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Australian Communications and Media Authority

Earth station siting

Guidance on the establishment of new Earth stations and other space communications facilities or the expansion of existing facilities

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communicating | facilitating | regulating

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Executive summary

Satellite Earth stations and other space communications facilities are an important part of the Australian radiocommunications industry and have developed over many decades. Historically, a number of these facilities were situated in city areas due to a lack of reliable broadband infrastructure and the need for staff and operational support to be located nearby. These facilities support a wide range of valuable communications services and represent a high-value use of the radiofrequency spectrum.

Given the fundamental importance of the satellite and space industries as part of Australia's spectrum asset base, the Australian Communications and Media Authority (the ACMA) believes it is prudent to consider any matters that could affect the long-term viability of this industry in light of current and predicted trends in the wider radiocommunications industry. Spectrum is a renewable natural resource that is in high demand, particularly in bands suitable for the transmission of data to mobile devices. These pressures are outlined in greater detail in the discussion paper *Towards 2020—Future spectrum requirements for mobile broadband.*[1] Many satellite and space services share spectrum with, or operate in spectrum suited to, mobile broadband services or other systems such as point-to-point fixed links.

Additionally, satellite and space services often require high levels of interference protection because the signals received from satellites and other space sources are very low. The operation of terrestrial services in proximity to Earth stations can be problematic due to the deep levels of protection required by satellite Earth stations. In some cases, terrestrial services are unable to operate in the same or adjacent spectrum in large areas around satellite Earth stations and space facilities. Therefore, Earth stations in high-population areas in particular compete for spectrum with mobile broadband and other terrestrial services.

Given the high levels of interference protection required by satellite and space services, and the competition between space and terrestrial services to use spectrum in an area, establishing a space or satellite facility near large population centres can deny terrestrial services that are of potentially higher value to a large number of consumers. A number of existing space communication facilities that were originally built outside, but in close proximity to, major cities have since become surrounded by those cities due to ongoing urban encroachment. These facilities often experience interference from terrestrial services.

Satellite and space service users are legitimate and important users of the radiofrequency spectrum. In light of these pressures, the ACMA believes the development of a long-term sustainable strategy for the siting of Earth stations is highly important and needed to provide certainty for this industry.

This discussion paper aims to provide a strategic approach to meeting the requirements for satellite Earth stations and space communications in a sustainable way into the future. While the ACMA has not decided on an approach to addressing these issues, it does consider that the ongoing uncertainty is a problem and developing a long-term strategy for Earth station siting is a high priority. As such, some

[1] See www.acma.gov.au/WEB/STANDARD/pc=PC_312514.

options for a framework to enable spectrum users and assets to move towards a more strategic approach to Earth station siting are also discussed.

The intention of this paper is not to restrict or regulate the geographical or frequency locations of current or future Earth station deployments, but to outline the factors that may impact the future viability of satellite Earth stations and radioastronomy facilities in different geographical areas and frequency bands. The purpose of this paper is to openly discuss some of the factors relevant to current and prospective operators when they consider the geographical and frequency location of Earth stations. Through this discussion, the ACMA intends to provide options for long-term certainty of operations to the satellite and space science industries.

1. Introduction

The satellite and space industries are a fundamentally important part of Australia's radiofrequency spectrum community. The development of satellite and space radiocommunications services in Australia over the past few decades has resulted in the deployment of satellite Earth stations and radioastronomy and space research facilities across the country. In the past, many facilities have been sited close to cities so that staff have easy access to amenities and other supporting requirements and due to the lack of widespread broadband infrastructure. These facilities support a wide range of valuable communications services and represent a high-value use of the radiofrequency spectrum.

However, the use of spectrum by existing and planned facilities is coming under pressure from a number of sources. Spectrum is in increasing demand for terrestrial services in bands used by the satellite and space industries. However, the high levels of interference protection often required by satellite Earth stations and other space communications facilities means sharing spectrum in the same area is problematic. In some areas, urban encroachment on existing facilities means that these facilities now cause significant spectrum denial to terrestrial services that operate in bands shared with these space services and future services that are planned for these bands.[2] These terrestrial services could potentially service significant population centres and provide possibly greater benefit to the community.

This paper outlines the factors that may impact the future viability of satellite Earth stations and radioastronomy facilities in different geographical areas and frequency bands. The intention of this paper is not to restrict or regulate the geographical or frequency locations of current or future Earth station deployments but to openly discuss some of the factors relevant to current and prospective operators when they consider the geographical and frequency location of Earth stations. Future spectrum pricing and policy is likely to be heavily influenced by these factors.

Through this discussion, the ACMA intends to provide options for long-term certainty of operations to the satellite and space science industries as deployments of mobile broadband and other terrestrial radiocommunications services continue to expand. It is recognised that an Earth station represents a significant infrastructure investment and is intended to support multiple satellite lifetimes in excess of 15 years. It is also recognised that providing surety of tenure will promote investment in suitable sites.

The ACMA is confident that a long-term strategy can be developed to relieve pressures on satellite Earth stations and other space communications facilities while meeting the needs of these facilities into the future. This paper discusses opportunities for operators to establish Earth stations at suitable locations away from areas where the population is expected to exceed 25,000 people in the medium to long term. The development of the population criterion is given in Chapter 2. The paper also seeks to aggregate several recurring planning issues applicable to Earth station operators mentioned in other ACMA policy initiatives and in the band-by-band analysis later in this paper.

The analysis in this paper is based on the premise that considerable public benefit is derived from both space and terrestrial services. With careful planning in shared bands, the full extent of the benefits of both these services could be realised. Additionally, through careful planning, long-term certainty of operations could be provided for both space and terrestrial services.

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[2] Terrestrial services are defined as radiocommunications surfaces where transmission and intended reception takes part on or near the Earth's surface.

1.1 Legislative and policy framework

The issues discussed in this paper and the options presented in it are consistent with the object of the *Radiocommunications Act 1992* (the Radiocommunications Act) and informed by analysis against a total welfare standard (TWS) and the *Principles for spectrum management* set out below.

1.1.1 The object of the Radiocommunications Act

Section 9 of the *Australian Communications and Media Authority Act 2005* (the ACMA Act) sets out the spectrum management functions of the ACMA including:

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

Consistent with the spectrum management functions set out in the ACMA Act, the object of the Radiocommunications Act is to provide for management of the radiofrequency spectrum in order to achieve a number of goals, including:[3]

- maximise, by ensuring the efficient allocation and use of the spectrum, the overall public benefit derived from using the radiofrequency spectrum;
- make adequate provision of the spectrum:
  - for use by agencies involved in the defence or national security of Australia, law enforcement or the provision of emergency services, and
  - for use by other public or community services.

This paper analyses the issues surrounding Earth station location and the additional public benefit that could be derived from their deployment in areas of low spectrum demand, particularly for frequency bands being pursued for mobile broadband and other terrestrial services.

1.1.2 The *Principles for spectrum management*

The ACMA has developed a series of *Principles for spectrum management* (the principles) to guide its decision-making on spectrum management within its existing legislative responsibilities and government policy settings.[4]

The principles aim to:

- promote consistency, predictability and transparency in the ACMA's decision-making
- provide guidance for major planning and allocation decisions to be made over the next few years
- increase the ACMA's ability to respond to challenges, including the impact of new technologies and increasing demand for spectrum for advanced services.

The principles recognise that a band's highest value use is not determined solely by an economic assessment but also by consideration of the broader public good or social benefit achieved by that use. A key theme of the principles is to optimise the use of market mechanisms with minimal regulatory intervention in order to maximise the public benefit.

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[3] The object of the Radiocommunications Act is explained in sections 3(a) to 3(h).

[4] See www.acma.gov.au/WEB/STANDARD/pc=PC_311683.

The principles are:

- ***Principle 1****—Allocate spectrum to the highest value use or uses.*
- ***Principle 2****—Enable and encourage spectrum to move to its highest value use or uses.*
- ***Principle 3****—Use the least cost and least restrictive approach to achieving policy objectives.*
- ***Principle 4****—To the extent possible, promote both certainty and flexibility.*
- ***Principle 5****—Balance the cost of interference and the benefits of greater spectrum utilisation.*

An analysis of the ideas presented in this paper against these *Principles for spectrum management* is presented here. As this paper is intended as a guiding document, it closely identifies with principles 2, 4 and 5.

Principle 1*—Allocate spectrum to the highest value use or uses*
In shared bands, services compete for spectrum in an area. However, the public benefits derived from the use of this spectrum need not be mutually exclusive. For example, placing Earth stations in rural areas—where sufficient spectrum exists for terrestrial services—enables spectrum to be used by other services in higher density areas where spectrum is congested and in greater demand.

Principle 2*—Enable and encourage spectrum to move to its highest value use or uses*
In May 2011, the ACMA released a discussion paper called *Towards 2020—Future spectrum requirements for mobile broadband* that identified a broad range of options to meet the longer term needs of the mobile broadband industry. Many of the bands identified as being suitable for the introduction of mobile broadband are shared with bands designated for use by the fixed-satellite, space research and radio astronomy services. As sharing opportunities between terrestrial and space services are limited, it may be appropriate to assess the highest value use of a particular band. However, as discussed above, uses of a particular frequency band are not necessarily mutually exclusive.

When considering the highest value of spectrum, geographic and population considerations must be taken into account. It is clear that both space services and wireless access services are high-value uses of spectrum. However, applying population-based considerations means that the value of mobile broadband services increases as population density rises. The value of satellite Earth receive services in relation to population density remains fairly constant, regardless of location, while the opportunity cost of spectrum denied rises dramatically in populated areas and falls to almost zero in remote areas.

Principle 3*—Use the least cost and least restrictive approach to achieving policy objectives*
The intent of this paper is not to restrict Earth station deployment but to provide a guide as to what operators should consider when establishing or expanding an Earth station. The ACMA seeks to be as flexible as possible while implementing policies in order to encourage investment in facilities that are viable in the long term.

Principle 4*—To the extent possible, promote both certainty and flexibility*
The intent of this paper is to openly discuss Earth station siting issues, in order to provide an increased level of certainty for both ongoing space operations and terrestrial services that seek to share spectrum with these services. The paper also provides an opportunity for operators to formally comment in these matters.

Principle 5*—Balance the cost of interference and the benefits of greater spectrum utilisation*
The ACMA has invited comment in Chapter 3 on potential interference mitigation mechanisms that would allow for greater spectrum utilisation. These include technical measures such as filtering, the use of guard bands and alternative site location. Economic measures, such as pricing are also discussed.

These measures are intended to increase the level of sharing in bands allocated to both the satellite and terrestrial services, and to increase spectrum utilisation overall.

1.1.3 Spectrum management decision framework

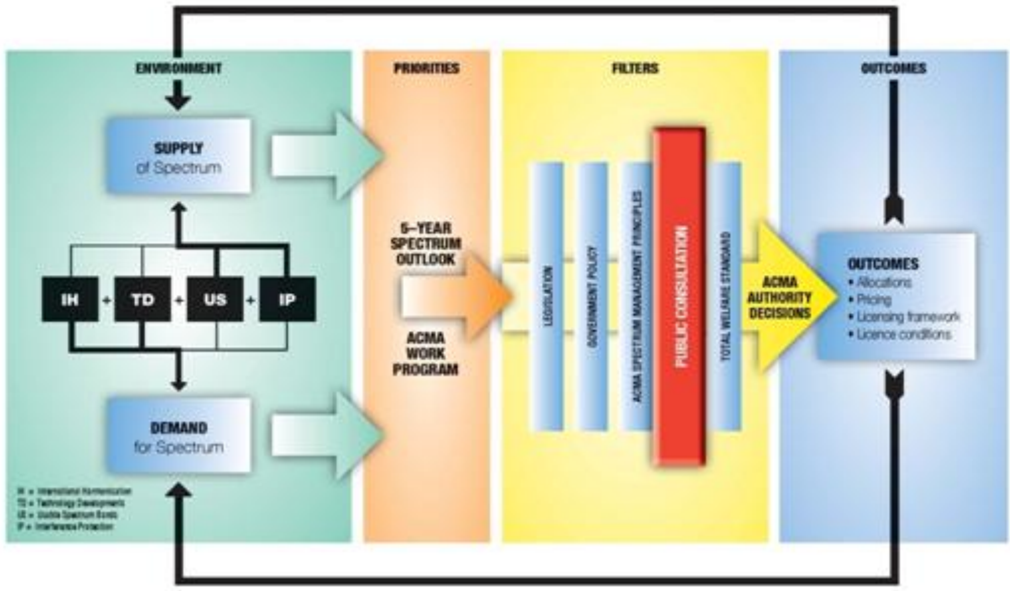
The ACMA has also considered a range of other factors in addition to the principles, as identified in its spectrum management decision framework. International harmonisation and developments in technology—in particular, in the bands identified for mobile broadband services and other terrestrial services—are key factors when considering the issue of Earth station siting. The framework is represented in Figure 1.1.

The diagram describes the ACMA's general approach to spectrum management decision-making. The review of Earth station siting was flagged in the ACMA's work program at Table 6.1 in the ACMA's *Five-year spectrum outlook 2011–2015*.[5]

In terms of the general approach, the release of this discussion paper represents the start of the ACMA's public consultation 'filter'. The ACMA will continue to apply the elements of its spectrum management decision framework, including the principles, as it considers the responses to this paper and determines the most appropriate way forward. While this discussion paper does not necessarily signal the development of regulatory measures for Earth station siting, it does outline the factors that the ACMA will consider when developing future spectrum policy in bands shared with space services.

[5] See www.acma.gov.au/WEB/STANDARD/pc=PC_312466.

Figure 1.1 Spectrum management decision framework



1.1.4 The Total Welfare Standard

In determining what actions maximise the public benefit, the ACMA uses a total welfare standard (TWS). The application of a TWS enables the ACMA to adhere to a consistent conceptual framework when assessing the public interest impact of the regulatory proposals it considers. A TWS requires consideration of the total benefit (economic surplus) of a regulatory decision. The approach that results in the greatest net benefits is regarded as the approach that best promotes the public interest. The impact of a decision on particular groups should be evaluated as part of the analysis, but issues associated with the distribution of benefits and costs between different parties should be addressed as a separate and distinct policy question.

In formulating and ultimately deciding on arrangements that may impact space services, the ACMA will consider the costs and benefits associated with any potential changes in line with a TWS. Feedback on the discussion in this paper, particularly regarding the costs and benefits of Earth station siting options, will form an important part of any future analysis in the development of future spectrum policy for space services.

This paper provides high-level consideration of the overall public benefits associated with improvements to Earth station siting arrangements. These issues are detailed in the discussion on spectrum planning drivers in Chapter 2 and the discussion on methods to improve spectrum utilisation in Chapter 3.

1.2 Objectives

In addition to the guidance provided by the Radiocommunications Act and the *Principles for spectrum management*, the ACMA has identified two major objectives in developing a long-term sustainable strategy for the siting of satellite Earth stations and other space communications facilities. These proposed objectives are to:

> provide a strategic framework for meeting the requirements for satellite Earth stations and space communications in a sustainable way into the future

> provide options for a pathway to enable spectrum users and assets to move towards this framework.

While the ACMA has not decided on an approach to addressing the pressures being faced by the satellite and space sectors, it does consider that the ongoing uncertainty is a problem and therefore developing a long-term strategy for Earth station siting is a high priority. The ACMA is seeking stakeholder feedback on these objectives, which are proposed in addition to the guidance provided by the Radiocommunications Act and the *Principles for spectrum management*.

1. The ACMA seeks comment on the proposed objectives for the development of a long-term sustainable strategy for the siting of satellite Earth stations and other space communications facilities.

1.3 Structure

The structure of this paper is as follows. Chapter 2 describes the spectrum planning drivers for the development of a long-term strategy for the siting of satellite Earth stations and other space communications facilities.

Chapter 3 examines the various tools available to both the ACMA and industry to address the pressures on the satellite and space industries discussed in Chapter 2. These tools fall into two categories—economic measures, and planning and technical measures.

Chapter 4 takes a band-by-band approach to the challenges of using each space frequency band up to 20 GHz, focusing primarily on Earth receive bands including radioastronomy bands.

Chapter 5 examines each major Earth station site in Australia, discussing the implications of spectrum demand on that particular site.

Chapter 6 discusses some potential elements of a long-term strategy for Earth station siting, including the establishment of special zones for the satellite and space industries, and future options for the use of guard bands.

1.4 Submissions

The ACMA invites comments on the issues set out in this discussion paper or any other issues relevant to Earth station siting. Submissions should be made:

By email: EarthStationSiting@acma.gov.au
By mail: The Manager
National Infrastructure, Government and Space Section
Spectrum Infrastructure Branch
Australian Communications and Media Authority
PO Box 78
Belconnen ACT 2616

The closing date for submissions is 7 October 2011.

Media enquiries should be directed to Emma Rossi on 02 9334 7719 or by email to media@acma.gov.au.

Any other enquiries may be directed by email to EarthStationSiting@acma.gov.au.

Electronic submissions in Microsoft Word or Rich Text Format are preferred.

Effective consultation
The ACMA is working to enhance the effectiveness of its stakeholder consultation processes, which are an important source of evidence for its regulatory development activities. To assist stakeholders in formulating submissions to its formal, written consultation processes, it has developed *Effective consultation: A guide to making a submission*.[6] This guide provides information about the ACMA's formal, written, public consultation processes and practical guidance on how to make a submission.

Publication of submissions
In general, the ACMA publishes all submissions it receives.

The ACMA prefers to receive submissions that are not claimed to be confidential. However, the ACMA accepts that a submitter may sometimes wish to provide information in confidence. In these circumstances, submitters are asked to identify the material over which confidentiality is claimed and provide a written explanation for the claim.

The ACMA will consider each confidentiality claim on a case-by-case basis. If the ACMA accepts a claim, it will not publish the confidential information unless authorised or required by law to do so.

