Lab #4: Effect of Pulse-shaping Filters in Communication Systems

Objective

The objective of this experiment is to study the impact of baseband pulse shaping filters on telecommunication system performance and to comprehend related measurement methods. The student will be familiar with the following items:

- Study of various filters and their effects on the communication system performance.
- Gaussian pulse shaping, BT product and time-bandwidth relations.
- Nyquist criterion, raised cosine (RC) filters, roll-off factor and time-bandwidth relations, comparison of Nyquist and Gaussian filters.
- The effect of filtering in EVM and BER measurements, inter-symbol interference, and polar diagram.
- The effect of matched and unmatched filtering under AWGN.
- Understand the effect of pulse shaping in the time and frequency domains.

Pre-lab

- Run MATLAB® and try to understand the following functions (MATLAB help menu or online help could be useful).
  - *repmat*
  - *reshape*
  - *rcosdesign*
  - *gaussdesign*
  - *pwelch*
  - *upsample*
  - *downsample*
  - *upfirdn*
  - *conv*

Procedure

FRAME GENERATION

1. Build a frame for transmission as follows. It has two parts: data part, where data symbols are loaded, and a preamble consisting of two identical m-sequences. The frame parameters are:
   - Preamble: two m-sequences each with (2^7-1) BPSK symbols.
   - Data: 512 QPSK symbols.
   - Filter: RC with 0.3 roll-off factor, 8 samples per symbols, and 12 symbols span.
   - Guard symbols: 10 symbols at each end of the frame.
2. Repeat (1) for different roll-off factor values (e.g., 0.0, 0.3, 0.5, 0.7, 1.0) and use the following measurements to compare the generated signals.
   - Power spectrum of the frame samples and record the 99% bandwidth and transmission (or null-null) bandwidth. Assume a sample rate of 1e6 samples/s (*Not symbol rate!*)
   - CCDF of the frame samples and record PAPR.
   - Eye and polar diagrams of the data samples only.
3. Repeat (1) but using a rectangular filter and plot the spectrum of the generated frame. Compare it with the results obtained in (2)
4. As you know the optimum down-sampling index, down-sample the data samples to recover the symbols again, but with an offset of one sample. Do that for different roll-off factor values and plot the constellation diagram for each. Comment on the results.

NYQUIST FILTERING

5. Send and receive a frame, generated as in (1), using the following hardware setup: (*keep 0.5-meter distance between the devices*)
   - Tx:
     - Gain: -10dB
     - CenterFrequency: 2.4GHz
     - BasebandSampleRate: 1e6 Samples/s
     - RadioID: (select the serial number using `findPlutoRadio` command)
   - Rx:
     - CenterFrequency: 2.4GHz
     - BasebandSampleRate: 1e6 Samples/s
     - SamplesPerFrame: 40e3 Samples
     - GainSource: 'Manual'
     - Gain: 20dB
     - OutputDataType: 'double'
     - RadioID: (select the serial number using `findPlutoRadio` command)
6. Using the received data samples calculate SNR using EVM measurement.

7. Generate another frame as in (1) but with a root raised cosine filter (RCC). Send and receive using `receive()` function while enabling match-filtering. Using the received data samples, calculate SNR using EVM measurement. Compare the result with that obtained in (6). What is the advantage of match filtering?
8. Repeat (7) but without match filtering. Compare the power spectrums of filtered and non-filtered received samples. How do you describe the effect of match filtering?
9. Plot eye diagrams for filtered and non-filtered received samples. Compare the two plots; is RRC alone a Nyquist filter?

GAUSSIAN FILTERING

10. Build a frame like the one in (1) but with a Gaussian filter that has different time-bandwidth (BT) products (e.g., 0.3, 0.5, 0.7). For each transmission, plot the constellation diagram and power spectrum. Comment on the results. Does this filter meet the Nyquist criterion? How do you explain the interference at different BT values?