GUIDE TO LEVEL MEASUREMENT

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There is a variety of common technologies available for continuous level measurement, including capacitance, free space radar, guided wave radar, gamma, pressure and ultrasonic. IPP&T's Level Handbook contains a number of articles that provide expert advice and applications that work best for each of these technologies.

Accuracy is paramount when choosing the right level measuring technology, and there are many factors to consider before purchasing, such as the existence of foam or gas fumes associated with the process, the dielectric or specific gravity of the process, pressure and temperature, and the use of an agitator, or the existence of a turbulent surface.

Point and continuous level measurement sensors play an important role in level measurement, and these technologies will be explained as to how they are applied in a plant environment. An important component of level measurement is the integration of an inventory management system into a plant using wireless communication devices and software, making operations more efficient.

IPP&T's Level Handbook provides specific applications and product information to executives, engineers and plant personnel who are looking to improve their industrial processing operations.

GUIDE TO
LEVEL MEASUREMENT

MARCH 2020 **VOLUME 2, NUMBER 1**

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IPP&T INDUSTRIAL PROCESS PRODUCTS & TECHNOLOGY

CANADA'S PROCESS NETWORK

Produced By
ANNEX BUSINESS MEDIA

5 TRENDS DRIVING INVENTORY MONITORING IN SILOS

Fast-paced work environments are driving the need for accurate, real-time data. Sensor manufacturers and software developers have been rigorously working to create new and innovative solutions

Is your operation seeking ways to more efficiently monitor inventory? Check out these popular trends

Sensors that work in dust

It wasn't that many years ago that the roofs of silos were a graveyard of level sensors. Plant managers were anxious to be more efficient and proactive when managing inventory. Many tried new products, but to no avail. The most common complaints were inaccurate readings, the sensors didn't work reliably over time, and they required far too much maintenance. Operations were frustrated by trust issues.

A 3D level scanner.

Their frustrations did not fall on deaf ears. Sensor manufacturers looked to new technologies and product improvements that could overcome challenges typical in silos storing powders and solids. The sensor had to work continuously in a dusty environment and in sticky materials. While traditional weight-and-cable-based sensors would work reliably, plants were also demanding a non-contact sensor that would measure continuously.

Two technologies emerged over the last decade that could finally meet these demands. One is an **acoustics-based sensor** that uses sound waves to measure multiple points on the material surface in the silo. The other completely revolutionized

A non-contact radar.

A Gateway radar.

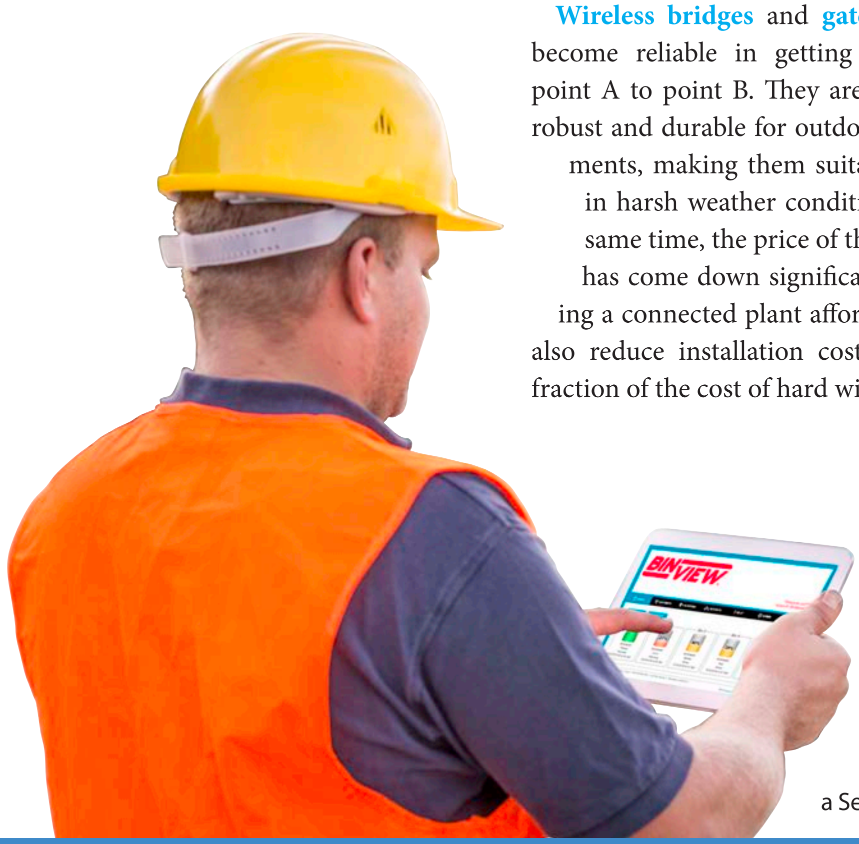
non-contact radar, using the 80 GHz frequency band to overcome the shortcomings of its predecessors.

Doing away with expensive wiring

Running long spans of wire outdoors is often unfeasible and impractical. The cost of installing hundreds if not thousands of feet of wire and the poles to support it cannot be easily justified. In many cases, wiring has prevented an operation from becoming "a connected plant." This causes personnel to be disconnected from their inventory.

