

# **ACMA's Proposed New 2GHz ENG Bands**

APRIL 2012

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# 1 Executive Summary

Kordia has been engaged by the Australian Subscription Television and Radio Association (ASTRA) to investigate and report on the spectrum available for wireless cameras and video links used for television outside broadcast activities.

Currently the ABC, Seven, Nine and Ten Networks have apparatus licences that give them exclusive use of 190MHz in the 2.5GHz band for Electronic News Gathering (ENG). They also use this spectrum for Television Outside Broadcasts (TOBs) (predominantly sports events).

Other organisations (who make up over half of the estimated 950 days of outside broadcasts annually) have relied on the licenced networks' good will in loaning the spectrum on a case by case basis. While this has provided working spectrum up until this point, it is not sustainable into the future. To guarantee business and operational certainty, and to ensure ongoing production quality in outside broadcast operations, greater certainty for all spectrum users regarding frequency availability is required.

As part of the "Digital Dividend" auction process, the spectrum currently used for wireless cameras and linking in the 2.5GHz band is to be reduced from 190MHz to 50MHz to harmonise use of the 2.5 GHz band with international practice for wireless access services.

An additional allocation of spectrum of a bandwidth of 260MHz (in two lots of 130MHz in the bands 1980-2110MHz and 2170-2300MHz) is proposed by the ACMA to meet current and future ENG, TOB and Electronic Field Production (EFP) spectrum requirements. There are likely to be a number of restrictions for the use of this new spectrum.

The ACMA is proposing<sup>1</sup> to allocate all but 60MHz of the new spectrum to the ABC, Seven, Nine and Ten networks. Not all of the 60MHz will be able to be used as it is adjacent to spectrum used for mobile phones. The tenure for this spectrum would also be limited.

60MHz (even before the restrictions requiring guard bands) is insufficient to meet the increasing demand for spectrum by those operations without assigned spectrum in the ENG bands, while the current practice of "borrowing" spectrum for events is unsustainable and likely to cause increased uncertainty for non-licensees. Currently some types of TOBs such as Golf and Marathons require 140MHz of spectrum to achieve a quality product. Innovative camera devices such as Oktocopter, Umpire Glasses and more yet to be realised will only add to the need for more spectrum.

With the new spectrum becoming available, an assessment of the current practice of sharing and assignment is appropriate to determine more sustainable spectrum access arrangements that reflect actual and likely future spectrum requirements by all operators.

This report proposes to partition the spectrum available to give an exclusive ENG allocation to existing licensees (ABC, Seven, Nine and Ten Networks) and use the remaining spectrum as a "bookable" resource available to all video camera and link users.

Each existing licensee would be allocated 30MHz each, enough for three separate links operating simultaneously.

The remaining "bookable" spectrum, after guard bands are allowed for, amounts to 160MHz.

Internationally, booking systems for all registered users for the purpose of TOB and EFP for planned events are used successfully and is proposed as a solution in this report.

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<sup>1</sup> ACMA, *Review of the 2.5 GHz band and long-term arrangements for ENG—Response to submissions*, October 2010.

## 2 Definitions

Throughout this document we have used a number of terms and abbreviations which are defined in the table below:

Term	Meaning in this document
Electronic News Gathering (ENG)	an unplanned event such as a breaking news story
Television Outside Broadcast (TOB)	a planned event such as a sporting fixture
Electronic Field Production (EFP)	a planned event such a drama production
2.5GHz band	the band extending from 2.5GHz to 2.690GHz
Central Collection Site	a tower mounted 2.5GHz receive system usually steerable to receive signal from ENG link vans or helicopters.
Camera Link	low power (<200mW) transmitter generally mounted on the rear of the camera
TOBN's	TOB Networks comprising of the ABC, Seven, Nine and Ten Networks. Currently the licensees of the ENG spectrum.
Non-TOBN's	Non-licensees of the ENG spectrum but either current users or aspirant users of the spectrum for TOB and EFP purposes e.g. Fox Sports.
Tx	Transmitter
Rx	Receiver
IBC	In Building Coverage

### 3 Introduction

As part of the "Digital Dividend" auction process, the spectrum currently used for wireless cameras and linking by the TV and Film industries in the 2.5GHz band is to be reduced from 190MHz to 50MHz.

Using information from the ACMA Licence Database, the table below shows the current Australia wide licencees, sorted by ascending frequency.

Assignment			Licensee	Special Conditions Allow		
Lower Band Edge (MHz)	Upper Band Edge (MHz)	Width (MHz)		Lower Band Edge (MHz)	Upper Band Edge (MHz)	Width (MHz)
2500	2517.5	17.5	Australian Broadcasting Corporation	2500	2523.5	23.5
2517.5	2535	17.5	CHANNEL SEVEN SYDNEY PTY LIMITED	2523.5	2547.5	24
2535	2552.5	17.5	Nine Network Australia Pty Ltd	2547.5	2571	23.5
2552.5	2570	17.5	Network Ten (Sydney) Pty Limited	2571	2595	24
2570	2585	15	Australian Broadcasting Corporation			
2585	2595	10	CHANNEL SEVEN SYDNEY PTY LIMITED			
2595	2605	10	Nine Network Australia Pty Ltd			
2605	2620	15	Network Ten (Sydney) Pty Limited			
2620	2637.5	17.5	Australian Broadcasting Corporation	2595	2619	24
2637.5	2655	17.5	CHANNEL SEVEN SYDNEY PTY LIMITED	2619	2642.5	23.5
2655	2672.5	17.5	Nine Network Australia Pty Ltd	2642.5	2666.5	24
2672.5	2690	17.5	Network Ten (Sydney) Pty Limited	2666.5	2690	23.5

The green shaded frequency range is the mid band 50MHz that will remain after the bulk of the 2.5 GHz band is auctioned as part of the Digital Dividend process.

The spectrum is contiguously assigned and currently uses 190MHz. The ABC and Network TEN each have 50MHz assigned while Channel Seven and Nine Network each have 45MHz. All licences are apparatus licences and due to expire on 6th Feb 2013.

The remaining frequencies may be allocated as follows:

Lower Band Edge (MHz)	Upper Band Edge (MHz)	Channel Width (MHz)	Licensee
2500	2570	70	For Auction
2570	2575	5	Guard Band
2575	2585	10	Australian Broadcasting Corporation
2585	2595	10	CHANNEL SEVEN SYDNEY PTY LIMITED
2595	2605	10	Nine Network Australia Pty Ltd
2605	2615	10	Network Ten (Sydney) Pty Limited
2615	2620	5	Guard Band
2620	2690	70	For Auction

The green shaded frequency range is the mid band 50MHz that will remain after the Digital Dividend auction process.

The spectrum would be contiguously assigned.

After guard bands of 5MHz to protect against adjacent users interference there would only be 40MHz useable.

The ABC, Ten Network, Channel Seven and Nine Network would each have 10MHz, which is enough for a single wireless camera link.

## ACMA proposals for alternative arrangements for ENG

The ACMA has identified an additional 260MHz (in two lots of 130MHz) of spectrum (1980-2110MHz and 2170-2300MHz) for ENG, TOB and EFP use.<sup>2</sup> The ACMA also proposes that the TOBNs will be exclusively assigned 200MHz of the 260MHz (2010-2110MHz and 2200-2300MHz) to compensate for losing spectrum in the 2.5GHz band. This leaves 60MHz of spectrum (1980-2010MHz and 2170-2200MHz) for non-TOBNs and the TOBNs on a shared non-exclusive basis.

Currently this spectrum is assigned to Mobile Satellite Services and its tenure is not secure – perhaps as short as 3 years.

There are a number of spectrum issues associated with this new spectrum:

- The 2200-2300MHz band is shared with space communications downlink and the 2010-2110MHz band is shared with space communications uplink both of which is problematical in Perth and Canberra;
- Adjacent channel spectrum is assigned to mobile phone applications WCDMA and WiMax.

## Adjacent band guard band

The new bands are adjacent to 3G and WiMax users. We have calculated that a 5MHz guard band is the likely minimum necessary for reliable operation. In some circumstances 10MHz will be required. See Appendix 1 for more details.

## Frequency reuse

There are Geographic Restrictions of the identified alternative ENG Band in Perth and Canberra due to Space Communications also using the alternative bands. See Appendix 1 for more details.

## The clearest spectrum

The clearest spectrum in the new spectrum assignment is:

- Away from the band edges (to avoid mobile phone overspill);
- In Perth and Canberra, spectrum other than in the 2200-2300MHz range to avoid Space communication disruption until 2016;
- In Perth, spectrum other than in the 2010 to 2110MHz range to avoid interference from the Landsdale uplink until 2016.

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<sup>2</sup> ACMA *Television Outside Broadcast Service (1980-2110 MHz and 2170-2300 MHz) Frequency Band Plan 2012*, 26 March 2012



## 4 Current Practice of ENG band use

There are two categories of video link use of the 2.5GHz band:

- planned events such as a sporting event; and
- unplanned events such as a breaking news story.

The links generally connect a wireless camera and may include several hops in the 2.5GHz band to relay the signal back to the studio or production facility. Each link uses the 2.5GHz band in one direction and can use a separate UHF frequency for a return path.

Digital links have replaced analogue links and reduced the spectrum required for a link from 24MHz to less than 10MHz, however additional camera links at an event are maintaining the need for the same overall amount of spectrum.

### Unplanned Events – ENG Use

A breaking news story requiring an immediate mobilisation of a news crew with wireless camera and link trunk needs to have a guaranteed and reliable link back to the studio. Spectrum dedicated to each network (ie ABC, Seven, Nine and Ten) for this purpose is entirely appropriate.

Occasionally up to 3 link hops using the 2.5GHz band maybe required to relay the signal back to the studio (for example: camera to link truck, link truck to helicopter, and then helicopter to the central collection site).

The central collection site is generally on a tower or building in the capital cities with a good line of sight visibility over most of the city. It usually has a steerable high gain antenna feeding a receiver/decoder.

Each of the TOBN's have 3 separate frequency allocations in the 2.5GHz band, each large enough for a video link of 10MHz bandwidth.

### Planned Events - TOB and EFP Use

Sporting and production events are the other uses for the 2.5GHz spectrum. Generally, details of these events and their requirements in terms of spectrum are known well in advance, sometimes 12 months ahead of the event.

On occasion, however, the location of an event may not be known until the week before due to the match venue being dependent on preceding results (for example, finals matches in the A-League, One Day Cricket, 20/20 Big Bash, Rugby and Baseball). For these events, frequency assignment needs to be rapid.

Below are some of the typical setups for differing TOB scenarios:

Event Type	Number of Wireless 2.5GHz Link Frequencies used	Bandwidth used	Total Bandwidth used if in adjacent Blocks <sup>2</sup>	Equipment
Football Stadium (Normal)	1	10MHz	10MHz	Wireless Camera
Football Stadium (Abnormal but becoming more normal) <sup>1</sup>	2	20MHz	40MHz	Additional wireless camera or flycam.
Cricket/AFL Grounds	3	30MHz	60MHz	Flycam, Segwaycam, Roving wireless AFL Goal umpires
Golf (Normal)	4	40MHz	80MHz	Wireless cameras and with high power amplifiers and high gain antennas
Golf (Abnormal) <sup>1</sup>	6	60MHz	120MHz	Wireless cameras and with high power amplifiers and high gain antennas
Marathon or bike races	7	70MHz	140MHz	2 motorbikes and 1 lead vehicle camera links to helicopter 1 Helicopter Camera 4 links from Helicopter
Special Event (Abnormal) <sup>1</sup>	6	60MHz	120MHz	E.g. Oprah Special, World Youth Day

Notes:

- 1) Abnormal means no more than several times a year
- 2) Due to adjacent channel interference problems, a guard band is usually employed between the 10MHz channels. A camera near a receive antenna can overload the wanted signal coming from a camera further away.

Recent innovations such as Umpire Glasses (camera in glasses worn by the umpire) and Oktocopter (remote control flying camera) will also require wireless bandwidth and also in the 2GHz to 2.5GHz range.

New innovations either in the pipe line or yet to be invented will only add to the demand for more links in the future.



## Typical Equipment Used By TOB

There are 3 brands of link transmitters dominantly used by the main suppliers of TOB services:

	Frequency agility (Between)	Modulation scheme	Bandwidth	Data Rate	Power
Gigawave D-Cam	2.2GHz and 2.7GHz	DVB-T 64QAM	8MHz	24Mbits	100mW
Link Research XP2	1.95GHz and 2.7GHz	LMS-T 16QAM (proprietary LR algorithm)	10MHz	19Mbits	100mW
Microlite HD 23MLT	2.2GHz and 2.4GHz	DVB-T, QPSK, 16QAM	8MHz	18Mbits	100mW

Amplifiers to give 250mW and 1W output are used for longer distances such as on a golf course.

Helicopter systems can use 2W to 5W power amplifiers. The altitude of the helicopter is dependent on the role: 300m for camera operations; 1500m for link relay; and, occasionally 3000m for long haul link relay (a light plane has also be known to be used for this long distance relay platform).

