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Performance of OFDM system with Modified SLM Technique under fading channel

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Abstract: **The popular modulation scheme which offers reliable high bit rate wireless system with reasonable complexity is Orthogonal Frequency Division Multiplexing (OFDM). OFDM is preferred in most high bandwidth efficient transmission systems because it effectively resists Intersymbol Interference (ISI) and is robust towards multipath fading. One of the main factor affecting the performance of an OFDM system is its high Peak to Average Power Ratio (PAPR). This paper presents implementation of communication system based on OFDM with modified selected mapping (SLM) algorithm in reducing the PAPR of the OFDM system. The PAPR and BER performance of OFDM system with modified selected mapping technique for QPSK and DQPSK modulation scheme under AWGN and Multipath Rayleigh fading channel are shown for simulations performed using Matlab tool Simulink.**

***Keywords*—OFDM, PAPR, SLM, Modified SLM.**

I. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) scheme is considered as the technology of choice for next generation wireless and wired communication systems due to its high speed data rates, high spectral efficiency, high quality service and robustness multipath fading [1]. OFDM is widely adopted in various communication standards like xDSL, digital audio broadcasting (DAB), digital video broadcasting- terrestrial (DVB-T), HIPERLAN/2, Wireless Local Area Networks (WLAN), Wireless Metropolitan Area Networks (WMAN), Wireless Personal Area Networks (WPAN), IEEE 802.11a and IEEE 802.16.

However the Peak to Average Power Ratio (PAPR) is still one of the major drawbacks in the transmitted OFDM signal [2] which results from the nature of the modulation where multiple subcarriers are added together to form the signal to be transmitted. For zero distortion of the OFDM signal, the RF High Power Amplifier (HPA) must operate with a large dynamic range which leads to complexity in HPA, A/D and D/A converters increasing system cost. Thus, if PAPR is reduced not only the cost and complexity of OFDM systems is reduced but also transmit power is improved. Power efficiency is very necessary in wireless communication systems as it provides adequate coverage area and less power consumption and allows small size terminals. Hence it is very important to reduce PAPR before OFDM signals are passed to HPA and DAC.

In this paper we firstly discuss definition of PAPR of OFDM signal. Then we analyse widely used PAPR reduction techniques. Finally we discuss the modified selected mapping algorithm and simulation results for the same.

II. PAPR OF OFDM SYSTEM

An OFDM symbol consists of N sub-carriers by the frequency spacing of Δf. The total bandwidth B is divided into N equally spaced sub-carriers with all sub-carriers being orthogonal to each other within a time interval of length $T = 1/\Delta f$. The complex baseband OFDM signal for N subcarriers can be represented as

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$$s(t)=\frac{1}{\sqrt{N}}\sum_{n=0}^{N-1}X_m.e^{j2\pi f_m t}, 0\le t<NT \qquad (1)$$

The PAPR of the transmit signal s(t), defined above, is the ratio of the maximum instantaneous power and the average power given by

$$PAPR=\frac{\max|s(t)|^2}{E\{|s(t)|^2\}} \qquad (2)$$

Where, E (.) denotes the expectation operator

III. PAPR REDUCTION TECHNIQUES IN OFDM SYSTEMS

There are large numbers of PAPR reduction techniques. This section discusses the most widely used PAPR techniques in OFDM.

A Clipping and Filtering

This is the simplest and widely used technique for PAPR reduction in OFDM signal. In clipping technique the parts of the signals that are outside the allowable region are clipped off [3]. This clipping is performed at transmitter side and for good performance of the system the receiver has to estimate the location and the size of the clip. As it is very difficult to get this information clipping method introduces in band distortion and out of band radiation into OFDM signal resulting degradation in the system performance. Filtering method reduces out of band radiation after clipping but it can not reduce in band distortion. Also improved clipping methods reduce out of band radiation using narrow band window such as guassian windows.

B Coding techniques

Various coding techniques for PAPR reduction of OFDM signal includes a simple block coding technique introduced in paper [4]. This technique maps 3 bit data to 4 bit codeword by adding a Simple Odd Parity Code (SOBC) as a last bit. But this method is suitable for PAPR reduction of only 4 bit codeword also the method is not effective when the frame size is large. Cyclic Coding (CC) to reduce the PAPR [5]. Complement Block Coding (CBC) and Modified Complement Block Coding (MCBC) schemes were proposed to reduce PAPR suitable for non restricted frame size [6]. CBC and MCBC proven to be more attractive due to their flexibility on choosing frame size and coding rate. Golay complementary sequences [7],[8] for PAPR reduction shown 3-dB PAPR reduction but observed reduced transmission rate for large number of subcarriers.

