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Performance Enhancement of OFDM System by reducing PAPR using DFT Spreading Technique

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Abstract- **Orthogonal Frequency-Division Multiple Access (OFDMA) and Single Carrier Frequency-Division Multiple Access (SC-FDMA) schemes are major part of Long Term Evolution (LTE).OFDM is more widely used technique due to its robustness against frequency selective fading channels. However, it suffers from a high Peak-to-Average Power Ratio (PAPR). In this paper, Discrete Fourier Transform (DFT) spreading technique has been proposed to improve the performance of OFDMA system by reduction of PAPR.OFDMA and SC-FDMA system has been investigated using different modulation schemes on the basis of PAPR and Bit Error Rate (BER). The results of proposed system show satisfactory improvement in system performance over OFDMA.**

Keywords- Peak-to-Average Power Ratio (PAPR),Long Term Evolution(LTE),Orthogonal Frequency-Division Multiple Access (OFDMA),SC-FDMA.

I. INTRODUCTION

Recent trends have shown a huge demand for high data rate to support multi-media services, online gaming and video on demand. To meet all these requirements a new radio technique called Long Term Evolution (LTE) came into the picture, whichis the brain child of the third generation partnership project (3GPP)[1][4].LTE supports 50Mbps in uplink and 100Mbps in downlink while operating in 20MHz of bandwidth[12].Due to the property of orthogonality the modulated subcarrier frequencies do not interfere with each other, hence multipath fading effect is reduced in OFDMA[14].Further the narrow spacing between the carriers makes the OFDMA bandwidth efficient.All these advantages make OFDMAto be used in the downlink transmission system [2]. Howeverhigh PAPR in OFDMAincrease the transmitted power in uplink and reduces the efficiency of the RF power amplifier [3]. So an uplink transmission scheme is considered which reduce transmitted power and PAPR as well. Hence a new and more robust technique called SC-FDMAhas been proposed. DFT spreading technique i.e. SC-FDMA overcomes the limitation of OFDMA by minimizing PAPR[13].

The paper is arranged as follows: Section II provides the differences between OFDMA and SC-FDMA and the DFT spreading technique is discussed.The system model is described in Section III. The system performances are analysed and the results are compared in Section IV.Finally, Section V gives the conclusion.

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II. THEORY

A.OFDMAVs SC-FDMA

OFDMA is a multiple access scheme based on OFDM technique. The signal is splited into number of narrowband orthogonal sub-carriers.The data is then divided into several parallel data streams. Each of these data stream is associated with a subcarrier.OFDMA combines both TDMA and FDMA technologies[5].The main advantages of OFDM includes high spectral efficiency,better resistance to multi-path environment and it reduces inter-symbol interference(ISI) effect by addition of cyclic prefix (CP) but it has high PAPR and consumes large power[11]. There are many techniques present in literature for PAPR reduction like Selected Mapping(SLM), Peak Windowing, Partial Transmit Sequence (PTS), Clipping, Filtering, Interleaving Technique and DFT Spreading[15][16].The analysis is given in Table 1.

TABLE 1: COMPARISON OF VARIOUS PAPR REDUCTION TECHNIQUES

Reduction Techniques	Distortion	Data Loss	Complexity
Clipping & Filtering	Yes	No	No
SLM	No	Yes	Yes
PTS	No	Yes	Yes

The results of DFT spreading technique which is also known as SC-FDMA has been analysed in this paper. SC-FDMA is a multiple access technique where number of subcarrier has been substantially reduced by method of subcarrier mapping.The data symbols are spreaded by the use of DFT prior to IFFT operation .This results in a lower PAPR than OFDM.For these reasons SC-FDMA becomes an attractive technique for uplink transmission systems.

B.DFTbased SC-FDMA system

Figure (3) shows the block diagram of OFDMA and SC-FDMA systems. First the multilevel sequence of symbols X(q) is mapped with data symbols and then passed through serial to parallel convertor for modulation onto P parallel sub-carriers, this process helps to eliminate the Inter-Symbol Interference (ISI). Whereas in SC-FDMA, the parallel complex sequence of symbols is spreading over subcarriers by using DFT as in [6][8]

$$Y(k)=DFT\{X(q)\} =\frac{1}{\sqrt{P}}\sum_{q=0}^{P-1} X(q)\, e^{-j2\pi qk/P} \qquad (1)$$

Where k=0,1,2,…..P-1

The DFT output is mapped depending on the mapper type i.e. localized or interleaved form. In Localized FDMA (LFDMA), the DFT output is mapped to a subset of the adjacent sub-carrier, taking only fractions of the total system bandwidth while in the interleaved FDMA (IFDMA), the complex output symbols are mapped equally over the entire system bandwidth [9].

