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Research Paper

A NOVEL APPROACH TO REDUCE PAPR IN OFDM SYSTEM USING DHT PRECODNG FOR M-QAM

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The main challenging issue for OFDM Systems is its high PAPR. In this paper a pre-coding based PAPR reduction technique is proposed using Discrete Hartley Transform (DHT). A comparative analysis is done with the proposed method against Walsh Hadamard Transform (WHT) and Discrete Fourier Transform (DFT), and Selective Mapping Method (SLM). Experimental analysis shows that the proposed method out performs when compared with WHT, SLM and Conventional OFDM Systems.

Keywords: OFDM, PAPR, DHT, DFT, WHT, SLM, PAPR

INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) is a multi carrier modulation technique which offers a High Spectral Efficiency, Multipath delay spread tolerance, immunity to the frequency selective fading channels and power efficiency. It provides high speed data rates and robust against narrowband interference. Due to these advantages it has become a technological choice for wired and wireless communication systems (Ramjee Prasad, 2004).

OFDM prevents Inter Symbol Interference (ISI) by inserting a Guard Interval (GI) WITH A Cyclic Prefix (CP), and reduces the frequency selectivity of the Multipath Channel with an equalizer. Which makes simpler design and cheap hardware design. OFDM is widely used in digital audio broadcasting, digital video broad casting, digital subscriber lines, wireless local area networks, wireless metropolitan area networks, wide area networks and in Wireless Asynchronous Transfer Mode, etc.

Though the OFDM is having so many advantages but it suffers from High Peak to Average Power Ratio (PAPR), which is a major drawback of the transmitted OFDM symbols. Due to this high PAPR the high power amplifier is unable to operate in its linear region, to prevent this problem the RF High Power Amplifier (HPF) with a large dynamic range is required, which are very expensive and

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increases the total cost of the system. The high PAPR also increases the complexity of Analog to Digital (A/D) and Digital to Analog (D/A) Converters. So by reducing the High PAPR, we can not only reduce the cost of the system, but also increase the transmitting power and we can achieve improved Signal to Noise Ratio (SNR) for the same range.

So many PAPR reduction methods are available. Among them, constellation shaping, coding methods, nonlinear companding techniques, Tone Reservation and Tone Injection, Clipping and Filtering method, Partial Transmit Sequence (PTS), Precoding based Selected Level Mapping (PSLM) (Ben Slimane, 2007), Precoding based Techniques are most popular (van Nee and and de Wild, 1998; and Tellado-Mourelo, 1999).

In the PTS based PAPR reduction technique proposed by Han and Lee the frequency bins are sub divided into sub blocks and then multiplied by a constant phase shift, which reduces PAPR. A search method is used to find out the optimal phase values (Hee Han and Hong Lee, 2004).

In the clipping technique proposed by Wang and Tellambura, the amplitude is cut off and phase is preserved. But this method is limited to a specific class of modulation techniques (Luqing Wang and Chintha Tellambura, 2005).

In the PSLM based technique for PAPR reduction, Zadoff-Chu based precoder is applied after multiplication of phase rotation factor before the IFFT. This method is signal independent and doesn't require any phase optimisation technique (Homayoun Nikookar and Sverre Lidsheim, 2002; and Varun Jeoti and Imran Baig, 2009).

OFDM AND PAPR REDUCTION

In OFDM, the high speed incoming data stream is sub divided into number of low speed data streams, and are transmitted by a number of Orthogonal Sub Carriers, and at the receiving side the low speed data streams are extracted and then combined to form the original bit stream.

Assumptions

- The data at the input side is available in frequency domain.
- Number of Sub carriers = 64.

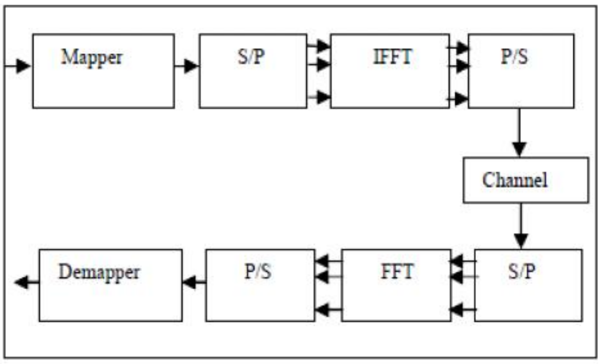
Modulation: Multi carrier Quadrature Amplitude Modulation (M-QAM).

