E_b/N_o. Vs. BER Analysis of PAM and QAM over AWGN, Rayleigh and Rician Channels for Mobile Communication

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***Abstract*—** The aim of future generation in mobile communication system is to integrate different types of real time services such as e-mail, speedy communication, video streaming and multimedia applications. Digital Modulation provides more information capacity, high data security, quicker system availability with great quality communication. Hence, digital modulation techniques have a greater demand, for their capacity to convey larger amounts of data than analog modulation techniques. As the order of the modulation increases more bits per symbol can be transmitted. Different order modulations allows a wireless communication system to send more bits per symbol and thus achieve higher throughputs or better spectral efficiencies. This paper examines the Eb/No vs BER for different orders of QAM and PAM over AWGN, Rayleigh and Rician channel. The work is carried out for various orders of Quadrature Amplitude Modulation (QAM) such as (4QAM, 16QAM, 32QAM & 64QAM) and different orders of Pulse Amplitude Modulation (PAM) such as 4PAM, 8PAM & 16PAM. The results are analyzed & compared.

Keywords—PAM; QAM; BER; modulation; Eb/No;

INTRODUCTION

Pulse amplitude modulation is an analog modulating scheme, in which the amplitude of the pulse carrier wave varies with instantaneous amplitude of the message signal. After the continuous wave modulation, the next division is the pulse modulation. The pulse modulation is further classified in to pulse amplitude modulation, pulse width modulation and pulse position modulation. In pulse width modulation, the bandwidth depends on the width of the pulse. In pulse amplitude modulation, the instantaneous transmitter power varies with the amplitude of the pulse. PAM is a one dimensional signal with four different amplitudes 0, 1, 2 & 3 with no phase information. QAM stands for Quarature Amplitude Modulation. It is a two dimensional modulation format, with one dimension in quadrature with the other. QAM contains both amplitude and phase information, where as PAM contains only amplitude information. The first section of this paper describes the PAM modulation system. In the second section of this paper describes QAM modulation technique with block diagram. The section 3 describes the generation of 16QAM using PAM-4 bit stream. The sections 4 detail the results. In section-5 results analysis and comparison are depicted.

PAM & QAM MODULATION SYSTEM

PAM Modulation System

It has simple modulation and demodulation process. The transmitter and receiver circuits are easier to construct. The block diagram is shown below in Fig.1. Sine wave and Cosine waves are applied to the product modulator to obtain the PAM signals.

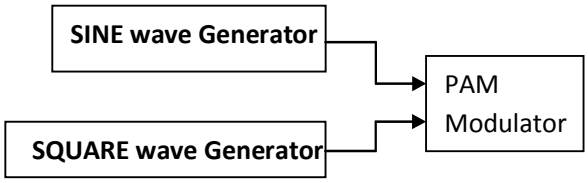

Fig. 1. PAM Modulator.

As shown in Fig.2, the modulating signal is applied to a low pass filter, which passes low frequency signals and blocks high frequency components. The low frequency signal component is selected by the data selector; a multiplexer combines several input digital or analog signals and forwards them in to single output line. The selected input signal is applied to the modulator block. The modulator converts analog information to a pulse format as shown below.

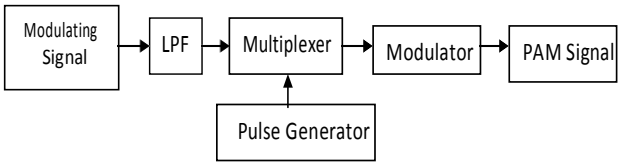

Fig. 2. The generation of PAM Signals.

QAM modulation system

Since PAM signals occupy twice the bandwidth required for the baseband. QAM uses half the bandwidth than that of the PAM signal. QAM is widely used method for transmitting data over band pass channels. The input data stream is scrambled. The scrambler manipulates the data stream before transmitting.

The manipulations are reversed by a descrambler at the receiver. The scrabbled data is encoded. The encoded data is applied to the interleaver block. The forward error correction is done by the interleaver. The Interleaver output is applied to the QAM modulator block as shown in Fig.3 below.

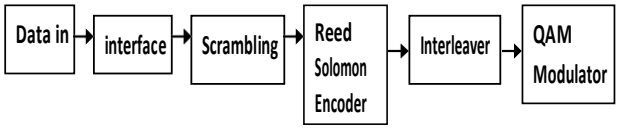

Fig. 3. QAM Modulator.

