Research Paper

An Improvement of Scrambling Technique by Using Modified Selected Mapping in OFDM System

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ABSTRACT

Orthogonal Frequency Division Multiplexing (OFDM) is a digital multi-carrier modulation scheme. It is commonly implemented in many applications for communication purpose. The major drawback of OFDM is the high Peak-to-Average Power Ratio (PAPR). This caused the increase of Bit Error Rate (BER) and power consumption. This paper proposed a Modified Selected Mapping (MSLM) scheme to reduce the PAPR. The scheme used the standard arrays of linear block codes. We select a vector with lowest PAPR in each coset of the linear block codes as its coset leader from several transmitted signal. Simulation results show that MSLM scheme was able to reduce PAPR 8.27% more than conventional SLM. This paper also found out that the PAPR of the system increases with the number of subcarriers used.

Keywords: OFDM, PAPR, SLM, Modified Selected Mapping (MSLM), linear block code

INTRODUCTION

Wireless communication plays an essential part in life in many parts of the world. This impacted many of the remote regions on earth. The commercialization of mobile technology has forced the exponential growth of wireless communication in telecommunication field.

Started from 2009, communication industry focuses on the development of fourth generation (4G) mobile communication systems. 4G is predicted to provide a secure and comprehensive IP solution where data, voice, and multimedia can be offered to users at anywhere and anytime. 4G systems require a minimum data rate of 10-20Mbps and at least 2Mbps in fast moving vehicles. Communication system is expected to provide higher data rate for future multimedia application. To improve spectrum performance and efficiency to achieve as high as 100Mbps in wireless transmission rate, 4G requires to implement more advanced communication technique. [1]

Due to excellent performance, Orthogonal Frequency Division Multiplexing (OFDM) and Multiple Input Multiple Output (MIMO) have been adopted. OFDM is more suitable and preferred for future wireless communication systems as it offers a high tolerance to multipath signals and is spectrally efficient. It also has high immunity to inter-symbol interference (ISI), and robustness to channel fading.

But, in order to obtain efficient transmission, OFDM still have a major drawback to be handled, the high Peak-to-Average Power Ratio (PAPR). OFDM transmitting signal is a composite signal characterised by large peaks. The non-linear behaviour of the power amplifiers (PAs) employed caused the increasing in the amount of inter-modulation interference and this will results in high PAPR. [2]

High PAPR set rigid requirements for the linearity of the power amplifier. High linearity requirement will then cause low power efficiency. Consequently, the power consumption would be high. Due to non-linearity of power amplifier, the Bit Error Rate (BER) degrades. This increases the complexity of the analogue-to-digital and digital-to-analogue conversion. [3]

Some techniques, such as partial transmit sequence (PTS), selected mapping (SLM), block coding, tone reservation (TR), tone injection (TI) and clipping & filtering able to tackle the problem. [4] In this paper, the major approach is Modified Selected Mapping (MSLM).

ORTHOGONAL FREQUENCY DIVISION MULRIPLEXING (OFDM)

OFDM is a form of digital modulation used in a wide array of communication systems. [5] It is a multicarrier modulation (MCM) system, where a single data stream is transmitted over a number of lower rate subcarriers. It is a multiplexing technique but can also be called as a modulation scheme. [6] It is a digital communication method that used Inverse Fast Fourier Transform (IFFT) to breaks a large bandwidth into small subcarriers. Having the subcarrier frequency be integer multiples of symbol rate enable it to removes Inter-symbol Interference (ISI). Total bandwidth is divided into independent sub-channels, multiple access is achieved by allocating sub-channels between users. It can achieve higher data rates by distributing power and sub-channels to users through Adaptive Modulation. [5]

A. Advantages and Applications of OFDM

The main advantages of OFDM are robustness against ISI and high spectral efficiency. IFFT/FFT operation ensures subcarriers do not interfere with each other. Due to simpler equalization, it can eliminate the equalizer. [5] Besides immunes to the frequency selective channels, it also tolerates to impulse noise and multipath delay spread. Cyclic prefix used allows the receiver to capture multipath energy more efficiently. It also can comply with world-wide regulations and coexist with current and future systems. [8]

