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BER Analysis of BPSK and QAM Modulation Schemes using RS Encoding over Rayleigh Fading Channel

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ABSTRACT
Everybody has to communicate with each other so do computers, it is a necessary phenomenon for exchange of information. Data is one of the most important entities in today's world, thus data reliability is of utmost importance. The data exchanged between computers is sent over various communication channels, which can induce noise in the data thus rendering data unreliable and inconsistent. The number of errors introduced in the data depends on the encoding scheme, the communication channel being used and also the modulation scheme. Various encoding schemes, communication channels and modulation schemes are used for data transmission, each of these schemes have their advantages and disadvantages depending on the scenario. In this paper performance BPSK and QAM modulation is compared using RS encoding scheme over Rayleigh fading channel and the result so produced is presented in terms of BER.

Keywords
BPSK Modulation, QAM, Rayleigh fading channel.

1. INTRODUCTION
Whenever communication takes place, data needs to be transmitted, be it human beings or computers [15]. Data is of utmost importance for an effective communication to take place, so the transmission of data should be such that the receiver of the data should receive the data in the same condition as it was sent by the sender [15]. If the data is prone to any disturbance, then the data received by the receiver will not be the same as it

was meant and thus it will convey different information than what it was meant to convey. Thus the goal of data transmission is to transmit the data over a communication channel without any errors .Various techniques have been developed over the past few years to secure and make the data transmission reliable. One of such techniques is Information Coding Theory. Coding theory the study of codes, including error detecting and error correcting codes, has been studied extensively for the past forty years. It has become increasingly important with the development of new technologies for data communications and data storage [15]. Coding theory makes use of various codes to encode the data for transmission over a channel and then the data is decoded at the receivers end to get the required data bits. Along with the encoding scheme the modulation scheme being used for data transmission also determines the extent to which the errors are introduced in the data being transmitted. The performance of modulation schemes vary depending on the encoding scheme used as well as channel. This paper discusses the performance comparison of BPSK and QAM modulation over Rayleigh fading channel using RS encoding scheme.

2. RELATED WORKS

During the past few years, researchers have started showing some interest in analyzing the performance of various forward error detecting and correcting codes. The reason being importance of data in present scenario. The performance of forward error correction techniques are taken into consideration by using these codes for transmitting data over various communication channels. In [2] authors have compared and analyzed the performance of different forward error correction techniques in case of wireless communication systems. In [9] authors have analyzed the suitability of Reed Solomon codes for low power communications and found out that Reed Solomon codes reduce the battery consumption but debated the overall suitability due to the extra overhead required to encode the information to be sent. In [10] authors made a comparative study of Reed Solomon code and BCH code over AWGN channel and concluded that BCH code performs better than RS code in a binary environment.

3. REED SOLOMON CODE

Reed Solomon code was developed in 1960 by Irving S. Reed and Gustave Solomon for reliable data transmission. This code was developed keeping in mind the importance of reliability of data transmission over various communication channels. This code is a type of block code in which *n* bit codeword is formed by adding redundant bits of information to the *k* bits of information bits where ($n>k$). The block so formed is used for actual transmission over a communication channel. 2^k codeword's can be formed from the *k* information bits which can be used for data transmission. Digital communication and storage use the services of RS code for reliable data transmission and data storage. This code finds its application in space communication, storage media, wireless communication, digital television etc.

2.1 RS Encoder

Consider a finite field of q elements with GF(2^m), thus the message f to be transmitted consists of k elements over GF(2^m) given by:

$$f = (f_0, f_1, f_2, \ldots. f_{k-1}) \quad (1)$$

where f_i € GF(2^m) .

The message polynomial is formed by multiplying the coefficients of message by appropriate powers of x as follows:

$$F(x) = f_0 + f_1 x \ldots\ldots\ldots + f_{k-1} x^{k-1} \quad (2)$$

The parity check polynomial is given by:

$$B(x) = b_0 + b_1 x + b_{2t-1} x^{2t-1} \quad (3)$$

The codeword is thus formed by adding the message and parity check polynomial as:

$$V(x) = F(x) + B(x) \quad (4)$$

The error correction capability of RS code is:

$$t = (n-k)/2 \quad (5)$$

2.2 RS Decoder

After the message has been encoded it is transmitted over the channel as a result which errors can be introduced in the message due to the presence of noise in the channel thus rendering the message useless, the RS decoder decodes this message and tries to correct the errors so introduced. The message received at the decoder is given by:

$$R(x) = C(x) + E(x) \quad (6)$$

where $C(x)$ is the original codeword and $E(x)$ is the error introduced in the message.

