International Journal of Electrical and Computer Engineering (IJECE)
Vol. 8, No. 1, February 2018, pp. 622~630
ISSN: 2088-8708, DOI: 10.11591/ijece.v8i1.pp622-630

Performances Concatenated LDPC based STBC-OFDM System and MRC Receivers

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Article Info

Article history:

Received Jul 17, 2017
Revised Dec 24, 2017
Accepted Jan 8, 2018

Keyword:

AWGN
LDPC
MRC
OFDM
STBC

ABSTRACT

This paper presents the bit error rate performance of the low density parity check (LDPC) with the concatenation of convolutional channel coding based orthogonal frequency-division-multiplexing (OFDM) using space time block coded (STBC). The OFDM wireless communication system incorporates 3/4-rated convolutional encoder under various digital modulations (BPSK, QPSK and QAM) over an additative white gaussian noise (AWGN) and fading (Raleigh and Rician) channels. At the receiving section of the simulated system, Maximum Ratio combining (MRC) channel equalization technique has been implemented to extract transmitted symbols without enhancing noise power.

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1. INTRODUCTION

The space-time block coding technique is considered one of the most attractive and representative multiple antenna techniques. It is also, an effective transmit diversity technique, was first proposed by Alamouti for flat fading channel [1]. Alamouti suggested a space time code for two transmit antennas, which provides a diversity gain and has a very simple decoder [2].

Space Time Block Codes (STBCs) have its application in cellular communications and wireless local area networks [3], and it's also the transmit diversity that has been studied extensively as a method of combating determine effects in wireless fading channel because of its relative simplicity of implementation and feasibility of having multiple antenna at the base station [4].

On the other hand, the Orthogonal Frequency Division Multiplexing is an efficient modulation technique used in certain wired and wireless application [5], it also is an attractive technology that is being implemented to achieve high bit data rate transmission invoked for high-bit-rate data transmission,especially in a highly dispersive multipath-fading environment that inflicts inter-symbol interference (ISI) by transforming a frequency selective fading channel into a set of parallel correlated fading channels [6].

In this context, the STBC-OFDM system may be one of most promising system configurations that can be adopted for 4th generation mobile systems. The combination of STBC and OFDM results in an enhanced system performance in wideband wireless channels [7].

Low Density Parity Check codes are a linear block codes were proposed by Gallager in 1962 [8], [9]. Owing to the codes' capability of approaching Shannon's performance limits, LDPC codes have been applied in conjunction with OFDM systems. J. Boutros and E. Viterbi presented the concept of modulation diversity in the Rayleigh fading channel.

In this paper, we consider a LDPC-based STBC-OFDM. At the receiver, Maximum Ratio combinig equalization technique is employed to separate transmitted symbols without enhancing the noise. In this contribution we evaluate the BER of the STBC-OFDM system with concatenation of outer low-density parity-check and inner convolutional channel coding schemes and compare the BER performance of the system under text message transmission and compare the BER performance of the system working under each of the three types of digital modulation (BPSK, QPSK and QAM) on the AWGN, Rayleigh and Rician fading channels.

This paper is organized as follows. Section 2 presents a brief survey and related works. Section 3 is a brief introduction to LDPC codes. Section 4 describes the MRC receiver with LDPC decoding. Section 5 presents the system model. Before concluding, section 6 presents the BER performance of the LDPC +3/4-rated convolutional encoded OFDM system under different modulation chemes in AWGN and fading (Rayleigh and rician) channels.

2. RELATED WORKS

A brief survey of literature in the area relevant to this paper is as follows. To enhance system performance M.Y. Alias et al. [10] proposed concatenated LDPC and Turbo coding assisted space-time block coded wireless OFDM system. J. Ha et al. [11] proposed LDPC code for both Alamouti-OFDM scheme and singular-value decomposition (SVD)-OFDM scheme to provide low BER at a high spectral efficiency and low SNR. Further. J. Wu and H-N Lee [12] have shown that channel capacity can be significantly increased by using LDPC coded modulation in multiple-input multiple-output (MIMO) multiple-access systems.

