Difference Between Ultrasonic and Radar Level Transmitter

A practical guide to difference between ultrasonic and radar level transmitter, covering the reader intent, the relationship to difference between ultrasonic and radar level transmitter, key evaluation criteria, common risks, and the information the intended project audience should confirm before taking the next step.

level-measurement
Main topic: Radar Level Meters
https://www.level-meters.com/products/radar-level-meters/

In modern industrial process control, selecting the correct non-contact level measurement technology is critical for operational efficiency, safety, and cost-management. Two of the most prevalent technologies used today are ultrasonic and radar. While both serve the purpose of measuring the distance to a liquid or solid surface without physical contact, they rely on fundamentally different physical principles. Understanding the technical difference between ultrasonic and radar level transmitter systems allows engineers to specify the right instrument for specific environmental conditions.

Measurement Principles: How They Work

Before comparing the two technologies, it is essential to understand the physics governing their operation.

Ultrasonic Level Measurement

Ultrasonic transmitters operate using mechanical sound waves. The sensor's transducer emits high-frequency sound pulses (typically in the range of 20 kHz to 200 kHz). These waves travel through the air or gas space above the medium, hit the surface, and reflect back to the transducer.

The instrument calculates the distance (D) using the Time-of-Flight (ToF) principle:

$$D = \frac{c \times t}{2}$$

Where:

c is the speed of sound in the medium (approx. 344 m/s in air at 20°C).

t is the total time elapsed between emission and reception.

Because the speed of sound is highly dependent on the temperature and density of the air it travels through, ultrasonic sensors almost always include an integrated temperature sensor to compensate for variations in the ambient environment.

Radar Level Measurement

Radar Level Meters utilize high-frequency electromagnetic waves, usually in the microwave spectrum (6 GHz to 80 GHz). Unlike sound waves, electromagnetic waves do not require a physical medium to propagate and travel at the speed of light ($c \approx 300,000$ km/s).

There are two primary types of radar technology:

1. Pulse Radar: Similar to ultrasonic, it measures the time it takes for a microwave pulse to travel to the surface and back.

2. FMCW (Frequency Modulated Continuous Wave): The transmitter emits a continuous signal with a constantly changing frequency. The difference in frequency between the emitted and reflected signal is proportional to the distance.

Radar systems are generally less sensitive to the properties of the gas phase above the liquid but are highly dependent on the Dielectric Constant ($εr$) of the material being measured, which determines how much signal is reflected back to the sensor.

Key Difference Between Ultrasonic and Radar Level Transmitter

The fundamental difference between ultrasonic and radar level transmitter technologies lies in the wave type—mechanical vs. electromagnetic—which dictates how they respond to process conditions.

1. Influence of Atmospheric Conditions

Ultrasonic waves rely on the air as a transmission medium. Therefore, changes in air temperature, pressure, or composition directly affect the speed of sound and, consequently, the accuracy of the measurement. If there is a significant temperature gradient in a tall tank, the ultrasonic reading may drift despite compensation.

Radar waves are unaffected by air temperature or pressure. They can operate in a total vacuum or at high pressures (exceeding 100 bar) where ultrasonic sensors would fail to function entirely.

2. Vapor, Steam, and Dust

In applications involving heavy steam, chemical vapors, or thick dust (such as in cement silos), ultrasonic waves suffer from attenuation and scattering. The sound waves are absorbed or reflected by these particles before reaching the actual product surface.

Radar, particularly at lower frequencies (e.g., 6 GHz or 26 GHz), can penetrate dust and vapor with minimal signal loss. While high-frequency 80 GHz radar can be affected by extremely dense steam, it remains significantly more robust than ultrasonic technology in these environments.

3. Surface Turbulence and Foam

Both technologies face challenges with foam. However, the type of foam matters:

Ultrasonic: Light, airy foam often absorbs the sound pulse, leading to a "loss of echo" error.

Radar: Depending on the dielectric properties of the foam, radar may reflect off the top of the foam, pass through it to the liquid, or be absorbed. Generally, radar offers better signal processing capabilities to filter out intermittent surface turbulence.

4. Measurement Range and Accuracy

Ultrasonic transmitters are typically limited to ranges of 15 to 30 meters. As the distance increases, the sound wave diverges and weakens significantly. Radar transmitters, however, can accurately measure distances up to 100 or 120 meters, making them the standard choice for large grain silos or tall oil storage tanks.

