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SIMULATION MODEL FOR COMPATIBILITY OF CO-SITED IMT-ADVANCED AND POINT TO MULTIPOINT SERVICES

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Abstract—3.5 GHz fixed wireless access system is a point-to-multipoint wireless technology providing broadband services. In this paper, point-to-multipoint fixed cellular service network structure such as Local Multipoint Distribution (LMDS) service is proposed to share same network area and frequency band (3400–3600 MHz) with the fourth generation of mobile (IMT-Advanced) represented by mobile Worldwide Interoperability for Microwave Access (WiMAX) service on base of co-sited systems. As a result of space and frequency domain sharing, harmful interference probability may be transpired between the two services. Different network cell sizes and different channel bandwidths were considered in dense urban area to investigate the intersystem interference effects based on the average interference to noise ratio *INR* as a fundamental criterion for coexistence and sharing coordination between different systems. Adjusting of antenna discrimination loss is also proposed to facilitate the frequency efficiency and accomplish frequency sharing.

1. INTRODUCTION

LMDS or Local Multipoint Communications Services (LMCS) is an immediate extension of MMDS (Microwave Multipoint Distribution Systems) more focused on residential market services, and may eventually replace it. LMDS are delivering broadband services from a central transmitter or base station to fixed customer stations mounted on individual buildings, blocks of apartments, or buildings

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of residential as well as business customers within its cell size [1]. Spectrum for these systems has been allocated at various frequencies from 2500–38000 MHz (2.5–38 GHz) [2]. Due to scarcity of the frequency spectrum on one hand and the drastic growth demand for wireless communications on the other hand, many bands are allocated for more than one radio service and therefore the sharing is necessity. Because of all that, International Telecommunication Union for Radiocommunication (ITU-R) Working Party 8F (WP 8F) has allocated the frequency band 3400–3600 MHz for International Mobile Telecommunication-Advanced (IMT-Advanced) on co-primary basis with fixed services. This means that intersystem interference will be occurred and cause performance degradation [3, 4] within C-band (3400-4200) which is characterized by excellent propagation features [5, 6].

There are several studies have been done to investigate the interference using carrier to interference ratio C/I within the same system [1, 5–9]. Our study will focus on intersystem interference and compatibility issue between two systems using average interference to noise ratio INR as coexistence and interference protection criteria between systems.

Some recent coexistence studies were carried out in the band 3.5 GHz [3, 4] between IMT-Advanced service and FWA as a point to point service in different terrestrial areas, different clutter loss and different intersystem interference scenarios. In this paper, we are proposing that FWA is a point to multipoint (P-MP) service uses an LMDS service structure in the band 3500 MHz [10] and IMT-Advanced service will share the same tower with point to multipoint service on co-sited systems basis. Different network cell sizes will be taken into account to evaluate coexistence and also to determine the minimum separation in spectral frequency and geographical space domains. In our simulation, spectral efficiency by modifying the off axis angles will be examined at different bandwidths by determining the minimum frequency offsets from the carrier frequency within dense urban area for a network cell size of 6×6 kms. 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, the deployment network area is described, and the co-sited systems model and intersystem scenario are in detail explained. In Section 3, systems sharing analysis will be introduced. Section 4 presents antenna discrimination loss concept. The results are discussed in Sections 5 and 6. Finally, conclusions will be introduced in Section 7.

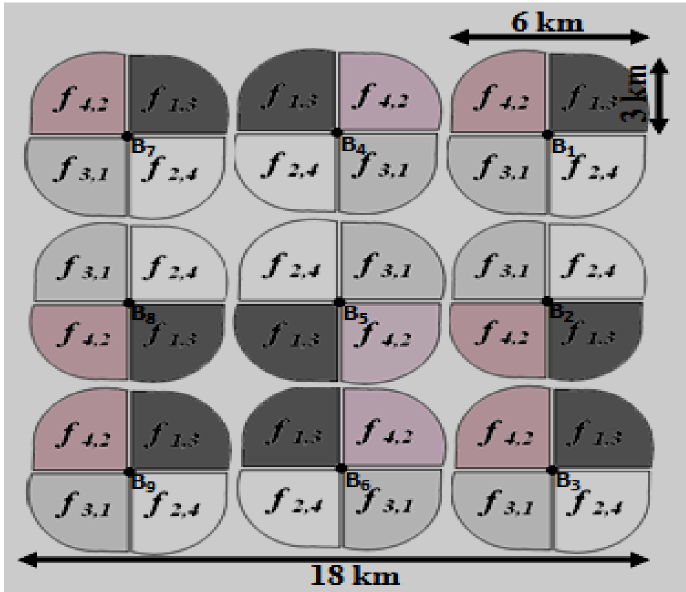

Figure 1. Establishing of IMT-Advanced and fixed services.

