Zero-Padded Symmetric Conjugate Technique for Intercarrier Interference Cancellation in MIMO-OFDM Systems

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Abstract*—This paper proposes a zero-padded symmetric conjugate self-cancellation technique in orthogonal frequency division multiplexing (OFDM) systems by padding zero in between two consecutive symbols for mitigating intercarrier interference (ICI) caused by a frequency offset in MIMO systems. The proposed system is not limited to the real-value channels as required in applying ICI cancellation technique in Alamouti-coded MIMO systems. The proposed system offers advantages of a symmetric conjugate cancellation scheme and MIMO systems such as efficiently mitigating ICI and enhancement of a diversity gain. The property of symmetric conjugate cancellation is investigated, a technique for ICI 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 Rayleigh fading channels, when frequency offset is 1-10%, the proposed system performance, i.e. BER, is significantly improved over the zero-padded conjugate cancellation in MIMO-OFDM systems when the frequency offset is not greater than 10% of subcarrier frequency spacing.

I. Introduction

Multiple-input and multiple-output (MIMO) has been a widely used technique in broadband wireless communication systems as it offers both diversity and multiplexing gain. The orthogonal frequency division multiplexing (OFDM) is a useful technique due to high spectral efficiency and robustness to multipath fading channels. By allowing spectral overlapping of subcarriers, OFDM suffers a sensitivity to frequency offsets, which are caused by a Doppler shift as well as a carrier frequency mismatch between local oscillators in the transmitter and receiver. Such frequency offsets destroy orthogonality among subcarriers, and thus can introduce intercarrier interference (ICI).

Currently, four approaches have been developed to mitigating ICI, namely frequency-domain equalization [1], time-domain windowing [2], ICI self-cancellation [3],[4],[5],[6] and two-path conjugate cancellation [7],[8]. A symmetric data conjugate ICI self-cancellation, which was proposed in [5], has received great attention in this research area owning to its simplicity and frequency diversity. [6] applied a symmetric data conjugate method for mitigation of phase noise (PHN). However, most of these techniques have been proposed for single-input and single-output (SISO) except in [9], which introduced the ICI self-cancellation scheme into MIMO-OFDM systems. However, the authors focused on the space-frequency-coding design. [10] 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. [11] proposed a zero-padded complex conjugate cancellation scheme for MIMO-OFDM systems, which support complex-valued fading channels.

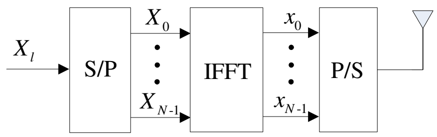
A lack of a self-cancellation scheme for multiple-antenna systems that supports complex-valued fading channels in MIMO-OFDM systems motivated us to improve the performance of MIMO-OFDM systems in the presence of a frequency offset by combining the zero-padded technique with symmetric conjugate self-cancellation. The main contributions of this paper are as follows

- The proposed zero-padded symmetric conjugate self-cancellation scheme in half-rate MIMO-OFDM systems achieves better performance than the ordinary zero-padded scheme in half-rate MIMO-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.
- The proposed system outperforms the zero-padded complex conjugate cancellation scheme in half-rate MIMO-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.

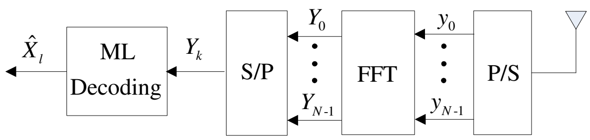
The rest of this paper is organized as follows. Section II describes the mathematical model of OFDM systems in a situation of frequency offsets and the symmetric conjugate self-cancellation scheme. In Section III, the proposed zero-padded symmetric conjugate cancellation scheme in MIMO-OFDM systems is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

II. OFDM Model with Frequency Offset

A. OFDM System Model



(a)



(b)

