Arijit Dutta

EE340 – Communications Laboratory (IIT Bombay)

Final Exam   Wednesday, November 04, 2015; 14:00 – 16:30 hrs
Roll No.: 13D070046 (Kanhaiya kumar)   Max. Marks: 25
TA Name: ____________

Important: Please save all the snapshots and the GNU-Radio files you've made in a folder (named by your roll number). Submit this folder as well as your question paper to the TA at the end of the session. Also sketch the observed waveforms (marking important points) and take your TA's initials on each observation.

1. Consider an amplifier, for which the output y for an input x is given by

$$y = \frac{5e^{(10x)} - 1}{e^{(10x)} + 0.9}.$$

   (a) Implement this amplifier in GNU-radio using a flowgraph and the 'Transcendental' block. Using Scope Sink with two inputs to plot the input-output transfer function in the X-Y mode. Sketch the output and save the snapshot.

   (b) What is the 'Gain' of the amplifier (obtained using your simulation), when the amplifier is not saturated.

   (c) A sinewave is applied to this amplifier as the input. Find the input sinewave amplitude that corresponds to the IP3 (the input amplitude that results in equal amplitudes of the fundamental and the third harmonic components in the output in the asymptotic plot). Make sure that your input amplitude is low enough, so that you are able to observe the asymptotic behaviour correctly. Show your calculation in your answer script.

   (d) Apply the real and imaginary components of the complex baseband signal from file `BatchA_input.bin` to the inputs of two such amplifiers. Comprehend the output observed on the Scope Sink in the X-Y mode (and sketch it).

   (e) Using two such amplifiers, make a differential amplifier. Sketch the input-output characteristics of this differential amplifier.

2. For this problem, which involves the digital communication blocks, you need to use 2 Import blocks in GNU-radio with the following statements:

```
from gnuradio import digital
from gnuradio import filter
```

The tap co-efficients for the Polyphase Clock Synchronizer and the Polyphase Arbitrary Resampler are given by:

`firdes.root_raised_cosine(32,32*input_sps,1.0,0.35,1024)`. Here `input_sps`, i.e. the input samples-per-symbol, for each block has to be chosen by you correctly (may not be same). For other parameters in various blocks, default values can be used.

The file `BatchA_input.bin` contains a complex baseband signal sampled at 400 kHz. The signal has 100 kSymbols/s QPSK data with a carrier frequency offset of 16 kHz (sign of the offset is not given). Also, the signal has been recorded by the receiver in a multi-path environment, such that the received signal $y(t) = x(t) + \alpha x(t - \tau)$, where $x(t)$ is the direct line-of-sight component of the received signal, $\tau = 7.5\,\mu\text{sec}$, α is real and $|\alpha| < 0.7$.

   (a) Sketch the spectrum of the baseband signal after removing frequency offset from it.

   (b) Sketch the symbol constellation after frequency offset removal and resampling the signal.

   (c) Equalize the signal using the signal and at most two delayed copies of it (use sliders for manual tuning of weight coefficients). Show the resultant constellation. Also show the CMA error before and after equalization.

   (d) What is the value of *alpha*.

   (e) If you don't use the Costas loop, you would observe that the symbol constellation rotates every few seconds. What could be the reason for these rotations?

$\frac{-1}{0.9} - \frac{4}{1.9}$

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EE340 – Communications Laboratory (IIT Bombay)

Final Exam Thursday, November 05, 2015; 14:00 – 16:30 hrs Max. Marks: 25

Roll No.: 13D070062 TA Name: P.L. Priyanka

Important: Please save all the snapshots and the GNU-Radio files you've made in a folder (named by your roll number). Submit this folder as well as your question paper to the TA at the end of the session. Also sketch the observed waveforms (marking important points) and take your TA's initials on each observation.

For experiments requiring the digital communication blocks in GNU-radio, you need to use two 'Import' blocks with the following statements:

```
from gnuradio import digital
from gnuradio import filter
```

The tap co-efficients for the Polyphase Clock Synchronizer and the Polyphase Arbitrary Resampler can be defined as:

`firdes.root_raised_cosine(32,32*input_sps,1.0,0.35,1024)`. Here `input_sps`, i.e. the input samples-per-symbol, for each block has to be chosen by you correctly (may be different for different blocks). You can use 0.0625 as the normalized loop bandwidth in various built-in blocks, and default values in the blocks for other parameters.

1. Make a flowgraph in GNU-radio to generate an 80 kSymbol/s 8-PSK baseband signal.
   (a) Record the symbol constellation before the pulse shaping filter and the signal spectrum after the pulse shaping filter.
   (b) Add 10 kHz carrier offset to this signal and sketch the resultant spectrum.
   (c) Obtain the error phase due to the carrier frequency offset in the resultant signal (in Part (b)) using the Viterbi-Viterbi phase estimator (and whatever other blocks may be required). Sketch the phase error plot vs. time and record the frequency of this waveform.

2. Now use the file `BatchB_input.bin` provided to you. It has a complex baseband signal with QPSK data at 100 kSymbols/s, and 400 kHz sample rate. This signal has a small carrier frequency offset of ~5 kHz. Further, the carrier frequency has been modulated by a two-tone analog signal.
   (a) Make a flowgraph to find the carrier frequency offset Δf_c as a function of time. Hint: The frequency offset is basically a scaled copy of the differential of the phase error. To obtain this, take the argument of the product of the M^{th} power of the appropriate signal and its delayed and conjugated copy, as done in Experiment 10. How much is the average frequency offset (you need to scale the result properly)?
   (b) Record the spectrum of this carrier frequency offset (it should have two tones).
   (c) Give this output to a VCO with the desired scaling factor (or VCO sensitivity) – it should depend on M and the *sample-period*. Multiply the VCO output with the input signal to remove frequency offset in it. You should now be able to observe the QPSK constellation. You can further use the Costas loop block (ready made block) to stabilize the constellation. Record the obtained constellation.
   (d) Use an alternate approach of employing an FLL and the Costas loop (ready made blocks) to obtain the QPSK constellation for baseband signal from the file `BatchB_input.bin`. Here, the FLL and Costas-loop loop bandwidth may have to be increased in order to overcome the high amount of variation in the carrier frequency. Record the constellation obtained using this approach.

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