International Journal of Current Engineering and Technology
E-ISSN 2277 – 4106, P-ISSN 2347 – 5161

Available at http://inpressco.com/category/ijcet

Research Article

A Comparative Performance Analysis of PAPR in SCFDMA with QPSK and 16QAM

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Accepted 15 Aug 2015, Available online 22 Aug 2015, **Vol.5, No.4 (Aug 2015)**

Abstract

Orthogonal Frequency Division Multiplexing (OFDM) is a well-known modulation technique for transmission of large amount of digital data with high data rate in both wired and wireless communication systems. High peak-to-average power ratio (PAPR) is the main problem of OFDM system which can be improved by using single carrier frequency division multiple access (SC-FDMA) technique. The simulation results show better performance of the proposed scheme than the existing technique. In this paper, we have analyze the PAPR reduction performance of single carrier frequency division multiplexing (SC-FDM) with QPSK and 16 QAM modulation and also compare PAPR performance of OFDMA,DFDMA,LFDMA and IFDMA with and without pulse shaping.

Keywords: *Orthogonal frequency division multiplexing, Peak to average power ratio. Location based frequency division multiple access, interleaved frequency division multiple access.*

1. Introduction

New Technologies and thereby new applications are emerging to provide better services over the wireless network. The success of second generation cellular system has accelerated the demand of multimedia applications availability over wireless communication systems. To achieve the goals, the next generation mobile systems are designed such that a minimum data rate of 10-20 Mbps (at least 2 Mbps in the moving vehicles) can be achieved in 4G. OFDM (Lee *et al*, 2005) technique is suitable for multipath environment and possesses high spectral efficiency, thus it is recommended for the fourth generation cellular network. OFDM is known since a long time but it is the advancements in digital signal processing techniques which enable it to be implemented in modern wireless systems.

OFDM is a multicarrier modulation technique possessing several favourable properties like better spectral efficiency, robustness against frequency selective fading channels, higher immunity to inter symbol interference, low implementation complexity, uniform average power spectral density, very much capable to handle strong echoes and less occurrence of non-linear distortion (Vijayarangan *et al*, 2009)

OFDM system has a lot of uses in the field of wireless and wired communication. It has been used in DAB, Digital television DVB-T(terrestrial), DVBH (handheld), digital television and high-definition television (Falconer *et al*, 2002) (HDTV, high-bit-rate digital subscriber lines (HDSL), very high-speed digital subscriber lines (VHDSL), asymmetric digital subscriber lines (ADSL) connections which follow the G.DMT (ITU G.992.1) standard, (where existing copper wires are used to gain high-speed data connections), and also in wireless LAN and MAN applications, including IEEE 802.11a/g/n, WiMAX and Mobile phone 4G .

OFDM system mainly suffered from two problem one is High PAPR and second one is frequency offset problem. High PAPR occurs in OFDM system when number of subcarrier may get added up in to the receiver at the same time. This Subcarrier constructively causes high power to transmit it, as compared to overall average power of the OFDM system (Sorger *et al*,1998).

The PAPR of the signal is given as the ratio between the peak instantaneous power and the average power occur in OFDM symbol transmission. It can be written as

$$\mathrm{PAPR} = \max_{0\le t\le T} \frac{|x(t)|^2}{E[|x((t)|^2]}$$

Where E[.] denotes the expectation operator.

In OFDM number of multi cariier are used to modulate the information

If X (0), X (1), X (2), X (3) - - - - - - - - - - - - X (N-1) are information symbols and each symbol has two peak value i.e. +a and –a.

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These information symbols are loaded on to the sub-carrier and passes through the IFFT operation.

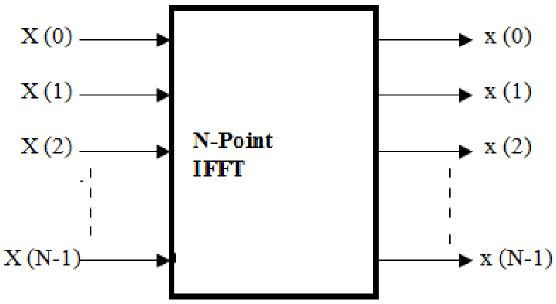

Fig. 1 N- Point IFFT of OFDM system

Where x (0), x (1), x (2)……. x (N-1) are IFFT sample of information symbols.

Peak power of each symbol = a^2

Average power = a^2/No. of sub carrier (N)

$$\text{PAPR} = \frac{\text{Peak power}}{\text{Average power}}$$

$$\text{PAPR}=\frac{a^2}{a^2/N}$$

PAPR= Number of sub-carrier (N)

PAPR = 10 log (N)

From expression it is clear that PAPR depend on Number of subcarrier.

