



High frequency radar such as SITRANS LR460 is the recommended level measurement technology for long-range, dusty applications.

## Effective Solids Level Measurement with Radar

Why high frequency radar is the best solution to level measurement applications on solids, and how to ensure the best measurement results

BY TIM LITTLE

Radar technology has been used successfully for level measurement since the mid 70s. Initially, this non-contacting technology was applied to custody transfer applications on large storage vessels using high cost, high accuracy devices.

More recently, as cost decreased and technology developed, radar devices are now used for a wider range of applications, including smaller liquid bulk storage as well as agitated process vessels. But, until now, a very limited number of solids material applications were even attempted. Why not?

In several ways, radar should be an appealing technology for solids. RADAR technology (RADio Detection And Ranging) uses electromagnetic waves in the microwave spectrum between 1 and 300 GHz. These waves travel at the speed of light, and are virtually unaffected by vapor, pressure, temperature, or dust, giving radar an advantage over other technologies. This, combined with radar's "non-contacting" approach, make it a very appealing technology for solids level measurement.

To be effective, however, a radar instrument needs to be developed with solids characteristics in mind. The same devices that work on liq-

uid applications often don't perform on solids. That's because the level measurement challenge on solids is different in many ways from measurement on liquids.

### The trouble with solids

Liquids in bulk storage offer a relatively easy environment for level measurement. The liquid surface is large and flat, offering excellent reflection properties for non-contacting technologies. For contacting devices, liquids present no abrasion issues or strong tensile forces to worry about. The environment above the liquid surface is typically "quiet." By contrast, solids materials can



Configuration of the SITRANS LR460 can be performed with a non-intrusive infrared handheld programmer.

present a “hellish” environment with a range of unique challenges, including different surface dynamics, tensile forces and silo obstructions.

The first is surface dynamics. The angle of repose (surface slope) of solids may be flat and smooth (cement, for example). More often, solids have a sharply sloped and irregular surface as with aggregate materials. Particle size ranges from very fine powders like flour to very coarse materials like coal.

Tensile forces further complicate solids measurement. Tensile forces in tall solids silos can reach several tons. As material is drawn from the vessel, the intense force can break off cables or moving parts within the silo. This makes contacting cable or mechanical systems problematic.

Vacuum dust collectors, filling streams, aeration devices, static electricity, acoustic and electromagnetic noise are also significant factors in solids silos. It’s no wonder that many customers still rely on manual measurements taken from the top of the silo using a rope.

### Contacting systems

Contacting systems are sometimes used to measure level of solids, but shifting material and tensile forces make them prone to broken or tangled cables that could interfere with the process and increase maintenance costs.

For TDR (time domain reflectometry, sometimes called cable radar), the bottom of the cable is usually anchored to ensure the cable doesn’t move around during material draw down or shifting. If the cable touches the side of the silo, it will report false measurements. Cables must be sized for the silo to ensure they can withstand the huge tensile forces present; however, if the cable is too strong, it can damage the silo roof. To install a cable system, you must wait until the vessel is completely empty before fastening the end of the cable to the bottom of the silo. Alternatively, weighted cables can be used, but again you must first empty the silo to allow the cable to stretch out to its full length.

Plumb-bobs (sometimes referred to as yo-yos) are mechanical devices that drop a weight into the silo at certain intervals to measure the level at that moment. It’s not uncommon to lose the weight on the end of a plumb-bob system in the turbulent environment of a cement homogenization vessel, potentially blocking the material outlet — a disaster for most processes.

### Ultrasonic systems

Ultrasonic level measurement continues to be the most cost-effective, practical solution for most basic solids applications. Ultrasonic waves reflect well from high density materials.

Ultrasonic systems are available from 5 KHz to 60 KHz, with the highest frequencies typically used on liquid applications. This allows

the use of smaller sensors to measure shorter distances, and gives increased resolution. Although high frequencies provide better reflection properties on sloped solids surfaces, they are limited to shorter range solids applications. Think of a foghorn that uses lower frequency sound to travel the longest distance possible. Similarly, dust attenuates the higher frequency sound waves; therefore, low frequency ultrasonic systems are the most common approach to long-range solids level measurement. For dusty solids applications, ultrasonic technology is limited when the dust is so severe that even a low frequency sound wave cannot travel through it, reflect from the surface, and return. And that’s where radar takes over.

### Limitations of traditional radar devices

Although the microwave spectrum ranges between 1 and 300 GHz, most radar level measurement systems operate between 6 and 26 GHz.

