

Impact of AWGN, Rayleigh and Rician Fading Channels on BER Performance of a Cognitive Radio Network

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Abstract— The paper discusses the model building of the cognitive radio system by using MATLAB Simulink model. This model is a useful tool for BER (Bit error rate) performance evaluation for the real data communication by the cognitive radio system under different communication channels and Multi level Quadrature Amplitude Modulation which are described in this paper. The performance measures presented in this paper are the bit error rate (BER) versus bit energy to noise power spectral density ratio (E_b/N_0). The simulation model built for this research work demonstrates that AWGN and Rician fading channels has better performance than Rayleigh channel.

Index Terms—PU, SU, Holes, Cognitive radio, CRN, WARM, FCC, MATLAB, Simulink, AWGN, Rayleigh, Rician, BER, 4-QAM, 16-QAM, 64-QAM.

1 INTRODUCTION.

Wireless technology has progressed very rapidly and has become an integral part of our daily routines. These devices use a limited amount of radio spectrum. With the increasing number of devices, the devices are competing to get the bandwidth that meets their needs which cause the problem of bandwidth scarcity. Moreover, traditional spectrum allocation policy is no longer capable of meeting the needs and services of wireless users. According to records from the Federal Communications Commission (FCC), spectrum allocated in the bands below 3GHz have a utilization range of 15% to 85% [1]. The first attempt to solve this problem came from Joseph Mitola when he published his first scientific paper in 1999 dealing with the subject of cognitive radio. Cognitive radio technology has opened new doors for researchers and interested technicians, because the CR contributed to the increased efficiency usage of spectrum frequency. Recently IEEE has developed a standard known as IEEE 802.22 WRAN (Wireless Regional Area Network) standards [2]. CR is the most important feature of next-generation networks. In his paper J. Mitola defines Cognitive Radio as "The point in which wireless personal digital assistants and the related networks are sufficiently computationally intelligent about radio resources and related computer to computer communications to detect user communication needs as a function of use context, and to provide radio resources and wireless services most appropriate to those needs" [3]. In order to achieve the CR concept, the secondary user (SU) must sense the spectrum to detect the holes in the licensed spectrum and explore primary user (PU) state [4]. PU has high priority to use spectrum band and has full authority in the use spectrum. Cognitive radio exploits the holes in PU spectrum with condition that there is no interference between PU and SU.

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Cognitive radio system must continuously sense the frequency spectrum in use in order to detect the reappearance of PU [5]. This and other functions of cognitive radio are contained in the basic cognitive cycle shown in figure 1 when implemented, the CR undergoes the different stages of the cognitive cycle. Thus determining how the radio learns and responds (adapts) to its operational environment [6].

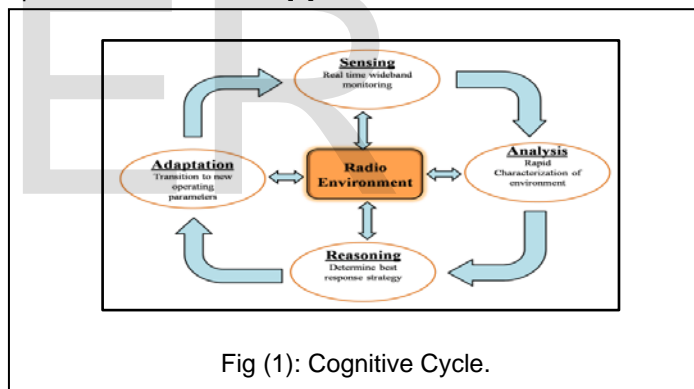


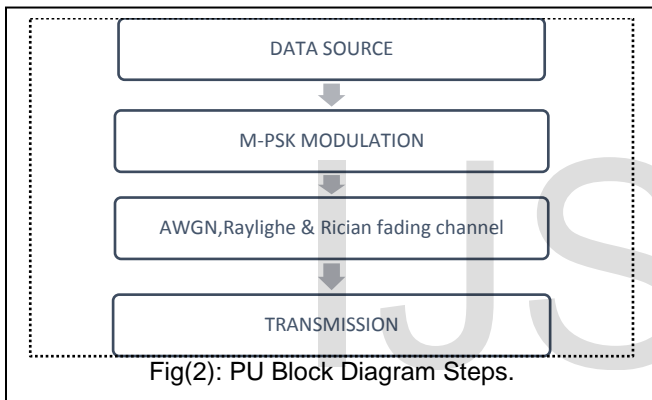
Fig (1): Cognitive Cycle.

