# Potential Penalty Distance between FSS Receiver and FWA for Malaysia

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*Abstract:* - This paper deals with the Interference between Fixed Satellite Service Earth Station (FSS-ES) receiver and Fixed Wireless Access (FWA) in term of possible separation distance, for Malaysian environment. The study began with detailed clarification of worldwide regulatory and C-Band user history. Subsequently, detailed calculations of the current and most useful formulas for path loss effect and clutter loss by using the existing parameters of both services had been done. Thereafter, FSS axis receiving gain and radiation pattern covered in term of maximum possible separation reduction. Moreover, Site shielding, isolation, off-Axis, In-Band and out of band have been discussed in several scenarios. Calculations, analysis and simulation have been done by using Matlab software. Extracted conclusions highlighted the subsistent situation and proposals for future work.

*Key-Words:* - Interference, FSS, FWA, Malaysia, LNB and Saturation.

## 1 Introduction

Living on a dynamic planet is big challenge for wireless communication [1]. Though, these rapid changes in services coverage are having serious effect on each others. With the increasing number of transmitters coming on the air, interference is becoming more prevalent in the wireless community [2]. Therefore, encouraging the establishment of modern legal and regulatory structures for telecommunications service delivery will be necessary to control the interference. By the same token, wireless transmission has many challenges and for each challenge there are possible solutions [3]. Recently Malaysia faced some problem regarding the interference between the Fixed Satellite Services and the Fixed Wireless access. However, Malaysia has a tropical weather so it depends a lot on the C-Band for the satellite communication because it's immunity against the rain attenuation. On the other hand we have a Fixed Wireless Access have being deployed to work on a part of C-band from 3400-3.600MHz [4], as clarify in Figure 1. Nevertheless C-band had been used over the last 40 years for FSS for many other reasons like the low atmospheric absorption of the signal received and transmits through the satellite, highly reliable space-to-earth communication and wide service coverage for the reason that C-band satellite can has a large footprint [5]. The International Telecommunication Union (ITU) originally allocated C-band for use by the global satellite industry [6], massive deployment of systems and services has been underway worldwide, and millions of users now rely upon satellites for essential communications [7].

Fig.1 Spectrum plan in Malaysia.

However, the reported impact on reception of those satellite services has been dramatic, including in-band interference, interference from unwanted emissions (outside the signal bandwidth), and overdrive of low-noise block converters (LNBs saturation) [6]. Key system characteristics had identified and discussed from a radio frequency (RF) perspective. Accordingly, once the interference is identified, the characteristics of the interference should be noted. The signal's duration, bandwidth, strength, sub-carriers, and time of occurrence will help begin the process of eliminating interference suspects in the area and solving the interference problem can done by characterize the local environment; Find neighboring transmitters, Locate the source of the interference and identify the problem and perform the separation distance analysis based on transmitters in the area [8]. In order to examine coexisting and sharing issues, it is necessary to clarify the parameters of FSS and FWA that will affect the interference level and criterion.

## 2 Worldwide Regulatory Information and some of problem history

Using of C-band for FSS is not limited to the tropical weather regions we may also see many countries relay on C-band for FSS for essential Communication services in mission-critical communications solutions like distance learning, universal access, tale-medicine, telemetry and command, direct to home (DTH), disaster recovery, and many other vital applications [9]. Up to the date of this study we counted 160 geostationary satellites operating in the band 3 400 - 4 200 MHz for the regions which stated according to the ITU-R table 1.

Table 1 ITU-R Spectrum worldwide regulatory

| Region 2 | Region 2 | Region 3 |
|---|---|---|
| 3400-3600<br>Fixed<br>Fixed-Satellite (space-to-earth)<br>Mobile<br>Radiolocation | 3400-3500<br>Fixed<br>Fixed-Satellite (space-to-earth)<br>Amateur<br>Mobile<br>Radiolocation 5.433 | |
| 3600-4200<br>Fixed<br>Fixed-Satellite (space-to-earth)<br>Mobile | 3500-3700<br>Fixed<br>Fixed-Satellite (space-to-earth)<br>Mobile except aeronautical mobile<br>Radiolocation 5.433 | |
| | 3700-4200<br>Fixed<br>Fixed-Satellite (space-to-earth)<br>Mobile except aeronautical mobile | |

