UNDERWATER ACOUSTICS

Underwater Acoustics — What is it?

Underwater acoustics is the science of utilizing sound waves underwater as a method of navigating, communicating or detection. This technology is also used to determine profiles of the earth's layer immediately below the ocean (sub-bottom profiling).

How does it Sound underwater?

Making a wave (Figure 1).
The most common way to generate an underwater acoustic signal is by creating an electronic signal that is then converted into mechanical energy. The mechanical energy is then transmitted in to the water as a sound wave which acts very much like the waves created by throwing a small pebble into a quiet pond (Figure 1). Sound underwater travels at the speed of 5000 ft (1500m) per second which is about five times as fast as it travels in air. This is due to water being a much denser medium. As a rule, the denser the medium, the faster sound will travel through it.

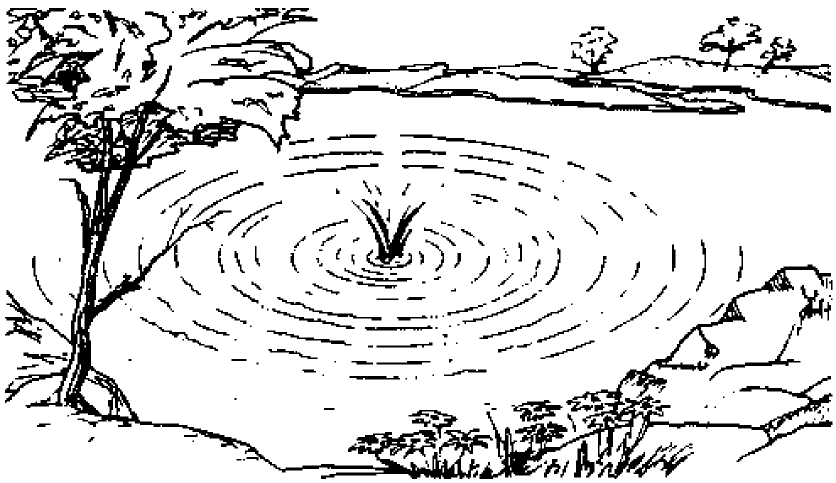
Figure 1. Making a wave.

What affects 'sound' underwater? — The Path of Sound

Sound waves travel in direct paths over limited distances and work on the concept called "line-of-sight." This means that an underwater acoustic signal will be best received when the receiving system is in the direct "line-of-sight" of the transmitting unit. Acoustic signals can be blocked by large natural or man-made objects much as a bridge or hill can block your favorite radio station.

When a sound wave or acoustic signal is being transmitted near a large object, a "zone of silence" or "shadow zone" is formed on the backside of such object and reception of the signal is blocked or greatly diminished. Shadow zones may be eliminated by moving away from such objects until a clear line-of-sight is reestablished.

What affects 'sound' underwater? — Sound and thermoclines

Sound waves in water will be reflected or refracted (bent) by thermoclines. a thermocline is the boundary between layers of water with different temperatures or densities. The lower layer will always be denser (heavier) and since denser water is colder, it will have a lower temperature than the upper layer. As mentioned earlier, the denser the medium, the faster sound will travel through it. Therefore, the colder the water, the faster sound waves will move through it. A thermocline acts like a fine mesh screen. Most signals will be reflected, but some will get through yet get distorted due to the change in speed. When transmitting through one or even several thermoclines, it is best to make the acoustic signal as strong as possible in order to compensate for the losses that will result.

