Review Ongoing Research of Several Countries on the Interference between FSS and BWA

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Abstract— **The purpose of this paper is to provide a general overview of previous and current communications governments and intergovernmental bodies around the world. They have been increasingly reporting incidents where fixed satellite services (FSS) are being disrupted by interference from terrestrial wireless services in the extended and standard C-band frequencies (3.4 to 4.2 GHz). However, comparisons, analysis and conclusions are included into this paper to provide the upcoming researchers with the best extracts. Furthermore, it gives an idea regarding how different countries can have different consequences based on different issues. Finally, realization the impact of forthcoming technology on satellite used under the C-band category have been discussed in the conclusions.**

Index Terms— **FSS, BWA, Interference study, mitigation techniques, IMT.**

I. Introduction

Living on dynamic planet makes very difficulty to balance wireless services without interruption; in addition new technology may always required occupying the purview of existing service. Whereas FSS is growing existing business [1] as clarified in Fig. 1, several frequency administrators were the pioneer to explore the interference between FSS and BWA which work on the same frequency range 3.4-4.2GHz, numerous studies, analysis, and measurements have been done since 1998 to improve the efficiency of receiving signals via FSS. Furthermore, various results issued from different regions needs to compare in order to understand the dissimilarity in each continent.

Since the International Telecommunication Union (ITU) originally allocated C-band for use by the global satellite industry [2], massive deployment of systems and services has been underway worldwide, and millions of users now rely upon satellites for essential communications. 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) [3].

Manuscript submitted December 12, 2007. This work was supported in part by the Malaysian Communication and multimedia commission (MCMC). Review Ongoing Research of Several Countries on the Interference between FSS and BWA.

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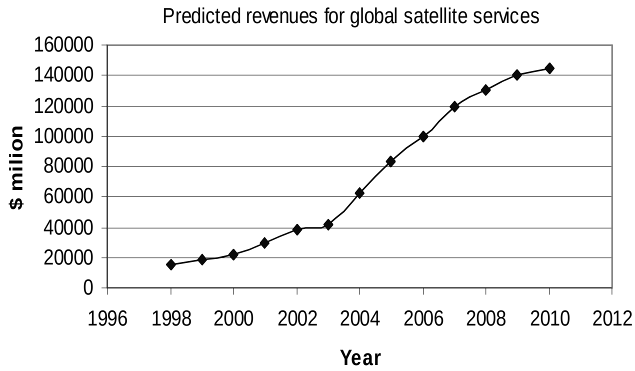


Fig. 1: predicted revenues for global satellite services.

In the ITU table of frequency allocations, the 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 (3,700-4,200MHz) is much more intense, followed by the utilization of the band 3,625-4,200 MHz. 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 [4].

II. Documented Interference in Europe

Within Europe, the lower end of the frequency range up to 3.8 GHz has already been identified or is under consideration for use by BWA services such as WiMAX [5]. Customers of satellite services where WiMAX services have been introduced have reported significant interference and service interruptions for satellite ground stations and their related services. Electronic Communication Committee (ECC) had put an assumptions of two sharing studies in there report to analysis two different BWA central stations (CS) peak output power effect on different satellite terminals (ST) diameter, the first BWA-CS has 43dBm as a peak output power, for the second was 35dBm [5]. This experiment shows the recommended separation distance for ST1, ST2, ST3, ST4, ST5, ST6, and there parameters are clarified in table1.

Table 1: earth station parameters

	ST-1	ST2	ST3	ST4	ST5	ST-6
Antenna Diameter (m)	4.5	4.5	8	8	32	32
Gain (dBi)	42.6	42.6	47.7	47.7	59.8	59.8
Antenna Height (m)	3	3	5	5	25	25
Elevation angle (°)	4	33	4	33	4	33
Azimuth (°)	104	190	104	190	104	190

It shows in fig.2 that the separation distance required for both CS1, and CS2. However CS1 was made to meet nomadic purposes, therefore its high power and needs more separation.

