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| Conditions for the 2.3 GHz band |
| A review of the 2.3 GHz technical instruments as part of the expiring spectrum licence process |
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| |  |  |  | | --- | --- | --- | | **Version** | **Release Date** | **Comments** | | 1 | 16 October 2012 | Initial release | | 2 | 18 February 2013 | Amendments as a result of TLG member input to version 1 | | 3 | 15 August 2013 | Amendments as a result of TLG member input to version 2 | | 4 | 11 October 2013 | Final version—no more amendments | |

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| --- | --- | --- | --- | --- | --- |
| |  |  |  |  |  | | --- | --- | --- | --- | --- | | **Canberra**  Purple Building  Benjamin Offices  Chan Street  Belconnen ACT  PO Box 78  Belconnen ACT 2616  T +61 2 6219 5555  F +61 2 6219 5353 | **Melbourne**  Level 44  Melbourne Central Tower  360 Elizabeth Street Melbourne VIC  PO Box 13112  Law Courts  Melbourne VIC 8010  T +61 3 9963 6800  F +61 3 9963 6899 | **Sydney**  Level 5  The Bay Centre  65 Pirrama Road  Pyrmont NSW  PO Box Q500  Queen Victoria Building  NSW 1230  T +61 2 9334 7700  1800 226 667  F +61 2 9334 7799 |  |  | |
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# Introduction

## 2.3 GHz spectrum licence

The ACMA develops a technical framework for each spectrum-licensed band. Each framework is a collection of technical and regulatory conditions applicable to the use of radiocommunications devices in a spectrum-licensed band. The purpose of the technical framework is to define the technical conditions and constraints under which a device may be deployed and operated with the specified geographic area and frequency band of the licence.

Although the technical framework is optimised for technologies or services most likely to be deployed in the band, it is intended to be technology flexible. This means licensees can operate any type of radiocommunications device for any purpose, provided they comply with the technical framework relevant to the licence.

The 2.3 GHz band is allocated Australia-wide in the 2302–2400 MHz band via the issue of spectrum licences under the *Radiocommunications (Spectrum Designation) Notice No. 1 of 2000[[1]](#footnote-2)*. The band was allocated in unpaired 7 MHz lots in a number of geographic areas (refer to section 3.1). Existing spectrum licences in the 2.3 GHz band are due to expire on 24 July 2015. The ACMA reviews the technical frameworks for a spectrum-licensed band as licences approach expiry. This helps to ensure the framework remains current and is capable of managing interference across the tenure period of a spectrum licence, which may be up to 15 years.

The ACMA also notes that the proposed re-allocation of the 2300–2302 MHz frequency range for spectrum licensing is currently on hold pending further analysis of stakeholder submissions. No decision has been made yet on the band. However, in the event this 2 MHz of spectrum is made available for spectrum licensing, the proposed revised technical framework has been developed to seamlessly incorporate it if required. Information on the consultation process for the 2300–2302 MHz band is available from the ACMA website [here](http://www.acma.gov.au/Citizen/Take-action/Consultations/Current/ifc-92013-proposed-reallocation-of-the-23002302-mhz-band-for-spectrum-licensing).

This paper details the updates to the technical framework made in consultation with the Technical Liaison Group for the 2.3 GHz band. The intention is that the updated technical framework will apply to any re-issued or re-allocated licences in the 2.3 GHz band from 25 July 2015.

## Technical liaison group

A technical liaison group (TLG) is a short term advisory body convened by the ACMA as a forum for consultation between the ACMA, industry and other stakeholders with interest in the technical framework relating to spectrum licences.

The task of the TLG is to consider and provide advice to the ACMA on the technical and regulatory aspects required for the development or review of a spectrum licence technical framework. The technical framework of a spectrum licence consists of three interlocking components made under the *Radiocommunications Act 1992*:

* the spectrum licence (part 3.2 of the Act)
* the subsection 145 (4) determination of unacceptable interference
* the section 262 advisory guidelines

This paper is a culmination of the work conducted in the TLG for consideration of the next spectrum licence period for the 2.3 GHz band beginning on 25 July 2015. It contains where appropriate, detailed analysis, input and consideration of various technical and regulatory issues associated with the development of the technical framework.

The TLG will not update the current marketing plan for the 2.3 GHz band. The TLG will consider technical conditions that may be affected as a result of aggregation and that would apply to any available lots for a market based allocation. Further consultation on release of the 2300-2302 MHz band, the making of a new marketing plan and subsequent allocation process will occur during a separate process.

Key changes to the existing technical framework:

* changes to allow inclusion of the band 2300–2302 MHz, if required;
* change of the minimum contiguous bandwidth to 5 MHz;
* use of a ‘restricted block’ concept to manage adjacent channel interference;
* reduction in the outside the area emission limit to 68 dBm per 5 MHz;
* modification to the outside the band emission limits;
* modification to the method to calculate the device boundary criterion;
* interference management to and from television outside broadcast (TVOB) systems; in the adjacent band 2200–2300 MHz;
* refinement of measures to manage interference to earth stations operating in the band 2200–2300 MHz, including the implementation of in-band and out-of-band coordination requirements for deep space research receivers in 2290–2300 MHz, specified in a new RALI MS 37;
* refinement of registration exemption requirements to allow for deployment of femtocells, smart repeaters and high gain user terminals.

## Comments specific to version 1

The ACMA received 7 submissions from 4 stakeholders (Telstra, Department of Defence, NBN Co and Optus) to the first version of the 2.3 GHz TLG consultation process (TLG v1) covering a wide range of issues throughout this document. Inputs were received from:

A summary of the concerns are provided in dot-point format:

* Issues in reducing the OOA limit too far, limiting the flexibility to licensees
  + Increase from 60 dBm/(5 MHz) to 68 dBm/(5 MHz) (Section 2.4, Table 2, and Section 3.3)
* Consideration of the deployment of fixed services
  + Inclusion of fixed service parameters (Section 2.4, Table 2)
* Issues with the use of the cascaded knife edge propagation model
  + Change to ‘Delta-Bullington Model’ of Rec ITU-R P.526-12 (Section 4.1 and Annex H)
* Variations to the system model to take account of actual performance of systems in the band
  + Increase of BS antenna height from 30 m to 40 m (Section 2.4, Table 2)
  + Inclusion of fixed UEs with directional antennas (higher EIRPs) (Section 2.4, Table 2)
  + Increase of UE antenna height from 1.5 m to 5 m (Section 2.4, Table 2)
  + Relaxation of non-spurious OOB emission limits from LTE MSR emission mask to LTE Cat B emission mask within the band and at the 2400 MHz band edge (Section 3.4.1)
  + Relaxation of non-spurious OOB emission limits from LTE UE mask for a 5 MHz emission, to that for a 10 MHz emission (Section 3.4.1)
* Third-party authorisations and adjacent area apparatus licensing
  + Addressed in Sections 3.6.1, 5.2.1
* Reference signals and physical channels in the 5 MHz restricted block
  + Addressed in Section 3.3.2
* Inter-licensee device registration exempt requirements
  + Inclusion of fixed UEs with directional antennas and higher EIRPs (Section 3.6.2.1)

## Comments specific to version 2

The ACMA received 3 submissions from CSIRO, Defence and NBN Co to the second version of the 2.3 GHz TLG consultation process (TLG v2).

A summary of the concerns are provided in dot-point format:

* Consideration of additional ITU-R Recommendations for protection of earth stations.
  + Addressed as part of a wider revision of protection of adjacent-band earth stations—see Sections 3.5 and 5.3.2.
* Requirements to register airborne transmitters.
  + Under investigation for Defence’s Delamere licence only and on a no interference and no protection basis.
* Lack of consideration of co-channel interference, including between base stations
  + No change proposed. The methodology implemented is a trade-off between interference management and usability of spectrum close to spectrum licence area boundaries. Greater protection can only be provided by increasing the size of deadzones at the boundary.
* Lack of consideration of handheld mobile UEs.
  + No changes required, but addressed in Section 4.2.2.
* Additional conditions for interference management between co-sited devices.
  + No changes required, but addressed in Section 3.7.1.
* Consideration of height benchmarking for interference resolution.
  + Not adopted.
* Restricted blocks.
  + No changes adopted.
* Registration exemption of high power UEs.
  + No changes adopted.
* Strictness of the UE out-of-band emission limits and UE registration exemption power requirements.
  + No changes adopted.
* Strictness of base station non-spurious out-of-band emissions.
  + Already addressed in Section 3.4.1.4 of TLG v2.

The ACMA has produced a separate response paper to provide an explanation of the changes made or not made to the TLG Consultation Paper. The most notable developments, resulting in significant modifications to the TLG Consultation Paper are:

* the ACMA’s intention to develop a Radiocommunications Assignment and Licensing Instructions (RALI) to address protection of SRS deep space facilities operating in 2290–2300 MHz (Sections 3.5 and 5.3.2).
* proposed simplification of notional receiver blocking requirement (Section 5.2.4)

## Comments specific to version 3

The ACMA received 3 submissions from Optus, CSIRO and NBN Co to the third version of the 2.3 GHz TLG consultation process (TLG v3).

A summary of the concerns are provided in dot-point format:

* Refinement of deep space research receiver protection requirements;
  + Incorporated in RALI MS 37.
* Concerns over spectrum denial resulting from deep space research receiver protection requirements:
  + No changes adopted.
* Further processes to manage co-channel, adjacent-area interference;
  + Addressed in Section 5.3.1.
* Registration exemption of high power UEs;
  + ‘No interference’ condition included in Other Condition 11 of the spectrum licence.
* Clarity of registration exemption requirements;
  + Addressed in Section 3.6.2.1.
* Strictness of the UE out-of-band emission limits and UE registration exemption power requirements;
  + Comments already provided for TLG v2, no changes adopted.

# Framework analysis

## Non-technical amendments

As part of the review of the technical framework for the 2.3 GHz band, the ACMA is requesting that TLG members consider a number of non-technical amendments to the legislative instruments. These broadly include:

* changes to formatting
* revision of definitions and reference documents
* amendments as a result of legislative change

Work on the expiring spectrum licence process has given the ACMA the opportunity to review the spectrum licence regulatory and technical frameworks. The ACMA has been reviewing this process since 2008, and a discussion paper[[2]](#footnote-3) was released as a result.

The discussion paper outlined a number of minor, incremental changes to the spectrum licence regulatory framework. The proposed changes will support all spectrum licences issued from 2012, providing increased flexibility and offering greater spectrum utility as a result.

With respect to formatting changes, the most important change has been to the structure of the spectrum licence – refer to section 3 and Annex I for more detail.

## Interpretations

Legislative instruments forming a technical framework typically contain a number of interpretations that define the particular intent of a word or words to be used in that instrument. A number of interpretations are also referenced to other legislative instruments; in particular, the *Radiocommunications Act 1992* is referenced extensively in the instruments.

In reviewing the technical frameworks for the 800 MHz and 1800 MHz bands as well as the development of the new technical frameworks for the 700 MHz and 2.5 GHz bands, the ACMA identified a number of interpretations that required clarification.

Without being exhaustive in this document, it is recommended TLG members consult the new technical framework instruments for the rewording of the interpretations. The ACMA will provide as a result of this TLG, draft legislative instruments for the TLG to consider which will contain the wording of the interpretations in the annexes.

Copies of the final technical instruments for the bands are available at:

* 700 MHz
  + [Radiocommunications Spectrum Marketing Plan (700 MHz Band) 2012](http://www.comlaw.gov.au/Details/F2012L02547)
  + [Radiocommunications (Unacceptable Levels of Interference — 700 MHz Band) Determination 2012](http://www.comlaw.gov.au/Details/F2012L02543)
  + [Radiocommunications Advisory Guidelines (Managing Interference from Transmitters – 700 MHz Band) 2012](http://www.comlaw.gov.au/Details/F2012L02546)
  + [Radiocommunications Advisory Guidelines (Managing Interference to Receivers – 700 MHz Band) 2012](http://www.comlaw.gov.au/Details/F2012L02544)
* 800 MHz
  + [Radiocommunications Advisory Guidelines (Managing Interference from Spectrum Licensed Transmitters - 800 MHz Band) 2012](http://www.comlaw.gov.au/Details/F2012L01775)
  + [Radiocommunications Advisory Guidelines (Managing Interference to Spectrum Licensed Receivers - 800 MHz Band) 2012](http://www.comlaw.gov.au/Details/F2012L01774)
  + [Radiocommunications (Unacceptable Levels of Interference - 800 MHz Band) Determination 2012](http://www.comlaw.gov.au/Details/F2012L01777)
* 1800 MHz
  + [Radiocommunications (Unacceptable Levels of Interference – 1800 MHz Band) Determination 2012](http://www.comlaw.gov.au/Details/F2012L02045)
  + [Radiocommunications Advisory Guidelines (Additional Device Boundary Criteria - 1800 MHz Lower Band) 2012](http://www.comlaw.gov.au/Details/F2012L02046)
  + [Radiocommunications Advisory Guidelines (Managing Interference from Spectrum Licensed Transmitters - 1800 MHz Band) 2012](http://www.comlaw.gov.au/Details/F2012L02048)
  + [Radiocommunications Advisory Guidelines (Managing Interference to Spectrum Licensed Receivers - 1800 MHz Band) 2012](http://www.comlaw.gov.au/Details/F2012L02047)
* 2.5 GHz
  + [Radiocommunications Spectrum Marketing Plan (2.5 GHz Band) 2012](http://www.comlaw.gov.au/Details/F2012L02552)
  + [Radiocommunications (Unacceptable Levels of Interference — 2.5 GHz Band) Determination 2012](http://www.comlaw.gov.au/Details/F2012L02545)
  + [Radiocommunications Advisory Guidelines (Managing Interference from Transmitters – 2.5 GHz Band) 2012](http://www.comlaw.gov.au/Details/F2012L02550)
  + [Radiocommunications Advisory Guidelines (Managing Interference to Receivers – 2.5 GHz Band) 2012](http://www.comlaw.gov.au/Details/F2012L02549)
* 2.5 GHz MBG[[3]](#footnote-4)
  + [Radiocommunications Spectrum Conversion Plan (2.5 GHz Mid-band Gap) 2012](http://www.comlaw.gov.au/Details/F2012L02542)
  + [Radiocommunications (Unacceptable Levels of Interference — 2.5 GHz Mid-band Gap) Determination 2012](http://www.comlaw.gov.au/Details/F2012L02553)
  + [Radiocommunications Advisory Guidelines (Managing Interference from Transmitters - 2.5 GHz Mid-band Gap) 2012](http://www.comlaw.gov.au/Details/F2012L02555)
  + [Radiocommunications Advisory Guidelines (Managing Interference to Receivers – 2.5 GHz Mid-band Gap) 2012](http://www.comlaw.gov.au/Details/F2012L02558)

As work on the new instruments and review of the technical framework occur, interpretations that are particular to the 2.3 GHz will be detailed in .

|  |  |
| --- | --- |
| **Interpretation** | **Definition** |
| front-to-back ratio | is the response of the highest peak of the antenna radiation pattern in the region 180° ±40° (i.e. azimuths from 140° to 220°) relative to the main beam |

Table : Interpretations specific to 2.3 GHz band

## Minimum contiguous bandwidth & standard trading unit

A spectrum licence may be traded in whole, or in part, by geographic area or frequency or both. Under section 88 of the Act, the ACMA may determine the rules that apply to trades under spectrum licensing. These rules are contained in the *Radiocommunications (Trading Rules for Spectrum Licences) Determination 2012[[4]](#footnote-5)* (trading determination).

The trading determination specifies the minimum contiguous holding of spectrum space required by a licensee after the completion of a trade. This is a combination of frequency and geographic requirements. Where:

1. the frequency requirement is referred to as the minimum contiguous bandwidth (MCB)
2. the geographical requirement is equal to the geographical component of the standard trading unit (STU)

The minimum quotas of frequency and area that can be traded are defined by the STU. Previously the STU was defined in the marketing plan for each spectrum licence. Changes to the trading determination in 2012 resulted in a redefinition of the STU for spectrum licensed bands.

The STU defined in the *Radiocommunications Spectrum Marketing Plan (2.3 GHz Band) 2009* means a parcel of spectrum space that consists of:

1. a geographic area equal to a cell of the spectrum map grid; and
2. a frequency band having lower and upper frequency limits defined by:
3. 2302 + [*n* x 3.5] MHz; and
4. 2302 + [(*n*+1) x 3.5] MHz;

respectively, where *n* is an integer from 0 to 27 (inclusive).

The STU that now applies to all bands, as defined in the trading determination, is a parcel of spectrum space that consists of:

1. a geographic area equal to a Level 1 cell of the 2012 Australian Spectrum Map Grid (ASMG)[[5]](#footnote-6) – approximately a 9×9 kilometre cell
2. a frequency band where the lower and upper frequency limits of each segment are integers when described in Hertz

The frequency bandwidth component of the STU has effectively changed to 1 Hz. This change is intended to provide licensees with greater flexibility in the quantum of spectrum that may be traded, subject to the value of the MCB. The minimum area is referenced to the ASMG mapped consistently in five-minute increments by latitude and longitude.

The frequency STU is 1 Hz and the geographic STU is a geographic area equal to a level 1 cell of the 2012 Australian Spectrum Map Grid (ASMG).

The minimum contiguous holding of frequency band applicable after the completion of a trade is defined as the MCB. The MCB is defined in the trading determination. The current MCB for the 2.3 GHz band (2302-2400 MHz) is 3.5 MHz.

The use of a 3.5 MHz MCB does not align well with the system model technologies of section 2.4, the need to harmonise with international arrangements and the demand for data services in this band. The majority of bands considered applicable to Wireless Access Services (WAS) use an MCB of 5 MHz which aligns well with modern technology standards.

The proposed minimum contiguous bandwidth (MCB) for the technical framework of the 2.3 GHz band (2300-2400 MHz) spectrum licence is 5 MHz.

The ACMA will consult formally on making amendments to the Trading Rules Determination to modify the 2.3 GHz MCB to 5 MHz and be applicable across the 2300-2400 MHz band if it is agreed amongst TLG stakeholders.

Section 3.1 details for the release of the 2300-2302 MHz band for spectrum licensing and its incorporation into what is considered the 2.3 GHz band. New and existing licensees will be encouraged to participate in the allocation of this spectrum.

As a general rule, the ACMA allocates lots in a band equal to or greater than the MCB; however, due to existing 2.3 GHz spectrum licences and any re-issue considerations that will occur, this may not be possible in all areas for the release of the 2300-2302 MHz band. In these areas, the ACMA will allocate lots that only have a frequency component of 2 MHz.

Licensees will need to be aware that in order to trade spectrum, that unless permission is granted by the ACMA, the minimum contiguous holding of spectrum as a result of the trade will need to consist of at least a single ASMG cell and a contiguous 5 MHz of spectrum.

## System models

System models are used to simplify the analysis of the technical framework. The development of the technical framework for current spectrum licences included analogue and digital multipoint distribution systems (MDS), CDMA2000 (TDD variant) and TD-SCDMA; however operationally, the band primarily utilises WiMAX with a growing trend toward LTE deployment.

The choice in technology type in the development of this technical framework is limited to WAS and the fixed service, but does not exclude the use of other technologies under the licence or operating systems using different parameters than those specified (increased transmitter gain at the expense of reduced transmitter power for example). Specific technologies being considered in the development of the new technical framework include:

* Long-term Evolution (3GPP 36-series)[[6]](#footnote-7)
* WiMAX (802.16e)[[7]](#footnote-8)

This TLG focuses on a change in primary use for the band, from MDS to WAS. This has a direct impact on the requirements of the framework, in particular, consideration of different technologies and systems in the band. This may result in significant changes to the outside the area and outside the band emission limits.

Licensees are requested to confirm that a change in use of the band from MDS to WAS is appropriate in the 2.3 GHz band. Licensees that wish to continue operating MDS in the band should consider what the proposed changes mean to their system and comment appropriately.

Whilst the technical framework is being tailored to suit WAS technologies, it does not prevent licensees from deploying other systems in the band. One licensee in its response to TLG v1 noted its deployment of fixed links servicing communities in remote areas. Because of the differing operational deployment of these systems, they are also included in the system models for the band[[8]](#footnote-9).

Licensees are requested to provide the ACMA with details of future systems they plan to deploy in the band. Licensees should consider what the proposed changes mean to their system and comment appropriately. Specifically, outside the area and outside the band emission requirements should be detailed.

TDD is considered to be the primary duplex type to be implemented in the band based on current and future use, as well as international planning trends. It is for this reason that only TDD implementations of the WAS technologies have been considered in this paper.

contains the base station (BS) transmitter and receiver parameters for TDD LTE, TDD WiMAX and transmitters in the fixed service.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Parameter** | **LTE TDD** | **TDD WiMAX** | | **Fixed service** |
| Allocated bandwidth (MHz) | 5, 10, 15 & 20 | 5 | 10 | 12 or 24 |
| Duplex method | TDD | | | FDD[[9]](#footnote-10) |
| Output power (typical) | 20W per 5 MHz | | | 5 W per channel |
| Antenna gain  (incl. losses) (dBi) | 17 | | | 28 – 35 |
| MIMO advantage (dB) | 6 | | | - |
| EIRPmax[[10]](#footnote-11) | 68 dBm per 5 MHz | | | 68 dBm per 5 MHz |
| Antenna tilt loss (dB) | 3 | | | 0 |
| Antenna height AGL (m) | 40 | | | 50 |
| F - Noise figure (dB) | 5 | 8 | |  |
| ACLR[[11]](#footnote-12) | 45 dB[[12]](#footnote-13) | 45 dB (1st adj)  50 dB (2nd adj) | |  |
| ACS[[13]](#footnote-14) 1st adj channel    2nd adj channel | -52 dBm/5 MHz – (*PREFSENS* + 6 dB)  (see in-band blocking requirement below) | 40 dB[[14]](#footnote-15)    50 dB | |  |
| Blocking | -43 dBm/(5 MHz) – (*PREFSENS* + 6 dB) | -40 dBm/(5 MHz) –  (*PREFSENS* + 6 dB) | |  |
| Reference sensitivity (dBm) | -101.5[[15]](#footnote-16) | -92.6note | -89.6note | -88 dBm per 5 MHz |
| Intermodulation response rejection (dBm/5 MHz) | -52 (wide area BS)  -44 (local area BS) | CW: -48 @ 7.5 MHz  WiMAX: -48 @ 7.5 MHz | |  |
| kTBF | -102 dBm/(5 MHz) | | |  |

Table : BS and FS transmit and receive parameters

*Note -* The reference sensitivity of a WiMAX OFDMA receiver is given in Amendment 2 and Corrigendum 1 to IEEE Std 802.16-2004[[16]](#footnote-17) equation 149b:



where

|  |  |  |
| --- | --- | --- |
| *SNRrx* | : | is the receiver SNR dependent on modulation and coding rate |
| *R* | : | is the repetition factor specified in 8.4.9 of 802.16e-2005 (assumed to be 2) |
| *Fs* | : | sampling frequency (in MHz) where  n : sampling factor specified in 8.3.2.4 of 802.16-2004 (for unknown channel multiples, 28/25 is used)  BW : is the nominal channel bandwidth |
| *Nused* | : | number of used subcarriers |
| *NFFT* | : | smallest power of two greater than *Nused* |
| *LI* | : | is the implementation loss (assumed 5 dB) |
| *NF* | : | is the receiver noise figure (8 dB) |

Therefore assuming a QPSK rate 1/2 modulation scheme (receiver SNR is 5 dB for this modulation scheme) utilising all sub-channels over a 5 MHz bandwidth, the reference sensitivity of a WiMAX receiver is:



Specification of antenna height is based on analysis of the relevant standards documentation and an extract from the Register of Radiocommunication Licences (RRL)[[17]](#footnote-18) of the 1690 registered devices in the 2.3 GHz band that do not have a height of 0 metres.

The majority of technology standards specify antenna heights between 15 and 45 metres, but traditionally base their macro deployment models on a transmitter height of 30 metres above ground level.

Figure 1 shows the distribution of antenna heights registered in the 2.3 GHz band. The average antenna height is 33 metres with a standard deviation of 14.5 metres. The maximum antenna height is 165 metres.

If only device registrations in the 12 months to August 2012 are considered, then the average antenna height is 33.6 metres with a standard deviation of 11.8 metres. The maximum antenna height is 125 metres. This shows that there is a slight shift toward higher antenna height deployments.

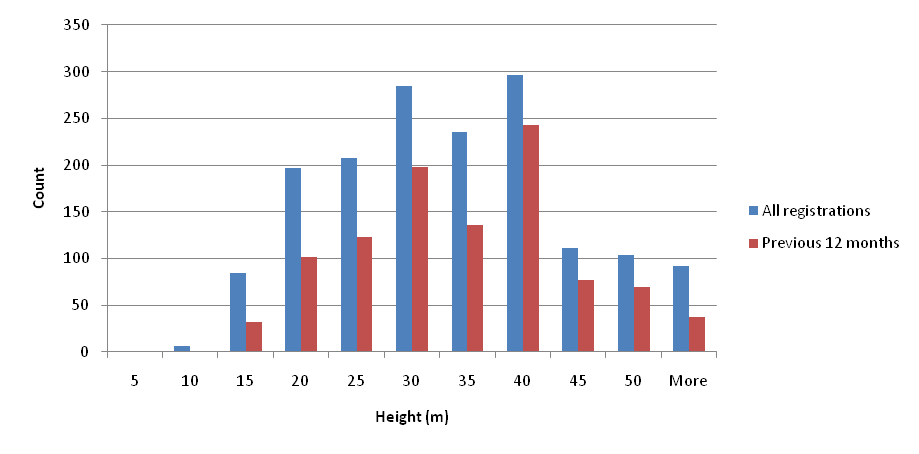


Figure : Distribution of antenna height in 2.3 GHz

Even though the practical deployment scenarios show that the antenna height is below the 40 metres specified in Table 2, for the purposes of analysing the likelihood for interference in the 2.3 GHz band, it has been determined that the BS transmitter antenna height be specified at 40 metres in line with current deployments and future planning based on discussions with current licensees.

Whilst Table 2 also defines the fixed service transmitter heights as 50 metres above ground level, given the overwhelming deployment density in favour of WAS, analysis in this paper is based on 40 metres.

Table 3 contains the user equipment (UE) transmitter and receiver parameters for TDD LTE and TDD WiMAX.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Parameter** | **LTE TDD** | | | **TDD WiMAX** | |
| Allocated bandwidth (MHz) | 5 | 10 | 20 | 5 | 10 |
| Duplex method | TDD | | | | |
| UE maximum output power (typical) | 23 dBm/5 MHz | | | 24 dBm/5 MHz | |
| Antenna gain (incl. losses)  (mobile/fixed) (dBi) | 0 / 17 | | | | |
| EIRPmax | 40 dBm/5 MHz | | | 41 dBm/5 MHz | |
| Antenna tilt loss (dB) | 0 | | | 0 | |
| Antenna height AGL (m) | 5 | | | | |
| Noise figure (dB) | 9 | | | | |
| ACLR | 30 dB | | | 30 dB (1st adj)  44 dB (2nd adj) | |
| ACS | 33 dB | 33 dB | 27 dB | 33 dB (1st adj)  47 dB (2nd adj) | |
| Reference sensitivity (dBm) | -100 | -97 | -94 | -94.5 | -91.5 |
| kTBF | -98 dBm/5 MHz | | | | |

Table : UE transmit and receive parameters

Stakeholders are requested to confirm that the proposed system models are suitable based on current and future use of the 2.3 GHz band. If information is missing or incorrect, please provide the necessary information in a response to this paper.

