Review of apparatus licence fees in 17.3-51.4 GHz band

Final Report for the ACMA

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Executive Summary

This is the Final Report for a project to review fees charged to satellite services in the frequency range 17.3 GHz to 51.4 GHz. The analysis presented is based on desk research, data supplied by the ACMA and Plum modelling.

Issues addressed

Fees for Ka band are mainly determined based on the following formula:

$$0.26 \times \text{Bandwidth} \times \text{Location weighting}$$

The annual taxes paid per kHz are as follows:

Spectrum location	Geographic location				
	Australia-wide	High density	Medium density	Low density	Remote density
>14.5 to 31.3 GHz	0.9768	0.2601	0.0571	0.0061	0.0029
>31.3 to 51.4 GHz	0.2664	0.1419	0.0308	0.0011	0.0005

Source: Apparatus licence fee schedule, ACMA, April 2015[1]

Our review of the current situation in Section 2 identified the following issues with the current fees:

- The apparatus tax fee levels are based on relative prices set in the 1990s. The ACMA has not previously tested whether the fees reflect the ACMA's policy of opportunity cost pricing.
- Some industry participants have argued the fees are too high given the relatively light use of the frequencies.
- There does not appear to be congestion in satellite bands, but the future outlook needs to be reviewed.
- There are two exceptions to the apparatus fees schedule for non-geostationary orbit (NGSO) systems and CDMA technology that have no obvious justification and their removal should be considered.
- The way the fees are currently structured does not take explicit account of the spectrum denial areas for licensed earth stations, and so may not provide incentives for efficient spectrum use.
- There is no explicit financial incentive for a licensee to collocate earth stations to minimise their impact on other services. Although, the ACMA has an administrative policy of promoting satellite parks[2] and one park has been established at Yarragadee/Mingenew in Western Australia.
- The increase in fees for remote area licences at 2.69 GHz should be removed as part of any consideration of the level of fees.

[1] Note that the ACMA will make a number of updates to the fee schedule in April 2016 including annual adjustments for inflation.

[2] http://www.acma.gov.au/theACMA/ifc-272011-earth-station-siting

Ka band is unlikely to become congested over the next 5 years

In Section 3 we analyse the ACMA's licensing data to come to a view about trends in demand for spectrum at Ka band. The main services responsible for this demand are fixed links, satellite services and space services. The situation for each service is as follows:

- Most frequency bands used by fixed links are not currently congested and have experienced declining demand trends. One possible exception is the 18 GHz band where demand has been flat in recent years, though in this band there appears to be capacity available for a doubling of demand over the next 5 years. We do not expect demand to increase at this rate over the next 5 years, largely because fibre will substitute for fixed links particularly in high demand urban areas. We note that other publicly available reports for Australia, the UK and Europe have concluded that there is unlikely to be excess demand for links in frequencies above 20 GHz[3] over the next 5 or so years.
- The number of assignments for all satellite services has either been flat or in decline, except for assignments for earth station licences above 18.4 GHz. The number of such assignments grew rapidly in 2013/2014 as gateway stations for the satellite broadband service were deployed. It can be expected there will continue to be on-going growth in assignments for gateway earth stations to support the HDFSS[4] service over the next five years, though not at the rate that was experienced in 2013/14 when the service was initiated.
- In respect of HDFSS downlink, the main issue is potential congestion in orbital slots and not in spectrum.
- There could be additional demand for spectrum at 21-22 GHz from broadcast TV services as ultra-HD (UHD) services are deployed, This demand could take at least 5 years to develop because UHD services are still at the trial phase, operators will initially seek to use Ku band[5] to support these services and a migration plan will be required to ensure compatibility with existing fixed services in the 21-22 GHz band.
- The number of sites used for space science activities in Australia is relatively stable. Not all of these sites use frequencies above 17.3 GHz but a limited number have been licensed for these frequencies as described in 2.3.3 and shown in Figure 2-2. There is an expectation that the use of Ka-band frequencies for download communications links will increase in the future but this is likely to be supported by existing earth station sites or a limited number of new sites.

In the five year timeframe for our forward look we did not identify any significant new services demand. There is likely to be future demand from 5G services once decisions about frequency bands are made at WRC-19 but at this stage it is not possible to identify which bands will be identified for 5G.

In summary, we conclude that Ka band is unlikely to become congested in a 5 year timeframe. The ACMA's policy principles therefore suggest that licence taxes in this frequency range should be set at a rate that reflects the low opportunity cost associated with uncongested bands. The ACMA is

[3] See 2014 Plum report for Ofcom on fixed links for example. The ACMA in the paper 'Beyond 2020: A spectrum management strategy to address the growth in mobile broadband capacity' identified the need to monitor and address the need for wireless backhaul to support growth in mobile broadband capacity including the higher bands. RSPG (Radio Spectrum Policy Group) in Europe recognised the potential growth but did not identify any shortage of spectrum above 20 GHz

[4] High density fixed satellite service. See section 3.3.2 of this report.

[5] http://www.tech-faq.com/ku-band.html

nevertheless interested in understanding how opportunity cost principles might be applied to satellite bands and so this was considered in Sections 5-7 of the report.

Possible approaches to setting fees

In Section 4 we examine the feasibility and relevance of a range of different approaches to setting fees and conclude that the following three approaches should be examined in detail.

- **Benchmarking of fees set by other regulators** – presented in Section 5
- **Spectrum market benchmarking** of values from spectrum market transactions – auctions and trades – for similar or the same frequency ranges in Australia and elsewhere – presented in Section 6.
- **Least cost alternative value** (or optimised deprival value) which involves estimating the value of spectrum to an average user based on the least cost alternative technology or service to enable the same output to be produced (with the same service quality) if a user is deprived of a small amount of spectrum – presented in Section 7.

The analyses in Sections 5-7 have informed our conclusions regarding the level of fees and their structure. The key findings are given below.

There is a case for reducing fees in high and medium density areas

We find that fees paid by satellite services in high and medium density areas in Australia can be said to be high based on:

- The least cost alternative[6] (LCA) estimates we have produced: These give values of spectrum for congested locations (similar to high density areas) that are in the range $0.1-0.2/kHz and so are less than the current annual licence annual licence tax of $0.26/kHz for 14.5-31.3 GHz. This evidence alone suggests that a 40-50% reduction in fees in high and medium density area fees for Ka band could be justified, particularly given we have not identified the band as congested.
- Fees in other countries (reported in Section 5): Fees for earth station transmissions in other countries are generally much less than Australian fees for high density areas, though Australian fees in low density and remote areas (where most satellite systems in Australia are located (see Section 2)) are low by international standards. Because satellite operators in most countries pay satellite licence fees in addition to (and sometimes instead of) spectrum fees, the international data cannot be used to draw precise conclusions about the appropriate level of fees in Australia. Rather the data would seem to suggest that at least for high density areas (and possibly medium density areas) there could be a case for reducing fees.
- By making a like for like comparison of satellite fees with fixed link fees (i.e. adjusting for differences in denial areas). Assuming fixed link fees remain unchanged, there could be a case for reducing satellite fees or the 14.5-31.3 GHz range by between 50-66%.

[6] Sometimes referred to as optimal deprival value (ODV).

The main argument against reducing fees in high and medium density areas is that long term nature of investments in gateway and similar satellite earth station transmission sites[7] (20 years or more) means it is important to have a strong incentive for operators to locate such earth stations in areas where there is the least possibility of congestion i.e. low density and remote areas. Our congestion analysis only has a 5 year time horizon and there is always therefore a risk of congestion occurring longer term in high and medium density areas if fees are reduced and as a result of demands from new services such as 5G. This means the tax schedule should always have a large difference between fees in high/medium versus low/remote areas and that moderate reductions in fees should be implemented initially (i.e. for the next 5 years).

Recommendation

We recommend that fee levels for Australia-wide licences and for licences in high and medium areas in the 17.3-51.4 GHz range are reduced to levels that are at the high end of the ranges we have obtained. We propose a 30% reduction in high density area and Australia-wide fees and a 10% reduction in medium density area fees. It might be thought that such a large reduction in fees would result in many more licence applications, however, the very large scale of irreversible upfront investments in satellite systems means that the spectrum fees will only be one of many factors influencing investment decisions i.e. we expect that demand will be relatively inelastic in the near term at least.

We do not propose any reductions in low density and remote areas as fees here are already low and there will still be a large difference between fees in these areas and those in high and medium density areas.

We recommend that fees in exclusive satellite bands should be set at the same levels as fees in shared bands. This is because there is no evidence that spectrum in shared bands is of higher or lower value than in exclusive bands. And there is no evidence of regulators elsewhere making this distinction in their fees structures.

Anomalies in the fees structure should be removed

There are several anomalies in the tax schedule and we suggest they should be removed. In particular:

- Fees for geostationary orbit (GSO) and non-geostationary orbit (NGSO) systems should be set on the same basis i.e. based on their relative denial areas. This implies a 50% premium for NGSO systems in the lower frequency band (14.5 – 31.3 GHz)
- There should not be a discount for use of CDMA technology
- The remote area fees should not increase at 2.69 GHz.
- Differences in propagation characteristics and reuse suggest the Australian tax schedule should have a break point at 24 GHz, so that the frequency range 14.5-31.3 GHz is segmented as 14.5-

[7] Rather than ubiquitous earth stations such as those for pay TV or satellite broadband to residential housing which are class licensed.

24 GHz and 24-31.3 GHz and that the fee for the 24-31.3 GHz band is 30% less than for 14.5-24 GHz.

There should be incentives for collocation

Finally it might be expected that fees for access to spectrum would vary according to factors that reflect spectrum occupancy or denial to other users, such as power, whether services are collocated or not and whether transmit or receive functions are undertaken. Introducing a power factor further complicates the fees schedule and given the current absence of congestion we do not think this is justified at present. Also the Australia-wide licence provides an indirect incentive for frequency reuse across Australia and this gives an incentive to use narrower spot beams because of the higher reuse obtained (all else being equal).

Recommendation

We have recommended that co-location of terminals should be encouraged by a 30% discount for each terminal within a 500m radius of another. This recognises the reduced impact of aggregated power as influenced by real-world propagation conditions

Summary of proposed fees for Ka band

Taken together our proposals imply the following annual taxes per kHz for GSO systems in shared and exclusive satellite bands:

Spectrum location	Geographic location				
	Australia-wide	High density	Medium density	Low density	Remote density
>14.5 to 24 GHz	0.68376	0.18207	0.05139	0.0061	0.0029
>24 to 31.3 GHz	0.478632	0.127449	0.035973	0.0061	.0029
>31.3 to 51.4 GHz	0.18648	0.09933	0.02772	0.0011	0.0005

NGSO systems would pay fees 50% higher than those given above and a 30% discount would apply to all collocated systems.

1 Introduction

This is the Final Report for a project to review fees charged to satellite services in the frequency range 17.3 GHz to 51.4 GHz. The objective of the study is to derive fees that are reflective of market value in line with the opportunity cost methodologies that the ACMA adopted in 2009-2010[8]. We were not asked to advise the ACMA on the level of fees for fixed links in the frequency range 17.3 GHz to 51.4 GHz.

The key steps in the opportunity cost methodology and the relevant sections of this report are as follows:

- Establish whether or not the frequency ranges in question are congested or likely to become so over the next 5 years as a result of demand from an existing use or an alternative use (Sections 2 and 3).
- Advise on possible approaches to setting fees given the results of the demand analysis (Section 4).
- Derive estimates of the opportunity cost of spectrum (where this is defined to be the value of spectrum at the margin to the next best use or user of spectrum) from market benchmarks and bottom-up calculations. Benchmarks are reported in Sections 5 and 6. Bottom-up least cost alternative calculations are given in Section 7.
- Advise on how the estimates of opportunity cost might be used in the context of a general tax formula, specifying in particular how prices would vary by type of satellite system, assumed interference parameters and the relative prices paid by fixed links versus satellite services. This requires modelling of denial areas for different systems which is given in Section 8.
- Our conclusions are given in Section 9.

Supporting material is given in Appendices A and B.

[8] The ACMA response to public submissions: Opportunity cost pricing of spectrum, January 2010 http://www.acma.gov.au/theACMA/acma-issues-for-comment-122009-opportunity-cost-pricing-of-spectrum-public-consultation-on-administrative-pricing-for-spectrum-based-on-opportunity-cost

2 Current situation

The purpose of this section is to describe current satellite and space spectrum use, licensing and fees. This both provides useful background for the report analysis and is used to identify issues that the study should address. The section is structured as follows:

- Frequency bands used (section 2.1)
- Licensing regime (section 2.2.
- Number and location of assignments (section 2.3)
- Market situation (section 2.4);
- Spectrum fees (section 2.5) and
- Issues to be addressed (section 2.6).

2.1 Frequency bands

This study is focussed on the frequency bands used by satellite and space services in the range 17.3 – 51.4 GHz – this is sometimes referred to as Ka band and Q/V band. The relevant communication bands (mainly with reference to the Fixed Satellite Service except where noted) are listed in Table 2-1: and Table 2-2, according to the direction of signals. As shown, each band is different in terms of amount of spectrum available, uses / users and whether the band is shared with the fixed service.

Table 2-1: Earth to space frequency bands

Frequency band	Other users	Notes
17.3 – 17.7 GHz		
17.7 – 18.4 GHz	Fixed	
19.3 – 19.7 GHz	Fixed	
24.65 – 25.25 GHz		
27.0 – 27.5 GHz		
27.5 – 28.5 GHz	Fixed	
28.5 – 29.5 GHz	Fixed	Designated for high density fixed satellite service (HDFSS) (28.5 – 29.1 GHz) by ITU RR.
29.5 – 30.0 GHz		Designated for HDFSS by ITU RR. Also MSS but Secondary 29.5 – 29.9 GHz.
30.0 – 31.0 GHz		Government use (including MSS).
42.5 – 43.5 GHz		
47.2 – 50.2 GHz	Fixed	
50.4 – 51.4 GHz	Fixed	MSS (Secondary)

Table 2-2: Space to earth frequency bands

Frequency band	Other users	Notes
17.7 – 19.7 GHz	Fixed	"HDFSS" (17.7 – 18.2 GHz) "HDFSS" (18.8 – 19.3 GHz)
19.7 – 20.2 GHz		Designated for HDFSS by ITU RR. Also MSS but secondary 19.7 – 20.1 GHz.
20.2 – 21.2 GHz		Government use (including MSS)
21.4 – 22 GHz	Fixed	Broadcasting SS
33.4 - 36 GHz		
37.5 – 42.5 GHz	Fixed	39.5 – 40.5 GHz also MSS. 40 – 40.5 GHz designated for HDFSS by ITU RR. 40.5 – 42.5 GHz also BSS.

Note: HDFSS in inverted commas ("HDFSS") indicates that ground terminals are able to operate under a class licence but are not specifically identified as HDFSS by the ITU Radio Regulations.

In addition to the communication based services summarised in the above tables there are also a number of "space science" services operating in the frequency range of interest. These services are

Earth-Exploration (active and passive), Space Research (including deep space) and Radio Astronomy. The main frequencies of interest to this community are listed in Table 2-3.

Table 2-3: Space science frequency bands

Frequency band	Services
18.6 – 18.8 GHz	EESS (passive)
21.2 – 21.4 GHz	EESS / SR (passive)
22.21 – 22.5 GHz	EESS / SR (passive) & Radioastronomy
22.55 – 23.15 GHz	SR (E-S)
23.6 – 24 GHz	EESS / SR (passive) & Radioastronomy
25.5 – 27 GHz	EESS / SR (S-E)
31.3 – 31.8 GHz	EESS / SR (passive) & Radioastronomy
31.8 – 32.3 GHz	SR (S-E) – deep space
34.2 – 34.7 GHz	SR (S-E) – deep space
35.5 – 36 GHz	EESS / SR (active)
36 – 37 GHz	EESS / SR (passive)
37 – 38 GHz	SR (S-E)
40 – 40.5 GHz	EESS / SR (E-S)
42.5 – 43.5 GHz	Radioastronomy
50.2 – 50.4 GHz	EESS / SR (passive)

2.2 Licensing

The ACMA issues three types of licence:[9]

- **Spectrum licence.** “*A spectrum licence authorises a licensee to use a parcel of spectrum space; that is, a particular frequency band within a particular geographic area, for up to 15 years. This approach provides exclusive spectrum access to a potentially large area, typically Australia-wide, or across a state or regional area.*”
- **Class licence.** “*The ACMA uses a class licence to manage spectrum used by services that employ a limited set of common frequencies using equipment under a common set of conditions. This type of licensing involves minimum licence administration by the ACMA. A class licence sets out the conditions under which any person is permitted to operate. It is not issued to an individual user and does not involve licence fees.*”
  - For example, class licences are issued for mass market consumer devices such as transmit and receive broadband devices.
  - Class licences generally provide no protection from interference.

[9] See page 10 of http://www.acma.gov.au/webwr/_assets/main/lib410116/ifc35-2011_licensing_for_earth_receive_stations.pdf

- **Apparatus licence.** *"Apparatus licences specify technical conditions, such as frequency, transmit power, emission type and, importantly, geographic location, for the operation of a specific device. An apparatus licence is issued to an individual party. Fees are payable for the issue and renewal of these licences."*

Transmitters must be licensed and users may choose to protect receivers through receiver licences.

Table 2-4: below summarises the different licensing options that apply to earth and space stations and the relationship between the two. Earth station and space station licences that are apparatus licensed afford protection from interference. There are two ways in which a link between an earth station and a satellite can be licensed:[10]

- License the **ground** segment with an apparatus licence.
- License the **space** segment with an apparatus licence. Earth stations could then be authorised under the Space Object Class Licence which protects them to the extent that they use spectrum in accordance with the apparatus licence of the space segment.

The approach taken depends on the number of earth stations – it is more efficient to have a class licence if the number of earth stations is large and the earth stations themselves are small – typically used by a consumer market such as direct to home (DTH) TV or for consumer broadband. Also, if the space segment is not licensed, for whatever reason, then the earth segment requires an apparatus licence.

Apparatus licences are usually site-specific, however, Australia-wide licences are also issued to satellite service providers. Such a licence does not normally authorise exclusive use of a frequency, only authorises the operation of one station, system or service and generally requires that the user operates on a 'no interference, no protection' basis[11].

Table 2-4: Licensing options for earth stations and space (satellite) stations

Option	Earth station transmit	Earth station receive	Satellite transmit	Satellite receive
1	-	Class licence	Space licence	-
2	Class licence	-	-	Space licence
3	-	Earth receive licence	No space licence required	-
4	Earth transmit licence	-	-	No space licence required

2.3 Number of assignments

Table 2-5 below provides an overview of the number of assignments in each of the frequency bands identified in Table 2-1: and Table 2-2. This data is obtained from an on-line data search and does not differentiate between the different types of apparatus licences (i.e. includes both transmitter and receiver licences). In some cases we have had to identify assignments based on a visual inspection of the data because it was not possible to sort the data by licence category.

[10] See page 11 of http://www.acma.gov.au/webwr/_assets/main/lib410116/ifc35-2011_licensing_for_earth_receive_stations.pdf

[11] P 42, Apparatus Licence Fee Schedule, ACMA, April 2015

As can be seen the main fixed link frequency bands are 18 GHz, 22 GHz and 38 GHz[12]. From the on-line data search we also found that there are a limited number of fixed link assignments in the 50.4 – 51.4 GHz band. Before January 2014, the band 27.5-28.35 GHz was subject to spectrum licensing and, under the Radiocommunications Act, the ACMA was unable to issue apparatus licences in spectrum licence bands unless there were special circumstances. With that band now subject to apparatus licensing, fixed point-to-point links are now supported in the 27.5-29.5 GHz band as per RALI FX 3[13]. It should be noted that Body Scanners have a centre frequency of 27.125 GHz and a bandwidth of 5.7 GHz hence they appear in a significant number of the bands in the table.

[12] This is also found in The following ACMA report: "Microwave fixed point-to-point services assignment statistics – 1 January 2008 to 1 January 2012, May 2014. (Spectrum planning report 2014/04)

[13] The need to share with satellite services might also have an impact.

Table 2-5: Number of transmit and receive licences by frequency band

Frequency band	Number of assignments (October 2015)	Uses and users licensed
17.3 – 17.7 GHz	44	Radiodetermination (IDS Australasia), Space Australia wide (NBN), Earth stations (Optus, Inmarsat, Lockheed Martin)
17.7 – 19.7 GHz	14977	Fixed point to point links (majority if not all)
19.7 – 20.2 GHz	29	Space (Inmarsat, NBN), Earth station receive (IPSTAR, Universal Space Network, Dept. of Defence)
20.2 – 21.2 GHz	5	Space (NBN), Earth station receive (IPSTAR, Dept. of Defence)
21.4 – 22 GHz	504	Fixed point to point links (majority if not all)
24.65 – 25.25 GHz	24	Radiodetermination – body scan at airports
27.0 – 27.5 GHz	133	Radiodetermination – body scan at airports, Fixed earth station (NBN), spectrum in 27 GHz band (XYZED LMDS, NBN, IPSTAR)
27.5 – 29.5 GHz	155	Radiodetermination – body scan at airports, Space receive (NBN), Fixed earth station (ITC Global, NBN, Universal Space Network, O3B Teleport Services, Iridium)
29.5 – 30.0 GHz	55	Radiodetermination – body scan at airports, Space receive (Inmarsat Solutions), Fixed earth station (NBN, IPSTAR, Universal Space Network), 30 GHz Defence Spectrum (Dept. of Defence)
30.0 – 31.0 GHz	28	Radiodetermination – body scan at airports, Fixed earth station (IPSTAR), 30 GHz Defence Spectrum (Dept. of Defence)
33.4 – 36.0 GHz	3427	Radiodetermination mainly for Police
37.5 – 39.5 GHz	2746	Fixed point to point links (majority if not all)
39.5 – 42.5 GHz	-	No assignments
42.5 – 43.5 GHz	-	No assignments
48.2 – 50.2 GHz	-	No assignments
50.4 – 51.4 GHz	78	Fixed point to point links

Source: On-line search of ACMA licensing database, October 2015. Both transmit and receive licences are reported.

2.3.1 Fixed service bands

18 GHz band

The 18 GHz band (17.7 – 19.7 GHz) is identified for low, medium and high capacity links and is used by Optus, Vodafone, the Government, Telstra and others. The band plan consists of paired channels of 7.5 MHz up to 55 MHz bandwidth. The most used channel plan is 2×27.5 MHz, and the usage is spread across the frequency range 18.3 – 18.7 GHz paired with 19.3 – 19.7 GHz with the majority of the assignments in the lower frequencies. This is consistent with the ACMA's policy of assigning in the lower frequency channels first.

22 GHz band

The 22 GHz band (21.2 – 23.6 GHz) is used for both fixed services and TV Outside Broadcasting (TOB). The band supports a wide range of different capacities and bandwidths (3.5, 7, 14, 28, 50 and 56 MHz paired channels[14]) although it is understood that the band has in the past been typically used for low capacity links of 2 and 8 Mbit/s. The first three 50 MHz channels are dedicated for TOB and the rest of the channels are used by the mobile operators (Vodafone, Hutchison, Optus) and the Government. The main demand, which is increasing, is for 27.5 MHz bandwidth with a decrease in demand for bandwidths of 7.5 MHz and below.

38 GHz band

The 38 GHz band (37 – 39.5 GHz) is split into paired channels of 7 MHz, 14 MHz and 28 MHz, and is used by the mobile operators, the Government and others, with the heaviest user being Optus. However, Optus significantly decreased the number of their assignments between 2010 and 2012 and the use by others stayed relatively unchanged so there was an overall fall in the number of assignments.

The 38 GHz band has been sub-divided into blocks of channels:

- 20 off 7 MHz paired channels,
- 18 off 14 MHz paired channels, and
- 10 off 28 MHz paired channels.

The highest demand is for 7 and 28 MHz bandwidth channels.

2.3.2 Satellite communication services

The key communication satellite services are:

- The fixed satellite service which can be point-to-point and point-to-multipoint at a trunking level (e.g. TV programme distribution) or to smaller terminals such as VSATs or even smaller consumer terminals for satellite broadband (often referred to as HDFSS). The fixed satellite service also supports feeder links for the broadcast satellite service and the mobile satellite service
- The mobile satellite service connects directly with consumer terminals with feeder links / gateway terminals using fixed satellite service frequencies.
- The broadcast satellite service connects directly with consumer terminals with feeder links / gateway terminals using fixed satellite service frequencies.

[14] See Appendix to RALI FX 3
http://www.acma.gov.au/~/media/Spectrum%20Engineering/Regulation/pdf/Appendix%201%20-%2022g%20Plan%20pdf.pdf

In general, consumer terminals associated with the three satellite services will fall under a class licence. Class licences[15] currently cover the following bands in the frequency range of interest to this study:

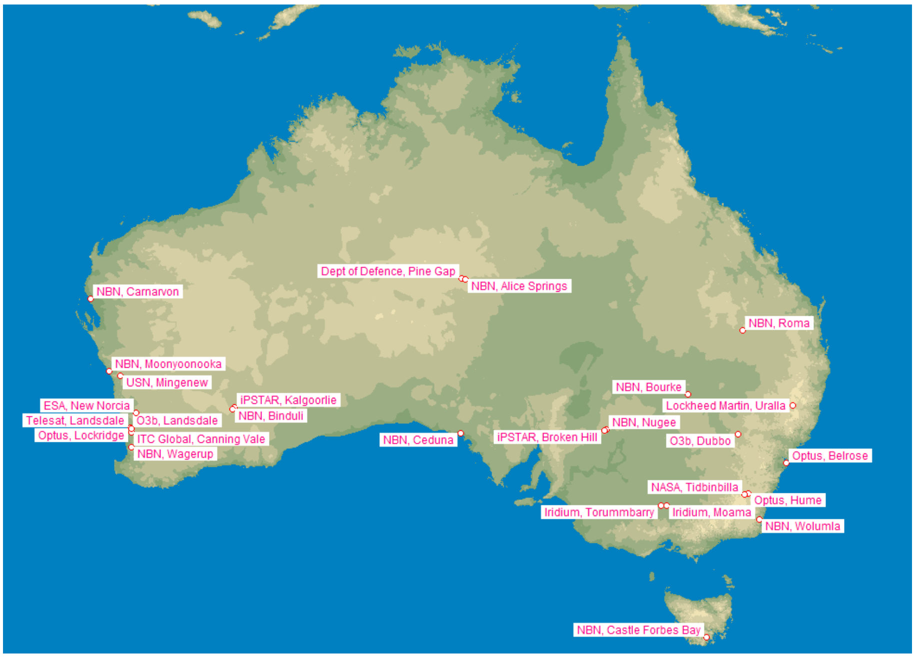
- Ground terminal transmit: 28.5 GHz to 29.1 GHz, 29.5 to 30 GHz
- Ground terminal receive: 17.7 to 18.2 GHz, 18.8 to 19.3 GHz, 19.7 to 20.2 GHz

Individual trunk and feeder links operating within the fixed satellite service have individual licences. The individual trunk / feeder link sites that use frequencies above 17.3 GHz are shown in Figure 2-1.

