Basic Talk about Sound

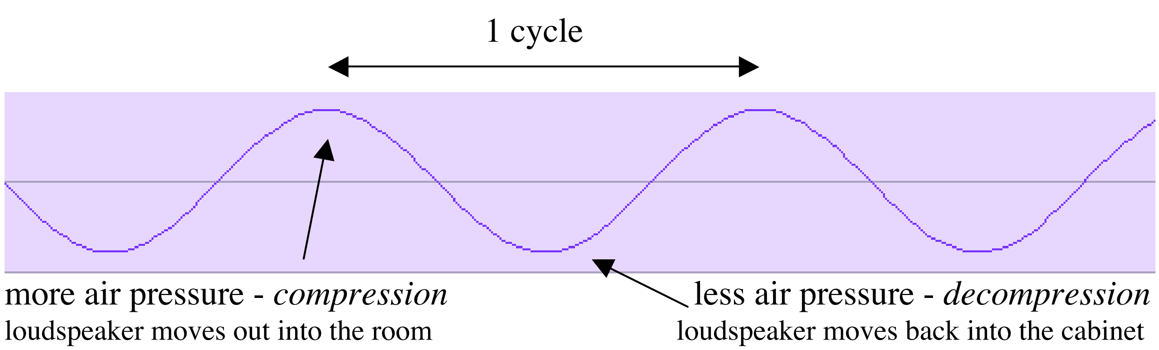
What is sound? First of all, it's a physical phenomenon which we experience with one of our senses, the sense of hearing. Sound can be described both in subjective terms (effect on the listener) and objective terms (as waveform energy), Usually, we mean sounds that can be heard by the human ear. But just as there are forms of 'light' that we can't see (infrared, ultraviolet, etc), there are also sounds that we can't hear (very high pitched bat sonar, for example). So we usually limit our discussions to sounds in the range of human hearing. There's a range of volume and a range of pitch that we can hear.

Sound comes in the form of a pressure wave. The pressure wave is like ripples on a pond. The wave has peaks and troughs, between 20 Hz and 20,000 of them per second. This is called **frequency**. And waves also have a certain amount of intensity, or energy. This is called **amplitude.** In the pond, amplitude would be how high the waves are.

Waves and Waveforms

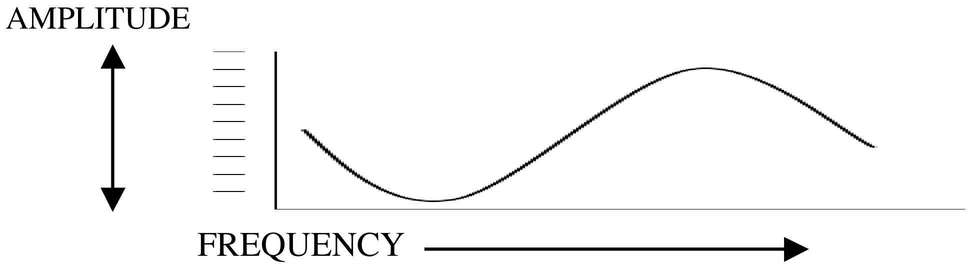
The energy generated by a sound-making event, such as hitting a snare drum or speaking a word, is transmitted through the air in the form of *waves*. This is called 'propagation'. **Sound propagates through the air at about 1130 feet per second.**

Wave propagation is the pushing and pulling of the air molecules by a sound source such as a loudspeaker, which creates compression and decompression of the air. This to-and-fro motion eventually reaches our ears, where it's translated into meaningful sounds by our eardrums and our brains.



Sound can travel through air or through solid materials. When you speak to someone, or listen to your stereo, the sound is traveling through the air. When you can hear a party going on next door through your apartment walls, the sound is traveling through a solid material.

The picture of a wave is called a waveform. When you see an image of a waveform (like in Cubase or ProTools), it may look something like this:



Frequency is measured horizontally, over time. The higher the frequency, the more up and down motions there will be in a given period of time. If the graph above represented a duration of 1 second, then this waveform would have a frequency of 1 Hz.