- For single carrier modulation

Then,

PAPR= 10 log N

PAPR= 10 log 1

PAPR= 0 dB

Hence PAPR for single carrier signal is 0 dB.

- If number of carrier signal is 1024

Then,

PAPR= 10 log 1024

=30.10 dB

For reduction of the high PAPR in OFDM transmission system, instantaneous peak power of the OFDM signal should be minimized. Since OFDM signal is the sum of the N signals then for highest PAPR, if we consider each signal of maximum amplitude of 1 volt and all of these signals are added up at the same time at these maximum amplitude which is unlikely but possible, making the OFDM signal amplitude of N volts which leads to N times higher PAPR then the PAPR of single carrier transmission system. If there is very high Peak-to-Average Power Ratio (PAPR) in OFDM based transmission systems then it requires the use of sophisticated and costly radio transmitters which have High Power Amplifiers (HPA) which can operate in a very large linear range.

These demands result in complex and costly hardware systems. Hence to minimize the problem of complex hardware design it is better to employ efficient PAPR reduction techniques.

There are different PAPR reduction techniques and their selection criteria which are given in the literature. There are different PAPR reduction techniques and their selection criteria which are given in the literature. Single carrier frequency division multiple access (SC-FDMA) is the technique which basically uses the single carrier modulation, which is an extension of the OFDMA system having similar overall complexity and performance.

It has a major advantage over OFDMA system that it has lower PAPR because of its integral single carrier structure and due to its high transmission power efficiency.

In OFDM system to reduce the PAPR, another type of companding technique is used, known as Non Linear Companding Transform. This technique converts the OFDM signals into a specific statistics form, which can be given by a piecewise probability density function with an inflexion point. Theoretical analysis shows that, this scheme may drastically decrease the impact of companding distortion on the BER performance to achieve a given PAPR level, while simultaneously achieving a favourable trade-off between the PAPR reduction and BER performance (Dwivedi *et al*, 2014). Single carrier frequency division multiple access (SC-FDMA) is a technique for reducing PAPR with similar structure, throughput performance and complexity which has low PAPR and high power efficiency It is single carrier modulation technique and suitable for uplink multiple access transmission of 3GPP LTE.

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2. Simulation setup

We have used MATLAB simulation software for solving the numerical problem. We have tried to improve the performance of OFDM system by reducing PAPR. For reduction of PAPR, SC-FDMA using nonlinear companding technique with sub-carrier mapping is used. Table1. Shows the required parameters for simulation design of the scheme for the reduction of peak to average power ratio.

Table 1 Simulation parameter

Parameter	Value
Number of sub-carrier(N)	1024
Bandwidth spreading factor	32
Transmission bandwidth	2 MHz
Input data block size	16
Modulation technique	QPSK and 16QAM
Pulse shaping filter	RC and RRC filter

2. Proposed PAPR reduction scheme

Figure2. Shows the block diagram of the proposed PAPR reduction scheme of the SC-FDMA with sub-carrier mapping. Single carrier frequency division multiple access (SC-FDMA) is an improved version of OFDMA system with similar structure, throughput performance and complexity which has low PAPR and high power efficiency. SCFDM system has two extra block M-Point FFT and sub-carrier mapping block. FFT Block converts time domain information symbol into the frequency domain symbol. Furthermore, this frequency domain information symbol passes through the sub-carrier mapping and mapped to a subset of subcarriers, then applied to the IFFT. Hence, PAPR can be reduced by using FFT block which converts the system into single carrier system. However, most important thing is that M<N while the remaining part of SC-FDMA is same as modified OFDM system. Subcarrier mapping can be classified into two types: Localized Mappingand Distributed Mapping.

