

Interference Analysis between Digital Television and LTE System under Adjacent Channels in the 700 MHz Band

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Abstract

This paper aims to analyze the impact of mutual interference between Long Term Evolution (LTE) and digital television (DTV) systems in adjacent channels in the 700 MHz band. During the analysis, minimum physical separation distances between the systems are determined to ensure their coexistence in this band. The interference impact is evaluated in a scenario where the DTV and LTE operate on channels 51 and 52 respectively. In order to obtain the results, this study was made using Monte Carlo simulations. Four classes of Digital Television were considered during the simulations: Special class, class A, class B and class C. The results show that the Special, A and B classes cause interference with the LTE, and the impact of such interference depends on the guard band and also the separation distance between the systems. Furthermore, the results also show that increasing the LTE bandwidth only has a greater impact if the LTE is the victim system. However, the coexistence of LTE and DTV in this band is possible once there is a minimum separation distance and an adequate guard band respected.

Keywords: Digital Television, LTE, Digital Dividend, Adjacent Channel, Coexistence, Interference.

I. INTRODUCTION

With the digitization of radio broadcasting a wide frequency range in Ultra High Frequency (UHF) will be released in a few years for commercial use in several countries. This frequency range is designated Digital Dividend (DD) [1]. Japan, United States and some European countries have already allocated a portion of (DD) for mobile services [4], but many countries are still in the process of regulating the use of the DD [5-6]. Presently, TV providers argue that the DD should be reserved for the transmission of high-definition TV, but phone/mobile providers suggest that this band should be destined to allocate the mobile broadband services, such as Long Term Evolution (LTE). Due to its propagation characteristics, DD is quite attractive for allocating services like LTE because the waves in the UHF band offer the possibility of long-range, in other words, it allows a larger coverage radius with few infrastructure [4]. In addition, this range has an immunity degree of signal degradation much higher compared to other frequencies above the UHF [2-3].

There are several studies about the coexistence of digital television (DTV) and LTE in DD. In [4], the authors analyze the interference caused by DTV in LTE. The results demonstrate that LTE suffers DTV interference and that it is more severe in the LTE uplink. In [7], the authors study the LTE performance in the adjacent channel of

DTV, however it is considered that the two systems are in different geographic regions, with about 50 km to 150 km away. The simulation results also showed that the interference will exist and be more severe in the LTE uplink compared to the downlink. In [8], it was analyzed the co-channel interference considering long separation distances between both systems. The objective was to evaluate the mutual interference comparing the effects between the two radio links and thus identifying the most critical cases.

Unlike the studies cited, this paper analyzes the interference between DTV and LTE systems in adjacent channels within the same geographic region. During the simulations, it was considered different DTV classes which are Special class, class A, class B and class C. This analysis considers a DTV station operating on channel 51 (CH 51) and the LTE operating on channel 52 (CH 52). Finally, it was determined the minimum physical separation distance between the systems to allow their coexistence.

The remainder of this paper is structured as follows. Section II briefly describes the DTV, LTE systems and DD. Section III shows the simulation scenario adopted. Section IV presents the mathematical modeling. The results and analysis are presented in Section V, and finally, the conclusion in Section VI.

II. DTV, LTE SYSTEMS AND DD

A. Digital Television

Because of several advantages, the Digital Television (DTV) is being implemented to replace analogue services. Among the advantages, some are highlighted such as better quality of the transmitted signal and more efficient use of the electromagnetic spectrum [9]. The digitization of TV is a process that takes a certain time to accomplish, there are few countries that have already finished the digitalization. Presently, the process is in a phase called *simulcast*, which is the simultaneous transmission of analog and digital TV while waiting for the *switch-off*. In other words, the *switch-off* consists of the analog TV shutdown. In Brazil, the analog TV will operate only until 2016.

According to N01/2010 [10] standard, the DTV stations are classified into four classes called Special class, class A, class B and class C [10]. The Special class is used only by Sounds and Images Broadcasting Service. In UHF, the Special class allows the transmission at a maximum power of 80 kW in channels 14-46; and 100 kW in channels 47-68 with a service contour maximum distance of 57 km. Moreover, the classes A, B and C include radio services and in the UHF band transmit at a maximum power of 8 kW, 0.8 kW, and 0.08 kW respectively, with service contour distance of 42 km, 29 km and 18 km [10].

