Guided wave radar (GWR) technology, the increasingly popular, industrial, loop-powered transmitters on the market today, burst on the scene in the late 1990s. Most of these devices are based on the revolutionary Lawrence Livermore National Lab patent that, in 1995, Popular Science magazine called ‘radar on a chip for US$10’.

At first, GWR technology (first introduced to process markets in 1998 by Magnetrol International with its Eclipse Model 705 GWR transmitter) was almost shunned. Why would a customer use an ‘RF capacitance-looking device’ with a probe? Non-contact devices available at the time had clear advantages over contacting devices, with ultrasonic and radar transmitters already carving out their own niche in the marketplace. Installing a probe seemed almost archaic. But, the probe was the secret.

What the last 17 years of experience has taught the process control industry is that the probe, the initial perceived weakness, is the real strength of the system. First, the probe offers a conductive path for the extremely low-energy signal to travel. This allows a maximum amount of energy to reach the surface where it is reflected and sent back to the transmitter for interpretation. Extremely low dielectric/low SG liquids such as propane and
butane can be measured relatively easily. Non-contact radar transmitters can measure these liquids using a stillwell/standpipe that essentially provides a guided wave device, but at a far greater cost. DPs can measure these materials but are subject to SG variations that will greatly affect accuracy. Secondly, since the probe is a conductive path that maintains control of the signal, energy is not scattered within the tank (as with non-contact radar) where it can encounter numerous objects that create false targets. GWR, as a technology, has slowly become the standard in process and storage tanks around the globe. First it was used as a problem solver then, as users gained confidence, it became a fixture on the level measurement menu.

This article will not explore the simple, generic applications that can be solved with almost any level measurement technology (including GWR). Rather, it intends to highlight a few of the special areas where users have found particular success in solving nagging measurement problems, and GWR has become a go to technology as application knowledge and product performance have evolved.

Radar echo
Much has been said in the radar world about the need for a strong signal, for example, a high amplitude transmitted signal to the medium being measured. It might seem like hearsay to suggest it is not the real issue, but is it? In some ways, the radar signal is like the sound from a radio, if it needs to be louder, the signal is amplified. However, if there is a high noise level behind the desired signal, then the feedback is distorted. The same situation occurs in the radar world. This relationship between these ‘desired’ and ‘undesired’ signals is called signal to noise ratio (SNR). Strong amplitude is a ‘brute force’ approach and is much easier to achieve than overall SNR. In practical use, the design with a greater SNR is more robust and far less likely to have issues with unwanted reflections than one that has an inferior value.

Modern radar designs strive to increase their SNR, and users would be wise to keep this lesser known trait in mind when choosing between the various devices offered in the market. Low dielectric, turbulence and other challenging conditions are made easier with a superior SNR.

Overfill capability
It is commonly understood that no level measurement technology is perfect in all applications – many have issues measuring accurately to the very top of the tank. The ability to read to the very top of the vessel is often called overfill capability. The most advanced of GWR designs remove this weakness that plagues so many devices in the radar category. This can be critical with media that are highly corrosive, toxic or otherwise dangerous in a spill.

Figure 1. State of the art GWR transmitters are capable of effectively measuring both an upper liquid level and an interface liquid level.

Figure 2. Overfill safe probes can measure accurate levels up to the process flange without any non-measurable zone at the top of the GWR probe.
European agencies such as WHG or VLAREM certify overfill proof protection, defined as the tested, reliable operation when the transmitter is used as an overfill alarm. It is assumed in this analysis that the installation is designed in such a way that the vessel or side-mounted cage cannot physically overfill. However, there are practical applications where a GWR probe can be completely flooded with level all the way up to the process connection (face of the flange). Although the affected areas are application dependent, typical GWR probes have a transition zone, or possibly dead zone, at the top of the probe where interacting signals can either affect the linearity of the measurement or, more dramatically, result in a complete loss of signal.

While some manufacturers of GWR transmitters may use special algorithms to ‘infer’ level measurement when this undesirable signal interaction occurs and the actual level signal is lost, advanced designs, such as what is featured in Eclipse models, offer unique solutions by utilising a concept called overfill safe operation. An overfill safe probe is defined by the fact that it has predictable and uniform characteristic impedance all the way down the entire length of the waveguide (probe). This allows the probe to measure the true level at all times.

This probe design has the ability to measure accurate levels up to the process flange without any non-measurable zone at the top of the GWR probe. Overfill safe GWR probes are a unique advancement because coaxial probes can be installed at any location on the vessel. Overfill safe probes are offered in a variety of coaxial and caged designs.

GWR in chambers/bridles and with magnetic level indicators

Bridles and chambers have become a popular means of level measurement; first due to use with displacer transmitters, and now as an efficient means of external mounting that allows isolation via shut-off valves. GWR has often been used in this configuration utilising coaxial probes. However, the recent popularity of single rod probes, primarily due to cost and higher immunity to buildup, has raised a set of important performance issues.

Coaxial probes are the most efficient propagators of microwave energy. Single rod probes, on the other hand, are inefficient in two key aspects:

- Launching the signal causes a large impedance mismatch at the top of the probe, which creates noise that interferes with good target acquisition.
- Propagation of energy along the single rod probe is the least efficient of all GWR waveguides, which is not the best approach for optimal performance.

