Performance Analysis of Sc-FDMA and OFDMA in LTE Frame Structure

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ABSTRACT
Long Term Evolution (LTE) is consents pliable spectrum distribution which renders enriched wireless data services to users at lower latency and multi-megabit throughput. LTE uses Orthogonal Frequency Division Multiple Access (OFDMA) and Single Carrier Frequency Division Multiple Access (Sc-FDMA) for downlink and Uplink transmission where OFDMA has been acquired in LTE for downlink transmission which diminishes the terminal cost and power consumption and Sc-FDMA has been allocates multiple users to a shared communication resources. Frequency Division Duplex (FDD) and Time Division Duplex (TDD) are the prevailing duplexing scheme in LTE that provides deployable tractability according to spectrum assignation. In this paper, we analyze the performance of SC-FDMA and OFDMA in LTE Frame Structure based on Peak to Average Power Ratio (PAPR) analysis. ITU Pedestrian A channel and ITU Vehicular A channel and also Additive White Gaussian Noise (AWGN) channel are used for analyzing the error performance between SC-FDMA and OFDMA.

General Terms
LTE, SNR, minimum BER, AWGN, FDD, TDD

Keywords
Long Term Evolution (LTE), Frequency Division Duplex (FDD), Time Division Duplex (TDD), Single Carrier Frequency Division Multiple Access (Sc-FDMA), Orthogonal Frequency Division Multiple Access (OFDMA), Additive White Gaussian Noise (AWGN)

1. INTRODUCTION
Long Term Evolution (LTE) enhances the susceptibility and speed of wireless data networks using various types of modulations (QPSK, 16QAM etc.). LTE redesigns and modifies the network architecture with substantially diluted transfer latent period. It depicts a wireless communication system which endorses downlink transmission using Orthogonal Frequency Division Multiple Access (OFDMA) scheme up to 300 mbps of data transmission and 75 mbps throughput for uplink data transmission using Carrier Frequency Division Multiple Access (Sc-FDMA). OFDMA transmits data over a large number of subcarriers [1]. These signals are spaced in reciprocally perpendicular axis assembling at right angles to each another and their summation will be zero which removes mutual interference. SC-FDMA aggregates multipath interference abjuration and flexible subcarrier frequency assignment which provides only one carrier at a time instead of multiple carriers in transmission. Frequency Division Duplex (FDD) and Time Division Duplex (TDD) are the two most common Frame Structure that are used in LTE where both transmitter and receiver operate on same frequency band and same time in FDD, but in TDD both transmitter and receiver works on same frequency at different time [2]. The purpose of this paper is to analysis the performance of OFDMA (Downlink transmission) and SC-FDMA (Uplink Transmission) in different types of LTE Frame structures with different modulation techniques. We analytically derive the OFDMA and SC-FDMA signals in FDD and TDD mode and also numerically compare PAPR characteristics using the complementary cumulative distribution function (CCDF) of PAPR

The rest of this paper is organized as follows: Section 2 and Section 3 provide the brief idea about the OFDMA system model and SC-FDMA System Model. Section 4 describes the LTE Frame Structure Types. In section 5, Simulation results are given and we finally conclude in Section 6.

2. OFDMA System Model
LTE (Long Term Evolution) uses OFDMA and SC-FDMA at downstream and upstream for downlink and uplink transmission. The OFDMA system model is shown in Figure 1. A brief description of the model is provided below.

At first, S symbols/second data are transmitted to the transmitter and the data symbols are pass through a serial to parallel converter and the data rate on every X line is S/X symbols [3].The input data stream on each carrier is then mapped by using different types of modulation scheme such as QPSK, 16-QAM, 64QAM etc. Then Inverse fast Fourier Transform is used to find the corresponding Time wave form, which means that M symbols are sent to an Inverse Fast Fourier Transform that performs N-point IFFT operation. The output is N time sample [4]. The Guard interval is then introduced at the start of each sample which is known as addition of cyclic extension in the prefix. Then the length of the output sample is $N+L_P$. The cyclically extended symbols are passed through a parallel to serial converter and then transmitted through a channel [5]. A channel model is then applied to the transmitted signal. The model allows for the signal to noise ratio, multipath to be controlled. The signal to noise ratio is set by adding a known amount of white noise to the transmitted signal which is known as AWGN Additive white Gaussian noise [16].The Receiver basically does the reverse operation of the transmitter. The transmitted signals which pass through the channel are then converted by using Serial to parallel converter and cyclic extension is also removed. The signals pass through an N-point Fast Fourier Transform which converted time domain signal into frequency domain. Then the signal is demapped and performs parallel to serial conversion using Parallel to serial convert block and the resultant signal is a M sample output [3].

