

# APPLYING ULTRASONIC TECHNOLOGY

Designers of ultrasonic systems have their choice of frequency, housing design, and mounting options when utilizing Airmar Airducer® Ultrasonic Sensors. Balancing the trade-offs between sensor performance, acoustic beam characteristics, and incorporated electronics is a critical step in the system design process. The transducer's performance can be affected by the propagating media, the environmental conditions, and the electronics themselves. Several parameters need to be considered when selecting a transducer appropriate to the application. The purpose of this overview is to outline key factors to be considered.

## Maximum Sensing Range

Several factors have an effect upon the maximum sensing range of a transducer. Ranges listed for Airmar Airducer Ultrasonic Sensors are derived from measurements in tone-burst pulse-echo mode and are listed under "Specifications." When designing an ultrasonic system, several factors should be considered beyond the transducer itself. These factors include atmospheric conditions, drive and receive electronics, and signal processing. Some of these factors are discussed below.

## Temperature And Humidity

Changes in temperature cause a change in sound speed of air as well as the materials of any ultrasonic transducer. Airmar transducers are optimized and specified for operation at 22°C. Operation at significantly higher or lower temperatures results in "detuning" of the acoustic matching layer of the transducer and shifting of the resonant frequency resulting in degraded performance. Resonant frequency shifts approximately -0.8% per 10°C (0.8% per -10°C). The reduced sensitivity is tolerable for most applications, but for applications with a wide temperature range, correction may be necessary.

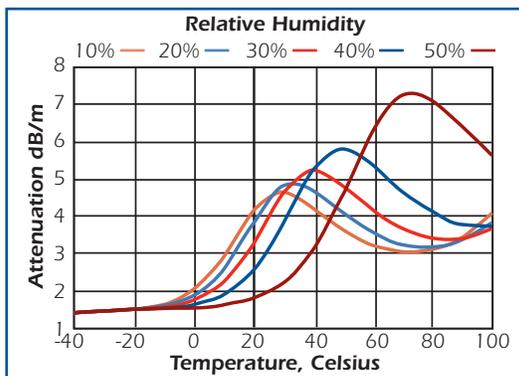


Figure 1: Signal attenuation in air at 1 atmosphere at 100 kHz

$$S.O.S. = 20.1 \sqrt{T_c + 273}$$

where  $T_c$  = Temperature in degrees Celsius

Figure 2: Speed of sound in air

The characteristics of air are dramatically changed by environmental conditions. Shown in Figure 1, signal attenuation is a function of temperature, humidity, frequency, and air pressure. The speed of sound is mainly a function of temperature, shown in Figure 2. Humidity plays a minor role in sound speed, accounting for less than 0.6% change in speed for the temperature range shown. Airmar offers optional internal thermistors for speed of sound compensation. External temperature sensors can be used for a more accurate calibration over a longer range.

## Air Currents and Atmospheric Influences

Maximum measurement ranges are affected by air turbulence, which may deflect or deteriorate sound waves and reduce echo signal. Air currents tend to carry sound downwind; large currents can deflect sound enough to miss the intended target. Large sudden temperature differentials will reflect sound.

Light snow or rain in the sound path will attenuate the sound waves thereby reducing range. Lower frequency transducers emit a longer wavelength and the degrading effect of snow and rain is not as significant as it is for high frequencies.

Airducer Ultrasonic Sensors are not damaged by wetting or by brief immersion in water. Liquid on the transducer's active surface temporarily degrades performance by detuning the matching layer. When the sensor is operating, water on the transducer face is typically vaporized. Standing water on the face of a sensor will impair its ability to function correctly.

## Interference (Electrical and Acoustical)

Airducer Ultrasonic Sensors are susceptible to RFI and EMI. AR series Airducers include standard internal shielding. Additional shielding may be required in certain environments and is optional on all AR series transducers. Shielded cabling options are also available.

High-pressure air nozzles, such as blow off guns, create large amounts of ultrasonic noise. This noise can be very wide band and difficult to filter out. Installations near air nozzles should be avoided.

Transducers mounted to vibrating equipment can receive mechanically coupled interference. If the transducer will be subject to vibration, a very compliant mounting material should be considered to minimize vibration transmission to the transducer.

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## Target Strength

Hard, smooth, and flat targets mounted orthogonally to the transmitted beam return the strongest signals and hence will be detectable at longer ranges. Examples of these mediums are liquid, glass, or metal. If the beam is not orthogonal, it will be reflected off at the angle of incidence and not be received by the transducer. For example, the signal for a transducer with a 10° beam angle will be degraded by 3 dB if the target is misaligned by 2.5°.

