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Statistical Analysis of Probability of Interference of LTE 700 MHz to Digital TV

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***Abstract-* Internationally the Radio spectrum Management is done by Radio communication Sector of International Telecommunication Union (ITU-R). The coordination of activities related to spectrum regulation and standardization of radio communication equipment is done by ITU-R. The amount of spectrum available due to the transition of terrestrial television broadcasting from analogue to digital is called as *Digital dividend.* This terrestrial television transition has opened the opportunity to reallocate a large portion of the radio frequency spectrum. The Frequency allocations are collectively decided at the by ITU World Radio communication Conferences (WRCs) organized in every three to four years. In the recent times, in the WRCs it has been discussed to provide new allocations for mobile service, so that the demand of wireless spectrum due to proliferation of mobile devices and internet-based services is coped up. In WRC-12 the international regulatory framework for the digital dividend was last refined for allocation of band 694-700 MHz to the mobile service. This resulted into the scale of economy for mobile equipment manufacturing and is thus of interest for mobile communication Industry. Such harmonization activity significantly is currently taking place. This paper is a study of LTE deployment in the 700 MHz band and its coexistence with the DTT service in neighbouring frequency bands. Monte Carlo simulations, which handle the stochastic nature of interference from LTE mobile equipment to DTT receivers is the base of study. The presumptions considered, simulation methodology used, and scenarios defined for simulation model and parameters in case of both LTE and DTT systems are as agreed by TV broadcaster and the mobile communication community. Assessment was done on the probable interference given by LTE to DTT broadcast frequencies as a function of the ability of the LTE transmitter to avoid out-of-band emissions which cause interference to the DTT service in the neighbouring band. The simulation results lead to some conclusions about the LTE-DTT coexistence requirements for LTE deployment in the 700 MHz band.**

Keywords- Digital dividend, LTE, Interference, Digital terrestrial television (DTT), ITU

I. INTRODUCTION

The extreme usage of the smart phone and the resulting increase in the amount of wireless data traffic that is generated and consumed by these devices has resulted in bandwidth shortcomings. In addition, the development of new services, such as video, is placing large demands on the bandwidth, and many studies are forecasting a bandwidth shortage in the coming years. As a result, this issue is addressed by being spectrally efficient, but the opportunistic use of available spectrum in license exempt bands appears to be a promising and complementary way to address the spectrum shortage [7]. The transition to digital television transmission has resulted in a “digital dividend,” opening up new spectrum bands (referred to as TV white space (TVWS)) and providing prime license-exempt (LE) spectrum. These white spaces are considered as band of interest as they are being opened for opportunistic access in many parts of the world. For example, the aggregation of licensed and TVWS bands would enable the operators to make use of freely available spectrum for offload. This paper investigates the interference of coexistence and sharing of DVB-T and LTE systems operating in 700 MHz band. The probability of interference has been simulated using Monte Carlo Simulation tool. The rest of paper is organized as follows: Section II describes the SEAMCAT tool, Section III discusses probability of interference, Section IV and V describes simulation results and conclusion.

II. SIMULATION TOOL: SEAMCAT

SEAMCAT (Spectrum Engineering Advanced Monte Carlo Analysis Tool) [2] is a statistical simulation model that is based on Monte Carlo analysis to assess the probable interference between various radio communication systems It applies simulation of random processes by selecting random values from a probability density function. The method uses following considerations:

(a) Unwanted emissions: It consists of spurious emissions and out-of band emissions from the interfering transmitter, and are represented by the Adjacent Channel Leakage Ratio (ACLR) [2] falling within the victim's receiver bandwidth; (b) Receiver blocking power: It is a combination of the Adjacent Channel Selectivity (ACS), which is actually filter receiver capacity to avoid unwanted emissions [2], and the blocking mode defined as the Ratio Protection Mode [3]). The techniques are represented in Figure 1.

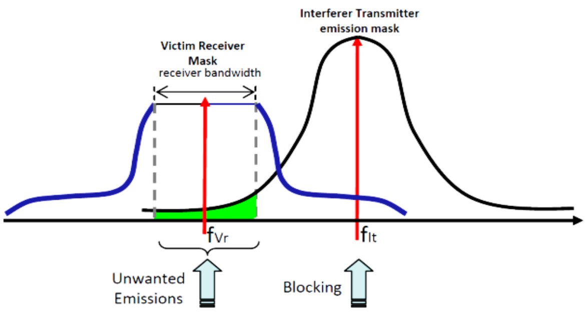

Fig. 1: Unwanted Emission and Receiver blocking Masks

For obtaining reliable results a large number of samples/events (>20,000) must be simulated. A basic framework is shown in Figure 2. In this SEAMCAT tool structure a Victim Receiver (V_r) is connected to a Wanted Transmitter (W_t) and it operates among number of Interferer Transmitters (I_t) out of which only a proportion are active. This kind of interference may belong either to the same system as the victim or a different system or a mixture of both.

