Zero padded Symmetric Conjugate Self Cancellation Technique in MB-OFDM System Design

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Abstract- ***Ultra- Wideband (UWB) systems use Multi-Band OFDM (MB-OFDM) techniques for transmission. UWB based systems are power limited by the regulation of Federal Communications Commission (FCC). CP introduces correlation in the transmitted data sequence and hence introduces ripples in the power spectral density (PSD) of the transmitted data. This in turn reduces the range of data transmission. The overlap and add(OLA) method length in UWB receiver depending on the current band of reception and the band wise estimated true FFT window start point. The delay in spread channel model (CM), gain, ICI are not better we can extend this delay spread channel by using Symmetric conjugate technique. The property of symmetric conjugate cancellation is investigated, a technique for ICI is cancelling and diversity combining is proposed. Simulation results show that the proposed scheme achieves a lower bit error rate (BER) compared to the ordinary zero-padded MIMO-OFDM systems in AWGN channel. In Rician fading channels, when frequency offset is 1-10%, the proposed system performance, i.e. BER, is significantly improved over the zero-padded symmetric conjugate self cancellation in MIMO-OFDM systems when the frequency offset is not greater than 10% of subcarrier frequency spacing.***

Index Terms- **Carrier to ICI Ratio, Fast Fourier Transform, OrthogonaL Frequency Division Multiplexing, Zero Padding.**

I.INTRODUCTION

The UWB technology brings in the benefit of high bit rate communication what broad spectrum can offer. The key lies in Shannon's channel capacity equation (1), which relates the channel capacity (*C*), with the channel bandwidth (*W*) and signal to noise
Ratio (*S/N*).

$$C = W.\log\left(1+\frac{S}{N}\right) \qquad (1)$$

As C varies linearly with W, but logarithmically with S ,so it is easier to increase bit rate, by increasing channel bandwidth W , rather than increasing signal power S .Although broad spectrum helps to increase the bit rate, it cannot increase the range of communication and hence power limited UWB systems are suitable for small-range high-speed communication. Over last few decades there has been some research interest on UWB system design. However the World has seen a real explosion on UWB research since FCC allowed license free operation of a wide spectrum of 7.5 GHz (3.1 GHz to 10.6GHz) in the year 2002. FCC ruled that UWB system must have instantaneous spectrum of more than 500 MHz or more than 20% of its central frequency. They also constrained the power spectral density not to exceed −41.3 dBm/MHz, so that UWB systems appear in the thermal noise floor of the existing narrowband services like GSM, GPS etc., and coexist with them without affecting their performance [1-2].Efficient utilization of such a large bandwidth of 7.5 GHz creates a huge challenge to the system designer community. Moreover the power constraints limits the range of communication to a short range only around 2m to 15m with scalable data rate of 53.3 Mbps to 480 Mbps and also create a serious coexistence problem of UWB in the existing narrow band transmission environment. Many disadvantages associated with pulsed multi band technique can be overcome if we can use symbol which is much longer in time domain and incorporating a modulation technique that can efficiently capture multipath energy .Multiband-Orthogonal Frequency Division Multiplexing (MB-OFDM) is the right candidate for this choice [3]. In this approach information is transmitted using OFDM symbol and interleaved over multiple bands, so that power of transmission remains same as the transmission scheme using the whole band instantaneously. The OFDM reaps its own benefits to this approach [4, 5] in terms of spectral efficiency, narrow band interference (NBI) mitigation, excellent robustness against multipath channel, and facilitating the use of low complexity equalizer in receiver. MB-OFDM based UWB system takes all the positives offered by the multi-banding scheme i.e. low power, low cost, simple analog design etc., and also is capable of capturing sufficient multipath energy using a single RF chain due to OFDM scheme adopted. Among the several proposals by different standardization groups, MB-OFDM has been accepted as commercially more viable compared to impulse radio based or code division multiple access(CDMA) based UWB transmission. ECMA-368 is one of such leading standard employing MB-OFDM technique [6].In MB-OFDM technique the whole spectrum of 3.1

