Expt No. 10. Performance Analysis of Digital Modulation Schemes on AWGN and / Rayleigh Fading Channels-Final Part

Objective:

To simulate and appraise the digital communication system performance in terms of BER for BASK, BPSK, QPSK and QAM schemes over the AWGN and or Rayleigh fading channels.

Theory:

Need for Performance Evaluation and Channel Characteristics

BER is a crucial characteristic which denotes chances of error in the received data bits over a communication channel which is usually affected by noise, interference and distortion or bit synchronization errors.

Wireless Channel Characteristics

Wireless channel is an unguided channel and signals not only contain the direct Line of Sight LOS waves; but also a number of signals as a result of diffraction, reflection and scattering. This propagation type is termed Multipath [2] degrades the performance of the channel. Similarly, the channel may introduce Doppler effect when the transmitter or receiver moves.

Additive White Gaussian Noise AWGN channel is a good model for the physical reality of channel, as long as the thermal noise at the receiver is the only source of disturbance [3]. The impairment this channel caused to signal is the addition of Gaussian distributed noise. Mathematically, it can be illustrated as:

$r(t) = s(t) + n(t)$, where r(t) is the received signal, s(t) is the transmitted signal and n(t) is the noise. AWGN is a channel model in which the only impairment to communication is a linear addition of wideband or white noise with a constant spectral density (expressed as watts per hertz of bandwidth) and a Gaussian distribution of amplitude.

Multi Path Fading Channels

An alternative class of channel used to model communication system is fading channels because mobile reception is harshly affected by multipath propagation which results in Fading or Inter-symbol Interference (ISI). This can be mathematically expressed as $r(t) = s(t) * h(t) + n(t)$

Flat and Frequency Selective Fading Channel

Time disperse signal are often affected by the delay spread. If the delay spread is less than the symbol period *Ts*, the signal channel is categorised as *Flat fading* which preserves of the spectral characteristics of the signal at the receiver [2]. In contrast, if signal bandwidth is more than the coherence bandwidth or delay spread is more than the symbol period, then the channel is categorised as *Frequency Selective fading* and leads to ISI which degrades the channel.

Channel Models:

Rayleigh and Rician Fading Model

Rayleigh 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 distribution model is often used for fading signal with infinite or large number of arrival paths at the same time whose gain are statistically independent and no dominant path. The phase component of the channel gain is Gaussian distributed. Similar to the distribution properties of Rayleigh is the *Rician Distribution* model except for the presence of a dominant path with numerous weak paths. Inclusive in its pdf is the peak amplitude *A* of dominant signal and zero-order Bessel function I, of the first kind.

Clarkes' Fading Model
The model assumes all multipath signals arrive at the same time in horizontal direction and when the mobile user moves, each path will experience a different Doppler shift. Hence, a uniform probability density function (PDF) of the rays is assumed and a Doppler effect is introduced.

ITU Model
International Telecommunications Union published some generic test models that are commonly used in the communication industry. Depicted in [2] is the three common cases of the model- Indoor, Pedestrian and Vehicular. But in this work, the interest is in the Channel B type of the Pedestrian model with 6 rays, median delay spread (750 *ns*) and 55% probability of occurrence in an outdoor to indoor environment. Each tap is modelled using Rayleigh fading distribution characterised by Clarkes' model to incorporate a model of the Doppler spectrum.

