SONAR Technology for Fish Finders

Compiled and Annotated

By

Nolan Laxamana
GetFeetwet Navigation Inc

Special Thanks
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Zack Floyd of GEMECO
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Explained: SONAR Technology of Fish Finders

Table of Contents

Introduction

The goal of this white paper is compile authoritative papers and literature on sonar technology with focus in sonar technology as it is applied to fish finding applications. This white paper will filter out the technical jargon that normally plaques serious sonar literature without reducing the white paper to anecdotes similar to those found in manufacturer marketing literature. This white paper will distinguish between the true science and technology versus the marketing hype that is generated by well-funded marketing campaign.

We will start with a brief overview of sonar and how it works. We will then discuss the hardware components that comprise a sonar system. From there, we will move on to the various sonar technology currently being incorporated by the fish finder manufacturers , including CHIRP (compressed high intensity radar pulse) that promises dramatic gains in sonar target definition and depth penetration. Finally, we will look at the current trend in fish finder technology and what kind of products and pricing we can expect from manufacturers implementing these new technologies.

Chapter 1: Overview

The Physics of Sound in Water

“It is clear to anyone who has immersed himself or herself in a lake or ocean that sounds can be heard underwater. The sounds of waves, power boats, and other bathers can be heard with remarkable clarity, even at considerable distances. In fact, sounds move quite efficiently through water, far more easily than they do through air. As an example, whales use sound to communicate over distances of tens or even hundreds of kilometers. The ability of sound to travel over such great distances allows remote sensing in a water environment. Devices that use sounds in such an application fall under the family of instruments known as sonars. To understand sonars, you must first understand sound. In particular, you must understand how sound moves in water.

Sound travels in water in a moving series of pressure fronts known as a compressional wave. These pressure fronts move (or propagate) at a specific speed in water, the local speed of sound. The local speed of sound can change depending on the conditions of the water such as its salinity, pressure, and temperature, but it is independent of the characteristics of the sound itself— all sound waves travel at the local speed of sound. In a typical ocean environment, the speed of sound is in the neighborhood of 1500 meters per second (m/s).

The physical distance between pressure fronts in a traveling sound wave is its wavelength. The number of pressure fronts that pass a stationary point in the water per unit time is the frequency of the wave. Wavelength, if measured in meters (m), and frequency, if measured in cycles per second (Hz), are related to each other through the speed of sound, which is measured in meters per second (m/s):

speed of sound = frequency ´ wavelength

When a sound wave encounters a change in the local speed of sound, its wavelength changes, but its frequency remains constant. For this reason, sound waves are generally described in terms of their frequency.

As a sound wave propagates, it loses some of its acoustic energy. This happens because the transfer of pressure differences between molecules of water is not 100% efficient— some energy is lost as generated heat. The energy lost by propagating waves is called attenuation. As a sound wave is attenuated, its amplitude is reduced.

Sound waves are useful for remote sensing in a water environment because some of them can travel for hundreds of kilometers without significant attenuation. Light and radio waves (which are used in radar), on the other hand, penetrate only a few meters into water before they lose virtually all of their energy. The level of attenuation of a sound wave is dependent on its frequency— high frequency sound is attenuated rapidly, while extremely low frequency sound can travel virtually unimpeded throughout the ocean. A sound wave from a typical sonar operating at 12 kHz loses about half of its energy to attenuation traveling 3000 meters through water.

While acoustic energy travels well in water, it gets interrupted by a sudden change in medium, such as rock or sand. When a moving sound pulse encounters such a medium, some fraction of its energy propagates [absorbed] into the new material. The energy that is not transmitted [absorbed] into the new material must go back into the original medium— the water— as sound. Some amount of it is reflected off the surface of the material—essentially it bounces off in a direction that depends on the angle of incidence (surface). The remainder is scattered in all directions. How much energy goes into reflection and how much goes into scattering depends on the characteristics of the material and the angle of incidence. The energy returned to the water (in other words, the energy that is not transmitted into the new medium) is called an echo. The echo maintains the frequency characteristics of the source wave. " [1]

Sound Waves versus Radio Waves

Sound waves are compression waves in that they oscillate in the direction of travel through a medium like gas (e.g., air). Radio waves are translational waves in that they oscillate perpendicular to the direction of travel in whatever medium the wave is traveling in.

Sound waves travel at the speed of sound, which depends on a lot of things like temperature, density of the medium, etc. Depending on such factors, the speed of sound is about 500-600 mph in air at sea level. This works out to be about 880 feet per second at 600 mph.

Radio waves travel about 186,000 miles per second in air or vacuum, which is the speed of light because radio waves are simply light waves in an invisible section of the spectrum. This light speed equates to very roughly 900,000,000 feet per second, which is about 900,000 times faster than sound in air. This accounts for why you see lighting before you hear its thunder.

Finally, light waves are made up of vibrating bundles of energy called photons...this applies to radio waves, which are a form of light. Sound waves are made up of molecules of gas (e.g., air) moving back and forth. So radio and sound waves are made up of entirely different components. They will not interfere.

Sound waves also need a medium to propagate, such as water or air. Radio waves don't need a medium. Sound cannot travel in a vacuum (such as space) and travels at different speeds depending on the medium.

Radio waves are part of the electromagnetic spectrum, which includes visible light, microwaves, gamma radiation, AM and FM radio, cell phone transmissions, tv transmissions (broadcast and satellite, not cable), infrared etc. Radio waves occur on the radio frequency portion (between 3Hz and 300GHz) of the electromagnetic spectrum. Sound waves have a

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[1] Multi-Beam Sonar Theory of Operation – Sea Beam

smaller range of frequencies (between 20Hz and 20KHz for human hearing, some animals can hear higher frequencies). [2]

Radio waves will produce a bit of electrical voltage and current in an antenna--just a bit of wire--that they happen to pass. In radio waves, electricity can be captured without using a intermediary material that needs to convert the wave energy into mechanical energy and then to electric energy. In sonar, sound waves (acoustic) are captured and converted by a ceramic element that vibrates (mechanical) as the sound wave pressure hits it. The ceramic element has properties that generate electricity when it vibrates which will allow mechanical energy to be converted to electrical energy.

While radar uses radio waves and sonar uses sound waves, they both operate in the same principle of transmitting signals and listening for any signal that bounced back (echos) after the signal hits an object. This basic echo principle is the reason why technologies such as CHIRP can easily be adapted from radar to sonar applications and vice versa.

Principles of Sonar

“A sound pulse generated in water expands spherically from its source—its energy travels equally in all directions. As the sphere of a pulse front expands, its energy is being spread over a larger and larger area (the surface of the expanding sphere), causing a drop in energy per unit area. This drop in energy is called spreading loss. The pulse also suffers from some attenuation, or absorption loss. Collectively, spreading loss and absorption loss are called transmission loss. The total amount of transmission loss that affects a sound wave is dependent on the distance it travels— the farther a wave propagates, the weaker it gets.

In every stage of this process— ping generation, propagation, echoing, and reception— there are sources of sound that add themselves to the final signal received. These include, but are not imited to, ocean sounds (waves, for example), marine creatures, and shipboard sounds from the survey vessel and other vessels. There are also spurious signals that enter the signal from the onar electronics. Collectively, the magnitude of these unwanted signals is called the noise level.

The noise level limits the maximum range of any remote sensing instrument. In a noiseless world, the tiniest sonar echo from the sea floor could be detected. While a ping and its echo have transmission losses

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[2] Are sound waves and radio waves the same? –http://answers.yahoo.com

that make them weaker and weaker, they never actually drop to zero. However, in the real, noisy world they will eventually become so weak that they are indistinguishable from the noise level, and are thus undetectable. The signal-to-noise ratio is the ratio of the received signal strength to the noise level. It gives a measure of the detectability of a signal. The minimal signal-to-noise ratio required for a signal to be detectable depends on the specific application. [3]

History of Fish Finder Sonar

As early as 1822, Daniel Colloden used an underwater bell to calculate the speed of sound underwater in Lake Geneva, Switzerland. This early research led to the invention of dedicated sonar devices by other inventors.

In the late 1950s, Carl Lowrance and his sons Arlen and Darrell began scuba diving to observe fish and their habits. This research, substantiated by local and federal government studies, found that about 90 percent of the fish congregated in 10 percent of the water on inland lakes. As environmental conditions changed, the fish would move to more favorable areas. Their dives confirmed that most species of fish are affected by underwater structure (such as trees, weeds, rocks, and drop-offs), temperature, current, sunlight and wind. These and other factors also influence the location of food (baitfish, algae and plankton). Together, these factors create conditions that cause frequent relocation of fish populations.

During this time, a few people were using large, cumbersome sonar units on fishing boats. Working at low frequencies, these units used vacuum tubes which required car batteries to keep them running. Although they would show a satisfactory bottom signal and large schools of fish, they couldn’t show individual fish. Carl and his sons began to conceptualize a compact, battery operated sonar that could detect individual fish. After years of research, development, struggle and simple hard work, a sonar was produced that changed the fishing world forever.[4]

Sonar Defined

The word "sonar" is an abbreviation for "SOund, NAvigation and Ranging." It was developed as a means of tracking enemy submarines during World War II. A sonar consists of a transmitter, transducer,

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[3] Multi-Beam Sonar Theory of Operation – Sea Beam
[4] Lowrance Sonar Overview - Knowledgebase

receiver and display.

In the simplest terms, an electrical impulse from a transmitter is converted into a sound wave by the transducer and sent into the water. When this wave strikes an object, it rebounds. This echo strikes the transducer, which converts it back into an electric signal, which is amplified by the receiver and sent to the display. Since the speed of sound in water is constant (approximately 4800 feet per second), the time lapse between the transmitted signal and the received echo can be measured and the distance to the object determined. This process repeats itself many times per second.[5]

Matching Sonar Components

Matching Sounder Frequency with Transducer Frequency

The frequency of the transducer must match the sonar unit's frequency. In other words, you can't use a 50 kHz transducer or even a 200 kHz transducer on a sonar unit designed for 192 kHz! A CHIRP sounder will require a broadband transducer designed to transmit a spectrum of frequencies. A structurescan transducer that transmits a narrow beam of high frequency sound wave can only be used by a structurescan sounder unit (receiver) that can process the significant amount of sonar data.

Matching Sounder Output and Transducer Power Requirements

Most sounders these days can have their power output configured so it can match transducer power requirements. A transducer is expecting the sounder to deliver power requirements dictated by manufacturer operating guidelines. A sounder that transmits more power than the transducer can handle will damage the transducer at some point. A sounder that transmits less power than what is needed by the transducer will either degrade the performance of the transducer or make it non-functional.

To automate or facilitate the matching of power requirements of sounder and transducers, a protocol was developed whereby sounders can query the transducer for an XID (transducer ID) to determine the transducer power requirements. Based on the information provided by the transducer, the sounder can make the necessary power output adjustments so that it delivers to the transducer the correct power output. The problem is that legacy sounders and transducers may not support the

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[5] Lowrance Sonar Overview - Knowledgebase

XID protocol. Mix and matching new equipment with legacy equipment will create situations where the power setting of the sounder will have to be done manually.

Zack Floyd, Senior Gemeco Technical Staff, discusses XID possible scenarios:

"XID is not present in the transducer nor is it required by the display [or sounder box] – The sounder will need to be manually set for the power output by the installer to match what the transducer is capable of. If the incorrect setting is chosen damage to the transducer is likely.

XID is present in the transducer but not required in the display [or sounder box] – The sounder will need to be manually set for the power output by the installer to match what the transducer is capable of. If the incorrect setting is chosen damage to the transducer is likely.

XID is present in the transducer and is required by the display [or sounder box] – The sounder will automatically identify the transducer and set the ranges properly for optimum performance.

XID is not present in the transducer but is required by the display [or sounder box] – The sounder will either A) not recognize a unit as being attached and not operate or B) the sounder will revert to 600 watts so there is no risk of damage to the sounder module or the transducer.

In regards to the last case, the manufacturer is responsible for setting the limitations of the sounder in regards to how it handles a transducer with no XID signature.

As an example, if an older 1000 watt transducer with no XID is attached to a Garmin sounder, which requires XID, then the sounder will revert to 600 watts. Performance wise, the customer will not lose the target definition or target separation of the 1000 watt transducer as long as they are within the range of a 600 watt transducer. The main difference is depth range. Instead of operating at 2000 feet the customer may only be able to operate and mark targets in 1500 feet as an example but the resolution will be very similar to a true 1KW unit and will certainly outperform a standard 600 watt transducer. In this case there are no performance issues when using a 1KW on a 600 watt scale other than the reduced depth range." [6]

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[6] Zack Floyd, Gemeco Technical Staff

Matching Sounder Output Impedance with Transducer Impedance Rating

Impedance in its simplest term means amount resistance against electrical impulse or current. Impedance of a transducer is important sounders in the same way that a speaker's impedance is important to an amplifier. The components must match to get the maximum performance. Unmatched components will result in either poor performance or worse, damage one or both components.

The more you impede (higher impedance) the less current will flow. In the inverse, components with lower impedance will require more current flow or in our garden hose analogy, more water flow. In general, higher wattage transducers have lower impedance compared to its 600 watts counterpart. If the sounder attached to a high wattage - low impedance transducer was not designed to deliver the power (wattage = current x voltage) needed by the transducer then the sounder will overheat and eventually, will be damaged.
(see Impedance: Why is it important)

Matching Sonar Solutions with Consumer Requirements

Sonar technologies are designed for a specific purpose and no one sonar technology can be the best solution for all sonar requirements. In fact, it is not uncommon for the ideal sonar solution to be combination of multiple sonar configurations or technologies. High frequency sonar that provides excellent target separation / definition can be combined with low frequency sonar to achieve desire depth penetration. Structurescan sonar that can paint underwater structure in great detail can help identify the areas where fish will likely be found can be combined with broadband scanner to identify the fish in these structures.

CHIRP SONARS

There has been a lot of buzz about CHIRP (Compressed High Intensity Radar Pulse) sonars lately. CHIRP is a highly advance technology that has been around for many years and has been, until recently, only found in military or specialized scientific applications. CHIRP demands precision hardware, lots of processing power, and complex algorithm. As should be expected, these translate to a very expensive technology to implement. The big breakthrough in the last few years is the development of **affordable** broadband transducers (sensors) that made it possible for sounder (transmitter and receiever) makers to develop the matching digital processors to convert the captured sonar signals into digital information that can be displayed on a screen.

How Does a Transducer See a Fish?

The transducer can see a fish, because it senses the air bladder. Almost every fish has an organ called an air bladder filled with gas that allows the fish to easily adjust to the water pressure at different depths. The amount of gas in the air bladder can be increased or decreased to regulate the buoyancy of the fish. Because the air bladder contains gas, it is a drastically different density than the flesh and bone of the fish as well as the water that surrounds it. This difference in density causes the sound waves from the echosounder to bounce off the fish distinctively. The transducer receives the echoes and the echosounder is able to recognize these differences. The echosounder then displays it as a fish.[7]

Chapter 2: Standards and Specifications

What does the "Q" rating in transducers mean.

AirMar Technology Corporation[8] is the leader and the dominant force in transducer research and manufacturing. It can be said that any company of significance in the fishfinder equipment market has some business relationship with Airmar to design and produce the transducer for them. It can even be said that AirMar is the enabler of sonar technology at least in the leisure and commercial market space. Perhaps, the exception to this rule will be Lowrance and Humminbird who on their own have deployed a special application sonar called structurescan. More on structurescan later.

AirMar uses a standard called "Q" (Quality) rating for comparing the performance of its various transducers.