Governments that assigned FWA frequencies in the extended C-band assumed the problem could be limited by frequency segmentation. However, this has proven to be ineffective in real-world tests [10]. Large-scale disruptions of services operating in non-overlapping frequency bands have occurred in several countries, and as a result, governments, intergovernmental bodies and the satellite industry – particularly in Asia, which is most dependent on these frequencies – have begun to recognize the threat that ill-considered assignment of standard C-band and extended C-band frequencies to terrestrial wireless services poses [11]. Even in the case where FWA and satellite earth stations operate on different frequencies in the same portion of the C-band, considerable geographic separation is necessary. In South America, the Bolivian Superintendencia de Comunicaciones (SITTEL) approved the usage of the 3.4 to 3.8 GHz band for telecommunication as the primary allocation for usage for the WiFi industry [12]. During the short testing period prior to the planned May 2006 rollout, satellite signals carrying television channels in Bolivia were severely interrupted and major interference was reported. SITTEL issued an administrative resolution mandating that wireless access system deployments in the 3.7 – 3.8 GHz band be suspended in the entire territory of Bolivia for a period of 90 days, so that SITTEL could adopt measures to solve this matter [13]. The resolution also instructed the spectrum planning department of SITTEL to propose a new norm for channels in the 3.4 – 3.8 GHz band. More recently, SITTEL indicated that it intends to accommodate the FWA operators in the band 3.4-3.5 GHz and had initiated the required procedures to finalize such arrangement [14]. The Asia-Pacific Telecommunity (APT – a regional intergovernmental organization) in a report from the APT Wireless Forum (AWF) has warned FWA systems within several kilometers of an FSS receive earth station operating in the same frequency band, but on a non-cochannel basis, would need to carefully conduct coordination on a case-by-case basis [11]. Moreover, to avoid interference in non-overlapping frequency bands a minimum separation distance of 2 km needs to be ensured with respect to all FSS receivers, even where FWA and FSS operate on different non-overlapping frequencies. This distance can be reduced to about 0.5 km if an LNB band pass filter is fitted at all FSS receivers, the BWA base station has additional filtering of spurious emissions and FWA user terminals are prohibited [15]. The effectiveness of any mitigation technique is dependent on its application to individual site situations and can be applied only when FSS earth stations are confined to a limited number of specific known locations. In Europe, CEPT prepared a new ECC Report on Compatibility Studies in the Band 3400 – 3800 MHz Between Fixed Wireless Access (FWA) Systems And Other Services. The studies have shown that to meet all relevant interference criteria for a representative FSS earth station [16]. Smaller separation distances may be achievable through coordination of each FWA central station. However, even with coordination it is clear that the necessary separation distances are at least in kilometers. The feasibility of the use of mitigation techniques by FWA systems to reduce the separation distances has not been demonstrated. The Asia-Pacific Broadcasting Union (ABU), a regional organization grouping government and non-government entities), has cautioned that FWA is a promising technology. However, if implemented in the same frequency bands as the satellite downlinks, it will have an adverse impact and may make satellite operation in the entire C-band impracticable [11]. These bands are by far the most important frequency bands for satellite communication in Asia. It is important to understand that satellite transmissions in the 3.4 – 4.2 GHz band are received by a large number of earth stations worldwide. Many of these stations are "receive only," and are therefore not registered at the ITU (or generally even with the local administrations) since such registration is not required. Co-frequency operation of FWA systems would severely disrupt reception of satellite transmissions [17] [18] [19].

## 3 Fixed Wireless access specifications

Fixed-wireless systems have a long history. Point-to-point microwave connections have long been used for voice and data communications, generally in backhaul networks operated by phone companies, cable TV companies, utilities, railways, paging companies and government agencies, and will continue to be an important part of the communications infrastructure. Frequencies used range from 1 GHz to 40 GHz [20]. But technology has continued to advance, allowing higher frequencies, and thus smaller antennas, to be used, resulting in lower costs and easier-to-deploy systems for private use and for a whole new generation of carriers that are planning to use wireless access as their last mile of communication. The terms wireless broadband and broadband wireless are not used consistently, but generally both apply to carrier-based services in which multiple data streams are multiplexed onto a single radio-carrier signal. Some vendors also use the terms to refer to privately deployed networks [21] [22].

