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SPACE TIME FREQUENCY CODED (STF) OFDM FOR BROADBAND WIRELESS COMMUNICATION SYSTEMS

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ABSTRACT

The current problems in wireless systems are multi-path propagation, frequency selective fading, Inter-Symbol Interference (ISI) and Inter-Carrier Interference (ICI), with the major challenge being transmission of information having high data rates over long distances. The Orthogonal Frequency Division Multiplexing (OFDM) systems solve a few of the above stated problems by the use of diversity schemes, which increase the reliability and security of the message. By adopting Multiple-Input Multiple-Output (MIMO) and OFDM technologies, wireless systems could reach data rates up to several hundreds of Mbps and achieve spectral efficiencies of several tens of bits/Hz/s, which are unattainable for conventional Single-Input Single-Output (SISO) systems. This paper deals with the simulation of Space Time Frequency (STF) coded OFDM system. The coding schemes like Space Time (ST), Space Frequency (SF) and Space Time Frequency (STF) coding are compared and from the results it is proved that STF scheme performs better than ST and SF schemes. The Space Time Frequency coded communication system when is used along with diversity schemes like MIMO and Multiple Input Single Output (MISO) is compared for their performance over a fading channel having inherent noise, and it is further proved that MIMO performs better than MISO schemes.

Keywords: *Orthogonal Frequency Division Multiplexing (OFDM), Multiple-Input Multiple-Output* **(***MIMO), Multiple-Input Single-Output (MISO), Space Time (ST), Space Frequency (SF), Space Time Frequency (STF)*

1. INTRODUCTION

The demand for high data rate wireless communication [1-3] is growing rapidly and the spectrum available to the service provider is limited. The designer for wireless communication systems has to concentrate on increased data rate and improved performance without any increase in bandwidth. The main problem in wireless channel is the delay spread due to the multipath components which lead to Inter Symbol Interference (ISI). Another problem is the variation over time due to the movement of the mobile units and objects in the environment which leads to deep fade.

Space Time Coding is a forward error correction technique for wireless application to reduce the effects of fading in wireless channels using multiple transmit antennas [4-8]. The design of Space-Time codes in frequency selective fading channel is complicated because of the existence of Inter Symbol Interference (ISI). OFDM is an efficient method to combat the ISI problem. OFDM effectively converts a frequency selective channel into parallel flat fading channels [9]. This paper deals with STFC-OFDM, which combines the special features of Space Time Frequency Coding and OFDM.

1.1 Orthogonal Frequency Division Multiplexing

OFDM is a multicarrier transmission technique in which the input high rate single data stream is transmitted over a number of lower rate subcarriers [10].Because of the low rate parallel subcarriers, the symbol duration increases which reduces the effect of multipath delay spread on the signal. A guard time introduced in every OFDM symbol

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eliminates ISI and in this guard time cyclic extension of the OFDM symbol is used to avoid Inter Carrier Interference (ICI) also .OFDM is used to increase the robustness against frequency selective fading. In a single carrier system, a single fade or interferer can cause the entire link to fail, but in a multi carrier system, only a small percentage of the sub carriers will be affected. Error correction coding can then be used to correct the few erroneous sub carriers.

1.2 Space Time Codes

Two types of Space Time Codes are Space Time Block Codes (STBC) and Space Time Trellis Codes (STTC) [11]. Space Time Block Codes take blocks of input symbols and produces an output matrix whose columns represent time and rows represent antennas. Coding gain is not provided by Space Time Block Codes, unless concatenated with an outer code. Their main advantage is the provision of full diversity with very simple decoding scheme. Space Time Trellis Codes on the other hand, considers one input symbol at a time, producing a sequence of vector symbols whose length represents antennas. Their important advantage over STBC is the provision of coding gain and disadvantage is that they are very difficult to design and require complex encoders and decoders.

1.3 Double ALMOUTI STF Code

Almouti code [5] is applied to two OFDM symbols, during two time slots and on two transmitting antennas. Basically two of the same Almouti code[12] can be applied in 2 different frequency bins and transmitted on two antennas with code rate 1/2 , but it exploits 4 degrees of diversity in total: 2in the spatial domain and 2 in the frequency domain. This STF coding scheme is shown in table1.If there are two samples s0 and s1 to be transmitted on the two sub-carriers f_i^k f_j^k on the kth antenna k=1,2…..