Release of submissions where authorised or required by law
Any submissions provided to the ACMA may be released under the *Freedom of Information Act 1982* (unless an exemption applies) or shared with other Commonwealth Government agencies under Part 7A of the *Australian Communications and Media Authority Act 2005*. The ACMA may also be required to release submissions for other reasons including for the purpose of parliamentary processes or where otherwise required by law (for example, under a court subpoena). While the ACMA seeks to consult submitters of confidential information before that information is provided to another party, the ACMA cannot guarantee that confidential information will not be released through these or other legal means.

[6] See www.acma.gov.au/WEB/STANDARD/pc=PC_312051.

2. Pressures on spectrum used by satellite and space services

As discussed in Chapter 1, the spectrum used by existing and planned satellite Earth stations and other space communications facilities is coming under pressure from a number of sources. In this chapter, these pressures are outlined in more detail. There may be other pressures on this spectrum that may be relevant. Comment is sought on any additional pressures that should be considered.

2. The ACMA seeks stakeholder comment on any additional pressures that should be considered in the context of Earth station siting.

2.1 Satellite industry growth

The growth that the satellite communications industry has experienced over the past decade (for example, a 38 per cent increase in revenue from 2000 to 2005) is expected to continue for at least the next decade. Satellite communications involves a 15-year investment cycle, necessitating long-term strategic planning so the industry can respond to spectrum allocation changes.

Factors that are expected to drive demand for satellite spectrum include:

- increasing consumer demand
- increasing government demand and investment in technology
- return of financial market interest and investment.

The growth of the past decade has been observed in a trend towards increased use of higher frequency bands such as Ku-band (10.7–12.75 GHz). These bands are relatively unencumbered in comparison to lower frequency bands and sharing with terrestrial services is less problematic. These frequency bands are well placed to meet the long-term capacity requirements of satellite users.

From a technical perspective, the higher frequency bands provide comparable performance to the lower frequency bands for satellite services. An exception is areas with high rainfall, where lower frequency bands are sometimes preferable to the higher frequency bands, which are subject to rain fade.

The ACMA is expecting current demand in existing satellite bands to continue, at least in the medium term, with further growth expected in the higher frequency bands such as Ku-band.

3. The ACMA seeks comment on areas of growth in the satellite industry. Where is the biggest growth expected? Are there any emerging applications for satellite services that are expected to impact spectrum requirements?

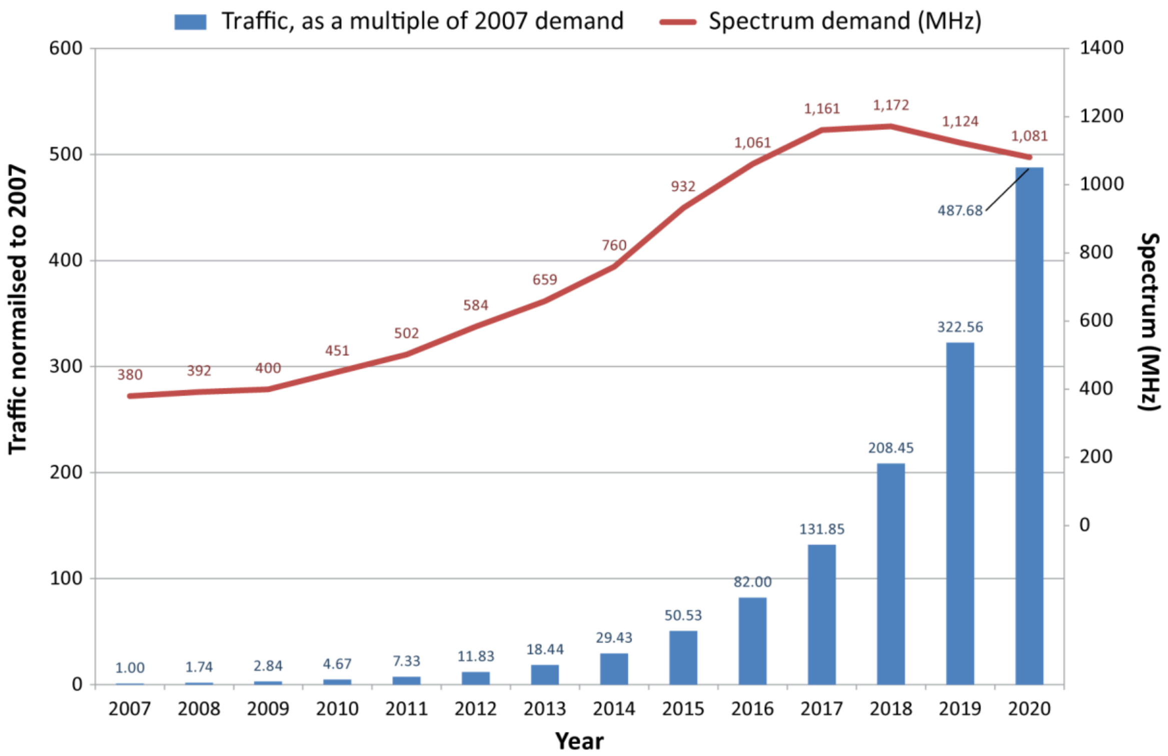
2.2 Planning for mobile data

2.2.1 Spectrum for fixed and mobile wireless broadband

The ACMA has been proactively monitoring trends in future wireless broadband spectrum needs since 2005. The most significant driver of spectrum needs is mobile broadband to support the growing proliferation of smartphones and mobile internet devices on the market. As these systems proliferate and capabilities increase, many vendors and carriers predict an exponential growth in the amount of data consumed.

The ACMA has recently commenced the *Future spectrum requirements for mobile broadband* project. The first discussion paper of this project, *Towards 2020—Future spectrum requirements for mobile broadband*, was released in May 2011.[7] This paper identifies the baseline spectrum requirements for future mobile broadband services. The ACMA's expectations for data and spectrum demands for mobile broadband services to 2020 are shown in Figure 2.1. The blue bar chart represents data demand based on industry assumptions to 2015 and ACMA trending to 2020. The figure predicts that over one thousand times the wireless data carried in 2007 will be carried in 2020.

Figure 2.1 Expectations for spectrum demand and traffic for mobile broadband services to 2020



However, spectrum demand does not linearly follow increased wireless data demand. Mitigating factors, such as increased infrastructure deployments (smaller cell sizes), improved coding and channel design (via MIMO technologies, for example) mean more bits per hertz can be carried. The red curve in Figure 2.1 shows the ACMA's anticipated level of spectrum demand to meet the needs of mobile broadband.

With the release of the 2.5 GHz band and the digital dividend, between 776 and 800 MHz of spectrum will be available for use by mobile broadband services in 2014. The analysis in the *Towards 2020* discussion paper estimates that up to a further 300 MHz of spectrum will be required for mobile broadband services by 2020, with up to 150 MHz of this being required by 2015.

[7] See www.acma.gov.au/WEB/STANDARD/pc=PC_312514.

These figures, however, relate only to areas of very high population density. In smaller cities and rural and remote areas, the need is much smaller, with existing mobile broadband spectrum, or less additional spectrum, able to meet demand. In such areas, the operation of Earth stations and their associated spectrum denial to other services may be less of an issue, with Earth stations likely able to continue operating in bands required for mobile broadband and other radiocommunications services long into the future.

In order to determine where these areas are, a benchmark population level needs to be established where mobile data needs can be met in other bands. Consideration also needs to be given to point-to-point backhaul needs in bands not currently slated for mobile applications.

Population is also not the only consideration. Ultimately, the determining factor is where spectral denial to a population exceeds that which could reasonably be serviced in other ways or using other frequency bands. This may occur directly as a result of spectrum being unavailable for a proposed new service or via the denial of other spectrum needed to host a service or services displaced to accommodate a new service. A good example of this is the deep space service denying spectrum in the 2.2 GHz band that was flagged for the relocation of Electronic News Gathering (ENG) services, potentially restricting ENG operations around space operations sites.

1.2.2 Estimating wireless data requirements

In most bands shared with space services, wireless data applications are predominantly fixed point-to-multipoint services. However, growth of mobile applications is anticipated into the future. Data needs may also be met via mobile applications (the USB dongle or inbuilt modem).

Carrier services using HSPA (high-speed packet access) are currently capable of delivering up to 40 MBit/s peak, with 7.2 MBit/s being a fair average. However, the Australian Government's policy objectives for the National Broadband Network (NBN) look at wireless data rates of 12 MBit/s, with industry exploring technologies that could provide up to 100 MBit/s to a user. So it would seem that a 20 MBit/s peak rate is a reasonable compromise for planning purposes.

Not all data users are online at the same time. However, many fixed and mobile applications carry machine-to-machine data that, while low-rate, is constant. This type of data carriage is expected to increase in the future, both in the number of devices and bandwidth needed. Taking into account the above figures, a contention ratio (the number of users per 20 MBit/s stream) of 10 would also appear to be reasonable.

For simplicity in small towns that may require only one or two cells, it seems reasonable to assume a spectrum re-use factor of four. This often depends on buildings, terrain and different population densities and may vary. The following also assumes a somewhat conservative 4 bits/Hz as the coding standard.

Given a mobile device penetration in excess of 100 per cent and the increasing prevalence of smartphones, the ACMA assumes every person in a town will require access to wireless data (mobile or fixed). If each person in a town or area has access to 125 kHz of spectrum, then their needs can be met in the medium term. This would suggest a population of around 6,400 could be serviced via wireless with the approximately 800 MHz of spectrum that will be available for mobile broadband in 2014—without needing to use any bands shared with space applications. A summary of this calculation is provided in Table 2.1.

Table 2.1 Summary of the calculation of a population benchmark

Target data rate	20 Mbps
Contention ratio	10
Re-use factor	4
Coding standard	4 bits/Hz
Spectrum available in 2014	800 MHz
Spectrum required per user	20 Mbps ÷ 10 ÷ 4 ÷ $\frac{4\text{bits}}{\text{Hz}}$ = 125 kHz
Users supported	800 MHz ÷ 125 kHz = 6,400 users

So, for an area served only by wireless, a population exceeding 6,400 may require access to bands shared with space applications.

Except in very lightly populated areas, not all data needs are carried by radio. It would appear reasonable to make a conservative assumption that, at any time, 25 per cent of a town in such areas relies on some form of wireless. In a town where only 25 per cent rely on wireless at any one time (either mobile or fixed applications), a population of 25,000 could be serviced. This figure is conservative as both fixed and mobile applications are considered and a greater penetration of wireless in the future is anticipated.

It seems reasonable to conclude that those Earth stations that deny spectrum suited to terrestrial services to a population of below 25,000 are relatively secure in the long term from relocation due to spectrum pressures. This is based on the assumption that more spectrum can be found that does not impact on satellite and space services.

The site-by-site analysis in Chapter **Error! Reference source not found.** uses these figures to make a basic analysis of whether established sites will face future pressures due to spectrum demand for terrestrial services.

However, this population baseline is potentially flexible. In some cases, tools that facilitate spectrum sharing may be applied so that a site under pressure from increasing demand for terrestrial services may continue operating.

4. The ACMA seeks comment on the methodology used to establish a benchmark population level below which Earth station operation would be reasonably secure in the long term.

3. Tools to facilitate more efficient spectrum utility

Given the pressures described in Chapter 2, the ACMA sees the need to develop a long-term strategy for the sustainable siting of Earth stations and other space communications facilities. In the development of this strategy, it is important to ensure the long-term sustainability of the satellite industry while also working towards achieving the highest value use of spectrum. This chapter examines the various tools available to both the ACMA and industry in order to accommodate these objectives.

The tools available fall into two categories—economic measures, and planning and technical measures. The key elements of each of these categories are outlined in this chapter. However, there may be other categories of tools not discussed that could be used to address the various pressures on spectrum used by the satellite and space sectors. Comment is sought on any additional categories of tools that should be considered.

5. **The ACMA seeks stakeholder comment on any additional categories of tools that could be used to address the various pressures on spectrum used by the satellite and space sectors.**

The overall planning framework that will be developed as an outcome of this consultation process will necessarily include a combination of these measures. The ACMA is inviting comment on both the individual aspects of each of these measures and the overall make-up of the future planning framework.

3.1 Economic tools

Spectrum pricing is a powerful tool that can be used to send signals to the radiocommunications industry that efficiencies need to be found in overall spectrum utility.

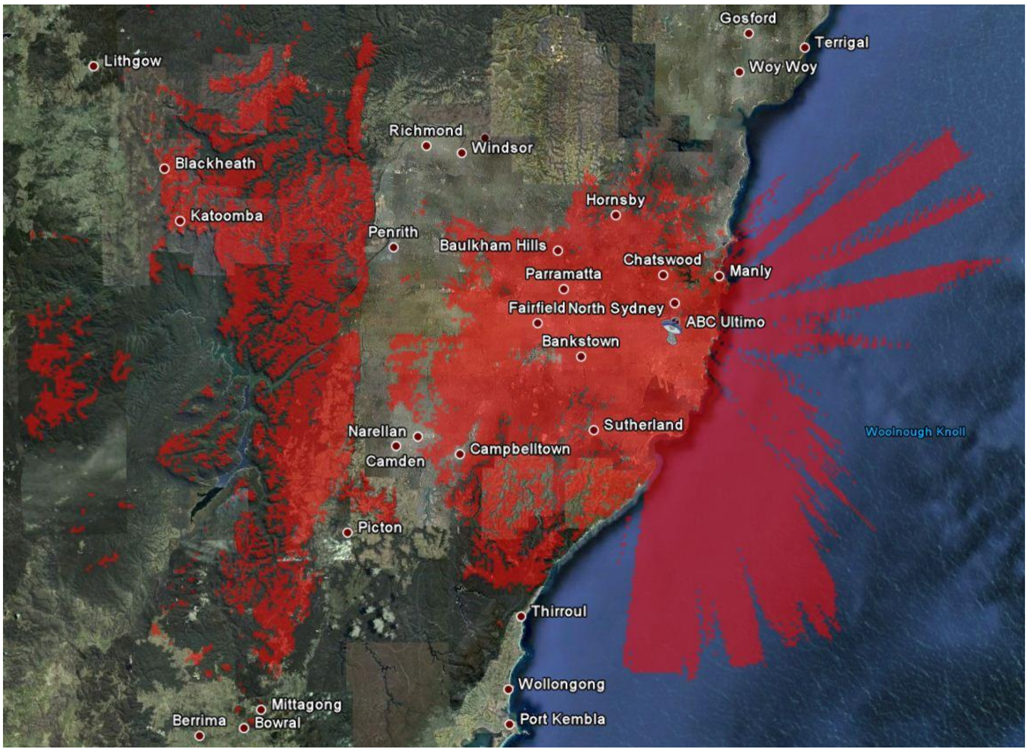
Australia is a vast land mass with an unevenly distributed population. With the ever-growing web of optical fibre backhaul available, traditional arguments about the need to establish or preserve satellite and space gateway facilities in populous areas no longer hold.

As spectrum increases in value—usually due to technologies becoming available that allow it to be used for fixed or mobile consumer services—its opportunity cost rises in populated areas. However, where there is no excess demand, the price of the spectrum can be expected to remain stable or even fall. The ACMA is committed to using opportunity-cost pricing as one of a suite of regulatory tools to send signals to industry of the value of spectrum, particularly in populated areas. In these areas, establishing and upgrading Earth stations may not necessarily be the highest value use in bands under demand from mobile broadband and other terrestrial services. Both types of services could be delivered if careful site selection or relocation is practised.

Sensitive receivers, including those used in Earth stations, deny the use of spectrum over a significant area. This area varies depending on its height and local terrain. As an example, Figure 3.1 depicts the geographical area of spectrum denial caused in the Sydney CBD by a receive station located at Ultimo (close to the CBD).

This site denies spectrum to a large part of the Sydney population, for all of its 51.4 MHz of bandwidth; however, the licences making up this site overlap with four fixed service channels totalling 160 MHz of spectrum denied, in areas as far away as the Blue Mountains. As the value of mobile broadband services increases, so will the opportunity cost of this spectrum. For a small facility such as this one, which is capable of being located remotely with fibre backhaul, the cost of spectrum could exceed the cost to relocate it in the medium term.

Figure 3.1 Spectrum denial area from C-band receiver at Ultimo in Sydney CBD



Opportunity cost for spectrum where there is little or no competing demand is also expected to be very low in bands that the satellite or space services communities do not share with other services. Using opportunity-cost pricing sends positive price signals that encourages the space community to locate or relocate to areas of overall lower population density.

Where a facility potentially denies spectrum for a service to a significant population base, the ACMA may also consider regulatory measures for its relocation as demand for spectrum increases.

6. The ACMA seeks comment on using opportunity-cost pricing of spectrum for satellite Earth station licensing based on spectrum denial caused to terrestrial services.

3.2 Planning and technical tools

There are primarily three types of interference that can be caused to an Earth station receiver—out-of-band, in-band and spurious. In each case, different mitigation techniques can be used to protect the receiver. However, some of these have the effect of denying a greater area and/or additional spectrum to other services and thus may impose a high effective cost to the economy depending on their location.

Out-of-band (OOB) interference is an issue for any receiver requiring significant levels of protection. There are essentially five tools, further discussed below, with which to mitigate OOB interference:

> geographic separation
> use of terrain
> filters
> guard bands
> antenna discrimination.

In-band interference is caused by other services or noise sources transmitting within the intended receive band. Assuming the interferer is within that part of the band that must be used for reception, four tools, further discussed below, are available to mitigate resulting interference. These are:

> geographic separation
> use of terrain
> increased transmit power
> antenna discrimination.

Spurious emissions emanate from a number of sources such as harmonic and intermodulation products. Such spurious emissions may fall into, or immediately adjacent to, the receive band causing a degradation to carrier to (noise plus) interference margins.

Intermodulation products can also form as the result of mixing in non-linear devices or ‘fault’ non-linearity such as corroded connectors. These can be the result of mixing ‘on-site’ transmissions, mixing ‘off-site and on-site’ transmissions or mixing ‘off-site’ transmissions. The ACMA considers emissions within 200 metres of a receiver to be a site management problem and does not generally take them into account in spectrum planning processes (they are treated as a fault condition). The ACMA expects site managers to take all reasonable steps to reduce intermodulation products through the use of high-quality components and maintenance.