The BER performance of a concatenated LDPC encoded OFDM system has been investigated by D. Haque et al. [13], [14] shows that compared with the conventional STTC, LDPC-based STTC can significantly improve the system performance by efficiently exploiting both the spatial diversity and selective-fading diversity in wireless channels. They also shown that compared with the recently proposed turbo-code-based STC scheme, and concluded that the proposed system is very much effective in proper identification and retrieval of transmitted color image in noisy and fading environment. M. M. Hossain et al. [15] also studied the impact of LDPC on the performance of an OFDM system under various digital modulations over an AWGN and other fading channels and they shown that the proposed system with deployment of QAM modulation is highly effective to combat inherent interferences and to retrieve the transmitted black and white image properly under noisy and fading situations.

3. LDPC CODE

Low density Parity check (LDPC) codes, also known asGallager codes are a type of linear block codes, first proposed by Gallager[1] and were scarcely considered in the three decades that followed due to its computational complexity and limited computational ability of the receiver at that time [16].

LDPC use in concatenated channel coding achieves considerable reduction of error probability with less complexity than a single code. A (n, k) LDPC encoder operateson an m × n sized H matrix where m = n-k. It is low density because the number of 1s in each row wr is « m and the number of 1s in each column wc is « n. A LDPC is regular if wc is constant for every column and wr = wc (n/m) is also constant for every row. Otherwise it is irregular. In LDPC encoding, the codeword (c0, c1, c2, c3, …,cn) consists of the message bits (m0, m1, m2,...,mk) and some parity check bits and the equations are derived from H matrix in order to generate parity check bits. The Figure 1 shows the tanner graph corresponding to the parity check matrix H for a (8, 4) code.

$$
\begin{array}{cccccccccc}
 & V1 & V2 & V3 & V4 & V5 & V6 & V7 & V8 & \\
\end{array}
$$

$$
\mathbf{H} = \begin{bmatrix} 0 & 1 & 0 & 1 & 1 & 0 & 0 & 1 \\ 1 & 1 & 1 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 1 & 1 & 1 \\ 1 & 0 & 0 & 1 & 1 & 0 & 0 & 0 \end{bmatrix} \begin{matrix} C1 \\ C2 \\ C3 \\ C4 \end{matrix} \quad (1)
$$

The sparse parity check matrix is best represented by a bipartite graphs know as Tanner graphs. Each row of the parity check matrix represents the variable node and each column represents the check node. The 1s in each row or column represents the connectivity between variable and check nodes. The set of bit nodes connecting to check node m is denoted by N(m)={n|hmn=1} and the set of check nodes connecting to bit node n is by M(m)={m|hmn=1} [17]. The Figure 1 shows the tanner graph corresponding to the parity check matrix H for a (8, 4) code.

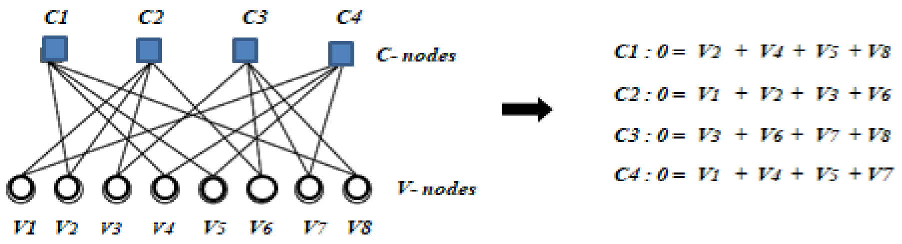

Figure 1. Tanner graph corresponding to the parity check matrix *H* for a (8, 4) code

The generator matrix G is found from H by Gaussian elimination. If H is put in the form: H = [PT: I] the generator matrix will become G = [I : P]. The general encoding and decoding of systematic linear block codes can be expressed respectively as :

$$c = xG = [x : xP] \quad (2)$$

and

$$cH^T = 0 \quad (3)$$

If c is a valid codeword and x is a message word. There are several algorithms used to decode LDPC codes defined to date and the most common ones are message passing algorithm, belief propagation algorithm and sum-product algorithm [18]. In this paper, we have employed sum-product decoding algorithm as presented in [19].

4. MAXIMAL RATIO COMBINING (MRC) RECEIVER WITH LDPC CODING

The Maximal Ratio Combining (MRC) is a receiver diversity combining technique used at receiver end which helps in estimating the channel conditions for transmit antenna selection. MRC also helps to maximize the output signal to noise ratio (SNR) at the receiver [20]. This classical approach of diversity involves multiple antennas at the receiver to improve signal quality.

