Interference Mapping for Spectrum Sensing in Cognitive Radio

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Abstract - This paper addresses an Issue of spectrum sharing between Long Term Evolution (LTE) systems and Digital Video Broadcasting-Terrestrial (DVB-T). If protection guard is not used then due to interference the coexistence of LTE and DVB-T is not possible. By applying Cognitive Radio (CR) access technique, the chance of interference can be decreased and also the obtainable spectrum will be used expeditiously. The most important objective in spectrum sensing in a given band is to optimize the performance of the LTE as secondary network. This performance has been tested employing a Statistical analysis tool embedded with Monte Carlo Simulations and Spectral Emission Mask (SEM) technique. Additionally, the dynamic access technique is employed to sense the spectrum over the primary users (PU) band to sight the existence/absence of a primary user and use the free spectrum for LTE system as a secondary system. The simulation results show that based on power level allotted and protection distances of the secondary transmitter in a given configuration, additional spectrum usage opportunities can be obtained without harmful interference to the primary system (DVB-T receiver).

Keywords: Cognitive Radio, White space devices, LTE , DVB-T,

I. INTRODUCTION

The extreme usage of the smartphone 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 freelyavailable spectrum for offload. Recently for underutilized spectrum bands CR is being touted as an

important technique for efficient utilization. In CR systems, the secondary users(SU) change their transmission parameters according to the environment so that they can access any free space(spectrum hole) and thus enhance the spectrum usage[11]. The important point to analyze is how to increase SU rate while maintaining an acceptable level of interference. This paper investigates the interference of coexistence and sharing of DVB-T and LTE systems. The sensing capability of CRs can tremendously decrease the interference and improve the QoS and system performance. 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. THE SEAMCAT SIMULATION TOOL

SEAMCAT (Spectrum Engineering Advanced Monte Carlo Analysis Tool) [2] is a statistical simulation model that uses Monte Carlo analysis to assess the potential interference between different radio communication systems applying simulation of random processes by randomly taking values from a probability density function. The methodology considers: (a) unwanted emissions, consisting of the spurious emissions and out-of band emissions of the interfering transmitter, that are represented by the Adjacent Channel Leakage Ratio (ACLR) [2] falling within the victim‟s receiver bandwidth; (b) the receiver blocking power, a combination between the Adjacent Channel Selectivity (ACS), that refers to the filter receiver capacity to avoid unwanted emissions [2], and the blocking mode defined, in this case Ratio Protection Mode [3]). The mechanisms are illustrated in Figure 1.

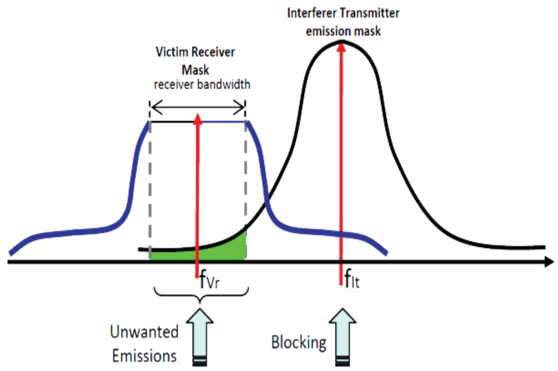

Figure 1. Unwanted Emission and Receiver blocking Masks

In order to obtain reliable results it is suggested that a large number of samples/events (>20,000) should be simulated. A basic scenario is shown in Figure 2, where the Seamcat tool model of a Victim Receiver (V_r) is connected to a Wanted Transmitter

(W_t) operating among Interferer Transmitter (I_t), only a proportion of which is activated. This type of interference may belong to the same system as the victim, a different system or a mixture of both.

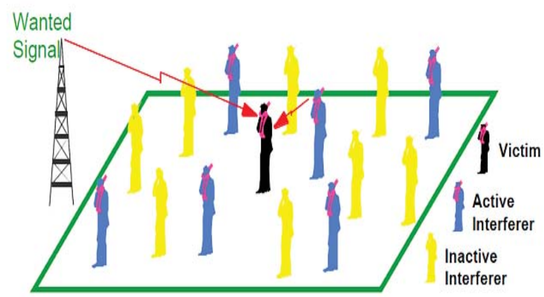

Figure 2. A typical Victim –Interferer Scenario for Monte Carlo simulation.

Interference occurs when the Carrier to Interference Ratio (i.e. C/I.) less than the minimum allowable value. In order to calculate the victim's , it is necessary to establish 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].

