Performance Investigation of M-ARY Modulations through Human Body Area Channel

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Abstract-- In this paper, the performance of M-ary modulations have been evaluated by carrying out extensive simulations at different carrier frequencies through Human Body Area Channel. Rayleigh and Weibull distributions have been used for generating fading power profiles[1] .The bit error rate has been obtained by using M-ary modulation schemes i.e. M-ary PAM(Pulse Amplitude Modulation) and M-ary BOK(Bi-orthogonal Keying) in the Human Body Area Network channel. With the aid of these graphs, bit error rate performance evaluation of M-ary modulations at different values of Carrier frequency has been done and the performance of various Rake receivers have been taken into account. The values of the carrier frequency are chosen within the constraints specified by the NICTA. Through simulative investigations of Bit Error Rate (BER), it has been found that the best suitable value of carrier frequency by using M-ary modulation in the Human BAN channel is 2400 Mhz[4]. It has been observed that the performance of selective rake receiver (for optimum number of fingers) is better than partial rake receiver for both modulations.

Index Terms – M-ary Modulations; Bit Error Rate; Signal to Noise Ratio (SNR)

1. INTRODUCTION

The Wireless Body Area Networks[1] is emerging as a new technology in medical and Consumer Electronics applications. We can do real time monitoring of patients with the help of small wearable and implantable sensors. These sensors are designed to measure and monitor events and physical properties such as temperature, pressure, movement, pulse rate and location. It has the smallest coverage area only surrounding the body of a human. It uses the ISM frequency band which is approved band of Regulatory and Medical authorities for in or around human body. The basic function of WBAN is to provide effective and reliable networking for transmission of data, voice or picture through wireless communication links.

The remainder of this paper is organized as follows:

In the following section the simulation methodology is given which explains how the curves have been drawn for SNR and BER. Section 3 and section 4 gives us the information about signaling scheme and simulation parameter respectively. Receiver structure is explained in section 5. The results and are given in section 6 followed by conclusion in section 7.

2. SIMULATION METHODOLOGY

With the help of above digital modulation techniques various graphs are plotted between Signal to Noise Ratio (SNR) and Bit Error Rate (BER).by using the following steps[1].

Step1: Generate power profile ([signal,time_samp,mean_path_loss] = generate_power_profile_wmban(), of Human BAN channel ( ).

Step2: Calculate absolute value of signal.

Step3: Calculate received SNR of each sample of power profile with the help of transmitted SNR and mean_path_loss.

Step4: Calculate received signal to noise ratio for various rake taps (all-rake, partial rake, selective rake).

Step5: (a) Calculate BER for BPSK receiver (all-rake, partial rake, selective rake).

Step6: BER vs SNR curves are plotted for BPSK at different carrier frequencies.

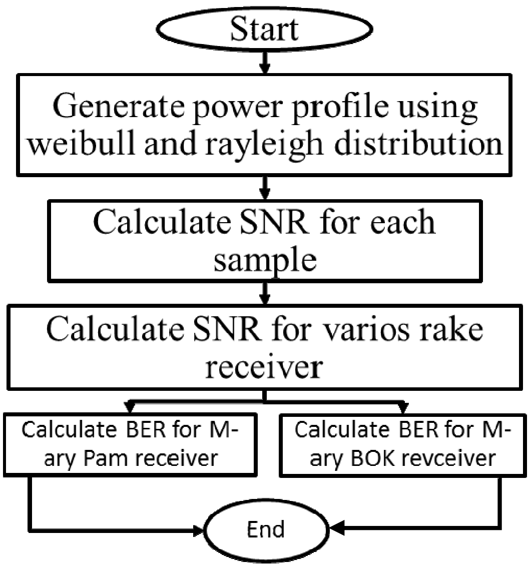


Fig. 1. Flow chart for generation of SNR vs BER

3. SIGNALLING SCHEME

An information carrying signal is generally limited by its channel. The bit streams to be transmit over channel are inherently discrete time and all physical media are continuous time in nature; hence modulation is required to represent the bit stream as a continuous time signal for transmission. In other word modulation is the process of varying signal so that it carry information. There are various possible modulation options depending on the range, transmission and reception power, quality of service requirements, regulatory requirements, hardware complexity, data rate, reliability of channel, and capacity. Therefore, it is crucial to choose the right modulation for the right purpose. Here we use compares M-ary modulating schemes[3]. In these modulations mapping is generally performed by taking blocks of $k = \log_2 M$ binary digits at a time from sequence $\{a_n\}$ and selecting one of symbols from

$$M = 2^k. \quad (1)$$

Where $M \rightarrow Number\ of\ symbol$ and $k \rightarrow Number\ of\ bits\ per\ symbol$