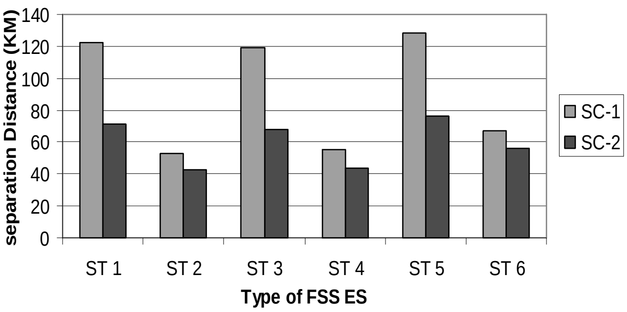


Fig. 2: summary of mitigation distances.

When they took CS2 as a vital illustration for urban place, they found very strong effect on I/N level for Satellite terminal as shown in Fig. 3. However, when assuming a dense of BWA CS, the size of mitigation area will increase due to the aggregate impact from the BWA CS.

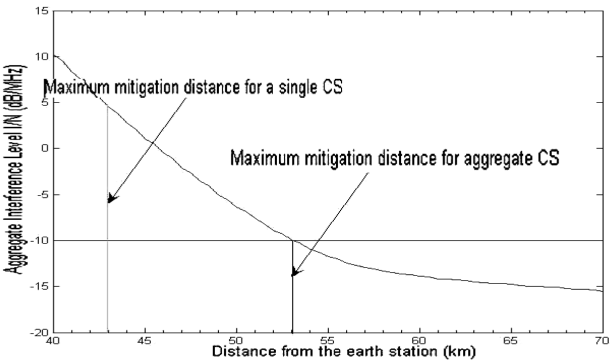


Fig. 2: summary of mitigation distances

It seems that most FSS activities in the C band can be found between 3700 and 4200 MHz. Therefore, BWA applications should be concentrated as much as possible within the band 3400-3700 MHz. In that situation, additional filtering at the FSS ES receiver may improve the operation of LNA/LNB. The required mitigation distances with respect to FSS ES naturally depend on the type and characteristics of the BWA station. BWA operation at distances shorter than the required mitigation distance is often feasible due to the benefits gained from using actual terrain topography and clutter database information in propagation loss calculations. BWA TS are generally less impacting than the CS. In addition, it has been demonstrated that the co-ordination of the BWA CS will generally be sufficient to ensure the co-existence with BWA TS. Furthermore, TS may benefit from the additional clutter loss which is available in some environments, particularly urban environments. Numerous studies have shown that terrestrial and satellite services are incompatible.

III. Realizing Determining and Measuring Signal Interruption in Asia

One of the most amazing studies has done in Hong Kong, in the Office of the Telecommunications Authority (OFTA) [6]. However, they came up with a full assessment of potential interference between broadband wireless access systems in the 3.4-3.6GHz band and fixed satellite services in the 3.4-4.2GHz band. Furthermore, they divided the interference into three types; in-band, out of band, and saturation receiver. Thereby, for in-band they found the co-primary allocation of BWA and FSS stations in the 3.5GHz band, besides they determined the co-existence of BWA in 3.5GHz band and FSS in 3.6-4.2GHz band, and lastly the analyze the receiver saturation of FSS stations[6]. For the BWA they used effective isotropic radiation power (e.i.r.p) for the central station and the terminal station to be 45dBm, in other side they used 2.4 antenna diameter for the FSS ES with 38dBi antenna gain and 57 degree elevation angle for reception. The in-band interference from a single BWA base station transmitter to a typical Very Small Aperture Terminal VSAT terminal is worked out and the results are summarized in the chart in Fig. 4. Nevertheless, it's produced assuming that in-band interference is caused by a BWA transmitter located at 300m above the FSS antenna at a distance of 1.2km. A clutter loss of 18.5 dB is taken under a dense urban environment and a shielding loss of 40 dB is assumed.

