EE3082 – Communication Engineering

Project 2 – Spring 2023

Released: 1/6/2023

Due: 5/6/2023, 23:55.

Use both Matlab and Simulink to complete the project. You must use Simulink to model each modulated transmission (MPAM/MQAM/MPSK/MFSK). You can call your Simulink model from a parent .m file for different values of M and Eb/N0.

Question 1 (60 pts)

Set the transmission bandwidth of the bandwidth limited modulations (MPAM, MQAM, MPSK) as 1 MHz.

(a) (30 pts) Plot Eb/N0 and Bit Error Rate (BER) curves of 16PAM and 16-QAM (Both theoretical and simulated BER). What is the data rate of each transmission? Show the constellation diagrams and bit to symbol mappings of each modulation and discuss which one is better in terms of BER and why?

$$Rb = W * log_2 M = 1Mhz * log_2 16 = 4000000\text{bps}.$$

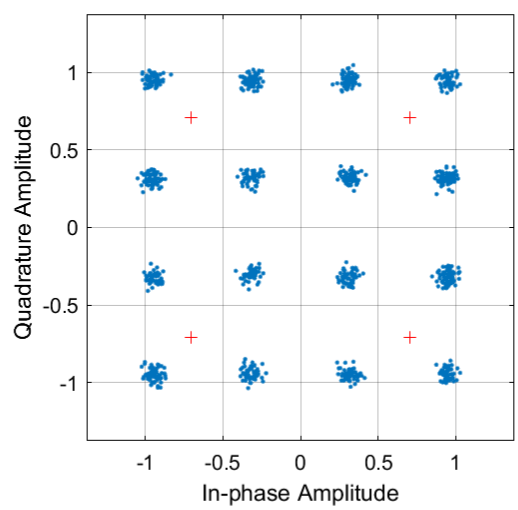

Figure 1 Constellation Diagram

Fig.1 shows the 16-QAM Constellation Diagram EbN0dB = 20. As the EbN0dB value increases, the points in the constellation diagram approach each other, so our Pb value decreases.

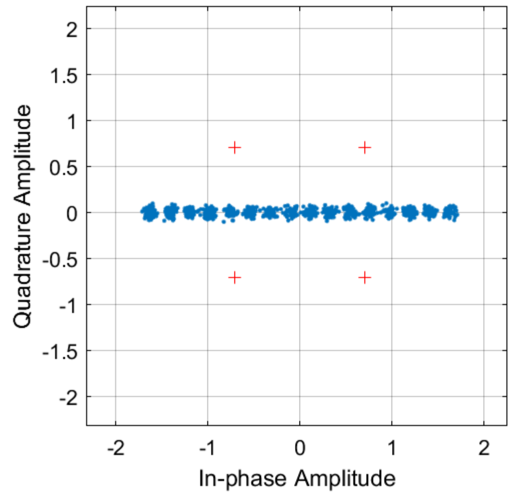

Figure 2 Constellation Diagram

Fig.2 shows the 16-PAM Constellation EbN0dB = 20. As the EbN0dB value increases, the points in the constellation diagram approach each other, so our Pb value decreases.

