Multiple Input Multiple Output Orthogonal Frequency Division Multiplexing (MIMO-OFDM) Based Image Transmission Using Hadamard Transform as PAPR Reduction Technique

Mehboob ul Amin, Randhir Singh, Javaid.A.Skeikh

Abstract: - High data rate wireless communications demands robustness, high spectral efficiency, frequency selective fading, and low computational complexity. Orthogonal Frequency Division Multiplexing (OFDM) is one of the most promising technologies to achieve these goals. OFDM can be used in conjunction with a Multiple-Input Multiple-Output (MIMO) transreceiver to increase the diversity gain and/or the system capacity by exploiting spatial domain. Because the OFDM system effectively provides numerous parallel narrowband channels, MIMO-OFDM is considered a key technology in emerging high-data rate systems such as 4G, IEEE 802.16, and IEEE 802.11n. However there is one main disadvantage of MIMO-OFDM that is the high peak-to-average power ratio (PAPR) of the transmitter's output signal on different antennas. High Peak to Average Power Ratio (PAPR) for MIMO-OFDM system is still a demanding area and difficult issue. By now, for reducing PAPR, numerous techniques have been recommended. In this paper Hadamard Transform based Selective Level Mapping as method of PAPR reduction technique has been proposed and simulated. The whole simulation work has been tested on image signal and the results at both transmitter and receiver have been verified in terms of various graphs and plots.

Index terms: - Multiple Input Multiple Out (MIMO), Peak to Average Power Ratio (PAPR), Orthogonal Space Time Block Code (OSTBC) Encoder, Hadamard Transform, Complementary Cumulative Distribution Function (CCDF).

I. INTRODUCTION

Speedy innovation in communication trends demands high data rates with reliable transmission system and has thus led to many new emerging modulation techniques. Multiple Input Multiple Output (MIMO) in combination with Orthogonal Frequency Division Multiplexing (OFDM) holds the ability to drastically improve spectral efficiency and link reliability in future wireless communications systems.

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In MIMO-OFDM system, a number of antennas are placed at the transmitting and receiving ends and the distances are placed far enough. The idea is to use spatial multiplexing and data pipes by developing space dimensions which are created by multi transmitting and receiving antennas. The transmitted signal bandwidth is so narrow that its frequency response can be assumed as being flat [1] The main advantage of using MIMO-OFDM system include high power spectral efficiency, robustness to channel fading, immunity to impulse interference, uniform average spectral density, capability of handling very strong echoes, lesser non linear distortion and use of small guard intervals [2] It increases system spectral efficiency by adopting the frequency reuse concept. Recently, the use of multiple antennas has been demonstrated to have the potential of achieving extraordinary data rates. Also, MIMO technology can be used to increase system diversity by providing the receiver with several (ideally independent) replicas of the transmitted signal. MIMO-OFDM has been adopted in several wireless standards such as digital audio broadcasting (DAB), digital video broadcasting (DVB-T) and IEEE802.11a [3] local area network (LAN) standard and IEEE802.16a [2] metropolitan area network (MAN).

However one of the main drawback associated with MIMO-OFDM signal is higher peak to average ratio (PAPR) than single carriers do, which causes poor efficiency and system degradation due to inherent non linearity in power amplifiers [4].The non linear effects on the transmitted OFDM symbols are spectral spreading, intermodulation and changing of the signal constellation. In other words the non linear distortion causes both in band and out of band interference to signals [5].

This paper investigates the PAPR reduction of MIMO-OFDM system using Hadamard transform based SLM technique. The whole simulation work has been tested on image signal. The OFDM modulator has been implemented by Inverse Fast Fourier Transform (IFFT). The output of IFFT is given to the OSTBC encoder and Hadamard code is applied after that. The Hadamard code spreads the signal there by reducing the peak. At the receiving end the encoded data is received by OSTBC combiner and demodulated. The demodulated data is then converted back to 8-bit word size data used for generating an output file of the simulation

