International Journal of Current Engineering and Technology
E-ISSN 2277 – 4106, P-ISSN 2347 – 5161

Research Article

BER Performance using Almouti-Based SC-FDMA using PN Codes

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Accepted 31 July 2015, Available online 05 Aug 2015, **Vol.5, No.4 (Aug 2015)**

Abstract

Due to various shortcomings of OFDM, like it is sensitive to Doppler shift, frequency synchronization problems, loss of efficiency caused by cyclic guard interval, it was endorsed to use coding algorithms like STBC which improves efficiency. Another way of increasing the efficiency is using a multiple – access technique like SC-FDMA. SC-FDMA can be described as linearly Pre-Coded OFDMA scheme, as it has an additional DFT Processing Step prefacing the ordinary OFDMA processing. In this paper, Almouti based SC-FDMA is proposed to enhance the system's BER performance and hence improve efficiency. To use the scheme efficiently, it is trained in time domain by appending the training sequence. Thus PN codes are combined with the Almouti based SC-FDMA, as they have less error probability and noise, to augment system's BER performance. The performance of the proposed system is compared with STBC-based TFT-OFDM.

Keywords: *DFT, Almouti, SC-FDMA, TFT-OFDM*

1. Introduction

OFDM has a reputation of high data rate transmission. However due to serious effects of fading, communication via multiple antennas can enhance the performance of the system by increasing the efficiency.

To improve the BER performance, various techniques based on OFDM have been proposed. STBC-based TFT-OFDM transmission scheme is proposed where the signal is trained in both time and frequency domain by appending the training sequence and by inserting the grouped pilots, to provide better spectral efficiency and reliability (Khusboo Singh, *et al*, 2014). Forward Error Correcting methods were used for BER performance of OFDM-BPSK, QPSK, QAM over AWGN channel (Vineet Sharma, *et al*,2012). Comparison of the performance of OFDM system using different modulation schemes under the influence of AWGN and Rayliegh fading channels was given in (Anurag Pandey, *et al*, 2014). Adaptive modulation and ICI cancellation methods were utilized in (Sangeeta Jajoria, *et al*, 2012) for combating the effects of channel fading and ICI respectively. Guard interval was inserted using cyclic prefix and zero padding to achieve error free communication (Dr. Amandeep Singh Sappal, *et al*, 2012). A technical view of MIMO-OFDM was given, presenting a view that an OFDM system can be combined with multiple antennas at both the access point and mobile terminal to increase diversity gain and/or enhance the system capacity on a time-varying multipath fading channel (Hongwei Yang, 2005). The proposal of space-time block coding (STBC) by Almouti in leads to many investigation performed on various STBC-based OFDM techniques (S.Almouti, 1998). A review of OFDMA and single carrier-FDMA is provided (Cristina Ciochina, *et al*, 2014). performance analysis of SC-FDMA and OFDMA in LTE frame structure is provided (Mohammad Mokhlesur Rahman, *et al*, 2012).

In this paper, SC-FDMA systems based on Almouti code is used in conjunction with PN codes. Almouti code is a multi-input multi-user code. This code is used as it reduces the Bit-error rate. STBC codes have given good results with OFDM, so it is expected to work more efficiently with SC-FDMA, To further enhance the system performance a combined approach of STBC codes and PN codes is used as they have less probability of error and also less noise.

Notations: Bold face lower case and upper case, denote vectors and matrices respectively, $(.)^*$ denotes complex conjugate, $(.)^H$ denotes complex conjugate transpose, I is identity matrix, $\hat{x}$ is estimate of x, |.| represents absolute operation.

Rest of the paper is organized as : Section 2 provides the system model of STBC- based SC-FDMA with PN codes. In Section 3 and 4 transmitter and receiver processing is described . Section 5 gives the simulation results and paper is conclude in 6.

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2. System Model

The Almouti based SC-FDMA using PN codes with two transmitting antennas and two receivers is considered. For the sake of simplicity the single receiver system is shown. An arbitrary signal is considered and modulated using QAM and symbol by symbol constellation mapping is done after parallelizing the data. An additional FFT step is performed in order to obtain the characteristics of single-carrier FDMA.. Subcarrier mapping is performed to assign each user a non-overlapping, different Fourier Coefficients. Now the signal is fed to the space-time block encoded which in this case is an Almouti encoder after performing IFFT and the output sequences and produced. If Z(n,p) represents the symbol on the nth subcarrier in the frame p, then for consecutive frames starting from pth frame, the symbol on the nth subcarrier is represented a [Z(n,p), − Z*(n,p+1)] in the first output sequence and [Z(n,p+1), Z*(n,p)] in the second output sequence, which are fed to representative transmitting branches. The signals in First and Second branch are given respectively as :

$$z(n,p) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} Z(n,p) W_N^{(-ns)} \tag{1}$$

$$z^*(n,p+1) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} Z^*(n,p+1) W_N^{(-ns)} \tag{2}$$

