327 links** in Group D, which may need to be retuned to other channels of the 2.1 GHz band, or relocated if this is not possible.

This count of 327 links includes 32 links in major city areas. The Group D links are listed in Annex B.

2. Relocation Options - Major City Fixed Services

This section looks at the options available for the relocation of fixed services with a high potential of being affected by future spectrum auctions in the 2.1 GHz band. Specifically, the services which are considered are 2.1 GHz fixed links in the major cities (ie Groups A & B) operating in the terrestrial IMT-2000 band.

As mentioned in Appendix 4, relocation into another frequency band is predicated upon the availability of alternative spectrum and a detailed case-by-case analysis of the relevant technical, environmental and economic constraints.

In some cases, a non-radio solution may be required. The following sections explore the options for relocating into alternative frequency bands, taking account of the information available for the services identified for relocation.

2.1 Consideration of Alternative frequency bands

The fixed services operating in the 2.1 GHz band are a mix of digital and analogue point-to-point links, of between 2 Mb/s to 34 Mb/s capacity. As mentioned in Appendix 4, the channelwidth sets the upper bound for the traffic capacity of the RF channel.

Many frequency bands offer arrangements compatible with the types of services being relocated from the 2.1 GHz band – potential candidate bands are listed in Table A.5.1. The 2.1 GHz services in the major cities mostly have a bandwidth of 18 MHz, otherwise 8 MHz or 24-29 MHz.

Assignment Bandwidth *Frequency Band (GHz)*

	6	**7.5**	**8**	**10**	**13**	**15**	**18**
8 MHz	-	✓	-	✓	-	✓	✓
18+ MHz	✓		✓		✓	✓	✓

Table A.5.1. Candidate bands for relocation of 2.1 GHz fixed services

As with the 1.8 GHz Band, Table A.5.1 options do not include 3.8, 6.7 and 11 GHz as these bands are used for high capacity applications, functionally incompatible with the medium capacity services accommodated at 2.1 GHz. Nevertheless, some licensees may choose to take relocation as an opportunity to replace a service with a high capacity system.

As discussed at §4.2.2, the relocation of a fixed service into another frequency band requires detailed planning, with the identification of the potential alternatives in Table A.5.1 representing only an initial step.

2.1.1 Path Lengths, Propagation & Link Performance

Whilst the bands above 10 GHz are potentially available for the relocation of 2.1 GHz fixed services, their utility is particularly limited by inherent propagation related constraints (ie rainfall outage). The severity of such propagation constraints are frequency, location and link path distance dependent and significantly more acute in the areas of high rainfall intensity.

A common feature of < 3 GHz bands is that good link performance is achievable even over relatively long single-hop path lengths. Nevertheless, similarly to the 1.8 GHz band, a significant proportion of 2.1 GHz services operates over relatively short link paths, with about 15% of all paths shorter than 20 km.

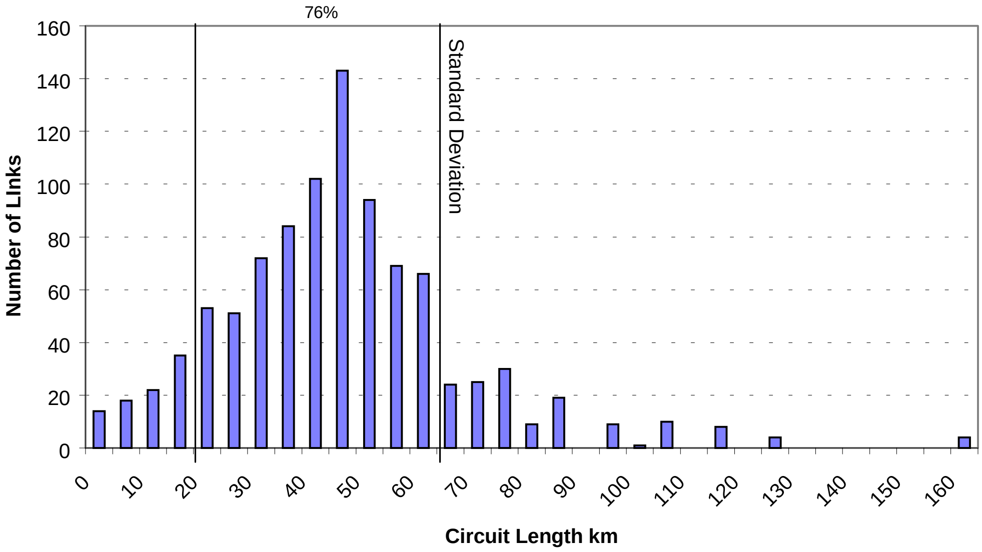


Figure A.5.5: Frequency Distribution of Path Lengths in the (entire) 2.1 GHz Band[6].

From Fig. A.5.5 it is also readily apparent that 76% of the single hop path lengths lie within the range 20 to 65km, with the average path length at 42 km. However, these figures represent Australia wide statistics and regional differences are to be expected – see Figure A.5.6, which shows the distribution of path lengths for major city area links (Groups A & B) in the terrestrial IMT-2000 band. Of these major city links, 30% have path lengths less than 20km.

Clearly, the links in the major city areas tend to have link paths significantly shorter than in the regional, rural and remote areas. As with the 1.8 GHz Band, the RALI FX-3 2.1 GHz assignment instructions specify a minimum path length of 20 km, but some links with shorter path lengths were commissioned prior to the introduction of the rule.

Many 2.1 GHz city area links may be relocated into higher frequency bands, including the rainfall limited higher microwave bands, but the majority would need to either:

- move to bands below 10 GHz due to large link paths; or
- build extra repeaters, enabling shorter paths to be used in higher frequency bands.

[6] ACA RADCOM licensing database information for 2.1 GHz fixed services, August 1999.

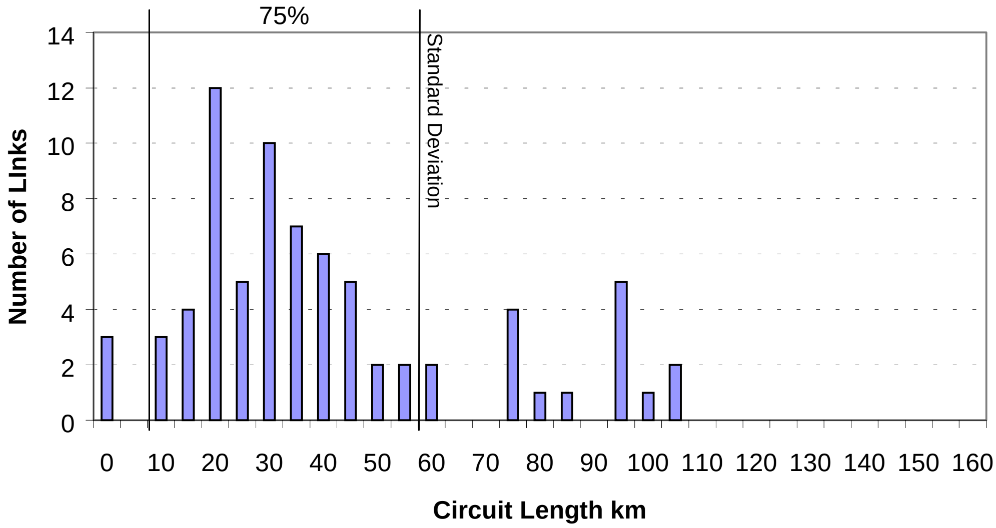


Figure A.5.6: Frequency distribution of path lengths in the major cities for 2.1 GHz links in the terrestrial IMT-2000 band.

2.1.2 Potential of Rain Limited (>10 GHz) Bands - Major City areas

As explained in section 2.1.2 of Appendix 4, most of the major city areas have maximum rain intensities of less than 40 mm/hr.

Location	Path Length* (km)			Rain Intensity**
	typical	80%	max.	max (mm/hr)
Australia Wide	*41*	*60*	*160*	*20..100+*
Sydney/Wollongong	*36*	*55*	*105*	*40*
Melbourne/Geelong	*39*	*75*	*90*	*30*
Brisbane	*39*	*50*	*100*	*50*
Perth	*20*	*35*	*35*	*30*
Adelaide	*18*	*35*	*35*	*25*

* From ACA RADCOM statistics ** From ITU-R Doc. 3/43 (18 March

Table A.5.2. Path length (2.1 GHz) vs rainfall intensity statistics.

