A Kalman Filter Approach to Reduce PAPR in OFDM Transmission

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ABSTRACT
The OFDM communication is very much inspired from the channel frequencies over the network. In such network some kind of orthogonal distortion occurs over the channel called PAPR. Here we will reduce the PAPR using Kalman Filtering. It is basically the statistical measure to identify the non-linearity over the signal. Once the PAPR is analyzed over the signal, this effective PAPR value is reduced from the signal. The work is implemented in Matlab environment. The obtained result shows that the presented work has improved the PAPR effectively.

Keywords
PAPR, OFDM, MIMO-OFDM, KALMAN FILTER.

1. INTRODUCTION
In the last years wireless communications have experienced a fast growth due to the high mobility that they allow. However, wireless channels have some disadvantages, like multipath fading, that make them difficult to deal with. A modulation that efficiently deals with selective fading channels is OFDM. The advancements in digital signal processing and very large scale integrated circuits allow efficient and cost-effective implementation of the FFT operations making OFDM an attractive solution for wireless channels.

Orthogonal Frequency Division Multiplexing (OFDM) is one of the most effective transmission technique adopted by most of the wireless communication. It supports different wireless standards to perform different kind of data communication including the Video, Audio, Text communication. It provide high communication rate with effective success rate [1, 2]. But, when the high speed communication is performed over the signal, the conversion of signal from serial to parallel is performed. When such kind of conversion is performed, from low to high frequency range as well as between different bandwidth, then there are the chances of occurrence of different kind of valunariites over the signal. Once of such impurity over the OFDM is PAPR (Peak to Average Power Ratio).

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2. OFDM SYSTEM
Multiple-input, multiple-output OFDM was developed by Iospan Wireless. Basically, MIMO-OFDM uses OFDM to break up a signal and wirelessly transmit the pieces simultaneously via multiple antennas. The receiver subsequently reassembles the pieces. MIMO-OFDM lets providers offer fixed broadband wireless access systems that don't require a line of sight between transmitter and receiver.

Mathematically, the OFDM signal is expressed as a sum of the prototype pulses shifted in the time and frequency directions and multiplied by the data symbols [2]. An OFDM signal in baseband is defined as:

$$x(t) = \sum_{n=0}^{N-1} (a_n e^{j2\pi f_n t} w(t)) \quad , 0 \le t \le T \qquad (1)$$

Where, a_n denotes the complex symbol modulating the n_{th} carrier, $w(t)$ is the time window function defined in the interval [0, T], N is the number of subcarriers, and T is the duration of an OFDM symbol. Subcarriers are spaced $\Delta f = 1/T$ apart. Each subcarrier is located at:

$$f = \frac{n}{T}, \quad 0 < n < N-1 \qquad (2)$$

In order to maintain the orthogonality between the OFDM symbols, the symbol duration and sub channel space must meet the condition $T.\Delta f = 1$. In equation (1) time-limited complex exponential signals $\{(e^{j2\pi f_n t})_{n=0}^{N-1}\}$ which represent the different subcarriers at $f = \frac{n}{T}$ in the OFDM signal. These signals are defined to be orthogonal if the integral of the products for their common (fundamental) period is zero, that is:

$$\rho_{ki} = \left(\frac{1}{T}\right) \int_0^T e^{j2\pi f_k t} e^{-j2\pi f_i t} dt \qquad (3)$$

$$\rho_{ki} = \left(\frac{1}{T}\right) \int_0^T e^{(\frac{j2\pi kt}{T})} e^{(\frac{-j2\pi it}{T})} dt \qquad (4)$$

$$\rho_{ki} = \left(\frac{1}{T}\right) \int_0^T e^{\left(j\frac{2\pi(k-i)t}{T}\right)} dt \qquad (5)$$

As can be seen from (5),

$$\rho_{ki} = \begin{cases} 1, & i = k \\ 0, & i \neq k \end{cases} \quad (6)$$

Therefore, OFDM signal of the form (1) satisfies the condition of mutual orthogonality between subcarriers in the symbol interval [2]. The k_{th} subcarrier OFDM symbol should be down converted with a frequency of k/T for data modulation, and then integrated over the symbol period [12]. We can assume that $w(t)$ is a rectangular window defined in [0, T] for simplicity.