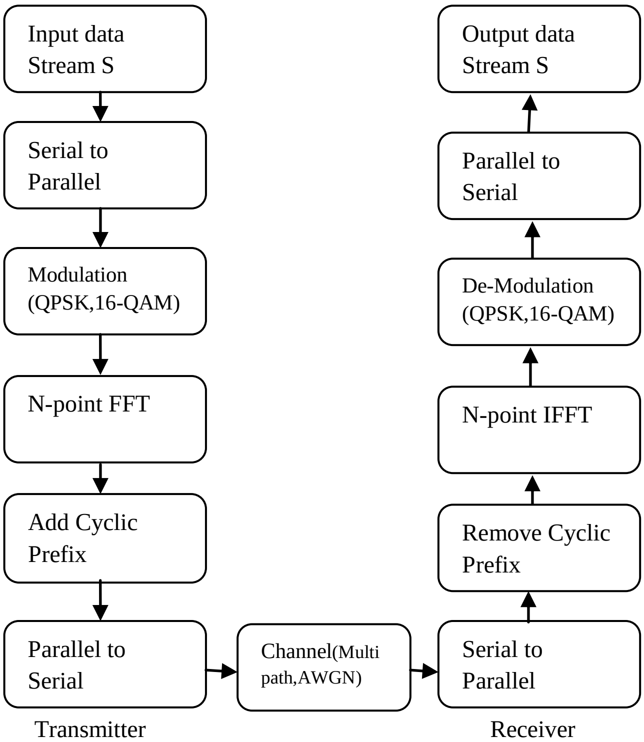


Fig 1: OFDMA System Model

3. Sc-FDMA System Model

The Sc-FDMA system model is shown in Figure 2. A brief description of the model is provided below. The main difference between SCFDMA and OFDMA is that SC-FDMA has more discrete Fourier transform (DFT) processing, so we can regarded as SCFDMA as a DFT-spread OFDMA where time domain data signals are transformed to frequency domain by a DFT before going through OFDMA modulation [6]. At first, the input data stream is first modulated to single carrier symbols by using Quadrature Phase Shift Keying (QPSK), 16-QAM (Quadrature Amplitude Modulator) or 64-QAM. The resultant modulated symbols become the inputs of the functional blocks of SCFDMA. Then the modulated symbols are converted into parallel symbols and organized into blocks. Now N-Point DFT (Discrete Fourier Transform) Converts time domain single carrier blocks into N discrete frequency tones. Then Subcarrier Mapping, controls the frequency allocation, and maps N discrete frequency tones to subcarriers for transmission. The mapping can be localized or distributed. In localized mapping, N-discrete frequency tones are mapped on N consecutive subcarriers where as in distributed mapping; N-discrete frequency tones are mapped on uniformly spaced subcarriers. Then M-Point IDFT converts the mapped subcarriers to time domain. If M >N then unused inputs are set to zero. If they are equal (M = N), they simply cancel out and it becomes a conventional single user single carrier system with frequency domain equalization. However, if N is smaller than M and the remaining inputs to the IDFT are set to zero, the output of the IDFT will be a signal with 'single-carrier' properties, i.e. a signal with low power variations, and with a bandwidth that depends on N [7]. Then the time domain subcarriers are converted back from parallel to serial. Cyclic Prefix CP is added to avoid ISI. The length of CP is larger than the channel delay spread in order to avoid ISI at the receiver. After passing through Channel the SC-FDMA receiver does the inverse of SC-FDMA transmitter.

