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DEVELOPMENT OF ERROR CORRECTION MECHANISM BASED ON RCIC TURBO CODES IN LTE NETWORK

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Abstract: This paper describes an error correction mechanism based on Rate-Compatible Insertion Convolutional (RCIC) Turbo codes.Rate-compatible Turbo codes are part of numerous mobile communication systems (LTE). The code rate about the fixed-rate mother Turbo code is adjusted by bit repetition and bit puncturing. The given CRC bits are encoded with the help of RCIC encoder.Lower code rates can be created by introducing known (dummy) bits into the information bit sequence before Turbo coding. Then, the resultant bits are modulated and demodulated based on Quadrature Amplitude Modulation (QAM). The demodulated signal is interleaved and deinterleaved in order to correct the burst errors and it helps to reduce the complexity. Finally, the deinterleaved signal is decoded using Linear Block Codes (LBC), hamming codes and cyclic decoder. The experimental result shows that the proposed method results higher throughput than the existing RCIC encoder method.

Index Terms—Cyclic Decoder, Error Correction, Linear Block Codes (LBC), Hamming Codes, Rate-Compatible Insertion Convolutional (RCIC), and Quadrature Amplitude Modulation (QAM).

1. INTRODUCTION

In a communication system, data is transmitted from a sender to a receiver through the physical medium of transmission or wireless channel[1]. Usually, the channel wired or wireless is damaged by fading or noise, which leads errors in the data being transmitted from sender to receiver. The transmission of data through the particular channel has to be pre-defined with particular bandwidth and data rate for channel estimation[2]. During data transmission over a channel, errors are noticeable having depth as per prevalent conditions instantly. For correcting the errors, we have to use error control strategies. There are two major error control strategies accepted in communication systems:

1. Error correcting techniques
2. ARQ technique

Error correction techniques[3] helps the communication system designer to alleviate the effects of a noisy transmission channel. Error control coding has been extensively used in all types of wired and wireless communication systems[4]. To overcome these errors in data, a forward error correction coding can be used to improve the accuracy and efficiency of datacommunicated. If ‘n’ number of bits is to be sent, a Forward Error Correction (FEC)[5] system will append ‘k’ redundancy bits, hence totally, there are n+k bits are transmitted through the transmission channel. Such a redundancy will assist the receiver to identify any error within the received data. Based on the FEC algorithm, receiver can correct data without querying the sender for more information, this is why it is called FEC technique, which is shown in fig.1. Nowadays, there are severalFEC techniques amongst them turbo codes are more frequently used due to their simplicity and compatibility.

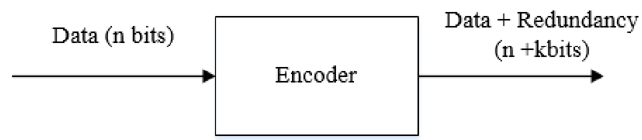

Fig.1 Forward Error Correction technique

Fundamentally, a Turbo code is anarrangement of several FEC components, frequently placed in parallel but sometimes in other schemes, for instance in serial or mixed. The idea is to have numerous FEC encoders that take the similar data pool as input but with bits ordered differently inside this data pool. To be more precise, it is a bit like if each FEC encoder had a different view angle of the data, therefore producing a different redundancy. At the contradictory, the decoding part uses the same number and types of FEC components, placed identically. As each decoder has its own view redundancy and angle of the data, one decoder may spot on some errors that other decoders won’t be able to correct and vice versa. For instance, this case is frequently encountered with burst errors. The key point of turbo code architecture is that each decoder sends its corrections to next decoder. The last decoder directs its corrections to the first one, involving an incremental and recursive correction process.

In this paper, an error correction mechanism is proposed and implemented based on RCIC encoder, QAM, LBC, hamming and cyclic decoder.The proposed algorithm is well-matched with all turbo codes, containing those of the LTE and WiMAX standards. These regular codes employ odd-even inter leavers, enabling a novel technique for decreasing the complexity of the proposed algorithm by 50%. More precisely, odd-even inter leavers allow the proposed algorithm to alternate between handling the odd- indexed bits of the initial component code at the similar time as the even-indexed bits of the second part, and vice-versa. Also, the proposed fully-parallel algorithm is shown to meetthe same error correction performance as the existing turbo decoding algorithm.

