THROUGHPUT IMPROVEMENT UTILIZING NOVEL PROPOSED MODEL COMBINING BCH (N, K) CODE WITH STBC CODE OVER MIMO SYSTEM WITH RAYLEIGH FADING CHANNEL

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Abstract: Several coding schemes have been implemented to improve capacity (throughput), minimize bit error rate, and the effect of fading. MIMO technique is still a powerful technique besides channel coding. The structure of the proposed system model relies on channel coding represented by BCH (n, k) code combined with MIMO-STBC code. In this research paper, focus on utilizing accessible wireless communication resources to improve the efficiency of the MIMO system in terms of capacity (throughput) and coding gain utilizing the proposed model combining BCH (n, k) code with STBC code over MIMO system with Rayleigh fading channel. Therefore, the outcomes achieved by the proposed model gave a better improvement in coding gain and capacity (throughput). Relative to BCH (31, 26), the improvement in coding gain about 6.94 dB and achieved even better improvement if increase length of BCH code. Thus, for BCH (31, 11), the improvement in coding gain about 16.9 dB at BER (10^{-3}). Additionally, the improvement in system performance reaches (65%-100%). This work is executed utilizing MATLAB simulation. The findings are analyzed and compared.

Keywords: MIMO, BCH code, coding gain, throughput, SNR, and Rayleigh fading channel.

1. Introduction

Owing to an ever-growing need for efficient and reliable digital transmission and growing demands for requirements such as BER, service efficiency, and increasing the number of

communication service users [1]. Modern technologies have demonstrated tremendous communication demands with insufficient transmission power and bandwidth constraints, which, in effect, will not allow us to develop all services [2]. So, finding a suitable strategy for these determinants is a significant challenge.

The efficiency of all wireless communications systems relies on the channel environment. The wireless channel is, therefore, rather complex and unpredictable in design. Furthermore, the fading and shadowing of multipath are primarily limited to decreasing system quality. Therefore, to obtain high spectral performance, several antennas must be used at transmitting and receiving ends. In this case, the multiple-input multiple-output system (MIMO) is a possible nominee for the 5G communication system [3]. MIMO systems have become very common in wireless communication, especially LTE and Wi-Fi [4-5]. MIMO technology uses many antennas at the transmit and receive to provide several benefits preferable over single input - single output (SISO) system [3]. Coding

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gain calculates the difference in SNR level among the coded and un-coded systems at a specified error rate [6].

Exploiting the MIMO strategy in communication regimes has two primary advantages: diversity and multiplexing. Through multiplexing, the transmitting rate has been increased, and the communication reliability of the system is enhanced via exploit space and time diversity[7]. Space-time block code (STBC) is a sufficient transmit diversity employed to contend drawback effects of fading in wireless channels due to its easy decoding and realizing full diversity and highest throughput[8].

Rayleigh fading channel (NLOS) is primarily produced by multipath reception when there is a large number of paths via the transmission channel that consists of the received signal at the recipient side. It is an appropriate model for the troposphere and ionosphere signals propagation. The impulse response of such a channel model will have a Gaussian distribution if a central limit theorem is adopted. When the process has a zero mean, the channel response envelope at any time will have a Rayleigh distribution PDF, and the phase will be distributed uniformly over the period $(0, 2\pi)$ [9-10].

Binary phase-shift keying modulation has been two-state phase shift keying in which the phase of the carrier is set to 0 or π depending on the modulating signal values. The modulation signal was a binary series and is multiplied via a sinusoidal carrier, which produces the modulated BPSK signal. Hence, When the symbol "1" was sent, the modulated signal is almost the same as the carrier with the 0° initial phase. The modulated signal gets a 180° initial phase carrier burst while "0" is sent[11].

In this respect, different research has been done to improve the performance of the MIMO system utilizing coding strategies attempt to get a perfect combination given enhancement in channel capacity with low complexity and maximum coding gain.