B. Long Term Evolution

On the other hand, the LTE is the evolution of the 3G technology, which significantly improves the throughput of the end user [11]. Voice traffic is primarily Voice over Internet Protocol (VoIP), which allows a better integration with other multimedia services. The LTE provides performance requirements that depend on physical layer technology, for instance, orthogonal frequency division multiplexing (OFDM) systems, multiple-input multiple-output (MIMO) and smart antennas [12]. The details on the operation of LTE are presented in [12-19].

C. Digital Dividend

The digital dividend can be defined as the frequency range not used for broadcasting after the transition from analog to digital. The European Commission defines as digital dividend the spectrum beyond the required frequency to meet the broadcasting services in a fully digitized environment [13]. Figure 1 illustrates the positioning of the digital dividend in the spectrum. It was noted that the range between 470 MHz to 698 MHz is used for digital TV and from 698 MHz on correspond of the digital dividend. Knowing that, the range from 698 MHz to 802 MHz will be used for LTE.

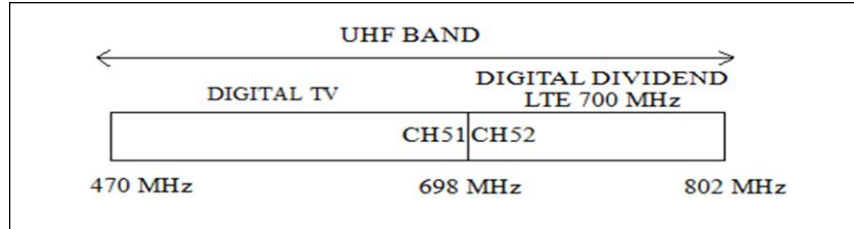


Figure 1. Digital Dividend.

III. SIMULATION SCENARIO

This section presents the simulations scenario adopted. The simulations were performed for an area of 900 square kilometers (30x30 km). In this scenario, the LTE was configured to operate in the same geographic space of the DTV station, as shown in Figure 2.

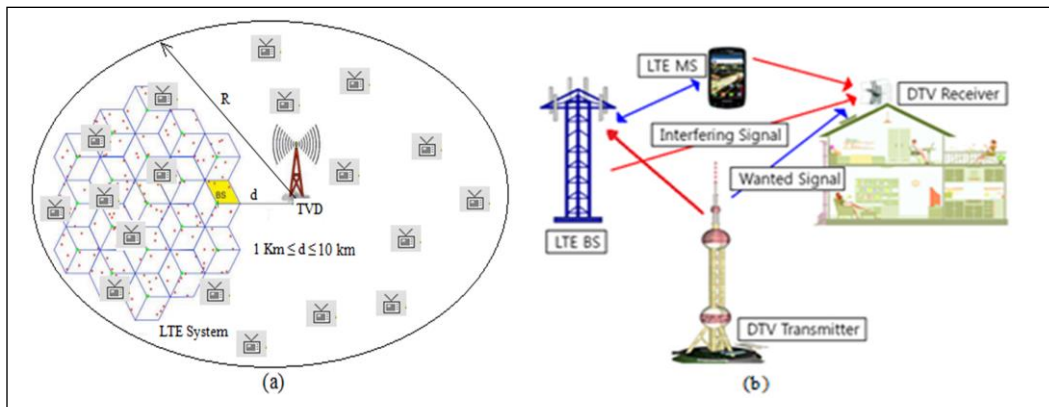


Figure 2. Simulation Scenario.

