Abstract—OFDM is one of the multicarrier modulation techniques used in various communication systems. The major problem one faces while implementing this system is the high peak to average power. For an efficient OFDM system this PAPR should be low.

In this paper a hybrid PAPR (peak to average power ratio) reduction technique for the OFDM (orthogonal frequency division multiplexing) signal which combines a multiple symbol representations method with a signal clipping method is proposed. In multiple symbol representations alternative signaling points are used to represent one symbol and PAPR is further reduced with the clipping scheme. The performance of the hybrid scheme is compared with the partial transmit sequence which is one of the other PAPR reduction scheme. In partial transmit sequence the input data is divided into disjoint blocks transformed in to time domain sequence and rotated by phase factors.

Theoretical analysis and simulation results validate that the proposed scheme has the ability to provide large PAPR reduction, low bit error rate. Performance analysis is also done with the partial transmit sequence scheme.

Keywords: OFDM, PAPR, Multiple symbol representation, Partial transmit sequence, BER

I. INTRODUCTION

With the ever growing demand of this generation, need for high speed communication has become an utmost priority. Various multicarrier modulation techniques have evolved in order to meet these demands, few notable among them being Code Division Multiple Access (CDMA) and Orthogonal Frequency Division Multiplexing (OFDM). Orthogonal Frequency Division Multiplexing is a frequency division multiplexing (FDM) scheme utilized as a digital multi – carrier modulation method. A large number of closely spaced orthogonal sub – carriers is used to carry data. The data is divided into several parallel streams of channels, one for each sub – carriers. Each sub – carrier is modulated with a conventional modulation scheme (such as QPSK) at a low symbol rate, maintaining total data rates similar to the conventional single carrier modulation schemes in the same bandwidth.

OFDM is one of the many multicarrier modulation techniques, which provides high spectral efficiency, low implementation complexity, less vulnerability to echoes and non–linear distortion. Due to these advantages of the OFDM system, it is vastly used in various communication systems. But the major problem one faces while implementing this system is the high peak – to – average power ratio of this system. A large PAPR increases the complexity of the analog – to – digital and digital – to – analog converter and reduces the efficiency of the radio – frequency (RF) power amplifier. Regulatory and application constraints can be implemented to reduce the peak transmitted power which in turn reduces the range of multi carrier transmission. This leads to the prevention of spectral growth and the transmitter power amplifier is no longer confined to linear region in which it should operate. This has a harmful effect on the battery lifetime. Thus in communication system, it is observed that all the potential benefits of multi carrier transmission can be out - weighed by a high PAPR value.

The OFDM system has the big problem of high PAPR ratio which will affect the proper working of the system. Different PAPR reduction techniques are used as a solution. The clipping method is a nonlinear techniques which is applied to the OFDM signal, where the amplitude of the signal is limited to a given threshold. Considering the fact that the signal must be interpolated before A/D conversion, a variety of clipping methods has been proposed.

Some methods suggest the clipping before interpolation, having the disadvantage of the peaks regrowth. Other methods suggest the clipping after interpolation, having the disadvantage of out-of-band power production. In order to overcome this problem different filtering techniques have been proposed. Filtering can also cause peak regrowth, but less than the clipping before interpolation [1].

Another clipping technique supposes that only subcarriers having the highest phase difference between the original signal and its clipped variant will be changed. This is the case of the partial clipping (PC) method [14].

To further reduce the PAPR, the dynamic of the clipped signal can be compressed. Some papers proposed µ-law/Alaw compounding functions exponential compounding function or piecewise-scales after the clipping.

Linear methods like partial transmit sequence (PTS) or selective mapping (SLM) has been proposed for the reduction of PAPR as well. These methods generate different versions of the OFDM signal, by rotating each vector from the original signal with phases selected from a given set. Then the signal variant with the smaller PAPR is chosen for the transmission.[15],[16]

Another PAPR reduction method is the tone reservation (TR). It uses tones on which no data is sent to reduce the transmitted signal peaks. Derivates of this method with lower computation complexity and improved performance have been proposed: One-Tone One-Peak (OTOP) and one by-one iteration.

A similar PAPR reduction method is the multiple symbol representations, where alternative signaling points are used to represent one symbol. The variant proposed [5] in uses an expanded constellation comprised of the original conventional constellation and the alternative signaling points located on a circle located in the origin. The increased radius is chosen to maintain the minimum distance of the
Original constellation.
In this paper PAPR reduction technique known as multiple symbol representation is used. A clipping and filtering technique is also used. A further reduction in PAPR is possible by this clipping method.

This paper is organized as follows: Section II includes the OFDM. Section III describes the combined MSR-clipping scheme. Section IV presents the numerical results and performance. The paper is concluded in Section V.

II. THE OFDM SIGNAL

In OFDM, the message bits are grouped in blocks \( \{ X_n, n=0,1,\ldots,N-1 \} \), and modulates in amplitude a set of N subcarriers, \( \{ f_n, n=0,1,\ldots,N-1 \} \). These subcarriers are chosen to be orthogonal, that is \( f_n=n\Delta f \), where \( \Delta f=1/T \), and T is the OFDM symbol period. The resulting signal can be written as:

\[
X(t) = \sqrt{\frac{1}{N}} \sum_{n=0}^{N-1} X_n e^{j2\pi f_n t}
\]

In order to avoid the inter symbol interference (ISI) generated by the multipath channels, a Cyclic Prefix (CP-corresponding to a guard interval) is added to the signal. After Digital-to- Analogue (D/A) conversion, the signal’s spectrum is centered on a high frequency carrier and applied to a PA which drives the antenna load.

At the receiver, after demodulation, the CP will be removed, the symbols being evaluated for a time interval of \([0,T]\).

