



ENHANCED METHOD TO REDUCE PAPR IN MIMO-OFDM SYSTEM USING STBC-DPC/THP

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Abstract: Orthogonal Frequency Division Multiplexing (OFDM) is a spectrally proficient multicarrier modulation technique over multipath fading channel for high speed data transmission. On the other hand, MIMO technology has attracted attention in wireless communications, because it offers significant increases in data throughput and link range without additional bandwidth. MIMO-OFDM is a powerful combination because it can achieve very high spectral efficiency even when the transmitter does not possess channel state information (CSI). This MIMO-OFDM system suffers from high Peak-to-average power ratio (PAPR) and high Bit Error Rate (BER). In this paper, the STBC-DPC system with the modulus operation i.e., Tomlinson-Harashima precoding (THP) scheme, is introduced to retain low peak-to-average power ratio (PAPR) in MIMO-OFDM system. Finally, with the Simulation results can conclude that the STBC-DPC/THP system with water filling Algorithm can provide excellent bit error rate (BER) performance and STBC-DPC system with THP precoding technique can limit the DPC signal and attain low PAPR.

Index Terms - Orthogonal Frequency Division Multiplexing (OFDM), Multiple Input Multiple Output (MIMO), Space Time Block Codes (STBC), Dirty Paper Coding (DPC), Tomlinson-Harashima Precoding (THP), Peak to Average Power Ratio (PAPR).

I. INTRODUCTION

Sending high data rate over a wireless channel has been a challenge for researchers. Due to the wireless channel environment phenomenon called fading and the additive noise, transmitting high data rate is not a simple task to accomplish. One solution to this problem is by using a combination of multiple-input multiple-output (MIMO) with orthogonal frequency division multiplexing (OFDM). The resulting signal of this combination has multi-path delay tolerance and immunity to frequency selective channel fading. In addition, such a system benefits from the high bandwidth efficiency of the OFDM. These positive characteristics make MIMO-OFDM a promising candidate for high data rate wireless communications [8]. On the other hand, STBC technique can provide more benefit for mobile users with computational efficiency over the fading channel environment. Due to multiple transmit antennas requirement for the STBC system, it is hard to realize on mobile devices. It's always deployed on base station, also called downlink system. However, it needs more computational complexity to combat the spatial interference at receiver, e.g., maximum likelihood (ML) and interference cancellation. In order to overcome the interference problem and reduce the computational loading for mobile user, we want to study the precoding technique at base station, which can pre-equalize or pre-cancel the spatial interference at base station. It is well known that the dirty paper coding (DPC) [1] uses precoding technique [6] to eliminate inter-symbol interference (ISI) on single user or multi-users interference. Moreover, due to the DPC with interference free and low complexity benefits [4]. The MIMO STBC transceiver structure with two transmitter antennas and one receiver antennas is studied. First, to reduce the complexity at receiver, the STBC-DPC precoding technique is done to achieve the low complexity benefit for mobile station. Besides, to improve the performance of the STBC-DPC system, the channel on/off assignment using water filling algorithm is used. It is obvious to enhance the system performance. Finally, it is well known that the precoding technique will conduct high Peak to Average Power Ratio problem. The STBC-DPC system with the modulus operation to limit the transmit signal level, i.e., Tomlinson-Harashima precoding (THP) scheme is introduced to constrain high peak power and retain low peak-to-average power ratio (PAPR).

II. MIMO – OFDM SYSTEM

Orthogonal Frequency Division Multiplexing (OFDM) is a multicarrier transmission technique, which divides the available spectrum into many carriers, each one being modulated by a low rate data stream. OFDM is similar to FDMA in that the multiple user access is achieved by subdividing the available bandwidth into multiple channels that are then allocated to users. However, OFDM uses the spectrum much more efficiently by spacing the channels much closer together. This is achieved by making all the carriers orthogonal to one another, preventing interference between the closely spaced carriers. To generate OFDM successfully the relationship between all the carriers must be carefully controlled to maintain the Orthogonality of the carriers. For this reason, OFDM is generated by firstly choosing the spectrum required, based on the input data, and modulation scheme used. Orthogonality is defined for both real and complex valued functions. The functions $\phi_m(t)$ and $\phi_n(t)$ are said to be orthogonal with respect to each other over the interval $a < t < b$ if they satisfy the condition:

$$\int_a^b \phi_m(t) \phi_n^*(t) dt = 0 \text{ where } n \neq m \quad (1)$$

Each carrier to be produced is assigned some data to transmit. The required amplitude and phase of the carrier is then calculated based on the modulation scheme. The required spectrum is then converted back to its time domain signal using an Inverse Fourier Transform.

