ESTIMATION OF ELECTROMAGNETIC COMPATIBILITY BETWEEN DVB-T/DVB-T2 AND 4G/5G IN THE 700 MHZ BAND FOR CO-CHANNEL CASE

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The 694–790 MHz band (700 MHz) known also as the second digital dividend was allocated to the mobile radiocommunication service on a primary basis in Region 1 and identified to International Mobile Telecommunications by the World Radiocommunication Conference 2012 (WRC-12). The designation of mobile service in Europe and other countries of Region 1 in 700 MHz band was obtained after the World Radiocommunication Conference 2015 (WRC-15). Administrations of Region 1 will be able to plan and use these frequencies for mobile networks, including IMT. The goal of this study is to estimate the electromagnetic compatibility of Digital Video Broadcasting – Terrestrial (DVB-T/DVB-T2) and LTE (Long Term Evolution) technology operating both in 700 MHz band. The study assumes frequency division duplex (FDD) channel arrangement of 703–733 MHz (for uplink) and of 758–788 MHz (for downlink).

The model contains two parts: a DVB-T/DVB-T2 system and LTE mobile broadband network. Co-channel scenario is considered in this paper, and possible impact of DVB-T/DVB-T2 on LTE base stations (receivers) is also investigated. The Monte Carlo simulations within SEAMCAT software and the Minimum Coupling Loss (MCL) method are used for interference investigation. The coordination trigger field strength value predetermined by GE06 Agreement is also used in this study. The Monte Carlo method presents more relaxed electromagnetic compatibility scenario in comparison with the MCL method. For SEAMCAT simulations, ITU-R P.1546-5 radio propagation model is used.

The obtained results present the required minimum separation distance between DVB-T/DVB-T2 and LTE networks in the 694–790 MHz in order to provide the necessary performance of LTE mobile network.

Keywords: 4G, 5G, DVB-T/T2, DTTB, electromagnetic compatibility, IMT, interference, LTE, mobile communication, Monte Carlo, NR, SEAMCAT.

1. INTRODUCTION

The World Radiocommunication Conference 2012 approved Resolution 232 (WRC-12) relating to the allocation of the 694–790 MHz frequency band (700 MHz) to the mobile radiocommunication service in Region 1 on a co-primary status with other primary services and identified the band to International Mobile Telecommunications (IMT) [1].

According to Resolution 232 (WRC-12), ITU-R has to study the compatibility between the mobile service and other services currently allocated in the 694–790 MHz [2]. The frequency band can be utilised only after all mandatory electromagnetic compatibility studies have been finished. This study provides the estimation of electromagnetic compatibility of Digital Video Broadcasting – Terrestrial (DVB-T and DVB-T2) operating in the 700 MHz band and LTE700. The study identifies the necessary minimum separation distance between these systems in the 700 MHz band to maintain the minimum performance level of the LTE700 base stations (BS).

Three different ways of investigation are used in this paper for electromagnetic compatibility evaluation: the Minimum Coupling Loss (MCL) method, calculations of a coordination trigger field strength value predetermined by GE06 Agreement, and Monte Carlo simulations method using SEAMCAT.

The authors have identified that studies on estimation of compatibility of DVB-T/T2 and LTE700 are performed within the JTG-4-5-6-7 study group of ITU-R [3]. The

studies in [3] present co-channel interference calculation results from Digital Terrestrial Television Broadcasting (DTTB) transmitters and GE06 Plan entries installed into IMT uplink. For protection of receivers of base stations, the I/N criteria were used in these studies. The studies demonstrate that coupling distances of up to 427 km and 269 km for High Power and Medium Power DTTB transmitters, respectively, would be required to keep safe the IMT base station receiver for 99 % time at a target I/N of -6 dB and with no additional discrimination by cross-polarization or receiving antenna directivity.

Unlike the aforementioned studies, the present research is based on the MCL method, Monte Carlo method, and a coordination trigger field strength value predetermined by GE06 Agreement. Different values of e.r.p. (Effective Radiated Power), frequencies, compatibility evaluation methodologies etc. were used in the studies [3]. This paper involves important contribution of compatibility evaluation of DVB-T/T2 and LTE700 operating in the 694–790 MHz. Evolved versions of LTE are planned to be used as a basis for development of 5G mobile services and networks in 700 MHz band.

The paper is organised as follows. The second section is devoted to the technical characteristics of LTE/LTE-A and DVB-T/DVB-T2. The third section describes the interference scenario. The fourth section is dedicated to the compatibility analysis and results. In the last section conclusions are drawn.

2. TECHNICAL CHARACTERISTICS

This study provides an assumption of a frequency division duplex (FDD) channel

arrangement of 2×30 MHz: 703–733 MHz for uplink and of 758–788 MHz for down-

link [4], [5].