In Malaysia the frequency range (3.4-3.6) GHz is allocated for FWA systems, It is divided into sub-bands for duplex use (non duplex systems can still be used in this band), 3400–3500 MHz paired with 3500–3600 MHz. However, Countries have various frequency channel spacing within the 3.5 GHz bands 1.25, 1.75, 3.5, 7, 8.75, 10, 14, and 28 MHz can be used according to capacity needs. Alternatively, if we change the parameters defiantly we will gate a grate change in the interference upshot. So, we will be focused on the parameters listed in Table 2 and we had considered that the center frequency of FWA is 3500 MHz for 3.4-3.6GHz [8].

Table 2 Fixed wireless access specifications

| Specification | FWA(CS) | FWA(TS) |
|---|---|---|
| Tx Peak output power (dBm) | 35 | 22 |
| Channel bandwidth (MHz) | 7 | 7 |
| Feeder loss (dB) | 1 | 1 |
| Power control(dBi) | 0 | 12 |
| Peak antenna gain (dBi) | 17 | 15 |
| Antenna gain pattern | ITU-R F.1336 | ITU-R F.1336 |
| Antenna height (m) | 20 | 10 |
| Noise figure (dB) | 5 | 7 |
| Receiver noise reference | -163 | -161 |

It has previously been suggested that the FWA channel bandwidth does not affect the result, this is not necessarily the case. If a more narrow FWA bandwidth is taken, then clearly more channels can be accommodated in the band. For example if 5MHz channel width is used the number of FWA cells permitted increases fourfold, to over 400 thousand. As the Power Spectral Density of the FWA signal has been kept constant, each FWA source contributes less to the total interfering noise power. Indeed it can be shown that to maintain the permitted number of cells constant at 100 thousand, the EIRP of each FWA carrier may be increased by 6dB back up to 2Watt [23].

## 4 Fixed Satellite services specifications

Satellites were first used for intercontinental telecommunications before undersea fiber was available and for communication in remote areas, including to remote islands and ocean-going ships. By the end of 1997, more than 160 communications satellites were deployed, and today satellite systems represent a sizeable industry [24]. For Malaysia the fixed satellite service is allowed to work within 3.4 to 4.2GHz, and the frequency bandwidth is varying from 4 KHz to 72MHz, base on different use. Following table is describing the typical FSS earth station already in use by Petronas (fuel stations).

Table 3 Fixed satellite services specifications

| Specifications | Satellite terminal |
|---|---|
| Antenna diameter (m) | 2.4 |
| Gain (dBi) | 38 |
| Antenna diagram | ITU RS.465 |
| Noise temperature | 114.8oK |
| Elevation angle | 75.95 |
| Azimuth | 263.7 |

Notes: the azimuth and elevation angle determined for Wireless communication center in UTM skudai, Johor, Malaysia.

## 5 Research methodology

For FSS receiver Signal received is very week due to distance, when FWA use C-band frequency in the same area it will block the FSS, interference of Co-channel and adjacent channel will come up to the battle and this paper will enumerate some of the most useful protection methods and it's effect on the both services, as it's clarified in the following flowchart

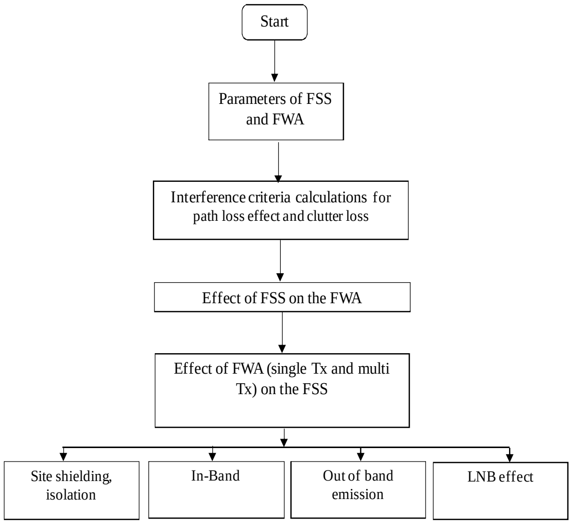

Fig.2 Research methodology.

In the simulation scenario we assumed the FSS antenna remained in a fixed location while a FWA base unit was moved to several locations operating at various angles and distances from the FSS antenna to simulate subscriber waveforms. This test modeled FWA subscribers in a nomadic deployment affecting FSS earth station. Simulation conducted within the immediate area showed that the digital signal was rendered unacceptable for use. Then we took the FWA base antenna and fixed at a different heights. The FSS antenna was positioned at several different locations and at various angles and significantly greater distances from the FSS antenna than during first scenario.