2. OPERATION NETWORK DESCRIPTION

According to [11,12] LMDS system network structure can be configured as in Fig. 1. *INR* conditions link budget directions are obtained. A frequency-sectored LMDS system applying 4-frequency and 90° sectorization with Time Division Multiple Access (TDMA) are investigated in the 3.5 GHz band, whereas IMT-Advanced employs Orthogonal Frequency-Division Multiple Access (OFDMA). The frequency sectorizations and the dominant interference situations are depicted in Fig. 3. The frequency duplex type is Time Division Duplex (TDD) for IMT-Advanced whereas LMDS employs Frequency Division Duplex (FDD). The different frequencies ($f_{1,3}$, $f_{2,4}$, $f_{3,1}$, and $f_{4,2}$) are signed by different color shades such that ($f_{x,y}$) means ($f_{\text{LMDS frequency, IMT-Advanced frequency}}$) as shown in Figs. 1–3. It is considered that the frequency band 3.4–3.6 GHz is equally divided within each cell such that every sector has a frequency bandwidth of 50 MHz. The two investigated services share nine masts for their BSs in a regular 3×3 BS configuration on co-sited antenna [13]. Both LMDS and IMT-Advanced cell in our simulation has a size of 6×6 kms; therefore a sector in each cell has a size (SeC) of 3×3 kms realizing an 18×18 kms LMDS coverage area. The used BSs antennas are a 90°

BFWA Sector Frequency	f_1= 3400-3450 MHz	f_2= 3450-3500 MHz	f_3= 3500-3550 MHz	f_4= 3550-3600 MHz
IMT-Advanced Sector Frequency	f_1= 3500-3550 MHz	f_2= 3550-3600 MHz	f_3= 3400-3450 MHz	f_4= 3450-3500 MHz

Figure 2. Sectors frequencies used for fixed and IMT-Advanced services.

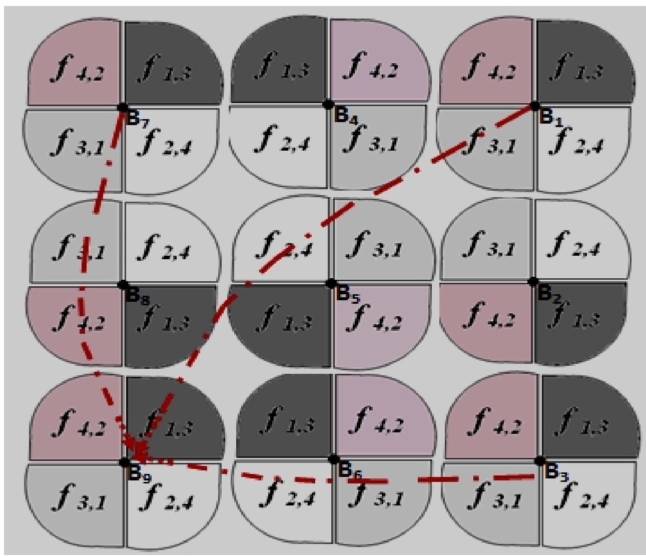

Figure 3. The simulated scenario between IMT-Advanced and fixed services.

space sectored antennas.

The coexistence and sharing scenarios which can occur between IMT-Advanced and FWA systems are base station (BS)-to-BS, BS-to-subscriber station (SS), SS-to-BS, and SS-to-SS. As mentioned by previous studies [3, 4, 14, 15] that, 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-to-BS interference is the most critical interference path between WiMAX and fixed services, and will be analyzed as a main coexistence challenge case for two systems. The worst case for sharing between WiMAX and fixed systems is simulated where interferers BSs affect BS of other

Table 1. WiMAX and fixed systems parameters.

