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# A Comparative Analysis For Peak To Average Power Ratio Reduction In LTE

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## Abstract

*In wireless communications, a multicarrier modulation technique, with high special efficiency and immunity to interference and other advantages, is Orthogonal Frequency Division Multiplexing (OFDM). Even though with many advantages it has disadvantage that the time domain of OFDM signal which is a sum of subcarrier sinusoidal, leads to high Peak to Average Power Ratio (PAPR). The OFDM signal is clipped to a maximum allowed value, at the cost of bit error rate (BER) degradation and out – of band radiation to reduce this PAPR. In other method, Selective mapping method (SLM) technique which is a probabilistic technique for PAPR reduction with aim of reducing the occurrence of peaks in a signal. In this project we are going to simulate Variable length scheme, using the threshold technique using Mat lab, which gives a better simulation results. This simulation compares the results of SLM and clipping methods.*

**Keywords.** *Bit Error Rate (BER) Degradation, Inverse Discrete Fourier Transform (IDFT), Inverse Fast Fourier Transform (IFFT), Orthogonal Frequency Division Multiplexing (OFDM), Variable Length Sequence(V LS), Peak-to-Average power ratio (PAPR) and Selective Mapping Method (SLM).*

## 1. Introduction.

Over the past few years, there has been increasing emphasis on extending the services available on wired public telecommunications networks to mobile/movable nonwired telecommunications users. In OFDM, available bandwidth of high data rate stream is split into N sub streams of lower data rate and into N non-overlapping sub channels by a parallel system. Each sub channel is modulated with the separate symbol and then the end sub channels are frequency multiplexed. This OFDM modulated signal can be expressed as

$$x(t) = \sum_{n=0}^{N-1} X_n \, e^{j2\Pi f_n t} \quad \text{for } (0 < t < T_s) \qquad (1)$$

Here $T_s$ is the duration of an OFDM symbol, 1/ $T_s$ is the distance between subcarriers (or sub channel space) in frequency domain ($\Delta f$) and $S_n$ a block of N data complex symbols chosen from a signal constellation like QAM or PSK. Each subcarrier is located at

$$f_n = n\, T_s \; (0 < n < N\text{-}1) \qquad (2)$$

If the symbol duration and sub channel space maintained at the condition $T_s \; \Delta_0 = 1$, then the orthogonality between the OFDM symbols can be maintained, by this the ICI can be eliminated, but it leads to poor spectral efficiency.

**2. OFDM System.** The word "orthogonal" indicates that there is a precise mathematical relationship between the frequencies of the carriers in the system. OFDM system involves the transmitter & receiver blocks.

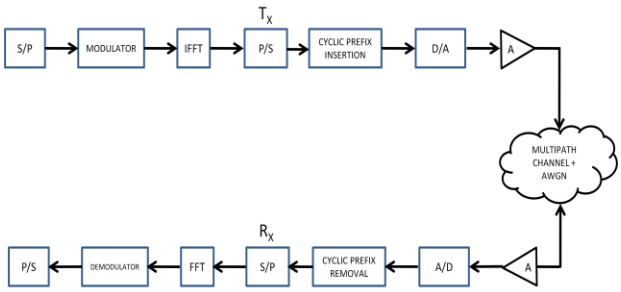



Fig1:Block diagram of OFDM

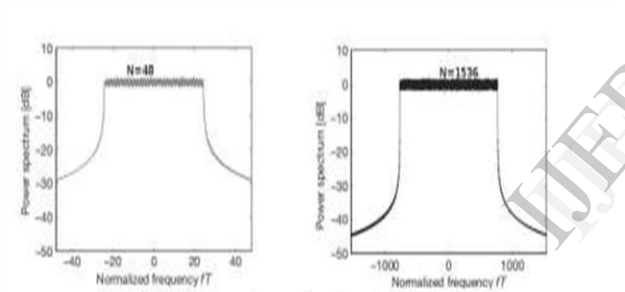



Fig2: OFDM spectrum for N sub carriers

Initial proposals for OFDM were made in the 60's and 70's. It has taken more than a quarter of a century for this technology to move from the research domain to the industry. The concept of OFDM is quite simple but the practicality of implementing it has many complexities. So it is a fully software project.