## 6 Determination of the maximum possible level of in-band interference signal

According to ITU SF.1486 interference would be significant to FSS when the victim receiver subject to degradation of thermal noise floor for more that 20% of any month. We consider the I/N to be 10 dB according to ITU regulation, then the limitation of typical in band interference border [25].

$$C/I = (10 + C/N)dB \\ = (10 + 5.7)dB = 15.7 \tag{1}$$

Where C: Carrier power at the receiver, C/N is the required carrier to noise ratio and C/ I: INBAND is the required protection ratio. We should note that some studies had considered the interference to noise ratio is 6 dB based on worst case calculation for $\Delta T/T = 6\%$ [25].

In term of calculating the $I_{inband}$ we have to find the C (the carrier power) as in the following formulas

$$I_{inband} = (C - 15.7)dBW \tag{2}$$

$$C = C/N + 10Log(kBT)dBw \tag{3}$$

Where; k = Boltzmann's Constant ($1.38*10^{-23}$ joules/kelvin), T = Temperature in Kelvin (K), B = Bandwidth.

$$C = 5.7 + (-156)dBW = -150.3dBW \tag{4}$$

Then, we used (4) in (2) to get $I_{inband}$

$$I_{Inband} = (C - 15.7)dBW \\ = -150.3 - 15.7 = -166dBW \tag{5}$$

So, the maximum possible level of in-band interference is -166dB or -136dBm, and if the interference exceeds more than -166 dB, that will destroy the received signal. Where I is the interference level in dBm, N is the thermal noise floor of receiver in dBm and α is the protection ratio in dB and here has value of -10 dB which means that the interference must be approximately 10 dB below thermal noise. Fig.3 shows the level of carrier, noise and interference [26].

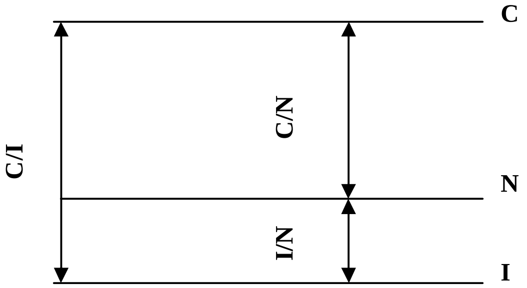

Fig.3 Interference protection criterions.

## 7 Determinations near far radiation pattern (for satellite dish)

The satellite antenna normally is a parabolic antenna pointed to the sky with a specific azimuth and elevation angle. As long as it's directed to the sky so we shouldn't wary about the fixed satellite antenna. Anyway, for analysis and understanding purposes we have done a simulation for the effect of FSS on FWA. Following figure shows the effect of the earth station antenna with a 2.4 diameter among different separation distances on the frequency range 3.4-3.6GHz

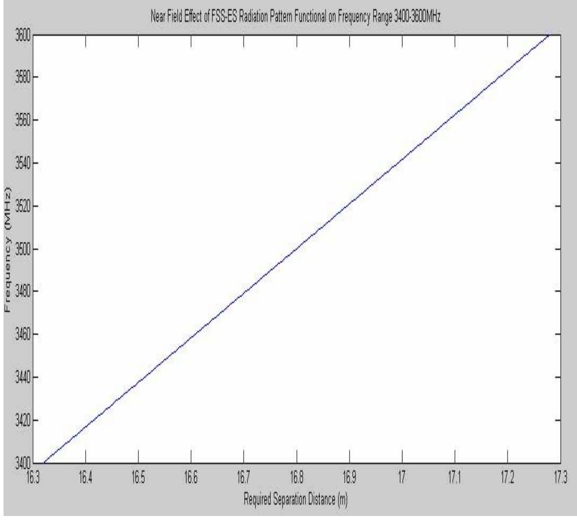

Fig.4 near field effect of FSS-ES radiation pattern.

