# Peak to Average Power Ratio (PAPR) Reduction in OFDM for Optic Communications based on Conventional Selected Mapping

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**Abstract**
OFDM is a modulation technique that utilizes the optic communication band efficiently by dividing the high-speed information sequence into parallel arms and lifting the frequency selectivity of the multi-carrier channel at the same time and using vertically selected carriers at the same time. Selected mapping is an accurate method for reducing peak to average power ratio from orthogonal frequency division multiplexing. A fundamental weakness of selected mapping is the high computational complexity. To reduce the complexity of the selected mapping, the real and imaginary part of the orthogonal frequency division multiplexing signals is treated separately. Numerical sequences and even real and imaginary elements are obtained using Fourier transform properties. More candidates are produced with a different combination of all the following sequences. The proposed scheme produces less computational complexity using the IFFT algorithm for M4 equations only. The simulation results show that the proposed design reduces the good performance of peak to average power ratio and also reduces computational complexity compared with the selected mapping design.

***Key words:***
*Orthogonal Frequency Division Multiplexing, Conventional Selected Mapping, Fast Fourier Transform.*

## 1. Introduction

In [1], Nagendra Kumar et al. explored “Performance analysis of OFDM based nonlinear AF multiple relay systems”. In recent years, the researches in optic communication systems are about reliability, enhance coverage, and spectral efficiency. Most of the researches are related with cooperative relaying network with orthogonal multiplexing technology.

Fiber optic communication is the method of transmitting information from one location to another by sending light signals through the optical fiber. The light acts as a directed electromagnetic carrier wave to convey information. The first light-transmission communication systems developed in 1970 revolutionized the telecommunications industry and played an important role in the coming of the information age. Due to the advantage of electrical conduction, the luminaires took place in the communication of copper wires in the core networks in the developed countries [2].

The light is used by many companies for purposes such as transmitting telephone signals, communicating internet, and transmitting cable television signals. Due to the much less impact and exposure to obstacles, the luminaires are more advantageous than copper cables in high demand and long-range applications. However, infrastructure development in cities is difficult and time consuming. These systems are expensive to install and operate due to the complexity of the systems. Because of these difficulties, the luminance communication systems are primarily installed in long-distance applications, which compensate for its high cost and operate with full transmission capacity. Since 2000, the price of light communication has declined considerably. The price of opening fiber to any house is more suitable than opening a copper network. In countries such as the United States and the Netherlands, where excavation costs are low and the accommodation density is high, prices are reduced to $ 850 per subscriber [3].

The information transmitted is usually digital information produced by computers, telephone systems and cable television companies [4]. Transceiver is a device that includes both the receiver and the transmitter in a single combination [5].

Nakagami-m is used to model fading scenario different conditions, mostly in non-LOS (Line of Sight) environment. It is explored to make easier the analysis by the researchers. Nakagami-m is also commonly used to model the fading statistics of received signal but it can model fading under generalized conditions up to a certain level. Besides Rician and Rayleigh fading, refined models for the pdf of a signal amplitude exposed to mobile fading have been suggested. It describes the amplitude of received signal after maximum ratio diversity combining [1].

In [6], Fan-Shuo Tseng mentioned “Nonlinear Transceiver Designs in MIMO Amplify-and-Forward Relay Systems”. Nonlinear transceiver designs with a linear quasi-successful interference canceller (SIC) receiver and a minimum mean-squared-error (MMSE) SIC receiver for a linear source and relay pre code system and another linear source and relay precoded system are proposed. The AF MIMO system considers linear precoders and linear receivers. In conventional MIMO systems, non-linear pre-

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coding may provide better performance than linear receivers. The author preferred to design the radio with a linear source pre-encoder, a linear relay pre-encoder, and a non-linear receiver. QR consecutive-interference-cancel (SIC) and MMSE-SIC are used as non-linear receivers. Successful interference cancellation is a physical layer technique with the ability to receive two or more signals at the same time to a receiver [7]. The minimum mean square error (MMSE) is a method of estimating the mean square root error of the embedded values of the dependent variable, which is a common criterion in the quality of the estimator [8].

