iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 5 **Issue:** IV **Month of publication:** April 2017

DOI: http://doi.org/10.22214/ijraset.2017.4104

www.ijraset.com Volume 5 Issue IV, April 2017
IC Value: 45.98 ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Combined Beamforming with Space Time Frequency Coding for Mimo-OFDM Systems

Mrs. M. Mary Rosalinetamil Selvi[1], R. Thanga Uthra[2], S. Saranya[3]
[1]Assistant professor, [2,3]Electronics and Communication Engineering
Mepco Schlenk Engineering College, Sivakasi

***Abstract:** Multiple antennas can be used in wireless systems to attain good quality of service and high data rate communication. Recently, efficient space-time-frequency (STF) codes have been developed to improve the diversity gain. Performance of multiple-input multiple-output orthogonal frequency-division multiplexing (MIMO–OFDM) system using STF Coding and random beamforming is analysed. Combined beamforming with STF code offers improved performance over STF in term of bit error rates (BER) when compared to existing combined space-time block code (STBC) with beamforming*

***Keywords:** space- time -frequency code,MIMO-OFDM,beamforming,diversity order.*

I. INTRODUCTION

Diversity is an real technique to combat fading and increase the transmission reliability over wireless channels since it provides multiple independent replica of the trans-mitted signal at the receiver. MIMO systems have achieved a focus of attention because it can significantly increase the spectral efficiency by exploiting the spatial degrees of freedom created by multiple antennas [1]. In wireless communications, where the channel involves frequency selectivity, called frequency diversity, can be exploited by taking advantage of the frequency-selectivity characteristics of the channel. Both transmit diversity and orthogonal frequency-division multiplexing (OFDM) have been receiving a lot of attention and have shown great potential for the next generation wireless communication systems [2] due to its toughness to multi path fading, high spectral efficiency, and high flexibility in resource allocation. Space-time (ST) coding deeds the spatial diversity provided by the number of transmit antennas [3]. However, frequency selective channels provide an extra diversity dimension: frequency diversity. Thus, space-time-frequency (STF) and space-frequency (SF) coding were developed to deed the maximum diversity provided by MIMO frequency selective channels [4].

In ST coding, the diversity is equal to the product of the number of transmit and receive antennas .In STF coding, diversity is given by the product of the number of its transmit antennas, the number of its receive antennas, and the number of independent channels taps[5]. Liu , Xin and Giannakis [6] introduced STF coding across multiple OFDM block for multiple transmit antenna. Gong and Letaief [2] introduced STF coding method over MIMO–OFDM channels. In [4],authors presented a STF coding method that expand the idea of frequency spreading and show how the symbols spread across several OFDM block transmission to perfectly isolate them at the receiver. In [7], authors use exponential correlation model and offer the BER by combining beamforming with space time block code (STBC) scheme. STF and beamforming techniques are two developing technologies that can be working at the base station (BS) with multiple antennas to deliver transmit diversity and beamforming gain to increase SNR of the downlink. This paper objects at performance analysis of multiple-input multiple-output orthogonal frequency-division multiplexing (MIMO–OFDM) system. Our involvement in this paper includes introduction of a new transmit scheme, by combined beamforming with STF for MIMO–OFDM systems.

The rest of this paper is ordered as follows. In Section 2, we present system model. In Section 3,we explain the proposed scheme. Simulation performance results are carried out in Section 4. Finally, conclusions are explain in Section 5.

II. SYSTEM MODEL

Consider a MIMO–OFDM system which has N_t transmit antennas, N_r receive antennas, and N_c subcarriers. Assume that the frequency-selective fading channels between each pair of transmit and receive antenna is having L channel taps. $h_{\mu,\eta}$ is a frequency-selective and time varying channel response between the μ^{th} transmit and η^{th} receive antenna pairs during the n^{th} OFDM symbol interval defined as $[h_{\mu,\eta}(0), h_{\mu,\eta}(L-1)]^T$, superscript T stand for transpose operation. The MIMO channel is expected to be constant over each OFDM symbol, but it may vary from one OFDM symbol to another. One OFDM symbol consists of N number of transmitted symbol. At the receiver, the signal is exposed to an additive white Gaussian noise. The received signal $y^{\eta}_{n}(p)$, after removing the cyclic-prefix (CP) and performing fast Fourier transform (FFT) on the η^{th} receive antenna during the n^{th} symbol interval can be stated as

$$y^{\eta}_{n}(p)=\sum_{\mu=1}^{N_t} H_{\mu\eta}(p)X^{\mu}_{n}(p)+W^{\eta}_{n}(p), \quad \eta=1,\ldots,N_r \; p=0,\ldots N_c-1$$

Where $H_{\mu\eta}(p)$ is the subchannel gain from the μ^{th} transmit antenna to the η^{th} receive antenna evaluated on the p^{th} subcarriers.

$$H_{\mu\eta}(p):=\sum_{l=0}^{L} h\mu\eta(l)e^{-j\left(\frac{2\pi}{N_c}\right)lp}$$

and the additive noise $w^{\mu}_{\eta}(p)$ is circularly symmetric, zero-mean, complex Gaussian with variance N_0 that is also assumed to be statistically independent with respect to μ ,η and p.