As an example, in 2G networks, Gaussian Minimum Shift Keying (GMSK) modulation scheme is widely used in GSM (Global System for Mobile) Communication. This modulation can only transmit data rate of 1 bit per symbol. This kind of modulation scheme is not suitable for the next generation communication system requiring higher data rates. However, the implementation of high data rate modulation techniques that have good bandwidth efficiency in communication requires perfect modulators, demodulators, filter and transmission path that are difficult to achieve in practical radio environment. Modulation schemes which are capable of delivering more bits per symbol are more immune to errors caused by noise and interference in the channel. Moreover, errors can be easily produced as the number of users is increased and the mobile terminal is subjected to mobility. Thus, it has driven towards the application of higher order modulations. Enhance Data Rate for the GSM Evolution (EDGE) is proposed as a transition to 3G as a new Time Division Multiple Access (TDMA) based radio access using the current (800, 900, 1800 and 1900 MHz) frequency bands. EDGE enables significantly higher peak rates and approximately triples the spectral efficiency by employing 8-Phase Shift Keying (8PSK) modulation. In cellular system, different users have different channel qualities in terms of signal to noise ratio (SNR) due to differences in distance to the base station, fading and interference. Link quality control adapts the data protection according to the channel quality so that an optimal bit rate is obtained for all the channel qualities. This experiment has been focused on the study and the performance measurement of different modulation schemes at those channels which are subjected to Multipath Rayleigh Fading and Additive White Gaussian Noise (AWGN). Modulation Schemes that will be studied are BASK, BPSK, QPSK, 8-ary QAM, etc.

Algorithm

BER performance estimation over AWGN channel

1. Generate a random binary sequence of 10000 values. Let's call it 'x' sequence.
2. Generate Gaussian noise and vary the snr (signal to noise ratio) from 0 to 24 in step of 4 db (or noise variance from 1 to 0.001), let's call it 'z' sequence. Use SNRdB = 10 log10(SNRlinear)
3. Now. Apply thresholding on 'z'.
4. Recover sequence ^x.
5. Find out the total error 'e' between input 'x' and recovered sequence '^x'.
6. Plot your conclusion.
7. Plot theoretical curve and verify.

BER performance estimation over Rayleigh channel

1. Generate a random binary sequence of 10000 values. Let’s call it ’x’ sequence.
2. Generate Gaussian noise and vary the snr (signal to noise ratio) from 0 to 24 in step of 4 db (or noise variance from 1 to 0.001), let’s call it ’z’ sequence. Use SNRdB = 10 log10(SNRlinear).
3. Now divide z by h.
4. Now Apply thresholding on ’z’.
5. Recover sequence ^x.
6. Find out the total error ’e’ between input ’x’ and recovered sequence ’^x’.
7. Plot your conclusion.
8. Plot theroretical curve and verify.

Model Codes:

BER Simulation of BASK modulation

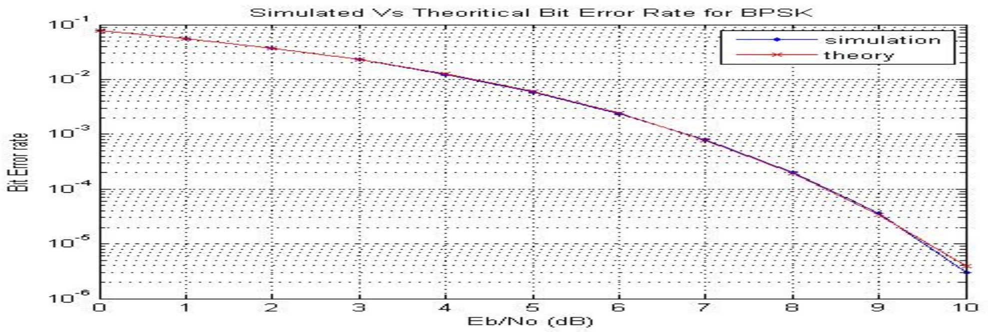
```
num_bit=1000000;%number of bit
data=randint(1,num_bit);%random bit generation (1 or 0)
SNRdB=0:10; % SNR in dB
SNR=10.^(SNRdB/10);
for(k=1:length(SNRdB))%BER (error/bit) calculation for different SNR%
y=awgn(complex(data),SNRdB(k));
error=0;
R=0;
M=[];
for(c=1:1:num_bit)
   if (y(c)>.5&&data(c)==0)||(y(c)<.5&&data(c)==1)%logic acording to BASK
      error=error+1;
        M=[M ~data(c)];
   else
      M=[M data(c)];
   end
end
 error=error/num_bit; %Calculate error/bit
m(k)=error;
end

semilogy(SNRdB,m,'o','linewidth',2.5),grid on,hold on;

BER_th=(1/2)*erfc(.5*sqrt(SNR));
semilogy(SNRdB,BER_th,'r','linewidth',2.5),grid on,hold on;

title(' curve for Bit Error Rate verses  SNR for Binary ASK modulation');
xlabel(' SNR(dB)');
ylabel('BER');
legend('simulation','theorytical')
axis([0 10 10^-5 1]);
```