M-PAM - Pulse amplitude modulation is the digital modulation in which the amplitude of the modulating signal vary in accordance with the carrier signal. In this carrier signal is in form of pulses which is modulated by digital modulating signal. With M=16,16-PAM allows 4 bits per symbol and with M=32,32-PAM allows 5 bits per symbol and for M=64,64-PAM allows 6 bits per symbol.

M-BOK – M-BOK stands for *M-ary* Bi-Orthogonal Keying modulation in which a set of *M* moderate length ternary codes (−1, 0, +1) is used to represent *M* symbols. . The *M*-BOK symbols are spaced on *M* orthogonal axes in the modulation symbol space, so the probability of symbol errors follows that of *M-ary* bi-orthogonal modulation.

4. SIMULATION PARAMETERS

In order to evaluate the performance of WBAN channel under varied channel conditions, some important and effective simulation parameters have been identified in this work. They include:

4.1. Carrier frequency

A **carrier signal** is a transmitted electromagnetic pulse or wave at a steady base frequency of alternation on which information can be imposed by increasing signal strength, varying the base frequency, varying the wave phase, or other means. This variation is called modulation. A carrier frequency[4] is frequency of carrier signal.

4.2. BIT ERRROR RATE

The bit error rate is the ratio of number of error bits to the total transferred bits during a time interval for which the performance of channel is measured. It is also called bit error ratio (BER)[3].The probability of bit error rate is an approximate estimation of bit error rate is calculated as follows:

M-ary PAM: The probability of symbol error is

$$P_M = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} \left[1 - \left(\frac{1}{\sqrt{2\pi}} \int_{-\infty}^{y} e^{-x^2/2}\, dx \right)^{M-1} \right] exp\left[-\frac{1}{2} \left(y - \sqrt{\frac{2E_s}{N_0}} \right)^2 \right] dy \quad (2)$$

Where $\frac{E_b}{N_o} \rightarrow signal\ to\ noise\ ratio$

The average bit probability error is

$$P_m = \frac{P_M}{M-1} = \frac{P_M}{2^k - 1} \quad (3)$$

M-ary BOK: The probability of symbol error is

$$P_M = 1 - \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} \left(\frac{1}{\sqrt{2\pi}} \int_{-\infty}^{v+\sqrt{\frac{2\gamma M}{M-1}}} \exp\left(\frac{-x^2}{2}\right) \right)^{M-1} dx * \exp\left(-\frac{v^2}{2}\right) dv \tag{4}$$

where $\gamma = \gamma_b \log(M)/\log(2)$ is the SNR per symbol and γ_b is the received SNR per information bit.

The average bit probability error is

$$P_m = P_M \frac{M}{2(M-1)} \tag{5}$$

5. RECEIVER STRUCTURE

We have generated the different multipath components (MPCs) of the same transmitted pulse in the WBAN channel. Number of multipath components depends upon time on which signal is generated. WBAN receiver can take advantage of diversity by using Rake combiner to improve performance of the system. The basic version of the Rake receiver consists of multiple correlators (fingers) where each of the fingers can detect/extract the signal from one of the multipath components provided by the channel. Different strategies for exploiting this temporal diversity include Selection Diversity, Partial Diversity. In this work, we have used all rake, partial rake and selective rake receiver[3]. Selective and partial rake have been used with the less and more number of taps. The A-Rake (All rake) structure used here to indicate the receiver with unlimited resources (fingers or correlators) and instant adaptability. In A-Rake number of receivers required is Td * Fs where the time duration of impulse is Td and Fs is sample rate of signal. Since the number of resolvable multipath components increases with the spreading bandwidth, the number of correlators required for the A-Rake receiver may become quite large for WBAN channels up to 20,000. Two sub-optimum reduced complexity rake structures i.e., S-Rake (Selective rake) and P-Rake (Partial rake) have been proposed here for performance evaluation. The S-Rake selects the best 16/32 taps (a subset of the available resolved multipath components) and P-Rake selects the first 16/32 taps (which are not necessarily the best) then combines the selected subset using MRC. The combiner produces a decision variable at its output which is then processed by a detector. Thus, the detector performance can be considered to be based on this equivalent channel created by the cascade of the radio channel and MRC rake structures.