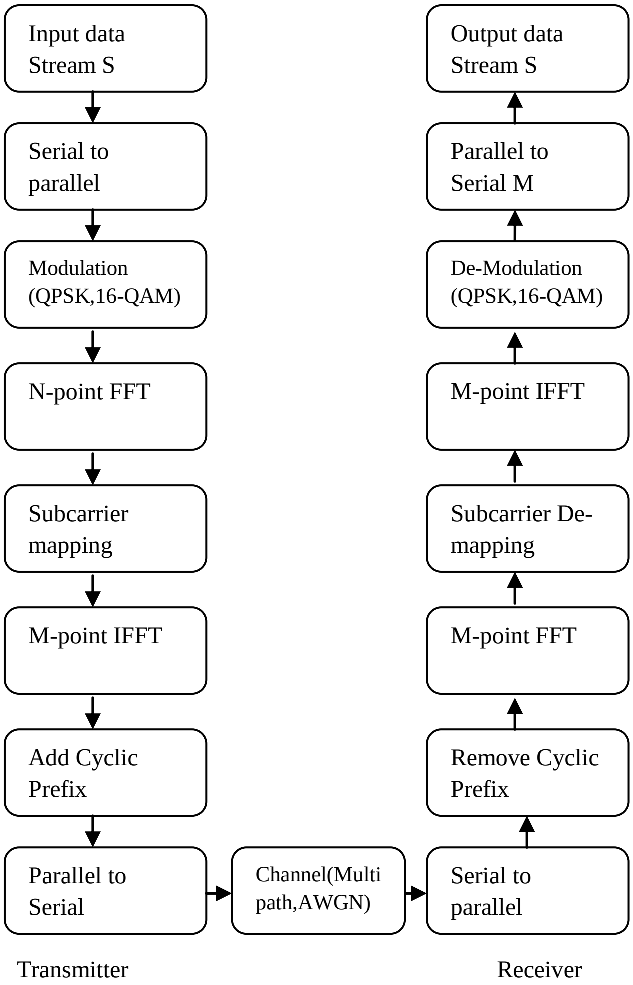


Fig 2: Sc-FDMA System Model

4. LTE Frame Type

In LTE, Downlink and uplink transmission are organized into radio frame with $T_f = 307200 * T_s$=10 millisecond long where T_s = 1/ (30.72 x 10^6) s ≈32.255 ns per clock period [8].Two types of Frame structure i.e. (i) Frame structure type 1 that endorses FDD duplexing scheme (LTE FDD) and (ii) Frame structure type 2 which supports TDD duplexing Scheme (LTE TDD) in LTE. In both LTE FDD and LTE TDD, the transmitted signal is organized into subframes of 1 millisecond (ms) duration and 10 subframes constitute a radio frame [9]. Each frame is 10 ms in duration. Each subframe is further divided into two slots, each of 0.5 ms duration. Each slot consists of either 6 or 7 ODFM symbols, depending on whether the normal or extended cyclic prefix is employed [10]. Dynamic scheduling of the uplink and downlink resources is used in both LTE FDD and LTE TDD.

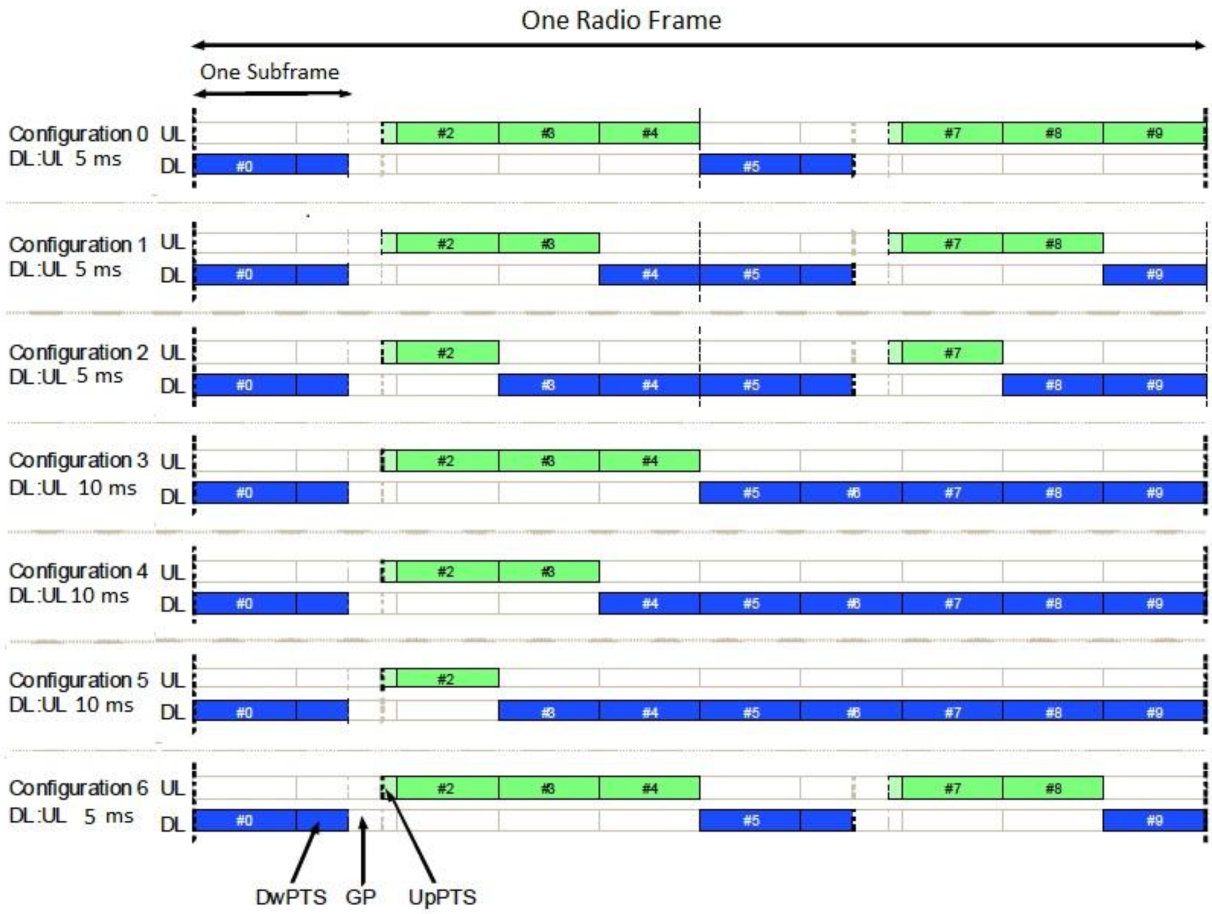


Fig 3: LTE TDD Special Subframe configuration

4.1 LTE FDD

In case of FDD operation, there are two carrier frequencies, one for uplink transmission (F_{UL}) and one for downlink transmission (F_{DL}). During each frame, there are consequently 10 uplink subframes and 10 downlink subframes and uplink and downlink transmission can occur simultaneously within a frame [9].