# Spectrum licence

A spectrum licence defines the rules that apply to the operation of radiocommunications devices in the spectrum space the licence applies. The licence contains the core conditions (defined by section 66 of the Act) specifying the:

* parts or parts of the spectrum in which operation of radiocommunications devices is authorised under the licence (refer to 3.1)
* maximum permitted level of radio emission, in parts of the spectrum outside such a part, that may be caused by operation of radiocommunications devices under the licence (refer to 3.4)
* area within which operation of radiocommunications devices is authorised under the licence (refer to 3.2)
* maximum permitted level of radio emission outside that area that may be caused by operation of radiocommunications devices under the licence (refer to 3.3).

The licence also includes a number of statutory conditions and additional conditions included by the ACMA.

The ACMA is currently in the process of introducing a new spectrum management tool that will allow the agency to issue a single spectrum licence in a single band release to a licensee. This decision comes as a result of work conducted in preparing the first tranche of re-issued spectrum licences and the development of a simplified licence template that was initially detailed in the discussion paper *Proposed updates to the spectrum licence framework*[[18]](#footnote-19).

At the request of licensees, the ACMA may issue separate licences for any particular frequency/area combination.

To better assist licensees in specifying parameter values and also ensuring that parameters meet the requirements of the licence, the value of a parameter must be estimated with a level of confidence not less than 95% that the true value of the parameter will always remain below the requirement specified. This is specified on the licence.

## Frequency bands

The 2.3 GHz band is currently allocated Australia-wide in the 2302-2400 MHz band via the *Radiocommunications (Spectrum Designation) Notice No. 1 of 2000*. The band was allocated in unpaired 7 MHz lots in a number of geographic areas (refer to section 3.2). In 2009, the STU was changed to 3.5 MHz to improve flexibility in trading.

As alluded to most recently in the band-by-band work program of the *Five-year spectrum outlook 2012-2016[[19]](#footnote-20)*, the ACMA will review options to expand the existing 98 MHz allocation in the 2.3 GHz band to include the frequencies 2300-2302 MHz. To facilitate this work, the ACMA has put in place Embargo 65[[20]](#footnote-21) which prevents any frequency assignments being made in this band.

As part of its regulatory requirements to designate parts of the spectrum for spectrum licences (subsection 36(4)), the ACMA will be consulting with the general public with a view to making a recommendation to the Minister about designation of the 2300-2302 MHz band (subsection 36(3)).

As a result of this ongoing work, this review of the technical framework will consider that the band 2300-2302 MHz is included as part of the 2.3 GHz spectrum licence.

### Aggregation

To improve spectrum utilisation and efficiency, the ACMA is encouraging licensees to aggregate the spectrum space in a particular geographic area such that they have contiguous frequency spectrum space. Although this can be achieved via trading at any time, it can also be facilitated by the ACMA.

There are two methods available to the ACMA to vary a spectrum licence to achieve aggregation:

1. variation with agreement under section 72 of the Act
2. variation of a re-issued licence under section 79 and section 82 of the Act

The ACMA propose to adopt option 2 and facilitate aggregation as part of the re-issue process and any subsequent procedure for the allocation of the 2300-2302 MHz.

The ACMA will discuss aggregation options with licensees as part of the re-issue process to determine a suitable outcome. The ACMA has a preference for the largest holder of spectrum within a geographic area to be licensed at the 2300 MHz boundary and subsequent licensees to be frequency adjacent to that licensee based on the quantum of spectrum they hold. If adjacent geographic areas have identical or similar spectrum holdings, then the preference is for these licenses to be adjacent.

The preference to aggregate the largest holder of spectrum at the 2300 MHz boundary is due to the proposed introduction of a ‘restricted’ block at the upper 5 MHz of all licences (is not required in the 2395-2400 MHz band) to manage adjacent channel interference between frequency adjacent licensees (see section 3.3). Aggregation reduces the number of ‘restricted’ blocks that are required in an area hence limiting the impact on licensees if they held disaggregated blocks.

This is illustrated in Figure 2 where there are 3 licensees with 2, 7 and 11 blocks allocated (using a proposed 5 MHz MCB).

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| L1 | | | | | | | | | | | L2 | | | | | | | L3 | |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 2300-2305 | 2305-2310 | 2310-2315 | 2315-2320 | 2320-2325 | 2325-2330 | 2330-2335 | 2335-2340 | 2340-2345 | 2345-2350 | 2350-2355 | 2355-2360 | 2360-2365 | 2365-2370 | 2370-2375 | 2375-2380 | 2380-2385 | 2385-2390 | 2390-2395 | 2395-2400 |

|  |  |  |  |
| --- | --- | --- | --- |
|  | Restricted (reduced transmitter power) |  | Unrestricted |

Figure : ‘Restricted’ block illustration

Further details and consultation on aggregation in the 2.3 GHz band will be conducted as part of the re-issue and/or re-allocation process.

## Geographic areas

The 2.3GHz band is allocated for spectrum licensing Australia-wide. The current geographic areas for the 2.3 GHz band are shown in .

The 2.3 GHz band is allocated Australia-wide.

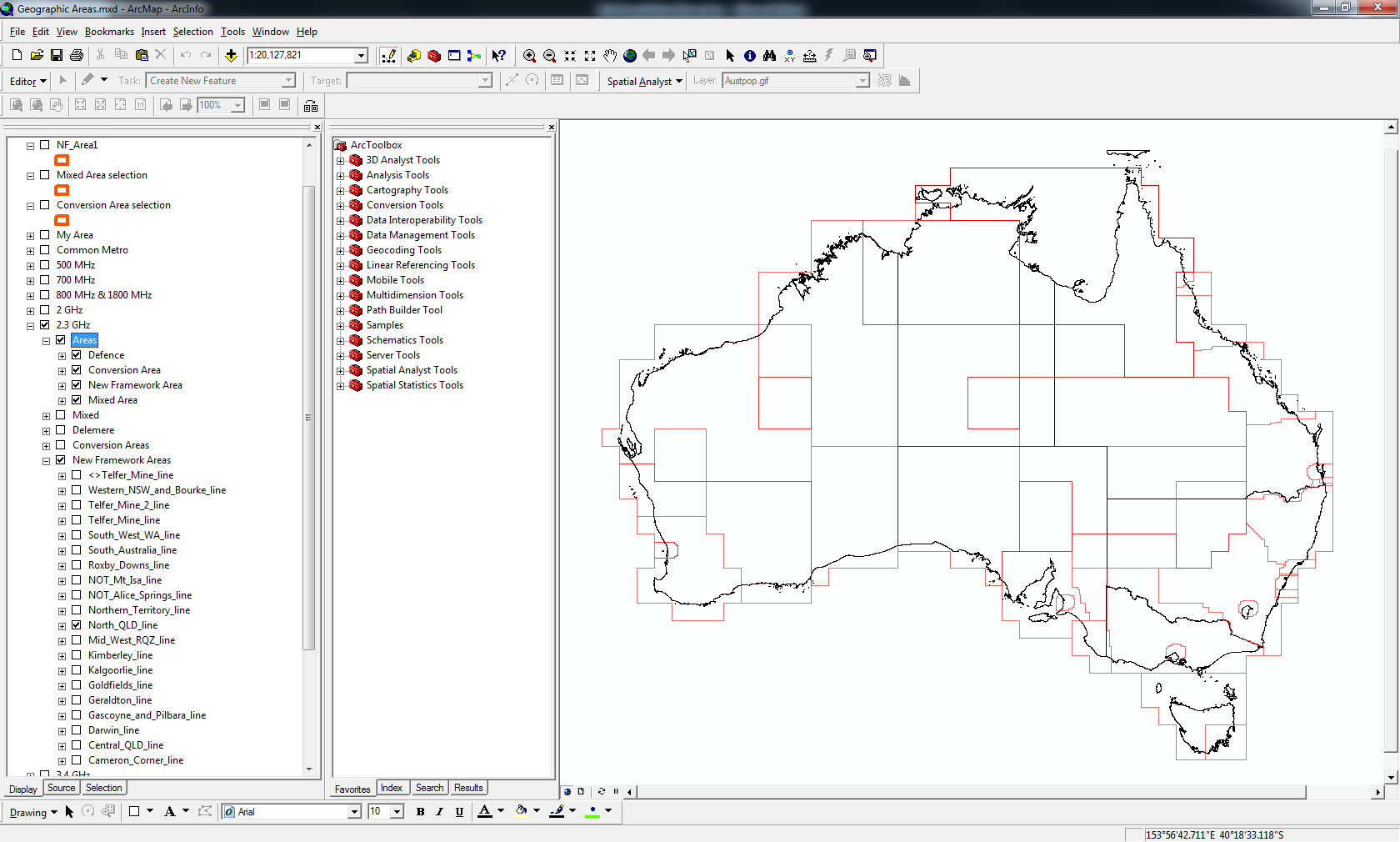


Figure 3: Geographic areas of the 2.3 GHz band

The ACMA has introduced a new method for describing the geographic areas known as the Hierarchical Cell Identifier Scheme (HCIS) which allows increased flexibility for the ACMA in defining coordinate systems as well as geographic area information.

The ACMA has made available a HCIS to KML conversion tool on the ACMA website available here: <http://www.acma.gov.au/speclic/hcis_to_kml.shtml>.

## Outside the area emissions

The outside the area (OOA) core condition limit is implemented to set a maximum radiated true mean power for devices operating under a spectrum licence. Primarily, the OOA core condition is designed to limit the potential for a high-powered emission to block an adjacent low-powered emission based on the adjacent channel selectivity of the frequency adjacent device or C/I requirement for the co-channel case.

Management of emissions in the co-channel case across the geographic boundary of the spectrum licence is in part managed by appropriate determination of the OOA core condition and the device boundary criterion in section 4.4.

The current OOA core condition emission limit is specified as a radiated power limit of 60 dBm per 30 kHz (equivalently, 82.2 dBm per 5 MHz). The development of this OOA emission limit accommodates MDS transmitters in the band with radiated power of up to 1kW.

There is concern that this limit is too constraining on the ability of adjacent frequency licensees to deploy sites that are located within the same service area (3-10 kilometres). It is anticipated that the majority of transmitter sites for a particular coverage area in the 2.3 GHz band will be co-located (within 200 metres) due to the increased requirements for line-of-sight paths to receivers due to additional propagation conditions (including the impact buildings and clutter have on loss) at this frequency.

The reference technologies chosen have a certain ability to limit emissions caused to adjacent channels and a certain ability to reject unwanted emissions caused by an adjacent channel transmitter.

The performance of a receiver in the 2.3 GHz spectrum licence is given by the notional receiver described in section 5.2.4 and includes parameters such as the adjacent channel selectivity (ACS) and receiver blocking. The performance requirements of transmitters and receivers necessary to determine the required geographic separation of base stations under this licence are provided in Table 4.

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **Notional Receiver** | **LTE** | **WiMAX** |
| ACS (1st adj)  (2nd adj) | 43.5 dB[[21]](#footnote-22)  - | -52 dBm/5 MHz  - | 40dB[[22]](#footnote-23)  50dB |
| Blocking | 89 dB | -43 dBm/5 MHz | -40 dBm/5 MHz |

Table : ACS and blocking parameters of the notional receiver

Depending on the geographical separation of two transmitters/receivers, interference is most prevalent where the transmission powers are high, high-gain antennas are used and the propagation model approaches free-space (line-of-sight conditions).

The minimum geographic separation can therefore be determined or what maximum adjacent channel transmitter EIRP is required to protect the adjacent channel case.

Figure 4: BS-to-BS interference scenario

To determine the maximum adjacent channel EIRP of an interferer, the following formula applies for the relative case:



or



|  |  |
| --- | --- |
| Parameter | Description |
|  | Is the maximum adjacent channel EIRP of an interferer in dBm per 5 MHz. In this scenario,  is the maximum possible transmitter EIRP in the first adjacent channel such that the ACS requirement of the receiver is not exceeded. |
|  | Is the relative adjacent channel selectivity of the receiver in dB. |
|  | Is the aggregate receiver antenna gain plus feeder loss, as specified in Table 2 in dBi. |
|  | Is the free space loss, calculated at 2350 MHz in dB |
| and | Is the associated reduction in peak gain of the transmitting and receiving antennas as a result of the use of downtilt. This value is attributed as a decibel (dB) rather than specifying a particular downtilt in degrees. |
|  | Is the thermal noise in the system as specified in in dB. |
|  | Is the compatibility requirement as specified by the notional receiver in section 5.2.4 in dB. |

Table : Parameter definition

In determining the maximum adjacent channel EIRP of an interferer, an appropriate separation distance needs to be chosen to consider loss between the wanted and victim antennas. As detailed in section on , the interference mechanisms for devices that are located within 200 metres are often difficult to model, and therefore, the ACMA includes additional conditions on the licence so that licensees work together to resolve any interference.

As a result, the maximum adjacent channel EIRP of an interferer is found based on a free space loss separation of 200 metres. At 2350 MHz, this equates to 85.9 dB.

Determining the adjacent channel maximum EIRP based on the notional receiver is a balance between the maximum transmitter EIRP (OOA) and the blocking requirement of the receiver specified in section 5.2.4.3. Any increase in the OOA emission limit requires an equivalent increase in the blocking requirement.

As detailed in section 5.2.4.3, additional filtering beyond the blocking requirements of the system models may be required to mitigate the potential for interference from geographically close transmitters in the second adjacent channel. The ACMA is not mandating the installation of additional filtering, but licensees must evaluate the risk of unwanted emission at offsets greater than 5 MHz.

In some of the submissions to TLG v1 (Telstra C1 & NBN C1), proposal were made to increase the OOA limit beyond that recommended in TLG v1 at 60 dBm EIRP per 5 MHz. Considering the parameters of the system model (Table 2), the maximum EIRP required is somewhere around 68 dBm per 5 MHz. This 8 dB increase needs to be considered broadly across the technical framework.

For the notional receiver, the first and second adjacent channel maximum adjacent channel EIRPs for a 200 metre separation are found to be:





For WiMAX, the first and second adjacent channel maximum adjacent channel EIRPs for a 200 metre separation are found to be:



The resulting adjacent channel interferer EIRP mask is given in Figure 5 for 200 metre separation, where the frequency offset is with respect to the centre frequency of a 5 MHz channel.

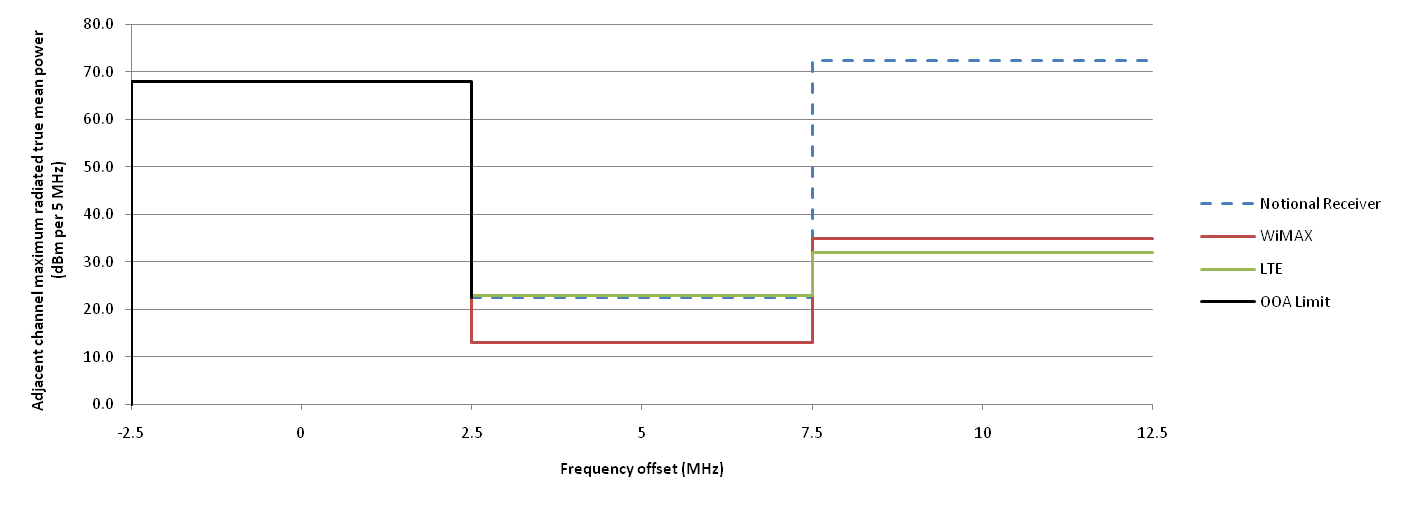


Figure : Adjacent channel interferer EIRP mask for 200 m separation

Figure 5 illustrates that some form of mitigation is required in order for adjacent channel transmitters to operate when the geographic separation is 200 metres. One potential option is to geographically separate transmitters and receivers; however, in order to allow the second adjacent channel transmitter to operate at up to an EIRP of 68 dBm per 5 MHz for LTE, separation of the order of 12.7 km under free-space loss conditions is required. Under most practical circumstances, this is not feasible. The first adjacent channel requires 35.8 km.

If the parameters of the notional receiver are considered, then a second adjacent channel transmitter can operate at up to an EIRP of 68 dBm per 5 MHz with a separation of 200 metres (is practically limited to the co-sited requirements of section ) and in the first adjacent channel a separation of 37.9 kilometres. The additional separation required in the first adjacent channel is due to the ACS requirement of the notional receiver being slightly less than LTE.

When developing the technical framework for a spectrum licence, the ACMA is forever cognisant of the requirements for interference management, but ensuring that operational ability and flexibility is maintained.

The first adjacent channel is the most difficult to manage, hence the development of the restricted block in section 3.3.1, but raising the OOA emission limit has implications for the second and subsequent adjacent channels and hence the notional receiver – in particular, the receiver blocking requirements of section 5.2.4.3.

Stakeholders are requested to confirm that the proposed maximum outside the area radiated true mean power of 68 dBm per 5 MHz is appropriate for implementation in the 2.3 GHz band.

### Restricted block

It is recognised that reducing the OOA emission limit alone does not ultimately mitigate the need for additional techniques to be employed in order to allow adjacent frequency services to operate. Mitigation techniques to assist in making deployment possible (non exhaustive) include:

* Synchronisation between adjacent frequency licensees
* Additional filtering (both transmit and receive side) to limit outside the band emissions
* Base station location
* Varying antenna setups (including main lobe isolation)
* Decrease in cell size (reduces transmitter EIRP requirements)

In the 2.5 GHz mid-band gap (2570-2620 MHz), the ACMA has proposed the introduction of ‘restricted’ blocks whereby the OOA emission limit is further decreased in order to better facilitate uncoordinated use of the first adjacent frequency block.

The previous analysis showed that in order for a transmitter in the first adjacent channel to operate at a separation of 200 metres, that its maximum EIRP not exceed 13.0 dBm per 5 MHz for WiMAX and 22.4 dBm per 5 MHz for the notional receiver. This is a reduction in EIRP from the recommended ‘unrestricted’ block of 47 dB and 37.6 dB respectively.

The ACMA recommend that a ‘restricted’ block in the upper 5 MHz of a licence be implemented with a maximum OOA emission limit of 23 dBm per 5 MHz and that all subsequent blocks operate under the ‘unrestricted’ OOA emission limit (68 dBm per 5 MHz). This is illustrated in Figure 6 where there are 6 licensees with a mix of 1, 2, 4, 5 and 7 blocks allocated.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| L1 | | | | | | | L2 | | | | | L3 | | | | L4 | | L5 | L6 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 2300-2305 | 2305-2310 | 2310-2315 | 2315-2320 | 2320-2325 | 2325-2330 | 2330-2335 | 2335-2340 | 2340-2345 | 2345-2350 | 2350-2355 | 2355-2360 | 2360-2365 | 2365-2370 | 2370-2375 | 2375-2380 | 2380-2385 | 2385-2390 | 2390-2395 | 2395-2400 |

|  |  |  |  |
| --- | --- | --- | --- |
|  | Restricted |  | Unrestricted |

Figure : ‘Restricted’ block illustration.

The proposed ‘restricted’ block limit of 23 dBm per 5 MHz is still 10 dB above the adjacent channel requirement for WiMAX. Noting the development of the notional receiver for the band in section 5.2.4, a receiver operating in the band should have an ACS and blocking requirement as specified in the RAG which should provide additional protection of the receiver.

The ‘restricted’ block limit applies to all radiocommunications transmitters operating in the band (including those that may be operated under the registration exempt requirements detailed in section 3.6.2.1). The impact of the ‘restricted’ block is discussed further in section 3.3.2.

Stakeholders are requested to confirm that the ‘restricted’ outside the area emission limits are appropriate for implementation in the 2.3 GHz band.

Licensees may come to agreement with the relevant frequency adjacent licensee to increase the OOA limit in the ‘restricted’ block up to the ‘unrestricted’ block OOA emission limit (68 dBm per 5 MHz). When such an agreement is in place, licensees are responsible for managing any interference that may occur to each other’s systems across the common frequency boundary.

### Impact of the restricted block

Optus C1 raised concerns that the proposal for a restricted block at the top of each 5 MHz of contiguous spectrum would have practical consequences for the deployment of channels in the 2.3 GHz band; specifically, the reference signals and physical channels (Layer 1) of the LTE system in particular are affected because of the way they are broadcast.

The physical layer (Layer 1) is the interface between the Medium Access Control (MAC) sub-layer of Layer 2 and the Radio Resource Control (RRC) Layer of Layer 3. This is shown in .



Figure : Radio interface protocol architecture around the physical layer

The reference signals and physical channels of both the uplink and downlink need to be treated separately. This is firstly because the uplink and downlink use different multiplexing methods (SC-FDMA and OFDM respectively) and because the function of the reference signals and physical channels in each direction is slightly different.

The impact of the restricted block on the downlink is primarily dependent on the channel bandwidth utilised and its impact on the Physical Broadcast Channel (PBCH). The PBCH is designed to be detectable without prior knowledge of system bandwidth and to be accessible at the cell edge (meaning that it is required to be transmitted at maximum power). It is mapped to the 72 centre sub-carriers (6 resource blocks) of the OFDM structure as shown in .

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Frequency | One frame | | | | | | | | | | | One frame | | | | | | | | | | ... |
|  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| ... | | | | | | | | | | | ... | | | | | | | | | |
|  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
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|  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| ... | | | | | | | | | | | ... | | | | | | | | | |
|  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Time | | | | | | | | | | | | | | | | | | | | | | |

Figure : Mapping to physical resource blocks for PBCH

Given the proposal for a 5 MHz ‘restricted’ block, it would therefore be required that either 15 MHz or 20 MHz channels are utilised, otherwise, use of a 10 MHz channel would mean that half the PBCH channel would be in the ‘unrestricted’ and the other in the ‘restricted’ block and hence not accessible at the cell edge.

All other downlink reference signal and physical channel information is contained within each individual resource block rather than spread across the frequency domain.

The impact of the restricted block on the uplink is independent of the channel bandwidth and is affected by the Physical Uplink Control Channel (PUCCH). The PUCCH comprises uplink data transmitted independently of the traffic data and includes HARQ, ACK/NACK, channel quality indicators (CQI), MIMO feedback and scheduling requests for uplink transmissions.

Transmission of this channel occurs in the frequency region at the edges of the system bandwidth (as shown in ), and hence a 20 MHz channel would have 15 MHz of its emission in ‘unrestricted’ spectrum and 5 MHz in ‘restricted’.



Figure : Mapping to physical resource blocks for PUCCH[[23]](#footnote-24)

Whilst a single 20 MHz uplink channel cannot be supported, a 15 MHz and a 5 MHz channel could be supported.

Accommodation of such a channel block arrangement would require separate transmissions, which admittedly involves control overhead. An alternative would be to incorporate the restricted block as part of fractional frequency reuse and inter-cell interference coordination where lower power subcarriers are used for cell-centre users (notwithstanding the higher SINR requirements for higher-order modulation and coding schemes (MCS) which may also correspond to such users).

The ACMA is aware that this may create deployment difficulties for licensees, but considers that there is enough flexibility available to licensees to manage their deployment such that downlink channels are large enough (or only take up the restricted block) so that the PBCH is not affected, or that uplink channels aren’t partly in unrestricted and restricted blocks.

Licensees are encouraged to coordinate their systems at the frequency boundary such that the restrictions in place on the restricted block can be relaxed.

## Outside the band emissions

Outside the band (OOB) emission limits control emissions affecting adjacent holdings across the frequency boundaries of the licence. These limits include requirements for both spurious and non-spurious emissions.

Non-spurious emissions are unwanted emissions outside the channel bandwidth resulting from modulation-generated noise or intermodulation products caused by the transmission of information, or broadband noise generated by the transmitter.

Spurious emissions are emissions including intermodulation products, harmonics and frequency conversion products not associated with the transmission of information by the transmitter. The domain over which spurious emissions apply is much broader than non-spurious emissions, and applies at a 10 MHz offset from the effective edge of the relevant operating bandwidth.

The following sections discuss the current framework masks, the results of considering new technologies in the band, and suggest some changes to the masks in order to improve adjacent channel interference.

### Non-spurious emission limits

The current non-spurious emission limits are based on the emission spectra for MDS transmitters, with some tightening of the mask as a result of the technologies considered at the time (including CDMA2000 and TD-SCDMA). The non-spurious emission limits apply to both the BS and UE.

