Evaluation of LTE 700 and DVB-T Electromagnetic Compatibility in Adjacent Frequency Bands

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Abstract— The 2012 World Radiocommunication Conference allocated the 694–790 MHz (700 MHz) band for the mobile service on a co-primary basis with other services in Region 1 (Europe, Africa, the Middle East). However, countries of Region 1 will also be able to continue the use of these frequencies for their digital terrestrial television services, if necessary. This allocation will be effective immediately after the WRC-15. The objective of this paper is to assess the electromagnetic compatibility of Digital Video Broadcasting-Terrestrial (DVB-T) operating below 694 MHz and mobile broadband (LTE) operating in 700 MHz band. The study contains an assumption of a preferred frequency division duplex (FDD) channelling arrangement which contains confined 2×30 MHz block: 703–733 MHz (uplink) and 758–788 MHz (downlink). The model consists of two elements, a LTE network and a DVB-T system. An adjacent channel scenario was analyzed in this paper: possible impact of LTE user equipment (uplink) to DVB-T receiver. The Minimum Coupling Loss method and Monte Carlo simulation within SEAMCAT software was used for interference analysis. The Minimum Coupling Loss method was chosen to calculate worst case (most conservative scenario) in order to understand most critical points of these two systems. The Monte Carlo simulations show more relaxed electromagnetic compatibility scenario. During simulations more appropriate propagation model was used (Recommendation ITU-R P.1546), which allows to analyse also non line of sight radio propagation conditions. The results obtained provide the minimum coupling distance required between LTE and DVB-T in the 700 MHz band to maintain the necessary performance level of the DVB-T system.

1. INTRODUCTION

The 2012 World Radiocommunication Conference drafted and 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, except aeronautical mobile service (according to ITU Radio Regulations (RR) footnote 5.312A), 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). The allocation will become effective immediately after the WRC-15. This band has already been allocated to the mobile service in Regions 2 and 3 [1]. The 700 MHz band is already being described as the *second digital dividend* following the allocation of frequencies in the 800 MHz band — the *first digital dividend* — for mobile broadband services. This part of spectrum is very valuable because it is optimum in terms of need of coverage and bandwidth. 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. These studies must be completed by the WRC-15. The following case study elaborates on evaluation of electromagnetic compatibility of LTE user equipment (UE) uplink operating in the 700 MHz band with TV broadcasting (DVB-T) operating below 694 MHz. 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 system.

Authors found that studies on evaluation of compatibility of LTE user equipment (uplink) operating above 703 MHz with DVB-T operating in digital terrestrial television (DTT) channel 48 (686–694 MHz) have been performed within the ITU-R study group JTG-4-5-6-7 [3]. According to the results of studies [3] the resulting critical separation distance between these systems is found to be around 22 meters. The Minimum Coupling Loss (MCL) method and Monte Carlo methodology was used in these studies. The studies were conducted for fixed outdoor and portable indoor DTT reception modes.

Authors found that a study [4] provides results on the coexistence requirements for the LTE deployment in the 700 MHz band and the DTT service in adjacent frequency bands. The study [4] is based on Monte Carlo simulations to assess the potential of interference from LTE uplink operating in the lower 700 MHz frequencies into DTT frequencies below 694 MHz. Even with several worst case assumptions and parameters, simulations revealed a low interference probability.

One of main tasks of calculations in studies [3, 4] was to derive IMT (LTE) UE out-of-band (OOB) emission limit to protect the broadcasting transmission in TV channel 48 and below from interference of the mobile service (IMT) in the band 694–790 MHz, taking into account also the 700 MHz band channel arrangement, which is provided in Table 1 of this paper. In our particular study we used DVB-T and LTE UE parameters, agreed within the ITU-R study group JTG-4-5-6-7. A general LTE spectrum emission mask of 3GPP, with OOB emission limit of −9 dBm/8 MHz (regarding the DTT channel 48) for the 10 MHz LTE channel, was used in our study. More strict OOB emission limit values were used in the studies [3, 4]. Only fixed outdoor DTT reception mode was considered in our study.

