# ELL720: Advanced Digital Signal Processing

# Assignment 1

# Due date: $18^{th}$ February 2018

$11^{th}$ January 2018

### Range and Velocity Estimation of a Moving Target

Radar systems operate by transmitting electromagnetic waves, most commonly of microwave frequency, toward an object and receiving the waves reflected from it. The properties of the received radio waves, or echoes, are amplified and analyzed by a signal processor. The transmitter sends out short, very intense bursts or pulses of electromagnetic energy, with a relatively long interval between pulses. The receiver picks up echoes from the closest objects soon after the transmission of a pulse, from objects at intermediate range later on, and from the most distant objects near the end of the interpulse interval. When sufficient time has elapsed to permit the reception of echoes from the most distant objects of interest, the transmitter sends another short pulse and the cycle repeats. By measuring the time delay between the transmission of the signal and the reception of its echo, and knowing the speed of the wave, we can determine the distance to the object, which reflects the signal. The delay between the transmission of a pulse and the reception of an echo can be estimated using several methods. The two most frequently used methods are: End-point detection and Correlation processing.

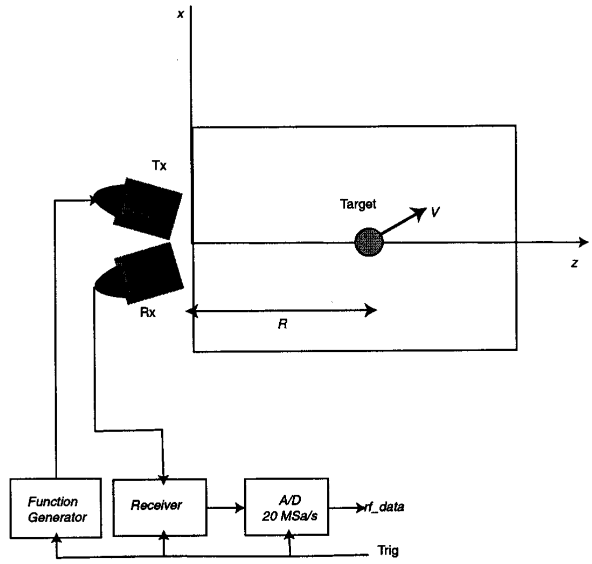


Figure 1: Experimental setup for collecting RF_data

In this assignment you will evaluate the efficacy of the above two methods in the following setting:

A pair of ultrasonic transducers operating in the frequency range of 1-5 MHz was used as transmitter and receiver in a water tank (see Fig. 1). Linear chirp pulses (1.5-4.5 MHz and $10\,\mu$s duration) are used to illuminate the target. Their echoes are sampled at 20 MSample/s through the receiving transducer. The target is a pendulum moving in the vicinity of the point of intersection of the axes of the Tx and Rx transducers. For simplicity, assume the pendulum motion is in the z-direction. RF data was acquired from 21 pulse-echo experiments and stored in a $500 \times 21$ matrix and is available here: `http://privateweb.iitd.ac.in/~seshan/rf_data.mat`. Each column represents data corresponding to echoes starting at a distance of 150 mm. Brief description of the data contained in the MAT-file is given below:

- `rf_data`: $500 \times 21$ matrix with each column formed from a sample echo with sampling frequency $f_s = 20$ Mhz,
- `timestamp`: $21 \times 1$ matrix representing the acquisition time in seconds, and
- `z`: $500 \times 1$ matrix representing the axial distance from the transducer in mm.

Using the above information:

- Determine the range and axial velocity profile of the moving target. Explore and compare two methods for accomplishing this task: correlation processing and end-point detection.
- Evaluate the performance of these algorithms in a noisy environment by adding Gaussian noise to the RF signal at different noise power levels representing different signal-to-noise ratios (SNRs).
- Understand the effect of pre-filtering on the accuracy of results obtained in a noisy environment.

You should prepare a report, giving a brief description of the algorithms you have implemented, compiling all your results and your interpretation of them, along with your overall conclusions. In particular, you should attempt to answer all of the questions posed above. Any graphs or other visualisations should also be included in the report. Make suitable assumptions where necessary and state them clearly in the report.