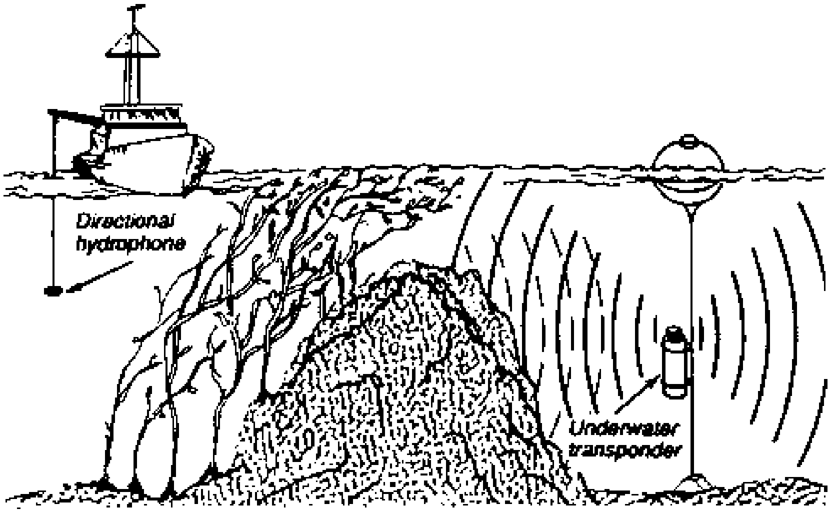

Figure 2.

What affects 'sound' underwater? — Noise, air, salt and their effects on sound.

Sound waves underwater are also affected by biological or man-made noises. Most warm waters have a high concentration of marine growth and life. These areas usually have high biological noise which is most commonly created by small marine animals such as shrimp and mussels. The range of an acoustic signal may be greatly reduced since it is being "drowned out" by the noise. Manmade noise such as engine noise or vibrations can have the same effect.

Most marine growth, like kelp, also has a high concentration of oxygen and therefore releases air bubbles. Air bubbles absorb and scatter sound waves, thereby distorting the acoustic signal and greatly reducing its range.

Sound waves in the water will be affected by the water's salinity (salt-content). A high salinity will cause the acoustic signals to be dispersed, absorbed or scattered, thereby reducing the distance the acoustic signal will travel.

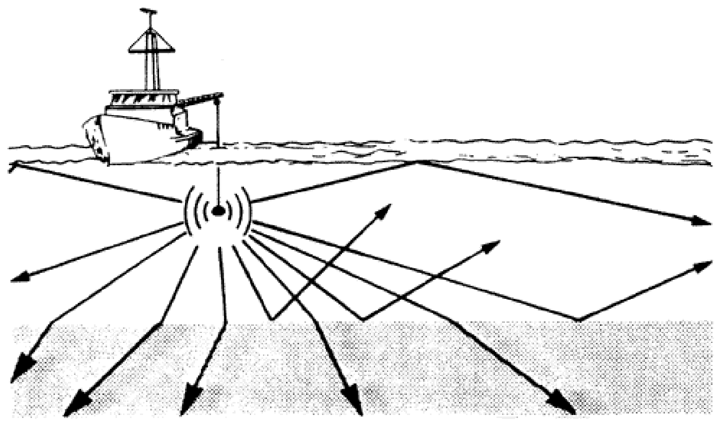

Figure 3.

The mechanics of making sound-underwater. — The frequency of sound.

Underwater sound waves can be generated in the frequency range from as low as 1KHz (one thousand cycles or waves per second) to as high as 500 KHz (five hundred thousand cycles per second). Most underwater acoustic equipment operates in the frequency range of 10 KHz to 100 KHz. As a rule, the lower the frequency of an underwater acoustic signal, the farther it will travel through water. For example, a 12 KHz acoustic signal will travel farther than a 50KHz signal if both are transmitted with the same amount of power.

The mechanics of making sound-underwater. — The power of sound.

We have already described how the frequency of a sound wave will effect the distance it will travel underwater. Another determining factor in how far a sound wave will travel is the power with which it is driven. As a rule, the higher the power of the acoustic signal, the greater the distance it will travel through the water. The strength of an underwater acoustic signal is measured in "watts" or decibels, also refereed to as dB's When measuring in decibels or dB's, a reference is required to provide a standard. Typically, a reference of l uPa (micro Pascal) at a distance of 1 yard is used. Listed below is a reference/conversion table for the most commonly used power ratings for underwater acoustic signals:

Acoustic Power Conversion Chart

Watts	dB re: 1uPa @ 1 yd	dB re: 1ubar @ 1 yd	dynes/cm
0.125	162.5	62.5	1300
0.25	165.5	65.5	1900
0.50	168.5	68.5	2700
1.00	171.5	71.5	3800
2.00	174.5	74.5	5300
10.0	181.5	81.5	11900
20.0	184.5	84.5	16800
40.0	187.5	87.5	23700

100	191.5	91.5	37600
200	194.5	94.5	53100

*To convert from 1 yard reference to 1 meter reference, subtract 0.78db's from each number.

