Toward Coexistence and Sharing between IMT-Advanced and Existing Fixed Systems

Zaid Ahmed Shamsan shamsan22@yahoo.com
Wireless communication center (WCC)
Faculty of Electrical Engineering
Universiti Teknologi Malaysia (UTM)
Skudai, 81310, Johor Bahru, Malaysia

Sharifah Kamilah Syed-Yusof kamilah@fke.utm.my
Wireless communication center (WCC)
Faculty of Electrical Engineering
Universiti Teknologi Malaysia (UTM)
Skudai, 81310, Johor Bahru, Malaysia

Tharek Abd. Rahman tharek@fke.utm.my
Wireless communication center (WCC)
Faculty of Electrical Engineering
Universiti Teknologi Malaysia (UTM)
Skudai, 81310, Johor Bahru, Malaysia

Abstract

In this paper coexistence and spectrum sharing between systems as a recently critical issue due to emerging new wireless technologies and spectrum scarcity are investigated. At *World Radiocommunication Conferences 2007* (WRC-07), *International Telecommunication Union - Radiocommunications* (ITU-R) allocated 3400-3600 MHz band for the coming fourth generation (4G) or IMT-Advanced on a co-primary basis along with existing Fixed Wireless Access (FWA) systems. Therefore, coexistence and sharing requirements like separation distance and frequency separation coordination must be achieved in terms of both co-channel and adjacent channel frequencies. Co-sited the two base stations antennas and non co-sited coexistence of the two systems are analyzed. The interference analysis models, Adjacent Channel Interference Ratio (ACIR) and spectrum emission mask are applied in the 3.5 GHz band to extract the additional isolation needed to protect adjacent channel interference. Also interference to noise ratio as a standard interference criteria is introduced. Finally, possible intersystem interference mitigation techniques are suggested and explained.

Keywords: ACIR, Additional isolation, Spectral emission mask, FWA systems, IMT-Advanced system,

1. INTRODUCTION

In wireless communication, Interference between two systems occurs when these systems operate at overlapping frequencies, sharing the same physical environment, at the same time with overlapping antenna patterns. ITU-R recommends expressing the level of interference in terms of the probability that reception capability of the receiver under consideration is impaired by the presence of an interferer. Concerning the different systems of International Mobile Telecommunication (IMT-Advanced) and Fixed Wireless Access (FWA) systems, it is natural to conclude that those technologies will work in the same environment that leads to occurrence of performance degradation. Main mechanisms of coexistence are: co-sited (co-located) and non co-sited (non co-located). FWA system and Fixed Satellite Service (FSS) downlink part use 3400-4200 MHz band. Meanwhile, the 3400-3600 MHz frequency band is identified at WRC-07 for IMT-Advanced in several countries in Asia with regulatory and technical constraints [1], which mean that frequency sharing between these systems is bound to happen. A few studies were done between terrestrial systems in the said band because this band did not use for mobile as the bands lower than 3 GHz as in WCDMA up to 2690 MHz.

The studies which carried out in this band (3.5 GHz) are in [2], [3]. In [2] the study implemented by using Advanced Minimum Coupling Loss (A-MCL) between beyond 3G systems and fixed microwave services to get the minimum separation distance and frequency between the two systems. Whereas in the [3], BWA system represented by FWA is studied to share the same band with point-to-point fixed link system also to determined the minimum separation distance and frequency separation. In our study the concept of spectral emission mask, adjacent channel leakage ratio and adjacent channel selectivity is presented such that the effect of both of transmitter and receiver are taking into account.

The reminder of this paper is organized as follows. In Sections 2 and 3 a vision for IMT-Advanced and its allocated spectrum are presented. Sections 3 to 7 describe in detail interference models used, systems parameters, protection criteria and propagation models. Sections 8 and 9 are devoted to describing the coexistence scenarios, results, analysis and compatibility between systems. Suggested intersystem interference mitigation methods are presented in Section 10. Finally, the conclusions are presented in Section 11.

2. IMT-ADVANCED SYSTEM CONCEPT

It is expected that the development of International Mobile Telecommunications -2000 (IMT-2000) will reach a limit of around 30Mbps [4]. IMT-Advanced is a concept from the ITU for mobile communication systems with capabilities which go further than that of IMT-2000. IMT-Advanced was previously known as “systems beyond IMT-2000” [5]. In the vision of the ITU, IMT-Advanced as a new wireless access technology may be developed around the year 2010 capable of supporting even higher data rates with high mobility, which could be widely deployed about 7 years (from now) in some countries. The new capabilities of these IMT-Advanced systems are envisioned to handle a wide range of supported carrier bandwidth: 20 MHz up to 100 MHz and data rates with target peak data rates of up to approximately 100 Mbps for high mobility such as mobile access and up to say 1 Gbps for low mobility such as nomadic/local wireless access [5].
IMT-Advanced will support connectivity, with increased system performance for a variety of low mobility environments, such as: Stationary (fixed or nomadic terminals); Pedestrian (pedestrian speeds up to 3 km/h); Typical vehicular (Vehicular speeds up to 120 km/h); High speed vehicular (high-speed trains up to 350 km/h).

Furthermore, IMT-Advanced shall support seamless application connectivity to other mobile networks and IP networks (global roaming capabilities), will deliver improved unicast and multicast broadcast services, and provide network support of multiple radio interfaces, with seamless handover, addressing both the cellular layer and the hot spot layer (and possibly the personal network layer) per ITU-R Rec. M.1645 [4]. Further, as technical requirements, IMT-Advanced systems shall support multiple input-multiple output (MIMO) and beamforming, including features to support multi-antenna capabilities at both the base station (BS) and at the mobile terminal, including MIMO operation. Also, IMT-Advanced shall support the use of coverage enhancing technologies according to [4], [6]. For the cell coverage, Table 1 records the IMT-Advanced deployment scenarios in which the deployment scenarios require availability for mobile access for nomadic users (short-range), for ad-hoc network users, for outdoor users (wide and metropolitan range), and for moving users (in a car or a high-speed train).

