Satellite Network Designer's Guide

This document contains information on the Optus Satellite System and includes descriptions of the A-Series and B-Series satellites.

The information contained in this document is based on the in-orbit measured performance of the Optus A2, A3 and B1 spacecraft and the pre-launch factory measurements of the B3 spacecraft.

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1. Introduction

Optus Networks operates an Australian domestic satellite system, which provides coverage over continental Australia, Tasmania and New Zealand. Limited options are available whereby coverage is possible of New Guinea, Norfolk Island, Lord Howe Island, Cocos Island and Christmas Island. An L-Band payload for mobile satellite services is also carried with coverage of continental Australia and territorial waters.

This booklet is an overview of the Optus satellite system describing the satellites and their general performance characteristics. There are two types of Optus satellite named the A-Series and the B-Series and each is described. The information in this document is intended for use by users, students and engineers from which an initial service application may be determined. The configuration information will indicate if a service is physically possible while performance information will enable "first pass" link calculations to identify earth station requirements and space segment usage.

Intending users are advised that earth stations accessing Optus satellites are required to conform to minimum performance standards which are imposed by national standards organisations such as Austel. Adoption of recommended international standards is encouraged in some instances and Optus may also require specific conditions to be met for a particular application.

A service licence may also be required for the operation of a satellite based service or earth station.

Information on the requirements for earth stations accessing Optus satellites is outside the scope of this satellite guide.

The information in this document is intended for use as a technical guide only and does not constitute an indication that services may be available. Optus will provide more detailed information on request. Technical assistance is also available from Optus for existing and intending customers for satellite and earth station options.

1.1 Satellite System Management

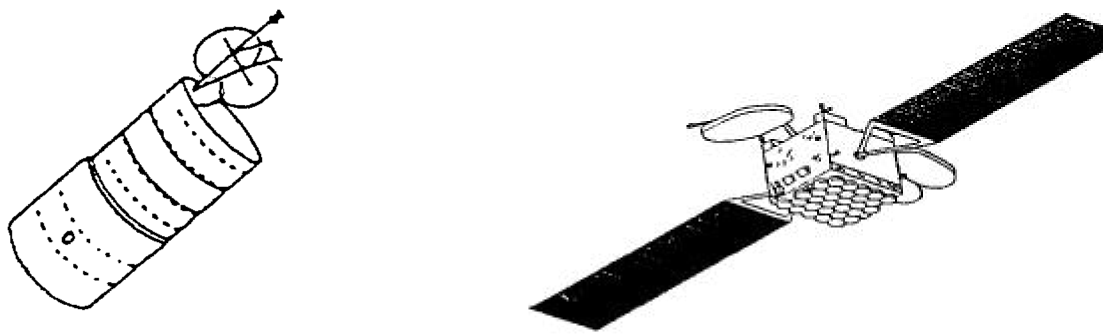
The Optus satellite system, described in this document, is operated within parameters, which are dependent on the satellite performance capability and the requirements of the communication services. The specific nature and application of the technical requirements is dependent on many factors such as the service technology, the amount of satellite capacity used and the transponder in which the service is operated. All these factors are interdependent and need to be managed to ensure the quality of all services is preserved over the life of the satellite. As the owner, operator and manager of the satellite system, Optus controls the performance of all satellite services an is responsible for determining transponder allocations and setting operating characteristics that meet the requirements of each user, while ensuring minimal interference to other services.

Satellite service management is not a simple task and in some cases Optus may need to apply special conditions to a service that will ensure the performance integrity of the satellite system is preserved.

2. The Optus Satellite Fleet

Optus operates two types of satellite in its fleet. Both are made by Hughes Aircraft Company in California but each has a different construction technology. They are the A-Series satellite, the older of the two versions , and the B-Series satellites.

Diagrams of the satellites in their deployed configuration are shown in **Figure 2.1.**



A-Series Satellite B-Series Satellite

Figure 2.1 Optus Satellites

Each OPTUS satellite consists of a space platform or "spacecraft bus" which provides various support systems that are required to control and maintain the satellite in orbit and operate the on-board communications system. The reliability of the platform itself is designed to be extremely high, and extensive protection from platform failures is provided by built-in redundancy and by extensive emergency operating procedures which have been developed to counter any foreseeable on-station emergency situation. The platform includes the power supply (solar cells and battery back-up) which have been designed with an adequate margin for successful in-orbit operation extending well beyond the satellite design life.

2.1 Basic Satellite Summary

The main characteristics of the two types of Optus satellite are listed in **Table 2.1** below.

	A-Series	B-Series
Physical Structure	Cylindrical (Hughes HS 376)	Cubic body with solar wings (Hughes HS 601)
Dimensions	6.4 metres by 2.2 metres diameter	21 meters across extended solar panels.
Dry Weight	540 kg	1270 kg
Stabilisation Method	Spin Stabilised	3 Axis Body Stabilised
Solar Power Capacity	1000 watts (at end of life)	3000 watts (at end of life)
Battery Capacity	Full operation during eclipse	Full operation during eclipse
Geostationary Life	10 years (A3), 7 years (A2)	13 years
Inclined Life Extension	5yrs (nominal)	5yrs (nominal)
Number of Transponders	15 Ku-Band	15 Linearised Ku-Band 1 L-Band
Transponder Power	11 transponders, 12 watts 4 transponders, 30 watts	Ku-Band transponders, 50 watts L-Band transponder, 150 watts
Transponder Bandwidth	45 MHz	54 MHz
Communications payloads	Ku-Band communications	Ku-Band Communications L-Band Communications UPC Beacon (Ku-Band) Ka Band Beacon

Table 2.1 Satellite Summary

2.2 Ku-Band Communications Payload

A simplified block diagram of the communications payload is shown in **Figure 2.2**. The diagram is applicable to both the A and B-Series satellites, with some exceptions, as described below.

The Ku-band payload is divided into two repeaters called A and B, with each repeater consisting of either seven or eight channels or "transponders" and operating on orthogonal polarisations. Satellite transponders 1 to 8 are identified as repeater A and receive on horizontal polarisation and transmit on vertical polarisation. Transponders 9 to 15 are identified as repeater B and receive on vertical polarisation and transmit on horizontal polarisation. The Ku-band part of transponder M (B-Series Mobile) is included in repeater B.

The M Channel and the B-Series L-band repeater are discussed in **Section 4** of this Guide.

The Ku-band payload can be conveniently divided into six sections described below:

i) Receive and Transmit Antennas

The receive and transmit antennas consist of a number of dual-gridded reflectors to provide orthogonal linear polarisations, combined with beam-forming feed networks mounted on the spacecraft body. These provide a large number of highly-shaped uplink and downlink beams: 4 receive and 8 transmit beams on the A-Series, and 3 receive and 8 transmit beams on the B-Series (excluding L-band). Although **Figure 2.2** shows separate uplink and downlink antennas, in a number of cases transmit and receive beams share reflectors and feed networks. In these cases the different frequency bands are separated by diplexers (as shown for the L-band array only).

ii) Receivers

The receiver section, which is common to both repeaters, contains five receivers in a 5-for-3 (A-Series) or 5-for-2 (B-Series) redundancy ring. The receivers amplify the entire 500MHz spectrum and translate it by 1748MHz from the 14GHz band to the 12GHz band.

iii) Input Multiplexers (IMUX)

The receivers are followed by the input multiplexers (IMUX). These are filter banks which divide or "channelise" the receive band into fifteen Ku-band channels and one Mobile channel, for the B-Series satellites.

iv) Channel Amplifiers

Each channel amplifier section consists of a Channel Control Unit (CCU) followed by a Travelling Wave Tube Amplifier (TWTA). The CCU controls the transponder gain setting and is discussed in **Section 3.5.**

On the A-Series there are two types of TWTA - 12 watts and 30 watts - providing 11 low-power and 4 high-power transponders. On the B-Series the TWTA includes a Limiter/Lineariser module (or Lim./Lin.) which provides pre-distortion to improve the intermodulation performance, plus hard-limiting protection against excessive overdrive. All 16 transponders are the same power - 50W.

The channel amplifiers are connected on the input and output via redundancy rings. On the A-Series two rings provide 13-for-11 and 6-for-4 redundancy for 12W and 30W TWTAs respectively. On the B-Series a separate 11-for-8 redundancy ring is provided for each repeater.

v) Transmit beam switch matrices (TSM)

Following the channel amplifiers are the transmit beam switch matrices (TSM). These are configured under ground command to select a particular transmit beam on a particular transponder.

On the B-Series A repeater channels only there is a variable power divider (VPD) included in each TSM which can divide the channel power between the NA/SE/WA beams on the one hand and the NZ beam on the other (see Section 3.3.2 for beam glossary). The VPD can be set for a 100/0, 0/100 or 80/20% power-split to achieve separate or combined Australian and New Zealand downlink coverage.

vi) Output Multiplexers (OMUX)

All transponders switched to a given transmit beam are recombined into a 500MHz spectrum in an output multiplexer (OMUX) bank before being fed to the transmit antenna. The OMUX banks provide channel filtering plus harmonic filters to absorb and reject TWTA harmonics.

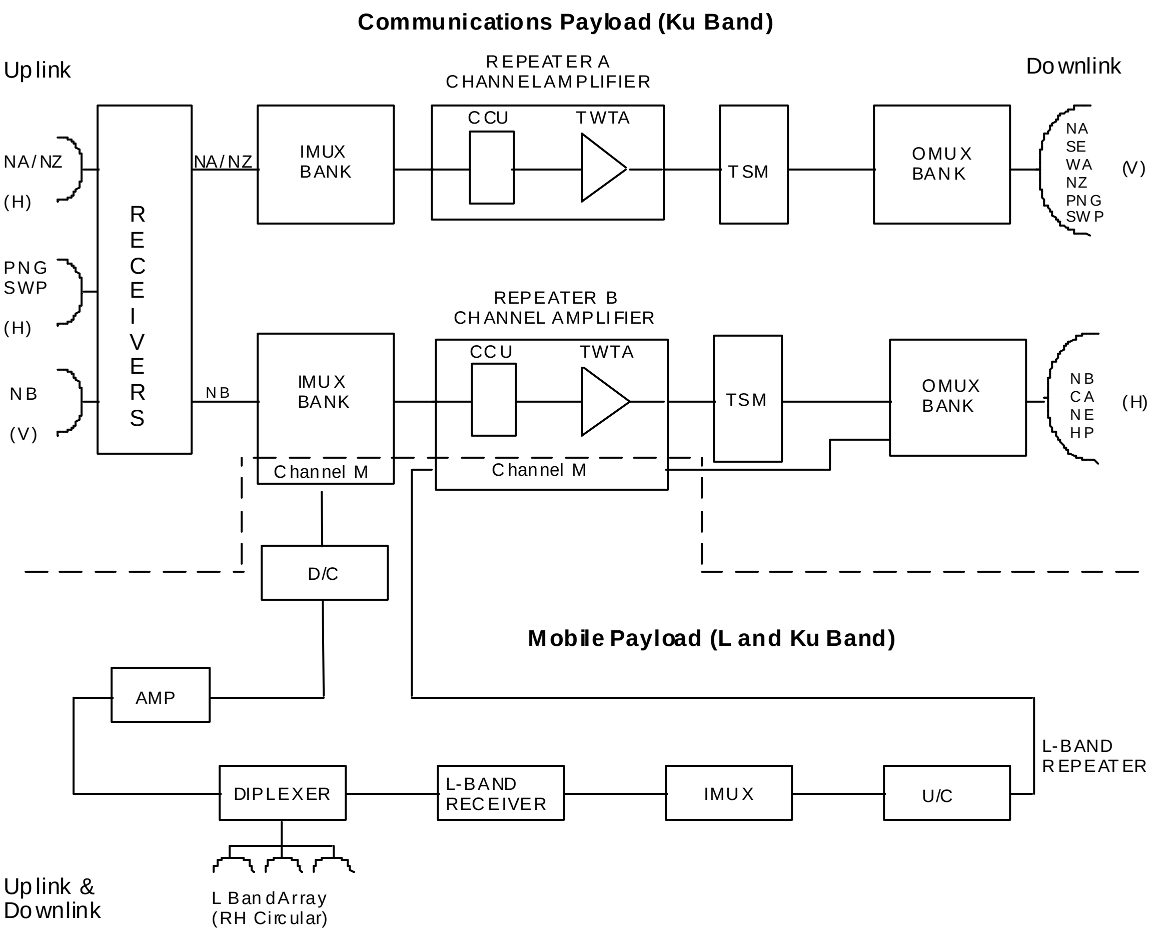


Figure 2.2 Communications Payload Block Diagram

2.3 Satellite Orbital Positions

The Optus satellites may be deployed at orbital slots on the geostationary arc above the equator. These orbital positions have been registered with the International Frequency Registration Board for operation of the Optus satellites and comprise the following positions of longitude.

152° East

156° East

160° East

164° East

Note: The orbit locations listed are as registered at the time of publication of this document was published.

2.4 Station Keeping Performance

A satellite in a "geostationary" orbit will gradually change its orbit position primarily due to the combined gravitational effects of the sun, moon and earth. Optus employs two forms of station-keeping to maintain the nominal satellite position.

2.4.1 Geostationary Satellites

During their normal lifetime the Optus satellites will be maintained in geostationary orbit with a tolerance of ±0.05° in latitude and longitude about the sub-satellite point. (The sub-satellite point is the point on the earth's surface directly below the nominal satellite position.) Earth station antennas of up to about 7m in diameter accessing the Optus Ku-band frequencies of 14/12GHz generally do not require tracking.

2.4.2 Inclined Orbit Satellites

The operational life of a geostationary satellite may be extended by ceasing north-south (or latitude) station-keeping while continuing with east-west (or longitude) station-keeping. The orbit inclination builds up from near zero approximately linearly at about 0.8° per year. This causes a latitude motion equal to the orbit inclination and additionally a 12 hourly longitude variation which builds up quadratically to about 0.06° after 5 years. This longitude variation occurs in addition to the ±0.05° inplane orbit motion. The orbit is kept essentially circular in the orbit plane, so that the diurnal satellite movement as seen from the ground will be a narrow figure-of-eight. Antennas operating to inclined-orbit satellites will require tracking systems. The maximum tracking speed required is about 0.02° per minute after 5 years.

Inclined-orbit satellites also suffer from other effects such as movement of the beam patterns as seen from the ground, degraded cross-polarisation performance, and increased range variation, range-rate and doppler shift. Further information may be obtained from Optus on these topics, plus specific information on the characteristics of an inclined-orbit satellite at a particular time.

3. Ku-Band Communications Payload

Each OPTUS satellite can provide fifteen active 14/12 GHz transponders operating in a dual polarisation frequency re-use scheme with eight transponders on one polarisation and seven on the other.

3.1 Frequency Plan

The OPTUS satellites will receive and transmit at the following Ku-Band frequencies:

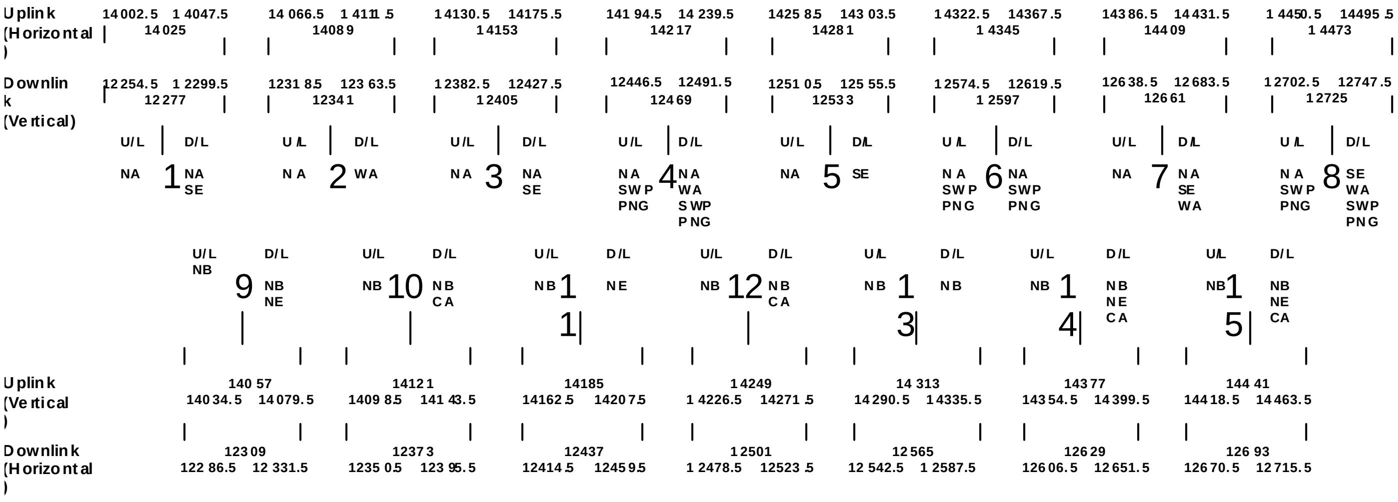
Receive	14,000-14,500 MHz	(14.00-14.50 GHz)
Transmit	12,250-12,750 MHz	(12.25-12.75 GHz)

The transponder channel plan for both the A and B-Series satellites is shown in **Figure 3.1**.

The frequency plan uses the following spacing of transponder centre frequencies.

	A-Series	**B-Series**
Adjacent transponder separation	64 MHz	62.6 MHz
Frequency Offset (Repeater A to Repeater B)	32 MHz	31.3 MHz

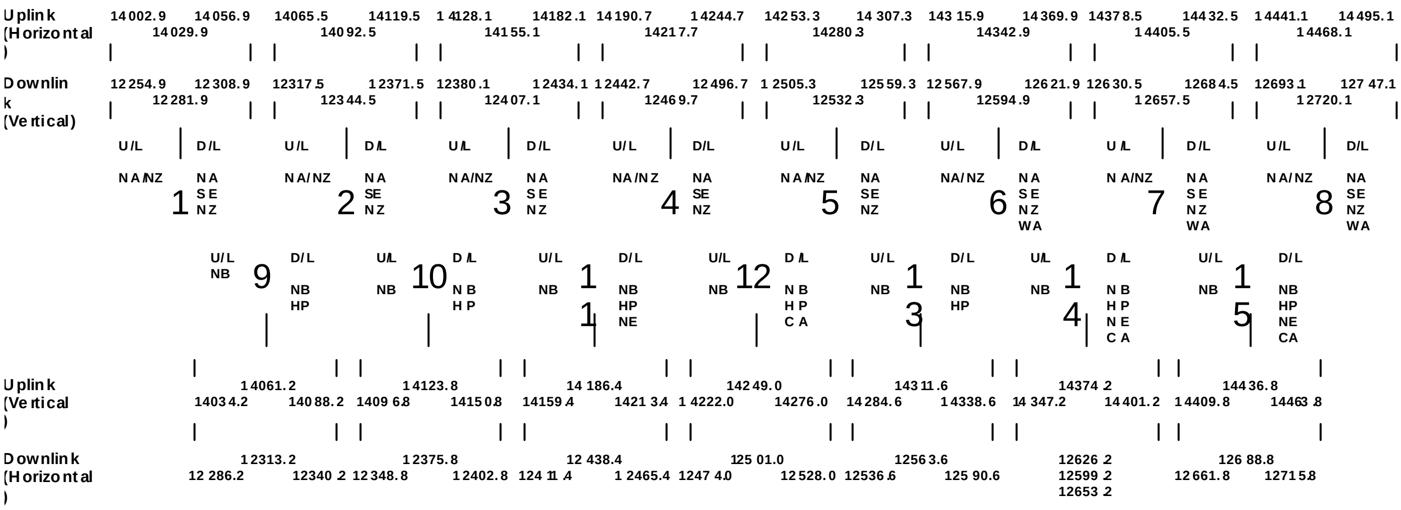
REPEATER A



REPEATER B

Optus A-Series Satellite

REPEATER A



REPEATER B

Optus B-Series Satellite

Legend:

U/L Uplink
D/L Downlink
Beam abbreviations refer to Table 3.3

Figure 3.1: Satellite Frequency, Polarisation & Connectivity

Figure 3.1 Satellite Frequency, Polarisation & Connectivity

3.2 Frequency Translation Characteristics

Satellite frequency translation characteristics for the Ku band communications payload, including expected stability performance, are as follows:

	A-Series Satellites	B-Series Satellites
Translation Frequency	1,748 MHz	1,748 MHz
Short-Term Drift	±2 kHz/month	±1.5 kHz/month
Long-Term Drift (over satellite life)	±20 kHz	±15 kHz

Table 3.1 Ku-Band Translation Frequency Characteristics

3.3 Satellite Beam Information

Each Optus satellite has several receive and transmit beams on both horizontal and vertical polarisation.

Receive and transmit connectivity may be configured by ground command from the Optus Satellite Control Centre to match system operational requirements as they evolve throughout the life of each satellite.

3.3.1 Receive Beams

The receive beams for both A and B-Series satellites are:

	A-Series	**B-Series**
Transponders 1-8	NA	Combined NA and NZ
Alternative beams Transponders 4, 6 and 8	PNG SWP	
Transponders 9-15	NB	NB

Table 3.2 Optus Satellite Receive Connectivity

3.3.2 Transmit Beams

The satellite transmit beams for both the A and B-Series satellites are shown in **Table 3.3** below.

Transmit connectivity may be configured by ground command from the Optus Satellite Control Centre to match system operational requirements as they evolve throughout the life of each satellite.

	Transmit Beams								
Transponder	NA Note 2	NZ	SE Note 2	WA Note 2	PNG/ SWP Note 1	NB	HP	NE	CA
1	A, B	B	A, B						
2	B	B	B	A					
3	A, B	B	A, B						
4	A, B	B	B	A	A				
5	B	B	A, B						
6	A, B	B	B	B	A				
7	A, B	B	A, B	A, B					
8	B	B	A, B	A, B	A				
9						A, B	B	A	
10						A, B	B		A
11						B	B	A, B	
12						A, B	B		A, B
13						A, B	B		
14						A, B	B	A, B	A, B
15						A, B	B	A, B	A, B

Table 3.3 OPTUS Satellite Transmit Connectivity
(Each transponder may be switched to one of the beams as shown)

Legend of beam abbreviations:

NA National Beam, repeater A

NB National Beam, repeater B

SE South Eastern Australia Beam

NE North Eastern Australia Beam

CA Central Australia Beam

WA Western Australian Beam

PNG Papua New Guinea Beam

SWP South West Pacific Beam

NZ New Zealand Beam

HP High Performance Beam

Notes: 1. Alternate selection of the PNG beam or SWP beam is possible on A3.

2. On the B Series satellites these beams may be combined with the NZ beam. The power split is

20% to NZ beam and 80% to the optional beam.

3.4 Satellite Beam Performance Levels

Contour maps of satellite beam performance, in terms of G/T, SFD and EIRP, are provided in **Attachment 1.**

Service designs based on satellite beam performances need to include allowances for the normal performance variations to be expected between different satellite transponders over the operating life of the satellites. To assist design engineers in taking these effects into account, Optus has established a number of "Beam Performance Levels" which include different assumptions about satellite performance. The most important of these is the "General Design Level" which is the only beam performance level for which information is provided in this guide.

3.4.1 General Design Level

The General Design Level (GDL) of beam performance represents the best estimate by Optus of the worst-case performance through to end-of-life for any satellite transponder switched to a particular beam. It allows for all possible cases of service restoration or transponder reallocation, and Optus recommends that it be used for the design of satellite systems to ensure that they will work on any satellite transponder through to end-of-life. In particular the General Design Level of beam performance is recommended for the sizing of earth station antennas and High Power Amplifiers (HPAs) on the uplink, and the calculation of earth station receive G/Ts on the downlink.

The contour maps in **Attachment 1** show the General Design Level of beam performance at the time of publication of this guide for both the A-Series and B-Series satellites operating in geostationary orbit.

3.4.2 Transponder Design Levels

Transponder design levels represent beam performance specific to a given transponder on a given satellite in a given orbit position at a given time. These design levels are used for the actual implementation of services on the Optus satellites, and will be provided by Optus to customers for contracted services for this purpose. They may also be provided in other circumstances upon request from Optus. Optus does not recommend that transponder design levels be used to design systems or size earth stations.

3.4.3 Inclined-Orbit Satellites

The orbital motion of an inclined-orbit satellite results in a complex movement of the beam patterns as seen from the ground. As a consequence an earth station will see a diurnal, roughly sinusoidal variation in the satellite G/T and EIRP which grows larger as the orbital inclination builds up. It is difficult to predict the precise beam performance at a given location at a specific time; rather Optus can provide beam patterns showing the minimum predicted daily G/T and EIRP across the beam coverage area for any given inclination, plus the corresponding daily peak-to-peak variation as appropriate.

