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# SPECTRUM INVESTIGATION FOR SHARING ANALYSIS BETWEEN BWA SYSTEM AND FSS RECEIVER

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**ABSTRACT**

In this research, testing the compatibility between Fixed Broadband Wireless Access (BWA) as a case study for the International Mobile Telecommunication (IMT-Advanced) and Fixed Satellite Services (FSS) networks in 3400-4200MHz range (C-band) has been studied and discussed in details. The interference between Fixed Satellite Service earth station(FSS ES) and Broadband Wireless Access(BWA) is considered and the aim of the article is to avoid interference between FSS ES and BWA by using minimum separation distance. Possibility of coexistence and sharing analysis were obtained by taking into account the detailed calculations of the most useful formulas for path loss effect and clutter loss by using the existing parameters of FSS and the BWA base station parameters located in the wireless communication center, Universiti Teknologi Malaysia (UTM). In-band interference has been concluded, analyzed and simulated (using Matlab) for several environments (rural, suburban, urban and densurban) in response to different clutter altitude. Channel prediction for two scenarios (rural and suburban) as a trail map was delineated by ATDI software. Simulation results indicate that the proposed mitigation scheme is highly efficient in terms of reducing the separation distances. Comparing the measurements with simulated result has also been done with high percentage of accuracy to show the amount of closeness or similarity between both results.

**Keywords:** *Coexistence, BWA, Mobile Service, FSS, Propagation Model, Interference, Separation Distance, And Co-Channel Interference.*

## 1. INTRODUCTION

As existing systems are subject to technological change and other systems may be deployed or developed in the future within e.g. IMT-Advanced. Use of the C-band for satellite communications is widespread throughout the world, but it is particularly vital for tropical areas because of its resilience in the presence of heavy rain. High availability, rates and reasonable dish sizes are important in FSS industry. C-band frequencies are used to provide a wide range of services in developing countries, including critical applications such as: Distribution of TV programs and signals, telemedicine and universal access services, Backhaul services, VSAT data links (e.g., bank transactions, corporate networks) Government/Emergency communication links, including disaster recovery services [1].

Also C Band was used to restore voice and data circuits for many customers. C-band beams cover large geographic areas, and facilitate intercontinental and global communications. C-band allows for economically viable coverage of low density regions (e.g., Pacific islands). C-band provides region-wide coverage at high availability, rates, irrespective of rain zones. C-band efficiencies cannot be replicated at Ku- or Ka-bands, or via terrestrial means. The economics of using Ku- or Ka-band will drive operators to focus beams on higher population centers in order to maintain required availability rates [2].

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In the ITU Table of Frequency Allocations, the Fixed Satellite Service (FSS), in the space-to-Earth direction, and the fixed service ("FS") are co-primary in the band 3,400-4,200 MHz. In some national tables of frequency allocations, the FSS is not primary in the band 3,400-3,700 MHz or over a portion of this 300 MHz range. There is currently FSS use over the whole 800 MHz range, but the utilization of the upper 500 MHz (3,700-4,200 MHz) is much more intense, followed by the utilization of the band 3,625-4,200 MHz. An analysis on the sharing between FSS receives earth stations and Fixed Wireless Access ("FWA") systems can be found in Recommendation 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 3400-3700 MHz Band"). It is interesting to note that, although the technical analysis would be equally applicable to the band 3,700-4,200 MHz, this ITU-R Recommendation focuses on the range 3,400-3,700 MHz In light of the fact that Recommendation ITU-R SF.1486 concludes that coordination distances between FSS terminals and FWA systems would be of several kilometers, the ITU studies are implicitly recognizing that co-frequency operation is not feasible and more so in the band 3,700-4,200 MHz where FSS deployment is more intense.

The fact that the band 3,400-4,200 MHz is currently shared between FSS receives earth stations and radio relay systems in the FS does not mean that sharing between FSS and FWA is feasible. The density of FWA transmits stations will be much higher than that of radio-relay transmit stations. Moreover, transmit antenna patterns are much more directional for radio-relay stations than for FWA stations [2].