In 2012, Abdul Kareem Abdurrahman [12] introduced a study involved modern methodology for achieving the best system performance utilizing the MIMO system and network coding with various types of channels. The outcomes demonstrated that combining MIMO technique and network coding lead to enhancement BER and throughput of the system.

In 2013 S. Zhao [13], presented a study involved concatenation scheme of polar codes and STBC codes over MIMO system, this concatenation is called (Polar-STBC) scheme, the outcomes showed this concatenation give significant enhancement in BER performance of MIMO system as when compared with the system of STBC only and achieved coding gain about 5 dB at BER (10^{-3}) and when incrementing the length of Polar codes, the BER performance of (polar –STBC) scheme is as well improved too.

In 2015, Elise Ghayoula [14], introduced a study involving the proposed concatenation of low-density parity-check(LDPC code) with STBC code over the MIMO system. The outcomes showed these concatenation improvements the performance of the MIMO system and achieved coding gain about 9 dB at BER (2×10^{-4}) as when compares with STBC only.

In this research paper, demonstrating throughput improvement utilizing the proposed model combining BCH (n, k) code with STBC code over the MIMO system and compares with un-coded state over Rayleigh fading channel

and exploited Binary phase shift keying as a modulation scheme.

The residue of this paper is organized as follows. In section II, BCH codes. In section. III, the proposed model. In section IV, Simulation results were described. And eventually, in section V, conclusions and future works.

2. BCH Codes

BCH codes are a new subclass of cyclic error-correcting code, discovered by (Bose- Ray-Chaudhuri-Hocquenghem) [15-16]. An essential aspect of this code, it is simple to encode and easy to decode the signal. Comparable to modernist coding techniques such as LDPCs and turbo codes, the BCH decoder is lower complexity and reliable bug control over symbol error numbers [17]. The properties of this code illustrate in Table 1.

Table 1. Properties of BCH code[15]

Type	Linear block code
Alphabet Size	2
Parameter	$(n, k, d)_2$
Number of corrected error (t)	t where $t < 2^m - 1$
Block length (n)	$2^m - 1$
Message length (k)	k
Code rate (R)	k/n
Distance (d)	d

Code-word being generated by dividing the $m(x)$ polynomial expressing the data (binary data) by $g(x)$ polynomial generator and take the remainder that is described as parity check bits $r(x)$. Code specifications are determined by selecting a polynomial generator $g(X)$ [18]. The generator polynomial $g(x)$ could be calculated employing the following equation:

$$g(X) = \text{LCM}[\Phi_1(X), \Phi_3(X), \dots, \Phi_{2t-1}(X)] \quad (1)$$

Where LCM refers to the lowest common multiple. The minimal polynomial (α_i) represent by $\Phi_i(X)$, and can be calculated by the following formula [19]:

$$\Phi_i(X) = \prod (X + \alpha^j) \quad (2)$$

Due to $g(X)$ is calculated from the production of t minimal polynomial for degrees about m. The maximum degree of $g(x)$ is $(m*t)$.its implies the parity check digit $(n-k)$ is almost equal to $(m*t)$.

The encoding process of BCH code taking the message block of length (k) and convert it to the code word with length (n). The following steps can explain the encoding procedure:

- Multiplying the message $m(x)$ by (X^{n-k}) , this multiplication is equal to a shift of the message bits though $(n-k)$ to the right.
- Calculate remaining $r(x)$ from division the $(X^{n-k} m(x))$ by the $g(X)$ polynomial generator. The remainder is the parity check digits.
- In order to obtain code-word polynomial $C(x)$, adding the calculated residual $r(x)$ to $((X^{n-k} m(x)))$.

This method as well guarantees that the code word in methodical form, which means that the data bits described by the polynomial $m(x)$ can be conveniently interpreted the code-word polynomial $c(x)$ by a look at the rightmost k coefficient.