3. PEAK AVERAGE POWER RATIO

3.1 Introduction to PAPR

The non linearity is one of the major drawbacks for any signal. One of the causes of non linearity is the PAPR. In case of OFDM signal, when high speed communication is performed as well as the signal transformation is been performed, there are possible chances of generation of PAPR over the signal. To achieve the linearity over the signal, it is required to control the PAPR. There are number of existing approaches to reduce the PAPR in OFDM signal. One of such approach is SLM based approach. According to which, the signal is analyzed for the PAPR value over the signal. Once the analysis is performed, the next work is to identify the lowest PAPR value. Now stable the signal respective to this lowest PAPR value [7, 8, and 9].

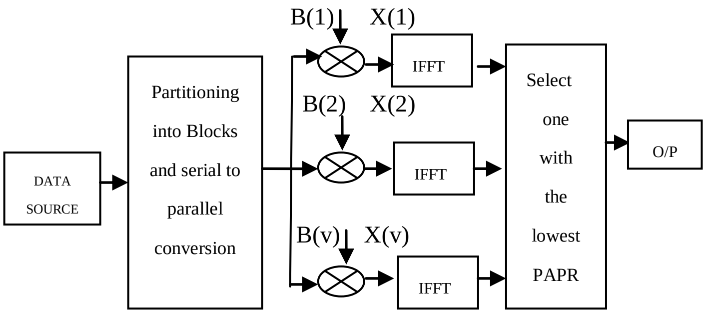


Figure 1: Block Diagram of OFDM transmitter with the SLM Technique

The PAPR is one of very series problem in OFDM signal that basically occur during the transformation of signal from digital to analog and analog to digital. PAPR increases the signal complexity so that the linearity over the signal is reduced. When the amplification is increased in signal, it also decreases the efficiency of the signal [10.11].

High PAPR corresponds to a wide power range which requires more complicated analog-to-digital (A/D) and digital-to-analog (D/A) converters in order to accommodate the large range of the signal power values. Therefore, high PAPR increases both the complexity and cost of implementation. In practical systems, commonly available circuits with a finite range and precision are used, thus introducing non-linear distortion to the reconstructed analog signal [14].

To avoid this distortion, for high PAPR, the RF power amplifiers needs to be operated under large back-offs due to the limited linear region. Thus high PAPR reduces the efficiency of RF power amplifiers. With these two effects degrading the system performance, we should try to keep away from high PAPR in the system design. Tons of research has been done on the PAPR reduction for OFDM system.

The conventional definition of the PAPR for the OFDM symbol in the time domain **x** may be expressed as

$$PAPR(x[n]) = \frac{\max(|x[n]|)^2}{E(|x[n]|^2)} \quad (7)$$

Where $E(.)$ denotes expected value of random variable. [8]

PAPR reduction techniques vary according to the needs of the system and are dependent on various factors. PAPR reduction capacity, increase in power in transmit signal, loss in data rate, complexity of computation and increase in the bit-error rate at the receiver end are various factors which are taken into account before adopting a PAPR reduction technique of the system.

3.2 PAPR Reduction Techniques

There are a numbers of techniques are available to reduce PAPR in OFDM system those are as follows:

- Block Coding Techniques
- Block Coding Scheme with Error Correction
- Selected Mapping (SLM)
- Interleaving Technique
- Tone Rejection (TR)
- Tone Injection (TI)
- Clipping and Filtering
- Partial Transmit Sequence (PTS)
- Kalman Filter (Proposed)

In this section, we will discuss mainly last three techniques.