Basic OFDM Block Diagram

Figure 1 Shows the basic block diagram of an OFDM system. Here the Mapper transforms the input bit stream into constellation, corresponding to various modulation techniques.Baseband modulated symbols are passed through serial to parallel converter which generates complex vector of size N. We can write the complex vector of size N as: $X = [X_0, X_1, X_2, \ldots, X_{N-1}]^T$

X is then passed through the IFFT block. The IFFT block converts the frequency domain

Figure 1: Block Diagram of OFDM System



baseband spectrum into its time domain equivalent. The complex baseband OFDM signal with N subcarriers can be written as

$$x_n = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k \cdot e^{-2\pi \frac{n}{N} k}$$

where $k = 0, 1, 2, \ldots, N-1$

Here $j = \sqrt{-1}$ and the PAPR of OFDM signal can be written as follows:

$$PAPR = \frac{\max |x_n|^2}{E\left[|x_n|^2\right]}$$

where $E[\cdot]$ denotes expectation or mean value, Complementary Cumulative Distribution Function (CCDF) for an OFDM signal can be written as:

$$P\left(PAPR > PAPR_0\right) = 1 - \left(1 - e^{-PAPR_0}\right)^N$$

where $PAPR_0$ is the clipping level. This equation can be read as the probability that the *PAPR* of a symbol block exceeds the clipping level $PAPR_0$.

PROPOSED MODEL FOR OFDM PAPR REDUCTION

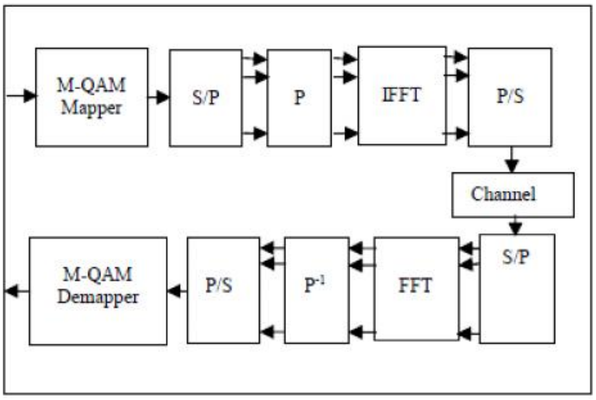
Precoding Matrix Based OFDM System

Figure 2 shows the block diagram of Pre-coding Based OFDM System. We implemented the Pre-coding matrix P of dimension N×N before the IFFT to reduce the *PAPR*.

The pre-coding matrix P can be written as:

$$P = \begin{bmatrix} p_{00} & p_{01} & \cdots & p_{0(N-1)} \\ p_{10} & p_{11} & \cdots & p_{1(N-1)} \\ \vdots & \vdots & \ddots & \vdots \\ p_{(N-1)0} & p_{(N-1)1} & \cdots & p_{(N-1)(N-1)} \end{bmatrix}$$

Figure 2: Block Diagram of Pre IFFT Based OFDM System



where *P* is a Pre-coding Matrix of size N × N is shown in above equation. The complex baseband OFDM signal with *N* sub carriers can be written as:

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

We can express modulated OFDM vector signal with *N* the subcarriers as follows.

$$X_N = IFFT\{P \cdot X_N\}$$

The PAPR of OFDM signal can be written as

$$PAPR = \frac{\max |x(t)|^2}{E\left[|x(t)|^2\right]}$$

Discrete Fourier Transform (DFT) Precoding

The DFT of a sequence of length *N* can be defined as:

$$X(k) = \sum_{n=0}^{N-1} x(n) \cdot e^{-j2\pi nk} \quad k = 0, 1, \ldots, N-1$$

And IDFTfor the above can be written as

$$X(n) = 1/N \sum_{n=0}^{N-1} X(K) \cdot e^{-j2\pi nk} \quad k = 0, 1, \ldots, N-1$$

where $p_{mn} = e^{-j2\pi mn}/N$, $k = 0, 1, \ldots, N-1$

Here the 'm' and 'n' are integers from 0 to N-1 and the precoding matrix is of size N x N given by equation (–).