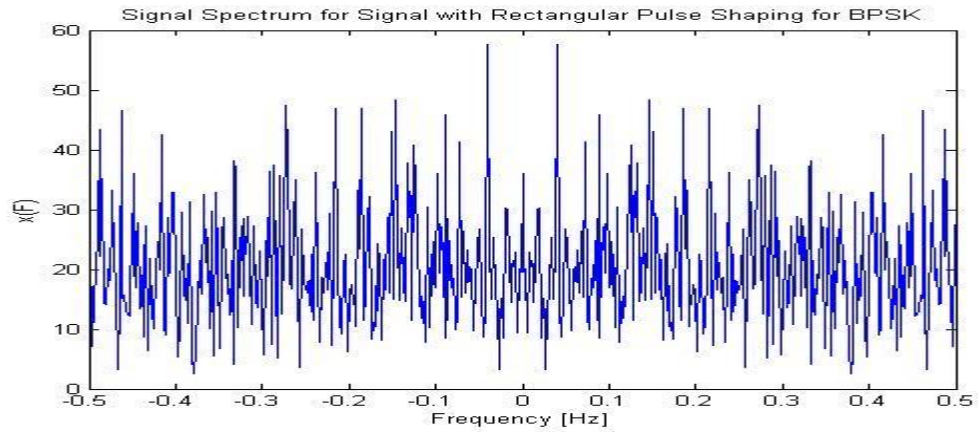
BER Simulation of BPSK

```
clc;
clear all;
bits=1000000;
data=randint (1,bits)>0.5;
ebno=0:10;
```

```
BER=zeros(1,length(ebno));
for i=1:length(ebno)
%---Transmitter---------
%mapping of bits into symbols
symb=2.*data-1;
%----Filter
psf=ones(1,1);
M=length(psf);
% inserting zeros between the bits
% w.r.t number of coefficients of
% PSF to pass the bit stream from the PSF
z=zeros(M-1,bits);
upsamp=[symb;z];
upsamp2=reshape(upsamp,1,(M)*bits);
%Passing the symbols from PSF
tx_symb=conv(upsamp2,psf);
%--------CHANNEL-----------
%Random noise generation and addition to the signal
ebnos=10.^(ebno(i)/10);
n_var=1/sqrt(2.*ebnos);
rx_symb=tx_symb+n_var*randn(1,length(tx_symb));
%xxxxxxxxxxxxxxxxxxxxxxxxxx
%-------RECEIVER-----------
rx_match=conv(rx_symb,psf);
rx=rx_match(M:M:length(rx_match));
rx=rx(1:1:bits);
recv_bits=(sign(rx)+1)./2;
%xxxxxxxxxxxxxxxxxxxxxxxxxxx
%---SIMULATED BIT ERROR RATE----
errors=find(xor(recv_bits,data));
errors=size(errors,2);
BER(i)=errors/bits;
%xxxxxxxxxxxxxxxxxxxxxxxxxxx
end
fs=1;
n_pt=2^9;
tx_spec=fft(tx_symb,n_pt);
f= -fs/2:fs/n_pt:fs/2-fs/n_pt;
figure
plot(f,abs(fftshift(tx_spec)));
title('Signal Spectrum for Signal with Rectangular Pulse
Shaping for BPSK');
xlabel('Frequency [Hz]');
ylabel('x(F)');
figure
semilogy(ebno,BER,'b.-');
hold on
thr=0.5*erfc(sqrt(10.^(ebno/10)));
semilogy(ebno,thr,'rx-');
xlabel('Eb/No (dB)')
ylabel('Bit Error rate')
```

```
title('Simulated Vs Theoritical Bit Error Rate for BPSK')
legend('simulation','theory')
grid on;
```



