Lab 9: Multipath Propagation and Equalization

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Aim of the experiment

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

Pre-lab Work

- Make sure that you have read the supporting material uploaded along with this document.
- For additional information about equalizers, refer Adaptive Filter Theory, Simon Haykin.

Part 1: Multipath model

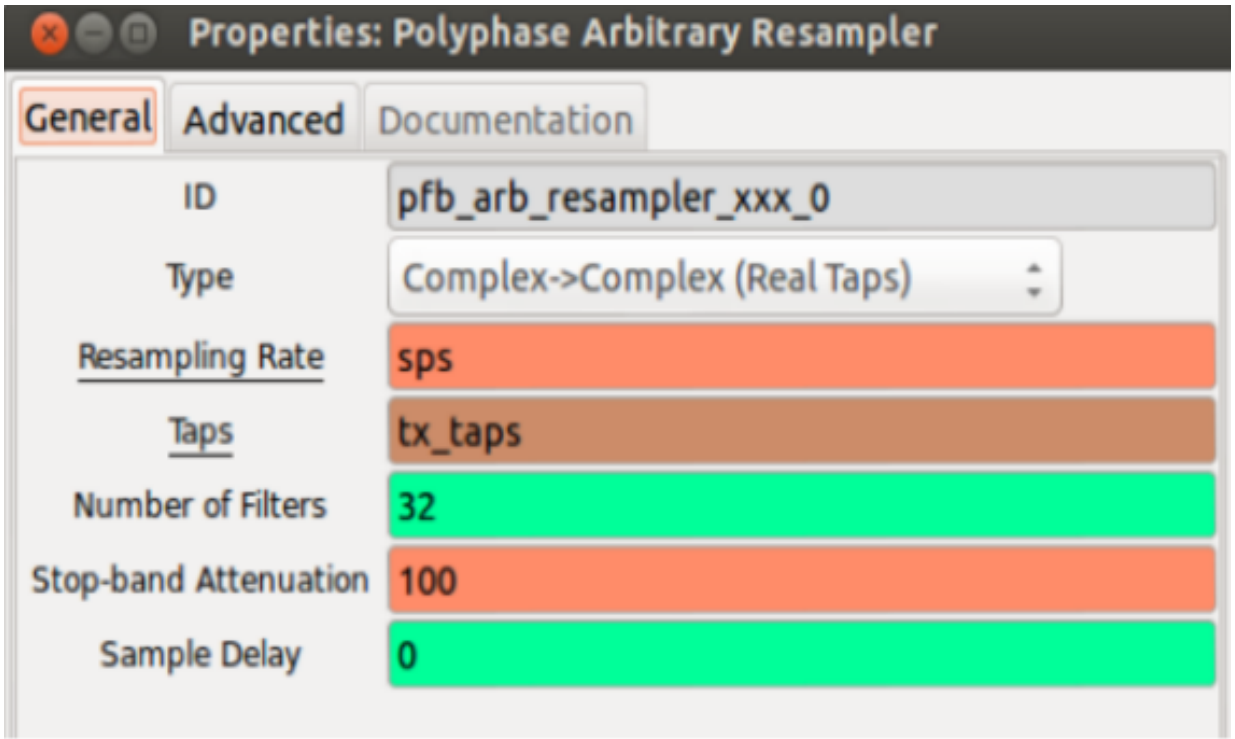
- Generate a QPSK and BPSK constellation using the blocks available in GNU Radio.
  - For this use the "Random Source" (generating bytes with min=0, max=2). Send the output to "Chunks to Symbols" block with 2 constellation points (equally separated on an unit on x-axis). This output goes to the pulse shaping filter implemented by raised root cosine filter i.e. expt 8.
  - Observe the output constellation.
- Design the transmitter as in expt 8 and continue.
- 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

- Design the reciever containing IQ demodulator, followed by match filtering and then add the equalizer.
- Calculate feed forward coefficients of 4-tap equalizer
- Connect the output of the matched filter (make sure to decrease the sps to 1) to the input of the equalizer and observe the equalizer output constellation.