Wireless devices were the missing link between sensors and the software that could provide workers with the data to do their jobs better. The advent and proliferation of wireless technology is changing the landscape at industrial plants.

Wireless bridges and gateways have become reliable in getting data from point A to point B. They are now more robust and durable for outdoor environments, making them suitable for use in harsh weather conditions. At the same time, the price of these devices has come down significantly—making a connected plant affordable. They also reduce installation costs to just a fraction of the cost of hard wiring.



Software as a Service (SaaS).

Accessing inventory on a phone

If there is one thing that almost every employee at any plant has in common, it's a cell phone. Now 86 percent of adults in Canada are reported to have a cell phone. The cell phone is the device relied on for almost everything personal and professional. On top of that, 91 per cent of Canadians are reported to use the internet. Those who do, expect it to make their life easier.

Software applications are user-friendly and are optimized for viewing on mobile devices. Any phone that has internet access can become a powerful business management tool. Personnel can now access their silo inventory data from their phone whether they are at the plant or offsite.

Software as a Service (SaaS) subscriptions now proliferate most industrial businesses. They are used for everything from Enterprise Resource Planning (ERP), to human resource management, to a company's website, and many more functions. At industrial plants, SaaS is used to manage inventory and optimize the purchasing function.

Displaying data locally

Industries such as mining, cement, and agriculture have plants that cover acres of terrain and multiple locations that can be miles from one another. Even in more industrialized environments such as food processing, plastics, and chemical plants, silos are often spread out across the plant or clustered in remote groups. Plant personnel need to know how much material is in each silo, which silos have remaining capacity, and which to pull from next.

Accessing silo levels in real-time is a real time saver. Eliminating climbing silos to check levels helps to make CCOHS compliance easier. Falls are among the most common hazards in the workplace and can be avoided using a small and simple device.

Digital panel meters have come a long way in design features and are very affordable. LED technology makes them easy to

A digital panel meter.

read even in bright sunlight and dust. Plants install digital panel meters to make level data available for every silo. They are used at loadouts by drivers and by personnel managing scheduling and production alike.

Simplifying sensor replacement

A common theme among manufacturers is a shortage of qualified staff to get maintenance work done. With unemployment in Canada hovering around 5.5 percent, it is hard to recruit full-time staff. This has resulted in outsourcing work to third-party vendors and licensed electricians to keep operations running smoothly.

Industrial plants are tough on level sensors. Many are characterized by dusty, dirty, or harsh environments. This dictates that equipment is maintained on a regular basis and occasionally replaced altogether. But when you couple a lack of staff and a rigorous preventive maintenance schedule, you need a solution to make the task go quickly with less qualified staff.


A Quick Disconnect (QD).

Adding a **Quick Disconnect**—or QD for short—has become a real time saver. These inexpensive accessories can take the tedious task of hard wiring sensors and turn it into a literal plug-in operation. No licensed electrician needed! Staff spend less time installing, replacing, or maintaining a sensor. QD connectors can be purchased separately for retrofit, or some manufacturers will ship new sensors with the QD option already installed.

Have an inventory problem you need solved? Be sure to reach out to a trusted partner. You are the future of inventory monitoring!

HOW 80 GHZ RADAR OVERCOMES LEVEL MEASUREMENT CHALLENGES IN HIGH DUST ENVIRONMENTS

Dust, with its infinitesimal size, is disproportionately problematic. A speck of dust is tiny – one-half to one micrometre in diameter on average. And yet, these little particles cause big problems for level measurement instrumentation. Thick dust clouds and buildup have historically prevented level measurement technologies from providing reliable and accurate measurements.

The mining and building materials industries understand these problems all too well because these industries deal with a disproportionate amount of high dust environments. Fortunately, level measurement instrumentation has evolved, and operations willing to adapt to newer technologies like 80 GHz radar are thriving with more efficient processes, less downtime, and higher throughputs.

The VEGAPULS 69 is an 80 GHz radar sensor specifically designed for the measurement of bulk solids.

Modern radar sensors like the VEGAPULS 69, which use an 80 GHz transmission frequency, deliver enhanced focus, higher sensitivity, and smarter electronics that can read through the dust and build-up. This enables users to make measurements in tight spaces, and users receive accurate continuous level measurements, even during fill cycles.

Seeing through the dust

From the crushers at the beginning of their process to the storage silos near the end, mines and quarries have clouds of dust and buildup everywhere. These two factors have made it challenging for level measurement technologies to work effectively and reliably, and that alone has impeded efficiency.

Crushers are loud, dusty machines, so they've always been a challenge to measure level in this application. The crusher is typically one of the first steps in the process, and without a level measurement to optimize its operation, it becomes an immediate bottleneck from the start.

Elsewhere, storage silos holding fine particles like cement or lime powder experience many of the same issues. These tall, narrow structures are often filled pneumatically, so the inside looks like a hazy cloud of dust. Without an accurate continuous level measurement here, it's impossible to know if these vessels are being used to their full capacity.

