

# Simulink Modelling of Reed-Solomon (Rs) Code for Error Detection and Correction

Okeke. C

*Department of Electrical /Electronics Engineering,  
Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria*

Iroegbu.C.

*Department of Electrical /Electronic Engineering,  
Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria*

**Abstract**— This paper is on the analysis of Reed-Solomon (RS) Codes as an efficient code for error detection and correction. Reed-Solomon codes are examples of error correcting codes in which redundant information is added to data so that it can be recovered reliably despite errors in transmission or storage and retrieval. They describe a systematic way of building codes that can detect and correct multiple errors. It can be used in any communication system where a significant power saving is required and where the operating signal-to-noise ratio is very low. Deep space communications, mobile satellite/cellular communications, microwave links, paging, error correction system used on CD's and DVD's and other communications systems are based on a Reed-Solomon code.

**Keywords:** Reed-Solomon (RS), Error Correction, Coding, Communication system

## I. INTRODUCTION

In communication systems, the transfer of information from the source to its destination has to be done in such a way that the quality of the received information should be as close as possible to the quality of the transmitted information. As illustrated by Shannon in his paper published in 1948 [1], for each physical channel there is a parametric quantity called the channel capacity. Shannon showed that there exist error control codes such that arbitrary small error probability of the data to be transmitted over the channel can be achieved as long as the data transmission rate is less than the capacity of the channel. There are two types of Forward Error Correction (FEC) coding techniques: linear block coding and convolution encoding [2]. Reed-Solomon codes come under the category of linear block codes. Reed-Solomon (RS) codes are non-binary cyclic error-correcting codes invented by Irving S. Reed and Gustave Solomon. They described a systematic way of building codes that could detect and correct multiple random symbol errors. A Block diagram of a typical data transmission is shown in Figure 1. The information source output can be either analog signal or digital signal. The source encoder transforms the source output into a suitable sequence of binary digits (bits) as it may give each symbol different length of bits to minimize the size of data and its output called the information sequence  $u$ . In case of an analog information source, the source encoder contains analog to digital converter (ADC). The channel encoder converts the information sequence  $u$  into an encoded sequence  $c$  called a codeword or code vector. The channel is the medium which the data is transferred through it and its nature depends on the application. It determines the type of errors which affects the encoded sequence  $c$ , it may be random errors or burst errors and this determines the type of code to be used. So the channel transforms the encoded sequence to received sequence  $r$  which may has some errors. The channel decoder corrects the errors in the received sequence  $r$  to transform it into a binary sequence  $\hat{u}$  called the estimated sequence. The decoding technique is based on the type of channel encoding. Ideally,  $\hat{u}$  will be the same as the information sequence  $u$ , but actually the noise may cause some decoding errors which make difference between the information sequence  $u$  and the estimated sequence  $\hat{u}$ . The source decoder transforms the estimated sequence  $\hat{u}$  into an estimate of the source output and delivers this estimate to the destination.

