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# Performance of LTE downlink communication system in presence of electronic warfare spot jamming

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**Abstract.** Wireless communication is one of the principally active zones of tools development and has become necessary part of everyday life. Simulation of wireless communication systems accurately is very important for predicting its performance under different scenarios. Long-Term Evolution (LTE) is named by next generation wireless communications. It is a standard for high-speed wireless communication for mobile phones and data terminals. In this paper, the performance of standard single-input-single-output (SISO) LTE Frequency Domain Duplex (FDD) downlink (DL) signal in additive white Gaussian noise (AWGN) channel is evaluated in two scenarios without jamming and in presence of electronic warfare spot jamming. Firstly, the performance of the standard LTE communication system in absence of jamming is investigated by calculating the probability of Bit Error Rate (BER) and Frame Error Rate (FER) versus Signal Noise Ratio (SNR). Secondly, the performance in presence of electronic warfare spot jamming scheme is investigated by constant Jamming to Signal Ratio (JSR) and different values of the normalized jamming bandwidth. In order to illustrate the impact of jamming on the standard LTE DL wireless communication system, the measurement is evaluated by using the aid of SystemVue software program.

## 1. Introduction

Long Term Evolution has long been seen as the primary development to reach a stronger, faster wireless communications systems. The data rate of communication systems under LTE can currently reach peak downlink rates of 100Mbps and uplink speeds of 50Mbit/s. The transmission of downlink LTE signals has been based on Orthogonal Frequency Division Multiple Access (OFDMA) [1] and uplink transmission has been based on Single Carrier Frequency Division Multiple Access (SC-FDMA) [2].

Synchronization sequences are used in LTE downlink signal for new cell identification and initial synchronization. A robust primary synchronization signal sequence detection algorithm is explained in [3]. Problems related to time and frequency synchronization as well as blind Cyclic Prefix (CP) type identification in 3GPP LTE system is discussed in [4]. The work in [5] compares the complexity, latency, and recognition probabilities of frequency and time domain LTE physical layer identity detection schemes.

The performance of a LTE communication system can be deteriorated due to the presence of another high power in band communication services or due to the intended jamming signal. In [6], the work investigated the problem of optimal jamming technique over an AWGN channel against digital modulation communication schemes (OFDM). In [7], the performance of multi-band OFDM ultra-wideband communication system was investigated in presence of in band OFDM-based WLAN interference. In order to participate in this interesting field of study. In this paper, the performance of the standard LTE communication system is investigated in presence of electronic warfare spot jamming technique in AWGN channel. This investigation is held by

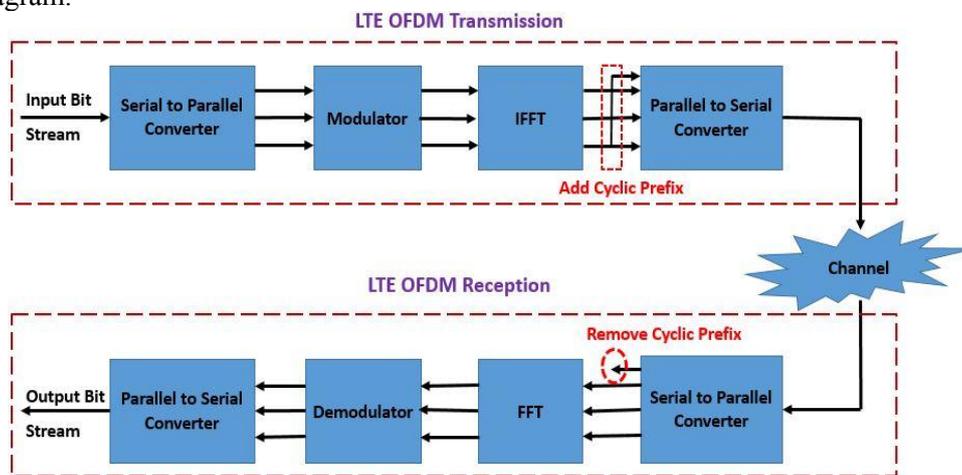


the aid of SystemVue software. The impact of such jamming technique is studied for different jamming bandwidth values. The rest of this paper is structured as follows, in section II, the basis of design LTE downlink communication system, OFDM technique, and Physical layer parameter are presented, in section III, different jamming techniques are presented, in section IV, explanation of the SystemVue, Experiment design circuits, and results are depicted and finally, in section, conclusions of the work are drawn.