Similar study using Monte Carlo simulations was done in article [5] where obtained results show the electromagnetic compatibility situation in co-channel and adjacent channel case between interferer E-UTRA (LTE) uplink and victim DVB-T. This study concludes that both co-channel interference and adjacent channel interference from interferer E-UTRA uplink to the reception of the DVB-T downlink service would be negligible, and that in general E-UTRA uplink will not disturb DVB-T receiver performance. Therefore, geographical separation is not necessary in that case. Unlike the abovementioned study this paper presents results of using both the Minimum Coupling Loss and Monte Carlo method. Different protection ratios values, channel bandwidths, propagation models and compatibility evaluation methodologies were used in these two studies.

This paper contains an important part of evaluation of DVB-T compatibility with LTE in adjacent channels in 700 MHz band.

2. TECHNICAL CHARACTERISTICS

The study contains an assumption of a frequency division duplex (FDD) channelling arrangement which contains 2 × 30 MHz block aligned with 3GPP band 28 lower frequency: 703–733 MHz for uplink and 758–788 MHz for downlink. The 700 MHz band frequency arrangement is presented in Table 1.

Table 1: 700 MHz band channel arrangement.

Guard band	**LTE Uplink**	**Duplex gap**	**LTE Downlink**	**Guard band**
694–703 MHz	703–733 MHz	733–758 MHz	758–788 MHz	788–791 MHz
9 MHz	30 MHz	25 MHz	30 MHz	3 MHz

If the 694–790 MHz band is used for mobile service, then it corresponds to decrease of twelve DTT channels from 49 to channel 60. The first LTE uplink channel (703–713 MHz) establishes possible interference problems with the DVB-T receivers in the DTT channel 48. LTE channels with 10 MHz bandwidth were used in this study in order to evaluate a more realistic scenario.

2.1. LTE Parameters

The LTE 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].

General E-UTRA spectrum emission mask was simulated according to Table 6.6.2.1.1-1 of 3GPP TS 36.101 [8]. This spectrum emission mask describes the harmful interference level in the DTT frequency band operating below 694 MHz.

2.2. DVB-T Parameters

The DVB-T parameters used in this study are taken from inputs to JTG 4-5-6-7 from WP6A for DVB-T [9]. The receiver blocking (filter) mask is the most critical parameter of the DVB-T station in this study. The receiver mask shows the selectivity level of the particular device. 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

Two methods were used in this study to assess the interference of LTE user equipment (uplink) operating above 703 MHz to DVB-T operating in DTT channel 48, namely Minimum Coupling

Loss (MCL) and Monte Carlo simulation. Two different protection criteria were used to analyse the interference from LTE user equipment (uplink) to DVB-T:

a) the protection criteria used in MCL calculations: $I/N = -10\,\text{dB}$ [6];
b) the protection criteria used in Monte Carlo simulations: according to ITU-R Working Party 6A proposed protection ratios PR (Table A1.15) [9].

4. COMPATIBILITY EVALUATION METHODOLOGY

4.1. MCL Method

The Minimum Coupling Loss method calculates the isolation required between the interferer transmitter and the victim receiver to warrant that there is no harmful interference. This method is the worst case analysis and produces a boundary result for scenarios of statistical nature. This method evaluates the required path loss level according to minimum protection criteria ($I/N = -10\,\text{dB}$).

4.2. Monte Carlo method

The Monte Carlo modelling is used for simulation methodology in this study in order to assess the interference from LTE UE uplink to DVB-T fixed reception receivers. Monte Carlo method is applicable to simulate mainly all possible radio communication based scenarios. This flexibility is ensured by the manner of the characterization of input parameters inside the system. The input type of each variable parameter (as horizontal and vertical antenna pattern, EIRP, propagation environment etc.) is modelled like statistical distribution function. The Monte Carlo modelling provides statistical elements of real life behaviour of mobile terminals and interference, enabling a realistic estimate of the potential interference. SEAMCAT software tool based on Monte Carlo method was used in this study [10].

5. INTERFERENCE SCENARIO

The interference scenario where LTE uplink interferes DVB-T downlink (receiver) station was evaluated in this study. SEAMCAT simulation scenario is given in Figure 1.

While there are several possible scenarios for the interference between broadcasting and mobile service, this contribution focuses only on a scenario that is mostly common as shown in figure above: outdoor mobile service UE interference into fixed outdoor DVB-T receiver.

In our simulations we addressed the case of digital broadcast receivers located randomly within the DDT cell in rural environment. For DTT network we addressed the case of fixed rooftop reception for the high power DTT transmitter for DVB-T technology.