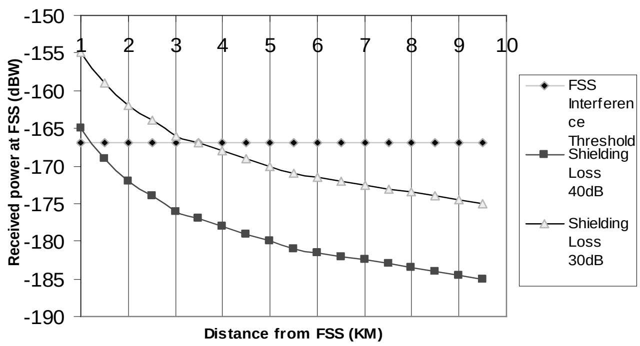


Fig. 4: Coordination distance for 2.4m FSS receiving antenna due to in-band emissions from single BWA transmitter.

Under the worst case situation, the required separation distance is of the order of 380m and 650m respectively for FSS station with LNB filter and without LNB filter added at the front end. It should be noted that in practical situation, these transmitters, in particular the terminal stations, may not all be pointing directly in line-of-sight of the FSS antenna. Additionally is produced assuming that the interferences are caused by BWA transmitters operating with 28MHz bandwidth per sector located at 300m above the FSS antenna fitted with LNB filter at a distance of 380m with clear line-of-sight is summarized in chart clarified in Fig. 5.

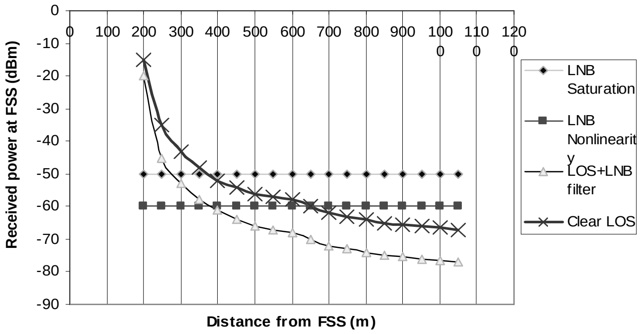


Fig. 5: Coordination distance for 2.4m FSS receiving antenna under LNB overload for multiple BWA transmitters.

Calculation on the aggregated out-of-band emissions from multiple BWA transmitters with direct line-of-sight with a FSS station is made, and the results are summarised in the chart in Fig. 6. The results show that the out-of-band emissions of BWA central stations (emission limit of -89 dBW/MHz) would not cause interference to FSS stations if there is a separation distance of 350m. The out-of-band emissions of BWA terminal stations (emission limit of -68 dBW/MHz) would not cause interference to FSS stations if there is a separation distance of 1.1 km.

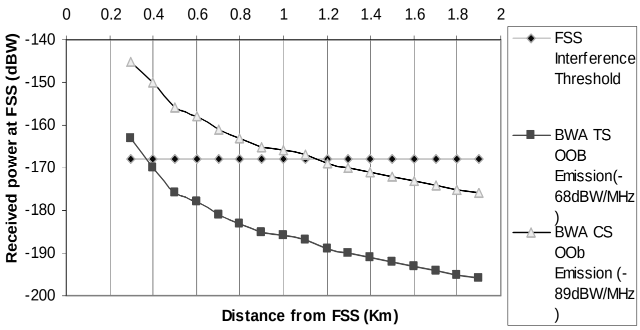


Fig. 6: Coordination distance for 2.4m FSS receiving antenna due Out-of-band emission from multiple BWA transmitters.

As a result, the interference discussed in three categories:

A. *In-band Interference from BWA*

In the absence of any coordination, BWA 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.

B. *FSS Station Saturation*

BWA 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 650 metres 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 BWA signals, the required separation distance is 130 – 380 metres depending on the number of BWA interferers.

