Investigation of Bit Error Rate of Different Modulation Schemes at different Modulation order of Bio-Medical Wireless System in AWGN and Rayleigh Channels

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Abstract - **The bit-error-rate (BER)is an important factor that decides the performance of different modulation techniques of bio-medical wireless system since the objective of any transceivers system is to receive the information with lowest errors because errors reduces the system performance. In this work, BER performance of some of digital modulation schemes (PAM, PSK, DPSK and FSK) are evaluated in additive white Gaussian noise (AWGN) and Rayleigh fading channels at different modulation order. The system is implemented in MATLAB 2018b Simulink environment. The results shows clearly that at 15 dB, FSK modulation scheme at higher modulation order 32 gave better performance with lowest errors (4.91x 10^{-28}) for biomedical RF transceivers system. The mean BER obtained at this highest modulation order is 0.0102 which is very low compared to PAM, PSK and DPSK modulation schemes. Hence, FSK at modulation order 32 would enhance the performance of the Bio-medical wireless system.**

Key words: **BER, Digital modulation, Modulation order, Modulation schemes, Transceivers.**

I. INTRODUCTION

The bit error rate is the ratio of the number of bit errors to the total number of transferred bits during a studied time interval. The performance of digital wireless signal (transmission and reception) is very important in a mobile communication environment and the accomplishment of this communication system depends on the unpredictable characteristics of the radio channel which is slowly varying with time and this makes the design of wireless communication system difficult [1]. This characteristics property of the channel results to event called fading which induce swift amplitude fluctuations in the received signal and this might lead to performance degradation. Digital modulation schemes have greater capacity to convey large amounts of information than analog modulation schemes but channel is the most important issue for any kind of communication system. These channels include; Additive white Gaussian noise (AWGN) channel, Rayleigh Fading channel, Rician Fading channel [2]. These channels are important parameters which are used to compare the performance indices and the parameters also help to analyze the detection and decoding of the signal power and strength. In an ideal channel, the transmitted signal will pass through channel up to the receiver, where it is demodulated to get an infallible representation of the original signal. But in reality, the received signal consists of mixture of path loss and reflected version of the transmitted signal [3]. In addition to these, the channel adds various types of noise to the signal. This affects the Bit Error rate (BER) and signal-to-noise ratio (SNR) of the Bio-signal wireless system. Hence, this work seeks to study the key characteristics of communication channel and compares the performances of four different digital modulation schemes (PSK, DPSK, PAM and FSK) in the presence of AWGN at different order of modulation. The study also recommends the modulation scheme that enhance the performance of bio-medical wireless transceivers.

II. THEORETICAL BACKGROUND

(A) Modulation order

The modulation order of a digital communication scheme is obtained by the number of the different symbols that can be transmitted using it. The simplest forms of digital modulation are of second order because they can transmit only two symbols (usually denoted as “0” and “1” or as “-1” and “1”). They are called binary shift keying (BSK). Modulations which have an order of 4 and above usually are termed as higher order modulations e.g. QPSK and its generalization as m-ary quadrature amplitude modulation (m-QAM) [4, 5, 6].

(B) Additive White Gaussian Noise (AWGN)

The term AWGN means that the noise is simply superimposed or added to signal that there are no multiplicative mechanisms at work. It is one of the channel model in which the only impairment to communication is a linear addition of white noise with a constant spectral density and a Gaussian distribution function of amplitude. This model does not account fading, interference, non-linearity or dispersion but produces simple and tractable mathematical models which are very useful to gain the insight into the underlying behaviour of a system. The channel capacity C for AWGN channel is given as [7]

$$C = Blog_2\left(1+\frac{S}{N}\right) \quad (1)$$

In AWGN channel with background noise n(t), the transmitted signal s(t) is given as [5]

$$S(t) = Re[u(t)e^{j2\pi fct}] \quad (2)$$

The received signal which passes through the AWGN channel is

$$r(t) = s(t) + n(t) \quad (3)$$

The value of the noise follows the Gaussian probability distribution function

$$P(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-(x-\mu)^2} \quad (4)$$

(C) Bit Error Rate (BER)

