Project WIFSS

Test Report of Potential Interference of WBA on FSS in Singapore

R-J6375-TR002

ISSUE B

Date of Issue:

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Prepared by :	Reviewed by:	Vetted by:
Foo Sek Joon and Chng Jhuning Engineer ICD/EMC Services & Consulting	Chow Wee Sing Manager ICD/EMC Services & Consulting	Dr. Ong Jin Teong Consultant / Director C2N Pte Ltd

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Contents

<u>Annexes</u>

List of Illustrations

Figure **Page**

Table **Page**

Amendment Record

AMDT NO.	AFFECTED PAGE(S)	ECR/DCR NO.	EFFECTIVE DATE

Chapter 1 - Executive Summary

The purpose of this study is to examine the potential interference of the Wireless Broadband Access (WBA) services on the existing Fixed Satellite Station (FSS) operating in the C-band in Singapore and to propose mitigation techniques to achieve mutual interference-free operation between the two services.

The Infocomm Development Authority (IDA) of Singapore is looking into the possibility of extending the 3.5GHz spectrum band to meet the growing demand of higher frequency needed by the commercial info-communication industry in Singapore.

The Worldwide Interoperability for Microwave Access (WIMAX) is currently seen as one of the most popular WBA services needed by the commercial info-communication industry, based on its increasing demand in the business and home broadband market.

The existing FSS in the C-band is widely used by the commercial sector in Singapore and they are operating at the 3.4 – 4.2GHz frequency spectrum for data downlink. The broadcasting data such as video and audio signals are continuously transmitted from the geostationary satellite and received at the ground FSS.

In order for the existing FSS to operate without interference from WBA, guard band of at least 100MHz is required. In addition, measures should be taken to prevent saturation at front-end receiver of FSS and to minimise adjacent channel interference. Hence by conducting radio frequency interference (RFI) analysis and on-site measurements, RF solutions can be proposed to minimise interference. It is also imperative that the proposed WBA services should not cause potential interference to the other FSS operating along the borders of the neighbouring countries.

The results of the measurements and analysis suggest that it is unlikely the WBA would interfere with FSS provided the following RF mitigation techniques are used:

(i) A frequency guard band is employed.

(ii) A minimum distance separation is specified.

(iii) A bandpass filter is employed at the front-end receiver of FSS.

The interference between the WBA and FSS can be further minimised if the power of the transmitter is reduced from the maximum effective isotropic radiated power (EIRP) of 48dBm.

From the analysis and measurements made, it is further deduced that WBA is not likely to interfere with FSS in Singapore if the following conditions are met:

1. A lateral distance separation of at least 2km from WBA, with **no** bandpass filter installed on the FSS and a guard band of at least 100MHz.

2. A lateral distance separation of at least 200m from WBA, **with** bandpass filter installed on the FSS and a guard band of at least 100MHz.

These suggestions were given based on the worst-case measurement results, with only one WBA antenna transmitting with an EIRP of 48dBm and a 6dB safety factor to take into account reflected signal from the ground or from nearby buildings.

Chapter 2 - Objective

The objective of the on-site measurement is to measure the RFI generated by a WBA base station operating in 3.4 – 3.6GHz to the FSS receiving signals in 3.4 – 4.2GHz frequency range. The effectiveness of mitigation techniques such as a bandpass filter (3700 – 4200MHz), distance separation and guard band shall be examined.

Chapter 3 - Theoretical Analysis of Potential Interference of WBA on FSS

3.1 Free Space Propagation

For a sinusoidal waveform propagating radially in a vacuum (free space), the free space path loss, PL_{fs}, between a transmitter and receiver antenna is given by,

$$PL_{fs} = -27.6 + 20Log\left(f \times d\right) \quad \text{Eq [1]}$$

Where,

f : transmitting frequency (MHz)
d : distance between transmitter & receiver antenna (m)

Although in a real world, there will be reflections from ground and other surfaces, the free space path loss formula provides the path loss for the direct ray from the transmitter to the receiver antenna and also serves as a useful reference in RF link analysis.

3.2 Plane Smooth Earth Model

Generally, when a grounded transmitter and receiver pair is placed at a distance apart, their line of sight propagation can be analysed using the plane smooth earth model as shown in Figure 1 below.

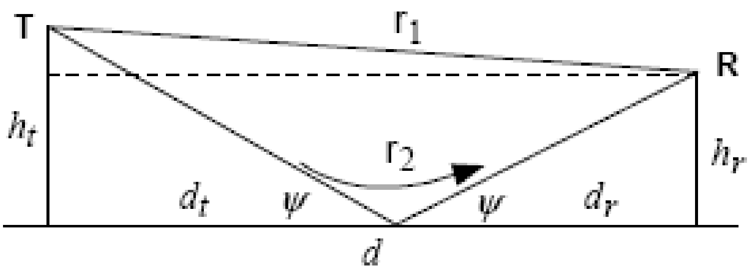

Figure 1 : Reflection from a plane smooth earth.

For a given receiver antenna location, there is both a direct ray with path length r_1 and a reflected ray with path length r_2. These two rays can either combine constructively or destructively depending on the phase conditions and the phase between the rays is dependent on the distance. The received power will therefore be periodically greater, and less than what it would have been in free space, when the distance is increased.

The grazing angle or angle of reflection, ψ, is given by,

$$\psi = \tan^{-1}\left[\frac{h_t + h_r}{d}\right] \qquad \text{Eq [2]}$$

Where,

h_t : transmitter antenna height (m)
h_r : receiver antenna height (m)
d : horizontal distance between transmitter and receiver antenna (m)

The path-length difference between the direct and reflected ray gives rise to the phase difference, $\Delta\Phi$

$$\Delta\phi = \frac{4\pi h_t h_r}{d\lambda} \qquad \text{Eq [3]}$$

Where,

λ : wavelength of the transmitting signal (m)

The complex reflection coefficient, ρ_v, due to a vertically polarised wave is given by,

$$\rho_v = \frac{\varepsilon_g \sin\psi - \sqrt{\varepsilon_g - \cos^2\psi}}{\varepsilon_g \sin\psi + \sqrt{\varepsilon_g - \cos^2\psi}} \qquad \text{Eq [4]}$$

Where

ε_g : the complex dielectric constant of the partially conducting earth.

Consequently ε_g is given by,

$$\varepsilon_g = \varepsilon_r - j\frac{\sigma}{2\pi f \varepsilon_0} \qquad \text{Eq [5]}$$

Where

ε_0 : free-space permittivity (8.85 x 10^{-12} Fm^{-1})

ε_r : relative permittivity of the ground

σ : conductivity of the ground ($\Omega^{-1}m^{-1}$)

f : transmitting frequency (Hz)

All calculations in this report have assumed that $\sigma = 0$ and $\varepsilon_r = 15$, for the average ground condition. The resultant received signal (relative to free space value), ***RL***, due to the interference between the direct and the reflected rays is given by,

$$RL = 20\text{Log}\left(\frac{E_{rec}}{E_{fs}}\right)$$
$$= 20\text{Log}\left[1 + F\left|\rho_v\right|e^{j(\Delta\phi+\theta)}\right] \qquad \text{Eq [6]}$$

Where,

E_{rec} : electric field due to direct and reflected ray (V/m)

E_{fs} : electric field (free space) due to direct ray (V/m)

F : transmitter antenna pattern factor

θ : phase angle of the complex reflection coefficient

The transmitter antenna pattern factor, ***F***, is given by,

$$F = \sqrt{10^{\frac{\Delta G}{10}}} \qquad \text{Eq [7]}$$

Where,

$\Delta G(dB)$: Difference between transmitter antenna gain of reflected ray and direct ray

The total path loss due to direct and reflected ray, PL_{tot}, is given by,

$$PL_{tot} = -RL + PL_{fs} \qquad \text{Eq [8]}$$

Where,

PL_{fs} : Free space path loss (dB)

Substituting for PL_{fs} from Eq [1],

$$PL_{tot} = -20Log\left[1 + F\left|\rho_v\right|e^{j(\Delta\phi+\theta)}\right] - 27.6 + 20Log(f \times d) \qquad \text{Eq [9]}$$

The predicted path loss profiles base on Eq [9] for different FSS height is as shown in Appendix B.

3.3 Interference Assessment

The common modes of interference to a receiver are co-channel interference, adjacent channel interference and saturation. Co-channel interference occurs when the frequency of the interfering signal falls within the receiver's IF pass band. Adjacent channel interference typically occurs when the frequency of the interfering signal falls outside, but close to the receiver's IF pass band. Saturation occurs when a strong signal drives the receiver front-end RF amplifier out of its linear mode of operation, causing amplification gain compression and generating inter-modulation products.

The measures to prevent co-channel and adjacent channel interference are the following:

(i) frequency separation between interference and desired signal
(ii) distance separation between interfering transmitter and receiver antenna

For the deployment of WBA within the city area, it is impractical to mitigate co - channel interference by using distance separation as it would require WBA and FSS to be separated by over a hundred kilometres (Pg 51, Ovum's Report [2]). Thus frequency sharing is not a feasible option and adequate frequency separation has to be implemented to prevent this form of interference.

Therefore the analysis will be focused on adjacent channel interference and saturation of FSS LNB low noise amplifier; a major concern when installed in close proximity with WBA antenna.

3.4 Interference Power Received by FSS

To analyse saturation and adjacent channel interference, the interference power at the input to the LNB and at the output of the receiver's IF filter are calculated. For simplicity of analysis, free space propagation is first assumed and accounting the effects of reflection at the later stage.

3.4.1 At the input of LNB

The level of interference power at the LNB of the FSS is given by,

$$I = P_t + G_t - L_{txf} - PL_{fs} + G_r - L_{rxf} - L_{filter}$$
$$= EIRP_{wba} - PL_{fs} + G_r - L_{rxf} - L_{filter}$$

Eq [10]

Where,

I : WBA interference power in the LNB bandwidth of 800MHz (dBm)
P_t : WBA transmit power in the transmit bandwidth of 5MHz (dBm)
G_t : WBA antenna gain (dBi)
L_{txf} : Transmitter feeder loss (dB)
PL_{fs} : Free space path loss (dB)
G_r : FSS off axis antenna gain (dBi)
L_{rxf} : Receiver feeder loss (dB)
L_{filter} : Receiver RF bandpass filter insertion loss (dB)
$EIRP_{wba}$: WBA EIRP (dBm)

The value of G_r can be derived by the formula in ITU-R BO.1213-1 [6], taking D = 3.05 m, λ = 0.084m

Co-polar pattern

$G_{co}(\varphi) = 41 - 2.5 \times 10^{-3}(36.5\varphi)^2$ for $0° \le \varphi < 2.6°$
$G_{co}(\varphi) = 29 - 25 \log\varphi$ for $2.6° \le \varphi < 22.9°$
$G_{co}(\varphi) = -5$ dBi for $22.9° \le \varphi < 70°$
$G_{co}(\varphi) = 0$ dBi for $70° \le \varphi < 180°$

Cross-polar pattern

$G_{cross}(\varphi) = 21 - 25 \log\varphi$ for $3.0° \le \varphi < 11°$
$G_{cross}(\varphi) = -5$ dBi for $11° \le \varphi < 70°$
$G_{cross}(\varphi) = 0$ dBi for $70° \le \varphi < 180°$

Where,

D : equivalent antenna diameter

λ : wavelength expressed in the same unit as the diameter

φ : off-axis angle of the antenna relative to bore sight (degrees)

ITU-R BO.1213-1 is also applicable for both the 1.8m and 3.1m diameter FSS operating in the frequency 3.4 – 4.2GHz as their D/λ ratio is comparable to that in the 11.7 – 12.75GHz band.

3.4.2 At the output of receiver's IF filter

Net Filter Discrimination

The physical phenomenon that could generate interference among two systems operating on adjacent channels is represented by the portion of the spectrum, emitted by the interfering (WBA) system that is in the band of the useful (FSS) system receiving filter.

The amount of interference can be evaluated by the Net Filter Discrimination (NFD) defined as the ratio between the power transmitted by the interfering system and its portion that could be measured after the receiving filter of the useful system.
The NFD is calculated by convolving the transmitter spectrum and receiver filter mask. The NFD method is fully detailed in ETSI TR 101 854 [8]. The methodology has been applied to derive the NFD available between the WBA carrier and the FSS carrier with respect to frequency offset.

The transmission spectrum mask (7MHz bandwidth) was assumed to be similar to that used in the Ovum's report [2] as shown in Figure 2 below. Though the transmission bandwidth used in this measurement is 5MHz, the transmission spectrum mask based on 7MHz bandwidth will be worst off in terms of interference.

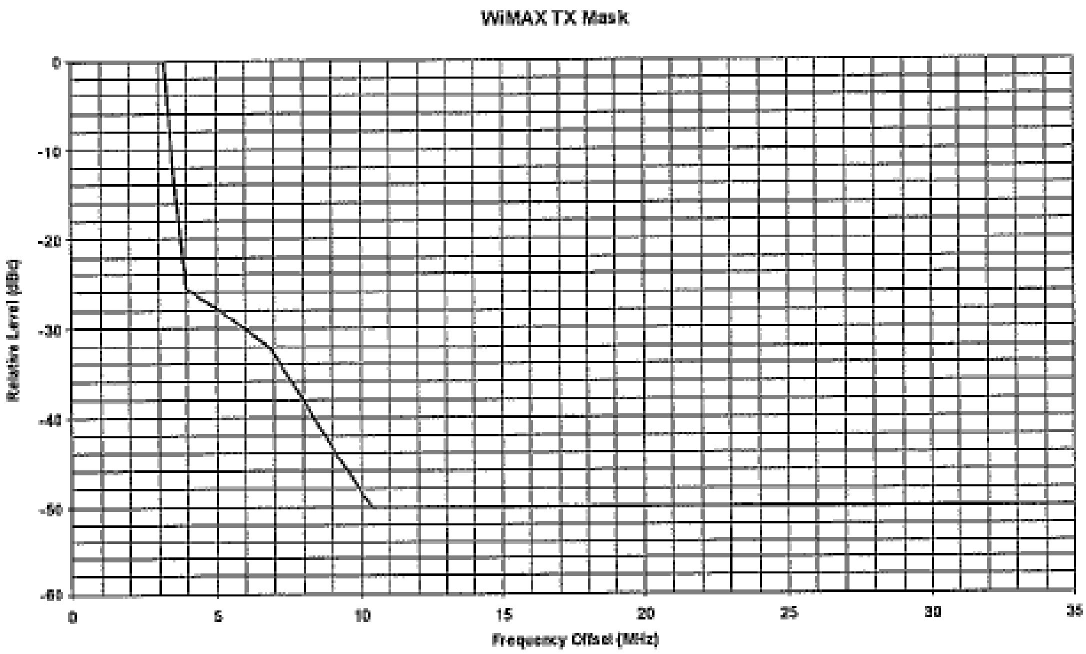

Figure 2: WBA spectrum mask.

The receive filter mask is obtained by superimposing the front-end bandpass filter on an assumed typical IF (70MHz) SAW filter (36MHz bandwidth) as shown in Annex C. The receiver filter mask is as shown in Figure 3.