3.5 Transponder Gain Control

Each satellite transponder contains a Channel Control Unit (see section 2.2) which provides a means of controlling the transponder gain. This gives the transponder a range of operating C/T values to suit the characteristics of the systems operating on it at a given time. The C/T (called "C-to-T") is the uplink saturated carrier-to-noise-temperature ratio and is a fundamental design parameter of a satellite transponder. It is related to the SFD and G/T by the following equation:

$$C/T = SFD + G/T + 10\log_{10}(\lambda^2/4p)$$

- where -

C/T = Saturated carrier-to-noise-temperature ratio (dBW/K)

SFD = Saturated flux density (dBW/m^2)

G/T = Satellite receive gain-to-noise-temperature ratio (dB/K)

$\lambda^2/4p$ = Isotropic area conversion factor (m^2)

Note that for a given transponder gain setting the C/T is fixed, meaning that the sum (SFD + G/T) is also fixed, i.e. the SFD and G/T vary in inverse proportion over the satellite receive beam pattern. It is therefore usual to quote the SFD at a "standard G/T contour" for a given C/T or gain step.

On the Optus satellites two methods are used to provide transponder gain control for a range of C/Ts: Fixed Gain Mode (FGM) and Variable Gain Mode (VGM).

3.5.1 Fixed Gain Mode (FGM)

FGM corresponds to traditional gain-step control in which a variable step-attenuator is switched under ground command to one of a number of settings or "gain steps". The A-Series have three gain steps (called L, M and H) in 5dB steps, covering an uplink saturated C/T range of approximately -127.5 to -137.5 dBW/K. In gain step L the SFD is -80 dBW/m^2 at the -3 dB/K G/T contour, while in gain step H it is -90 dBW/m^2.

The B series have eight gain steps (called 1 to 8) in 3dB steps, covering a nominal uplink saturated C/T range of -120 to -141 dBW/K. In gain step 1 the SFD is -77.5 dBW/m^2 at the +2dB/K G/T contour, while in gain step 8 it is -98.5 dBW/m^2. (On the B1 A polarisation the C/T range and SFDs are 2dB higher.) Note that there is no direct comparison between gain steps on the A and B series because of the very different receive beam shapes.

The predicted maximum initial values of satellite SFD in the lowest gain step are shown in Attachment A1-2 (excluding the B1 A polarisation which is 2dB higher than shown). The SFD can be expected to vary from these values due to gain step tolerances, operating temperature variations and ageing effects. The SFD will be maintained over life to within ±3.5dB on the A-Series and ±2.5dB on the B-Series. Optus will advise customers of the actual SFD performance of a particular transponder at the commencement of a customer's service in order to allow uplinks to be properly aligned, and will keep customers advised of any changes in SFD performance over life which may necessitate changes in uplink EIRP.

3.5.2 Variable Gain Mode (VGM)

VGM provides a form of automatic gain control and is only available on the B-Series. Under VGM a feedback-loop maintains a constant input drive level to the transponder TWTA over an uplink C/T range of -120 to -141 dBW/K, i.e. the same operating range as for FGM. This compensates for uplink fading at the cost of gradually degrading the uplink C/N. The TWTA input drive level can be separately set under ground command between about 0 and 12dB IBO in 1dB steps (the precise IBO will depend on exactly how the transponder is operated).

VGM operates on the total transponder power and is therefore intended for either single-carrier operation, or for multiple carriers where all carriers are uplinked from the same location and therefore undergo an uplink fade at the same time. VGM may be used with uplink power control if desired to extend the range of uplink fade compensation.

3.6 Amplitude Transfer Characteristics.

Representative AM/AM transfer characteristics for the TWTA's used in both the OPTUS A and B-Series satellites are shown in Figure 3.2 and Figure 3.3. These include transfer curves for single carrier and two equal carriers operation and as a guide to assessing intermodulation, the level of third-order IM products is given for the two carrier cases. The X axes define the Input Backoff (IBO) relative to TWTA saturation for the total of the carriers whilst the Y axes define the Output Backoff (OBO) for each carrier.

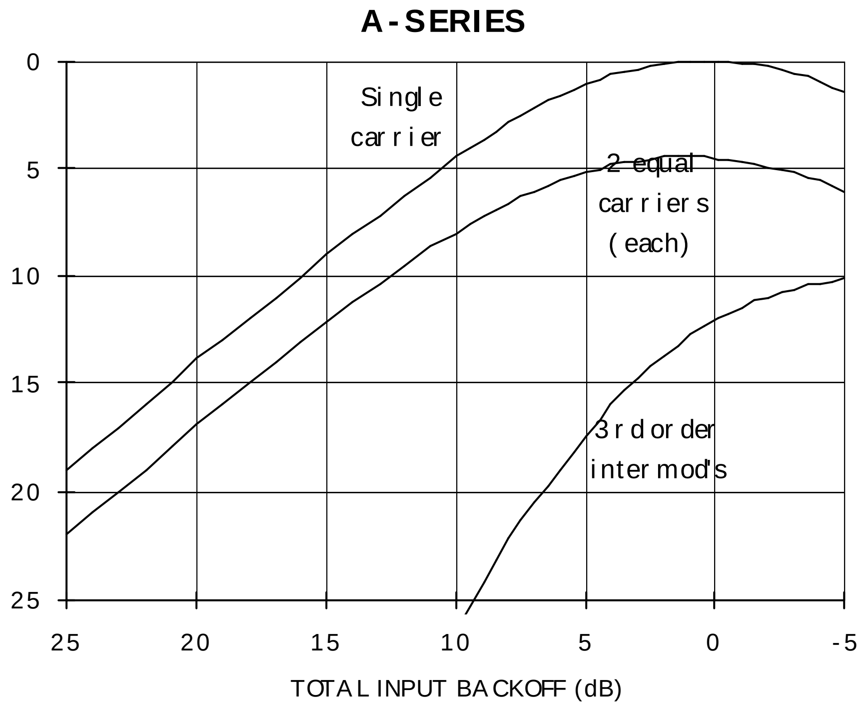


Figure 3.2 Typical A-Series Amplitude Transfer Characteristic

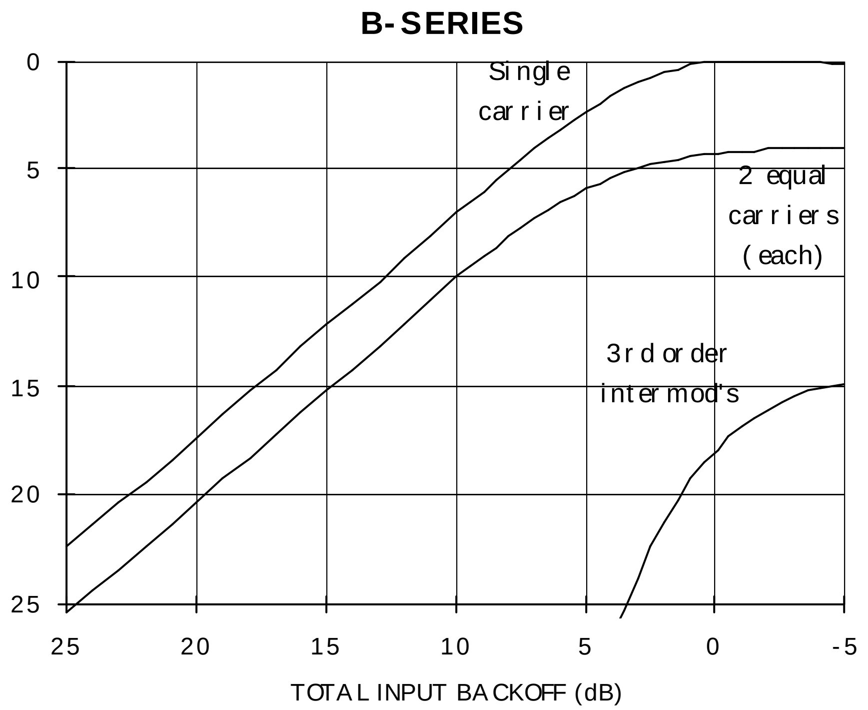


Figure 3.3 Typical B-Series Amplitude Transfer Characteristic

Figure 3.4 shows the Normalised TWTA gain of a typical A-Series transponder as a function of Total IBO for a single carrier, two equal carriers and many (equal) carriers. **Figure 3.5** provides the same information for a typical B-Series transponder.

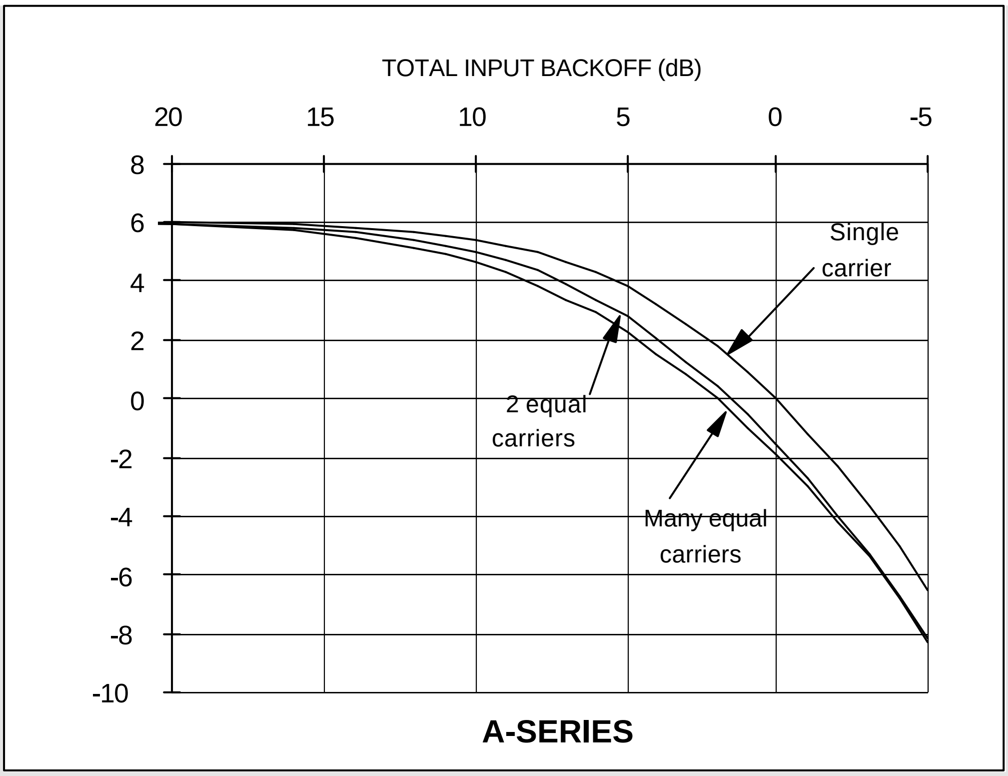


Figure 3.4 Typical A-Series Transponder Gain Characteristic

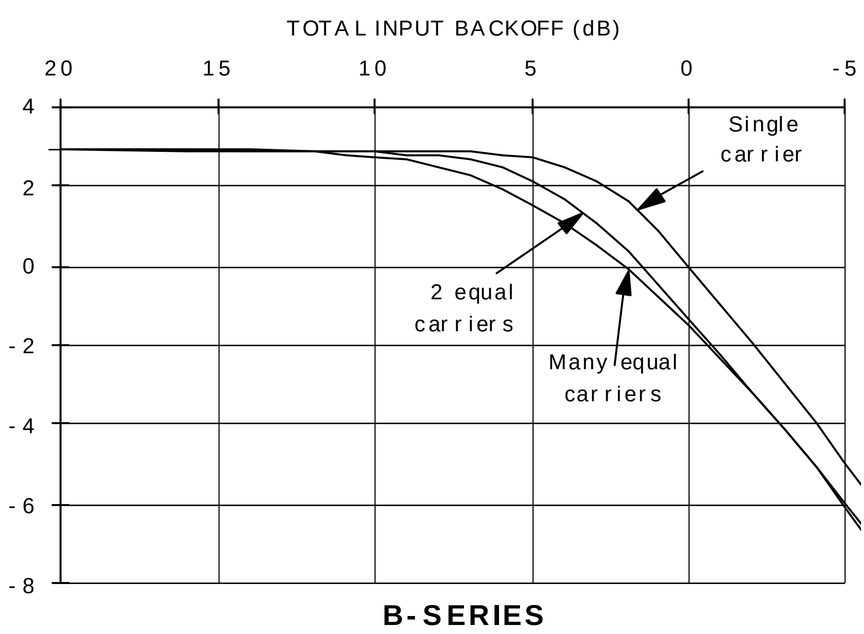


Figure 3.5 Typical B-Series Transponder Gain Characteristic

3.7 Satellite Cross Polarisation Discrimination

Cross polarisation performance of the orthogonally polarised repeater A and repeater B, for each satellite receive and transmit beam, will exceed the following performance levels.

Cross-polarisation performance of the satellite link can be expected to degrade during rain storms and under other adverse weather conditions.

3.7.1 Receive Cross Polarisation Discrimination

The A-Series satellite minimum receive cross polarisation discrimination is 33dB and for the B-Series it is 35dB. The actual cross polarisation, for both satellites, is generally better than 45dB over Australia and New Zealand.

3.7.2 Transmit Cross Polarisation Discrimination

The A-Series satellite minimum transmit cross polarisation discrimination is 32dB and for the B-Series it is 33dB. The actual cross polarisation, for both satellites, is generally better than 40dB over Australia and New Zealand.

4. L-Band Communications Payload

The Optus B-Series spacecraft include a L-Band communications payload which provides the Mobilesat® communications services using both Ku-Band and L-Band satellite links to and from a vehicle or small fixed terminal. This transponder service is optimised for many simultaneous low power voice terminals with low antenna gain.

The L-Band block diagram is included in the lower portion of Figure 2.2 above, while Figure 4.1 below depicts a typical L-Band communications application.

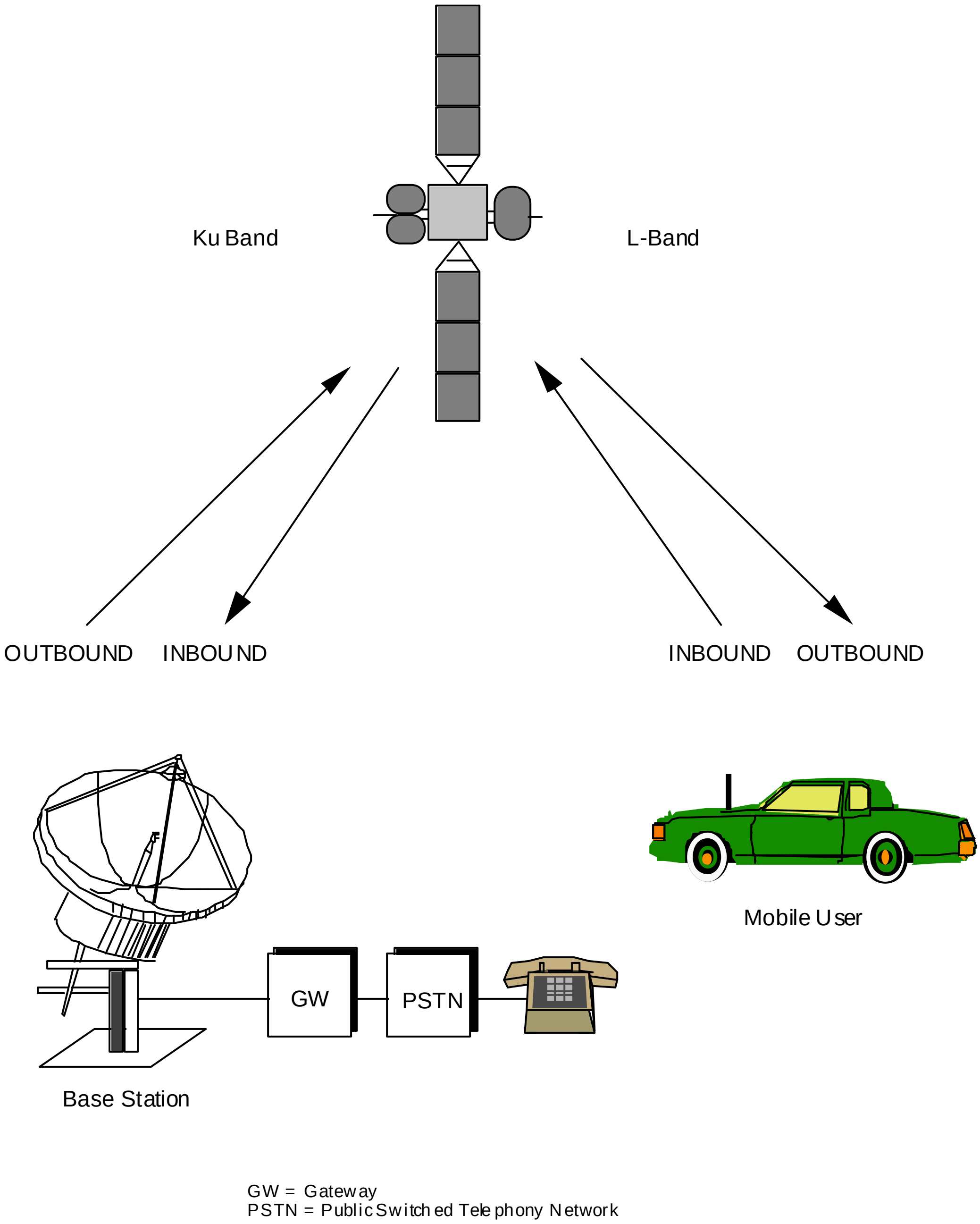


Figure 4.1 Typical MobilesatÒ Service

The configuration of the L-Band repeater consists of an outbound transponder (Ku-Band uplink and L-Band downlink) and an inbound transponder (L-Band uplink and Ku-Band downlink). The inbound transponder receives signals from the mobile terminal at L-Band and re-transmits to a Ku-Band base station. The outbound transponder receives signals from the Ku-Band base station and transmits to the mobile terminal at L-Band.

4.1 Frequency Plan

The Optus L-Band communications payload receives and transmits on the following Ku and L-Band frequencies:

Outbound   Ku-Band receive   14,011.5 - 14,025.5 MHz
L-Band transmit   1545.0 - 1559.0 MHz

Inbound   L-Band receive   1646.5 - 1660.5 MHz
Ku-Band transmit 12,263.5 - 12,277.5 MHz

The L-Band communications payload frequency and polarisation plans are shown in **Figure 4.2** below.

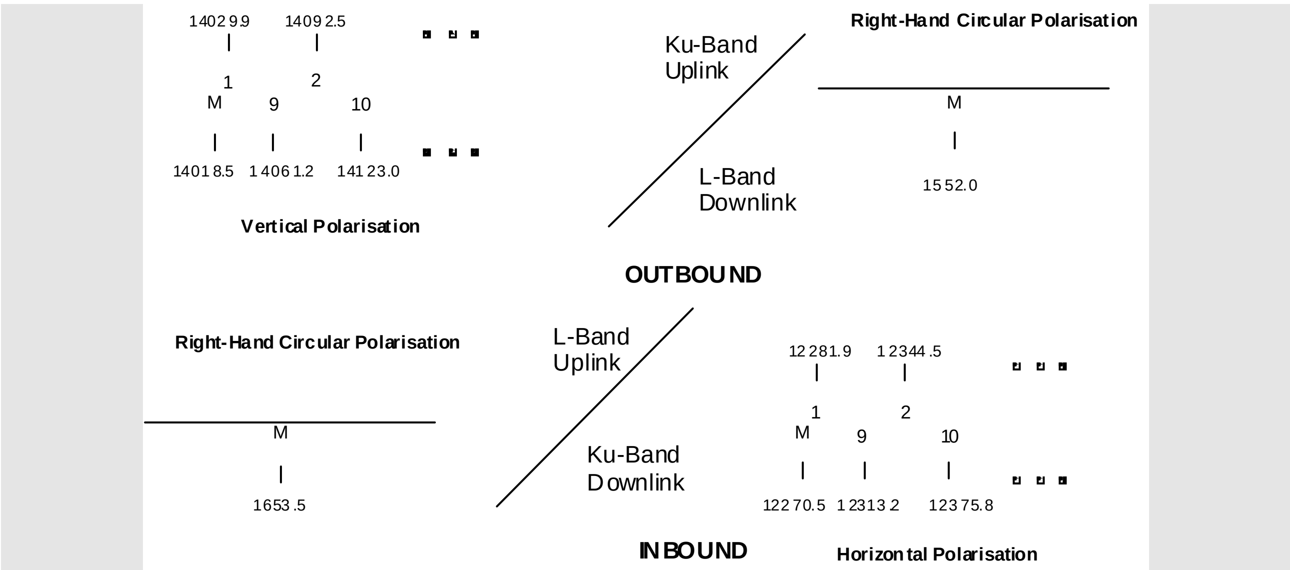


Figure 4.2 L-Band Frequency (MHz) and Polarisation Plan

4.2 Frequency Translation Characteristics

	Inbound Transponder (L to Ku)	Outbound Transponder (Ku to L)
Translation Frequency	10,617 MHz	12,466.5 MHz
Short Term Drift (over 24 hours)	±2.5 kHz	±3.0 kHz
Long Term Drift (over life)	±25 kHz	±35 kHz

Table 4.1 L-Band Frequency Translation Summary

4.3 Description of L-Band Communications Payload

A simplified block diagram of the L-band communications payload is shown in Figure 2.2. The L-band payload consists of two transponders or channels: an "In bound" L-to-Ku-band transponder and an "Out bound" Ku-to-L-band transponder.

i) In Bound Transponder

On the in-bound link, L-band signals are received by a phased-array antenna mounted on the body of the spacecraft and fed to a diplexer which splits/combines the receive and transmit bands. The receive band is fed to a receiver in a 2-for-1 redundancy matrix, then through input multiplex filters (IMUX) before being up-converted to the 12GHz band. The Ku-band signal is then fed into the channel amplifier section of channel M (refer to Figure 2.2) of repeater B of the Ku-band payload.

ii) Out Bound Transponder

On the out bound link, 14GHz signals are received on repeater B of the Ku-band payload, translated to 12GHz and separated by the input multiplexers into channel M. This channel is then fed to a down-converter unit consisting of a 12GHz-to-L-band down-converter, a step attenuator providing channel gain control, and a driver amplifier. The signal is then split and fed to a bank of solid-state power amplifiers (SSPAs). The SSPAs use 12-for-8 redundancy and provide a usable multi-carrier output power of 150W. The outputs from the SSPAs are phase-combined in pairs and fed to the output filter/diplexer and thence to the L-band array. The array is driven in quadrants and the final signal is phase-combined in space.

4.4 L-Band Beam Performance Levels

General Design Level contours of G/T and EIRP are shown for the L-Band payload in **Attachment 2.**

Section 3.4 above explains the General Design Level which also applies to the Mobilesat® communications payload for both L and Ku-Band components.

The information is supplied for terminal station design and evaluation purposes. As Optus offers a Mobilesat® service customer design is not relevant to the L-band payload.

Optus Mobilesat® service operates in a multi-carrier mode on the satellite and the contour diagrams provided show the transponder performance for the nominal fully loaded condition.

5. Earth Station Pointing, Polarisation Angles and Sun Outages

To correctly align an earth station antenna to point at a satellite from a specific site, pointing information in terms of azimuth and elevation is required. It is also necessary to align the antenna polarisation with the satellite at each site. Attachment 3 provides the pointing information for aligning a satellite earth station to operate on an Optus satellite.

5.1 Earth Station Pointing Angles

The figures in Section A3-1 show the earth station azimuth and elevation angles for the three currently occupied Optus orbit locations.

Please note the azimuth angles shown in Attachment 3 provide the satellite pointing information, offset from true north.

For the inclined orbit satellites the pointing angles provide the nominal "box" centre of the figure eight pattern exhibited in the orbital variations as described in Section 2.4.2 above.

5.2 Magnetic Variation

The difference between true north and magnetic north varies over the service area of the Optus satellites.

Section A3-2 includes a contour map showing the variation for the year 1991. This map may be used for correcting the true azimuth angle when aligning antennas using a magnetic compass. The map should remain accurate to 1° over 8-10 years.

5.3 Earth Station Polarisation Angles

The polarisation angles provided in Section A3-3 apply to the Ku-Band communications payload which uses linear, orthogonally polarised transmission and reception.

The L-Band communications payload uses circular polarisation for the L band component and the same linear orthogonally polarised system as the Ku-Band payload. The polarisation angles provided in the attachment apply to the Ku band transmission and reception and not to the L band payload.

5.4 Sun Outages

Twice a year an earth station will experience a series of "sun outages" when all or part of the sun's disk crosses behind the satellite as seen from the earth station. This results in a substantial increase in the sky noise temperature with a consequent reduction in the earth station G/T, and is thus similar to a downlink rain fade event. The "outages" occur on about three to five consecutive days within one month on either side of the equinox. Each outage lasts for a few minutes, with the precise depth and duration depending on the size of the receive antenna and the downlink carrier fade margin.

In the southern hemisphere sun outages occur after the March equinox when the sun is moving from south to north. The greater the latitude of an earth station the longer it is after the equinox when the outages occur. In September when the sun is moving from north to south this situation reverses, with the outages occuring before the equinox and starting at greater latitudes first. East of a satellite the outages occur after (local) noon and west of a satellite before noon, with the time difference depending on the longitude difference between the earth station and the satellite. Thus in Australia which is west of the Optus satellites, sun outages occur before noon after the March equinox starting in the north and working south, and before noon before the September equinox starting in the south and working north.