The ACMA reported that in 2011[16] there were 4x17 GHz BSS feeder link sites and 2x30/20GHz FSS sites. Our analysis of current licensing data suggests that the number of BSS feeder link sites has not changed but the number of FSS sites using 30/20 GHz has increased, noting that a few of these operate in the defence part of Ka-band and/or are related to activities other than commercial communications.

In addition to the licensed locations discussed above and shown in Figure 2-1 there is also a protected site at Yarragadee/Mingenew in Western Australia. At this site, which is addressed by Embargo No.49, new frequency assignments are not made to terrestrial services within 100 km of the site for frequencies above 12 GHz. This embargo is designed to support the siting of space communication facilities at Yarragadee/Mingenew rather than elsewhere thereby potentially reducing the impact of these services on the availability of spectrum in locations where there is high demand from other services.

Figure 2-1: BSS feeder link and FSS sites (> 17.3 GHz)



Source: ACMA online licensing database accessed October 2015

[15] Radiocommunications (Communication with Space Object) Class Licence 2015.

[16] Earth station siting, Guidance on the establishment of new Earth stations and other space communications facilities or the expansion of existing facilities, ACMA, August 2011 http://www.acma.gov.au/webwr/_assets/main/lib410042/ifc27-2011_earth_station_siting.pdf

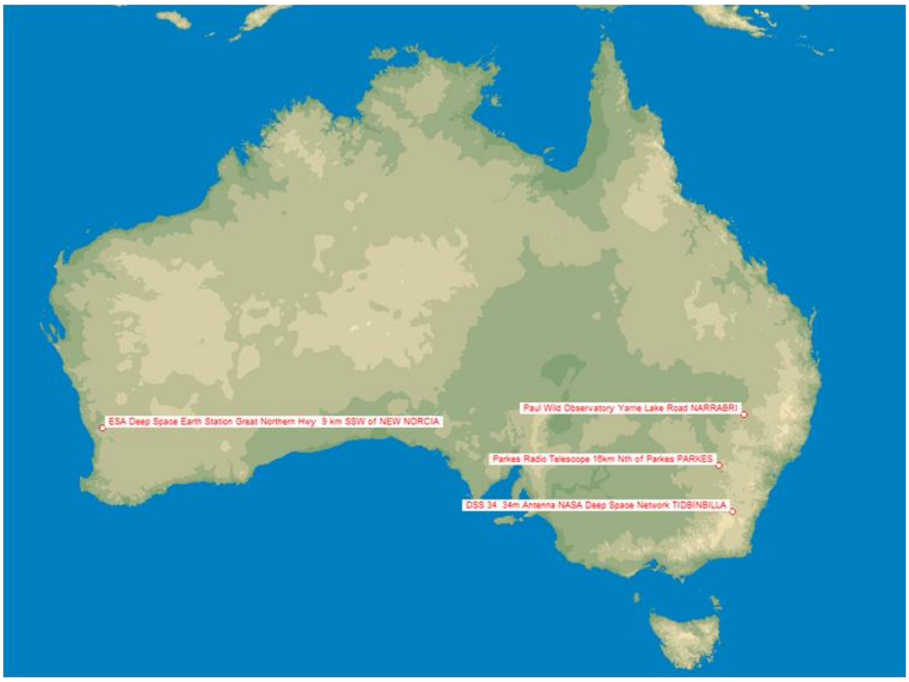
2.3.3 Space Science services

The key space science services are:

- The earth exploration satellite service which can be active or passive
- The space research service which can be active or passive and include deep space operations
- Radioastronomy

For frequencies above 17 GHz these services are supported at four sites across Australia (Tidbinbilla, Narrabri, Parkes and New Norcia) as shown in Figure 2-2. The ACMA reported that in 2011 there were three other sites at Coonabarabran, Ceduna and Hobart that required use of frequencies in the range 16 to 26 GHz in the longer term[17]. Footnote AUS87 to the Australian Radiofrequency Spectrum Plan 2013 indicates that the Narrabri and Coonabarabran sites might also operate in the band 30 – 50 GHz.

Figure 2-2: Space science sites (> 17.3 GHz)



Source: ACMA online licensing database accessed October 2015

2.3.4 Further site location information

Table 2-6 provides further information obtained from the ACMA on-line licensing database (in October 2015), on those sites which currently are used for assignments above 17.3 GHz and are shown in Figure 2-1 and Figure 2-2. The majority of the sites are located in remote and low density geographic areas.

[17] Earth station siting, Guidance on the establishment of new Earth stations and other space communications facilities or the expansion of existing facilities, ACMA, August 2011 http://www.acma.gov.au/webwr/_assets/main/lib410042/ifc27-2011_earth_station_siting.pdf

Table 2-6: Information on sites with assignments above 17.3 GHz – October 2015

Site ID	Location	Licensee	Geographic factor
140932	2 Abattoir Rd, MOONYOONKA	NBN Co Ltd	Low
141308	Corner Santa Teresa Rd and Davis Rd, ALICE SPRINGS	NBN Co Ltd	Remote
140893	Lot 101, Peter Bryant Drive, BOURKE	NBN Co Ltd	Remote
141426	End of Grau Place (Off Mahoney Avenue), CARNARVON	NBN Co Ltd	Remote
140986	Lot 617, Goode Rd, CEDUNA	NBN Co Ltd	Remote
101172	Cobb Highway, MOAMA	Iridium	Low
55761	Defence Site, PINE GAP	Dept. of Defence	Remote
11552	DSS 43 70m Antenna NASA Deep Space Network, TIDBINBILLA	Commonwealth Scientific and Industrial Research	Low
131922	ESA Deep Space Earth Station, Geat Northern Highway, 9 km SSW of NEW NORCIA	INMARSAT SOLUTIONS BV	Remote
140920	Geeveston 479 Harwoods Rd, CASTLE FORBES BAY	NBN Co Ltd	Low
9019152	ITC Global Earth Station Site, 48 Mordaunt Circuit, CANNING VALE	ITC Global	Medium
140987	Kalgoorlie Lot 300 Halls Road, BINDULI	NBN Co Ltd	Remote
141006	Lot 1 Barrier Highway, NUGEE	NBN Co Ltd	Remote
101171	Murray Valley Highway, TORRUMBARRY	Iridium Australia LLC	Low
9016627	O3b Earth Station 7.3 Metre Antenna, 620 Gnangara Rd, LANSDALE	O3B Teleport Services	Medium
138526	Optus Canberra 1 13.1 m Earth Station, 47 Raws Crescent, HUME	Optus Satellite Network Pty Ltd	Low
138527	Optus Canberra 2 13.1 m Earth Station, 47 Raws Crescent, HUME	Optus Satellite Network Pty Ltd	Low
4254	Optus Earth Station Challenger Drive BELROSE	Optus Satellite Network Pty Ltd	High
132056	Optus Lot 4 Altone Rd, LOCKRIDGE	Optus Satellite Network Pty Ltd	Medium

Site ID	Location	Licensee	Geographic factor
131146	Pivotel Satellite Gateway off Burraway Road, DUBBO	O3B Teleport Services	Low
140988	Roma 6 Kimbler Rd, ROMA	NBN Co Ltd	Remote
132295	Shin Satellite Earth Station, BROKEN HILL	iPSTAR Australia Pty Ltd	Remote
132294	Shin Satellite Earth Station, KALGOORLIE	iPSTAR Australia Pty Ltd	Remote
131776	Site 1 Big Ridge Road URALLA	Lockheed Martin Australia Pty Ltd	Low
204818	Telesat 13 m Antenna 620 Gnangara Road LANSDALE	INMARSAT SOLUTIONS BV	Medium
140173	USN Yatharagga Depot Hill Rd, MINGENEW	Universal Space Network Inc	Low
140998	Waronna Lot 1 South Western Highway WAGERUP	NBN Co Ltd	Low
140864	1210 Wanatta Lane WOLUMLA	NBN Co Ltd	Low

Source: ACMA online licensing database accessed October 2015

2.4 Market situation

Two potential growth areas in Ka band are satellite broadband services and new satellite TV services. In both receivers are usually class licensed because of their ubiquitous nature. The market situation for these services is described below.

2.4.1 Satellite broadband

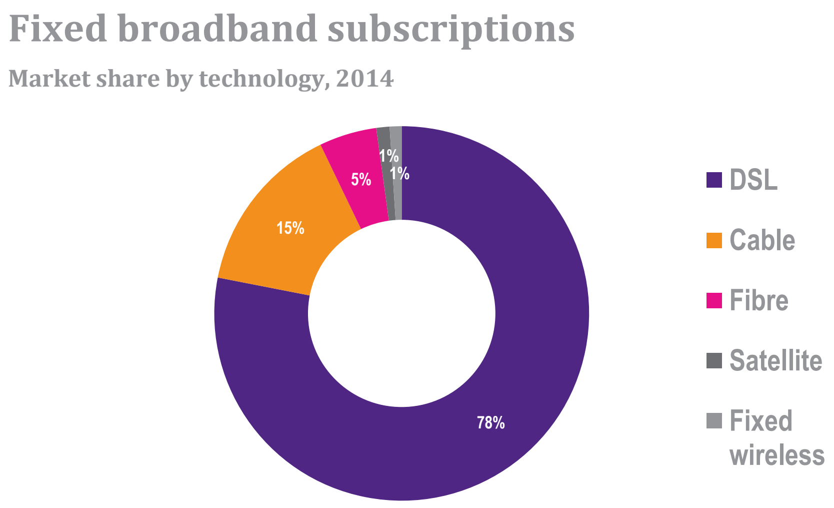
According to the ACMA's Communications Reports[18] the number of satellite broadband internet subscribers has fallen 29% since the peak in June 2010 of 113,000 to 80,000 in June 2014. The total number of internet subscriptions (fixed and mobile) in Australia was over 33 million in June 2014 – hence satellite internet services serve a small section of the total market (see Figure 2-3). This is not surprising given the low proportion of the Australian population that lives in rural areas: around two thirds of the population live in the Capital Cities[19] and 89% live in urban areas[20].

[18] http://www.acma.gov.au/theACMA/Library/Corporate-library/Corporate-publications/communications-report

[19] http://www.abs.gov.au/ausstats/abs@.nsf/Latestproducts/3218.0Main%20Features12013-14?opendocument&tabname=Summary&prodno=3218.0&issue=2013-14&num=&view=

[20] http://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS

Figure 2-3: Fixed broadband subscriptions - 2014[21]



Source: Plum Consulting, OECD

The future take-up of satellite broadband services will be largely determined by nbn policy and its implementation. A key part of the nbn strategy is fixed satellite broadband for rural areas.[22] The nbn satellite broadband network, replacing an interim service offering and operated in Ka band by IP Star, will use ten earth stations and two satellites; the first satellite was launched on the 1st October 2015[23] and the second will be launched in mid-2016. Services, offering up to 5 Mbps uplink and up to 12 Mbps and 25 Mbps downlink will be available from mid-2016 through the nbn's retail partners. The nbn expects that its two satellites will deliver broadband services to more than 200,000 rural and remote homes and businesses[24].

Even if demand were to increase beyond this it is unlikely that congestion with respect to the space and ground segments will occur within the timescale being addressed by this study (i.e. 5 years) and probably longer term. The space segment spectrum is managed internationally and availability of orbit / spectrum "slots", insofar as service to Australia is concerned, is unlikely to be constrained unless ITU administrative procedures fail to operate efficiently. Congestion in the ground segment with respect to gateway earth stations (rather than user terminals) is similarly unlikely to be constrained as the number of locations will be limited in quantity for commercial reasons.

2.4.2 Satellite TV

Foxtel offers subscription TV services via cable, satellite and IPTV. It currently has 2.8 million subscribers,[25] but it is unclear how many use the satellite platform. Foxtel use DVB-S2 for their 4 HD downlinks on Optus D3.

[21] OECD Broadband Portal accessed in October 2015 http://www.oecd.org/sti/broadband/oecdbroadbandportal.htm

[22] http://www.nbnco.com.au/connect-home-or-business/information-for-home-or-business/satellite.html

[23] http://www.nbnco.com.au/content/dam/nbnco2/documents/lift-off-for-first-nbn-satellite.pdf

[24] http://www.nbnco.com.au/connect-home-or-business/information-for-home/satellite.html

[25] http://www.theaustralian.com.au/business/foxtel-subscriber-numbers-surge-9-per-cent/story-e6frg8zx-1227481420595

The only other direct to home (DTH) satellite operator in Australia[26] is VAST (Viewer Access Satellite Television) – a free-to-air publically-owned venture which launched in 2010 with the aim of providing a limited number of public service radio and television channels in areas not reached by other services[27]. VAST uses two Optus satellites to broadcast across the country. VAST transmit using DVB-S2.

2.4.3 Satellite operators at Ka band

The majority of the satellite operators we have identified operate in Ku band[28]. According to the ACMA apparatus licence data there are two satellite licensees, namely Inmarsat and nbn that operate in Ka band.

In August 2015 Inmarsat launched Inmarsat 5F3 which is the third of the Inmarsat Global Xpress constellation and operates in Ka band. Inmarsat 5F3 is intended to provide high speed broadband coverage to the Pacific, Asia and West Americas[29]. The satellite has 89 Ka band narrow spot beams and 6 steerable beams that can be used to provide additional capacity in real time as necessary.

nbn launched the Sky Muster satellite on October 1 2015 and it has 101 Ka spot beams that are intended to provide services across Australia in Q2 2016 (Figure 2-4).

Figure 2-4: Example of possible coverage from nbn Sky Muster satellite[30]

Source: nbn

[26] Foxtel bought its main competitor Austar in 2012.

[27] https://www.myvast.com.au/

[28] http://www.tech-faq.com/ku-band.html

[29] http://www.inmarsat.com/service/global-xpress/

[30] http://www.nbnco.com.au/blog/five-questions-with-nbns-satellite-program-director.html

In addition spectrum was awarded in the 27 GHz auction to Shin Satellite Public Co Ltd (now Thaicom) in the band 27.35 – 27.5 GHz to provide regional / remote services in Western Australia and Optus in the band 26.85 – 27.35 GHz[31]. The Thaicom 4 satellite operates in both Ku and Ka bands and in the Ka band provides 18 spot gateway (uplink) beams to provide voice, video and broadband Internet services to 14 countries including Australia.

The Optus C1 (Optus and Defence C1) satellite has a military Ka payload of 4 x 33 MHz active transponders and one spare and provide medium to high data rate defence theatre coverage and duplex video, along with voice and data communications. In addition it also provides X-band telecommunications links to the military.

2.5 Spectrum fees

There are two types of fees applicable to apparatus licences used to deliver satellite services:

- An administrative charge upon licence issue or renewal "*to recover the direct costs of spectrum management*".
- Annual taxes "*to recover the indirect costs of spectrum management and provide incentives for efficient spectrum use*". Consistent with this principle the amount of annual taxes paid varies with the spectrum access assigned in licences (or equivalently denied to other users), where access is defined in terms of bandwidth assigned, geographic area covered and the duration of an assignment.

These fees maybe either for space transmit or receive or terrestrial transmit or receive licences as described in Section 2.2 of this report. The fees described below are given in the April 2015 Apparatus licence fee schedule[32].

2.5.1 Administrative charges

Administrative charges are levied on the issue and renewal of licences. The charges for issuing licences are the fixed amounts shown in Table 2-7, although before April 2015 the administrative charges depended on the time taken to perform administrative tasks and published hourly rates. Renewal of licences is charged at $4.00.

[31] This spectrum is now apparatus licensed.

[32] http://www.acma.gov.au/theACMA/About/Making-payments/Apparatus-licence-fees/apparatus-licence-fees-acma

Table 2-7: Administrative charges

Licence	Administrative charge from April 2015 (AU$)
Earth receive station	148
Fixed Earth station	197
Mobile Earth station	99
Space	99
Space receive	99

2.5.2 Annual taxes

The taxes are calculated using the general formula:

Normalisation factor × Bandwidth × Power × Location weighting × Adjustment factor

Where the factors in the formula for satellite services are as defined in Table 2-8.

The bandwidth and power variables reflect the frequency and geographic aspects of spectrum denial whereas the normalisation factor and the location weighting reflect the value of the spectrum in different frequency bands at more/less congested locations.

Table 2-8: Annual tax formula definitions for satellite services

Factor	Definition
Normalisation factor	The constant converts the relative spectrum values provided by the rest of the formula to an actual dollar figure. It is updated by CPI adjustments every year to keep licence taxes constant in real terms. It is 0.263214738784162.
Bandwidth	Taxes vary depending on the bandwidth within which a service is licensed to operate.
Power[33]	There is no power factor for satellite services.
Location weighting	There are spectrum and geographic location combinations, which have each been assigned a location weighting. The location combinations reflect the density of services and demand for spectrum at different frequencies and geographic areas. Higher taxes in locations of higher density and demand encourage efficient spectrum use. The geographic categories are: Australia-wide High density Medium density Low density Remote density The relevant spectrum locations categories are: 14.5-31.3 GHz 31.3-51.4 GHz Thus there are 10 location combinations relevant for our study.
Adjustment factor	There are five adjustment factors that modify the tax levels of some licensing options. This introduces the flexibility to vary taxes according to parameters that are not included in the tax formula. None of these apply to satellite services: hence the factor equals one.

Hence for satellites the apparatus licence fees formula is:

$$0.26 \times \text{Bandwidth} \times \text{Location weighting}$$

This gives the taxes shown in Table 2-9 for the frequency ranges that are the subject of this study.

[33] In general apparatus licence fees include a power factor which allows a reduced tax for low-power spectrum accesses, as they deny spectrum to other users over a small area. Spectrum accesses that are not low power have a power factor of one. Low-power spectrum accesses permit the operation of one or more devices, each with a radiated power level of 8.3 watts EIRP or less, and designed for operation within a radius of two kilometres. These types of services pay one-tenth of the annual tax that would otherwise apply (subject to the minimum tax of $37.48).

Table 2-9: Annual tax ($) per kHz

Spectrum location	Geographic location				
	Australia-wide	High density	Medium density	Low density	Remote density
>14.5 to 31.3 GHz	0.9768	0.2601	0.0571	0.0061	0.0029
>31.3 to 51.4 GHz	0.2664	0.1419	0.0308	0.0011	0.0005

Source: Apparatus licence fee schedule, ACMA, April 2015

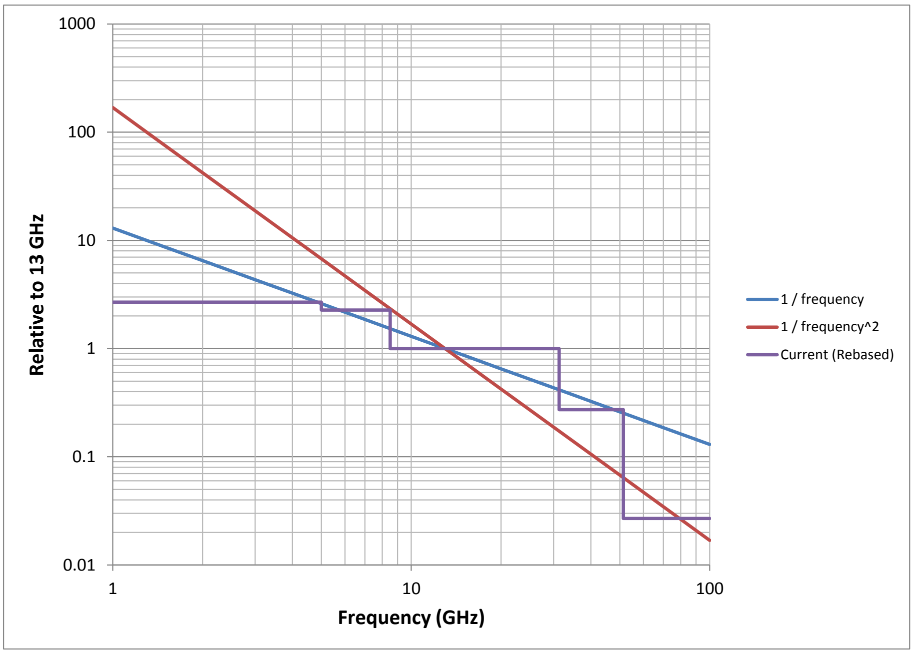
As can be seen from Table 2-9, the taxes fall significantly moving from high density to remote density areas. There are three high density and three medium density areas in Australia.

The Australia-wide tax for the 14.5-31.3 GHz range is greater than the maximum sum of taxes that could be charged for high and medium density areas but this is not the case for the 31.3-51.4 GHz range. While in the latter case there could be a strong incentive for operators to apply for an Australia-wide licence this is not the case because of the many limitations that apply to such a licence.

Figure 2-5, Figure 2-6 and Figure 2-7 show the Australia-wide fee schedule for frequencies above 1 GHz (normalised to equal 1 at 13 GHz)[34] together with lines showing values for hypothetical schedules in which fees vary inversely with frequency and frequency squared. Comparison of these schedules suggests the Australia-wide and medium density area schedules are relatively invariant with frequency below 30 GHz. The schedule for the remote area declines more steeply with frequency though oddly increases in value at 2.69 GHz (Figure 2-7) suggesting there is an anomaly in the remote area tax schedule.

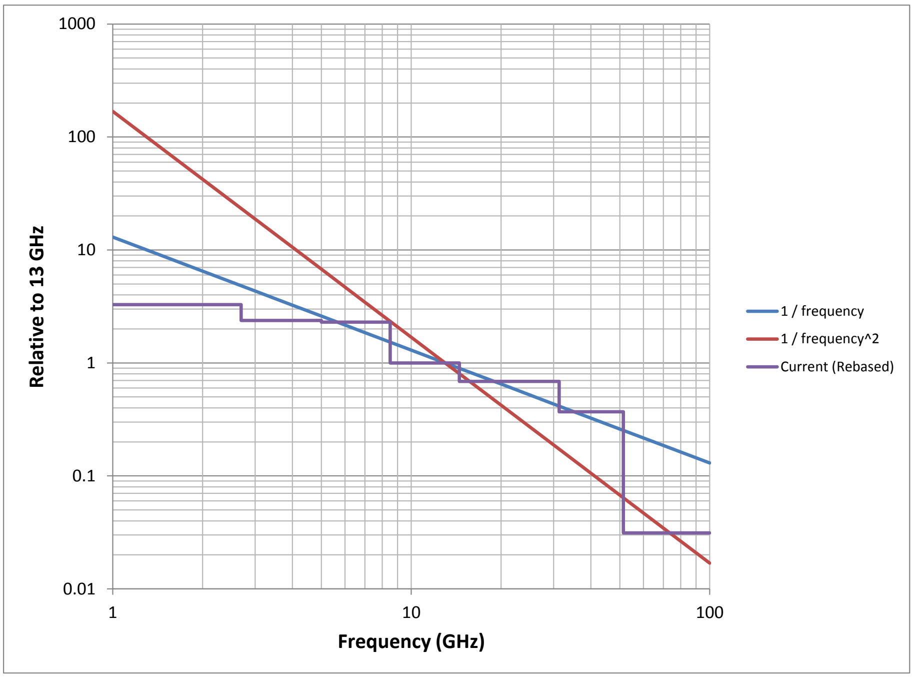
[34] As the values generated from the current fee schedule show relative values, they are invariant to annual inflationary adjustments.

Figure 2-5: Australia-wide tax schedule in relation to inverses of frequency and frequency squared



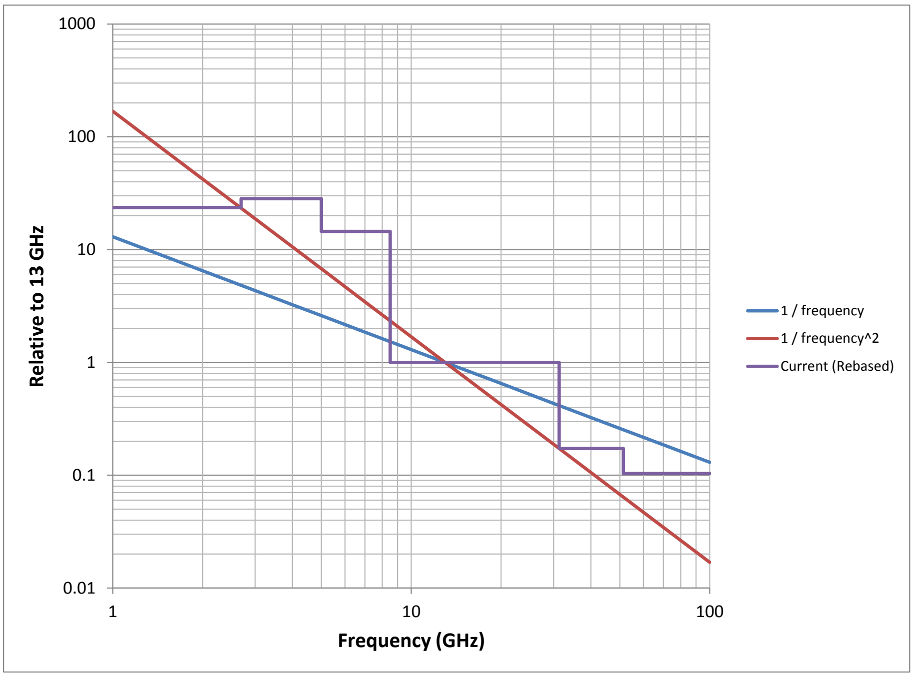
Source: Plum analysis

Figure 2-6: Medium density area tax schedule in relation to inverses of frequency and frequency squared



Source: Plum analysis

Figure 2-7: Remote area tax schedule in relation to inverses of frequency and frequency squared



Source: Plum analysis

There are two exceptions to the tax fees schedule for satellite licensees:

- The tax is reduced by 75% where CDMA technology is used for a space licence in the 2483.5–2500 MHz band or a space receive licence in the 1610–1626.5 MHz band.
- NGSO satellites operating above 8.5 GHz have a fixed annual tax of $275 per MHz[35] or $0.275/kHz.

The basis for these exceptions is not known.