Cell Range	Performance Target
Up to 100 m	Nomadic Performance, up to 1 Gbit/s
Up to 5 km	Performance Targets for at Least 100Mbps
5-30 km	Graceful Degradation in System/Edge Spectrum Efficiency
30-100 km	System Should be Functional (Thermal Noise Limited Scenario)

Table 1: IMT-Advanced Deployment Scenarios [6]

3. WRC-07 OUTCOMES FOR IMT-ADVANCED BANDS

At WRC-07 in Geneva, concerning item 1.4, the candidate bands for IMT systems have been discussed [1] and the results of this item in the conference can be summarized in Figure 1. The NO sign indicates that WRC-07 decided not to change the table of allocation regarding the candidate bands 410-430 MHz, 2700- 2900 MHz and 4400- 4900 MHz.

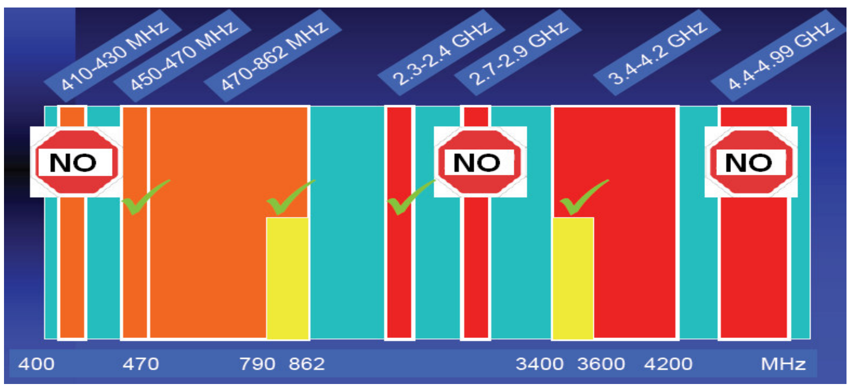

FIGURE 1: WRC-07 outcome for IMT system bands [7]

3.1 Globally Allocation

The frequency bands 450-470 MHz and 2300-2400 MHz are now identified for IMT and globally harmonized. However, the use of this band is dependant on every administration.

3.2 Region 1 Allocation (Europe, Africa & Arab countries)

The band 790-862 MHz that was only allocated for broadcasting systems is now equally allocated Mobile Service and identified for IMT in Europe/Africa and Arab countries with equal rights (co-primary basis). Mobile Service, and by that IMT, can now also use the band 3 400- 3 600 MHz on a co-primary basis with other services sharing this band (Fixed and Fixed Satellite Services), under regulatory and technical conditions, in 83 countries in Region 1, including most of the European countries.

3.3 Region 2 Allocation (Americas)

The band 698-806 MHz has now a Mobile allocation on a co-primary basis in this region (noting that 806-862 MHz was already co-primary for Mobile) except in Brazil where this band is secondary basis (operational restrictions compared with broadcasting services). This band is also identified for IMT. The band 3400-3500 MHz is now allocated for Mobile on co-primary basis with FS and FSS but without IMT identification in a number of countries in Latin America.

3.4 Region 3 Allocation (Asia)

The band 470-862 MHz was already allocated to the Mobile service on co-primary basis. The part 698-790 MHz is now identified for IMT in some countries but the part 790-862 MHz is identified for IMT in the whole Asia. The band 3400-3500 MHz is now allocated for Mobile on co-primary basis with FS and FSS and identified for IMT in several countries with regulatory and technical constraints. The band 3500- 3600 MHz that was already allocated to Mobile on co-primary basis is now identified for IMT under regulatory and technical constraints in several countries. With the outcome of WRC-07, the utilization of the new bands, can be classified into the global ones (450-470 MHz and 2300-2400) and regional ones (790-862 MHz and 3400- 3600 MHz). The amount of spectrum for Mobile Service and identified for IMT at WRC-07 could be generalized to 120 MHz globally and 392 MHz (120 + 72 + 200) in many areas. For our focusing on the band 3400-3600 MHz in all three Regions can be depicted in Figure 2, 3400-3600 MHz are allocated to the mobile service on a primary basis or identified for use by administrations wishing to implement IMT as in Figure 2.

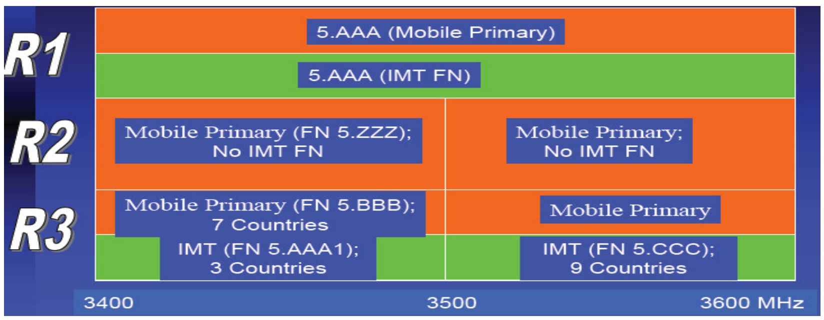

FIGURE 2: WRC-07 Outcome on IMT Band 3.4-3.6 GHz Item 1.4 [9], 5.BBB: Different category of service: in Bangladesh, China, India, Iran (Islamic Republic of), New Zealand, Singapore and French Overseas Communities Countries, 5.AAA1: In Korea (Rep. of), Japan and Pakistan, 5.CCC: In Bangladesh, China, Korea (Rep. of), India, Iran (Islamic Republic of), Japan, New Zealand, Pakistan and French Overseas Communities.

4. INTERFERENCE MODELS

When a system IMT-Advanced of other is considered, main type of interference is intrasystem interference, including interference coming from given cell, adjacent cell, and thermal noise. Whereas two systems coexist in the same geographic area, the interference includes not only intrasystem interference, but also intersystem interference which is considered in this paper.
The forms of interference modeled in this paper are spectral emission mask of FWA system and ACI of IMT-Advanced system that arises from the ACLR from BS transmissions in the IMT-Advanced and Adjacent Channel Selectivity (ACS) of the BS receivers in FWA systems and the ability of this receiver to reject power legitimately transmitted in the adjacent channel.