And,

$$z^*(n,p) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} Z^*(n,p) W_N^{(-ns)} \tag{3}$$

$$z(n,p+1) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} Z(n,p+1) W_N^{(-ns)} \tag{4}$$

Where $W_N^{(-ns)} = e^{(-\mathrm{j}2\mathrm{ns}\pi/\mathrm{N})}$, $(0 \le s < N)$ and j, is imaginary unit and N =3780.

After dividing the signal into two branches for two transmitting antennas, cyclic prefix is added in order to avoid inter symbol interference. A time domain PN sequence is added to the generated signals. A PN-sequence generator is used to generate such sequence which is added. At the receiver end, the TS is extracted, CP is removed. The data is parallelized and FFT is performed to obtain the frequency domain. Demaping is performed followed by equalization. After that IFFT is performed to convert the data to time domain. The data is converted to parallel for detection. The block diagram of Transmitter and Receiver is shown in Fig. 1.

3. Transmitter

The input signal is modulated using QAM. In order to make it different from OFDMA , an FFT step is performed before the subcarrier mapping is performed to assign each user a non-overlapping, different Fourier coefficient. The data is then divided into two streams after performing the IFFT, by STBC, which is defined by the transmission matrix:

$$\mathrm{A}= \begin{bmatrix} a_1 & a_2 \\ -a_2^* & a_1^* \end{bmatrix} \tag{5}$$

This matrix is a linear combination of symbols and their conjugates.

Now, for n^{th} subcarrier, we set a$_j$ = $C_{i,n}^{(j)}$ where $C_{i,n}^{(j)}$ is the element in i^{th} row and j^{th} column.

$$A = \begin{bmatrix} a_1 & a_2 \\ -a_2^* & a_1^* \end{bmatrix} = \begin{bmatrix} C_{(i,n)}^1 & C_{(i,n)}^2 \\ C_{(i+1,n)}^1 & C_{(i+1,n)}^2 \end{bmatrix} \tag{6}$$

Here,

$C_{(i,n)}^1 = Z$ (n,p) ,

$C_{(i+1,n)}^1 = -Z^*$ (n,p+1)

$C_{(i,n)}^2 = Z$ (n,p+1)

and $C_{(i+1,n)}^2 = Z^*$ (n,p).

In the time domain, this signal is composed of the SC-FDMA data block and a known PN sequence. Suppose the length of the sequence is L and SC-FDMA is Q then the length of the SC-FDMA symbol is T=L+Q. Subsequently the signals are transmitted via respective antennas.

4. Reciever

At the receiver end, the received symbol vector is

$$\mathrm{Y}= \begin{bmatrix} Y_i(n) \\ Y_{i+}(n) \end{bmatrix}$$

$$= \begin{bmatrix} H_{1,i}(n) & H_{2,i}(n) \\ H_{2,i+1}^*(n) & -H_{1,i+1}^*(n) \end{bmatrix} \begin{bmatrix} X_i(n) \\ X_2(n) \end{bmatrix} + \begin{bmatrix} N_i(n) \\ N_{i+1}(n) \end{bmatrix} \tag{7}$$

Where,

$$H= \begin{bmatrix} H_{1,i}(n) & H_{2,i}(n) \\ H_{2,i+1}^*(n) & -H_{1,i+1}^*(n) \end{bmatrix}$$

is the channel matrix imposed by Almouti's code

$$\begin{bmatrix} N_i(n) \\ N_{i+1}(n) \end{bmatrix}$$

is additive noise.

