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Performance Evaluation of Hybrid MIMO-OFDM System using Matlab® Simulink with Real Time Image Input

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Abstract—Multiple Transmit and receive antenna are now popularly used to form multiple input, multiple output (MIMO) channels to increase the capacity as well as to reduce the Bit Error Rate (BER). This paper describes the performance of Hybrid MIMO-OFDM (Orthogonal Frequency Division Multiplexing) models, which are developed & analyzed in Matlab® Simulink. In this study 2×2 STBC-OFDM and 2×2 SM-OFDM system models are designed.. The performance of both systems is measured with respect to BER and Throughput results & the applications of this system is also demonstrated using 64 QAM modulations by processing real time image as an input. The results indicate that for low to medium SNR, STBC-OFDM system outperforms SM-OFDM system whereas for high SNR the SM-OFDM system can provide double throughput than the STBC-OFDM system.

Index Terms —STBC, SM, MIMO, OFDM, Hybrid MIMO-OFDM

1 INTRODUCTION

Designing of future wireless systems has been emerging one of the key area of interests for researchers and academicians. MIMO system used in wireless communications offers various benefits such as higher capacity (bits/s/Hz) through spatial multiplexing(SM) scheme and better transmission quality (BER, outage) through transmit diversity scheme.(STBC) The growing demand of communication application services including the growth of internet related contents, multimedia, mobile communications etc lead to increasing interest to high speed communications technologies this further leads higher demand of the bandwidth. This creates shortage of usable bandwidth required for fast and error free communications.[1] Therefore, the wireless communication devices must have very high spectrum efficiency and the capacity of overcoming the channel fading in the environment of multi-path channel.

Spatial transmit diversity is achieved by applying Alamouti's Space-Time block coding. In space time block coding single data stream is replicated and transmitted with the multiple transmission of coded data stream there is a increased opportunity for the receiver to identify the strong signal which is less affected by fading. STBC provides diversity gain is equal to number of transmit antennas in to number of receive antennas.. STBC provides strong diversity gain, but cannot increase the link throughput at high SNR but gives low BER at lower order modulation.[2]

In SM data stream is subdivided in to number of independent substream one for each transmit antenna employed. SM provides multiplexing gain is equal to (r=R/log SNR) .SM provides high throughput at high SNR but to achieve low BER higher order modulation is required. MIMO system (includes both STBC and SM) can resist multi-path fading, however for frequency selective deep fading, the MIMO system remains powerless. The solution of this complexity is to use MIMO system along with OFDM which is the core technology of the next-generation mobile communications.[3]

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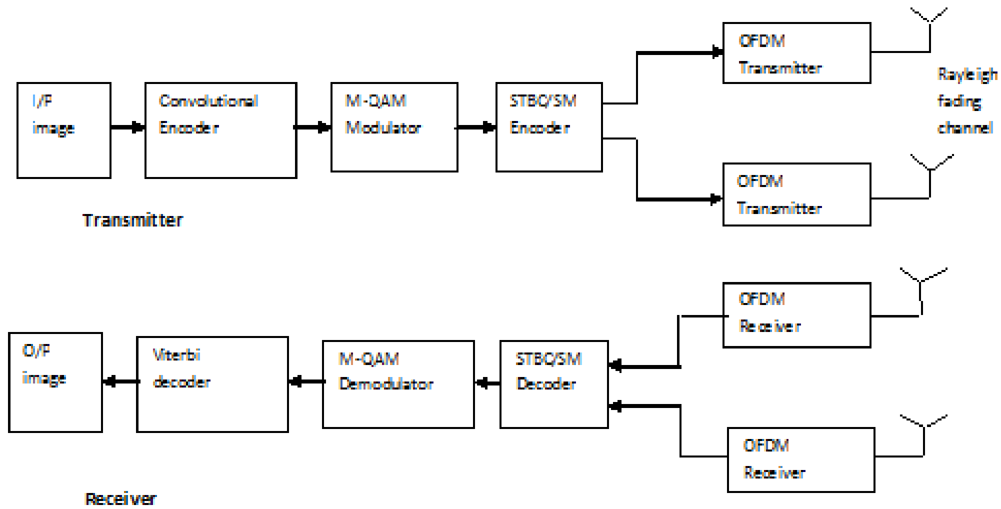

Figure 2 Experimental System Model – MIMO- OFDM model with 2 transmit and 2 receive antennas

Orthogonal Frequency Division Multiplexing (OFDM) is a well-established technique for achieving low-cost broadband wireless connectivity, and has been chosen as the air interface for a range of new standards, including IEEE802.16d/e. The ideas of MIMO and OFDM have been combined by a number of authors to form a new class of MIMO-OFDM system [4] [5]. This approach represents a promising candidate for WiMAX applications.