Amplitude will be measured vertically. At any given moment in time, the sound has a certain amplitude. You can see in the graph above that the amplitude is constantly changing as time passes. The waveform has an amplitude which appears to be about 100%. That is, its highest and lowest points are pretty close to the edge of the graph.

<u>Frequency</u> of a Waveform - Hertz (Hz)

The *frequency* of a waveform is the number of waveform cycles that are completed each second. It is measured in Hertz (Hz). Low frequencies (like 100 hertz) sound like low notes on the piano. Higher frequencies (like 2000 hertz) sound like high notes on a flute. The rumbling of a streetcar is a very low frequency (transmitted through the ground). The squealing of the streetcar's metal wheels is a high frequency (transmitted through the air). The sound of a human voice is a mid-range frequency. So is the sound of an alto saxophone, or an acoustic guitar.

The tuning note of an oboe at the beginning of a symphony concert has a frequency of 440 Hz. A common test tone in the broadcast industry is 1000 Hz, or 1 kHz.

The human ear can hear frequencies from 20 Hz to 20,000 Hz. We would say the range of human hearing is 20Hz-20Khz. This range gets narrower as we get older, because our eardrums grow weaker and less elastic, just like our skin.

In the studio, we break frequencies up into 'bands'. There is a low band, a low midrange band, a midrange band, a high midrange band, and a high band. A low-cost mixer will sometimes offer 2 or 3 bands of EQ. The low band is also called Bass, and the high band is also called Treble.

<u>Amplitude</u> of a Waveform - Decibels (dB)

Amplitude means the intensity of the wave. We can use decibels (dB) to measure volume, amplitude, power, sound pressure, intensity, and so on. Confusing? Well, for now, just remember that the **decibel** (dB) is based on powers of 10.

For example, if we multiply the sound power by about 10, it will seem 'twice as loud' to the average listener. For example, it would require 10 violins playing together to 'double' the loudness of 1 violin. And it would take 100 violins (!) playing together to 'double' the loudness of 10 violins. Since our ears can tolerate a really wide range of volume changes, the numbers on the dB meters on your mixer would get really huge, really soon! Imagine if you wanted to turn up the snare drum by about six times its current volume. You'd have to have a marking on the meters of 1,000,000! No way! So instead, you can use dB.

Doubling the intensity of a sound is measured at 3dB. Intensity is a measurement of power (watts).

Doubling the pressure of a sound (SPL) is measured at 6dB. Sound pressure is the force of the sound energy on the eardrum or on a microphone.

Some experts say that increasing the SPL by 6dB sounds twice as loud. Others say that increasing it by 10dB sounds twice as loud.

For this course, when we're talking about microphones and ears, we'll say that 6dB is "twice as loud".

<u>Loudness – A Subjective Measurement</u>

When we hear a sound, we might say it's loud, or very loud, or very soft. But 'loudness' is not a precise way of measuring, like decibels are.

Loudness is the *subjective* word for how loud a sound seems to be. It's how we describe our perception of the sound. Some sounds may *seem* to be louder than others, or softer, although if we measured the sound scientifically, the opposite might be true.

Here's an example. If you're outdoors in a city neighborhood, and you sneeze, it may not seem very loud. BUT if you're in a very quiet library or museum, the same sneeze can seem deafening! This is an example of the word *subjective*.

It's really important for a mixing engineer to realize that when a certain sound, like the lead vocal, isn't loud enough, it may not be because it doesn't have enough amplitude. It might be because it doesn't have enough clarity, or presence, or because it is not panned into the center of the mix. Making the vocal 'sound' louder might require EQ or compression, or processing, or panning, and not just 'turning it up'.

Just Noticeable Difference – JND

How small a change in volume can you hear? If I raise the volume control on my stereo, how many decibels do I need to add before you would say it's louder?

The Just Noticeable Difference (JND) is the minimum amount of change in dB that can be noticed by the human ear. *The JND turns out to be about 1 decibel*. Most people cannot hear a volume change of less than 1 dB.