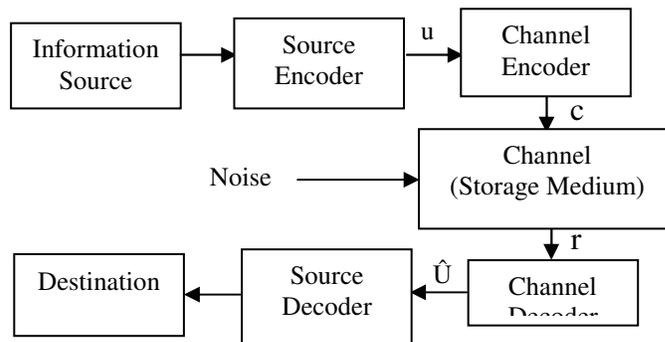


Fig1: A Block diagram of a typical data transmission system

## II. REED-SOLOMON CODES (RS)

In June 1960, Irving Reed and Gus Solomon who were then staff members of MIT Lincoln Laboratory, published a paper in the Journal of the Society for Industrial and Applied Mathematics with title "Polynomial Codes over Certain Finite Fields" [3]. This paper described a new type of error control codes that are now called Reed-Solomon codes. Reed-Solomon Codes are non-binary block codes so it has the properties of block codes. These codes are encoded by the same way of encoding the binary codes, but decoding was very complicated and a great effort was exerted by Berlekamp and others to improve its decoding algorithm [4]. In 1971, Reed-Solomon codes were used by NASA for some of their missions to Mars. In 1977, RS codes were notably implemented in the Voyager program in the form of concatenated codes. The first commercial application in mass-produced consumer products appeared in 1982 with the compact disc, where two interleaved RS codes are used. A Reed Solomon code can bridge a series of errors in a block of data to recover the coefficients of the polynomial that drew the original curve [5][6]. The most important advantage of Reed-Solomon codes over binary linear block codes is the ability of correcting the burst errors. As in Reed-Solomon codes the information bits are divided into message blocks of  $k$  information symbols each and each symbol consists of  $m$  bits. The encoder encodes each message independently to  $n$  symbols. The RS  $(n, k)$  can correct up to  $t$  symbols where  $t = \lfloor (n-k)/2 \rfloor$  and that regardless the number of error bits in each symbol. The properties of Reed-Solomon codes make them especially well-suited to applications where errors occur in bursts. This is because

- It does not matter to the code how many bits in a symbol are in error-if multiple bits in a symbol are corrupted it only counts as a single error. Alternatively, if a data stream is not characterized by bursts error but by random single bit errors, a Reed-Solomon code is usually a poor choice. More effective codes are available for this case.
- Designers are not required to use the "natural" sizes of Reed-Solomon code blocks. A technique known as "shortening" can produce a smaller code of any desired size from a larger code.
- Its capability to correct both burst errors and erasures makes it the best choice for the designer to use it as the encoding and decoding tool.

Today RS codes are widely in used in many applications that involve data transmission, like wireless computer networks, in telephony such as GSM, GPRS, UMTS, in broadcasting such as DVB-T, DVC-C and in data storage, like hard disk drives (HDD). Memory cards in cameras and telephones and in optical storage like Compact Discs (CD), Digital Versatile Discs (DVD) and Blu-ray Discs (BD) are all using Reed-Solomon codes.

## III. DESIGN METHODOLOGY

Figures 2 and 3 shows the block diagrams of Encoder and decoder of the Reed-Solomon

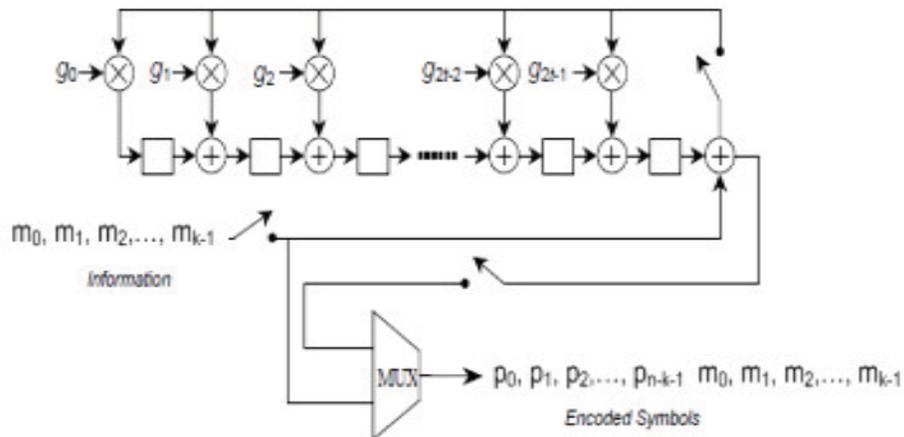


Fig2: Block Diagram of RS Encoder

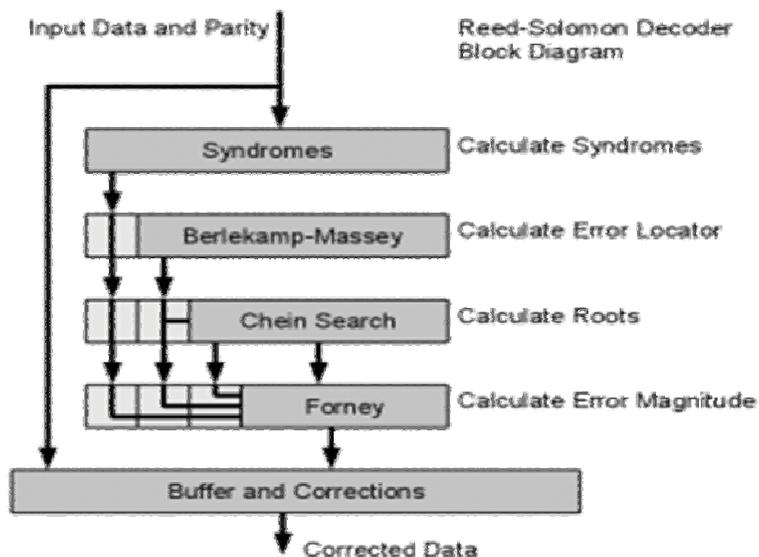


Fig3: Block diagram of RS

A. Finite (Galois) Field Arithmetic

A finite field  $Fq$  is a field  $F$  which has a finite number of elements and order of the field  $q$ .