6. Satellite Beacons

All Optus satellites transmit beacon signals which may be used by customer earth stations for antenna tracking and uplink power control (UPC). The A-Series satellites carry only telemetry beacons, but the B-Series satellites also carry a UPC beacon which should be used in preference to the telemetry beacons.

6.1 Telemetry Beacons

Each satellite transmits two modulated telemetry beacons, one at a unique frequency for each satellite and the other at a common frequency (but different between the A and B-Series). These beacons use the NB beam and therefore appear only on the B polarisation covering Australia. The beacon frequencies and approximate levels in Sydney are shown in **Table 6.1**. (The levels elsewhere may be estimated by correcting for the difference in the National beam EIRP pattern between Sydney and the other location - see **Attachment 1**.)

6.2 Uplink Power Control Beacon

The B-Series satellites carry a special uplink power control beacon which should be used in preference to the telemetry beacons for tracking and Uplink Power Control (UPC). This beacon is unmodulated, has a temperature-stabilised EIRP, and uses separate horns which give it "global" coverage on both polarisations (thus it appears to have an arbitrary elliptical polarisation). The frequency and approximate level of the UPC beacon are given in **Table 6.1**. The level is constant to within about 0.5dB across Australia, and within 1dB in New Zealand.

Satellite/Beacon	Frequency	Downlink Polarisation	Nominal Power Level (at Sydney)
A-Series Satellites			
Common Beacon	12,749.75 MHz	H	14 dBW
A2 Satellite	12,748.5 MHz	H	14 dBW
A3 Satellite	12,748.25 MHz	H	14 dBW
B-Series Satellites			
Common Beacon	12,749 MHz	H	33 dBW
B1 Satellite	12,748 MHz	H	33 dBW
B3 Satellite	12,747.5 MHz	H	33 dBW
UPC	12,750 MHz	V and H	13 dBW

Table 6.1 Optus Satellite Beacons

7. Uplink Power Control Operation

Customers may use uplink power control systems (UPC) to compensate for uplink rain attenuation. Since a malfunctioning UPC system can interfere with other services and even damage a satellite TWTA, UPC systems must be tested and approved by Optus before use and are strictly limited in the amount of uplink compensation permitted. Details of the amount of UPC permitted under various operating conditions may be obtained from Optus.

UPC systems use the attenuation measured on a downlink beacon to compensate for attenuation on the uplink. However attenuation is frequency-dependent and a scaling factor needs to be applied to determine the correct uplink compensation. At 14/12GHz Optus recommends a scaling factor of 1.3.

The satellite telemetry beacons are not temperature-stabilised, they carry modulation, and frequently have their modulation switched during the normal course of satellite operations. As a result there may be variations in the telemetry beacon carrier component of up to 3dB. If a customer intends to use the telemetry beacons for UPC, then a minimum filter bandwidth of 100kHz should be used in order to minimise level variations caused by modulation and modulation-switching. These problems do not apply to the B-Series UPC beacon which should be used as the preference.

Customers intending to use the A polarisation UPC beacon should note that it appears at the edge of the transponder 8 output filter. The beacon C/N will therefore be degraded by the transponder thermal and intermodulation noise; consequently a narrower beacon filter bandwidth is recommended (10kHz or less).

7.1 Satellite Beam Contours for the Ku-Band Communications Payload

The contour diagrams below show the General Design Levels for geostationary Optus satellites.

The satellite G/T and SFD indicates the satellite transponder receive performance level as "seen" from the ground.

The contour diagrams of EIRP show the radiated satellite transponder power as "seen" on the ground for a single saturating carrier.

The contour diagrams of G/T and EIRP show the performance of the A-Series satellite at 156^{o} east longitude.

The contours for the B-Series satellites apply to orbit locations of either 156^{o} or 160^{o}.

With B-Series transponders, if the NANZ, WANZ or SENZ options are implemented for the NZ capable downlink beams, 1.0dB should be deducted from the EIRP contours shown in Figs A1-3.3, A1-3.6 or A1-3.15 respectively and 7.0dB should be deducted from NZ EIRP contours shown in Fig A1-3.17.

For the B-series transponders 1 to 8 both the Australian and the New Zealand uplink contours as shown in Fig A1-1.2, A1-1.3, A1-2.2 and A1-2.3 simultaneously apply.

Note. An explanation of General Design Levels is included in **Section 3.4** of this document..

7.1.1 A1-1 Receive Gain on Temperature G/T

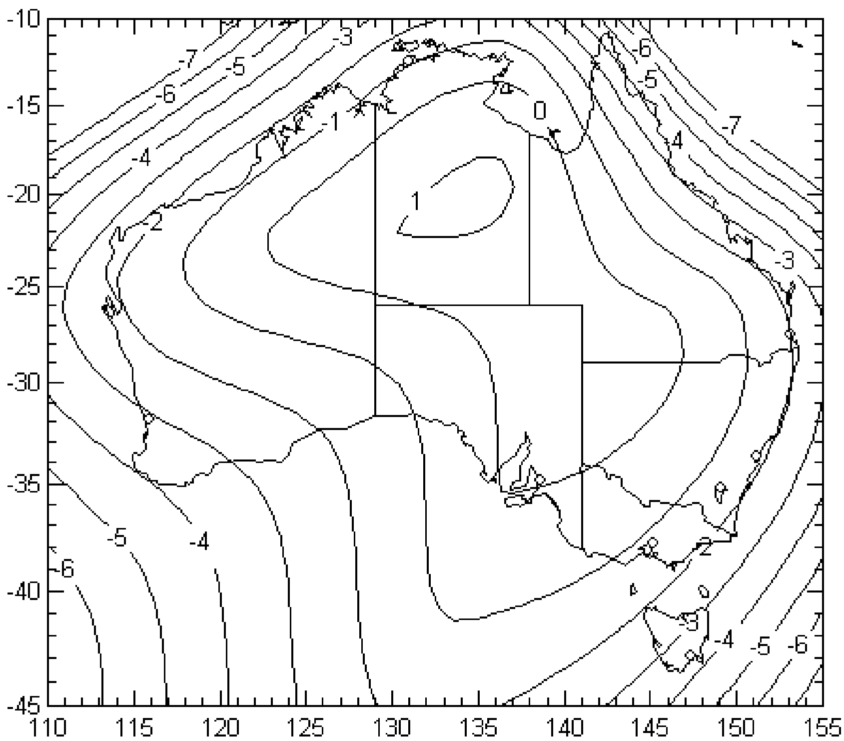


Figure A1-1.1 National Beam Receive G/T (dB/K) A3 Satellite

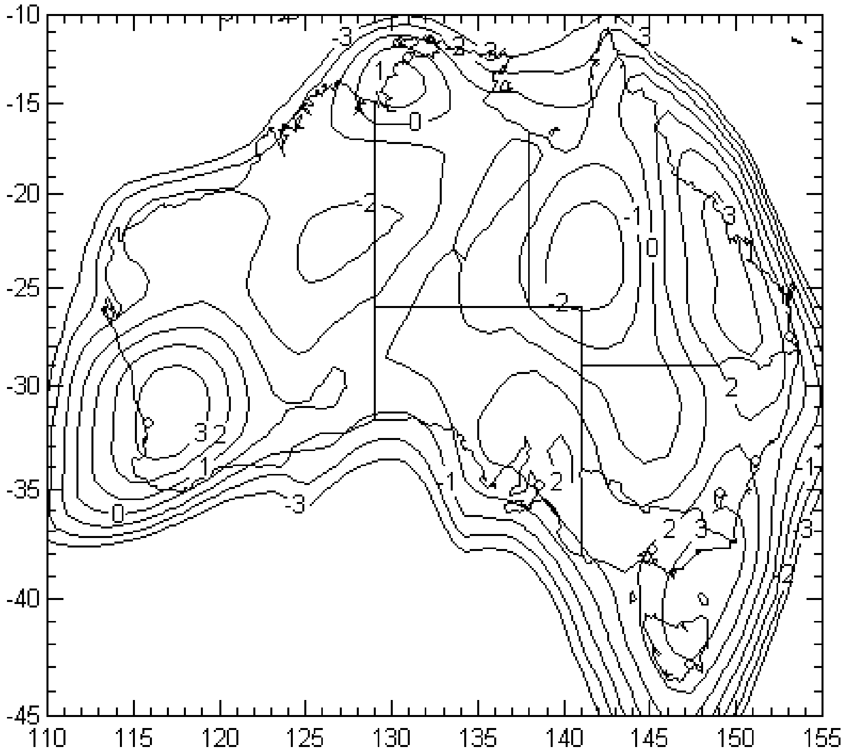


Figure A1-1.2 National Beam Receive G/T (dB/K) B-Series Satellite

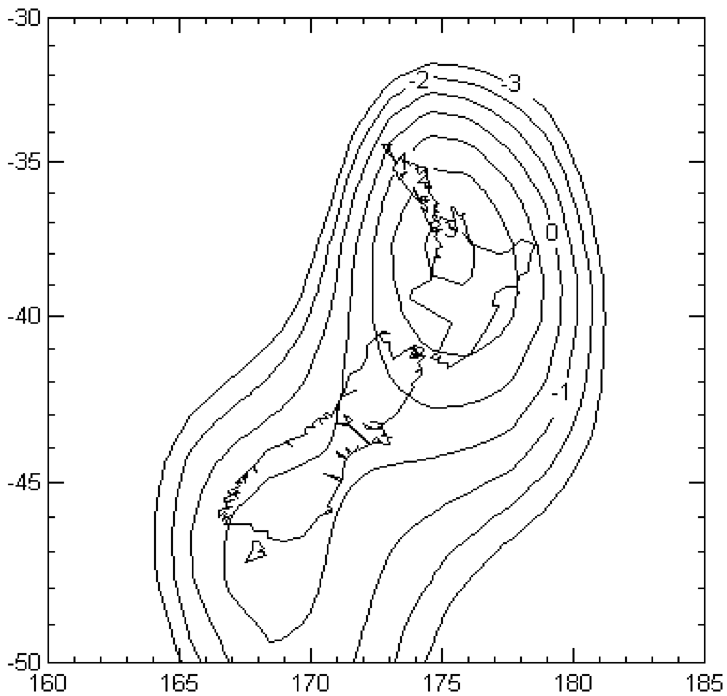


Figure A1-1.3 New Zealand Beam Receive G/T (dB/K) B-Series Satellite

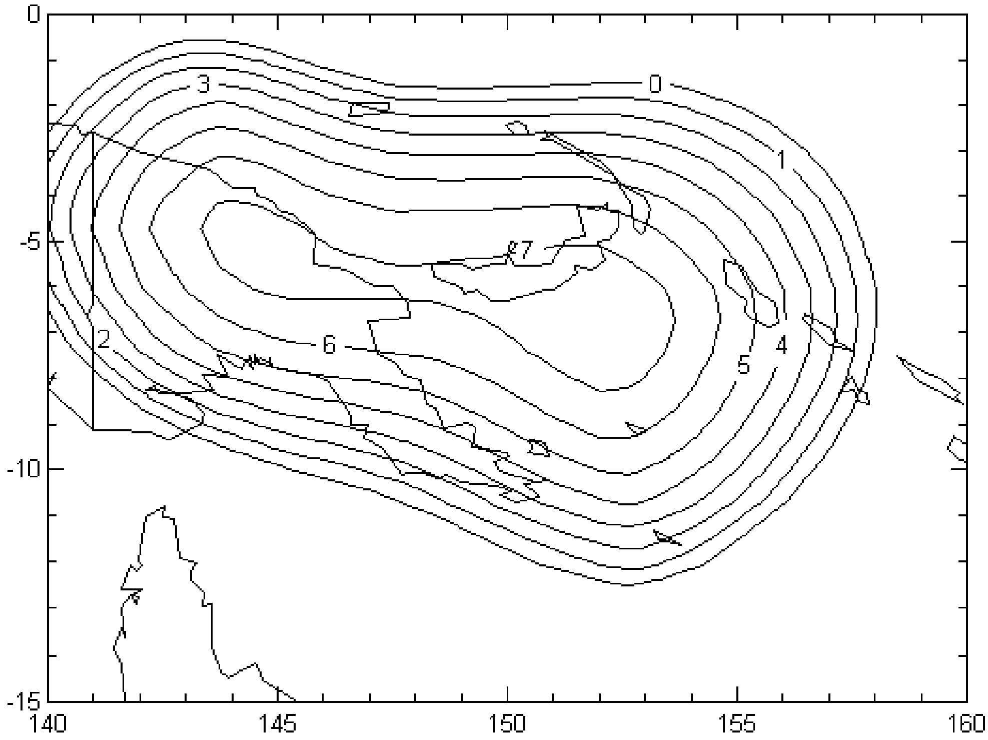


Figure A1-1.4 Papua New Guinea Beam Receive G/T (dB/K) A3 Satellite

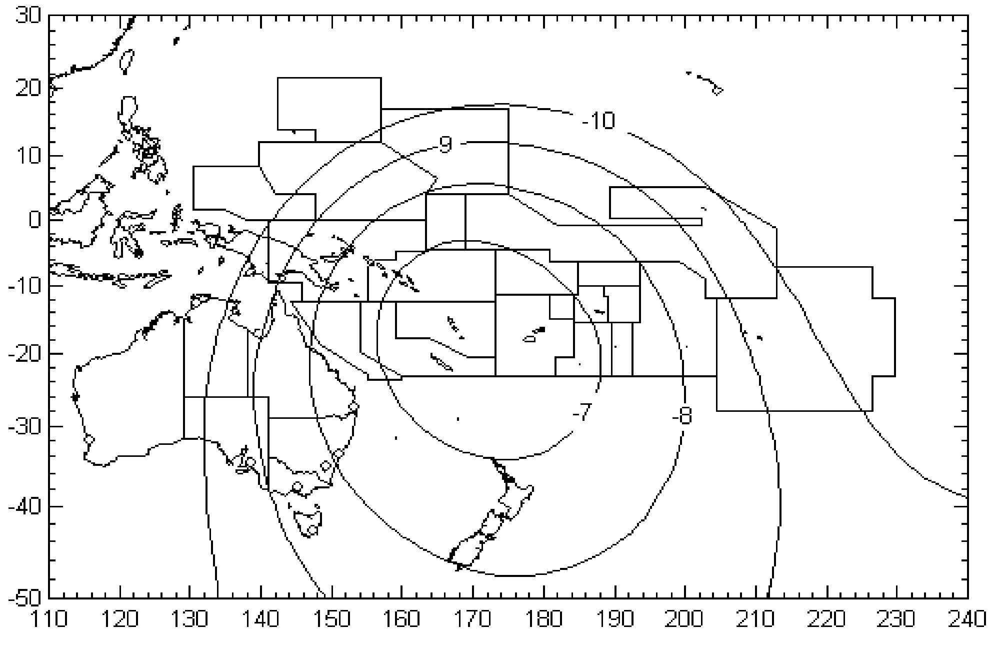


Figure A1-1.5 South West Pacific Beam Receive G/T (dB/K) A3 Satellite

7.1.2 A1-2 Transponder Saturated Flux Density (SFD)

The transponder saturation flux density for a single, centre frequency carrier is shown below under clear sky conditions.

For the A3 satellite the L gain step is assumed. For the B series satellites the gain step 1 is assumed.

Note 1: For the B1 A polarisation transponders the SFD is 2dB higher that shown in figures A1-2.2 and A1-2.3.

Note 2: An explanation of the transponder gain steps is included in **Section 3.5**

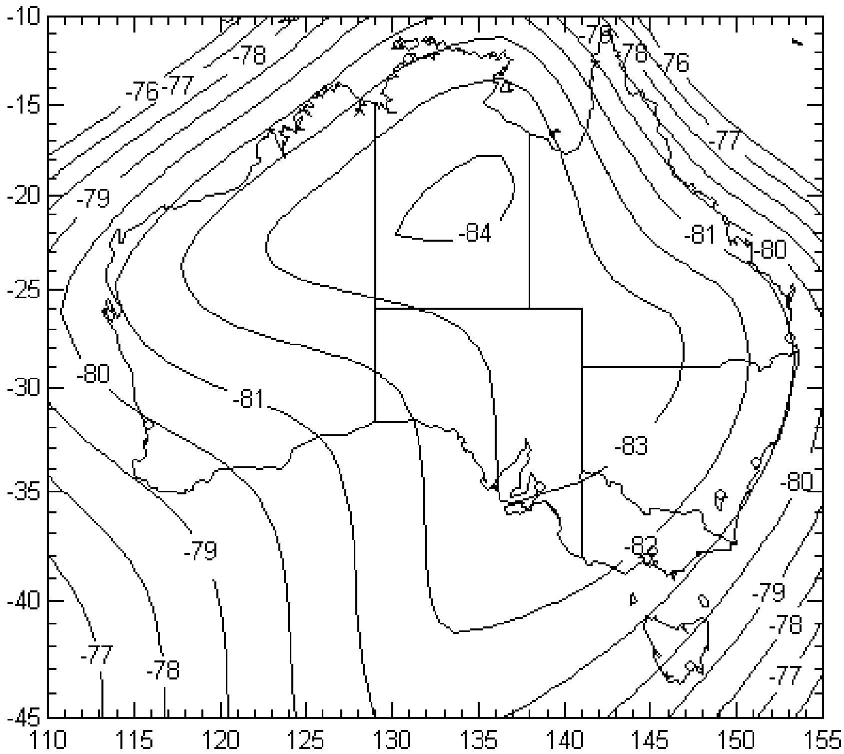


Figure A1-2.1 National Beam Transponder SFD (dBW/m^2) A3 Satellite

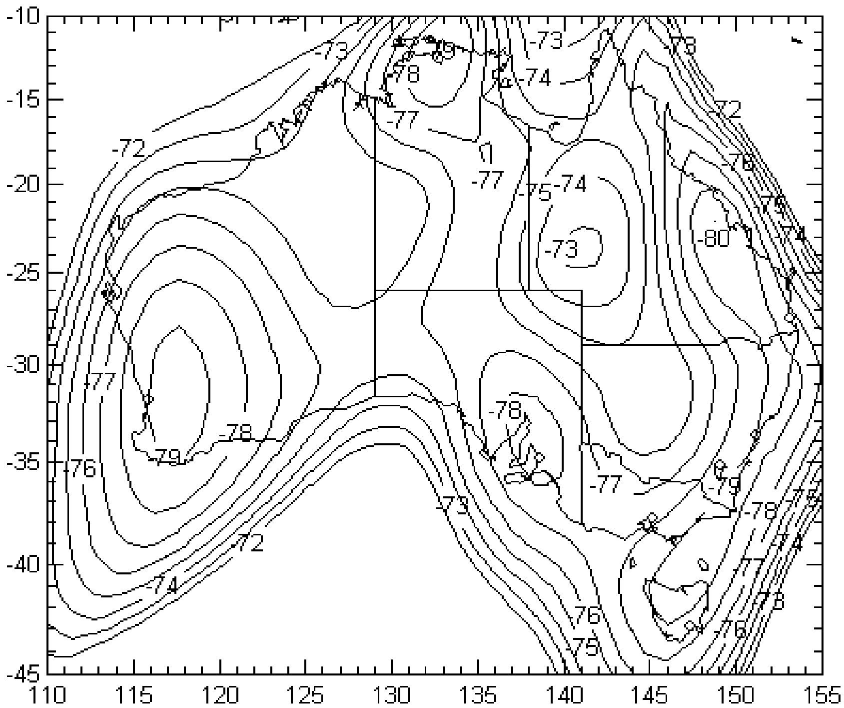


Figure A1-2.2 National Beam Transponder SFD (dBW/m^2) B Series Satellite (see Note 1)

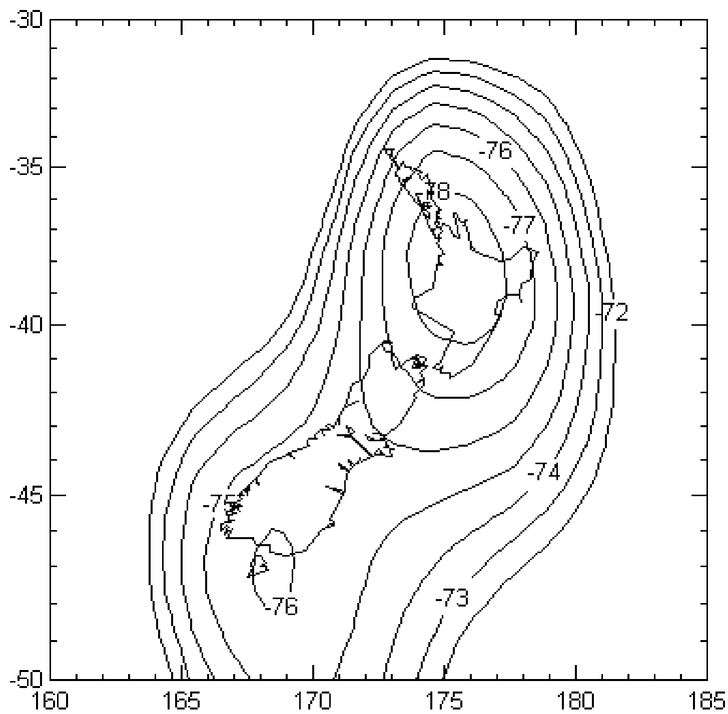


Figure A1-2.3 New Zealand Beam Transponder SFD (dBW/m^2) B Series Satellite (see Note 1)