The separation distance between the DTV transmitter and the reference cell, where the nearest LTE base station to the TV transmitter is located, varies between 1km to 10km as shown in Figure 2(a). LTE is installed within the DTV coverage radius (R) of 18 km, 29 km, 42 km and 57 km, varying according to the class adopted. Furthermore, the LTE system has been configured to operate with 57 base stations (BS), which are the points in green in Figure 2(a), each representing three base stations (tri-sectorization). The red points represent LTE mobile stations (MS), randomly distributed throughout the cells. The LTE performance was analyzed for three different bandwidth values: 5 MHz, 10 MHz and 20 MHz, supporting the maximum of 200 users per cell. Figure 2(b) [14] illustrates the scenario of mutual interference between the systems, where the blue arrows represent the wanted signals and the red arrows represent the

interfering signals. The study focused on the LTE uplink because it is the most interfered direction [4-7]. Tables I and II show the simulation parameters for DTV and LTE.

TABLE I. LTE SIMULATION PARAMETERS ACCORDING TO [4-7].

Parameters	Value
Cell radius	3 km
Operation frequency	700 MHz (CH 52)
Number of base stations	57
Cluster size	3
Antenna height (BS)	30 m
Reception gain (BS)	15 dBi
MS generated	200
MS height	1.5 m
Transmit power	23 dBm
Coupling loss	70 dB
Bandwidth	5 MHz, 10MHz and 20 MHz
Noise figure	4 dB
Propagation model	Extended Hata Model
Modulation scheme	SC-FDMA (Uplink)

In the DTV configuration, it was considered the following classes: Special, A, B and C. The coverage radius adopted varies according to the class simulated. The DTV receivers are randomly distributed throughout its coverage radius. It was noted that some of these receptors are located in both DTV and LTE coverage area.

TABLE II. DIGITAL TV SIMULATION PARAMETERS ACCORDING TO [10-15].

Parameters	Value	
Transmission gain	15 dBi	
Transmit power (ERP)	Special class	80 dBm
	Class A	69.03 dBm
	Class B	59.03 dBm
	Class C	49.03 dBm
Antenna height	150 m	
Antenna pattern	Omnidirectional	
Central frequency	695 MHz (CH 51)	
Maximum protection boundary distance	Special class	57 km
	Class A	42 km
	Class B	29 km
	Class C	18 km
Bandwidth	6MHz	
Propagation model	ITU-RP. 1546 LAND	

IV. MATHEMATICAL MODELING

This section presents the mathematical equations used to calculate the probability of interference, signal to interference plus noise ratio (SINR) and channel capacity (C_c) of LTE. The probability of interference in the DTV receiver is defined as:

$$P_I = 1 - P_{NI} \quad (1)$$

Where: P_I is the LTE probability of interfering with DTV and P_{NI} is the LTE probability of not interfering with DTV.

$$P_{NI} = \frac{P\left(\frac{dRss}{iRss_{comp} + N} > \frac{C}{I + N}, dRss > sens\right)}{P(dRss > sens)} \quad (2)$$

C is the power transmitted by the LTE; I is the interference power from LTE; N is the noise in the channel; and $iRss_{comp}$ is the power of the composed interfering signal [16].

The channel capacity of LTE is determined by the Shannon formula which enforces a limit to the maximum transmission rate of the channel, obtained as:

$$Cc = B \cdot \log_2(1 + SINR) \quad (3)$$

Where: Cc is the channel capacity in Mbps; B is the system bandwidth in MHz. $SINR$ is the signal to interference plus noise ratio, and it is defined as:

$$SINR = \frac{P}{I} \quad (4)$$

Where: P is the power received by the LTE base station (BS); I is the total interference power affecting the LTE, where P is expressed as:

$$I = I_{inter} + I_{ext} + N_t \quad (5)$$

I_{inter} corresponds to the power of internal interference among users of the LTE system. Assuming that the system is fully orthogonal (OFDMA) and with no interference caused by frequency reuse, this interference can be considered null [16]. I_{ext} is the external interference power caused, in this case, by the interfering external system which is the digital TV.

The loss of the LTE channel capacity is calculated as:

$$C_l = 1 - \frac{Cc}{C_{max}} \quad (6)$$

Where: Cc is the LTE channel capacity considering the DTV interference; C_{max} is the LTE channel capacity with no interference from any other systems. The threshold for the LTE capacity loss is determined considering the value 50 Mbps of data rate for 20 MHz of bandwidth. [12]. This theoretical value corresponds to 56.8% of C_{max} which is 88.04 Mbps, for LTE operating at 20 MHz bandwidth. It implies in a LTE capacity loss of 43.2%.

