Improvement the Performance of MIMO Channel Employing Concatenation (BCH –STBC ) Codes.

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Abstract. Wireless communication system has been matured as a key technique to realize high data rates, more handling power, and optimizing 5G applications to increase users rapidly. Due to the issues of fading, it is difficult to obtain high data rates and maximum capacity. Different coding schemes have been implemented to contend the effect of fading. Multiple – input multiple-output (MIMO) technology remains robust technology besides channel coding. Here in this research paper, concentrate on employing the available resources in the wireless communication system to enhance the performance of the MIMO system when concatenated STBC code with forward error correction (FEC ) code, such as (BCH) code without additional power or further bandwidth. The outcomes show the coding technique gives better improvement in the BER and obtain good coding gain when using BCH(31,16)-STBC, BCH(127,106)-STBC the coding gain is about 5.8 dB,3.7 dB consecutively under AWGN channel and improved by 13.25 dB, 9 dB successively under Rayleigh fading channel at BER about 10⁻³, when compared with uncoded system. Additionally, this research manifests that the proposed model gives the improvement in BER performance about (5% to 86% )over AWGN channel and (6% to 100%) over Rayleigh fading channel when compared with the uncoded system.

Keywords: MIMO; BCH code; BER; STBC Code; Coding gain.

1. Introduction
Recently, due to the always rising request for reliable and effective digital transmission, and increment requests for criteria like BER, quality of service, and the number of users for communication service [1]. Modern methods have manifested to provide enormous communications requests within restrictions of limited transmit power and bandwidth, which in turn do not permit to improve all services. so, an Appropriate strategy to this challenge must be discovered.

In wireless telecommunications, MIMO is a remarkable technology that multiplies the capacity of a telecommunication system when more than one send and receive antennas are obtainable to employ the properties of multipath propagation and one of the best research areas in telecommunications because of the key interest of the MIMO system is increased high data rates achieved via spatial multiplexing and reliability achieved via diversity [2]. This technology has been employed today to improve 5G networks[3]. Intensive research effort has shown on the MIMO system motivated by his different works of Foschini and Telatar[4]. Coding techniques can be employed to save communication reliability in the existence of interference and keep data from intentional interference in military applications. Space-time block code (STBC) is an effectively transmit diversity employed to contend drawback effects of fading in wireless channels due to its easy decoding and realizing full diversity and highest throughput [5], these coding system when concatenated with an outer code generally provide coding gain to enhance the BER of system.
In this respect, different research has been done on the concatenation of FEC and STBC that attempt to get a perfect combination with low complexity and maximum coding gain with high error correction. In 2000 T. H. Liew [6] presented a study of various schemes of concatenated STBC and channel coding such as Convolutional Code and turbo trellis coded modulation. The outcomes showed the concatenation (Turbo- STBC) achieved better coding gain with acceptable complexity. In 2013 Shengmei Zhao [7] presented a study the concatenation scheme of polar codes and STBC codes, this concatenation is called (Polar-STBC) codes, the outcomes showed this concatenation give significant enhancement the BER performance of MIMO system as when compared with the system of STBC only and achieved coding gain about 5dB at BER(10^-3) and when incrementing the length of Polar codes, the BER performance of (polar – STBC) is as well improved too. 

In 2015, Elies Ghayoula [8] introduced a study the concatenation of low-density parity-check (LDPC code) to STBC, the outcomes showed these concatenation improvements the performance of MIMO system and achieved coding gain about 9 dB at BER(2*10^-4) as when compares with uncoded STBC. In this research paper study, the performance MIMO system when concatenated STBC code with forward error correction (FEC) code such as (BCH) code and this concatenation is called (BCH – STBC) codes with Bpsk modulation under adaptive white Gaussian noise (AWGN) and Rayleigh fading channel. 

The residue of this paper is organized as follows. In section II, Description of forward error correction code. In section III, the proposed model of concatenation (BCH-STBC) codes over MIMO system. In section IV, Simulation results were described. And eventually in section V, conclusions.

1.1 Motivation.
The main goal in developing communication systems is to achieve a higher data rate with a limitation on available bandwidth. Also, to achieve reliable data transmission for the power efficiency having the lowest error probability (bit error rate) represent another target. STBC codes are desirable as they ensure maximum diversity gain and maximum throughput. It is an efficient transmission method employing multiple transmitting antennas, and these codes have a simple decoding algorithm that is based only on linear processing. But these codes will not offer coding gain. Except if concatenated with an outer code. BCH codes are a powerful category of cyclic codes with the ability to correct multiple errors and well-defined mathematical features. We attempted to accomplish the coding gain advantages with enhancement in a BER by employing the concatenation BCH codes with STBC code over MIMO system.