When we increase the antenna diameter emphatically we will gate swell in the radiation pattern plus increasing the gain subsequently we will have longer protection distance. Fig.5 shows for different earth station antenna diameter we should have different radiation pattern as in the figure below:

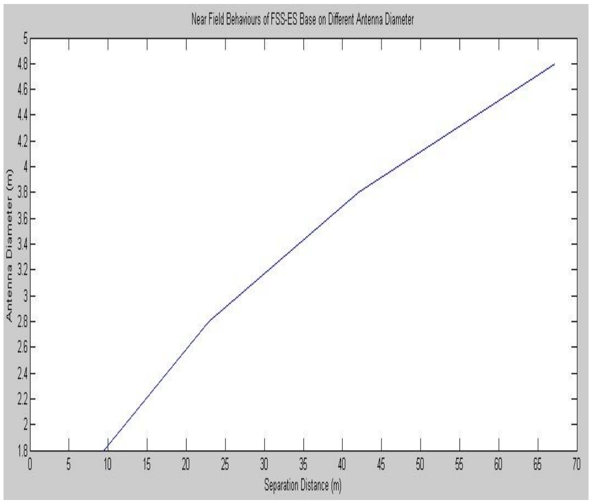

Fig.5 Near Field behavior of FSS-Es for different antenna diameter

It's clear that the near field radiation pattern of the fixed satellite earth station does not have that much effect on the services surrounding the system terminal. However, for typical antenna diameter 3 m which work on 3.5GHz, the near field effect will be 26m only, for the 2.4 separation will be 16.8m and for 1.8 the separation will be 9.45m. The separation distance that we have identified therefore assists in our understanding of the role of interference avoidance, so more broadly regarding the effect of FSS-ES on the other services will be useless.

## 8 Path loss Effect

Interference into a receiving Earth Station will be an aggregate from a large number of high density fixed service HD-FS cells as in Fig. 6, each containing a large number of transmitters.

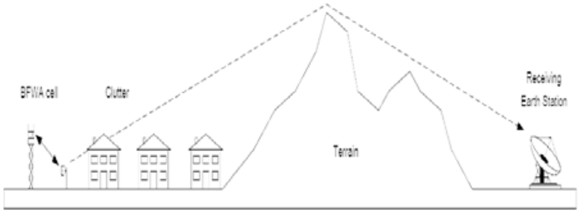

Fig.6 Interference into a receiving ES will be an aggregate from a large number of HD-FS cells.

The path loss calculations between the FSS-ES and FWA-TS (transmitter) $L_{FWA}(d)$ is pedestal in ITU-R P.452 based on calculating the loss for a given percentage of time between two specific points, taking into account a wide range of atmospheric effects such as fading and ducting. The following model is used for this coexistence study includes the attenuation due to clutter in different environments

$$L_{FWA}(d) = 92.5 + 20\log d + 20\log f + Ah \quad (6)$$

Where d is the distance between interferer and victim receiver in kilometers, f is the carrier frequency in GHz, and Ah is loss due to protection from local clutter or called clutter loss, it is given by the expression:

$$Ah = 10.25 e^{-d_k}\left[1-\tanh\left[6\left(\frac{h}{h_a}-0.625\right)\right]\right]-0.33 \quad (7)$$

Where $d_k$ is the distance in kilometer from nominal clutter point to the fixed satellite earth station antenna, h is the antenna height (m) above local ground level, and ha is the nominal clutter height (m) above local ground level. Clutter losses are evaluated for different categories: trees, rural, suburban, urban, and dense urban, etc. Increasing of antenna height up to the clutter height leads to decrease the clutter loss, as shown in Table 4 and Fig. 7 which contain the four categories. In our case, dense urban category will be considered [26].

Table 4: ITU-R P.452, the Clutter Loss

| Clutter category | Clutter height ha | Nominal distance $d_k$ |
|---|---|---|
| Rural | 4 | 0.1 |
| Suburban | 9 | 0.025 |
| Urban | 20 | 0.02 |
| Dense urban | 25 | 0.02 |

Thereby, we can see the Clutter loss for rural, suburban, urban, and dense urban areas effects base on different antenna height, as clarified in the figure bellow:

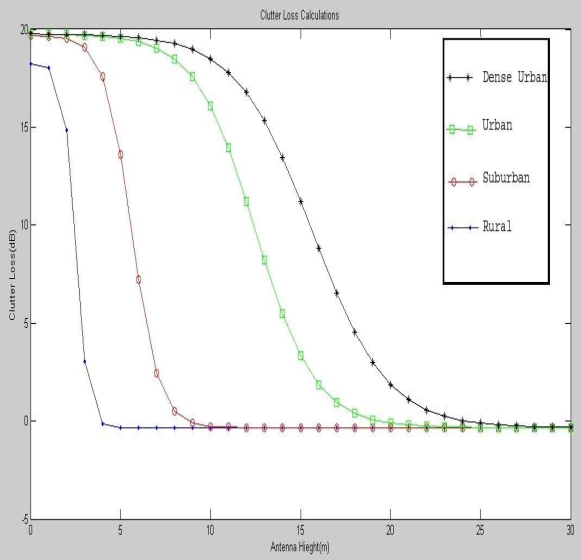

Fig.7 clutter loss base on ITU-R P.452

## 9 Site shielding study

To provide insight into the practicality of affording shielding isolation in a range about 30-40dB, subtitled number 11 addresses the possible isolation calculated in accordance with Recommendation ITU-R P.526. The advantages of mounting the VSAT antenna closer to the ground can be appreciated, together with typical isolation values for diffraction edge to VSAT spacing that would be consistent with mounting near to, say, a one-story building wall, etc [27]. To effect tolerable separation distances, use normally needs to be made of additional diffraction or other losses in the vicinity of the VSAT. For analysis single edge diffraction can be taken to approximate the case of a building, tree grove or similar which is not too close (see Fig. 8).

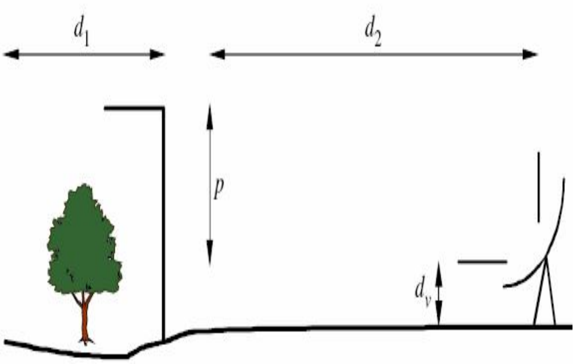

Fig.8 edge diffraction loss.

Clearly the diffraction source should be clear of the Fresnel zone. For guidance, at this frequency this can be taken as extending in a cone some 9 m out from the VSAT reflector dish to a diameter of some 3.2 m and then of this same diameter out to at least 17 m from the antenna. The calculated sensitivity of the diffraction loss with transmitter/edge distance, d1 may readily be shown to be negligible for all practical cases here. Predicted diffraction losses for a notional single edge model calculated and summarized within the examples studied here are in the range 2-40 dB; this covers plausible situations corresponding to values for $\rho$ of 5 m, spacing $d_2$ of 5 to 20 m and heights $d_v$ of 1 to 6 m. The TS units are generally seldom sited higher than around 10 m. A common situation is that of exposed roof-top mounting for a VSAT, and the effect of this rather than the more desirable sitting at ground level protected by suitable shielding can be approximately 33 dB, as calculated in accordance with Recommendation ITU-R P.526 [27].

## 10 Required protection distance

Different available mitigation techniques already existing like shielding, filtering, and separation distance. Practically, protection by separation distance is the most expensive so we should focus on it to find the most suitable separation between the services. Deferent components will add in way to calculate the separation for local environment. However, the FSS station off Axis antenna receiving gain, for given off Axis angle from main receiving beam of the station, Gvs($\alpha$) for a typical receiving antenna of 2.4m diameter is given by:

$$G_{vs}(\alpha) = 32 - 25 Log(\alpha) dBi \quad Where\ 3.6^o < \alpha < 48^o \quad (8)$$

$$G_{vs} = -10 dBi \qquad where\ 48^o < \alpha < 180^o \quad (9)$$

And, we mentioned for the shielding cover as an attenuation interference power (R), and R may take a value between 0dB to 40dB in the best condition. Now we can do simple calculations to fine that the required protection distance determine from the following formula:

$$\begin{aligned} 20\,Log\,(d) &= -I + EIRP_{FWA} - 92.5 \\ &- 20\,Log\,(F) - A_h + G_{vs}(\alpha) - R \end{aligned} \quad (10)$$

$EIRP_{FWA}$: effective isotropic radiation pattern, Shown in Table 2.

## 11 In-band interference by single FWA

The In-band Interference is the worst consequent of the coexistence of two channels or more in the same frequency range. When we considered an urban area within clutter loss about 16 dB which may turn out to be a normal for most of Malaysian cities, the results of the simulation Fig.9 reviles that minimum separation distance for In-band interference is 1.2Km if we are using powerful shielding technique (40dB) and 2 Km for 30 dB shielding loss.