OFDM technique is used in various applications, which included Wireless Local Area Network (WLAN), Wireless Metropolitan Area Network (WMAN) and digital audio/video broadcasting etc. In addition, it also supports high speed cellular data and digital subscriber line (DSL). [9]

B. Peak-to-Average Power Ratio (PAPR)

Given an OFDM transmit symbol, PAPR is the relation between the maximum power divided by the average power of that symbol. In multicarrier system, the phase difference between sub-carriers results in PAPR. [2]

Definition of PAPR:

$$PAPR = \frac{P_{peak}}{P_{average}} = 10\log_{10}\frac{\max\,[|x_n|^2]}{\mathrm{E}[|x_n|^2]} \qquad (1)$$

P_{peak} = Peak power of the OFDM system

$P_{average}$ = Average power of the OFDM system

$E[\cdot]$ is the expectation operator

PAPR is the major drawbacks in OFDM signals. The quadrature time domain series formed as a weighted sum of sinusoids by IFFT leads to large PAPR formed. According to central limit theorem, when numbers of carriers are large, a real and imaginary values of time domain signal are Gaussian distributed. Hence, the amplitude of multicarrier signal is Rayleigh distributed. Figure 1 clearly shows that the peak power of the signal is very high. [7]

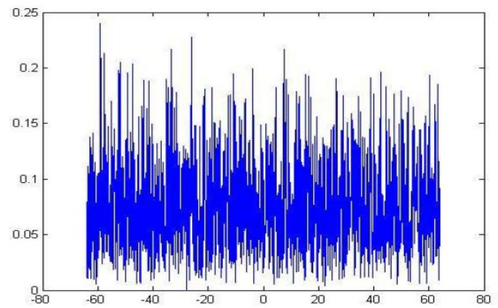


Figure 1: OFDM signal containing sinusoidal high peaks

High PAPR caused the conversion of OFDM signals from A/D and D/A to be more difficult. Then, the resulting in band interference will increase the ISI while out band interference will leads to high Adjacent Channel Interference (ACI). These phenomena are unwanted in communication system. [6]

C. PAPR Reduction Techniques

Various techniques have been proposed to reduce PAPR. PAPR reduction methods vary according to the system requirement and dependent on some parameters, such as transmit signal power, complexity of computation, spectral efficiency, data rate, BER and also capacity reduction at receiver end. Basically, the techniques can be classified into two groups, signal scrambling techniques and signal distortion techniques: [10]

Signal Scrambling Techniques

- Selected Mapping (SLM)
- Partial Transmit Sequence (PTS)
- Interleaving Technique
- Block Coding Techniques
- Block Coding Scheme with Error Correction
- Tone Reservation (TR)
- Tone Injection (TI)

Signal Distortion Techniques

- Clipping and Filtering
- Peak Windowing
- Envelope Scaling
- Peak Reduction Carrier

MODIFIED SELECTED MAPPING TECHNIQUE

The MSLM scheme's block diagram is shown in Figure 2. First of all, the data source will be send into a linear block encoder. Then, a divider divides the binary information source into blocks of 4 bits. By using [7, 4] hamming encoder, each of the information block is encoded into a codeword c. A control bit is added to the most significant side of codeword c to produce an extended hamming code of 8 bits. Next, construct the standard array of an $[n, k]$ linear block code by calculating the error table and assign coset leader, 16 in number. The sixteen vectors are constructed as $c + e_1, c + e_2,\ \ c + e_3,$ ……..etc. Then, calculate the decision criteria, Z for each of the scrambled codeword using the formula $Z = U^2 + V^2 + W^2$. After that, scrambled codeword with the minimum value of Z is selected and then performed the constellation mapping. Then, the data blocks is multiplied with D different phase factors $p_D = [p_1, p_2, \dots \dots p_D]$, where d=1,2,3,……D. After that, the frequency domain signals are converted to time domain by going through IFFT block. Finally, one of the signal with the lowest PAPR is selected for transmission. [12]