Let the message to be transmitted be m1, m2.........,mk. Each block of k message bits are fed to an LDPC encoder with rate R = k/K resulting on K-length codewords S1, S2…...,SK .These LDPC codewords are then transmitted to the M receiving antennas as shown in Figure 2.

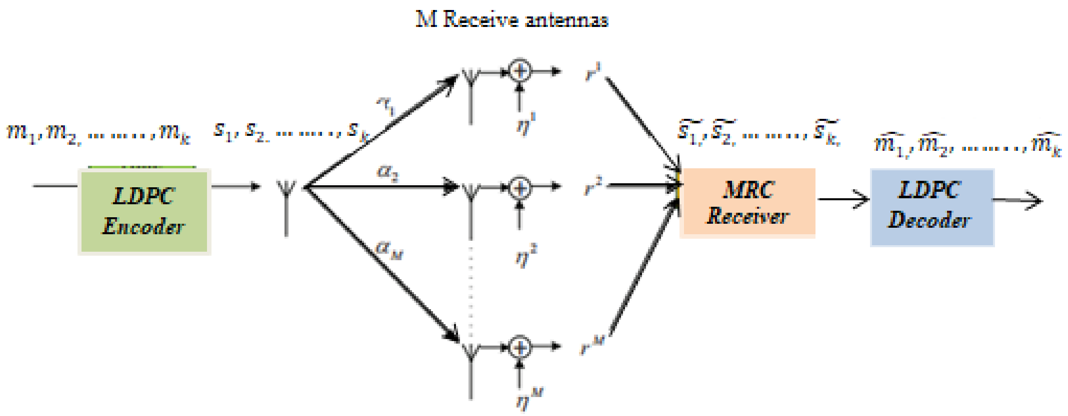

Figure 2. Maximal ratio combining receiver with LDPC code

5. CHANNEL MODEL

In general, the power profile of the received signal can be obtained by convolving the power profile of the transmitted signal with the impulse response of the channel. Convolution in time domain is equivalent to multiplication in the frequency domain. Therefore, the transmitted signal x, the received signal vector can be expressed as

$$y = hx + n \quad (4)$$

where ‘y’ is received signal vector, ‘x’ is STBC encoded signal vector, ‘h’ is channel gain matrix and ‘n’ is noise vector.

5.1. Rayleigh Channel Model

The Rayleigh distribution has probability density function (PDF) given by:

$$P_R(r) = \frac{2r}{\Omega} e^{\frac{-r^2}{\Omega}}, \qquad r \geq 0 \quad (5)$$

where r is the envelope of a sample of electric field and Ω is multiplication of in phase and quadrature component of electric field. The cumulative distribution function (CDF) for Rayleigh distribution is given by:

$$F_R(r) = 1 - e^{\frac{-r^2}{\Omega}} \quad (6)$$

where:

$$\Omega = 2\sigma^2 = E[r^2]$$

5.2. Rician Channel Model

In case the channel is complex Gaussian with non-zero mean the envelope $r = |h|$ is Ricean distributed. Here we denote $h = \alpha e^{j\emptyset} + Ve^{j\theta}$, where α follows the Rayleigh distribution and ν > 0 is a constant such that ν2 is the power of the LOS signal component. The angles φ and θ are assumed to be mutually independent and uniformly distributed on [-π; π). Ricean pdf can be written as:

$$P_R(r) = \frac{2r}{\Omega} e^{\frac{-(v^2+r^2)}{\Omega}} I_0\left(\frac{rv}{\Omega}\right), \qquad r \geq 0 \quad (7)$$

where I_0 is the modified Bessel function of order zero and $2\sigma^2 = E[\sigma^2]$. The Rice factor $k = v^2/\Omega$ is the relation between the power of the LoS component and the power of the Rayleigh component.

6. SYSTEM MODEL

Figure 3 shows the architecture model for our LDPC channel encoded OFDM system with the implementation of MRC channel equalization scheme for text message transmission that utilizes a concatenated LDPC scheme with 2 transmit and 1 receive antennas.

At the transmitter, we have take as an input the message text: “Information Technology is a very important sector in modern world. It is a computer based education.” The text message is converted into binary data of length 696 bits. The binary bits are encoded at the LDPC encoder.

