Performance Analysis of MIMO-OFDM using Space Time Block Codes

Ch.KrishnaPriya[1], M Lakshman Naik[2], Dr. S. Siva Reddy[3]

[1]*Department of electronics and communication engineering, Loyola institute of technology and management, dhulipalla, sattenapalli, Ap, India.*

[2]*Associate professor Department of electronics and communication engineering, Loyola institute of technology and management, dhulipalla, sattenapalli, Ap, India.*

[3]*Professor Department of electronics and communication engineering, Loyola institute of technology and management, dhulipalla, sattenapalli, Ap, India.*

krishnapriyamedikonda@gmail.com[1], sureddysiva@rediffmail.com[3]

Abstract— **One of the biggest challenges in wireless communication is to operate in a time varying multipath fading environment under limited power constraints. The other challenge is the limited availability of the frequency spectrum. Future commercial and military wireless systems will be required to support higher data rates with reliable communication under spectrum limitations and multipath fading environments. In order to improve the reliability without increasing the emitted power, time, frequency or space diversity could be exploited. To exploit space diversity, the same information is transmitted or received through multiple antennas. Employing multiple antennas at the receiver and/or the transmitter improves the quality of a wireless communication link without increasing the transmitted power or bandwidth. Therefore, the design and implementation of multiple-input multiple-output (MIMO) communication systems is an attractive research area. Multi-carrier modulation (MCM) has recently gained fair degree of prominence among modulation schemes due to its intrinsic robustness in frequency selective fading channel .Orthogonal frequency division multiplexing (OFDM) is a widely used method in wireless communication systems. The combination of OFDM and MIMO systems presents better solutions by adding more diversity gain to the conventional OFDM systems employing a single antenna at both the receiver and the transmitter. In this paper we have simulated various MRRC & STBC schemes in Matlab environment .Then they were used to simulate the relationship between the signal to noise ratio (SNR) and bit error rate (BER). It has been shown that the performance of the 1x1 scheme vs. that of the 2x1 scheme and 1x2 scheme vs. that of the 2x2 scheme by exploiting transmit diversity results in a lower bit error rate even though the same number of receive antennas and transmitted power was used.**

Keywords— **MIMO, OFDM, BER, SNR**

I. Introduction

Array and diversity gains increase coverage and QOS. Multiplexing gain increases spectral efficiency. Multiple antenna techniques can be broadly classified into two categories: Spatial multiplexing techniques and Diversity techniques. The fundamental goal of the antenna diversity techniques is to convert an unstable time-varying wireless fading channel into a stable AWGN-like channel without significant instantaneous fading, thereby steepening the BER versus SNR curve .Among many different types of antenna diversity techniques, transmit diversity techniques have been widely adopted in practice, since it is useful in reducing the processing complexity of the receiver. Furthermore, it requires multiple antennas only on the transmitter side. Diversity techniques are used to mitigate degradation in the error performance due to unstable wireless fading channels .The probability that multiple statistically independent fading channels simultaneously experience deep fading is very low. Orthogonal frequency division multiplexing (OFDM) transmission scheme employs multiple sub carriers .The multiple orthogonal sub carrier signals, which are overlapped in spectrum, can be produced by generalizing the single-carrier Nyquist criterion into the multi-carrier criterion. In practice, discrete Fourier transform (DFT) and inverse DFT (IDFT) processes are useful for implementing these orthogonal signals. OFDM scheme places a guard band at outer subcarriers, called virtual carriers (VCs), around the frequency band to reduce the out of band radiation. The OFDM scheme also inserts a guard interval in the time domain, called cyclic prefix (CP), which mitigates the inter-symbol interference (ISI) between OFDM symbols.

