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RS Codes for Downlink LTE System over LTE-MIMO Channel

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Abstract

Nowdays, different applications require a modern generation of mobile communication systems; long term evolution (LTE) is a candidate to achieve this purpose. One important challenge in wireless communications, including LTE systems, is the suitable techniques of controlling errors that degrade system performance in transmission systems over multipath fading channels. Different forward Error correction (FEC) techniqes are required to improve the robustness of transmission channels. In this paper, Reed-Solomon (RS) codes were used with a downlink LTE system over a LTE-MIMO channel. This research contributes by combining RS codes that have low decoding complexity (by using hard decision decoding) with a LTE-MIMO channel to improve downlink LTE system performance. The results show that using RS codes clearly improves LTE system performance and thus decreases Bit Error Rates (BER) more than convolutional and turbo codes which have high decoding complexity. Lastly, the results show also extra improvements of downlink LTE system performance by increasing the number of antennas of the LTE-MIMO channel.

Keywords: *LTE, RS, MIMO, BPSK, QPSK*

1. Introduction

Using data and voice services in mobile communication systems has become a life necessary today, so there is huge demand for improvements in these technologies. LTE is a good solution to provide these applications and thus is a candidate for future technological innovation [1, 2] due to it supports high data rates systems [3, 4]. Orthogonal Frequency Division Multiplexing (OFDM) is considered a key technology of 3GPP LTE and 4G, as well as 802.11n WLAN and IEEE 802.16m WiMAX, due to its combating selective fading channel. It can be easily implemented using Discrete Fourier Transform (DFT), which makes OFDM an attractive technology for Broadband mobile wireless. Combining the Multi Input Multi Output (MIMO) technique with OFDM provides a good solution for 4G networks [5]. MIMO technique is applied through using multi antennas in both of transmitter and receiver to improve data rates, channel capacity, network coverage and link reliability [6].

The channel in mobile environments is divided into frequency and time selective fading; using OFDM will combat any Inter Symbol Interference (ISI) that occurs [5]. An orthogonal Frequency Division Multiplexing Access (OFDMA) is used in the transmission scheme for downlink LTE; this is a multi-user version of OFDM [7, 8]. When time-invariance exists in the frequency selective channel, OFDM systems support using simple one-tap equalization [9]. In contrast, in high mobility cases, performance is degraded and equalization is needed to improve performance [10, 11]. Achieving robustness in the radio link of any wireless communication systems requires channel coding techniques. When performing source coding, channel coding will add a new controlled redundancy [12].

Powerful techniques are needed in a LTE system to control errors in the transmission channel. Adding parity bits to the signal data stream is considered a method of error control; the goal of adding these bits is to detect and correct errors [12, 13]. Some powerful techniques for FEC have been suggested in LTE system such as convolutional codes in [13-15], although their techniques improved the system performance but they also faced the problem of high convolutional decoding complexity [16]. In contrast, other studies such as [17-19] are adopted turbo codes with LTE to improve the reliability. However, high decoding complexity is still a

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common demerit of turbo codes [20], as well the results of the decoding are not stabile and thus it is necessary to achieve the balance between the decoding performance and complexity [12]. In wireless communication systems, RS codes are widely used due to the high capability of correcting burst errors and random errors. There are two RS decoding process; Soft Decision Decoding (ASD) and Hard Decision Decoding (HDD). Practically, HDD is popular used in different application due to its lower complexity than ASD [21]. Therefore, to achieve robust error control in Downlink LTE system over LTE MIMO channel, RS codes (that using HDD) which have low decoding complexity are proposed in this paper, while the channel capacity can be enhanced using MIMO technique [6]. The performance of proposed system was tested using a multipath fading LTE MIMO channel. The simulation was done using two types of modulation (BPSK and QPSK) to show which type gives extra imporvement to the system performance.