i. Clipping and Filtering

The simplest and most widely used technique of PAPR reduction is to basically clip the parts of the signals that are outside the allowed region [a11]. For example, using HPA with saturation level below the signal span will automatically cause the signal to be clipped. For amplitude clipping, that is

$$C(x) = \begin{cases} x, & x \le A \\ A, & x > A \end{cases} \quad (8)$$

Generally, clipping is performed at the transmitter. However, the receiver needs to estimate the clipping that has occurred and to compensate the received OFDM symbol accordingly. Typically, at most one clipping occurs per OFDM symbol, and thus the receiver has to estimate two parameters: location and size of the clip. However, it is difficult to get this Information. Therefore, clipping method introduces both in band distortion and out of band radiation into OFDM signals, which degrades the system performance including BER and spectral efficiency. Filtering can reduce out of band radiation after clipping although it cannot reduce in-band distortion. However, clipping may cause some peak re-growth so that the signal after clipping and filtering will exceed the clipping level at some points. To reduce peak re-growth, a repeated clipping-and-filtering operation can be used to obtain a desirable PAPR at a cost of computational complexity increase. As improved clipping methods, peak windowing schemes attempt to minimize the out of band radiation by using narrowband windows such as Gaussian window to attenuate peak signals.

ii. Partial Transmit Sequence (PTS)

In a typical OFDM system with PTS approach to reduce the PAPR, the input data block in X is partitioned into M disjoint sub blocks, which are represented by the vectors $\left\{X^{(m)}, m = 0,1,2,.....,M-1\right\}$. Therefore, we have

$$X = \sum_{m=0}^{M-1} X^{(m)} \quad (9)$$

Where $X^{(m)} = [X_0^{(m)}, X_1^{(m)}, ...X_{N-1}^{(m)}]$ with $X_k^{(m)} = X_k$ or 0 $(0 \le m \le M-1)$. In general, for PTS scheme, the known sub block partitioning methods can be classified into three categories: adjacent partition, interleaved partition and pseudo- random partition. Then, the sub blocks $X^{(m)}$ are transformed into M time-domain partial transmit sequences

$$x^{(m)} = [x_0^{(m)}, x_1^{(m)}, ...x_{LN-1}^{(m)}] = IFFT_{LN \times N}[x^{(M)}] \quad (10)$$

These partial sequences are independently rotated by phase factors $b = \left\{b_m = e^{j\theta m}, m = 0,1,...,M-1\right\}$. The objective is to optimally combine the M sub blocks to obtain the time domain OFDM signals with the lowest PAPR

$$\bar{x} = \sum_{m=0}^{M-1} b_m x^{(m)} \quad (11)$$

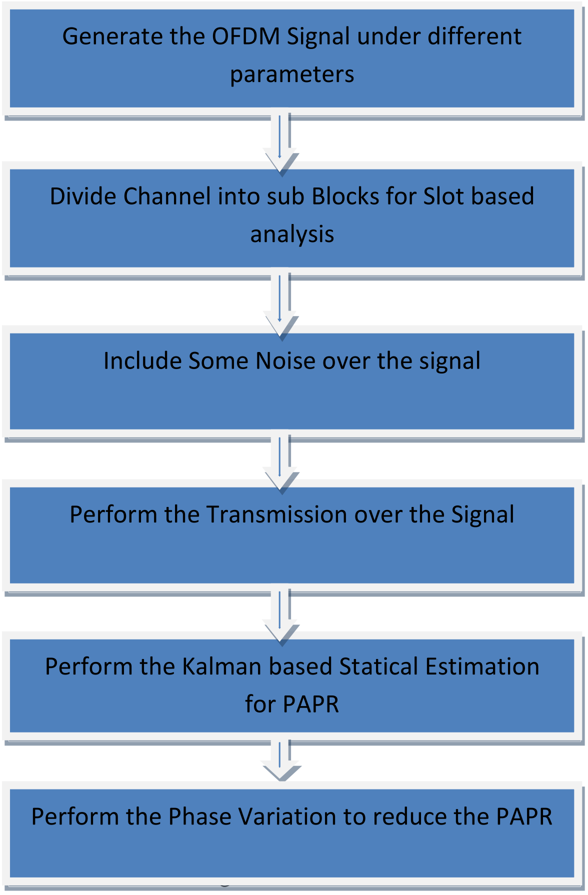
Therefore, there are two important issues should be solved in PTS: high computational complexity for searching the optimal phase factors and the overhead of the optimal phase factors as side information needed to be transmitted to receiver for the correct decoding of the transmitted bit sequence.

