PERFORMANCE OF SPATIAL MULTIPLEXING, DIVERSITY AND COMBINED TECHNIQUE FOR MIMO-OFDM SYSTEM

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ABSTRACT

In this paper, Space Time Block Code (STBC), Spatial Multiplexing (SM) and hybrid model with OFDM are designed for Rayleigh fading channel. Combination of SM and STBC forms hybrid MIMO model. The performances of the above mentioned models with different modulations such as Quadrature Phase Shift Keying (QPSK) and Quadrature Amplitude Modulation (QAM) with multiple antennas are measured with respect to BER. In this paper, it is shown that Hybrid MIMO provides low BER. Thus, in wireless communication, hybrid model improves the data rate and link reliability.

KEYWORDS

STBC, SM, MIMO, OFDM, Hybrid MIMO-OFDM, BER

1. INTRODUCTION

A future wireless communication system will demand high quality multimedia services with mobility. Researchers face a great challenge to use more efficiently, the limited bandwidth spectrum. Multiple Input Multiple Output (MIMO) system uses multiple antennas to increase data rate and reliability for the same bandwidth. There are two basic MIMO techniques, spatial diversity and spatial multiplexing. Spatial diversity is obtained by transmitting more copies of signal through multiple antennas which improves reliability. The spatial multiplexing with Bell Laboratories Layered Space Time (BLAST) [1] increases the data rate and spectral efficiency by transmitting data streams simultaneously from multiple antennas.

Alamouti [2] has shown that, Space Time Block Code (STBC) can achieve full transmit diversity gain for two antennas. His scheme is simple because decoding is done with linear maximum likelihood detection. Tarokh *et al*. [3], [4] have modified this scheme to increase the order of diversity. The combination of Spatial Multiplexing (SM) and STBC improves multiplexing gain and diversity gain simultaneously. MIMO techniques presented by [5-7] give good results for flat fading channel.

Orthogonal Frequency Division Multiplexing (OFDM) is a multicarrier transmission technique and is a well established technique for multipath fading channel. The hybrid scheme combines SM and STBC with OFDM to achieve variable data rate. The MIMO-OFDM technology presented by [8-10] is the core technology for various next generation standards used for commercial wireless products and networks, such as broadband wireless access systems, Wireless Local Area Networks (WLAN), Wireless Metropolitan Area Network (WMAN), 4G networks and beyond, Long Term Evolution (LTE), etc.

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This paper focuses on performance improvement of MIMO system in terms of reliability and spectral efficiency by reducing Bit Error Rate (BER). This is done by Hybrid MIMO-OFDM, with antenna configuration of 4x4. Performance of this Hybrid system is evaluated and compared with SM and STBC systems for BER.

This paper is organized as follows. Section 2 describes Spatial Multiplexing (SM) and section 3 describes Space Time Block Code (STBC). Hybrid MIMO-OFDM technology developed in this paper is presented in section 4. Simulation Model of the Hybrid system is presented in section 5 and section 6 presents results and discussions.

2. SPATIAL MULTIPLEXING

The spatial multiplexing was invented and prototyped by Bell Laboratory and is called *Bell Labs layered space/time* (BLAST) [1]. Spatial multiplexing technique offers increase in the transmission rate (or capacity) for the same bandwidth with no additional power expenditure. In this technique, input data stream is split into two half-rate streams and transmitted simultaneously from two transmit antennas. The receiver, having complete knowledge of the channel, recovers these individual bit streams and combines them so as to recover the original bit stream. A variety of techniques can be used at the receiver to separate the various streams from one another. These techniques include Zero Forcing (ZF), Minimum Mean Squared Estimation (MMSE) and Maximum Likelihood detection (ML). Since the receiver has knowledge of the channel, it provides receive diversity, but the system has no transmit diversity since the data streams are completely different from each other. This can be extended to more number of antennas.