Fig. 1. Structure of a baseband OFDM system (a) Transmitter (b) Receiver

Fig.1 shows the system block diagram of a baseband OFDM system in single-input and single-output (SISO) systems. At the transmitter, $X_l(l = 0, ..., N-1)$ is the modulated symbols on the l^{th} transmitting subcarrier of OFDM symbol, which are assumed to be independent, zero-mean random variables with unit average power. At the output of the IFFT, the complex baseband OFDM signal can be expressed as

$$x_n = \frac{1}{\sqrt{N}} \sum_{l=0}^{N-1} X_l e^{j\frac{2\pi}{N}nl}, \quad n = 0, \ldots, N-1 \tag{1}$$

where N is the total number of subcarriers in an OFDM frame and T is the OFDM symbol duration.

At the receiver, the received OFDM signal is mixed with the local oscillator signal, with the frequency offset deviated from Δf compared to the carrier frequency of the received signal owing to frequency estimation error. The received signal can be given by

$$y_n = (x_n \otimes h_n) e^{j\frac{2\pi}{N}n\Delta fT} + z_n \tag{2}$$

where h_n, $e^{j\frac{2\pi}{N}n\Delta fT}$, and z_n represent the time-domain channel impulse response, the corresponding frequency offset of received signal at the sampling instants with ΔfT being the frequency offset to subcarrier spacing ratio, and the AWGN respectively, while $\otimes$ denotes the circular convolution. Assuming that the frequency offset is constant over an OFDM frame and a cyclic prefix is inserted at the transmitter, the receiver has a perfect time synchronization. Then the output of the FFT in frequency domain signal on the k^{th} receiving subcarrier becomes

$$\begin{aligned} Y_k &= \sum_{l=0}^{N-1} X_l H_l U_{l-k} + Z_k, \quad k = 0, \ldots, N-1 \\ &= X_k H_k U_0 + \sum_{l=0, l\neq k}^{N-1} X_l H_l U_{l-k} + Z_k \end{aligned} \tag{3}$$

The first term of (3) is a desired transmitted data symbol and the second term represents the ICI from the undesired data symbols caused by other subcarriers in OFDM symbols. H_k is the frequency-domain channel impulse response and Z_k denotes the frequency domain of z_n. The term U_{l-k} is the coefficient of FFT and $IFFT$, is given by

$$U_{l-k} = \frac{1}{N} \sum_{n=0}^{N-1} e^{j\frac{2\pi}{N}n(l-k+\Delta fT)} \tag{4}$$

This coefficient can be considered as a complex weighting function of the transmitted data symbols in frequency domain.

B. Symmetric Conjugate Self-Cancellation Scheme and Its Property

The symmetric conjugate self-cancellation was proposed in [5]. This method maps the modulated symbols onto l^{th} and $(N-1-l)^{th}$ 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. Let investigate the weighting function of U^*_{k-l} from (4), the result can be expressed as

$$U^*_{k-l} = \frac{1}{N} \sum_{n=0}^{N-1} e^{j\frac{2\pi}{N}n(l-k-\Delta fT)} \tag{5}$$

It is worth noting that, the weighting function U^*_{k-l} 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

$$\frac{U_{l-k} + U^*_{k-l}}{2} \approx \begin{cases} 1 & \text{if } l = k \\ 0 & \text{if } l \neq k \end{cases} \tag{6}$$

III. The Proposed Zero-Padded Self-Cancellation in MIMO-OFDM Systems

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.2. The modulated symbols $X_l(l = 0, ..., N/4-1)$ are encoded with the zero-padded space-frequency coding. Then the transmitted symbols can be denoted as $D_{1,l} = (X_0, 0, X_1, 0, ..., X_{N/4-2}, 0, X_{N/4-1}, 0,$ for $l = 0, ..., N/2-1$, respectively) for antenna one and $D_{2,l} =$