1.2 Contributions of research work.
The research paper is dedicated to studying the effect of coding technique employing concatenation BCH codes with STBC over Binary shift keying (Bpsk) modulation. The demonstrated contribution as follows.

- Study and evaluated the effect of space-time block code (Alamouti) over the MIMO system.
- The main contribution studies the effect of BCH codes when concatenation with STBC over MIMO system and exploited the advantage of error correction capability in BCH codes to improve bit error rate, coding gain, and the performance of the system.
- Evaluated System performance for the wireless communication for data transmission with 2x2 MIMO channel in AWGN channel and Rayleigh fading channel.

2. Description of Forward Error Correction Code.
Forward error correction (FEC) codes can be regarded as a type of time diversity [9]. To exploitation of FEC demand either reduce transmission rate or increment the bandwidth of the channel. Requires FEC techniques for high error correction and higher bandwidth, for achieving reliability and high transmission rate. Nevertheless, the big problem for communication represents bandwidth. For this reason, it’s not a prudent decree to increment the bandwidth. As well the FEC technique added some redundancy to the data, which help the receiver to detect and correct errors. BCH is FEC techniques that operate by adding further data at the ending every message, which is called a codeword. In this part, some preparatory classifications are presented of BCH.
2.1. **BCH Codes.**

These codes are discovered by (Bose - RayChaudhuri- Hocquenghem) [10]. It is named after their discoverer BCH code, which is a new subclass of cyclic error-correcting code. Code words are constructed by division m(x) polynomials over finite field representing the data (binary data) by a generator polynomial g(x) and given the remainder, which will be described as parity check bits r(x) [11]. These codes have a rigorous algebraic structure, and features are determined by the selected polynomial generator g(x) [12]. One of the most important features of this code is easy to be encoded and simple to be decoded. Compared with modernistic coding techniques like LDPC and turbo codes, the decoder of the BCH code is low complexity and accurate error control over the number of symbol errors [13]. Furthermore benefit is that the BCH code was able to detect and correct errors reach almost 25% [2]. Its possible code for BCH code with integer m and t demonstrative the table 1 [11].

*Table 1. Properties of the BCH code.*

| Type                      | Linear block code |
|---------------------------|-------------------|
| Alphabet Size             | 2                 |
| Parameter (n, k, d)       | (n, k, d)         |
| Number of corrected error (t) | t where t< 2^m - 1 |
| Block length (n)          | 2^m - 1           |
| Massage length (k)        | k                 |
| Code rate (R)             | k/n               |
| Distance (d)              | d                 |

3. **The Proposed Model of concatenation (BCH – STBC) Codes Over MIMO System.**

This section illustrates the proposed model of concatenation (BCH-STBC) codes over MIMO system. Depending on the MIMO system with two sending and receiving antennas. The BCH code and orthogonal STBC system model is illustrated in figure 1.

![Proposed model of concatenation (BCH-STBC) codes over MIMO system.](image)

**Figure 1.** Proposed model of concatenation (BCH-STBC) codes over MIMO system.

The data bit (binary data) encoded by BCH encoder block, and the code words n bit is modulation in the modulated block (Bpsk is employed for modulation) to the transmitted symbol that will be s to STBC encoder later. In the resultant STBC code matrix, the data is sent via the antenna of transmitting. In the receiving part, the data from the obtained multiple antennas is estimated by channel estimation and merge by combined of a signal. The maximum likelihood decoding algorithm is used to demodulate the STBC merger signal. Eventually, decoded the data by the BCH decoder.

In the proposed system model, the STBC code (Alamouti) offers spatial diversity in the form of MIMO systems to ensure safe wireless communication at the high data rate. STBC must be employed to assure orthogonality at the receiver, the received signal is shown:

\[
\begin{bmatrix}
y_{11} \\
y_{12} \\
y_{21} \\
y_{22}
\end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\
h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} s_1 \\
s_2 \end{bmatrix} + \begin{bmatrix} N_{11} \\
N_{12} \\
N_{21} \\
N_{22} \end{bmatrix}
\]  

(1)

Where

- \(s_1, s_2\) : are the data transmitted.
- \(y_{11}, y_{12}\) : are data received for the 1st-time slot.
- \(y_{21}, y_{22}\) : are data received for the 2nd-time slot.
( * ) : refers to conjugate.

\( h_{11}, h_{12}, h_{21}, h_{22} \) : are Rayleigh channel.