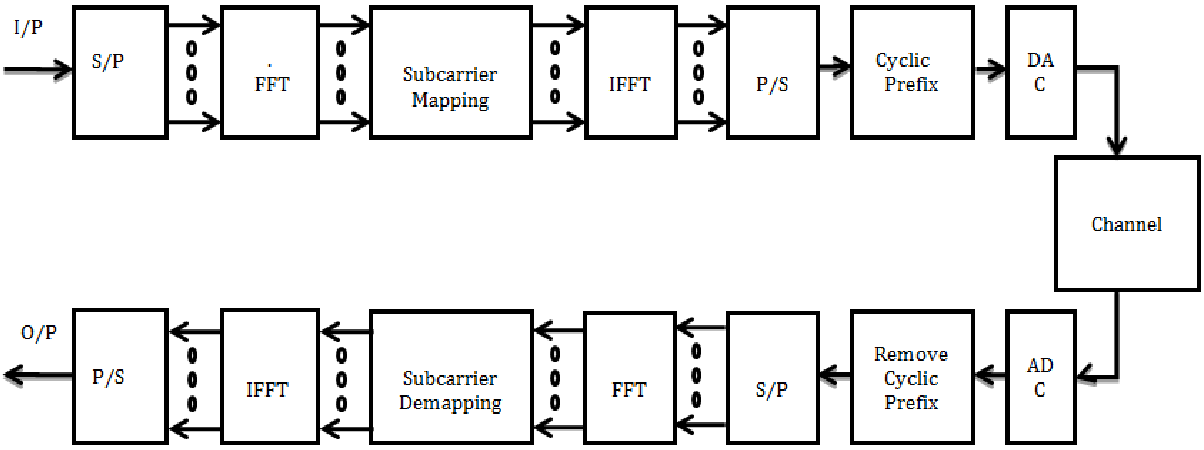

Fig.2 Block diagram of proposed scheme

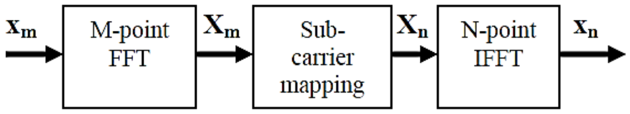

Fig.3 Generation of M to N symbol mapping

In interleaved frequency division multiple access (IFDMA) mapping scheme, FFT outputs of the input data are placed with zero padding over the entire subcarriers having the equal distance in between each subcarrier [12].

X(0)	0	0	X(1)	0	0	X(2)	0	0

Fig.4 Interleaving mapping with 9 sub-carrier

$$X_{n=Q.m}=\begin{cases} X_m\ , & 0 \le m \le M-1 \\ 0\ , & \text{otherwise} \end{cases}$$

In Located FDMA (LFDMA) based scheme, FFT outputs of the input data are placed on the consecutive subcarriers in the form of chunk.

$$X_{n=Q.m}=\begin{cases} X_m & 0 \le n \le M-1 \\ 0 & M \le n \le N-1 \end{cases}$$

0	0	X(0)	X(1)	X(2)	X(3)	0	0

Fig.5 Location based mapping with 8 sub-carrier

Where N =Total number of subcarriers, M=Data block size, Q=Bandwidth spreading factor.

After taking the IFFT of the frequency domain subcarrier mapped signal X_n we will get the time domain samples as x_n.then modulate the symbol by using two technique first is QPSK and second one is 16QAM modulation.

3. Result and Discussion

The performance of the proposed scheme is evaluated in terms of the reduction of the PAPR and BER performance through numerical simulations. PAPR statics are shown in terms of CCDF (Complementary Cumulative Distribution Function) which gives the probability that PAPR is greater than a certain PAPR value PAPR0 (Pr{PAPR>PAPR0}). So we have compared the performance of OFDMA, SC-FDMA and the proposed scheme

In our simulation model we have taken the total number of subcarriers as 1024, input data block size to 16 and bandwidth spreading factor to 32. To acquire the CCDF of PAPR to be ten thousand times, a uniformly random data points were generated. Transmission bandwidth of 2 MHz and symbol constellations as QPSK and 16-QAM was considered.

In our simulation model we have applied the raised-cosine (RC) pulse and squared-root raised-cosine (RRC) pulse which are widely used for pulse shaping in wireless communications. So these are used in SC-FDMA signals which suffer from the higher instantaneous out of band radiation. The effect of out of band radiation is more in case of IFDMA since out of band radiation increases by increasing the roll of factor over the range 0 to 1 but at the same time PAPR also decreased. So we can see a trade-off between PAPR performance and out of band radiation.

In figure 6,7 and 8,9 plots of CCDF of PAPR for the SC-FDMA of QPSK and 16QAM modulation formats are shown respectively. We compare the value of PAPR which exceeded with probability less than 0.01% (Pr{PAPR>PAPR0} = 10-4), or 99.99-percentile PAPR.

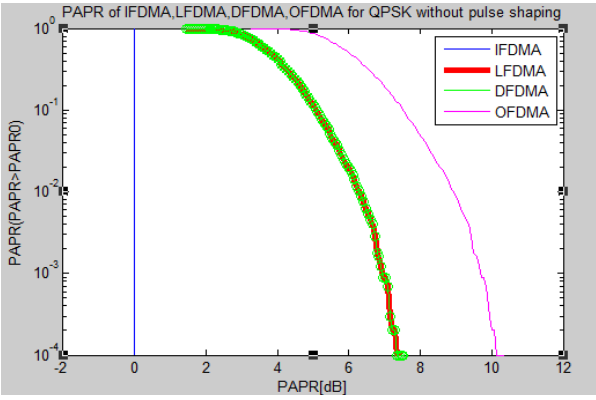

Fig.6 CCDF plot of PAPR for IFDMA ,LFDMA, DFDMA and OFDMA without pulse shaping using QPSK modulation.

