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A Study on Space Time Block Code and Space Frequency Block Code with MIMO-OFDM in Wireless Communication Systems

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ABSTRACT: Wireless communication is a popular method used worldwide for data transmission and reception. For larger capacity and higher data rate we use MIMO system. MIMO-OFDM combines multiple input, multiple output (MIMO) technology and orthogonal frequency division multiplexing (OFDM). This work provides an overview of Space-Time Block Code (STBC)-OFDM system and Space-Frequency Block Code (SFBC)-OFDM and a comparison between them are introduced.

KEYWORDS: OFDM, MIMO, STBC, SFBC.

1. INTRODUCTION

OFDM (Orthogonal frequency division multiplexing) is the dominant air interface standard for wireless communication system. Now a day, the demand of high data rate with high efficiency is very difficult to achieve. One of the favourable solution of this is to combine MIMO and OFDM system as MIMO-OFDM [1].MIMO is the multiple inputs and multiple output system which is used for multiplying the capacity of a radio link .i.e. MIMO-OFDMs increases the data rate rather using a single input single output system. OFDM uses multiple carrier signals to transmit information in parallel over the channel which improves the data rate as well as bandwidth efficiency.

The wireless channel mainly suffers from frequency selective fading due to multipath propagation of the transmitted signal, which makes it difficult for the receiver section to determine the transmitted signal unless some less attenuated replica of the signal are provided to the receiver. Transmitting the replica of the original message signal is called diversity. A successful scheme to reduce the effects of the signal fading is that introduction of channel diversity to the system[11]. The principle behind channel diversity is to transmit multiple copies of the signal of interest to the receiver which is transmitted over independently fading channels, thus the probability that the entire signal components will fade simultaneously is considerably reduced [6,7]. Spatially separated multiple antennas reduce the probability of losing the signal, which combines the antenna signals in order to increase the received average power and the OFDM modulation is implemented using IFFT.

Wireless communication system offers different sources of diversity .Diversities should be properly exploited by coding and transmission scheme. The main diversity schemes are temporal diversity, frequency diversity and spatial diversity. Spatial diversity is obtained by using space-time codes and multiple antennas. Space-time block coding (STBC)is an efficient method for achieving a near optimal transmitter diversity gain in MIMO system [1].Transmit diversity is a new method, which enables the system designer to move the diversity burden from the mobile units to the base station. Space frequency block coding (SFBC) achieves similar diversity gain as STBC-OFDM in Slow fading channels. Here the coding is applied in frequency domain rather than in time domain [4].

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II. RELATED WORKS

A) MIMO-OFDM

MIMO-OFDM is the most popular air interface standard for 4G and 5G wireless communications. It combines multiple input, multiple output (MIMO) technology and OFDM. MIMOs multiplies capacity of radio by transmitting different signals over multiple antennas and orthogonal frequency division multiplexing (OFDM) divides the channel into a large number of closely spaced sub channels to provide multipath propagation at high speeds.

MIMO-OFDM has the greatest spectral efficiency, therefore it delivers the highest capacity and data throughput. So this is the foundation for most wireless local area network (Wireless LAN) and mobile broadband network standards. That is, by using multiple antennas and precoding the data, different data streams could be sent over different paths [10, 12]. Studies conducted by Raleigh concluded that the processing required by MIMO at higher data rates would be most manageable using OFDM; Because OFDM converts a high-speed data channel into a number of parallel, lower-speed channels[1].

A set of sinusoidal subcarrier generators and demodulators were used in OFDM earlier, which imposed a high implementation complexity. Later, modulation and demodulation are performed by inverse discrete Fourier transforms (IDFT)and discrete Fourier transforms(DFT), which significantly reduces the implementation complexity of OFDM. The main advantage of OFDM is, multiple symbols can be transmitted in parallel, while maintaining a high spectral efficiency. To maintain robustness against frequency-selective fading, channel coding techniques are introduced in OFDM system, where errors are encountered at specific subcarriers in the frequency domain. It is a cost-effective approach to obtain high throughput for wireless communications [1][2]. Fig.1 is the representation of OFDM in MIMO system with M_T transmit and M_R receive antennas.