Antennas on the cameras are omni-directional with 3dB gain. Higher gain and more directional antennas can be used for the longer distances with an assistant to the cameraperson directing the antenna toward the TOB receive antenna (golf is a good example).

In stadiums, a pair of diversity reception antennas is deployed either on the sideline or on the camera deck near the players' tunnel. These antennas are omnidirectional with a nominal 3dB gain.

## The need To Use Frequencies below 3GHz

There is a need to maintain the 2GHz to 3GHz range for video links:

- frequencies above 3GHz do not lend themselves to non-line of sight propagation due to the increased attenuation losses (shoulder mounted cameras in a crowd or amongst trees and buildings is a typical scenario where higher frequency equipment fails);
- above 5GHz there are problems for camera links travelling at high speed due to Doppler shift with 2.5GHz good for speeds up to 250km/hr and 5GHz good to 125km/hr (this would affect helicopter and racing car/boat coverage).
- At higher frequencies, higher powers are required to achieve the equivalent quality of reception which means the Electro-Magnetic Radiation (EMR) levels are higher. These levels are highest at the transmit antenna which is regularly on a shoulder mounted camera or close to the body.

Consideration should also be given to the significant costs for industry that would be associated with a forced move to higher frequencies for ENG, TOB and EFP operations. There is a large existing base of equipment for outside broadcast operations used across the broadcasting industry that would need to be either re-purposed or replaced.

Internationally, the 2GHz to 3GHz frequency range is used extensively for ENG and TOB purposes.

## Number of TOBs Annually

The table below shows FOX Sports OB RF Camera Usage against the Nine Network's OB RF Camera Usage in a period from 16 Feb 2011 – 17 Feb 2012. Please note that total TX Days may include more than one system so the number of days reflects the number of times in the 12 month period that frequencies needed to be secured.

Client	Event	TX DAYS
Fox Sports	AFL	18
	AFL DRAFT	1
	CRICKET	38
	DALLY M	2
	NRL	116
	TENNIS	14
	AFL AWARDS	1
	MVP AWARDS	1
	AFL BREAKFAST	1
	FOX ON NRL	1
	ALEAGUE	6
	SUPER 15	40
	INTERNATIONAL RUGBY	6
	INTERNATIONAL FOOTBALL	6
	JOHN EALES MEDAL	1
<b>Total</b>		<b>252</b>
TCN Channel Nine	AFL LEGENDS	1
	CAROLS	2
	CRICKET	35
	GOLF	14
	HORSE RACING	14
	NRL	102
	TODAY SHOW	2
<b>Total</b>		<b>170</b>

The table below is derived from a number of sources to show the approximate days per year that at least one 2.5GHz link is used in a TOB (i.e. on some days multiple links are used but counted as a single day).

	TOB 2.5GHz Transmission Days per Year
TOBN's	350
Non-TOBN's	600
<b>Total</b>	<b>950</b>

The non-TOB's are currently responsible for over 60% of the TOB 2.5GHz transmission usage.

## Current Practice for Frequency Assignment

For a TOB for the TOBNs, the frequencies used come from within the networks' assigned 2.5GHz ENG spectrum. If more are required for a major event then they are "borrowed" from another network.

The non-TOBNs, must either "borrow" ENG spectrum from the TBONs or request spectrum from the ACMA. When requested, the ACMA has been temporarily assigning a frequency outside to the 2.5GHz band in the Mobile Satellite Services (MSS) bands (1980-2010MHz and 2170-2200MHz) for TOB use.

There have been occasions when three frequencies are required, one being borrowed from the TBONs and two requested from the ACMA however only one being forthcoming from the ACMA.

The practice of borrowing ENG spectrum from the FTA Networks or having temporary assignments leaves no certainty for non-TBON users.

## 5 Models for Spectrum Sharing

### United Kingdom Model – OFCOM

The United Kingdom communications regulator Ofcom outsources the management of UK TOB spectrum for "Program Making and Special Events" (PMSE). PMSE use includes a much wider range of usage including wireless microphones, talkback channels etc.

In the 2GHz range they have the following available:

Frequency Range	Designated Usage
2025 -2110MHz	Video used on the basis of no interference to, and no-protection from, MoD Services operating in 2025-2070 MHz.
2200 -2300MHz	Video used on the basis of no interference to, and no-protection from, MoD Services operating in 2200-2245 MHz.
2390 - 2500MHz	Video.

Ofcom has contracted JFMG Ltd to manage and license the radio spectrum used for PMSE. This means that JFMG is authorised to grant PMSE licences on Ofcom's behalf. JFMG has been the spectrum manager since 1997. JFMG's contract was recently extended for another 5 years after a re-tendering process. JFMG are privately owned and independent of Ofcom.

JFMG operates an extensive online booking system that includes fee payment and invoicing to pre-registered users. Large events are coordinated manually.

Relevant equipment needs to meet Ofcom technical specifications as outlined in the document "UK Interface Requirement 2038 – Programme Making and Special Events".<sup>3</sup> An extract is below:

Annex A4 - Minimum Requirements for Programme Video Links				
Wireless telegraphy apparatus designed or adapted for carrying broadcast-quality video together with music and/or speech signals.				
Frequencies or Frequency Band (GHz)	Radiated level	Maximum Channel Bandwidth	Notes	Reference Standard <sup>1</sup>
2.025 to 2.110	30 dBW <sub>erp</sub>	10 MHz	Digital video links and Wireless cameras.	EN 302 064
2.200 to 2.290	30 dBW <sub>erp</sub>	10 MHz	Digital Wireless cameras	
2.39 to 2.69	20 dBW <sub>erp</sub>	20 MHz	Temporary point-to-point, mobile & portable links. Digital Wireless cameras	
2.39 to 2.69	40 dBW <sub>erp</sub>	20 MHz	Temporary point-to-point, mobile & portable links. Analogue Wireless cameras	

The system provides users with information on the restrictions for use for each frequency as it is booked and this potentially reduces the possibility of interference.

An extract from the Technical Licence Conditions showing some of the restrictions is below:

<sup>3</sup> Ofcom UK Interface Requirement 2038 – Programme Making and Special Events Feb 2006

## Report on ACMA's Proposed new 2GHz ENG Bands

Band	Frequency (MHz)	Maximum in-band power (ERP)	BEM	Apparatus/restrictions	Airborne
76	2390-2410	40 dBW	16	Not available within an exclusion zone of 5 km radius around Bude (SS 205 126), Menwith Hill (SE 209 561), Manorbier (SS 074 967) and Hebrides (NF 781 406).	
77	2410-2450	40 dBW	16	Not available within an exclusion zone of 5 km radius around Bude (SS 205 126), Menwith Hill (SE 209 561), Aberporth (SN 247 518), Shoeburyness (TQ 949 857), Eskmeals (SD 070 930), Pendine Sands (SN 252 087), Fort Halstead (TQ 497 600), Farnborough (SU 850 544), Hum (SZ 083 982), Chertsey (TQ 497 166) and Copehill Down (Salisbury Plain) (SU 065 455).	
78	2410-2450	20 dBW	16	Not available for airborne use (i) in the airspace volume described by $\pm 1^\circ$ of elevation from the geostationary arc (for elevation of $4^\circ$ or more) of an earth station within 5 km radius of Bude (SS 255 116) and Menwith Hill (SE 205 594), (ii) within 5 km of Bude (SS 255 116), Menwith Hill (SE 205 594), Copehill Down (Salisbury Plain) (SU 065 455), Eskmeals (SD 070 930), Pendine Sands (SN 252 087), Fort Halstead (TQ 497 600), Farnborough (SU 850 544), Hum (SZ 083 982) and Chertsey (TQ 497 166) or (iii) within an exclusion zone of 64 km/1,000 feet above ground level from Aberporth (SN 247 518) and Shoeburyness (TQ 949 857).	Yes

Fees for booking a frequency are reduced if booked online rather than manually via telephone or email. A screen shot is shown below:

[Home](#) > [Our Fees](#) > [Video Links](#)

### Video Link Fee Calculator

#### Frequency Range

2 - 5 GHz

- ☐ Analogue - Up to 20 MHz Bandwidth  
☒ Digital - Up to 10 MHz Bandwidth

<b>Start Date</b> 1 Aug 2012 <b>Start Time</b> 0000	<b>Finish Date</b> 1 Aug 2012 <b>Finish Time</b> 2400
--	--

Calculate

Cost for 1 Day(s) and 0 Hour(s) £56.00 per frequency

Or 2 Category 15 Carnet(s)

£24.00 Or 2 Category 85 Carnet(s) per frequency if booked on-line (subject to frequency availability)

Note that for 24hours the fee is GBP56 or GBP24 if booked on line.  
And for 12 hours the fee reduces to GBP12 if booked on-line but still GBP56 if not booked on-line.

There is a "No refunds" policy – that is, no refunds are available if the event doesn't proceed, frequencies are not used or errors entered in the booking system.

The advantages of this approach are:

- Provides a historical usage pattern which currently the Australian system does not easily produce;
- The user pays system discourages spectrum hoarding or blocking;
- The system is relatively self-managing as the users themselves can book on line and also view what is available;
- Being independent, JMFG are in a position to be seen to make fair and unbiased decisions if there is contention for frequencies.

## New Zealand Model

In New Zealand, a 200MHz block between 2.7GHz and 2.9GHz is allocated for ENG and TOB.

This spectrum is divided into six 30MHz blocks and/or nineteen 10MHz blocks.

A 5MHz guard band is employed at the top and bottom of the 200MHz for protection to and from adjacent services.

### OX Band 2700 - 2900 MHz

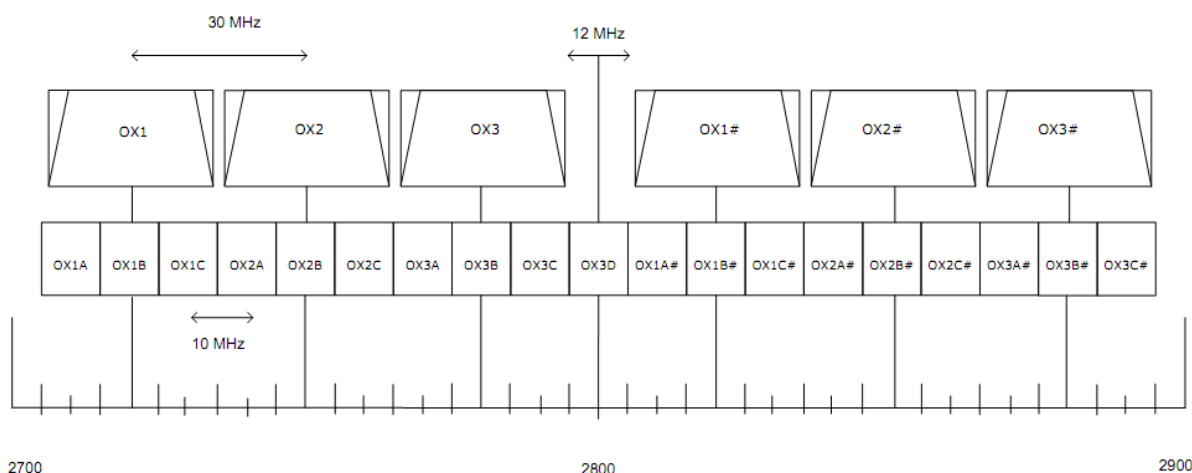


Diagram above Sourced from Ministry of Economic Development, PIB 22, Issue 7 November 2011. The six 30MHz blocks allow for analogue links and the 10MHz blocks for digital links. In practice analogue links are almost never used nowadays.

There are three licenced users, Television New Zealand, Kordia and the New Zealand Racing board. All three organisations are licenced to operate on any frequency and country-wide. Fees are nominal, not dependant on usage and paid annually.

Television New Zealand (TVNZ – the National Broadcaster) uses the band for ENG and for TOB. In the three major cities (Auckland, Wellington and Christchurch) TVNZ has a high Central Collection Site with a steerable antenna and good visibility to most of the city for ENG purposes. In each city it also has at least one link truck each with associated wireless camera or cameras, and a TOB truck with three wireless cameras.

Kordia uses the band to provide linking back to clients' studios when no permanent link exists and predominately for weekly sporting outside broadcasts. They have eight 2W links, four low power camera back links and a 5W helicopter link.



The New Zealand Racing Board (horse racing) uses the band for wireless cameras, with up to five cameras operating on a race course during race meetings. The Board has approximately 20 camera links – these cameras are moved around the country to provide racing coverage and could be operating at four race courses simultaneously. This band is not used for linking the race courses to the studio but solely for wireless cameras.

The New Zealand regulator, the Ministry of Economic Development, is not involved with the in band frequency co-ordination. A requirement of the licence is that licensees agree to co-ordinate with all other nominated parties (ie the other users) and provide contact details which need to be kept up to date.

Co-ordination to prevent interference between the three users is achieved by a weekly email between the three users. The email lists the frequencies to be used, locations, times and durations.

The advantage of this approach is that it is self-managing (with no regulator or third party input required) and low cost. Aspirant new users would need to apply for a licence and then join the co-ordination group.

Feedback is that the system works quite well thanks to the relatively small number of users and geographical isolation between the users.