In most applications, an Inverse Fast Fourier Transform (IFFT) is used. The IFFT performs the transformation very efficiently, and provides a simple way of ensuring the carrier signals produced are orthogonal signal. In Conventional multicarrier modulated system, each subcarrier has to be allocated with a dedicated oscillator and a modulator to generate a output.

If N subcarriers are allocated over a bandwidth B with a fundamental frequency $f_0 = B/N$ then the net transmitted signal $x(t)$ is given as

$$x(t) = \sum_{k=0}^{N-1} X(k)e^{j2\pi kf_0 t} \tag{2}$$

Since the signal is a band limited signal, we can replace the conventional system with a N – point IFFT as the k^{th} transmitted signal $x(k)$ is given as

$$x(k) = \frac{1}{N} \sum_{i=0}^{N-1} X(i)e^{\frac{j2\pi ki}{N}} \tag{3}$$

MIMO-OFDM is a particularly powerful combination because MIMO does not attempt to mitigate multipath propagation and OFDM avoids the need for signal equalization. MIMO-OFDM can achieve very high spectral efficiency even when the transmitter does not possess channel state information (CSI). When the transmitter does possess CSI (which can be obtained through the use of training sequences), it is possible to approach the theoretical channel capacity.

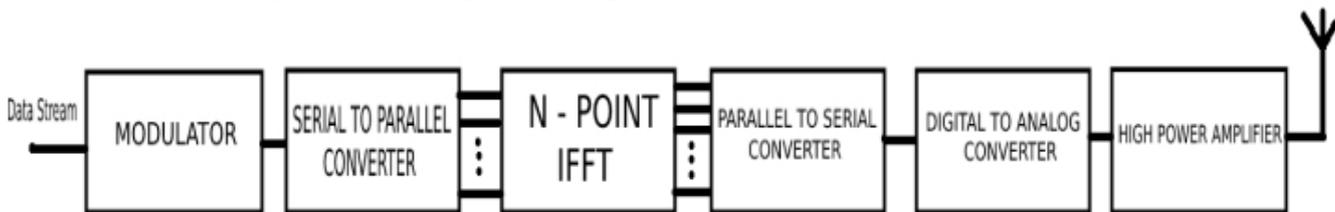


Fig 1. Block diagram of OFDM system

III. PEAK TO AVERAGE POWER RATIO (PAPR)

The PAPR is the relation between the maximum power of a sample in a given OFDM transmit symbol divided by the average power of that OFDM symbol. In simple terms, PAPR is the ratio of peak power to the average power of a signal. It is expressed in the units of dB.

$$PAPR\{s(t)\} = \frac{\max([s(t)]^2)}{\text{Expected } ([s(t)]^2)} \tag{4}$$

It occurs when the signals from the IFFT block is transmitted over the parallel to serial converter, then there would be a cumulation of these signals at the output of parallel to serial converter which might result in high peak values comparatively then the average value of the signal. If these signals are not taken into consideration and sent to the high power amplifier, the high power amplifier which has to be operated in linear region tends to operate in non-linear region which results in high PAPR and leads to inter carrier interference and loss of orthogonality among subcarriers.

Since PAPR can have random variable value, it can be denoted as complementary cumulative distribution function: CCDF. When CCDF, $PAPR_0$ threshold is exceeded, PAPR value of OFDM sign can be expressed as:

$$PAPR(X(n)) = p_r(PAPR(X(n)) > PAPR_0) \tag{5}$$

IV. STBC AND DPC SYSTEM

3.1 STBC and DPC SIGNAL MODEL

STBC is a technique used in wireless communications to transmit multiple copies of a data stream across a number of antennas and to exploit the various received versions of the data to improve the reliability of data-transfer. An STBC is usually represented by a matrix. Each row represents a time slot and each column represents one antenna’s transmissions over time.

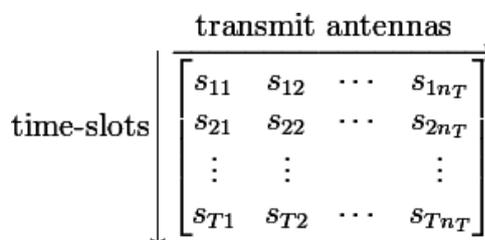


Fig 2. Modulated symbols in a STBC system

Here, s_{ij} is the modulated symbol to be transmitted in time slot i from antenna j . There are to be T time slots and n_T antennas as well as n_R receive antennas. This block is usually considered to be of 'length' L .

The code rate of an STBC measures how many symbols per time slot it transmits on average over the course of one block. If a block encodes K symbols, the code-rate is

$$r = \frac{k}{T} \tag{6}$$

Only one standard STBC can achieve full-rate — Alamouti’s code.