Nonetheless, non-linearity does occur in low-noise amplifiers, filters and other components, and the presence of high-power nearby signals can cause intermodulation interference.

The tools available to site designers and managers to manage spurious emission interference are:

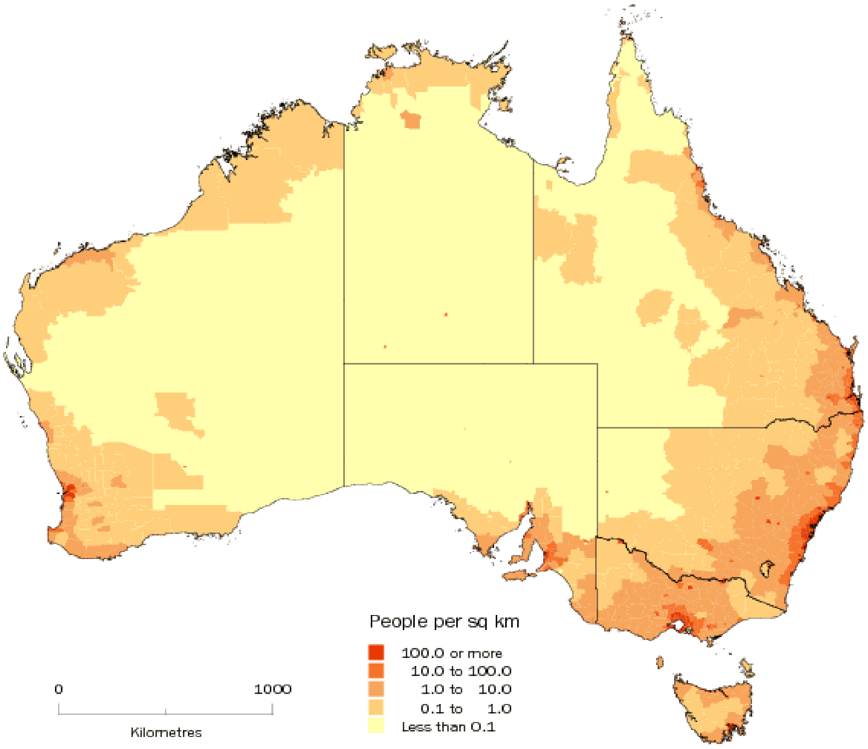
> geographic separation
> use of terrain
> filters
> guard bands
> high quality ‘linear’ components
> thorough maintenance.

The first four of these tools are further discussed below. The final two are factors that would ordinarily be considered by a systems designer.

A study of population and growth trends is useful in establishing the viability of a location in the medium to long term. This needs to be examined to determine the need for and appropriateness of physical interference mitigation mechanisms. Figure 3.2 shows population density for Australia in June 2009.

While this chart is indicative only (because of its size), similar data will give the same conclusions. When establishing a new facility or upgrading an existing one, maximum service life expectancy can be achieved by avoiding areas of high population. These are represented by the red and orange in this map.

Figure 3.2 Australia's population density at June 2009[8]



The following briefly considers each of the planning and technical tools available to mitigate interference and outlines in which interference situation they can be applied. Comment is sought on additional planning and technical tools that could be used to manage interference into satellite Earth stations and other space communications facilities.

> **7. The ACMA seeks information on any additional planning and technical tools that could be used to manage interference into satellite Earth stations and other space communications facilities.**

3.2.1 Geographic separation

Geographic separation is an effective way to mitigate the effects of OOB, in-band and spurious emission interference. Maintaining geographic separation from potential interference sources over time is not always viable from a spectrum management perspective. In many cases, an Earth station is constructed well away from existing population centres but with the passage of time the population grows to encircle the site.

This is the case for the Perth International Telecommunications Centre on Gnangara Road Landsdale, WA, and a Department of Defence facility near Darwin. The problem exists to a lesser extent for the Optus sites at Lockridge, WA, and Oxford Falls near Sydney. In other cases, such as a site at Mawson Lakes near Adelaide, the Earth

[8] ABS, *Regional Population Growth (2008–2009) Report,* www.abs.gov.au/AUSSTATS/abs@.nsf/mf/3218.0.

station was established after the population centre had evolved. Therefore, geographic separation cannot always guarantee protection in the long term.

In effect, geographic separation enables the ACMA to protect facilities, but only where the site location is carefully selected to avoid areas of population exceeding about 25,000 people or where future populations are expected to reach 25,000 within the design life of the station.

In recognising the increasing difficulty of accommodating Earth stations in high spectrum use areas and planning alternative opportunities, the ACMA established a 'satellite park' around Mingenew, WA, in 2009. This park was established to preserve the radio environment to provide an opportunity for Earth station operators to reliably plan future systems in any space band at this site. This protection is reflected in spectrum Embargo 49, which has the effect of preserving an area around the site for Earth station users against in-band emissions.[9] Coordination is, however, required from adjacent services in accordance with normal procedures so, in effect, and mainly due to the low population density in the area, the whole area is protected.

The ACMA is considering another similar area on the east coast that is further discussed in Chapter 6.

The ACMA has also established the Radio Quiet Zone (RQZ) around Boolardy Station in WA within which all radio transmissions from 70 MHz to 25.25 GHz are managed by way of the Radiocommunications (Mid-West Radio Quiet Zone) Frequency Band Plan 2011, Embargo 41 and a supporting RALI.[10] This site was chosen because of its extremely low population density. This is important because it enables strict regulation of radio services inside this zone.

3.2.2 Use of terrain

Establishing a facility that is protected by terrain, particularly from adjacent population centres, is a valuable form of long-term protection for Earth receivers. This is an effective way to mitigate the effects of OOB, in-band and spurious emission interference.

Such terrain protection exists to varying degrees around some sites, such as Oxford Falls and Geraldton. Conversely, other sites such as the Perth ITC and the facility at Mawson Lakes, lack any natural terrain protection.

When considering the establishment of new facilities, operators are advised to consider a combination of geographic separation and terrain shielding in order to preserve the longevity of the facility.

3.2.3 Filters

Filters fitted to transmitters can be very good at resolving OOB and spurious emission interference. However, more powerful interference requires a more complex and expensive filter. For very high power interferers, filters may introduce non-linearities into the system and thus increase intermodulation products (spurious emissions interference).

Satellite receivers often have to be licensed for large bandwidths in order to accommodate reception of transmissions from multiple satellite transponders. This is an important consideration in the reception of broadcast content via satellite as it is often not known in advance what particular transponder a satellite operator will use to

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[9] See www.acma.gov.au/webwr/radcomm/frequency_planning/spectrum_embargoes/embargo_49.pdf.

[10] See www.acma.gov.au/webwr/radcomm/frequency_planning/spectrum_embargoes/emb41.pdf and www.acma.gov.au/WEB/STANDARD/pc=PC_100628.

deliver the feed. This leads to the situation where the Earth station often overlaps with a number of channels in shared bands, causing a much greater spectrum denial than the licensed receive bandwidth implies.

Satellite Earth stations are highly sensitive to interference. The very low received signal levels from satellites necessitate a very sensitive receiver, which, when combined with the need for these receivers to operate over a large bandwidth, often over the entire band, creates this situation. The openness of the receiver front end to the entire band leaves it particularly susceptible to interference from adjacent band transmitters. Although the interfering signal may not directly overlap with the wanted satellite signal, it may still drive the receiver into overload given that the receiver front end is open to a wide bandwidth.

Filters fitted to receivers are intended to provide some protection from adjacent band transmitters and can be successful in preventing overload, but they also raise the noise floor of the receiver. This may be intolerable in circumstances where the received signal strength is very low. One such example is reception from deep space missions such as those conducted at New Norcia in WA.

8. The ACMA seeks comment on the use of filtering in Earth receive stations and its applicability and usage in interference mitigation.

3.2.4 Guard bands

Guard bands are unused segments of spectrum between an Earth receive band and adjacent services. They are intended to provide interference protection to receivers by providing frequency separation from transmitters. This measure can be used to mitigate the effects of OOB and spurious emission interference. Historically, guard bands are negotiated on a site-by-site or service-by-service basis. In the past, fees have not been charged for guard bands. However, unused spectrum that comes free of charge carries no incentive to use other methods of interference mitigation.

The ACMA will be investigating the basis upon which fees for guard bands are set, with a view to maximising the value achieved from the spectrum and providing incentives to use other interference mitigation strategies such as filters or, in some cases, relocation to more appropriate sites. The ACMA is also conducting studies into developing a new approach to guard bands for the protection of Earth receive stations as a measure to improve spectrum utilisation. This is further discussed in Chapter 6.

9. The ACMA seeks comment on alternative methods of interference management should guard bands be reviewed in the future.

3.2.5 Antenna discrimination

Antenna discrimination can be used to mitigate the effects of in-band and OOB interference. The use of larger or more efficient antennas can reduce the interfering power while improving the received signal power, thus reducing the effect of the interference. However, beyond a certain size, antennas become difficult and expensive to construct and as a mitigating factor after the fact are often prohibitively costly.

3.2.6 Increased transmit power

Increasing transmitter power serves to improve signal to interferer ratios and potentially mitigate the interference situation. However, increases in transmit power are not available to many services (such as radio astronomy) and such increases may reduce the life of a satellite, be impossible due to power budgets or not be feasible due to International Telecommunication Union (ITU) limits on power flux density (PFD) at the Earth's surface. Additionally, as satellites age their solar panels degrade, causing a reduction in transmitted power in some cases.

3.3 Summary of site protection mechanisms

To maximise longevity and security of spectrum, it is advisable that any new deployment of Earth stations and radioastronomy or space research facilities should be located well away from population centres exceeding 25,000 or any population centre (or area) expected to exceed this number at any time during the life of the facility. Protection from interference can be expanded through the use of the tools discussed above where available and appropriate.

Exceptions to this are the RQZ, where protections are in the process of being negotiated (however, the very low population density in that region is not expected to change), and the Mingenew Satellite Park, where all space receive bands are protected (excluding radioastronomy). In July 2011, the ACMA introduced the *Radiocommunications (Mid-West Radio Quiet Zone) Frequency Band Plan 2011* to protect this area.[11] The ACMA is open to suggestions for a similar zone on the east coast, which would give operators a similar site where long-term operation could be supported. This is further discussed in Chapter 6.

The ACMA expects site managers to take the spectrum needs of the community into account when locating or expanding such facilities. Where they broadly do not meet these principles the ACMA may not be able to offer them protection into the future.

10. The ACMA seeks comment on all matters related to site interference protection.

[11] See www.comlaw.gov.au/Details/F2011L01520.

4. Analysis of pressures in spectrum used by space services

Many spectrum bands are shared between various space services and other terrestrial services. Space services include but are not limited to:

> the fixed-satellite service (FSS)
> the broadcasting-satellite service (BSS)
> the mobile satellite service (MSS)
> the space research service (SRS)
> the radio astronomy service (RAS)
> tracking, telecommand and control (TT&C).

These services share spectrum with terrestrial services including, but not limited to:

> the fixed service (FS), which includes point-to-multipoint (P-MP)
> the mobile service (MS), which includes public mobile telephony service (PMTS) and other mobile wireless applications
> electronic news gathering (ENG).

Most space-related activities require significant levels of interference protection, which denies the use of shared spectrum for many kilometres around a facility. Where the facility is in a highly populated area it is possible that the service denied is the highest value use of the band.

In addition, Earth station transmitters and receivers can also deny significant amounts of spectrum to other radiocommunications in planned bands due to their varying spectrum overlap of plan channels. This aspect of spectrum denial is compounded for bands with planned channel pairings by significantly reducing the utility of paired channels.

For example, RALI FX 3 includes a 6 GHz channel plan for fixed point-to-point links for 29.65 MHz channels in the frequency range 5925–6425 MHz.[12] The plan comprises paired channels for two-way links with half of the band for forward direction paths and half for the reverse direction. Earth station transmitters also use this band and may occupy varying bandwidths ranging from less than one channel to many channels. The resulting potential spectrum denial ranges from a minimum of one channel, regardless of whether the Earth station bandwidth is less than one channel width, to all of the channels overlapped. In addition, considering that the plan is intended to support two-way communications, the utility of the associated paired channels, while not directly victims of interference, are also potentially significantly affected.

Applying the TWS, the actual worth of a facility combined with the services it provides must be taken into account when it comes under pressure from a terrestrial service that is denied. This is not the case for new facilities and a balance between community needs and the ability of such facilities to be located away from population centres must be found.

In general, higher bands are easier to share—the propagation distances for transmitters are smaller and, when parabolic antennas are used, the beamwidth is

[12] See www.acma.gov.au/webwr/radcomm/frequency_planning/frequency_assignment/docs/fx3/6g.pdf.

narrower. This means the interference environment may be more favourable at higher frequencies and alternative paths 'around' space facilities may be easier to find. In general, it is in the lower shared frequency bands that the future viability of some facilities may be impacted. The lower bands are more likely to be pressured to change use first as new technologies vie for spectrum use.

4.1 Discussion on particular bands and associated issues

This paper discusses only facilities using shared bands. A table of these bands is available in Appendix B. This section focuses primarily on Earth station receive bands; however, consideration is also given to certain Earth station transmit bands below 7 GHz as these have the potential to cause spectrum denial, particularly as they may be used for deep space operations. For the purpose of this initial consultation paper, transmit bands above 7 GHz are not discussed explicitly in this section as they are more able to be coordinated. However, they are included in Appendix A as they may be considered in the further development of spectrum policy.

To determine if a new facility should be permitted in populated areas, or if an existing facility should cease operations in a particular band or area, alternative uses are examined in each case and the pros and cons of sharing in that situation are discussed.

A band-by-band analysis has been completed from 840 MHz to 20.1 GHz and advice given on the long-term prospects for shared operations.

4.1.1 840–845 MHz

This band has been spectrum-licensed and is used for public mobile telephony services (PMTS); in particular, the Telstra Next G network. PMTS is the expected use of this band in the foreseeable future.

The band is also subject to Footnote AUS 63, which states it may be used by the radio astronomy service at a location near Canberra. This facility, known as the Molonglo Observatory Synthesis Telescope (MOST), was licensed until the end of 2009. This licence has not been renewed. Urban encroachment in the area has meant that noise around the telescope from PMTS mobile handsets and other sources is increasing, making the location less than ideal.

The ACMA has also created the RQZ, an area around Boolardy Station in WA. While this site was established primarily to preserve radio quietness for Australia's bid for the Square Kilometre Array (SKA), it would be suitable for other passive applications such as facilities like the MOST.

As this band is spectrum-licensed Australia-wide, the ACMA no longer supports or licenses radioastronomy services in this band. However, operators are free to negotiate with the spectrum licence holders—in this case, Telstra—for continued interference protection. No other radioastronomy services will be licensed in this band, except in the RQZ, unless separately negotiated.

4.1.2 1400–1427 MHz

This band is considered to be part of the 'L-band' in satellite terminology. The band is set aside for passive services; that is, no transmitters are permitted. However, as the band is used for space services requiring significant levels of interference protection, it is included here as it is adjacent to fixed and mobile bands.

The adjacent band 1427.9–1462.9 MHz is under consideration for mobile broadband as part of the ACMA's *Future spectrum requirements for mobile broadband* project.[13] Therefore, the levels of adjacent band protection systems operating in this band may not be able to be guaranteed in the long term. As such, continued protection against out-of-band emissions from future fixed or mobile services, except within the RQZ, may not be able to be supported.

4.1.3 1427–1429 MHz

This band is shared between the space operations, fixed and mobile services. Because the band has an allocation to the MS, it is possible that it may be used to support PMTS-like services or mobile broadband in the near future. Considering these demand pressures, the viability of Earth station operation in proximity to areas of significant population in this band appears in doubt and raises issues of certainty of tenure. The ACMA will potentially need to make decisions on this matter in the future.

4.1.4 1452–1492 MHz

This band is shared between the BSS, FS, MS and broadcasting service. The BSS (Sound) service has been found to be able to share with terrestrial services on a no protection basis. That is, BSS(S) receivers are not afforded any protection from interference from any terrestrial service.

It is possible that in the future either terrestrial broadcasting or mobile services (such as PMTS) may use this band, making the viability of BSS(S) unlikely. In particular, the establishment of Earth receive stations for program monitoring and TT&C cannot be supported in populated areas.

The band is also subject to a band plan (1.5 GHz Band Plan), preventing the licensing of services other than specified terrestrial and satellite broadcasting for the time being.

This band plan has been identified for review as outlined in the *Towards 2020* paper, as this band is being considered for mobile broadband applications.

4.1.5 1525–1535 MHz

This band is shared between the space operation service (SOS), FS and MSS. The MSS is a service used primarily in remote areas, while the FS is used in most areas of Australia.

No current SOS assignments have been made; however, given the complexity of the band, the ACMA will need to consider any such application on a case-by-case basis.

The ACMA's *Five-year spectrum outlook* outlines the issues associated with this band.[14]

4.1.6 1610–1930 MHz

This band is annotated with a reference to the RAS via Footnote AUS 87, which states:

> Radio astronomy facilities operated by the CSIRO at the Paul Wild Observatory Narrabri (latitude 30° 59' 52.048" S, longitude 149° 32' 56.327" E), the Parkes Observatory (latitude 32° 59' 59.8657" S, longitude 148° 15' 44.3591" E), and the Mopra Observatory Coonabarabran (latitude 31° 16' 4.451" S, longitude 149° 5' 58.732" E) and by the University of Tasmania at the Mount Pleasant Observatory Hobart (latitude 42° 48' 12.9207" S, longitude 147° 26' 25.854" E) and the Ceduna Observatory (latitude 31° 52' 08.8269" S, longitude 133° 48' 35.3748" E), and at the

[13] See www.acma.gov.au/WEB/STANDARD/pc=PC_312514.
[14] See www.acma.gov.au/WEB/STANDARD/pc=PC_312466.

> Canberra Deep Space Communication Complex (latitude 35° 23' 54" S, longitude 148° 58' 40" E) conduct passive observations in the frequency bands 1 250 - 1 780 MHz, 2 200 - 2 550 MHz, 4 350 - 6 700 MHz, 8 000 - 9 200 MHz and 16 - 26 GHz using receivers that are highly sensitive to interference.