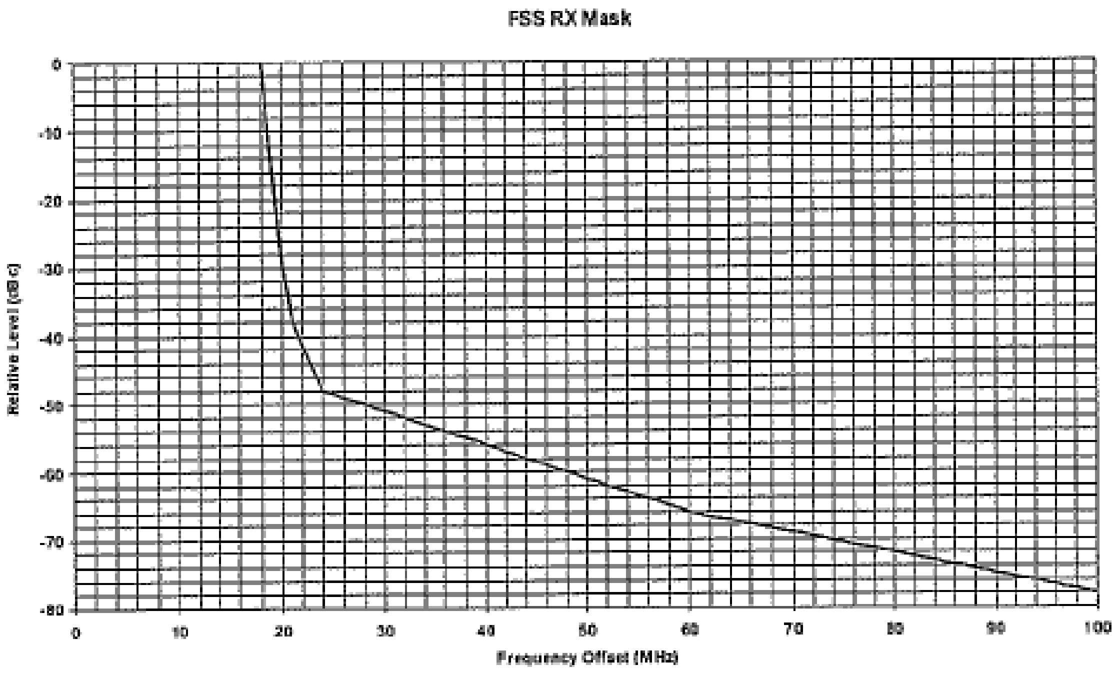

Figure 3: Receive filter mask (front-end plus IF).

The resulting NFD obtained from Ovum's report [2] is shown in Figure 4 below.

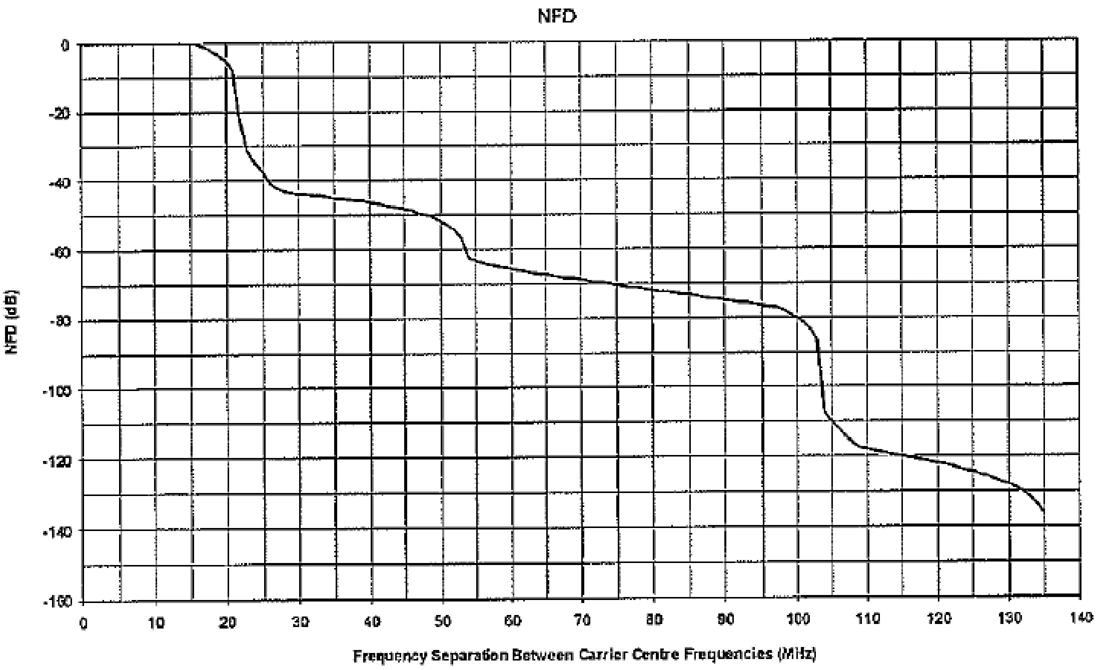

Figure 4 : ***Net filter discrimination.***

The level of interference power at the FSS receiver's IF output is given by,

$$I = P_t + G_t - L_{txf} - PL_{fs} + G_r - L_{rxf} + NFD$$
$$= EIRP_{wba} - PL_{fs} + G_r - L_{rxf} + NFD$$

Eq [11]

Where,
I : WBA interference power in the IF bandwidth of 36 MHz (dBm)
P_t : WBA transmit power in the transmit bandwidth of 5 MHz (dBm)
G_t :: WBA antenna gain (dBi)
L_{txf} : Transmitter feeder loss (dB)
PL_{fs} : Free space path loss (dB)
G_r : FSS off axis antenna gain (dBi)
L_{rxf} : Receiver feeder loss (dB)
NFD: Net Filter Discrimination (dB)
$EIRP_{wba}$: WBA EIRP (dBm)

3.5 Distance Separation between WBA and FSS

3.5.1 Saturation of FSS receiver

By substituting for PL_{fs} in Eq [9], the required distance separation, ***d***, between WBA and FSS to avoid saturation can be calculated by,

$$20\mathrm{Log}(d) = -I + EIRP_{wba} + G_r - L_{rxf} - L_{filter} + 27.6 - 20\mathrm{Log}(f)$$

Eq [12]

The parameters below are being used to calculate the distance separation required to prevent saturation of FSS. The transmit frequency of WBA is selected to be 3590MHz as it is close to it's upper operating frequency limit. The parameter ***I*** in Eq [11] is being substituted by the typical saturation threshold of LNB at -55dBm [5]. The attenuation of the bandpass filter is taken to be 40dB at 3590MHz (Annex C, Satellite TVRO Interference Filter).

Parameters:	**Values**
I:	-55dBm
EIRP:	48dBm (63 W)
G_r**:**	0dBi
L_{rxf}**:**	0.2dB
L_{filter}**:**	40dB(with filter); 0dB(no filter)
F:	3590MHz

Base on the above parameters, if there is no bandpass filter installed on the FSS, the distance separation calculated is approximately 918m.

If bandpass filter is installed on the FSS, the distance separation calculated is approximately 9m.

3.5.2 Adjacent Channel Interference

ITU Rec. SF1486 [7] describes a sharing analysis method for the fixed wireless access systems and VSATs in the 3.4 - 3.7GHz band. The recommendation states that the fixed satellite service receiver protection criterion can be based on an interference level 10dB below the receiver thermal noise floor. In addition, a typical receive system noise temperature is specified as 115K.

Therefore by substituting for $\boldsymbol{PL_{fs}}$ in Eq [10], the required distance separation, ***d***, between WBA and FSS to avoid adjacent channel interference can be calculated by,

$$20\mathrm{Log}(d) = -I + EIRP_{wba} + G_r - L_{rxf} + NFD + 27.6 - 20\mathrm{Log}(f)$$

$$= -\left(\frac{I}{N} + N\right) + EIRP_{wba} + G_r - L_{rxf} + NFD + 27.6 - 20\mathrm{Log}(f)$$

$$= -(-10 + 10\mathrm{Log}[KTB]) + EIRP_{wba} + G_r - L_{rxf} + NFD + 27.6 - 20\mathrm{Log}(f)$$

Eq [13]

Where,

K : Boltman's constant (JK^{-1})
T : Receiver temperature (K)
B : Receiver's IF bandwidth (Hz)

Table 1 below shows the parameters that are being used to calculate the distance separation required to prevent adjacent channel interference of the FSS. The transmit frequency of WBA is selected at 3590MHz as it is close to its upper operating frequency limit. The NFD at WBA-FSS carrier frequency offset of 70.5, 110 and 115MHz are also shown.

Parameters	Values		
K	1.38 x 10^{-23} JK^{-1}		
T	115 K		
B	36 MHz		
EIRP	48 dBm		
G_r	0 dBi		
L_{rxf}	0.2 dB		
NFD	Carrier Freq Offset (MHz)	Guard Band (MHz)	NFD (dB)
(From Figure 4)	70.5	50	-68
	110	89.5	-117.5
	115	94.5	-120
F	3590 MHz		

Table 1: Parameters used in WIFSS.

Base on the above parameters, the distance separation required to prevent adjacent channel interference for the various carrier frequency offsets are calculated and summarised in Table 2.

Carrier Freq Offset (MHz)	Guard Band (MHz)	Distance Separation (m)
70.5	50	273
110	89.5	0.9
115	94.5	0.7

Table 2 : Distance separation vs carrier frequency offset.

From Table 1 above, it can be seen that as the carrier frequency offset increases from 70.5 to 115MHz, the effect of adjacent interference diminishes. This can be seen by the extremely small distance separation of 0.7m calculated at a frequency offset of 115MHz.

3.5.3 Overall Consideration of Interference

Without bandpass filter

When there is no bandpass filter installed on the FSS and when the WBA is transmitting at 48dBm EIRP, the minimum distance separation predicted to prevent saturation at the LNB is 918m (section 3.5.1).

The minimum distance separation required to prevent adjacent-channel interference is expected to be much greater than 918m, in the range of several kilometres.

It is to be noted that the distance calculated in section 3.5.1 is base on an imaginary "free space" environment, considering only the direct ray. In the real world there will be reflections from ground and other surfaces which have to be taken into account. Assuming a two ray model; in the worst-case the direct and reflected signal will add in phase at the FSS antenna, causing a 6dB increase in received signal power. With this in mind, a safety factor of 6dB or a factor of 2 is to be added to the "free space" distance calculated.

Therefore a minimum distance separation of 1.8 km from WBA is recommended to prevent saturation to the FSS.

With bandpass filter

If a bandpass filter, model FLT-MFC-13961 (Annex C) is being installed on the FSS, the minimum distance separation predicted to prevent saturation to the LNB is 9m (section 3.5.1) when WBA is transmitting at 3590MHz, 48dBm EIRP. This constitutes a frequency separation of 110MHz or a guard band of 89.5MHz with reference to 3700MHz (lower edge of filter's pass band).

With a guard band of greater than 89.5MHz between WBA and FSS, the minimum distance separation predicted to prevent adjacent channel interference is less than 1 m (section 3.5.2).

Therefore a minimum distance separation of 9m would be required to prevent both saturation and adjacent channel interference to the FSS. Considering real world reflections and adding a factor of 2, a minimum distance separation of 18m is recommended.

Chapter 4 – Testing Methology

4.1 Test Site

The field test was conducted on a large open and flat terrain in Tuas, to allow the direct line of sight between the WBA and FSS. Figure 5 below shows the location of the FSS at the measurement site which is at latitude of 01°16′28.8″N and longitude of 103°38′8.1″E.

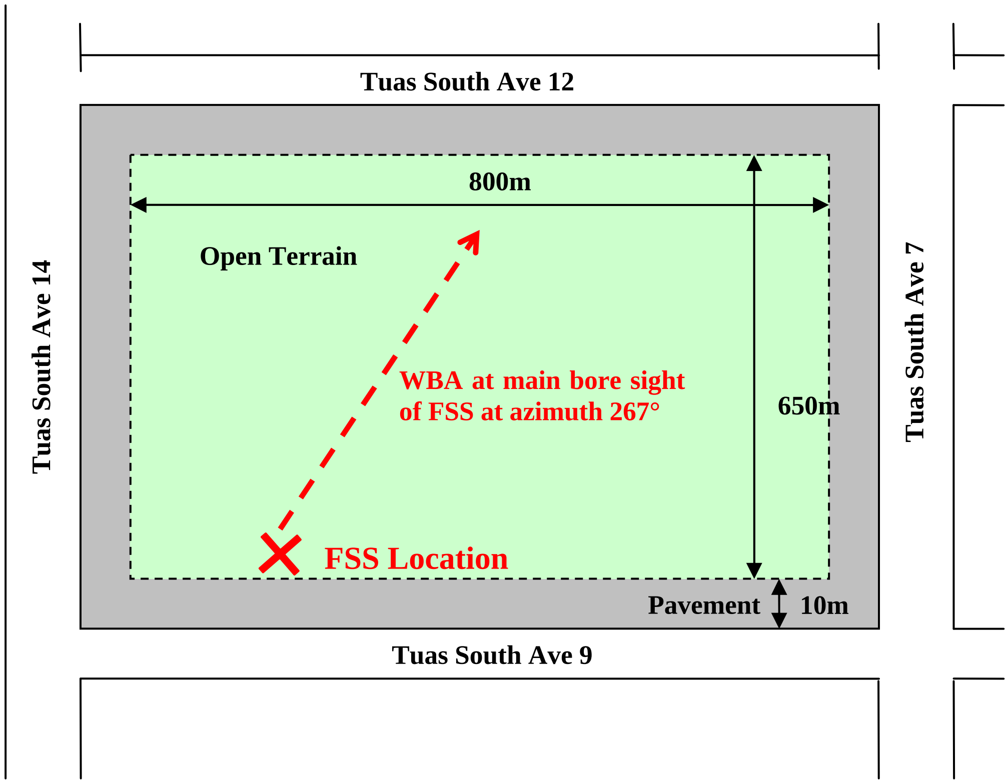

Figure 5 : Field test measurement site.

4.2 Methodology

Two different FSS satellite dish are being used in the measurement, one is a mesh dish and the other is a solid dish. Their diameters are 3.1m and 1.8m respectively.

With different structures and dimensions, each dish will demonstrate different characteristics such as susceptibility to interference and the ability to receive the required satellite signals. For example, the 1.8m solid dish is poor in receiving satellite signals due to its small dish size and also making it more susceptible to interference. As a result, the measurements for the 1.8m dish were only done on MeaSAT3 and this is the only satellite where there is marginal reception picture quality on the RTM channel. Incidentally, both the 3.1m and 1.8m satellite dishes are commonly used by many FSS commercial companies in Singapore and the neighbouring countries, hence the study of the 1.8m dish was necessary.

Both of the receiving satellites are fixed at a location as indicated in Figure 6. While the WBA antenna was mobile, they are located at different distance away at multiple locations.

Figure 6 : FSS satellite dish set up at the field test.

In this measurement, the FSS was tuned to three TV geostationary satellites, namely AsiaSAT3S, MeaSAT3 and InSAT2E. These satellites were chosen among many others because they offer good coverage of broadcast services with many choices of Free-to-Air (FTA) TV channels. More importantly, these available FTA TV channels fall within the frequency range that is critical to the scope of study that is from 3524MHz to 3878MHz.

There are a total of six FTA channels being studied for this measurement and the number of test data collected for each channel using the different test setups varied from each other. The details of all the selected channels are shown in Table 3 below with main emphasis on why these channels have been selected.

<u>Summary of the Channels Used</u>

Satellite	Channel	Frequency (MHz)	Guard Band w.r.t 3590MHz (MHz)	Polarization	Symbol Rate (Msym/sec)	FEC	Reason
AsiaSAT3S (Height of FSS at 3.3m)	Bloomberg	3760	149.50	Horizontal	26000	7/8	• FTA channel that is close to 3590MHz • Strong downlink signal from geostationary satellite • Good BER at FSS
	BTV	3725	114.50	Vertical	4450	3/4	• FTA channel that has the same code rate as C.N.A • Strong downlink signal from geostationary satellite • Good BER at FSS • Is vertically polarised to allow simultaneous measurements using dual feed horn
	Channel News Asia (C.N.A)	3706	95.50	Horizontal	6000	3/4	• FTA channel that is closest to 3590MHz among the three selected channels • Satisfactory downlink signal from geostationary satellite • Satisfactory BER at FSS

Table 3: Selected channels for WIFSS measurement.

Satellite	Channel	Frequency (MHz)	Guard Band w.r.t 3590MHz (MHz)	Polarization	Symbol Rate (Msym/sec)	FEC	Reason
MeaSAT (Height of FSS at 3.26m)	RTM	3878.42	267.92	Vertical	12525	7/8	• FTA channel that is close to 3590MHz • Satisfactory downlink signal from geostationary satellite • Satisfactory BER at FSS
InSAT2E (Height of FSS at 3.16m)	TV9 Kanada	3582.79	Co-Channel	Vertical	3255	3/4	• FTA channel that is closest to 3590MHz • Good downlink signal from geostationary satellite • Good BER at FSS
InSAT2E (Height of FSS at 3.16m)	RajTV	3774	163.5	Vertical	13021	3/4	• FTA channel that is close to 3590MHz • Satisfactory downlink signal from geostationary satellite • Satisfactory BER at FSS • Give sufficient guard-band to conduct Test Setup III at close distance of 20m

Table 3: Selected channels for WIFSS measurement (Cont'd).