Both of these issues are resolved when a single rod probe is carefully impedance matched to the typical chambers/bridles seen in the process industries. In this way, there is no top of probe mismatch and, when done very carefully, the single rod probe/cage combination effectively becomes a coaxial arrangement creating excellent propagation efficiency. This probe/chamber matching design yields excellent performance at the lower cost of a single rod probe.

Non-standard measurement techniques

GWR is a time of flight technology with a microwave echo that yields a reliable level reading, even in changing process conditions. This direct measurement of true product level is key to accurate performance. However, there are times when a calculated (inferred) measurement may be necessary. Again, the probe becomes a critical component because knowing the exact probe length (a standard parameter) allows the transmitter to look for the end of probe signal to be in a precise location. In applications of extremely low dielectric (<1.4), due to inherent media characteristics or process conditions (e.g., flashing), detecting the ‘apparent location’ of the end of probe can be used to calculate the amount of the medium.

Why? The speed of propagation of the microwave signal is constant when passing through the typical vapour space of liquids normally measured. However, when the signal passes into a low dielectric liquid, the speed of the electromagnetic signal slows based on the equation: velocity = speed of light divided by the square root of dielectric. By knowing the dielectric constant of the process medium and the expected end of probe location, based on the probe length, the level of the medium can be calculated based on the apparent end of probe location.

The delayed position of the end of probe will vary as the dielectric of the process medium varies. As a result, this technique will not provide the same accuracy as measuring the true product level. For that reason, this is not a commonly used technique but it can come in

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**Figure 3. A higher signal to noise ratio (SNR) is a better measure of signal quality than signal strength.**
handy when using today’s more sophisticated GWR transmitters in troublesome applications. The goal of dedicated GWR manufacturers is to always detect the true level signal, so this feature should only be used when conventional gain or threshold troubleshooting techniques are exhausted.

GWR measurement bonus: interface

Many industries encounter interface applications that contain two immiscible liquids of different specific gravities. The oil and gas industry is rife with oil and water vessels, in which separation is critical. Water can be a major liquid that accompanies hydrocarbons from within their original rock formations, or a minor liquid that condenses out after long periods. In many cases, it is advantageous to measure both the hydrocarbon that rises to the top and the water that settles to the bottom.

GWR transmitters that feature the latest technological advances are capable of effectively measuring both an upper liquid level and an interface liquid level. As only a portion of the pulse is reflected from a low dielectric upper surface, some of the transmitted energy continues down the GWR probe through the upper liquid. The remaining initial pulse is again reflected when it reaches the higher dielectric lower liquid. It is typically required that the upper liquid has a dielectric constant less than 10, and the lower liquid has a dielectric constant greater than 15. A typical interface application would be oil over water, with the upper layer of oil being non-conductive ($\varepsilon_r \approx 2.0$), and the lower layer of water being very conductive ($\varepsilon_r \approx 80$). Some advanced GWR transmitters such as Eclipse models can accurately detect upper layer thicknesses as small as 2 in. (50 mm) while the maximum upper layer is limited to the length of the GWR probe.

One consideration with interface applications is emulsion layers, or ‘rag layer’, of 4 in. or less, the GWR transmitter will detect the emulsion and water interface level. For applications with an emulsion layer greater than approximately 4 in., GWR will tend to read the top of the emulsion (the oil/emulsion interface).

Advanced diagnostics: unattended echo capture

It would be a wonderful world if transmitters never experienced a process upset or problem throughout their entire life cycle. Of course, this utopia has never been found. The best that can be done is to improve the speed at which a user can turn around a problem and get the device back online to minimise downtime. One of the most important tools used to troubleshoot a GWR application is the echo curve.

Figure 4’s representation of a GWR echo speaks volumes to those trained to interpret them. It is like a snapshot in time of the health of the transmitter. The challenge with echo curves is acquiring them in a timely fashion. However, most problems develop when there is a skeleton crew and no one is watching the tank. By the time an instrument technician can investigate, the alarm has cleared and no one understands why it occurred or, more importantly, when it will happen again. Since an echo curve is so important in troubleshooting the device, it is critical to capture the curve at the instant a problem occurs. Too often this means connecting a laptop and gathering information after the first signs of the problem, which is obviously not ideal. Advanced GWR design, such as what can be found in the Eclipse model 706 GWR, makes this much less painful. These advanced designs are shipped from the factory so an echo curve is captured based on time, using an onboard clock, or a key event such as the loss of echo or low echo strength. The transmitter has the ability to store a number of echo curves in its onboard memory. These echo curves can then be downloaded to a laptop running software such as PACTware. The user can then email the information to the factory for expert assistance in troubleshooting. This enables the problem to be resolved much more quickly, minimising possible downtime.

Conclusion

GWR has emerged as a level measurement staple in many industries around the world. With technology advances, such as those found in the new Eclipse model 706, significant process performance has been achieved. The most advanced GWR instrumentation can effectively and reliably measure up to the process seal of the probe. With specially bent probes, GWR can also often measure to very low retention levels in a tank. This makes GWR technology particularly attractive for industries with extremely high value products. With unparalleled performance in changing process conditions, it is no wonder GWR transmitters, such as the Eclipse model 706, have become the go to level control solution for some of the toughest industry applications, yet they are seen worthy of even the most generic plant applications.