The current non-spurious emission mask offset from the upper frequency limit of the licence is:

|  |  |  |
| --- | --- | --- |
| **Frequency**  **offset range** | **Radiated maximum true mean power**  **(dBm EIRP)** | **Specified bandwidth** |
| 0 Hz ≤ foffset <500 kHz | 10 | 30 kHz |
| 500kHz ≤ foffset <1 MHz | 5 | 30 kHz |
| 1 MHz≤ foffset <3.5 MHz | 0 | 30 kHz |
| 3.5 MHz≤ foffset <7 MHz | -10 | 30 kHz |
| 7 MHz≤ foffset <17.5 MHz | -16 | 30 kHz |

Table : Non-spurious emission limit offset from the upper frequency limit

The current non-spurious emission mask offset from the lower frequency limit of the licence is:

|  |  |  |
| --- | --- | --- |
| **Frequency**  **offset range** | **Radiated maximum true mean power**  **(dBm EIRP)** | **Specified bandwidth** |
| 0 Hz ≤ foffset < 1 MHz | 10 | 30 kHz |
| 1 MHz≤ foffset < 3.5 MHz | 5 | 30 kHz |
| 3.5 MHz≤ foffset < 5 MHz | 0 | 30 kHz |
| 5 MHz≤ foffset < 7 MHz | -10 | 30 kHz |
| 7 MHz≤ foffset < 17.5 MHz | -16 | 30 kHz |

Table : Non-spurious emission limit offset from the lower frequency limit

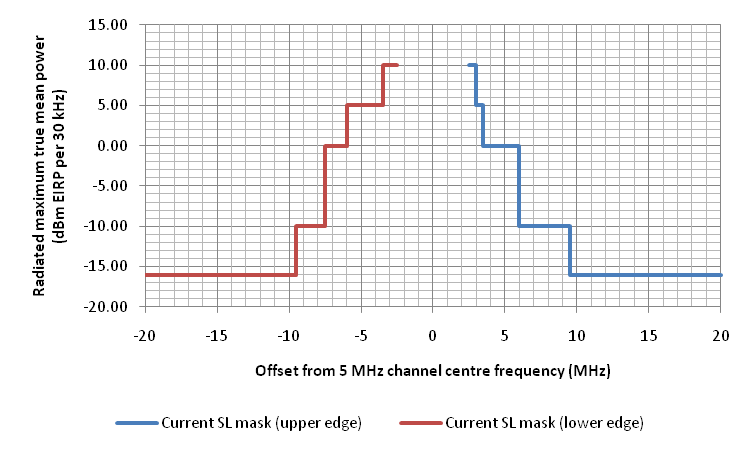


Figure : Current non-spurious emission masks

Additional emission limits at the 2302 MHz frequency boundary are in force and described in section 3.5. These emission limits apply to non-spurious emissions in the 2290-2300 MHz band caused by transmitter’s operating under the licence and are given in Table 18. Please refer to section for additional information and the process for how non spurious emissions below 2300 MHz will be dealt with under this technical framework.

#### Base station emission limits

Figure 11 shows a comparison between the base station non-spurious emission masks of LTE (Table 8) and WiMAX (Table 9). The WiMAX emission mask drawn is the most restrictive, and at most offsets, the LTE emission mask is the least restrictive.

Both non-spurious emission masks (Table 8 and Table 9) are applicable within the band 2290-2410 MHz.

|  |  |  |
| --- | --- | --- |
| **ΔfOOB (MHz)** | **Maximum true mean power (dBm)** | **Specified**  **bandwidth** |
| ± 0-5 |  | 100 kHz |
| ± 5-10 | -14 dBm | 100 kHz |
| > 10 | -15 dBm | 1 MHz |

Table : LTE Category B base station non-spurious emission mask

|  |  |  |  |
| --- | --- | --- | --- |
| **Maximum true mean power (dBm)** | | | |
| **ΔfOOB (MHz)** | **5 MHz** | **10 MHz** | **Specified**  **bandwidth** |
| ± 0-1 | -13 dBm | - | 50 kHz |
| ± 0-1 | - | -13 dBm | 100 kHz |
| ± 1-5 | -13 dBm | -13 dBm | 1 MHz |
| ± 5-5.5 | -16 dBm | - | 500 kHz |
| ± 5-6 | - | -13-12×(ΔfOOB (MHz)-5) dBm | 1 MHz |
| ± 5.5-10 | -25 dBm | - | 1 MHz |
| ± 6-20 | - | -25 dBm | 1 MHz |

Table : WiMAX base station non-spurious emission mask[[24]](#footnote-25)

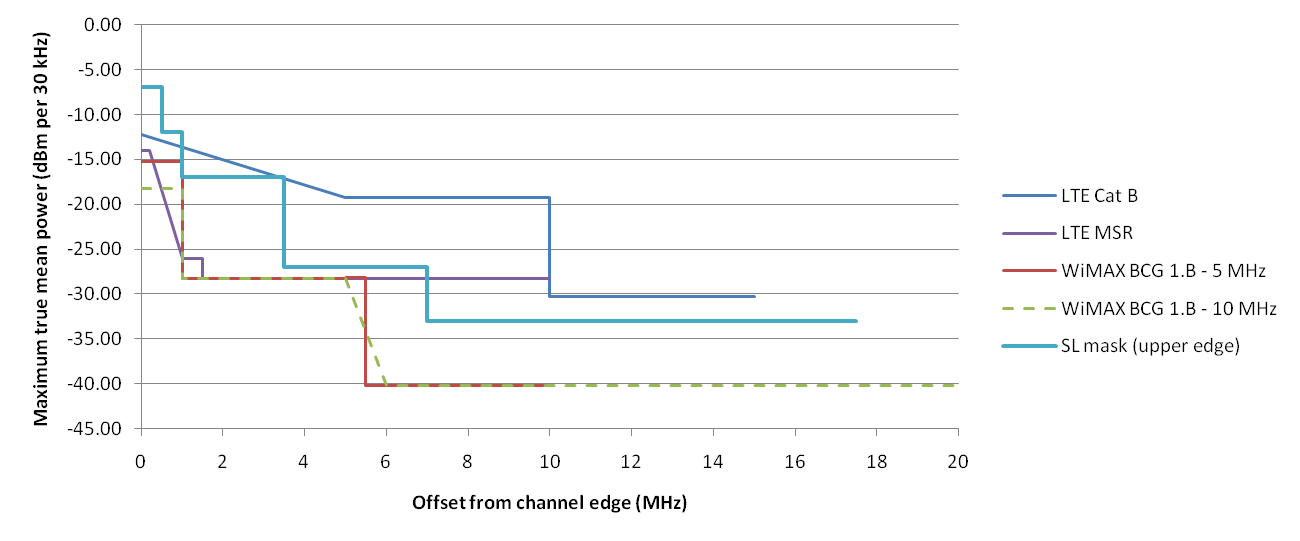


Figure : Comparison of base station emission masks

Additional restrictions on the LTE Cat B mask can be considered if the base station is configured as a multi-standard radio (MSR) base station[[25]](#footnote-26) (refer to Table 10). It is considered that equipment manufacturers might design base station equipment to include more than one radio access technology or band in the one system, but practically, this demonstrates that it is possible to filter outside the band emissions to a greater degree than the Cat B mask.

|  |  |  |
| --- | --- | --- |
| **ΔfOOB (MHz)** | **Maximum true mean power (dBm)** | **Specified**  **bandwidth** |
| ± 0-0.2 | -14 dBm | 30 kHz |
| ± 0.2-1 |  | 30 kHz |
| ± 1-1.5 | -26 dBm | 30 kHz |
| ± 1.5-10 | -13 dBm | 1 MHz |
| > 10 | -15 dBm | 1 MHz |

Table : LTE base station MSR non-spurious emission mask

#### User equipment emission limits

The 3GPP standards specify different outside the band emission masks for the BS and UE, WiMAX on the other hand are the same as those in Table 9. Figure 12 shows the E-UTRA spectrum emission mask for 5, 10 and 20 MHz channels from Table 6.6.2.1.1-1 of 3GPP TS 36.101 V10.6.0 shown in Table 11.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Maximum true mean power (dBm)** | | | | |
| **ΔfOOB (MHz)** | **5 MHz** | **10 MHz** | **20 MHz** | **Specified**  **bandwidth** |
| ± 0-1 | -15 | -18 | -21 | 30 kHz |
| ± 1-5 | -10 | -10 | -10 | 1 MHz |
| ± 5-6 | -13 | -13 | -13 | 1 MHz |
| ± 6-10 | -25 | -13 | -13 | 1 MHz |
| ± 10-15 | - | -25 | -13 | 1 MHz |
| ± 15-20 | - | - | -13 | 1 MHz |
| ± 20-25 | - | - | -25 | 1 MHz |

Table : LTE user equipment non-spurious emission mask

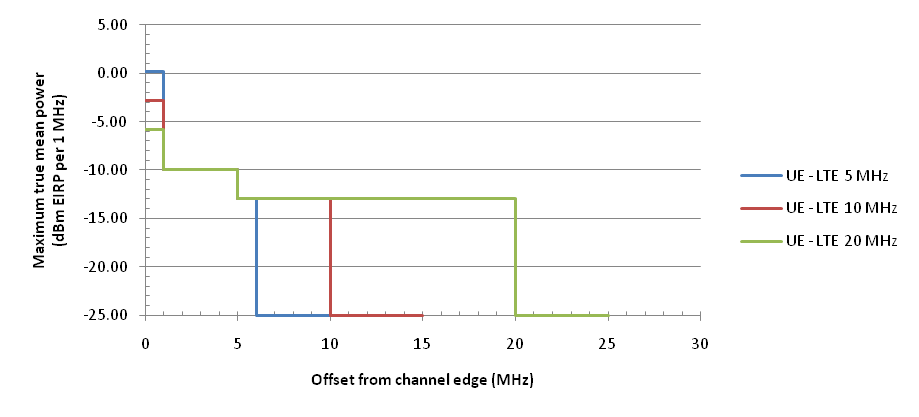


Figure : LTE user equipment non-spurious emission masks

#### Adjacent channel leakage ratio

The adjacent channel leakage power ratio (ACLR) of a system is the ratio of the filtered mean power centred on the assigned channel frequency to the filtered mean power centred on an adjacent channel frequency[[26]](#footnote-27).

This is an alternative method of defining non-spurious emissions outside the band, where the emission limit is an average of the outside the band emission of a particular channel. ACLR is often particular to specific technologies and channel rasters; therefore, it is often only a useful mechanism where the deployed technology in the band (or at adjacent frequencies) is the same.

The 3GPP specification defining ACLR is provided for paired spectrum and unpaired spectrum with synchronised operation. In the 2.3 GHz band, the interference caused by outside the band emissions is most prevalent in a base station to base station scenario where the two sites are unsynchronised.

Analysis in section 3.3 looked at the impact that outside the area emissions have on the first and second adjacent channels (assuming a 5 MHz channel raster), but consideration of outside the band emissions into an adjacent channel need also be considered. The ACLR requirements of a system are based on both the anticipated outside the band emission mask of the system and the geographic separation of the systems.

|  |  |  |
| --- | --- | --- |
| Technology | LTE TDD Technology | TDD WiMAX |
| 1st channel | 45 dB or  -13 dBm/MHz | 45 dB |
| 2nd channel | - | 50 dB |

Table 12: System model ACLR requirements

In order to determine the level of outside the band emission falling in-band that is appropriate to ensure continuing operation of the adjacent channel, an adjacent channel interference ratio (ACIR) can be defined as:



The required ACIR of 41.2 dB can be achieved through variation of the ACLR and ACS of the interferer and victim respectively, but ultimately, the burden should be equally shared. As a result, we require that the:



The calculated ACLR requirement is 0.8 dB less stringent than the requirement of LTE and WiMAX provided in the system models. Given an interferer ACLR of 44.2 dB, the baseline requirement for outside the band emissions in the first adjacent channel is:



As discussed in the proposal for non-spurious emission limits, the option exists to use this value in place of an outside the band emission mask for emissions within the band 2300-2400 MHz.

#### Proposal

Figure 13 shows a comparison of the emission masks considered in this paper in a specific bandwidth of 30 kHz. It shows that the additional suppression of outside the band emissions obtained by operating base stations in accordance with the MSR rather than Category B mask is significant, especially within an offset of 10 MHz from the channel edge. There is no consideration of antenna gain in Figure 13.

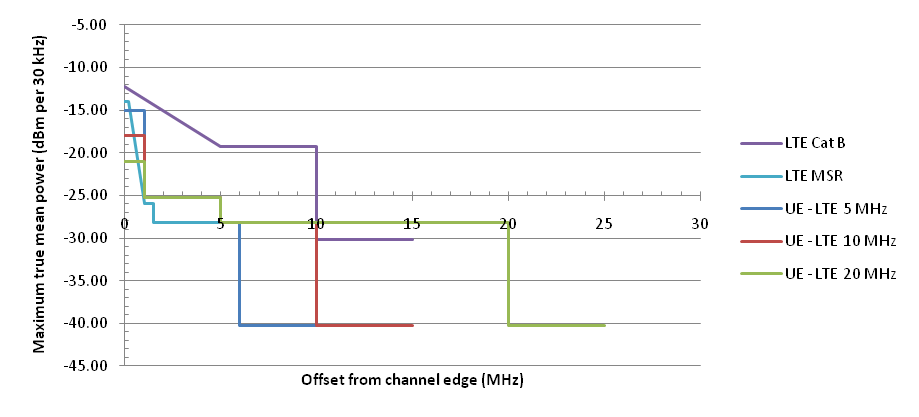
****

Figure : Comparison of LTE Cat B, MSR and UE non-spurious emission masks

Licensees also need to be aware that to enable additional adjacent channel protection to services operating below 2300 MHz (in particular television outside broadcast which are not at specific locations like those defined by the additional emission limits in section 3.5), that below 2295 MHz, the non-spurious emission mask will be stricter (refer to section 5.3.5).

|  |  |  |
| --- | --- | --- |
| **ΔfOOB (MHz)** | **Maximum true mean power (dBm)** | **Specified**  **bandwidth** |
| ± 0-0.2 | -14 dBm | 30 kHz |
| ± 0.2-1 |  | 30 kHz |
| ± 1-1.5 | -26 dBm | 30 kHz |
| ± 1.5-10 | -13 dBm | 1 MHz |
| > 10 | -15 dBm | 1 MHz |

Table : LTE base station MSR non-spurious emission mask

TLG member should also consider the applicability of defining a specific adjacent channel average EIRP limit as detailed in section within the band 2300-2400 MHz rather than specifying an emission mask. There are a number of pros and cons associated with defining and adjacent channel EIRP limit, but ultimately it comes down to the ability of licensees to implement and necessary filtering or operational requirements in order to meet either the adjacent channel EIRP limit or the emission masks.

The ACMA is proposing that consideration of devices registered on the RRL and those that are not (i.e. those that meet the registration exempt requirement of ) are treated separately. This is because greater control over emissions can be made on base station equipment than user terminals.

The following dot points detail the proposed outside the band emissions applicable to devices in the 2.3 GHz band.

* For devices registered on the RRL within the band 2300-2400 MHz, the LTE Cat B non-spurious emission mask plus an additional 17 dBi antenna gain applies
* For devices operating at the 2400 MHz band edge, the LTE Cat B non-spurious emission mask plus an additional 17dBi antenna gain applies
* For devices operating at the 2300 MHz band edge, with outside the band emissions in the:
  + 2295-2300 MHz band, the LTE MSR () non-spurious emission mask plus an additional 17 dBi antenna gain applies
  + 2290-2295 MHz band, the non-spurious emission limit is a radiated maximum true mean power of -30 dBm per 1 MHz
* For devices not registered on the RRL (i.e. those that meet the registration exempt requirement of ), the LTE UE mask for a 10 MHz emission () with no additional antenna gain applies

Licensees should be aware that the requirements of the additional emission limits of section and transmitter spurious emission limits of section also apply. Full descriptive detail of the outside the band emission limits are provided in the draft licence in Annex I.

Stakeholders are requested to consider the implication of implementing the proposed non-spurious emission solution on their current and future systems in the 2.3 GHz band.

Studies into the interference potential at the 2400 MHz boundary is given in . Whilst there is the potential for interference to class-licensed service in 2400-2483.5 MHz, the nature and deployment of these services, as well as its class licensed status mean that providing additional protection beyond what is proposed by the outside the area emission limit and outside the band emission limits is not necessary.

### Transmitter spurious emission limits

The current transmitter spurious emission limits apply to transmitters operating under the spectrum licence and emissions outside the frequency band of the licence (2302-2400 MHz). These limits are shown in Table 14.

|  |  |  |
| --- | --- | --- |
| **Frequency (f)** | **Radiated mean power**  **(dBm EIRP)** | **Specified bandwidth** |
| 9 kHz ≤ f < 150 kHz | -36 | 1 kHz |
| 150 kHz ≤ f < 30 MHz | -36 | 10 kHz |
| 30 MHz ≤ f < 1 GHz | -36 | 100 kHz |
| 1 GHz ≤ f < 4.8 GHz | -1 | 1 MHz |
| 4.8 GHz ≤ f < 24 GHz | -30 | 1 MHz |

Table : Current transmitter spurious emission limits

Section 6.6.4 in 3GPP standard 36.104 recommends that the spurious emission limits apply from 9 kHz to 12.75 GHz, excluding the frequency range ±10 MHz of the operating band.

In order to provide additional spurious emission protection to services operating in other bands, the ACMA recommends the adoption of the Category B emission limits of Table 6.6.4.1.2.1-1 of 36.104. The proposed transmitter spurious emission limits are shown in Table 15 and apply outside the band 2290-2410 MHz. It should be noted that the spurious emission limits are not defined as a *radiated* power, so the measurement is made at the antenna connector.

|  |  |  |
| --- | --- | --- |
| **Frequency (f)** | **Maximum true mean power**  **(dBm)** | **Specified bandwidth** |
| 9 kHz ≤ f < 150 kHz | -36 | 1 kHz |
| 150 kHz ≤ f < 30 MHz | -36 | 10 kHz |
| 30 MHz ≤ f < 1 GHz | -36 | 100 kHz |
| 1 GHz ≤ f < 12.75 GHz | -30 | 1 MHz |

Table : Proposed transmitter spurious emission limits

Stakeholders are requested to confirm that the proposed transmitter spurious emission mask of Table 15 and its applicability outside the 2290-2410 MHz band is appropriate for implementation in the 2.3 GHz band.

### Receiver spurious emission limits

The current receiver spurious emission limits apply to receivers operating under the spectrum licence outside the frequency band of the licence (2302-2400 MHz). These limits are shown in Table 16.

|  |  |  |
| --- | --- | --- |
| **Frequency (f)** | **Radiated mean power**  **(dBm EIRP)** | **Specified bandwidth** |
| 9 kHz ≤ f < 1 GHz | -57 | 100 kHz |
| 1 GHz ≤ f < 4.8 GHz | -20 | 100 kHz |
| 4.8 GHz ≤ f < 24 GHz | -47 | 100 kHz |

Table : Current receiver spurious emission limits

The receiver emission limits of section 7.7 in 3GPP standard 36.104 are very similar to those in Table 16, but align better to current requirements, especially those already detailed in ITU texts.

The ACMA propose the adoption of the receiver spurious emission limits in Table 7.7.1-1 of 3GPP standard 36.104, and apply outside the band 2290-2410 MHz.

|  |  |  |
| --- | --- | --- |
| **Frequency (f)** | **Radiated mean power**  **(dBm EIRP)** | **Specified bandwidth** |
| 30 MHz ≤ f < 1 GHz | -57 | 100 kHz |
| 1 GHz ≤ f < 12.75 GHz | -47 | 1 MHz |

Table : Proposed receiver spurious emission limits

Stakeholders are requested to confirm that the proposed receiver spurious emission mask of Table 17 and its applicability outside the 2290-2410 MHz band is appropriate for implementation in the 2.3 GHz band.

## Additional emission limits

The 2.3 GHz band is frequency adjacent to the SPACE RESEARCH (deep space) (space-to-Earth) service in 2290-2300 MHz and the SPACE OPERATION (space-to-Earth) (space-to-space) and SPACE RESEARCH (space-to-Earth) (space-to-space) services in the 2200-2290 MHz band. These services operate with sensitive receivers that require additional protection beyond that provided by the outside the area and outside the band emission limits proposed.

In summary the proposed measures to protect adjacent-band space service receivers are:

* + - to remove the current protection measures involving additional out-of-band emission limits and instead define site-by-site protection and coordination requirements;
    - to maintain and improve the clarity of the existing licence condition providing in-band protection to space service receivers that requires any devices to be registered under a 2.3 GHz spectrum licence to coordinate with earth stations; and
    - to define additional out-of-band coordination requirements and procedures for the protection of space research services operating in the 2290-2300 MHz band;

To assist licensees in the protection of space research services operating in the 2290-2300 MHz band, a new RALI will be made. This RALI will contain site-by-site specific information on the technical characteristics of space research services and relevant coordination criteria. Details of this RALI are contained in Annex A.

### Current additional limits

To provide the necessary additional protection, emission limits are incorporated into the licence. These emission limits apply to unwanted emissions in the 2290-2300 MHz band caused by transmitters operating under the licence and are given in Table 18.

|  |  |  |  |
| --- | --- | --- | --- |
| **Frequency**  **range**  **(f)** | **Radiated unwanted**  **emission level**  **(dBm EIRP)** | **Specified**  **bandwidth** | **Equivalent EIRP**  **(dBW per Hz)** |
| 2302 ≤ f ≤ 2309 MHz | -5 | 1 kHz | -65 |
| 2309 ≤ f ≤ 2400 MHz | -30 | 1 kHz | -90 |

Table : Additional emission limits

### Proposal

Protection of the facilities in Table 19 is to be provided in the 2290-2300 MHz band at   
-222 dBW per Hz. At -90 dBW per Hz (i.e. the EIRP limit in dBW per Hz over 2309–2400 MHz), the separation distance between the deep space antenna and transmitter assuming free space propagation is 40 km.

Given additional propagation mechanisms may apply beyond the free space model, the specification of absolute emissions limits like those in Table 18 is not necessarily appropriate as it potentially does not facilitate protection at -222 dBW per Hz and may be especially onerous on licensees that are not geographically close to the facilities in Table 19.

The ACMA proposes to not include additional emission limits like those in Table 18 in the new spectrum licence. Instead, appropriate in-band and out-of-band coordination requirements will be specified in a new RALI (discussed below).

With the assistance of the agencies operating the facilities in Table 19, the ACMA is considering the necessary protection requirements for three facilities located at (coordinates in GDA94):

|  |  |  |  |
| --- | --- | --- | --- |
| **Location** | **ACMA Site #** | **Latitude** | **Longitude** |
| CDSCC | 11552 | -35.402505 | 148.981393 |
| New Norcia | 131922 | -31.048228 | 116.191496 |
| Landsdale | 26582  132429 | -31.802504  -31.808414 | 115.885132  115.887652 |
| Mingenew | 132024 | -29.045754 | 115.348613 |

Table : Location of deep space facilities in Australia

The facility at Landsdale, though currently operational, will be non-operational by 31 December 2015[[27]](#footnote-28). As a result, specific protection requirements for this facility will not be developed in this TLG, but spectrum licensees should provide protection to the facility until 31 December 2015 taking into account the relevant Reports and Recommendations referenced in Annex A.

The facility at Mingenew is being afforded the same protection as the other facilities in Table 19 even though at this time, the facility does not operate any deep space receivers in the 2290-2300 MHz band. The ACMA recognise that this facility is becoming a key gateway for commercial space research and space operations on the west coast of Australia and providing sufficient protection of this facility will encourage operators to co-locate their systems there.

The additional protection requirements developed and applicable to these systems take into account the blocking requirements of the deep space LNA receivers.

The ACMA has developed a new Radiocommunications Assignment and Licensing Instructions (RALI) with coordination requirements and procedures for the protection of the New Norcia and Mingenew facilities when registering spectrum-licensed transmitters. The RALI includes in-band coordination requirements addressing the impact of noise within the 2290-2300 MHz band directly and based on Annex 7 of Appendix 7 of the Radio Regulations. Out-of-band interference into the LNA is also addressed In the in-band coordination requirements of the RALI. The draft RALI is included at Annex A. Protection requirements for Tidbinbilla are already managed through the implementation of a frequency and geographic guard band, but may be included in the RALI at a later date if any part of this guard band is released to the market.

The requirements of the new RALI will be referenced in the spectrum licence and the RAG managing interference from spectrum-licensed transmitters, and will hence be mandatory for licensees within a particular frequency and geographic separation from the facilities in Table 19.

## Statutory Conditions

Each licence contains a number of statutory conditions which are applicable under requirements defined in the Act. These include obligations on payments, third party use, device registration (and exemption) and residency requirements.

### Third party use

Defence C1 raised concerns about third party access to the 2.3 GHz spectrum licence and adjacent area/frequency apparatus licensing in offshore areas. To further clarify options available to stakeholders for device registration in spectrum licensing under third party use, Table 20 is provided.

Issues and options surrounding adjacent area/frequency apparatus licensing in offshore areas is provided in section 5.2.

|  |  |  |
| --- | --- | --- |
| Scenario | Coordination | Licence options |
| Operation required inside the area and frequency range of an existing spectrum licence | Written agreement for third-party operations must be obtained from spectrum licensee. | For a device that meets the requirements of the subsection 145(4) determination, subject to any requirements of the written agreement, devices may be registered by an accredited person[[28]](#footnote-29). |
| Subject to any requirements of the written agreement, registration exempt devices may be used with notification to the spectrum licensee. |

Table 20: Third party authorisations

### Device registration requirements

Notionally, device registration and certification is a precondition for operating a radiocommunications device under a spectrum licence. The primary purpose of device registration is to enforce the requirements of devices operating under a spectrum licence so they do not cause unacceptable interference (as defined by the subsection 145(4) determination).

Specific devices may be exempt from the registration requirements and these cases are detailed in section 3.6.2.1.

Device registration requirements considered in the technical framework include:

* allowing the use of transmitters operating below a certain power level and meeting certain deployment constraints in the licence area without registration (exemption from registration – refer to section 3.6.2.1);
* definition of groups of transmitters and receivers (refer to section 4.3);
* simplification for devices located far enough away from the licence geographic boundary (refer to section 4.4);
* deployment constraints (refer to section 4.5)

#### Registration exempt requirements

The registration exempt requirements are designed to facilitate the use of devices in the band by exempting those that operate in a particular way and meet the core conditions of the licence.

The current registration exempt requirements apply to a mobile or indoor[[29]](#footnote-30) fixed transmitter that operates with a radiated true mean power within its effective occupied bandwidth that is always less than or equal to 21 dBm per 30 kHz.

The registration exempt requirement across spectrum licensed bands varies considerably when normalised to 5 MHz bandwidth as shown in Table 21.

|  |  |  |
| --- | --- | --- |
| **Spectrum licence** | **Exempt requirement**  **(native)** | **Exempt requirement**  **(normalised to 5 MHz)** |
| 700 MHz | 23 dBm per occupied (lower band)  30 dBm per occupied (upper band) | 23 dBm per 5 MHz  30 dBm per 5 MHz |
| 800 MHz | 30 dBm per 1 MHz | 37 dBm per 5 MHz |
| 1800 MHz | 33 dBm per occupied (fixed)  39 dBm per occupied (mobile) | 33 dBm per 5 MHz  39 dBm per 5 MHz |
| 2 GHz | 25 dBm per 30 kHz | 47.2 dBm per 5 MHz |
| 2.3 GHz | 21 dBm per 30 kHz | 43.3 dBm per 5 MHz |
| 2.5 GHz | 35 dBm per 5 MHz | 35 dBm per 5 MHz |
| 3.4 GHz | 25 dBm per 30 kHz | 47.2 dBm per 5 MHz |

Table : Spectrum licence registration exempt requirements

Direct comparison isn’t necessarily practical because the technologies vary across the bands and the currency of some of the frameworks mean they are based on obsolete technologies.