GHz to 10.6GHz is divided into 14 bands, each of BW of 528MHz. All the 14 bands are grouped into 5 band-groups as shown in Fig. 1. Band-group #1 to #4 is having 3 bands each, whereas band-group #5 is having only 2 bands. At present band-group #1 is made compulsory for use, and there st is kept for future expansions. Texas Instruments has come up with time frequency interleaving (TFI) scheme by which the OFDM signal hops over three bands across time [3, 8]. Figure 2 shows one example of TFI scheme employed in MB-OFDM system. OFDM symbol duration is 312.5ns. Out of that, 60.6 ns is the cyclic prefix (CP) or zero pad (ZP) duration and 9.5 ns is guard interval, kept to ease switching between different bands, proposed application of ICI self-cancellation to Alamouti Coding for cooperative systems. Thereby, the resulting system is a system in which channel impulse response is limited to real values. [10] Proposed a zero-padded complex conjugate cancellation scheme for OFDM systems, which support complex-valued fading channels. A lack of a self-cancellation scheme for multiple-antenna systems that supports complex-valued fading channels in OFDM systems motivated us to improve the performance of OFDM systems in the presence of a frequency offset by combining the zero-padded technique with symmetric conjugate self-cancellation. The main contributions of this paper are as follows:

(1) The proposed zero-padded symmetric conjugate self-cancellation scheme in half-rate OFDM systems achieves better performance than the ordinary zero-padded scheme in half-rate OFDM systems for both AWGN and Rayleigh fading channels in the presence of small frequency offsets. In addition, this proposed scheme can be used in the realistic fading channels.

(2) The proposed system out performs the zero-padded complex conjugate cancellation scheme in half-rate OFDM Systems in the presence of small frequency offsets in Rayleigh fading channels. Moreover, the proposed scheme offers an enhancement on the diversity gain of the system.

The rest of this paper is organized as follows. Section II describes the mathematical model of OFDM systems in a situation of frequency offsets and the symmetric conjugate self-cancellation scheme. In Section III, simulation results are presented to verify the theoretical analysis. Conclusions are given in Section IV.

