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Statistical Multipath Detection and BER calculation using BPSK

H. Umadevi
E-mail ID : umadevi.ait@gmail.com

K.S. Gurumurthy
E-mail ID : drksgurumurthy@gmail.com

***Abstract* – The rapid growth in the wireless communication in recent years has significantly affected our daily lives. The transition from analog to digital wireless communication, the rise of second & third generation of cellular systems, and replacement of wired connection with Wi-Fi are enabling consumers to access a wide range of information without physical wired connection. As a consumer demands larger bandwidth for multimedia services, the constraints on the availability of the RF spectrum become stricter. The development of multiuser detection has proceeded along a path which is typical of other areas in communication. Initially, optimum solutions were obtained along with the best possible performance achievable in Gaussian noise channels. This paper presents the implementation of multipath signal detection based on highest signal strength and calculating the BER for the same.**

Keywords – Wi-Fi, RF, BER.

I. Introduction

It is important to evaluate the performance of wireless devices by considering the transmission characteristics, wireless channel parameters and device structure. The performance of data transmission over wireless channels is well captured by observing their BER, which is a function of SNR [1] at the receiver. In wireless channels, several models have been proposed and investigated to calculate SNR. All the models are a function of the distance between the sender and the receiver, the path loss exponent and the channel gain. Several probability distributed functions are available to model a time-variant parameter i.e. channel gain. We describe the three important and frequently used distributions. Those are AWGN, Rayleigh and Rician models. The signal is detected and decoded by employing several replicas of the received signal. So, we consider multilink receiver structure. The PHY layer transmission mode consists of a specific set of modulation, binary convolution coding and data rate. According to IEEE 802.11 standard [2], each device should use a wireless transmission technique among OFDM (Orthogonal Frequency Division Multiplexing), DSSS (Direct Sequence Spread Spectrum), FHSS (Frequency Hopping Spread Spectrum) and IR (InfraRed). In our evaluation, we consider OFDM and DSSS. For binary convolution coding, the receiver uses a Viterbi decoding, which is recommended by the IEEE standard.

Fading refers to the distortion that a carrier-modulated telecommunication signal experiences over certain propagation media.

In wireless systems, fading is due to multipath propagation and is sometimes referred to as multipath induced fading. To understand fading, it is essential to understand multipath. In wireless telecommunications, multipath is the propagation phenomenon that results in radio signals' reaching the receiving antenna by two or more paths. Causes of multipath include atmospheric ducting, ionosphere reflection and refraction, and reflection from terrestrial objects, such as mountains and buildings. The effects of multipath include constructive and destructive interference, and phase shifting of the signal. This distortion of signals caused by multipath is known as fading. In other words it can be said that in the real world, multipath occurs when there is more than one path available for radio signal propagation. The phenomenon of reflection, diffraction and scattering all give rise to additional radio propagation paths beyond the direct optical LOS[3] (Line of Sight) path between the radio transmitter and receiver. The paper is organized as follows. Section II explains Rayleigh fading. Section III deals with the implementation. Section IV deals with results and discussions. The paper is concluded in Section V.

II. Rayleigh Fading

The Rayleigh fading is primarily caused by multipath reception [4]. Rayleigh fading is a statistical model for the effect of a propagation environment on a radio signal. It is a reasonable model for troposphere and ionospheres signal propagation as well as the effect of heavily built-up urban environments on radio signals. Rayleigh fading [5] is most applicable when there is no line of sight between the transmitter and receiver**.**

Rayleigh fading is a statistical model for the effect of a propagation environment on a radio signal, such as that used by wireless devices. Rayleigh fading models assume that the magnitude of a signal that has passed through such a transmission medium (also called a communications channel) will vary randomly, or fade, according to a Rayleigh distribution the radial component of the sum of two uncorrelated Gaussian random variables. Rayleigh fading model: The Rayleigh fading is primarily caused by multipath reception. Rayleigh fading is a statistical model for the effect of a propagation environment on a radio signal. It is a reasonable model for troposphere and ionosphere signal propagation as well as the effect of heavily built-up urban environments on radio signals. Rayleigh fading is most applicable when there is no line of sight between the transmitter and receiver.