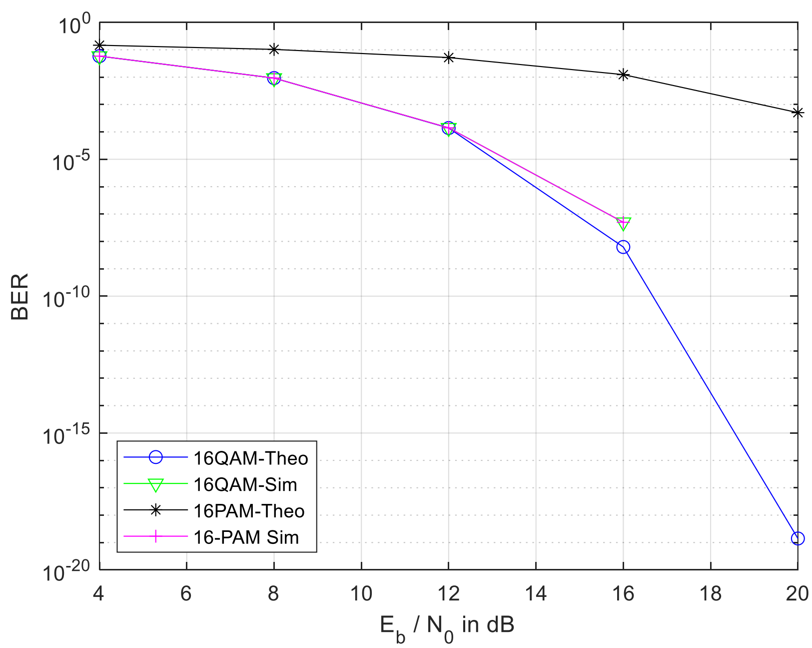

Figure 3 Plot of BER

Fig.3 shows the Plot of 16-PAM and 16-QAM BER (Simulated and Theoretical are together)

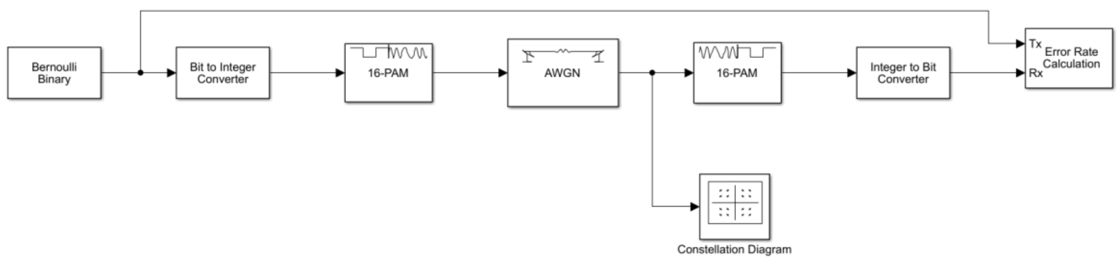

Figure 4 Simulink Diagram

Fig.4 shows the Simulink Diagram of 16-PAM.

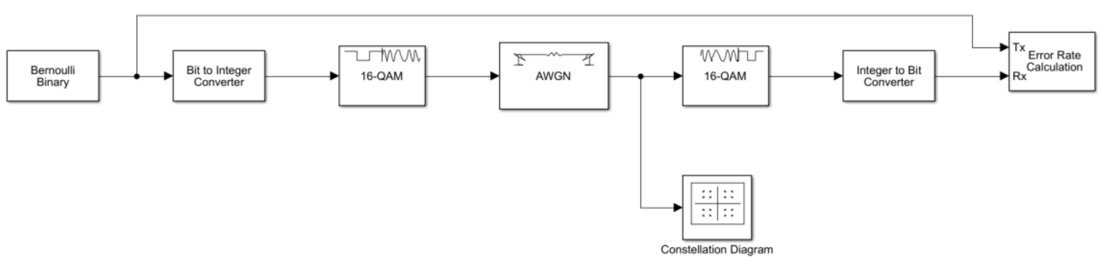

Figure 5 Simulink Diagram

Fig.5 shows the Simulink Diagram of 16-QAM.

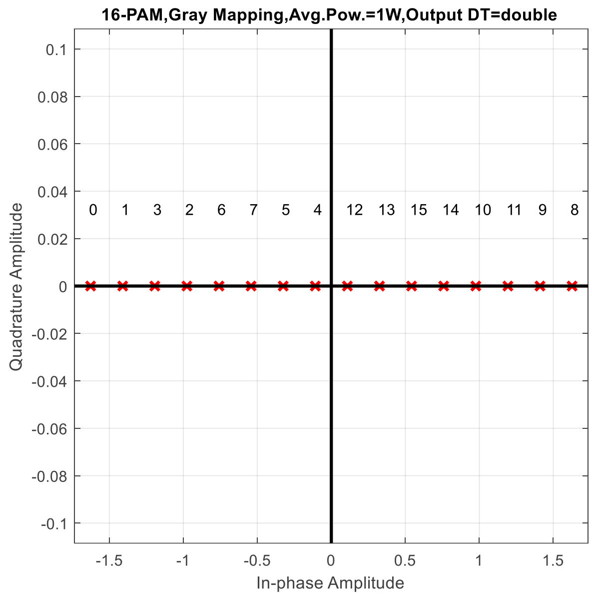

Figure 6 View Constellation

Fig.6 shows the View Constellation of 16-PAM.