Definition of "Q": A transducer's quality factor that describes the amount of bandwidth and the ringing of the ceramic element, or elements undergo when voltage [sometimes referred to as electrical or transmit pulse] is applied to the transducer.

Rating: Q is reported from a range of 1 to 35. The lower the Q, the better the performance. A low Q transducer has more bandwidth [range of frequencies it can operate in]. All of the transducers designed for use with CHIRP sounders have a Q or 3 or less.

A transmit pulse sent by the sounder to the transducer will result [in a] sound wave of a specified length. Example, A transmit pulse of 500

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[7] How does transducers work – Airmar Technology
[8] Airmar Technology Corporation: http://www.airmartechnology.com/

microseconds equates to a sound wave length of 0.7m(2.4’). In a non-CHIRP system, fish located within 2.4' of each other will not be displayed as individual targets as the there is only one single tone pattern (ping) at a specific frequency and transducer can only acknowledge one echo result from a single ping. Moreover, fish less than 2.4' from seabed are likely to blend into bottom return for almost the same reason.

Lower Q transducers can send out less elongated soundwaves which can be result in better target separation and better performance on shallow waters. The inverse is true when it comes to transducers with high Q ratings. [9]

Let us remember, however, that sounders must also be matched with the transducers in order to achieve the decide results. The inverse is also true. Any inadequacies in any of either component will severely hamper performance. This is true with non-CHIRP implementations but more so with CHIRP implementations where more coding and decoding are done for each CHIRP sonar cycle.

Impedance – Why is it important?

In general, sounder manufacturers work closely with transducer manufacturers to determine what transducers will work their transducers. Both side will look at the impedance value of their component and make sure that the component has an impedance value that is within the acceptable impedance range of the component it will be attaching to. What this means is that as long as the consumer confines his selection choice to the manufacturer approved list of components, the consumer does not have to worry about the component impedance mismatching. It will be different, however, if the consumer is attempting to setup a configuration not the manufacturer list of approve components such as when a new sounder is being match with an old transducers that is already installed in the boat. The installer will be well advised to research impedance values of both sounder and transducer.

AirMar Technology made a very good analogy of speakers and amplifiers to explain how transducers work. So, let’s take this analogy further to explain impedance.

Preston Electronics writes, “In order to relate it (impedance) to something you are more familiar with, let's consider the ordinary garden hose. Print this off and go outside, hook up the hose (no nozzle) and turn

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[9] Airmar Technology Corporation: http://www.airmartechnology.com/

on the water. Pretty soon, water should start flowing out the end of the hose. This flow of water through the hose is similar to electric current, which is usually described as the flow of electrons through the wire and is measured in Amperes.

Now put your thumb over the end of the hose and try to stop the flow of water. Feel the pressure? This pressure is similar to Voltage. It is the force of electricity that pushes the electrons through the wire. Notice that if you succeed in plugging the water flow, (no current) the pressure is still there. This is like an amplifier (sounder) with no speakers (transducer) attached, or an AC outlet with nothing plugged in. Voltage is present, but there is no current flow.

Finally, move your thumb a bit to allow some water to spray. By varying the position of your thumb, you can control how much water comes out of the hose. Your thumb is restricting the flow of water. In an electrical circuit, things that restrict or control the flow of current are said to **impede** current flow, and are described as having **impedance**. In a hose, we use a nozzle to restrict the flow. In an electrical circuit, the device that uses electrical energy and has impedance is called the LOAD."

It should be apparent by now that there is a relationship between pressure (voltage), flow (current) and restriction (impedance). Since voltage or pressure is what moves the current, increasing the voltage pressure should increase the current, assuming the impedance doesn't change. Decreasing the voltage should decrease the current. On the other hand, increasing the impedance restricting the flow of current will cause the current to decrease, like turning the nozzle toward OFF. Lowering the impedance is like opening the nozzle to allow more flow. [10]

Transducer Cone Angles

Cone angle (in degrees) determines horizontal beamwidth at various depth levels. The larger the cone angle the larger the target area from which the sonar can pick up targets. The larger cone angle, however, the less range or depth penetration as the power that send the sonar signal down is consumed more quickly at shallower depths simply because of the larger area it has to send the sonar signals to. A good analogy is you flashlight. The flashlight has a fix amount of light it can deliver. Depending on the lens and reflectors used, the light can be focused into a narrow beam and reach more distant targets or the light can be spread out to illuminate more area at the expense of target range.

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[10] Meditations on Speaker Impedance: Preston Electronics LLC

In the inverse, if sonar signal can be confined to a narrow cone, the power can be focused to this narrow cone and the sonar signals can reach deeper depths. The downside to narrow cone is less area of coverage at any given time.

You can increase the area of coverage and the range by increasing the power of the transducer. Everything else being the same, a 1 kilo watt transducer will cover more area as it can extend range of the cone regardless of cone angle versus a 600 watt transducer.

Note that cone angle determines coverage (horizontal) and penetration (vertical) of the sonar but it does not define the target definition or separation of the objects found in the cone. Target separation and definition is more function of the sonar frequency value and pulse length.

While thickness of ceramic element(s) determines the frequency of sound waves, the cone angle is determined by the size and shape of the ceramic element used. As general rule the wider the element, the narrower the cone angle can be made.

Inside a dual frequency transducer, you will see either one or two sets of elements. Each set of elements may have one or more elements. In a multi-element transducer, the narrow cone sonar is generated from the larger elements and the larger cone sonar is generated from smaller elements.

Some sonars are now built to provide maximum coverage even for the high frequency sonars which traditionally has a narrower cone that it low frequency counterpart. This can be achieved by manipulating the shape of the ceramic element. Advance manufacturing techniques have now made is possible to diffuse sonar waves by shaping thin high frequency ceramic elements.

The transducer concentrates the sound into a beam. When a pulse of sound is transmitted from the transducer, it covers a wider area the deeper it travels. If you were to plot this on a piece of graph paper, you would find that it creates a cone shaped pattern, hence the term "cone angle." The sound is strongest along the center line or axis of the cone and gradually diminishes as you move away from the center.

In order to measure the transducer's cone angle, the power is first measured at the center or axis of the cone and then compared to the power as you move away from the center. When the power drops to half (or -3db[decibels] in electronic terms), the angle from that center axis is measured. The total angle from the -3db point on one side of the axis to the -3db point on the other side of the axis is called the cone angle.

This half power point (-3db) is a standard for the electronics industry and most manufacturers measure cone angle in this way, but a few use the -10db point where the power is 1/10 of the center axis power. This gives a greater angle, as you are measuring a point further away from the center axis. Nothing is different in transducer performance; only the system of measurement has changed. For example, a transducer that has an 8 degree cone angle at -3db would have a 16 degree cone angle at -10db.[11]

Modern day sonars can detect targets beyond the rated sonar cone of the transducer being used. Some transducers are reported to detect targets outside a 20 degree up to 60 degrees.

Wide cone angles will show you more of the underwater world, at the expense of depth capability, since it spreads the transmitter's power out. Narrow cone angle transducers won't show you as much of what's around you, but will penetrate deeper than the wide cone. The narrow cone transducer concentrates the transmitter's power into a smaller area. A bottom signal on the sonar unit's display will be wider on a wide cone angle transducer than on a narrow one because you are seeing more of the bottom. The wide cone's area is much larger than the narrow cone.[12]

High frequency (192 - 200 kHz) transducers come in either a narrow (11 degrees) or wide cone angle. The wide cone angle should be used for most freshwater applications and the narrow cone angle should be used for all saltwater applications. Low frequency (50 kHz) sonar transducers are typically in the 30 to 45 degree range. Although a transducer is most sensitive inside its specified cone angle, you can also see echoes outside this cone; they just aren't as strong. The effective cone angle is the area within the specified cone where you can see echoes on the display. If a fish is suspended inside the transducer's cone, but the sensitivity is not turned up high enough to see it, then you have a narrow effective cone angle. You can vary the effective cone angle of the transducer by varying the receiver's sensitivity. With low sensitivity settings, the effective cone angle is narrow, showing only targets immediately beneath the transducer and a shallow bottom. Turning the sensitivity control up

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[11] Lowrance Sonar Overview - Knowledgebase
[12] Lowrance Sonar Overview - Knowledgebase

increases the effective cone angle, letting you see targets farther out to the sides.

Most people picture the cone of sound to be triangle shaped. This is true only for the specified cone angle. The actual cone of sound is shaped much like the drawing. As you can see there is a lot of area outside of the specified cone. You may or may not be able to see a target in this area. It depends on how well the target reflects the signal back to the depth finder. Good fisherman understand this and can actually identify schools of fish that are way off to the side of them. They look at the depth finder in the area beyond the bottom. If this area is normally clear, but suddenly a group signal appear, then its a good bet that there is something out there. Also, notice the side lobes of the actual cone of sound. This area is generally considered undesirable and a good transducer has minimal side lobes.[13]

Area of Coverage

The chart below shows the difference in area of coverage for our various transducers. It is meant to give you a rough idea of what the diameter of the circle, in feet, on the bottom you are seeing at a specific depth.

DEPTH	**8°**	**9°**	**12°**	**19°**	**20°**
10	1.4	1.6	2.2	3.4	3.5
20	2.8	3.2	4.3	6.7	6.9
30	4.2	4.7	6.3	10.0	10.6
40	5.6	6.3	8.4	13.4	14.1
50	7.0	7.9	10.6	16.7	17.6
60	8.4	9.4	12.6	20.0	21.2

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[13] Choosing a Transducer Beam Angle - Vexilar

70	9.4	11.0	14.7	23.4	24.7
80	11.2	12.6	16.8	26.8	28.2
90	12.6	14.2	20.0	30.1	31.7
100	14.0	15.7	21.0	33.5	35.3
120	16.8	18.9	25.2	40.2	42.3
150	21.0	23.6	31.5	50.2	52.9

Frequency[14]

In general

Frequency is the number of complete cycles or vibrations that occur within a certain period of time, typically one second. Sound waves can vibrate at any one of a wide number of frequencies. The easiest way to understand frequency is to think of it in terms of sounds that are familiar. For example, a kettle drum produces a low-pitched sound (low-frequency). That is, it vibrates relatively few times per second. Whereas, a flute produces a high-pitched sound (high-frequency). It vibrates many more times per second than a kettle drum. The frequency of sound of sound waves are measured in a unit called a Hertz. A Hertz is one cycle per second. For example: a 150 kHz transducer operates at 150,000 cycles per second.

A higher-frequency transducer will put out quicker, shorter, and more frequent sound waves. Like the ripples made when a small pebble is thrown into still water, small waves of sound move evenly out and away from the source. Because they are just small waves, they will not travel far, and small obstacles will cause them to bounce back. Higher frequencies are more sensitive to small objects and will send back detailed information which will show as crisp high-resolution pictures on

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[14] Lowrance Sonar Overview - Knowledgebase

the echosounder screen. The range of high-frequency sound waves, however, is short. In fact,sound waves emitted by a 200 kHz transducer have a limited range of about 200 m.

Now, think of the large waves created by a large boulder thrown into still water. Low-frequency sound waves are like these large waves; they travel much farther than high-frequency waves. But because low-frequency waves are so large, they wash right over small obstacles. Low-frequency sound waves are not as sensitive in detecting small fish or other small obstacles as are high-frequency waves, and although they can see to greater depths, they will not send back detailed information or clear crisp pictures.

Can Fish Hear the Sound waves produced by a transducer?

No, the sound waves are ultrasonic. They are above (ultra) the sound (sonic) that human ears are able to hear. Humans can hear sound waves from 10 Hz to 20 kHz. Most fish are unable to hear frequencies higher than about 500 Hz to 1 kHz. The ultrasonic sound waves sent out by Airmar transducers have frequencies ranging from 10,000 kHz to 2 Megahertz (200,000,000 Hz), clearly beyond the hearing of fish. However, most people can hear the transmit pulses of our 10 kHz transducers; they sound like a series of clicks.[15]

Why is it important to know the Length of a Sound Wave?

Knowing the length of sound waves is particularly important, because it determines where the sound waves will bounce. A sound wave will bounce strongly off something that is larger than itself. If the object is smaller, then the sound wave will almost wash over the object, and the echo will be very weak.

The length of a sound wave is determined by the frequency of the sound vibrations and the density of the medium that the sound is traveling through. Wave length is calculated by dividing the speed of sound in water by the frequency.

The speed of sound in water is 4,800 feet per second. If we have a 200 kHz transducer then our equation would look like this:

4800 ft/sec divided by 200,000 cyc/sec = 0.024 ft/cyc = 0.29 inches/cyc.

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[15] Theory of Operation, AirMar Technologies

One sound wave at 200 kHz is slightly longer than 1/4 of an inch, so a 200 kHz sound wave will be able to detect fish as short as a quarter of an inch.

Let us compare the 200 kHz transducer to the size of a wave length of a 50 kHz transducer:

4800 ft/sec divided by 50,000 cyc/sec = 0.096 ft/cyc = 1.15 inches/cyc.

One sound wave at 50 kHz is slightly over one inch, so a 50 kHz sound wave will only detect fish if their air bladders are large, slightly longer than an inch.[16]

Fixed Frequency

Frequency refers to the number of sound waves that radiate from a transducer each second. Sound waves are made up of high pressure and low-pressure pulses traveling through a given medium. The wavelength of sound is de? ned as the distance between two successive highpressure pulses or two successive low-pressure pulses. For example, when an electrical pulse is applied to a 200kHz transducer the element vibrates at a frequency of 200,000 cycles per second – that is, 200,000 individual sound waves are transmitted from the element each second. Short-wavelength, high frequency transducers produce sharp, crisp images on the Fishfinder display.

For recreational and sportfishing applications, the 50/200kHz pairing of frequencies offers an ideal balance of both shallow- and deep-water performance. The 200kHz frequency produces sharp, crisp images in shallow water while 50kHz allows you to “see” much deeper.[17]

There are advantages to each frequency, but for almost all freshwater applications and most saltwater applications, 192 or 200 kHz is the best choice. It gives the best detail, works best in shallow water and at speed, and typically shows less "noise" and undesired echoes. Target definition is also better with these higher frequencies. This is the ability to display two fish as two separate echoes instead of one "blob" on the screen.

There are some applications where a 50 kHz frequency is best. Typically, a 50 kHz sonar (under the same conditions and power) can penetrate

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[16] Theory of Operation, AirMar Technologies
[17] Furuno Transducer Handbook

water to deeper depths than higher frequencies. This is due to water's natural ability to absorb sound waves. The rate of absorption is greater for higher frequency sound than it is for lower frequencies. Therefore, you'll generally find 50 kHz used in deeper saltwater applications. Also, 50 kHz transducers typically have wider coverage angles than 192 or 200 kHz transducers. This characteristic makes them useful in tracking multiple downriggers. Thus, even when these downriggers are in relatively shallow depths, 50 kHz is preferred by many fishermen. In summary, the differences between these frequencies are:

192 or 200 kHz
- Shallower depths.
- Narrow cone angle.
- Better definition and target separation.
- Less noise susceptibility.

50 kHz
- Deeper depths.
- Wide cone angle.
- Less definition and target separation.
- More noise susceptibility.

CHIRP

CHIRP is the acronym for Compressed High Intensity Radar Pulse. CHIRP transducers are engineered with ceramics designed to operate over a broad range of frequencies (28kHz – 210kHz) with no sensitivity loss.

CHIRP sounders transmit a long pulse across a wide frequency band. Most traditional sounders operate at dual fixed frequencies such as 50kHz and 200kHz. This can limit what targets can be detected in the water column. Moreover, there is a gap between the operational peak effectiveness of these frequencies that is the user must simply have to recognize and deal with.