Of the 30% of city links that have path lengths less than 20 km, many can be relocated to the bands above 10 GHz. In order to derive accurate figures it is necessary to apply case-by-case consideration and detailed knowledge of individual link design performance objectives, terrain and local microclimates. Bands above 18 GHz would not normally be suitable for links currently operating in the 2.1 GHz band, unless several repeaters are added.

The remaining city area 2.1 GHz links with longer path lengths require relocation strategies making use of the fixed service bands in the range 3-10 GHz and the establishment of additional repeaters where link path hops exceed about 55 km.

2.1.3 Potential in the 3 to 10 GHz Bands

The dominant limiting factor in the lower microwave bands is multipath fading (§ 2.8.1 of main report), typically of high intensity but of short event duration, hence the impact on availability is diminished in comparison to the dominant events in rain limited bands.

In the 3 to 10 GHz frequency range, similarly to the 1.8 GHz case, relocation opportunities for 2.1 GHz fixed services are primarily limited to the 6.0/7.5/8.0 and 10 GHz bands, since the requirement is to find alternative bands with arrangements supporting 'like' point-to-point services. As the majority of assignments have a bandwidth of 18 MHz or more, the key alternatives for most links are the 6.0 and 8.0 MHz bands.

As outlined in §4.2.2 "*Relocating into another band*", the relocation of a link from the 1-3 GHz frequency range requires at least the replacement of equipment terminals, up to 30 metres of waveguide and new parabolic dish antennas. Some of the relocated links are likely to require additional countermeasures against multipath fading (eg. space diversity antennas), with consequent further loading of existing antenna structures and possibly requiring the strengthening or replacement of an antenna mast or tower. Depending on the required link performance and local geoclimatic factors, additional repeaters may be needed where link path hop distance greater than about 55 km are needed.

Gaining access to spectrum in the potential alternative bands is another risk factor that needs to be addressed. Gauging the risk accurately requires detailed case-by-case consideration, since spectrum availability is highly location and orientation (ie. subject to detailed coordination) dependent.

2.1.4 Spectrum Availability in the Alternative Bands

In the previous sub-sections, we have established that the principal bands for possible relocation of 2.1 GHz fixed services are the 6.0, 7.5, 8.0 and 10 GHz bands and for some links the rain limited bands at 13, 15 & 18 GHz. The ultimate choice depends not only on individual assessment of technical and economic factors, but also spectrum availability in the alternative bands at the link location.

1. Short Path (< 20 km), small to medium capacity services. About 30% of the major city (Group A & B) links have link paths shorter than 20 km and these should be readily accommodated in the 13, 15 and 18 GHz bands (and the 10 GHz band for small capacity links). Although the use of the higher microwave bands has increased dramatically in recent years, channelling and readily available radio equipment products are available to accommodate the whole range of short-hop small to medium capacity (2-34 Mb/s & analogue) relocated services;

2. Long Path (>20 km), medium capacity services. Due to the reasons outlined in the previous sections, practical relocation options for long path medium capacity links are limited to the 6.0 and 8.0 GHz bands, both with 29.65 MHz channel spacing. As confirmed by Attachment 3 "*Utilisation and Growth Statistics: Australian Microwave Fixed Service Bands*", September 1999, fixed networks in the 6.0 and 8.0 GHz bands are relatively mature, with static link assignment growth. Nevertheless, the potential remains for relocating substantial numbers of

medium capacity (8-34 Mb/s digital and analogue 2.1 GHz incumbent fixed services with path lengths in excess of 20 km;

3. Long Path (>20 km), small capacity services. The small proportion of links of 8 MHz bandwidth could be accommodated in the 7.5 GHz band. In some cases the 10 GHz band could also accommodate these services.

Overall, the most critical aspect to any future relocation of major city services from the 2.1 GHz band is the need to find spectrum for the majority of displaced links, which are the medium capacity services (2 to 34 Mb/s) with path lengths over 20 km. The 8 GHz band is heavily utilised in city areas, but opportunities still exist in the 6 GHz band, as shown in Figure A5.7.

In conclusion, as with the 1.8 GHz case, alternative spectrum opportunities exist for any future relocation of 2.1 GHz links even in the high-density city areas of Sydney, Melbourne and Brisbane. However, given that more services are being consolidated into fewer frequency bands, inevitably there will be situations where suitable channels may not be available at particular locations or they may be difficult to find. This risk is particularly relevant at high-density nodal sites.

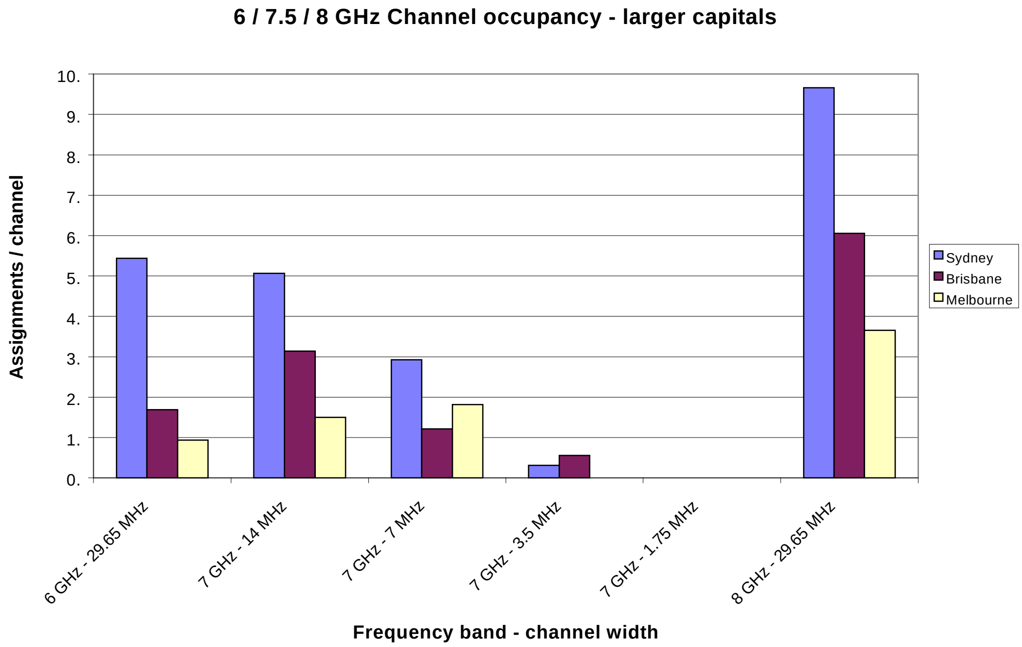


Figure A.5.7: Channel occupancy 6/7.5/8 GHz, Sydney, Melbourne & Brisbane

2.2 Relocation Costs

Relocation costs for a possible auction of parts of the 2.1 GHz band have not been prepared, as details of any spectrum auction that may occur are not available yet.

It is expected that relocation costs would be as much, if not slightly more than costs for relocating 1.8 GHz services, on a per-link basis.

3. Conclusion

- The 2.1 GHz (1900-2300 MHz) band accommodates 1094 fixed links (mostly bi-directional, some one-way), a mix of digital (57%) and analogue.

- Telstra is the main user of the 2.1 GHz band at 71%, with television broadcasters (using FM Video) and public utilities making up the remaining usage;

- The Government is seriously considering allocating the terrestrial 'IMT-2000' band (1885-1980, 2010-2025 and 2110-2170 MHz) by spectrum auction, for use in certain areas of Australia for 3rd Generation Mobile services.