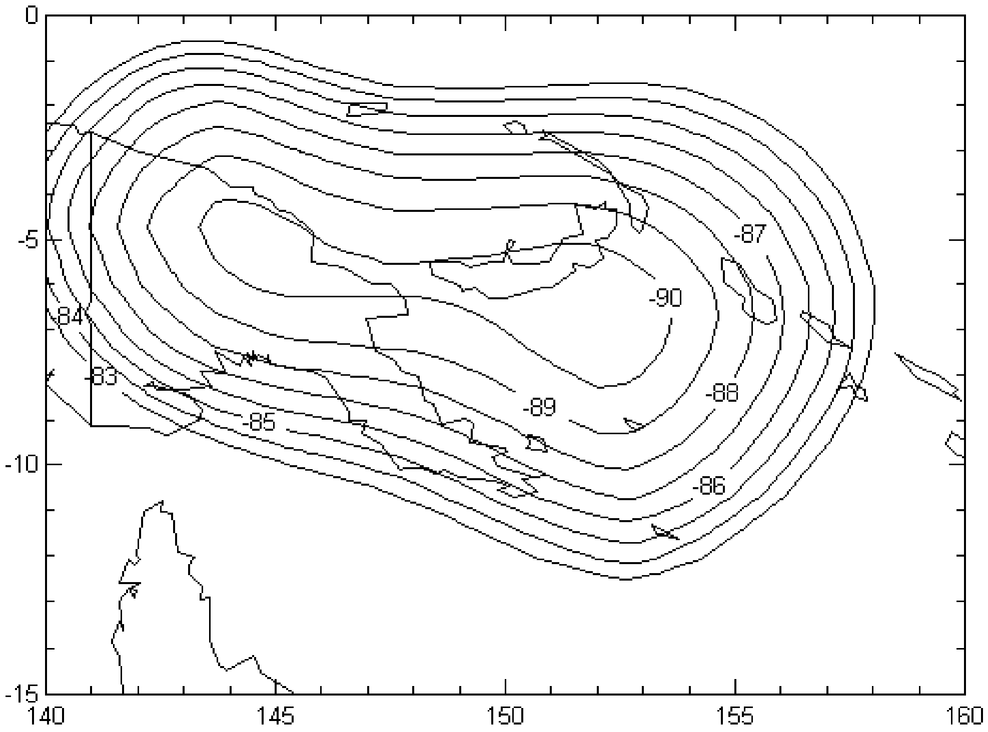


Figure A1-2.4 Papua New Guinea Beam Transponder SFD (dBW/m^2) A3 Satellite

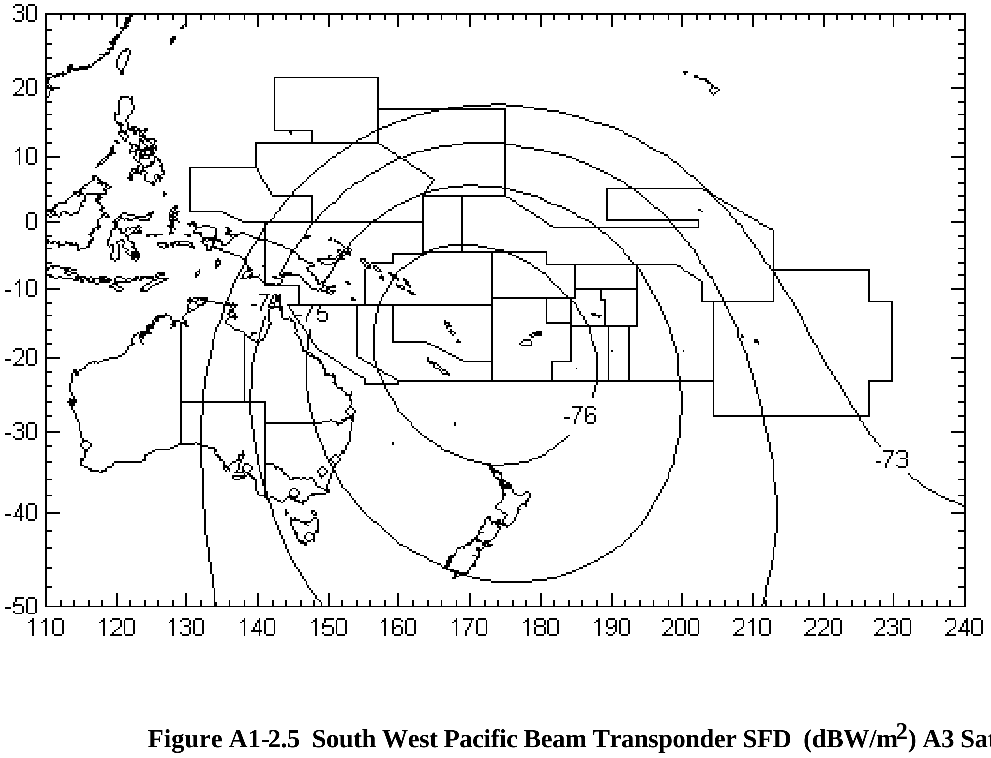


Figure A1-2.5 South West Pacific Beam Transponder SFD (dBW/m^2) A3 Satellite

7.1.3 **A1-3 Radiated EIRP**

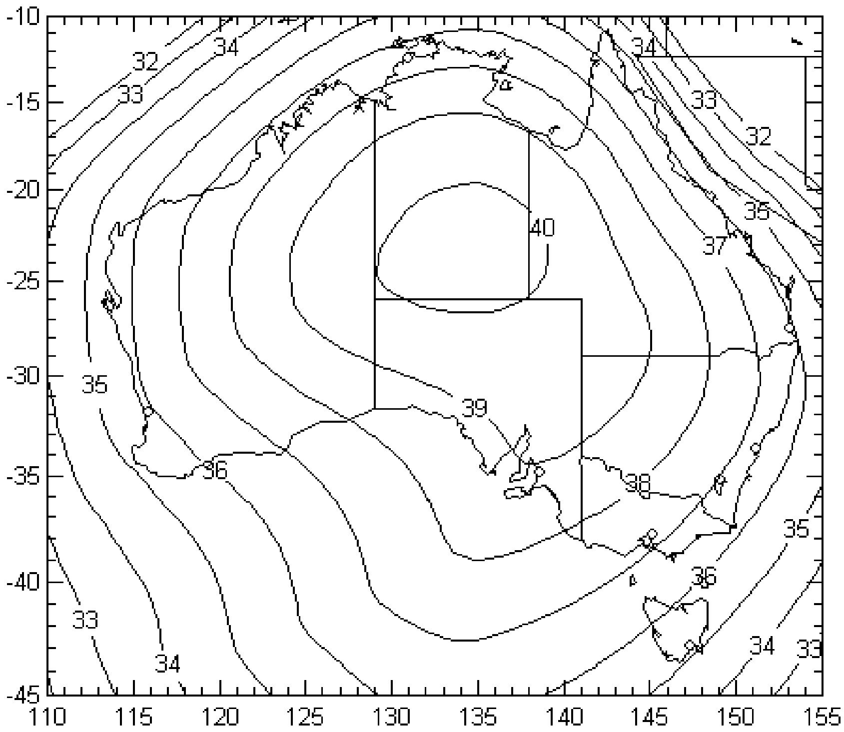


Figure A1-3.1 National Beam Radiated EIRP (dBW) Low Power, (12W) A3 Satellite

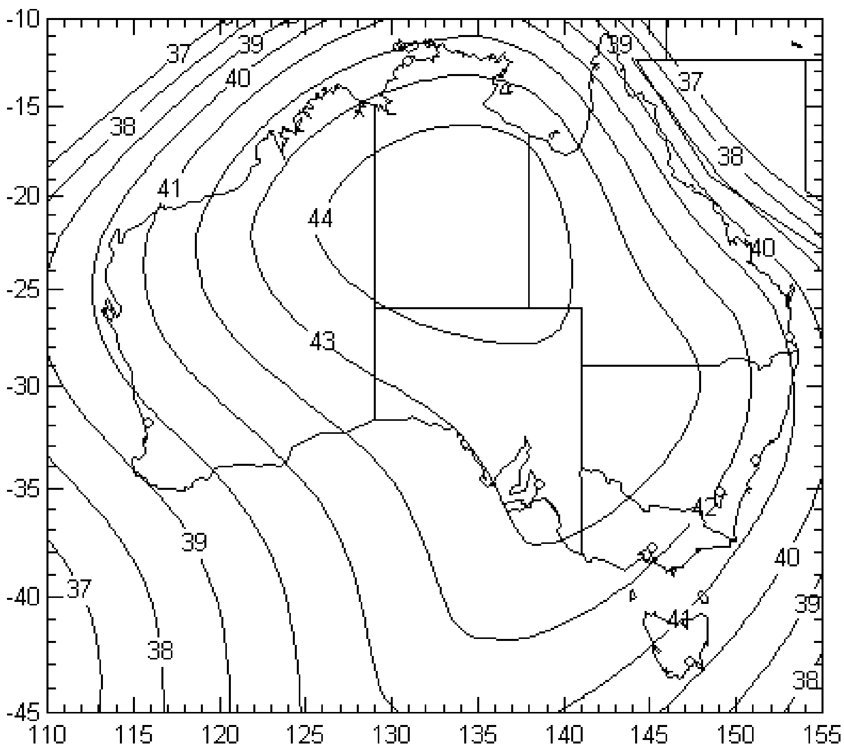


Figure A1-3.2 National Beam Radiated EIRP (dBW) High Power, (30W) A3 Satellite

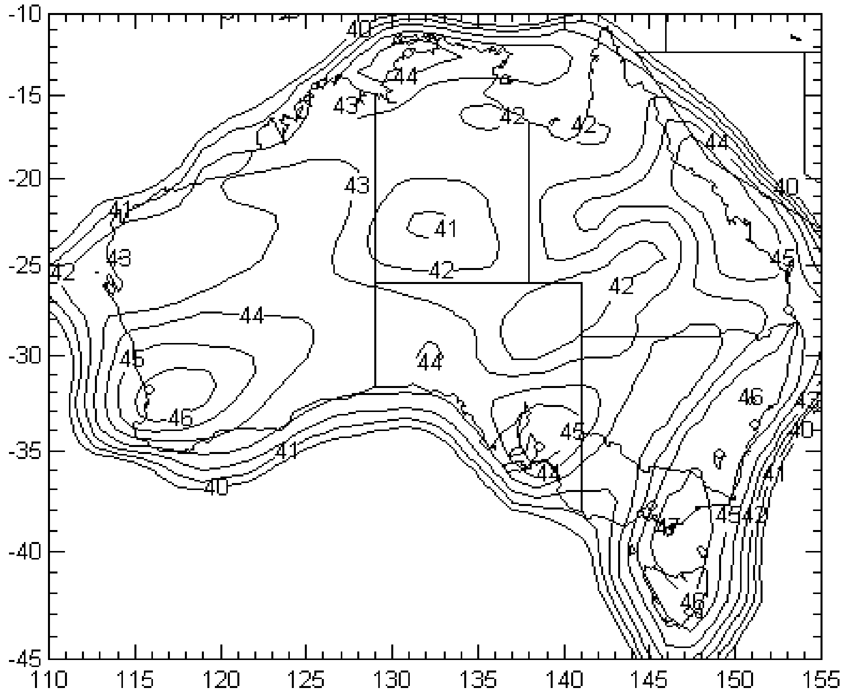


Figure A1-3.3 National Beam Radiated EIRP (dBW) B-Series Full Transponder

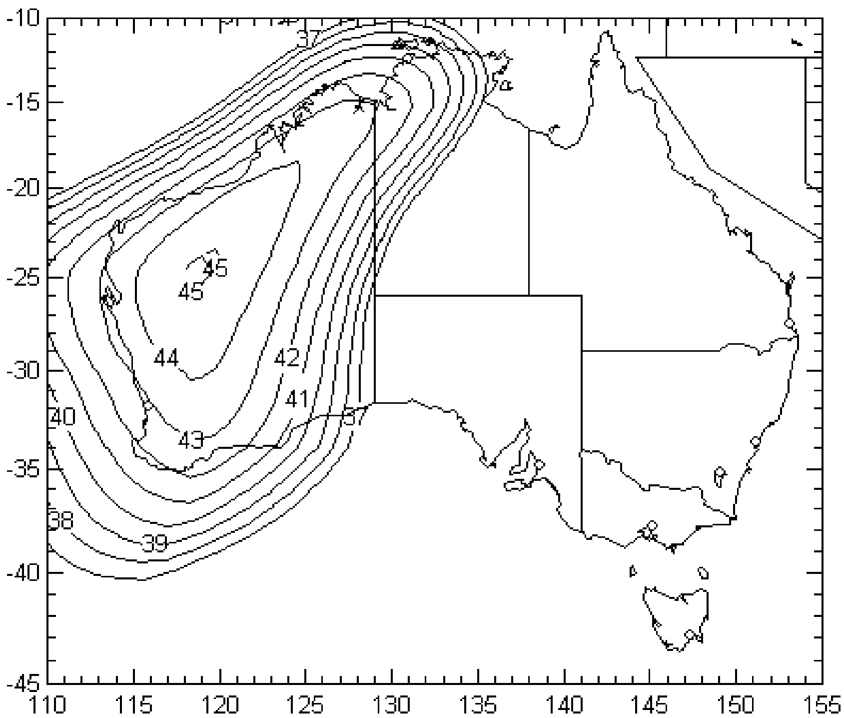


Figure A1-3.4 West Australia Beam Radiated EIRP (dBW) Low Power, (12W) A3 Satellite

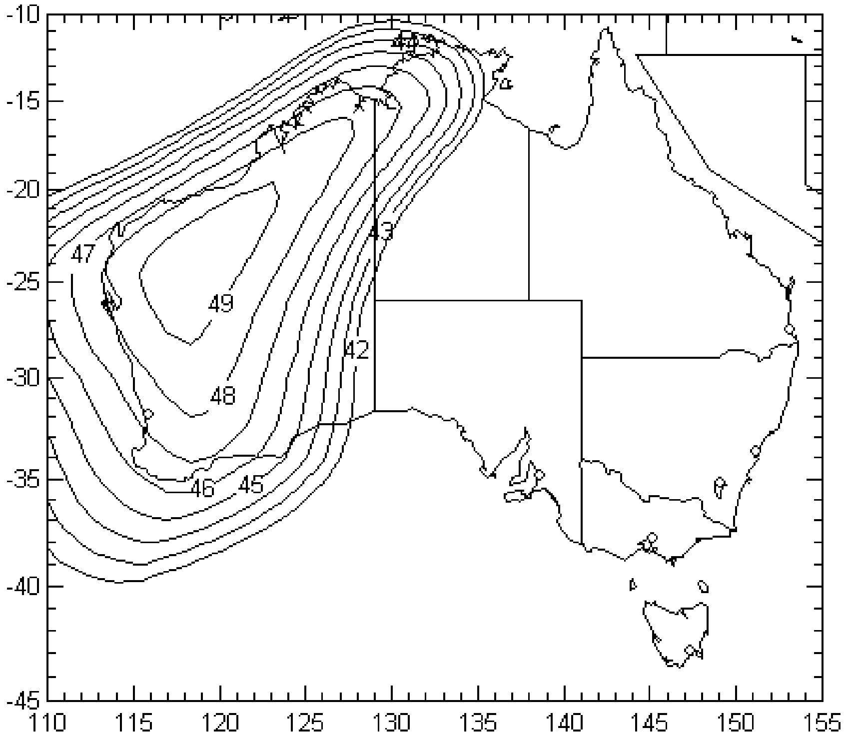


Figure A1-3.5 West Australia Beam Radiated EIRP (dBW) High Power, (30W) A3 Satellite

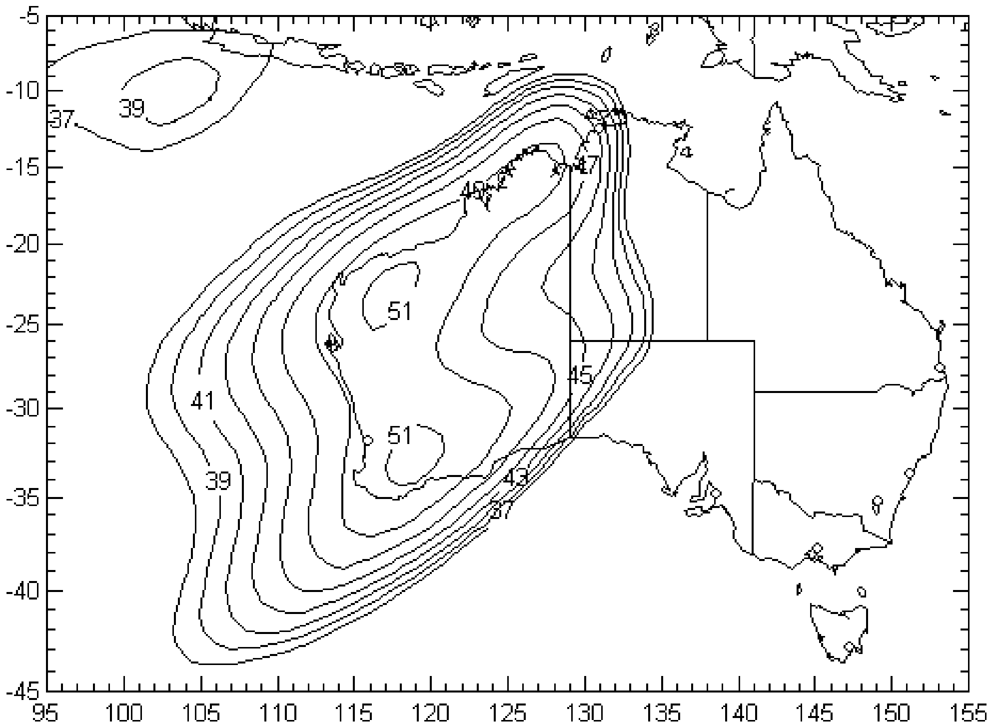


Figure A1-3.6 West Australia Beam Radiated EIRP (dBW) B-Series Full Transponder

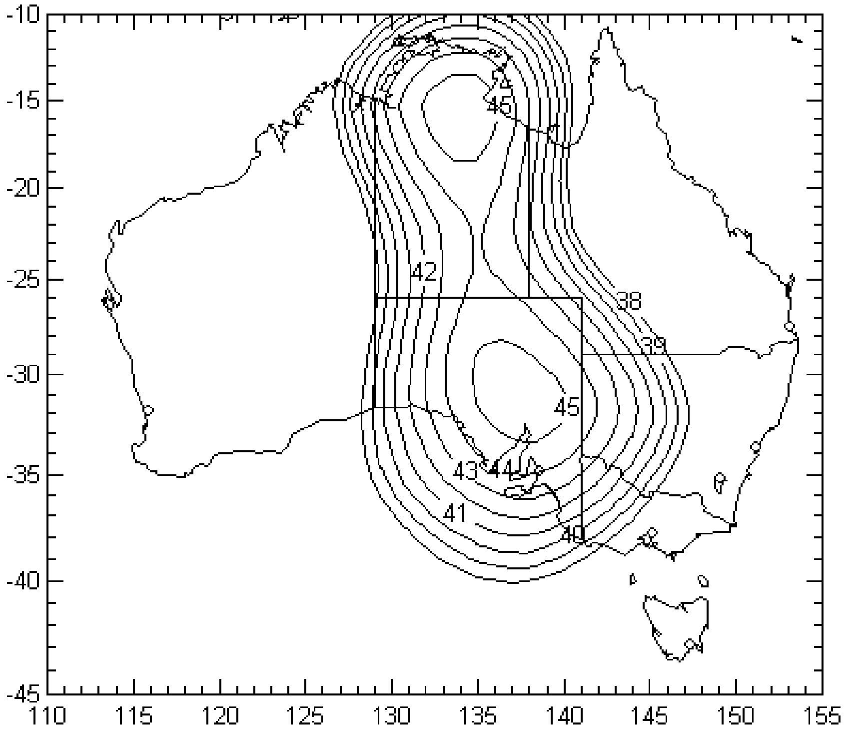


Figure A1-3.7 Central Australia Beam Radiated EIRP (dBW) Low Power, (12W) A3 Satellite

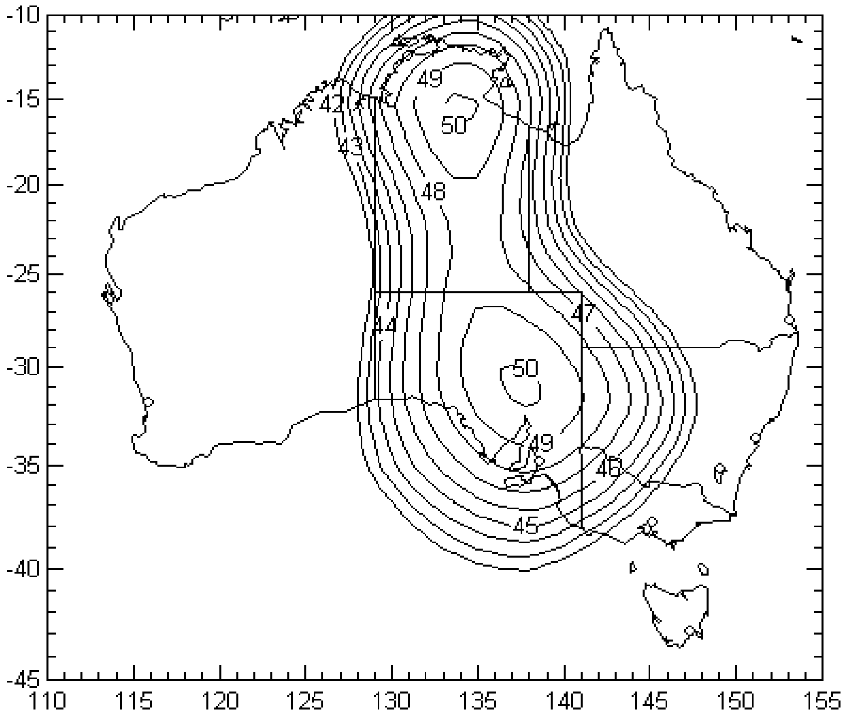


Figure A1-3.8 Central Australia Beam Radiated EIRP (dBW) High Power, (30W) A3 Satellite

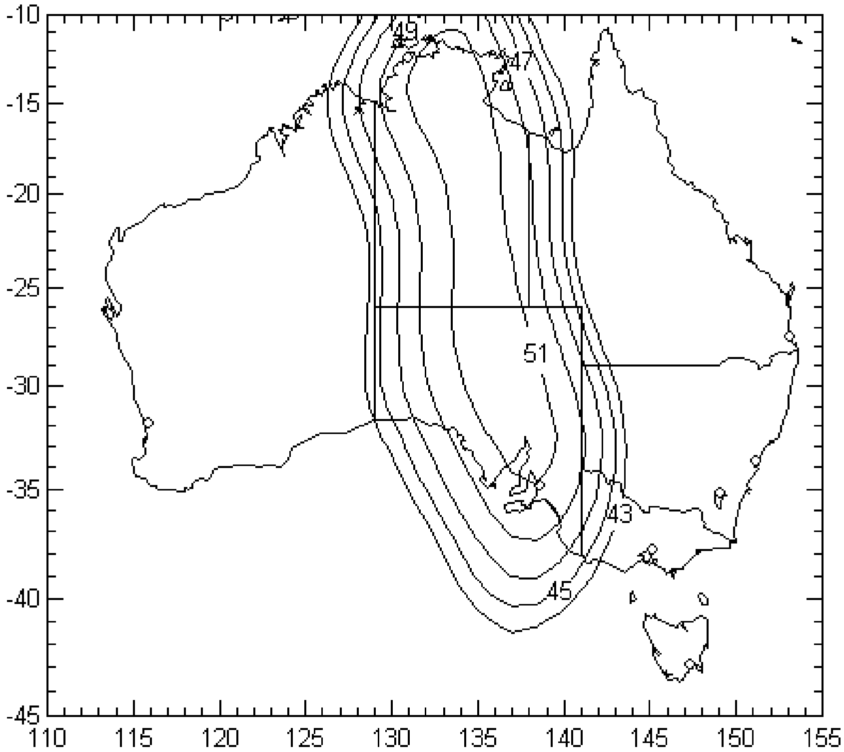


Figure A1-3.9 Central Australia Beam Radiated EIRP (dBW) B-Series Full Transponder

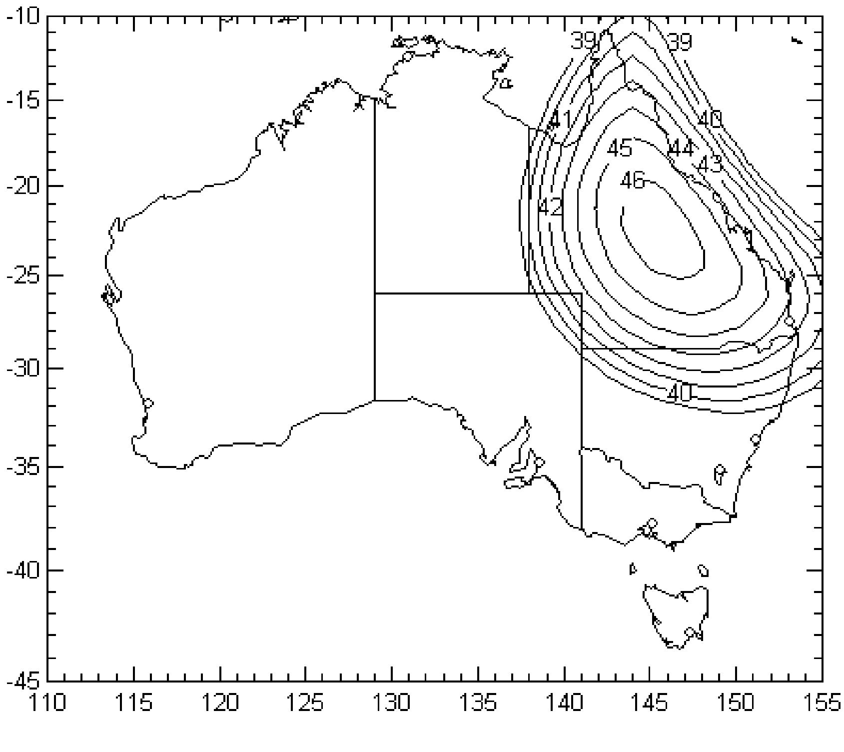


Figure A1-3.10 North East Beam Radiated EIRP (dBW) Low Power, (12W) A3 Satellite

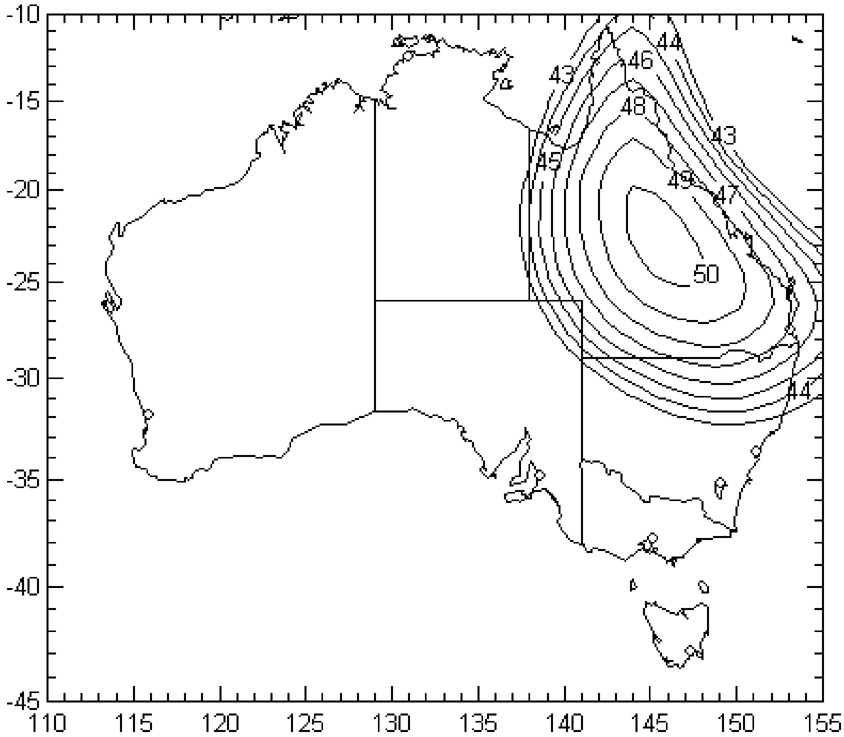


Figure A1-3.11 North East Beam Radiated EIRP (dBW) High Power, (30W) A3 Satellite

