Coexistence between WiMAX and Existing FWA Systems in the Band 3500 MHz

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***Abstract*—In this paper, the coexistence of WiMAX system and existing fixed wireless access (FWA) systems is studied. Spectral emission mask is used as well as interference to noise ratio (*I/N*) of -6 dB as one of standard sharing criterion value at FWA systems recommended by international telecommunication union radio sector ITU-R. Three channel bandwidths of (3.5, 7, and 10 MHz) of WiMAX system are selected to be studied with 7 MHz FWA channel in dense urban area. All parameters of the two systems are presented and methodology is explained. It is well known that frequency distance rules are an important of frequency coordination process in most radio services, so frequency and distance separations are determined and analyzed for both terms co-channel interference and adjacent channel interference in the different interference scenarios which are supposed.**

***Index Terms*—Coexistence and sharing, fixed wireless access (FWA) systems, interference-to-noise ratio, spectral emission mask, WiMAX systems.**

I. Introduction

The radio spectrum is a limited and valuable resource, and as a result of the drastic growth demand for wireless communication applications, radio spectrum regulation and management have become increasingly significant [1]. Due to scarcity of the frequency spectrum, many bands are allocated for more than one radio service and therefore the sharing is necessity. The increased sharing of spectrum translates into a higher likelihood of users interfering with one another [2]. WiMAX (worldwide interoperability for microwave access) is based on IEEE 802.16 standard [3] recently considered as the 3rd generation broadband wireless access (BWA) system designed mainly for wireless metropolitan area networks (WMAN) [4]. WiMAX addresses the last-mile BWA problem in metropolitan areas and underserved rural areas for the advantages of fast and cost-effective deployment, it uses the band 3500 MHz which is currently allocated to Fixed Wireless Access (FWA) systems. Therefore, the impact of the interference of WiMAX as a new technology on FWA systems and vice versa needs to be studied. The interest for the use of 3500 MHz band (3400-3800) for FWA/BWA applications has increased because its large size, high degree of reliability and wide coverage, particularly in geographical areas with severe rain. A different compatibility studies in the band 3500 MHz between broadband FWA and other services (point-to-point fixed links, electronic news gathering/outside broadcasting systems, fixed satellite systems and radiolocation) were reported in [5], also impact from Ultra Wide Band (UWB) systems on BWA has been studied in [6]. Han-shin Jo *et al*. [7] studied the coexistence of orthogonal frequency division multiplexing (OFDM)-based systems beyond 3G (B3G) and point-to-point fixed services in the band 3500 MHz.

The reminder of this paper is organized as follows. In section II, parameters of WiMAX (802.16) and FWA systems are presented in detail. Section III is devoted to discuss sharing criterion. The method and procedure to do this work and the used propagation model as well as spectral emissions mask are elaborated and described in details in the sections IV, V, and VI. Sharing and coexistence scenarios and analyses as well as the compatibility between WiMAX and FWA in co-channel and adjacent channel are executed in sections VII and VIII. Finally, the conclusion is presented in section IX.

II. WiMAX and Fixed Systems Parameters Description

In order to examine coexisting and sharing issues, it is necessary to clarify the parameters of WiMAX and FWA that will affect the interference level and criterion.

A. Parameters of WiMAX

WiMAX moves toward higher data rates through wider modulation bandwidths from 1.25 to 20 MHz for point-to-point and point-to-multipoint fixed applications. IEEE BWA working group [8] defined the radio frequency parameters and characteristics of WiMAX (fixed and mobile), this study will only focus on fixed WiMAX, and these parameters are shown in Table I for both transmitter and receiver. As the system can occupy a bandwidth up to 20 MHz we chose three different channel bandwidths 3.5, 7, and 10 MHz (in order comparison with current FWA system) each with center frequency of 3500 MHz. The spectral emission mask requirements follow ETSI-EN302326-2 (EqC-PET=O, EqC-EMO=6) or Type-G mask ETSI-EN301021 [9], [10] specifications and according to [11].

Note- EqC-PET means Equipment Classification-Primary Equipment Type and EqC-EMO means Equipment Classification- Equivalent Modulation Order.