6. RESULTS AND DISCUSSIONS

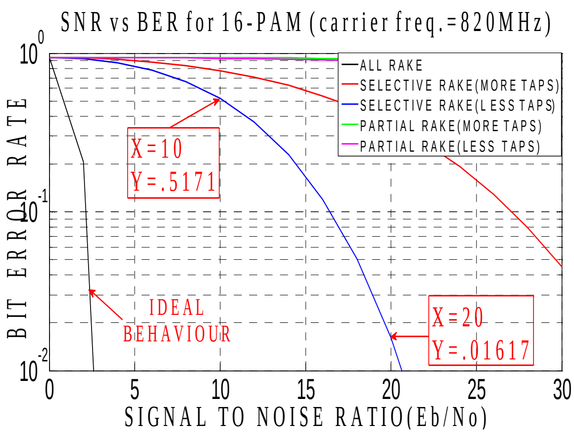
Bit Error Rate (BER) specifies the number of error bits occurs in transmitting signal in one second .In this work , extensive simulations have been carried out to observe the variations of the BER performance for various M-ary modulations for different carrier frequencies within the constraints specified by NICTA. In these graphs ,y-axis represents bit error rate and x-axis represents signal to noise ratio(SNR).BER vs SNR has been plotted at different carrier frequency for different modulation scheme as follow:

6.1 SNR vs BER for M–ary PAM

M-ary PAM (Pulse Amplitude Modulation) is digital modulation scheme where $M = 2^k$ or $k = \log_2 M$,here k represents number of bits/symbol and M represents number of symbols. In these modulating scheme, k binary digits are taken at a time for mapping .The modulation scheme in which amplitude of the pulse varies in accordance with the modulating signal is called PAM.

6.1.1 SNR vs BER for 16-PAM **:**

In 16-PAM , number of bits/symbol is 4 and number of symbols are 16. In figure2, 16-PAM is compared for various rake taps(i.e. All rake ,Partial rake and Selective rake) and for different carrier frequencies(i.e. 820Mhz,1900Mhz and 2400Mhz).



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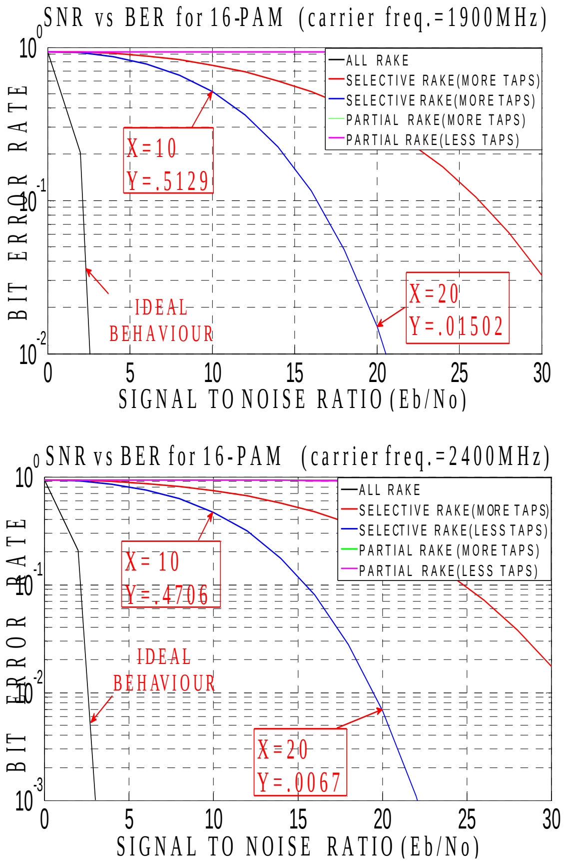

Figure2: BER performance for 16-PAM for different carrier frequencies.

Table1: Comparison of BER of 16-PAM for different carrier frequencies.

Carrier frequency	S/N ratio(x)	Bit error rate(y)
820	10	0.5171
1900	10	0.5129
2400	10	0.4706
820	20	0.01617
1900	20	0.01502
2400	20	0.006784

From above graphs (figure2) it is clear that performance of partial rake is poor than selective rake.Table1 concludes that minimum value of BER for 16-PAM for selective rake is at 2400Mhz of carrier frequency which makes it most suitable for this modulating scheme.