The rest of the paper is structured as follows. Section II presents a description about the previous research which is relevant to the error correction techniques in wireless communication. Section III involves the detailed description about the proposed method. Section IV presents the performance analysis and the comparative

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results. This paper concludes in Section V.

2. RELATED WORKS

Breddermann and Vary formulated a Rate Compatible Insertion Convolutional (RCIC) Turbo Codes which were known as dummy bits. The dummy bits were inserted into the information bit sequence at turbo encoding. It offers better apri knowledge to the mother decoder.A Hybrid Automatic Repeat request (HARQ) scheme for LTE based on the RCIC turbo codes was also presented to obtain higher throughput[6].*Breddermann and Vary*provided a hybrid ARQ scheme for UMTS LTE depends on insertion convolutional turbo codes. UMTS LTE performs a rate matching and HARQ was applied to deliver adequate performance above a wide range of channel conditions. The rate matching scheme was performed based on bit repetition and bit puncturing. UMTS LTE was realized based on the fixed rare convolutional turbo code. RCIC turbo codes proved considerable performance gains in systems without HARQ[7].

*Beermann et al*proposed a rate compatible Low Density Parity Check (LPDC) codes using optimized dummy bit insertion. This scheme addresses the problem of using one mother code and marching arbitrary code rates. It was lesser than the mother code rate by appending the bits into the information bit sequence prior encoding. A novel rule was presented to determine the enhanced positions of dummy bits inside the information bit sequence appropriate for LPDC codes [8].*Nistazakis et al* formulated an estimation of outage capacity for free space optical links over I-K and K turbulent channels. The performance was based on the atmospheric conditions in the link area. The closed form expressions for the calculation was also derived [9].*Fowdur et al* designed a modified asymmetric LTE turbo codes with reliability based on hybrid ARQ. The modified LTE turbo codes includes an asymmetric encoder and it uses a diverse channel reliability at iterative decoding. An adaptive extrinsic scaling factor was incorporated in the decoder to improve its performance and deliver a stopping criterion [10].

Heath et al designed a distributed antenna schemes for the downlink of cellular systems. The research trends in distributed antennas for the downlink of cellular systems were described. The fundamental observation were tightly integrated into the cellular architecture[11].*Kasai et al* introduced a quantum error correction beyond the bounded distance decoding limit [12]. *Han et al* presented a binary linear block codes based on their supercodes. It used the Viterbi algorithm backwardly to a trellis resulting from the parity-check matrix of the supercode of the linear block code [13]. *Song et al* proposed a hybrid maximum likelihood decoding for linear block codes. The convolutional and block codes were hugely used in digital communications. Word correction method can be applied to use the channel measurement information to decode the clock codes [14].*Chatterjee and Singh*presented the analysis of turbo coded OFDM performance in a frequency selective fading channel along with AWGN. The incorporation of powerful turbo code and OFDM could mitigate ISI and the additive noise at minimum SNR [15].

Breddermann et al proposed a new Hybrid Automatic Repeat request (HARQ) for offering adequate decoding performance over a conditions of wide channel range. This scheme was employed for LTE based on the RCIC turbo codes. By the integration of a low rate RCIC code and a low complexity ring buffer, the effort of performance and implementation was obtained well than the conventional HARQ scheme of LTE [7]. *Jego and Gross* introduced a novel simplification of the ABP algorithm for the turbo decoding of product codes via the BCH component codes. It has high degree of parallelism for high data rate applications and lower decoding complexity. This scheme necessitates fewer iterations than the traditional ABP algorithm [16]. *Stoian and Perisoara*presented a block turbo code, which was constructed by the extended hamming codes. Depending on the soft decoding and a soft decision of the component codes, these codes were further decoded using the block turbo decoder. This system provides the better unequal error detection, joint error detection, and error correction [17].

