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Ber Analysis and Interference Cancellation In SFBC-Mimo OFDM With Timing Offset

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Abstract

In this paper, we proposed an iterative receiver for MIMO-OFDM systems. Based on this receiver, solutions to two of the most important problems in OFDM systems have been provided, namely, inter carrier interference cancellation and inter symbol interference cancellation over time-selective and frequency-selective fading channels. In this topic we consider an SFBC-OFDM system with timing offset (μ) and derive the mathematical expressions for the interference provoked and propose the interference cancelling receiver. The influence of timing offset (μ) on a MIMO OFDM system has been derived theoretically and evaluated from results of bit error rate (BER) simulations.

Index terms: Multiple Input Multiple Output, Orthogonal Frequency Division Multiplexing, Timing offset, Inter carrier Interference, Inter Symbol Interference, Space Frequency Block Code

Introduction

SFBC-OFDM signals usage is advantageous in high-mobility broadband wireless access, where the channel is largely frequency as well as time -selective because of which the receiver struggles both ISI and ICI. ISI inducess mainly with the infraction of the `quasi-static' fading due to frequency- and/or time-selectivity of the channel. In continuation, ICI count because of time-selectivity of the channel which leads to consequences in loss of orthogonality among the subcarriers [1] .

In the literature there are adequate procedures and algorithms to cancel ICI in MIMO OFDM systems. Stamoulis et al., in [2], presented ICI-mitigating schemes with block linear filters for STBC OFDM. However, they are not scrutinize the cost of QS inference in large delay spread channels. D. Sreedhar et al [3], proposed an interference mitigation procedures for MIMO system at the receiving node, and showed that the presented algorithm adequately cancels the ISI and ICI effects. They proposed an interference mitigation algorithm with AF protocol and phase compensation at the relays for a CO-SFBC-OFDM system. They also proposed an interference mitigation procedure for the same system when DF protocol is used at the relays, instead of AF protocol with phase compensation. Their simulation results showed that, with the proposed algorithms, the achievement of the CO-SFBC-OFDM was better than OFDM without co-operation even in the presence of carrier synchronization errors. It is also proved that in these CO-SFBC-OFDM systems DF protocol better functioning than the AF protocol. However, they considered MIMO OFDM with carrier frequency offset (CFO) and they do not acknowledge the timing offset effects in MIMO OFDM systems.

Methodology

The SFBC-OFDM presented in the literature assumes excellent timing synchronization i.e. the frames transmitted by two transmitting antennas appear at the same time at the receiver. This is very onerous to achieve in a practical system and requires lot of time and feedback channel bandwidth. More over when there is a instant adjustment in the channel in a wireless mobile communication system the synchronization gets disturbed. Because of this the frames transmitted by two antennas arrive at different time intervals which we regard to as the timing offset [4].

The system with timing offset, the system gets synchronized to the frame transmitted by one antenna but the synchronization is lost for the frame transmitted by the other antenna. The other frame which arrives with the timing offset may appear at the receiver, before or after the frame with perfect synchronization. In the first case we call the timing offset as negative ($\mu < 0$) and in next case we call it as positive ($\mu > 0$) is illustrated through processing window in fig. 1.[5]. For various values of μ the expressions for the interference terms are different.

