Performance Analysis of BER Using Efficient Coding and Interleaving Techniques in MIMO-OFDM System

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Abstract - Error free transmission is the main aim of wireless communication. However nowadays with the increase in multimedia services there is a demand for ever increasing data rates. To reduce the bit error rate forward error correction methods (FEC) methods are now employed. In this paper we compare the BER performance of 16-QAM and 64-QAM modulation techniques with and without interleaving process. Also further we analyze the performance of MIMO OFDM system using OSTBC coding technique and compare it with convolution coding.

Keywords - *MIMO- OFDM, Forward Error Correction (FEC), OSTBC Coding, Convolution Coding.*

1. Introduction

MULTIPLE-INPUT MULTIPLE-OUTPUT (MIMO) technology combined with orthogonal frequency-division multiplexing (OFDM) and channel coding, has recently attracted significant attention and is mainly used for high speed data communication[12]. MIMO offers high spectral efficiency through spatial multiplexing, OFDM is a multicarrier modulation technique which provides resilience against interference caused by multipath propagation, and coding combines the ability to exploit the diversity in a frequency-selective wideband MIMO channel with a straightforward approach to rate adaptation. Due to these significant advantages, the combination of these three technologies constitutes the basis for many next generation wireless communication systems.

Recently MIMO OFDM systems have been studied at various levels for consumer applications and other wireless systems. FEC is one of the important aspect of MIMO OFDM system. In this paper we analyze the performance using a combination of per antenna coding and cross antenna interleaving.

This paper evaluates the performance of 16- QAM and 64-QAM when interleaving process is performed. It is shown that Bit Error Rate (BER) is improved due to interleaving process. Also two encoders are used. The analysis has been performed using MATLAB for simulation and evaluation of BER for both modulation techniques and by using convolution encoder and OSTBC. The analysis shows that BER further reduces when OSTBC encoding is used for both modulation techniques.

We have divided this paper in different sections. Section II gives the system description with special emphasis on MIMO, OFDM and coding schemes. Section III shows the comparison of bit error rate (BER) with the help of various graphs. Section IV provides the future scope. Section V concludes this paper.

2. System Description

2.1 Multiple Input Multiple Output Systems

The key challenge faced by wireless communication systems is developing of very high speed wireless communication links that allow good quality-of-service (QOS) and coverage capability in non-line-of-sight (NLOS) environments. As we know that bandwidth spectrum is a limited source and propagation conditions are not suitable due to multipath component at receiving side and interference from other users, this requirement calls for means to genuinely enhance spectral efficiency and to improve link reliability. Multiple-input Multiple-output (MIMO) wireless technology achieve these demands by offering increased spectral efficiency through spatial multiplexing gain, and improved link reliability due to antenna diversity gain without additional bandwidth or increased transmit power.

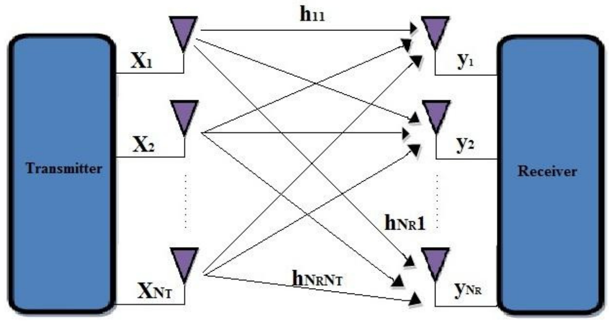

Fig. 1 MIMO- OFDM System.

MIMO system consists of three components, mainly transmitter, channel and receiver Transmitter sends a multiple data such as *x1, x2, x3… xN* say xi from different transmit antenna and signal is received by each receive antenna *(r1, r2, r3….rN say rj)* simultaneously. The relation between transmit data and receive data is given by [14]:

r1= h11 x1 + h12 x2+…+ h1N xN, (1)

r2= h21 x1 + h22 x2+…+ h2N xN, (2)

…

rN = hN1 x1 + hN2 x2+...+ hNN xN (N)

The MIMO signal model is described as r= Hx+n where r is Nr*1 received signal vector, H is Nr*Nt the channel matrix, x is Nt*1 transmitted vector and n is Nr*1 Gaussian noise vector. With Nt inputs and Nr outputs the channel can be expressed as Nr*Nt channel matrix H. By showing the channel in a matrix form, we can fully recover the transmitted data. The channel matrix can be represented as:

$$H = \begin{bmatrix} h_{11} & h_{12} & \cdots & h_{1N_t} \\ h_{21} & h_{22} & \cdots & h_{2N_t} \\ \vdots & \vdots & \ddots & \vdots \\ h_{N_r1} & h_{N_r2} & \cdots & h_{N_rN_t} \end{bmatrix}$$

where hij is the attenuation and phase shift between the jth transmitter and ith receiver. It is assumed the MIMO channel behaves in the quasi static manner [12].