Both system model technologies specify a maximum BS output power of 20W per 5 MHz and a maximum UE output power of 23 dBm per 5 MHz and 24 dBm per 5 MHz respectively. The registration exempt requirement is typically specified as a radiated maximum true mean power to take into account the variability in the antennas that may be utilised in the band.

In the 2.3 GHz band, user terminals may be deployed with antenna gains up to 17 dBi. This results in an EIRP of up to 43 dBm over the occupied bandwidth.

The ACMA has investigated the feasibility of exempting from registration terminals operating with a maximum radiated true mean power within their occupied bandwidth less than or equal to 43 dBm. The analysis conducted is provided in Annex F. The outcome of the study results in the follow registration exempt proposal in the 2.3 GHz band:

It is proposed that the following kinds of radiocommunications transmitters are exempt from the registration requirement and their operation must not cause harmful interference to other licensees:

1. a transmitter that operates in the 2.3 GHz band with a maximum radiated true mean power of less than or equal to 23 dBm per occupied bandwidth;

or

2. a transmitter that operates in the 2.3 GHz band where:

a) the maximum radiated true mean power is always less than or equal to 43 dBm per occupied bandwidth; and

b) the phase centre of the antenna is less than or equal to 10 metres above ground level; and

c) the antenna has a front-to-back ratio greater than or equal to 20 dB.

The registration exempt requirements are to apply to all transmitters, regardless of their type (e.g. fixed, mobile, indoor, outdoor, etc.)

Devices that meet the registration exempt requirements of this section still need to meet the ‘restricted’ block outside the area emission requirements unless an agreement between adjacent licensees exists to operate at radiated true mean powers up to the registration exempt requirement.

Through application of the ‘restricted’ block, inter-licensee interference issues when devices are operating at 43 dBm per occupied bandwidth are minimised, because those device operating in the ‘restricted’ block must not exceed an EIRP of 23 dBm per occupied bandwidth unless agreement is reached between adjacent frequency licensees.

## Other conditions

### Co-sited devices

The interference mechanisms for devices that are located within 200 metres are often difficult to model, and therefore, the ACMA includes additional conditions on the licence so that licensees work together to resolve any interference caused between radiocommunications devices where the phase centre of each antenna is separated by less than 200 metres. This is consistent with similar requirements in other spectrum licensed bands. This co-sited separation has been reduced from 500 metres as specified in the current licence.

To provide TLG members with an indication of what these conditions include, an excerpt from Licence Schedule 4 of the sample Spectrum Licence of the *Radiocommunications (Spectrum Marketing Plan—700 MHz) 2012* is provided here:

**Co-sited devices**

3. If:

(a) interference occurs between a radiocommunications device:

(i) operated under this spectrum licence; and

(ii) operated under another licence

when the measured separation between the phase centre of the antenna used with each device is less than 200 metres; and

(b) that interference is not the result of operation of a radiocommunications device in a manner that does not comply with the conditions of the relevant licence; and

(c) either the licensee or the holder (or authorised third party) of the other licence wishes to resolve the interference;

the licensee must manage interference with:

(d) the holder of the other licence; or

(e) if a site manager is responsible for managing interference at that location, that site manager.

### Protection of the Radio Quiet Zone

The *Radiocommunications (Mid-West Radio Quiet Zone) Frequency Band Plan 2011[[30]](#footnote-31)* establishes a radio quiet zone (RQZ) and provides for the establishment of supplementary radio quiet zones, to prevent harmful interference to radio astronomy services.

Existing spectrum licences that include the area established for the RQZ must follow the procedures set out in *Radiocommunications Assignment and Licensing Instruction (RALI) MS 32[[31]](#footnote-32)* before seeking to register a radiocommunication transmitters for use in and around the RQZ.

The ACMA will include the following condition in the spectrum licence for the 2.3 GHz band to enforce this requirement:

Before seeking to register a radiocommunications transmitter for use in or around the RQZ, as defined by the *Radiocommunications (Mid-West Radio Quiet Zone) Frequency Band Plan 2011*, the licensee must follow the procedures set out in *Radiocommunications Assignment and Licensing Instruction (RALI) MS 32* as in force from time to time.

Note: RALI MS 32 is available on the ACMA website.

### Protection of Earth stations

The current spectrum licence includes a requirement for licensees to “comply with the requirements specified in Appendix 7 of the Radio Regulations relating to the levels of interference protection to be afforded to receiving Earth stations”. This clause applies to all Earth stations regardless of their geographic and frequency nearness to the 2.3 GHz band.

The ACMA proposes three amendments to this clause to improve clarity in its interpretation and implementation:

* The clause currently does not clearly specify whether it applies on a first-in-time basis. It is proposed to amend the condition to make this clear.
* It is proposed that the reference to Appendix 7 of the Radio Regulations be changed to point directly to the protection requirements stated in Annex 7 of Appendix 7.
* To provide guidance for licensees in coordinating with earth stations a reference will be made to the procedures described in Recommendation ITU-R SF.1006-0—*Determination of the interference potential between earth stations of the fixed-satellite service and stations in the fixed service*.

The ACMA proposes to include the following requirement in the spectrum licence:

If the licensee operates a radiocommunications device under this licence, the licensee

must comply with the requirements specified in Annex 7 of Appendix 7 of the ITU

Radio Regulations relating to the levels of interference protection to be afforded to

Earth station receivers, if the receiver:

a) is licensed under the Act; and

b) was registered in the Register prior to the date on which the devices operated

under this spectrum licence is registered.

*Note* Recommendation ITU-R SF.1006 provides guidance on the procedure to use.

# Determination of unacceptable interference

The *Radiocommunications (Unacceptable Levels of Interference - 2.3 GHz Band) Determination* defines the level of interference caused by a radiocommunications transmitter operated under a spectrum licence that is deemed to be unacceptable. It is made under subsection 145(4) of the Radiocommunications Act.

Typically, a radiocommunications transmitter that operates outside the maximum permitted levels of radio emission defined by the core conditions, does not meet the requirements of the device boundary criterion, or does not meet any applicable deployment constraints, will be determined to not comply with the subsection 145(4) Determination.

## Propagation modelling

The propagation model chosen for the technical framework appears in the subsection 145(4) determination as part of the device boundary criterion. The propagation model selected for the technical framework needs to be:

* suitable for TDD and FDD systems
* a generic model that does not require detailed information on terrain or land usage
* not too complex and can be repeated with certainty
* suitable for use in the 2300-2400 MHz range

The propagation model selected here does not need to be suitable for the detailed planning of services and licensees are free to use any model for their own planning needs. The selected propagation model will be the basis of the device boundary criterion on which the ACMA may decide to reject the registration of a transmitter to be operated under the spectrum licence.

There are a range of available propagation models that could be implemented including: ITU-R P.1546, ITU-R P.526, ITU-R P.452 or ITU-R Report SM.2028 and ERC Report 68.

The primary interference mechanism in TDD systems is from high-to-high site systems operating as base station infrastructure, but the nature of TDD systems means that all site scenarios are of interference concern to licensees.

The most appropriate model is therefore one which relaxes to a free-space or smooth-Earth model for unobstructed paths and one that considers terrain features where appropriate for obstructed paths.

In section 7 of ITU-R P.526-12, a general guide to propagation by diffraction is provided via a flow chart summarising the procedure to be adopted in a number of cases. When an automatic process is required, the Delta-Bullington implementation of section 4.5 of ITU-R P.526-12 should apply.

The ACMA recommends the adoption of the ‘Method for a general terrestrial path’ of Recommendation ITU‑R P.526 (see section 4.5 of P.526-12) for the 2.3 GHz technical framework.

Whilst the 2.5 GHz mid-band gap (2570-2620 MHz) has similar interference mechanisms and the cascaded knife edge propagation model is adopted, P.526-12 was not available at the time the 2.5 GHz TLG developed its propagation modelling and hence the cascaded knife edge model was the best model to be implemented. Comparison between the two models and additional analysis of the Delta-Bullington method is provided in Annex H.

In determining the necessary set-back from the geographic area boundary to reduce the risk of co-channel interference between licensees when calculating the device boundary criterion (refer to section 4.4.1); the worse-case scenario involves a line-of-sight propagation path, and will hence be constrained by free-space loss conditions.

Stakeholders are requested to confirm the suitability of the ’Delta-Bullington Model’ method in section 4.5 of Recommendation ITU-R P.526-12 as the proposed propagation model in the 2.3 GHz band.

The implementation of P.526-12 applicable in the 2.3 GHz band is provided in Annex J.

## Level of protection

The level of protection (LOP) is the benchmark protection given to receivers from co-channel emissions from transmitters operating in adjacent geographic licence areas. The level of protection is a compromise between the level of emissions over the geographic boundary of the licence and the protection requirements of receivers.

This benchmark level is necessary for the calculation of the device boundary criterion.

Emissions from devices operating in adjacent frequencies in the same geographic area are not directly related to the protection provided by the LOP. The level of protection chosen to provide protection from devices operating in adjacent frequencies should reflect those contained in the relevant radiocommunications advisory guidelines or any agreements reached between affected licensees.

Three methods are available for determining the LOP:

1. noise floor plus interference-to-noise margin (I/N) of -6 dB resulting in a 1 dB increase in noise floor
2. reference sensitivity of the receiver and consideration of fading mechanisms
3. proposed compatibility requirement of the receiver (see section 5.2.4.1) and consideration of fading mechanisms

If option 1 is chosen, then the LOP becomes -108 dBm per 5 MHz assuming a NF of 5 dB. If option 2 is chosen, then analysis of the reference sensitivities and fading mechanism of the devices considered in the system models is required.

|  |  |  |
| --- | --- | --- |
| **Parameter** | **LTE** | **WiMAX** |
| BS Reference sensitivity | -101.5 dBm | -92.6 dBm |
| UE Reference sensitivity | -100 dBm | -94.5 dBm |

Table 22: Reference sensitivity in a 5 MHz reference channel

Notionally, it will be the user equipment that approaches the geographic area boundary rather than base stations, therefore, the most restrictive UE reference sensitivity of the system models is taken into account.

Annex E contains a derivation of the fade margin applicable in the 2.3 GHz band for a 95% coverage requirement assuming a standard deviation of 7 dB. In the calculations contained in Annex E, the resulting fade margin is 8 dB. Therefore, if 95% coverage is required at the reference sensitivity level, an additional 8 dB protection is required to ensure this is met.



The level of protection as calculated under Option 2 is -108 dBm per 5 MHz. This limit is the same as that determined under Option 1.

If option 3 is chosen, the same method as applied to option 2 is used, but the minimum wanted signal level of -95.5 dBm per 5 MHz specified in the compatibility requirement of section 5.2.4.1 is used rather than reference sensitivity.



The level of protection as calculated under Option 3 is -103.5 dBm per 5 MHz and is equivalent to a noise floor plus interference-to-noise margin (I/N) of -5.5 dB (for a NF of 9 dB in the UE) resulting in a 1.1 dB increase in noise floor.

To promote additional deployment flexibility in the 2.3 GHz band, the proposed level of protection is -103.5 dBm per 5 MHz.

A system model showing separation distances between BS, UE and the geographic boundary based on the proposed level of protection is difficult to provide given the choice of propagation model. At its worst, free-space propagation can be assumed, whereby BS to UE separation is 172 km, and BS to the geographic boundary is 1090 km. It should be noted that for a 30m BS antenna to a 1.5m UE antenna, the radio horizon is only 27.5 kilometres.

Given the propagation model (section 4.1) and level of protection proposed in this section, licensees are requested to confirm whether they are satisfied that the use of these parameters in calculation of the device boundary criterion (section 4.4) will meet the co-channel interference requirements of their systems.

## Groups of transmitters or receivers

Group registration arrangements provide additional flexibility to licensees when deploying systems within the band. The 2.3 GHz band in particular uses an effective radius for the registration of a group of transmitters that are not constrained by a specific distance specification between the phase centre of all antennas within the group.

Two or more fixed transmitters may be registered as a group of transmitters if all transmitters in the group have the same centre frequency, emission designator and the associated antennas have the same identification number.

Two or more fixed receivers may be registered as a group of receivers if the associated antennas have the same identification number and all receivers are associated with either a single transmitter or a group.

An individual fixed transmitter or receiver may belong to more than one group.

When determining the centre location and effective radius of a group of transmitters in the 2.3 GHz band, they can be divided into two types:

* those having an antenna phase centre located within 10 metres of the same central point (*le*) resulting in the effective radius (*re*) being zero
* those having a central point (*le*) that is the centre point of the straight line joining the two transmitters with greatest separation distance of the group of transmitters, and effective radius (*re*) being the distance from *le* to the furthest transmitter of the group

The second option is particular to the 2.3 GHz band, because it allows a large number of transmitters to be covered by a single registration over a large area (the extent of the transmitter deployment).

The concern with the second option is that it is difficult for licensees to conduct interference management within the area because there is no defined transmitter location, and for the ACMA, the transparency of the RRL is difficult to maintain.

In the TLG’s for the 800 MHz, 1800 MHz, 700 MHz and 2.5 GHz bands, the consensus was for group registration to primarily support the registration of systems that have their antenna phase centre’s located within a defined proximity (20 metres in this case). Additionally, the parameters of the equipment being considered in the group should be essentially identical, and that a transmitter or receiver can only belong to one group.

The group registration of systems under the second option was not included in the technical framework for the 800 MHz, 1800 MHz, 700 MHz and 2.5 GHz bands. Instead a broader definition for devices that are exempt from registration was made. This typically allowed any devices operating below a specific EIRP limit to be exempt from registration. Any devices operating outside these requirements must be registered.

The ACMA propose that the use of effective radius in the calculation of the device boundary not apply given that the phase centre of all antennas must be within the defined proximity of 20 metres. Therefore when determining the location of a group of radiocommunications transmitters, the location is the centre point between the phase centre of each radiocommunications transmitter antenna within the group.

## Device boundary criterion

The device boundary of a radiocommunications transmitter, calculated using the device boundary criterion, must lie within the geographic boundary of the licence; otherwise the transmitter may be declared under the subsection 145(4) determination to cause unacceptable interference.

The device boundary aims to manage co-channel interference across the geographic boundary of the licence. Interference across the frequency boundary of the licence is discussed in section .

Further description of the device boundary and the methodology updated for spectrum licensing is available in *SPP 02/12* – *Device boundary methodology*. It mirrors the methodology put in place for the new/revised technical framework for the 800 MHz, 1800 MHz, 700 MHz and 2.5 GHz bands.

### Proposed device boundary criterion

The ACMA considers the propagation model in section 4.1 and the level of protection of section 4.2 to be appropriate to provide adequate radiocommunications transmitter separation from the geographic boundary to enable co-existence between adjacent area services while not placing overly restrictive constraints on transmitter deployment near the geographic boundary.

In recent technical frameworks, development has resulted in an effective antenna height cap of 500 metres being chosen, though occasionally, some site scenarios may result in an effective antenna height greater than this level. It is felt appropriate to maintain this effective antenna height restriction in the 2.3 GHz band.

Note that the implementation of the proposed methodology in *SPP 02/12* – *Device boundary methodology* requires the definition of two variables:

* *hgr =* nominal receive antenna height above ground level (m); and
* *Gr* = nominal receiving antenna gain including feeder loss set (dBi).

Based on the *LOP* values derived in section 4.2, the values for these parameters is set to *hgr* = 5 m and *Gr* = 0 dBi at the boundary.

Assuming a maximum base station height of 500 metres (equivalent to the effective antenna height when calculating propagation over smooth Earth), the propagation model described in section , the outside the area emission limit of section (68 dBm per 5 MHz) and the proposed level of protection of section , the maximum radial length achievable is radio horizon limited[[32]](#footnote-33) to 111 kilometres.

Therefore, devices located greater than 111 kilometres from the geographic boundary of the licence and meet the core conditions of the licence, are deemed to comply with the device boundary criterion on account of the radio horizon, and are taken not to cause unacceptable interference.

Stakeholders are asked to consider whether the follow parameters for the device boundary criterion are appropriate:

> the nominal receive antenna height above ground level, *hgr* = 5 metres;

> the nominal receiving antenna gain, *Gr* = 0 dBi; and

> the maximum radial length of 111 km

An indicative Schedule 2 of the subsection 145(4) determination is provided in Annex J.

### Conditions

Where a part of the device boundary lies outside the boundary of the ASMG [[33]](#footnote-34), then additional consideration applies to whether the device causes a level of interference taken to be unacceptable in calculation of the device boundary. A radiocommunications transmitter operated under a spectrum licence is taken not to be unacceptable for those parts of the device boundary where the device boundary:

1. lies outside the boundary of the ASMG; and
2. is connected to a radial that:
   1. is mentioned in Part 1 of Schedule 2; and
   2. does not cross the geographic area of another licence.

This is illustrated in Figure 14, where the resulting DBC pass point is located outside the ASMG, and illustrates a fail if the radial crosses the geographic area of another licence.

ASMG

Licensee 1

Licensee 2

Coastline

Figure : The DBC and ASMG

This condition is necessary due to the fact that on occasions, radiocommunications transmitters that are located close to the coast line may have part of the device boundary outside the ASMG. This is considered to be unacceptable under the existing subsection 145(4) Determination.

## Deployment constraints

The existing 2.3 GHz technical framework did not allow transmitters to be operated on an airship or balloon, but did not specifically define what an airship or a balloon was or the limits of their operation.

It is the intention of the ACMA that specific deployment constraints do not apply in the updated framework.

Under the technical framework, airborne transmitters are deployable, but because they aren’t considered to be at a fixed location, they are only able to be deployed under the registration exempt requirements of section 3.6.2.1. In that case, they are only able to be operated at a maximum radiated true mean power of less than 23 dBm per occupied bandwidth, and hence should not cause any more interference than a typical UE in the band.

Licensees should be aware that constraints apply to some transmitters that are to be operated under the registration exempt requirements proposed in section 3.6.2.1.

# Radiocommunications advisory guidelines

Radiocommunications advisory guidelines (RAGs) are made under Part 5.3, sub-section 1 of section 262 of the Act, and authorise the ACMA to make written advisory guidelines about any aspect of radiocommunication or radio emissions. These guidelines are not mandatory requirements and the ACMA may consider alternative interference management arrangements where necessary.

The use of the RAGs provides flexibility for licensees to make arrangements to manage the risk of interference between services. In the case that licensees are unable to resolve interference issues amongst themselves, they can expect the ACMA to have regard to the RAGs in dealing with any such dispute.

It should be noted that spectrum licensees are required to manage interference between devices operated under their own licences. This includes devices operated under third party authorisations. This is not a requirement of either RAG.

## Adjacent frequency allocations

The Australia Radiofrequency Spectrum Plan (ARSP)[[34]](#footnote-35) provides the table of frequency allocations and specifies the general purpose for which the bands may be used. Adjacent frequency services to the 2300-2400 MHz band are shown in the extract of the ARSP in Table 23.

Below the 2300 MHz frequency boundary, the primary adjacent band services are:

* space research, space operations and earth exploration-satellite services. The locations of these space services are provided in the RRL and the AUS87 footnote (non exhaustive)
* fixed services operating in accordance with the 2.1 and 2.2 GHz band channel arrangements specified in RALI FX3
* Aeronautical mobile telemetry (AMT) systems operated by the Department of Defence in the 2200-2290 MHz band at specific land and territorial water areas. The location where AMT systems may be deployed is available in Spectrum Planning Report 10/01[[35]](#footnote-36).

The Australian Communications and Media Authority have also made the *Television Outside Broadcast Service (1980–2110 MHz and 2170–2300 MHz) Frequency Band Plan 2012[[36]](#footnote-37)*. This band plan supports the introduction of television outside broadcast services.

Above the 2400 MHz frequency boundary, the Radiocommunications (Low Interference Potential Devices) Class Licence 2000[[37]](#footnote-38) (the LIPD Class Licence) permits the operation of a number of different classes of transmitter in the band 2400-2483.5 MHz. Most notably, the operation of Wi-Fi and Bluetooth devices in this band is authorised. Amateur licensees also operate services in the 2400-2450 MHz portion of the band on a secondary basis.

The 2400-2500 MHz is designated for use by Industrial, Scientific and Medical (ISM) applications; the most prevalent use of this application is the domestic microwave oven. Emission limits for ISM devices are regulated through the ACMA Electromagnetic Compatibility (EMC) regime[[38]](#footnote-39).

|  |  |  |  |
| --- | --- | --- | --- |
| Column 1:  ITU Radio Regulations Table of Allocations | | | Column 2:  Australian Table of Allocations |
| Region 1 | Region 2 | Region 3 |  |
| **2 200 – 2 290**  SPACE OPERATION (space‑to‑Earth) (space‑to‑space)  EARTH EXPLORATION‑SATELLITE (space‑to‑Earth) (space‑to‑space)  FIXED  MOBILE 391  SPACE RESEARCH (space‑to‑Earth) (space‑to‑space)  392 | | | **2 200 – 2 290**  SPACE OPERATION (space‑to‑Earth) (space‑to‑space)  EARTH EXPLORATION‑SATELLITE (space‑to‑Earth) (space‑to‑space)  FIXED  MOBILE 391  SPACE RESEARCH (space‑to‑Earth) (space‑to‑space)  392 AUS87 |
| **2 290 – 2 300**  FIXED  MOBILE except aeronautical mobile  SPACE RESEARCH (deep space) (space‑to‑Earth) | | | **2 290 – 2 300**  FIXED  MOBILE except aeronautical mobile  SPACE RESEARCH (deep space)  (space‑to‑Earth)  AUS87 AUS93 |
| **2 300 – 2 450**  FIXED  MOBILE 384A  Amateur  Radiolocation  150 282 395 | **2 300 – 2 450**  FIXED  MOBILE 384A  RADIOLOCATION  Amateur  150 282 393 394 396 | | **2 300 – 2 450**  FIXED  MOBILE 384A  RADIOLOCATION  Amateur  150 282 AUS87 |
| **2 450 – 2 483.5**  FIXED  MOBILE  Radiolocation  150 397 | **2 450 – 2 483.5**  FIXED  MOBILE  RADIOLOCATION  150 | | **2 450 – 2 483.5**  FIXED  MOBILE  RADIOLOCATION  150 AUS87 |

Table : Adjacent frequency allocations

In addition to those services allocated via the ARSP, the Mid Western Radio Quiet Zone (RQZ) in remote central Western Australia has been identified for future radio astronomy facilities. Parts of the spectrum licence are contained within the area that consist of the RQZ (a 70 km radius centred on a site latitude 26°42’ 15” S and longitude 116°39’ 32” E (AGD66)) and as such, it is necessary for the ACMA to apply exclusion and protection zones in order to protect the facility from undue radio emissions. Details necessary for the coordination with the site can be found in *RALI MS32 - Coordination of apparatus licensed services within the mid west Radio Quiet Zone[[39]](#footnote-40)* and specific licence conditions are detailed in section 3.7.2.

## Managing interference to spectrum licensed receivers

The current equivalent RAG (*Radiocommunications Advisory Guidelines (Managing Interference to Receivers — 2.3 GHz Band) 2009*) provides in-band and out-of-band interference levels based on the receiver minimum performance level (notional receiver) and compatibility requirement.

Individual mobile or nomadic receivers operated under the spectrum licence are not subject to the protection and coordination procedures contained within the guideline. The outside-the-band emission limits and device boundary arrangements contained in the technical framework for the band provide the necessary protection for mobile and nomadic receivers operating in conjunction with registered fixed (base) stations.

Interference to spectrum licensed receivers from radiocommunications devices can be caused by in-band or out-of-band interference mechanisms dependent on whether the adjacent service is at the frequency or geographic area boundary of the spectrum licence. Sections 5.2.2 and 5.2.3 provide the definition of in-band and out-of-band interference for the purposes of the RAGs.

### Adjacent area/frequency licensing options

The ACMA encourages licensees to work together if the coordination requirements of the RAGS are not suitable. In these cases, licensees may come to agreement to operate in ways outside the conditions of the RAG – these scenarios are detailed in Table 24.

|  |  |  |
| --- | --- | --- |
| Scenario | Coordination | Licence options |
| Area adjacent apparatus licence operating co-channel to a spectrum licence | Using criteria in section 262 advisory guidelines[[40]](#footnote-41). | Obtain appropriate apparatus licence. |
| Agreed coordination criteria with the spectrum licensee. | Obtain appropriate apparatus licence. |
| Adjacent frequency apparatus licence | Using criteria in section 262 advisory guidelines. | Obtain appropriate apparatus licence. |
| Agreed coordination criteria with the spectrum licensee. | Obtain appropriate apparatus licence. |

Table 24: Apparatus licensing options

Licensees are reminded that if interference is caused and cannot be resolved, that the ACMA will take the interference criteria and coordination procedures defined in these RAGS into account when settling interference disputes.

### In-band interference

The definition of in-band differs slightly dependent on whether the device is operating under a spectrum licence or apparatus licence; but in general refers to emissions ***within*** the upper and lower frequencies specified in the licence.

***in-band*** means:

1. for a radiocommunications transmitter or radiocommunications receiver operated under a spectrum licence, the frequencies within the frequency band in which operation of those radiocommunications devices is authorised under the licence; and
2. for a radiocommunications transmitter or radiocommunications receiver operating under an apparatus licence, the frequencies within the lower frequency limit and the upper frequency limit specified in the licence.

Management of in-band interference by radiocommunications transmitters operating under an adjacent spectrum licence is via the core conditions of the licence imposed under section 66 of the Act and the section 145 Determination.

In-band interference by radiocommunications transmitters operating under an apparatus licence issued on or after the date the spectrum licence takes effect is managed as if the radiocommunications transmitter is operated under a spectrum licence. This means that apparatus licensees are required to meet the device boundary criterion in the section 145 Determination.

### Out-of-band interference

The definition of out-of-band differs slightly dependent on whether the device is operating under a spectrum licence or apparatus licence; but in general refers to emissions ***outside*** the upper and lower frequencies specified in the licence.

***out-of-band*** means:

1. for a radiocommunications transmitter or radiocommunications receiver operated under a spectrum licence, the frequencies outside the frequency band in which operation of those radiocommunications devices is authorised under the licence; and
2. for a radiocommunications transmitter or radiocommunications receiver operating under an apparatus licence, the frequencies outside the lower frequency limit and upper frequency limit specified in the licence.

By its very nature, out-of-band interference is difficult to predict because the levels and frequencies of the emissions depends on both the nearness of, and operating frequencies of, radiocommunications transmitters and receivers that are close in terms of both frequency and distance.

Out-of-band interference from intermodulation products, harmonic and parasitic signals and other spurious signals may extend for many megahertz outside the licence frequency band. As a result, it is possible for devices operating under non-adjacent spectrum licences to interfere with each other.