2.5.3 Application of the fees

Fees are paid by all transmit spectrum accesses. Receive spectrum accesses are only chargeable where the Receiver Tax Determination applies. Earth Receive and Space Receive licences are an example of where this would apply. Licences for earth stations either authorise a transmitter (Earth) or they authorise a receiver (Earth Receive). The same is true for Space licences with transmit being authorised by a Space licence and receive being authorised by a Space Receive licence. It is not obligatory for a satellite operator to obtain receive apparatus licence since there is an option for receivers to be authorised under the Space Objects Class Licence. An earth receive licence can be sought if the operator wishes to secure interference protection for their receiver.

The Radiocommunications (Transmitter Licence Tax) Determination 2015[36] governs the application of taxes if a device is licensed via a transmitter licence. Part 2 of the determination states that each

[35] Division 6 of the fees schedule

[36] http://www.acma.gov.au/theACMA/About/Making-payments/Apparatus-licence-fees/apparatus-licence-fees-acma#legislation

‘spectrum access’ incurs a tax. Under this determination a spectrum access is defined as: “*access to the spectrum that is authorised for the operation of one or more radiocommunications devices that involves a unique combination of:*

(a) a particular transmit frequency; and

(b) a particular bandwidth; and

(c) a particular site or access area.”

The ACMA’s Radiocommunications site data requirements appear to define antennas that are 30m distant from each other as different sites[37]. However, in practice if two transmitters are collocated and they use the same frequency and bandwidth they incur two spectrum tax payments.

The Radiocommunications (Receiver Licence Tax) Determination 2015 governs the application of receiver taxes. So if a device is licensed via a receiver licence (as sometimes applies for space and earth station licences) then each spectrum access under a receiver licence incurs a separate tax.

If an Australia-wide licence is obtained and receivers are class licensed then the satellite operator may reuse the frequency as many times as technically possible. In this circumstance the Australia-wide licence provides an indirect incentive for high frequency reuse across Australia and to use narrower spot beams because of the higher reuse obtained (all else being equal)[38]. If spot beams are used by a satellite and an Australia-wide licence is not required then the tax is based on the tax for highest density area covered i.e. if a high and a low density area are covered then the tax will be that for the high density area.

2.6 Issues to be addressed

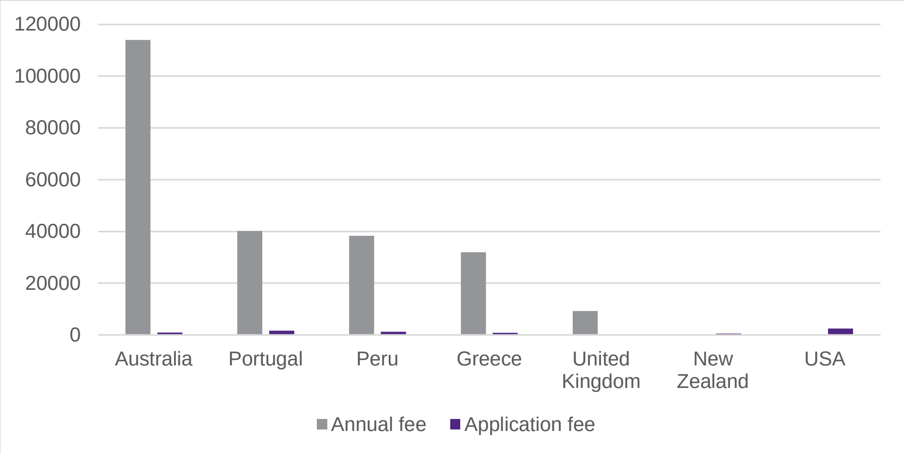
The basis for the current levels of the apparatus tax fees levels is not known and some industry participants have argued the fees are too high given the relatively light use of the frequencies. For example O3b Limited (“O3b”) raised the issue of satellite fees in their response to the ACMA’s five year outlook, 2012–2016[39] and presented the data shown in Figure 2-8 showing that Australian fees for a tracking, telemetry and control (TT&C) gateway earth station are greater than elsewhere.

[37] See Section 7, Page 12 of Radiocommunications site data requirements, August 2012.

[38] Information from the ACMA’s licensing database suggests that at Ka band use of spot beams would allow reuse of 32 would be possible as compared with 4 using a wide beam.

[39] Letter to the ACMA from O3b dated 31 August 2012 http://www.acma.gov.au/~/media/Spectrum%20Licensing%20Policy/Report/submissions%20to%202012%20to%202016%20FYSO/20120831%20O3b%20comments%20ACMA%205%20yr%20spectrum%20outlook%20consultation%20FINAL%20PDF%20pdf.

Figure 2-8: Comparison of fees for a TT&C gateway earth station provided by O3b



Source: O3b data

The appropriate level of fees should in principle depend on the extent of spectrum congestion – the greater the congestion the higher the opportunity cost of spectrum. Assignment data presented in this section suggest most satellite spectrum use is in rural and remote parts of Australia where congestion is unlikely to occur. Furthermore we understand from the ACMA that its frequency assigners have not had any problem finding spectrum to meet requests from satellite operators at Ka band, which suggests there is not a congestion issue. However, we investigate the congestion issue further in Section 3 where we report trends in satellite demand and whether there is likely to be demand from other services for spectrum in bands used by satellite services.

Issues concerning the structure of fees that need to be considered are:

- The two exceptions to the apparatus fees schedule for NGSO systems and CDMA technology have no obvious justification and their removal should be considered.
- The way the fees are currently structured does not take explicit account of the spectrum denial areas for licensed earth stations. However, this issue does not arise for satellite systems because with an Australia-wide licence an operator has a strong incentive to maximise its capacity by using spot rather than narrow beams, as no additional fee is paid for frequency reuse.
- There is no explicit financial incentive for a licensee to collocate earth stations to minimise their impact on other services. However, the ACMA has an administrative policy of promoting satellite parks[40] and one park has been established at Yarragadee/Mingenew in Western Australia.
- The increase in fees for remote area licences at 2.69 GHz should be removed as part of any consideration of the level of fees.

[40] http://www.acma.gov.au/theACMA/ifc-272011-earth-station-siting

3 Trends and future demand

This section looks at how demand for spectrum in the range 17.3 – 51.4 GHz could develop in the next five years. Demand for spectrum from the following services is considered:

- 5G
- Fixed links
- Satellite services
- Space science services
- Other services e.g. body scanners.

For fixed links and satellite services we provide data on trends in assignments and their characteristics to inform the discussion of possible future levels of demand for spectrum from these services.

3.1 5G[41]

There may be future demand for spectrum in the 17.3 – 51.4 GHz range from 5G services. A large number of bands above 6 GHz were identified as potential candidates for future 5G deployment prior to WRC-15. At WRC-15 it was agreed that there should be an agenda item at WRC-19 to identify frequency bands for 5G but a reduced set of bands were agreed at the conference preparatory meeting (CPM), that followed WRC-15, for study[42], namely:

- 24.25 – 27.5 GHz
- 31.8 – 33.4 GHz
- 37 – 43.5 GHz
- 45.5 – 50.2 GHz
- 50.4 – 52.6 GHz
- 66 – 76 GHz, and
- 81 – 86 GHz[43].

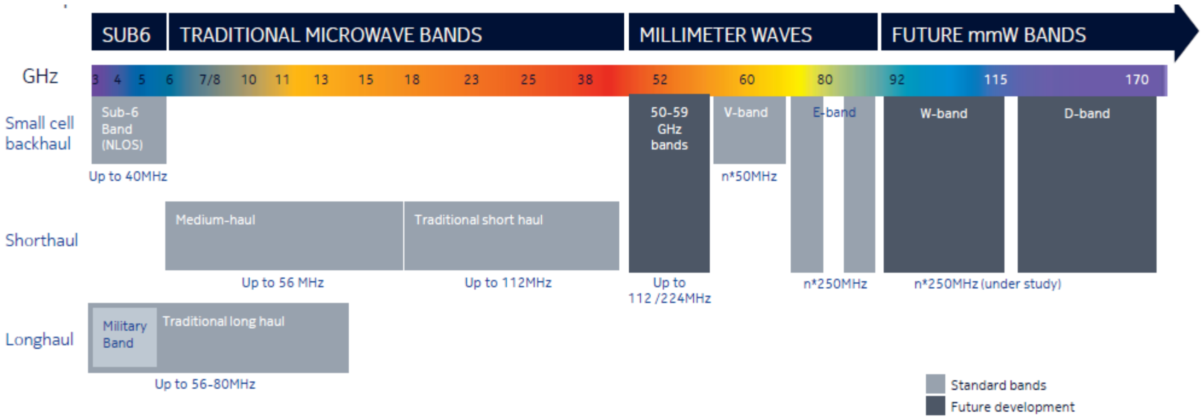
All bar three of these bands are already identified as a co-primary allocation for mobile in the Radio Regulations. In addition some of these bands are already being used for fixed links, or have been identified, to provide 5G mobile backhaul links (see Figure 3-1). Similarly some of these bands are already utilised / identified for satellite.

[41] The ACMA has recently consulted on 5G http://www.acma.gov.au/theACMA/5g-and-mobile-network-developments

[42] Source: p426, Provisional Final Acts World Radiocommunication Conference (WRC-15) 2 – 27 November 2015http://www.itu.int/dms_pub/itu-r/opb/act/R-ACT-WRC.11-2015-PDF-E.pdf

[43] A number of bands that had been proposed prior to WRC-15 were omitted from the list but there may be further lobbying to include additional bands for 5G mobile deployment such as the 28 GHz band.

Figure 3-1: Indicative bands for 5G backhaul



Source: Nokia Presentation on "Carrier Aggregation in microwave backhaul". Layer 123 Webinar, 9th February 2016

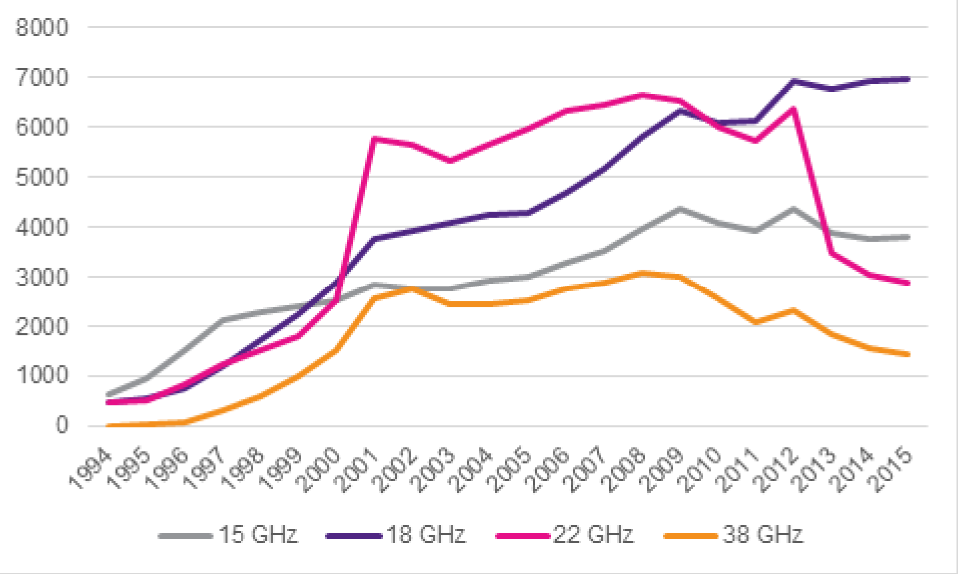
However, the bands that will be designated for 5G will not be known until after WRC-19 – at the end of the five year timeframe for the demand analysis. This uncertainty makes it impossible to conclude there will be congestion in particular frequency ranges as a result of demand from 5G. Therefore, as agreed with the ACMA, the demand analysis will not directly consider the impact of 5G and congestion in satellite bands.

3.2 Fixed links

3.2.1 Assignment trends

Figure 3-2 below shows the trends in the number of assignments for 15 GHz and the three main fixed links bands above 17 GHz based on data provided by the ACMA. It can be seen that there has been a significant decrease in demand for the 22 GHz band since 2012 and a decrease in demand for 38 GHz since 2008. The 15 and 18 GHz bands show a different demand pattern with demand growth levelling out and falling somewhat in recent years. The fact that demand is either levelling off or decreasing in bands adjacent to 18 GHz (i.e. 15, 22 and 38 GHz) means it is unlikely that the 18 GHz band will need to be used as a substitute bands for assignments that cannot be supported in the 15, 22 and 38 GHz bands.

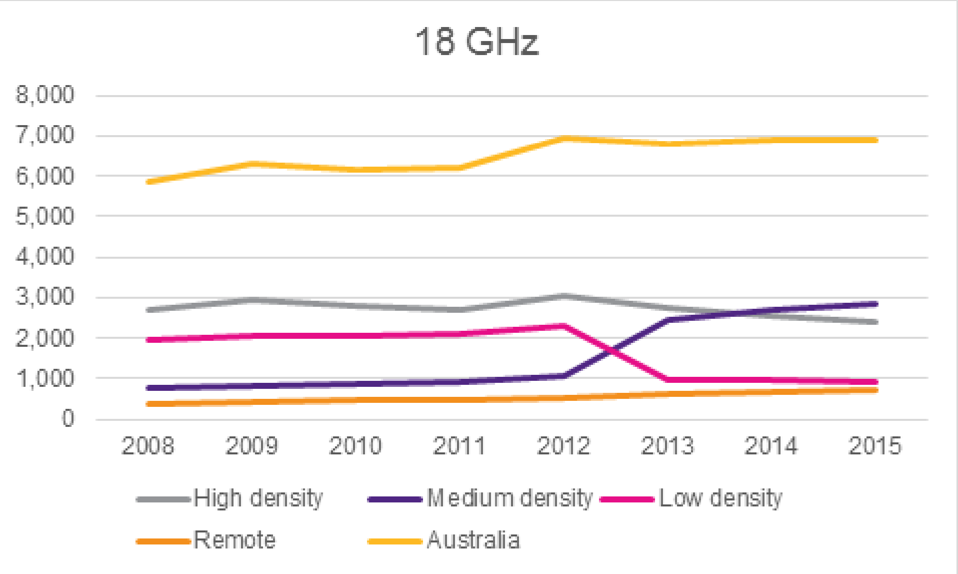
Figure 3-2: Fixed link band assignment trends at 15, 18, 22 and 38 GHz 1994-2015



Source: ACMA

In addition we have analysed the fixed links data, from 2012 to 2015, on a geographic basis and the figures below also show the ACMA analysis of assignment by frequency band between 2008 and 2012[44]. Not surprisingly the highest demands are in high density areas for the 22 and 38 GHz bands as these frequencies are often used to provide links in support of cellular networks in urban areas. Demand in high and medium density areas are similar at 18 GHz. There is no evidence of rapidly increasing demand in any area, except perhaps in medium density areas at 18 GHz.

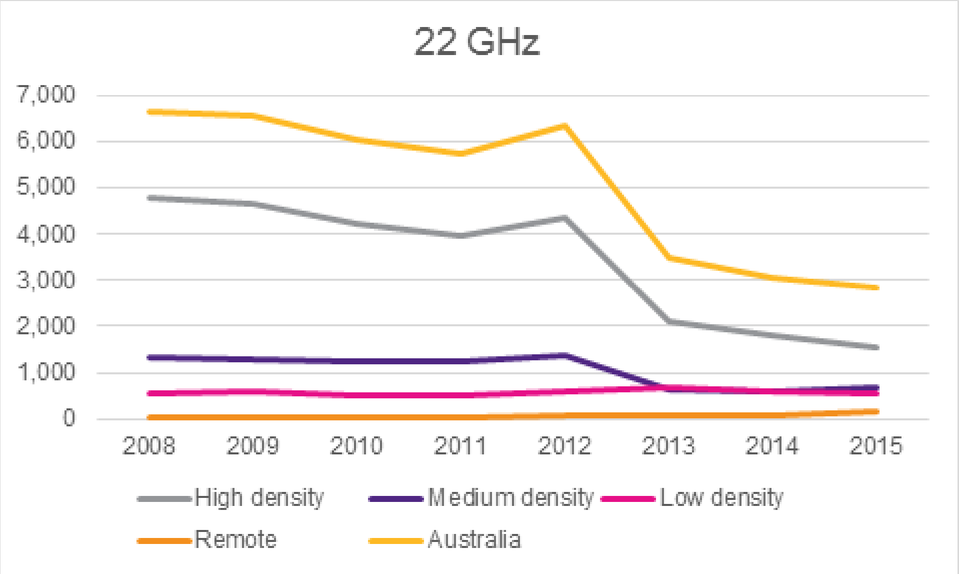
Figure 3-3: 18 GHz fixed link assignments by licence area 2008-2015



Source: ACMA

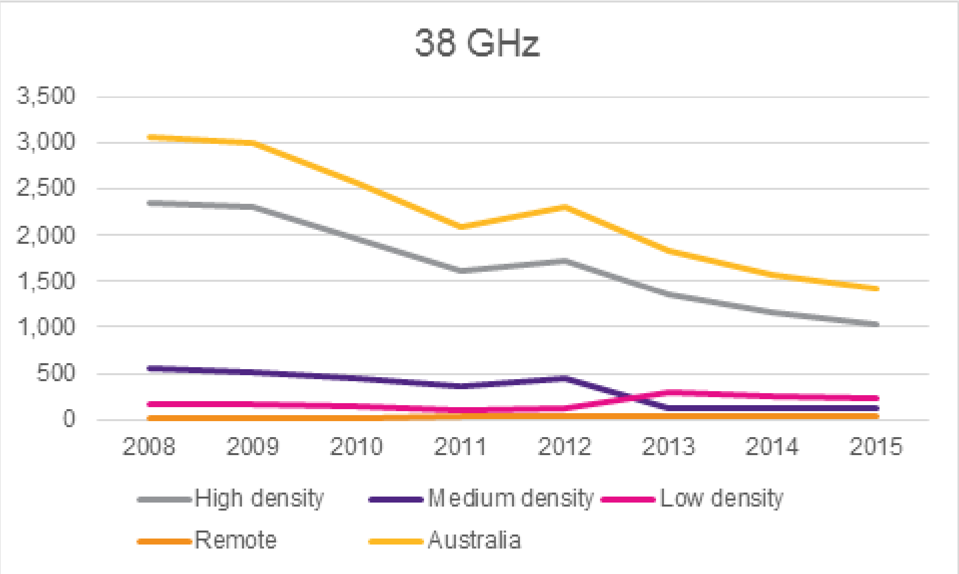
[44] As found in the ACMA report May 2014, titled "Microwave fixed point-to-point services assignment statistics – 1 January 2008 to 1 January 2012. Spectrum planning report 2014/04)

Figure 3-4: 22 GHz fixed link assignments by licence area 2008-2015



Source: ACMA

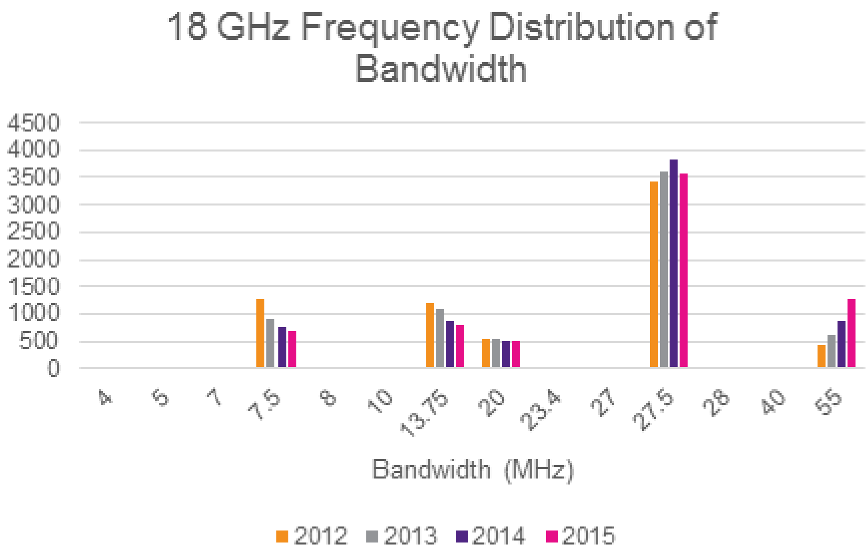
Figure 3-5: 38 GHz fixed link assignments by licence area 2008-2015



Source: ACMA

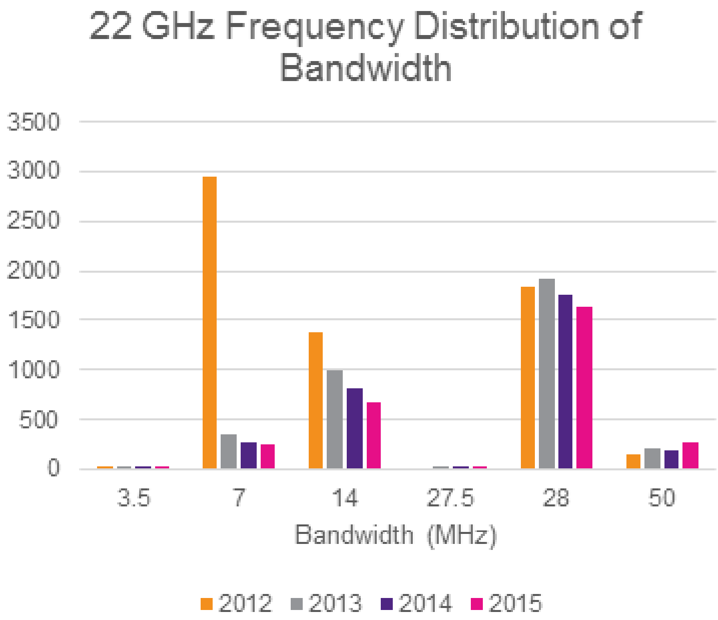
The number of assignments does not provide a complete picture of likely spectrum demand because it does not take account of the bandwidth of each assignment. Figure 3-6, Figure 3-7 and Figure 3-8 provide data on trends in assignments by bandwidth. It can be seen that in the 18 GHz band there is a definite increase in assignments for higher capacity links that require 55 MHz bandwidth. The same trend applies at 22 GHz and 38 GHz, with the proportion of links at higher bandwidths increasing though this is masked by a decrease in the number of assignments in these bands. This trend towards wider bandwidths is not surprising if the band is used for backhaul in mobile networks and broadband wireless access.

Figure 3-6: Distribution of assignment bandwidths in the 18 GHz band



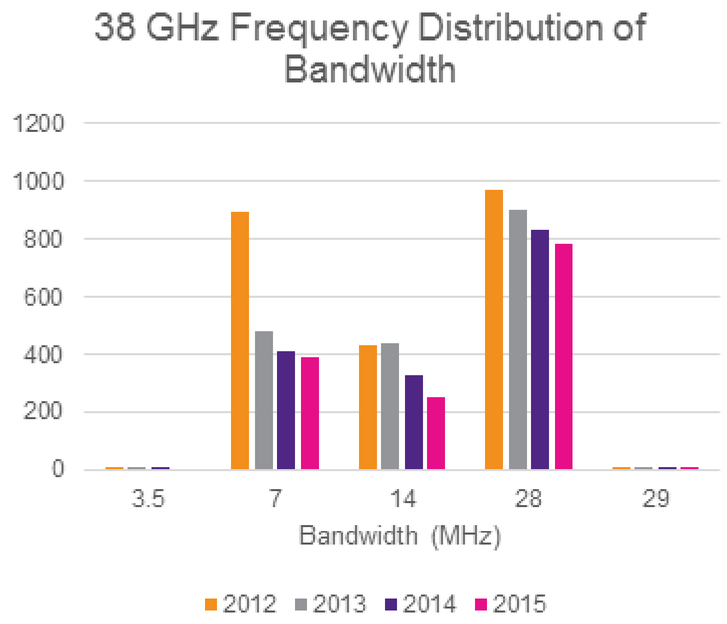
Source: ACMA

Figure 3-7: Distribution of assignment bandwidths in the 22 GHz band



Source: ACMA

Figure 3-8: Distribution of assignment bandwidths in the 38 GHz band



Source: ACMA

3.2.2 Trends in total bandwidth

In Figure 3-9, Figure 3-10 and Figure 3-11 total spectrum requirements are calculated by multiplying the number of assignments by the bandwidth of the assignment. This approach does not take into account the re-use of frequencies which could significantly reduce the total spectrum required. The bandwidth totals show that demand for the 22 GHz and 38 GHz bands is not currently increasing. In the case of the 18 GHz band totals have now increased to around 2012 levels.