Now for the assumption of the conservative SC-FDMA symbol, the complex channel gains are same and H is , then

$$H^H H = \eta I \tag{8}$$

$$\begin{bmatrix} H_{1,i}(n) & H_{2,i}(n) \\ H_{2,i+1}^*(n) & -H_{1,i+1}^*(n) \end{bmatrix}^H \begin{bmatrix} H_{1,i}(n) & H_{2,i}(n) \\ H_{2,i+1}^*(n) & -H_{1,i+1}^*(n) \end{bmatrix} =$$

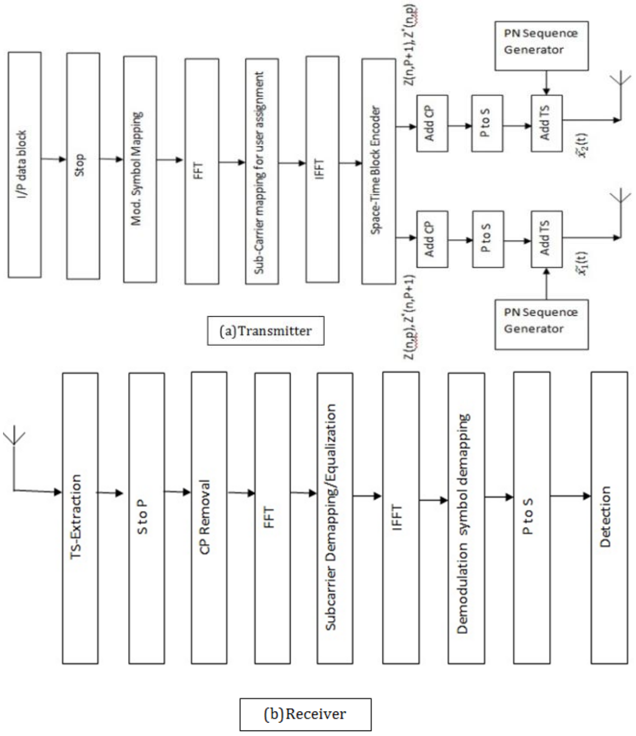
$$\begin{bmatrix} \rho & \beta \\ \beta & \sigma \end{bmatrix},$$

Where,

$\rho = \left|H_{1,i}(n)\right|^2 + \left|H_{1,i+1}(n)\right|^2,$

$\beta = H_{1,i}(n)H^*_{2,i}(\mathrm{n}) - H_{1,i+1}(n)H^*_{2,i+1}(\mathrm{n}),$

$\sigma = \left|H_{1,i+1}(n)\right|^2 + \left|H_{2,i}(n)\right|^2.$



(a)Transmitter

(b)Receiver

Fig. 1: Transmitter and Receiver of proposed

The two channel gains for two conservative symbol are considered same i.e.

$H_{1,i}(\mathrm{n}) = H_{1,i+1}(\mathrm{n})$
$H_{2,i}(\mathrm{n}) = H_{2,i+1}(\mathrm{n})$
And

$H_{1,i}(n)H^*_{2,1}(n) - H_{1,i+1}(n)H^*_{2,i+1}(n) = 0$
The above =n becomes

$$\begin{bmatrix} \eta & 0 \\ 0 & \eta \end{bmatrix} = \eta \mathrm{I} \qquad (9)$$

Where

$$\left[H_{1,i}(n)\right]^2 + \left[H_{2,i+1}(n)\right]^2 = \left[H_{1,i+1}(n)\right]^2 + \left[H_{2,i}(n)\right]^2 = \eta$$

Thus using (9) the symbol is detected as :

$$\tilde{X} = \frac{1}{\eta}Q(\tilde{X}) = \frac{1}{\eta}Q(H^H Y) = \frac{1}{\eta}Q[\eta X + H^H N] \qquad (10)$$

For, Perfect Channel, the channel gains of the two conservative symbol are not same, thus for STBC based SC-FDMA, the channel matrix H is not orthogonal which implies.

$$H^H H = \begin{bmatrix} \eta_1,(n) & \alpha(n) \\ \alpha^*(n) & \eta_2(n) \end{bmatrix} = \eta_{\,\mathrm{n}}\mathrm{I} \qquad (11)$$

Where $\eta_1(\mathrm{n}) = \left|H_{1,i}(n)\right|^2 + \left|H_{2,i+1}(n)\right|^2$
$\eta_2(\mathrm{n}) = \left|H_{i}(n)\right|^2 + \left|H_{2,i+1}(n)\right|^2$
And

$\alpha(n) = H_{1,i}(n)\, H^*_{2,i}(\mathrm{n}) - H_{1,i+1}(n)\, H^*_{2,i+1}(\mathrm{n})$

Thus on the basis of above (11), symbol is detected as :

$$\tilde{X} = \begin{bmatrix} X_1(n) \\ X_2(n) \end{bmatrix} =$$

$$\begin{bmatrix} \eta_1(n)X_1(n) + \alpha(n)X_2(n) + N_i'(n) \\ \alpha(n)X_1(n) + \eta_2(n)X_2(n) + N_{i+1}'(n) \end{bmatrix} \qquad (12)$$

$$N' = \begin{bmatrix} N_1'(n) \\ N_2'(n) \end{bmatrix} = H^H N \quad (13)$$

The channel conditions are estimated via signals using the time domain. There estimated conditions are used for generating the signal used for detection.