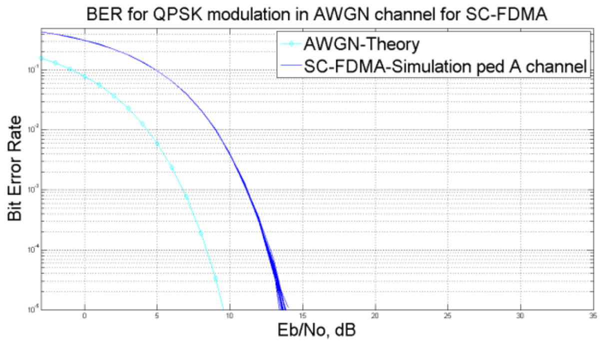
4.2 LTE TDD

In case of TDD operation, there is only one single carrier frequency for uplink and downlink transmissions in the cell are always separated in time. As the same carrier frequency is used for uplink and downlink transmission, both the uplink and downlink transmission must switch from transmission to reception. Thus, as a subframe is either an uplink subframe or a downlink subframe, the number of subframes per radio frame in each direction is less than 10 [4]. Two switching point periodicities are supported by TDD– 5ms and 10ms [14]. For the 5ms switching point periodicity, subframe 6 is likewise a special subframe identical to subframe 1. For the 10ms switching point periodicity, subframe 6 is a regular downlink subframe [11]. LTE supports seven different uplink/downlink configurations as shown in Figure 3.In each frame, eight of the ten subframes carry physical signals. Subframes 0 and 5 always carry downlink signals. The other frames can carry either uplink or downlink physical channels. Subframes 1 and 6 carry synchronization signals [13].

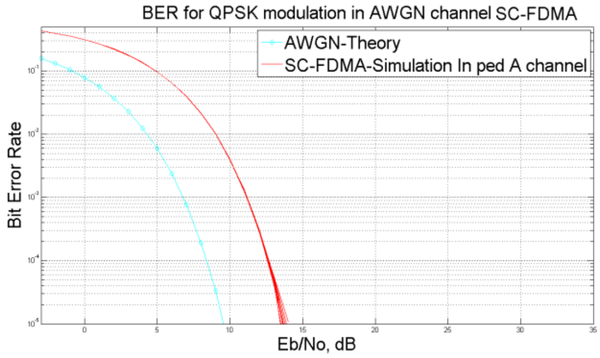
5. SIMULATION AND RESULTS

1.4 MHz channel bandwidth is chosen in this system and the number of Resource Blocks is set to 6, number of symbols in each resource block are 7, occupied subcarriers are 72, number of IDFT(transmitter)/DFT(Receiver) points are 128,sampling rate 1.92 MHz and 960 samples Per slot and also used Normal Cyclic Prefix(In slots with seven symbols, the duration of a normal cyclic prefix is 160 clock periods for the first symbol and 144 clock periods for the other six symbols [15]). The LTE uplink transmits demodulation reference signals with every resource block at the base station for channel estimation. The demodulation reference signal resides in the fourth SC-FDMA symbol of the slot [22]. The reference signal is generated using CAZAC (Constant Amplitude Zero Auto-Correlation) sequences such as Zadoff-Chu sequences [23]. A QPSK and 16-QAM symbol constellation is considered. In this simulation we used configuration 0 of Figure 3.ITU Pedestrian A, ITU Vehicular A and AWGN channel are used and also SNR (Signal to noise ratio) is calculated. MMSE is used as the equalization scheme.

From Figure 4(a), 4(b), 5(a), 5(b), 6(a) and 6(b) we see that FDD has a continuous reduction of BER (Bit Error Rate) and it minimizes the BER up to a certain values of SNR. In case of TDD the performance is changed. From the all figure of TDD, we observe that the value of BER is slightly increased in TDD.

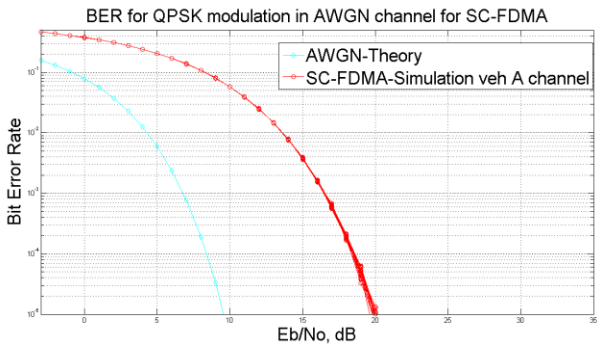


(a)



(b)

Fig 4: Performance of Pedestrian A channel in SC-FDMA (MMSE-Minimum Mean Square equalization scheme) – (a) FDD mode (b) TDD mode in QPSK



