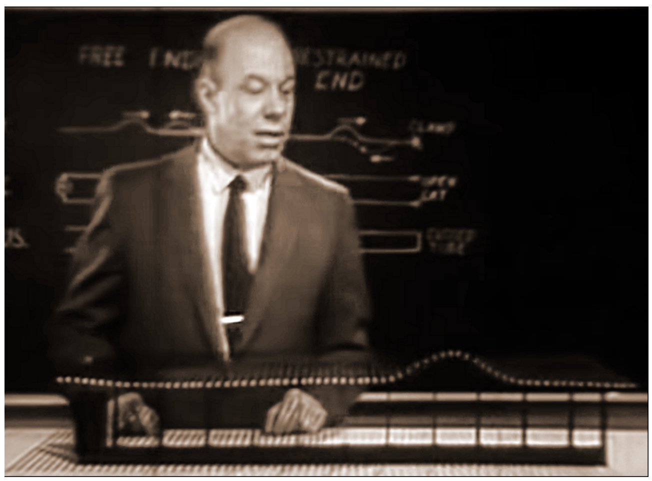
Subtractive Music Synthesis

As opposed to *Additive Music Synthesis*, or the way in which synthetic sounds can be created by combining several tones, *Subtractive Music Synthesis* shapes sounds by removing frequencies through filtering.

Properties of waves (such as resonant frequency) are similar for mechanical, acoustic, and electrical waves. A Bell Laboratory film, Similarities of Wave Behavior, provides one of the clearest explanations of these properties.

The Bell Lab scientist, John Shive, developed a mechanical wave machine consisting of metal bars attached to a central wire. Bearings allowed the bars to pivot independently, allow Shive to demonstrate the way in which a mechanical wave rippled through the wave machine.



The resonant frequency of the wave machine was equal to the length of time that it took a mechanical wave to propagate to the end of the machine and back. For example, if it took the wave one second to travel to the end of the machine and one additional second for the reflected wave to return to the beginning point, the resonant frequency of the wave machine would be 30 times per minute. Tapping the first bar of the wave machine to start a new wave every two seconds would result in an optimal amplitude of the wave.

When waves were propagated at a rate other than every two seconds, the new wave collides with the previous reflected wave in the middle of the machine. As a result, some of the energy is dissipated by the collision when the frequency is not at the optimal rate of 30 times per minute.

An acoustic wave in a tube has characteristics that are similar to mechanical waves in a Bell Lab wave machine. Sound travels at a rate of about a thousand feet per second. (The precise speed of sound is 1,125 feet per second at sea level when the temperature is 68 degrees.) Therefore the wavelength of a 100 Hz sound would be 11.25 feet (i.e. 1,125 feet per second divided by 100 Hz). Consequently, the resonant frequency of an open-ended 11 foot tube would be approximately 50 Hz (dictated by the time required for the sound wave to travel to the end of the tube and back again).

The physicist Heinrich Reubens developed a method visualizing the bands of rarefication and compression in a sound wave by drilling a series of holes in a tube filled with propane gas. More gas escapes from the tube at the points of higher pressure, resulting in taller flames.

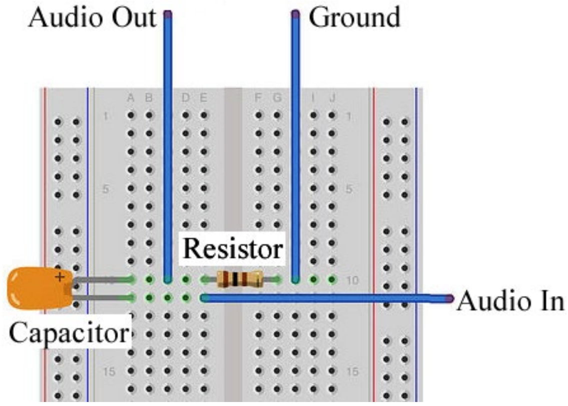
A similar effect can be obtained by placing styrofoam pellets in a sealed glass tube. The peaks and valleys that result also show the points of rarefaction and compression created by the sound waves.

These visualization tools demonstrate the relationship between frequency and wavelength of an acoustic wave form. They can be used to illustrate the effect of filtering on the amplitudes of the frequencies displayed. The peak amplitude of the waveform will be at its highest when the frequency of the tome matches the resonant frequency of the tube. The amplitude of other frequencies will be diminished. It is important to note that these frequencies are not blocked completely. Rather, the intensity of these frequencies is decreased.

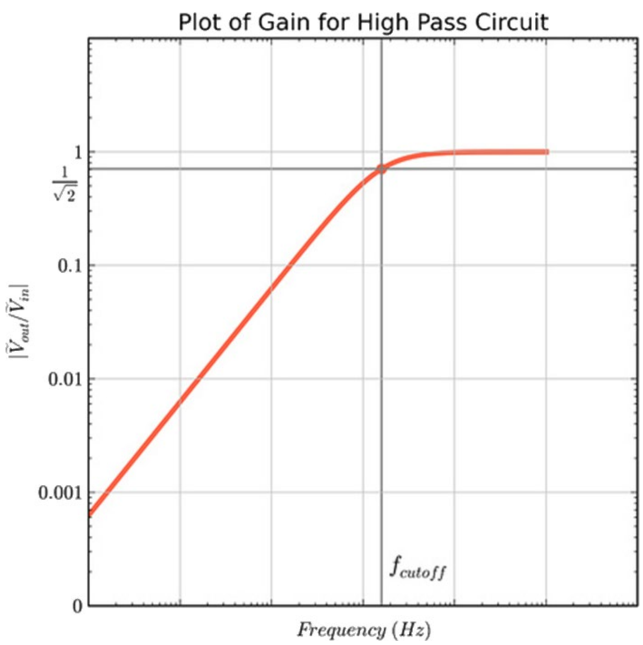
The extent to which this occurs can be plotted by using a tube with a sound level meter at one end. A speaker at the other end of the tube can be used to play tones of varying frequencies. The sound level meter will register its highest reading when the frequency of the tone matches the resonant frequency of the tube.

A sound can be converted into an electrical signal by a transducer such as a microphone or a guitar pickup. The electrical circuit that transmits the converted audio signal also has a resonant frequency. Consequently, electronic filters are also feasible. This characteristic of electrical circuits is the basis of subtractive synthesis in electronic music synthesizers.

The simplest electronic filter consists of one resister and one capacitor.



When the amplitude of the frequency of the incoming audio signal is compared to the frequency of the output audio signal, the greatest amplitude will be registered for the higher frequencies. Below a cutoff frequency, the amplitude of the signals measured begins to diminish.



The controls on the Caustic SubSynth filter can be adjusted to create a cutoff frequency for three types of filters: a high-pass filter (that passes the higher frequencies), a low pass filter (that passes the lower frequencies), and a band pass filter (that passes frequencies in the middle of the spectrum).