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Cross Border Interference between IMT-Advanced and DVB-T in the Digital Dividend Band

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Abstract

The 470–862 MHz band has recently incurred two major spectrum reallocations: the introduction of digital broadcasting (DB) and the allocation of the 790–862 MHz sub-band as a co-primary base for mobile services. While some countries have accomplished full digital switchover (DSO) and implemented DB as their platform for TV broadcasting, others are still in the trial phase. Until 2015, this sub-band will be usable for either broadcasting or mobile service; lack of coordination between neighboring countries could thus result in co-channel interference. Using a Monte Carlo method, we evaluated the minimum separation distance (MSD) and carrier frequency separation necessary to achieve compatibility. Digital video broadcasting-terrestrial (DVB-T) systems can be protected from international mobile telecommunications-advanced (IMT-A) systems using a carrier frequency separation of 17 MHz. Although IMT-A systems are not protected from DVB-T in this sharing scenario, coexistence between adjacent channels is ensured without recourse to interference mitigation by use of a carrier frequency of at least 15 MHz.

Keywords: *Compatibility Analysis; Spectrum Sharing; Monte Carlo Methodology, Interference, Coexistence, Cross Border Interference*

1. Introduction

In the latest Regional Radiocommunications Conference in 2006 (RRC-06), the International Telecommunication Union (ITU) set deployment requirements for digital video broadcasting-terrestrial (DVB-T) service in Bands IV and V (*i.e.*, 470–862 MHz) [1]. In 2007, Resolution 794 of the World Radio Conference (WRC-07) allocated this band as a co-primary basis for mobile and broadcasting services starting in 2015 and indicated that studies on sharing between the two services should be conducted [2].

In 2008, the European Commission directed the European Conference of Postal and Telecommunication (CEPT) to set the requirements for harmonizing spectrums between European Union countries; included in this mandate was the stated need to study technical conditions within the 790–862 MHz band. A detailed study was carried out [3] to identify

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frequency channel arrangements within this band for mobile services. The recommendations of the study were adopted in 2009 as the response of the European Union to the ITU request at WRC-07 to conduct sharing studies between mobile and broadcasting services [4]

Based on the facts that a) the ITU has set aside the 470–862 MHz band for terrestrial digital broadcasting and b) future IMT-A mobile services will operate in the 791–862 MHz band [4], frequency sharing between the two systems (and consequently, performance degradation) are inevitable. The goal of this paper is to quantify the possibilities for compatibility between the two services and to propose a practical guideline for guaranteeing efficient spectrum usage and reliable service.

2. Related Work

Our paper is inspired by the limitations of recent compatibility studies [5-9]. Although the radio interference effects of Long Term evolution-Advanced (LTE-A) base station (BS) and user equipment (UE) on DVB-T receivers were examined in [5], reverse interference was not investigated. In [6], the possibility of co-existence of IMT-A BS and DVB-T BS in the 790–862 MHz band by use of sensitive and non-sensitive spectrum emission masks (SEMs) on DVB-T transmitters was analyzed. In [7], interference from DVB-T BS to IMT-A BS was investigated using minimum coupling loss methodology over three co-existence scenarios: co-channel, adjacent channel, and zero guard band. In neither of these studies, however, was the receiver blocking response assessed as a part of the interference effect, and other interference scenarios, such as DVB-T BS to IMT-A UE and IMT-A UE to DVB-T subscriber station (SS), were excluded. In [8], the required guard band (GB) and minimum separation distance (MSD) between evolved-UMTS terrestrial radio access (E-UTRA) and digital broadcasting (DB) services were assessed for co- and adjacent-channel interference scenarios. However, the results were inexact, since the study did not utilize an E-UTRA-specified SEM [10] and system specifications were not provided, making testing (or implementation) of the results impossible. Finally, in [9] an inter-system performance measurement was conducted by developing a methodology based on a previous technical report [11]. This study revolved around co-channel interference, and adjacent channel interference was only suggested for future work; furthermore, only urban deployment was assessed.

In order to obtain reliable co-existence and compatibility results, a more general and exact approach is clearly desirable. The effects and parameters that should be studied include transmitter interference leakage, receiver imperfection, and exact system specification, all of which should be assessed under all potential interference scenarios. In particular, for the study described in this paper, we quantify the possibility of compatibility under various interference scenarios in both rural and urban environments: (i) DVB-T BS to IMT-A BS and UE, (ii) IMT-A BS to DVB-T SS, and (iii) IMT-A UE to DVB-T SS. By adopting Monte Carlo (MC) methodology to conduct these assessments, we are able to provide more realistic compatibility results by randomly distributing users within the service coverage.

