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).

Generating the Test Signals

As in previous labs we will use Octave or Matlab to generate the signals in `.csv` format suitable for loading into the AWG. The file `linecodes.m`. The `linecodes.m` script generates 10,000 random bits and encodes them using the three line codes.

Procedure

Read through `linecodes.m` (particularly the comments) to learn how it works and answer the following questions. You can also use the `help` command and evaluate expressions in Matlab to answer questions about operators and functions.

- 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 at the input to the encoder if the sampling rate is set to 1 MHz?

Generate Waveforms

Run the `linecodes.m` script to generate the three `.csv` files. You may want to copy the script to your working directory and `cd` to this drive/directory[1] before running the script so that all the files end up in the same folder.

Load the `nrz.csv` file into the AWG using the instructions in previous labs. 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.

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). Use the `scopegrab.py` utility menu to acquire 140 kSamples.

Capture a 'scope screen shot for your report.

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

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

Be careful not to confuse the `.csv` files used to configure the AWG with those obtained from the 'scope.

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

Analyze Waveforms

As in the previous lab, run Octave (or Matlab) and read the samples from the `.csv` file for the NRZ-encoded data using the `csvread()` function.

```
x=csvread('f:nrz.csv');
x=x(:,2);
```

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:

```
[nrzpsd,f]=pwelch(x,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))
```

Check your results by comparing to the spectra given in the lecture notes.

Compute the spectrum for the Manchester- and 4B5B-MLT3-encoded signals and plot them together for comparison[2]:

```
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.

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[3]:

- data rate
- baud rate
- the 10 dB bandwidth (the frequency at which the PSD has dropped by 10 dB compared to the maximum value)
- frequency of first (lowest frequency) null *above DC* ($f = 0$)
- PSD at DC (0 Hz), in dB relative to the maximum

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

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