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FEASIBILITY OF LOG-DOMAIN TECHNIQUE FOR HIGH PERFORMANCE LDPC DECODING CONCATENATED WITH STBC

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ABSTRACT

An approach concerned with low-density parity-check (LDPC) codes that have high performance decoding capability. With help of Alamouti STBC (space time block codes) which is concatenated with LDPC, it has been deduced that, the so constructed model has better performance than the existing in terms of Bit Error Rate (BER). A soft decision based decoding algorithm shows best performance than other decoding algorithms. Thus, for better performance Log-domain decoding of LDPC codes is implemented.

Keywords: MIMO, LDPC, alamouti STBC (Space Time Block Codes).

1. INTRODUCTION

Exchanging information across space and time with the help of natural or technical means is called communication. Recently, several technologies have been developed to achieve efficient and reliable communication system. The design should have high throughput and provide effective data transmission with minimum error rate. One such technique is Low Density Parity Check (LDPC) codes invented by Robert Gallager [1].

LDPC codes are utilized in optical communication and in satellite based digital video broadcasting. The standard of 802.11n adopts LDPC as an optional coding scheme [2].

STBC (Space Time Block Codes) are used for implementing diversity in MIMO systems. Thus we have concatenated STBC codes with LDPC to achieve high performance. For low complexity decoding, log-domain decoding technique is used which contains messages in the form of Log likelihood ratios (LLR).

2. FORWARD ERROR CORRECTION USING LDPC

A. Introduction to forward error correction

Without the need for retransmitting the data stream, limited number of errors can be corrected using Forward error correction (FEC) codes. There are two types of FEC codes, block codes and convolution codes. The main advantage of using FEC is that sometimes no feedback channel is necessary and also, avoids multicast problems. LDPC codes are linear block the term "low density" refers to fewer 1's in parity check matrix. At present LDPC codes are the best error correcting codes that achieves capacity near Shannon's limit.

B. Implementation of LDPC

In a forward error correcting technique the message bits are augmented with extra bits to generate the codeword for the message which has to be transmitted. The simplest coding method is single parity check codes (SPC). Inversion of single bit due to channel noise can be detected using SPC codes. But, multiple bit inversion which may satisfy the constraint and goes undetected by this method. Hence, detecting more than a single bit error needs additional parity bits and multiple parity-check equations.

Thus, if a code c is transmitted in a noisy channel and code z is obtained at the receiving end then z is a valid code word of the code with parity-check matrix H if and only if it satisfies the matrix multiplication, $H.z'=0$. Were, H is the parity-check matrix of size (m*n) for the code c with m parity check constraints and codeword length n. z' is the transpose of the received code.

The decoding complexity and minimum distance increases linearly with the code length due to the sparseness of LDPC codes. The only difference between other block codes and LDPC codes is that the sparseness of the H matrix or parity matrix. LDPC codes differ from classical block codes in its decoding algorithm. Maximum likelihood decoding was adopted for classical block codes but iterative decoding is adopted for LDPC codes.

3. MULTIPLE INPUT MULTIPLE OUTPUT SYSTEM

In a wireless fading channel, reliable communication can be obtained by exploiting the spatial diversity [8]. In a Multiple Input Multiple Output (MIMO) system as the name suggests, there are multiple antennas at both transmitter and receiver side. This type of modelling has many advantages in terms of capacity, bit rate and reliability when compared to Single Input Single Output (SISO) system. There are three types of MIMO systems, spatial multiplexing, spatial diversity, and Beam forming. Data or message is sub-divided into streams in a Spatial multiplexing system. This technique provides higher data rate but less system performance in terms of Bit-rate. Spatial diversity is the techniques in which multiple copies of the same signal is received through different antenna. Thus, even if one signal undergoes deep fading, others may have strong signal. Thus, by combining all the received signals, we can extract maximum amount of data in spite of fading.