3. System Parameters

In this study, we assess the parameters of LTE-A parameters (shown in Table 1), as this is one of the candidate technologies for IMT-A systems [12-13] .

Table 1. LTE-A [12-13] parameters in rural and urban area deployment

	LTE-A (BS)		LTE-A (UE)	
Parameter	Rural	Urban	Rural	Urban
Transmitted power (dBm)	46≤ 5MHz 43≥ 5MHz	23	24	
Bandwidth (MHz)	20		20	
Height (m)	30	23.5	1.5	
Gain (dBi)	15		0	
Noise figure (dB)	5		9	
Coverage (km)	4.3	0.5	----	
Antenna	Tri Sector [14]		Omni	
ACS (dB)	27 (for BW = 20 MHz)			
Thermal noise (dBm)	-95.98 (20 MHz)		-91.98 (20 MHz)	
Interference threshold (dBm)	-101.98 (20 MHz)		-97.98 (20 MHz)	
Sensitivity (dBm)	-90.98		-86.98	
Propagation model	Extended Hata [15]			
Cell layout	Wrap around 57tri sector cells, uncoordinated		----	
Scheduling algorithm	Round Robn			
Number of users	----		20	50
SEM	[12] (when Tx)		[13] (when Tx)	
Receiver blocking attenuation mode	Sensitivity mode			
Minimum coupling Loss (inter-system) [14]	80	70	80	90

Here, DVB-T is used for the DB system [1]. All of the broadcasting deployment requirements, specifications, and protections used for this and other services assessed here were previously addressed in [1]. Table 1 contains LTE-A and DVB-T parameters for rural and urban environments.

Table 2. DVB-T [1] parameters in rural and urban area deployment

	DVB-T (BS)		DVB-T (SS)	
Parameter	Rural	Urban	Rural	Urban
Transmitted power (dBm)	74.6	63.6	----	
Bandwidth (MHz)	8			
Height (m)	200	100	10	
Gain (dBi)	0		14.15	
Noise figure (dB)	----		7	
Coverage radius (km)	51.76	17	----	
Antenna	Omni		ITU-R BT.419-3 [16]	
Thermal noise (dBm)	----		-98	
Sensitivity (dBm)	----		-78	-82
Propagation model	Extended Hata Model			
Network Type	RN1	RN3	----	

C/N (dB)	21	17	----	
C/I (dB)	27	-30	23	-30
Reception configuration	----		RPC 1	
SEM	GE06 [1]		----	
Receiver blocking attenuation mode	----		PR	
Allowed Maximum interfering signal (dBm)	----		-104	
Receiver type	----		Silicon USB[17]	

4. Compatibility Method

In the MC simulation used for this study, a series of trials was repeated using a set of varied, user-defined parameters in order to calculate a protection criterion, such as the carrier-to-interfering *(C/I)* or the interfering-to-noise *(I/N)* ratio, for each trial. After a sufficient number of trials (*i.e.*, 10,000 snapshots), the probability of interference P_{int} can be calculated as follows [15]:

$$P_{int} = 1 - P_{non\_int}\,, \tag{1}$$

where P_{non_int} is the probability of non-interference of the victim receiver when (D_E/I_E > C/I). Here, D_E is the desired signal power and I_E is the interference power.

In each trial (or snapshot), the victim receiver obtains a desired D_E (dBm) and an interference I_E (dBm) signal. The desired signal, D_E, is given by

$$D_E = P_{wt} + G_{wt} + G_{vr} - L_p\,, \tag{2}$$

where P_{wt} is the transmitting power of the desired transmitter (dBm), G_{wt} is the antenna gain of the desired transmitter (dBi), G_{vr} is the gain of the victim receiver (dBi), L_p is path loss (dBm) based on an extended Hata model, P_{it} is the power of interference (dBm), and G_{it} is the gain of the interfering antenna (dBi).

The interference signal IE is composed of two sources, unwanted emission ($I_{E\_unwanted}$) and receiver imperfection ($I_{E\_blocking}$):

$$I_E = I_{E_{unwanted}} + I_{E_{Blocking}}\,, \tag{3}$$

The total interference over the *n* trials owing to unwanted transmitter emission is then given as follows [15]:

$$I_{E\_unwamted}(dBm) = 10\,\log_{10}\left\{\sum_{i=1}^{n} 10^{\frac{I_{E\_unwanted\_i}}{10}}\right\}, \tag{4}$$

For the *i-th* trial, $I_{E\_unwanted}$ is given by

$$I_{E\_unwanted\_i} = iT_{emission}\left(f_{it}, f_{vr}\right) + G_{it} + G_{vr} - L_p, \tag{5}$$

where G_{it} is the antenna gain of the interfering system (dBi) and $iT_{emission}$ (f_{it},f_{vr}) is the emission leakage from an interfering transmitter operating at a frequency offset of f_{it}, into the victim receiver, which in turn operates at frequency *fvr*.

