19AIE204: Introduction to Communication Systems

Project Report

Implement Multipath Model for Communication in Wireless channel

Bachelor of Technologyin

Artificial Intelligence & Engineering

Submitted by *Group No.: 7*

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OBJECTIVE

Implementation of Bit Error Rate for multipath models like AWGN, Rayleigh, and Rician Fading Channel models under BPSK Modulation Scheme.

INTRODUCTION

The wireless industry has developed and deployed an infrastructure for providing many services for the users. The design, production and deployment of such technological infrastructure have high cost therefore manufacturers search for different alternatives to avoid high costs. One of these alternatives is simulating a real wireless system. The advantage of simulation is that allows less expensive testing of designs.

One major characteristic of wireless channel is multipath fading effect. Multipath is the propagation phenomenon that results in radio signals' reaching the receiving antenna by two or more paths. 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. There are two types of fading effects that characterize mobile communications: large-scale and small-scale fading.

- Large-scale fading represents the average signal power attenuation or path loss due to motion over large areas. This phenomenon is affected by prominent terrain contours (hills, forests, billboards, clumps of buildings, etc.) between the transmitter and receiver.
- Small-scale fading is also called Rayleigh fading because if the multiple reflective paths are large in number and there is no line-of-sight signal component, the envelope of the received signal is statistically described by a Rayleigh distribution. When there is a dominant non fading signal component present, such as a line-of-sight propagation path, the small-scale fading envelope is described by a Rician distribution.

Types Of Fading Channels

A signal that has chosen should be error free, or close to being error free. If the signal is error free, then the high quality of voice and data transmission can be done. The main issue arises while the development of the application is that the selection of the fading model. Here, the analysis of fading channels is based on the BPSK modulation scheme.

There are three main basic fading channel models,

- Non-Line of Sight (Rayleigh) Fading Channel models.
- Line of Sight (Rician) Fading Channel
- Additive White Gaussian Noise (AWGN)

RAYLEIGH FADING CHANNEL

Rayleigh fading model considers the fading is caused by multipath reception. 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. Rayleigh fading is most applicable when there is no dominant line-of-sight propagation between the transmitter and receiver.

$$P_R(R) = \frac{R}{e^2}\ e - \frac{R^2}{2\sigma^2}$$

RICIAN FADING CHANNEL

Rician fading is similar to Rayleigh fading, with the exception that Rician fading has a strong dominating component. This dominant component is a stationary (non-fading) signal and is commonly called the LOS (Line of Sight Component).

$$P_R(R) = \frac{R}{e^2}\ e - \frac{R^2+A^2}{\sigma^2}\ I_0\left(\frac{RA}{\sigma^2}\right)$$

AWGN FADING CHANNEL

Additive white Gaussian noise (AWGN) is the commonly used to transmit signal while signals travel from the channel and simulate background noise of channel. It is the basic communication channel model and used as a standard channel model. The AWGN channel is represented by:

r (t) = s (t)+ n(t)

where s(t) is transmitted signal and n(t) is white Gaussian noise.

Modulation

Modulation is defined as the process of superimposing a low-frequency signal on a high-frequency carrier signal. Modulation is the process of encoding information from a message source in a way that is suitable for transmission. This is achieved by altering the characteristics of a wave. The receiver then recovers the original signal through a process called demodulation.

Modulation techniques are expected to have three positive properties:

- Good Bit Error Rate performance
- Power efficiency
- Spectral efficiency

There are various types of modulating schemes involves in the communication system like Phase shift keying (PSK), Frequency shift keying(FSK), Minimum shift keying(MSK), Quadrature phase shift keying(QPSK), Quadrature amplitude modulation(QAM) and Binary Phase Shift Keying (BPSK).

Binary Phase Shift Keying (BPSK)

Binary Phase Shift Keying (BPSK) is a two-phase modulation scheme, where the 0's and 1's in a binary message are represented by two different phase states in the carrier signal: $\theta = 0°$ for binary 1 and $\theta = 180°$ for binary 0.

In digital modulation techniques, a set of basis functions are chosen for a particular modulation scheme. Generally, the basis functions are orthogonal to each other. Basis functions can be derived using Gram Schmidt orthogonalization procedure. Once the basis functions are chosen, any vector in the signal space can be represented as a linear combination of them. In BPSK, only one sinusoid is taken as the basis function. Modulation is achieved by varying the phase of the sinusoid depending on the message bits.

Bit Error Rate (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.

$$BER = \frac{Bits\ in\ Error}{Total\ bits\ reveived}$$

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.