C. *Out of Band Emissions from BWA*

Out-of-band emissions from BWA 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 [6].

In Thailand Bangkok during the 3rd Interim Meeting of the APT Wireless Forum co-existence of broadband wireless access networks in the 3400-3800MHz band and fixed satellite service networks in the 3400-4200MHz band [7], they had setup an important summit to the interference problem as follow:

1. Co-frequency Emission Problem: Interference will be caused by BWA working in 3.4 – 3.6 GHz to FSS systems receiving satellite signals by the same frequencies. Separation distances of tens of kilometers, even in excess of 100 km in some cases, will be required if no shielding arrangement can be implemented at the earth stations. If there are only limited number of licensed earth stations in an area, the required separation distance to protect individual earth stations could be less than the worst case figures since it can be worked out on a case-by-case basis depending on the geographical and operating characteristics.

2. Out-of-band Emission Problem: Out-of-band emissions from BWA operating in 3.4 – 3.6 GHz can also affect FSS systems receiving signals in the adjacent band of 3.6 – 4.2 GHz. Assuming that normal BWA equipment with out-of-band emissions are deployed, a separation distance of up to about 2 km between BWA transmitters and FSS receiving stations would be required. If additional filtering can be implemented at the BWA base stations to reduce the unwanted emission levels and the use of outdoor BWA terminal stations is prohibited, the distance may be shortened to about 0.5 km.

3. FSS Receiver Saturation Problem: Signals from nearby BWA equipment transmitting in the 3.4 – 3.6 GHz band will also cause saturation of FSS receivers with their LNB operating in the 3.4 – 4.2 GHz range. Although a number of technical solutions (e.g. filter, shielding etc) may be available in principle to minimize / overcome the problem, the most practical one is to add a bandpass filter in front of the FSS receiver. According to a field test conducted, an off-the-shelf filter can reduce the interference level by 10 dB. With this solution, a separation distance of about 0.5 – 0.6 km is required between BWA and FSS systems. For those FSS systems without implementing the filter solution, a separation distance of about 1.2 km would be required [7].

IV. USA Research Work

The NTIA report of U.S department of commerce they invention a new technique measure the pulsed CO-Channel Interference in 4GHz digital earth station receiver. However, this glorious study opened a wide way to affirmative the signal imbrications. The study based on documented the results of measurements in which a variety of co-channel pulsed signals were injected into the radio frequency (RF) front-end of an operational as shown in Fig. 7, digital earth station. The results indicate that digital Earth station receivers may be vulnerable to interference that creates either a contiguous block of symbol errors or a long series of symbol errors. Interference with lower pulse repetition rates, pulse widths, and duty cycles may also produce effects [8].

ISBN: 978-988-17012-1-3

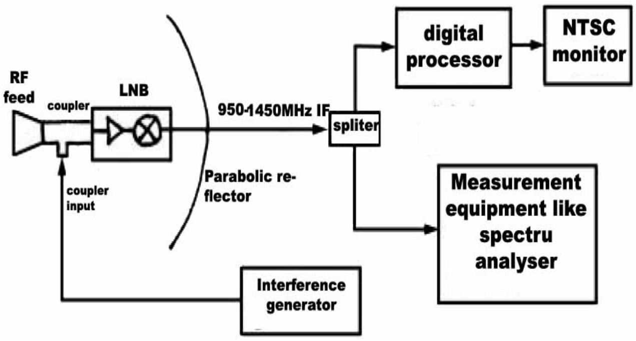


Fig.7: Digital earth station test and measure block diagram.