Parameter	Value	
	WiMAX	FWA
Center frequency of operation (MHz)	3400 –3600	
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)	15	15
Clutter height (m)	25	
Nominal distance (km)	0.02	
Noise figure of base station (dB)	4	5
Up and Down link Duplex Type	TDD	FDD
Antenna Type	Sectored	

system. As seen from Fig. 3 that IMT-Advanced antenna at base station 9 ($B9$) suffers from three intersystem interference signals ($B1$, $B7$, and $B3$) (the intra-system interference is not considered here). Therefore, the separation distance between the interferer $B1$ and the victim BS (B9) antenna is $(\sqrt{((\mathrm{SeC})^2 + (\mathrm{SeC})^2)} \times 4)\,\mathrm{km}$, whereas $B3$ and $B7$ have an equivalent distance to the victim $B9$ of $(4 \times \mathrm{SeC})\,\mathrm{km}$. All geographical separation distances between every effective interferer base station and the victim base station are listed in Table 2. All FWA links utilize directional antennas, however, antenna patterns are not considered 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 BSs parameters in Fig. 3 of two systems are detailed in Table 1. Spectral emission mask Type-G European Telecommunications Standardisation Institute standard EN 301021 (Type-G ETSI-EN301021) [16] is applied to interference from WiMAX, while Type-F ETSI-EN301021 [16] is applied when WiMAX is victim and FWA is interferer. The resultant attenuation via mask can be represented by a linear equation on each segment with respect to frequency offset from

Table 2. Frequency offset, guard band, and the distance between interferer and victim in various coexistence scenarios and different network cell size.

Victim Receiver	WiMAX Band width (MHz)	Interference scenario	Network cell size (km)	Frequency offset from carrier (MHz)	Frequency guard band (MHz)	Interference d_1 distance (km)	Interference d_3 and d_7 distance (km)
LMDS	10	Adjacent Channel	3×3	Not Allowed	Not Allowed	8.4853	6
			4×4	19.650	11.15	11.3137	8
			5×5	18.126	9.626	14.1421	10
			6×6	16.858	8.358	16.9706	12
		Zero guard band	22.9×22.9	8.50	00.00	64.7710	45.8000
		Co-Channel	1201.3×1201.3	00.00	-8.50 (overlapping)	3397.8	2402.6
LMDS	20	Adjacent Channel	3×3	38.457	24.957	8.4853	6
			4×4	34.58	21.08	11.3137	8
			5×5	31.508	18.008	14.1421	10
			6×6	29.053	15.553	16.9706	12
		Zero guard band	33.8×33.8	13.50	00.00	95.6008	67.6000
		Co-Channel	849.49×849.49	00.00	-13.50 (overlapping)	2402.7	1699.0
WiMAX	10	Adjacent Channel	3× 3	12.158	3.658	8.4853	6
			4×4	11.255	2.755	11.3137	8
			5× 5	10.570	2.070	14.1421	10
			6×6	9.990	1.490	16.9706	12
		Zero guard band	9.6×9.6	8.50	00.00	27.1529	19.2000
		Co-Channel	536.6× 536.6	00.00	-8.50 (overlapping)	1517.7	1073.2
WiMAX	20	Adjacent Channel	3×3	11.09	-2.410 (overlapping)	8.4853	6
			4×4	10.176	-3.324 (overlapping)	11.3137	8
			5×5	9.468	-4.032 (overlapping)	14.1421	10
			6×6	8.890	-4.610 (overlapping)	16.9706	12
		Zero guard band	1.404×1.404	13.50	00.00	3.9711	2.8080
		Co-Channel	379.46×379.46	00.00	-13.50 (overlapping)	1073.3	758.9200

the carrier frequency:

$$Mask\_Attenuation\,(\Delta f) = af + b \tag{1}$$

where a represents the amount of attenuation in dB in the segment, f is the frequency offset from the carrier and b is the attenuation in dB at a certain frequency offset of f from the reference (0 dB is usually considered as a reference).

3. 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 INR, or carrier-to-interfering signal power ratio C/I [17].

In this paper, and according to ITU R F. 758-2, an INR of -6 dB is the fundamental criterion for coexistence and intersystem interference coordination [15, 18], and this can be justified as in Appendix A:

$$INR = I[\text{dBm}] - N[\text{dBm}] \leq \alpha \quad (\alpha = -6\,\text{dB}) \tag{2}$$

In case of point to multipoint system network, there are more than one interference signal will affect the victim receiver base station as shown above in Fig. 3, and thus:

$$INR = I_{total}[\text{dBm}] - N[\text{dBm}] \leq \alpha \tag{3}$$

$$I_{total} = \frac{\sum_{j=1}^{M} I_{Bj}(\Delta f)}{M} \tag{4}$$

where I_{total} represents the total interference received power at victim receiver in watt and M is number of the effective interferer base stations on victim receiver. In our case, there are three effective interference base stations (B_1, B_3, and B_7).