The WBA transmitting antenna was mounted onto a rigid antenna stand and erected to a height of 3.5 meters as shown in Figure 7.

Figure 7 : WBA antenna mounted on pole.

During each measurement, the antenna will be aligned to face the FSS dish, to obtain the line of sight shown in Figure 8 below. The power level will then be configured, using the WBA software, to the intended power level and to transmit at various separations distance.

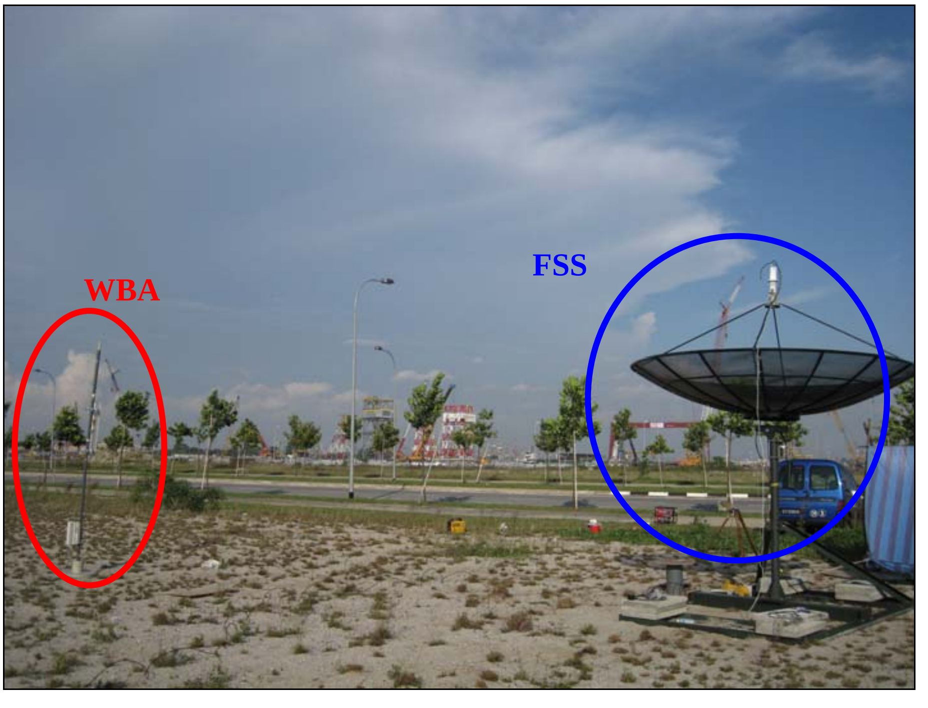

Figure 8 : WBA and FSS setup at field test.

4.3 Acceptance Criteria

Before every WBA transmission, the C/N and BER values of the receiving TV channel signal were measured to establish a baseline and used as comparison after the WBA had transmitted. The main objective is to achieve the BER of 2×10^{-4} in accordance to ETSI TR 101 290 [9] for all the channels prior to WBA transmission.

In the event when BER of 2×10^{-4} is not obtainable prior to transmission due to poor signal strength, the current BER will be used as the baseline. During WBA transmission, the power will be increased gradually until there is a deviation from this baseline or until there is a breakage in the picture reception, whichever is earlier.

The C/N measured by the PROMAX receiver ranged from 8dB to 16dB depending on the tuned channel and the BER before the forward-error correction ranged from low quality of 6.95×10^{-3} to the best quality of 1.6×10^{-6}. The PROMAX receiver also has a build-in spectrum analyser and the spectrum of the before and after interference can be seen in Figure 9.

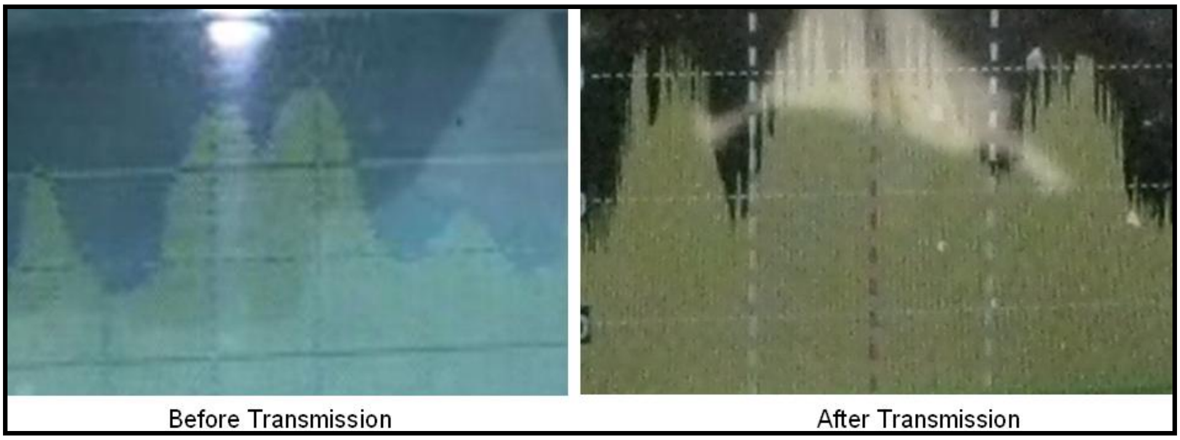

Figure 9 : Spectrum analyser of PROMAX, before and after transmission.

Before the transmission, the spectrum was observed to have smooth edges. However, after transmission and when there is substantial interference, "spikes" which are inter-modulation products, were formed at the edges of the spectrum. Such observation on the spectrum analyser coincides with the loss of picture and audio on the receiver. The results collected from this test were compared against the predictions made using the two-ray link budget as described in the earlier section.

4.4 Test Setup

The height of the WBA was set at 3.5m in this measurement. This is to obtain strong signal field illumination towards the horn feed of the FSS.

There were two sets of measurements collected for this setup; one with filter installed on the single horn feed of the FSS and one without filter. Figure 10 below shows the close-up view of the horn feed with filter installed.

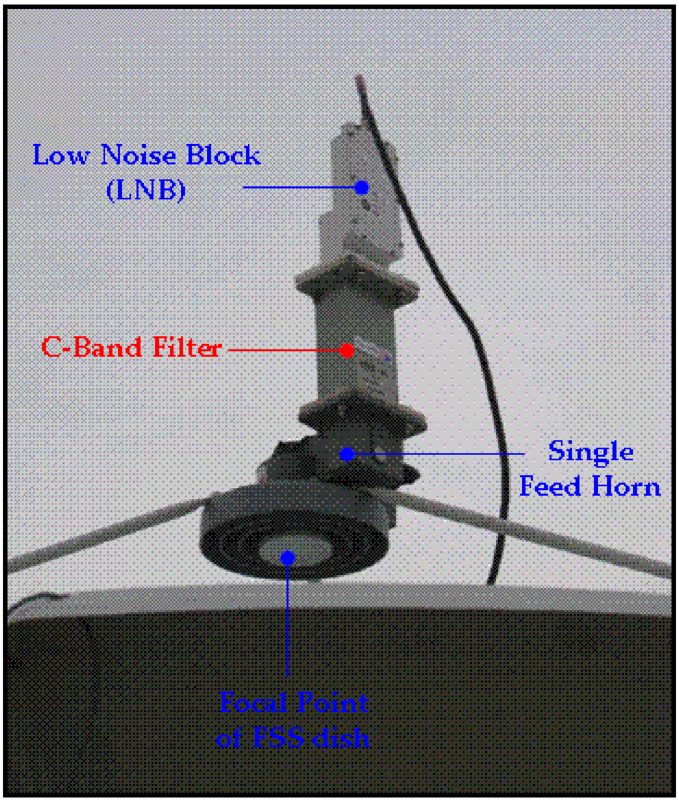

Figure 10 : Close-up view of dish focal point

4.4.1 WBA System Specifications

The system specifications for WBA are given in Table 4.

Operating Frequency	**3590 MHz**
Mode of Operation	Time Division Duplex (TDD)
Base Station	
- Maximum transmitter	2.5W (34dBm)
- Antenna Type	Directional, Gain, 16.5 dBi Vertically Polarised Elevation Beamwidth, 7° 3dB Azimuth Beamwidth, 60°
- TDD Down/Up Link Traffic	50% / 50%

Table 4 : Parameters of WBA.

4.4.2 Test Setup I

Figure 11 shows the system configuration of the field test where the distances of the WBA antenna were varied along the projected bore sight of the FSS. These distances are pre-determined from the theoretical analysis where the plane earth path loss curve meets the free space path loss curve. Since the path loss for free space assumes a single direct signal path, the uncertainties that could result from the reflected signal paths of WBA will be eliminated at these equivalent distances.

To fine tune the measurements, the power level of transmission were varied by configuring the settings of the software that could allow the range of 24dBm to 34dBm, at the step size of 1dB. In the event when transmit power lower than 24dBm is required, the variable attenuator will be used at the output of the ODU to reduce the power further. Such change of power will simulate the change of distance without having to alter the physical distance of WBA.

The main objective of this test is to determine the power threshold level with acceptable BER.

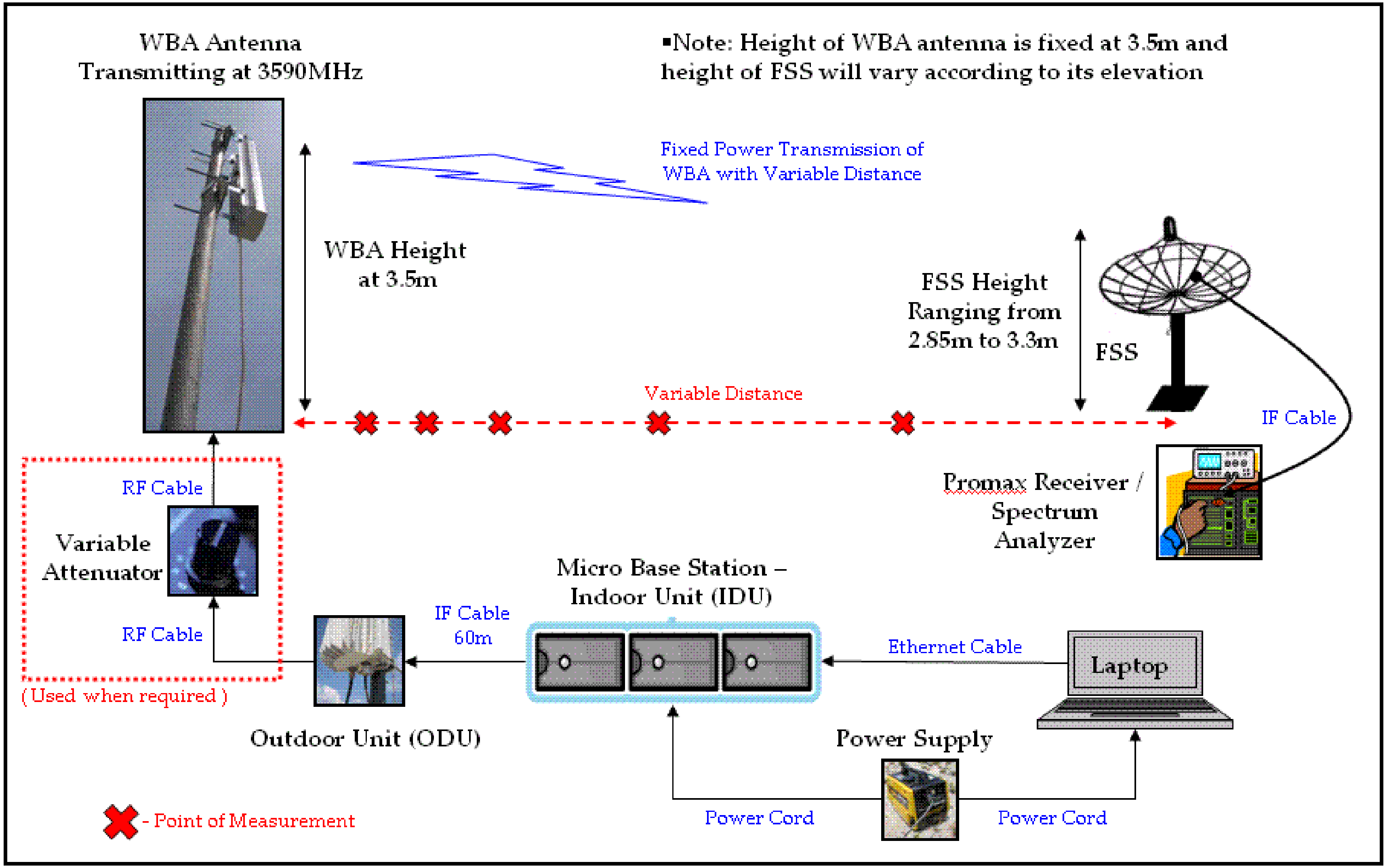

Figure 11 : System configuration of Test Setup I.

4.4.3 Test Setup II

This is a slight variation from Test Setup I as a dual feed horn is being used instead of single feed horn, as shown in Figure 12 below. The purpose of having dual feed horn is to study the effects of the bandpass filter on one feed horn when the WBA is transmitting, against another feed horn without filter. The C-band filter was attached on the horizontal polarised feed and the vertical polarised feed is left without filter. With the dual feed horn it is possible to receive two FSS signals from the same geostationary satellite but of different polarizations simultaneously. As there was only one PROMAX receiver available, a power splitter is required to switch between the two polarizations to observe the received signals on the PROMAX.

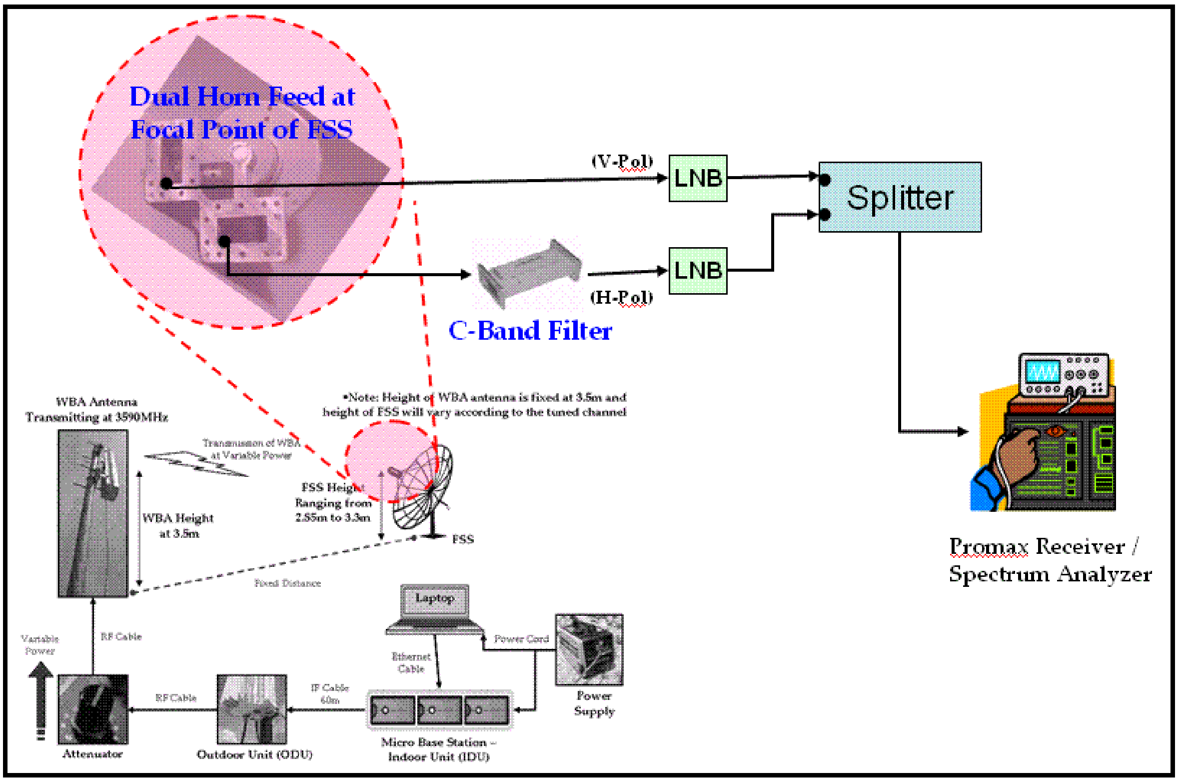

Figure 12 : System configuration of Test Setup II.