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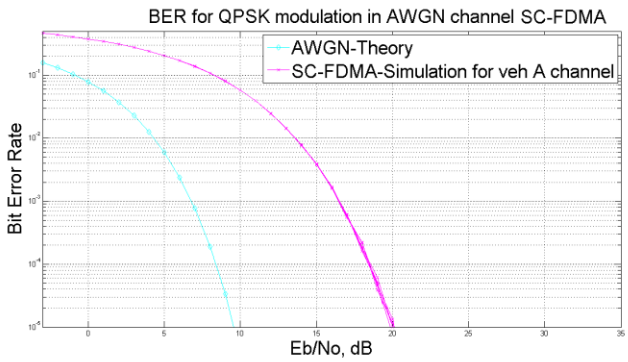
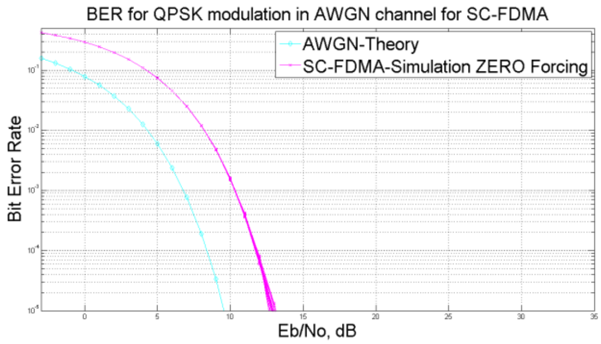


(b)

Fig 5: Performance of Vehicular A channel in SC-FDMA (MMSE-Minimum Mean Square equalization scheme) - (a) FDD mode (b) TDD mode in QPSK



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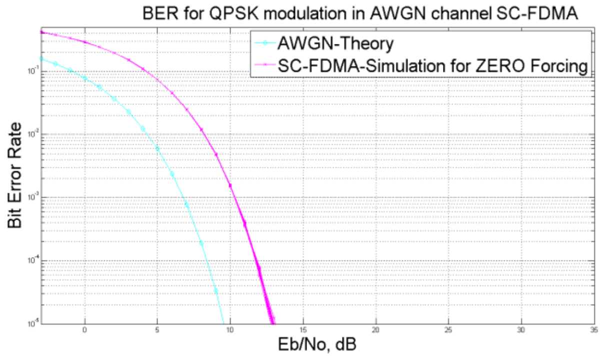
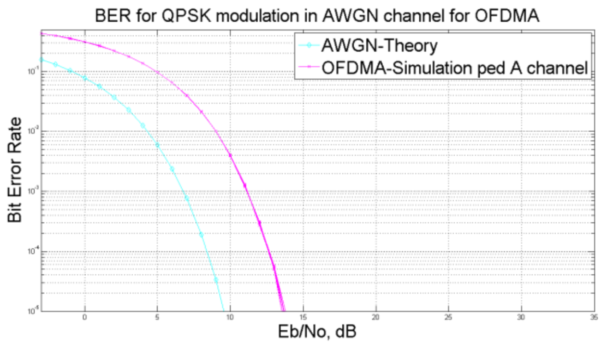


(b)

Fig 6: Performance of SC-FDMA using Zero Forcing in AWGN Channel - (a) FDD mode (b) TDD mode in QPSK



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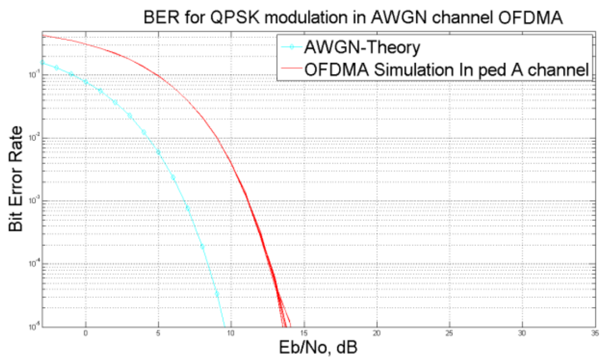
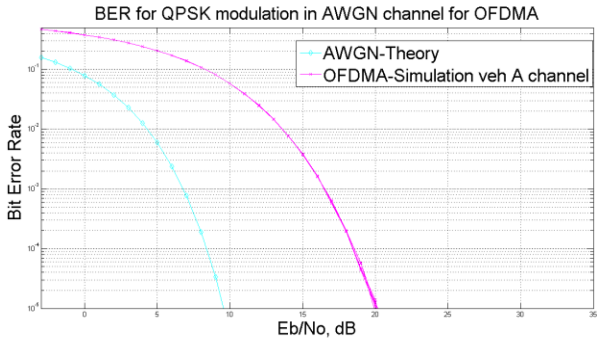


(b)

Fig 7: Performance of Pedestrian A channel in OFDMA (MMSE-Minimum Mean Square equalization scheme) - (a) FDD mode (b) TDD mode in QPSK



