Q1

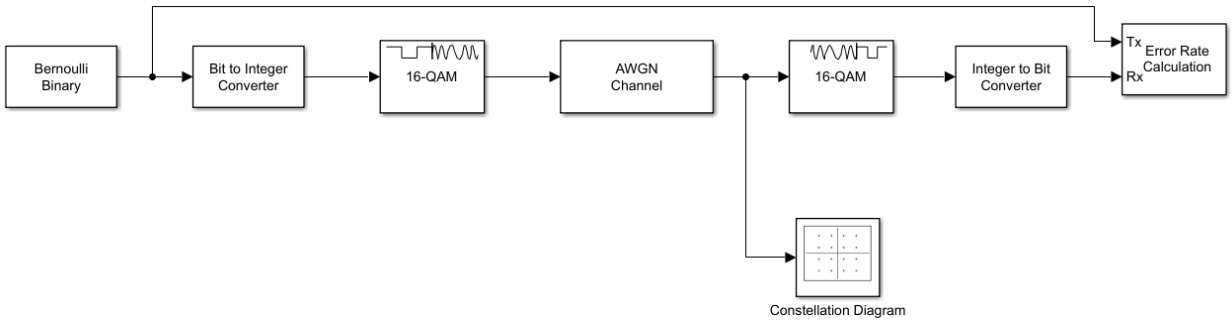

Figure 1 – M-QAM Simulink Model

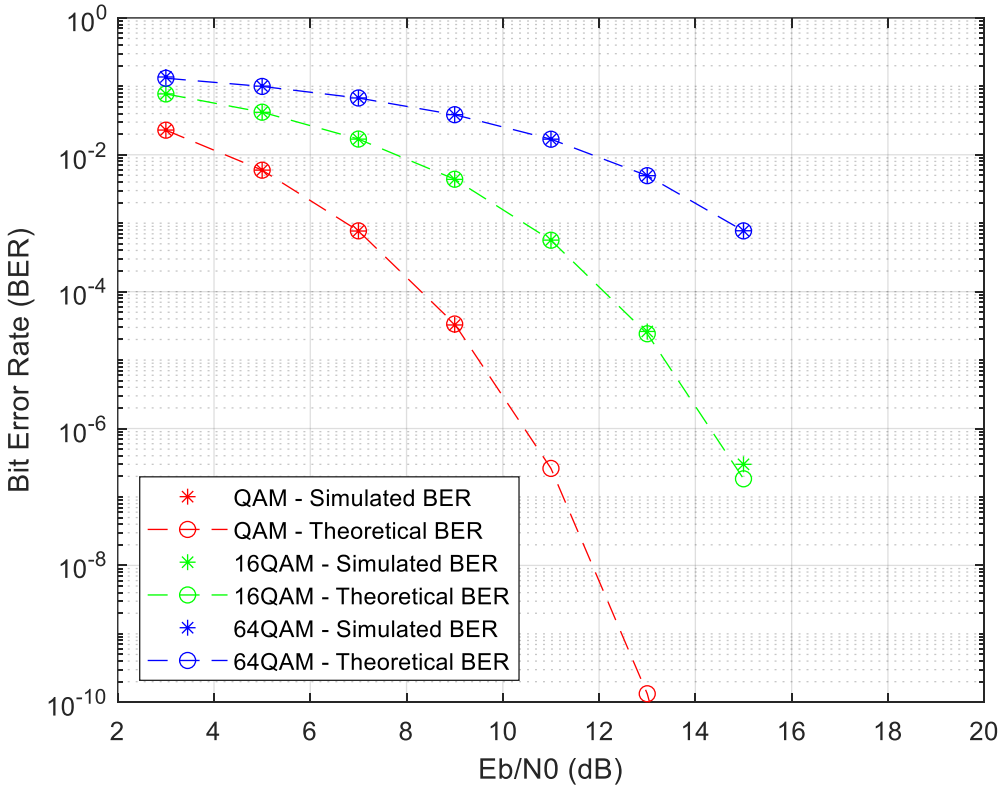

Figure 2 – E_b/N_0 versus BER for M-QAM

```
4-QAM -> Simulated BER: 2.7994e-06, Theoretical BER: 3.8721e-06
16-QAM -> Simulated BER: 1.7549e-03, Theoretical BER: 1.7542e-03
64-QAM -> Simulated BER: 2.6487e-02, Theoretical BER: 2.6533e-02
```

