PAPR Analysis of OFDM using Selective Mapping Method

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Abstract

A common standard modulation for several high data rate wireless communication systems is Orthogonal Frequency-Division Multiplexing (OFDM). It operates by splitting up large streams of data into several parallel streams with minimal data rates. Compared to single carrier modulation systems, OFDM offers various benefits. Some of these benefits are high transmission bit rates, great spectral efficiency, and sensitivity to frequency fading channels. However, there are drawbacks with OFDM. Among the major issues is the high Peak to Average Power Ratio (PAPR), due to which the system complexity increases. The Selective Mapping approach is used in this study to lower the OFDM PAPR. In this article, simulation has been done using MATLAB, evaluated PSD, spectral efficiency, BER performance and PAPR analysis of OFDM system.

Keywords: OFDM, SLM, PAPR, BER, PSD, SNR

1. Introduction

Due to the rising demand for wireless applications and the exponential development in the number of connected users, the current Wireless Communication (WC) infrastructures are saturated [1]. By assuring ultra-high data rates, ultra-wide radio coverage, a big number of linked devices that are extremely efficient and have low latency, researchers and network designers are encouraged to develop solutions for these basic difficulties [2]. The development of the fifth generation (5G) of wireless networks will be facilitated by wireless network solutions utilizing sophisticated and effective technology. 5G needs to be ready to handle significant obstacles in order to offer a dependable, secure, and effective 5G network [1-3].

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Over the last few decades, several communication systems have used Multicarrier (MC) communication techniques to convey large amounts of data [4-5]. In Multi Carrier Modulation (MCM), the transmitted bit stream is divided into several smaller sub streams and sent across numerous sub channels. The sub channels will be orthogonal under optimal propagation circumstances. The related sub channel Bandwidths (BWs) are less than system BWs, and sub channel data rates are lower than overall data rates [6-7]. The most well-known and widely used MC technology among communication systems that rely largely on wireless transmission is OFDM. Larger data rates will be necessary for future communications systems, thus traditional OFDM enables reduced latency, and higher data rates will necessitate flexible frequency and temporal resource allocation [8-9]. MCM is a technique for parallel data transmission employing a number of orthogonal carriers to improve communication system performance [10]. Multipath fading is restricted in OFDM, and it can’t be affected with impulse noise, also the OFDM simplifies the hardware design of equalizers for minimizing the complexity by utilizing DWT and FFT techniques for the development of WC systems. The spectrum ranges are shared by the carriers while having multiple modulated low BW signals into them using OFDM. OFDM distributes the available spectrum effectively to reduce interferences in the separated orthogonal channels moderately. On orthogonal carriers, distinct subsets of information are modulated and seem to be stored [11-14].

Recently, OFDM has received a lot of attention as a method for high-speed WC. It is distinguished by improved tolerance to multipath fading and impulsive noise as well as higher frequency multiplicity [13]. It has been demonstrated that the OFDM system outperforms the single carrier modulation method in frequency selective fading channels [9]. The main problem with OFDM is its significant amplitude fluctuations, measured by the Peak to Average Power Ratio (PAPR), which results in power waste and necessitates a costly High-Power Amplifier (HPA) with excellent linearity [24]. In [15], several PAPR minimization approaches have been proposed to address this high PAPR. The approach of Selective Mapping (SLM) is suggested in [16]. An input symbol sequence is multiplied by each of the phase sequences, which are present sequences in SLM to produce different input symbol sequences. The sequence with the smallest PAPR is then chosen and broadcasted from among the several time-domain sequences produced following the Inverse Fast Fourier Transform (IFFT) for the phase rotated symbol sequences. The PAPR of an OFDM signal is particularly sensitive to phase changes in the frequency domain data, and the SLM technique makes use of this sensitivity. However, the approach has been demonstrated to be effective and distortion-free using a straightforward parallel signal processing architecture. Additionally, it is claimed that the SLM is preferable to Partial Transmit Sequences (PTS), a technique that is identical to the SLM and uses the same amount of side information [17]. The amount of IFFT calculations and phase sequence multiplication needed to improve PAPR reduction efficiency is proportional to the number and length of the phase sequences employed.

