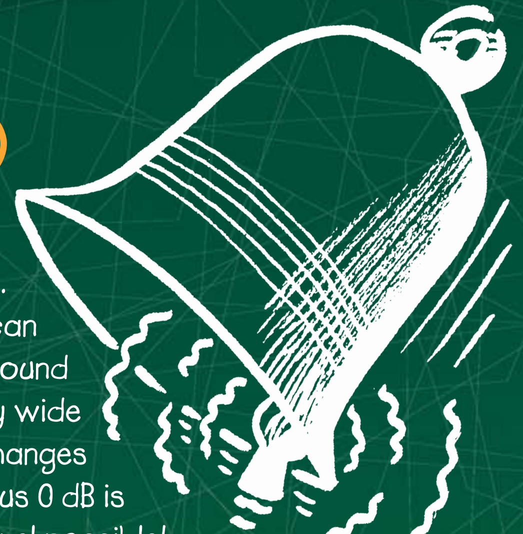
NPL National Physical Laboratory

Acoustics

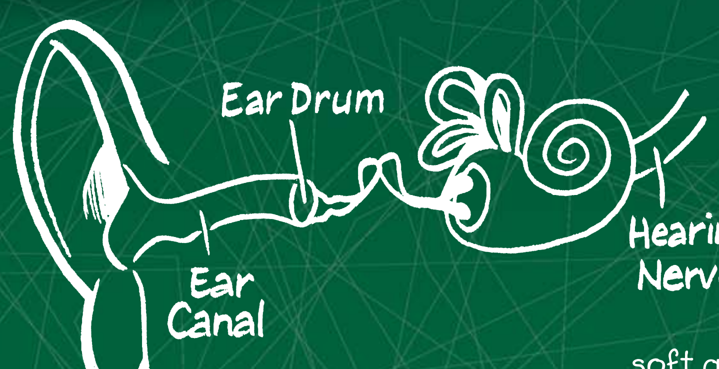
Acoustics is the name given to the branch of science that deals with sound. The scientific study of sound attempts to characterise, quantify and describe sound. Acoustics originated with music, showing the close relationship that exists between art and science. Acoustics is based fundamentally on the study of motion: the movement of a source (e.g. the voice), the propagation of acoustic waves through a medium (e.g. the air) and the subsequent detection of the movement by a receiver (e.g. the ear).

The Decibel (dB)



In the measurement of sound, we are concerned with the amplitude of the acoustic pressure, measured in pascals (Pa). The range of acoustic pressures that the human ear can detect is very wide - from the lower limit of hearing at around 20 µPa (2×10^{-5} Pa) to the threshold of pain at around 20 Pa. This very wide range of values is unwieldy, so it is converted into a logarithmic decibel scale. This changes the range of values shown above to the more manageable range of 0 dB to 140 dB. Thus 0 dB is roughly the lowest level a normal person can hear, but it is not the lowest level possible!

Hearing



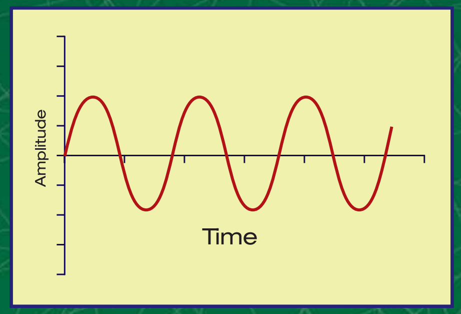
Audible sounds enable communication and they can tell us what and where things are. They certainly have a significant effect on how we feel. The human ear is an organ of complex design and function. The ear forms the receiver and transmission line to the brain, which then processes this information and converts the received signal into something that we can understand. The sound is then perceived as loud or soft, as a high or a low note, or on a more general level, perhaps as noise, or as music.

Measurement of Sound

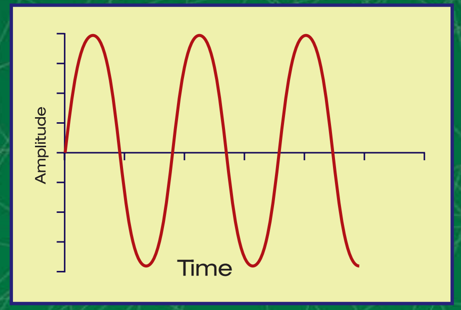
The measurement of sound determines how loud something is, whether it is too noisy, or even whether it is safe to be near. The National Physical Laboratory (NPL) measures airborne sound using microphones consisting of a sensitive element that converts the acoustic pressure into a proportional output voltage which can then be measured. The output of the microphone can be filtered to match the sensitivity of the human ear.

NPL microphones are calibrated against a source which is traceable to base units of measurement (the kilogram, metre, second). Through international comparisons with other standards laboratories, NPL's realisation of the acoustic pascal is checked on a regular basis. Using these calibrated microphones, other sound sources may then be characterised; these may themselves be used to calibrate other microphones. In this way, manufacturers and users of acoustic equipment can demonstrate that their equipment is traceable to national standards.

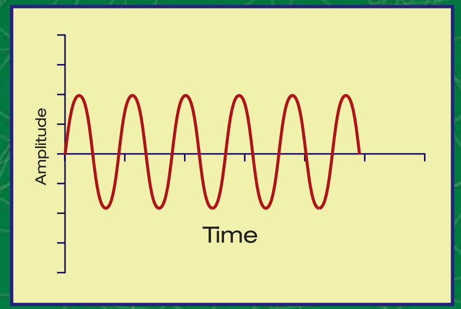
Sound Waves



Transmitted sound



Increased strength of source



Exciting the sound source

Sound is transmitted via the movement of the particles in a medium, such as air or water. Energy is transferred from one region to another via a series of compression and tension cycles: the motion of the particles is parallel to the propagation direction. The acoustic disturbance can be represented as a wave, with the x-axis representing time, and the y-axis the displacement of a given particle in the medium from its rest position.

