Signals, systems, acoustics and the ear
Lab 2: The frequency response of an acoustic tube

Introduction

To characterise a linear time-invariant system, we plot its *frequency response*. This shows the change in amplitude of sinusoidal signals passed through the system. The response at frequency *f* is simply the ratio of the output amplitude at frequency *f* to the input amplitude at frequency *f*.

In this experiment you will plot the frequency characteristics of an acoustic tube. You will do this for two sizes of the tube, to see how the measured response depends upon the volume of the cavity enclosed.

Data from this report will be needed for a future problem set, so be sure to keep it safe.

Objectives

- To understand the concept of frequency response.
- To learn the calculations necessary for the determination of a frequency response.
- To learn how to draw the graph of a frequency response.
- To gain further practice in the use of dB.

Apparatus

The system under study here is an acoustic tube whose length (and hence enclosed volume) can be varied by moving a piston through it. The volume of air in the tube is set vibrating by a signal from a sine wave oscillator played into a loudspeaker in the piston. A microphone in the piston records the changes in air pressure resulting from loudspeaker oscillations. The input amplitude is determined directly from the setting on the oscillator, and the output amplitude from the microphone is displayed on a voltmeter.

You will find that one particular sinusoidal input frequency in the range we investigate will result in a greater output than any other. This is known as the *resonant* frequency.

Method

Set the tube length to 100 mm. You must first find the resonant frequency of this tube (also known as the *centre frequency* of the resonance). With the sine wave generator at 100 Hz, slowly increase the frequency until the voltmeter connected to the microphone goes through a peak. (You may need to adjust the frequency of the generator up and down to be sure you have the peak accurately.) Note the frequency that produces the peak voltmeter reading: this is the resonant frequency of the resonator for the particular size of the tube you have set (100 mm). Leave the generator set to the resonant frequency and adjust the oscillator amplitude so that you get an **output** amplitude reading just above 9 mV on the output voltmeter.

Make measurements of the output using the voltmeter for frequencies in the region of about 100 Hz to 400 Hz. (The level of the input from the oscillator should not change with frequency, but you can check this with the input voltmeter). Choose enough frequencies so you can get a clear curve with enough detail for a peak to be seen. Following this, adjust the length of the tube to 150 mm, and do the set of measurements again.

Observations

Set out your results in two tables supplied, one for each set of measurements:

a) Input frequency (Hz)
b) Input amplitude (mV)
c) Output amplitude (mV)
d) Response (dB re input amplitude)
i.e., $20\log_{10}$(output amplitude/input amplitude)

Plot the two sets of measurements on the **same** graph with a horizontal axis of Frequency (Hz) and a vertical axis of Response (dB). It is probably best to do the plots as you make the measurements, so that you can ensure you are getting a sensible result.

Questions to think about

1. Comment on the shape of the response in the two sets of measurements and the effect of changing the size of the tube.

2. Suppose you measured the frequency response of a tube that was 200 mm long. How would the frequency response graph for this tube differ from the ones you measured? What about the frequency response for a 70 mm tube?

3. The system you measured here (everything in the tube, but not counting the oscillator and voltmeter) is actually composed of three of subsystems in cascade. What are these? What are their input and output signals?

length of tube			
Input frequency (Hz)	***Input amplitude (mV)***	***Output amplitude (mV)***	***Response (dB)***

length of tube			
Input frequency (Hz)	***Input amplitude (mV)***	***Output amplitude (mV)***	***Response (dB)***