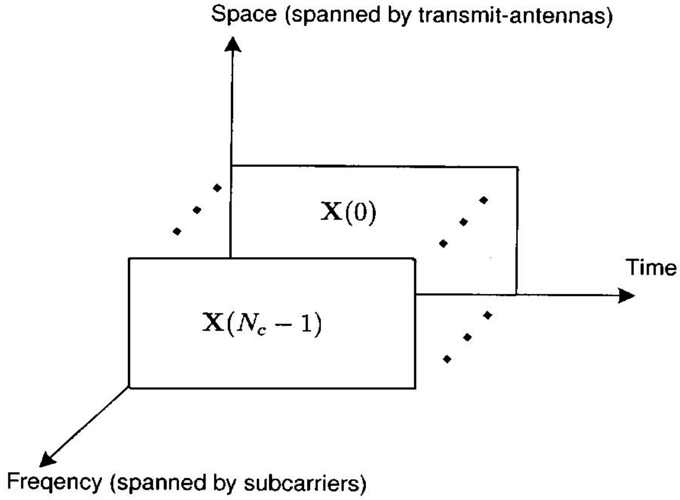

Fig.1 Illustration of STF-coded transmissions

Let $X^{\mu}_{n}(p)$be the data symbol transmitted on the p^{th} subcarrier (frequency bin) from the μ^{th} transmit antenna during the n^{th} OFDM symbol interval. As defined, the symbols are transmitted in parallel on subcarriers by transmit antennas. Notice that three variables, and have been introduced to the index of the antenna (space), time, and frequency dimensions associated with the transmission of $X^{\mu}_{n}(p)$. Thus, it can be viewed as a point in a three-dimensional (3D) space-time-frequency (STF) parallelepiped. From Fig.1 It is important to note that the transmissions of $X^{\mu}_{n}(p)$ are separable in both time and frequency but not in space.

III. PROPOSED SCHEME

Here, we assume a MIMO system employing N_t transmit and N_r receive antennas.

A. Combining STF Coding with Beamforming

Recollecting that each $X^{\mu}_{n}(p)$ is a point in 3D, we define each STF code word as the collection of transmitted symbols within the parallelepiped, spanned by N_t transmit antennas, N_x OFDM symbol intervals, and N_c subcarriers. Thus, one STF code word contains $N_tN_xN_c$ transmitted symbols, $x^{\mu}_{n(P)}$(where μ=1…Nt, P=0,1,…..Nc-1, n=0,1,…Nx-1) which for mathematical convenience can be organized in a block matrix

$$X := [X(0)\ X(1)\ \ldots.\ \ X(N_c-1)]$$

For STF coding, the first step towards subchannel grouping is to choose the number of subcarriers equal to an integer multiple of the channel length

$$N_c=N_g(L+1)$$

For a certain positive integer N_g is the number of groups. When L=1,3 QPSK modulation is given by

$$\Theta=1/\sqrt{2}\begin{bmatrix}1 & e^{j\left(\frac{\pi}{4}\right)}\\ 1 & e^{j\left(\frac{3\pi}{4}\right)}\end{bmatrix}$$

$$\theta = \frac{1}{2}\begin{bmatrix} 1 & e^{j(\pi/8)} & e^{j(2\pi/8)} & e^{j(3\pi/8)} \\ 1 & e^{j(5\pi/8)} & e^{j(10\pi/8)} & e^{j(15\pi/8)} \\ 1 & e^{j(9\pi/8)} & e^{j(18\pi/8)} & e^{j(27\pi/8)} \\ 1 & e^{j(13\pi/8)} & e^{j(26\pi/8)} & e^{j(39\pi/8)} \end{bmatrix},$$