## 2. LTE downlink communication system

### 2.1. OFDM technique

The LTE communication system is design bases of a very complex system because of the requirements that can be represented by high peak transmission rate (100 Mbps DL/50 Mbps UL), multiple channel bandwidths (1.4, 3, 5, 10, 15 and 20 MHz) and spectral efficiency. To achieve these requirements, orthogonal frequency division multiplexer (OFDM) has been chosen to be the basis of LTE communication system. Figure 1, depicts the LTE OFDM transceiver block diagram.



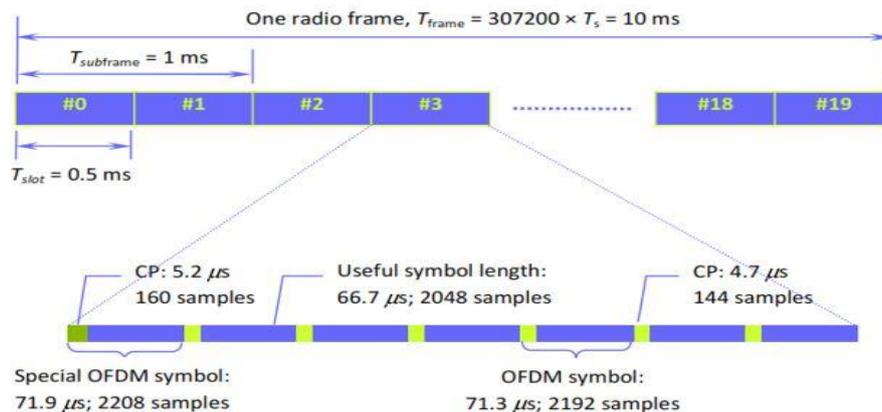
**Figure 1.** LTE OFDM transceiver block diagram.

The intersymbol interference (ISI) is mitigated by using cyclic prefix (CP). The second advantage for using OFDM technology was converted the frequency selective fading that destroyed the mobile signal to flat fading seen by each sub-carrier.

### 2.2. Physical layer parameter

The LTE physical layer downlink is based on OFDMA. OFDMA has two main problems. The first problem is high peak-to-average power ratio (PAPR) and the second problems is high sensitivity to frequency offset. There are two different modes of operation in building LTE downlink signal. The two modes of operation are frequency domain duplex (FDD) modes and time domain duplex (TDD). In this paper, the FDD mode is selected.

In the time domain, the OFDM symbol period  $T_s$  equals  $(1/30720000)$ . Subcarriers are collected in 180 kHz blocks, each block consists of 12 subcarriers. In case of normal cyclic prefix, every 0.5 ms slot in length  $(T_{slot} = 15360 \cdot T_s)$  7 consecutive OFDM symbols have been transmitted and 6 in case of the extended cyclic prefix. The frame in length  $(T_{Frame} = 307200 \cdot T_s)$  is consisted of 10 subframes in length  $(T_{subframe} = 30720 \cdot T_s)$  and subframe is consisted of two slots. The LTE frame structure in FDD is represented in Figure 2.

