International Journal of Scientific Engineering and Technology (ISSN : 2277-1581)
www.ijset.com, Volume No.1, Issue No.2 pg:11-15 01 April 2012

SPACE FREQUENCY CODED OFDM

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Abstract—**We are going to implement and study a space frequency coded OFDM system which consists of two transmitters and a single receiver. Simple Alamouti space-time code is used. An M-ary PSK modulation is used to modulate the symbols across an OFDM channel. We will also propose a variation of the scheme which tries to spread additional symbols across time-frequency attempting to increase the rate of transmission without changing the type of modulation employed or increasing bandwidth. A Rayleigh frequency selective slow fading channel is assumed through-out the analysis. SER performance of the above systems is carried-out with emphasis on the modulation scheme, no. of carriers and bit SNR.**

Keywords: Space time coding,OFDM, frequency-selective channel.

I. INTRODUCTION

The possibility of high data rate reliable transmission over wireless channels is only due to the invention of Space-time codes. Space-time codes rely on transmits diversity and is particularly suitable when the signal undergoes frequency flat fading due to the channel. This paper discusses the performance of the OFDM with space frequency coding technique. Following the introduction this chapter is organized as under Section II describes the space frequency coding technique. Section III describes about overloaded OFDM. Section IV describes simulation result. Section V provides concluding remarks.

II. SPACE FREQUNENCY CODING TECHNIQUE

In the original space-time code scheme [1], Alamouti showed that it is possible to obtain the same diversity as with multiple receivers. Since then, transmit diversity has been pursued with great interest among the research community. However, the fundamental assumption based on the which the scheme works is that that channel is frequency flat, i.e., the coherence bandwidth of the channel is much smaller than bandwidth of the signal which may not be true in wideband communication [2- 5]. This assumption may not be generally true in wideband communication systems. For example, high-data rates are made possible with increased resources in terms of bandwidth in WLAN and outdoor wireless WANs. There is need to developing new technologies for providing wideband wireless communications. OFDM has matured into a very practicable technique and has been incorporated into the IEEE 802.11a [6]. OFDM splits the channel into sub-channels equal to the no. of carriers under use. Each subchannel is treated independently and the multiplexed modulated symbols are sent over each carrier. This operation is performed via IFFT at the transmitter side and with FFT at the receiver side. This is another interesting aspect of OFDM.

Thus marrying OFDM with Space-time codes appears vary natural in frequency selective fading scenarios. OFDM splits the channel into near frequency -flat sub channels and Space time codes exploit the transmit diversity under these frequency-flat sub-channels. Together they form a promising technological alternative for high data rate broadband communications. This space-frequency coded OFDM system [7] is shown in Fig. 1.

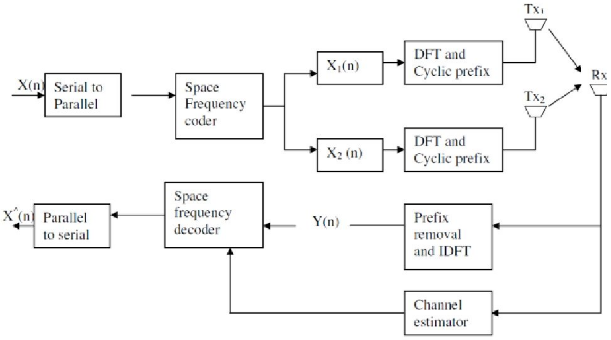

Fig.1 A Space Frequency Coded System

Here, we simulate 2 x 1 Alamouti space-time code with OFDM (which is called as space frequency code, as the space-time codes are transmitted over another carrier rather than another time-slot). A frequency selective Raleigh channel is assumed. Information bits are M-ary PSK modulated, which are then converted into space-frequency codes. These are multiplexed to form OFDM frames for final transmission. Symbol error rates are computed at different bit-SNRs for different M in the M-ary PSK. Later on, ways are investigated to improve the system. In particular, the performance of the system in which information about few more symbols is spread over all the carriers by varying both the phase and energy of that particular constellation in a controlled manner is studied. Details about the encoding and decoding mechanisms are given. Symbol error rates are also compared.

