BER, SNR, PAPR Analysis for Multiple Accesses in LTE

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Abstract— The Long term Evolution (LTE) Uses Orthogonal Frequency Division Multiple Access (OFDMA) in the downlink and Single Carrier Frequency Division Multiple Access (SCFDMA) in the uplink. This paper introduces the transceiver of OFDMA and SCFDMA, discusses difference between the OFDMA and SCFDMA, and highlight the factor that leverages the performance of both multiple access technique, the graphical results shows the relation between SNR, BER, Pe with the type of modulation used in LTE, and the PAPR graphical results shows the main reason of choosing the SCFDMA for the uplink with proposed subcarrier mapping LFDMA and DFDMA (IFDMA).

Index Terms— BER (Bit Error Ratio), CP (Cyclic prefix) DFDMA(Distributed Frequency Division Multiple Access), E-UTRA(Evolved Universal Terrestrial Radio Access), FDMA(Frequency Division Multiple Access), GSM(Global System for Mobile), ISI(Inter Symbol Interference), Interim Standard-95 (IS-95), LFDMA(Localized Frequency Division Multiple Access), LTE (Long Term Evolution), OFDMA (Orthogonal Frequency Division Multiple Access), PAPR (Peak to Average Power Ratio), Pe (Error Probability), SCFDMA(Single Carrier Frequency Division Multiple Access), SNR (Signal to Noise Ratio), TDMA(Time Division Multiple Access).

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1 INTRODUCTION

Mobile communication has become an everyday commodity and digital communication techniques appeared in the Second Generation (2G) systems, and main access schemes are TDMA and CDMA. The two most commonly accepted 2G systems are GSM and IS-95. These systems mostly offer speech communication, but also data communication limited to rather low transmission rates. The concept of the Third Generation (3G) system and the LTE marketed as "4G" came in picture for high data transmission. The main targets and requirements for designing the LTE Systems can be summarized as.

- Data rate: for 20 MHz spectrum, the targets for peak data rate are 50 Mbps (for uplink) and 100 Mbps (for downlink).
- Bandwidth: the new system is now required to facilitate frequency allocation flexibility with 1.5, 3, 5, 10, 15, 20MHz allocation.
- Latency: the LTE control-plane latency is less than 100 ms (for idle to active), and is less than 50 ms (for dormant to active). The User Plane latency is less than 10 ms from UE (user end) to server.
- Supported antenna configuration for Downlink: 4X2, 2X2, 1X2, 1X1 and for uplink: 1X2, 1X1.
- Mobility: Optimized for low speeds (<15 km/hr), High performance at speeds up to 120 km/hr., Maintain link at speed up to 350 km/hr.

3GPP specified LTE, also called E-UTRA to promote higher data rate performance through reducing overhead. The LTE Downlink is based on the on OFDM which provides multi user access, robustness to time dispersion of radio channel. SC-FDMA is employed in uplink that provides low peak-to-average power ratio [1], [2].

2 OFDMA VS SC-FDMA

OFDMA is a multi-user version of a digital modulation scheme OFDM. In OFDM the signal is first split into independent, closely-spaced orthogonal subcarriers which are used to carry the data. The data is divided into several parallel data streams or channels. Each data stream is associated with one subcarrier. OFDMA is a modulation & access technique that combines both TDMA & FDMA technologies [1], the main advantage of the OFDMA is high spectrum efficiency, more tolerant to multipath environment and eliminates ISI by cyclic prefix addition. On other hand the main disadvantage it has high PAPR, due to the unpredictable envelope fluctuation of the signal after IFFT output, and high PAPR value makes the amplifier consumes large power so, SC-FDMA is defined which spread the user data over the all subcarrier before computing the IFFT and results in smaller variation of instantaneous power of transmitting signal. Figure1 shows the common comparison between OFDMA and SC-FDMA and in SC-FDAM data is spread on the all the subcarriers instead of the transmitting over one subcarrier like OFDMA.

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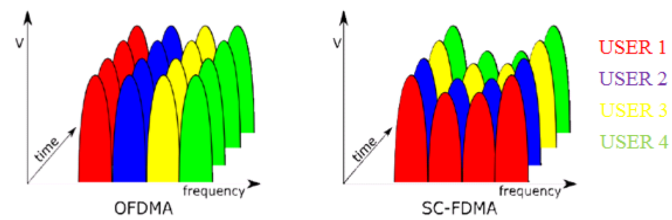


Fig 1. Difference between ODFDMA and SC-FDMA Subcarrier allocation

3 TRANSMITTER AND RECEIVER FOR OFDMA

OFDMA transmitter and receiver [1], [5] are shown in figure2, in this figure the available spectrum is divided into number of orthogonal subcarriers. The subcarrier spacing for LTE system is 15 KHz with 66.67 µs OFDMA symbol duration. The high bit-rate data stream passes through the modulator, where adaptive modulation scheme such as BPSK, QPSK, 16-QAM 64-QAM is applied. This multilevel sequence of modulated symbol is converted into parallel frequency component by serial to parallel converter. The IFFT stage converts these complex data symbols into time domain and generates the OFDMA symbols. And in order to cancel the ISI the Cyclic prefix is added to output of the IFFT stage, and this is nothing but the guard period. Addition of cyclic prefix is shown in figure 3. OFDMA uses two type of CP namely normal CP and extended CP. The normal CP is used for high frequencies and extended CP for lower frequencies.