Figure 3-9: Total bandwidth utilised by assignment bandwidth in 18 GHz band

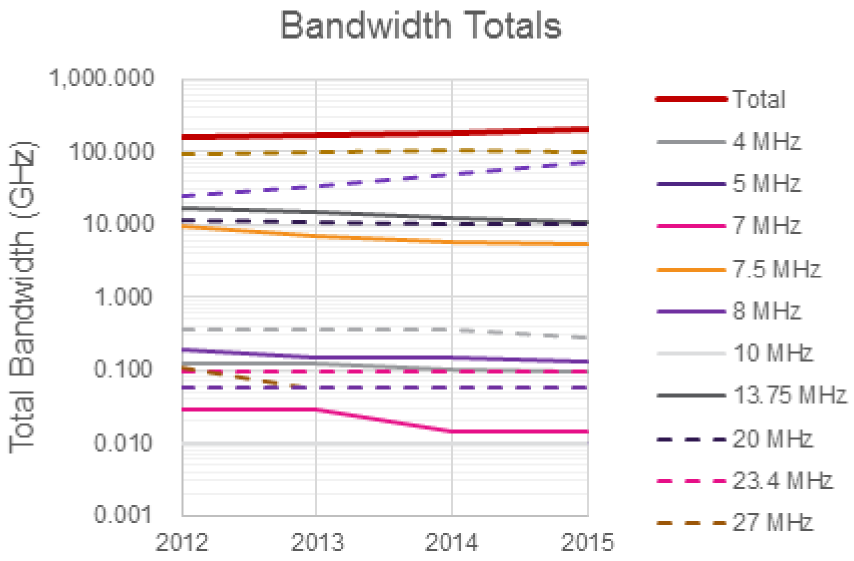


Figure 3-10: Total bandwidth utilised by assignment bandwidth in 22 GHz band

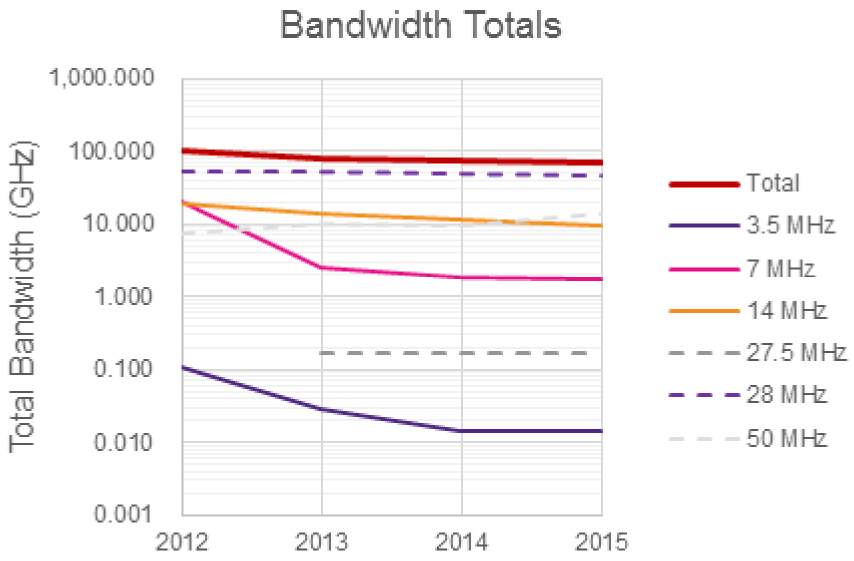
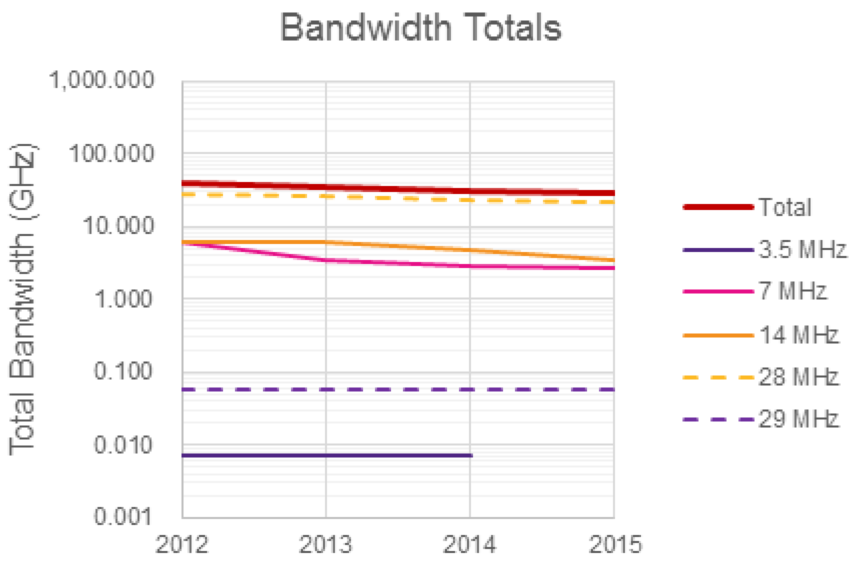


Figure 3-11: Total bandwidth utilised by assignment bandwidth in 38 GHz band

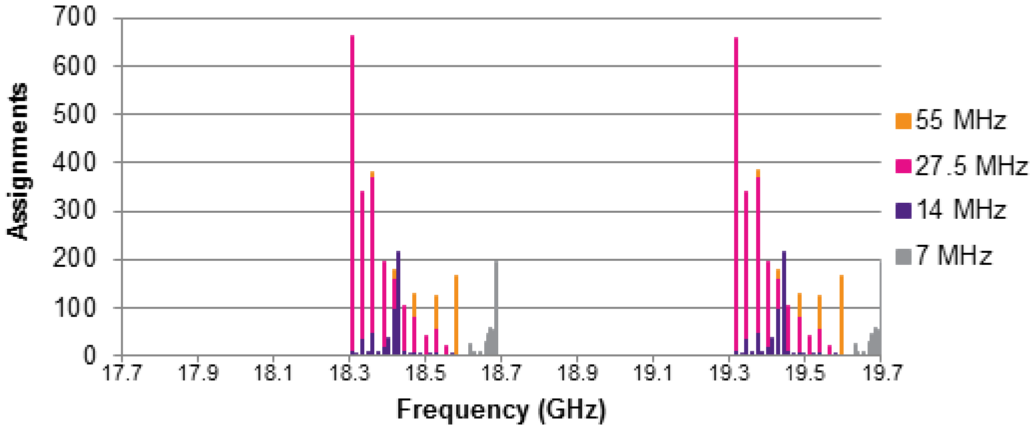


3.2.3 The future outlook

The trend data suggest that the only band in which congestion might occur is the 18 GHz band. However, channel loading information from 2012, shown in Figure 3-12 below, indicates a significant number of frequencies had not been assigned in 2012 and the number of assignments per frequency could potentially double (assuming demand was geographically dispersed). There are also numerous vacant frequencies between 17.7 and 18.305 GHz in the lower band and similarly in the upper band[45] now that the embargo on use of these frequencies has been lifted. A conservative estimate would be to assume that a doubling of spectrum demand at 18 GHz could be accommodated in existing capacity.

[45] For example ITU-R Recommendation F.595-7 indicates that one channel plan could support up to 17 off 55 MHz bandwidth links.

Figure 3-12: Channel loading in the 18 GHz band



Source: ACMA

Where might this demand come from? Future spectrum demand growth from fixed links could potentially come from requirements for backhaul from mobile operators, fixed wireless broadband or a major government user. Of these mobile backhaul, to additional cell sites or to provide higher capacity links from existing sites, is most likely to require additional spectrum[46]. However, this depends on the extent of fibre deployment to base station sites. In urban areas it can be expected that most LTE base stations will be connected to fibre for backhaul. The data show declining demand at 22 and 38 GHz in urban areas (these are generally high and medium density), probably because of substitution by fibre and we expect fibre substitution to continue as the nbn is rolled out. Use of fibre is less likely in rural areas because of the high cost relative to fixed links, though it is more likely that lower frequency bands (i.e. 10 GHz and below) will be used because of the long distances involved. Also fibre is used for very high capacity backhaul (e.g. from major gateway earth stations) because fixed links cannot reliably provide very high capacity links. Taken together these factors suggest demand for Ka-band spectrum for fixed links is unlikely to grow rapidly.

In summary, most frequency bands used by fixed links are not currently congested and have experienced declining demand trends. One possible exception is the 18 GHz band where demand has been flat in recent years, though in this band there appears to be capacity available for a doubling of demand over the next 5 years. In other words demand from fixed links is unlikely to cause congestion at Ka band and above over the next 5 years. We note that other publicly available reports for Australia, the UK and Europe have concluded that there is unlikely to be excess demand for links in frequencies above 20 GHz[47] over the next 5 or so years.

[46] We understand that a new emergency services network is unlikely over the next 5 years. See http://www.pc.gov.au/inquiries/current/public-safety-mobile-broadband#report

[47] See 2014 Plum report for Ofcom on fixed links for example. The ACMA in the paper 'Beyond 2020: A spectrum management strategy to address the growth in mobile broadband capacity' identified the need to monitor and address the need for wireless backhaul to support growth in mobile broadband capacity including the higher bands. RSPG (Radio Spectrum Policy Group) in Europe recognised the potential growth but did not identify any shortage of spectrum above 20 GHz

3.3 Satellite services

The figures below provide assignment data for satellite services, and specifically earth stations, over the period 2012 to 2015 in frequency bands above 17.3 GHz based on licensing data provided by the ACMA. The values for 2012, 2013 and 2014 are for the beginning of January, and additional data is provided for the end of 2014 and also August 2015.

Figure 3-13 and Figure 3-14 show that overall there has been an increase in earth station licences with the most significant increase occurring in the period January 2013 to December 2014 for earth station licences for the Fixed Satellite Service (FSS). Figure 3-15 and Figure 3-16 show that there has been little change in the number of licensed earth stations especially those for the FSS in the frequencies up to 18.4 GHz. Hence growth in demand for satellite service licences has been mainly in frequency bands above 18.4 GHz as a result of demand from systems delivering HDFSS such as the nbn network. It can be expected there will continue to be on-going growth in assignments for gateway earth stations to support the HDFSS service over the next five years, though not at the rate that was experienced in 2013/14 when the service was initiated.

Demand for earth stations to support space operations has recently decreased and earth station licences for space tracking have remained unchanged. The licences for fixed earth stations in the radionavigation satellite service were not renewed after 2012.

Looking to the future, Agenda Item 1.5 for WRC-19 is to consider use of the bands 17.7 – 19.7 GHz (S-E) and 27.5 –29.5 GHz (E-S) by earth stations in motion communicating with GSO FSS Satellites. This proposal is elaborated in Resolution COM6/17 (WRC-15). Two key principles are included in this Resolution, namely:

- Earth stations in motion would be expected to comply with the technical characteristics of FSS earth stations and not behave like conventional mobile earth stations (i.e. pseudo-omnidirectional terminals or terminals having limited discrimination)
- Existing services in these frequency bands and their future development should be protected without undue constraints

Assuming that these conditions are satisfied, which may or may not need to be done through band segmentation and/or exclusion areas, then the main implication for ACMA licensing is that an area rather than a location will need to be specified. It is uncertain whether this agenda item will be approved at WRC-19 and the situation should be reviewed after WRC-19.

Figure 3-13: Transmit earth stations licensed in frequency bands above 17.3 GHz

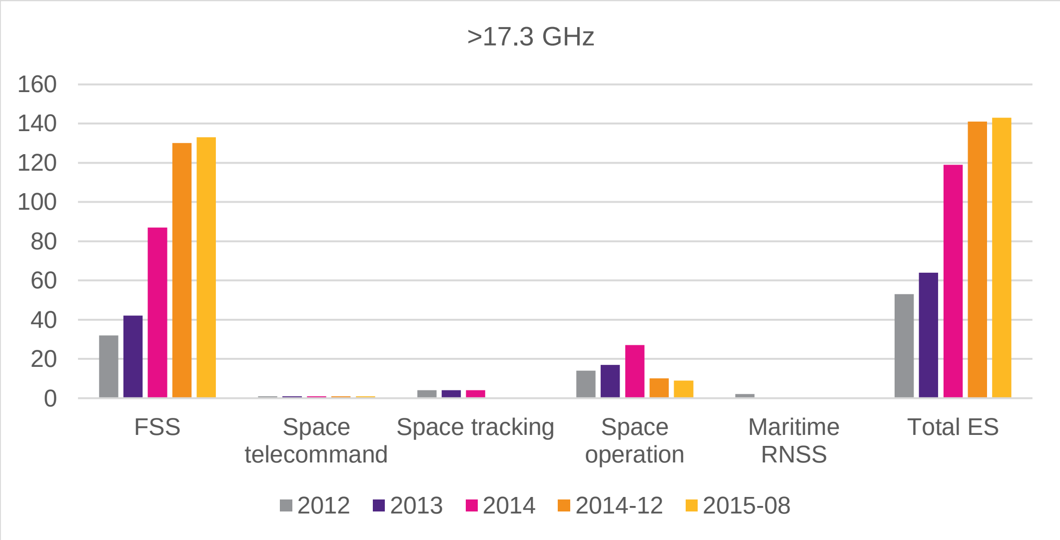


Figure 3-14: Receive earth stations licensed in frequency bands above 17.3 GHz

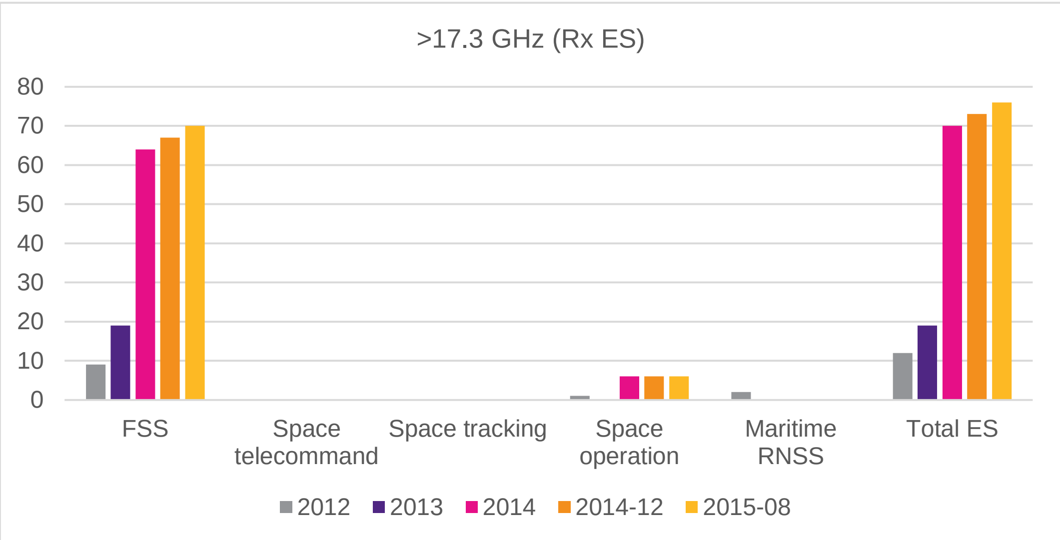


Figure 3-15: Transmit earth stations licensed in frequency band 17.3 – 17.7 GHz

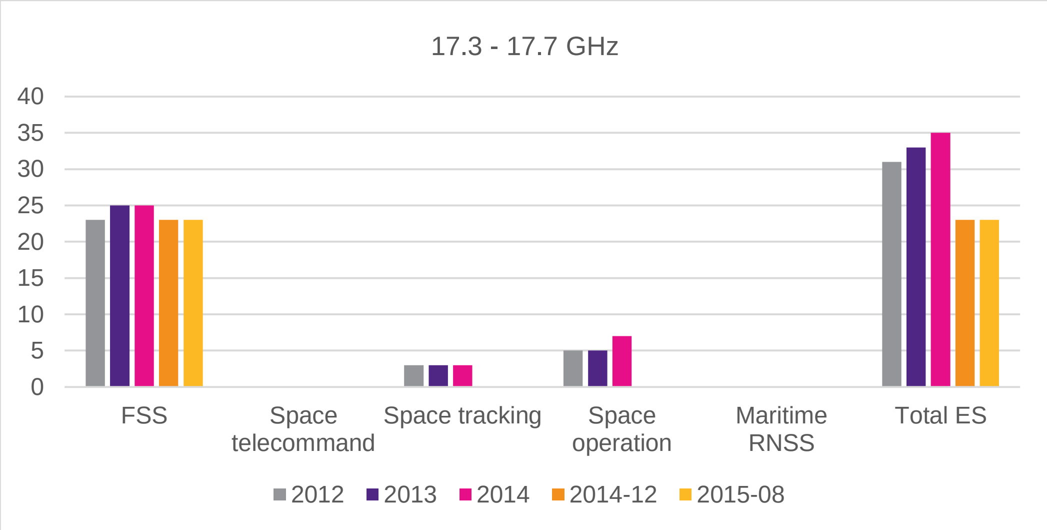


Figure 3-16: Transmit earth stations licensed in frequency band 17.7 – 18.4 GHz

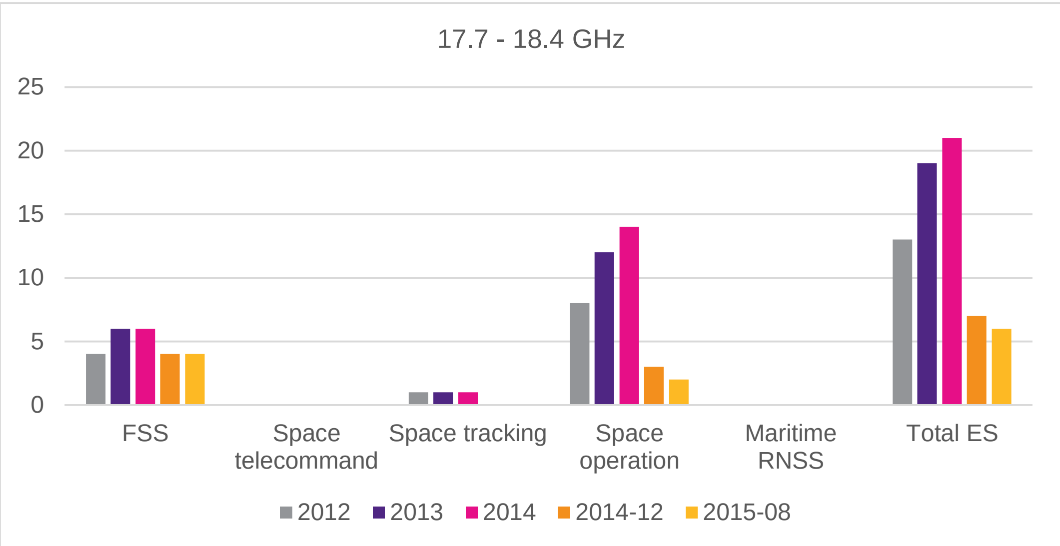
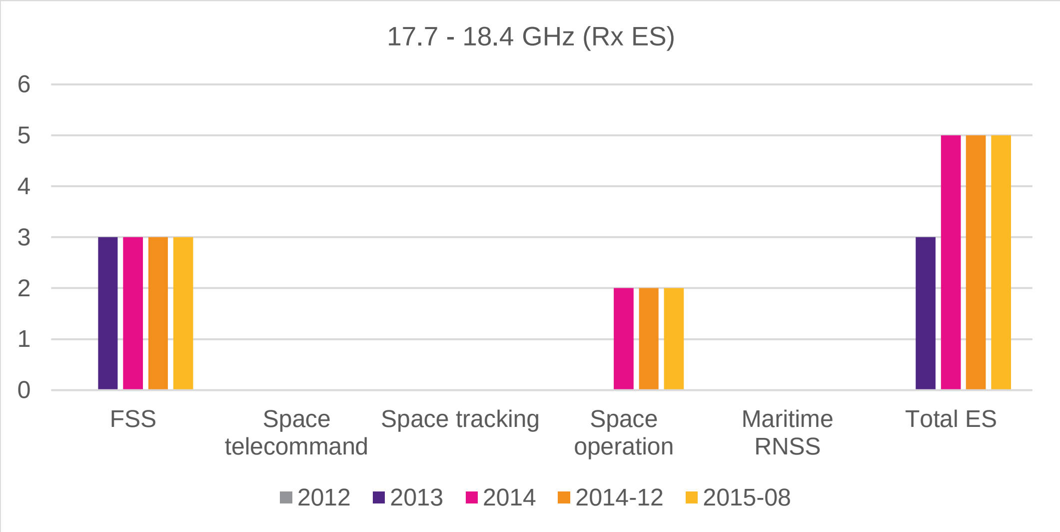


Figure 3-17: Receive earth stations licensed in frequency band 17.7 – 19.7 GHz



3.3.1 Telecommunications satellite services

Trunked satellite communications services have shown slow growth in recent years partly because of competition from fibre for long-haul traffic. There is little reason to expect any change in this situation, suggesting weak demand for spectrum though there may be some movement in demand from C-band and Ku-band to Ka-band

There have been pre-operational missions using Q/V-band frequencies although these have largely been used to investigate propagation conditions and to test new technologies. It is not expected that a commercial communications system using these frequencies will become operational prior to 2020.

3.3.2 High density fixed satellite service (HDFSS) / Mobile

More rapid growth is expected in HDFSS / Mobile services; however, demand in Australia (as in other highly urbanised countries) is uncertain.

In addition to the nbn, over the past few years HDFSS Ka-band systems have become more prevalent (e.g. Greg Wyler's O3B MEO system serving countries closest to the equator and Avanti's European system HYLAS). While Google's and Facebook's mooted satellite systems appear to have withered for the time being Elon Musk / Space-X has proposed a 4000 satellite system[48]. Other systems using Ka-band are Inmarsat's Global Xpress, Eutelsat's Ka Sat, Hughes Spaceway 3 and the UAE's Yahsat.

Of these the most important systems to Australia are nbn, O3b and Global Express. While the consumer terminals supported by these systems will be covered by class licences, the feeder link stations will be individually licensed and it is notable that one of the demonstrable growth areas is in this field. It is unlikely that the number of earth station licences for feeder links will increase much in the medium term or until the systems that these feeder links support have been proved technically and commercially.

[48] OneWeb has proposed a 648 satellite LEO system but this latter constellation is planned to be Ku-band rather than Ka-band.

WRC15 considered in agenda item 1.10 '*Additional primary allocations to the mobile-satellite service within the bands from 22 GHz to 26 GHz*'[49] the shortfall between the amount of forecast spectrum demand[50] by MSS and the amount of spectrum available by 2020. In the event no allocation was made to the mobile-satellite service in the range 22-26 GHz.

3.3.3 Broadcasting

With regard to satellite broadcasting above 17.3 GHz the two main issues are the future development of Ku-band broadcasts and the potential use of the BSS allocation at 21.4 – 22 GHz.

In the case of the former, the interest to this study is in the feeder links that operate just above 17.3 GHz rather than the Ku-band service links. Licences for spectrum use at a number of feeder link sites using frequencies greater than 17.3 GHz have been granted. The number of sites has remained static at 3 between 2011 and 2015 and the number of sites is unlikely to increase much if at all in the near future.

High Definition and in particular Ultra High Definition satellite broadcasts may use either the vacant allocation at 21.4 – 22 GHz and/or Ku band by employing more spectrally efficient technologies. Satellite HD channels, some of which are already in use in Australia, employ an average bit rate of 8 to 10 Mbps and UHD channels (using DVB-S2 + HEVC) have an average bit rate of the order twice that (20 Mbps). Satellite UHD channels are in use elsewhere (e.g. SES and Eutelsat) but so far these are either trials or have limited programming.

It is our view that there is adequate supply of spectrum / orbital opportunities and that technologies such as DVB-S2 and HEVC can or are already available to exploit the Ku-band (service) spectrum and associated feeder links (at 18 GHz) fully. The main issue concerns the higher frequency allocation of 21.4 – 22 GHz as this band is currently used by fixed links. The compatibility of these two systems is not good and a migration plan will be required. This will take some time to be developed and it is therefore unlikely that this higher frequency band will be extensively used within a 5 year timeframe.

3.4 Space science services

The number of sites used for space science activities in Australia is relatively stable. Not all of these sites use frequencies above 17.3 GHz but a limited number have been licensed for these frequencies as described in 2.3.3 and shown in Figure 2-2. There is an expectation that the use of Ka-band frequencies for download communications links will increase in the future but this is likely to be supported by existing earth station sites or a limited number of new sites.

Perhaps the biggest change in this field comes from Australia hosting one of the sites for the Square Kilometre Array (SKA) in Murchison Shire, Western Australia. It is intended that this site will use frequencies up to 25.25 GHz[51] / 25.5 GHz[52]. Construction is due to start in 2018 with observations commencing in 2020. The site is remote so frequency sharing constraints are unlikely to arise.

[49] http://www.itu.int/dms_pub/itu-r/oth/0c/0a/R0C0A00000A0012PDFE.pdf

[50] https://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-M.2077-2006-PDF-E.pdf

[51] http://www.acma.gov.au/theACMA/science-services-future-needs-58-1 and www.acma.gov.au/webwr/radcomm/frequency_planning/frequency_assignment/docs/ms32.pdf

[52] http://astronomers.skatelescope.org/wp-content/uploads/2015/11/SKA1-Observing-Bands-V4.pdf

3.5 Other services

Two other applications operate in the frequency range of interest neither of which is likely to contribute to congestion above 17.3 GHz because of the low power/localised nature of the systems.

One is the airport body scanner used for security purposes. This device which is made by L3-Com has a centre frequency of 27.125 GHz and a bandwidth of 5.7 GHz. As it uses a narrowband frequency that sweeps across the very wide frequency range the duty cycle is effectively very low and the potential for interference to other radio applications operating in the band it employs is also correspondingly low especially since body scanners generally operate indoors. The body scanners however require an apparatus licence to operate.

The other application is ultra-wideband short range vehicle radar employed for safety purposes. This operates across the range 22 – 26.5 GHz. It is considered a Low Interference Potential Device and is Class Licensed accordingly (statute of 2000). There is a restriction on their use near Radio astronomy sites. The licensing of these devices has been a cause of some debate in Europe because of the potential to interfere with fixed links when a certain density of devices is reached. These devices are required to migrate to higher frequencies around 70 GHz at a certain time which has slipped because their introduction has not been as rapid as expected and the technology at the higher frequency is proving a bit more difficult to implement than expected.

3.6 Conclusions

Based on the above information and analysis we conclude that there is unlikely to be congestion in frequency bands in the range 20 GHz - 51.4 GHz as a result of demand from terrestrial or space services. This is consistent with the results of similar analysis for the UK where bands above 20 GHz were found to be uncongested and the bands supported more than double the number of links in Australia in a much smaller land area[53]. However, the 18 GHz band is worth further consideration as there could be increased demand from satellite and/or fixed link services beyond our 5 year outlook.

In respect of satellite services, there has been rapid growth in assignments in the last few years as result of the deployment of new HDFSS systems. Future growth in the number of assignments is likely to depend importantly on the launch of new satellite services. We expect demand will grow over time but are not aware of imminent launches that could stimulate a large increase in demand in Australia over the next 5 years. Also we note that the commercial success of new satellite services is difficult to predict and it is not guaranteed that the new HDFSS services that are being launched will all succeed.

In respect of fixed link services at 18 GHz demand has been relatively flat in recent years though future demand growth could come from requirements for backhaul from mobile operators, fixed wireless broadband or a major government user[54]. The channel plan used for fixed links[55] has not so far included the frequencies identified for HDFSS (Figure 3-18). The lifting of the embargo in this band and the recent low rates of demand growth at 18 GHz suggest that even a doubling in demand could

[53] See Sections 3 in http://stakeholders.ofcom.org.uk/binaries/consultations/review-spectrum-fees-fixed-links-satellite/annexes/plum_report.pdf

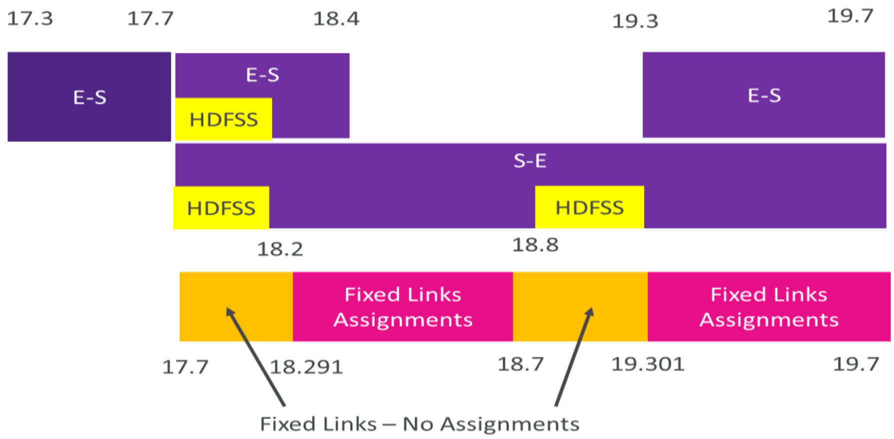
[54] A recent independent study by the Productivity Commission concluded that a dedicated emergency services network was not the best option. . See http://www.pc.gov.au/inquiries/current/public-safety-mobile-broadband#report

[55] There are however earth station receive licences within the current fixed links channel plan but the majority of earth station sites are located in low density and remote density areas. This significantly reduces the potential for fixed links to cause interference to earth station receivers.

be accommodated in current supply and so there is unlikely to be congestion in the band in a 5 year timeframe.