C Scrambling Techniques

Signal scrambling techniques includes Selected Mapping (SLM) technique [9], modified version of SLM using standard arrays [10] and Partial Transmit Sequence (PTS) [11]. These techniques introduces limited redundancy to the code before it is transformed into OFDM signals then a probabilistic approach is used to transmit only one OFDM frame based on frame with lowest PAPR. These techniques aim at not to eliminate the peaks but to achieve greater probability of OFDM frames with lowest PAPR. PTS and SLM are considered important probabilistic schemes for PAPR reduction. SLM scheme produces multiple independent time domain OFDM signals whereas the OFDM signals generated by PTS are interdependent. PTS divides the frequency vector into sub blocks before applying the phase transformation. Therefore, some of the complexity of the full IFFT operations can be avoided in PTS this is more advantageous than SLM if the computational complexity is limited [12]. Also the PAPR reduction in PTS is better than that of SLM. However, the required bits of the side information in PTS are larger than that of SLM. But still both PTS and SLM has drawback of transmission of side information along with actual signal to be transmitted which was very difficult and more number of required IFFT blocks at transmitter both these drawbacks increased the computational complexity significantly.

To reduce complexity further another method proposed to reduce PAPR of OFDM signal is the standard arrays of linear block codes (STA-SLM). This scheme is considered as a modified version of the selected mapping (SLM). This is also a probabilistic method to reduce the PAPR by selecting a signal with minimum PAPR from

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several candidates as the transmit signal. In this a standard array is formed with coset leaders which are properly chosen vectors in terms of their minimum PAPR instead of weight vectors in conventional method. As the coset leaders of a linear code are used for scrambling hence no side information is required to be transmitted and the received signal can be easily decoded by syndrome decoding. Results shown that this scheme has good performance in PAPR reduction with reduced burden of sending side information. But as the transmitted sequence is chosen after IFFT the system is still complex.

To reduce the complexity further approach of selecting OFDM frame with lowest PAPR was done before IFFT by decision algorithm was tried in paper A Modified Selected Mapping Technique to Reduce the Peak-to-Average Power Ratio of OFDM Signal [13]. This technique shown good performance in PAPR reduction of OFDM system using only one IFFT block at the transmitter and no side information needs to be transmitted. Both of these two advantages reduce the complexity of the system to the greater extent. Hence Modified Selected Mapping (SLM) algorithm was chosen to evaluate the performance of OFDM signal with DQPSK modulation scheme under multipath Rayleigh fading channel.

IV. MODIFIED SELECTED MAPPING (SLM) TECHNIQUE

In Modified Selected Mapping Technique to Reduce the Peak-to-Average Power Ratio in OFDM Signal proposed in paper [13] the system performance was evaluated using QPSK modulation scheme under AWGN channel. In this paper it is used to evaluate OFDM system performance with DQPSK modulation scheme under multipath Rayleigh fading channel. The block diagram of the modified SLM technique is shown in Fig.1 [13]. The operation of the modified technique is explained with an example based on [8, 4] extended hamming code. First the binary information sequence is divided into blocks of 4 bits. Each information block is encoded into a codeword *c* which is 7 bits by a [7, 4] hamming encoder. Then a control bit which verifies all the symbols is added to the codeword *c* to construct an extended hamming code ĉ of 8 bits.

Standard array for extended hamming code ĉ of 8 bits is constructed using syndrome decoding as shown below in table 1.

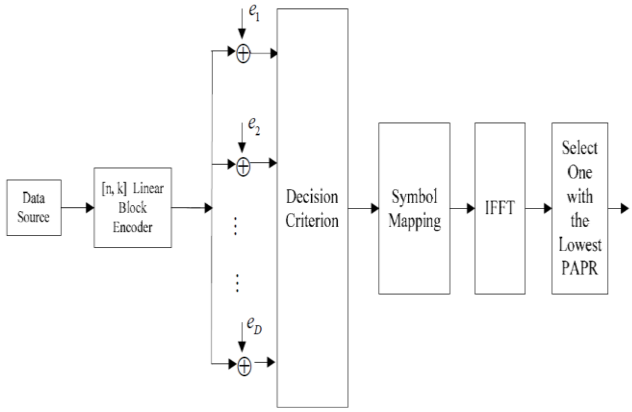

Fig. 1: Block diagram of the modified SLM technique [13]

