Modified SLM Technique for PAPR Reduction in OFDM System

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***Abstract*---**Orthogonal Frequency Division Multiplexing (OFDM) systems have gained popularity over the last few years for broadband wireless communication. OFDM is a method that allows transmitting high data rates over extremely hostile channel set a relatively low complexity. However, OFDM faces the Peak-to-Average Power Ratio(PAPR) problem that is a major drawback of multicarrier transmission system which leads to power inefficiency in RF section of the transmitter .PAPR (Peak to average power ratio) nothing but several sinusoidal leads. In this paper we propose SLM(selective mapping) schemes to reduce the peak-to-average power ratio. SLM is phase rotation scheme it applies scrambling rotation to all sub-carriers independently.

Keywords:- OFDM(Orthogonal Frequency Division Multiplexing), PAPR(Peak to average power ratio), SLM(selective mapping), complementary cumulative distribution function (CCDF).

I. INTRODUCTION

OFDM is multicarrier modulation techniques, which have high spectral efficiency, less implementation complexity, less vulnerability to echoes and non– linear distortion. Due to these advantages, OFDM system is vastly used in various communication systems such as Digital Video Broadcasting (DVB) and Wi-MAX. However OFDM system suffers from serious problem of high PAPR. In OFDM system output is superposition of multiple sub-carriers. In this case some instantaneous power output might increase greatly and become far higher than the mean power of system. To transmit signals with such high PAPR, it requires power amplifiers with very high power scope. These kinds of amplifiers are very expensive and have low efficiency-cost. If the peak power is too high, it could be out of the scope of the linear power amplifier. This gives rise to non-linear distortion which changes the superposition of the signal spectrum resulting in performance degradation. If no measure is taken to reduce the high PAPR, MIMO-OFDM system could face serious restriction for practical applications .

PAPR can be described by its complementary cumulative distribution function (CCDF). In this probabilistic approach certain schemes have been proposed by researchers. These include signal distortion and signal scrambling techniques. clipping, clipping and filtering are signal distortion techniques and Partial transmit sequence (PTS) ,Selected Mapping (SLM) are signal scrambling techniques. A large PAPR increase the complexity of the ADC(analog – to – digital converter) and DAC(digital – to – analog converter) and distorts the signal if the transmitter contains nonlinear components such as radio – frequency (RF) power amplifiers (PAs). it also has a harmful effect on the battery lifetime. Therefore, reducing the PAPR is of practical interest. These techniques achieve PAPR reduction hence transmit signal power increase but along with bit error rate (BER) increase, data rate loss, computational complexity increases, and so on.

II. SIGNAL CHARACTERISTICS OF OFDM

An OFDM symbol is made of sub-carriers modulated by constellations mapping. This mapping can be done by phase-shift keying (PSK) or quadrature amplitude modulation (QAM). For an OFDM system with N sub-carriers, the highspeed binary serial input stream is denoted as { a_i}. After serial to parallel (S/P) conversion and constellation mapping, a new parallel signal sequence {d_0,d_1,d_2,….di,…d_{N-1}} is obtained, di is a discrete complex-valued signal . Here, di ∈{±1} when BPSK mapping is adopted. When QPSK mapping is used, di ∈{±1, ±i}.Each element of parallel signal sequence is supplied to N orthogonal sub-carriers { $e^{j2\pi f0t}$, $e^{j2\pi f1t}$,…………… $e^{j2\pi f(N-1)t}$ }for modulation . Finally, modulated signals are added together to form an OFDM symbol. Use of discrete Fourier transform simplifies the OFDM system structure. The complex envelope of the transmitted OFDM signals can be written as

$$x(t) = \frac{1}{\sqrt{N}}\sum_{k=0}^{N-1} X_k e^{j2\pi f_k t} \text{ , } 0\leq t \leq NT$$

Signals with large N become Gaussian distributed with Probability Density Function (PDF) is given by

$$P_r\{x(t)\} = \frac{1}{\sqrt{2\pi\sigma}} e^{-\frac{[x(t)]^2}{2\sigma^2}}$$

where σ is the variance of x(t).