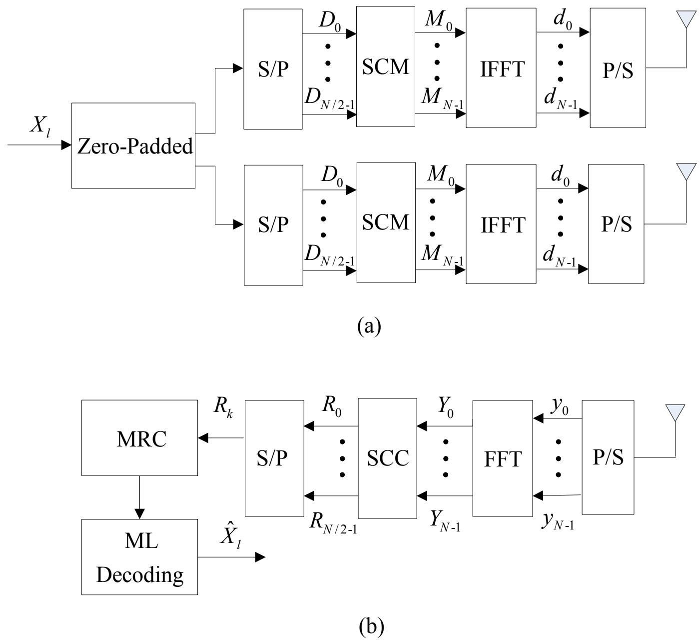


Fig. 2. Structure of a zero-padded symmetric conjugate self-cancellation scheme in MIMO-OFDM systems (a) Transmitter (b) Receiver

$(0, X_1, 0, X_0, ..., 0, X_{N/4-1}, 0, X_{N/4-2}$, for $l = 0, ..., N/2-1$, 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 $M_{1,l}(l = 0, ..., N-1)$; $M_{1,l} = D_{1,l}$, $M_{1,N-1-l} = -D^*_{1,l}$ and for antenna two can be represented as $M_{2,l}(l = 0, ..., N-1)$; $M_{2,l} = D_{2,l}, M_{2,N-1-l} = -D^*_{2,l}$. 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

$$d_{1,n} = \frac{1}{\sqrt{N}} \sum_{l=0}^{N/2-1} [D_{1,l} e^{j\frac{2\pi}{N}nl} - D^*_{1,l} e^{j\frac{2\pi}{N}n(N-1-l)}] \qquad (7)$$

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

$$d_{2,n} = \frac{1}{\sqrt{N}} \sum_{l=0}^{N/2-1} [D_{2,l} e^{j\frac{2\pi}{N}nl} - D^*_{2,l} e^{j\frac{2\pi}{N}n(N-1-l)}] \qquad (8)$$

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

$$\begin{aligned} Y_k \quad = \quad & \sum_{l=0}^{N/4-1} [D_{1,2l} H_{1,2l} U_{2l-k} \\ & - D^*_{1,2l} H_{1,N-1-2l} U_{N-1-2l-k} \\ & + D_{2,2l+1} H_{2,2l+1} U_{2l+1-k} \\ & - D^*_{2,2l+1} H_{2,N-2-2l} U_{N-2-2l-k}] + Z_k \end{aligned} \qquad (9)$$

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

$$\begin{aligned} Y_{N-1-k} \quad = \quad & \sum_{l=0}^{N/4-1} [D_{1,2l} H_{1,2l} U_{k-(N-1-2l)} \\ & - D^*_{1,2l} H_{1,N-1-2l} U_{k-2l} \\ & + D_{2,2l+1} H_{2,2l+1} U_{k-(N-2-2l)} \\ & - D^*_{2,2l+1} H_{2,N-2-2l} U_{k-(2l+1)}] + Z_{N-1-k} \end{aligned} \qquad (10)$$

B. 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.2. Then the combined received signal on even subcarriers R_{2k} and odd subcarriers R_{2k+1} for $k = 0, ..., N/4-1$, respectively. Then the combined received signal on even subcarriers can be described as follows

$$R_{2k} = \frac{1}{2}(H^*_{1,2k} Y_{2k} - H_{1,N-1-2k} Y^*_{N-1-2k}) \qquad (11)$$

and on odd subcarriers, it is

$$R_{2k+1} = \frac{1}{2}(H^*_{2,2k+1} Y_{2k+1} - H_{2,N-2-2k} Y^*_{N-2-2k}) \qquad (12)$$