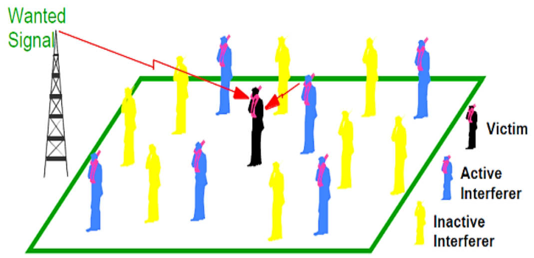

Fig. 2: Framework of Victim –Interferer model for Monte Carlo simulation

Interference is caused when the Carrier to Interference Ratio (i.e. C/I.   ) is less than the minimum permitted value. For calculating the victim's interference, the Victim's Wanted Signal Strength or Desired Received Signal Strength (dRss), corresponding to "C", and the interfering signal strength (iRss) corresponding to the "I" [4] is established.

A. Desired Received Signal Strength and Interfering Signal Strength

The desired Received Signal Strength (dRss) is the strength of the signal received at the Victim Receiver (V_r) from the Wanted Transmitter (W_t) and all interfering Signal Strengths (iRss), which is the strength of a signal from the Interfering Transmitter (i_t) received at the V_r [2] The generated samples are processed to find out the desired Received Signal Strength (dRss) and the process is repeated N times, where N is the number of events, also known as snapshots. Figure 3 shows a representative interference scenario.

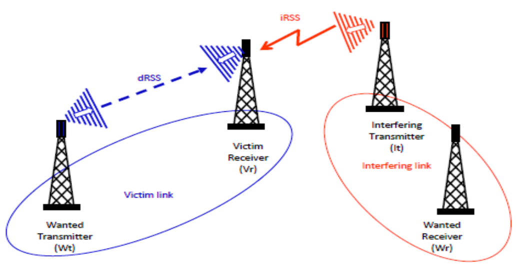

Fig. 3: Representative Victim Link and Interfering Link Scenario

The desired Received Signal Strength (dRSS) is represented by

$$dRss = pwt\ supplied + g\ wt \rightarrow vr - plwt \rightarrow vr(fvr) + gvr \rightarrow wt \qquad (1)$$

. where, the variables are:

- pwt $supplied$, power supplied to the wanted transmitter antenna
- gwt→vr, the antenna gain towards Victim receiver
- plwt→vr(fvr) ,the path loss occurring from the wanted transmitter to the victim receiver
- fvr, the frequency of the Victim receiver, Vr
- gvr→wt, the antenna gain towards Wt

The unwanted and blocking interference are given by equations shown below:

$$iRSSunwanted = f(emission\ it, git\ PC, git \rightarrow vr, pl\ it \rightarrow vr, gvr \rightarrow it)i \qquad (2)$$

$$iRSS\ blocking = \sum_{i=1}^{n\ interferes} f(p\ it\ supplied, git \rightarrow vr, pl\ it \rightarrow vr, a\ vr, g\ vr \rightarrow it)i \qquad (3)$$

here:

- emission i_t, is used to enable calculations of interference among systems in the same or adjacent bands
- gi_t PC, is the power control gain for the Interferer transmitter i_t with the power control function.
- $g_{it\rightarrow vr}$, is the i_t antenna gain towards victim receiver v_r.
- pl $i_{t\rightarrow vr}$, corresponds to the path loss between the interfering transmitter and the victim receiver
- $gv_r \rightarrow i_t$, is the v_r antenna gain towards i_t.
- p i_t supplied, is the power supplied to the i_t antenna.
- a_{vr}, is the blocking attenuation of the victim receiver.

B. Sensing Received Signal Strength

The Sensing Received Signal Strength (sRss) is the signal transmitted by the Wanted Transmitter (W_t) and sensed by the Interfering Transmitter(i_t). Note that W_t acts as a transceiver, that means when the energy is being sensed through the bandwidth of the sensing device (i.e. i_t) it acts as a receiving device [3][4] as shown in Figure 4.