A potential issue could arise when insufficient spectrum is available for all users. Who gets priority and who makes the decision? Currently in the absence of a clear set of "rules" then ultimately the regulator would have to make the decision. If Australia were to implement such a system then a clear set of guidelines would need to be developed and agreed upon.

## 6 Licencing Mechanisms

There are three types of licence for spectrum use available under the *Radiocommunications Act 1992*:

- Apparatus licence
- Class Licence
- Spectrum Licence

**Apparatus licence** – An apparatus licence authorises the operation of an individual device or type of device or devices at a particular location or locations and with specified output characteristics to deliver an approved service. Apparatus licences are generally purchased over the counter from the ACMA for a fixed fee for a maximum of 5 years and may only transfer (sell) their licence to other operators with the prior approval of the ACMA. However, in practice, apparatus licensees trade their licences whenever they wish, as the ACMA encourages licence trading.

**Class Licence** – Under a class licence, all users operate in the same spectrum segment on a shared basis and are subject to the same licence conditions. These conditions prescribe the frequencies that may be used, common equipment standards and any other relevant technical and operational parameters. Class licences do not have to be applied for and no licence fees are payable as the license is not issued to individuals. They automatically authorise anyone to use complying devices on a no interference/no protection basis within the band. They are typically used for remote locking devices (for vehicles and garage doors), wireless headsets for mobile phones, remote control for TV, CB radio operation, WiFi and much more.

**Spectrum Licence** – provides exclusive spectrum access ('private spectrum') to a single licensee. The licence gives access Australia-wide or a large geographic area, for a 15 year term and usually awarded through an auction process conducted by the ACMA. Interference is managed at the frequency and geographic boundaries and this gives the license a degree of technology flexibility.

Currently the ENG spectrum from 2.5GHz to 2.690GHz is issued as separate Apparatus Licences to the TOBN's. However, as part of the spectrum re-allocation process for the Digital Dividend, the spectrum within the band 2570-2620 MHz has been designated by the Minister for Broadband, Communication and the Digital Economy as part of the spectrum to be allocated by issuing spectrum licences.<sup>4</sup>

**Private Park Concept** – An alternative to the licence types above and contemplated by the ACMA in the past for other bands the Private Park concept. This is similar to a class licence (as per above) but only registered users are eligible to operate in the spectrum. This provides a degree of flexibility not available in the other forms of licencing. Key to this concept is that it is "managed" spectrum for the users and potentially by the users. This can result in the most efficient use of the spectrum.

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<sup>4</sup> Radiocommunications (Spectrum Designation) Notice No. 1 of 2012.

## 7 Preferred Model for Australia

This report has established that 30MHz of spectrum per TOBN (to a total of 120MHz) is sufficient for current and future ENG needs of the existing commercial and national television broadcasting services. After spectrum is allocated in both the mid-band gap of the 2.5 GHz band, and in 1980-2110 MHz and 2170-2300 MHz bands to ensure the ENG operations of the incumbent TOBN users, 160 MHz of spectrum could be made available for planned TOB and EFP operations, to be shared by all operators with TOB and EFP requirements, including the incumbent TOBNs.

The ACMA suggests<sup>5</sup> that bands 1980-2010MHz and 2170-2200MHz will be available on a shared non-exclusive basis with licensees required to self-coordinate usage with other TOB users. We recommend that these principles of non-exclusive, shared spectrum access, with industry-based coordination of spectrum use, should be extended to the 160MHz of spectrum identified in this report as available after ongoing ENG spectrum needs for the incumbent broadcasters are satisfied.

Shared use would be most efficiently and effectively implemented through a system of bookable spectrum. The ideal Australian solution for booking this spectrum is likely to be somewhere between the current practice and the UK model (as outlined in the previous Chapter). This could be in the form of a private park concept for registered users managed by the licensees or outsourced to an independent organisation.

The advantages of a systematic booking system:

- Provides certainty ahead of events
- Provides certainty for purchasing equipment
- An online system is likely to be quicker than the current assignment process
- Allows other users such as the Earth/Space services to also co-ordinate and view potential interference sources
- Provides ACMA with a usage history to demonstrate spectrum utilisation and efficiency.
- A booking system with known constraints and limits may allow for more spectral efficiency than for the current practice

Funding for the costs of running the booking system could be met by the users who would be charged a booking fee. In a private park concept, this would be additional to an annual licence fee to be eligible to use the spectrum.

### Potential Frequency Plan

Below is a notional frequency assignment plan that allocates each TOBN three blocks of 10MHz for exclusive use as ENG, a total of 120MHz for ENG. Exactly where the dedicated ENG blocks sit within the spectrum is notional in the plan below however it should be assigned in the most reliable and interference free portion to give the best certainty for linking to the unplanned events (i.e. News).

The purpose of the plan below is to show that after allowing for 5MHz guard bands, there is 160MHz available as bookable spectrum for TOBs in four blocks of 40MHz, additional ENG and EFP.

Lower Band Edge (MHz)	Upper Band Edge (MHz)	Channel Width (MHz)	Users	Purpose
1980	1985	5	Guard Band	Guard Band
1985	2025	40	For the existing TOBN licensees and others	Bookable for TOB
2025	2035	10	Australian Broadcasting Corporation	ENG

<sup>5</sup> "Review of the 2.5GHz band and long term arrangements for ENG" by ACMA October 2011

# Report on ACMA's Proposed new 2GHz ENG Bands

2035	2045	10	CHANNEL SEVEN SYDNEY PTY LIMITED	ENG
2045	2055	10	Nine Network Australia Pty Ltd	ENG
2055	2065	10	Network Ten (Sydney) Pty Limited	ENG
2065	2105	40	For the existing TOBN licensees and others	Bookable for TOB
2105	2110	5	Guard Band	Guard Band

2170	2175	5	Guard Band	Guard Band
2175	2215	40	For the existing TOBN licensees and others	Bookable for TOB
2215	2225	10	Australian Broadcasting Corporation	ENG
2225	2235	10	CHANNEL SEVEN SYDNEY PTY LIMITED	ENG
2235	2245	10	Nine Network Australia Pty Ltd	ENG
2245	2255	10	Network Ten (Sydney) Pty Limited	ENG
2255	2295	40	For the existing TOBN licensees and others	Bookable for TOB
2295	2300	5	Guard Band	Guard Band

2500	2570	70	For Auction	
2570	2575	5	Guard Band – not usable	
2575	2585	10	Australian Broadcasting Corporation	ENG
2585	2595	10	CHANNEL SEVEN SYDNEY PTY LIMITED	ENG
2595	2605	10	Nine Network Australia Pty Ltd	ENG
2605	2615	10	Network Ten (Sydney) Pty Limited	ENG
2615	2620	5	Guard Band – not usable	
2620	2690	70	For Auction	

Highlighted in green is the bookable spectrum i.e. four blocks of 40MHz.

The ENG allocation effectively has additional guard bands in the 40MHz of Bookable TOB above and below.

The Table below shows the type of restriction relevant to band under consideration. Appendix 1 has more details.

Lower Band Edge (MHz)	Upper Band Edge (MHz)	Channel Width (MHz)	Victim	Potential Interferers
1980	1985	5	Guard Band – not usable	
1985	2025	40	1985-1990 MHz Camera Link Rx VHA 3G Base Station Rx 1990-2025 MHz Camera Link Rx	VHA 3G Mobile Handset Tx Camera Link Tx Earth station Tx (Narrow band)(PER, CAN)
2025	2035	10	Camera Link Rx	Earth Station Tx (PER, CAN)
2035	2045	10	Camera Link Rx	Earth Station Tx (PER, CAN)
2045	2055	10	Camera Link Rx	Earth Station Tx (PER, CAN)
2055	2065	10	Camera Link Rx	Earth Station Tx (PER, CAN)
2065	2105	40	2065 -2100 Camera Link Rx 2100-2105 MHz Camera Link Rx	Earth Station Tx (PER, CAN) VHA 3G Base Station Tx
2105	2110	5	Guard Band – not usable	

2170	2175	5	Guard Band – not usable	
2175	2215	40	2175-2180 MHz Camera Link Rx 2180-2200 is clear Earth Station Rx (PER, CAN)	VHA 3G Base Station Tx  Camera Link Tx
2215	2225	10	Earth Station Rx (PER, CAN)	Camera Link Tx
2225	2235	10	Earth Station Rx (PER, CAN)	Camera Link Tx
2235	2245	10	Earth Station Rx (PER, CAN)	Camera Link Tx
2245	2255	10	Earth Station Rx (PER, CAN)	Camera Link Tx
2255	2295	40	2255-2290 MHz - Earth Station Rx 2290-2295 MHz Camera Link Rx WiMax Rx	Camera Link Tx WiMax Base Station Camera Link Tx
2295	2300	5	Guard Band – not usable	

Note 1: Airborne operation is possible in the lower band and should be avoided in the upper band between 2200MHz and 2300MHz in Perth and Canberra (See Appendix 1).

## **APPENDIX 1 – Compatibility Study**

### **Proposed ENG Frequency Allocation Compatibility Study with Existing Services**



# 1 Compatibility Introduction

In order to study the compatibility of the proposed Frequency band allocation for the ENG services it is necessary to know the adjacent allocations around the proposed frequency band.

Figure 1 below shows the proposed ENG frequency band and the existing allocations in the adjacent bands. Frequency band 1920 to 1980 MHz (Mobile Transmit) and 2110 to 2170 MHz (Base Station Transmit) is the WCDMA(3G) spectrum allocation. Frequency band 2300 to 2400 MHz is the Spectrum allocation for WiMax which is on Time Division Duplex (TDD) meaning the same frequency is used for transmitting and receiving. For the 3G, channel bandwidth is 5 MHz and for WiMax it is 10MHz.

The frequency bands adjacent to the ENG allocation are licensed for Vodafone Hutchinson Australia (VHA). In metropolitan areas VHA has 10MHz spectrum and in regional areas they own 5 MHz and the adjacent 5MHz is owned by Telstra. In metro areas, first 20 MHz of the spectrum adjacent to the 2300MHz belongs to Vivid Wireless but for Canberra the band 2302 to 2033 MHz remains unallocated.

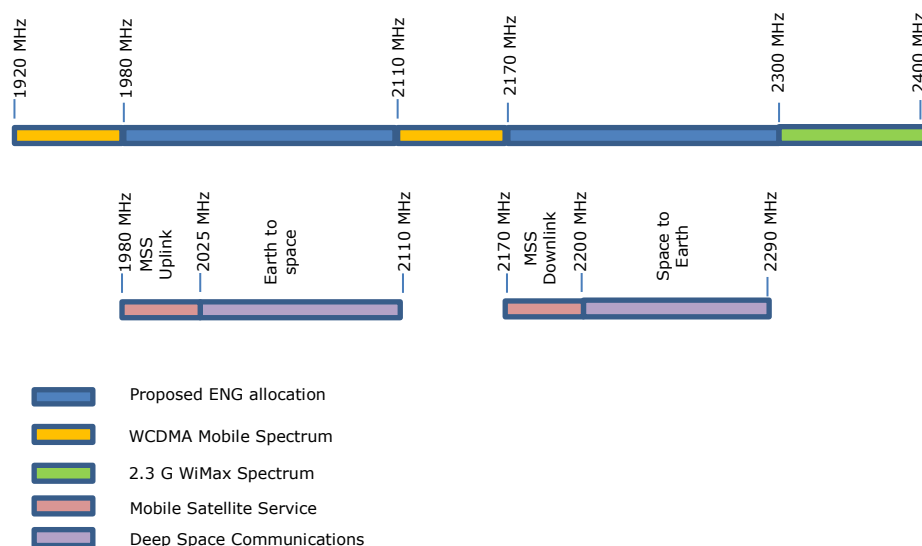


Figure 1: ENG allocation and adjacent bands

The proposed frequency band for Camera Link has incumbent users as well as depicted in above figure. Frequency bands from 1980 to 2025 MHz and 2170 to 2200MHz have been allocated for Mobile Satellite Service (MSS) Uplink and Downlink respectively.

Frequency bands from 2025 to 2110 MHz and 2200 to 2290 have been allocated for Deep Space Communications Uplink and Downlink respectively. The MSS band is currently not in use but the concern is the DSS band which is in use in Canberra (Tidbinbilla), Perth (Landsdale), New Norcia and Mingenew Earth Stations. Perth Earth Station operations will cease by 1, January 2016.

For satisfactory operation of Camera Link, mutual interference from the above services need to be assessed. The following types of interference have been identified for consideration:

- 3G Mobile transmit into Camera Link receive (lower 1980 to 2110 MHz band)
- 3G BS transmit into Camera Link receive (upper 1980 to 2110 MHz band & Lower 2170 to 2300 band)
- Wimax Transmit into Camera Link receive (upper 2170 to 2300 MHz band)

- Camera Link transmit into 3G BS receive (lower 1980 to 2110 MHz band)
- Camera Link transmit into 3G Mobile receive (upper 1980 to 2110 MHz band & Lower 2170 to 2300 band)
- Camera Link Transmit into Wimax receive (upper 2170 to 2300 MHz band)
- Mutual interference between the Camera link and each of the Earth Stations.