Wattage

Your depth finder puts out a constant amount of power. It does not matter where you have the gain level set. Gain simply controls how much you amplify the signal that is bounced off of the bottom. Therefore, a narrow beam transducer will appear to be much more powerful than a wide beam transducer. This is because you are putting that same amount of power into a smaller area.[18]

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[18] Choosing a Transducer Beam Angle - Vexilar

Higher output power equates to greater depth range [regardless of the cone angle or beamwidth], as well as stronger returns on your fish finder screen. The actual depths you can reach with your fish finder will vary depending on a number of factors including salinity, temperature and frequency [cone angle or beamwidth] as well as the quality of the transducer.

Chapter 3: What Component does what

Sounder (transmitter and receiver)

The sounder is the brains of the sonar system. It sends an electronic pulse to the transducer which then causes the transducer ceramic elements to vibrate and generate the sound waves that are directed to the sonar target.

The sounder also receives the returned electrical impulse from the transducer, converts electrical impulse to digital data , applies the algorithm that translates digital data into meaningful data and packages the information into network data packets so it can be transmitted to the display unit.

"The sounder also has an extremely wide range of signals it has to deal with. It must dampen the extremely high transmit signal and amplify the small signals returning from the transducer. It also has to separate targets that are close together into distinct, separate impulses for the display."[19]

Transducer

Transducer converts electrical impulse and converts this electrical impulse to acoustics or sound waves and directs these sound waves to the water below.

Transducers then listens for sound waves (echoes) bounced by targets within the sonar range. Transducers then convert these bounced sound waves into electrical impulses and pass the electrical impulse to the sounder for further processing.

AirMar couldn't have explained it any simpler. "The easiest way to understand how a transducer functions is to think of it as a speaker and a microphone built into one unit. A transducer receives sequences of high

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[19] Lowrance Sonar Overview - Knowledgebase

voltage electrical pulses called transmit pulses from the echosounder. Just like the stereo speakers at home, the transducer then converts the transmit pulses into sound. The sound travels through the water as pressure waves. When a wave strikes an object like a weed, a rock, a fish, or the bottom, the wave bounces back. The wave is said to echo—just as your voice will echo off a canyon wall. When the wave of sound bounces back, the transducer acts as a microphone. It receives the sound wave during the time between each transmit pulse and converts it back into electrical energy. A transducer will spend about 1% of its time transmitting and 99% of its time quietly listening for echoes. Remember, however, that these periods of time are measured in micro seconds,so the time between pulses is very short. The echosounder can calculate the time difference between a transmit pulse and the return echo and then display this information on the screen in a way that can be easily understood by the user."[20]

Transducers contain ceramic elements that vibrate at certain frequencies. The shape and thickness of the ceramic determines the frequency it will vibrate. The size of the ceramic determines the cone angle or beam width at varying depths. Transducer engineers have also started using arrays of smaller ceramics to achieve maximum performance and shape these elements to define the cone angle.

As a general rule, there is a direct relationship between the number of elements and the performance or Q rating of a transducer. CHIRP transducers require very low Q rated transducers and these transducers have arrays of ceramics to allow the transducer to span the spectrum of frequency that the CHRIP sonar will be operating in.

As mentioned above, ceramic elements inside the transducer will vibrate when electrical pulse is introduced and they will vibrate at pre-defined frequencies as determined by their physical properties. Fixed frequency (non-CHIRP) transducers will have ceramics vibrating and creating sound waves at the same frequency throughout the duration of the electrical pulse.

Most fixed transducers nowadays are “dual frequency” transducers. This is accomplished sometimes using two separate sets of ceramic elements and sometimes using a single large ceramic element. Multiple frequencies can be processed using a single element because the single disk actually resonates (vibrates) at multiple but fixed frequencies.

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[20] How does transducer work – Airmar Technology

Transducer makers have determined that 200khz and 50khz provide the most useful frequencies for dual fixed frequency sonar applications. This observation is the reason why almost all dual frequencies in the market are 50/200 khz. Lowrance has recently introduced an 83/200 khz for shallow water applications. For shallow water applications, the 50khz deep penetration properties are not essential for shallow waters. The higher frequency 83 khz will provide better target separation and definition relative to the 50 khz.

Structurescan featured by Lowrance and Humminbird units uses 455/800 khz transducers which saturates the water with short high frequency sound waves. Structurescan is also engineered to send a sonar pattern that resembles more like a fan (also sometimes referred to as a “slice”) than the traditional inverted cone shape pattern of down scope transducers. These focused beam, short pulse and high frequency sonar characteristics make it possible to draw very fine details of underwater structure. The downside to scanstrut is that the range is limited (cannot see far), the coverage is limited (the cone is very small to effectively identify fish targets) .

Ceramic Element

In General

The active element is the heart of the transducer as it converts the electrical energy to acoustic energy, and vice versa. The active element of most acoustic transducers used today is a piezoelectric [Electricity created by pressure] ceramic, which can be cut in various ways to produce different wave modes.

The first piezoceramic in general use was barium titanate [BT], and that was followed during the 1960's by lead zirconate titanate [PZT] compositions, which are now the most commonly employed ceramic for making transducers. New materials such as piezo-polymers and composites are also being used in some applications.

Piezoceramic elements are most often in a disk form, but they may also be in the shape of a bar or a ring. A transducer may contain one element or a series of elements linked together called an array.

The thickness of the active element is determined by the desired frequency of the transducer. A thin wafer element vibrates with a wavelength that is twice its thickness. Therefore, piezoelectric crystals are cut to a thickness that is 1/2 the desired radiated wavelength. The higher the frequency of the transducer, the thinner the active element. [21]

How are they made?

Both BT and PZT begin in powdered form. The powder is pressed into the desired shape. Firing—The pressed shapes are baked in a kiln just like we might fire a clay pot made in an art class. The temperature of the kiln depends upon the element's maximum heat tolerance. It is important to fire the piezoceramic at precisely the right temperature.

Like a piece of china that has been fired in a kiln, the piezoceramic element is very strong, yet brittle and easily cracked or broken. Any piezoceramic element that has been cracked or chipped, even slightly, will not function properly in a transducer. Coating—After pressing, the piezoceramic element is coated on two opposite sides with a layer of silver and baked a second time, so the silver actually bakes onto the element. This silver functions as the electrode, the material that will conduct electric current through the element. Polarizing—Next the piezoceramic element is polarized. Piezoceramic elements are made up of individual crystals that have a positive (+) and negative (–) electric charge on respective ends. These crystals are normally resting in a haphazard way in the piezoceramic element. But if a high voltage electric current is applied to the element, the crystals will adjust their alignment until nearly all are positioned in straight columns with their positive (+) and negative (–) poles lying in the same direction.

The internal arrangement of the piezoceramic element's crystals with their positive (+) and negative (–) poles lying in the same direction is the key factor. Pulses of alternating current (AC) from the sounder activate the piezoceramic element. The AC changes its direction of flow back and forth. Which is why it is said to alternate, and this change in the direction of the flow is noted as (+) and (–).] Because the piezoceramic elements are polarized, they will expand when a positive voltage is applied and contract when a negative voltage is applied. The piezoceramic's expansion and contraction changes the electrical pulse into sound waves that will travel through the water until they bounce off an object or weaken and finally dissipate. When an echo returns to the transducer, the pressure of the sound waves act on the piezoceramic element causing it first to contract and then to expand as each cycle in the echo hits it. This alternating pressure on the element creates a small voltage which is then sent back to the transceiver and microprocessor. The element expands

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[21] Piezoelectric Transducers, NDT Resource Center

and contracts at the frequency of the electrical pulse. This occurs very rapidly, faster than can be seen by the eye. The frequency of the expansion and contraction is controlled by the frequency of the pulse generator in the sounder.

GetfeetWet Annotation: At first glance, there seems to be an apparent inconsistency between the following statements:
1) The frequency of the expansion and contraction is controlled by the frequency of the pulse generator in the sounder.
2) The thickness of the active element is determined by the desired frequency of the transducer. A thin wafer element vibrates with a wavelength that is twice its thickness.

These statements can be reconciled. On one hand, the "frequency" of the pulse or how often the sounder sends an electronic pulse to the transducer is controlled by the sounder. This makes statement number 1 a true statement. On the other hand, the thickness of the ceramic element determines how fast it will vibrate when electronic pulse is applied. The frequency referred to in this case is the sound wave frequency which is determined by how fast the ceramic is vibrating. This makes statement number 2 also correct. In short, the term "frequency" is can be used in different context which unfortunately creates confusion.

How they work?

The ceramic element is responsible for generating the soundwaves from electrical impulses on one hand and capturing the bounced sound waves (echos) and generating electrical impulses that can then be passed on to sounder for processing. While ceramics perform dual function: 1) vibrating in reaction to electrical impulse coming from the sounder and generate sound waves 2) receive vibrations from returned sounders to create electric impulses, it can only one function at a time.

Ceramic elements spend a very small percentage (about 1%) of sonar cycle vibrating to generate sound waves. The rest of the cycle is spent either waiting for the element to stop vibrating from the transmit phase or listening for any bounced sound waves.

When ceramic elements “listen”, they actually will vibrate in reaction to any sound waves that it hit them. The returned sound waves put pressure on the ceramic elements which then generate electrical impulse due to their piezoelectric properties. There is a period of time after the ceramic stopped receiving electrical impulse from the sounder where the ceramic continues to vibrate but not generating usable frequencies. It can be referred to as the “ceramics recovery period.” This period in the cycle is non-productive as the element is neither creating usable sound wave frequencies nor listening for a sound waves bouncing back. Transducers with low “Q” rating (remember lower the “Q” the better the performance) have ceramics that are engineered to minimize the recovery period and therefore increase performance.

Some transducers have a single large ceramic element and some transducers have multiple smaller ceramics arrange in an array. Transducer makers arrange and shape ceramics elements to achieve maximum efficiency for the desired frequency and cone angle they want. As a rule, multiple smaller ceramics elements working as unit will outperform a single large ceramic element. Single element transducers are less costly to manufacture and assemble. This will explain why lower cost transducers mostly have a single element that is designed to resonate at various fixed frequencies. This allows transducer makers to manufacturer dual frequency transducers using a single element. On the other hand, high performance transducers, while they cost more, will typically have more ceramic elements working in unison to achieve desired level of performance.

How do the engineers know which piezoceramic element to use?

When an electrical voltage is applied to a piezoceramic element, it will vibrate best at a certain frequency. Piezoceramic materials can be thought of as bells. When a bell rings, it produces a tone. Each bell has its own natural resonant frequency. Those who cast bells know the size and shape necessary to create a bell that produces a certain tone. Like bells, every piezoceramic material has its own natural resonant frequencies. The size, shape, and thickness of the piezoceramic element determine the frequency at which it will vibrate best. Engineers very carefully control these factors to produce transducers that resonate at the correct frequency to meet the customers’ needs. Most of the piezoceramic elements that Airmar uses are thickness resonant. The thickness dimension of the piezoceramic element, rather than its diameter or shape, determines the resonant frequency. A transducer can be designed with one piezoceramic that operates at two frequencies. Our popular 50/200 kHz transducer houses a piezoceramic element that can vibrate efficiently at two separate frequencies. It resonates at 200 kHz in the thickness mode and at 50 kHz across its diameter which is called the radial mode. A transducer that can operate at two frequencies will have the characteristics of both frequencies—the ability to “see” well in both shallow and deep water with good bottom definition.

Chapter 4: What Affects Transducer performance

In General

The detection, classification and localisation performance of a sonar depends on the quality of hardware and the operating environment.

Hardware

Transducer

There are four facets to a good sonar unit:

- High power transmitter.
- Efficient transducer.
- Sensitive receiver.
- High resolution/contrast display.

High transmitter power increases the probability that you will get a return echo in deep water or poor water conditions. It also lets you see fine detail, such as bait fish and structure. [i.e. 1 Kilowatt transducers perform better versus 600 watt transducers as water depth gets deeper] The transducer must not only be able to withstand the high power from the transmitter, but it also has to convert the electrical power into sound energy with little loss in signal strength. At the other end of the spectrum, it has to be able to detect the smallest of echoes returning from deep water or tiny bait fish.

Installation and Maintenance

In General

For the best results, the transducer should be placed where a smooth, undisturbed flow of water will pass across the face of the transducer at all boat speeds.

Transom Mount

The transom mount transducer design performs best when it is slightly below the boat's hull. A plastic transducer is recommended on aluminum or steel-hulled boats to avoid potential electrolysis problems.

DO NOT mount the transducer directly behind the ribs, or thru-hull fittings. Typically, on aluminum boats, mounting the transducer between two ribs works best. On all hulls, mount the transducer at least one foot away from the engine's lower unit. This helps to prevent air bubbles from the transducer interfering with the propeller.

Periodically wash the bottom of the transducer with soap and water to remove any oil film or growth that may collect. Oil and dirt reduce the transducer's sensitivity and can even prevent its operation.

Shoot-Thru-Hull Mount or In-Hull

In this installation, the transducer is bonded to the inside of the hull with epoxy. Ideally, the transducer is placed in the aft third of the hull close to the centerline. The signal "shoots through" the hull with some loss of signal strength. This installation must be made in an area of the hull that is made from solid fiberglass, with no air bubbles or separated layers. If the hull is of multi-layer or "sandwich" construction, you will have to remove the inner layer of fiberglass and the wood or foam core to expose the outer layer of the hull. This type of mount is recommended only with 192 or 200 kHz transducers.

Bolt-Thru-Hull Mount or Thru-Hull

In this type of installation, a hole is cut in the hull and the transducer is mounted through the hull by means of a threaded shaft and nut. [In traditional designed where the ceramic element is not tilted] If the boat hull has a dead rise higher than 10 degrees, fairing blocks made from wood or plastic must be fabricated so that the transducer will mount in a completely vertical position.[22]

Newer designs from transducer companies have been released which has the ceramic element inside the transducer tilted a certain degree (normally 12 or 20 degrees) which allow the transducer to be flush mounted to the hull. Depending on the deadrise of the hull where the hole is located, these transducers can be installed and the tilted angle of the ceramic element will compensate for the deadrise (angle of the hull relative to the sea bottom) eliminating the need for a fairing block.

On in-boards, the transducer must be installed ahead of the propeller, shaft(s), and engine water intake(s).

If the boat's hull is made of steel or aluminum, use a plastic transducer to prevent electrolysis problems.

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[22] Lowrance Transducer Selection Guide

Transom Mount Transducer Installation

The ideal mounting location on a boat powered by an outboard or an I/O engine is about 18-24 inches starboard of the engine's lower unit. If the boat has inboard power, mount the transducer far enough to starboard to clear any propeller turbulence.

Look for a flat area of the hull between lifting strakes on a fiberglass boat and between the longitudinal ribs on a metal hull. Don't mount it behind through-hull fittings, patches of rivets or other hull features that could generate turbulence.

The transducer may have to be mounted closer to the centerline of a high performance hull that rides on a narrow pad when fully planed. If the transducer is mounted beside the pad, it will raise up out of the water as the boat climbs onto the pad, and the sonar unit will lose its bottom reading the instant the transducer's face loses contact with the water.

A transducer mounted directly in front of the prop on a high-performance boat can cause prop cavitation. Sometimes pad hulls don't have a trouble-free mounting spot on the transom, and you are better off epoxying down a transducer inside the sump area where it shoots through the pad.

The side-to-side angle should be as close as possible to parallel with a straight edge laid across both gunwales at the transom. The boat's floor is another good parallel, but it's not visible while you are on your hands and knees behind the boat adjusting the transducer's bracket.