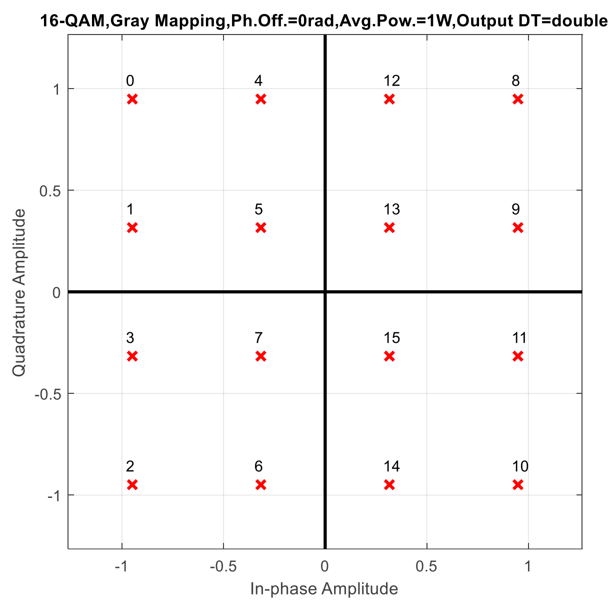

Figure 7 View Constellation

Fig.7 shows the View Constellation of 16-QAM.

COMMENT: When we examine Figure 3, the 16-QAM theo. and 16-QAM sim. give a similar BER value as the EbN0 value increases. The 16-PAM theo. and 16-PAM sim. give different BER values as the EbN0 value increases. If we compare 16-QAM theoretical and 16-PAM theoretical, the BER values are close to each other at low EbN0 values, while the BER value of 16-QAM decreases as the EBN0 value increases(this is something we want), the BER value of 16-PAM does not change much. For example, EbN0dB = 20 BER of 16-QAM(theo) = 1.40e-19 and BER of 16-PAM(theo) = 0.0005 Looking at this result, we can say that 16-QAM is better. Because the BER value of 16-QAM is lower at the same EbN0dB value.

(b) (30 pts) Plot Eb/N0 and BER curves of 16PSK and 16-QAM (Both theoretical and simulated BER). What is the data rate of each transmission? Show the constellation diagrams and bit to symbol mappings of each modulation and discuss which one is better in terms of BER and why?

$Rb = W * log_2 M = 1Mhz * log_2 16 = 4000000$bps.

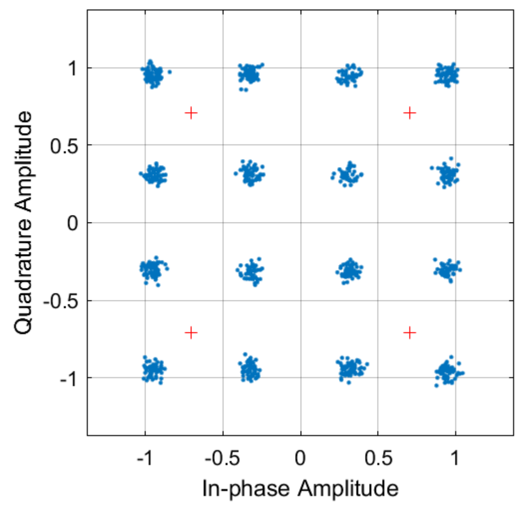

Figure 8 Constellation Diagram

Fig.8 shows the 16-QAM Constellation Diagram EbN0dB = 20. As the EbN0dB value increases, the points in the constellation diagram approach each other, so our Pb value decreases.