Let Hi,j be the frequency domain channel matrix relative to the application of the double Almouti code on the ith and jth frequencies, and on the two transmit antennas. This shows that diversity order of 4 in the double Almouti code that is traded for a rate ½.

$$H_{i,j}^H H_{i,j} = (|h_i^1|^2 + |h_i^2|^2 + |h_j^1|^2 + |h_j^2|^2) I_2 \quad (1)$$

Through the 1st and 2nd Transit Antennas Respectively

	T_0	T_1
Frequency f_i	S_0	S_1
Frequency f_j	S_1	S_0

	T_0	T_1
Frequency f_i	$-S_1^*$	S_o^*
Frequency f_j	S_o^*	$-S_1^*$

Table 1 Double Almouti STF Code.

1.4 Frequency Improved STF 2 Tx Half rate scheme

An improved STF code [10] uses the same principle of coding as the double Almouti 2 Tx code and makes use of 3 frequencies instead of 2 and keeping the rate as 1/2. This code has a property that each symbol transmits through a different equivalent channel with great diversity. Improved Double Almouti STF Coding concept through the 1st and 2nd transmission Antennas Respectively is given in Table 2.

	T_0	T_1
Frequency f_i	S_0	S_1
Frequency f_j	S_1	S_2
Frequency f_k	S_2	S_0

	T_0	T_1
Frequency f_i	$-S_1^*$	S_o^*
Frequency f_j	$-S_2^*$	S_1^*
frequency	$-S_o^*$	S_2^*

Table 2: Improved Double Almouti STF Code

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The OFDM symbol S considered at the input of the space time frequency block is divided in to three vectors S= [S0, S1, S2]. Three samples s0, s1, s2 taken from the three OFDM symbol portions S0, S1 and S2 are considered here. The samples are coded and transmitted during two symbol periods T0, T1 in the frequency subcarriers i, j and k on the two antennas as shown in the above table. The channel coefficients relative to the three subcarriers (i, j, k) and to the antenna n, n=1, 2 are respectively h_i^n , h_j^n and h_k^n

At the receiver end the samples received during two symbol periods on the ith frequency sub carrier are given by

$$y_i^1 = h_i^1 s_0 - h_i^2 s_1^* + n_i^1 \quad (2)$$

$$y_i^2 = h_i^1 s_1 + h_i^2 s_0^* + n_i^2 \quad (3)$$

And the same equations are found for the jth and kth frequency sub-carriers by replacing:

1) i by j, and respectively i k, 2) (s0, s1) by (s1, s2) and by (s2, s3) respectively.

Then the decisions on the three transmitted samples will be taken on the di , i = 0,1,2 using the maximum likelihood decoding:

$$d_0 = \left(|h_i^1|^2 + |h_i^2|^2 + |h_k^1|^2 + |h_k^2|^2 \right) s_0 \quad (4)$$

$$d_1 = \left(|h_i^1|^2 + |h_i^2|^2 + |h_j^1|^2 + |h_j^2|^2 \right) s_1 \quad (5)$$

$$d_2 = \left(|h_i^j|^2 + |h_i^2|^2 + |h_k^1|^2 + |h_k^2|^2 \right) s_2 \quad (6)$$

2. ST COMMUNICATION SYSTEM

The Space Time wireless communication system has MT transmit antennas and MR receiver antennas [6]. The input data stream enters into the Space time encoder, after encoding the bits are interleaved across space, time and frequency and mapped to data symbols to generate MT outputs. At the receiver side the signal plus noise is matched, filtered and sampled to produce MR output streams. These MR output streams are then ST de-interleaved and ST decoded to produce the desired output data stream.

3. SPACE TIME FREQUENCY CODED OFDM SYSTEM

The Space Time Frequency Block (STFB) coding scheme [4] [5] [10] is used to improve the system performance by taking advantage of diversity in space, time and frequency inherence in MIMO-OFDM system. In the STF coded OFDM system the input data sequence is convolution encoded and interleaved by a block interleaver. After the symbol mapping is performed by the modulator, the tones enter the STF encoder and then are applied to OFDM transmitters of the different antennas. Each antenna of the OFDM system consists of M subcarriers. The M tones at each antenna are passed through Inverse Fast Fourier Transform blocks (IFFT) with a cyclic prefix added to each of the signal components. To avoid the inter-symbol interference, the guard time is chosen to be longer than the channel delay spread. The resultant signal is frequency up-converted to the desired transmission frequency and transmitted through the wireless channel. The code rate of the STF encoder is p/n, where the encoder takes p sequences of M tones and outputs n sequences of M tones. The STF coded OFDM system has been simulated using MATLAB and its performance is compared with Space Time and Space Frequency Coded OFDM systems.