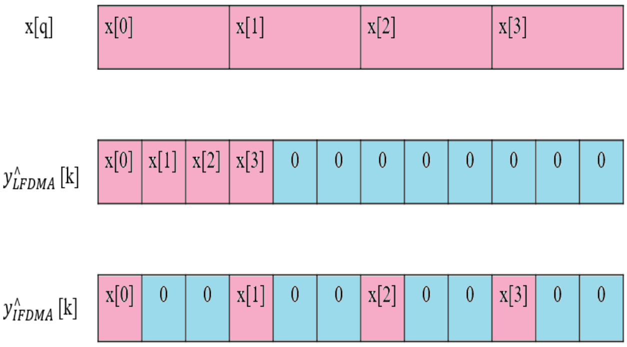

Fig. 1: Subcarrier Mapping for uplink in OFDM system: LFDMA and IFDMA

To transform the frequency domain modulated symbols from the output of the sub-carrier mapper $y^\wedge(k)$ to time domain sample x(q),P-point IFFT is used. This can be written as in [8]

$$(q)=\text{IFFT}\{y^\wedge(k)\} = \frac{1}{\sqrt{Q}}\sum_{q=0}^{Q-1} y^\wedge(k)\, e^{j2\pi qk/Q} \qquad (2)$$

Where k=0,1,2,……….Q-1, Q>P
Insertion of cyclic prefix is done to the transmitted modulated signal to overcome the inter-symbol interference(ISI) through the transmission in multipath fading channel by acting as a guard interval. The equation for implementation of cyclic prefix addition can be written as in [6]

$$x(q)=\begin{cases} x(Q+q)\,, q = -\mathrm{Ng}+1, \dots \dots . . -1 \\ x(q), q = 0,1, \dots \dots \dots . Q-1 \end{cases} \qquad (3)$$

Where Ng is the cyclic prefix period
Additive White Gaussian Noise (AWGN)was added to the transmitting signal as channel modelling.It is expressed in watt per hertz. The received signal is expressed as in [7][8]

$$y(q)=\sum g(q,l)x(q-l)+w(q) \qquad (4)$$

Where l is the total number of frequency selective channel,
w(q) is the AWGN with zero mean,
g(q,l) is the channel response.

After cyclic prefix removal, the received signal y^(q) is converted into the frequency domain by using Fast Fourier Transform(FFT), whereas the output signal Y(k) is calculated as in [7][8]

$$Y(k) = \frac{1}{\sqrt{Q}}\sum_{q=0}^{Q-1} X(q)\, e^{-j2\pi qk/Q} \qquad (5)$$

where k=0,1,…,Q−1
The output signal is given by

$$Y(k)=X(k)G(k)+W(k) \qquad (6)$$

Where G(k) represents the channel frequency response

$$G(k) = \frac{1}{Q}\sum_{k=0}^{Q-1} G(k,q) \qquad (7)$$

and $W(k)$represents the Fourier transform of the vector w(p) is[10]

$$W(k)=\frac{1}{\sqrt{Q}}\sum_{p=0}^{Q-1} W(p)\, e^{-j2\pi pk/Q} \qquad (8)$$

Complementary Cumulative Distribution Function (CCDF). For finding out the CCDF,Cumulative Distribution Function (CDF) is required which is given as;

$$\mathrm{CDF}=(1-\mathrm{e}^{-z^2})^{\mathrm{N}}$$

So, the CCDF is given as ;

