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BER Analysis of Reed-Solomon Codes using M-Ary FSK Modulation in the Presence of AWGN Channel

Rashmi, Satnam Singh, Raminder Preet Pal Singh

Abstract*: The main aim of this paper is to analyze the Bit error rate performance by using Reed Solomon codes in the presence of noisy channel i.e. (Additive White Gaussian Noise. In this paper, (16, 32, 64) FSK (Frequency Shift Keying) modulation is used for simulation of coded communication system. For simulation, we use MATLAB/SIMULINK as a tool to calculate BER rate using Monte Carlo method. The forward error correction technique is used to detect and correct errors received from AWGN Noise channel. For encoding the received signal by removing burst errors or noise and improves the performance by using Reed Solomon codes. The results are plotted by using BERTOOL (Monte Carlo, Theoretical, and Semi-analytic) values can be evaluated at different parameters. At constant code rate and error correcting capability, BER increases as the code length increases. The Bit-Error-Rate performance improves as the redundancy increases is also observed. The properly chosen error-correction code can significantly improve the BER performance is the key observation of this simulation calculation.

***Index Terms*: Bit-Error-Rate, FSK-Frequency Shift Keying, MATLAB/SIMULINK, Reed-Solomon codes.**

I. INTRODUCTION

The overall purpose of the digital communication system is 'to collect information from the source and carry out necessary electronic signal processing such that the information can be delivered to the end user (information sink) with acceptable quality'. It is an important operation for the digital communication system transmitting digital information over a noisy channel [2]. A digital communication system has several distinguishing features when compared with an analog communication system. Both analog (such as voice signal) and digital signals (such as data generated by computers) can be communicated over a digital transmission system. When the signal is analog in nature, an equivalent discrete-time-discrete-amplitude representation is possible after the initial processing of sampling and quantization. So, both a digital signal and a quantized analog signal are of similar type, i.e. discrete-time-discrete-amplitude signals [1][2]. The main problem in communication is to achieve reliable and consistent transmission of data from the information source to the destination.

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* Correspondence Author
Er. Rashmi*, Department of ECE, Sri Sai College of Engineering and Technology, Badhani, Pathankot, Punjab Technical University, Punjab, (India).
Satnam Singh , Asst. Prof., Department of ECE, Sri Sai College of Engineering and Technology, Badhani, Pathankot, Punjab Technical University, Punjab, (India).
R. P. P. Singh, Asso. Dean & Head, Department of ECE/EEE Arni University Kathgarh, (H.P), India.

The transmission of data may be digital or analog. The transmission of data with the minimum error rate is the objective of any communication system. In this communication system model the information is transmitted using Gray Code model with Frequency modulation technique (FSK) in the attendance of Additive White Gaussian Noise channel. Frequency Shift Keying modulation is a power proficient modulation method considered for low power applications [1].

II. THEORY OF REED – SOLOMON CODES

Reed Solomon (R-S) codes form an important sub-class of the family of Bose-Chaudhuri-Hocquenghem (BCH) codes and are very powerful linear non-binary block codes capable of correcting multiple random as well as burst errors.[4]. Reed-Solomon coding is a type of forward-error correction that is used in data transmission (vulnerable to channel noise) plus data-storage and retrieval systems. Reed-Solomon codec's (encoders/decoders) can detect and correct errors within blocks of data. Reed-Solomon codec's operate on blocks of data, these codes are generally designated as (n, K) block codes, K is the number of information symbols input per block, and n is the number of symbols per block that the encoder outputs. This enables to reduce the complexity and also the number of computations involved in their implementation. A large number of R-S codes are available with different code rates. [3] [10]. RS code is demonstrated below:-