OFDM is used in many wireless broadband communication systems because it is simple and scalable solution to Inter-Symbol Interference (ISI) caused by a multi path channel.

In a single carrier system a single fade (or) interference can cause the whole link to fail but in multicarrier system, only a few of the total subcarriers will be affected. In this way multi path fading in frequency selective channels which are characterized either by delay spread or by the channel coherence bandwidth, can be eliminated. When the OFDM is transformed to time domain the resulting signal is the sum of all the subcarriers and when all the subcarriers add up in phase, the result is a peak N times higher than the average power which the main disadvantage of OFDM. i.e. the high PAPR. This high PAPR forces the analog amplifier to work in non-linear region distorting the signal and making the amplifier to consume more power and degrades the performance of OFDM signals.

In this paper, a clipping method, selective mapping method and variable length sequence scheme have been simulated. The methods have been simulated with Matlab and the simulation results show that proposed technique performs better than the existing ones with low computational complexity.

## 3. Advantages & Disadvantages.

The OFDM transmission scheme has the following key advantages:

- OFDM is an efficient way to deal with multipath; for a given delay spread, the implementation complexity is significantly lower than that of a single-carrier system with an equalizer.
- In relatively slow time-varying channels, it is possible to enhance capacity significantly by

adapting the data rate per SC according to the signal-to-noise ratio (SNR) of that particular SC.

• OFDM is robust against narrowband interference because such interference affects only a small percentage of the SCs.

• OFDM makes single-frequency networks possible, which is especially attractive for broadcasting applications.

On the other hand, OFDM also has some drawbacks compared with single carrier modulation:

• OFDM is more sensitive to frequency offset and phase noise.

• OFDM has a relatively large peak-to-average-power ratio, which tends to reduce the power efficiency of the radio frequency (RF) amplifier.

## 4. PAPR Reduction schemes.

Presence of large number of independently modulated sub-carriers in an OFDM system the peak value of the system can be very high as compared to the average of the whole system. This ratio of the peak to average power value is termed as Peak-to-Average Power Ratio.

$$\mathbf{PAPR} = \mathbf{10.log_{10}} \frac{\boldsymbol{Max}\{|\boldsymbol{x_n}|^2\}}{\boldsymbol{E}[|\boldsymbol{x_n}|^2]} (\boldsymbol{dB}) \qquad \textbf{(3)}$$

PAPR reduction techniques are two types. They are Distortion based techniques and Redundancy based techniques. In distortion based techniques the time domain signals are directly suppressed for which the power signal exceeds a certain threshold level. Some of the examples of this type are clipping method, Variable length scheme method etc. In Redundancy based techniques number of candidate signals are generated and then selects the one candidate signal which will have lowest PAPR for actual transmission. Some of the examples of this type are SLM method, Tone reservation method, Tone rejection method, etc.

### i) Clipping Method.

Clipping is a nonlinear process and may cause significant in-band distortion and out-band distortion in spectral efficiency. Clipping is a simple method. Presence of large number of independently modulated sub-carriers in an OFDM system the peak value of the system can be very high as compared to the average of the whole system. This ratio of the peak to average power value is termed as Peak-to-Average Power Ratio.