This article has the following format. Section 2 gives a basic explanation of OFDM, while Section 3 illustrates the Selective Mapping approach. Simulation results are described in Section 4, and Section 5 briefs the conclusion.

2. Orthogonal Frequency Division Multiplexing

A unique type of MCM technology utilized in several recent wireless standards is OFDM. Broadcast standards, including Digital Video Broadcasting (DVB) and Digital Audio Broadcasting (DAB) standards, have implemented OFDM [1-3]. Additionally, it is utilized in Wireless Local Area Networks (WLAN) that support WIMAX and the 802.11g and 802.11n protocols. Long Term Evolution (LTE), a cellular telecommunications standard, also uses OFDM [13]. A huge number of orthogonal carriers that are closely spaced make up an OFDM. These carriers are used to spread out the data to be conveyed, and all the orthogonal carriers are modulated at a modest data rate. Frequency spectrum efficiency is one of the main benefits of OFDM, since there is no interference on the receiver side due to carrier overlapping. Interference is reduced via carrier orthogonality [24]. OFDM systems have some disadvantages. High PAPR, which reduce power amplifier efficiency, is a significant disadvantage of OFDM systems. Therefore, for OFDM systems, PAPR reduction is crucial. The underlying idea of OFDM is shown in Figure 1. The input data is mapped to the transmitter side using a modulation technique called Quadrature Amplitude Modulation (QAM). The signal is subjected to an IFFT after being transformed from serial to parallel using an IFFT method [13,20]. Before being sent to a channel, signals are first transformed to serial (P/S). Signals are parallelized (S/P) and demodulated using FFT on the receiver side. The signal is then converted from parallel to serial (P/S) and demodulated to provide the data output [18]. By selecting the best modulation schemes, it is possible to increase BW efficiency and overcome multipath fading in WCs. One of the greatest methods for attaining these goals is OFDM. In this instance, a high PAPR resulted in an inefficient radio frequency portion that in turn caused an inefficient transmitter section [19].

OFDM is a more organized and effective 4G modeling technique, in addition to being more efficient and requiring less time. A significant problem with OFDM is that, its PAPR is greater. The ability of OFDM receivers to perceive nonlinear devices, such as HPA and digital amplifiers, is clearly demonstrated by their circuitry [20-21]. When an OFDM signal is split up into M subcarriers, the resulting complex baseband representation is as follows:

$$f(t) = \frac{1}{\sqrt{M}} \sum_{m=0}^{M-1} F_k e^{\frac{j2\Pi mt}{M}} \quad for \;\; 0 \le t \le M-1$$

Here, a sequence of input symbols is provided by $F = [F_0, F_1, ..., F_{N-1}]^T$, and discrete time index is t.