2. The Proposed Method

The proposed Downlink LTE system by using RS codes has been depicted in Figure 1 to explain the whole block diagram of the proposed LTE system. While, the parameters of LTE environments that used in the suggested LTE system design are explained in Table 1. In this paper, MATLAB software has been used to evaluate the performance of LTE system over LTE-MIMO channel in presence of multipath fading channel.

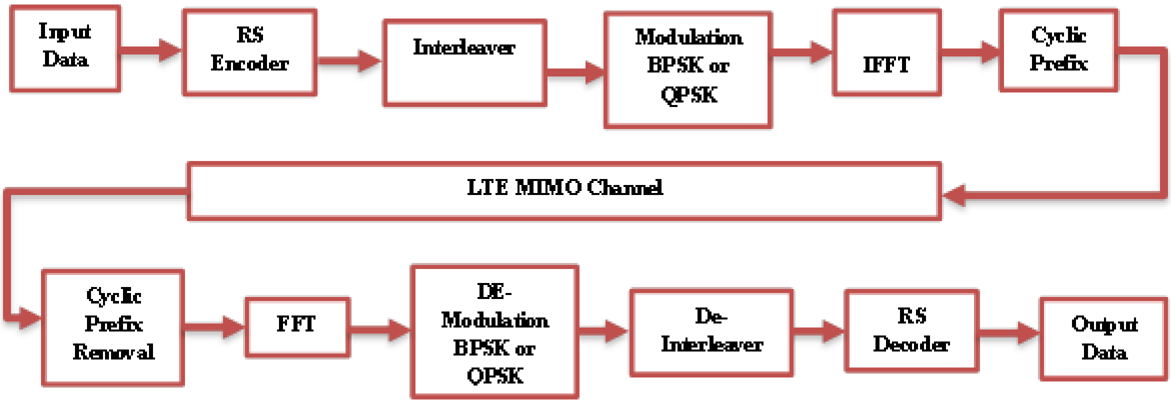

Figure 1. Proposed LTE system

Table 1. Simulation Environment of the LTE System

Transmission Bandwidth	20MHz
Channel	LTE-MIMO Channel Multipath Fading Channel
Number of IFFT/FFT Points	2048
No. of Occupied Sub-carrier	1200
Cyclic Prefix Length	144
Modulation	BPSK and QPSK
Sampling Rate	30.72MHz
Error Correcting Techniques	Reed-Solomon Codes (HDD)

2.1. Reed-Solomon Codes

Reed and Solomon proposed a new type of ECC in [22] and called reed-solomon codes. It is considered non-binary cyclic codes. The symbols of RS codes consist of positive integer values (> 2) of m bit sequences. The form of RS codes is represented as [23].

$$RS(n, k) \qquad 0<k<n<2m+2$$

Since, n defined as total number of code symbols (in the encoded block) and the value of data symbols k that have been encoded. Classic RS (n, k) code is as follows [23].

(n, k)=(2m–1, 2m–1–2t)

The capability of the code's symbol error correcting is represented by t, where (t=n-k) represents the parity symbols number. RS codes are also considered cyclic and linear codes. RS codes have a good capability of error correction, especially when dealing with burst of errors [23].

In general, RS decoding procedure phases as following [24]:

a. Determine the syndrome from received codeword.
b. From syndrome and using own derived equations could select the error location and error value polynomial.
c. By using error value polynomial and error location, could correct the symbols that have errors.

Suppose, α is the primitive element of GF (q) and α^{q-1} equal to 1. Then, RS code can be obtained by the following polynomial [25].

$$\begin{aligned} g(x) &= (X-\alpha)(X-\alpha^2)\ldots\ldots(X-\alpha^{n-k}) \\ &= (X-\alpha)(X-\alpha^2)\ldots(X-\alpha^{2t}) \\ &= g_0+g_1X+g_2X^2+\ldots\ldots+g_{2t-1}X^{2t-1}+g_{2t}X^{2t} \end{aligned} \quad (1)$$

By a given generator polynomial of (1), an RS code $C_{RS}(n, n-2t)$ is a linear and cyclic block generated consist of code polynomial c(x) that have (n-1) degree or less. All coefficients of these polynomials are elements in GF(2^m). When multiplies the code polynomials by generator polynomial, will obtaining all its roots [25].

