

Bit error rate for BPSK:

$$P_B(BPSK) = Q\left(\sqrt{\frac{2E_b}{N_0}}\right)$$

Symbol Error Rates:

$$P_E(MPSK) = 2Q\left(\sqrt{\frac{2E_s}{N_0}} \sin \frac{\pi}{M}\right) \quad \text{for } M \geq 4$$

$$P_E(MQAM) = 4\left(\frac{\sqrt{M}-1}{\sqrt{M}}\right)Q\left(\sqrt{\left(\frac{3}{M-1}\right)\frac{E_s}{N_0}}\right) \quad \text{for } M \geq 4$$

Bit Error Rates:

$$P_B(\text{Gray}) = \frac{P_E}{\log_2 M}$$

$$P_B(\text{Non-Gray}) = \frac{M/2}{M-1} P_E$$

Bandwidth Occupancy:

$$\text{BW}(MPSK) = \text{BW}(MQAM) = (1 + \beta) \frac{1}{T_s} = (1 + \beta) R_s$$

$$T_s = T_b \log_2 M$$

$$E_s = E_b \log_2 M$$

$$P_r = E_b R_b = E_s R_s$$