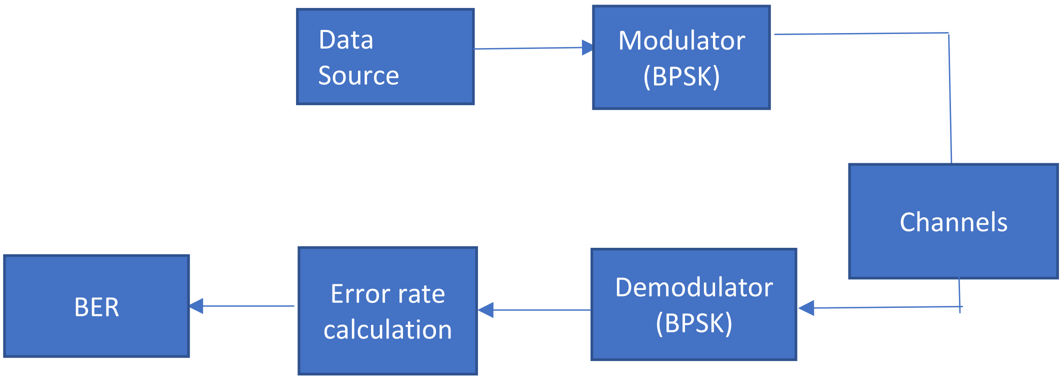
Signal to Noise Ratio (SNR)

SNR is the ratio of the received signal strength over the noise strength in the frequency range of the operation. SNR and BER are inversely connected, therefore a high BER causes a low SNR. Packet loss, latency, and throughput suffer because of high BER. Signal to noise ratio (SNR) is an indicator commonly used to evaluate the quality of a communication link and measured in decibels and represented by

$$SNR = 10log_{10}\left(\frac{Signal\ Power}{Noise\ Power}\right)dB$$

The higher the signal-to-noise ratio, the easier it is to identify, isolate, and eliminate the source of noise. A SNR of zero means that the desirable signal and undesired noise are nearly indistinguishable.

BLOCK DIAGRAM AND DESCRIPTION



The above block diagram shows the basic digital communication model. The basic digital communication model is depicted in the diagram. The transmitter-related blocks (data source and modulator). The system model's data source creates a stream of random bits as 0s and 1s. In the modulator block, the random bits are modulated using BPSK. The modulated signal is then passed to the channel block, to propagate the suitable channel, inducing Gaussian noise, Rician, or Rayleigh fading channels into the modulated signal. The demodulate block in the receiver reverses the operation and extracts the binary signal. It generates a series of random binary bits that are estimations of the transmitted data.

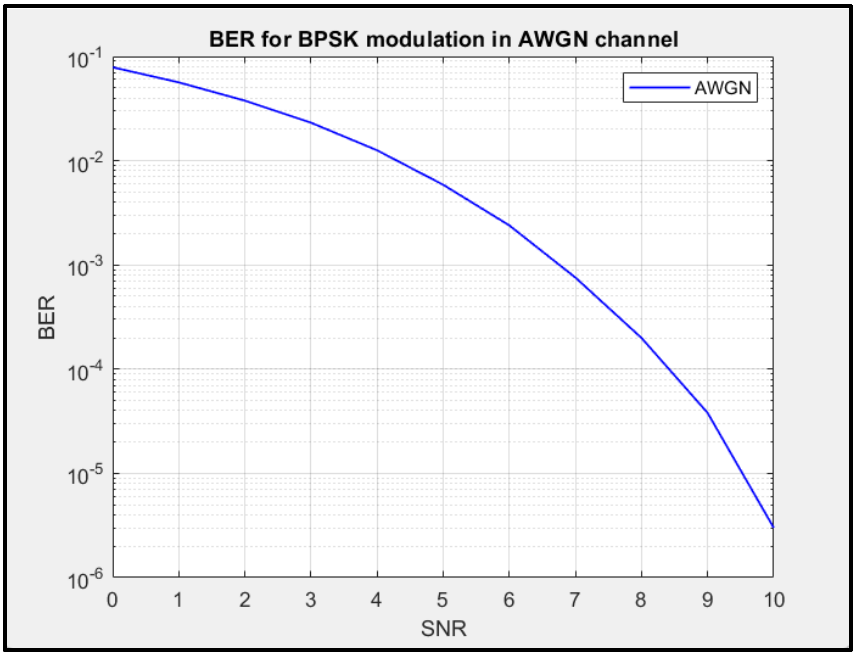
SIMULATION RESULTS

This section we present and evaluate the results using the Matlab. The results are used the ratio of signal energy per bit to noise power density SNR($Eb/N0$) and bit error rate BER to evaluate and analyse the performance of BPSK over AWGN, Rician, and Rayleigh fading channels.