The last critical setting is the transducer's running depth. The ideal depth will keep the transducer in contact with the water as the boat maneuvers while adding minimal drag. Metal hulls are not generally as smooth as fiberglass hulls, and usually require a deeper running depth to reach below any turbulence caused by hull irregularities.

A properly installed transom-mounted transducer performs just as well as a shoot-through model, and you can take advantage of the temperature sensor built into most of them and the speed wheel optional on many with no additional rigging.

The transducer will also deliver greater sensitivity because it suffers none of the signal loss associated with shooting sound through a hull.[23]

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[23] Be smart when installing transducer - Allan Tarvid - Louisiana Sportsman

Acoustic Window

Acoustic windows [material at the bottom of the transducer where the sound waves will pass through] can be “hard” or “soft.” Soft acoustic windows made of urethane provide excellent sensitivity to echoing sound waves, therefore soft windows can “read” through deeper water with better clarity of detail. This material is extremely stable in water, therefore providing excellent reliability for years. Because the acoustic properties of urethane are similar to water, the acoustic window can be made in the shape of a dome, wedge, or an arc. Hard plastic and epoxy acoustic windows are especially good for boats that are trailered or often in and out of the water, because these windows become wet quickly. They also have characteristics which are good in shallow water and in fishfinding.

What is Ringing?

Ringing is the continued vibration of the piezoceramic element after each transmit pulse. Imagine the ringing of a large church bell. After the church bell is struck by the clapper, it continues to ring for a time if the vibrations are not dampened. This phenomenon also occurs in piezoceramic elements.

The vibrations of the element continue after the transmit pulse. These vibrations decrease in amplitude (or “loudness” if we could hear them) just as the ring of the church bell gets softer over time. The tapering off of the vibrations is called the ring down. In effect, ringing causes a “stretching” of the transmit pulse, because it generates unnecessary sound waves. These additional sound waves add additional microseconds to the dead band, interfering with the reception of echoes. If a desired echo arrives during the ring down it will appear on the echosounder screen as a smear or it may even be hidden by the ring down and not appear on the echosounder screen at all. Ringing, therefore, reduces the clarity of the display on the echosounder screen. Ringdown also keeps the transducer from “seeing” in very shallow water. Ringing can never be totally eliminated. With the proper engineering, however, it can be greatly reduced. A transducer with a high “Q” factor is one which will ring for a long time after being struck with a transmit pulse. Conversely, a low “Q” transducer exhibits less ringing.

Deadband and Blank Zone

As you have learned, during the transmit pulse the piezoceramic is vibrating, so no echoes can be received—in the same way that you cannot listen when you are talking. The microseconds when the transducer is transmitting is the deadband for the reception of echoes.

When something very close to the transducer (usually between one and three feet), the bouncing echoes will return before the piezoceramic has stopped ringing. Since the echo is in the deadband, these echoes cannot be received—the object will be invisible. The minimum distance between the transducer housing and an object that can be "seen" is called the blanking zone.

Environmental Conditions

Target Masking (Dead Zone)

Target masking is a phenomenon where acoustic energy from the transducer encounters a ledge which is only partially within the beam. This produces an echo which is sent back to the transducer sooner than the echo returned by either the sea bottom or fish targets. The result is that these fish targets will not be discernible on the fishfinder screen. This phenomenon can occur with trenches as well as when traveling over sloping ground. It is also possible to pick up a second echo from the sea bed, which will show as an echo on the screen at a greater depth than that of the ledge.[24]

It can happen if the lake or sea bottom drops off suddenly or contains a large rock. The sound waves will bounce off all of the sea bottom within the sound beam and return as strong echoes. The echoes from the highest point, the rock or drop-off, return to the transducer first, falsely indicating the apparent depth of the bottom. Small fish below the highest point will produce relatively small echoes which will return after the larger ones. Therefore, fish can be swimming around the sides of a large rock or a drop-off, be in the sound field, and yet remain invisible to the echosounder.

Dead Zone is the area within the transducers cone of sound that is blind to you. The wider the beam angle the greater the possible dead zone. The sonar will mark bottom as the nearest distance it sees. If you are fishing over a slope it may see the high side of the slope, at the edge of the cone, and mark that as bottom. The fish that are hanging on the bottom in the center of the cone will be invisible to you because they are actually within the bottom signal on your depth finder. A narrower beam angle will reduce this effect.[25]

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[24] Furuno Transducer Handbook
[25] Choosing a Transducer Beam Angel – Vexilar.com

Interference

When two or more echo sounders are operating in close proximity and at the same frequency, it is possible for each to receive false returns from the others transducer. In such cases the operator will see noise and clutter, false returns, multiple bottoms or other video anomalies on the screen. This is most common in and around marinas or harbors where there may be multiple fish finders operating at the same frequencies.

Thermocline (Water Temperature)

Ocean temperature varies with depth, but at between 30 and 100 meters there is often a marked change, called the thermocline, dividing the warmer surface water from the cold, still waters that make up the rest of the ocean. Sound originating on one side of the thermocline tends to be bent, or refracted, through the thermocline. The thermocline may be present in shallower coastal waters. However, wave action will often mix the water column and eliminate the thermocline.[26]

Scattering

Scattering occurs from small objects in the sea as well as from the bottom and surface. This can be a major source of interference. This acoustic scattering is analogous to the scattering of the light from a car's headlights in fog: a high-intensity pencil beam will penetrate the fog to some extent, but broader-beam headlights emit much light in unwanted directions, much of which is scattered back to the observer, overwhelming that reflected from the target ("white-out"). For analogous reasons active sonar needs to transmit in a narrow beam to minimise scattering.

Cavitation

Cavitation is a major obstacle to achieving high speed operation. If the flow of water around the transducer is smooth, then the transducer sends and receives signals normally. However, if the flow of water is interrupted by a rough surface or sharp edges, then the water flow becomes turbulent. So much so that air becomes separated from the water in the form of bubbles. This is called "cavitation." If these air bubbles pass over the face of the transducer (the part of the housing that holds the crystal), then "noise" is shown on the sonar unit's display. You see, a transducer is meant to work in water - not air. If air bubbles pass over the transducer's face, then the signal from the transducer is reflected by the air bubbles right back into it. Since the air is so close to the transducer, these

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[26] Wikipedia, SONAR Definition

reflections are very strong. They will interfere with the weaker bottom, structure, and fish signals, making them difficult or impossible to see.

Because air is much less dense than water, air bubbles scatter and reflect sound waves. Any air bubbles in the acoustic window material or in the water will interfere with the proper working of the transducer, greatly reducing its performance. To minimize the chance for tiny, flecklike, micro-bubbles in the acoustic window material, it is placed under a vacuum for a specific amount of time. Air bubbles must, also, be carefully guarded against by
the installer and user. If the transducer is glued to the inside of the hull of a boat, even the glue cannot have air bubbles in it. Indeed, a transducer needs to be placed away from anything, including the propeller, that will cause air bubbles to form while the boat is underway.[27]

Water and Bottom Conditions

The type of water you're using the sonar in affects its operation to a large degree. Sound waves travel easily in a clear freshwater environment, such as most inland lakes.

In salt water however, sound is absorbed and reflected by suspended material in the water. <u>Higher frequencies are most susceptible to this scattering of sound waves and can't penetrate salt water nearly as well as lower frequencies.</u> Part of the problem with salt water is that it's a very dynamic environment - the oceans of the world. Wind and currents constantly mix the water. Wave action creates and mixes air bubbles into the water near the surface, which scatters the sonar signal. Micro-organisms, such as algae and plankton, scatter and absorb the sonar signal. Minerals and salts suspended in the water do the same thing. Fresh water also has wind, currents and micro-organisms living in it that affect the sonar's signal - but not as severely as salt water.

Mud, sand and vegetation on the bottom absorb and scatter the sonar signal, reducing the strength of the return echo. Rock, shale, coral and other hard objects reflect the sonar signal easily. You can see the difference on your sonar's screen. A soft bottom, such as mud, shows as a thin line across the screen. A hard bottom, such as rock, shows as a wide line on the sonar's screen.

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[27] Theory of Operation – Airmar Technology

Water Salinity

With water conditions and quality being the same, sound travels more slowly in fresh water than in salt water, though the difference is small. In real-world applications, the scattering and cavitation environmental factors play a more significant role in sonar performance than the salinity of the water. This is why sonar will perform better in lakes (fresh water) where the waters are clearer and quieter than in coastal waters (salt water) where the water close to water are more turbulent.

Chapter 5: Sonar Technologies

Fixed Frequency Sonar

When a SONAR wave strikes an object, it rebounds. This echo strikes the transducer, which converts it back into an electric signal, which is amplified by the receiver [sounder] and sent to the display. Since the speed of sound in water is constant (approximately 4800 feet per second), the time lapse between the transmitted signal and the received echo can be measured and the distance to the object determined. This process repeats itself many times per second.

The most common frequencies used for fishfinder sonar is 50 khz and 200 khz. In summary, the differences between these frequencies are:

192 or 200 kHz
- Shallower depths.
- Narrow cone angle.
- Better definition and target separation.
- Less noise susceptibility.

50 kHz
- Deeper depths.
- Wide cone angle.
- Less definition and target separation.
- More noise susceptibility.

Most of the sonar units operate at 200 kHz (kilohertz). Some are dual-frequency capable, meaning they can use both 50 and 200 kHz transducers. And a few new models are dual-search capable, allowing for both 83 and 200 kHz operation. Typically, high frequency (200 or 192 kHz) sonar units provide the best resolution and definition of structure and targets. They excel at showing minute details of the underwater world. 50 and 83 kHz frequencies have much greater depth penetration capability, but show less definition.

You must match the transducer's frequency to the sonar unit. For example, a 200 kHz sonar unit requires a 200 kHz transducer.[28]

The transducer is the sonar unit's "antenna." It converts electric energy from the transmitter to sound waves. The sound wave from the transducer travels through the water and bounces back from any object in the water [within the scope or range of sonar cone]. When the returning echo strikes the transducer, it converts the sound back into electrical energy which is sent to the sonar unit's receiver [sounder]. The frequency of the transducer must match the sonar unit's frequency. In other words, you can't use a 50 kHz transducer or even a 200 kHz transducer on a sonar unit designed for 192 kHz! The transducer must be able to withstand high transmitter power impulses, converting as much of the impulse into sound energy as possible. At the same time, it must be sensitive enough to receive the smallest of echoes. All of this has to take place at the proper frequency and reject echoes at other frequencies. In other words, the transducer must be very efficient.[29]

The active element in a transducer is a man-made crystal (lead zirconate or barium titanate). To make these crystals the chemicals are mixed, then poured into molds. These molds are then placed in an oven which "fires" the chemicals into the hardened crystals. Once they've cooled, a conductive coating is applied to two sides of the crystal. Wires are soldered to these coatings so the crystal can be attached to the transducer cable. The shape of the crystal determines both its frequency and cone angle. For round crystals (used by most sonar units), the thickness determines its frequency and the diameter determines the cone angle or angle of coverage (see Cone Angles section). For example at 192 kHz, a 20 degree cone angle crystal is approximately one inch in diameter, whereas an eight degree cone requires a crystal that is about two inches in diameter. That's right. The larger the crystal's diameter - the smaller the cone angle. This is the reason why a twenty degree cone transducer is much smaller than an eight degree one - at the same frequency.[30]

To listen to how a single frequency Ping sound like, follow link to below:[31]
http://www.getfeetwet.com/sonarlinks.aspx

Benefits of fixed frequency sonar are:

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[28] Lowrance Transducer Selection Guide
[29] Lowrance Sonar Overview - Knowledgebase
[30] Lowrance Sonar Overview - Knowledgebase
[31] Sonar Resource – GetFeetwet Navigation Inc

- Low Cost compared to CHIRP Sonars
- Cross compatible across different generations of sonars and across sounder manufacturers
- Mature and proven technology

Structurescan Sonar

StructureScan gives anglers an unprecedented picture-like view of the water around and under a boat. Displaying precise depth and distance information as well as images that require no interpretation, StructureScan HD takes the guesswork out of sonar technology. A sunken tree looks like a tree, weeds like weeds and rock piles like rock piles. StructureScan features a high intensity single frequency sonar to paints a picture of submerge structures and other elements found on either side of the boat. This is commonly referred to as sidescanning.

Aside from the sonar sidescan, structurescan implementations can also incorporate sonar image downscanning which is the same technology implemented in sidescan but points straight down below the boat.

Structurescan sidescan can quickly eliminate unproductive waters and find the locations most likely to hold fish.

Navico Lowrance Structure Scan (LSS) -
LSS uses the 455KHZ and the 800KHZ and both are side imaging frequencies. The LSS transducer has two sets of elements, one to cover the right side and another to cover the left side. Structure scan side imaging uses a very a narrow 0.9 degree high frequency beam. LSS also features down imaging using 1.1 degree beam Due to the very narrow beam, the LSS beams are sometime referred to not as "cones" but as "slices". The beam covers about 90 degree angle on both sides of the boat.

The narrow beam of the LSS depends on the boat moving within a range of speed where it will allow it to scan the structure but not too fast where it has no time to listen back to the sound echos which is what is used to draw the structure.
800 KHZ frequency will provide better definition at expense of range. 455khz will provide more range but will not provide definition of the 800 khz. Both frequencies have the same beam angle.

Lowrance structure scan does side imaging and down imaging. Lowrance LSS transducer has a dedicated element for down imaging. The

Humminbird structure scan units extrapolates the down imaging data via software translation of the side imaging beams.

"Just remember conventional sonar utilizes a search "cone" (20 deg, 60 deg, etc) where as Structure Scan utilizes a "beam" which is 2 deg wide (fore to aft) and looks like a fan. The DownScan fan angle is roughly 48 to 50 deg, and the SideScan angles are approximately 60 deg per side."

"Sonar uses flat circular disk crystals. The thickness determines frequency and the diameter controls the cone angle. The larger the diameter, the narrower the cone angle for a given thickness. The SI/DI transducers are basically cubical...they cannot produce a cone shaped beam."

"The construction of the transducers and signal processors separate Humminbird and Lowrance technology. Lowrance utilizes 3 piezo electric crystals and Humminbird uses 2. Both use common signal processors and the beams transmit at the same time, which in wave theory is a very bad idea. In this case it is done to conserve energy usage. Interference from the 3rd (downscan) crystal is very problematic because when transmitting at the same time, the different channels cannot be seen as separate systems. The three channels add in phase and because of overlapping main beams, erratic "interference" can result. This phenomena drives the fundamental difference in approach between Humminbird and Lowrance."

General Specifications
Transmit Power: 500 watts
Transducer Frequency: 455 khz
Communication: Ethernet
Sidescan Specification
Max Range: 600 ft (300ft each side)
Max Speed: 35 mph
Mark Objects: 15 mph
Optimum Speed: 2-8 mph
DownScan
Max Depth: 300 ft (300ft each side)
Max Speed: 55 mph
Mark Objects: 35 mph
Optimum Speed: 2-8 mph

Benefits

- High intensity narrow beam or slice yields very detailed images of structures within a short range
- Side imaging allows quick target area identification and selection

CHIRP Sonar

CHIRP is the acronym for Compressed High Intensity Radar Pulse. In some sources, the term chirp is used interchangeably with sweep signal.[32]. Garmin refers to their CHIRP implementation as Spread Spectrum technology. ClearPulse CHIRP Technology is Raymarine's CHIRP implementation

A completely functional CHIRP sonar system will comprise of a CHIRP sounder, broadband transducer and some display. The CHIRP sounder can be stand-alone or sometimes referred to as a black box. It can also be built-in to some display which can be dedicated to sonar in which case it is called a fishfinder. It can also be connected to a display that also acts as a chartplotter in which case it is called a combo unit or simply a "sounder."