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Table I: WiMAX system parameters

Parameter	Value
Center frequency of operation (MHz)	3500
Bandwidth (MHz)	3.5, 7, 10
Base station transmitted power (dBm)	36
Terminal station transmitted power (dBm)	24
Spectral emissions mask requirements	Type-G ETSI-EN301021
Base station antenna gain (dBi)	16
Receiver antenna gain (dBi)	8
Base station antenna height (m)	30
Receiver antenna height (m)	2
Noise figure of Base station (dB)	4
Noise figure of receiver (dB)	7

B. *Parameters of the Current FWA*

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. The spectral emission mask (is discussing in a next section) requirements follow ETSI-EN302326-2 (EqC-PET=O, EqC-EMO=4) [9] or Type-F mask ETSI-EN301021 [10] specifications according to [5]. We will focus on the parameters listed in Table II.

III. Sharing Criterion

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, the short- term interference 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 [12], [13]. 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* as shown in Fig. 1 [13]. 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. 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 [14], so it should be that [15]:

Table II: Existing FWA system parameters

Parameter	Value
Center frequency of operation (MHz)	3500
Bandwidth (MHz)	7
Base station transmitted power (dBm)	35
Terminal station transmitted power (dBm)	22
Spectral emissions mask requirements	Type-F ETSI EN301021
Base station antenna gain (dBi)	17
Terminal station antenna gain (dBi)	20
Base station antenna height (m)	20
Terminal station antenna height (m)	1.5-10
Noise figure of base station (dB)	5
Noise figure of terminal station (dB)	7

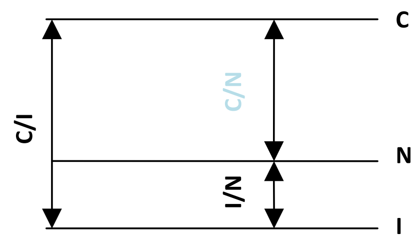

Figure 1: Interference protection criterions

$$I - N \geq \alpha \quad (1)$$

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 value of -6 dB which means that the interference must be approximately 6 dB below thermal noise as Fig. 1 shows.

IV. Method and Procedure

The method consists in calculating the *I/N* ratio and then comparing it with the necessary *I/N* (-6 dB) at the victim receiver.

Step 1:

Calculate the interference level *I* (dBm) at the victim receiver by assessing the level of emissions from the interferer falling within the victim receiver bandwidth for both co-channel frequency and adjacent frequency situations according to [7]:

$$I(\Delta f) = Pt + Gt + Gr + Mask(\Delta f) + corr\_band - Att \quad (2)$$

Where

Pt: transmitted power of the interferer in dBm,
Gt: gain of the interferer transmitter 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.
corr_band: correction factor of band ratio, where
corr_band= 0 dB if $BW_{interference} < BW_{victim}$ or
corr_band=-10log($BW_{interference}/BW_{victim}$), if not.

Att: attenuation due to the propagation (model in ITU-R P.452 is used).

Step 2:

Determine the thermal noise floor of victim receiver as the following:

$$N = -114 + NF + 10\log_{10}\left(BW_{victim}\right) \quad (3)$$

Where NF is noise figure of receiver in dB and BW_{victim} represent victim receiver bandwidth in MHz.

Step 3:

Substitute I and N of steps 2 and 3 above into (1) to determine the sharing and coexistence feasibility between the two systems and derive the relationship between:

a). frequency separation Δf and I/N ratio

b). distance separation and I/N ratio.

V. Propagation Model

In particular, 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. WiMAX has a specific usage as it may be fixed or mobile and to operate 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 [16]. This is model which is used for this coexistence study includes the attenuation due to clutter in different environments.

$$L(d) = 92.5 + 20\log d + 20\log f + Ah \quad (4)$$

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:

$$Ah = 10.25e^{-d_k}\left[1-\tanh\left[6\left(\frac{h}{h_a}-0.625\right)\right]\right]-0.33 \quad (5)$$

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 ha is the nominal clutter height (m) above local ground level. In [16], clutter losses are evaluated for different categories: trees, rural, suburban, urban, and dense urban, etc. The most geographical considered where WiMAX technology will be operated and deployments can be profitable [17] 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). Increasing of antenna height up to the clutter height leads to decrease the clutter loss, as shown in Table III and Fig. 2 which contain the four categories. In our case, dense urban category will be considered.