From the cognitive cycle, CR system collects information from the surrounding environment and then analyzes it to detect holes and determines the possibility of exploiting these holes and finally works to reset its parameters according to the operating environment [7]. But transmission medium faces in CRN affected by two major problems in CR system. These problems are AWGN noise & Rayleigh and Rician Fading. AWGN noise is a random signal with equal intensity at different frequencies and giving a constant power spectral density, it effects in transmitted signal when a signal passes through the channel [8]. Rayleigh fading model using a statistical approach to analyze signal propagation and can be used in many environments. Rayleigh fading occurs when radio signal propagated in several paths at any ground environment [9]. Rician fading occurs when one path is much stronger than others signal path. i.e. receive signal comprises on both direct and indirect multipath waves [10]. The objective of this project is to implement and simulate the IEEE 802.22

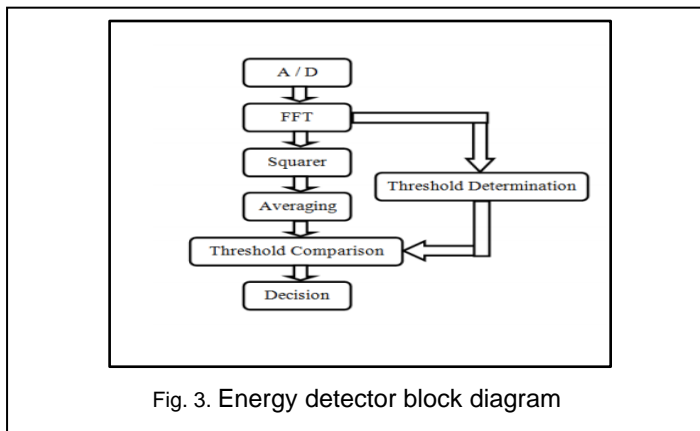
wireless regional area network (WRAN) using MATLAB Simulink in order to have a better understanding of evaluating the system performance based on the effect of different communication channels. This involves studying through simulation, the various PHY modulations, and evaluating the bit error rate (BER) performance of the CR system under different channel models such as, AWGN, Rayleigh, Rician channels.

2 DESCRIPTIVE ANALYSIS.

The MATLAB Simulink program was used to design a simulation model to simulate the nature work of cognitive radio by measuring the error rate in the data versus Eb/No, where BER is the most important factors to determine quality and efficiency of the system that works on the transfer digital data. Cognitive radio simulation scheme consists of: PU block, SU block, cognitive radio system, energy detection, error rate calculator with BER monitoring error. Figure 2 show the PU steps in simulation.



SU is same technology like PU, the difference only PU has the license. The energy detection technique one of the important techniques used in cognitive radio as a guidance of secondary user to detect white space (hole's) in PU spectrum. Energy detection was designed to detect radio wave depending on its energy. Figure 3 below shown blocks diagram of energy detection steps implemented in simulation.



3 MATHEMATICAL MODEL.

The BER performance of any digital modulation scheme generally defined as:

$$BER = \frac{\text{Number of Error Bits}}{\text{Number of Total Bits}} \quad (1)$$

For square constellations of QAM, where

$$k = \log_2 M \quad (2)$$

The symbol error rate is given by: [11-12]

$$P_s = 4 \frac{\sqrt{M}-1}{\sqrt{M}} Q\left(\sqrt{\frac{3}{M-1}} \frac{k E_b}{N_o}\right) - 4 \left(\frac{\sqrt{M}-1}{\sqrt{M}}\right)^2 Q^2\left(\sqrt{\frac{3}{M-1}} \frac{k E_b}{N_o}\right) \quad (3)$$

While the BER according to [13] is:

$$P_b = \frac{2}{\sqrt{M} \log_2 \sqrt{M}} \times \sum_{k=1}^{\log_2 \sqrt{M}} \sum_{i=0}^{(1-2^{-k})\sqrt{M}-1} \left\{ (-1)^{\lfloor \frac{i2^{k-1}}{\sqrt{M}} \rfloor} \left(2^{k-1} - i2k - 1M + 12Q(2i+1)6 \log_2 M E_b 2(M-1)N_o \right) \right\} \quad (4)$$

