SM High Data Rate Transmission over Multipath Channel Using MIMO with LDPC

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Abstract-- **The most important type of Multiple Input Multiple Output (MIMO) is the Spatial Multiplexing (SM) which is used to increase the data rate depending on the number of transmitted and received antennas. The main challenge of SM is high Bit Error Rate (BER) at low Signal to Noise Ratio (SNR), which leads to increase the power expended. In this paper, the performance of MIMO system for Space Time Block Code (STBC) and SM has been investigated. We expected that the STBC increase the reliability of data rate but it can't increase the data rate, while SM increase the data rate with significant BER. The proposal of this research is to add effective channel code to reduce the BER in SM to achieve reliable data rate with the exploitation of SM potential to increase the speed of data. Low density Parity Check (LDPC) is become an effectiveness type of channel coding to improve the performance of wireless system in multipath environments. To avoid the higher complexity stem from adding such code, this research is attempt to design a special matrix to get better performance with acceptable complexity for MIMO system. A simulation model will be designed using Matlab Package to apply the proposed model to show its performance compared with other system. The expectancy that such system will present better performance can be applied in modern wireless communications in multipath environments. The results confirm that the proposed system gives better performance with acceptable complexity. It achieves 10^{-4} Bit Error Rate (BER) at 7dB of Signal to Noise Ratio (SNR).**

Keywords- component; MIMO; SM; STBC; LDPC

I. INTRODUCTION

In wireless communications, to obtain high data rate at an acceptable bit error rate, large bandwidth or/and high transmit power are required. Also higher transmitted power level is required to combat severe fading channel conditions. MIMO communication system is used to provide increased capacity and reliability without increasing the bandwidth or transmitted power [1].STBC is an efficient transmit diversity used to combat disadvantageous effects of wireless fading channels because of its simple decoding and achieving full diversity at a radio receiver. A transmit diversity technique using STBC is an important technique for future wireless systems, since it can provide high diversity gain by exploiting the multi-path environment without needing additional bandwidth [2].

In SM, a high data rate signal is divided into multiple low rate data streams and each stream is transmitted from a different transmitting antenna. These signals arrive at the receiver antenna array with different spatial signatures, the receiver can separate these streams into parallel channels thus enhancing the capacity. Thus SM is a very powerful technique for increasing channel capacity at SNR values [3].

Low-density parity-check (LDPC) codes are block codes, which introduced by Gallage [4] in 1962. Because of its very good error correcting performance close to the Shannon limit, it has been widely studied and became part of various standards in the recent years [5]. Many researcher was apply various method to improve the BER of SM in order to achieve reliable high data rate. In [6], they proposed an algorithm called expectation propagation to get low complexity Gaussian that approximate the posterior to solve the problem of marginalization. They used such technique in LDPC to improve its performance. Reference [7] used LDPC code with OFDM- MIMO system in extremely noisy channel to improve the poor signal reception channel.

This research attempt to design an efficient LDPC decoder for 2×2 MIMO system that can address the high BFR problem and evaluate the performance without such code to show the amount of code gain taking into account the information redundancy that added by LDPC.

II. MUTIPLE INPUT MULTIPLE OUTPUT SYSTEM

MIMO systems consist of multiple antennas in both transmit and receive ends to divide the channel into many parallel sub-channel in order to address the multipath scattering environment by creating independent propagation channels. Fig. 1 shows the propagation channel that improves the channel capacities over the same bandwidth in rich scattering. The design of MIMO systems has been conventionally posed on two different perspectives: either the increase of the capacity through SM or the enhancement of the system reliability through the increased diversity of antenna. In fact, the capacity and the reliability can be simultaneously got subject to a primal tradeoff between the two [8]. MIMO technique offer a diversity gain which is defined as the negative of the slope of the logarithm of the bit error rate (BER) versus the logarithm of the SNR curve and expressed by [9]:

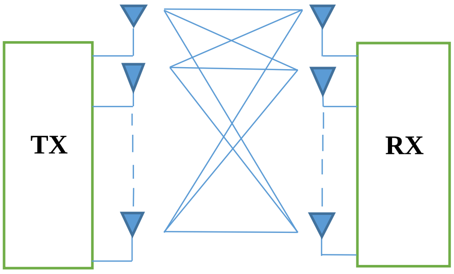

Figure 1: MIMO system

$$d = -\lim_{SNR \to \infty} \frac{\log(P_e(SNR))}{\log(SNR)} \qquad (1)$$

where, P_e is the probability of error.

A. Channel Capacity

The capacity is given by the celebrated Shannon formula [10]:

$$C = B \log_2(1 + SNR) \qquad (2)$$

Where B, is the channel bandwidth.