In 2012, C. Alexandre et al. published an article [9] named "Outage Performance of Cooperative Amplify-And-Forward OFDM Systems with Nonlinear Power Amplifiers" which mentions the nonlinear distortions resulting from nonlinear power amplification describe the theoretical analysis of the probability of interruption of a diversity OFDM system based on an amplification-forward (AF) cooperative algorithm. Since non-linear pre-coding performs better than linear pre-coding, the inclusion of linear precoding in MIMO bidirectional transition systems is expected to further improve network performance [10].

## 2. Conventional Selected Mapping (CSM) Technique

The concept of the CSM technique that the data block X of length N is divided into the number of the split sub-blocks V. The IFFT is calculated alone for each one of these sub-blocks and then via a phase factor $b_v$ weighted it. To get time domain OFDM signal with minimal PAPR all of the sub-blocks are optimally combined with alone multiplying with phase factors. A block diagram of the proposed method is show in Figure 1. The PAPR reduction relies on the number of sub-blocks V and the number of all phase factors $b_v$ where the sub-block partitioning. It is the method of split of the subcarriers into multiple sub-blocks. The proposed method demands IFFT methods for all data block and complexity increases exponentially with the number of sub-blocks V.

With simple form, suppose X = [X(0) X(1)…X(N − 1)] represent the OFDM signal in the frequency domain, which N is the number of the sub-carrier for the frequency domain signal. The OFDM signal for the time-domain is represent by

$$x(n) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X(k) e^{\frac{j2\pi kn}{N}} \tag{1}$$

The definition of the OFDM signal which is shown by x(n) is showing in (2).

$$PAPR = 10\log \frac{\max_{0 \le n \le N-1} |x(n)|^2}{\sigma^2} \tag{2}$$

Here the average power of x(n) is shown by σ2. Assumed the threshold rate PAPR0, the complementary cumulative distribution function (CCDF) of the PAPR is shown by equation (3)

$$CCDF[PAPR(x)] = \Pr(PAPR > PAPR_0) \tag{3}$$

In conventional selected mapping, the original OFDM signal X will reproduce with dissimilar phase rotation vectors as P (P = [P1 P2 … PM]) to get extra frequency domain sequences as shown in figure 1. The consistent time-domain signal xm of the frequency domain signal Xm could be found by the IFFT operation which is shown in equation (4).

$$x^m = IFFT[X^m] = IFFT[X \otimes P^m] \tag{4}$$

After this operation the x* signal is selected and transmitted. Also this signal with the minimum PAPR among M alternative candidates is selected.

In this paper, the imaginary and real part of the x are used. The imaginary part of x we show by xI and the real part is shown by xR. Also here we used the fourier transform for getting the even and odd parts of the x. we show this scenario as the subsequences xR,E, xI,E and xR,O, xI,O.

All the subsequences is used for rebuild the new candidates. The proposed method has a simple PAPR reduction procedure by the signal processing in the time domain. At first, some properties of FFT will be introduced here which will be used in the proposed removed selected mapping scheme. With this techniques we can reduce the complexity of the convolutional operations.

For the signal reversal in the time domain we can use the equation (5):

$$F_1[x(n)] = x(N-n)_{\text{mod } N} = \begin{cases} x(n), & n = 0 \\ x(N-n), & 1 \le n \le N-1 \end{cases} \tag{5}$$

Rendering with equation (5) and the conjugate anti-symmetric properties of OFDM signal

$$\text{FFT}[x^*((N - n) \text{mod } N)] = X^*(n)) \tag{6}$$

In this equation the xR and xI can be expressed as:

$$x_R = IFFT[X_R] = IFFT[(X + X^*)/2] = (x + F_1[x^*])/2$$
$$x_I = IFFT[X_I] = IFFT[(X - X^*)/2] = (x - F_1[x^*])/2 \tag{7}$$

For the circular shifting in time-domain we can write:

$$F_2[x(n),k] = x((n-k)_{\mathrm{mod}\,N}) \Leftrightarrow F_2[X(n),k] = X(n).e^{-j2\pi kn/N} \quad (8)$$

With choosing the k =N/2 in equation (8) we can get the corresponding frequency domain signal, and this frequency is shown in equation (9).

$$F_2[X(n),\frac{N}{2}] = X(n).e^{-j\pi n} = \begin{cases} X(n), & n \text{ is even} \\ -X(n), & n \text{ is odd} \end{cases} \quad (9)$$