BER is the number of bit errors that occur for a given number of bits transmitted. It is related to the error probability because is the ratio of bit errors to bits transmitted while the energy per bit is the amount of power is a digital bit for a given amount of time. The BER performance of any digital modulation scheme in a slow flat fading channel can be evaluated by the following integral [8]

$$P_b = \int_o^\infty P_b AWGN\ (\gamma)\ P_{df}(\gamma)d\gamma \quad (5)$$

where$P_b AWGN\ (\gamma)$ is the probability of error of a particular modulation scheme in AWGN channel, $\gamma = h^2\, {E_b}/{N_o}$ which is the specific signal to noise ratio, ${E_b}/{N_o}$is the ratio of bit energy to Nosie power density in a non-fading AWGN channel, h^2 is the instantaneous power of the fading channel and $P_{df}(\gamma)d\gamma$ is the probability density function of γ due to the fading channel.

(D) Energy per bit to Noise ratio (Eb/No)

Energy per bit to noise ratio is the ratio of information (i.e. without channel coding) bit energy per symbol to noise power spectral density in decibels. To improve the reliability of data transmission, the designer will have to increase the signal power or to maximize the value of the ratio Eb/No. The mathematical expression of energy per bit is

$$E_b = P_s \times T_b \quad (6)$$

where Ps = average signal power, Tb = bit duration.

In a noisy channel, the BER may be expressed as a function of signal to noise ratio denoted as Eb/No and it is given as [7][8]

$$BER = \frac{1}{2} erfc\sqrt{{E_b}/{N_o}} \quad (7)$$

(D) Rayleigh Fading

Rayleigh fading is the name given to the form of fading that is often experienced in an environment where there is a large number of reflections present. The Rayleigh fading channel refers to a multiplicative distortion h (t) of the transmitted signal s (t). It is given as, [9, 10]

$$y(t) = h(t)[s(t) + n(t)] \quad (8)$$

where y(t) is the received waveform and n (t) is the noise. Rayleigh fading is the specialized model for stochastic fading when there is no line-of-sight propagated signal and is sometimes considered as a special case of the more generalized concept of Racian fading. In Rayleigh fading the amplitude gain is characterized by a distribution.

III. METHODOLOGY

In this paper, simulations of digital modulation technique was carried out using MATLAB R2018b and a real time simulation model was created using Simulink. The flowchart for obtaining the BER Vs Eb/No key characteristics of communication channel and compares the performances of different digital modulation schemes (PSK, DPSK, PAM and FSK) in the presence of AWGN and Rayleighchannels with diversity order of (4, 8, 16 and 32) for transmission of the modulated signals is shown in figure 1.

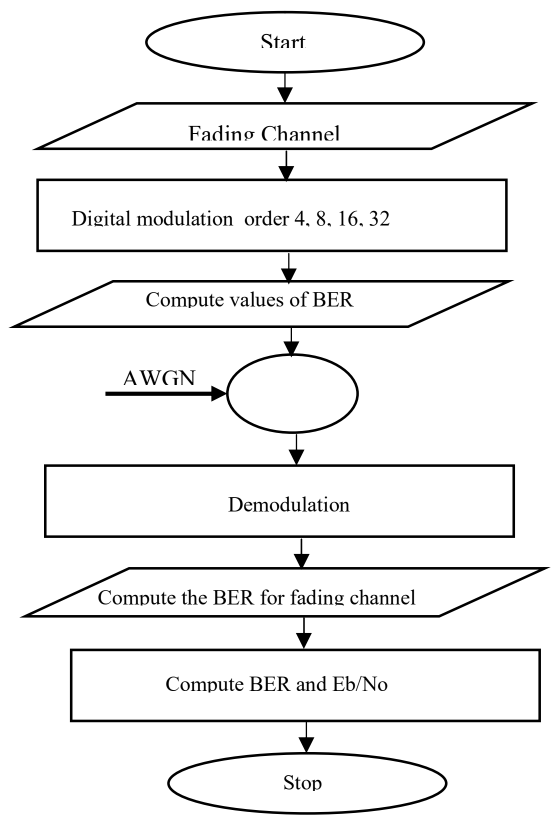

Fig. 1: Flow-chart for obtaining BER Vs Eb/No plot.