Initially, level measurements in these applications were made manually. A person kept a watchful eye on the crusher, and another would climb to the top of every silo and look inside. These methods are labour-intensive and inefficient. A lot of downtime is spent waiting for dust to settle just to get a visual. In lieu of waiting, crushers and silos became underutilized and underfilled, and on occasion, too much material would choke the crusher and spill out of silos. Both scenarios require lengthy maintenance, cleanup, and unexpected downtime.

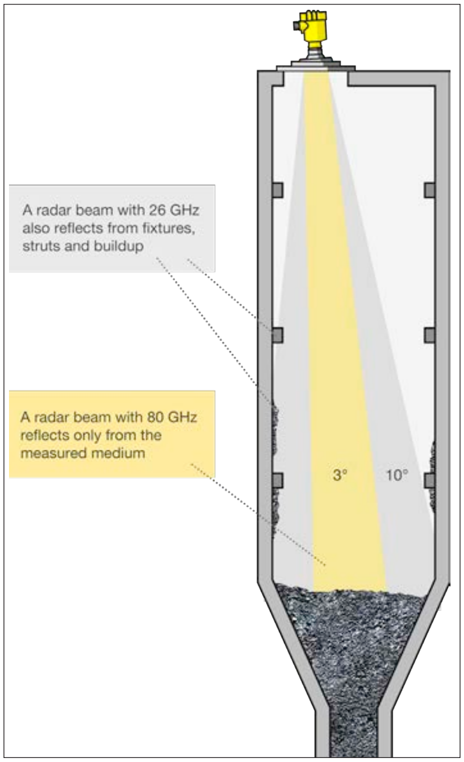
Mechanical contact measurement sensors could see through the dust in storage silos, but it came at the cost of additional maintenance and regular replacements. Then, users are left without a level measurement and additional labour to repair or replace a sensor. Contact sensors were never an option in crushers because of falling product and moving parts. A non-contact solution was needed that could withstand the dust, buildup, and noise.

Non-contact for no mess and longer service life

When non-contact level measurement technologies like ultrasonic transmitters and radar sensors hit the market, there were significant improvements. Sensors could see through a little bit of dust, and they could withstand buildup for longer. Both technologies operate using a similar principle: a signal travels through the air, bounces off the surface of the product being measured and back to the sensor, and the sensor electronics use the time of flight to calculate distance and output a level measurement. Their differences, however, are why 80 GHz radar has become the go-to level measurement technology, especially in high-dust environments.

Ultrasonics use sound waves to make a measurement. Sound waves are mechanical and require a medium – in this case, air – to transmit energy from one place to another. Dust in the air dampens sound waves, interrupts their transmission, mechanically prevents their propagation, and makes level detection nearly impossible. And in the crusher, loud noises can add to the interference. For measuring level during filling, an ultrasonic device won't do, and users should turn to radar.

All radar level measurement sensors emit electromagnetic radio waves that are unaffected by dust or noise. Unlike sound waves, a radar signal's transmission or propagation is not inhibited by dust. In fact, it has no effect on any radar sensor, regardless of transmission frequency. This is due to wavelength. Dust particles are about 1,000 times too small to be detected by radar sensors with the shortest wavelength on the market – 80 GHz radars. This means radar can accurately measure level during fill cycles when dust is rampant. This is a major advantage for any automated process.



Radar sensors using a higher 80 GHz frequency have better focus, which helps to provide a more accurate level measurement.

Even though both technologies are non-contact, dust and dirt eventually build up on the face of ultrasonic transmitters and inside the horn of low-frequency radars. Buildup on an ultrasonic transmitter results in a weaker or lost signal relatively quickly, so these sensors need to be cleaned regularly. For radar, the buildup is a slower process as condensation inside the horn attachment glues and cements dust particles into place until a signal can no longer penetrate the solid block of buildup inside. The workaround – build a radar that doesn't need a horn attachment.

80 GHz radar brings focus and accuracy

Radar beam angle is a matter of antenna size and frequency; they're inversely proportional. As antenna size or frequency increases, the beam angle decreases. Low-frequency radars get around this by using large antennas or horn attachments to focus the radar signal into a smaller area. With the development of high-frequency 80 GHz radar sensors, users can achieve a narrow focus without the need for a large process connection or a horn attachment.

A radar signal with a better focus enables users to get a precise measurement in a small space. This feature is crucial in crushers and in the narrow silos holding fine powders. Plus, with more of the signal in a confined spot, users will see a larger return signal, giving them a clearer picture of exactly where their level measurement truly is. With the VEGAPULS 69, the improved signal is compounded by the radar sensor's higher sensitivity.

Despite better focusing and improved sensitivity, the 80 GHz VEGAPULS 69 is able to ignore any potential buildup that's so common in these high dust environments. Smart electronics within the sensor can differentiate between product being measured and any buildup on the face of the sensor. And without a horn attachment, there's never a chance for excessive buildup to block the signal all together.

Choosing 80 GHz for high dust environments

In high dust environments, visibility and buildup are the two biggest challenges level measurement instrumentation faces. Users have a wide range of technologies to choose from, but the forward-thinking operators who see their level measurement instrumentation as an investment in the efficiency of their entire process will know 80 GHz radar is the right choice. With exceptional focus, improved sensitivity, and intelligent electronics, high-frequency 80 GHz radar sensors like the VEGAPULS 69 are the only sensors that can see through the dust and buildup.

