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A Hybrid VLM Preceded SLM Technique Using Clipping and Filtering Method for PAPR Reduction in MIMO-OFDM Systems

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ABSTRACT
MIMO-OFDM is an attractive interface for the next generation WLANs, WMAN, 4G and 5G mobile cellular systems. However the performance of the MIMO-OFDM systems is affected by Peak to Average Power Ratio (PAPR). PAPR is the main disadvantage associated with the MIMO-OFDM systems. So far, many techniques have been proposed to reduce the value of PAPR but high PAPR for MIMO-OFDM systems is still a demanding area and a different issue.In this paper, a hybrid VLM precoded SLM scheme using Clipping & Filtering has been proposed to reduce PAPR in MIMO-OFDM systems. And it has been observed that the proposed scheme has achieved a significant gain in PAPR reduction without increasing the system complexity and affecting the error performance of the system.
Keywords*: *MIMO-OFDM, PAPR, SLM.

I. INTRODUCTION

MIMO-OFDM is the foundation for most advanced Wireless LAN and mobile broadband network standards because it achieves the greatest spectral efficiency and, therefore, delivers the highest capacity and data throughput. Orthogonal frequency division multiplexing is a special case in which all the carrier signals are orthogonal to each other. Data throughput enhancement in orthogonal frequency division multiplexing (OFDM) systems are regarded as the promising basis for the future high data rate communication systems because this system provides high spectral efficiency, multi delay spread spectrum tolerance and immunity against frequency selective fading channels . Orthogonal frequency division multiplexing (OFDM) is a special case of frequency division multiplexing (FDM) where all the carrier signals are orthogonal to each other. OFDM enables reliable broadband communications by distributing user data across a number of closely spaced, narrowband sub channels. This arrangement makes it possible to eliminate the biggest obstacle to get reliable broadband communication and inter symbol interference.

OFDM signals exhibit high peak to average power ratio (PAPR), causing MIMO-OFDM signals transmitted on different antennas to exhibit a prohibitively PAPR resulting in-band distortion, undesired spectral spreading, low power efficiency, high cost of the RF power amplifier and large performance degradation of a system due to the non-linearity of high-power amplifier. If the PAPR level can be lowered, the high power amplifier back off value lowers and its operating range also gets reduced which eventually result in high power efficiency. This leads to the prevention of spectral growth and the transmitter power amplifier is no longer confined to linear region in which it should operate. This has a harmful effect on the battery lifetime. Thus in communication system, it is observed that all the potential benefits of multi carrier transmission can be out - weighed by a high PAPR value. A lot of techniques can be used to reduce this PAPR.

Clipping and Filtering is a simplest technique used for PAPR reduction. Clipping means the amplitude clipping which limits the peak envelope of the input signal to a predetermined value. Also, there is a technique called Selective Mapping can be used for PAPR reduction. The basic idea of Selected Mapping (SLM) Techniqueis first generate a number of alternative OFDM signals from the original data block and then transmit the OFDM signal having minimum PAPR. But data rate loss and complexity at the transmitter side are two basic disadvantages for this technique. The reason behind using VLM transform is to reduce the auto correlation of the input sequences before the IFFT operation is applied.

In this paper, a hybrid VLM precoded SLM scheme has been proposed to reduce PAPR in MIMO-OFDM systems. And it has been observed that the proposed scheme has achieved a significant gain in PAPR reduction without increasing the system complexity and affecting the error performance of the system.

II. THE OFDM SYSTEM

Orthogonal frequency division multiplexing (OFDM) transmission scheme is a type of multichannel system that employs multiple subcarriers on adjacent frequencies. These subcarriers are orthogonal to each other and their overlapping maximizes the spectral efficiency without interfering. In OFDM system, a block of N symbols represented as $\{Xn, n = 0,1 \ldots., N-1\}$ is formed with the modulation of each symbol, where N in the block represents the total number of sub-carriers. These sub-carriers are chosen to be orthogonal. So, $fn = n\Delta f$ where Δf is the sub-carrier spacing and $\Delta f = 1/NT$ where NT is the OFDM symbol period. The transmitted OFDM signal after the IFFT operation can be represented as:

$$x(t) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} Xn\, e^{j2\pi fnt}, 0 \leq t \leq NT$$