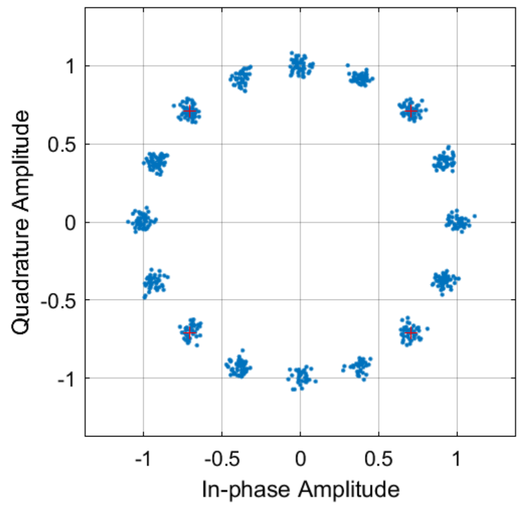

Figure 9 Constellation Diagram

Fig.9 shows the 16-PSK Constellation Diagram EbN0dB = 20. As the EbN0dB value increases, the points in the constellation diagram approach each other, so our Pb value decreases.

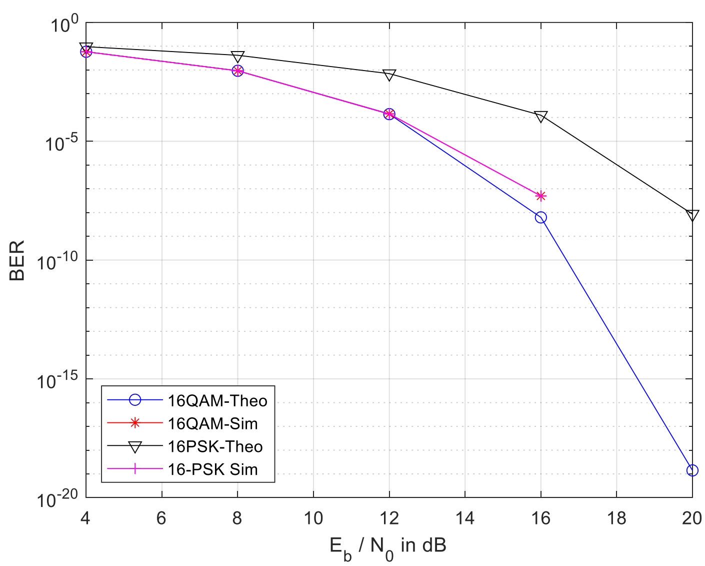

Figure 10 Plot of BER

Fig.10 shows the Plot of 16-QAM and 16-PSK BER (Simulated and Theoretical are together)

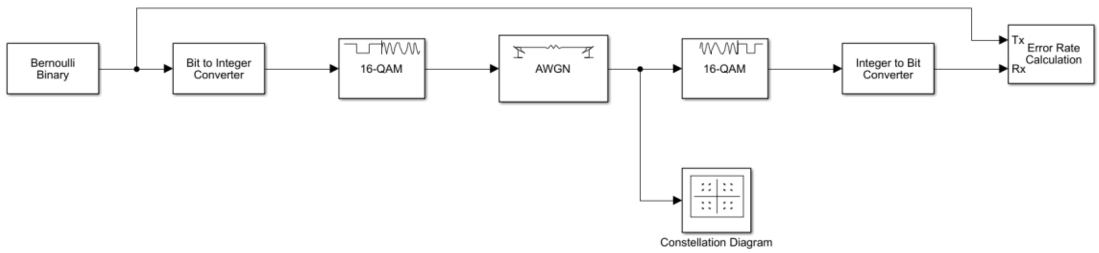

Figure 11 Simulink Diagram

Fig.11 shows the Simulink Diagram of 16-QAM.

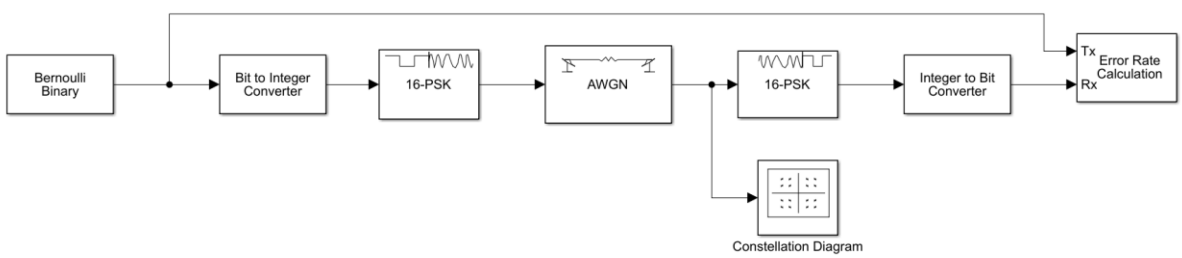

Figure 12 Simulink Diagram

Fig.12 shows the Simulink Diagram of 16-PSK.

