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SPECTRUM SHARING STUDIES OF IMT-ADVANCED AND FWA SERVICES UNDER DIFFERENT CLUTTER LOSS AND CHANNEL BANDWIDTHS EFFECTS

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Abstract—Spectrum sharing between wireless systems becomes a critical issue due to emerging new technologies and spectrum shortage. Recently, IMT-Advanced system has been allocated in the same frequency band (3500 MHz) along with fixed services on co-primary basis, which means that harmful interference probability may be transpired. Channel bandwidths (BW) and natural of deployment areas of wireless systems are of the main effective factors in spectrum sharing. Spectrum Emission Mask (SEM) model will be used to study these factors effects beside the interference to noise ratio (I/N) as a fundamental criterion for coexistence and sharing between systems. The frequency and distance separation and antenna height effects are essential to be investigated to achieve spectrum sharing.

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. Concerning the different systems of International Mobile Telecommunication (IMT-Advanced) and Fixed Wireless Access (FWA) systems, it is natural to conclude that these technologies will work in the same environment that leads to occurrence of performance degradation. Main mechanisms of coexistence are in co-channel and adjacent channel. Formerly FWA system band has been allocated in the frequency band 3400–3800 MHz. At the same time, the 3400–3600 MHz frequency band is identified at World Radiocommunication Conferences 2007 (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. C-band (3400–4200 MHz) is characterized by excellent features, such as lower atmospheric absorption, high degree of reliability, wide coverage , and low rain attenuation particularly in tropical geographical areas [2, 3]. In some administrations, FS is not deployed in the sub-band 3400–3600 MHz. A few studies were done between terrestrial systems in the said band because this band was not used for mobile, since the mobile uses bands lower than 3 GHz for better transmission characteristics as in WCDMA where it is used up to 2690 MHz.

There are several studies have been done to investigate the interference using carrier to interference ratio C/I within the same system [4–7]. Our study will focus on interference and coexistence issue between two systems using interference to noise ratio I/N as coexistence and interference protection criteria between systems.

Some of recent coexistence studies which were carried out in the band (3.5 GHz) are in [8, 9]. In [8] 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 [9], BWA system represented by FWA is studied to share the same band with point-to-point fixed link system also to determine the minimum separation distance and frequency separation. In our study different BWs, frequency offsets from the carrier frequency and dense urban area clutter loss are proposed to study their effects on sharing the band 3.5 GHz. WiMAX is the candidate technology for IMT-Advanced systems; therefore some parameters of WiMAX will be used instead of IMT-Advanced which are not officially released.

The paper is organized as follows: In Section 2, different clutter loss areas are introduced, and the propagation model of spectrum sharing studies is investigated. In Sections 3 and 4, systems bandwidth and sharing analysis will be introduced. Sections 5 and 6, sharing scenarios and simulation results will be made. Finally, conclusions will be explored in Section 7.

2. DIFFERENT DEPLOYMENT AREAS

The most geographical areas considered where WiMAX (fixed, nomadic and mobile) technology will be operated and deployments can be profitable [10] are dense urban and rural (the availability of other alternatives is limited) as well as low profitable in suburban and urban (medium population densities and high availability of other access network alternatives). For different sharing studies, particularly, there is no single propagation model used because of the particular deployment of the systems requires using specific propagation model relevant to the specific system. WiMAX operates in line or non-line of sight environment. The standard model agreed upon in CEPT and ITU for a terrestrial interference assessment at microwave frequencies is clearly marked in ITU-R P.452-12 [11]. This model is used for this sharing study and includes free space loss and the attenuation due to clutter in different environments.

This attenuation Ah is loss due to protection from local clutter or called clutter loss, and is given by the expression:

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

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 [11], 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 in clutter loss, as shown in Table 1 and Figure 1 for above mentioned four categories. In our paper, the dense urban clutter category will be considered to show clutter loss effects.

Table 1. Nominal clutter heights and distances.