2.2 Orthogonal Frequency Division Multiplexing

Orthogonal Frequency Division Multiplexing (OFDM) is a multicarrier transmission technique, which utilize the bandwidth available many carriers; each which is modulated by a low rate data stream. In term of multiple access technique, OFDM is similar to FDMA in that the multiple user access is achieved by subdividing the available bandwidth into multiple channels that are then allocated to users. However, OFDM uses the spectrum much more efficiently by spacing the channels much closer together [2]. This is achieved by making all the carriers orthogonal to one another, which prevent interference between the closely spaced carriers. This helps in reducing the spacing between carriers

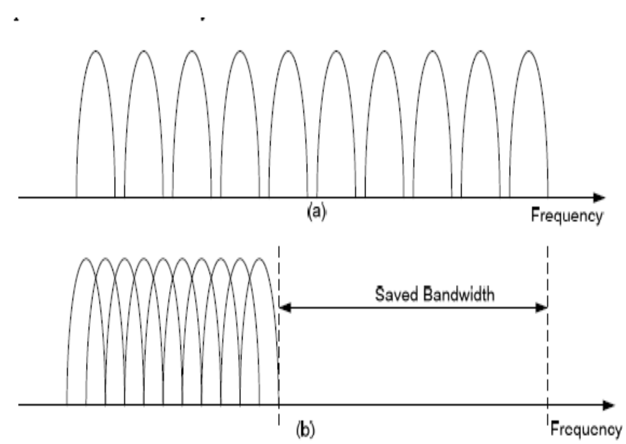

Fig. 2 Concept of OFDM Signal: (a) conventional multicarrier technique (FDM), and (b) orthogonal frequency division multiplexing technique.

The basic OFDM communication system's block diagram is shown in Figure 1. The forward error correction (FEC) blocks include convolution encoding, puncturing, and interleaving.

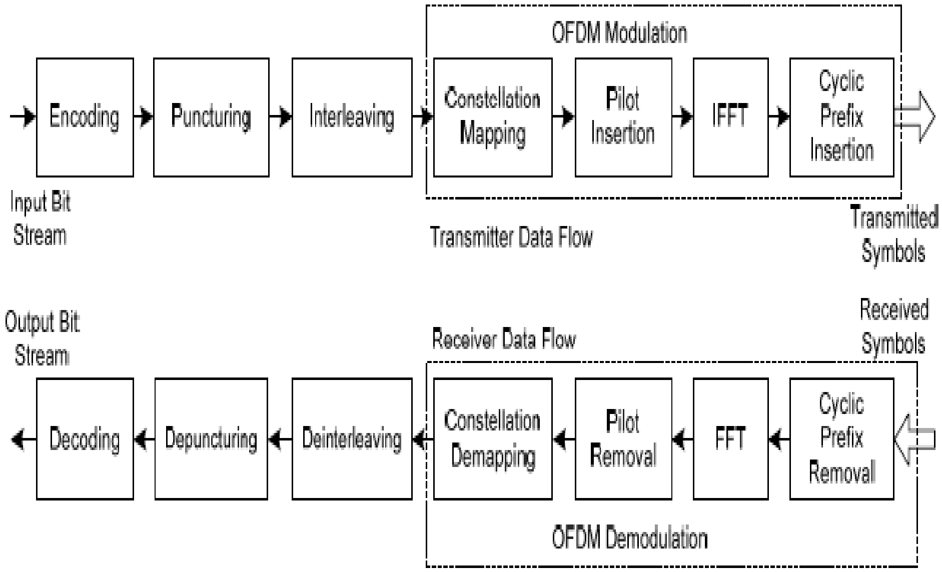

Fig. 3 Block Diagram OF OFDM [1].