In the adjacent bands we need to calculate the adjacent channel interference.

Adjacent channel Interference Ratio (ACIR) is contributed by Adjacent Channel Leakage Ratio (ACLR) of the interfering transmitter and Adjacent channel selectivity (ACS) of the victim receiver and is given by  $ACIR-1 = ACLR-1 + ACS-1$ . We have assumed the new digital video receivers have high adjacent channel selectivity, therefore we have ignored the effect of ACS and taken ACIR as approximately equal to ACLR and used in our calculations.

This appendix covers the compatibility of the proposed system with existing services within and around the band.

## 2 Interference from other services into Camera link receiver

### 3G Mobile Transmitter into Camera link receiver

For operation of the Camera Link receiver in the 1980 to 2110 MHz band the interference from a 3G mobile phone into the Camera Link receivers need to be studied. In order to quantify the interference from a 3G mobile phone into the Camera Link receiver we need to consider the Adjacent Channel Leakage power Ratio (ACLR) of the 3G mobile transmitter. Below is the ACLR specification for the 3G User Equipment (Mobile) reproduced from 3GPP TS 25.101 V11.0.0 (2011-12)<sup>1</sup>. Most of the older mobiles are class 4 and some new mobiles are class 3.

Handset Power Class	Adjacent channel frequency relative to assigned channel frequency	ACLR limit
3 & 4	+ 5 MHz or - 5 MHz	33 dB
3 & 4	+ 10 MHz or - 10 MHz	43 dB

Table 1: 3G Mobile ACLR specifications

Figure 2 below shows a case where the 3G 5MHz carrier is adjacent to a 10MHz slot of the proposed Camera Link spectrum. In this case we need to consider the Adjacent Channel Leakage power from the 5MHz 3G transmitter into the 10 MHz Camera Link receiver.

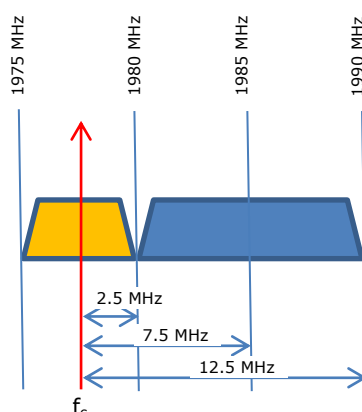


Figure 2: 3G Mobile Transmitter and adjacent 10MHz Camera Link Receiver

Mobile transmitter power for the Class 3 Mobile is +24dBm (tolerance +1 or -3 dB)<sup>1</sup> and for the class 4 Mobile is +21 dBm (tolerance +2 or -2 dB)<sup>1</sup>. Mobile power per MHz is calculated by  $+24 - 10 \cdot \log(4)$  where 4MHz is assumed to be the occupied bandwidth of the modulated signal. This gives a transmit power of  $+24 - 6 = +18$  dBm/MHz. Adjacent channel leakage (ACL) power is as follows.

+18 -33 = -15dBm/MHz for Frequency off set of 2.5 to 7.5 MHz and

+18-43 = -25 dBm/MHz for Frequency off set of 7.5 to 12.5 MHz

Based on the above calculated mean ACL power in the 10MHz bandwidth is -7.39 dBm.

Calculation of Wanted signal to Unwanted signal ratio:

For satisfactory operation Carrier to Interference (C/I) ratio should be better than 20dB<sup>2</sup>. This is the wanted signal to unwanted signal ratio and is calculated as follows:

$W/UW = \text{Camera EIRP} - \text{Mobile EIRP} - 20 \log (\text{Camera range from receiver} / \text{Mobile range from receiver})$

$= 23 - (-10.6) - 20 \log (D/d) = 33.6 - 20 \log (D/d) \geq 20$

Ie  $33.6 - 20 \log (D/d) - 20 \geq 0$

From the above, the ratio of  $d/D$  should be  $\geq 0.302$  to satisfy the C/I target of 20dB.

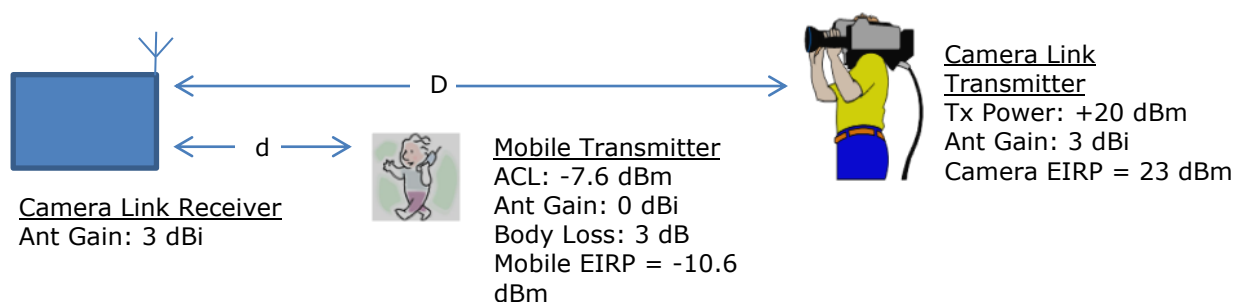


Figure 3: Interference from 3G mobile phone – Land based operation

Minimum distances of 3G mobile phones from the camera link required for satisfactory operation of the camera link transmitter for power options of 100mW, 200mW, 2W and 5W were calculated receiver with guard bands of 0, 5 and 10 MHz respectively were calculated and presented in table below. Considering that the ranges of the transmitting devices in close proximity to the receiver, free space propagation conditions have been assumed. No allowances have been made for any clutter loss or body loss.

Camera Dist	3G MS-Camera Tx: 20 dBm - 0 GB	3G MS-Camera Tx: 23 dBm - 0 GB	3G MS- Camera Tx: 33 dBm - 0 GB	3G MS-Camera TX: 37 dBm - 0 GB	3G MS-Camera Tx: 20 dBm - 5MHz GB	3G MS-Camera Tx: 23 dBm - 5MHz GB	3G MS- Camera Tx: 33 dBm - 5 MHz GB	3G MS- Camera TX: 37 dBm - 5MHz GB	3G MS-Camera Tx: 20 dBm - 10MHz GB	3G MS-Camera Tx: 23 dBm - 10MHz GB	3G MS- Camera Tx: 33 dBm - 10 MHz GB	3G MS- Camera TX: 37 dBm - 10MHz GB
5	1.5	1.1	0.3	0.2	0.5	0.3	0.1	0.1	0.4	0.3	0.1	0.1
10	3.0	2.1	0.7	0.4	0.9	0.7	0.2	0.1	0.7	0.5	0.2	0.1
20	6.0	4.3	1.4	0.9	1.9	1.3	0.4	0.3	1.4	1.0	0.3	0.2
50	15.1	10.7	3.4	2.1	4.7	3.3	1.1	0.7	3.5	2.5	0.8	0.5
100	30.2	21.4	6.8	4.3	9.4	6.6	2.1	1.3	7.1	5.0	1.6	1.0
200	60.4	42.8	13.5	8.5	18.8	13.3	4.2	2.7	14.2	10.0	3.2	2.0
500	151.1	107.0	33.8	21.3	47.0	33.2	10.5	6.6	35.4	25.1	7.9	5.0

Table 2: Calculated distances of Mobile phone Vs Camera Link Transmitter from the Camera Link Receiver

In this analysis only a single mobile has been considered. But in a real situation there will be several mobile users in the area and the sum of all the interferers should be taken into account. On the other hand we have taken the full power of class 3 Mobile. The mobiles have power ramp down feature which according to its range from the 3G base station (Node B) controls its power. If the base station is near to the mobile then the power would be minimum and if it is far away from the base station then the power would be maximum.

Figure 4 shows the break-even distances for the 3G mobile phone against the Camera link transmitter in relation to the Camera link receiver. All distances are in metres. In summary adjacent channel operation is not practical in most of the cases.

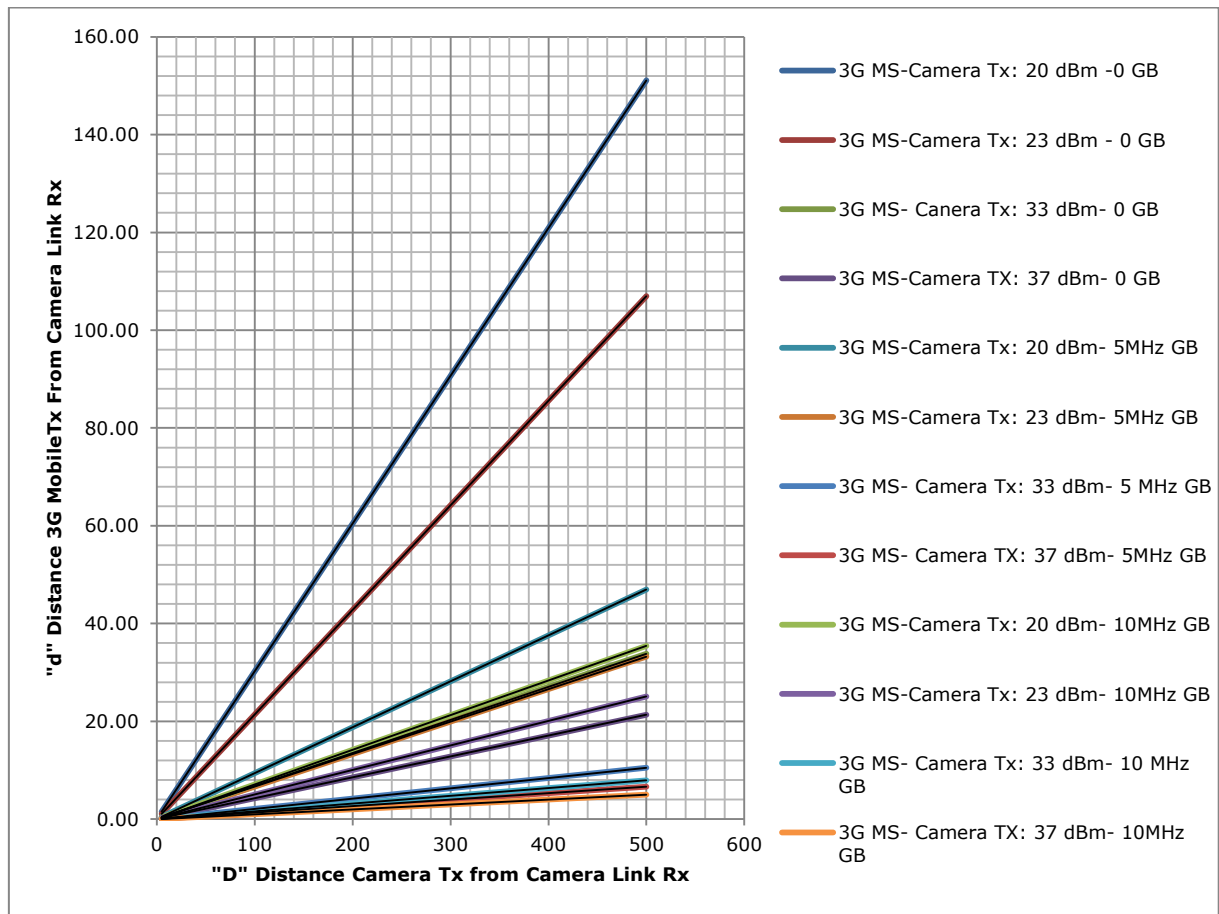


Figure 4: Graph of Camera link Tx distances Vs 3G mobile Tx distances from Camera Link Rx for various combinations of Camera link Tx power and guard bands.

### News Gathering by Helicopter

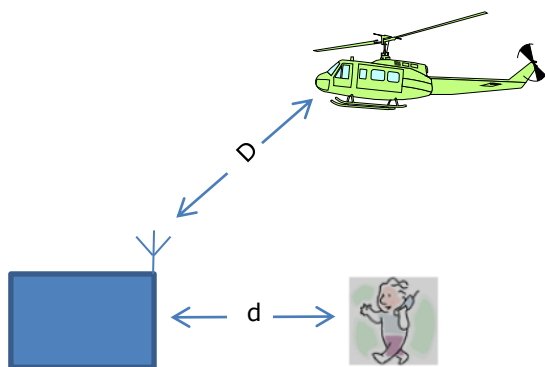


Figure 5: Interference from 3G mobile phone – Airborne operation

The same theory applies to this scenario as well. In this the range "D" is the slant distance from the helicopter to the Camera Link receiver.

### 3G Base Station Transmitter into Camera Link receiver

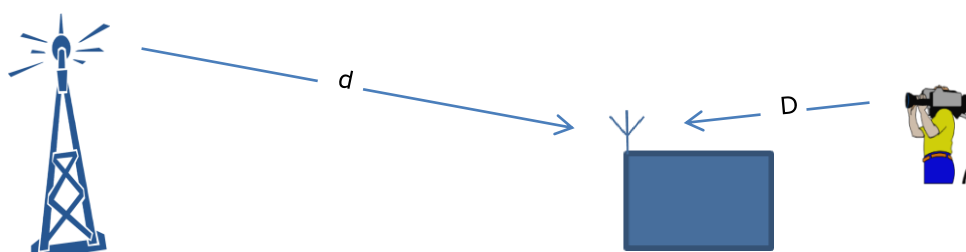


Figure 6: Interference from 3G Base Station Transmitter into Camera Link Receiver

For operation of the Camera Link service in the 2170 to 2300 MHz band the Interference from a 3G Base Station into the Camera Link base receivers need to be studied. Two adjacent channels one between 2100 to 2110 and 2170 to 2180 may suffer from interference from the 3G base station depending on the spatial separation between the two and the nature of the propagation path. Adjacent channel leakage power requirement for 3G base stations is given in table below<sup>3</sup>.

