

PEAK TO AVERAGE POWER RATIO and BIT ERROR RATIO Analysis of MIMO SFBC CI-OFDM System

Dr.D.K.Shrivastava

B.I.E.T.
JHANSI (UP), India

Preeti Agarwal

AISECT UNIVERSITY
Bhopal (MP),India

Anshul Soni

L.N.C.T
Indore (MP),India

Abstract- In this paper we are going to discuss OFDM, CI-OFDM, MIMO, SFBC. The OFDM design is fairly complex and some important design blocks are chosen for verification purposes. The CI-OFDM (carrier interferometry orthogonal frequency division multiplexing) system has been widely studied in the multi-carrier communication system. In this paper, focusing on the two Tx (transmit) / one Rx (receive) antennas and two Tx / two Rx antennas configuration, we evaluate the performance of MIMO OFDM and MIMO CIOFDM system. SFBC (space frequency block coding) is applied into both MIMO OFDM system and MIMO CIOFDM system. For CI- OFDM realization, digital implemented CI-OFDM structure is used in which CI code spreading operation and carrier allocation are separately processed by simple IFFT type operation. From the simulation results, it is shown that MIMO SFBC CI-OFDM reduces PAPR significantly compared with MIMO SFBC-OFDM system. The out-of band re-growth of signal spectrum in MIMO SFBC CI-OFDM system is much smaller than MIMO SFBC OFDM. In the NBI (narrow band interference) channel MIMO SFBC CI-OFDM system achieves considerable BER improvement, compared with the MIMO SFBC-OFDM system in which error floor occurs in most of SNR range.

Keywords-OFDM (orthogonal frequency division multiplexing), CI (carrier interferometry), PAPR(peak to average power ratio), MIMO(multiple input and multiple output), SFBC(space frequency block coding)

I INTRODUCTION

OFDM : It is a technology used to compress a large amount of data into a small amount of bandwidth This is done by dividing a large amount of data into smaller chunks, then sending that data simultaneously over a number of frequencies. Such parallel data transmission method is analyzed for the first time in a paper published in 1967. In this method, an available bandwidth is divided into several sub-channels. These sub-channels are independently modulated with different carrier frequencies. It was proved that the use of

a large number of narrow channels combats delay and related amplitude distortion in a transmission medium effectively. Based on this concept, OFDM was introduced through a US patent issued in 1970. The name orthogonal comes from the fact that the subcarriers are orthogonal to each other.

The key advantages of this technique are:

- OFDM is an efficient way to deal with multipath; for a given delay spread, the implementation complexity is significantly lower than that of a single carrier system with an equalizer.
- In relatively slow time-varying channels, it is possible to significantly enhance the capacity by adapting the data rate per subcarrier according to the signal-to-noise-ratio of that particular subcarrier.
- OFDM is robust against narrowband interference, because such interference aspects only a small percentage of the subcarriers.

A standard block diagram implementation of OFDM is shown in

Transmitter:

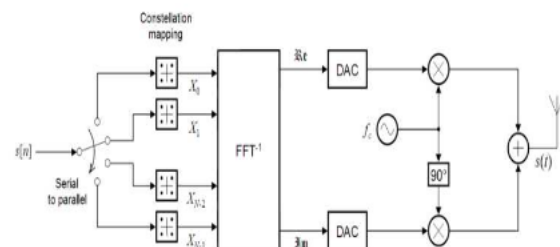


Figure 1: Block Diagram Implementation Of OFDM

An OFDM carrier signal is the sum of a number of orthogonal sub-carriers, with data on each sub-carrier being independently modulated commonly using some type of quadrature. Amplitude modulation (QAM) or phase-shift

keying (PSK). This composite baseband signal is typically used to modulate a main RF carrier. An inverse FFT is computed on each set of symbols, giving a set of complex time-domain samples. These samples are then quadrature-mixed to passband in the standard way. The real and imaginary components are first converted to the analogue domain using digital-to-analogue converters (DACs); the analogue signals are then used to modulate cosine and sine waves at the carrier frequency, f_c , respectively. These signals are then summed to give the transmission signal, $s(t)$.