For cross shaped QAM where $k = \log_2 M$ is odd, $M = I \times J$, $I = 2^{\frac{k-1}{2}}$ and $J = 2^{\frac{k+1}{2}}$ and the symbol error rate is given by:

$$P_s = \frac{4IJ - 2I - 2J}{M} \times Q\left(\sqrt{\frac{6 \log_2(IJ) E_b}{(I^2 + J^2 - 2) N_o}}\right) - \frac{4}{M} (1 + IJ - I - J) Q^2\left(\sqrt{\frac{6 \log_2(IJ)}{(I^2 + J^2 - 2) N_o}}\right) \quad (5)$$

From [13] the BER for shaped QAM is given by:

$$P_b = \frac{1}{\log_2(IJ)} \left(\sum_{k=1}^{\log_2 I} P_i(k) + \sum_{i=1}^{\log_2 J} P_j(i) \right) \quad (6)$$

Where,

$$P_i(k) = \frac{2}{I} \sum_{i=0}^{(1-2^{k-1})I-1} \left\{ (-1)^{\lfloor \frac{i2^{k-1}}{I} \rfloor} \left(2^{k-1} - \lfloor \frac{i2^{k-1}}{I} + \frac{1}{2} \rfloor \right) Q\left((2i + 16 \log_2 IJ E_b I^2 + J^2 - 2N_o) \right) \right\} \quad (7)$$

And

$$P_j(k) = \frac{2}{J} \sum_{j=0}^{(1-2^{k-1})J-1} \left\{ (-1)^{\lfloor \frac{j2^{k-1}}{J} \rfloor} \left(2^{k-1} - \lfloor \frac{j2^{k-1}}{J} + \frac{1}{2} \rfloor \right) Q\left((2i + 16 \log_2 IJ E_b I^2 + J^2 - 2N_o) \right) \right\} \quad (8)$$

4 COMPUTER MODEL.

The procedures that we have followed to develop the computer model of cognitive radio simulator is briefly stated as follows:

At first we have generated a random data stream of length 86400 bit as our input binary data using Bernoulli binary generator.

Then various digital modulation techniques, 4-QAM, 16-QAM and 64-QAM are used to modulate the data.

The signal modulated pass through AWGN, Rayleigh and Rician fading channels.

Then sensing the spectrum by energy detector unit to provide status of adjacent environment to the cognitive system and detect holes in primary frequency.

If the primary signal detected; cognitive radio system will start analysis primary user environment and choice frequency to operate the secondary signal within primary spectrum holes,

if primary signal is not detected. Energy detector unit will keep searching to determine PU signal Scheme.

The implementation of cognitive radio system based on status of primary user signal scheme, holes on spectrum and idle period of the spectrum.

In case of spectrum availability, the secondary user can exploit holes in primary user spectrum, otherwise cognitive radio system set idle.

After the CR system succeeds in using unlicensed spectrum BER is calculated.

5 SIMULATION PARAMETER.

TABLE 1 SIMULATION PARAMETERS

Parameter	Value
SNR Range	0-30 dB
Modulation Technique	4-QAM, 16-QAM, 64-QAM
Noise Channels	AWGN, Rayleigh and Rician
Number Of Bits	86400
Simulation Time	24 hours
Data source	Bernoulli binary generator 61
K-factor	3
Doppler shift frequency	1/100 Hz With Jakes Model
Input Signal Power	1Watt

6 RESULT & DISCUSSION.

After execute the simulation of the cognitive radio system, the results are obtained in Figure (5, 6 and 7). The results are represented in terms of bit error rate (BER) versus bit energy to noise power spectral density ratio (Eb/No). over AWGN channel and Rayleigh, Rician channels using 4-QAM, 16-QAM and 64-QAM modulation schemes respectively.