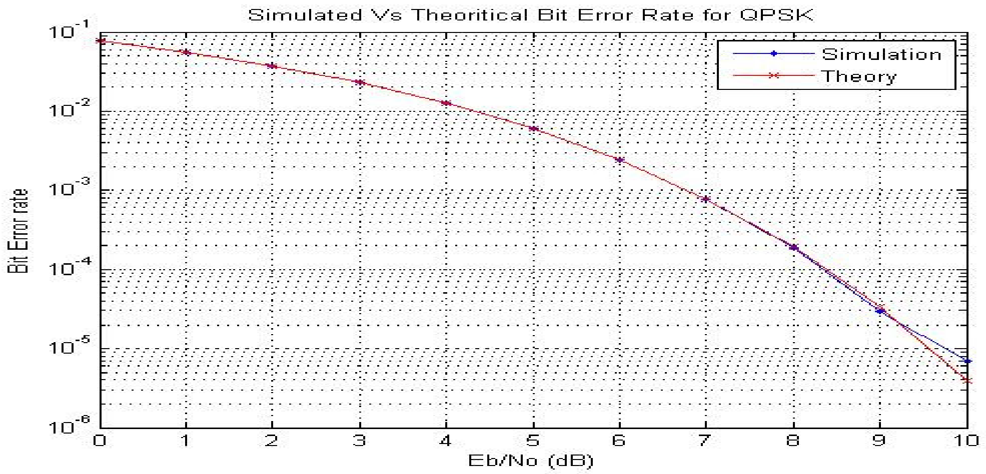


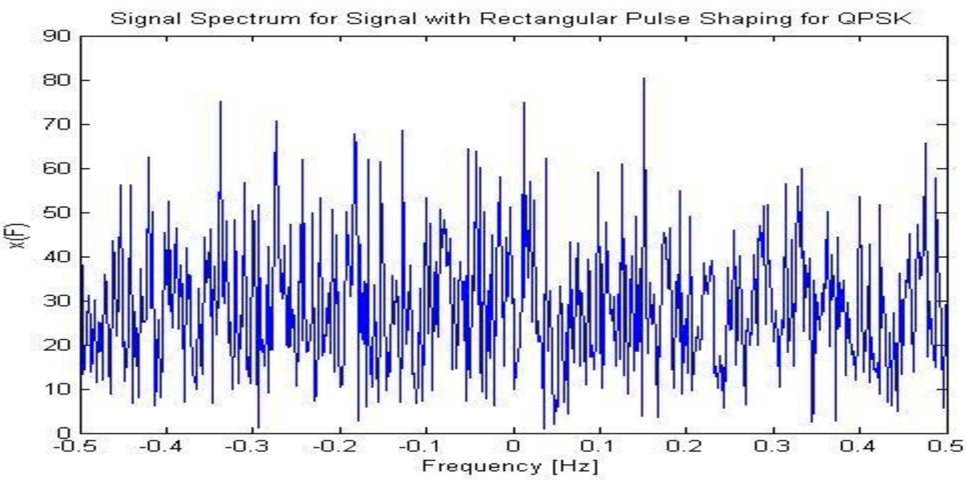
BER Performance of QPSK:

```
clc
clear all
bits=1000000;
data=randint(1,bits)>0.5;
%---debugging---
%data=[1 1 1]
%xxxxxxxxxx
ebno=0:10;
BER=zeros(1,length(ebno));
%---Transmitter---------
%Gray mapping of bits into symbols
col=length(data)/2;
I=zeros(1,col);
Q=I;
I=data(1:2:bits-1);
Q=data(2:2:bits);
I= -2.*I+1;
Q= -2.*Q+1;
symb=I+j.*Q;
%----Filter
psf=ones(1,1);
%----
M=length(psf);
for i=1:length(ebno)
% inserting zeros between the bits
```

```
% w.r.t number of coefficients of
% PSF to pass the bit stream from the PSF
z=zeros(M-1,bits/2);
upsamp=[symb;z];
upsamp2=reshape(upsamp,1,(M)*bits/2);
%Passing the symbols from PSF
%tx_symb=conv(real(upsamp2),psf)+j*conv(imag(upsamp2),psf);
tx_symb=conv(upsamp2,psf);
%--------CHANNEL-----------
%Random noise generation and addition to the signal
npsd=10.^(ebno(i)/10);
n_var=1/sqrt(2.*npsd);
rx_symb=tx_symb+(n_var*randn(1,length(tx_symb))
+j*n_var*randn(1,length(tx_symb)) );