Receiver:

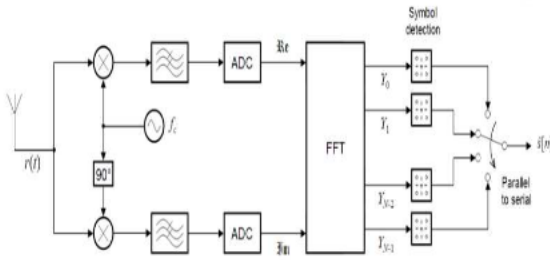


Figure 2: Block Diagram Receiver

The receiver picks up the signal $r(t)$, which is then quadrature-mixed down to baseband using cosine and sine waves at the carrier frequency. This also creates signals centered on $2f_c$, so low-pass filters are used to reject these. The baseband signals are then sampled and digitised using analog-to-digital converters (ADCs), and a forward FFT is used to convert back to the frequency domain.

CI – OFDM: In the CI-OFDM technique, each information symbol is sent simultaneously over all carriers and the each carrier for the symbol is assigned a corresponding orthogonal CI spreading code. This CI/OFDM system not only can reduce PAPR problem significantly but also achieve frequency diversity gains without any loss in throughput. Recently, CI-OFDM system was proposed for the PAPR reduction using CI phase offset codes and it shows the BER improvement by frequency diversity effect in the narrow band interference channel. This system spreads one information data into N sub carrier and the orthogonal CI spread codes are multiplied. So, it can achieve the good BER performance because of the frequency diversity benefit in each bit. However CI-OFDM system will be degraded when there is mismatch of phase effect due to the random phase noise.

MIMO : Multiple-input and multiple-output, or MIMO is the use of multiple antennas at both the transmitter and

receiver to improve communication performance. It is one of several forms of smart antenna technology. Note that the terms *input* and *output* refer to the radio channel carrying the signal, not to the devices having antennas. MIMO technology has attracted attention in wireless communications, because it offers significant increases in data throughput and link range without additional bandwidth or increased transmit power. It achieves this goal by spreading the same total transmit power over the antennas to achieve an array gain that improves the spectral efficiency (more bits per second per hertz of bandwidth) or to achieve a diversity gain that improves the link reliability (reduced fading). Because of these properties, MIMO is an important part of modern wireless communication standards such as IEEE 802.11n (Wi-Fi), 4G, 3GPP Long Term Evolution, Wi-MAX and HSPA+.

SFBC : The SFBC (space-frequency block coding) method is more efficient for the high quality transmission.

II SYSTEM DESCRIPTION

In this paper, SFBC transmit diversity technique is applied into the OFDM system. Simply, the 2Tx/1Rx and 2Tx/2Rx antenna configuration are considered to compare the system performance of the MIMO OFDM and MIMO CI-OFDM system. First, we discuss the traditional MIMO SFBC OFDM structure with 2Tx/1Rx and 2Tx/2Rx antenna.

A) 2Tx-1Rx SFBC OFDM system

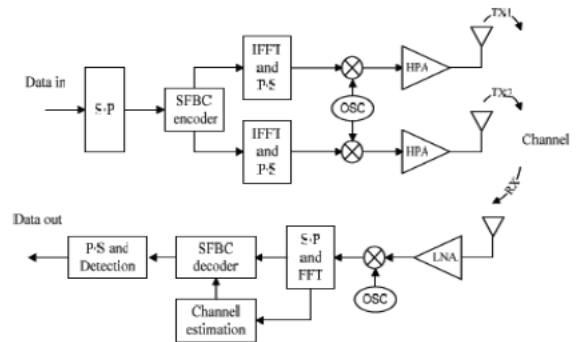


Figure 3: MIMO SFBC OFDM Transceiver Diagram With 2 X 1 Diversity.

When 2 Tx antennas and 1 Rx antenna are considered, assuming the system transmits data symbol $X_0, X_1, \dots, X_k, X_{k+1}, \dots, X_{N-1}$ carriers $0, 1, \dots, k, k+1, \dots, N-1$, respectively, the encoding algorithm is

$$\begin{bmatrix} f_k \\ f_{k+1} \end{bmatrix} \begin{bmatrix} \text{Tx1} & \text{Tx2} \\ X_k & X_{k+1} \\ -X_{k+1}^* & X_k^* \end{bmatrix}.$$

Channel description between the Tx antennas and Rx antenna is as Fig.2.

