Solution of Homework # 8

1. BER of a wireless QPSK link with ADALM-PLUTO software radio emulation

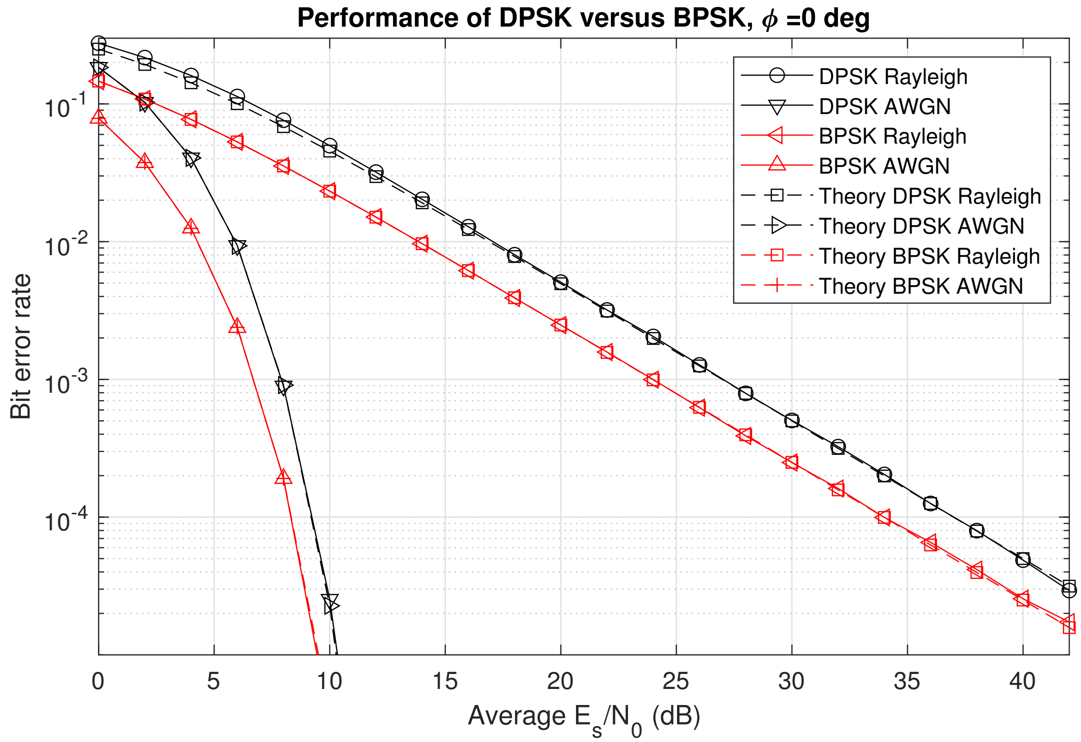
   (a) Simulation results (shown with `seed = 123456`)::

Δf	`SNR`	BER
3000	12	4×10^{-4}
3000	15	3.9×10^{-4}
3000	9	2.3×10^{-4}
3000	6	0.1
500	12	1.9×10^{-5}
500	15	2.5×10^{-6}
500	9	8.4×10^{-3}
500	6	0.1
0	12	1×10^{-5}
0	15	0
0	9	4.7×10^{-4}
0	6	9.2×10^{-2}