BS adjacent channel offset below the first or above the last carrier frequency used	ACLR Limit
5 MHz	45 dB
10 MHz	50 dB

Table 3: 3G Base Station Adjacent Channel Leakage power Ratio (ACLR) Specifications

For a BS with +43dBm power, calculated power leak into the adjacent 10MHz bandwidth is 0.33 dBm. Assuming a BS antenna gain of 18dBi EIRP in the adjacent channel is 18.33 dBm. To calculate the unwanted signal from the 3G BS into the Camera Link receiver we can consider two scenarios:

- 1) 3G BS and the Camera link receiver are closely located.  
In this case we assume line of sight propagation and the loss can be found using the free space formula.  
EIRP difference (Wanted – Unwanted) = 23-18.33 = 4.66 dBm  
Path differential = 20 LOG(D/d)  
For 20 dB C/N,  $5.8 - 20 \text{ LOG}(D/d) - 20 \geq 0$   
 $d/D \geq 5.85$   
where d: distance of the base station from the Camera link receiver &  
D: distance of the camera link transmitter from the camera link receiver.
- 2) 3G BS located at more than 1km from the Camera Link receiver.  
For distances greater than or equal to 1 km, Cost 231 model was used to calculate the unwanted signal and the free space model for the wanted signal. This is the model that is used for 3G coverage prediction. The worst case wanted to unwanted ratio for Camera at 300m and BS at 1 km from the Camera Link receiver was found to be 55dB. This has a margin better than 35 dB above the requirement and will not cause any interference.

In summary if the base station distance is more than 1 km then adjacent channel operation is possible and if there is clear line of sight between the base station and the Camera link receiver then the adjacent channel operation is not possible.



## Use of Guard Band

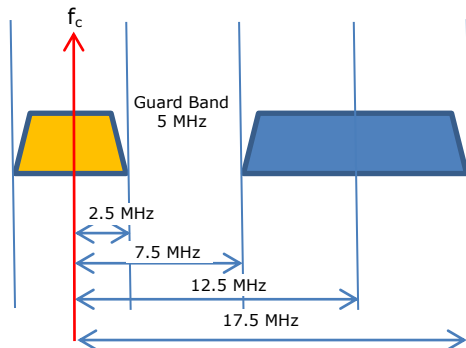


Figure 7: 3G BS Tx and Camera Link Rx with 5 MHz Guard Band

The above shows the 3G BS transmitter and Camera link receiver with a 5 MHz guard band. ACLR from the 3G BS transmitter for the 7.5 to 12.5 MHz offset is 50dB below carrier.

Unwanted power in the band 12.5 to 17.5 MHz offset is  $43-50 = -7$  dBm

Spurious emission in the next 5 MHz band 12.5 to 17.5 MHz band =  $-30\text{dBm/MHz} = -20$  dBm/10MHz or  $-23$  dBm/5 MHz. Total power in the 10 MHz bandwidth is  $-6.89$  dBm.

Assuming a BS antenna gain of 18dBi, EIRP in the adjacent channel is 11.11 dBm.

EIRP difference (Wanted – Unwanted) =  $23-11.11 = 11.89$  dBm

Path differential =  $20 \text{ LOG}(D/d)$

For 20 dB C/N,  $11.89 - 20 \text{ LOG}(D/d) - 20 \geq 0$

$d/D \geq 2.54$

If the guard band is increased to 10 MHz spurious noise in the channel is  $-30 + 10 \text{ LOG}(10) = -20$  dBm/10MHz. For an 18dBi antenna gain EIRP =  $-2$  dBm

For 20 dB C/N,  $25 - 20 \text{ LOG}(D/d) - 20 \geq 0$

Camera Dist	3G BS-Camera Tx: 20 dBm - 0 GB	3G BS-Camera Tx: 23 dBm - 0 GB	3G BS- Camera Tx: 33 dBm- 0 GB	3G BS-Camera TX: 37 dBm- 0 GB	3G BS-Camera Tx: 20 dBm- 5MHz GB	3G BS-Camera Tx: 23 dBm- 5MHz GB	3G BS- Camera Tx: 33 dBm- 5 MHz GB	3G BS- Camera TX: 37 dBm- 5MHz GB	3G BS-Camera Tx: 20 dBm- 10MHz GB	3G BS-Camera Tx: 23 dBm- 10MHz GB	3G BS- Camera Tx: 33 dBm- 10 MHz GB	3G BS- Camera TX: 37 dBm- 10MHz GB
5	29.2	20.8	6.6	4.2	22.3	15.8	5.0	3.2	0.4	0.3	0.1	0.1
10	58.5	41.6	13.2	8.3	44.7	31.6	10.0	6.3	0.7	0.5	0.2	0.1
20	117.0	83.2	26.3	16.6	89.3	63.2	20.0	12.6	1.4	1.0	0.3	0.2
50	292.4	208.1	65.8	41.5	223.4	158.1	50.0	31.5	3.5	2.5	0.8	0.5
100	584.8	416.2	131.6	83.0	446.7	316.2	100.0	63.1	7.1	5.0	1.6	1.0
200	1169.5	832.3	263.2	166.1	893.4	632.5	200.0	126.2	14.2	10.0	3.2	2.0
500	2923.8	2080.8	658.0	415.2	2233.6	1581.2	500.0	315.5	35.4	25.1	7.9	5.0

Table 4: : Calculated distances of 3G BS Vs Camera Link Tx from the Camera Link Receiver

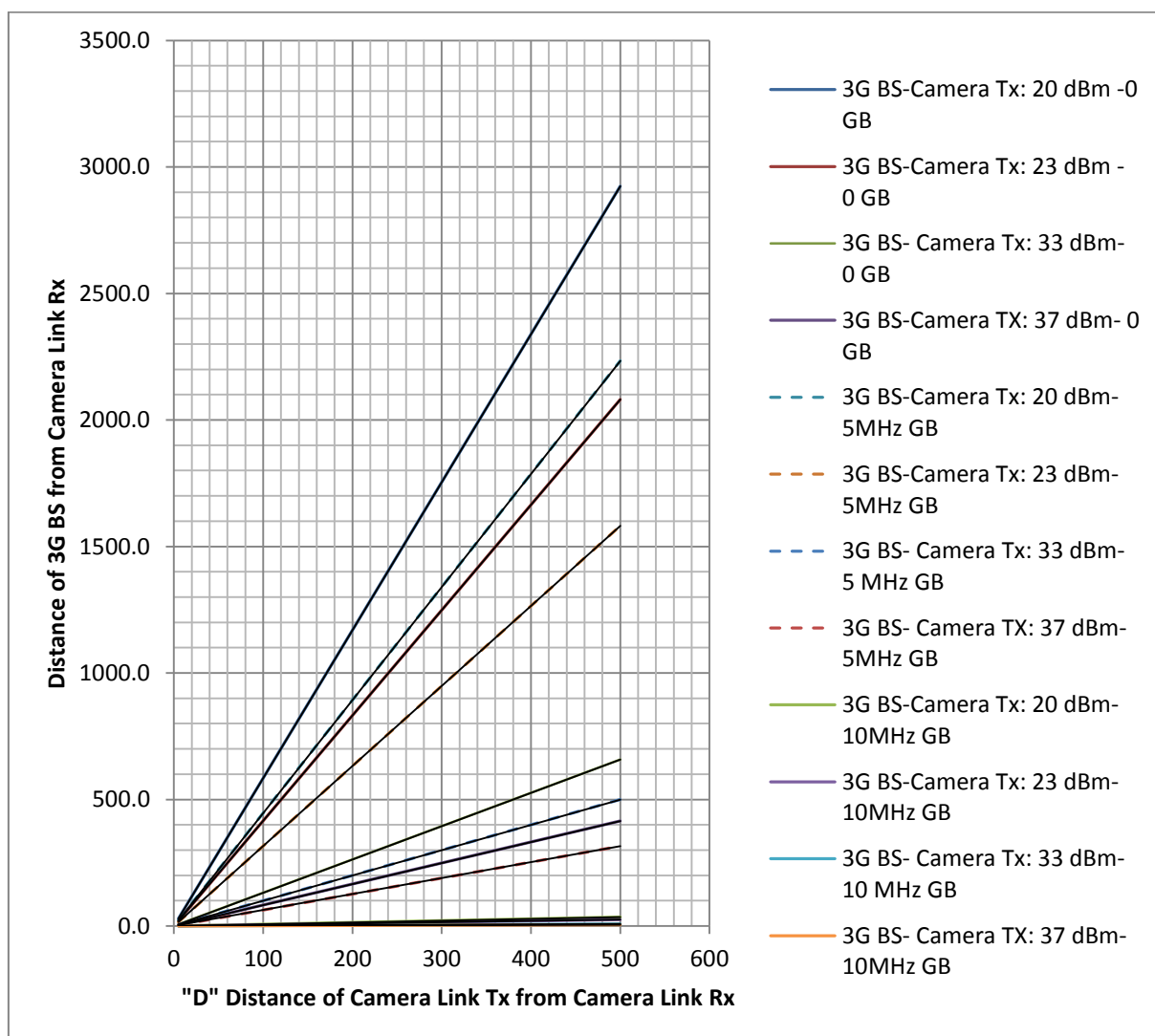


Figure 8: Graph of Camera link Tx distances Vs 3G BS Tx distances from Camera Link Rx for various combinations of Camera link Tx power and guard bands.

## Wimax Base Station Transmitter into Camera Link receiver

Wimax spectrum licence covers the band 2300 to 2400MHz. Any Wimax base stations located in the area where Camera Link service is to be used may cause adjacent channel interference into the Camera Link receiver operating at the upper end of the 2170 to 2300 band. ACMA have stipulated<sup>4</sup> the Out of band emission levels for the 2300 to 2400 MHz spectrum licence as in table below.

Offset from channel edge MHz	OoB emission dBm/30 kHz	OoB converted dBm/MHz
0-1	10	+25.2
1 – 3.5	5	+20.2
3.5 - 5	0	+15.2
5-7	-10	+5.2
7-17.5	-16	-0.8

Table 5: ACMA 2300MHz Out of Band emission specifications

This works out to +23.375 dBm in the 10MHz bandwidth covered by 2290 to 2300MHz band.

To establish a distance ratio following assumptions have been made:

Camera Link transmit EIRP = 23 dBm

WiMax BS to Camera Link Receiver distance = d

Camera Link Transmitter to Camera Link receiver distance = D

$$\begin{aligned} \text{Wanted / Unwanted ratio} &= \text{EIRP}_{\text{Camera Link}} - \text{EIRP}_{\text{WiMax}} - 20 \cdot \text{LOG}(D/d) \\ &= (23-28.17) - 20 \cdot \text{LOG}(D/d) \end{aligned}$$

For C/I ratio to be better than 20dB,  $-5.17 - 20 \cdot \text{LOG}(D/d) - 20 \geq 0$

$$d/D \geq 18.13$$

Camera Dist	WiMax BS-Camera Tx: 20 dBm - 0 GB	WiMax BS-Camera Tx: 23 dBm - 0 GB	WiMax BS- Camera Tx: 33 dBm- 0 GB	WiMax BS-Camera TX: 37 dBm- 0 GB	WiMax BS-Camera Tx: 20 dBm- 5MHz GB	WiMax BS-Camera Tx: 23 dBm- 5MHz GB	WiMax BS- Camera Tx: 33 dBm- 5 MHz GB	WiMax BS- Camera TX: 37 dBm- 5MHz GB	WiMax BS-Camera Tx: 20 dBm- 10MHz GB	WiMax BS-Camera Tx: 23 dBm- 10MHz GB	WiMax BS- Camera Tx: 33 dBm- 10 MHz GB	WiMax BS- Camera TX: 37 dBm- 10MHz GB
5	90.7	64.2	20.3	12.8	12.9	9.2	2.9	1.8	10.2	7.2	2.3	1.4
10	181.3	128.4	40.6	25.6	25.9	18.3	5.8	3.7	0.7	0.5	0.2	0.1
20	362.7	256.8	81.2	51.2	51.8	36.6	11.6	7.3	1.4	1.0	0.3	0.2
50	906.7	641.9	203.0	128.1	129.4	91.6	29.0	18.3	3.5	2.5	0.8	0.5
100	1813.4	1283.8	406.0	256.2	258.8	183.2	57.9	36.6	7.1	5.0	1.6	1.0
200	3626.9	2567.6	812.0	512.3	517.6	366.5	115.9	73.1	14.2	10.0	3.2	2.0
500	9067.1	6419.0	2029.9	1280.8	1294.1	916.2	289.7	182.8	35.4	25.1	7.9	5.0

Table 6: Calculated distances of WiMax BS Vs Camera Link Tx from the Camera Link Receiver

This means a WiMax base station located at a distance of 1 km from the Camera Link receiver will limit the coverage radius of coverage of the camera to  $1000/9.6 = 104$  meters. In this estimation it is assumed that the WiMax Base station has line of site to the Camera Link receiver. This may not be true for all cases. If the path is blocked then there will be additional losses which will permit increased coverage radius depending on the actual clutter loss.