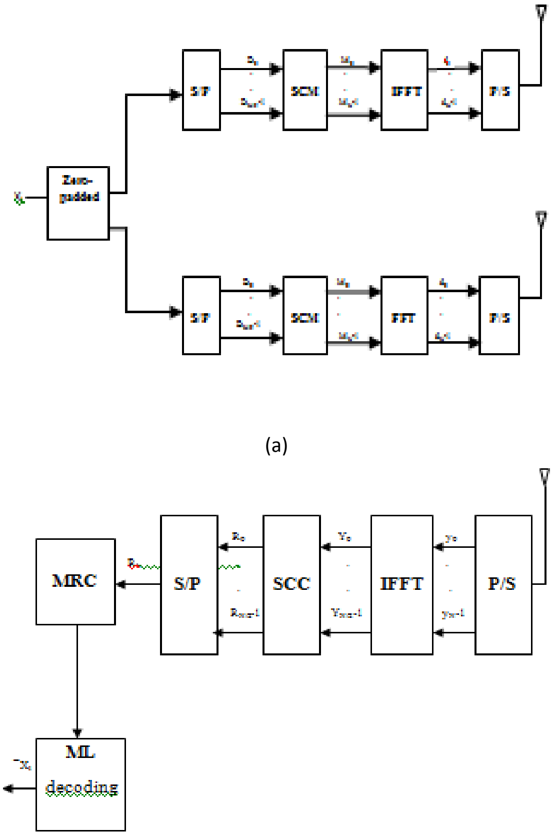
II.SYSTEM MODEL

A. System Model for Zero-Padded Symmetric Conjugate Transmission in MIMO-OFDM Systems

In this section, we propose a symmetric conjugate self-cancellation (SC) in multiple-input and multiple-output (MIMO) systems as shown in Fig.1.The modulated symbols X_l($l = 0,\dots,N/4 - 1$) are encoded with the zero-padded space-frequency coding. Then the transmitted symbols can be denoted as $D_{1,l}$=(X_0,0,X_1,0, ...,XN/4−2,0,$X_{N/4-1}$,0,for $l = 0,\dots, N/2-1$ respectively) for antenna one and $D_{2,l}$= (0,X_1,0,X_2,...,0,$X_{N/4-1}$,0,$X_{N/4-2}$, for $l = 0,\dots,N/2-1$, Respectively) for antenna two. Next, the transmitted symbols are remapped by symmetric conjugate mapping (SCM). Then the transmitted signal on l_{th} transmitting subcarrier for antenna one can be denoted as $M_{1,l}$($l = 0,\dots,N - 1$); $M_{1,l}= D_{1,l}$,$M_{1,N-1-l}= -D^*_{1,l}$ and for antenna two can be represented as $M_{2,l}$ ($l = 0,\dots,N - 1$); $M_{2,l}= D_{2,l}$, $M_{2,N-1-l}= -D^*_{2,l.}$ Assuming that the cyclic prefix is employed and the receiver has perfect time synchronization. Note also that the frequency offset is constant over an OFDM frame. The time domain transmitted signal for the first transmit antenna can be

Expressed as follows and the time-domain transmitted signal for the second antenna, it can be expressed by

$$d_{1,n} = \frac{1}{\sqrt{N}} \sum_{l=0}^{\frac{N}{2}-1} \left[D_{1,l} e^{\frac{j2\Pi nl}{N}} - D^*_{1,l} e^{\frac{j2\Pi n(N-1-l)}{N}} \right] \quad (2)$$



(a)

(b)

Fig.1. Structure of a zero-padded symmetric conjugate self-cancellation scheme in MIMO-OFDM systems (a) Transmitter (b) Receiver

$$d_{2,n} = \frac{1}{\sqrt{N}} \sum_{l=0}^{\frac{N}{2}-1} \left[D_{2,l} e^{\frac{j2\Pi nl}{N}} - D^{*}_{2,l} e^{\frac{j2\Pi n(N-1-l)}{N}} \right] \quad (3)$$

For the sake of simplicity, the transmitted symbols of zero padded Subcarriers are not expressed on following equations, and then the frequency-domain received signal on the k $^{\text{th}}$ receiving subcarrier can be expressed as

$$Y_k = \sum_{l=0}^{\frac{N}{4}-1} \begin{bmatrix} D_{1,2l} H_{1,2l} U_{2l-k} \\ - D^{*}_{1,2l} H_{1,N-1-2l} U_{N-1-2l-k} \\ + D_{2,2l+1} H_{2,2l+1} U_{2l+1-k} \\ - D^{*}_{2,2l+1} H_{2,N-2-2l} U_{N-2-2l-k} \end{bmatrix} + Z_k \quad (4)$$

And, it is straight forward to get the frequency-domain received signal on the (N − 1 − k)$^{\text{th}}$ receiving subcarrier which can be represented as

$$Y_{N-1-k} = \sum_{l=0}^{\frac{N}{4}-1} \begin{bmatrix} D_{1,2l} H_{1,2l} U_{k-(N-1-2l)} \\ - D^{*}_{1,2l} H_{1,N-1-2l} U_{k-2l} \\ + D_{2,2l+1} H_{2,2l+1} U_{k-(N-2-2l)} \\ - D^{*}_{2,2l+1} H_{2,N-2-2l} U_{k-(2l+1)} \end{bmatrix} + Z_{N-1-k} \quad (5)$$

