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Problem 1: Write a function in MATLAB that simulates the train-horn-Doppler scenario discussed in lecture. Assume that the train tracks are rectilinear. Your function should adhere to the following interface:

```
function [fDVec,tVec] = ...
      simulateTrainDoppler(fc, vTrain, t0, x0, xObs, dObs, delt, N, vs)
% simulateTrainDoppler : Simulate the train horn Doppler shift scenario.
%
% INPUTS
%
% fc ------ train horn frequency, in Hz
%
% vTrain -- constant along-track train speed, in m/s
%
% t0 ------ time at which train passed the along-track coordinate x0, in
%           seconds
%
% x0 ------ scalar along-track coordinate of train at time t0, in meters
%
% xObs ---- scalar along-track coordinate of observer, in meters
%
% dObs ---- scalar cross-track coordinate of observer, in meters (i.e.,
%           shortest distance of observer from tracks)
%
% delt ---- measurement interval, in seconds
%
% N ------- number of measurements
%
% vs ------ speed of sound, in m/s
%
%
% OUTPUTS
%
% fDVec --- N-by-1 vector of apparent Doppler frequency shift measurements as
%           sensed by observer at the time points in tVec
%
% tVec ---- N-by-1 vector of time points starting at t0 and spaced by delt
%           corresponding to the measurements in fDVec
%
%+------------------------------------------------------------------------------+
% References:
%
%
% Author:
%+==============================================================================+
```

Plot the output of your function for various input values. For convenience, you may wish to use the script `topSimulateTrainDoppler_temp.m` on iLearn to set up the problem and call your function. This script also lets you listen to and record the audio time history.

Problem 2: Download the audio file `trainout.wav` from iLearn. This file was created with the following input argument values:

```
fh = 440;
vTrain = 20;
t0 = 0;
x0 = 0;
delt = 0.01;
N = 1000;
vs = 343;
```

Set up your simulator with these same values. Estimate the values of `xObs` and `dObs` by adjusting them in your simulation until you get an apparent received frequency profile that matches the one in the audio file.

Problem 3: In this problem, we'll examine the effects of a sampling clock frequency bias on Doppler estimation. Assume that some oscillator with a perfect clock produces a pure sinusoid of the form $x(t) = \cos(2\pi f_c t)$. The period of this signal is $T = 1/f_c$ seconds. Suppose that you receive this signal and make a measurement f_m of the signal's frequency as follows. You sample the signal with a local clock having a true sampling interval $\Delta t \ll T$ and you observe the number of sample intervals N (including fractional intervals) that fit within one period T. Thus, $N = T/\Delta t$. However, you don't know the true sampling interval Δt of your local clock; you only know its *nominal* value, Δt_{nom}, which is the sampling interval that would obtain if your clock were oscillating exactly at its *advertised* frequency (i.e., the one printed on the clock's data sheet). Thus, you take as your measurement of the period of the incoming signal the value $T_m = N \cdot \Delta t_{\text{nom}}$, from which you can obtain the measured frequency as $f_m = 1/T_m$. The apparent Doppler is obtained by subtracting the known frequency from your measured frequency, i.e., $f_D = f_m - f_c$.

If there is no motion between your receiver and the signal transmitter, and if your receiver's sampling clock was perfect, you would measure $f_D = 0$. But as with all physical clocks, your local clock has a frequency offset (bias). We characterize this offset with a ratio $\Delta f/f$ called the *fractional frequency error*. For example, suppose your clock is advertised to oscillate at 1000 Hz, but it actually oscillates at 1001 Hz. Then its fractional frequency error is $\Delta f/f = 0.001$. Derive an expression for the apparent Doppler f_D in terms of f_c and $\Delta f/f$.

Problem 4: GPS satellites direct their power toward the earth, but some power escapes around the edge of the earth and reaches geostationary satellites on the other side. What is the approximate power at a geostationary satellite?

Problem 5: Compare the cascaded noise figures of the following two systems. System A is a cable, followed by an amplifier, followed by a receiver. System B uses the same elements, but in the following order: amplifier, cable, and receiver. The cable has a loss of 5 dB. The amplifier has a gain of 20 dB and a noise figure of 2 dB. The receiver has a gain of 50 dB and a noise figure of 7 dB.

Problem 6: Consider a cable followed by an amplifier. The cable loss is 1 dB for every 100 m, and the amplifier noise figure is 7 dB. The source temperature is 290 K. How long can the cable be before the output signal-to-noise ratio is 5% of the input signal-to-noise ratio?