$$\begin{aligned} I_{total} &= \frac{\sum_{j=1}^{3} I_{Bj}(\Delta f)}{3} \\ &= \frac{I_{B1}(\Delta f)[\text{watt}] + I_{B3}(\Delta f)[\text{watt}] + I_{B7}(\Delta f)[\text{watt}]}{3} \end{aligned} \tag{5}$$

$$I_{Bj}(\Delta f)[\text{watt}] = 10^{\left(\left(I_{Bj}(\Delta f)[\text{dBm}]/10\right)\times 10^{-3}\right)} \tag{6}$$

$$\begin{aligned} I_{Bj}(\Delta f)[\text{dBm}] = {} & Pt[\text{dBm}] + Gt[\text{dBi}] + Gr[\text{dBi}] + MaskAtt(\Delta f)[\text{dB}] \\ & + Corr\_band[\text{dB}] + Losses_{dj}[\text{dB}] \end{aligned} \tag{7}$$

where Pt is transmitted power of the interferer, Gt and Gr are the gains of the interferer transmitter and the victim receiver antennas, and $MaskAtt(\Delta f)$ represents 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 straight line as in Eq. (1).

$Corr\_band$ denotes correction factor of band ratio and depends on bandwidth of interferer and victim receiver, where,

$$Corr\_band = \begin{cases} -10\log_{10}\left(\dfrac{BW_{\text{interferer}}}{BW_{victim}}\right)\text{ dB} & \text{if } BW_{\text{interferer}} \geq BW_{victim} \\ 0\text{ dB} & \text{if } BW_{\text{interferer}} < BW_{victim} \end{cases} \tag{8}$$

The interference signal power is from different base stations and it mainly depends on spectral mask and distance between each effective interferer base station and the victim receiver. The Losses are the propagation model effects and include free space and clutter loss attenuation and for our considered frequency (3500 MHz), the Losses formula becomes:

$$\begin{aligned} Losses_{dj}[\text{dB}] &= 103.33 + 20\log_{10}(dj) \\ &\quad + 10.25e^{-d_k}\left[1 - \tanh\left[6\left(\frac{h}{h_a} - 0.625\right)\right]\right] - 0.33 \end{aligned} \tag{9}$$

where dj denotes distance between each interferer base station Bj and the victim receiver, 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. Therefore, Eq. (4) becomes:

$$\begin{aligned} I_{total} &= \frac{\sum_{j=1}^{3} I_{Bj}(\Delta f)}{3} \\ &= \frac{\left[\begin{array}{l} 10^{\left((I_{B1}(\Delta f)[\text{dBm}]/10)\times 10^{-3}\right)} + 10^{\left((I_{B3}(\Delta f)[\text{dBm}]/10)\times 10^{-3}\right)} \\ +10^{\left((I_{B7}(\Delta f)[\text{dBm}]/10)\times 10^{-3}\right)} \end{array}\right]}{3} \end{aligned} \tag{10}$$

For deriving the thermal noise floor (N) of receiver in dBm, it depends on bandwidth and noise figure of victim receiver:

$$N[\text{dBm}] = -114 + NF + 10\log_{10}\left(BW_{victim}\right) \tag{11}$$

where NF is noise figure of receiver in dB and BW_{victim} represents victim receiver bandwidth in MHz. The interference to noise criterion can be expressed as a ratio in (12) or as a dB in (13):

$$INR = \frac{I_{total}}{10^{((N[\text{dBm}]/10)\times 10^{-3})}} \leq 0.26 \tag{12}$$

$$INR[\text{dB}] = 10\log_{10}\left(I_{total}/10^{-3}\right) - N[\text{dBm}] \leq -6\text{ dB} \tag{13}$$

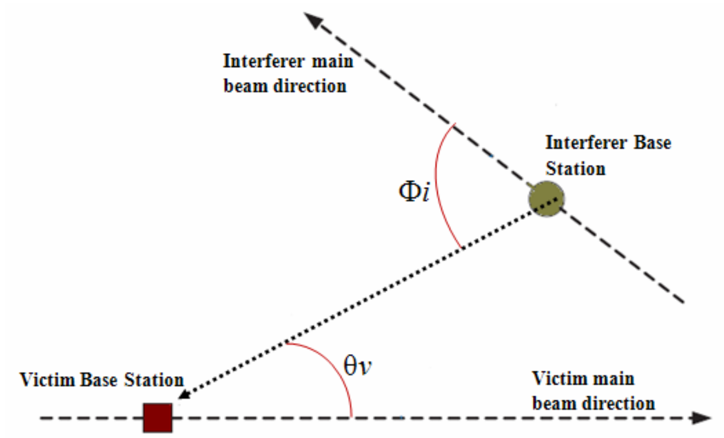

Figure 4. Interference scenario for one interferer base station to victim station with off axis angles Φi and θv.

