

Tune-Up Tuesday for October 9, 2018

Virtual Bass. Human auditory systems have the ability to perceive a frequency that is not present when enough of its harmonics are. [1] This principle is used in virtual bass generation and the original telephone service. The latter system transmitted frequencies between roughly 300 Hz and 3300 Hz, yet the pitch frequency in human voices lies below 300 Hz. The human auditory system had the potential to perceive the pitch frequency when there was harmonic structure in the utterance (e.g. a vowel sound).

Write the MATLAB code for the following. Use a sampling rate of $f_s = 8000$ Hz.

(a) Generate/play a cosine signal at frequency $f_0 = 105$ Hz.

```
fs = 8000;
Ts = 1/fs;
f0 = 105;
Tmax = 5;
t = 0 : Ts : Tmax;
x = cos(2*pi*f0*t);
soundsc(x, fs);
% Most students reported that their laptop speaker(s) could not produce
% a tone at 105 Hz.
% Four students reported that they could hear the 105 Hz in their headphones
% even though they could not hear it when played over the laptop speakers.
% Two students reported that they could feel their laptop speakers vibrating
% when playing the 105 Hz tone even though the tone was not audible.
```

(b) Generate/play a signal with frequencies of 210 Hz, 315 Hz, 420 Hz, 525 Hz, 630 Hz, 735 Hz, 840 Hz, and 945 Hz, which are harmonics of 105 Hz. [2] Can you hear a 105 Hz tone?

```
fs = 8000;
Ts = 1/fs;
f0 = 105;
Tmax = 5;
t = 0 : Ts : Tmax;
x = zeros(1, length(t));
for i = 2:9
    x = x + cos(2*pi*i*f0*t);
end
soundsc(x, fs);
% About 1 out of 6 students reported hearing a 105 Hz tone.
% Students described the sound in part (b) as unpleasant. Two exceptions:
% 1. Sounds like the last part of Emergency Alert System sound, which
% starts with three long bursts of 70 Hz harmonics over 680-3000 Hz,
% continues with a pair of tones at 853 Hz and 960 Hz, and
% ends with three short bursts of 60 Hz harmonics over 680-3000 Hz.
% The Emergency Alert System sound is available at
% https://www.fema.gov/media-library-data/1499692075026-f85f137f1391f19963cb426bfa4a9330/EASheaders\(null\).mp3
% Save the sound file as EmergencyAlertSystemSound.mp3.
% [y, fs] = audioread('EmergencyAlertSystemSound.mp3');
% spectrogram(y, hamming(fs), fs/4, fs, fs, 'yaxis'); % 1 Hz resolution
% 2. Sounds like a woodwind instrument (e.g. bassoon) playing a chord.
```

[1] A description of the “missing frequency” effect comes from https://en.wikipedia.org/wiki/Missing_fundamental

[2] Principal frequencies correspond to the English phoneme ‘aw’ as reported on page 5 of <http://www.physics.indiana.edu/~courses/p109/P109fa08/11.pdf>