In summary, we conclude that the 17.3-51.4 GHz frequency band is unlikely to be congested in any part of Australia over the next 5 years.

Figure 3-18: 18 GHz band plan



4 Valuation approaches

4.1 Pricing principles

The ACMA has proposed to apply the following high level principles to determine priority bands in which to implement opportunity cost (OC) pricing[56]. This includes bands where an auction is not considered optimal but:

- there is evidence of congestion; or
- there is evidence of inefficient pricing; or
- new high-value uses become apparent; or
- there are expected net benefits to OC pricing; or
- OC pricing is expected to contribute to the object of the Act.

The ACMA has stated that "*Bands that are considered to exhibit high demand, or where there is an expectation that demand will be high in the near future (and where an auction is not considered to be an appropriate allocation method), may be priorities for OC pricing.*

It may also be appropriate to review existing prices in bands exhibiting significant excess supply. When there is substantially more spectrum than is required to meet current and expected levels of demand, the opportunity cost of that spectrum may be close to zero". ….

Where this is found to be the case, the ACMA will continue to set administrative charges to cover the direct cost of services (such as licence issue or renewal), but the ACMA will also move to set annual apparatus licence taxes at a rate that reflects the low opportunity cost and does not discourage use of spectrum."

Previous sections have shown that the frequency range under review (17.3-51.4 GHz) is not currently congested and is unlikely to be congested for at least the next 5 years. The ACMA's policy principles therefore suggest that licence taxes in this frequency range should be set at a rate that reflects the low opportunity cost associated with uncongested bands. The ACMA is nevertheless interested in understanding how opportunity cost principles might be applied to satellite bands and so this is considered below as well as the basis for setting fees in uncongested bands.

4.2 Setting fees in uncongested bands

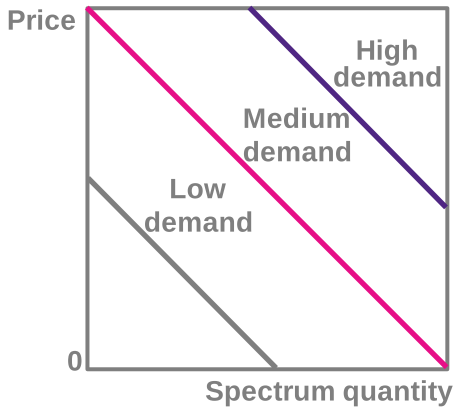
The value of spectrum in bands that are uncongested is likely to be low, but may not equal zero because there is always some low probability the spectrum could become congested in future (and so

[56] The ACMA response to public submissions: Opportunity cost pricing of spectrum, January 2010 http://www.acma.gov.au/theACMA/acma-issues-for-comment-122009-opportunity-cost-pricing-of-spectrum-public-consultation-on-administrative-pricing-for-spectrum-based-on-opportunity-cost

http://www.acma.gov.au/webwr/_assets/main/lib310867/ifc12-09_final_opportunity_cost_pricing_of_spectrum.pdf there is some scarcity value) and there may also be an option value to spectrum access i.e. a value to the flexibility offered by having spectrum should uncertain market circumstances change[57].

Even where there is no excess demand for spectrum the opportunity cost of spectrum may be positive[58]. To see this Figure 4-1 shows three demand curves (low, medium and high) with only high demand resulting in congestion and a positive opportunity cost. One can think of these demand curves as representing three alternative and uncertain future states of the world.

Figure 4-1: Three possible states of future demand



Source: Plum

In Figure 4-1 expected demand is assumed to be equal to the medium demand state of the world. Since low and high demands are equidistant and we assume that each demand outcome has equal probability, expected demand implies zero opportunity cost. However, whilst under low and medium demand opportunity cost is zero, under high demand it is positive, and the average or expected value of opportunity cost is therefore positive. In other words:

Expected opportunity cost ≠ opportunity cost implied by expected demand

One implication of this is that a user might want to hold (or purchase) "excess" spectrum even though expected demand is not expected to result in congestion. The user is maintaining or acquiring the option to meet higher than expected demand, should such demand eventuate.[59]

The implication for spectrum pricing is that expected opportunity cost may be higher than an analysis of expected demand implies. This provides a reason for setting positive prices in areas of moderate demand where there is still excess supply. These prices lie somewhere between zero and the value in a congested band. Judgement is required to set this value. To inform these judgements in Section 5 we examine international benchmarks for satellite spectrum fees some of which have been set on a cost recovery basis.

[57] The option value of spectrum is the value to a firm of having the flexibility to invest at the optimal time, where there are irreversible costs associated with making investments, there is the possibility of waiting for new information to arrive and uncertainty over investment returns.

[58] Principles for implementing opportunity cost pricing, Plum for ACMA, July 2010

[59] This analysis depends on an assumption that a completely fluid spot market for arbitrarily small quantities of spectrum does not exist at all points in time; or on the assumption that he user wishes to hedge against the price of spectrum implied by possible scarcity by owning additional spectrum.

4.3 Setting fees in congested bands

In congested bands additional demand cannot be met and so users wanting additional spectrum, either to provide the current service or an alternative service, will be denied access to the band. As a result they may forgo revenues, incur higher costs or both effects may occur. The value of spectrum in a congested band can be estimated considering the cost/revenue impact on a potential user of being denied spectrum access.

4.3.1 Approaches

Possible approaches to deriving estimates of opportunity cost prices are discussed in ACMA (2009)[60] Plum (2008)[61] and Nordicity (2012)[62]. These approaches are based on either market information about spectrum value or the value of spectrum producing services or direct calculation based on models of potential spectrum users. We have grouped the possible approaches under the following headings:

- **Spectrum market benchmarking** of values from spectrum market transactions – auctions and trades – for similar or the same frequency ranges in Australia and elsewhere. These are often lump sum values and need to be converted to annual value using an appropriate discount rate.
- **Values derived from the price of capacity sales or share prices for spectrum users**. This approach involves deriving spectrum value as the residual value once other factors are taken into account. In the case of capacity sales, the other costs of producing capacity (including the cost of capital) are subtracted from the price of capacity giving spectrum value as a residual. In the case of the share prices, the value of other assets is subtracted from the company value to give a residual which may be attributed to spectrum and possibly other intangible assets.
- **Discounted cash flow (DCF) value (or net present value)** which involves calculating the net present value of the future cash flow from using an incremental block of spectrum. This will provide an upper bound to the value as factors other than spectrum may contribute to net cashflow e.g. brand value and customer loyalty.
- **Least cost alternative value** (or optimised deprival value) which involves estimating the value of spectrum to an average user based on the least cost alternative technology or service to enable the same output to be produced (with the same service quality) if a user is deprived of a small amount of spectrum.

These different approaches to estimating value do not all measure the same thing – see Figure 4-2.

- The least cost alternative value is likely to place a lower bound on value because users may use spectrum to both reduce costs and increase revenues, and this approach captures only the cost element.
- The DCF approach and values derived from capacity sales or share prices are likely to overstate opportunity cost because spectrum is often not the only intangible asset that contributes to revenues and net cashflow.

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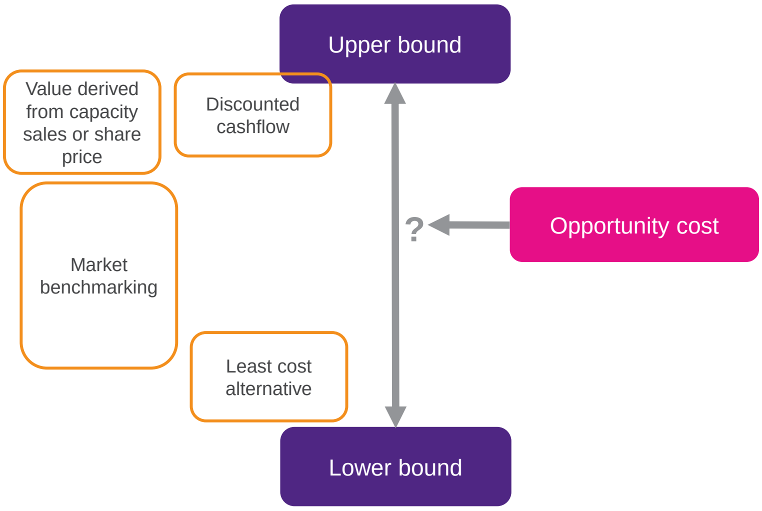
[60] http://www.acma.gov.au/webwr/_assets/main/lib310867/ifc12-09_final_opportunity_cost_pricing_of_spectrum.pdf

[61] http://www.acma.gov.au/webwr/_assets/main/lib310867/ifc12-09_app_a_1_plum_report_to_acma.pdf

[62] http://www.nordicity.com/media/20121112fcdqfyra.pdf

- Market benchmarks should lie between these two limits though this depends on the comparability of the benchmarks with the situation in Australia.

Figure 4-2: Different valuation approaches



Spectrum fees for fixed links (Division 2 of the Apparatus Licence Tax Schedule) could also be used to provide an indication of the value of spectrum in frequency bands above 17.3 GHz. Fixed links users pay these fees in numerous bands above 17.3 GHz and in principle fixed links could be an alternative user for the satellite bands. Fixed link users have not argued that the fees they pay are too high and so these values could be said to at least provide a lower bound on the value of bands in the 17.3-51.4 GHz range. To implement this approach and derive values for satellite services it is necessary to multiply the fixed service fee by the relative denial area of representative satellite and fixed services[63]. Section 8 provides denial area calculations that could be used to implement this approach.

4.4 Implementation of approaches

The main challenges in implementing the approaches described above for the 17.3-51.4 GHz frequencies arise from lack of suitable data. In particular:

- There are relatively few market benchmarks (see Section 6)
- The DCF approach may be not be able to be implemented because:
  - There are no revenues directly associated with the activity e.g. in the case of defence use
  - Providers of rural satellite broadband services may operate at a loss (and so are subsidised by governments) in which case DCF calculations will show a negative value. Analysis by the Bureau of Bureau of Communications Research[64] shows this is the case for the Australian nbn.

[63] We do not propose to review the basis of the fees schedule for point to point fixed links as this would be a major study in itself.

[64] https://www.communications.gov.au/departmental-news/further-consultation-nbn-non-commercial-services

- The revenues associated with the venture may be impossible to identify e.g. if the satellite connection is partly used to provide internet connections for traffic/customers in other countries as may be case with ob3 and Inmarsat operations for example.
- The satellite operation in Australia is a small part of a much larger organisation (e.g. as is the case with Optus and Thaicom) and so there is no publicly available data that relates only to satellite operations in Australia
- Revenues are earned from several bands and there is no obvious way to attribute them to a particular band e.g. (IPStar has a hybrid Ku and Ka band offering)

- The least cost alternative LCA approach is problematic in the case of satellite systems because:
  - The option of moving to higher, less congested frequency ranges is not at present feasible (as there are no systems at these frequencies)
  - Satellite operators already have very strong incentives to deploy the most efficient technology on satellites because the satellite (which has a life of at least 15 years) cannot be changed/upgraded over time
  - There is no "typical user" in the case of satellite operations which can make it difficult to choose realistic alternatives in the case spectrum access is denied. Possible actions for a permanent earth station could be relocation to another site where spectrum is less congested or increased shielding of an existing site. In both cases the incremental costs associated with more efficient use are highly specific to the satellite operation under consideration.

The data requirements and data availability for each approach are summarised in Table 4-1. From this we conclude that the most promising way forward are to:

- Undertake least cost alternative/optimal deprival value (ODV) calculations for the situation of a permanent earth station that is to be moved away from an area of high spectrum demand. This analysis is reported in Section 7.
- Compare the findings with:
  - the spectrum fees set by spectrum managers in other countries reported in Section 5
  - the few available spectrum market benchmarks reported in Section 6
  - the fees paid by fixed link users in similar bands adjusting for differences in denial areas reported in Section 8.

Table 4-1: Data required and available to implement opportunity cost valuation approaches

Approach	Data requirements	Data availability	Conclusion
Spectrum market benchmarks	Auction results for bands in the 17.3-51.3 GHz range from Australia and elsewhere	Ka band frequencies are rarely awarded through the use of auctions. Historically there has been little competition for this spectrum and in such situations regulators often choose to set an appropriate price themselves, and thus not use market mechanisms which would reveal the market value of the spectrum.	See Section 6.
Capacity sales	Transponder lease prices and satellite costs	Generally difficult to obtain because of market confidentiality.	Not possible
Share price data	Share values for satellite operators in Australia	No operators meet this requirement. Satellite operators in Australia are owned by foreign companies that also operate in other countries.	Not possible
Discounted cashflow	Revenues and costs for satellite operators in Australia	Not publicly available as satellite operators in Australia are owned by foreign companies that also operate in other countries. Hence revenue and cost data do not just reflect Australian market conditions. Also Foxtel (the Australian satellite broadcaster) does not publish standalone accounts.	Not possible because of negative value for main user i.e. nbn
Least cost alternative	Identification of a feasible alternative action if satellite operator is denied spectrum access. Possible action for a permanent earth station would be relocation to another site where spectrum is less congested. This requires information on the communications costs of being in a more remote location.	Data on optic fibre trenching or fixed link site and operating costs can be obtained.	See section 7.

Approach	Data requirements	Data availability	Conclusion
Spectrum fees set by other regulators	Fees from elsewhere. Main issue is that different countries place more/less importance on the satellite licence fees, fees for orbital slots and spectrum fees.	Data is published. Basis for fee levels is generally not known.	See Section 5
Spectrum fees for fixed links	Fixed link apparatus fees and relative denial areas	Denial areas calculated in this study	See Section 8

5 International fees set by regulators

In this section we compare the fees charged for spectrum access by satellite services in Australia with fees in ten countries likely to be relevant comparators for Australia. The countries chosen are: Canada, France, Germany, Hong Kong, Luxembourg, New Zealand, Singapore, UAE, UK and the US. All are high income countries, some in the Asia Pacific region (Hong Kong, New Zealand, Singapore), some have large a land mass like Australia (Canada, US) and some have significant or growing satellite industries (Luxembourg, UAE).

The fees information for the 10 comparator countries is summarised in Appendix B. There is a considerable variance in the fees regimes in these countries and depending on the jurisdiction, principal fees are applied to space stations, earth stations, orbital slots, or transmission and reception[65]. Data on space station licence fees and fees for orbital slots is not always available and cannot be readily converted to a per MHz fee. Despite all of these caveats fees in Australia are likely to be judged "reasonable" by comparison with fees elsewhere and so we report international values for information. Also the structure of fees elsewhere may provide useful insights for Australia.

5.1 Comparison of fee structures

We have found that the approach to licensing spectrum access by satellite services varies considerably between countries as does the basis for setting fees. In particular:

- Very few countries license spectrum access by space stations, though there is often a charge for licences to operate a space station (e.g. the US).
- Earth station receive licences are not commonly issued. More usually protection for earth station receive is implicitly bundled with earth station transmit and so is not charged for separately from the transmit fee. Receive only services are either class licensed (e.g. DTH TV reception) or not licensed at all (e.g. such as radio astronomy). Exceptionally, the UK has introduced a form of spectrum access, called Recognised Spectrum Access (RSA), which provides explicit protection for receive only devices (i.e. devices that receive transmissions from satellites or further out in space). In Singapore fees are charged for downlink frequencies.

Access to spectrum for transmissions from permanent earth stations is typically licensed, though the basis for setting fees varies considerably as shown in Table 5-1.

- Six of the ten comparator countries charge a fee per earth station (transmission) assignment that does not vary by the bandwidth of transmissions, the frequency band used or the power of transmissions. In other words there is no attempt to relate fees to the spectrum access denied to other users or the relative value of spectrum across band.
- Four countries relate the fees charged to bandwidth and two of these also vary fees by frequency band, as is also the case in Australia.
- Only the UK includes a factor for the power of the transmission to take account of the area over which spectrum access to others is denied.
- No countries vary fees by geographic location, though this is now proposed in the UK.

[65] This was also found in a study for Industry Canada, Study on the Market Value of Fixed and Broadcasting Satellite Spectrum in Canada, Nordicity 2012 http://www.nordicity.com/media/20121112fcdqfyra.pdf

- The UK provides an incentive for a licensee to locate its earth stations close to one another as fees are based on an aggregation of power from a site where earth stations are within 500m of one another.

Table 5-1: Basis for fees charged for transmissions from permanent earth station

	One off / application fees	Annual spectrum fee	Annual spectrum fee parameters			
Basis for spectrum licence fees		Per assignment	Bandwidth	Frequency	Power	Location
Canada	No		Yes	No	No	No
France	Yes		Yes	Yes	No	No
Germany	Yes	Yes				
Hong Kong	No	Yes				
Luxembourg	No	Yes				
New Zealand	No	Yes				
Singapore	Yes	Yes if above 20 MHz bandwidth	Yes – up to 20 MHz bandwidth.	No	No	No
UAE	No	Yes				
UK	No		Yes	Yes	Yes	No, but proposed
US	No	Yes				
Australia	**Yes**		**Yes**	**Yes**	**No**	**Yes**

Source: Information given in Appendix B of this document

In the last 5 years Canada[66] and the UK[67] have undertaken studies that have addressed the level and structure of fees for satellite services with a view to setting fees based on opportunity cost:

- In Canada, consultants recommended fees at levels that were around 4 times higher than the existing levels at that time based on an assessment of the market value of spectrum. Consultants also recommended varying fees by the frequency band used and bandwidth licensed to incentivise efficient spectrum use. Following consultation, Industry Canada, in fact reduced fee levels and set a constant fee/MHz across all bands.
- In the UK, Ofcom has reviewed both the level of congestion in bands used by satellite services (and fixed links) and the structure and level of fees in these bands. It was found that C and Ku band were likely to be congested as was the 18 GHz band – because of competing demand from mobile and fixed link services. Congestion was thought to be unlikely in frequency bands above

[66] Study on the Market Value of
Fixed and Broadcasting Satellite Spectrum in Canada, Nordicity 2012 http://www.nordicity.com/media/20121112fcdqfyra.pdf

[67] http://stakeholders.ofcom.org.uk/consultations/review-spectrum-fees-fixed-links-satellite/

20 GHz. Ofcom has proposed increased fee levels for bands below 20 GHz and reduced fees above 30 GHz (possibly down to cost recovery levels) to reflect changes in congestion and so the market value of spectrum. Variations in fees by location – with higher fees in more congested areas - are also proposed.

5.2 Comparison of fee levels

Given the structure of fees differs considerably between countries to compare fee levels between countries it is necessary to first define some typical satellite systems, so that the comparison is on a like for like basis. As already discussed, there is very wide variation in the licensing (or more commonly not) of spectrum access for satellite space stations and so we focus here on comparing fees for some typical earth station deployments at Ka band.

Inspection of the Australian assignment information at some typical earth station sites suggests the following two examples:

- Example 1: 18 GHz Receive/28 GHz transmit – 216 MHz bandwidth, 500W transmission power
- Example 2: 18 GHz Receive/28 GHz transmit – 1000 MHz bandwidth, 500W transmission power

In Australia fees are paid for transmit licences and possibly also for receive licences, should a user wish to obtain formal receive protection. Elsewhere only the licence the transmit activity is licensed. In Australia, the majority of assignments at Ka band are in low density and remote areas – there is one high density assignment and 2 assignments in medium density areas. We report values for medium density, low and remote areas, and note that fees in high density areas are around 4 times those in medium density areas. In other countries examined the fees do not vary by geographic area.

Table 5-2: Fees by country for Earth station transmit/receive - Examples 1 and 2

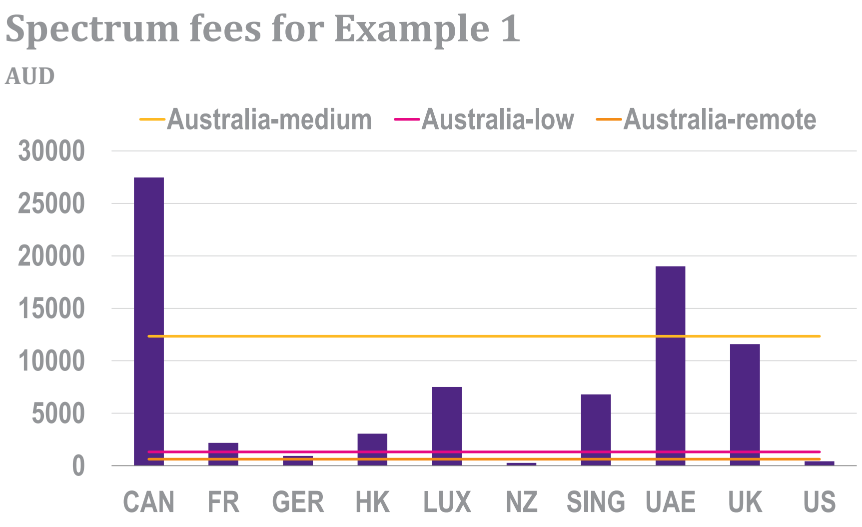
	Fees for Example 1 ($AU)	Fees for Example 2 ($AU)
Australia (remote, low density, medium density)	626 or 1253; 1317 or 2635; 12, 333 or 24,667	1450 or 2900; 3050 or 6100; 28, 550 or 57,100
Canada	27,475	63,600
France	2,179	4,979
Germany	934	934
Hong Kong	3,060	3,060
Luxembourg	7,500	7,500
New Zealand	276	276
Singapore	6,200	6,200
UAE	19,000	19,000
UK[68]	11,594	17,640
US	434	434

Source: Regulators' websites, Plum calculations

In Figure 5-1 and Figure 5-2 we compare Australian fees with those elsewhere assuming that only a transmit licence is obtained. As can be seen in medium density areas Australian fees appear high relative to the international benchmarks. The high density Australian fees are around five times the level of the medium density fees and so are extremely high by international standards. Australian fees in the low density and remote areas appear more "reasonable".

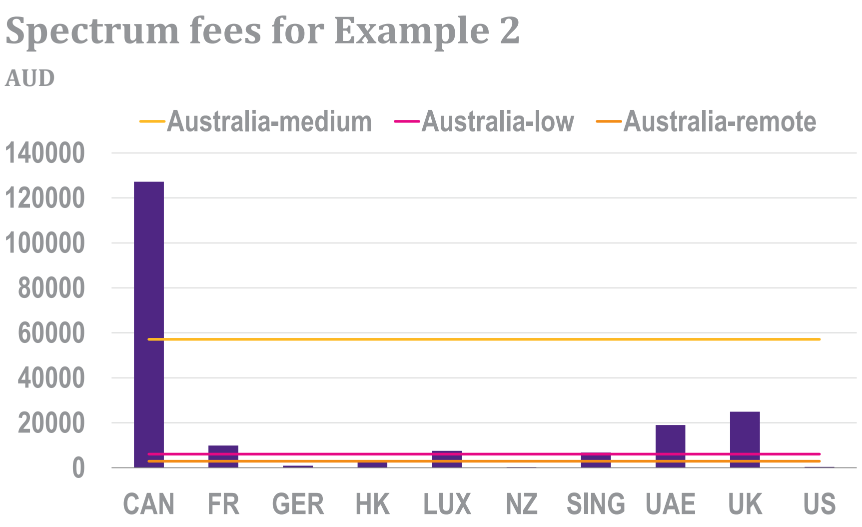
[68] Ofcom is currently consulting on substantially reducing fees for Ka band, though no decisions have been made yet.

Figure 5-1:



Source: Plum Consulting

Figure 5-2:



Source: Plum Consulting

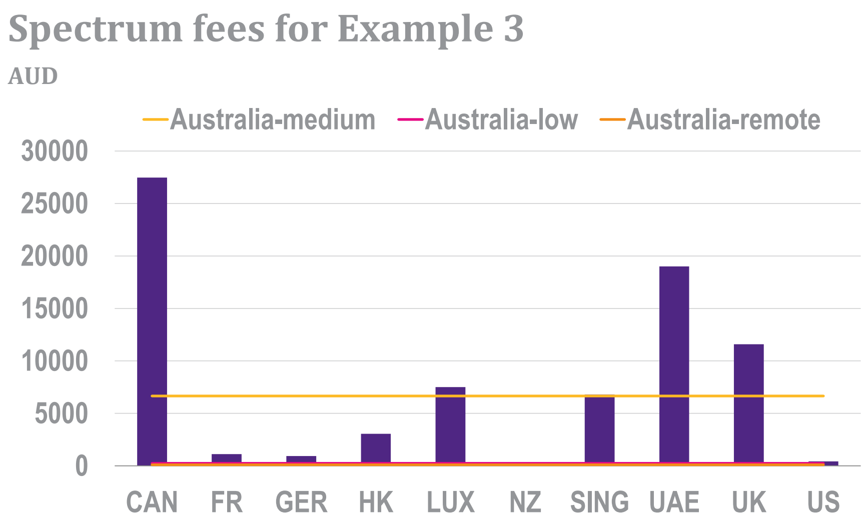
We also compare the fees for a higher frequency range – namely above 30 GHz for the following two examples:

- Example 3: 216 MHz bandwidth, 500W transmission power
- Example 4: 1000 MHz bandwidth, 500W transmission power

The results are given in the two figures below. As might be expected the Australian medium density area values look more reasonable because in Australia fees are reduced as frequency increases above 30 GHz whereas this is not the case in most other countries (with the exception of France).

