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GENERATIONS AHEAD IN SONAR & ULTRASONIC TECHNOLOGY

Ultrasonic Transducer Optimization Can Increase Sensor Reliability - Even in Caustic Environments

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Reliability is a key component in any desirable product. In fact, reliability combined with performance, quality, accuracy, and cost considered together are what allow one to determine the overall value of a product. This drives decisions. Therefore identifying what makes a product reliable, along with understanding how the environment and reliability of a product are related, is critical. This paper discusses the reliability of ultrasonics used in chemical level sensing. More specifically it focuses on how a reliable transducer is the driving factor in a long lasting, well performing ultrasonic sensor. Ultrasonics can be chosen and employed much more effectively in a variety of environments, including turbulent water and wastewater, or the chemicals used with processing – even those once believed to be incompatible with the technology. Ultrasonics, in fact, can be optimal technology across a broad range of process industries from paper mills to semiconductor fabs to agricultural chemicals.

By understanding what features in the ultrasonic design, of the transducer and the sensor, influence sensor reliability when used in/with chemicals – ultimate performance results can be achieved. Ultrasonic sensors are a very cost-effective solution for level measurement, and recognizing how to choose the most reliable products allows control over the desired outcome, lowers cost of ownership, and may minimize the need for more expensive technologies.

OVERVIEW:

Ultrasonic sensors are often used for a wide variety of non-contact distance measuring applications, such as monitoring the level of liquids or solid materials in tanks. These devices all work in the same fundamental manner – they transmit a short burst of ultrasonic sound towards a target, which then reflects back to the sensor. These types of sensors measure the time from when the sound pulse is transmitted until the echo returns to the sensor and computes the distance to the target using the speed of sound in the medium.

However, not all ultrasonic sensors are created equal. To be a quality product with high reliability, it is imperative that all aspects of the sensor work properly and dependably in order to ensure that accurate distance measurements are continually obtained. Some people may think that quality does not affect the overall reliability of an ultrasonic sensor, but that is simply not the case. This paper emphasizes the fact that true quality results in long lasting products that continue to perform and meet specifications for years, even decades. If it doesn't – it's not really quality, and it sure isn't reliable. Those who learn this simple point will save money on their projects, and for their companies, because they will always pick high-quality sensors, made with high-quality components, which will perform above expectations for an incredible period of time. This will also eliminate the costly downtime that comes with using inferior products.

There are several factors that can affect the reliability of the sensor. Some of which will be discussed in the following sections of this report. The most critical components in ultrasonic sensors are the electroacoustic transducers that transmit the sound pulses and receive the return echoes. The quality of the transducer, and the craftsmanship of the transducer design, can drastically affect the reliability and performance of the sensor in which it's used. This also lowers the infant mortality rate of the products they go into, because sub-standard transducers are screened out long before they hit the market.

There are two major areas which affect transducer reliability that need to be considered. The first is to ensure that the transducers have the proper electroacoustic and mechanical design for each application. The second is how the transducers are fabricated.

THE DESIGN:

The acoustic and the mechanical design are interrelated in many respects, because one affects the other. Therefore, a strong understanding of both is critical for proper transducer design. There are, however, some clear differences between the two as well. The acoustic items include frequency, beam type, beam angle, and the attenuation of sound (to name a few). The mechanical items include the materials used in fabrication, so that the transducer not only holds up, but also performs well in multiple environments, mediums, and applications. The relationship between the acoustic and mechanical design items, with the environment, is imperative for the design and the assessment of the reliability of ultrasonic sensors and transducers.

Various chemicals can affect the attenuation, thereby affecting the perceived reliability and performance of ultrasonic level sensors in such environments. Designing a transducer that is adjusted for the attenuation for the environment will deliver more accurate results, and it will help the ultrasonic in its performance within the medium for a longer period of time.