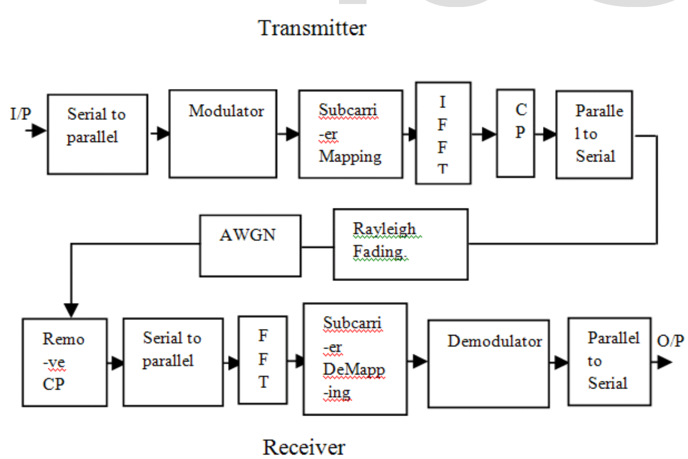


Fig 2. The block diagram of OFDMA-LTE

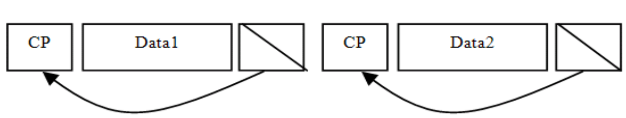


Fig 3.OFDM symbol with cyclic prefix

4 TRANSMITTER AND RECEIVER FOR SC-FDMA

A block diagram describing the SC-FDMA transceiver structure is shown in figure 4. Relative to the OFDMA, the SC-FDMA transmitter has an extra L-point DFT Stage combined with Subcarrier Mapping Module, as well as an extra L-point IDFT stage at the receiver. The L-point DFT transforms L-modulated symbol into the frequency domain, which are then mapped to the N-point IFFT (where L<N) by the subcarrier mapping module where L subcarrier belong to a single user. SC-FDMA is categorized as LFDMA and DFDMA. In LFDMA, the L subcarriers are adjacent in the available N bins whereas in DFDMA they are spread in the available N bins. Usually, in DFDMA the L subcarrier are spread equidistantly [6] and DFDMA also known as IFDMA.

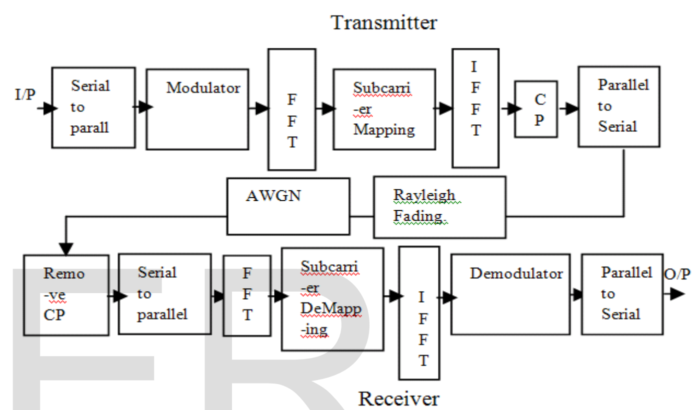


Fig 4. The block diagram of SC-FDMA transceiver

The LFDMA and DFDMA are shown in the figure 5, 6 respectively.

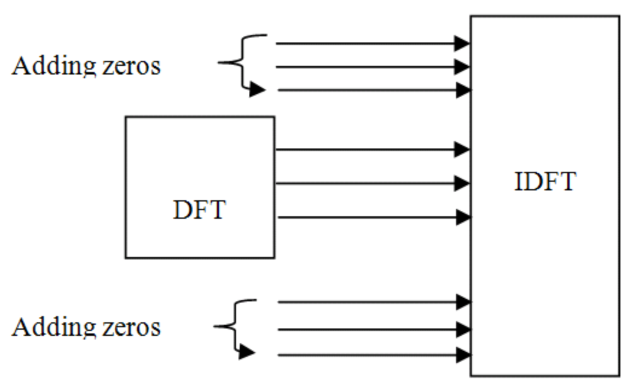
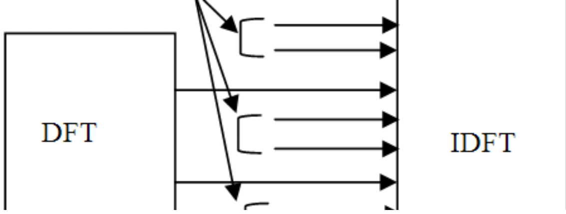