Rayleigh fading is a reasonable model when there are many objects in the environment that scatter the radio signal before it arrives at the receiver. The central limit theorem holds that, if there is sufficiently much scatter, the channel impulse response will be well-modeled as a Gaussian process irrespective of the distribution of the

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individual components. If there is no dominant component to the scatter, then such a process will have zero mean and phase evenly distributed between 0 and 2π radians. The envelope of the channel response will therefore be Rayleigh distributed.

Calling this random variable R, it will have a probability density function.

$$p_R(r) = \frac{2r}{\Omega} e^{-r^2/\Omega}, r \geq 0$$

Where

$$\Omega = E\left(R^2\right)$$

Often, the gain and phase elements of a channel's distortion are conveniently represented as a complex number. In this case, Rayleigh fading is exhibited by the assumption that the real and imaginary parts of the response are modeled by independent and identically distributed zero-mean Gaussian processes so that the amplitude of the response is the sum of two such processes. The performance (Eb/N0 Vs BER) of BPSK modulation (with coherent detection) over Rayleigh Fading channel and its comparison over AWGN channel is considered. We first investigate the non-coherent detection of BPSK over Rayleigh Fading channel and then we move on to the coherent detection. For both the cases, we consider a simple flat fading Rayleigh channel (modeled as a – single tap filter – with complex impulse response – h). The channel also adds AWGN noise to the signal samples after it suffers from Rayleigh Fading[6].

The received signal y can be represented as

Y=hx+n

where n is the noise contributed by AWGN which is Gaussian distributed with zero mean and unit variance and h is the Rayleigh Fading response with zero mean and unit variance. (For a simple AWGN channel without Rayleigh Fading the received signal is represented as y = x+n).

Non-Coherent Detection

In non-coherent detection, prior knowledge of the channel impulse response ("h" in this case) is not known at the receiver. Consider the BPSK signaling scheme with 'x=+/- a' being transmitted over such a channel as described above. This signaling scheme fails completely (in non coherent detection scheme), even in the absence of noise, since the phase of the received signal y is uniformly distributed between 0 and 2pi regardless of whether x[m]=+a or x[m]=-a **is** transmitted. So the non coherent detection of the BPSK signaling is not a suitable method of detection especially in a Fading environment.

A. Coherent Detection

In coherent detection, the receiver has sufficient knowledge about the channel impulse response. Techniques like pilot transmissions are used to estimate the channel impulse response at the receiver, before the actual data transmission could begin. Let's consider that the channel impulse response estimate at receiver is known and is perfect & accurate. The transmitted symbols ('x') can be obtained from the received signal ('y') by the process of equalization as given below.

$$\hat{y} = \frac{y}{h} = \frac{hx+n}{h} = x + z$$

here z is still an AWGN noise except for the scaling factor 1/h. Now the detection of x can be performed in a manner similar to the detection in AWGN channels. The input binary bits to the BPSK modulation system are detected as

B. Theoretical BER

The BER, or quality of the digital link, is calculated from the number of bits received in error divided by the number of bits *transmitted.*

BER= (Bits in Error) / (Total bits received).

In digital transmission, the number of bit errors is the number of received bits of a data stream over a communication channel that has been altered due to noise, interference, distortion or bit synchronization errors. The BER is the number of bit errors divided by the total number of transferred bits during a particular time interval. BER is a unit less performance measure, often expressed as a percentage [7].

