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# PAPR Reduction in OFDM System Based on SLM Technique

**Amit Shukla, Vineeta Saxena Nigam**

***Abstract*— The term OFDM is a special type of FDM which has very vast application in the field of wired and wireless communication systems. In this paper we are discussing about the main problem of OFDM i.e. Peak to Average Power Ratio (PAPR) which affects the performance and efficiency of Power Amplifier. We also discuss various reduction techniques of PAPR for Selective Mapping (SLM) with Inverse Discrete Fourier Transform (IDFT) and Selective Mapping (SLM) with Inverse Fast Fourier Transform (IFFT). In this paper we are dealing with most promising reduction technique SLM with IFFT, its non-uniform phase factor for PAPR reduction in OFDM system. In addition, approximate expression for the complementary cumulative distribution function (CCDF) of the PAPR of the modified SLM technique is derived and compared with the simulation results.**

***Index Terms*—Frequency Division Multiplexing (FDM), Orthogonal Frequency Division Multiplexing (OFDM), Peak to Average Power Ratio (PAPR), Selective Mapping (SLM)**

## I. INTRODUCTION

OFDM is a method of encoding digital data on multiple carrier frequencies. OFDM is a multicarrier modulation technique which is used in broadband wireless communication system like Wi -Max, DVB-T and future 4G because of its various features multipath delay spread tolerance spectral bandwidth efficiency, immunity to frequency selective fading channels [1]. OFDM signals is the superposition of a high number of modulated sub channel signals that may exhibit a high instantaneous signal peak with respect to the average signal level. An OFDM signal consists of a number of independently modulated subcarriers, which can give a large peak to average power ratio and these subcarriers are mutually orthogonal that's why its name occur as orthogonal frequency division multiplexing [2]. OFDM is a combination of modulation and multiplexing. It transforms a signal from frequency domain to time domain. The time domain OFDM signal is constituted by the sum of complex exponential functions, whose amplitudes and phases are determined by the data symbols transmitted over the different carriers. OFDM is a multicarrier system which uses Discrete Fourier Transform (DFT) or Fast Fourier Transform (FFT).The basic principle behind OFDM technique is that high rate data stream is splitting into a number of lower rate data stream and transmit them simultaneously over multiple number of carriers. In OFDM the cyclic prefix is used for lower multi-path distortion.

It uses various interpolation techniques which are linear, second order and time domain [3].

Discrete Multi-Tone (DMT) is a special case of OFDM in which different sub-carriers whose signal to noise ratio (SNR) values is utilized in these ways. The first way is the sub-carrier with high S/N ratio carry more bits and the second one is the sub-carriers with low S/N carry less bits due to frequency selective fading. OFDM is so popular for new broadband systems due to the reason that most broadband system contains multipath transmission and it gives a simple way of dealing with multipath. But this multipath transmission causes some attenuation in the frequencies of the signals; this problem is corrected in the receiver side. OFDM is a special case of FDM [4-5]. As an analogy, a FDM channel is like water which flows out of a faucet while OFDM signal is like a shower. In a faucet all water comes in one big stream and cannot be sub-divided. OFDM shower is made up of a lot of little streams.

In this paper modified SLM technique is used to reduce PAPR. Although we have many other methods to reduce PAPR but the coding comes with an advantage over all of them which is error correction capability, but for this advantage we need to compromise with our transmission efficiency i.e. transmission of some extra bits are done.

The rest of the paper is organized as follows. In section 2, a brief about Orthogonal Frequency Division Multiplexing (OFDM) system and peak average peak ratio (PAPR) is given. In section 3 discuss the modified SLM technique. Section 4 provides the simulation results obtained. Section 5 provides the conclusion obtained.

## II. ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING SYSTEM AND PEAK AVERAGE PEAK RATIO

Now let x (t) and y (t) denote the real and imaginary parts of the output signal. A complex baseband signal, defined over the time interval t ε [0, Ts] can be expressed as

$$\tilde{S} = x(t) + jy(t) \quad \ldots\ldots\ldots\ldots\ldots(1)$$

$$= \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} A_k e^{j2\pi(k/T_S)t} \quad \ldots\ldots\ldots(2)$$

where $A_k$ is the complex data of the $K_{th}$ subcarrier and T is the OFDM symbol period [6].