CHIRP sounders transmit a long pulse across a wide frequency band. Most traditional sounders operate at dual fixed frequencies such as 50kHz and 200kHz. This can limit what targets can be detected in the water column. Moreover, there is a gap between the operational peak effectiveness of these frequencies that is the user must simply have to recognize and deal with.

"AIRMAR's new CHIRP transducers are engineered with ceramics designed to operate over a broad range of frequencies (28kHz – 210kHz) with no sensitivity loss."[33]

CHIRP techniques have been used for a number of years above the water in many commercial and military RADAR systems. CHIRP publications date back as early as the 1950s. The techniques used to create an electromagnetic CHIRP pulse have now been modified, miniaturized, produced in volume and adapted to commercial acoustic imaging sonar systems.

In 2011 - 2012, the fishing community was buzzing from product announcements made by couple of major vendors featuring sounder featuring CHIRP. Prior to that, AirMar Technology, the leading commercial transducer company, developed a series of CHIRP transducers for prototype fishfinders. These transducers are high performance broadband transducers that can transmit within a range of frequencies (bandwidth). This is the enabling hardware and technology

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[32] Weisstein, Eric W. "Sweep Signal." From MathWorld--A Wolfram Web Resource

[33] Getting to the Bottom of CHIRP Technology by Jen Matsis, AIRMAR Technology

that will allow fishfinder companies to develop hardware and software the will incorporate CHIRP functionality as have been seen in radar and other military applications. Moreover, the initial target price point for these new breed of broadband transducers and CHIRP sounders, while still not inexpensive, is certainly within the reach of discriminating fishermen who will not settle for average solutions to their requirements. The CHIRP sounder and transducer solution is priced in the $3,700 range (Sounder $2,000 + Transducer $.1,200)

“CHIRP has been used by the military for some time,” says Airmar president Steve Boucher. “Nobody talked about it because the signal processing was too expensive. Three years ago we saw where processing was going with DSP [digital signal processing] — chips are now down below $25 dollars — and decided to come out with broadband transducers.”[34]

In 2013, we are seeing the rush to market by all the major vendors product lines that features sonar CHIRP. Some manufacturers have announced units with some supposed implementation of CHIRP built-in to the unit. What is significant about these new product lines is the price point at which they are being offered. Garmin 741xs (MRP $1,699) is 7 inch display sounder with some implementation of CHIRP built-in into the unit. Clearly, we can expect that the trend is for these vendors to continue to incorporate CHIRP in their sonar units and the price will continue to drop as economies of scale drive the cost to manufacturer down.

“The [CHIRP] technology, methodology and signal processing and mechanics are now only possible because we [now] have the [affordable] transducers,” says Don Korte, senior engineer for Simrad. “A couple of years ago we couldn’t do CHIRP. We didn’t have the sensors.”[35]

To understand the benefits of using CHIRP acoustic techniques, we need to analyze the limitations using conventional monotonic techniques. An acoustic pulse consists of an on/off switch modulating the amplitude of a single carrier frequency.[36]

The ability of the acoustic system to resolve targets is determined by the pulse length; this, however, has its drawbacks. To get enough acoustic

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[34] Fish-finding sonar enters an intense new realm with CHIRP technology by Glenn Law, Yachting Magazine

[35]

[36] CHIRP Sonars by Tritech Company - UK

energy into the water for good target identification and over a wide variety of ranges, the transmission pulse length has to be relatively long.

In monotonic (single fixed frequency) sonar implementation, any target that is picked-up by same acoustic pulse is registered as one object with the object nearest the transducer defining the target to the exclusion of the target further down the reachable sonar cone area.

The ability of the sonar to distinguish between targets is sometime referred to Range Resolution or target resolution. The formula to calculate sonar resolution is:

Range resolution = (pulse length x velocity of sound in water) / 2

Note that velocity of sound in water is for most part fixed but can vary slightly based on the other elements in the water such as salt

Based on the formula, the pulse determines the target resolution and as the pulse length increases, the target resolution decreases. As noted before, however, he longer the pulse, the greater the chance that you catch the target. Quite simply, in a monotonic sonar implementation, the ability of the transducer to acquire target has the opposite effect on the target resolution of the acquired target. The inverse is also true. Longer pulse = better target acquisition but lower target resolution. Shorter pulse = lower target acquisition but more defined target resolution.

CHIRP signal processing overcomes these limitations. Instead of using a burst of a single carrier frequency, the frequency within the burst is swept over a broad range throughout the duration of transmission pulse. This creates a 'signature' acoustic pulse; the sonar knows what was transmitted and when. Using **'pattern-matching'** techniques, it can now look for its own unique signature being echoed back from targets.

Instead of length of the pulse in monotonic systems, in a CHIRP system, the critical factor determining range resolution is now the bandwidth (range of frequency) of the CHIRP pulse.

The range or target resolution formula for CHIRP is as follows:

Range resolution = (velocity of sound) / (bandwidth x 2)

As the formula indicates, the higher the bandwidth the better the range resolution or target resolution. Target acquisition is not reduced as the

CHIRP pulse can elongated with no impact to range resolution. In fact, CHIRP systems send out 10 – 10,000 more energy than monotonic fixed frequency systems mostly due to longer duration pulses containing multi-frequency sonar waves.

It is important to note that while the electronic pulse (sonar signal is active) may have a longer duration, the duration or length of time at which pulse is at a specific sonar frequency is much shorter within the pulse active period. This is important to understand as it will explain why sonar targets in CHIRP systems that are very close each other can be separated despite the pulse duration being longer than distance between the two targets.

In CHIRP, when two acoustic echoes overlap, the CHIRP pulses do not merge into a single return. The frequency at each point of the pulse is different, and the sonar is able to resolve the two targets independently.

Reminder: Only one echo is processed for each pulse sent out but 2 echo coming from two different pulse can reach the transducer at the same time as one pulse may have been transmitted at earlier time and hit a farther target while succeeding pulse may have hit the a target that is closer.

In monotonic systems, the sonar frequency is the same for all pulses therefore cannot be used distinguish targets. All targets within the pulse duration length look the same to the monotonic system and eventually will be reflected to the sonar display as one large object. Not only is the displayed information inaccurate but it is also misleading.

As the frequency modulates, the width of the signal cone changes. Make a V with your index and middle fingers and lay it on your desk. Now move your fingers in and out, changing the distance between your fingertips. That’s the same way that the cone angle changes as the pulse frequency modulates.

Because the modulated pulse is so sensitive to targets, the power needed to drive CHIRP sonar is considerably lower than that of fish finders with traditional 2 kW and 3 kW output. The sonars coming on the market currently operate on 250 to 650 watts of output power. That alone greatly reduces the amount of noise or interference in the image that appears on the fish-finder screen[37]

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[37] Fish-finding sonar enters an intense new realm with CHIRP technology by Glenn Law, Yachting Magazine

An adjunct to the impressive resolution is the lack of noise or interference in the return image. This is due partially to the modulated frequency of the pulse, but it is also augmented by the low power requirements of the transducers. “We don’t need that much power. These depths are all reached at 250 watts,” Korte (Simrad) says.[38]

If you want to hear what CHIRP soundwave sound like, follow the link below:
http://www.getfeetwet.com/sonarlinks.aspx

Benefits

- 10 to 1,000 times more energy on targets
- 5 to 10 times greater detail and resolution compared to fixed-frequency sonars
- Larger transmission pulse lengths for increased operating ranges (target acquisition)
- Accuracy at depths all the way down to 3,000 m (10,000’)
- Better target separation and target definition. Precise separation between bait fish and game fish
- Ability to pull targets from within the noise floor. better signal to noise ratio
- Improved bottom tracking at high boat speeds
- Low Q improve shallow water performance
- Improved discrimination between closely spaced targets
- Reduced power consumption, from high speed digital circuitry

CHRIP versus Non-CHIRP Systems

- Non-CHIRP fishfinders operate at discrete frequencies like 50kHz and 200kHz
- Typical Non-CHIRP fishfinder operate with a maximum duty cycle of 1%, meaning they transmit a voltage to the Transducer no more than 1% of the time. Consequently, the transmit pulse can be high power but
- very short duration, limiting the total energy that is transmitted into the water column.
- CHIRP sounders use a precise sweep pattern of many frequencies (28kHz – 210kHz) within a long-duration transmit pulse, sent to a CHIRP transducer.

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[38] Fish-finding sonar enters an intense new realm with CHIRP technology by Glenn Law, Yachting Magazine

- The equivalent sound energy transmitted into the water is 10 to 1,000 times greater than a conventional marine fishfinder, resulting in more energy on target.
- Results are 5x greater resolution and depth capability than current fishfinders due to the advanced signal processing of the return echo.
- Key to the signal processing is knowing what they CHIRP
- signal looked like, "Pattern Matching"[39]

Chapter 6: Choosing the Appropriate Transducer

Mount Type

Transom Mount

Ideal low cost solution that is easy to install and will not require the boat to be taken to dry dock. In almost all cases, transom mount transducer (sometimes referred to as stern mount) are made of hard plastic material.

A properly installed transom-mounted transducer performs just as well as a shoot-through model [or thru-hull], and you can take advantage of the temperature sensor built into most of them and the speed wheel optional on many with no additional rigging.

The transducer will also deliver greater sensitivity because it suffers none of the signal loss associated with shooting sound through a hull.[40]

The lower cost of transom mount transducers when compared to thru-hull counterpart does not mean that it will be inferior in performance. The lower cost is simply a reflection of the lower cost of housing materials and the manufacturing process to produce it.

Many factors will affect transducer performance. The mounting type, however, is not as important how or where it installed.

Thru-Hull

Traditionally, sonar requirements that require deep depth penetration demand higher wattage transducers. These transducers are mostly mounted as thru-hull. Higher wattage transducers also feature larger ceramic elements. These elements require bigger and heavier housing.

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[39] Getting to the Bottom of CHIRP Technology by Jen Matsis, AIRMAR Technology
[40] Be smart when installing transducer - Allan Tarvid - Louisiana Sportsman

These dimensions will be difficult to implement as a transom mount especially in smaller boats.

It is said that thru-hull implementations offer the best chance of getting the best sonar performance among mounting options. With thru-hull, sonar performance can be maximized by choosing to install the thru-hull transducer in a location where cavitation is minimal. Furthermore, certain thru-hull models can use a fairing block to help quiet the waters surrounding the transducer to achieve the desired level of performance.

Not all boats can use use a thru-hull with fairing blocks. Smaller boats (28ft or less) may not have a long enough hull to have enough separation between the outboard propeller or rudder/propellers and the fairing block. In this case, vibrations in boat may occur as the water hitting the outboard propeller or the propeller/rudder is skewed or redirected by the fairing block. For smaller boats, the flush mount thru-hull with tilted element inside the housing is preferred.

Boats that are hauled in boat trailers back and forth between storage and launch ramps are advised to use either flush mounted thru-hull, in-hull or transom mount with a “kick up” bracket. Thru-hull with fairing block may be a problem in this situation as the protruding fairing block may easily be damaged as the boat slides to and from the boat trailer..

Shoot-through-the-hull (in-hull)

Shoot-through-the-hull is a viable mounting option as long as: 1) the hull is not metallic 2) hull does not have a metallic core 3) hull does is not hallow or have acoustic dampening inserts like cork . Any of the situations mentioned above will severely degrade shoot-through-the-hull sonar performance. When properly done, a shoot-through-the-hull implementation will perform just as good as transom mount or thru-hull implementation. There will still be a slight signal loss, however, due to the sonar sound waves having to pass through the hull material.

The benefits of shoot-through-the-hull includes lower cost, no need to dry dock boat to install, easy installation and can use temporary adhesive for trial-and-error installation.

Low-Frequency versus High-Frequency

Low frequency sound waves will travel farther than high frequency sound waves. Low frequency sound waves typically have wider cone angles which translates to not only deeper penetration but wider coverage.

High frequency sound waves on the other hand does not provide the same range and coverage as low frequency sound waves but high frequency sound waves provide a finer target definition and target separation. High frequency sound waves are typically propagated in a narrow cone where sound waves are focused and concentrated. High frequency sound waves also has smaller wave length that enables it to mark smaller targets.

Dual fixed frequency transducers (e.g. 50/200 khz or 83/200 khz) are designed to deliver the benefits of both low and high frequency sound waves. When choosing a transducer, it is important to prioritize requirements. Is depth penetration more important that target definition such as in jig or bottom fishing. In this case, the high frequency with a shorter range may not be able to reach bottom and only the low frequency will provide any useful data.

If the sonar target are suspended in the water column or at termocline at shallower depths, then a high frequency sonar is more appropriate as depth penetration is not as important. Typically, high frequency sonars have narrower cone angle but transducer engineers have now been able to expand the cone angle of high frequency transducers by shaping the ceramic elements using advance manufacturing technology.

CHIRP sonars provides a superior solution versus fixed frequency sonars as CHIRP transmits sound waves within a range of frequency. CHIRP sonars provide better target definition and target separation without limiting depth pentration. (see discussion of CHIRP Technology) CHIRP technology is the future of sonars. The only hindrance that is preventing CHIRP sonar from dominating the sonar market is the high cost of CHIRP sonar.

Transducer Wattage

Wattage (current x voltage) rating of a transducer determines how far sound waves can be propagated to it carrier medium (water). Higher wattage means the soundwaves will have deeper penetration and will also cover more area regardless of cone angle. When comparing transducers with wattage, target definition or target separation is not affected by wattage within the common operating range of the transducers. Higher wattage transducers, however, will continue to deliver the desired performance beyond the range of lower wattage transducers. Other factors not being considered, higher wattage transducers will outperform lower wattage counterparts in 90% of situations.

Higher wattage transducers require more hardware to manage the higher power resources. Higher wattage transducers require more ceramic or bigger ceramic elements which then require bigger housing. It comes at no surprise that higher wattage transducers cost more relative to their lower wattage counterparts. Budget constraints can also become a factor.

Higher wattage transducers are also typically physically bigger than their lower wattage counterparts. Boat size must then be taken into account when choosing the appropriate transducer.

Power requirements may also be factor when the power resource is limited. This may be the situation on some sail boats. Higher wattage transducers will draw more current and will drain the power source quicker.

Aluminum Hulls (Galvanic Corrosion)

Galvanic corrosion is what happens when two dissimilar metals are immersed in an electrolyte, and are electrically connected. Less noble metals are anodic, or negative, and if connected, will sacrifice themselves to any more noble metal they are electrically in contact with while immersed in an electrolyte. The more noble metal is cathodic (either positive, or just less negative). The less noble metal is the giver, and the more noble metal, the taker. If you put the two in an electrolyte that conducts current like sea water, the atoms from one are “sacrificed” and plated onto he other metal. This happens when you have dissimilar metals such as aluminum and bronze close to each other. The aluminum disappears. Plastic is, of course, non-conducting and does not corrode. This why transducers made of plastic or plastic like materials are recommended for boats with metallic hulls like aluminum.

Chapter 7: What the Future Holds

With all the benefits that CHIRP (Compressed High Intensity Radar Pulse) has to offer, there is no doubt that the trend will be to make this technology more affordable and available to commercial or leisure fishing community. The year 2013 will perhaps be remembered as the year when products featuring CHIRP became available for less that $1000 with the introduction of Raymarine’s Dragonfly. Garmin is also expected to ship in 2013 the Garmin 741xs (Minimum Retail Price $1699). At the time of this writing, it is still unclear how these units will perform in comparison to CHIRP solutions that are already available in the market although at much steeper price (e.g. Garmin GSD 26, Raymarine Clearpulse, Simrad BSM-2 sounders).

