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PAPR Reduction in MIMO-OFDM Using Hadamard Transform for Image and Video Transmission

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Abstract:

Orthogonal Frequency Division Multiplexing (OFDM) is one of the most promising technologies to achieve High data rate wireless communications that demands robustness, high spectral efficiency, frequency selective fading, and low computational complexity. The OFDM system effectively provides numerous parallel narrowband channels, can be used in conjunction with a Multiple-Input Multiple-Output (MIMO) trans receiver to increase the diversity gain and/or the *system capacity by exploiting spatial domain. MIMO-OFDM is considered a key technology in emerging high-data rate systems such as 4G, IEEE 802.16, and IEEE 802.11n. OFDM signals suffer from high peak-to-average power ratios (PARs) which lead to power inefficiency in the RF portion of the transmitter. 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 and video signals and the results at both transmitter and receiver have been verified in terms of various graphs and plots.*

Key words: 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).

1. Introduction

With the advance of communications technology comes the demand for higher data rate services such as multimedia, voice, and data over both wired and wireless links. New modulation schemes are required to transfer the large amounts of data which existing 3rd generation schemes such as Global System Mobile (GSM), its enhanced version Enhanced Data Rates for Global Evolution (EDGE), and Wideband Code Division Multiple Access (WCDMA) cannot support. These new modulation schemes must be able to act over point to point links and in broadcast mode, support bi-directional communications, and be able to adapt to different requirements of individual services in terms of their data rate, allowable Bit Error Rate (BER), and maximum delay. One new modulation scheme which has received significant attention over the last few years is a form of multicarrier modulation called Orthogonal Frequency Division Multiplexing (OFDM) [1].

Orthogonal frequency division multiplexing techniques have been applied in both wired and wireless communications, such as the asymmetric digital subscriber line (ADSL) and the IEEE 802.11 standard [2]. ODFM is a good solution for high speed digital communications [3]. One of the major problems of OFDM signal that may strictly limit its application is its high peak-to-average power ratio (PAPR) [4]. If the number of subcarriers increases, however, the peak-to-average power ratio (PAPR) of the OFDM signal also increases. In many wireless applications, both the peak power efficiency and the bandwidth efficiency are the two most important factors [5]. As one of characteristics of the PAPR, the distribution of PAPR, which bears stochastic characteristics in OFDM systems, often can be expressed in terms of Complementary Cumulative Distribution Function (CCDF) [6].To reduce the PAPR, many techniques have been proposed. Such as clipping, coding, partial transmit sequence (PTS), selected mapping (SLM), interleaving, nonlinear companding transforms, hadamard transforms and other techniques etc. Hadamard transform may reduce PAPR of OFDM signal while the error probability of system is not increased [7]. It directly limits the amplitude of OFDM signals to a desired value [8]. In 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. The organization of this paper is as follow. Section II System Design Model, Simulation results are reported in section III and conclusions are presented in IV.

2. System Design Model

2.1 MIMO-OFDM SYSTEM

Traditionally, multiple antennas (at one side of the wireless link) have been used to perform interference cancellation and to realize diversity and array gain through coherent combining. The use of multiple antennas at both sides of the link offers an additional fundamental gain — spatial multiplexing gain, which results in increased spectral efficiency [9]. MIMO systems may be implemented in a number of different ways to obtain either a diversity gain to combat signal fading or to obtain a capacity gain. Generally, there are three categories of MIMO techniques. The first aims to improve the power efficiency by maximizing spatial diversity. Such techniques include delay diversity, space–time block codes (STBC) and space–time trellis codes (STTC). The second class uses a layered approach to increase capacity. One popular example of such a system is V-BLAST. Where full spatial diversity is usually not achieved. Finally, the third type exploits the knowledge of channel at the transmitter. It decomposes the channel coefficient matrix using singular value decomposition (SVD) and uses these decomposed unitary matrices as pre- and post-filters at the transmitter and the receiver to achieve near capacity [19]. MIMO-OFDM system is "smooth" across tones because the delay spread in the channel is limited. Computational complexity reductions are obtained by performing channel inversion in the case of a minimum mean-squared error (MMSE) receiver. While spatial multiplexing aims at increasing spectral efficiency by transmitting independent data streams, the basic idea of space-time coding is to introduce redundancy across space and time to realize spatial diversity gain at the transmitter. This is achieved by applying forward-error-correction coding and interleaving across tones; most practical systems employ bit-interleaved coded modulation [9].