2.1 PAPR

The transmitted OFDM signal consist N number of independently modulated subcarriers which can give a large PAPR when added up coherently for the whole system. PAPR is defined as the ratio between the maximum power and the average power of the modulated signal. When a large number of signal as N of the same phase are added together, they produce a large PAPR. The PAPR computed from the OFDM signal can be given as:

$$PAPR = \frac{\max_{0 \leq t \leq NT} |x(t)|^2}{1/_{NT} \int_0^{NT} |x(t)|^2}$$

For a baseband OFDM signal with N number of sub-channels has PAPR which is given as:

$$PAPR = 10 \log_{10} N$$

2.2 Discrete Cosine Transform (DCT)

The DCT is a part of sinusoidal unitary transforms group. It is closely relative to Discrete Fourier Transform (DFT). This technique is used to convert signal into elementary signal components. The idea of applying DCT is to reduce the autocorrelation of the input sequence before the IFFT operation is applied. In this transform, the data gets compressed passing through it. This transform is real and orthogonal. The computational formula for DCT of length N can be given as:

$$y(k) = w(k) \sum_{n=1}^{N} x(n) \cos\left(\frac{\pi(2n-1)k}{2N}\right)$$

Where *k=1, 2….N,* and w*(k)* is the scaling parameter.

2.3 Hadamard Transform

The hadamard transform belongs to the generalized class of Fourier Transforms. It performs orthogonal, symmetric, involutive and linear operations on 2^m real numbers. This transform also is used to reduce the effect of PAPR in OFDM systems. The standard orthogonal Hadamard Transform matrix of order *n* can be given as:

$$H_{n*}H_n^t = n*In$$

The Hadamard Transform matrix of order n can be expressed as

$$H_n = H_n \otimes H_{n-1}$$

$$H_n = 1/\sqrt{2} \begin{bmatrix} Hn-1 & Hn-1 \\ Hn-1 & Hn-1 \end{bmatrix}$$

The vector represented as $X=[X_1, X_{2\ldots,} X_n]$ is the modulated OFDM signal which is transformed into a hadamard matrix of order n. Hence, the signal having minimum PAPR is selected for further transmission.

2.4 Selective Mapping

Selected Mapping (SLM) technique is the most promising techniques to reduce Peak to Average Power Ratio(PAPR) of Orthogonal Frequency Division Multiplexing (OFDM) system. The idea of using this technique is based on the phase rotation. The lowest PAPR signal will beselected for transmission from a number of different data blocks which have independent phase sequences but same information at thetransmitter.

2.5 Vandermonde-like matrix (VLM)

VLM is a type of matrix in which each row is in terms of Geometric Progression (GP) i.e. a m*n matrix. The formula for VLM can be given as:

$$V(i,j) = \sqrt{\frac{2}{N+1}} \left(cos\left(\frac{(i-1)(j-1)\pi}{N-1} \right) \right)$$

VLM transform is used to reduce the autocorrelation of the input sequences.

III. PROPOSED WORK

In this paper, a hybrid VLM based SLM scheme has been proposed to reduce PAPR in OFDM systems. The proposed method consists of two techniques i.e. VLM precoded SLM scheme and Clipping & Filtering PAPR reduction technique. It has been observed that the proposed scheme has achieved a significant reduction in PAPR without increasing the system complexity and affecting the error performance of the system. The other advantage of the proposed method is that the computation time has also been reduced.

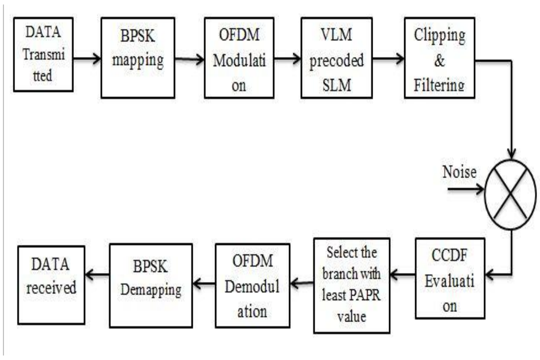

Fig 1: Block diagram of the Hybrid VLM precoded SLM scheme.

IV. SIMULATION & RESULTS

In OFDM systems, to reduce the value of PAPR, DCT, Hadamard Transform and VLM precoded SLM techniques are applied to the OFDM signals and the results are compared with the original OFDM. To further reduce the value of PAPR, Clipping & Filtering technique is combined with VLM precoded SLM technique.