The sound wave or acoustic signal is created by a "transducer" which is a technical term for an underwater antenna. The transducer converts electrical energy into mechanical energy (vibrations) which in turn create the sound waves. A transducer, depending upon the application, can transmit as well as receive. The heart of the transducer is a piezo-electric ceramic element, usually in the shape of a tube, which is then encapsulated in polyurethane. Applying an electric signal (voltage) to this piezo-electric ceramic element will cause it to alternately contract and expand thereby creating a pressure or sound wave. Thus a sound wave or acoustic signal is transmitted through the water.

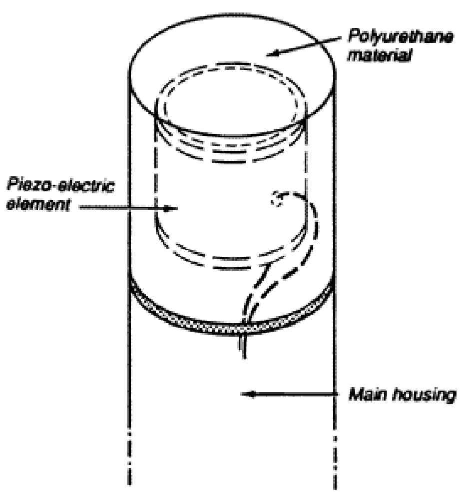

Figure 4.

The size of the transducer is determined by the frequency that is to be transmitted. As a rule, the lower the frequency of the signal to be generated, the bigger the diameter of the transducer. This is due to the fact that the piezo-ceramic tube will be most efficient when operating at its natural resonant frequency and the larger the diameter of the tube, the lower its resonant frequency will be. To give you an example, a 12 KHz transducer may have a typical diameter of 4 in. (10cm) whereas a 50 KHz transducer will have a diameter of less than 1 in. (2.5cm). An analogy would be if you bang on a large drum you will get a low tone or low frequency note; whereas, if you bang on a small drum you will get a high tone or high frequency note.

When a transducer is being used as a receiving antenna, it is generally referred to as a "hydrophone." It receives or detects an acoustic signal and then converts this signal from mechanical energy into electrical energy which is then processed by electronics. Most hydrophones receive in an omnidirectional pattern which means they can detect signals from any direction. These types of hydrophones are called listening hydrophones. They are commonly used to study biological noise as a reference standard for testing, for detection of noise made by vehicles such as submarines or for underwater acoustic survey work. When it is necessary to determine the direction or the source of an underwater acoustic signal, a specially designed hydrophone is utilized.

The mechanics of making sound-underwater. — The intelligence behind the sound.

Acoustic signals can be created in various different forms, shapes or frequencies with varying power outputs. The characteristic of the signal are determined by the "electronics module" which is the brain of the system. We can also encode information such as data or voice transmission onto the acoustic signal. The type of acoustic signal and necessary electronics are determined by the specific application. An underwater pinger requires a straight pulse at a given frequency whereas a wireless underwater communication system will require a carrier frequency (similar to AM or FM) in which the audio or voice information is encoded. Generally, the more complex the application, the larger the electronics package will be. Power consumption is determined by the efficiency of the electronics and how powerful a signal will need to be created. The stronger the signal, the higher the power consumption. This is an important factor since most underwater electronics are powered by batteries and therefore offer a limited operating life. getting the most life out of a battery is a key consideration in the design of underwater electronics.

So far we have discussed all the major components of how to create an underwater acoustic signal. Now we have to take our transducer or hydrophone, the electronics and the batteries and package them into a housing. We can't just use any kind of housing since we are working in the most hostile environment on earth. The major factors affecting our underwater housing are pressure and corrosion. Pressure is one of the biggest factors to consider when designing an underwater housing. Pressure underwater increases proportionately with depth. For every 10 meters (33Ft) of depth, the pressure increases by 14.8 lbs. per square-inch or one atmosphere (see Depth to Pressure Chart on page 7). So, if a housing has to operate at a depth of 3300 ft (1000m), it is subjected to a pressure of 1480 lbs. per square-inch or 102 Bars (atmospheres)!