After the analysis they found that Continuous-wave (CW) interference effects occur at the lowest thresholds, approximately 8 dB below that of the desired signal in the bandwidth of the Earth station receiver. Nevertheless, Digital Earth station receivers are relatively robust in the presence of low duty cycle interference. When duty cycle is less than 0.005 (a half percent), interference thresholds exceed 10 dB above the desired signal level. But interference thresholds converge rapidly to the CW level of 8 dB (C /I) ratios when duty cycle exceeds 1 percent. In effect, the Earth station performance is severely affected if 5 percent or more of symbols are deleted from the data stream. In addition, when less than 0.5% of symbols are affected, the system's error correction routines work well. Within a transitional zone of 1-5% of symbols affected, degradation is easier to inflict but the system is still robust enough to withstand peak interference levels on the order of 10 to 20 dB above the desired signal level. But when more than 5% of symbols are affected on a continuous basis, the system's error correction capabilities become inadequate to compensate under almost any incident signal level equaling or exceeding the desired signal level, and the Jittering of pulsed interference does not change the interference thresholds of the Earth station. Whether data bits or symbols are errored on a periodic basis (as for fixed-prr interference sequence) or on a random basis makes no difference, because interleaving effectively randomizes the deleted bits and symbols in both cases [8].

Technical analysis of the potential for interference from terrestrial broadband wireless access ("BWA") transmitters to fixed-satellite service ("FSS") receive earth stations in the band 3,400-4,200 MHz arise a high demand for spectrum needs to avoid the interference consequences as follow:

A. *In-band interference*

The impact on FSS earth stations of the interference generated by co-frequency BWA emissions is summarized in Table 2; this table calculates the minimum distance needed between a BWA transmitter and an FSS earth station operating in the 3,400–4,200 MHz band, for various arrival angles.

Table 2: Required Separation Distances between BWA Transmitter (e.i.r.p. = 25 Watt/25 MHz or 14 dBW/25 MHz) and FSS Receive Earth Station (In-Band Interference).

Arrival angle of BWA signal at FSS E/S relative to Boresight	5^0	15^0	48^0
FSS E/S antenna gain towards BWA transmitter (dBi)	11.5	2.6	-10
Allowable interference level for I/N = 3% (dBW/MHz)	-162.3	-162.3	-163.3
Interference path loss required (dB)	173.8	164.9	152.3
Frequency of operation (MHz)	3675	3675	3675
Separation distance (km) Model (i): free space loss	3184.3	1139.2	266.2
Separation distance (km) Model (ii): free space loss+48.5 dB	12	4.3	1.0
Separation distance (km) Model (iii): urban environment	26.7	17.0	7.7
Separation distance (km) Model (iii): rural environment	37.7	22.6	10.9

All results show that separation distances of several kilometers are required to ensure protection of FSS earth stations. Moreover, if short term effects are taken into consideration larger separation distances will result. Actually, the 150 km separation distance adopted by the FCC is consistent with the consideration of short-term effects [8].

B. *Saturation of FSS receiver*

C-band receivers utilize Low Noise Block down-converters (LNBs). The LNB amplifies this signal and down-converts it from C-band to L-band, in order to facilitate transporting the signal using coaxial cable. Most LNB, manufacturers consider the pass band of LNBs to be 3,625-4,200 MHz, and therefore no rejection will typically occur within this band. Table 3 presents the total power at the input of the LNB including the power of the interfering signal.

Table 3: Comparison of Total Power at LNB Input (Including BWA Interference) with LNB Saturation Level.

Distance m/Free Space Loss (dB)	Interfering Power at FSS Antenna (dBm)	FSS Antenna Off-Axis Angle (º) / Gain(dBi)	Interfering PowerdBm/ Total Power in dBm at Output of Antenna	Excess Over LNB Saturation Level of -55dBm
50 / 77.7	-33.7	5 / 11.5	-22.2 / -22.18	32.8
200 / 89.3	-45.7		-34.2 / -34.22	20.8
600 / 99.3	-55.3		-42.8 / -43.76	11.2
1000 / 103.7	-59.7		-48.2 / -48.19	6.8
50 / 77.7	-33.7	15 / 2.6	-31.1 / -31.11	23.9
200 / 89.3	-45.7		-43.2 / -43.15	11.9
600 / 99.3	-55.3		-52.7 / -52.66	2.3
1000 / 103.7	-59.7		-57.1 / -57.05	-2.0
50 / 77.7	-33.7	30 / -4.9	-38.6 / -38.63	16.4
200 / 89.3	-45.7		-50.7 / -50.66	4.3
600 / 99.3	-55.3		-60.2 / -60.05	-5.0
1000 / 103.7	-59.7		-64.7 / -64.20	-9.2