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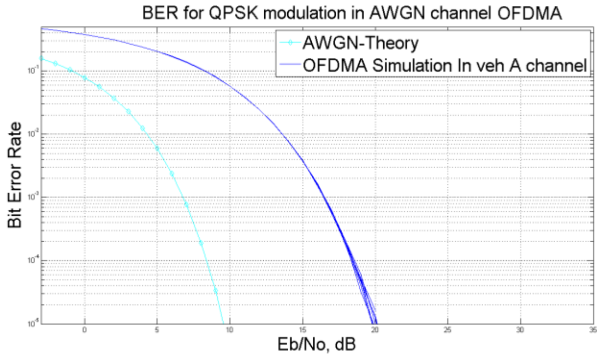
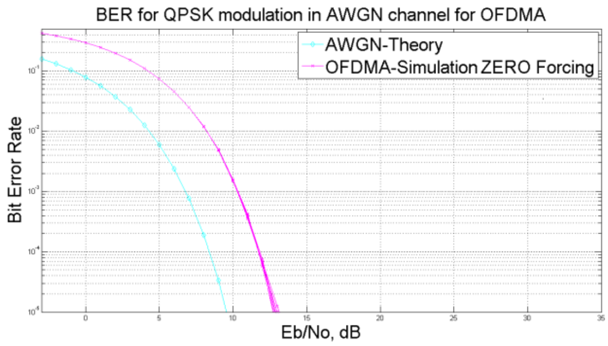


(b)

Fig 8: Performance of Vehicular A channel in OFDMA (MMSE-Minimum Mean Square equalization scheme) - (a) FDD mode (b) TDD mode in QPSK



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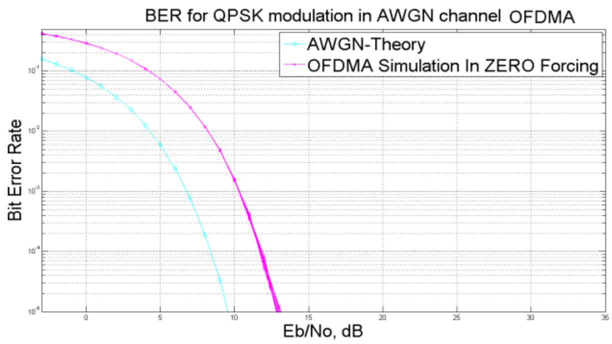
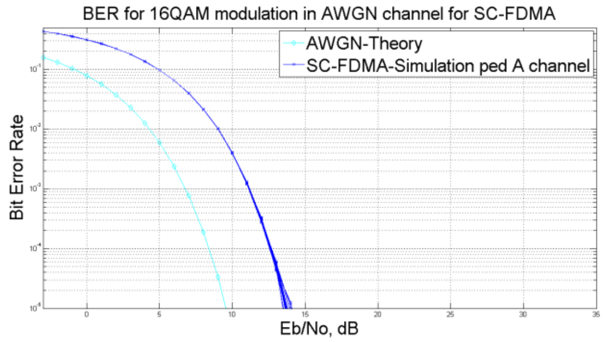
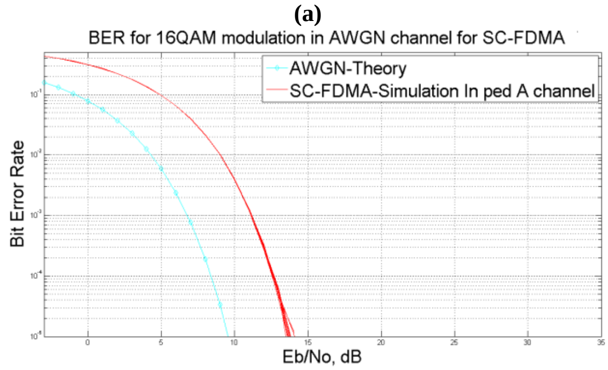


(b)

Fig 9: Performance of OFDMA using Zero Forcing in AWGN Channel - (a) FDD mode (b) TDD mode in QPSK

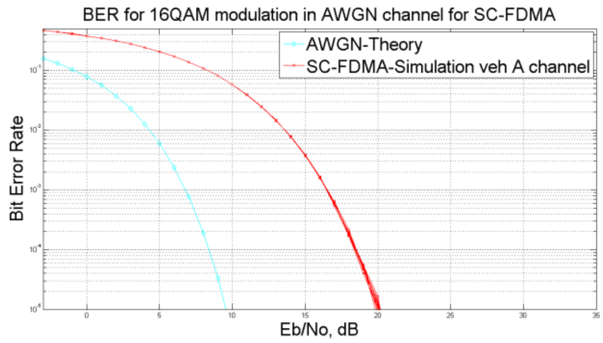


(a)



(b)

Fig 10: Performance of Pedestrian A channel in SC-FDMA (MMSE-Minimum Mean Square equalization scheme) - (a) FDD mode (b) TDD mode in 16-QAM