II.SPACE TIME BLOCK CODES FOR MIMO

In most scattering environments, antenna diversity is a practical, effective and, hence, a widely applied technique for reducing the effect of multipath fading. The classical approach is to use multiple antennas at the receiver and perform combining or selection and switching in order to improve the quality of the received signal. The major problem with using the receive diversity approach is the cost, size, and power of the remote units. The use of multiple antennas and radio frequency (RF) chains (or selection and switching circuits) makes the remote units larger and more expensive. As a result, diversity techniques have almost exclusively been applied

The technique proposed here is a simple transmit diversity scheme which improves the signal quality at the receiver on one side of the link by simple processing across two transmit antennas on the opposite side. The obtained diversity order is equal to applying maximal-ratio receiver combining (MRRC) with two antennas at the receiver. The scheme may easily be generalized to two transmit antennas and M receive antennas to provide a diversity order of 2M. This is done without any feedback from the receiver to the transmitter and with small computation complexity. The scheme requires no bandwidth expansion, as redundancy is applied in space across multiple antennas, not in time or frequency. The new transmit diversity scheme can improve the error performance, data rate, or capacity of wireless communications systems.

III. Two-Branch Transmit Diversity with M Receivers

There may be applications where a higher order of diversity is needed and multiple receive antennas at the remote units are feasible. In such cases, it is possible to provide a diversity order of 2M with two transmit and M receive antennas. For illustration, we discuss the special case of two transmit and two receive antennas in detail. The generalization to M receive antennas is trivial.

Fig.1shows the baseband representation of the new scheme with two transmit and two receive antennas. The encoding and transmission sequence of the information symbols for this configuration is identical to the case of a single receiver, shown in Table1 defines the channels between the transmit and receive antennas, and Table 2 defines the notation for the received signal at the two receive antennas.

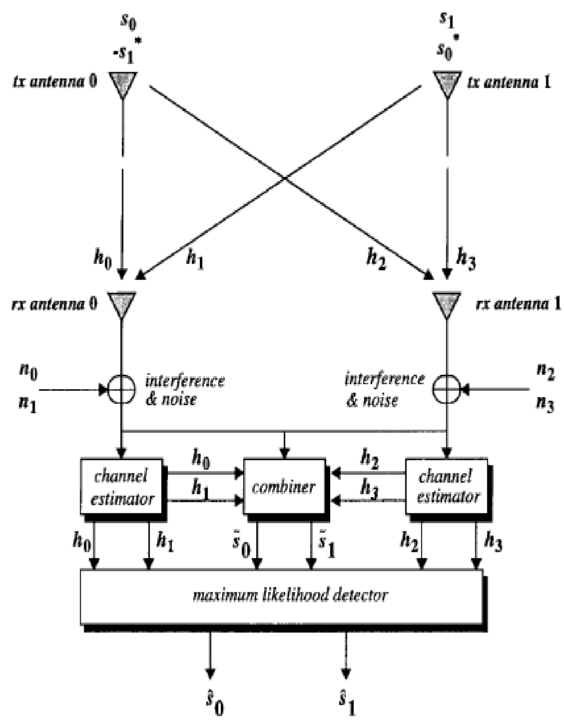

Fig. 1. The new two-branch transmit diversity scheme with two receivers.

Table 1: The definition of channels between the transmit and receive antennas

Tx antennas	Rx antenna 0	Rx antenna 1
Tx antennas0	h_0	h_2
Tx antennas1	h_1	h_3

Krishna Priya et al./ IJAIR Vol. 2 Issue 7 ISSN: 2278-7844

Table 2: The notation for the received signals at the two receive antennas

	Rx antenna 0	Rx antenna 1
Time t	r_0	r_2
Time t+T	r_1	r_3

Where

$$r_0 = h_0 s_0 + h_1 s_1 + n_0$$

$$r_1 = -h_0 s_1^* + h_1 s_0^* + n_1$$

$$r_2 = h_2 s_0 + h_3 s_1 + n_2$$

$$r_4 = -h_2 s_1^* + h_3 s_0^* + n_3 \quad (1)$$

n_0, n_1, n_2, and n_3 are complex random variables representing receiver thermal noise and interference. The combiner in Fig. 1 builds the following two signals that are sent to the maximum likelihood detector:

$$\check{s}_o = h_0^* r_0 + h_1 r_1^* + h_2^* r_2 + h_3 r_3^*$$

$$\check{s}_1 = h_1^* r_0 - h_0 r_1^* + h_3^* r_2 - h_2 r_3^* \quad (2)$$

Substituting the appropriate equations we have

$$\check{s}_0 = (\alpha_0^2 + \alpha_1^2 + \alpha_2^2 + \alpha_3^2) s_0 + h_0^* n_1 + h_1 n_1^* + h_2^* n_2 + h_3 n_3^*$$

$$\check{s}_1 = (\alpha_0^2 + \alpha_1^2 + \alpha_2^2 + \alpha_3^2) s_1 - h_0 n_1^* + h_1^* n_0 - h_2 n_3^* + h_3^* n_2$$

(3)

These combined signals are then sent to the maximum likelihood decoder which for signal s_0 uses the decision criteria expressed in (4) or (5) for PSK signals

choose s_i if

$$(\alpha_0^2 + \alpha_1^2 + \alpha_2^2 + \alpha_3^2 - 1)|s_i|^2 + d^2(\check{s}_0, s_i) \le (\alpha_0^2 + \alpha_1^2 + \alpha_2^2 + \alpha_3^2 - 1)|s_k|^2 + d^2(\check{s}_o, s_k),$$

$$\forall\, i \neq k \quad (4)$$

choose s_i if

$$d^2(\check{s}_0, s_i) \le d^2(\check{s}_o, s_k), \forall\, i \neq k \quad (5)$$

Similarly, for s_1 using the decision rule is to choose signal s_i if

$$(\alpha_0^2 + \alpha_1^2 + \alpha_2^2 + \alpha_3^2 - 1)|s_i|^2 + d^2(\check{s}_1, s_i) \le (\alpha_0^2 + \alpha_1^2 + \alpha_2^2 + \alpha_3^2 - 1)|s_k|^2 + d^2(\check{s}_1, s_k) \quad (6)$$

or, for PSK signals,

choose s_i if

$$d^2(\check{s}_1, s_i) \le d^2(\check{s}_1, s_k), \ \forall\, i \neq k \quad (7)$$

The combined signals in (3) are equivalent to that of four branch MRRC. Therefore, the resulting diversity order from the new two-branch transmit diversity scheme with two receivers is equal to that of the four-branch MRRC scheme. It is interesting to note that the combined signals from the two receive antennas are the simple addition of the combined signals from each receive antenna, i.e., the combining scheme is identical to the case with a single receive antenna. We may hence conclude that, using two transmit and M receive antennas, we can use the combiner for each receive antenna and then simply add the combined signals from all the receive antennas to obtain the same diversity order as 2M-branch MRRC. In other words, using two antennas at the transmitter, the scheme doubles the diversity order of systems with one transmit and multiple receive antennas.

An interesting configuration may be to employ two antennas at each side of the link, with a transmitter and receiver chain connected to each antenna to obtain a diversity order of four at both sides of the link.

IV.GENERALIZED COMPLEX ORTHOGONAL DESIGNS AS SPACE TIME BLOCK CODES:

The simple transmit diversity schemes described above assume a real signal constellation. It is natural to ask for extensions of these schemes to complex signal constellations. We develop the Alamouti scheme as a 2 X 2 complex orthogonal designs. Motivated by the possibility of linear processing at the transmitter, we define complex linear processing orthogonal designs, but we shall prove that complex linear processing orthogonal designs only exist in two dimensions. This means that the Alamouti Scheme is in some sense unique. However, we would like to have coding schemes for more than two transmit antennas that employ complex constellations. Hence the notion of generalized complex orthogonal designs is introduced. We then prove by explicit construction that rate ½ generalized complex orthogonal designs exist in any dimension specifically, examples of rate ¾ generalized complex linear processing orthogonal designs in dimensions three and four are provided.

Complex Orthogonal Designs:

We define a complex orthogonal design of size O_c of size n as an orthogonal matrix with entries the in determinates, $\pm x_1$, $\pm x_2$,… $\pm x_n$ their conjugates $\pm x_1^*$, $\pm x_2^*$,… $\pm x_n^*$, or multiples of these in determinates by $\pm$ i where i = √-1. Without loss of generality, we may assume that the first row of O_c is x_1 , x_2 ,… x_n.