Fig 5. Localized FDMA



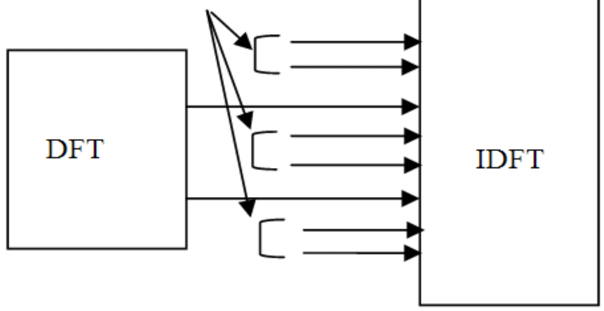


Fig 6. Distributed FDMA

5 PERFORMANCE CALCULATIONS

The performance analysis of OFDMA and SC-FDMA in LTE are characterized by following parameters [5], [9].

5.1 BER

The BER is ratio of errors bits to the total number of bits transmitted during the time interval i.e.

BER = (error bits) / (number of transmitted bits)

5.2 SNR

The SNR is the ratio of bit energy (Eb) to the noise power spectral density (N0) and is expressed in db.

SNR = Eb / N0

For any modulation scheme, the BER is expressed in terms of SNR. BER is measured by comparing the transmitted signal with received signal, and compute the error counts over the total number of bits transmitted

5.3 Pe

The probability of error or error probability (Pe) is the rate of errors occurs in the received signal. For the coherent detection the symbol error probability of M-ary PSK and M-ary QAM in the AWGN channel is determined by following expressions,

For M-ary PSK the Pe is given by

$$Pe \approx 2\,(1 - 1/\sqrt{M})\ \mathrm{erfc}\,[\sqrt{(3Eav/2(M-1)N0)}]$$

Where,

N0 = Noise density in AWGN

Eav = Average value of transmitted symbol energy in M-ary QAM or M-ary PSK

5.4 PAPR

The PAPR is calculated by representing a CCDF (Complementary Cumulative Distribution Function) of PAPR. The CCDF of PAPR is the probability that the PAPR is higher than a certain PAPAR value PAPR0 (Pr {PAPR>PAPR0}).

6 PERFORMANCE EVALUATIONS

The performance evaluation of OFDMA and SC-FDMA is done in the MATLAB. The simulation parameters used are shown in the table 1, and results for SNR Vs BER, SNR Vs Pe, and PAPR are obtained for all modulation scheme.

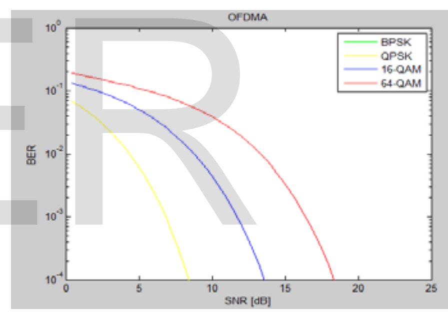


Fig 7. The SNR Vs BER in OFDMA for different modulation.

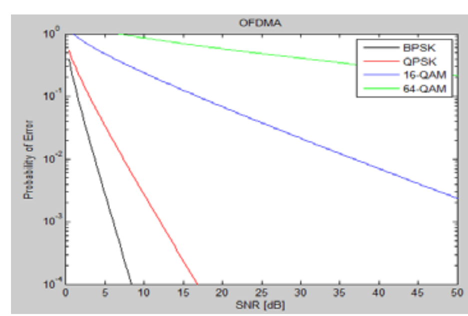


Fig 8. The relation between SNR and Pe in OFDM for different modulation.

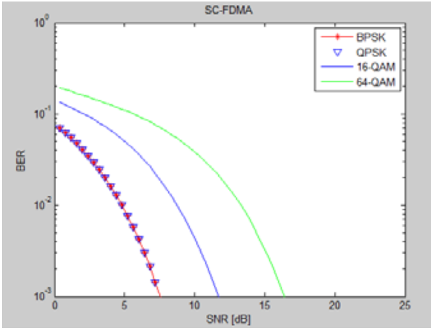


Fig 9. The SNR Vs BER in SCFDMA for different modulation.

