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Implementation of Reed Solomon Encoder and Decoder for Wireless Communications

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ABSTRACT

In Digital communication error correcting codes are used for detection and correction of errors. The most powerful and widely used is Reed Solomon error correcting codes and is part of channel coding in the family of linear block codes. It can correct both burst errors and erasures. Galois field arithmetic is used for encoding and decoding of Reed Solomon code. The process involves adding redundant data to the information message to withstand effect of noise, interference and fading and retrieving it at the receiver. The implementation of proposed work is done using the matlab.

Keywords – Reed Solomon codes, Generator polynomial, Encoder, Decoder, Parity bits

I. INTRODUCTION

Error correcting codes are used for error correction and detection of errors. There are different types of error correcting codes. Forward error correcting codes are mostly preferred in digital communication. In forward error correction, reed Solomon codes are preferred due its burst error correction and detection and are part of channel coding.

Reed Solomon codes are binary in nature and are a type of systematic linear block codes. These codes are defined systematic because the original data contains the extra redundant data, block codes because the original information is splitted into fixed block length and the size of block is 'm' bit symbols and linear because each splitted block of 'm' bit symbol is valid. The process involves appending of redundant data at the end of the message so that when a number of errors are introduced either during the process of transmission or on storage it can be recovered at the receiver. This helps the signal bearing information to be protected from noise, interference and fading when transmitted through channel.

In reed Solomon coding scheme, the symbols are elements of a finite field or galois field (GF). Galois field is used because it contains a set of finite elements. Galoi field is represented as GF (z^m) where 'z' is prime number and 'm' can be any integer. Encoding and decoding of RS code uses galois field arithmetic. Galois field arithmetic uses GF multipliers for encoding the message with parity symbols using a predefined algorithm before transmission.

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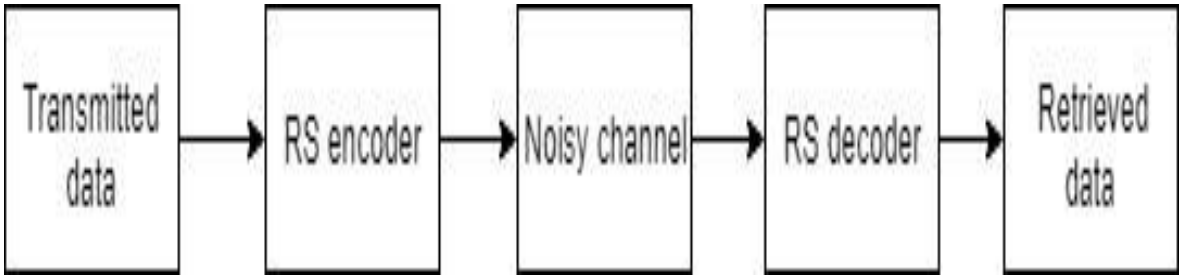

Figure (1): Block diagram of Communication channel

II. REED SOLOMON CODES

Rs codes are BCH codes and non-binary in nature. The RS codes are defined as RS (p, q) where p is total number of words i.e. original data and parity and q is length of message. RS codes use Galois field arithmetic because of finite fields [4]. Finite fields exist only when they are defined over GF (Z^m), Z is a prime number and m can be any integer. There are two types of finite fields determined by 'm'. When 'm' is equal to 1 they are said to be prime fields and when 'm' is greater than 1 they are said to be extension fields. The elements of prime fields GF (p) are the integers in the following sets {0, 1…p-1}. The elements of extension field GF ($Z^{m)}$, usually the smallest possible prime number is taken i.e. z=2. The polynomial representation of elements over GF (2^m) as,

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

Where A(x)€ GF(2^m)

a_i € GF (2) = {0,1}.