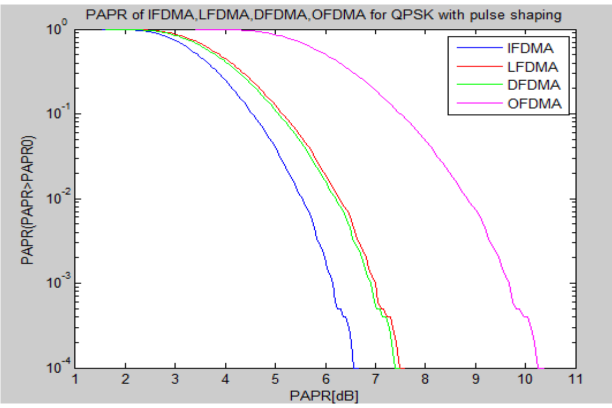

Fig.7 CCDF plot of PAPR for IFDMA , LFDMA, DFDMA and OFDMA with pulse shaping using QPSK modulation

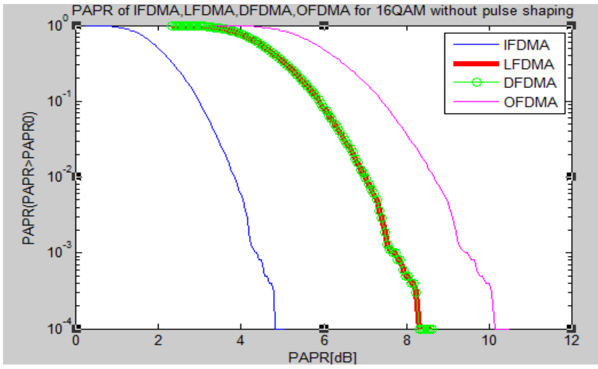

Fig.8CCDF plot of PAPR for IFDMA ,LFDMA, DFDMA and OFDMA without pulse shaping using 16QAM

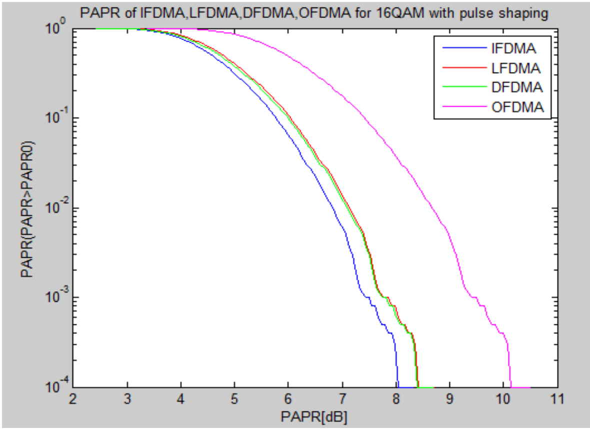

Fig.9 CCDF plot of PAPR for IFDMA ,LFDMA, DFDMA and OFDMA without pulse shaping using 16QAM

Table.2 99.99-percentile PAPR for SC-FDMA with QPSK and 16QAM

Modulation scheme	Pulse shaping	OFDMA	LFDMA	DFDMA	IFDMA
QPSK	None	10.2	7.4	7.3	0
	yes	10.3	7.5	7.4	6.7
16QAM	none	10.2	8.3	8.2	4.9
	yes	10.2	8.5	8.4	8.0

From our results we can see that all the cases of SC-FDMAwith QPSK modulation is most effective and reliable for reduction of PAPR as compared to the 16 QAM modulation technique.

PAPR reduction performance of IFDMA carrier mapping with or without pulse shaping is better than OFDMA,LFDMA and DFDMA with or without pulse shaping.

Conclusion

Aim of this paper is to analyze the PAPR reduction performance of OFDMA, LFDMA,DFDMA and IFDMA sub-carrier mapping with QPSK and 16QAM modulation technique. Furthermore compared the PAPR performance of the SCFDMA system with and without Pulse shaping.

After analysis the simulation result it can be conclude that PAPR reduction performance of IFDMA carrier mapping with or without pulse shaping for both modulation technique like QPSK and 16QAM is better than OFDMA, LFDMA and DFDMA with or without pulse shaping.

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