Lab 6 - Digital Passband Data Link - BPSK

Goal

Characterizing binary passband phase-shifted keyed (BPSK) in the presence of two common impairments: phase noise and fading.

Pre- lab

Reading

1. Sections 7.3.3 on phase noise and ZT 7.6 and 7.7 on interference and fading.
2. Notes on fading and phase noise on the class Web site.
3. **Not required**. A through review of fading is here. (Requires UCSD domain.)

Problems and Simulations

1. *Phase noise error*

   a) Convert the variance in rads^2 to an rms error in degrees.

   b) Determine the rms error in degrees for variance of 0.1 rads^2. Compare this value at $z = E_b/N_0 = 9$ dB to the curve in the notes on phase noise. Are they consistent?

2. *Phase noise simulation*
   Modify the single sample per bit Matlab code used to simulate the error rate for antipodal keying in Lab 3 to incorporate the effect of phase noise in BPSK. This involves modifying the *mean* value s used to determine the error rate to $s \cos\theta$ where θ is a zero-mean gaussian random variable with rms phase noise error σ expressed in degrees. Plot P_e vs. E_b/N_0 for rms phase errors of 0, 10, 20 and 45^o. The results should agree with the plot in the notes. From these plots determine the power penalty at a error rate of 10^{-3} for a rms phase error of 20^o.

3. *Fading*
   Using the analytic expression for a Rayleigh fade

$$\overline{P_e} = \frac{1}{2}\left(1 - \sqrt{\frac{z}{1+z}}\right)$$

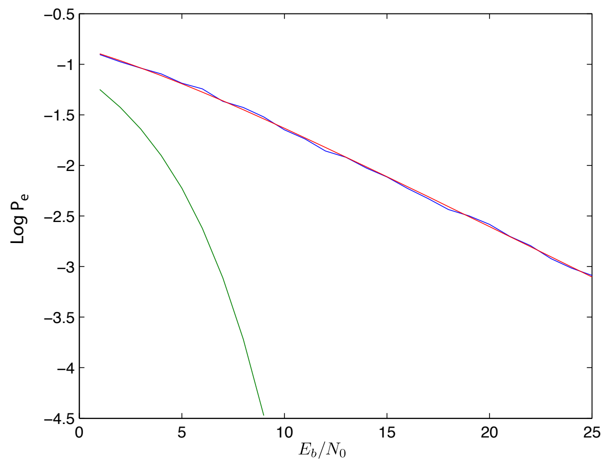

Figure 1: Unfaded $P_e$vs. E_b/N_0 (green); Rayleigh faded $P_e$vs. E_b/N_0 analytical (red); Rayleigh faded $P_e$vs. E_b/N_0 simulation (blue) for 1000 errors per point.

determine the slope on log-log scale for large values of z. Compare this slope to the slope to the unfaded case and comment. (See the figure below.)

4. *Fading simulation*
   Modify the single sample per bit Matlab code used to simulate the error rate for antipodal keying in Lab 3 to incorporate the effect of fading in BPSK. This involves modifying the *mean* value s used to determine the error rate to sR where R is a Rayleigh random variable with rms noise of $\sigma = 1/\sqrt{2}$ for each quadrature component so that $2\sigma^2 = 1$. which is derived in ZT. The two results should agree and should look the same as the figure in the notes. An example figure showing the unfaded curve, the faded curve using the analytical expression, and the simulation is below.

1 P_e vs. E_b/N_0 for BPSK

1.1 Generation

To make the experiment more realistic, we will generate the BPSK data on one station and use it on another. You will tune your receiver to use one of the other lab stations data streams.

1. Using the same VIs as in Lab 3, generate a PRBS data stream with $N = 5$ at a data rate of 100 ksamples/s. Do not add noise. This will be added at the receiver.

2. Using the upconversion VI from Lab 4, generate a BPSK data stream at carrier frequency that the TA will provide. Each station will use a slightly different carrier in the range of 100 MHz.

3. Connect the modulated output to *Cal_SA,* and determine the total transmitted power before the antenna. Adjust the amplitude so that the total transmitted power is 0 dBm.

4. Once the power is set, connect a telescoping antenna to the output so that the other lab stations can receive your data signal.

1.2 Detection

1. Connect a second antenna to input of the downconverter and using *Cal_SA* find the other channels that are broadcasting in lab.

2. Determine the total received power and the loss in dB from each of the other stations. Dump the spectrum of each station measured.

1.3 Effect of Fading on a Carrier Signal

1. Across the room, there is a 600 MHz carrier being broadcast. Tune *Cal_SA* to a 1 MHz band centered on 600 MHz carrier and set the averaging and resolution bandwidth so that the spectrum responds in real time.

2. Connect the antenna to a 4' SMA cable and holding the antenna in a vertical position, move it about and watch the power on the spectrum analyzer. What is the range of powers in dB?

3. Now place the antenna on the lab bench and see how much the power fluctuates as you move about. Why?

2 BER Measurements

2.1 Baseline measurement with no impairments

Using a modified form of the VI used for BER measurements in Lab 3, measure the BER vs. E_b/N_0 down to an error rate of $\approx 10^{-4}$. Collect about 10 data points as you did in Lab 3.

2.2 Measurement in the presence of phase noise.

Using the VI, measure the BER vs. E_b/N_0 for an rms phase error of 20^o over the same range of E_b/N_0 values used earlier.

2.3 Measurement in the presence of fading.

Using the VI, measure the BER vs. E_b/N_0 for a Rayleigh fade over the same range of E_b/N_0 values used earlier.

2.4 Combined phase noise and fading. (Optional if there is time.)

Using the VI, measure the BER vs. E_b/N_0 for a Rayleigh fade and a rms phase error of 20^o over the same range of E_b/N_0 values used earlier.

3 Post Lab

1. Plot and compare the baseline BER vs. E_b/N_0 measurements with theory and discuss the differences knowing the issues determined in Lab 3.

2. Plot and compare the baseline BER vs. E_b/N_0 measurements with and without phase noise. Note that while the baseline measurements may be slightly off from theory, the *relative* performance difference should agree with the Prelab simulations because the impairment is being added at the receiver. From the curve determine the power penalty in dB at $P_e = 10^{-3}$.

3. Plot and compare the baseline BER vs. E_b/N_0 measurements with and without fading. Determine the power penalty in dB at $P_e = 10^{-3}$.
4. (Optional) From the results of the last section, at an error rate of $P_e = 10^{-3}$, does the overall power penalty in the presence of phase noise and fading equal the sum of the power penalties of the impairments separately? Why or why not?