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Minimization of peak to average power ratio by selective mapping technique in OFDM environment

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Abstract— **Orthogonal FDM technique is frequent used multiplexing technique of 4G communication system. It improves the bandwidth and efficiency of the system but also increases system complexity. The main problem with OFDM system is high peak-to-average power ratio (PAPR). Phase rotation, mapping, coding, clipping and partial transmit sequence etc. are among many schemes that have been proposed to solve the problem of PAPR in many literatures. This paper presents an analysis for minimization of PAPR problem in OFDM environment by using selective mapping technique.**

***Keywords*— Frequency Division Multiplexing (FDM); Orthogonal Frequency Division Multiplexing (OFDM); Peak-To-Average Power Ratio (PAPR); Selective Mapping Technique (SLM); Multi Carrier Modulation (MCM).**

I. Introduction

In all communication system, the transmitted signals may not reach the receiver antenna directly because of diffraction, reflection, and scattering, which caused by buildings, mountains, and that resulting in blocking the line-of-sight path (LOS). In case of blocking LOS the received signals will come from different directions and this effect is known as multipath propagation. The frequency selective channel has affects the transmitted data, and there are many techniques used to decrease these affects of the frequency selective channel. The wireless multimedia applications becoming more and more popular, the required bit rates are achieved due to OFDM multicarrier transmissions. For video communication, very high bit rate (High-speed) communication is required. To satisfy this, we must have the modulation scheme that can read more number of bits at a time and send it with considerable low bit errors. The quality of the reception is also must be good enough. Orthogonality between two signals means that the two coexisting signals are independent of each other in a specified time interval and do not interact with each other. The concept of orthogonal signals is essential for the understanding of orthogonal frequency division multiplexing (OFDM) system. Orthogonality is a property that allows multiple information signals to be transmitted perfectly over a common channel and detected without interference [40]. Loss of orthogonality results in blurring between these information signals and degradations in communication. One of the advancement of the latest communication systems depends on the recent modulation technique, i.e. orthogonal frequency division multiplexing (OFDM). The OFDM transmission is a technique with a long history that has recently seen rising popularity in wireless and wire line applications [36].

Many common multiplexing schemes are orthogonal. Time division multiplexing (TDM) allows transmission of the multiple signals over a single channel by assigning unique time slots for each of the information signals. During each time slot, one and only one information signal is transmitted, thus preventing any interference between the multiple interference sources. Because of these, TDM is orthogonal in nature. But in TDM, the time synchronization problem is the limitation.

In the frequency domain, most FDM systems are orthogonal in the sense that each of the separate transmission signals is well spaced out in frequency, preventing the interference and hence it consumes a lot of spectrum [24].

The mathematical representation of the orthogonal continuous time and discrete time signals is given by Equations (1) and (2) respectively; these are the conditions for orthogonality.

For Continuous time signal:

$$\int_0^T \cos(2\pi n f_0 t) \times \cos(2\pi m f_0 t)dt = 0 \; (n \neq m) \qquad (1)$$

For Discrete time signal:

$$\sum_{k=0}^{N-1} \cos\left(\frac{2\pi kn}{N}\right) \times \cos\left(\frac{2\pi km}{N}\right) = 0 \; (n \neq m) \qquad (2)$$

where N = period of k samples.

II. Literature Review

An efficient and distortion less technique is introduced by Stefan H. Muller and Johannes B. Huber for peak power reduction in OFDM [1]. In the work, the approach is flexible and continues with arbitrary number of sub-carriers without restriction on the type of modulation applied. Finally, it is shown that this technique is close to the theoretical one and may operate with decreased power back-off, resulting increased efficiency. It is one of the most effective and flexible technique for peak power reduction without non linear distortion.

