TASK 1

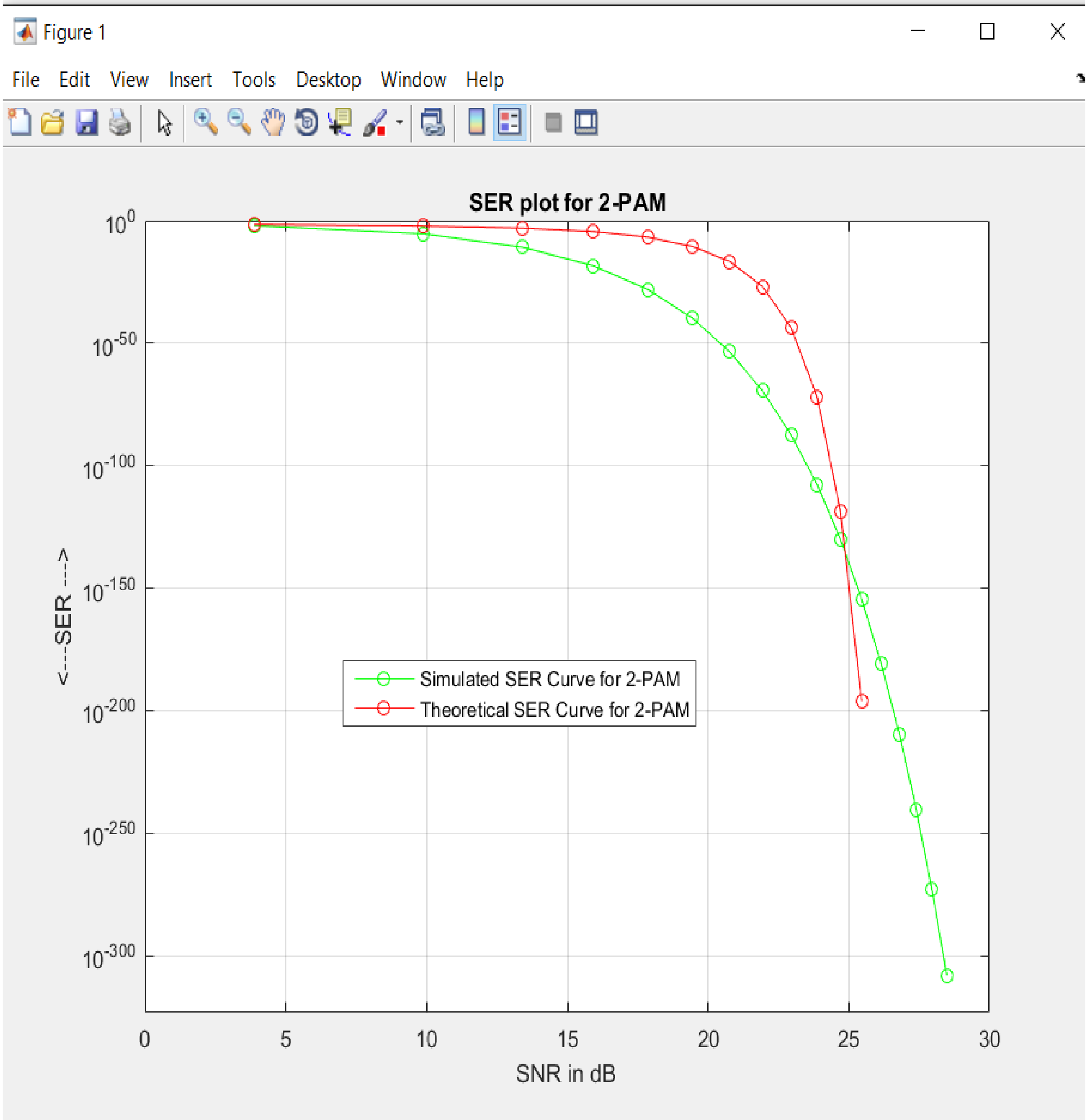
QUESTION:

Simulate the system with binary-PAM modulation/demodulation, and plot symbol error rate (SER) curve in terms of various SNR levels. In the same figure, also plot the theoretical SER curve and compare it with the simulation result. (Use semilogy(.) to plot SER curve, show SNR in dB.)