4.1 Spectral Emission Mask

The spectral emission mask is a graphical representation of a set of rules that apply to the spectral emissions of radio transmitters. Such rules are set forward by regulatory bodies such as FCC and ETSI. It is defined as the spectral power density mask, within ± 250 % of the relevant channel separation (ChS), which is not exceeded under any combination of service types and any loading. The masks vary with the type of radio equipment, their frequency band of operation and the channel spacing for which they are to be authorized. FWA 7 MHz channel bandwidth mask according to [8], [9] is tabulated in Table 2. The spectral emission mask is considered in this study because it may be used to generate a “worst case” power spectral density for worst case interference analysis purposes, where the coexistence study can be applied by spectrum emission mask as an essential parameter for adjacent frequency sharing analysis to evaluate the attenuation of interference signal power in the band of the victim receiver.

Freq./Ch. Separation (Normalized (MHz)	**0**	**0.5**	**0.5**	**0.71**	**1.06**	**2**	**2.5**
Ch. Spacing (MHz)	**dB**	**dB**	**dB**	**dB**	**dB**	**dB**	**dB**
	0	0	-8	-27	-32	-50	-50
7	0	3.5	3.5	4.97	7.42	14	17.5

Table 2: Reference Frequencies Points for Spectrum Masks of Type-F ETSI- EN301021 (FWA)

4.2 Adjacent Channel Interference

The level of interference received depends on the spectral 'leakage' of the interferer's transmitter and the adjacent channel blocking performance of the receiver. For the transmitter, the spectral leakage is characterized by the ACLR, which is defined as the ratio of the transmitted power to the power measured in the adjacent radio frequency (RF) channel at the output of a receiver filter. Similarly, the adjacent channel performance of the receiver is characterized by the ACS, which is the ratio of the power level of unwanted ACI to the power level of co-channel interference that produces the same bit error ratio (BER) performance in the receiver. In order to determine the composite effect of the transmitter and receiver imperfections, the ACLR and ACS values are combined to give a single Adjacent Channel Interference Ratio (ACIR) value using the following equation [10],

$$ACIR = \frac{1}{\frac{1}{ACLR} + \frac{1}{ACS}} \qquad (1)$$

5. IMT-ADVANCED & FIXED WIRELESS ACCESS SERVICES PARAMETERS

In order to examine coexisting and sharing issues, it is necessary to clarify the parameters of IMT-Advanced and FWA systems that will affect the interference level and criterion as clarified in a next section.

5.1 IMT-Advanced Parameters

Now, the term IMT means IMT-2000 and IMT-Advanced [11]. As stated, IMT-Advanced target peak data rates are 100 Mbps for high mobility systems and 1 Gbps for low mobility of fixed and nomadic systems. The required channel bandwidths is ranging between 20-100 MHz where 50 MHz for suburban and 100 MHz for urban coverage [12]. Table 3 contains the IMT-Advanced parameters assumed for the comparison of the different studies. Where 5 MHz, 10 MHz and 15 MHz are offsets of 1st adjacent channel, 2nd adjacent channel and 3rd adjacent channel separation from center frequency, respectively.

5.2 FWA System Parameters

In Malaysia the frequency range 3.4-3.7 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 as well as 3600-3650 MHz paired with 3650-3700 MHz. These FWA bands are to be used for direct radio connection in the last mile between a fixed radio central station and subscriber terminal stations in a point-to-point and/or point-to-multipoint configuration. 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 [13]. FWA parameters are shown in Table 3.

Parameter		Value	
		IMT-Advanced	**FWA**
Center Frequency of Operation (MHz)		3500	3500
Base Station Transmitted Power (dBm)		43	36
Minimum Coupling Loss (dB)		30	30
Base Station Antenna Gain (dBi)		18	17
Base Station Antenna Height (m)		30	30
Interference Limit Power (dBm)		-109	-109
Channel Bandwidth (MHz)		20, 50, 100	7
ACLR (dB)	Offset @ 5 MHz	45	53.5
	Offset @ 10 MHz	50	66
	Offset @ 15 MHz	66	-----
ACS (dB)	Offset @ 5 MHz	45	70
	Offset @ 10 MHz	50	70
	Offset @ 15 MHz	66	70

Table 3: IMT-Advanced and FWA Systems Parameters (Macro Cell)

6. PROTECTION CRITERION

The interference threshold, in the deterministic analysis, of -109 dBm is used as the maximum interference limits that can be tolerated by both of the IMT-Advanced and FWA equipment. This threshold is specified in Report ITU-R [12] and the RF parameters specified by the WiMAX Forum [14] for the IMT-Advanced and FWA equipment, respectively. For discussion of various sharing scenarios, it is necessary to develop appropriate rules for sharing. Intersystem interference can be described as short term or long-term. It is referred to as “long term” interference for percentage of time of greater than 20% While a small percentage of the time in range of 0.001% to 1.0% is referred to “short-term” interference which is rarely evaluated in the coordination literature as it is very much statistical in nature and not found for many services and will be specific to the cases considered [15] [16]. In this paper we consider long term interference only.

The interference protection criteria can be defined as an absolute interference power level *I*, interference-to-noise power ratio *I/N*, or carrier-to-interfering signal power ratio *C/I* [16]. ITU-R Recommendation F.758-2 details two generally accepted values for the interference–to–thermal-noise ratio for long-term interference into fixed service receivers. When considering interference from other services, it identifies an *I/N* value of –6 dB or –10 dB matched to specific requirements of individual systems.

This approach provides a method for defining a tolerable limit that is independent of most characteristics of the victim receiver, apart from noise figure. Each fixed service accepts a 1 dB degradation (i.e., the difference in decibels between carrier-to-noise ratio *(C/N)* and carrier to noise plus interference ratio *C/(N + I)* in receiver sensitivity. In some regard, an *I/N* of –6 dB becomes the fundamental criterion for coexistence [17], so it should be that [18]:

$$I - N \geq \alpha \tag{2}$$

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 a value of -6 dB.

7. PROPAGATION MODELS

Particularly, there is no single propagation model used for different sharing studies because the particular deployment of the systems requires using specific propagation model relevant to the specific system.

7.1 Co-sited Macrocellular Base Stations Model

For co-sited BSs, a coupling loss value of 30 dB is assumed between co-sited antennas for all frequency bands, 30 dB was also a value measured by [19] for all frequency bands, horizontally separated antennas of the order of 1 meter [20].