For 5G NR (New Radio) non-AAS (non-Active Antenna Systems), the 3GPP defined transmit and receive characteristics for UE (User Equipment) and BS (Base Station) (TS38.101-1 and TS 38.104) that are generally comparable to those defined for LTE (TS36.101 and TS 36.104). Taking into account that in-band and out-of-band

e.i.r.p. (Equivalent Isotropically Radiated Power) of the NR signal transmitted by the NR non-AAS base station does not exceed the limits, which apply to LTE carrier, the NR signal does not create more interference to other services in the same band or to adjacent band services than an LTE signal using the same bandwidth and transmitting at the same power [6].

A. Parameters of LTE/LTE-A

The LTE/LTE-A parameters used in this study are derived from inputs to JTG 4-5-6-7 task group from WP5D working group for IMT (LTE700) [7] and ITU-R Report

M.2292-0 [8].

Mobile service (LTE700) base station parameters used in this study are given in Table 1.

Table 1. Characteristics of LTE Base Station

Parameter	Value
Transmitting (Tx) frequency	763 MHz
Receiving (Rx) frequency	708 MHz
Channel bandwidth	10 MHz
Signal bandwidth	9 MHz
Maximum output power	46 dBm
e.i.r.p.	58 dBm
Antenna height	30 m
Antenna gain	15 dBi
Base station antenna pattern	3GPP Tri-sector antenna (60°)
Feeder loss	3 dB
Antenna downtilt	3°
Receiver noise figure	NF=5 dB
Cell size/radius	8 km (rural environment)
Sectorization	3 sectors
Antenna polarization	$\pm 45^\circ$
Reference sensitivity	-101.5 dBm
Noise floor	$10 \cdot \log_{10}(k \cdot T_0 \cdot B) + NF =$ -99.4 dBm
I/N	-6 dB
Receiver blocking mask	Table 7.6.1.1-1 of 3GPP TS 36.104 (V14.3.0)

The main parameters of LTE user equip-

ment are provided in Table 2.

Table 2. Characteristics of LTE User Equipment

Parameter	Value
Transmitting (Tx) frequency	708 MHz
Receiving (Rx) frequency	763 MHz
Channel bandwidth	10 MHz
Maximum output power, e.i.r.p	23 dBm
Antenna height	1.5 m
Antenna gain	-3 dBi
Body loss	4 dB
Receiver noise figure	NF=9 dB
Reference sensitivity	-95.5 dBm
Number of active LTE UE per BS cell	3

B. Parameters of DVB-T/DVB-T2

The DVB-T and DVB-T2 characteristics used in this study are derived from inputs to JTG 4-5-6-7 task group from

WP6A working group for DTTB [9]. The DVB-T and DVB-T2 parameters used in this paper are provided in Table 3.

Table 3. Characteristics of DVB-T / DVB-T2

Parameter	Value
Transmitter power e.r.p.	200 kW (High Power) 5 kW (Medium Power)
Transmit power e.i.r.p.	85.15 dBm (High Power) 69.15 dBm (Medium Power)
Tx/Rx frequency	706 MHz (TV channel 50)
Bandwidth	8 MHz
Signal bandwidth	7.6 MHz for DVB-T 7.77 MHz for DVB-T2
Tx antenna height	300 m (High Power) 150 m (Medium Power)
Tx antenna gain	0 dBi
Rx antenna gain (including feeder loss)	9.15 dBi
Rx antenna height	10 m
Antenna downtilt	1° (High Power) 1.6° (Medium Power)
Feeder loss	4 dB
Rx antenna pattern	Horizontal: omnidirectional BT.419
Rx sensitivity (P_{min} at the receiver input)	-77.17 dBm for DVB-T -79.07 dBm for DVB-T2
Rx noise level	-98.16 dBm for DVB-T -99.07 dBm for DVB-T2
DVB-T coverage range	70.53 km (High Power) 32.11 km (Medium Power) (using P.1546-4 with 10 m clutter)
Receiver noise figure (NF)	7 dB for DVB-T 6 dB for DVB-T2

In this study, $I/N = -6$ dB protection criteria are used to investigate the interference

from DVB-T/T2 transmitters to LTE base station receivers (uplink).

3. INTERFERENCE SCENARIO

It is assumed that LTE700 network works in a 10 MHz channel (BS Rx frequencies between 703 MHz and 713 MHz). DVB-T/T2 station operates in TV channel 50 (frequencies between 702 MHz and 710 MHz). Co-channel interference case is presented in Fig. 1.

Fig. 1. Interference scenario model in the frequency plane.