When the frequency offset is small, we have

$$U_0 = \frac{1}{N} \sum_{n=0}^{N-1} e^{j\frac{2\pi}{N}n\Delta fT} \approx 1 \qquad (13)$$

Substituting (9) and (10) in (11), then the combined received signal on even subcarriers becomes

$$R_{2k} = \frac{1}{2}(|H_{1,2k}|^2 + |H_{1,N-1-2k}|^2)D_{1,2k} + I_{2k} - J_{2k} + W_{2k} \tag{14}$$

where

$$\begin{aligned} I_{2k} &= \frac{1}{2}\sum_{l=0,2l\neq k}^{N/4-1}[H^*_{1,2k}H_{1,2l}U_{2l-2k} \\ &+ H_{1,N-1-2k}H^*_{1,N-1-2l}U^*_{2k-2l}]D_{1,2l} \\ &+ \frac{1}{2}\sum_{l=0}^{N/4-1}[H^*_{1,2k}H_{2,2l+1}U_{2l+1-2k} \\ &+ H_{1,N-1-2k}H^*_{2,N-2-2l}U^*_{2k-(2l+1)}]D_{2,2l+1} \end{aligned} \tag{15}$$

$$\begin{aligned} J_{2k} &= \frac{1}{2}\sum_{l=0}^{N/4-1}[(H^*_{1,2k}H_{1,N-1-2l}U_{N-1-2l-2k} \\ &+ H_{1,N-1-2k}H^*_{1,2l}U^*_{2k-(N-1-2l)})D^*_{1,2l} \\ &+ (H^*_{1,2k}H_{2,N-2-2l}U_{N-2-2l-2k} \\ &+ H_{1,N-1-2k}H^*_{2,2l+1}U^*_{2k-(N-2-2l)})D^*_{2,2l+1}] \end{aligned} \tag{16}$$

$$W_{2k} = \frac{1}{2}(H^*_{1,2k}Z_{2k} - H_{1,N-1-2k}Z^*_{N-1-2k}) \tag{17}$$

The first terms on the right hand side of the (14) is the desired transmitted data symbols on even subcarriers. The ICI terms are I_{2k} and J_{2k} while W_{2k} is the AWGN. Similarly, substituting (9) and (10) in (12), then the combined received signal on odd subcarriers becomes

$$\begin{aligned} R_{2k+1} &= \frac{1}{2}(|H_{2,2k+1}|^2 + |H_{2,N-2-2k}|^2)D_{2,2k+1} \\ &+ I_{2k+1} - J_{2k+1} + W_{2k+1} \end{aligned} \tag{18}$$

where

$$\begin{aligned} I_{2k+1} &= \frac{1}{2}\sum_{l=0,l\neq k}^{N/4-1}[H^*_{2,2k+1}H_{2,2l+1}U_{2l-2k} \\ &+ H_{2,N-2-2k}H^*_{2,N-2-2l}U^*_{2k-2l}]D_{2,2l+1} \\ &+ \frac{1}{2}\sum_{l=0}^{N/4-1}[H^*_{2,2k+1}H_{1,2l}U_{2l-(2k+1)} \\ &+ H_{2,N-2-2k}H^*_{1,N-1-2l}U^*_{2k+1-2l}]D_{1,2l} \\ &- J_{2k+1} + W_{2k+1} \end{aligned} \tag{19}$$

$$\begin{aligned} J_{2k+1} &= \frac{1}{2}\sum_{l=0}^{N/4-1}[(H^*_{2,2k+1}H_{1,N-1-2l}U_{N-2-2l-2k} \\ &+ H_{2,N-2-2k}H^*_{1,2l}U^*_{2k-(N-2-2l)})D^*_{1,2l} \\ &+ (H^*_{2,2k+1}H_{2,N-2-2l}U_{N-3-2l-2k} \\ &+ H_{2,N-2-2k}H^*_{2,2l+1}U^*_{2k-(N-3-2l)})D^*_{2,2l+1}] \end{aligned} \tag{20}$$

$$W_{2k+1} = \frac{1}{2}(H^*_{2,2k+1}Z_{2k+1} - H_{2,N-2-2k}Z^*_{N-2-2k}) \tag{21}$$