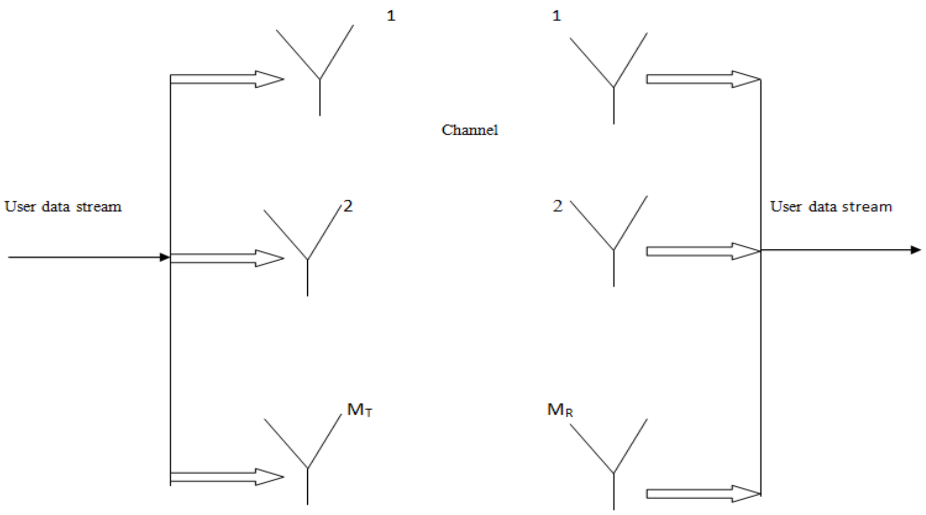

Fig.1. OFDM in MIMO SYSTEM for $M_T \times M_R$ antenna

B) SPACE TIME BLOCK CODED (STBC) OFDM

Space time block coding is used to transmit multiple copies of an information signal across a number of antennas to improve reliability of the received signal [2]. STBC combines all the copies of the received signal. Here the codes are orthogonal and can achieve full transmit diversity [9]. STBC-OFDM achieves spatial diversity gain over frequency selective fading channels [7, 8]. Fig.2 shows the simple block diagram of space time coding for OFDM system. At the transmitter, the information signal is coded, modulated and finally send to the channel.

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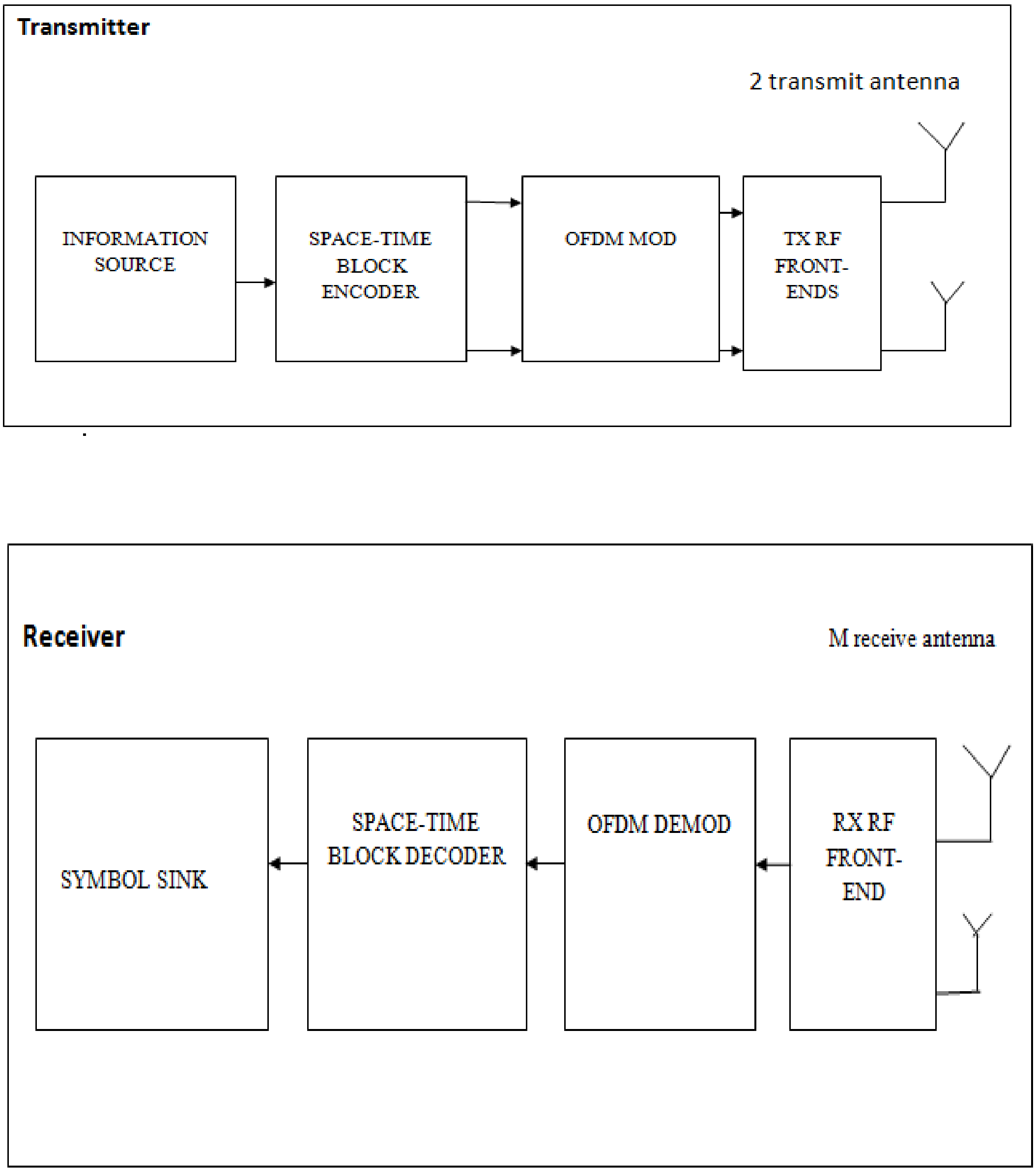