2.2 PEAK – TO – AVERAGE POWER RATIO (PAPR)

The PAPR is the relation between the maximum powers of a sample in a given OFDM transmit symbol divided by the average power of that OFDM symbol. PAPR occurs when in a multicarrier system the different sub-carriers are out of phase with each other. At each instant they are different with respect to each other at different phase values. When all the points achieve the maximum value simultaneously; this will cause the output envelope to suddenly shoot up which causes a 'peak' in the output envelope. Due to presence of large number of independently modulated subcarriers 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. An OFDM signal consists of a number of independently modulated sub-carriers which can give a large PAPR when added up coherently [3]. Let the data block of length N be represented by a vector $X = [X_0, X_1, \dots, X_{N-1}]^T$ Duration of any symbol X_{N-1} in the set X is T and represents one of the sub – carriers$\{f_n, n = 0,1, \dots, N-1\}$ set. As the N sub – carriers chosen to transmit the signal are orthogonal to each other, so we can have $f_n = n\Delta f$ where nΔf=1/NT and NT is the duration of the OFDM data block X. The complex data block for the OFDM signal to be transmitted is given by

$$x(t) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_n \cdot e^{j2\pi n \Delta f t}, \quad 0 \le t \le NT \qquad (1)$$

The PAPR of the transmitted signal is defined as

$$PAPR = \frac{max|x(t)|^2}{1/_{NT} \int_0^{NT} |x(t)|^2 dt} \qquad (2)$$

Reducing the max|x (t)| is the principle goal of PARP reduction techniques. Since, discrete- time signals are dealt with in most systems, many PAPR techniques are implemented to deal with amplitudes of various samples of x (t). Due to symbol spaced output in the first equation we find some of the peaks missing which can be compensated by oversampling the equation by some factor to give the true PAPR value [21].

2.3 CCDF (Complementary Cumulative Distributive Function)

The Cumulative Distribution Function (CDF) is one of the most regularly used parameters, which is used to measure the efficiency of any PAPR technique [21]. However, 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. And this is given by:

$$CCDF = P_r\ (PAPR > PAPR_0) \tag{3}$$

Where P_r the probability distribution is function and $PAPR_0$ is the threshold value [7]. The CCDF of PAPR can be used to estimate the bounds for the minimum number of redundancy bits required to identify the PAPR sequences and evaluate the performance of any PAPR reduction schemes. We can also determine a proper output back-off of HPA to minimize the total degradation according to CCDF [6].

2.4 HADAMARD TRANSFORM

There exist basically two classes of possible solutions which are intended to reduce PAPR. The first is based on coding and second is based on amplitude processing such as level clippingThe 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 while destroying the orthogonality among the subcarriers [22]. The proposed hadamard transform scheme may reduce the occurrence of the high peaks comparing the original OFDM system. The idea to use the hadamard transform is to reduce the autocorrelation of the input sequence to reduce the peak to average power problem and it requires no side information to be transmitted to the receiver [7]. We assume H is the hadamard transform matrix of N orders, and hadamard matrix is standard orthogonal matrix. Every element of hadamard matrix is either 1 or -1. The hadamard matrix of 2nd order is stated by

$$\mathrm{H}_2 = \frac{1}{\sqrt{2}}\begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix} \quad (4)$$

Hadamard matrix of 2*N* order may be constructed by

$$\mathrm{H}_{2\mathrm{N}} = \frac{1}{\sqrt{2\mathrm{N}}}\begin{bmatrix} \mathrm{H}_\mathrm{N} & \mathrm{H}_\mathrm{N} \\ \mathrm{H}_\mathrm{N} & -\mathrm{H}_\mathrm{N} \end{bmatrix} \quad (5)$$

Where $-H_N$ is the complementary of H_N. Hadamard matrix satisfy the relation

$$\mathrm{H}_{2\mathrm{N}}\mathrm{H}_{2\mathrm{N}}^{\mathrm{T}} = \mathrm{H}_{2\mathrm{N}}^{\mathrm{T}}\mathrm{H}_{2\mathrm{N}} = \mathrm{I}_{2\mathrm{N}} \quad (6)$$

Where H_{2N}^T is the transport matrix, I_{2N} is the unit matrix of 2N order.