Author: Luis Santiago, Mining and Aggregates Industry Manager, VEGA Americas

Radar sensor for bulk solids measurement: from fine to coarse, from gritty to dusty

VEGAPULS 69

With its high frequency of 80 GHz, the VEGAPULS 69 radar sensor can measure practically any kind of bulk solid material – even in a dusty atmosphere. The radar sensor scores big with its wide measuring range and accuracy in large or small applications: in bunkers, containers, silos. Even internal installations have no effect on the measuring result.

The non-contact radar sensor is ideal for use in many industries, such as building materials, rocks, aggregates and cement, as well as for use in the chemical industry, in wastewater management, and in recycling.

www.vega.com/radar

Wireless adjustment via Bluetooth with smartphone, tablet or PC. Compatible retrofit to all plics® sensors manufactured since 2002.

Looking Forward VEGA

FREQUENCY-MODULATED CONTINUOUS-WAVE (FMCW) RADAR LEVEL MEASUREMENT SYSTEMS

Radar (radio detection and ranging) level measurement systems are very successfully utilized for assessing the filling level of liquids in tanks and of bulk solids in silos. They continuously demonstrate their advantages against other techniques in a very wide field of industrial applications. The major benefit is the contactless measurement principle, which is based on using microwave based time-of-flight distance measurements in the free space above the measured medium. Reliable measurements are possible under various practical conditions even with aggressive media like acids and bases and even in low reflecting products like solids. Given their high frequency basis, the microwaves easily propagate through dust and mist in the air. Furthermore, in most industrial applications, their propagation speed is constant and independent of the composition of the air and of parameters like pressure, temperature, and others. Accordingly, radar systems also allow for accurate and very repeatable level measurements even in 'dirty' applications, where the radar antenna may be covered by bulk solid build-up, condensation, or anything else.

In the field of radar level measurement systems, two concepts are commonly used. The first is known as FMCW which stands for Frequency-Modulated Continuous-Wave, the other is simply known as pulse. FMCW radars have many advantages, the most important of which is the substantial measurement sensitivity (dynamic range). This is why since the very first industrial radar was introduced by KROHNE in 1989, we have opted to exclusively use FMCW as the basis for all its OPTIWAVE radar level measurement systems.

RADAR SYSTEMS DESCRIPTION

Radar level measurement is based on discerning the round-trip time-of-flight based on emitting microwaves from an antenna and receiving those reflected from the measured product's surface along with any which are backscattered from anything else in the tank.

Pulse

In pulse radar systems, this is achieved by emitting a short pulse signal waiting for a while and then directly acquiring the resulting echo signal. A sequential of sampling technique is typically employed. Instead of a single pulse, a sequence repeated pulses is issued and the echo signal is sampled using a second sequence of pulses with a slightly different repetition time period. The energy of each transmitted pulse is relatively small because the peak amplitude is very limited. Therefore with the sequential sampling, this generally results in a relatively small dynamic range and limited signal-to-noise ratio (SNR) performance which is acceptable for most simple installations but could be problematic in some use cases.

FMCW

The concept of FMCW radar systems is completely different in order to achieve a much better SNR and for the broadest applicability range. In FMCW radars, a continuous-wave signal is generated and emitted. This signal has very large time duration and more energy than the emitted signal in a pulse radar system (even with equivalent peak amplitude). Depending on the device, the frequency of the continuous-wave signal is linearly modulated over time, in a saw tooth pattern, from low to high according to its frequency sweep capability. For example some devices have 1, 2 or 4 GHz sweeps starting at different nominal frequencies. With this approach the 'sweep-duration' can be chosen independently from the bandwidth and the signal can simply be generated by means of a voltage-controlled oscillator (VCO) and the resulting spectral purity of the signal is very high.

The approach for processing the continuous-wave signal echo is to mix the received signal with the transmit signal. After low pass filtering, the so-called intermediate-frequency signal is directly obtained. As another advantage of the FMCW concept, this signal can directly be digitized using a low-cost, low sampling frequency, analogue-to-digital converter (ADC) and no sequential sampling has to be performed.

In the past, the challenge was to accurately generate a highly linear and stable frequency sweep in a loop-powered instrument. Early on KROHNE solved this requirement in the OPTIWAVE radar by employing phase-locked loop (PLL) technology.

RADAR SYSTEM PARAMETERS

Each radar level measurement system and an antenna is characterized by a set of technical parameters as follows:

- Utilized frequency band (nominally this is the center frequency and bandwidth)
- Antenna size (diameter and length)
- Type of antenna (horn antenna, dielectric 'drop' antenna, dielectric lens antenna)
- Antenna gain and efficiency

The angular beam width of the antenna radiation field is inversely proportional to the aperture diameter of the antenna and to the center frequency. The choice of antenna is mostly dependent on the given application conditions.

On the one hand, the angular beam width should be small in the case of tall narrow tanks or silos in order to avoid the unwanted 'illumination' of the tank or silo wall or to avoid any disturbing echo signal from tank internals (e.g. agitators or reinforcement structures). On the other hand, the beam width should not be too small, for example, if movements ('waves') are given on the liquid surface or if a perpendicular incident direction towards the planar surface of the liquid cannot be guaranteed. The latter might be the case, for example, if the flange on a given tank is not perfectly horizontal. In either of these scenarios, the reflected microwaves would not arrive back at the radar if the angular beam width is too small and consequently no echo would be detected by the radar.