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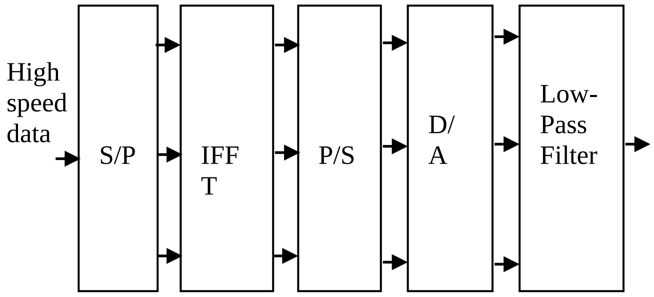


**Figure 1**: Orthogonal Frequency Division Multiplexing (OFDM)
Transmitter, S/P: - Serial to parallel, P/S: - Parallel to Serial, D/A: - Digital to Analog Converter

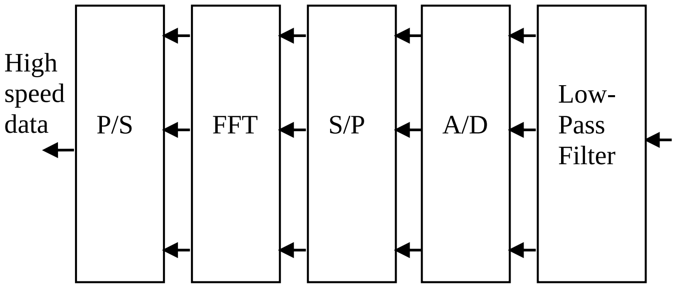


**Figure 2**: Orthogonal Frequency Division Multiplexing (OFDM)
Receiver, A/D: - Analog to Digital Converter

In Figure 1, the transmitter section consist IFFT in which parallel data streams are used as inputs. The output of IFFT is the sum of signal samples. It does modulation and multiplexing in one step. In this section cyclic prefix is placed after the IFFT which acts like guard interval and hence equalization becomes easier. IFFT generates the required time domain waveform. Serial to Parallel acts as time to frequency mapper.
Then after passing from filter and A/D converter samples results in baseband signals. In the receiver, pilot signals are used for correcting the magnitude and phase shift offsets of the received symbols. These pilot sub-carriers must be inserted at certain frequencies to equalize the frequency response of a frequency selective channel. In this side of the OFDM system equalizer is required to recover the data.
In Figure 2 the receiver sections, the values of signals contained by pilot sub-carriers. Cyclic prefix is removed in this side. Parallel to Serial acts like a frequency to time mapper.
OFDM has been popularly standardized in many applications such as high performance wireless LAN, IEEE 802.11 (Wi-Fi), in Asynchronous Digital Subscriber Line (ADSL) and in power line communication. It is used in the Australian digital television system. It uses in military application. It has great importance in wireless internet service. It used in WiBro and WiMax services.
Low let us discuss some advantages of OFDM: It has maximum spectral efficiency according to Nyquist rate. It controls overlapping of bands in channels. Its implementation technique is easier because it uses IFFTs. It has perfect synchronization of transmitter and receiver. It is well suited for high bit rate applications. In OFDM system timing recovery is very straight forward. In this system effects of delay spread can be easily compensated using cyclic prefix. It uses efficient bandwidth range.

OFDM also has some disadvantages. The main disadvantage of multicarrier modulation is that it exhibits a high peak to average power ratio. Because of high PAPR two problems occur which are: Problem 1- It increased the complexity of A/D and D/A converters and problem 2 –It reduced the efficiency of RF power amplifier .The other disadvantages are OFDM system is very sensitive for frequency errors, it causes carrier offset problem. It needed higher input back off factor before the peaks in the signal experience significant distortion.
The PAPR of the discrete time baseband OFDM signal is defined as the ratio of the maximum peak power divided by the average power of the OFDM signal.

$$PAPR(a_n) \overset{\Delta}{=} \frac{\max |a_n^2|}{P_{av}(a_n)} \text{.........(3)}$$

$$P_{av}(a_n) = \frac{1}{N}\sum_{n=0}^{N-1} E\{|a_n^2|\} \text{..........(4)}$$

Where E {.} denotes the expected value.