$$Bit\ Error\ Rate: P_b = \frac{2*(L-1)}{L*\log_2 L} * Q\left(\sqrt{\frac{6*\log_2 L}{L^2-1}*\frac{E_b}{N_0}}\right), L^2 = M$$

$$10 = 10*\log_{10}\left(\frac{E_b}{N_0}\right) \rightarrow \frac{E_b}{N_0} = 10$$

$$W = R_s = \frac{R_b}{\log_2 M}$$

$$4-QAM: L = 2$$

$$P_b = \frac{2*(2-1)}{2*\log_2 2} * Q\left(\sqrt{\frac{6*\log_2 2}{2^2-1}*10}\right) = Q(4.47) = 0.3911E-05$$

$$W = R_s = \frac{10^{-6}}{2} = 10^{-6}$$

$$16-QAM: L = 4$$

$$P_b = \frac{2*(4-1)}{4*\log_2 4} * Q\left(\sqrt{\frac{6*\log_2 4}{4^2-1}*10}\right) = \frac{3}{4} * Q(2.83) = 0.1745E-02$$

$$W = R_s = \frac{10^{-6}}{4} = 0.25*10^{-6}$$

$$64-QAM: L = 8$$

$$P_b = \frac{2*(8-1)}{8*\log_2 8} * Q\left(\sqrt{\frac{6*\log_2 8}{8^2-1}*10}\right) = \frac{7}{12} * Q(1.69) = 0.2655E-01$$

$$W = R_s = \frac{10^{-6}}{8} = 0.125*10^{-6}$$

	R_b	W (Bandwidth)
4-QAM	10^{-6}	$1*10^{-6}$
16-QAM	10^{-6}	$0.25*10^{-6}$
64-QAM	10^{-6}	$0.125*10^{-6}$