The band is also shared with many other services including fixed and mobile services.

Some of the aforementioned radio astronomy facilities are in close proximity to high-population density areas and have the potential to deny valuable spectrum to a high number of potential users.

Each of the facilities listed above operate in a number of other bands (in which AUS 87 is applied and listed above) and, if these facilities are licensed, may cause significant spectrum denial, as with other Earth receive facilities.

These facilities will be discussed in an examination of existing facilities in the following section.

4.1.7 2025–2120 MHz (Earth-to-space)

The band 2025–2110 MHz is allocated to the SOS (Earth-to-space), the Earth exploration-satellite service (EESS) (Earth-to-space), SRS (Earth-to-space), FS and MS. This band is used by the FS and the SOS. The SOS and SRS community and others have been proactive in establishing new services in this band in the Mingenew zone supported by ACMA spectrum Embargo 49.[15]

The segment 2110–2120 MHz is allocated to the SRS (Earth-to-space) (deep space), FS and MS. Earth stations operating in this band to support deep-space missions are located in Canberra and New Norcia. These facilities operate at very high transmit powers and cause large areas of spectrum denial to terrestrial services.

Ongoing operation or the establishment of new sites that deny spectrum to large population centres may not be viable in the future.

4.1.8 2200–2290 MHz

This band is allocated to the SOS (space-to-Earth), the EESS (space-to-Earth) and the SRS (space-to-Earth). It is shared with the FS and MS, and in the future will accommodate ENG to facilitate ENG moving from the 2.5 GHz band.

The band is also referred to in Footnote AUS 87.

With ENG moving into this band, protection for space facilities will become very difficult in areas of high population. Considering the comments in this section, it would appear that the viability of Earth station operation in proximity to areas of significant population in this band is in doubt and raises issues of certainty of tenure. The ACMA will potentially need to make decisions on this matter in the future.

Some existing facilities located in or near large population centres will be required to relocate. These are outlined in the station-by-station analysis.

4.1.9 2290–2300 MHz

This band is allocated to the SRS (deep space, space-to-Earth). The nature of deep space operations means they require significant levels of interference protection.

The band is shared with the FS and MS and will be allocated to ENG in the near future.

[15] See www.acma.gov.au/webwr/radcomm/frequency_planning/spectrum_embargoes/embargo_49.pdf.

The band is also referred to in Footnote AUS 87 and is adjacent to a spectrum-licensed band that supports WiMax. WiMax is a TDD technology, which effectively means that the band is adjacent to a fixed transmit band.

With ENG moving into this band, protection for space facilities will become very difficult in areas of high population. Considering the comments in this section it would appear that the viability of Earth station operation in proximity to areas of significant population in this band is in doubt and raises issues of certainty of tenure. The ACMA will potentially need to make decisions on this matter in the future.

Some existing facilities located in or near large population centres will be required to relocate. These are outlined in the station-by-station analysis.

4.1.10 2690–2700 MHz

This band is allocated to the EESS, RAS and SRS. It is adjacent at the lower end to the band 2500–2690 MHz, which is an internationally harmonised International Mobile Telecommunications (IMT) band. It is likely that IMT systems will be deployed nationally in this band and, while some protection for existing CSIRO sites at Parkes and Narrabri may be possible in the medium term, operations in this band are best suited to the RQZ and so no new assignments should be made except to systems within the RQZ.

This band is adjacent to radiolocation (radar) at the upper end of the band. Radar is a particularly high-power application and where radar is installed space activities may be interfered with. This again suggests the RQZ is the best location for space communications services in this band.

Operations in this band at Parkes and Narrabri may need to be reviewed once IMT deployments commence. This is discussed in the site-by-site analysis.

4.1.11 3400–3600 MHz

This band is allocated on a secondary basis to the FSS and on a primary basis to the FS and radiolocation service. The band is commonly referred to as the ‘Lower C-band’.

The band is not generally supported in Australia for space services.

Within the FS, it is currently possible to deploy WiMax P-MP data systems, which is a high-value use of the band. Radiolocation is reserved for the Department of Defence via Footnote AUS 11 and is deployed offshore.

Secondary services are not normally offered protection from primary services.

Considering the comments in this section it would appear that the viability of Earth station operation in proximity to areas of significant population in this band is in doubt and raises issues of certainty of tenure. The ACMA will potentially need to make decisions on this matter in the future.

The ACMA has established a zone around Mingenew to protect facilities within the zone for most satellite bands as outlined in Embargo 49. However, no such zone exists around Darwin and, as facilities there are situated within areas of increasing population density, their future is subject to review.

4.1.12 3600–4200 MHz and 5925–7075 MHz

This band is allocated on a primary basis to the FSS, FS and MS. It is commonly referred to as ‘C-band’ and the upper part of the transmit band as ‘Extended C-band’.

C-band systems are not able to be deployed ubiquitously in Australia, unlike some higher bands, such as Ku and Ka. Thus the band is not supported for space services involving ubiquitous Earth stations.

The ACMA has released the bands 3400–3700 MHz for P-MP systems via spectrum and apparatus licences. Protection for satellite Earth terminals in these bands is subject to review.

As more pressure comes from mobile broadband services seeking spectrum access, the ACMA will review the future of the 3700–4200 MHz band. These future pressures are outlined in the *Towards 2020* paper.

The frequency band 5925–7075 MHz accommodates Earth station transmitters. While typically spectrum denial from this use is not as great as for Earth station receivers in 3600–4200 MHz, for reasons outlined at the beginning of this chapter, they can deny large amounts of spectrum to areas of high-density population.

Considering the comments in this section it would appear that the viability of Earth station operation in proximity to areas of significant population in this band is in doubt and raises issues of certainty of tenure. The ACMA will potentially need to make decisions on this matter in the future. Prior to any changes, all existing Earth stations that deny spectrum to high-population centres will potentially need to be reviewed individually. These stations are discussed in the station-by-station review.

4.1.13 7250–7850 MHz

This band is commonly called ‘X-band’ and supports a variety of satellite services (space-to-Earth) and is shared with the FS and, in part, the MS. Most segments of the band are designated with either footnote AUS 1 (band intended to be used principally for the purposes of defence) or AUS 11 (fixed-satellite allocation intended to be used principally for the purposes of defence).

Parts of the band are used for television outside broadcast (TOB) and, with pressure on ENG in lower bands increased, use of TOB in these bands can be expected.

The future requirements of the FS are unclear as optical fibre networks grow. However, as with most systems, the current FS congestion is expected in highly populated areas for some time.

The ACMA is able to support ongoing operation of existing X-band satellite facilities in the medium term in locations away from populated areas. However, operators of existing facilities should carefully consider alternatives before expanding such systems, particularly in populated areas.

Considering the comments in this section it would appear that the viability of Earth station operation in proximity to areas of significant population in this band is in doubt and raises issues of certainty of tenure. The ACMA will potentially need to make decisions on this matter in the future.

4.1.14 8025–8400 MHz

This band is also considered to be part of X-band and the same conditions apply as for the band 7250–7850 MHz. The band is designated AUS 11 (fixed-satellite allocation intended to be used principally for the purposes of defence).

4.1.15 10.7–11.7 GHz

This band is shared between the FSS (space-to-Earth), FS and MS. The predominant use of this band in Australia is for fixed links. The ACMA does not support the ubiquitous deployment of FSS Earth terminals in this band.

There does not appear to be a need to move or restrict licensing of Earth stations in the band at this time provided they can coordinate with all existing fixed links.

However, operators would be prudent to consider locating new facilities away from populated areas, to avoid having to move if congestion or pressure from alternative uses of this band further increases in the future.

4.1.16 11.7–12.75 GHz

The bands 10.7–11.7 GHz and 11.7–12.75 GHz are known as the Ku band in Australia. The band 11.7–12.75 GHz is not shared with other services and is supported for ubiquitous deployment of satellite systems via a class licensing system.

The ACMA will continue to support deployment of these systems. No future pressures on the band from alternative technologies are anticipated.

4.1.17 17.7–18.1 GHz

This band portion is allocated to the FS and FSS (Earth-to-space) via International Footnotes 484A and 516.

The 18 GHz fixed plan in RALI FX-3[16] outlines fixed use of this band. Fixed service deployments are limited in number in this band; however, coordination is made easier as the band is relatively high frequency. There exists potential for continued operation of existing Earth stations in this band and some potential for new facilities, but not in high- or medium-density areas.

The band 17.7–18.2 GHz is currently being considered for an additional allocation to the Communications with Space Objects class license to support ubiquitous VSAT deployment for satellite broadband applications.

4.1.18 18.1–18.6 GHz

This band is allocated to the FSS, and shared with the FS and MS.

The 18 GHz fixed plan in RALI FX-3 outlines fixed use of this band. FS deployments are extensive; however, coordination is made easier as the band is relatively high frequency. There exists potential for continued operation of existing Earth stations in this band and some potential for new facilities, but not in high- or medium-density areas.

Because of extensive networks of fixed links, there is no scope for ubiquitous deployment of FSS Earth stations.

4.1.19 18.6–18.8 GHz

This band is used by the FSS (space-to-Earth) and shared with the FS, MS and passive EESS.

The 18 GHz fixed plan in RALI FX-3 outlines fixed use of this band. Fixed service deployments are extensive; however, coordination is made easier as the band is relatively high frequency. There exists potential for continued operation of existing

[16] See www.acma.gov.au/WEB/STANDARD/pc=PC_2599.

Earth stations in this band and some potential for new facilities, but not in high- or medium-density areas.

Because of extensive networks of fixed links, there is no scope for ubiquitous deployment of FSS Earth stations.

4.1.20 18.8–19.3 GHz

This band is class-licensed for FSS Earth (receive) terminals. The ACMA continues to support this band for downlinks to ubiquitous terminals in the FSS.

4.1.21 19.3–19.7 GHz

This band is used by the FSS (space-to-Earth) shared with the FS and MS.

The 18 GHz fixed plan in RALI FX-3 outlines fixed use of this band. FS deployments are extensive; however, coordination is made easier as the band is relatively high frequency. There exists potential for continued operation of existing Earth stations in this band and some potential for new facilities, but not in high- or medium-density areas.

Because of extensive networks of fixed links, there is no scope for ubiquitous deployment of FSS Earth stations.

4.1.22 19.7–20.1 GHz

The FSS is the sole primary allocation in this band and continued operation is supported in all areas.

The band 19.7–20.2 GHz is currently being considered for an additional allocation to the Radiocommunications (Communication with Space Object) Class Licence 1998[17] to support ubiquitous VSAT deployment for satellite broadband applications.

4.2 Conclusion

The coverage gains afforded by the more favourable propagation characteristics of lower frequency bands mean that this spectrum will continue to be highly sought after. It is in these lower frequencies bands, typically below 5 GHz, where it will be more difficult to establish whether or not an Earth station will be secure in the medium to long term.

The higher frequency bands are also subject to pressure to support new applications and technologies but not yet to the same extent as lower bands.

11. The ACMA seeks comment on issues raised in the band-by-band analysis chapter, particularly comments on specific frequency bands. Do you agree with the analysis? Why or why not?

[17] See www.acma.gov.au/WEB/STANDARD/pc=PC_302.

5. Site-by-site analysis

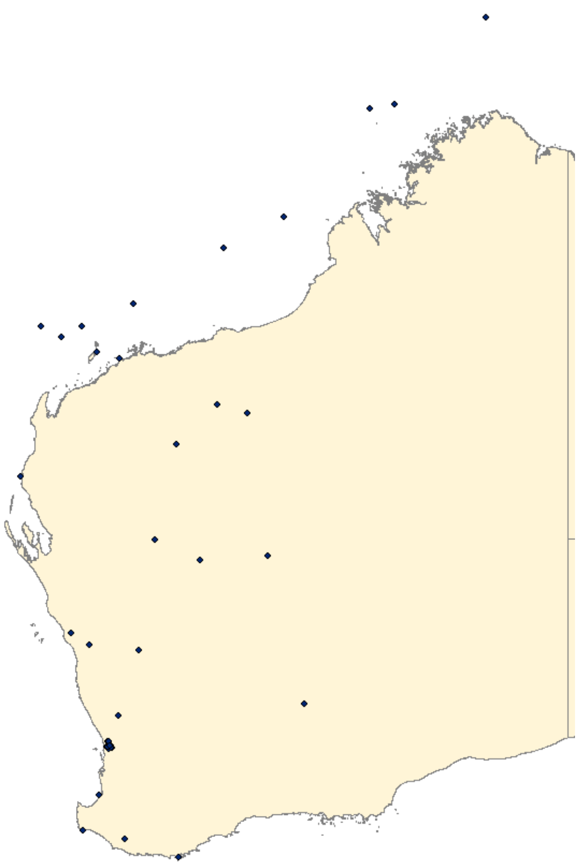
Each major existing space receive site (satellite, space research and radio astronomy) will be examined on a state-by-state basis outlining the factors affecting their longevity. In this section we will only explore significant sites or sites where long-term viability may be an issue.

A full list of apparatus-licensed Earth stations appears at Appendix B. This list is not exhaustive and does not contain those held in the ACMA's register of security-classified services.

This section explores the salient issues at each site with some band analysis and then discusses issues with the site's future.

5.1 Western Australia

Figure 5.1 Map of licensed Earth stations in WA



Satellite Earth station deployments in WA are extensive. However, as shown in Figure 5.1, most are located in areas where population will not be a significant threat to continued operations. Exceptions to this are Earth stations located in shared bands in and around Perth as discussed below.

5.1.1 Perth International Telecommunications Centre, Landsdale

The Perth ITC is located on Gnangara Road, Landsdale. When the facility was first established as a HF transmission facility for the Overseas Telecommunications Commission (OTC), it was far from the centre of Perth, which was in those days a small city. Population had not then spread to the northern beaches of Perth.

Perth now is a rapidly growing city and this facility is surrounded by housing and industrial development on all sides. As a result, the noise floor has grown and OOB interference has become a serious issue.

In addition, many of the bands used at the site are needed for other services such as ENG.

S-band operation

Space operations communications functions at the Perth ITC are carried out in S-band with the frequencies 2025–2120 MHz used for Earth-to-space communication and 2200–2300 MHz used for space-to-Earth communications. The European Space Agency (ESA) and Japan Aerospace Exploration Agency (JAXA) both make significant use of these bands to support their space communications activities. The operation of their facilities has caused significant levels of spectrum denial to other radiocommunications for many years. In recent years, the demand for other radiocommunications, including wireless broadband, has developed to the extent that these operations are no longer viable. Considering this, ESA has agreed to relocate its S-band services to another location by the end of 2015 and JAXA is also aware of ACMA's intention to relocate existing S-band services from the site.

These bands are shared with the FS. Immediately above that are the spectrum-licensed WiMax bands and above that the current 2.5 GHz ENG band, which is being auctioned for mobile broadband. Given the high value of the 2.5 GHz band to the community, ENG will largely be relocated from that band to the 2 GHz FS bands. As stated above, these are also the bands used at Perth ITC for space operations.

Given the nomadic nature of ENG and the flat terrain between Perth and the ITC, there are no opportunities for sharing. The Perth ITC has been advised that it must discontinue operations in these bands by the end of 2015.

C-band operation

C-band is partitioned into two bands. The first—'Extended C'—covers 3400–3600 MHz, where the FSS is secondary in Australia. Secondary services receive no protection from primary services in the band, in this case the FS. Radiolocation also has an allocation in this band; however, its operation is restricted to offshore radars.

The band is also suitable for wireless broadband, both fixed and mobile, and most of it has been spectrum-licensed. The segments 3425–3442.5/3475–3492.5 MHz in metropolitan areas and 3442.5–3475/3542.5–3575 MHz in metropolitan and regional areas were auctioned during the spectrum licence process in 2000. Thus, FSS operations in this band are not supported.

The second part of C-band is 3600–4200 MHz. Parts of this band have recently been released for broadband wireless access (3575–3700 MHz) and there are restrictions on spectrum availability for space services. The ACMA has determined some potential for interference, and mitigation measures through the use of receiver filters, in Earth station receivers from these adjacent band broadband services. This is also discussed in section 3.2.

The band 3700–4200 MHz is not currently under formal consideration for mobile broadband services. However, the band is suited to this application and caution is advised when establishing new stations or expanding existing ones close to populated areas.

Summary

The Perth ITC is now located within the suburbs of a rapidly growing city. This facility is significant in size. Careful analysis is needed to balance the value of the facility with community needs in the CBD for other radiocommunications services.

Operations above 3700 MHz may be supportable in the medium term, noting the abovementioned matter of receiver filters to mitigate potential adjacent band interference; however, at lower frequencies continued operation is already under threat. S-band operations will be required to cease by the end of 2015.

5.1.2 Lockridge

This is an Optus site located at Altone Rd, Lockridge (near Perth). Only standard C-band operations at this site, above 3700 MHz, are of medium-term interest.

The band 3700–4200 MHz is not currently under formal consideration for mobile broadband services. However, the band is suited to this application and caution is advised when establishing new stations or expanding existing ones close to populated areas.

5.1.3 New Norcia

New Norcia is an ESA site approximately 110 km north-east of Perth. The site has moderate terrain protection between it and Perth. However, there has been a gradual increase in population in the area around New Norcia as Perth has expanded. While some 2 GHz legacy use of the facility is being supported, its viability in S-band is short term.

S-band operation

As for the Perth ITC, ENG in 2.5 GHz will be relocated to the 2 GHz FS bands. These are also the bands used at New Norcia for space operations and ESA wish to relocate additional space operations from Perth ITC to this facility.

Given the nomadic nature of ENG and the moderate to hilly terrain between Perth and New Norcia, there are some opportunities for sharing. However, ENG is nomadic and often operated by inexperienced personnel. The possibility of unintentional interference from untrained operation or anomalous propagation from the Perth CBD is real.

ESA have stated they will relocate 2 GHz systems from the Perth ITC. The ACMA believes that if this involves substantial hardware relocation then the systems should move to within the Mingenew zone, or another suitable location, to achieve more assured protection in the long term.

