



EE 340: Communications Laboratory
Autumn 2021

Lab 7: Multipath Propagation and Equalization

Legends



Question/Observation: Show it to the TA and explain (carries marks)



Recall/think about something



Caution



Additional information - weblink



Aim of the experiment

- To study the effect of multipath propagation using a suitable multipath model.
- To understand working of an equalizer when the signal propagates through a multipath environment.
- To use an adaptive equalizer for blind equalization of a signal with unknown multipath transfer function.

Pre-lab Work

- Study how to determine a transfer function of a discrete time signal using z - transform and how to find its inverse.
- Make sure that you have read the supporting material uploaded on moodle.



For additional information about equalizers, refer Adaptive Filter Theory, Simon Haykin

Important note

- For observing constellation, use X-Y scope plot only.
 - ✓ To ensure that the symbols are sampled at the centre of symbol period, the “Polyphase Clock Synchronizer” should be used before each X-Y plot, with “output sps=1.”
 - For “Polyphase Clock Synchronizer” the same filter taps should be used as used for the pulse shaping filter (experiment 7).
 - You may also have to use “Costas Loop” for carrier phase synchronization after the “Polyphase Clock Synchronizer” if carrier phase/frequency offset is expected.
 - The “output sps=1” should be used only for the “Polyphase Clock Synchronizer” before the X-Y plot, the “Costas loop” before the XY plot, and for estimating the error (discussed later). For all other blocks, use sps= 3 or more.

Part 1: Multipath model

- Generate a 8 - PSK constellation using the blocks available in GNU Radio.
 - For this use the “Random Source” (generating bytes with min=0, max=8). Send the output to “Chunks to Symbols” block with 8 constellation points (equally separated on a unit circle). This output should go to the pulse shaping filter implemented by “Polyphase Arbitrary resampler” with taps generated using “firdec.root_raised_cosine (nfilts, nfilts, 1.1, 0.4, ntaps)” (nfilts, ntaps as used in digital modulation schemes i.e. expt 7).
- ✓ Observe the output using the XY plot.
- Make a multi-path model ($H(z)$) with tap coefficients 1 and 0.5 (such that coefficient of 1 corresponds to direct line-of-sight reception and coefficient of 0.5 corresponds to a signal reflected from an object and received after one symbol period delay (use the “delay” block in Gnu - radio :- one delay count corresponds to one sample delay)).

Part 2: Equalizer design



- Pass the 8-PSK constellation through the multipath model after adding Gaussian noise (from the random noise block) with amplitude of 0.05. Can you still observe the constellation with distinct clusters of points.
- Implementing a feed forward 4-tap equalizer with adjustable coefficients
 - Limit the number of tap coefficients to 4 (in addition to the one direct signal to the output with gain coefficient = 1) and neglect tap coefficients that come after the fourth tap. Use sliders to change their values (each slider should have a value between -1 and +1). The tap delays should be equal to the symbol period delay.
 - Connect the output of the multipath model designed in the previous part to the input of the equalizer and observe the equalizer output constellation as you adjust the coefficients.

... Equalizer design

- Generate the error magnitude from the equalizer output (y) as the absolute value of


$$e = (|y|^2) - 1$$

- To observe this error output, send it through a low pass filter implemented by the “IIR Filter” block (with feedforward taps = [0.001], feedback taps = [1, 0.98], “Old Style of Taps”=“True”), followed by a Scope Sink.
- ✓ Adjust the taps manually to reduce the error (starting with the first coefficient first). Observe that reducing error improves the constellation. Try to minimize the error by adjusting coefficients.

Part 3: Equalizer for known multipath model

- Now invert $H(z)$ analytically to find the first four tap coefficients of $E(z)=1/H(z)$
 - Set the slider values corresponding to the obtained coefficients.
- ✓ Observed constellation should be very good

Part 4: CMA Equalizer for multipath model

- Use the in - built CMA Equalizer in GNU Radio to to remove the multipath effect and observe the desired constellation.
-  - Tweak the gain of the Equalizer and observe its effect on the constellation.
- Observed constellation should be very good