7.2 Not Co-sited Macrocellular Base Stations Model

The standard model agreed upon in CEPT and ITU for a terrestrial interference assessment at microwave frequencies is clearly marked in [21]. This is model includes the attenuation due to clutter in different environments.

$$L(d) = 92.5 + 20\log d + 20\log f + Ah \tag{3}$$

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:

$$Ah = 10.25e^{-d_k}\left[1 - \tanh\left[6\left(\frac{h}{h_a} - 0.625\right)\right]\right] - 0.33 \tag{4}$$

Where d_k is the distance (km) from nominal clutter point to the antenna, h is the antenna height (m) above local ground level, and h_a is the nominal clutter height (m) above local ground level. In [21], clutter losses are evaluated for different categories: trees, rural, suburban, urban, and dense urban, etc. The geographical area considered for sharing studies is urban area [22]. Increasing of antenna height up to the clutter height leads to decrease the clutter loss, as shown in Table 5 and Figure 3 which contain the urban and suburban categories.

Clutter Category	Clutter Height h_a (m)	Nominal Distance d_k (km)
Suburban Area	9	0.025
Urban Area	20	0.02

Table 5: Nominal clutter heights and distances

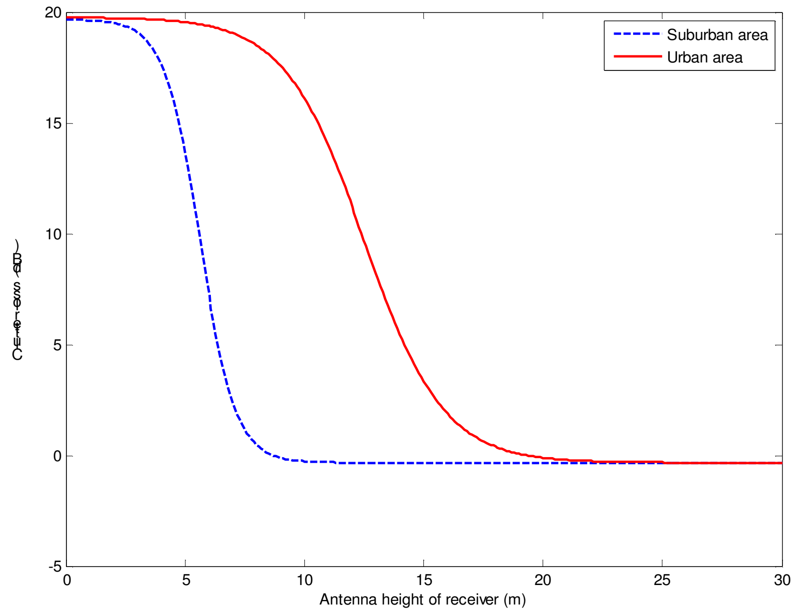

FIGURE 3: Clutter loss for suburban and urban areas

8. COEXISTENCE SCENARIOS & RESULTS

The coexistence scenarios which can occur between IMT-Advanced and FWA systems are BS-BS, BS-subscriber station, subscriber station-BS, subscriber station-subscriber station interference. As mentioned by [23], [24], [25], [26], BS-subscriber station, subscriber station-BS, subscriber station - subscriber station interference will have a small or negligible impact on the system performance when averaged over the system. Therefore, the BS-BS interference is the most critical interference path between IMT-Advanced and FWA will be analysis as a main coexistence challenge case for two systems. IMT-Advanced has no spectrum mask up to now, therefore, in case interference from IMT-Advanced toward FWA, The only form of interference modeled in this case is ACI that arises from the ACLR from BS transmissions in the IMT-Advanced system and the ACS of the BS receiver FWA system. Spectral emission mask of FWA systems in Table 2 will be used for the interference fall into IMT-Advanced system form FWA systems.

8.1 Co-sited Macrocellular Base Stations Analysis

In order to get additional isolation which is required to prevent adjacent channel interference for a collocated systems the following formula should be calculated.

$$\mathrm{A}_{addiso} = Pt - ACL - ACIR - I_{\lim it} \tag{5}$$

Where A_{addiso} is additional Isolation (dB) required to prevent adjacent channel interference, Pt is the transmitter power, and I_{limit} is the Interference Limit. ACL is the antenna coupling loss which has practical values for macro, micro, and pico cell types, for BS-to-BS macro interference the antenna coupling loss is 30 dB [19], [20]. The additional isolation needed when the interference is generated from an IMT-Advanced BS to a FWA BS is shown in Table 6. Similarity, the additional isolation needed when the interference is generated from a FWA BS to an IMT-Advanced is tabulated in Table 7.

Parameter	Frequency Offset	
	5 MHz	10 MHz
Transmit Power (dBm)	43	43
Coupling Loss (dB)	30	30
ACIR (dB)	44.98	49.96
Interference Power at Receiver Input (dBm)	–32	–37
Allowed Interference Power (dBm)	–109.0	–109.0
Additional Isolation Needed (dB)	77	72

Table 6: Analysis For Co-Sited Macrocellular BS, Where the FWA is the Interference Victim

Parameter	Frequency Offset	
	5 MHz	10 MHz
Transmit Power (dBm)	36	36
Coupling Loss (dB)	30	30
ACIR (dB)	44.43	49.89
Interference Power at Receiver Input (dBm)	–39	– 44
Allowed Interference Power (dBm)	–109.0	–109.0
Additional Isolation Needed (dB)	70	65

Table 7: Analysis For Co-Sited Macrocellular BS, Where the IMT-Advanced is The Interference Victim

8.2 Not Co-sited Macrocellular Base Stations Analysis

8.2.1 FWA BS Interference on IMT-Advanced BS

As seen from Figures 4, 5, and 6, the interference from FWA BS (as an interferer) into IMT-Advanced BS (as a victim receiver) is applied, where the minimum separation distance and frequency separation for the minimum I/N ratio of -6 dB are analyzed according to the three selected bandwidths of IMT-Advanced channels in the urban area. It can be observed that the minimum separation distance between the two base stations must be greater than 10m, 6.5m and 4.5m for frequency offset of 14MHz to achieve the adjacent channel coexistence of FWA with 20MHz, 50MHz, and 100MHz channel bandwidth, respectively. The guard band between systems is 0.5MHz for 20MHz only while there is no guard band for 50 and 100MHz channel bandwidth. The zero guard band is represented by a vertical line in the graphs and equals to:

$$Z.G.B = 0.5(BW_{IMT-Advanced} - BW_{FWA}) \qquad (6)$$

Where $BW_{IMT\text{-}Advanced}$ and BW_{FWA} are bandwidths of IMT-Advanced and FWA, respectively. Sharing the same channel (co-channel) is feasible between two systems only in case of separation distances are of the order of 3.25km, 2km, and 1.4km for 20MHz, 50MHz and 100MHz IMT-Advanced channel bandwidth, respectively, because at these distances or more the interference is always 6 dB or more below the thermal noise floor as the Figures show.

