Evaluation of LTE700 and DVB-T and DVB-T2 electromagnetic compatibility for co-channel case

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Abstract— The 2012 World Radiocommunication Conference (WRC-12) allocated the 694-790 MHz (700 MHz) band for the mobile service on a co-primary basis with other services including digital terrestrial television service in Region 1. Countries of Region 1 will also be able to continue the use of these frequencies for their digital terrestrial television services. This allocation of mobile service in Region 1 in 700 MHz band became effective after the WRC-15. The objective of this article is to assess the electromagnetic compatibility of mobile broadband (LTE) and Digital Video Broadcasting - Terrestrial (DVB-T and DVB-T2) operating both in 700 MHz band. The study contains an assumption of a preferred frequency division duplex (FDD) channelling arrangement which contains confined 2x30 MHz block: 703-733 MHz (uplink) and 758-788 MHz (downlink). The model consists of two elements, LTE network and DVB-T / DVB-T2 (or DVB-T/T2) system. Co-channel scenario was analyzed in this paper, and possible impact of LTE base stations to DVB-T/T2 fixed outdoor reception receivers. The Minimum Coupling Loss (MCL) method and Monte Carlo simulation within SEAMCAT software was used for interference analysis. The MCL method was chosen to show single interferer scenario of LTE base station. The Monte Carlo simulations investigated cumulative effect of LTE network. During simulations the propagation model was used Recommendation ITU-R P.1546-5. The results obtained provide the minimum coupling distance required between LTE and DVB-T and DVB-T2 in the 700 MHz band to maintain the necessary performance level of the DVB-T/T2 systems.

1. INTRODUCTION

The 2012 World Radiocommunication Conference adopted Resolution 232 (WRC-12) relating to the allocation of the frequency band 694-790 MHz (700 MHz) in Region 1 to the mobile service on a co-primary basis with other services to which this band is allocated on a primary basis and identified it to International Mobile Telecommunications (IMT) [1]. The allocation became effective immediately after the WRC-15. This band has already been allocated to the mobile service in Regions 2 and 3. The Long Term Evolution (LTE) with 700 MHz frequency band will reduce the number of needed base stations that will further save costs of LTE network development.

Resolution 232 (WRC-12) invites ITU-R to study the compatibility between the mobile service and other services currently allocated in the frequency band 694-790 MHz [2]. This frequency range can be put into use only after all the necessary electromagnetic compatibility studies have been completed. The following case study elaborates on evaluation of electromagnetic compatibility of LTE700 and Digital Video Broadcasting - Terrestrial (DVB-T and DVB-T2) operating in the 700 MHz band. The case study assesses the necessary minimum coupling distance between these systems in the 700 MHz band to maintain the necessary performance level of the DVB-T and DVB-T2 systems.

Authors found that studies on evaluation of compatibility of LTE700 and DVB-T and DVB-T2 operating in 758-788 MHz (downlink) have been performed within the ITU-R study group JTG-4-5-6-7 [3]. According to the results of study 1A [3] the required separation distance for a single LTE base station of the mobile service should be about 61 km for protection of DVB-T receiving system, but taking into account cumulative effect the required separation distance is found to be about 212 kilometres. In the study 1A [3] the GE06 coordination trigger field strength value (25 dBµV/m for upper Band V) for the protection of broadcasting from mobile service was used. According to the results of the study 1B [3] for protection of Digital Terrestrial Television Broadcasting (DTTB) from co-channel IMT downlink, even without accumulation of interfering field strength, a single IMT base station need to be positioned 53 km (for land path) from the DTTB service edge, i.e. from the border of the affected Administration. The study 1B [3] shows that when conducting compatibility studies, the cumulative interference of signals from the mobile service base stations should be considered. The cumulative interfering field strength from increasing numbers of base-stations was also calculated in study 1 B. The results show that the excess of the cumulative interference from mobile service network over the single interferer can be up to 20 dB which causes a significant increase in the required separation distance when using the same field strength threshold for cumulative interference as for single entry interference. Based on the parameters used in the study 1 B [3], the resulting separation distance could be increased up to 200 km when using the same field strength threshold for cumulative interference as for single entry interference (25 dBµV/m for upper Band V). The interference probability was calculated using Monte Carlo simulation. However according to the conclusion of the Report of the Conference Preparatory Meeting (CPM) to the WRC-12 the potential impact of cumulative effect of interference from base stations, which individually did not trigger the need for coordination with broadcasting service might be less significant in practice. The calculations of study 1B are made according to Report ITU-R BT.2265 which contains a methodology to assess the impact of interference from multiple base -station networks on DTTB reception [3].