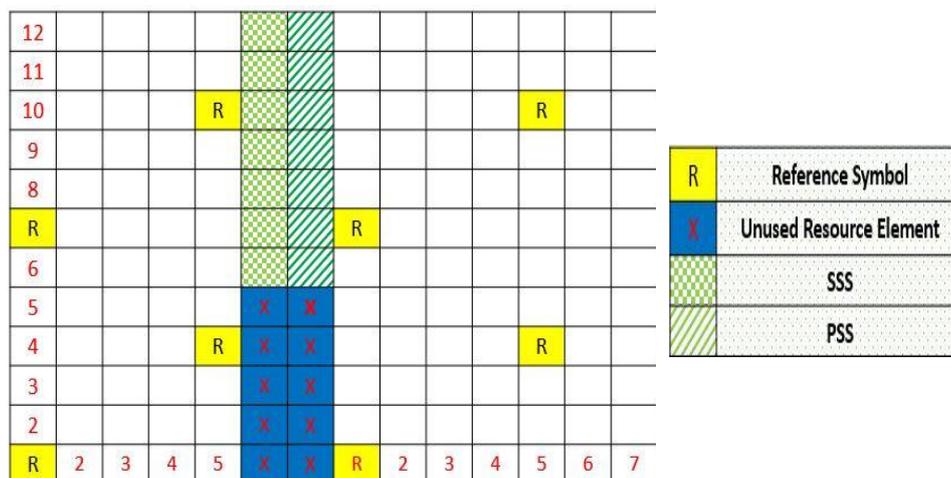


**Figure 2.** The LTE frame structure in FDD mode,  $\Delta f = 15$  kHz.

All the symbols transmitted in a single slot on all subcarriers in a block form a Resource block (RB) which consists of 180 kHz, for the duration of one slot (0.5 ms), or 12 consecutive sub-carriers. A Resource element (RE) is the smallest defined unit that consists of one OFDM sub-carrier during one OFDM symbol interval. As shown in Figure 3, some resource elements are used for special purposes like as, Reference signals(RS), Primary Synchronization Sequence (PSS), Secondary Synchronization Sequence (SSS), control signaling, and critical broadcast system information. The data transmission has been used the remaining.

In case of normal CP, Each RB consists of  $12 \cdot 7 = 84$  (RE).

In case of extended CP, Each RB consists of  $12 \cdot 6 = 72$  (RE).



**Figure 3.** Resource block and resource element in case of normal CP mode.

### 3. Jamming techniques

Wireless communication system facilities the communication among peoples and exchanges the data. In the military field, it has additional function which investigated in control the leader its forces and give them orders and information. The field work for accomplish the intercept or denial of communications is named by Electronic Warfare (EW). Jamming is one way to disconnect between Wireless communications systems. It has several techniques, like, Barrage Jamming, Spot Jamming, Tone Jamming, Pulsed Jamming and Smart Jamming. Barrage jamming is named by Broad Band Jamming (BBJ). It spreads jamming signal power ( $J$ ) over all the band of transmitted signal ( $W_{ss}$ ). Jamming power spectral density ( $N_j$ ) is given by

$$N_j = \frac{J}{W_{ss}} \tag{1}$$

In case of Partial Band Jamming (PBJ) or Spot, jamming, jamming signal power spreads on a partial of transmitted signal band ( $W_{ss}$ ). The bandwidth of jamming ( $W_j$ ) is less than the transmitted signal bandwidth. The ratio between the jamming bandwidth and transmitted signal bandwidth is defined by

$$\delta = \frac{W_j}{W_{ss}} \leq 1 \tag{2}$$

The jamming technique that concentrate more jamming power on a fraction of the transmitted bits denoted by Spot jammers. This concentration can cause high error probabilities comparing with that broadband jammer. In this paper, we are concerned about the Spot Jamming technique. Jamming power spectral density ( $N'_j$ ) is given by