Beamforming can be taken as linear filtering in the spatial domain. Beamforming is a signal-processing technique that is used to control the directionality of the radiation pattern of an antenna system. When receiving a signal, beamforming can rise the receiver sensitivity in the direction of desired signals and decrease the sensitivity in the direction of interference and noise. When transmitting a signal, a beam-forming antenna system can increase the radiated power in the intended direction. Beamforming techniques can also be useful, in order to reduce the delay spread of the physical channel caused by multipath signal propagation .In RBF, the BS transmits a signal modulated by a RBF matrix to users. Each user then measures the channel quality via SINR and feeds it back to the BS .Let N_t random orthogonal beams $Wi(N_t \times 1)$ have been generated for $i = 1, 2, 3, \ldots, N_t$. These beams are generated using isotropic distribution .The size of the beamforming matrix W is $N_t \times N_t$. Now after applying beamforming, we have the overall message signal matrix as $[WX^T]^T$. The size of this matrix is $N_xN \times N_t$.

The signals from the N_t transmit antennas which arrive at the η^{th} receive antennas may be expressed as

$$y^{\eta}_{n}(p)=\sum_{\mu=1}^{N_t} H_{\mu\eta}(p)X^{\mu}_{n}(p)+W^{\eta}_{n}(p),$$

In matrix form,

$$Y(p)=H(p)X(p)+W(p)$$

where Y, H, and W stand for received signal matrix, channel matrix and noise signal matrix respectively. Now each entry in W is a complex Gaussian noise with zero mean and unit variance. Gaussian distribution has been used. Therefore, the probability density function (PDF) of the additive noise is given as [8]

$$f(p_{\mu,\eta})=1/\pi \exp(-(p_{\mu,\eta})^2)$$

B. Pairwise Error Probability

Assuming that the channel state information (CSI) is exactly known at the receiver side and the noise components are independent, the conditional PDF of the received signal.

$$f(p)=\sum_{\mu=1}^{NtNNr} 1/\pi \exp(-(p)2)$$

ML estimation:

$$Z_{ML}=\arg_{Z}\max f(p)$$

IV. SIMULATION RESULT

We present simulations to study the performance of the proposed scheme .The proposed algorithm for finding the BER are implemented in MATLAB R2014.In all the simulations, BPSK modulation is used and ML decoding at the receiver is implemented. QPSK modulation may also be used. The number of subcarriers N is set to 48(HIPERLAN 2).

Fig.2 displays the BER performance combined beamforming STF for 2x1 and 4x2 combinations of MIMO antennas system. Fig.3 shows the BER performance of the combined beam-forming with STF and STF (without beamforming) for 2x1 of combination of MIMO antenna systems It is observed that, for the BER of 10^{-4},proposed scheme gives better performance as compared to the STF scheme. It gives a gain of approximately 0.4 dB as compared with STF scheme.

Fig.4 shows the BER performance of the combined beamforming with STF and STBC. It is observed that, for the BER of 10^{-4}, Eb/No for combined beamforming with STFC and STBC is 8 dB and 10 dB respectively. Proposed combined beamforming with STFC scheme gives a gain of approximately 2.0 dB over STBC with beamforming.

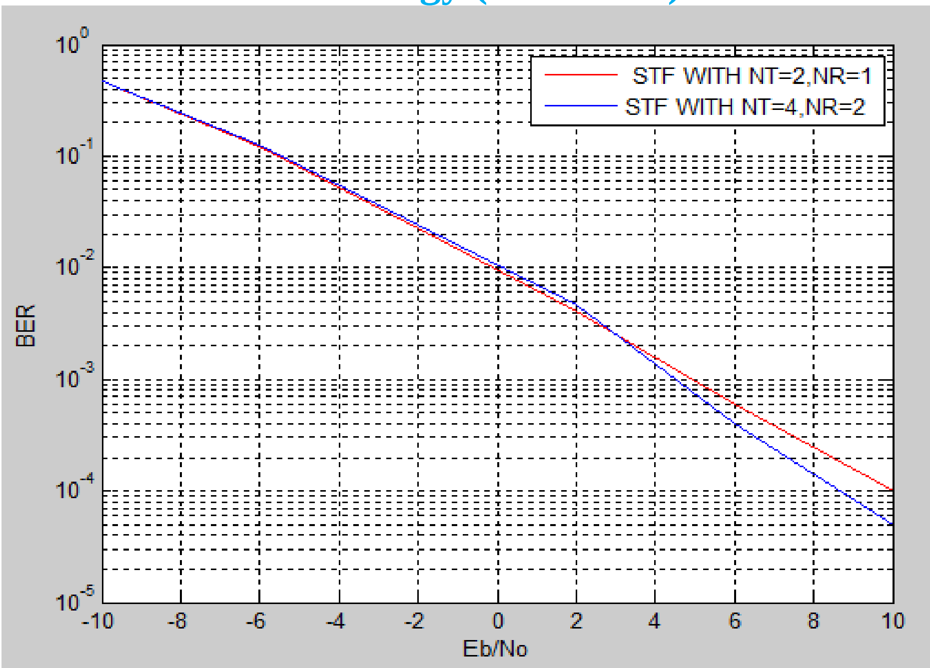

Fig.2 BER performance of combined beamforming with STF for 2x1 and 4x2 combinations of MIMO antenna systems.