Increasing the strength of the sound source extends the displacement of the particle, and so the acoustic pressure will also increase. This is heard as an increase in loudness.

Exciting the sound source more rapidly increases the frequency of the sound, and produces more cycles in a given period. This is heard as an increase in pitch.

Two basic quantities that can describe the nature of a sound are frequency and amplitude (of displacement or acoustic pressure). Sounds can be formed by a simple harmonic mixture of frequencies (as produced by a guitar string), an intentional mixture of frequencies and amplitude (music) or a seemingly random mixture of frequencies and amplitudes (noise).

Frequency

The frequency or pitch of sound is measured in hertz (Hz), or cycles per second. The general range of hearing for young people is 20 Hz to 20 kHz. The upper frequency limit decreases with age, and so the older a person gets, the less well they can hear high notes. The male hearing range decreases more quickly than the female, so women can generally hear higher pitch notes than men of similar age.

Underwater Acoustics

Underwater acoustics covers a wide range of applications, from sea-bed imaging to submarine detection, from whale-tracking to diver communication, from mine-hunting to oil exploration. But why use sound underwater? In the turbid, saline environment of the sea, sound signals can travel for thousands of kilometres and with techniques such as sonar, shipwrecks can be found and fish stocks counted - all using underwater sound.

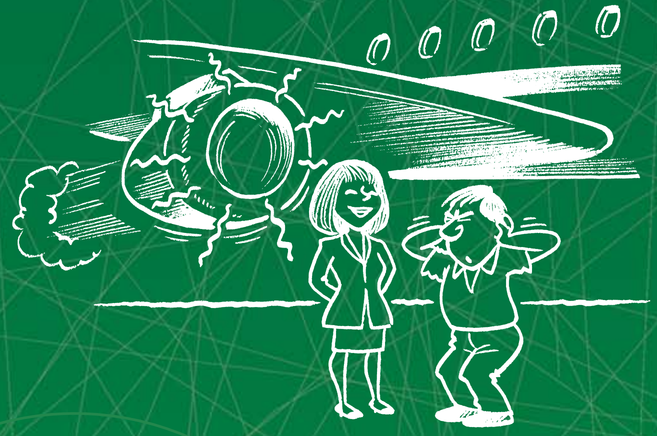
Ultrasound

Sound that is beyond the upper limit of human hearing is termed ultrasound and generally refers to frequencies above 20 kHz.

Many people are familiar with ultrasound as a way of looking inside the human body: specifically, for imaging unborn babies. Measurement of ultrasound fields is carried out at NPL using hydrophones, which are simply microphones designed to operate under water. NPL is involved in developing standards in this area, to ensure that the safe track record of medical ultrasound is maintained. However, there are many other applications of ultrasound, such as cleaning, industrial processing and testing in the aircraft industry.

Courtesy of ATL Medical Systems

Noise



Noise is an important form of pollution caused by unwanted sound. At low levels noise can be a nuisance, but exposure to sustained high levels, for example in a noisy workplace, can cause hearing loss. Impulsive noise, such as the sound of a pneumatic tool, or tonal noise, such as the whine of a machine, can be particularly irritating. Studying subjective noise response is also important.

Animal Acoustics

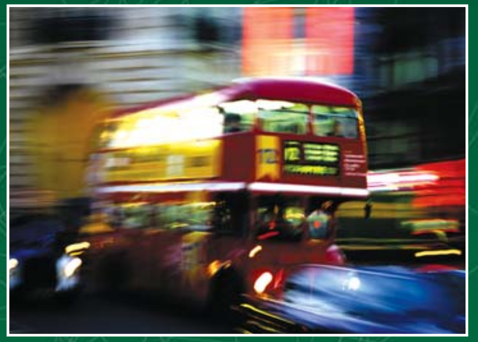
Like humans, animals communicate by sound. In some species the frequency of sound used is far above the limit of human hearing - and is hence ultrasonic. Bats can fly and navigate in darkness by echolocation, whereby they produce short bursts of sound.

The ocean is awash with sound, as dolphins, whales and even snapping shrimp all join in the chorus. Bottlenose dolphins produce characteristic "clicks" of sound at frequencies up to 150 kHz which are used in echolocation when feeding. Dolphins also produce whistles with each individual having a unique "signature" consisting of sound in the range 4 kHz to 20 kHz lasting for a few seconds. In this way they can communicate with other dolphins, vital for a social animal in an environment of limited visibility.

How Noisy is...

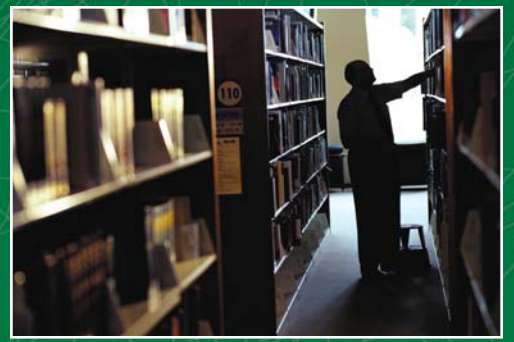
Plane 125 dB

Pneumatic Drill 105 dB



Heavy Traffic 90 dB

Business Office 65 dB



Library 35 dB

Quiet Forest 15 dB

Threshold of Hearing 0 dB

If you have a measurement query contact us on: telephone: 020 8943 6880 e-mail: enquiry@npl.co.uk or visit: www.npl.co.uk