Ultrasonic level measurement in water and wastewater plants

While radar is popular for level measurement in many applications, ultrasonic sensors are often a better choice for water and wastewater plants.

By Tim Thomas, Level Product Business Manager, Endress+Hauser, Inc.

Radar technology is often viewed as the “best” method of level measurement, but this isn’t necessarily true in the water industry. Although radar technology certainly does offer high performance and accuracy, in many water and wastewater applications non-contact level measurement using ultrasonic (Figure 1) is the best choice due to its lower cost and application-specific benefits.

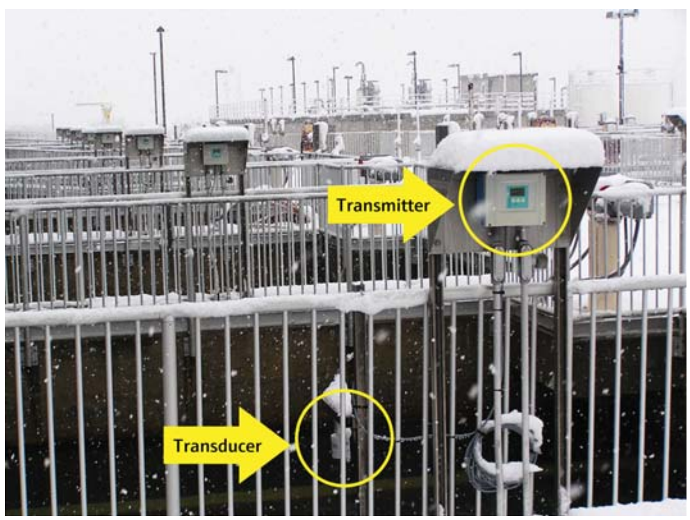

Figure 1: Ultrasonic sensors are used even in harsh environments for water applications. Here, ultrasonic transmitters are being used to measure level on the incoming water in a water plant.

This paper will compare ultrasonic and radar sensors, and provide examples where ultrasonic instruments are the best choice.

Level measurements

Continuous level measurements and limit level detection are needed in water and wastewater treatment plants from a process engineering, water management and safety perspective. Level monitoring and control are key factors in optimizing operation between influent flow to the plant and treatment processes, as well as for calculating and controlling costs.

Because no single level technology exists that is suitable for all processes, each technology has its place depending upon the process material, process conditions and environmental conditions. Installation options are also a consideration in selecting the "best fit" technology. In many processes, multiple level technologies may perform equally well, leaving cost as a key consideration. Selecting the appropriate level technology for a particular application is critical to a successful measurement as well as controlling the initial costs of instruments and costs associated with maintaining a less than ideal technology.

Ultrasonic versus Radar

When a continuous level measurement is needed in the water and wastewater industry, free-space radar and ultrasonic instruments are both frequently used and offer advantages over other technologies.

Ultrasonic sensors (Figure 2) use piezo crystals to generate a mechanical pulse which is launched from the sensor membrane. This sound wave reflects off the surface of the process medium due to a change in density between air and the medium. The reflected pulse is then received back at the sensor membrane. The time of flight between transmission and reception of the reflected pulse (echo) corresponds directly to the distance between the sensor membrane and the surface of the medium. Because an empty calibration distance (distance from the sensor membrane to the bottom of the vessel) is programmed upon commissioning the instrument, the instrument can report the actual level by subtracting the measured distance from the empty calibration distance.

Figure 2: An ultrasonic sensor sends a sonic pulse to the surface of a liquid or solid, and measures the time of flight for the reflected signal to determine level.

An ultrasonic pulse is a mechanical sound wave which requires air as a transmission medium, and ultrasonic instruments operate based on the speed of sound in air. For this reason, ultrasonic sensors cannot be used for level measurement in a vacuum. If the space between the sensor membrane and the surface of the process contains other gases, such as nitrogen, methane or carbon dioxide, the velocity of sound is different and will result in large measuring errors.

Free space radar (Figure 3) operates based on the same time of flight principle; however, radar uses high frequency microwaves emitted from an antenna. Rather than reflecting based on a change in density as sound waves do, microwaves reflect based on a change in the dielectric constant of the process medium. Since microwaves are electromagnetic and do not require air as a transmission medium, radar is well-suited for use in a vacuum or when other gases are present in the empty space.

Figure 3: A radar instrument sends a microwave to the surface of a liquid or solid, and measures the time of flight for the reflected signal to determine level.

Ultrasonic applications

Many level applications such as wet wells, rainwater basins and wastewater chemicals (without vapor), are perfect spots for ultrasonic sensors. Ultrasonic sensors offer flexible installation options and minimal maintenance. Some users moved away from ultrasonic sensors because of past problems caused by condensation; however, an ultrasonic sensor equipped with automatic self-cleaning, such as the Endress+Hauser Prosonic FDU91, eliminates failures caused by condensation.

By monitoring the amplitude of the signal at the sensor membrane, condensation is detected by a dampening of the amplitude. The unit automatically increases frequency to the piezo crystals, creating a self-cleaning effect and ensuring the sensor membrane is free from the dampening effects caused by condensation or buildup. This feature allows ultrasonic to be used without concerns for condensation.