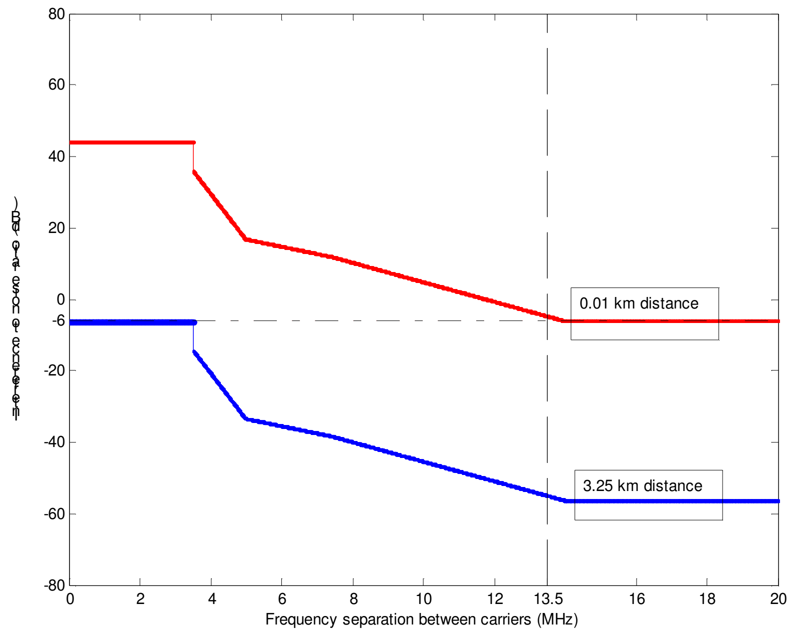

FIGURE 4: Interference from FWA into IMT-Advanced (20MHz)

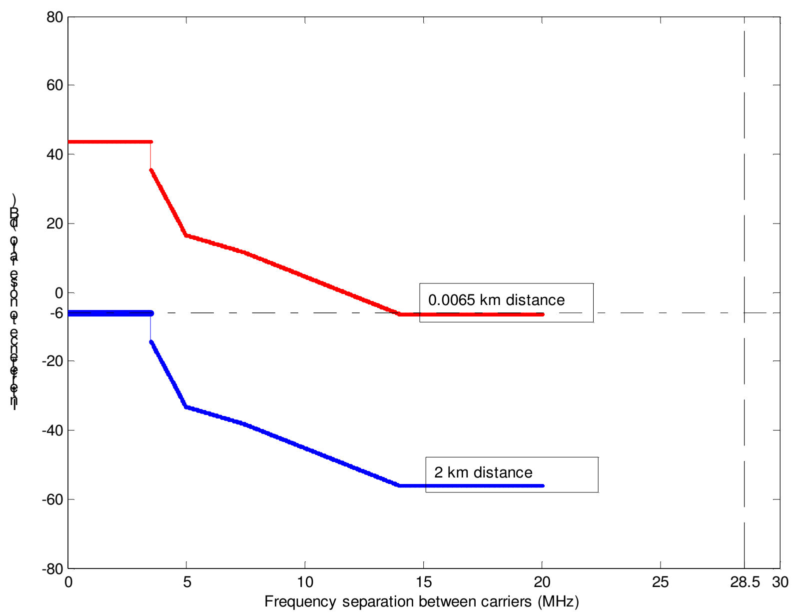

FIGURE 5: Interference from FWA into IMT-Advanced (50MHz)

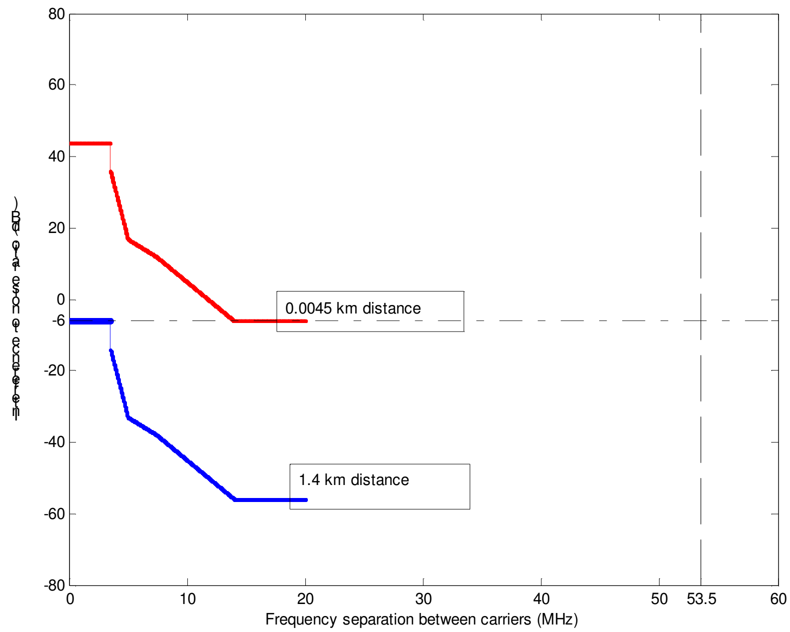

FIGURE 6: Interference from FWA into IMT-Advanced (100MHz)

8.2.2 IMT-Advanced BS Interference on FWA BS

As mentioned earlier, adjacent channel interference is used in this section, therefore the Additional isolation needed for certain distances can be extracted and expressed by

$$\mathrm{A}_{addiso} = Pt + G_t + G_r - L_p - ACIR - I_{\mathrm{limit}} \qquad (7)$$

