

Acoustics Essentials – fundamental concepts

In the first in a series of educational articles, **DIRK NOY**, Walters-Storyk Design Group (WSDG), introduces the acoustic concepts that he will elaborate on in future issues.

While we may sometimes think — or maybe the manufacturers make us believe — that it's all about the gear, let it herewith be known that many of the fundamental building blocks for the creation of audio have been around significantly longer than even the most vintage piece of audio equipment. One of these building blocks deals with the generation, transmission and reception of sound waves — acoustics is the domain of science that studies mechanical pressure waves in gases, liquids, and solids including vibration, sound, ultrasound and infrasound. The word 'acoustics' is derived from the Greek word akoustikos, meaning 'for hearing, ready to hear' and that from akoustos, 'heard, audible', which in turn derives from the verb akouo, 'I hear'. In fact, some of the earliest contributions to acoustics — harmonic intervals and the first principles of wave mechanics — came from the Greek philosophers and scientists Pythagoras and Aristotle.

The Latin synonym for acoustics is 'sonic' and the Romans also made their contributions; the engineer and architect Vitruvius studied the acoustical properties of theatres, including discussion of interference, echoes, and reverberation, which may well be the early beginnings of architectural acoustics. The Age of Enlightenment brought with it a further dramatic increase in scientific observations and studies. Galileo Galilei, Leonhard Euler, Joseph Fourier, Isaac Newton, Lord Rayleigh, Hermann von Helmholtz and Wallace Clement Sabine, to name a few, are most certainly among the timeless personalities in acoustics.

CAUSE AND EFFECT — In any acoustical process, such as an earthquake, a rock concert or a sonography scan we can identify the five basic steps shown in the diagram.

There are many types of intentional and unintentional causes, like an atmospheric discharge, dropping a Chinese vase, or physically pressing a key on a grand piano's keyboard. The following transduction process transforms energy from some other form into sonic energy — such as the grand piano's hammer that hits a set of strings whereby the strings start to vibrate and will produce clearly defined sound waves.

These created sound waves then travel through the medium (in our case it's usually air) while transporting energy until the sound waves reach a point where they are transformed into other forms of energy, such as a microphone which transforms incoming sound waves into tiny bits of electrical current that can be amplified, processed and recorded. The final effect may be purely physical, or it may reach far into biological or psychological domains.

The central stage in the acoustical process is the wave propagation. Sound waves can be fully described by studying their pressure levels and their frequency distribution.

SOUND PRESSURE — The Sound Pressure is the local pressure deviation from the ambient atmospheric pressure caused by a sound wave. Sound Pressure in air can be measured using a microphone. The international standard unit for Sound Pressure is the Pascal (Pa). The Sound Pressure Level (SPL) is a logarithmic measure of the effective sound pressure of a sound relative to a given reference value. It is measured in Decibels (dB) above a standard reference level. The commonly used 'zero dB' reference sound pressure in air is 20µPa RMS, which is considered the threshold of human hearing. The SPL level can easily be measured using handheld devices. The dynamic range of human hearing spans 0dB (threshold of hearing) to about 120dB (threshold of pain).

FREQUENCY — Frequency is perceived as pitch — low frequency numbers correspond to bass notes, high frequencies correspond to high notes. Human hearing extends over a frequency range of about 20Hz to 20kHz. The frequency content of a given signal can be analysed and displayed by use of a Real Time Analyzer (RTA) in which the number of lights represent the level that is present at a particular frequency.



From left: **Hermann Ludwig Ferdinand von Helmholtz (1821-1894)** and **Wallace Clement Sabine (1868-1919)**.



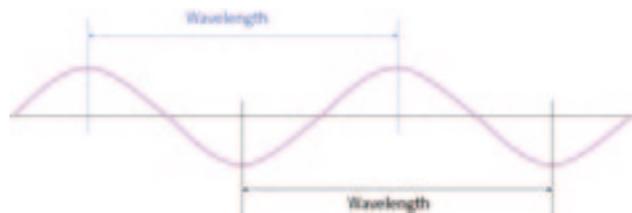
Fundamental cause-and-effect diagram.



Simple Sound Pressure Level meter



Boombox spectrum analyser.