Coordination distances of several kilometers may be compatible with light deployment of very directional FS transmit stations, but will severely constrain both FSS and FWA deployments. FWA deployment will be limited by the need to protect existing FSS earth stations, while the future FSS deployment will be precluded around any area where FWA systems may be able to deploy.This article is about understanding of a new class of communication system where pairs of transmitters and receivers can adapt their modulation/demodulation method in the presence of interference to achieve the best performance due the coexistence. Since IMT-Advanced system targets (100 Mb/s and 1 Gb/s with high mobility and low mobility, respectively) defined by the international telecommunication union (ITU) [3], many bands are allocated for more than one radio service and therefore the sharing is a necessity. The 3400–4200 MHz overlapping with the potential nominee bands for 4G systems is currently allocated to the fixed satellite service (FSS). Consequently, the impact of the interference of 4G on FSS systems needs to be studied. However, the expected 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) [3]. Key system characteristics had identified and discussed from a radio frequency (RF) perspective, by counting the power transmit interference to the FSS receiver. Solving the interference problem can be done by characterizing 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 [4].

## 2. ANALYSIS AND CALCULATION METHOD

The interference power received from the BWA transmitter at the FSS earth station depends on many specifications the BWA output power in the direction of the FSS receiver, the radio propagation loss, the FSS receiver gain in the direction of the BWA transmitter and the isolation of the receiving site. To find the separation distance, two issues have been proposed and as follows:

The assessment would firstly establish the maximum permissible level of interference signal from the BWA station, which would not cause in-band interference with the FSS station and as shown the formulas to calculate the Maximum permissible level of In-band interference level:

$$C/I_{\text{In-band}} = (10+C/N)\text{dB} \qquad (1)$$

$$=(10+5.7)\text{dB}=15.7\text{dB}$$

Where $C/I_{\text{In-band}}$ is carrier to interference ratio and C/N is the required carrier to noise ratio (5.7dB according to Recommendation ITU-R SF.1486) I , is the interference level, C is the carrier signal, N is the receiver noise level [5][8].

It follows that

$$I_{\text{In-band}} = (C - 15.7)\text{dB} \qquad (2)$$

Furthermore

$$C = C/N + 10 \log (KTB) \text{ dBw} \qquad (3)$$

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Where the KTB is the thermal noise floor, K is the Boltzmann's constant (1.38 *10 -23), B is the channel bandwidth and T is the noise temperature according to the FSS station parameters [7].By substitute all the values the carrier power can calculated:

C=5. 7 + (-140) =-134.3dBW

By substituting C in the eq. (2) ,the $I_{In\text{-}band}$ will equaled to -150dBw. Figure (1) illustrates the relationship between carriers to interference level in related to the noise level, as shown:

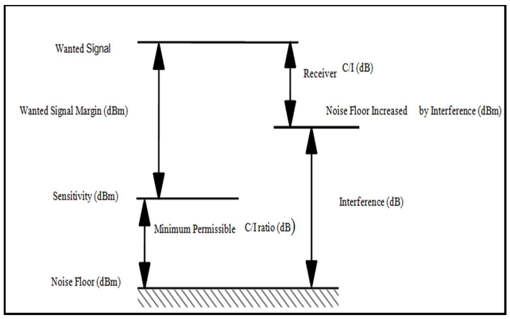


*Figure 1: Carrier To Interference Level In Related To The Noise Level*

The separation distance calculated by depending on the formula that uses it to calculate the permissible received interference power as shown:

$I_{Max,inband}$=$EIRP_{BWA}$ - $L_{BWA}$(d) +$G_{vs}$ -R (4)

Where:

i. $EIRP_{FW\ A}$= off-axis EIRP from the BWA transmitter (dBw)

ii. $L_{BWA}$(d) = path loss (dB)

iii. $G_{vs}$= FSS station off-axis antenna receiving gain (dBi)

iv. R= isolation from site shielding.

The path loss can be even free loss space (Line of Sight) or Non-LOS as follows:

$L_{BWA}$(d)=92.5+20Log(d)/Km+20Log(F)/GHz (5)
$L_{BWA}$(d)= 92.5 +20 Log(d)/Km+ 20 Log(F)/GHz+ $A_h$ (6)

Where:

i. f= frequency (GHz)
ii. d = distance (km)
iii. Ah = clutter loss (dB)
iv. Correction factor (92.5dB)

The clutter loss can be found through Eq.(7):

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

Where:

i. $d_k$ :is the distance (km) from nominal clutter point to the antenna,

ii. h :is the antenna height (m) above local ground level, and

$h_a$ :is the nominal clutter height (m) above local ground level.