$$N'_j = \frac{J}{W_j} = \frac{J}{\delta W_{ss}} = \frac{N_j}{\delta} \tag{3}$$

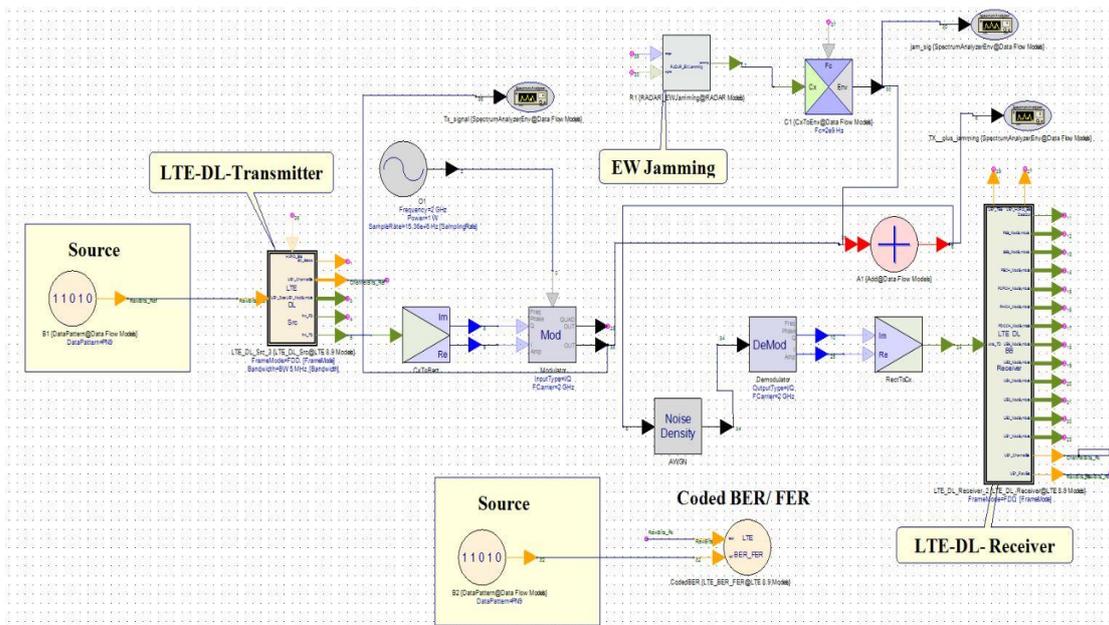
### 4. SystemVue

#### 4.1. Definition

Keysight SystemVue software is a powerful, electronic system level (ESL) design environment. The physical layer (PHY) of wireless communication systems can architected by using SystemVue software. It provides unique value to RF, DSP and FPGA/ASIC implementers who rely on both RF and digital signal processing to deliver the full value of their hardware platforms that adhere to the PHY of modern emerging standards.

#### 4.2. Design circuit

The practical environments can be simulated by using tools that have been designed on SystemVue software. Figure 4, shows the schematic for transmitter and receiver of downlink SISO LTE signal and EW Jamming. This schematic is used for measurement of the both Bit error rate (BER) and Frame error rate (FER) on (AWGN) channel for different modes of operation (with respect to the jamming).

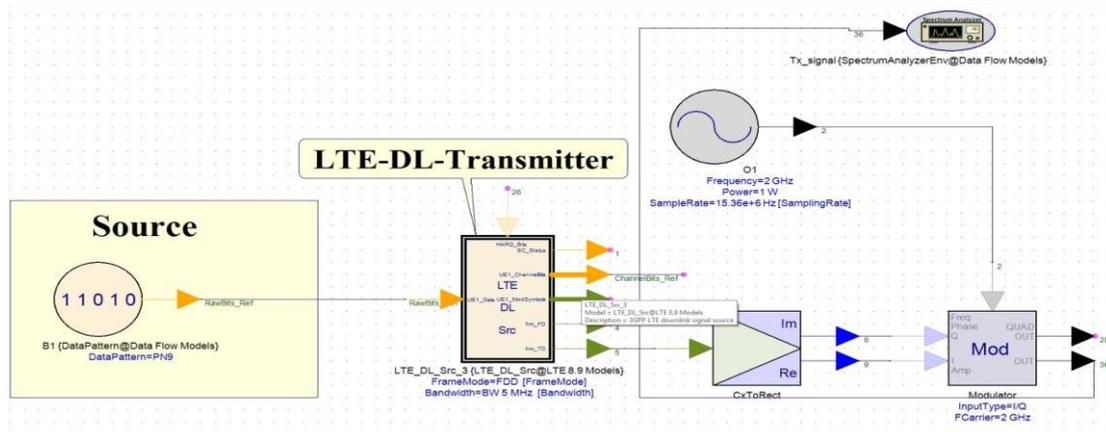


**Figure 4.** Layout of a complete transceiver downlink SISO LTE signal on AWGN and EW Jamming using keysight SystemVue software.

The used block can be classified as:

#### 4.2.1. Transmitter

The transmitter of downlink SISO LTE signal consists of several simulated blocks shown in Figure 5. Every block has its own function, as follow.



**Figure 5.** Layout of a complete transmitter of downlink SISO LTE signal.

##### a) Source block

It generates the pattern data, where pseudorandom sequence (PN9) was used. This random sequence generates a 511-bit pseudo-random test pattern.

##### b) LTE downlink signal source block

In this block the downlink LTE signal with frame mode (FDD) is generated. The used cyclic prefix (CP) mode is normal, with band width (BW) [5MHZ], and using QPSK modulation.

##### c) CxToRect block

CxToRect converts input complex values to output real and imaginary values.

##### d) Oscillator block

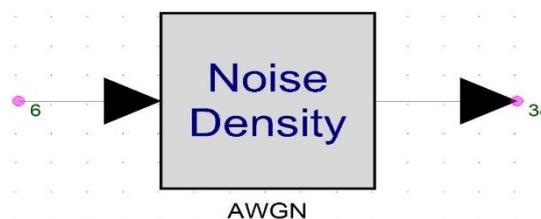
It's generates carrier signal with defined value of amplitude, phase, and carrier signal frequency.

##### e) Modulator block

The modulator block performs different modulation schemes such as, amplitude, phase, frequency, or I/Q modulation signals. This occur at defined carrier frequency according to the carrier frequency generated by the oscillator block.