%xxxxxxxxxxxxxxxxxxxxxxxxxx
%-------RECEIVER-----------
rx_match=conv(rx_symb,psf);
rx=rx_match(M:M:length(rx_match));
rx=rx(1:1:bits/2);
recv_bits=zeros(1,bits);
%demapping
k=1;
for ii=1:bits/2
recv_bits(k)= -( sign( real( rx(ii))) -1)/2;
recv_bits(k+1)=-( sign( imag( rx(ii)))-1)/2;
k=k+2;
end
%sign( real( rx ) )
%sign( imag( rx ) )
%data
%tx_symb
%rx_symb
%recv_bits
%xxxxxxxxxxxxxxxxxxxxxxxxxxx
%---SIMULATED BIT ERROR RATE----
errors=find(xor(recv_bits,data));
errors=size(errors,2);
BER(i)=errors/bits;
%xxxxxxxxxxxxxxxxxxxxxxxxxxx
end
fs=1;
n_pt=2^9;
tx_spec=fft(tx_symb,n_pt);
f= -fs/2:fs/n_pt:fs/2-fs/n_pt;
figure
plot(f,abs(fftshift(tx_spec)));
title('Signal Spectrum for Signal with Rectangular
Pulse Shaping for QPSK');
xlabel('Frequency [Hz]');
ylabel('x(F)');
figure
```

```
semilogy(ebno,BER,'b.-');
hold on
thr=0.5*erfc(sqrt(10.^(ebno/10)));
semilogy(ebno,thr,'rx-');
xlabel('Eb/No (dB)')
ylabel('Bit Error rate')
title('Simulated Vs Theoritical Bit Error Rate for
QPSK')
legend('Simulation','Theory'; grid on;
```