In this work we have used the 1/2-rated irregular LDPC matrix of size 696×1392. Thus the output of the LDPC encoder is 1392 bits which are then passed through interleaver to minimize bursts errors and subsequently applied to the 3/4-rated convolutional encoder with the constraint length of 7 and modulated digitally by binary phase shift keying (BPSK), quadrature phase shift keying (QPSK), quadrature amplitute modulation (QAM) at the modulator. The modulated data streams are then passed through Alamouti STBC encoder to encode the bit streams into two parts, where the symbol values are multiplexed to the two antennas and which are converted from serial into parallel in each path independently. To mitigate the effects of inter-symbol Interference (ISI) caused by channel time spread, each block of IFFT coefficients is typically preceded by a cycle prefix.After cycle prefixing these data are converted in serial form using parallel to-serial converter and transmitted over the channel. The Figure 3 shows Block diagram of a concatenated STBC-LDPC encoded OFDM system.

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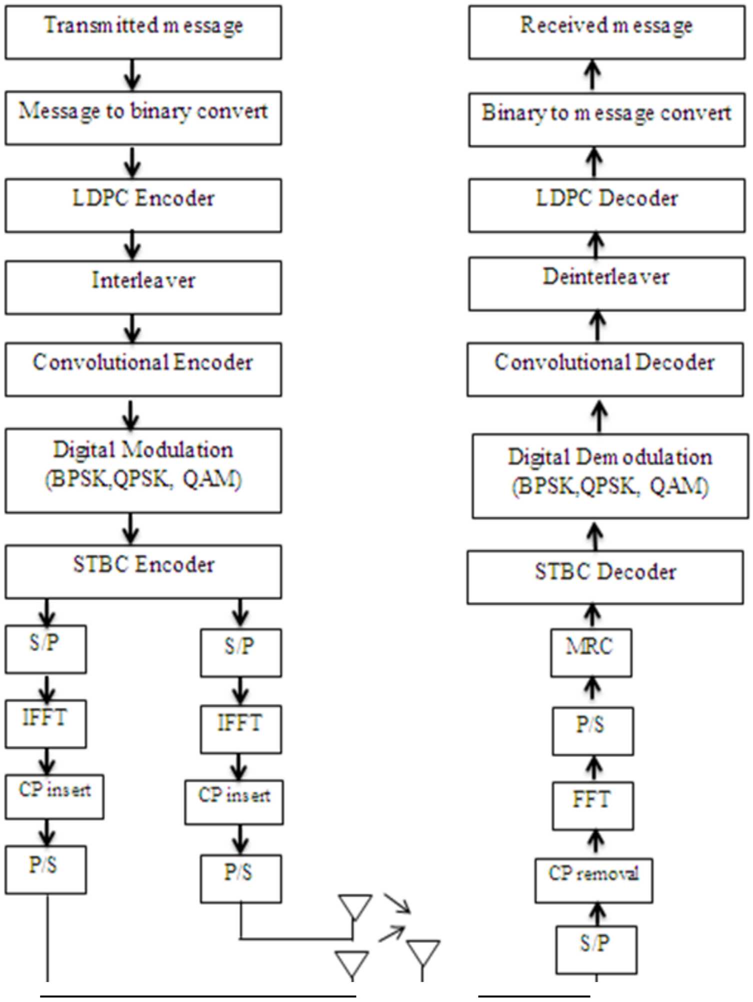


Figure 3. Block diagram of a concatenated STBC-LDPC encoded OFDM system

In the OFDM block instant (2i), $x_{1,k}$ and $x_{2,k}$ are mapped to the k-th subcarrier to be transmitted from antenna 1 and 2.

Next at the block instant (2i +1), $-x*_{2,k}$ and $x*_{1,k}$ are mapped to the k-th subcarrier to be transmitted from antenna 1 and 2. The transmitted STBC-OFDM symbols are given by:

$$\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} \longrightarrow \begin{bmatrix} x_1 & -x*_2 \\ x_2 & x*_1 \end{bmatrix}$$

At the receiving section, the received time domain signals after discarding the cyclic prefix are passed through an fast Fourier transform (FFT) operation to obtain the k-th subcarrier values for symbol period (2*i*) and (2*i* +1).The signals are then fed to the Alamouti STBC decoder which apply maximum ratio combining (MRC) technique for providing strongest outputs. In MRC, signals from all paths are cophased and summed with optimal weighting to maximize combiner output signal to noise ratio (SNR). The outputs of the STBC decoder are subsequently demapped, convolutionally decoded, deinterleaved and then fed to the LDPC decoder to retrieve bits using an iterative sum-product algorithm. Finally the LDPC decoded binary bit stream isconverted into text message.