6.1.2 SNR vs BER for 32-PAM :

In 32-PAM, number of bits/symbol is 5 and numbers of symbols are 32 . In figure3, 32-PAM is plotted for different rake taps at different carrier frequencies. The table 2 evaluates BER performance for different carrier frequencies for 32-PAM.

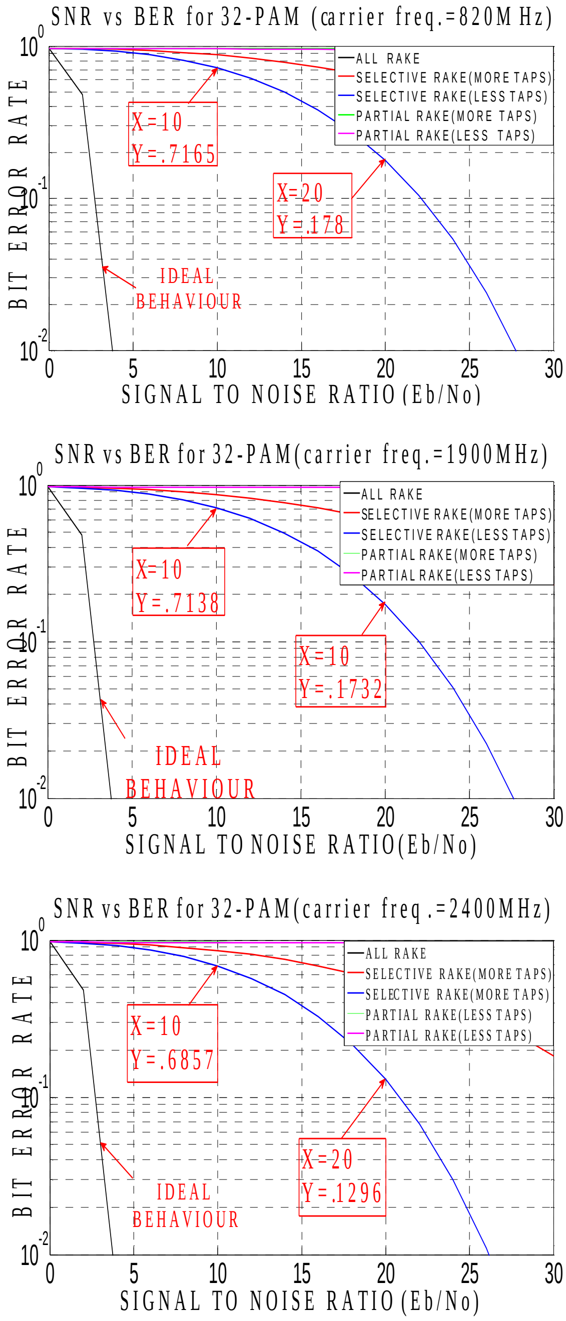

Figure3: BER performance of 32-PAM for different carrier frequencies.

Table2: Comparison of BER of 32-PAM for different carrier frequencies.

Carrier frequency	S/N ratio(x)	Bit error rate (y)
820	10	0.7165
1900	10	0.7138
2400	10	0.6857
820	20	0.178
1900	20	0.1732
2400	20	0.1296

In figure3,selective rake gives better performance than partial rake. As concluded from table 2, 2400Mhz of carrier frequency for selective rake is better than 820Mhz and 1900Mhz ,as with this frequency the value of bit error rate is most effective.

6.1.3 SNR vs BER for 64-PAM :

In 64-PAM, number of bits/symbol are 6 and number of symbols are 64.The 64-PAM is compared for different carrier frequencies and various rake taps and corresponding results are shown in table3.

Table3: Comparison of BER of 64-PAM for different carrier frequencies.

Carrier frequency	S/N ratio(x)	Bit error rate(y)
820	10	.8423
1900	10	.8407
2400	10	.8243
820	20	.4595
1900	20	.4545
2400	20	.4053

The selective rake is better than partial rake for 64-PAM as shown in figure4 .The table 3 concludes the best performance of 2400Mhz of carrier frequency for selective rake, with least values of bit error rate as compares to 820Mhz and 1900Mhz.
From above results it is clear that for M-ary PAM's 16-PAM shows best results with selective rake at 2400Mhz carrier frequency.