#### 4.2.2. Channel

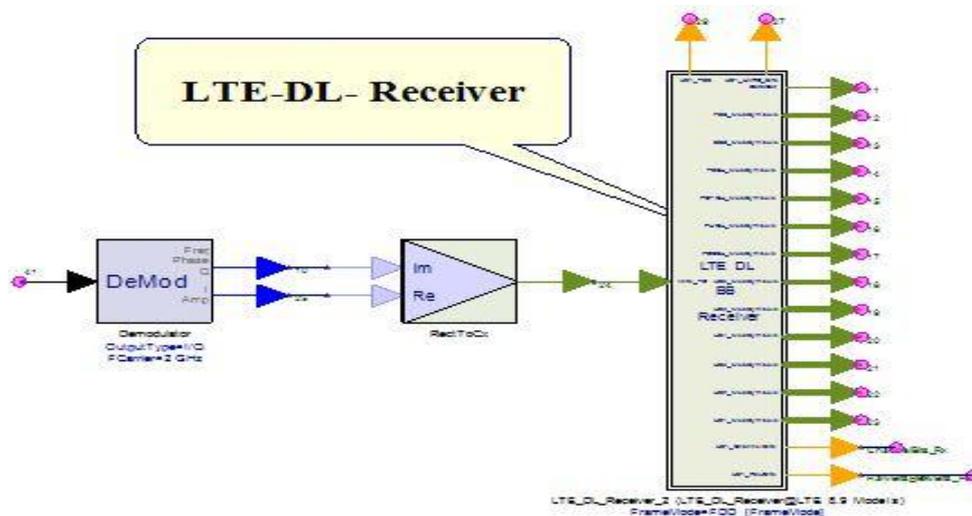
The second step on our work is to design the AWGN channel. The block in Figure 6 generates the AWGN channel.



**Figure 6.** AWGN channel model.

#### 4.2.3. Receiver

The receiver of downlink SISO LTE signal consists of three blocks shown in Figure 7. Every block has its own function, as follows.



**Figure 7.** Layout of a complete receiver of downlink SISO LTE signal.

##### a) Demodulator block

The demodulation block demodulates the received signal and produces the Inphase and Quadrature components of the signal.

##### b) Rect\_to\_complex block

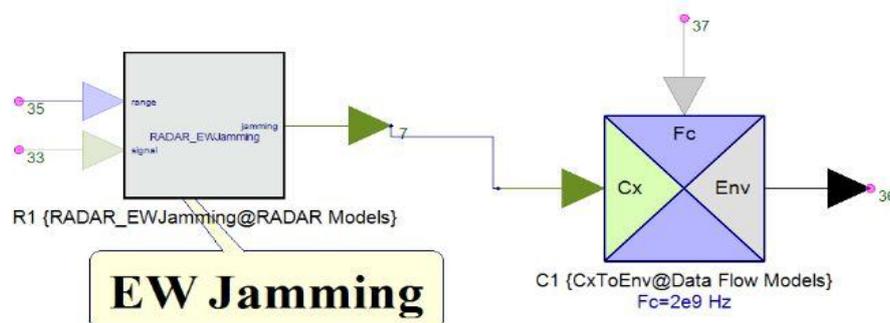
It converts input real and imaginary values to output complex values.

##### c) LTE\_DL\_Receiver block

It recovers back the original data which be the input of the downlink LTE signal source. This block is depended on the priori information of downlink LTE signal source parameters. These parameters are frame mode (FDD), cyclic prefix mode (normal), transmitted signal bandwidth [5MHZ], and modulation type (QPSK).

#### 4.2.4. EW Jamming

The EW Jammer consists of two blocks as shown in Figure 8. Every block has its own function, as follows.



**Figure 8.** Layout of EW Jamming.

##### a. Jamming source block

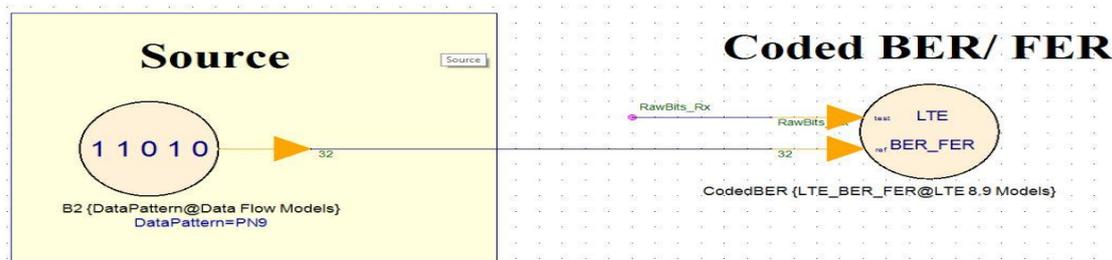
It generates the spot jamming signal for different bandwidth, power, and frequency band values.

