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PERFORMANCE ANALYSIS OF REED-SOLOMON CODES IN DIGITAL COMMUNICATION SYSTEM USING LABVIEW

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Abstract

5G uses various types of access networks and has a high frequency spectrum. At present, there are no mobile handsets that support all spectrum ranges due to limitations of hardware and the expenses involved in the process. This challenge can be addressed with the help of Software Defined Radio (SDR). Universal Software Radio Peripheral (USRP) is a range of software-defined radios and most USRPs connect to a host computer through a high-speed link, which the host-based software uses to control the USRP hardware and transmit/receive data. In general, error occurs during data transmission through different communication channel. These errors can be corrected using Forward Error Correction (FEC) techniques. In this paper, an error correction code named as Reed-Solomon (RS) code, which is suitable for correcting burst error is presented. Further, a Simulation module in LabVIEW for RS Codes using MSK modulation scheme through AWGN channel is presented and its Bit Error Rate (BER) performance for codes such as RS (32,16), RS (127,111) and RS (255,239) are evaluated.

Keywords:

AWGN, BER, FEC, LabVIEW, Modulation, RS Code, SDR, SNR

1. INTRODUCTION

Communication has got many applications that encode the messages into the communication channel and then decode it at the receiver's end. During the transfer of message, the data might get corrupted due to lots of disturbances in the communication channel. This necessitates the need for an error detection and correction method.

In Forward error correction (FEC) approach [1], error is both detected and corrected at the receiver's end. Error correcting codes for forward error corrections can be broadly categorized into two types, namely, block codes and convolution codes. The message is divided into fixed-sized blocks of bits to which redundant bits are added for error correction in Block codes. Whereas, the message comprising of data streams of arbitrary length and parity symbols are generated by the sliding application of a Boolean function to the data stream in convolutional codes [2]. Reed-Solomon code is one of the type of block codes and is a subset of BCH codes. Reed Solomon code has very high coding rate and low complexity. Hence it is suitable for many applications including storage and transmission.

There are many other challenges to address other than error correction when we move towards 5G standard which demands much higher data rate, ultra-low latency, high reliability and security. LTE advanced has already been deployed all over the world. 5G technology requires a new standard to support ultrafast, low latency services to customers [3].

1.1 OVERVIEW OF SDR AND LABVIEW

SDR system is based upon a programmable dedicated hardware and associated control software. It enhances the functionality by means of software that would automatically reconfigure the radio parameters and interact with the network using it [4]. The NI USRP (Universal Software Radio Hardware) connects to a host PC to act as a software-defined radio. For high performance wireless communication systems, USRP provides an integrated hardware and software solution for rapid prototyping.

Laboratory Virtual Instrument Engineering Workbench (LabVIEW) [5] is a development environment for a visual programming language and is a system design platform. Graphical Programming module has three components- block diagram, front panel, connector pane. The block diagram contains structures and functions which perform operations on controls, and supply data to indicators. The front panel is built using controls as input and indicators as output. The connector pane defines the inputs and outputs wired to the VI so that it can be used as a sub VI.

2. CONCEPT MAPPING

The information source generates the output, which is the data to be communicated. In other words, it produces the messages to be transmitted to the receiver/destination. When a digital source is transmitting a message, it is in the form of sequences of symbols. The transmitter takes the source data as input and produces an associated signal suited for the channel. It ensures a reliable transmission across the noisy channel. This is typically done by adding structured redundancy in the message and through encryption, which hides or scrambles the message to prevent its real information content from being discerned by unintended listeners. Modulation increases the strength of a signal without changing the parameters of the original signal. The channel is the medium used to transmit the signal from the source to the destination as shown in Fig.1.The receiver ordinarily performs the inverse operation done by the transmitter. It reconstructs the original message from the received signal. The destination is the system or person for whom the message is intended.