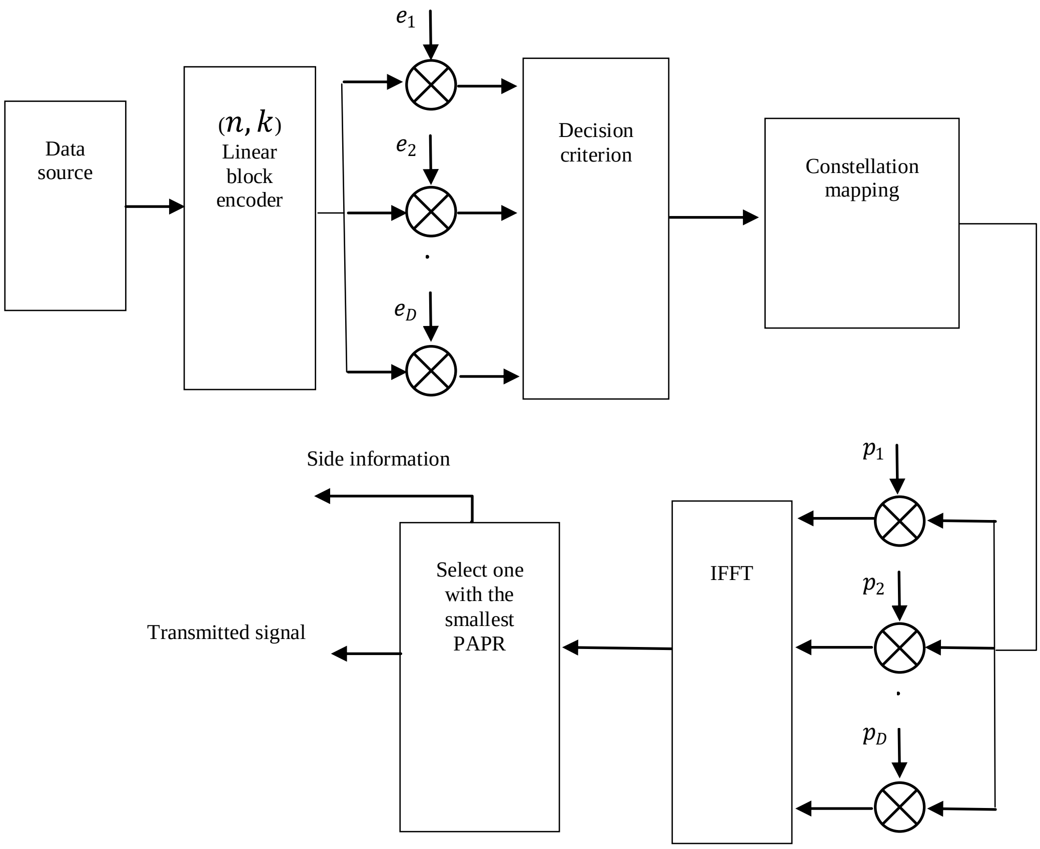


Figure 2: Block diagram of MSLM scheme [12]

LINEAR BLOCK CODE

Consider an $[n, k]$ linear code C with parity-check matrix H, where n is the length and k is the dimension of C. Since ${H_x}^t = 0$ for any code word $c \in C$, any vector $X \in e + c$ has the same syndrome as e, that means

$${H_x}^t = H(e+c)^t = {H_e}^t$$

A stream of binary data sequence is divided into blocks of 4 bits. By using [7, 4] hamming encoder, each message block is encoded into a 7 bits codeword C. The purpose of designing hamming codes were correction. The parameters for the family of binary hamming codes are typically denoted as a function of a single integer $m \geq 2$. The value of m is not necessarily prime, it may be any positive integer. For example, $m = 3$, a (7, 4) hamming code was produced. A hamming code on Galois Field of two elements GF(2) has a code length of $n = 2^m - 1$, message length of $k = 2^m - 1 - m$. The redundancy is given by $m = n - k$ and error connecting capability $t = 1$ bit. [11]

STANDARD ARRAY

A normal hamming code is only capable for single error correction. Thus, parity check digit is added to improve the error detection and connection capability. The transformed code is called the extended binary hamming code. Assume that c is a code over the alphabet {0, 1}. By adding a single character to the end of each word, $\hat{C}$ which has even weight for every word in it was obtained. The parity check matrix of [8, 4] extended hamming code $\hat{C}$ is expressed as:

$$\hat{H} = \begin{bmatrix} & & 0 \\ & & \vdots \\ & H & 0 \\ 1 & 1 & 1 \end{bmatrix} \qquad (2)$$