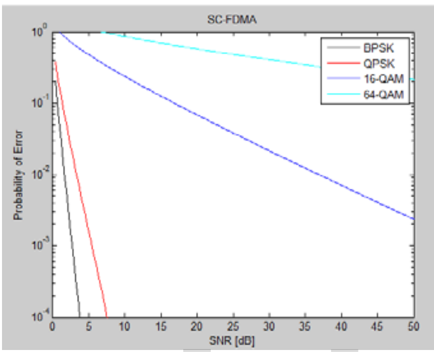


Fig 10. The relation between SNR and Pe in SC-FDMA for different modulation.

TABLE 1
Simulation parameters

Parameters	Value
Number of Subcarrier	512
CP	64
Modulation Scheme	BPSK, QPSK, 16-QAM, 64-QAM
Data Block size	16 symbol
Channel	AWGN (SNR 100db)
Fading	Rayleigh (frequency Selective)
Rayleigh fading parameter	Input sample period = 1.00e-3 sec Maximum Doppler shift = 100 Hz Vector path delays = [0 2.00e-5] sec Average path gain vector = [0 -9] dB
FFT and IFFT Size	512

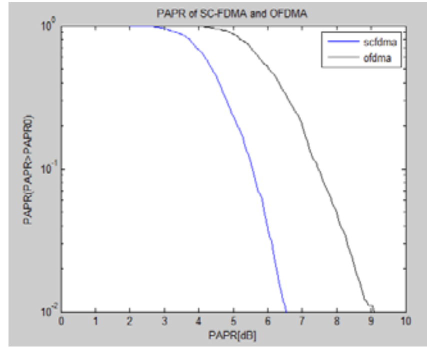


Fig 11. PAPR of OFDMA and SC-FDMA for BPSK

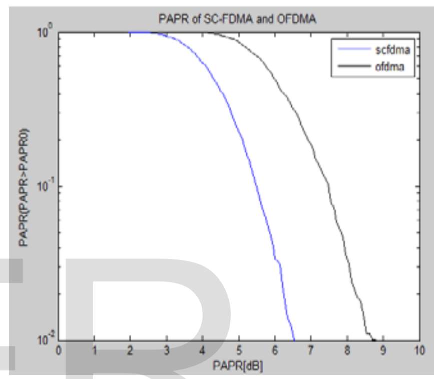


Fig 12. The PAPR of OFDMA and SC-FDMA for QPSK

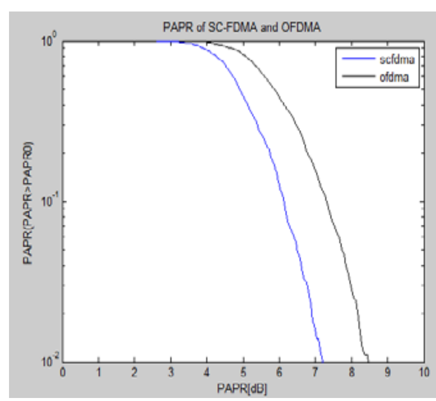


Fig 13. The PAPR of OFDMA and SC-FDMA for 16-QAM

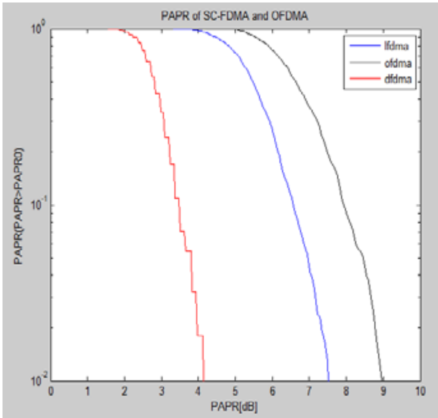


Fig 14. The PAPR of DFDMA, LFDMA and OFDMA for QPSK

7 CONCLUSIONS

The performance of OFDMA and SC-FDMA in LTE depend mainly on the type of modulation which are BPSK, QPSK, 16QAM and 64QAM. From figure 7, 8, 9, 10 we can conclude that as we go for higher modulation the probability of error, Bit Error rate and SNR increases in both OFDMA and SC-FDMA. The power consumption at the user end such as portable devices is again a vital issue for uplink transmission in LTE system. From the figure 11, 12, 13 we can conclude that the higher order modulation scheme have an impact on the PAPR of both OFDMA and SC-FDMA. The PAPR increases in SC-FDMA and slightly decreases in the OFDMA as we go from lower to higher modulation scheme but the overall value of PAPR in SC-FDMA is still less than that of OFDMA in all modulation schemes, and from figure 14 we can conclude that DFDMA has lower PAPR value than that of the LFDMA and OFDMA, that's why SC-FDMA has been adopted for the uplink transmission in LTE system, hence low order modulation i.e. BPSK, QPSK are adopted in the uplink in order to have less PAPR at user end.

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