4.1 Clipping & Filtering

Clipping & Filtering is one of the best methods to reduce PAPR value in OFDM systems. In this method, clipping of high peaks in OFDM signal is done before passing it through the power amplifier. A clipper is used I this method which limits the signal envelop to the pre-determined level. That level is known as Clipping Level. If the signal goes beyond the Clipping Level, only then the clipper works. Otherwise it passes the signal without any changes. The clipped signal can be given as:

$$y[n] = \begin{cases} -CL, & if\ x[n] \le -CL \\ x[n], & if\ -CL \le x[n] \le CL \\ CL, & if x[n] > CL \end{cases}$$

The Clipping Ratio (CR) is related to the Clipping Level by the relation:

$$CR = 20\log_{10}\left(\frac{CL}{E[X[n]]}\right)$$

Where *CL* is the Clipping Level and *E[X[n]]* is the average of the OFDM signal.

4.2 CCDF

The Complementary CDF (CCDF) is used instead of CDF, which helps us to measure the probability that the PAPR of a certain data block exceeds the given threshold.
The CDF of the amplitude of a signal sample is given by

$$F(z) = 1 - \exp(z)$$

The CCDF of the PAPR of the data block is desired is our case to compare outputs of various reduction techniques. This is given by

$$\begin{aligned} P(PAPR > Z) &= 1 - P(PAPR \le Z) \\ &= 1 - F(Z) \\ &= 1 - (1 - \exp(Z))^N \end{aligned}$$

4.3 Performance Analysis

The performance of the proposed hybrid scheme is analyzed with the MATLAB simulator. The results are represented in the following graphs and the reduction in PAPR value has been observed.

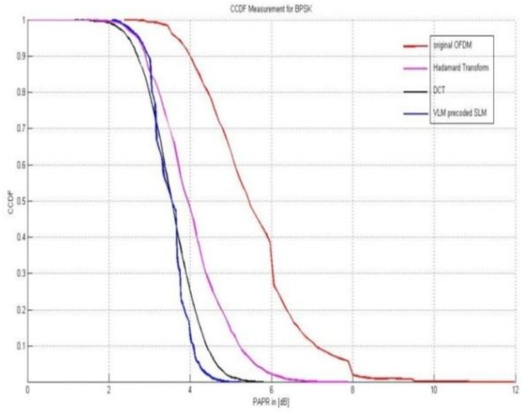

Fig 2: CCDF of PAPR for different techniques in OFDM systems

In OFDM system, CCDF versus PAPR graph is shown above. The graph clearly shows that at CCDF rate of 10^{-3}, the value of PAPR for original OFDM is 9.558 dB. When the Discrete Cosine Transform is applied to the OFDM signal, the value of PAPR decreases by 308dB. After DCT, Hadamard Transform is applied to the original OFDM and the PAPR value decreases by 2.02 dB from PAPR value of original OFDM. Further VLM precoded SLM technique is applied and the value of PAPR decreases by 2.37 dB.

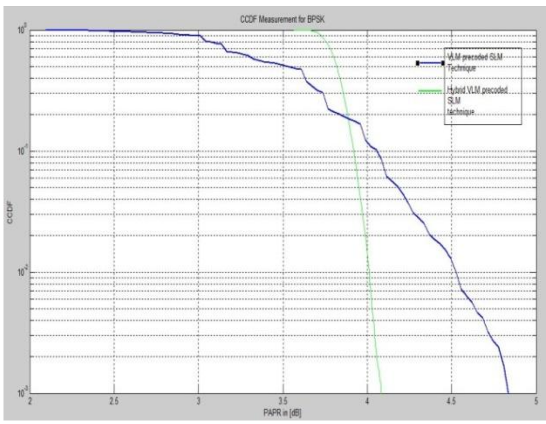

Fig 3: CCDF of PAPR for Proposed hybrid scheme.

When the proposed hybrid VLM based SLM scheme is applied to the original OFDM signal, it has been observed that the value of PAPR further decreases by 0.91 dB.

Table 1: Values of PAPR with different techniques and also proposed method.

Techniques	PAPR value (in dB)
Original OFDM	9.59
Hadamard Transform OFDM	7.35
Discrete Cosine Transform OFDM	5.67
VLM precoded SLM technique OFDM	4.98
Hybrid VLM precoded SLM technique using Clipping & Filtering	4.07

V. CONCLUSION

In this article, a PAPR reduction technique i.e. Clipping & Filtering is combined with the VLM precoded SLM scheme. After the simulation of the hybrid scheme, it is observed that the value of PAPR has reduced to some extent. The PAPR has been reduced by clipping the excessive high peaks and then filtering them from the pass band. This hybrid scheme has provided a good PAPR reduction without increasing the system complexity.

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