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Modified Selective Mapping Technique for PAPR Reduction in OFDM System

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Abstract-At present, only low rate data services are available for mobile applications. However, there is a demand for high data rates for multimedia applications. In single carrier system, the symbol duration reduces with an increase in data rate. Therefore multicarrier transmission is a way to increase the data rate. Multicarrier modulation, and especially OFDM, is one of the promising candidates that employ a set of subcarriers in order to transmit the information symbols in parallel over the communication channel. OFDM is the key technology of 4th Generation wireless communication. OFDM is an efficient method of data transmission for high speed communication systems. However, the main drawback of OFDM system is the high Peak to Average Power Ratio (PAPR) of the transmitted signals. OFDM consist of large number of independent subcarriers, as a result of which the amplitude of such a signal can have high peak values. There are different techniques which are used for reduction of PAPR. This paper uses a modified SLM technique which presents a new scheme for selected mapping sequences to reduce peak to average power ratio (PAPR). This paper concludes that modified SLM is better compare to SLM technique for PAPR reduction.

Index terms -Orthogonal frequency division multiplexing (OFDM), Peak to Average Power Ratio (PAPR), Complementary cumulative Distribution function (CCDF), Selected Mapping (SLM). Inverse Fast Fourier Transform (IFFT).

I. INTRODUCTION

OFDM is the basis for all fourth generation wireless mobile systems. It is a multicarrier transmission technology in which data is transmitting over several carriers and these carriers are called subcarriers. Data are modulated with different frequencies at different subcarriers. So it needs many modulators and demodulators. OFDM system uses IFFT and FFT instead of using Bank of modulators and bank of demodulators.

A complete block diagram of an OFDM transceiver is shown in the Fig. 1. As shown in Fig. 1 the serial information is converted into serial OFDM symbol by using a serial to parallel converter. After conversion IFFT is done to modulate the data and then cyclic prefix of suitable length is inserted to combat the effect of ISI.

Finally the discrete time OFDM signal is converted into analog OFDM signal and amplified up to the desired power level.

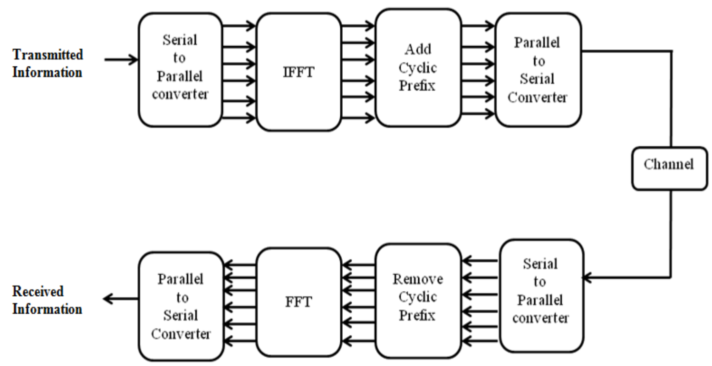

Figure 1. OFDM transceiver

The obtained signal is transmitted over communication channel. The signal received y (t) at the receiver has the effect of multipath propagation and AWGN (n (t)). The received signal at the receiver is first converted into analog by using the D/A converter and cyclic prefix is removed. The obtained signal is applied to a serial to parallel converter and then subcarrier demodulation is performed by using FFT operation. After that one tap frequency equalization can be utilized to cancel the effect of multipath fading channel and then passed through a parallel to serial converter to obtain serial data signal.

OFDM has many significant advantages such as high bandwidth efficiency, high-speed broadband transmission, robustness to multipath interference and frequency selective fading. The main disadvantage of OFDM is that FDM signal exhibits a very high peak to average power ratio (PAPR). PAPR is directly proportional to N. Hence PAPR in an OFDM system can be significantly higher. Further, the PAPR rises with N, where N is the number of subcarriers. PAPR in an OFDM system essentially arises because of the IFFT operations. PAPR are fluctuating since symbols are random.When N sinusoids add, the peak magnitude would have a value of N, where the average might be quite low due to the destructive interference between the sinusoids. Due to high PAPR some of the transmitted signals are much larger than the permissible limit. This out of band power of OFDM makes nonlinear response of any amplifier. In the nonlinear region additional noise is added. To prevent this out-of band radiation, the transmit amplifier must be operate in its linear region. There are many techniques to resist with the problem of PAPR to achieve the good result of PAPR reduction such as Clipping, Companding, Partial transmit sequence (PTS), Selected Mapping. This paper includes modified SLM technique for PAPR reduction