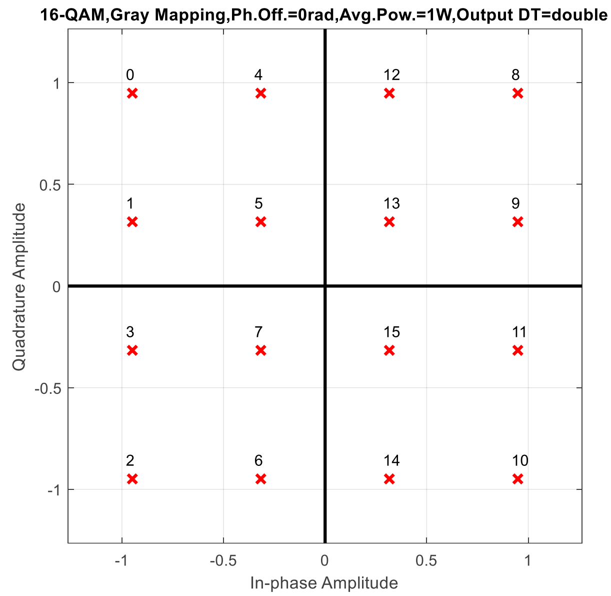

Figure 13 View Constellation

Fig.13 shows the View Constellation of 16-QAM.

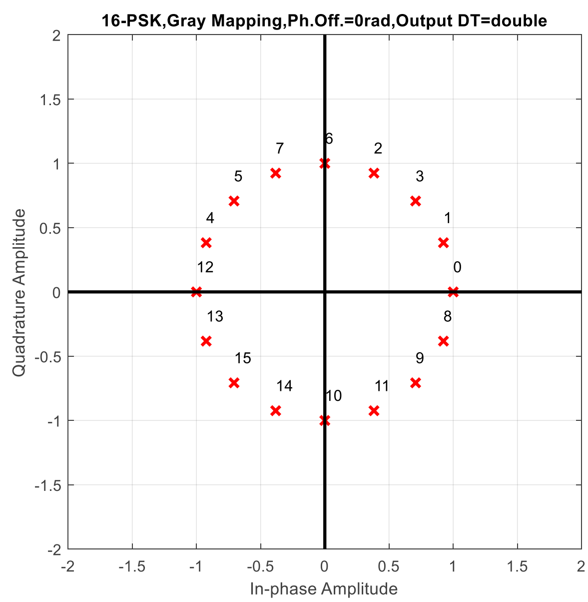

Figure 14 View Constellation

Fig.14 shows the View Constellation of 16-PSK.

COMMENT: When we examined Figure 10, we interpreted 16-QAM in part a. When we examine the M-PSK, the 16-PSK theo. and 16-PSK. sim give different BER values as the EbN0dB value increases, the BER values of the 16-PSK sim. are lower. If we compare 16-QAM theoretical and 16-PSK theoretical, we see that 16-QAM has lower BER values as the EbN0dB value increases. For example, EbN0dB = 20 BER(16-AM) = 1.40e-19 and BER(16-PSK) = 8.57e-9 looking at these results, we can say that 16-QAM is better. Because the BER value of 16-QAM is lower at the same EbN0dB values.

Question 2 (40 pts)

Set the data rate of an MFSK (orthogonal, non-coherently detected) transmission as 10 kbps. Show the spectrum of the noisy MFSK signal under Eb/N0 = 10 dB. Compare the theoretical signal bandwidth with the ones observed in spectrum analyzer under BFSK, 4FSK and 8FSK.