Regardless of how these lower price units perform alongside their top-of-the-line counterparts, the trend will continue to be for sounder manufacturers and transducer makers to add CHIRP products to their product lineup. Competition among manufacturers will drive prices down which in turn will make it more affordable to consumers. Given the release of CHIRP sounder units below $1000, it is a safe bet that the CHIRP solutions will reach critical mass in 2013 or 2014 which will allow manufacturers to drive the price even lower.

CHIRP sonar will effectively replace the fixed frequency transducers as both products addresses the same type of requirements. We will see CHIRP solutions replacing fixed dual frequency configurations for new installations except perhaps for installation where the consumer has significant budget constraints (total cost of solution is less than $400).

Structurescan technology will not be affected by the CHIRP onslaught as the technology provides a solution to need that still cannot be efficiently addressed by CHIRP. The competition between Lowrance and Humminbird will continue to drive development of structurescan and will keep the prices affordable.

Chapter 8: Resources

GetFeetWet Sonar Resource –
http://www.getfeetwet.com/sonarlinks.aspx
Furuno Beam Width Calculator -
http://www.furunousa.com/LearningCenter/Transducer-Beam-Angle-Calculator.aspx
AirMar Technology Transducer Sounder Cross Reference Guide -
http://www.airmartechnology.com/2009/cross-reference.php

Chapter 8: Glossary of Sonar Terms

Glossary - Sonar Terms[41] [42]

2D-echo	A general term for an acoustic tag echo which has been assigned a Tag ID, either through a 2D-tracking procedure or from manual marking.
2D-tracking	An automated procedure for extracting tag data from the ambient noise on an individual hydrophone basis.
3D-echo	See description for position echoes.
3D-positioning	A process by which tracked acoustic tag data is used to create a 3D position echo. In order to calculate a 3D position, data must be obtained from at least four hydrophones which have their exact locations (x,y, and z) known.
3D-tracking	See 3D-positioning.
8 kHz output	The acoustic output from an echo sounder's receiver shifted from the operating frequency to 8000 Hz (cycles/sec).
A byte	An eight bit (0 and 1) digital number.
A calibration	Method of defining and setting characteristics of the electronic/mechanical equipment which allows repeatability of results. Very important in quantitative hydroacoustic work.
A constant	A value that contains echo sounder calibration constants, transducer and sound velocity parameters, duration of transmitted pulse, and mean backscattering cross section estimates. It is used to scale the output of the integrator to obtain biomass or density estimates.
A device bottom tracking	A special circuit or algorithm that predicts the location of the bottom based on previous bottom detections. Bottom tracking is used to terminate processing of the acoustic return just prior to the bottom pulse.
A/D	Analog to digital converter. A device used to convert a continuous time (analog) signal into a digital form. Specified by the number of bits per

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[41] Humminbird Glossary of Sonar Terms

[42] Glossary HTI Sonar

	sample and the number of samples per second (sampling rate).
absorption coefficient	The coefficient a, denoting the power loss due to absorption (symbol a). This gives the attenuation of the sound level in dB/m during the transmission of the signal through sea water. This attenuation can vary according to the sea water conditions (particularly salinity). For example, the absorption in sea water at frequencies between 5 and 50 kHz has been found to be up to 30 times that in distilled water. It also increases with the square of the frequency.
absorption loss	A temperature and frequency dependent power loss to acoustic waves, linear with distance (symbol a R: unit dB).
acoustic	The transmission of sound waves and measuring the time it takes for their echo to return after reaching an object. Having to do with the science of sound (see also sonar).
acoustic axis	The center axis of the acoustic beam. The direction of highest acoustic intensity. Region of maximum response, normally perpendicular to the face of a transducer.
acoustic calibration	Measuring the performance of an acoustic system to a specified standard (unit dB).
acoustic equation	See sonar equation.
acoustic equipment	Devices for the generation or reception of acoustic waves.
acoustic intensity	Amount of acoustic power through unit area. Reference is a plane wave intensity having an rms pressure equal to 1 m Pa (one micro pascal) (symbol I: unit dB/1 m Pa).
acoustic power	Acoustic energy per unit time. Usually given in dB||1 watt.
acoustic signature	Particular reverberation of sound and reflections from a target (usually with swim bladder), which typifies that target and may someday be used for species identification.
acoustic speed	Speed at which acoustic waves travel (symbol c; unit m/s).
acoustic tag echo	Repetition of sound produced by the reflection of

	sound waves returning from an obstruction.
acoustics	The theory of acoustic waves and their propagation.
AcousticTag	Acoustic tag software that can collect data and post-process data. During data collection, it communicates with the Acoustic Tag Receiver (ATR), which can receive up to 16 separate channels of acoustic data. One channel is assigned to each hydrophone. The received signals are synchronized in order to determine time of arrival for each detected pulse (see conceptual ping illustration). The arrival times of the transmitted signal pulses are used to determine the 3D location of the acoustic tag passing through the study area.
aggregation	A group of organisms of the same or different species living closely together.
airbladder resonance	See swimbladder resonance.
Alarm, Depth	Depth Alarm is a user-controllable, audible alert that sounds when depth is less than or equal to the setting.
Alarm, Temperature	Temperature Alarm is a user-controllable, audible alert that sounds when the water surface temperature equals the setting.
amplification	Amount by which a signal is increased, see gain (unit dB).
amplifier	The device which increases signal size.
amplitude	Size of a signal.
angular resolution	The amount of discrimination between targets separated in angle (unit degrees). This expresses, in degrees, the echo sounder's ability to distinguish between targets at different bearings but at the same distance from the transducer. Transducers with narrow beams have good angular resolution.
aquaculture	The cultivation of aquatic animals and plants, esp. fish, shellfish, and seaweed, in natural or controlled marine or freshwater environments; underwater agriculture.
array	Multi-element transducer.

ASCI-based text files	General formatting for database files.
attenuation	Loss or reduction of acoustic signal strength due to spherical spreading and absorption of the waves (unit dB/km) or internal friction within a water body. Attenuation is greater for salt water systems.
automatic gain control	Amplification varied in proportion to a received signal to reduce output voltage variation.
auto-tracking	An automated procedure for extracting tag data from the ambient noise. Several methods and algorithms are employed within the auto-tracking phase and can be adjusted via tracking settings.
B values	A user-selected input for the echo integrator. A different B value may be calculated for each discrete depth interval selected by the operator to compensate for errors in the TVG.
back scattering	Amount of acoustic power scattered by a target into the direction of the transmitting transducer.
back scattering cross-section	A measure of the reflectivity of a target. Target strength (TS) is equal to 10 log10(bs/4) of the backscattering cross section bs, which is defined by the relationship: bs = 4R2Ib/Ii where R = range to target; Ii = intensity at the midpoint of the incident wave at the target; Ib = intensity at the midpoint of the backscattering pulse.
back scattering layer	Biomass layer which back-scatters acoustic power.
Backlight	Backlight is a user-controllable illumination for the LCD for night and low light use.
bandwidth	The bandwidth of an amplifier is given as a difference between the two frequencies (in Hz) where a drop of dB occurs in the amplification of each side of the center frequency. Bandwidth of a sounder should be set to approximately 2/pulse length. For example, 1 msec pulse should have a 2 kHz bandwidth. The amount frequencies extend on either side of the nominal acoustic frequency (symbol BW; unit Hz).
Beam (Sonar Beam)	A sonar beam is the wide, cone-shaped projection of sound waves formed as sound travels underwater. See Cone Angle.

beam angle	Full included angle between the half-power points (symbol q ; unit degrees).
beam deflection	Amount by which a beam is moved in angle from its normal acoustic axis.
beam dual	See dual beam.
beam half angle	Angle where the acoustic power is half that of the axis (symbol q /2 unit degrees).
beam narrow	When full angle is less than 10°.
beam overlap	Amount by which successive pings cover the same area.
beam pattern	Two-dimensional pattern showing the relative response of a beam. The beam pattern is shown as a polar plot of the sensitivity of the transducer against direction.
beam pattern factor	In active hydroacoustics, the loss in signal intensity due to the target's position in the beam. If the target is located on the central axis of the transducer (in both X and Y planes), then the beam pattern factor will be zero. As the target moves further away from the transducer axis, the beam pattern factor becomes more negative, at a rate that is dependent on the transducer beam width.
beam width	A nominal value in degrees describing the full angular width of the acoustic sound cone, usually determined by the angle at which the transducer directivity pattern is 3 dB down for one way (transmitting or receiving). Transducers are usually classified as wide (perhaps 15) or narrow (perhaps 4) beam units.
behavioral studies	Scientific surveys, population modeling, and fishery management strategies are all dependent upon a fundamental understanding of fish behavior. Behavioral studies provide critical information needed to improve predictions on population abundance, distribution and survival, and to conserve populations of economically significant resource species and their habitats.
biological background noise	Noise due to biological sources, usually much lower in frequency than hydroacoustic signals and not a problem in signal interpretation.

biomass	The amount of living matter in a given habitat, expressed either as the weight of organisms per unit area or as the volume of organisms per unit volume of habitat.
biomass density	Measured as g/m3, or kg/10,000 m3, or # fish/10,000 m3, for example.
blocking	When receiving function is stopped by a very large signal, as in 'white line'.
body towed	See towed-body.
bookmarking	To mark or track a particular location or track within a data set in an acoustic tag tracking software application.
Bottom Contour	Bottom Contour is the profile of the bottom graphed to the display as the depth changes.
bottom detect	A circuit that generates a square pulse to inform a processor of the bottom position. A user adjustable threshold usually determines the signal level at which the bottom detect circuit creates it pulse.
bottom discrimination	Determining the nature of the bottom.
Bottom Hardness	Bottom Hardness is the density (or composition) of the bottom, which can often be determined by interpreting the main sonar return. Varying levels of hardness can be determined by interpreting the "thickness" of the sonar return. Hard returns appear thin and black, softer returns appear thicker and less black. It is important to note that a sonar return from a sloping bottom can have the appearance of a softer bottom.
bottom lock	A device which "locks" the recording or processing range of the display or processor relative to the bottom, instead of the surface. The bottom signal forms a reference for echoes just above it (also seabed lock).
bottom noise	Noise generated by tidal flow.
bottom pulse	Electrical pulse produced from bottom echo.
bottom tracking	A special circuit or algorithm that predicts the location of the bottom based on previous bottom detections. Bottom tracking is used to terminate processing of the acoustic return just prior to the bottom pulse.

bottom window	User-selectable range window centered around the range of the leading edge of the bottom detect pulse. The range window is used in the bottom tracking algorithm.
cal tone	A known level signal that is injected into the echo sounder receiving electronics. For recorded data, the cal tone signal can be recorded and later used to adjust playback level.
calibration	Method of defining and setting characteristics of the electronic/mechanical equipment which allows repeatability of results. Measuring or adjusting the performance of a system to a specified standard is very important in quantitative hydroacoustic work.
calibration equipment	Signal generators, hydrophones, standard targets, projectors, oscilloscopes, voltmeters, etc.
cavitation	Production of voids in the water due to negative pressure.
Cavitation	Cavitation is the effect of air bubbles created as the propeller rotates and the boat moves through the water.
channeling	Restriction of acoustic waves by boundaries.
chart recorder	Equipment used for data acquisition.
Chart Speed	Chart Speed is a user-controllable feature that sets the speed at which sonar information moves across the display. A faster setting displays sonar information from more pings and shows more detail, but the information moves quickly across the display
Cone Angle	The cone angle is the angular measurement of the sonar beam at a specific dB down point (i.e. -10 dB). See dB Down Point.
conical-beam	A sonar beam that is cone-shaped.
dB Down Point	The dB Down Point is the standard decibel level at which the sonar cone angle is measured, and is written as "@ -10 dB" or "@ -3 dB". Measurements at smaller down points (bigger negative numbers) indicate that the less intensive sonar signals are being used for the measurement.
dead zone	Volume of the transducer beam, usually close to the seabed, where targets cannot be detected.

Dead Zone	The dead zone is the area of the sonar beam that receives the sonar signal after the main bottom return. Fish and other objects close to the bottom that fall within the dead zone will probably not be visible in the sonar beam.
decibel	A logarithmic system for expressing the wide range of values in the sonar equation. Intensity level in decibels (dB) is defined as 10 log (I1/Ist), where I1 is the intensity of sound at a given point in an acoustic field; and Ist is a standard or reference intensity. For power, a 3 dB change corresponds to a factor of 2. For voltage gain (voltage squared is proportional to power), a 6 dB change corresponds to a factor of 2, since voltage level in dB is 20 log (V1/Vst).
Decibel	A Decibel is the measurement for sound pressure level, or "intensity" of the sonar return. See dB Down Point.
deep scattering layer	Layer of small fish and invertebrates in the deep ocean which undergoes diel vertical migrations and shows up as a 'fake bottom' echo on echograms.
default value	A value that a microprocessor like a fish tracker will accept unless the user enters a replacement value.
demodulation	Process of extracting information from a signal.
DEP	Data collection software for hydroacoustic studies. Provides the interface for properly configuring the system and visually monitoring real-time operation of a hydroacoustic system during data collection.
depth finder	Simple hydroacoustic device for determining water depth; often not suitable for fisheries research.
depth interval	Selected interval between two depths, also known as a gate (unit meters).
depth range	The total depth indicated on the display (unit meters).
depth recorder	Device which indicates and records the depth of acoustic targets and the seabed.
depth sounder	See depth finder.
detected signal	The positive going envelope of a signal with carrier frequency filtered out.