The first terms on the right hand side of the (18) is the desired transmitted data symbols on odd subcarriers. The ICI terms are I_{2k+1} and J_{2k+1} while W_{2k+1} is the AWGN.

When the channel is flat, the frequency response of the channel $H_{1,l}$ and $H_{2,l}$ is assumed to be equal to 1 [12] such as an AWGN channel. Then the received signal (14) on even subcarriers becomes

$$\begin{aligned} R_{2k} &= D_{1,2k} + \frac{1}{2}\sum_{l=0,l\neq k}^{N/4-1}[U_{2l-2k} + U^*_{2k-2l}]D_{1,2l} \\ &+ \frac{1}{2}\sum_{l=0}^{N/4-1}[U_{2l+1-2k} + U^*_{2k-(2l+1)}]D_{2,2l+1} \\ &- \frac{1}{2}\sum_{l=0}^{N/4-1}[(U_{N-1-2l-2k} + U^*_{2k-(N-1-2l)})D^*_{1,2l} \\ &+ (U_{N-2-2l-2k} + U^*_{2k-(N-2-2l)})D^*_{2,2l+1}] \\ &+ \frac{1}{2}(Z_{2k} - Z^*_{N-1-2k}) \end{aligned} \tag{22}$$

and the received signal (18) on odd subcarriers becomes

$$\begin{aligned} R_{2k+1} &= D_{2,2k+1} + \frac{1}{2}\sum_{l=0,l\neq k}^{N/4-1}[U_{2l-2k} + U^*_{2k-2l)}]D_{2,2l+1} \\ &+ \frac{1}{2}\sum_{l=0}^{N/4-1}[U_{2l-(2k+1)} + U^*_{2k+1-2l}]D_{1,2l} \\ &- \frac{1}{2}\sum_{l=0}^{N/4-1}[(U_{N-2-2l-2k} + U^*_{2k-(N-2-2l)})D^*_{1,2l} \\ &+ (U_{N-3-2l-2k} + U^*_{2k-(N-3-2l)})D^*_{2,2l+1}] \\ &+ \frac{1}{2}(Z_{2k+1} - Z^*_{N-2-2k}) \end{aligned} \tag{23}$$

Note also that modulated symbols are assumed independent, zero-mean random variables with unit average power. From (22) and (23), the 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

$$CIR_0 = \frac{4}{ICI_0} \tag{24}$$

and

$$CIR_1 = \frac{4}{ICI_1} \tag{25}$$

where

$$\begin{aligned} ICI_0 &= \sum_{l=1}^{N/4-1}|U_{2l} + U^*_{-2l}|^2 \\ &+ \sum_{l=0}^{N/4-1}(|U_{2l+1} + U^*_{-(2l+1)}|^2 \\ &+ |U_{N-1-2l} + U^*_{-(N-1-2l)}|^2 \\ &+ |U_{N-2-2l} + U^*_{-(N-2-2l)}|^2) \end{aligned} \tag{26}$$