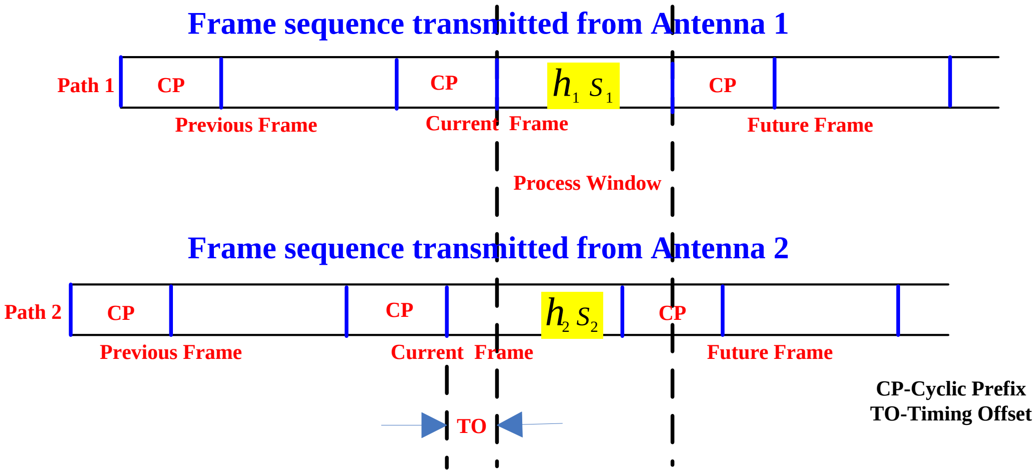

Figure 1: Processing Window

SFBC-OFDM System Model

In this we propose the derivation for one case where the frame transmitted from the second antenna arrive with positive timing offset and present the interference mitigating receiver for such a system. To derive these Expressions we examine the SFBC system with N-subcarriers in which the complex symbol vector transmitted is X=[x0,x1,x2,….,xN-1]. After SFBC Alamouti (2X1) coding we get two vectors given by

$v_1 = [v_0^1, v_1^1, v_2^1, ..., v_{N-1}^1]$ in which $v_n^1 = x_n$, where *n=0,1,2..,N-1* and $V_2 = [v_0^2, v_1^2, v_2^2, ..., v_{N-1}^2]$ in which $v_n^2 = x_{2n+1}^*$ for n even and $v_n^2 = -x_{2n}^*$ for n odd, where *n=0,1,2..,N-1.*

The N-point IFFT of v_1 with cyclic prefix added to get s_1. s_1 is transmitted by the transmitting antenna 1 and that of v_2 with cyclic prefix added to get s_2 is transmitted by the transmitting antenna 2.

Assuming that the frame transmitted by the first antenna reaches the receiver through the Rayleigh flat faded channel with channel co-efficient h_1 with perfect timing to get $\boldsymbol{R_1} = h_1 \,.\, \boldsymbol{S_1} + w_1$ after dropping the cyclic prefix. And the kth output of the N-point FFT block at the receiver is given as

$$Y_1(k) = h_1\, x(k) + W_1(k) \tag{1}$$

Similarly, the frame transmitted by the second antenna reaches the receiver through the Rayleigh flat faded channel with channel co-efficient h_2 with positive timing offset μ for which the frame sequences presented in the Fig. 1 , the received signal vector related to the signal from the transmitted from antenna 2 is

$$r_2(n) = \begin{cases} h_2\, s_2((n+\mu))_N + w_2 & 0 \le n \le N-1-\mu \\ h_2\, s_2^f((n+\mu))_N + w_2 & N-\mu \le n \le N-1 \end{cases} \tag{2}$$

The kth result of the N- point FFT block for the complex conjugate of this input is

$$\begin{aligned} Y_2(k) &= FFT\{r_2(n)\} \\ &= \sum_{n=0}^{N-1} r_2(n) e^{-j\frac{2\pi}{N}kn} = \sum_{n=0}^{N-1-\mu} r_2(n) e^{-j\frac{2\pi}{N}kn} + \sum_{N-\mu}^{N-1} r_2(n) e^{-j\frac{2\pi}{N}kn} \qquad (3) \\ &= \sum_{n=0}^{N-1-\mu} s_2((n+\mu))_N\, h_2 . e^{-j\frac{2\pi}{N}kn} + \sum_{n=N-\mu}^{N-1} s_2^f((n-N_g-\mu))_N\, h_2 . e^{-j\frac{2\pi}{N}kn} + W_2(k) \\ &= \sum_{n=0}^{N-1-\mu} \frac{1}{N} \left\{ \sum_{q=0}^{N-1} v^2(q) e^{j\frac{2\pi}{N}q\mu} e^{j\frac{2\pi}{N}qn} \right\} h_2 . e^{-j\frac{2\pi}{N}kn} \qquad (4) \\ &\quad + \sum_{n=N-\mu}^{N-1} \frac{1}{N} \left\{ \sum_{q=0}^{N-1} v^{2f}(q) e^{-j\frac{2\pi}{N}q(N_g+\mu)} e^{j\frac{2\pi}{N}qn} \right\} h_2^f . e^{-j\frac{2\pi}{N}kn} + W_2(k) \end{aligned}$$