Code Word	**e_1=c_1 (Coset leader)**	**c_2**	**…**	**c_N**
Forbidden Code Word	e_2	$c_2 + e_2$	…	$c_N + e_2$
	e_3	$c_2 + e_3$	…	$c_N + e_2$
	…	…	…	…
	e_D	$c_2 + e_D$	…	$c_N + e_2$

Table 1: Standard Array of an [n, k] linear block code [8]

Sixteen vectors are constructed as ĉ +e1, ĉ +e2, ĉ +e16, where e1 = 0 and e1, e2, e16 are properly selected as the coset leaders of the standard arrays in terms of their PAPR.

Then the decision criterion based on three approaches as the frequency test, calculating the number of the runs in a sequence and the aperiodic autocorrelation function respectively [13,14] is used for each scrambled codeword to calculate the value of Z. The equation for Z is given by;

$$Z = U_n^2 + V_n^2 + W_n^2 \tag{3}$$

Where

U_n = Difference between the number of zeros and ones in a sequence and is defined by the equation (4) given below for the sequence $b = b_1, b_2, ...b_n$

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$$U_n = (2b_1 - 1) + (2b_2 - 1) + ... + (2b_n - 1) \qquad (4)$$

V_n = number of runs in the sequence. Runs are the sub-sequences with continuous 0 OR 1. V_n for the sequence $b = b_1, b_2, ...b_n$ is defined as below.

$$v_n = \sum_{k=1}^{n-1} c_k c_{k+1} \qquad (5)$$

Where $c_k = 2b_k - 1$, k=1, 2 …n.

W_n = R (i) ... i=1, 2...n, R (i) – periodic auto-correlation function of m sequence and it is defined as:

$$W_n = R(2) = \sum_{k=1}^{n-2} c_k c_{k+2} \qquad (6)$$

Word with minium value for sum of ($|U_n| + |V_n| + |W_n|$) is considered as a word with good randomness

Finally, the scrambled codeword with the minimum Z is selected and then transformed to an OFDM signal by constellation mapping and IFFT. At the receiver, the received signal is converted into a codeword r by FFT and constellation demapping. The syndrome calculated from r is used to estimate the coset leader e chosen at the transmitter. The codeword c is obtained by calculating e+r and then is converted into an information sequence of k bits.

V. SIMULATION RESULTS

The PAPR and BER performance of OFDM system with modified selected mapping technique for QPSK and DQPSK modulation scheme under AWGN and multipath Rayleigh fading channel are measured for the simulations performed using MATLAB tool Simulink as it allows us to model, simulates and analyse dynamic systems. Fig. 2 shows constructed simulation model for OFDM system to simulate the modified SLM technique using MATLAB Simulink.

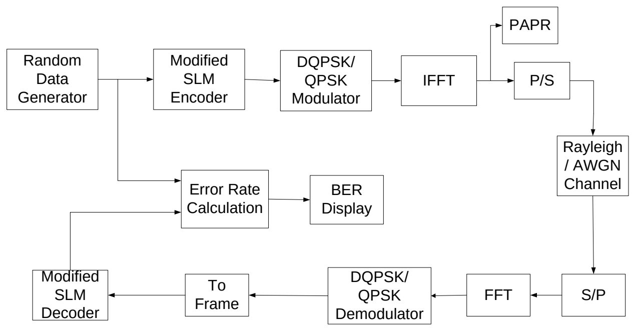

Fig.2: The simulation model of the modified SLM technique using Simulink

With this model two results are observed one is PAPR, the other is BER of the system with different signal-to-noise ratios (SNR).