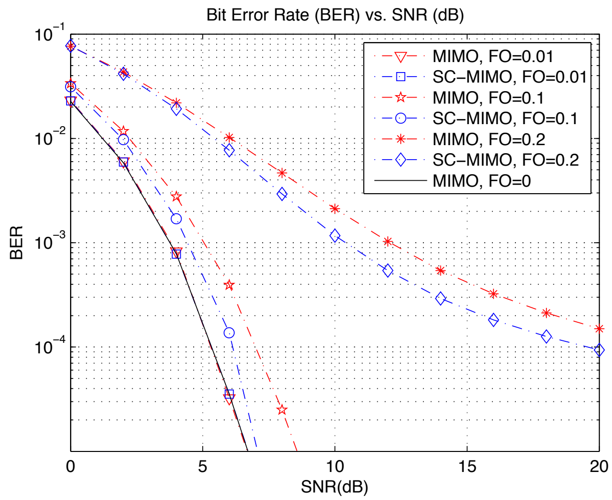


Fig. 3. The curves of BER versus SNR (dB) for AWGN channels

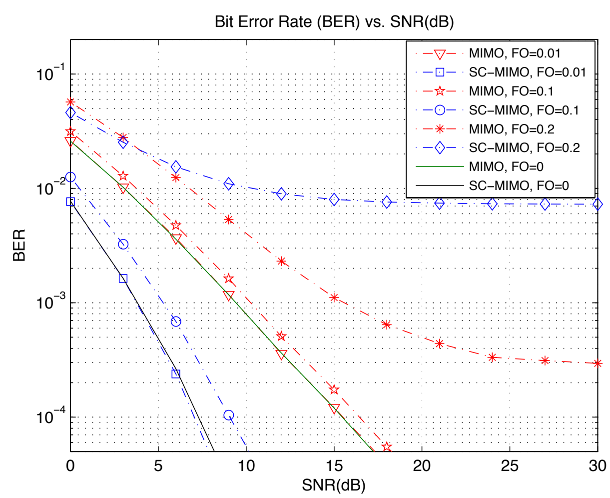


Fig. 4. The curves of BER versus SNR (dB) for Rayleigh fading channels

and

$$ICI_1 = \sum_{l=1}^{N/4-1} |U_{2l} + U^*_{-2l}|^2 + \sum_{l=0}^{N/4-1} (|U_{2l-1} + U^*_{1-2l}|^2 + |U_{N-2-2l} + U^*_{-(N-2-2l)}|^2 + |U_{N-3-2l} + U^*_{-(N-3-2l)}|^2) \quad (27)$$

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

$$CIR = \frac{|U_0|^2}{\sum_{l=1}^{N-1} |U_l|^2} \approx \frac{1}{\sum_{l=1}^{N-1} |U_l|^2} \quad (28)$$

It is worth noting that when the frequency off is small, the ICI_0 and ICI_1 approach 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.

After the process of ICI cancelling and diversity combining, the maximal ratio combining [13] is used to combine a pair of received signals in (14) and (18). The following combined signal will be sent to the maximum likelihood detector for detecting transmitted symbol

$$\tilde{X}_{\frac{i}{4}-2} = \frac{R_{\frac{i}{2}-4}}{N_0} + \frac{R_{\frac{i}{2}-1}}{N_0} \quad (29)$$

$$\tilde{X}_{\frac{i}{4}-1} = \frac{R_{\frac{i}{2}-3}}{N_0} + \frac{R_{\frac{i}{2}-2}}{N_0} \quad (30)$$

Note that i can be denoted as ($i = 8, 16, 32, ..., N$, respectively), N is the total number of subcarriers in an OFDM frame and N_0 represents a noise variance.

IV. Simulation Results

In this section, the proposed zero-padded symmetric self-cancellation scheme in MIMO-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 MIMO-OFDM systems. The bandwidth efficiency is 1 b/s/Hz, and the QPSK modulation is employed for the proposed system, while BPSK is used for ordinary zero-padded MIMO-OFDM systems. The simulation is conducted under both AWGN and frequency-selective Rayleigh fading channels by using Jake's model [14] with a normalized Doppler shift of 5,000 Hz with the six paths Typical Urban (TU) delay profile [15]. The frequency offset to subcarrier spacing ratio (ΔfT) is chosen as 0.01, 0.1 and 0.2, respectively. Assuming that the receiver has perfect knowledge of the channels and the cyclic prefix is employed so that the receiver has the perfect time synchronization. An OFDM modulation for each system utilizes $N = 64$ subcarriers. In comparison with another technique, the two-path complex conjugate cancellation, the proposed system is compared to the zero-padded complex conjugate cancellation in MIMO-OFDM systems which was proposed in [11]. In addition, the QPSK modulation is used for both systems.