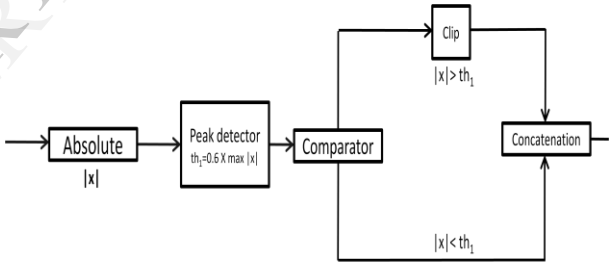



Fig3: Block diagram of clipping method

Let the complex base band of signal is clipped such that the maximum absolute value of x is A that is $|x| = A$, taken absolute of each element of $|x|$ that is $x_1, x_2, x_3, x_4 \ldots\ldots x_n$ and if any x"s exceeds A, it is clipped so that maximum absolute value of x"s is A.

Clipping is accomplished by

$$\mathbf{x = A \ \ if \ \ x > A} \qquad \textbf{(4)}$$

$$x = x \text{ if } x \leq A \qquad (5)$$

After clipping let x be the received signal (assuming no addition of external noise) but due to clipping, there is certain bit error rate (BER).

$$\text{PAPR} = \max\{x^2\} / E[x^2] \qquad (6)$$

### ii) Selective Mapping Method.

SLM is an effective and distortion less technique used for the PAPR reduction in OFDM. The name of this technique indicates that one sequence has to be selected out of a number of sequences. According to the concept of discrete time OFDM transmission we should make a data block considering N number of symbols from the constellation plot. Where N is the number of subcarriers to be used. Then using that data block U number of independent candidate vectors are to be generated with the multiplication of independent phase vectors. Let us consider X is the data block with X (k) as the mapped sub symbol(i.e. the symbol from the constellation). Where k = {0, 1, 2, .....N − 1}. Let the $u^{th}$ phase vector is denoted as $B^{(u)}$,where u = {1, 2, .....U}. The $u^{th}$ candidate vector that is generated by the multiplication of data block with the phase vector is denoted as $X^{(u)}$. So we can write the equation to get the $k^{th}$ element of $u^{th}$ candidate vector as

$$X^{(u)}(k) = X(k)\, B^{(u)}(k) \qquad (7)$$

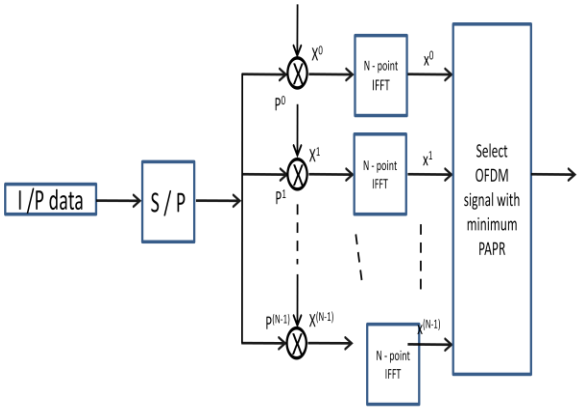



Fig 4 : Block Diagram of SLM technique

SLM method reduces PAPR without any signal distortion but it has higher system complexity and computational burden.

### iii) Variable Length Sequence scheme.

Variable length Sequence scheme method is a distortion less optimization scheme. The Variable length Sequence scheme partitions an i/p data block of N symbols into V disjoint sub blocks.

$$X = [X^0, X^1, X^2, \ldots, X^{V-1}]^T \qquad (8)$$

Where $X^i$ are the sub blocks that are consecutively located.

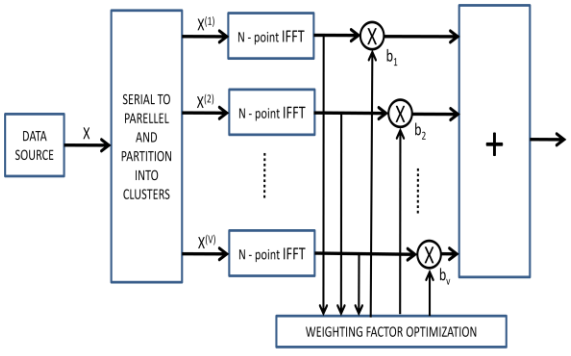



Fig 5:Block diagram of variable length scheme

Each sub block is multiplied by a corresponding complex phase factor $b^{\nu} = e^{j\phi_{\nu}}$ where ν = 1,2,3, …. V. Next taking its IFFT will give,

$$\mathbf{X=IFFT}\ \{\sum_{\nu=1}^{V} \boldsymbol{b^{\nu}}\, \boldsymbol{X^{\nu}}\} \qquad (9)$$

$$= \sum_{\nu=1}^{V} b^{\nu}\, x^{\nu}$$

Where $\{x^{\nu}\}$ is referred to as Variable length scheme argument.