The method of encoding can be applied to obtain a transmit diversity scheme that achieves the full diversity. The decoding metric again separates into decoding metrics for the individual symbols x_1 , x_2 ,… x_n. An example of a 2 X 2 complex orthogonal design is given by

$$\begin{pmatrix} x_1 & x_2 \\ -x_2^* & x_1^* \end{pmatrix} \tag{8}$$

The Alamouti Scheme :

The space – time block code proposed by Alamouti[1] uses the complex orthogonal design

$$\begin{pmatrix} x_1 & x_2 \\ -x_2^* & x_1^* \end{pmatrix} \tag{9}$$

Suppose that there are 2^b signals in the constellation. At the first time slot, 2b bits arrive at the encoder and select two complex symbols s_1 and s_2 . These symbols are transmitted simultaneously from antennas one and two, respectively. At the second time slot, signals $-s_2^*$ and s_1^* are transmitted simultaneously from antennas one and two, respectively. Maximum-likelihood detection amounts to minimizing the decision statistic over all possible values of s_1 and s_2

$$\sum_{j=1}^{m}\left(\left|r_1^j-\alpha_{1,j}s_1-\alpha_{2,j}s_2\right|^2+\left|r_2^j+\alpha_{1,j}s_2^*-\alpha_{2,j}s_1^*\right|^2\right) \tag{10}$$

The minimizing values are the receiver estimates of $s_1$and s_2, respectively. As in the previous section, this is equivalent to minimizing the decision statistic

$$\left|\left[\sum_{j=1}^{m}\left(r_1^j\alpha_{1,j}^*+(r_2^j)^*\alpha_{2,j}\right)\right]-s_1\right|^2 +\left(-1+\sum_{j=1}^{m}\sum_{i=1}^{2}|\alpha_{i,j}|^2\right)|s_1|^2 \tag{11}$$

for detecting s_1 and the decision statistic

$$\left|\left[\sum_{j=1}^{m}\left(r_1^j\alpha_{2,j}^*-(r_2^j)^*\alpha_{1,j}\right)\right]-s_2\right|^2 +\left(-1+\sum_{j=1}^{m}\sum_{i=1}^{2}|\alpha_{i,j}|^2\right)|s_2|^2 \tag{12}$$

for decoding s_2. This is the simple decoding scheme. Thus Alamouti's scheme provides full diversity 2m using m receive antennas. This is also established by Alamouti who proved that this scheme provides the same performance as level maximum ratio combining.

V. PERFORMANCE COMPARISION OF MRRC & STBC SCHEMES:

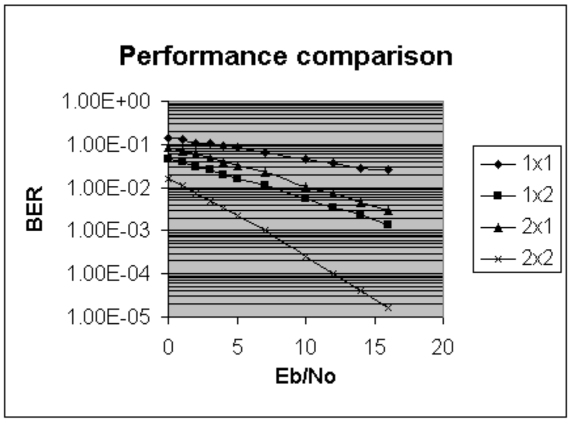

Fig.2The BER vs. Eb/N_0 performance comparison of four BPSK transmission schemes

The performance of the 1x1 scheme vs. that of the 2x1 scheme shows that exploiting transmit diversity results in a lower bit error rate even though the same number of receive antennas and transmitted power was used. As the Eb/N0 ratio is increased the 2x1 scheme's bit error rate pulls away from that of the 1x1 scheme. This results in greater and greater transmitted power savings as Eb/N_0 increases, or alternatively as the required bit error rate decreases. A similar result is readily seen for the comparison of the 1x2 MRRC scheme to the 2x2 scheme, with the 2x2 outperforming its counterpart.