7. SIMULATIONS RESULTS AND DISCUSSIONS

The simulation has been performed in MATLAB according to the above described system to evaluate the BER performance of the the concatenated LDPC encoded OFDM system under different modulation schemes on text message transmission. The simulation parameters are listed in Table 1.

Table 1. Simulation Parameters

Size of the parity check matrix in LDPC code	696*1392
Total number of bits in a codeword	1392
Number of information bits in a codeword	696
Channel	AWGN,Rayleigh, Rician
Modulation	BPSK, QPSK, QAM
Doppler shift	100 Hz
Cyclic prefix length	1
Bit rate	100000

The Figure 4 shows the performance comparison of the OFDM signal with LDPC coding and without LDPC coding respectively, the system outperforms at BPSK modulation on the AWGN channel.

From the figure, it is shown that for the two different values of energy per bit to noise ratio (Eb / N0) of 4db, the BER values of OFDM with and without LDPC coding are 0.0062 and 0.022 respectively wich implies that the BER is improved by 1.015 dB. We conclude that the OFDM signal with LDPC coding gives better results than that of the OFDM signal with LDPC coding.

Figure 5 shows the LDPC encoded OFDM system in AWGN channels, from the figure it is shown that the system provides satisfactory performance with BPSK modulation and provides worst performance in the case of QPSK and QAM on the AWGN channel. For a typical value of energy per bit to noise ratio (Eb / N0) of 3dB, the BER values of BPSK and QPSK are 0.065 and 0.46 respectively which indicate the BER improvement in BPSK modulation is about 3.02 dB than that of the system with QPSK modulation for a typical value of 3dB.

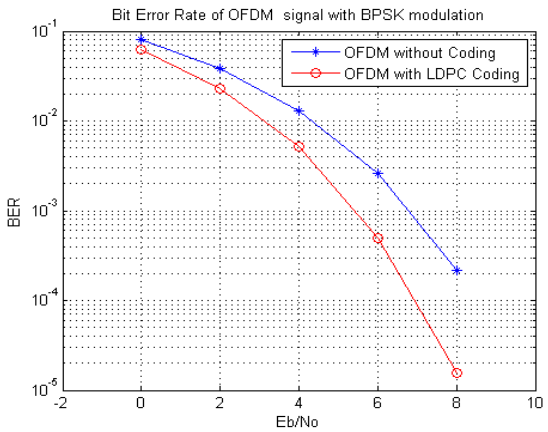


Figure 4. BER of OFDM signal with and without LDPC Coding

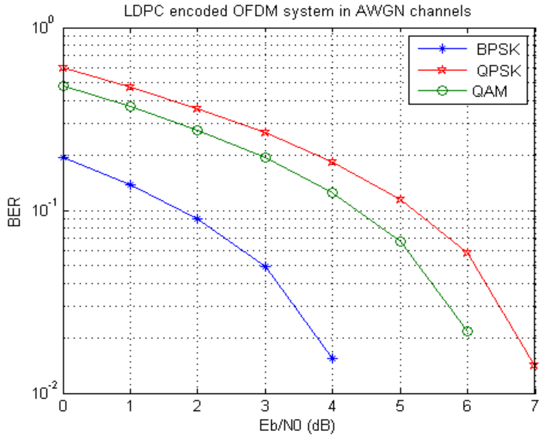


Figure 5. BER of LDPC encoded OFDM system in AWGN channel

Figure 6 shows 3/4-rated convolutional and LDPC encoded OFDM system. As seen from the figure the system outperforms at BPSK modulation and provides worst performance in the case of QPSK on the AWGN channel. For a typical value of energy per bit to noise ratio (Eb / N0) of 1dB, the BER values of BPSK and QPSK are 0.0056 and 0.0078 respectively which implies that the system performance with BPSK modulation is about 2.02 dB better than that of the system with QPSK modulation .