3. PROPOSED METHOD

The proposed algorithm is well-matched with all turbo codes, including those of the LTE and WiMAX standards. The flow of the proposed method is shown in fig.2.The CRC bits is given as the inputs to the RCIC encoder. It is further modulated and demodulated based on the Quadrature amplitude modulation (QAM) approach. Then, interleaving and deinterleaving process is carried out for error correction and reduce the complexity, which helps to solve the memory issues. Finally, decoding is applied based on the linear block code, hamming and cyclic decoding methods. The methods and algorithms used in the proposed method are explained in the following sections.

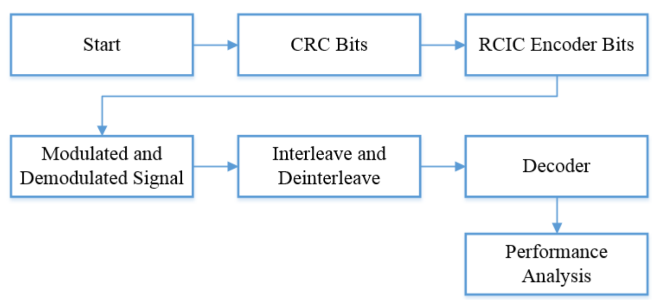

Fig.2 Flow of the proposed method

3.1 CRC BITS

Cyclic redundancy check (CRC) code provides a simple,yet powerful method for the detection of burst errors. It is an error detecting code.The CRC assisted rule relies on CRC checking at the end of each iteration. If the CRC checksum does not indicate errors, iterative decoding can be stopped. In terms of reducing the average decoding complexity, the CRC assisted rule can achieve.

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3.2 RCIC ENCODER

The framework for the RCIC encoder is shown in fig.3.

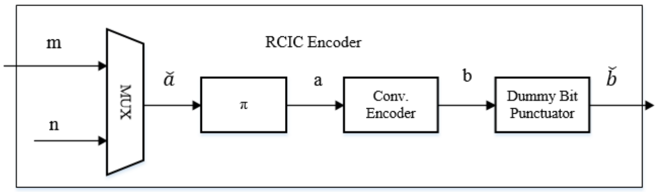

Fig.3 RCIC Encoder

The multiplexed vector$\breve{a} = [m, n]$, containing the information bits m and the dummy bits n = ($n_1,\ldots,n_l,\ldots,n_{ln}$), which is interleaved by a bit interleaver π. This interleaver allocates the information bits into the positions$i$ and the dummy bits to the remaining places in a.

$$i = round\left((k-1).\frac{l_m + l_n}{l_m}\right) + 1 \quad (1)$$

The *round (.)* operator rounds the corresponding argument to the nearby integer value. This step guarantees an equidistant spacing of dummy bots within the interleaved data frame *a*for cases:$\frac{l_a}{l_n} \in$ N and for all other cases, there is at least homogenous distribution.

Subsequently, the convolutional codes are present a robust dependencies among the neighboring bits. The information given by the dummy bits are homogeneously distributed over the complete frame. Therefore, this is a suitable choice for Equal Error Protection (EEP). The output sequence a = ($a_1,\ldots,a_l,\ldots,a_{la}$) of length $l_a = l_m + l_n$ is later encoded by a convolutional encoder with the code rate C_R. It results the output vector b = ($b_1,\ldots,b_n,\ldots,b_{lb}$) of length:

$$l_b = l_a.C_R^{-1} \quad (2)$$

If RCIC code is systematic,puncturing can be achieved to eliminate all organized dummy bits. The code rate of RCIC code is given as follows:

$$C_S = \begin{cases} \frac{l_a - l_n}{l_b} : non - syst. RCIC\ code \\ \frac{l_a - l_n}{l_b - l_n} : systematic\ RCIC\ code \end{cases} \quad (3)$$

Since $C_S \leq C_R$, this method is a substitute for bit repetition.