The interference scenario where DVB-T/T2 transmitter interferes LTE700 receiving stations (uplink) in a co-channel

is evaluated in this paper. Simulation scenario in SEAMCAT is given in Fig. 2.

Fig. 2. SEAMCAT simulation scenario.

This contribution focuses on a scenario as shown in figure above: DVB-T/T2 transmitter interference into mobile service BS receivers. In our simulations, we address the case where LTE700 receiving BSs (cellular network) are randomly located at the DTTB cell edge in a rural environment.

4. COMPATIBILITY ANALYSIS AND RESULTS

According to Ericsson paper [8], LTE will explicate in a way of providing coverage for mobile users. 5G networks will

comprise LTE access based on Orthogonal Frequency Division Multiplexing (OFDM) along with new radio interfaces.

A. MCL Method Calculation Results

For initial estimation of compatibility, MCL calculations are used. The minimum path loss of MCL method, $L_{Req\_path\_loss}$, between the interfering DVB-T/T2 trans-

mitter (I_t) and the victim LTE700 base station receiver (V_r) to secure that there is no harmful interference is derived from

$$L_{Req\_path\_loss} = P_{DTTB\_e.i.r.p.Tx} + G_{BS\_Rx} - P_{I\_BS\_Rx}, \quad (1)$$

where $P_{DTTB\_e.i.r.p.Tx}$ – e.i.r.p. of the interfering DVB-T/T2 transmitter (dBm); G_{BS_Rx} – victim LTE700 base station receiver antenna gain (dBi). In these MCL calculations, DVB-T/

T2 Tx frequency is 706 MHz. The interference strength at the LTE700 base station receiver, $P_{I\_BS\_Rx}$, is derived from

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

where $P_{n\_BS\_Rx}$ – noise power at the LTE700 base station receiver ; I/N – interference to noise ratio.

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

where P_n – receiver noise input power (dBW); NF – receiver noise figure (dB); k – Boltzmann's constant ($k=1.38 \times 10^{-23}$ J/K); T_0 – absolute temperature $T_0=290$ K; B – receiver noise bandwidth (7×10^6 Hz for a 10 MHz LTE700 channel). The minimum path loss between the DVB-T/T2 (High Power) and the LTE700 base station receiver is

$$\begin{aligned} L_{Req\_path\_loss\_High\_Power} &= 85.15 \text{ dBm}/8 \text{ MHz} + 15 \text{ dBi} \\ -(-106.5 \text{ dBm}/7 \text{ MHz}) &= 206 \text{ [dB]}. \end{aligned} \quad (4)$$

The path loss value is converted into a coupling distance using the ITU-R Recommendation P.1546-5. The allowable interference level emitted by interfering DVB-T/

T2 transmitter, $P_{I\_DTTB\_permissible\_BS\_Rx}$, at LTE700 base station receiver is derived from

$$P_{I\_DTTB\_permissible\_BS\_Rx} = P_{DTTB\_e.i.r.p\_Tx} - L_{Req\_path\_loss\_High\_Power}. \quad (5)$$

The maximum allowable interference level emitted by interfering DVB-T / DVB-

T2, $P_{I\_DTTB\_High\_Power\_max\_permissible\_BS\_Rx}$, at LTE700 base station receiver is

$$\begin{aligned} P_{I\_DTTB\_High\_Power\_max\_permissible\_BS\_Rx} &= 85.15 \text{ dBm}/8 \text{ MHz} \\ -206.65 \text{ dB} &= -121 \text{ [dBm]}. \end{aligned} \quad (6)$$

The calculated minimum protection distance (using ITU-R Recommendation P.1546-5), $d_{sep\_req\_DTTB\_High\_Power\_BS}$, between DVB-T/DVB-T2 transmitter and the victim receiving LTE700 base station is about 484 km (for T: 10 %; L: 50 %, at

30 m receiving antenna height).

The maximum allowable interference level emitted by interfering DVB-T/DVB-T2 transmitter, $P_{I\_DTTB\_Medium\_Power\_max\_permissible\_BS\_Rx}$, at LTE700 base station receiver is

$$P_{I\_DTTB\_Medium\_Power\_max\_permissible\_BS\_Rx} = 69.15 \text{ dBm/8 MHz} \quad (7)$$

$$-190 \text{ dB} = -121 \text{ [dBm]}.$$

The calculated minimum protection (coupling) distance, $d_{sep\_req\_DTTB\_Medium\_Power\_BS}$, between DVB-T/DVB-T2 transmitter and the victim LTE700 base station receiver is about 298 km (for T: 10 %; L: 50 %, at 30 m receiving antenna height).

According to MCL calculations, the

minimum separation distance needed between DVB-T/T2 and LTE BS receivers in the 694–790 MHz band to provide necessary performance of the LTE700 BS is 484 km (for High Power DTTB transmitter) and 298 km (for Medium Power DTTB transmitter).