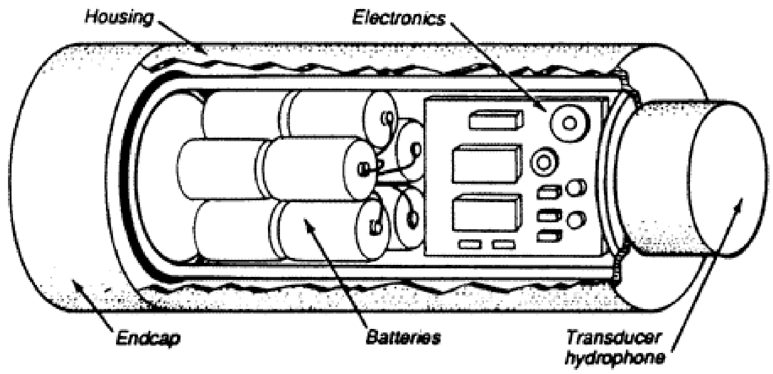

Figure 6.

Another big factor effecting our housing is corrosion. Since ocean water contains salt, minerals and chemicals which will cause many kinds of materials to corrode, we have to carefully consider the material we want to use. The best type of material to use is plastics since they are non-corrosive; however, most plastics have limits with regard to holding up under extreme pressure and can therefore only be used for applications in shallower depths. Besides plastics, the best materials to use are marine grade stainless steel or chemically treated aluminum which makes it resistant to corrosion.

The most commonly used shape for an underwater housing is a cylindrical design. This is due to the fact that the pressure is evenly distributed on the surface of a cylinder due to its geometric shape. The electronics and batteries are installed inside this cylindrical housing with the transducer mounted on one end and an endcap on the other. To allow access to the batteries and/or electronics, the endcap is designed to be removable. To insure that the endcap does not allow water to leak into the housing, it must be designed with some type of seal. The most commonly used and most effective seal is what is called an "O" ring seal. An "O" ring seal uses a ring made of rubber which is fitted into a groove that is cut into the side of the endcap. When the endcap is pushed into the housing, the "O" ring is compressed and forms a perfect seal between the inside of the housing and the endcap.

Depth to Pressure Chart

DEPTH IN METERS	DEPTH IN FEET	PRESSURE P.S.I.G.	PRESSURE BARS
50	164	74	5.101
100	328	148	10.202
150	492	222	15.303
200	656	296	20.404
250	820	370	25.505
300	984	444	30.606
400	1312	592	40.808
500	1640	740	51.01
600	1969	888	61.21
700	2297	1036	71.41
800	2625	1184	81.61
900	2953	1332	91.81

General Summary

- A sound wave is created by converting electrical energy into mechanical energy via a transducer.
- Sound in water travels about five times as fast as it travels in air.
- Sound waves travel in direct paths based on the “line-of-sight” concept.
- Sound waves will be reflected or distorted when traveling through a thermocline.
- Sound waves will be affected by biological or man-made noise, air bubbles and salt.
- Most underwater acoustic equipment operates in the frequency range of 10 to 100 KHz
- The lower the frequency of a sound wave, the farther it will travel.
- The higher the acoustic power output of a soundwave, the greater the distance it will travel.

- A transducer is an underwater antenna that converts electrical energy into sound waves.
- The lower the frequency of a soundwave, the bigger the diameter of the transducer.
- A receiving-only antenna is called a hydrophone.

Reader feedback, requests, recommendations.

This publication is intended to familiarize people with the basic principles of underwater acoustics without going into great technical detail. We will always be looking for improvement and look forward to receiving your input on how to do that. Whether you have a comment, a request to include additional information, a recommendation on how to better illustrate a principle or a suggestion for words to be added to the glossary, please let us know! Write us, FAX us or just call us! We value your opinion and look forward to hearing from you.