The syndromes of non-error and one error patterns could be obtained by applying the formula of $S = e\hat{H}^T$. Furthermore, another seven two errors patterns might be get from the other syndromes. Hence, standard array of $\hat{C}$ is constructed. The formula of $M \times N$ array is applicable for both standard array of $[n, k]$ and extended array of [8, 4] for binary linear code of C and $\hat{C}$ respectively, where $M = 2^{n-k}$ and $N = 2^k$. Remember, the main idea of using standard array here is not for error correction, it is for the reduction of PAPR in OFDM system. [12]

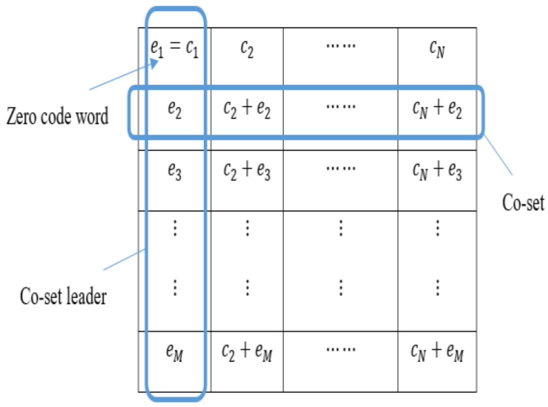
Next, sixteen vectors are structured as $\hat{C} + e_1, \hat{C} + e_2, \hat{C} + e_3, \cdots\cdots \hat{C} + e_{16}$. The value of $e_1 = 0$ and $e_1, e_2, e_3, \cdots\cdots e_{16}$ are then carefully selected as the coset leaders of the standard array in terms of their PAPR.

There are M rows in this array, each row is a coset *c* which represents the codeword and *e* represents the error in transmission. The value of each codeword is calculated based on the method shown in Table 1. After the standard array has been constructed, the value of Z is calculated by using decision criterion formula, which is $= U^2 + V^2 + W^2$. [12]

DECISION CRITERION

The key of this decision algorithm is actually the way on how to judge from a sequence itself that it's the best sequence, scilicet, the sequence with the best randomness. First of all, calculate the value of U. The first approach is the frequency test. The purpose of this test is to check that if the number of 0 is approximate to the number of 1 in a binary sequence. The closer the number of 0 approximates to the number of 1 in a sequence, the more possible the sequence having good randomness. For the bits sequence of $= b_1, b_2, \dots, b_n$, U_n is defined as $U_n = (2b_1 - 1) + (2b_2 - 1) + \cdots + (2b_n - 1)$. In other word, $|U_n|$ denotes the difference between the number of 0 and the number of 1 in a sequence. Hence, the smaller the value of $|U_n|$ is, the better the randomness of a sequence is.

Table 1: Standard array of an $[n, k]$



Next, the value of V need to be calculated, it can be explained as the number of the runs in a sequence. The term runs is refer to the sub-sequences with continuous 0 or 1. The preferred sequence is the one with the number of runs approximating to the half of the sequence-length. For example, a sequence of $b = b_1, b_2, \dots, b_n$, V_n is defined as $V_n = \sum_{k=1}^{n-1} c_k c_{k+1}$, where $c_k = 2b_k - 1$, $k = 1,2, \dots, n$. The smaller the $|V_n|$ is, the closer the number of the runs approximate to $n/2$.

However, the sequence 110011001100…. is a special case. Although the number of 0 is equal to the number of 1 and it's runs is half of the sequence-length, but it is a short cycle sequence with high PAPR. Therefore, based on the two foregoing decision standards, the possibility of getting a wrong decision is high. The decision standard need to be amended. The aperiodic autocorrelation function of m-sequence is denoted by $R(i)$. V_n is the value of $R(1)$. As long as $i \neq 0$, the value of $R(i)$ is very small. W_n can be defined as $W_n = R(2) = \sum_{k=1}^{n-2} c_k c_{k+2}$ where the value of $|W_n|$ must be small.