4.4.4 Test Setup III

This test is similar to the first setup but the measurements were carried out only with filter installed and with WBA at a distance of 20m. The main difference is that the azimuth of the transmitting WBA is varied 180° around the FSS, at the interval of 45°, as shown in Figure 13 below. With the assumption that the receiving pattern of the FSS dish is symmetrical, it is not necessary to conduct the test 360° around the FSS.

The purpose of this test is to study the effects of the WBA transmission signal at different azimuth with respect to the FSS. InSAT2E satellite was used for this test as it has the lowest elevation angle of 65.5°, among the other three satellites as this is assumed to give the worst-case scenario.

RajTV (3774MHz) is used to carry out this test as it has good BER (bit-error rate) ratings and is within the filter's pass band.

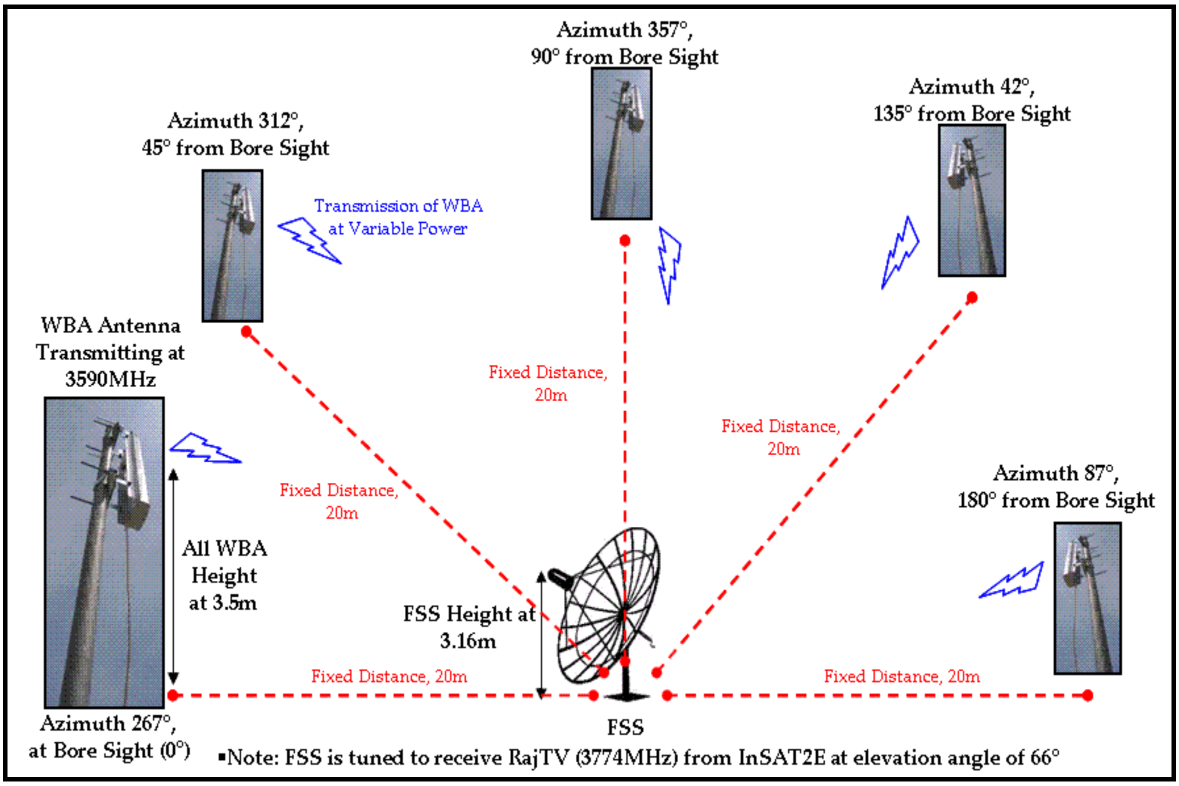

Figure 13 : System configuration of Test Setup III.

4.4.5 WBA Isotropic Radiated Power

The radiated power at the output of the antenna is calculated by the following equation:

$$EIRP_{wba}\,(dBm) = P_t\,(dBm) - L_{txf}\,(dB) - L_{attn}\,(dB) + G_t\,(dBi) \qquad \text{Eq [14]}$$

$EIRP_{wba}$ (dBm)	: Effective Radiated Power of WBA
P_t (dBm)	: Configured Transmission Power of ODU using Software
L_{txf} (dB)	: Transmitter Feeder Loss
L_{attn} (dB)	: Attenuator Insertion Loss
G_t (dBi)	: Antenna Gain of WBA

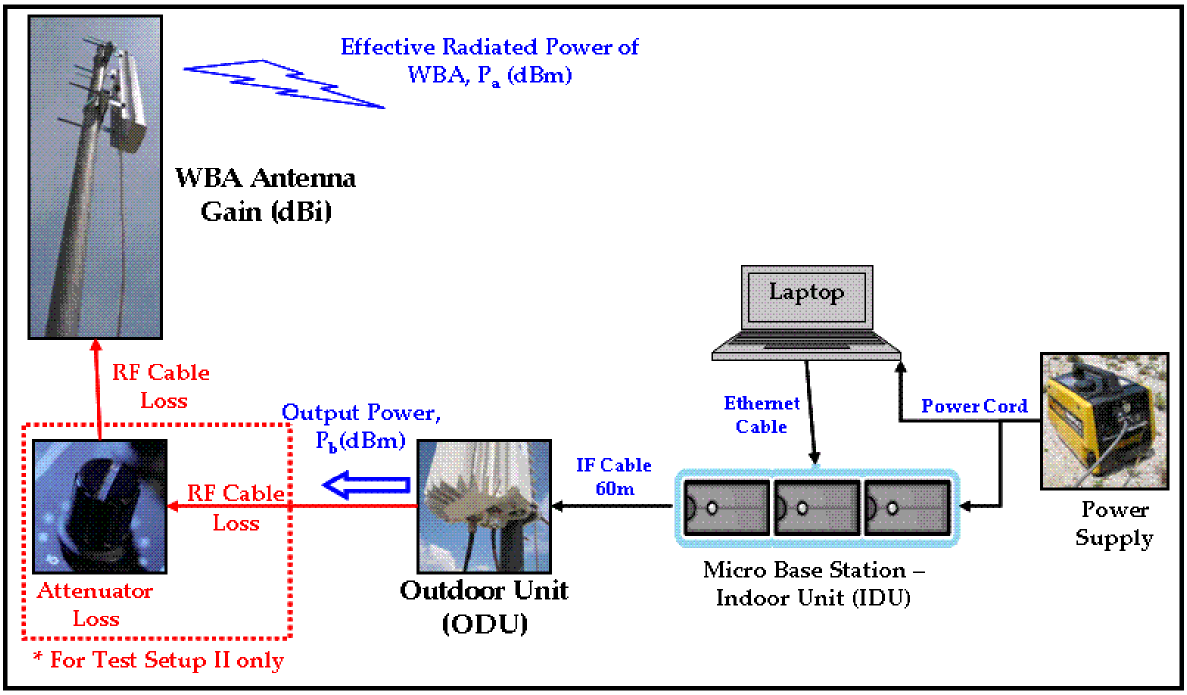

Figure 14 : Effective radiated power of WBA.

The attenuator and feeder losses have been calibrated and pre-determined in the laboratory. The magnitudes of the losses are determined at the frequency point of 3590MHz, similar to the transmission frequency of WBA.

For a typical measurement using Test Setup I and with configured power of 34dBm, the effective isotropic radiated power of WBA can be calculated by:

$$EIRP_{wba}\,(dBm) = P_t\,(dBm) - L_{txf}\,(dB) - L_{attn}\,(dB) + G_t\,(dBi))$$
$$= 34 - 4.23 - 0 + 16.5$$
$$= 46.27\ dBm$$

For Test Setup I, various transmission power levels were used. These configured powers are changed via the WBA software.

Pt (dBm) , ODU power level	Tx Feeder Loss (dB)	Ant Gain (dBi)	$EIRP_{wba}$ (dBm), Effective Isotropic Radiated Power
24	4.23	16.5	36.27
29	4.23	16.5	41.27
34	4.23	16.5	46.27

Table 5 : Effective isotropic radiated power.

Chapter 5 – Test Results Summary

5.1 Analysis of Measurement Results

5.1.1 Calculation of Free Space Distance

As mentioned earlier, in the real world, the received RF signal oscillates around the free space value. Consequently, the path loss also oscillates around the free space value. The value of this path loss does not necessarily increase with distance. At some locations there may be signal maxima due to constructive interference of the direct and reflected ray. This would result in a reduced path loss value.

The value of signal maxima and minima and where they occur depends on the WBA and FSS antenna height amongst other factors. Therefore it is generally not possible to compare measurements taken at various antenna heights but at the same distance separation. In order to compare measurements taken at different antenna positions or heights, it is necessary to establish a common reference using free space approach. The approach is as follows:

Path loss (over ground) that is required to achieve an acceptable BER reading at the test distance is first computed, followed by the distance required to obtain the same path loss in an imaginary "free space" (no reflection) environment. The formula for the calculation of the projected "free space" distance is as follows

$$d_{fs} = d \times 10^{\frac{(PL_{ref} - PL_{fs})}{20}} \qquad \text{Eq [15]}$$

Where

d	:	distance between FSS and WBA during test (m)
***PL**ref*	:	path loss due to ground reflection (theoretical) at test distance, ***d*** (dB)
***PL**fs*	:	free space path loss at distance, ***d*** (dB)
***d**fs*	:	projected free space distance (base on value of ***PL**fs*) (m)

The graphical representation is shown in Figure 16.

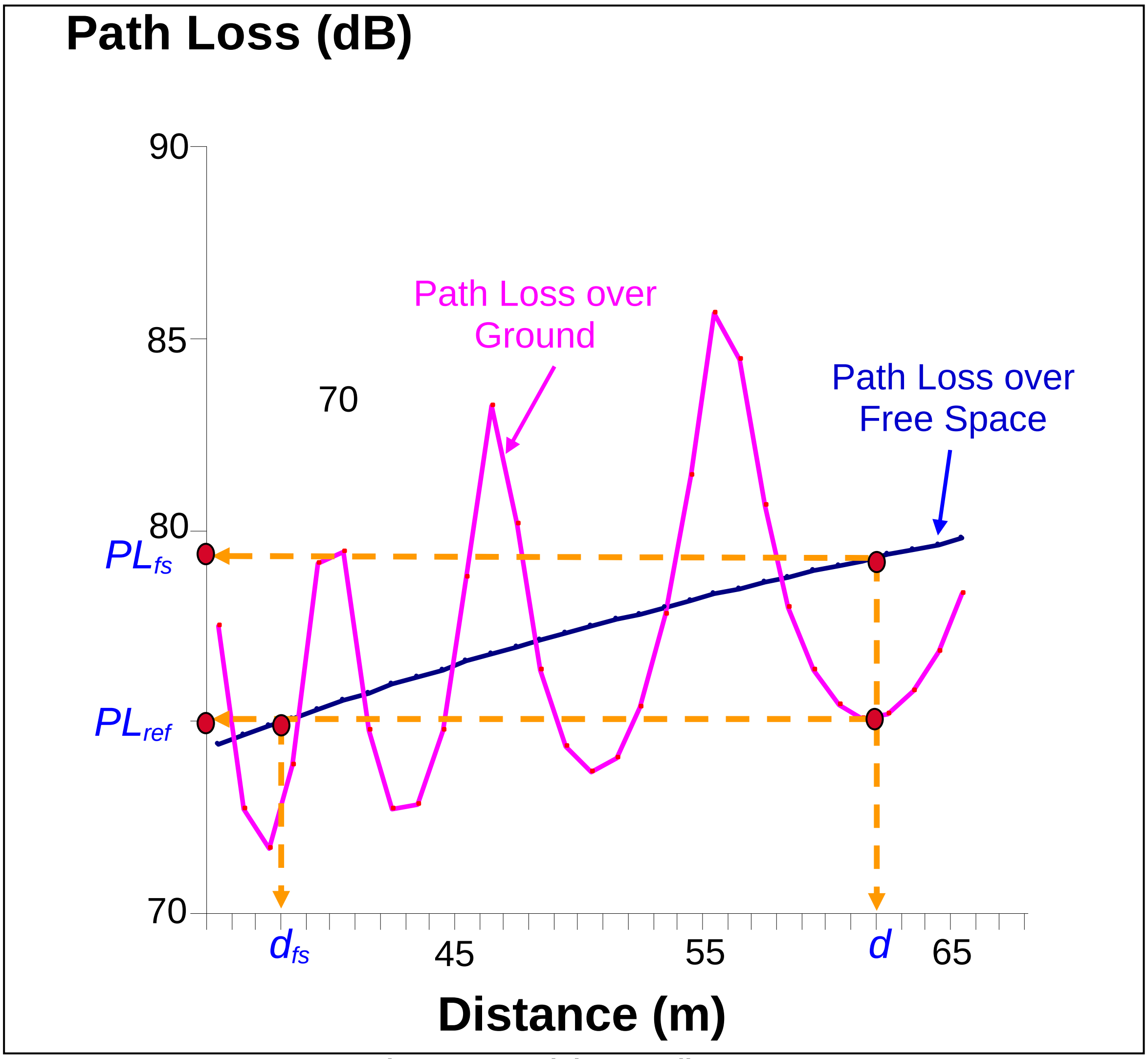

Figure 15 : Path loss vs distance.

5.1.2 Extrapolation of Free Space Distance Base on 48dBm EIRP

The projected free space distance required to obtain good BER reading is dependent on the actual EIRP settings for the various measurement scenarios. To have a fair comparison between them, there is a need to calculate the distance base on a reference EIRP. For this report, 48dBm (63W) is used. The formula for the extrapolation is given as follows,

$$d_{expl} = d_{fs} \times 10^{\frac{(48-E)}{20}} \qquad \text{Eq [16]}$$

d_{fs} : free space distance (base on E dBm, EIRP) (m)

d_{expl} : extrapolated free space distance (base on 48dBm, EIRP) (m)

E : actual EIRP (dBm)

5.2 Summary of Measurements

5.2.1 Without Bandpass Filter on 3.1m Ø FSS

Table 6 shows the summary of the measurement results taken without bandpass filter being installed on the 3.1m diameter FSS.

From the table it can be seen that, Bloomberg channel reception requires the shortest distance separation of 250m base on the EIRP of 48dBm followed by RTM (256m) and C.N.A (1005m).

Generally it can be observed that satellite channel with a higher receive power or C/N ratio will require a shorter distance separation than one with a lower receive power level or C/N ratio. This is probably because higher level signals are less susceptible to saturation effect of WBA transmission, usually characterized by a gain compression of the LNB. Also a higher C/N ratio will result in good BER and consequently good picture quality.

According to the link budget calculated for AsiaSat3S, the Bloomberg and C.N.A has a margin of 6.1dB and 2.52dB respectively above their QEF (Quasi Error Free) E_b/N_0 threshold. This is consistent with the observation that Bloomberg has a much better C/N ratio or signal strength than C.N.A.

It is also observed that the elevation angle of the FSS has not much impact on the distance separation; even at its lowest (65.5°). This could be explained by the constant FSS side lobe antenna gain of 0dBi from 70° elevation onwards and a marginal decrease of 5dB at 65.5° (see page 3-5).

There is a breakage in the reception of TV9 Kanada signal (3582.79 MHz) at an EIRP of 9.74dBm. Due to measurement constraint, it is not possible to reduce the EIRP further to determine the threshold power. However, base on this result, it is deduced that the distance separation required is greater than 3942m for an EIRP of 48dBm. The cause of this large distance separation is because TV9 Kanada (3582.79 MHz) is co-channel with WBA (3590 MHz).