4. PROPOSED WORK USING KALMAN FILTER

In radio communication systems, filtering is a desirable factor. As radio communication signals are often corrupted with noise, a good filtering algorithm is required to remove noise from electromagnetic signals while retaining the useful information. Kalman Filtering is an effective method to filter impurities in linear systems. The Kalman filter basically consists of a set of mathematical equations that provides an efficient computational means to estimate the state of a process that minimizes the mean of the squared error. It operates recursively on streams of noisy input data to produce statistically optimal results.

In this present work at first the OFDM spectrum is define with the specific parameters. These parameters include the channel length block size, frequency offset etc. Under these all constraint the OFDM signal is generated. As the signal generated it may have some internal interference noise in it. This signal is divided in number of sub blocks as the proposed system is a slot based system and the process will be performed on each slot. The work is about to remove the interference noise and some other errors from the signal. For this some external error is included in the form of Noise. The noise considered here is the Gaussian noise. As in case of data is transmitted in the form of block so that the serial to parallel conversion is performed. As the blocks are defined each block defines the number of bits parallel transferred.

The flow of presented work is shown in figure 2.



Now respective to the subcarrier specification the mapping is performed using the modulation scheme. The modulation considered here includes the BPSK, QPSK and the QAM. While specifying the modulation scheme the number of combination bits is specified. According these bits the mapping vector is generated and the effective communication is performed. Once the modulation is performed the next work is to convert the signal to the time domain. For this conversion the fast Inverse Fourier transformation is performed. Once this conversion is performed now the data is ready for the transmission and the communication is performed.

The equations used in Kalman filter are called as Time Update and Measurement Update equations as given below:

Time Update Equations are as follows:

$$\hat{x}_k^- = A\hat{x}_{k-1} + Bu_{k-1} \quad (12)$$

$$P_k^- = AP_{k-1}A^T + Q \quad (13)$$

Measurement Update Equations are as follows:

$$K_k = P_k^- H^T \left(HP_k^- H^T + R \right)^{-1} \quad (13)$$

$$\hat{x}_k = \hat{x}_k^- + K_k \left(z_k - H \hat{x}_k^- \right) \quad (14)$$

$$P_k = \left(I - K_k H \right) P_k^- \quad (15)$$

The presented work is based on the kalman filter. The first layer is about to identify the PAPR over the signal. To identify the PAPR the statistical analysis is performed and based on this analysis the PAPR is identified. As we know maximum the PAPR more nonlinearity over the signal exist. Now to reduce the PAPR the phase variation is performed over the signal. This process will improve the linearity factor over the signal.

5. SIMULATION & RESULTS

In this section, we present the results of computer simulations used to evaluate PAPR reduction capability. In the simulation, an OFDM system with a sub-carrier of N = 128,512 and QAM modulation was considered. We can evaluate the performance of the PAPR reduction scheme using the complementary cumulative distribution (CCDF) of the PAPR of the OFDM signal.

Table no. 1 shows comparison among various PAPR reduction schemes. **Figure** 3 and **Figure 4** shows the PAPR reduction in OFDM systems by using PTS scheme and Kalman Filter scheme. If we compare both the figures we see that Kalman Filter outperforms PTS scheme. The value of PAPR in case of PTS scheme at CCDF 10^{-4} is 7.8 db while in companding scheme it is 4.8 db thus from this comparison we see that Kalman Filter scheme provides better results than PTS scheme.

The presented work is implemented in Matlab 7.8 environment and the obtained results from the system are given as under. The parameters taken for presenting work are given as under:-