3.3 MODULATION AND DEMODULATION: QAM

In digital modulation techniques, an analog carrier signal is modulated with the help of binary code. The digital modulator device can act as an interface between the channel and the transmitter. The modulation schemes can be characterized based on their detection characteristics or based on their bandwidth compaction features. The fundamental measures for best modulation techniques depends on their Bit Error Rate (BER), Signal to Noise Ratio (SNR) and available Bandwidth. The Quadrature Amplitude Modulation (QAM) is a modulation technique where its amplitude is permitted to vary with phase. This method can be observed as an integration of Amplitude Shift Keying (ASK) as well as Phase Shift Keying (PSK). It is greatly applied in many digital data communication applications, where data rates away from 8-PSK are required through a radio communication system then QAM modulation scheme is extensively used because QAM achieves a higher distance among the adjacent points in the I-Q plane by allocating the points are more distinct and data errors are reduced. The QAM modulation is more beneficial and effective than the others and is practically applicable for all the advanced modems. The proposed method uses the QAM modulation for modulation and demodulation of signals. It will double the effective bandwidth. It conveys two analog signals or two digital bit streams.Demodulation is used to recover the information from modulation.

3.4 INTERLEAVE AND DEINTERLEAVE

Interleaving is a forward error correction technique and it is more robust with burst errors. It is used for improving the speed of access to memory and moreover it reduces the coefficient of polynomials. Interleaving is a high level technique for solving memory issues. Deinterleave mainly used to prevent the burst errors and mainly it reduces the complexity.

3.5 DECODING BASED ON LINEAR BLOCK CODE, HAMMING AND CYCLIC

In the proposed method, the final decoding process consists of three methods:

- Linear Block Code
- Hamming and
- Cyclic approach

3.5.1 Linear Block Code

Linear block code is the error correcting code and it is more efficient for decoding algorithms than other code. A linear block code that works over relatively small block sizes to protect a packet or message made up of a much larger number of bits. The conversion in a linear block code involves only linear operations over the message bits to produce code words. In linear block code, it divide a packet into one or more blocks and protect each block using an error correction code.

Let us consider the communication of binary elements (0, 1) coded by a linear block code E with the parameters (x,y,j) on Gaussian channel based on symbols {-1, +1}. Then, consider the following mapping of the symbols 0 → -1 and 1 →+1. The observation O = ($o_1,\ldots,o_l,\ldots,o_x$) at the result of the Gaussian channel for the transmitted code word T = ($t_1,\ldots,t_l,\ldots,t_x$) is given as follows:

$$O = T + H \quad (4)$$

Where, components h_l of H = ($h_1,\ldots,h_l,\ldots,h_x$) are additive white Gaussian noise samples of σ.The optimum decision F = ($F_1,\ldots,F_l,\ldots,F_x$) corresponding to the transmitted code word T is given as follows:

$$I = G^i \ if \left|O - G^i\right|^2 \leq \ |O - G^l|^2 \quad \forall l \in [1, 2^y], l \neq i \quad (5)$$

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Where, $G^i = (g_1^i, \dots, g_l^i, \dots, g_n^i)$ is the ith codeword of G and

$$\left|O - G^i\right|^2 = \sum_{l=1}^{x}(o_l - G_l^i)^2 \quad (6)$$

The above equation is the squared distance between O and G^i.

The procedure used to identify the set of the most probable code words are discussed as follows:

1: Calculate the position of p = [j/2] least dependable binary elements W using O.

2: For test patterns Z^q defined for all n-dimensional binary vectors with the single element '1' in the least dependable positions and '0' in the other positions, two '1's in the least dependable positions and '0' in the other positions up to p in the least positions and '0' in the other positions.

3: Form test sequences $V^q$where $v_l^q = w_l \oplus z_l^q$ and decode V^q using an algebraic decoder and append the code word $G^q$to subset Ω.

3.5.2 Hamming Code

Hamming codes can notice up to two-bit errors or spot on one-bit errors without revealing of uncorrected errors. By the Hamming algorithm, we can detect and correct the single bit errors in this code word. Hamming codes are the codewords formed by adding redundancy check bits or parity bits.The Hamming distance between two code words is the number of bits in which two code words differ.This pair of bytes has a Hamming distance of 3:

1 0 0 0 1 0 0 1

1 0 1 1 0 0 0 1

Hamming codes are useful in correcting burst errors that occur when a series of adjacent bits are damaged.Hamming Codes are still widely used in telecommunication, and other applications.