Once the signal is detected, the demapping is and symbol demodulation to obtain the original signal.

Once the signal is obtained, BER is calculated and used for comparison.

5. Simulation Results

The proposed modal of the STBC-based or Almouti based SC-FDMA is compared with STBC-based TFT-OFDM on the basis of BER performance. In (Khusboo Singh, *et al*, 2014), simulation was performed for comparison between STBC based TDS-OFDM, CP-OFDM, ZP-OFDM and STBC-based TFT-OFDM. It was shown that at BER of 10^{-4}, the STBC based TFT-OFDM was performing better than other variants of STBC based OFDM viz. CP-OFDM, TDS-OFDM, ZP-OFDM by the SNR gain of 4.8 db, 1.8db and 4db as shown in Fig. 2.

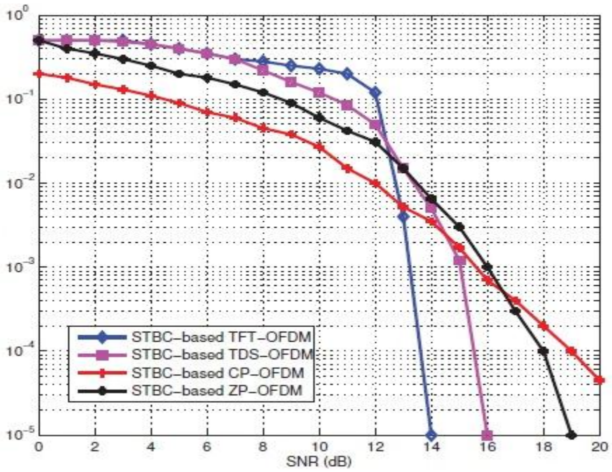


Fig.2: Shows the comparison between STBC-based TFT-OFDM and other variants of OFDM as was proposed in (Khusboo Singh, *et al*, 2014)

In Fig.3 the simulation result of BER performance of the proposed model is shown. The comparison between the proposed system and STBC-based TFT-OFDM is shown in Fig. 4.

The results show that STBC-based SC-FDMA with PN codes outperforms the STBC-based TFT-OFDM by 2.6db.

The proposed system works better than all other variants of OFDM viz. CP-OFDM, TDS-OFDM, ZP-OFDM and TFT-OFDM.

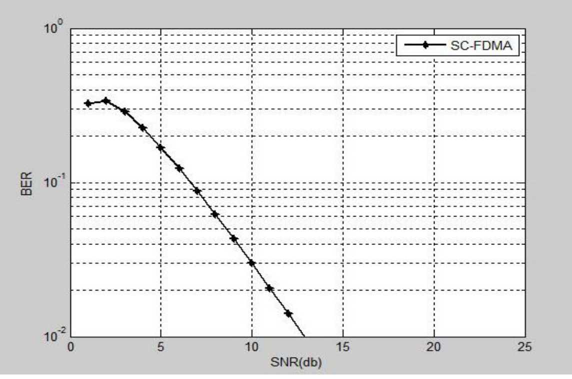


Fig. 3 Simulation result of proposed system

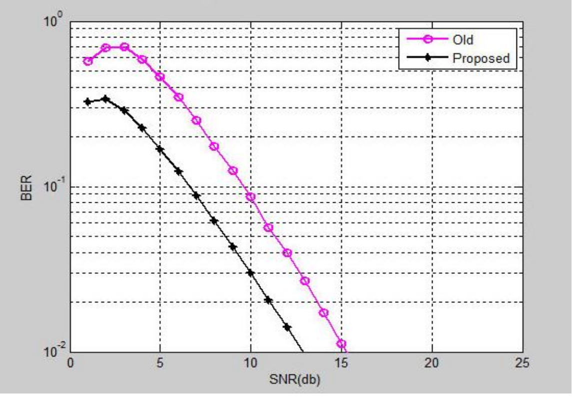


Fig. 4: Comparison between proposed system and STBC-based TFT-OFDM

Conclusions

In this paper, Almouti-based SCFDMA system with PN Codes is proposed. The performance of applying these codes to the proposed system is analysed over AWGN and Rayliegh channels and a comparison is made with STBC based TFT-OFDM. The results showed that proposed system performed better in terms of BER, than all other variants of OFDM viz. CP-OFDM, ZP-OFDM, TDS-OFDM and TFT-OFDM.

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