International Association of Geophysical Contractors

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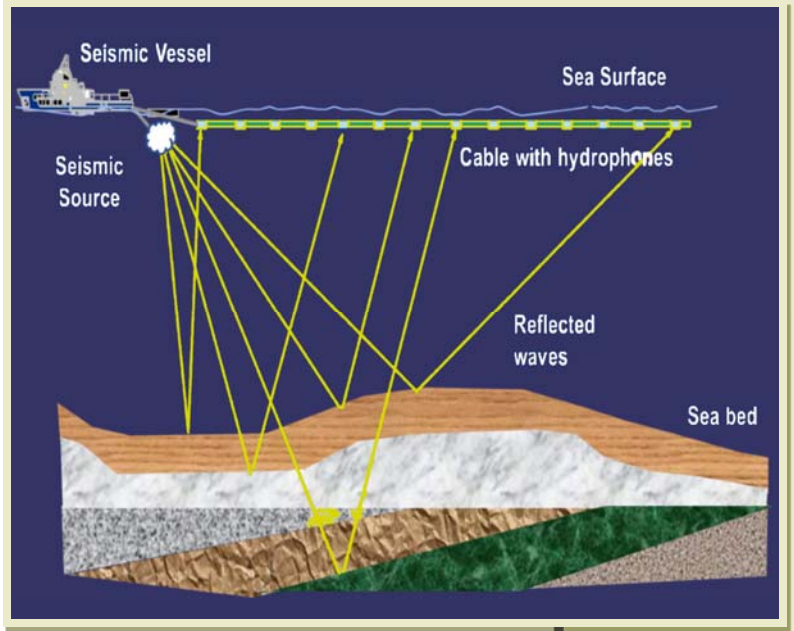
# Fundamentals of Sound in the Marine Environment

## What Is Sound?

Sound is a vibration or pressure wave that transmits energy from its source through a medium such as air or water. Sound pressure waves will alternately compress and decompress as they travel away from their source through a medium, such as air or water. The compressions and decompressions associated with sound waves are detected as changes in pressure and are then perceived as sound by a human ear or other acoustic receiver (such as a microphone or hydrophone) that may be in the path. The pressure fluctuations (amplitude or height of the sound pressure wave) determine the loudness. The decibel (dB) system is used to express the relative loudness (amplitude) of sound. The decibel system is logarithmic, which results in an exponential scale being represented as a linear scale, like the Richter scale that expresses the strength of earthquakes. Decibel is not a measuring unit, but a ratio that must be expressed using a reference (benchmark) value (See *Sound in Water in Not the Same as Sound in Air* section). Also, sound pressure levels are not to be confused with sound intensity (power), which is the acoustical energy emitted by a sound source over a specified unit of time. Sound pressure is what our ears hear and what sound meters measure.

Frequency is another measure of sound. It is the number of pressure waves that pass by a reference point per unit of time and is measured in Hertz (Hz), or cycles per second. To the human ear, an increase in frequency is perceived as a higher pitched sound, while a decrease in frequency is perceived as a lower pitched sound. Humans generally hear sound waves where frequencies are between 20 and 20,000 Hz. Similar to the differences in hearing between humans and bats or dogs, some marine mammals hear well at higher frequencies and relatively poorly at lower frequencies. Others hear better at lower frequencies.

Specific ocean sounds are classified as transient, such as a pulse or as continuous, which is ongoing. Continuous sound can include ambient or background noise. Ambient or background noise is any sound other than the primary sound being monitored.




## Sound in Water is Not the Same as Sound in Air

Confusion arises because sound levels given in dB in water are not the same as sound levels given in dB in air. A 150 dB sound in water is not the same as a 150 dB sound in air. This is equivalent to reporting temperature, in which it is important to specify the reference level, as 50 degrees Celsius is not the same as 50 degrees Fahrenheit. When reporting sound levels, it is important to not only specify "dB", but also the reference level. For sounds in water, the reference level is expressed as "dB re 1 μPa" – the amplitude of a sound wave's loudness with a pressure of 1 microPascal (μPa).