The ACMA has been working with ENG operators and ESA on the New Norcia facility; however, until the outcome of the impending 2.5 GHz auction is known, it is not possible to fully define sharing between ENG and New Norcia.

5.1.4 NewSat Networks Bayswater

This facility operates in L-band (MSS) and C-band.

L-band is currently under scrutiny for IMT services, meaning the future of this facility in this band cannot be guaranteed. Considering the comments in the band-by-band analysis, it would appear that the viability of Earth station operation at this site in this band is in doubt and raises issues of certainty of tenure. The ACMA will potentially need to make decisions on this matter in the future.

Standard C-band is 3600–4200 MHz. Parts of this band have recently been released for broadband wireless access (3575–3700 MHz) and no further assignments to space services will be made except in exceptional circumstances. Continued operation in this part of the band cannot be supported in the long term near areas of high population. Considering the comments in the band-by-band analysis, it would appear that the viability of Earth station operation at this site in this band is in doubt and raises issues of certainty of tenure. The ACMA will potentially need to make decisions on this matter in the future.

The band 3700–4200 MHz is not currently under formal consideration for mobile broadband services. However, the band is suited to this application and caution is advised when establishing new stations or expanding existing facilities close to populated areas.

5.1.5 Australian Defence Satellite Communications Station (ADSCS), Geraldton

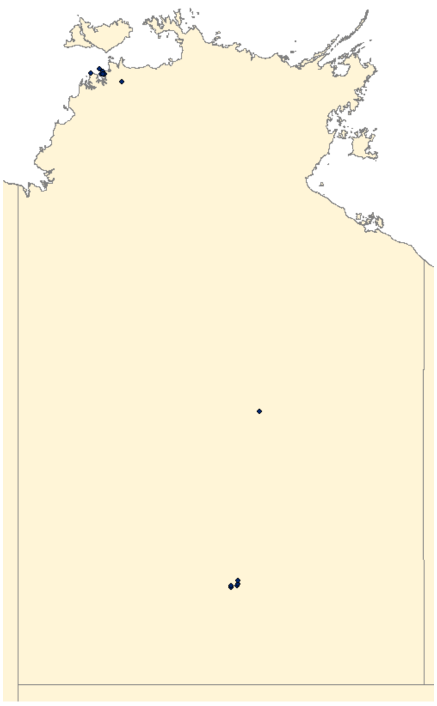
This site operates in multiple bands and lies within the Mingenew zone, thus affording it long-term protection for current and future operations.

5.1.6 ASKAP, Boolardy Station

The Australian Square Kilometre Array Pathfinder (ASKAP) and Australian proposed SKA radio telescopes lie within the Midwest RQZ and are afforded protection.

5.2 Northern Territory

Figure 5.2 Map of licensed Earth stations in the NT



As is the case with WA, while there are a number of facilities deployed (see Figure 5.2), the low population density of the NT means that the facilities that cause major concern are located in and around Darwin.

5.2.1 Shoal Bay Receiving Station (SBRS), Darwin

The Defence Shoal Bay Receiving Station lies to the east of Darwin city. The facility was originally established as a HF receiving facility; however, it now carries out space communication functions in various bands including C-band. Recent urban encroachment has seen suburbs developed close to these facilities, which will impact both on the noise floor and increase demand for mobile services

The Australian Bureau of Statistics has released the following comment on Darwin's population:

> *The population of Darwin Statistical Division (which includes Darwin City, Palmerston-East Arm and Litchfield) is projected to increase from 103,500 in 1999 to between 126,500 and 184,500 by 2021, according to a series of projections just released by the Australian Bureau of Statistics.*

C-band is partitioned into two bands. First is Extended-C-band, which covers 3400–3600 MHz where the FSS is secondary in Australia. For the reasons stated in the previous section on the Perth ITC, FSS operations in Extended C-band are not supported.

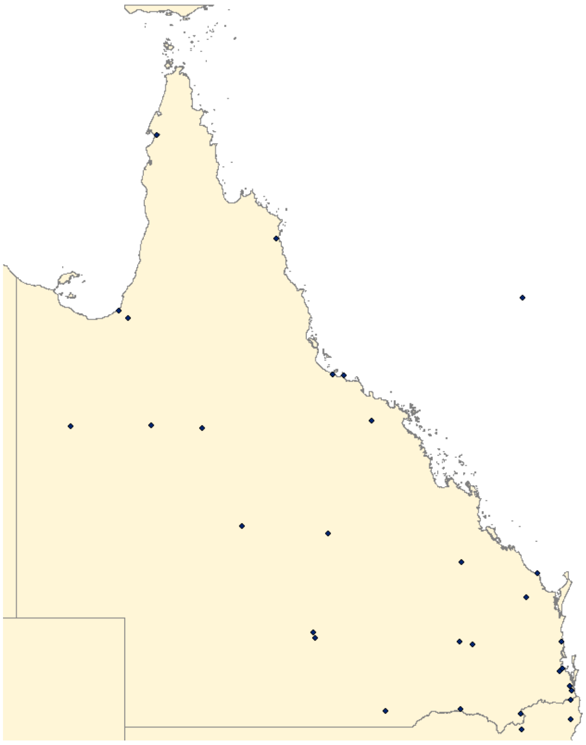
The second part of C-band is 3600–4200 MHz. Parts of this band have recently been released for broadband wireless access (3575–3700 MHz) and no further assignments to space services will be made, except in exceptional circumstances. Continued operation in this part of the band cannot be supported in the long term near areas of high population.

The band 3700–4200 MHz is not currently under formal consideration for mobile broadband services. However, the band is suited to this application and caution is advised when establishing new stations or expanding existing ones close to populated areas.

Darwin's population of 125,000 to 185,000 with its significant rural communities will need access to various wireless broadband products over time. The viability of this facility cannot be guaranteed in the medium term and no further expansion should be contemplated.

5.3 Queensland

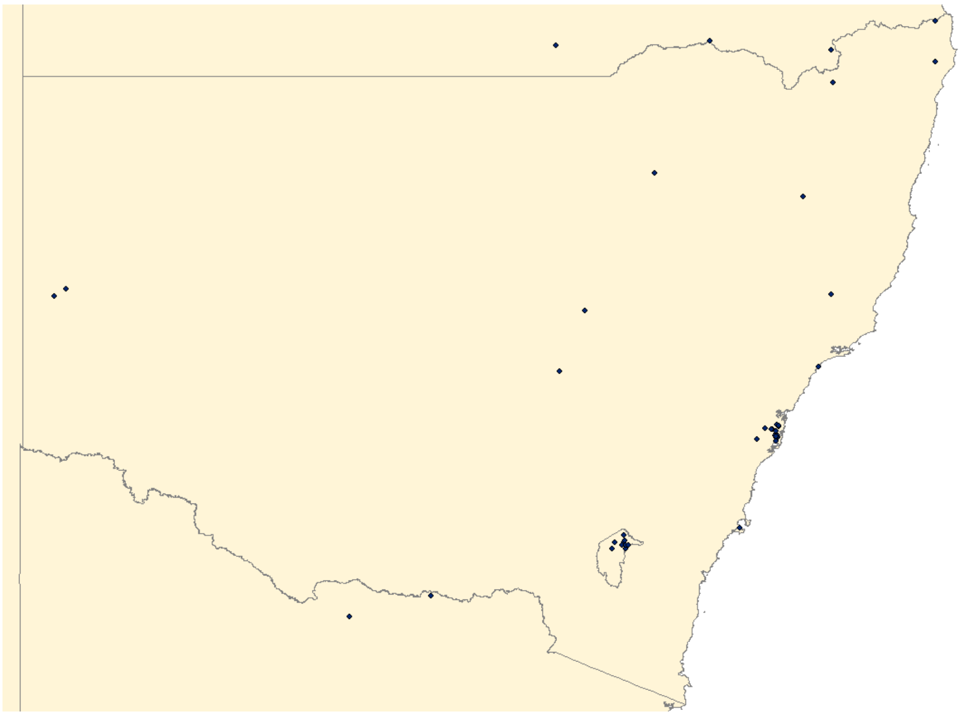
Figure 3 Map of licensed Earth stations in Qld



No significant Earth station facilities are located in Queensland. Earth stations, including Earth receive stations in frequency bands of concern, are located in areas of low population where population growth is not expected to impact on their viability.

5.4 New South Wales and ACT

Figure 5.4 Map of licensed Earth stations in NSW



Major Earth stations of concern in NSW are located near the population centres of Sydney and Canberra. Earth stations deployed in regional and remote areas are of less concern in the medium to long term unless they deny spectrum to significant population centres.

5.4.1 HMAS Harman

This site operates in the 3700 MHz band. The band 3700–4200 MHz is not currently under consideration for broadband wireless access; however, the band is suited to this application and caution is advised when establishing new stations or expanding existing ones close to populated areas.

Other bands can be accommodated in the short term while the Department of Defence establishes a permanent station away from highly populated areas.

5.4.2 Canberra Deep Space Communications Complex, Tidbinbilla

This facility lies to the west of Canberra inside a national park and with significant terrain shielding towards Canberra city. However, the facility operates in S-band, which, as previously explained, will be used for ENG relocation.

In addition, the station enjoys protection via a significant guard band above 2300 MHz. The ACMA may wish to explore technical and economic tools to improve how efficiently this spectrum is used.

Operations in S-band are of interest to the ACMA due to proximity to a large city, albeit mitigated by terrain.

5.4.3 Optus Belrose

This is Optus's main gateway located adjacent to Garigal National Park in Sydney's east. The facility operates in most standard FSS communication bands, including Standard C-band.

Standard C-band is 3600–4200 MHz. Parts of this band have recently been released for broadband wireless access (3575–3700 MHz) and no further assignments to space services will be made except in exceptional circumstances. Continued operation in this part of the band cannot be supported in the long term near areas of high population.

The band 3700–4200 MHz is not currently under formal consideration for mobile broadband services. However, the band is suited to this application and caution is advised when establishing new stations or expanding existing ones close to populated areas.

This facility is significant in size and, while situated close to the Sydney CBD, has some terrain shielding. Careful analysis would be needed to balance the value of the facility with community needs in the CBD for wireless services.

5.4.4 Numerous C-band receive sites around the Sydney CBD

There are numerous small C-band receive sites within Sydney.

Standard C-band is 3600–4200 MHz. Parts of this band have recently been released for broadband wireless access (3575–3700 MHz) and no further assignments to space services will be made except in exceptional circumstances. Continued operation in this part of the band cannot be supported in the long term near areas of high population.

The band 3700–4200 MHz is not currently under consideration for broadband wireless access; however, the band is suited to this application and caution is advised when establishing new stations or expanding existing ones close to populated areas.

These sites are mostly used to receive broadcast programming and do not necessarily need to be within the CBD. As pressure for wireless services increases, the viability of these facilities will need to be explored.

5.5 South Australia

Figure 5.5 Map of licensed Earth stations in SA

Deployments of satellite Earth stations in SA are limited. Facilities of concern are located in and around Adelaide.

5.5.1 NewSat Networks, Mawson Lakes

This facility is located close to the Adelaide CBD and operates in C-band, among others.

Standard C-band is 3600–4200 MHz. Parts of this band have recently been released for broadband wireless access (3575–3700 MHz) and no further assignments to space services will be made except in exceptional circumstances. Continued operation in this part of the band cannot be supported in the long term near areas of high population.

The band 3700–4200 MHz is not currently under formal consideration for mobile broadband services; however, the band is suited to this application and caution is advised when establishing new stations or expanding existing ones close to populated areas.

5.6 Victoria

Figure 5.5 Map of licensed Earth stations in Vic. and Tas.

No significant facilities appear on the ACMA register in Victoria.

5.7 Tasmania

There are no significant facilities beyond the radio astronomy facilities already described.

5.8 Summary

This chapter has commented on spectrum usage of some of the more significant facilities providing communications with space stations. The growing demand for spectrum for radiocommunications, including new technologies and wireless broadband growth, is such that their use of shared frequency bands in proximity to significant areas of population is problematic. It is clear that this trend will not abate and will continue to place pressure on spectrum shared with space communications facilities.

Future certainty of access to this spectrum for Earth stations near areas of population will continue to be compromised. Certainty will need to be obtained through other means, including proposals presented in the next chapter.

12. The ACMA seeks comment on issues raised in the site-by-site analysis. Do you agree with the analysis? Why or why not?

6. Potential future strategies for Earth station siting

The ACMA is committed to developing a long-term strategy for the sustainable siting of Earth stations and other space communications facilities. The aim of this strategy is to release pressures on satellite Earth stations and other space communications facilities while meeting the needs of these facilities into the future and providing long-term planning certainty.

The ACMA has identified two approaches that could be included in the overall Earth station siting strategy—the increased use of satellite parks and improved methods for implementing guard bands for satellite services. The ACMA has not decided on the implementation, or otherwise, of these proposed approaches. The ACMA is seeking feedback on these or any other approaches that could be included in a future Earth station siting strategy.

6.1 Increased use of satellite parks

Satellite parks are a tool that the ACMA and industry can jointly use to preserve the long-term security of the satellite industry while enabling spectrum in more populous areas to reach its highest value use. This approach involves identifying an area where regulatory measures can be implemented to protect the operation of the satellite and space sectors. It uses a combination of the tools discussed in Chapter 3, often involving geographic separation from populated areas and the use of terrain protection if available.

With the expansion of optical fibre networks throughout Australia there is no longer a concrete need to establish Earth stations within capital cities. Locating Earth stations away from capital cities in areas of low population density enables the ACMA to protect an area around these sites. While the ACMA has not yet made a decision on the future of the satellite park concept, it is interested in exploring the concept further.

13. The ACMA seeks comment on the concept of satellite parks. Do you support this concept? Why or why not?

6.1.1 The Mingenew Satellite Park

The ACMA recognised the value of locating Earth stations in areas of low population density and established a 'special zone' around Mingenew in WA. This zone was established in order to preserve options for the future deployment of space communications facilities and is protected in all space bands by Embargo 49.[18]

The creation of this zone follows on from the creation of an adjacent zone around Geraldton. The Geraldton zone was put in place to preserve options for Department of Defence systems both planned and unplanned at a facility east of Geraldton and is protected in its bands of operation by Embargo 47.[19]

The two embargoes have the complementary effect of preserving a large area for the provision of space radiocommunications services. The ACMA is currently considering whether to give this zone stronger legislative protection via a band plan.

[18] See www.acma.gov.au/webwr/radcomm/frequency_planning/spectrum_embargoes/embargo_49.pdf.

[19] See www.acma.gov.au/webwr/radcomm/frequency_planning/spectrum_embargoes/embargo47.pdf.

The Mingenew Satellite Park has been used by the space and satellite industries and the ACMA will continue to support this usage into the future. The ACMA is seeking comment on current and future usage of this satellite park. Specifically, comment is sought on the effectiveness of the Mingenew Satellite Park and the effectiveness of current regulatory measures.

14. The ACMA seeks comment on the usage and effectiveness of the Mingenew Satellite Park. Are the current regulatory arrangements effective?

15. The ACMA seeks comment on the potential to implement a band plan to provide stronger legislative protection to the Mingenew Satellite Park.

6.1.2 Potential east coast satellite park

There is the potential to identify an area or areas on the east coast of Australia within which some or all space receive bands could be protected and transmit bands managed. However, to date industry have not embraced the concept.

The Department of Defence is in the process of establishing a facility near Wagga Wagga in NSW and this site is offered protection in its bands of operation through Embargo 59.[20] However, this is a population centre of 50,000 and careful consideration would need to be given to the wireless data needs of this community before protection of additional satellite bands in the region could be considered.

However, given the pressure on spectrum balanced with the service that satellite gateways provide and Australia's diverse geography, the ACMA remains interested in pursuing the issue if industry feels it is warranted. Such a zone could potentially share the increased protection as per the Mingenew special zone.

16. The ACMA seeks comment on all issues surrounding the development and establishment of an east coast satellite park, particularly on what factors would be necessary to make it an attractive option for Earth station location.

6.1.3 Issues to consider when establishing a special satellite communications zone

This paper has briefly explored population trigger points below which the ACMA feels that wireless data needs can be met in bands other than those shared with space services. This trigger was set at an area where other services would be denied to a population of 25,000 or fewer. Identifying such an area is the first stage for establishing a suitable location.

However, population centres also provide amenities for station staff, so an area as close as possible to a population centre yet protected from it by terrain would be advantageous. Effective 'blocking' terrain should also figure prominently.

Once an area or a number of areas has been identified, the availability of a nearby optical fibre to feed data back to major centres is essential.

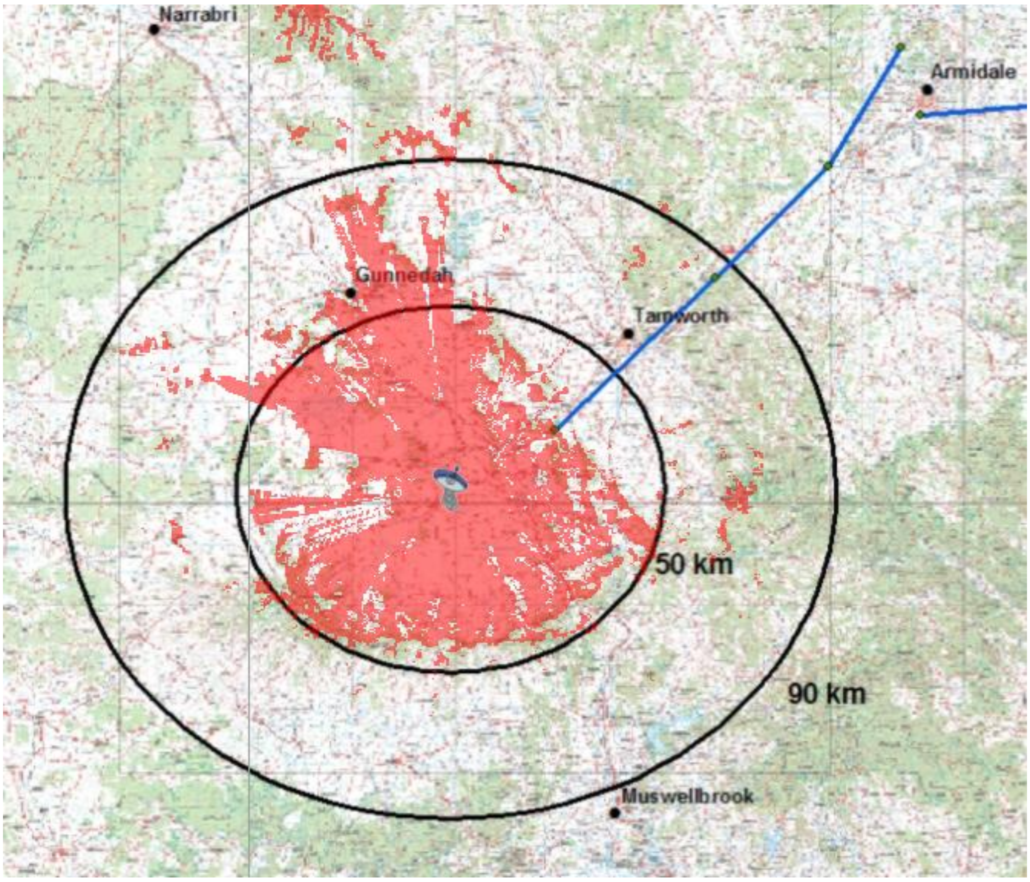
Once the choices have been refined in such a way usual considerations such as planning, environment, power supply and land availability come into play.