Fig. 4 shown below depicts the generation of QAM modulated signal. The data input stream is applied to level generator to separate out the ODD and EVEN bit streams, this generated bits are multiplied with COS data and SINE data respectively, this multiplied data in I arm and Q arm are added together to generate the QAM modulated signal. Eq. (1) indicates the QAM modulated signal.

$$S(t)= m_1(t) \cos (2\pi fct+\theta) – m_2\sin(2\pi f ct + \theta) \quad (1)$$

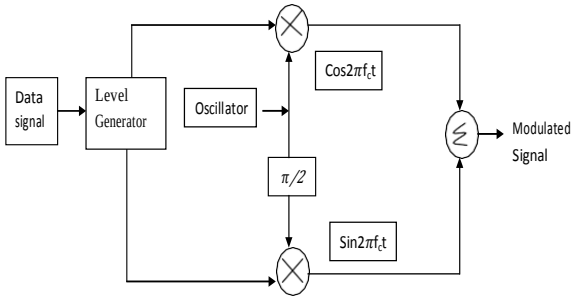

Fig.4. Generation of QAM Modulated Signal.

Generation 16QAM signal using PAM streams

16QAM signal is generated from two PAM-4 signals. This signal has twice the capacity of a PAM-4 signal.

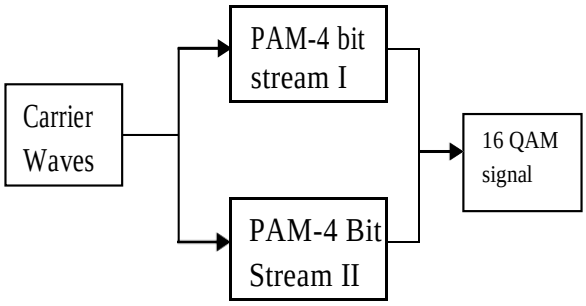

Fig. 5. Geneation of 16QAM signal using PAM streams.

RESULTS

Fig. 6 below shows the Bit Error Rate Analysis of QAM over AWGN channel. As the order of the modulation increases, the bit error rate increases.

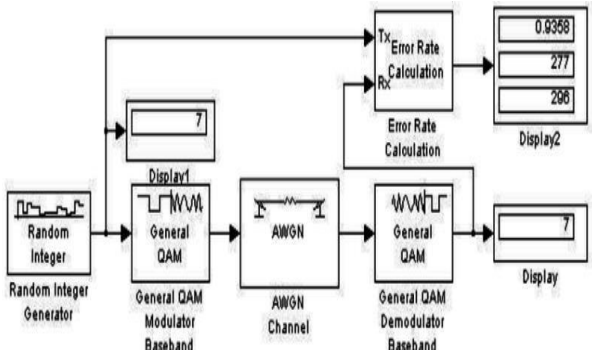

Fig. 6. BER of QAM over AWGN channel.

RESULTS COMPARISON

Results and Analysis of QAM modulation system

The Table I. below depicts E_b/N_o vs. BER of 4QAM over AWGN, Rayleigh and rician channesl. As E_b/N_o increases, the error rate decreases as indicated below.

The maximum error rate can be noticed in rayleigh and rician channel than AWGN channel.

TABLE I

E_B/N_O VS. BER OF 4QAM OVER AWGN, RAYLEIGH AND RICIAN CHANNEL			
Eb/No	***AWGN***	***Rayleigh***	***Rician***
0	0.0786	0.1464	0.1464
2	0.0375	0.1084	0.1084
18	1.39E-29	0.0039	0.0039

Table II below depicts E_b/N_o vs. BER of 16QAM over AWGN, rayleigh and rician channels. As E_b/N_o increases, the error rate decreases as indicated. The maximum error rate can be noticed in rayleigh and rician channel than AWGN channel.

By Comparing Table I data with Table II, it can be seen that error rate at 4QAM is minimum in comparison with the error rate in 16QAM over AWGN, rician and rayleigh channels.

BER is tabulated for E_b/N_o of 0, 2 and 18 respectively.

TABLE II

E_B/N_O VS. BER OF 16QAM OVER AWGN CHANNEL			
Eb/No	***AWGN***	***Rayleigh***	***Rician***
0	0.1409	0.1975	0.1975
2	0.0977	0.1570	0.1570
18	4.52E-13	0.0076	0.0076

Table III below depicts E_b/N_o vs. BER of 32QAM over AWGN, rayleigh and rician channels. As E_b/N_o increases, the error rate decreases as indicated in Table III. The maximum error rate can be seen in rayleigh and rician channels than in AWGN channel.

By comparing Table I, Table II and Table III, that is the error rate at E_b/N_o of 0 dB, 2dB and 18dB respectively in 4QAM, 16QAM and 32QAM over AWGN channel is 0.0786, 0.1409 and 0.1894. The error rate is minimum in 4QAM and noticed to be maximum in 32QAM.