Assume m(X) is message polynomial and created as in (2). While, all coefficients of these message polynomials are also elements of GF(2m). The systematic method is used to obtain the remainder p(x) through divided Xn-k m(X) by g(X) as in (3) [25].

$$m(X) = m_0+ m_1X+m_2X^2+\ldots\ldots+m_{k-1}X^{k-1} \quad (2)$$

$$X_{n-k}\,m(X) = q(X)g(X) + p(X) \quad (3)$$

Table 2. The Galois Field GF(2^3) Produced by p_i (X)=1+X+X^3

Expression Repr.	Polynomial Repr.	Vector Repr.
0	0	0 0 0
1	1	1 0 0
α	α	0 1 0
α^2	α^2	0 0 1
α^3	$1+\alpha$	1 1 0
α^4	$\alpha+\alpha^2$	0 1 1
α^5	$1+\alpha+\alpha^2$	1 1 1
α^6	$1+\alpha^2$	1 0 1

2.2. Interleaver/ De-Interleaver

To combat the burst of errors in the transmission channel, an interleaver has been used to re-request input bit series to a non-adjacent method [26]. Where, using the interleaving process after RS encoder is very important to enhancing the capability of error correcting in the receiver [27]. Therefore, by using Interleaver/De-Interleaver process in LTE system, the system will be more effictive in combating the errors and thus improving the system performance through decreasing BER.

2.3. Modulation

Two modulation schemes have been used in this paper for comparison in the proposed system. We chose both BPSK and QPSK, due to their good performance compared with other types of modulation. Where, lower order modulations (for instance QPSK and BPSK) improve system performance better than high order modulations (for instance as 64-QAM and 16-QAM) in terms of BER and Signal to Noise Ration (SNR) [28].

2.4. LTE MIMO Channel

A 3GPP-LTE of Release 10 was created in this channel; it was particular for the MIMO system over multipath fading channel. The signal has been passed via multipath fading channel using the LTE-MIMO channel [29]. First, a MIMO system using two transmitter and receiver antennas was used, then four transmitter and receiver antennas were used in a second scenario.

3. Results and Discussion

MATLAB software was used in this paper to simulate a Downlink LTE system. It was done to test the proposed system performance over a multipath fading channel using a LTE-MIMO channel. The performance of Downlink LTE system was improved using RS coding technique for both of modulation types BPSK and QPSK. The system performance is presented by the curve of BER versus SNR.

The comparison of the system performance was done among each of un-coded, convolutional codes, turbo code and reed Solomon codes to show the improvements of BER for each case. Figure 2 shows the simulation results of RS-Downlink LTE system performance using BPSK over (2X2) LTE-MIMO channel against each of un-coded, convolutional codes, turbo code. It is clearly shows that the performance of un-coded system was the worst, while the performance began to improve after (8 dB) SNR using convolutional and turbo codes. The performance when using RS codes was the best compared with un-coded, convolutional and turbo codes for all values of SNR. Therefore, using RS codes with Downlink LTE system over (2X2) LTE-MIMO channel gave good coding gains and thus clearly improved system performance more than using both of convolutional and turbo codes with BPSK.