The Discrete Hartley Transform (DHT) Precoding

The discrete Hartley transform is a linear, invertible function H: $R^n \rightarrow R^n$ (where R denotes the set of real numbers). The N real numbers $x_0, ..., x_{N-1}$ are transformed into the N real numbers $H_0, ..., H_{N-1}$. The N point DHT can be written as:

$$H_k = \sum_{n=0}^{N-1} x_n \left[\cos\left(\frac{2\pi nk}{N}\right) + \sin\left(\frac{2\pi nk}{N}\right)\right]$$

$$= \sum_{n=0}^{N-1} x(n) \cdot cas\left(\frac{2\pi nk}{N}\right)$$

where $cas\,\theta = \cos\theta + \sin\theta$ and $k = 0, 1, ..., N$-1

$$p_{m,n} = cas\left(\frac{2\pi mn}{N}\right)$$

P is the pre-coding matrix of size N × N. m and n are integers from 0 to N-1. The DHT is also invertible transform which allows us to recover the X_n from H_k and inverse can be obtained by simply multiplying DHT of H_k by 1/N.

SIMULATION RESULTS

The randomly generated data is modulated by M-QAM (where M = 16, 32, 64, 256), PAPR Analysis these modulated symbols are simulated and plotted in MATLAB. Here we have compared the performance of the DHT Precoding with DFT Precoding, WHT-Precoded OFDM, SLM OFDM and with the Original OFDM Systems.

Figure 3 shows the performance analysis for M = 16. Which gives that the DHT Precoding gains 3, 2.4, 1.99 db over OFDM-Original, WHT-Precoding and SLMPrecoding

Figure 3: CCDF Comparison of DHT-Precoder Based OFDM System with DFT-Precoder Based OFDM System, WHT-Precoder Based OFDM System, SLM-OFDM (V = 2) System and OFDM Original System for 16-QAM

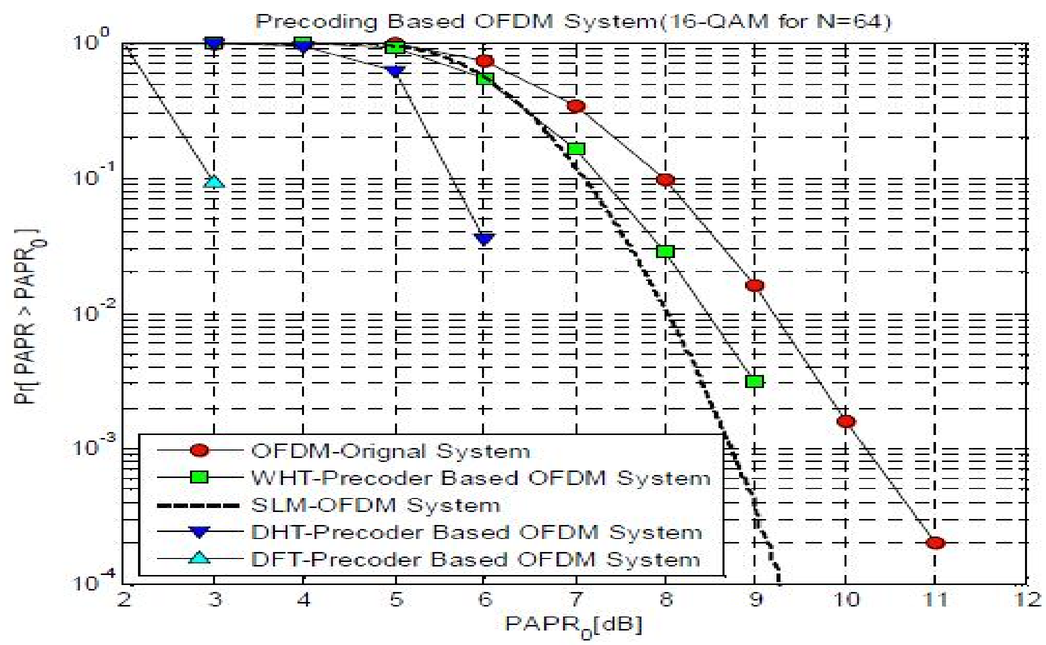


Figure 4: CCDF Comparison of DHT-Precoder Based OFDM System with DFT-Precoder Based OFDM System, WHT-Precoder Based OFDM System, SLM-OFDM (V = 2) System and OFDM Original System for 32-QAM