The present study is focused on 2×2 STBC-OFDM and 2×2 SM-OFDM systems and these systems are evaluated & compared for Bit Error Rate (BER) and throughput results.

2 MIMO-OFDM TECHNIQUES

MIMO-OFDM systems make the most of the space and frequency diversity simultaneously to improve the performance of system. The coding can be done across OFDM subcarriers rather than OFDM symbols. MIMO-OFDM hybridization has potential to meet high data rate requirements and high performance over various challenging channels that may be time-selective and frequency selective.[3] The MIMO-OFDM wireless communication system can be based on various transmit (Tx) and receive (Rx) antenna combinations e g , 2×1, 2×2, 3×2, 4×2. These systems can support 64, 128, 256 and 512 point FFT transform along with Rayleigh fading channel and QPSK, MQAM etc modulation techniques.[3]

2.1 STBC OFDM System:

Space diversity of multiple antennas both in the transmitter and the receiver have excellent performance against frequency selective fading. There are three types of Space diversity techniques. Transmit diversity, receive diversity an receive-transmit Diversity.System with transmit diversity set multiple antennas in the transmitter, and it will simultaneously transmits information symbols within a given period T. In STBC encoder input symbols are divided into two groups.{s1,s2}

s1 is transmitted from antenna 1 and s2 is transmitted from antenna 2. -s2* will be transmitted from antenna 1 and s * is transmitted from antenna 2 at T+1 time period, where (*) denotes the conjugate of a number. [6].gain spatial diversity by way of coding in different antennas

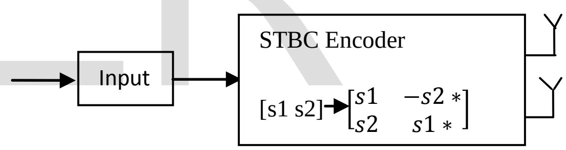

Fig 1.STBC encoder block diagram

The System equation becomes

R=Hs+W (1)

$$\begin{bmatrix} r11 & r12 \\ r21 & r22 \end{bmatrix} = \begin{bmatrix} h11 & h12 \\ h21 & h22 \end{bmatrix} \begin{bmatrix} s1 & -s2* \\ s2 & s1* \end{bmatrix} + \begin{bmatrix} w1 & w2 \\ w3 & w4 \end{bmatrix}$$

The above matrix shows that the two rows/columns of STBC matrix, that are orthogonal to each other [2]. r11 and r12 denotes receiver 1 and r21 and r22 denotes receiver 2. H is the channel matrix and W is the white Gaussian noise. The s1 and s2 symbols along with their conjugates are placed on OFDM subcarrier for further transmission through channel.

2.2 SM OFDM System

Spatial multiplexing technique offers a linear (in the number of transmit-receive antenna pairs or min (RX , TX)) increase in the transmission rate (or capacity) for the same bandwidth and with no additional power expenditure. It is only possible in MIMO channels Consider the case of two transmit and two receive antennas. This can be extended to more general MIMO channels. The bit stream is split into two half-rate bit streams, modulated and transmitted simultaneously from both the 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. Since the receiver has knowledge of the channel it provides receive diversity, but the system has no transmit diversity since the bit streams are completely different from each other in that they carry totally different data. Thus spatial multiplexing increases the transmission rates proportionally with the number of transmit-receive antenna pairs.[7]

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

$$R=Hs+W \quad (2)$$

In matrix form

$$\begin{bmatrix} r1 \\ r2 \end{bmatrix} = \begin{bmatrix} h11 & h12 \\ h21 & h22 \end{bmatrix} \begin{bmatrix} s1 \\ s2 \end{bmatrix} + \begin{bmatrix} w1 \\ w2 \end{bmatrix}$$

The s1 and s2 symbols are placed on OFDM subcarrier for further transmission through channel.

3 EXPERIMENTAL SYSTEM DESIGN

In the present study block scheme of a STBC or SM with OFDM is designed. As shown in Figure 2 block diagram represents the whole system model. The block system is divided into 2 main sections namely the transmitter and the receiver. The parameters used in this model are given in Table 1

Table 1 Parameters Used for STBC and SM-OFDM System

Parameters	Specifications
Channel Model	Rayleigh fading channel
Modulation	64 QAM
Noise	AWGN
Detector	ML,MMSE detector
Diversity Schemes	2×2 antennas
Separation Distance	½
Antennas Transmitting Power	Equally
FFT Size	512
Number of Data Subcarriers	360
Number of Pilot Subcarriers	60
Number of Guard band Subcarriers	92
Cyclic prefix or Guard Time	1/8

3.1 Transmitter

The data is generated from a real time image [8]. The transmission is completed block wise when forward error correction (FEC) is used. Furthermore, the size of the data generated is depends on the block size. The modulation schemes used to map the bits to symbols is 64-QAM. The generated data is passed on to the next stage, either to the FEC block or directly to the symbol mapping if FEC is not used. The general definitions of FEC, modulation, MIMO encoder & IIFT are noted below.