[20] See www.acma.gov.au/webwr/radcomm/frequency_planning/spectrum_embargoes/embargo_59.pdf.

6.1.4 An example of a potentially suitable area

Figure 6.1 shows an area in the central west of NSW that, from a population and terrain perspective, would be suitable for a satellite park on the east coast.

Figure 6.1 Spectral denial of site near Quirindi, NSW, in C-band



Regulatory support for such special zones includes mechanisms to provide assurance of spectrum availability and use into the future. A necessary requirement for assurance of spectrum availability involves restrictions on the establishment of other radiocommunications within potential interference distances using frequency bands allocated to space communications.

The red colouration area of Figure 6.1 portrays necessary restriction areas from terrestrial services to protect the site at C-band. Higher frequencies would require less restriction area whereas lower frequencies would require greater restriction area.

The base of the zone is constrained by a semi-circular ridge at about 50 km, which prevents spill-over towards Sydney and Newcastle and protects the site from emissions emanating from these cities. Thus, the spectral denial of the area is low.

The blue lines are existing in-band fixed links. It is likely that these links could remain as they do not appear to threaten the viability of the site. Nonetheless, relocating a small number of links to alternative bands would be a small price to pay for the certainty such an area would provide.

This site is within an hour of a number of population centres where amenities for workers could be found and is also within two hours of Newcastle.

The site meets all of the spectrum management requirements but unfortunately is in the Liverpool Plains, an area of intense current debate as coal mining companies vie with local farmers for control of the land. It is unlikely that land security in such an area would be viable in the long term, making it unsuitable for the level of investment needed.

Nonetheless, the site is presented as an example of an area that would meet the needs of gateway operators without denying the surrounding population the spectrum needed for delivery of data services.

6.1.5 Summary

The Mingenew Satellite Park has successfully provided options for operators faced with the population growth of Perth and associated implications for spectrum availability. The ACMA remains receptive to the need to establish a similar zone on the east coast and potentially in other areas if justified. However, to date the proposal has met with mild support from some smaller operators and intense opposition from larger ones and the Global VSAT Forum.

Considering the potential uncertainties for the viability of some Earth station locations outlined in this paper, satellite parks give the ACMA another way to provide certainty to the satellite industry consistent with the *Principles for spectrum management*. The release of this paper intends to create a communication channel for discussion on an east coast satellite park that, in addition to the Mingenew zone, would give operators the certainty and flexibility to plan future systems reliably. Submissions to this discussion paper will guide the ACMA in how best it can provide such certainty and flexibility. The ACMA will leave the option of an east coast satellite park open, pending further discussion with industry.

17. The ACMA seeks information on areas that may be potentially suitable for the establishment of an east coast satellite park.

6.2 Future options for guard bands

Guard bands for space services are used to provide sufficient frequency separation between a source of out-of-band interference and the affected satellite receiver in order to ensure that harmful interference is not caused to the satellite receiver or that it is not driven into saturation.

Historically, guard bands have been assigned on a site-by-site or service-by-service basis; however, with increasing congestion and demand for the radiofrequency spectrum, this approach becomes less viable both practically and economically. Unused spectrum that is not charged for gives no incentive for other methods of interference mitigation to be used and little incentive for it to be moved to its highest value use.

6.2.1 Maximum guard band width

The ACMA is investigating an approach to assigning guard bands whereby a maximum guard band of a preliminary size of 10 MHz or, for ACMA-planned bands, one adjacent channel width, whichever is smaller, will be provided to a site or Earth station. If protection is required beyond this guard band, then the satellite Earth station operator may choose to license the extra guard band, subject to an appropriate licensing fee.

This approach will encourage operators to use alternative methods of interference mitigation such as filtering, alternative siting or relocation. In cases where other interference mitigation techniques are not appropriate or practical, this method will ensure that the spectrum that is being denied imposes a smaller burden on overall spectrum utilisation and efficiency.

It is noted, however, that this approach is presented purely for information purposes as an option that could be employed to improve spectrum utilisation and is considered preliminary in its development. Development of this and other options is subject to further studies and consultation with industry.

6.2.2 Technical basis

The 10 MHz, or nearest adjacent channel guard band width, was chosen based on studies conducted by the ACMA. It aligns with the decisions made in the recent revisions to *RALI FX 19 Frequency Coordination and Licensing Procedures for Apparatus Licensed Broadband Wireless Access Services in the 1900–1920, 2010–2025 and the3575–3700 MHz Bands* on Earth station coordination with wireless access services.[21] It was chosen based on what was deemed to be an acceptable balance between the cost of spectrum denied and the costs of other interference management techniques. The parameters from FX 19 were themselves based on worst-case parameters and may be conservative in many cases.

The following outlines a study in the 3.8 GHz band supporting the proposed 10 MHz or nearest adjacent channel guard band width proposal.

Assuming a 10 MHz spectral guard band and, for the case of C-band, a 20 km exclusion zone, the cases of out-of-band interference into the pass band of the receiver and receiver overload must be considered.

The parameters for the base, remote and mobile stations are taken from RALI FX 19 and are shown in Table 6.2 to Table 6.4. The FSS Earth station parameters are taken from ITU studies and recommendations, and are shown in Table 6.1. In most cases, these parameters are worst-case values; typical values may be different. For example C-band Earth stations typically operate with an elevation greater than 20 degrees.

Table 6.1 FSS Earth station parameters

Parameter	Value	Unit	Reference
Reference bandwidth	1	MHz	RALI FX 19
Frequency	3700	MHz	RALI FX 19
Minimum elevation angle	5	Degrees	ITU-R Report S.2199
Antenna reference pattern	ITU S.465-5		ITU-R Report S.2199
Horizon antenna gain	14.5	dB	Calculation
Feeder losses	0	dB	ITU-R Report S.2199
Long-term interference threshold	–130.1	dBm/MHz	ITU-R Report S.2199
Onset of non-linear operations	–65	dBm	RALI FX 19
System noise figure	70	°K	RALI FX 19

[21] See www.acma.gov.au/WEB/STANDARD/pc=PC_2972.

Table 6.2 BWA base station parameters

Parameter	Value	Unit	Reference
Channel bandwidth	20	MHz	RALI FX 19
Frequency	3700	MHz	RALI FX 19
EIRP	43	dBm/20MHz	RALI FX 19
Antenna gain	19	dB	RALI FX 19
Front to back ratio	30	dB	RALI FX 19
Max. allowable EIRP PSD 3670–3700 MHz	30	dBm/MHz	RALI FX 19
Net filter discrimination between WAS BS and FSS ES	GB >10 MHz =55	dBc	RALI FX 19

Table 6.3 BWA remote station parameters

Parameter	Value	Unit	Reference
Channel bandwidth	20	MHz	RALI FX 19
Frequency	3700	MHz	RALI FX 19
EIRP	43	dBm/20MHz	RALI FX 19
Antenna gain	17	dBi	RALI FX 19
Antenna pattern	ITU-R F.1245		RALI FX 19
Front to back ratio	25	dB	RALI FX 19
Max. allowable EIRP PSD 3670–3700 MHz	30	dBm/MHz	RALI FX 19
Emission mask	ETSI 302 326-2		RALI FX 19
OOB emission level at channel edge + 10 MHz	29.5	dBc	ETSI 302 326-2
Number of interferers	10		ITU-R Report M.2116-1

Table 6.4 BWA mobile station parameters

Parameter	Value	Unit	Reference
Channel bandwidth	20	MHz	RALI FX 19
Frequency	3700	MHz	RALI FX 19
EIRP	30	dBm/20MHz	RALI FX 19
Antenna gain	5	dBi	RALI FX 19
Antenna pattern	0		RALI FX 19
Front to back ratio	25	dB	RALI FX 19
Max. allowable EIRP PSD 3670–3700 MHz	20	dBm/MHz	RALI FX 19
Emission mask	ETSI 302 326-2		RALI FX 19
OOB emission level at channel edge + 10 MHz	29.5	dBc	ETSI 302 326-2
Number of interferers	10		ITU-R Report M.2116-1

Scenarios

In conducting an assessment of the potential for interference, three scenarios are analysed in order to cover the breadth of interference cases:

> BWA station and FSS Earth station with maximum gain towards each other

> BWA with maximum gain towards an FSS Earth station that has minimum gain towards the BWA station

> FSS Earth station with maximum gain towards the BWA station that has minimum gain towards the FSS Earth station.

Receiver overload

Receiver overload or saturation occurs when the input power to the antenna low noise block converter (LNB) or low noise amplifier (LNA) is of sufficient strength to drive the device into a non-linear mode of operation. This occurs when satellite receivers are employed that are designed to cover the whole of standard or standard plus extended C-band because BWA overlaps directly with all of extended C-band and the portion 3600–3700 of C-band. Receiver overload can be mitigated by filtering in front of the LNB or LNA. Band pass or notch filtering can be used based on the nature of the interfering BWA signals. For these studies a band pass filter is assumed.

Therefore, the interference power required to overload the receiver is given by:

$$I_{Overload}(dBm) = EIRP + 10log10(interferers) + G_R - PL(d) - L_{Filter}$$

Where EIRP = effectively isotropically-radiated power (EIRP) of interferer
G_R = Gain of Earth station antenna in the direction of the interferer
PL(d) = Path loss
L_{Filter} = Additional loss provided by Earth station filter.

From ITU studies and input from Australian satellite industry stakeholders, the threshold for the onset of non-linear operations is set at –65 dBm.

Base station

Table 6.5 shows the separation distances required to avoid receiver overload for each scenario outlined above for the case of a base station.

The worst-case scenario for this situation would involve a 20 MHz BWA base station centred on 3680 MHz transmitting at full power in the direction of the FSS antenna on axis.

At the 20 km boundary, no additional filtering is needed to protect the FSS receiver.

Table 6.5 Separation distances required to avoid receiver overload for each scenario (Base station)

Scenario	Separation distance required
1	8.64 km
2	0.51 km
3	0.27 km

Remote station

Table 6.6 shows the separation distances required to avoid receiver overload for each scenario for the case of a remote station.

To account for the worst case for receiver overload, 10 remote stations—as per ITU-R Report M.2116-1—are assumed, all with maximum gain towards the FSS receiver.

At the 20 km boundary, additional losses of 2.7 dB are needed to protect the FSS receiver in the worst case of both antennas operating with maximum gain towards each other. Using data from commercially available filter types, this is able to be achieved with a band pass filter or notch filter. It is noted, however, that this case is extremely unlikely and that an increase in antenna elevation or the remote stations being off axis by as little as two degrees will result in a required separation distance of less than 20 km.

Table 6.6 Separation distances required to avoid receiver overload for each scenario (remote station)

Scenario	Separation distance required
1	27.37 km
2	1.63 km
3	1.54 km

Mobile station
Table 2.1 shows the separation distances required to avoid receiver overload for each scenario for the case of a mobile station.

Mobile or subscriber stations are assumed to have nominally omnidirectional antennas. As with the remote station scenario, 10 interferers are assumed.

At the 20 km boundary, no additional filtering is needed to protect the FSS receiver.

Table 6.7 Separation distances required to avoid receiver overload for each scenario (mobile station)

Scenario	Separation distance required
1	6.12 km
2	0.36 km
3	6.12 km

The 10 MHz/20 km guard band is therefore feasible to protect the FSS from receiver overload, provided filtering is employed or the receiver is designed to only operate over standard C-band in the range 3700–4200 MHz. In most cases, the antenna will have an elevation of greater than seven degrees and in these cases filtering is not required. Base stations could be allowed to deploy to this limit provided that coordination can be achieved with the FSS Earth station. The ACMA expects licensees to take appropriate measures to mitigate overload interference from adjacent band sources.

Adjacent channel interference
Assuming the presence of filtering in order to sufficiently reject out-of-band emissions, the main limiting factor in developing the approach to guard bands will be adjacent channel interference into the pass band of the satellite receiver. To characterise this, a simulation was conducted as follows.

Given that the guard band is defined as the range from the top edge of the interfering service to the lower edge of the FSS service, the worst-case scenario for interference would involve a 20 MHz channel centred on 3680 MHz.

Using the out-of-band emission mask for BWA stations specified in ETSI 302 306-2, we see that for a 20 MHz channel size, the net filter discrimination (NFD) can be assumed to be 29.5 dB. This assumes that the emission mask of the BWA station dominates the NFD calculation here. The interference level is then given by:

$$I\ (dBm/MHz) = EIRP_{PSD} - NFD + G_R - PL(d)$$

Where $EIRP_{PSD}$ = Power spectral density (PSD) of interferer
NFD = Net filter discrimination
G_R = Gain of Earth station antenna in the direction of the interferer
PL(d) = Path loss.

Base station
Table 6.8 shows the separation distances required to avoid adjacent channel interference for each scenario for the case of a base station.

In addition to complying with spectrum masks defined in ETSI EN 302 326, the base station transmitter must comply with the block edge mask defined in RALI FX 19. This block edge mask ensures that, even in the worst-case scenario of maximum gain between the two antennas, the separation distance of 20 km will be sufficient to protect the FSS Earth station.

Table 6.8 Separation distances required to avoid adjacent channel interference for each scenario (base station)

Scenario	Separation distance required
1	6.17 km
2	0.36 km
3	0.19 km

Remote station
Table 6.9 shows the separation distances required to avoid adjacent channel interference for each scenario for the case of a remote station.

The remote station represents the worst case for interference as it does not have to comply with the band edge mask as does the base station, yet is able to operate at the same EIRP PSD as the base station in the range 3670–3700 MHz.

There is the potential for remote stations to cause harmful interference to licensed FSS Earth stations beyond the 20 km zone in certain cases. As remote stations operate on a ‘no-interference, no-protection’ basis, it will remain up to operators to coordinate their own remote stations to avoid the worst-case interference scenarios as locations of Earth stations are known. In many cases, the equipment will not operate at the limits set in RALI FX 19 so this method is suitable.

The worst case assumes free space loss only; if a path loss exponent of 3.2 is used, as is typical with suburban deployments, then the required separation distance reduces to 19.38 km. Given the above, the 10 MHz/20 km guard band is sufficient to protect the FSS as it is relatively unlikely that one or more of the remote stations (operating greater than 20 km from the BS) will be pointing directly at the main lobe of an FSS antenna operating at five degrees elevation with line of sight. In the event interference does occur, remote stations are operated under a 'no-interference, no-protection' basis; therefore, the BWA operator is required to take action to remedy this.

Table 6.9 Separation distances required to avoid adjacent channel interference for each scenario (remote station)

Scenario	Separation distance required
1	114.76 km (19.38 km γ=3.2)
2	6.82 km
3	6.45 km

Mobile station
Table 6.10 shows the separation distances required to avoid adjacent channel interference for each scenario for the case of a mobile station.

Mobile stations also operate on a no interference, no protection basis; however, with the out-of-band mask of ETSI 302 326-2, the maximum separation distance required is 6.45km. In this calculation, clutter losses were assumed.

The studies show that a guard band width of 10 MHz with a 20 km separation distance is sufficient to protect FSS terminals operating in standard C-band from adjacent channel interference from deployed and planned BWA scenarios.

Table 6.10 Separation distances required to avoid adjacent channel interference for each scenario (mobile station)

Scenario	Separation distance required
1	6.45 km
2	0.38 km
3	6.45 km

The outcome for the 3.8 GHz band is presented here; however, the ACMA intends to explore the concept of 10 MHz or one adjacent channel guard band across all satellite bands with differing separation distances based on the respective operating parameters of each service involved.

6.2.3 Summary

The definition of a maximum guard band width is a possible way to improve the overall efficiency of spectrum use by space services while still affording sites an acceptable level of protection. As justified in the technical analysis above, the ACMA is proposing to implement a maximum guard band of 10 MHz or, for ACMA-planned bands, one adjacent channel width, whichever is smaller. This would be paired with geographic exclusion zones that will vary depending on the frequency band of operation. For C-band, an exclusion zone of 20 kilometres is proposed. Smaller exclusion zones would be used in higher frequency bands. The ACMA is seeking comment on this proposal. This and other options may continue to be investigated by the ACMA in the future.

18. The ACMA seeks comment on the concept of defining a maximum guard band width for space services—both on the technical and policy basis for the development of this option and the proposed figures of 10 MHz or one adjacent channel width, whichever is smaller. Comment is also sought on the implementation of geographic exclusion zones and the proposal for a 20 km exclusion zone for C-band Earth receive stations.

6.3 Conclusion

In this chapter, two approaches have been identified that could be included in the overall Earth station siting strategy. The increased use of satellite parks and improved methods for implementing guard bands for satellite services could be used to provide certainty for satellite and space operations while also improving overall spectrum utility, particularly in bands shared with terrestrial services.

The ACMA remains open to suggestions from industry on other measures that could be included in a long-term strategy for the sustainable siting of satellite Earth stations and other space communications facilities.