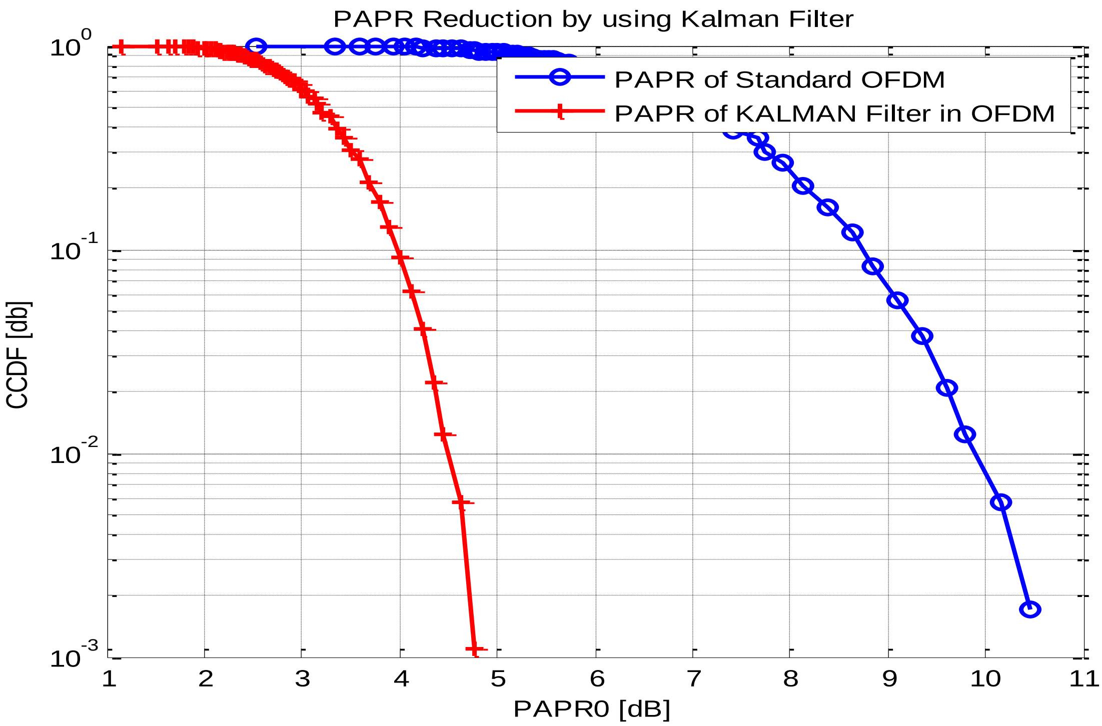


Fig 3: PAPR's CCDF by using PTS scheme

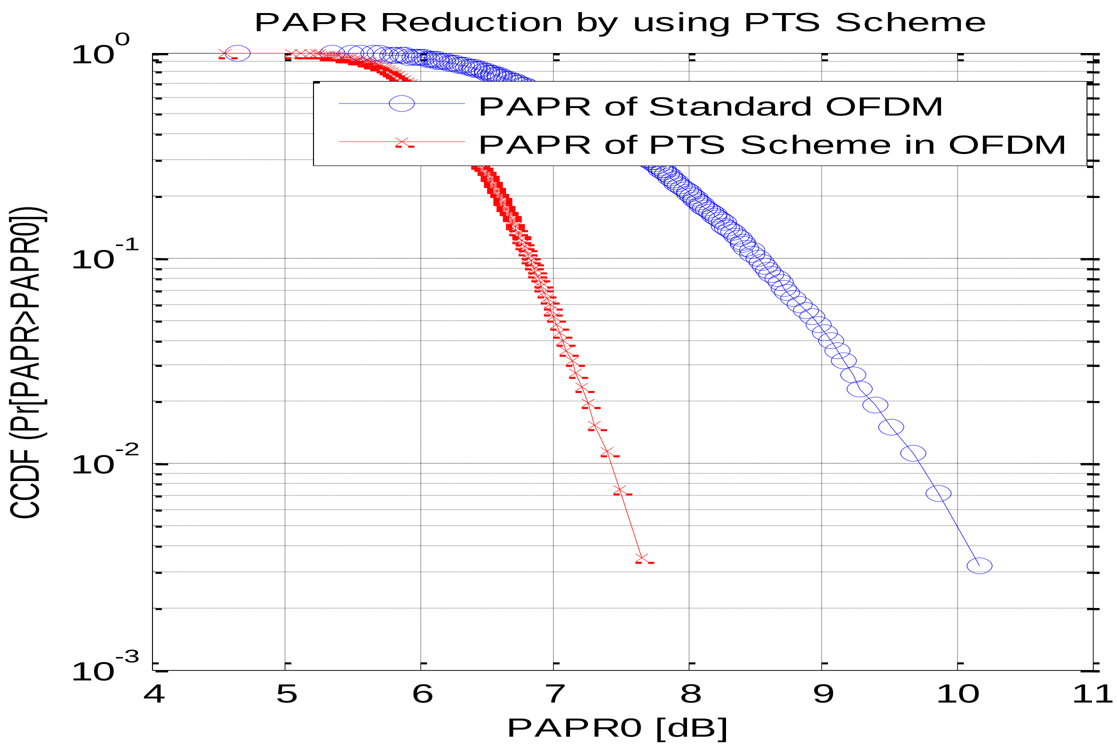


Fig 4: PAPR's CCDF by using Kalman Filter scheme

S.No.	PAPR Scheme	PAPR in dB
1.	Zadoff-chu of Matrix Scheme in OFDM system	10 dB
2.	Partial Transmission Scheme in OFDM system	7.8 dB
3.	Proposed scheme with Kalman filter in OFDM system	4.8 dB

Table 1 Comparison among various PAPR reduction schemes.

From the above Table 1 we see that proposed scheme provide better results among all other schemes.

6. ACKNOWLEDGMENTS

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7. REFRENCES

[1] Kamal Singh, Abhinav Dogra and Gopal Singh Naryal, "*A New Phase Sequence PAPR Reduction Technique Based On SLM And PTS Techniques*", International Journal of IT, Engineering and Applied Sciences Research (IJIEASR), ISSN: 2319-4413, Volume 1, No. 3, December 2012

[2] Malhar Chauhan, Prof. Abhishek Chobey, "*PAPR Reduction in OFDM system Using Tone Reservation Technique*", International Journal of Computer Technology and Electronics Engineering (IJCTEE) Volume 2, Issue 4, August 2012

[3] epin Magnangana Zoko Goyoro, Ibrahim James Moumouni, Sroy Abouty, "*SLM Using Riemann Sequence Combined with DCT Transform for PAPR Reduction in OFDM Communication Systems*", World Academy of Science, Engineering and Technology 64, 2012.

[4] Abhishek Arun Dash, Vishal Gagrai, "*OFDM Systems and PAPR Reduction Techniques In Ofdm Systems*", 2010.

[5] Mohammad Zavid Parvez, Md. Abdullah Al Baki, "*Peak To Average Power Ratio (Papr) Reduction In Ofdm Based Radio Systems*", 2010