B. Calculation Results of Coordination Trigger Field Strength Value Method Predetermined by GE06 Agreement

The protection of mobile service BSs against DTTB is defined in the GE06 Agreement, and the protected field strength value used in this paper complies with the GE06

Agreement. The ITU-R Recommendation P.1546-5 (using flat terrain) is used in this estimation. Calculation results are provided in Table 4.

Table 4. Calculation Results

Parameter	Value	
DTTB Tx/ BS Rx frequency	706 MHz (TV channel 57) / 708 MHz	
Transmitting DTTB station height	300 m (High Power), and 150 m (Medium Power)	
Receiving LTE BS height	30 m	
Coordination trigger field strength value predetermined by GE06 Agreement for protection of the mobile service base stations	14.6 dBμV/m at 20 m (or 18.3 dBμV/m at 30 m) in a 8 MHz reference bandwidth (BS corresponds to generic case, code NB) using ITU-R Recommendation P.1546-5 (T: 10 %; L: 50 %) [10]	
DTTB Tx power e.i.r.p.	85.15 dBm (High Power), and 69.15 dBm (Medium Power)	
DTTB system type	DVB-T/T2 High Power transmitter	DVB-T/T2 Medium Power transmitter
Calculated separation distance between DTTB Tx and LTE BS Rx	422 km	252 km

The calculation results present that the needed coupling distance between DVB-T/ DVB-T2 and LTE700 base station receivers

must be more than about 422 km for DVB-T/T2 High Power case and 252 km for DVB-T/T2 Medium Power case.

C. Monte Carlo Method Calculation Results

SEAMCAT simulation results demonstrate the required coupling distance between the DVB-T/T2 Tx and LTE BS Rx according to the protection criteria $I/N = -6 \text{ dB}$ defined for LTE BS receivers. In our study, the probability of interfer-

ence (PoI) is assumed to be less than 5 % to ensure a sufficient protection level. For SEAMCAT simulations, 200 000 events are used. Results of Monte Carlo simulations are given in Table 5.

Table 5. Results of SEAMCAT Simulations

Separation distance between DVB-T/T2 Tx and LTE BS Rx, km	Probability of inter- ference (<i>PoI</i>), % for DVB-T/T2 High Power case	Separation distance between DVB-T/T2 Tx and LTE BS Rx, km	Probability of interference (<i>PoI</i>), % for DVB-T/T2 Medium Power case
154	100.0	68	100.0
300	49.72	94	98.35
400	17.34	150	56.47
459	4.97	278	4.97
472	3.29	300	1.81

The simulation results demonstrate that the separation distance required has to be more than approximately 459 km regarding

DVB-T/T2 High Power case and 278 km regarding DVB-T/T2 Medium Power case.

5. CONCLUSION

The paper has addressed a leading problem – coexistence requirements for the LTE and DVB-T/T2 deployment in the 700 MHz band in co-channel scenario between neighbouring countries.

Electromagnetic compatibility between DVB-T/T2 transmitter and LTE BS receivers has been estimated using three different methods: the MCL method, calculations of a coordination trigger field strength value predetermined by GE06 Agreement for single interferer scenario of DTTB station, and Monte Carlo simulations method using SEAMCAT.

According to MCL calculations, the minimum required separation distance between DVB-T/T2 and LTE BS receivers in the 694–790 MHz band to provide the necessary performance level of the LTE700 system is 484 km for High Power DTTB transmitter and 298 km for Medium Power DTTB transmitter.

According to the calculation results of coordination trigger field strength predetermined by GE06 Agreement, the required coupling distance is about 422 km for High Power DTTB transmitter and 252 km for

Medium Power DTTB transmitter.

The SEAMCAT simulations demonstrate that the needed coupling distance has to be more than approximately 459 km regarding DVB-T/T2 High Power case and 278 km regarding DVB-T/T2 Medium Power case under condition that the probability of interference (*PoI*) less than 5 % is considered as a sufficient protection level.

The Monte Carlo method contributes to a more relaxed electromagnetic compatibility scenario in comparison with the MCL method. Applying different kinds of mitigation techniques, it is possible to improve electromagnetic compatibility of DVB-T/T2 and mobile service (LTE) systems used in neighbouring countries.

Since 5G NR non-AAS base station does not create more interference to other services in the same band or to adjacent band services than an LTE signal, the acquired results of this paper are also valid for 5G NR system.

These electromagnetic compatibility evaluation results can be used by National Regulatory Authorities (NRAs), mobile radiocommunication operators, equipment

manufacturers and other involved parties when planning broadcasting and mobile

service networks in the 700 MHz frequency band.

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