There's also a JND for pitch. Most people cannot hear a change of pitch that is smaller than about 5 cents. There are 100 cents in a semitone, so a 5 cent change of pitch is pretty small.

Period of a Waveform

- The *period* of a waveform is the time needed to complete one full cycle of the waveform. It's measured in seconds or milliseconds, and it depends on the frequency.
- A test tone with a frequency of 10 cycles per second (10Hz) has a period of 1/10th of a second, or 100 milliseconds. Each cycle of the waveform takes 1/10th of a second, or 100 milliseconds, to pass.
- Knowing the *period* of a waveform helps us to figure out how timing problems will affect the different frequencies of a sound in an acoustic space.

$$\text{PERIOD (in milliseconds)} = \frac{1000}{\text{frequency}}$$

Wavelength of a Waveform

- The *wavelength* of a waveform is the physical distance needed to complete one full cycle of the waveform. It's measured in feet, and it depends on the frequency.
- A test tone with a frequency of 10 cycles per second (10Hz) has a wavelength of 113 feet. Sound travels at about 1130 feet per second, and 10 cycles squeezed into that space would be 113 feet long each.
- Knowing the *wavelngth* of a waveform helps us to figure out how room dimensions will affect the different frequencies of a sound in an acoustic space.

$$\text{WAVELENGTH (in feet)} = \frac{1130}{\text{frequency}}$$

The Speed of Sound (SOS)

Just as we speak of the 'speed of light' which is VERY fast, we can also speak of the 'speed of sound'. The speed of light, according to most astronomers, is fixed, at 186,000 miles per second. But the speed of sound is variable. The speed of sound (SOS) depends on the medium through which the sound is traveling, and the temperature of the medium. A ***medium*** could be air, water, a wall, etc. In acoustics, the most important medium is the air.

Air temperature has a big effect on the speed of sound. If the air temperature is 10 degrees C, the speed of sound is about 1107 feet per second. And at 20 degrees C, 'room temperature', the speed of sound is close to 1126 feet per second. Finally, at 30 degrees C (a hot afternoon, an outdoor concert) the speed of sound is almost 1145 feet per second. Sound speeds up as the temperature increases.

Temperature	0 deg C	10 deg C	20 deg C	30 deg C
Speed of Sound	1087 fps	1107 fps	1126 fps	1145 fps

For this course, we'll agree that the speed of sound is 1130 feet per second (fps).

<u>Threshold of Hearing</u>? / <u>Threshold of Pain</u>!

In professional audio situations, like recording sessions, acoustic treatment, or live sound mixing, we need a basic sense of how 'loud' something typically is. The chart below gives you some idea of how loud *loud* really is. Imagine what each of these sounds is like. I've defined the Threshold of Hearing for you down below. The Threshold of Pain should be self explanatory!

Noise Source	***Decibel Level***	***Noise Effect***
Jet takeoff at 25 meters . . .	**150 dB**	**Eardrum rupture**
Earphones at high vol . . .	140	**Danger!**
Jet takeoff at 100 meters . . .	130	**Danger!**
Thunderclap, Live music, Chainsaw .	**120 dB**	**Threshold of Pain**
Steel mill, Car horn at 1 meter . .	110	Major ear damage
Lawnmower, motorcycle . . .	100	
Busy urban street, food blender . .	90 dB	Ear damage after long exposure
Garbage disposal, Piano . . .	80	Minor ear damage
Vacuum cleaner, shouting. . .	70	Annoying
Bar conversation, office, dishwasher .	60 dB	Harder to hear ordinary speech.
Quiet suburb, conversation at home .	50	Comfortable
Library	40	
Quiet rural area	30 dB	Quiet
Whisper, rustling leaves . . .	20	Very Quiet
Breathing	10	Almost inaudible
Threshold of Hearing . . .	**0 dB**	Minimum level at **which we perceive** sound waves.

Although there can be sound waves (really just pressure waves) <u>below</u> the Threshold of Hearing, the average human being would never know it!

THE MORAL OF THE STORY:
Wear good quality earplugs when the situation warrants it!