Where G_t is transmitter antenna gain, G_r is victim receiver antenna gain, L_p is propagation path loss, and I_{limit} is Interference Limit. The equation (7) can be represented by the following expression.

$$\mathrm{A}_{addiso} = ACI - I_{\mathrm{lim}\,it} \qquad (8)$$

Where ACI is adjacent channel interference which it should be minimum as much as possible. Figure 7 clarifies the high values of the additional isolation needed against separation distance for coexisting and sharing the same frequency band (3500MHz) when interference from IMT-Advanced BS on FWA BS is applied. The co-channel interference produces high additional isolation values ranging from 55dB (100MHz) to 62dB (20MHz) which are required for coexisting at a distance of 8km. In case of adjacent frequency bands, these additional isolation values are decreased to be 0dB at 5.5km, 3.5km, and 2.5km for 20MHz, 50MHz and 100MHz IMT-Advanced channel bandwidth, respectively, as shown in the Figures 8, 9 and 10. A negative value in the Figures signifies that the isolation provided by the standard equipment is sufficient to limit the interference in that particular case to acceptable levels and the absolute value indicates the size of the 'margin' available in the adjacent channel protection. As mentioned earlier, the interference to noise ratio is the considered protection criteria here, it is shown in the Figures11, 12 and 13 the amounts of interference noise ratio versus separation distance between BSs in case co-channel and adjacent channel frequencies. These Figures indicate that there is no communication possibility for the assumed scenarios between the two BSs except in the case of the third adjacent channel frequency and above provided achievement the required separation distances as in the Figures below.

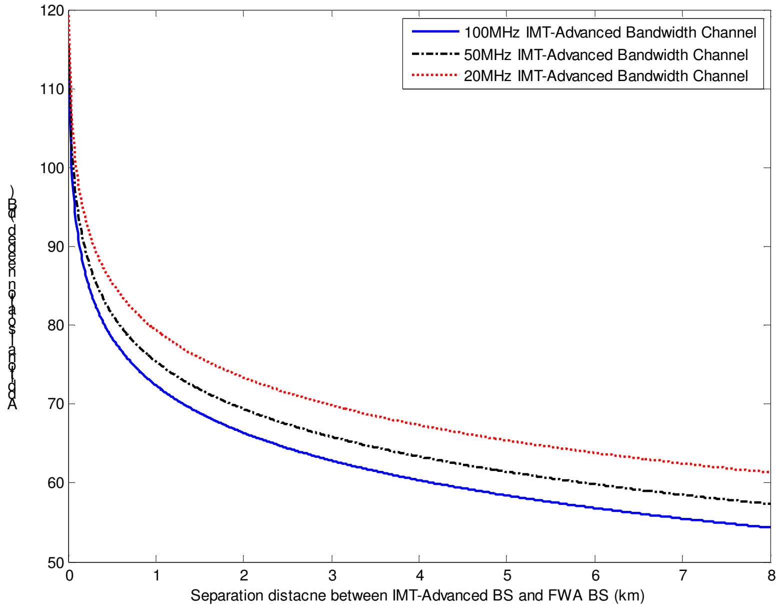

FIGURE 7: Required Additional Isolation When FWA is Victim (Co-Channel Frequency Sharing)

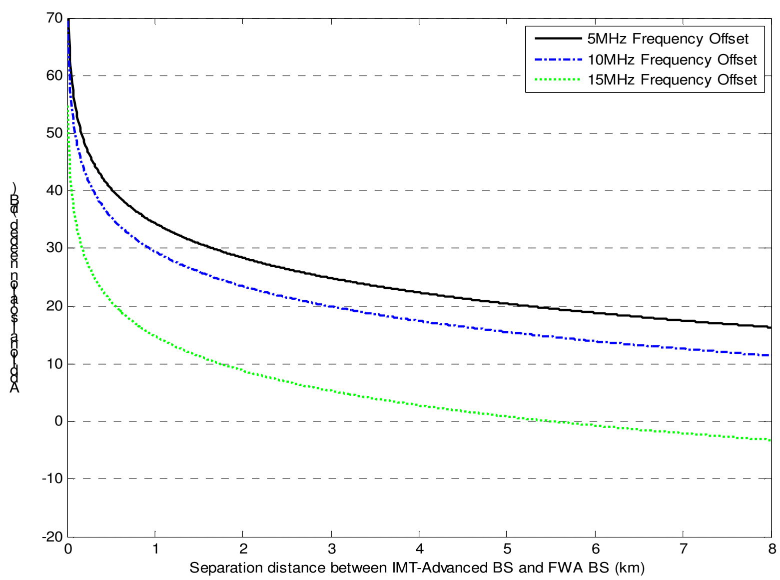

FIGURE 8: Required Additional Isolation When FWA is Victim (IMT-Advanced 20MHz)

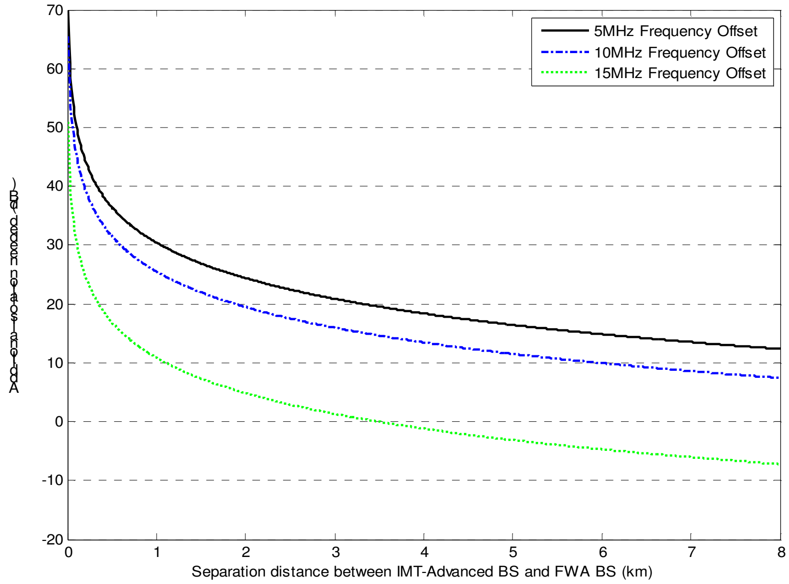

FIGURE 9: Required Additional Isolation When FWA is Victim (IMT-Advanced 50MHz)