The *iT* emission (f_{it} ,f_{vr}) factor is a function of operating frequency offset (MHz), unwanted emission power, and the reference bandwidth (MHz):

$$iT_{emission}\left(f_{it}, f_{vr}\right) = P_{it} + emission_{unwanted}\left(f_{it}, f_{vr}\right), \tag{6}$$

$$emission_{unwanted}(n)\left(f_{it}, f_{vr}\right) = 10\,log_{10}\left\{\int_a^b P_{unwanted}(\Delta f)\,d\Delta f\right\}, \tag{7}$$

where P_{it} is the transmission power of the interfering system (dBm), $\Delta f = f_{it} - f_{vr}$ (MHz), and $emission_{unwanted}(f_{it}, f_{vr})$ (dBm) is the total power falling into in the victim receiver filter as an integrated function of the unwanted power $P_{unwanted}$ (dBm) over the frequency range between $a = f_{vr}$-f_{it}-(b_{vr}/2) and $b = f_{vr}$+f_{it}-(b_{vr}/2), where b_{vr} is the victim receiver bandwidth.

The interference owing to victim receiver blocking over *n* trials can be given by

$$emission_{unwanted}\left(f_{it}, f_{vr}\right) = 10\log_{10}\left\{\int_a^b P_{unwanted}(\Delta f)\,d\Delta f\right\} \tag{8}$$

For the *i-th* trial, the interference blocking can be given as a function of frequency:

$$I_{E\_Blocking} = P_{it} + G_{it} + G_{vr} - Lp - avr\left(\Delta f\right), \tag{9}$$

where *avr(*Δ*f)* (dBm) is the blocking attenuation of the victim receiver, which can be calculated using one of two modes, sensitivity mode or PR mode, chosen based on receiver type. In the simulation used here, PR mode was chosen for the broadcasting receiver, while sensitivity mode was chosen to calculate receiver-blocking attenuation in the mobile receiver, as is shown in Tables 1 and 2. Using sensitivity mode, the blocking attenuation can be given as follows [15]:

$$avr(\Delta f) = I_{max} + C/(N+1) + Sen_{vr} \tag{10}$$

where I_{max} (dBm) is the maximum allowed interference and Sen_{vr} (dBm) is the sensitivity level of the victim receiver.

For PR mode, we use

$$avr(\Delta f) = 3+ C/(N+1) + Block_{att}(f_{it} - f_{vr}) \tag{11}$$

where I (dBm) is the level of interference and N (dBm) is the noise floor level of the receiver. Both of these factors are functions of the frequency difference, Δf

5. Interference Scenario

Figure 1 illustrates frequency sharing between LTE-A and DVB-T systems in both uplink (UL) and downlink (DL) communication modes. This condition is relevant to the situation that will apply under all administrations that agree to Geneva Agreement 2006 (GE-06), under which LTE-A is to be used as the IMT-A system. Here, DVB-T channels 61 to 63 and 66 to 68 overlap totally or partially with the LTE-A DL channel, causing co-channel interference, while channels (60, 64) and (65, 69) produce adjacent channel interference. The LTE-A UL/DL channels are assumed to have a 20 MHz bandwidth. This scenario can occur if one country (such as Singapore) decides to deploy a mobile system in the 790–862 MHz band, while its neighbor (*e.g.*, Malaysia) is still using DB.

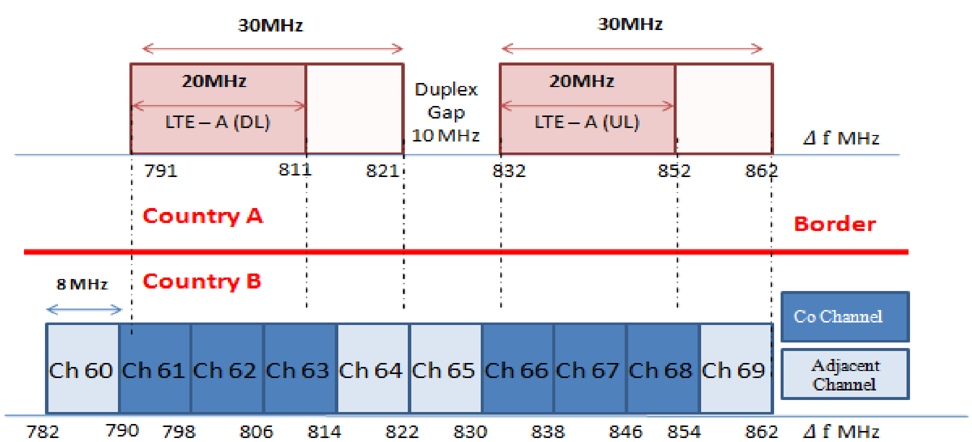

Figure 1. Sharing of the 790-862MHz band between LTE-A (UL/DL) and DVB-T

We consider here four interference scenarios: (i) LTE-A BS interfering with DVB-T SS, (ii) LTE-A UE interfering with DVB-T SS, (iii) DVB-T interfering with LTE-A BS, and (iv) DVB-T BS interfering with LTE-A UE. In each scenario, the systems are assumed to be deployed in both rural and urban environments.