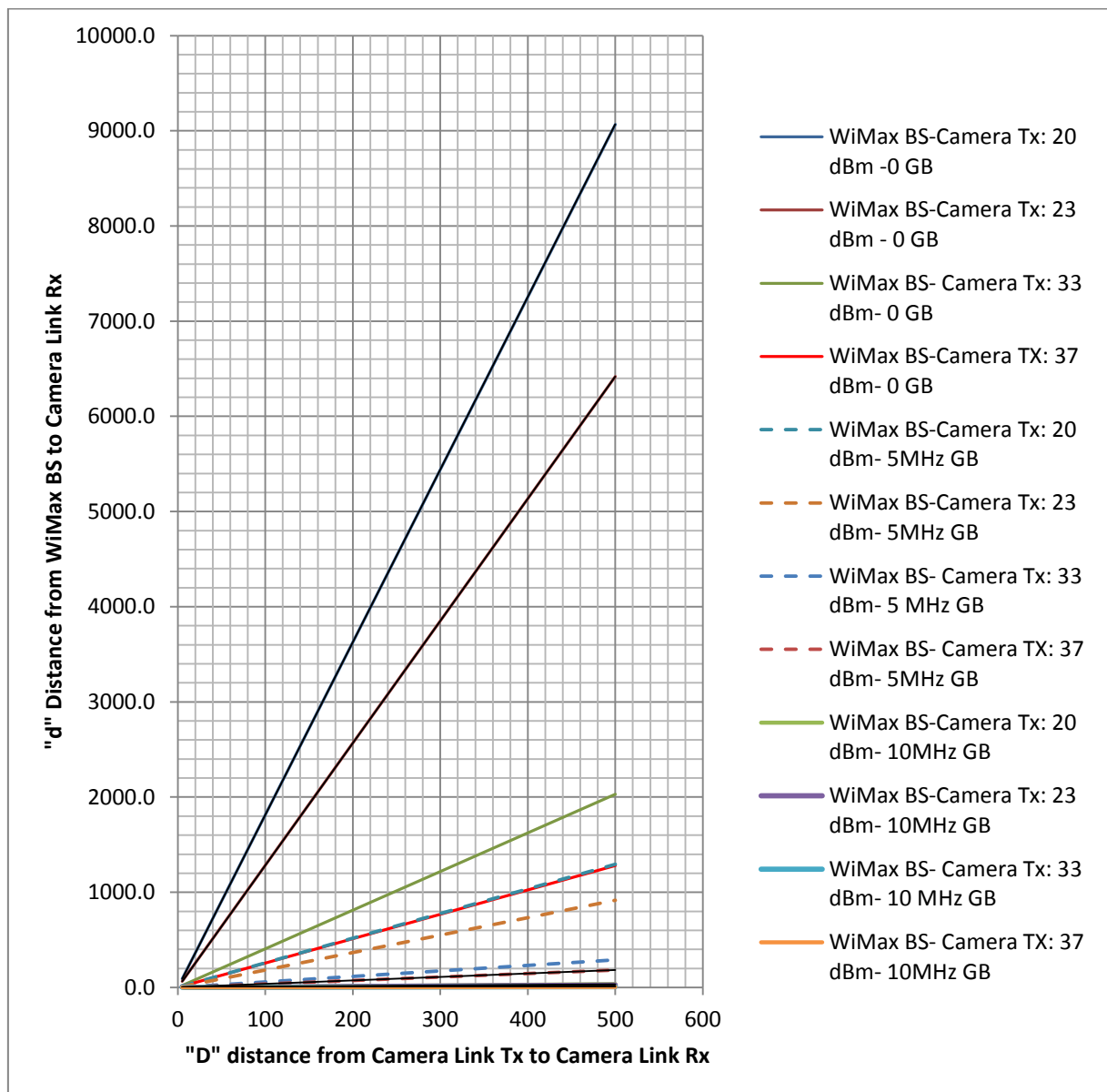


Figure 9: Graph of Camera link Tx distances Vs WiMax BS Tx distances from Camera Link Rx for various combinations of Camera link Tx power and guard bands.

### 3 Interference from the Camera Link Transmitter into the other services.

In order to calculate the interference from the Camera Link transmitter, the out of band emission specifications of the transmitter should be known. ETSI specifications EN 302 064<sup>5</sup> stipulates the Out of band power limits as in table below.

	Power out (eirp) < 0.3W	Power out (eirp) > 0.3W
Block 2	-36 dB	-36 dB - 10 log (P <sub>out</sub> /0.3)
Block 3	-42 dB	-42 dB - 10 log (P <sub>out</sub> /0.3)

Table 7: ETSI Out of Band emission specifications for Camera Link transmitter

Block 2 refers to adjacent channel and block 3 refers to the 2<sup>nd</sup> adjacent channel. Reference bandwidth is the occupied bandwidth of the modulated carrier. For this study we have chosen the Camera Link transmitter EIRP to be 23 dBm which is 0.2 Watts. Out of band emission level for the calculations is -37.25 dB below carrier; ie 23-37.25 = -14.25 dBm. Bandwidth of the Camera Link transmitter is 10 MHz.

#### Camera Link transmitter into 3G Base Station receiver

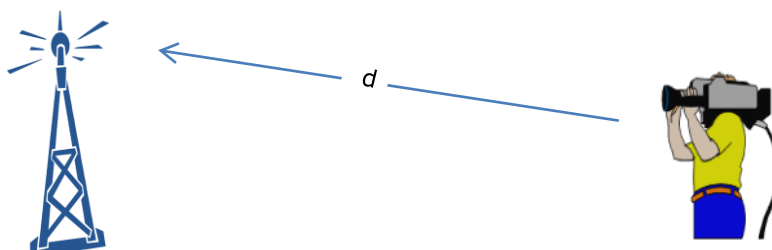


Figure 10: Interference from Camera Link transmitter to 3G base station

The noise threshold for the 3G BS receiver is -103 dBm/5 MHz calculated using kTBF where F is 4 dB<sup>6</sup>. Camera Link transmitter Out of band level is -17.25 dBm/5MHz. To calculate the worst case distance separation we assume clear line of site between the 3G base station and the Camera Link transmitter.

$$\text{EIRP}_{\text{Camera Link}} - \text{Pathloss} + G_{\text{BS-Ant}} - \text{Loss}_{\text{Feeder}} \leq -103$$

-17.25 - (92.45 + 20 LOG 2.1 + 20 LOG d) + 18 - 2 ≤ -103 where d is the distance between the Camera Link transmitter and the 3G BS.

$$20 \text{ LOG } d \geq 2.86$$

$$d \geq 1.39 \text{ km}$$

The above shows that, for adjacent channel operation, a 3G Base Station located within 1.39 km of the Camera Link transmitter and has clear line of sight will receive harmful interference from the Camera Link transmitter.

### Camera Link transmitter into 3G Mobile receiver

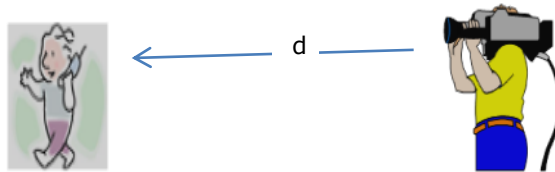


Figure 11: Interference from Camera Link transmitter to 3G mobile

The noise threshold for the 3G Mobile receiver is -99 dBm/5 MHz calculated using kTBF where F is 8 dB<sup>6</sup>.

Camera Link transmitter Out of band level is -17.25 dBm/5MHz. To calculate the worst case distance separation we assume clear line of site between the 3G Mobile and the Camera Link transmitter.

$EIRP_{\text{Camera Link}} - \text{Pathloss} + G_{\text{Mobile-Ant}} \leq -99$   
 $-17.25 - (92.45 + 20 \text{ LOG } 2.1 + 20 \text{ LOG } d) + 0 \leq -99$  where d is the distance between the Camera Link transmitter and the 3G BS.  
 $20 \text{ LOG } d \geq -17.14$   
 $d \geq 0.139 \text{ km} \approx 140 \text{ metres.}$

In this calculation body loss has not been included. In actual situation there may be other clutter losses that will attenuate the unwanted signal from the Camera Link transmitter towards the Mobile.

In summary, in the absence of any obstruction, operating the camera link transmitter on adjacent channel within 140 metres of the 3G mobile phone may cause unacceptable level of interference to mobile phone reception.



### Camera Link transmitter into WiMax Base Station receiver

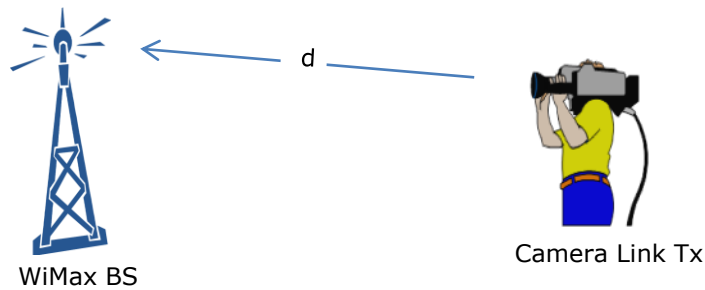


Figure 12: Interference from Camera Link transmitter into WiMax base station

The noise threshold for the WiMax BS receiver is -100 dBm/10 MHz calculated using kTBF where F is 4 dB. Camera Link transmitter Out of band level is -14.25 dBm/10MHz. To calculate the worst case distance separation we assume clear line of site between the WiMax base station and the Camera Link transmitter.

$$\text{EIRP}_{\text{Camera Link}} - \text{Pathloss} + G_{\text{WiMax-Ant}} - \text{Loss}_{\text{Feeder}} \leq -100$$

$$-14.25 - (92.45 + 20 \text{ LOG } 2.1 + 20 \text{ LOG } d) + 20 - 2 \leq -100$$

where d is the distance between the Camera Link transmitter and the WiMax Base station.

$$20 \text{ LOG } d = 4.86$$

$$d \geq 1.75 \text{ km}$$

The result is same as for the 3G base station. A WiMax Base Station located within 1.75 km of the Camera Link transmitter will receive harmful interference from the Camera Link transmitter and adjacent channel operation is not possible.

## 4 Frequency Reuse (Co-channel)

### Ground Based Operation

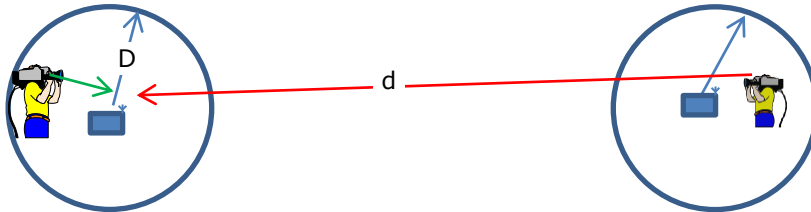


Figure 13: Co-channel reuse – Ground based operation

In the above  $d$  is the re-use distance and " $D$ " is the radius of coverage of individual cameras. The range of the handheld camera is assumed to be about 200metres and for the path loss Free space model has been used. In the above figure the green arrow indicates the wanted signal and the Red arrow shows the unwanted signal.

Received power at the Camera Link receiver is given by:

$$P_r = P_t + G_t + G_r - FSL + G_r = P_t + G_t + G_r - (92.45 + 20 \text{ LOG}(F) + 20 \text{ LOG } D)$$

$$P_{r \text{ wanted}} = P_t + G_t + G_r - (92.45 + 20 \text{ LOG}(F) + 20 \text{ LOG } D)$$

$$P_{r \text{ unwanted}} = P_t + G_t + G_r - (92.45 + 20 \text{ LOG}(F) + 20 \text{ LOG } d)$$

Frequency, transmit power, and antenna gain being the same for both camera transmitters wanted to unwanted ratio is given by  $-20 \text{ LOG}(D/d)$  and for 20dB C/I margin the W/UW ratio should be  $\geq 20 \text{ dB}$  which gives  $d/D = 10$ . For reuse of the same channel, the separation between the two Camera Link receivers should be equal to or greater than 11 times the coverage radius of the two cameras.