It is therefore necessary to define a minimum level of receiver performance (the notional receiver in section 5.2.4) to be afforded protection under the spectrum licence, and to allow adjacent licensees to accurately plan and deploy networks without concern for causing interference to adjacent receivers.

### Notional receiver

In order to enable efficient coordination with spectrum licensed receivers, the adjacent licensee must be aware of the associated receiver infrastructure (metrics) upon which the technical framework for the spectrum licence is derived. This infrastructure is shown in the notional receiver model in .

RF Filtering

Antenna gain

Feeder and combiner losses

Receiver

Measurement point

Figure 15: Notional receiver model

The minimum notional performance level for a receiver will specify requirements for:

* Compatibility requirement
* Adjacent channel selectivity
* Receiver blocking
* Receiver intermodulation rejection

An important receiver performance requirement also includes receiver spurious emissions, but these limits are a licence condition. The limits proposed for the new technical framework are provided in section 3.4.3.

The notional receiver is defined by the parameters and values in Table 25 with the derivation of each parameter provided in the sections following.

|  |  |
| --- | --- |
| **Parameter** | **Value** |
| Compatibility requirement | -95.5 dBm per 5 MHz |
| Adjacent channel selectivity | 43.5 dB @ 0 to ≤ 5 MHz offset |
| Receiver blocking | 89 dB @ > 5 MHz offset |
| Receiver intermodulation rejection | ‑52 dBm per occupied bandwidth |

Table : Parameters of the notional receiver

The RAG will explicitly express that the notional receiver performance is the combined performance at the antenna connector made up of the performance of the receiver equipment and any additional external filter.

#### Compatibility requirement

Specification of the notional receiver may either be done using absolute or relative values and is usually determined by the range of technologies that are in use or planned for use in the band. Where a particular technology type is dominant, it is possible to define absolute notional receiver parameters because over the course of the licence it is not anticipated that the service type will change. This may not offer flexibility to the licensee to deploy new service types without either meeting the notional receiver requirements or by making a variation to the relevant RAG.

It is also recognised that it is not practical to specify requirements to the noise floor as this limits flexibility in the adjacent bands. As a result, it is proposed to specify a minimum wanted signal level and use relative notional receiver performance metrics in the 2.3 GHz band where possible.

The current compatibility requirement specifies a maximum unwanted signal level at the registered receiver of -105 dBm per 30 kHz. The compatibility requirement was derived from the MDS system model of the original 2.3 GHz conversion plan; that is, wide area coverage (> 1000 square km, or equivalently 50 km radius) utilising high-sited (> 100 m) omni-directional (base) transmitters to fixed receivers with directional antenna (at height 10 m).

The value of -105 dBm per 30 kHz is a result of the MDS sensitivity for an analogue emission being -65 dBm with a C/N requirement of -40 dB. Digital systems have a more stringent requirement of -110 dBm per 30 kHz.

As MDS is no longer the primary service type envisaged in the 2.3 GHz band, it is necessary to re-evaluate the compatibility requirement with respect to IMT technologies including LTE and WiMAX.

In the system models of section 2.1, the reference sensitivity specifies the minimum true mean power at the antenna connector at which a throughput requirement shall be met for a specified reference measurement channel. For the 2.3 GHz band, it is proposed that the reference measurement channel[[41]](#footnote-42) be 5 MHz with all resource blocks (LTE) or sub-channels (WiMAX) allocated, with a QPSK rate 1/3 (LTE) and QPSK rate 1/2 (WiMAX) modulation and coding scheme.

|  |  |  |
| --- | --- | --- |
| **Parameter** | **LTE** | **WiMAX** |
| Reference sensitivity (per 5 MHz) | -101.5 dBm | -92.6 dBm |

Table : Reference sensitivity

The reference sensitivity for LTE is only 0.5 dB above the noise floor for a 5 MHz channel with NF of 5 dB. WiMAX on the other hand is 9.4 dB above the noise floor with equivalent parameters.

Both technologies are required to maintain a throughput requirement of 95% in the specific reference measurement channel. In order to achieve this and to take into account other anomalous effects, (fading, body loss, etc.) the minimum wanted signal level is proposed to be -95.5 dBm per 5 MHz for 95% of time in any 1 hour period.

The proposed compatibility requirement is a minimum wanted signal level at the antenna connector of -95.5 dBm per 5 MHz for 95% of time in any 1 hour period.

#### Adjacent channel selectivity

The ACS in the current framework is based on minimum IF (intermediate frequency) characteristics as equipment operating or planned for operation in the band did not share a common channel structure. The minimum IF attenuation requirement is given in Table 27 at the given frequency offset from the edge of a channel.

|  |  |
| --- | --- |
| **Frequency offset in MHz** | **Attenuation in dB** |
| 0 | 0 |
| 0.35 | 3 |
| 0.5 | 10 |
| 1 | 40 |
| 1.5 | 50 |

Table : Minimum IF attenuation requirement

Given that the technologies in use or planned for use in the band have converged (a common channel structure), it may be possible to specify the ACS requirements at the RF rather than IF stage.

The ACS of those technologies provided as system models for the development of this technical framework are provided in Table 28. The ACS specified for LTE is for a single offset, whilst WiMAX considers a second adjacent channel.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **ACS** | **TDD LTE** | | **TDD WiMAX** | |
| **BSnote** | **UE** | **BS** | **UE** |
| 1st adjacent channel | 43.5 dB | 33 dB | 40 dB | 33 dB |
| 2nd adjacent channel | - | - | 50 dB | 47 dB |

Table : ACS of the system models

*Note:* the minimum ACS for LTE BS is specified as an absolute value in the form of an unwanted signal level at a given offset from the wanted signal edge. To convert into a wanted-to-unwanted ratio (relative value to align with the WiMAX specification), a known wanted level for the system must be considered. In this case, the wanted level for a 5 MHz channel is -95.5 dBm (LTE reference sensitivity + 6 dB) and the unwanted level is -52 dBm centred at 2.5025 MHz offset from the channel edge; therefore the ACS is -95.5-(-52) = 43.5 dB.

The proposed technical framework includes the use of restricted blocks between licensees (refer to section 3.3, in particular Figure 6) which operate at reduced power levels.

Taking the restricted block power limit of 23 dBm per 5 MHz, assuming a minimum wanted signal level (the compatibility requirement) of ‑95.5 dBm per 5 MHz, receiver antenna gain of 14 dBi (17 dBi gain minus 3 dB downtilt), separation of 200 m and free space propagation loss (85.9 dB @ 2350 MHz), results in the conformance with the ACS for the first channel.



Specifying an ACS of 43 dB is possible if the use of the restricted block is taken into account (95.5 dBm per 5 MHz + (-51.9 dBm per 5 MHz) = 43.6 dBm per 5 MHz). If the restricted block is not taken into account, then licensees will most likely need to be synchronised in order to avoid interference into their systems.

For the second adjacent channel, the situation is more complex. In the 2.5 GHz TLG, noting work conducted in ECC Report 119[[42]](#footnote-43), it was found that additional base station receiver filtering would be required to protect the receiver from high level signals if TDD BS transmitters are deployed in the second adjacent channel. ECC Report 119 proposes that the second adjacent channel ACS be a value of 99 dB. In reality, such a large ACS value at small offsets is not practical without additional filtering (in this case, 56 dB additional over the first adjacent channel ACS).

It is proposed that the receivers ability to reject unwanted signals on adjacent channels greater than 5 MHz offset from the channel edge be covered by the receiver blocking metric (section 5.2.4.3).

Stakeholders are requested to confirm if the ACS requirement for a frequency offset between 0 and 5 MHz from the upper and lower frequency limits of a specified channel is 43.5 dB is applicable in the 2.3 GHz band.

#### Receiver blocking

Receiver blocking is a measure of the ability of a receiver to receive the wanted signal in the presence of a high level unwanted signal on frequencies other than the first adjacent channel. Blocking occurs where high levels of unwanted signal outside the wanted channel change the operating point of the RF amplifier or mixing stages reducing receiver sensitivity and effectively blocking the reception of low level signals in the wanted channel.

The receiver blocking requirements of those technologies provided as system models for the development of this technical framework are provided in Table 29. The two blocking requirements are specified both within ±20 MHz of the 2300-2400 MHz band and outside this range.

|  |  |  |
| --- | --- | --- |
| **Blocking** | **TDD LTE**  **(channel edge to centre frequency)** | **TDD WiMAX**  **(channel edge to centre frequency)** |
| 2280-2420 MHz | -43 dBm per 5 MHz  ±7.5 MHz | -40 dBm per 5 MHz  ±12.5 MHz |
| Outside 2280-2420 MHz  (assume CW) | -15 dBm | -15 dBm |

Table : Blocking requirements for the system models

The WiMAX blocking requirement in Table 29 does not apply to the second adjacent channel, in this case, the adjacent channel specifications in Table 28 show the ACS of the BS is 50 dB and the UE 47 dB (relative to the noise floor).

The receiver power level of -43 dBm per 5 MHz for LTE is 9 dB greater than the first adjacent channel ACS requirements of section 5.2.4.2, or is equivalent to a relative requirement of 52.5 dB (which aligns closely with that specified for a WiMAX BS). As noted in section 5.2.4.2, additional base station receiver filtering would be required to protect the receiver from high level signals from possible TDD BS transmitters in the second adjacent channel (greater than 5 MHz offset).

As previously discussed in section 3.3, any increase in the outside the area emission limit results in an equivalent increase in the blocking requirement for offsets greater than 5 MHz.

Taking the unrestricted block power limit of 68 dBm per 5 MHz, assuming a minimum wanted signal level (the compatibility requirement) of ‑95.5 dBm per 5 MHz, transmitter antenna gain with 3 dB discrimination due to downtilt, receiver antenna gain of 14 dBi (17 dBi gain minus 3 dB downtilt), separation of 200 m and free space propagation loss (85.94 dB @ 2350 MHz), results in:



This received power at the antenna connector is 88.56 dB above the minimum wanted signal requirement, and 36 dB above the blocking requirements specified in the system model for LTE. This suggests that additional filtering beyond the blocking requirements of Table 29 may be required to mitigate the potential for interference from geographically close transmitters in the second adjacent channel.

The ACMA is not mandating that licensees install additional filtering to achieve the necessary attenuation for unwanted signals at offsets greater than 5 MHz from the upper and lower frequency limit of the spectrum licence.

The ACMA will expect licensees to evaluate the risk of unwanted emissions at offsets greater than 5 MHz and their own requirement to fit additional filtering; however, should licensees experience interference from a transmitter operating in accordance with its licence to a receiver that does not meet the blocking requirement (with or without filtering), the ACMA will generally resolve the issue in favour of the interfering transmitter.

The relationship between *ACS*, *ACLR* and adjacent-channel protection ratio is normally given as:

*PR*(0) – *PR*(∆*f*) = *ACIR* = –10log10[10-*ACS*/10 + 10-*ACLR*/10]

where *PR*(0) = co-channel protection ratio

*PR*(∆*f*) = adjacent-channel protection ratio

While a co-channel CW interferer will have a different impact on receiver performance compared to white noise, in the absence of more detailed information, the assumptions are made that:

* *PR*(0) = *C*/*N* = *PREFSENS – PN*
* *PR*(∆*f*) = (*PREFSENS* + 6 dB) – *Pint*

In order to test the receiver’s blocking capability it is assumed that receiver degradation tested should not be due to out-of-band emissions of the CW interferer, and therefore it is also assumed that *ACLR* >> *ACS*, and therefore *ACIR* = *ACS*. Therefore:

*ACS* = *PREFSENS – PN* – [(*PREFSENS* + 6 dB) – *Pint*] = *– PN* – 6 dB + *Pint*

According to Tables 2 and 29, for both LTE and WiMAX, *PN* = –102 dBm/(5 MHz) and   
*Pint* = –15 dBm, and therefore *ACS* ≈ 81 dB. This is less stringent than the requirement of 89 dB proposed for offsets greater than 5 MHz.

The blocking requirement is 89 dB at an offset greater than 5 MHz from the upper and lower frequency limit of the spectrum licence.

Noting that the blocking requirement defined by technical specifications (i.e. maintaining throughput, with a wanted signal level of *PREFSENS* + 6 dB, in the presence of an out-of-band CW interferer with a power level of –15 dBm), is likely to be less stringent than the above blocking requirement, licensees are requested to confirm whether this additional requirement can be removed for clarity.

#### Receiver intermodulation rejection

Receiver intermodulation rejection is a measure of the ability of a receiver to receive the wanted signal without exceeding a specified degradation in output quality caused by the presence of two or more unwanted signals with a specified amplitude and frequency relationship to the wanted signal frequency. Receiver intermodulation rejection is a function of the receiver front end linearity and the radio frequency filter characteristics.

A

1448.5 MHz

1875.5 MHz

2302.5 MHz

f1

f2

Figure : Graphical depiction of receiver intermodulation

Figure 16 shows that if two separate frequencies (f1 and f2) exist in a non-linear device (A), sum and difference frequencies are also produced (the red triangle at 2302.5 MHz). In particular, 3rd and 5th order harmonics are likely to be the most interfering. In this example, the 3rd order harmonic produces an intermodulation product centred on 2302.5 MHz.

The current framework provides both the minimum RF filter attenuation requirement at specific frequency offsets from the channel edge (Table 30) and the minimum intermodulation conversion ratios for front end linearity (Table 31).

|  |  |
| --- | --- |
| **Frequency offset (MHz)** | **Attenuation (dB)** |
| 0 | 0 |
| 3.5 | 3 |
| 7 | 10 |
| 14 | 20 |
| 30 | 40 |

Table : Minimum RF filter attenuation requirement

|  |  |
| --- | --- |
| **Intermodulation type** | **Conversion ratio (dB)** |
| Two-signal 3rd order (2f1±f2) | 11 |
| Two-signal 5th order (3f1±f2) | 28 |
| Three-signal 3rd order (f1±f2±f3) | 5 |

Table : Front end linearity requirement

The receiver intermodulation rejection of those technologies provided as system models for the development of this technical framework are provided in Table 32 with the referenced levels being the interfering signal mean power at the input to the BS antenna port and wide area base stations only.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Receiver intermodulation rejection** | **TDD LTE** | | **TDD WiMAX** | |
| **BS** | **UE** | **BS** | **UE** |
| CW interferer at ±7.5 MHz | -52 dBm | -46 dBm | -48 dBm | -55 dBm |
| Wideband interferer at ±17.5 MHz | -52 dBm | -46 dBm | -48 dBm | -55 dBm |

Table : RIR of the system models

It is proposed to define the receiver intermodulation rejection requirement as a maximum power level from an individual out-of-band signal when in the presence of another signal with a specified amplitude and frequency relationship that may result in a third or higher order odd intermodulation product on the operating frequency of the spectrum licensed receiver.

The receiver intermodulation rejection requirement is a minimum level of ‑52 dBm per occupied bandwidth for each out-of-band signal at frequency offsets greater than 5 MHz from the upper and lower frequency limit of the spectrum licence.

Receiver intermodulation rejection of out-of-band signals at frequency offsets less than or equal to 5 MHz should be restricted by the ACS limits in section 5.2.4.2.

## Managing interference from spectrum licensed transmitters

### Spectrum-licensed receivers

The device boundary criteria, as defined in Section 4.4 (to be incorporated in the s.145 Determination), is the primary mechanism for managing interference across geographical boundaries. However, it is prudent for licensees to consider existing services and, if necessary, negotiate with other spectrum licensees when deploying services in order to avoid harmful interference.

The ACMA is proposing that licensees should coordinate against existing spectrum-licensed receivers when registering devices to be operated under a 2.3 GHz spectrum licence. Guidance on the recommended preliminary coordination procedure with existing spectrum-licensed receivers is detailed in the draft RAG in Annex K.

### Space science service receivers

Space research, space operations and earth exploration-satellite service receivers operate at specific locations in the 2200-2300 MHz. Existing services operating in the 2200-2300 MHz band are provided in Table 33. Coordinates are provided in AGD66.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Bands** | **Location** | **ACMA Site #** | **Latitude** | **Longitude** |
| 2200-2290 MHz  2290-2300 MHz | Tidbinbilla (ACT) | 11552 | ‑35.404056 | 148.980175 |
| 2200-2290 MHz  2290-2300 MHz | New Norcia (WA) | 131922 | -31.04945 | 116.190053 |
| 2200-2290 MHz | Mingenew (WA) | 132024 | -29.046989 | 115.347197 |
| 2200-2290 MHz  2290-2300 MHz | Landsdale (WA) | 26582  132429 | -31.803714  -31.809624 | 115.883677  115.886197 |
| 2200-2290 MHz | Mawson Lakes (SA) | 131796 | -34.814346 | 138.619196 |
| 2200-2290 MHz | Cambridge (TAS) | 140545 | -42.807074 | 147.436749 |
| 2200-2290 MHz | Battery Point (TAS) | 32799 | -42.888636 | 147.337514 |
| 2200-2290 MHz | Alice Springs (NT) | 50214 | -23.758483 | 133.881553 |

Table : Location of space facilities operating in 2200-2300 MHz located in Australia[[43]](#footnote-44)

Licensees are required to take note, protect and coordinate with these Earth stations in accordance with a number of ITU-R Reports, Recommendations and the requirements of the Radio Regulations (Appendix 7). The ACMA encourages direct liaison between spectrum licensees and Earth station operators during the system planning phase.

Further guidance on the protection and coordination requirements for space service receivers are set out in the following recommendations:

* ITU-R Recommendation SA.1154 – Provisions to protect the space research, space operations and Earth Exploration Satellite Services and to facilitate sharing with the mobile service in the 2025-2110 MHz and 2200-2290 MHz bands.
* ITU-R Recommendation SA.363 – Space operation system frequencies, bandwidths and protection criteria.
* ITU-R Recommendation SA.609 – Protection criteria for radio communication links for manned and unmanned near Earth research satellites.
* ITU-R Recommendation SA.1157 – Protection criteria for deep space research
* ITU-R Recommendation SA.509 – Space research earth station and radio astronomy reference antenna radiation patterns for use in interference calculations, including coordination procedures.
* ITU-R Recommendation SA.1014 – Telecommunications requirements for manned and unmanned deep space research.
* ITU-R Recommendation SA.1016 – Sharing considerations relating to Deep Space Research.
* ITU-R Recommendation SA.1743 – Maximum allowable degradation to radiocommunications links of the space research and space operation services arising from interference from emissions and radiations from other radio sources.

Licensees and space service receiver operators are asked to confirm if the list of Recommendations is complete.

The space research (deep space) (space-to-Earth) service in the band 2290-2300 MHz is to be provided additional blocking protection beyond the requirements of Annex 7 of Appendix 7 of the Radio Regulations. These systems receive time-critical communications from spacecraft located out to many billions of kilometres from Earth. The ACMA has developed a new Radiocommunications Assignment and Licensing Instructions (RALI) with coordination requirements and procedures for the protection of the New Norcia and Mingenew facilities. The RALI includes in-band coordination requirements addressing the impact of noise within the 2290-2300 MHz band directly and based on Annex 7 of Appendix 7 of the Radio Regulations. Out-of-band interference into the LNA is also addressed in the out-of-band coordination requirements of the RALI. The draft is included at Annex A.

Embargo 49[[44]](#footnote-45) restricts the assignment of new apparatus licensed terrestrial radiocommunications services within 300 kilometres of the Mingenew facility in the 2280-2310 MHz band. This embargo does not apply to current and future spectrum licensed devices as an embargo cannot prevent the registration of devices unless referenced appropriately as a licence condition. In order to provide additional protection to the Mingenew facility from spectrum-licensed transmitters, in line with the protection required at the sites in Table 19, the ACMA will include the Mingenew facility in the proposed new RALI. This is with a view to promoting the deployment of future space research facilities in the area.

Additional protection will not be provided to the facility at Landsdale as it will be non-operational from 31 December 2015.

Protection from out-of-band interference into LNA’s operating at the Canberra Deep Space Communications Complex (CDSCC) is already in place with the implementation of frequency and geographic area guard bands as a result of non-conversion or sale of spectrum licences in the 2302-2330 MHz band in the area shown in Figure 17.

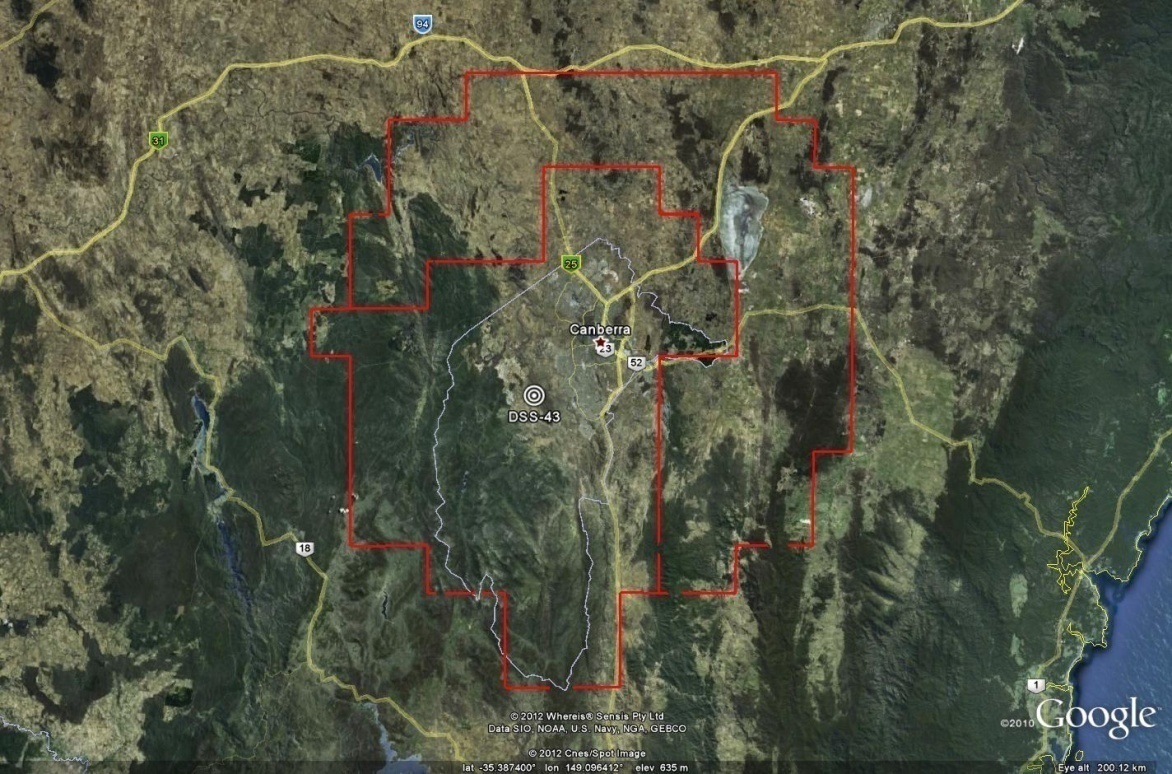


Figure 17: CDSCC guard band[[45]](#footnote-46)

The ACMA is currently working with the CSIRO to ensure that the guard band implemented and changes to the technical framework are appropriate to continue to provide the necessary protection of the facility for the next spectrum licensing period. Coordination requirements for protection of the CDSCC may be included in the proposed new RALI at a later date. For now, the frequency and geographic guard bands will continue to serve to protect the CDSCC from adjacent-band interference from spectrum-licensed transmitters.

The ACMA proposes to develop a new RALI specify additional coordination requirements and procedures to protect space research (deep space) facilities operating in the 2290-2300 MHz band. At this stage specific details for coordination will be included for services at New Norcia and a notional location at Mingenew. Licensees and space facility operators are asked to revise the proposed coordination requirements and procedures outlined in Annex A.

### Radio astronomy service receivers

The radio astronomy service (RAS) conducts passive observations in a number of frequency bands identified by the AUS87[[46]](#footnote-47) footnote in the ARSP. Due to the nature of observing passive signals, spectrum licensees are requested to have regard to RAS receivers operating on frequencies in and adjacent to the 2.3 GHz spectrum licensed band.

RAS facilities and frequency bands where licensees are requested to have regard are identified by the AUS87 footnote in the ARSP. The ACMA encourages direct liaison between spectrum licensees with RAS operators during the system planning phase to minimise the potential for interference. Spectrum licensees are requested to follow the notification arrangements in *RALI MS31 – Notification zones for apparatus licensed services around radio astronomy facilities[[47]](#footnote-48)*.

### Fixed service receivers

Fixed services operate below 2300 MHz in accordance with the frequency assignment criteria set out in *RALI FX03 –* *Microwave fixed services frequency coordination*[[48]](#footnote-49). The channel plan and guidance on interference criteria and frequency coordination to achieve a certain performance objective are contained in the RALI.

Apparatus licensed fixed service receivers are to be provided with out-of-band and in-band protection in accordance with RALI FX03. This coordination is performed on a first-in-time basis.

RALI FX03 is subject to continuous review and licensees are urged to consult the current version when planning systems in the 2.3 GHz band.

### Mobile service receivers

The 2200-2300 MHz band supports the operation of mobile services; in particular, the band is used for aeronautical mobile telemetry (AMT) in the band 2200-2290 MHz at specific locations provided in footnote 81. These stations are operated by the Department of Defence.

Refer to Annex G for analysis of the impact 2.3 GHz spectrum licensed transmitters will have on AMT receivers operating in the 2200-2290 MHz band.

The ACMA do not propose to include any specific coordination requirements in the RAG, except that where interference is caused to AMT receivers in the 2200-2290 MHz band, that unless the 2.3 GHz device meets all licence conditions, including the core conditions of the licence, they may be deemed to cause unacceptable interference.

### Television outside broadcast (TOB) service receivers

The *Television Outside Broadcast Service (1980–2110 MHz and 2170–2300 MHz) Frequency Band Plan 2012* supports the introduction of television outside broadcast services in the bands 1980-2110 MHz and 2170-2300 MHz.

The development of the framework has already proposed that non-spurious emissions below 2295 MHz do not exceed -30 dBm per 1 MHz to offer protection to TOB service receivers in that band. This additional emission limit can only be applied to registered transmitters, as the nature of manufacturing for user terminals does not often allow additional filtering to be installed.

This protection is being offered to TOB because deployment of TOB in the 2295-2300 MHz band will be restricted to low powered devices in order to provide protection to 2.3 GHz receivers as well as TOB receivers accepting any interference from devices meeting the technical framework of the 2.3 GHz band.

The detailed coordination requirements between TOB receivers and 2.3 GHz spectrum licensed transmitters are being conducted in the development of the appropriate RALI that will define TOB use of the band 2200-2300 MHz.

As a result, the procedure for coordination between 2.3 GHz spectrum licensed transmitters and TOB will not be detailed in the RAG; rather, the RAG will point to the RALI which contains the coordination requirements. Implementation in the RAG is provided in Annex K.

Spectrum licensees are encouraged to participate in the development of the RALI and ensure that the coordination requirements are acceptable to their deployment.