Conceptually, multiple data streams can be obtained from the MIMO systems to be transmitted simultaneously at the same frequency; hence the number of data streams employed increasing the bandwidth efficiency. The capacity, of MIMO system, can be determine by [11]:

$$C = \log_2\left(det\left(I + \frac{SNR}{n_T} HH^+\right)\right) \qquad (3)$$

where, $\det(.)$ is determinant, I is the identity matrix, $n_T$is the number of transmit antenna, H is the channel matrix and the superscript $+$ denotes transpose conjugate.

In the received side, if the decoder of STBC is used, the equivalent channel capacity is defined by [12]:

$$C_{STBC} = \left[BR \log_2 det\left(I_r + \frac{SNR}{Rn_T} HH^+\right)\right] \qquad (4)$$

where, R is the code rate and n_T is the number of received antenna.

B. Spatial Multiplexing

SM is a transmission technique in MIMO wireless communication system, in SM the space dimension is reused or multiplexed more than one time or SM is used to transmit independent and separately encoded data signals from each of the multiple transmit antennas, called as streams. For the same bandwidth and with no additional power disbursal SM gives a linear (in the number of transmit-receive antenna pairs or min (n_T, n_R)) increase in the channel capacity [3, 13].

There are many detection techniques available with SM system such as Zero Forcing (ZF), Minimum Mean Square Error (MMSE) and Maximum likelihood (ML). In this paper it has been employed the ZF for low complexity but it is suffer from poor performance, so that the proposed system in this work is to add effective channel code to support the performance of such system and reduce the BER and maintain acceptable complexity.

C. Zero Forcing Detection

It is a technique that apply the invers response of the channel to the received signal. ZF technique nullifies the interference by [3]:

$$W_{ZF} = (H^H H)^{-1} H^H \qquad (5)$$

Where $(\,.\,)^H$ denotes the Hermitian transpose operation. All transmitted signals except for the desired stream from the target transmit antenna, linear signal detection method treats it as interferences. Therefore, to detect the desired signal from the target transmit antenna interference signals from other transmit antennas are minimized or nullified.

III. LOW DENSITY PARTY CHECK CODE

LDPC codes are a class of linear block codes, because the characteristics of parity-check matrix of these codes which contains only a few non-zero elements in comparison to the number of zero elements, the name of LDPC codes comes from their parity-check matrix [14]. LDPC parameters defined the (Z, M, h) matrix as Z columns, h number of ones in each row and M number ones in each column. The code rate is defined as [15]

$$R = 1 - M/h \qquad (6)$$

There are two methods for LDPC decoding hard decision and soft decision. For simplicity hard decision is employed in this paper. More detail about this code is in [16].

IV. SYSTEM MODEL

The proposed system model is shown in Fig. 2. In this paper, it has been proposed to insert the LDPC code with SM to support its performance. Number of iterations in LDPC decoder play significant role to reduce the BER by increasing the reliable decision of iteration. This leads to more delay time that makes this system unsuitable for real time applications. To reduce the number of iterations of LDPC decoder, special parity check matrix size is designed with (261×522) , three 1s in each row, six 1s in each column and 1/2 code rate is used. Binary Phase Shift Keying (BPSK) is used as better type of modulation that can reduce the noise.

The LDPC encoder adds the redundancy bits to the data by using some constraints according to the data. The parity check matrix of an LDPC code comprises z bit nodes and f check nodes. The decoding process of LDPC decoder is used the message passing algorithm. Iteration is applied between bit nodes and check nodes to compute the message by rounding each value of message passing from each bit node to all adjacent bit nodes. Another round of information passing from each check node to all adjacent bit nodes.

The iteration is included each demodulator in addition to decoder. So that soft decision demodulator is used in order to complete the demodulation within iteration. Two types of iterations in this scheme; the first one is between decoder and detector, and the second is within the decoder itself.

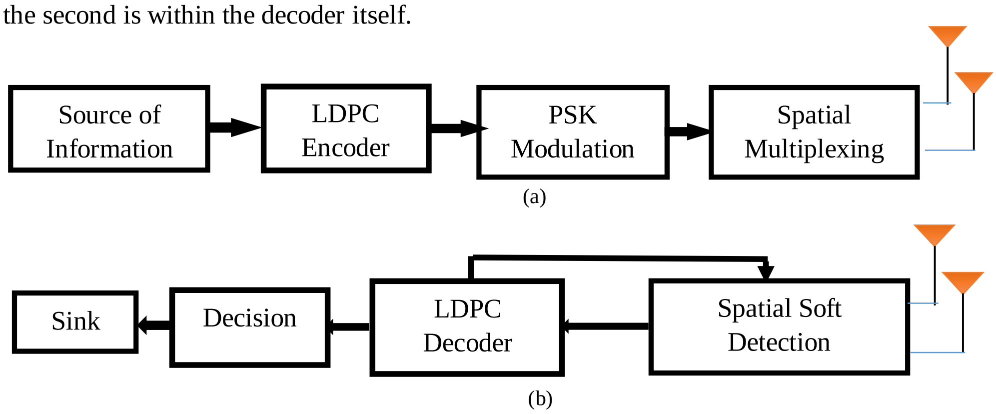

Figure 2. Block diagram of system model; (a) Transmitter, (b) Receiver

V. SIMULATION AND RESULTS

The simulations are applied using Matlab R2014b Package. The BER is used as a tool to measure the performance of the system and taking into account the cost as a complexity in contrast to each investigated gain. The number of antennas are used her in all steps are 2×2 for simplicity and to increase the speed of simulation.