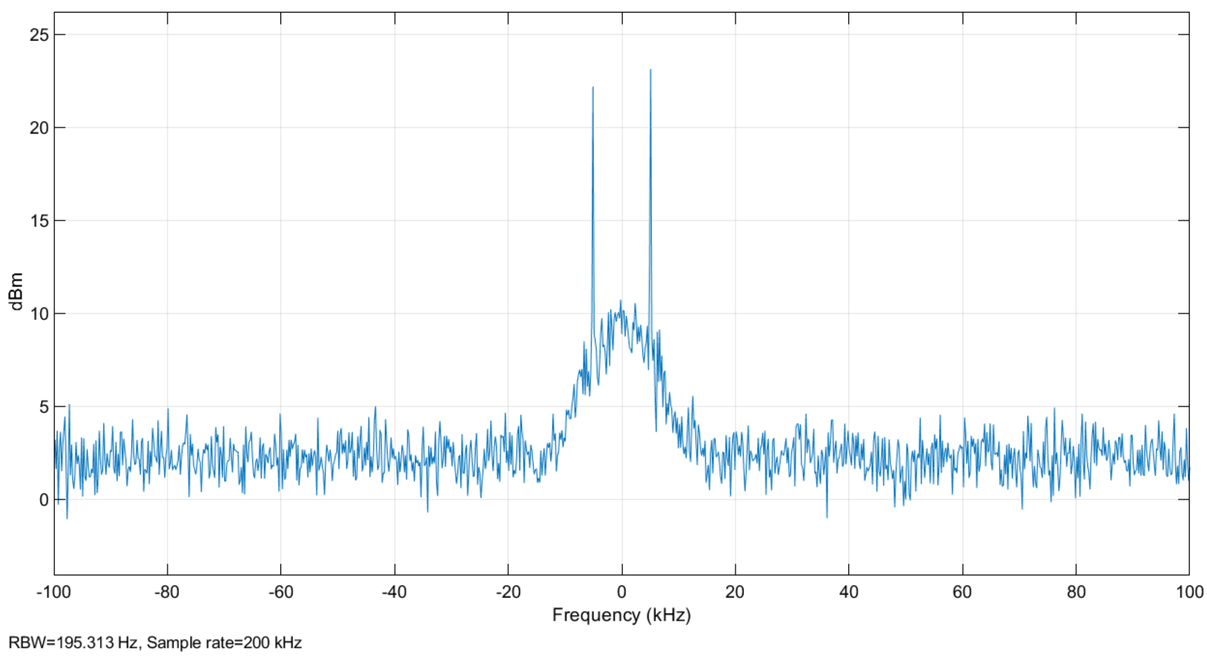

Figure 15 Spectrum Analyzer of AWGN Channel

Fig.15 shows the Spectrum Analyzer of M-FSK at M=2 , Rb=10kbps , EbN0dB = 10. Since it is B-FSK, we see 2 straight lines. It's sample rate is 200 kHz and RBW is 195.313 Hz.