Generally, Clutter losses are evaluated in different categories: rural, suburban, urban, and dense urban, etc. as shown in Table 1.

*Table 1: ITU-R P.452, The Clutter Loss [6]*

| 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 area effect base on different antenna height, as clarified in the figure 2 bellow:

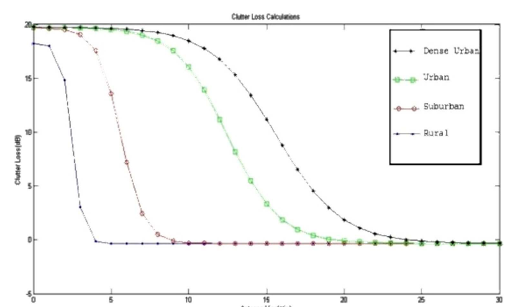


*Figure 2: Clutter Loss Base On ITU-R P.452 [6]*

The clutter loss (Ah). According to ITU-R P.452, the clutter loss is set at 18.5 dB for dense urban areas and 0 dB for clear line of sight propagation (LOS).

The FSS station off Axis antenna receiving gain, for giving off Axis angle from the main receiving beam of the station, Gvs($\alpha$ ) for a typical receiving antenna of 2.4m diameter is given by [9]:

$$G_{vs}(\alpha) = 32 - 25Log(\alpha)dBi \quad (8)$$

$$Where\ 3.6^o < \alpha < 48^o$$

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$$G_{vs} = -10 dBi$$

$$where\, 48^o < \alpha < 90^o$$

Finally, the Calculation of required protection distance ,d, is where the interference power from a BWA transmitter to an FSS receiver reaches the threshold level and is given by substituted the Eq. (5) or Eq. (6) in Eq. (4) the protection distance (separation distance) will be:

$$20Log(d) = -I + EIRP_{FWA} - 92.5 - 20Log(F) + G_{vs}(\alpha) \quad (9)$$

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

$$d = 10^{((-I + EIRP_{FWA} - 92.5 - 20 Log(F) - A_h + G_{vs}(\alpha) - R)/20)}$$

(11)

The calculation of the separation distance (d) has been done by Mat Lab and ATDI simulation as, will displayed in section IV.

## 3. REQUIRED PROTECTION DISTANCE

The result of the interference calculation is the minimum required loss. Having chosen an appropriate path loss model, this can subsequently be converted into a physical separation. The standard model agreed upon in the ITU and CEPT for a Terrestrial interference assessment at microwave frequencies is clearly denoted in ITU-R Recommendation P.452-8. Therefore, this propagation model, which includes the attenuation due to LOS-propagation as well as additional attenuation due to clutter in various environments, is used in the frequency sharing study for FSS systems and BWA systems. As well as, the separation distance calculation needs to dedicate the parameters for each BWA and FSS system and how the radiation pattern also specific the propagation model as shown in Table 2 and 3:

*Table 2: FSS ES System Parameters*

| Parameter | Value |
|---|---|
| Centre frequency of operation | 3500 MHz |
| Channel bandwidth | 72 MHz |
| Receiver noise temperature | 60 K |
| Antenna diameter/type | 2.4 m (ITU RR AP7)/ Parabolic |
| Maximum antenna gain | 41 dBi |
| Antenna radiation pattern | Rec. ITU-R SM.1541 |
| Antenna height above ground | 5 m |
| Elevation angle | 5 ~ 80 deg |
| Coexistence criteria (I/N) | -10 dB |
| Receiver thermal noise, N=KTB | -140.03 dBW |

*Table 3: BWA Station Parameters*

| Parameter | Value to be used in this calculations |
|---|---|
| Center Frequency of operation | 3500MHz |
| Multiple access | OFDM |
| Subcarrier freq. spacing | 12.2 kHz |
| Total number of subcarriers | 4096 |
| Bandwidth | 4MHz per Sector |
| Output power | 27 dBm/4MHz |
| Maximum antenna gain | 14.5 dBi |
| Antenna height | 10m |
| Antenna pattern | Omni |