4. ANTENNA DISCRIMINATION LOSS

Antenna discrimination is the differential gain compared to maximum for an antenna in the specified direction; usually, masks are provided for the main lobe, the first sidelobe, and other sidelobes [19]. Antenna discrimination loss is resultant from the antenna direction of the interferer transmitter and victim receiver services which is dependant on the off axis angles Φi and θv as in Fig. 4. Therefore, as it is seen from Fig. 4, the interference signal emitted from one interferer base station (it can be supposed that the same scenario is applied for the other effective interferers signals) impacts one victim base station. Any interferer signal goes under different losses which include propagation path loss, dense urban clutter loss, and antenna discrimination loss. As a result of presence more than one interferer signal (multi interferers) will influence the other receiver service, the interferer signals power from the aggressive base stations can be estimated as an average received power.

5. RESULTS AND DISCUSSIONS

The analytical studies in Sections 5.1 and 5.2 have considered dense urban area deployment. It is assumed that the victim $B9$ is the fixed service base station when the interference is coming from WiMAX as in Section 5.1, whereas Section 5.2 assumes that $B9$ is a victim WiMAX base station.

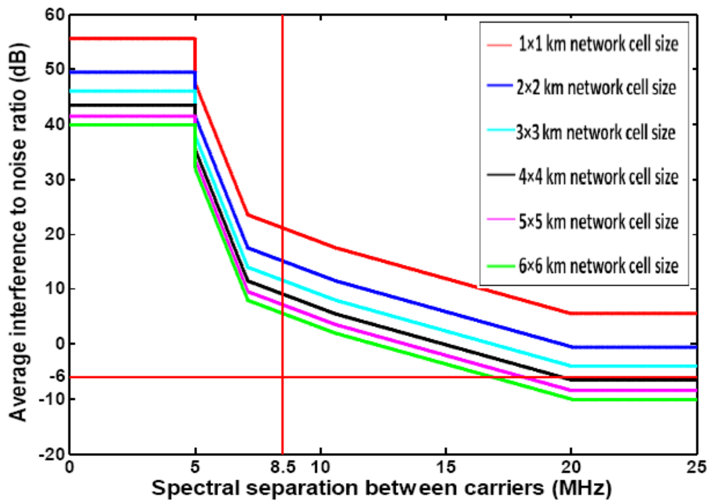

Figure 5. Interference within different network cell size (1×1 kms up to 6×6 kms) from 10 MHz WiMAX to 7 MHz FWA.

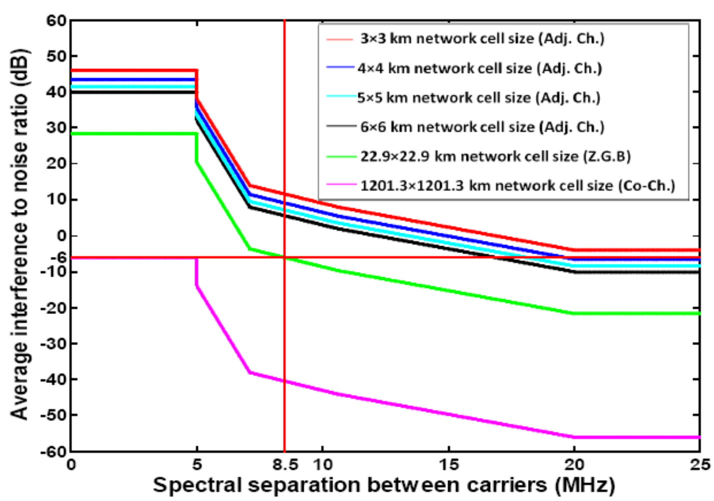

Figure 6. Intersystem interference scenarios in different network cell size from 10 MHz WiMAX to 7 MHz FWA.