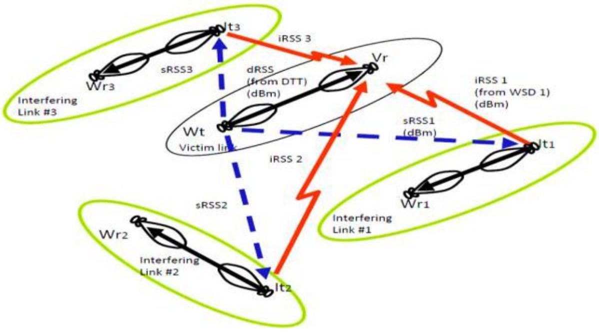

Fig. 4: Illustration of cognitive radio system having 3 systems and a victim system link.

The sRSS is found as the unwanted mask of the interfering system at the channel “m”, and expressed by

$$sRSS_{(fm)} = P_{wt(fm)} + G_{wt\rightarrow it} + G_{it\rightarrow wt} + L \qquad (4)$$

where:

- $P_{wt(fm)}$, the transmit power in dBm from w_t
- f_m the frequency of the Wireless sensing device
- $G_{wt\rightarrow it}$, is the gain of antenna in dBi of the W_t to i_t direction.
- $G_{it\rightarrow wt}$, the gain of antenna in dBi of the i_t to w_t
- L , path loss in dB between the i_t and the w_t

III. SCENARIOS USED FOR SIMULATION

20,000 events were generated to get the most reliable results and the SEAMCAT simulations scenarios were assessed to assure the stability of the probability interference results obtained [8]. The parameters used for simulation corresponding of the LTE Release 10 [2] [9] [10] and DVB-T were used and are summarized in the Table I. The propagation model employed

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is a variation of the Okumura Extended Hata [10] [12] developed by CEPT within the Project TEAM SE24 for studies of Short Range Devices (SDR). The model is called Hata-SRD [10] [12] and only differs of the HATA model by the antenna gain factor b (H_b), which is given by:

$b = (1.1\log(f) - 0.7) \cdot \min(10, H_b) - (1.56\log(f) - 0.8) + \max(0, 20\log(H_b/10))$ (5)

It is also important to take into account the spectrum emission and blocking mask correspond to the DVB-T, and the characteristics of the LTE User Equipment.The Cognitive radio criteria assumed were a probability of failure (false alarm) equal to 10% and the spectrum sensing detection threshold of -110dBm.This value is considered as capable of sensing digital TV signals.

TABLE I. SYSTEM PARAMETERS

Parameter	**LTE**	**DVB-T**
Frequency Band (MHz)	700	700
Base Station transmitted power (dBm)	33	33
BS antenna height(m)	1.5	1.5
Modulation	64 QAM	64 QAM
Detection Threshold(dBm)	-110	-110
Propagation Model	Extended Hata	Extended Hata
c/I (dB)	19	19

IV. RESULTS OF SIMULATION

The transmitter power of the victim receiver considered to obtain simulation results SEAMCAT software is 33dBm. Each simulation gave *iRss unwanted* and the *iRss blocking* .

For different distances between the LTE and DVB-T the probability of interference due to unwanted and blocking signals obtained is shown in Figures 5 to 8. Figure 9 shows the scenario outline.

