ES-244 Signals, Systems, and Random Processes
Instructor: Dr. Himanshu Shekhar
Assignment - 3

Instructions to submit:

- The submission has to be in the form of a zip file consisting of .m files for each question individually, proper readme file and Report with perfect explanations and plots.
- Zip file should be named as 'rollno_assignment2'.
- Each question should consist of its own individual .m file with proper commenting and should be named as 'QX rollno'(where X is the question no.).
- There will be deduction of marks if this format is not followed for submission.

Question 1:

Calibration of Ultrasound Transducer through Impulse Excitation

Ultrasound is widely used for medical imaging applications. To test a system, we need to characterize the subsystems (i.e., individual components). Ultrasound systems have a transducer which converts electrical energy to mechanical waves. To measure the impulse response of a transducer, we use a special receiver called a hydrophone. Consider the experimental setup of a water tank with a transducer and hydrophone. The ultrasound transducer generates ultrasound waves through electrical input (voltage). These waves propagate through the water and are received by a hydrophone, and are converted into voltage signals. We can measure the input voltage signal to the transducer and the received voltage signal through a Digital Signal Oscilloscope (DSO).

We measure the impulse response of the Transducer and calculate the Frequency response using Fourier Transform as follows:

1. We generate a practical impulse signal (very high amplitude ~200V, short duration ~few microseconds) through a pulse generator. The output of pulse generator drives the transducer.
2. The generated Ultrasound signal propagates through the water. The attenuation of the medium can be neglected as the transducer and Hydrophone are placed close (~ 5cm). Therefore the frequency response of water can be considered constant=1.
3. The hydrophone used to receive the Ultrasound signal has a broadband frequency response, constant gain for a wide rage of frequencies.
4. The output voltage measured through DSO is the impulse response of the transducer.

Given is the raw ultrasound data measured by the hydrophone. Plot the magnitude and phase spectrum of the signal received from the hydrophone. Also, measure the -3 dB bandwidth of the transducer from the received signal.

Note:
- In the file- hydrophone.csv, Column 5 contains hydrophone-measured voltage values, and column 10 has the time instants.
- Plot the magnitude spectra in dB scale.

Question 2:

This question requires you to calculate the essential bandwidth of a square pulse. The essential bandwidth (W) of any signal that contains a fraction β of the energy of the signal (τ) is given by:

$$\frac{1}{2\pi}\int_{-W}^{W}|X(\omega)|^2\,d\omega = \beta\tau$$

Using MATLAB, find the 90 % essential bandwidth of a unit amplitude rectangular pulse with a 1-second duration.

Question 3:

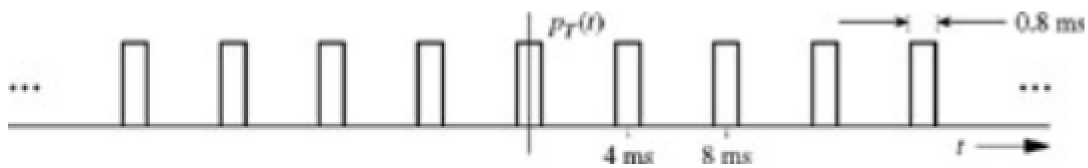
Generate the audio sequence using MATLAB and find its DFT
without using MATLAB inbuilt functions and compare your result with MATLAB built functions

Question 4:

Use the FFT function in MATLAB to compute the Fourier transform of e^{-2t} u (t). Plot the resulting Fourier spectra.

Question 5 (subjective):

A signal $x(t) = \text{sinc}(200\pi t)$ is sampled (multiplied) by a periodic pulse train $p_T(t)$ represented in the figure below. Find and sketch the spectrum of the sampled signal. Explain whether you will be able to reconstruct $x(t)$ from these samples. Find the filter output if the sampled signal is passed through an ideal lowpass filter of bandwidth 100 Hz and unit gain. What is the filter output if its bandwidth B Hz is between 100 and 150 Hz? What happens if the bandwidth exceeds 150 Hz?



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