3.5.3 Cyclic Code

Cyclic code is an efficient error correction and detection code.Cyclic codes are of interest and importance due to the nature of rich algebraic structure that can be utilized in a range of ways. They have tremendously concise specifications. They can be efficiently executed using simple Shift registers. Cyclic codes improves the decoding speed by reducing the computational complexity. Cyclic codes are equivalent to hamming codes.

4. PERFORMANCE ANALYSIS

In this section, the performance of the proposed method is evaluated and the resultant output is compared with the existing method[8]. In order to show the efficiency of the proposed method, the throughput is analyzed for the proposed and the existing method.The input message bits are shown in fig.4, and their corresponding CRC bits are shown in fig.5.

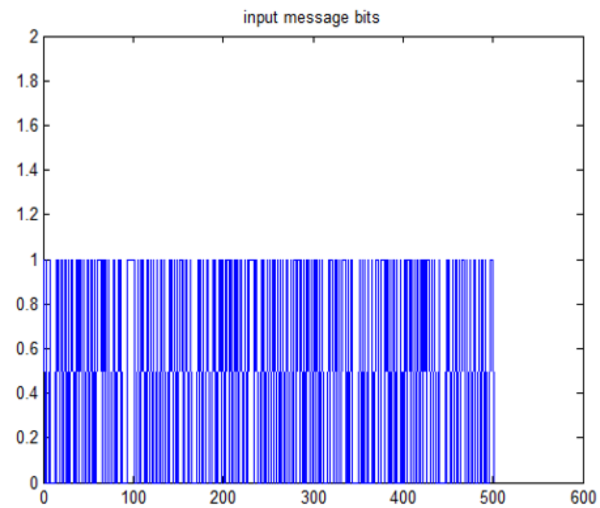

Fig.4. Visualization of input message bits

Specifically,CRCs are designed to guard against mutual types of errors on communication channels, where they can deliver reasonable and quick declaration of the integrity of messages delivered. However, they are not appropriate for protecting against intentional modification of data. To calculate n-bit binary CRC, the line bits denotes the input in a row, and position the (n + 1)bit pattern denotes the CRC's divisor below the left-hand end of the row.

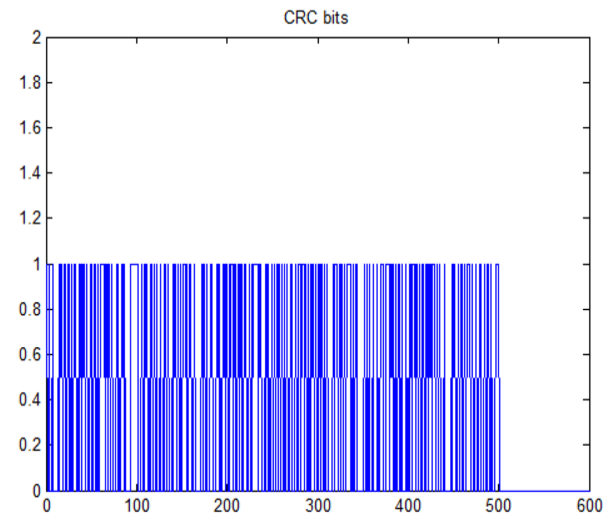

Fig.5. Visualization of CRC bits

The RCIC encoded bits are shown in fig.6. Here, the encoded bits are ranges between -1 to 1. It is further need to modulated and demodulate based on the QAM technique.