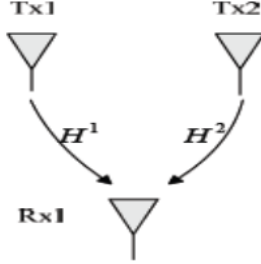


Figure 4: Channel Definition In 2*1 Diversity Scheme .

Received signals at the Rx antenna is defined as:

	Rx antenna 1
k th carrier	R_k
$k+1$ th carrier	R_{k+1}

So, received signal in frequency domain can be

$$R = \begin{bmatrix} R_k \\ R_{k+1} \end{bmatrix} = HX + N = \begin{bmatrix} H_k^1 & H_k^2 \\ H_{k+1}^1 & -H_{k+1}^1 \end{bmatrix} \begin{bmatrix} X_k \\ X_{k+1} \end{bmatrix} + \begin{bmatrix} N_k \\ N_{k+1} \end{bmatrix} \quad (1)$$

Let's assume that adjacent two carriers have same channel characteristic, such as

$$H_k^1 = H_{k+1}^1 = H^1, H_k^2 = H_{k+1}^2 = H^2.$$

Then, decoding algorithm is as follows.

$$\begin{aligned} \hat{R} &= \begin{bmatrix} \hat{R}_k \\ \hat{R}_{k+1} \end{bmatrix} = H^H R = \begin{bmatrix} H^{1*} & H^2 \\ H^{2*} & -H^1 \end{bmatrix} \begin{bmatrix} R_k \\ R_{k+1} \end{bmatrix} \\ &= (|H^1|^2 + |H^2|^2) \cdot \begin{bmatrix} X_k \\ X_{k+1} \end{bmatrix} + \begin{bmatrix} \tilde{N}_k \\ \tilde{N}_{k+1} \end{bmatrix} \end{aligned} \quad (2)$$

where H^H means the conjugate transpose of H , and

$$\begin{bmatrix} \tilde{N}_k \\ \tilde{N}_{k+1} \end{bmatrix} = \begin{bmatrix} H^{1*} & H^2 \\ H^{2*} & -H^1 \end{bmatrix} \begin{bmatrix} N_k \\ N_{k+1} \end{bmatrix}. \quad (3)$$

B) 2TX-2RX SFBC OFDM SYSTEM

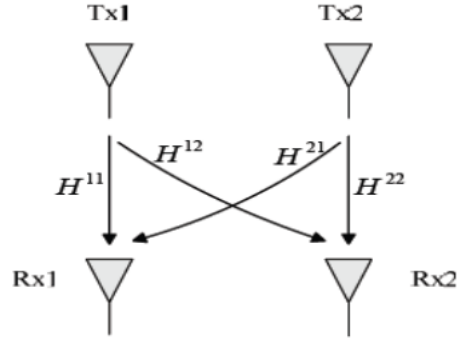


Figure 5: Channel Definition In 2 X 2 Diversity Scheme

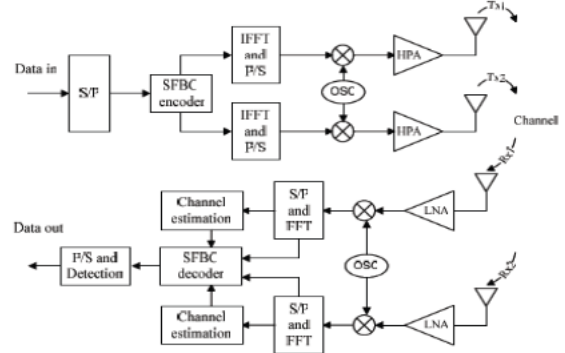


Figure 6: MIMO SFBC OFDM Transceiver Diagram With 2 X 2 Diversity.