After the sequence $X = [X_1\ X_2 \ldots X_N]^T$ is transformed by hadamard matrix of N order, the new sequence is

$$\mathrm{Y} = \mathrm{HX} \quad (7)$$

The Hadamard code is given after applying IFFT [22].

Note that Hadamard transform is an orthogonal linear transform and can be implemented by a butterfly structure as in FFT. This means that applying Hadamard transform does not require the extensive increase of system complexity [13].

3 Simulation Results

In this paper, the work with simulation of MIMO-OFDM that based in wireless communication. This work showed and achieved how the performance changed by varying some of major parameters. This met by developing MATLAB program into simulation system. From processing the mechanism of system can be study with MATLAB program, complete characteristics can be discovering. The simulation has been done to test on video signals. Where video is converted into image frames and the 8x8 block image as the input data. It can be calculated by choosing M- array PSK from four provided variances (M=2, 4, 8, 16). After we put the number to signal processing operations like vision frame, serial to parallel convertor, and D-PSK the output D-PSK is given to OFDM modulator to modulate multiple frames. OFDM modulator performed using inverse fast Fourier transform. Before the exit of the transmitter, the modulated frames or time signal coming in together along with guard frame added in between it as well as to pair of identical headers added to the beginning and the end of data stream. The output of frames given to (OSTBC) encoder, which encode input symbol serial using orthogonal space time block code (OSTBC). It maps input symbol block-wise and concatenates the output code-word matrices in the time domain. The wireless channel designed by MIMO channel element and hadamard code added with MIMO channel. In the end of receiving the encoded data received by (OSTBC) combiner, which combine the input signal from all receiving antennas and channel estimate signal to extract the soft information from encoded symbols by using (OSTBC) encoder. The receiver detects the beginning and the end of each frame in receiving signal by using envelop detector. Each frame detected to time signal will be detected to useful data. The detected data after that changed to8x8 block image that used to generate output file from simulation.

4 Figures

Fig.1: video input

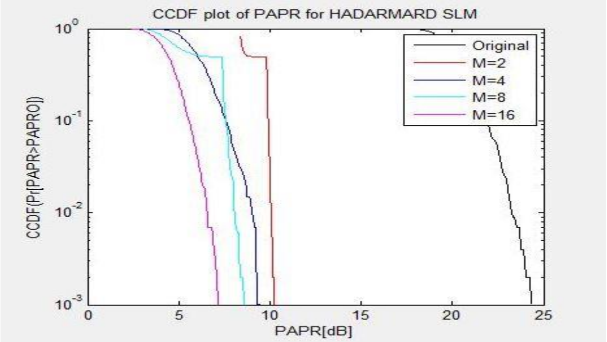

Fig.2: CCDF plot of PAPR for HADARMARD_SLM

Fig.2 shows PAPR values in horizontal axis and CCDF values in vertical axis and from the figure we observe that the original signal have PAPR value (24dB) and if we take M=2 (where M means M-array PSK)we get on PAPR value (10.5dB) and there is reduction in PAPR value about(13.5dB) and when take M=4 we get on PAPR value (9.5dB) and this less than PAPR value of original signal about(14.5dB) and when take M=8 we get on PAPR value (9.0dB) and this less than PAPR value of original signal about(15dB) and finally when we take M=16 we get on PAPR value (7.5dB) and this less than original signal about (16.5dB) and this good development.

5 Conclusion

High PAPR of transmitted signal is one of the major drawbacks of OFDM systems. In this paper, a PAPR reduction scheme based on hadamard transforms. And we discussed how series of detailed simulation that happened in complex system to reduce PAPR. The simulation results show how the PAPR reduced when M= 16 as compared to original OFDM signal. These results are obtained with bpsk modulation, 2048 IFFT size, and 1009 carriers and with 15 SNR.

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