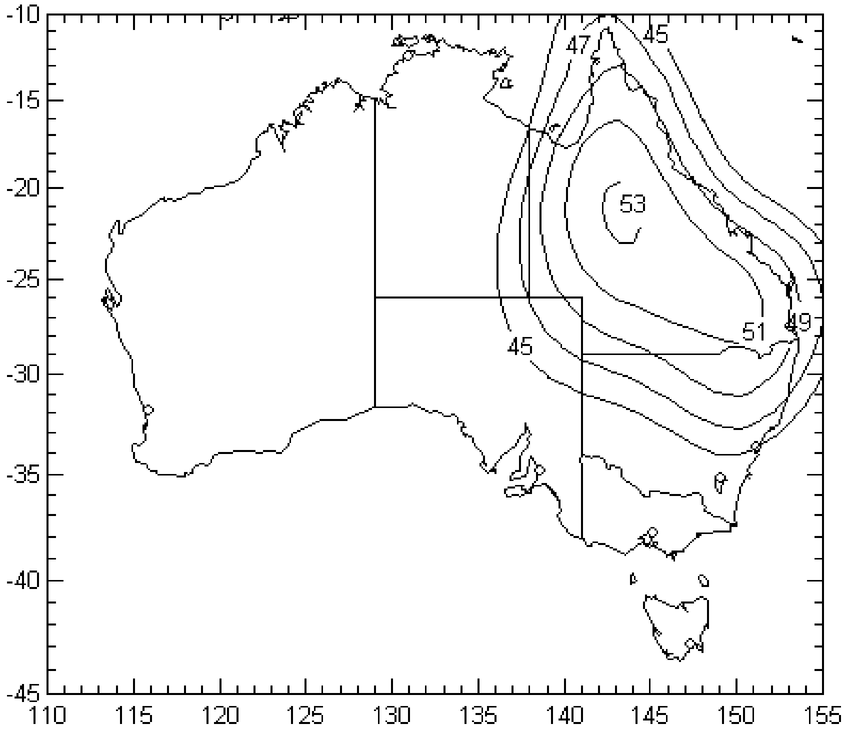


Figure A1-3.12 North East Beam Radiated EIRP (dBW) B-Series Full Transponder

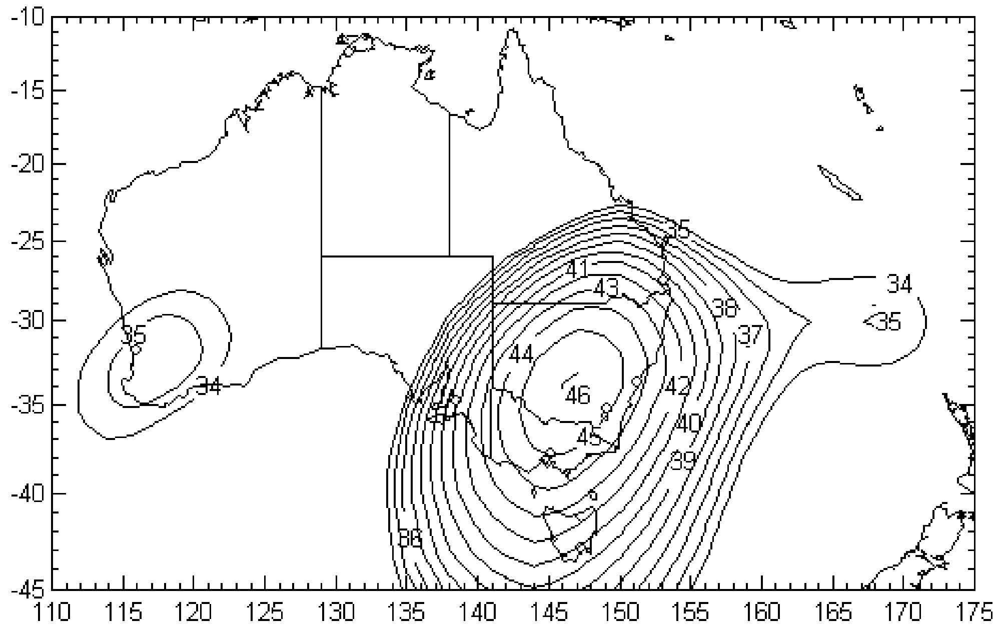


Figure A1-3.13 South East Beam Radiated EIRP (dBW) Low Power, (12W) A3 Satellite

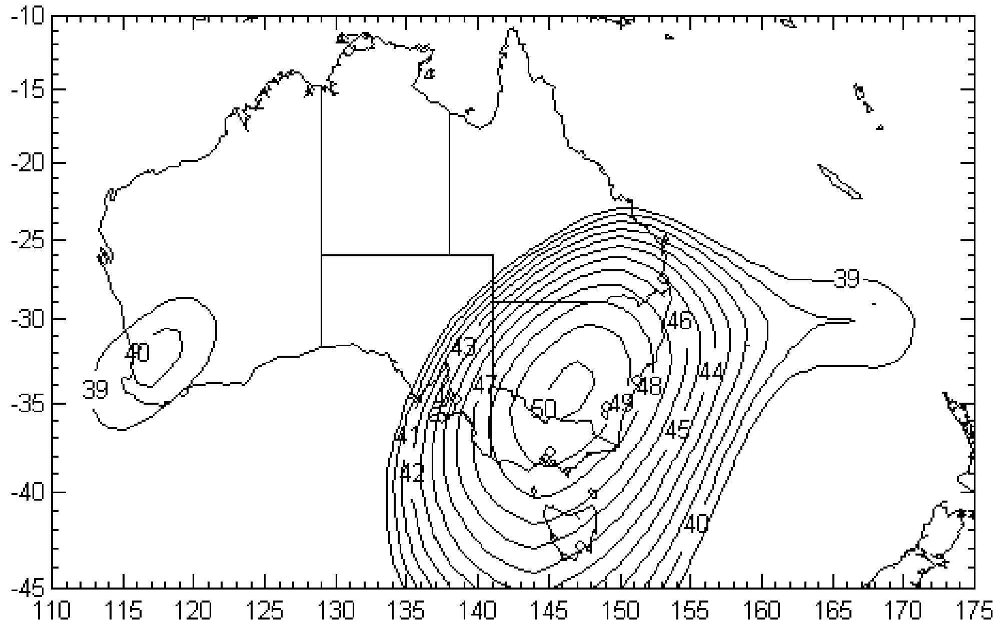


Figure A1-3.14 South East Beam Radiated EIRP (dBW) High Power, (30W) A3 Satellite

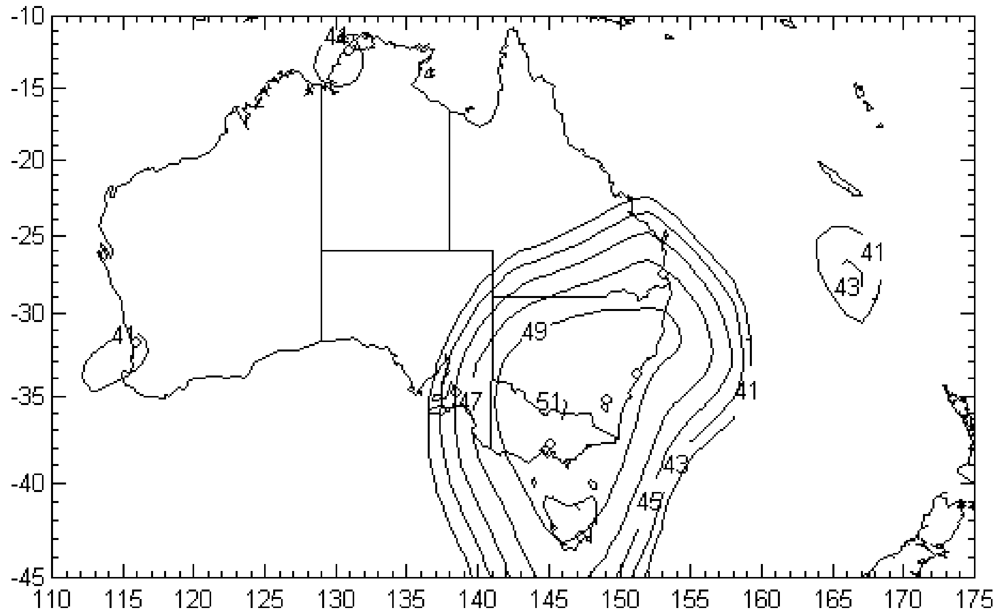


Figure A1-3.15 South East Beam Radiated EIRP (dBW) B-Series Full Transponder

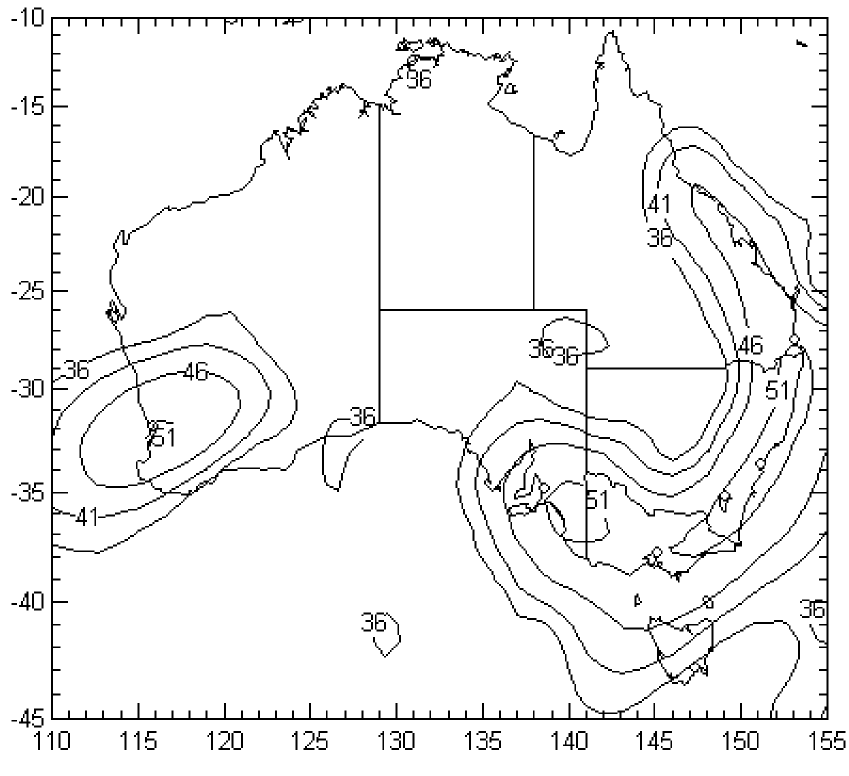


Figure A1-3.16 High Performance Beam Radiated EIRP (dBW) B-Series Full Transponder

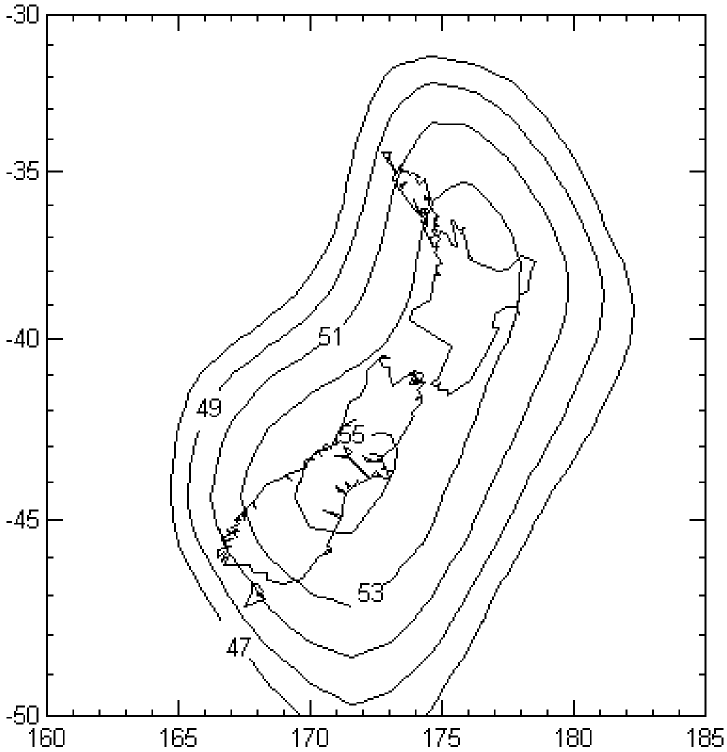


Figure A1-3.17 New Zealand Beam Radiated EIRP (dBW) B-Series Full Transponder

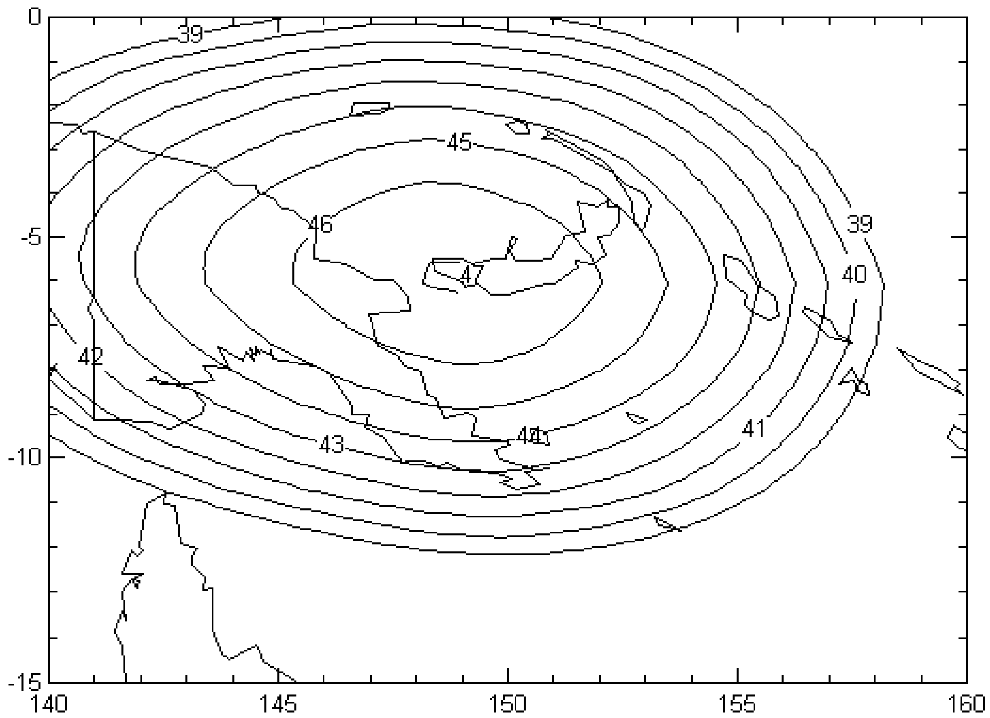


Figure A1-3.18 Papua New Guinea Beam Radiated EIRP (dBW) Low Power, (12W) A3 Satellite

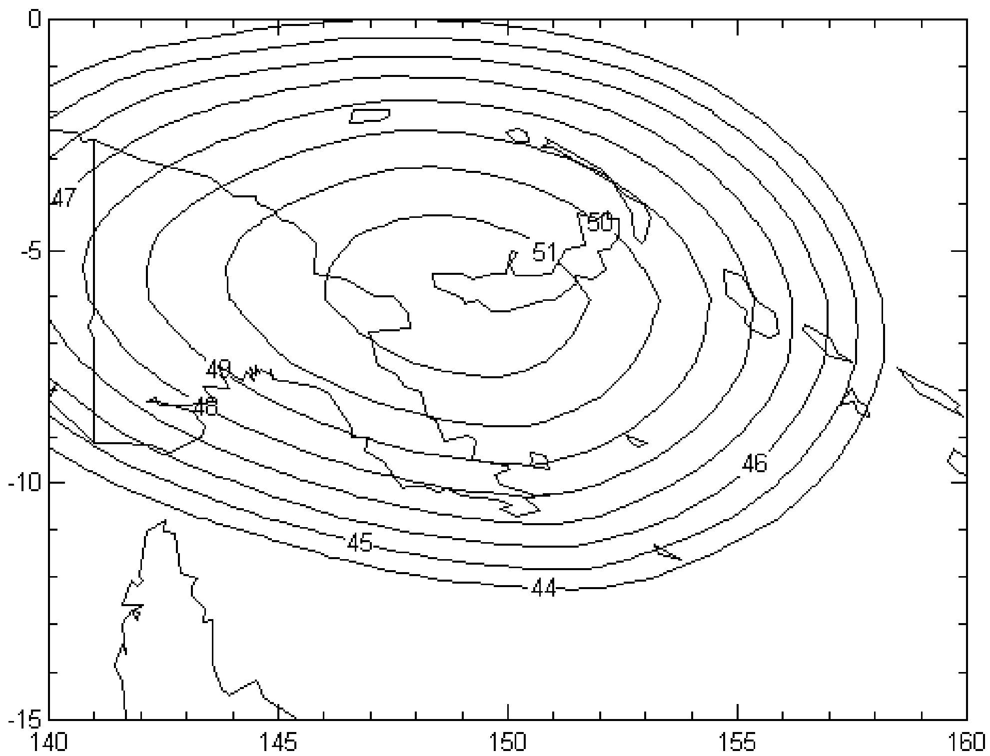


Figure A1-3.19 Papua New Guinea Beam Radiated EIRP (dBW) High Power, (30W) A3 Satellite

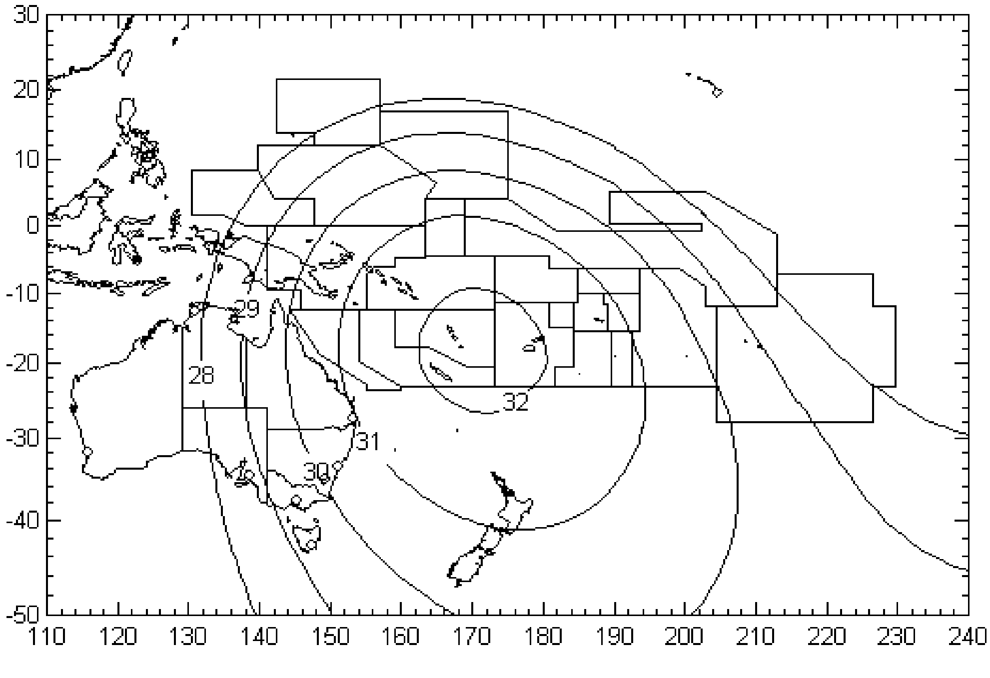


Figure A1-3.20 South West Pacific Beam Radiated EIRP (dBW) Low Power, (12W) A3 Satellite

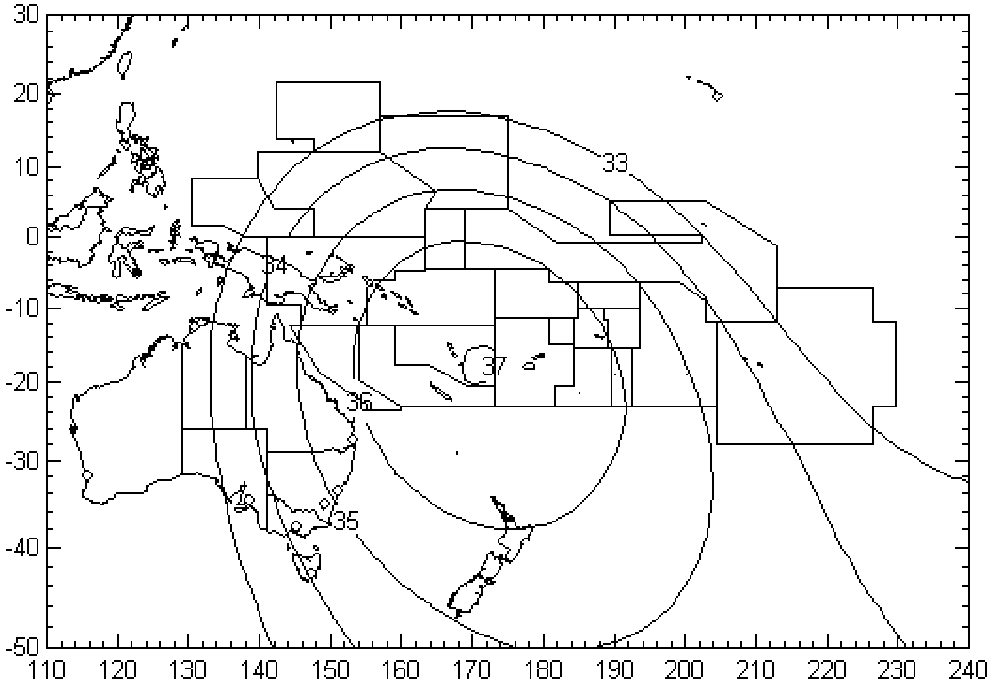


Figure A1-3.21 South West Pacific Beam Radiated EIRP (dBW) High Power, (30W) A3 Satellite

7.2 Satellite Beam Contours for the L-Band Payload

The contour diagrams below show the General Design Levels for geostationary Optus satellites.

The satellite G/T indicates the satellite receive performance level as "seen" from the ground.

The contour diagrams of EIRP show the radiated satellite transponder power, as "seen" on the ground, for a fully loaded Mobilesat® service. The fully loaded EIRP contours correspond to a total output back-off (OBO) of:

L-Band	2.4 dB
Ku-Band	6.0 dB

The contours for the L and Ku-Band transponders apply to orbit locations of either 156° or 160°.

Note. An explanation of General Design Levels is included in **Section 3.4** in the main body of the Satellite Network Designer's Guide.