Clutter Category	**Clutter Height** ha **(m)**	**Nominal Distance** d_k **(Km)**
Rural	4	0.1
Suburban	9	0.025
Urban	20	0.02
Dense urban	25	0.02

3. SYSTEMS BANDWIDTHS

Channel bandwidths can be defined through SEM which is used as a spectrum sharing model in this paper. Three channel BWs are chosen for mobile WiMAX (5 MHz, 10 MHz and 20 MHz) to investigate on coexistence and sharing, while the channel band width for FWA will be fixed value (7 MHz). Therefore the following Table 2 clarifies the SEM for both WiMAX and FWA systems for the mentioned BWs.

Table 2. Reference frequencies for SEM of Type-G (WiMAX) and Type-F (FWA) ETSI-EN301021.

Freq./Ch. Separation (Normalized) (MHz)		**0**	**0.5**	**0.5**	**0.71**	**1.06**	**2**	**2.5**
Ch. Spacing (MHz)		dB						
		0	0	−8	−32	−38	−50	−50
Type-G	5	0	2.5	2.5	3.55	5.3	10	12.5
	10	0	5.0	5.0	7.1	10.6	20	25
	20	0	10	10	14.2	21.2	40	50
Ch. Spacing (MHz)		dB						
		0	0	−8	−27	−32	−50	−50
Type-F	7	0	3.5	3.5	4.97	7.42	14	17.5

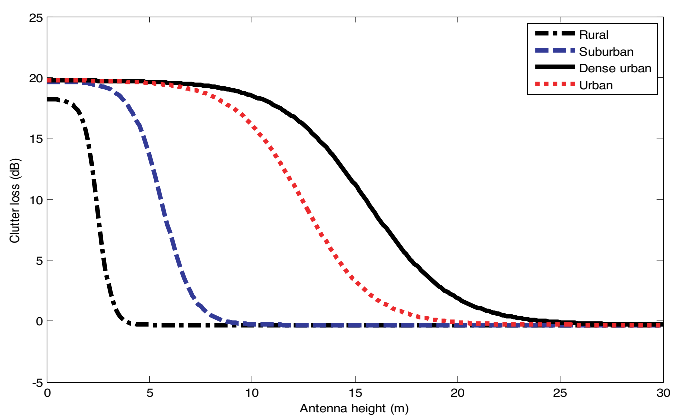

Figure 1. Clutter loss for rural, suburban, urban, and dense urban areas.

4. SYSTEMS SHARING ANALYSIS

The two systems can be coexisted if the sharing fundamental criterion is achieved. The coexistence and 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

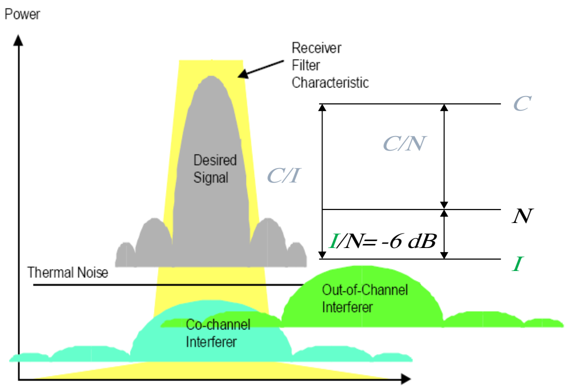

Figure 2. Types of interference and coexistence criterion.

C/I as shown in Figure 2 [12]. ITU-R Recommendation F.758-2 details two generally accepted values for the interference-to-thermal-noise ratio (I/N) for long-term interference into fixed service receivers. 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.