19. The ACMA also seeks suggestions and information on other incentives that could potentially be offered to encourage the siting of Earth stations in areas of low population density.

7. Summary

This paper is intended to formally open discussion on issues related to the siting of satellite Earth stations. Comment is sought on the issues raised in this paper. Additionally, the ACMA is giving stakeholders the opportunity to outline other relevant issues related to Earth station siting that have not been considered in this discussion paper.

20. The ACMA seeks comment on any other issues regarding Earth station and space communication facility siting that should be considered.

21. The ACMA invites suggestions for alternative approaches to achieving greater opportunities for both terrestrial and space services to achieve their highest value use.

Submissions to this paper will be used to guide the development of an Earth station siting policy. Further discussion papers will be released at a later date outlining responses to stakeholder feedback and seeking comment on intended directions and options.

7.1 Issues for comment

The list below is a summary of questions raised in this paper.

1. The ACMA seeks comment on the proposed objectives for the development of a long-term sustainable strategy for the siting of satellite Earth stations and other space communications facilities.
2. The ACMA seeks stakeholder comment on any additional pressures that should be considered in the context of Earth station siting.
3. The ACMA seeks comment on areas of growth in the satellite industry. Where is the biggest growth expected? Are there any emerging applications for satellite services that are expected to impact spectrum requirements?
4. The ACMA seeks comment on the methodology used to establish a benchmark population level below which Earth station operation would be reasonably secure in the long term.
5. The ACMA seeks stakeholder comment on any additional categories of tools that could be used to address the various pressures on spectrum used by the satellite and space sectors.
6. The ACMA seeks comment on using opportunity-cost pricing of spectrum for satellite Earth station licensing based on spectrum denial caused to terrestrial services.
7. The ACMA seeks information on any additional planning and technical tools that could be used to manage interference into satellite Earth stations and other space communications facilities.
8. The ACMA seeks comment on the use of filtering in Earth receive stations and its applicability and usage in interference mitigation.
9. The ACMA seeks comment on alternative methods of interference management should guard bands be reviewed in the future.
10. The ACMA seeks comment on all matters related to site interference protection.
11. The ACMA seeks comment on issues raised in the band-by-band analysis chapter, particularly comments on specific frequency bands. Do you agree with the analysis? Why or why not?
12. The ACMA seeks comment on issues raised in the site-by-site analysis. Do you agree with the analysis? Why or why not?
13. The ACMA seeks comment on the concept of satellite parks.
14. The ACMA seeks comment on the usage and effectiveness of the Mingenew Satellite Park. Are the current regulatory arrangements effective?

15. The ACMA seeks comment on the potential to implement a band plan to provide stronger legislative protection to the Mingenew Satellite Park.
16. The ACMA seeks comment on all issues surrounding the development and establishment of an east coast satellite park, particularly on what factors would be necessary to make it an attractive option for Earth station location.
17. The ACMA seeks information on areas that may be potentially suitable for the establishment of an east coast satellite park.
18. The ACMA seeks comment on the concept of defining a maximum guard band width for space services—both on the technical and policy basis for the development of this option and the proposed figures of 10 MHz or one adjacent channel width, whichever is smaller. Comment is also sought on the implementation of geographic exclusion zones and the proposal for a 20 km exclusion zone for C-band Earth receive stations.
19. The ACMA also seeks suggestions and information on other incentives that could potentially be offered to encourage the siting of Earth stations in areas of low population density.
20. The ACMA seeks comment on any other issues regarding Earth station and space communication facility siting that should be considered.
21. The ACMA invites suggestions for alternative approaches to achieving greater opportunities for both terrestrial and space services to achieve their highest value use.

Appendix A—Earth stations on the ACMA Register of Radiocommunications Licences

This is a list of all Earth stations on the ACMA’s unclassified register as of 1 April 2011. For each site, the frequencies used are sorted according to whether they may influence the viability of the site in the short or medium term, or if the frequencies used at that site are secure in long-term operation. For sites with multiple assignments in the same band, the frequency range spanning the assignments is given, bearing in mind that the station is not licensed for this whole bandwidth. Frequency ranges may be approximate in some cases.

Site name	Location	Coordinates		Frequencies		
		Lat.	**Long.**	**May influence short-term viability**	**May influence medium-term viability**	**Secure in long term**
HMAS Harman, Bonshaw/Harman	Bonshaw/Harman, ACT	–35.35	149.2	3.732–3.738 GHz (R)	5.957–5.963 GHz (T) 7.266–7.75 GHz (R) 7.9–8.4 GHz (T)	
Russell Offices, Russell	Russell, ACT	–35.30	149.15		7.623–7.626 GHz (R) 7.674–7.675 GHz (R) 7.699–7.6995 GHz (R) 7.917–7.9181 GHz (T) 7.9268–7.9274 GHz (T) 8.250–8.2524 GHz (T/R) 8.347–8.351 GHz (T) 8.3991–8.3995 GHz (T)	
Geoscience Australia, Jerrabomberra Ave	Symonston, ACT	–35.35	149.16		4.0521–4.0525 GHz (R) 6.276–6.2772 GHz (T)	
CDSCC Tidbinbilla	Tidbinbilla, ACT	–35.40	148.98	2.025–2.12 GHz (T) 2.2–2.301 GHz (R) 2.2–2.5 GHz (RA passive)	4.35–6.7 GHz (RA passive) 7.13–7.23 GHz (T) 8.4–8.5 GHz (R)	14.084–14.36 GHz (R) 14.93–15.19 GHz (R) 15.299–15.327 GHz (T) 25.53–26.85 GHz (R) 1.25–1.178 GHz (RA passive) 8–9.2 GHz (RA passive) 16–26 GHz (RA passive) 31.9–32.2 GHz (R) 34.3162–34.3164 GHz (T)
Optus Canberra, 47 Raws Cr, Hume	Hume, ACT	–35.40	149.16			17.3–17.8 GHz (T)
Captains Point, Jervis Bay	Jervis Bay, ACT	–35.15	150.71	3.732–3.738 GHz (R)		5.957–5.963 GHz (T)

Site name	Location	Coordinates		Frequencies		
		Lat.	Long.	May influence short-term viability	May influence medium-term viability	Secure in long term
117 Flemington Rd, Mitchell	Mitchell, ACT	–35.22	149.14		3.999–4.002 GHz (R) 6.224–6.226 GHz (T)	
National Circuit, Barton	Barton, ACT	–35.31	149.13		3.958–3.994 GHz (R)	
47 Culgoa St, Canberra	Canberra, ACT	–35.35	149.11		4.1714–4.1715 GHz (R) 6.39652–6.39657 GHz (T)	
Observatory, Mount Stromlo	Mount Stromlo, ACT	–35.32	149.01		2.0362–2.0363 GHz (T)	401.237–401.262 MHz (T)
Oxford Falls Rd, Belrose	Belrose, NSW	–33.73	151.23	3.62–4.2 GHz (R)	5.9–6.41 GHz (T)	12.23–12.25 GHz (R) 13.98–14 GHz (T) 17.79–17.8 GHz (T)
Oxford Falls Rd, Oxford Falls	Oxford Falls, NSW	–33.73	151.24	3.67–4.2 GHz (R)	5.86–6.42 GHz (T)	
5 Thomas Holt Dr, Macquarie Park	Macquarie Park, NSW	–33.79	151.13	3.74–4.142 GHz (R)		
400 & 700 Harris St, Ultimo	Ultimo, NSW	–33.88	151.2	3.72–3.74 GHz (R) 3.76–3.8 GHz (R)	3.90–3.91 GHz (R) 4.122–4.126 GHz (R)	11.47–11.474 GHz (R) 14.271–14.275 GHz (T)
MLC Centre Martin Place, Sydney	Sydney, NSW	–33.87	151.21	3.752–3.755 GHz (R) 3.758–3.762 GHz (R) 3.786–3.793 GHz (R) 3.819–3.82 GHz (R)	3.924–3.935 GHz (R) 3.946–3.952 GHz (R) 3.978–3.982 GHz (R) 5.974–5.983 GHz (T) 6.154–6.163 GHz (T)	
Robert St, Rozelle	Rozelle, NSW	–33.87	151.18	3.742–3.778 GHz (R)	3.942–4.018 GHz (R) 4.122–4.178 GHz (R)	14.018–14.094 GHz (T) 14.258–14.294 GHz (T)
Sydney University, Sydney	Sydney, NSW	–33.89	151.19		3.958–3.994 GHz (R)	

Site name	Location	Coordinates		Frequencies		
		Lat.	Long.	May influence short-term viability	May influence medium-term viability	Secure in long term
Artamon Rd, Willoughby	Willoughby, NSW	–33.81	151.20	3.777–3.780 GHz (R) 3.884–3.886 GHz (R)	3.903–3.907 GHz (R) 3.912–3.916 GHz (R) 4.018–4.027 GHz (R) 4.061–4.071 GHz (R)	
Pactel Lord St, Botany	Botany, NSW	–33.94	151.19	3.71–3.7105 GHz (R) 3.733–3.734 GHz (R)		11.535–11.536 GHz (R)
Shin Satellite Earth Station	Broken Hill, NSW	–31.98	141.43			18.3–18.675 GHz (R) 19.7–20.2 GHz (R) 29.5–30 GHz (T)
756 Pennant Hills Rd, Carlingford	Carlingford, NSW	–33.77	151.05		3.930–3.931 GHz (R) 3.933–3.934 GHz (R) 6.149–6.155 GHz (T)	
Mosbri Cres, Cooks Hill	Cooks Hill, NSW	–32.93	151.78		6.045–6.063 GHz (T)	10.95–11.004 GHz (R) 13.914–13.95 GHz (T)
Globalstar Gateway Site	Dubbo, NSW	–32.18	148.614		5.09–5.25 GHz (T) 6.875–7.055 GHz (R)	
Dungay Creek Rd, Dungay Creek	Dungay Creek, NSW	–28.26	153.35		6.247–6.256 GHz (T)	
8 Central Ave, Eveleigh	Eveleigh, NSW	–33.90	151.19	3.816–3.834 GHz (R)		
79 Frenchs Forest Rd, Frenchs Forrest	Frenchs Forrest, NSW	–33.75	151.24	3.809–3.818 GHz (R)	6.034–6.043 GHz (T)	
Rebel Media Site Kiaora Lookout	Gloucester, NSW	–31.96	151.95		3.995–3.996 GHz (R)	
Site 1, 742 Ballina Rd, Goonellabah	Goonellabah, NSW	–28.81	153.34			14.051–14.052 GHz (T)
CSIRO Mopra Observatory	Coonabarabran, NSW	–31.27	149.10	2.2–2.5 GHz (RA passive)	4.35–6.7 GHz (RA passive) 8–9.2 GHz (RA passive)	1.25–1.78 GHz (RA passive) 16–26 GHz (RA passive)

Site name	Location	Coordinates		Frequencies		
		Lat.	**Long.**	**May influence short-term viability**	**May influence medium-term viability**	**Secure in long term**
Sydney Cricket Ground, Driver Ave, Moore Park	Moore Park, NSW	–33.89	151.22		6.247–6.265 GHz (T)	
New Tenterfield Council Site, 7 km SW of Tenterfield	Mt Mackenzie, NSW	–29.09	151.97			3.995–3.996 GHz (R)
Paul Wild Observatory, Yarrie Lake Road	Narrabri, NSW	–30.31	149.55	2.69–2.7 GHz (R)		1.4–1.427 GHz (R) 1.61–1.614 GHz (R) 1.66–1.67 GHz (R) 4.825–4.835 GHz (R) 22.21–22.5 GHz (R) 23.6–24 GHz (R) 1.25–1.178 GHz (RA passive) 2.2–2.5 GHz (RA passive) 4.35–6.7 GHz (RA passive) 8–9.2 GHz (RA passive) 16–26 GHz (RA passive)
Cable Station, Ansen Bay Rd	Norfolk Island, NSW	–29.01	167.92			5.918–5.925 GHz (T)

Site name	Location	Coordinates		Frequencies		
		Lat.	Long.	May influence short-term viability	May influence medium-term viability	Secure in long term
Parkes Radio Telescope	Parkes, NSW	–32.99	148.26	2.2–2.5 GHz (RA passive)	4.35–6.7 GHz (RA passive)	1.61–1.614 GHz (R) 1.66–1.67 GHz (R) 2.69–2.7 GHz (R) 22.21–22.5 GHz (R) 23.6–24 GHz (R) 1.25–1.178 GHz (RA passive) 8–9.2 GHz (RA passive) 16-26 GHz (RA passive)
55 Pyrmont Bridge Rd, Pyrmont	Pyrmont, NSW	-33.87	151.19			14.125-14.161 GHz (T)
Seismic Site, 15 km NE of Broken Hill	Stephens Creek Reserve, NSW	-31.88	141.59			4.052-4.053 GHz (R) 6.276-6.278 GHz (T)
Site 1 Big Ridge Road, Uralla	Uralla, NSW	-30.63	151.56	3.4-3.401 GHz (R) 3.696-3.701 GHz (R) 3.846-3.847 GHz (R)	4.199-4.2 GHz (R) 5.925-5.926 GHz (T) 6.142-6.725 GHz (T) 6.723-6.725 GHz (T)	12.244-12.253 GHz (R) 12.747-12.75 GHz (R) 13.9914.002 GHz (T) 14.49–14.5 GHz (T)
48–50 Scrivener Street, Warwick Farm	Warwick Farm, NSW	–33.92	150.93			1.6944–1.6944 GHz (R)
National Measurement Institute, Bradfield Rd, West Lindfield	West Lindfield, NSW	–33.78	151.15			12.38–12.383 GHz (R) 14.13–14.133 GHz (T)
Pruen Road Berrimah, Darwin	Darwin, NT	–12.44	130.92	3.79–3.81 GHz (R)	6.01–6.02 GHz (T)	
CSIRO Site via Alice Springs	Alice Springs, NT	–23.80	133.87	1.529–1.5451 GHz (R) 1.625–1.647 GHz (T) 2.1063–2.1064 GHz (T) 2.287–2.29 GHz (R)		

Site name	Location	Coordinates		Frequencies		
		Lat.	Long.	May influence short-term viability	May influence medium-term viability	Secure in long term
34 Schwarz Cr, Alice Springs	Alice Springs, NT	–23.69	133.88	4.029–4.03 GHz (R) 4.0521–4.0524 GHz (R)	6.251–6.252 GHz (T) 6.276–6.278 GHz (T)	
Lot 4572 Heath Rd, Acres Site, Alice Springs	Alice Springs, NT	–23.76	133.88	2.286–2.289 GHz (R)		1.69–1.7 GHz (R) 8.0–8.4 GHz (R)
Jdsrf Hatt Rd, Alice Springs	Alice Springs, NT	–23.83	133.74			5.965–5.975 GHz (T)
Building 5,13 Scaturchio St, Casuarina	Casuarina, NT	–12.37	130.88		1.684–1.71 GHz (R)	
Section 34, Hundred of Bray	Cox Peninsula, NT	–12.41	130.63	3.82–3.84 GHz (R)		
Lot 33 Charles Pt Rd, Cox Peninsula	Cox Peninsula, NT	–12.41	130.63			4.13–4.132 GHz (R)
Grandstand Darwin Turf Club, Dickward Drive, Fannie Bay	Fannie Bay, NT	–12.43	130.84			6.207–6.216 GHz (T)
Lot 1716, 350 Anzac Parade, Middle Point	Middle Point, NT	–12.60	131.30			7.765–7.844 GHz (R) 8.15–8.22 GHz (R)
19 Pera Circuit, Nhulunbuy	Nhulunbuy, NT	–12.19	136.78			6.357–6.358 GHz (T)
Central Receiving Site Seismic Array NT Portion, 1375, 36.4 km SE of Tennant Creek	Warramunga, NT	–19.93	134.35			4.0521–4.0525 GHz (R) 6.276–6.278 GHz (T)
525 Stuart Highway, Winnellie	Winnellie, NT	–12.43	130.89		4.0521–4.0525 GHz (R)	6.276–6.278 GHz (T)
Water Tower Dryden St, Alpha	Alpha, Qld	–23.65	146.63			3.963–3.964 GHz (R)
Control Tower, Airport Drive, Brisbane Airport	Brisbane Airport, Qld	–27.39	153.11		3.914–3.9153 GHz (R) 6.139–6.141 GHz (T)	

Site name	Location	Coordinates		Frequencies		
		Lat.	**Long.**	**May influence short-term viability**	**May influence medium-term viability**	**Secure in long term**
AMSA Cospas/Sarsat Lut Site	Bundaberg, Qld	–24.76	152.41			1.544–1.545 GHz (R)
AIMS Main Building, East Wing, Cape Cleveland Road	Cape Ferguson, Qld	–19.27	147.05			1.696–1.708 GHz (R) 8.15–8.17 GHz (R) 8.202–8.223 GHz (R)
TVNZ(A) HF Rx MSCS remote site, Charleville	Charleville, Qld	–26.54	146.26		3.999–4.002 GHz (R)	6.224–6.227 GHz (T)
Broadcast Site, 2km NW of Charleville	Charleville, Qld	–26.40	146.22			6.224–6.225 GHz (T)
Water Tower, cnr Middle & Colamba Sts, Chinchilla	Chinchilla, Qld	–26.74	150.62		3.995–3.996 GHz (R)	
Ergon Energy Site, Mt Tully, 6 km WSW of Cooktown	Cooktown, Qld	–15.48	145.19			3.995–3.996 GHz (R)
Water Tower, Dirranbandi	Dirrabandi, Qld	–28.59	148.22		3.963–3.964 GHz (R)	
Bureau of Meteorology, Ingham Road, RAAF Base, Townsville	Garbutt, Qld	–19.25	146.76		4.052–4.052 GHz (R) 6.276–6.278 GHz (T)	
Council Depot, Boundary Road, Goondiwindi	Goondiwindi, Qld	–28.53	150.30		3.995–3.996 GHz (R)	
168 Siganto Drive, Helensvale	Helensvale, Qld	–27.89	153.32		3.995–3.996 GHz (R) 6.22–6.221 GHz (T)	
Water Tower Burke Street, Julia Creek	Julia Creek, Qld	–20.66	141.74		3.963–3.964 GHz (R)	
Broadcast Site, Water Tower, Karumba	Karumba, Qld	–17.50	140.84			3.963–3.964 GHz (R)
4LG Studio, Galah St, Longreach	Longreach, Qld	–23.44	144.25		6.2049–6.2051 GHz (T)	