Now, employing three steps to achieve the decoding process of BCH code described as follow:

- Syndrome $S = (S_1, S_2, S_3, \dots, S_{2t})$ was determined via code-word received $r(x)$.

- Error location in the polynomial $\sigma(x)$ is calculated employing syndrome-derived equations S_{2t} .
- Polynomial error location was employed for defining and correcting erroneous bits.

For (t) error correction code, the syndrome (S) composed of $2t$ is called $S_1, S_2, S_3 \dots S_{2t}$. The components of the syndrome can be determined by employing the following equations:

$$S_i = r(\alpha^i) \quad (3)$$

In order to acquire the code-word polynomial $e(x)$, addition the polynomial error pattern $e(x)$ with sent polynomial code-word $c(x)$, and can be expressed as:

$$r(x) = c(x) + e(x) \quad (4)$$

Because each polynomial code-word should have the roots α . The components of syndrome rely solely on the polynomial error pattern $e(x)$. Consequently, we could be express as:

$$S_i = e(\alpha^i) \quad (5)$$

Assume that $e(x)$ error patterns have v errors at the location $X^{j_1}, X^{j_2}, X^{j_3} \dots \dots X^{j_v}$. Can be express as:

$$e(X) = X^{j_1} + X^{j_2} + X^{j_3} + \dots \dots \dots + X^{j_v} \quad (6)$$

From equation (5) and (6), acquired the following equations:

$$S_1 = \alpha^{j_1} + \alpha^{j_2} + \alpha^{j_3} + \dots \dots \dots + \alpha^{j_v} \quad (7)$$

$$S_2 = (\alpha^{j_1})^2 + (\alpha^{j_2})^2 + \dots \dots + (\alpha^{j_v})^2 \quad (8)$$

$$S_3 = (\alpha^{j_1})^3 + (\alpha^{j_2})^3 + \dots \dots + (\alpha^{j_v})^3 \quad (9)$$

$$S_{2t} = (\alpha^{j_1})^{2t} + (\alpha^{j_2})^{2t} + \dots \dots + (\alpha^{j_v})^{2t} \quad (10)$$

Where $0 \leq j_1 < j_2 < j_3 \dots \dots < j_v < n$, and $\alpha^{j_1}, \alpha^{j_2}, \alpha^{j_3} \dots \dots, \alpha^{j_v}$ are not defined. Thus,

any approach to solving such equations is a BCH code decoding algorithm [19].

3. The Proposed Model

In this section, demonstrates the proposed model in Fig.1.

Figure 1. The proposed model

The data (binary data) encoded through the BCH encoder block, and the code-words n bit is modulation in the modulated block (Binary phase-shift keying is employed for modulation) to the sent 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 illustrate the STBC merger signal. Eventually, decoded the data by the BCH decoder.

In the proposed model, the STBC code 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:

$$\begin{bmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} s_1 & -s_2^* \\ s_2 & s_1^* \end{bmatrix} + \begin{bmatrix} N_{11} & N_{12} \\ N_{21} & N_{22} \end{bmatrix} \quad (11)$$

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 additive white Gaussian noise (AWGN).

$$y_{11} = h_{11}s_1 + h_{12}s_2 + N_{11} \quad (12)$$

$$y_{12} = -h_{11}s_2^* + h_{12}s_1^* + N_{12} \quad (13)$$

$$y_{21} = h_{21}s_1 + h_{22}s_2 + N_{21} \quad (14)$$

$$y_{22} = -h_{21}s_2^* + h_{22}s_1^* + N_{22} \quad (15)$$

Assume:

$$k = |h_{11}|^2 + |h_{12}|^2 + |h_{21}|^2 + |h_{22}|^2 \quad (16)$$

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

$$\tilde{s}_1 = \frac{1}{K} [h_{11}^* y_{11} + h_{12} y_{12} + h_{12}^* y_{21} + h_{22} y_{22}] \quad (17)$$

$$\tilde{s}_2 = \frac{1}{K} [h_{12}^* y_{11} - h_{11} y_{12} + h_{22}^* y_{21} + h_{21} y_{22}] \quad (18)$$

4. Simulation Results

In this section, we focus on BER performance and throughput on the proposed model. Table 2 demonstrates the main parameters utilizing in simulation.