II. PEAK TO AVERAGE POWER RATIO

PAPR of the OFDM signal x(t) is defined as the ratio between the maximum instantaneous power and its average power during an OFDM symbol. The PAPR can be defined as,

$$PAPR = 10\log_{10}\frac{P_{peak}}{P_{av}} \quad (1)$$

Where P_{peak} and P_{av} are given by,

$$P_{peak} = max|x(t)|^2 \& \quad (2)$$

$$P_{av} = \frac{1}{T}\int_0^T |x(t)|^2 dt \quad (3)$$

Hence PAPR is expressed as,

$$PAPR = 10\log_{10}\frac{max|x(t)|^2}{\frac{1}{T}\int_0^T |x(t)|^2 dt} \quad (4)$$

When N sinusoids add, the peak magnitude would have a value of N, where the average might be quite low due to the destructive interference between the sinusoids. High PAPR signals are usually undesirable for it usually strains the analog circuitry. For *e.g.* power amplifier has High PAPR, signals would require a large range of dynamic linearity from the analog circuits which usually results in expensive devices and high power consumption with lower efficiency.

In OFDM system, some input sequences would be resulted in higher PAPR than others. Which mean, input sequence that requires all such carriers to transmit their maximum amplitudes would certainly result in a high output PAPR. Thus by limiting the possible input sequences to a smallest sub set, it should be possible to obtain output signals with a guaranteed low output PAPR.

High PAPR could cause problems when the signal is applied to transmitter which contains non-linear components such as High Power amplifier (HPA) in the Transmitter chain. The PAPR has the worst case value which depends on the number of subscribers N. The non-linear effects on the transmitted OFDM symbols are spectral spreading, inter-modulation and changing the signal constellation. In other words, the nonlinear distortion causes both in-band and out-of-band interference to signals.

III. PAPR REDUCTION TECHNIQUES

A. Selected Mapping (SLM)

SLM is a popular distortion-less PAPR reduction technique first described by Cimini etal. In this scheme, a set of U independent data sequences is generated by multiplicationof a block of N modulated data symbols$\{X_k\}_{k=0}^{N-1}$ with a phase sequence set containing U phase vectors of length N. The set of U independent signals can be mathematicallyexpressed as follows:

$$X_k^u = X_k . P_K^U, 1 \le u \le U \ \& \ 0 \le k \le N-1 \quad (5)$$

Here, each phase vector $\{P_k^u\}_{k=0}^{N-1}, 1 \le u \le U$ has a length N and its elements, i.e. phase factors,

$$P_k^u \in \left\{ \emptyset_l = \exp\left(\frac{j2\pi l}{W}\right) \quad 0 \le l \le W-1 \right\} \quad (6)$$

where W denotes the number of phase factors. The set of U independent discrete-time OFDM signals, $x^u, 1 \le u \le U$ can be obtained from a set of U data sequences as

$$x^u[n] = \frac{1}{\sqrt{N}}\sum_{k=0}^{N-1} X_k^u e^{\frac{j2\pi kn}{N}} \quad 0 \le n \le N-1 \quad (7)$$

Out of these U signals, one of them satisfying following criterion is selected for transmission

$$x^{\overset{0}{u}} = \underset{1 \le u \le U}{\arg\min} \ PAPR\,(x^u) \quad (8)$$

where $\overset{0}{u}, 1 \le \overset{0}{u} \le U$ is the index of phase vector in the phase sequence set that generates an OFDM signal with least PAPR. Therefore, the information about $\overset{0}{u}$should be transmitted along with each OFDM symbol, which requires $\log_2(U)$ bits, if straight binary coding is used to encode the SI. The SI bits are extremely important for data recovery at the receiver; therefore sometimes we sacrifice the data rate and allocate few redundant bits to ensure accurate recovery of$\overset{0}{u}$. But it further increases the loss in data rate of a SLM-OFDM system.

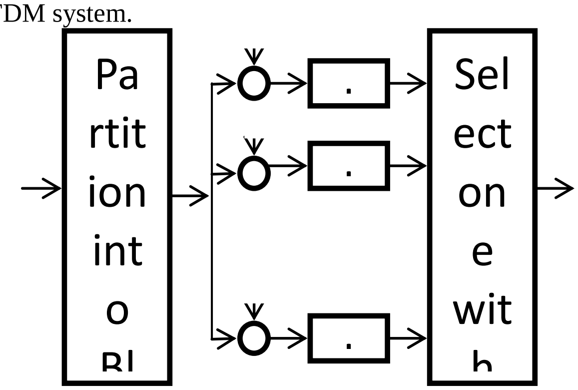

Figure 2. Block diagram of conventional SLM-OFDM transmitter

B. Proposed Selected Mapping (SLM)

In SLM, the information sequence is multiplied by M random sequences of length N. In our approach a set of phase sequences for SLM is proposed so that the resultant vector is close to the Newman phase sequence.