System Description:

No. of carriers: Nc Total
Bandwidth: W Hz
Input symbols (M-ary coded) in a frame: X_o $X_1,\ldots,X_{Nc}$ Modulation: M-ary PSK
No. of Tx: 2
No. of Rx: 1
Space time code: Alamouti 2 x 2 code

$$h_i(n)=\sum_{l=1}^{L} a_i(n)\delta(t-l/W)\ldots\ldots.1$$

Channel Model [34,35, 36]: No. of taps: L = 6

Where a_i are zero mean complex Gaussian random variables with variance 1/L

$$H_i\ (k)=\sum_{j=1}^{Nc} h_i\ (j)\ \exp(-\,j2\_kn\,/\,Nc)\ldots\ldots2$$

Space-frequency code at Tx -1 (total NC symbols) : $X1 = [X0 - X1^*,\ldots..XNc-2 - XNc-1^*]^T$

Space-frequency code at Tx -2 (total NC symbols): $X2 = [X1,X0^*,\ldots,XNc-1,X^*Nc-2]^T$

Received symbols at the receiver:

$Y_e=A_{le}X_{le}+A_{l\,e}X_{2e}+N_e$
$Y_o=A_{lo}X_{lo}+A_{2o}X_{2o}+N_o$
where $X_{ie}=X_i(2k)$
$X_{io}= X_i(2k+1)$, k =0,1,…Nc/2
and N ,Y , defined likewise.

is a diagonal matrix with *Hi(k)* as its diagonal elements The estimated (decoded) symbols (assuming that two adjacent sub-channels have approximately same frequency response) after stripping the cyclic prefix and performing FFT operation on the received symbols are [7]

$$\hat{\mathbf{X}}_e=(|\mathbf{\Lambda}_{1e}|^2+|\mathbf{\Lambda}_{2e}|^2)\mathbf{X}_e+\mathbf{\Lambda}^*{}_{1e}\mathbf{N}_e+\mathbf{\Lambda}_{1e}\mathbf{N}^*{}_o$$
$$\hat{\mathbf{X}}_e=(|\mathbf{\Lambda}_o|^2+|\mathbf{\Lambda}_{2o}|^2)\mathbf{X}_o+\mathbf{\Lambda}^*{}_{2e}\mathbf{N}_e-\mathbf{\Lambda}_{1o}\mathbf{N}^*{}_o$$

This equation enables us to study the performance of the scheme completely in the constellation domain.

Performance analysis:

We studied the performance of the above scheme with different M-ary groupings and different number of carriers. We varied the SNR from 0 to 20dB. M is varied at from 2 to 4. As we can see from the graph in Fig. 2, the SER is decaying with almost unity slope for all the schemes except the case with Nc=16. The reason might be that, there bandwidth is too small to assume that the channels are frequency flat and also the assumption that adjacent channels have approximately same frequency response may also be violated. The effect of employing carriers from 256 to 512 did not seem very significant as the capacity almost linearly adds up and the sub-channels would tend to be frequency flat. However, this constant SER is at the expense of bandwidth. The effect of varying M from 2 to 4 did shift the SER curve by about 2dB which is expected in M-ary modulation. To achieve the same SER, more power is required so as to push the constellation further away from the origin.

III. OVER-LOADED OFDM

We tried to spread a message symbol onto all the carriers. An explanation is sought to suggest a way of spreading the message symbols. In the OFDM case, message symbols are modulated on to separate carriers which are orthogonal. Suppose if we use time-varying signals to modulate these message symbols, we can overload the time frequency plane i.e., besides all the carriers, we can modulate some additional symbols using these time-varying signals. In the context of M-ary FSK, this affects the constellation in two ways:

The phase as well as radius of the constellation is varied. In the regular M-ary OFDM, the constellation is cylinder. The radius is equal to the symbol energy and each section of the cylinder corresponds to a carrier. When chirp signals are used to modulate additional symbols, then, the phase of the message symbol in a particular is corrupted by the phase of the chirp signal and phase of the message symbols this chirp signal is carrying. The radius is affected by the addition of instantaneous energy of the chirp signal. The modified constellation can be represented as:

These modified symbols 'are now used to form the space-frequency codes. The decoding is performed by inverting the weight matrix to obtain an approximate Nc+Ne constellation vectors which is subjected to M-ary PSK detection. In the simulation studies, we have used BPSK modulation with Nc=256 and Ne=l. The choice of the weight matrix affects the performance matrix severely. It is of much interest to study how to do design the weight matrix for a given modulation and given number of carriers. Our initial results were not promising and a careful

study to construct such pseudo orthogonal weight matrix is of great interest.

$$\begin{bmatrix} S'_o \\ : \\ S'_{Nc} \end{bmatrix} = \begin{bmatrix} 1\ 0 \ldots 0\ W_1^0 \ldots W_{Ne} \\ : \\ 0\ \ldots\ 1\ W_1^{Nc} \ldots W_{ne}^{Nc} \end{bmatrix} \begin{bmatrix} S_o \\ : \\ S_{Nc} \\ S_{Nc+1} \\ : \\ S_{Nc+Ne} \end{bmatrix}$$