6. Results and Discussion

Tables 3 and 4 show the minimum separation distances *MSD* (km) required for coexistence in the four interference scenarios. These separation distances are functions of frequency offset Δf (MHz); *GB* (MHz) is the guard band, while *Ch* is the channel number. The red highlighted results in the tables show the worst cases, while the yellow highlighted results represent cases where co-existence can be achieved. In any sharing study between mobile and broadcasting services, channel frequency assignments must be taken into consideration in order to obtain realistic results.

Table 3. Minimum separation distance between the LTE-A (BS, UE) and the DVB-T SS

	[1st interference scenario] LTE-A (BS) (DL) → DVB-T (TS)									
	Rural					***Urban***				
	Co-Ch PR = 27dB			***Adj-Ch PR = -30dB***		***Co-Ch PR = 17 dB***			***Adj-Ch PR = -30 dB***	
Ch	61	62	63	60	64	61	62	63	60	64
***MSD* (km)**	215	220	210	0		35	40	33	0	
***Δf* (MHz)**	7	1	9	15	17	7	1	9	15	17
***GB* (MHz)**	0			1	3	0			1	3
[2nd interference scenario] LTE-A (UE) (UL) → DVB-T (SS)										
Ch	66/68		67	65/69		66/68		67	65/69	
***MSD* (km)**	1.5		1.6	0		0.6		0.4	0.1	
***Δf* (MHz)**	8		0	16		8		0	16	
***GB* (MHz)**	0			2		0			2	

In the first interference scenario, co-existence can be achieved for adjacent channels 60 and 64; *i.e.*, *GB* is 1 and 3 MHz, respectively, for each channel in urban deployment. In the second interference scenario, co-existence can be achieved for adjacent channels 65 and 69, as *GB* = 2 MHz in rural deployment. As a minimum separation distance between systems is quite hard to maintain, owing to the random deployment of UEs, this scenario is considered crucial for determining the interference effect of an LTE-A on a DVB-T system. For example, in an urban environment the two systems should be at least 100 m apart when using adjacent channels 65 or 69, while an *MSD* of 600, 400, and 600 m is required for co-channels 66, 67, and 68, respectively.

In the fourth interference scenario, coexistence in rural deployment can only be achieved by sharing the adjacent channels of 65/69 (*i.e.*, *GB* = 2), and in the third scenario, co-existence cannot be achieved for both co-channel and adjacent channel sharing in rural and urban environments, as the distances required to protect the victim service are very large compared to those in the other sharing scenarios, owing to the high transmitted power levels of the DVB-T BS.

Table 4. Minimum separation distance between the DVB-T BS and the LTE-A (BS, UE)

	[3rd interference scenario] DVB-T → LTE-A (BS) (UL)									
	Rural					*Urban*				
	Co-Ch I/N =-6dB			*Adj-Ch I/N =-6dB*		*Co-Ch I/N=-6dB*			*Adj-Ch I/N =-6dB*	
Ch	***61***	62	63	60	64	61	62	63	60	64
MSD (km)	***200***			103	105	95	100	95	10	
Δf (MHz)	***7***	1	9	15	17	7	1	9	15	17
GB (MHz)	***0***			1	3	0			1	3

	[4th interference scenario] DVB-T → LTE-A (UE) (DL)					
Ch	67	66/68	65/69	67	66/68	65/69
MSD (km)	50	50	0	25	25	5
Δf (MHz)	0	8	16	0	8	16
GB (MHz)	0		2	0		2

7. Conclusion

On the whole, the simulation results discussed in this paper show that coexistence between the two services described here is impossible in co-channels as well as, in some situations, adjacent channels. These results differ from those of previous studies [5-8], in which it was found that the two systems can coexist under all adjacent channel sharing scenarios. Our results should serve as an alert to the possible consequences of international cross-border interference in the 790–862 MHz band.

Our results can also aid in the successful deployment of IMT-A and DVB-T systems within the 790–862 MHz band by ensuring that adequate distance is maintained and a guard band is used. In other sharing scenarios, however, interference mitigation will still be required.

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