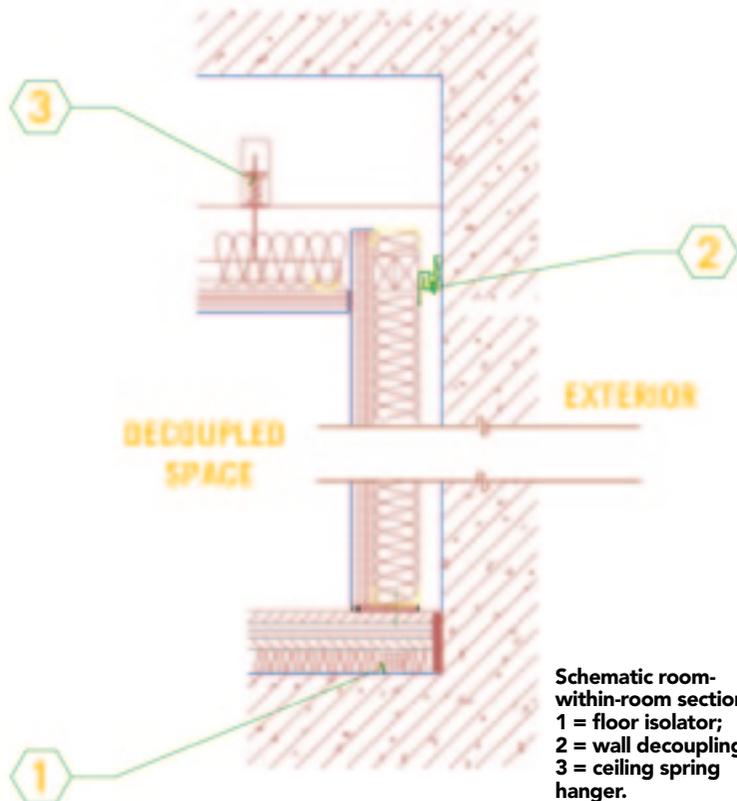


Wavelength.

Directly coupled to frequency is the concept of the wavelength. This is measured in meters and describes the physical dimensions of a sound wave; similar to waves in water their wavelength is measured from crest to crest. Low frequencies do — perhaps surprisingly — have substantial physical proportions, their wavelength can measure up to 15 meters and more.

Frequency [Hz]	Wavelength
32	10.68m
63	5.34m
125	2.67m
250	1.34m
500	1.34m
1k	66.8cm
2k	33.4cm
2k	16.7cm
4k	8.35cm
8k	4.18cm
16k	2.09cm
c=334m/s	

Frequencies and their corresponding wavelengths.



ACOUSTICAL TRANSDUCERS — A transducer is a device for converting one form of energy into another. In an acoustical context, this means converting sound energy into electrical energy (or vice versa). Electroacoustical transducers include loudspeakers, microphones and pickups (for instruments or turntables). These devices convert a sound pressure wave to or from an electrical signal. The most widely used transduction principles are electromagnetism, electrostatics and piezoelectricity.

ROOM ACOUSTICS VERSUS STRUCTURAL ACOUSTICS — Room acoustics and structural acoustics are two entirely different branches of acoustics. Room acoustics discusses the behaviour of sound within a room — the focus is on the geometry of the space, the properties of surfaces, sound sources, furnishings and furniture. Structural acoustics is involved when it comes to transmission of sound signals to neighbouring zones, where these can be other rooms in the same facility or outside it. The main issues here are the internal structure of walls, floors and ceilings, and other construction elements, such as doors and windows. This is specifically critical at low frequencies, where parts of the structure can be excited to mechanical vibrations. These in turn can then be radiated as airborne sound, which the less music-loving family next door will not appreciate. Structural acoustic issues can be modified by the introduction of physical mass and mechanical decoupling, which ultimately leads to complex room-within-room construction technology.

Although in this series we promise not to have too much maths, there's one equation that I specifically want to point out.

$$c = \lambda f$$

c = Velocity of Sound [m/s]
 λ = Wavelength
f = Frequency [Hz]

Equation

This is one of the basic equations in acoustics. The most interesting way to look at it is to understand that *c* (the velocity of sound) is a constant, hence the equation shows the dependability of frequencies ('what you hear') upon dimensions ('what you see') — can there be a nicer reference to connect architecture and acoustics? Stay tuned for the next article in the series, where we will explore this precise subject in much more depth. ■

Walters-Storyk Design Group (www.wsdg.com), founded by John Storyk and Beth Walters, has designed more than 3000 media production facilities in the US, Europe, the Far East and Latin America. WSDG credits range from the original Jimi Hendrix Electric Lady Studio in Greenwich Village to New York City's Jazz At Lincoln Center performance complex, broadcast facilities for CBS and WNET, and corporate clients such as Hoffman-La Roche and T-Mobile. Recent credits include private studios for Timbaland's Tim Mosley, Tracy Chapman, Aerosmith, Green Day, Jay-Z, Goo Goo Dolls, Bruce Springsteen, R. Kelly and Alicia Keys. WSDG is a seven-time winner of a TEC Award for outstanding achievement in Acoustics/Facility Design. The firm maintains offices in New York, San Francisco, Argentina, Brazil, Beijing, Switzerland, Germany and Spain.