The transmission loss is the ratio between the transmitted power and the received power, and this parameter is largely dependent on the properties of the antenna (gain and efficiency), the utilized frequency, and also of course, on the reflection or backscattering properties of the liquid or bulk solid respectively. While the reflection coefficient of the planar liquid surface does not change with frequency, the backscattering at fine granulated bulk solids largely increases with increasing frequency. Accordingly, the penetration of microwaves into the bulk solid heap decreases.

As a general rule of thumb, the received power generally increases with increasing frequency and with increasing diameter of the antenna. For this reason, the echo signal level can generally be increased by using a high frequency and an antenna with a large diameter.

At first glance it looks advantageous to always configure a radar system for minimum transmission loss and minimum beam width, but there are exceptions and each specific application should be reviewed with a technical specialist.

Range resolution is another interesting parameter of the radar system. It describes the ability to separate different radar targets from each other over distance. This parameter is inversely proportional to the bandwidth. For this reason, a large bandwidth is required to allow a good separation between echoes from the filling medium and from other 'disturbing' objects such as the antenna outlet reflection which is often the root cause for the so-called 'upper dead zone'. Another example is the weld seams in the tank or silo wall. Typically, the bandwidth of a radar system is proportionally increasing with its center frequency.

Radar antennas

A variety of radar antennas based on different designs concepts are available to address many applications.

Dielectric lens antenna

This type of antenna is available for the 80 GHz frequency range radar systems. Here, a dielectric lens is given at the interface between the radar and the tank or silo and can directly fulfill the function of a 'barrier element'. Advantageously with this design, the overall length of the antenna is very small, while offering a good electrical matching.

Horn antenna

This is the standard type of antenna, especially for the 10 GHz and 24 GHz frequency ranges, and horn antennas usually have very good applicability in most applications. The overall length of horn antennas is relatively large, but they provide a very good electrical matching to the free space. Additionally, antenna waveguide feeds including a so-called 'metaglass' or plastic component are available as a 'barrier element' between the tank or silo and the environment. This is relevant for means of explosion protection if an inflammable or explosive atmosphere is given inside the tank or silo.

Dielectric 'drop' antenna

This type of antenna has been specially designed and optimized for offering a smaller overall length with the same (and even better) performance as a horn antenna of the same diameter and for directly functioning as a 'barrier element'.

Furthermore, the 'drop' antenna is the perfect choice for bulk solid applications and 'dirty' environments, because adherences of bulk solid material, condensed water, etc. are largely avoided by the smooth surface of the antenna. Also, adherences are generally less critical with the volumetric plastic body of the antenna. The 'drop' antenna shows a good electrical matching and is available for the 24 GHz frequency range.

The overall length of the antenna is especially interesting with regard to the decay of disturbing echoes ('antenna ringing') over distance, which result from multiple reflections inside the antenna caused by the (always given) mismatching at the front face of the antenna and at its feeding point. This decay is faster the smaller the overall length of the antenna is. Accordingly, a short antenna is very favorable if level measurements should also be done at very small distances, i. e. close to the antenna.

SUMMARY AND CONCLUSIONS

The answer to every challenging level measurement application cannot be given by only one radar system. The solution is always based on the proper selection of the radar system and the antenna combination selected for the specific application.

Now a complete range of FMCW radar systems and a large variety of corresponding antennas is the real enabler to finding the right solution for contactless level measurement in nearly every application.

It should be noted that given the intrinsic technical advantages of FMCW, and with recent advances and availability of monolithic microwave integrated circuits (MMIC) other radar vendors are now migrating from pulse radar systems to the FMCW radar technology.

While a large variety of pulse radars is still available in the market, KROHNE will persist with FMCW as its core technology.