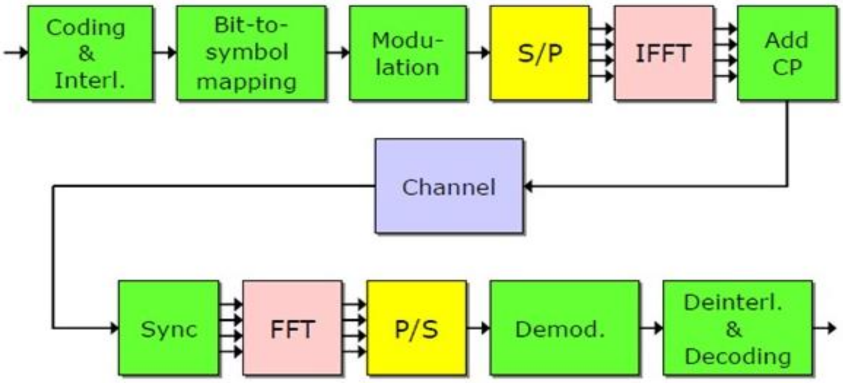

Figure 1. OFDM block diagram

3. Selective Mapping (SLM) Method

The PAPR in OFDM systems are reduced using SLM. In the SLM approach, each phase sequences are multiplied by its data sequence [15]. The same data is therefore sent in a sequential order. The PAPR of transferred signals is the smallest. In the SLM technique, a M phase sequence multiplies the initial data block. As a result, M sequences with the same information are generated. Out of the created M sequences, the sequence that has the minimum PAPR has been selected to send. Along with the data, side information is also provided. On the side information, a phase sequence with a minimal PAPR is noted [22]. A possible PAPR reduction solution for the OFDM system is selective mapping. Figure 2 depicts the fundamental idea of selective mapping. Producing U different forward sequences from its same data source and choosing the transmit signal displaying lowest PAPR, is the fundamental tenet of SLM. The concept is based on the observation that, because the transmit data vectors' sequence determines the PAPR, multiplying the transmit data vectors X^m by an arbitrary phase would alter the PAPR's characteristics after the IFFT [15,23].

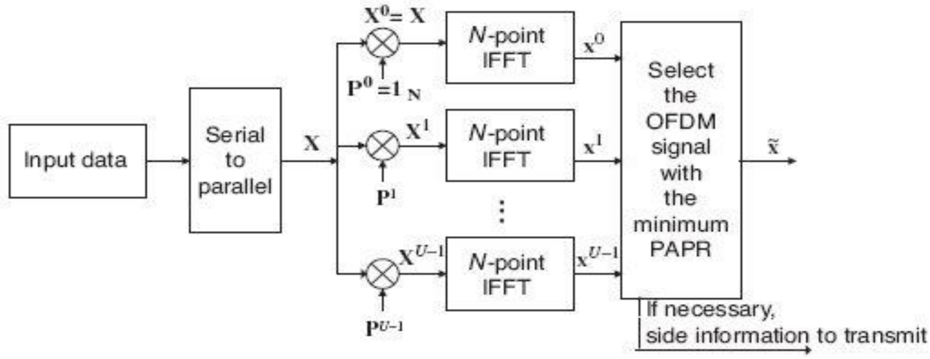

Figure 2. Selective Mapping

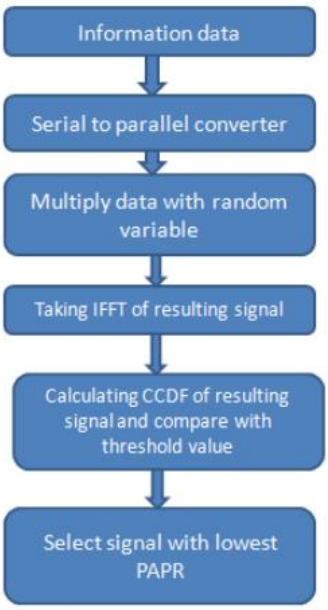

Figure 3. Flow Chart of SLM method

A collection of U significantly diverse, pseudo-random fixed vectors is produced mathematically. It is assumed that separate phase sequences $P = \left[P^{0(u)}, P^{1(u)}, \ldots\ldots, P^{N-1(u)} \right]$, u= 0 to U-1. The number of phase sequences U, is multiplied by the initial input data X $[X^1, X^2, \ldots. X^{N-1}]$. The length N of the phase sequences is the same as that of the input data. After multiplication, each sequence will pass an IFFT to change the signal's frequency domain to time domain. The outcome of multiplication will produce an OFDM data block with several time domain signals, each with a length of U, and various PAPR values, X(u). In the last stage, the independent data blocks' PAPRs are compared, and the candidate with the lowest PAPR is chosen for transmission.

Advantages:

- Less distortion is introduced.
- Irrespective of the number of carriers.
- Less complexity.