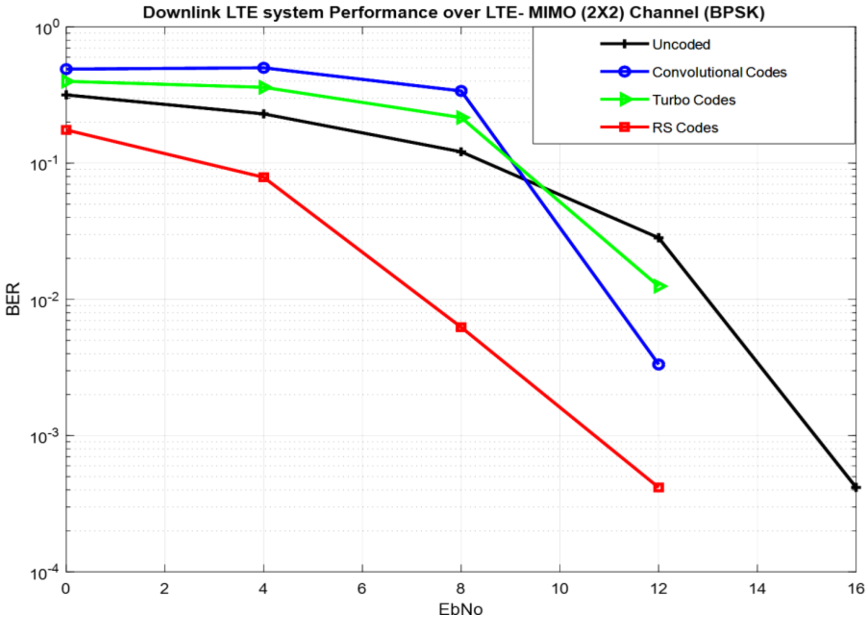

Figure 2. The Downlink LTE system performance over LTE-MIMO channel (BPSK)

Figure 3 shows the simulation results of RS- Downlink LTE system performance using QPSK over LTE-MIMO channel against each of un-coded, convolutional code, turbo code. The performance of the uncoded system was also the worst with a QPSK modulation scheme compared with using coding techniques. Then, the system performance improved starting after around 12dB by using both of convolutional and turbo codes. The best performance for each values of SNR compared with all of uncoded, convolutional and turbo codes was when using RS codes. Therefore, the Downlink LTE system performance over (2X2) LTE-MIMO channel clearly improved for both BPSK and QPSK modulation schemes compared with using both of convolutional or turbo codes, as shown in both of Figures 2 and 3.

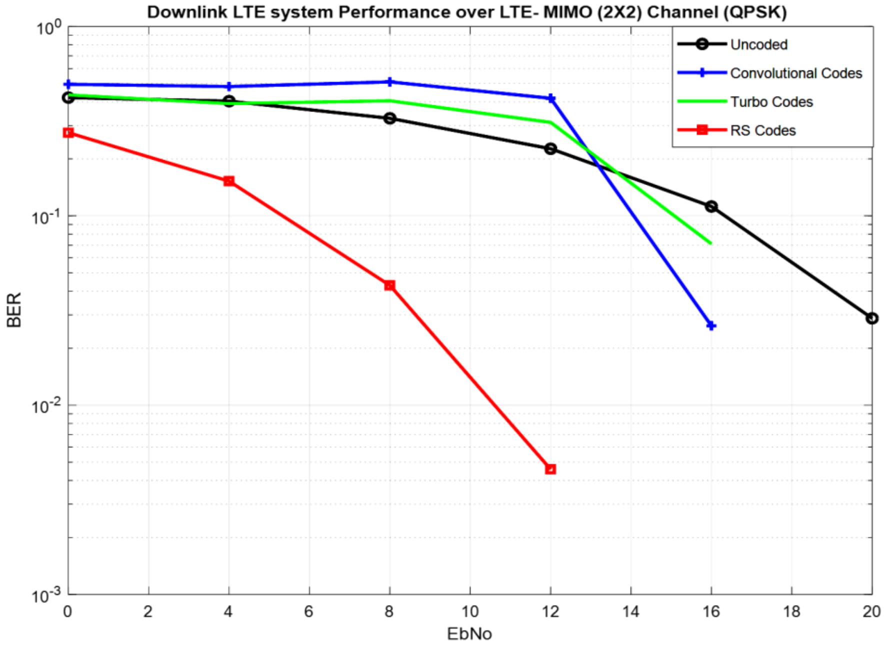

Figure 3. The Downlink LTE system performance over LTE-MIMO channel (QPSK)

Figure 4 shows a comparison of proposed system performance when using BPSK versus QPSK modulation schemes. The Downlink LTE system performance over (2X2) LTE-MIMO channel clearly improved more with BPSK than with QPSK modulation scheme for both uncoded and RS codes as shown in Figure 4. The coding gain achieved using RS codes with BPSK in the proposed system was around 4 dB at 10^{-2} compared with QPSK.