7.2.1 A2-1 Receive G/T

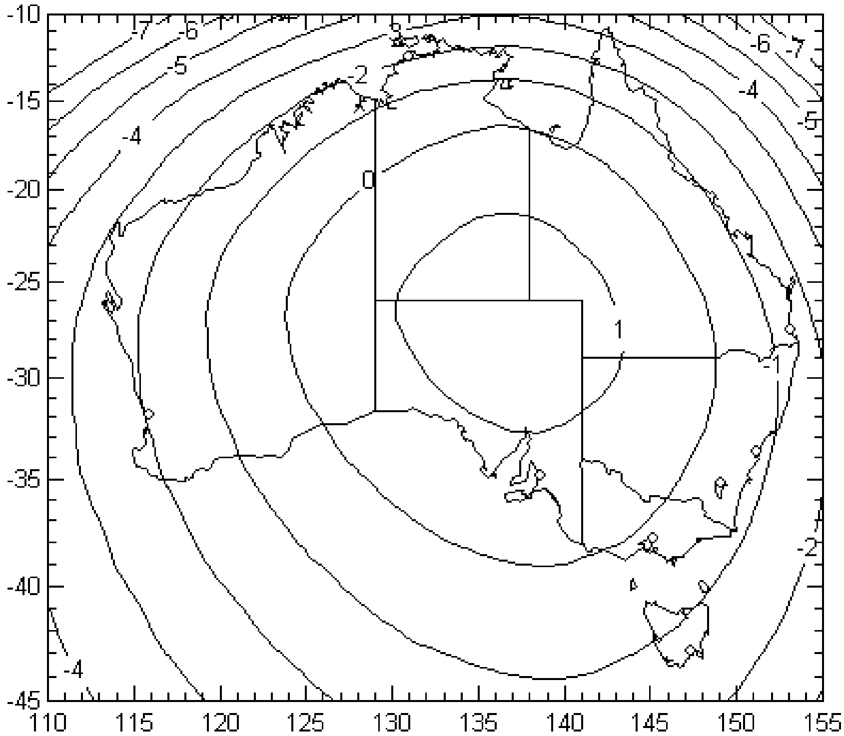


Figure A2-1.1 L Band Receive G/T (dB/K)

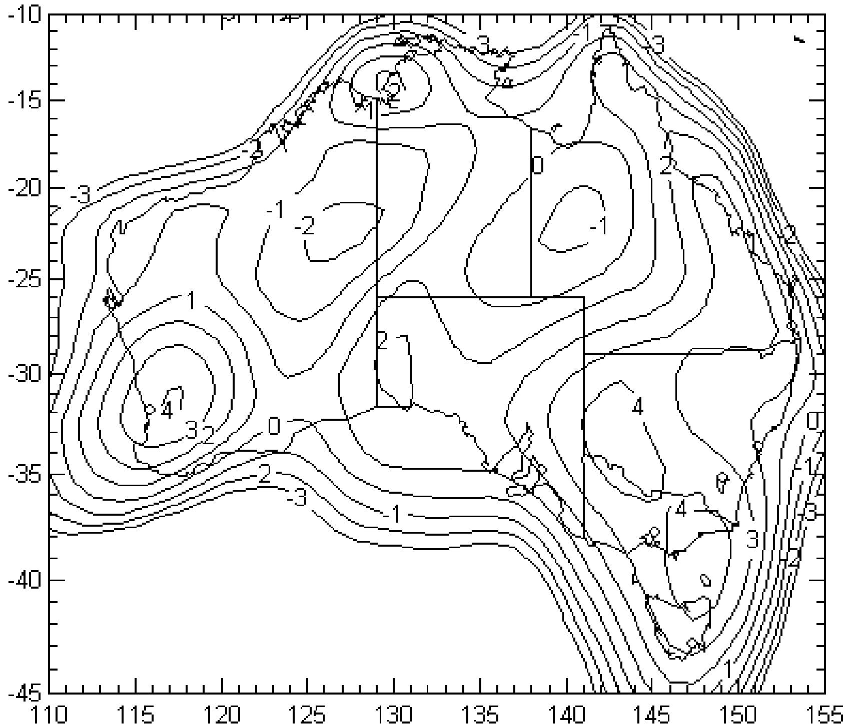


Figure A2-1.2 Ku Band Receive G/T (dB/K)

7.2.2 A2-2 Radiated EIRP

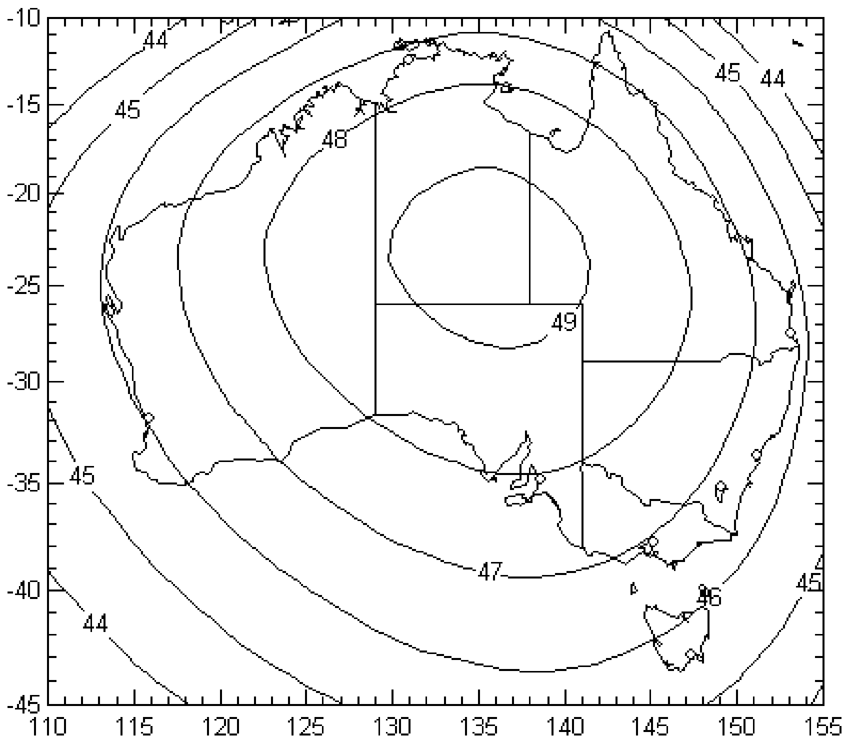


Figure A2-2.1 L Band Radiated EIRP (dBW)

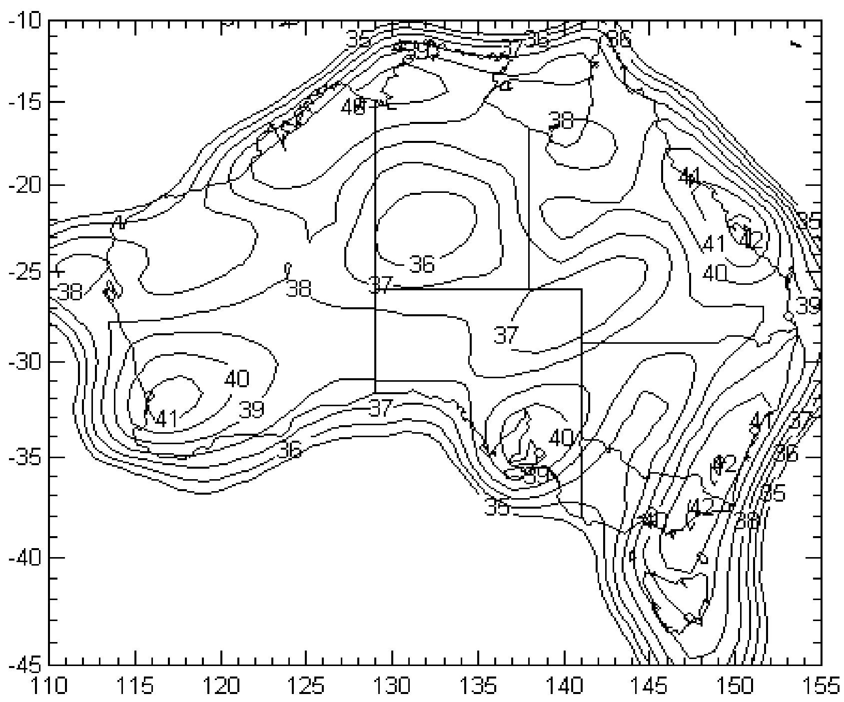


Figure A2-2.2 Ku Band Radiated EIRP (dBW)

7.3 Earth Station Pointing and Polarisation Angles

7.3.1 A3-1 Earth Station Pointing Angles

The azimuth is defined as the horizontal angle, referenced to true north at the earth station location, looking towards the satellite; it is measured positive clockwise.

The elevation is defined as the vertical angle, above local horizontal at the earth station location, looking towards the satellite; it is measured as a positive angle.

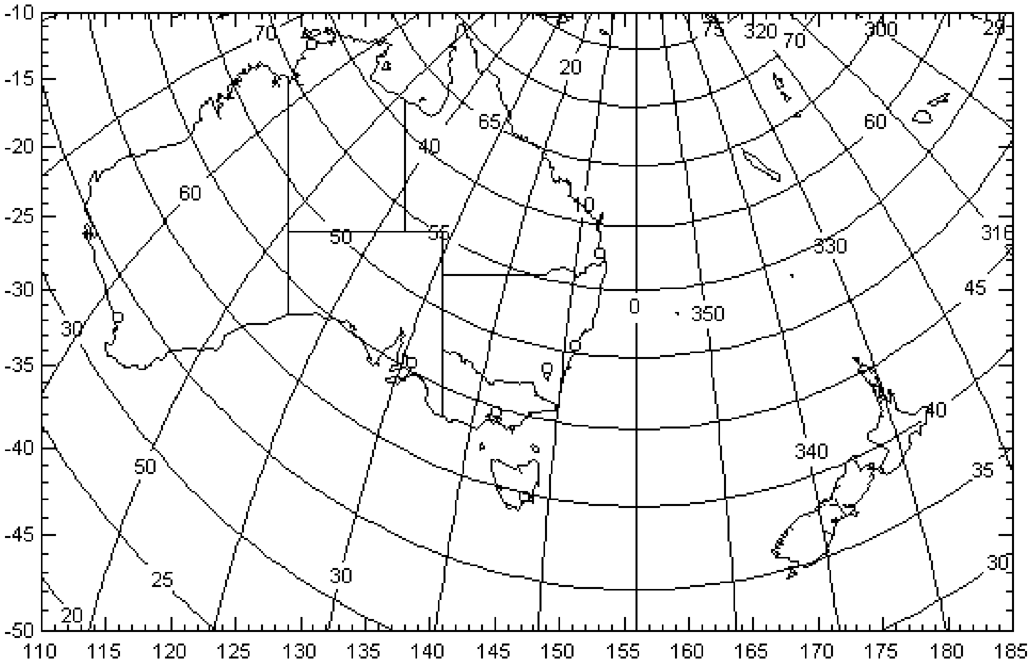


Figure A3-1.1 Azimuth and Elevation Look Angles (Degrees)
to Satellite at Orbital Location 156º Longitude

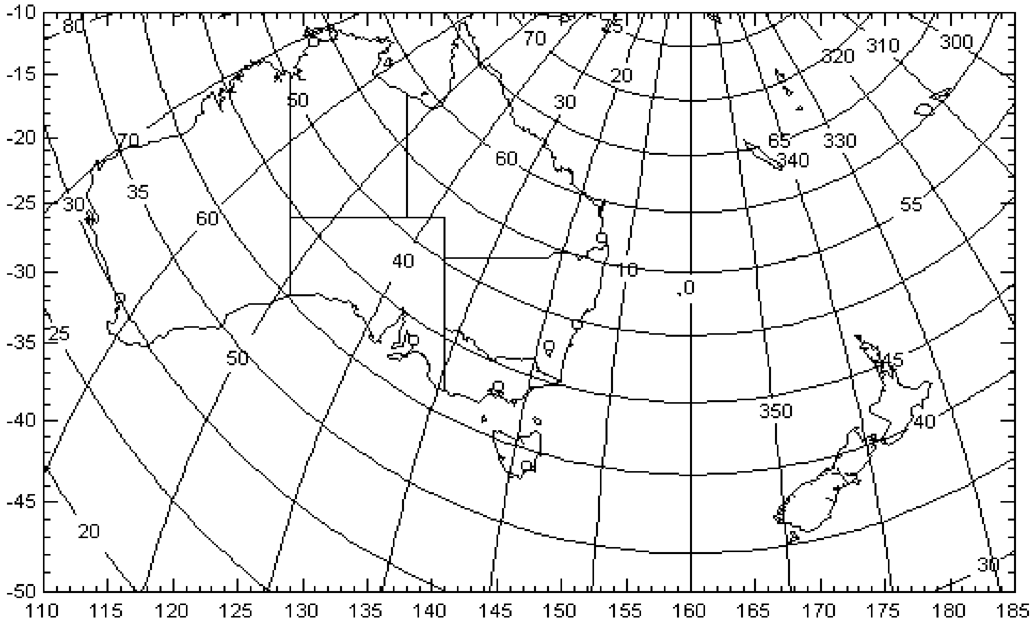


Figure A3-1.2 Azimuth and Elevation Look Angles (Degrees) to Satellite at Orbital Location 160º Longitude

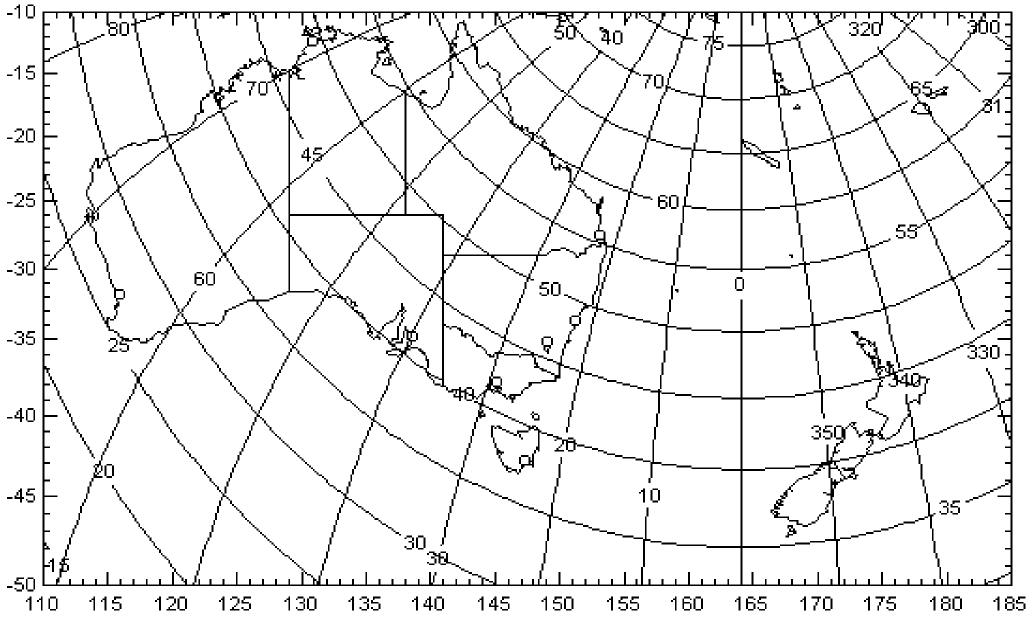


Figure A3-1.3 Azimuth and Elevation Look Angles (Degrees) to Satellite at Orbital Location 164º Longitude

7.3.2 A3-2 Magnetic Variation (Declination)

The magnetic variation (also called "declination") at a particular location is the angular difference between magnetic north from true north. A positive angle indicates a variation to the east of north and a negative angle to the west of north. The map below shows the approximate magnetic variation across Australia for the year 1991.

The map should remain within 1° for 8-10 years.

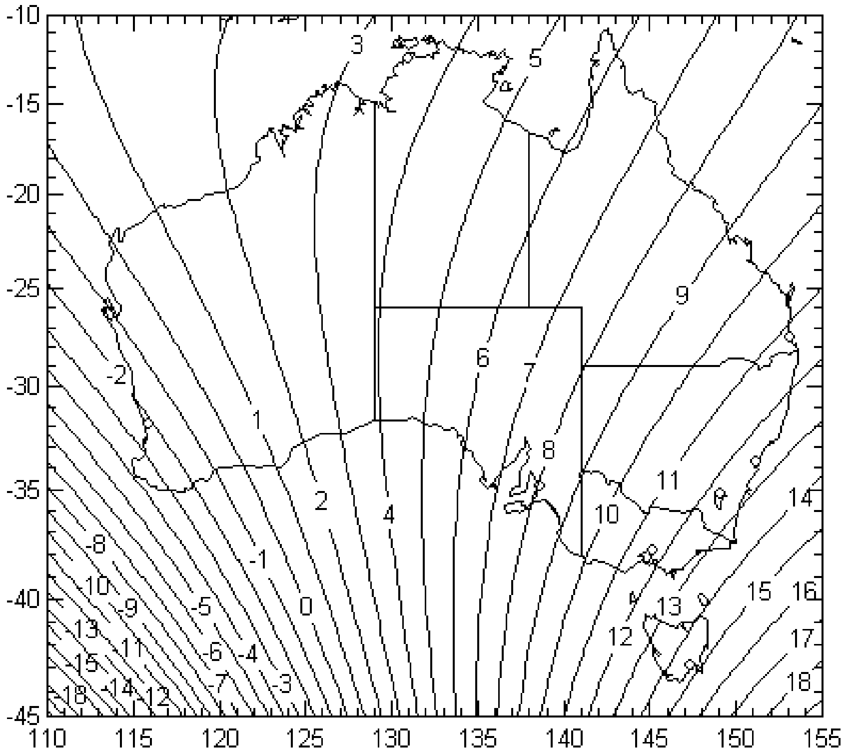


Figure A3-2.1 Magnetic Variation (Degrees)

7.3.3 A3-3 Earth Station Polarisation Angles

The orientations of the satellite "H" and "V" polarisation relative to local Horizontal and Vertical directions on the ground are a function of geographic location and satellite orbital position.

The figures show the nominal horizontal signal polarisation angles at locations throughout Australia. Looking at the back of an antenna towards the satellite, the horizontal polarisation angle is measured positive anticlockwise from the horizontal. The vertical polarisation is at 90^{o} to the horizontal angle.

It should be noted that accurate alignment of earth station polarisation angles will be necessary to minimise the levels of interference of a customer's transmissions into cross-polarised transponders, and vice versa. The variation in polarisation angles due to satellite attitude (yaw) errors will be less than ±0.25° relative to the nominal orientations.

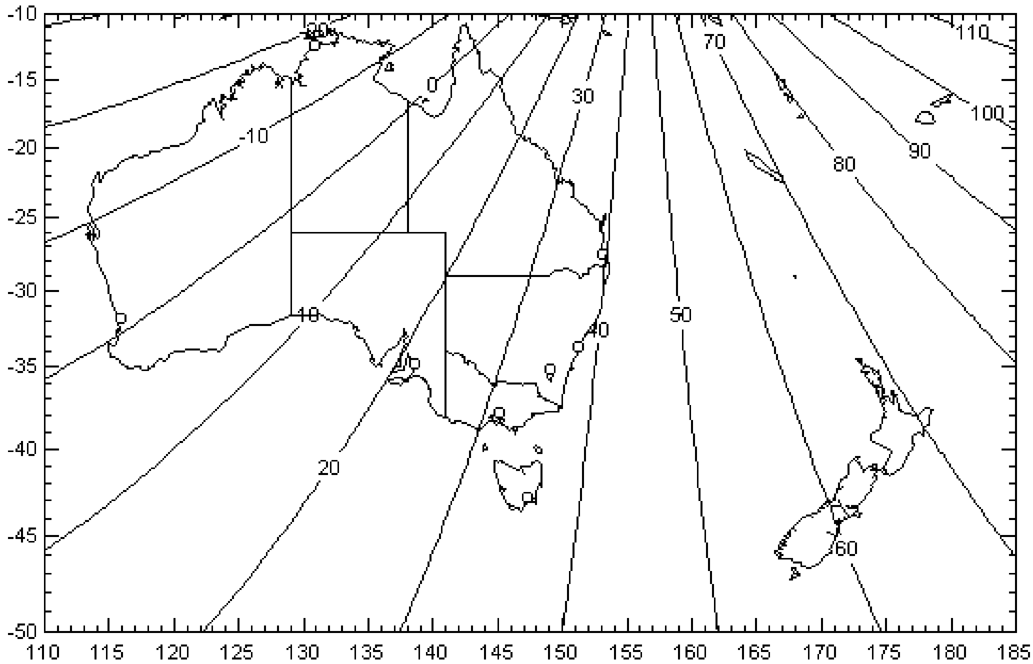


Figure A3-3.1 Horizontal Polarisation Angles (Degrees) for Satellite at Orbital Location 156° Longitude

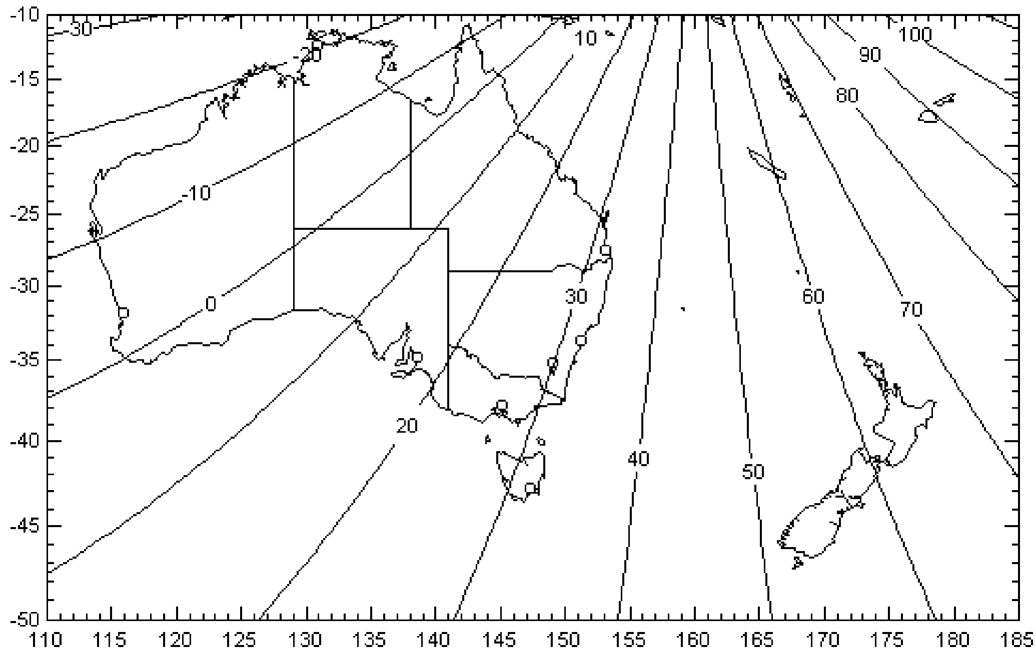


Figure A3-3.2 Horizontal Polarisation Angles (Degrees) for Satellite at Orbital Location 160º Longitude

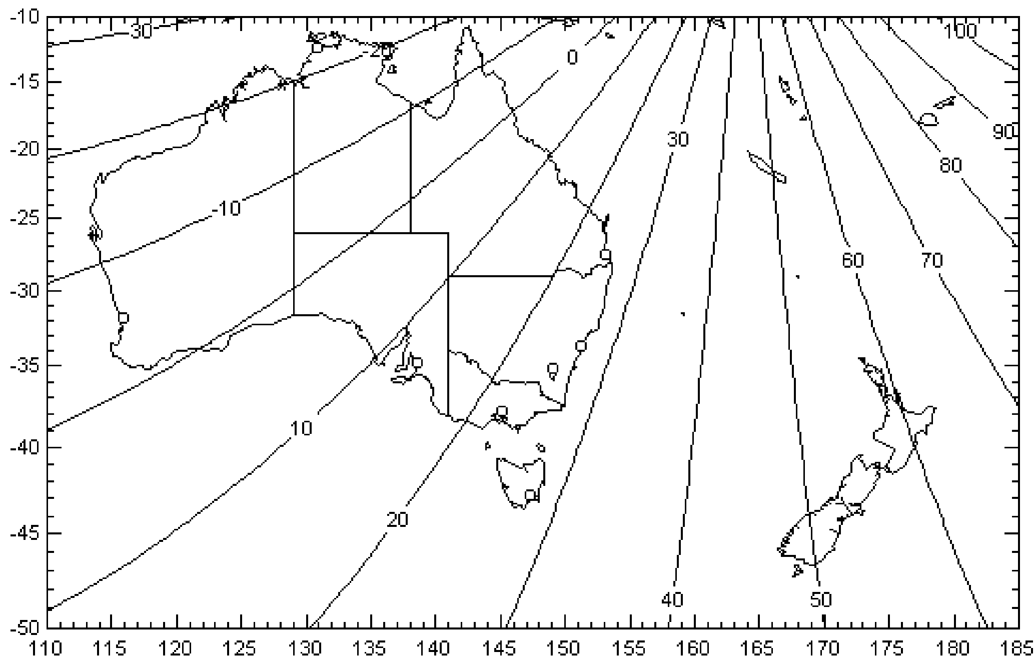


Figure A3-3.3 Horizontal Polarisation Angles (Degrees) for Satellite at Orbital Location 164º Longitude

7.4 Rain Attenuation Information

Ku-Band satellite transmissions suffer degradation for small percentages of time, due to rainfall. Rain attenuation has two effects, one being a reduction in received signal level, and the other being an increase in downlink receiver system noise temperature. Rainfall also produces depolarisation of microwave signals, however this is a second order effect and in most circumstances can be ignored.

The following contour maps show the estimated Annual and Worst Month rain attenuation for the 12GHz downlink frequency band. These statistics are based on rainfall data provided by the Bureau of Meteorology and, in the absence of specific data for a site, may be used for general service planning. Multiply the dB figures shown by 1.3 to estimate 14GHz uplink rain attenuation.

The contours in the figures below have been interpolated and smoothed to express regional rain characteristics from the specific location information from the Bureau.

It should be noted that there can be considerable variation between these estimates and the actual statistics experienced at a site owing to local geographical features. Where local data is available it should preferably be used.