The first radar devices used 10 GHz FMCW technology and this frequency is still widely used today. Low frequency devices operate around 6 GHz, and high frequency radar devices operate around 24 GHz. For a given output signal amplitude, low frequency radar requires a much larger antenna; for example, a 6 GHz radar device will require a 400 mm (16”) diameter horn to obtain the same signal as a 24 GHz radar device using a 100 mm (4” horn).

Low frequency, traditional radar devices are well suited for liquid applications. To use them effectively on solids applications, however, you would need a large horn up to 250 mm (10”) diameter or even a parabolic dish antenna to capture sufficient signal. This large antenna is just not practical on most ves-

sels. Where process connections are available at all, they are normally too small to accommodate a large antenna without costly modifications. If a connection must be created, it's much easier to create a small hole than a large one, especially if the vessel roof is concrete. With its smaller antenna sizes and ease of installation, high frequency radar offers significant advantages for solids applications.

### 24 GHz – the ideal frequency for solids

Vessels vary in shape and size, and may contain various internal challenges. Silos assembled in sections have seams that may create false signals. Internal ladders, man-way access hatches, point level switches, and even fill streams are potential false-echo signals for level measurement equipment. Silos containing bulk solids are often tall and narrow, often well over 50 m (150 ft) high. For all of these situations, narrow conical beam angles are preferable to reduce side-wall path interference and reduce false signals from internal obstructions. High frequency radar provides a narrower beam angle than low frequency radar. A 24 GHz radar instrument, for example, has a narrow 9° conical beam angle compared to a 36° angle for a 6 GHz instrument with a 100 mm (4") diameter horn antenna. This makes high frequency radar instruments more effective on solids.

Smaller antenna, easier installation and a narrow beam angle are important advantages of the higher frequency radar instruments. Another tremendous benefit of higher frequencies is the reflection property from sloped solids surfaces as it relates to wavelength and “skip” effect. A wave striking a sloped surface may reflect directly back or it may skip away from the sloped surface. This

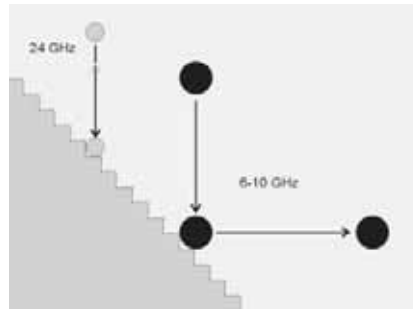


Figure 1: The skipping effect is a common problem for low frequency systems on solids. A wave striking a sloped surface may reflect directly back or away from the surface, splitting the signal so that the receiver sees two signals instead of one. A high frequency radar device ensures maximum direct reflection.

causes the pulse to “split” into two paths so that the receiver sees two signals instead of one. Severe “skipping” may result in the second echo being higher than the first one (see *figure 1*). This is a common problem for low frequency systems. Using a high frequency like 24 GHz ensures the largest amount of signal reflects directly from the sloped surface rather than skipping away.

### You’ve got to have the power

Two-wire, loop-powered radar devices are a good solution for liquid bulk storage vessels. These applications are generally short range, typically less than 15 m (50 ft), on slow moving, flat surfaces.

The problem comes when you try to use the same devices on long range solids applications. Some loop-powered devices may perform on short range solids applications where the material rests very flat but, in most solids applications, the return signals will be weak. Signal amplitude is reduced with beam spreading, which means that signals are weaker as the distance increases.

In addition, any slope or irregular surface of the solids material will further reduce the available signal. For these reasons, a high power radar device is a more appropriate solution for solids measurement.

The latest innovation in high power radar devices is SITRANS LR460, recently introduced by Siemens. It uses 4-wire line power to ensure sufficient signal return and to accommodate the challenges within a long-range solids level measurement application.

### Intelligent signal processing for solids

Regardless of the technology chosen, the echo-processing techniques are very important. The echo-processing requirements for liquid applications are far less challenging than for solids because the large, flat surface of liquids produces high signal amplitudes and a relatively simple echo characteristic or profile. It's easy to see your reflection in a mirror surface like a large pond, but difficult to receive a reflection and measure the distance to an irregularly shaped and sloped solids surface in the middle of a sandstorm!

Radar devices designed for liquids and applied directly on solids applications will quickly become confused or may even lose their signal completely. A solids material profile provides a different signal characteristic than a liquid material reflection and requires a different approach.

The base noise floor of the received signal will be different when the silo is filling compared to when it's empty. As the silo is filled or emptied, the characteristic profile will change and it's imperative that the signal processor knows how to respond positively to these changes.