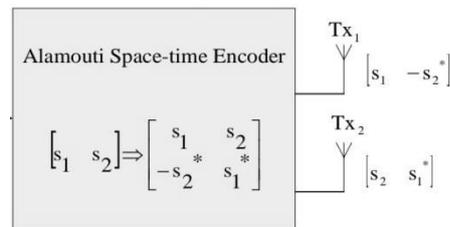


Fig 3. Alamouti Space-Time Encoder

On the other hand, dirty paper coding (DPC) is a technique for efficient transmission of digital data through a channel subjected to some interference known to the transmitter. The technique consists of precoding the data in order to cancel the effect caused by the interference. The joint STBC-DPC precoding technique can be used to acquire the spatial diversity and multiplexing gain.

First, for Alamouti's STBC system, 2-transmit antennas and 1-receiver antenna are used to achieve transmit diversity. That is, in time slot 1, antenna-1 and antenna-2 transmit signal x_1 and x_2 and time slot 2 transmit signal $-x_2^*$ and $-x_1^*$, respectively. The received signal is given by

$$[y_1 \ y_2] = [h_1 \ h_2] \begin{bmatrix} x_1 & x_2^* \\ x_2 & -x_1^* \end{bmatrix} + [n_1 \ n_2] \quad (7)$$

The transmitted signal can be detected by

$$[\hat{x}_1 \ \hat{x}_2]^T = H^H [y_1 \ y_2]^T = (H^H H) [x_1 \ x_2]^T + [\tilde{n}_1 \ \tilde{n}_2] \quad (8)$$

where $H = \begin{bmatrix} h_1 & h_2 \\ h_2^* & -h_1^* \end{bmatrix}$ with $H^H H = \text{diag}\{|h_1|^2 + |h_2|^2, |h_1|^2 + |h_2|^2\}$

As shown in above equation, we can find that the diagonal term of $(H^H H)$ matrix has the transmit diversity. Next, the dirty paper coding system uses the concept of precoding. It involves two characteristics, i.e., interference free and lower receiver complexity. The system structure is shown as follow. The system is assumed by 2x1 MIMO system, where the transmitted signal can be expressed as

$$\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} r_{11} & r_{12} \\ 0 & r_{22} \end{bmatrix}^{-1} \begin{bmatrix} r_{11} & 0 \\ 0 & r_{22} \end{bmatrix} \begin{bmatrix} \tilde{x}_1 \\ \tilde{x}_2 \end{bmatrix} \quad (9)$$

$$R = \begin{bmatrix} r_{11} & r_{12} \\ 0 & r_{22} \end{bmatrix} R_{diag} = \begin{bmatrix} r_{11} & 0 \\ 0 & r_{22} \end{bmatrix} \quad (10)$$

After DPC precoding, the original signal \tilde{x}_1, \tilde{x}_2 can be transmitted by x_1 and x_2 , the received signal y_1, y_2 can be given by

$$\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = Q^H H \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} n_1 \\ n_2 \end{bmatrix} \quad (11)$$

3.2 WATERFILLING ALGORITHM (WFA)

In the previous section, we can see the improvement in Bit Error Rate performance by using STBC-DPC system. However, if the composite channel response r_{ii} is degraded, the ML searcher cannot detect the i^{th} symbol \tilde{x}_i . In order to overcome the problem, the channel on/off assignment is done by introducing the water filling algorithm. That is, the i^{th} original signal is weighted by the channel pre-assignment factor w_i , i.e.,

$$\tilde{\tilde{x}}_i = w_i \tilde{x}_i \quad (12)$$

where $w_i \in \{0,1\}$ is determined by signal variance, noise variance, and the composite channel response r_{ii} , i.e., water filling algorithm:

$$w_i = \left(\mu - \frac{\sigma_n^2}{|r_{ii}|} \right) > 0 \quad (13)$$

With $\mu = \frac{1}{4} \left(\sigma_x^2 + \sum_{i=1}^4 \frac{\sigma_n^2}{r_{ii}} \right)$ and σ_x^2, σ_n^2 being the signal and noise variance, respectively.

3.3 TOMLINSON-HARASHIMA PRECODING (THP)

It is well known that the precoding technique will induce the high PAPR problem. So, to reduce this problem, Tomlinson-Harashima Precoding Technique is introduced to reduce PAPR. Tomlinson-Harashima Precoding was invented for reducing the peak-to-average power ratio. Due to DPC scheme conducting transmit signal variation, the modulus operation, i.e., THP, is introduced to use for the DPC signal and retain the transmitted signal power. The modulus operation which can be represented as

$$\text{mod}_A(x) = x - 2A[(x + A + jA)/2A] \quad (14)$$

where x is the DPC signal, $A = \sqrt{M}$ is the limited signal level, M is M -ary PAM constellations. The TH precoding indeed reduces PAPR. It will be verified in the simulation section.