Unlike the abovementioned studies this paper presents results of using both the Minimum Coupling Loss and Monte Carlo method, and also GE06 predetermined trigger field strength values. Different parameters like effective radiated power (e.r.p.), frequencies, a cell range, DTT systems (DVB-T and DVB-T2) etc., and compatibility evaluation methodologies were used in these two studies. This paper contains an important part of evaluation of LTE 700 and DVB-T/T2 operating in the 700 MHz band.

2. TECHNICAL CHARACTERISTICS

The study contains an assumption of a frequency division duplex (FDD) channelling arrangement which contains 2x30 MHz block aligned with 3GPP band 28 lower frequency: 703-733 MHz for uplink and 758-788 MHz for downlink [4]. LTE channels with 10 MHz bandwidth were used in this study in order to evaluate a more realistic scenario [5]. The LTE /LTE-A parameters used in this study are taken from inputs to JTG 4-5-6-7 from WP5D for IMT (LTE) [6] and Report ITU-R M.2292-0 [7]. The DVB-T and DVB-T2 parameters used in this study are taken from inputs to JTG 4-5-6-7 from WP6A for Digital Terrestrial Television (DTT) [9]. The DVB-T receiver blocking mask used in this study was the same like in CEPT ECC WGSE SE7 working group studies.

3. PROTECTION CRITERIA AND COMPATIBILITY EVALUATION METHODOLOGY

Two methods were used in this paper to assess the interference of LTE 700 operating in 758-768 MHz and DVB-T/T2 operating in DTT channel 57, namely Minimum Coupling Loss (MCL) and Monte Carlo method. Two different protection criteria were used to analyse the interference from LTE base stations (downlink) to DVB-T/T2 receivers:

a) the protection criteria used in MCL and in Monte Carlo simulations calculations: $I/N = -10dB$ [9];

b) the protection criteria used in MCL calculations: in GE06 Agreement [10] provided predetermined trigger field strength values.

4. INTERFERENCE SCENARIO

The interference scenario where LTE700 downlink interferes DVB-T/T2 receiving stations in a co-channel was evaluated in this paper. DVB-T/T2 station operates in 57 channel (frequencies between 758 MHz and 766 MHz). It is assumed that LTE700 networks works in a 10 MHz channel (frequencies between 758 MHz and 768 MHz). Mobile operators usually have only one 10 MHz frequency block in LTE800 frequency band, so similar situation also is likely in the LTE700 frequency band. The interference scenario where LTE700 downlink interferes DVB-T/T2 downlink (receiver) stations was evaluated in this study. SEAMCAT simulation scenario is given in Figure 1.