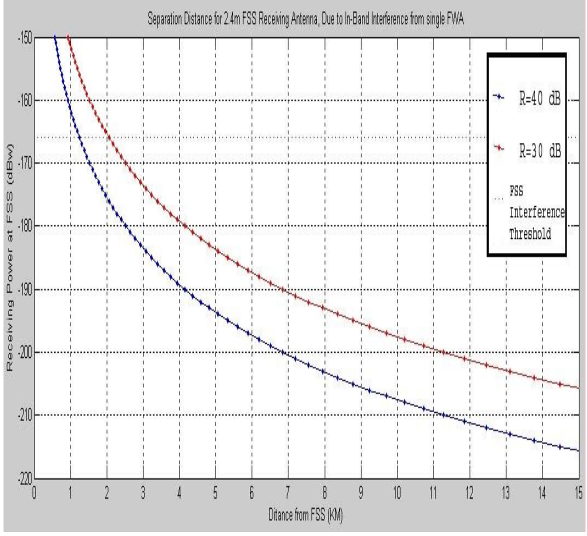

Fig.9 separation distances for 2.4m FSS receiving antenna due to in-band interference from single FWA.

Result of In-band interference hint us that coexistence in same band of two services needs high separation distance, but we still have do some simulation regarding the different off axis angle. Though, next part will deal with the different off-axis effect on different fixed satellite services earth station positions.

## 12 FSS Saturation

### 12.1 Different distance required base on different Off-Axis Angle of single FWA Interfere

Without any remedial measures, the required separation distance should be25 – 300m base on the clear line of sight environment as shown in fig.10. This result can be enhanced more by using LNB filter. Nevertheless, this result shows how the off-axis tremendously affects on the received signal from victim FSS receiver.

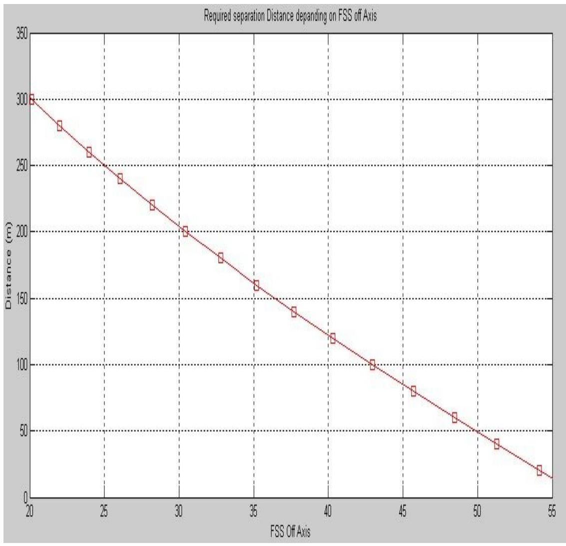

Fig.10 required separation distances base on different off-axis angle of FSS.

When we applied the previous mathematical formulas to calculate the interference for the short distance which required for the LNB saturation point we found that the saturation happen when I=-65.92dBm.

To assuage the saturation problem, one counteractive measure would be using a suitable bandpass filter (with pass band in 3.6 – 4.2 GHz) to reduce the level of the RF signals in 3.5 GHz to the LNB working in the entire C band (3.4 – 4.2 GHz).

### 12.2 Multiple FWA interferers

To examine the cumulative effects of interference from multiple BWA transmitters, calculation is made for the required separation distance for consideration of the worst case scenario at NLOS; the aggregated interference is calculated by summation of the interference power from these transmitters of FWA received at the FSS station input. The results as summarized in fig.11 show that under the worst case situation, the required separation distance is of the order of 170m and 275m respectively for FSS station with LNB filter and without LNB filter added at the front end.

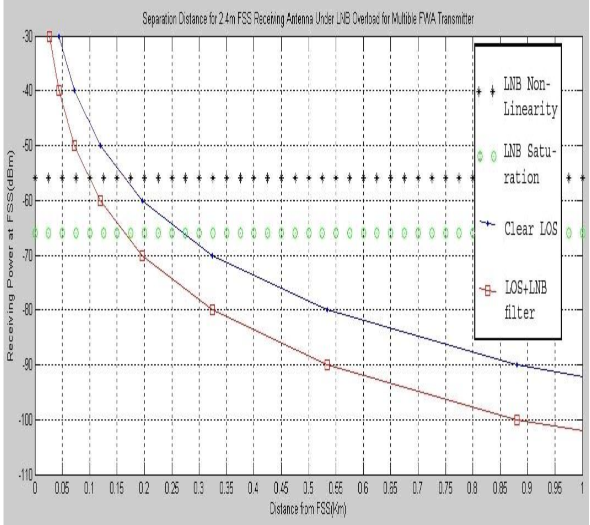

Fig.11 separation distances for 2.4m FSS receiving antenna under LNB and Multiple FWA transmitters.