### Class licensed receivers

In the band 2400-2483.5 MHz, the LIPD Class Licence permits the operation of a number of different classes of transmitter. Most notably, the operation of Wi-Fi and Bluetooth devices in this band is authorised.

The operation of devices under the LIPD Class Licence are typically on a no-interference, no-protection basis and because of their ubiquitous nature, make developing coordination requirements problematic. Despite this, the ACMA has given consideration to the potential for interference to be caused to class licensed receivers operating above the 2400 MHz boundary in Annex B.

The potential for interference from the existing and planned systems in the 2.3 GHz band may cause interference on an intermittent basis to class licensed devices operating above the 2400 MHz boundary; in particular, devices that incorporate Wi-Fi, Bluetooth and 2.3 GHz services.

Devices operating under a spectrum license that meet the requirements of the determination of unacceptable interference and the core conditions of the licence will be deemed to not cause unacceptable interference into devices operating under a class licence.

# Annex A

## Protection of SPACE OPERATIONS and SPACE RESEARCH allocations in 2200-2300 MHz

See RALI MS 37 – *Coordination of spectrum-licensed devices operating in the 2.3 GHz band with SRS Earth Stations in the 2290–2300 MHz Band*.

# Annex B

## Interference analysis above 2400 MHz

The aim of this study is to determine the impact (if any) on these systems from the deployment of spectrum licensed services in the 2.3 GHz band, in particular those given in the system models.

### Bluetooth

Bluetooth (BT) devices operate in the 2.4 GHz ISM band using a frequency hopping transceiver in order to combat interference and fading. Two modulation modes are defined – a mandatory mode called the *basic rate* and on optional mode called *enhanced data rate*. For full duplex transmission, a TDD scheme is used in both modes.

#### System characteristics

System characteristics for BT are available in Bluetooth Core Package 4.0 dated 30 June 2010[[49]](#footnote-50) and the parameters necessary for this study are provided in Table 34.

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Value** | |
| Operating range | 2400-2483.5 MHz | |
| Carrier frequency |  | |
| Bandwidth | 1 MHz | |
| Transmitter Power | PC1 | 20 dBm (100 mW) |
| PC2 | 4 dBm (2.5 mW) |
| PC3 | 0 dBm (1 mW) |
| Antenna gain | 0 dBi | |
| Reference sensitivity | -70 dBm | |

Table : Bluetooth system characteristics

#### Impact of Bluetooth to 2.3 GHz spectrum licensed devices

The maximum mean input power received at the UE antenna port for a 2.3 GHz device at which the specified throughput requirement is met shall not exceed -25 dBm for LTE[[50]](#footnote-51). If the 2.3 GHz receiver and BT transmitter are collocated[[51]](#footnote-52), the BT transmitter is operating at 20 dBm (band class PC1) and assuming an antenna coupling loss of 10 dB (this could be as high as 15 dB but is dependent on the configuration within the phone), means the input signal at the LNA of the UE would be 10 dBm.

An additional 35 dB of coupling loss is required to not saturate the 2.3 GHz receiver frontend. ECC Report 172 §6.1.2[[52]](#footnote-53) provides a typical filter implementation for BT as well as proposed filtering for 2.3 GHz devices. In both cases, neither additional filtering or the in-band and out-of-band blocking of the 2.3 GHz receiver are sufficient to prevent operations in the upper 20 MHz of the 2.3 GHz band being prone to interference from collocated BT transmitters operating in the 2400-2420 MHz band.

A Bluetooth Special Interest Group report on *Filter recommendations for coexistence with LTE and WiMAX**[[53]](#footnote-54)* notes that for coexistence within the same device that a guard band between the 2.3 GHz band and ISM band of 20 MHz is required anywhere between 2380 MHz and 2420 MHz. A guard band between 2380 and 2400 MHz is not possible in the Australian context because the 2.3 GHz band is allocated in this 2380-2400 MHz band, and does not represent efficient spectrum allocation where BT is only likely to cause interference in specific cases.

A number of mitigation methods are available for collocated devices.

The BT standard includes a function known as adaptive frequency hopping (AFH) and is used to improve the performance of physical links in the presence of interference as well as reducing the interference caused by physical links on other devices in the ISM band. Backward compatibility cannot be ensured as this feature is only supported in devices that meet the Bluetooth V1.2 standard and greater.

If the operator is experiencing collocated interference caused by BT, then if sufficient spectrum is available, they could avoid the use of the upper 20 MHz given the roll-off characteristics of both systems. This isn’t often practical given antenna sectoring and the frequency reuse arrangements of the deployment area.

If the 2.3 GHz receiver and BT transmitter are not collocated, the need for a guard band depends primarily on the distance between the devices that need to be supported. The minimum coupling loss between a BT transmitter operating at 20 dBm into a 2.3 GHz receiver with a notional receiver blocking requirement of -15 dBm is:



If we assume that the free-space propagation model applies, 35dB of propagation loss at 2400 MHz equates to a separation distance of:



#### Impact of 2.3 GHz spectrum licensed devices to Bluetooth

The BT standard specifies a reference sensitivity of -70 dBm (refer to Table 34), but other reports noting real-world implementations state a reference sensitivity of ‑90 dBm for a desensitisation of 3 dB.

Figure 4, of the document referenced by footnote 58, shows BT receiver noise degradation as a function of the interference level present at the LNA. The automatic gain control (AGC) of the system compensates the front end gain of the system to prevent overload, meaning that saturation of the receiver occurs for higher interference levels.

If we assume the system can tolerate a degradation of 20 dB, the tolerated LNA input interference level is approximately -6 dBm. Assuming antenna coupling loss of 10 dB (as was done in section 7.1.1.2), means the maximum tolerated LTE transmit power at its output antenna is 4 dBm. This is some 19 dB below the maximum output power of the system models, but some 39 dB below that proposed as the maximum registration exempt requirement.

It is assumed that devices that meet and are operated under the maximum registration exempt requirement will not have collocated 2.3 GHz and BT transmitters; however, the reduction in output power of 19 dB of 2.3 GHz spectrum licensed transmitters is not useful.

The above scenario assumes that the 2.3 GHz transmitters are co-channel with BT; however, there is at least 2 MHz of frequency separation and hence the interference at 2402 MHz and greater will be the outside the band emission limits of section 3.4. For offsets greater than 1.5 MHz and less than 5 MHz, the outside the band emission limit is -13 dBm per 1 MHz.

The tolerated interference level found above was -6 dBm for a degradation of 20 dB, therefore an emission of -13 dBm plus 10 dB of antenna coupling loss results in a received interfering signal level of -23 dBm which causes degradation in the system of less than 5 dB.

As a result, if transmitter and receiver are not collocated within the same device, additional propagation mechanisms will be sufficient to mitigate the potential for interference between 2.3 GHz transmitters and BT receivers.

#### Conclusions

The analysis presented in sections 7.1.1.2 and 7.1.1.3 shows that some mitigation may be required to ensure interference into either system does not cause a significant degradation in operating performance.

In the non collocated case, a separation distance greater than 0.50 m satisfies the receiver input requirements of both services and hence interference is unlikely to be caused.

The potential for interference from BT transmitters into 2.3 GHz receivers in collocated devices is possible, especially at the 2400 MHz band edge. It is anticipated that device manufacturers are aware of this issue and hence will implement appropriate mitigation technique (including AFH as discussed) to prevent interference into 2.3 GHz receivers operating at the 2400 MHz band edge.

The potential for interference from 2.3 GHz transmitters into BT receivers is minimal if the maximum transmit powers of the 2.3 GHz transmitter are not used, and if directional antennas are not incorporated in the device. Additional antenna coupling loss in devices may also improve the ability of BT receivers to reject high power emissions from 2.3 GHz transmitters.

As a result of the analysis conducted in this section, it is not proposed to implement any additional licence conditions on 2.3 GHz spectrum licensees. With respect to coordination requirements in the RAG, it is difficult to specify any additional requirements to BT systems operating above 2400 MHz given the density of device deployment already in place and the licensing nature of the band. Importantly, the evolution of the BT standard (now at version 4) to include AFH (implemented as of version 1.2) has meant that the likelihood of causing interference to compatible BT devices is small, and if both bands are collocated within the same device, the management of interference to 2.3 GHz receivers should be possible at the implementation phase by the manufacturer.

### Wireless Local Area Network (WLAN)

The two primary WLAN systems that operate in the 2.4 GHz ISM band are IEEE Standards 802.11g (11g) and 802.11n (11n). The 802.11 series of standards are continually evolving (support and devices still exist for 802.11b) and devices in the band can also be paired with the 5 GHz ISM band in the 802.11n and 802.11ac standards.

#### System characteristics

System characteristics for 11g are available in IEEE 802.11g-2003[[54]](#footnote-55) or IEEE 802.11g-2007 and for 11n are available in IEEE 802.11n-2009. The parameters necessary for this study are provided in Table 35.

|  |  |  |
| --- | --- | --- |
| **Parameter** | **11g** | **11n** |
| Operating range | 2400-2483.5 MHz | 2400-2483.5 MHz |
| Carrier frequency (20 MHz channel) |  |  |
| Carrier frequency (40 MHz channel) | - |  |
| Channel bandwidth | 20 MHz | 20 MHz or 40 MHz |
| Occupied bandwidth | 16.6 MHz | 18 MHz or 38 MHz |
| Transmitter Power[[55]](#footnote-56) | 10 mW (EIRP) | 10 mW (EIRP) |
| Antenna gain | 0 dBi | 0 dBi |
| NF | 10 | 10 |
| N | -91.77 dBm | -94 |
| C/I objective | 10 dB | 10 dB |
| Reference sensitivity | -70 dBm | -77 dBm[[56]](#footnote-57) |
| Transmitter mask  (20 MHz spacing) | Refer to Annex I 2.3 in IEEE 802.11g-2007  refer to Table 36 | |
| Receiver mask | Refer to Table 20-22 in IEE 802.11n-2009  refer to Table 37 | |

Table : WLAN system characteristics

|  |  |
| --- | --- |
| **Frequency**  **offset range** | **dBc** |
| 0 Hz ≤ foffset < 9 MHz | 0 |
| 9 MHz ≤ foffset < 11 MHz | -20 |
| 11 MHz ≤ foffset < 20 MHz | -28 |
| 20 MHz ≤ foffset < 30 MHz | -40 |
| foffset > 30 MHz | -40 |

Table : WLAN transmit mask

|  |  |
| --- | --- |
| **Frequency**  **offset range** | **dBc** |
| 0 Hz ≤ foffset < 20 MHz | -11 |
| 20 MHz ≤ foffset < 40 MHz | -27 |

Table : WLAN receiver mask

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Value** | **Unit** |
| BS coordinates | -35.2492, 149.1345 | GDA94 |
| Maximum BS transmitter power | 13  43 | dBW  dBm per 5 MHz |
| BS antenna gain (incl. feeder loss) | 17 | dBi |
| BS dynamic range | 5 MHz: 13.9  10 MHz: 16.9  20 MHz: 20 | dB  dB  dB |
| BS height | 35 | m |
| BS transmitter mask | Refer to Table 10 and Table 15 |  |
| Maximum UE transmitter power | -7 | dBW |
| UE dynamic range | 63 | dB |
| UE height | 1.5 | m |
| BS-UE separation | 0-2 | km |
| Minimum receiver level | -125.5  -122.5  -119.5 | dBW per 5 MHz  dBW per 10 MHz  dBW per 20 MHz |
| C/I requirement | 6 | dB |
| I/N requirement | -6 | dB |
| Propagation model | ITU-R P.526  ITU-R P.525 |  |
| Wall loss | 8 | dB |
| WLAN location wrt BS | 0-2 | km |
| WLAN Frequency | C1: 2412  C5: 2432 | MHz  MHz |
| Terrain | SRTM 3 second |  |
| Samples | 50000 |  |

Table : Parameters considered in analysis

#### Impact of WLAN to 2.3 GHz spectrum licensed devices

The following analysis considers interference from 20 WLAN devices deployed within 5 kilometres of a base station which is connected to six user devices over the same deployment area. This analysis simulates the interference into the user devices and the base stations in the top 20 MHz (2380-2400 MHz) caused by the WLAN devices.

The WLAN devices are shifting in frequency between the four operating channels for a 20 MHZ bandwidth (2.412, 2.432, 2.452, 2.472 MHz). Results are taken over 50000 samples, with the BS at 30 metres and the UE and Wi-Fi transmitter at 1.5 metres.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | All channels | | 2412 MHz  C1 | 2432 MHz  C5 | 2452 MHz  C9 | 2472 MHz  C13 |
| Scenario | Direct | C/I | I/N | C/I | C/I | C/I | C/I |
| UE1 | DL | 1.01% | 0.68% | 2.19% | 0.67% | 0.67% | 0.67% |
| UL | 13.48% | 21.98% | 29.28% | 8.21% | 8.17% | 8.17% |
| UE2 | DL | 1.09% | 0.77% | 2.23% | 0.68% | 0.68% | 0.68% |
| UL | 13.79% | 21.88% | 29.74% | 8.52% | 8.48% | 8.48% |
| UE3 | DL | 1.11% | 0.78% | 2.30% | 0.69% | 0.68% | 0.68% |
| UL | 13.81% | 21.75% | 26.60% | 8.45% | 8.42% | 8.42% |
| UE4 | DL | 1.08% | 0.67% | 2.20% | 0.70% | 0.69% | 0.69% |
| UL | 13.37% | 21.82% | 29.15% | 8.18% | 8.13% | 8.13% |
| UE5 | DL | 1.19% | 0.73% | 2.37% | 0.78% | 0.78% | 0.78% |
| UL | 13.45% | 22.02% | 29.51% | 8.40% | 8.36% | 8.36% |
| UE6 | DL | 1.10% | 0.75% | 2.28% | 0.71% | 0.71% | 0.71% |
| UL | 13.74% | 22.1% | 29.86% | 8.36% | 8.32% | 8.32% |

Table : Probability of interference from WLAN

The results in Table 39 show that the dominant candidate for interference is the base station (UL), primarily because of the additional gain and antenna height against the mobile units. There is also no consideration of wall loss in this scenario to take account of terminals operating outdoors.

Analysis is done for single channel interference, and for all channel interference. Intuitively, as the separation between the 2400 MHz band edge and centre frequency of the Wi-Fi transmitters is increased, the probability the C/I requirement is exceeded reduces. Channels 9 and 13 have identical interference probabilities because the frequency dependent rejection advantage is the same in both cases.

Figure 18 shows that the area surrounding a WLAN terminal that could cause interference into a user terminal is restricted to the immediate area around the WLAN terminal. Therefore, when a user terminal is co-located, the potential for interference exists; however, in an outdoor environment with potentially an additional 8 dB of separation loss (to account for the building loss) the interference potential is even further reduced.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | >-6 dB |  | -8 dB |  | -10 dB |

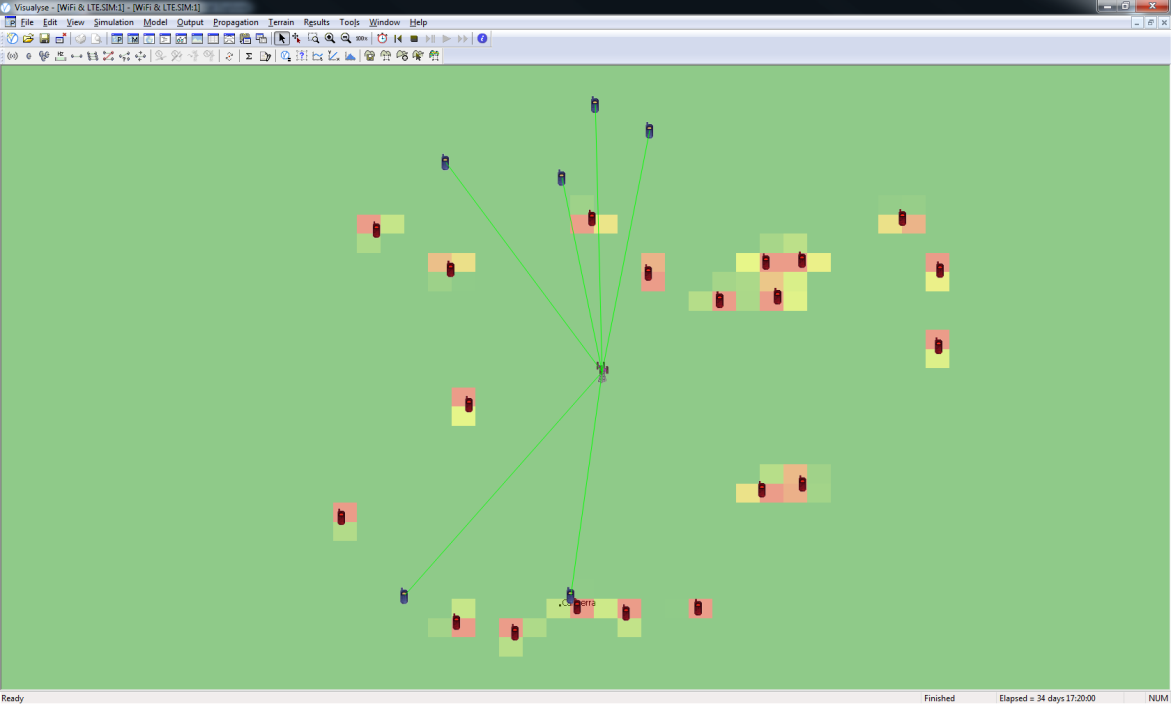


Figure : Area[[57]](#footnote-58) surrounding a WLAN terminal where I/N criteria exceeded

The blocking requirement of the receiver (85 dB in the case of the notional receiver) offers the greatest mitigation against interference caused by WLAN devices.

#### Impact of 2.3 GHz spectrum licensed devices to WLAN

The following analysis considers interference from equipment operating in the 2380-2400 MHz band into 802.11 devices operating on the first (2412 MHz) and fifth channel (2432 MHz). Parameters for the analysis are provided in Table 38 and the results are presented in Table 40 based on the interference from a base station and six user terminals randomly placed within the environment tested.

Based on the system parameters in Table 38, the anticipated coverage of the base station is shown in Figure 19. The coloured overlay details the required transmitter power of the user terminal such that a link satisfies the C/N requirement of the system. In this case, the C/N requirement of the system is 2.5 dB. If a user terminal transmitter power of greater than 23 dBm (the maximum EIRP of the user terminal) is required for communications with the base station, then no coverage can be expected in this region.

If the registration exempt requirement is utilised, whereby antennas must be below 10 metres AGL and the maximum EIRP of the user terminal is 43 dBm, then the coverage is increased and shown in Figure 20 such that a link satisfies the C/N requirement of the system. In this case, the C/N requirement of the system is 2.5 dB.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | >23 dBm |  | 15 dBm |  | 0 dBm |

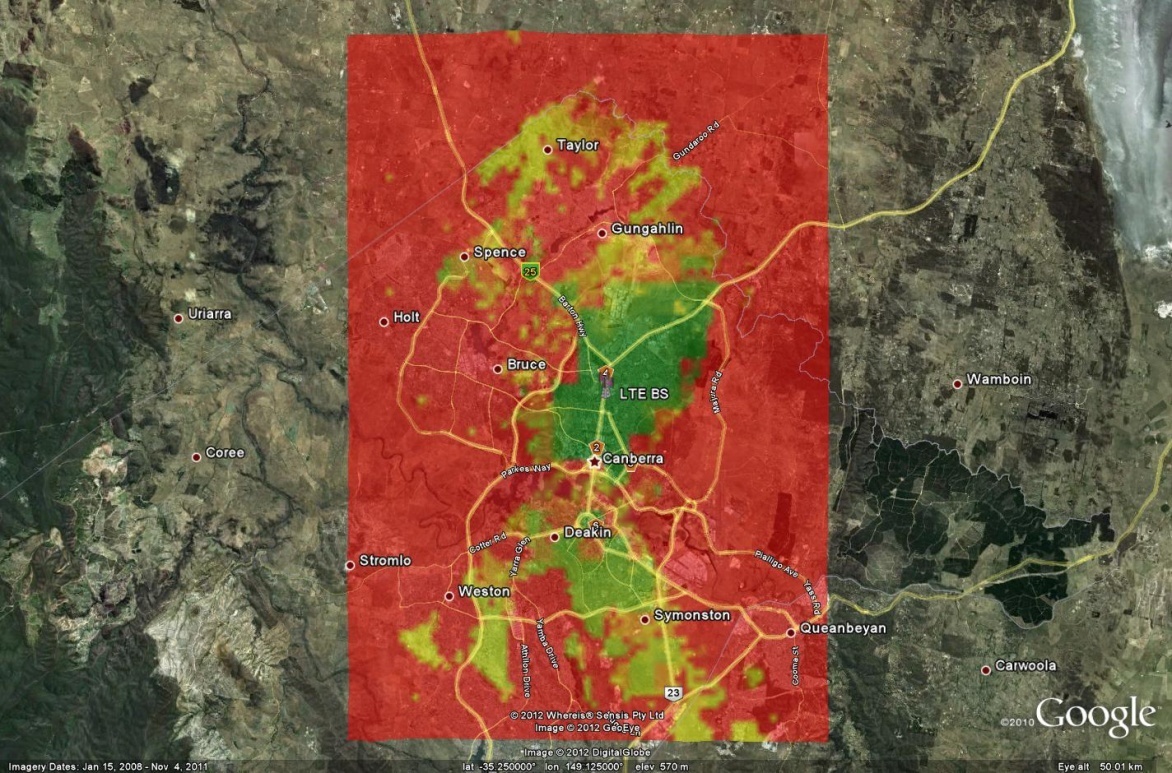
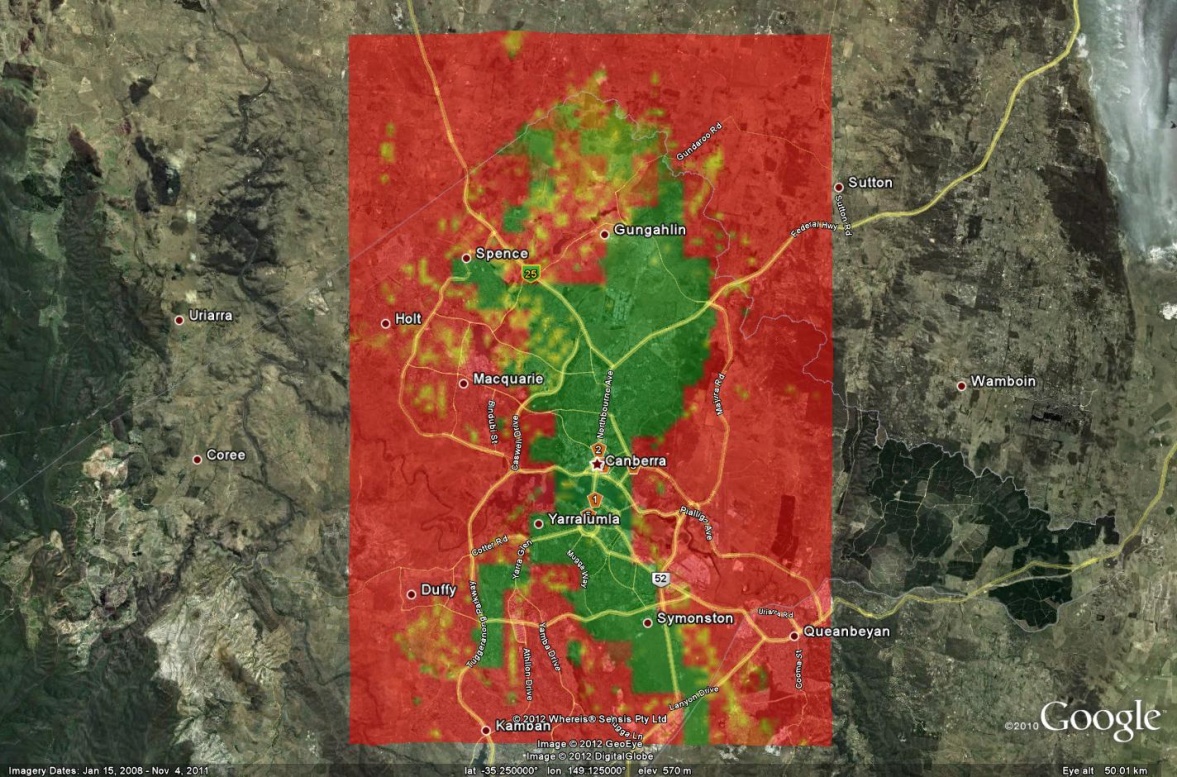
 

Figure : BS coverage (UE - 0 dBi) Figure : BS coverage (UE - 17 dBi)

The base station coverage is reduced significantly when an additional loss of 8dB is considered for UE located indoors. This is shown in Figure 21.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | >23 dBm |  | 15 dBm |  | 0 dBm |

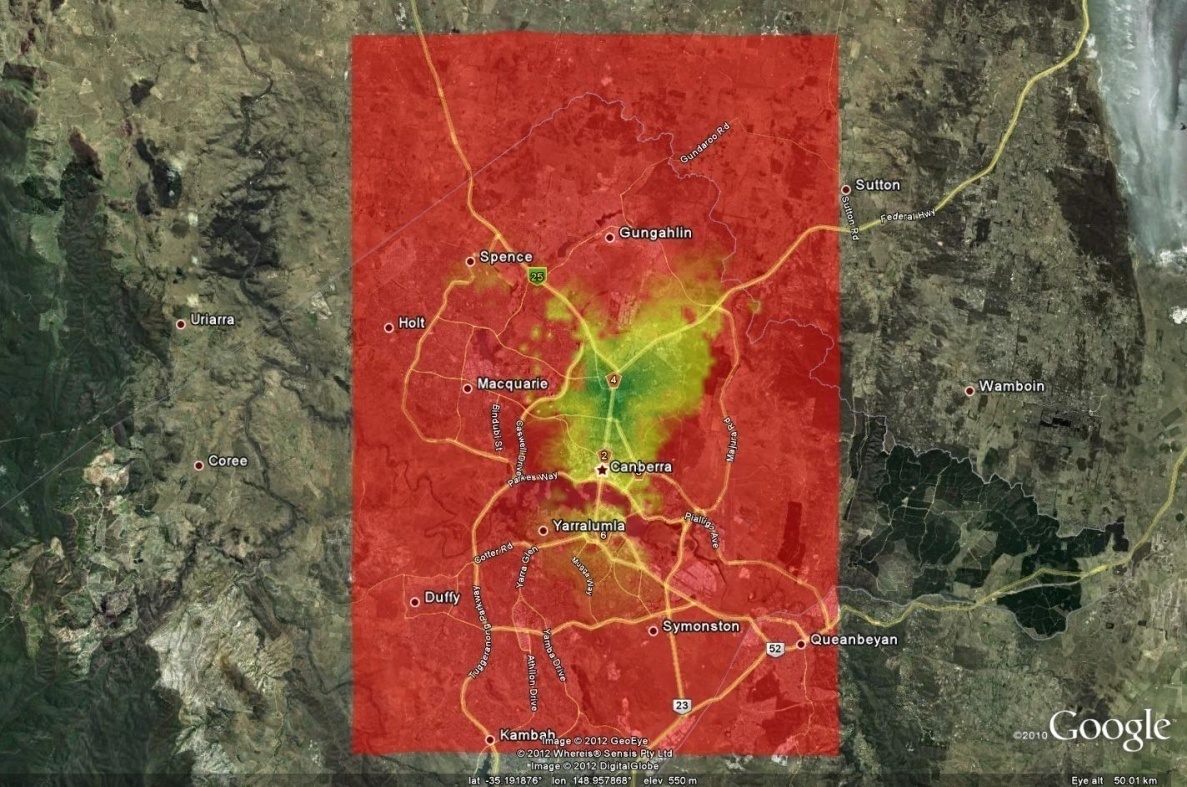


Figure : BS coverage (UE – 0 dBi, 8 dB wall loss)

When the LTE bandwidth in Table 40 is less than 20 MHz, the centre frequency is randomised such that the bandwidth is somewhere within the 2380-2400 MHz range. This in some way simulates the difference in a sectored base station that does not use one-to-one frequency reuse.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **WLAN AP location** | **WLAN AP height** | **LTE BW** | **Centre frequency** | **Interference Probability Channel 1 2412 MHz** | **Interference Probability Channel 5 2432 MHz** |
| Outdoor | 10 m | 5 MHz | 2382.5 - 2397.5 MHz | 99.00% | 39.56% |
| Outdoor | 10 m | 10 MHz | 2385 – 2395 MHz | 96.15% | 20.61% |
| Outdoor | 10 m | 20 MHz | 2390 MHz | 93.41% | 9.14% |
| Outdoor | 10 m | 5 MHz | 2382.5 - 2387.5 MHz | 98.77% | 37.77% |
| Outdoor | 10 m | 10 MHz | 2385 MHz | 95.53% | 16.85% |
| Outdoor | 10 m | 20 MHz | 2380 MHz | 83.07% | 4.05% |
| Indoor | 1.5 m | 5 MHz | 2382.5 - 2397.5 MHz | 90.00% | 6.31% |
| Indoor | 1.5 m | 10 MHz | 2385 – 2395 MHz | 76.44% | 3.07% |
| Indoor | 1.5 m | 20 MHz | 2390 MHz | 52.54% | 1.37% |
| Indoor | 1.5 m | 5 MHz | 2382.5 - 2387.5 MHz | 89.2% | 6.03% |
| Indoor | 1.5 m | 10 MHz | 2385 MHz | 70.84 | 2.54% |
| Indoor | 1.5 m | 20 MHz | 2380 MHz | 27.07% | 0.53% |

Table : Interference from BS to WLAN AP

If we consider the interference from the base station only communicating with a number of user terminals (maximum BS-UE separation 5 km) at operating powers within its dynamic range (to ensure a minimum received signal power of -119.5 dBW, with the WLAN terminals randomly placed within 5 kilometres of the base station we get the results in Figure 22.