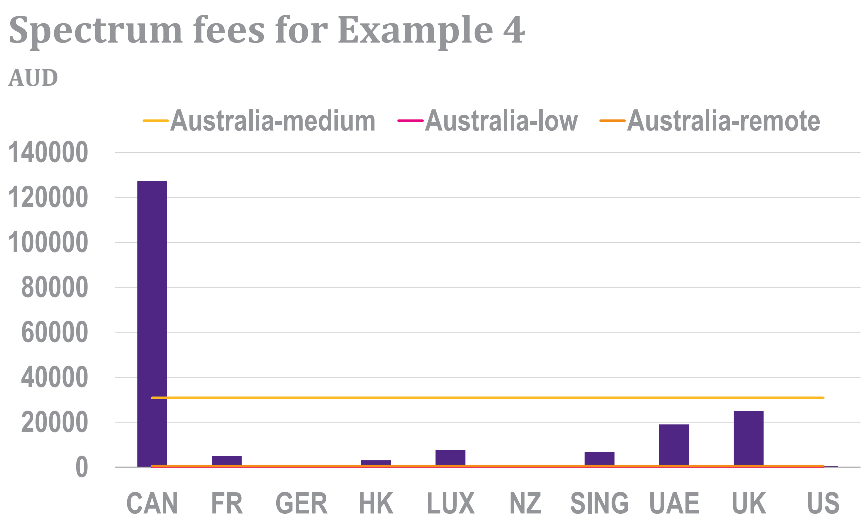
However the fees in high density areas (not shown) which are over four times those in medium density areas are still high by international standards.

Figure 5-3:



Source: Plum Consulting

Figure 5-4:



Source: Plum Consulting

5.3 Conclusions

5.3.1 Fee levels

In respect of the level of spectrum fees for earth station transmissions we find that fees for high density areas in Australia are extremely high – more than five times levels in most other countries. Fees for medium density areas in Australia are somewhat higher than most of the benchmarks , though this is not the case for fees in low density and remote areas where most satellite systems in Australia are located (see Section 2). Because satellite operators in most countries pay satellite licence fees in addition to (and sometimes instead of) spectrum fees, the international data cannot be used to draw precise conclusions about the appropriate level of fees in Australia. Rather the data would seem to suggest that at least for high density areas and possibly medium density areas there could be a case for reducing fees. In particular, in the UK fees are set on an opportunity cost basis and these fees are less than those for high density areas of Australia and are similar to those for medium density areas.

5.3.2 Fees structure

Differences in the structure of spectrum fees across countries are informative. None of the countries reviewed vary spectrum fees by location (though this is proposed in the UK) and it might be argued that this is a failing in their fees systems as it means there is no incentive to locate away from high density areas where congestion is more likely to occur. In this regard, we note that once established satellite earth stations have a long economic life (20 years or more) and are costly to move (or alter). So even if a spectrum use in an urban location is not expected to be congested over the next 5 years it would still be prudent to provide satellite operators incentives to locate in low density areas to avoid the risk of congestion and having to move systems in the long term.

The frequency band factor reflects variations in the value of spectrum by band that may arise, for example, from differences in the physical properties of bands and demand for the band. France and the UK fees have such variations as does Australia, as shown in Table 5-3. Fees elsewhere differentiate between frequencies above and below 24 GHz, typically having lower fees for the 28 GHz earth transmit band as compared with the 17/18 GHz earth receive band. This is because the weaker propagation characteristics of the higher band mean greater reuse is possible and so on a per kHz basis it is generally less valuable. We suggest that the Australian tax schedule also has a break point at 24 GHz, so that the frequency range 14.5-31.3 GHz is segmented as 14.5-24 GHz and 24-31.3 GHz and that a lower band factor of say 0.6 applies to the 24-31.3 GHz band.

Table 5-3: Band factors by frequency band for France, the UK and Australia (normalised so 14 GHz factor =1)

Band	France	UK (UK proposed)	Australia – medium density	Australia – remote area
14 GHz	1	1 (1)	1	1
17/18/19/20 GHz	0.7	.7 (,7)	0.7	1
21/22/23 GHz	0.6	.7 (.4)	0.7	1
24 -31 GHz	0.5	.6 (.3)	0.7	1
31-38 GHz	0.5	.6 (.3)	0.4	0.2
38-50 GHz	0.3	.6 (.2)	0.4	0.2

Source: Data in Appendix B

In principle, it would be expected that fees for access to spectrum by satellite operators would vary according to factors that reflect spectrum occupancy or denial to other users, such as: power and a discount for collocation. In the UK fees depend on power and also include a financial incentive for earth stations to collocate. In Section 9 we return to the issue of whether there is a case for including such factors in a fees formula in Australia.

6 Market benchmarks

In this section we report values of spectrum revealed in auctions for frequencies in the 17-51 GHz range. Very few countries have auctioned these frequencies. This is not surprising as auctions are typically used to allocate spectrum when demand exceeds supply and demand for frequencies in the 17-51 GHz range has tended not to exceed supply.

6.1 Method

To compare values from different countries in a like-for-like basis we adjust the auction results as follows:

1. Auction lump sums are annualised using a discount rate of 10%. Appendix A gives the rationale for choosing this discount rate. The annualised lump sums are added to any annual fees.
2. This figure is converted into AUD using the exchange rate at the time of the auction.
3. The figure is converted into 2015 prices using Australian CPI.
4. The figure is divided by the population covered by the licence (at the time of the auction) and the number of 2x1 MHz (i.e. an auction where 2x28 MHz was sold would be divided by 28).
5. This is multiplied by the Australian population in 2015 to get a price per 2x1 MHz covering the whole of Australia.

6.2 Choice of dataset

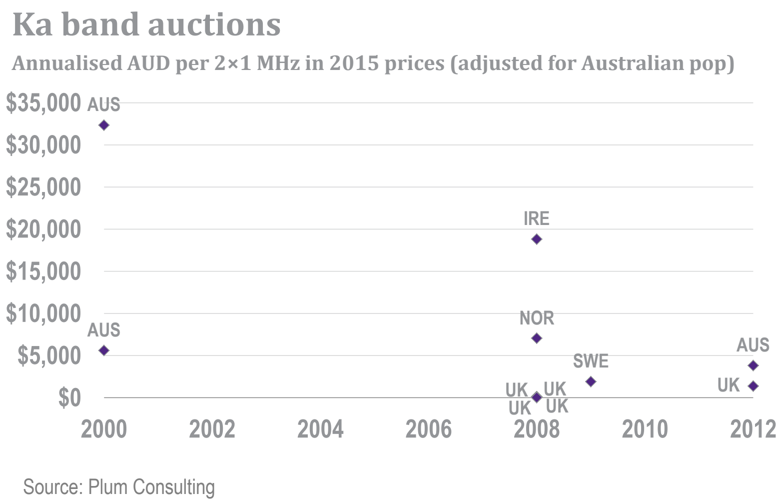
Key to benchmarking is the choice of dataset. We only consider auctions since 2005 to be relevant comparators: the 17-51 GHz band auctions of early 2000s were marked by dotcom optimism in the potential usage of the band for fixed wireless broadband. Such hopes did not materialise (the rapid diffusion of ADSL followed by VDSL and fibre meant that fixed wireless broadband remained a niche product) and the prices paid at auction fell significantly in the following years. However, we give the results of the November 2000 Australian Ka band auction to show the history of the band.

Usually the benchmarking process involves reducing the data to countries which are relevant comparators for Australia; however, the scarcity and location of data mean that this step is unnecessary.

6.3 Results

The figure below shows the auction benchmarks for the 17-51 GHz band since 2005, with the addition of the older Australian datapoints.

Figure 6-1



In most cases spectrum sold at the reserve price and in half the cases spectrum was left unsold suggesting that the market clearing price (at which all spectrum would have sold) would be below the prices revealed by the auction.

Table 6-1: Benchmark auction results

Auction	Sold at reserve price	Some spectrum left unsold
Australia 2000 27 GHz	Yes	Yes
UK 2008 multiband	No	No
Ireland 2008 26 GHz	Yes	Yes
Norway 2008 23 GHz	No	No
Sweden 2008 28 MHz	Yes	No
Australia 2012 27 GHz	Yes	Yes

Each datapoint is discussed below:

- The 27 GHz band (26.5 – 27.5 GHz) was first awarded in Australia through the SMRA auction of November 2000[69], although much of the spectrum was unsold. The band, which is unpaired, was originally allocated to LMDS services. However, usage by LMDS services has been light, and the band's most heavy user is satellite (the 27 GHz band is part of the satellite Ka band). It awarded 500 MHz nationwide to Optus and 150 MHz in two areas to Thaicom[70]. The country was divided into 21 regions with the spectrum sold in 6 unpaired lots in each region. All the licences that were sold were bought at the reserve price. The licences started in January 2001 were for 15 years.

[69] http://www.acma.gov.au/Industry/Spectrum/Radiocomms-licensing/Spectrum-licences/auction-summary-27-ghz-broadband-wireless-access-2000

[70] The current Thaicom licences started in 2010 as they were moved from one arm of the company to another at this time, but Thaicom has owned the spectrum since the 2000 auction.

Rather than renewing these licences the ACMA has decided to revert these licences to apparatus licences[71].

- In May 2012 the ACMA auctioned 150 MHz of the residual unsold spectrum in the 27 GHz band, and because there was only one applicant, the nbn, lots were sold at the reserve prices[72]. The nbn won 150 MHz in six areas.

Table 6-2: Resulting 27 GHz spectrum assignments from auctions

Lower (GHz)	Upper (GHz)	Regional/Remote SA, Regional/Remote WA	Regional Remote Vic, NT, East Coast of Australia	Perth, Tasmania, Regional East Australia
26.5	26.85		Residual	
26.85	27.35		**Optus**	
27.35	27.5	**Thaicom**	Residual	**nbn**

Source: The ACMA

- In 2008 Comreg, the Irish regulator, auctioned frequencies in the 26 GHz band for national point-to-point and point-to-multipoint fixed links. Supply exceeded demand as not all the spectrum sold (only 14 out of 17 blocks of 2x28 MHz sold). The reserve price was equivalent to an annual fee of AU$18,809 per 2x1 (for the Australian population).
- NKOM, the Norwegian regulator, auctioned 2x140 MHz of the 23 GHz band in 2008. The sealed bid auction sold the frequencies above reserve price, at a price equivalent to an annual fee of AU$7,055 per 2x1 (for the Australian population).
- In 2009 the Swedish regulator, the PTS, auctioned 18 blocks of 2x28 GHz in the 28 GHz band. The spectrum sold at the reserve price (small additional amounts were paid to get the most desirable blocks) which was equivalent to an annual fee of AU$1,912 per 2x1 MHz (for the Australian population).
- Ofcom, the UK regulator, auctioned four high frequency bands in February 2008 (10, 28, 32 and 40 GHz). The spectrum sold on a national and sub-national basis, with differing per MHz pop numbers. The implied annual values (per 2x1 MHz for the Australian population) from the national spectrum were AU$111, AU$114 and AU$11, for the 28, 32 and 40 GHz bands respectively. The sub-national lots of the 28 GHz band sold at AU$31 (when scaled up to the national population). The auction was a combinatorial clock auction meaning it is difficult to see if the prices sold at reserve or above.

[71] See the ACMA's condoc http://acma.gov.au/theACMA/Consultations/Consultations/Current/review-of-licensing-arrangements-in-the-27-ghz-band and the ACMA's database of licences http://web.acma.gov.au/pls/radcom/spectrum_search.show_table?pLICENCE_TYPE_NAME=Spectrum&pLICENCE_CATEGORY_NAME=27%20GHz%20Band

[72] See Applicant Information Package, March 2012 https://www.google.co.uk/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0CCEQFjAAahUKEwjootPsvMvHAhVLVxoKHa2nC3I&url=http%3A%2F%2Fwww.acma.gov.au%2Fwebwr%2F_assets%2Fmain%2Flib410193%2F27ghz_residual_lots-applicant_information_package.docx&ei=WyvgVaiJHsuuaa3PrpAH&usg=AFQjCNGI1rMfvnQ4uns1TleowfsPejrMtg

- In 2012 one sub-national licence in the 28 GHz band was traded in the UK (Vodafone bought it from Transfinite). The reported price is equivalent to an annual fee of AU$1,368 per 2x1 MHz (for the Australian population).

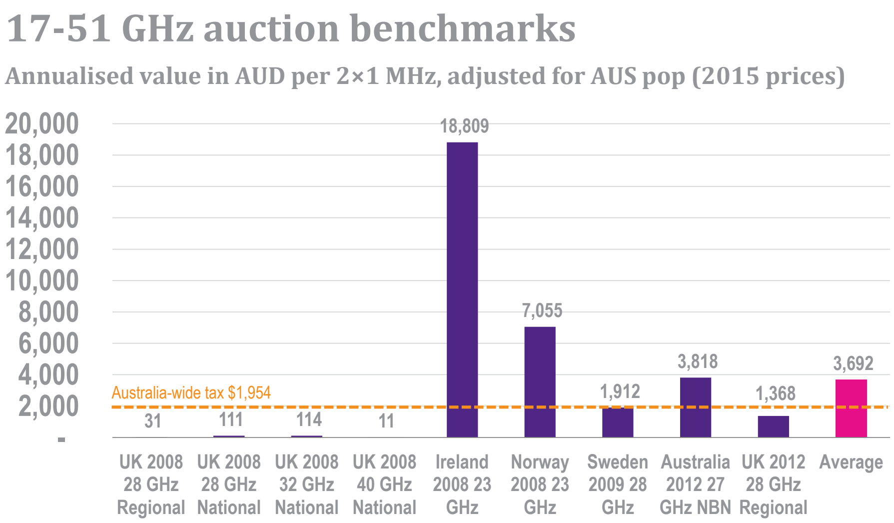
There is some data which is not included in the benchmarking data set:

- The Greek regulator, the EETT, published a consultation on the auction of 24.5 – 26.5 GHz in September 2015. The result of the consultation is not clear, but one response has been made public. The proposed auction would award the spectrum as technology and service neutral for 15 years, starting January 2016. The EETT suggested reserve prices based on their own benchmarking which are the equivalent of an annual fee of AU$4,100 – AU$5,900 per 2x1 MHz (for the population of Australia). The industry response stated that AU$1,500 would be a more appropriate reserve price.
- In 2013 the Norwegian regulator, NKOM, received a request to auction an idle 2x7 MHz in the 23 GHz band. The resulting auction had a reserve price equivalent to an annual fee of AU$4,400 per 2x1 MHz (for the population of Australia) and the spectrum failed to sell. This was not used as a benchmark as the reserve price was above the market willingness to pay.

6.4 Summary

The resulting benchmark values (adjusted for the Australian population) are given in Figure 6-2 and most relate to the frequency range up to 32 GHz. They should therefore be compared with the Australia-wide fee in the apparatus licence fee schedule of $1954/2x1 MHz for the 14.5 - 31.3 GHz range. This value is just over half the amount the nbn paid at auction for spectrum at 27 GHz and is somewhat higher than UK and Swedish payments for frequencies in this frequency range. This might suggest the Australia-wide apparatus licence fee values are “reasonable” there are relatively few market auction comparators and some of these are much lower and higher than the Australia-wide value.

Figure 6-2:



Source: Plum Consulting

7 Least cost alternative approach

7.1 General approach

In this section we set out how the least cost alternative (sometimes called optimal deprival value) approach to spectrum valuation might be applied to satellite services, on the assumption that the frequency range used by the service is congested.

The least cost alternative approach involves an assessment of the additional costs faced by a typical user denied access to the amount of spectrum required in a particular location or area. These additional costs indicate the value to the user of being able to access a particular frequency band i.e. reflect the value of spectrum in that band in that particular location or area. Additional costs arise if a user is denied access to spectrum because the user must then meet its communications needs by other means.

We focus on the cost trade-offs for installation of an earth station and not for construction of a satellite space station. The satellite service provider has every incentive to make the space station as efficient as possible because once in orbit the satellite space station cannot be reconfigured over its economic life – usually 15 years or more.

The situation we are considering is that of an earth station operator wishing to use particular frequencies in an area which is already congested. The operator will therefore be denied access to the band in the desired location. There are a number of actions the operator could then take to ensure it can still provide the required service including:

i. Using a less congested band i.e. a higher frequency band which in this case means Q or V band.
ii. Locating the earth station in a moderately congested and possibly also shielding the earth station to reduce interference to other users
iii. Locating the earth station in an uncongested area i.e. an area designated as low density rather than medium or high density. In this case there would be no need for shielding.

Option i) is not feasible because Q/V band has not come into commercial use, and so we do not consider this option. Of the other two options, we expect that an operator would prefer to stay as close to its existing location as possible to ensure reliable (and fully duplicated) backhaul communications and to minimise disruption to staff and service provision. Option ii) is more difficult to model primarily because choice of this option depends on the cost of shielding which is likely to be site specific. We have therefore derived values for Option iii). In this case the value of spectrum in the congested area to an earth station operator is at least the additional costs incurred by having to locate in an uncongested area. In other words:

Value/MHz = Additional costs of uncongested versus congested location/Bandwidth of links (up and down if appropriate)

7.2 Additional costs required for the calculation

The figures below show schematically the two situations we are comparing. In the congested location (Figure 7-1) the datacentre and the earth station are collocated and there is no need to backhaul to points of presence in fibre networks. By contrast in the uncongested location (Figure 7-2) backhaul (with diversity) is required to the datacentre which continues to be located in an urban/congested area to enhance reliability and because the datacentre may support other business activities. Backhaul is assumed to be provided by optical fibre and not microwave links because the long range microwave links cannot provide the capacity required (say 1 Gbps) to support an earth station providing consumer and business broadband services.

Figure 7-1: Situation for an earth station at a congested location

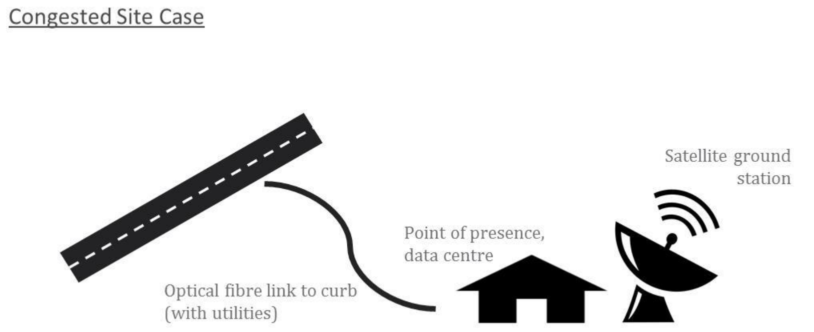
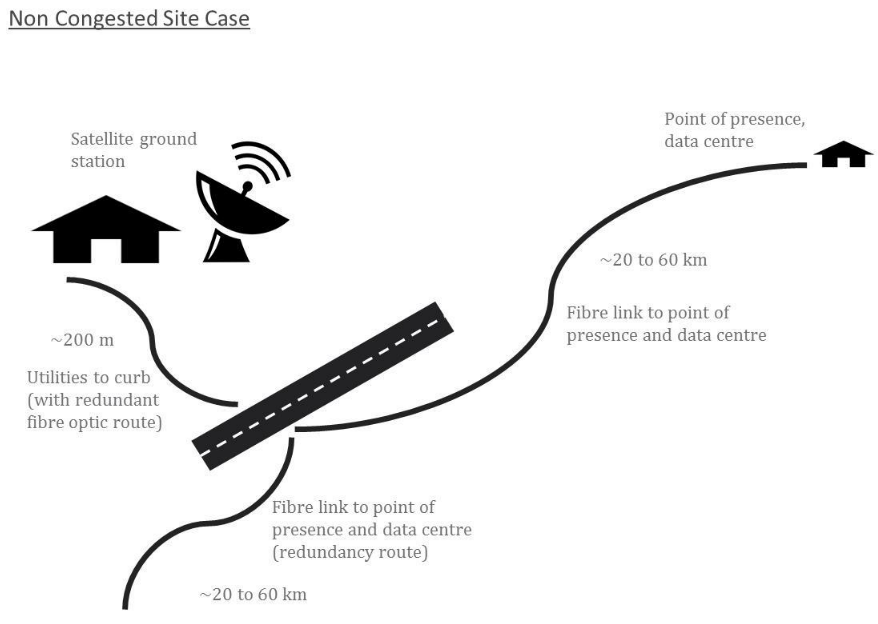


Figure 7-2: Situation for an earth station at an uncongested location



A key assumption concerns the amount of optical fibre that has to be laid to a network point of presence where there may be competing providers of fibre backhaul. An example is given by the Yarragadee/Mingenew is 75 km south east of Geraldton and 46 km north east of Dongara, giving a total of around 120km fibre to be laid to nearby connection points. Alternatively if we assume optical repeater points of 80km separation, perhaps less in some locations where breakouts are required, an earth station placed at an intermediate point with fibre cable laid from the earth station to access points on either side for diversity would imply approximately 80km of cable to be laid. In summary we have assumed that the fibre connections have an average length of 40km, and tested assumptions of 20km and 60km.

The additional cost items for locating an earth station in a low density versus a high density area are shown in Table 7-1. We assume operating costs, comprising mainly electricity and labour for occasional maintenance and emergency operation of the site, are broadly the same in the congested versus the uncongested location. Labour costs are likely to be lower in the uncongested location but electricity costs could be higher.

Some of the costs are lump sums incurred when the site is deployed and others are on-going annual costs. To put all costs on an annual basis we need to make assumptions about a suitable discount rate (nominal and pre-tax) and the life of the installation. In Appendix A we conclude that a suitable rate is 10% and a sensitivity test for 8% should also be considered. We have also tested two assumptions for the installation life – 15 years and 25 years.

The other key assumption is the bandwidth of links at the earth station site. We have examined two cases:

- A case based on the NBN installations which have an uplink of 1 GHz and a downlink of 600 MHz
- A case based roughly on an Optus broadcasting feeder link (at Lockridge) with an uplink bandwidth of around 500 MHz (the installation in fact uses 12 frequencies each with 36 MHz bandwidth).

Finally we have tested the effect of locating at a satellite park in a low density area. In this case only a fraction of the capital and operating costs for the site (i.e. land, backhaul and site access) will be incurred by the licensee. We test the impact of two assumptions - 50% of the site costs (with 1 other sharer) and 33% of the site costs (with 2 other sharers) are incurred[73].

[73] This assumes moving from a site which was not shared in a congested area to moving to a site which is shared in an uncongested area.

Table 7-1: Cost inputs for LCA calculation

Cost Item	Congested site	Uncongested site	Derivation of uncongested location cost minus congested location cost	Amount
Land acquisition	1 Hectare of industrial zoned land Average value in NSW is around $5m/hectare	2 hectares - For provision of access the land required would likely be twice that required in a congested area.	NSW Valuer General published data 74 shows small industrial sites in uncongested areas are 20% of those in congested areas.	-$3m (i.e.2x0.2x5 – 1x5)
Backhaul	Not applicable	At the site laying fibre cable would occur with construction of vehicular access, provision of power supply and any other utility. Need to lay fibre to reach POP for suppliers – assume two optic fibre connections required to give diversity Minimum connection length assumed to be 20km and max. 60km. This is assumed to be the distance to a regional town. Cost per km of trenching etc is assumed to be $25k/km (Plum estimate).	$25k x connection lengths x 2 (for diversity)	$1m - $3m
Site access	Not applicable	We assume a 200 metre vehicle and utility access to the closest roadway and power connection	Estimated cost A$250,000 (Plum engineering estimate)	$0.25m

[74] http://www.valuergeneral.nsw.gov.au/land_values/historical_land_values (Table 7 & 9)

Cost Item	Congested site	Uncongested site	Derivation of uncongested location cost minus congested location cost	Amount
Earth station build cost	$18m – NBN Co reported on 25 October 2012 http://www.nbnco.com.au/content/dam/nbnco/media-releases/2012/satellite-ground-station-construction-contracts.pdf contracts for construction of ten satellite ground stations for a total of $180million.	10% higher in remote area to cover additional labour and freight costs (Plum engineering estimate)	18x 0.1	$1.8m
Datacentre lease cost	None – integrated with earth station	Building for data centre in same location as for congested site case -	Lease cost of $40k per annum (Plum estimate based on industry)	$40k per annum
Spectrum fees	To be calculated	Assume fees for a remote area i.e. $3/MHz for 14.5-31.3 GHz. Source Apparatus Fees Schedule 2015, ACMA	n.a.	n.a.
Sharing of site related costs for a satellite park	Not applicable	33% share and 50% share tested		

7.3 Modelling results

We have developed a simple spreadsheet to give estimates of spectrum value for the congested area under different cost and bandwidth assumptions. The most important cost inputs (in numerical terms) are the land acquisition, backhaul and incremental earth station build costs.

We have made the following assumptions for a "base case" and then undertaken "reasonable" variations from this base case:

- Land acquisition cost saving of $3m
- Backhaul of 40km x2 (to provide diversity) implying additional cost of $2m
- Site access cost of $0.25m
- Additional earth station build cost of $1.8m
- Additional datacentre lease cost of $40k/year
- Bandwidth of 1.6 GHz
- 10% pre-tax nominal discount rate (see Appendix A)
- 15 year amortisation period

The spectrum value implied by the base case is AUD 0.1063/kHz which is only 41% of the current spectrum tax in high density areas (for 14.5-31.3 GHz) of AUD 0.2601/kHz. The most uncertain assumptions concern backhaul costs and bandwidth assumptions and as can be seen in Table 7-2 plausible variations in these assumptions have a large impact on the valuations. The negative values in the last two rows of the table mean that if costs in an uncongested area can be shared with other operators then users are financially better off locating in uncongested vs congested areas even without there being lower spectrum fees in uncongested areas.