Satellite	Channel	Frequency (MHz)	Elevation (°)	Measured EIRP (dBm)	After Transmission			*PL_{fs} (dB)	*PL_{ref} (dB)	Test Distance, d (m)	Projected Free Space Distance, d_{fs} (m)	Extrapolated Distance Based on 48dBm EIRP, d_{expl}(m)
					Power Level (dBuV)	C/N (dB)	*CBER (dB)					
AsiaSAT3S	Bloomberg	3760	87.5	43.27	82.9	15	7.0×10^{-5}	87.3	86.7	155	145	**250**
AsiaSAT3S	C.N.A	3706	87.5	31.17	71.9	11.1	5.1×10^{-4}	87.3	86.7	155	145	**1005**
InSAT2E	TV9 Kanada	3582.79	65.5	**9.74	67	NA	NA	93.9	93.7	331	322	**> 3942**
MeaSAT3	RTM	3878.2	75.5	45.27	78.9	14.8	1.9×10^{-5}	90.4	88.9	221	187	**256**

Table 6 : Without bandpass filter on FSS.

*Note: ***PL_{fs}*** - Free Space Path Loss, ***PL_{ref}*** – Path Loss due to Ground Reflection

CBER – Bit error rate before forward error correction

** There is a break in signal reception at EIRP of 9.74dBm

5.2.2 With Bandpass Filter on 3.1m Ø FSS

Table 7 shows the summary of the measurement results taken with bandpass filter being installed on the 3.1m diameter FSS.

From the table it can be seen that, Bloomberg channel reception requires the shortest distance separation of 64m base on an EIRP of 48dBm followed by RTM (72m), RajTV (95m) and C.N.A (276m). Again this is attributed to the fact that higher level signals are less susceptible to saturation effect of WBA transmission.

Generally it is observed that there is no significant variation in the distance separation for the various satellite channels with the exception of the C.N.A channel. The extrapolated distance calculated for C.N.A is much larger than the other received channels. This is due to the fact that the C/N and BER readings of C.N.A were poor at 9dB and 3.0×10^{-3} respectively even before WBA transmission. This is because a substantial amount (30MHz) of C.N.A spectrum lies outside the filter's pass band (3700 - 4200MHz), resulting in signal attenuation. As a result, the interference threshold power for C.N.A is lower, translating to a larger distance separation required.

The frequencies of the other satellite channels measured are sufficiently far apart from the WBA frequency and they are within the filter's pass band. Therefore the WBA carrier would have been attenuated substantially by FSS front-end bandpass and IF filter. The main concern here is the potential saturation of the LNB rather than adjacent channel interference; which is largely dependent on the power of the WBA carrier received after the bandpass filter.

From Table 7 it was also observed that there is no noticeable correlation between the elevation angle of the FSS and the distance separation. This is attributed to the FSS antenna gain characteristics as highlighted in section 5.2.1.

Hence from the measurement results, the worst-case separation distance, 95m, is rounded up to 100m and comparing with the rounded up figure of 10m from the prediction, there is a 20dB margin. One possible cause of this margin could be due to the variability in the level of the actual received sidelobe antenna gain of FSS, which could not be accurately accounted for in the prediction.

Satellite	Channel	Frequency (MHz)	Elevation (°)	Measured EIRP (dBm)	After Transmission			*PL_{fs} (dB)	*PL_{ref} (dB)	Test Distance,d (m)	Projected Free Space Distance, d_{fs} (m)	Extrapolated Distance Based on 48dBm EIRP, d_{expl}(m)
					Power Level (dBuV)	C/N (dB)	*CBER (dB)					
AsiaSAT3S	Bloomberg	3760	87.5	44.27	82.1	13.7	2.1×10^{-4}	77.5	75.9	50.3	41	**64**
AsiaSAT3S	C.N.A	3706	87.5	29.17	69.8	8.9	3.6×10^{-3}	73.5	73.5	31.5	31.5	****276**
InSAT2E	RajTV	3774	65.5	34.65	70.3	10.9	8.6×10^{-4}	69.5	69.7	20	20	**95**
MeaSAT3	RTM	3878.2	75.5	37.07	79.7	12.9	7.1×10^{-5}	69.5	69.7	20	20	**72**

Table 7 : With bandpass filter on FSS.

*Note: ***PL_{fs}*** - Free Space Path Loss, ***PL_{ref}*** – Path Loss due to Ground Reflection

CBER – Bit error rate before forward error correction

** - Distance is large as the C/N and BER of C.N.A signal was poor at 9dB and 3.0×10^{-3} respectively even before WBA transmission, due to partial attenuation by the bandpass filter

5.2.3 With Dual Polarised Feed on 3.1m Ø FSS

Table 8 shows the summary of the measurement results taken with dual polarised feed installed on the 3.1m diameter FSS.

From the table it can be seen that, Bloomberg channel reception requires a shorter distance separation of 17m as compared to C.N.A (36m) base on an EIRP of 48dBm. This is attributed to the fact that Bloomberg has a stronger receiving signal than C.N.A which makes it less susceptible to saturation effect of WBA transmission.

BTV requires a much larger distance separation of 505m than Bloomberg (17m). This is attributed to the fact that a bandpass filter had been installed on the horizontal feed for Bloomberg and C.N.A reception. Attenuation of the WBA signal by the filter greatly reduces the distance separation required.

It is to be noted that the distance separation for the above 3 channels are for relative comparison only. As a dual polarised feed and power splitter are being used in this measurement set up, there are additional insertion losses compared to a single polarised feed. This would cause the distance separation for the dual polarised feed set up to be shorter than that of the single polarised feed.

Satellite	Channel	Frequency (MHz)	Elevation (°)	Measured EIRP (dBm)	After Transmission			*PL_{fs} (dB)	*PL_{ref} (dB)	Test Distance, d (m)	Projected Free Space Distance, d_{fs} (m)	Extrapolated Distance Based on 48dBm EIRP, d_{expl}(m)
					Power Level (dBuV)	C/N (dB)	*CBER (dB)					
AsiaSAT3S	Bloomberg	3760	87.5	40.65	76.7	13.5	3.1×10^{-4}	63.5	63.9	10	10	**17**
AsiaSAT3S	C.N.A [1]	3706	87.5	41.65	64.1	9.4	2.7×10^{-3}	71.4	71.3	25	25	**36**
AsiaSAT3S	BTV [2]	3725	87.5	23.24	66.1	10.8	1.4×10^{-4}	77.5	75.9	50	41	**505**

Table 8 : With dual horn feed on FSS.

*Note: ***PL_{fs}*** - Free Space Path Loss, ***PL_{ref}*** – Path Loss due to Ground Reflection

CBER – Bit error rate before forward-error correction

1. Bloomberg and C.N.A are receiving on horizontal polarised feed (WITH bandpass filter installed)
2. BTV is receiving on vertical polarised feed

5.2.4 WBA at Different Azimuth w.r.t. 3.1m Ø FSS

Table 9 shows the summary of the measurement results taken with WBA at different azimuth with respect to the FSS at a distance of 20m. The FSS is aligned to InSAT2E satellite and its elevation angle for InSAT2E at 65.5°, is relatively lower than the rest of the satellites.

The FSS has a highest antenna gain at azimuth 312° N (45° clockwise with respect to FSS), corresponding to a threshold EIRP of 34.65dBm.

- Satellite: InSAT2E
- Channel: RajTV
- Frequency: 3774MHz
- Orientation of FSS Dish (Magnetic North): 267°
- Elevation of FSS Dish: 65.5°
- Distance Separation: 20m

Angular Separation w.r.t FSS (°)	Azimuth w.r.t Magnetic North (°)	Threshold EIRP (dBm)
0	267	40.65
45	312	34.65
90	357	39.65
135	42	40.65
180	87	43.65

Table 9 : Measurement with different azimuth.

From the table it can be seen that, the threshold EIRP for RajTV good picture reception range from 34.65dBm to 43.65dBm (9dB deviation) for azimuth 0° to 180°, with respect to FSS. This deviation could be attributed to the change in the sidelobe level as the azimuth angle between the FSS bore sight and WBA azimuth changes.

Chapter 6 - Conclusion

The extrapolated free space distance base on 48dBm EIRP is summarised in Table 10 below. From the table, it was observed that for FSS without filter installed, C.N.A requires the largest distance separation (free space) of 1005m. With filter installed on FSS, with the exception of C.N.A, the largest distance required is 95m (free space) for RajTV reception.

No.	TV Channel	Frequency (MHz)	Extrapolated free space distance (m) @48dBm EIRP (WITH FILTER)	Extrapolated free space distance(m) @48dBm EIRP (WITHOUT FILTER)
1	RTM	3878.42	72	256
2	Bloomberg	3760	64	250
3	C.N.A	3706	***276	1005
4	RajTV	3774	95	**NC

**NC - Measurement not carried out
*** - Distance is large as the desired signal suffers partial filter attenuation

Table 10: Final results for the distance separation.

Due to the weak satellite signals received by the 1.8m solid dish and by virtue of its size, it was not possible to obtain the recommended BER of 2.0×10^{-4}. The best BER recorded before any transmission was 2.2×10^{-3} on RTM channel and this is much higher than the recommended standard. Even before WBA transmission, there were occasion breakages in the reception of the satellite signals. Hence it was not possible to derive any meaningful assessment on the impact of WBA interference on FSS using 1.8m solid dish.

The extrapolated free space distances (base on 48dBm EIRP) that have been derived thus far is base on an imaginary “free space” environment, considering only the direct ray. In the real world there will be reflections from ground and other building surfaces which have to be taken into account. Assuming a two ray model; in the worst-case the direct and reflected signal will add in phase at the FSS antenna, causing a 6dB increase in received signal power. With this in mind, a safety factor of 6dB or a factor of 2 is to be added to the “free space” distance calculated.

Therefore it is suggested that for one single WBA antenna to operate at 48dBm EIRP without interference:

1. A lateral distance separation of at least 2km from WBA, with **no** bandpass filter installed on the FSS and a guard band of at least 100MHz

2. A lateral distance separation of at least 200m from WBA, **with** bandpass filter installed on the FSS and a guard band of at least 100MHz.

There appears to be discrepancy on the distance separation deduced for the above two scenarios. Based on the 40dB attenuation of the bandpass filter it is expected that the separation distance between the case of with and without filter to be 100 times different. However, due to one possible variation as explained in section 5.2.2, the worst-case values have been adopted.

Chapter 7 – References

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2	Project CYR05	Study on the use of 3.5GHz Spectrum for deployment of Wireless Broadband services in Singapore, Ovum
3	R-J6375-TR002	Project WIFSS Theoretical Analysis of Potential Interference of WBA on FSS in Singapore
4	R-J6375-TP001	Project WIFSS Measurement Plan of Potential Interference of WBA on FSS in Singapore
5	http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6518348357	Presentation by The Satellite Industry Association at the FCC on Thursday May 25th, 2006
6	ITU-R BO.1213-1	Reference Receiving Earth Station Antenna Pattern for the Broadcasting-Satellite Service in the 11.7-12.75 GHz Band
7	ITU-R SF.1486	Sharing Methodology between Fixed Wireless Access Systems in the Fixed Service and Very Small Aperture Terminals in the Fixed-Satellite Service in the 3 400-3 700 MHz Band
8	ETSI TR 101 854 V1.3.1 (2005-01)	Fixed Radio Systems; Point-to-point equipment; Derivation of receiver interference parameters useful for planning fixed service point-to-point systems operating different equipment classes and/or capacities
9	ETSI TR 101 290 V1.2.1 (2001-05)	Digital Video Broadcasting (DVB); Measurement guidelines for DVB systems

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Chapter 8 - Glossary

Glossary

WBA	Wireless Broadband Access
FSS	Fixed Satellite Station
Ant	Antenna
TX	Transmit
Freq	Frequency
BS	Base Station
C/N	Carrier over Noise Ratio
EIRP	Effective Isotropic Radiated Power
BER	Bit Error Rate

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Annex A

Detail Measurement Results

Annex A – Measurement Setting

Date	Satellite	FssRxCh	FssRxFreq (MHz)	FssHt (m)	FssPol	FssDish (m)	FssFltr	FssElv (°)	WbaAzi_wrt_Fss (°)	WbaTxFreq (MHz)	WbaTxPwr (W)	WbaHt (m)	WbaAttn	AttnVal	HornFeed	Dist (m)
26-Nov-08	AsiaSat3S	C.N.A	3706	3.3	Horizontal	3.1	Yes	87.5	127	3590	34	3.5	Yes	0	Dual	25.0
26-Nov-08	AsiaSat3S	BTV	3725	3.3	Vertical	3.1	No	87.5	287	3590	24	3.5	Yes	10	Dual	50.0
26-Nov-08	AsiaSat3S	Bloomberg	3760	3.3	Horizontal	3.1	Yes	87.5	127	3590	33	3.5	Yes	0	Dual	10.0
2-Dec-08	Measat3	RTM	3878.42	3.26	Vertical	3.1	Yes	75.5	264	3590	29	3.5	Yes	3	Single	20.0
3-Dec-08	Insat2E	TV9Kanada	3582.79	3.19	Vertical	3.1	No	65.5	287	3590	24	3.5	Yes	10	Single	331.0
4-Dec-08	Insat2E	RajTV	3774	3.19	Vertical	3.1	Yes	65.5	312	3590	24	3.5	No	0	Single	20.0
5-Dec-08	AsiaSat3S	Bloomberg	3760	3.3	Horizontal	3.1	Yes	87.5	287	3590	32	3.5	No	0	Single	50.3
5-Dec-08	AsiaSat3S	Bloomberg	3760	3.3	Horizontal	3.1	No	87.5	287	3590	31	3.5	No	0	Single	155.0
5-Dec-08	AsiaSat3S	C.N.A	3760	3.3	Horizontal	3.1	Yes	87.5	287	3590	24	3.5	Yes	6	Single	31.5
5-Dec-08	AsiaSat3S	C.N.A	3760	3.3	Horizontal	3.1	No	87.5	287	3590	24	3.5	Yes	4	Single	155.0
5-Dec-08	Measat3	RTM	3878.42	3.26	Vertical	3.1	No	75.5	287	3590	33	3.5	No	0	Single	221.0

Annex A – Measurement Taken Before Transmission

					Before Transmission							
Date	**Satellite**	**FssRxCh**	**HornFeed**	**Dist (m)**	**B4_CnAvg**	**B4_CberAvg**	**B4_VberAvg**	**B4_MberAvg**	**B4_PwrAvg**	**B4_TvQuality**	**GndCondition**	**Remarks**
26-Nov-08	AsiaSat3S	C.N.A	Dual	25.0	9.7	1.30E-03	1.00E-08	10.8	64.1	Good	Dry	
26-Nov-08	AsiaSat3S	BTV	Dual	50.0	10.7	1.35E-04	1.00E-08	12.5	66.1	Good	Dry	
26-Nov-08	AsiaSat3S	Bloomberg	Dual	10.0	13.2	2.05E-04	1.00E-08	12.4	76.3	Good	Dry	
2-Dec-08	Measat3	RTM	Single	20.0	13.0	2.20E-05	1.00E-08	14.1	79.3	Good	Dry	
3-Dec-08	Insat2E	TV9Kanada	Single	331.0	11.7	1.90E-05	4.55E-08	16.1	67.0	Good	Dry	
4-Dec-08	Insat2E	RajTV	Single	20.0	10.7	4.44E-04	1.00E-08	10.8	70.3	Good	Dry	
5-Dec-08	AsiaSat3S	Bloomberg	Single	50.3	13.8	1.70E-04	1.00E-08	12.4	82.5	Good	Dry	
5-Dec-08	AsiaSat3S	Bloomberg	Single	155.0	14.9	1.40E-05	2.95E-08	14.2	82.3	Good	Dry	
5-Dec-08	AsiaSat3S	C.N.A	Single	31.5	9.0	3.00E-03	1.15E-07	10.2	70.4	Good	Dry	
5-Dec-08	AsiaSat3S	C.N.A	Single	155.0	11.2	4.80E-04	1.00E-08	12.1	71.8	Good	Dry	
5-Dec-08	Measat3	RTM	Single	221.0	14.7	1.60E-06	1.00E-08	15.6	79.8	Good	Dry	