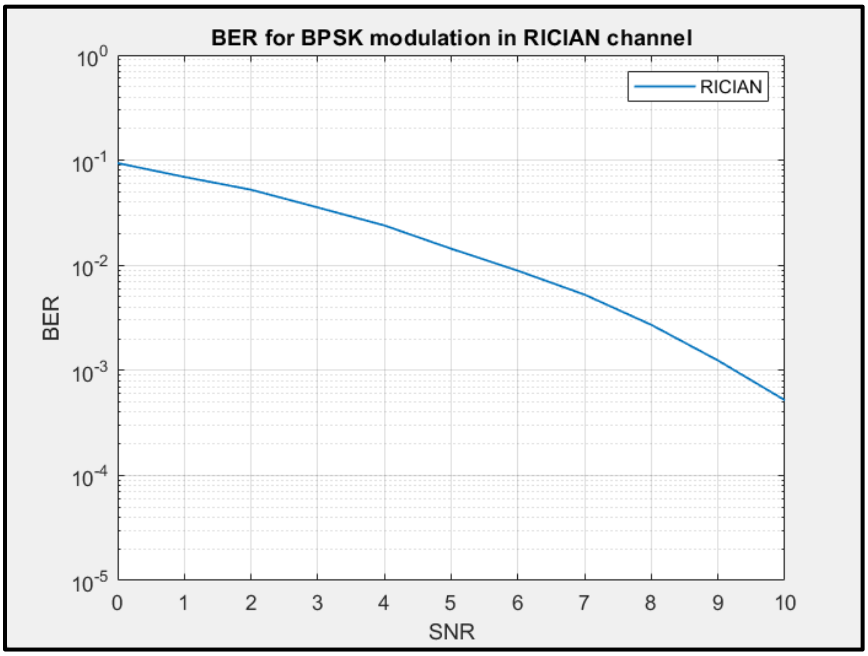
Simulation table

SNR	BER in AWGN	BER in RICIAN	BER in RAYLEIGH
1	0.055986	0.06949	0.126805
2	0.037199	0.05235	0.10852
3	0.022736	0.03631	0.091984
4	0.012395	0.02374	0.076871
5	0.005928	0.01463	0.064083
6	0.002383	0.00872	0.052312

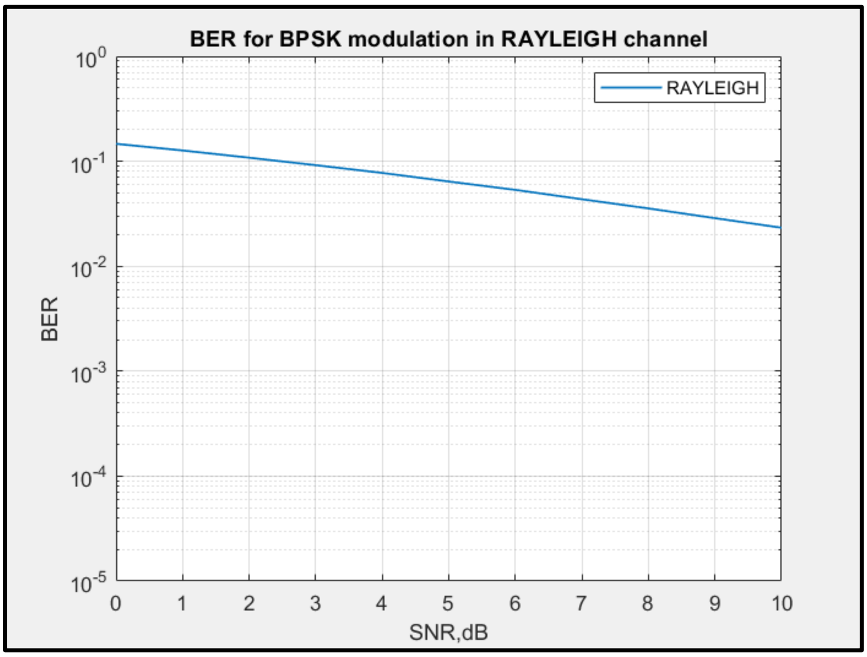
BER for BPSK in AWGN channel



BER for BPSK in RICIAN channel



BER for BPSK in RAYLEIGH channel



INFERENCE

From the figures we can see that the AWGN channel has lower BER than different fading channels. The Rayleigh fading channel has higher BER than Rician and AWGN fading channels. The Rician fading channel has BER between the AWGN and Rayleigh channels.

CONCLUSION

From the simulation results, The Bit Error Ratio of a digital communication system is an important figure of merit used to quantify the integrity of data transmitted through the system. The criterion is comparison of the variation of BER for different SNR. It is observed that the BER is minimum for AWGN and maximum for RAYLEIGH. In this project, we Implemented Bit Error Rate for multipath models like AWGN, Rayleigh, and Rician Fading Channel models under BPSK Modulation Scheme.