Figure 7 demonstrates that the BER performance of the LDPC 3/4-rated convolutional encoded OFDM system under different digital modulations on a Raleigh fading channel degrades due to fading channel effect. The system outperforms at BPSK modulation and shows worst performance at QPSK modulation. At Eb/N0 value of 0.78 dB the system performance is improved by 2.7195 dB in the case of BPSK modulation as compared with QPSK where the BER values for BPSK and QPSK are 0.0068 and 0.0095 respectively.

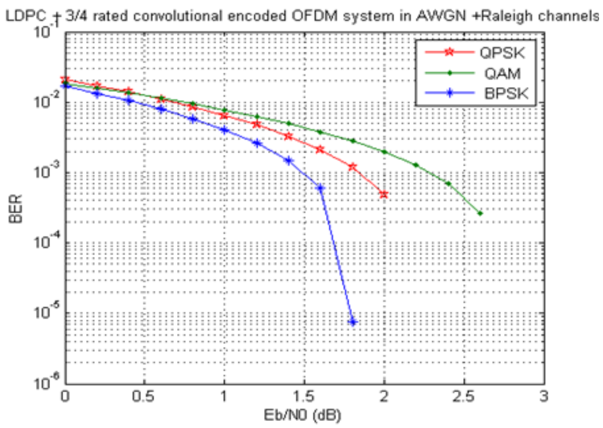


Figure 6. BER of the LDPC +3/4-rated convolutional encoded OFDM system under different modulation chemes in AWGN channel

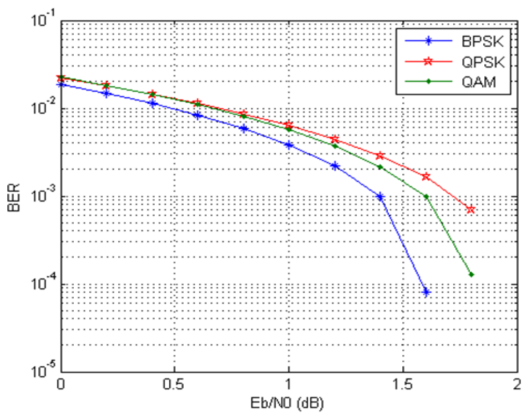
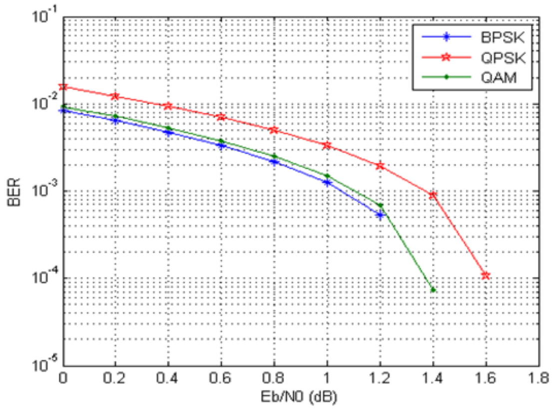


Figure 7. BER of the LDPC +3/4-rated convolutional encoded OFDM system under different modulation chemes in AWGN and Rayleigh channels

The BER performance of the LDPC 3/4-rated convolutional encoded OFDM system under different digital modulations on a Raleigh fading channel is shown in Figure 8. We have observed that the system outperforms at BPSK modulation and the system performance undergoes significant degradation in QPSK modulation due to fading effect. In comparison of the BPSK with QPSK modulation, it is found that the system performance is improved by 2.097 dB in the case of BPSK for a typical Eb/N0 value of 1dB where the BER values for BPSK and QPSK are 0.0018 and 0.0056, respectively.



gure 8. BER of the LDPC +3/4-rated convolutional encoded OFDM system under different modulation chemes in AWGN and Rician channel

8. CONCLUSION

In this paper, we evaluated the BER performance concatenation of an interleaved low density parity check (LDPC) code with convolutional channel coding based space-time block coded Orthogonal frequency division coded Orthogonal frequency division multiplexing system with the implementation maximum ratio combining (MRC) technique for providing strongest outputs under different digital modulations over AWGN, Raleigh and Rician fading channels. It has been showed that the proposed system achieves good error rate performance under BPSK modulation technique in AWGN, Rayleigh and Rician fading channels. On the basis of the results obtained in the present simulation based study, it can be concluded that the deployment of a concatenated channel coding scheme with low-density parity-check and convolutional codes and Alamouti's transmit diversity technique in Orthogonal frequency division multiplexing based wireless communication system under BPSK modulation is very much effective in proper identification and retrieval of transmitted text message in noisy and fading environments.