III. PAPR (PEAK TO AVERAGE POWER RATIO)

An OFDM signal consist of independently modulated subcarriers which can give large peak to average ratio.
Problems from high PAPR are

– It increased complexity of the system.
– It reduced efficiency of the power amplifiers.
– High power consumption.

In OFDM, the input bit stream is converted into N parallel streams, which are encoded and modulated, gives the OFDM symbols. These symbol consists of N modulated tones, which can be represented by a vector “X” with elements X_k (1 ≤ k <N). A sampled version of the time domain waveform is generated via an IFFT. This time domain symbol is denoted by “x” with elements x_n(1 ≤ n<N).

$$x = IFFT(X)$$

The IFFT operation can be regarded as a linear combination of N modulated tones to produce another N tones which are nothing but OFDM symbols that are to be transmitted. Hence according to central limit theorem, when N tends to infinity the distribution of linear combination of N inputs tend to be of Gaussian nature. Hence the samples of the discrete time signal obtained after OFDM operation can exhibit large peaks, which are caused by the addition of the many independently modulated tones as shown in Fig. below.

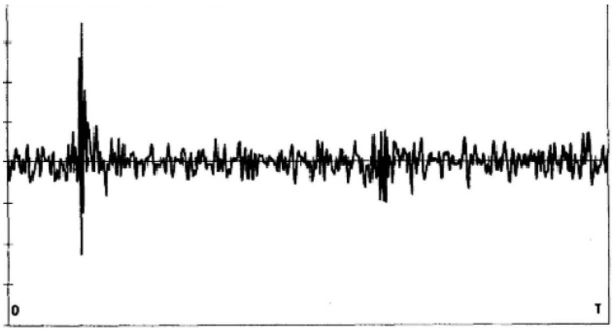

Fig. 1: Amplitude of one OFDM symbol for N = 256

The Peak-to-Average power Ratio (PAPR), defined by above figure is high.

$PAPR=(X_n^2) / E[X_n^2] \quad for \quad 1 \leq n < N$

In this equation E [.] denotes taking the expected value .E[xn]^2 is equal to the variance ó^2, since the symbols are zero mean.

A. Need Of PAPR Reduction: During the generation of OFDM signal The processing is start from serial to parallel converter, modulation and IFFT blocks, the OFDM system involves digital to analog converters and high power amplifiers as the last stage of transmitter side in order to convert the discrete OFDM symbols into analog domain and amplify their magnitude before transmission. The high PAPR of OFDM symbols after IFFT causes problems at these stages.

Most radio systems employ the HPA in the transmitter to obtain sufficient transmission power. For the purpose of achieving the maximum output power efficiency, the HPA is usually operated near the saturation region. The nonlinear characteristic of the HPA is very sensitive to the variation in signal amplitudes. However, the variation of OFDM signal amplitudes is very wide with high PAPR. Therefore, HPA will introduce inter-modulation between the different subcarriers and introduce additional interference into the systems due to high PAPR of OFDM signals. This additional interference leads to an increase in BER. In order to reduce the signal distortion and maintain low BER, it requires a linear work in its linear amplifier region. However, this linear amplifier has poor efficiency as well as expensive too. Power efficiency is very necessary in wireless communication as it provides required area coverage, saves power consumption and allows small size terminals etc.

It is therefore important to aim at a power efficient operation of the non-linear HPA with low back-off values and try to provide possible solutions to the interference problem brought about. Hence, a better solution is to try to prevent the occurrence of such interference by reducing the PAPR of the transmitted signal with some manipulations of the OFDM signal itself.

1) Power Efficiency

When a HPA have a high dynamic range, it exhibits poor power efficiency. As PAPR reduction can significantly save the power, in which the net power saving is directly proportional to the average output power and it is highly dependent upon the clipping probability level.