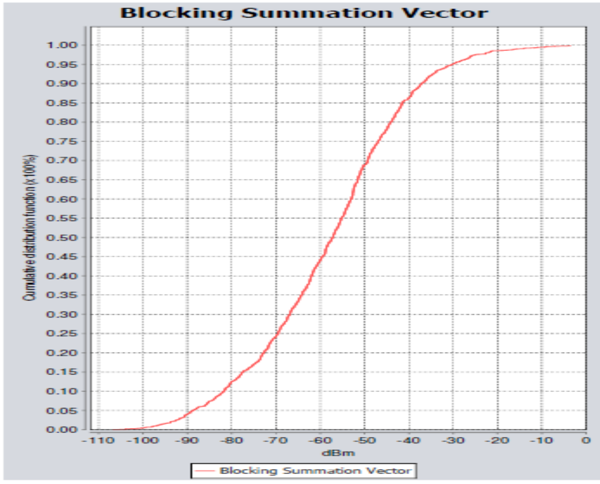

Fig. 5: IRSS blocking

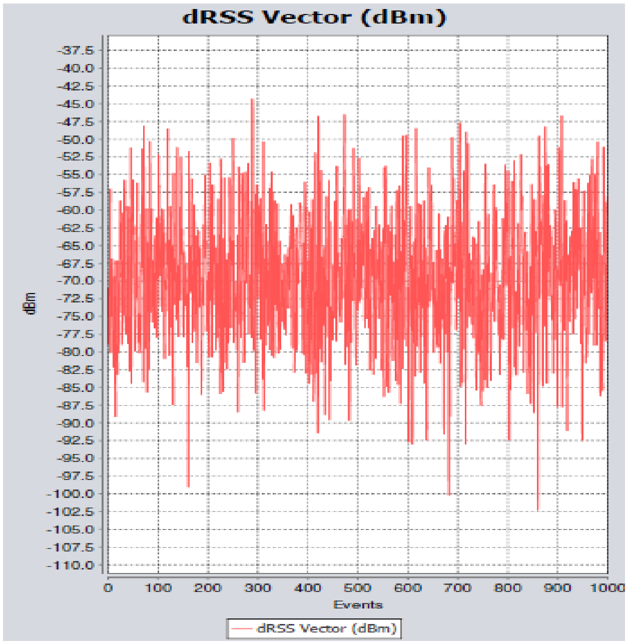

Fig. 6: dRss

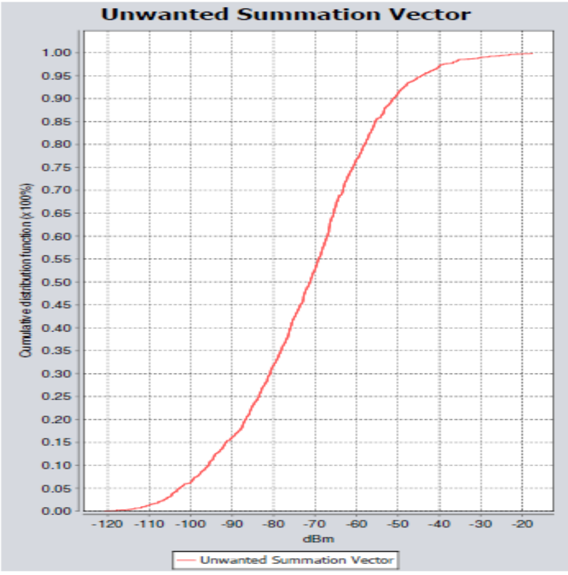

Fig. 7: IRss unwanted

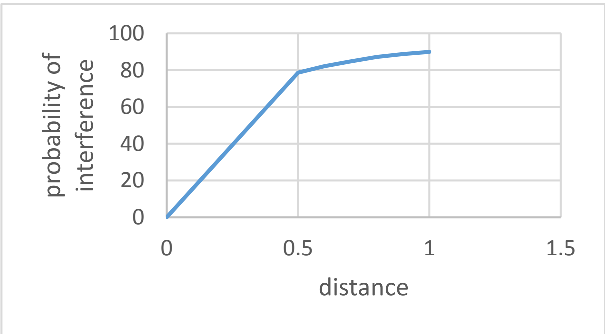

Fig. 8: Probability of interference vs distance

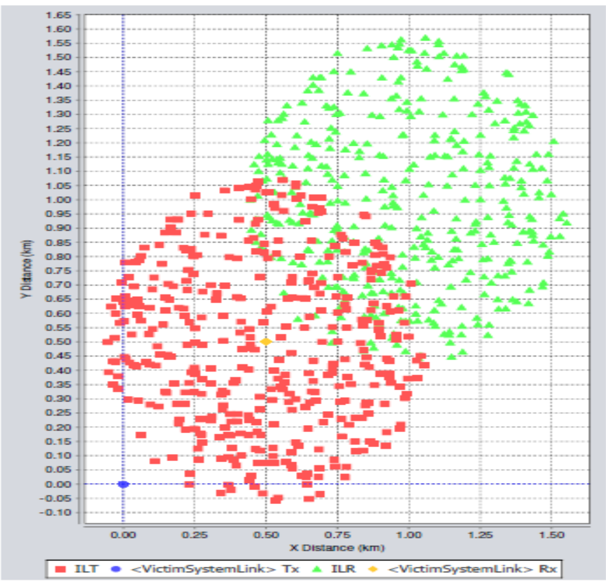

Fig. 9: Scenario outline

IV. CONCLUSION

The goal of this paper was mapping the interference of LTE to DTT signal. The studies were carried out using Monte Carlo simulation software. Various statistical parameters of real-life mobile terminals and interference taken into consideration so as to estimate the probability of interference. The interference for varying distance between the two systems was measured and the potential of LTE interfering with Digital TV was measured. The statistical results for various parameter combinations can be used for avoidance of harmful interference to DTT receivers.

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