If a surface is rough and irregular, the signal returned is varied in amplitude due to the scattering of sound. This type of target has the disadvantage that the return signal is smaller, but has the advantage that the target's alignment is less critical. Further, different materials have widely different abilities to reflect sound. For example, surfaces such as fabric and foam have the lowest reflectivity resulting in low amplitude echoes thereby significantly reducing the effective range of the transducer.

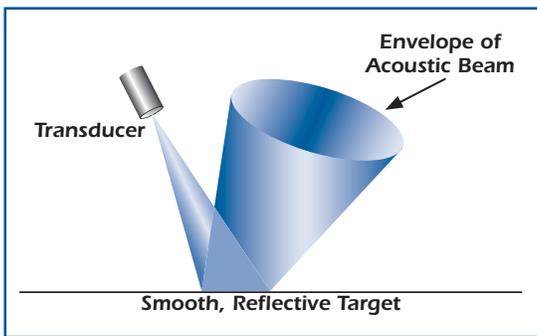


Figure 3: Sound reflective at the angle of incidence

## Beam Angle

A transducer transmits energy in a beam pattern. Most of the energy is concentrated in the main lobe which defines the beam width. Energy outside the main lobe is concentrated in sidelobes. Sidelobes can disguise the true location of targets by generating phantom echoes. No transducer is ever completely free of sidelobes but at Airmar, we strive to design transducers with low sidelobes. Most Airducer Ultrasonic Sensors are designed with side lobe levels at least 17 dB below the main lobe.

Beam width is specified at the -3 dB level of the beam pattern at the full angle. The beam angle of each particular model is noted in the specifications in our catalog. Wide beam angles reduce the sensing range of the transducer and provide less target discrimination when compared to narrow beam models. Wide beams spread acoustic energy over a greater volume and hence less acoustic energy is reflected from potential targets than from a narrower, more concentrated beam. When compared to wide beams, narrow beam angles tend to have greater variations in echo amplitude with irregular surfaces such as a wavy fluid target.

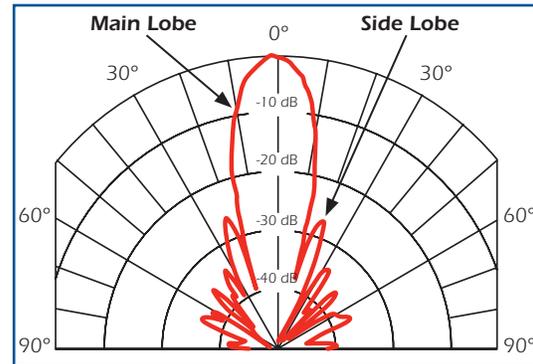


Figure 4: Typical beam pattern

## Environmental Conditions

AT and AR models can be used in most environments where the sensor will not be in contact with (or in a condensing environment of) corrosive materials. Most chemical vapors do not damage AT or AR series sensors (except ketones). ATK and ARK series sensors are designed for installations in which the sensor may come in contact with a corrosive chemical or with damaging vapors. Custom design models are available for hazardous environment applications.

## Minimum Sensing Range

The distance from the active surface of a transducer to the minimum sensing range is often referred to as the Blanking Zone. Within this zone no echo signals can be received. Ideally, this distance would be zero.

The blanking zone is caused by a phenomenon called ringing. Ringing is the continued vibration of the piezoelectric transducer element beyond the electrical excitation pulse. Due to the nature of piezoelectric ceramics and the constraints of transducer design, there will always be some amount of ring time. This time is necessary to dissipate mechanical and electrical energy after excitation ceases.

The extent to which a transducer rings depends on its design. The amount of ring will also vary slightly from transducer to transducer of the same design due to manufacturing tolerances.

The type of electrical pulse used to drive the sensor can have a profound effect on the amount of ring. Airmar's characterizations of ring time are based on a tone burst drive (i.e., typically ten cycles at best operating frequency). A transducer has many modes of vibration, some are strongly coupled to air and some are not. When designing a system, the objective is to drive the transducer at a frequency strongly coupled to air and avoid exciting extraneous resonances. Hence, the use of a tone burst (narrow bandwidth) is beneficial. In contrast, the use of a wide-band transmit scheme can excite undesirable vibration

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modes. For example, “impulse” drive electronics in which a high-voltage, short duration burst of energy is applied to the transducer excites virtually all vibration modes. Modes of vibration other than the desired resonance often dissipate their energy more slowly. When these undesirable frequencies are stimulated, ring time increases.

