Filière Cycle Ingénieure d'Informatique et Numérique
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Semester 7
Module: Mobile Network

RAPPORT

Digital Modulation PSK, QAM, FSK
Spread Spectrum Techniques DSSS

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Introduction

Digital modulation is the process of encoding a digital information signal into the amplitude, phase, or frequency of the transmitted signal. The encoding process affects the bandwidth of the transmitted signal and its robustness to channel impairments. In general, a modulation technique encodes several bits into one symbol, and the rate of symbol transmission determines the bandwidth of the transmitted signal. Since the signal bandwidth is determined by the symbol rate, having a large number of bits per symbol generally yields a higher data rate for a given signal bandwidth. However, the larger the number of bits per symbol, the greater the required received SNR for a given target BER.
Digital modulation techniques may be linear or nonlinear. In linear modulation the amplitude and/or phase of the transmitted signal varies linearly with the digital modulating signal, whereas the transmitted signal amplitude is constant for nonlinear techniques.

Linear modulation techniques, including all forms of quadrature-amplitude modulation (QAM) and phase-shift-keying (PSK), use less bandwidth than nonlinear techniques, including various forms of frequency/minimum-shift-keying (FSK and MSK). Since linear techniques encode information into the amplitude and phase of linear modulation, this type of modulation is more susceptible to amplitude and phase fluctuations caused by multipath flat-fading. In addition, the amplifiers used for linear modulation must be linear, and these amplifiers are more expensive and less efficient than nonlinear amplifiers. Thus, the bandwidth efficiency of linear modulation is generally obtained at the expense of hardware cost, power, and higher BERs in fading. Linear modulation techniques are used in most wireless LAN products, whereas nonlinear techniques are used in most cellular and wide area wireless data systems.

In this report, we are going to verify the principles of digital Modulation PSK, QAM, FSK and understand the concept and tools used in spread spectrum transmission (DSSS) using MATLAB.

A. Phase shift modulation (phase shift keying)

A.1 Simulation using M file :

Phase-shift keying (PSK) is a digital modulation process which conveys data by changing (modulating) the **phase** of a constant frequency reference signal (the carrier wave). The modulation is accomplished by varying the sine and cosine inputs at a precise time.

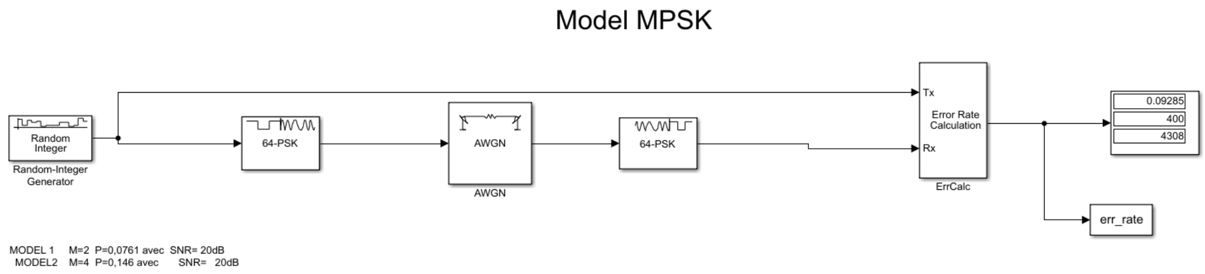

Figure 1: Simulink model for M-ary PSK

- ✓ To run the simulation correctly:

```
M=8;
esnos=20:40;
err_vec1=[];


for i=1:length(esnos)
    ESNO=esnos(i);
    sim('Mpsk_bb1');
    err_vec1(i,:)=err_rate
end;
%semilogy(esnos,err_vec1(:,1),'r-*');
l0=plot(esnos,err_vec1(:,1),'r-*');

hold on
M=16;
esnos=20:40;
err_vec1=[];


for i=1:length(esnos)
    ESNO=esnos(i);
    sim('Mpsk_bb1');
    err_vec1(i,:)=err_rate
end;
%semilogy(esnos,err_vec1(:,1),'r-*');
l1=plot(esnos,err_vec1(:,1),'g-o');

hold on
```

```
M=32;
esnos=20:40;
err_vec1=[];
for i=1:length(esnos)
    ESNO=esnos(i);
   sim('Mpsk_bb1');
    err_vec1(i,:)=err_rate
end;
%semilogy(esnos,err_vec1(:,1),'r-*');
l2=plot(esnos,err_vec1(:,1),'c-*');
xlabel('Eb/No');
ylabel ('error rate');
%legend(l2, {'M=8'});

hold on

M=64;
esnos=20:40;
err_vec1=[];
for i=1:length(esnos)
    ESNO=esnos(i);
    sim('Mpsk_bb1');
    err_vec1(i,:)=err_rate
end;
%semilogy(esnos,err_vec1(:,1),'r-*');
l3=plot(esnos,err_vec1(:,1),'b-*');

legend([l0,l1,l2,l3], {'M=8','M=16','M=32','M=64'}); %creation des legendes
```

Figure 2: Simulation code

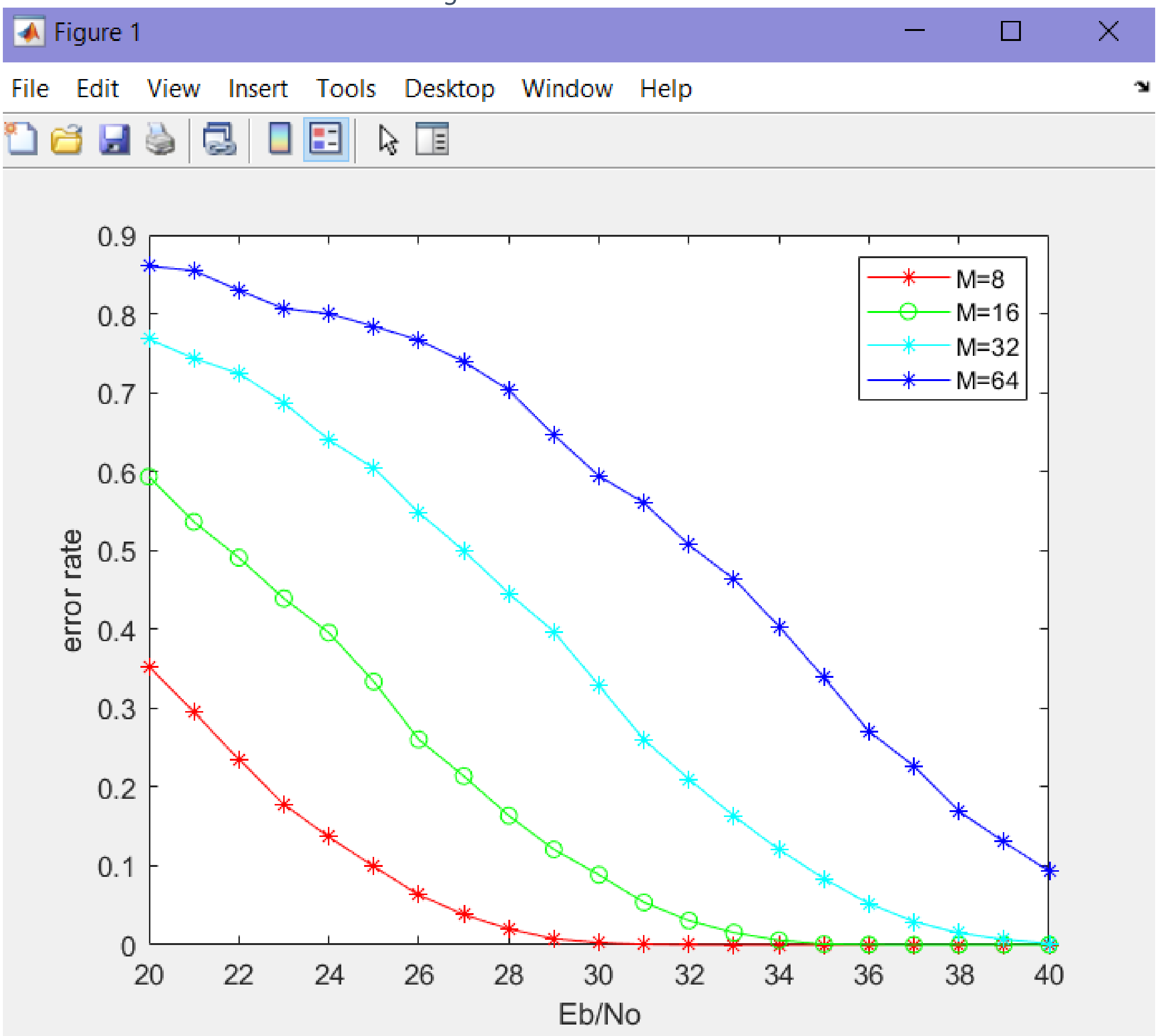

Figure 3: Comparison of symbol error rate (BER) on same graph

```
clear;clf;
M=2;
esnos=20:40;
err_vec=[];

for i=1:length(esnos)
  ESNO=esnos(i);
  sim('Mpsk_bb');
  err_vec(i,:)=err_rate
end;
semilogy(esnos,err_vec(:,1),'b-*');
```