- For the terrestrial IMT-2000 band, three groups[7] of potentially affected fixed links have been defined to analyse the effects of re-allocation of the 2.1 GHz band:
  - Group A (Sydney & Melbourne), which accommodates 53 links
  - Group B (other major city areas), which accommodates 16 links
  - Group C (Regional areas, excluding city areas), which accommodates 484 links

- For the IMT-2000 satellite (MSS) band, another group has been defined to analyse the effects of re-allocation in this band:
  - Group D (Australia-wide, in IMT-2000 satellite band), which accommodates 327 links

- If the entire band identified for 3rd Generation Mobile Phone services (IMT-2000) was auctioned, this would affect channels 1-4 (main) and 1-5 interleaved of the 2.1 GHz fixed services band;

- Occupied bandwidths typically lie in the range 8 to 24 MHz, and are predominantly (65%) 18 MHz in the major cities;

- As with the 1.8 GHz case, many 2.1 GHz city links (Groups A & B) have short paths (30% are less than 20km) in comparison to links in regional areas and the national average and there is scope to relocate them into the bands above 10 GHz;

- The utility of the above 10 GHz bands is somewhat constrained by lack of detailed propagation data (microclimates). The poorly defined planning data discourages operators from making more effective use of these bands;

- For the links with longer (20-60km) paths, cost effective options are limited to the 6.0 and 8.0 GHz bands, already well utilised and crowded at some high-density node locations;

- Relocation costs are likely to be similar to the case for the 1.8 GHz band on a per link basis.

[7] The Groups are defined in section 1.2 of this appendix and use the ACA's 1.8 GHz Spectrum Licence Area boundaries.

Annex A to Appendix 5 "2.1 GHz Relocation Strategies".

1. Services possibly affected by future spectrum auctions in the 2.1 GHz band.

Group A, B & C links - Fixed links and licensees in each designated area[1] in the terrestrial IMT-2000 band (1885-1980, 2010-2025 and 2110-2170 MHz)

One-way links are shown in brackets

Licensee	Sydney	Melbourne	Total Group A (Syd/Mel)	Adelaide	Brisbane	Perth	Total Group B (other Major Cities)	Total Group C (Regional areas)
Airservices Australia								9
Australian Capital Television								(1) 1
Brisbane Television					(1) 1		(1) 1	
Commissioner of Police NSW Police Service								2
Cwlth of Aust Repd by the NTA								3
Department of Defence						1	1	2
Electricity Transmission Authority	19		19					26
Energy Australia	1		1					
ESSO Australia								10
ETSA Transmission Corporation								11
ETSA Transmission Corporation				1			1	3
QLD Rail Telecommunications					1		1	35
Golden West Network								(2) 2
GPU PowerNet Pty Ltd								7
HSV Channel 7		2	2					
Hydro Electric Corporation								2
Mackay Television								(4) 9
NBN Limited	(4) 4		(4) 4					2
Network Ten Adelaide				1			1	
Northern Rivers Television	3		3		(2) 4		(2) 4	(9) 18
Optus Mobile								2
Optus Networks Pty Ltd								1
Prime Television Northern								(1) 8
Prime Television Southern								(4) 4
Prime Television Victoria		(1) 1	(1) 1					(2) 2
QLD Electricity Transmission Corp.					1		1	8
Snowy Mts Hydro Electric Authority								2
Southern Cross Communications								(3) 3
Southern Cross Television TNT9								(1) 1
Sunshine Television Network								(4) 4
Telstra Corporation	(3) 12	8	(3) 20		3	1	4	(18) 272
WA Government Railways						1	1	
Western Power								5
WIN Television NSW	(3) 3		(3) 3		1		1	(16) 21
Win Television SA								(2) 2
WIN Television VIC								(7) 7
TOTAL	(10) 42	(1) 11	(11) 53	2	(3) 11	3	(3) 16	(74) 484*

Based on Australian Communications Authority RADCOM data @ August 1999.

[1]Spectrum Licensing Areas as defined in the *Spectrum Reallocation Declaration No.3 of 1997. (1.8 GHz areas)*

* This count for regional areas includes 151 links on channels of the 1.8 GHz band. These links may not be affected by 1.8 GHz re-allocations, but are potentially affected by terrestrial IMT-2000.

Annex B to Appendix 5 "2.1 GHz Relocation Strategies".

Services Possibly affected by IMT-2000 Mobile-satellite services

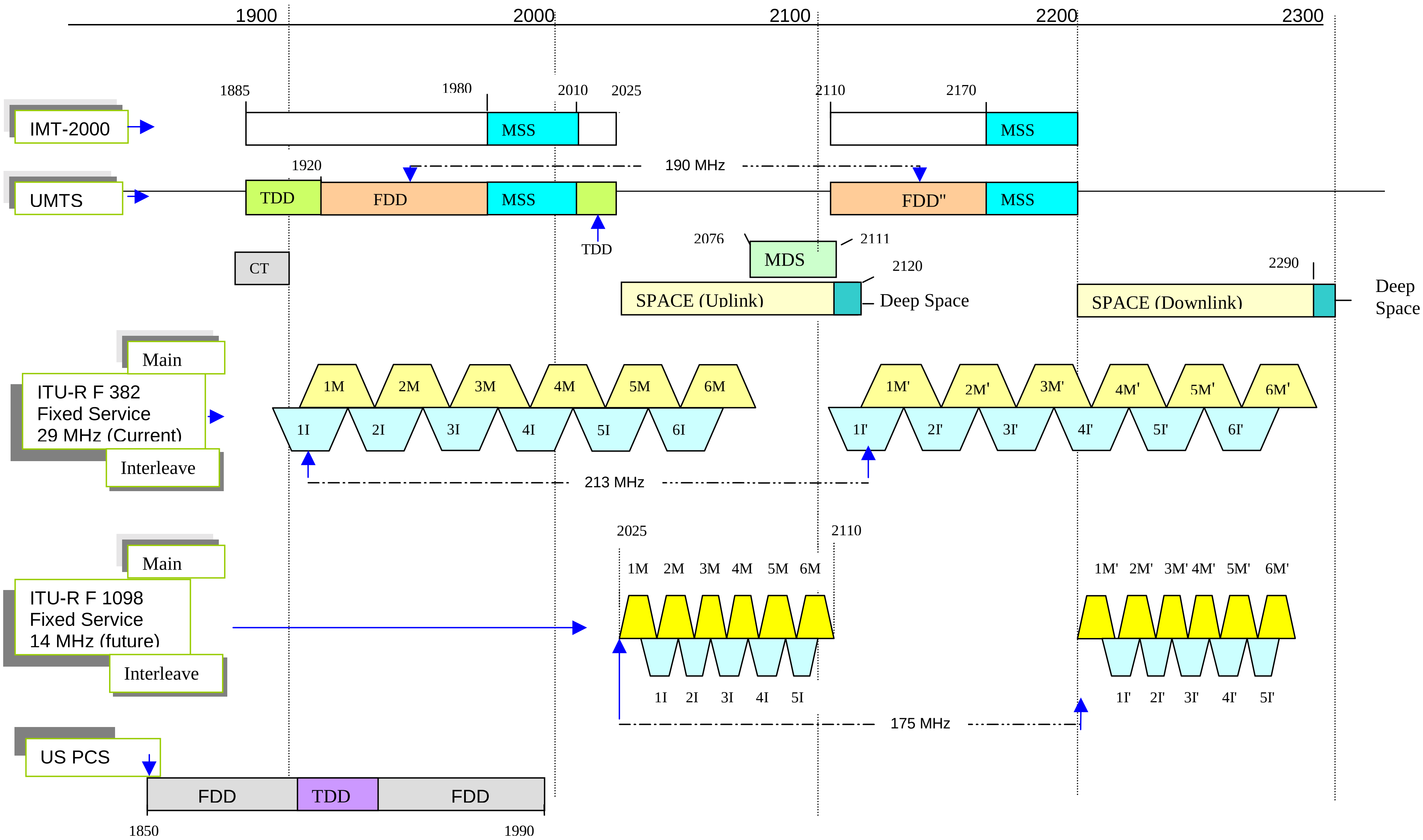
Group D links - Fixed links and licensees affected across Australia by IMT-2000 satellite (MSS) band (1980-2010 and 2170-2200 MHz)

One-way links are shown in brackets

Licensee	Group D (Australia-wide)	
Cwlth of Aust Repd by the NTA		15
Department of Defence		2
Electricity Transmission Authority		19
Energy Australia		1
ESSO Australia		10
ETSA Transmission Corporation		2
HSV Channel 7		1
JT Jeffrey	(1)	1
Mackay Television	(3)	6
NBN	(3)	6
Network Ten Adelaide	(1)	1
Northern Rivers Television	(7)	13
Prime Television Northern	(1)	4
Prime Television Southern	(4)	4
Prime Television Victoria	(4)	4
Pro Octa Productions	(1)	1
Queensland Electricity Transmission Corporation		7
Southern Cross Communications	(4)	4
Sunshine Television Network	(1)	1
Telstra Corporation	(8)	199
West Australian Government Railways		1
WIN Television NSW	(16)	20
Win Television SA	(1)	1
WIN Television VIC	(4)	4
TOTAL	(59)	**327**

Based on Australian Communications Authority RADCOM data @ August 1999.

