Minimization the Effect of Different Channel Model on QAM and PAM Systems in Term of Bit Error Rate

Fatima Faydhe AL-Azzawi

Abstract/ Quadrature amplitude modulation (QAM) has been widely used in adaptive modulation because of its efficiency in power and bandwidth while Pulse Amplitude Modulation (PAM) used for high rate data link where transmitting more bits is a symbol time, QAM and PAM systems are both tested under AWGN, Rayleigh fading, Rician Fading channels as comparison performance in term of BER between the two systems, to improve the performance of both systems convolutional code, diversity order and K-factor are used, where these techniques decrease the BER on both systems.

Index Terms—QAM and PAM, fading channel, Convolutional AWGN channel, QAM in rician channel.

I. INTRODUCTION

The basic idea in PAM for communication channel is to transmit a sequence of pulses of some pre-specified shape p(t), with the sequence of pulse amplitudes carrying the information. The associated baseband signal at the transmitter (which is then usually modulated onto some carrier to form a bandpass signal before actual transmission.

$$x\ (t) = \sum_n a\ [n]\ p(t - n\ T)\text{.............................}(1)$$

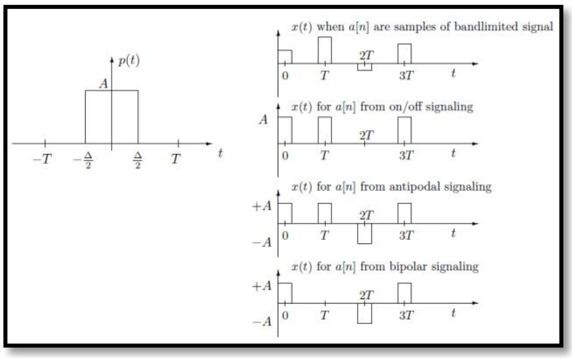

Fig. (1) : Baseband signal at the transmitter in Pulse Amplitude Modulation (PAM).

where the numbers a[n] are the pulse amplitudes, and T is the pulse repetition interval or the inter-symbol spacing, so 1/T is the symbol rate (or "baud" rate). An individual pulse may be confined to an interval of length T and some type of signaling is illustrated Figure 1. At the receiver PAM signal will be effected by characteristics of the channel, this affect our ability to accurately recover the pulse amplitudes a[n] from the received signal r(t). We might model r (t) as

r (t)= h(t)* x(t) + noise ……….(2)

Where noise parameter in above equation is change according to the type of channel as mentioned in BER analysis.

QAM Modulation technique is one of M-array modulation type where two or more bits are grouped together to form symbols and one of *M* possible signals is transmitted during each symbol period. Usually, the number of possible signals is *M* =2n, where *n* is an integer. Depending on whether the amplitude, phase, or frequency is varied, the modulation technique is called M-ary ASK, M-ary PSK, or M-ary FSK. Modulation which alters both amplitude and phase is M-ary QAM.

A comparison between M- QAM and M-PAM in term of advantages , disadvantages and application is illustrated in table 1. [1]

Modulation type	Advantages	disadvantages	application
QAM	Sharp cutoff band-pass filters are not required.	QAM is more exacting in terms of the carrier frequency and phase or the requirement for a distortion-less transmission medium	The transmission of digital television DTV and internet traffic between cable modem and modem termination systems.
PAM	Transmits more bits in a symbol time.	Require more power (M^2) less system complexity	High rate data links

As with many digital modulation techniques, the constellation diagram is a useful representation. It provides a graphical representation of the complex envelop of each possible symbol state. 4-QAM and 4-PAM constellations is shown in figure (2),

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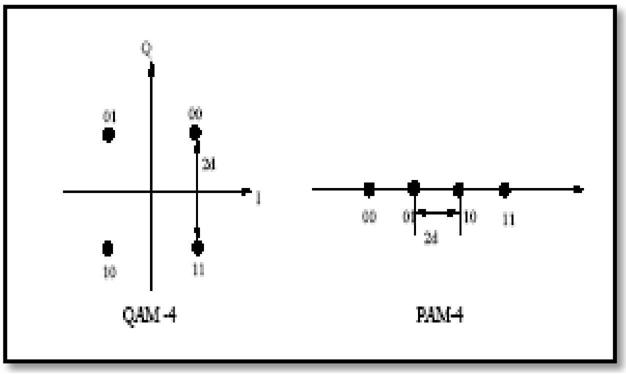

Fig.2 : . 4-QAM and 4-PAM constellations

II. BIT ERROR RATE ANALYSIS

A. *PAM and QAM in AWGN channel*

BER equation of PAM in AWGN channel[2]:

$$P_b = \frac{2}{M \log_2 M} \times \sum_{k=1}^{\log_2 M} \sum_{i=0}^{(1-2^{-k})M-1} \left\{ (-1)^{\left\lfloor \frac{i2^{k-1}}{M} \right\rfloor} \left(2^{k-1} - \right. \right.$$

i2k−1M+12Q2i+16 log2MM2−1EbN0…………………(3)