RS (n , k) codes on m-bit symbols exist for all n and k for which:-

$$0<k<n<2m+2 \qquad (1)$$

Here k is the number of message bits to be encoded, n is the size of code word in an encoded block and m is the number of bits per symbol. Thus RS (n, k) can be written as follows:-

$$(n, k) = (2(m-1),2(m-1)-1-2t) \qquad (2)$$

Number of parity bits added to the message bits is calculated by (n-k) = 2t where t is the number of errors corrected by RS code. The distance of the RS code is given by:-

$$dmin= n-k+1 \qquad (3)$$

A. RS- Encoder

If a finite field of q elements is chosen , whose GF(2m),as a result the message f to be transmitted, consists of k elements of GF(2m) which are given by:-

$$f = (f0, f1, \ldots..fk-1) \qquad (4)$$

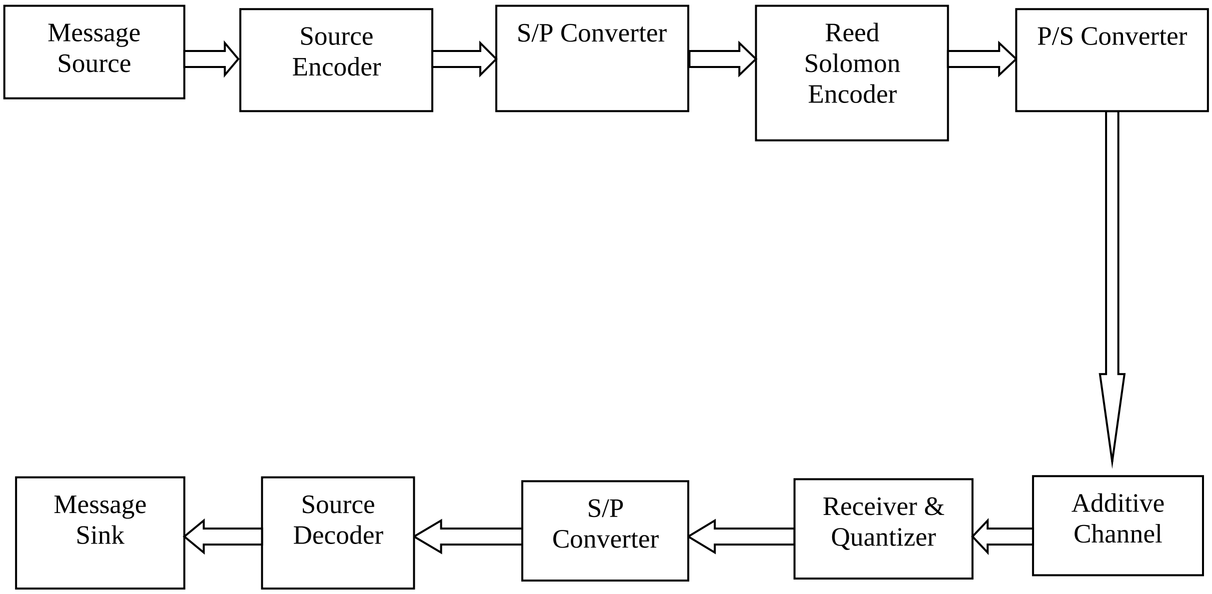

Fig. 1 Block Diagram of Communication System Using Reed- Solomon Codes [7]

Where fi € GF (2m)

Thus message polynomial is calculated by multiplying coefficients of the message with appropriate power of x which is given as follows:- [5]

$$F(x) = f0 + f1x + \_\_\_\_\_\_ + fk-1xk-1 \quad (5)$$

The remaining polynomial is known as parity check polynomial:-

$$B(x) = b0 + b1x + \_\_\_\_\_\_ + b2t-1x2t-1 \quad (6)$$

Then the codeword is form by adding the two polynomials as follows:-

$$V(x) = F(x) + B(x) \quad (7)$$

B. RS Decoder

When the message is being transmitted, then the data can be corrupted due to noisy channel etc. Let r(x) is the received message at the receivers and is given by following expression:-

$$R(x) = C(x) + E(x) \quad (8)$$

E(x) is the error and C(x) refers to the original codeword transmitted. Error E(x) is given by expression given as follows:-

$$E(x) = en-1xn-1 + \_\_\_\_\_\_\_\_\_ + e1x + e0 \quad (9)$$

Using RS Code t= {n-k}/2 errors can be corrected.