Figure 1 depicts the attenuation of sound in the air as a function of humidity for different frequencies. This relationship becomes more complex when various chemical vapors are introduced. Thus, if such matters are properly considered with choosing the frequency of the transducer design, the ultrasonic sensor used with certain chemicals can give the impression to the user of being unreliable. Whereas in reality ultrasonics themselves are not unreliable, but rather have been misused due to misunderstanding. Therefore, if a transducer is designed with respect to such influencing factors, such as the effects of specific chemicals, reliable and desirable level measurement can be attained with ultrasonics.

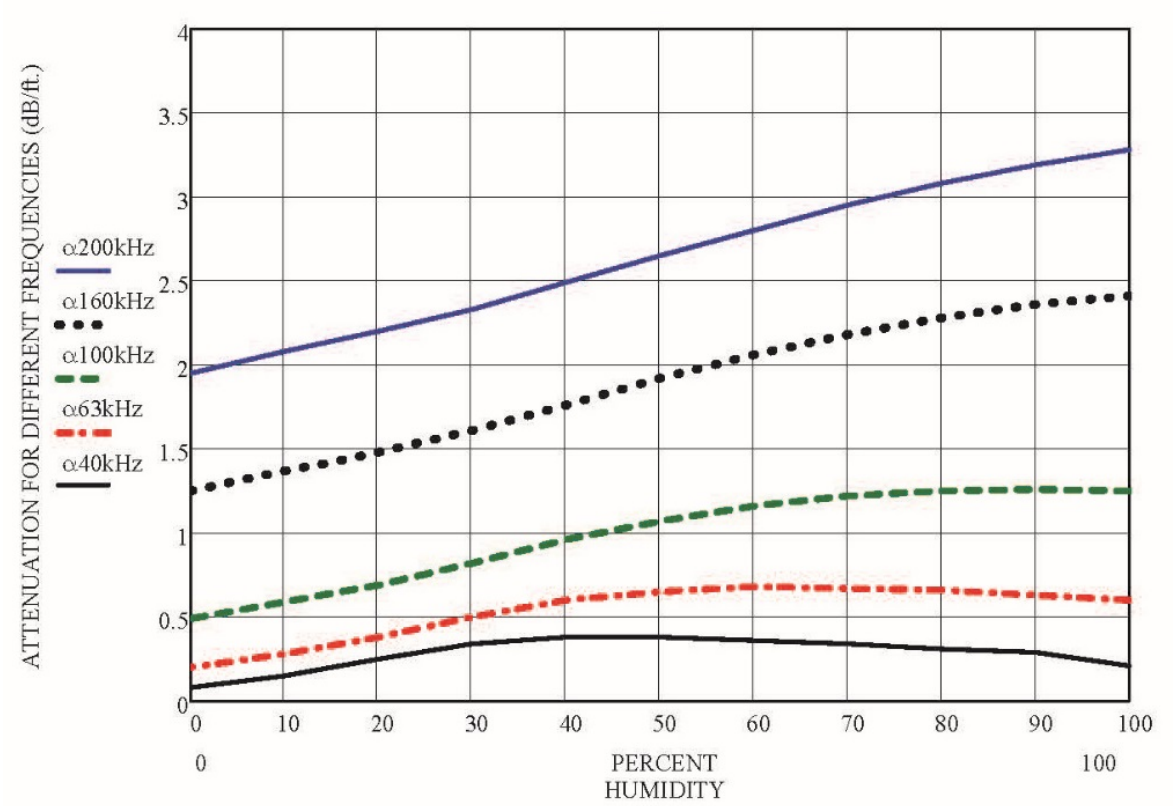


Figure 1

Attenuation of Sound in Air in dB/ft. as a Function of Percent Humidity
for Frequencies of 40 kHz, 63 kHz, 100 kHz, and 200 kHz

Many chemicals can also attack various materials. This can even affect the transducer within a sensor housing. Therefore, just using any "off the shelf" transducer is not the most reliable choice in sensor design. The transducer must be designed to withstand the challenges presented in the setting in which it is required to perform. This means the transducer needs to be built to withstand the attenuation of sound issues, and be constructed with proper materials that can hold up to the environment without interfering with the acoustic performance of the transducer. Dependable transducer design must begin with a proper characterizing of the conditions in which the sensor will be exposed to and required to operate. The acoustic properties of the environment, and the mechanical challenges that may exist, must also be understood to optimize performance and durability. This is true for both ultrasonic and sonar transducers and systems.