2) Digital To Analog Converters (Dacs):

Large PAPR also demands the DAC with enough dynamic range to accommodate the large peaks of the OFDM signals. A high precision DAC supports high PAPR with a reasonable amount of quantization noise, but it is very expensive for a given sampling rate of the system. However, a low-precision DAC can be cheaper, but its quantization noise will be significant, and as a result it reduces the signal Signal-to-Noise Ratio (SNR) when the dynamic range of DAC is increased to support high PAPR. Furthermore, OFDM signals show Gaussian distribution for large number of subcarriers, which means the peak signal quite rarely occur and uniform quantization by the Analog to Digital converter is not desirable. If peak signal got clipped, it will introduce in band distortion and out-of-band radiation (adjacent channel interference) into the communication systems. Therefore, the best solution is to reduce the PAPR before OFDM signals are transmitted into nonlinear HPA and DAC.

B. The Selective Mapping Technique: The SLM technique was first described by Bauml. Selective mapping scheme is a technique in which multiple phase rotations are applied to the constellation points, and the one that minimizes the time signal peak is used. Selective mapping involves generating a large set of data vectors all representing the same information. The data vector with the lowest resulting PAPR is selected. Information about the selected and transmitted data vectors is coded and these codes are by an additional sub carriers.

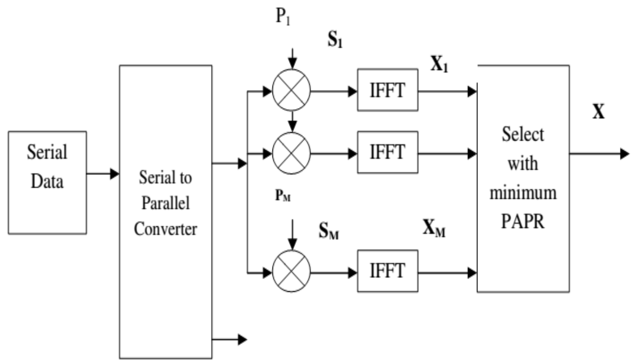

Fig. 2: Block Diagram of OFDM Transmitter with the Modified SLM Technique

In this technique the actual transmit signal lowest PAPR is selected from a set of sufficiently different signals which all represents the same information. SLM Technique is very flexible as they do not impose any restriction on modulation applied in the subcarriers or on their number

The CCDF of the original signal sequence PAPR above threshold PAPR0 is written as Pr{PAPR>PAPR$_0$}. Thus for K statistical independent signal waveforms, CCDF can be written as [Pr{PAPR>PAPR$_0$}]^R , so the probability of PAPR exceed the same threshold. The probability of PAPR larger than a threshold Z can be written as

$$P(PAPR < Z) = F(Z)^N = (1- \exp(-Z))^N$$

Assuming that M-OFDM symbols carry the same information and that they are statistically independent of each other. In this case, the probability of PAPR greater than Z is equals to the product of each independent probability. This process can be written as

$P(PAPR_{LOW} > Z) = (P(PAPR > Z))^M = ((1- \exp(-Z))^N)^M$

In selection mapping method, firstly M statistically independent sequences which represent the same information are generated, and next, the resulting M statistically independent data blocks $S_m = [S_{m,0} , S_{m,1}, S_{m,2}, \ldots\ldots\ldots S_{m,N-1}]^T$ for m=1,2,...,M are then forwarded into IFFT operation simultaneously. $X_m = [X_1 , X_2 , X_N]^T$ in discrete time-domain are acquired and then the PAPR of these M vectors are calculated separately. Eventually, the sequences xdwith the smallest PAPR is selected for final serial transmission. Figure 1 shows the basic block diagram of selection mapping technique for suppressing the high PAPR.