Thus, 43.2% is fixed as the loss threshold, and it corresponds to different values of data rates depending on the bandwidth of the LTE.

All loss values below the threshold are considered acceptable, whereas, with values above the loss threshold, the LTE performance will be considered unsatisfactory.

V. RESULTS

A. First Case

In the first case, where is analyzed the interference of LTE caused on the DTV, the results are presented in the form of probability of interference as a function of separation distance between the systems. In this case, it is considered three different guard bands: 2 MHz, 3MHz and 4MHz. Thus, the probability of interference is 100%, it means that the LTE will always interferes with the DTV. In the other hand, if the probability of interference is 0%, it means no LTE interference with the DTV. For purposes of analysis, it was considered a threshold probability of interference equal to 5% [14]. Therefore, the probability of interference below the threshold (5%) is considered acceptable, in other words, the LTE may operate on adjacent channels without causing degradation of DTV signal, whereas if the probability is above threshold it will be considered nocuous to the DTV operation.

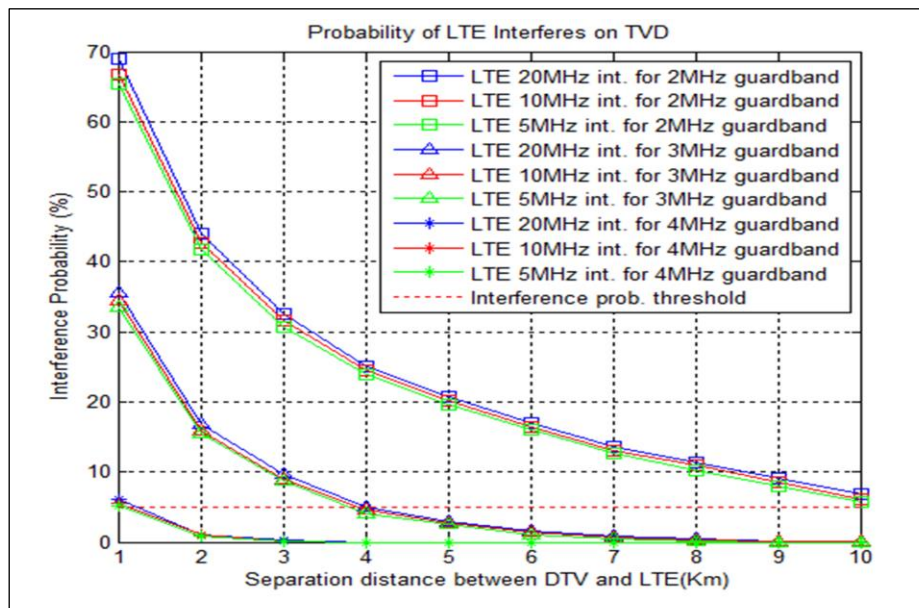


Fig. 3. Probability of LTE interfere with TVD for 2, 3 e 4 MHz of guard band.

Figure 3 shows the probability of LTE interferes with the DTV. The results show that for the 2 MHz guard band interference can occur with a probability of about 70% for separation distance up to 1km. This probability of interference decreases when separation distance increases. In other words, up to 10km separation the probability of interference is above the 5% threshold, which means the DTV signal will be degraded.

For 3 MHz guard band, the results show that the probability of interference decreases to about 35% for separation distances less than 1 km. This probability of interference reaches the 5% threshold when the separation distance is 4km and 0% when it is 9 km. Thus, if the systems have 3 MHz guard band, it means that from 4 km separation the DTV is able to operate without signal degradation.

Finally, for 4 MHz guard band, the probability of interference is below 7% for separation distances greater than 1 km. When the separation distance is over 1.5 km, the probability of interference is always below the threshold. Consequently, with a separation distance above 1.5 km the TVD does not suffer degradation.

B. Second Case

For the second case, which the DTV interferes with the LTE, the results are presented in the form of capacity loss of the uplink channel.