Table III: Nominal clutter heights and distances

Clutter category	Clutter height ha	Nominal distance d_k
Rural	4	0.1
Suburban	9	0.025
Urban	20	0.02
Dense urban	25	0.02

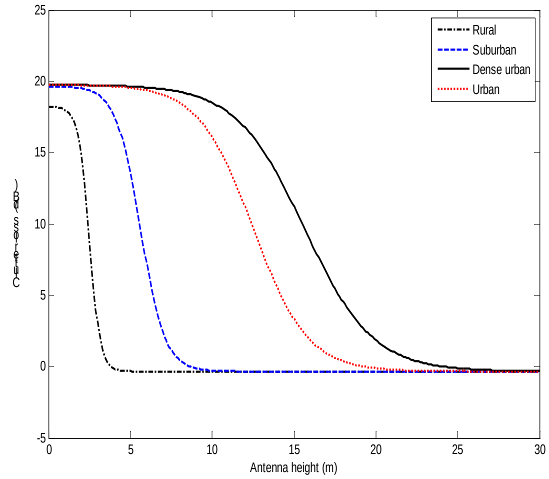

Fig. 2: Clutter loss for rural, suburban, urban, and dense urban areas

VI. Spectral Emissions Masks

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. WiMAX and FWA masks according to [9] and [10] are depicted and tabulated, where spectrum masks for WiMAX is declared in Table IV for three channel bandwidths and 7 MHz channel spacing is only depicted in Fig. 3 in order to compare that with FWA mask for 7 MHz which is shown in Fig. 4 and Table V.

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.

To carry out this study the spectral emissions mask in the Fig. 3 is applied for coming interference from WiMAX systems and Fig. 4 is applied for coming interference from FWA systems as the following section details.

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Table IV: Reference frequencies for spectrum masks of Type-G ETSI-EN301021 (WiMAX)

Freq./Ch. Separation (Normalized) (MHz) ⇒	0	0.5	0.5	0.71	1.06	2	2.5
Ch. Spacing (MHz) ⇓	0 dB	0 dB	-8 dB	-32 dB	-38 dB	-50 dB	-50 dB
3.5	0	1.75	1.75	2.49	3.71	7.0	8.75
7	0	3.5	3.5	4.97	7.42	14	17.5
10	0	5.0	5.0	7.1	10.6	20	25

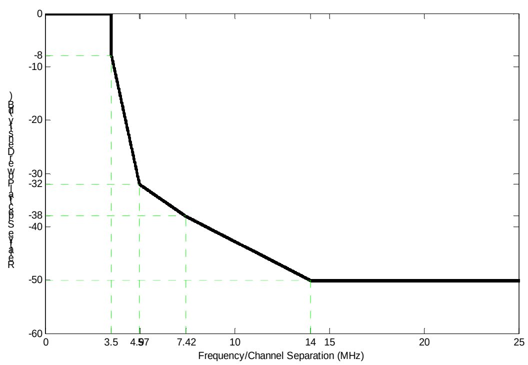

Figure 3: WiMAX spectral emission mask for 7 MHz

Table V: Reference frequencies for spectrum masks of Type-F ETSI-EN301021 (FWA)

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

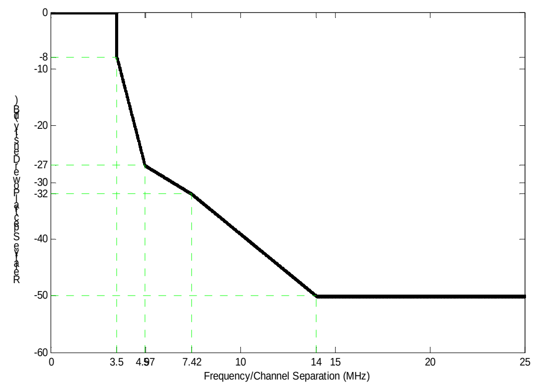

Figure 4: FWA spectral emission mask for 7 MHz

VII. Sharing, Coexistence Scenarios and Analysis

A. Interference from WiMAX into FWA BS in dense urban area

As seen from Figs. 5, 6, and 7 the interference from WiMAX base station (BS) systems into 7 MHz FWA 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 bandwidth of WiMAX channels in the dense urban area. It can be observed that the minimum separation distance between the two base stations must be greater than 14 m and 11 m for frequency separation of 3.5 and 7 MHz, respectively. For frequency separation of 10 MHZ a 0.009 km must be taken into account for adjacent channel coexistence.

For deploying the two systems with a null guard band the separation distances must be greater than 29 m, 48 m, and 54 m for WiMAX bandwidth of 3.5, 7, and 10 MHz, respectively. The frequency separation equals to:

$$Zero\_Guard\_Band = 0.5(BW_{WiMAX} + BW_{FWA}) \quad (6)$$

Where BW_{WiMAX} and BW_{FWA} are bandwidth of WiMAX and FWA, respectively. Zero guard band is represented by a vertical line in the graphs.