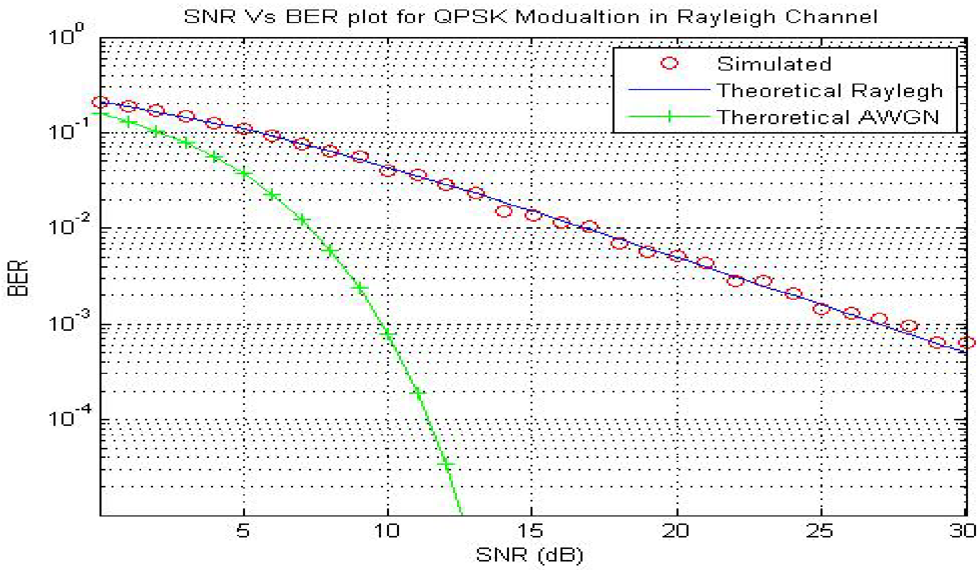




QPSK with Rayleigh fading & AWGN

```
format long;
bit_count = 10000;
Eb_No = -3: 1: 30;
SNR = Eb_No + 10*log10(2);
for aa = 1: 1: length(SNR)
T_Errors = 0;
T_bits = 0;
while T_Errors < 100
uncoded_bits = round(rand(1,bit_count));
B1 = uncoded_bits(1:2:end);
B2 = uncoded_bits(2:2:end);
```

```
qpsk_sig = ((B1==0).*(B2==0)*(exp(i*pi/4))+(B1==0).*(B2==1)...
*(exp(3*i*pi/4))+(B1==1).*(B2==1)*(exp(5*i*pi/4))...
+(B1==1).*(B2==0)*(exp(7*i*pi/4)));
ray = sqrt(0.5*((randn(1,length(qpsk_sig))).^2+(randn(1,length(qpsk_sig))).^2));
rx = qpsk_sig.*ray;
N0 = 1/10^(SNR(aa)/10);
rx = rx + sqrt(N0/2)*(randn(1,length(qpsk_sig))+i*randn(1,length(qpsk_sig)));
rx = rx./ray;
B4 = (real(rx)<0);
B3 = (imag(rx)<0);
uncoded_bits_rx = zeros(1,2*length(rx));
uncoded_bits_rx(1:2:end) = B3;
uncoded_bits_rx(2:2:end) = B4;
diff = uncoded_bits - uncoded_bits_rx;
T_Errors = T_Errors + sum(abs(diff));
T_bits = T_bits + length(uncoded_bits);
end
figure; clf;
plot(real(rx),imag(rx),'o'); % Scatter Plot
title(['constellation of received symbols for SNR = ', num2str(SNR(aa))]);
xlabel('Inphase Component'); ylabel('Quadrature Component');
BER(aa) = T_Errors / T_bits;
disp(sprintf('bit error probability = %f',BER(aa)));
end
figure(1);
semilogy(SNR,BER,'or');
hold on;
xlabel('SNR (dB)');
ylabel('BER');
title('SNR Vs BER plot for QPSK Modualtion in Rayleigh Channel');
figure(1);
EbN0Lin = 10.^(Eb_No/10);
theoryBerRay = 0.5.*(1-sqrt(EbN0Lin./(EbN0Lin+1)));
semilogy(SNR,theoryBerRay);
grid on;
figure(1);
theoryBerAWGN = 0.5*erfc(sqrt(10.^(Eb_No/10)));
semilogy(SNR,theoryBerAWGN,'g-+'); grid on;
legend('Simulated', 'Theoretical Raylegh', 'Theroretical AWGN');
axis([SNR(1,1) SNR(end-3) 0.00001 1]);
```