Selection Criteria: When to Choose Which?

Choosing between these two technologies requires an analysis of the process media and the vessel environment.

Use Ultrasonic When:

Budget is a primary concern: Ultrasonic sensors are generally more cost-effective for simple, ambient-pressure water applications.

The medium is water or wastewater: In open channels, sumps, or irrigation tanks, ultrasonic is the industry standard.

The application is non-corrosive: While chemical-resistant coatings exist, ultrasonic transducers are often made of materials best suited for standard industrial fluids.

Use Radar When:

High Temperature/Pressure: If the process exceeds 80°C or is under significant pressure.

Vacuum Conditions: Radar is the only non-contact option for vacuum chambers.

Accuracy is Paramount: Radar typically offers higher precision (down to ±1 mm) compared to ultrasonic (±0.25% of range).

Complex Internal Geometries: Radar beams (especially 80 GHz) have a very narrow beam angle, allowing them to avoid internal tank obstructions like agitators or ladders.

Technical Comparison Table

Feature	Ultrasonic Level Transmitter	Radar Level Transmitter
Wave Type	Sound (Mechanical)	Microwave (Electromagnetic)
Medium Required	Yes (Air/Gas)	No (Works in Vacuum)
Max Temperature	Typically < 80°C	Up to 250°C+ (Specialized up to 1000°C)
Max Pressure	Typically < 3 bar	Up to 160 bar+
Accuracy	± 0.25% to 0.5% of span	± 1 mm to ± 5 mm
Typical Range	0.3m to 30m	0.3m to 120m
Influence of Vapor	High	Low to Moderate
Cost	Low to Moderate	Moderate to High

Installation Considerations

Successful deployment of either technology depends on proper installation. Both sensors have a "Dead Zone" (also known as a blocking distance) directly beneath the sensor face where measurements cannot be taken.

1. Beam Angle: Radar typically has a narrower beam angle (as low as 3°) compared to ultrasonic (often 10°-12°). A wider beam is more likely to hit the side of a tank wall or an internal pipe, causing false echoes.

2. Nozzle Height: If the sensor is mounted on a tall nozzle, the beam must be narrow enough to exit the nozzle without reflecting off the nozzle walls. Radar is generally superior for tall nozzle installations.

3. Orientation: The sensor must be mounted perpendicular to the liquid surface to ensure the maximum signal return. For solids, aiming flanges may be required to point the sensor at the angle of repose.

Limitations and Risks

While highly reliable, both technologies have limitations that can lead to measurement errors if ignored.

Ultrasonic Limitations: Wind can literally "blow" the sound wave away in outdoor applications. Additionally, if the gas composition changes (e.g., a tank filling with CO_2 instead of air), the speed of sound changes, leading to massive errors (CO_2 is denser than air, so the sound travels slower, making the tank appear emptier than it is).

Radar Limitations: The primary risk for radar is a low Dielectric Constant ($εr$). Materials like liquid nitrogen, certain oils, or dry plastic pellets have low reflectivity. If the $εr$ is below 1.4, the radar signal may pass through the material and reflect off the bottom of the tank instead.

Frequently Asked Questions (FAQ)

Q: Can I use an ultrasonic sensor in a vacuum?

A: No. Sound waves require a medium (molecules) to vibrate. In a vacuum, there is no medium, so the sound cannot travel.

Q: Does the color of the liquid affect the measurement?

A: No. Unlike optical or laser sensors, neither ultrasonic nor radar is affected by the color or transparency of the liquid.

Q: Is radar always better than ultrasonic?

A: Not necessarily. For simple water level monitoring in a sump or open pond, an ultrasonic sensor is more economical and perfectly adequate. Radar is "better" for complex, high-temp, or high-pressure process environments.

Q: How does heavy dust affect radar?

A: Low-frequency radar (6-26 GHz) is virtually unaffected by dust. Very high-frequency radar (80 GHz) can experience some attenuation in extremely dense dust clouds, but it usually outperforms ultrasonic in these conditions.

Conclusion

The difference between ultrasonic and radar level transmitter selection ultimately comes down to the environment of the application. For stable, ambient-temperature water applications, ultrasonic offers a cost-effective solution. However, for industrial processes involving pressure, temperature extremes, or vapors, Radar Level Meters provide the reliability and precision required for modern automation. By evaluating the dielectric constant of the media and the atmospheric conditions of the vessel, engineers can ensure long-term measurement stability.