A. STBC versus SM

The first step is compare between STBC and SM in the term of BER and measure the amount of gain between them. It clear from Fig. 3 that the STBC is outperform SM by more than 15dB at BER of 10^{-4} because the first one used its code to robust the SNR without any increasing in the data rate. In contrast the decoder of SM uses ZF decoder which is poor in low SNR but it is doubled bit rate here with 2×2 MIMO system, so that the gain here for SM are low complexity with high data rate but STB achieve better BER in low SNR.

Also a simulation is done in this subsection to show the comparison in term of data rate. Fig. 4 clear out that the data rate of SM having linear relation with SNR while the data rate of STBC is near to Single Input Single Output (SISO) through all values of SNR.

A. The Results of Proposed Scheme

The previous results confirm that SM is useful for high data rate but the problem is that the BER is high, so that

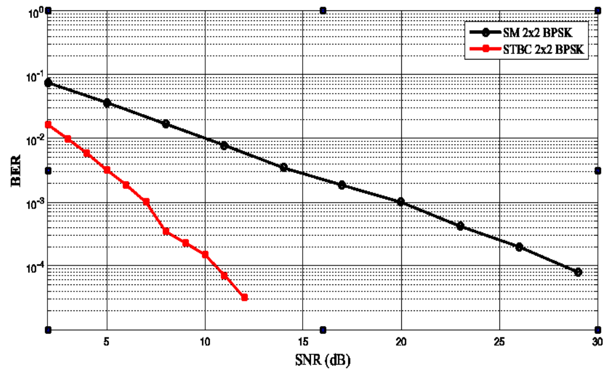

Figure 3. Comparison between STBC and SM

this research proposed to insert an active channel code LDPC to support the performance of SM. Such code will add a redundancies information which may leads to reduce the original data rate but it can be overcomes by increasing the number of transmitted and received antennas. On the other hand a special matrix of such code is designed to improve the performance of LDPC code to achieve low BER with less number of iteration not exceed 5. Also it can be said that the complexity is in acceptable range by using ZF decoder for SM which is the least complex.

Fig. 5 shows the results of the system with LDPC code as compared with SM without such code. It is clear that the code add large improvement to the system which indicate that the redundancy add by code such can be overcomes by large amount of code gain which is about 15 dB.

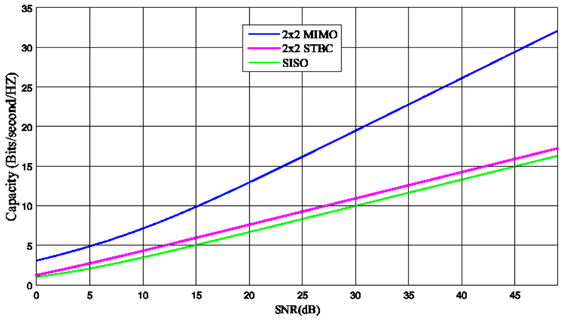

Figure 4. Data rate Versus SNR

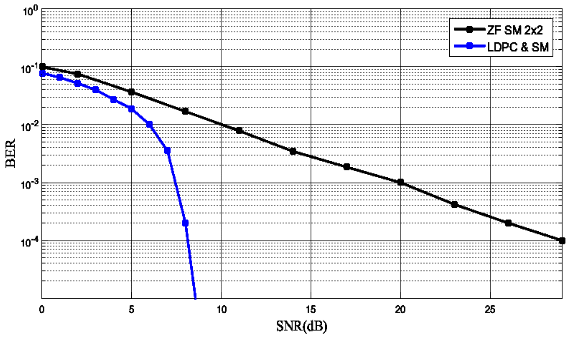

Figure 5. The results of proposed scheme

VI. CONCLUSSIONS

In this paper, it has been proposed a scheme of MIMO system to exploit the SM capabilities to increase the data rate. In order to address its week point which is the high BER, LDPC with special design of parity check matrix is added to the system to get better performance with only 5 iterations. The features of proposed scheme is acceptable complexity with ZF decoder for SM and good BER that achieves 10^{-4} at 7dB of SNR which represent in our view good results for modern wireless communications. In addition the less iteration of LDPC decoder is acceptable for real time applications.

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