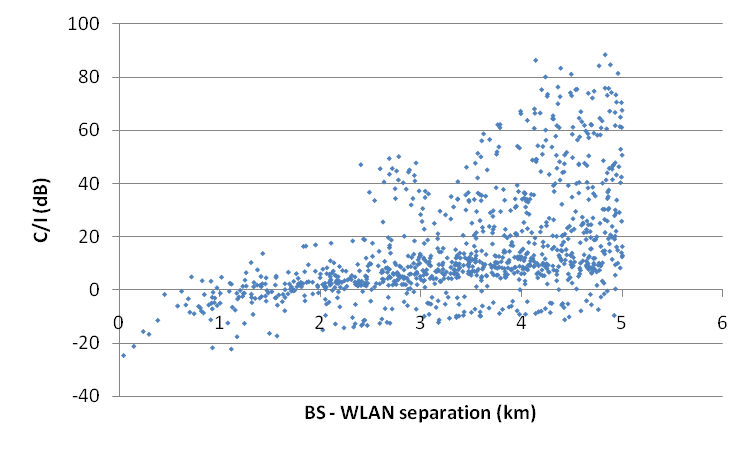


Figure : Plot of BS-WLAN distance vs C/I from interference by BS

Figure 22 shows the relationship between the separation of the BS and WLAN terminal in the first channel (2412 MHz) for interference caused by the base station based on a C/I requirement of 10 dB.

Interestingly, interference from the UE to the WLAN terminal in the first channel (2412 MHz) is more prevalent as the distance separation increases, this is because the UE has a much broader dynamic range than the base station and is required to increase its transmitter power in order to maintain the link. The results based on a WLAN C/I requirement of 10 dB are shown in Figure 23.

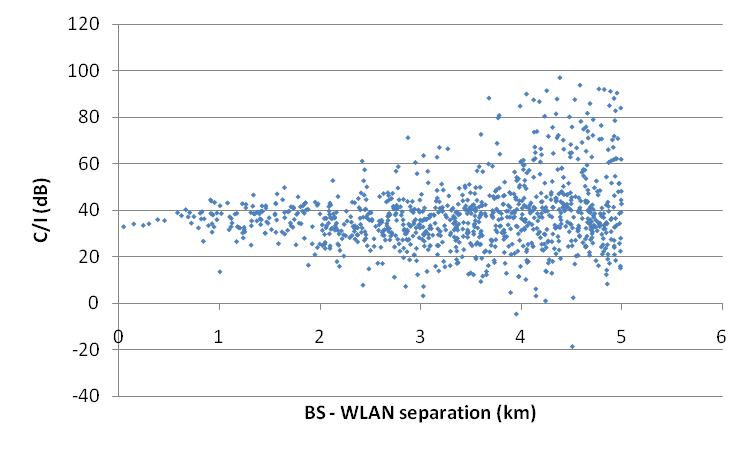


Figure : Plot of BS-WLAN distance vs C/I from interference by UE

The results in this section show that the potential for interference from 2.3 GHz transmitters into the first 20 MHz channel in the 802.11 family of systems is quite high for both the indoor and outdoor environments. The ability to offload data intensive applications to the 2.4 GHz band is becoming quite prominent, with a number of systems being installed in major public places such as train stations and parks in the metropolitan areas. It is these systems which are most likely to be interfered with at the minimum sensitivity of -70 dBm.

The major interference case comes from the BS given its higher transmitter EIRP compared with the UE, and the fact that the dynamic range of the BS is limited when compared with the UE. This is primarily because of the differing data requirements in the DL and UL.

Interference into the second channel (2432 MHz) shows the probability of interference is much lower, with wider channels offering additional protection. Once devices operating on the second channel move indoors, the probability of interference never exceeds 10%.

#### Conclusions

This study in section 7.1.2 shows that there is the potential for interference both too and from WLAN and 2.3 GHz devices depending on the deployment and operating scenarios considered.

The results in Table 39 show that there exists a potential for WLAN devices to cause ongoing interference to 2.3 GHz receivers, though making a change in WLAN channel is suitable to mitigate the interference. Of course, this requires user intervention in their router setup which may not necessarily be practical.

Whilst the potential for interference approaches 30% in the uplink scenario (interference to the base station), consideration of additional loss mechanisms beyond diffraction, including clutter and wall loss were not considered. It is likely that this will improve the interference scenario, along with, increasing the system minimum receiver sensitivity to support higher data rates which are likely in the operation of a 2.3 GHz system. The interference scenario in section 7.1.2.2 was based on a WLAN system using the maximum operating transmitter power, though it is believed that some power control exists in most WLAN access points on the market.

Given the deployment density of 2.4 GHz Wi-Fi in the Australian market, it is unlikely that all interference sources can be managed by the licensee. The ACMA would recommend that if licensees are deploying their own equipment, that they restrict WLAN operation in that device to use channels greater than channel 5. By shifting operation from channel 1 to channel 5, the probability of interference reduces from 30% to about 9% in the uplink.

Interference into WLAN devices from 2.3 GHz transmitters, in particular the base stations, is very problematic in the first channel, but reduces significantly for channel five when the WLAN receiver is located outdoors and at 10 metres antenna height. Once the device is located indoors, the additional attenuation caused by wall loss means that interference on the first channel reduces by a minimum of 9 points (to 90 %) to a maximum reduction of 56 points (to 27%).

The greatest reduction comes when additional frequency separation of the channel edge is included. The study in Table 40 shows that when the band 2390-2400 MHz is not utilised (a guard band of 10 MHz is used), that interference, particularly into channel 5 decreases to less than 1% in the case of use of 20 MHz channels.

The ACMA is aware that issues exist at the 2400 MHz boundary, but note that licensees should also be aware of the issues and design their systems appropriately. A number of 2.3 GHz licensees already have devices operating in the 2380-2400 MHz band, and the ACMA has not been made aware of specific instances of interference.

# Annex

## Current use

In Australia, the 2.3 GHz spectrum licence covers the frequency range 2302-2400 MHz Australia-wide and is currently[[58]](#footnote-59) allocated to eight licensees plus a single area allocation to Defence. The eight licensees include:

|  |  |
| --- | --- |
| * Vividwireless (as BKAL Pty Ltd) | * NBN Co |
| * DB Sawtell | * Newcrest Mining Limited |
| * Ausgrid (as Energy Australia) | * Optus (as Optus Vision Investments Pty Ltd) |
| * Metropolitan Fire | * Telstra Corporation Limited |

A number of licensees have significant deployments in a number of geographic areas, but for the most part, device registrations in the 2.3 GHz band dwarf those in other spectrum licensed bands. There are currently 1916 devices registrations and the share of those device registrations is shown in .

|  |  |
| --- | --- |
| Licensee | Total device registrations |
| Ausgrid (as Energy Australia) | 233 |
| DB Sawtell | 60 |
| Metropolitan Fire | 2 |
| NBN Co | 842 |
| Newcrest Mining Limited | 20 |
| Optus (as Optus Vision  Investments Pty Ltd) | 10 |
| Telstra Corporation Limited | 2 |
| Vividwireless (as BKAL Pty Ltd) | 747 |

Table : Share of device registrations in 2.3 GHz

Only the following areas (Figure 24) contain device registrations, showing that use in the 2.3 GHz band is primarily constrained to major metropolitan areas. It should be noted that the 2302-2330 MHz band in Canberra has not been sold for spectrum licensing. This has been done to protect deep space receivers operating at Tidbinbilla based on the emissions of MDS transmitters.

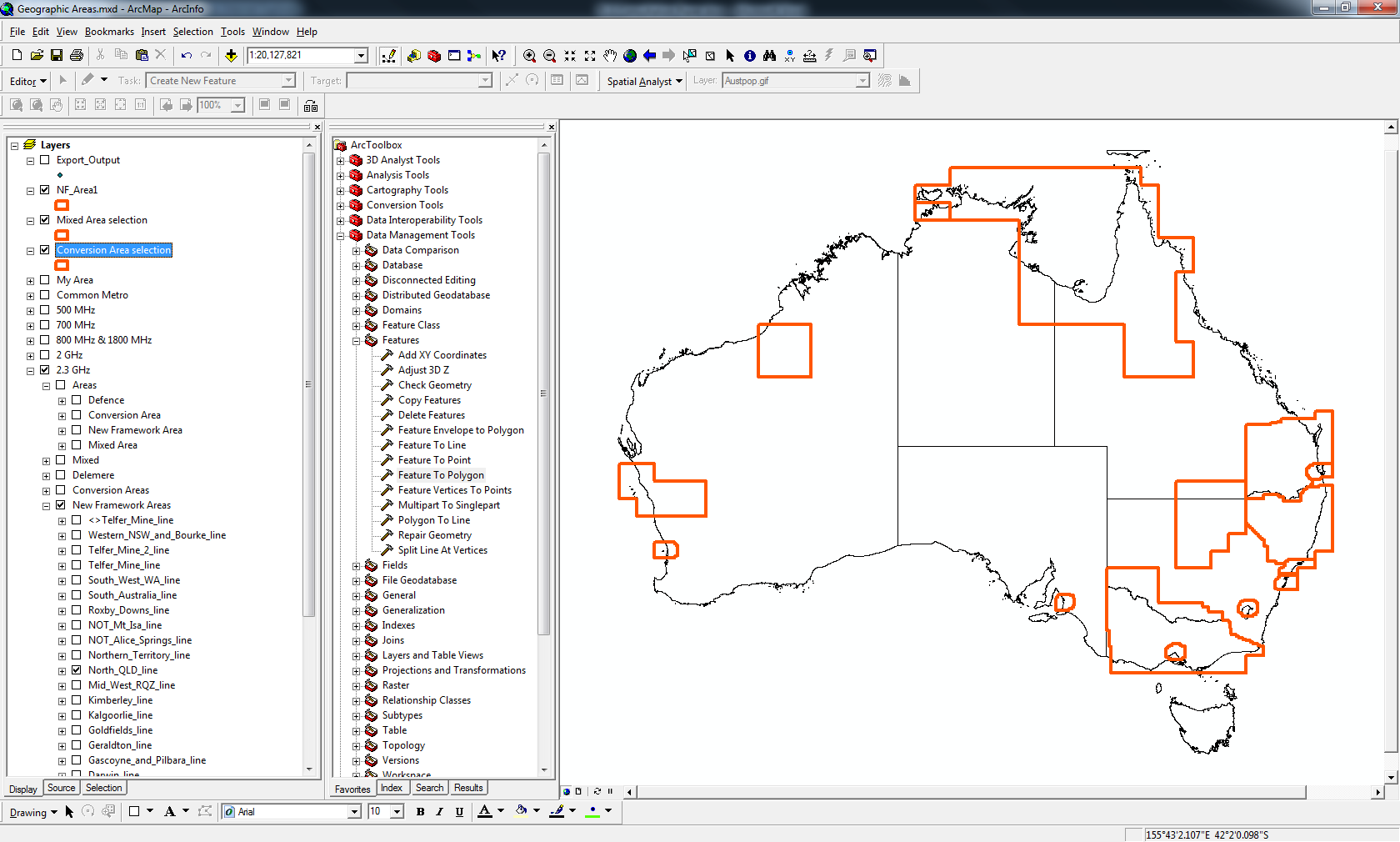


Figure : Areas containing device registrations

# Annex

## Analysis of international use

### United States of America

In April 1997, the 2.3 GHz band was auctioned for a period of 10 years to 17 bidders over 126 licences[[59]](#footnote-60). The band plan for wireless communications services (WCS) in the 2.3 GHz band in the US has a mid-band gap of 25 MHz which is allocated to (and provides) Satellite Digital Audio Radio Services (SDARS). The band plan and adjacent allocations is shown in Figure 25.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Deep Space**  2290-2300 MHz | **Amateur**  2300-2305 MHz | **WCS**  2305-2310 MHz | **WCS**  2310-2320 MHz | **SDARS**  2320-2345 MHz | **WCS**  2345-2360 MHz | **Aviation**  2360-2390 MHz |
| **Amateur**  2305-2310 MHz | **Aviation**  2310-2320 MHz | **Aviation**  2345-2360 MHz |

Figure : Allocations in the 2.3 GHz band in the US

The bands 2305-2310/2350-2355 MHz and 2310-2315/2355-2360 MHz are allocated as paired blocks in major economic areas[[60]](#footnote-61); 2315-2320 MHz and 2345-2350 MHz are unpaired blocks in regional economic areas[[61]](#footnote-62).

Specific “substantial service” build-out requirements were included on the licence; however, due to restrictions in place in order to protect sensitive satellite signals in the band 2320-2345 MHz allocated to SDARS, the build-out requirement to be met by 2007 (which was also the time for licence renewal) was extended to 2010.

Licensees have to meet two build-out requirements detailed[[62]](#footnote-63) in 47 USC §27.14(p) by March 4, 2014, and September 1, 2016, depending on whether the system is deployed as a point-to-multipoint or point-to-point.

The technical conditions are contained in section 27 of Title 47 of the Code of Federal Regulations[[63]](#footnote-64).

### Canada

In June 2001, the 2.3 GHz band was designated for WCS, and following industry consultation, 849 spectrum licences in 172 service areas were auctioned in February of 2004 for a period of 10 years[[64]](#footnote-65).

Initial industry consultation recognised that the Region 3 plan for the 2.3 GHz band (2300-2400 MHz) was the preferred option for issuing spectrum licences in the band, primarily because it provided the largest tranche of spectrum that could be released to market, and would align with future economies of scale in Region 3.

Due to Canada’s proximity to the United States, and the market for equipment already existing in the US, Canada aligned its channel arrangement with the US. The bands 2305-2320 MHz and 2345-2360 are allocated in a paired arrangement to support FDD equipment in the band.

Licensees were required to demonstrate that the spectrum had been used to an acceptable level within five years of receipt of the licence. In March 2012, Industry Canada (IC) wrote to licensees clarifying the level of use expected under each licence and that the deadline for demonstration of use was extended to the end of the 10 years. This decision was made due to the lack of available equipment which had contributed to low deployment, and follows a similar extension granted in the US by the FCC for similar reasons.

In October 2012, IC began a consultation with licensees on the renewal process for the 2300 MHz and 3500 MHz band[[65]](#footnote-66) with industry responses published on 20 December 2012[[66]](#footnote-67). Deployment levels in Canada that meet the deployment requirements for expectation of renewal are only 1 in 172 licences.

The technical conditions are available in RSS-195[[67]](#footnote-68) and SRSP-302.2[[68]](#footnote-69).

### New Zealand

In November 2006, the New Zealand Government decided to reconfigure the 2.3 GHz spectrum band and allocate new rights via auction. Following industry consultation on the design of the auction, two 35 MHz bands (2300-2335 MHz and 2335-2370 MHz) were allocated New Zealand wide to two bidders via auction in December 2007 with a commencement date of 26 November 2010 for a period of 20 years[[69]](#footnote-70).

The period of 20 years is subject to a ‘continuous ongoing service’ requirement to be met by 31 December 2014.

Additionally, a nationwide lot of 25 MHz is reserved for Maori in the 2370-2395 MHz band subject to particular management rights.

The band plan and adjacent allocations is shown in Figure 26.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Private Management Rights - suitable for FWA and fixed services**  2200-2300 MHz | **Private Management Rights - suitable for MMDS, FWA or Fixed services**  2300 - 2395 MHz | | | **Amateur**  2396-2450 MHz | |  |
|  | **ISM band**  2400-2483.5 MHz | |
| 2300-2335 MHz | 2335-2370 MHz | 2370-2395 MHz |

Figure : Allocations in the 2.3 GHz band in New Zealand

Technical conditions in the band are defined in the auction catalogue[[70]](#footnote-71).

### Hong Kong

In January 2009, the then Telecommunications Authority made available the 2300-2390 MHz band via auction, but no bidder(s) acquired the band. Subsequently, an additional expression of interest in December 2010 for the spectrum was made for the provision of broadband wireless access services. The spectrum was successfully allocated to three licensees; each obtaining 30 MHz and each will be assigned a 15 year unified carrier licence.

The band plan and adjacent allocation is shown in Figure 27.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Electronic News Gathering**  2200-2290 MHz |  | **Broadband Wireless Access**  2300 - 2390 MHz |  | **ISM band**  2400-2483.5 MHz |

Figure : Allocations in the 2.3 GHz band in Hong Kong

### CEPT

In Europe, and in particular, CEPT countries, the penetration of wireless access services in the 2.3 GHz band is low due to incumbent government and broadcaster use, particularly for programme making and special events (PMSE).

At the 74th meeting of the CEPT Electronic Communications Committee (ECC) Working Group FM, the results of a questionnaire[[71]](#footnote-72) on current and future use of the frequency band 2300-2400 MHz was presented.

39 member countries responded to the questionnaire, with 27 stating their use of the 2300-2400 MHz band is PMSE, including SAP/SAB and ENG/OB as defined in ECC Report 002[[72]](#footnote-73). Other uses include Amateur, Aeronautical Telemetry (ERC REC 62-02), Government, mobile and fixed.

16 member countries indicated that all or part of the frequency band is planned for future use of IMT.

Additionally, ECC Report 172 released in March 2012 provides compatibility studies with respect to the potential use of the band 2300-2400 MHz by broadband wireless systems; in particular, LTE and Mobile WiMAX.

# Annex E

## Calculation of fade margin

In order to determine the minimum required signal level at a receiver, it is necessary to consider a fade margin as a result of area coverage and consideration of body loss. Typical outdoor mobile coverage probability for a single cell case is 95%; under a multi-cell environment with coverage overlap, the actual coverage requirement of an individual cell can be smaller.

Estimation of the area coverage probability for the single-cell case is given by the following equation[[73]](#footnote-74):



where:





Assuming a path-loss exponent () of 2.5 in the 2.3 GHz band given additional requirements for line-of-sight paths (represents minimal terrain features – is approaching free-space conditions which has an *n* of 2) and a standard deviation () of 7 dB, results in a fading margin () of 8.0 dB for a single-cell area coverage probability of 95%.







# Annex

## Aeronautical mobile telemetry

In Australia, the band 2200-2290 MHz includes a Primary allocation to the mobile service as shown in Table 42 extracted from the ARSP. Services in this band are operated by the Department of Defence for aeronautical mobile telemetry (AMT) at particular sites identified in SPP 2001/10[[74]](#footnote-75). Footnote No. **391** states that

*In making assignments to the mobile service in the bands 2024-2110 MHz and 2200-2290 MHz, administrations shall not introduce high-density mobile systems, as described in Recommendation ITU-R* ***SA.1154****, and shall take that Recommendation into account for the introduction of any other type of mobile systems. (WRC-97)*

|  |
| --- |
| Australian Table of Allocations |
| **2 200 – 2 290**  SPACE OPERATION (space‑to‑Earth) (space‑to‑space)  EARTH EXPLORATION‑SATELLITE (space‑to‑Earth) (space‑to‑space)  FIXED  MOBILE 391  SPACE RESEARCH (space‑to‑Earth) (space‑to‑space)  392 AUS87 |
| **2 290 – 2 300**  FIXED  MOBILE except aeronautical mobile  SPACE RESEARCH (deep space)  (space‑to‑Earth)  AUS87 AUS93 |

Table : AMT allocations in the ARSP

The system consists of a ground station receiving telemetry from airborne stations which may include missiles, manned and unmanned systems. Defence operations are licensed in the 2200-2290 MHz band with three registered receiver sites[[75]](#footnote-76).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Licence  Number | Site Name | Latitude  (AGD66) | Longitude  (AGD66) | Centre  frequency | Emission  designator | Conditions |
| 1231201 | Tasman Sea Range Telemetry Receiver Site Bherwerre Ridge JERVIS BAY | -35.161137 | 150.730796 | 2250 MHz | 100MF1D | BL[[76]](#footnote-77) |
| 1231202 | Woomera Prohibited Area Telemetry Receiver Site WOOMERA | -31.146135 | 136.805274 | 2250 MHz | 100MF1D | BL |
| 1231203 | Weather Monitoring Site RAAF Base EDINBURGH | -34.719391 | 138.651419 | 2250 MHz | 100MF1D | BL |

Table : Registered AMT receivers

### AMT system characteristics

A number of the required parameters for this study have been taken from the registrations provided in Table 43, ITU-R Recommendation M.1459, IRIG Standard 106-11, ERC Report 172 and advice provided by Defence.

|  |  |  |
| --- | --- | --- |
|  | **Parameter** | **Value** |
| Airborne transmission | Bandwidth | 1-40 MHz |
| Transmitter power | 2-25 W |
| Antenna gain | 0-3 dBi |
| Maximum EIRP | 47 dBm |
| Antenna height (AGL) | 0–20000 m |
| Range | 320 km[[77]](#footnote-78) |
| Spurious emissions[[78]](#footnote-79) | < 320μV/m @ 30 m |
|  |  |  |
| Ground reception | Noise level | -110.7 dBm per MHz |
| Noise figure | 5 dB |
| Feeder loss | 1 dB |
| C/I Requirement | 6 dB |
| Antenna gain | 20-41 dBi (tracking) |
| System noise temperature | 200-500 K |
| Antenna pattern | Refer to M.1459 and Figure 29 |
| Antenna height (AGL) | 5 to 30 m |
| Polarisation | CR, CL and linear |
| Az/El | ±180° and 0-90° |

Table : AMT system characteristics



Figure : AMT receiver antenna pattern[[79]](#footnote-80)

### Impact of 2.3 GHz to AMT

Interferers in the 2.3 GHz band include both the UE and BS transmitters with the telemetry ground station as the victim.



Figure : Scenarios for 2.3 GHz to AMT study

Coexistence is calculated based on the necessary attenuation required in the system such that the received signal power at the telemetry ground station and its C/I requirements are not exceeded. The minimum coupling loss (MCL) is calculated as follows:

The following parameters are used in the calculation:

|  |  |
| --- | --- |
| Parameter | Definition |
|  | is the power being fed to the antenna (dBm) |
|  | is the peak gain of the transmitting antenna (dBi) |
|  | is the feeder loss of the system (dB) |
|  | is the gain of the receiving antenna (dBi) |
|  | is the interference requirement of the system (dBm) |

Table 45: Definitions required for MCL calculation

There is no co-channel scenario to consider in this study like in other countries where the band 2300-2400 MHz is allocated to AMT. The requirements of non-spurious outside the band emissions proposed in this band (section 3.4.1) state that less than 2390 MHz will meet the transmitter spurious emission requirements of Table 15.

This means that the variable.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **2.3 GHz BS** | | | **AMT** | | | **MCL**  **(km**) | **Separation distance (km)** | |
| **Scenario** | **Interferer main**  **beam directed**  **toward** | ***P***  **(dBm)** | ***Gt***  **(dBi)** | ***Lf***  **(dB)** | ***Gr***  **(dBi)** | ***Lf***  **(dB)** | ***IC***  **(dBm)** | ***Free-***  ***space*** | ***Cost/HATA-231***  ***(suburban)[[80]](#footnote-81),[[81]](#footnote-82)*** |
| Spurious | Victim main beam | -30 | 17 | 3 | 20 | 1 | -116.7 | 119.7 | 9.9 | 5.5 |
| -30 | 17 | 3 | 41 | 1 | -116.7 | 140.7 | 110.6 | 20.5 |
| Victim side lobes | -30 | 17 | 3 | -2 | 1 | -116.7 | 97.7 | 0.8 | 0.8[[82]](#footnote-83) |

Table : Coexistence between 2.3 GHz BS and AMT ground receiver

The results in Table 46 show that some free-space separation is required, and when considering the maximum MCL, a separation of 20.5 kilometres is required assuming Cost/HATA-231 propagation modelling. In the majority, interference will be into the side lobes of the AMT receiver given that its primary operations are pointing above an elevation angle of 15 degrees communicating with airborne systems.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **2.3 GHz UE** | **AMT** | | | **MCL**  **(km**) | **Separation distance (km)** | |
| **Scenario** | **Interferer main**  **beam directed**  **toward** |  | ***Gr***  **(dBi)** | ***Lf***  **(dB)** | ***IC***  **(dBm)** | ***Free-***  ***space*** | ***Cost/HATA-231***  ***(suburban)[[83]](#footnote-84)*** |
| Spurious | Victim main beam | -30 dBm per MHz | 20 | 1 | -116.7 | 105.7 | 2 | 0.5 |
| 41 | 1 | -116.7 | 126.7 | 22.1 | 1.5 |
| Victim side lobes | -2 | 1 | -116.7 | 83.7 | 0.2 | 0.1 |

Table : Coexistence between 2.3 GHz UE and AMT ground receiver

The results in Table 47 show the improved results when there is no additional antenna gain on the spurious emissions and the reduction in transmitter height are considered. Even under free-space conditions, the maximum separation distance is 22.1 kilometres, or assuming Cost/HATA-231 propagation modelling only 1.5 kilometres.