In summary, if the sequence has good randomness, the sum of $|U_n|, |V_n|$ and also $|W_n|$ must be small. Therefore, the decision criterion is defined as $Z = U^2 + V^2 + W^2$. Based on this criterion, the transmitted sequence can be selected. [13]

The coding technique used in this scheme is linear block codes. There are various number of subcarriers has been used for simulation, which are 32, 64, 128 and 256. Besides that, modulation technique used is 16-QAM and the constellation mapping is the 16-point mapping method. Then, the size of IFFT used is 64 and the oversampling factor, $L = 4$. To choose the sequence with lowest PAPR, the decision criteria used is $Z = U^2 + V^2 + W^2$

RESULT AND DISCUSSION

The simulation result of CCDF versus PAPR with number of subcarriers, N=32 is shown in Figure 3. The CCDF curves were decreased for all three types of signal. At CCDF = 0.01% $(or\ 10^{-4})$, the PAPR values of original OFDM, SLM and MSLM signals are 10.36dB, 6.443dB and 5.846dB respectively. The MSLM signal's PAPR value is 0.597dB less than the conventional SLM signal. The decrement is about 9.27%.

In other word, it means that the signal power exceeds the average by at least 5.846dB for 0.01% of the time by using MSLM scheme.

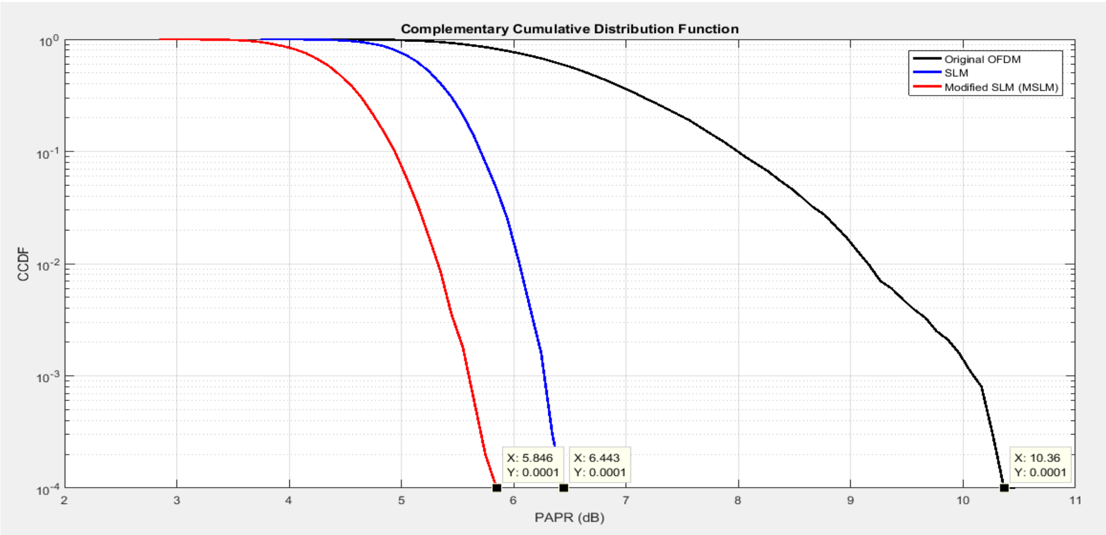


Figure 3: CCDF vs PAPR with number of subcarriers, N=32

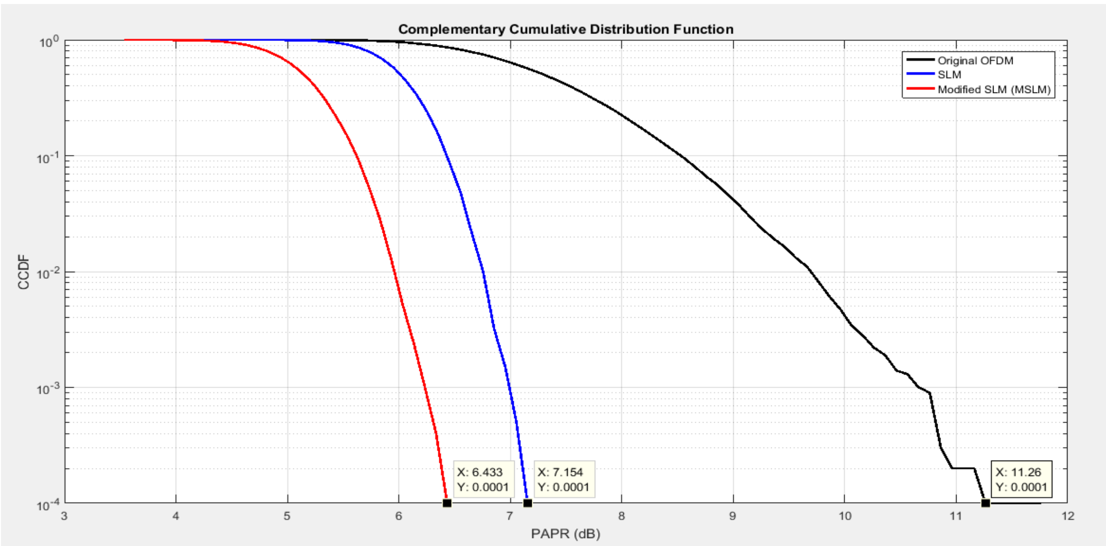


Figure 4: CCDF vs PAPR with number of subcarriers, N=64

From Table 2, it clearly shown that with increasing number of subcarriers, N, the PAPR values for all type of techniques used were increased. The original OFDM signals have highest PAPR value, which is within the range of 10.36dB - 11.620dB. For SLM and MSLM techniques, their PAPR values are closer to each other. SLM is within the range of 6.443dB – 8.235dB while MSLM is of 5.846dB – 7.699dB.

By comparing the MSLM technique with the conventional SLM technique, there are obvious reductions in PAPR values. For number of subcarriers, N=32 and 64, the decrements are 9.27% and 10.08% respectively. While N=128 and 256, the decrements are 7.2% and 6.51% respectively. Therefore, in average, MSLM is 8.27% higher in PAPR reduction capability compare to SLM. Can be noticed that follow the increment of number of subcarriers, the PAPR decrement percentage generally decreased.