B. Symmetric conjugate self-cancellation scheme and weighted coefficients

The symmetric conjugate self-cancellation was proposed in [5]. This method maps the modulated symbols onto l$^{\text{th}}$ and (N−1−l)$^{\text{th}}$ transmitting subcarriers in symmetrical structure. At the transmitter, the modulated symbols are mapped as denoted by $X_l = (X_0, X_1, ..., X_{N/2-1}, X^{*}_{N/2-1}, ..., X^{*}_1, X^{*}_0$, for l = 0,...,N − 1, respectively). At the receiver, the received signals on symmetric pair of subcarriers are combined and the combined received signal can be denoted as $R_k = (Y_k + Y^{*}_{N-1-k})/2$, for k = 0,...,N/2−1, respectively. The weighting function of U^{*}_{k-l} from (4), the result can be expressed as

$$U^{*}_{k-l} = \frac{1}{N} \sum_{n=0}^{N-1} e^{j\frac{2\Pi}{N} n(l-k-\Delta fT)} \quad (6)$$

it is worth noting that, the weighting function U^{*}_{k-1} for symmetric conjugate self-cancellation is exactly the same as the weighting function of conjugate path for two-path complex conjugate scheme as described in [11], when the frequency offset is small, the property of the symmetric conjugate self cancellation should be written as

$$\frac{U_{l-k} + U^{*}_{k-l}}{2} \approx \begin{Bmatrix} 1 & if & l = k \\ 0 & if & l \neq k \end{Bmatrix} \quad (7)$$

C.ICI cancellation and Diversity Combining for MIMO-OFDM Systems

In the proposed zero-padded symmetric conjugate self-cancellation for MIMO-OFDM systems, the ICI cancelling and diversity combining is performed by symmetric conjugate combining (SCC) as shown in Fig.1. Then the combined received signal on even subcarriers R_{2k} and odd subcarriers $R_{2k+1}$for k = 0,...,N/4−1, respectively.

Note also that modulated symbols are assumed independent, zero-mean random variables with unit average power. From the above equations carrier to ICI power ratio (CIR) of zero-Padded symmetric conjugate self-cancellation scheme on even and odd subcarriers at k = 0 in MIMO-OFDM systems can be expressed as follows

$$CIR_0 = \frac{4}{ICI_0} \quad (8)$$

And

$$CIR_1 = \frac{4}{ICI_1} \quad (9)$$

Where

$$ICI_0 = \sum_{l=1}^{\frac{N}{4}-1} \left| U_{2k} + U^{*}_{-2l} \right|^2 + \sum_{l=0}^{\frac{N}{4}-1} \begin{pmatrix} \left| U_{2l+1} + U^{*}_{-(2l+1)} \right|^2 \\ + \left| U_{N-1-2l} + U^{*}_{-(N-1-2l)} \right|^2 \\ + \left| U_{N-2-2l} + U^{*}_{-(N-2-2l)} \right|^2 \end{pmatrix} \quad (10)$$

And

$$ICI_1 = \sum_{l=1}^{\frac{N}{4}-1} \left| U_{2l} + U^*_{-2l} \right|^2 + \sum_{l=0}^{\frac{N}{4}-1} \left(\begin{array}{l} \left| U_{2l-1} + U^*_{1-2l} \right|^2 \\ + \left| U_{N-2-2l} + U^*_{-(N-2-2l)} \right|^2 \\ + \left| U_{N-3-2l} + U^*_{-(N-3-2l)} \right|^2 \end{array} \right) \tag{11}$$

The CIR of the ordinary zero-padded MIMO-OFDM systems [11] was given as follows

$$CIR = \frac{|U_0|^2}{\sum_{l=1}^{N-1} |U_l|^2} \approx \frac{1}{\sum_{l=1}^{N-1} |U_l|^2} \tag{12}$$

It is worth noting that when the frequency off is small, the ICI_0 and ICI_1 approaches zero, CIR_0 and CIR_1 are then Increased. As a result, the ICI of this scheme is significantly mitigated. Moreover, the CIR of the proposed scheme is four- time higher than the ordinary zero-padded MIMO-OFDM systems.