In reality, some coordination is required to consider actual terrain and operating conditions of the AMT receivers located at primary locations across Australia (refer to Table 43). Temporary licences at other locations (refer to SPP 2001/10[[84]](#footnote-85)) may be licensed when flight testing is required; however, first in time principles apply and AMT operators should take every effort to site equipment with appropriate shielding from transmitters licensed in the 2.3 GHz band.

### Impact of AMT to 2.3 GHz

The scenario considers interference from airborne transmitters in the 2200-2290 MHz band to BS and UE receivers in the 2.3 GHz band.



Figure : Scenarios for AMT to 2.3 GHz study

Coexistence is calculated based on the necessary attenuation required in the system such that the received signal power at the 2.3 GHz receiver and its C/I requirements are not exceeded. The minimum coupling loss (MCL) is calculated as follows:

It is assumed that for an offset of 10 MHz, that the transmitter would be in the spurious rather than non-spurious domain and hence the spurious emission limit in Table 44 and further described by footnote 85 applies.

The technical framework for the 2.3 GHz bands proposes that the minimum wanted signal level at the antenna connector is -95.5 dBm per 5 MHz for 95% of time in any 1 hour period. The blocking requirement, applicable to emissions generated outside the 2300-2400 MHz band is -15 dBm.

The determination of the minimum wanted signal level is the reference sensitivity level of LTE plus a C/I requirement of 6 dB. Therefore, the maximum received signal level from an interfering source co-channel is -101.5 dBm per 5 MHz. Only the main-beam case is considered in Table 48.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **AMT** | | | **2.3 GHz BS** | | | **MCL**  **(km**) | **Separation distance** |
| **Scenario** | ***P***  **(dBm)** | ***Gt***  **(dBi)** | ***Lf***  **(dB)** | ***Gr***  **(dBi)** | ***Lf***  **(dB)** | ***IC***  **(dBm)** | ***Free-space  (km)*** |
| Spurious | -14 | 3 | 1 | 17 | 3 | -101.5 | 103.5 | 1.5 |

Table : Coexistence between AMT airborne transmitter and 2.3 GHz BS receivers

The results in Table 48 show that only 1.5 kilometres of separation is required between AMT airborne transmitters and 2.3 GHz BS receivers. Notionally, a BS receiver antenna is tilted less than zero degrees elevation, and hence it is unlikely that an aircraft will regularly be in the high-gain region of the BS antenna. This further reduces the likelihood for interference from airborne AMT.

The separation distance is even less when 2.3 GHz UE receivers are considered in Table 49.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **AMT** | | | **2.3 GHz UE** | **MCL**  **(km**) | **Separation distance** |
| **Scenario** | ***P***  **(dBm)** | ***Gt***  **(dBi)** | ***Lf***  **(dB)** |  | ***Free-space  (km)*** |
| Spurious | -14 | 3 | 1 | -101.5 dBm per 5 MHz | 89.5 | 0.3 |

Table : Coexistence between AMT airborne transmitter and 2.3 GHz UE receivers

### Conclusions

In Australia, the band 2302-2400 MHz is unavailable to AMT because the band has been spectrum licensed Australia wide. Whilst Defence hold a licence in the band, it is only for a specific geographic area and not nationwide coverage.

This makes the coexistence of 2.3 GHz systems and AMT only need to consider the spurious emissions case as service separation is at least 10 MHz. Based on the results summarised in Table 50, the maximum free-space separation loss of all scenarios is 110.6 kilometres for interference from 2.3 GHz BS into an AMT receiver with a receive antenna gain of 41dB. A 41dB antenna at 2250 MHz equates roughly to a 6.5m parabolic antenna. A reduction to a 20 dB antenna reduces free-space separation distance to 9.9 kilometres.

AMT victim main beam interference is the worst case, but it is unlikely during operations that the primary pointing of the AMT receiver will be toward the horizon, but rather be at elevations greater than 15 degrees. In these cases, it can be assumed that the side lobe gain is more appropriate and free-space separation distances reduce to 0.8 kilometres.

|  |  |  |  |
| --- | --- | --- | --- |
| Scenario (spurious) | Antenna  isolation | MCL (dB) | Free-space  separation distance (km) |
| 2.3 GHz BS → AMT | main | 140.7 | 110.6 |
| side lobe | 97.7 | 0.8 |
| 2.3 GHz UE → AMT | main | 126.7 | 22.1 |
| side lobe | 83.7 | 0.2 |
| AMT → 2.3 GHz BS | main | 103.5 | 1.5 |
| AMT → 2.3 GHz UE | main | 89.5 | 0.3 |

Table : Summary of AMT results

Table 50 shows that so long as the interferer is not into the main lobe of the victim receiver, then separation distances are less than 1 kilometre. Given that AMT receivers are notionally deployed within Defence training areas (refer to SPP 2001/10), it is unlikely that 2.3 GHz transmitters will be deployed without consultation with the Defence establishment in which the AMT receiver is located.

The ACMA do not propose to include any specific coordination requirements in the RAG, except that where interference is caused to AMT receivers in the 2200-2290 MHz band, that unless the 2.3 GHz device meets the core conditions of the licence, they may be deemed to cause unacceptable interference.

# Annex

## Delta-Bullington model

Recent activity in ITU-R Study Group 3 has resulted in an updated model known as the ‘Delta-Bullington Model’ replacing the cascaded knife edge method of Recommendation ITU‑R P.526 (see section 4.4.2 of P.526-10).

Section 4.5 of P.526-12 refers to a ‘Method for a general terrestrial path’ that is recommended for situations where an automatic process is required to predict diffraction loss for any type of path as defined by a profile.

The method contains two sub-models:

* The Bullington diffraction method (section 4.5.1 of P.526-12) used with a tapered correction to provide a smooth transition between line-of-sight and trans-horizon
* The spherical Earth method (section 3.2 of P.526-12).

Technical frameworks such as the 2.5 GHz mid-band gap have been developed utilising the cascaded knife edge method, and because of the similarities in deployment between the two bands (TDD), as well as the implementation of cascaded knife edge being relatively well known, a comparison between the two methodologies is being conducted with 2.3 GHz in mind.

Direct implementation in Matlab is conducted based on the procedure in section 4.5.2 of P.526-12. The propagation loss over the path (Lp), including diffraction (Ld), is shown between the transmitter (T) and receiver (R) chosen in Table 52 (coordinates in GDA94) with transmitter (Ht) and receiver heights (Hr) and the use of DEM-9S.

The result in and vary slightly, in particular cases 1 and 3 where the cascaded knife edge model does not pick up a diffraction loss over those paths and hence resolves to free-space.

One of the issues in implementing P.526-12 in the subsection 145(4) determination of unacceptable interference is that it is a more detailed implementation than cascaded knife edge; mainly because it contains two separate procedures that form the complete method.

In order to implement the Delta-Bullington method, the ACMA will not provide the mathematical procedure in the determination, but rather, refer to the procedure in section 4.5.2 of P.526-12.

|  |  |  |
| --- | --- | --- |
| Case | Ld (dB) | Lp (dB) |
| 1 | 0 | 130.91 |
| 2 | 0 | 128.16 |
| 3 | 0 | 125.28 |
| 4 | 35.52 | 157.80 |
| 5 | 38.63 | 160.26 |

Table 51: Implementation of section 4.4.2 in P.526-10

| Case | T  (lat, long) | R  (lat, long) | d (m) | Ht (m) | Hr (m) | Path profile | Ld (dB) | Lp (dB) |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 1 | ‑35.4617, 149.1469 | -35.1405, 149.1640 | 35670 | 40 | 5 |  | 4.59 | 135.5 |
| 2 | -30.5465,  151.6499 | -30.3124,  151.6616 | 25980 | 34 | 10 |  | 0 | 128.16 |
| 3 | -31.7562,  115.8158 | -31.6372,  115.9548 | 18645 | 46 | 1.5 |  | 5.28 | 130.56 |
| 4 | -12.8134,  130.9870 | -12.8133,  131.1587 | 18645 | 43 | 5 |  | 31.58 | 156.87 |
| 5 | -27.5541,  152.0401 | -27.6646,  152.0401 | 12250 | 46 | 5 |  | 36.70 | 158.33 |

Table 52: Implementation of section 4.5 in P.526-12

Further, in conducting its own work in implementing the Delta-Bullington method, the ACMA believes it has found a number of errors in its description, notably, in equations 58, 59 and 64a of section 4.5.2 of P.526-12 and in the minimum number of profile points that form the completed path length.

In order for equations 61a, 61b, 61c and 61d to meet the index bounds that apply (*i* takes the values from 2 to *n*-1), *n* must be greater than 2, hence, an intermediate profile point is always required in the method to calculate propagation loss between the transmitter and receiver. Modification to Part 1, Schedule 2 of the subsection 145 (4) Determination (refer to Annex J) such that the device boundary criterion is calculated for increments *m* equals 2 through 202 (the value 202 – *m*×500 metres – comes from the maximum length the model applies before automatically passing the device boundary – refer to section 4.4.1) has been made.

Both equations 58 and 59 should be summed from *i = 2 to n* (based on the values *i* can take in the description of *i* provided in section 4.5.1) and in equation 64a, *hrs* should be replaced with *hts*.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | |  | | | (58) | |
|  |  | | | | | (59) |
|  | | |  | (64a) | | |

The ACMA requests licensees to confirm if they agree with the ACMA’s identification of these four errors. Further investigation may be required.

# Annex I

## Draft spectrum licence

See Annex I – *Draft Spectrum Licence for the 2.3 GHz Band*.

# Annex

## Radiocommunications (Unacceptable Levels of Interference - 2.3 GHz Band) Determination 2013

See Annex J – *Radiocommunications (Unacceptable Levels of Interference – 2.3 GHz Band) Determination 2013*.

# Annex

## Radiocommunications Advisory Guidelines (Managing Interference from Spectrum Licensed Transmitters – 2.3 GHz Band) 2013

See Annex K – *Radiocommunications Advisory Guidelines (Managing Interference from Spectrum Licensed Transmitters – 2.3 GHz Band) 2013*.

# Annex

## Radiocommunications Advisory Guidelines (Managing Interference to Spectrum Licensed Receivers – 2.3 GHz Band) 2013

See Annex L – *Radiocommunications Advisory Guidelines (Managing Interference to Spectrum Licensed Receivers – 2.3 GHz Band) 2013*.

# Annex

## CDSCC geographic guard band

### Canberra (Nth West)

| Latitude | Longitude |
| --- | --- |
| -35.7484 | 149.2512 |
| -35.3318 | 149.2512 |
| -35.3318 | 149.4179 |
| -35.1651 | 149.4179 |
| -35.1651 | 149.3345 |
| -35.0818 | 149.3345 |
| -35.0818 | 149.2512 |
| -34.9984 | 149.2512 |
| -34.9984 | 149.0012 |
| -35.1651 | 149.0012 |
| -35.1651 | 148.7512 |
| -35.2485 | 148.7512 |
| -35.2485 | 148.5846 |
| -35.0818 | 148.5846 |
| -35.0818 | 148.6679 |
| -34.9151 | 148.6679 |
| -34.9151 | 148.8345 |
| -34.8318 | 148.8345 |
| -34.8318 | 149.5012 |
| -34.9151 | 149.5012 |
| -34.9151 | 149.5845 |
| -34.9984 | 149.5845 |
| -34.9984 | 149.6679 |
| -35.4984 | 149.6679 |
| -35.4984 | 149.5845 |
| -35.6651 | 149.5845 |
| -35.6651 | 149.4179 |
| -35.7484 | 149.4179 |
| -35.7484 | 149.2512 |
| -35.7484 | 149.2512 |

Table 53: Canberra (Nth West) coordinates GDA94

### Canberra (metro)

| Latitude | Longitude |
| --- | --- |
| -35.9155 | 148.9182 |
| -35.9154 | 149.1682 |
| -35.7484 | 149.1682 |
| -35.7484 | 149.2512 |
| -35.3314 | 149.2512 |
| -35.3314 | 149.4182 |
| -35.1654 | 149.4182 |
| -35.1654 | 149.3342 |
| -35.0814 | 149.3342 |
| -35.0814 | 149.2512 |
| -34.9984 | 149.2512 |
| -34.9984 | 149.0012 |
| -35.1654 | 149.0012 |
| -35.1655 | 148.7512 |
| -35.2485 | 148.7512 |
| -35.2485 | 148.5012 |
| -35.3315 | 148.5012 |
| -35.3315 | 148.5842 |
| -35.6655 | 148.5842 |
| -35.6655 | 148.7512 |
| -35.7485 | 148.7512 |
| -35.7485 | 148.9182 |
| -35.9155 | 148.9182 |
| -35.9155 | 148.9182 |

Table 54: Canberra (metro) coordinates GDA94

1. Available at: <http://www.comlaw.gov.au/Details/F2004B00494> [↑](#footnote-ref-2)
2. *Proposed updates to the spectrum licence framework* published in March 2012. Available at: <http://www.acma.gov.au/WEB/STANDARD/pc=PC_410314> [↑](#footnote-ref-3)
3. The 2.5 GHz mid-band gap (MBG) refer to 2570-2620 MHz and allocated to television outside broadcast [↑](#footnote-ref-4)
4. Available at: <http://www.comlaw.gov.au/Details/F2012L01718> [↑](#footnote-ref-5)
5. Available at: <http://www.acma.gov.au/WEB/STANDARD/pc=PC_300172#map-grid> [↑](#footnote-ref-6)
6. LTE equipment specifications from 3GPP are specified with respect to release 10, including documents TS 36.104, TS 36.101, Report ITU-R M.2039-1 [↑](#footnote-ref-7)
7. WiMAX equipment specifications for band class 1.B: ETSI TR 102 837 V1.1.1, EN 301 908, WMF-T23-005-R015v06: “WiMAX Forum Mobile Radio Specification”, Report ITU-R M.2039 [↑](#footnote-ref-8)
8. Fixed service equipment specifications are drawn from a number of sources, including the RRL (as at 1 December 2012) and Telstra who provided input to the TLG process. [↑](#footnote-ref-9)
9. The paired band (frequency) may not be in the 2.3 GHz spectrum licence. [↑](#footnote-ref-10)
10. EIRP is effective isotropic radiated power [↑](#footnote-ref-11)
11. Definition of Adjacent Channel Leakage Ratio (ACLR) contained in 3GPP TS 36.104 v10.5.0 paragraph 6.6.2 [↑](#footnote-ref-12)
12. This ACLR value is defined for unpaired spectrum with synchronised operation. There is no ACLR definition for unpaired spectrum with unsynchronised operation. Either the relative or absolute value applies, depending on whichever is less stringent [↑](#footnote-ref-13)
13. Adjacent channel selectivity (ACS) is a measure of the ability of a receiver to receive a wanted signal without exceeding a specified degradation in output quality due to the presence of an unwanted adjacent channel signal. [↑](#footnote-ref-14)
14. Relative to the thermal noise (kTBF = -102 dBm). [↑](#footnote-ref-15)
15. Assumes 25 resource blocks are allocated in a 5 MHz channel, QPSK modulation at 1/3 code rate. [↑](#footnote-ref-16)
16. IEEE Std 802.16e-2005 from: <http://www.ieee802.org/16/pubs/80216e.html> [↑](#footnote-ref-17)
17. Extraction from the RRL dated 01 September 2012 [↑](#footnote-ref-18)
18. IFC 08/2012 is available at: <http://www.acma.gov.au/WEB/STANDARD/pc=PC_410314> [↑](#footnote-ref-19)
19. FYSO 2012-2026 is available at: <http://www.acma.gov.au/WEB/STANDARD/pc=PC_410352> [↑](#footnote-ref-20)
20. Embargo 65 is available at: <http://www.acma.gov.au/WEB/STANDARD/pc=PC_2712> [↑](#footnote-ref-21)
21. The ACS and receiver blocking parameters are specified with reference to the compatibility requirement of the notional receiver in section 5.2.3.1 [↑](#footnote-ref-22)
22. Relative to the thermal noise [↑](#footnote-ref-23)
23. Figure 5.4.3-1 from 3GPP TS 36.211 V11.1.0 (2012-12) [↑](#footnote-ref-24)
24. From Table 20 and Table 21 in WMF-T23-005-R015v06: “WiMAX Forum Mobile Radio Specification” [↑](#footnote-ref-25)
25. 3GPP TS 37.104 V10.6.0 (2012-03) - *Multi-Standard Radio (MSR) Base Station (BS) radio transmission and reception (Release 10)*, available at: <http://www.3gpp.org/ftp/Specs/html-info/37104.htm> [↑](#footnote-ref-26)
26. TS 36.104 paragraph 6.6.2 [↑](#footnote-ref-27)
27. One means to enforce the non-operational status of the facility is provided in section 11 of the *Television Outside Broadcast (1980-2110 MHz and 2170-2300 MHz) Frequency Band Plan 2012* available at: <http://www.comlaw.gov.au/Details/F2012L00731> [↑](#footnote-ref-28)
28. Devices can only be registered by an Accredited Person who has been authorised by the relevant spectrum licensee to register devices in that spectrum licence. All devices should be checked to ensure they meet relevant requirements of the ACMA and any additional conditions imposed by the written agreement. [↑](#footnote-ref-29)
29. An *indoor fixed transmitter* means a transmitter located at a fixed point on land or sea having an antenna that (a) is located within an enclosed space and (b) is illuminating the enclosed space within its half-power beamwidth [↑](#footnote-ref-30)
30. Available at: <http://www.comlaw.gov.au/Details/F2011L01520> [↑](#footnote-ref-31)
31. Available at: <http://www.acma.gov.au/webwr/radcomm/frequency_planning/frequency_assignment/docs/ms32.pdf> [↑](#footnote-ref-32)
32. [↑](#footnote-ref-33)
33. Available at: <http://www.acma.gov.au/WEB/STANDARD/pc=PC_300172#map-grid> [↑](#footnote-ref-34)
34. The information contained in this section is obtained from the January 2009 ARSP, available from: <http://www.acma.gov.au/WEB/STANDARD/pc=PC_2713> [↑](#footnote-ref-35)
35. Available at: <http://www.acma.gov.au/webwr/radcomm/frequency_planning/spps/0110spp.pdf> [↑](#footnote-ref-36)
36. Available at: <http://www.comlaw.gov.au/Details/F2012L00731> [↑](#footnote-ref-37)
37. Available t: <http://www.acma.gov.au/WEB/STANDARD/pc=PC_297> [↑](#footnote-ref-38)
38. Further information regarding the ACMA Electromagnetic Compatibility regime is available from: <http://www.acma.gov.au/WEB/STANDARD/pc=PC_310704> [↑](#footnote-ref-39)
39. Available at: <http://www.acma.gov.au/WEB/STANDARD/pc=PC_2708> [↑](#footnote-ref-40)
40. This criteria typically requires adherence to the device boundary criteria stated in the s.145 determination. [↑](#footnote-ref-41)
41. The actual occupied bandwidth may be much smaller; for example, a 5 MHz LTE channel utilising 25 resource blocks in the downlink will have an occupied bandwidth of 4.515 MHz. [↑](#footnote-ref-42)
42. ECC Report 119 - Coexistence between mobile systems in the 2.6 GHz frequency band at the FDD/TDD boundary available at: <http://www.erodocdb.dk/Docs/doc98/official/pdf/ECCREP119.PDF> [↑](#footnote-ref-43)
43. The location of space research facilities in the 2200-2300 MHz is accurate to September 2012. [↑](#footnote-ref-44)
44. Available at: <http://www.acma.gov.au/WEB/STANDARD/pc=PC_2712> [↑](#footnote-ref-45)
45. Coordinates can be found in Annex L [↑](#footnote-ref-46)
46. When considering RAS sites and frequencies identified in the AUS87 footnote, the most current version of the ARSP (available at [www.comlaw.gov.au](http://www.comlaw.gov.au)) should be consulted to determine if any changes have been made to any published version of the ARSP available from the ACMA. [↑](#footnote-ref-47)
47. Available at: <http://www.acma.gov.au/WEB/STANDARD/pc=PC_2708> [↑](#footnote-ref-48)
48. Available at: <http://www.acma.gov.au/WEB/STANDARD/pc=PC_2599> [↑](#footnote-ref-49)
49. Available at: <https://www.bluetooth.org/docman/handlers/downloaddoc.ashx?doc_id=229737> [↑](#footnote-ref-50)
50. Refer to §7.4 of 3GPP TS 36.101 V10.6.0 [↑](#footnote-ref-51)
51. Collocated in this sense refers to the transmitter, receiver and antennas of the systems being in the same device, such as a mobile user terminal. It does not refer to the collocation requirements of co-sited devices in section 3.7. [↑](#footnote-ref-52)
52. Available at: <http://www.erodocdb.dk/Docs/doc98/official/pdf/ECCREP172.PDF> [↑](#footnote-ref-53)
53. Available at: <https://www.bluetooth.org/docman/handlers/downloaddoc.ashx?doc_id=228067> [↑](#footnote-ref-54)
54. 802.11 standards are available at: <http://www.techstreet.com/cgi-bin/browse?publisher_id=95&subgroup_id=36721> [↑](#footnote-ref-55)
55. As limited by the *Radiocommunications (Low Interference Potential Devices) Class Licence 2000* available at: <http://www.comlaw.gov.au/Details/F2011C00543> [↑](#footnote-ref-56)
56. Based on a 20 MHz channel spacing, operating QPSK rate 3/4 [↑](#footnote-ref-57)
57. Each coloured pixel represents a square of 0.3×0.3 kilometres [↑](#footnote-ref-58)
58. Extraction from the RRL dated 01 January 2013 [↑](#footnote-ref-59)
59. Further details on the allocation of 2.3 GHz spectrum in the United States is available at: <http://wireless.fcc.gov/services/index.htm?job=service_home&id=wcs> [↑](#footnote-ref-60)
60. Major economic areas are defined at: <http://wireless.fcc.gov/auctions/data/maps/mea.pdf> [↑](#footnote-ref-61)
61. Regional economic areas are defined at: <http://wireless.fcc.gov/auctions/data/maps/REAG.pdf> [↑](#footnote-ref-62)
62. <http://www.gpo.gov/fdsys/pkg/CFR-2010-title47-vol2/pdf/CFR-2010-title47-vol2-sec27-14.pdf> [↑](#footnote-ref-63)
63. Section 27 is available at: <http://wireless.fcc.gov/index.htm?job=rules_and_regulations> [↑](#footnote-ref-64)
64. Further details on the allocation of 2.3 GHz spectrum in Canada is available on its auction website at: <http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/h_sf05472.html> [↑](#footnote-ref-65)
65. DGSO-006-12, *Consultation on Renewal Process for 2300 MHz and 3500 MHz Licences,* [*http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf10470.html*](http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf10470.html) [↑](#footnote-ref-66)
66. Comments Received on Gazette Notice DGSO-006-12, <http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf10549.html> [↑](#footnote-ref-67)
67. RSS-195, *Wireless Communications Service Equipment Operating in the Bands 2305-2320 MHz and 2345-2360 MHz*, <http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf08111.html> [↑](#footnote-ref-68)
68. SRSP-302.3, *Technical Requirements for Wireless Communications Service Operating in the Bands 2305-2320 MHz and 2345-2360 MHz*, <http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf08112.html> [↑](#footnote-ref-69)
69. Management rights deed for the 2.3 GHz band available at: <http://www.rsm.govt.nz/cms/pdf-library/policy-and-planning/spectrum_auctions/auction-2-3-2-5-ghz-9/schedule-2-to-auction-9-catalogue-management-right-deed-60-kb-pdf> [↑](#footnote-ref-70)
70. 2.3 GHz auction catalogue available at: <http://www.rsm.govt.nz/cms/pdf-library/policy-and-planning/spectrum_auctions/auction-2-3-2-5-ghz-9/auction-9-catalogue-300-kb-pdf> [↑](#footnote-ref-71)
71. FM(12)017 Rev1 available at: <http://www.cept.org/Documents/wg-fm/5035/FM(12)017-Rev1_Summary-Questionnaire-2300-2400-MHz> [↑](#footnote-ref-72)
72. Available at: <http://www.erodocdb.dk/Docs/doc98/official/pdf/ECCREP002.PDF> [↑](#footnote-ref-73)
73. Mishra. A. R, *Advanced cellular network planning and optimisation: 2G/2.5G/3G – evolution to 4G*, John Wiley and Sons, 2007, pg. 48 [↑](#footnote-ref-74)
74. Available at: <http://www.acma.gov.au/webwr/radcomm/frequency_planning/spps/0110spp.pdf> [↑](#footnote-ref-75)
75. Defence is currently reviewing requirements for operation over 100 MHz. [↑](#footnote-ref-76)
76. Condition BL - This frequency band is currently under review to accommodate changes in technology. This review may lead to a requirement to change frequency or to cease transmission. [↑](#footnote-ref-77)
77. The maximum air space for a telemetry receiving site is defined as a cylinder with a horizontal radius of 320 km around the site, with the lower bound determined by visibility and the upper bound determined by an altitude of 20 km. [↑](#footnote-ref-78)
78. Assuming free-space loss over the 30 metres, an additional 70dB of propagation loss needs to be accounted. Converting into dBm/MHz, results in a spurious emission of -21dBm/MHz at the antenna rather than a separation of 30 metres. [↑](#footnote-ref-79)
79. Figure 7 of Report ITU-R M.2238 - *Compatibility study to support line of sight control and non-payload communications links for unmanned aircraft systems proposed in the frequency band 5 091–5 150 MHz* [↑](#footnote-ref-80)
80. ERC Report 68 (Feb 2000) part b) of Appendix 1 to Annex 2: (Reference (3)) : Propagation model [↑](#footnote-ref-81)
81. LTE BS height is 30m AGL and AMT receiver is 20 AGL [↑](#footnote-ref-82)
82. Free-space loss limited [↑](#footnote-ref-83)
83. LTE UE height is 1.5m AGL and AMT receiver is 20 AGL [↑](#footnote-ref-84)
84. Available at: <http://www.acma.gov.au/webwr/radcomm/frequency_planning/spps/0110spp.pdf> [↑](#footnote-ref-85)