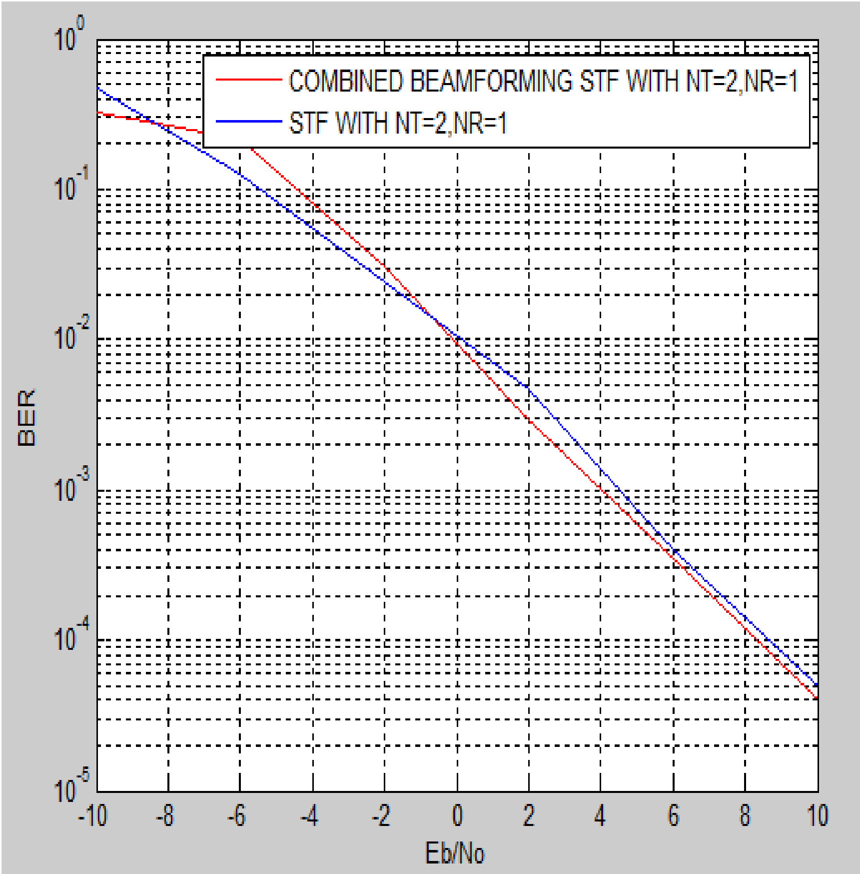

Fig.3 BER performance of combined beamforming with STF and STF(without beamforming) for 2x1 of combination of MIMO antenna system.

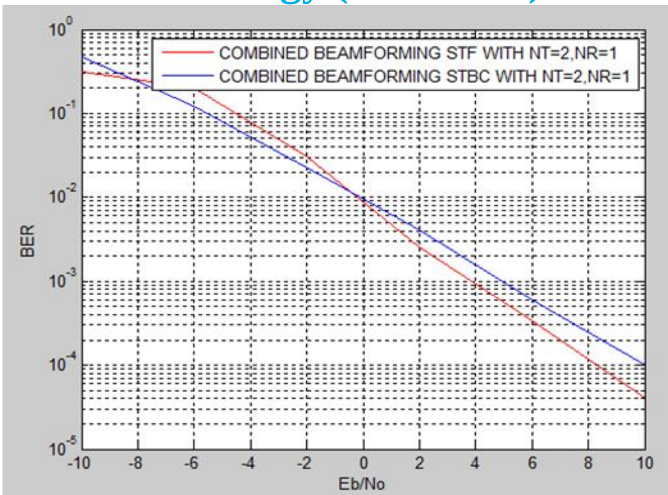

Fig.4 BER performance of combined beamforming with STF and STBC.