Measuring inlet flow with a level sensor in an open channel weir or flume is a primary measurement in a wastewater plant. A level sensor is used to measure the level in a flume or weir and converts the level to a flow rate using a Q-H curve (flow vs head). Many ultrasonic sensors contain pre-programmed Q-H curves for a wide variety of flumes and weirs. Alternately, many ultrasonic instruments allow for entry of a manual table for non-standard flumes or weirs. The measurement accuracy of an ultrasonic sensor is sufficient for open channel flow measurement, thus the added cost of a radar device is not typically justified.

Rainwater basins (Figure 4) are used to prevent the overloading of wastewater plants. In these buffer basins it's necessary to measure both the level in the basin as well as the volume of overflow into the drainage channel. Some ultrasonic instruments can measure both variables simultaneously using only one sensor in the basin connected to a level transmitter which can be mounted up to 1,000 feet away from the sensor.

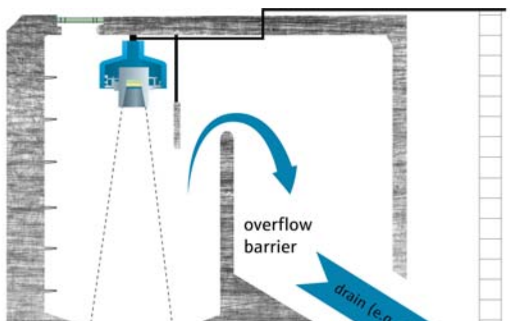

Figure 4: An ultrasonic sensor can measure level in a rainwater basin and the volume of water being diverted to the outfall.

Ultrasonic sensors are ideal for installation in tight places due to the relatively small size of the sensor and the ability to mount a sensor directly to a ceiling (Figure 5). When used with a flooding protection tube, an ultrasonic sensor can ensure a high measurement is indicated even if the sensor is flooded and under water. In outdoor installations where temperatures can drop below freezing, ultrasonic sensors should be ordered with integral heaters to prevent ice formation on the sensor, ensuring reliable measurement year round.

Figure 5: An ultrasonic level sensor, such as this Endress+Hauser FDU90 Prosonic is small enough to mount directly on the roof or ceiling.

Cleaning mechanical bar screens is most efficient when performed on an as-needed basis rather than on a timer or when an overload condition occurs. To achieve this, two ultrasonic sensors can be installed—one upstream of the bar screen and one downstream—to measure the difference in level. When the bar screen is clean, the levels will be nearly equal. As the bar screen traps solids and debris, flow through the bar screen is restricted and the upstream level will rise higher than the downstream level. The levels can be monitored by a transmitter, such as the Endress+Hauser Prosonic FMU90, which can analyze the levels and control the bar screen cleaning process.

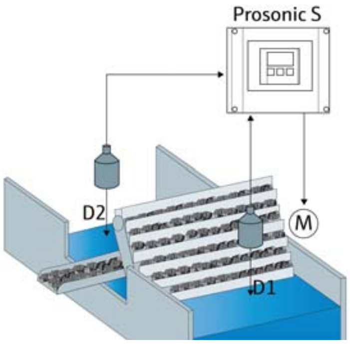

Figure 6: Ultrasonic sensors such as Endress+Hauser Prosonic FMU90 monitor levels on both sides of a bar screen.

Radar applications

In some wastewater applications, radar is clearly a better option than ultrasonic sensors. Because radar uses microwaves, the gas in the head space is irrelevant, and while radar is certainly not a “silver bullet” for use in foam, it does perform superior to ultrasonic with regard to foam on the level surface.

Sludge digesters are very common in wastewater treatment. Sludge digestion is a bacterial process that can be carried out either in the presence of oxygen (aerobic digestion) or the absence of oxygen (anaerobic digestion). In both cases the sludge is converted from complex proteins and sugars into more simple compounds such as water and carbon dioxide or methane. These digesters often generate foam and certainly contain gases that would rule out using ultrasonic. Radar works well in this application.

A variety of chemicals are used in wastewater treatment. Because a level measurement using ultrasonic sensors is based on the speed of sound in air, if the empty space in the tank has anything other than air, large errors can be generated. For example the speed of sound in chlorine is around 38% slower than in air, thus a level may be reported that is 38% lower than the actual level. The speed of sound in nitrogen is around 11% faster than in air which could indicate a level 11% higher than the actual level. In these tanks, radar is a better option than ultrasonic.

Summary

Radar is an excellent, high performing choice for many level applications, but not necessarily the best choice in wastewater. Some ultrasonic level instruments on the market today have features implemented specifically for the wastewater industry. Ultrasonic level instruments can be a cost effective and beneficial part of an efficient and safe wastewater treatment plant and should be considered when selecting instruments.

Tim Thomas has spent the last 19 years working in the process automation industry. He received electronics training from the US Army Intelligence School in Ft. Devens, Massachusetts. He began his career at Eli Lilly and Company writing software. From there, Tim went on to work at Endress+Hauser in the Service Department as a Technical Support Engineer supporting level and analytical product. From there, he became the Level Product Specialist. Currently, Tim works as the Product Business Manager for the Midwest region with a dual responsibility as the Gamma Business Driver for the US.

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