Table 2: Summary of PAPR performance for different technique used

Number of subcarriers, N	Value of PAPR when CCDF = 0.01% (dB)			Decrement achieved from SLM to MSLM (%)
	Original OFDM	SLM	MSLM	
32	10.360	6.443	5.846	9.27
64	11.260	7.154	6.433	10.08
128	11.380	7.708	7.153	7.2
256	11.620 (CCDF=0.02%)	8.235	7.699	6.51

By looking at the results of journal, [12] it can be clearly seen that they are different because some of the parameters used are different, such as number of subcarriers and size of IFFT.

DISCUSSION

Due to the high transmission speed, high efficiency and reliability, Orthogonal Frequency Division Multiplexing (OFDM) became one of the most commonly used digital modulation scheme in telecommunication industry nowadays. However, there is a major drawback in OFDM system, which is high PAPR value. This could cause high power consumption and high BER issues to occur. These problems will lead to low spectral and also power efficiency.

In this paper, the conventional SLM technique has been modified and called Modified SLM (MSLM) technique. Basically, it is the combination of linear block coding and selected mapping (SLM) techniques. MSLM scheme was carried out to improve the system by further reduce the PAPR.

Based on the simulation results, the MSLM scheme has successfully improved the PAPR performance of SLM scheme after reduced the PAPR by average of 8.27%. By comparing the MSLM scheme with the conventional SLM scheme, the PAPR reduction ability of MSLM is higher. After decrease the number of IFFT block used in SLM, MSLM now has lower system complexity and computational burden. Therefore, MSLM can be said as the improve version of SLM. After repeated the identical simulation by using different number of subcarriers, found out that the PAPR of the system is increased when the number of subcarriers is increased. The MSLM scheme is able to reduce the PAPR significantly and this research project was completed successfully.

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How to cite this article: Othman WAFW, Alhady SSN, Wong KE et.al. An improvement of scrambling technique by using modified selected mapping in OFDM system. International Journal of Research and Review. 2018; 5(10):457-464.

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