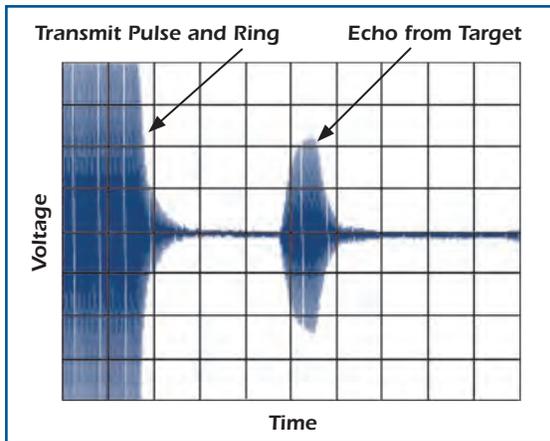


Figure 5: Transmit ring example

All air transducers have a secondary resonance adjacent in frequency to the desired resonance. This secondary resonance is a direct result of the use of an acoustic matching layer to better couple the piezoelectric ceramic element to air. Please refer to Figure 6. The secondary resonance is more weakly coupled to air and also exhibits greater ringing than the desired resonance.

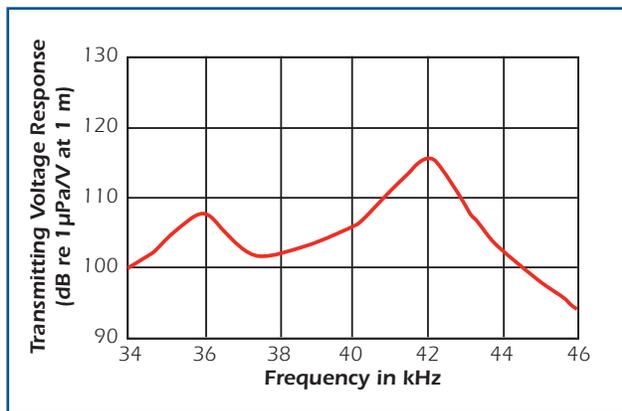


Figure 6: Transmitting response showing adjacent responses

## Mounting

Since the transducer is an electromechanical device, some vibrational energy is transmitted to the transducer housing. A rigid mount of the transducer can accentuate these vibrations and cause an increase in ring time. A compliant mount typically has the least effect on sensor performance. Transducers should not be forced into a press fit mounting location. If a rigid mount is required on an AT sensor, glue the sensor into a slip fit hole, preferably touching only the front or rear edges of the sensor. Use a soft encapsulant if a sensor is to be mounted in a pocket.

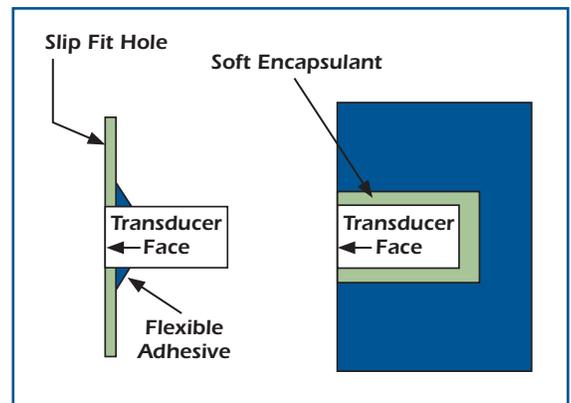


Figure 7: AT mounting examples

AR sensors should be mounted by the supplied threads on the cap. Mounting the transducer on the outside diameter of the housing could cause an increase in ring time. If additional isolation is necessary, the use of an isolation bushing (as shown) is recommended.

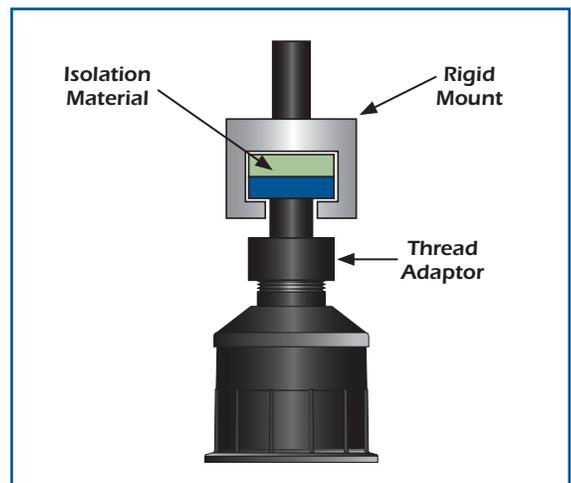


Figure 8: Isolation bushing example