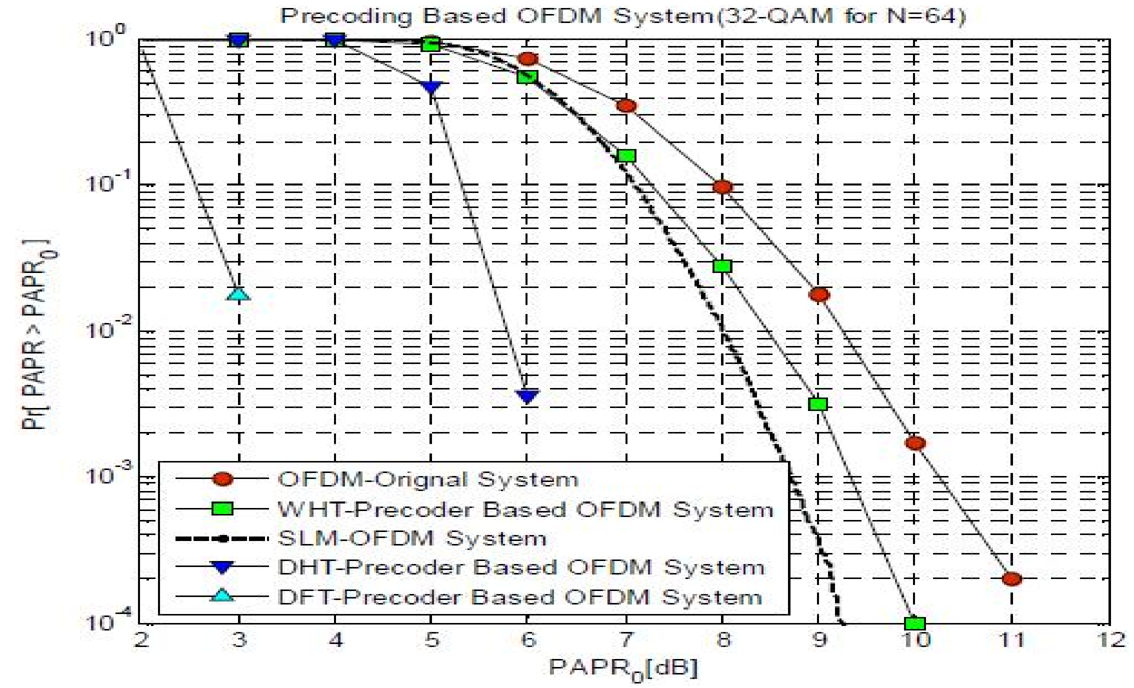


Figure 5: CCDF Comparison of DHT-Precoder Based OFDM System with DFT-Precoder Based OFDM System, WHT-Precoder Based OFDM System, SLM-OFDM (V = 2) System and OFDM Original System for 64-QAM