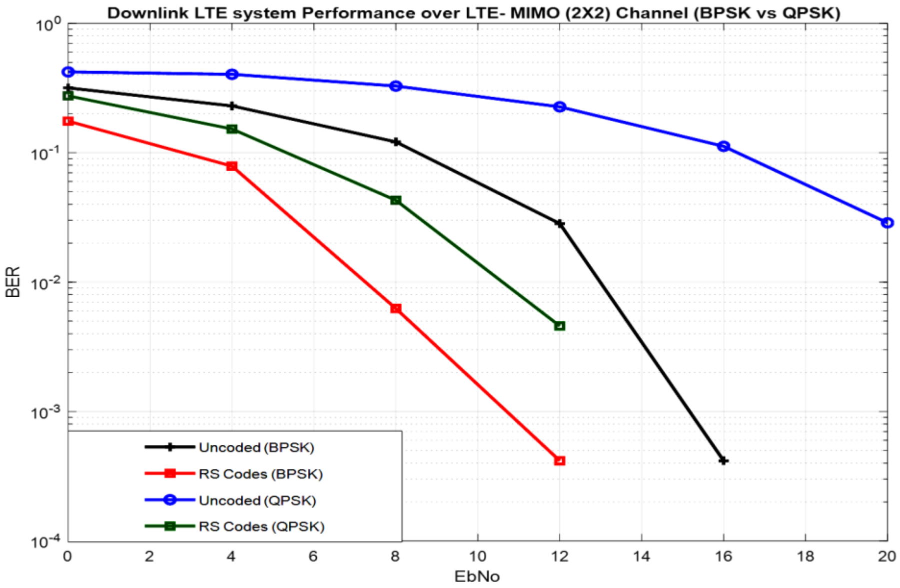

Figure 4. Comparison between Downlink LTE system performance over LTE-MIMO channel (QPSK versus BPSK)

Figure 5 shows the comparison between using (2X2) versus (4X4) MIMO channel for the proposed system. The comparison shows extra improvement using a (4X4) compared with using a (2X2) antennas MIMO system. Therefore, the Downlink LTE system performance was enhanced by increasing the number of antennas in the MIMO channel for both of BPSK and QPSK modulation schemes.