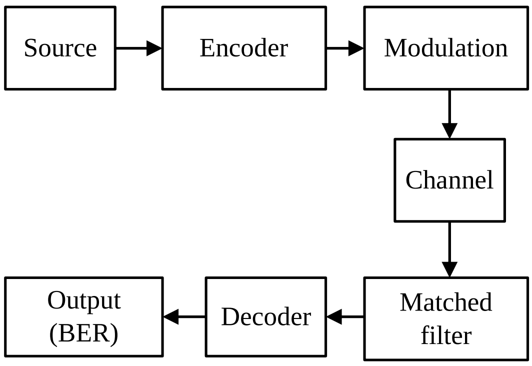

Fig.1. Block diagram of Communication system

3. LITERATURE SURVEY

In an error-prone data transmission environment, the Bit Error Rate (BER) achieved is less. Such systems need a forward error correction (FEC) block which consists of the RS encoder/decoder and the convolutional interleaver/deinterleaver [5]. RS Encoder and Decoder play an important role in improving the BER performance of the system. In the conventional RS Decoder, errors are detected and corrected. To improve the RS decoder's capability of correcting both errors and erasures, the bursty error characteristic of the convolutional deinterleaver that is located before the RS decoder can be exploited to predict the location of erasures in advance.

4. REED-SOLOMON CODES

Every error detection and correction code has primary characteristics such as code length, dimension and minimum distance. The code length n, represents the number of symbols per code word. The dimension of the code k, represents the number of actual information symbols transmitted in one code word. The minimum distance is the minimum number of symbol differences between code words [6].

They have linear and cyclic characteristics. Linearity is the property of an already constructed code word to form a new code word. The cyclic characteristic is seen as the ability to produce a new code word by cyclically shifting the symbols of a given code word.

Reed-Solomon codes are suited for detecting and correcting burst data errors. If a symbol has error in more than one bit, that error still counts as one symbol error that can be corrected and this shows that Reed-Solomon codes can correct many bit errors.

4.1 RS ENCODER

Reed Solomon codes are specified as RS(n,k) with s-bit symbols. The process of encoding a message consists of dividing the message which needs to be transmitted into sub-messages of specified length. Then, parity protection information is added to the end of each sub-message, thus forming one block of specified length as shown in Fig.2(a).

The encoder takes k data symbols of s bits each and adds parity symbols to make an n symbol code word. There are n-k parity symbols of s bits each. A Reed-Solomon decoder can correct up to t symbols that contain errors in a code word, where $2t=n-k$.

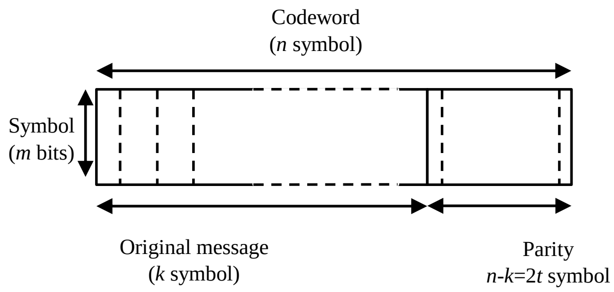

Fig.2(a). RS Encoder

4.2 GALOIS FIELD

Finite field or Galois Field (GF) is an algebraic theory and is very important in coding theory. The Reed-Solomon codes studied in this paper are based on finite fields. If the number of elements on a field F is finite, this field is called a finite field, or a Galois Field. The number of elements is called the order of the field.

Galois field consists of elements that are generated from a primitive element, which is usually denoted by α [8]. For a given primitive element α Field Elements takes values: 0, α_0, α_1, α_2,..., α_{N-1}, where $N = 2^{m-1}$.

GF elements can be represented in the polynomial expression of form:

$$a_{m-1}x^{m-1}+\ldots+a_2x^2+a_1x^1+a_0 \quad (1)$$

where $a_{m-1},...,a_1a_0$ take the values 0 or 1 i.e. polynomial representation of a GF element is nothing but the binary number a_{m-1}, $a_{m-2},...,a_1a_0$. This representation of GF element helps to describe the addition and subtraction operation among GF elements.