Current Spectrum Arrangements in the 1900-2300 MHz Band
(full page chart)



Appendix **CURRENT SPECTRUM ARRANGEMENTS AND FUTURE PLANNING OPTIONS: 1900 - 2300 MHz BAND**

APPENDIX 6 – 1.5 GHz RELOCATION STRATEGIES

General relocation issues and strategies are discussed in §4.2 of the main report document. This appendix discusses relocation strategies and options for fixed services potentially affected by allocations to Digital Radio Broadcasting (DRB), Broadcasting Satellite Service (Sound) (BSS-S) and Mobile Satellite Service (MSS) in parts of the 1.5 GHz (1427-1535 MHz) band.

1. 1.5 GHz FIXED SERVICES AND RELOCATION REQUIREMENTS

The 1.5 GHz band is a long established fixed service band, accommodating a range of analogue (37%) and digital (63%) small capacity point-to-point links and thin-route radio relay applications. Based on ACA licensing information[1], the 1427-1535 MHz band accommodates a total of 1500 point-to-point link spectrum accesses. A further 2800 (Telstra) 1.5 GHz point-to-point and point-to-multipoint spectrum accesses provide for rural and remote area telecommunication services (see §2.4.1 and §3.1.5 of main report).

As demonstrated by Figure A6.1, the band is extensively utilised by Telstra, including a significant proportion of rural and remote area telecommunication feeder networks. Other major users include government and non-government utilities, using the 1.5 GHz band to support operational communication and telemetry networks.

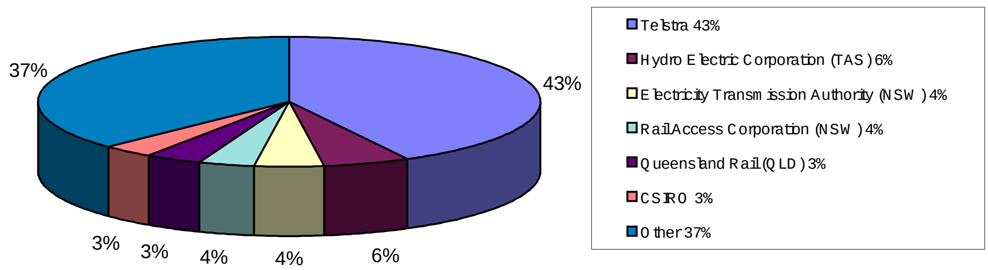


Figure A6.1. Users of the 1427-1535 MHz band.

As detailed under §2.6 of the main report, infrastructure for the 1.5 GHz band is relatively cheap due to mass market equipment availability and the relatively modest antenna support structures possible with the grid type parabolic antennas used in the bands below 3 GHz.

The majority (63%) of point-to-point fixed links in the 1.5 GHz band are digital and of between about 700kb/s to 4 Mb/s capacity, consistent with the 4 MHz channelling.

[1] ACA RADCOM licensing database, August 1999.

Occupied bandwidths range from 0.25 MHz up to the full channelwidth. The 0.7/ 2 Mb/s DRCS systems operating in the overlaid (2 MHz channel raster) rural wireless access band are all digital, with 1.4/ 2 MHz bandwidths.

1.1 Current Status of 1.5 GHz Re-allocation Arrangements

As discussed at §3.6.2.4 and §3.6.2.5, the *1.5 GHz Band Plan*[2], December 1996, preserves spectrum options for the introduction of terrestrial DRB and BSS(S) in the band 1452-1492 MHz and the expansion of mobile satellite services (1525-1535 MHz). The plan also facilitates the ongoing operation of existing fixed services until such time as decisions are made concerning the introduction of digital radio broadcasting in the 1452-1492 MHz band. Although there are no imminent plans to relocate fixed services from the band, a planning process is in progress and it is reasonable to assume that some fixed services could be affected by a future deployment of terrestrial DRB and/or BSS(S) services.

The remainder of this section identifies services potentially affected by the future introduction of terrestrial DRB and Australian BSS(S) services.

1.2 Identifying Potentially Affected Services

Figure A6.2 shows the RF Channel Arrangements for the 1.5 GHz (1427-1535 MHz) point-to-point band, overlaid with the frequency blocks allocated to DRB, BSS(S) (1452-1492 MHz) and MSS (1525-1535 MHz) services. Similarly, Figure A6.3 identifies the relationship between DRCS channels and the DRB/MSS allocations.

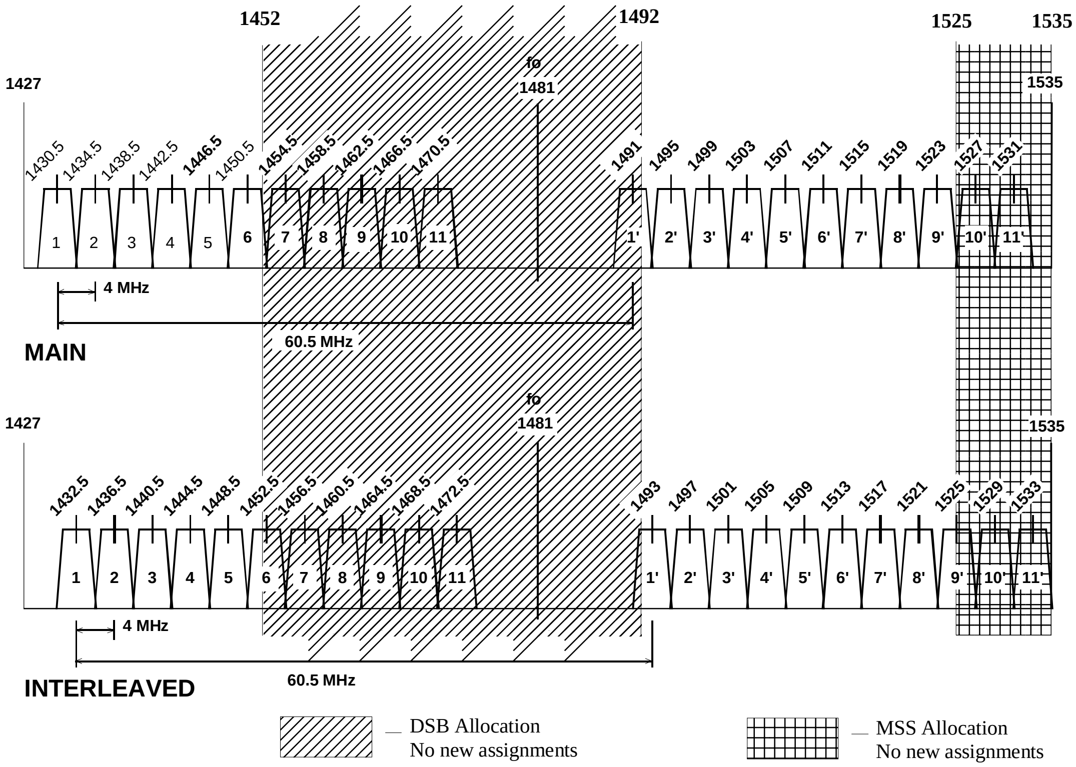


Figure A.6.2. 1.5 GHz fixed (point-to-point) services RF channel arrangements[3].

[2] See http://www.aca.gov.au/frequency/bands.htm
[3] Extract from the ACA's RALI FX-3 for the 1.5 GHz band.