7.4.1 A4-1 AUSTRALIA, DOWNLINK ANNUAL ATTENUATION

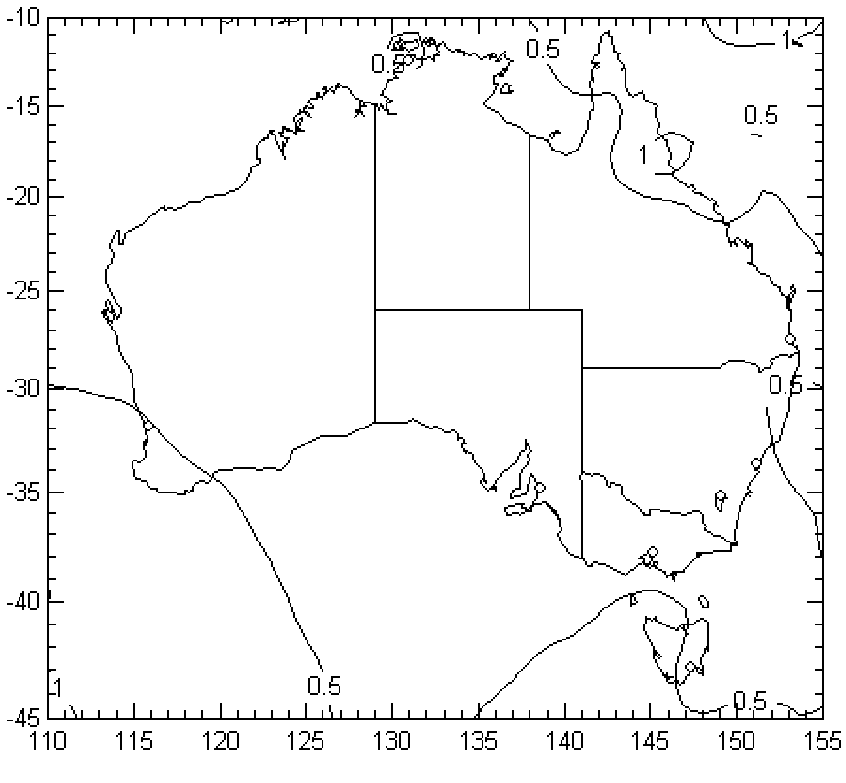


Figure A4-1.1 Australia, Downlink Annual Attenuation (dB) Exceeded for 1.0% of the Year

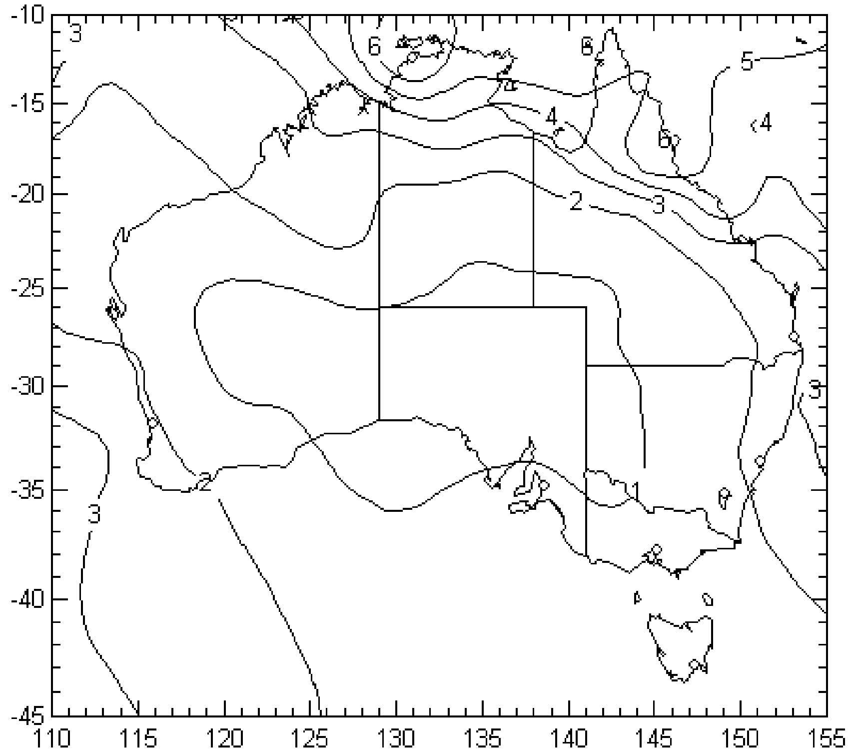


Figure A4-1.2 Australia, Downlink Annual Attenuation (dB) Exceeded for 0.1% of the Year

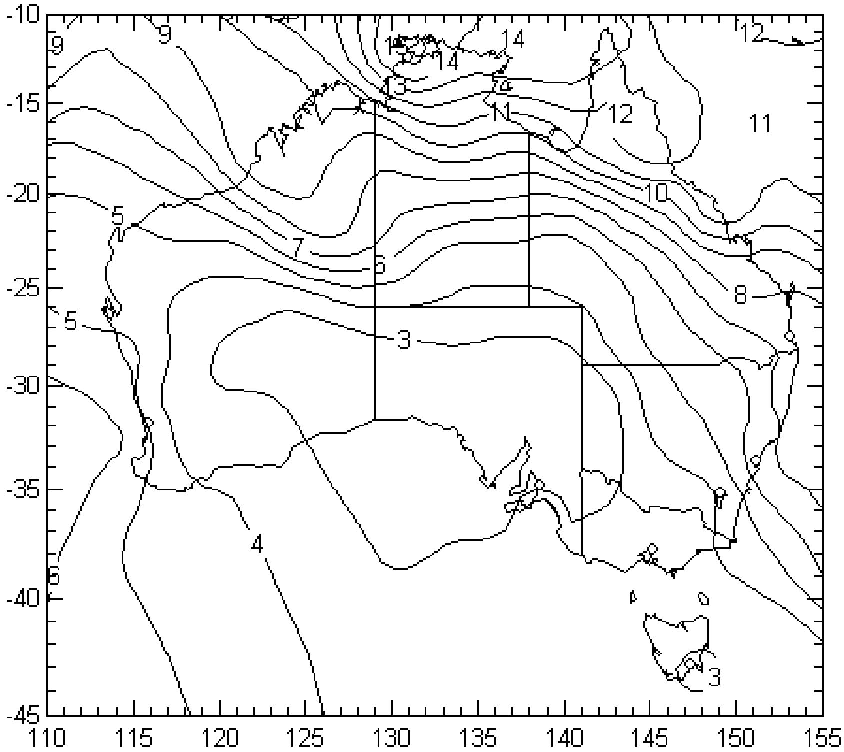


Figure A4-1.3 Australia, Downlink Annual Attenuation (dB) Exceeded for 0.01% of the Year

7.4.2 A4-2 Australia, Downlink Worst Month Attenuation

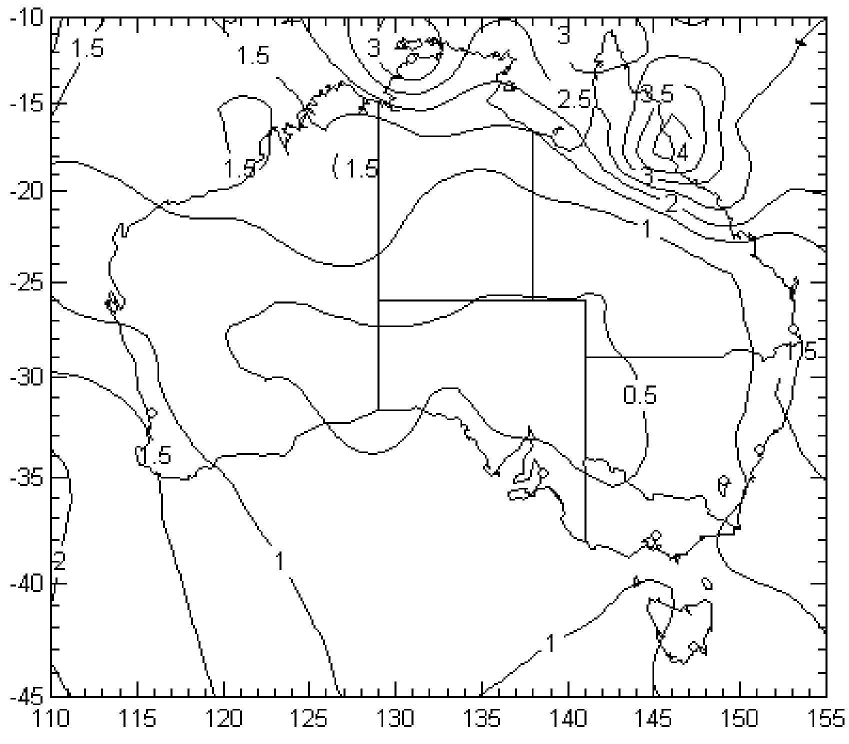


Figure A4-2.1 Australia, Downlink Worst Month Attenuation (dB) Exceeded for 1.0% of Worst Month

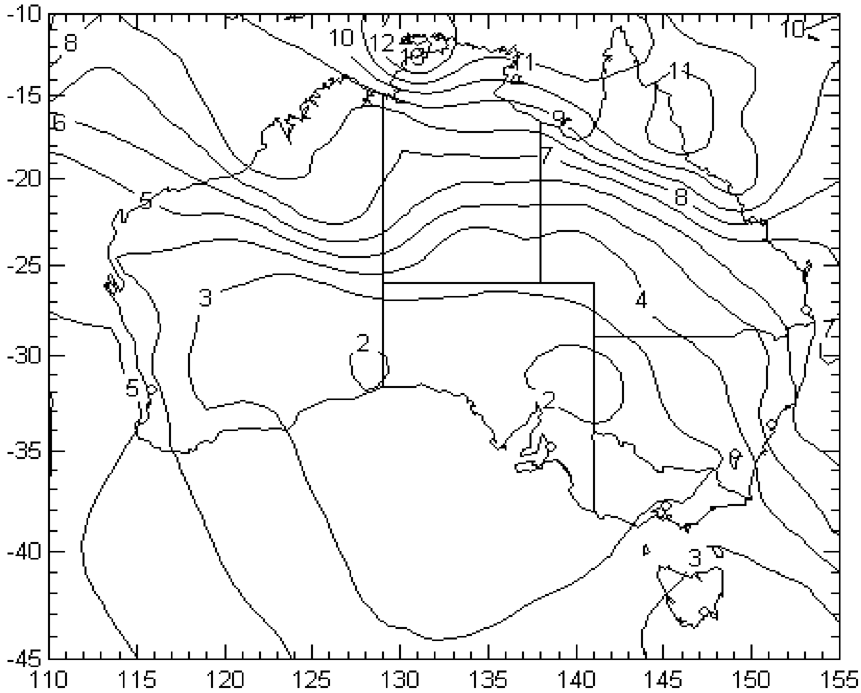


Figure A4-2.2 Australia, Downlink Worst Month Attenuation (dB) Exceeded for 0.1% of Worst Month

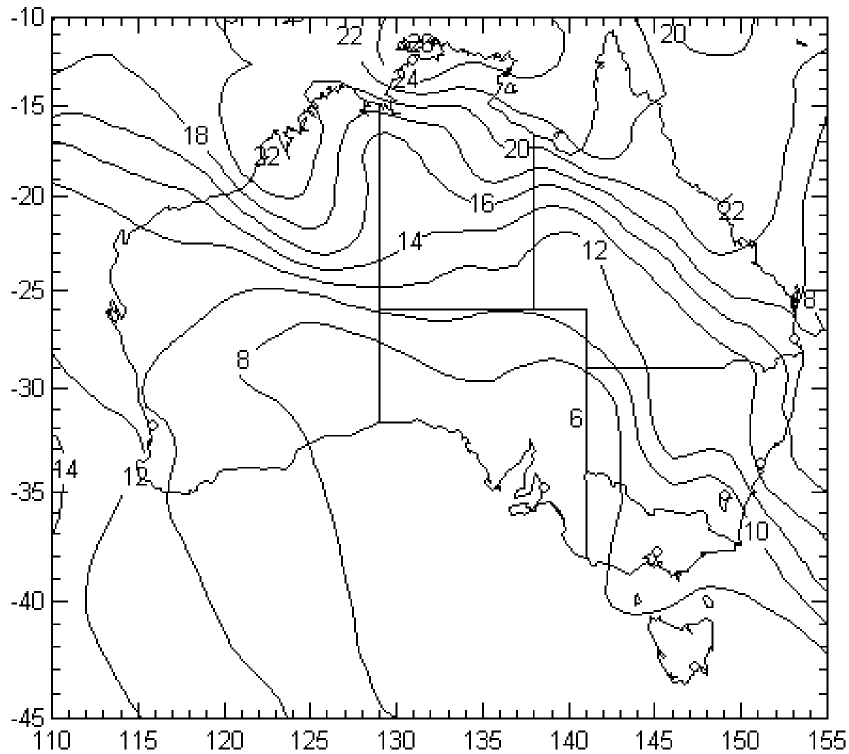


Figure A4-2.3 Australia, Downlink Worst Month Attenuation (dB) Exceeded for 0.01% of Worst Month

7.4.3 A4-3 New Zealand, Downlink Annual Attenuation

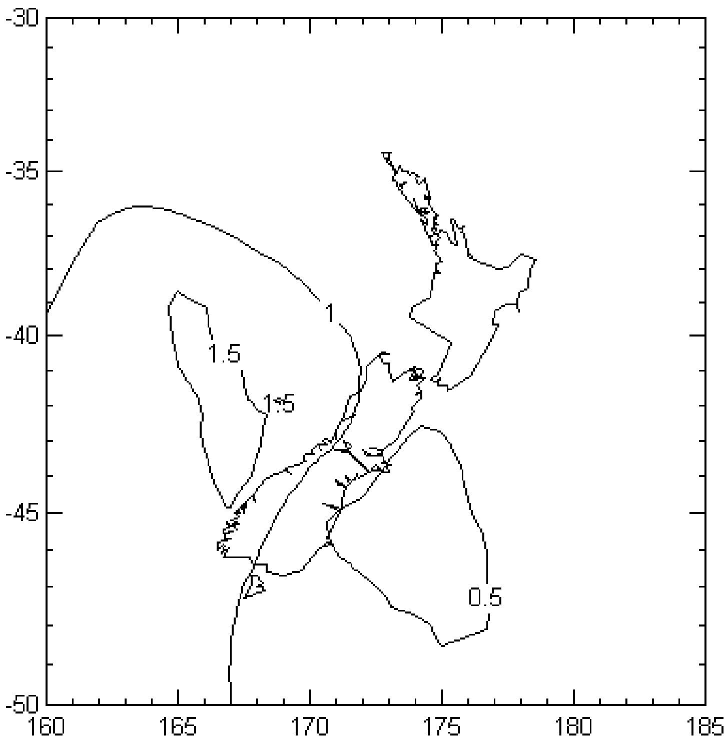


Figure A4-3.1 NZ Downlink Annual Attenuation (dB) Exceeded for 1.0% of the Year

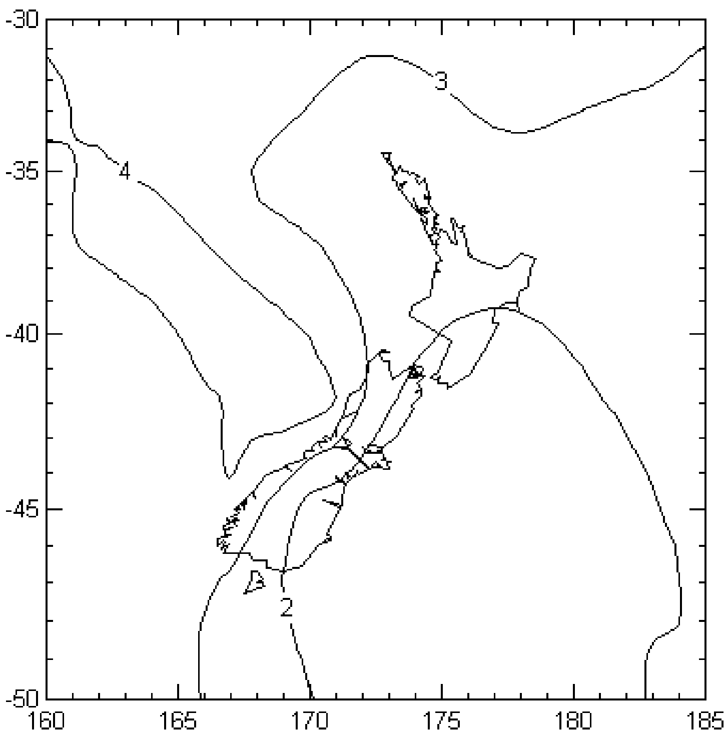


Figure A4-3.2 NZ Downlink Annual Attenuation (dB) Exceeded for 0.1% of the Year

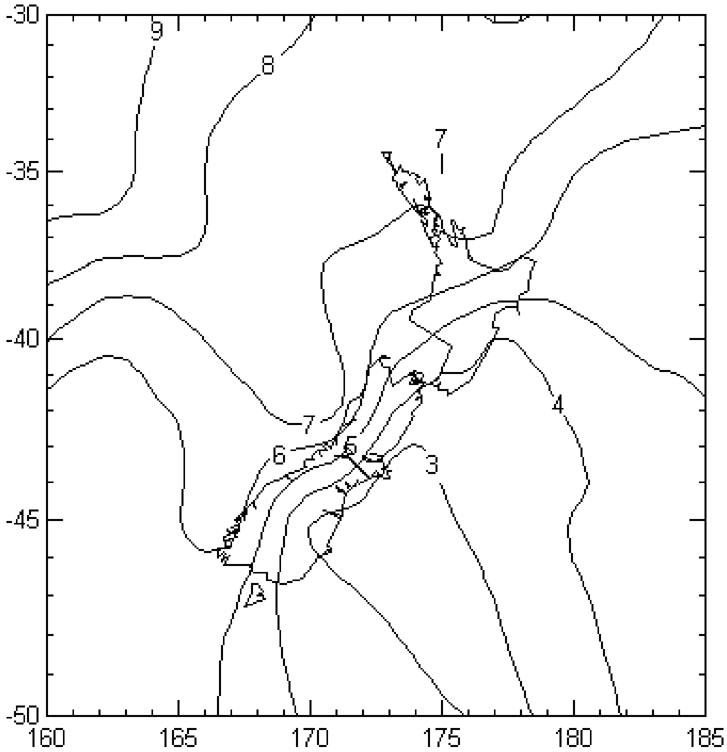


Figure A4-3.3 NZ Downlink Annual Attenuation (dB) Exceeded for 0.01% of the Year

7.4.4 A4-4 New Zealand, Downlink Worst Month Attenuation

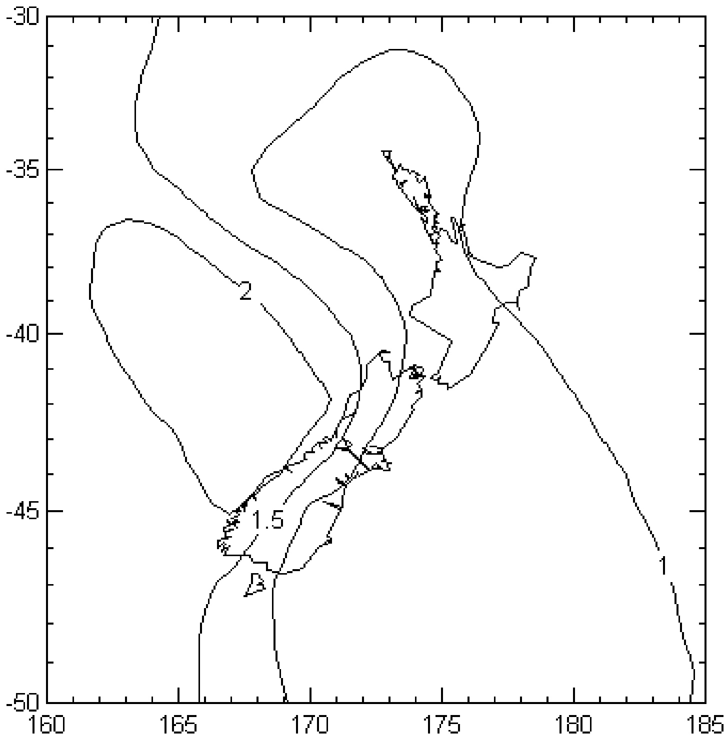


Figure A4-4.1 NZ Downlink Worst Month Attenuation (dB) Exceeded for 1.0% of Worst Month

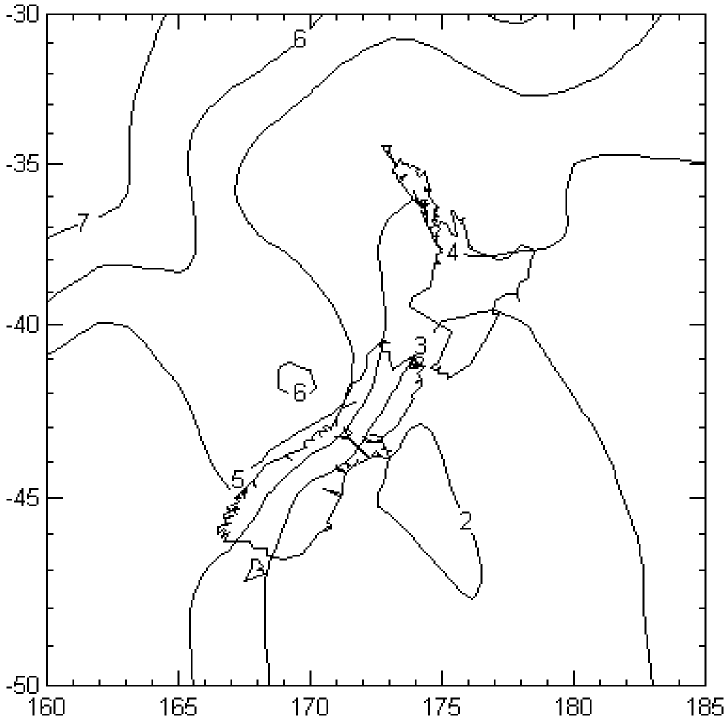


Figure A4-4.2 NZ Downlink Worst Month Attenuation (dB) Exceeded for 0.1% of Worst Month

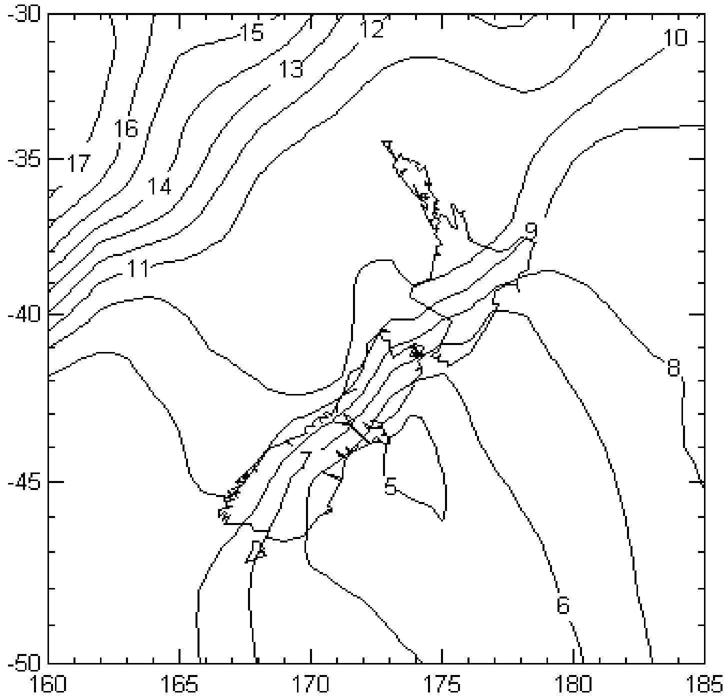


Figure A4-4.3 NZ Downlink Worst Month Attenuation (dB) Exceeded for 0.01% of Worst Month

7.5 A5-1 Sample Link Budget Calculations

This appendix describes some sample Ku-band link budget calculations to illustrate the factors that should be considered in assessing the likely performance of a satellite link on Optus and other satellites. Link budget calculations require a detailed knowledge of satellite communications theory and a very large number of parameters. The purpose of this Attachment is to generally describe some of the considerations in satellite link budgets for Optus satellites.

7.5.1 A5-1.1 Types of Transponder Operation

The starting point in any link calculation is the operating parameters of the satellite transponder. For the Optus satellites there are three basic types of transponder operation:

1. TV transponders

These transponders carry either a single full-transponder or two half-transponder (analogue) TV carriers. Such transponders operate non-linearly and baseband effects such as amplitude and group-delay slope and intelligible cross-talk are at least as important as the basic RF link budget. Such effects must be examined through simulation and testing to establish the appropriate transponder operating parameters; these considerations are outside the scope of this guide. Example 1 below contains sample RF link budgets for carriers in transponders of this type.

2. General multi-carrier transponders

A general multi-carrier transponder is basically one where no single carrier or uplink site significantly affects the transponder behaviour. Under these circumstances the transponder behaves linearly and a number of simplifying assumptions can be made about its operation. Baseband effects are less important and are usually budgeted for in the RF link budget. Example 2 below contains link budgets for transponders of this type.

3. Mixed transponders

Transponders carrying "mixed" TV and multi-carrier traffic must be carefully modelled to determine the operating conditions of the transponder. For this reason a discussion of the operating characteristics of services in this type of transponder is outside the scope of this guide.

7.5.2 A5-1.2 Effects of Rain on Satellite Links

Rain has three main effects on satellite transmissions at frequencies above about 10GHz: attenuation, depolarisation, and an increase in sky noise temperature. On the uplink only attenuation is significant. On the downlink depolarisation is a second-order effect which is usually not significant; however both attenuation and the increase in sky noise temperature are very significant as both affect the downlink thermal-noise C/N.