As seen in this equation (9), with using of the x signal and its time-domain circular shift F2[x(n), N/2] = x(N − N/2)mod N, the consistent time-domain signal for even and odd parts of X will be got.
Here, F2[x] will attitude for F2[x, N/2]. In equation (10) the odd and even parts of the real and imaginary parts of the original x signal is shown,

$$\begin{aligned} x_{R,E} &= (x_R + F_2[x_R])/2 \\ x_{R,O} &= (x_R + F_2[x_R])/2 \\ x_{I,E} &= (x_I + F_2[x_I])/2 \\ x_{I,O} &= (x_I + F_2[x_I])/2 \end{aligned} \quad (10)$$

So, the time-domain signal can be written as x = [xR,E, xR,O, xI,E,xI,O]. Mean xi = IFFT[Xi], anywhere Xi attitudes for the ith candidate for the conventional selected mapping scheme. In this paper, the corresponding sub sequences of the signal will be exchanged. With two time-domain candidates x1 and x2, the corresponding sub-block has the information of the original part. If we suppose an example, the first part x1R,E is generated by the original signal XR,E where x1R,E = IFFT[XR, E]; x2R,E can be written as

$$x^2_{R,E} = IFFT[X^2_{R,E}] = IFFT[X_{R,E} \otimes P^2] \quad (11)$$

We can obtain two candidates by performing the swapping for the first sub-block. That is, the original signal

$$x^1 = [x^1_{R,E}, x^1_{R,O}, x^1_{I,E}, x^1_{I,O}] \quad (12)$$

and

$$x^2 = [x^2_{R,E}, x^2_{R,O}, x^2_{I,E}, x^2_{I,O}]. \quad (13)$$

Obviously, the two candidates have different PAPR performance. The same operations are performed for all other sub-blocks. Using the swapping of all the subsequences for the two signals, we can obtain in total 24=16 candidates. Out of these 24 sequence sets, one of them with a minimum PAPR is selected for transmission. If there are M candidates in the conventional selected mapping scheme, a total of M4 candidates will be obtained by swapping all the subsequences in the selected mapping scheme. The specific steps of the selected mappping scheme are shown in figure 1.

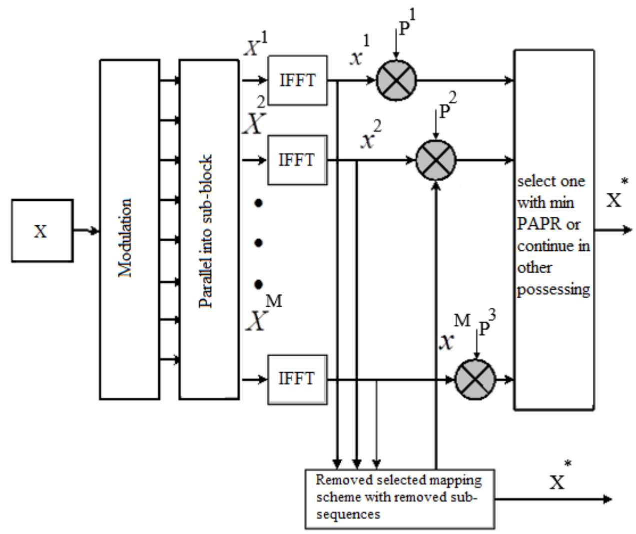


Fig. 1 Block diagram of proposed selected mapping schemes

## 3. Computational Complexity

It is well known that an LN-point IFFT operation requires numbers of complex multiplication and complex addition, which are LN/2 log2 LN and LN log2 LN, respectively. The conventional selected mapping scheme with M4 candidates requires M4 IFFT operations.
Hence, the total numbers of complex multiplication and complex addition are M4LN/2log2LN and M4LNlog2LN, respectively. To generate the same number of M4 candidates, the proposed selected mapping scheme requires M IFFT operations to obtain the time-domain signals and (3M4 −M) LN numbers of complex addition are required to obtain all candidates. Hence, the total numbers of complex multiplication and complex addition are MLN/2log2LN and MLN log2 LN+(3M4−M) LN, respectively.
The computational complexity reduction ratio (CCRR) of the proposed S-SLM scheme over the conventional selected mapping scheme is defined as

$$CCRR = (1 - \frac{\text{Complexity of the selected mapping}}{\text{Complexity of the convolutional mapping}}) \times 100\% \quad (14)$$

## 4. Simulation Result and Discussion

In this section, we simulated and calculated some values of the PAPR schemes as mentioned in previous sections; we also used the QPSK as the modulation scheme. All the simulations were applied using MATLAB 2018a.