IV. RESULTS AND DISCUSSION

Figure 2 to 5 depicts the BER against energy per bit-to-noise ratio, Eb/No. It was observed that generally, for all the digital modulation considered, the BER decreases with increase in the signal power with respect to AWGN noise energy Eb/No. At lower modulation order (order 4), PSK gave better performance but at higher modulation order (8, 16 and 32), FSK gave better performance. At Eb/No of 15 dB, the BER of PSK, DPSK, PAM and FSK obtained were 0.0162, 0.0435, 0.0657 and 4.91x 10^{-28}respectively. It was also noted that the BER of only FSK modulation scheme decreases with increase modulation order (inverse relations) in both AWGN and Rayleigh fading channels. The BER of other modulation schemes considered in this work shows a direct relations with modulation order in AWGN channel as shown in figure 6. The work shows clearly that FSK modulation scheme at higher modulation order (32) shows better performance with lowest errors for biomedical RF transceivers system. The BER obtained at this highest modulation order is 0.0102. Hence, FSK at modulation order 32 will enhance the performance of the system. Table 1 shows the comparison between modulation schemes at different modulation order.

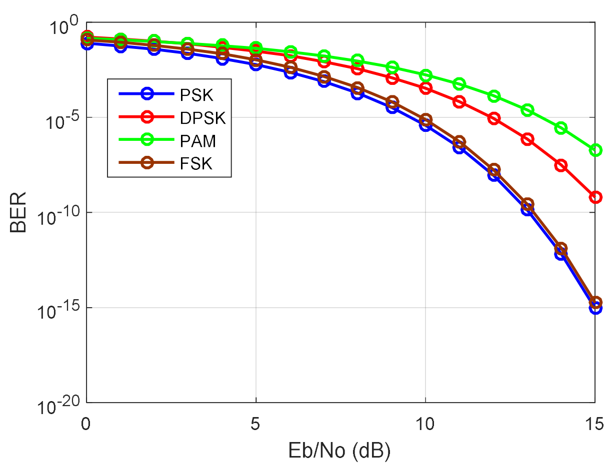

Fig. 2: A graph of BER against Eb/No at modulation order 4