A. Desired Received Signal Strength and Interfering Signal Strength :-

The generated samples are processed to calculate the desired Received Signal Strength (dRSS), which 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], this process is repeated N times, where N is the number of events, also denoted as snapshots. Figure 3 depicts a typical interference scenario.

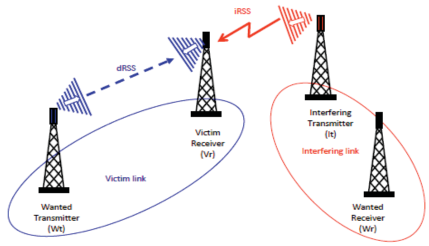

Figure 3. Typical Victim Link and Interfering Link Scenario

The desired Received Signal Strength (dRSS) is given 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 Vr
- plwt→vr(fvr) ,the path loss between the wanted transmitter and the victim receiver
- fvr , the frequency of the Vr
- gvr→wt ,the antenna gain towards Wt

The following two equations give the unwanted and blocking interference:

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

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

where:

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

B. Sensing Received Signal Strength :-

The Sensing Received Signal Strength (sRSS) represents the signal that is transmitted by the Wanted Transmitter (W_t) and is sensed by the Interfering Transmitter(i_t) . Note that the acts as a transceiver, meaning that when the energy is sensed though the bandwidth of the sensing device (i.e. i_t) it is acting as a receiving device [3][4] as illustrated in Figure 4.

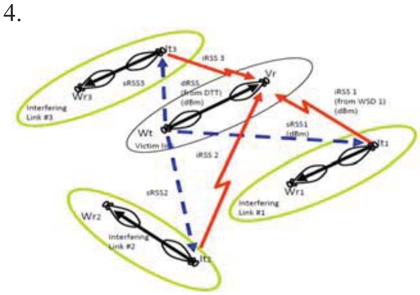

Figure 4. Illustration of three cognitive radio system and a victim system link.

The sRSS is calculated as the unwanted mask of the interfering system at the channel "m", given 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 WSD
- $G_{wt\rightarrow it}$,the antenna gain in dBi of the W_t to i_t direction.
- $G_{it\rightarrow wt}$, the antenna gain in dBi of the i_t to w_t
- L , is the path loss in dB between the i_t and the w_t

III. SIMULATION SCENARIOS

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

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

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 1 . 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. SIMULATION RESULTS

The simulation results obtained with the SEAMCAT software considered the maximum 33dBm transmitter power of the victim receiver. For each simulation iRss unwanted and the iRss blocking were obtained.

Figures 5 to 8 show the probability of interference due to unwanted and blocking signals for different distances between the LTE and DVB-T. Figure 9 shows the scenario outline.