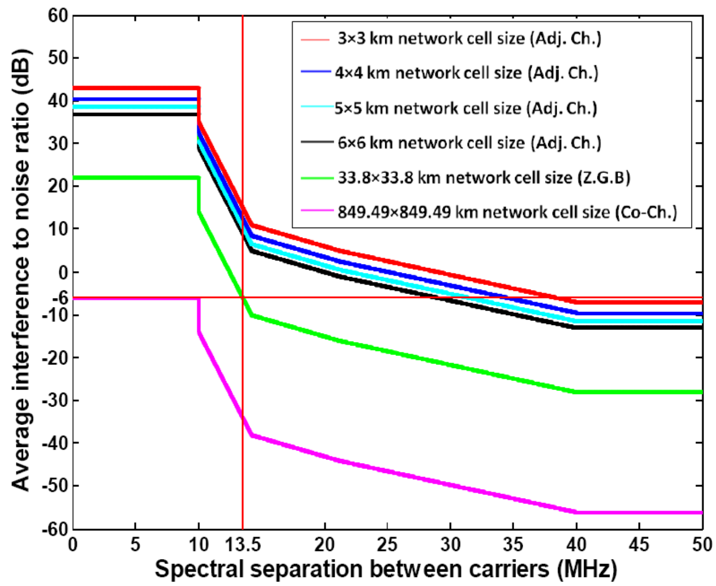

Figure 7. Intersystem interference scenarios in different network cell size from 20 MHz WiMAX to 7 MHz FWA.

5.1. Intersystem Interference When WiMAX is the Interferer Service

Figures 5–7 show the external interference effects into 7 MHz fixed service $B9$ from 10 MHz and 20 MHz WiMAX service in terms of INR ratio, co-channel, adjacent channel, and zero guard band between the two systems at different network cell sizes. Fig. 5 shows the interference from 10 MHz WiMAX channel band width within different network cell sizes of 1×1 kms, 2×2 kms, 3×3 kms, 4×4 kms, 5×5 kms, and 6×6 kms. Figs. 5–6 clarify that interference is harmful for 1×1 kms, 2×2 kms, and 3×3 kms, however, there is a possibility to coexist the two services by spectral frequency offset of 19.650 MHz, 18.126 MHz, and 16.858 MHz for deployment area with cell size of 4×4 kms, 5×5 kms, and 6×6 kms, respectively. By using 20 MHz WiMAX channel bandwidth, a cell size of 3×3 kms is valid for coexisting the two systems with a frequency separation of 38.457 MHz. Null guard band between WiMAX and fixed service is applicable if the network cell has a size of 22.9×22.9 kms and 33.8×33.8 kms for 10 MHz and 20 MHz WiMAX channel bandwidth, correspondingly. This is due to that at these network cell sizes the interference is always 6 dB or more below the thermal noise floor as shown in the figures.

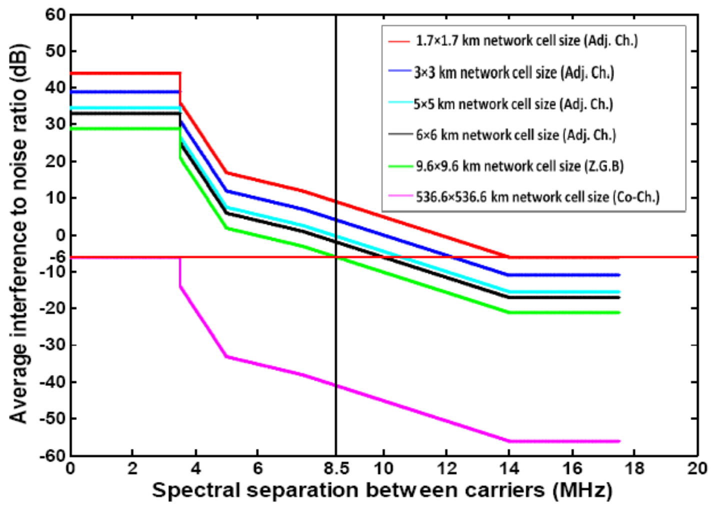

Figure 8. Intersystem interference scenarios in different network cell size from 7 MHz FWA into 10 MHz WiMAX.

The minimum network cell size for co-channel is 1201.3×1201.3 kms and 849.49×849.49 kms for 10 MHz and 20 MHz WiMAX channel bandwidth, correspondingly. These values are too large to be practically realizable. The detail analysis of how to share co-channel frequency has been done in further Section.

5.2. Intersystem Interference When WiMAX is the Victim Service

It can be seen from Figs. 8 and 9 that the largest frequency separation is 14 MHz because of the interferer has fixed channel bandwidth. In comparison with the interference from WiMAX service, the minimum network cell sizes here are smaller. These cell sizes are 1.7×1.7 kms and 1.2×1.2 kms by a frequency offset from the desired carrier frequency of 14 MHz for 10 MHz and 20 MHz channel bandwidth, in that order. Null guard band setting up is feasible for a cell size of 9.6×9.6 kms in case of 10 MHz WiMAX channel bandwidth, whereas it degrades up to 1.404×1.404 kms for 20 MHz WiMAX channel bandwidth. Similarly, co-channel frequency compatibility can be deployed within a network cell size of 536.6×536.6 kms and 379.46×379.46 kms for 10 MHz and 20 MHz, respectively.