Fig.2. System block diagram of Space-time Coding for OFDM

Here the encoder generates the code words of length M=2. Where *M* is the number of transmit antennas. These code words are then given to the OFDM modulator and finally to the radio frequency (RF) front-ends. At the receiver, *N* antennas are used for reception. Then the received RF signals are down-converted and then passed to the OFDM demodulator and the space time block decoder.

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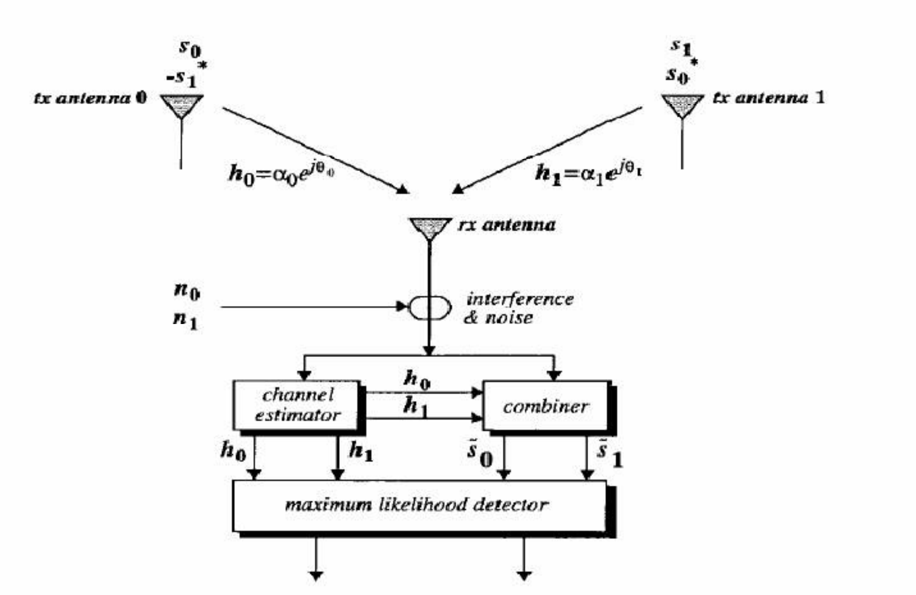

Fig.3 Diagram of Alamouti Based Space-time Coding for OFDM

Fig.3 shows the diagram of an Alamouti based spaced time coded OFDM. Here the encoder takes two data vectors **X**(*i*) and **X**(*i*+1) and transmits as follow[2][4][5]:

$$X_2^C = \begin{bmatrix} x_0 & x_1 \\ -x_1^* & x_0^* \end{bmatrix} (1)$$

The key feature of Alamouti's scheme is that the sequence transmitted from the different antennas are orthogonal since the matrix of X times the Hermitian matrix X is equal to the identity matrix such as:

$$X_2^C\, X_2^{C\,H} = \begin{bmatrix} x_0 & x_1 \\ -x_1^* & x_0^* \end{bmatrix} \begin{bmatrix} x_2^* & -x_1 \\ X_1^* & x_0 \end{bmatrix} = |x_0{}^2| + |x_0{}^2|\, \mathrm{I}\ (2)$$

Here assumes the channel parameters are constant over two consecutive symbols;

$$h_1(t) = h_1(t+T) = h_1 = \left|h_1{}^2\right| e^{j\theta 1}\ (3)$$

$$h_2(t) = h_0(t+T) = h_2 = \left|h_2{}^2\right| e^{j\theta 2}\ (4)$$

Where $|hi|$ is the amplitude shift and θi is the phase shift with i=1, 2 . The received signals are

$$r_1 = r(t) = h_1 x_1 + h_2 x_2 + w_1\ \ (5)$$

$$r_2 = r(t+T) = -h_1 x_1^* + x_0^* + w_2\ (6)$$

Where $w1$ and $w2$ are the white Gaussian noise samples. Both signals are then passed through the maximum likelihood (ML) detector to determine the most likely transmitted symbols.

