Q1

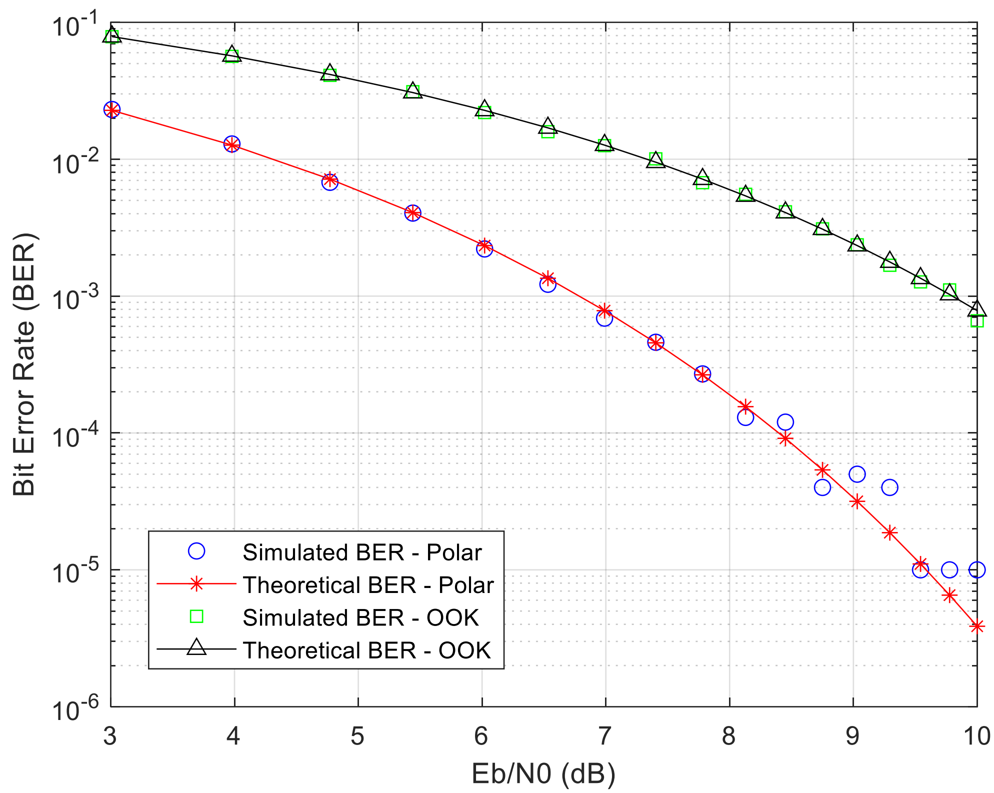

Figure 1 – Theoretical And Simulated BER vs E_b/N_0 (in dB)

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Simulated Polar BER: 0.000930
Theoretical Polar BER: 0.000783
Simulated On-Off BER: 0.012680
Theoretical On-Off BER: 0.012674
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$$P_b = Q\left(\frac{A}{\sigma_0}\right) = Q\left(\sqrt{\frac{2 * E_b}{N_0}}\right), E_p = E_q, E_{pq} = -E_p$$

$$P_b = Q\left(\sqrt{\frac{E_p + E_q - 2 * E_{pq}}{2 * N_0}}\right) = Q\left(\sqrt{\frac{E_p + E_p - 2 * (-E_p)}{2 * N_0}}\right) = Q\left(\sqrt{\frac{4 * E_p}{2 * N_0}}\right)$$

$$E_b = \frac{1}{2} * E_q + \frac{1}{2} * E_p = \frac{1}{2} * E_p + \frac{1}{2} * E_p = E_p$$

$$For\ Polar\ Signaling: E_b = 10, \frac{N_0}{2} = 1\frac{W}{Hz}$$

$$P_b = Q\left(\sqrt{\frac{2*10}{2}}\right) = Q\left(\sqrt{10}\right) = Q(3.16) = 0.0007888$$

$$P_b = Q\left(\frac{A}{\sigma_0}\right) = Q\left(\sqrt{\frac{E_b}{N_0}}\right), E_q = 0, E_{pq} = 0$$

$$P_b = Q\left(\sqrt{\frac{E_p + E_q - 2*E_{pq}}{2*N_0}}\right) = Q\left(\sqrt{\frac{E_p + 0 - 2*0}{2*N_0}}\right) = Q\left(\sqrt{\frac{E_p}{2*N_0}}\right)$$

$$E_b = \frac{1}{2}*E_q + \frac{1}{2}*E_p = \frac{1}{2}*0 + \frac{1}{2}*E_p = \frac{E_p}{2}$$

$$For\ On-Off\ Keying\ (OOK): E_b = 10, \frac{N_0}{2} = 1\frac{W}{Hz}$$

$$P_b = Q\left(\sqrt{\frac{10}{2}}\right) = Q\left(\sqrt{5}\right) = Q(2.24) = 0.01255$$

The “randn” function used in simulation generates random numbers from a standard normal distribution, which has a mean of zero and variance of one. However, in theoretical BER analysis, noise is often modeled using a general normal distribution. Therefore, in simulations, the generated noise is scaled appropriately to match the theoretical model

Once scaled, the noise in the simulation becomes consistent with the theoretical Gaussian noise model. Nevertheless, since the simulation uses a finite number of samples, it cannot perfectly match the continuous probability distribution assumed in theory. As a result, small discrepancies between the simulated and theoretical BER values may appear.