Newman Phase sequence is expressed as:

$$\emptyset_n = \frac{(n-1)^2.\pi}{N} \text{where} n=1,2,..........N \quad (9)$$

N is the length of the sequence. The PAPR of the above sequence is only 5.85 dB [8].

Here our idea is to make the transmit sequence have a phase distribution as close as possible to that of the Newman phase sequence. As a first step using a randomly generated set of data sequences M-I phase error sequences are calculated. Let the randomly generated data sequence be expressed as:

$$P_n(m) = A_n(m).e^{j\theta_n(m)} \text{ where m=1,1,........M-1} \quad (10)$$

Then the phase error sequence corresponding to this particular data sequence can be found by:

$$\emptyset_n(m) = \theta_n(m) - \emptyset_n \quad (11)$$

Similarly a set of phase error sequencesare found for randomly generated data vectors. This phase error vector is then used for the rest of the transmission to generate low PAP sequences. For the transmission each data vector is modified using these M phase error vectors as follows.

$$d_n = A_n.e^{j\theta_n} \quad (12)$$

$$\bar{\theta}_n(m) = \theta_n - \emptyset_n(m) \quad (13)$$

The modified data vector would be

$$d_n(m) = A_n.e^{j\bar{\theta}_n(m)} \quad (14)$$

Then a 4N IFFT is taken and PAPR is measured, above procedure is followed for all M-1 phase error vectors and the one with minimum PAPR is selected for transmission. Corresponding system block diagram is shown in figure 3.

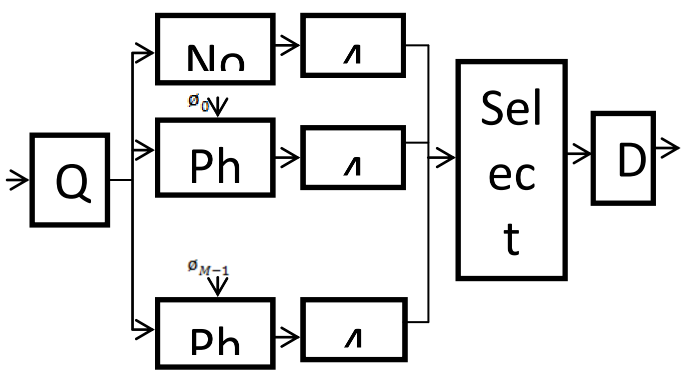

Figure 3: Selected mapping using Newman phase sequence

Side information is also transmitted about the phase error sequence. Oversampling of factor 4 is used to locate the true peak factor. Very high PARR reduction can be observed in this method with the increase of the number of phase sequences but with increasing complexity.

IV. Specification

- Number of bits per OFDM symbol = 52
- Number of symbols = 1600
- FFT size = 64
- Number of data subcarriers = 52

V. Result

The model of OFDM transmitter and receiver has been implemented in an m file. In order to compare the transmission performance in conventional OFDM output, OFDM output with PTS scheme and OFDM output with selected mapping, we evaluate the Peak to Average Power Ratio (PAPR) for all systems.
For comparison we obtained the results for following:

1. Conventional OFDM and SLM
2. Conventional OFDM and SLM with Newman 4 phase error sequences
3. Conventional OFDM and SLM with Newman 8 phase error sequences

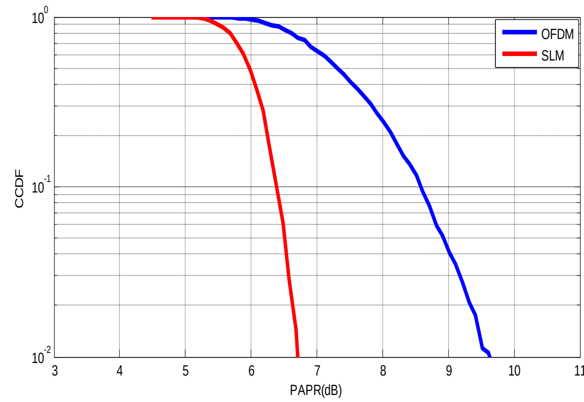

Figure 4: CCDF plot for Conventional OFDM and OFDM with selected mapping (SLM)

The performance of figure 4 shows that PAPR is reduces up to 6.7 dB at 10^{-2} CCDF when Selected Mapping technique is used.