The error function $E(x)$ is given by:

$$E(x) = e_{n-1} x^{n-1} + \ldots\ldots\ldots e_1 x + e_0 \quad (7)$$

$$0 < k < n < 2m + 2 \quad (8)$$

where n is the size of the codeword k is the number of message bits to be encoded and m is the number of bits per symbol. Thus RS(n, k) can be expressed as:

$$(n, k) = (2(m-1), 2(m-1) - 1 - 2t) \quad (9)$$

The number of extra bits or parity bits that are added to the message for error detection and correction can be calculated as follows:

$$(n\text{-}k) = 2t \qquad (10)$$

where t is the number of errors corrected by RS code.

The distance of RS code can be calculated as follows:

$$d_{min}=n\text{-}k+1 \qquad (11)$$

Reed-Solomon code is based on Galoi's field.

3. MODULATION

The process of changing one or more properties of a periodic waveform, called the *carrier signal* with a modulating signal that typically contains information to be transmitted is called Modulation. By the use of modulation a message signal, can be conveyed inside another signal which can be physically transmitted.

3.1 Binary Phase Shift Keying

The simplest PSK is Binary PSK in which we have only two signal elements, one with a phase of 0^0 and other with a phase of 180^0.BPSK is as simple as PSK but it is much less susceptible to noise compared to PSK In Ask the criterion for bit detection is amplitude but is PSK it is phase. Noise can change amplitude easier than it can change phase of the signal. PSK is superior to ASK because we don't need two carrier signals [14].

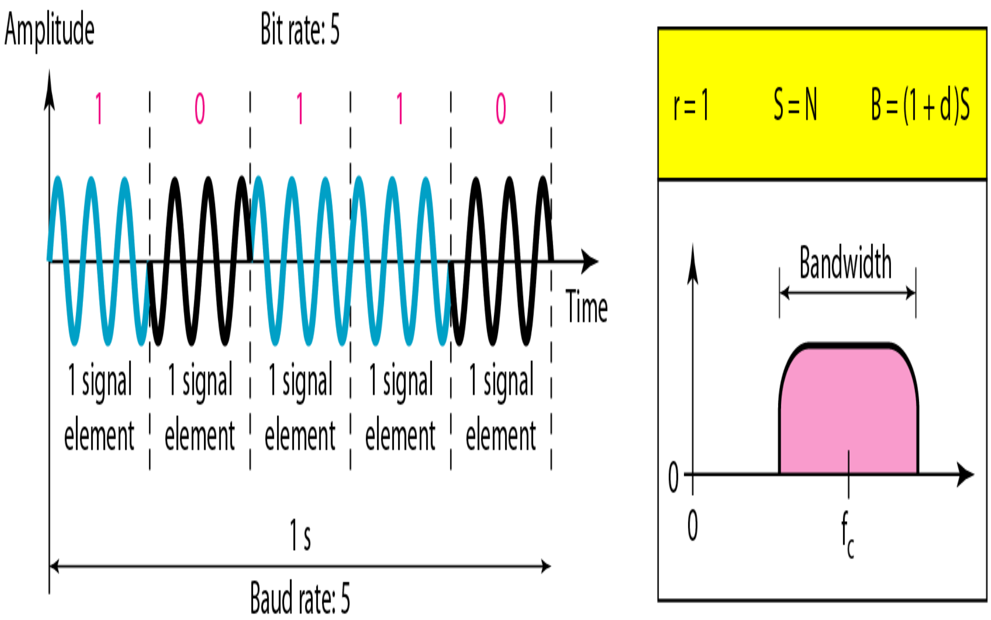
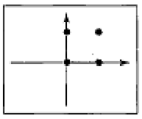