Sharing the same channel (co-channel) is feasible between two systems only in case of separation distances are of the order of 3.5 km for 3.5 and 7 MHz and 2.9 km for 10 MHz channel bandwidth, because at these distances the interference is always 6 dB or more below the thermal noise floor as the figures show. These entire requirements are summarized in Table VI.

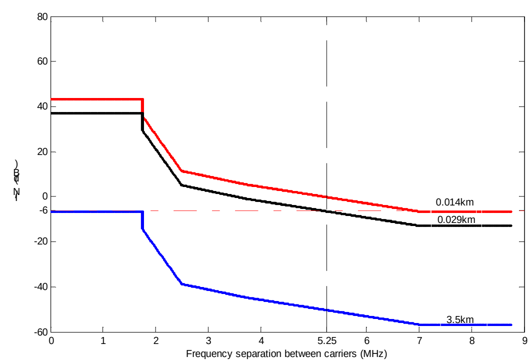

Figure 5: Interference from WiMAX BS (3.5 MHz) into FWA BS (7MHz)

B. Interference from FWA BS into WiMAX in dense urban area

This scenario is applied using 7 MHz channel FWA emission mask as interferer on WiMAX BS. Here, interferer is FWA system assumed has fixed channel bandwidth and thus fixed spectrum emission mask whereas WiMAX BS is the victim receiver with three selected bandwidths Figs. 8-10 depict the required minimum separation distance and frequency separation versus the standard interference to noise ratio (-6 dB) for 3.5, 7, and 10 MHz bandwidth of WiMAX channels. In the three plots, it is clearly observed that the co-channel coexistence can be satisfied as distance between base stations of two systems increase, where the minimum separation distance is 4.4 km for both 3.5 and 7 MHz, and it equals to 3.7 km for 10 MHz.

In order to deploy the two systems in adjacent band, the minimum frequency separation is 14 MHz and the minimum separation distance must be greater than 0.014 km for 3.5 and 7 MHz, and 0.012 km for 10 MHz.

Table VI: Minimum required separation distance and frequency separation for different channel bandwidths and interference cases in dense urban area (interference from WiMAX into 7 MHz FWA)

WiMAX bandwidth (MHz)	Minimum required separation distance (km) and frequency carriers separation (MHz)					
	Co-channel sharing		Adjacent channel sharing		Zero guard band	
	km	MHz	km	MHz	km	MHz
3.5	3.5	0.0	0.014	7.0	0.029	5.25
7	3.5	0.0	0.011	14	0.048	7.0
10	2.9	0.0	0.009	20	0.054	8.5

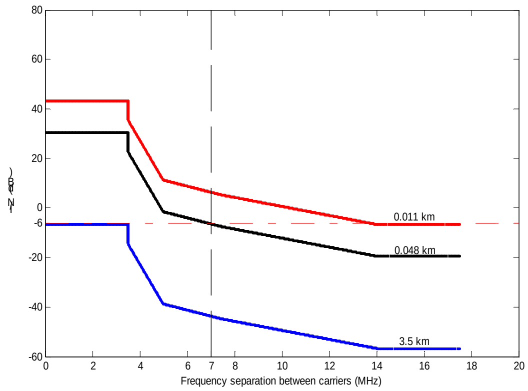

Figure 6: Interference from WiMAX (7 MHz) into FWA (7MHz)

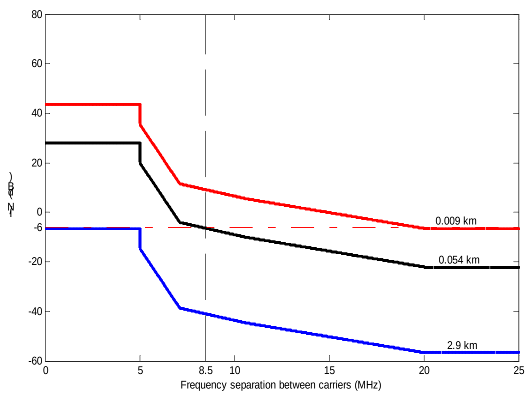

Figure 7: Interference from WiMAX (10 MHz) into FWA (7MHz)

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

VIII. Compatibility between WiMAX and FWA

According to previous results and by comparing Table VI and Table VII, it is can be stated that WiMAX system and FWA system able to share and coexist in the co-channel frequency and adjacent channel by considering the separation distance and frequency separation as well as type of spectral emission mask and characteristics of two systems parameters. It should be noted that the results are more favourable for compatibility when using 10 MHz bandwidth channel for WiMAX which means higher data rates. The results are also indicate that interference impacts form FWA