A companding technique is proposed by X. Wang, T.T. Tjhung and C.S. Ng to reduce the PAPR of OFDM signal by using probability distribution function and Gaussian distribution [2], [28] and [29].It is found that this companding approach is effective to reduce the PAPR and also the density function is obtained for OFDM signals. To improve the performance of the system, optimal companding coefficient is also determining [2]. Further, in the literature of the K. Sathananthan and C.Tellembura , the PAPR problem in multi code CDMA is solve with the help of statistical distribution of PAPR and the achievable PAPR reduction for a given code rate is estimated [3].This shows that the bit error rate performance improves when the PAPR reduced MC-CDMA signal is passes through a non linear amplifier. It is also added to the above contribution by proposing the use of PTS scheme [3], [30] and selecting mapping [31] to reduce the PAPR in MC-CDMA.

An effective scheme is proposed by Ye (Geoffery) Li, Jack H. Winters and Nelson R. Sollenberger for MIMO-OFDM [4]. It uses two independent space time codes for two set of two transmit antennas and at the receiver end, the independent space time codes are decoded resulting the number of receiving antennas increases than the overall system performance are improved. A new approach with algorithms for multicarrier communication of PAPR scheme is introduced by Y.J. Kou, W.S. Lu and A. Antoniou [5]. In the work of Y.J. Kou the two new PAPR reduction algorithms for pass-band multicarrier system have been proposed by applying optimal constellation modification in active subcarriers and it is found that in many practical conditions the performance improvement can be achieved by the proposed algorithms. Further, on the same path a comparative analysis of various frequency equalization methods for downlink of a wireless OFDM-CDMA is done by Tomoki Ki SAO [6] and by S. Hara, M. Mouri, M. Okada and N. Morinaga under the title "Transmission performance analysis of multicarrier modulation in frequency selective fast fest Ray leigh fading channel" [32] .

Also a unique scheme is introduced by Seung Hee Han and Jae Hong Lee in which the phase sequence issued for lower the PAPR of data block are considered and show that the PAPR reduction from SLM is achieved with as error performance improvement from the channel coding with no loss in data rate from the transmission of information [7] and [39]. In addition of that the approximate expression for CCDF of the PAPR for the modified SLM technique is also derived. An adaptive sub carrier allocation and an adaptive modulation for multiuser OFDM are considered by Inhyong Kim, In-Soon Park and Yong H. Lee and show that the linear programming based suboptimal and heuristic algorithms are much simpler than the optimal integral programming and the system performance is very close to those of the optimal one for a single carrier FDMA [8]. PAPR of SC-FDMA with pulse shaping is introduced and shows that SC-FDMA signals indeed have lower PAPR compared to those of OFDMA [9] and [13]. PAPR reduction using pilot tones and unused carrier are used and shows that it significantly reduces the high peaks but introduced very low out band distortion [10]. Also a comparative analysis of different- different PAPR reduction technique is done and the overall system performance is enhanced [12]. Efficient hardware implementations can be realized using Fast Fourier Transform (FFT) techniques for small numbers of carriers. So, OFDM has emerged as the standard of choice in a number of important high data applications in past few days [17].

Xin-Chun Wu proposed PTS technique for reduction of PAPR by using IFFT processor resulting the operation time of IFFT is decreased by 75% compared to the grouping approach [13], [16] and [20]. For the improved system performance unitary peak power reduction with multiple transmit antennas are introduced by Heechoon Lee [14]. In the literature of V. K. Dwivedi, S.Tripathi, V. S. Tripathi, R. Tripathi and S. Tiwari a work on shared power allocation among subcarriers of OFDM system was done, it is based on use of variable amplitude of subcarriers resulting power can be increased to the users who has crossing the reference boundary and moving farther towards footprint of a cell [15]. Use of tree based interleaver in RS Turbo code for PAPR is proposed by V. K. Dwivedi, S.Tripathi, V. S. Tripathi, R. Tripathi and S. Tiwari and shows that RS Turbo coding scheme is an attractive solution of PAPR with large frame size and high coding rate [18]. Another adaptive subcarrier allocation schemes for wireless OFDM system in Wi-max are considered by Alessandro Biagioni [16].