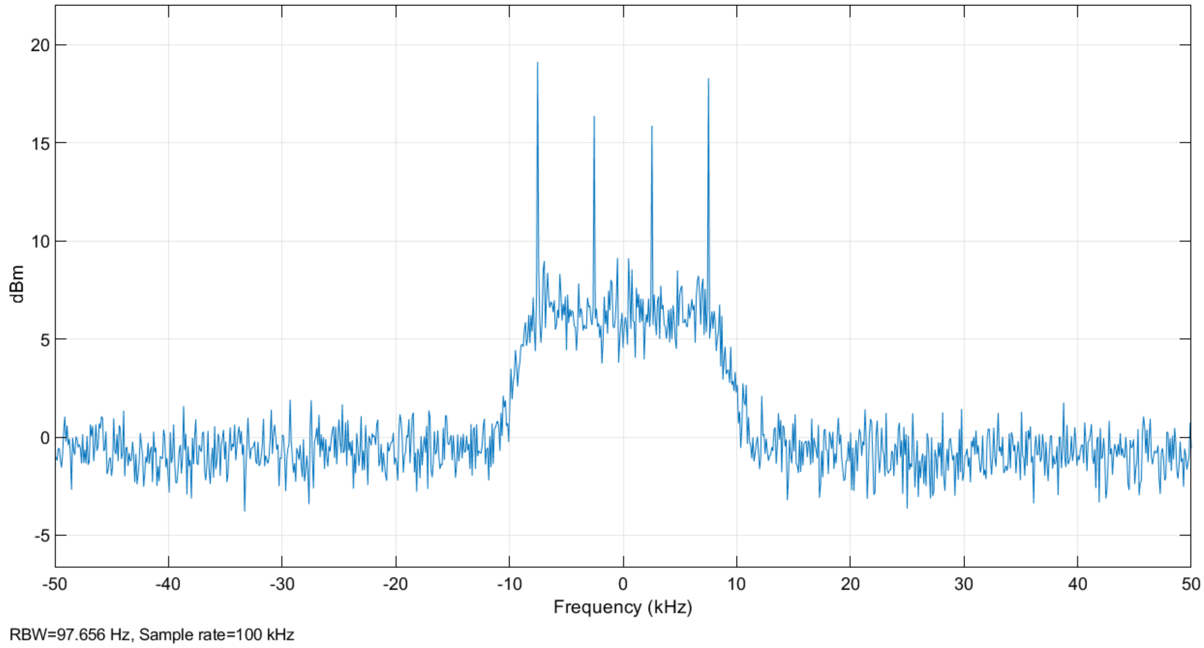

Figure 16 Spectrum Analyzer of AWGN Channel

Fig.16 shows the Spectrum Analyzer of M-FSK at M=4 , Rb=10kbps , EbN0dB = 10. Since it is 4-FSK, we see 4 straight lines. It's sample rate is 100 kHz and RBW is 97.656 Hz.

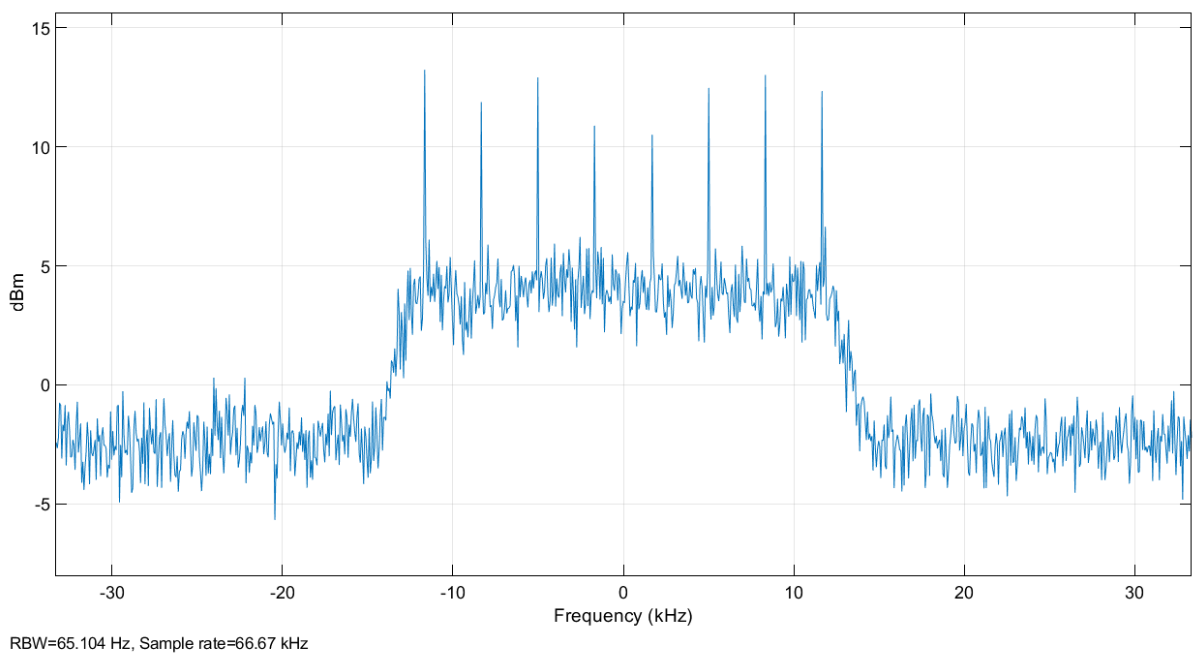

Figure 17 Spectrum Analyzer of AWGN Channel

Fig.17 shows the Spectrum Analyzer of M-FSK at M=8 , Rb=10kbps , EbN0dB = 10. Since it is 8-FSK, we see 8 straight lines. It's sample rate is 66.67 kHz and RBW is 65.104 Hz.