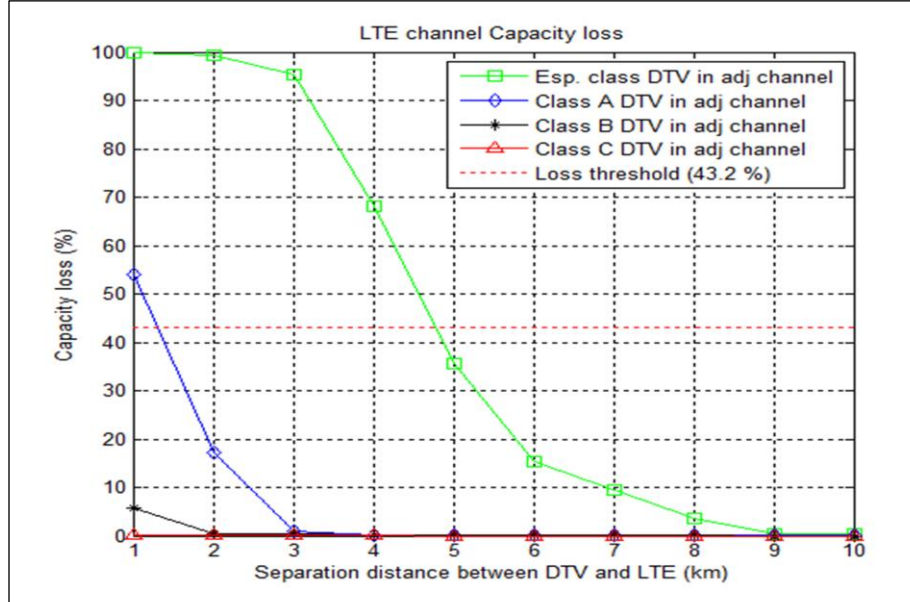


Figure 4. LTE Capacity loss for 20 MHz bandwidth.

Figure 4 shows the LTE results operating at 20 MHz bandwidth. In this case, the Special class DTV causes greater losses on the capacity of LTE. The LTE performance requirement for 20 MHz bandwidth is 50 Mbps data rate. [12]. Thus, this value is satisfied from 4.8 km of separation. In the other hand, the class A DTV interference causes a LTE capacity loss around 54% for a separation distance of 1 km; and it reaches 0% from 4 km. With the class A DTV interference, LTE ensures the minimum transmission conditions from 1.4km. The DTV Class B only interferes with LTE in separation distances of less than 2 km. Plus, the DTV class C interference is irrelevant due to its low level of transmit power.

The LTE capacity loss was also analyzed for 5 MHz and 10 MHz bandwidth, but in both cases the results showed relatively higher losses compared to 20 MHz. Thus, it was concluded that higher LTE bandwidths significantly reduce the interference impact.

VI. CONCLUSION

In this paper, it was made a study of the effects caused by mutual interference between digital television (DTV) and Long Term Evolution (LTE) in the range of 700 MHz. In order to obtain the results, the Monte Carlo method was used for the simulations. The results of this paper show that there is interference between DTV and LTE while operating in adjacent channels, 51 and 52. However, the impact of this interference depends on the class of DTV implanted in the adjacent channel to LTE; the guard band; and the separation distance between the systems. Additionally, the simulation results show that due to its low transmit power the DTV class C does not cause interference with the LTE, and also that increasing the bandwidth of the LTE only causes the most significant impact if the LTE itself is the victim system.

Once there is a minimum separation distance and an adequate guard band respected, the coexistence of LTE and DTV is possible in the range of 700 MHz, avoiding high levels of interference.

The study results show that there is a need to evaluate the effects caused by mutual interference between DTV and LTE in order to ensure the systems coexistence in the 700 MHz band.