Calculation of required protection distance, derive through equaled the minimum required loss Lr by appropriate path loss model as shown:

$$20Log(d) = -I + EIRP_{FWA} + Gr + Lr - 32.5 - 20Log(F) - A_h - R \quad (12)$$

$$L_{min} = Pt + Gt + Gr + Lr - I_{max} \quad (13)$$

Where Pt is the transmit power of the interferer (dBw) in the reference bandwidth and $I_{max}$ is the maximum permissible interference power (dBw) in the reference bandwidth to be exceeded for no more than p % of the time at the terminals of the antenna of receiving FSS systems. The antenna gains are to be Gt and Gr for the interfering transmitter and the victim receiver in dBi, respectively. Both antenna gains are towards the physical horizon at a given azimuth. Lr is the interfering signal power loss.

For more explanation, Figure (3) illustrate how the eq.(11) , eq.(12) and the eq.(13) it's working to find the best separation distance as shown:

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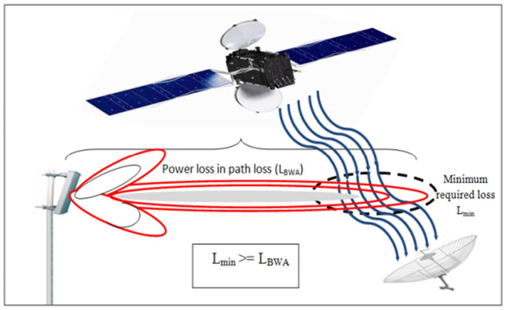


*Figure 3: Interference Between BWA Transmitter And FSS ES Receiver.*

So, as long as the minimum power loss at FSS ES still equaled or greater than the power that is lost from BWA through the path loss its mean the FSS signal will be not blocked or corrupted and vies versus.

## 4. SIMULATION RESULTS

### A. Line Of Sight (LOS) Calculation By Mat Lab

The calculation of the separation distance when the BWA station located line of sight (LOS) with FSS ES by applying Equation (11) by considering the clutter loss (Ah) is 0 and shielding loss (R) is 0, as shown in figure (4):

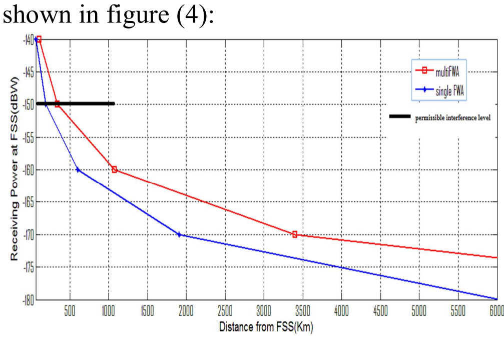


*Figure 4: Separation Distance For 2.4m FSS Receiving Antenna Under LNP Overload For Single BWA And Multi BWA Stations*

Table (4) presents how the permissible interference, changing the separation distances in term of considering all the other constant parameters, as shown below:

*Table 4: Separation Distance In Different Interference Level.*

| separation distance (Km), multiple BWA transmitter(eirp=14 dBW) | separation distance(d)in Km at single BWA transmitter(eirp=8dBW) | shielding loss(R) and clutter loss (Ah) in dB | maximum permissible interfering (I)in dBw |
|---|---|---|---|
| 107.5 | 60 | 0 | -140 |
| 220 | 125.5 | 0 | -145 |
| 390 | 190 | 0 | -150 |
| 1073 | 600 | 0 | -160 |

### B. Non- Line Of Sight (NLOS) Calculation By Mat Lab

The calculation of the separation distance when the BWA station located non line of sight (N-LOS) with FSS ES by applying Equation (11) by considering The clutter loss (Ah) of 20dB is taken under dense urban environment, shielding loss (R) will take as range of measurement from 10 to 40 dB and the maximum permissible interfering (I) will be on -150dBw, as shown in Figure 5 and 6:

