# Power Spectral Density of Line Codes

## Introduction

In this lab you will measure the Power Spectral Density (PSD) of three common line codes: NRZ, Manchester, and 4B5B combined with MLT-3 (the line code used by 100 Mb/s Ethernet).

## Power Spectral Density

We cannot compute the frequency spectrum of random signals by computing their Fourier Transforms. However, we can compute a statistic called the power spectral density (PSD) which allows us to compute the power within a range of frequencies. This is often useful when analyzing distortion and interference.

## Pre-Lab Report

You will use Octave (or Matlab) to run the `linecodes.m` script, available on the course website, to generate waveforms of 10,000 random bits that have been encoded using three different line codes.

Read through the script to learn how it works and answer the following questions. You can use the `help` or `doc` commands (in Octave or Matlab) to look up how operators and functions work and you can also try out different expressions to check your understanding.

- What does the `rand(1,n)` function return? Is it a row or column vector? (try the command `help rand`).

- What values result from applying the `>` operator? (`doc gt`).

- How many rows and columns does a matrix defined as `[ 1 0 ; 1 0 ; 1 0 ]` have? (`help size`)

- What is the effect of subscripting the above matrix with `(:)`? (`help colon`)

- What does the `.'` operator do? What is the effect of applying it to the above vector? (`help transpose`)

- What do the `cumsum()` and `mod()` functions return?

- How does the expression `mod(cumsum([1 0 1 1 0 0 1]),4)` perform MLT-3 encoding?

- What is the bit rate if the sampling rate is set to 1 MHz?

## Generate Waveforms

Run the `linecodes.m` script to generate three `.txt` files, one for each line code. The files will be placed in the directory from which you run the script so you may want to copy the script to the directory where you want these files to end up and `cd` to this drive/directory[1] before running the script.

Load the `nrz.txt` file into the AWG using the instructions in a previous lab. Set the sample rate to 1 MHz, the high voltage to 1 V and the low voltage to -1 V.

## Capture Waveforms

Connect the signal generator to the 'scope and look at the waveform. Measure the amplitude and bit period and confirm it's what you expected. Capture a 'scope screen shot for your report.

Follow the instructions in a previous lab to configure the 'scope to sample a waveform (configure channel 1 of the 'scope for an appropriate vertical scale, a sampling rate of 1 MSa/s, memory depth of 140,000 samples). Acquire 140,000 samples and save the waveform as a `.csv` file (e.g. `nrz.csv`).

Repeat the steps above for the data encoded using the Manchester and 4B5B-MLT3 line codes (using the files `manchester.txt` and `4b5mlt3.txt` respectively).

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[1]e.g. `cd 'f:'`

You should now have three screen captures and three `.csv` sample capture files on your flash drive.

### Analyze Waveforms

As in a previous lab, run Octave (or Matlab) and read the samples from the `.csv` file for the NRZ-encoded data (e.g. `nrz=csvread('nrz.csv');`) and remove any headers and the first (sample time) column.

You will need to load the signal processing package to access the `pwelch` function:

```
pkg load signal
```

Compute the power spectrum using the following Matlab function[2]:

```
[nrzpsd,f]=pwelch(nrz,hamming(256), ...
   [],256,1e6,'onesided');
```

This will compute the (one-sided, i.e. positive) power spectrum over 256 frequencies assuming a sampling rate of 1 MHz using a "Hamming" window.

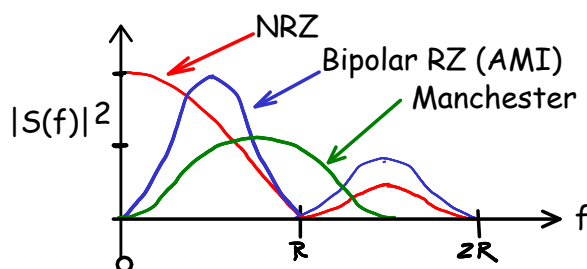You can then plot the power spectrum (in dB) versus frequency using the command:

```
plot(f,10*log10(nrzpsd))
```

Compute the spectrum for the Manchester- and 4B5B-MLT3-encoded signals and plot them together for comparison[3]:

```
plot(f,10*log10([nrzpsd,manchesterpsd,mlt3psd]))
```

As in the previous lab, save this plot to an image file so that you can include it your report.

You can check some of your results by comparing them to the spectra given below where $R$ is the *bit rate*:



### Lab Report

Your report should include the usual identification information, three 'scope screen captures showing your waveforms, one plot showing the computed spectra of the three line codes in dB and the values of the following parameters for each line code[4]:

- data rate

- baud rate

- the 10 dB bandwidth (the range of frequencies over which the PSD is within 10 dB of to the maximum value)

- frequency of first (lowest frequency) null[5] *above* $DC (f = 0)$

- PSD at DC (0 Hz), in dB relative to the maximum

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[2]The ellipsis (...) is optional; it allows you to continue a long expression on the next line.

[3]Substituting the variable names you used for the other power spectra.

[4]Formatted as a table might be a good idea.

[5]A null is a frequency where the PSD has a minimum or zero value.