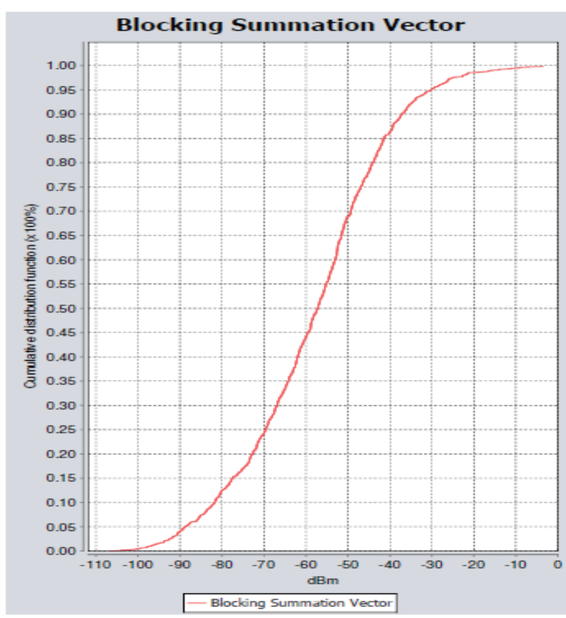

Figure 5: irss blocking

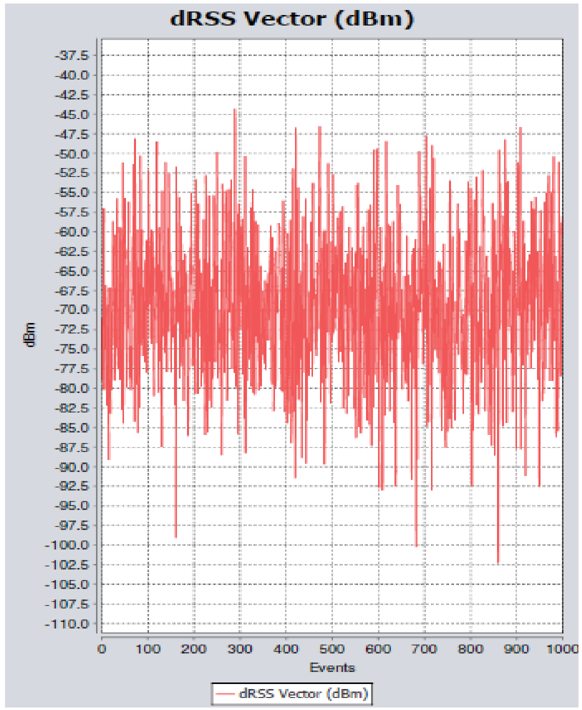

Figure 6: dRss

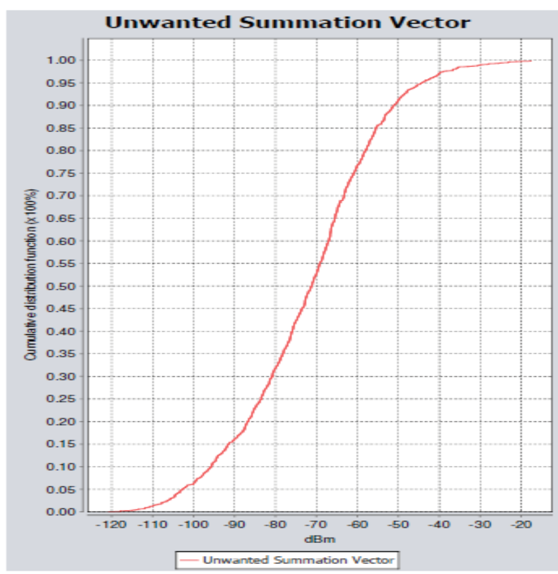

Figure 7: iRss unwanted

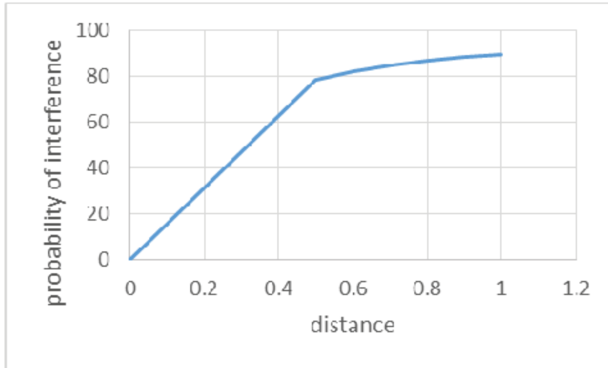

Figure 8: Probability of interference using CR vs distance

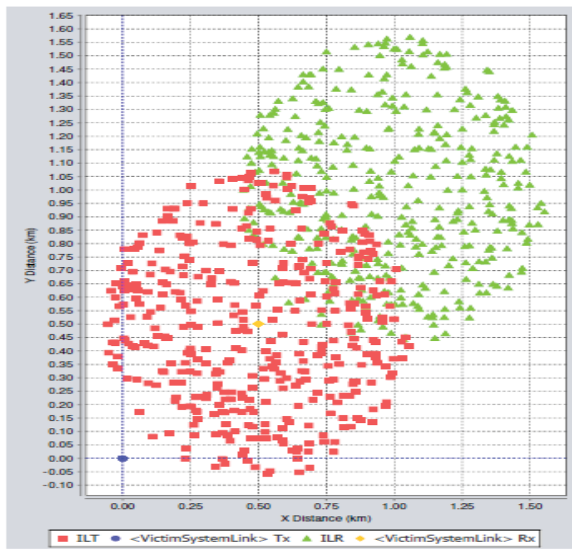

Figure 9: Scenario outline

V. CONCLUSION

The goal of this paper was study the sensing function in cognitive radio.This has been analysed by mapping the interference of LTE to DTT signal using Monte carlo simulation software. The result obtained in the simulations demonstrate that when the cognitive radio function was applied in SEAMCAT software , the interference generated between the LTE and DVB-T could be used as a parameter to infer about the presence of spectrum holes. The interference for varying distance between the two systems was measured and spectrum availability prevails where its probability is low.

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