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In Time diversity, the copies of signal that is to be transmitted are provided across time. Whereas, in space diversity which is also called as antenna diversity the copies of data that is to be transmitted is sent through different antennas. If both Space and Time diversity are applied the resultant will be space-time codes. Space time coding is divided into STTC (Space Time Trellis Code) and STBC (Space Time Block Codes). STTC provide both diversity and coding gain. They have good decoding capability. But, as the complexity increases exponentially with transmission rate and diversity level Alamouti found the STBC codes [3]. Alamouti STBC is simple in its structure with two transmit antenna and N_k receive antennas and maximum diversity order is about $2N_k$. STBC finds its usage in CDMA 2000 and W-CDMA standards.

4. MIMO SYSTEM MODELED WITH STBC

A. System model

We have considered a two transmitter two receiver system model as shown in Figure-1. In an LDPC encoder, the message bits are converted into codeword c, by matrix multiplication of the message vector u with the generator matrix G,

$c = uG.$

The modulation technique used here is BPSK and QASK and their performance are compared in terms of BER. After modulation, the Alamouti STBC shown in Figure-2, is used which is the diversity technique that reduces fading effects. STBC are orthogonal and it's full transmit diversity is determined by number of transmit antennas [5]. Thus, the signal is now ready for transmission and is transmitted in a Rayleigh fading channel as illustrated in Figure-3. Tx 1, transmits [x1 -x2*] at time t and at t+T respectively, and Tx 2, transmits[x2 x1*] at time t and at t+T respectively. Finally the received signals are combined linearly by performing maximum likelihood detection. The demodulation of the signal is performed and later LDPC decoder employs log-domain decoding to decode the message. The structure of parity check matrix and decoding algorithm decides the performance of the LDPC codes [6].

B. Algorithm of Log-Domain decoding

The log-domain decoding is a soft decoding algorithm. Softdecoding was introduced in [7]. The steps involved in decoding are given below.

Step-1: The LLR value of the received symbol Ri is initialized to the corresponding variable nodes L(vi) and associate these L(vi) values with nonzero elements of parity check matrix H. LLR value of input bit Ri is given by,

$$L(vi) = \log\left[\frac{\Pr[vi=0]}{\Pr[vi=1]}\right] \qquad (1)$$

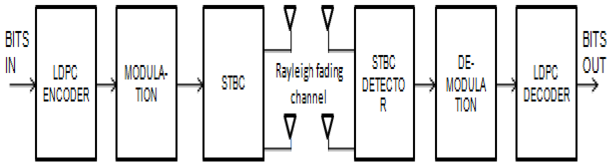

Figure-1. Block diagram of MIMO system modeled with Almouti STBC.

Step-2: Variable node is updated.
Step-3: Check node is updated.
Step-4: Decision loop is executed, if the parity check is satisfied the iterations are stopped, else executed again from step-2.

Thus, finally the original message is obtained after all these processes.

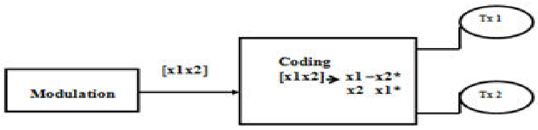

Figure-2. Alamouti STBC principle diagram.

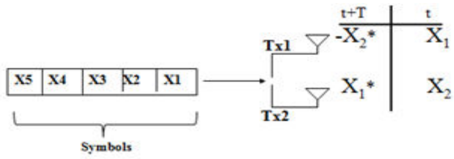

Figure-3. Transmission of Alamouti codes.

5. SIMULATION RESULTS

The Figure-4(a) plotted between BER and SNR, uses QASK modulation technique and Figure-4(b) uses BPSK for a two transmitter and two receiver MIMO system. It shows that the system with STBC has got a reduced bit error rate thus, high performance than system designed without STBC. Space time block codes help in reducing the fading of signals thus, its clearly seen from simulation results that the bit error rate reduces when STBC is implemented in a MIMO system. When there is reduced error in the received bits obviously decoding performance increases.