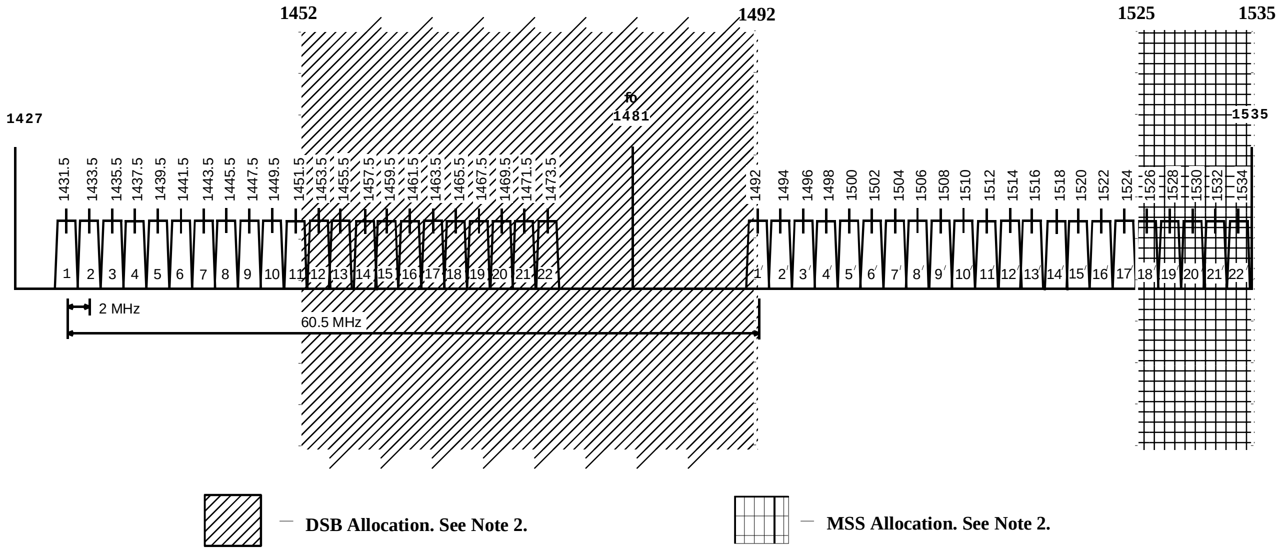


Figure A.6.3. 1.5 GHz DRCS (point-to-multipoint) RF channel arrangements[4].

Figure A.6.4 shows the geographic distribution of the 680 point-to-point links, 61 DRCS hubstations and 145 DRCS network link services operating within the 1452-1492 MHz DRB allocation.

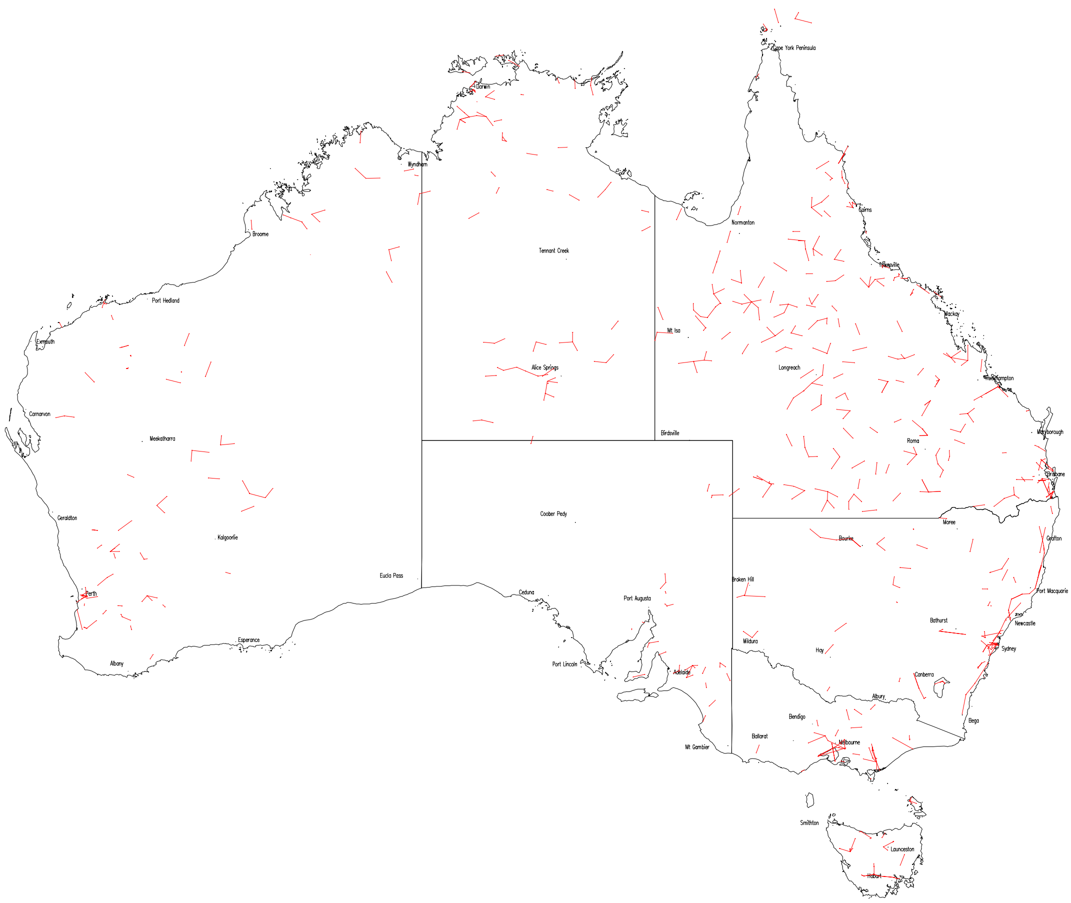


Figure A.6.4. Fixed Services operating in the 1452-1492 MHz Band[5].

[4] Extract from the ACA's RALI FX-3 for the 1.5 GHz DRCS band.

As shown by the FS channel plans (Figures A6.2 and A6.3), the frequencies within the range 1475 to 1490 MHz are almost completely clear of fixed services by virtue of the 'mid-band gap' in the 1.5 GHz RF channel arrangements. Accordingly, this 15 MHz block is seen as a desirable destination for BSS(Sound) and/or at least the initial deployment of terrestrial DRB services.

The services operating in the band 1525-1535 MHz are not considered further in this document. The *1.5 GHz Band Plan* restricts the assignment of new fixed services in this sub-band, but existing services may continue to operate for the foreseeable future – ie. it is unlikely that any of the currently operating services in the MSS band (1525-1535 MHz) will require relocation, except where affected through channel pairing with frequencies within the DRB (1452-1492 MHz) band.

1.2.1 Terrestrial DRB vs Point-to-Multipoint (DRCS) Services

As described at §2.4.1, DRCS services are FWA services with a hybrid point-to-point and point-to-multipoint system architecture, providing telephone services in rural and remote areas.

Preliminary studies indicate that the proposed introduction of terrestrial DRB in the band 1452-1492 MHz is unlikely to have a major impact on the ongoing operation of rural and remote area DRCS services. The most extensive spectrum requirement for terrestrial DRB services is anticipated within the major city and metropolitan areas – ie. locations where the operation of the DRCS is specifically excluded. Assuming that the deployment of DRB takes place, the new service is likely to extend into regional and rural areas over a period of time. Due to a more modest DRB spectrum demand in such areas (and the use of the 'mid-band gap' spectrum for DRB), the deployment of terrestrial DRB is expected to be achieved without the extensive clearance of DRCS services.

Accordingly, through careful planning, the introduction of L-band DRB could be achieved without the need for the extensive relocation of DRCS services.

1.2.2 Terrestrial DRB vs Point-to-Point Services

The point-to-point 1.5 GHz channel plan (Figure A.6.2) is used throughout Australia, including major city, metropolitan and regional areas. Based on preliminary studies, the initial phase of DRB deployment could be facilitated without the need for the relocation of incumbent fixed services, by taking advantage of the spectrum in the mid-band gap at 1475-1490 MHz.