When there are 2 Tx antennas and 2 Rx antennas, channel between the Tx and Rx antennas is described as Fig.3. Received signals at the two Rx antennas are defined as

	Rx antenna 1	Rx antenna 2
k th carrier	R_k^1	R_k^2
$k+1$ th carrier	R_{k+1}^1	R_{k+1}^2

So, received signals in frequency domain are expressed as follows:

$$R = \begin{bmatrix} R_k^1 \\ R_{k+1}^1 \\ R_k^2 \\ R_{k+1}^2 \end{bmatrix} = HX + N = \begin{bmatrix} H_k^{11} & H_k^{21} \\ H_{k+1}^{11} & -H_{k+1}^{11} \\ H_k^{12} & H_k^{22} \\ H_{k+1}^{12} & -H_{k+1}^{12} \end{bmatrix} \begin{bmatrix} X_k \\ X_{k+1} \end{bmatrix} + \begin{bmatrix} N_k^1 \\ N_{k+1}^1 \\ N_k^2 \\ N_{k+1}^2 \end{bmatrix} \quad (4)$$

Suppose adjacent two carriers have same channel characteristic, such as

$$\begin{aligned} H_k^{11} &= H_{k+1}^{11} = H^{11}, H_k^{12} = H_{k+1}^{12} = H^{12}, \\ H_k^{22} &= H_{k+1}^{22} = H^{22}, H_k^{21} = H_{k+1}^{21} = H^{21}. \end{aligned}$$

Then decoding algorithm is as follows

$$\begin{aligned} \hat{R} &= \begin{bmatrix} \hat{R}_k \\ \hat{R}_{k+1} \end{bmatrix} = H^H R = \begin{bmatrix} H^{11*} & H^{21} & H^{12*} & H^{22} \\ H^{21*} & -H^{11} & H^{22*} & -H^{12} \end{bmatrix} \begin{bmatrix} R_k^1 \\ R_k^2 \\ R_{k+1}^1 \\ R_{k+1}^2 \end{bmatrix} \\ &= (|H^{11}|^2 + |H^{22}|^2 + |H^{12}|^2 + |H^{21}|^2) \cdot \begin{bmatrix} X_k \\ X_{k+1} \end{bmatrix} + \begin{bmatrix} \tilde{N}_k \\ \tilde{N}_{k+1} \end{bmatrix} \end{aligned} \quad (5)$$

Where

$$\begin{bmatrix} \tilde{N}_k \\ \tilde{N}_{k+1} \end{bmatrix} = \begin{bmatrix} H^{11*} & H^{21} & H^{12*} & H^{22} \\ H^{21*} & -H^{11} & H^{22*} & -H^{12} \end{bmatrix} \begin{bmatrix} N_k^1 \\ N_{k+1}^1 \\ N_k^2 \\ N_{k+1}^2 \end{bmatrix} \quad (6)$$

III MIMO SFBC CI-OFDM SYSTEM

In the MIMO SFBC CI-OFDM system, the CI spreading process can be expressed as follows:

$$\begin{aligned} C_i(t) &= \sum_{k=0}^{N-1} e^{j2\pi k \Delta f t} \cdot e^{j k \Delta \theta_i} \\ \Delta \theta_i &= \frac{2\pi}{N} i, \quad i = 0, 1, \dots, N-1 \end{aligned} \quad (7)$$

where, $j = -1$, N is the total number of sub-carriers, Δf means the carrier spacing and $\Delta \theta_i$ is the assigned base spreading phase offset for the i th parallel data. Here, for general expression, we define CI spreading sequence series for the i th parallel data as before passing through nonlinear HPA, the l th Tx transmitted signal for one entire MIMO SFBC CI-OFDM symbol is as follows:

$$\begin{aligned} [c_i] &= \{c_i^0, c_i^1, \dots, c_i^{N-1}\} = \left\{ e^{j \frac{2\pi}{N} i \cdot 0}, e^{j \frac{2\pi}{N} i \cdot 1}, \dots, e^{j \frac{2\pi}{N} i \cdot (N-1)} \right\} \\ S^l(t) &= \sum_{k=0}^{N-1} \sum_{i=0}^{N-1} x_k^l \cdot e^{j2\pi k \Delta f t} \cdot e^{j k \Delta \theta_i} \cdot e^{j2\pi f_c t} \cdot p(t) \\ &= e^{j2\pi f_c t} \cdot \sum_{k=0}^{N-1} s_k^l \cdot e^{j2\pi k \Delta f t} \end{aligned} \quad (8)$$

where, $l k x$ is the time domain SFBC coded data on the k th carrier and l th Tx antenna, $c f$ is the center frequency and $P(t)$ is the pulse shaping for the bit duration $b T$. Besides,

$$\text{here, } \sum_{i=0}^{N-1} x_k^l \cdot e^{j k \Delta \theta_i} \text{ is defined as } s_k^l.$$