1. FEC: The data is encoded using tail biting convolutional codes (CC) whose constraint length is 7 and the native code rate is ½
2. Modulation: 64QAM is used with gray coding in the constellation map
3. Space Time Encoder (MIMO encoder): The Space Time Encoder stage converts one single input data stream into multiple output data streams. How the output streams are formatted depends on the type of MIMO method employed. Different symbols are simultaneously transmitted over these antennas to reduce noise interference. The receiver after receiving the signal retrieves the bits using Maximum Likelihood decoding algorithm and passes the data to the guard band removal block.
4. IFFT and cyclic prefix: IFFT is used in generation of OFDM symbol. The addition of cyclic prefix is done on the time domain symbol obtained after IFFT.[3] The IFFT size ('N' value) is considered as 512 in simulations. This data is fed to the channel which represents 'Rayleigh fading channel model' in diagram.

3.2 Receiver

According to the system for MIMO-OFDM module there will be two receive antennas and for MISO (Multiple input and single output)-OFDM module will be having one receive antenna.

The first task performed at the receiver (in simulation) is removal of cyclic prefix. This eliminates the inter symbol interference (ISI). The data is then passed through the serial to parallel converter of size 512 first and then passed to the FFT for frequency domain transformation. The signal was found distorted by the channel, however, to reconstruct the original signal, the information on how these channels are acted on the transmitted signal need to be obtained to mitigate its effect. This is called equalization. In OFDM system, this is done by channel estimation and interpolation, and reverse process (including decoding) is executed to obtain the original data bits.

3.3 Rayleigh Fading Channel

Rayleigh Fading is one kind of statistical model which propagates the environment of radio signal. According to Rayleigh distribution magnitude of a signal which has passed though the communication channel and varies randomly. Rayleigh Fading works as a reasonable model when many objects in environment which scatter radio signal before arriving at the receiver [3]. When there is no propagation dominant during line of sight between transmitter and receiver on that time Rayleigh Fading is most applicable.

Throughput calculation of MIMO-OFDM System Together with modulation and coding, the link throughput for each user can be calculated from Packet Error Rate (PER) by:

$$C_{link} = \frac{N_D * N_b * R_{FEC} * R_{STC}}{Ts} x\ (1 - PER) \qquad (3)$$

Where, Ts, ND, Nb, RFEC and RSTC denote the OFDM symbol duration, the number of assigned data subcarriers, and the number of bits per subcarrier, FEC coding rate, and space-time coding rate for the user[3].

4 SIMULATION RESULTS & DISCUSSION

In this section 2×2 STBC-OFDM and 2×2 SM-OFDM BER and Throughput results along with output images are presented. The Simulation model was implemented in Matlab®.R2011b Simulink. For Spatial Multiplexing Minimum Mean Square Error (MMSE) receiver is used to remove the inter-stream interference on a per sub-carrier basis. The link throughput is calculated from the PER as given by equation (3). Figure 3 shows input image for both STBC-OFDM and SM-OFDM system. Input image is 8 bit gray coded image and BER and throughput results are performed using 64QAM with code rate1/2. Figure 4 and figure 5 displays the BER performance of 2x2 STBC-OFDM and 2×2 SM-OFDM systems.

Figure 3. Input Image for STBC-OFDM and SM-OFDM System

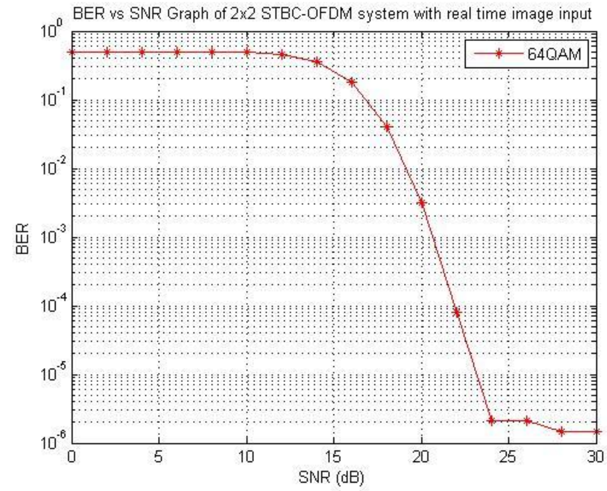

Figure 4. BER vs SNR of STBC-OFDM System

It can be observed from these figures that at 30 SNR, BER of STBC-OFDM system is significantly lower (1.4468×10-6) as compare to SM-OFDM system (1.3284×10-5). The BER can be correlated with the clarity of received images processed through STBC-OFDM & SM-OFDM models. From figures 6 it can be conformed that STBC-OFDM model with low BER resulting negligible noise in received image whereas SM-OFDM model with relatively higher BER leads to noticeable noise in the revived image as shown figure 7.