MATLAB PROGRAM:

```
clear all;

N0 = 4.1*(10^ -21);
A=10;
fc = 1000;
T= 5;
t = 0:0.001:T;

gm = A*rectpuls((t-(0.5*T)),T);
Am1= [-1 1];
Am=randsrc(1,1,Am1);
sm=Am*gm.*cos(2*pi*fc*t);

Es_N0_db=(-3:20);

c=awgn(sm,N0/2);

Amp=(10^-10)*(1:10000);

for i=1:length(Amp)

SNR(i)= sqrt(2*(Amp(i)^2)/N0);
SNR_db(i)=10*log10(Amp(i)^2/N0);

end;

SER_theory=berawgn(SNR,'pam',2);
SER_sim=0.5*erfc(sqrt(10.^(SNR/10)));

semilogy(SNR_db,SER_sim,'g-o',SNR_db,SER_theory,'r-o');
hold on;

xlabel('SNR in dB');
ylabel('SER');
grid on;

title('Symbol Error rate of binary-PAM');
legend('Simulated SER curve for 2-PAM','Theoretical SER curve for 2-
PAM');
```

OUTPUT:



OBSERVATION:

Good agreement between the simulated and theoretical plots for 2-PAM modulation is seen.

TASK 2

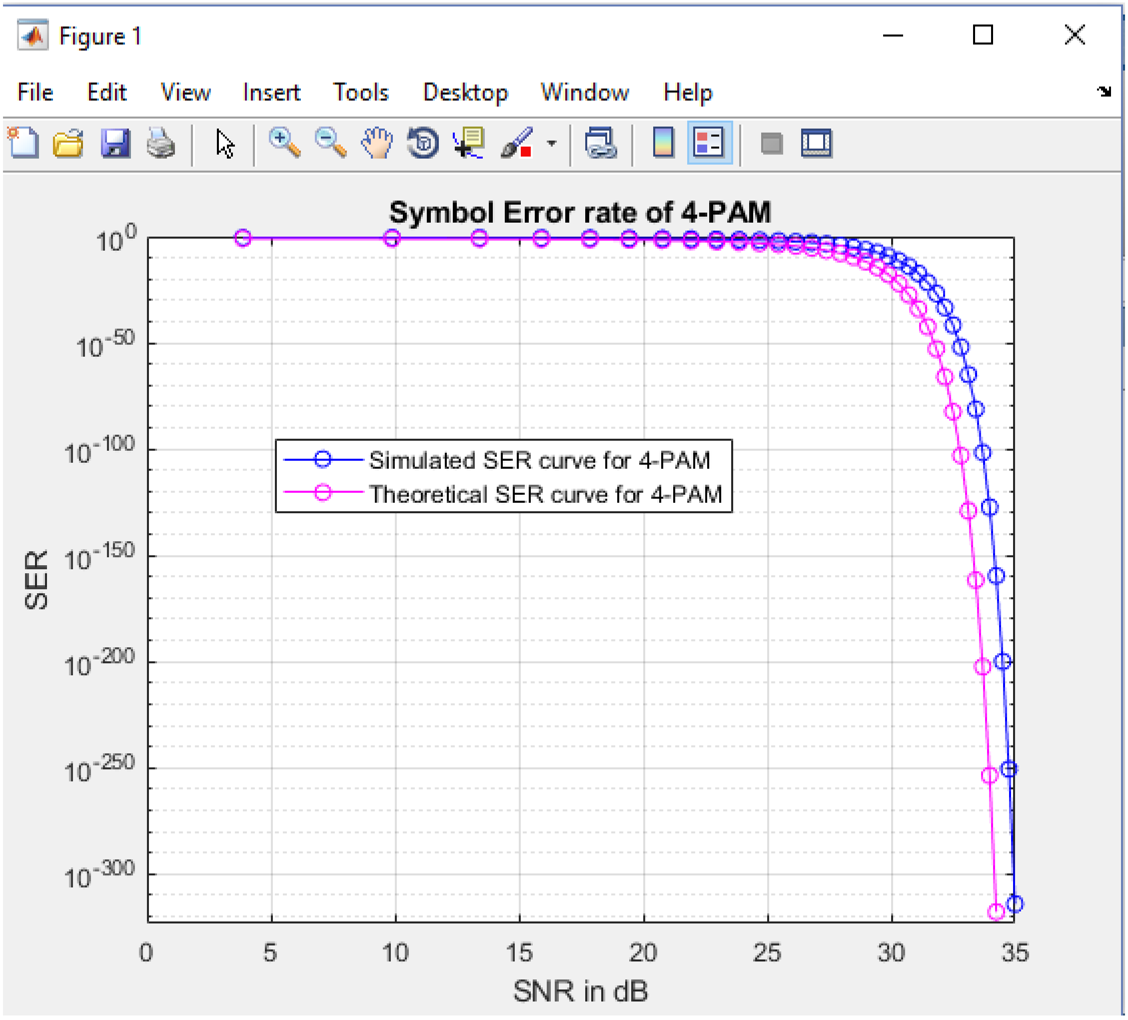
QUESTION:

Simulate the system with 4-PAM modulation/demodulation, and plot the SER curve in terms of SNR. In the same figure, also plot the theoretical SER curve and compare it with the simulation result.

MATLAB PROGRAM:

```
clear all;

N0 = 4.1*(10^ -21);
A=10;
fc = 1000;
T= 5;
t = 0:0.001:T;

gm = A*rectpuls((t-(0.5*T)),T);
Am1= [-3 -1 1 3];
Am=randsrc(1,1,Am1);
sm=Am*gm.*cos(2*pi*fc*t);

Es_N0_db=(-3:20);

c=awgn(sm,N0/2);

Amp=(10^-10)*(1:1000);

fori=1:length(Amp)

SNR(i)= sqrt(2/5*(Amp(i)^2)/N0);
SNR_db(i)=10*log10(Amp(i)^2/N0);

end;

SER_theory=berawgn(SNR,'pam',4);
SER_sim=0.75*erfc(sqrt(0.2*(10.^(SNR/10))));

semilogy(SNR_db,SER_sim,'b-o',SNR_db,SER_theory,'m-o');
hold on;

xlabel('SNR in dB');
ylabel('SER');
grid on;

title('Symbol Error rate of 4-PAM');
legend('Simulated SER curve for 4-PAM','Theoretical SER curve for 4-
PAM');
```

OUTPUT:



OBSERVATION:

Good agreement between the simulated and theoretical plots for 4-PAM modulation is seen.

TASK 3

QUESTION:

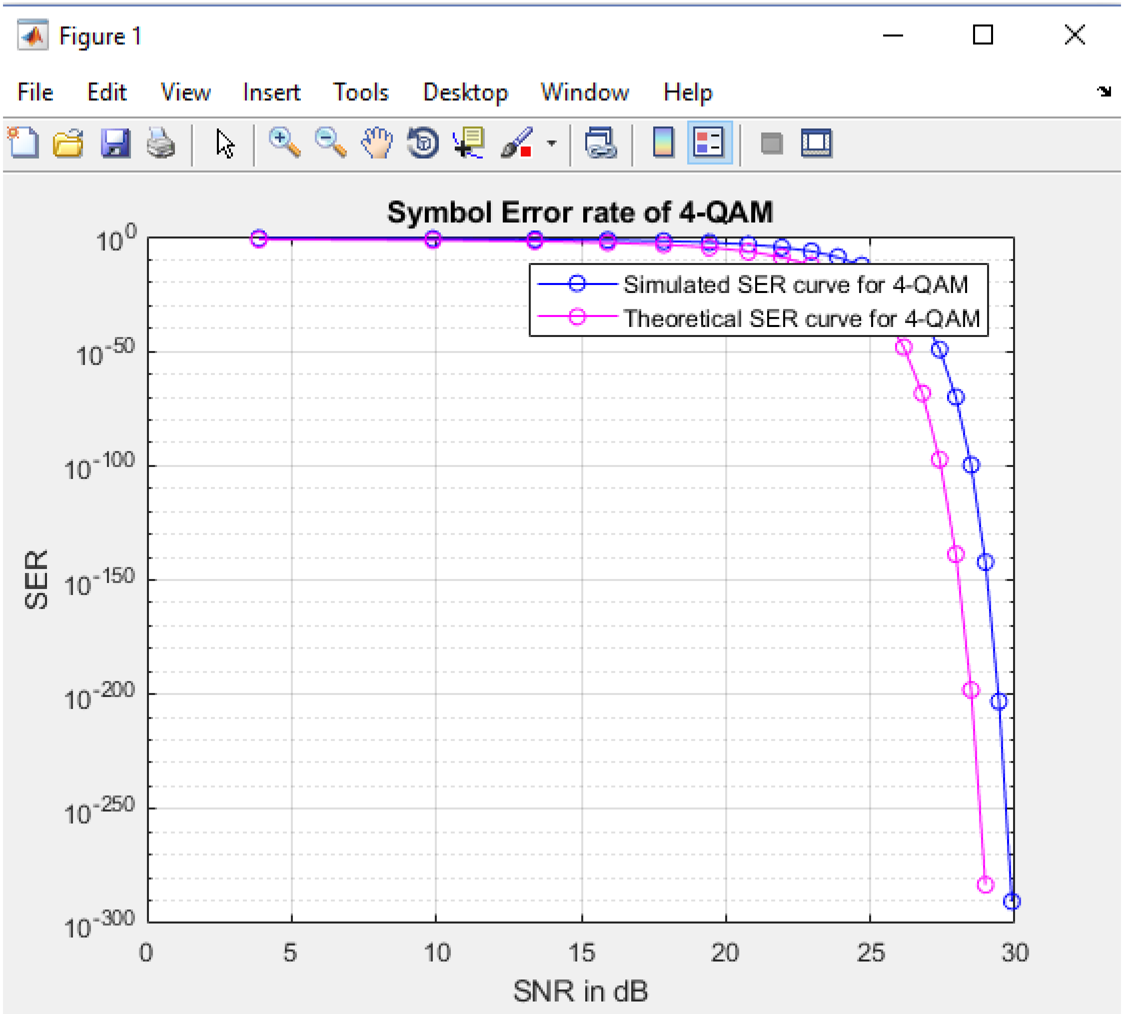
Simulate the system with 4-QAM modulation/demodulation, and plot the SER curve in terms of SNR. In the same figure, also plot the theoretical SER curve and compare it with the simulation result.

