

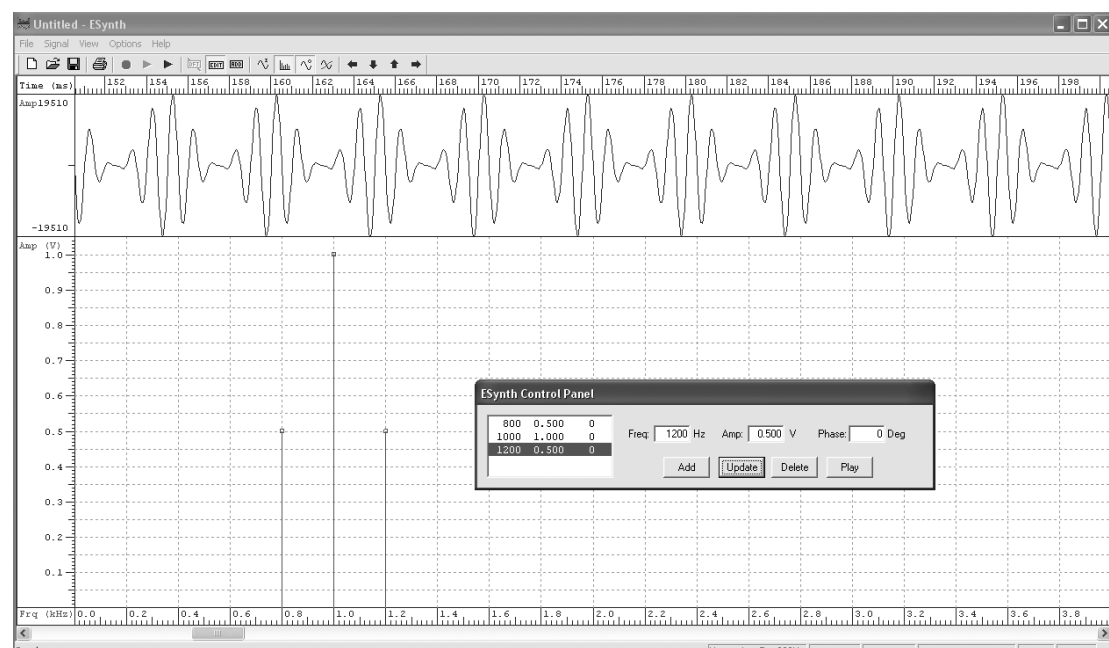
## AUDL4007: 2011. Week 3. Pitch Laboratory.

### *1/ Effects of relative phase on perception of complex tones.*

Pitch cues can be conveyed both by resolved harmonics and by the temporal details of the neural firing in response to the basilar membrane vibration due to several unresolved harmonics. This demonstration reflects the limits to the resolution of harmonics as made evident in effects of relative phase. You will use the program Esynth in the LAB programs folder to generate and listen to complex tones containing 3 adjacent harmonics.

Before you do anything else with Esynth check that “harmonise” is ticked on the options menu. And then select the button labelled EDIT (two to the right of the blue play button). This opens a control panel where you can specify the frequency, amplitude and phase of each harmonic. Note that specifying  $0^\circ$  phase in this program results in a sinusoid that starts at 0 and then goes up (normally known as sine phase), so that  $90^\circ$  phase results in a wave that starts at 1 and then goes down (normally known as cosine phase).

Start with the 4<sup>th</sup> 5<sup>th</sup> and 6<sup>th</sup> harmonics of 200 Hz. Give them all a phase angle of 0 and make the middle harmonic have twice the amplitude of the outer two. Select and zoom in to about 50ms duration of the waveform. Your screen should look like this.



Listen to the tone a few times. Use the double blue arrow button to play the whole sound and not just the zoomed selection. Then change the phase of the middle (1000 Hz) harmonic to 90 degrees (select the harmonic in the box on the left of the control panel, type 90 in the Phase box then click update).

Listen again. Do you hear any difference? To make it easier to compare, open the file AM\_QFM\_1000.wav into Wasp and play it. This contains both of these two sounds one after the other.

Compare the temporal details of the waveform for 0 and 90 degree phases of the middle harmonic? What is the time interval between major peaks in the waveforms in each case?

Now try with higher harmonics of 200 Hz: 1800, 2000 and 2200 Hz. You should hear a change in the quality of the sound when you change the phase of the middle harmonic. You may also hear a difference in the pitch or the pitch quality between the two sounds. Try to summarise the difference you hear –

You can hear both sounds one after the other by opening the file AM\_QFM\_2000.wav into Wasp.

How can you explain that the relative phase of the harmonics makes a difference to how we hear a combination of 1800, 2000 and 2200 Hz, but not for the combination of 800, 1000 and 1200 Hz?

How might you explain this effect of relative phase for the higher harmonic numbers?