3.2 Convolution Coding

Convolution coding technique implies various types of category. Orthogonal convolution coding, Super orthogonal convolution coding, Standard convolution coding, Punctured convolution coding are the basic categories of Convolution coding which generally applied on MIMO-OFDM. Encoder consist of two shift registers whose length is K in which parallel output of the first shift register are connected to second with a connecting block. Second shift register is heaving modulo 2 adder and the coder output formed by this shift register [15].

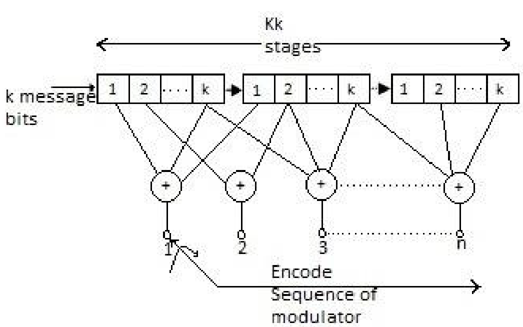

Fig. 4 Convolution Encoder

Where, k = number of bits shifted into the encoder at one time

n = number of encoder output bits corresponding to the k information bits

Code rate =k/n," The quantity k/n called the code rate, is a measure of the efficiency of the code.

3.3 Puncturing

To ensure high reliability, however, convolution codes tend to occupy a large bandwidth. This is due to the fact that convolution codes add redundancy to each transmitted bit, producing a code rate of smaller than 1. The larger number of redundancy bits added to each transmitted bit, the stronger the protection given to the said bit against transmission errors [14]. One way to reduce the occupied bandwidth is by using punctured convolution codes [1]. Puncturing is the process of deleting some parity bits from the codeword according to a puncturing matrix. Puncturing is the trade-off between rate and performance. Puncturing increases code rate without increasing complexity for code rate from 1/3 to ½ or more and decreases free distance of code. The redundant bits in coding decrease the bandwidth efficiency. The bandwidth efficiency decreases with increase in redundant bits in coding. The puncturing pattern adjust code rate to achieve system requirement, the puncturing pattern adjust code rate.

3.4 Interleaving

A primary technique which is effective in overcoming error bursts, is interleaving [1]. Interleaving is a standard signal processing technique used in a variety of communication system. The classical use for interleaving is to disperse sequences of bits in a bit stream so as to minimize the effect of burst errors introduced in transmission and the BER reduces at the output [11]. This has become an extremely useful technique for minimization of errors. The basic work done by an interleaver is that it rearranges the order of symbols to be transmitted following a particular rule and at the receiver the reverse rule can be used to restore the original sequence.

4. Simulation Results and Analysis

This paper analyses the bit error rate performance of Convolution and OSTBC code in AWGN channel using 16-QAM and 64-QAM as modulation schemes. Block interleaver and time interleaving process is used. There is a significant performance improvement of BER when inter leaving process is performed for both 16 QAM and 64 QAM modulation techniques.

4.1 BER Analysis of 16-QAM

In this section BER analysis of MIMO-OFDM system using Convolution code and OSTBC code structure is done for 16-QAM modulation over AWGN channel.

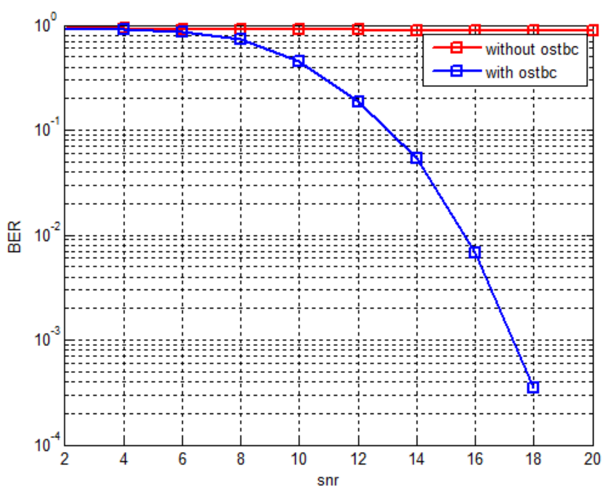

Fig. 5 BER Analysis of 16-QAM.

From above graph it was found that OSTBC coded system performs better as compared to convolutional coded system. BER for OSTBC 16-QAM is very less as compare to its neighbor techniques. Following table shows the comparative analysis of BER for both techniques at different SNR values.