II. PAPR PROBLEM

The transmit signals in a MIMO-OFDM system can have high peak values in the time domain since many subcarrier components are added via an IFFT operation. Therefore, OFDM systems are known to have a high PAPR (Peak-to-Average Power Ratio), compared with single-carrier systems. The Peak to Average power Ratio can be simply defined as the ratio between the average signal power and the maximum or minimum signal. Mathematically, the PAPR for a given OFDM block can be written as

$$PAPR(x[n]) = \frac{\max_{0\le n\le N-1}|x[n]|^2}{E\{x^2[n]\}} \quad (1)$$

Where $\max_{0\le n\le N-1}|x[n]|^2$ denotes the maximum instantaneous power and $E\{x^2[n]\}$ denotes the average power of the signal. In fact, the high PAPR is one of the most detrimental aspects in the OFDM system, as it decreases the SQNR (Signal-to-Quantization Noise Ratio) of ADC (Analog-to-Digital Converter) and DAC (Digital-to-Analog Converter) while degrading the efficiency of the power amplifier in the transmitter. The PAPR problem is more important in the uplink since the efficiency of power amplifier is critical due to the limited battery power in a mobile terminal .To transmit a signal that has high peaks require from the power amplifier in the transmitter to have a high signal span. Such amplifier consumes high power and is also costly. If the average power of the signal is lowered then this will also lower the peaks that a power amplifier needs to handle. However reducing the average power of the signal will reduce the SNR at the receiver thus degrading performance. If we do not lower the average power of amplifier input signal and allow large peaks to pass through the amplifier, this will introduce nonlinearities into the transmitted OFDM signal. So in order to overcome the problem of high Peak to Average Power Ratio we have two solutions, Amplifier Linearization and PAPR Reduction. The amplifier linearization method is very much costly and high power consuming method because to achieve the linearlized operation the use of High Power Amplifier is required which require high power to operate however several PAPR signal distortion and signal distortion less reduction techniques have been proposed during the last decades with different levels of success and complexity.

III. HADAMARD TRANSFORM

There exist basically two classes of possible solutions which are intended to reduce PAPR. The first is based on coding[6] and second is based on amplitude processing such as level clipping[7]

The clipping technique employs clipping or nonlinear saturation around the peaks to reduce the PAPR. It is simple to implement, but it may cause in-band and out-of-band distortion [8][9] while destroying the orthogonality among the subcarriers. The Hadamard transform reduces the occurrences of high peaks comparing the original OFDM signal and requires no side information to be transmitted [10].The main advantage of using Hadamard transform over clipping process is that latter technique results in both in band and out of band distortion which results in performance degradation of OFDM system [8]. Hadamard transform reduces the PAPR while Bit Error Rate is not increased [11]

The Hadamard transform H_n is a $2^m \times 2^m$ matrix that transforms 2^n real or complex number x_n into 2^n real numbers x_n^* . Every element of Hadamard matrix is either 1or -1. The Hadamard matrix of the order n is stated by

$$H_n = \frac{1}{\sqrt{2}}\begin{bmatrix} H_{n-1} & H_{n-1} \\ H_{n-1} & -H_{n-1} \end{bmatrix} \quad (2)$$

By definition $H_{0=1}$ thus,

$$H_1 = \frac{1}{\sqrt{2}}\begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix} \quad (3)$$

After the sequence X= $[X_1, X_2, \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots X_n]$ is transformed by Hadamard matrix of order N, the new sequence obtained is

Y=HX (4)