6.2 SNR vs BER for M-ary BOK

M-ary BOK is also a digital modulation scheme in which symbols are spaced on *M* orthogonal axes in the modulation symbol space such that probability of symbol errors follows the *M-ary* bi-orthogonal modulation. here k represents number of bits/symbol and M represents number of symbols.

6.2.1 SNR vs BER for 16-BOK **:**

In figre4,simulation graphs for 16-BOK(i.e. for total 16 symbols and 4 bits/symbol) are plotted for different rake taps (i.e. All rake, Partial rake and selective rake) and for different carrier frequencies(i.e.820Mhz,1900Mhz and 2400Mhz).

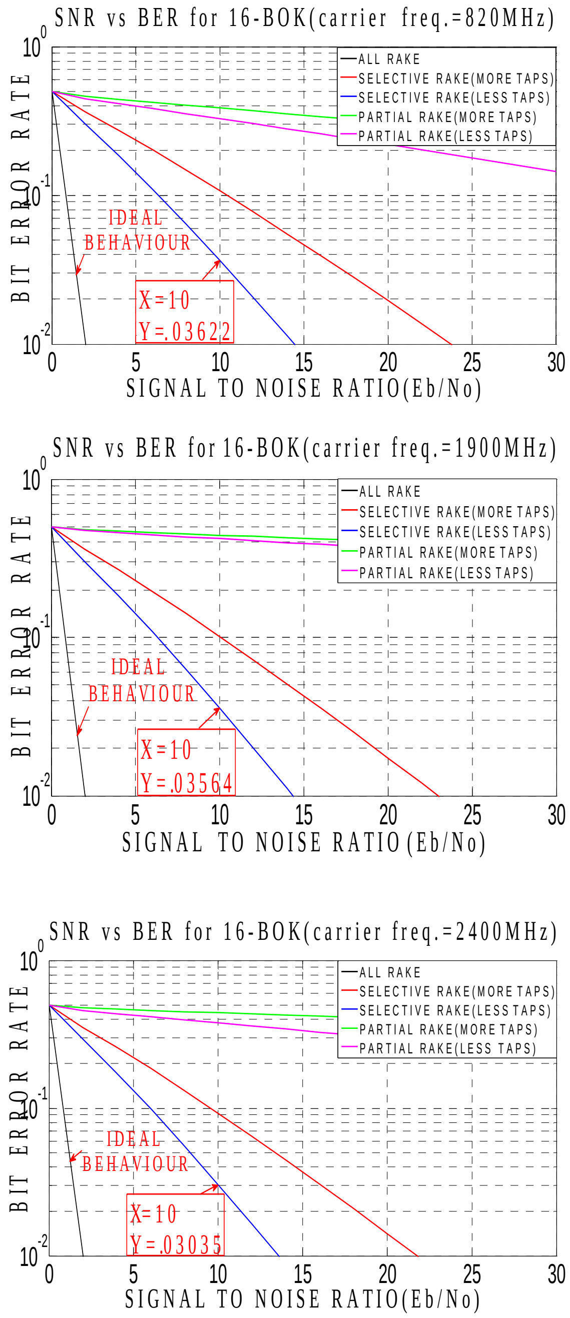

Figure4: BER performance of 16-BOK for different carrier frequencies.

Table4: Comparison of BER of 16-BOK for different carrier frequencies

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Carrier frequency	S/N ratio(x)	Bit error rate(y)
820	10	.03622
1900	10	.03564
2400	10	.03035
820	20	.001903
1900	20	.001839
2400	20	.001308

In figure4,selective rake gives better performance than partial rake. As concluded from table 4, 2400Mhz of carrier frequency for selective rake is better than 820Mhz and 1900Mhz ,as with this frequency the value of bit error rate is most effective.

6.3.2 SNR vs BER for 32-BOK :

Extensive simulations has been carried out to obtain the graphs of figure6 for 32-BOK (i.e. M =32 and k=5) at different carrier frequencies for different rake taps.