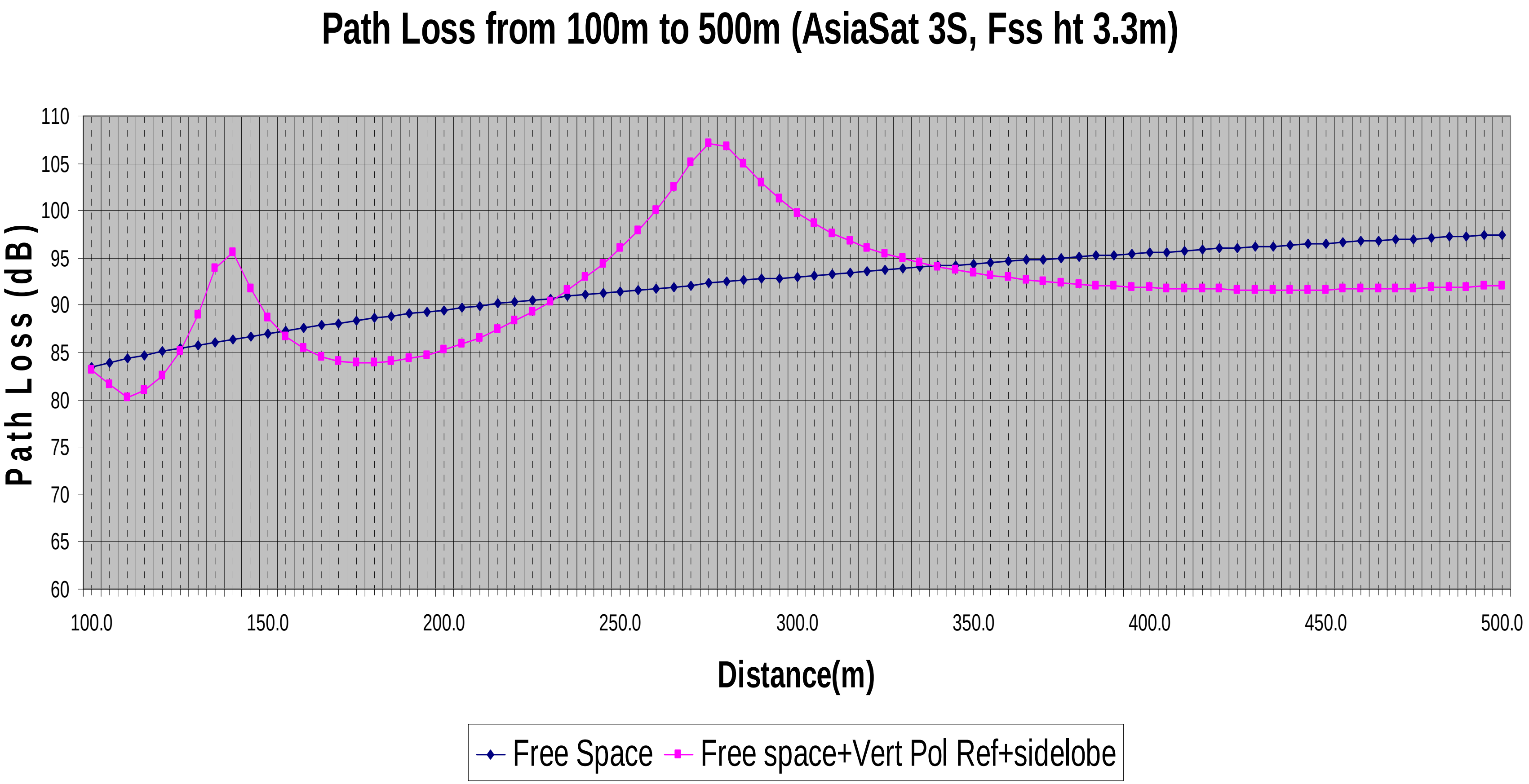
Annex A – Measurement Taken After Transmission

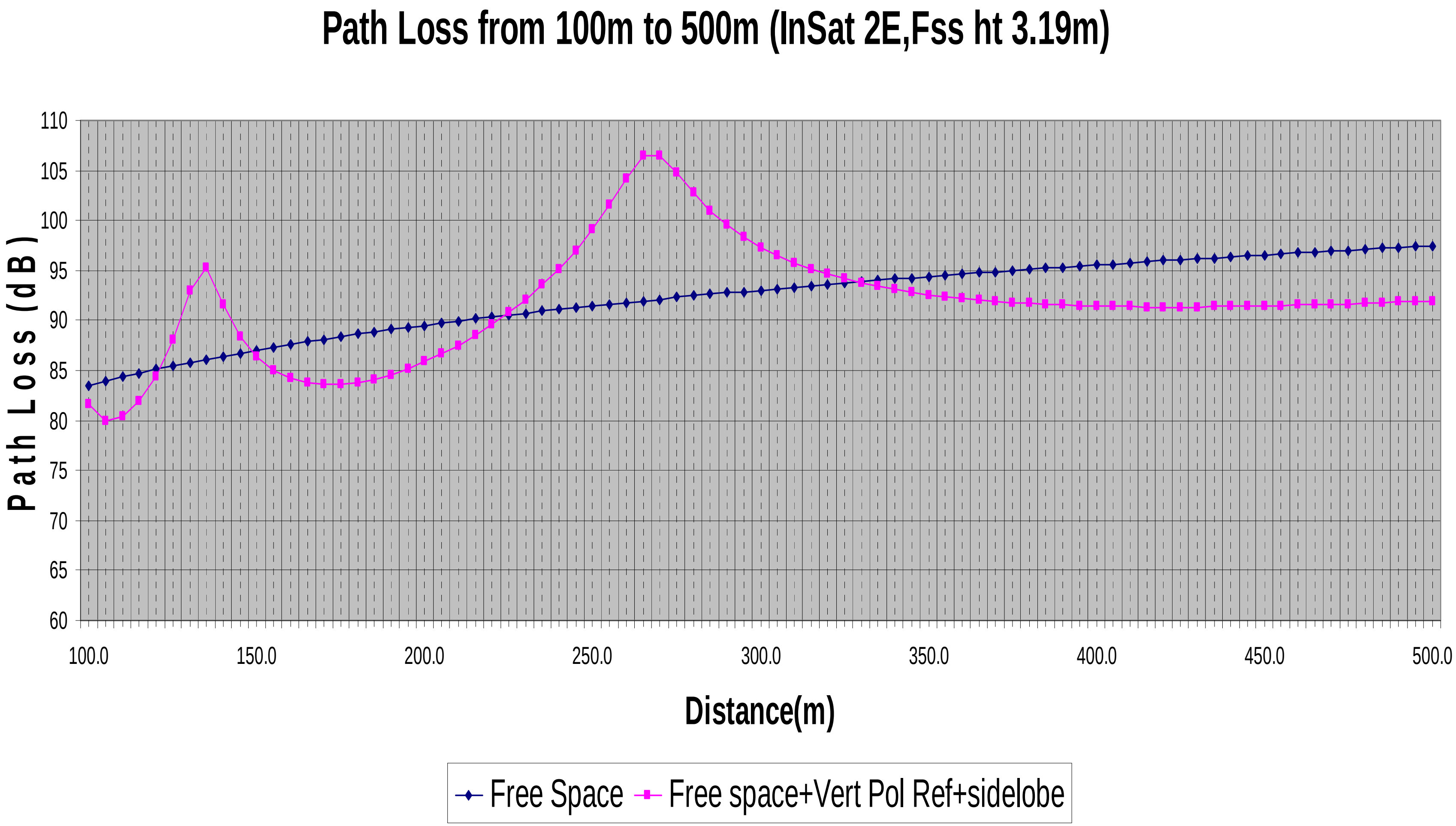
					After Transmission							
Date	**Satellite**	**FssRxCh**	**HornFeed**	**Dist (m)**	**Aft_CnAvg**	**Aft_CberAvg**	**Aft_VberAvg**	**Aft_MerAvg**	**Aft_PwrAvg**	**Aft_TvQuality**	**GndCondition**	**Remarks**
26-Nov-08	AsiaSat3S	C.N.A	Dual	25.0	9.4	2.70E-03	8.05E-07	9.2	63.3	Good	Dry	
26-Nov-08	AsiaSat3S	BTV	Dual	50.0	10.8	1.40E-04	1.00E-08	12.5	65.8	Good	Dry	
26-Nov-08	AsiaSat3S	Bloomberg	Dual	10.0	13.5	3.10E-04	1.83E-04	9.8	76.7	Good	Dry	
2-Dec-08	Measat3	RTM	Single	20.0	12.9	7.10E-05	3.95E-07	12.2	78.7	Good	Dry	
3-Dec-08	Insat2E	TV9Kanada	Single	331.0	11.9	1.85E-05	1.31E-06	16.1	66.8	Good	Dry	
4-Dec-08	Insat2E	RajTV	Single	20.0	10.9	8.55E-04	1.00E-08	10.7	70.3	Good	Dry	
5-Dec-08	AsiaSat3S	Bloomberg	Single	50.3	13.7	2.05E-04	1.00E-08	11.3	82.1	Good	Dry	
5-Dec-08	AsiaSat3S	Bloomberg	Single	155.0	15.0	7.00E-05	4.95E-06	12.5	82.9	Good	Dry	
5-Dec-08	AsiaSat3S	C.N.A	Single	31.5	8.9	3.60E-03	8.00E-07	8.4	69.8	Good	Dry	
5-Dec-08	AsiaSat3S	C.N.A	Single	155.0	11.1	5.05E-04	1.00E-08	11.9	71.9	Good	Dry	
5-Dec-08	Measat3	RTM	Single	221.0	14.8	1.90E-05	1.22E-05	12.7	78.9	Good	Dry	