Drawbacks:

- It's necessary to provide side/background information.
- Performance of BER is decreased.

4. Results

In this section, based on computer simulations (MATLAB), the effectiveness of the OFDM technique has been evaluated.

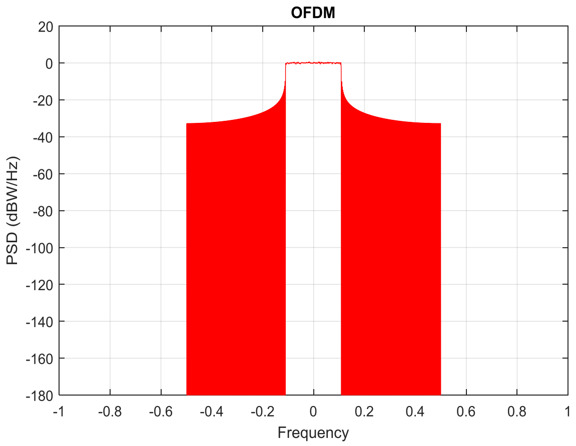

Figure 4. PSD of OFDM

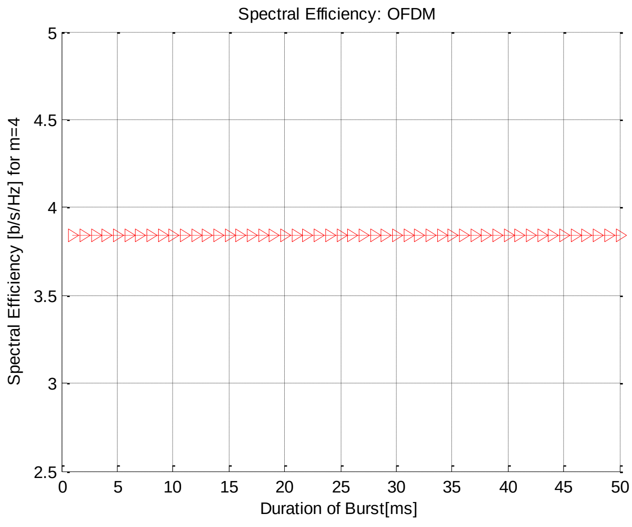

Figure 5. Spectral Efficiency

The PSD for OFDM is shown in Figure 4. Until a normalized frequency of 0.2, the spectrum is typically flat. However, OFDM has a very wide sideband.