The Hadamard code is given after applying IFFT

IV. SIMULATION RESULTS AND DISCUSSIONS

The work carried out in this paper is concerned with simulation of MIMO-OFDM based wireless communication system. In this work the concept and feasibility of an MIMO-OFDM system, have been demonstrated and investigated how its performance is changed by varying some of its major parameters. This objective is met by developing a MATLAB program to simulate a basic MIMO-OFDM system. From the process of this development the mechanism of a MIMO-OFDM system can be studied and with a complete MATLAB program, the characteristics of an OFDM system can be explored. The whole simulation work has been tested on image signal. The input data has been taken as 8- bit gray scale bit map. The image data has been mapped onto symbol size (bits/symbol) determined by the choice of M- array Phase Shift Keying (PSK) from four provided variations (M=2, 4, 8, 16). After performing number of signal processing operations like frame division, serial to parallel conversion and D-PSK modulation, and the output of D- PSK has been given to OFDM modulator which modulates the multiple frames. The OFDM modulator has been implemented by Inverse Fast Fourier Transform (IFFT). Before the exit of the transmitter, the modulated frames of time signal are cascaded together along with frame guards inserted in between as well as a pair of identical headers added to the beginning and at the end of the data stream. The framed output has been given to Orthogonal Space Time Block (OSTBC) encoder, which encodes an input symbol sequence using orthogonal space time block code. It maps the input symbols block-wise and concatenates the output code-word matrices in the time domain. The wireless channel has been modelled by MIMO channel object, the Gaussian White noise and Hadamard code has also been added with the MIMO channel. At the receiving end the encoded data is received by OSTBC combiner which combines the input signal (from all the receiver antennas) and channel estimate signal to extract the soft information of the symbols encoded by an OSTBC Encoder. The receiver then detects the start and end of each frame in the received signal by an envelope detector. Each detected frame of the time signal is then demodulated into the useful data. The demodulated data is then converted back to 8-bit word size data used for generating an output file of the simulation.

A. System Configuration and Parameters

This MATLAB simulation program consists of five files. At the beginning of this simulation MATLAB program, various OFDM parameters and program variables are initialized to start the simulation. Some variables are entered by the user. The rest are either fixed or derived from the user-input and fixed variables. The user input variables include:

1) Input file – an 8-bit gray scale (256 gray levels) bitmap file (*.bmp);
2) IFFT size – an integer of a power of two;
3) Number of carriers – not greater than [(IFFT size)/2 – 2];
4) Digital modulation method – BPSK, QPSK, 8-PSK, or 16-PSK;
5) Signal-to-Noise Ratio in dB.

The number of carriers needs to be no more than [(IFFT size)/2 – 2], because there are as many conjugate carriers as the carriers, and one IFFT bin is reserved for DC signal while another IFFT bin is for the symmetrical point at the Nyquist frequency to separate carriers and conjugate carriers.

B. Performance Evaluation

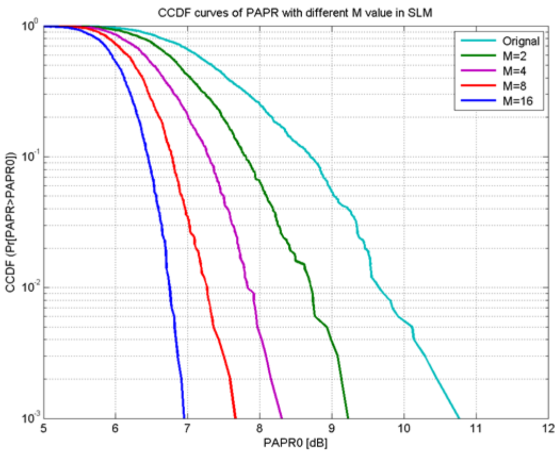


Figure1:-CCDF plot of PAPR for HADARMARD_SLM

Figure 1 shows the simulation result of Hadamard code (Hadamard_SLM) .The PAPR decreases for increasing values of M. The PAPR for M=16 reduces to about 6.97db as signal of 10.8.Thus there is a reduction of 3.73db which is as significant development

C Plotting

Four graphs are plotted during this OFDM simulation:

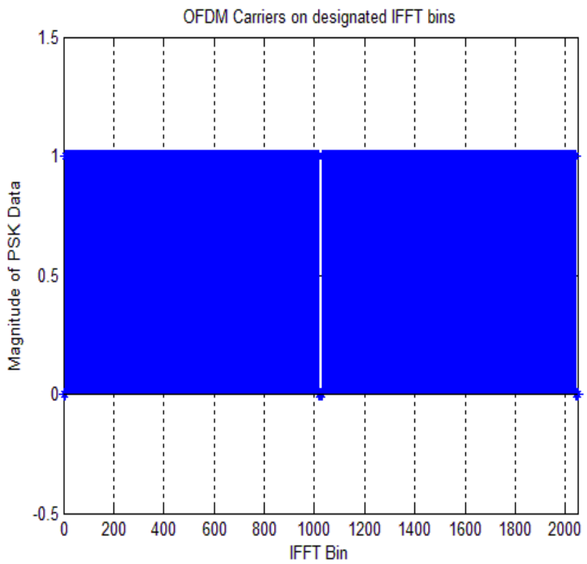
1. Magnitudes of OFDM carrier data on IFFT bins. Since all magnitudes are ONE, what this plot really shows is how the carriers are spread out in the IFFT bins.
2. Phases translated from the OFDM data. In this graph, it's easy to see that the original data has a number of possible levels equal to 2 raised to the power of symbol size.
3. Magnitudes of the received OFDM spectrum. This is to be compared to the first graph.
4. Phases of the received OFDM spectrum. This is to be compared to the second graph