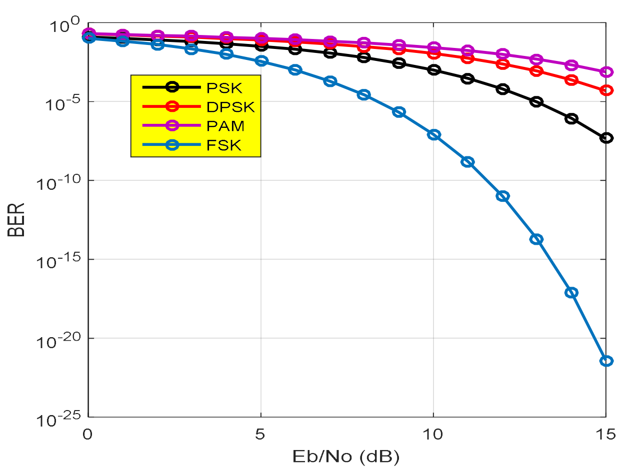

Fig. 3: A graph of BER against Eb/No at modulation order 8

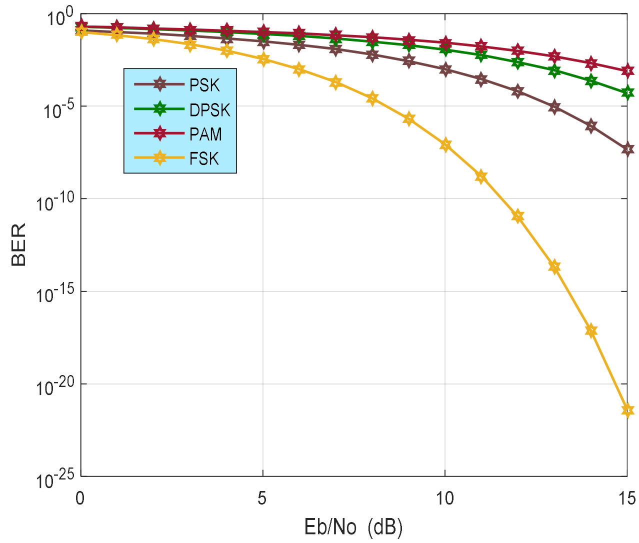

Fig. 4: A graph of BER against Eb/No at modulation order 16

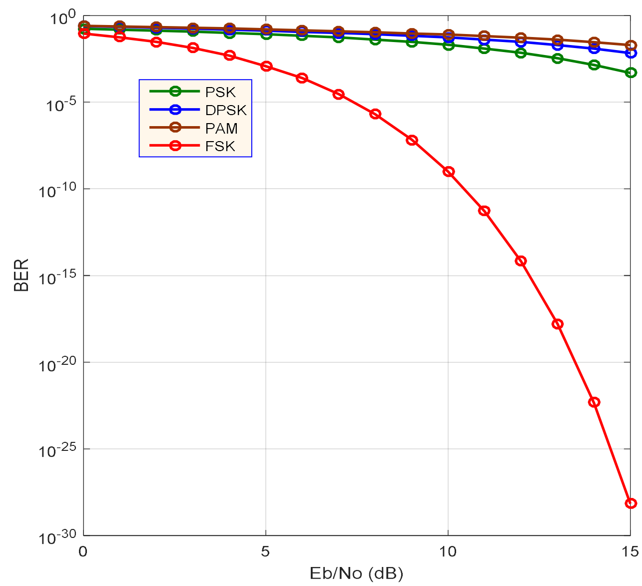

Fig. 5: A graph of BER against Eb/No at modulation order 32

Table 1: Comparison between modulation schemes at different modulation order

Modulation Order	Mean BER			
	FSK	PAM	DPSK	PSK
4	0.0215	0.0372	0.0360	0.0135
8	0.0154	0.0746	0.0613	0.0304
16	0.0122	0.1245	0.1028	0.0623
32	0.0102	0.1701	0.1520	0.1073

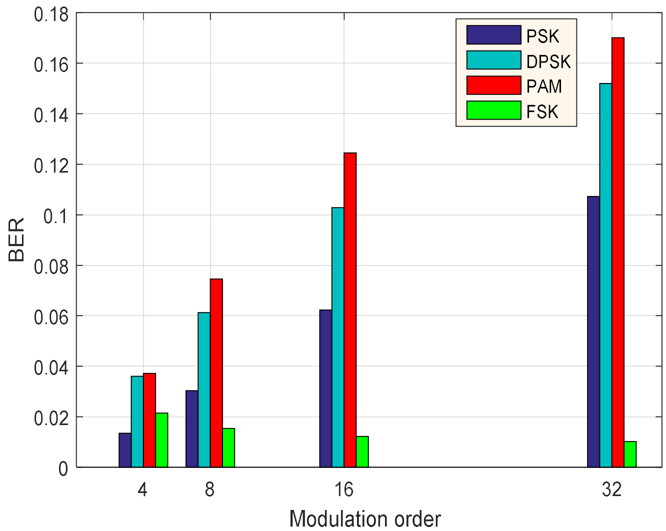

Fig. 6: Mean BER of the modulation schemes at different modulation order in AWGN channel

Figure 7 shows the comparison of BER performance of the four digital modulation schemes considered at Rayleigh fading channel. It is obvious from the figure that FSK modulation technique shows better performance compared to PSK, DPSK and PAM. Generally, for all the modulation schemes, it was observed that an Additive white Gaussian noise (AWGN) channel shows low BER compared to Rayleigh Fading channel. Hence, the performance indices of a bio-medical RF system would be excellent by suing FSK modulation scheme at modulation order 32, this would also help to analyze the detection and decoding of the signal strength.