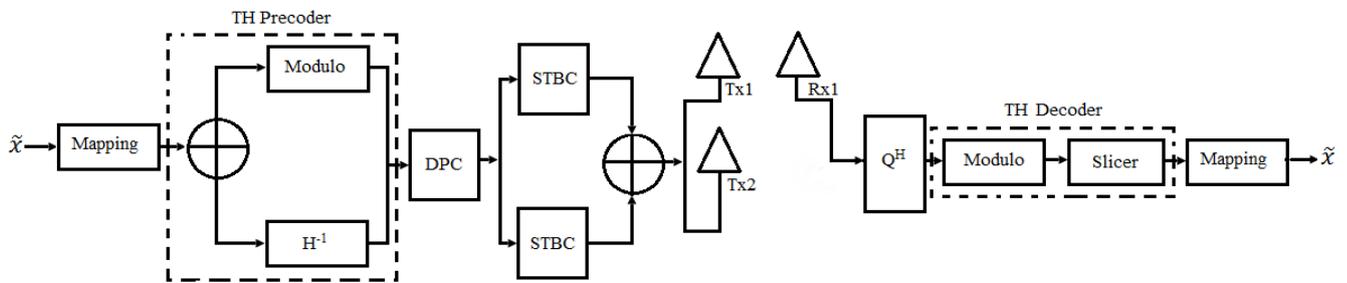


Fig 4. STBC-DPC with THP system

V. SIMULATION RESULTS

In this section, the simulation results are demonstrated to showcase the performance of the STBC-DPC system.

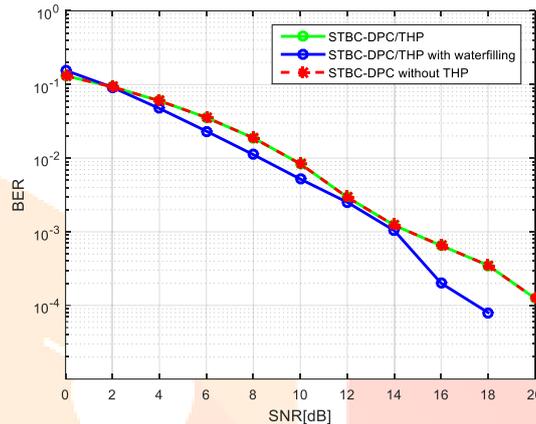


Fig 5. Bit Error Rate Vs Signal to Noise Ratio

This simulation result evaluate the BER performance for the STBC-DPC systems. Figure 4. shows the output BER curves. It is observed that the STBC-DPC/THP with water filling Algorithm can provide better performance than the STBC-DPC/THP and STBC-DPC systems at SNR>24 dB.

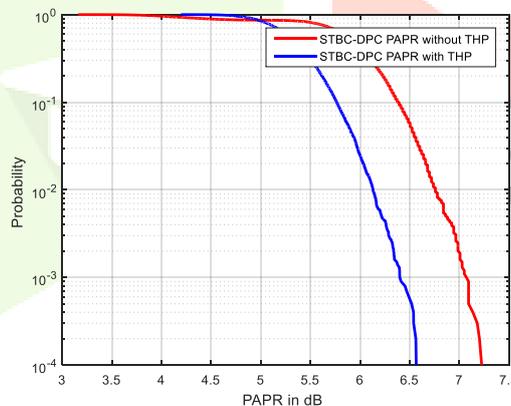


Fig 6. PAPR Performance of STBC-DPC system With and Without THP

Figure 5 shows the PAPR of STBC-DPC system with THP is demonstrated. It shows that the STBC-DPC with THP system can provide lower PAPR values than without THP system about 1 dB at Probability= 10^{-3} . It confirms that the modulus operation of Tomlinson-Harashima Precoding (THP) precoding can limit the DPC signal and attain better PAPR performance.

VI. CONCLUSION

In this paper, we have understood that the STBC-DPC structure not only reduces the complexity, but also improves the Bit Error Rate performance. However, the higher Peak to Average Power Ratio (PAPR) is a drawback about DPC scheme. Finally, the Simulation results conclude that the STBC-DPC/THP system with water filling Algorithm can provide excellent bit error rate (BER) performance and STBC-DPC system with THP precoding technique can limit the DPC signal and attain low PAPR value in the MIMO-OFDM system.

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