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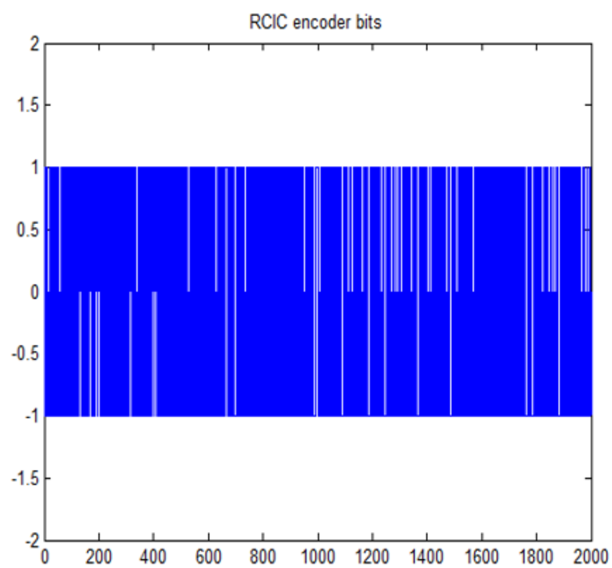
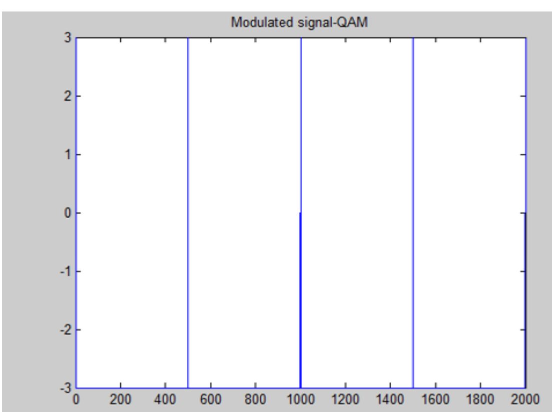


Fig.6. Visualization of RCIC Encoder Bits

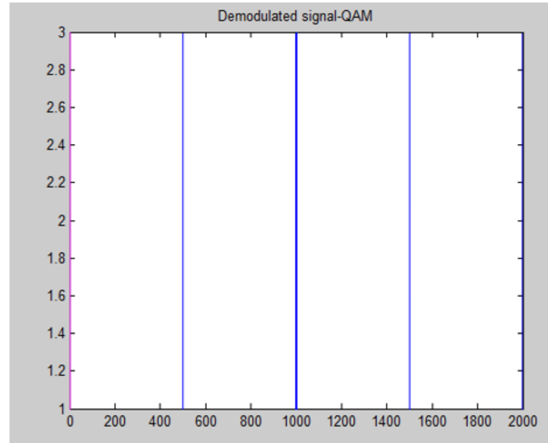
4.1 MODULATED AND DEMODULATED SIGNALS

Modulation is a process of intercourse a signal with a sinusoid to generate a new signal. This new signal, possiblyhave certain assistances over an un-modulated signal, particularly at the time of data transmission. The proposed method uses the QAM technique to modulate the signal which is shown in fig.6. (a).

Demodulation is the process of extracting the original signal behavior from a modulated carrier wave. It is a computer program or electronic circuit in a software defined radio that is utilized to recover the content from the modulated carrier wave. The demodulate signal for the proposed method is shown in fig.7. (b).



(a)

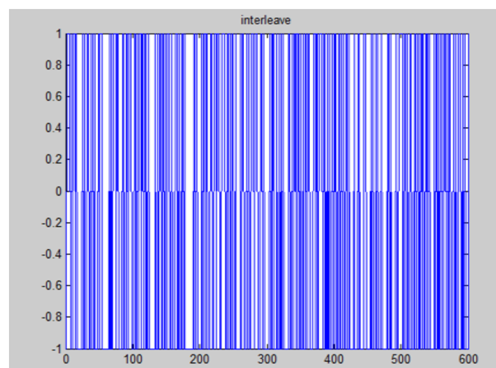


(b)

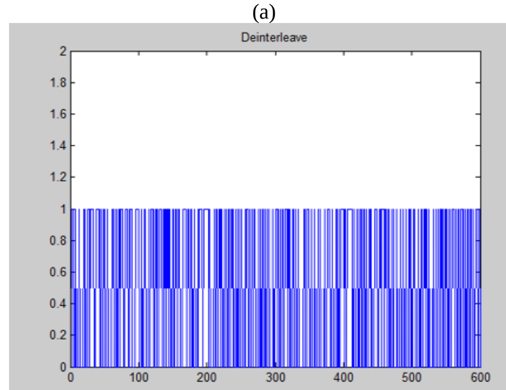
Fig.7. (a) Modulated Signal (b) Demodulated Signal

4.2 INTERLEAVING AND DEINTERLEAVING

Interleaving is applied on the demodulated signal for constructing forward error correction more robust with respect to burst errors. Deinterleaving is the reversible process of interleaving. Fig.8 shows the result of the interleaving and deinterleaving signal.