4. *ANTENNA DIVERSITY COMPARISON MIMO V/S MISO*

The antenna diversity [3][6][10] is primarily used to ensure that symbol reaches the receiver and to make the symbol retrievable in case of fading effect by the channel. After a symbol is coded it is passed through the antennas to be finally transmitted. The symbols are received after being corrupted by the noise at the receiver. The noise is assumed to be fading channel while being additive.

Suppose (s_1, s_2) represent a set of 2 consecutive symbols in the input data stream to be transmitted. During the first symbol period t1, Tx antenna 1 transmits symbol s1 and Tx antenna 2 transmits symbol s2 .Next, during second symbol period t2, Tx antenna 1 transmits symbol s2* and Tx antenna 2 transmits symbol –s1*.Let h1 be the channel response from Tx antenna 1 to the receiver and h2 be the channel response from Tx Antenna2 to the receiver.

Case 1:- 2 Tx antennas, 1 Rx antennas

The received signal samples r1 and r2 correspond to symbol period’s t1 and t2.

$$r_1 = h_1 s_1 + h_2 s_2 + n_1 \quad (7)$$

$$r_2 = h_1 s_2^* - h_2 s_1^* + n_2 \quad (8)$$

Where n_1 and n_2 are the noise terms.

The receiver does the following computations to estimate s_1 and s_2.

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$$x_1 = h_1^* r_1 - h_2 r_2^* = \left(|h_1|^2 + |h_2|^2\right) s_1 + h_1^* n_2 - h_2 n_2^* \quad (9)$$

$$x_2 = h_2^* r_1 + h_1 r_2^* = \left(|h_1|^2 + |h_2|^2\right) s_2 + h_2^* n_1 + h_1 n_2^* \quad (10)$$

Case 2:- 2 Tx antennas, 2 Rx antennas
For receiver antenna 1

$$r_{11} = h_{11} s_1 + h_{12} s_2 + n_{11} \quad (11)$$

$$r_{12} = h_{11} s_2^* + h_{12} s_1^* + n_{12} \quad (12)$$

For receiver antenna 2

$$r_{21} = h_{21} s_1 + h_{22} s_2 + n_{21} \quad (13)$$

$$r_{22} = h_{21} s_2^* + h_{22} s_1^* + n_{22} \quad (14)$$

Receiver estimates the symbols s_1 and s_2 using

$$x_1 = h_{11}^* r_{11} - h_{12} r_{12}^* + h_{21}^* r_{21} - h_{22} r_{22}^* = \left(|h_{11}|^2 + |h_{12}|^2 + |h_{21}|^2 + |h_{22}|^2\right) s_1 + h_{11}^* n_{11} - h_{12} n_{12}^* + h_{21}^* n_{21} - h_{22} n_{22}^* \quad (15)$$

$$x_2 = h_{12}^* r_{11} - h_{11} r_{12}^* + h_{22}^* r_{21} - h_{21} r_{22}^* = \left(|h_{11}|^2 + |h_{12}|^2 + |h_{21}|^2 + |h_{22}|^2\right) s_2 + h_{12}^* n_{11} + h_{11} n_{12}^* + h_{22}^* n_{21} - h_{21} n_{22}^* \quad (16)$$

These equations clearly show that the receiver fully receives the fourth order diversity of 2*2 systems. The primary aim of using multiple antennas is to reduce the bit error rate.

5. RESULT & DISCUSSION

Fig1 shows the time domain representation of OFDM symbols prior to up conversion. The signal amplitudes of various frequency components of the symbols are observed. Fig2. Shows the up converted OFDM symbol in time domain.