The materials need to work well with the acoustics, and both the materials and the acoustics need to be fashioned to achieve desired operation in the environment. Again, the quality and the reliability of the sensor you are building, or using, is greatly enhanced by the quality of the transducer within. Understanding the materials and the acoustics can give you an edge.

Acoustic properties change in different mediums, and can give a false impression that they will not work as well as other technologies. When the transducer/sensor supplier is truly knowledgeable with respect to the acoustic properties, the materials, and is skilled in the manufacturing of electroacoustic devices – one will discover many new truths regarding the success, performance, reliability, and cost-effectiveness of ultrasonic and sonar measurement in a variety of applications and mediums. This saves time and money!

To explore this concept in greater detail, let's discuss the acoustics further: Transducers can be designed to operate at different ultrasonic frequencies and to have different acoustic radiation patterns. Sound energy is absorbed as it travels through the air. The higher the frequency, the larger the attenuation of the sound pressure for each inch in the path from the transducer to the target, and then back to the transducer. Therefore, the further the distance to the target, the lower the frequency of the transducer will have to be. An acoustic specialist can identify what the proper frequency and beam pattern should be for any given application. It is inaccurate to assume that certain applications require some "standard" frequency or beam width. The more that a transducer designer knows about an application, the better the transducer and sensor will be – guarantying performance that outlasts all others.

The design of the radiation pattern of the transducer is also important. Most ultrasonic sensors use transducers that utilize the teachings of U.S. Patents 3,928,777 and 4,011,473 that were issued to Frank Massa in 1975 and 1977 respectively. Transducers of this design have a 10° beam angle (8° system beam angle) for any frequency of operation. This is good for flat reflecting surfaces; however, a broader beam angle is necessary if the reflecting surface is turbulent, uneven, or tilted relative to the axis of the sound beam.

SENSOR RELIABILITY:

A sensor is actually a system. The system includes the transducer, the electronics, and the sensor housing. Ultrasonic sensor reliability is greatly affected by the quality of the transducer and the relationship between the electronics and the materials. A higher quality transducer and a lower level of complexity in electronics result in a better sensor that is also lower in cost.

Ultrasonic waveforms can be utilized to determine if there are any reflecting objects that could cause false alarms or unwanted echoes. The ability to adjust the thresholds of detection to rule out false echoes in any given material increases the overall reliability of the ultrasonic sensor is part of a high-quality design. Waveform capture also allows for troubleshooting, which allows for fast assessment in real time. Figures 2 and 3 on the following page depict how MassaSonic® Sensors can make such adjustments.

Figure 2

Ultrasonic Waveform from a MassaSonic® PulStar® Plus Sensor Showing a False Target Being Detected Instead of the Echo from the Surface of a Liquid or Solid Material