(a)



(b)

Fig.8 (a) Interleaving (b) Deinterleaving

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4.3 DECODED SIGNAL BASED ON LINEAR BLOCK CODES, HAMMING AND CYCLIC

Finally, the signals are decoded and the system results the message bits. The resultant signal is shown in the following fig.9. The proposed method results better error correction, which helps to reduce the complexity of the system.

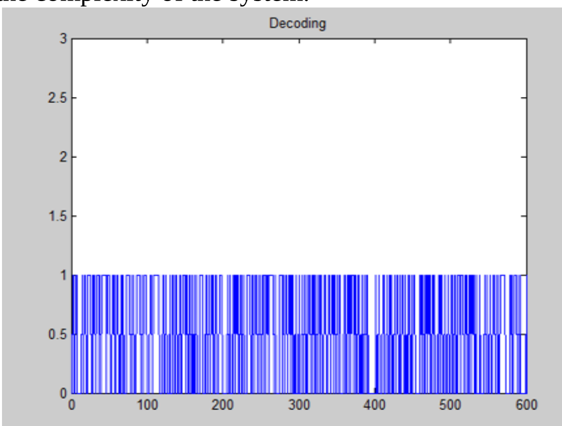

Fig.9. Decoded Signal

4.4 THROUGHPUT ANALYSIS

Throughput is the average rate of successful message delivery over a communication channel. Throughput improves on-time delivery and increases the flexibility and moreover it reduces the process delay and wait time. A wide range of channel conditions is covered by both systems; the complete SNR range is divided into a lower SNR range and a higher SNR range. The Shannon bound is also depicted in both figures as reference (dash dotted lines). In the AWGN environment, dummy bit insertion is most effective in the lower SNR range. So far, it has been assumed that the transmitter receives perfect Channel State Information (CSI) to make a decision for the optimal MCS mode. However, this cannot be guaranteed in "real-world" scenarios. If the CSI is inaccurately estimated or outdated, decoding may fail more frequently resulting in an increased number of additional HARQ transmissions. Fig. 10 shows the throughput analysis of the proposed method.

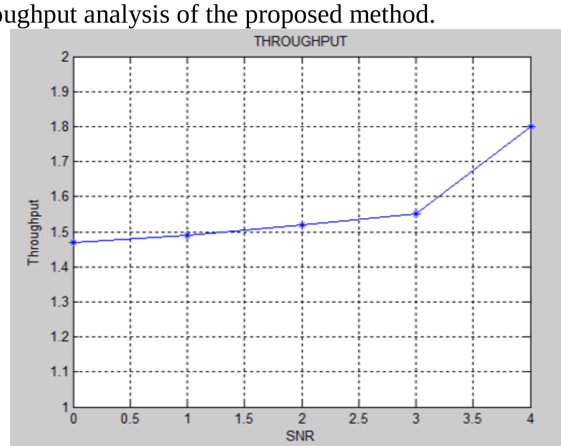

Fig.10. Throughput analysis

Table 1 shows the comparative throughput analysis of the proposed method in terms of SNR.

Table 1 Throughput analysis

SNR	Proposed Throughput	Existing Throughput
0.27	1.49	1.26
0.29	1.50	1.28
0.42	1.52	1.30
0.43	1.55	1.32
0.44	1.8	1.36

5. CONCLUSION

This paper proposed an error correction mechanism for correcting the error bits on the message transmitted in wireless communications. The proposed method uses the RCIC encoder to encode the input CRC bits. It is modulated and demodulated with the help of QAM approach due to its better performance. Interleaving and deinterleaving process helps to reduce the complexity and errors on the input message. Hence, the memory complexity also reduced. Finally, the combination of three decoding codes such as Linear Block Code (LBC), Hamming and cyclic codes decodes the signal. The final output results higher throughput and provides improved performance in terms of SNR.

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