V. CONCLUSION

In this paper, an method has been proposed for combined STF and beamforming in MIMO–OFDM broadcast system with no CSI at the transmitter. This proposed scheme offers improved performance over STF. Simulations are made to evaluate the performance of the MIMO system in term of BER. In all the simulations, ML decoding at the receiver is implemented. For the BER of 10^{-4}, proposed scheme gives better performance as compared with STF. It gives a gain of approximately 0.4 dB over STF scheme. It is observed that, for the BER of 10^{-4}, proposed scheme gives better performance as compared with STBC combined with beamforming. It is observed that, for the BER of 10^{-4}, Eb/No for combined beam-forming with STFC and STBC is 8 dB and 10 dB respectively. It gives a gain of approximately 2.0 dB over this scheme.

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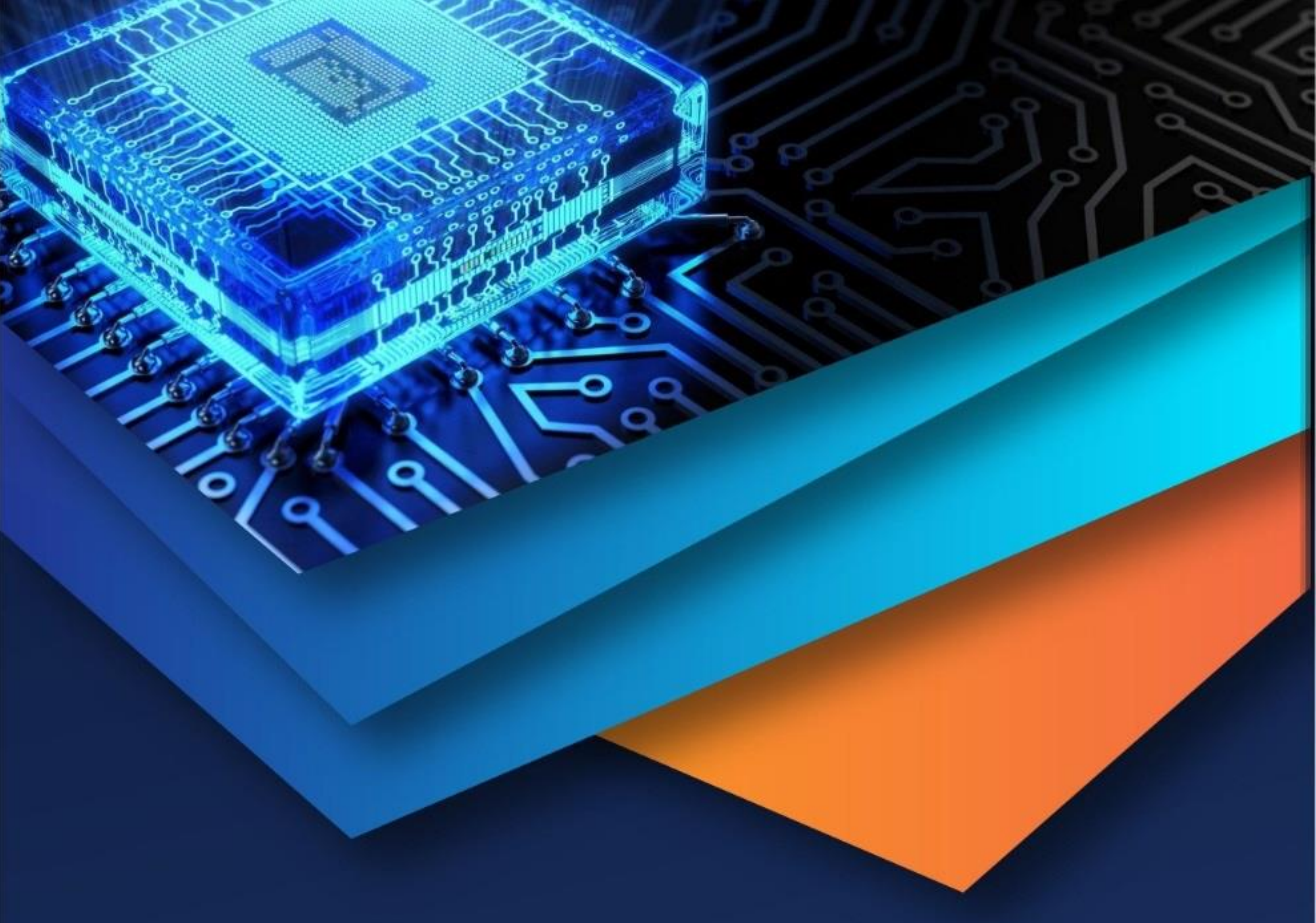

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