Polyphase Arbitrary Resampler

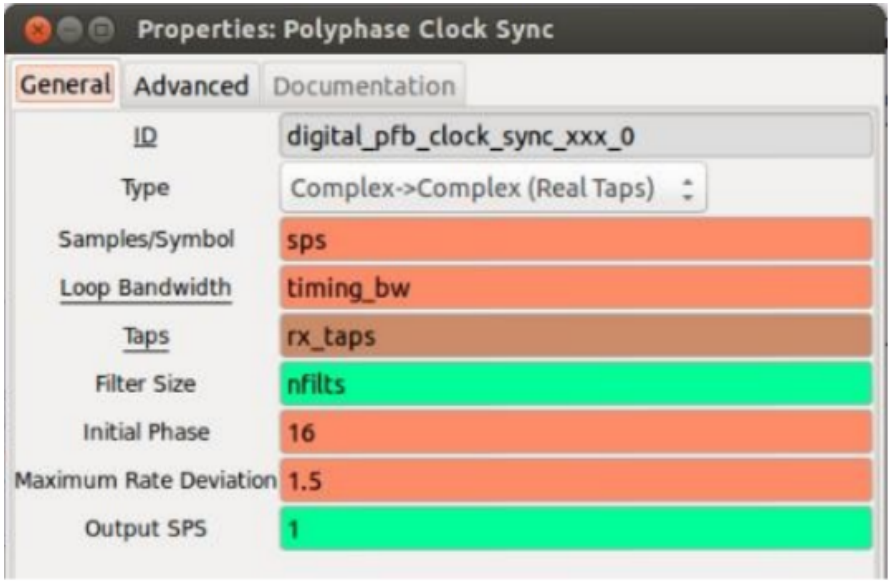
- This block is used in building the Transmitter



  - **tx taps** are the Root Raised Cosine FIR filter tap coefficients generated by the FIR design utility.
    tx_taps = firdes.root_raised_cosine(gain,sps*symb_rate,symb_rate,excess_bw,ntaps)

Polyphase Clock Sync

- This block is used in building the receiver



- **timing bw** is 2*pi/100 (normalised loop bandwidth for Polyphase Clock Synchronizer) and **nfilts** is equal to 32.
- **rx_taps** = firdes.root_raised_cosine(gain,nfilts*sps*symb_rate,symb_rate,excess_bw,ntaps)

Part 3:Implementing the model

- Implement the model using polyphase arbitary resampler and polyphase clock sync (inbuilt GNU blocks) with added Multipath and Equalization blocks by applying a random source as input

Part 4: Equalizer design

- Pass the generated QPSK constellation through the multipath model after adding Gaussian noise (using noise source) with amplitude (0.05 in between 0 and 1). Can you still observe the constellation with distinct clusters of points.
- Implementing a feed forward 4-tap equalizer with adjustable coefficients.
  - Implementing a feed forward 4-tap equalizer with adjustable coefficients.
  - 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 5: 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 6: CMA Equalizer for multipath model

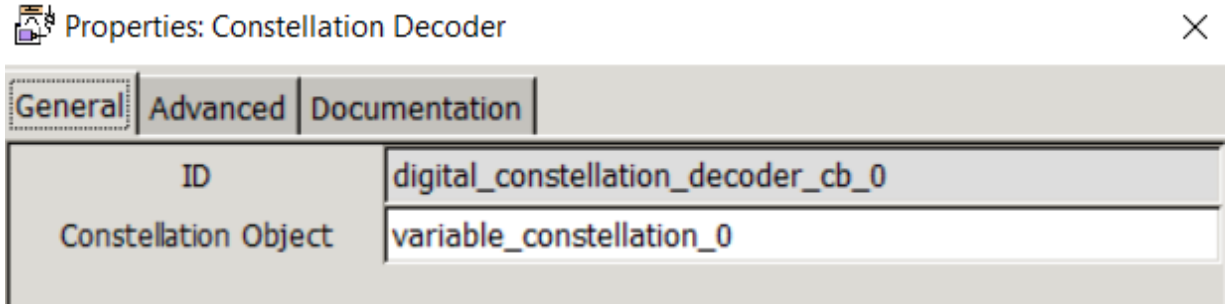
- For GNU Radio version 3.10, you might not find this block. To complete this task join with other students who have GNU radio version 3.9 or below.
- Use the in–built CMA Equalizer in GNU Radio to observe the desired constellation.
  - Tweak the gain of the Equalizer.
- Observed constellation and compare with o/p of previously designed equalizer.

