EE 286: Digital Audio Signal Processing

Exercise 3: Threshold of Hearing

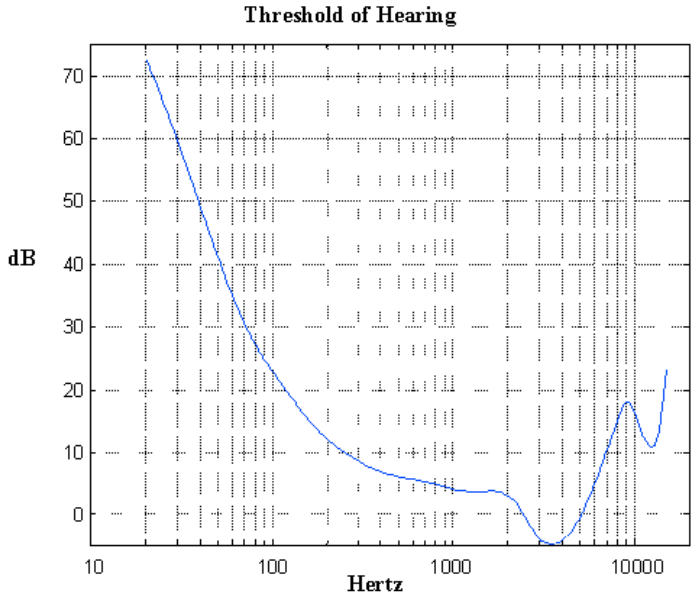
The human auditory system is sensitive to a wide range of sounds, both in terms of frequency (pitch) and intensity (loudness). Typically, a young person is able to hear frequencies ranging from 20 to 20,000 Hz. Humans can also detect sounds with intensities ranging over 13 orders of magnitude (powers of ten). In other words, the loudest sound a human can perceive is 10,000,000,000,000 times as loud as the softest sound that can be perceived.

When comparing sound intensities over such a wide range, it is inconvenient to keep lugging all of those zeros around, so units of decibels (dB) are commonly used instead. A decibel is defined as $10 \times \log(I / I_{ref})$, where I and I_{ref} are the two intensities being compared.

So if I is 10 times louder than I_{ref}, that corresponds to an increase of:
$10 \times \log(10/1)$ dB = 10 x 1 dB = 10 dB.

Decibels define a *relative* measure of sound intensity. In other words, it will tell you how much louder or softer one sound is than another. However, if we choose a fixed point for the reference intensity level, then we have an absolute measure of sound intensity. A reference level that is often used in human auditory science is Sound Pressure Level (SPL), the lower limit of human hearing, which is defined as 10^{-12} W/m^2, and is given a value of 0 dB (SPL).

Humans can hear a wide range of intensities and also, a wide range of frequencies. The lowest sound (in pitch) we can typically hear is about 20 Hz, and the highest sound 20,000 Hz. However, we are not equally sensitive at all frequencies. On average, the threshold of hearing of the human auditory system varies with frequency as shown in the following figure (ISO R226, 1961):



The objective of this experiment is to measure your threshold of hearing as a function of the frequency of the sound.

DEEE Building, Velasquez Street, University of the Philippines Diliman, Quezon City, 1101 Philippines
Tel: 981-8500 local 3300 TeleFAX: 925-2957 URL: http://www.eee.upd.edu.ph

Procedure:

1. Adjust the volume on your computer for proper playback of the tones.
    a. Use the best quality audio headphones available.
    b. Do your test in the quietest room available. Background noises will interfere with the sounds you are trying to hear, and may change your threshold values.
    c. Play the 3500 Hz file and adjust the volume so that you hear only the first 18 or 19 levels in the sequence. There are 25 levels in the file, so this means that you have adjusted the volume so that levels 20-25 are below your threshold of hearing.
    d. Write down the number of levels you can hear in the 3500 Hz sequence.
2. For a given frequency, generate a 0.1-second tone with an amplitude of 1. Use a sampling rate of 44100 Hz.
3. Listen to the tone. If you can hear the tone, reduce the sound intensity by 3 dB.
4. Listen again to the tone. Continue reducing the sound intensity until you cannot hear the tone and take note the corresponding sound intensity reduction.
5. Complete the table below to indicate the sound reduction until a tone is inaudible.

Frequency (Hz)	Sound intensity reduction (dB)	Frequency (Hz)	Sound intensity reduction (dB)
40		3500	
60		4000	
100		5000	
200		6000	
400		8000	
500		9000	
600		10000	
1000		11000	
2000		12000	
		15000	

6. Plot your result. Were you able to get a similar plot above?

Questions:

1. A 3 dB decrement corresponds to what fractional decrease in amplitude?
2. Using your results, how much "louder" does a tone at 40 Hz have to be compared to a tone at 3500 Hz in order to be perceived as equally loud? Give your answer both in dB, and as a numerical factor.
3. Repeat the experiment using 0.5-second tones. How does it affect your curve?

Together with your plots and answers to the questions, submit the Matlab script yoursurname_threshold.m. Compress your files as a zip file then upload in UVLE. **You are on your honor that your submission is your own work.**

Reference:
Science Buddies Staff. "Measuring Your Threshold of Hearing for Sounds of Different Pitches" *Science Buddies*. Science Buddies, 6 Oct. 2014. Web. 15 Aug. 2015 <http://www.sciencebuddies.org/science-fair-projects/project_ideas/HumBio_p011.shtml>

DEEE Building, Velasquez Street, University of the Philippines Diliman, Quezon City, 1101 Philippines
Tel: 981-8500 local 3300 TeleFAX: 925-2957 URL: http://www.eee.upd.edu.ph