The reference level for sound in air is "dB re 20 μPa." The amplitude (loudness) of a sound wave depends not only on the pressure of the wave, but also on the density and sound speed of the medium (air, water) through which the sound is traveling. Because of such environmental differences, 62 dB must be subtracted from any sound measurement under water to make it equal to the same sound level in the air.

Sound travels further in water than it does in air because water is denser. However, in both air and water, the loudness of a sound diminishes as a sound wave radiates from its source. In air and water, the sound level reduces by 6dB as the distance doubles whereas in water. As in air, underwater sound is also subject to additional attenuation as it interacts with obstacles and barriers, water temperature differences, currents, etc. Because sound level in water halves (i.e. 6dB reduction) as the distance doubles, high levels of sound are only experienced very close to the source and the loudness diminishes very quickly close to the source and more slowly away from the source.

Find out more at www.iagc.org

# *Seismic Surveys and Sound in the Marine Environment*

The ocean is filled with sound. Underwater sound is generated by a variety of natural sources such as wind, waves, and marine life as well as underwater volcanoes and earthquakes. There are also man-made (anthropogenic) sounds in the ocean which include shipping, commercial and recreational fishing, pile-driving for marine construction and dredging and military activities.

The geophysical and offshore oil industry relies on transient sound - in the form of seismic surveys - to determine the location of hydrocarbon deposits. Seismic surveys are used to define geological structure below the sea floor by sending low frequency (5 to 200Hz) acoustic sound waves into layers beneath the sea floor and recording the time it takes for each wave to bounce back, while also measuring the amplitude of each returning wave. The sound is transient and temporary. Once the survey is complete, the sound is no longer part of the ambient environment. Transient sounds of this nature also do not accumulate in the marine environment.

The sound produced during seismic surveys is comparable in loudness to many naturally occurring and other man-made sound sources. The seismic surveys are predominantly carried out in a frequency range well below 200 Hz. Approximately 98% of all the acoustic energy in a seismic pulse is within this band.

| Sound Source: | In Air (dB re 20µPas @ 1m, rms) | In Water (dB re 1µPa @ 1m, rms) |
|---|---|---|
| **Continuous:** | | |
| Whisper at 1 Meter | 20 dB | 82 dB |
| Normal Conversation in Restaurant | 60 dB | 122 dB |
| Live Rock Music | 110 dB | 172 dB |
| Thunderclap or Chainsaw | 120 dB | 182 dB |
| Large Ship | 118-128 dB | 180-190 dB |
| Jet Engine at 1 Meter | 180 dB | 242 dB |
| Underwater Earthquake | 207 dB | 269 dB |
| **Impulsive:** | | |
| Bottlenose Dolphin | 145 dB | 207 dB |
| Sperm Whale Click | 174 dB | 236 dB |
| Seismic Array | 178 dB Theoretical* | 240 dB Theoretical* |
| Lightning Strike | 186 dB | 248 dB |

* For a source array, the actual maximum sound output is less than the theoretical back-calculated value, typically some 15-25 dB less. (See page 21 of Reference Source 5).

## Additional Resources on the Fundamentals of Sound in the Marine Environment

1. Fundamentals of Underwater Sound - OGP: http://www.ogp.org.uk/pubs/406.pdf.
2. Discovery of Sound in the Sea: www.dosits.org.
3. Seismic and the Marine Environment: http://www.appea.com.au/wp-content/uploads/2013/05/Seismic_and_the_Marine_Environment.pdf.
4. Seismic Surveys & Marine Mammal, OGP & IAGC: http://www.iagc.org/media/files/page/OGP_IAGC_doc_Seismic-Surveys-Marine-Mammals-Position-Paper_VF_2004.pdf
5. An Overview of Marine Seismic Operations, OGP & IAGC: www.ogp.org.uk/pubs/448.pdf.
6. Airport Noise Law: http://airportnoiselaw.org/dbleels/html.

## *IAGC Vision Statement*

***The International Association of Geophysical Contractors is the most credible and effective voice for promoting and ensuring a safe, environmentally responsible and competitive geophysical industry.***