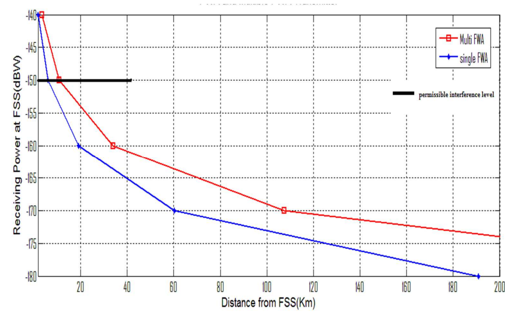


*Figure 5: Coordination Distance For 2.4m FSS Receiving Antenna Due To In-Band Emissions From Single And Multiple BWA Transmitter At Shielding Loss (R)=10db.*

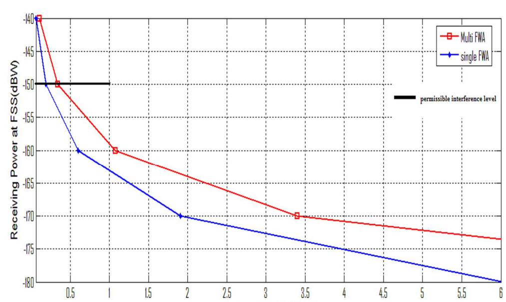


*Figure 6: Coordination Distance For 2.4m FSS Receiving Antenna Due To In-Band Emissions From Single And Multiple BWA Transmitter At Shielding Loss (R)=40db.*

The in-band interference from a single and multiple BWA base station transmitter to an FSS ES terminal is worked out and the results are summarized in Figure (5) and Figure (6) as well the

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separation will be less in each time the shielding loss (R) increases .Table (5), will represent how the distance will be changing in term of shielding loss (R) and as shown:

*Table 5: Separation Distance In Different Shielding Loss*

| separation distance(d)in Km at multiple BWA transmitter (eirp=14dBW) | separation distance(d)in Km at single BWA transmitter( eirp=8dBW) | shielding loss(R)in dB | maximum permissible interfering (I)in dBw |
|---|---|---|---|
| 18 | 13 | 10 | -150 |
| 1.3 | 1.9 | 20 | -150 |
| 0.4 | 0.7 | 30 | -150 |
| 0.125 | 0.2 | 40 | -150 |

Also, the calculation represents that The signal power from the BWA station also has an impact on the FSS station and as long as decreased it the separation go small.

### C. SUBURBAN REGION WITHOUT BUILDINGS(RURAL) BY ATDI

Using ATDI simulation software on map for University Technology Malaysia (UTM), Johor Bahro, Malaysia ,simulation and analysis of BWA system and check the coverage of the area around 19 Km$^2$ as shown in figure (7), where figure (7) illustrates how well interference is reduced by a terrain propagation effect, i.e., FSS receiver can be deploy it anywhere except the red area. In other word, the FSS station can install at the region not impact with BWA station.

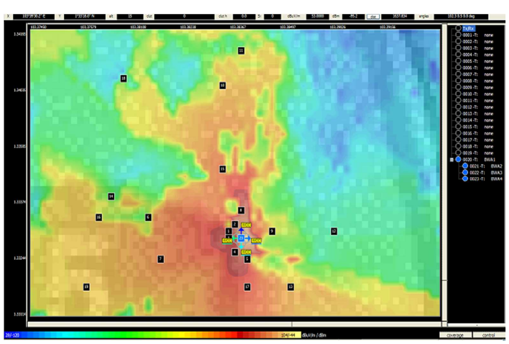

*Figure 7: ATDI Simulation Coverage Result*

18 points at different places at UTM established using Google earth program as displayed in figure (8) below, then all these points are loaded or transferred the grid for each point to the ATDI program, to distribute these points at ATDI program using a UTM map. By using a central station transmitter have frequency 3553.75 MHz - 3564.25 MHz at WCC in Google earth map [7].

*Figure 8: Locations Sites Inside Utm (Google Earth Map)*

The most striking result to emerge from the data is the best signal in this area, and approximately there is a good converge for UTM, but these results for this simulation from UTM map without any building layers. The interference effects from BWA base station to the FSS ES can be reduced by terrain effect. Actual propagation characteristics of 3.5GHz band are different from under the 2GHz band. This band is more affected by reflection loss and diffraction loss by terrain effect elements like buildings and mountains figure (9) illustrate the signal profile and how is the terrain effect on the transmitted signal.