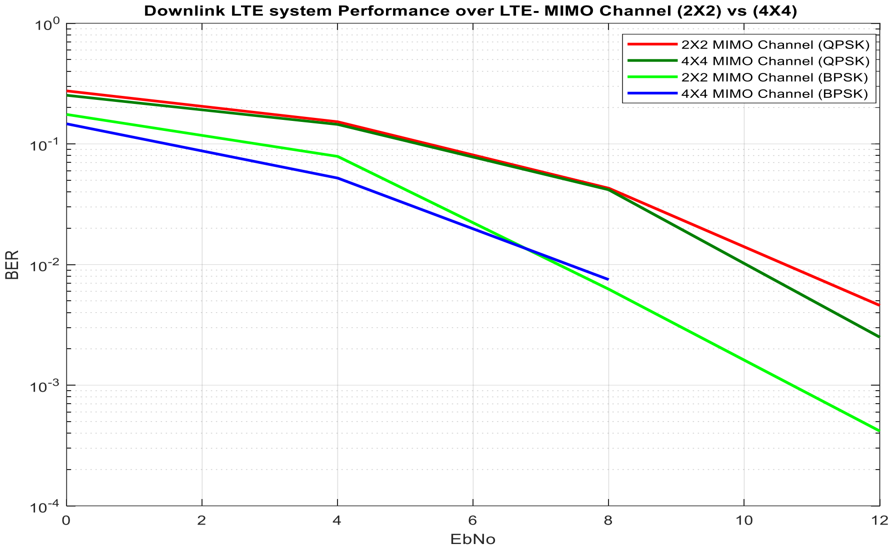

Figure 5. Downlink LTE system performance over LTE-MIMO channel

4. Conclusion

One of the important challenges facing wireless communication systems, including LTE, is controlling errors in transmission systems over multipath fading channels. The simulation of a Downlink LTE system performance over LTE-MIMO channel was carried out using Reed-Solomon (RS) codes. The combining of RS codes with a LTE-MIMO channel to improve the downlink LTE system performance is a novel contribution of this paper. A comparison between using RS codes and both of convolutional and turbo codes that already suggested in Downlink LTE system was presented in this paper. The results show an advantage of using RS codes compared with all of uncoded, convolutional and turbo codes in the proposed system's performance. On the other hand, the coding gain achieved in the proposed system using RS codes with BPSK was around 4 dB at 10^{-2} compared with QPSK. This research proves that Downlink LTE system performance is improving when utilizing RS codes and extra improvements can be gained by increase the number of antennas in the LTE-MIMO channel for both the BPSK and QPSK modulation schemes.

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References

[1] Members of 3GPP. *Technical Specification Group Radio Access Network; Physical Channels and Modulation (3GPP TS 36.211 Version 8.8.0).* 3GPP, *Tech. Spec*. 2009.

[2] Haustein T, Eichinger J, Zirwas W, Schulz E. *MIMO-OFDM for a Cellular Deployment-Concepts*. Real-Time Implementation and Measurements towards 3GPP-LTE. Presented at 15th European Signal Processing Conference (EUSIPCO 2007), Poznan, Poland. 2007: 3-7.

[3] Putra M, Perdana D, Negara R. Performance analysis of data traffic offload scheme on Long Term Evolution (LTE) and IEEE 802.11AH. *TELKOMNIKA Telecommunication Computing Electronics and Control.* 2017; 15(4): 1659-1665.

[4] Sirait F, Dani A, Pangaribowo T. Capacity Improvement and Protection of LTE Network on Ethernet Based Technique. *TELKOMNIKA Telecommunication Computing Electronics and Control.* 2018; 16(1): 200-209.

[5] Dixit S, Katiyar H. *Performance of OFDM in time selective Multipath fading channel in 4G Systems*. Presented at Fifth International Conference on Communication Systems and Network Technologies. 2015: 421-424.

[6] Salihah S, Jamaluddin M, Selvaraju R, Hafiz M. A MIMO H-shape Dielectric Resonator Antenna for 4G Applications. *Indonesian Journal of Electrical Engineering and Computer Science.* 2018; 10(2): 648-653.

[7] Haselmayr W, Schellander D, Springer A. *Iterative Channel Estimation and Turbo Equalization for Time-Varying Channels in a Coded OFDM-LTE System for 16-QAM and 64-QAM*. Presented at 21st International Symposium on Personal Indoor and Mobile Radio Communication, IEEE. 2010: 26-30.

[8] Gayathri S, Sabitha R. Resource Allocation in downlink of LTE using Bandwidth prediction through Statistical Information. *Indonesian Journal of Electrical Engineering and Computer Science*. 2018; 10(2): 680-686.

[9] Nee R, Prasad R. OFDM for Wireless Multimedia Communications. First edition. Artech House Publishers, Inc. Norwood, MA, USA. 2000: 48-49.

[10] Rugini L, Banelli P, Leus G. Simple Equalization of Time-Varying Channels for OFDM. *IEEE Communications Letters.* 2005; 9(7): 619-621.

[11] Schniter P. Low-Complexity Equalization of OFDM in Doubly Selective Channels. *IEEE Transactions on Signal Processing.* 2004; 52(4): 1002-1011.

[12] Anghel C, Paleologu C, Stanciu C. *Performances Evaluation of CTC Turbo Decoder for LTE Systems*. Presented at 57th International Symposium ELMAR, Zadar, Croatia. 2015: 28-30.