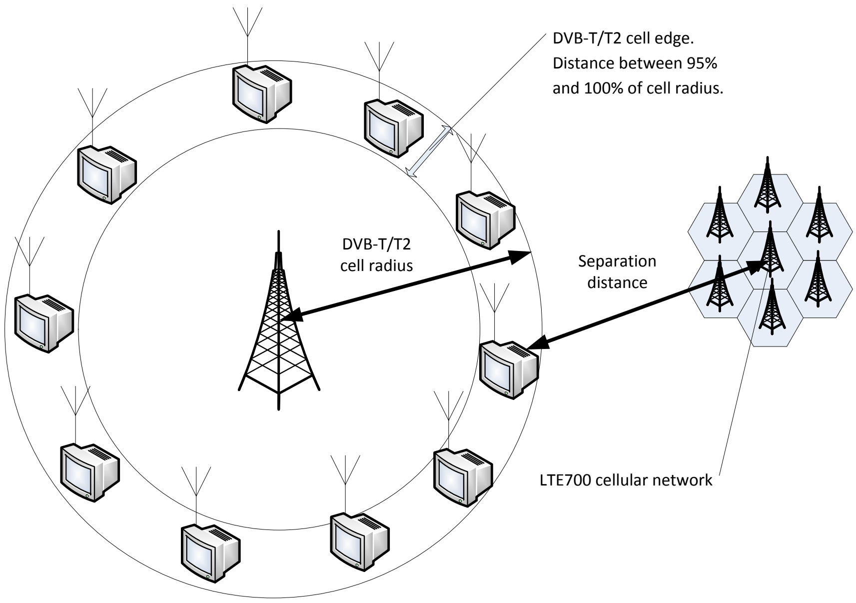

Figure 1. SEAMCAT simulation scenario.

While there are several possible scenarios for the interference between mobile and broadcasting service, this contribution focuses only on a scenario that is mostly common as shown in figure above: mobile service BS interference into fixed outdoor DVB-T/T2 reception. In our simulations we addressed the case where digital broadcast receivers are randomly located at the cell edge (distance between 95% and 100% of cell radius) in rural environment. For DTT network we addressed the case of fixed outdoor reception for the high power DTT transmitter for DVB-T and DVB-T2 technology.

5. COMPATIBILITY ANALYSIS AND RESULTS

5.1. MCL calculation results

The MCL method is useful for the initial assessment of compatibility. The required path loss or isolation (MCL), $L_{\mathrm{Re}quired\_path\_loss}$, between the interfering transmitter (I_t) and the victim receiver (V_t) to ensure that there is no harmful interference is obtained from

$$L_{\mathrm{Re}quired\_path\_loss} = P_{BS\_Tx} + G_{DTT\_Rx} - P_{I\_DTT\_Rx}, (1)$$

where: P_{BS_Tx} – e.i.r.p. of the interfering BS; G_{DTT_Rx} – victim DTT system antenna gain. The interference level at the DTT fixed outdoor reception receiver, $P_{I\_DTT\_Rx}$, is obtained from

$$P_{I\_DTT\_Rx} = P_{n\_DTT\_Rx} + I/N, \quad (2)$$

where: $P_{n\_DTT\_Rx}$ – noise power at the DTT receiver; I/N – interference to noise ratio.

$$P_n = NF + 10 \cdot \log_{10}(k \cdot T_0 \cdot B), \quad (3)$$

where: P_n – receiver noise input power (dBW); NF – receiver noise figure (dB); k - Boltzmanns's constant (k=1.38x10^{-23} J/K); T_0 – absolute temperature (T_0=290 K); B – receiver noise bandwidth (7,6x10^6 Hz for a 8 MHz DVB-T channel, and 7,77x10^6 Hz for a 8 MHz DVB-T2 channel).

The required path loss between the LTE BS transmitter and the DVB-T fixed outdoor reception receiver of 8 MHz bandwidth is

$$L_{\mathrm{Re}quired\_path\_loss\_DVB-T} = 57 dBm/8MHz + 9.15 dBi - (-98.16\, dBm/7.6MHz + (-10 dB)) = 174.3[dB]. (4)$$

The isolation figure is further converted into a separation distance using the Recommendation ITU-R P.1546-5. The permissible interference level produced by interfering base station, $P_{I\_BS\_permissible\_DVB-T\_Rx}$, at DVB-T fixed outdoor reception receiver is obtained from

$$P_{I\_BS\_permissible\_DVB-T\_Rx} = P_{BS\_Tx} - L_{Required\_path\_loss} . (5)$$

The maximum permissible interference level produced by interfering LTE BS, $P_{I\_BS\_\max permissible\_DVB-T\_Rx}$, at DVB-T fixed outdoor reception receiver of 8 MHz bandwidth is

$$P_{I\_BS\_\max permissible\_DVB-T\_Rx} = 57 dBm/8MHz - 174.3dB = -117.3[dBm]. (6)$$

The calculated required protection (coupling) distance, $d_{sep\_req\_BS-DVB-T}$, between LTE base station and the DVB-T fixed outdoor reception receiver is about 84.7 km (for T%1; L%50, at 10 m receiving antenna height).