A primitive polynomial is predefined for every possible value of 'm' and based on that a generator polynomial is defined. Some of the primitive polynomials of predefined 'm' are given in table below

m	Primitive polynomial
1	$1+x$
2	$1+x+x^2$
3	$1+x+x^3$, $1+x^2+x^3$
4	$1+x+x^4$, $1+x^3+x^4$
5	$1+x^2+x^5$, $1+x+x^2+x^3+x^5$
6	$1+x+x^6$
7	$1+x^3+x^7$

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8	$1+x^2+x^3+x^4+x^8$
9	$1+x^4+x^9$
10	$1+x^3+x^{10}$

Codeword length $N=2^m-1$, Message length=k, Symbol length (m) =5

Error correcting capability (2t) =N-k

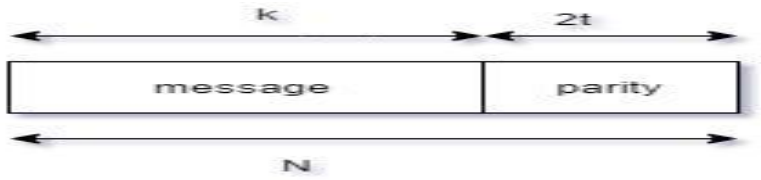

Figure (2): structure of code word

III CONSTRUCTION OF ENCODER

The construction of encoder is done using generator polynomial [3]. Encoding of RS (N, k) code is same as BCH codes. The multiplication and addition must be performed over GF (2^m) is the only difference between them. In encoder, the message polynomial m(X) is divided with generator polynomial g(X) and the reminder b(X) is added to the original message at the end of data. This forms an encoded data that can be retrieved at the receiver and is shifted message polynomial.

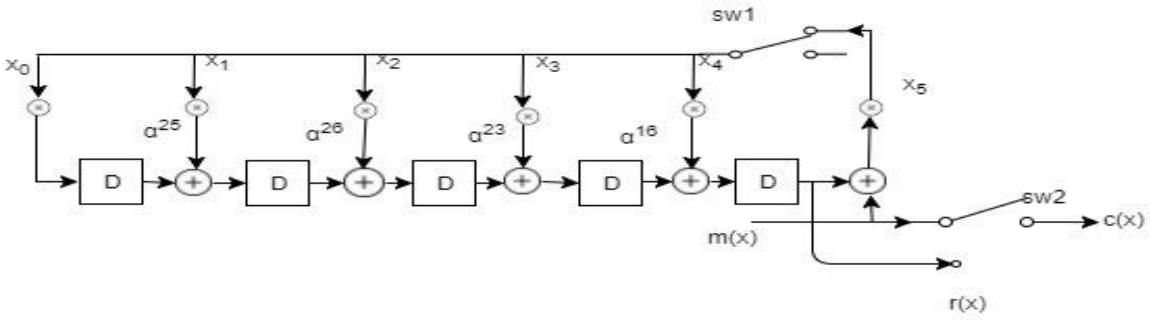

Figure (3): RS encoder for GF (2^5)

For t-error correcting RS code of length $p=2^m-1$, the input message to the encoder is of the form,

$m(X)= a_{(m-1)}X^{(m-1)}+a_{(m-2)}X^{(m-2)}+\ldots\ldots+a_1x^1+a_0$, $b(X) = X^{(N-k)}m(X) \mod g(x)$, the resulting codeword ,

$C(X) =b(X) +m(X)$.

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The narrow sense generator polynomial of RS (31, 26) is represented as,

$g(X) = (x-\alpha)(x-\alpha^2)(x-\alpha^3)(x-\alpha^4)(x-\alpha^5)$.

After multiplying all the terms in the equation we get, $g(x) = x^5-x^4\alpha^{16}+x^3\alpha^{23}-x^2\alpha^{26}+x\alpha^{25}+\alpha^{28}$.

IV. RS DECODER

The decoder consists of four steps in error correction of received data. The decoder is designed in such a way that it can detect and correct up to three errors. They computation involves:

1. Syndrome computation
2. Error position
3. Error evaluation
4. Error correction

Syndrome computation:

In syndrome computation the received data is divided with generator polynomial and checked for reminder. If there is no reminder then the data received contains no errors and if reminder exists then data is said to have some errors. A polynomial is obtained that represents errors and it is represented in vector form. FFT is applied to the vector to know the errors which gives DFT of the vector [5].

$$\mathbf{S_i=\sum_{i=1}^{N} C_i\alpha^{(N-1-i)}}$$

ERROR POSITION:

After syndrome calculation, the obtained polynomial is further processed for finding the position of errors. The t- error positions are calculated using Berlekamp Massey algorithm. Here the roots are calculated by trial and error method. The β (Z) is obtained will determine the error position [9].