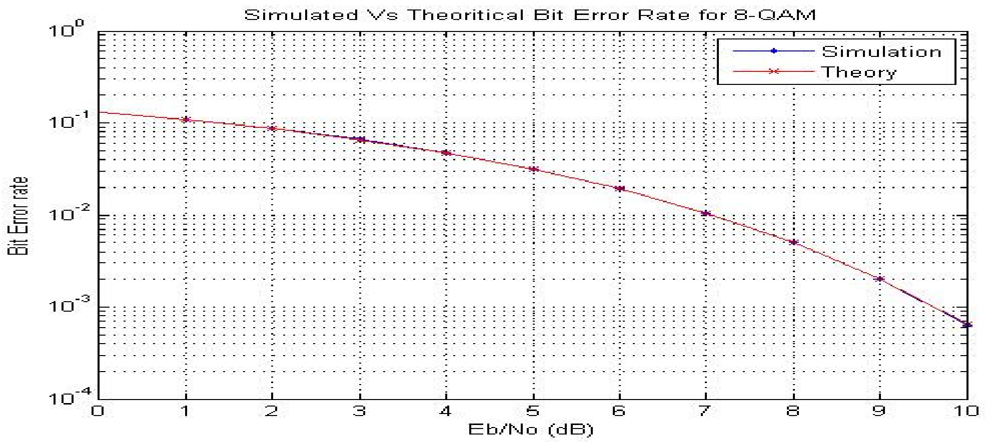
QAM and QAM BER Simulation

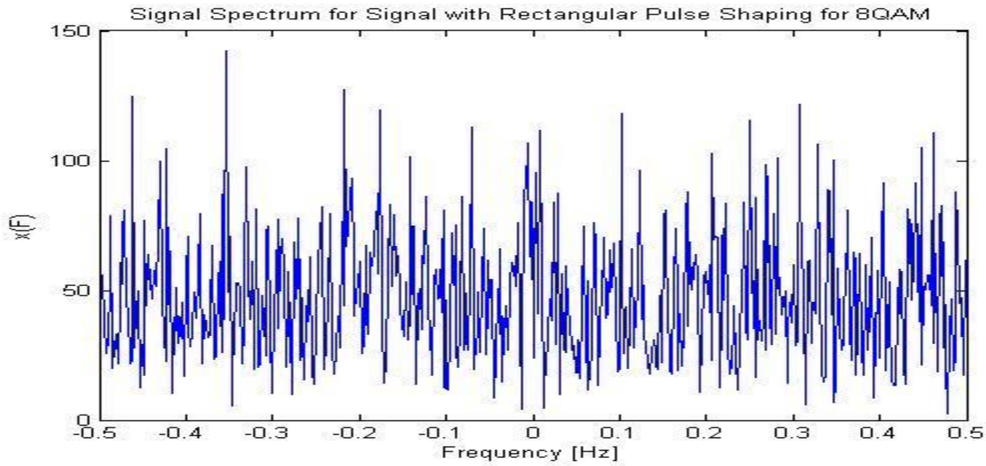
```
bits=3000000;
data=randint(1,bits)>0.5;
%---debugging---
%data=[1 1 1]
%xxxxxxxxxx
ebno=0:10;
BER=zeros(1,length(ebno));
thr=BER;
%---Transmitter---------
%Gray mapping of bits into symbols
col=length(data)/3;
I=zeros(1,col);
Q=I;
k=1;
for i=1:3:length(data)
if(data(i:i+2)==[0 0 0])
I(k)=1;
Q(k)=1;
k=k+1;
elseif(data(i:i+2)==[0 0 1])
I(k)=3;
Q(k)=1;
k=k+1;
elseif(data(i:i+2)==[0 1 0])
I(k)=-1;
Q(k)=1;
k=k+1;
elseif(data(i:i+2)==[0 1 1])
I(k)=-3;
Q(k)=1;
k=k+1;
elseif(data(i:i+2)==[1 0 0])
I(k)=1;
```

```
Q(k)=-1;
k=k+1;
elseif(data(i:i+2)==[1 0 1])
I(k)=3;
Q(k)=-1;
k=k+1;
elseif(data(i:i+2)==[1 1 0])
I(k)=-1;
Q(k)=-1;

k=k+1;
elseif(data(i:i+2)==[1 1 1])
I(k)=-3;
Q(k)=-1;
k=k+1;
end
end
symb=I+j*Q;
%real(symb)
%imag(symb)
%----Filter
psf=ones(1,1);
Es=sum(psf.^2);
eb=Es/3;
eb=2;
%----
M=length(psf);
for i=1:length(ebno)
% inserting zeros between the bits
% w.r.t number of coefficients of
% PSF to pass the bit stream from the PSF
z=zeros(M-1,bits/3);
upsamp=[symb;z];
upsamp2=reshape(upsamp,1,(M)*bits/3);
%Passing the symbols from PSF
%tx_symb=conv(real(upsamp2),psf)+j*conv(imag(upsamp2),psf);
tx_symb=conv(upsamp2,psf);
%--------CHANNEL-----------
%Random noise generation and addition to the signal
ebno2=10.^(ebno(i)/10);
%no=eb/ebno2;
%n_var=sqrt(no/2);
n_var=sqrt(eb/(2*ebno2));
rx_symb=tx_symb+(n_var*randn(1,length(tx_symb))
+j*n_var*randn(1,length(tx_symb)) );
%xxxxxxxxxxxxxxxxxxxxxxxxxxx
%-------RECEIVER-----------
rx_match=conv(rx_symb,psf);
rx=rx_match(M:M:length(rx_match));
rx=rx(1:1:bits/3);
recv_bits=zeros(1,bits);
%demapping
```

```