Figure 4 code simulation with M=2

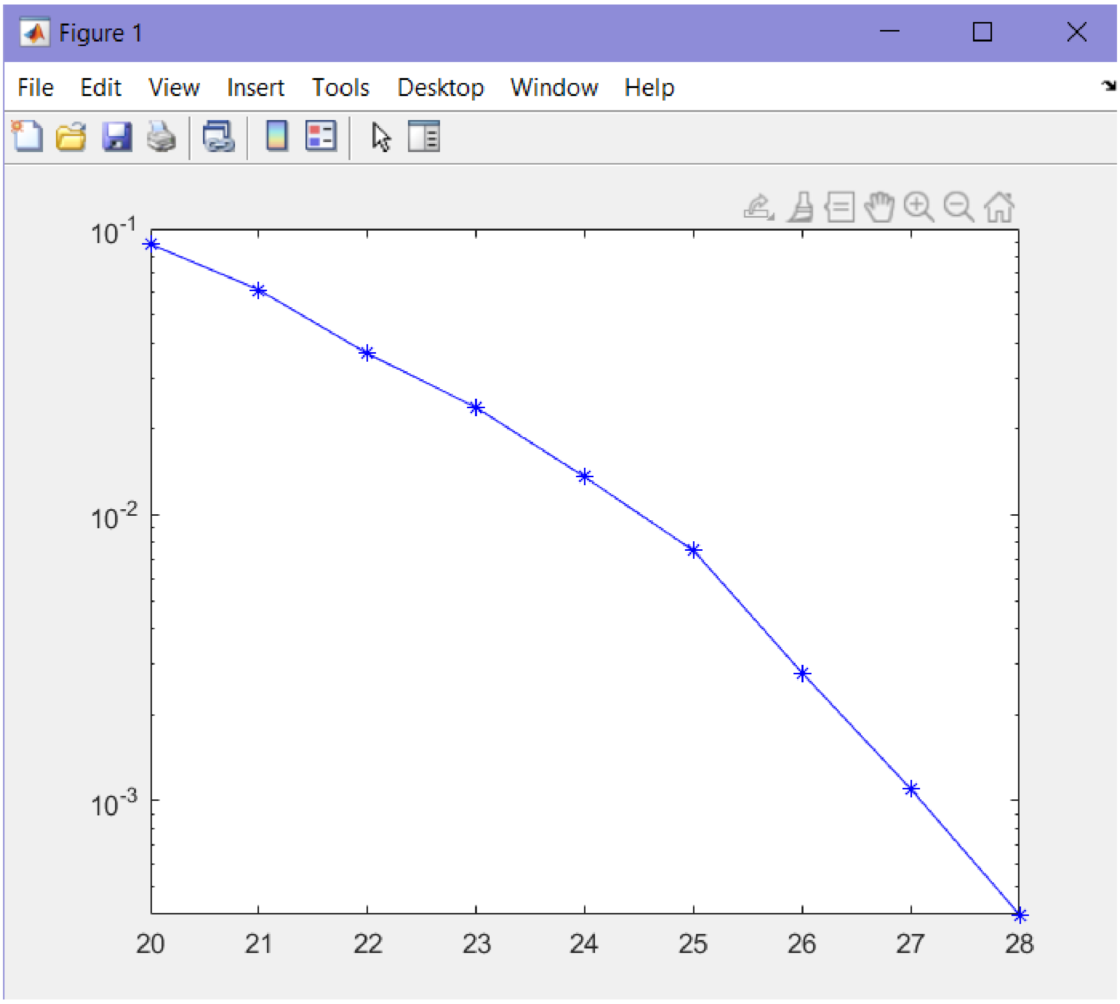

Figure 5: BER for PSK using MPSK with M=2

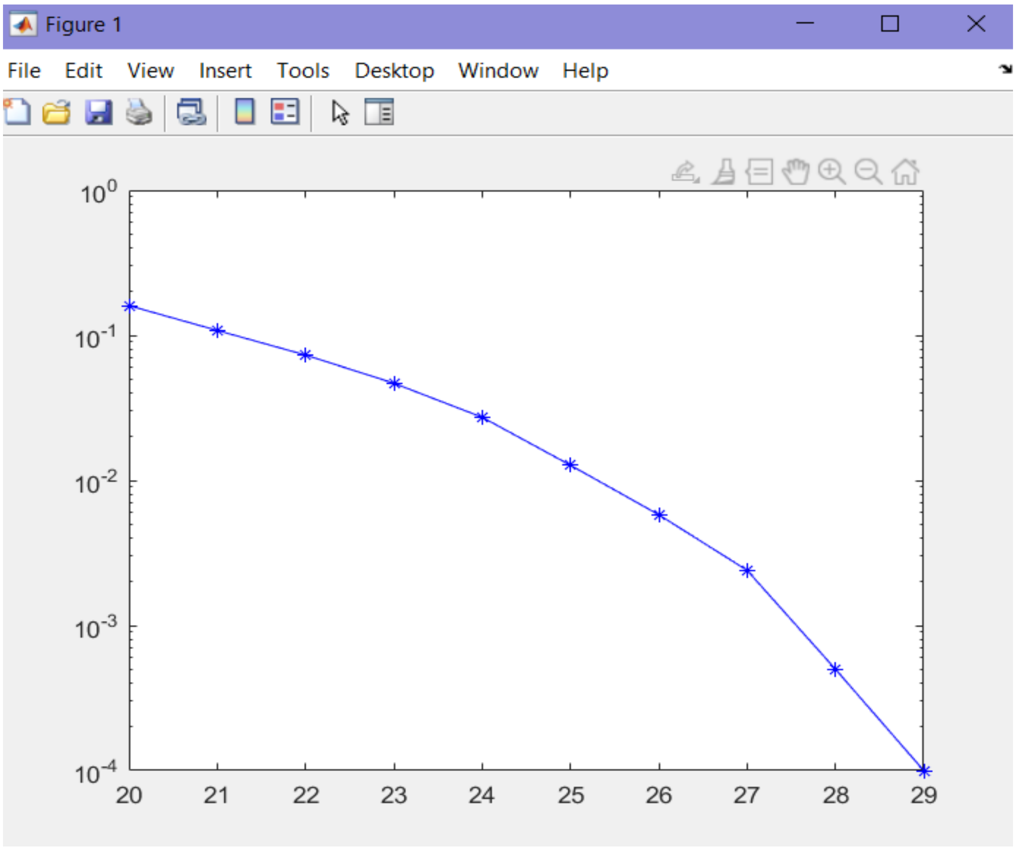

Figure 6:BER for PSK using MPSK with M=4

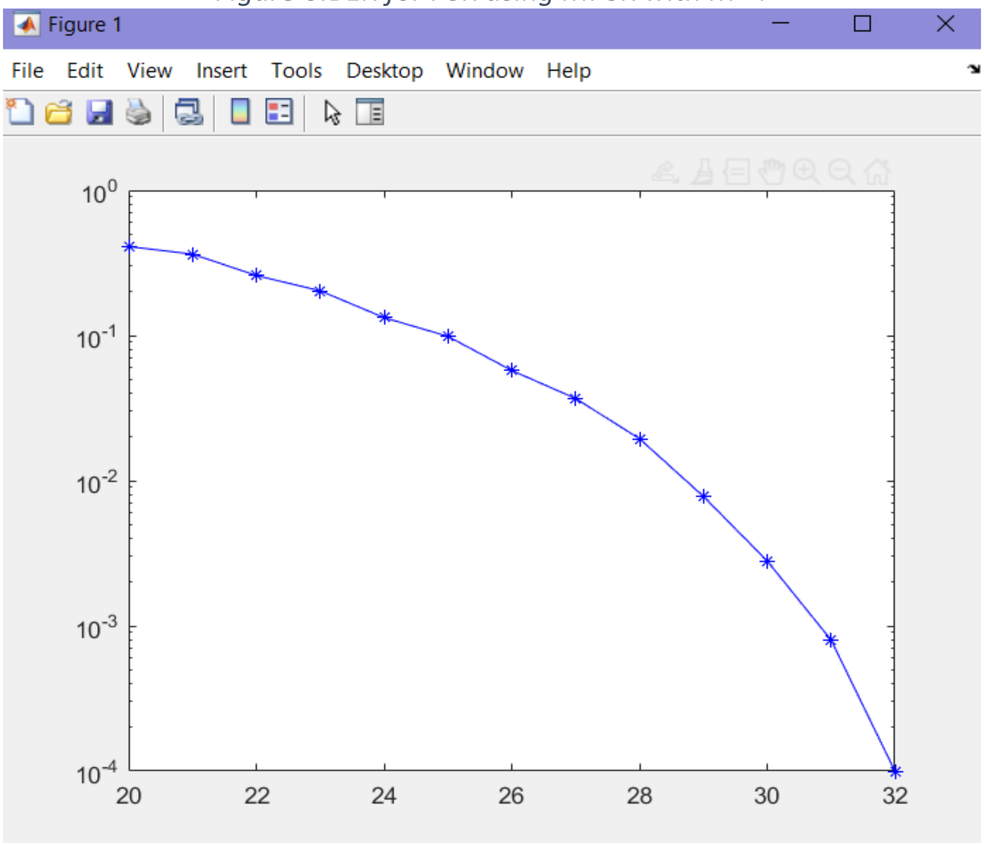

Figure 7:BER for PSK using MPSK with M=8

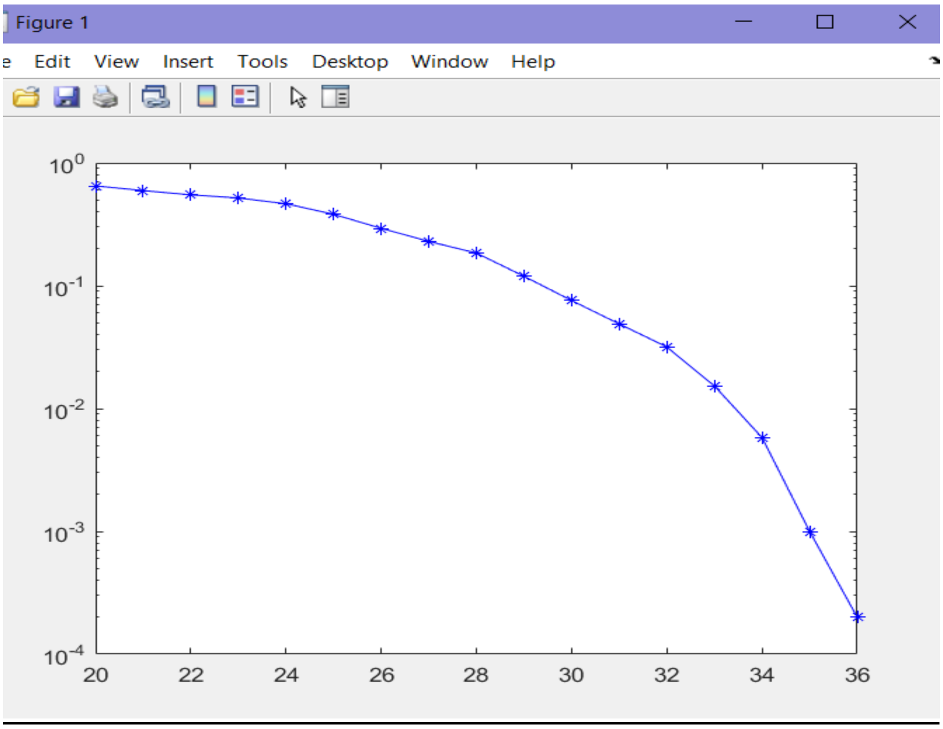

Figure 8:BER for PSK using MPSK with M=16

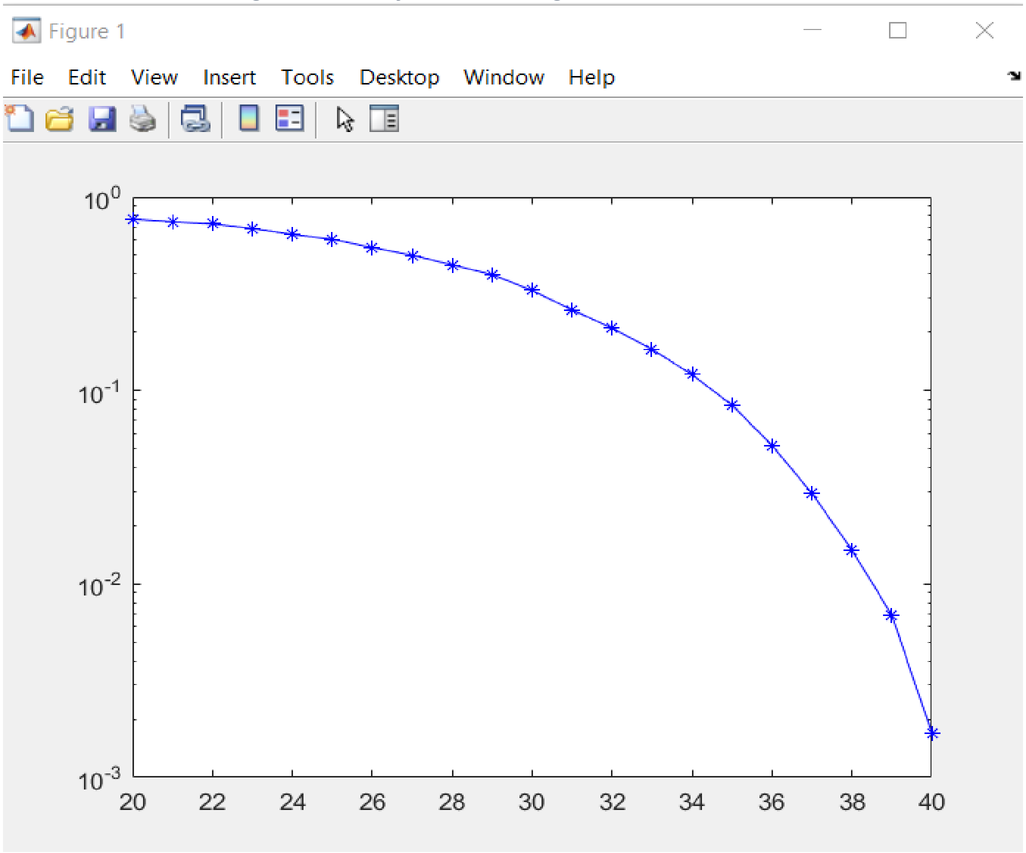

Figure 9:BER for PSK using MPSK with M=32

A.2 Simulation of BER Performance vs. SNR using AWGN channel and analysis

A.2.1 Simulation result for evaluation on BER vs. Es/N0, stop time =100s

Es/N0 (dB) = ESNO+10*log10(log2(M)) / M=2, P=0,0761 avec SNR= 20dB / M=4, P=0,146 avec SNR= 20dB

Tableau 1:The table below gives a summary of the bit rates of different forms of PSK

M	Total Error	Total symbols	BER