All the above mentioned results are summarized in Table 2. The results indicate that more spectral separation between interferer and

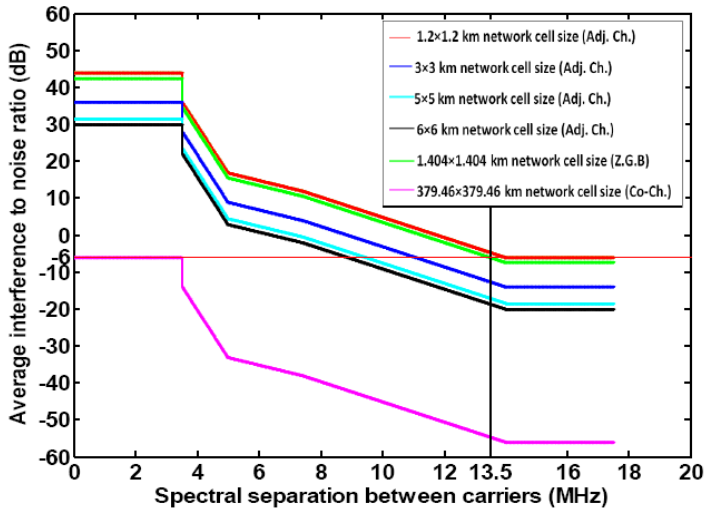

Figure 9. Intersystem interference scenarios in different network cell size from 7 MHz FWA into 20 MHz WiMAX.

victim services leads to an improvement in systems compatibility especially if the interferer has a bandwidth much less than that of victim receiver. Therefore the interference from fixed service has less serious effects than that of WiMAX depending on their parameters, and wave propagation.

6. FREQUENCY EFFICIENCY WITH ANTENNA DISCRIMINATION

6.1. Antenna Discrimination When WiMAX is the Interferer Service

It is clear from Fig. 10 which simulates a 6×6 kms network area that frequency efficiency goes better when antenna discrimination loss goes high. For example, for using co-channel scenario, the antenna discrimination loss should be not less than 47.58 dB, 46.03 dB, and 43.02 dB for WiMAX channel bandwidth of 5 MHz, 10 MHz, and 20 MHz, respectively. Minimum antenna discrimination attenuation of 35 dB, 38 dB and 39 dB is required for 5 MHz, 10 MHz and 20 MHz WiMAX channel bandwidth, correspondingly, to get peacefully coexistence at half WiMAX channel bandwidth frequency offset, this means that 2.5 MHz, 5 MHz and 10 MHz are the required frequency offset from the carrier frequency of FWA service for

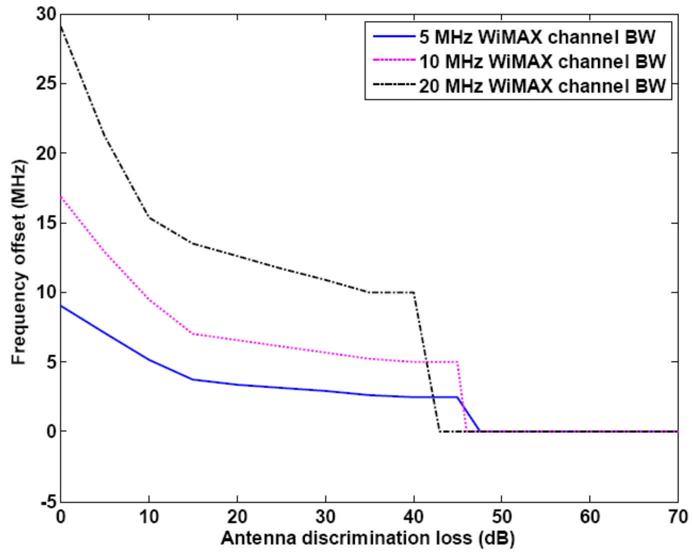

Figure 10. Effect of antenna discrimination loss on spectrum efficiency when interference from WiMAX into fixed service in case of 6×6 kms network cell size.