The noise generated by “randn” follows a standard normal distribution, whereas the theoretical model uses a general normal distribution with specific variance. Even though this is corrected by scaling in the simulation, differences can still arise due to randomness and finite sample size.

Q2

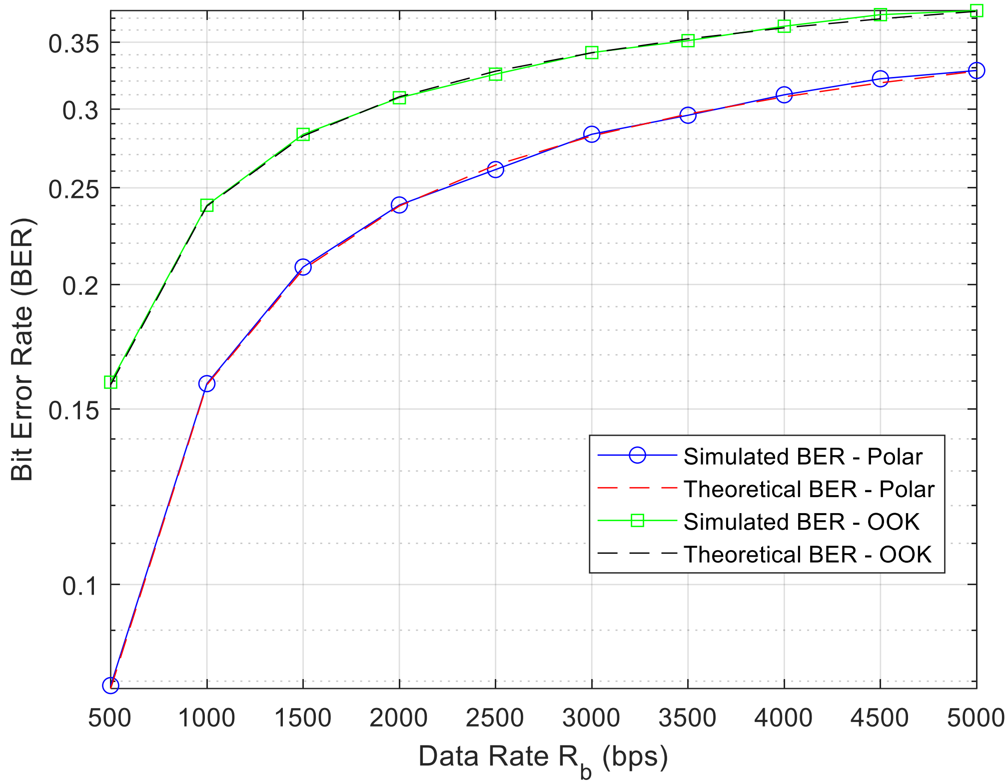

Figure 2 – Theoretical And Simulated BER vs R_b (in bps)

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Simulated Polar BER: 0.328190
Theoretical Polar BER: 0.327360
Simulated On-Off BER: 0.377540
Theoretical On-Off BER: 0.375915
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$$P_b = Q\left(\frac{A}{\sigma_0}\right) = Q\left(\sqrt{\frac{2 * E_b}{N_0}}\right), E_b = \frac{P_r}{R_b}$$

$$For\ Polar\ Signaling: P_r = 10\ mW, R_b = 5000\ bps, \frac{N_0}{2} = 10^{-6}\frac{W}{Hz}$$

$$P_b = Q\left(\sqrt{\frac{2 * \frac{10^{-3}}{5000}}{2 * 10^{-6}}}\right) = Q\left(\frac{\sqrt{5}}{5}\right) = Q(0.45) = 0.3264$$

$$P_b = Q\left(\frac{A}{\sigma_0}\right) = Q\left(\sqrt{\frac{E_b}{N_0}}\right), E_b = \frac{P_r}{R_b}$$

$$For\ On - Off\ Keying\ (OOK): P_r = 10\ mW, R_b = 5000\ bps, \frac{N_0}{2} = 10^{-6}\frac{W}{Hz}$$

$$P_b = Q\left(\sqrt{\frac{\frac{10^{-3}}{5000}}{2 * 10^{-6}}}\right) = Q\left(\frac{\sqrt{10}}{10}\right) = Q(0.32) = 0.3745$$

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Once scaled, the noise in the simulation becomes consistent with the theoretical Gaussian noise model. Nevertheless, since the simulation uses a finite number of samples, it cannot perfectly match the continuous probability distribution assumed in theory. As a result, small discrepancies between the simulated and theoretical BER values may appear.

The noise generated by “randn” follows a standard normal distribution, whereas the theoretical model uses a general normal distribution with specific variance. Even though this is corrected by scaling in the simulation, differences can still arise due to randomness and finite sample size.