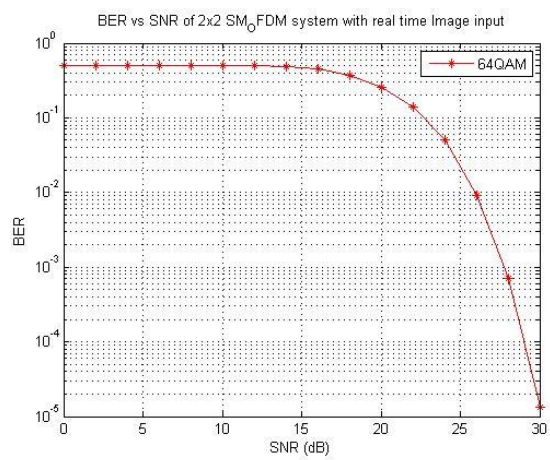

Figure 5: BER vs. SNR of SM-OFDM System

Figure 8 and figure 9 illustrates the simulated STBC-OFDM and SM-OFDM system throughput versus SNR data. For SM-OFDM model obtained throughput is almost doubles than throughput obtained in STBC-OFDM model.

Figure 6 Output Image of STBC-OFDM System

Figure 7: Output Image of SM-OFDM System

The results obtained in this study substantiate that SM-OFDM can increase the MIMO channel capacity which leads to higher data throughput by simultaneously transmitting different signals on different transmit antennas, at the same carrier frequency. However SM-OFDM might suffer from poor link reliability which leads to higher BER.

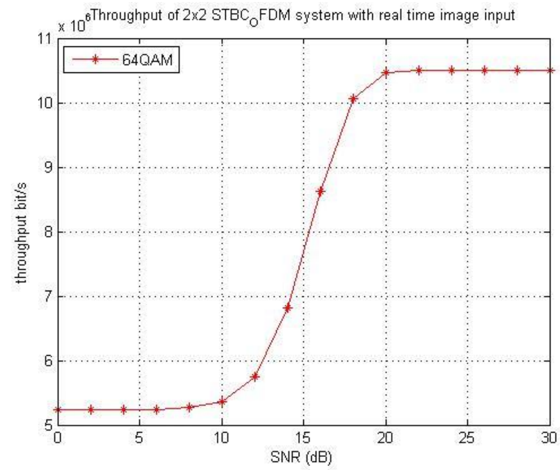

Figure 8 Throughput of 2x2 STBC-OFDM system

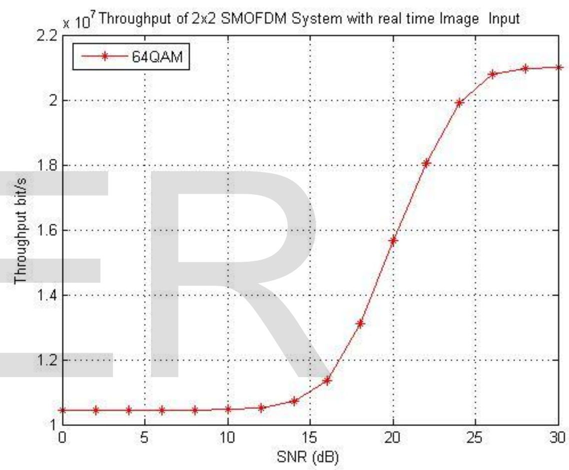

Figure 9: Throughput of SM-OFDM System

It can be established with this study that STBC-OFDM systems are capable to offer the best performance at low to medium values of SNR, due to its robustness in poor channel conditions. On the other hand, at high SNR the increased error-free data rate makes SM the best choice.

5 CONCLUSIONS

This study demonstrates that BER is significantly reduced in STBC-OFDM system in low to medium SNR region as compare to SM-OFDM system. Hence at low SNR, STBC-OFDM can be used for better performance. However at high SNR, SM-OFDM can provide not only double throughput but also minimal error rate. These results show that OFDM can be combined with STBC or SM systems based on channel conditions required in the particular applications. Besides throughput & BER, these models are also evaluated for the quality of the received images transmitted through both the models. It is reconfirmed from image output results that STBC-OFDM system generates no or very negligible noise in received image as compare to noticeable noise generated in image transmitted through SM-OFDM model. Further work may be needed in MIMO-OFDM hybrid models to understand power consumption pattern as well as design complexity of the receiver with respect to BER & throughput rate.

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