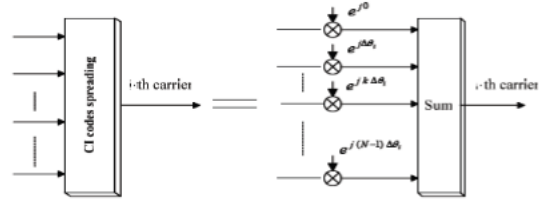


Figure7: CI Codes Spreading Block.

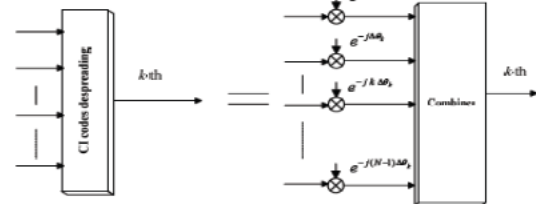


Figure 8: CI codes despreading block

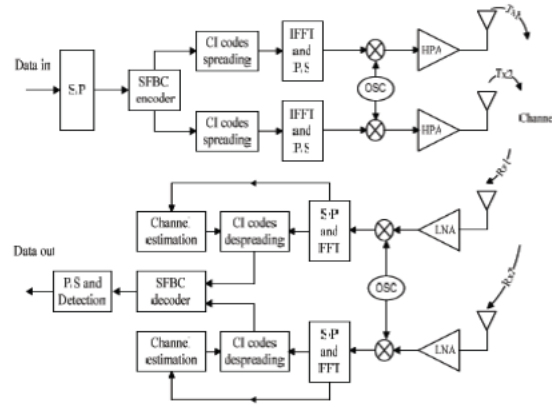


Figure 9: MIMO SFBC CI-OFDM Transceiver Diagram (2Tx-2Rx).

Theoretically, in the MIMO SFBC CI-OFDM receiver side, the j th Rx received signal can be expressed as follows:

$$\begin{aligned} R^j(t) &= e^{j2\pi f_c t} \cdot \sum_{l=1}^L \sum_{k=0}^{N-1} h_{lk}^j \cdot s_k^l \cdot e^{j2\pi k \Delta f t} + n^j(t) \\ &= e^{j2\pi f_c t} \cdot \sum_{l=1}^L \sum_{k=0}^{N-1} \alpha_{lk}^j \cdot s_k^l \cdot e^{j2\pi k \Delta f t} \cdot e^{j\phi_{lk}^j} + n^j(t) \\ &= e^{j2\pi f_c t} \cdot \sum_{l=1}^L \sum_{k=0}^{N-1} \alpha_{lk}^j \cdot e^{j2\pi k \Delta f t} \cdot e^{j\phi_{lk}^j} \cdot \sum_{i=0}^{N-1} x_k^l \cdot e^{j k \Delta \theta_i} + n^j(t) \\ &= \sum_{l=1}^L \sum_{k=0}^{N-1} \sum_{i=0}^{N-1} \alpha_{lk}^j \cdot x_k^l \cdot e^{j2\pi k \Delta f t} \cdot e^{j k \Delta \theta_i} \cdot e^{j2\pi f_c t} \cdot e^{j\phi_{lk}^j} + n^j(t) \end{aligned} \quad (9)$$

where L is the total transmit antenna number and here supposed to $L = 2$. $R^j(t)$ is the j th Rx antenna received signal, h_{lk}^j is the time domain channel response of the k th carrier from l th Tx antenna to j th Rx antenna when channel is frequency selective fading channel, α_{lk}^j and ϕ_{lk}^j are the fade parameter and phase offset of h_{lk}^j respectively, and $n^j(t)$ is the AWGN (additive white Gaussian noise) with a power spectral density equal to $0.0/N$ from l th Tx antenna to j th Rx

antenna. The above received signal is separated into its N orthogonal sub-carriers through FFT process. After channel state estimation, each symbol stream's phase offset due to spreading is removed from each carrier by CI codes despreading. The obtained vectors from each carrier are then combined by certain combining strategy. The combining strategy is employed to help restore orthogonality between symbol streams, maximize frequency diversity benefits, and minimize interference and noise. In AWGN or flat fading channel, EGC (equal gain combining) can be used. In the frequency selective channel, MMSEC (minimum mean-square error combining) can be used to minimize inter-symbol interference from other spreading codes and noise.