Conventional Selected Mapping for PAPR Using CCDF

Simulation results of the PAPR reduction utilizing version different subcarriers are given. The result of conventional selected mapping with M4 = 27is shown in figure 1. This figure shows that PAPR increase when subcarriers are increasing. The function (CCDF) is employed for measuring the efficacy of PAPR technique. We used different subcarriers for N = 64, N = 256 and 1024 with modulation scheme QPSK OFDM system. We observed that CCDF is 10-2 at PAPR 6.459 dB when N = 64, 7.654 when N = 256, 8.589 dB when N = 1024. In Figure 2, PAPR for different $N$ with QPSK is illustrated

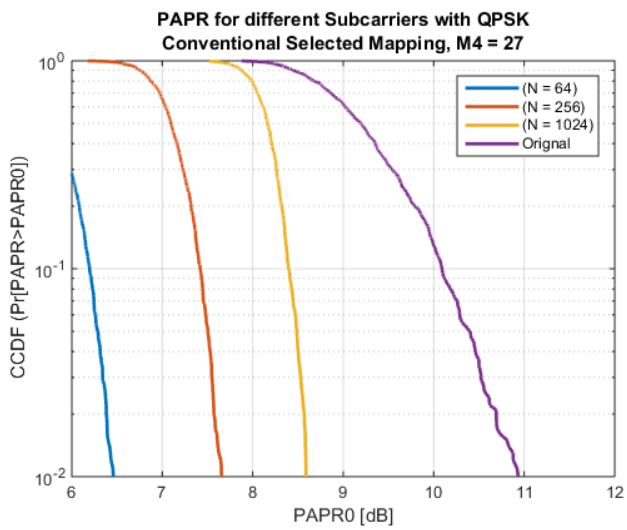


Fig. 2 PAPR for different subcarriers with QPSK (conventional selected mapping with M4 = 27).

In another modulation scheme we used conventional selected mapping with M4 = 8 with different sub-carriers for N = 64, N = 256 and 1024 with modulation scheme QPSK OFDM system. We observed that CCDF is 10-2 at PAPR 7.154 dB when N = 64, 8.207 when N = 256, 9.072 dB when N = 1024. In Figure 3, PAPR for different N with QPSK is illustrated.

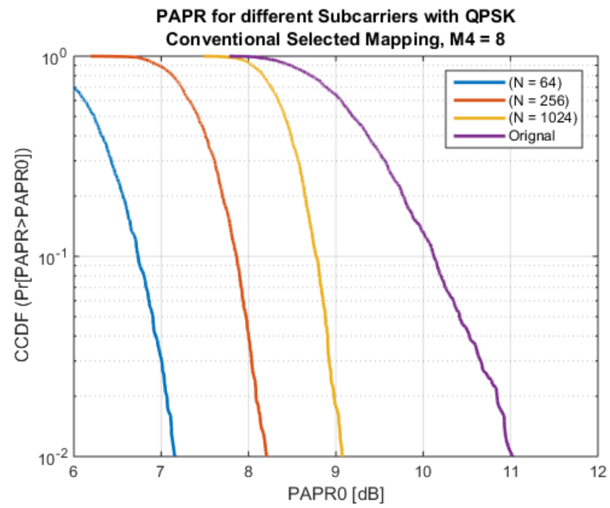


Fig. 3 PAPR for different subcarriers with QPSK (conventional selected mapping with M4 = 8).

Finally, it can be concluded that PAPR increases when subcarriers increase and conventional selected mapping with M4 = 8 gives a better result compared to the conventional selected mapping with M4 = 27.

Remodeled Selected Mapping for PAPR Using CCDF

In another modulation scheme we used remodeled selected mapping with M = 9 with different sub-carriers for N = 64, N = 256 and 1024 with modulation scheme QPSK OFDM system. We observed that CCDF is 10-2 at PAPR 6.717 dB when N = 64, 7.843 when N = 256, 8.782 dB when N = 1024. In Figure 4, PAPR for different N with QPSK is illustrated.