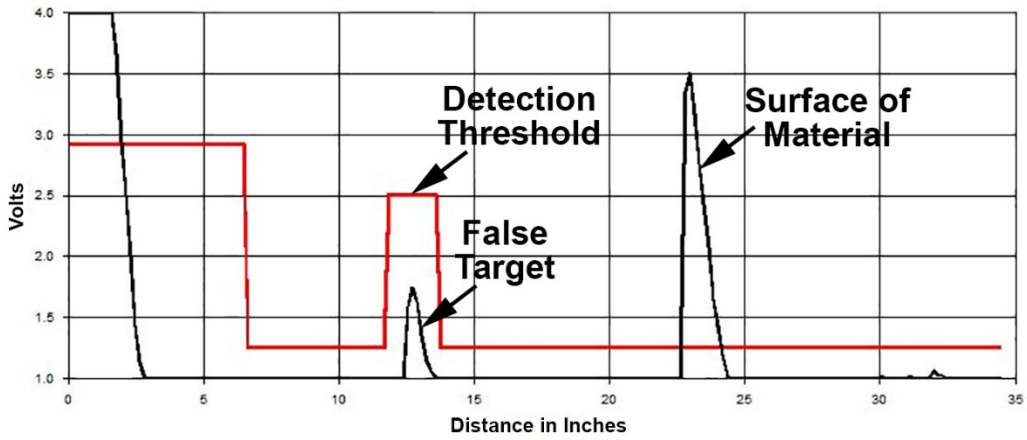


Figure 3

Ultrasonic Waveform from a MassaSonic® PulStar® Plus Sensor with the Same Targets As in Figure 2, But with the Detection Threshold Modified to Ignore the False Target

FABRICATION:

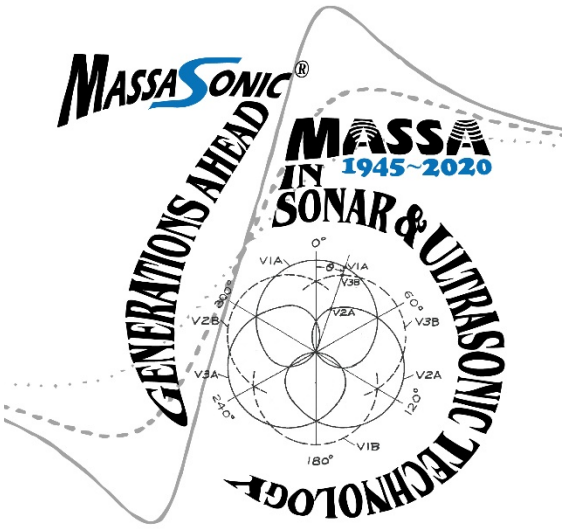
Manufacturing is much more than simple assembly. In order to properly build transducers and sensors that are high in quality and reliability, it is vital to have a high level of expertise, knowledgeable and skilled workmanship, and cooperation between production and design engineering so that the best possible product is fabricated. The facility should have high-quality controls and procedures in place.

The production line must contain proper tools, fixtures, and processes to control the quality of the manufacturing. Highly qualified people must also be employed to construct instruments of this sophistication. They need to be trained in the proper techniques to build, seal, and test the ultrasonics – this greatly reduces, and even eliminates, the failure rate of the products.

CONCLUSION:

Implicit expertise in the design and manufacture of electroacoustic transducers is the main factor that affects the quality and the reliability of an electroacoustic sensor. This is the case for both ultrasonics and sonar. It is only with this complete understanding that an electroacoustic sensor can be optimized to perform properly in challenging and caustic environments. Common transducers are not as "plug and play" as once believed. The belief that they are, is what has contributed to the common misunderstanding that ultrasonic sensors are unreliable when used in certain environments. If a transducer and sensor are optimized for the environment, then ultrasonic technology is a successful cost-effective choice for level measurement that will result in a lower cost of ownership.

Massa designs, engineers, and manufactures all of its transducers and systems in-house and has done so for over 75 years. There is fluidity in Massa design from conception through production, and this is the case for transducers, sensors, and systems used in both air and liquid. Massa implements the same quality controls in place for the sonar systems manufactured for the U.S. Navy in all industrial and commercial products. Some MassaSonic products used in industry that were deployed in the 1980's are still running in the field without replacement required. Massa has manufactured advanced sonar products used on the submarines that protect the American people for years with zero rejects.



Massa is the pioneer in the design and manufacture of ultrasonic transducers and systems for industrial applications and sonar for the U.S. Navy, and has been for over 75 years.