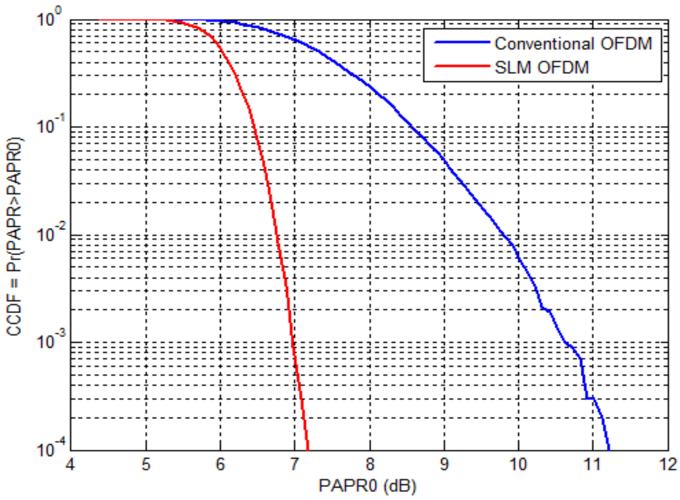

Figure 6. PAPR minimization using SLM method

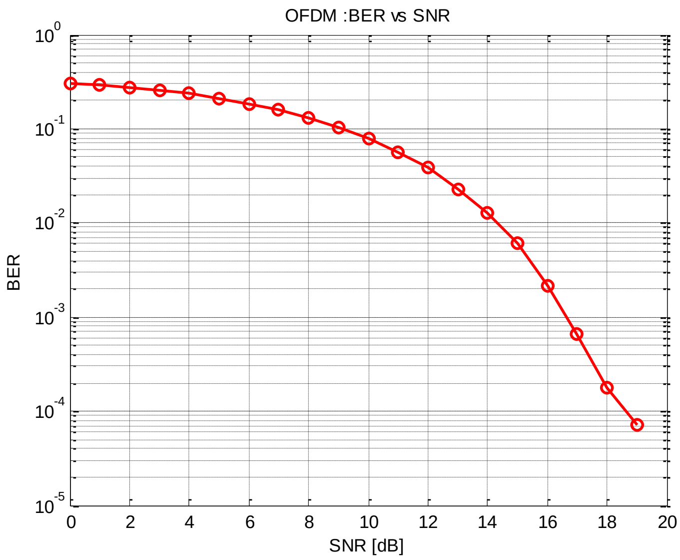

Figure 7. SNR vs BER

The PAPR of the traditional OFDM is 11.2 dB. PAPR is lowered to about 7.2dB after SLM operation. PAPR is reduced by around 4dB. As a result, a very considerable improvement can be seen, showing the SLM technique's better performance as in figure 6. The SNR vs BER of OFDM is shown in Figure 7.

The Frequency spectrum of original OFDM signal is shown in figure 8, wherein the transmitted symbols are 64, 4 zeros are padded in middle, the number of subcarriers are 4 and the total frequency is 100MHz.