5 MHz, 10 MHz and 20 MHz WiMAX channel bandwidth, respectively. Moreover, for coexistence the two services by frequency offset equals to the same WiMAX channel bandwidth, it is needed to 10 dB, 9 dB, and 6 dB antenna discrimination loss for 5 MHz, 10 MHz, and 20 MHz respectively. These results indicate that achieving the same intersystem interference scenario by high channel bandwidth requires lower antenna discrimination loss than that in case of low channel bandwidth. This is due to high channel bandwidth is technically having high thermal noise floor which increases the margin between interference and noise floor and thus the required antenna discrimination loss becomes low.

6.2. Antenna Discrimination When WiMAX is the Victim Service

Similarly, Fig. 11 describes the intersystem interference from FWA service into WiMAX service when the network cell size is 6×6 kms under different antenna discrimination values. It is not like Fig. 10, the interference from fixed service into 5 MHz is poor than the interference from fixed service to 10 MHz and 20 MHz because of the interferer transmitter bandwidth is wider than that of the victim receiver. It

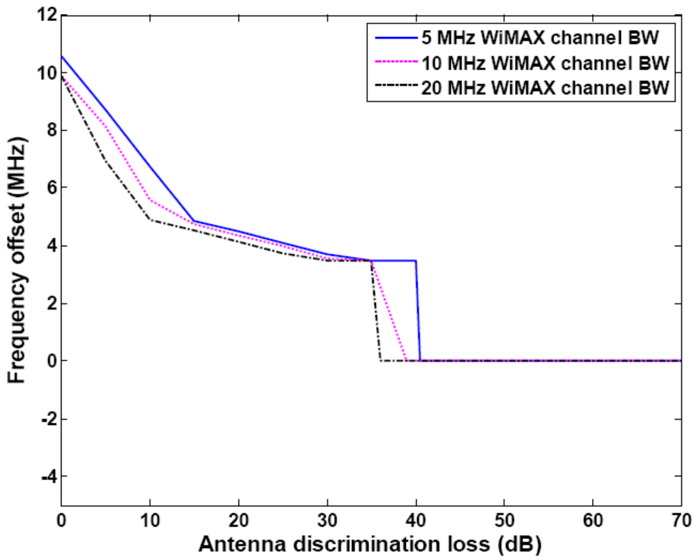

Figure 11. Effect of antenna discrimination loss on spectrum efficiency when interference from fixed into WiMAX service in case of 6×6 kms network cell size.

is shown that for intersystem interference coordination, 3.5 MHz (half of the fixed service frequency bandwidth) is the minimum frequency offset from the carrier frequency in order to initiate the operation of WiMAX and FWA simultaneously. This frequency offset is applicable for all WiMAX channel bandwidths because it depends on the assigned channel bandwidth of interferer spectral mask which here has a value of 7 MHz. Adjacent channel coexistence sharing requires antenna discrimination loss of 35 dB, 34.5 dB, and 29 dB in case of interference to 5 MHz, 10 MHz, and 20 MHz, respectively. Moreover, frequency sharing by co-channel may be valid for antenna discrimination loss of 40.58 dB, 39.03 dB, and 36.03 dB when channel bandwidth of WiMAX is 5 MHz, 10 MHz, and 20 MHz, in that order.

7. CONCLUSION

In the present study, we have introduced a simulated model for evaluating sharing and coexistence circumstances between IMT-Advanced represented by WiMAX and point-to-multipoint service. A coexistence analysis is thoroughly performed in this article based on co-sited of the base stations of two systems and applying the spectral emission mask in a 6×6 kms cellular network cell size. Average interference to noise ratio have been used with different channel bandwidths, and network cell sizes for estimating impact of intersystem interference between WiMAX and fixed service. Antenna discrimination loss have to be adjusted by modifying the off axis angles between WiMAX and fixed services to provide at least 47.58 dB, 46.03 dB, and 43.02 dB to achieve co-channel compatibility for WiMAX channel bandwidth of 5 MHz, 10 MHz, and 20 MHz, respectively. High spectral efficiency in intersystem interference situations could be satisfied by maintaining a significant antenna discrimination loss value.

APPENDIX A.

$$\begin{aligned}
((C/N) - (C/N + I))[\mathrm{dB}] &= 1\,\mathrm{dB} \\
C/N \Big/ C/N + I &= 1.26 \qquad \text{(as a ratio)} \\
(N + I) \Big/ N &= 1.26 \\
I/N &= 0.26 \\
I/N[\mathrm{dB}] &= -6\,\mathrm{dB}
\end{aligned}$$

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