Fig3: Block diagram of RS

The following is always valid for all numbers in a binary Galois field:

- Fields contain 0 or 1.
- Adding two numbers gives one number in the set.
- Subtracting two numbers gives one number in the set.
- Multiplying one number gives one number in the set.
- Dividing one number by one gives number in the set, division by 0 is not allowed.
- The distributive law holds for all elements in the field

B. Generator Polynomial

A Reed-Solomon codeword is generated using a special polynomial. Primitive polynomials are of interest here because they are used to define the Galois field

All valid code words are exactly divisible by the generator polynomial.

### C. Encoder

The encoder is essentially a  $2t$  tap shift register where each register is  $m$  bits wide. The Reed-Solomon encoder reads in  $k$  data symbols, computes the  $n-k$  parity symbols, and appends the parity symbols to the  $k$  data symbols for a total of  $n$  symbols. The multiplier coefficients are the coefficients of the RS generator polynomial. The general idea is the construction of a polynomial; the coefficients produced will be symbols such that the generator polynomial will exactly divide the data/parity polynomial.

### D. Decoder

The decoder processes each block and attempts to correct errors which may occur during transmission. It divides received codeword polynomial by the RS code generator polynomial. If the remainder is zero, then no errors are detected, else indicates the presence of errors. The RS decoder works on “syndrome decoding” and has five steps:

- Calculate the syndromes.
- Use the syndromes to determine the “error locator polynomial.”
- Find the roots of the error locator polynomial. The inverses of these roots give the locations of errors.
- Use the syndromes, roots, and error locator polynomial to determine the error magnitudes.
- Use the information about error location and magnitude to actually correct the errors.

Figure4 shows a SIMULINK model constructed for the analysis of performance of RS coding system over AWGN channel.

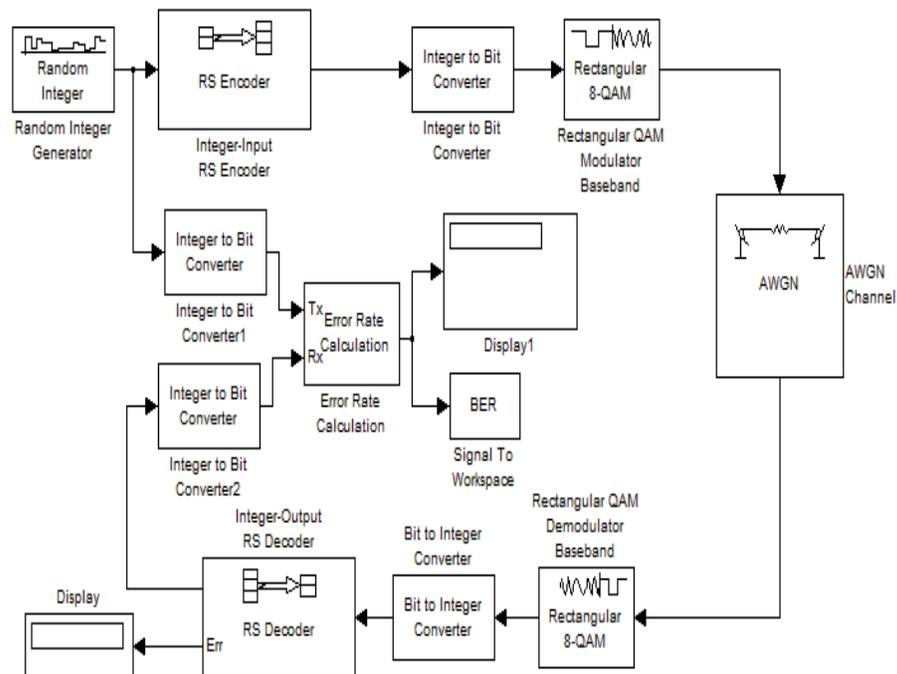


Fig4: A SIMULINK model for RS coding system over AWGN channel

#### IV. SIMULATION RESULTS AND DISCUSSION

Simulating the model in figure4, and extracting BER performance curve by using BER tool functions. The simulation result is shown in figure 5. In the error probability graph, it was seen that for a particular range of SNR, the number of error bits present can be found out using the bit error rate probability. For different error correcting capabilities of RS code, the range of SNR goes on increasing as the error correcting capability increases.