Figure 2 shows the main two scenarios co-channel and adjacent channel interference which can be considered for sharing studies. An I/N of -6 dB is the fundamental criterion for coexistence [13, 14], so it should be:

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

where I is the interference level in dBm from co-channel or adjacent channel interferer, and is given by:

$$I(\Delta f) = Pt + Gt + Gr + Mask(\Delta f) + corr\_band - Att \tag{3}$$

where

Pt: transmitted power of the interferer in dBm,

Gt: gain of the interferer transmitter antenna in dBi

Gr: gain of the victim receiver antenna in dBi

Mask(Δf): attenuation of adjacent frequency due to mask where Δf is the difference between the carriers of interferer and the victim. The attenuation can be derived by using the Equations of a Straight Line.

corr_band: denotes correction factor of band ratio and depends on bandwidth of interferer and victim, where,

$$corr\_band = \begin{cases} -10\log\left(\frac{BW_{\text{interferer}}}{BW_{\text{victim}}}\right)\text{dB} & \text{if} \quad BW_{\text{interferer}} \geq BW_{\text{victim}} \\ 0\,\text{dB} & \text{if} \quad BW_{\text{interferer}} < BW_{\text{victim}} \end{cases} \tag{4}$$

Att: attenuation due to the propagation in free space and clutter loss as in Eq. (1).

N is the thermal noise floor of receiver in dBm,

$$N = -114 + NF + 10\log_{10}(BW_{\text{victim}}) \tag{5}$$

where NF is noise figure of receiver in dB and BW_{victim} represents victim receiver bandwidth in MHz. α is the protection ratio in dB and has value of -6 dB which means that the interference must be approximately 6 dB below thermal noise as depicted in Figure 2.

5. SHARING SCENARIOS

The coexistence and sharing scenarios which can occur between IMT-Advanced and FWA systems are base station (BS)-to-BS, BS-subscriber station (SS), SS-to-BS, and SS-to-SS. As mentioned in previous study [14], BS-to-SS, SS-to-BS, and SS-to-SS 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 WiMAX and FWA, and will be analyzed as a main coexistence challenge case for two systems. The worst case for sharing between WiMAX and FWA is simulated where each BS face the BS of other system. All FWA links utilize directional antennas, however, antenna patterns are not considered at all except for the maximum antenna gain in link budget, so it is assumed they are considered as omnidirectional in order to study the worst case scenario. The following Figure 3 describes the considered sharing scenario.

The BSs parameters in Figure 3 of two systems are detailed in Table 3 and Equations (2)–(5). SEM Type-G is applied to interference from WiMAX, while Type-F is applied when WiMAX is victim and FWA is interferer.

6. RESULTS AND DISCUSSIONS

The analytical studies in Sections 6.1 and 6.2 have considered that antenna heights are fixed at 20 m to carry out coexistence feasibility between WiMAX and FWA. Antenna height of 20 m means that clutter loss provides isolation of 2.7 dB to prevent interference in dense urban area.

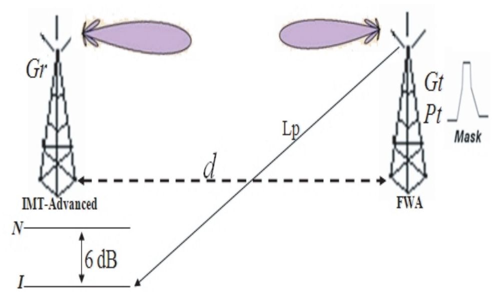

Figure 3. The simulated scenario between WiMAX BS and FWA BS.

Table 3. WiMAX and FWA systems parameters.

Parameter	**Value**	
	WiMAX	**FWA**
Center frequency of operation (MHz)	3500	3500
Bandwidth (MHz)	5, 10, 20	7
Base station transmitted power (dBm)	43	35
Spectral emissions mask requirements	ETSI-EN301021	
	Type G	Type F
Base station antenna gain (dBi)	18	17
Base station antenna height (m)	20	20
Noise figure of base station (dB)	4	5

6.1. Interference from WIMAX BS on FWA BS

Figures 4–6 show the interference from WiMAX (5 MHz, 10 MHz, and 20 MHz) into FWA (7 MHz) in terms of I/N ratio, co-channel, adjacent channel, and zero guard band between the two systems. In these figures, the separation distances are 30 km, 25 km, and 17.5 km at frequency offsets from carriers of 10 MHz, 20 MHz and 40 MHz, for 5 MHz, 10 MHz, and 20 MHz WiMAX channel BW, respectively. For deploying the two systems with a null guard band the separation distances must be greater than 95 km, 150 km, and 220 km for same WiMAX BW. Note that zero guard band is represented by a vertical line in the figures.