k=1;
for n=1:bits/3
I=real(rx(n));

Q=imag(rx(n));
if (I > 0) && (I < 2) && (Q > 0)
recv_bits(k:k+2)=[0 0 0];
elseif (I > 0) && (I < 2) && (Q < 0)
recv_bits(k:k+2)=[1 0 0];
elseif (I > 2) && (Q >0)
recv_bits(k:k+2)=[0 0 1];
elseif (I > 2) && (Q < 0)
recv_bits(k:k+2)=[1 0 1];
elseif (I < 0) && (I > -2) && (Q > 0)
recv_bits(k:k+2)=[0 1 0];
elseif (I < 0) && (I > -2) && (Q < 0)
recv_bits(k:k+2)=[1 1 0];
elseif (I < -2) && (Q > 0)
recv_bits(k:k+2)=[0 1 1];
elseif (I < -2) && (Q < 0)
recv_bits(k:k+2)=[1 1 1];
end
k=k+3;
end
tx_symb;
rx_symb;
data;
recv_bits;
%xxxxxxxxxxxxxxxxxxxxxxxxxxxx
%---SIMULATED BIT ERROR RATE----
errors=find(xor(recv_bits,data));
errors=size(errors,2);
BER(i)=errors/bits;
ebno_lin=(10^(ebno(i)/10))
thr(i)=(5/12)*erfc(sqrt(ebno_lin/2));
%xxxxxxxxxxxxxxxxxxxxxxxxxxxx
end
fs=1;
n_pt=2^9;
tx_spec=fft(tx_symb,n_pt);
f= -fs/2:fs/n_pt:fs/2-fs/n_pt;
figure
plot(f,abs(fftshift(tx_spec)));
title('Signal Spectrum for Signal with Rectangular
Pulse Shaping for 8QAM');
xlabel('Frequency [Hz]');
ylabel('x(F)');
figure;
semilogy(ebno,BER,'b.-');
hold on
%ebno2=(10.^(ebno/10));
```

```
%thr=(5/12).*erfc(sqrt((10.^(ebno/10))./2));
semilogy(ebno,thr,'rx-');
xlabel('Eb/No (dB)')
ylabel('Bit Error rate')
title('Simulated Vs Theoritical Bit Error Rate for 8-QAM')
legend('Simulation','Theory'); grid on;
```





Results:

The performance of various modulation techniques in AWGN and or Rayleigh Fading channel was investigated. The simulated results of BER agree with the theoretical values obtained for the modulation schemes. It was observed that BER performance of bandpass modulation in AWGN channel offers a better performance than in Rayleigh fading channel.