2	0	1e+04	0
4	0	1e+04	0
8	0	1+e+04	0
16	0	1e+04	0
32	17	1e+04	0.0017
64	100	1183	0.08453

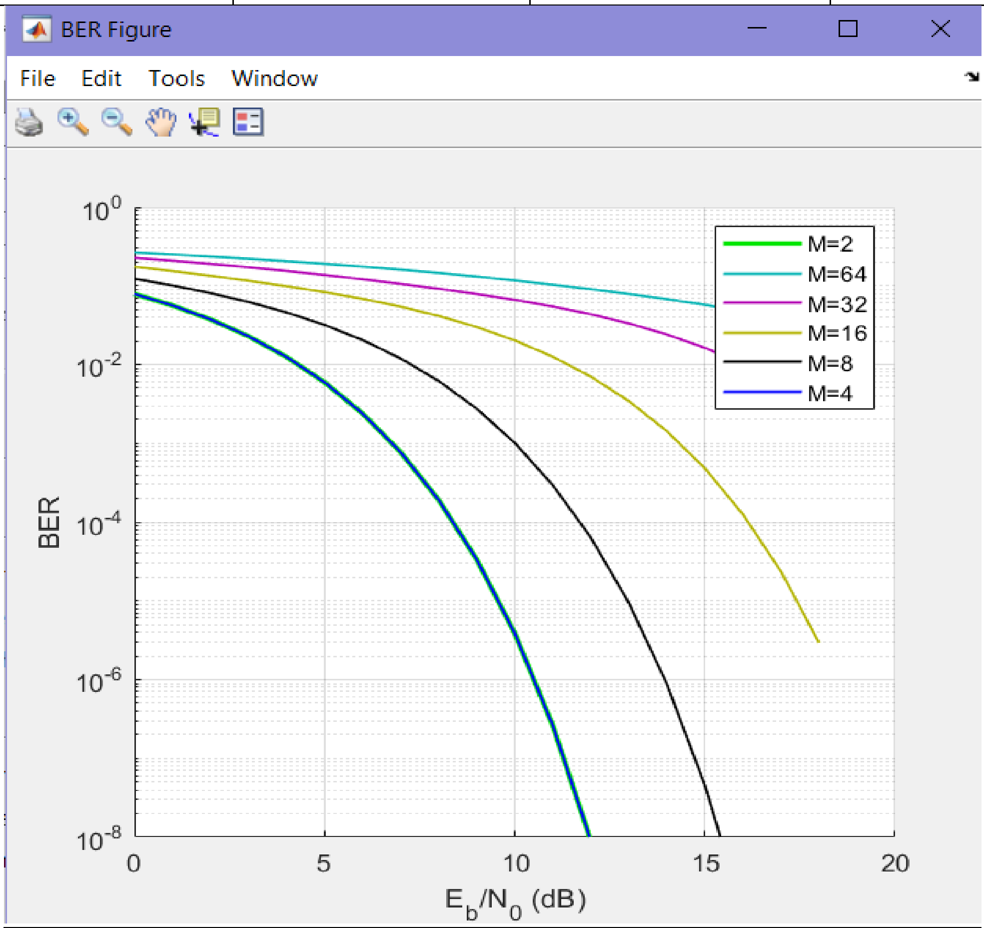

Figure 10:Performance of MPSK in model AWGN Channels

A.2.2 Simulation analysis

Figure 3, 5, 6, 7, 8 and 9 present the BER values as a function of varying SNR, which means represent the probability of errors as a function of SNR. In the simulation represented in *figure 10,* the BERs are obtained by varying the values of Eb/No in the range of 0 to 40. The iteration is done 100 times where the total number of data transmitted is 100. M-ary

numbers are simulated on the same graph as it is shown in *figure 3 and 10*.
we notice from these simulations, when M increases the probability of error (Pe) also increases, on the other hand as one SNR increases the probability of error decreases.