Conical bottoms are typical on silos containing solids to facilitate smooth discharge of contents;

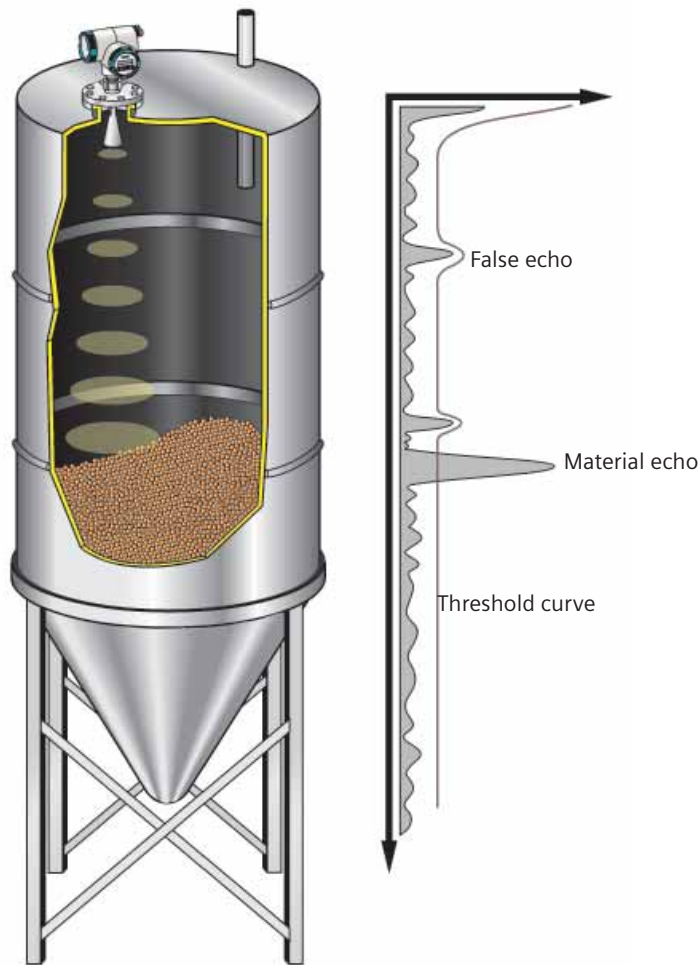


Figure 2: Auto False-Echo Suppression is an added feature of the SITRANS LR460 radar instrument for solids applications. Easily enabled, it automatically detects and suppresses false echoes from tank obstructions.

however, this feature causes grief for most level measuring systems because of the highly sloped surface. Multiple signals, indirect path signals, very weak signals, and false signals from internal fixed obstructions all contribute to the difficulties. The measurement instrument must be able to filter out all this noise and lock onto the correct echo signal from the material.

A powerful solution to these problems is Process Intelligence, a

patented echo-processing software built into the new SITRANS LR460 radar transmitter from Siemens Milltronics. This sophisticated software differentiates between true echoes from the material and false echoes generated by obstructions or electrical noise. Process Intelligence is supported by field data gained in more than 20 years of experience in over 1 million applications in many industries. This in-depth knowledge and experience is built into the software

to provide intelligent processing of echo profiles. It includes sophisticated algorithms, window tracking, multiple-shot averaging, and Auto False-Echo Suppression for highly advanced and reliable echo selection (see figure 2). In addition, Process Intelligence features a unique Quick Start guide that allows fast and easy set up and virtually “Plug-n-play” performance.

**Aim the antenna for even better results**

Using high frequency instruments ensures optimum reflection properties, but you can further enhance the return signals by aiming the antenna towards the angle of repose. Granted, the angle of repose will change dur-

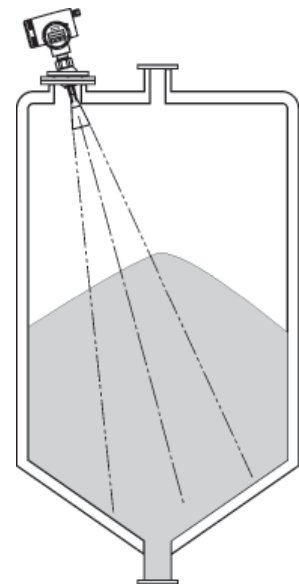


Figure 3: Using an Easy Aimer device allows you to angle the radar instrument to meet the angle of repose for the solids material in the silo or bin.



With its high power, high frequency and narrow beam angle, SITRANS LR460 provides excellent performance on dusty solids. It is shown here with an Easy Aimer device to facilitate aiming of the antenna system.

ing filling and emptying; however, aiming the antenna toward the material outlet is a good compromise that provides highest signals possible over the full measurement range. A radar instrument like SITRANS LR460 which has been designed for solids applications has an “Easy Aimer” device to facilitate simple installation and aiming of the antenna system. Proper aim significantly increases the amplitude of the signal and reduces subsequent indirect or multiple echo signals (see *figure 3*). Aiming reduces the “skip” effect.