From table 3, LNB saturation may occur for BWA transmitters located a few hundred meters from the FSS earth station, whereas at least 3 dB of LNB input back off would be required for the adequate transmission of digital carriers and moreover, depending on the specific LNB under consideration, the saturation level can be lower than the -55dBm assumed here.

C. Out-of-band

Out-of-band emissions from BWA transmitters, if not properly limited, may cause unacceptable interference to FSS earth stations, Table 4 gives the minimum distances that transmitters would have to be from the FSS earth station in order for the allowable interference level of -162.3dBW/MHz not to be exceeded assuming free space loss.

Table4: Required Separation Distances between BWA Transmitter and FSS Receive Earth Station (Out-of-Band Interference: -72 dBW/MHz).

Arrival angle of BWA signal at FSS E/S relative to Boresight	5^0	15^0	48^0
FSS E/S antenna gain towards BWA transmitter (dBi)	11.5	2.6	-10
Allowable interference level for I/N = 3% (dBW/MHz)	-162.3	-162.3	-163.3
Interference path loss required (dB)	101.8	92.9	80.3
Frequency of operation (MHz)	3700	3700	3700
Separation distance (km) free space loss	3184.3	1139.2	266.2

It can be conclude from the above that co-frequency operation of BWA systems and FSS receive earth stations in the same geographic area is not feasible. Separation distances of several kilometers, probably as high as 150 km, are required to ensure protection of FSS earth stations. Therefore, Mitigation techniques may be employed to reduce the likelihood of LNB saturation. The potential for interference caused by out-of band emissions generated by BWA transmitters can be appropriately reduced by limiting the level of such emissions. It has been tentatively concluded that a limit of approximately -72dBW/MHz for the out-of-band e.i.r.p. density generated by a BWA transmitter would provide adequate protection [9].

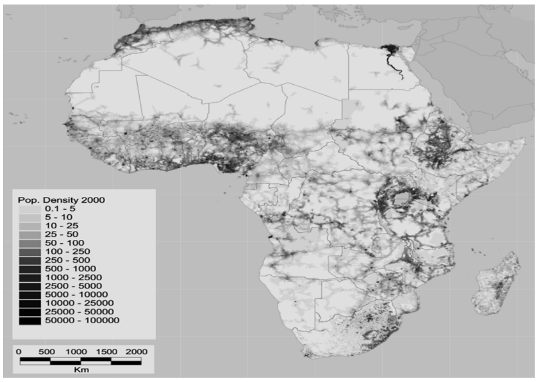
Some studies related to WiMAX Forum have been done to see the compatibility of services using WiMAX technology with the satellite services in the 3.3-3.8GHz band. In addition they mentioned that for countries which have few gateway-type earth stations in the satellite downlink band 3.6-4.2GHz then co-channel WiMAX technology deployment should be possible via coordination and use of mitigation techniques, possibly on a case-by-case basis with each earth station whose location is assumed to be known. Without mitigation, then there will be some geographical areas around the earth stations where deployments of WiMAX technology may be excluded from operation [10].

The state of FSS and wireless access systems in Brazil is a good example of the case where there is intensive FSS use above 3625 MHz and the intention of the administration is to make further use of the 3400-3600 MHz band for broadband wireless access [10]. The BWA deployment would, on the one hand, be severely limited by the need for protecting existing FSS earth stations, and would, on the other hand, unduly constrain the deployment of future FSS earth stations.