MATLAB PROGRAM:

```
clear all;

N0 = 4.1*(10^ -21);
A=10;
fc = 1000;
T= 5;
t = 0:0.001:T;
gm = A*rectpuls((t-(0.5*T)),T);
M=4;
m=[1:M];

for ii=1:sqrt(M)

Ai(ii)=2*ii-1-sqrt(M);
Aq(ii)=2*ii-1-sqrt(M);

end;

Aii=randsrc(1,1,Ai);
Aqq=randsrc(1,1,Aq);
sm=Aii*gm.*cos(2*pi*fc*t)-Aqq*gm.*sin(2*pi*fc*t);

Es_N0_db=(-3:20);

c=awgn(sm,N0/2);

Amp=(10^-10)*(1:1000);

fori=1:length(Amp)

SNR(i)= sqrt((Amp(i)^2)/N0);
SNR_db(i)=10*log10((Amp(i)^2)/N0);

end;

SER_theory=berawgn(SNR,'qam',4);
SER_sim=erfc(sqrt(0.5*(10.^(SNR/10))))-
(1/4)*(erfc(sqrt(0.5*(10.^(SNR/10)))));

semilogy(SNR_db,SER_sim,'b-o',SNR_db,SER_theory,'m-o');
hold on;

xlabel('SNR in dB');
ylabel('SER');
```

```
grid on;
title('Symbol Error rate of 4-QAM');
legend('Simulated SER curve for 4-QAM','Theoretical SER curve for 4-
QAM');
```

OUTPUT:



OBSERVATION:

Good agreement between the simulated and theoretical plots for 4-QAM modulation is seen.

TASK 4

QUESTION:

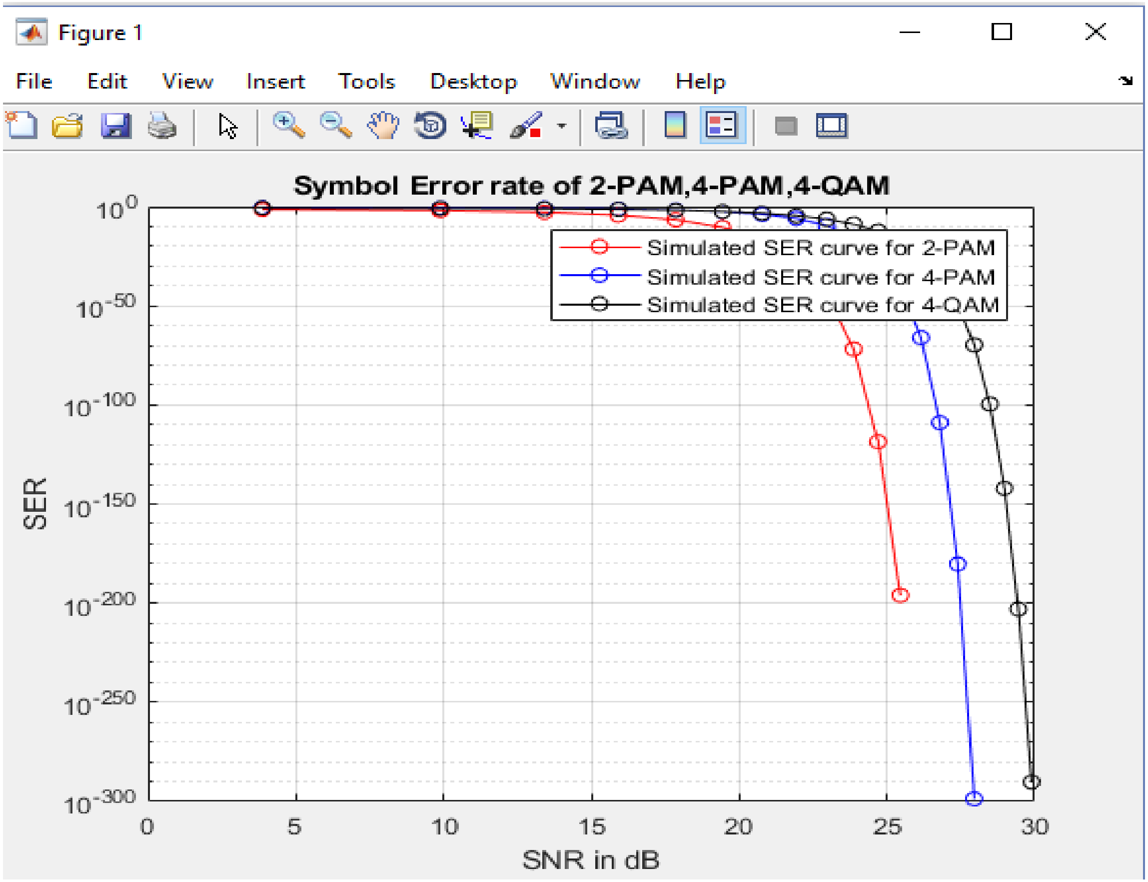
Based on the simulation results in (1)-(3), plot in one figure the SER curves of the three modulation schemes (Binary-PAM, 4-PAM, and 4-QAM). What do you observe?

MATLAB PROGRAM:

```
clear all;

N0 = 4.1*(10^ -21);
A=10;
fc = 1000;
T= 5;
t = 0:0.001:T;

gm = A*rectpuls((t-(0.5*T)),T);
Am1= [-1 1];
Am=randsrc(1,1,Am1);
sm=Am*gm.*cos(2*pi*fc*t);

Am2= [-3 -1 1 3];
Am4=randsrc(1,1,Am2);
sm4=Am4*gm.*cos(2*pi*fc*t);

Es_N0_db=(-3:20);

c=awgn(sm,N0/2);
c4=awgn(sm4,N0/2);

Amp=(10^-10)*(1:10000);

fori=1:length(Amp)

SNR(i)= sqrt(2*(Amp(i)^2)/N0);
SNR_db(i)=10*log10(Amp(i)^2/N0);

end;

SER_sim=0.5*erfc(sqrt(10.^(SNR/10))); %2-PAM

SER_sim4=0.75*erfc(sqrt(0.2*(10.^(SNR/10)))); %4-PAM

semilogy(SNR_db,SER_sim,'r-o',SNR_db,SER_sim4,'b-o');
hold on;

%4-QAM
M=4;
m=[1:M];
for ii=1:sqrt(M)
    Ai(ii)=2*ii-1-sqrt(M);
Aq(ii)=2*ii-1-sqrt(M);
end;
Aii=randsrc(1,1,Ai);
Aqq=randsrc(1,1,Aq);
```

```
sm=Aii*gm.*cos(2*pi*fc*t)-Aqq*gm.*sin(2*pi*fc*t);

Es_N0_db=(-3:20);

c=awgn(sm,N0/2);

Amp=(10^-10)*(1:1000);
fori=1:length(Amp)

SNR(i)= sqrt((Amp(i)^2)/N0);
SNR_db(i)=10*log10((Amp(i)^2)/N0);

end;

SER_simq=erfc(sqrt(0.5*(10.^(SNR/10))))                                  -
(1/4)*(erfc(sqrt(0.5*(10.^(SNR/10))))).^2;

semilogy(SNR_db,SER_simq,'k-o');
hold on;

xlabel('SNR in dB');
ylabel('SER');
grid on;
title('Symbol Error rate of 2-PAM,4-PAM,4-QAM');
legend('Simulated  SER  curve  for  2-PAM','Simulated  SER  curve  for  4-
PAM','Simulated SER curve for 4-QAM');
```