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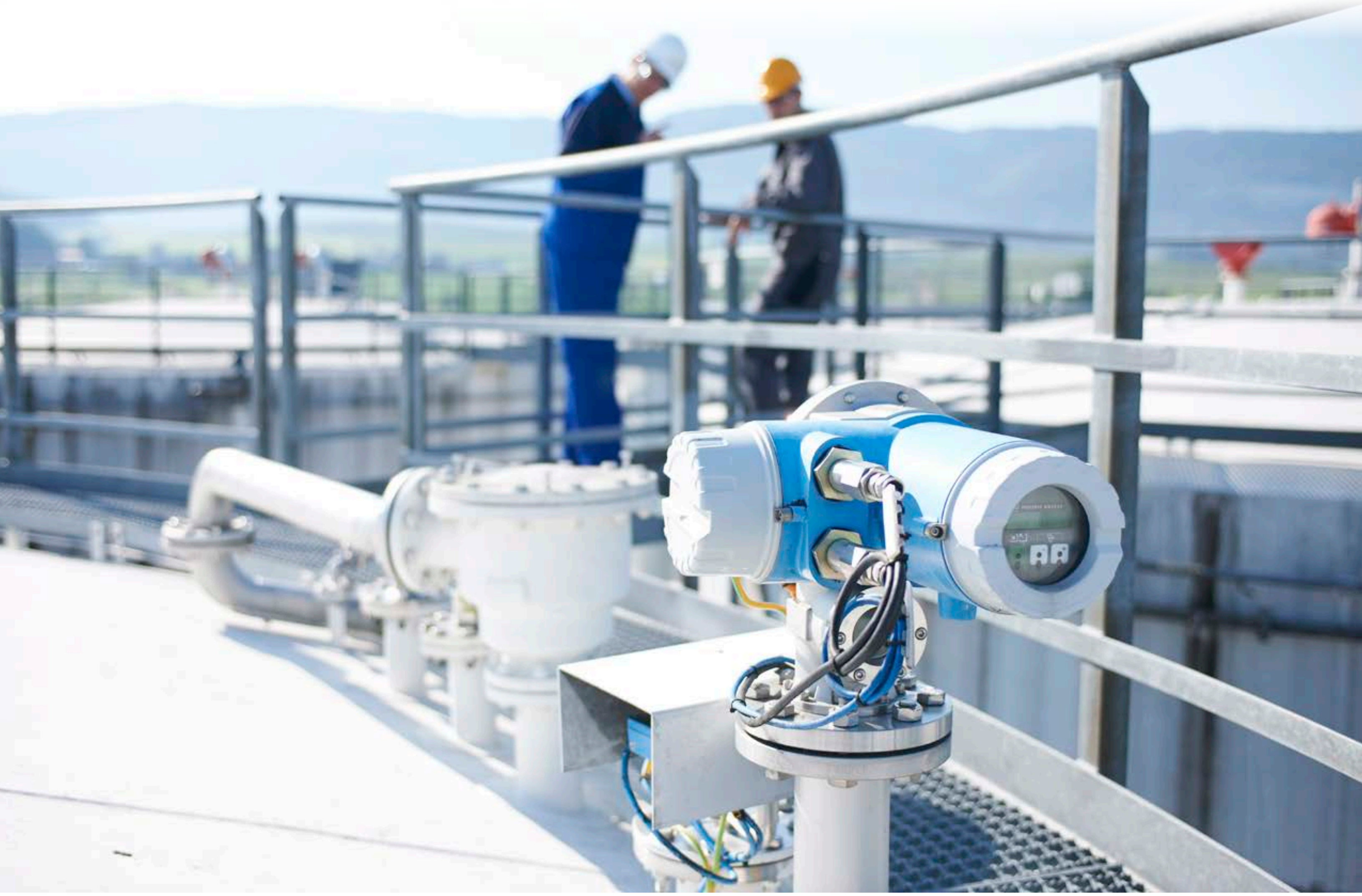
STATE-OF-THE-ART TANK GAUGING: HIGH ACCURACY WITH A BIG PAYOFF



From a cost-benefit perspective, there has never been a better time for tank farms and other bulk storage operators to upgrade their tank gauging infrastructure. Adopting a holistic strategy combining the latest measurement and communications technologies and analytical components can provide compelling arguments to move off of legacy devices or manual measurement. Today's state-of-the-art servo and radar tank gauging instrumentation generates data in real-time, with unprecedented accuracy – as precise as ±0.4 mm for servo gauge or ±0.5 mm for free-space or stilling well radar. The high quality data derived from that provides great reliability, consistency and visibility in calculating inflows and outflows, estimating inventory in storage and available capacity, on a per-tank and facility-wide basis.

Yesterday's tank gauging methods produce large variances in measurement data and reconciliation of inventories. That, in turn, widens the exposure to business risks like shortfalls of inventory or capacity that affect deliveries to customers, on-time acceptance of new product, uncertainty about custody transfer and revenue accounting, or losses due to as-yet undetected leakage.

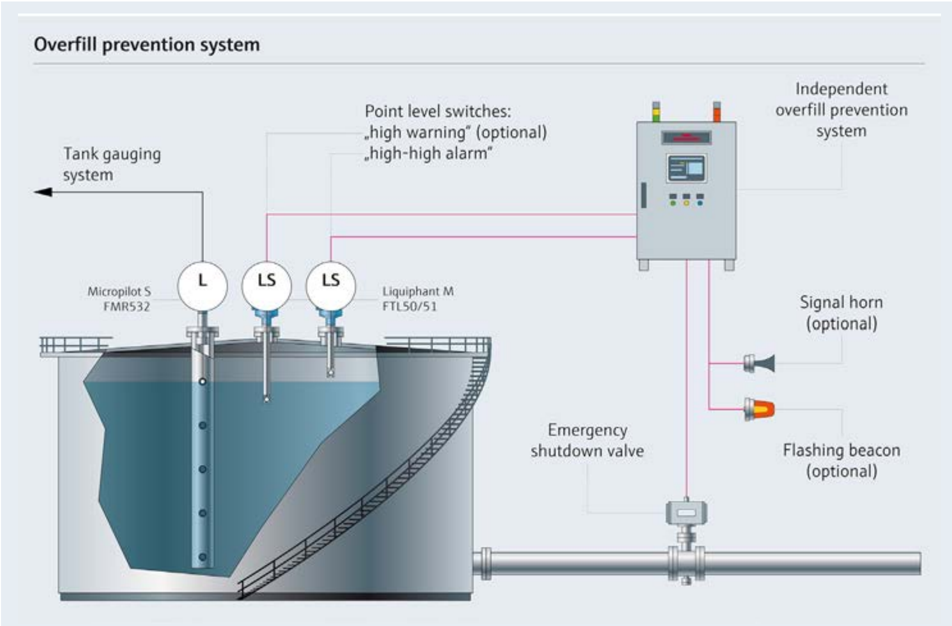
These risks tend to be greatest with manual measurement. Critical information such as product temperature, density or water bottoms in fuel storage tanks can't be adequately measured or anticipated. Manual measurement is labour intensive and must be performed in all types of weather. It also relies on manual reconciliation of inflows and outflow data, generally resulting in wide variances in inventory and capacity tracking.