Q2

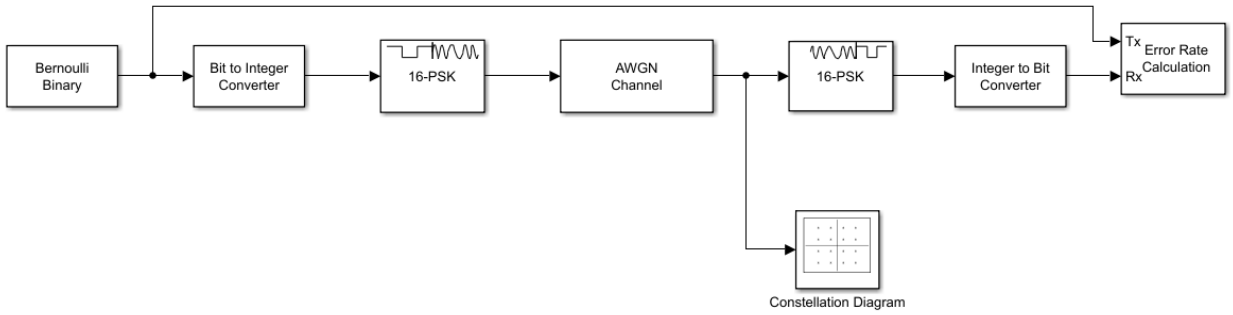

Figure 3 – M-PSK Simulink Model

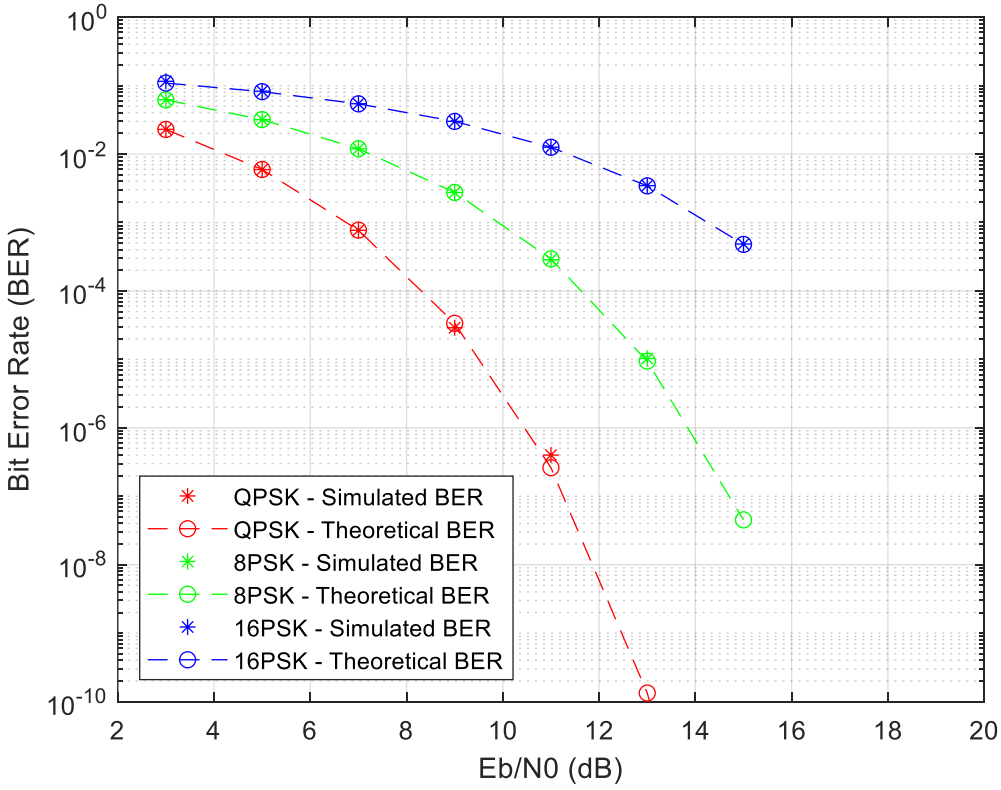

Figure 4 – E_b/N_0 versus BER for M-PSK

```
4-PSK -> Simulated BER: 3.0994e-06, Theoretical BER: 3.8721e-06
8-PSK -> Simulated BER: 1.0079e-03, Theoretical BER: 1.0114e-03
16-PSK -> Simulated BER: 2.0268e-02, Theoretical BER: 2.0249e-02
```

$$Bit\ Error\ Rate: P_s = 2 * Q\left(\sqrt{\frac{2 * E_s}{N_0}} * \sin\left(\frac{\pi}{M}\right)\right), \frac{E_s}{N_0} = \log_2(M) * \frac{E_b}{N_0}, P_b = \frac{P_s}{\log_2(M)}$$

$$10 = 10 * \log_{10}\left(\frac{E_b}{N_0}\right) \rightarrow \frac{E_b}{N_0} = 10$$

$$W = R_s = \frac{R_b}{\log_2 M}$$

$$4 - PSK: \frac{E_s}{N_0} = 20$$

$$P_s = 2 * Q\left(\sqrt{2 * 20} * \sin\left(\frac{\pi}{4}\right)\right) = 2 * Q(4.47) = 0.7822E - 05$$

$$P_b = \frac{P_s}{\log_2(4)} = \frac{0.3911E - 05}{2} = 0.3911E - 05$$

$$W = R_s = \frac{10^{-6}}{2} = 0.5 * 10^{-6}$$

$$8 - PSK: \frac{E_s}{N_0} = 30$$

$$P_s = 2 * Q\left(\sqrt{2 * 30} * \sin\left(\frac{\pi}{8}\right)\right) = 2 * Q(2.96) = 0.3076E - 02$$