The expression of the PAPR for a given OFDM symbol is given by

\[
PAPR(x) = \max_{E[\cdot]} \frac{\mathbb{E}[|x(t)|^2]}{\mathbb{E}[|x|^2]} \]

Where \( E[\cdot] \) denotes the expectation operator. Another quality measure refers to the non-linearity of the transmitted signal which is produced by the PA. This is the Signal-to-Distortion Ratio (SDR) defined as:

\[
SDR = \frac{|x|^2}{|x-g(x)|^2}
\]

Where \( g(.) \) is the memory less nonlinearity representing the effects of the PA.

The optimal solution for PAPR problem may not be the best solution for the SDR problem and vice versa. Because these two problems are correlated, in practice a suboptimal solution may be chosen.

III. MULTIPLE SYMBOL REPRESENTATION-CLIPPING SCHEME

In this paragraph the proposed PAPR reduction technique which has been obtained by combining alternative symbol represent and the signal clipping method is presented [11]. The performance of the proposed PAPR reduction technique is analyzed with a MATLAB simulator as presented in Fig.1.

Within this simulator, the samples from the generated signal are grouped in blocks of same size like the OFDM symbols. Each sample, group of M bits, is transformed using the MQAM or the M-PSK modulation, obtaining the frequency domain OFDM symbols. They are applied to the multiple symbol representations block, where the amplitude and phase of some of the data carriers are modified for the first peak reduction.

The used multiple symbol representations technique is derivated from [5], and is presented in the block diagram from Fig.2.

Fig. 1: MATLAB model of the hybrid PAPR reduction technique

It selects Q carrier positions from the complete set of N carriers representing the OFDM symbol. For these carriers, an extended constellation with R possible points for each symbol is considered. The obtained search space of \( R^Q \) combinations is used by the algorithm to generate alternative OFDM symbols, the one with minimum PAPR being chosen for the transmission.

Fig. 2: Multiple Symbol representations PAPR reduction method

This search space may lead to an increased amount of data computation. The multiple symbol representations algorithm decreases the computation complexity by attempting a reduced search space by trying all R alternatives on the first carrier position \( P[0] \), while the other carriers, \( P[1],\ldots,P[Q-1] \), have the initial state. Once an optimal value \( C[0] \) is found, a similar procedure is repeated on the other pilot positions.

The multiple symbol representations algorithm considers both symmetrical and asymmetrical repartition of data carriers selectable for PAPR reduction. The alternative symbol’s points from the expanded constellation are placed on different concentric circles with the radius delta equal with the minimum distance of original constellation as presented in Fig 3.

To further reduce the PAPR a clipping technique [1] is applied next.

It is presented in the block diagram from Fig 4 as well. Here the input vector \([a0… aN-1] \) is first converted from
frequency to time domain using an oversize IFFT. For the oversampling factor $p$, the input vector is padded with $N(p-1)$ zeros placed in the middle of the vector. This results in a trigonometric interpolation of the time domain signal, which fits well for the signals with integral frequencies over the original FFT window, like is the case of OFDM. The interpolated signal is then clipped by limiting its amplitude. The clipping ratio is defined as the clipping level $A$ divided by the root-mean-square power $\sigma$ of the unclipped baseband signal.

$$CR = 20 \log_{10} \left( \frac{A}{\sigma} \right) \quad (4)$$

In order to evaluate the performance of the proposed PAPR reduction scheme, the MATLAB simulator evaluates the complementary cumulative distribution function (CCDF) of the PAPR of the given OFDM signal. This is expressed as:

$$CCDF(Y) = Pr(PAPR > Y) = 1 - Pr(PAPR < Y) \quad (5)$$

Where $Y$ is a PAPR threshold
The expression for CCDF of PAPR higher than the threshold $r_0$ of OFDM with $N$ subcarriers

$$CCDF(r_0) \approx 1 - (1 - e^{-r_0})^N \quad (6)$$

A. Partial transmit sequence

A partial transmit sequence scheme for PAPR reduction is also used in this paper for the performance comparison with the multiple symbol representation and clipping method. The figure 5 shows the conventional PTS method.

The data is divided into clusters, transformed to time domain and finally find out the signal with minimum PAPR.

The MATLAB simulations have been performed for baseband OFDM symbols with different length and configurations, using M-QAM. This is a system consisting of 100 symbols and 64 sub carriers.4 QAM modulation is used.

$$(\text{Fig. 6: comparison of PAPR in MSR-clipping and PTS method})$$

$$(\text{Fig. 7: comparison of BER in MSR-clipping and PTS method})$$
OFDM applying Partial transmit sequence method have 64 element OFDM symbols. Here PAPR of the original is calculated and compared. The signal with low PAPR is taken.

From fig 6 it is noted that the PAPR value is low in the case of MSR –clipping scheme. So the proposed method has high PAPR reduction. While considering BER, PTS have almost high BER. There will be sufficient reduction in BER in the case of hybrid method. The reduction of PAPR in MSR-clipping scheme with respect to PTS is 71.26% the reduction in BER of Hybrid scheme with respect to PTS is 65.51%, so MSR-clipping scheme have low PAPR and low BER with respect to PTS method.

V. CONCLUSION

OFDM is a very attractive technique for multicarrier transmission and has become one of the standard choices for high – speed data transmission over a communication channel. It has various advantages; but also has one major drawback: it has a very high PAPR. In this paper the different properties of an OFDM System are analyzed and the advantages and disadvantages of this system are understood. The PAPR reduction and the reduction in bit error rate is mainly considered.

The combined multiple symbol representation and clipping method have high PAPR reduction and low bit error rate compared with the partial transmit scheme.

REFERENCES