For example, when we have M=2 in SNR=20 dB the error probability is 10^ (-1) as shown in *figure 5 and 10*, in M=8 Pe=10^(-1.5) as shown in *figure 7 and 10* and in M=16 Pe=10^(-1.2) as shown in *figure 8 and 10*. Now if we have SNR= 20 dB the Pe=10^-1, SNR= 24.5 dB the Pe=10^-2 and SNR= 27 dB the Pe=10^-3 as shown in all the curves above.

For M- ary PSK it is seen from Figure 11 that if the value of M increases for 8 to 16 the value of bit error rate also increases. As a result, the performance of the system decreased. We can say the 8-ary PSK is better than 16-ary PSK.

The BER (bit error rate is all the lower the better the signal-to-noise ratio. The BER increases sharply with the M-ary numbers. So quality transmission is trickier with modulation with many M-ary numbers.

B. Quadrature Amplitude Modulation :

B.1.1 Simulation using M file :

Quadrature Amplitude Modulation, **QAM** utilizes both amplitude and phase components to provide a form of modulation that can provide high levels of spectrum usage efficiency. **QAM**, quadrature amplitude modulation has been used for some analogue transmissions including **AM** stereo transmissions, but it is for data applications where it has come into its own. It can provide a highly effective form of modulation for data and as such it is used in everything from cellular phones to Wi-Fi and almost every other form of high-speed data communications system.

