EE 340: Communications Laboratory
Spring 2021

Lab 6: 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 seperated on an unit circle). This output should goes to the pulse shaping filter implemented by “Polyphase Arbitrary resampler” with taps generated using “firdes.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 coefficents.

… 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 coeffiecients.

✅ 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