The maximum permissible interference level produced by interfering LTE BS, $P_{I\_BS\_\max permissible\_DVB-T2\_Rx}$, at DVB-T2 fixed outdoor reception receiver of 8 MHz bandwidth is

$$P_{I\_BS\_\max permissible\_DVB-T2\_Rx} = 57 dBm/8MHz - 175.2dB = -118.2[dBm]. (7)$$

The calculated required protection (coupling) distance, $d_{sep\_req\_BS-DVB-T2}$, between LTE base station and the DVB-T2 fixed outdoor reception receiver is about 90.1 km (for T%1; L%50, at 10 m receiving antenna height).

5.2. GE06 predetermined trigger field strength value calculation results

The protected field strength values used in this paper are in accordance with GE06 Agreement. The Recommendation ITU-R P.1546-5 (using flat terrain) was used in this evaluation. The calculation results are presented in Table 4.

Table 4. Calculation results.

Parameter	DTT system type
	DVB-T / DVB-T2
Receiving station	Fixed outdoor reception at 10 m
Tx/Rx frequency	762 MHz (TV channel 57)
Predetermined trigger field strength value	25 dBµV/m at 10 m in a 8 MHz reference bandwidth using ITU-R Recommendation P.1546 (T%1; L%50)
Separation distance between LTE BS Tx and DTT Rx	55 km

The calculation results present that the required separation distance from LTE700 base station must be more than about 55 km for DVB-T / DVB-T2 receivers.

5.3. Monte Carlo calculation results

SEAMCAT Monte Carlo simulation results show the required separation distance between the LTE BS (downlink) and DVB-T/T2 fixed outdoor reception receivers, according to the protection $I/N = -10dB$ defined for DVB-T/T2 receivers. Monte Carlo simulations were performed taking into account cumulative effect – LTE700 network of seven BS is used in the simulations working in the same frequency. In our study the probability of interference (PoI) less than 5% was considered to be a sufficient protection level. Results of SEAMCAT simulations are given in Table 5.

Table 5. Results of SEAMCAT simulations.

Separation distance between LTE BS T_x and DVB-T/T2 R_x, km	Probability of interference (*PoI*), % for DVB-T case	Probability of interference (*PoI*), % for DVB-T2 case
1	100.00	100.00
30	99.95	99.99
50	52.84	58.36
100	23.77	25.46
152	4.77	7.10
159	2.71	4.94

The simulation results show that the required separation distance must be more than approximately 152 km regarding DVB-T receivers and 159 km regarding DVB-T2 (which is more sensitive) receivers.

6. Conclusions

In this paper is evaluated a leading problem - coexistence requirements for the LTE deployment in the 700 MHz band and the DVB-T and DVB-T2 in co-channel scenario between neighbouring countries. The 700 MHz spectrum part is very valuable because of it optimum radio wave propagation and bandwidth.

Electromagnetic compatibility between LTE BS downlink and DVB-T/T2 fixed outdoor reception receivers was assessed with three different methods: MCL and GE06 predetermined trigger field strength value calculations for single interferer scenario of LTE base station, and Monte Carlo simulations for investigated cumulative effect of LTE BS network. According to MCL calculations the minimum coupling distance required between LTE BS downlink and DVB-T/T2 fixed outdoor reception receivers in the 700 MHz band to maintain the necessary performance level of the DVB-T/T2 system is 84.7 km (for DVB-T system) and 90.1 km (for DVB-T2 system). According to the GE06 predetermined trigger field strength value calculation results the required separation distance is about 55 km. The Monte Carlo simulation results show that the required separation distance must be more than approximately 152 km regarding compatibility with DVB-T and 159 km regarding DVB-T2 (which is more sensitive) with condition that the probability of interference (*PoI*) less than 5% is considered to be a sufficient protection level.

