How Loud is the Navy Noise?

There is an understandable level of confusion around how loud the SURTASS/LFAS noise source is – and how much impact the noise will have on our ocean environment. Part of the confusion is due to the Navy noise being underwater. We humans mostly hear sound in air, so we understand airborne acoustics better. Sound works differently in air than in water, and the only tools of comparison we can effectively argue about are numerical, or mathematical models. Visceral comparisons – how humans and sea animals are affected by sound – are speculative and difficult to argue because these affects are by nature subjective to each individual species. It is also difficult to argue because humans and ocean creatures use sound in different ways.

How humans use sound.

Humans use our sense of vision to inform us of our immeadiate surroundings. We use sound to complement our sense of placement, direction and spatial navigation. We use sound mostly in close proximity – to speak and hear information and music, but we also get a sense of our environment through sound, so without the benefit of sight, we can tell whether we are in a crowded or empty room, in an open field, or on the train tracks with an oncoming train. Sound helps inform us of things occuring that we may not be able to see; with this aspect of our hearing, we can avoid uncomfortable or harmful encounters or draw toward beneficial encounters.

Noise is any sound that interferes with our use of sound. The louder the noise, the more it interferes with our use of sound – and the more annoying and potentially dangerous it is.

How sea animals use sound.

Many sea animals do have vision, but throughout most of their environment vision is not very useful. While many sea creatures use very sensitive chemical and thermal perception to know where they are, many sea creatures rely on sound to inform them of their surroundings. If they can see, their vision compliments their auditory sense of placement, direction and navigation. Many sea animals can use vision in close proximity to capture prey and forage for food; all other perceptual cues of community, navigation and communication occur through their use of sound.

Whales use sound to communicate over long distances, dolphins use sound to identify fast moving prey and keep in touch with their community. Schooling fish use acoustical energy to keep their swimming bodies synchronized with their school. Some sea animals use sound to detect the proximity of turbulence such as waves and currents. They can also use acoustical energy to help them evade fast approaching predators. Without seeing an attacking sea lion a school of fish can evade the oncoming threat, strictly through their perception of acoustical energy.

Many sea creatures depend predominantly on sound and acoustical energy to survive. Even jellyfish use acoustical energy to help them navigate; migrating jellyfish near the coast can keep out of dangerous turbulence and away from coastal breakers by sensing the turbulence through their organs of acoustical perception.

For sea animals, like humans, noise is any sound that interferes with their use of sound. The louder the noise, the more it interferes with their use of sound and the more annoying and potentially dangerous it is.

Some whales make sounds as loud as SURTASS/LFA, why is the Navy Noise more dangerous?

There are some whales such as blue whales, that can make noises as loud as the Navy noise. Even some crustaceans, such as snapping shrimp, use very loud sound to stun their prey – a sound tool that some dolphins also use. One of the lynchpins to the Navy SURTASS argument is that animals capable of making these loud sounds can also withstand equally loud noise. This argument does not account for the fact that ocean creatures use all levels of sound; like humans, they can, whisper, talk, sing and shout. They are adapted to these various sound levels much as humans are. But the Navy noise is ALWAYS shouting. Permitting their noise would be like having a guest in your home who can do nothing but shout all of the time. This would be intolerable in your home, and even your neighbors would be bothered and stressed out by it. If everyone in your neighborhood had shouting guests, the whole community would eventually break down.

The numbers.

Much of the confusion about the intensity of SURTASS/LFA revolves around numbers. A common aspect of this confusion is that we use similar numbers to represent two distinctly different environments – the ocean, and our air environment. Sound works differently in each of these environments, so the numbers we use to express the physics of each environment also work in different ways. There are two conversion factors that help bring numerical parity between the environment models, one factor is strictly a numerical conversion, the second factor has to do more with the physical properties of each medium.

For folks who don't typically use numbers to model their environment, the numbers seem to take on a life of their own. This is aggravated by the use of "decibels" or "dB" to express numerical relationships.

What are Decibels?

It is important to know that decibels, (dB) are not an expression of a specific quantity or amount, rather decibels is an expression of relative quantities or amounts. The term "0 dB" is not a measure or expression of nothing, but rather it is the reference point for the specific decibel scale in question.

In acoustics, the decibel is used to evaluate energy levels in terms of Sound Pressure Level (SPL,) with the term "dB_{SPL}". By convention, 0dB refers to any specific reference point. The reference point for airborne SPL equates to the lowest threshold of human hearing which happens to be 0 dB = 20 microPascals (20 μPa) – a convenience tailored to a known pressure quantity relative to human perception. This measure has no significance underwater, so the reference level for ocean sound shifts down to a mathematically more convenient number – to a reference point of 0 dB = 1 microPascal.

The mathematical consequence of this is a numerical shift of 26 dB. This simply means that any specific SPL number expressed relative to 20 μPa will be 26 dB less than that same number expressed relative to 1 μPa. Two simple mathematical expressions for this are:

$$0\ dB_{SPL}\ re{:}\ 20\mu Pa = -26\ dB_{SPL}\ re{:}\ 1\mu Pa$$

and

$$0\ dB_{SPL}\ re{:}\ 1\mu Pa = +26\ dB_{SPL}\ re{:}\ 20\mu Pa$$

Both of these equations express the same sound pressure level regardless of the medium. It is the same amount of energy in air, water, wood or steel.

The decibel is also a logarithmic scale. Logarithmic scales are a way of expressing orders of magnitude in simple numbers without having to print out lots of zeros in an equation. This means that every increase of 10 dB represents a tenfold increase of energy. 10 dB is ten times greater than 0 dB, 20 dB is 100 times greater, 30 dB is 1000 greater, 60 dB is 1,000,000 times greater and so forth.