V. Fixed Wireless Access and the Erosion of Satellite Communications Services on the African Continent

Many reports have documented the impossibilities of coexist the FSS in most of Africa, since the Current C-band Position in Africa has a spectrum band from 3.4 – 4.2GHz it's allocated to Fixed Satellite Services (FSS). However, it's widely used for vital communications services across continent, robust and reliable to the connectivity backbone. The Current Uses of C-band in Africa including backhaul services for telecoms networks, point-to-point trunking, government and strategic communications, high-volume data and broadcast transmission, rural telephony services, avionics, maritime services, and 'Lifeblood of the satellite industry'. Therefore if other signal affect on the FSS Government, strategic, and commercial FSS services will suffer signal delays, synchronization loss, blackout periods, blackout areas, and total loss of transmission. Nevertheless, population density in Africa is highest where the rain effect is strongest, that makes shifting to KU band is unimaginable as it shown in Fig. 1. [11].

Fig.1: the highest population density concentrate in the most heavily rain density.



However, BWA is an access technology in Africa, and it's best implemented in bands below 3 GHz, it may appear be complementary to satellite C band services, but spectrum assignments must be coordinated with satellite use leading to exclusions area for WiMAX. However, use of WiMAX at C band does not require a new allocation, since WiMAX operates under the existing FS allocation, and there will be no further change required [11].

VI. Summary and Conclusions

Analysis has demonstrated that exclusion zones around earth stations would be required for terrestrial wireless and satellite services to co-exist in the affected band, but technical data suggests that exclusion zones around earth stations would be impractical because they would have to be large and there would be too many to be feasible due to the millions of

ISBN: 978-988-17012-1-3

C-band satellite earth stations already deployed worldwide. The density of BWA transmit 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 BWA stations. BWA deployment will be limited by the need to protect existing FSS earth stations, while future FSS deployment will be precluded around any area where BWA systems may be able to deploy. In addition to these technical difficulties, there are licensing issues that would further complicate the situation. New earth station sites required to demonstrate efficient use of the spectrum. The use of smart antennas on BWA base stations and beam steering will also be a way of protecting earth stations. For the case where earth station deployment in this band is widespread and terminals are generally not registered with the administration concerned (e.g. for VSAT applications, TV cable-head end terminals etc.), coordination on a site-by-site basis is not feasible and co-frequency operation is difficult without geographical separations between the services. The difficulty with the different services in close geographic proximity is much alleviated if the earth stations are operating at high elevation angles and it is expected that this is the case for many countries with ubiquitously deployed earth station terminals like TV cable-head ends and VSATs.

In addition, some national administrations in Europe are now considering identifying new terrestrial IMT services (UMTS / 4G in Europe) in the upper end of the frequency range (3.7 to 4.2 GHz). It should be recalled that within Region 1 of the ITU which encompasses all of Europe, satellite services today have priority over mobile services above 3.4 GHz in C-band. For UMTS/ 4G services, some European administrations advocate this band as a harmonized band on a world-wide basis, this approach is flawed and that some major countries will likely not support such use in order to protect important satellite communications. In related business, an effort is underway by the terrestrial wireless community to secure a global allocation from the ITU to put future mobile phone networks like IMT advanced and 4G services in the 3.4 – 4.2 GHz frequency band. These frequencies are a primary means by which the satellite industry provides millions of users with mission-critical communications solutions for distance learning, tele-medicine, universal access, disaster recovery, and many other vital applications. A viable alternative is needed to ensure continued access to satellite communications, while facilitating the delivery of terrestrial wireless services. This study related to the possibility of sharing frequencies in Malaysia, headed for looking through the problems, issues and effects of services coexistence in C-band, then propose a tolerable mitigation techniques which can avoid the current and expected interference.

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