In SM, input symbols are divided equally and transmitted over two transmit antennas. The signal received by the two antennas are given by,

$$r_1=h_{11}S_1+h_{12}S_2+n_1 \quad \ldots\ldots\ldots\ldots.(1)$$

$$r_2=h_{22}S_1+h_{22}S_2+n_2 \quad \ldots\ldots\ldots\ldots.(2)$$

The received signal in matrix form,

$$\begin{bmatrix} r_1 \\ r_2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} S_1 \\ S_2 \end{bmatrix} + \begin{bmatrix} n_1 \\ n_2 \end{bmatrix} \ldots\ldots\ldots (3)$$

S_1 and S_2 symbols are placed on OFDM subcarrier for further transmission through channel. In general, received signal can be represented as,

$$R = Hs + N \quad \ldots\ldots.(4)$$

where H is channel matrix of size (n x m) and N is complex random variable representing receiver noise and interference.

3. SPACE TIME BLOCK CODE

Alamouti presented [2] space diversity scheme which has been modified by Tarokh *et. al*. to form generalized Space-Time Block Coding (STBC) [3], [4]. This scheme provides transmit and receive diversity to MIMO system. The scheme uses two transmit antennas and two receive antennas and may be defined by the following three functions:

- Encoding and deciding transmission sequence information symbols at the transmitter,
- Combining signals with noise at the receiver and
- Maximum likelihood detection.

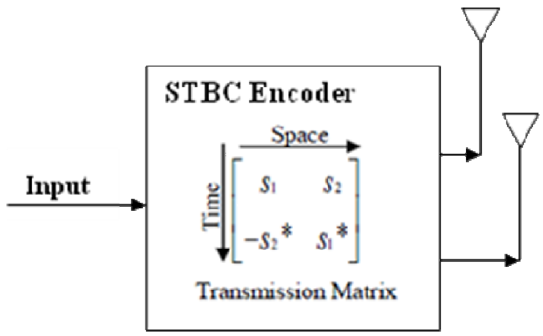

Figure 1: STBC encoder diagram

S_1 is transmitted from antenna 1 and S_2 is transmitted from antenna 2 in first time slot t. In second time slot (t+1), $-S_2^*$ is transmitted from antenna 1 and S_1^* is transmitted from antenna 2, where (*) denotes the conjugate of a number [2].

Therefore, received signal in matrix form would be,

$$\begin{bmatrix} r_{11} & r_{12} \\ r_{21} & r_{22} \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} S_1 & S_2^* \\ S_2 & S_1^* \end{bmatrix} + \begin{bmatrix} n_{11} & n_{12} \\ n_{21} & n_{22} \end{bmatrix} \ldots\ldots\ldots (5)$$

Then maximum likelihood detection (ML) detects the signal which depends upon Euclidian distance between two signals. We have done Simulation of STBC as per our previous paper [11, 12].

4. HYBRID MIMO-OFDM TECHNOLOGY

A hybrid model is a combination of SM and STBC [5-7]. A Hybrid MIMO-OFDM system is as shown in Fig.2.

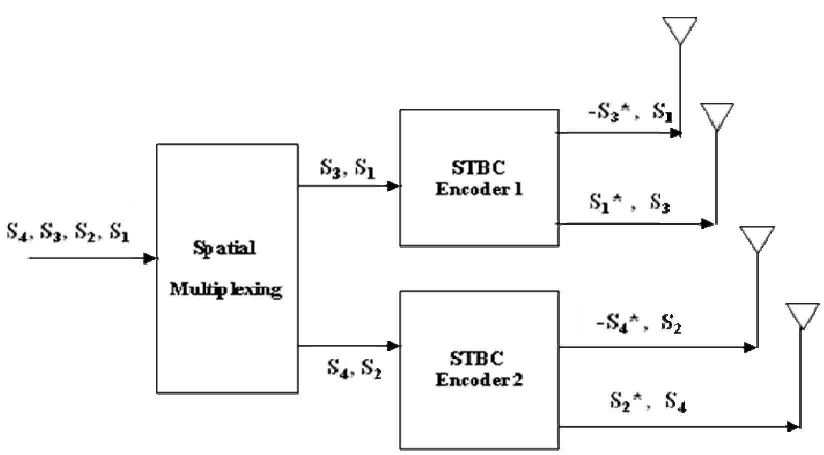

Figure 2: Hybrid MIMO Model

The input data is passed through spatial multiplexing block into two streams. The output of each stream is given to Alamouti space time block coding with antenna configuration of (2×2). Output of STBC encoder is the input to OFDM transmitter. This transmitter is with (4x4) antennas. Then the signal is passed through Rayleigh fading channel. AWGN noise is added to each signal. Input data stream having symbols S_1, S_2, S_3, S_4 are equally divided by spatial multiplexing and passed through STBC encoder as stated in Table 1.