4.3 RS DECODER

Reed Solomon decoder considers the incoming message as a polynomial $R(x)$, the transmitted message as $T(x)$, and the error introduced as polynomial $E(x)$ [7]. i.e.

$$R(X) = T(x) + E(x)$$

Now the decoder's task is to identify the $E(x)$ so that $T(x)$ can be calculated as,

$$T(X) = R(x) + E(x)$$

4.4 SYNDROME CALCULATOR

The transmitted code word is always divisible by the generator polynomial without remainder, and this property extends to the individual factors of the generator polynomial. Therefore,

1) Divide the received polynomial by each of the factors $(x+\alpha^i)$ of the generator polynomial.

$$S_i = \mathrm{R}(\alpha^i) = R_{n-1}(\alpha^i)^{n-1} + R_{n-2}(\alpha^i)^{n-2}+....+R_1\alpha^i+R_0 \quad (3)$$

where, coefficients R_{n-1} ... R_0 are the symbols of the received code word.

2) The syndrome values can be obtained by substituting $x = \alpha_i$ in the received polynomial, as an alternative to the division of $R(x)$ by $(x+\alpha_i)$ to form the remainder.

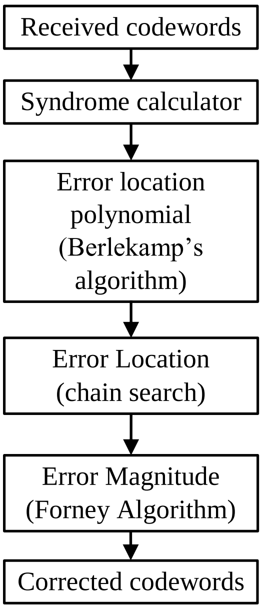

Fig.2(b). RS Decoder

4.5 BERLEKAMP ALGORITHM

The Berlekamp-Massey (B-M) algorithm is a method used as decoding algorithm for RS and BCH codes as follows:

1) To calculate the coefficients of the error locator polynomial for the error locations, and the coefficients of the error evaluator polynomial for the error values.
2) The values of the errors are binary so we only calculate the coefficients of the error locator polynomial. The error locator polynomial $\sigma(X)$ presents the locations of the error.

4.6 CHAIN SEARCH ALGORITHM

After getting the error locator and evaluator polynomials from the decoding algorithm, we need to find the roots of the error location polynomial $\sigma(X)$, which present the inverse of the error locations. There is no closed form solution for solving the roots of $\sigma(X)$ [9]. Since the root has to be one of the elements of the field $GF(2^m)$, we search for the roots by substituting each of the finite field elements in the error location polynomial $\sigma(X)$ and checking for the following condition:

$$\sigma(\alpha^i) = 0$$

1) If this condition is satisfied, it indicates that an error has occurred in the inverse position of i, i.e. in position $(n-i)$.
2) If this condition is not satisfied, it means that there is no error.

4.7 FORNEY ALGORITHM

The final stage in decoding algorithm is to calculate the value of the errors. To calculate the error value, there are two popular methods, the first one is "transform decoding process" in the frequency domain and the second one is Forney algorithm in the time domain. Forney algorithm is preferred because of its lower circuit complexity.

5. LABVIEW IMPLEMENTATION

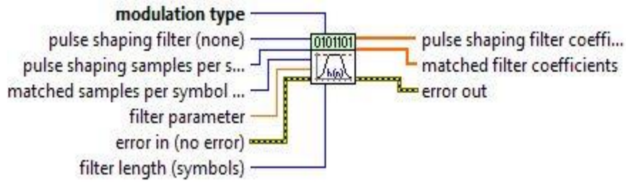

Fig.3. Filter coefficients

It calculates filter coefficients for pulse-shaping and matched filters.