Dae-woon Lim, Seok-Joong Heo and Jong –Seon No gives the overview of PAPR reduction schemes for OFDM signals and review the conventional PAPR reduction schemes and their modification for achieving the low computational complexity required for practical implementation [20], [17], [18], [19] and [25]. Development of an efficient OFDM system has been the center of attention of many research efforts [36], [37], and [38]. Several strategies have been reported in the current literature. Initially, OFDM systems with oscillator bank were introduced [36].

The growth of the number of mobile subscribers over the last years led to a saturation of voice-oriented wireless telephony. From a number of 214 million subscribers in 1997 to 1.162 millions in 2002 [51] and in 2010 this will be 1700 million subscribers worldwide [52].

III. ORTHOGONAL FDM SYSTEM

The OFDM signal is a sum of subcarriers and they are modulated individually by using appropriate modulation scheme and then they are simultaneously transmitted as data

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stream. In OFDM modulator the inverse fast Fourier transform (IFFT) is performed. Because of the orthogonality relationship of the subcarriers the demodulator can be represented digitally, the inverse fast Fourier transform (IFFT) to the fast Fourier transform (FFT), modulation to demodulation of the OFDM signal. Orthogonal Frequency Division Multiplexing (OFDM) is a multicarrier transmission technique, which divides the available spectrum into many carriers, each one being modulated by a low rate data stream. OFDM is similar to FDMA in that the multiple user access is achieved by subdividing the available bandwidth into multiple channels, which are then allocated to users. However, OFDM uses the spectrum much more efficiently by spacing the channels much closer together. This is achieved by making all the carriers orthogonal to one another, preventing interference between the closely spaced carriers [39] and [40]. The block diagram of OFDM modulator and demodulator are shown in Fig. 1 and Fig. 2, respectively:

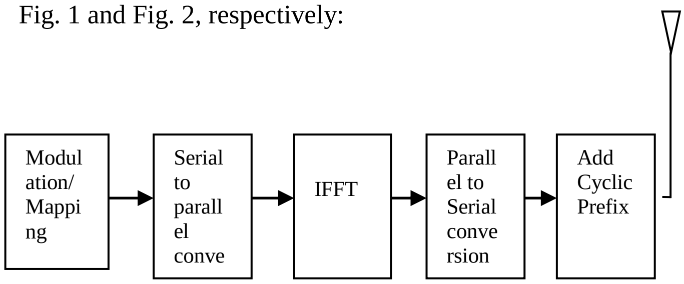

Fig. 1 Block diagram of OFDM Modulator

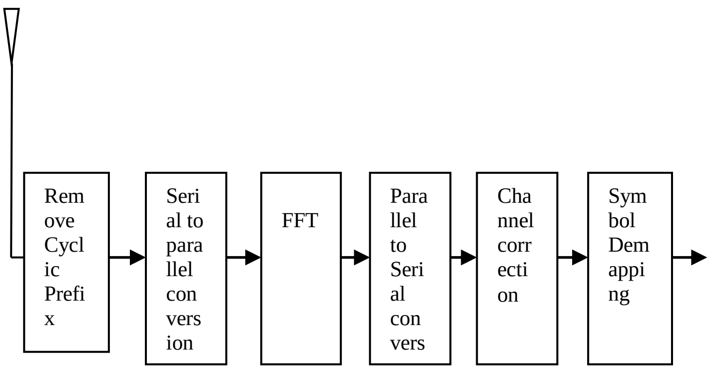

Fig. 2 Block diagram of OFDM Demodulator

The required equation of IFFT also called orthogonal frequency division multiplexed signal are given as [39]:

$$x\,(L) = \sum_k X_k \, e^{j2\pi(\frac{kL}{N})} \qquad (3)$$

The above equation shows the principle of orthogonal frequency division multiplexing. It was also noted that the transmit signal is the band limited signal. IFFT at transmitter and FFT at receiver is the key step of Orthogonal FDM. Also in multicarrier modulation system separate modulations are required. On other words, in Orthogonal FDM we are dividing the broadband bandwidth among the subcarriers with each band having bandwidth B/N [17, 39].