III. THEORY OF FSK

A. *Frequency-Shift Keying (FSK)*

Frequency-shift keying (FSK) is a frequency modulation scheme in which digital information is transmitted through discrete frequency changes of a carrier wave. [1] The simplest FSK is binary FSK (BFSK). BFSK uses a pair of discrete frequencies to transmit binary (0s and 1s) information. [2] With this scheme, the "1" is called the mark frequency and the "0" is called the space frequency.[10] Minimum frequency-shift keying or minimum-shift keying (MSK) is a particular spectrally efficient form of coherent FSK. In MSK, the difference between the higher and lower frequency is identical to half the bit rate. Consequently, the waveforms that represent a 0 and a 1 bit differ by exactly half a carrier period. The maximum frequency deviation is δ = 0.25 fm, where fm is the maximum modulating frequency. As a result, the modulation index m is 0.5. This is the smallest FSK modulation index that can be chosen such that the waveforms for 0 and 1 are orthogonal. A variant of MSK called GMSK is used in the GSM mobile phone standard [8] [9].

B. Theory of BER

The bit error rate or bit error ratio (BER) is the number of bit errors divided by the total number of transferred bits during a studied time interval. BER is a unit less performance measure, often expressed as a percentage.

The bit error probability pe is the expectation value of the BER. The BER can be considered as an approximate estimate of the bit error probability. This estimate is accurate for a long time interval and a high number of bit errors.

Example, assume this transmitted bit sequence:

0 1 1 0 0 0 1 0 1 1, and

the following received bit sequence:

<u>0</u> 1 0 <u>1</u> 0 1 0 <u>0</u> 1,

The number of bit errors (the underlined bits) is in this case 3. The BER is 3 incorrect bits divided by 10 transferred bits, resulting in a BER of 0.3 or 30%.

The BER may be improved by choosing a strong signal strength (unless this causes cross-talk and more bit errors), by choosing a slow and robust modulation scheme or line coding scheme, and by applying channel coding schemes such as redundant forward error correction codes. The power capability improves as "M"increases and undesirably complexity of system is also increased [7].

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VI. PROPOSED SIMULATION MODEL