BER equation of QAM in AWGN channel[A]:

$$P_b = \frac{2}{\sqrt{M} \log_2 \sqrt{M}} \times \sum_{k=1}^{\log_2 \sqrt{M}} \sum_{i=0}^{(1-2^{-k})\sqrt{M}-1} \left\{ (-1)^{\left\lfloor \frac{i2^{k-1}}{\sqrt{M}} \right\rfloor} \left(2^{k-1} - \right. \right.$$

i2k−1M+12Q2i+16log2M2M−1EbN0…………………(4)

Where:

P_b : Bit error rate (BER)

M : Size of modulation constellation

K : Number of bits per symbol → k= $\log_2$ M

$\frac{E_b}{E_0}$: Energy per bit-to-noise power-spectral-density ratio

B. *PAM and QAM in AWGN with Convolutional Code.*

Bit error rate of PAM in AWGN channel with convolutional code P(d) is in the fallowing equation [3,4]:

$$P\,(d) = \sum_{k=(d+1)/2}^{d} \binom{d}{k} P^k (1-p)^{d-k} \ldots\ldots\ldots\ldots(5)$$

Where:

d : distance

p: is the bit error rate (BER) in an uncoded AWGN channel

Bit error rate of QAM in AWGN channel with convolutional code P(d) is in the fallowing equation [3,4]:

$$P\,(d) = P_b |_{\frac{E_b}{N_0} = \gamma_d R_c d} \qquad \ldots\ldots\ldots(6)$$

Where:

γ_d: Energy-per-information bit-to-noise power-spectral-densitRatio.

R_c : code rate → $R_c = \frac{k}{N}$, k is message length, N is code length.

C. *PAM and QAM in fading channel*

BER of PAM in fading channel P_b is [2,5,6]:

$$P_b = \frac{2}{\pi M \log_2 M} \times \sum_{k=1}^{\log_2 M} \sum_{i=0}^{(1-2^{-k})M-1} \left\{ (-1)^{\left\lfloor \frac{i2^{k-1}}{M} \right\rfloor} \left(2^{k-1} - \right. \right.$$

i2k−1M+120π/2t=1LMγl−2i+123/M2−1sin2θdθ…
…….(7)

Where

L : diversity branch

M_{γ_l}: Moment generating functions for each diversity branch

For Rayleigh fading:

$$M_{\gamma_l}(s) = \frac{1}{1 - s\,\overline{\gamma_l}}$$

For Rician fading[2,7]:

$$M_{\gamma_l}(s) = \frac{1+K}{1-K-s\,\overline{\gamma_l}}\, e^{\left[\frac{Ks\,\overline{\gamma_l}}{(1+K)-s\,\overline{\gamma_l}}\right]} \ldots\ldots\ldots\ldots\ldots(8)$$

Where K is the ratio of energy in the specular component to the energy in the diffuse component (linear scale).

For identically-distributed diversity branches:

$M_{\gamma_l}(s) = M_{\gamma}(s)$ for all l.

III. BIT ERROR RATE RESULTS

A. *PAM and QAM in AWGN channel*

PAM and QAM are both tested in AWGN channel as shown in figure 3 in term of BER, under this channel QAM performance better than PAM where QAM's BER reach to 10^{-8} at 12 dB E_b/N_0 and at same E_b/N_0 in PAM system BER reach to almost 10^{-4}, so in AWGN channel QAM saving 4dB of E_b/N_0 on PAM system.

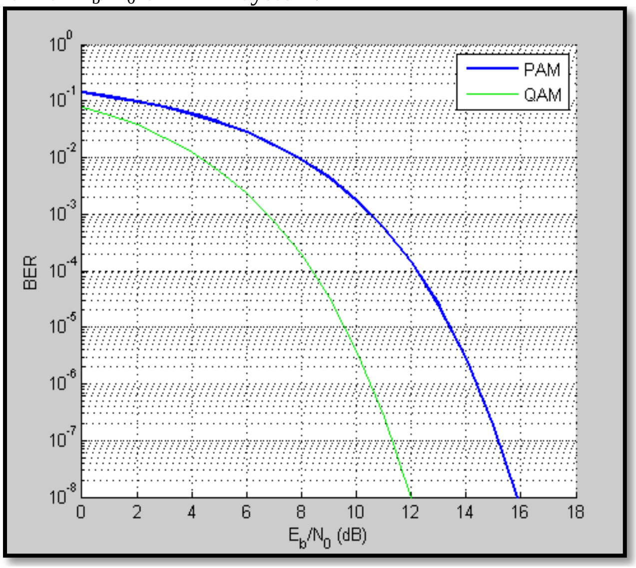

Fig. (3) : PAM and QAM in AWGN channel BER

B. <u>PAM and QAM in AWGN with Convolutional Code.</u>

Convolutional code on both system are tested and show better results in BER on both system as compared with BER without convolutional code, QAM also has batter performance with Convolutional code than PAM, where QAM's BER reach to 10^{-8} at 6 dB E_b/N_0 and at same E_b/N_0 in PAM system BER reach to almost 10^{-1}, so in AWGN channel with convolutional code QAM saving 4dB of