C) SPACE FREQUENCY BLOCK CODED (SFBC) OFDM

The main problem that associated with STBC-OFDM system is flat time variations, which is known as fast fading. To overcome flat fading we use SFBC-OFDM .Here orthogonal symbols are transmitted on the neighbouring

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sub-carriers of the same OFDM rather than on the same subcarrier of the subsequent OFDM symbols. This reduces the transmission delay[4][5].

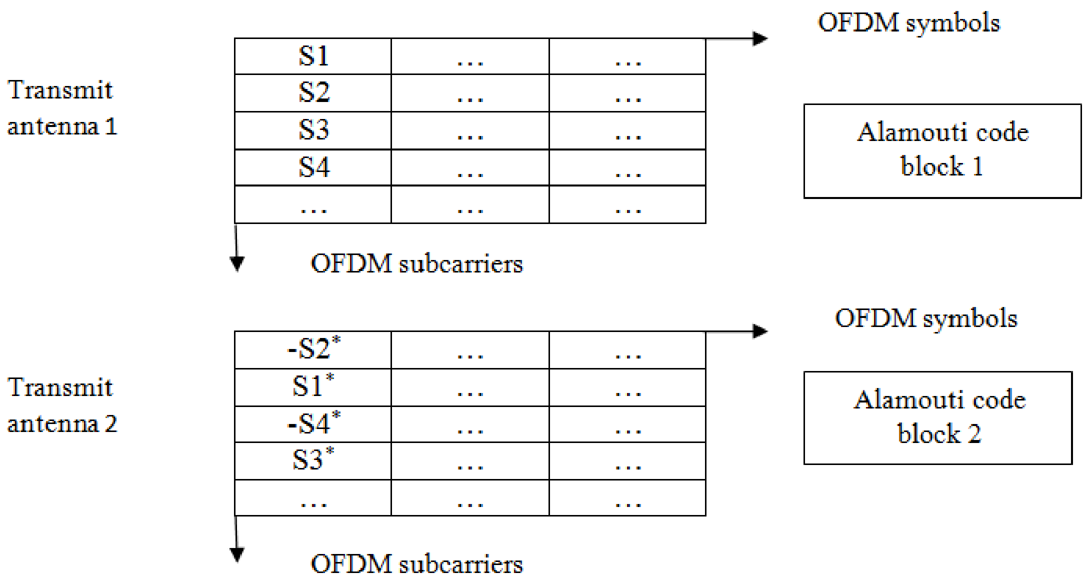

Fig.4. An example of SFBC encoding

The received signal can be expressed as:

$$R_j\ (n) = \sum_{j=1}^{N_R} H_{1,j}\ \ (n) + X_1(n) + H_{2,j}(n)X_2(n) + W_j(n)\ \ (9)$$

where *Wj*(*n*) is the white Gaussian noise[3]. Data vector X1(N) and X2(N) can also be expressed as:

$$X_1\ = [x_0, -x_1^*, \dots \dots . x_k, -x_k^*, \dots \dots x_{N-2}, -x_{N-2}^*]^T\ (10)$$

$$X_2\ = [x_1, -x_0^*, \dots \dots . x_{k+1}, x_k^*, \dots \dots x_{N-1}, -x_{N-2}^*]^T(11)$$

Data symbols can recovered using only one OFDM symbol, therefore we can vomit *n* .here we assumes the channel parameters are constant for two consecutive subcarriers and that channel parameters are known at the receiver. At the receiver, the received signals are demodulated by using FFT and then it is given to the space frequency decoder. Finally it is then sent to the ML decoder and to the demapper to recover the data signal [4].

III. CONCLUSION

Here we have studied and compared STBC-OFDM and SFBC-OFDM. By investigating STBC and SFBC, SFBC-OFDM is more sensitive to channel gain variation over frequency and STBC-OFDM is more sensitive to channel gain variation over time.

In an Alaumouti code block, both STBC and SFBC are free of large ISI. This achieves similar performance with SFBC slightly better than STBC due to channel selectivity. Both STBC/SFBC achieve satisfy performance with slight difference at low mobility with small delay spread by using ML decoders. At high mobility, SFBC often outperforms STBC, while with large delay spread; SFBC has worse performance than STBC.

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BIOGRAPHY

Mr. Jijo Varghese, who is a member of ISTE, has done his M.E in Communication System from Anna University. He has more than 4.5 years of teaching experience in Electronics and Communication Department of SNGCE. He has published papers in various national journals. His research interests include mobile and satellite communication.