III.SIMULATION RESULTS

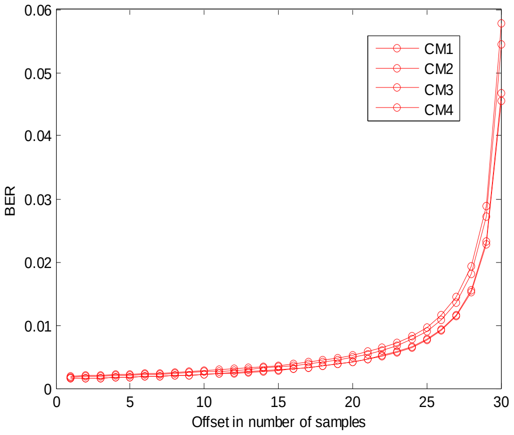


Fig 2.Offset sensitivity of BER for all channel models at 10 dB Eb/N0 with fixed (32 samples) ‘ZP_LEN’.

Fig 2 shows the offset sensitivity of BER performance of MB-OFDM system. Here offset = 0 implies the true start point of FFT window if there is no noise and there exists a non-zero multipath component at the first sample location. Note that, even if there is no non-zero multipath component at 0^{th} location, still a start point of FFT window at that location will always perform optimally in no noise condition, because equalizer can take care as no multipath component to equalizer will appear as non-causal component. Note that, the curves show that MB-OFDM system is quite sensitive to the ISI incursions from the next OFDM symbol.

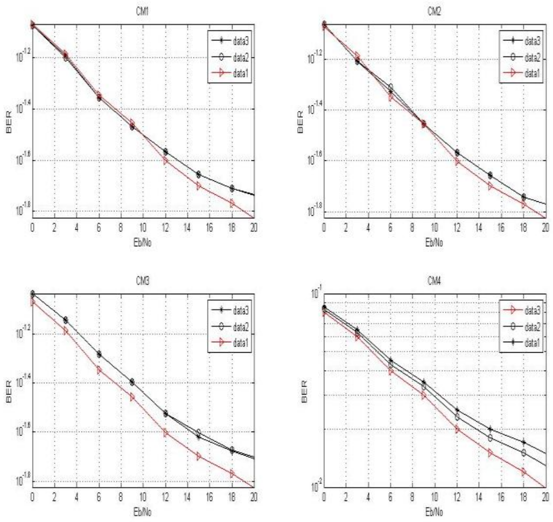


Fig 3: BER vs Eb/No (in dB) simulation for all channel models in uncoded MB-OFDM system. Data1: using fixed ZP length of 32. Data2: Using variable ZP length. Data3: Using zero-padded symmetric conjugate self-cancellation curve with frequency offset zero.

It shows the BER curves for un-coded MB-OFDM based UWB system with and without band wise variable ZP length for overlap and add operation. For large delay-spread channels in UWB systems the mean excess delay is more compared to small delay-spread channels. This implies for large delay spread channel, the estimation of FFT window will be more away from the true FFT window resulting in more ISI incursions from next OFDM symbol. Hence the proposed technique is more promising for large delay-spread channels. The curves show a significant amount of performance improvement (for CM4 around 1 dB of Eb/N0 savings at 10^{-2} BER for un-coded system) is achieved for large delay-spread channels.

IV.CONCLUSION

In this paper, the zero-padded symmetric conjugate self-cancellation in MIMO-OFDM systems has been proposed. The proposed system can be used in the realistic fading channels. As compared to the ordinary zero-padded MB-OFDM systems, the proposed system offers better CIR than the ordinary one. Simulation results show that the proposed system achieves lower BER in AWGN channels as compared to the ordinary zero-padded MB-OFDM systems. In this section, the proposed zero-padded symmetric self-cancellation scheme in OFDM systems is examined the performance through a computer simulation. Total power of the system is 1 Watt. The transmitted power of zero-padded symmetric conjugate scheme is a half of the ordinary zero-padded OFDM systems. Moreover in this method all the signal processing is dependent on one independent process i.e. estimation of the FFT window and hence the question of dependency of two independent process does not arise at all. The method is more promising for large delay spread channels and provides a significant Eb/N0 improvement in the detection process. A natural choice of future work would be to mix the above two independent ideas and study its impact on overall system performance.

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