The theoretical BER for BPSK modulation scheme over Rayleigh fading channel (with AWGN noise) is given by

$$P_b = \frac{1}{2}\left(1 - \sqrt{\frac{E_b/N_0}{1 + E_b/N_0}}\right)$$

Table1. BER in AWGN and Rayleigh fading channel

E_b/N_0	BER in AWGN	BER in Rayleigh
-5 : 0	0.1064	0.1033
0: 5	0. 0952	0.0944
5: 10	0. 0578	0.0608
10: 15	0. 0235	0.0275
15: 20	0. 0078	0.01
20 : 25	0. 0025	0.0029

The theoretical BER for BPSK modulation scheme over an AWGN channel is given here for comparison

$$P_b = \frac{1}{2} erfc\left(\sqrt{E_b/N_0}\right)$$

The following model is used for the simulation of BPSK over Rayleigh Fading channel and its comparison with AWGN channel

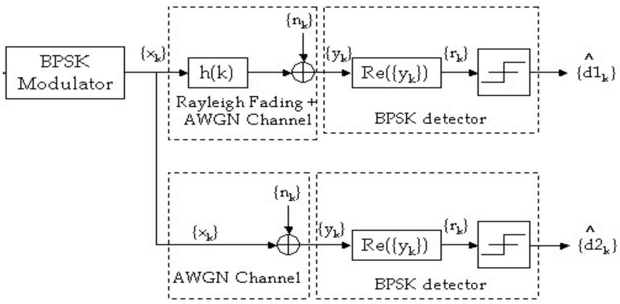

Fig.1. BPSK Modulation over Rayleigh and AWGN channel

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C. Simulation Results

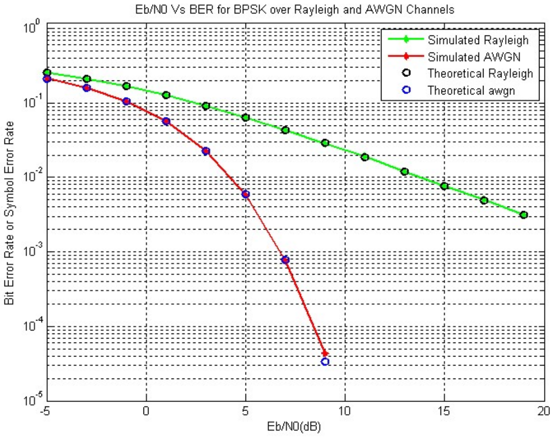

Fig.2. Eb/N0Vs BER

The Simulated and theoretical performance curves (Eb/N0 Vs BER)[8,9] for BPSK modulation over Rayleigh Fading channel and the AWGN is shown in table and in figure 2.

III. Implementation

Figure 3 shows the generated signal from modulator is transmitted in multipath via Rayleigh fading channel and at the receiver side having highest received power signal is compared with threshold value and reordered in ascending order using statistical algorithm.[10,11**]**. The signal having highest receiving power is selected for BER calculation. The implementation here is considered for five channels.

In this paper, one of the important topic in wireless communications that is the concept of fading is demonstrated by the approach available in MATLAB. Simulink is a graphical extension to MATLAB for the modeling and simulation of systems. In Simulink, systems are drawn on screen as block diagrams. Many elements of block diagrams are available (such as transfer functions, summing junctions, etc.), as well as virtual input devices and output devices. Simulink is integrated with MATLAB and data can be easily transferred between the programs.

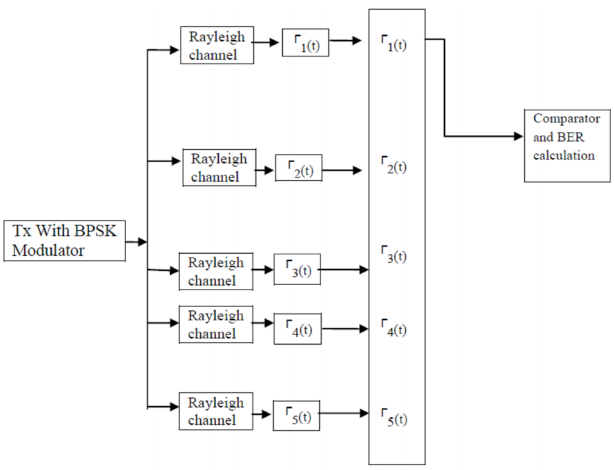

Fig.3. Five channels with BPSK Modulation

IV Results and Discussions

The reverse and forward Link interoperations comprise of convolution encoding and repetition, block interleaving, long PN sequence, data scrambling, Walsh coding and Quadrature modulation shown in figure 4 and 5and figure6 shows BER for five channels.