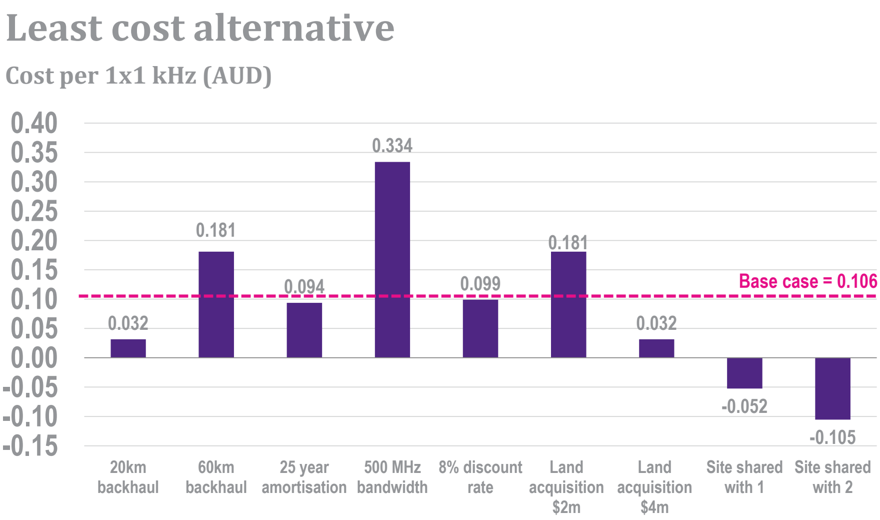
Table 7-2: Spectrum value estimates for a congested area based on the LCA approach

Case	Value/kHz[75]
Base case	**0.1063**
Base case with backhaul distance cost reduced to 20km and so cost reduced to $1m	0.0316
Base case with backhaul distance increased to 60km and so cost increased to $3m	0.1810
Base case with 25 year amortisation	0.0936
Base case with 500 MHz bandwidth	0.3339
Base case with 8% discount rate	0.0898
Base case with saving on land acquisition reduced to $2m	0.1810
Base case with saving on land acquisition increased to $4m	0.0316
Base case with saving due to site sharing with 1 other operator	-0.0524
Base case with saving due to site sharing with 2 other operators	-0.1053

Source: Plum analysis

These values are also shown in Figure 7-3.

Figure 7-3: Spectrum value estimates for a congested area based on the LCA approach



Source: Plum Consulting

The effect of reducing the discount rate from 10% to 8% is minimal, as is the effect of increasing the lifespan of the earth station from 15 to 25 years. However, the least cost alternative value is

[75] A negative value is obtained when the costs of locating in a high density area are higher than in a low density area, in which case a user will locate in a low density area even if the spectrum fees are the same in low and high density areas.

responsive to assumptions over the length of the backhaul required, the cost of acquiring the land and the amount of spectrum that the user requires.

The effect of sharing the site in an uncongested area is to make the least cost alternative negative. This means that the new satellite operator would always opt to locate at a shared site in a remote area as compared with being located in a congested area i.e. satellite parks are attractive to new users. It is important to note that the calculations do not take account of the costs of unreliable backhaul or the inconvenience of operating remotely.

7.4 Conclusions

The LCA estimates we have produced give values of spectrum for congested locations (similar to high density areas) that are in the range $0.1-0.2/kHz and so are less than the current annual licence tax of $0.26/kHz for 14.5-31.3 GHz. This evidence suggests there could be a case for reducing high density area fees across the entire Ka band (17.3-51.4 GHz), particularly given we have not identified the bands as congested. In section 9, we discuss the level of any fees reduction that might be justified based on this evidence and the international data reported in sections 5 and 6.

8 Denial areas

Division 1 of the apparatus licence schedule does not explicitly take account of denial areas. In this section we consider what changes to the schedule might be implied by an approach to setting fees that took account of denial areas. In particular we examine

- The relative level of satellite to fixed link fees for geostationary satellites and the ratio of satellite transmit to receive fees based on denial area calculations (Section 8.1).
- Variables in the denial area relationship (Section 8.2)
- Denial areas for non-geostationary systems versus geostationary systems (Section 8.3).

8.1 Denial areas - satellite versus fixed links

Satellite earth stations pay fees based on Division 1 of the Fee Schedule and fixed links pay fees based on Division 2. As fixed links could in principle use much of the spectrum allocated to satellite services (and indeed the services share some bands) fees for the two services should be set on a consistent basis i.e they should face the same opportunity cost of spectrum per MHz per km^2. If this was the case the linkage between satellite earth station and fixed link fees would be based on the relative denial areas of the two spectrum uses. These denial areas can be calculated based on the assumption that a typical satellite earth station transmitter can be characterised as a unidirectional fixed link. The approach takes explicit account of the relative geographical areas impacted by spectrum used by a satellite earth station versus fixed links installations. To do this it is necessary to:

- Step 1: Determine the area that a typical fixed link denies to another fixed link where no assumption is made regarding the relativity of the two links in terms of a real deployment. Conceptually, this translates into fixed link receive terminal being positioned in a fixed location (the centre of the area) with fixed pointing. Another fixed link terminal (transmitter) is then positioned at another location where the distance away is determined to meet a certain level of acceptable interference at the central receive terminal. The location of the second fixed link terminal (transmitter) is then moved around the first fixed link terminal (receiver) with its antenna always pointing at the first fixed link terminal and the separation distance calculated for each point. This process provides a potential denial area[76].
- Step 2: Determine the area that a typical satellite earth station denies a typical fixed link. The same considerations as in the step above also apply here. However, rather than a fixed link receive terminal being at the centre of the area being calculated, it is a receive earth station at the centre with a fixed link terminal (transmitter) pointing at and moving around it.
- Step 3: Obtain the ratio of impacted areas which sets the difference in reference values.

Note that Step 2 can be considered twice; when the earth station is a receiver (as described above) and when it is a transmitter? For this latter case the corresponding fixed link terminal would be a receiver.

[76] This does not necessarily mean that a fixed link cannot operate in this area. If for example the antenna of the second fixed link terminal points away from the first fixed link terminal then operation would be possible. The area we are interested in is a generic potential area particularly in a congested environment.

Below we report estimates of the relative denial areas for systems at 18 GHz and 50 GHz, and compare the ratios obtained with the ratio of satellite to fixed link fees.

8.1.1 Denial area calculations – 18 GHz

Using representative parameter values for both services as shown in Table 8-1 (for the 18 GHz band), and using the smooth earth diffraction model of ITU-R Recommendation 452 for 20% probability, we have derived the relative areas denied as a satellite earth station / fixed link ratio[77]. The ratio falls in the range 0.62 ±0.02 for a receiving satellite earth station and 0.96 ±0.02 for a transmitting satellite earth station where the ranges given relate to the assumed elevation angles of 5 and 50 degrees.

It can be seen from Figure 8-1 that there is little elevation dependence since the increased satellite earth station horizon gain at low elevation angles is mitigated by the diffraction.

Table 8-1: Assumed operating parameters for fixed links and earth stations at 18 GHz

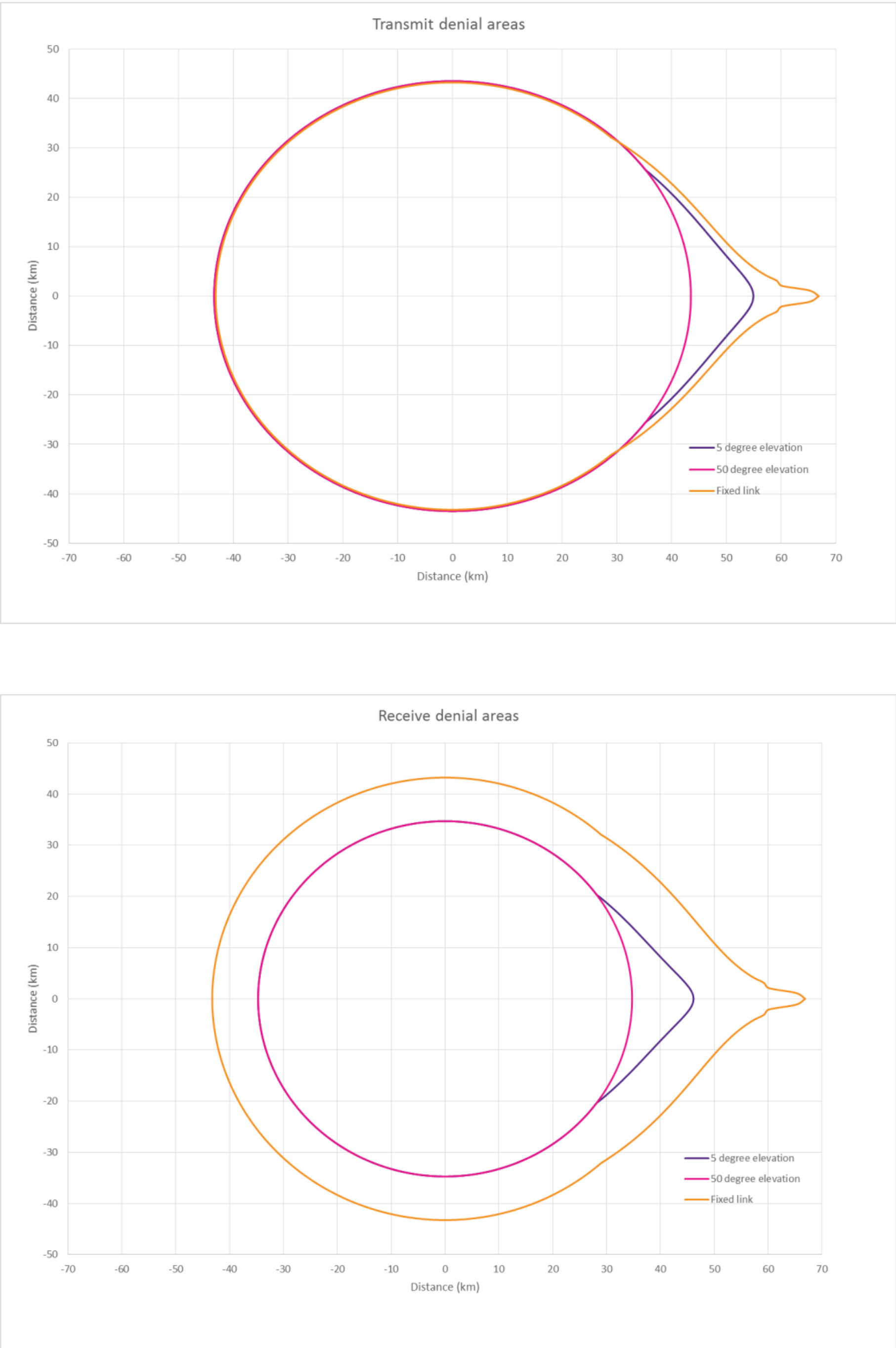
Fixed link		
Antenna gain	38.7 dBi	Median value
Antenna pattern	ITU-R Recommendation 699	D/λ=35.5, G(180°)=-5.5 dBi Front/Back = 44.2 dB
Height a.g.l.	22 m	Median value
Transmitter power density	-24.9 dBW/MHz	Median value
Receiver noise power density	-139 dBW/MHz	ITU-R Recommendation F.758-6
Criterion	-149 dBW/MHz	I/N = -10 dB
Earth station		
Antenna gain	66 dBi	Median value
Antenna pattern	RR Appendix 7	
Height a.g.l..	8 m	Representative[78]
Transmitter power density	-3.5 dBW/MHz	Median value
Receiver noise power density	-143.8 dBW/MHz	T = 300 K (RR Appendix 7 Table 6)
Criterion	-153.8 dBW/MHz	I/N = -10 dB

Source: ACMA database & ITU sources

[77] We have used a long term interference criterion here in order to derive a general relationship between fixed link and earth station denial areas. Consideration of short term effects can also be considered and may give a different relationship.

[78] Although there are several examples at 24 m

Figure 8-1: Relative transmit and receive denial areas of a satellite earth station and a fixed link – using the 18 GHz values of Table 8-1



Source: Plum analysis using the parameters given in Table 8-1.

8.1.2 Denial area calculations – 50 GHz

At the other extreme of the frequency range being considered by this report, namely 50 GHz, the denial areas are based on the parameter values shown in Table 8-2 and shown in Figure 8-2. Whereas at 18 GHz the denial areas approach parity, at 50 GHz the satellite earth station denial areas are significantly greater than those of a fixed link.

The satellite earth station / fixed link denial area ratio falls in the range 1.53 ±0.01 for a receiving satellite earth station and 2.41 ±0.01 for a transmitting satellite earth station where the ranges given relate to the assumed elevation angles of 20 and 50 degrees. It can be seen from Figure 8-2 that there is even less elevation dependence since we have assumed a minimum operating earth station elevation angle of 20 degrees.

Table 8-2: Assumed operating parameters for fixed links and earth stations at 50 GHz

Fixed link		
Antenna gain	44 dBi (note 1)	Representative from ITU-R Recommendation F.758-6 and RR Appendix 7 Table 7c
Antenna pattern	ITU-R Recommendation 699	D/λ=65.3, G(180°)=-8.1 dBi Front/Back = 52.1 dB
Height a.g.l.	22 m (note 2)	As used for lower frequency band
Transmitter power density	-30 dBW/MHz (note 3)	Representative from ITU-R Recommendation F.758-6
Receiver noise power density	-135 dBW/MHz	Representative from ITU-R Recommendation F.758-6
Criterion	-145 dBW/MHz	I/N = -10 dB
Earth station		
Antenna gain	40 – 59 dBi Higher value in range likely to be associated with trunk or feeder link earth stations.	(ITU-R Recommendation S.1557) D/λ = 41 – 367
Antenna pattern	RR Appendix 7	
Height a.g.l..	8 m	As used for lower frequency band
Transmitter power density	-3.5 dBW/MHz	As used for lower frequency band but see note 4.
Receiver noise power density	-141.6 dBW/MHz	T = 500 K (from a range of 350 – 800 K in ITU-R Recommendation S.1557)
Criterion	-151.6 dBW/MHz	I/N = -10 dB

Source: ITU references

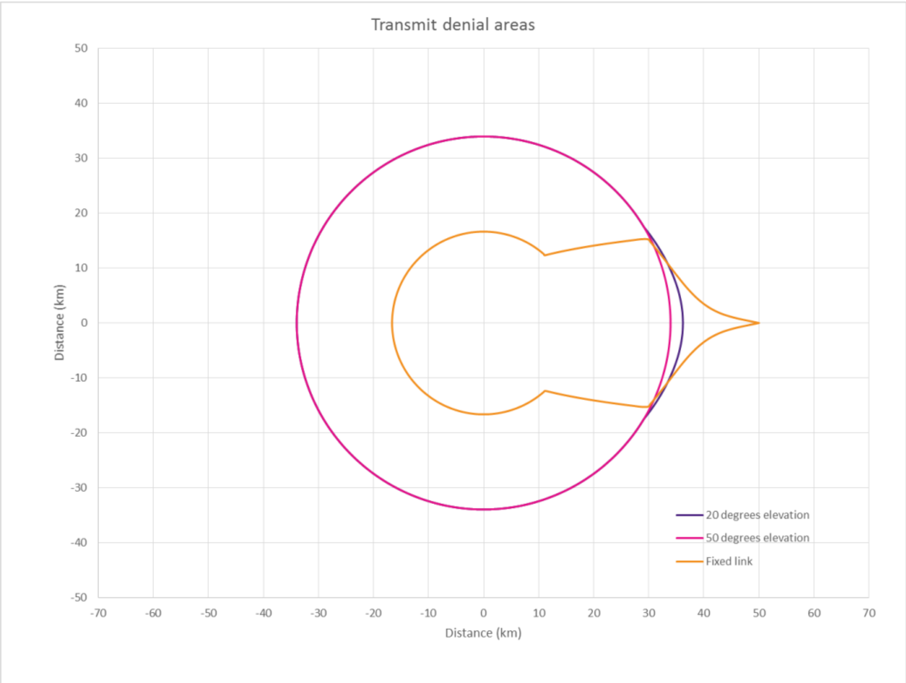
Note 1: 44 dBi can be compared with the 40.1 dB ACMA data median for the 38 GHz band

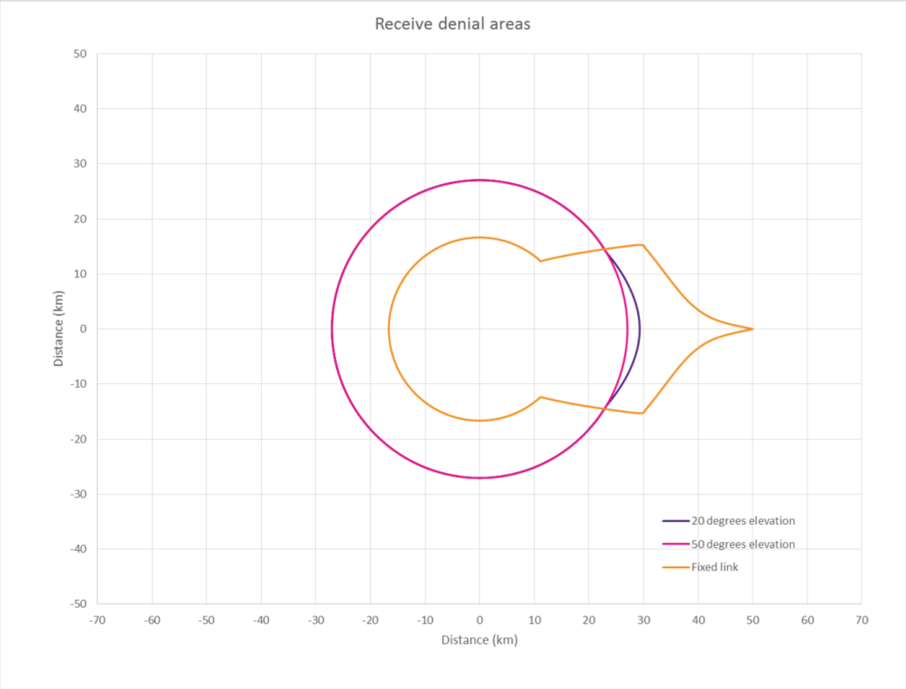
Note 2: 22 m can be compared with the 23 m ACMA data median for the 38 GHz band

Note 3: -30 dBW/MHz can be compared with the -28.5 dBW/MHz ACMA data median for the 38 MHz band

Note 4: ITU-R Recommendation S.1782 indicates that small terminals (G = 41.7 dBi) would require a transmitter power density of between -7 and -1.3 dBW/MHz under clear sky conditions and between 11.6 and 17.2 dBW/MHz using power control to accommodate short term rain fades.

Figure 8-2: Relative transmit and receive denial areas of a satellite earth station and a fixed link – using the 50 GHz values of Table 8-2





Source: Plum analysis using the parameters given in Table 8-2.

8.1.3 Implications

Table 8-3 compares the denial ratios with the fees ratios for satellite and fixed link services. If fees reflected denial areas then we would expect that the denial and the fees ratios would be broadly the same, however, this is clearly not the case. The ratios suggest that:

- For the 14.5-31.3 GHz range the satellite fees are high relative to unidirectional fixed link fees. In particular reductions in satellite fees of 50-66% are implied by our calculations.
- For the 31.3-51.4 GHz range the denial area ratios are better aligned with the fees ratios
- For both frequency ranges the transmit denial area is much larger than a receive denial area, suggesting that if bands are congested then the fees structure could be modified to include a discount for receive as compared with transmit activities.

Table 8-3: Denial area ratios (satellite/fixed link) and ratios of satellite to fixed link fees

	Denial area ratio satellite to fixed link		Fees ratio – satellite to fixed links			
	Transmit	Receive	High density	Medium density	Low density	Remote density
14.5-31.3 GHz	1	0.6	3.1	3.3	2.3	2.2
31.3-51.4 GHz	2.5	1.5	2.3	2.3	2.2	2.5

Source: Plum calculations

8.2 Variables impacting denial areas

The relationship between fixed link and earth station denial areas is primarily used to establish a ratio between spectrum fees attributable to these two types of terminal. However, as noted above, this relationship is based on a static representative set of parameter values. Not all systems will adhere to these values as they will have differing performance requirements. While there may be limited variation when it comes to receive characteristics there is likely to be a larger variation when it comes to transmit characteristics. This variation will in effect lead to a greater or lesser denial area and this should be reflected in a variation in the fees if significant. We do not perform the required calculations here but indicate the factors that might need to be taken into account if congestion were to become acute at Ka band such that fees for fixed links and satellite services would need to be put on a common footing.

In the case of fixed links, which we are not really addressing here, the variables are significant and in some cases it might be more suitable to use some characteristics as a proxy for power which itself is a dominant factor e.g. availability rather than power itself. This is done in the UK for example as it is the regulator that determines the power level permitted based on the applicants operational requirements rather than the applicant.

For earth stations it is generally the satellite operator that determines power levels that should be used by an earth station and the number of variables is therefore more straightforward, namely:

- The power (into the antenna) transmitted – not necessarily a linear factor depending on propagation behaviour
- The bandwidth used taking account of polarisation – a linear factor but noting the aggregation effect at a site as discussed below
- A band factor that decreases as frequency increases – depending on propagation behaviour and therefore not necessarily a linear factor as noted above

Taking account of these variables for a single earth station terminal is straightforward enough in concept but where multiple earth station terminals at a site each operating to a different satellite and on the same frequency are deployed it gets more complicated. In this instance an aggregation method would be required that represents the combined denial effect of multiple co-frequency carriers.

Recognising that spectrum denial does not increase linearly with each additional earth station terminal where usage of spectrum is coincident or overlaps, it is necessary to arrive at a discounting factor which encourages the co-location of terminals. In theory, and under free space conditions, two overlapping transmissions of equal power could effectively double the denial area and this would be achieved in the fee algorithm simply by using a power summation. However, less benign propagation conditions will reduce the aggregation effect significantly such that, for the example given, the result would fall between a factor of 1 and 2. Ofcom in the UK already use an aggregation factor in their fees formula for terminals operating within a circle of radius 500 m such that a square root is applied to the summed powers of spectrum that is coincident or overlaps. This encourages co-location of earth stations. We propose that a simple 30% reduction in fees[79] is applied when two or more co-frequency terminals are located within a circle of radius 500 m.

[79] This being between an aggregation factor of 1 and 2.

8.3 Denial areas – geo-stationary versus non-geostationary satellites

The values reported in Section 8.1 are based on an assumption that the earth station is pointed at a geostationary satellite and has an elevation in the range 5 to 50 degrees for the lower frequency and 20 to 50 degrees for the higher frequency. It has been seen in the preceding material that elevation makes little difference to the areas being considered. For NGSO operations it might reasonably be assumed that low elevation operations occur in all directions of azimuth and therefore the earth station exclusion areas of Figure 8-1 and Figure 8-2 become circular (and somewhat larger) for the low elevation cases.

In the case of the higher frequency (50 GHz), the increase in area will be minimal because of the minimum operating elevation of 20 degrees. At the lower frequency (18 GHz), the increase in area is more significant. For a transmit earth station the area increases from 6220 sq km to 9480 sq km, an increase of approximately 50% and for a receive earth station 4010 sq km to 6690 sq km and increase of approximately 67%.

The denial area ratios for the lower frequency range (18GHz) then increase from 1 to 1.5 (Tx) and 0.6 to 1.1 (Rx) for NGSO operations. What this implies is that in congested bands NGSO systems should pay fees that are roughly 50% higher than those paid by GSO systems. However, in practice NGSO space licensees (operating above 8.5 GHz) pay a fixed annual tax of $275 per MHz or 0.275/kHz which is roughly the same as the fee paid by GSO space licensees with a beam covering a high density area.

It should be noted that the implications of NGSO operations discussed above assume that the median and other representative values as used earlier for the GSO case also apply here. This may not necessarily be the case. However, if power were to be introduced as a variable to the earth station fees formula it can be argued that any power variation between a GSO system and an NGSO system will already be taken into account and a straightforward area factor could be applied. Based on the area increase discussed above a 50% premium could be considered for NGSO systems in the lower frequency bands.

8.4 Conclusions

The analysis presented in this section suggests:

- Assuming fees for fixed links remain unchanged, there is a case for reducing satellite fees in the 14.5-31.3 GHz range by 50-66%.
- If bands are congested in future then the fees structure could be modified to include a discount for receive as compared with transmit activities.
- Co-location of terminals should be encouraged by a 30% discount for each terminal within a 500m radius of another. This recognises the reduced impact of aggregated power as influenced by real-world propagation conditions
- GSO and NGSO systems should pay fees set on the same basis i.e. based on their relative denial areas. This implies a 50% premium for NGSO systems in the lower frequency band (14.5 – 31.3 GHz).

9 Findings and recommendations

In sections 2 and 3 we found that the frequency range under review (17.3-51.4 GHz) is not currently congested and is unlikely to be congested for at least the next 5 years. The ACMA's policy principles therefore suggest that licence taxes in this frequency range should be set at a rate that reflects the low opportunity cost associated with uncongested bands. The ACMA is nevertheless interested in understanding how opportunity cost principles might be applied to satellite bands and so this is considered below as well as the basis for setting fees in relatively uncongested bands.

9.1 Fee levels

We find that fees paid by satellite services in high and medium density areas in Australia can be said to be high based on:

- The LCA estimates we have produced: These give values of spectrum for congested locations (similar to high density areas) that are in the range $0.1-0.2/kHz and so are less than the current annual licence annual licence tax of $0.26/kHz for 14.5-31.3 GHz. This evidence alone suggests that a 40-50% reduction in fees in high and medium density area fees for Ka band could be justified, particularly given we have not identified the band as congested.
- Fees in other countries (reported in Section 5): Fees for earth station transmissions in other countries are generally much less than Australian fees for high density areas, though Australian fees in low density and remote areas (where most satellite systems in Australia are located (see Section 2)) are low by international standards. Because satellite operators in most countries pay satellite licence fees in addition to (and sometimes instead of) spectrum fees, the international data cannot be used to draw precise conclusions about the appropriate level of fees in Australia. Rather the data would seem to suggest that at least for high density areas (and possibly medium density areas) there could be a case for reducing fees.
- By making a like for like comparison of satellite fees with fixed link fees (i.e. adjusting for differences in denial areas). Assuming fixed link fees remain unchanged, there could be a case for reducing satellite fees or the 14.5-31.3 GHz range by between 50-66%.

The main argument against reducing fees in high and medium density areas is that long term nature of investments in gateway and similar satellite earth station transmission sites[80] (20 years or more) means it is important to have a strong incentive for operators to locate such earth stations in areas where there is the least possibility of congestion i.e. low density and remote areas. Our congestion analysis only has a 5 year time horizon and there is always therefore a risk of congestion occurring longer term in high and medium density areas if fees are reduced and as a result of demands from new services such as 5G. This means the tax schedule should always have a large difference between fees in high/medium versus low/remote areas and that moderate reductions in fees should be implemented initially (i.e. for the next 5 years).

On balance, therefore, we recommend that fee levels for Australia-wide licences and for licences in high and medium areas in the 17.3-51.4 GHz range are reduced to levels that are at the high end of the ranges we have obtained. We propose a 30% reduction in high density area and Australia-wide

[80] Rather than ubiquitous earth stations such as those for pay TV or satellite broadband to residential housing which are class licensed.

fees and a 10% reduction in medium density area fees. It might be thought that such a large reduction in fees would result in many more licence applications, however, the very large scale of irreversible upfront investments in satellite systems means that the spectrum fees will only be one of many factors influencing investment decisions i.e. we expect that demand will be relatively inelastic in the near term at least.