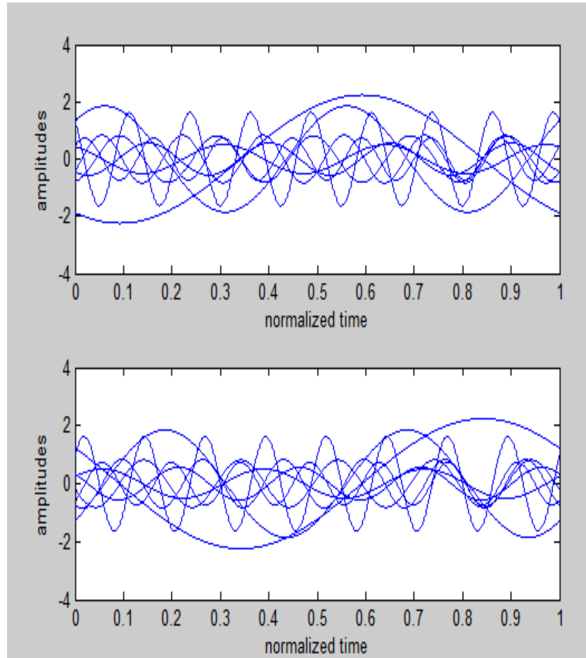

Figure 1. Time domain representation of OFDM symbol.

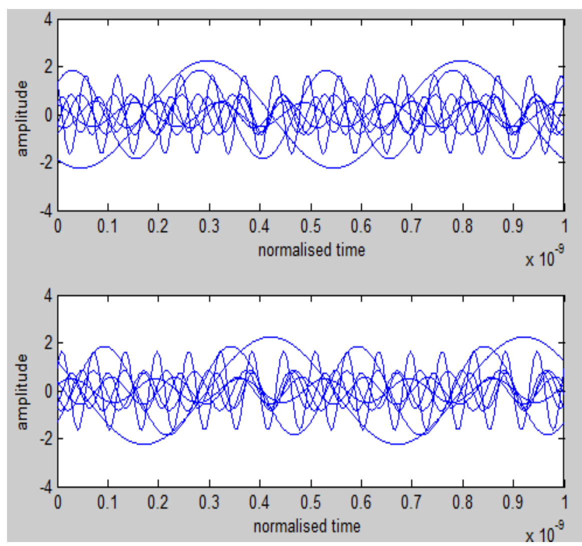

Fig 3 The amplitudes of frequency components of up converted OFDM symbol in Time Domain

The frequency domain representation of OFDM symbols are obtained by taking the Fast Fourier Transform of the OFDM symbols and then plotting the magnitude and phase response of the obtained symbols as function of normalized frequency as shown in the Fig3.

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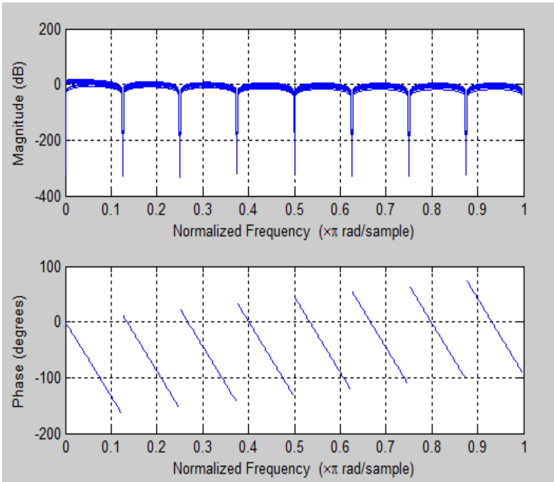

Fig 3. Frequency and Phase response of the OFDM symbol

The ST coded OFDM, SF coded OFDM and STF coded OFDM systems are simulated and bit error performances are compared. Performance comparison between these schemes is shown in Fig4. From the results it is proved that performance of STF OFDM is better than the other two schemes. It is due to the double almouti STF code which has 4 degrees of diversity, 2 in spatial domain and 2 in frequency domain.

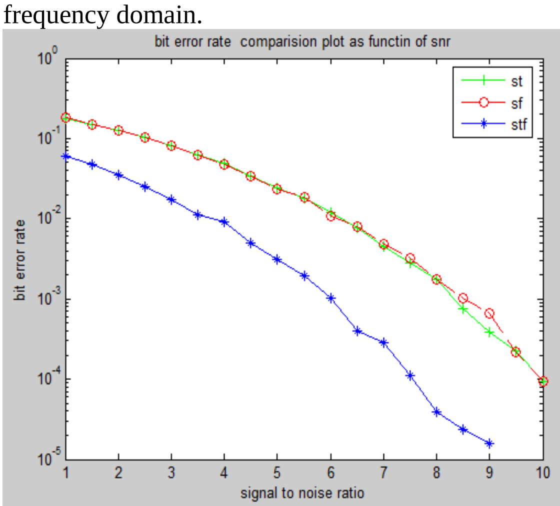

Fig4. Comparison of Space Time, Space Frequency and Space Time Frequency coded OFDM

It is observed that the Space Time Frequency coded OFDM performs better than Space Time and Space Frequency coded OFDM. It is also proved that the Space Time and Space frequency coded OFDM have a similar bit error rates, as a function of increase in signal to noise ratio.