### Airborne Operation

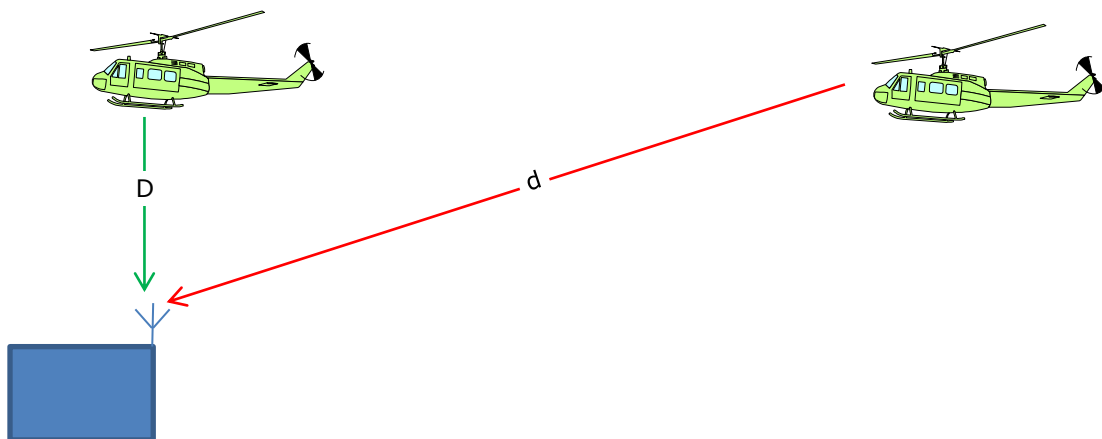


Figure 14: Co-channel reuse – Airborne operation

The same criteria as for the ground operation apply to this as well. " $D$ " and " $d$ " are the slant ranges of the two helicopters to the receiver.  $d/D$  should be  $\geq 10$

## 5 Geographic Restrictions of the Proposed Camera Link band

The geographic restrictions are mainly to offer protection for earth stations that are used for deep space communications. There are four earth stations that need to be considered in the compatibility study and these are Tidbinbilla Earth Station, Lonsdale Earth Station, New Norcia Earth Station and Mingenew Earth Station.

### Canberra Earth Station



Canberra DSS Earth Station – DSS43 Antenna

Type:	Azimuth-Elevation
Diameter:	70 metres
Height:	40 metres (Phase centre)
Transmit:	X-band (7145-7190 MHz) S-band (2025-2120 MHz)
Receive:	X-band (8400-8500 MHz) S-band (2200-2300 MHz) L-band (1626-1708 MHz) K-band (12.5 GHz) Ku-band (18-26 GHz)

Figure 15: Canberra DSS Earth station

Canberra DSS earth station is located in Tidbinbilla and is surrounded by hills. Figure above is a Google image of the earth station and the figure below is a location map of the earth station showing its position in relation to the city. The earth station uses the entire band 2200 to 2300 MHz for the reception as shown in table x below. As this frequency band falls within the proposed Camera Link band it is necessary to investigate the interference that the Camera Link operations may cause to the earth station receiver. From WRC Appendix 7, Table 8b, there are three categories of operation. Permissible interference power for each category is as below:

	Category	Freq band MHz	dBW	dBm/10MHz
1	Space operation deep space (non-GSO & GSO)	2200 to 2290	-154/MHz	-114
2	Space research deep space (non-GSO)	2290 to 2300	-222/Hz	-122
3	Space research near-Earth (non-GSO & GSO)	2200 to 2290	-216/Hz	-116

Table 8: Permissible interference limit for Earth Stations for space research.

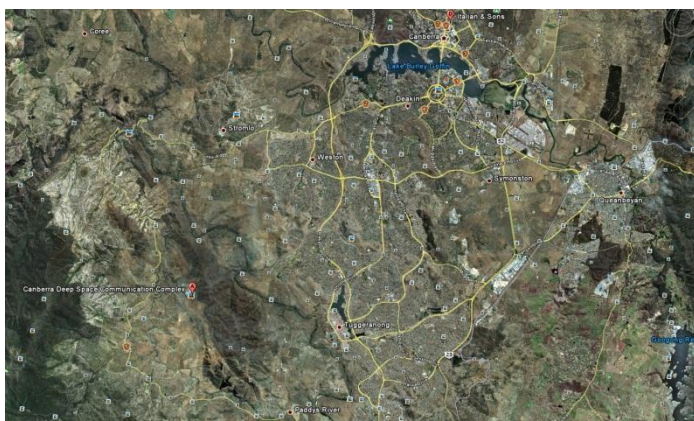


Figure 16: Tidbinbilla Earth station in relation to the Canberra CBD

FREQ MHz	BW MHz	2200-2205	2205-2210	2210-2215	2215-2220	2220-2225	2225-2230	2230-2235	2235-2240	2240-2245	2245-2250	2250-2255	2255-2260	2260-2265	2265-2270	2270-2275	2275-2280	2280-2285	2285-2290	2290-2295	2295-2300
2212.425	15.150																				
2230.000	3.230																				
2238.000	2.140																				
2249.000	20.000																				
2259.910	0.800																				
2270.400	3.000																				
2281.153	38.102																				

Table 9: Existing 2.5 GHz band Frequency assignments for Tidbinbilla DSS Earth Station

Assuming Free space propagation conditions minimum range for Camera Link transmitter is calculated as follows.

For the 70m Earth Station antenna, gain at 10° elevation is given by 32 – 25 LOG(10) which is 7 dBi.

$$\begin{aligned}
 P_{r \text{ ES}} &= P_{t \text{ Camera Link}} + G_t - \text{FSL} + G_a \text{ ES} \\
 &= 20 + 3 - 92.45 - 20 \text{ LOG}(2.25) - 20 \text{ LOG}(d) + 7 \\
 &= -55.41 - 20 \text{ LOG}(d)
 \end{aligned}$$

Distance km	5	10	15	20	25	30	35	40	45	50
$P_{r \text{ ES}}$ dBm	-83.5	-89.5	-93.0	-95.5	-97.5	-99.0	-100.4	-101.5	-102.6	-103.5
Margin Cat1 dB	-30.5	-24.5	-21.0	-18.5	-16.6	-15.0	-13.6	-12.5	-11.4	-10.5
Margin Cat2 dB	-38.5	-32.5	-29	-26.5	-24.6	-23	-21.6	-20.5	-19.4	-18.5
Margin Cat3 dB	-32.5	-26.5	-23	-20.5	-18.6	-17	-15.6	-14.5	-13.4	-12.5

Table 10: Path loss & margin from the specification against line of sight distance from Earth Station

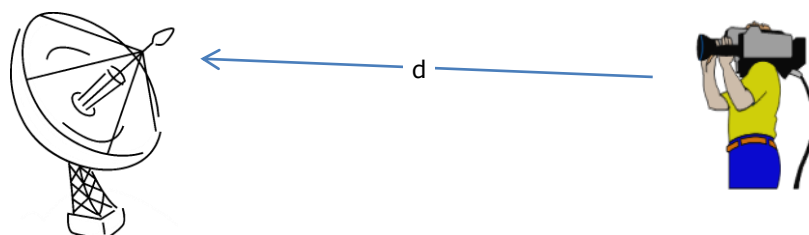


Figure 17: Interference from Camera Link transmitter into Earth Station

In order to satisfy the Earth station protection criteria the margins need to be positive. If there is additional obstruction loss due to terrain and or clutter in excess of the margin then the transmission will not cause any interference to the earth station. For example if the obstruction loss from the selected location at 10km to the earth station is more than 32.5 dB then it will satisfy the protection criteria for all three categories.

Considering that the Tidbinbilla earth station is surrounded by hills and most of the Camera Link operations are carried out in built up areas there will be sufficient obstruction loss for ground based operations. Figure below shows a path profile between the earth station and Canberra Stadium.

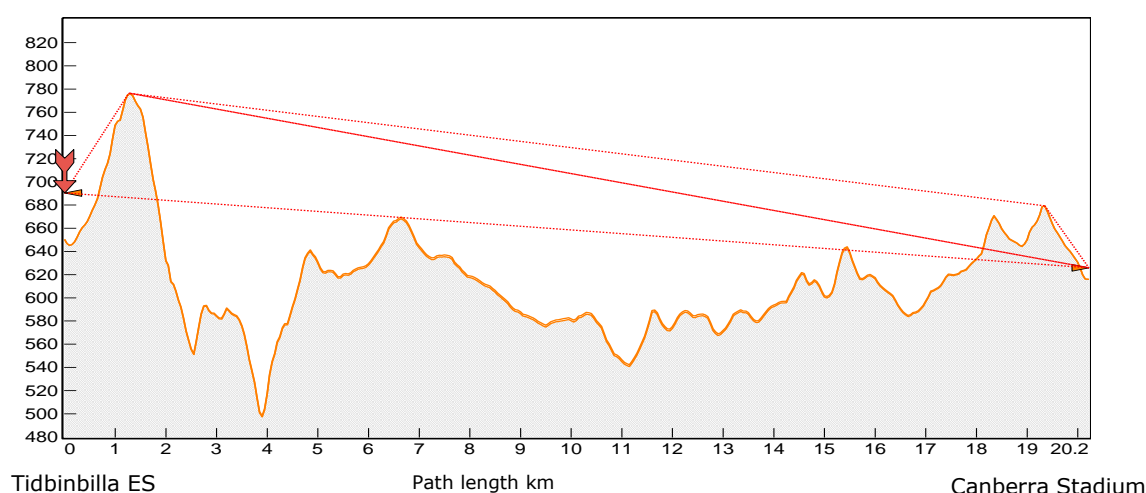


Figure 18: Path Profile between Tidbinbilla ES and Canberra Stadium

Below is a summary of results of obstruction losses calculated for some of the candidate sites to the earth station.

Site Name	Distance from Earth Station	Free Space Loss	Diffraction Loss	Atmosp Loss	Total Loss
Parliament House	16.7 km	123.37	66.71	0.1	190.18
Canberra Airport	22.6 km	125.99	81.6	0.14	207.73
Canberra Stadium	20.2 km	125.43	84.1	0.12	210.47

Table 11: Total path loss from candidate sites to the earth station.

In these calculations earth station antenna height and the Camera Link transmitter height are taken as 40m and 10m respectively. Camera Link transmitter antenna height would be usually less than 2m. Even without applying any clutter losses the diffraction loss is adequate to block any interference into the earth station.



## Landsdale Earth station



Figure 19: Landsdale Earth station complex.

There are two Earth Station antennas used by "Stratos" for deep space and near-earth space research within the Landsdale complex. Below are their characteristics necessary for the interference study.

Earth Station ACMA ID	26582	132429
Latitude (AGD 66)	-31.803714	-31.809624
Longitude (AGD 66)	115.883677	115.886197
STATION CLASS	TH, TK, TR, TT, TD	TH, TT, TC, TR, TD
Antenna Height (m)	10	8
Antenna Size (m)	15	10
RX Threshold 2290MHz-2300MHz	-222 dBW/Hz (-132dBm/MHz)	-216 dBW/Hz (-126dBm/MHz)
RX Threshold 2200MHz-2290MHz	-216 dBW/Hz (-126dBm/MHz)	
Azimuth	ND	ND
Elevation	10 deg	10 deg

Table 12: Landsdale Earth Station characteristics

Protection levels necessary for protection of Earth station receivers are -132dBm and -126 dBm. Interference power received from the Camera Link transmitter is given by

$$P_{r-int} = 30 - L_{FS} - L_{diff} - L_{clutter}$$

$$\text{The criteria is } -132 \geq 30 - L_{FS} - L_{diff} - L_{clutter}$$

$$\text{Margin} = -162 + (L_{FS} + L_{diff} + L_{clutter})$$

If the Margin  $\geq 0$  is "PASS" otherwise it is a "FAIL"

Table below shows the results for some of the candidate sites around the Landsdale Earth station. This does not include any losses due to clutter. From the results it appears that operations from WACA cricket ground may cause interference. Subiaco Oval margin is 2dB low and it will not cause interference as there will be additional clutter losses which has not been calculated and added to the losses.



#### Earth Station JAXA 1 & 2

Site Name	Distance km	Free Space Loss dB	Diffraction Loss dB	Atmosp Loss dB	Total Loss dB
Subiaco Oval	16.04	123.62	33.90	0.1	157.61
WACA Cricket Ground	16.83	124.03	19.25	0.1	143.39

Table 13: Total path loss from candidate sites to the earth station.

#### Earth Station Telstra (26582)

Site Name	Distance km	Free Space Loss dB	Diffraction Loss dB	Atmosp Loss dB	Total Loss dB
Subiaco Oval	16.58	123.9	39.76	0.1	163.77
WACA Cricket Ground	17.47	124.36	13.73	0.11	138.20

Table 14: Total path loss from candidate sites to the earth station.

Airborne operation in the area is not possible as the helicopter flying at 100m height in the CBD area will have direct line of site to the earth station and would cause interference. Alternative is to use the Camera Link lower band for both land based and airborne operations. In this case interference from the earth station into the Camera Link receiver need to be considered.

#### Use of the 1980 to 2110 Band for Perth Area

In this case we need to evaluate the interference from Earth station transmitter.

Typical Earth station power is 2000 Watts (+63 dBm). The horizontally radiated power at 10° elevation angle is +63dBm+ 7dBi = +70dBm

$$P_{r-\text{Camera Link}} = 70 + 3 - 92.45 - 20 \text{ LOG}(2.1) - 20 \text{ LOG}(D) - L_{\text{diff}} - L_{\text{clutter}}$$

$$= -13 - 20 \text{ LOG}(D) - \text{Diff Loss} + \text{Clutter Loss}$$

For Subiaco oval highest diffraction loss calculated was 40 dB and the interference level would be -37.6-40 = -77.6 dBm.