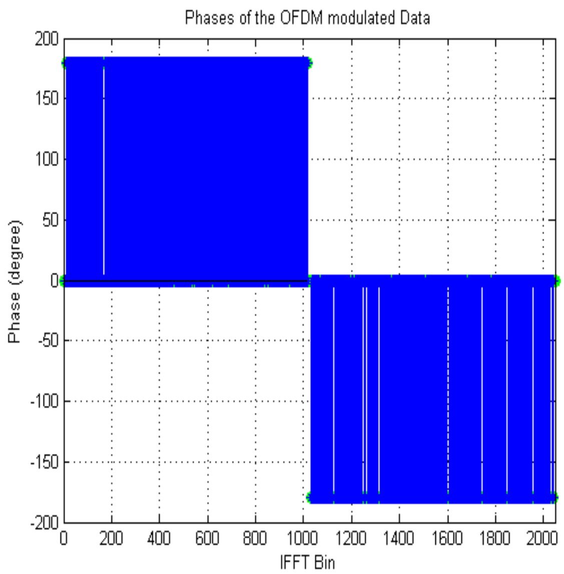
Input And Output Images

Original image

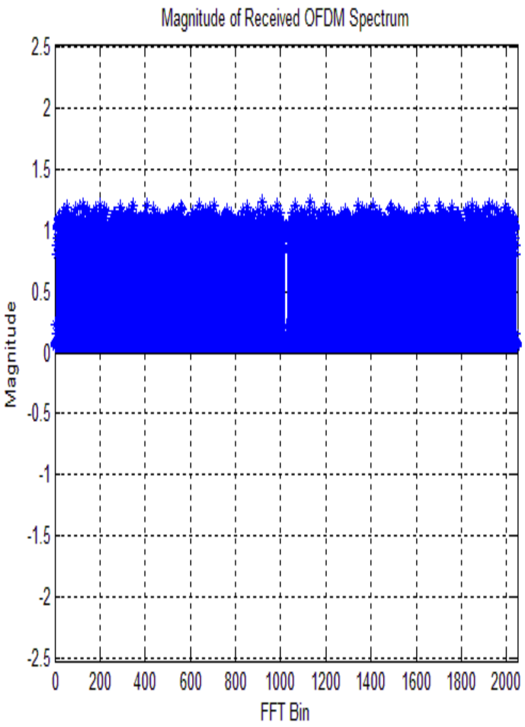
Received image

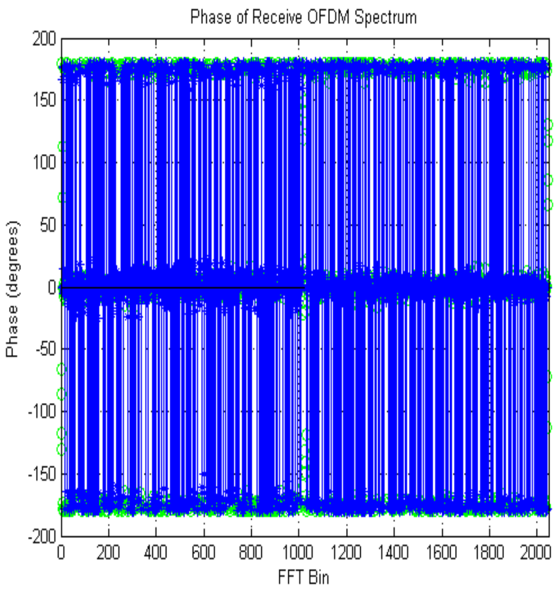
TRANSMITTER PLOTS





RECIEVER PLOTS





CONCLUSION

This paper investigates one of the bottleneck problems that exist in OFDM wireless communication system i.e. High Peak-Average Power Ratio (PAPR of OFDM signal), and discusses how to reduce it by applying Hadamard code. A series of detailed simulations were conducted for comparison and results were obtained for the PAPR reduction in a complex system. Simulation results show that there is a reduction of 3.73 db for M=16 as compared to original OFDM signal. By verifying the plots of transmitter and receiver it is seen that the magnitude of the amplitude of the peak of received OFDM signal is shrinked These results are obtained with bpsk modulation, 2048 IFFT size, and 1009 carriers and with 15 SNR

REFERENCES

[1] N.Chan and G.T,Zhou, “Peak-to-average Power ratio reduction in OFDM with blind selected pilot tone modulation,” Proc.IEEEIntl.conference on Acoustics, speech,and signal processing,Mar 2005

[2] H.Ochiai and H.Imai, “Performance analysis of deliberately clipped OFDM signals,” IEEE Trans commun, vol.50 no1,pp 89-101,Jan 2002

[3] H.Ochiai and H.Imai, “Performance of the deliberate clipping with adaptive symbol selection for strictly band limited OFDM system,” IEEE J.Select.Areas commun,Vol18,no.11,pp.2270-2277,Nov-2000

[4] H.Rohling,T.May, K.Bruninghaus, and R.Grunheid, “Broadband OFDM radio transmission for multimedia applications,” Proc.IEEE,Vol.87,pp 17788-17789

[5] N.Chan and G.T Zhou, “Peak-to-average power ratio reduction in with blind selected pilot tone modulation”IEEE Trans. Wireless commun, vol.5,no.8,pp 2210-2216,Aug.2006