S_i : mapped symbol $i \in [0, Nc - 1]$

W_i^k : weight of ith symbol over ith carrier

$$\sum_{i=0}^{Nc-1} W_i^k = 1$$

IV. SIMULATION RESULTS

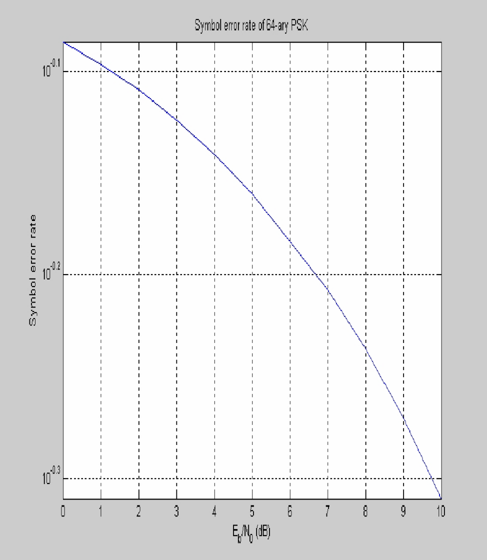

Fig. 2 SER Vs EbNo for 64 ary PSK

V. CONCLUSION

For large number of carriers for a given band-width, the SER rate is almost the same. This is because, the sub-channels are frequency flat, and each sub-channel can be used to its full capacity. The assumption that adjacent sub-channels are identical is also valid. Increasing M, the SER shifts by 2dB. This is expected because, to achieve the same SER, more power is required to push the constellation further away from the origin to offer more resolution ordetection capability. The initial weight matrix we have chosen was not performing as expected. We expect that there should be no degradation in the SER because, the Ne symbols are spread over all the carriers and all the carriers suffers independent fading. So we expect frequency diversity to offer some advantage here. This lets us think to design new weight pseudo orthogonal matrices.

References

[1] S.M. Alamouti, "A simple transmitter diversity scheme for wireless communications," IEEE JSAC, Vol. 16, No. 3.

[2] Salzberg, B. R., Performance of an efficient parallel data transmission system, IEEE Trans. Comm., Vol. COM-15, pp. 805 - 813, Dec. 1967.

[3] Orthogonal Frequency Division Multiplexing, U.S. Patent No. 3, 488,4555, filed November 14, 1966, issued Jan. 6, 1970.

[4] S. Weinstein and P. Ebert, "Data transmission by frequency-division multiplexing using the discrete Fourier transform," IEEE Trans. on Communications., vol. 19, pp. 628--634, Oct. 1971.

[5] R.W. Chang, and R.A. Gibby [1968], "Theoretical Study of Performance of an Orthogonal Multiplexing Data Transmission Scheme," IEEE Transactions on Communications, **16**, 4, pp. 529-540.

[6] http://www.nari.ee.ethz.ch/commth/pubs/files/proc03.pdf

[7] A. Peled and A. Ruiz, "*Frequency domain data transmission using reduced computationally complexity algorithms*," in Proceedings of IEEE International Conference of Acoustics, Speech and Signal Processing, (Denver), pp. 964--967, April 1980**.**

[8] D. Agarwal, V. Tarokh, A. Naguib, and Nambi Seshadri, "Space-time coded OFDM for High Data Rate Wireless Communication over wideband," Proc. VTC, Ottawa, Cananda, Vol. 3, pp. 2232-2236, 1998

[9] M, *Torabi, M.R. Soleymani," Adaptive* bit allocation for space-time block coded OFDM system," Acoustics, Speech, and Signal Processing, 2003. Proceedings. (ICASSP '03). 2003 IEEE International Conference on, Volume: 4, 6-10 April 2003, Pages: IV - 409-12 vol.4

[10] G. Yi, and K. B. Letaief, \Space-frequency-time coded OFDM for broadband wireless communications", in 2001 Global Telecommun. Conf., vol. 1, pp. 519-523.

[11] Taub and Schilling, “Principles of communication systems”, TMH second edition

[12] Intuitive Guide to Principles of Communications By Charan Langton.

[13] Ramjee Prasad, “OFDM for Wireless Communications systems”, Artech House Publishers, 2004.

[14] L. Hanzo, M. Munster, B.J. Choi, T. Keller, “OFDM & MC-CDMA for Broadband Multiuser Communications, WLANs and Broadcasting” John Wiley Publishers, 2003.

[15] Anibal Luis Intini, “Orthogonal Frequency Division Multiplexing For Wireless Networks” Standard IEEE 802.11a, University Of California, Santa Barbar.