REFERENCES

- [1] Goth, Greg, "Something's in the Air: Broadband Advances Depend on Wireless," *Internet Computing, IEEE*, vol.14, no.5, pp.7,9, Sept.-Oct. 2010.
- [2] Young-June Choi; Shin, K.G., "Opportunistic Access of TV Spectrum Using Cognitive-Radio-Enabled Cellular Networks," *Vehicular Technology, IEEE Transactions on*, vol.60, no.8, pp.3853,3864, Oct. 2011.
- [3] Fitch, M.; Nekovee, M.; Kawade, S.; Briggs, K.; MacKenzie, R., "Wireless service provision in TV white space with cognitive radio technology: A telecom operator's perspective and experience," *Communications Magazine, IEEE*, vol.49, no.3, pp.64,73, March 2011.
- [4] Weidong Wang; Weidong Wang; Zhi Lv; Wei Huang; Yinghai Zhang, "Analysis of interference from digital Terrestrial Television Broadcast to LTE TDD in Digital Dividend spectrum," *Network Infrastructure and Digital Content, 2010 2nd IEEE International Conference on*, vol., no., pp.692,697, 24-26 Sept. 2010.
- [5] ANATEL, Consulta pública nº 12. "Proposta de Regulamento sobre Condições de Uso de Radiofrequências, na Faixa de 698 MHz a 806 MHz," ANATEL, Feb. 2013.
- [6] R. Prescott, "Brazil speeds up availability of 2.5 GHz, 700 MHz bands for LTE," *RCWireless Americas*, 2013.
- [7] Wei Li; Jiadi Chen; Hang Long; Bin Wu, "Performance and Analysis on LTE System under Adjacent Channel Interference of Broadcasting System," *Computer and Information Technology (CIT), 2012 IEEE 12th International Conference on*, vol., no., pp.290,294, 27-29 Oct. 2012.
- [8] Guidotti, A.; Guiducci, D.; Barbiroli, M.; Carciofi, C.; Grazioso, P.; Riva, G., "Coexistence and Mutual Interference between Mobile and Broadcasting Systems," *Vehicular Technology Conference (VTC Spring), 2011 IEEE 73rd*, vol., no., pp.1,5, 15-18 May 2011.
- [9] Alencar, M. S., *Digital Television*. New York: Cambridge University Press, 2009. 310p.
- [10] M. das Comunicações, "Norma número 01/2010. Norma técnica para execução dos serviços de radiodifusão de sons e imagens e de retransmissão de televisão com utilização da tecnologia digital," Ministério das Comunicações, Tech. Rep., 2010.
- [11] Andreas Molisch, "Wireless Communications," Wiley-IEEE Press, John Wiley and Sons Ltd., 2011, ISBN 978-0-470-74186-3, Paperback, 827 Pages.
- [12] Motorola, "Long term evolution (LTE): A technical overview," Motorola Inc., Tech. Rep., 2010.
- [13] P. R. H. Balduino, "Dividendo digital," *Revista da Sociedade Brasileira de Engenharia de Televisão (SET)*, vol. 22. Ed. 126, Maio 2012.
- [14] In-kyoung Cho, Il-kyoo Lee and Youn-ok Park, "Study on Coexistence between Long Term Evolution and Digital Broadcasting services," *International Journal of Advanced Science and Technology* Vol. 38, January, 2012.
- [15] Recommendation ITU-R P.1546-1. "Method for point-to-area predictions for terrestrial services in the frequency range 30 MHz to 3000 MHz," Oct. 2009.
- [16] European Communication Office. "Spectrum Engineering Advanced Monte Carlo Analysis Tool (SEAMCAT-4)." Oct. 2013. <http://www.seamcat.org>.
- [17] European Communication Office. "SEAMCAT Manual". <http://tractool.seamcat.org/wiki/Manual>
- [18] Honglin Hu; Jian Zhang; Xiaoying Zheng; Yang Yang; Ping Wu, "Self-configuration and self-optimization for LTE networks," *Communications Magazine, IEEE*, vol.48, no.2, pp.94,100, February 2010
- [19] S. Sesia, I. Toufik and M. Baker "LTE – The UMTS Long Term Evolution: From Theory to Practice," © 2009 John Wiley & Sons, Ltd. ISBN: 978-0-470-69716-0.
- [20] 3GPP. "Overview of 3GPP Release 8 V0.3.0 (2013-12)". http://www.3gpp.org/ftp/Information/WORK_PLAN/Description_Releases/.