ERROR MAGNITUDE:

The magnitude of error is calculated after error position. This helps to find the decoded data. This result gives by how much the original data is varied from received data. Error evaluation is done using gamma Ω (Z)

$$\mathbf{\beta'(Z)\,S(Z) = \Omega(Z) \bmod Z^{2t}}$$

Error correction:

The obtained magnitude is subtracted from received data to get the original data or the formula is used to get the decoded output.

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$$e^{i_m} = \frac{\Omega(e^{-i_m})}{\Lambda(\alpha^{-i_m})}$$

Where e^{i_m} is the error magnitude in the i_mth position in the codeword, 'm' is a value less than the error correcting capability of the code, Ω(Z) is the error magnitude polynomial β´ is the formal derivative of the error locator polynomial β(Z), and α is the primitive element of the Galois field.

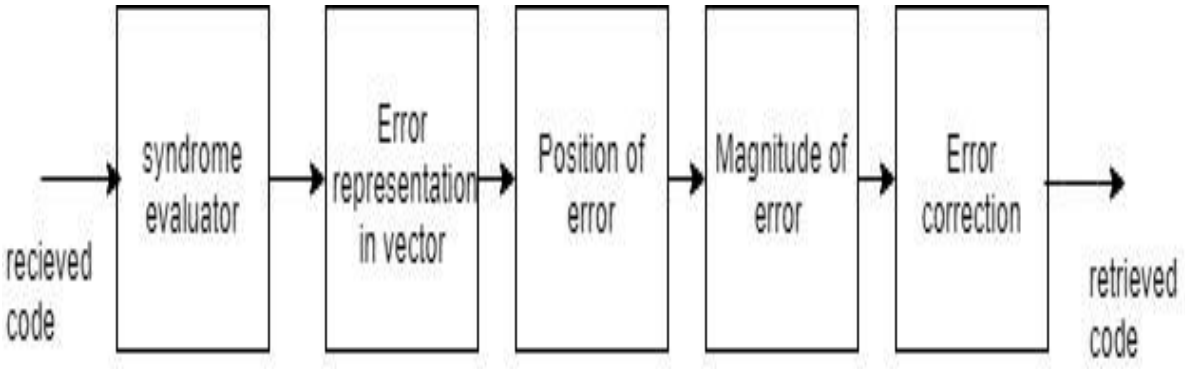
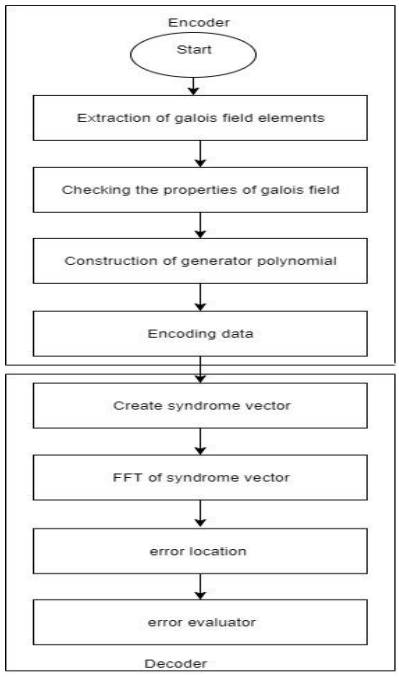


Fig (4): General architecture of Decoder

V. ALGORITHM IMPLEMENTATION:



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VI SIMULATION RESULTS

The implementation of RS codes in MATLAB to understand the phenomenon as how the signal is being encoded and, what would happen if the signal has some error and up to what extent, the decoder can detect and correct errors. In first simulation MATLAB, a random symbol of integers was taken as input. These random symbols were encoded using RS encoder. Following this the signal is passed through noisy channel, these symbols were received at the decoder end. Now at the decoder end, the decoder can correct up to t symbols. After correcting the error, however the decoder takes the redundant bits out which were generated while encoding the symbols. To verify the capability of RS code in detecting and correcting the errors, it was implemented as per the block diagram shown in figure (2). For this case one set of RS code is used for simulation, i.e. RS (31, 26). The figure (5) shows the result of randomly generated input data, where the number of data points is equal to k i.e. k=17