The PAPR (in dB) of the OFDM signal can be defined as

$$PAPR = 10\log_{10}\{\frac{P_{peak}}{P_{avg}}\} \text{.........(5)}$$

Where, $P_{avg}$ is the average power consumed by each frame, and $P_{peak}$ is the maximum of power for one OFDM frame. When BPSK modulation is used on each subcarrier, binary block coding can be directly implemented before modulation. If the power in each subcarrier is normalized to 1 W, $P_{avg}$ is $N$ W. So the PAPR of uncoded BPSK OFDM systems with a frame size of $N$ is equal to $10\ log_{10}(N)$ (dB) [7, 8].
The PAPR puts a stringent requirement on the power amplifier and reduces the efficiency in the sense that a higher input back off factor is needed before the peaks in the signal experience significant distortion due to power amplifier nonlinearity.

## III. MODIFIED SELECTED MAPPING TECHNIQUE

- ***SLM Technique with IDFT***

This technique has ability to reduce PAPR which depends upon the number of required bits and their design. SLM can produce multiple times domain OFDM signal that are asymptotically independent .SLM generate several OFDM signals in a special manner and select the lowest PAPR for actual transmission .The number of required bits as side information in this technique is less. This technique does not increase the power of OFDM signal but bandwidth expansion occurs. The implementation complexity of this method is high. This technique gives output distortion lessly. The model of this technique consist moderate complexity. In SLM one favorable transmit signal is selected by the transmitter from a set of sufficiently different signals which all represents the same information.


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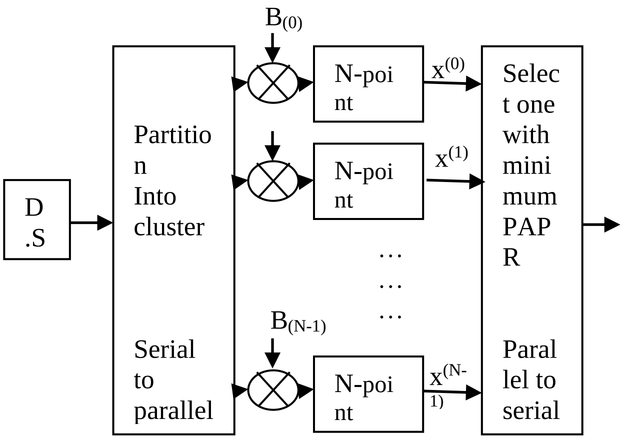


Figure 3: Block Diagram of OFDM Transmitter with the SLM Technique. D.S.- Data Source

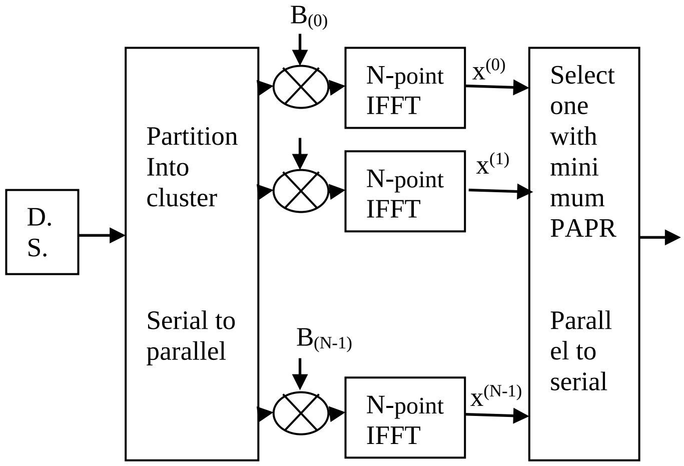


Figure 4: Block Diagram of OFDM Transmitter with the Modified SLM Technique

To begin with, we briefly review the ordinary SLM technique [9]. Shown the block diagram of SLM technique in Figure 3, at first, input data is partitioned into a data block Y of length M. Then the OFDM data block is multiplied element by element with phase sequences

$$A^{(u)} = transpose[A_{u,0}, A_{u,1}, \cdots A_{u,N-1}] .........(6)$$

U=1, 2, 3 …U to make the U phase rotated OFDM data blocks.

SLM technique needs U IDFT operations for each OFDM data block and the number of required side information bits is [$\log_2$U] where [A] denotes the smallest integer which does not exceed A. The phase sequences are selected in a way such that the phase rotated OFDM data blocks are 'sufficiently' different.

- ***Modified SLM Technique with IFFT***

Figure 4 shows the block diagram of the modified SLM technique. In this technique changes the block of N-point inverse discrete fourier transform (IDFT) to N-point inverse fast fourier transform (IFFT). N-point IDFT has strong disadvantages for some applications

  - Complex
  - Poor Energy Compaction

Energy compaction is the ability to pack the energy of the spatial sequence into as few frequency coefficients as possible this is very important for image compression we represent the signal in the frequency domain high only have transmit 2 if compaction is high, we to a few coefficients instead of the whole set of pixels a much better transform, from this point of view, is the IFFT.