\( N_{11}, N_{12}, N_{21}, N_{22} \) : are adaptive white Gaussian noise.

\[
y_{11} = s_1 h_{11} + s_2 h_{12} + N_{11} \tag{2}
\]

\[
y_{12} = -s_2^* h_{11} + s_1^* h_{12} + N_{12} \tag{3}
\]

\[
y_{21} = s_1 h_{21} + s_2 h_{22} + N_{21} \tag{4}
\]

\[
y_{22} = -s_2^* h_{21} + s_1^* h_{22} + N_{22} \tag{5}
\]

Assume

\[
k = |h_{11}|^2 + |h_{12}|^2 + |h_{21}|^2 + |h_{22}|^2 \tag{6}
\]

After the STBC decoder, Therefore, the data transmitted at the receiver with channel effect and noise.

\[
\tilde{s}_1 = \frac{1}{k} \left[ h_{11}^* y_{11} + h_{12} y_{12} + h_{12}^* y_{21} + h_{22} y_{22} \right] \tag{7}
\]

\[
\tilde{s}_2 = \frac{1}{k} \left[ h_{12}^* y_{11} - h_{12} y_{12} + h_{22}^* y_{21} + h_{22} y_{22} \right] \tag{8}
\]

4. Simulation Results

In this section, we concentrate on the performance of BER on the proposed (BCH-STBC) system model. In this contribution, the research discusses the BER performance of the suggested concatenated scheme under various types of channels and various lengths of BCH code. The essential parameters of the simulation are illustrated in Table 2.

| No | Parameter | Details |
|----|-----------|---------|
| 1  | BCH code  | Block length(n) | 31 31 127 127 |
|    |           | Massage length (k) | 26 21 16 120 113 106 |
|    |           | Number of corrected error (t) | 1 2 3 1 2 3 |
| 2  | Modulation type | Binary phase-shift keying (Bpsk) modulation |
| 3  | Type of channels | Adaptive white Gaussian noise (AWGN) channel Rayleigh fading channel |
| 4  | Number of transmitting and receiving antenna over MIMO system | 2*2 |

Figures (2,3), and figures (4,5) are demonstrated the comparison of a BER performance of 2*2 MIMO with (BCH-STBC) codes with various lengths of BCH codes over AWGN channel and Rayleigh fading channel respectively. BCH (31,26), and BCH(127,120) codes having the capability to correct one error (t=1) and when concatenated with STBC codes over MIMO system, acquired improvement in coding gain over AWGN channel at BER (10e-3) approximately 2.55 dB, 1.25 dB successively compared with uncoded system. whereas is enhanced by 6.94 dB, 3.86 dB successively over Rayleigh fading channel.

Furthermore, the outcomes demonstrated that the coding gain is better when using BCH(31,21) and BCH(127,113) having the capability to correct two errors (t=2). The improvement in coding gains
approximately 4.37 dB, 2.62 dB consecutively over AWGN channel at BER (10^{-3}) compared with the uncoded system, whereas it is enhanced about 10.78 dB, 6.97 dB consecutively over Rayleigh fading channel.

In another case, when using BCH(31,16), and BCH(127,106) codes having the capability to correct three errors (t=3) acquired more improvement in coding gain approximately 5.8 dB, 3.7 dB consecutively over AWGN channel at BER (10^{-3}) compared with the uncoded system whereas is enhanced about 13.25 dB, 9 dB consecutively over Rayleigh fading channel.

Figure 2. Comparison of BER performance with (BCH -STBC) system with various length of BCH codes over AWGN channel.

Figure 3. Comparison of BER performance with (BCH -STBC) system with various length of BCH codes over Rayleigh fading channel.
Figure 4. Comparison of BER performance with (BCH-STBC) system with various length of BCH codes over Rayleigh fading channel.

![Figure 4. Comparison of BER performance with (BCH-STBC) system with various length of BCH codes over Rayleigh fading channel.](image)

Additionally, the proposed model of concatenation (BCH-STBC) codes over MIMO system help to significant enhancement in BER performance as when compared with the uncoded system. The outcomes illustrated in the table 3.

Table 3. BER of 2*2 MIMO improvement of the proposed scheme compared with uncoded system

| No | BCH code – STBC | AWGN channel | Rayleigh fading channel | SNR [dB] |
|----|-----------------|--------------|-------------------------|----------|
| 1  | BCH(31,26)-STBC | 5%           | 65%                     | 10       |
| 2  | BCH(31,21)-STBC | 58%          | 95%                     | 10       |
| 3  | BCH(31,16)-STBC | 86%          | 100%                    | 10       |
### 5. Conclusions

In this research contribution, we have suggested a concatenation scheme of (BCH -STBC) codes to improve the BER performance over MIMO system under AWGN channel and Rayleigh fading channel with various lengths of BCH codes and using Bpsk type as modulation. The simulation results offering that the proposed scheme has good results not only when using AWGN channel but also when using Rayleigh fading channel compared with uncoded system. But, the proposed system even better outcomes when using a Rayleigh fading channel. Additionally, the proposed model achieved better coding gain with acceptable complexity and help to enhance the BER performance of the system exploited an advantage of error correction capability in BCH codes.

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