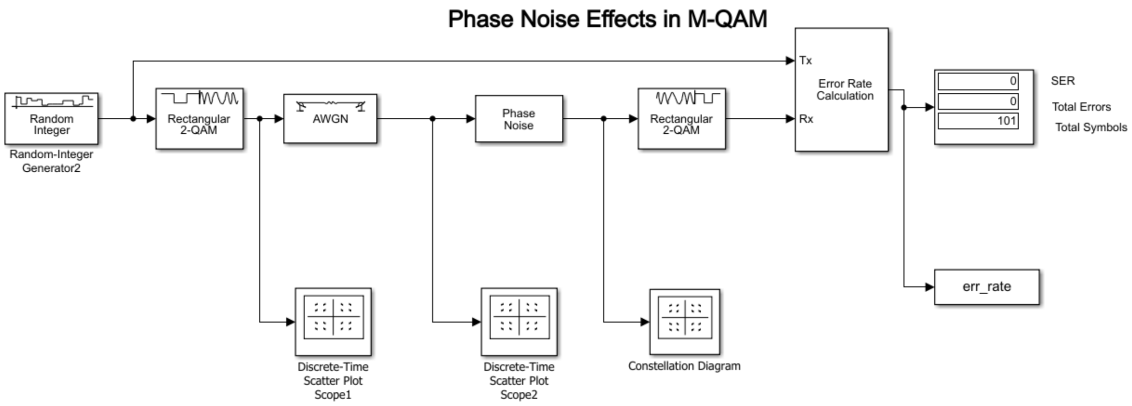

Figure 11: Simulink Model for QAM

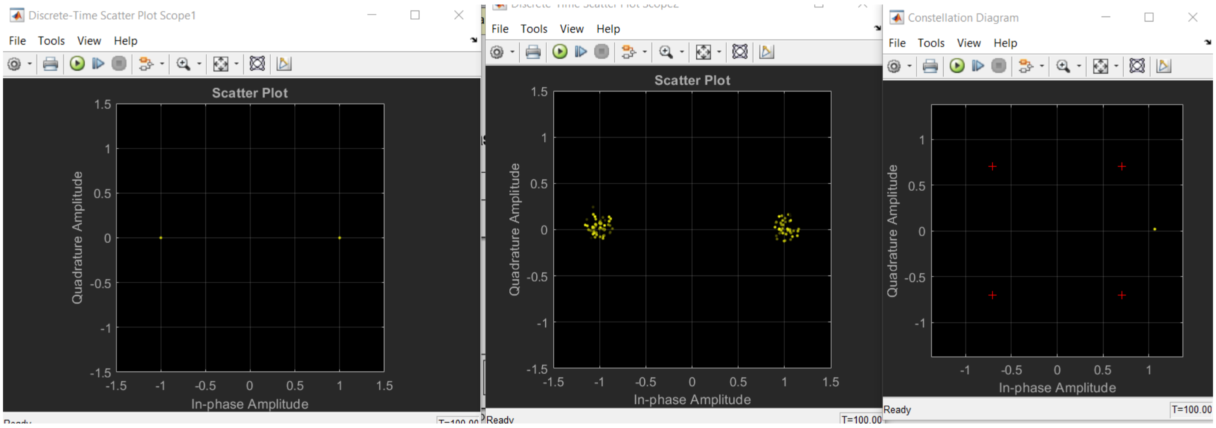

Figure 12: constellation diagram shows performance of QAM with M=2

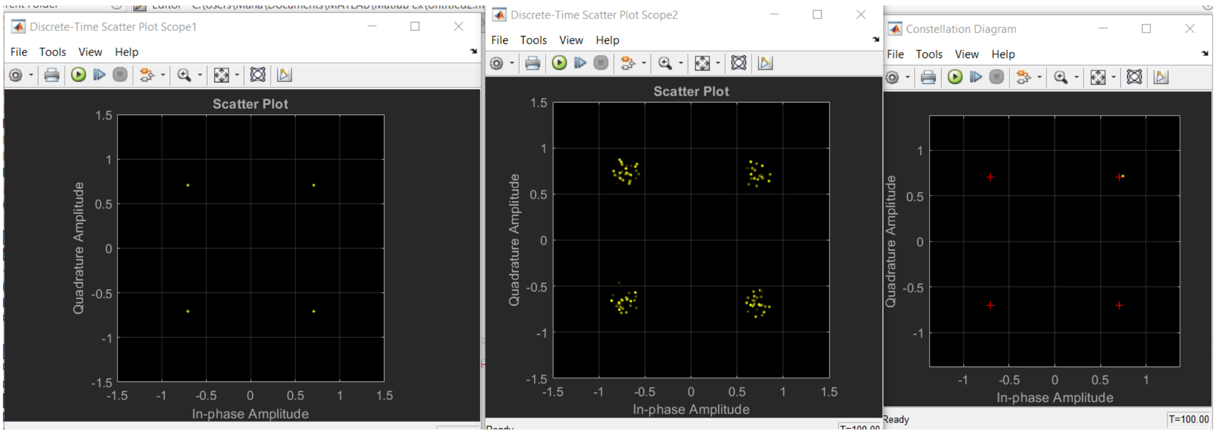

Figure 13:constellation diagram shows performance of QAM with M=4

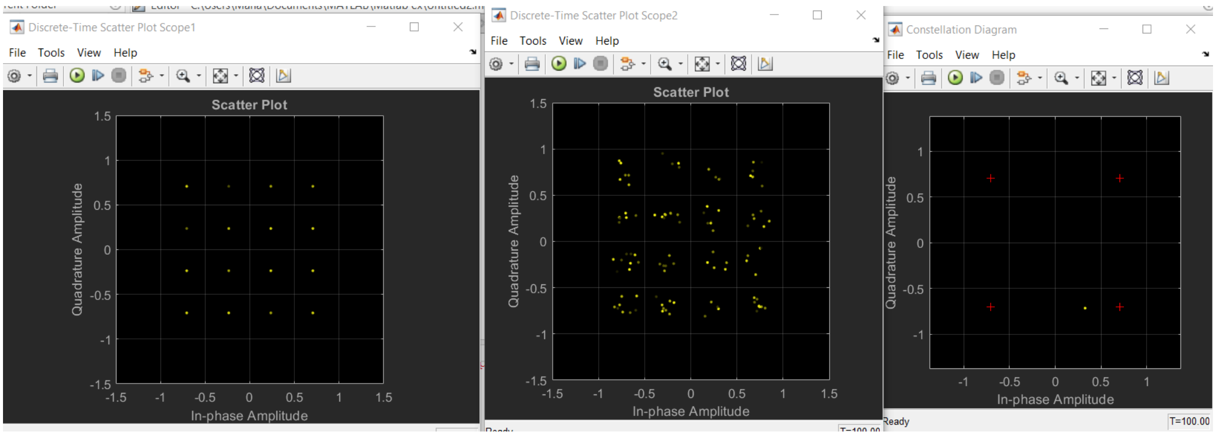

Figure 14:constellation diagram shows performance of QAM with M=16

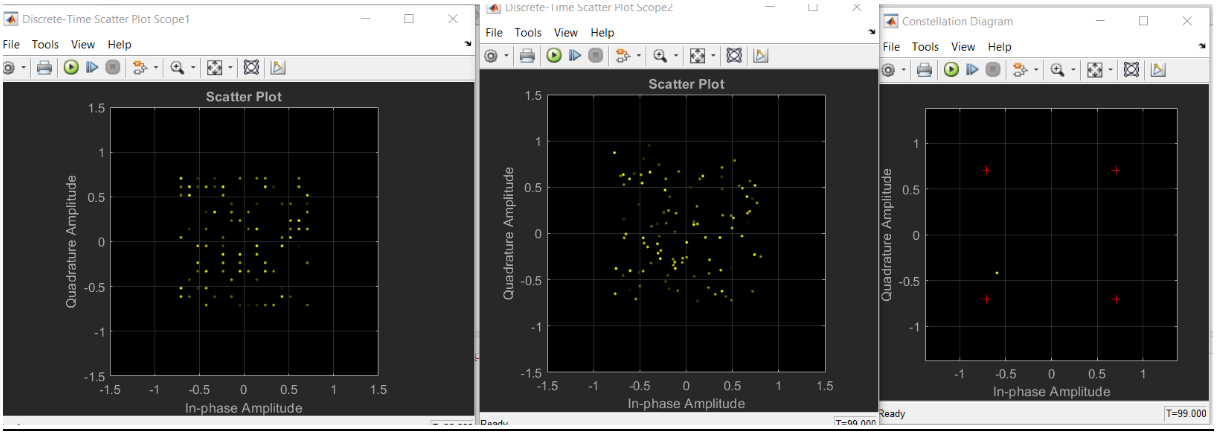

Figure 15:Phase Noise effects in 256-QAM

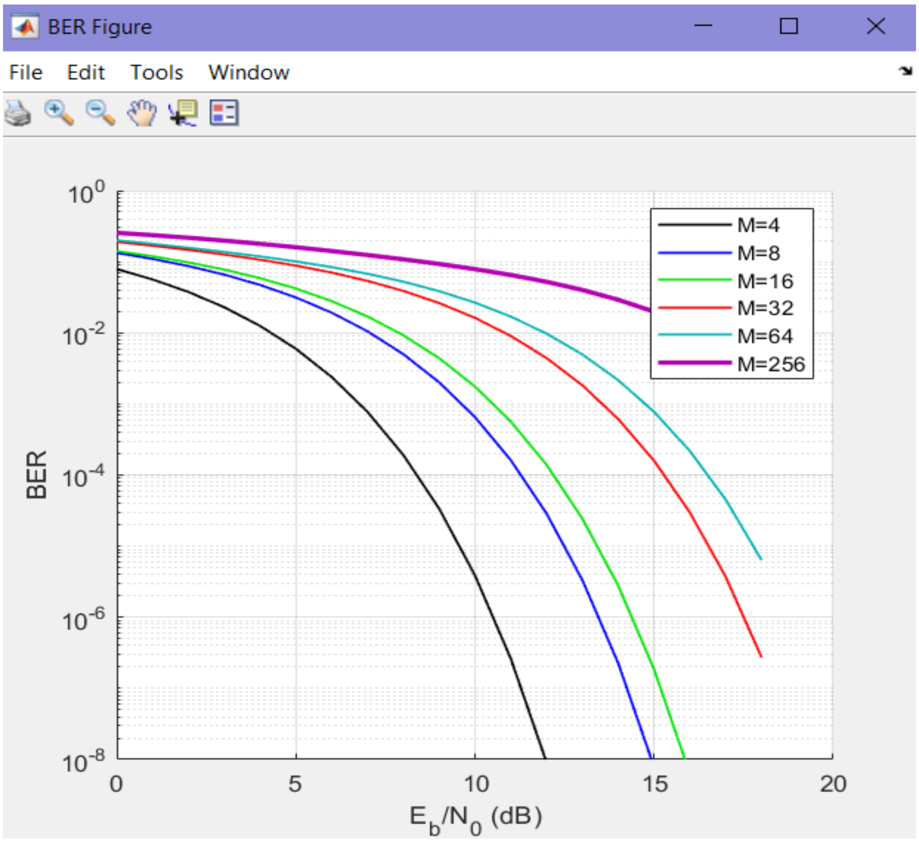

Figure 16:Performance of QAM in model AWGN Channels with ESNO =20dB

Tableau 2:The table below gives a summary of the bit rates of different forms of QAM

Modulation	Total of Symbols	BER
16-QAM	100	0.28
32-QAM	100	0.34
64-QAM	100	0.53
256-QAM	100	1

B.1.2 Simulation analysis

Figures 12, 13, 14, 15 represent transmit and received constellation. For figure 16 shows the BER for different QAM configuration.
For the modulation type of 16 QAM considering 100 symbols the BER is 0.28, for 32 QAM it is 0.34, for 64 QAM it is 0.53 and for other higher order modulation the bit error rate prevailed is 1 and for the same symbol rate, as the order of modulation increased the error rate is also raised as shown in Table 2.

The BER (bit error rate) corresponds to a higher signal-to-noise ratio when the M-ary numbers increases. The BER is growing strongly with M-ary numbers.

C. Frequency shift keying (FSK)

C.1.1 Simulation using M file

Frequency-shift keying (**FSK**) is a **frequency** modulation scheme in which digital information is transmitted through discrete **frequency** changes of a carrier signal. ... The simplest **FSK** is binary **FSK** (BFSK). BFSK uses a pair of discrete **frequencies** to transmit binary (0s and 1s) information.

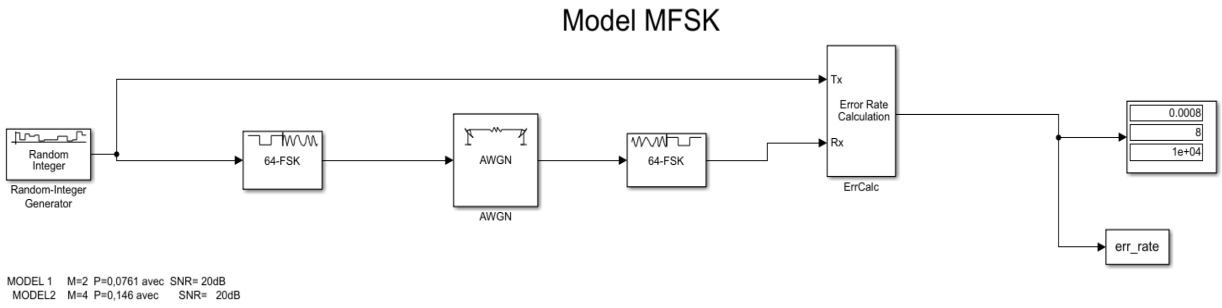

Figure 17: Simulink Model for M-ary FSK

Simulation code to simulate different variations of M

```
clear;clf;
M=2;
esnos=20:40;
err_vec=[];

for i=1:length(esnos)
  ESNO=esnos(i);
  sim('Mfsk_bb');
  err_vec(i,:)=err_rate
end;
semilogy(esnos,err_vec(:,1),'b-*');
```