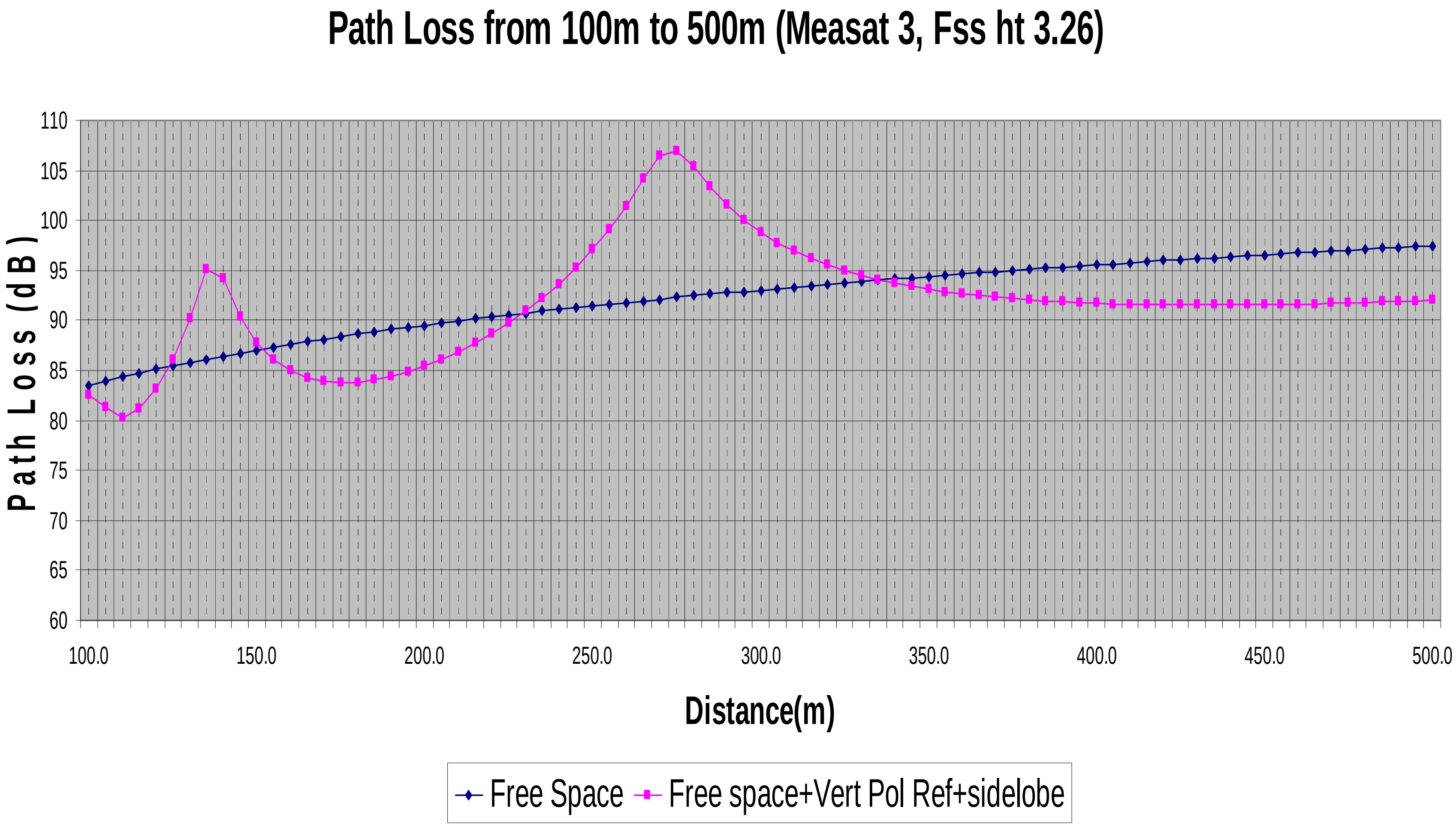
Annex B

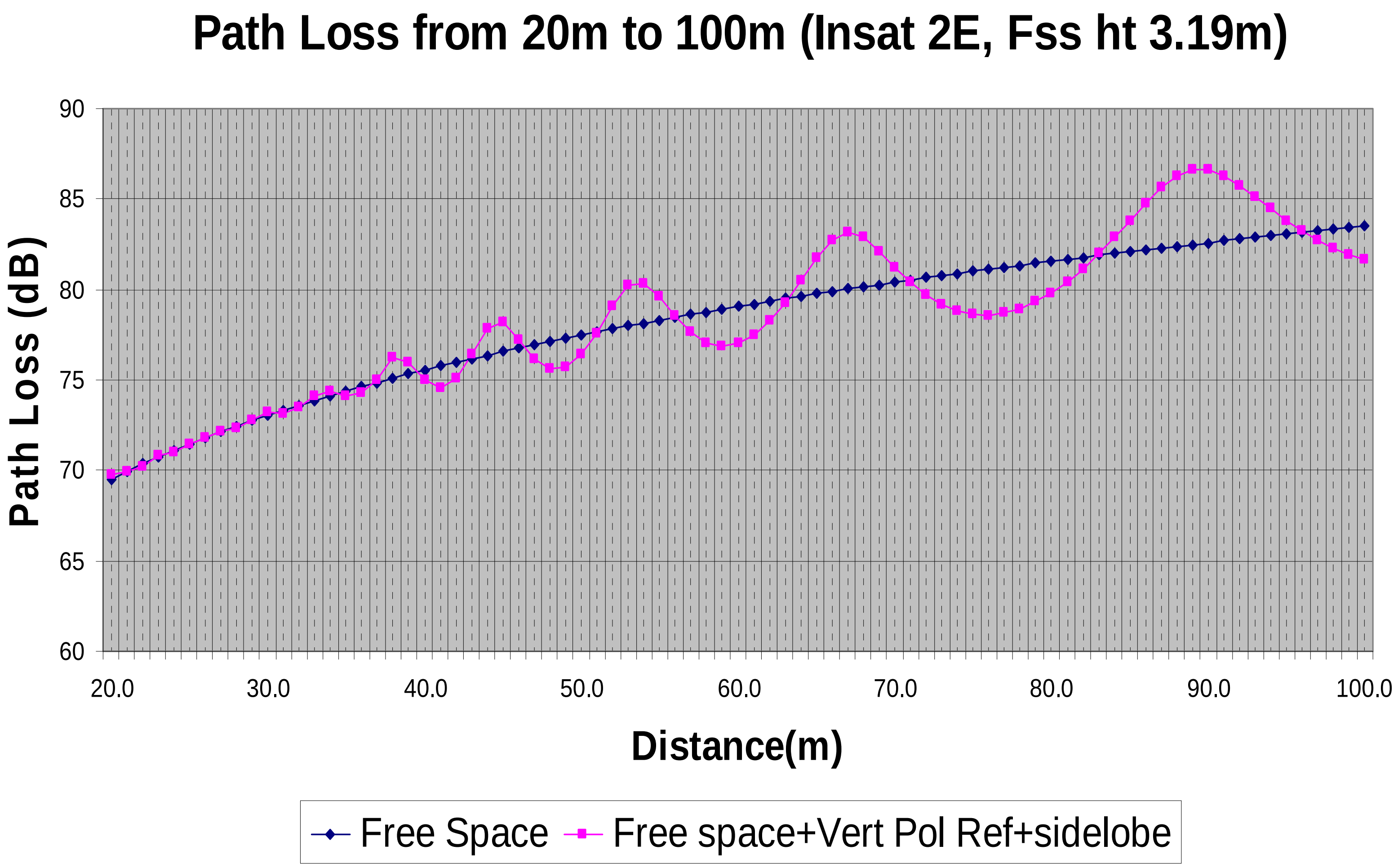
Predicted Path Loss Profiles

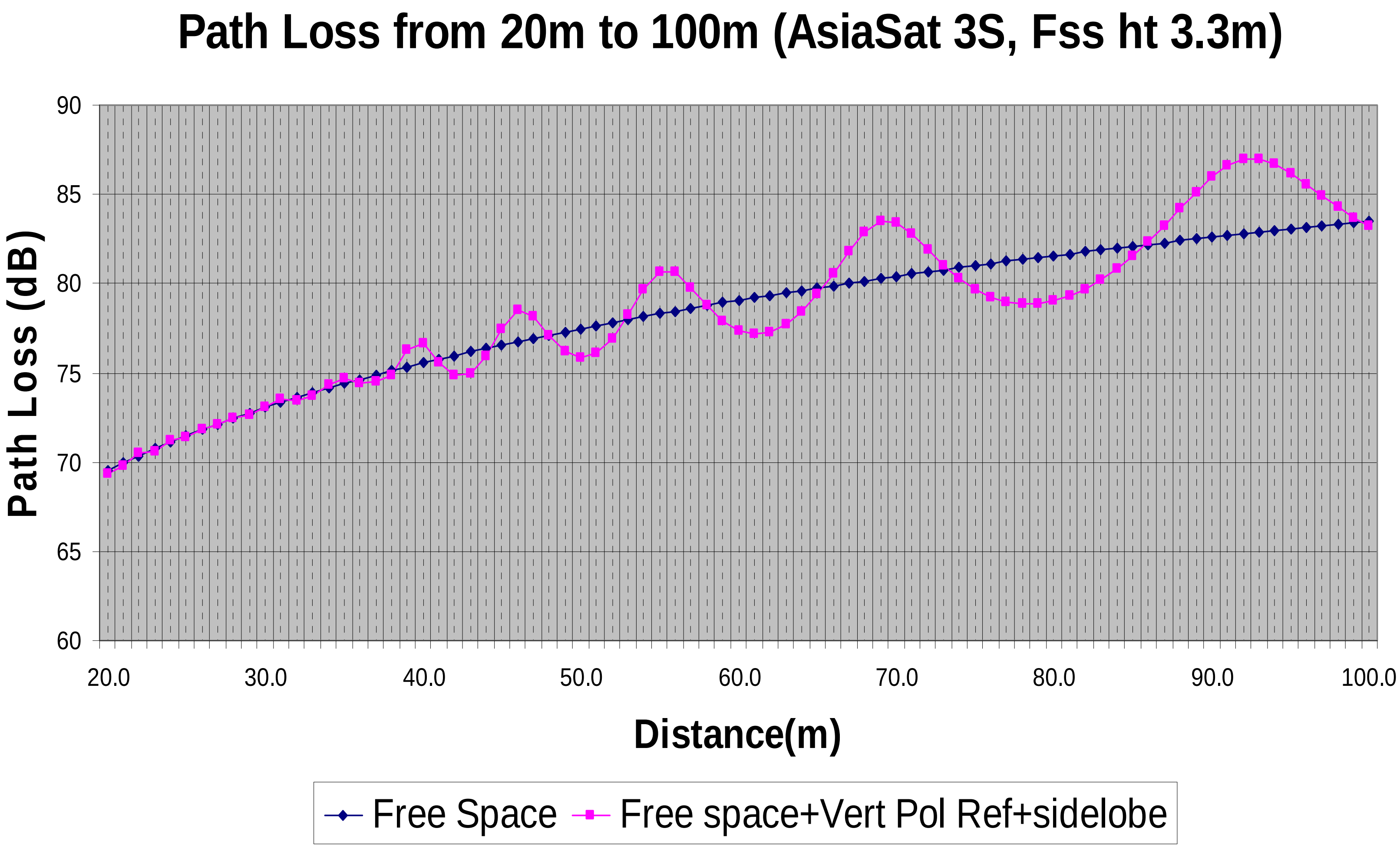
Annex B

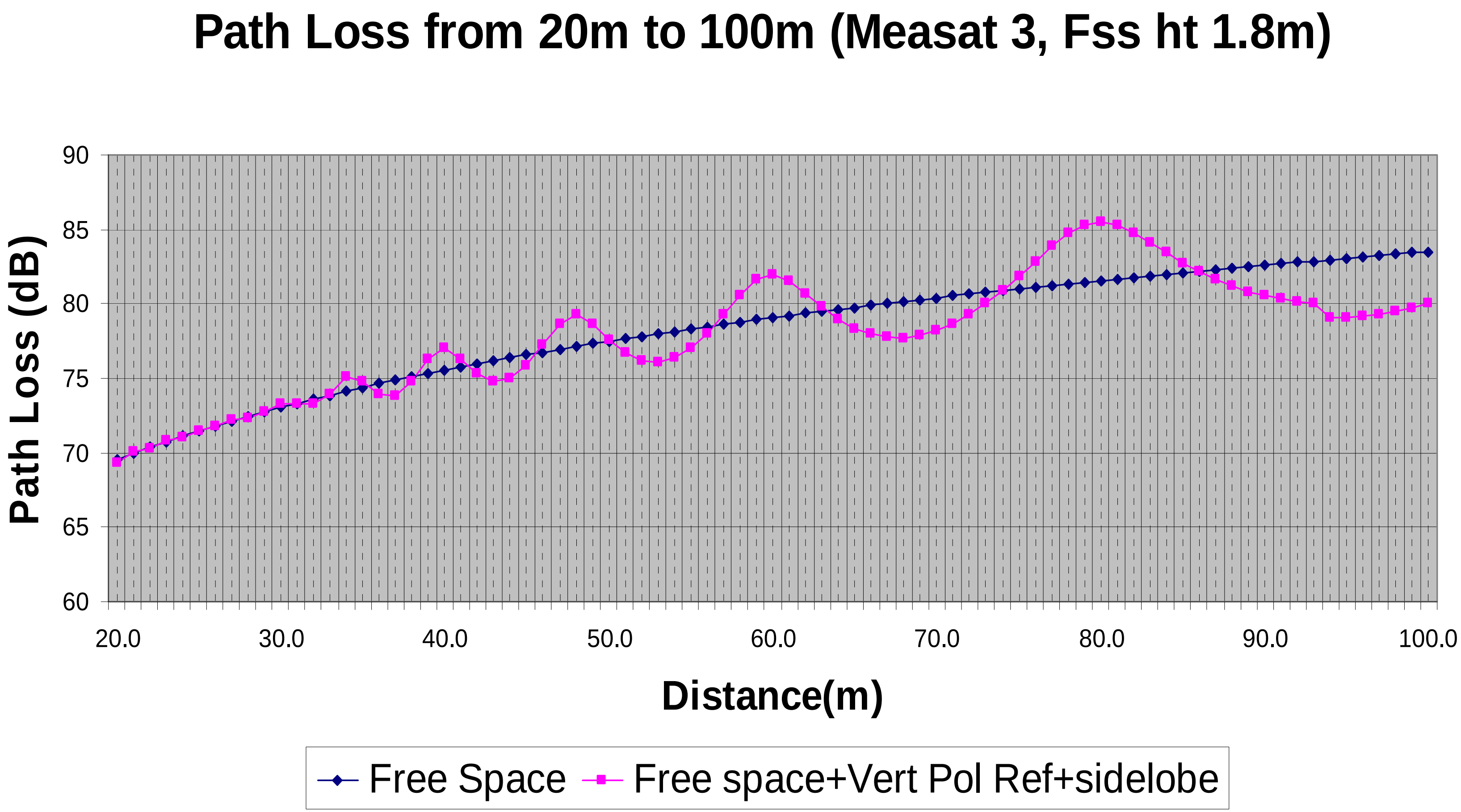

Path Loss from 100m to 500m (AsiaSat 3S, Fss ht 3.3m)
Path Loss (dB)
110
105
100
95
90
85
80
75
70
65
60
100.0
150.0
200.0
250.0
300.0
350.0
400.0
450.0
500.0
Distance(m)
Free Space
Free space+Vert Pol Ref+sidelobe

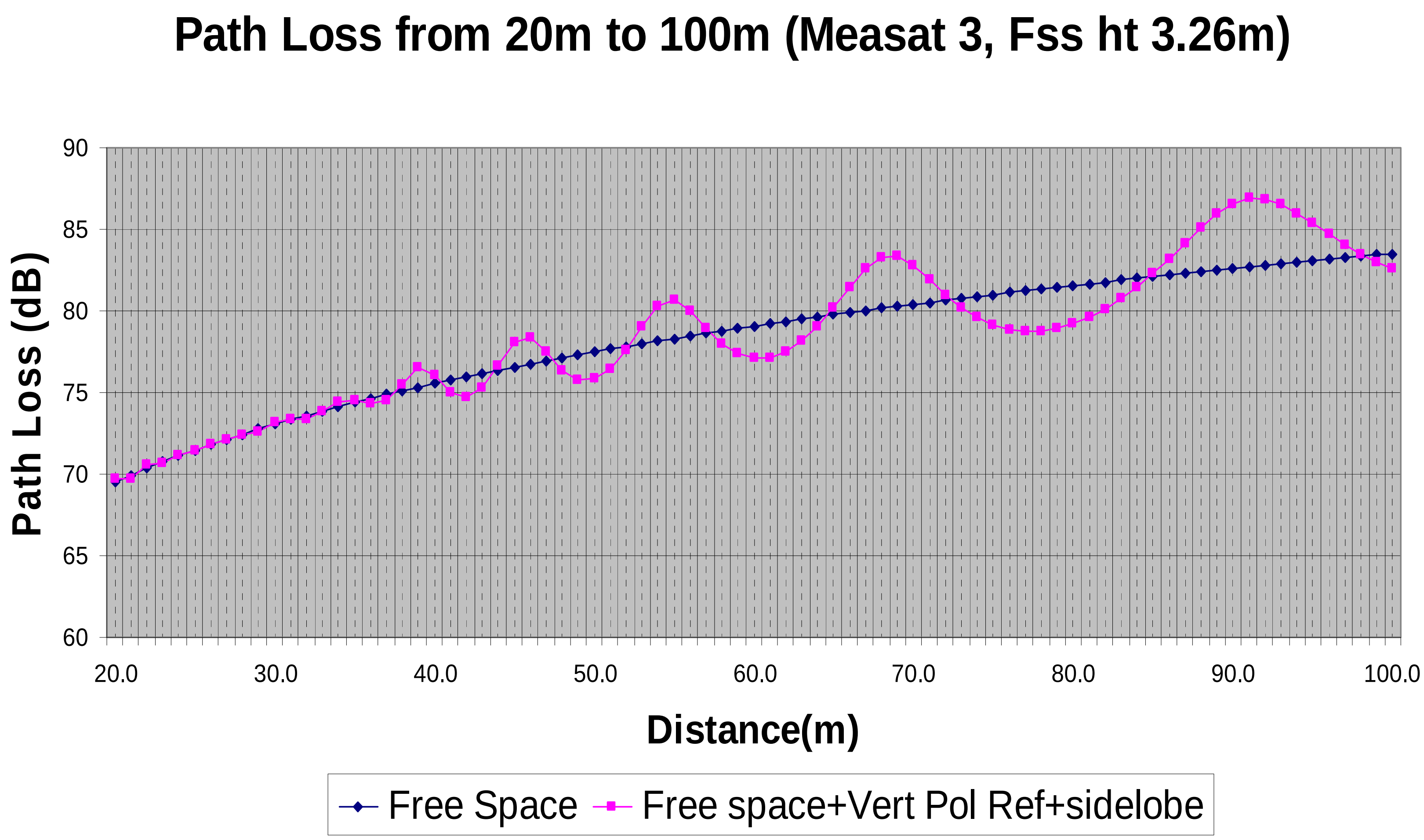

Path Loss from 100m to 500m (InSat 2E,Fss ht 3.19m)
Path Loss (dB)
110
105
100
95
90
85
80
75
70
65
60
100.0
150.0
200.0
250.0
300.0
350.0
400.0
450.0
500.0
Distance(m)
Free Space
Free space+Vert Pol Ref+sidelobe

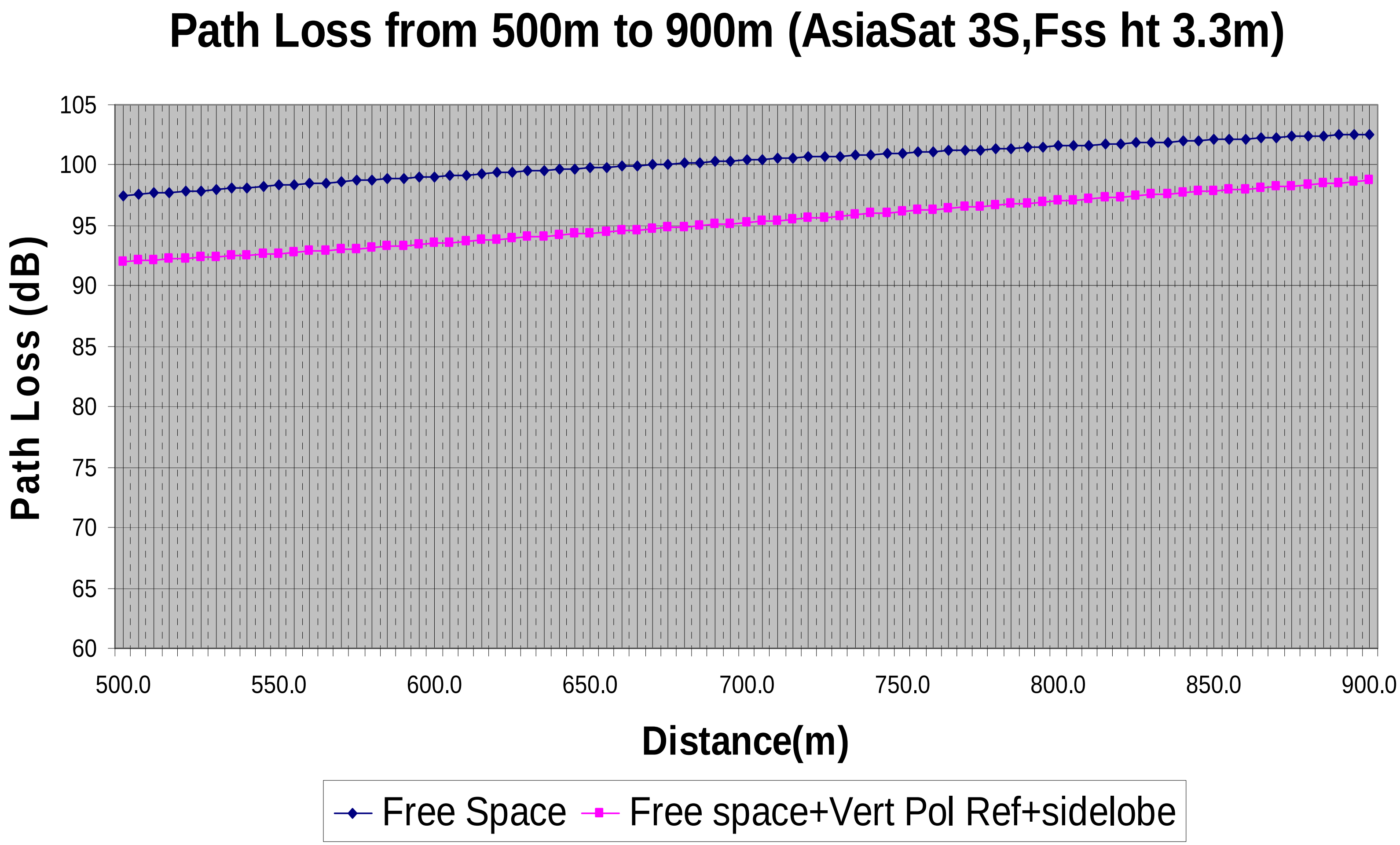

Path Loss from 100m to 500m (Measat 3, Fss ht 3.26)
Path Loss (dB)
110
105
100
95
90
85
80
75
70
65
60
100.0
150.0
200.0
250.0
300.0
350.0
400.0
450.0
500.0
Distance(m)
Free Space
Free space+Vert Pol Ref+sidelobe


Path Loss from 20m to 100m (Insat 2E, Fss ht 3.19m)
Path Loss (dB)
90
85
80
75
70
65
60
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
Distance(m)
Free Space
Free space+Vert Pol Ref+sidelobe


Path Loss from 20m to 100m (AsiaSat 3S, Fss ht 3.3m)
Path Loss (dB)
90
85
80
75
70
65
60
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
Distance(m)
Free Space
Free space+Vert Pol Ref+sidelobe


Path Loss from 20m to 100m (Measat 3, Fss ht 1.8m)
Path Loss (dB)
90
85
80
75
70
65
60
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
Distance(m)
Free Space
Free space+Vert Pol Ref+sidelobe


Path Loss from 20m to 100m (Measat 3, Fss ht 3.26m)
Path Loss (dB)
90
85
80
75
70
65
60
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
Distance(m)
Free Space
Free space+Vert Pol Ref+sidelobe


Path Loss from 500m to 900m (AsiaSat 3S,Fss ht 3.3m)
Path Loss (dB)
105
100
95
90
85
80
75
70
65
60
500.0
550.0
600.0
650.0
700.0
750.0
800.0
850.0
900.0
Distance(m)
Free Space
Free space+Vert Pol Ref+sidelobe

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Annex C

Equipment Specifications

SATELLITE METER

PROMAX TV EXPLORER

PROMAX TV EXPLORER, and US TV EXPLORER
Universal TV Explorer
(Formally known as the Prodig-5)

Promax TV Explorer Shown

Features:

- Coverage of satellite, cable and television.
- Tuning by channel and frequency (IF or direct in the case of satellite)
- Automatic channel search with the possibility to create channel plans for each new session.
- Automatic identification of the type of signal.
- Multi-standard analog measurements: Level, Video-Audio, C/N.
- Digital measurements: Power, C/N, Channel Identification.
    - COFDM 2k/8k: MER, VBER, CBER
    - QPSK: CBER, VBER, MER.
    - QAM 16/32/64/128/256: BER, MER.
- Simultaneous display of all the measurements and main associated parameters.
- MPEG decoding.
- List of services and PID's.
- TFT Monitor (320 candles/cm²).