If a LNB filter with sharper cut-off characteristics is used, in addition to other remedial measures that may be applied, it is possible that the LNB overload problem should be further contained or overcome even at the worst case scenario.

## 13 Out of band emission from FWA

The following fig.12 shows the calculation result of out of band interference for the emitted signal from FWA transmitters within direct line of sight.

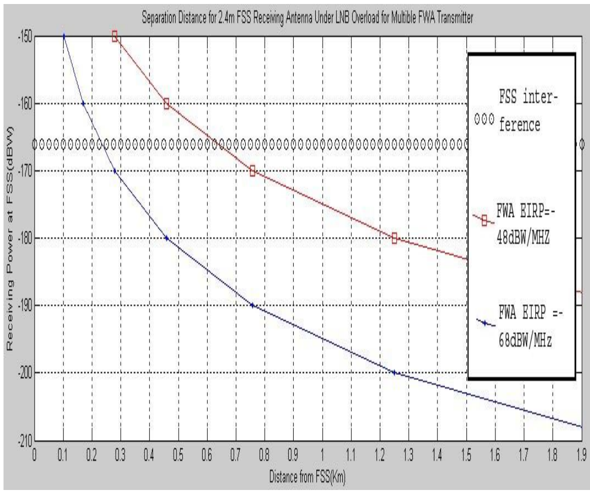

Fig.12 Separation distance for 2.4m FSS for out of band emission case.

The results shows that out of band emission of FWA limited of -69dBW/MHz, would not cause interference to FSS station if there is a separation distance of 250m. the out of band emission of FSS limited of -48dBW/MHz would not cause interference to FSS station if there is a separation distance of 650m.

## 14 Dynamic spectrum allocation

Dynamic spectrum allocation is a magnificent technique for spectrum efficiency and the most favorable for radio resources distribution. In the case when an earth station changes its frequency of operation, the FWA system may also have to change its frequency in the surrounding area. On the other hand the FWA system should have data where all the relevant information of current FSS ES using the radio resources in this area. Normally the FSS earth stations are not registered which make this method difficult to implement. Using Beacon (broadcasting beacon or network beacon) may also considered as a good solution when the FWA will be reduced control information co-located with the FSS earth station (respectively FWA base station). Though, provide dynamic and active information on its spectrum usage to the FWA system (respectively FSS earth station) to Allow optimum usage of the unused spectrum to eliminate the inter-system interference [28].

## 15 Techniques can be used to reduce the interference

Recently many researchers indicate to different mechanized on the way to avoid the interference between the FSS and FWA like sector disabling in the direction of the victim fixed satellite services Earth station, aim of this method is to reduce the transmitting output power of fixed wireless access base station. Conversely, this method cause a reduction in the FWA base station outcomes which mean business lose in the direction of inactivated sector. Antenna downtilting also considered a very effective technique to enhance the performance of FWA to support high speed transmissions since the cell size will be reduced at the same time we will have limitation of transmission power and mitigate the interference toward fixed satellite services earth station

## 16 Conclusions

In the absence of any coordination, FWA systems operating in the 3.5 GHz band will cause unacceptable interference to FSS stations in the extended C band (3.4 – 3.6 GHz) if the two systems operate on the same frequency channels. Over and above, FWA systems in the 3.5 GHz band which are located nearby and with clear line-of-sight to FSS stations will cause interference to the latter operating in 3.6 – 4.2 GHz band if the separation distance is less than about 275 meters and there are no protection measures. By adding a bandpass filter at the FSS station front-end giving a 10 dB loss to the received FWA signals, the required separation distance about 170 metes depending on the number of FWA interferers. In addition, out-of-band emissions from FWA systems in the 3.5 GHz band should not cause unacceptable interference to FSS in 3.6 – 4.2 GHz band if suitable emission limits are adopted for the BWA equipment. This assessment is done in response to IMT-advanced threats to all the services work within same frequency. However, one of the most expecting frequency ranges for IMT-Advanced is C-Band. Consequently, as futures work the results in this study will be used to estimate and reduce the affect of IMT-Advanced on the existing services.

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