At this time, it is too early to predict whether particular fixed services are likely to be affected, as the overall market demand for DRB is still uncertain and planning is at a preliminary stage. Nevertheless, assuming that the deployment of DRB takes place, it is almost certain that many of the fixed services operating within and around the major metropolitan centres of Sydney, Melbourne, Brisbane and Perth would need to be relocated. A somewhat lesser relocation requirement could then be anticipated around the other capital cities of Darwin, Hobart, Adelaide and the larger regional

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[5] Based on ACA RADCOM licensing data, at September 1999.

centres. In this event, the point-to-point systems operating on channels 7 through 11 (main & interleaf) and channel 6 (interleaf) of Figure A.6.2 are potentially affected.

1.2.3 BSS(Sound) vs Fixed Services

The inclusion of Australia within the service area of a BSS(Sound) satellite (eg. "DBSTAR 151.5E") could have an impact on the operation of some terrestrial fixed services including the DRCS. Because of the relatively high power flux density (pfd) required for a broadcasting satellite service, co-channel terrestrial services including point-to-point links and DRCS hubstations would be susceptible to potentially strong interference, with consequent quality of service degradation. However, by quarantining the operation of any Australian BSS(S) service to the mid-band gap at 1475-1490 MHz, the incompatibility with terrestrial fixed services could be avoided.

2. Relocation Options

This section assumes that relocations from the 1.5 GHz band will be required and looks at the available band options. Clearly, not the entire 1.5 GHz band is affected by the allocations to new services. Accordingly, in some cases, existing fixed services operating in the affected segments could be relocated through simple retuning (assuming that channels in the unaffected spectrum are available). In other cases, services may need to be relocated into other frequency bands.

The relocation of 1.5 GHz DRCS services into other frequency bands is not considered in this document. This is because there are no available practical alternative frequency bands that offer arrangements suitable for the relocation of DRCS services.

As discussed at §4.2.1, relocation into another (higher) frequency band is predicated upon the availability of alternative spectrum and a detailed analysis of the relevant technical, environmental and economic constraints.

2.1 Consideration of Alternative frequency bands

As outlined at §A.6.1.0, the majority of fixed services operating in the 1.5 GHz band are digital, of up to 2*E1 (4 Mb/s) capacity. In considering alternative frequency bands for the relocation of point-to-point link services, the 4 MHz (RF) channel bandwidth of the 1.5 GHz sets the upper bound for the traffic capacity of the RF channel. Potential candidate bands for relocation are somewhat limited (especially below 10 GHz) in comparison to the 1.8 and 2.1 GHz relocation options – potential candidate bands are shown in Table A6.1.

Capacity *Frequency Band (GHz)*

	6	7.5	8	10	13	15	18	22	38
1/2E1	-	✓	-	✓	-	✓	✓	✓	✓
FDM	-	✓	-	✓	-	✓	✓	✓	✓

Table A.6.1. Candidate bands for relocation of 1.5 GHz fixed services

The table excludes the 3.8, 6.7 and 11 GHz bands as these are used for high capacity applications, functionally incompatible with the small capacity services accommodated at 1.5 GHz. The 29 MHz channelling of the 6, 8 and 13 GHz bands is also largely incompatible with the types of (2, 2+2 Mb/s, 60 ch FDM) small capacity services potentially displaced from the 1.5 GHz band. Nevertheless, there is no impediment to licensees to take relocation as an opportunity to replace a 1.5 GHz small capacity service with a higher capacity system.

As discussed at §4.2.2, the relocation of a fixed service into another frequency band requires detailed planning, with the identification of the potential alternatives in Table A.3.1 representing only an initial step.

2.1.1 Path Lengths, Propagation & Link Performance

Key factors to take into account in considering viable options for relocation is the necessary performance and availability criteria vs multipath and rainfall induced outage (see §2.6.2 and §2.8 of the main report). Whilst the bands above 10 GHz are potentially available for the relocation of 1.5 GHz fixed services, their utility is particularly limited by inherent propagation related constraints (ie rainfall outage).

The severity of such propagation constraints are frequency, location and link path distance dependent and significantly more acute in the areas of high rainfall intensity.

A common feature of < 3 GHz bands is that good link performance is achievable even over relatively long single-hop path lengths. Nevertheless, as demonstrated in Figure A.6.4 (distribution of 1.5 GHz link path lengths, Australia wide), a significant proportion of 1.5 GHz services operate over relatively short link paths, with about 22% of all link paths in the 1427-1535 MHz band shorter than 20 km.

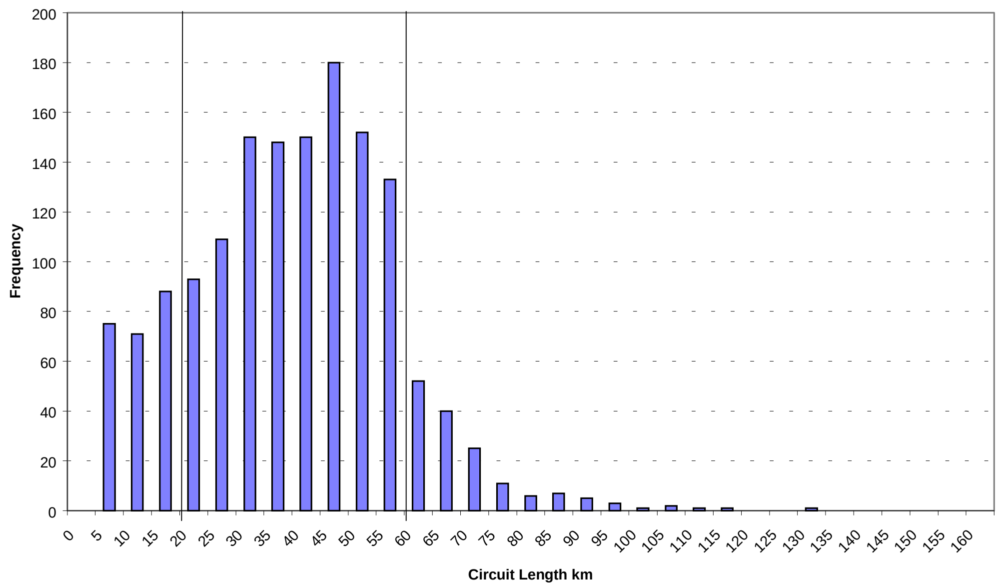


Figure A.6.4. Frequency Distribution of Path Lengths in the 1.5 GHz Band[6].

[6] ACA RADCOM licensing database information for 1.8 GHz fixed services, September 1999.

From the graph, 80% of the single hop path lengths lie within the range 20 to 80km, with the most common path length at about 45 km. However, these figures represent Australia wide statistics for the whole 1427-1535 MHz band and regional differences can be expected – see Figure A.6.5, comparing the cumulative distribution of fixed link path lengths inside the 1452-1492 MHz DRB allocation, within a 200 km radius of the major cities of Sydney, Melbourne, Brisbane, Perth and Adelaide.

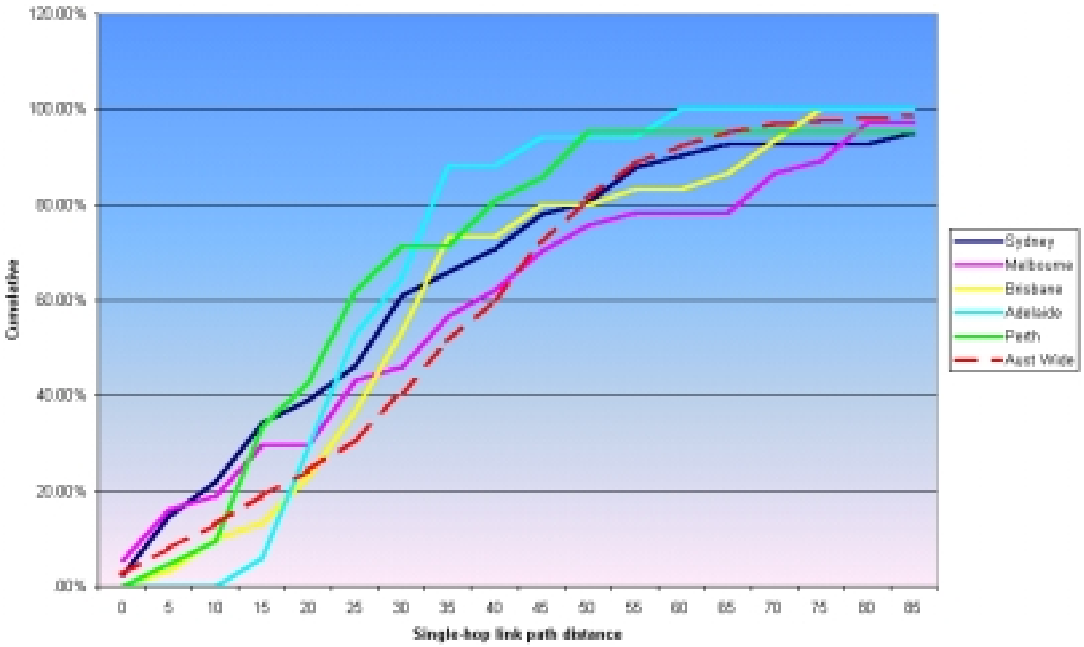


Figure A.6.5. Cumulative distribution of path lengths, 1452-1492 MHz band.