Site name	Location	Coordinates		Frequencies		
		Lat.	Long.	May influence short-term viability	May influence medium-term viability	Secure in long term
Cnr Plaza Pde & Carnaby St, Maroochydore	Maroochydore, Qld	–26.66	153.09			12.375–12.625 GHz (R)
8 km E of Miles, off Warrego Hwy	Miles Hill, Qld	–26.65	150.27		3.995–3.996 GHz (R)	
Lot 33 Lake Moondarra Rd, Mount Isa	Mount Isa, Qld	–20.68	139.50			5.091–5.25 GHz (T) 6.875–7.055 GHz (R)
Bowen Council Site, 3.7 km NNW of Collinsville	Mt Devlin, Qld	–20.52	147.83		3.995–3.996 GHz (R)	
Queensland Comms Site. Mt Goonaneman Access Rd, 60 km WNW of Maryborough	Mt Goonaneman, Qld	–25.42	152.12		3.995–3.996 GHz (R)	
Hospital Hill, Normanton	Normanton, Qld	–17.68	141.08			3.963–3.964 GHz (R)
Concrete Water Tower, Goldring St, Richmond	Richmond, Qld	–20.74	134.14			3.963–3.964 GHz (R)
Mt Marlay, Stanthorpe	Stanthorpe, Qld	–28.66	151.95		3.995–3.996 GHz (R)	
Water Tower, Weipa	Weipa, Qld	–12.63	141.88		3.995–3.996 GHz (R)	
NewSat Networks Teleport, 12 Park Way, Mawson Lakes	Mawson Lakes, SA	–34.82	138.62	3.73–4.2 GHz (R)	5.98–6.4 GHz (T)	10.95–12.72 GHz (R) 12.747–12.748 GHz (R) 13.75–14.47 GHz (T)
SPRI Building (Bld W), Mawson Lakes Boulevard, Mawson Lakes	Mawson Lakes, SA	–34.81	138.62	2.2017–2.2023 GHz (R) 2.2265–2.2275 GHz (R) 2.254–2.255 GHz (R)		
11–15 Aruma St, Regency Park	Regency Park, SA	–34.86	138.57		3.988–3.9882 GHz (R) 4.151–4.152 GHz (R) 6.2125–6.2157 GHz (T) 6.358–6.3582 GHz (T)	

Site name	Location	Coordinates		Frequencies		
		Lat.	Long.	May influence short-term viability	May influence medium-term viability	Secure in long term
49 Port Road, Thebarton	Thebarton, SA	–34.92	138.57			12.328–12.74 GHz (R) 14.079–14.81 GHz (T) 14.49–14.491 GHz (T)
85 North East Road, Collinswood	Collinswood, SA	–34.89	138.61	3.726–3.738 GHz (R)		
Ceduna Observatory	Ceduna, SA	–31.87	133.81	2.2–2.5 GHz (RA passive)		1.25–.178 GHz (RA passive) 4.35–6.7 GHz (RA passive) 8–9.2 GHz (RA passive) 16–26 GHz (RA passive)
Mount Pleasant Observatory	Hobart, Tas.	–42.80	147.44	2.2–2.5 GHz (RA passive)		1.25–.178 GHz (RA passive) 4.35–6.7 GHz (RA passive) 8–9.2 GHz (RA passive) 16–26 GHz (RA passive)
CSIRO Laboratory, Castray Esplanade	Battery Point, Tas.	–42.89	147.34	2.218–2.221 GHz (R) 2.271–2.276 GHz (R)		1.544–1.545 GHz (R) 1.686–1.709 GHz (R)
Defence Training Area, Sand River Rd	Buckland, Tas.	–42.52	147.70			4.0521–5.0524 GHz (R) 6.276–6.277 GHz (T)
CSIRO Earth Station, Droughty Hill	Droughty Hill, Tas.	–42.92	147.42			8.005–8.205 GHz (R) 8.125–8.325 GHz (R)
ANARE Base	Macquarie Island, Tas.	–54.50	158.95			6.352–6.357 GHz (T)
700 Collins St	Docklands, Vic.	–37.82	144.95			137.025–137.9875 MHz (R) 1.6846–1.7095 GHz (R)

Site name	Location	Coordinates		Frequencies		
		Lat.	Long.	May influence short-term viability	May influence medium-term viability	Secure in long term
RAAF Base, East Sale	East Sale, Vic.	–38.10	147.13			1.67985–1.68015 GHz (R) 3.372–3.378 GHz (R) 5.957–5.963 GHz (T)
Wilson Ave, HMAS Cerberus	HMAS Cerberus, Vic.	–38.37	145.17		2.0317–2.047 GHz (T)	137.025–137.9875 MHz (R) 1.6835–1.7095 GHz (R)
Army School of Signals	MacLeod, Vic.	–37.72	145.09			7.629386–7.63 GHz (R) 8.22–8.220614 GHz (T)
Temporary Broadcast Compound, Rod Laver Arena	Melbourne, Vic.	–37.82	144.98			6.127–6.154 GHz (T) 6.282–6.403 GHz (T)
SNG Site, Brunton St	Melbourne, Vic.	–37.82	144.98			6.136–6.154 GHz (T)
141 Capel Street	North Melbourne, Vic.	–37.81	144.95		5.97425–5.98275 GHz (T)	
Phillip Island Racing Circuit, Back Beach Rd	Phillip Island, Vic.	–38.50	145.23			5.974–5.983 GHz (T)
GES Crown Allot No.3 Sector K Parish, Gooramadda	Rutherglen, Vic.	–36.03	146.53		4.053175–4.053535 GHz (R) 6.278535–6.278745 GHz (T)	137.53–137.59 MHz (R) 149.995–150.055 MHz (T)
HF Broadcast Station	Shepparton, Vic.	–36.32	145.42			3.882–3.920 GHz (R)
Building 3/6 Riverside Quay	South Melbourne, Vic.	–37.82	144.96		7.045827–7.0745 GHz (T)	12.48589–12.48611 GHz (R) 14.23589–14.23611 GHz (T)

Site name	Location	Coordinates		Frequencies		
		Lat.	Long.	May influence short-term viability	May influence medium-term viability	Secure in long term
120 Southbank Blvd Tower	South Melbourne, Vic.	–37.82	144.97		3.7264–3.7376 GHz (R) 3.9025–3.9075 GHz (R) 4.10033–4.10867 GHz (R)	
12 Riverside Quay	Southbank, Vic.	–37.82	144.96		4.1108–4.111 GHz (R) 6.3358–6.336 GHz (T)	
Receiver Site, Swan Island No. 2	Swan Island, Vic.	–38.25	144.69		3.732–3.738 GHz (R) 5.957–5.963 GHz (T)	
619 Lower Plenty Road, Yallambie	Yallambie, Vic.	–37.73	145.10		4.0521879–4.0524279 GHz (R) 6.2766839–6.2771342 GHz (T)	
NewSat Networks sites, Bayswater	Bayswater, WA	–31.91	115.92	1.52–1.56 GHz (R) 1.62–1.66 GHz (T) 3.6–3.629 GHz (R)	3.885–4.017 GHz (R) 4.137–4.163 GHz (R)	6.11–6.138 GHz (T) 6.173–6.362 GHz (T) 6.17–6.176 GHz (T) 6.41–6.44 GHz (T) 10.96–11.2 GHz (R) 12.542–12.543 GHz (R) 12.675–12.71 GHz (R) 12.74–12.75 GHz (R) 13.82–13.824 GHz (T) 13.92–14.45 GHz (T) 14.49–14.5 GHz (T)
620 Gnangara Rd, Landsdale	Landsdale, WA	–31.8	115.88	2.03–2.1 GHz (T) 2.2–2.3 GHz (R) 3.6–4.15 GHz (R)	5.8–6.4 GHz (T) 7.1–7.24 GHz (T) 8.4–8.5 GHz (R)	12.25–14.5 GHz (T) 17.3–18.1 GHz (T)
Altone Rd, Lockridge	Lockridge, WA	–31.88	115.94	3.77–4.1 GHz (R)	5.99–6.31 GHz (T) 7.255–7.265 GHz (R) 7.98–7.99 GHz (T)	12.2–12.75 GHz (R) 13.98–14.5 GHz (T) 17.32–17.8 GHz (T)

Site name	Location	Coordinates		Frequencies		
		Lat.	**Long.**	**May influence short-term viability**	**May influence medium-term viability**	**Secure in long term**
ESA Deep Space Earth Station, New Norcia	New Norcia, WA	–31.05	116.19	2.035–2.117 GHz (T) 2.21–2.3 GHz (R)	7.15–7.231 GHz (T) 8.4–8.5 GHz (R)	
Cave Point Lighthouse, The Gap Road, Frenchman Bay Road	Albany, WA	–35.12	117.90			1.5441–1.5449 GHz (R)
Curtin University (Bldg 204) Kent St, Bentley	Bentley, WA	–32.01	115.89			1.684–1.71 GHz (R)
1 Spencer St, Bunbury	Bunbury, WA	–33.33	115.64			14.175–14.176 GHz (T)
Burswood Dome Victoria Park Drive, Burswood	Burswood, WA	–31.96	115.90		5.965–5.974 GHz (T)	
BOM ATWS Site, Cape Cuvier Jetty, Cape Cuvier	Cape Cuvier, WA	–24.22	113.39			5.934–5.9345 GHz (R)
Augusta Ranger Station, Cnr Wishart and Leeuwin Roads Barracks Point	Cape Leeuwin, WA	–34.35	115.16			4.112–4.1121 GHz (R) 6.311–6.3112 GHz (T) 6.337–6.338 GHz (T)
MCC Construction Offices, 53km SW of Dampier	Cape Preston, WA	–20.84	116.21			12.5925–12.5936 GHz (R) 13.8376–12.8387 GHz (T)
Comms Site Christmas Island	Christmas Islands, WA	–10.43	105.68			3.887–3.893 GHz (R) 6.108–6.114 GHz (T)
Comms Site Cocos Island	Cocos Islands, WA	–12.18	96.83			3.889–3.903 GHz (R) 6.11–6.15 GHz (T)
Met Bureau Office, Airport, Cocos Islands	Cocos Islands, WA	–12.19	96.83			4.112–4.1122 GHz (R) 6.311–6.338 GHz (T)
Airservices/Promo Radio Site, 5.3 km NNW of Airport, Cocos Islands	Cocos Islands, WA	–12.14	96.82			4.112–4.1122 GHz (R) 6.311–6.338 GHz (T)

Site name	Location	Coordinates		Frequencies		
		Lat.	Long.	May influence short-term viability	May influence medium-term viability	Secure in long term
Jack Hills Mine, Berringirra Road, Cue	Cue, WA	–26.04	117.23			3.994–3.995 GHz (R) 6.219–6.220 GHz (T)
Hyatt Regency Hotel, 99 Adelaide Tce, East Perth	East Perth, WA	–31.96	115.87			11.516–11.537 GHz (R) 12.418–12.442 GHz (R) 14.043–14.057 GHz (T) 14.055–14.059 GHz (T)
SNG Site, approx. 50m SE of WACA Players Pavilion, Hay Street	East Perth, WA	–31.96	115.88		6.247–6.265 GHz (T)	
2 Harrison Rd, Forrestfield	Forrestfield, WA	–31.97	116.0	3.725–3.73 GHz (R)	3.986–3.9863 GHz (R) 3.994–3.9951 GHz (R) 5.95–5.955 GHz (T) 6.2–6.206 GHz (T)	
Earth station site, Geraldton	Geraldton, WA	–28.69	114.84			7.375–7.75 GHz (R) 7.9–7.975 GHz (T) 8.025–8.4 GHz (T)
Shin Satellite Earth Station site, Kalgoorlie	Kalgoorlie, WA	–30.73	121.48			13.75–13.76 GHz (T) 18.48–18.49 GHz (R) 19.7–20.2 GHz (R) 29.5–30.0 GHz (T)
8 Marchesi St, Kewdale	Kewdale, WA	–31.98	115.96			12.328–12.3281 GHz (R) 14.0781–14.0783 GHz (T)
Yanget Rd, Kojarena	Kojarena, WA	–28.69	114.84			26.55–26.85 GHz (R)
Globalstar Site West End of Airport, Meekatharra	Meekatharra, WA	–26.60	118.52			5.091–5.25 GHz (T) 6.875–7.055 GHz (R)

Site name	Location	Coordinates		Frequencies		
		Lat.	Long.	May influence short-term viability	May influence medium-term viability	Secure in long term
Depot Hill Road Yarragadee, 18.5 km NW of Mingenew	Mingenew, WA	–29.05	115.34			2.03–2.049 GHz (T) 2.077–2.0973 GHz (T) 2.203–2.278 GHz (R) 8.165–8.215 GHz (R)
10338 Middleton Rd, Northcliffe	Northcliffe, WA	–34.59	116.35			4.112–4.1122 GHz (R) 6.311–6.338 GHz (T)
Christmas Creek, approx. 13km west of Marble Bar Road, Nullagine	Nullagine, WA	–22.41	119.86			12.61–12.611(R) 13.854–13.855(T)
Channar, approx. 20km south of Tom Price–Paraburdoo Road, Paraburdoo	Paraburdoo, WA	–23.3	117.83			12.61–12.611(R) 13.854–13.855(T)
28 The Esplanade, Perth	Perth, WA	–31.98	115.86		3.869–3.87 GHz (R)	6.0944–6.0948 GHz (T)
BOM Office Northern Perimeter Road, Perth Airport	Perth Airport, WA	–31.93	115.97			4.112–4.1122 GHz (R) 6.311–6.338 GHz (T)
Karara, approx. 50km SW of Great Northern Highway	Rothsay, WA	–29.18	116.76			12.61–12.611(R) 13.854–13.855(T)
Apache Energy Tower, Varanus Island	Varanus Island, WA	–20.66	115.58			14.2498–14.2502 GHz (T)
9 Havelock St, West Perth	West Perth, WA	–31.95	115.84		3.632–3.633 GHz (R) 5.857–5.858 GHz (T)	
24 Outram St, West Perth	West Perth, WA	–31.95	115.84		3.882–3.918 GHz (R) 5.907–5.943 GHz (T)	
TVNZ(A) HF Rx MSCS Remote Site near Wiluna	Wiluna, WA	–26.50	120.45		3.999–4.002 GHz (R) 6.224–6.227 GHz (T)	

Appendix B—Overview of shared bands

Band	Frequencies	Space services	Terrestrial services
L-band (1–1.98 GHz)	1.25–1.525 GHz	Radioastronomy	Fixed service Mobile
	1.525–1.559 GHz	MSS downlink Passive radioastronomy	Fixed service Mobile
	1.610–1.6265 GHz	MSS uplink Passive radioastronomy Space research	Aeronautical radionavigation
	1.6605–1.6684 GHz	Passive radioastronomy	Fixed service Mobile
	1.6684–1.7 GHz	Passive radioastronomy Meteorological aids	Fixed service Mobile
S-band (1.98–3.4 GHz)	1.980–2.010 GHz	MSS uplink	Fixed service Mobile
	2.025–2.11 GHz	Space research (Earth-to-space)	Fixed service Mobile
	2.11–2.2 GHz	Space research (Earth-to-space)(deep space)	Fixed service Mobile
	2.17–2.2 GHz	MSS downlink	Fixed service Mobile
	2.2–2.29 GHz	Space research (space-to-Earth)(space to space) Space operation (space-to-Earth)(space to space)	Fixed service Mobile
	2.29–2.3 GHz	Space research (space-to-Earth)(deep space)	Fixed service Mobile
	2.4835–2.5 GHz	MSS downlink Passive radioastronomy	Fixed service Mobile Radiolocation
C-band (3.4–7.25 GHz)	3.4–3.55 GHz	'Extended' C-band FSS	Fixed service Radiolocation
	3.55–3.7 GHz	'Extended' C-band FSS	Fixed service Mobile
	3.7–4.2 GHz	C-band FSS	Fixed service Mobile
	4.35–5.85 GHz	Passive radioastronomy	Fixed service Mobile
	5.850–5.925 GHz	'Extended' C-band FSS Passive radioastronomy	Fixed service Mobile Radiolocation
	5.925–6.425 GHz	C-band FSS Passive radioastronomy	Fixed service Mobile
	6.425–6.725 GHz	'Extended' C-band FSS Passive radioastronomy	Fixed service Mobile
X-band (7.145–10.7 GHz)	7.145–7.25 GHz	FSS Space research (Earth-to-space)	Fixed service Mobile
	7.25–7.75 GHz	FSS	Fixed service Mobile

Band	Frequencies	Space services	Terrestrial services
	7.9–8.4 GHz	FSS Passive radioastronomy	Fixed service Mobile
Ku-band (10.7–18.4 GHz)	10.7–11.7 GHz	FSS	Fixed service Mobile
	12.2–12.75 GHz	FSS	Fixed service Land mobile satellite Mobile
	12.75–13.25 GHz	Space research (space-to-Earth)(deep space)	Fixed service Mobile
	13.75–14 GHz	FSS	Radiolocation
	14–14.5 GHz	FSS Space research (space-to-Earth)	Fixed service Mobile
	17.3–18.4 GHz	BSS feeder link Passive radioastronomy	Fixed service Mobile Radiolocation
Ka-band (17.7–37.5 GHz)	17.7–19.7 GHz	FSS Passive radioastronomy	Fixed service Mobile
	22.21–22.5 GHz	Passive radioastronomy	Fixed service Mobile
	24.75–25.25 GHz	FSS Passive radioastronomy	Fixed service Mobile
	25.25–27 GHz	Passive radioastronomy Space research (space-to-Earth)	Fixed service Mobile
	27–29.1 GHz	FSS	Fixed service Mobile