Message Transfer

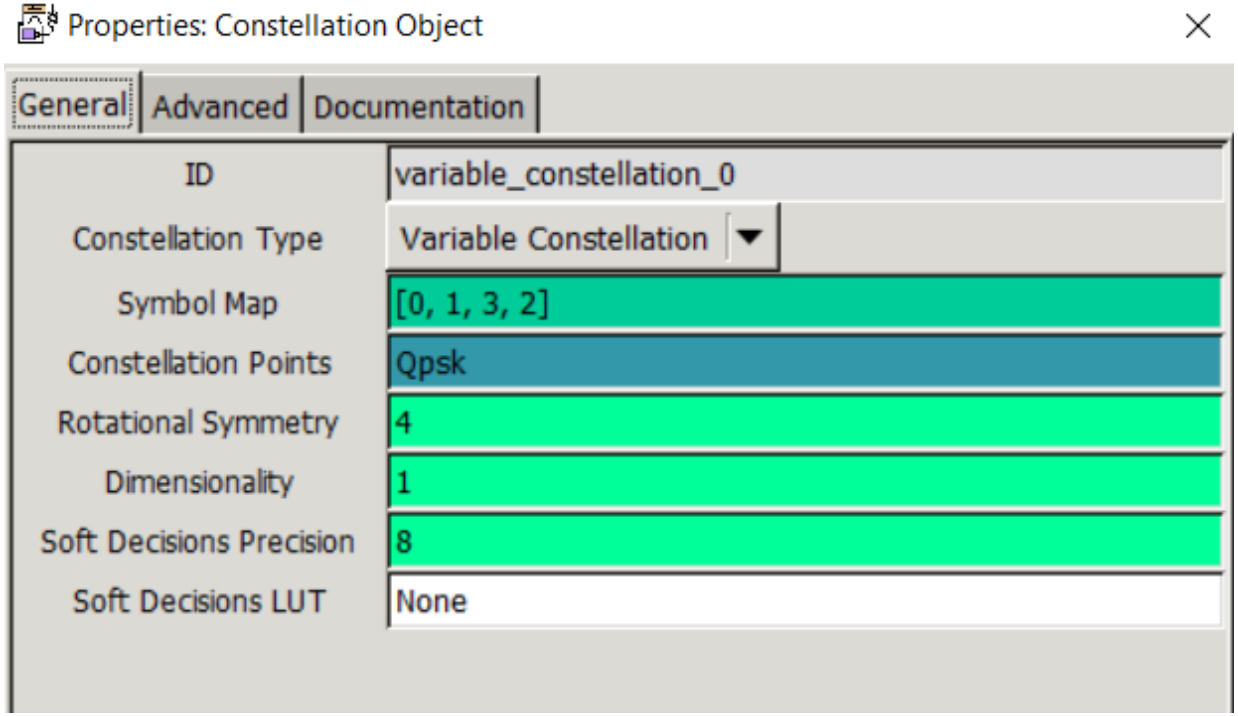
- Try to send and receive the a text file (Original.txt) as done in previous experiment in the presence of multi-path and noisy channel.
  (This part is optional)

Constellation decoder

- This block is used for symbol coding



- This block requires constellation object



- Ensure that constellation points are same as symbol table value given at input (at transmitter)