As in other bands, links within the major city areas tend to have a higher proportion of short link paths in comparison to links deployed in rural and remote areas. The RALI FX-3 1.5 GHz assignment instructions specify a minimum path length of 20 km, but many links with shorter path lengths were commissioned prior to the introduction of the rule. Based on RADCOM statistics, 43% of Perth (1452-1492 MHz) links operate over path distances less than 20 km, followed by Sydney (39%), Melbourne (30%), Adelaide (29%) and Brisbane (23%), on par with the national average of 23%.

So the extent of the potential relocation requirement in city areas is ameliorated by the fact that many city links have relatively short path lengths (in comparison to regional, rural and remote areas where long single-hop paths are more prevalent). Accordingly, some 1.5 GHz city area links may be relocated into higher frequency bands, including the rainfall limited higher microwave bands.

2.1.2 Potential of Rain Limited (>10 GHz) Bands

In order to gauge the useability of rain limited bands, it is necessary to make assumptions about the performance criteria of incumbent 1.5 GHz systems.

Typical 1.5 GHz small capacity links have fade margins of the order of 30 to 40 dB and performance commensurate with multipath propagation dominated worst month outage probability. Translating link availability and fade margin requirements into the higher bands where rainfade is the dominant limiting factor, we can assume that fade margins of a similar order (30-40 dB) and annual per-hop link outage probabilities in the range 0.01% to 0.001% (for an average up to a high grade system). Achievable link path distances vs frequency bands are shown at §2.8.2 of the main report. The examples (Figures 2.13, 2.14) are for the Sydney region (rainfall intensity of 40 mm/hr exceeded for 0.01% annually).

Different sets of possibilities exist for other regions of Australia, with rainfall intensities within the range 20-100+ mm/hr. However, as shown in Table A.6.2, most of the designated city areas subject to 1.5 GHz fixed link relocations have maximum rain intensities of less than 40 mm/hr.

Location	Path Length* (km)			Rain Intensity**
	typical	80%	max.	max (mm/hr)
Australia Wide	*45*	*60*	*135*	*20..100+*
Sydney/Wollongong	*30*	*50*	*95*	*40*
Melbourne/Geelong	*25*	*65*	*100*	*30*
Brisbane	*35*	*50*	*75*	*50*
Perth	*20*	*35*	*85*	*30*
Adelaide	*25*	*40*	*109*	*25*

* From ACA RADCOM statistics Sep 1999 ** From ITU-R Doc. 3/43 (18 March 1999)

Table A.6.2. Path length (1.5 GHz) vs rainfall intensity statistics

Accordingly, taking account of the path length statistics established in §2.1.1 and regional variation, between 20 to 40% of the major city area 1.5 GHz point-to-point links can potentially be accommodated in the bands above 10 GHz. For a more accurate assessment it is necessary to apply case-by-case consideration and detailed knowledge of individual link design performance objectives, terrain and local microclimates.

The remaining 80-60% of city area 1.5 GHz links with longer path lengths require relocation strategies making use of the 7.5 GHz fixed service band and the establishment of additional repeaters where link path hops exceed about 55 km.

2.1.3 Potential in the 3 to 10 GHz Bands

The dominant limiting factor in the lower microwave bands is multipath fading (§ 2.8.1 of main report), typically of high intensity but of short duration, hence the impact on availability is diminished in comparison to the dominant events in rain limited bands.

In the 3 to 10 GHz frequency range, relocation opportunities for 1.5 GHz fixed services are limited to the 7.5 and 10 GHz bands, since the requirement is to find alternative bands with arrangements supporting ‘like’ point-to-point services. The 3.8, 6.0, 6.7 and 8 GHz band arrangements accommodate medium to high capacity (16 to 155 Mb/s) services and are therefore inconsistent with the types of small to medium capacity (0.7-4 Mb/s & FDM) 1.5 GHz links requiring relocation.

Nevertheless, there is no reason why some relocations could not take advantage of the higher capacity arrangements, in situations where a higher capacity replacement fulfils an operator's business plan requirement.

As outlined in §4.2.2 "*Relocating into another band*", the relocation of a link from the 1-3 GHz frequency range requires at least the replacement of equipment terminals, up to 30 metres of waveguide and solid parabolic dish antennas to replace existing 1.5 GHz grid parabolics. Some of the relocated links are likely to require additional countermeasures against multipath fading (eg. space diversity antennas), with consequent further loading of existing antenna structures and possibly requiring the strengthening or replacement of an antenna mast or tower. Depending on the required link performance and local geoclimatic factors, additional repeaters may be needed where link path hop distance greater than about 55 km are needed.

Gaining access to spectrum in the potential alternative bands is another risk factor that needs to be addressed. Gauging the risk accurately requires detailed case-by-case consideration, since spectrum availability is highly location and orientation (ie. subject to detailed coordination) dependent.

2.1.4 Spectrum Availability in the Alternative Bands

In the previous sub-sections, we established that the principal band for the relocation of 1.5 GHz fixed services are the 7.5 and 10 GHz bands and the rain limited bands at 15, 18, 23 & 38 GHz. The ultimate choice depends not only on individual assessment of technical and economic factors, but also spectrum availability in the alternative bands at the link location.

1. Short Path (< 20 km) links. About 20% the incumbent links have link paths shorter than 20 km and these should be readily accommodated in > 10 GHz bands, at least in areas of low to moderate rainfall intensity. Suitable channelling and radio equipment products are available to accommodate relocated services;

2. Long Path (>20 km) links. Due to the reasons outlined in the previous sections, practical relocation options are limited to the 7.5 GHz band.

Overall, the most critical aspect to the relocation of services from the 1.5 GHz band is the need to find alternative spectrum for small capacity digital services of between 0.7 to 4 Mb/s in capacity and able to support single-hop path lengths of 20-50km with acceptable reliability. As confirmed by Attachment 3 "*Utilisation and Growth Statistics: Australian Microwave Fixed Service Bands*", September 1999, regional fixed networks in the 7.5 GHz band are in demand, with strong link assignment growth.

Although potential remains in the 7.5 GHz band to relocate substantial numbers of small capacity digital and analogue fixed services, the band is subject to strong demand for new services and services relocated from the 1.8 and 2.1 GHz bands. Accordingly, if and when 1.5 GHz relocation becomes necessary, the 7.5 GHz band may not be able to accommodate the relocation requirement, especially in the metropolitan areas of Sydney, Melbourne and Brisbane. Given that more services are being consolidated into fewer frequency bands, inevitably there will be situations where suitable channels may not be available at particular locations or they may be difficult to find. This risk is particularly relevant at high density nodal sites.

3. Relocation Costs

In general, it is premature to consider relocation costs from the 1.5 GHz band at this time and no attempt is made in this document to quantify the potential costs of relocation from this band.

On a case-by-case basis, individual link relocation costs can be anticipated to be similar to those derived in Appendix 4 for the 1.8 GHz band.