COMMENT: When we examine the 3 graphs above, the RBW and sample rate values decrease as the M value increases at the same Rb(10kbps) value.

Plot Eb/N0 (in dB) and BER graph for BFSK, 4FSK and 8FSK (Both theoretical and simulated BER). For each case, comment on the BER when Eb/N0 = 7 dB, and comment on Eb/N0 when BER is around 1e-3.

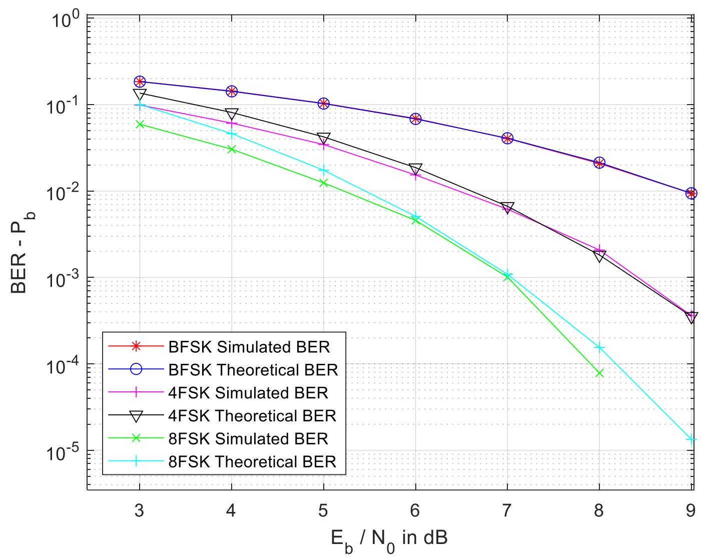

Figure 18 Plot of BER

Fig.18 shows the Plot of M-FSK BER (Simulated and Theoretical are together) M = 2,4,8

COMMENT: When we examine Figure 18, we can observe that 8-FSK has lower BER values. This confirms the information we learned in our classes that as the value of M increases, the BER decreases. Let's consider this at EbN0dB = 7 and BER = 1e-3. At EbN0dB = 7, the BER value for B-FSK is 0.04, for 4-FSK it is 0.006, and for 8-FSK it is 0.001. We can conclude that at the same EbN0dB value, 8-FSK has a lower BER value. Furthermore, when we examine other EbN0dB values, we can say that as the EbN0dB value increases for M-FSK, the BER value decreases. At BER = 1e-3, the EbN0dB value for B-FSK is 7, for 4-FSK it is between 8 and 9, and for 8-FSK it is greater than 9. We can say that at the same BER value, 8-FSK has a lower EbN0dB value. Additionally, when we examine other BER values, we can say that as the BER value decreases for M-FSK, the EbN0dB value increases.

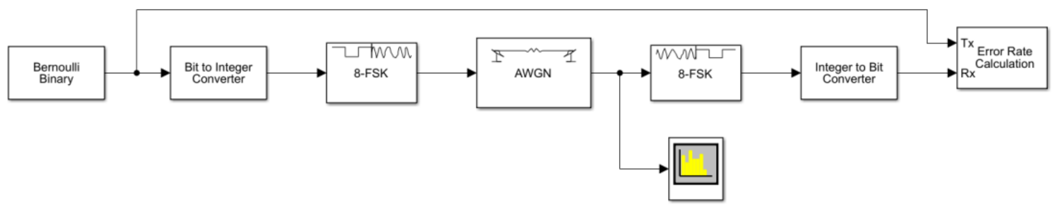

Figure 19 Simulink Diagram

Fig.19 shows the Simulink Diagram of M-FSK