DYNASAT SATELLITE DISH

DYNASAT
www.dynasat.com

Specification

MODEL	6´	7´	7.5´	8´	10´	12´
DIAMETER	183 cm.	213 cm.	228.6cm.	243.8 cm.	304.8 cm.	365.6cm.
TYPE	|------------ PRIME FOCUS ALUMINIUM MESH DISH. ------------|					
FOCAL LENGTH	64 cm.	78.5 cm.	86.8 cm.	92.6 cm.	115.8 cm.	138.9 cm.
F/D RATIO	0.35	0.37	0.38	0.38	0.38	0.38
GAIN (C BAND)	36 dB.	37 dB.	38 dB.	39 dB.	41 dB.	44 dB.
GAIN (KU BAND)	45 dB.	46 dB.	47 dB.	48 dB.	51 dB.	54 dB.
PANEL	4	4	4	4	4	8

Dynamic Satcom Co., Ltd. Tel (662) 910-8935 to 9 Fax (662) 587-2443 E-Mail sales@dynasat.com
158,158/1-2 Soi Wattaipratumrung (Wongsawang21), Wongsawang Rd., Bangsue, Bangkok 10800, THAILAND


THAILAND
Dynasat
DYNASAT
MOUNTS
Fix (AzEl)
Move (Polar)
6', 7', & 7.5'
All Models
6', 7', & 7.5'
7.5'
8' & 10'
With 24" ring
Aluminum Mesh Dish Antennas.
S / C / KU Band Reception .
High Accuracy Parabolic Curvature Design.
Thicker & Flatter Laminated Mesh Sheets.
Bigger & Thicker ribs for Better Strongness.
Intermediate Support Rings.
Big Screw Fixing Heads.
Smart Quad Feed Supports.
Powder Coated Finishing.
Free for LNB Cover Hood (PE with UV Protection).
Fast & Easy Assembly and Installation.
Heavy Duty PRE - ASSEMBLED Mount.
Adjustable Declination 0 - 15 Degrees without Stress.
Precise Direction Tracking.
Ease of Transportation and Space Management by 4-8 panels / CKD.
Gold Gavalnize Plated for all Nuts & Screws same as Industrial Grade.
Shot Blasting for Steel Surface Preparation not Chemical Cleaning
for Neat Finishing. No Rust Longer & Save Environment.
Robotic Welding Machines give Excellent Works.
WELDING ROBOTS
DYNASAT
DYNASAT
Small Hood
Big Hood
Feed Supports
S, C & KU Band mesh
We open the world of satellite
DYNAMIC SATCOM CO., LTD.
Sangsue, Bangkok, THAILAND
http://www.dynasat.com

1.8M C/Ku BAND SATELLITE DISH

1.8M C/KU BAND FIXED POSITION SOLID DISH

Rear Mount

Item Description

This 180cm Solid C/Ku Band dish is a movable polar mount.

Specifications

Diameter: 180cm
Panel (Sector divided): 6 panels
C-Band Gain @ 4GHz: 35.89dB
KU-Band Gain @ 12.5GHz: 45.54dB
F/D Ratio 0.38
Focus Length: 72cm
Mounting Type: Pole 76mm od (not supplied)
Material: Steel
Finish: Polyester Powder Coating
Elevation Alignment: 0-90°
Azimuth Alignment: 0-360°
Operational Winds: 90kph
Survival Wind: 200kph

SATELLITE LNB

PATRIOT Antenna Systems

PAT -8115

PATRIOT Antenna Systems

C-Band DRO LNB ± 100 KHz

Input Frequency	3.4 to 4.2 GHz
Output Frequency	950 - 1750 MHz
Noise Temperature	15°K @ 25°C
Gain	60 dB Typical
Gain Flatness	1 dBp-p max per 27 MHz segment
Image Rejection	45 dB Min
Output VSWR	2.5:1 Typical, 75 ohm
LO Stability	± 100 KHz
LO Frequency	5.15 GHz
Phase Noise	-65 dBc/Hz @ 1 KHz
DC Input	+15 to +20 VDC
Current Drain	200 mA typical
Operating Temperature	-40°C to +50°C
Input Interface	Flange, WR 229G
Output Interface	75 Ohm, Type "F" Female
Finish	Powder Coat
Physical Size	7.1 x 3.9 x 2.8 in
Weight	15 oz

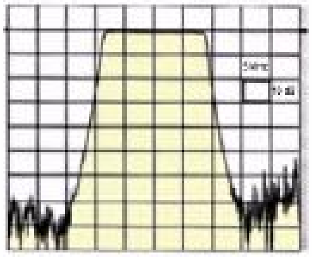
Phone (517) 629-5990 – Fax (517) 629-6690 – 704 North Clark St. – Albion, MI 49224 – www.sepatriot.com

SATELLITE TVRO
INTERFERENCE FILTERS

TVRO Interference Filters

Ideal For Multifeed Applications

FLT-MFC-13961
Interference filter



Typical Response Curve

13961 Series

The Series 13961 waveguide bandpass filter eliminates interference caused by navigational communications (radar) of commercial and military aircraft, as well as coastal and marine vessels operating at frequencies above and below the C-band. The unit is installed between the LNA or LNB and the feedhorn. This lightweight, low profile filter is ideal for multifeed applications which require side-by-side placement of filters (adequate radome clearance is required). Since the unit does the filtering at the C-band frequencies, LNA and LNB overload is prevented and overall picture quality is improved.

Specifications:

Passband:	3.7-4.2 GHz
Insertion Loss:	0.5 dB typical at center frequency 0.75 dB roll-off at band edge
VSWR:	1.92:1 Typ
Group Delay:	Less than 8 ns typical
Rejection:	
25 dB typical	3.65/4.25 GHz
60 dB minimum	3.56/4.35 GHz
70 dB minimum	3.50/4.40 GHz

Mechanical Specifications:

Dimensions:	5 3/4"L x 2 3/4"H x 3 7/8"D
Weight	1.3 lbs
Flanges*	CPR-229G, CPR-229F

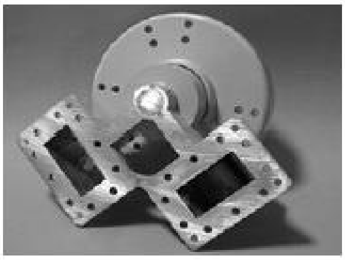
*Half gasket is supplied with each model

Features:

- •Lightweight, Low Profile
- •Ideal for Digital Applications (Low Differential Group Delay)
- •Low Insertion Loss
- •High Interference Rejection
- •Other Frequency Bands Available Upon Request (Including International)

SATELLITE C/Ku BAND FEEDHORNS

ADL ANTENNA FEEDS

C / Ku-Band Feeds	ADL-RP3-OR-100	ADL-RP3-2+2B
		
Model	ADL-RP3-OR-100	ADL-RP3-2+2B
Frequency	3.625 - 4.2 GHz	3.625 - 4.2 GHz 11.7 - 12.5 GHz
Polarities	2 C	2C / 2Ku
F/D Range	.300 - .365	.300 - .365
Polarization	Linear	Linear
RF Port	2 WR-229	2 WR-229 2 WR-75
Mounting	3 & 4 Hole Pattern on a 5.750°	3 & 4 Hole Pattern on a 5.750°
Polarization Operation	Manual	Manual
VSWR	1.40 Average	1.40 Average
Polarization Isolation	17 dB typ	17 dB typ (C) 25 dB typ (Ku)
Rotation	360°	360°
Weight	3.75 LB	4.00 LB

WIMAX SYSTEM

ALVARION BREEZEMAX 3.5B TDD

alvarion
Your Open WiMAX Choice

Radio & Modem

General Parameters (2.x & 3.xGHz)

Parameter	Value
Frequency (2.x)	Base Station & CPE: 2.3GHz WCS: 2305-2317, 2348-2360MHz (A&B pairs, including 2MHz of the C&D bands). 2.3GHz ROW: 2300-2360MHz 2.5 A: 2496-2602MHz 2.5 B: 2590-2690MHz
Frequency (3.x)	Base Station & CPE: 3.3 A: 3300-3355 MHz 3.3 B: 3345-3400 MHz 3.4 A: 3399.5 – 3455 MHz 3.4 B: 3445 – 3500 MHz 3.5 A: 3500 – 3555 MHz 3.5 B: 3545 – 3600 MHz 3.6 B: 3650 – 3700 MHz
Radio Access Method	DL-OFDMA, UL-OFDMA-1, 1/2, 1/4, 1/8, 1/16
Modulation	OFDM/OFDMA modulation, 256 FFT points: BFSK, QPSK, 16QAM & 64QAM, DL – 208 Subcarriers (3.5 & 5MHz), UL – 200 subcarriers
Standard Compliance	Radio – FCC Part 27 Safety – IEC 60 950 US/C
Channel bandwidth	3.5MHz; 5MHz – software selectable
Duplexing Technology	TDD
Central frequency resolution	125KHz
Antenna (2.x)	BMAX PRO-S CPE: Integrated (2.3GHz) – 13dbi, Integrated (2.5GHz) – 14dbi. SI CPE: integrated 7dbi, Window – 11.5dbi. BST (V&DS): 60-16.5 dBi, 90-15.5 dBi, 120-14dbi.
Antenna (3.x)	BMAX PRO-S CPE: Integrated (3.5GHz) – 17dbi SI CPE: integrated 9dbi, Window – 11dbi (for 3.5GHz only) BST (V &DS): 60/65-16.5 dBi, 90-15.5 dBi, 120-14dbi. BST (Omni): 10dBi
CPE Antenna Port	N-type, 50 ohm
No. FFT points	256 DL - 208 sub-carriers for 3.5MHz / 5Mhz channels UL - 200 sub-carriers for 3.5MHz / 5MHz channels

WIMAX BASE STATION ANTENNA

Antenna Technical Specifications

BASE STATION ANTENNA

3.3 – 3.8 GHz 60° VERTICAL

P.N. 300615

REGULATORY COMPLIANCE	ESTI EN 302 085 V.1.1.2 (2001-02) CS3 RoHS Compliance
ELECTRICAL	
FREQUENCY RANGE	3.3 - 3.8 GHz
GAIN	16.5 dBi (min)
VSWR	1.6:1 (max)
3 dB AZIMUTH BEAMWIDTH	60° (typ)
POLARIZATION	Vertical
ELEVATION BEAMWIDTH	7° (typ)
SIDELOBES LEVEL	ESTI EN 302 085 V.1.1.2 (2001-02) CS3
ELEVATION NULL FILL	Down to -25°
CROSS POLARIZATION	ESTI EN 302 085 V.1.1.2 (2001-02) CS3
F/B RATIO	ESTI EN 302 085 V.1.1.2 (2001-02) CS3
INPUT IMPEDANCE	50 (ohm)
INPUT POWER	10W (max)
LIGHTNING PROTECTION	DC Grounded
MECHANICAL	
DIMENSIONS (LxWxD)	766 x 150 x 87 mm (max)
WEIGHT	2.2 Kg (max)
CONNECTOR	N-Type Female
RADOME	ASA White
BASE PLATE	Aluminum with chemical conversion coating
Pole mounting hardware	Tilt Mounting Kit for 2" to 4.5" Dia pole

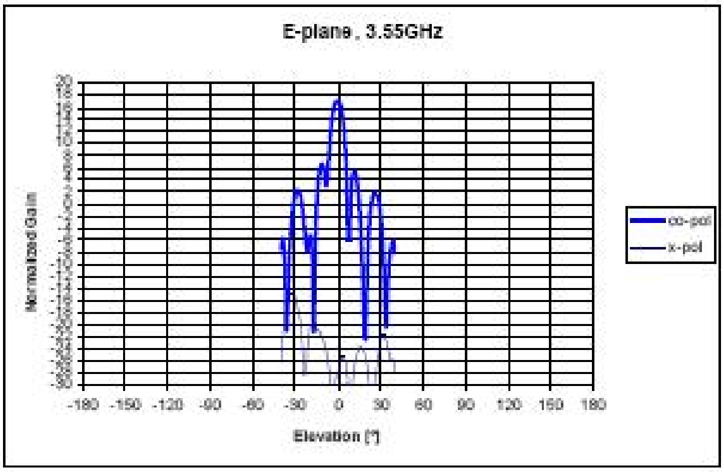
P/N 300615 Rev. A Page 1 of 3

ENVIRONMENTAL	
TEMP. CYCLING	IEC 68-2-14 -40°C to +70°C
VIBRATION	IEC 60721-3-4 Random 4M3
SHOCK MECHANICAL	IEC 60721-3-4 4M3
HUMIDITY	ETSI EN300-2-4 T4.1E
WATER TIGHTNESS	IEC 529 IP-54
SOLAR RADIATION	ASTM G53
FLAMMABILITY	UL 94 Class HB
SALT SPRAY	IEC 68-2-11 Ka
ICE AND SNOW	25mm Radial
WIND SPEED: SURVIVAL OPERATION	 220 Km/h 160 Km/h

ANTENNA PATTERNS

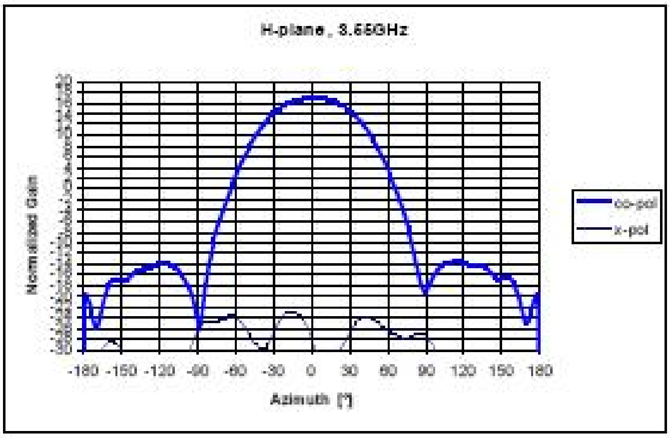
Elevation Pattern

Frequency 3.55GHz



Azimuth Pattern

Frequency 3.55GHz



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