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E_b/N_0 on PAM system as shown in figure 4.

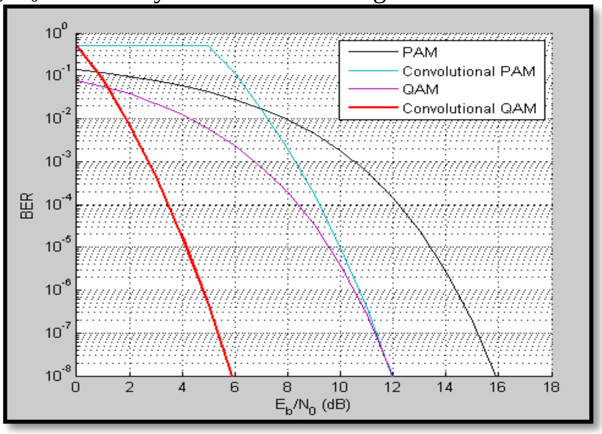

Fig (4) : PAM & QAM in AWGN with Convolutional code BER.

C. PAM and QAM in Rayleigh fading channel

In Rayleigh fading channel QAM has better performance in term of BER, where QAM's BER reach to 7.8*10 $^{-4}$ at 25 dB E_b/N_0 and at same E_b/N_0 in PAM system BER reach to almost 1.5*10^{-3}, so in Rayleigh channel QAM saving 3dB of E_b/N_0 on PAM system as shown in figure 5.

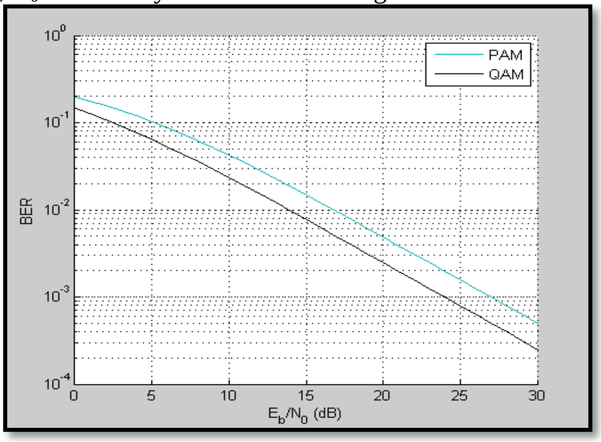

Fig (5) : PAM & QAM in Rayleigh fading channel BER.

D. PAM and QAM in Rayleigh fading channel with the effect of diversity.

As diversity order increased BER on both systems are decreased in Rayleigh fading channel, where QAM's BER reach to 3.3*10 $^{-9}$ at 25 dB E_b/N_0 when diversity order 4 and at same E_b/N_0 and diversity order in PAM system BER reach to almost 10^{-7}, so in Rayleigh channel with the increasing of diversity order QAM saving 4 dB of E_b/N_0 on PAM system as shown in figure 6.

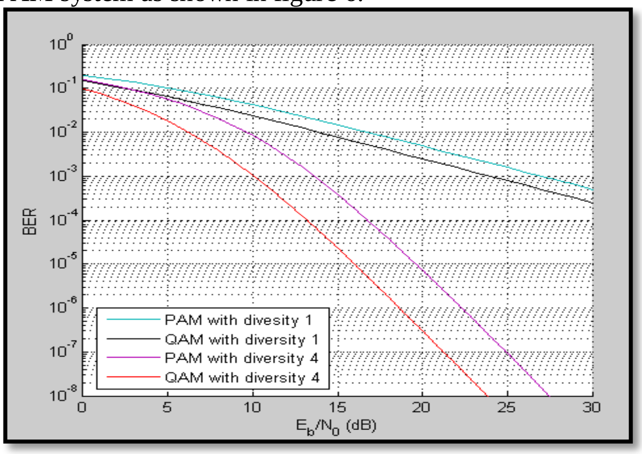

Fig. (6): Effect of diversity on PAM and QAM in Rayleigh fading channel.