Table 1: Hybrid MIMO Transmitted signals

Time	Antenna 1	Antenna 2	Antenna 3	Antenna 4
t	S_1	S_3	S_2	S_4
t+1	$-S_3^*$	S_1^*	$-S_4^*$	S_2^*

The Hybrid MIMO system equations in matrix form would be as under,

$$\begin{bmatrix} r_{11} & r_{12} \\ r_{21} & r_{22} \\ r_{31} & r_{32} \\ r_{41} & r_{42} \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} & h_{13} & h_{14} \\ h_{21} & h_{22} & h_{23} & h_{24} \\ h_{31} & h_{32} & h_{33} & h_{34} \\ h_{41} & h_{42} & h_{43} & h_{44} \end{bmatrix} \begin{bmatrix} S_1 & -S_3^* \\ S_3 & S_1^* \\ S_2 & -S_4^* \\ S_4 & S_2^* \end{bmatrix} + \begin{bmatrix} n_{11} & n_{12} \\ n_{21} & n_{22} \\ n_{31} & n_{32} \\ n_{41} & n_{42} \end{bmatrix} \quad \ldots\ldots(6)$$

The received antenna signals after combining are passed through maximum likelihood detection (ML)

5. SYSTEM MODEL

In this paper, the simulation model of the Hybrid MIMO-OFDM system with antenna configuration of (4×4) has been designed and developed. The model is shown in Figure 3. The parameters used in the simulation are given in Table 2.

Table2: Parameters Used for MIMO-OFDM System

Parameters	**Specifications**
Channel Model	Rayleigh fading channel
Modulation	QPSK,16QAM, 64QAM,
Noise	AWGN
Detector	ML,MMSE detector
Antenna configuration	2×2 and 4×4 antennas
Antennas Transmitting Power	Equally
FFT Size	512

The system is divided into two main blocks namely the transmitter and the receiver. The channel is assumed as Rayleigh fading channel. Description of the blocks used in this hybrid system along with Rayleigh fading channel is given below.