### b. Complex to Envelope block

It converts the complex signal to envelope signal which is suitable to be added with the LTE signal and to be represented it in the spectrum graph.

#### 4.2.5. BER and FER measurement

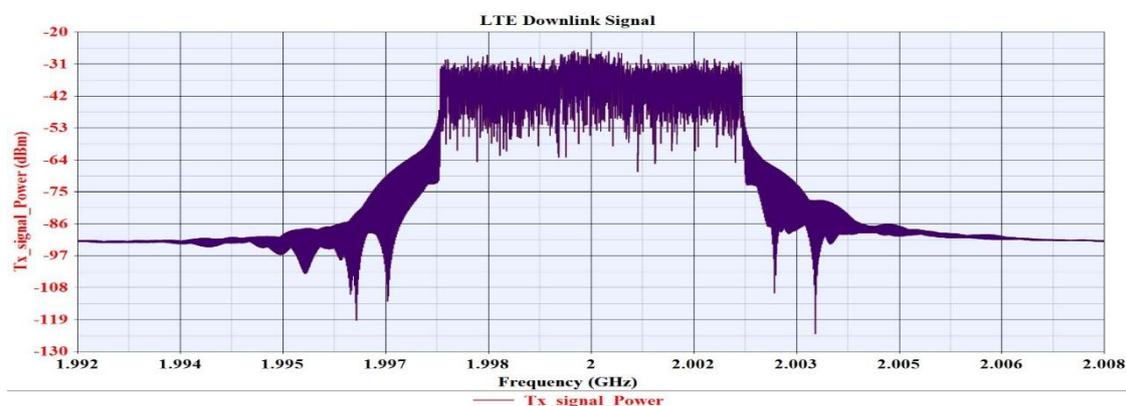
The LTE BER and FER are calculated by using the BER and FER blocks as shown in Figure 9. In this block a comparison with the original transmitted data is held.



**Figure 9.** Layout of BER and FER measurement using SystemVue.

### 4.3. Results

This section presents the simulation results and the performance analysis of the LTE standard communication system in presence of EW jamming signal. Simulation and experiment focused on the impact of increasing the jamming signal bandwidth with respect to the LTE wireless communication system. The spectrum of transmitted LTE DL signal at carrier frequency [2 GHz] with band width [5 MHz] is represented in Figure 10.