[6] A.E Jones,etal, “Block coding schemes for modulation of peaks to mean envelope Power ratio of multicarrier transmission schemes”, Electronics letters ,vol 30,1994,pp 2098-2099

[7] D.P.G Mestdagh and PMP Spruyt, “A method to reduce the probability of clipping in DMF based transmission,” IEEE Trans on comm. Vol 4,No ,10,Oct 1990

[8] A Zolghadrasli and M.H Ghamat, “An overview of PAPR Reduction Techniques for PAPR Reduction”, Iranian Journal of Electiical and computer Engineering, vol 7,no2 summer 2008

[9] Tao.Jing and Ylyanwu, “An overview of Peak to Average power Ratio Reduction Techniques for OFDM symbols,” IEEE Transactions on Broadcasting,vol.54,no2 ,June 2008

[10] Park.M.Heeyong.j,Cho.N,Hong.D,andKongC., “PAPR reduction in OFDM transmission using Hadamard transform”, IEEE international conference on communication,Vol.1 June 2000 pp 430-433

[11] XiaodangZhu,GuangXizhu,Taojiang, “Reducing the peak to average Power ratio using Unitary Matrix transformation”, IET Communication,2008,3(2) pp, 161-171

[12] “Layered space-Time Architecture for wireless Communication in a Fading Enivironmentwhen using Multi-Element Antennas”, G.J. Foschini,Bell Labs Tech Journal, 1996

[13] “An overview of MIMO Communication-A key to Gigabit wireless,” A.J Paulraj, Gore, Naber and Bolcskei,IEEE Trans Comm,2003

[14] “A simple Transmit Diversity Technique For wireless communications,” Alamounti, IEEE Sel, comm.,1998

[15] “Diversity and Multiplexing: A FundamentakTradeoff in Multiple-Antenna channels,” Zheng and Tsc, IEEE Trans Info Theory, 2003

[16] Yong soo Cho, Jeakwonkin,Won Young Yang,” MIMO – OFDM wireless Communication with MATLAB,” JohWilong and Sons (Asia) PVT Ltd. 2010

[17] G.L Stuber, JR Barry ,S.W.mclaughlin, M.A.Ingram, T.G Pratt, “BroadBAND MIMO-OFDM wireless Communications,” Proceedings of the IEEE, VOL .92 No.2, Februry 2004