Fig.3 shows the BER versus SNR (dB) for the zero-padded symmetric conjugate self-cancellation scheme in MIMO-OFDM systems and the curve for the ordinary zero-padded MIMO-OFDM systems in AWGN channel. It is worth noting that, at BER of 10^{-4} for $(\Delta fT = 0.1)$, the proposed scheme has 1 dB gain over the ordinary zero-padded MIMO-OFDM systems. In the small ΔfT $(\Delta fT = 0.01)$, the difference between both systems is not significant. In addition, when ΔfT is large $(\Delta fT = 0.2)$, the proposed system offers 2 dB gain at BER of 3×10^{-4} compared to the ordinary zero-padded MIMO-OFDM systems.

Fig.4 shows the BER versus SNR (dB) for the proposed scheme and the curve for the ordinary zero-padded MIMO-OFDM systems in Rayleigh channels. It is worth noting that,

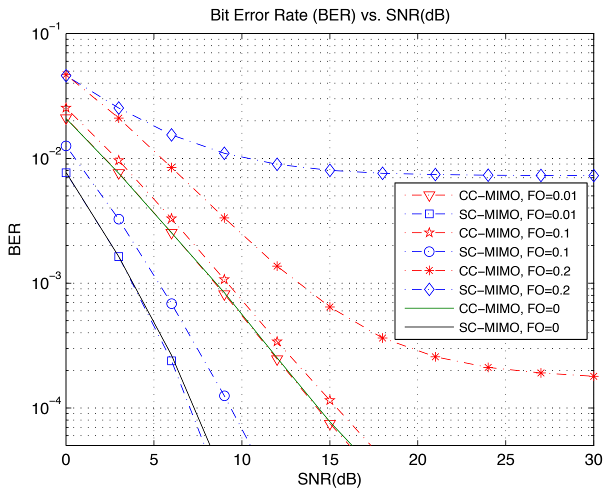


Fig. 5. The curves of BER versus SNR (dB) for zero-padded symmetric conjugate self-cancellation and zero-padded complex conjugate cancellation in Rayleigh fading channels

when ΔfT is small $(\Delta fT = 0.01, 0.1)$, the proposed scheme provides better performance than that of ordinary one about 7.5 dB at BER of 10^{-4}. Moreover, when ΔfT is large, $(\Delta fT = 0.2)$, the BER of the ordinary zero-padded MIMO-OFDM systems is precisely better than the proposed system.

Fig.5 shows the BER versus SNR (dB) for the proposed scheme and the curve for the zero-padded complex conjugate cancellation in MIMO-OFDM systems in Rayleigh channels. It is worth noting that, when ΔfT is small $(\Delta fT = 0.01, 0.1)$, the proposed scheme is better than that of the zero-padded complex conjugate cancellation scheme in MIMO-OFDM systems about 7 dB at BER of 10^{-4} at $(\Delta fT = 0.01)$ and about 6 dB at BER of 10^{-4} at $(\Delta fT = 0.1)$. In addition, when ΔfT is large $(\Delta fT = 0.2)$, the BER of the zero-padded complex conjugate cancellation scheme in MIMO-OFDM systems is obviously better than the proposed scheme.

V. 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 MIMO-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 MIMO-OFDM systems. In Rayleigh fading channels, the proposed system offers the SNR gain of 7.5 dB at BER of 10^{-4} in the presence of small frequency offsets of 1-10%. In addition, the proposed system outperforms the zero-padded complex conjugate cancellation in MIMO-OFDM systems about 6 dB at BER of 10^{-4} in the presence of frequency offset of 10%. Thus, it was also proven by the simulation that the proposed scheme is useful for the MIMO-OFDM systems in the presence of small frequency offset situations.

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