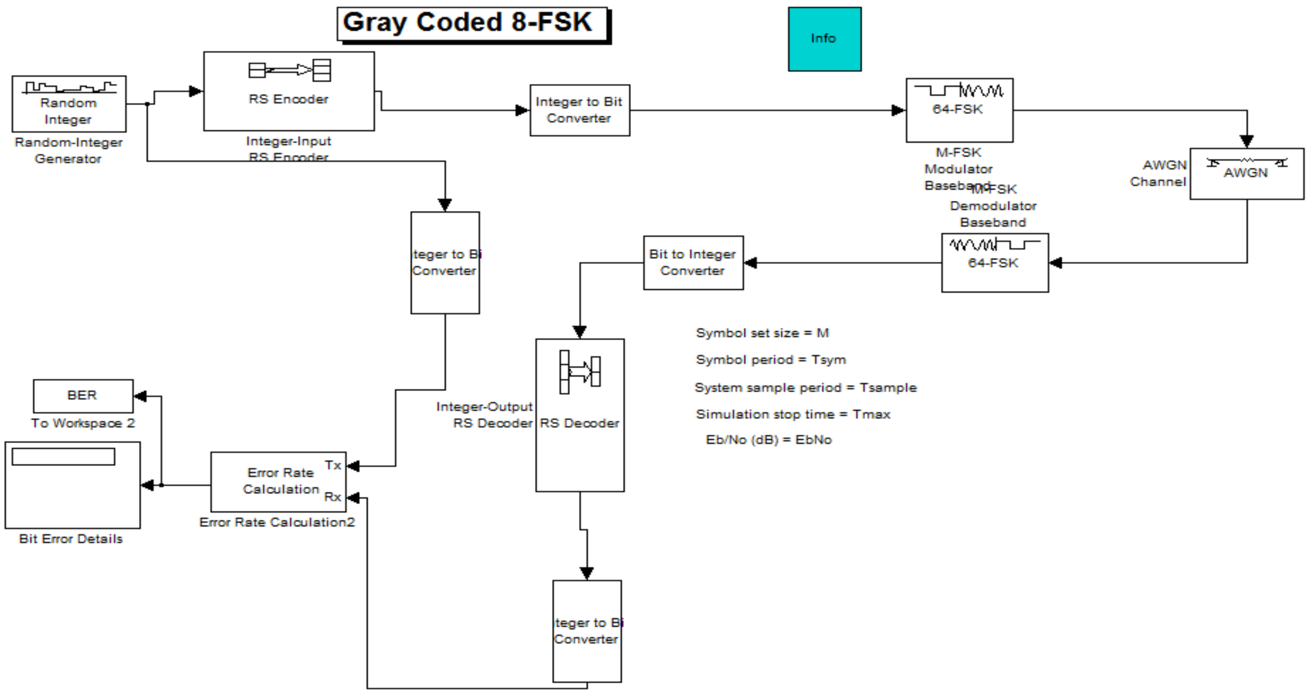

Fig. 2 Proposed Simulation Model

IV. MODEL DISCRIPTION

Block diagram of the digital RS coded communication system is shown in Figure4. The basic functional blocks of a RS coded communication system are as follow: Source of information Random integer generator is used ,RS Encoder, 64-FSK Modulator, AWGN communication channel, Integer to Bit convertor, bit to Integer convertor, 64-FSK Demodulator, RS Decoder , Error rate calculator and Display respectively. The binary numbers (0 and 1) are sequence of discrete symbols used in digital communication. The source of information produces digital information i.e. (0 or 1) and transmits it electronically to the Display with the aid of transmitter-receiver pair through communication channel [4]. The source encoder processes the source output to eliminate redundancy, compressing the digital sequence into a more competent symbol for transmission. The channel encoder adds redundancy to the compressed information in order to control the errors offered by channel impairments. The modulator of communication system converts the digital information sequence into a signal appropriate for transmission through the provided channel. The noisy communication (AWGN) channel is assumed for transmitting information from source to sink in communication system model [6] [11].

V. RESULTS

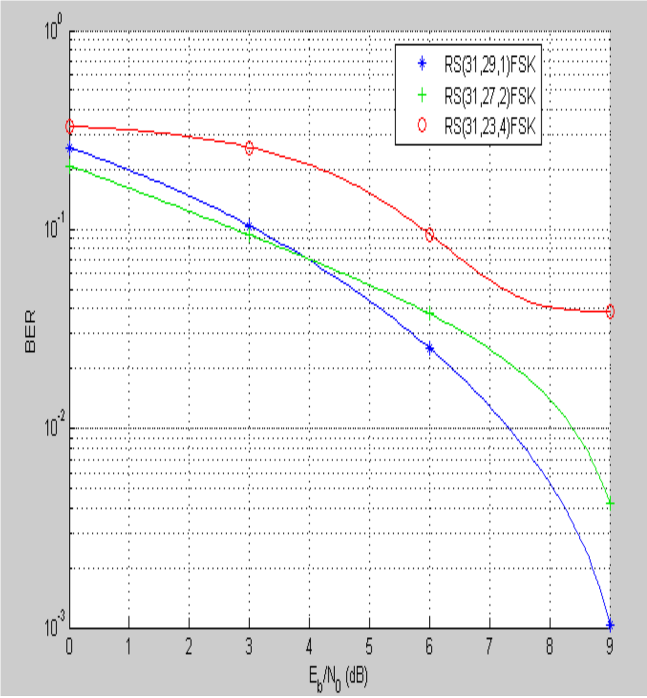

Fig. 3 Performance Evaluation as the Function of Redundancy

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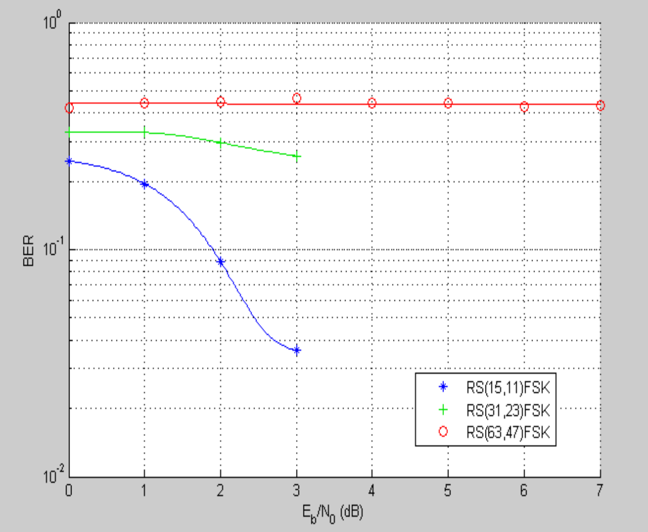

Fig. 4 Performance Evaluation as the Function Code Length (at Constant Code Rate)

Table 1: For Codeword symbol, RS code and Code Rate.