OUTPUT:



OBSERVATION:

It is observed that the simulated curve of 4-PAM is greater than 2-PAM and 4-QAM. When compared with 4-PAM modulation, the 4-QAM modulation requires only around 2dB lower SNR for achieving similar symbol error rate. This is because, SER of 4-PAM is much higher than 4QAM and 2 PAM . Hence 2-PAM is preferred over 4-PAM and 4-QAM.

TASK 5

QUESTION:

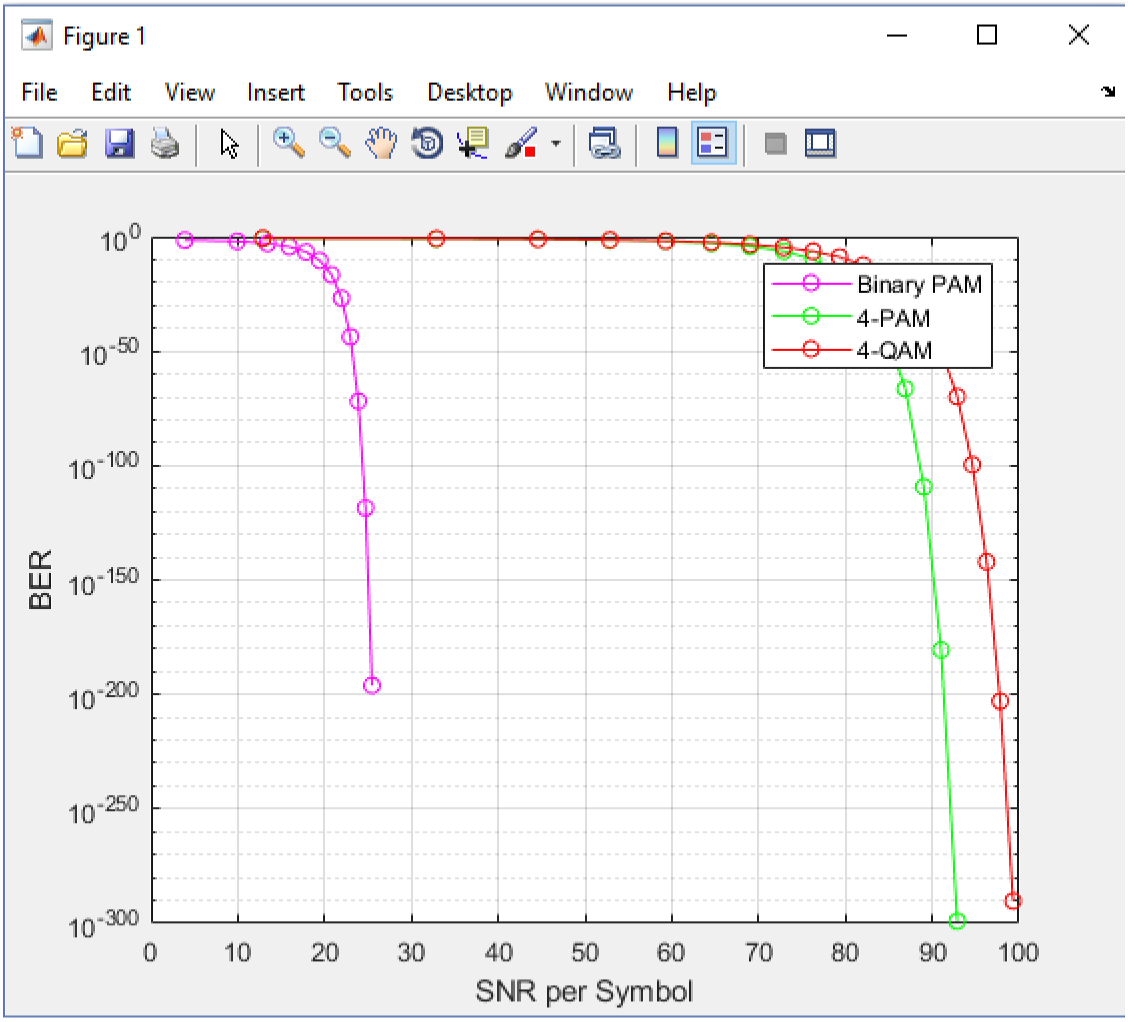
Based on the simulations in (1)-(3), plot in one figure the bit-error-rate (BER) curves of the three modulation schemes (Binary-PAM, 4-PAM, and 4-QAM) in terms of SNR per symbol. What do you observe?