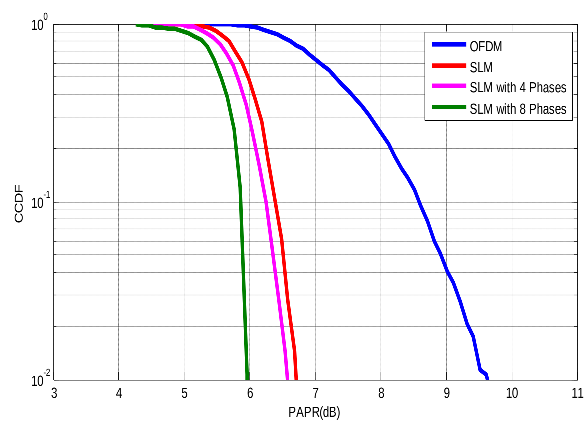

Figure 5: CCDF plot for Conventional OFDM, OFDM with selected mapping (SLM) and modified selected mapping SLM

The performance of SLM with Newman phase sequence is presented in figure 5. Performance is observed for different number of phase error sequences, respectively 4 and 8. These sequences reduce PAPR up to 6.6 dB at 10^{-2} CCDF and 5.95 dB at 10^{-2} CCDF respectively.

OFDM Technique Name	PAPR at 10^{-2} CCDF (in dB)	PAPR at 10^{-1} CCDF (in dB)	Reduction in PAPR at 10^{-2} CCDF (in dB)

Conventional OFDM	9.65	8.58	-
SLM OFDM	6.70	6.38	2.95
4 Phase error SLM	6.60	6.25	3.05
8 Phase error SLM	5.95	5.85	3.70

It is analysed that PAPR is reduced in both SLM and modified SLM technique. It is also analyzed that modified SLM is more efficient method for PAPR reduction.

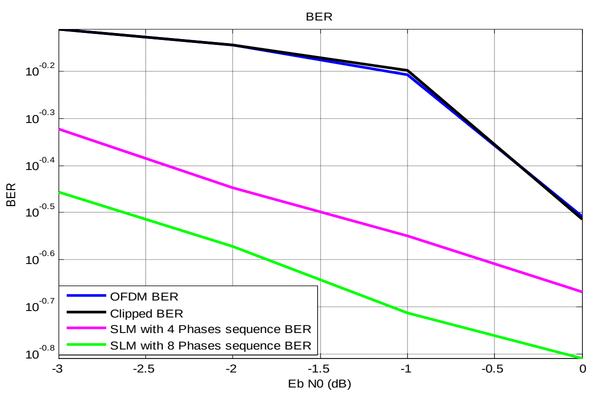

Figure 6: BER plot for SLM output

VI. 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, different results are shown. The bit – error – rate is also plotted against the signal – to – noise ratio to understand the performance of the OFDM system. It is observed that when SLM technique is used, PAPR is reduced by about 2.95 dB. With modified SLM technique PAPR is reduced by about 3.05 dB in 4 phase error sequence and by about 3.70 dB in 8 phase error sequence. From the comparison curve and chart it is conclude that Modified SLM is better than SLM technique. However, no specific PAPR reduction technique is the best solution for the OFDM system. Various parameters like loss in data rate, transmit signal power increase, BER increase, computational complexity increase should be taken into consideration before choosing the appropriate PAPR technique.

VII. Future Aspects

An OFDM signal consists of a number of independently modulated subcarriers, which can give a large peak to average ratio when added up coherently. This produces the distortion in channel. Mostly non-linear amplitude clipping algorithm was used to reduce the PAPR of OFDM systems. Amplitude clipping resulted in out-of-Band spectrum spillage. Also the BER performance was degraded by the implementation of the amplitude clipping algorithms. An alternative direction is use to non-distortion techniques such as SLM and PTS.

In this thesis, PAPR problems of OFDM system has been considered and suitable solutions have been provided. As it is an established fact, that research is never ending process, a new beginning is always waiting. Therefore, following are the works that may be considered as a future scope in this direction:

1. The channel estimation is an area which required a lot of attention and improper channel estimation degrades the performance of system. In this work, it is assumed that channel is estimated perfectly. Hence one can evaluate the performance of proposed work with different channel estimation method.
2. The algorithm PAPR reduction can be extended for channel estimation in OFDM system.
3. The proposed PAPR reduction method can be used with MIMO OFDM system.
4. Algorithm of BER can be derived for OFDM system with proposed PAPR reduction method.

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