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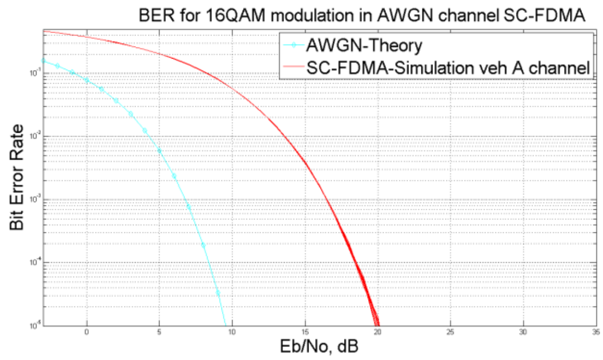
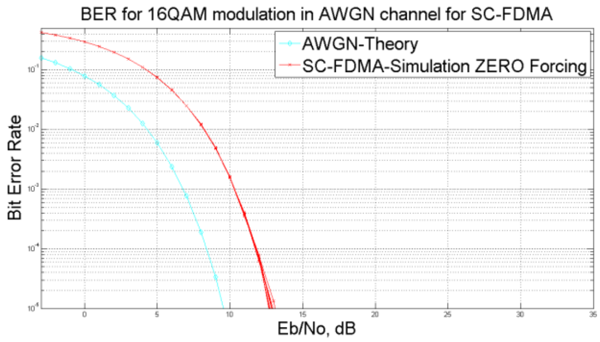
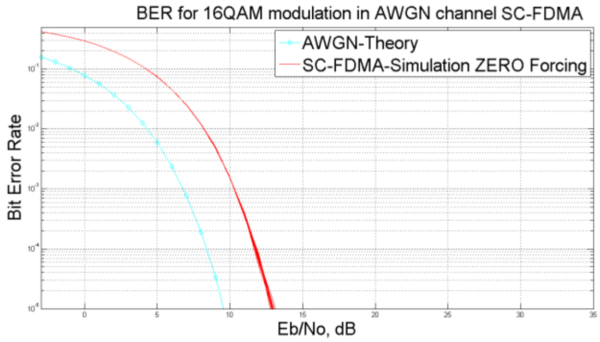


(b)

Fig 11: Performance of Vehicular A channel in SC-FDMA (MMSE-Minimum Mean Square equalization scheme) - (a) FDD mode (b) TDD mode in 16-QAM

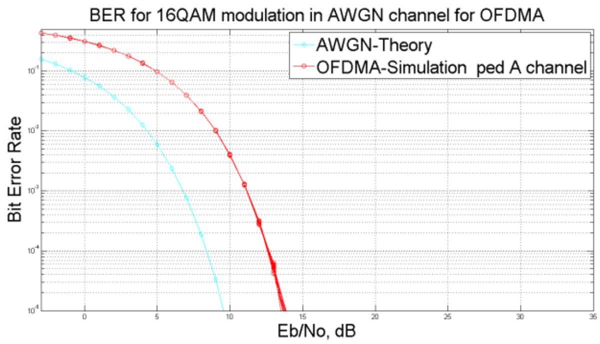


(a)



(b)

Fig 12: Performance of SC-FDMA using Zero Forcing in AWGN Channel. (a) FDD mode (b) TDD mode



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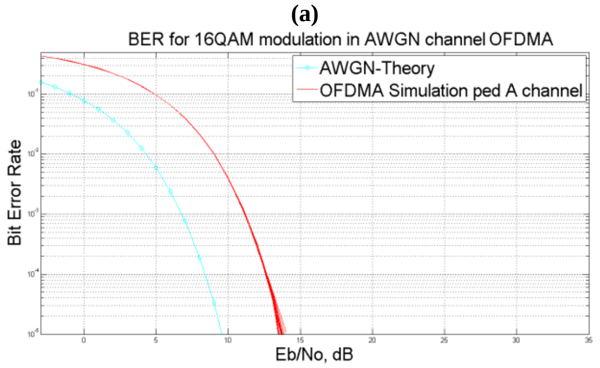
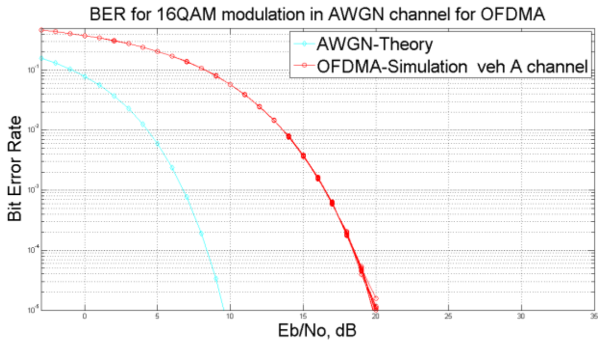


(b)

Fig 13: Performance of Pedestrian A channel in OFDMA (MMSE-Minimum Mean Square equalization scheme) - (a) FDD mode (b) TDD mode in 16-QAM



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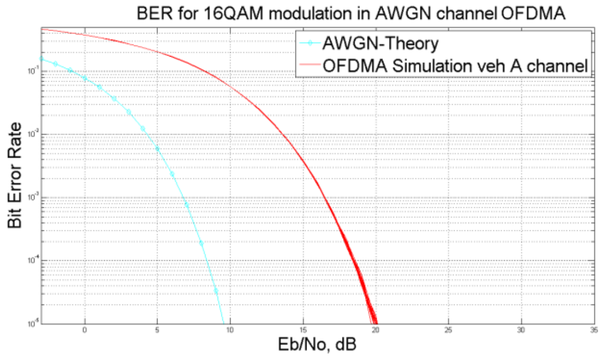