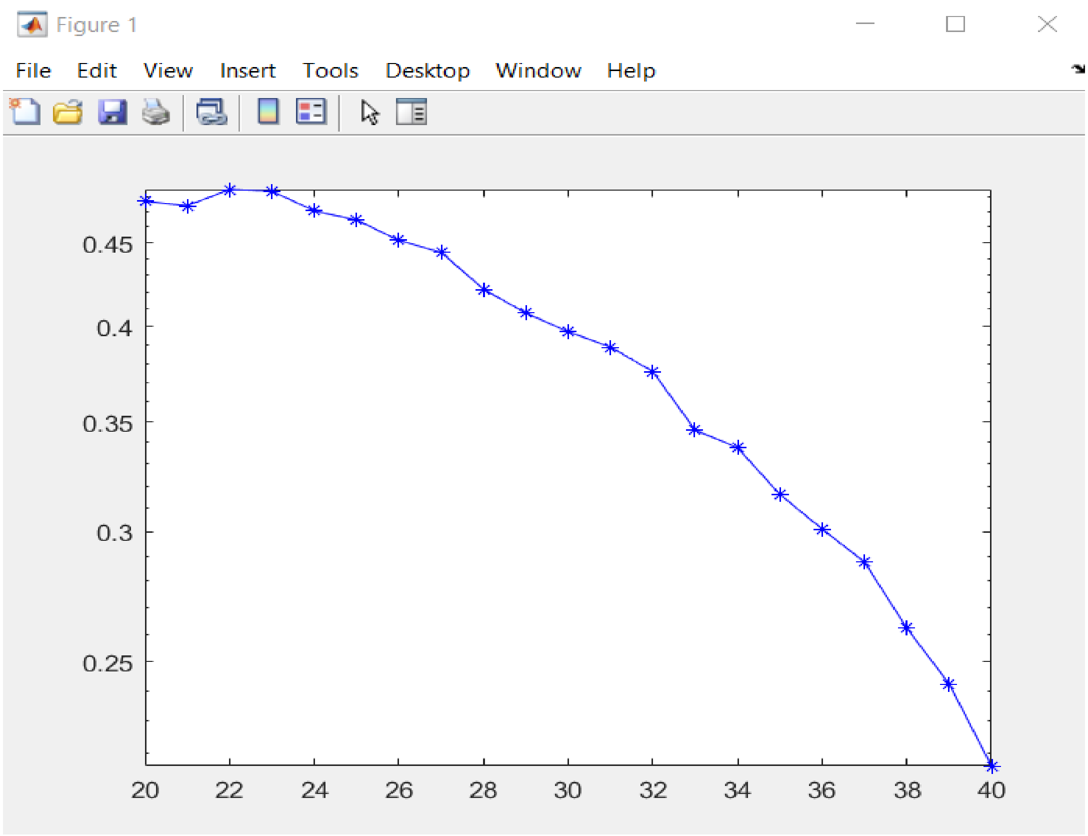

Figure 18:BER for FSK using MFSK with M=2 with ESNO=40 dB

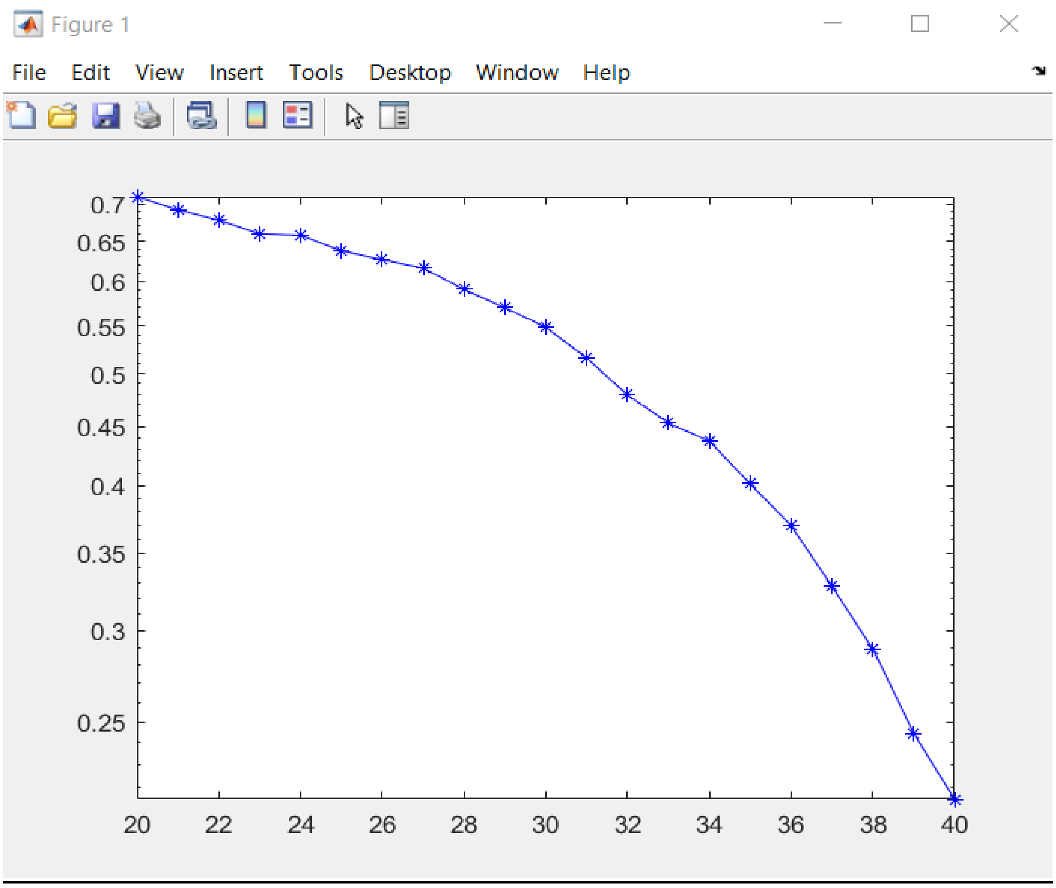

Figure 19:BER for FSK using MFSK with M=4

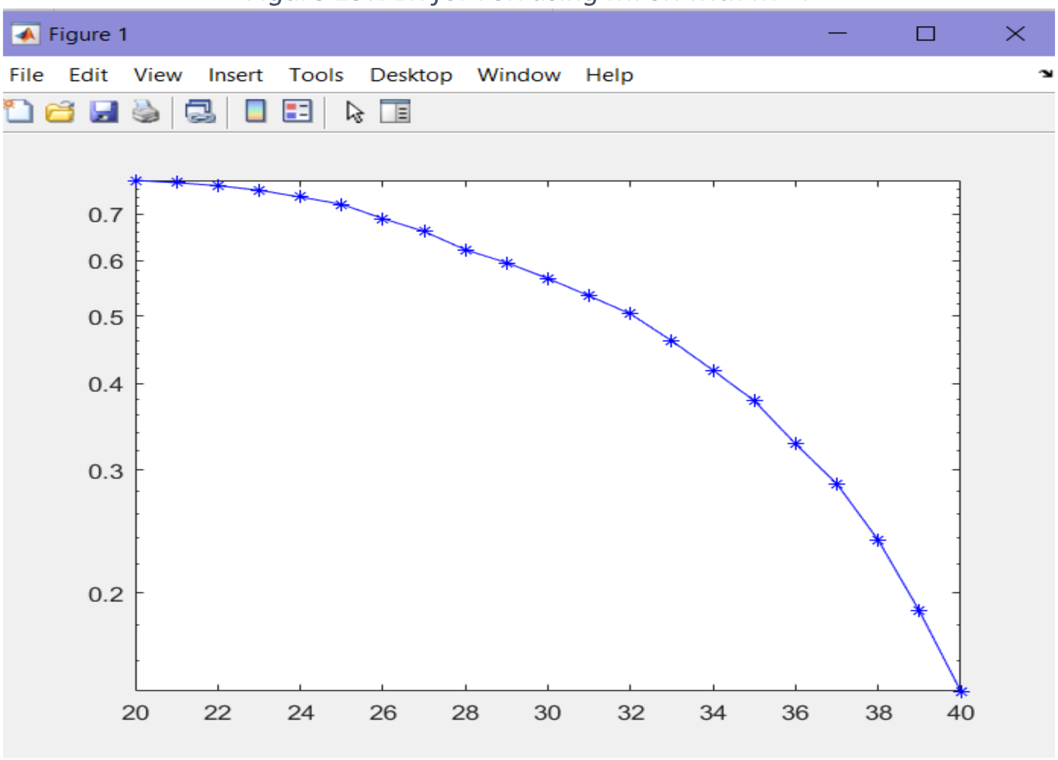

Figure 20:BER for FSK using MFSK with M=8

C.1.2 Simulation analysis

Figures 18, 19 and 20 represent the error probability as a function of SNR. We notice that when M increases the probability of error (Pe) increases however as one SNR increases the probability of error decreases. In M=2 and SNR=20 dB the error probability Pe=0.47 as show in figure 18, for M=8 the Pe=0.75 as show in figure 20.

D. Spread Spectrum Techniques DSSS

D.1 Simulation using M file

With DSSS, the data is divided and simultaneously **transmitted** on as many frequencies as possible within a particular frequency band (the channel). **DSSS** adds redundant **bits** of data known as chips to the data to represent binary 0s or 1s.

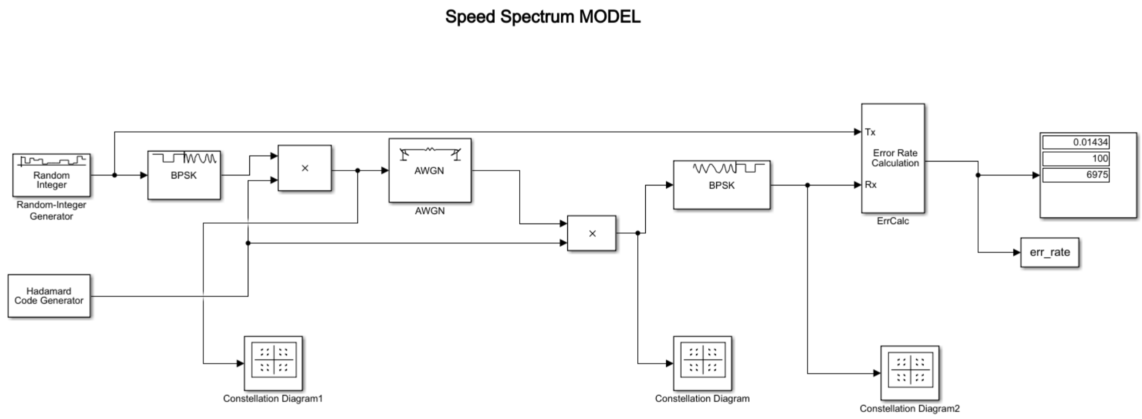

Figure 21: Simulink Model for Spread spectrum Technique DSSS

D.1.1 Simulation code to simulate different variations of M:

```
M=8;
esnos=20:40;
err_vec1=[];


for i=1:length(esnos)
    ESNO=esnos(i);
    sim('Mpsk_bb');
    err_vec1(i,:)=err_rate
end;
%semilogy(esnos,err_vec1(:,1),'r-*');
l0=plot(esnos,err_vec1(:,1),'r-*');

hold on
M=16;
esnos=20:40;
err_vec1=[];


for i=1:length(esnos)
    ESNO=esnos(i);
    sim('Mpsk_bb');
    err_vec1(i,:)=err_rate
end;
%semilogy(esnos,err_vec1(:,1),'r-*');
l1=plot(esnos,err_vec1(:,1),'g-o');

hold on
```

```
M=32;
esnos=20:40;
err_vec1=[];
for i=1:length(esnos)
    ESNO=esnos(i);
    sim('Mpsk_bb');
    err_vec1(i,:)=err_rate
end;
%semilogy(esnos,err_vec1(:,1),'r-*');
l2=plot(esnos,err_vec1(:,1),'c-*');
xlabel('Eb/No');
ylabel ('error rate');
%legend(l2, {'M=8'});

hold on

M=64;
esnos=20:40;
err_vec1=[];
for i=1:length(esnos)
    ESNO=esnos(i);
    sim('Mpsk_bb');
    err_vec1(i,:)=err_rate
end;
%semilogy(esnos,err_vec1(:,1),'r-*');
l3=plot(esnos,err_vec1(:,1),'b-*');

legend([l0,l1,l2,l3], {'M=8','M=16','M=32','M=64'}); %creation des legendes
```