Sharing the same channel (co-channel) is feasible between two systems only in case of separation distances that are of the order of 9500 km, 7800 km and 5500 km for the same channel BW, because at these distances the interference is always 6 dB or more below the thermal noise floor as shown in the figures.

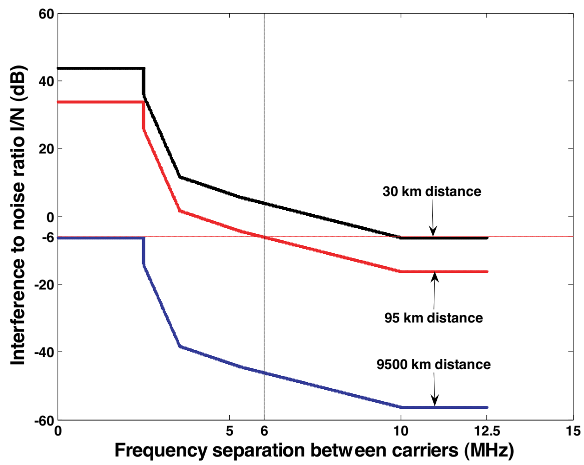

Figure 4. Interference from 5 MHz WiMAX into 7 MHz FWA.

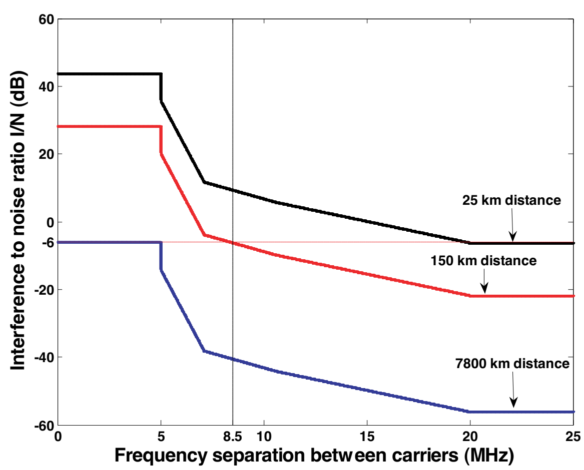

Figure 5. Interference from 10 MHz WiMAX into 7 MHz FWA.

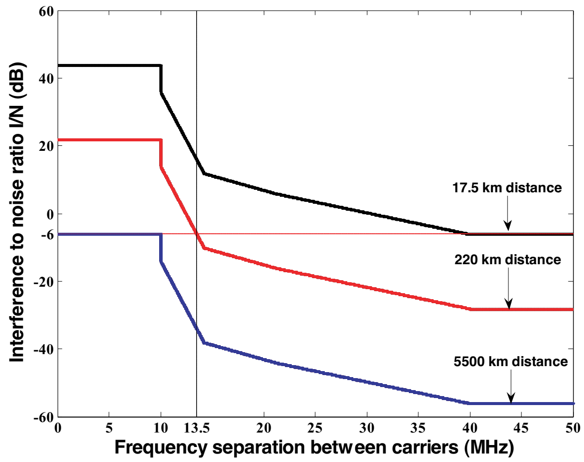

Figure 6. Interference from 20 MHz WiMAX into 7 MHz FWA.