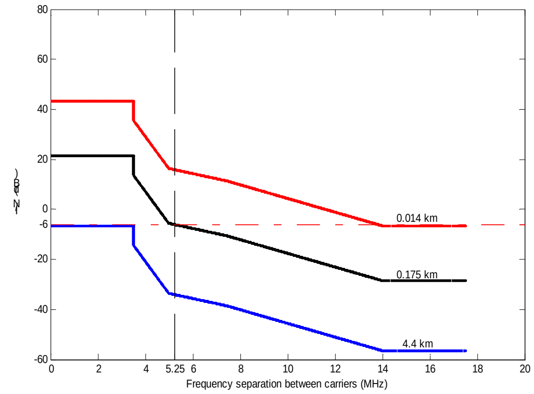

Figure 8: Interference from FWA (7MHz) into WiMAX (3.5 MHz)

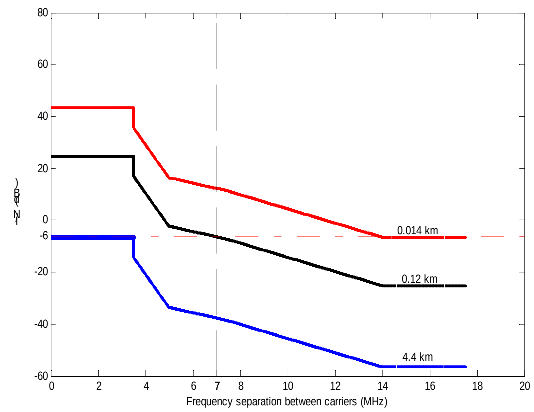

Figure 9: Interference from FWA (7MHz) into WiMAX (7 MHz)

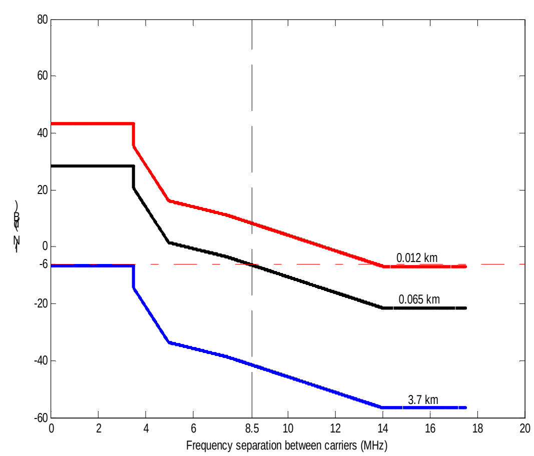

Figure 10: Interference from FWA (7MHz) into WiMAX (10 MHz)

Table VII: Minimum required separation distance and frequency separation for different channel bandwidths and interference cases in dense urban area (interference from 7 MHz FWA into WiMAX)

WiMAX bandwidth (MHz)	Minimum required separation distance (km) and frequency carriers separation (MHz)					
	Co-channel sharing		Adjacent channel sharing		Zero guard band	
	km	MHz	km	MHz	km	MHz
3.5	4.4	0.0	0.014	14	0.175	5.25
7	4.4	0.0	0.014	14	0.12	7.0
10	3.7	0.0	0.012	14	0.065	8.5

on WiMAX is more worst than the interference form WiMAX into FWA, this is because of the wide mask requirements of FWA, higher antenna height of WiMAX, and higher antenna gain of FWA. Therefore, the minimum separation distance and frequency separation in Table VII should be taken into account for deploying the two systems because it represents the worst case scenario between them. Interference-to noise ratio degrades as separation distance increases, and the same behavior occurs when frequency separation between carriers increases.

IX. Conclusion

In the above discussion the required frequency and distance separation between WiMAX and FWA systems have been derived. A coexistence analysis is thoroughly performed in this paper based on spectral emission mask and interference to noise ratio to determine mutual interference between BSs of both systems in the dense urban area. The coexistence problem is divided into two alternating terms, co-channel frequency sharing and adjacent channel coexistence, also a coexistence with zero guard band between the two systems is introduced.

The frequency separation required to protect both systems will be quite important when WiMAX and FWA are supposed to be close vicinity (distance around 0.014 km) for adjacent channel sharing and decreases significantly to deploy co-channel frequency sharing where the separation distance is larger than (4.4 km) for both 3.5 MHz and 7 MHz and (3.7 km) for 10 MHz WiMAX channel bandwidth. We are looking further for studying coexistence between IMT-Advanced and current broadband FWA, more studies are required in different categories areas and using other mitigation techniques.

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