Table 2.Main parameters utilizing in simulation

No	Parameter	Details		
		Block length(n)	Message length (k)	Number of corrected error (t)
1	BCH code	31	26	1
		31	21	2
		31	16	3
		31	11	4
2	Modulation type	Binary phase-shift keying modulation.		
3	Type of channel	Rayleigh fading channel		
4	Number of transmitting and receiving antenna over MIMO system	2*2		

Fig.2 demonstrates the comparison of a BER performance of the proposed model with various lengths of BCH codes over the MIMO system, with a Rayleigh fading channel, respectively. BCH (31,26) codes having the capability to correct one error (t =1) , Also BCH(31,21) correct two errors (t=2). BCH(31,16) correct three errors (t =3) ,and BCH(31,11) correct four error (t =4). The proposed model achieved enhancement in coding gain. For the BCH (31, 26) code accomplished enhancement in coding gain approximately 6.94 dB at BER about(10^{-3}), while obtaining even better enhancement when the BCH (31, 21) about 10.7 dB Furthermore, when BCH (31, 16) nearly enhancement 13.25 dB, and finally when BCH (31, 11) the enhancement about 16.9 dB .

Furthermore, the proposed model achieved improvement in the performance of the MIMO system, and this improvement is maximized with an increased length of BCH code. Thus, it can be calculated this improvement at the (SNR = 10 dB). For the BCH(31,26), BCH(31,21), BCH(31,16), BCH(31,11) improvement of system about 65%, 95% ,100% ,100% ,respectively, when compared with the un-coded MIMO system

Figure2. BER comparison of combining BCH (31, 26), (31, 21), (31, 16), (31, 11) codes with STBC code over MIMO system, with un-coded state, over Rayleigh fading channel

Fig.3 demonstrates throughput comparison of the proposed model with various lengths of BCH codes over the MIMO system with a Rayleigh fading channel.

Figure 3. Throughput comparison of combining BCH (31, 26), (31, 21), (31, 16), (31, 11) codes with STBC codes over MIMO system, with un-coded state, over Rayleigh fading channel

Typically, the enhancement of the throughput relies on the coding techniques utilizing and SNR [dB]. The throughput estimated will be as predicted proportional directly with the SNR [dB].

The (green, blue, black, pink) curves in Fig.3 indicate a comparison of throughput of the

proposed model with various length of BCH codes utilized, with un-coded MIMO state. Thus, accomplished maximum improvement throughput at (SNR ≥ 18 dB), (SNR ≥ 13 dB) (SNR ≥ 10 dB), and (SNR ≥ 6 dB).respectively.

5. Conclusions

The main objective of several communication systems is to achieve the highest system throughput and minimize BER. In this research paper, we proposed a model combining BCH (n , k) code with STBC code over the MIMO system with the Rayleigh Fading channel to improve throughputs and minimize bit error rate (BER) performance. The proposed model accomplishes good performance in terms (BER, throughput, coding gain, and system improvement) compared with the un-coded MIMO system. So, better outcomes were obtained when using the BCH (31, 11) code in the proposed model. It achieved coding gain about 16.9 dB and improve system performance 100% compared with the un-coded MIMO system, also getting maximum throughput at (SNR ≥ 6 dB). Moreover, all these improvements obtained by exploiting the error correction capability feature that having in BCH (n, k) codes and utilizing a remarkable MIMO technique over Rayleigh fading channel. The obtained result supports the major idea and achieves the required goal.

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Conflict of interest

The authors declare that there is no conflict of interest.

6. References

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