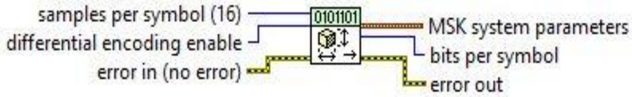

Fig.4. Generates system parameters

It is used to generate the symbol map for modulated systems and it accepts an array of symbol values that explicitly specifies the positions of the symbol map.

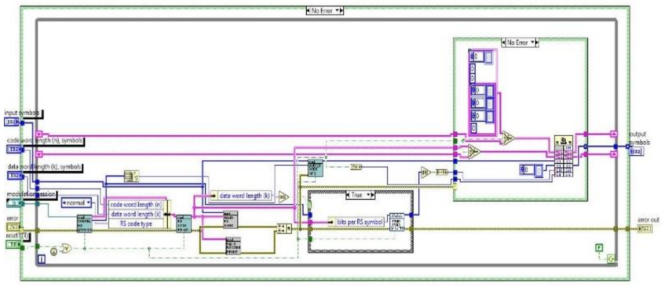

Fig.5. RS Encoder

It generates a normal or shortened Reed-Solomon (RS) encoded integer symbol stream.

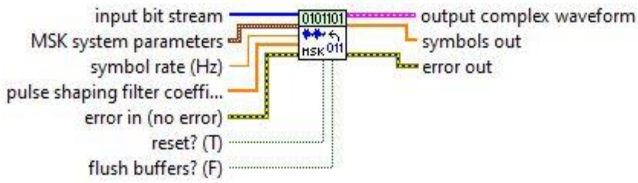

Fig.6. MSK modulation

It receives a sequence of data bits, performs MSK modulation, and returns the modulated complex baseband waveform in the output complex waveform parameter [10].

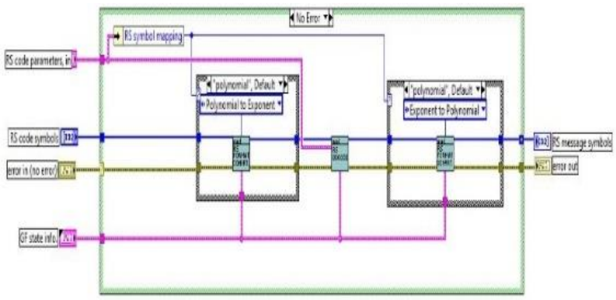

Fig.7. RS Decoder

It decodes a normal or shortened Reed-Solomon (RS) encoded integer symbol stream.

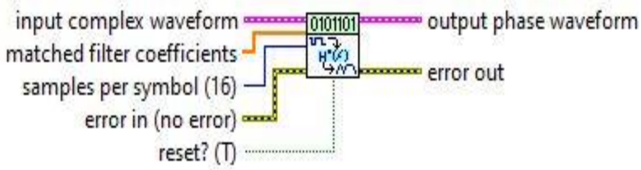

Fig.8. Matched filter

This applies specified matched-filter coefficients to the input complex I/Q baseband waveform [11]. It returns the matched filtered output with a duration equal to an integer number of symbols, thus ensuring continuality from one iteration to the next.

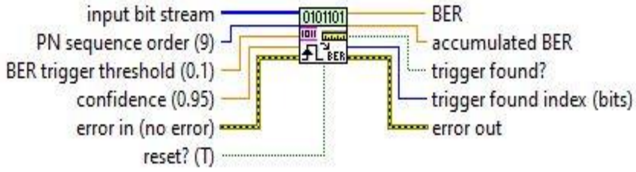

Fig.9. BER Calculator

It calculates the average bit error rate (BER) against a PN sequence or a reference bit pattern.

6. SIMULATION SCENARIO

Table.1. Simulation Scenario

Parameters	Values
Modulation type	MSK
Symbol rate	1MHz
Samples per symbol	4
PN sequence order	19
Maximum iterations	100

In Fig.10 and Fig.11, white and red coloured lines indicate the variation in BER with respect to E_b/N_0 values ranging from 5 to 9dB with no coding and RS coding respectively. The plot shows that for lesser E_b/N_0 values BER is high, and that as the E_b/N_0 values increase the BER decreases. In the case of coded bit streams, BER results to zero for lesser E_b/N_0 values.