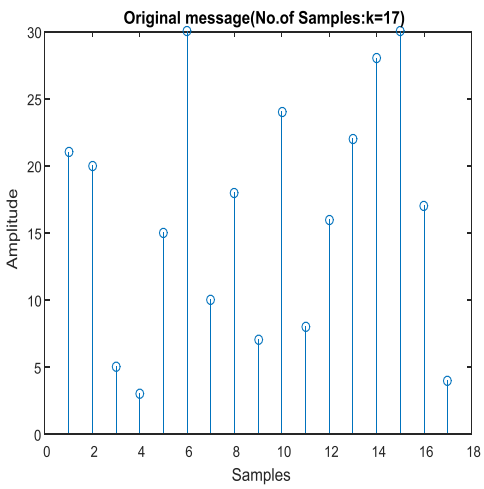

Figure (5): Input samples

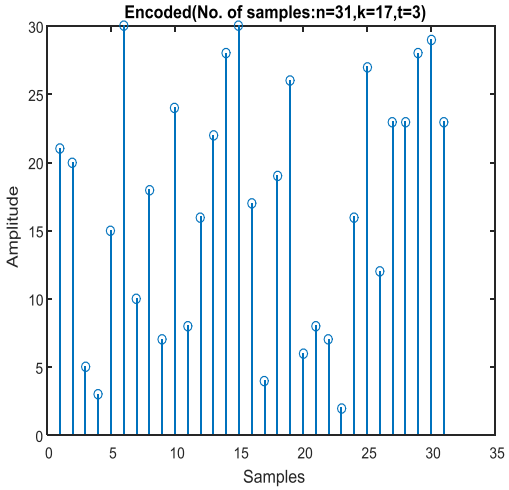

Figure (6): Encoded data

This input data was encoded by RS encoder and the number of samples at the output of encoder is n (i.e. 31), which is equal to message plus parity (in this case n=k+2t, where k=17 and t=3). This encoded data is adde with some noise and the RS decoder detect the errors and correct‘t’ number of errors.

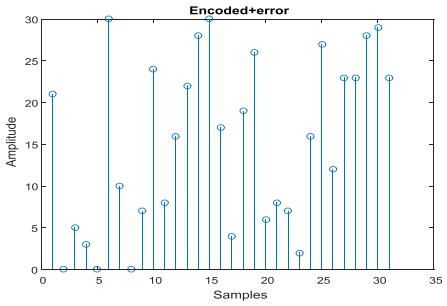

Figure (7): Transmitted data

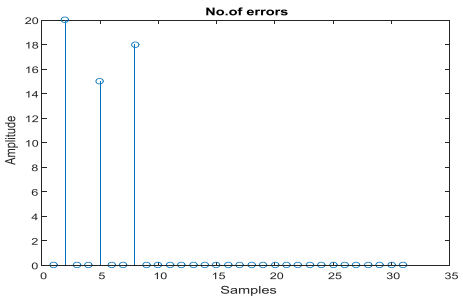

Figure (9): Decoded data

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VII CONCLUSION

Reed Solomon code process on block by block basis. The actual maximum code rate allowed depends on error correcting code used. Reed Solomon code are systematic code for which the actual information appears unaltered in the encoded data, redundant bits are added for detection and correction of error. Key idea behind Reed Solomon code is data visualized as a polynomial.

In encoder redundant symbols are added using generator polynomial. In RS (31, 26) after encoding information remaining same while extra 5 –bit parity symbol are added. Before data transmitted the encoder attached parity symbol using a predefined algorithm. It was found that if the error is in parity symbols even then the decoder is able to detect the output. The decoder first corrects the symbols and then removes the redundant parity symbols from the code word and produces the original message. From the simulation result it has been shown that the decoder can correct up to‘t’ number of errors.

FUTURE SCOPE: The proposed work is implemented in VHDL for FPGA implementation.

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