Figure 22: simulation code

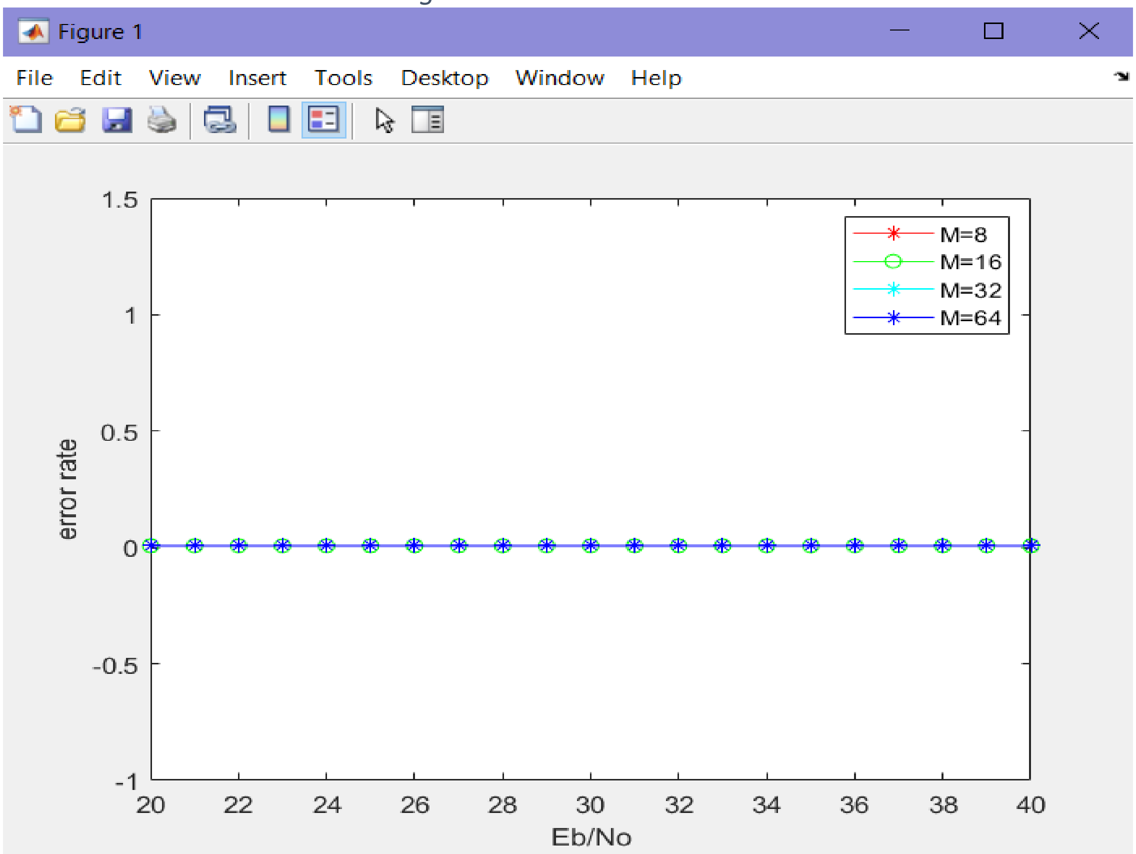

Figure 23:Performance of BER in different variantions of M with SNR=5dB

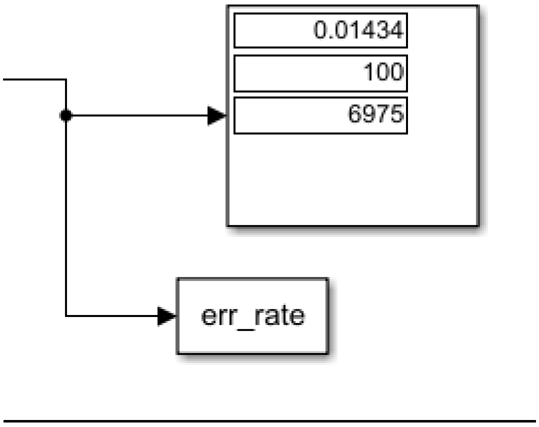

Figure 24: Display shows total symbols of Error and BER with M=2 and SNR=5dB

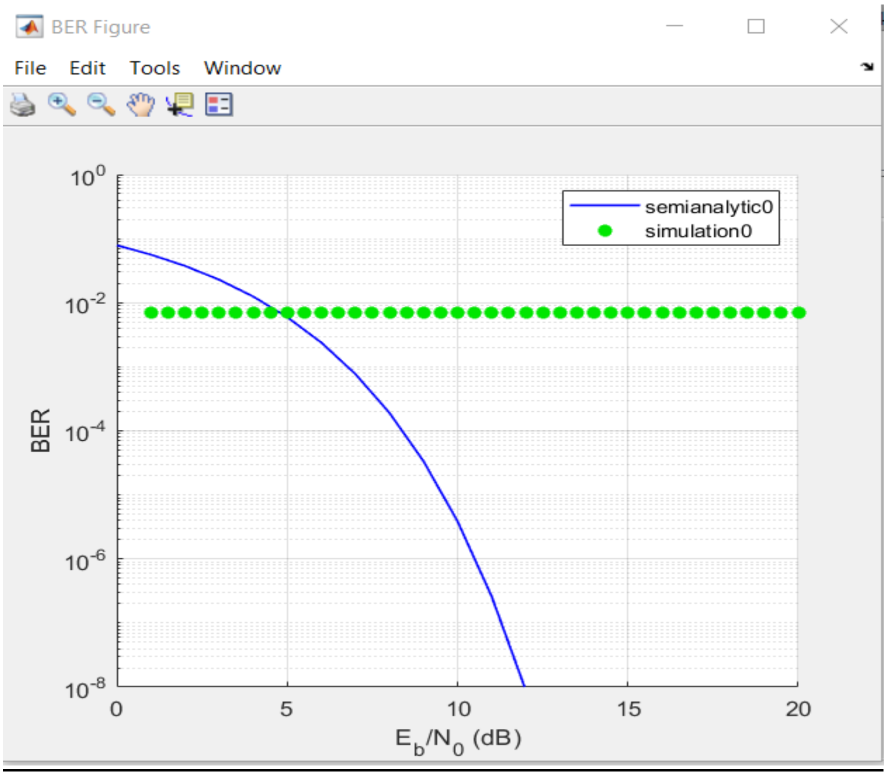

Figure 25: performance of BER with M= and SNR =5dB

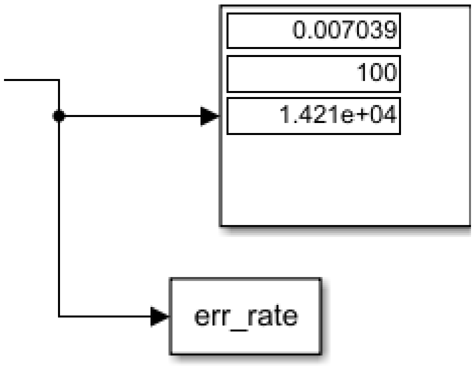

Figure 26:Display shows total symbols of Error and BER with M=2 and SNR=12dB

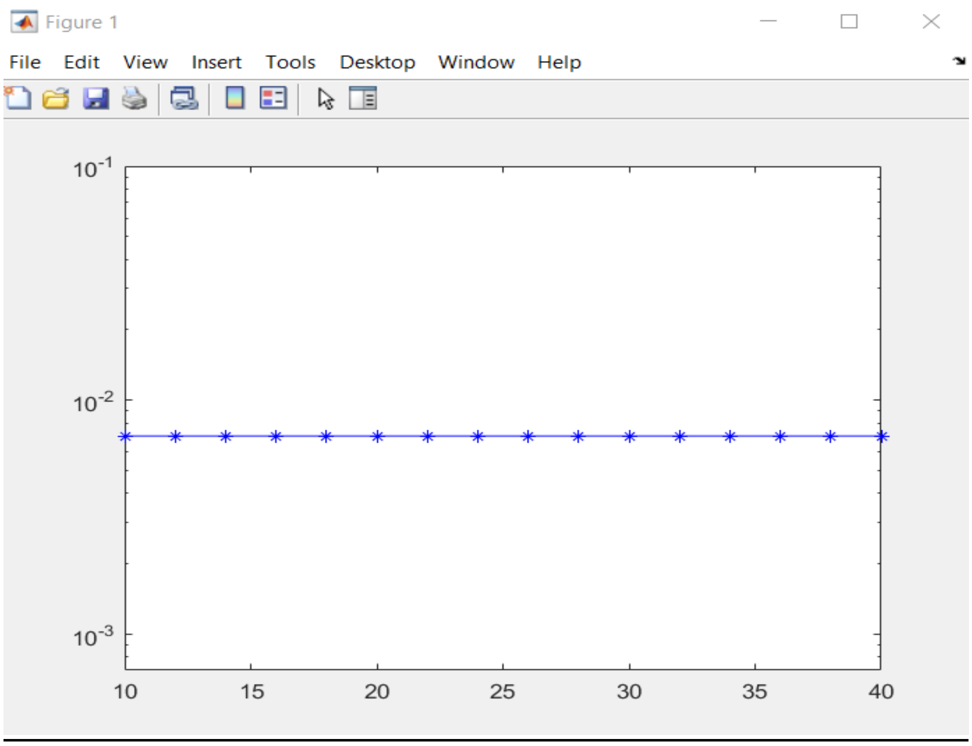

Figure 27: result of simulation M=2 and SNR =12dB

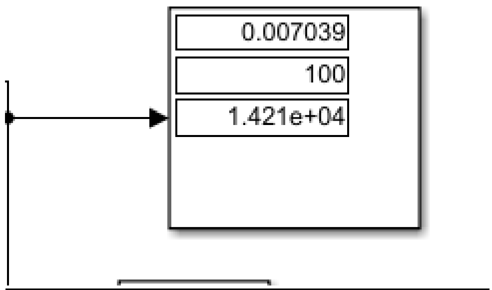

Figure 28:Display shows total symbols of Error and BER with M=2 and SNR=20dB

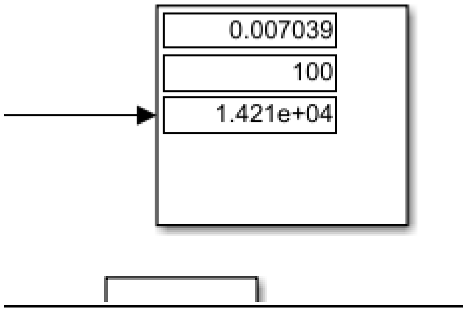

Figure 29:Display shows total symbols of Error and BER with M=2 and SNR=52dB

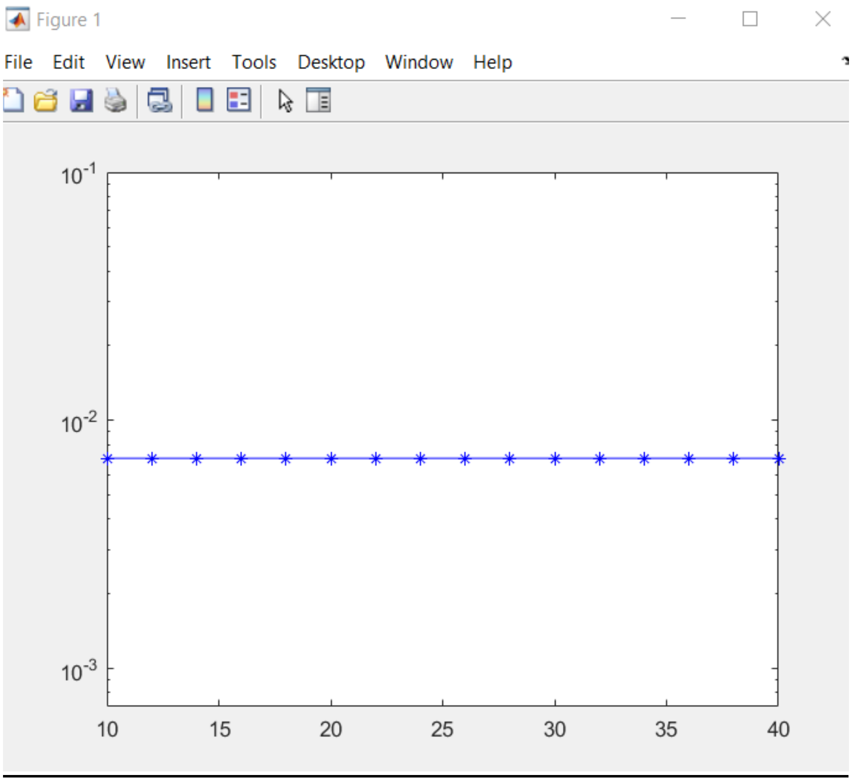

Figure 30: Results of simulation (SNR= 20 dB , 52 dB)

D.1.2 Simulation result for evaluation on BER vs. SNR

Tableau 3:Simulation result for evalution on BER vs SNR for BPSK

SNR	Total of error	BER
5	100	6975
12	100	1.421e+04
20	100	1.421e+04
52	100	1.421e+04