$$\mathrm{CCDF}=1\text{-}\mathrm{CDF}=1\text{-}(1-e^{-z^2})^N$$

The flow chart used for PAPR reduction technique is given in Fig.2

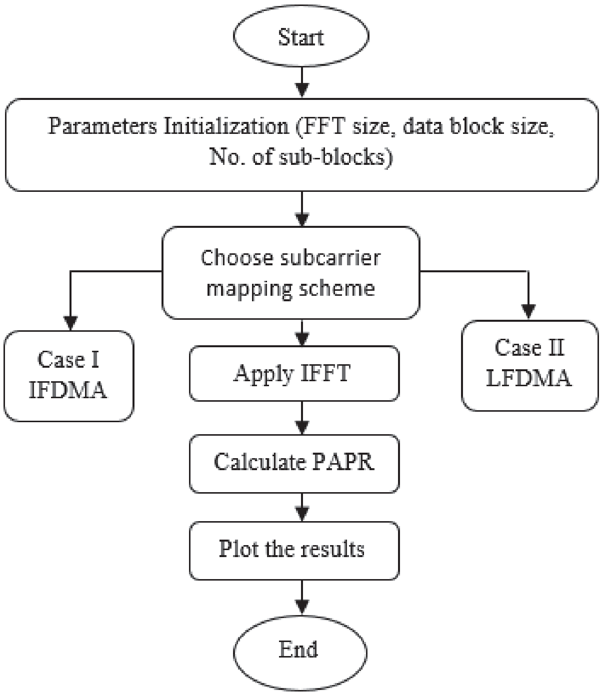

Fig.2: Flow chart of PAPR reduction using DFT spreading method

III.SYSTEM MODEL

Peak Average Power Ratio (PAPR)

The PAPR of the signal x(q),is given as the ratio of the peak instantaneous power to the average power, written as

$$\mathrm{PAPR}(x) = 10 log_{10}\frac{\max|x(q)|^2}{E[x(q)]^2}$$

Lower is the PAPR higher is the efficiency of the system.

Bit Error Rate (BER)

The ratio of error bits to the total number of transmitted bits in a particular interval in a transmission system is known as the BER.

$$\text{BER}=\frac{\textit{error bits}}{\textit{total number of bits}}$$

Signal to Noise Ratio (SNR)

It is the ratio of signal power to noise power.It is expressed in decibels(dB). The greater the SNR, BER is lower, the easier it is to identify and subsequently isolate and eliminate the source of noise[5].

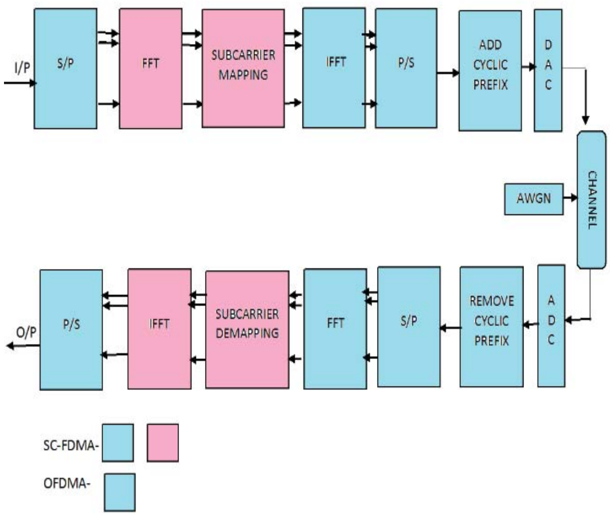

Fig.3: Block Diagram of proposed model

TABLE.2 PARAMETERS USED FOR SIMULATION

Parameters	Values
System Bandwidth	5MHz
Cyclic Prefix Length	5
FFT size	256
SNR Range	0-30Db
Modulation Scheme	QPSK,QAM(N=4,8,16,32,64)
Subcarriers	32

IV.RESULTS AND DISCUSSIONS

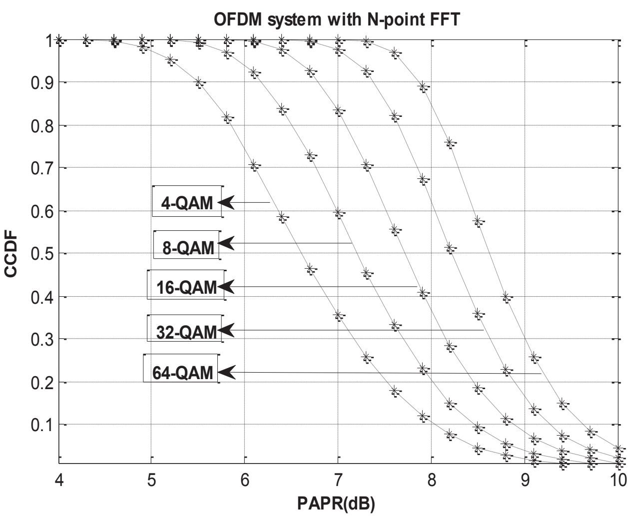

Fig.4: CCDF Vs PAPR plot for OFDM system

For analysing the effect of the proposed set up in Fig.1 the parameters in Table.1 has been considered for the uplink of LTE system. The results are reported in figures 4-7. Fig.4 shows the CCDF Vs PAPR for OFDM system for different QAM modulations.The PAPR of SC-FDMA for QPSK and 16, 64-QAM are shown in Fig.5, 6 and 7respectively.