IV PERFORMANCE ANALYSES AND DISCUSSION

Based on the above theoretical analysis, in order to compare the transmission performance both in the MIMO SFBC OFDM and MIMO SFBC CI-OFDM system

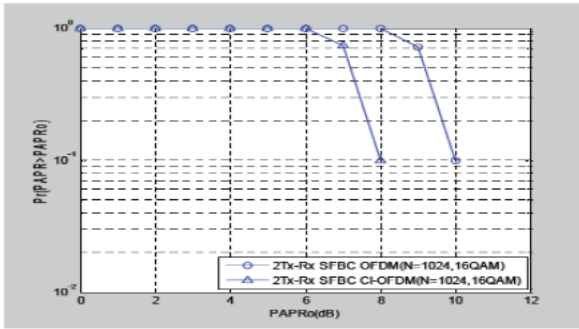


Figure 10 : PAPR In MIMO SFBC OFDM And MIMO SFBC CI-OFDM (N=1024,16QAM)

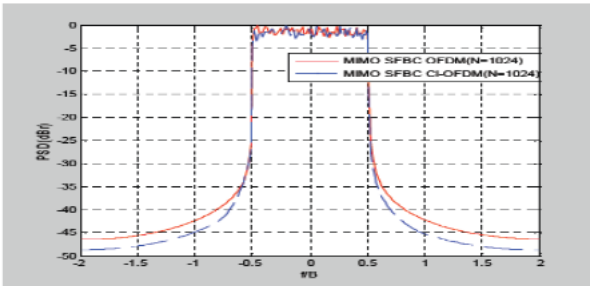


Figure 11: Spectrum in MIMO SFBC OFDM and MIMO SFBC CI-OFDM (N=1024, 16QAM)

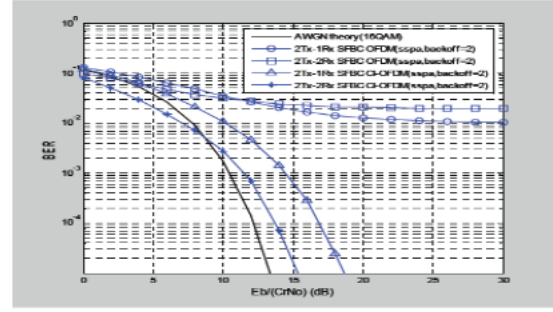


Figure 12: BER in MIMO SFBC OFDM and MIMO SFBC CI-OFDM with SSPA (N=1024, 16QAM, AWGN channel)

V CONCLUSION

In this paper, focused on the two Tx/one Rx antenna and two Tx/two Rx antenna configurations, we evaluate the system performance of MIMO SFBC OFDM and MIMO SFBC CIOFDM system on the basis of MIMO technique theoretical analysis. SFBC coding is applied in both MIMO OFDM system and MIMO CI-OFDM system. For CI-OFDM realization, digital implemented CI-OFDM structure is used, in which CI codes spreading operation and carrier allocation are separately processed by simple IFFT type operation.

(a) From the simulation results, it is found that MIMO SFBC CI-OFDM reduces PAPR significantly compared with MIMO SFBC-OFDM system. The carefully selected CI codes result in one symbol stream's power reaching a maximum, when the powers of the remaining $N-1$ symbol streams are at a minimum. Therefore, a more stable envelope, average PAPR and standard deviation of PAPR far smaller than traditional schemes can be achieved.

(b) The out-of band re-growth of signal spectrum in MIMO SFBC CI-OFDM system is much smaller than MIMO SFBC OFDM.

(c) When the Narrow band interference exists, MIMO SFBC CI-OFDM system achieves considerable BER improvement compared with the MIMO SFBC-OFDM system in which error floor occurs even in high SNR. It is because that CIOFDM method has frequency diversity benefit so that it brings robustness to the narrow band interference.

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