VI .Conclusion

Here we have simulated 1x1, 2x1, 1x2, and 2x2 schemes (transmitter X receiver system) in matlab. The 1x1 and 1x2 schemes were uncoded, though the 1x2 system had maximum likelihood detection. The 2x1 and 2x2 were Space-Time Block Coded Systems.

The results shown were recorded for an uncoded BPSK (1x1), a two-branch MRRC (1x2), and Space-Time Block Codes for one and two transmit antennas. The transmission rate was 1 bit/s/Hz.In this paper the Alamouti coding and MRRC are compared in terms of BER performance.Here,weassumethe independent Rayleigh fading channels and perfect channel estimation at the receiver. Note that the Alamouti coding achieves the same diversity order as1×2MRRCtechnique (implied by the same slope of the BER curves).

In this paper it is shown that as number of transmit antennas is increased the BER is reduced. For this reason, multi-antenna MIMO channels have recently become an attractive scheme means to increase quality of wireless communications by the use of spatial diversity at both sides of the link and occupies a considerable part of today's academic research. STBC is an efficient system for transmission of MIMO in Wireless Communication. By using Stbc for MIMO-OFDM the channel capacity can be increased.

REFERENCES

[1] S. M. Alamouti, "A simple transmitter diversity scheme for wireless communications," IEEE J. Select. Areas Commun., vol. 16, pp. 1451–1458, Oct. 1998.

[2] G. J. Foschini Jr. and M. J. Gans, "On limits of wireless communication in a fading environment when using multiple antennas," Wireless Personal Commun., Mar. 1998.

[3] A. V. Geramita and J. Seberry, Orthogonal Designs, Quadratic Forms and Hadamard Matrices, Lecture Notes in Pure and Applied Mathematics, vol. 43. New York and Basel: Marcel Dekker, 1979.

[4] J.-C. Guey, M. P. Fitz, M. R. Bell, and W.-Y. Kuo, "Signal design for transmitter diversity wireless communication systems over Rayleigh fading channels," in Proc. IEEE VTC'96, 1996, pp. 136–140.

[5] V. Tarokh, N. Seshadri, and A. R. Calderbank, "Space–time codes for high data rate wireless communication: Performance analysis and code construction," IEEE Trans. Inform. Theory, vol. 44, pp. 744–765, Mar. 1998.

[6] V. Tarokh, A. Naguib, N. Seshadri, and A. R. Calderbank, "Space-time codes for high data rate wireless communications: Performance criteria in the presence of channel estimation errors, mobility and multiple paths," IEEE Trans. Commun., vol. 47, pp. 199–207, Feb. 1999.

[7] J. Winters, J. Salz, and R. D. Gitlin, "The impact of antenna diversity on the capacity of wireless

communication systems," IEEE Trans. Commun., vol. 42. Nos. 2/3/4, pp. 1740–1751, Feb./Mar./Apr. 1994.

[8] A. Wittneben, "Base station modulation diversity for digital SIMUL-CAST," in Proc. IEEE VTC, May 1991, pp. 848–853.

[9] V. Tarokh, H. Jafarkhani, and A.R. Calderbank, "Space-time block codes for orthogonal designs," IEEE Transactions on Information Theory, Vol.45, No.5, July 1999, pp.1456-1467.

[10], "A new bandwidth efficient transmit antenna modulation diversity scheme for linear digital modulation," in Proc. IEEE ICC, 1993, pp. 1630–1634.

[11]. G. D. Durgin, T. S. Rappaport, And D. A. de Wolf, "New analytical models and probability density functions for fading in wireless communication," IEEE Trans. Commun., vol. 50, no. 6, pp. 1005-1015, Jun. 2002.

12. Soon H. Oh and Kwok H. Li, "BER performance of BPSK receivers over two-wave with diffuse power fading channels" IEEE Trans. Wireless Commun., vol. 4, no. 4 pp. 1448-1454, Jul. 2005.