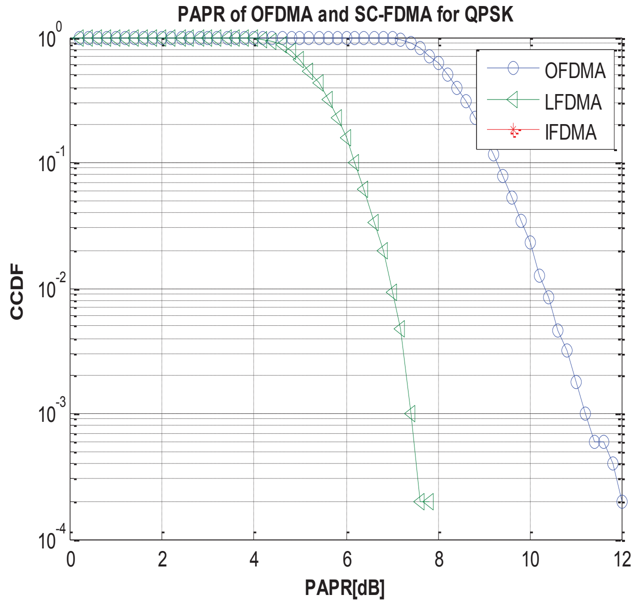

Fig.5: PAPR comparison of OFDMA and SC-FDMA system under QPSK modulation

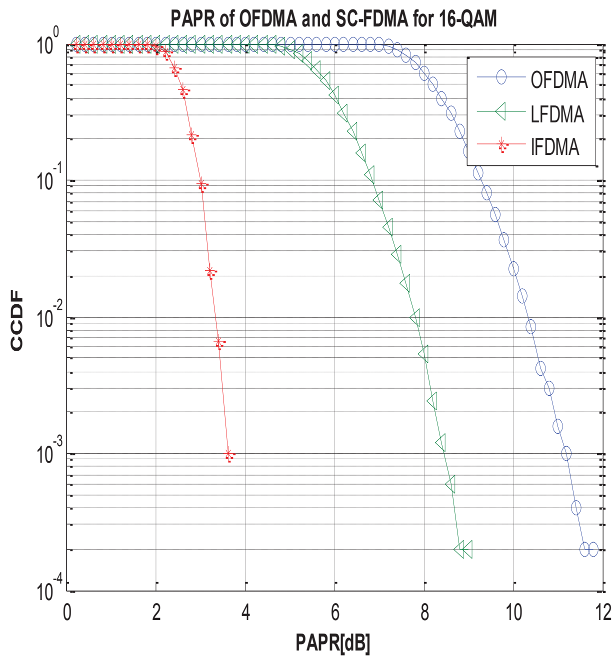

Fig.6: PAPR comparison of OFDMA and SC-FDMA system under 16-QAM modulation

It can be easily identified that SC-FDMA scheme gives lower PAPR as compared to OFDMA, further among subcarrier mapping schemes of SC-FDMA, IFDMA scheme is better than the LFDMA.