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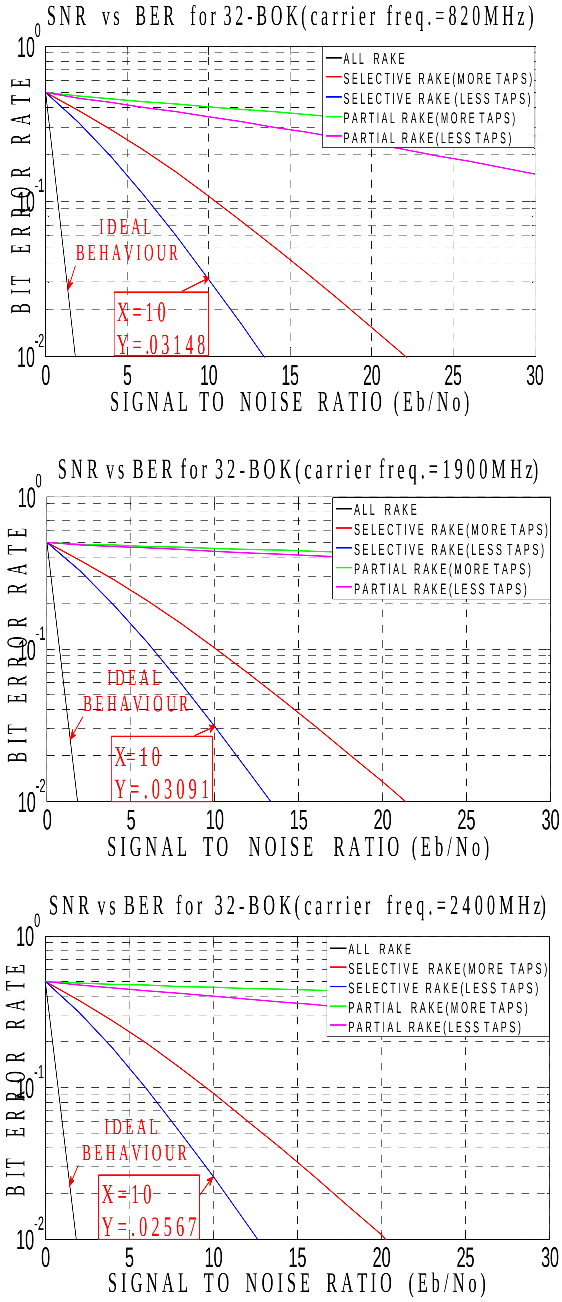

Figure5: BER performance of 32-BOK for different carrier frequencies.

Table5: Comparison of BER of 32-BOK for different carrier frequencies .

Carrier frequency	S/N ratio (x)	Bit error rate (y)
820	10	.03148
1900	10	.03091
2400	10	.02567
820	20	.0009813
1900	20	.0009421
2400	20	.0006272

It is concluded from table 5 that performance of partial rake for 2400Mhz of carrier frequency is better than that for partial rake and for frequencies 820mhz and 1900Mhz.

6.3.3 SNR vs BER for 64-BOK :

In table 6, 64-BOK(i.e. M=64 and k=6) is compared for different rake taps(i.e. All rake ,selective rake and partial rake) at different carrier frequencies (820Mhz,1900Mhz and 2400Mhz). .

Table6: Comparison of BER of 64-BOK for different carrier frequencies .

Carrier frequency	S/N ratio (x)	Bit error rate (y)
820	10	.02704
1900	10	.02647
2400	10	.02143
820	20	.0004869
1900	20	.0004642
2400	20	.0002881

It is clear that behaviour of BER for selective rake is more effective than partial rake and for 2400 Mhz of carrier frequency it shows best performance.
From above results it is clear that 64-BOK shows best result from all other M-ary BOK's selective rake at 2400 Mhz carrier frequency.

7. CONCLUSION

The Human Body Area Network Channel requires an efficient modulating scheme to carry out its signal processing so that there is minimum losses. So in this work, the Performance evaluation of different digital modulations at different carrier frequency is done for Human BAN channel model. The performance of various rake receivers i.e. A-rake, S-rake and P-rake has been evaluated and compared for optimum values. From the simulations results it has been obtained that performance of selective rake is better than the partial rake. The 64-

BOK shows the best BER results as compared with other M-ary modulating scheme and the performance is more effective at 2400 Mhz. of carrier frequency. So 64-BOK with selective rake at 2400Mhz of carrier frequency provides most efficient performance of Human BAN channel. Thus, the results obtained will provide great help in designing the effective Human BAN based products in the near future.

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