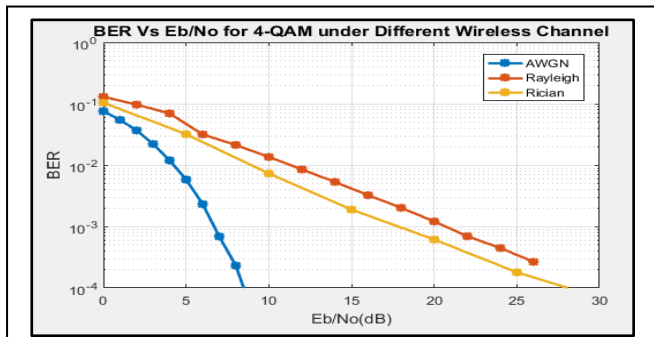


Fig (5): Bit error rate (BER) performance of AWGN, Raleigh and Rician channels for QAM modulation technique.

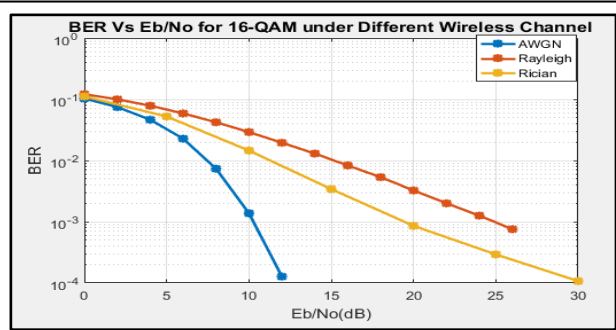


Fig (6): Bit error rate (BER) performance of AWGN, Raleigh and Rician channels for 16-QAM modulation technique.

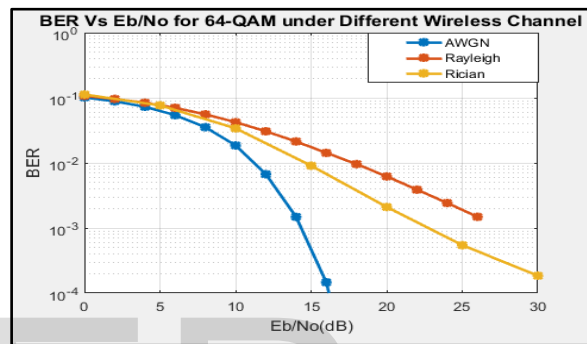


Fig (7): Bit error rate (BER) performance of AWGN, Raleigh and Rician channels for 64-QAM modulation technique.

From the results we observe that the BER decrease as the Eb/No increase. And the BER for AWGN channel is better than Rayleigh and Rician fading channel. While the Rician fading channel with AWGN is better than Rayleigh with AWGN.

For 4-QAM modulation scheme, the average BER at Eb/No value of 10 dB is 0, 0.01357, and 0.007321 for AWGN, Rayleigh and Rician channel respectively. And the number of M-ary level of QAM increased the BER increase.

For 16-QAM modulation scheme, the average BER at Eb/No value of 14 is 0, 0.01302 and 0.003417 for AWGN, Rayleigh and Rician channel respectively. And the number of M-ary level of QAM increased the BER increase.

For 64-QAM modulation scheme, the average BER at Eb/No value of 20 is 0, 0.006213 and 0.0021081 for AWGN, Rayleigh and Rician channel respectively. And the number of M-ary level of QAM increased the BER increase.

7 CONCLUSION.

The performance evaluation of a cognitive radio system at different M-ary QAM have been done. The results highlights the impact of AWGN and fading (Rayleigh & Rician) channels under 4-QAM, 16-QAM and 64-QAM modulation techniques. From this research work, conclusions can be drawn regarding the BER performance evaluation of CR system over AWGN, Rayleigh and Rician channels are shown below:

The performance of AWGN channel is the best of all channels, it has lowest BER under 4-QAM, 16-QAM & 64-QAM modulation schemes. The amount of noise occurs in the BER of this channel is quite slighter than fading channels.

The performance of Rayleigh fading channel is the worst of all channels as BER of this channel has been much affected by noise under 4-QAM, 16-QAM and 64-QAM modulation schemes.

The performance of Rician fading channel is worse than AWGN channel and better than Rayleigh fading channel. Because Rician fading channel has higher BER than AWGN channel and lower BER than Rayleigh fading channel. BER of this channel has not been much affected by noise under 4-QAM, 16-QAM and 64-QAM modulation schemes.

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