Codeword Symbol	Assumed RS code	Code Rate Rc=k/n
16	RS(15,11,4)	0.73
32	RS(31,23,5)	0.74
64	RS(63,47,6)	0.74

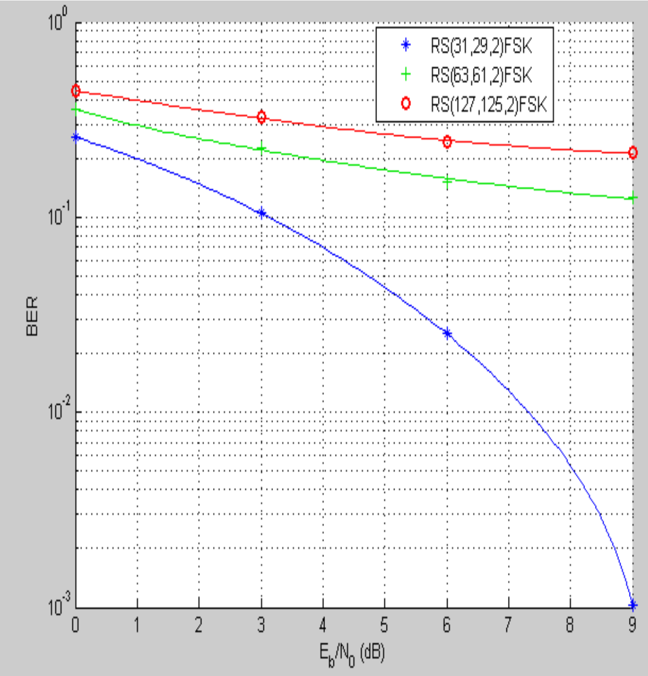

Fig. 5 Performance as the Evaluation of Code Length (at Similar Error Correcting Capability)

VI. CONCLUSION

In this paper, we compare the performance in terms of BER at different M-ary values. We compare the results by evaluating the results at different code rate, constant code rate and redundancy. From the simulation results following points have been observed.

A. The high code rate (0.93) is better than the low code rate (0.74) (see Fig. 3).

B. With the increase in redundancy i.e. (n-k), BER performance improves as shown in figure 3.

C. At constant code rate and error correcting capability, BER increases as the code length increases (shown in figure 4 and 5).

We evaluate Bit Error Rate by performing the RS codes at different parameters. The Monte Carlo values can be plotted on the graph with the help of bertool. On comparing the different M-ary at different (n, k, t) we found better results. We also perform the redundancy and code length at same code rate and different code rate at different RS values.

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AUTHOR PROFILE

Er. Rashmi, is doing M.Tech. in Electronics and Communication Engineering from Sri Sai College of Engineering and Technology, Badhani , affiliated to Punjab Technical University Jalandhar. She completed her B.Tech. in Electronics and Communication Engineering in 2012 from Lovely Professional University Jalandhar, affiliated to Lovely Professional University Jalandhar. She is currently working as Lecturer in the Department of Electronics and Communication Engineering in Minerva Polytechnic College Indora. (H.P). She is involved in teaching since Jan, 2014 and her major research interest includes Coding Theory, Communication, error Controlling Techniques.

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Er. Satnam Singh, working as a Assistant Professor in Sri Sai College of Engineering and Technology Badhani under Punjab Technical University Jalandhar. He has published many papers in International Journals and conference proceedings. His research interest covers a wide range of image processing include 2D &3D shape analysis edge detection segmentation Image based Modeling Android rendering texture analysis and synthesis.

Preet Pal Singh, received his M.Tech.Degree in Electronics and Communication Engineering from Beant College of Engineering and Technology,Gurdaspur (Punjab) affiliated to Punjab TechnicalUniversity, Jalandhar (Punjab). He is presently working asAssociate Dean and Head in ECE/EEE Department, ARNI University, Kathgarh (Himachal Pradesh) and pursuing Ph.D in Nano-technology. His research interests include Low-Power VLSI Design, Digital System Design, and Microcontroller Based System Design. He has published research papers in reputed International Journals/Conferences.