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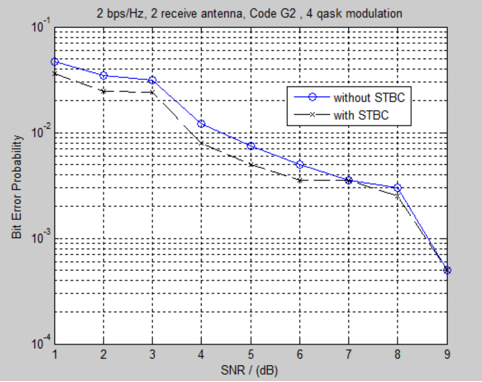

Fig.4(a)

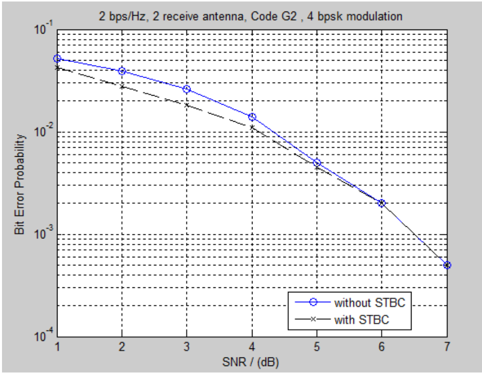

Fig.4(b)

Figure-4. BER comparison between system using STBC and system without using STBC for (a) QASK modulation (b) BPSK modulation.

The Figure-5(a) uses QASK modulation technique and plots the graph between SER (Symbol error rate) and SNR (Signal to noise ratio) similarly Figure-5(b) shows the plot for BPSK modulation. Thus, the graph shows that the system with STBC has got a reduced symbol error rate so, high performance than system without STBC. In a BPSK modulation there is one bit per symbol. One bit is mapped into one symbol they 0 and 1. Both symbol error rate and bit error rate are same in case of BPSK because there is one single bit per symbol. But in case of QASK two bits are associated with one symbol so,SER is not the same as BER in QASK modulation.

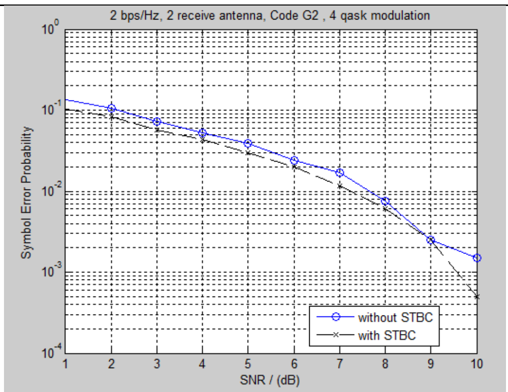

Fig.5(a)

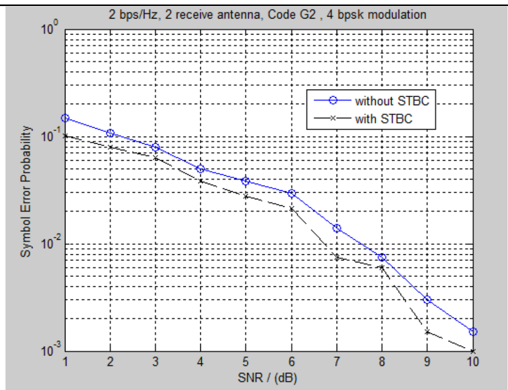

Fig.5(b)

Figure-5. BER comparison between system using STBC and system without using STBC for (a) QASK modulation (b) BPSK modulation.

6. CONCLUSIONS

Thus, we have implemented error correction in digital communication system using LDPC codes concatenated with STBC codes. For reducing the complexity of decoding, Log-domain decoding is used. Space Time Block Coding has been provided by using Alamouti STBC. The Alamouti scheme has been simulated for BPSK and QPSK modulation and BER performances are compared. This proves that the system modeled with STBC has better BER than without STBC.

The SER (Symbol error rate) comparison also proves the same. A particular application decides which modulation can be employed. Thus, as a future scope of the project other modulation techniques can be compared and different decoding algorithms can be employed.

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