3.13.1.2: Vocal Formants

As in the case of a brass instrument, the shape and size of the resonance cavities in the body select some of the buzzing frequencies but diminish other ranges of frequencies. The nasal cavity, the oral cavity, the larynx, the trachea and the lungs are all air cavities that can have an effect on the sound being produced. Lets look at a simple example; buzzing sound fed through three Helmholtz resonators.

The buzzing sound produced by the vocal folds has a wide range of frequencies between $60\ \text{Hz}$ and about $7,000\ \text{Hz}$ when overtones are included (technically it is called pink noise which will be discussed in Chapter 18). Below is a diagram of the frequencies (in hertz) of pink noise; all frequencies are present but the amplitude gets progressively smaller for higher and higher frequencies.

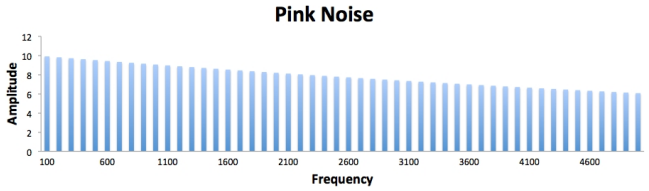
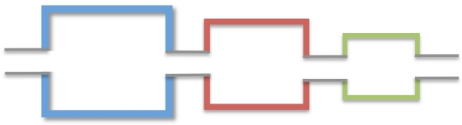


Figure 3.13.1.2.1

Suppose we have three Helmholtz resonance cavities, all linked together as shown in this figure:



Three Helmholtz cavities with different resonance frequencies.

Figure 3.13.1.2.2

These resonating cavities are of three different sizes so they will have three different resonance peaks (review Chapter 4 if you have forgotten what resonance is) as shown in the following figure.

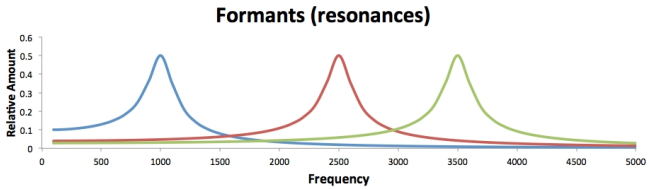


Figure 3.13.1.2.3

The result of feeding pink noise into the three different resonators is shown in the graph below (frequency in hertz). Notice that the available frequencies are now limited by an envelope as the result of the resonance cavities. This envelope imposed on the spectrum of available frequencies is called a ***formant***. Its particular shape is controlled by the shape of the resonance cavity.

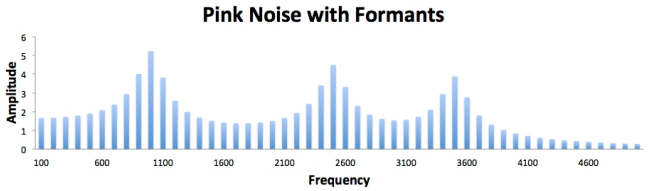


Figure 3.13.1.2.4

A simple model of the human vocal system is that of two resonance cavities, the mouth and the larynx. Both cavities change shape when you talk or sing but the mouth changes more. In the following figure the vocal tract is modeled for the sound 'ah' (written as /a/ in the International Phonetic Alphabet). If you think about what shape your vocal tract has when it makes this sound, the mouth

is very open. Below the vocal tract figure is a two cavity model with the first cavity (the mouth) bigger than the second. A sketch of the formant is also shown on the right. Notice that lower frequencies are emphasized over higher frequencies.

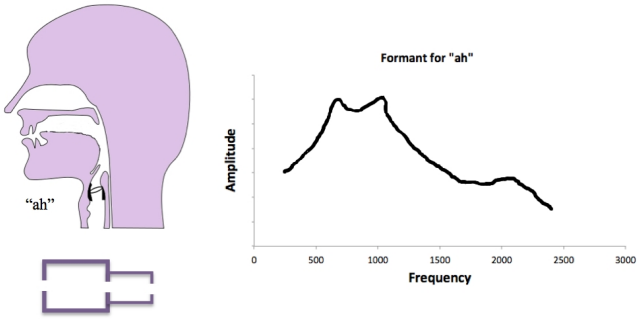


Figure 3.13.1.2.5

When you make the sound "ee" (written as /i/ in the International Phonetic Alphabet) the mouth closes up to make a small resonance cavity. The figure below shows the vocal tract, a two cavity model and the approximate formant. For this sound there is more sound at higher frequencies as seen by the three peaks on the right side of the graph.

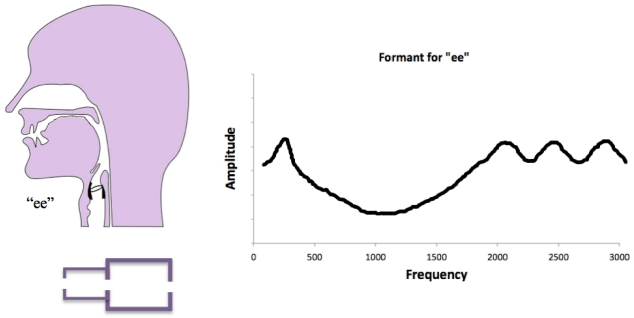


Figure 3.13.1.2.6

Here is a graph of formant vowel frequencies. The graph shows the first two formants of English vowel sounds. Notice that the /i/ sound ("ee" as in the word 'seat') for most speakers lies in the upper left of the graph so the first formant has low frequencies and the second formant has high frequencies. The /a/ ("ah" as in the word 'sought') for most speakers lies towards the lower right; high first formant frequencies and second formant frequencies lower than for /i/.

Because the mouth cavity and larynx are so flexible, a wide variety of formants can be made resulting in a wide variety of sounds. Try saying the words "heed", "hid", "head", "had", "hod", "hawed", "hood", "who'd". How does your mouth and larynx structure change for each sound?

Video/audio examples:

- Here is a video of a talking mouth, created by scientists at Kagawa University, Japan. You will notice something is missing in the sounds. This is because the robot only produces formants; it does not have a tongue or lips to produce the other phonemes needed for speech.
- Here is an interactive graph of formant vowel frequencies.
- The vowel formants, in Canadian English.
- Formants, explained with sample frequencies.
- Formants, explained with sample frequencies and MRI images.