TABLE III

E_B/N_O VS. BER OF 32QAM OVER AWGN CHANNEL			
Eb/No	***AWGN***	***Rayleigh***	***Rician***
0	0.1894	0.2390	0.2390
2	0.1461	0.1996	0.1996
18	2.72E-7	0.0136	0.0136

Table IV below depicts E_b/N_o vs. BER of 64QAM over AWGN, rayleigh and rician channels. As E_b/N_o increases, the error rate decreases as indicated in table IV. The maximum error rate can be noticed in rayleigh and rician channels than in comparison with the AWGN channel.

TABLE IV

E_B/N_O VS. BER OF 64QAM OVER AWGN CHANNEL			
Eb/No	***AWGN***	***Rayleigh***	***Rician***
0	0.1998	0.2470	0.2470
2	0.1569	0.2088	0.2088
18	6.35E-6	0.0163	0.0163

By comparing Table I, Table II, Table III and Table IV, the error rate at E_b/N_o vs. BER of 64QAM over AWGN, rayleigh and rician channels at 0 dB in 4QAM, 16QAM, 32QAM and 64QAM over AWGN channel is 0.0786, 0.1409, 0.1894 and 0.1998 respectively.

BER value is lower in 4QAM and noticed to be higher in 64 QAM as shown in Fig.7 below.

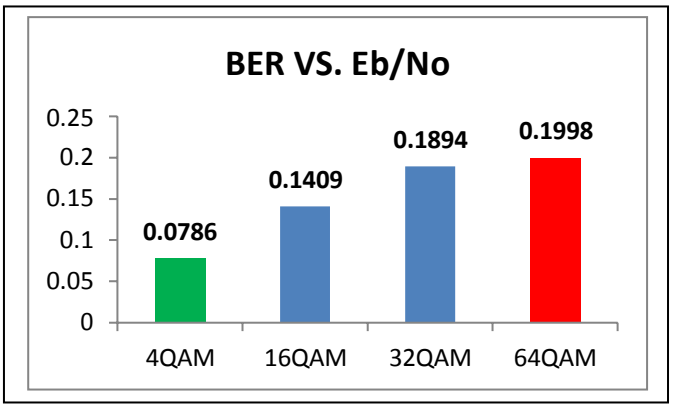

Fig. 7. BER of 4QAM, 16QAM, 32QAM and 64QAM over AWGN channel.

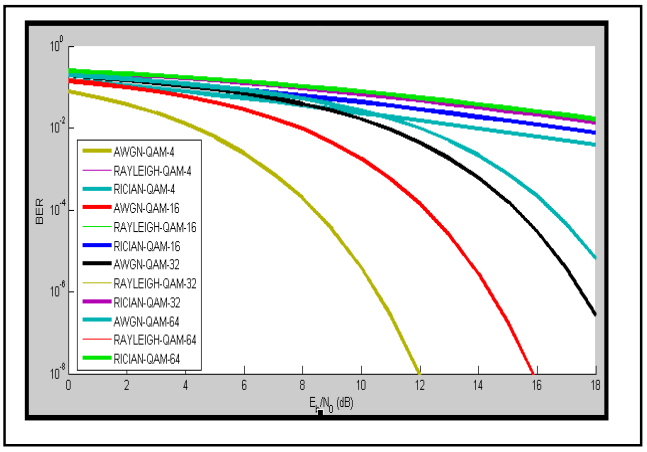

Fig. 8. BER vs. E_b/N_o of 4QAM, 8QAM, 16QAM, 32QAM and 64QAM over AWGN channel.

Fig. 8 shows E_b/N_o vs. BER of 4QAM, 16QAM, 32QAM and 64QAM over AWGN channel. Error rate is maximum in 64QAM comparatively with the other types of modulation as indicated with green line in the graph. Error rate is minimum with 4QAM over AWGN channel as indicated in yellow curve in the above graph.

Results and Analysis of PAM modulation system

The Table V. below depicts E_b/N_o vs. BER of PAM-4 over AWGN, rayleigh channel. As E_b/N_o increases, the error rate decreases as indicated in the Table V. The maximum error rate can be noticed in rayleigh channel than AWGN channel. At E_b/N_o of 0 dB, the BER is 0.1409, at E_b/N_o of 2 dB, the error rate is 0.0977, at E_b/N_o of 18dB the error rate is 4.52E-13 over AWGN channel. BER value is higher over Rayleigh channel than AWGN channel.

TABLE V

E_B/N_O VS. BER OF PAM-4 OVER AWGN CHANNEL		
Eb/No	***AWGN***	***Rayleigh***
0	0.1409	0.1975
2	0.0977	0.1570
18	4.52E-13	0.0076

The Table VI below depicts E_b/N_o vs. the error rate. The maximum error rate can be noticed in rayleigh channel than AWGN channel. At 0dB Eb/N_o bit error noticed is 0.1998, at 2dB error rate is 0.1569 and at 18dB the error value noticed is 6.35E-6. The error rate is lower at 18dB comparatively with 0dB.