MATLAB PROGRAM:

```
clear all;
N0 = 4.1*(10^ -21);
Amp=(10^-10)*(1:10000);

%2-PAM
M=2;
for i=1:length(Amp)

SNR(i)= sqrt(2*(Amp(i)^2)/N0);
SNR_db(i)=10*log10(Amp(i)^2/N0);

end;

BER=0.5*erfc(sqrt(10.^(SNR/10)));

x0 = BER;
x1 = SNR_db;

% 4-PAM
M=4;
for i=1:length(Amp)

SNR(i)= sqrt(2*(Amp(i)^2)/N0);
SNR_db(i)=10*log10(Amp(i)^2/N0)/0.301;

end;

BER=0.75*erfc(sqrt(0.2*(10.^(SNR/10))))/2;

y0 = BER;
y1 = SNR_db;

% 4-QAM
M=4;
for i=1:length(Amp)

SNR(i)= sqrt((Amp(i)^2/N0));
SNR_db(i)=10*log10(Amp(i)^2/N0)/0.301;

end;

BER=erfc(sqrt(0.5*(10.^(SNR/10))))                                          -
(1/4)*(erfc(sqrt(0.5*(10.^(SNR/10))))).^2/2;
z0 = BER;
z1 = SNR_db
```

```
semilogy(x1,x0,'m-o');
xlabel('SNR per Symbol');
ylabel('BER');
hold on;
semilogy(y1,y0,'g-o');
grid on;
hold on;
semilogy(z1,z0,'r-o');
legend('Binary PAM','4-PAM','4-QAM');
```

OUTPUT:



OBSERVATION:

4QAM performs much better than the 4PAM system due to the following reasons: first the noise variance in the 4PAM system is higher so we expect its error rate to be higher; on the other hand the PAM system is not fully utilizing the bandwidth as opposed to 4QAM. But 2-PAM is more efficient than 4 PAM.

TASK 6

QUESTION:

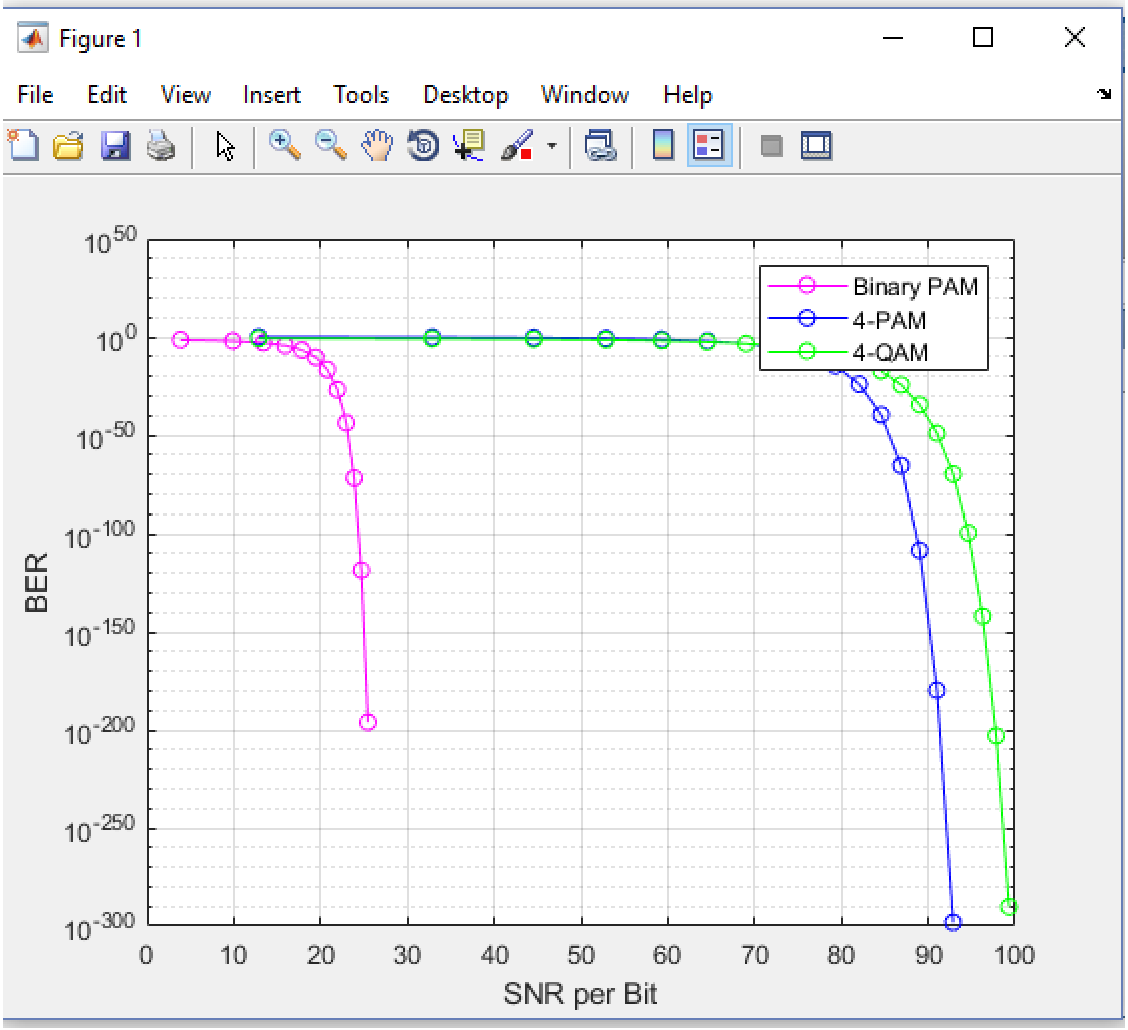
Based on the simulations in (1)-(3), plot in one figure the BER curves of the three modulation schemes (Binary-PAM, 4-PAM, and 4-QAM) in terms of SNR per bit. What do you observe?

MATLAB PROGRAM:

```
clear all;
N0 = 4.1*(10^ -21);
Amp=(10^-10)*(1:10000);

%2-PAM
M=2;
fori=1:length(Amp)

SNR(i)= sqrt(2*(Amp(i)^2)/N0);
SNR_db(i)=10*log10(Amp(i)^2/N0);

end;

BER=0.5*erfc(sqrt(10.^(SNR/10)));

x0 = BER;
x1 = SNR_db;

%4-PAM
M=4;
fori=1:length(Amp)

SNR(i)= sqrt(2*(Amp(i)^2)/N0);
SNR_db(i)=10*log10(Amp(i)^2/N0)/0.301;
end;

BER=0.75*erfc(sqrt(0.2*(10.^(SNR/10))))/0.301;

y0 = BER;
y1 = SNR_db;

%4-QAM
M=4;
for i=1:length(Amp)

SNR(i)= sqrt((Amp(i)^2/N0));
SNR_db(i)=10*log10(Amp(i)^2/N0)/0.301;

end;

BER=erfc(sqrt(0.5*(10.^(SNR/10))))                                          -
(1/4)*(erfc(sqrt(0.5*(10.^(SNR/10))))).^2/0.301;
z0 = BER;
z1 = SNR_db

semilogy(x1,x0,'m-o');
xlabel('SNR per Bit');
```

```
ylabel('BER');
hold on;
semilogy(y1,y0,'b-o');
grid on;
hold on;
semilogy(z1,z0,'g-o');
legend('Binary PAM','4-PAM','4-QAM');
```

OUTPUT:



OBSERVATION:

This model ascertains as to which modulation has the lowest bit error rate. The bit error rates of various digital modulation schemes were compared, the effect of varying signal energy per bit to Noise ratio (E_b/N_o) on the error rate of various digital modulation schemes was analysed. From this, Binary PAM offer better BER and better coverage integrity of the signal as it is transmitted along an AWGN channel.

FINAL PROJECT

EE538 PRINCIPLES OF MODERN DIGITAL COMMUNICATIONS

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