At first, input data is mapped into -ary symbols and then processed by a rate code over. After channel code encoding, data symbols and check symbols are separately mapped to -ary symbols and are grouped into blocks of length. The number of code words required to make an OFDM data block of length is given by

$$M = \frac{N \log_2 P}{n \log_2 q} \}..................(7)$$

## IV. SIMULATION RESULT

The simulation is done for 16 point and 64 point IFFT. Random signals are generated and coded by different coding rates for the SLM technique. The coded signals are then BPSK modulated simply to ease the process. CCDF of PAPR for the 16 point IFFT with U=8 SAM coded signal and uncoded signal are plotted together and observed that uncoded signal has a maximum PAPR of 12.04 dB and this coding scheme can reduce PAPR up to 2.32 dB. As we go for coding rate U=16 with same 16 point IFFT, the uncoded signal have a maximum of 12.04 dB of PAPR and the coded signal can have reduced PAPR up to 1.76 dB. Again for the 64 point IFFT, the uncoded signal has a maximum of 14.40 dB of PAPR.

Hence, it is obvious that, with the increase in the phase rotated (i.e. U) the performance of reducing the PAPR degrades. Also, for higher IFFT points (i.e. for large number(N) of carriers)

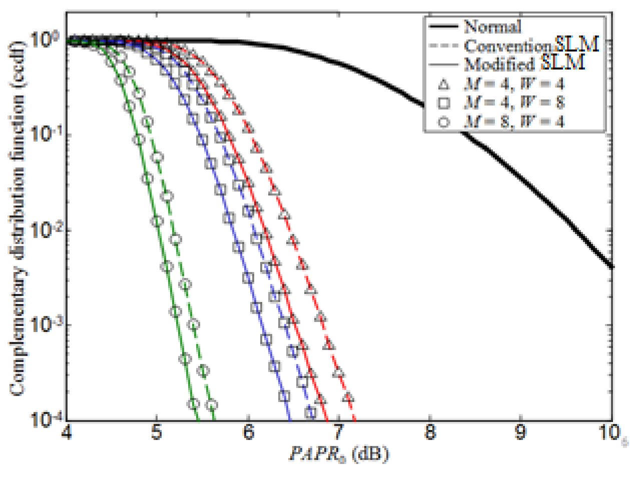


Figure 5: PAPR for 16 point IFFT.


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OFDM signals the PAPR reduction performance by the cyclic coding technique is lower and for lower IFFT points OFDM signal, PAPR is reduced more effectively. PAPR reduction performance is better in 16 point IFFT OFDM signal rather than 64 point IFFT OFDM signal for the same coding rates.

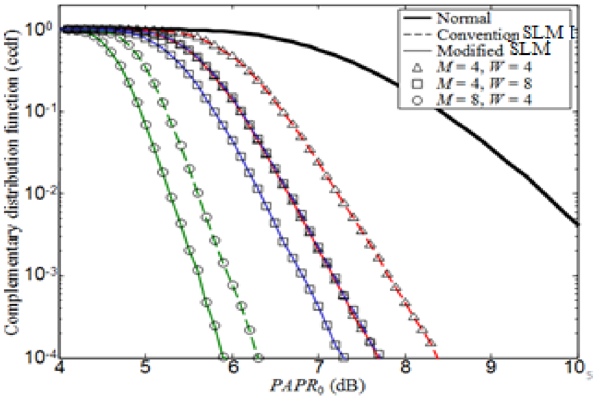


Figure 6: PAPR for 64 point IFFT.

## V.CONCLUSION

Going for lower value of N (number of carriers) for OFDM signal is good practice for having a lower value of PAPR in the signal. We have proposed a modified SLM scheme by applying pre-determined non-uniform phase sets for PAPR reduction in OFDM systems. It must be noted that the optimal set of phase factors can be determined in advance based on system parameters. In this paper, the side information is assumed not to be erroneous for analyzing the pure effect of multiple candidates. The analytical estimation matches well the simulation results, and with this study, we conclude that the more the candidates, not only the better PAPR reduction performance, but also the better error performance and the more gain of channel capacity, under the assumption of side information transmission without error.

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