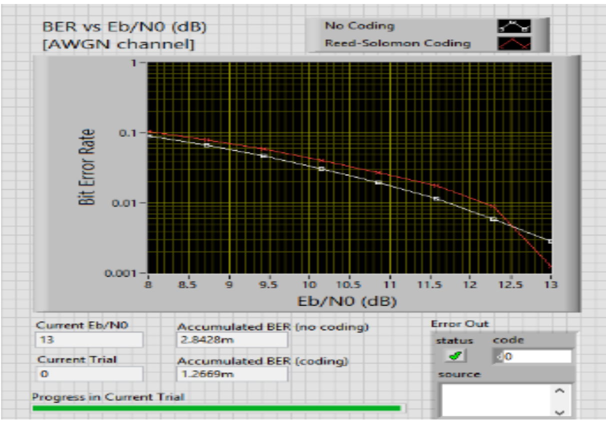

Fig.10. BER of RS(32,16)

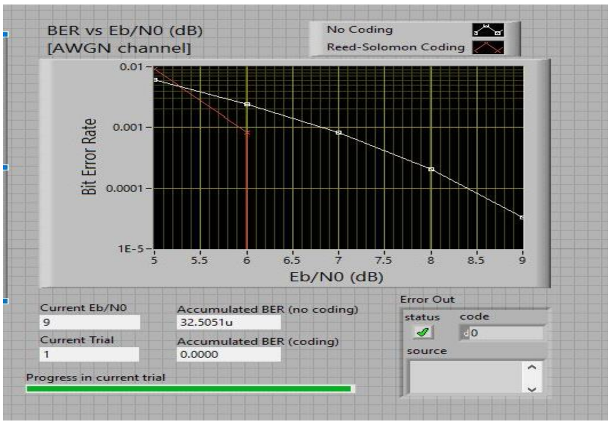

Fig.11. BER graph of RS(127,111)

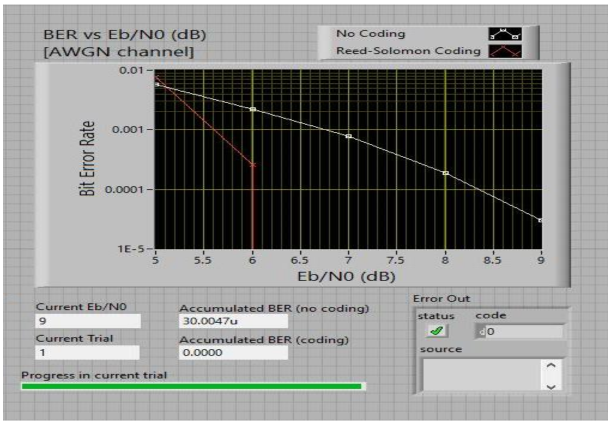

Fig.12. BER of RS (255,239)

Table.2. BER comparison

E_b/N_0	RS(127,111)	RS(255,239)
5	10^{-2}	$8*10^{-3}$
5.2	$6*10^{-3}$	$4*10^{-3}$
5.4	$3*10^{-3}$	$2*10^{-3}$
5.5	$2*10^{-3}$	$0.5*10^{-3}$
5.8	$0.5*10^{-3}$	$6*10^{-4}$

Constellation diagram used to examine the modulation in signal space.