Attenuation on both the uplink and downlink directly reduces the carrier level, while the increase in downlink sky noise temperature acts to degrade the receive earth station noise temperature and hence the G/T. The increase in noise temperature can be estimated from the following equation:

$$?Tsky = Train.(1-10^{-A/10})$$

- where -

?Tsky = Increase in sky noise temperature, K

Train = Assumed rain thermal temperature = 280 K

A = Rain attenuation, dB

7.5.3 A5-1.3 Designing Satellite Links in the Presence of Rain

Satellite links affected by rain should be designed to meet both a faded and a clear-sky performance. The clear-sky performance is specified in terms of either a clear-sky C/N or a link margin above a design (faded) C/N. For video services, the design faded performance may be expressed as a minimum S/N, which is derived directly from the C/N. The faded performance is specified in terms of a link availability, which is the percentage-time for which the design C/N or S/N must be exceeded. This may be either "Worst Month" or "Annual" depending on the type of rain statistics used; Worst Month statistics are recommended.

The amounts of rain attenuation required on the uplink and downlink to reduce the clear-sky C/N or S/N to the design faded value are known as the "uplink and downlink fade margins." **These are not the same as the clear-sky link margin!** Once the fade margins for a link are known then the corresponding availabilities can be determined from the rain attenuation statistics for the uplink and downlink sites. In the absence of specific statistics for a site the rain attenuation maps in **Attachment 4** may be used.

The total link availability is given by the product of the uplink and downlink availabilities (or with negligible error by the sum of the unavailabilities). The division of the total availability between the uplink and downlink depends on the relative significance of the uplink and downlink in the total link budget, for which the most important factors are: whether UPC is used on the uplink; the G/T of the downlink antenna; and the relative rain statistics at the uplink and downlink sites. For a full-duplex service between two earth stations the two-way availability is determined from the product of the minimum "cross-availabilities" (corresponding pairs of uplink and downlink availabilities), since an uplink fade on one carrier occurs simultaneously with a downlink fade on the other.

The faded performance of a link may be determined in either of two ways: either by selecting an availability and fading the link to determine if it meets the availability; or by calculating the fade margins and the corresponding availabilities directly. The first method is suitable for link calculations done by hand using the rain attenuation maps in **Attachment 4**, but it requires an arbitrary division of the link availability into separate uplink and downlink availabilities. **Example 1** uses this method. The second method is preferable but requires an iterative solution and interpolation of the rain statistics; it is usually only amenable to computer-based link calculations. **Example 2** has been calculated using this method.

7.5.4 A5-1.4 Interference

Any satellite link calculation must include allowances for interference. Unfortunately the calculation of such allowances is something of a “black art” where the designer must attempt a balance between being overly conservative and too optimistic. No set of allowances will suit all circumstances, and in the final analysis any link calculation should be checked against the actual satellite environment when a service is allocated to a transponder. This section discusses the major sources of interference in satellite systems that link designers should be aware of. The examples later in this Attachment provide more advice on specific interference allowances for TV and multi-carrier transponders.

1. Cross-polarisation Interference.

Since the Optus satellites use dual orthogonal linear polarisations, carriers which fall in the overlap region of oppositely polarised transponders will suffer cross-polarisation interference. The cross-polarisation discrimination specifications for the Optus satellites are given in Section 3.7 of this guide.

2. Internal transponder interferences from other services sharing the same transponder.

Where more than one service carrier is passed through a transponder the possibility of “cross-talk” interference between the carriers arises. Such interference may be caused by a number of mechanisms including:

(a) overlap of frequency components;

(b) intermodulation between the carriers; and

(c) FM to AM conversion with transfer between carriers and subsequent conversion back to FM.

Such interference may be minimised by selecting appropriate operating levels, carrier frequency separations, signal deviation, uplink transmit filter specifications and ensuring that AM is minimised by equalising overall uplink frequency responses to be flat. Parameters are specified in the Optus Operating Procedures which are designed to manage internal transponder interference.

3. Adjacent-satellite interference.

The sidelobes of earth station antennas will cause interference to other satellites on the uplink, and receive interference from them on the downlink. Previously this form of interference was restricted to Optus satellites; however from about mid-1994 other satellite systems operating in the region at Ku-band frequencies will become increasingly important as sources of interference.

On the uplink there are limits on the absolute power level which may be radiated by antennas as a function of off-axis angle; coupled with the sidelobe pattern this places a limit on the input power to antennas. On the downlink there are no mandatory sidelobe specifications but Optus recommends that antennas conform at least to the limits in ITU-R Recommendation 580.

4. Uplink earth station interference.

Uplink earth stations radiate thermal noise, spurious signals and HPA intermodulation products. The allowable levels of all of these are specified in the relevant earth station transmission standards for the Optus system. Designers requiring further details should contact Optus.

5. Other interference.

Other possible sources of interference are less significant in the Optus system. The most noteworthy omission - interference from terrestrial radio-relay systems - is not significant in Australia although it is in some other countries covered by the Optus satellites (such as New Zealand).

Designers should also be aware of the limitations of their systems and add in appropriate allowances to cover any relevant degradations which may or may not be classifiable as "interference". This covers such things as amplitude and group-delay slope and other channel non-linearities, adjacent-carrier interference, frequency stability and jitter, phase noise, filter sideband truncation, etc.

In the absence of specific interference allocations, Optus recommends that designers allocate a minimum of 14% of the total link noise budget to interference. This represents a required increase in the link C/N of about 0.7dB. Provided appropriate allowances are made for other interference sources as listed above, this allowance need not be included in a link budget.

7.5.5 A5-2 EXAMPLE 1

A. Video Links in TV Transponders

This example is for broadcast-quality (analogue) video links using both the A-Series and B-Series transponders. This type of service is typically used for a program compilation or distribution service to TV stations throughout Australia.

B. A5-2.1 TV Transponder Parameters

On the A-Series only one video carrier per transponder is normally possible. The transponder is therefore operated with a single saturated carrier using the single-carrier TWTA gain transfer curve from **Figure 3.2** of this guide.

On the B-Series the wider bandwidth, improved G/T and EIRP, and linearised TWTAs allow two high-quality analog video services to be carried per transponder. In this case the transponder is operated with two carriers at 6dB IBO per carrier. (This IBO has been primarily determined from tests of intelligible cross-talk between the carriers under typical operating conditions.) The TWTA gain transfer curve is the two-carrier case from **Figure 3.3** of this guide. The two-carrier C/IM is better than 35dB; in fact the "perceived" C/IM is better than the measured C/IM because it is either AM or occurs at high frequencies which are rejected by the video baseband filter.

These services normally use National beams in gain step L (A-Series) or 1 (B-Series). The satellite beam performance assumed is the General Design Level from the National beam contour maps in **Attachment 1**. A mid-band transponder has been assumed (frequencies of 14.25 and 12.5GHz).

C. A5-2.2 Earth Station Parameters

This type of service typically employs non-tracking 6.8m receive earth stations. In these examples a 13m uplink in Sydney feeds a 6.8m in Canberra which is fitted with a 180K low noise amplifier for an assumed system temperature of 234K. A receive pointing loss allowance of 0.5dB has been included in the link budget; it is significant for a non-tracking antenna of this size. (Based on the 0.05° station-keeping specification for the satellite a 1dB loss could be used; however statistically this error occurs for only a small percentage of the time.)

D. A5-2.3 Video Carrier Parameters

The transmission parameters for high-quality broadcast video applications are generally standardised and the basic parameters used for the example link budget are as follows:

		A-Series	B-Series
Video modulation		PAL or E-PAL	PAL or E-PAL
Receiver bandwidth	B	30 MHz	25MHz
Peak to peak deviation	?Fpp	22.3 MHz/V	17.74MHz/V
Equivalent LF deviation (black to white)		4.4 MHz	3.5MHz
Pre-emphasis		625 line	625 line
Video bandwidth	b_V	5.0 MHz	5.0 MHz

The equation used to determine the unweighted S/N from the C/N (above threshold) is:

$$S/N = C/N + 10\log_{10}\left[\frac{3}{2}.\frac{\Delta Fpp^2.B}{b_v^{\ 3}}\right] + 2.2 \ \text{dB}$$

The 2.2dB factor is an allowance for the reduction in noise due to de-emphasis and has been empirically derived from measurements of similar PAL services.

E. A5-2.4 Target Performance

The desired performance of video links varies with each application. This example is for a program compilation or distribution service where the desired performance is a faded unweighted S/N of 38dB for 99.9% of the worst month on each of the uplink and downlink, and a clear-sky unweighted S/N of 42dB. (The corresponding C/Ns may be determined from the FM equation in the previous section.)

F. A5-2.5 Rain Parameters

The assumed rain attenuations for 0.1% of the worst month are from **Attachment 4 Figure A4-2.2** for Sydney (uplink, multiply figure by 1.3) and Canberra (downlink).

It should be noted that in the B-Series half-transponder case it is assumed that both video carriers on the transponder are uplinked from the same site and therefore undergo uplink fading at the same time. This enables the two-equal-carrier gain transfer curve from **Figure 3.3** to be used in this example for the uplink fading calculation. If the carriers are uplinked from different sites so that they fade separately, then the transponder behaves quite differently with the unfaded carrier compressing the faded one. This would result in an additional imbalance of the OBOs which could further degrade the overall performance of the faded link being examined. UPC operation in a two TV carrier transponder is usually implemented for this reason.

.

G. A5-2.6 Interference Parameters

In this example of high-quality video links it is difficult to include interference allowances in the simple link budget as conservative allowances often indicate that a link will have sub-standard performance or not work at all. In fact experience on the Optus satellites to date indicates that for video link budgets the effect of interference is minimal, largely because of the relatively small number of uplinks and satellites in this region and Optus's careful transponder allocation planning. However in some circumstances interference is unavoidable and may have a significant effect on overall performance. Designers should always contact Optus for specific information on the actual interference environment for any proposed video service. The following general guidelines apply:

i) Cross-polarisation interference.

On the A-Series satellites where only centre-frequency full-transponder carriers are used there is essentially no cross-polarisation interference.

On the B-Series satellites full-carrier overlap between two half-transponder carriers or half-carrier overlap between a centre frequency carrier and a half transponder carrier is possible. The significance of this increases for a spot beam service opposite a national beam service.

ii) Internal transponder interference

This form of interference only arises in the B-Series case where two similar carriers are assumed to share the same transponder. With 6dB IBO per carrier and assuming the other “half-transponder” requirements of Optus Operating procedures are met the total C/I due to such interference should not be less than 35dB.

iii) Adjacent-satellite interference.

For this example to large receive antennas adjacent-satellite interference is not significant; for other types of video service to small receive dishes it must be taken into account. . Optus suggests designers assume at least full-carrier overlap from an identical service in a Spot beam with a possible power mismatch of 2dB (50W into 30W).

iv) Uplink earth station and other interference.

These are generally not significant by themselves.

In the example link budgets a combined interference C/I has been included to account for all interference mechanisms, except for the internal transponder “cross-talk” interference. For the latter a separate allowance of 50dB (i.e. infinity) and 35dB are respectively assumed for the A and B-Series satellites.

These allowances will not in general be applicable to other types of video service.

EXAMPLE 1

Typical A and B-Series PAL Video Link Budgets

Uplinks from Sydney to a 6.8m downlink in Canberra.

	--- A Series Single-Carrier --- from Sydney to Canberra				--- B Series Dual-Carrier --- from Sydney to Canberra		
	Clear Sky	Up Faded	D'n Faded		Clear Sky	Up Faded	D'n Faded
Target availability		99.9	99.9	% WM		99.9	99.9
Uplink frequency	14.2	14.2	14.2	GHz	14.2	14.2	14.2
Uplink Power Control (UPC)	0.0	3.0	0.0	dB	0.0	3.0	0.0
Uplink EIRP	81.3	84.3	81.3	dBW	79.1	82.1	79.1
Uplink path loss	207.0	207.0	207.0	dB	207.0	207.0	207.0
Uplink rain attenuation	0.0	7.1	0.0	dB	0.0	7.1	0.0
Flux density conversion	44.5	44.5	44.5	dB/m^2	44.5	44.5	44.5
Carrier flux density at satellite	-81.2	-85.3	-81.2	dBW/m^2	-83.4	-87.5	-83.4
Tr'npdr Sat. Flux Density (SFD)	-81.2	-81.2	-81.2	dBW/m^2	-77.4	-77.4	-77.4
Carrier Input Back-Off (IBO)	0.0	4.1	0.0	dB	6.0	10.1	6.0
Transponder G/T	-1.8	-1.8	-1.8	dB/K	1.8	1.8	1.8
Receiver bandwidth	30.0	30.0	30.0	MHz	25.0	25.0	25.0
Saturated transponder EIRP	37.0	37.0	37.0	dBW	45.3	45.3	45.3
Carrier Output Back-Off (OBO)	0.0	0.7	0.0	dB	5.0	7.4	5.0
Downlink frequency	12.5	12.5	12.5	GHz	12.5	12.5	12.5
Downlink path loss	205.7	205.7	205.7	dB	205.7	205.7	205.7
Downlink rain attenuation	0.0	0.0	3.5	dB	0.0	0.0	3.5
Receive antenna diameter	6.8	6.8	6.8	m	6.8	6.8	6.8
LNA temperature	180.0	180.0	180.0	K	180.0	180.0	180.0
Earth station G/T	33.4	33.4	31.2	dB/K	33.4	33.4	31.2
Receive pointing loss	0.5	0.5	0.5	dB	0.5	0.5	0.5
Uplink thermal C/N	26.3	22.2	26.3	dB	28.5	24.4	28.5
Interference allowance	35.0	30.9	35.0	dB	33.6	29.5	33.6
Two carrier "Cross-Talk" C/I	50.0	50.0	50.0	dB	35.0	35.0	35.0

Downlink thermal C/N	18.0	17.3	12.3	dB	22.2	19.7	16.4
Total C/N	17.3	15.9	12.1	dB	20.8	18.0	16.0
Video deviation	22.3	22.3	22.3	MHz/V	17.7	17.7	17.7
FM improvement factor	24.7	24.7	24.7	dB	22.0	22.0	22.0
Unweighted video S/N	42.1	40.7	36.8	dB	42.8	40.0	38.0

7.5.6 A5-3 EXAMPLE 2

A. Digital Links in General Multi-Carrier Transponders

This example considers the case of link budgets for general multi-carrier transponders. The particular example used is a digital 2Mb/s link between large earth stations on the A-Series, and into a small earth station in a high-rainfall area on the B-Series.

B. A5-3.1 Multi-Carrier Transponder Parameters

A general multi-carrier transponder behaves linearly and operates at a constant loading. The normalised transponder gain (difference between IBO and OBO) is essentially the same for all carriers and the transponder gain-transfer is given by the multi-carrier curve in **Figures 3.4** and **3.5** of this guide. The TWTA multi-carrier intermodulation noise (IMs) can be reasonably approximated by a flat noise density. A multi-carrier transponder also operates linearly during uplink fading, which means that the uplink fade margin equals the clear-sky margin plus any UPC compensation. The same does not hold true for the downlink fade margin, which remains highly non-linear.

As the loading on a multi-carrier transponder increases, the transponder gain compresses and the IMs noise increases. Therefore link budget design must be done for the worst-case fully-loaded transponder. The optimum loading will depend on the type of earth stations and carriers accessing a transponder; however Optus has adopted reference loadings which should be assumed for link budget designs. The reference loadings, gain steps and multi-carrier intermodulation noise are shown in **Table A5-3.1** below.

Multi-carrier transponders normally use National beams. In these examples the satellite beam performance assumed is the General Design Level from the National beam contour maps in **Attachment 1**. A mid-band transponder has been assumed (frequencies of 14.25 and 12.5GHz).

	A-Series	B-Series	Note
Minimum gain step	1	3	
Input loading (IBO, dB)	8	5	
Output loading (OBO, dB)	4	3.5	
Normalised transponder gain (dB)	4	1.5	1
IMs Noise-density, IMo (dB/Hz)	-95.5	-99.8	2

Table A5-3.1 General Multi-Carrier Transponder Parameters

Notes to Table A5-3.1

1. Gain = IBO - OBO dB. Gain is constant and applies to all carriers.
2. Carrier C/IMo = - OBOc - IMo dBHz, where OBOc = Carrier OBO.

C. A5-3.2 Earth Station Parameters

The A-Series link budget is for a 13m uplink in Sydney to a 13m downlink in Melbourne (system noise temperature of 285K, G/T of 38dB/K). This link illustrates the case where the carrier clear-sky performance requirement is more important than the faded performance requirement.

The B-Series link budget is for a 13m uplink in Sydney to a 4.6m downlink in Townsville (65% receive efficiency, 0.5dB pointing loss, 112K LNA, 161K system temperature, 31.6dB/K G/T). This link illustrates the opposite case to the A-Series budget, where the faded performance requirement is more important than the clear-sky requirement.

D. A5-3.3 Carrier Parameters

The digital carrier parameters are as follows:

Bit Rate	2048 kb/s
Modulation	QPSK
FEC Rate	3/4
Decoder	Sequential
Design BER (faded)	10^{-5}
Faded Eb/No (IF loop)	6.6 dB
Delta Eb/No (RF loop)	0.4 dB
Design C/No (faded)	70.1 dBHz

Design C/N (faded)	8.8	dB
Noise Bandwidth (1.0xSR*)	1365	kHz
Allocated Bandwidth (1.3xSR*)	1530	kHz

* SR = Symbol Rate

E. A5-3.4 Target Performance

The design faded performance is for a BER of 10^{-5} for 99.8% of the worst-month (total link availability), and the clear-sky performance is for a minimum link margin of approximately 4dB. The minimum margin guarantees both a minimum clear-sky BER and an "implementation" margin; in this case a 4dB margin will guarantee a clear-sky BER substantially better than 10^{-10}.

F. A5-3.5 Rain Parameters

In this example the uplink-faded and downlink-faded link budgets have been computed for the amount of fade which reduces the total C/N to the design (faded) value. The corresponding uplink and downlink availabilities are given at the bottom of the up-faded and down-faded columns. Note that the uplink/downlink availability split can be quite asymmetric! (NB: Downlink rain depolarisation has been included in the link budgets to illustrate that is has a negligible effect. Information on rain-faded cross-polarisation statistics has not been included in this guide.)

For uplink fading the uplink fade margin equals the clear-sky margin plus any UPC compensation - 6dB in this case. (Note that this is only true for multi-carrier transponders. For TV or Mixed transponders as defined in **section A5-1.1**, an uplink fade may change the transponder operating point and cause the uplink and downlink to fade unequally. Inter-carrier compression may also be important; refer to example 1 **section A5-2.5**.)

For downlink fading the downlink fade margin is highly non-linear and its relationship to the clear-sky margin depends on the relative importance of the downlink thermal-noise C/N in the total link budget. In this example it is significantly different in the A and B-Series cases.

For the A-Series link budget the clear-sky performance requirement is more important than the faded performance. (NB: The clear-sky margin is slightly less than 4dB because the carrier IBO has been rounded to 0.5dB.) This is a consequence of the use of UPC on the uplink, plus a very large receive antenna at a relatively low rainfall site on the downlink. In contrast, for the B-Series link budget it is the faded performance requirement which is the most important, and it is almost entirely determined by downlink-fading. This is a consequence of the use of a small receive antenna at a high rainfall site.

G. A5-3.6 Interference Parameters

For general multi-carrier transponders Optus has established recommended interference allowances for use in general link budget calculations. These allowances are shown in **Table A5-3.2** below and require some explanation:

1. Uplink interference.

On the uplink the allowances in **Table 5-3.2** represent the sum of all uplink interference sources referenced to a standard point on the satellite receive beam pattern - the "standard G/T contour." In the link budgets this level is corrected for the difference in the satellite G/T at the uplink site.

2. Downlink interference.

On the downlink **Table 5-3.2** specifies separate interference allowances for cross-polarisation and adjacent-satellite interference (currently Optus has no "other" interference allowance). Unlike the uplink, the interference allowances refer to the level on the interfering transponder, not the wanted transponder; this is because the correction to the wanted transponder requires a knowledge of the receive antenna cross polarisation performance and sidelobe levels, which is link-specific. The downlink levels are also referred to a "standard (EIRP) contour" as for the uplink, and in the link budgets are adjusted for the difference in saturated EIRP at the downlink site.

	A-Series	**B-Series**	**Note**
Standard U/L G/T contour (dB/K)	-3	+2	
U/L Interference flux density (dBW/MHz/m2)	-122	-125.5	1
Standard D/L EIRP contour (dBW)	36	45	
D/L Xpol Interference density (dBW/Hz)	-39	-29.3	2
D/L Adj-Sat Interference density (dBW/Hz)	-39	-29.3	2

Table A5-3.2 General Multi-Carrier Interference Allowances

Notes to Table A5-3.2

1. Referenced to the standard G/T contour:

   Carrier C/Io = C' - (Io - 60) dBHz

   - where C' = Carrier power flux density corrected to the standard G/T contour.

     Io = Interference flux density from above table.

2. Referenced to the standard EIRP contour:

   Carrier C/Io = C' - Io + X dBHz

   - where C' = Carrier downlink EIRP corrected to the standard EIRP contour.

Io = Interference EIRP density from above table.

X = Cross-polarisation discrimination or adjacent-satellite protection.

EXAMPLE 2

Typical A and B-Series Multi-Carrier Link Budgets

2Mb/s Digital Carriers

	-- A Series Multi-Carrier ---- from Sydney to 13m in Melbourne				--- B Series Multi-Carrier --- from Sydney to 4.6m in Townsville		
	Clear Sky	Up Faded	D'n Faded		Clear Sky	Up Faded	D'n Faded
Uplink Power Control (UPC)	0.0	6.0	0.0	dB	0.0	6.0	0.0
Uplink EIRP	60.3	66.3	60.3	dBW	60.2	67.7	61.7
Uplink path loss	207.0	207.0	207.0	dB	207.0	207.0	207.0
Uplink rain attenuation	0.0	9.7	0.0	dB	0.0	13.6	0.0
Flux density conversion	44.5	44.5	44.5	dB/m^2	44.5	44.5	44.5
Carrier flux density at satellite	-102.2	-105.9	-102.2	dBW/m^2	-100.8	-108.4	-100.8
Tr'npdr Sat. Flux Density (SFD)	-81.2	-81.2	-81.2	dBW/m^2	-83.3	-83.3	-83.3
Carrier Input Back-Off (IBO)	21.0	24.7	21.0	dB	17.5	25.1	17.5
Transponder G/T	-1.8	-1.8	-1.8	dB/K	1.8	1.8	1.8
Receiver bandwidth	1365.0	1365.0	1365.0	kHz	1365.0	1365.0	1365.0
Uplink interference flux	-123.2	-123.2	-123.2	dBW/M Hz/m^2	-125.3	-125.3	-125.3
Saturated transponder EIRP	37.2	37.2	37.2	dBW	45.4	45.4	45.4
Carrier Output Back-Off (OBO)	17.1	20.8	17.1	dB	16.0	23.6	16.0
Xpol EIRP density	-37.8	-37.8	-37.8	dBW/Hz	-28.9	-28.9	-28.9
Xpol Discrimination (XPD)	30.0	30.0	23.7	dB	30.0	30.0	29.2
Adjacent satellite EIRP density	-37.8	-37.8	-37.8	dBW/Hz	-28.9	-28.9	-28.9
Antenna protection factor	47.0	47.0	47.0	dB	37.7	37.7	37.7
Intermodulation noise density	-95.5	-95.5	-95.5	dB/Hz	-99.8	-99.8	-99.8
Downlink path loss	205.8	205.8	205.8	dB	205.6	205.6	205.6
Downlink rain attenuation	0.0	0.0	6.1	dB	0.0	0.0	8.9
Receive antenna diameter	13.0	13.0	13.0	m	4.6	4.6	4.6
LNA temperature	225.0	225.0	225.0	K	112.0	112.0	112.0

Earth station G/T	38.2	38.2	35.7	dB/K	31.6	31.6	27.6
Receive pointing loss	0.2	0.2	0.2	dB	0.4	0.4	0.4
Uplink thermal C/N	18.7	15.1	18.7	dB	23.7	16.1	23.7
Uplink C/I	19.6	16.0	19.6	dB	23.1	15.5	23.1
Downlink Xpol C/I	26.5	22.9	20.2	dB	26.9	19.3	26.1
Downlink Adjacent Satellite C/I	43.5	39.9	43.5	dB	34.6	27.0	34.6
Intermodulation noise C/Im	17.0	13.4	17.0	dB	22.4	14.8	22.4
Downlink thermal C/N	19.5	15.9	11.0	dB	22.3	14.7	9.4
Total C/N	12.4	8.8	8.8	dB	16.4	8.8	8.8
Design faded C/N	8.8	8.8	8.8	dB	8.8	8.8	8.8
Link margin	3.6	0.0	0.0	dB	7.6	0.0	0.0
Availability (Worst Month)		99.97	99.94	% WM		99.97	99.84