The simulation results for Peak-to-Average-Power-Ratio (PAPR) with QPSK and DQPSK modulation scheme is shown in fig. 3 and fig. 4 shows Bit-Error-Rate (BER) in OFDM signal with QPSK and DQPSK modulation scheme under AWGN and multipath Rayleigh fading channel. For the simulation parameters as shown in Table 2**.**

Number of Subcarriers	8
Number of IFFT Points	32
Modulation	DQPSK, QPSK
Channel	Rayleigh, AWGN
Length of frame	16 bits

TABLE 2: SIMULATION PARAMETERS

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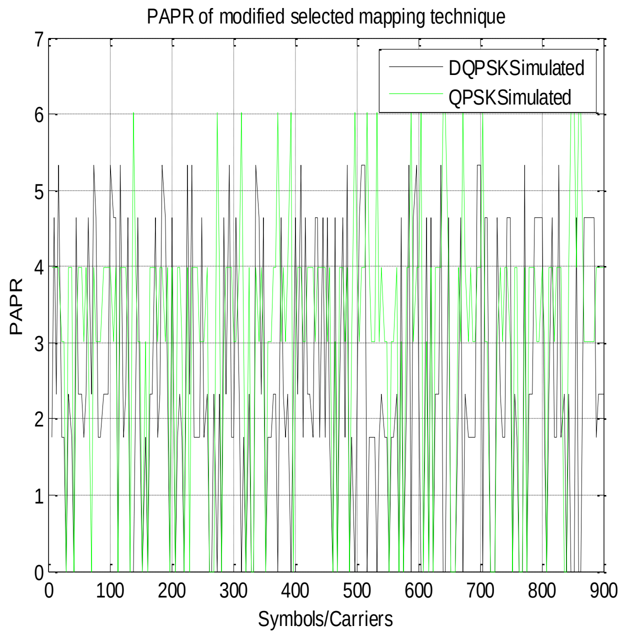

Fig. 3: PAPR of Modified Selected mapping technique with DQPSK and QPSK

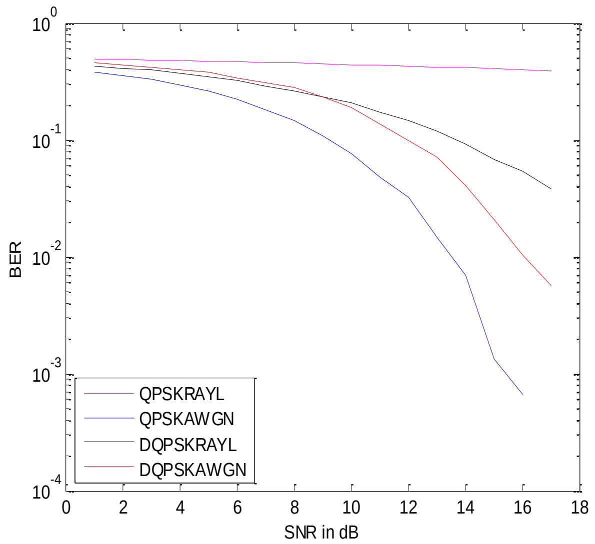

Fig 4: BER of modified selected mapping technique with DQPSK and QPSK under AWGN and Rayleigh Fading channel.

Simulation results from fig. 3 compares simulated values of PAPR for Modified SLM with QPSK and DQPSK modulation techniques. Comparison shows maximum value for PAPR with QPSK modulation scheme is 6.021dB and for DQPSK maximum simulated PAPR value is 5.33dB. This shows PAPR performance of Modified SLM technique is improved with DQPSK. Fig. 4 shows BER comparison for Modified SLM technique with QPSK and DQPSK modulation schemes with AWGN and multipath Rayleigh fading channel. Although BER of Modified SLM technique with DQPSK is inferior to QPSK under AWGN channel but BER performance is improved with DQPSK over QPSK under Rayleigh fading channel.

V. Conclusion

PAPR performance of the system is improved by 0.7dB with DQPSK over QPSK. Also BER performance is improved with DQPSK over QPSK if Rayleigh fading channel is considered. The aim behind choice of DQPSK scheme and rayleigh fading channel was that DQPSK is modification of QPSK which has the merit that it eliminate the ambiguity about whether the demodulated data is or is not inverted. In addition DQPSK Avoids the need to provide the synchronous carrier required at the demodulator for detecting QPSK Signal. As it is a non-coherent scheme, which is helpful to reduce complexity of system. The Rayleigh fading is viewed as a reasonable model for signal propagation as well as the effect of heavily built-up urban environments on radio signals. Rayleigh fading is most applicable when there is no dominant propagation along a line of sight between the transmitter and receiver. Rayleigh fading is a statistical model for the effect of a propagation environment on a radio signal, such as that used by wireless devices. Hence Modified SLM technique with DQPSK will be the better scheme to evaluate performance of OFDM system under Rayleigh channel.

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