E. PAM and QAM in Rician fading channel.

Performance of both systems in Rician fading channel are the same performance in Rayleigh fading channel as compering figure below with figure (7).

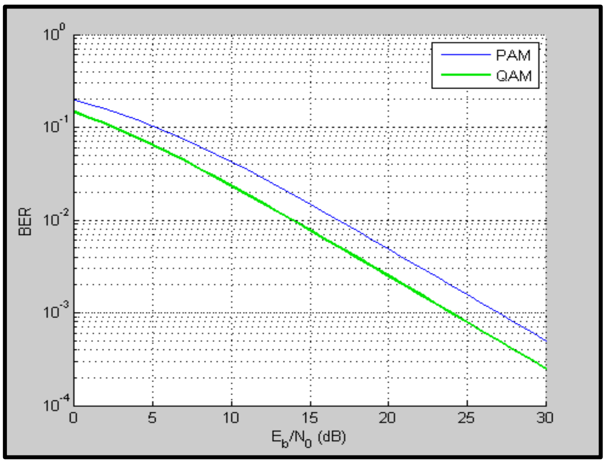

Figure (7) , PAM and QAM in Rician fading channel.

F. PAM and QAM in Rician fading channel with effect of diversity and K-factor

Effect of diversity alone on both systems in Rician fading channel is the same effect on Rayleigh fading channel, But increasing diversity and K-factor will improve the performance of both system under Rician fading channel. where QAM's BER reach to 4.6*10 $^{-13}$ at 25 dB E_b/N_0 when diversity order 4 and K-factor 4 at same E_b/N_0 , diversity order and K-factorin PAM system BER reach to almost 3*10^{-11}, so in Rician channel with the increasing of diversity order and K-factor QAM saving 4 dB of E_b/N_0 on PAM system as shown in figure below.

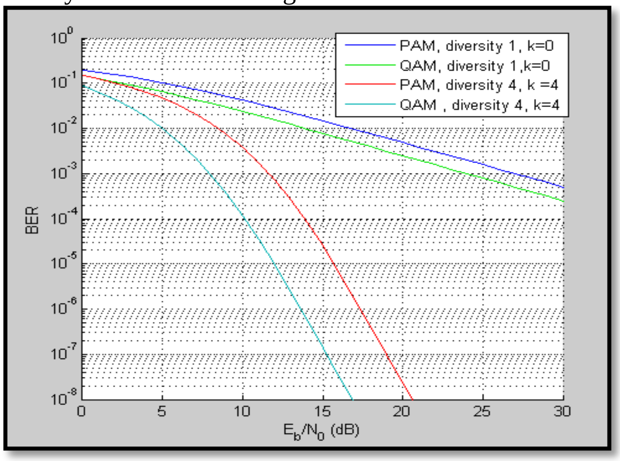

Fig. (8) effect of diversity and K-factor on PAM and QAM in Rician fading channel.

IV. CONCLUSION

QAM and PAM modulation technique were both tested under AWGN, Rayleigh fading, Rician Fading channels as comparison performance in term of BER, in term of BER caparison results shows QAM performance in all type of channel that in used in this paper will saving approximating 4 dB of E_b/N_0 on PAM system,

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convolutional code decreases BER in AWGN of both systems where QAM save 6 dB and PAM save 4 dB with convolutional code, Increasing diversity in Rayleigh fading channel decrease BER of both system where 10 dB of E_b/N_0 are saving, Increasing diversity and K-factor in Rician Fading channel decreasing BER of both systems where 10 dB of E_b/N_0 are saving.

REFERENCE

[1] M.S. Richer et al," The ATSC digital television system", proc. IEEE, vol.94, pp.37-43, Jan, 2006.

[2] Cho, K., and Yoon, D., "On the general BER expression of one- and two-dimensional amplitude modulations", IEEE Trans. Commun., vol. 50, no. 7, July 2002, pp. 1074-1080.

[3] Proakis, J. G., Digital Communications, 4th Ed., McGraw-Hill, 2001.

[4] Simon, M. K , Hinedi, S. M., and Lindsey, W. C., Digital Communication Techniques – Signal Design and Detection, Prentice-Hall, 1995.

[5] Simon, M. K., and Alouini, M. S., Digital Communication over Fading Channels – A Unified Approach to Performance Analysis, 1st Ed., Wiley, 2000

[6] Vo Nguyen Quoc Bao, Hyung Yun Kong, Seong Wook Hong, 'Performance Analysis of M -PAM and M -QAM with Selection Combining in Independent but Non-Identically Distributed Rayleigh Fading Paths', IEEE, 2008 .

[7] Daniel J. Ryan, 'Blind Detection of PAM and QAM in Fading Channels' , IEEE TRANSACTIONS ON INFORMATION THEORY, VOL. 52, NO. 3, MARCH 2006.

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