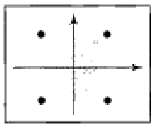
Figure 1. Binary phase shift keying.[14]

3.2 Quadrature Amplitude Modulation

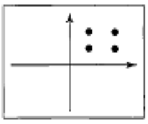
There is a limitation to the PSK scheme and that is the inability of the equipment to distinguish small differences in phase, which limits its potential bit rate. The concept behind Quadrature amplitude modulation is to use two carriers, one in phase and other quadrature, with different amplitude levels for each carrier.[14]



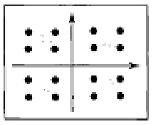
4-QAM using Unipolar NRZ signal



4-QAM using polar NRZ



QAM using 2 positive levels to modulate 2 carriers



16-QAM with 8 levels

Figure 2. QAM Modulation[14]

4. COMMUNICATION CHANNEL

A physical medium or a logical connection over which data can be transferred is known as a communication channel. The importance of a communication channel is to send information from one or multiple senders to one or multiple receivers. Limited amount of information can be transferred over a channel depending on the data rate or the bandwidth of the communication channel. Simulation of wireless channels accurately is very important for the design and performance evaluation of wireless communication systems and components.

4.1 Rayleigh fading channel

Rayleigh fading is considered when there are many objects in the environment that scatter the radio signal before it arrives at the receiver. According to central limit theorem, if there is a lot of scatter, the channel impulse response will be well-modeled based on Gaussian process irrespective of how the individual components are distributed. In case a significant component to scatter is not present, then the process will have zero mean and its phase will be distributes between 0 and 2p radians. The response of the channel will be said to follow Rayleigh model. Complex numbers usually represent the gain and phase of the channels distortion. In such a situation it is assumed that Rayleigh is exhibited such that the real and imaginary parts of the response are modeled by independent and identically distributed zero-mean Gaussian processes so that the amplitude of the response is the sum of two such processes.

5. METHODOLOGY

SIMULINK in MATLAB was used for simulating BPSK and QAM modulation scheme in Rayleigh channel. The process is described as follows:

The encoder accepts K random information symbols as input. Each of the input sequences is mapped unique n symbol sequence known as a Codeword. The codeword thus formed is sent to the next module known as the modulator which helps in transmitting the codeword over the communication channel. BPSK and QAM modulation schemes are used by the modulator to transform the data into signal waveforms. Once the data has been transformed to a signal waveform, it is sent over to Rayleigh fading channel for transmission. Rayleigh fading channel mimics the terrestrial environments, thus a lot of disturbances are present in the channel which can induce errors in the data being transmitted thus rendering the data corrupt or unusable. At the receiver end before decoding the data, it has to be separated from the carrier signal by the process called demodulation, the module performing demodulation is known as a demodulator. After separating the data from the carrier wave, the next step is to send the data for decoding. The demodulator output is connected to the decoder which receives the data and finally decodes the data into original information sequence also detecting and correcting errors depending on the error detection and correction capability of the code being used. Finally bit error ratio (BER) is calculated.