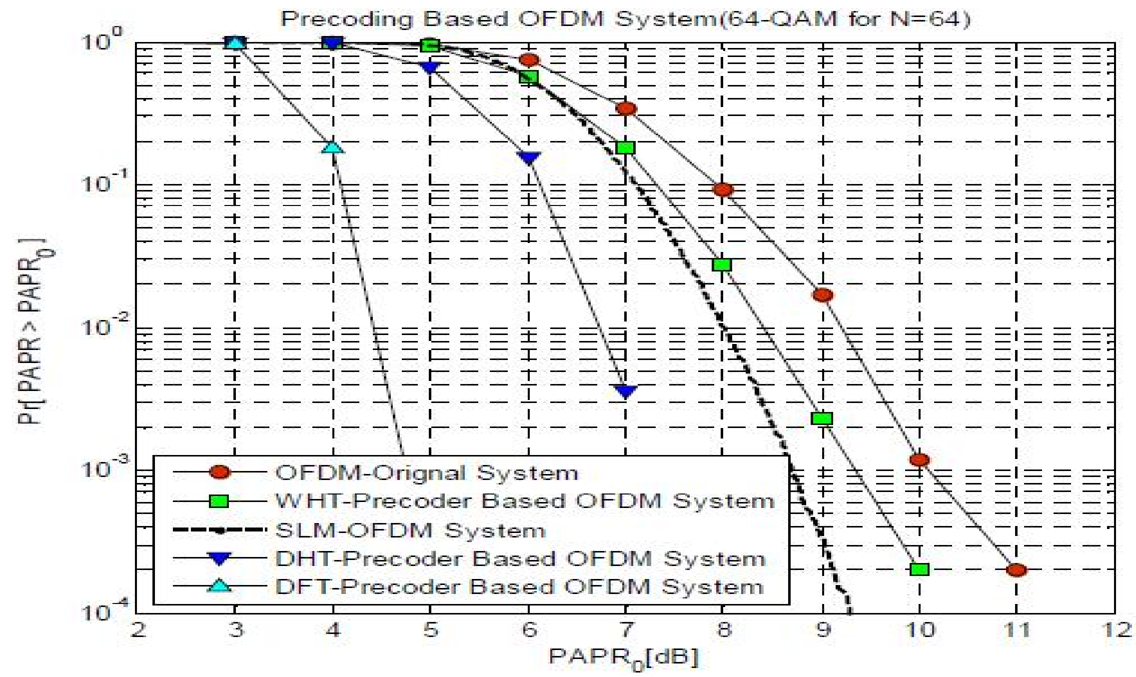
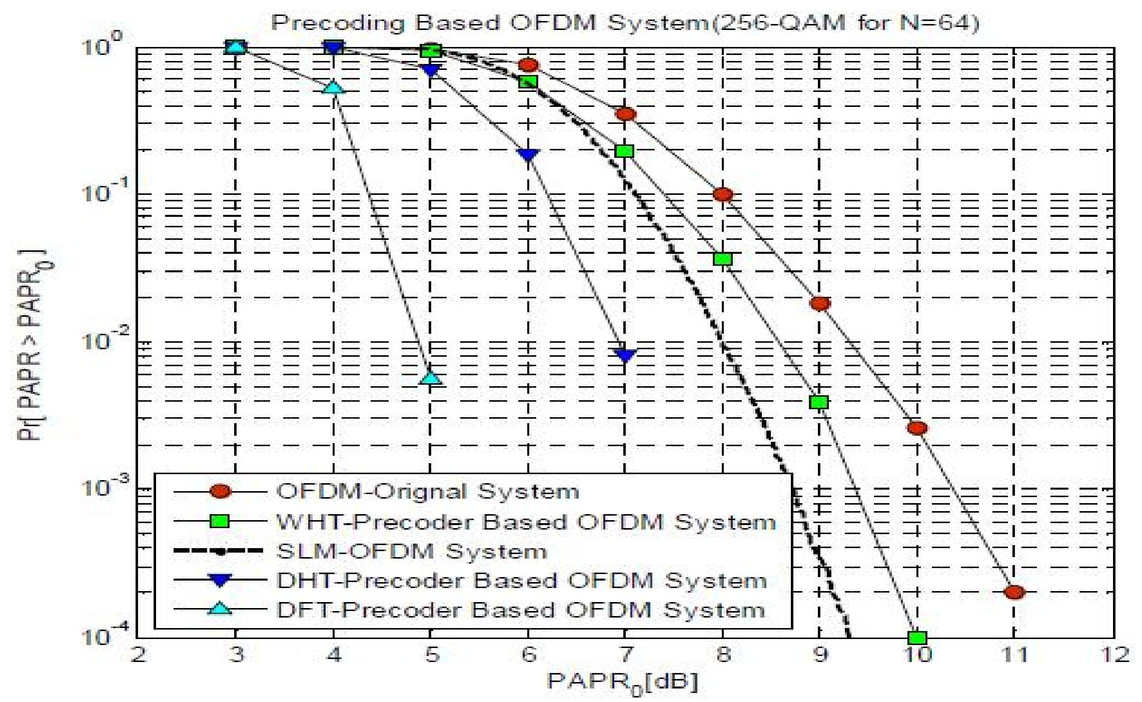


Figure 6: CCDF Comparison of DHT-Precoder Based OFDM System with DFT-Precoder Based OFDM System, WHT-Precoder Based OFDM System, SLM-OFDM (V = 2) System and OFDM Original System for 256-QAM



respectively. But it lags 3 db gain behind the DFT Precoding.

Figure 4 shows the performance analysis for '*M* = 32'. Which gives that the DHT Precoding gains 3, 2.4, 1.99 db over OFDM-Original, WHT-Precoding and SLM Precoding respectively. But it lags 2.5 db gain behind the DFT Precoding.

Figure 5 shows the performance analysis for '*M* = 64'. Which gives that the DHT Precoding gains 2.8, 3, 1.0 db over OFDM-Original, WHT-Precoding and SLM Precoding respectively. But it lags 1.9 db gain behind the DFT Precoding.

Figure 6 shows the performance analysis for *M* = 256. Which gives that the DHT Precoding gains 2.2, 1.5, 1.7 db over OFDM-Original, WHT-Precoding and SLM Precoding respectively. But it lags 1 db gain behind the DFT Precoding.

CONCLUSION

In this paper, we have analyzed the PAPR of DHT-Pre-coded OFDM system for M-QAM (where *M* = 16, 32, 64, 256). MATLAB simulation shows that DHT-Pre-coded OFDM System shows better PAPR gain as compared to Conventional OFDM-Original system, WHT-Pre-coder Based OFDM system and SLMOFDM (with *V* = 2) system respectively. The DHT-Pre-coded OFDM system does not require any power increase, complex optimization and side information to be sent for the receiver. It requires simple circuitry as there is no complex operations.

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