Lab #7: Receiver Design

Objective

The objective of this experiment is designing a digital baseband receiver. The student will be familiar with the following items:

a) Practical frame structures in wireless communication systems.

b) Correlation characteristics of m sequences (synchronization sequence).

c) Time offset estimation and compensation (i.e., time synchronization).

d) Frequency offset estimation and compensation (i.e., frequency synchronization).

e) Symbol synchronization/sample timing estimation.

f) Effect of synchronization mismatch in the system.

g) Channel estimation and compensation.

Procedure

The goal is to synchronize received signal in time and phase to recover transmitted symbols. Follow TA explanation of the methods below.

Frame Structure:
The frame has two parts; data part, where QAM symbols are loaded, and a preamble consisting of two cascaded, identical m-sequences. Both data and preamble symbols are filtered using RRC filter. The frame parameters are as follows:

- Preamble: two m-sequences each with (2^7-1) BPSK symbols.
- Data: 512 16-QAM symbols
- Filtering: RRC filter with 0.5 roll-off factor, oversampling ratio of 8 samples per symbol and a span of 16 symbols.
- Sampling Rate: 10^6 samples/second.

After sending and receiving the generated samples, perform the following:

a) Observe and comment on the received signal in time and frequency domains. Select *manually* one complete frame to be used in next steps. (*Synchronize for one frame and not multiple ones*.)

b) Perform edge detection by correlation-based or energy-based method using the preamble.

   - Show and comment on results.

   - Plot the selected frame again and show the location of estimated edge sample. Comment on the result.

c) Apply match filtering and plot eye diagram of the signal.

Note: There are different ways to continue the synchronization process; frequency offset compensation is performed then down sampling, or the opposite, where frequency offset compensation is performed at the symbol rate.

d) Estimate and compensate for frequency offset based on the duplicated m-sequence.

   - What is the estimated frequency offset value?

   - Plot eye diagram of the compensated sequence of samples and compare it with the one obtained in (c).

     Note. At this stage it is not necessary to get the correct number of signal levels as still there is phase ambiguity to be compensated later.

e) Perform down sampling and fine edge detection using the correlation-based method (*Ask TA for help if needed*).

- Plot correlation output at each sample index within the window you have selected around the estimated edge sample.

- Extract data symbols and plot their constellation diagram. Comment on the result.

f) Repeat step (e) without frequency offset compensation in step (d) and plot constellation diagram of symbols. Compare it with the result obtained in (e).

g) Estimate and compensate phase ambiguity (i.e., the phase rotation due to channel propagation and synchronization).

- Compare the detected preamble with a locally generated one. If they match, calculate the rough bit error rate.

h) Calculate EVM & SNR based on the obtained data symbols.