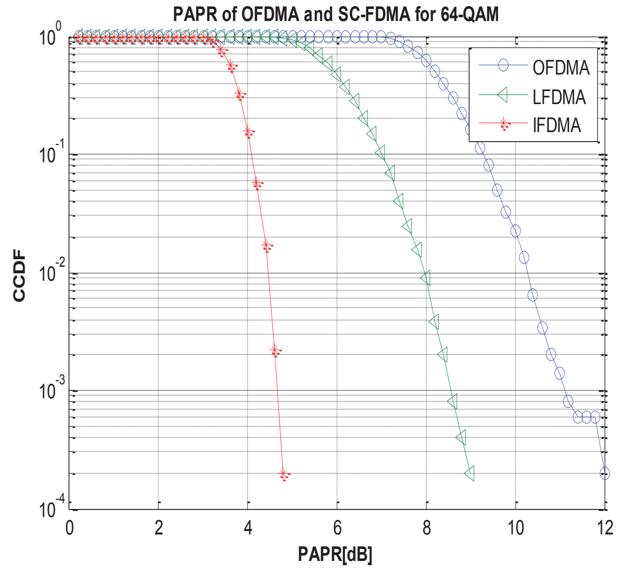

Fig.7: PAPR comparison of OFDMA and SC-FDMA system under 64-QAM modulation

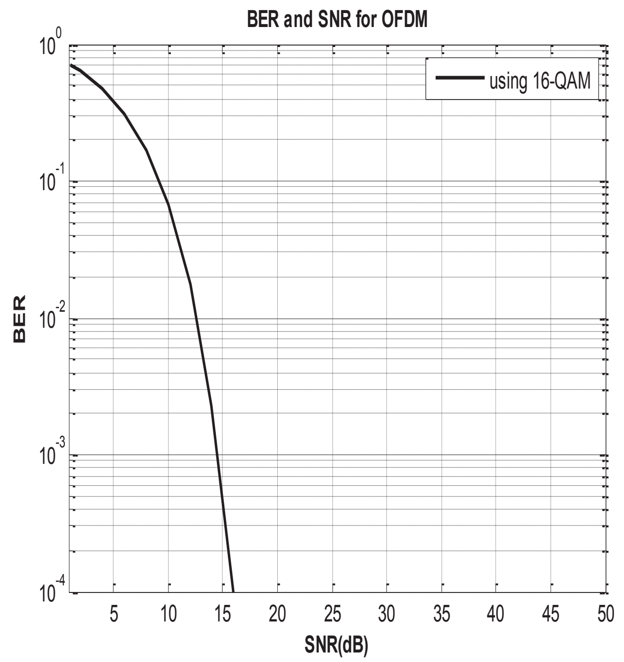

Fig.8: BER Vs SNR plot of OFDM system

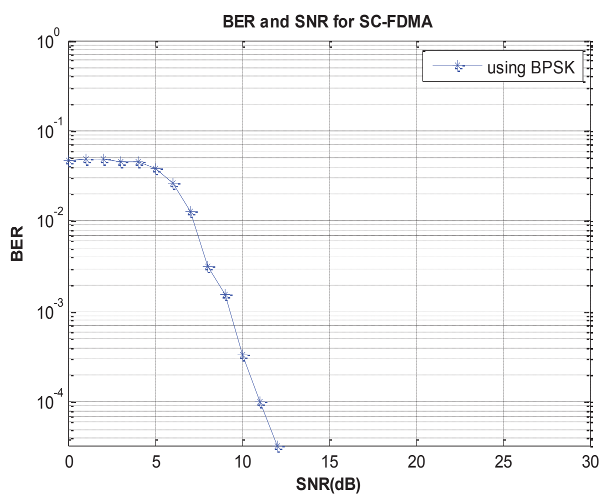

Fig.9: BER Vs SNRplot of SC-FDMA system

TABLE.3 PAPR ANALYSIS BETWEEN OFDMA AND SC-FDMA FOR DIFFERENT MODULATION SCHEMES.

Modulation Type	PAPR(dB)		
	OFDMA	SC-FDMA	
		LFDMA	IFDMA
QPSK	12	7.5	0
16-QAM	11.5	8.8	3.8
64-QAM	12	9	4.8

Fig.8 and Fig.9 shows BER comparison between OFDM and SC-FDMA system under 16-QAM and BPSK respectively. SC-FDMA gives better result over OFDMA with respect to BER.

V. CONCLUSION

One of the promising multicarrier communication systems, OFDM has been accepted by many wireless communication standards due to its several advantageous features in multipath environments. Despite of numerous features of OFDMA systemits high PAPR is a major issue. From the simulation results it can be concluded that the higher order modulation scheme reduces the PAPR of both OFDMA and SC-FDMA. The value of PAPR in IFDMA gives better resultcompared to LFDMA and OFDMA in all modulation schemesfor which it has been adopted for uplinktransmission in LTE system. Based on the results low order modulation scheme BPSK, QPSK, 16-QAM, 64-QAM adopt for uplink in order to have less PAPR. In 64-QAM, however PAPR increases but it can be applied for system demanding higher data rate.

LFDMA is preferred over IFDMA for implementation in spite of having higher PAPR because IFDMA requires additional guard band and pilots for allocation over the entire band which creates hardware complexity.

BER plays an instrumental role to measure the system performance in any communication link design. Higher order modulation like 16-QAM, 64-QAM outperforms PSK, QPSK. From results it can be observed that for a fixed value of SNR there is an increase in BER for higher order modulation in both the multiple access techniques (OFDMA and SC-FDMA) used in LTE system.

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