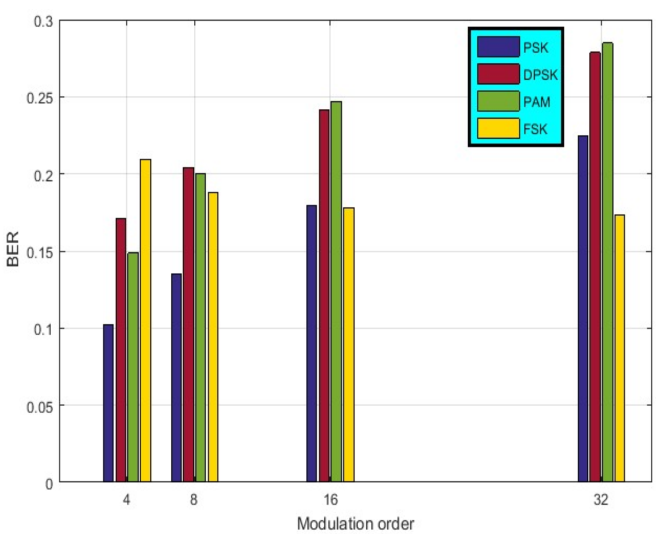

Fig. 7: Mean BER of the modulation schemes at different modulation order in Rayleigh channel

V. CONCLUSION

In this work, evaluation of four digital modulation schemes, that is, PSK, PAM, FSK and DPSK in terms of BER is performed on AWGN and Rayleigh channels of bio medical RF transceivers. It was noted that the BER of only FSK modulation scheme decreases with increase modulation order (inverse relations) in both AWGN and Rayleigh fading channels.The BER of other modulation schemes considered in this work shows a direct relations with modulation order. The work shows clearly that at 15 dB, FSK modulation scheme at higher modulation order 32 gave better performance with lowest errors (4.91×10^{-28}) for biomedical RF transceivers system. The mean BER obtained at this highest modulation order is 0.0102 which is very low compared to PAM, PSK and DPSK modulation schemes. Hence, FSK at modulation order 32 would enhance the performance of the Bio-medical wireless system performance.

REFERENCES

[1]. Miki, N., Kishiyama, Y., Higuchi, K and Sawahashi, M. (2007) "Optimum Adaptive Modulation and Channel Coding Scheme For Frequency Domain Channel-Dependent Scheduling in OFDM Based Evolved UTRA," IEEE WCNC.

[2]. Yang, Hong-Chuan and M-S. Alouini. "Closed-form formulas for the outage probability of wireless communication systems with a minimum signal power constraint." *Vehicular Technology, IEEE Transactions on* 51.6 (2002): 1689-1698.

[3]. Bruce, A. C and Paul, B. C, Communication Systems, 5th ed., McGraw-Hill, pp 663-692

[4]. Herbert Taub, Donald L. Schilling and GoutamSaha, Principles of Communication Systems, 3rd ed., Tata MaGraw Hill, pp 322-418.

[5]. Mohammaed Slim Alouini and Andrea J. Goldsmith (1999) “Capacity of Rayleigh fading channels under different Adaptive Transmission and Diversity combining Techniques”, IEEE Transactions on Vehicular Technology, Vol. 48, No. 4, July 1999.

[6]. Gary Breed, High Frequency Electronics, (2003) Summit, Technical Media LLC “Bit Error Rate: Fundamental Concepts and measurement issues”.

[7]. Proakis J G, (2001): Digital. Communications, 4th Ed., New York, McGraw-Hill.

[8]. Deergha, K. Rao: Channel Coding Techniques for Wireless Communications, DOI 10.1007/978-81-322-2292-72

[9]. Yahong Rosa Zheng and Chengshan Xiao, (2003) Senior Member IEEE, Simulation Models With Correct Statistical Properties for Rayleigh Fading Channels, IEEETransactions on Communications, Vol. 51, No. 6, June 2003.

[10]. Patel, C. S,.Stuber, G. L and Pratt, T. G (2005) “Comparative analysis of statistical models for the simulation of Rayleigh faded cellular channels,”IEEE Trans. Commun., vol. 53, pp. 1017-1026, June 2005.