With regard to the number of active mobile users, we chose the worst case for OOB emissions of one active mobile user per cell (3 users per base station), so that the number of subcarriers per user was equal to the total number of subcarriers. In that situation the minimum required separation distance between LTE UE and DVB-T receiver was found to DVB-T receiver would work without disruption. This situation could be difficult to control because user equipment moves randomly in area and DVB-T receivers could be placed everywhere.

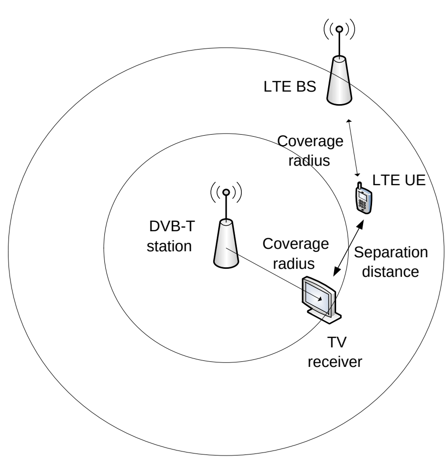

Figure 1: SEAMCAT simulation scenario.

6. COMPATIBILITY ANALYSIS AND RESULTS

6.1. MCL Calculation Results

The MCL method is useful for the initial assessment of compatibility. MCL between the interfering transmitter (I_t) and the victim receiver (V_r) is calculated further:

$$L_{Required\_path\_loss} = P_{TX} - S_{RX} + G_{RX} + BW_{Unwanted\_emissions\_BW\_conversion}, \quad (1)$$

where: $L_{Required\_path\_loss}$ — required path loss; P_{TX} — EIRP of interferer, dBm; S_{RX} — victim sensitivity level, dBm; G_{RX} — victim antenna gain, dBi; $BW_{Unwanted\_emissions\_BW\_conversion}$ — unwanted emissions bandwidth conversion or I/N value, dB.

$$L_{Required\_path\_loss_{OFDM}} = (-9\,\text{dBm}/8\,\text{MHz}) - (-98\,\text{dBm}/8\,\text{MHz}) + 9.15 + 10 = 108.15\,\text{dBm}. \quad (2)$$

The result of an MCL calculation is an isolation figure which can subsequently be converted into a physical separation choosing an appropriate path loss model [10].

The isolation is then converted into a separation distance using the *Free-Space* attenuation, $L(loss)$, between isotropic antennas by formula [11]:

$$L\,(loss) = 32.4 + 20\log_{10}(f) + 20\log_{10}(d)\,, \quad (3)$$

where: f — frequency (MHz); d — distance (km).

The required protection distance, $d_{sep\_req\_DVB\text{-}T\text{-}BS}$, between the mobile service base station and the DTT station is 8.84 km.

6.2. Monte Carlo Simulation Results

SEAMCAT Monte Carlo simulation results show the required separation distance between the LTE UE (uplink) and DVB-T receiver, according to the protection ratios (PR) defined for DVB-T receiver. 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 2.

Table 2: Results of SEAMCAT simulations.

Separation distance between LTE UE T_x and DVB-T R_x, km	**Probability of interference (PoI), %**
0.01	31.63
0.05	15.04
0.1	6.45
0.15	4.54

The simulation results show that the required separation distance must be more than approximately 0.15 km.

7. CONCLUSIONS

This study presents important results on the evaluation of coexistence requirements for the LTE deployment in the 700 MHz band and the DVB-T in adjacent frequency band below 694 MHz. This part of spectrum is very valuable because it is optimum in terms of need of coverage and bandwidth.

Electromagnetic compatibility between LTE UE uplink and DVB-T receiver was assessed with two different methods: MCL calculations for worst case scenario and Monte Carlo simulations for more realistic case. The minimum coupling distance required between LTE UE uplink and DVB-T receivers in the 700 MHz band to maintain the necessary performance level of the DVB-T system is 8.84 km according to MCL calculations. The Monte Carlo simulation results show that the required separation distance must be more than approximately 0.15 km with condition that the probability of interference (PoI) less than 5% is considered to be a sufficient protection level.

The results of this study identify that when using the selected frequency arrangement additional mitigation techniques, such as downtilting of antennas, antenna discrimination, limitation of LTE UE out-of-band emission level etc., for LTE network planning and deployment are required in order to assure the compatibility between these two services. 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 services in the 700 MHz band and broadcasting service below 694 MHz.

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