Where $v^2(q)$ and $v^{2f}(q)$ are the symbols from the current and interference frames, respectively.

$$= \sum_{q=0}^{N-1} \left\{ v^2(q) e^{j\frac{2\pi}{N}q\mu} \right\} (\frac{1}{N}) h_2 \sum_{n=0}^{N-1-\mu} e^{-j\frac{2\pi}{N}(k-q)n} \tag{5}$$

$$+ \sum_{q=0}^{N-1} v^{2f}(q) e^{-j\frac{2\pi}{N}q(N_g+\mu)} (\frac{1}{N}) \sum_{n=N-\mu}^{N-1} h_2 . e^{-j\frac{2\pi}{N}(k-q)n} + W_2(k)$$

$$= \underbrace{v^2(k) h_2 e^{j\frac{2\pi}{N}k\mu} (\frac{N-\mu}{N})}_{Desired\,term} + \underbrace{(\frac{1}{N}) \sum_{\substack{q=0 \\ q\neq k}}^{N-1} \left\{ v^2(q) e^{j\frac{2\pi}{N}q\mu} \right\} h_2 . \sum_{n=0}^{N-1-\mu} e^{-j\frac{2\pi}{N}(k-q)n}}_{ICI} \tag{6}$$

$$+ \underbrace{\sum_{q=0}^{N-1} v^{2f}(q) e^{-j\frac{2\pi}{N}q(N_g+\mu)} (\frac{1}{N}) \sum_{n=N-\mu}^{N-1} h_2 . e^{-j\frac{2\pi}{N}(k-q)n}}_{ISI} + W_2(k)$$

In this, ICI is the interference from the symbols from the current frame and ISI is the interference from the symbols of the next frame.

$$Y_2[k] = \underbrace{V^2[k]H[k]}_{Desired} + \underbrace{\sum_{\substack{q=0 \\ q\neq k}}^{N-1} V^2[q]H[q]}_{ICI} + \underbrace{\sum_{q=0}^{N-1} V^{2f}[q]H^f[q]}_{ISI} + W_2(k) \tag{7}$$

where

$$H[k] = \left[h_2 . e^{j\frac{2\pi}{N}k\mu} \Gamma_{kk} \right]$$

$$H[q] = \left[h_2 . e^{j\frac{2\pi}{N}q\mu} \Gamma_{qk} \right]$$

$$\Gamma_{qk} = \frac{1}{N} \sum_{n=0}^{N-1-\mu} e^{j\frac{2\pi}{N}(q-k)n}$$

using $Y_1[k]$ and $Y_2[k], Y[k] = Y_1[k] + Y_2[k]$ is obtained.

Proposed Algorithm

ICI cancellation using Interference Cancellation (IC) Algorithm

Stage 1*:* Using $Y[k]$, the estimate of symbols $\hat{X}^1[q]$,$\forall q = 0\, to\, N-1$ is obtained.

Stage 2*:* Using $\hat{X}^1[q]$ for each k and known $H[q]$, $ICI_1[k]$ is computed using the formulae

$ICI_1[k] = \sum_{\substack{q=0 \\ q\neq k}}^{N-1} \hat{X}^1[q]H[q]$ and subtracted from Y[k] to get $Y^1[k]$, where

$$\begin{aligned} Y^1[k] &= Y[k] - ICI_1[k] \\ &= \underbrace{V^2[k]H[k]}_{Desired} + \underbrace{\sum_{\substack{q=0 \\ q\neq k}}^{N-1} V^2[q]H[q]}_{ICI} + \underbrace{\sum_{q=0}^{N-1} V^{2f}[q]H^f[q]}_{ISI} + W_2(k) - \underbrace{\sum_{\substack{q=0 \\ q\neq k}}^{N-1} \hat{X}^1[q]H[q]}_{ICI_1[k]} \end{aligned} \tag{8}$$

Stage 3: Using $Y^1[k]$, $X^2[q]$ is calculated. Using which, $ICI_2[k]$ is computed and subtracted from Y[k] to get

$$\begin{aligned} Y^2[k] &= Y[k] - ICI_2[k] \\ &= \underbrace{X[k]H[k]}_{Desired} + \underbrace{\sum_{\substack{q=0 \\ q\neq k}}^{N-1} X[q]H[q]}_{ICI} + \underbrace{\sum_{q=0}^{N-1} X^f[q]H^f[q]}_{ISI} + W_2(k) - \underbrace{\sum_{\substack{q=0 \\ q\neq k}}^{N-1} X^2[q]H[q]}_{ICI_2[k]} \end{aligned} \tag{9}$$

This process is repeated until we get considerable improvement in the performance of the system. In the similar way the ISI also can be cancelled.