### Antenna covers for minor buildup

A well designed solids radar device like the SITRANS LR460 will include an optional cover to prevent material from plugging the inside of the antenna. Generally, radar devices can tolerate minor build up inside the antenna so long as it doesn't completely block the emitter component. A low dielectric window covering over the

antenna like PTFE can be used to prevent this build up from occurring. This cover will be machined to precise tolerances to ensure the thickness is optimally matched to the frequency used. The cover must be held tightly in place to ensure no moisture can enter the antenna and condense on the inside. Antenna lens covers are recommended on materials like flour and calcium carbonate, materials known to compact over time inside the antenna.

### Purge the antenna if it's really nasty

Solids like plastic powder or cement powder are typically very dry. Let's face it, if there's water in your powdered cement silo, you've got serious problems! Dry powders may accumulate on the inside of the horn antenna system but will be virtually transparent to the instrument. Materials like plastics and cement powder have very low dielectric constants, and the electromagnetic waves will pass through them easily.

For solids materials with a high moisture content, usually in climates with very high humidity, material tends to stick inside the vessel. This is undesirable as it creates material flow problems and even blockages. A telltale sign of this moisture problem will be dents in the lower conical area of the vessel where operators have hit it with large hammers to improve the flow inside.

These “sticky” conditions can also cause problems with the radar measurement system by fouling the antenna system. “Sticky” usually means wet, and wet means water with a high dielectric constant so that electromagnetic waves reflect from the material build-up in the antenna. During this condition, a radar device will normally produce a false high level reading, signaling operators

to remove the antenna and clean it. If the problem is minimal, it is easy to remove and clean the antenna perhaps once every six months. But if build-up is severe, a self-cleaning antenna system (purging system) is an excellent solution. A purging system provides an inlet on the topside of the flange for injection of a purging medium such as air, gas, water or other liquid. The purge medium can then be turned on periodically either manually or by automatic control valve. Purging takes only a few seconds, and the temporary loss of signal will go unnoticed by the process.

### SITRANS LR460 – designed for solids

The unique characteristics of solids measurement require a different approach from liquids measurement. The most effective approach for long range or very dusty solids measurement is high power, high frequency radar. This accounts, in part, for the recent success of the new SITRANS LR460 radar instrument. This instrument is proving to be a breakthrough because it is effective even in extreme dust. It succeeds in difficult applications where other technologies and other radar devices have failed.

SITRANS LR460 is the only radar measurement instrument that features 4-wire power, high frequency (24 GHz) and Process Intelligence echo processing. With a range of 100m (328 feet), you can be sure it will have enough signal to handle virtually any solids application available. An easy aimer device and an antenna purge system are available to further enhance the operation on the most challenging applications.

SITRANS LR460 is a 24 GHz, high power radar unit using FMCW (frequency-modulated, continuous wave) technology. High power, high frequency and narrow beam

angle combine to produce excellent reflection characteristics and exceptional measurement performance on virtually any solids medium, regardless of the particle size. The strong signal-to-noise ratio and advanced echo-processing technology produce reliable readings even through severe dust. This makes it ideal for applications in the cement industry such as petroleum coke, homogenizing silos or vessels storing clinker, kiln dust, or finished cement. These same capabilities can also serve applications on fly-ash, flour, powders and other dusty materials.

Its long measuring range of 100 m (328 ft) makes it suitable for tall cement silos. It can handle the high temperatures up to 200°C (392°F) often found in hot clinker and kiln dust applications in cement plants. In fact, major cement companies are currently specifying Siemens radar as standard equipment in all their dusty applications, including finished cement, homogenization, kiln dust, and clinker.

Installation is simple and usually without interruption to the process. The Quick Start wizard makes start-up easy with its eight menu-driven steps. Set up can be accomplished using the infrared handheld programmer, which is non-intrusive so there's no need to open up the enclosure. It can also be programmed remotely with Siemens SIMATIC PDM (Process Device Manager) using a brand new Enhanced Device Descriptor with brilliant new graphics. It is HART compatible, with optional Profibus-PA.

The instrument uses non-contacting technology and there are no moving parts, so it is low maintenance, with no risk of broken or tangled cables. The benefit is reduced maintenance costs and trouble-free, reliable measurement on solids applications.

With this new development in ra-

dar technology, we can expect to see dramatic growth of radar on solids applications. ■

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