NB When all three harmonics have 0 degree phase and the outer two are half the amplitude of the middle harmonic, the signal is identical to the result of applying a 200 Hz sinusoidal *amplitude* modulation to a single sine-wave with the frequency of the middle harmonic. When the middle harmonic has a 90 degree start phase, the resulting signal resembles the result of applying a 200 Hz *frequency* modulation to the middle harmonic. In the scientific literature on pitch, you will see the effects you explore here referred to as comparisons of FM and QFM (quasi-frequency modulated) tones.

## ***2/ Pitch discrimination with purely temporal cues compared to pitch discrimination for a harmonic complex tone***

Here you will measure your ability to hear a difference in a purely temporally coded pitch produced by amplitude modulation of noise. You will also measure pitch discrimination for a synthetic vowel sound. The modulated noise you hear in the purely temporal condition is modulated by the envelope of the vowel as would happen in the speech processing of a cochlear implant.

### **Method**

You will be using an adaptive technique in a three-interval, two-alternative forced-choice (3I-2AFC) format as implemented in a computer program known as Glimpse.

A fuller description of Glimpse can be found at:

<http://www.phon.ucl.ac.uk/courses/spsci/audper/HelpGlimpseNotch.htm>

Once Glimpse is loaded press the right mouse button and then select Tasks> Triples>Triples2AFC (with the left mouse button) and enter your initials so that you can find your results later. Then load the file Triples\_VSP.txt for the synthetic vowel or Triples\_V1.txt for the AM noise.

When you run the task each trial has 3 sounds. The variable sound will be either the 2<sup>nd</sup> or 3<sup>rd</sup>, never the 1<sup>st</sup>, and will always be HIGHER in pitch than the other two – although sometimes the difference will be too small for you to detect. The sounds vary slightly and randomly in loudness to ensure that you do not learn to answer correctly on the basis of slight loudness changes that may go along with changes in pitch.

When the adaptive procedure finishes use the right mouse button to access the ‘Toggle Data’ option to inspect the results. This will show you both an adaptive track as well as summary statistics. The adaptive track resembles the sequence of sound levels you would run through in measuring a PTA, and it should stabilize at the level at which you can hear the pitch difference correctly about 7 times out of 10. Your threshold is expressed as an arbitrary number from 1 to 47 which you can interpret as indicated below.

The fixed standard sound has an F0 of 80 Hz. Use the table overleaf to interpret the threshold value from Glimpse as a frequency difference in Hz (DLF) and a relative frequency difference limen (DLF/F).

Compare the threshold values that you get with the vowel and the AM noise and compare your results to the class as a whole. How might you explain the difference between the two conditions?

level	F0 comparison (Hz)	DLF (Hz)	DLF/F %	F0 difference in semitones
47	160.00	80.00	100.00%	12.00
46	143.29	63.29	79.12%	10.09
45	130.60	50.60	63.25%	8.49
44	120.80	40.80	51.01%	7.14
43	113.14	33.14	41.42%	6.00
42	107.07	27.07	33.83%	5.05
41	102.22	22.22	27.77%	4.24
40	98.31	18.31	22.88%	3.57
39	95.14	15.14	18.92%	3.00
38	92.55	12.55	15.69%	2.52
37	90.43	10.43	13.04%	2.12
36	88.68	8.68	10.85%	1.78
35	87.24	7.24	9.05%	1.50
34	86.05	6.05	7.56%	1.26
33	85.05	5.05	6.32%	1.06
32	84.23	4.23	5.29%	0.89
31	83.54	3.54	4.43%	0.75
30	82.97	2.97	3.71%	0.63
29	82.49	2.49	3.11%	0.53
28	82.09	2.09	2.61%	0.45
27	81.75	1.75	2.19%	0.38
26	81.47	1.47	1.84%	0.32
25	81.23	1.23	1.54%	0.27
24	81.04	1.04	1.30%	0.22
23	80.87	0.87	1.09%	0.19
22	80.73	0.73	0.91%	0.16
21	80.62	0.61	0.77%	0.13
20	80.52	0.52	0.65%	0.11
19	80.43	0.43	0.54%	0.09
18	80.37	0.37	0.46%	0.08
17	80.31	0.31	0.38%	0.07
16	80.26	0.26	0.32%	0.06
15	80.22	0.22	0.27%	0.05
14	80.18	0.18	0.23%	0.04
13	80.15	0.15	0.19%	0.03
12	80.13	0.13	0.16%	0.03
11	80.11	0.11	0.14%	0.02
10	80.09	0.09	0.11%	0.02
9	80.08	0.08	0.10%	0.02
8	80.06	0.06	0.08%	0.01
7	80.05	0.05	0.07%	0.01
6	80.05	0.05	0.06%	0.01
5	80.04	0.04	0.05%	0.01
4	80.03	0.03	0.04%	0.01
3	80.03	0.03	0.03%	0.01
2	80.02	0.02	0.03%	0.00
1	80.01	0.01	0.01%	0.00
0	80.00	0.00	0.00%	0.00