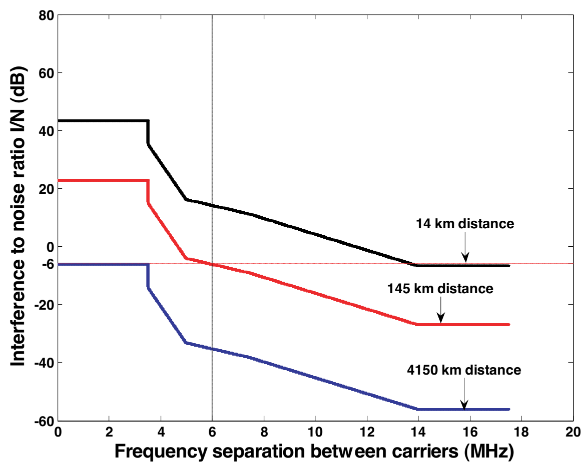

Figure 7. Interference from 7 MHz FWA into 5 MHz WiMAX.

6.2. Interference from FWA BS on WiMAX BS

Similarly, Figures 7–9 describe the interference from FWA (7 MHz) into WiMAX (5 MHz, 10 MHz, and 20 MHz) in terms of I/N ratio, co-channel, adjacent channel, and zero guard band between the two systems. Here, interferer is FWA system assumed to be fixed channel bandwidth with fixed spectral emission mask. In the three plots, it is clearly observed that the co-channel coexistence can be satisfied as distance between base stations of two systems increases, where the minimum separation distance is 4150 km, 3500 km and 2450 km for WiMAX channel BW of 5 MHz, 10 MHz and 20 MHz, respectively. In order to deploy the two systems in adjacent band, the minimum frequency separation is 14 MHz while the minimum separation distance must be greater than 14 km, 11 km, and 7.8 km.

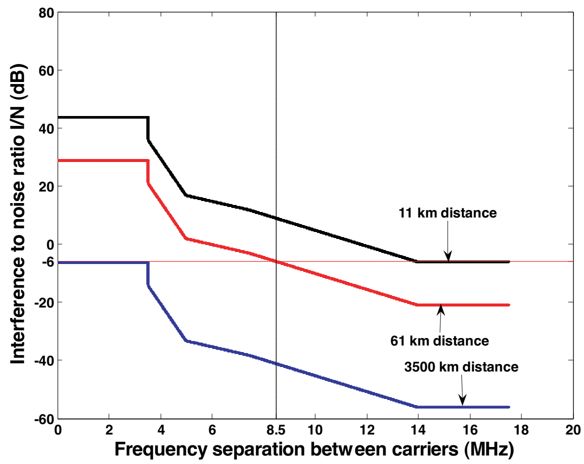

Figure 8. Interference from 7 MHz FWA into 10 MHz WiMAX.

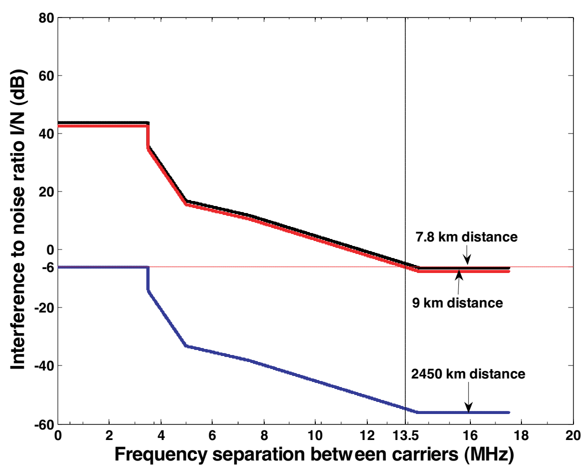

Figure 9. Interference from 7 MHz FWA into 20 MHz WiMAX.