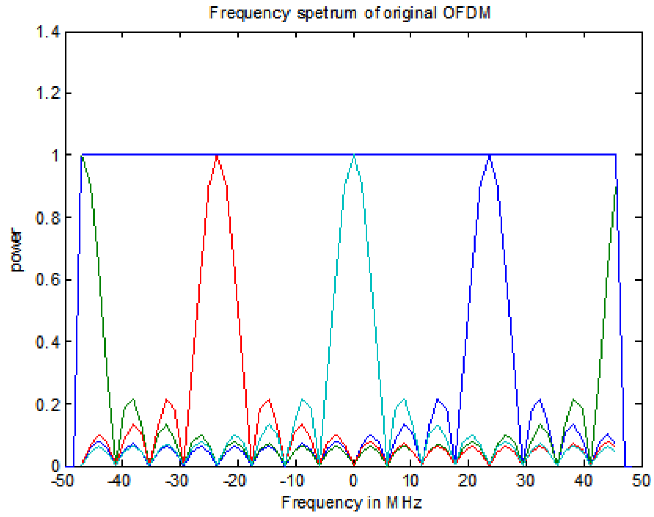

Figure 8. Frequency spectrum

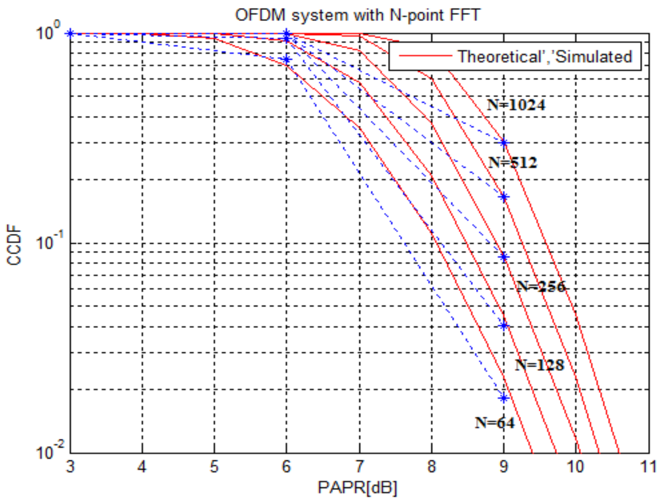

Figure 9. CCDFs of OFDM with different values of N

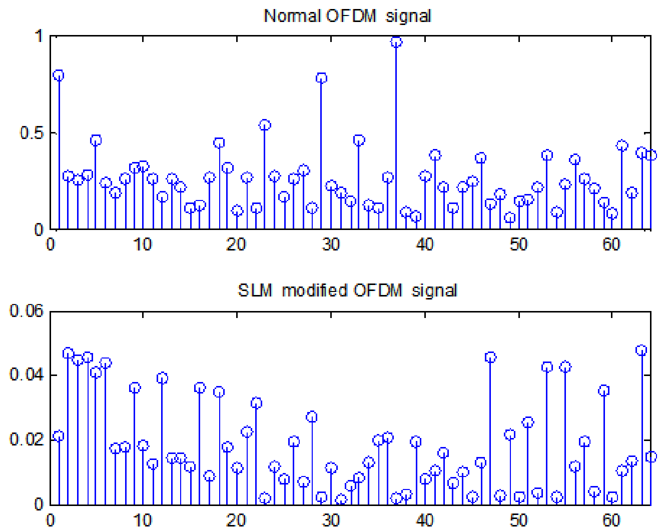

Figure 10. PAPR minimization: SLM Technique

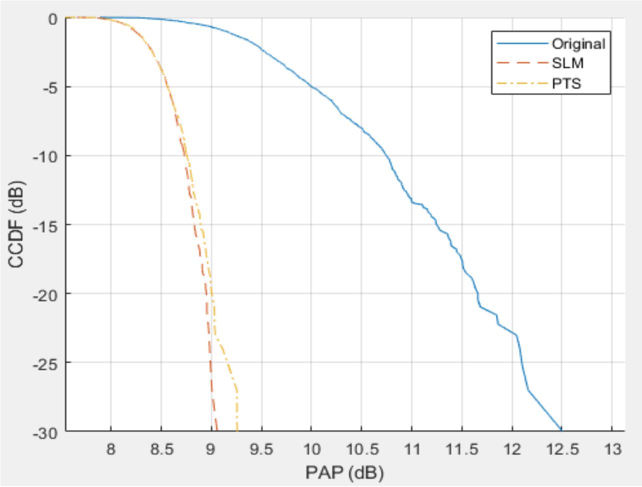

Figure 11. PAPR of SLM vs PTS

Table 1. PAPR comparison of original OFDM signal, SLM and PTS

N	**Original OFDM**	**SLM**	**PTS**
	PAPR (dB)		
2048	12.8	9.2	9.27
1024	12.48	9.11	9.21
512	12.11	8.7	8.6

The CCDFs for OFDM signals with different values of N are displayed in figure 9. As N changes, the simulated results vary from the theoretical results. According to figure 10, the peak signal amplitude is close to one if SLM is not used. The PAPR of typical OFDM is 22.40dB when there are 64 transmitted symbols and an alphabet size of 8. The peak level of the amplitude is significantly lower in the case of SLM (0.08), and a modified SLM OFDM signal has a PAPR of 14.43dB. The PAPR can be considered to be lower in the case of SLM. From figure 11, the PAPR of the original OFDM is 12.48dB. PAPR is lowered to about 9.21 and 9.11dB after PTS and SLM operation, respectively.

5. Conclusion

In this paper, the Orthogonal Frequency-Division Multiplexing (OFDM) system has been presented. It states that the features of OFDM make it a popular communication technology. But the main disadvantage is high Peak to Average Power Ratio (PAPR). There are several PAPR minimization methods. In this article, Selective Mapping (SLM) approach for PAPR minimization of OFDM signals has been suggested. The results of the simulation demonstrate that the PAPR is decreased when employing this method. The efficiency of the PAPR reduction in the OFDM system is impacted by the modulation method. The performance of PAPR reduction improves with higher order modulation. When compared to the original OFDM, it is shown that the SLM scheme significantly improves PAPR reduction performance.

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