REFERENCES

[1] S.M. Alamouti, "A simple transmit diversity technique for wireless communication," *IEEE J. Select. Areas Commun,* vol. 16, pp. 1451-1458, Oct. 1998.

[2] H. Jafarkhani, "A quasi-orthogonal space-time block code, "IEEE Trans. Commun., vol. 49, pp.1-4, Jan. 2001.

[3] V. S. Hendre, *et al.,* "Performance Analysis of Transmit Antenna Selection with MRC in MIMO for Image Transmission in Multipath Fading Channels Using Simulink," *International Journal of Electrical and Computer Engineering (IJECE),* vol. 5, pp. 119-128, February 2015.

[4] V. Tarokh, *et al.*, "Space-time block coding for wireless communication: Performance results, " *IEEE J.Select. Areas Commun,* vol. 17, pp. 451-460, Mar. 1999.

[5] P. Manhasa1 and M. K Sonib, "Performance of OFDM System under Different Fading Channels and Coding," *Bulletin of Electrical Engineering and Informatics,* vol. 6, pp. 54-61 March. 2017.

[6] M.D. , *et al.*, " "BER performance analysis of a concatenated LDPC encoded OFDM system in AWGN and fading channels," *J. Sci. Res*., vol. 2, pp. 46-53, 2010.

[7] D. Agrawai, et al., *"Space-time Coded OFDM for High DatarateWireless Communication over Wideband Channels,"* in Proceedings of IEEE VTC 1998, (Ottawa, Canada), pp. 2232–2236, 1998.

[8] R. G .Gallager, Low density parity check codes, IRE Transaction Information Theory IT -8, 21 (1962).

[9] R. G. Gallager, Low Density Parity Check Codes, Research Monograph Series (Cambridge, MIT Press, 1963).

[10] G.L. Stuber, *et al.*, "Broadband MIMO-OFDM wireless communications, " *Proc. IEEE*, vol 92, pp. 271-294, 2004.

[11] J. Ha, *et al.*, "LDPC coded OFDM with Alamouti/SVD diversity technique," *Wireless Personal Communications*, vol. 23, pp. 183-194, 2002.

[12] J. Wu and H. N. Lee, "Performance analysis for LDPC coded modulation in MIMO multiple access systems, "*IEEE Transactions on Communications*, vol. 55, pp. 1417-1426, July 2007.

[13] D. Haque, *et al.*, "Performance evaluation of a FEC encoded MIMO-OFDM wireless communication system on color image transmission," J. Mobile Commun. 3(4): 62-67, 2009.

[14] Ben Lu, *et al.*, "LDPC-Based Space–Time Coded OFDM Systems Over Correlated Fading Channels: Performance Analysis and Receiver Design," *IEEE Transactions on Communications*, vol. 50, No. 1, January 2002.

[15] M.M. Hossain, *et al.*, "BER evaluation of LDPC coded OFDM system under different modulation schemes," *Inst. Eng. Tech.,* Vol. 1, pp. 1-4, Jan.2010.

[16] W. Ullah and A. Yahya, "Comprehensive Algorithmic Review and Analysis of LDPC Codes, "*TELKOMNIKA (Telecommunication Computing Electronics and Control),* Vol. 16, pp. 111 – 130, October 2015.
[17] W. Ullah, *et al.,* "QC LDPC Codes for MIMO and Cooperative Networks using Two Way Normalized Min-Sum Decoding, "*TELKOMNIKA (Telecommunication Computing Electronics and Control),* vol. 12, pp. 5448 -5457 July. 2014.
[18] M. Ergen, "Mobile Broadband including WiMAX and LTE," Springer Science and Business media, LLC, USA, 2009.
[19] M. Ergen, "Mobile Broadband including WiMAX and LTE," Springer Science and Business media, LLC, USA, 2009.
[20] V. S. Hendre *et al.,* "Performance Analysis of Transmit Antenna Selection with MRC in MIMO for Image Transmission in Multipath Fading Channels Using Simulink," *International Journal of Electrical and Computer Engineering (IJECE),* vol. 5, pp. 119-128, February 2015.