[6] V. B. Malode, Dr. B. P. Patil, "*PAPR Reduction Using Modified Selective Mapping Technique*", Int. J. of Advanced Networking and Applications 626, Volume: 02, Issue: 02, Pages: 626-630 (2010)

[7] Mohit Chandwani, Arjun Singhal, Naga VishnuKanth I, and Vijaykumar Chakka, "*A Low Complexity SLM Technique for PAPR reduction in OFDM using Riemann Sequence and Thresholding of Power Amplifier*", INDICON 2009, 18-20 Dec, 2009. Reference Subject to Publication by IEEE Xplore

[8] V. Vijayarangan, DR. (MRS) R. Sukanesh, "*An Overview Of Techniques For Reducing Peak To Average Power Ratio And Its Selection Criteria For Orthogonal Frequency Division Multiplexing Radio Systems*", Journal of Theoretical and Applied Information Technology, 2009.

[9] S. Y. L. Goff, S. S. Al – Samahi, B. K. Khoo, C. C. Tsimenidis, B. S. Sharif, "*Selected Mapping Without Side Information for PAPR Reduction in OFDM*", IEEE Transactions on Wireless Communications, Vol. 8, No. 7, July 2009.

[10] Xiaodong Zhu, Student Member, IEEE, Tao Jiang, Member, IEEE and Guangxi Zhu, Senior Member, IEEE, "*Novel Schemes Based on Greedy Algorithm for PAPR Reduction in OFDM Systems*," IEEE Transactions on Consumer Electronics, Vol. 54, No. 3, AUGUST 2008.

[11] S. H. Han, J. H. Lee, "*An Overview of Peak – to – Average Power Ratio Reduction Techniques for Multicarrier Transmission*", IEEE Transaction on Wireless Communication, April 2005.

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