IV. PAPR FOR ORTHOGONAL FDM SYSTEM

In the orthogonal frequency division multiplexing (OFDM) the peak power might be much larger than the average power, due to adding up subcarriers coherently which resulting in large peak-to-average power ratio (PAPR). PAPR is a very important situation in the communication system because it has big effects on the transmitted signal. Low PAPR makes the transmit power amplifier works efficiently, on the other hand, the high PAPR makes the signal peaks move into the non-linear region of the RF power amplifier which reduces the efficiency of the RF power amplifier.

From the definition of PAPR-

PAPR= Peak power/Average Power

Or PAPR= a2/(a2/N)

Or PAPR= N (4)

It is clear from above equation that, for a multicarrier system the PAPR is equal to the N. It means in multicarrier environment PAPR is equals to the number of subcarrier and can be significantly high. The high PAPR in an OFDM system is essentially arises because of the IFFT operation at transmitter. Data symbols across subcarrier can add up to produce a high peak value signal [40] and [49]. By superimposing the continuous time baseband OFDM signal with the radio frequency signal (also called carrier signal) introduces continuous time pass band OFDM signal. It does not change the peak power but the average power of the pass band OFDM signal is half the average power of the continuous time baseband OFDM signal [39]. Thus, the PAPR of the continuous time pass band signal is generally larger than that of the continuous time baseband OFDM signal by three dB [17]. The relationship between PAPR of discrete time baseband OFDM signal [$PAPR(a_n)$], PAPR of continuous time baseband OFDM signal [$PAPR(a_n)$] and PAPR of continuous time pass band OFDM signal [$PAPR\,(g_t)$] are given as [11] and [39]:

$$PAPR(a_n) \leq PAPR(a_n) < PAPR\,(g_t) \qquad (5)$$

So, as per the introduction of PAPR it is concluded that reduction of PAPR is very important for Orthogonal FDM system.

V. PROPOSED SELECTIVE MAPPING TECHNIQUE

Selective mapping is a promising PAPR reduction technique of OFDM system. The main idea of SLM technique is to generate a number of OFDM symbols as candidates and then select the one with the lowest PAPR for actual transmission. Selected Mapping technique is the most promising reduction technique to reduce Peak to Average

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Power Ratio of Orthogonal Frequency Division Multiplexing system. The first Selective mapping scheme was introduced by Bauml, Fischer and Huber in 1996 [24].The basic idea of this technique is based on the phase rotation. The lowest PAPR signal will be selected for transmission from a number of different data blocks (independent phase sequences) that have the same information at the transmitter.

For the same consider that the entire data stream is divided into different blocks of M. Each block is multiplied with P different phase factors to generate the modified blocks before giving to IFFT block. Each modified block is given to different IFFT block to generate OFDM symbols. Then PAPR is calculated for each modified block and select the block having minimum PAPR and transmitted. This technique can reduce PAPR considerably. But this technique will increase circuit complexity since it contains several IFFT calculations [45]. Selective mapping method effectively reduces PAPR without any signal distortion. But it has higher system complexity and computational burden. This complexity can less by reducing the number of IFFT block [46, 47, and 48]. For faithful transmission and reception it is very important to know the sequence of minimum peak to average power ratio among different IFFT blocks. Hence, the receiver is required to learn information by selected phase sequence and ensure that the sequence of phase vector is received faithfully and also correctly. It may be realized by sending the block number or passage number of vector sequences but it is possible only when the receiving end is able to know and restore the random phase sequences by means of some methods. Since, the side information having an important role to restore the signal at the receiver end. Channel coding technique is also used for the same purpose. If channel coding technique is used for data transmission then all possible passages are detected at the receiver end. The selecting mapping technique reduces the PAPR but it has a slight increase in redundancy and completely avoids signal distortion [4], [34]. In the technique of selective mapping [17], M alternative input symbol vectors $A^m = [A_0^m\ A_1^m \ldots A_{N-1}^m]T$, where $1 \leq m < M$, are generated by component wise vector multiplication of the input symbol vector A and M phase sequences as $P^m = [P_0^m\ P_1^m \ldots P_{N-1}^m]T$ as shown in block diagram of selective mapping technique Fig. 3.