Wanted signal level from the camera 200m away would be -55.91 dBm. Wanted to unwanted ratio is 21.7 dB which is workable.

Same for WACA -37.5-13.7 = -51.2 dBm and the wanted signal would be -55.91 dBm. This is unworkable as the interference level is 4.7 dB higher than the wanted signal.

### New Norcia Earth Station

New Norcia earth station is located about 100km north of Perth. ACMA database shows that the band from 2210 to 2230 MHz is being used for reception. From 1 January 2016 they will use only the bands 2215 -2230 MHz and 2290-2300MHz. There will be an embargo for the use of these bands within 300km of this earth station as in table below.

Before 1 January 2016: Band 2200 to 2300

After 1 January 2016: Bands 2215 -2230 MHz and 2290-2300MHz

Because of this embargo the bands that will be available for TOB would be limited to the lower band 1980 to 2110 MHz and the partial upper band 2230 – 2290 MHz. Figure below is path profile between Subiaco oval and the New Norcia Earth station. Calculated diffraction loss between the sites is 90.5dB. For a height of 300m at Subiaco end (airborne operation) calculated diffraction loss is 68 dB.

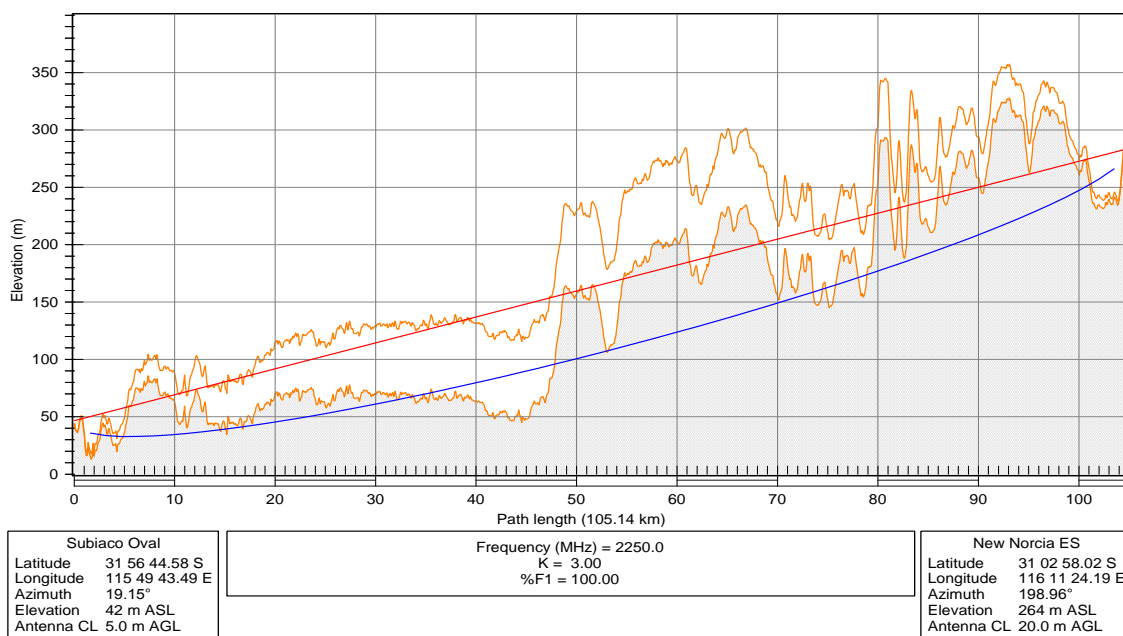


Figure 20: Path Profile between Subiaco Oval and New Norcia ES

In this case it can be shown that both ground based and airborne operation up to 300m height would not cause unacceptable level of interference into the New Norcia Earth station.

### Mingenew Earth Station

This earth Station is about 320km north of Perth and protected by ACMA Embargo 49 which stipulates that no frequency assignments shall be made for terrestrial services in the 2100-2130 MHz and 2280 to 2310 MHz bands within a Radius of 300km from this earth station. Below is a path profile which shows the terrain blocking between Mingenew Earth station and Subiaco oval. For a height of 300m at Subiaco end (airborne operation) calculated diffraction loss is 56 dB. Path distance between the Earth station and Subiaco stadium is 324km which is outside the embargo zone. Both ground based and airborne operation up to 300m height would not cause unacceptable level of interference into the Mingenew Earth station.

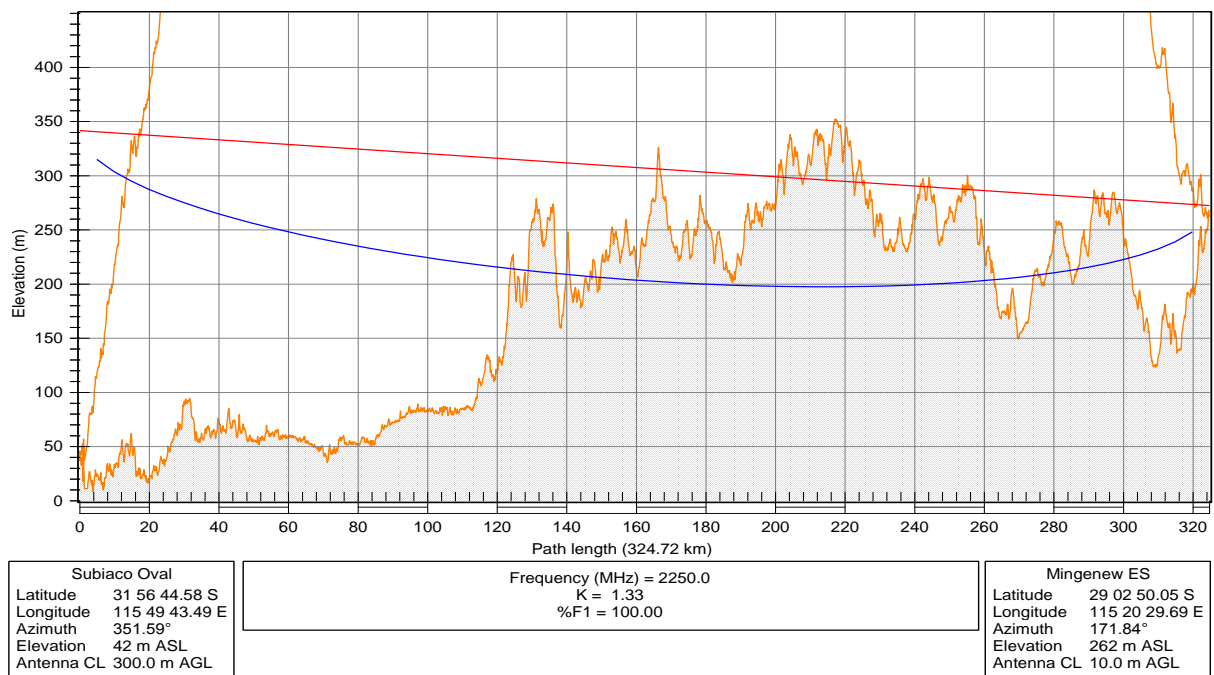


Figure 21: Path Profile between Subiaco Oval and Mingenew Earth Station

## 6 Conclusions and Recommendations

Compatibility study has been made to cover all adjacent services namely 3G mobile, WiMax (2300-2400MHz) and Space communications bands.

The Camera links are meant to cover short link distances of less than 500m and it is assumed that there is line of site between the camera link transmitter and its associated receiver. As a worst case analysis, we have assumed that the interferers / victims have direct line of site. For all the calculations Free Space Model has been used except for interference with earth stations where diffraction loss has been taken into account. For the Camera link a channel bandwidth of 10 MHz has been assumed.

For 3G Base station interference we have only considered the Macro base stations. In some cases there can be In Building Coverage (IBC) systems which operate on low EIRP levels. In this case, to make an interference assessment, actual system parameters of the IBC should be known. This may involve practical measurements to quantify the coupling loss between the IBC and the Camera link receiver.

Following are our conclusions and recommendations.

### Use of the lower band 1980 – 2110 MHz

The lower end of the band is adjacent to 3G base station receive and 3G mobile transmit and the upper end is adjacent to 3G base station transmit and 3G mobile receive. The study showed that with a 100mW camera link transmitter, if a channel immediately adjacent to the 1980MHz frequency is used then a 3G base station will receive unacceptable level of interference from a camera link transmitter if it is located within 1.4km of the transmitter. For satisfactory operation a guard band of at least 5MHz from the band edge should be maintained. The upper end of the band may suffer interference from 3G base station transmitter. Interference study was performed for different Camera Link Transmitter power options (100mW, 200mW, 2W & 5W) and guard bands. Increasing the power and or guard band reduced the interference into the camera link receiver (Ref table 4 & figure 8). 3G Mobile phone interference into the Camera link receiver study results are in table 2 and figure 4. As in the case of Interference from 3G base station, increasing the Camera link power and the guard band improved the link performance.

In band interference from the Earth Stations were also studied. The Earth station at Canberra is surrounded by hills and offers adequate shielding. The Earth stations at New Corcia and Mingenew are far away from the Metro areas and may not cause any unacceptable levels of interference into the Camera link receiver. Landsdale earth station may cause unacceptable levels of interference.

### Use of the upper band 2170 – 2300 MHz

Lower end of this band is the 3G base station transmit band which may interfere with Camera link receive. The upper end is WiMax base station transmit and receive (TDD) and may cause mutual interference with Camera link (Camera link transmit into WiMax receive and WiMax transmit into Camera link receive). The result for the interference due to 3G base station transmitter is same as for the lower band discussed in paragraph above. Results of the WiMax interference study are shown in table 6 & figure 9. It can be seen that increasing the Camera link transmit power and guard band improves the performance. Interference study for Camera link transmitter into WiMax base station receiver also shows the need for a guard band.

In-band interference into the Earth Stations was studied. As in the case of the lower band, Camera link transmitters will not cause unacceptable levels of interference into the earth station at Canberra due to shielding offered by hills around it. Airborne operations may cause interference and is not recommended. There may be mutual interference in areas around the Landsdale Earth station as there is no terrain shielding.

Recommendations

The results of the study show a need to maintain a guard band of 5 to 10MHz depending on the actual spectrum usage in the area of interest.

### **6.1.1 OPERATIONS AROUND EARTH STATION AREAS**

We have studied Tidbinbilla Earth Station in ACT and the three earth stations in WA namely Landsdale, New Corcia and Mingenew in relation to Metro areas of Canberra and Perth respectively. It has been shown that there is no significant mutual interference between the ENG service and the two earth stations at Mingenew and New Corcia. Below are the recommendations for the other two earth stations.

#### **Sites in Canberra**

For sites that are closer to Canberra Earth station use of lower band is suggested for both ground based and airborne operations. The upper band should be limited to ground based operations only.

#### **Sites Around Landsdale Earth Station**

This earth station will be closed down by 1 January 2016. To our knowledge the earth station does not operate on low elevation angles all the time and the schedule of operation is known well in advance. ENG service is possible by coordinating with the Earth Station operator. Uplink transmission is always narrow band. We recommend that if ENG service is required before 1/1/2016 coordinate with Earth station operator to select a suitable channel in the lower band

### **6.1.2 RECOMMENDATIONS COMMON TO ALL AREAS**

The lower band is the mobile phone transmit band and there may be several users of the mobile phones in the area. In our calculations we have assumed full power for the mobile but actual power depends on the range of the mobile from its serving base station. Our concern is only VHA 3G mobile phones and base stations. If the Base stations are more than a kilometre away and if there is no direct line of site between the Base station and the camera link receiver there will be adequate isolation. WiMax transceivers operating at the upper end of the band will cause mutual interference.

In order to alleviate form these, as a minimum, a guard band of 5 MHz should be provided. In some cases it may require 10MHz of guard band.

## 7 References:

- 1) 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; User Equipment (UE) radio transmission and reception (FDD)- Release 11  
3GPP TS 25.101 V11.0.0 (2011-12)
- 2) Australian Broadcasting Authority Canberra, March 2005 "Digital Terrestrial Television Broadcasting Planning Handbook, section 2.2.1"
- 3) Universal Mobile Telecommunications System (UMTS); UTRA (BS) FDD;  
Radio transmission and reception (3GPP TS 25.104 version 4.3.0 Release 4)  
ETSI TS 125 104 v4.3.0 (2001-12)
- 4) ACMA document "Technical Framework Development 2.3 GHz Spectrum Licence Band Discussion Paper No. 1 Design Requirements for the Technical Framework Reference Technologies / Standard Trading Units / Core Conditions"
- 5) Electromagnetic compatibility and Radio spectrum Matters (ERM); Wireless Video Links (WVL) operating in the 1,3 GHz to 50 GHz frequency band; Part 1: Technical characteristics and methods of measurement ETSI EN 302 064-1 v1.1.2 (2004-07)
- 6) ERC Report 65 "Adjacent band compatibility between UMTS and other services in the 2 GHz band."