detection threshold	Signal power in the receiver bandwidth relative to the noise power in a 1 Hz band which permits the detection of a target against specified criteria (unit: dB).
digital sampling	Electronic sampling or storing X and Y points of volts over time at a rate of 48,000 bits per second. Allows hydroacoustic data to be internally processed in fine-scale detail.
directed net fishing	Use of hull, towed, and especially net mounted transducers to direct trawls to proper location and depth to maximize catch.
directivity pattern	A diagram showing the angular response of a transducer. Pattern of sensitivity or efficiency of a transducer in transmitting and receiving hydroacoustic signals. Best efficiency is on-axis, usually falling off rapidly off-axis.
direct-path	Acoustic echoes received by a hydrophone from the direct transmission signal of a tag. Direct-path echoes always arrive first and usually have a stronger signal strength than multi-path echoes.
display unit	For the display of signals and other information relating to the echo sounder.
Display, FSTN	FSTN is an acronym for Film Super-Twist Nematic. FSTN is a monochrome display technology characterized by black, high-contrast pixels. All monochrome fixed mount Humminbird® products use FSTN technology.
distributions	A spatial or temporal array of aquatic life.
Doppler effect	The alteration of apparent frequency when the sound source is moving relative to the observer, or when the target is moving relative to a transducer. The frequency shift in Hz is given by: f = (2v/c)f where f = the frequency of the transmitted pulse in Hz, v = the relative speed between the acoustic source and the target in m/sec, c = the velocity of sound in sea water in m/sec, and f = the frequency shift in Hz.
double-pulse	An HTI Model 795 Acoustic Tag which produces a primary transmit signal followed by a secondary transmit signal. The primary transmit signal is based on the tag's defined Period (i.e. ping rate) while the secondary transmit signal is based on

	the period and the defined subcode setting.
down-scan sonar	A downward-looking transducer.
DualBeam	sonar that uses two sonar beams simultaneously, and combines the information from both beams into one view by overlapping the data on-screen, or shows each beam individually side by side, or permits each beam to be viewed individually full screen.
dual-beam	Multi-element transducer from which two concentric beams of the same frequency but different beam widths are formed.
dual-beam sonar	Simultaneous use of wide and narrow beam transducers, allowing in-situ estimation of target strength.
dynamic range	The extent to which signals can be processed without distortion (unit dB).
echo	An acoustic wave reflected from a target of density differing from the medium in which the sound is traveling.
echo integration	The processing technique that determines the average squared echo sounder output voltage for selected range intervals and average times. The integrator output is proportional to fish biomass.
echo integrator	Unit to process and add the acoustic intensities from selected depth intervals.
echo level	Acoustic intensity at the receiving transducer (symbol: EL; unit dB).
echo paper dry	Recording paper conductive with high voltage.
echo paper moist	Recording paper conductive with low voltage.
echo ranging	Finding the distance to a target by measuring the time from transmission to echo.
echo sounder	System comprising acoustic transmitter, echo receiver and display.
echo sounding	Finding the depth of a target by measuring the time from transmission to echo.
echo trace	Mark on a record caused by an echo.
echogram	Record of a sequence of echoes.
EchoScape	Hydroacoustic post-processing software that provides instant and automatic tracking of fish

	data on-screen. Used to perform data analysis and display results (works with HTI's split-beam
electro-acoustical efficiency	The ability of a transducer to convert electrical energy into acoustic energy. It can be expressed in dB [efficiency in dB = 10 log (% efficiency)].
electro-strictive	Material which changes its dimensions under the influence of an electric field.
elliptical-beam	A sonar beam having the form of an ellipse.
entrainment	Trapping.
equipment log sheet	A table of equipment readings.
equivalent angle	The included angle of an 'ideal' beam, calculated from actual transducer characteristics.
expanded dynamic range	A technique to improve the range of tones on a paper record.
expanded scale	Display of a portion of range or depth at a size exceeding its basic scale.
far-field	Distance beyond where the initial fluctuations of intensity occur when transmitted by a transducer.
figure of merit	Comparative performance of acoustic systems based on maximum allowable two-way transmission loss related to a target strength of 0 dB (symbol: FM; unit: dB).
fish abundance	The quantity of fish in a population.
Fish Arch	A Fish Arch is the apparent "arch" that appears on the display when any object moves through the sonar cone. The arch results from a gradual decrease in distance to an object as it moves into the sonar cone. The distance to an object changes due to the conical shape of the sonar beam, which causes the distance to be greater at the edges of the beam than at the center of the beam. When this distance change is graphed on the display, an arch appears.
fish detection	Location of fish by acoustic means.
fish target strength	Ratio of the acoustic intensity IR reflected from a fish and measured 1 m away, to the incident acoustic intensity Ii, 10 log IR/Ii dB (symbol: TS; unit: dB).
fish traces	Acoustic tracks or 'traces' of fish travel.

fixed-location hydroacoustics	A hydroacoustic survey technique where the transducer is attached to a solid object, with its aiming angle set and stable. In contrast to a mobile survey, the fixed-location survey samples fish as they move toward and pass through the acoustic beam.
FM slide/chirp	A technique for significantly improving the signal-to-noise performance in hydroacoustic assessment systems.
free-field	Volume of water clear of boundaries.
frequency	The number of oscillations a sinusoidal signal source makes each second. Usually expressed in Hertz (Hz, cycles/sec) or kiloHertz (kHz, 1000 cycles/sec). Hydroacoustic systems usually have frequencies in the range of 20-500 kHz.
Frequency	Frequency is a measure of the number of sound wave cycles per second of a sound impulse transmitted underwater. A typical frequency for fishfinders is 200 kHz, which offers a good balance of performance under many conditions. Lower frequencies, such as 50 kHz, are capable of penetrating to greater depths, but with less resolution. Higher frequencies, such as 455 kHz, offer greater resolution, but are limited in depth performance.
frequency counter	A device to count the number of complete cycles to pass a given point in a given time.
frequency response	The extent to which a system is sensitive to a range of frequencies (unit Hz).
gain	Amount by which the amplitude (size) of a signal is increased (unit dB).
geometric cross-section	Projected area of a target in the direction of isonification.
geometric zone	Where the relationship of wavelength l to the dimensions of a fish enables TS to be deduced from the laws of geometric optics.
geometrical loss	Dispersal of energy of an acoustic wave due to the spreading effect within the geometry of the beam.
geometrical spreading	The increase in the ensonified cross-sectional area with distance traveled by the sound waves.
ghost echo	An echo falsely related to the depth scale.
GPS position	A location defined by a Global Positioning System.

ground truth	Use of trawls, gill-nets, etc., to independently estimate biomass and provide species identification to hydroacoustic data.
Hertz	Frequency, defined as one-per-second, abbreviated as Hz.
history (within tag programming sessions)	A systematic account of any set of software steps in a sequential order in time.
horizontal distribution	The frequency of occurrence or the natural range of aquatic life viewed in a parallel or horizontal perspective within a water column.
hydroacoustics	The study or use of sound in water to remotely obtain information about the physical characteristics of the water body, its bathymetry, or biotic populations.
hydrophone	Device to receive acoustic waves and convert them to electrical signals.
impedance	Ratio of generally complex quantities of pressure and particle velocity or of voltage and current at the same time and place.
incident intensity	Acoustic intensity falling on a target.
incident sound	Sound which impinges on a target.
insonified volume	Volume of water into which acoustic signals are directed to obtain biomass information.
insonify	To 'illuminate' by means of acoustic waves.
integrated layer	Layer of water, defined by upper and lower depths, on which integrated biomass estimates or fish counts are based.
integrator	The computerized integration of fish echoes to estimate biomass.
intensity	The acoustic power per unit area of a propagating acoustic wave.
interval mark	A voltage pulse created by the integrator for the purpose of marking the chart at each printed output.
isotropic	Having non-directional properties.
kilohertz (kHz)	1,000 Hz
layer	See scattering layer.
live fish calibration	Overall calibration of an echo-sounder/echo-integrator system by insonifying captive fish and measuring the received intensity.
magneto-strictive	Material which changes its dimensions under the

	influence of a magnetic field.
marked	A raw acoustic tag echo which has been assigned a specific tag identification (i.e. period and subcode).
marking	The process of assigning a raw acoustic tag echo a specific Tag Identification (i.e. period and subcode). Marking raw echoes can be either a manual or an automated (i.e. auto-tracked) process.
MarkTags	A post-processing program, the primary acquisition and 3D analysis software for Model 290/291/295 Acoustic Tag acquisition systems. MarkTags selects and separates all the data contained in the raw data files and makes marked data files. These files now contain Tracked Acoustic Tag Echoes (TAT files). The file can be used to produce summary information (i.e. survival studies, travel times, horizontal distribution) or can be further processed in AcousticTagto produce 3D analysis results.
medium	Substance in which sound is traveling.
minimum recordable signal	Smallest amplitude (size) of signal which can be seen on the display.
mobile survey	A hydroacoustic survey conducted from a moving boat.
modulation	The process of impressing information on a signal (e.g. pulse).
multi-path	Acoustic echoes received from the same tag but from different sources due to reflections from the water surface or surrounding structures. Multipath echoes always arrive at the hydrophone after the direct-path transmission and are usually (but not always) weaker in signal strength compared to direct-path echoes.
multiple targets	More than one target within the beam of the transducer.
multiplexing	
near field	This is the region in front of the transducer where the wave-fronts produced by the transducer are not parallel and the beam is not properly formed (inverse square law does not apply).

noise	Unwanted electrical signals originating within the equipment or from hull or water sounds picked-up by the transducer.
Noise	Noise is unintentional, external sound waves that interfere with the optimal operation of sonar. Noise appears as random "dots" on the display, and is caused by a variety of sources. Electrical noise (from trolling motors, bilge pumps, VHF radios) typically manifests as a consistent dot pattern. Electrical noise can be isolated by selectively turning on and off other electrical devices to determine the source. Often re-routing the power cable, or connecting to an alternative power supply (second battery) can help overcome electrical noise. Hydrodynamic noise (from propeller and/or hull cavitation) has a more random appearance and is generally related to boat speed, so that faster operation results in more noise. Hydrodynamic noise can be overcome by proper transducer installation.
noise level	Number of dB by which noise is above or below a given reference.
noise limited	Distance at which detection is no longer possible because the signal is obscured by noise.
noise reduction	Number of dB by which noise is reduced from a reference.
noise spectrum level	Noise power for one cycle of energy, (symbol: SPL; unit: dB/1 m Pa/Hz).
oscillation	An uncontrollable state of an amplifier, or the result of an oscillatory state.
oscillator	Electronic circuit for generating controlled oscillations.
oscilloscope	An instrument for viewing and measuring oscillations or signals.
Peak-to-Peak	Normally used to describe the output power of a sonar transmitter. This value is a measurement of the total swing of an AC voltage from its peak negative value to its peak positive value.
performance test	Measurements to establish the standard to which a system is working.
period	Time required for a single oscillation of a sine wave. The period equals 1/f where f is the

	frequency. Always presented in msecs.
phase	The time relationship of one wave to another.
ping	A name for the transmitted acoustic pulse.
Pixels	Pixels are the "picture elements", or small square blocks, that make up the image on the LCD. Measured as a vertical by horizontal number (i.e. 640 V x 320 H), this key specification typically indicates the quality of resolution. In fishfinders, the total resolution (vertical multiplied by horizontal) is often less important than the "Vertical Pixel" resolution. See Pixels, Vertical.
Pixels, Vertical	Vertical Pixels are a number of vertical picture elements in a single column on an LCD display. A greater number of vertical pixels provide finer resolution of targets detected by sonar. Essentially, a vertical distance (the depth), when divided by a larger number, breaks that distance into smaller samples, each representing a smaller area and thus providing more detail. In fishfinders, vertical pixels are more critical than horizontal pixels because the horizontal axis of the display represents time, or history. Sonar information on the horizontal axis can vary greatly, depending on boat speed and the Chart Speed setting. A greater number of horizontal pixels show more sonar history that the boat has passed through.
Position Acoustic Tag Echo	Also known as a position or 3D Echo, is an echo position which has been calculated using a 3D-positioning process using tracked acoustic tag echo data.
Position Acoustic Tag Files (*.PAT)	These files contain the individual position acoustic tag echoes generated within the 3D tracking process. This file type is created during real-time tracking, or when exporting position echoes.
position echoes	Echoes which have been generated by the 3D-positioning process either during real-time data acquisition or post processing procedures. To generate real-time position echoes, the ATS must be properly configured in terms of having valid hydrophone positions, correct released tag information, and proper settings for the auto-tracking and 3D-positioning processes.

position set	A group or set of defined hydrophones with known positions (X,Y,Z coordinates) used either in data acquisition and/or in post-analysis.
Power Output	Power output is the amount of sound energy emitted into the water by the sonar transmitter. Power output is measured using either RMS (Root Mean Square) or P-T-P (Peak-to-Peak) measurement systems. Either method is acceptable, but it is important, when comparing power outputs, to make sure that the same measurement system is being used for both outputs, because P-T-P numbers are 8 times higher than RMS numbers. Greater power output allows the sonar signal to penetrate through weeds and thermoclines, reach deeper depths and operate more effectively in noisy environments, such as when the boat is running at high speed.
pre-amplifier	Boosts signals before the main amplifier.
projector	Transmitter of acoustic power.
propagation	Ability of acoustic signals to progress outward in a medium.
pulse	Sound in water. A momentary, sudden fluctuation in an electrical quantity, as in voltage or current.
pulse duration	Length of time a pulse of a given frequency is emitted by the transducer.
pulse length	The distance a pulse extends (unit meters).
Pulse Length	The length of time a sonar unit transmits a pulse of sound into the water. Sometimes referred to as Pulse Width.
pulse rate	Number of pulses in a given time.
pulse repetition rate	The rate of repetitive acoustic pulses, of a given duration and frequency, emitted by a transducer. Typically referred to as the "ping rate."
pulse volume	The volume contained within the included angle of the beam for the extent of one pulse length at a given range (unit m3).
pulse width	The width or duration in time of the transmitted acoustic pulse, usually expressed in msec.
Pulse Width (Pulse Length)	Pulse Width is the length of time that a sonar sound burst is transmitted into the water. Shorter pulse widths provide better target separation, but

	cannot travel to great depths. Longer pulse widths provide better depth penetration, but result in poorer target separation. n.
radio tags	Radio tags technology identifies objects remotely through the use of radio frequencies that requires transmitters to emit the signals, receivers to detect and record them, and additional supporting equipment. They depend on steering the fish in a particular path (requiring the fish to be routed through a restricted sensing area).
range	Distance from the transducer face to the target (symbol: R; unit: m). Often used synonymously with depth in vertical sounding.
Range	Range is the depth of the water column - from the surface down - displayed on the sonar screen.
range resolution	The minimum range separation between distinguishable targets. For a CW pulse acoustic system, the range resolution is equal to c/2 where c is the velocity of sound and is the pulse length.
Raw Acoustic Tag Echoes	Echoes received by the individual hydrophones of an ATS. These echoes can be comprised of direct path as well as multipath sources. Raw echoes are not associated with Tag ID.
Raw Acoustic Tag Files (*.RAT)	The AcousticTag program generates raw acoustic tag echoes based on the echo selection criteria using the data collected from the hydrophones of an ATS. These raw echoes are written to a *.RAT (RAT = Raw Acoustic Tag) files during data collection. Located at the beginning of each *.RAT file is header information which contains the data acquisition settings used when the file was created. Following this header information are the individual entries for each raw acoustic echo. It is important to note that these raw echoes are not associated with any specific Tag ID, nor is there any spatial (i.e. x, y or z) positioning assigned to a raw echo.
Rayleigh scattering zone	Where fish scattering cross-section varies inversely with the fourth power of wavelength, fish length much greater than l.
real-time	Of or relating to computer systems that update information at the same rate as they receive data,

	enabling them to direct or control a process such as an automatic pilot.
real-time tracking	Any auto-tracking (2D and/or 3D tracking) procedure used during the data acquisition phase of the AcousticTag program.
receiver	Instrument to amplify, filter and otherwise process electronic signals (echoes) produced by the transducer.
Receiver	See Transmitter.
receiving voltage response	Number of dB relative to 1 Volt for a given acoustic pressure at the transducer face (symbol: VRT; unit: dB/V).
reciprocity	Exhibited by mutually interchangeable transducers.
reflection	The "bouncing" of sound off a target, due to the differences in density between medium and target and target orientation.
refraction	Deflection of sound from a straight path, e.g., when passing through a thermo cline at an angle.
resonance	When a circuit, or a target, is excited to different modes of vibration by a particular frequency.
resonant frequency	The natural frequency of operation for a transducer or circuit (symbol f: unit Hz).
reverberation	Acoustic interference caused by scattering off objects other than those of interest. The main source of reverberation in fisheries assessment are the bottom, surface, other boundaries, air bubbles, plankton, and particles in water.
Rf (radio frequency) output	Signal out of the sounder that has not been shifted to a lower frequency.
root mean square	The square root of the averaged sum of all squared values of a waveform (symbol rms).
sample period	A sequence is divided up into a number of intervals referred to individually as a sample period. Sample periods are linear by definition and are always associated with the sequence in which they are contained. For example, the sample periods defined for sequence one of a sampling plan would be labeled as "S1P1" for period one, "S1P2" for period two and so on. Whenever more than one sampling period is defined for a sequence, the system is in fast multiplexing