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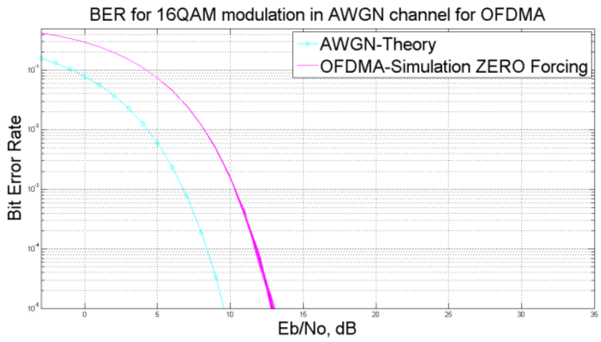
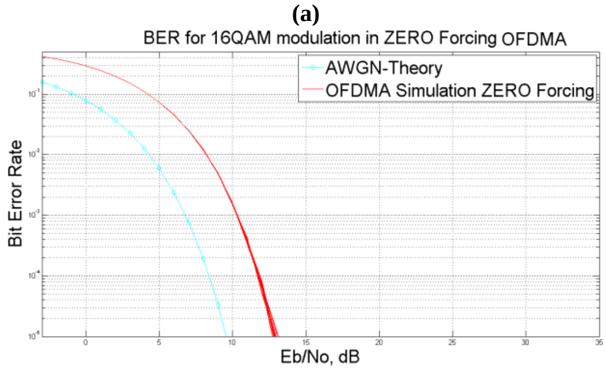
Fig 14: Performance of Vehicular A channel in OFDMA (MMSE-Minimum Mean Square equalization scheme) - (a) FDD mode (b) TDD mode in 16-QAM



(a)



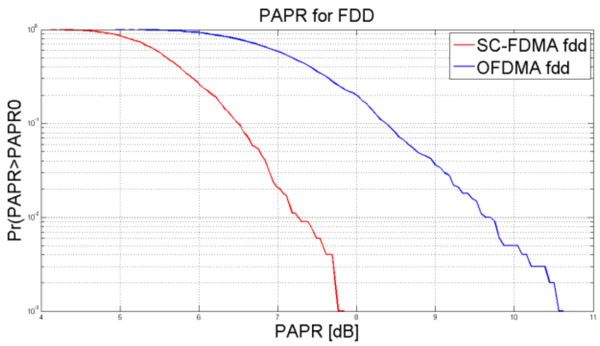
(b)

Fig 15: Performance of OFDMA using Zero Forcing in AWGN Channel. (a) FDD mode (b) TDD mode in 16-QAM

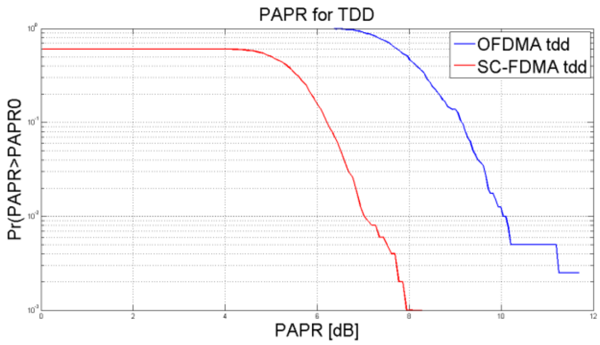
The simulation results of FDD and TDD in Figure 7(a), 7(b), 8(a), 8(b), 9(a), 9(b), 10(a), 10(b), 11(a), 11(b), 12(a), 12(b), 13(a), 13(b), 14(a), 14(b), 15(a) and 15(b) show that in case of FDD mode SC-FDMA has slightly changed than TDD. Even though the BER is abridged in both case of FDD and TDD, the BER of TDD is little higher than FDD.

5.1 *Performance Analysis*

The bases used for performance analysis is peak-to-average power ratio (PAPR). If there is a high PAPR, the device is forced to run with lower amplification so the peak power does not lie in the non-linear gain region [17]. In this paper the simulation of PAPR is evaluated for LTE frame structure. Modulation scheme (QPSK, 16-QAM) and complementary Cumulative Distribution Function (CCDF) are used in this PAPR calculation.



(a)



(b)

Fig 16: CCDF of PAPR of (a) LTE FDD & (b) LTE TDD

To obtain an empirical measure of the PAPR, the SC-FDMA and OFDMA signal that is passed through a raised-cosine pulse shaping filters, and rectangular pulse shaping filters. The measured CCDF of the PAPR experiment can be seen in Figure 16. Compared to LTE FDD frame type, LTE TDD frame type is more likely to have the higher PAPR ratios.

6. CONCLUSION

In this paper, we compare the PAPR characteristics of LTE Frame Structure Type (LTE FDD & LTE TDD) of SC-FDMA and OFDMA. From the result we conclude that, LTE FDD has better performance than LTE TDD. PAPR of SC-FDMA and OFDMA in LTE FDD achieve lower values on average. We see that FDD has a continuous reduction of BER (Bit Error Rate) and it minimizes the BER up to a certain values of SNRs. Comparing the Performance analysis, we can conclude that LTE FDD is the better option than in LTE TDD in uplink Transmission-SC-FDMA and downlink Transmission-OFDMA, because of its higher efficiency due to low PAPR.

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