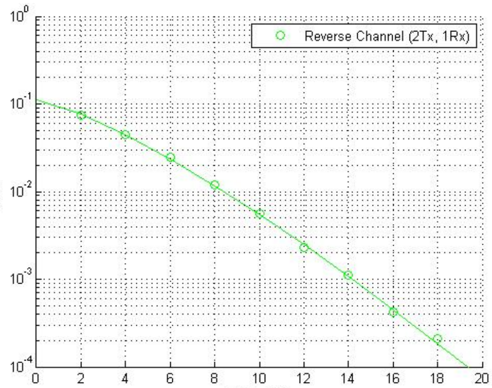

Fig.4. Reverse channel

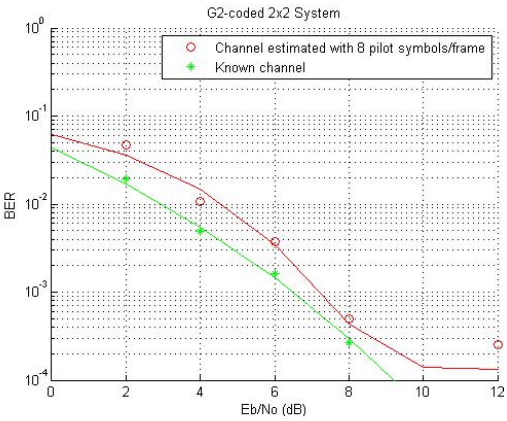

Fig.5. Forward channel.

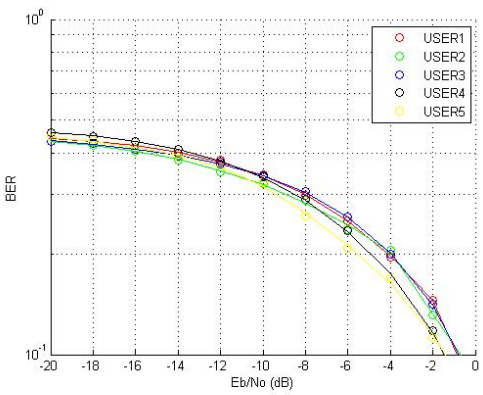

Fig.6. BER for five channel

V. Conclusion

In this paper, the simulation of statistical multipath signal passing through five different channels is presented. The signal having the highest SNR is considered at the receiver and the BER for that particular signal is calculated. This could be used in wireless communication to identify the signal having the highest SNR.

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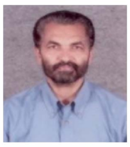
AUTHOR'S PROFILE

H. Umadevi

completed her Bachelor of Engineering in Electronics and Communication, from Mysore University and Master of Engineering in Electronics from Bangalore University and pursuing Ph.D. in Bangalore university in the field of Wireless communication. Currently working as an Associate professor in the Department of Electronics and communication at Dr.Ambedkar Institute of Technology (Dr.A.I.T) Bangalore-560056.



Dr. K. S. Gurumurthy

completed his Bachelor of Engineering in Electronics and Communication, from Mysore University and Master of Engineering in Solid State Electronics from U.O.R., Roorkee (now IIT, Roorkee), and Ph.D. from Indian Institute of Science, Bangalore, India. His major field of study includes VLSI and microelectronics. He has two years of industrial experience and more than 30 years of rearch and academic experience. He has given more than 50 guest lectures on different topics of VLSI DESIGN at various colleges, WIPRO, CRL and at IETE. He has published more than 85 research papers in various international journals and conferences. His research interests are VLSI Design, Embedded System and Communication. Dr Gurumurthy is the professional member of IEEE and ISTE. He is the recipient of. KHOSLA AWARD for the BEST Technical Paper presented at UOR, Roorkee, India. Currently working as a Chairman in Department of Electronics and Communication Engineering, University Visvesvaraya College of Engineering, (UVCE) Bangalore, India