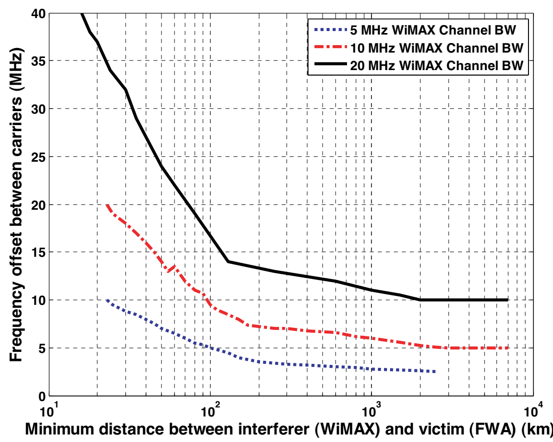

Figure 10. Minimum separation distance in dense urban area versus frequency offsets when WiMAX is the interferer.

Deploying FWA BS and WiMAX BS with zero guard band separation can be satisfied provided both separation distance and frequency separation are taken into account as shown in the figures.

6.3. Bandwidth and antenna height Effects

In Figure 10, the minimum separation distance in dense urban areas versus frequency separation from the carrier frequency is summarized for the three selected channel BW of WiMAX service. The results indicate that the required distance and frequency separation increase as interference bandwidth increases and vice versa. From Figure 10, in order to initiate the operation of WiMAX and FWA simultaneously, the frequency offset has to be larger than half of the nominal system BW. For example, for 5 MHz WiMAX channel BW it should be larger than 2.5 MHz. Frequency offset less than that would require very high separation distances.

Figure 11 depicts the required minimum separation distance versus antenna height of the FWA system BS as a victim and 10 MHz WiMAX BW in dense urban area. In the plot it is clearly observed that the increment of minimum required distance corresponds to the increase in the antenna height at the base station, and the minimum required distance no longer increases when the antenna height is higher than the clutter height. It is clear from the Figure 11 that the distance becomes constant for antenna height lower than 6 m and higher than

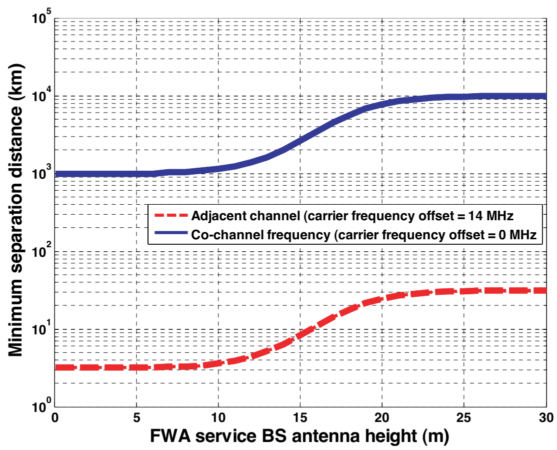

Figure 11. Minimum separation distance in dense urban area versus antenna height of FWA BS when 10 MHz WiMAX is the interferer.

28 m in dense urban area. This result is expected because the clutter loss increases as the clutter height increases, and the clutter loss values present a constant value when the antenna height higher than the clutter height. It should be noted that the results are more favourable for compatibility when using 20 MHz bandwidth channel for WiMAX which means higher data rates. Since the higher BW means higher noise bandwidth in receiver, which again means higher noise floor level. This allows the interfering signal to be stronger (in dBm) or the distance to be closer. The results also indicate that interference impacts from WiMAX on FWA is poor than the interference from FWA into WiMAX, this is because of the high power of WiMAX and SEM requirements.

7. CONCLUSION

Spectrum sharing and coexistence between systems is difficult to be achieved and depends on many factors such as systems specifications, propagation wave model, deployment area, interference type, etc. In this paper, spectral emission mask model have been used with different channel bandwidths, frequency separations and different receiver antenna heights for estimating the impact of interference between IMT-Advanced represented by WiMAX and FWA service. Comparative simulation results showed that the separation distance decreases when the channel bandwidth increases, and the clutter loss values present a constant value when the antenna height is higher than the clutter height, therefore the distance become constant also. Approximately, the distance remains constant for antenna height lower than 6 m and higher than 28 m in dense urban area.

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