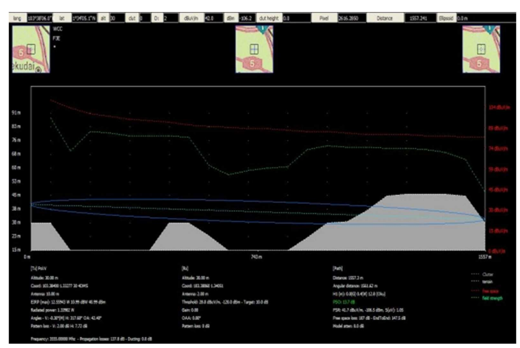

*Figure 9: Profile Terrain From BWA Station Towards FSS ES (Point 18)*

### D. SUBURBAN REGION WITH BUILDINGS BY ATDI

In this scenario the clutter loss included buildings, ATDI applied on the high resolution map in the region located in French to study the coverage of BWA station and find the best regions to deploy FSS ES without any effective coming from BWA transmitter also to find the effects of the buildings

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on the signal coverage, figure (10) illustrate the coverage area.

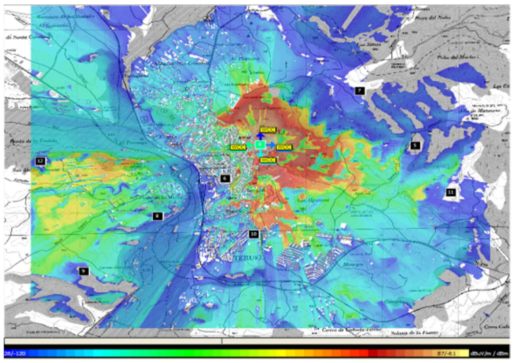

*Figure 10: Coverage Area In Terual State, French*

These points in Figure (10) above represent the best site to deploy FSS ES where there is no impact from BWA station, and figure (11) illustrate the signal profile and how the terrain effect and buildings effect on the transmitted signal.

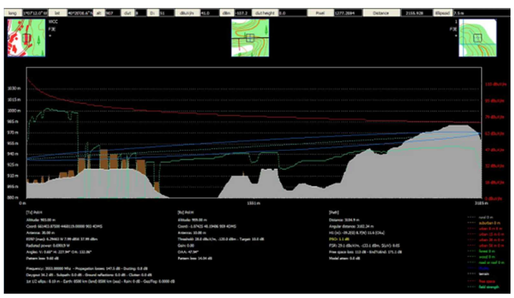

*Figure 11, Profile Terrain From Bwa Station Towards Fss Es (Point 6)*

## 5. CONCLUSION

The way that used to protect the signal that received from the FSS ES receiver from the BWA station's transmitter it is coming by controlling the signal power in the same direction of the FSS as well, the minimum required loss at FSS receiver must be specified and always be greater than or equal the path loss power, to make sure that the BWA transmitter not impact or block the signal received from the satellite.

Theoretically ,the separation distance in term of LOS longer than the distance in term NLOS and that is back to the BWA transmitted signal will be directly affected on the FSS earth station signal received because there is no clutter loss or shielding through the propagation just free path loss will be considered as we present in Table 4 and Table 5 .

Furthermore, the results that been found from the ATDI simulation for two scenarios, the separation distance will be more smaller in the suburban with buildings than this suburban without buildings(Rural) especially in N-LOS , and that is back to the effect of buildings to make restriction or limitation on the BWA transmitter signals , where in the first scenario the best separation distance (best distance to deploy FSS ES) is 1.5Km (at point 18 in figure 7) ,at the time of ,in second scenario the best separation distance is 800m (at point 6 in figure 10) ,the two scenarios used the same parameters for BWA station .For that, buildings played vital turn to find the specific separation distance because the low penetration of the 3.5 GHz and that is will present another issues to make the subject more complete representing by to give a good coverage and users serve much better many BWA stations must deploy through a small region especially in urban and densurban region and that's will indicate not to use FSS receiver for a long region.

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