REFERENCE

- Evaluation of BER for AWGN, Rayleigh and Rician Fading Channels under Various Modulation Schemes (ijcaonline.org)
- Effect of Various Parameters on BER of Wireless Communication System (ijert.org)
- Eb n0 vs ber for bpsk over rician fading channel.pdf (idc-online.com)
- Calculating BER for BPSK in Matlab - Stack Overflow
- (PDF) BER Vs Eb/N0 BPSK Modulation over Different Types of Channel (researchgate.net)

APPENDIX

BER for BPSK in AWGN channel

```
%Computing BER for BPSK modulation in a AWGN channel
clear; close all; clc; tic;
n=10^6;% numBER of samples or bits
bits=randn(1,n)>0.5;% generating 0,1 with equal
probability
signal=2*bits-1;% BPSK modulation 0 -> -1; 1 -> 0
noise=1/sqrt(2)*(randn(1,n)+1i*randn(1,n)); %generating
noise with zero mean and var. equal to 1.
mean(abs(noise.^2)) %test the power of the noise
SNR=0:10; %set SNR in dB
snr_lin=10.^(SNR/10); %calculate linear snr from dB SNR.
y=zeros(length(SNR),n);
 %multiply sqrt of snr to signal and add noise:
for i=1:length(SNR)
    y(i,:)=real(sqrt(snr_lin(i))*signal+noise);
end
%reciever and BER count
err=zeros(length(SNR),n); Err=zeros(10,2);
for i=1:length(SNR)
    for j=1:n
       if y(i,j)>=0
           y(i,j)=1;
       else
           y(i,j)=0;
       end
    end
      err(i,:)=abs(y(i,:)-bits);
      Err(i,:)=size(find(err(i,:)));
end
 %calculating BER
BER=zeros(length(SNR),1);
for i=1:length(SNR)
    BER(i)=Err(i,2)/n;
end
semilogy(SNR,BER,'b-','linewidth',1); grid on;  hold on;
xlabel('SNR'); ylabel('BER'); legend('AWGN') ; toc;
title('BER for BPSK modulation in AWGN channel');
```

BER for BPSK in RICIAN channel

```
% Computing BER for BPSK modulation in a Rician fading
channel
clear; close all; clc; tic;
n=10^6;%no of samples or bits
bits=randi([0,1],1,n);% generates random integers 0's and
1's
signal=2*bits-1;% BPSK modulation 0 -> -1; 1 -> 0
k_factor=10; % Rician factor
mean=sqrt(k_factor/(k_factor+1));% mean
variance=sqrt(1/(2*(k_factor+1)));% variance
Nr2=randn(1,length(signal))*variance+mean;
Ni2=randn(1,length(signal))*variance;
RFC=sqrt(Nr2.^2+Ni2.^2); % Rician fading coefficient
for k=0:1:40
    snrl=10^(k/10);% convert the SNR in dB value
    Np=1/snrl;% To generate the noise power
    sd=sqrt(Np/2);% standard deviation of guassian noise
    noise=random('Normal',0,sd,1,length(signal)); %
Generates Gaussian noise
    t1=signal.*RFC+noise; % s means transmitted signal
    z1=t1./RFC;
 op1=(z1>0); % threshold detection
    BER(k+1)=sum(xor(op1,bits))/n; % observed BER
    end;
    %figure;
    k=0:1:20;
    semilogy(k,BER(k+1),'-','LineWidth',1);
    hold on;
    axis([0 10 10^-5 1]);
title('BER for BPSK modulation in RICIAN channel');grid
on;
xlabel('SNR');ylabel('BER');
hleg=legend('RICIAN')
```

BER for BPSK in RAYLEIGH channel

```
% Computing BER for BPSK modulation in a Rayleigh fading
channel
clear; close all; clc; tic;
n = 10^6; % number of bits or symbols
bits = rand(1,n)>0.5; % generating 0,1 with equal
probability
signal = 2*bits-1; % BPSK modulation 0 -> -1; 1 -> 0
Eb_n0_dB = [0:10]; % multbitsle Eb/n0 values
for i = 1:length(Eb_n0_dB)
   gn = 1/sqrt(2)*[randn(1,n) + j*randn(1,n)]; % white
gaussian noise, 0dB variance
   h = 1/sqrt(2)*[randn(1,n) + j*randn(1,n)]; % Rayleigh
channel
   y = h.*signal + 10^(-Eb_n0_dB(i)/20)*gn;% Channel and
noise noise addition
   yHat = y./h;% equalization
   bitsHat = real(yHat)>0;% receiver - hard decision
decoding
   num_Error(i) = size(find([bits- bitsHat]),2); % counting
the errors
end
sim_BER = num_Error/n; % simulated ber
Ebn0Lin = 10.^(Eb_n0_dB/10);
figure;
semilogy(Eb_n0_dB,sim_BER,'-','LineWidth',1);
axis([0 10 10^-5 1]);grid on;
legend( 'RAYLEIGH');xlabel('SnR,dB');ylabel('BER');
title('BER for BPSK modulation in RAYLEIGH channel');
```