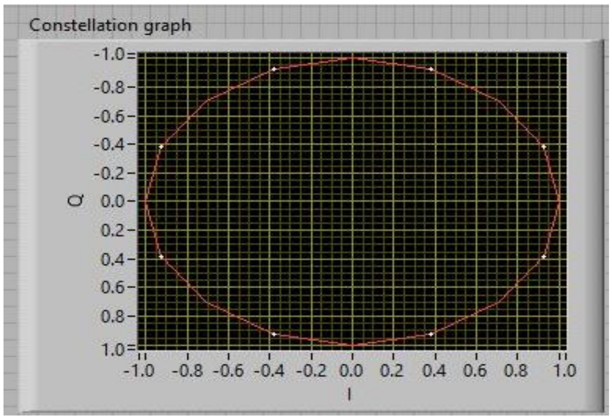

Fig.13. Constellation graph

7. INFERENCE

The values of *n* and *k* are getting higher, but are maintaining the same error correction capability (*t*=8); and the error performance of RS algebraic decoding for (32,16), (127,111,8) and (255,239,8) with MSK system over AWGN channels is shown in the red line.

When E_b/N_0 of the codes (127,111) and (255,239) are 5.5dB, the BER varies as $3*10^{-3}$ for RS (127,111,8) and $0.5*10^{-3}$ for RS (255,239,8).

Table.2 indicates that as the codeword length ‘*n*’ increases, BER decreases as shown in Fig.10, Fig.11 and Fig.12 [9]. It also shows the BER variation for coded and uncoded systems. It indicates that the BER is high for uncoded systems in comparison to the coded systems.

8. CONCLUSION

The RS codes are used for correction of burst errors in digital communication systems. It is established that the RS codes given in the paper are able to correct 8 symbols with errors. In the case of AWGN, bit errors happen randomly. Hence, it cannot be fully corrected for large number of n values. In the future, it will be implemented in USRP 2954R and the Bit Error Rate for RS codes could be obtained in real time.

REFERENCES

[1] Z. Yuan and X. Zhao, “Introduction to Forward Error Correction and its Application”, *Proceedings of 2nd International Conference on Consumer Electronics, Communications and Networks*, pp. 1-7, 2012.

[2] W.W. Peterson and E.J. Weldon, “*Error Correcting Codes*”, 2nd Edition, MIT Press, 1972.

[3] B. Sklar and F.J. Harris, “*Digital Communications-Fundamentals and Applications*”, Prentice Hall, 1998.

[4] Frederic J. Harris, “Software Defined Radio”, *Proceedings of International Conference on Signals and Electronic Systems*, pp. 321-338, 2008.

[5] K. Kyungsu, O. Ilhyuk, K. Dongkuk and J. Byung Gi, “Improving Performance of Reed-Solomon Decoder by Error/Erasure Correction”, *Proceedings of International Symposium on Signal Processing and Information Technology*, pp. 444-457, 2011.

[6] W. Zhan, J.R. Porter and J.A. Morgan, “Experiential Learning of Digital Communication using LabVIEW”, *IEEE Transactions on Education*, Vol. 57, No. 1, pp. 34-41, 2014.

[7] S.B. Wicker and V.K. Bhargava, “*Reed-Solomon Codes and Their Application*”, IEEE Press, 1983.

[8] F.J. Mac Williams and N.J.A. Sloane, “*The Theory of Error Correcting Codes, Part I*”, North-Holland Publishing Company, 1977.

[9] K. Satyanarayana Reddy and S. Neethu, “Analysis and Implementation of Reed-Solomon Codes for Forward Error Correction using LabVIEW”, *International Research Journal of Engineering and Technology*, Vol. 3, No. 12, pp. 1057-1065, 2016.

[10] D.S. Suresh, K.P. Vidyarani, R. Sekar and D.V. Shalini, “Implementation of Digital Modulation Scheme using LabVIEW: An Easy and Interactive Approach”, *Proceedings of International Conference on Power, Controls, Signals and Instrumentation Engineering*, pp. 1-6, 2017.

[11] Cathy Y. Liu and Shu Lin, “Turbo Encoding and Decoding of Reed-Solomon Codes through Binary Decomposition and Self-Concatenation”, *IEEE Transactions on Communications*, Vol. 52, No. 9, pp. 1484-1493, 2004.

[12] C.K.P. Clarke, “Reed Solomon Error Correction”, White Paper, Research and Development, British Broadcasting Corporation, pp. 1-47, 2002.