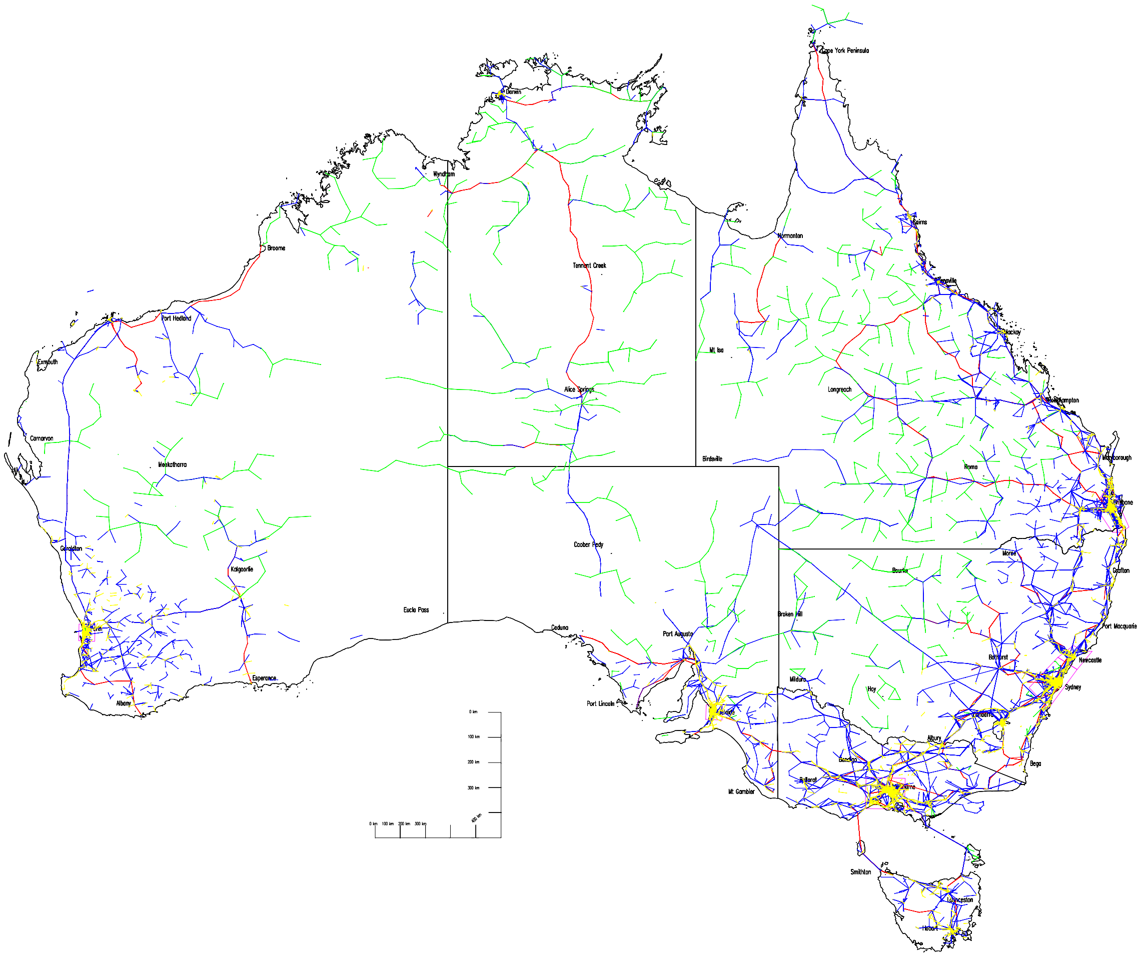
3.1.1 Timing

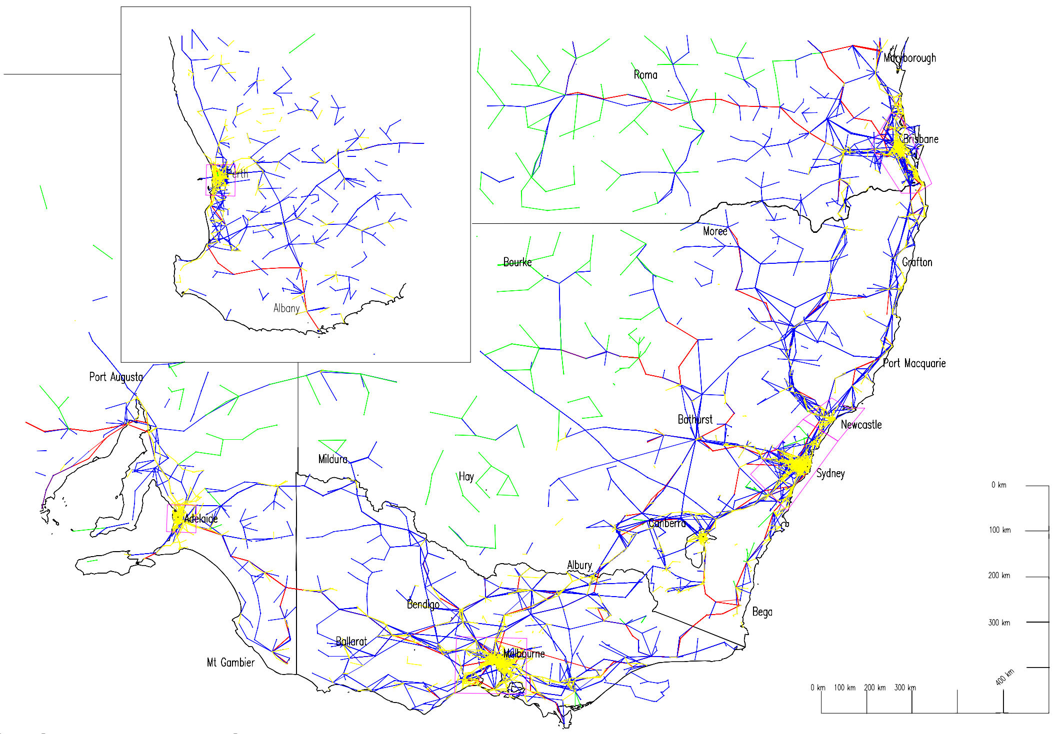
No decisions have yet been made concerning the proposed introduction of 1.5 GHz DRB services at this time. Further industry consultation may be anticipated before any timing issues are resolved.

4. Conclusion

- The 1.5 GHz (1427-1535 MHz) band accommodates about 750 two-way point-to-point fixed services, with the majority (63%) being digital and links between 0.7-4 Mb/s capacity and a smaller proportion of analogue links;
- The 1.5 GHz band also accommodates a further 2800 Telstra spectrum accesses providing point-to-multipoint FWA in support of rural and remote area telecommunications;
- The DRB band 1452-1492 MHz accommodates a total of 680 point-to-point links, 61 DRCS hubstations and a further 145 DRCS network links (August 1999);
- The provisions of the *1.5 GHz Band Plan 1996* provide for the ongoing operation of fixed services currently operating in the bands 1452-1492 MHz and 1525-1535 MHz, but no new point-to-point fixed services are permitted into these bands;
- Although a DRB planning process is under way, no decisions have yet been made on the future use of the 1452-1492 MHz band or any fixed clearance issues;
- Initial operation of DRB and Australian BSS(S) services (eg. DBSTAR at 151.5 E) may be anticipated to take advantage of the mid-band gap (1475-1490 MHz), at least initially avoiding coordination and incompatibility with fixed services;
- Assuming that the deployment of DRB services will proceed, the clearance of a significant number of point-to-point services is inevitable within the greater metropolitan regions of Sydney, Melbourne and Brisbane and smaller numbers in around other capital cities and major regional centres;
- DRCS services are not likely to be greatly affected, considering the geographic separation between DRCS and major DRB service areas and the intention to use the mid-band gap (1475-1490 MHz) for BSS(S);
- Other than using fibre or re-tuning to other parts of the 1.5 GHz band, relocation options below 10 GHz are limited to the 7.5 GHz band, already subject to significant relocations from other long haul (ie. 1.8 and 2.1 GHz) bands;
- The cost of relocating individual 1.5 GHz links is of a similar to that defined in Appendix 4 for the 1.8 GHz band.

The Geographic Distribution of Microwave Fixed Services





based on ACA RADCOM data @August 1999

Legend: RED – High Capacity (3.8/5.0/6.7 GHz) Trunk Radio Relay BLUE – Regional (< 10 GHz) Radio Relay YELLOW – Urban (>10 GHz) Short Haul GREEN - 500/1500 MHz DRCS (USO).