$$P_b = \frac{P_s}{\log_2(8)} = \frac{0.3076E - 02}{3} = 0.1025E - 02$$

$$W = R_s = \frac{10^{-6}}{3} = 0.3333 * 10^{-6}$$

$$16 - PSK: \frac{E_s}{N_0} = 40$$

$$P_s = 2 * Q\left(\sqrt{2 * 40} * \sin\left(\frac{\pi}{16}\right)\right) = 2 * Q(1.74) = 0.8186E - 01$$

$$P_b = \frac{P_s}{\log_2(16)} = \frac{0.8186E-01}{4} = 0.2047E-01$$

$$W = R_s = \frac{10^{-6}}{4} = 0.25 * 10^{-6}$$

	R_b	W (Bandwidth)
4-PSK	10^{-6}	$0.5*10^{-6}$
8- PSK	10^{-6}	$0.3333*10^{-6}$
16- PSK	10^{-6}	$0.25*10^{-6}$

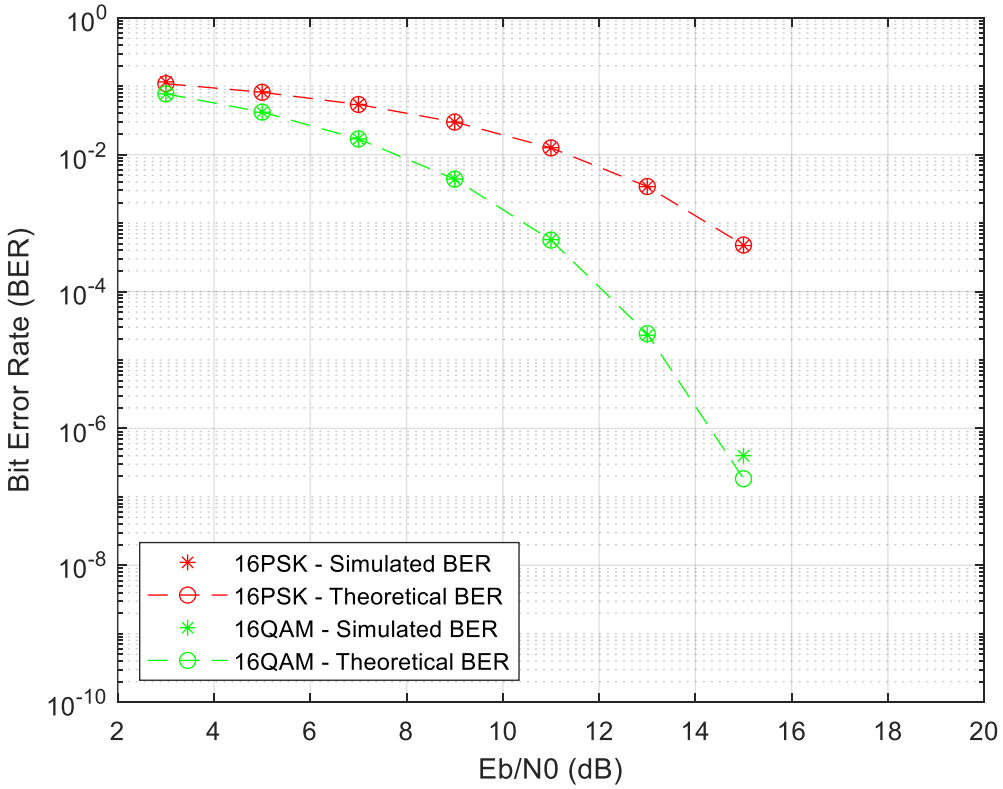

Figure 5 – E_b/N_0 versus BER for 16-QAM and 16-PSK

When the same Eb/N0 value is the same, the Pb of 16PSK will be greater than 16QAM. In terms of bandwidth, the bandwidth of 16QAM will be 2 times larger than 16PSK. Therefore, the Rb (data rate) will also be larger.