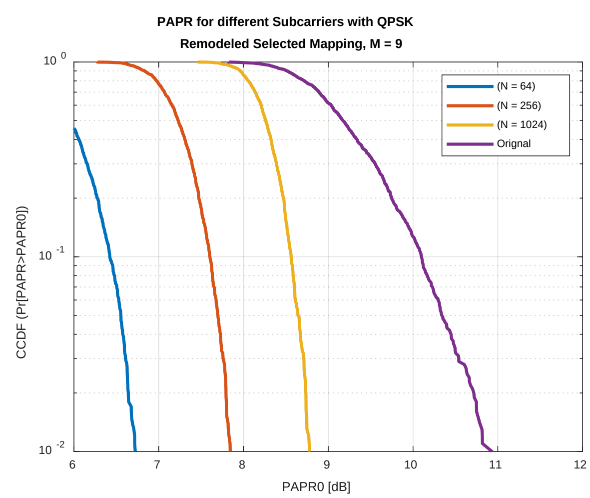


Fig. 4 PAPR for different Subcarriers with QPSK (remodeled selected mapping with M = 9).

In another modulation scheme we used remodeled selected mapping with M = 8 with different sub-carriers for N = 64, N = 256 and 1024 with modulation scheme QPSK OFDM system. We observed that CCDF is 10-2 at PAPR 7.129 dB when N = 64, 8.277 when N = 256, 9.032 dB when N = 1024. In Figure 5, PAPR for different N with QPSK is illustrated.

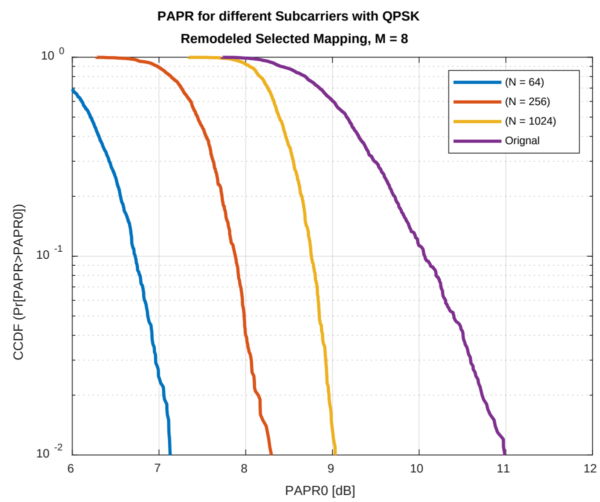


Fig. 5. PAPR for different Subcarriers with QPSK (remodeled selected mapping with M = 9).

The figure 6 shows the CCDF against of the PAPR0 [dB].

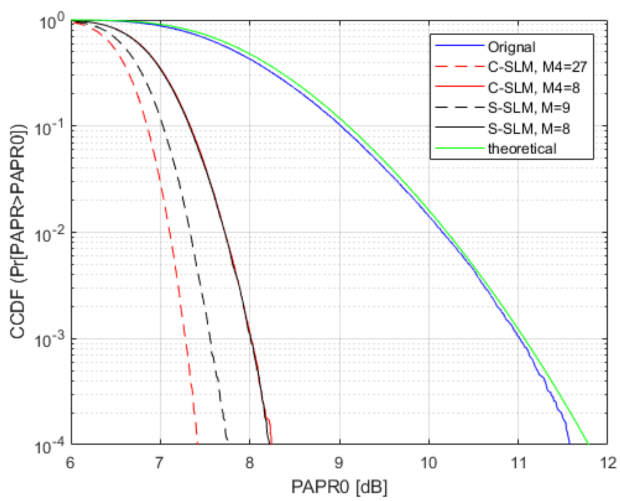


Fig. 6 CCDF against of the PAPR0 [dB]

## 5. Conclusion

In this paper, selected mapping which is an accurate method for reducing peak to average power ratio from orthogonal frequency division multiplexing is used. A fundamental weakness of selected mapping is the high computational complexity. To reduce the complexity of the selected mapping, the real and imaginary part of the OFDM signals is treated separately. Numerical sequences and even real and imaginary elements are obtained using Fourier transform properties. More candidates are produced with a different combination of all the following sequences. The proposed scheme produces less computational complexity using the IFFT algorithm for M4 equations only. The simulation results show that the proposed design reduces the good performance of peak to average power ratio and also reduces computational complexity compared with the selected mapping design.

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