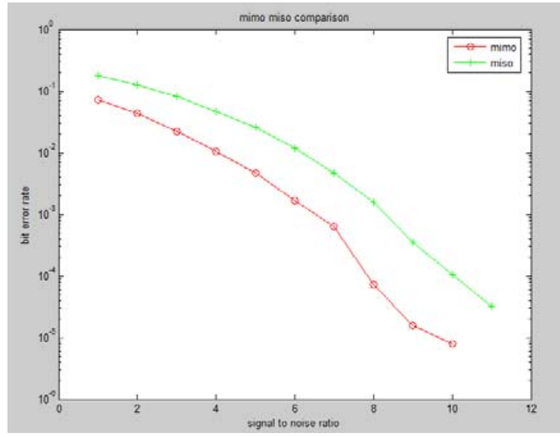

Fig5. Comparison of antenna diversities MIMO and MISO

Performance comparison between MIMO and MISO schemes is shown in Fig5. It is observed that MIMO scheme performs better than MISO scheme

6. CONCLUSION

The scheme of STF coding can be extremely useful for transmitting information which needs high security. This scheme has a very high potential commercially, because of the security and high data rates which will serve the interests of the future mobile customers who demand high bandwidths. MIMO scheme is used to provide high capacity with the same bandwidth. The performance of the wireless communication systems can be improved significantly by adopting Space time frequency coding technique.

REFRENCES:

[1] Harsh P Sha. Performance Analysis of Space Time Codes. M.S.Thesis, The University of Texas at Dallas, December 2003.

[2] Hemalatha, M., Thenmozhi, K., Prithiviraj, V., Bharadwaj, D., Vignesh, R. Diversity reception for CDMA based mobile communication systems. Procedding of Wireless VITAE 2009 , art. no. 5172525, pp. 660-664

[3] Thenmozhi, K., Prithiviraj, V. Suitability of Coded Orthogonal Frequency Division Multiplexing (COFDM) for multimedia data transmission in wireless telemedicine applications. Proceedings of ICCIMA 2007 4, art. no. 4426494, pp. 288-292

[4] Vahid Tarokh, Nambi Seshadri, Calderbank. Space time codes for high data rate wireless communication: Performance criterion and

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code construction. IEEE Transactions on Information theory 1998; 44: 744-765.

[5] SM Alamouti. A simple transmitter diversity scheme for wireless communication. IEEE Journal on selected Areas in communication 1998; 16: 1451-1458.

[6] Vahid Tarokh, Calderbank, Hamid Jafarkhani. Space Time Block Coding for Wireless Communications: Performance Results. IEEE Journal on selected areas in communications 1999; 17: 451-460.

[7] Vahid Tarokh, Hamid Jafarkhani, Calderbank. Space time block coding from orthogonal designs. IEEE Transactions on Information theory 1999; 45: 1456-1467.

[8] Arogyaswami Paulraj, Rohit Nabar, Dhananjay Gore. Introduction to Space Time Wireless Communications, Cambridge University Press 2003.

[9] Deniz Rende, Tan F Wong. Bit interleaved Space–Frequency Coded Modulation of OFDM Systems. IEEE Transactions on Wireless Communications 2005; 4: 2256-2266.

[10] Van Nee Richard, Prasad Ramjee. OFDM for Wireless Multimedia Communications, Artech House, Boston 2000

[11] Lei Poo.Stanford University, Space–Time Coding for Wireless Communication:Survey. http://www.ece.ubc.ca/~paull/teaching/eece_496/STC_tutorial.pdf.

[12] Iiihem Ouachani, Karine Gosse, Pierre Duhamel “Trading rate versus diversity in Space Time Frequency Block Coding schemes” First International Symposium on Control,Communications and Signal Processing,2004;171-174

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