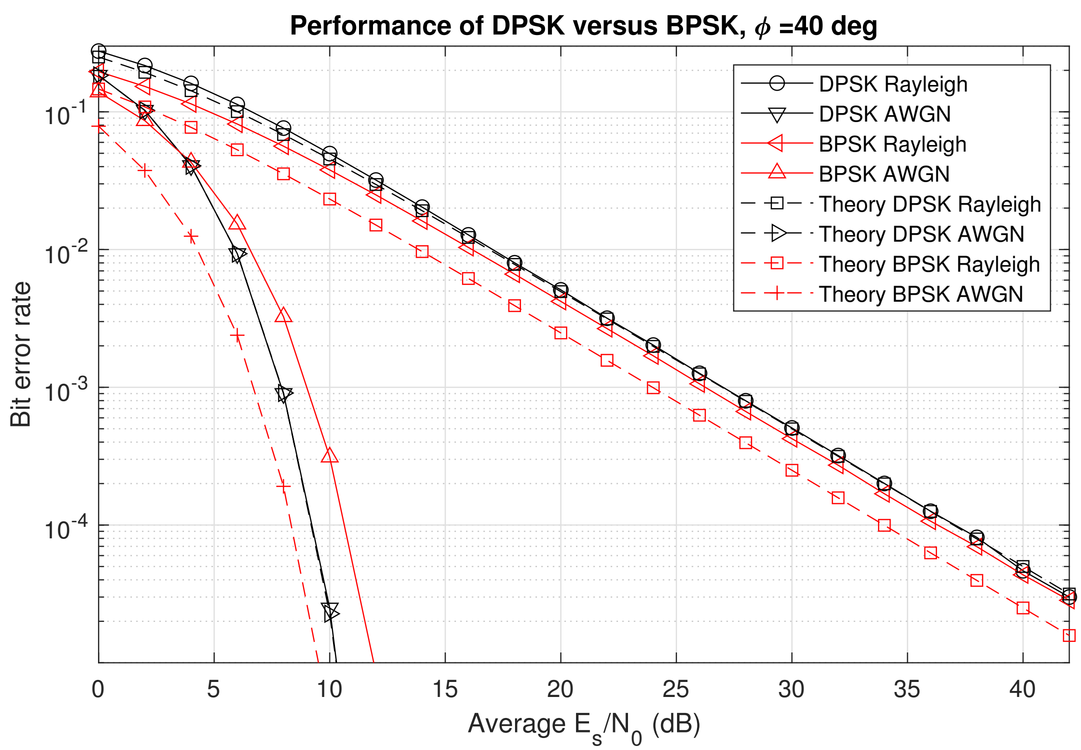
   (b) In general terms, the BER decreases with the frequency error. However, because of the nonlinear nature of the carrier recovery loop, there are cases where the noise is high the BER increases at low values of frequency error (e.g., SNR equal to 9 dB, from 1000 Hz to 500 Hz) . As commented in class, the model does not include clock errors to which timing recovery is much more sensitive to when frequency errors are added. Thus you must make sure that the frequency error of the wireless link is small when doing the experiment in the lab.

2. DPSK versus BPSK under AWGN and flat Rayleigh fading with phase errors

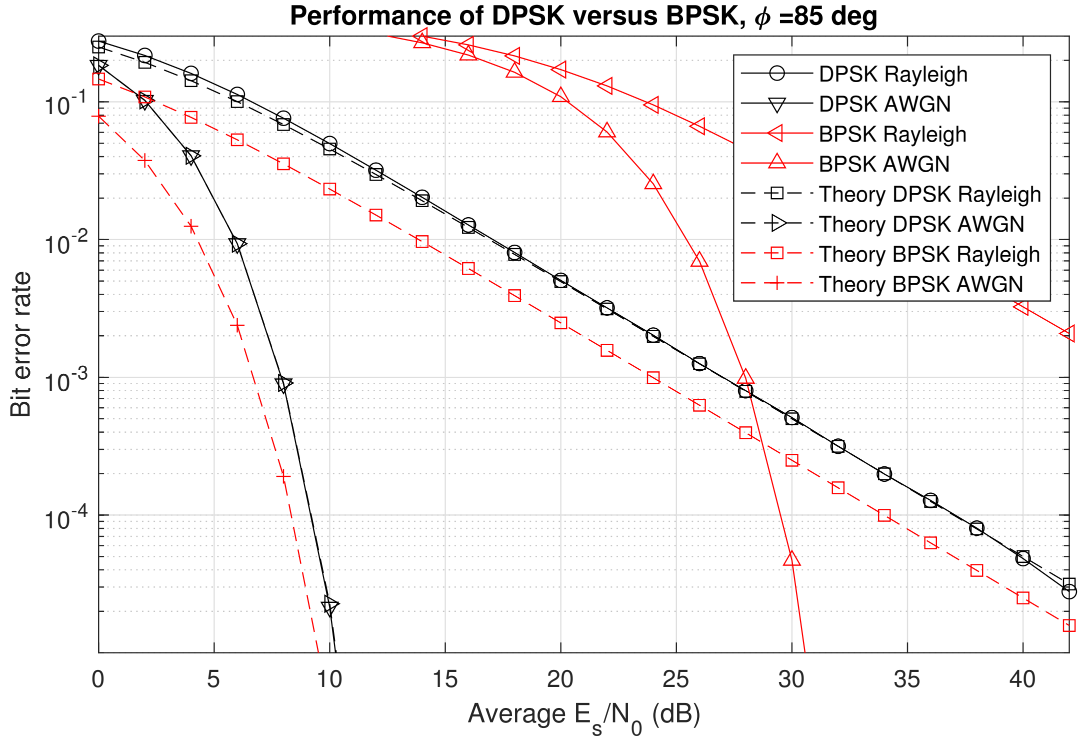
(a) i. $\phi = 0$ deg:



ii. $\phi = 40$ deg:



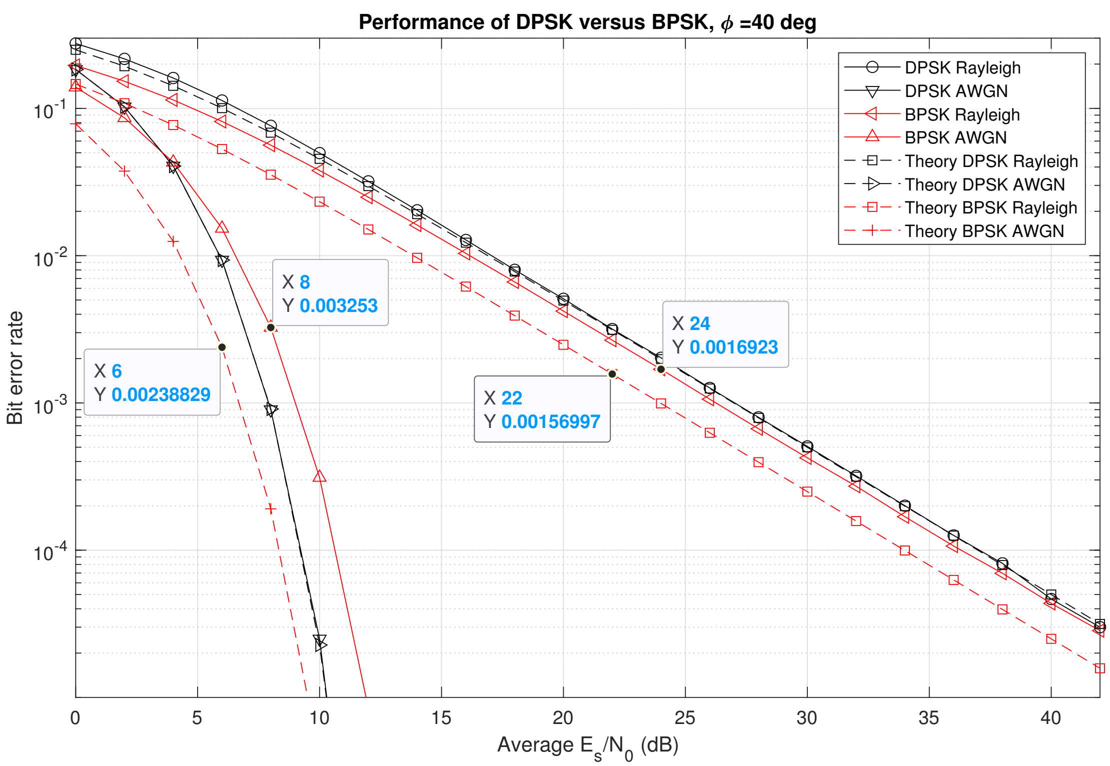
iii. $\phi = 85$ deg:



(b) (BONUS) For $\phi = 40$ deg, the loss L in dB is

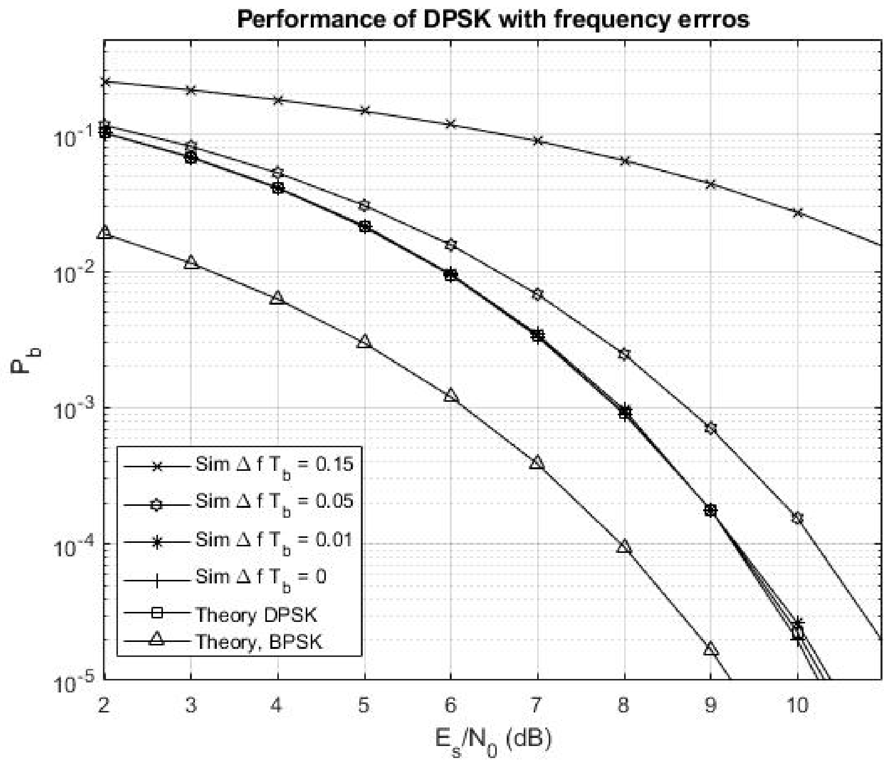
$$L = -10\ \log_{10}\left[\cos^2(40^\circ)\right] = -20\ \log_{10}\left[\cos(40^\circ)\right] = 2.315\ \text{dB}.$$

This value does match the simulation results, as shown in the figure below:



3. DPSK under frequency errors

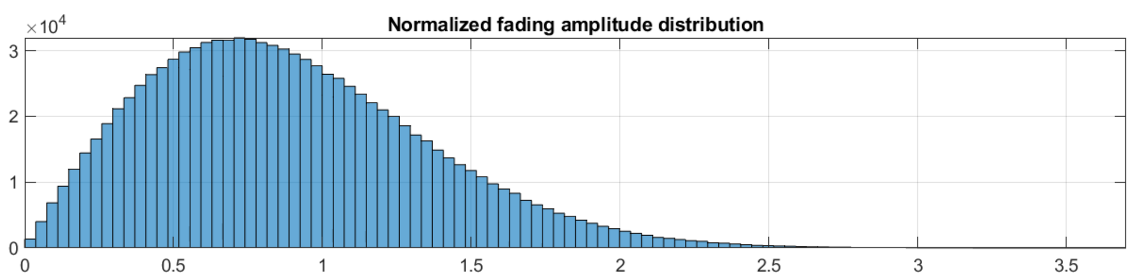
(a) Simulation results:

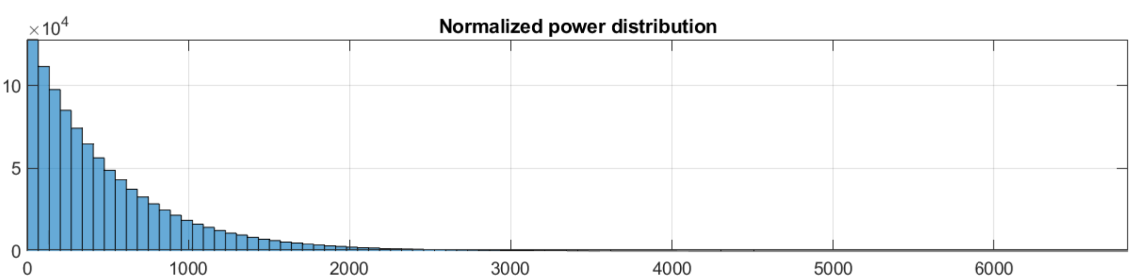


(b) DPSK performance is invariant to frequency errors up to approximately 1% of the bit rate. High values of frequency error result in degradation of performance

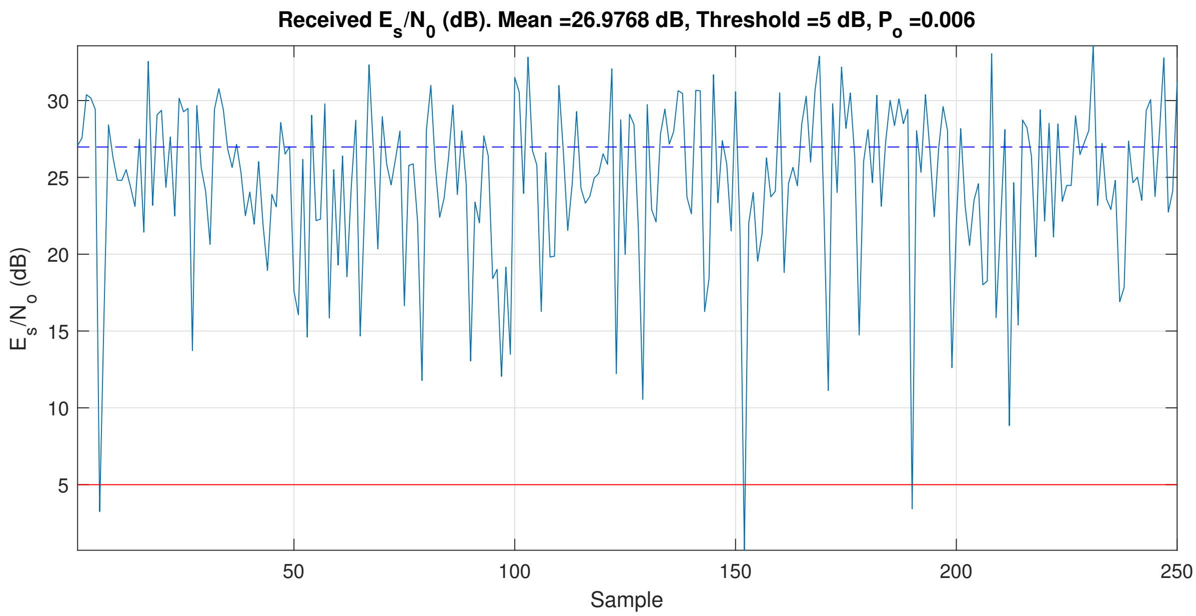
4. Outage probability

(a) Simulation results (Student ID number: 1234557):





Notice the Rayleigh distribution of fading amplitude and the exponential distribution of fading power.



(b) The simulation results in part (a) are for $\gamma_0 = 26.977$ dB and threshold $\gamma_T = 5$dB. To compute the outage probability we first convert from dB to relation:

$$\gamma_0 = 10^{(26.977/10)} = 498.52, \qquad \gamma_T = 10^{(5/10)} = 3.16.$$

This gives

$$P_o = 1 - \exp\left(-\frac{\gamma_T}{\gamma_0}\right) = 0.0063,$$

matching the simulated outage rate.