Variable length scheme technique involves V IFFT operations for each data block. The PAPR performance of Variable length Sequence scheme is affected not only by the number of subblocks V, phase factors W but also sub block partitioning.

## 5. PAPR disadvantages.

The major disadvantages of a high PAPR are-

1. Increased complexity in the analog to digital and digital to analog converter.

2. Reduction is efficiency of RF amplifiers.

## 6. Proposed Variable length Sequence Scheme with Low Complexity.

A VLS is presented based on listing the phase factors into multiple subsets table and utilizing the correlation among the phase factors in each subset, in order to reduce the computational complexity.

i. Find the basis vectors of all phase weighting vectors and put them in the first row, note that only one element in the adjacent basis vectors is different.

ii. In each column, the phase weighting vectors have the same basis vector.

iii. For the adjacent phase weighting vectors in the same column, only the sign of one element is different.

iv. The sign of the last phase weighting vectors in one column is the same as the first weighting vectors in the next column.

## 7. Performance Analysis.

By employing the threshold to the PAPR reduction techniques the computational complexity is reduced. The computational complexity of a VLS based can also be reduced by reducing the number of candidate signals, but the computational complexity is reduced at the cost of performance loss for PAPR reduction. Unlike these methods without the loss of performance PAPR can reduced based on the threshold so that if the required PAPR is threshold is fixed, then the candidate signal of the lowest PAPR is only transmitted. The sub block partition method that is used is interleaved partition.

## 8. Simulation result comparison.

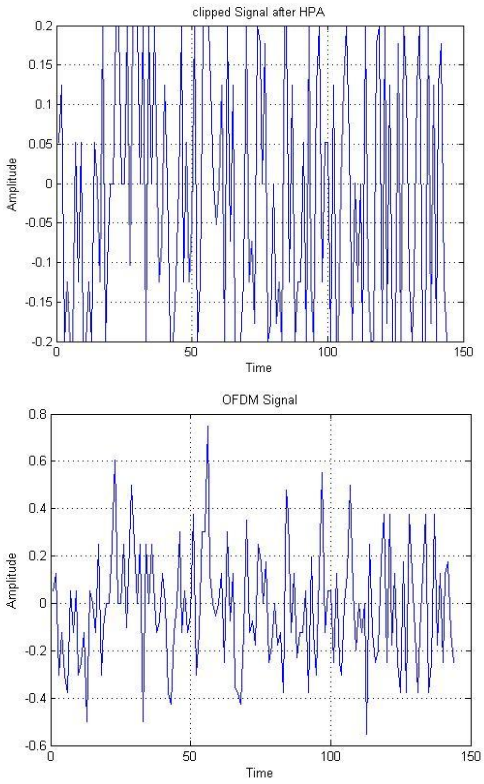
PAPR reduction methods considered:

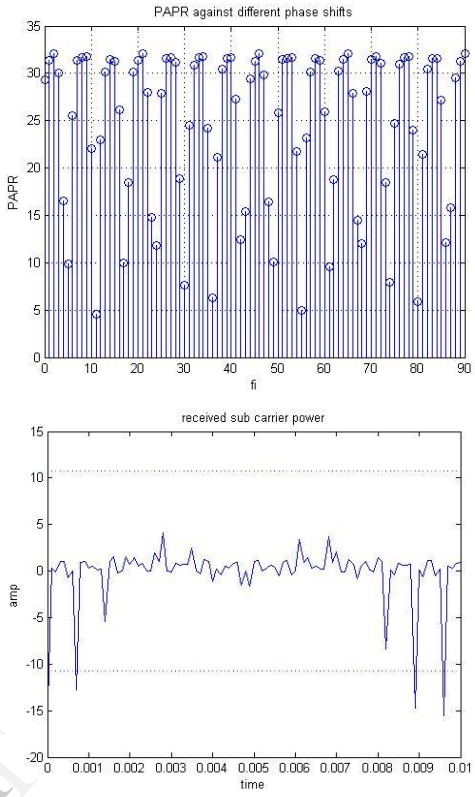
1. Clipping

2. Selective mapping

3. Variable length scheme.

In the first method of clipping, peak-to-average power ratio was reduced but there was substantial data loss. This method can be adopted where retransmission is not a problem. However this method causes in band signal distortion resulting in more errors.



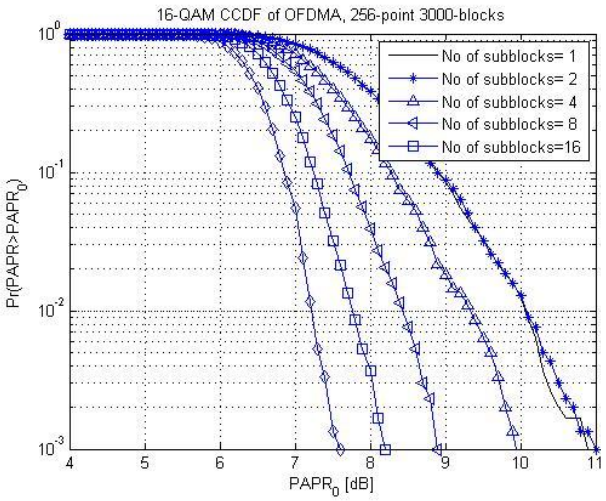




From the graph we can see that at the high power amplifier the ofdm signal is clipped in its amplitude.

Selective mapping is the simplest technique available for PAPR reduction. In this method we need to determine the phase shift where the lowest PAPR occurs. Then that phase will be added to all orthogonal carriers.

From the results of selective mapping we can see that at a phase rotation of 11 degree the PAPR is reduced to its minimum value. So by adding that phase rotation methods the overall PAPR can be reduced for next ofdm signal transmissions.

In variable length sequence method, the data is partitioned into multiple disjoint blocks and scrambling(similar to slm) is applied to each subblock. Then each subblock is multiplied by corresponding phase factor. Later IFFT is taken for multiplexing the subblocks. The performance of system depends on phase factors and no. of subblocks. But it has drawback of searching for optimum phase factor.




The CCDF of PAPR for a 16-QAM/OFDM system using variable length sequence technique as the number of subblock varies is shown. It is seen that the PAPR performance improves as the number of subblocks increases with V =1,2,4,8,16

From the above techniques we can conclude that selective mapping technique has got ease of simplicity and can be practically implemented to reduce PAPR.

| Method | Simplicity | Performance |
|---|---|---|
| Clipping | moderate | poor |
| SLM | Very simple | Good |
| Variable length sequence | complex | >slm |

All the above mentioned schemes must abide to standards of B3G(beyond 3 G) and 4G wireless communications for implementation.

## 9. Conclusion& Forthcomings.

High PAPR of transmitted signal is one of the major drawbacks of OFDM systems. In the VLS scheme, the computational complexity that has been increased extensively with the number of sub blocks, in order to reduce this complexity has been reduced by utilizing the correlation among the candidate signals. In addition to that with the addition of Threshold technique, the PAPR value has been reduced. On comparison with the Clipping method and SLM method the proposed method has given the best PAPR results required.In the OFDM systems the orthogonality can be obtained using the Walsh Hadmard codes, IIFT instead of IDFT.

## 10. Acknowledgement.

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