[13] Elwazan A, Zekry A, Zayed H. Matlab Code for LTE Convolutional Code and Viterbi Decoder. *International Journal of Engineering Research & Technology (IJERT)*. 2017; 6(3): 578- 581.

[14] Adiono T, Ramdani A, Putra R. Reversed-Trellis Tail-Biting Convolutional Code (RT-TBCC) Decoder Architecture Design for LTE. *International Journal of Electrical and Computer Engineering (IJECE).* 2018; 8(1): 198-209.

[15] Li-fu L, Hai-wen L, Hong-liang L, Yong-jun G. *Research and Implementation of Viterbi Decoding in TD-LTE System*. IEEE 2nd, Advanced Information Technology, Electronic and Automation Control Conference (IAEAC). 2017: 890-894.

[16] Chatzigeorgiou I, Demosthenous A, Rodrigues D, Wassell J. Performance-complexity tradeoff of convolutional codes for broadband fixed wireless access systems. *IEEE, IET Communications.* 2010; 4(4): 419-427.

[17] Wang J, Li J, Cai C. Two Novel Decoding Algorithms for Turbo Codes Based on Taylor Series in 3GPP LTE System. *TELKOMNIKA Indonesian Journal of Electrical Engineering.* 2014; 12(5): 3467-3475.

[18] Studer C, Benkeser C, Belfanti S, Huang Q. Design and Implementation of a Parallel Turbo-Decoder ASIC for 3GPP-LTE. *IEEE Journal of solid–state circuits*. 2011; 46(1): 8-17.

[19] Li A, Xiang L, Chen T, Maunder G, Al-Hashimi M, Hanzo L. VLSI Implementation of Fully Parallel LTE Turbo Decoders. *IEEE Journals & Magazines.* 2016; 4: 323-346.

[20] Mataveli O, Almeida C. Complexity Reduction of Convolutional and Turbo Decoding Based on Reliability Thresholds. *Springer, Wireless Personal Communications.* 2015; 82(3): 1279-1290.

[21] Ji W, Zhang W, Peng X, Liu Y. High-efficient Reed–Solomon decoder design using recursive Berlekamp–Massey architecture. *IEEE, IET Commun*. 2016; 10(4): 381-386.

[22] Reed I, Solomon G. Polynomial Codes Over Certain Finite Fields. *SIAM Journal of Applied Mathematics*. 1960; 8: 300-304.

[23] Sanghvi A, Mishra N, Waghmode R, Talele K. Performance of Reed-Solomon Codes in AWGN Channel. *International Journal of Electronics and Communication Engineering*. 2011; 4(3): 259-266.

[24] Al-Barrak A, Al-Sherbaz A, Kanakis T, Crockett R. *Utilisation of Multipath Phenomenon to Improve the Performance of BCH and RS Codes*. IEEE, 8th Computer Science and Electronic Engineering Conference (CEEC). 2016: 6-11.

[25] Moreira C, Farrell G. Essentials of Error-Control Coding. John Wiley & Sons Ltd, The Atrium, Southern Gate, Chichester, West Sussex PO19 8SQ, England. 2006.

[26] Han Y, Harliman P, Kim W, Kim K, Kim C. A Novel Architecture for Block Interleaving Algorithm in MB-OFDM Using Mixed Radix System. *IEEE Transactions on Very Large Scale Integration (VLSI) Systems.* 2010; 18(6): 1020-1024.

[27] Chen M, Xiao X, Li X, Yu J, Huang R, Li F, Chen L. Improved BER Performance of Real-Time DDO-OFDM Systems Using Interleaved Reed–Solomon Codes. *IEEE Photonics Technology Letters.* 2016; 28(9): 1014-1017.

[28] Sukar M, Pal M. SC-FDMA & OFDMA in LTE physical layer. *International Journal of Engineering Trends and Technology (IJETT).* 2014; 12(2): 74-85.

[29] Oestges C, Clerckx B. *MIMO Wireless Communications: From Real-World Propagation to Space-Time Code Design*, Academic Press. 2007.