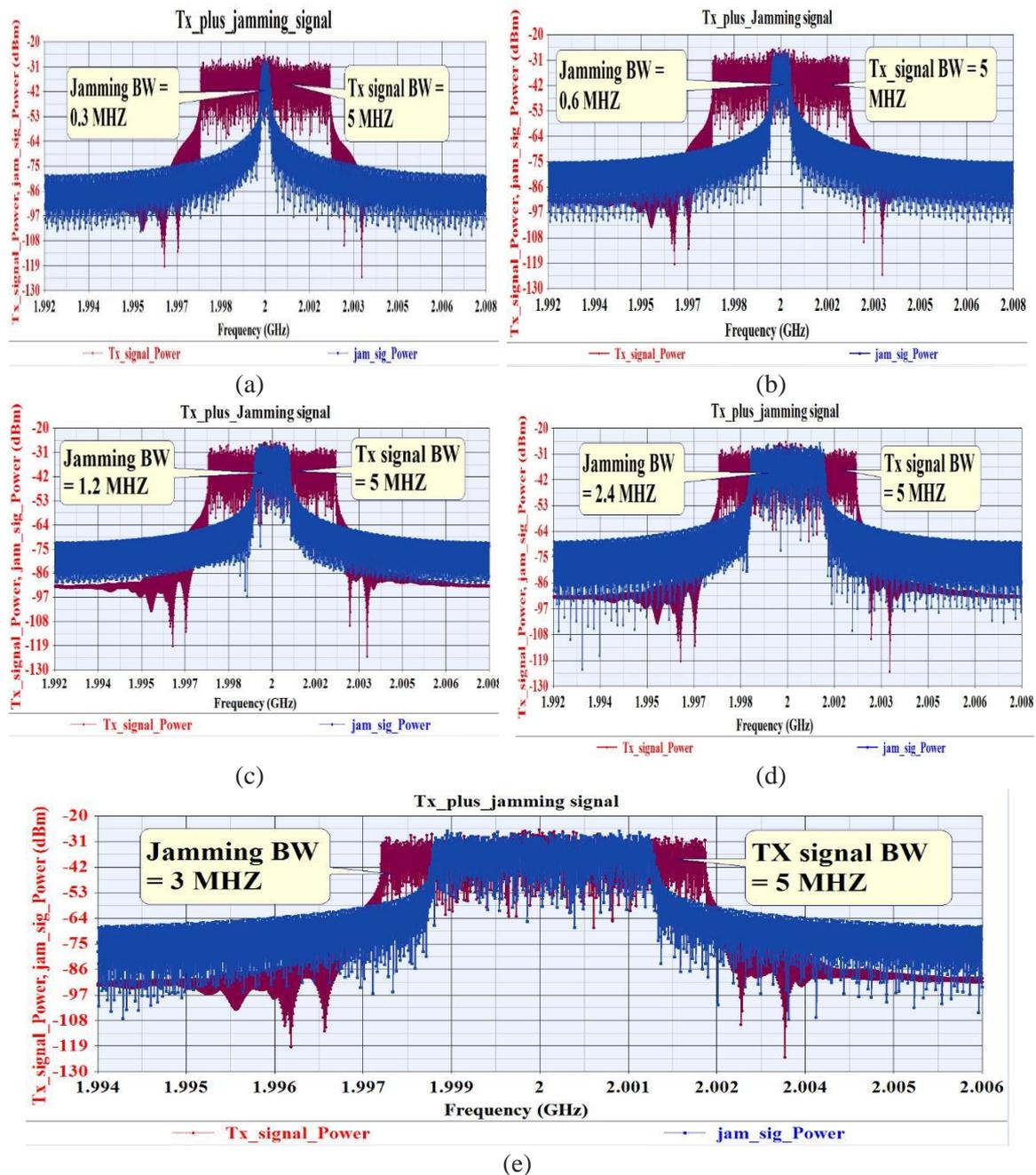
**Figure 10.** Transmitted LTE DL signal.

The spectrum of transmitted LTE DL signal at carrier frequency 2 GHz with constant 5 MHz BW and spot jamming signal at centered frequency 2 GHz with different BW values are shown in Figure 11. In the Figure 11 (a) the jamming signal BW equals to 0.3 MHz, (b) the jamming signal BW equals to 0.6 MHz, (c) the jamming signal BW equals to 1.2 MHz, (d) the jamming signal BW equals to 2.4 MHz, and (e) the jamming signal BW equals to 3 MHz.

The impact of Jamming signal on the LTE DL signal is measured by the probability of Bit Error Rate (BER) and Frame Error Rate (FER) versus Signal Noise Ratio (SNR) and depicted in Figure 12 and Figure 13 respectively.

It can be seen in Figure 12 that the presence of jamming signal can easily degrade the performance of the slandered LTE communication signal. As shown at BER equals to  $10^{-4}$ , a SNR degradation of nearly 7 (dB) for the LTE BER performance in presence of EW spot jamming with BW equals to 0.6 MHz (12% of the LTE BW is jammed) and BW equals to 2.4 MHz (48% of the LTE BW is jammed).

For Figure 13, it can be seen that also, the FER of the slandered LTE communication system is degraded due to the presence of EW spot jamming signal. It can be seen that at FER equals to  $10^{-5}$ , a SNR degradation of nearly 8 (dB) is achieved if the jamming bandwidth is increased from 0.3 MHz (6% of the band) to 2.4 MHz (48% of the band).



**Figure 11.** Transmitted LTE DL signal with constant BW [5MHz] and Jamming signal with different BW values; (a) [0.3 MHz] Jamming signal BW, (b) [0.6 MHz] Jamming signal BW, (c) [1.2 MHz] Jamming signal BW, (d) [2.4 MHz] Jamming signal BW and (e) [3 MHz] Jamming signal BW.