	mode. The system will execute the sample periods within a sequence in the order in which they have been defined, starting with the first and ending with the last defined sample period for that particular sequence. After the last sample period has been completed, the system will then begin with the first sample period for that sequence once again.
sampling cross section	The cross-sectional area sampled by the acoustic beam.
sampling plan	Data collection is performed by defining a sampling plan within the system based on start times and duration, as well as ping rates. The sampling plan can be set to sample within hourly intervals, or by a set of defined intervals which are repeated. Defining a sampling plan must be the first step taken before any data are acquired by the system.
sampling volume	The volume of water ensonified by the acoustic beam.
scattering layer	Extensive horizontal distribution of acoustic targets.
Second Return	The Second Return is a term that describes the appearance of a second sonar return below the primary sonar return (bottom contour) at exactly twice the true depth. The second return is caused by the same sonar energy bouncing off the bottom once, rebounding to the water surface and then traveling back down to the bottom to be reflected again. Second returns are more common in shallow water and over hard bottoms; it is actually possible to see a third sonar return under some circumstances. The second return provides useful information to help determine bottom hardness, as areas with harder bottoms will generally create a second return. The second return can be used as a guide to set Sensitivity when in shallower water.
secondary echo	When the echo from a target or seabed is reflected back from the surface and causes a second echo from the target or seabed to be received.
sector scanning	The use of a multiple transducer array, with each transducer ensonifying only a portion of the total area of interest, to increase overall transducer

	coverage.
sensitivity	Degree of response to an acoustic or electrical signal.
Sensitivity	Sensitivity is a user feature that adjusts the sensitivity of the sonar system to show more or less detail in the water. Higher sensitivities are often preferred, however, when the water contains debris (silt, storm debris, etc.) and it can be difficult to pick out targets. Conversely, if sensitivity is set too low, relevant targets may be missed.
sequence	A specific time event within the application when data is processed. A sampling plan is comprised of defined time intervals referred to individually as a sequence. These sequences are linear by definition and are labeled as "S1" for sequence one, "S2" for sequence two, and so on. The system will execute a particular sequence for its defined duration. When the duration for a sequence has been completed, the system switches to the next defined sequence in the sampling plan. After the last defined sequence has been completed, the system will then execute the initial sequence it started and will continuously repeat the procedure.
shadowing	The effect caused by one target lying in the 'shadow' of another.
side lobe	All beams of a transducer except the main beam.
side-scan sonar	Side-looking transducer, usually used by commercial fisherman to spot distant fish schools.
signal encoding	Proprietary encoded code-phase modulated pulse/signal.
signal generator	Instrument which produces electrical signals at controlled frequencies and amplitudes.
signal strength	Intensity of an acoustic wave or amplitude of an electrical wave.
signal-to-noise ratio (SNR)	Ratio of signal strength to background noise level (symbol: SNR; unit: dB).
single-pulse	An HTI Model 795 Acoustic Tag which produces a single transmit signal. The transmit signal is based on the tag's defined Period (i.e. ping rate).
sonar	Commonly referred to as the transmission of

	sound waves and measuring the time it takes for their echo to return after reaching an object.
SONAR	SONAR is the acronym for SOund and NAvigation Ranging. Sonar technology uses precision sound bursts transmitted underwater to determine the distance and other attributes of objects in the water. Distance can be determined because the speed of sound in water is constant, and the time for the signal to return is measured. Sound also travels very quickly underwater, making sonar a responsive, cost-effective tool. Sonar is the basic technology behind all recreational and commercial fishfinding and depthfinding devices.
Sonar Echo Enhancement	Sonar Echo Enhancement is a Humminbird® feature that describes the high degree of sonar sensitivity achieved through a combination of transmitter/receiver and software algorithms. The result of Sonar Echo Enhancement is to display virtually everything in the water that is of interest to the angler, including bait fish, game fish, thermoclines, weed beds, subtle structure, and more.
sonar equation	The equalities from which the performance of an acoustic system can be calculated, (units in dB) Now called acoustic equation.
Sonar Update Rate	Sonar Update Rate is the number of times per second that the transmitter/receiver sends and receives sonar signals. A very fast sonar update rate collects more information and provides a more detailed image of the bottom, fish and structure.
sound intensity	Power of sound waves, measured in ergs/cm3/s.
sound radiation	Spreading of sound equally in all directions.
sound velocity	Velocity of sound through a medium; in water, about 1500 m/sec, and dependent upon temperature, salinity and depth.
sound wave	Pressure maxima and minima moving within a compressible medium.
source level	Ratio of acoustic intensity on the axis of a source at 1 m, to a plane wave of rms pressure 1 m Pa (symbol: SL; unit: dB/1 m Pa/m).

Speed	Speed is the rate at which the boat moves through the water. Boat speed can be measured as Speed Over Ground or Speed Through Water. Speed Over Ground is provided by GPS, and is the measurement of the boats progress across a given distance. Speed Through Water is provided by a speed paddlewheel, and is the measurement of the flow past the boat, which may vary depending on current speed and direction. Speed Through Water is most critical for anglers using downriggers, as it impacts the running depth of the down riggers. Speed Over Ground is optimal for navigation, as accurate destination times can be derived from this measurement.
speed of acoustic waves	See acoustic speed.
spherical spreading loss	Describes the decrease in sound intensity as the beam spreads (i.e., decreases with range).
standard target	A target possessing a known target strength, used for the calibration of acoustic systems (unit dB).
stationary transducer	Transducer fixed to a buoy or to the bottom looking upward, sideways or downward.
Structure	Structure is a general term for objects on the bottom that present a discontinuity and are a likely attractor for fish. This includes bottom contour features (drop-offs, humps, and holes), standing structure (stumps, timbers, brush piles) and a wide range of other potential objects (sunken boats, reefs).
subcode	A setting used for double-pulse tags. Subcode settings range from 1 to 15 which defines a specific time interval at which the secondary signal is transmitted after the primary signal has been transmitted.
sub-meter	Less than one meter in diameter. Often referred to with HTI’s Model 795 acoustic tags fine-scale tracks.
Summary Files (*.SUM)	Files containing summary information for all raw acoustic tag echoes which have been marked. *.SUM files contain a list of Tags in which data was marked for each hydrophone of the system. Within MarkTags, summary data is only

	available after the data has been marked either through manual or Auto-Tracking methods.
Surface Clutter	Surface Clutter is a phenomenon where sonar returns are reflected off of tiny objects near the surface of the water, including algae and even air bubbles. Typically, saltwater environments have significantly greater surface clutter than freshwater due to continuous wind and wave action that causes aeration at the surface. The Surface Clutter menu provides manual control to bias the default settings under extreme conditions.
survival studies	Research or investigations to assess the effects and influences on the long-term viability of fish stocks, commonly used for salmonids listed as threatened or endangered under the U.S. Endangered Species Act (ESA).
swimbladder resonance	Characteristic "ringing" of air-filled swim bladders when ensonified by a hydroacoustic system.
swimming path	Track or travel of an organism in water.
synchronization	The keeping together in time of recorders: units comprising an echo-sounder, a sonar, or electrical waveforms.
tag double-pulse mode	In addition to the period, there is another setting that can also be used to increase the number of possible unique tag identifiers. Within the tag programming software, TagProgrammer, there is an option for enabling the double pulse or subcode mode. If this option is turned on, the tag will produce a primary transmit signal followed by a secondary transmit (subcode) signal. There are 15 different subcodes possible for each period. This gives up to 100,000 unique codes. This option should be used when a project involves the release of thousands of tags. Using this feature does affect the life of the tag since the tag's signal is being transmitted twice.
tag ID	The tag's identification which consists of the period and subcode setting used when the tag was programmed. A tag ID is always represented by the period value followed by a "." then the subcode. For example a Tag ID of 4200.05

	designates a tag was programmed with a period of 4200 msecs with a subcode setting of 05. If a tag is not programmed with a subcode setting, it would be designated as 4200.00. All single-pulse tag IDs will have a subcode of "00" (ex. 1000.00, 2010.00, etc).
tag period	The period (i.e. rep rate, tag code) is the rate at which the tag emits a pulse into the water. Period is measured from the leading edge of one pulse to the leading edge of the next pulse in sequence. By using slightly different periods, single pulse tags can be individually identified (up to 16,000 unique periods). The timing of the start of each transmission is precisely controlled by a microprocessor within the tag. When conducting a study where multiple tags are to be released, each tag must be programmed to have its own unique period in order to identify one tag from one another.
tag programming	Model 795 Acoustic Tags are NOT pre-programmed and need to be programmed by the user prior to use. Tags have a finite shelf life and a finite operational life. Do not turn tags on until they are intended to be used. To program a Model 795 Acoustic Tag requires the Model 490 Acoustic Tag Programmer, a computer installed with the TagProgrammer software, and a supplied serial cable connecting the computer to the Model 490. It is also advisable to have an oscilloscope connected to the Model 490 to verify and measure the programmed state of the tag. There are two main settings that need to be addressed prior to programming tags, these being the pulse width and period. The tag's battery life is limited and is affected by the combination of these two settings. Refer to the tag life section on how these two settings affect the longevity of the battery.
tag pulse width	The pulse width (or pulse length) for each Model 795 Acoustic Tag is configurable where the duration of the tag transmission is precisely controlled by a microprocessor within the tag. When conducting a study where multiple tags are to be released, all tags must be programmed with

	the same pulse width. This is so the Model 290/291/295 AcousticTag Receivers can "filter" out the specific pulses coming from the acoustic tags from the ambient background noise.
TagProgrammer	Software that programs acoustic tags and can turn the tags “on”. Model 795 Acoustic Tags are NOT pre-programmed, allowing the user to configure tags prior to the study and keeps them in a sleep mode until they are ready for use.
Target Separation	Target Separation is the measurement of minimum distance that a fishfinder needs to be able to recognize two very close objects as two distinct targets (i.e. two fish hanging very close, or a fish hanging very close to structure). Target separation decreases as depth increases due to the need for longer Pulse Width to achieve greater depth. See Pulse Width.
target strength	Acoustic size of target in dB (see backscattering cross section). The ability of a given target to reflect acoustic signals; usually given in terms of negative dB's.
thermal noise	The ultimate limit to detection due to molecular activity, mainly evident above 100 kHz.
thermocline	Temperature discontinuity where organisms often collect, thus making it acoustically 'visible'.
Thermoclines	Thermoclines are water layer(s) of distinctly different temperatures that create a sonar reflection due to the density of the differing water temperatures. Typically a thermocline will appear as a continuous band across the display at some distance above the bottom contour. Thermoclines are of interest to anglers because fish will suspend above or below the thermocline as they seek the optimum temperature and oxygen levels.
threshold	An amplitude value below which all echoes are rejected. A threshold is applied to reject noise and signals from very small targets which are not of interest.
Time Variable Gain	Time Variable Gain is a processing step applied to the sonar return to "normalize" the data so that objects of equal size (i.e. fish) appear to be the

	same size, even if they are separated by a good distance. Time Variable Gain is a fundamental attribute of good sonar, but is often promoted as a feature. Total Screen Update®
timebase	The time reference to which signals on a paper recorder, or an oscilloscope, are displayed.
time-varied-gain (TVG)	A successive increase in the amplification of the receiver with range (time) during the reception period of each sounding. For single targets, 40 log(R) compensates for geometric spreading loss and absorption. For multiple targets, such as produced by fish schools, a 20 log(R) TVG will provide an output that is a function of the density of the scattering and not a function of range.
towed-body	Also refered to as towed-body. Hydrodynamically shaped body into which a transducer may be fitted for towing.
track fish	To observe or follow the course of a fish in 2D or 3D.
tracked	Raw acoustic tag echoes which have been selected and assigned a tag ID through an auto-tracking method. Also referred as auto-tracked.
tracked acoustic tag echo	Tracked echo is a raw echo which has been assigned a tag ID. Assigning a tag ID to an echo can be done using a manual or auto-tracked method. All echoes within a *.TAT file are assigned tracked echoes.
Tracked Acoustic Tag Files (*.TAT)	These files contain the individual tracked acoustic tag echoes which have been assigned a tag ID. Within the 2D tracking phase of the real-time tracking process, raw echoes are assigned tag IDs based on the specific tag defined for real-time tracking within the tag information dialog box. The *.TAT (TAT = Tracked Acoustic Tag) files are always associated with a specific *.RATfile since the data within a *.TAT file will always be a subset of the data found in a *.RAT file.
transducer	Electro-mechanical device which translates electrical energy to sound energy to produce the hydroacoustic signal, and converts returning echoes back into electrical signals.

Transducer	The transducer is part of the sonar system, which mounts on the boat and is in contact with the water, that converts the electrical energy from the transmitter into sound energy, and that forms the sonar beam in turn. Internally, the transducer consists of one or more piezo electric disks that expand by very minute amounts to create the sound wave. This element also works in reverse, converting the returned sound energy back into an electrical signal that the receiver interprets. Transducers are available for many specific mounting applications for the boat, such as a transom mount, trolling motor mount, etc. Humminbird® offers many sophisticated transducers, often with multiple piezo electric elements designed to form specifically-shaped sonar beams, providing the angler with superior tools for finding and catching fish. See Transmitter and SONAR.
transducer beamwidth	Angular width of the beam measured at the half-power point (i.e., at -3 dB points down).
transducer impedance	An electrical characteristic of the transducer that must be matched to the cable and echo sounder to have maximum efficiency of operation.
transducer, electrostrictive	Transducers with elements made of ceramic materials such as barium titanate or lead zincronate. They expand and contract according to the electric field.
transducer, magnetostrictive	Transducer which consists of nickel plates which expand and contract according to the magnetic field induced in it.
transmission locked	Display of signals related to time of transmission.
transmission loss	Sum of absorption loss and geometric loss (symbol TL, unit dB).
transmitter	Unit which produces electrical power at the required frequency.
Transmitter	The transmitter and receiver are matched parts of the sonar system that send (transmit) and listen to (receive) the sonar signals, and work in conjunction with the transducer. Additionally, the transmitter has the capability to create very

	precise Additionally, the receiver offers a wide "dynamic range" which provides the ability to receive very strong signals alternating with very weak signals, without the strong signal overwhelming the weak signal. See Transducer and Noise.
travel times	Referring to time calculations that measure a journey or a distance (points of reference along a waterway) for a particular fish track.
trigger interval	Amount of time between sound transmissions. A pulse repetition rate of 2 pulses/sec corresponds to a trigger interval of 0.5 sec/pulse.
trigger pulse	A pulse generated either by the chart recorder or by the echo sounder that occurs at the time of transmission. Its purpose is to keep all equipment synchronized for data collection and display.
tungsten carbide	A chemical compound that is unbelievably durable, and is a cheaper and more heat-resistant alternative to diamond.
Viewing Angle	Viewing Angle is an attribute of an LCD that characterizes visibility of the display when viewing from off the central access, such as when standing to the side of the fishfinder. Wider viewing angles are better because the information remains visible even when viewing from the side.
voltmeter	Device for the measurement of voltages, either arising from direct or alternating current.
wavelength	The distance traveled by a sinusoidal acoustic wave in a time equal to the period of the sine wave. The wavelength is important in determining the directivity of transducers and the characteristics of scattering.
wavenumber	Spatial frequency of a propagating sine wave acoustic signal.
white line	Effect of a circuit which cuts off the seabed echo recording shortly after it appears, then allows it to resume after a fixed period.
zero line	Base line of a chart recorder (echo sounder, depth sounder) representing zero time (zero depth or depth of the transducer).