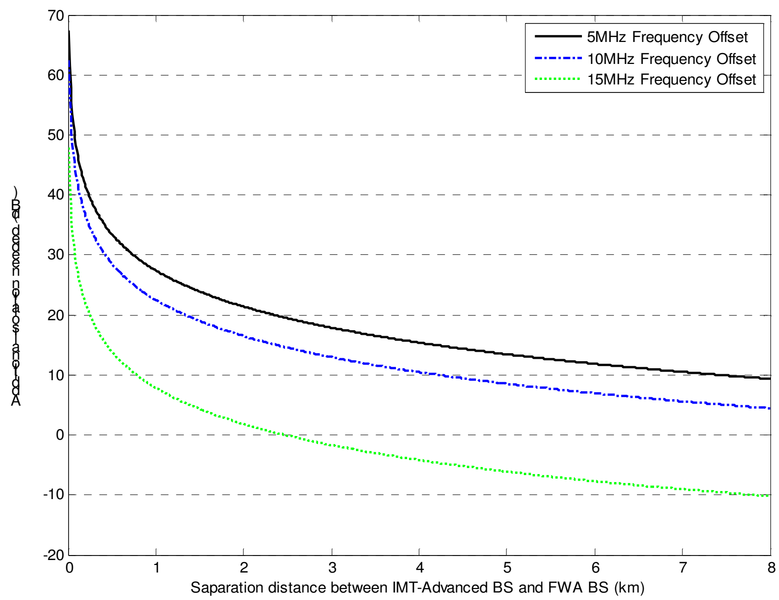

FIGURE 10: Required Additional Isolation When FWA is Victim (IMT-Advanced 100MHz)

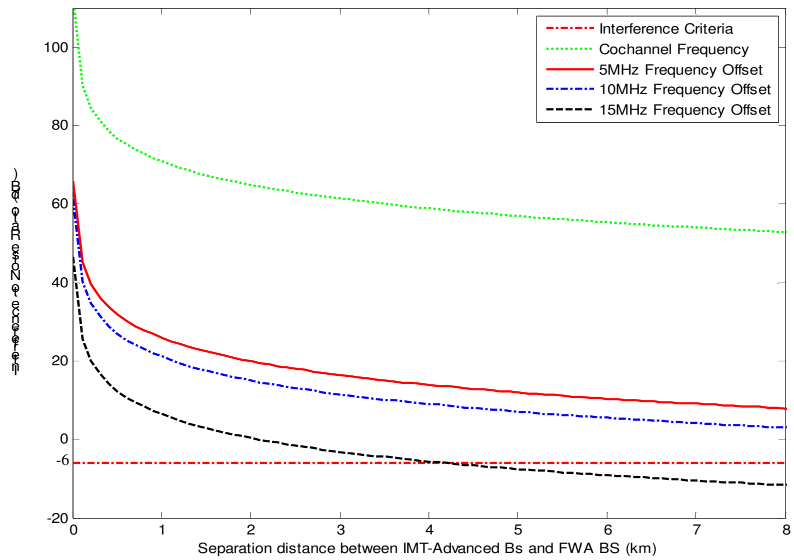

FIGURE 11: Interference from IMT-Advanced (20MHz) into FWA (7MHz)

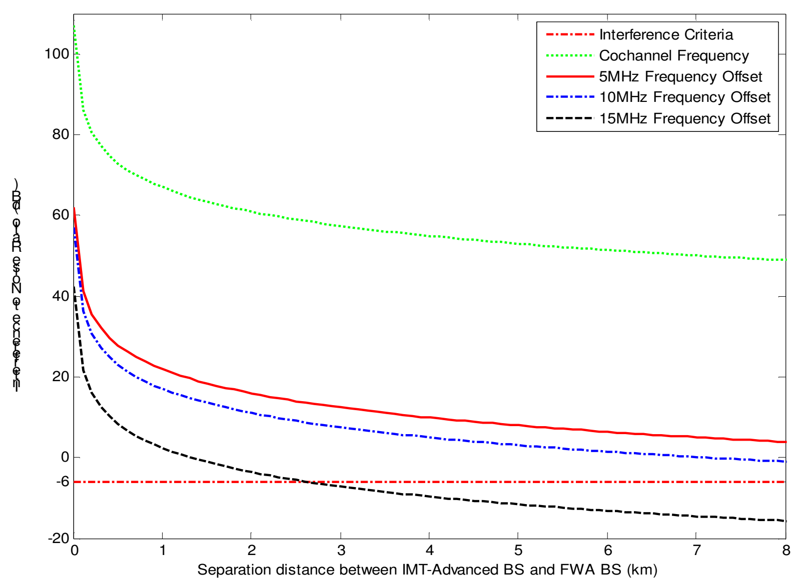

FIGURE 12: Interference from IMT-Advanced (50MHz) into FWA (7MHz)

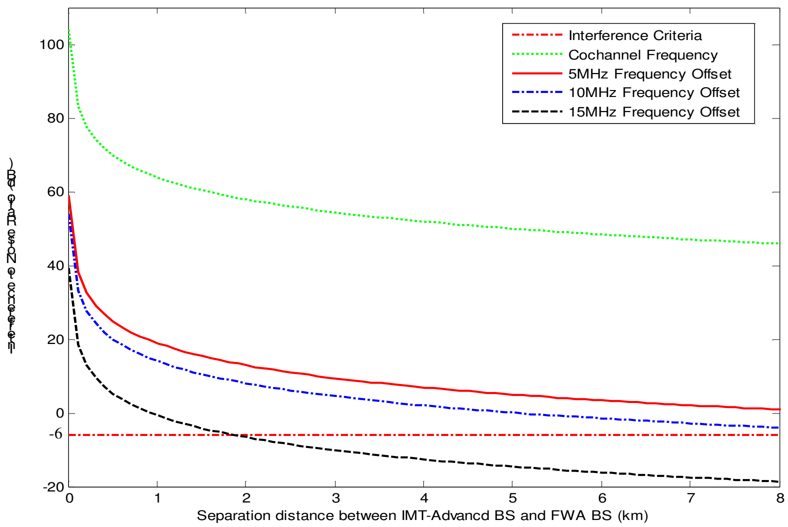

FIGURE 13: Interference from IMT-Advanced (100MHz) into FWA (7MHz)