For a direct “apples to apples” comparison of how decibels work, see Appendix A.

What are the two conversion factors used in expressing dB of sound in air and dB of sound in water?

As mentioned above, the first conversion factor used is strictly a mathematical reference number of 26 dB. The number used to express sound energy in water is 26 dB larger than the number used to express sound energy in air. It represents the same amount of energy with a different number.

The second conversion factor has to do with the differences in physical properties of air and water; specifically the difference in density between the two mediums. It is here where opinions enter into the conversion discussion, mostly in terms of what the impact of this density difference means, and how sound affects things in water as opposed to things in air.

Water is 3500 times denser than air. This accounts for the ability of water to transmit sound energy over long distances better than air. To get a feel for the affects of density on sound transmission, place your ear firmly on a table, reach out with your hand and lightly scratch the tabletop as far from your ear as you can reach. Take note of how loud the scratching seems. When you lift your ear off the table, take note of how loud the scratching sound is in air. Chances are that if you were scratching softly enough, you could hear the scratching through the table top, but may not be able to hear it through the air. This is because the tabletop is much denser than air and transmits acoustical energy more efficiently than air does.

There is a numerical expression for this difference. In water this expression is approximately 35.5 dB and relates to a physical property called “Sound Intensity.” In the SUTASS/LFAS argument, the Navy has simply added this 35.5 dB sound intensity number to the 26 dB mathematical expression, yielding a numerical difference of 61.5 dB. They then use this as a conversion factor to derate the acoustical model of their system.

There may be some reasons to flop this 35.5 dB into the conversion factor to express the difference between sound and air and sound in water, but it would account for some sloppy math. Math serves as a tool to help simplify complex systems, enabling us to understand them better, but it is clear that this oversimplification doesn't necessarily yield better understanding.

To get a feel for how this 35.5 dB works, imagine a jet engine on a runway blasting away at 130 dB_{SPL} re: 20µPa. If you take this same noise source and drop it in the water along with your SPL meter, the level on the meter would jump up 35.5 dB to 165.5 dB_{SPL} re: 20µPa. This doesn't mean that there is more acoustical energy in the system, it just means that there is more sound intensity at the meter. The results of this supports the fact that because sound transmits more efficiently in water, (by 35.5 dB) the effect of a specific SPL at the organism is more pronounced underwater than in air.

Now for the opinion: I don't feel that it is appropriate to use this apparent difference of 35.5 dB as a simple derating factor when expressing the numerical differences between sound pressure levels in air and water. Because the physical effect of sound is perceivably stronger underwater by 35.5 dB, this number wouldn't not be an accurate "derating" of SURTASS/LFAS impact on living organisms.

That being said, the attached chart titled "Comparative Chart of Airborne and Underwater Noise Sources" uses the Navy's direct conversion factor of 61.5 dB with the caveat that the Navy number does not take into account any of the complexities of human and sea creature sound perception mechanisms; how sound works in complex undersea thermal and pressure gradients, or even what sound is used for by any living creature, human or otherwise.

On the chart I use the proponent's numbers because they will not likely agree to using any other numerical models. I believe that the numbers as presented, and the above description point out the merits or lack of merits of the U.S. Navy's SURTASS/LFAS numerical arguments regardless of the proponent's mathematical bias.

- Michael Stocker

Appendix A – an "apples to apples" description of how Decibels work.

Putting sound into numerical terms can be confusing to almost anyone not specifically engaged in evaluating sound with numbers. Sound is not perceived in numerical terms, but is usually described in terms of "Quite," "Loud," and "Excessive." Coming to terms with the numbers is aggravated by the use of decibels to express sound levels. Decibels are not an expression of a specific quantity, rather they are an expression of relative quantities or amounts, expressed in terms of relative orders of magnitude.

Decibels becomes a useful tool when working with large ranges of numbers such as 1, 100, 1,000,000 and 1,000,000,000. It is a way of keeping lots of "zeros" from confusing your math.

In order to take advantage of decibels, you first need to establish a useful quantity that the dB scale relates to. This sets your "0 dB" reference. From that point, every number in dB expresses a relationship to that "0 dB point." This relationship is in terms of factors of 10 (hence the word **deci**bel.) Every increase of 10 dB indicates a ten-fold increase in quantity, i.e.: 0 dB = 1, 10 dB = 10, 20 dB = 100, 30 dB = 1,000, and so forth.

To put this in tangible terms we will express relative quantities of apples in terms of dB.

For me, a single apple is a useful number of apples, so I can express one apple as "$0\ dB_{apple}$" A bag of 10 apples is "$10\ dB_{apple}$", a bushel of 100 apples is "$20\ dB_{apple}$" and a trunk load of a 1000 apples is "$30\ dB_{apple}$". Beyond this number, quantity of apples is not useful to me.

For an industrial distributor of apples, a single apple is not a useful reference point, so they might use a trunkload of 1000 apples as their reference point of "$0\ dB_{APPLE}$". For them, a storage unit of 10,000 apples is "$10\ dB_{APPLE}$", and a boxcar of 100,000 apples is "$20\ dB_{APPLE}$", and a cargo ship of 1,000,000 apples is "$30\ dB_{APPLE}$". As long as we know that "$0\ dB_{apple}$" is a single apple and "$0\ dB_{APPLE}$" is 1000 apples, we can keep track of how many apples we have.

The difference between "$0\ dB_{apple}$" and "$0\ dB_{APPLE}$" expressed in mathematical terms is:

$$\text{“}0\ dB_{APPLE}\text{”} = \text{“}+30\ dB_{apple}\text{”}$$

and

$$\text{“}0\ dB_{apple}\text{”} = \text{“}-30\ dB_{APPLE}\text{”}$$

The conversion factor between these numbers is 30 dB.

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