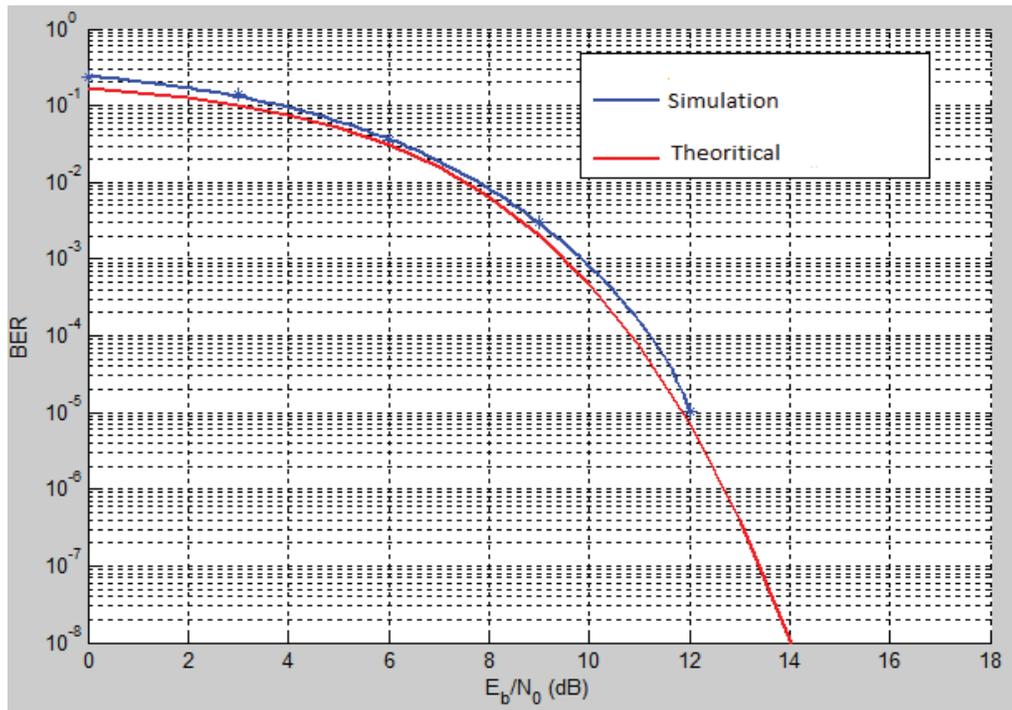


Fig5: Graph between SNR and Bit error rate (BER)

#### V. CONCLUSIONS

Reed Solomon (255,251) code was simulated in SIMULINK. It was found that if the number of bits in error is beyond the range of error correcting capability, the signal can be ignored in the same place and an acknowledgement can be sent to the signal again. But, if the number of bits in error is within the range then also we can estimate using those bits about how many symbols will be in error and then decide whether to try decode the transmitted signal or not. In the error probability graph, it was seen that for a particular range of SNR, the number of error bits present can be found out using the bit error rate probability.

#### REFERENCES

- [1] C. E. Shannon: "A mathematical theory of communication," Bell System Technical Journal, vol. 27, October 1948, pp. 379– 423.
- [2] Daniel J., Costello, JR., Error Control Coding, Fundamentals and Applications, Prentice Hall, Inc. Englewood Cliffs, New Jersey, 1983
- [3] I. S. Reed and G. Solomon, "Polynomial Codes over Certain Finite Fields,"SI AM Journal of Applied Mathematics, Vol. 8, June 1960.
- [4] E. Berlekamp, Algebraic Coding Theory. McGraw-Hill, 1968.
- [5] Stephen B.Wicker , —Reed-Solomon code And Their Application, I IEEE Press, 1994.
- [6] Reed-Solomon error correction, I [http://en.wikipedia.org/wiki/Reed-Solomon\\_error\\_correction](http://en.wikipedia.org/wiki/Reed-Solomon_error_correction), Jan. 11, 2011.
- [7] R.J.McEliece, L.Swanson, "On the decoder error probability for Reed-Solomon codes", IEEE Trans.on Inf.Theory, Vol. IT-32, pp.701-703.