We do not propose any reductions in low density and remote areas as fees here are already low and there will still be a large difference between fees in these areas and those in high and medium density areas.

We have been asked to consider whether fees in exclusive satellite bands should be set at different levels from fees in shared bands. For example, it might be argued that the value of exclusive bands is higher because use limitations are not imposed by other services. However, we have no way of knowing whether this is the case in practice or not. This is because we have not found market data showing the value to satellite services of shared versus exclusive bands. Also our bottom-up calculations do not depend on the type of band occupied and we have not found any evidence of regulators elsewhere making this distinction in their fees structures. For all these reasons we consider that the same fees schedule should apply to shared and exclusive satellite bands.

9.2 Structure of fees

Fees for Ka band are mainly determined based on the following formula:

$$0.26 \times \text{Bandwidth} \times \text{Location weighting}$$

The annual taxes paid per kHz are as follows:

Spectrum location	Geographic location				
	Australia-wide	High density	Medium density	Low density	Remote density
>14.5 to 31.3 GHz	0.9768	0.2601	0.0571	0.0061	0.0029
>31.3 to 51.4 GHz	0.2664	0.1419	0.0308	0.0011	0.0005

Source: Apparatus licence fee schedule, ACMA, April 2015

There are several anomalies in the tax schedule and we suggest they should be removed. In particular:

- Fees for GSO and NGSO systems should be set on the same basis i.e. based on their relative denial areas. This implies a 50% premium for NGSO systems in the lower frequency band (14.5 – 31.3 GHz)
- There should not be a discount for use of CDMA technology
- The remote area fees should not increase at 2.69 GHz.

We consider that differences in propagation characteristics and reuse suggest the Australian tax schedule should have a break point at 24 GHz, so that the frequency range 14.5-31.3 GHz is segmented as 14.5-24 GHz and 24-31.3 GHz and that the fee for the 24-31.3 GHz band is 30% less than for 14.5-24 GHz.

Finally it might be expected that fees for access to spectrum would vary according to factors that reflect spectrum occupancy or denial to other users, such as power, whether services are collocated or not and whether transmit or receive functions are undertaken. Introducing a power factor further complicates the fees schedule and given the current absence of congestion we do not think this is justified at present. Also the Australia-wide licence provides an indirect incentive for frequency reuse across Australia and this gives an incentive to use narrower spot beams because of the higher reuse obtained (all else being equal).

We recommend that co-location of terminals should be encouraged by a 30% discount for each terminal within a 500m radius of another. This recognises the reduced impact of aggregated power as influenced by real-world propagation conditions

Appendix A: Weighted average cost of capital

The pre-tax nominal weighted average cost of capital (WACC) is commonly used to discount future costs and revenues. Estimates of the WACC for Australian satellite operators and more generally telecom operators are relevant to coming to a view on the WACC we should use in our calculations. WACC estimates and their sources as of January 2016 are given in Table A-1.

Table A-1: WACC estimates for Australian telecom and satellite operators

Source	Estimated WACC	Link to source
ACCC, 2011	Telstra pre-tax nominal WACC of 9.04% (6.25% real)	http://www.accc.gov.au/system/files/Discussion%20paper%20-%20FADs%20for%20fixed%20line%20services%20-%20public%20version.pdf
Macquarie, 2012	Telstra pre-tax nominal WACC of 9.6%	http://www.macquarie.com.au/dafiles/Internet/mgl/au/apps/retail-newsletter/docs/2012_07/TLS120712e.pdf
Credit Suisse, 2015	Telstra pre-tax nominal WACC of 7.75%	https://doc.research-and-analytics.csfb.com/docView?language=ENG&source=ulg&format=PDF&document_id=1046077381&serialid=9FeS0PQR32Uokygw%2BoFUPcCtO%2FLPiI7CO3V1JsB4rUc%3D
Optus, 2013	Industry pre-tax nominal WACC of 10.5% (post-tax of 8.4%)	http://www.acma.gov.au/webwr/_assets/main/lib550036/ifc41_2012-optus_supplementary.pdf
Phillip Capital, 2013	Optus (excl. Singtel) pre-tax nominal WACC of 8.1%	http://www.btinvest.com.sg/system/assets/18562/singtel20130815.pdf
Optus, 2015	Optus (Australia only) pre-tax nominal WACC of 10.4%	https://media.optus.com.au/wp-content/uploads/2015/07/Singtel-Annual-Report-2015.pdf
Maybank, 2013	Thaicom pre-tax nominal WACC of 12.64%	http://kelive.maybank-ke.co.th/KimEng/servlet/PDFDownload?DBId=2&rid=19788&lang=1
The Nation, 2015	Thaicom pre-tax nominal WACC of 9.8%	http://www.nationmultimedia.com/business/Thaicom-Plc-30247712.html
McKinsey-KPMG, 2010	nbn pre-tax nominal WACC of 9%	https://www.communications.gov.au/have-your-say/final-consultation-nbn-non-commercial-services-funding-options
Telstra/NBN agreements, 2011	nbn pre-tax nominal WACC of 10%	https://www.communications.gov.au/have-your-say/final-consultation-nbn-non-commercial-services-funding-options
Telstra/NBN TUSMA agreements, 2011	nbn WACC of 8%	https://www.communications.gov.au/have-your-say/final-consultation-nbn-non-commercial-services-funding-options

Source	Estimated WACC	Link to source
Vertigan CBA, 2014	nbn pre-tax nominal WACC of 8.3%	https://www.communications.gov.au/have-your-say/final-consultation-nbn-non-commercial-services-funding-options
DoC, 2015	nbn pre-tax nominal WACC of 6.46%	https://www.communications.gov.au/have-your-say/final-consultation-nbn-non-commercial-services-funding-options

Most estimates fall in the range of 8-10%. The latest estimation of the nbn's WACC is 6.46%; however, the benchmarking and LCA analysis models the cost to a private sector operator which one would expect to have a higher cost of capital than the Government-backed nbn. The private sector satellite operator estimates include 8-10% for Telstra and Optus, and 10-13% for Thaicom.

We conclude that 10% is a reasonable average to use, especially given that a new operator to the Australian satellite industry (which the LCA models) might expect to have a higher WACC than incumbent operators due to greater risk. On this basis we use 10% as our base case with 8% as a sensitivity test.

Appendix B: Satellite Fees

This appendix documents the fees charged to satellite services in ten countries likely to be relevant comparators for Australia, listed below.

- Canada
- France
- Germany
- Hong Kong
- Luxembourg
- New Zealand
- Singapore
- United Arab Emirates (UAE)
- UK
- US

B.1 Canada

Industry Canada (IC) commissioned a report by Nordicity in 2010[81] which used the discounted cash flow model to estimate the value of spectrum used by satellite services, in particular C band, Ku band and Ka band.

In May 2015 IC published the new fees schedule which will come into effect in April 2016[82]. IC are also adopting a new licensing approach and are replacing the radio licence with spectrum licences and also adopting a first-come first-served (FCFS) approach to licensing earth stations and satellites.[83]

For all BSS and FSS spectrum IC set a single fee of CA$120 per MHz which is applicable regardless of the frequency band.[84] IC had consulted on using different fee levels for each band (as recommended by Nordicity) but the majority of respondents preferred the simplicity of a single fee. The total amount of spectrum assigned is used to determine the amount of bandwidth (MHz) and is not affected by multiple spot beam re-use.

The full fee is charged when the satellite is operational, or four years after the licence has been issued (with fee increasing by CA$25 each of the intervening years). The new fees schedule reduces the fees charged (from CA$333 per MHz to $120/MHz). The adopted level of fees is an order of magnitude lower than those proposed by Nordicity which were as follows:

- C band spectrum: $1,400 per MHz per annum

[81] Study on the Market Value of Fixed and Satellite Spectrum in Canada, July 2010

[82] Supporting Satellite Services for Rural and Remote Communities, May 2015 http://news.gc.ca/web/article-en.do?nid=970859

[83] Gazette Notice — SMSE-021-14 http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf10909.html

[84] Decisions on the Licensing Framework for Fixed-Satellite Service (FSS) and Broadcasting-Satellite Service (BSS), Implications for Other Satellite Services in Canada, and Revised Fee Proposal, November 2013 http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf10602.html

- Ku band spectrum: $1,900 per MHz per annum
- Ka band spectrum: $2,200 per MHz per annum

That the adopted fees are radically different from the numbers estimated by Nordicity raises the question over whether the approach used by Nordicity (i.e. discounted cashflow) is relevant for calculating an appropriate level of fees for satellite spectrum.

B.2 France

The Nordicity report for Industry Canada discusses the licensing regime in France. According to Nordicity:

> *ARCEP charges a one-time space station application fee charge of €20,000.*
>
> *ARCEP sets the licence fees for ground stations based on cost recovery of its administrative costs.*
>
> - *A €20,000 licence fee for ground station(s) operated by telecommunications operators.*
> - *A management fee for costs related to spectrum management which varies according to the number of ground station assignments and whether fixed or mobile satellite service.*
> - *A frequency availability fee which varies according to the number of assignments and whether fixed or mobile satellite service.*

The frequency availability fees[85] were set in 2007 in French legislation.[86] The fees are set through generic formulae that contain parameters that are set by The Ministry.

In the case of earth stations for fixed or mobile satellite services the frequency availability fees are calculated by multiplying the coefficients of bf (frequency band factor) and k3.

$$k3 \times bf$$

The value of k3 is currently set at €15.5 per MHz and the value of bf varies as shown below and in the case of the Ka band is 0.6. Thus it becomes for the Ka band:

$$€15.5 \times 0.6 = €9.3 \; per \; MHz$$

[85] http://www.arcep.fr/sides/index.php?id=8082#c8079

[86] Decree of 24 October 2007 implementing Decree No. 2007-1532 of 24 October 2007 on charges for use of radio frequencies due by holders of frequency use authorizations issued by the Regulatory Authority for Electronic Communications and posts. NOR: ECEI0753536A = Arrêté du 24 octobre 2007 portant application du décret n° 2007-1532 du 24 octobre 2007 relatif aux redevances d'utilisation des fréquences radioélectriques dues par les titulaires d'autorisations d'utilisation de fréquences délivrées par l'Autorité de régulation des communications électroniques et des postes. NOR: ECEI0753536A

http://www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000000791516&dateTexte=vig&fastPos=1&fastReqId=1035830194&oldAction=rechTexte

Decree No. 2007-1532 of 24 October 2007 on radio frequency usage fees payable by holders of frequency use authorizations issued by the Regulatory Authority for electronic communications and postal services. NOR: ECEI0753560D = Décret n°2007-1532 du 24 octobre 2007 relatif aux redevances d'utilisation des fréquences radioélectriques dues par les titulaires d'autorisations d'utilisation de fréquences délivrées par l'Autorité de régulation des communications électroniques et des postes. NOR: ECEI0753560D

http://www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000000619224&categorieLien=cid

Table B-1: Values of bf (frequency band factor)

Band	Frequencies	Factor - bf
u (FSS)	10.7 and 14.5 GHz	1
17/18/19/20	17.3 and 20.2 GHz	0.7
Ka band (FSS)	17.3 and 30 GHz	0.6
21/22/23	21.2 and 23.6 GHz	0.6
25/26/28/32	24.25 and 33.4 GHz	0.5
38	37 and 39.5 GHz	0.3
40	39.5 and 43.5 GHz	0.3
60	59 and 66 GHz	0.2
70/80 and higher	Above 71 GHz	0.07

Source: ARCEP

For an FSS or MSS allotment (i.e. an assignment to the satellite service to use a block of spectrum in a given geographic area) the annual frequency availability fee is calculated by multiplying the coefficients of k3 and a (allotment variable) to provide a per MHz fee.

$$k3 \times a$$

Table B-2: Values of a (allotment variables)

FREQUENCY BANDS	VALUE of the coefficient a
Fixed service frequencies below 20 GHz.	400
Fixed service frequencies above or equal to 20 GHz.	1000
Frequencies of fixed-satellite service.	2.5
Frequencies of mobile-satellite service.	30
Frequency of independent mobile service networks.	2

Source: ARCEP

In the case of FSS the fee per MHz for an allotment will therefore be:

$$€15.5 \times 2.5 = €38.75 \; per \; MHz$$

And for MSS will be:

$$€15.5 \times 30 = €465 \; per \; MHz$$

The annual frequency management fee is €50 for each allotment of satellite system and €50 multiplied by the number of assignments for cases where frequencies are assigned.[87]

[87] http://www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000000619224&categorieLien=cid
http://www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000000791516&dateTexte=vig&fastPos=1&fastReqId=1035830194&oldAction=rechTexte

B.3 Germany

In Germany the Federal Network Agency levies an arrangement fee and annual contribution charges (TKG and EMVG) for a frequency assignment. The fees payable are:

- Fees related to initial licensing of satellite services. They need to be paid once upon the assignment of the frequencies. They can be found in the FGebV (frequency fee ordinance). [88] Last modification was 24th September 2013 and given in Table B-3.
- Annual contribution charges (TKG and EMVG) are payable under the "Verordnung über Beiträge zum Schutz einer störungsfreien Frequenznutzung" (Ordinance on contribution charges to protect interference-free frequency use). The contribution charges are recalculated annually on the basis of the Agency's expense for satellite communications users as determined by means of cost-results accounting and can be found in the FSBeitrV[89]. The latest fees are from 2011 and are shown in Table B-4.

Satellite receive-only equipment does not require a frequency assignment and so no fees are paid.

Table B-3: Fee related to initial licensing of satellite services (FGebV)

Chargeable event	Fee (€)
Satellite broadcasting	-
Allocating frequency to an earth station (without co-ordination)	68
Allocating frequency to an earth station (with co-ordination). The fees vary by type of assignment.	100-1000
Frequency assignment for a satellite network that requires a licence	500-3500

Source: BnetzA

Table B-4: Annual fees for satellite links resulting from the TKG and EMVG

Chargeable event	Fee per	TKG (€)	EMVG (€)
Coordinating relevant satellite radio link	Frequency	259.51	132.15
Not coordinating relevant satellite radio link	Frequency	23.85	110.06
Satellite earth station network	Frequency	200.67	421.75
Registered satellite system with the ITU in the name of Germany	Satellite system	3,285.63	0

Source: BnetzA

[88] http://www.gesetze-im-internet.de/fgebv/BJNR122600997.html
[89] http://www.gesetze-im-internet.de/fsbeitrv/BJNR095800004.html

plum

B.4 Hong Kong

In Hong Kong OFCA has introduced Spectrum Utilisation Fees (SUF) for congested bands for fixed links and satellite however the highest applicable frequency is 11.7 GHz[90].

The spectrum utilisation fee (SUF) charged on satellite spectrum is:[91]

- SUF will not be imposed on the spectrum in the 5850 – 5875 MHz band used by satellite uplinks or fixed links;
- SUF for C-band satellite uplinks in the 5875 – 6425 MHz band will be HK$350 per MHz per annum. The same level of SUF is also applicable to fixed links that share such C-band uplink spectrum on a non-protected and uncoordinated basis; and
- SUF for satellite uplink in the 6425 – 7075 MHz band will be HK$3,000 per MHz per annum

In addition there are also annual fees provided in the Communications Authority Document detailing validity and licence fees[92] and for self provided telecommunication services they are as follows:

- HK$ 6000 for VSAT earth station that requires co-ordination
- HK$ 5000 for VSAT earth station where no co-ordination is required
- HK$ 17000 for earth station other than VSAT
- HK$ 11000 for earth station where no frequency co-ordination is required.

B.5 Luxembourg

According to the Nordicity report, administrative fees are set by cost recovery and include a tax on turnover. An ILR (the regulator) document from 2006 supports this.[93] It would be difficult to benchmark a tax on turnover which was set to cover the regulators costs.

The current fees schedule (2013) states that:[94]

- There is a fixed fee of €5,000 per earth station site, regardless of the number of satellite links using the site.
- For additional earth stations in a MSS network the fee is €500 per MHz.
- Administrative charges to file a satellite with the ITU vary from €150 to €1,750 per filing.

B.6 New Zealand

The RSM only charges cost recovery fees on satellite services.[95] These fees do not vary with the amount of MHz assigned.

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[90] http://www.hlspectrumreview.com/2011/09/articles/spectrum-management/hong-kong-applies-new-spectrum-use-fees/

[91] http://tel_archives.ofca.gov.hk/en/tas/spectrum/ta20110923.pdf

[92] http://www.coms-auth.hk/filemanager/en/content_54/fee_validity_e.pdf

[93] Décision 06/103/ILR du 15 décembre 2006 http://www.ilr.public.lu/communications_electroniques/decisions/2006/06103.pdf

[94] Grand Ducal Regulation, At Memorial A No. 45 of 03.12.2013, royalties radio frequency https://translate.googleusercontent.com/translate_c?depth=1&hl=en&ie=UTF8&prev=_t&rurl=translate.google.com&sl=fr&tl=en&u=http://www.legilux.public.lu/leg/a/archives/2013/0045/index.html&usg=ALkJrhjjUrxC8LTYqZ21MQX_BIxt9b-JFg#2013A0598A

Table B-5: Cost recovery fees in New Zealand

Service (Radio rather than spectrum licences only)	Annual cost recovery fee (NZD)
Fixed-satellite service (per transponder accessed)	306.67
Other satellite services (non-shared with fixed services)	306.67
Other satellite services (shared with fixed services)	306.67
Radio determination (including radiolocation and radionavigation)	255.55
Telemetry and telecommand (including space telecommand)	255.55

Source: RSM

B.7 Singapore

The following fees are provided in the IDA Spectrum Management Handbook 2015:[96]

- Application fees for satellite downlink frequencies are SG$750 per band.
- Annual frequency management fee for satellite downlink frequencies SG$600 per band.

For other spectrum (such as satellite uplink) there are both application and annual fees.

Table B-6: Application fees (applicable to satellite uplink not downlink)

Radio Frequency Spectrum	Application & Processing Fee Payable Per Frequency
25 kHz or less	SG$290
25 kHz < bandwidth < 500 kHz	SG $450
500 kHz ≤ bandwidth < 1 MHz	SG $1,350
1 MHz ≤ bandwidth < 20 MHz	SG $2,700
Bandwidth ≥ 20 MHz	SG $4,650

Source: IDA

[95] http://www.rsm.govt.nz/licensing/licence-fees/annual

[96] https://www.ida.gov.sg/~/media/Files/PCDG/Licensees/SpectrumMgmt/SpectrumNumMgmt/SpectrumMgmtHB.pdf

Table B-7: Annual fees (applicable to satellite uplink not downlink)

Radio Frequency Spectrum	Fee payable per frequency per annum
1. Frequencies for Networks and Systems (a) exclusive use (i) bandwidth of less than 1 MHz	SG$300 per 25 kHz of occupied bandwidth or part thereof
(ii) bandwidth of 1 MHz or more	SG$12,000 for the first MHz of occupied bandwidth, and SG$300 per subsequent MHz of occupied bandwidth or part thereof
(b) shared use (i) bandwidth of less than 300 kHz	SG$300 per 25 kHz of occupied bandwidth or part thereof
(ii) bandwidth of 300 kHz or more but less than 20 MHz	SG$3,500
(iii) bandwidth of 20 MHz or more	SG$6,200

Source: IDA

Regarding orbital slots there are annual fees and variable fees.

Table B-8: Orbital slot fees in Singapore

Annual fees	
Satellite orbital slot with frequency assignment for which co-ordination is mandatory	SG$80,000 for first orbital slot and SG$10,000 for every subsequent slot
Satellite orbital slot with frequency assignment for which frequency co-ordination is non-mandatory	SG$4,000 for first orbital slot and SG$500 for every subsequent slot
Variable fees	
ITU's processing fees for each applicable satellite network filing	Cost of ITU
Co-ordination meeting(s) with other administrations that require IDA's presence	SG$30,000 per meeting plus SG$3,000 per day for duration of meeting

Source: IDA

Additionally, there is an annual charge of SG$100 per earth station.[97]

A licence for a satellite operator to operate is SG$5,000 per annum.[98]

B.8 UAE

The 2009 fees schedule contains the following charges on satellite users of spectrum.[99]

97 https://www.ida.gov.sg/~/media/Files/PCDG/Licensees/Licensing/Framework%20and%20Guidelines/GuidelinesLicensingSch/GuideSateComm.pdf

98 https://www.ida.gov.sg/~/media/Files/PCDG/Licensees/SpectrumMgmt/RightsIssued/AscentMedia.pdf

Table B-9: Satellite fees in the UAE

Chargeable event	Annual fee (AED)
Each private VSAT	5,000 for each private VSAT
Each earth station	50,000
TVRO (TV receive only)	-
Each DSNG (Digital Satellite News Gathering)	5,000
For offering Aeronautical or Maritime Mobile Satellite Service	10,000
For offering Earth Exploration Satellite service	10,000
Up linking of DAB, DVB-S and DVB-SH	200,000 AED per multiplex unit
Up linking of DVB-RCS	400,000 AED per multiplex unit

Source: TRA Note: 1 AED = 0.38 AUD

B.9 UK

In the UK the earth station fees are calculated using algorithms based on four main components:

- The power (into the antenna) transmitted
- The bandwidth used
- A band factor that decreases as frequency increases
- An aggregation method (square root and summations) that represents the combined denial effect of multiple carriers over multiple frequencies operating at an earth station site, noting that the effect of different frequency bands is kept separate.

The fees are detailed in the Statutory Instrument[100]. The fees have been recently reviewed by Ofcom and are now the subject of a consultation.[101]

Permanent Earth Station

The algorithm that currently applies to Permanent Earth Stations (PES) is:

$$\text{AIP Fee} = \sum_{bands} \left[\beta \times BF_{band} \times \sqrt{\sum_{paths_{band}} \left(P_{path} \times BW_{path}\right)} \right]$$

where:

[99] http://www.tra.gov.ae/files/documents/2014/12/20141217133419-spectrum_affairs-Spectrum%20Fees%20Regulations%20v2.0_En.pdf

[100] Statutory Instrument 2011 No.1128 "The Wireless Telegraphy (Licence Charges) Regulations 2011" and http://licensing.ofcom.org.uk/binaries/spectrum/satellite-earth-stations/fees.pdf

[101] http://stakeholders.ofcom.org.uk/consultations/review-spectrum-fees-fixed-links-satellite/
http://www.plumconsulting.co.uk/pdfs/Plum_Apr_2015_Fixed_links_PES_fees_review.pdf

β	=	the reference fee and has a value of 28
P_{path}	=	peak power delivered into the antenna for each transmission path (W)
BW_{path}	=	transmit authorised bandwidth for each transmission path (MHz)
BF_{band}	=	band factor equal to: 2.33 for frequencies less than 5 GHz; 1.72 for 5-10 GHz; 1 for 10-16 GHz; 0.7 for 16-24 GHz; and 0.60 for frequencies greater than and equal to 24 GHz. The 14 GHz band is defined as the reference band and has a band factor of 1.
Band	=	five defined band ranges with boundaries at 5, 10, 16 and 24 GHz
Path	=	between a transmit earth station and a satellite receiver being defined by frequency, polarisation, peak power and bandwidth.

The reference fee for the algorithm was derived from AIP fees for a typical unidirectional fixed link in the 14 GHz band and assuming typical earth station power and bandwidth values for the band[102].

In the case of a receive-only PES that has protection under RSA, the fee derived from the PES algorithm is applied to the receiver. There is a baseline fee of £17/MHz but this can be reduced through the use of site shielding or may be increased if the earth station receiver is more sensitive and requires greater protection. A minimum fee of £500 applies.

Transportable Base Station

The fees payable for Transportable Base Stations are based on the value of p which is calculated by multiplying the widest bandwidth, WBW, (in MHz) and the operational maximum power, OMP, (in Watts) as shown in the table below. The fee also varies by the applicable band.

Table B-10: Transportable base station fee in the UK

Column 1: Range of p	Column 2: Fee (£) per earth station in the band 5.925 – 7.075 GHz	Column 3. Fee (£) per earth station in the band 13.78 – 14.5 GHz	Column 4. Fee (£) per earth station in the bands 27.5 – 27.8185, 28.4545 – 28.8265, 29.4625 – 29.4630 GHz
0 < p ≤ 100	500	300	200
100 < p ≤ 2,500	2,400	1400	800
p > 2,500	7,400	4300	2600

Source: Ofcom

Other fees

In addition there is a one off fee of £200 for each terminal in an earth station network requiring technical co-ordination.

[102] Annex 5, Modifications to spectrum pricing, Statement, Ofcom, 2007 http://stakeholders.ofcom.org.uk/binaries/consultations/pricing06/statement/statement.pdf

Also earth stations for non-fixed satellite services and non-geostationary satellite are charged an annual fee of £3500 for each site. A site is defined as an area within a circle of radius 500 metres centred on a point defined by the licensee.

B.10 USA

As described by the FCC[103][104] there are annual fees payable on satellite services.

Table B-11: Annual satellite fees for 2015 in the USA

Type of fee	Regulatory fee payment (USD)
Earth stations	$310 per station or Hub Station
GSO Space Stations and Direct Broadcast Satellite Services Licensees	$119,150 per operational space station
NGSO Satellite Systems	$132,125 per operational system
International Bearer Circuits: terrestrial Common Carrier; Satellite Common Carrier; and Satellite Non-Common Carrier (capacity as of 31/12/2013)	$0.03 per active 64 KB circuit or equivalent. See below.

Source: FCC, Regulatory fees fact sheet, September 11, 2015

According to the Nordicity report, there is also a performance bond placed on the space station licence holders to build and launch the satellite:

> *"To incent satellite licensees to build and launch satellites within an appropriate time frame, the FCC mandates licences post $3-$5 million performance bonds within 30 days of licence grant ($3 million for GSO space stations and $5 million for NGSO space stations). The bonds are posted for 3 to 5 year terms as appropriate, and the cost of capital associated with posting the bonds is therefore a de facto licence fee. Using the weighted average cost of capital (WACC) of 9% calculated in Section 4.3.4, the cost of posting a USD 3 million bond for three years is approximately USD 885,087."*

This information is corroborated by another source[105] and an FCC document[106].

[103] https://apps.fcc.gov/edocs_public/attachmatch/DOC-335227A1.pdf

[104] https://www.fcc.gov/document/fy-2015-payments-and-procedures-public-notice-regulatory-fees

[105] https://www.law.cornell.edu/cfr/text/47/25.165

[106] https://apps.fcc.gov/edocs_public/attachmatch/FCC-13-111A1.pdf