C. PAPR Reduction Using SLM Technique: In selective mapping method scrambling rotation to all sub-carriers are done independently. Table 1 shows the parameters of OFDM signal which is used for PAPR reduction. Here, the number of sub-carriers used are N=16,64, 128 and the pseudo-random partition scheme is applied for each carrier, adopting QPSK constellation mapping, weighting factor being bv ∈ [±1, ±j].

Table. 1: Parameter used for PAPR Reduction

PARAMETERS	VALUE USED
Number of sub-carriers (N)	16,64,128
Oversampling factor (OF)	2
Modulation scheme	QPSK
Route numbers used in SLM method (M)	2,4,16,64
Number of generated OFDM signal	1000

D. Simulation Resultss: Figure 3 shows the CCDF as a function of PAPR distribution when SLM method is used with 16 numbers of subcarrier. Figure 4 shows the same result for 64 numbers of subcarrier and Figure 5 shows the same result for 128 numbers of subcarrier. M takes the value of 1 (without adopting SLM method), 2, 4, 16 and 64. It is seen in Figure 3 , Figure 4and Fig 5 that with increase of branch number M, PAPR's CCDF gets smaller

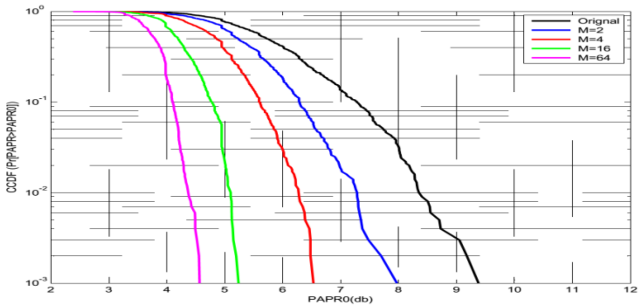

Fig. 3: PAPR's CCDF using SLM method with N=16.

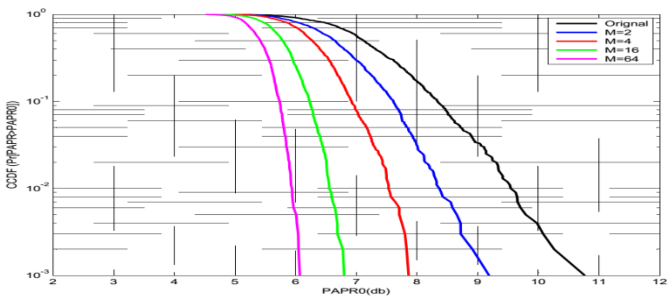

Fig. 4: PAPR's CCDF using SLM method with N=64.

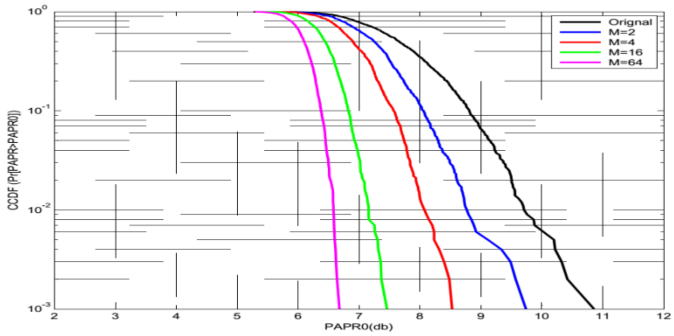

Fig. 5: PAPR's CCDF using SLM method with N=128.

IV. CONCLUSION

OFDM is a very useful and attractive technique for wireless communications due to its spectrum efficiency and channel robustness. One of the serious drawbacks of OFDM systems is high PAPR in this paper we discussed about selected mapping technique which is one of the signal scrambling technique to reduce PAPR. In this paper we modified SLM technique little bit and different route no. are used for simulation and as we can see in graph that when we are increasing the route no PAPR is reducing every time, but at the same time complexity is also increased. However when no of subcarrier is increased the PAPR is also increased. Going for lower value of N (number of carriers) for OFDM signal is good practice for having a lower value of PAPR

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