Simulation Results

In simulations we contemplate the 16-subcarrier SFBC-OFDM that uses Alamouti's coding with 2 transmit and 1 receive antenna [6]. We simulated the system that has only ICI and assumed the perfect knowledge of channel co-efficient and timing offset.

The plot presented in the Fig. 2 obtained by simulations, in which the BER of the system is plotted as a function of SNR for different stages of the IC receiver. In this plot we can see considerable improvement in the BER performance of the system in the second stage itself, for example it is improving from 10^{-2} to 10^{-3} at 25 dB SNR. During the same SNR the improvement given by the third stage is less which becomes $5x10^{-4}$. This shows that the performance of the SFBC-OFDM system with timing offset can be considerably improved using the IC algorithm developed in this work.

Conclusion

It must be noted that OFDM systems are sensitive to timing offset which induces the ICI problem. The design of robust timing offset mitigation algorithm without using additional training symbols will be a challenge. Although the interference suppression scheme and the channel parameter estimation scheme proposed in this paper can be applied to ICI cancellation effectively for MIMO-OFDM systems.

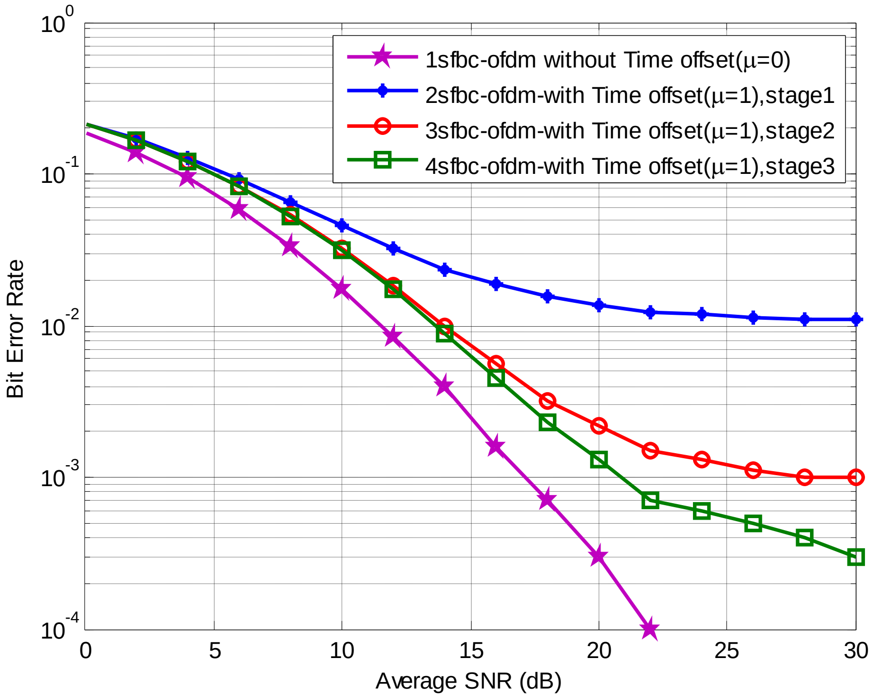

Figure 2: BER performance of the proposed IC detector in Rayleigh flat fading (QPSK)

In this work, we described the development and simulation of an interference cancelling algorithm for cancelling frequency selectivity induced ISI and time-selectivity induced ICI in MIMO SFBC-OFDM systems with timing offset. In this work, first we consider an SFBC-OFDM system with timing offset (μ), we derived the expressions for the interference caused and proposed the interference cancelling receiver. The simulations showed that considerable performance improvement is achieved, which intern proves the fidelity of the expressions derived.

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