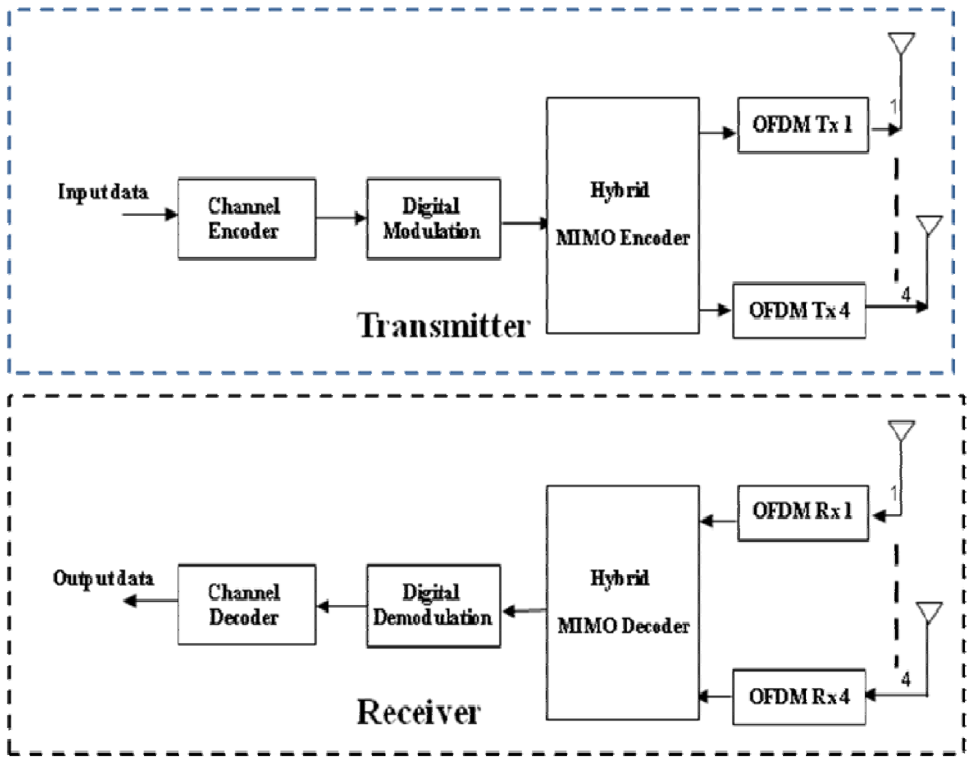

Figure 3 System Model of Hybrid MIMO- OFDM with 4x4 antennas

The data is generated with a random integer generator. This data is passed through convolutional channel encoder and modulated through QPSK and MQAM and then to Hybrid MIMO encoder. In Hybrid MIMO encoder first modulated symbols are spatial multiplexed into two streams. The output of each stream is given to 2×2 Alamouti space time block coding. Output of Hybrid MIMO encoder is the input of OFDM encoder [13] and then data passed through Rayleigh fading channel. At the receiver side first cyclic prefix is removed then OFDM decoder is used to decode the data then data passed through STBC combiner to select the most possible and efficient combination from received data.

6. RESULTS AND DISCUSSION

In this section performances of STBC-OFDM, SM-OFDM and Hybrid MIMO-OFDM models with respect to BER obtained in the simulation process are presented. The Simulation model was implemented in Matlab/ Simulink. For SM model, Minimum Mean Square Error (MMSE) detector is used to remove the inter-stream interference on per sub-carrier basis. Figure 4, Figure 5 and Figure 6 show the BER performance of STBC-OFDM (2x2), SM-OFDM (2x2) and Hybrid MIMO-OFDM (4x4) respectively for different modulations.

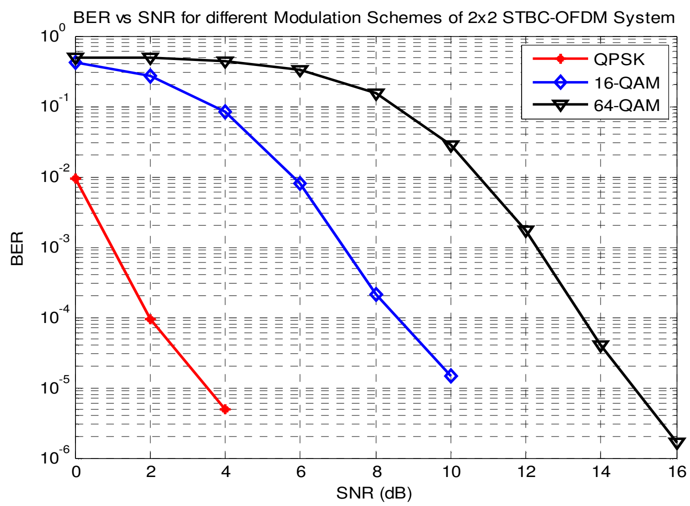

Figure 4. BER plot of STBC-OFDM for different modulation Scheme

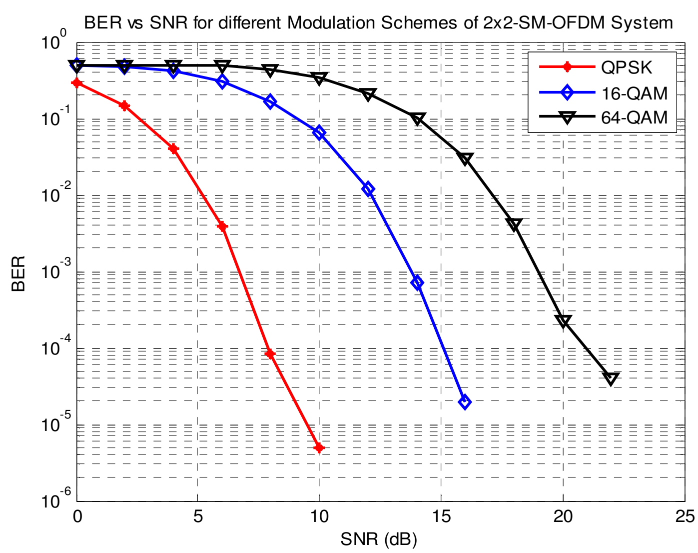

Figure 5. BER Plot of SM-OFDM for different modulation Scheme

SNR vs BER graph is plotted for QPSK and M-QAM with convolution encoder rate is ½. It can be observed from Figure 4 and Figure 5 that obtained BER is significantly less in STBC-OFDM system as compare to SM-OFDM system. These results demonstrate that STBC-OFDM system is suitable for applications which demands low BER. However, the SM-OFDM can be the best choice for the applications where speed or data transmission rate is having primary importance than bit error rate.