9. ANALYSIS & COMPATIBILITY

With equipment that just conforms to the standards, it is unlikely to be possible to use a macrocellular IMT-Advanced BS in the same area as a macrocellular FWA BS if LOS path exists between the two antennas and each site is in the main beam of the other site's antenna (i.e., a worst case scenario) without mitigation techniques. As shown in Table 9, by taking ACIR into account, if the BSs operate on the same radio channels they can not coexist for a distance of 8 km or less, because the additional isolation values are 55 dB as aforementioned from the figures. However, coexistence the two BSs in co-channel frequency can be achieved for different separation distances when spectral emission mask of FWA BS is applied as in Table 8. Using ACIR, it makes 1st and 2nd Adjacent channels offsets useless even up to 8 km separation, while 14 MHz adjacent channels may be used for the separation distances in Table 8.

The results indicate that interference impacts form IMT-Advanced on FWA is more worst than the interference from FWA into IMT-Advanced, This is because of the effect of ACIR is more strict than spectral mask of FWA system, high power and high antenna gain of IMT-Advanced system. For coexistence reliability, either or both large separation distance and more frequency separation should be achieved. Therefore, the minimum separation distance and frequency separation in Table 9 should be taken into account for deploying the two systems without an interference mitigation technique because it represents the worst case scenario between them. This means that (when FWA is a victim) the coexistence is feasible only for the 3rd adjacent channel frequency (15MHz) at separation distances of 4km, 2.3km, and 1.8km for IMT-Advanced bandwidths of 20MHz, 50MHz and 100MHz, respectively.

IMT-Advanced Bandwidth	Co-channel Frequency		Adjacent Channel Frequency		Required Guard Band	
	km	MHz	km	MHz	km	MHz
100 MHz	1.4	0.0	0.0045	14	------	NO
50 MHz	2	0.0	0.0065	14	------	NO
20 MHz	3.25	0.0	0.01	14	0.01	0.5

Table 8: The Possible Minimum Separation Distance and Frequency Offset To Achieve Coexistence When IMT-Advanced BS is Victim (Using Spectral Emission Mask)

IMT-Advanced Bandwidth	Co-Channel Frequency	Adjacent Channel Frequency		
		offset @ 5MHz	offset @ 10MHz	offset @ 15MHz
100 MHz	NO	NO	NO	1.8km
50 MHz	NO	NO	NO	2.3km
20 MHz	NO	NO	NO	4km

Table 9: Possible Minimum Separation Distance (Less Than 8 Km) to Achieve Coexistence When FWA BS is Victim (Using ACIR)

10. ADDITIONAL ISOLATION BALANCE & INTERFERENCE MITIGATION

There are many intersystem interference mitigation techniques which may be applied to reduce interference and increase isolation between systems. The suggested mitigation techniques which are able to compensate additional isolation and get *I/N* ratio high are as follows.

10.1 Site Engineering Techniques

The techniques mentioned in [27] and [28] aim to improve antenna coupling and isolation, they can be categories into co-sited antennas techniques like, vertical separation (vertical end-to-end), horizontal separation (side-by-side) and horizontal separation (back-to-back). Also non co-sited antennas techniques using down tilt the antennas and mounting the antennas at different heights.

10.2 Transmitter & Receiver Equipments Enhancement

Improving of ACLR of transmitter, ACS of receiver and thus improving net filter discrimination lead to reduce interference between systems. Strict spectral emission mask may be provide a coexistence environment as well [25], [26].

10.3 Additional Filtering

In order to reduce the interference between systems operating in adjacent frequency bands an additional filtering is included to improve the transmitter ACLR and /or the receiver ACS. Filtering can add 9 to15dB improvements at 5MHz offset, 68dB at 10MHz offset [28], while, power amplifier linearization techniques can achieve 18dB at 5MHz offset and 13dB at 10MHz offset 60dB attenuation with minimal insertion loss is achievable with readily available low cost technology [29].

10.4 Antenna Adjustment

This scheme includes antenna polarization, antenna azimuth and antenna discrimination, it may be used to lower interference impacts [24], [28].

10.5 Transmission Power Reducing

The automatic power control is being used in the most existing cellular systems. To achieve the same coverage with less power more base stations may be required. Alternatively reducing propagation losses can be employed by moving of the base stations to be closer to the system users. This mechanism provides 0 to 15dB isolation for all interference modes [23], [25].

10.6 Smart (Adaptive) Antenna

Smart antenna [20] systems employ digital signal processing and introduce the concept of beam agility (beam forming), null steering and represent an evolutionary step in BS implementation. With this capability, smart antennas can ‘track’ users and, by dynamically adapting the composite beam pattern, realize significant Signal to Interference Ration (SIR) gains that, in turn, can be used to improve coverage and/or capacity and reduce interference caused to and received from other networks operating in the vicinity especially in mobile. Smart antennas provide a little impact on ‘peak’ interference but do significantly reduce the probability of interference. They can also substantially reduce the system sensitivity to incoming interference, particularly in the case of the more advanced MIMO systems, which are a core feature of IMT-Advanced, and mobile WiMAX systems [30].

11. CONCLUSION

The additional isolation, separation distance and frequency separation required to protect interference are calculated and simulated. From above analysis and results, the most severity interference appears at co-located BSs scenario and the effect of ACIR is stricter than spectral emission mask for adjacent channel coexistence. Methods for enabling the coexistence of both systems would be inevitable especially at small geographical offset between two systems and at co-channel, 1st and 2nd adjacent channels frequencies. In general, the BSs which are either co-sited or non co-sited may be require antenna adjustment, additional filtering and site engineering to facilitate coexistence and sharing between the two terrestrial systems. Therefore, in order to help and ease both systems to operate together at either co-channel or adjacent channel mitigation techniques must be deployed and developed.

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