Table 1: BER values for 16-QAM

SNR(dB) value	BER without OSTBC	BER with OSTBC
8	1	0.7
10	0.99	0.45
12	0.9	0.2

4.2 BER Analysis of 64-QAM

In this section BER analysis of MIMO-OFDM system using Convolutional code and OSTBC code structure is done for QPSK Modulations over AWGN channel.

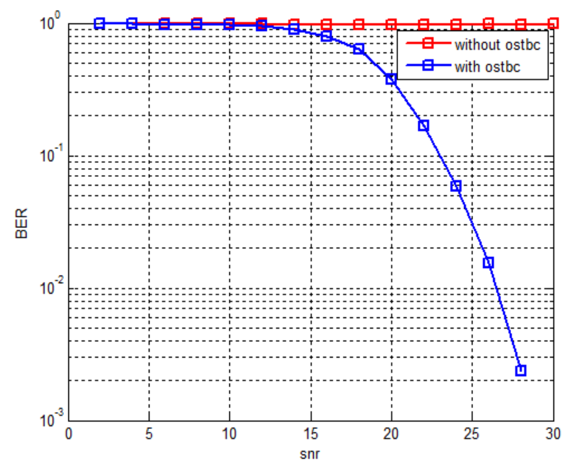

Fig. 6 BER Analysis of 64-QAM

Following table shows the comparative analysis of BER for both techniques at different SNR values.

Table 2: BER values for 64-QAM

SNR(dB) value	BER without OSTBC	BER with OSTBC
10	1	0.9
15	1	0.8
20	1.1	0.35

4.3 BER Analysis of 16- QAM with Interleaving

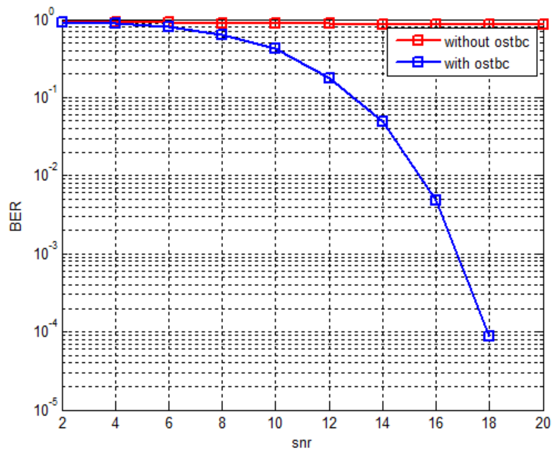

Fig. 7 BER Analysis of 16-QAM with interleaving.

From the above graph it is observed that the 16-QAM system performs better when interleaving is performed for both types of coders.

4.4 BER Analysis of 64-QAM with interleaving

From the graph below it is observed that the 64-QAM system performs better when interleaving is performed for both types of coders.

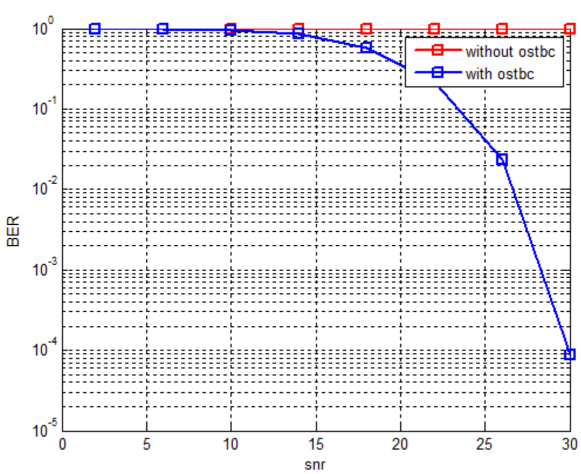

Fig. 8 BER Analysis of 64-QAM with interleaving.

5. Conclusion

In this paper we compare the performance of MIMO-OFDM system in terms of BER using Forward Error Correction codes on AWGN channel. Here Convolutional codes are used as FEC codes. We evaluate Bit Error Rate of convolutional codes for 16-QAM and 64-QAM modulation schemes and compare them with OSTBC code. Results show that BER performance is improved when OSTBC coder is used. Also BER performance is further enhanced when interleaving is performed for both the modulation techniques.

6. Future Scope

The work presented in this paper, i.e. the BER performance of 16-QAM and 64-QAM for MIMO-OFDM system can be extended to other modulation techniques like BPSK, QPSK, DPSK etc. The results drawn from this paper can also be extended to include other types of error correcting codes like Reed-Solomon codes, BCH codes.

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