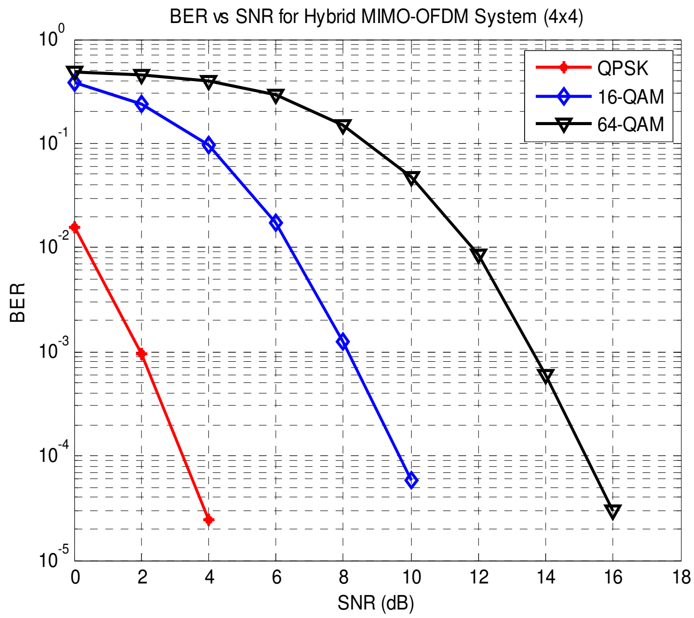

Figure 6. BER Plot of Hybrid MIMO-OFDM 4x4 for different modulation Scheme

Figure 6 shows BER result of Hybrid MIMO-OFDM system. It is evident from these graphs that Hybrid MIMO-OFDM system gives low BER like STBC-OFDM system.

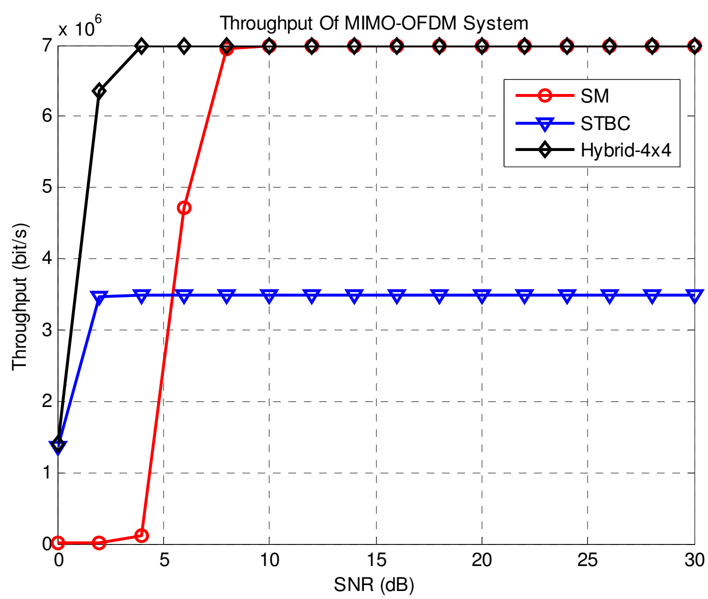

Figure 7. Throughput Plot of Hybrid MIMO-OFDM 4x4 for QPSK

Throughput vs SNR is plotted in figure 7. Throughput of Hybrid MIMO-OFDM is more even at low SNR than SM-OFDM.

Hybrid MIMO-OFDM system presents low BER and high throughput in one system itself. This system offers tremendous potential in high speed applications.

7. CONCLUSION

Hybrid MIMO-OFDM system demonstrates superior performance than STBC and SM systems. The simulation results show that for low to medium SNR, STBC-OFDM system is better whereas for high SNR the SM-OFDM system is better. Hybrid MIMO-OFDM model gives low BER and high throughput in one system model itself. The Hybrid MIMO-OFDM model demonstrated in this paper can be used for real time data.

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