In order to reduce separation distance between LTE BS and DVB-T/T2 systems the additional mitigation techniques, such as downtilting of antennas, use of cross polarisation, reducing the power of interfering transmitter, adjusting the LTE 700 BS transmitter antenna height, antenna discrimination for LTE network planning and deployment are required in order to assure the compatibility between these two services.

Another questionable issue is protection criteria I/N = -10 dB used in this study for DVB-T/T2 receivers. CEPT countries also consider more relaxed protection criteria as C/(I+N) = 21 dB (Source ITU-R BT 2383 aligns with value used in CEPT Report 53 and ECC Reports 239 & 240), which indicates shorter separation distances. Some additional practical measurements could be performed to facilitate improvement of evaluation of this issue. The acquired compatibility evaluation results can be used by National Regulatory Authorities (NRAs), which are responsible for spectrum planning at the national level, mobile operators, equipment manufacturers and other interested parties when planning mobile and broadcasting services in the 700 MHz band.

References

[1] "Use of the frequency band 694-790 MHz by the mobile, except aeronautical mobile, service in Region 1 and related studies," Resolution 232 (WRC-12), Radio Regulations, Resolutions and Recommendations, International Telecommunications Union (ITU), Vol. 3, edition of 2012.

[2] Ancans, G., Bobrovs, V. and Ivanovs, G., "Spectrum usage in mobile broadband communication systems," *Latvian Journal of Physics and Technical Sciences*, Vol. 50, Issue 3, 2013, p. 53.

[3] "Co-channel sharing and compatibility studies between digital terrestrial television broadcasting and international mobile telecommunication in the frequencyband 694-790 MHz in the GE06 planning area", draft new Report ITU-R BT.[IMT_DTTB_694-790-Co-channel], Annex 9 to Joint Task Group 4-5-6-7 Chairman's Report, document 4-5-6-7/715-E 14 August 2014.

[4] G. Ancans, V. Bobrovs, G. Ivanovs, "Frequency arrangement for 700 MHz Band", Latvian Journal of Physics and Technical Sciences, vol. 52, iss. 1, February 2015.

[5] G. Ancans, E. Stankevicius, V. Bobrovs, "Assessment of DVB-T compatibility with LTE in adjacent channels in 700 MHz band", Elektronika ir Elektrotechnika, vol. 21, no. 4, 2015.

[6] "Sharing Parameters for WRC-15 Agenda Item 1.2," Liaison statement to Joint Task Group 4-5-6-7, ITU Working Party 5D, Document 4-5-6-7/49-E, 16 October 2012.

[7] "Characteristics of terrestrial IMT-Advanced systems for frequency sharing / interference analyses," Report ITU-R M.2292-0, December 2013, p. 13.

[8] "Evolved Universal Terrestrial Radio Access (E-UTRA). User Equipment (UE) radio transmission and reception", ETSI TS 136 101 V10.7.0, (3GPP TS 36.101 V10.7.0 Release 10), ETSI, 2012.

[9] "Technical characteristics and other technical issues for terrestrial television broadcasting in connection with WRC-15 Agenda Item 1.2," Liaison statement to Joint Task Group 4-5-6-7, Working Party 6A, Document 4-5-6-7/55, 5 November 2012.

[10] “Final acts of the Regional Radiocommunication Conference for planning of the digital terrestrial broadcasting service in parts of Regions 1 and 3, in the frequency bands 174-230 MHz and 470-862 MHz (RRC-06)”, International Telecommunication Union (ITU), Geneva, 2006.