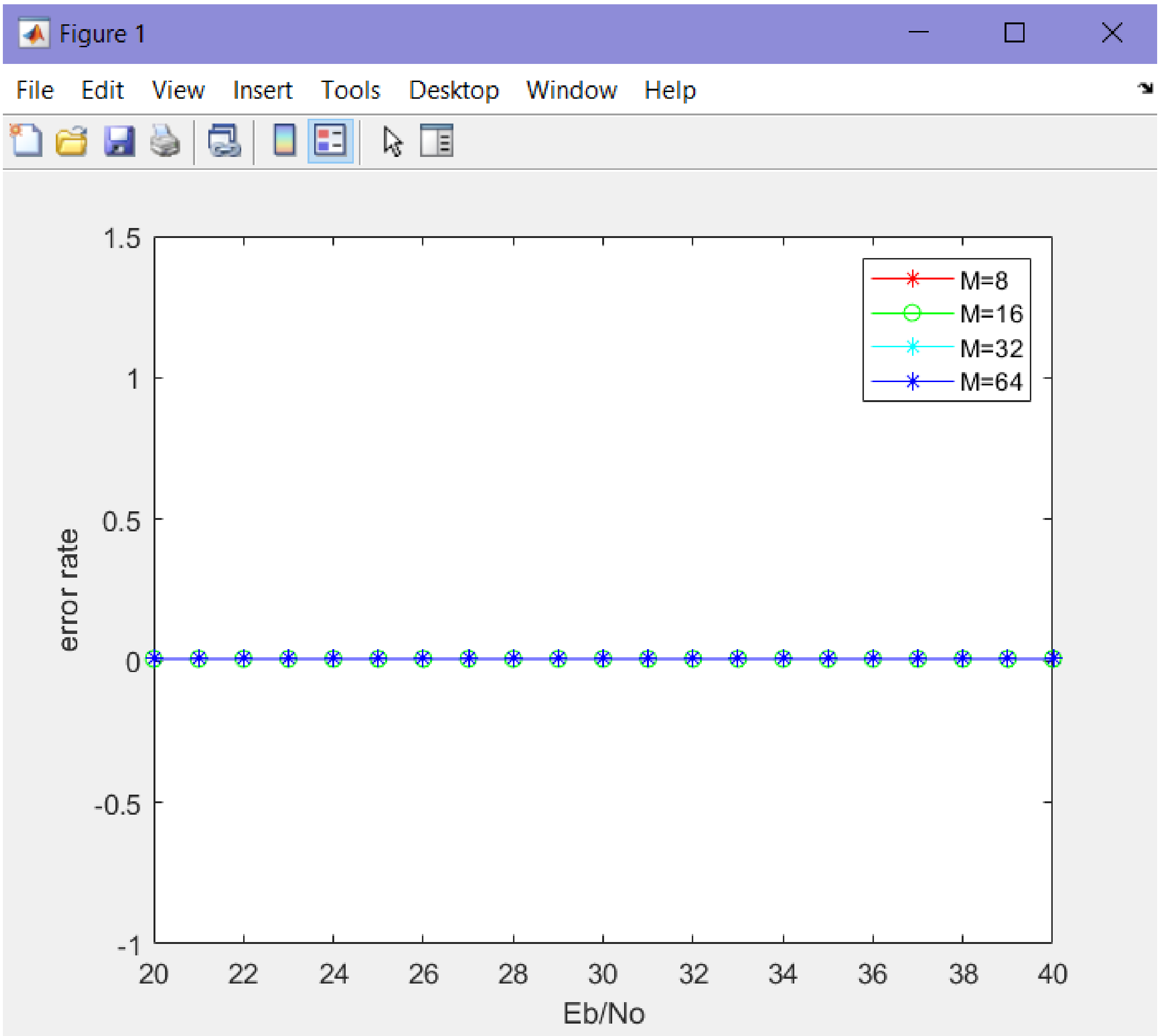

Figure 31: Results of different simulation and different code index

D.2 Simulation analysis

Figure 31 represents the error probability as a function of SNR. We noticed that
When we changed the SNR parameter to 12 in the AWGN channel we noticed that total symbols increases and SER decreases as shown in figure 24, 26 and Table 3

When we changed SNR to values greater than 12 we noticed that SER and total symbols get fixed in one value as shown in figure 28,29,30 and Table 3.

Conclusion

According to the simulation parameters, we can get the following conclusions: BER is clearly low for BPSK, so this is the best modulation technique for data transmission on all the channels used and for both the equalizers.

In this report, three basic types of modulation were discussed. Several modulation schemes such as BPSK, M-PSK, M-FSK and QAM have been consider for MATLAB simulation purposes. Their BER have been evaluated using MATLAB. We have concluded from the above figures depending on bit error rate that BPSK is the most effective modulation schemes in a practical communication system.

Tables

Figures