As for legacy tank gauging devices, a facility full of complex variants from different vendors is a step up from manual tank gauging depending on how the data is reconciled, but still provides limited visibility about inventories when compared with today's state-of-the-art systems.

The optimal configuration for upgrading to best-of-breed is based on single-vendor uniformity and simplicity across all field instrumentation. In supporting such a project, Endress+Hauser specialists would suggest how best to combine high measurement accuracy with a site-optimized communications strategy for real time wired or wireless data transfer, monitoring and analysis. The extremely high accuracy provided by the latest technology assures improved inventory and capacity control, and greatly increases the potential for early recognition of anomalies pointing to leakage. The highest environmental and safety considerations can be incorporated into the plan, like an overfill protection system to prevent spills of volatile or toxic substances. This holistic approach is conceptually the best from a risk management standpoint. It minimizes business risk; the efficiency and reliability improvements feed through to the bottom line. The uniformity and simplicity in field instrumentation make the system easier and more cost-effective to manage and maintain. Reducing on-site safety and environmental risks demonstrates a tangible commitment to the operator's Corporate Social Responsibility (CSR) program. Other soft benefits include reinforcing relationships with suppliers, customers, investors, employees and local communities.

Such a comprehensive solution can be developed for a wide range of storage situations – liquid, gaseous and solids like slurries and bituminous substances.

Using a single solutions provider such as Endress+Hauser adds value during the planning stage. One size – or one type of measurement technology – doesn't necessarily fit all situations. Factors such as tank geometry and contents and the site size and layout are taken into consideration. For measuring storage of a high value product, premium, high accuracy radar measurement would likely be recommended; the larger such a tank, the greater the need to limit financial exposure. For lesser products, standard accuracy radar might suffice.



Endress+Hauser's new platform of high-performance tank gauging instruments supports both radar and servo technologies, each with a range of sensing elements and process connections to ensure accurate and reliable measurement in almost any process and environmental condition. State-of-the-art level and temperature measurement technologies with industry-proven communication protocols allow accurate measurements and data collection. Endress+Hauser's tank gauging instruments, Micropilot, Proservo and Prothermo meet the NMi and PTB requirements and also have local approvals according to OIML R85. The uncompromising usage of web server technology allows easiest access to tank data and comprehensive data presentation to anyone in need.

It's the world's first platform of both typical tank gauging measuring principles designed according to IEC 61508 and certified SIL2/SIL3 capable. The platform also includes unique Endress+Hauser management and analysis features for highest reliability as well as fast, easy commissioning, maintenance and diagnostics. Endress+Hauser can propose process instrumentation and software packages for pressure, flow and temperature devices, loading metering skids as well as data interfaces and its inventory management software solutions: Tankvision®, Terminalvision® and SupplyCare®.

Upgrading of sites with an existing tank gauging architecture accumulated over the years may not be financially feasible. In that case, a gradual upgrading strategy can be applied. Operators can migrate their existing instruments and advance their tank farm to state of the art step by step. Endress+Hauser will help managers determine how migration can be managed without losing the existing installed base but allow progression into an easier maintainable and flexible site architecture.

For more information, CLICK HERE:

To watch our Tank Gauging video, CLICK HERE:

LWT SERIES:

a new way to work with guided wave radars

ABB is introducing a new guided wave radar product line based on smart sensing and advanced algorithms that provide the simplest user interaction on the market.

Guided wave radar (GWR) technology is now well established as an industrial continuous level measurement method. This technology is based on the emission of a low energy microwave pulse sent down a metal probe (e.g., a cable or rigid rod) that spans the length of the vessel to keep a continuous physical contact with the measured process. Contrary to non-contact radars whose beam expands at it travels, the microwave pulse that is captured within the probe keeps the pulse diameter constant at about 40 cm, thus maintaining its high intensity regardless of the distance it travels.

The microwave pulse travels along the length of the probe and is reflected at the point of contact (a.k.a. the interface) between different media found inside the vessel, like air and oil for example. The pulse then comes back up the probe, and the transmitter measures its time of flight. Time measurement of electronic pulses is very precise, allowing GWR to reach accuracies down to 2 mm. In that regard, GWRs are similar to time-domain reflectometers which are instruments used to characterize and locate faults in metallic cables, connectors or printed circuit boards. There are even optical time-domain reflectometers used to identify faults in optical fibers. These instruments are all based on the same time measurement principle of a pulse reflected along a cable.