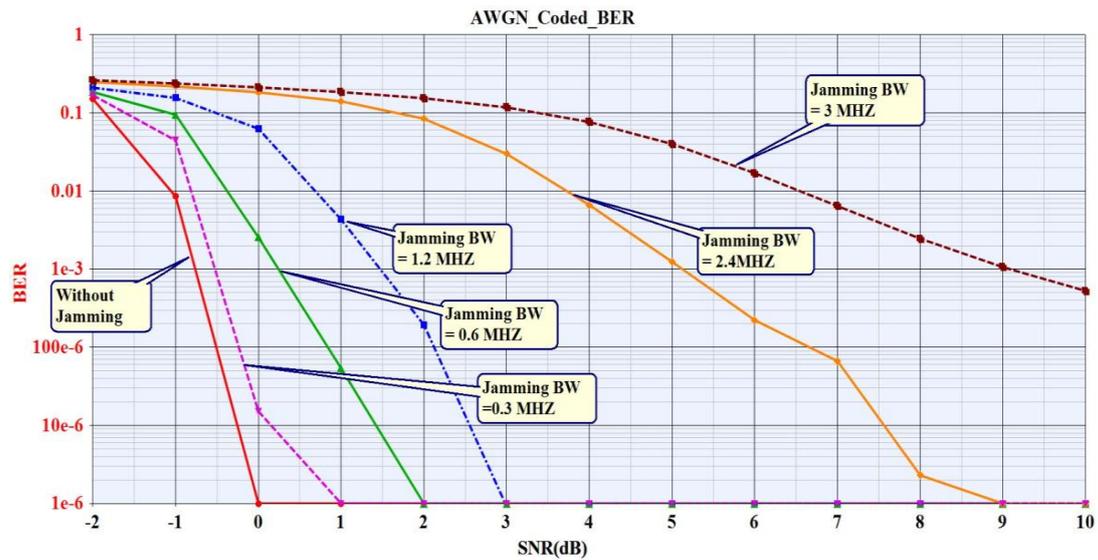


Figure 12. BER vs SNR.

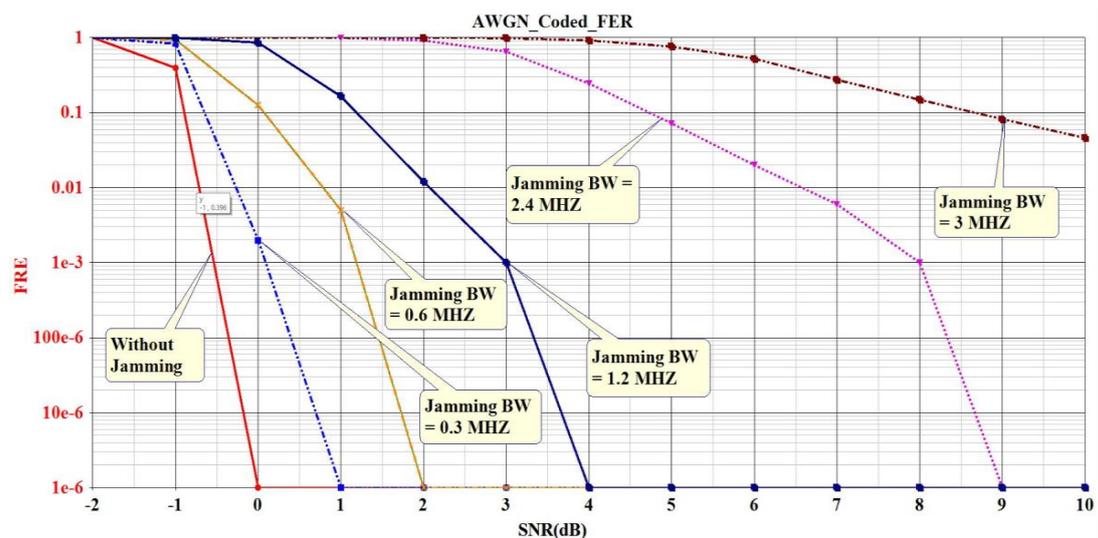


Figure 13. FER vs SNR.

## 5. Conclusion

The topics investigated in this paper are important when the presentation of LTE air interface for public safety communication is considered. The performance of LTE DL SISO communication system was simulated by the aid of keysight SystemVue software in presence of EW spot jamming in AWGN channel. The results show that the performance of LTE Downlink communication system was decreased by the presence of EW spot jamming. The performance was evaluated by measuring the Bit Error Rate and Frame Error Rate of standard LTE DL communication system against Signal to Noise Ratio in presence of EW spot jamming signal at fixed SJR equals to 0 (dB). The results also show that increasing the jamming bandwidth increase the amount of performance degradation.

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