Using Rayleigh channel, at 0dB BER value is 0.2470, at 2dB the error rate is 0.2088 and at 18dB the error rate observed is 0.0163 as depicted in the graph in Fig.9.

TABLE VI

E_B/N_O VS. BER OF PAM-8 OVER AWGN CHANNEL		
Eb/No	***AWGN***	***Rayleigh***
0	0.1998	0.2470
2	0.1569	0.2088
18	6.35E-6	0.0163

The Table VII below depicts E_b/N_o vs. BER of PAM-16 over AWGN and rayleigh channel. As E_b/N_o increases, the error rate decreases as indicated in the Table VII. The maximum error rate can be noticed in rayleigh channel than AWGN channel.

Using AWGN channel at 0dB E_b/N_o bit error noticed is 0.2546, at 2dB error rate is 0.2170 and at 18dB error value noticed is 0.0034, the error rate is minimum at 18dB and noticed higher at 0dB Eb/N_o.

Using Rayleigh channel at 0dB BER value is 0.2890, at 2dB the error rate is 0.2558 and at 18dB error rate observed is 0.0357 as depicted in the graph in Fig.9.

TABLE VII

E_B/N_O VS. BER OF PAM-16 OVER AWGN CHANNEL		
Eb/No	***AWGN***	***Rayleigh***
0	0.2546	0.2890
2	0.2170	0.2558
18	0.0034	0.0357

The Fig.8 below shows the BER values of 4PAM, 8PAM and 16 PAM over AWGN channel at Eb/No of 0dB, 2dB and 18dB. BER value is higher at 16PAM than 4PAM. As depicted in yellow and purple lines in the graph below.

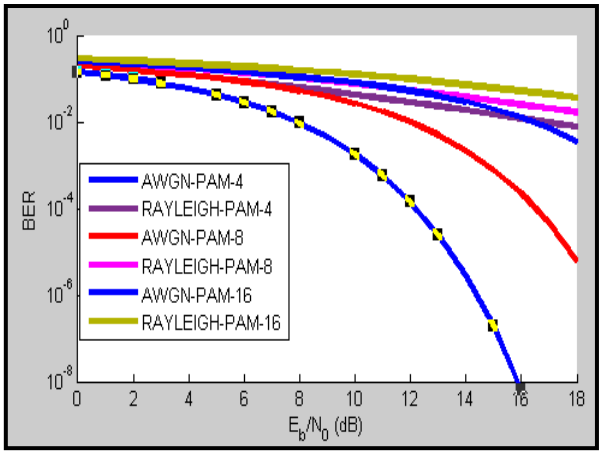

Fig. 8. BER of 4PAM, 8PAM and 16PAM over AWGN channel.

As shown in Fig. 9 QAM and PAM modulations are compared. 4QAM is compared with 4PAM, 16QAM is compared with 16PAM. As the results show that the bit error rate is higher with PAM modulation over AWGN channel than QAM modulation. The error rate at 2dB in 16PAM over AWGN channel is 0.217 and in 16QAM at 2dB is 0.0977. PAM signals are more prone to errors than QAM signals.

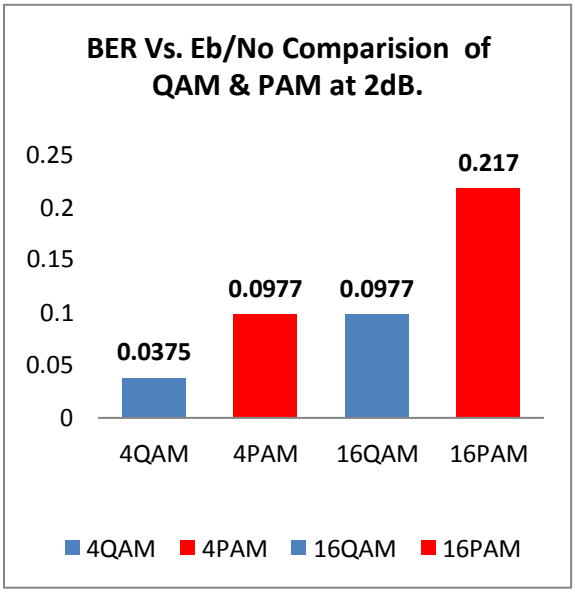

Fig. 9. BER of 4QAM, 4PAM, 16QAM and 16PAM over AWGN channel at Eb/No of 2dB.

CONCLUSION

In this work, Bit Error Rate with QAM and PAM modulation is compared for different values of E_B/N_O over AWGN, Rayleigh and Rician channels. The work is analyzed and compared. The comparison results depicts that PAM signals are more prone to errors than QAM signals. Digital QAM is more suitable for wireless communication than PAM.

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