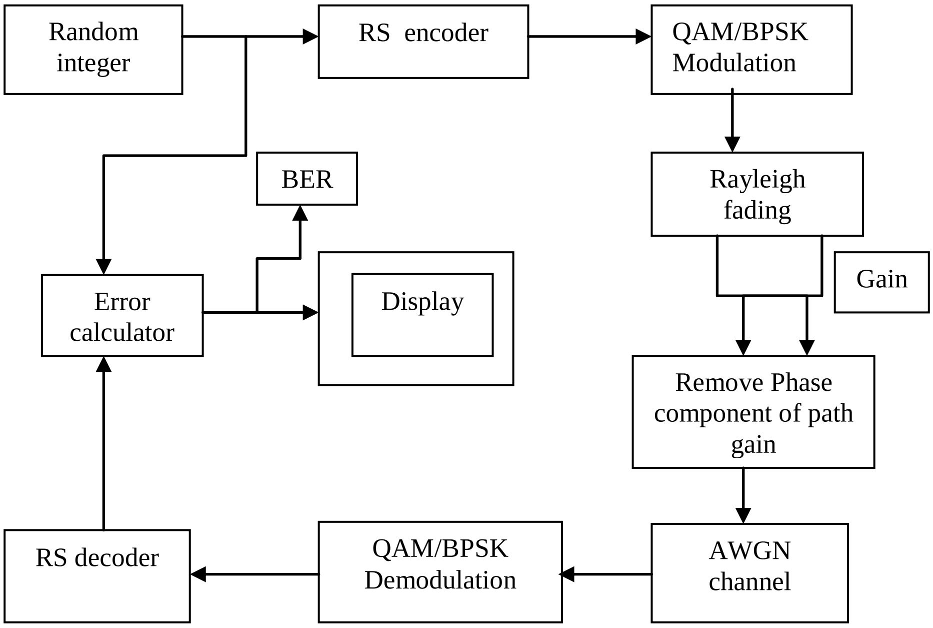


Figure 3. Simulation Model.

6. RESULTS

In this paper analysis on BPSK and QAM modulation was done by using RS encoding scheme of block length (15, 11) . BER ratio was calculated by varying Eb/N0 from 0 to 10. Doppler shift value was set as .0001. The analysis results are given in table 1:

TABLE 1. Performance Comparison for BPSK and QAM modulation and using RS encoding scheme in the presence of Rayleigh Fading channel.

E_b/N_0	RS_QAM	RS_ BPSK
0	0.8802	0.897
1	0.8719	5 0.8906
2	0.8727	0.892
3	0.8636	2 0.882
4	0.8556	6 0.8727
5	0.8443	0.8619
6	0.8289	0.846
7	0.8061	0.8392
8	0.7913	0.8239
9	0.7621	0.7913
10	0.7215	0.7513

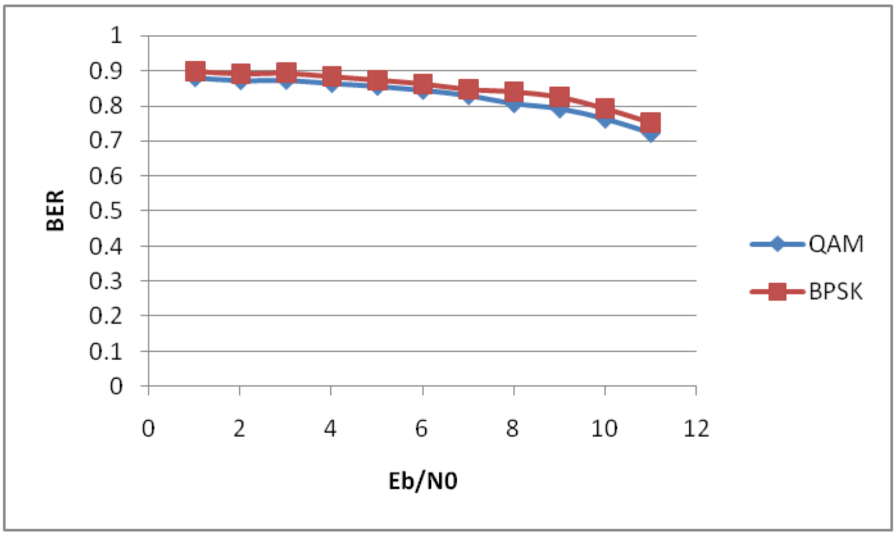


Figure 4. BER of QAM modulation and BER of BPSK modulation in Rayleigh Fading channel using RS encoding.

From the above graph it was found that QAM modulation produced better results using RS encoding scheme in presence of Rayleigh channel under binary environment.

7. CONCLUSIONS

In this paper performance of BPSK and QAM modulation was simulated in the presence of Rayleigh fading channel using RS encoding scheme. Several iterations were performed to find out that BPSK modulation outperforms QAM using RS encoding in presence of Rayleigh fading channel. Eb/No ratio was varied from 1 to 10 and it was noticed that at every value of E_b/N_o QAM modulation performed better than BPSK modulation. The graph plotted between BPSK and QAM modulation shows the performance gain of QAM modulation over BPSK modulation in Rayleigh fading channel using RS encoding.

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