Different materials generate weaker or stronger reflections based on their dielectric constant. The higher the dielectric constant, the stronger the reflections when the microwave pulse hits the material interface. For example, oils have dielectric constants close to 2, which is considered low for GWR, whereas water has a very high dielectric constant of 80 which leads to strong pulse reflections. A very useful GWR feature is its ability to measure the interface between two liquids (oil floating above water, for example). Since oil has a low dielectric constant, a large portion of the pulse will travel through the oil layer and hit the water underneath. This will return two pulses: one from the air-oil interface and one from the oil-water interface. Both will be measured, leading to the measurement of the top oil level and the interface level between oil and water. If the densities of oil and water were reversed, and water was floating on top of oil, this would not be possible as the reflection from water would be so strong that very little energy would go through the water layer and reach the oil interface below. Fortunately, this is not the case, and measurements of oil and water interfaces are very common in the oil and gas industry.

Figure 1.

Figure 1. The head sends a very short pulse of microwave energy through the coupler and down the probe (1). That pulse travels along the length of the probe (2) and, when it encounters the product surface, some of the energy is reflected and travels back towards the coupler (3). When the reflected energy reaches the coupler, it is sensed by the electronics (4). By measuring the time elapsed between the initial pulse and the reflected one, the electronics can calculate the product level (5).

For challenging liquid applications such as those with low dielectric constants and harsh conditions, it is possible to use a coaxial probe. This type of probe is made of a middle rigid rod surrounded by a metal tube. The microwave pulse is then even more tightly confined inside the metal tube, thus ensuring that the intensity is always high and that the pulse does not scatter and leave the confinement of the probe.

GWR can also measure levels of solids, as they reflect enough microwave pulses to be measured. However, solids usually generate weaker return pulses than liquids. In many cases, solids will have a low density as they contain a large portion of air by volume, so their dielectric constant will be low. Also, their surface can be at an angle with respect to the probe, and the surface itself can be uneven and rough. This causes portions of the microwave pulse to be lost, or spreads the pulse, thus weakening the signal.

Figure 2. LWT310 guided wave radars with different types of probes. From left to right: flexible cable, rigid rod, and coaxial probe.

Though GWR technology has been around for more than a decade and its core principles are well established, most of the recent developments are centered around sensor intelligence and data processing. Most GWRs are very low power devices (powered from a 4-20 mA loop for instance). This has limited progress in the past. However, advances in low-power processors now enable powerful real-time data analysis at low power and at a cost point compatible with the demands of the industrial market. This has allowed the development of the LevelExpert™ algorithms used in ABB's LWT series of instruments.

Usually, configuration of a GWR requires the user to look at a waveform on which various radar echoes appear. These echoes can be caused by many factors such as the coupling of the pulse inside the probe, the end of the probe, the surface to measure, potential reflections of these echoes along the probe, and also from other external factors (build-up on the probe, nozzles at the top of a vessel, waves, etc.). With this waveform, the user then needs to identify the echo created by the surface to measure and set parameters that will identify that echo like a signal threshold (implying that the surface echo is larger than the others), a signal shape, or similar parameters. This also implies that such parametrization will remain valid over time. If not, the user will need to change the parameters to find the right echo again.

Figure 2.

ABB's LevelExpert works differently. Instead of having to set many technical parameters such as sensor gain, offset, detection threshold, signal shape, etc., the user inputs application details. For instance, the user will indicate if the GWR is placed on a nozzle or on a stilling well. The user can also determine process conditions. A series of conditions is presented to the user and each condition can be enabled or disabled based on actual process conditions. For instance, if buildup can be present in the application, the user can enable the buildup condition. Other conditions presented to the user are the presence of foam on the surface of a liquid, the potential for flashing of the tank, the presence of an emulsion layer or of strong agitation in the tank, and changes in the dielectric constant of a material, which might happen when a change in material state occurs (water turning into vapor, for instance).

By enabling or disabling these conditions, the LevelExpert knows how to interpret the waveform and find the right surface amongst the different echoes. All these conditions lead to waveform shapes that can be interpreted and categorized, enabling differentiation between buildup and a change in level, for instance. All waveform echoes are tracked and categorized, which allows for real level measurement without forcing the user to set specific parameters to find it.

This has the additional benefit of being more robust to long term changes. For instance, if the echo is defined by a specific threshold and, in time, echo amplitude becomes lower than that set threshold (e.g., liquid in the tank changed and now has a lower dielectric constant), it stops being detected. Relying on tracking and echo qualification is more robust: even if echo amplitude goes down, LevelExpert keeps identifying it as the real surface.

In conclusion, the technology used in ABB's GWRs is based on the time-domain reflectometry of microwave pulses travelling along a metallic probe spanning the length of a vessel. Pulses are reflected by material changes, such as air-water interfaces, based on the dielectric constant of each material.

This technique has been developed more than a decade ago but advances in data processing have enabled a more intuitive approach to GWR setup. This means that a wider range of people will be able to use GWRs since parameter selection is now based on plain words describing well-known process conditions. It also means that, by using advanced algorithms to analyze radar waveforms, it is now possible to automatically find the echo that actually represents the level to measure through a clutter of measurement data.

For more information, CLICK HERE:

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