Here, Am = $A \otimes P^m$ used to represent the component wise multiplication, i.e.

$$A_k^m = A_k P_k^m, \quad 0 \leq k \leq N-1 \quad (6)$$

The phase sequence Pm is generated by using the unit magnitude complex number and it is given as:

$$P_k^m = e^{j\phi_k^m}; \quad \text{where, } \phi_k^m = [0,2\pi] \quad (7)$$

In general, binary or quaternary elements are used for p_k^m, that is, {±1} or {±1,±j}. IFFT is performed for each of alternative input symbol vectors to generate M alternative OFDM signal vectors as:

$$a^m = QA^m = Q(A \otimes P^m), 1 \leq m \leq M \quad (8)$$

where Q = IFFT matrix

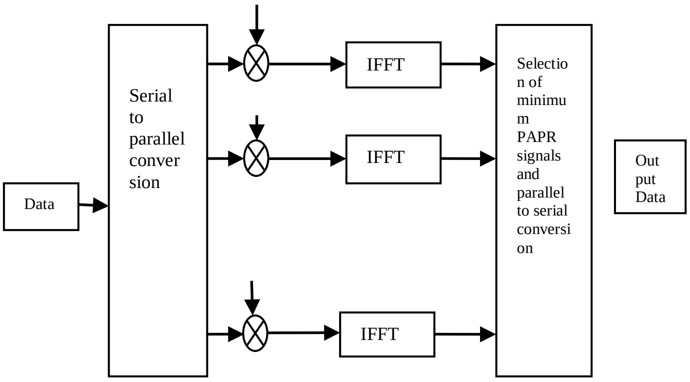

Fig. 3 Block diagram of selective mapping technique

Then, the OFDM signal vector aḿ with the minimum PAPR among M alternative OFDM signal vectors am is selected and transmitted, where the term ḿ of the transmitted vector is obtained by the expression given as:

$$\acute{m} = \underset{1 \leq m \leq M}{\text{argmin}} \left(\underset{0 \leq n \leq n-1}{\max} |a_{m,n}| \right) \quad (9)$$

It is also clear that as M increases, PAPR reduction becomes large while the computational complexity becomes too high, mainly due to M times IFFT at transmitter. The probability of PAPR larger than a threshold z can be written with the help of equation as:

Pr (PAPRlow > z) = {Pr (PAPR > z)}M
= {1- F (z) N}M = {1- (1- e^{-z}) N}M (10)

Consider that, M OFDM symbols carry the same information and they are statistically independent of each other. In this case, the probability of PAPR greater than z and it is equal to the product of each independent OFDM symbol probability.

At the receiver end to demodulate the received signal, it is necessary to know which sequence is linked to the smallest PAPR among M different symbols after performing the dot product. Hence, the receiver is required to learn information about selected phase vector or passage and ensure that the particular passage is received correctly. The key feature of this method is that, how to generate multiple OFDM signals when the information is the same.

VI. RESULT AND DISCUSSION

This paper analyzes the principle of OFDM. For the same selective mapping technique has been used in MATLAB environment. The performance of the system has been evaluated in terms of CCDF of PAPR. Based on the principles of Selective mapping algorithm, it is apparently that the ability of PAPR reduction using Selective mapping (SLM) technique is affected by the number of OFDM symbol M and the number of sub-carrier N. It is also noted that due to the saturation effect PAPR reduction gain decreases as M increases. The main consideration of this paper is to investigate the principle of Selective mapping algorithm and point out the related factors. The Performance evaluation of PAPR reduction are given as:

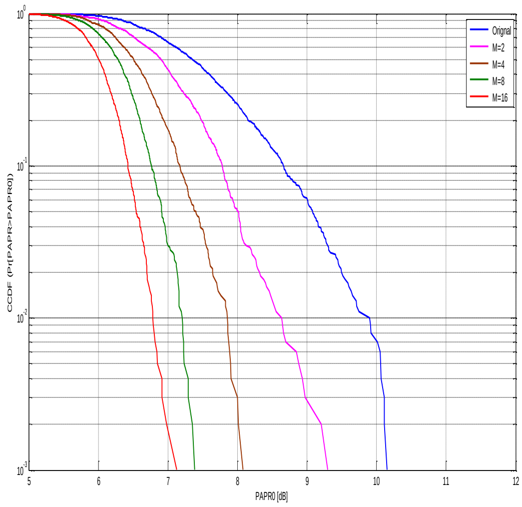

Fig.4 Performance of PAPR when No. of subcarriers is 64.

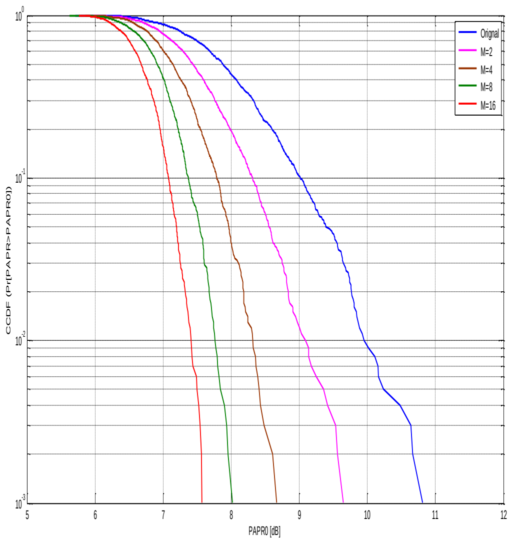

Fig. 5 Performance of PAP.R when No. of subcarriers is 128.

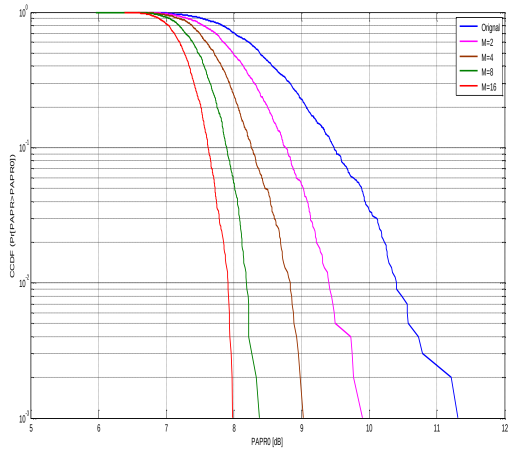

Fig. 6 Performance of PAPR when No. of subcarriers is 256

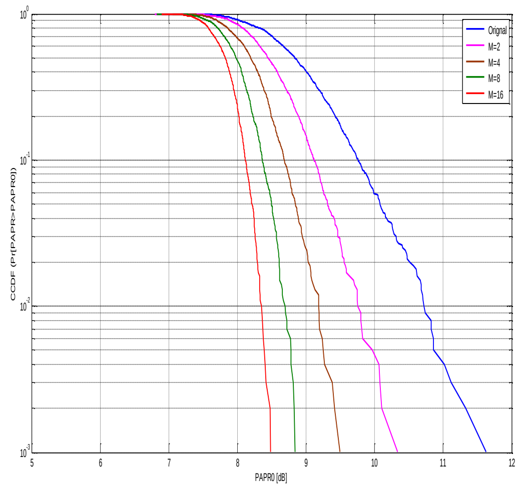

Fig. 7 Performance of PAPR when No. of subcarriers is 512.

VII. CONCLUSIONS

In this paper, an attempt has been make for reduction of PAPR using selective mapping technique. It can significantly improve the performance of Orthogonal FDM system by reducing the PAPR but complexity of its implementation in practical environment. IFFT and FFT at transmitter and receiver, respectively, is the key step for Orthogonal FDM system. And finally it was concluded that the PAPR problem of Orthogonal FDM system was not removed completely but with some compromise and assumptions the overall system performance was enhanced.

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