The Benefits of a Digital Moisture Measurement Technique

The benefits of accurate moisture management are now widely accepted to clearly outweigh the investment and onward cost for concrete producers. Monitoring the moisture in the raw materials, controlling water addition during the mixing process and finally checking the moisture of the materials in their finished form brings substantial benefits. Product yields may be maximised, materials efficiently utilised, energy consumption reduced and a quality finished product ensured.

With 30 years' experience using low power microwaves to measure moisture, Hydronix has become the industry leader in the field of microwave moisture measurement technology. The sensor's microwaves penetrate into the materials being measured and they are not affected by dusty environments or colour changes. Due to the high volume of sensors produced, Hydronix has reduced the cost of measuring moisture in-line, making it more widely available to all producers.

Measurement Technique

There are various methods of using microwaves to measure moisture. The most common method used in the concrete industry is the resonant cavity technique. In the past, an analogue microwave sensor would measure moisture through a combination of frequency shift (the left to right movement of the response) and amplitude attenuation (the change in the height of the response) of the resonator, see figure 1. This combination was measured as a single analogue response and therefore frequency shift and attenuation could not be separated. Hydronix went on to break new ground in the 1980's with the introduction of an innovative digital microwave sensor whereby the frequency shift component could be accurately measured using precise digital techniques. This development resulted in two significant improvements in the sensors, an improvement in accuracy and also a very significant extension of the moisture range for which the sensor would give a true linear response as moisture levels increased.

Every material will have a different effect on the microwave field generated by the sensor. As moisture increases the response will shift and reduce in amplitude.

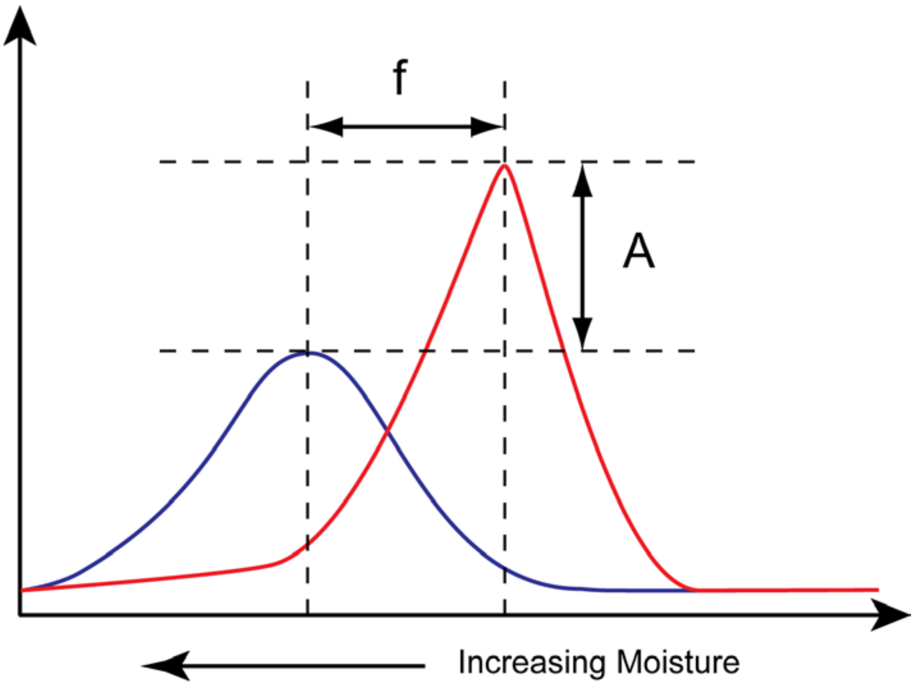

Figure 1: Moisture causes a change in the dielectric property of a material resulting in a frequency shift and amplitude attenuation

Less advanced sensors simply measure a change in amplitude at a fixed frequency. Measuring across a custom frequency range gives more accurate results than those sensors that work within the confines of a single frequency using an open band such as those used by Burglar Alarm Systems or Wi-Fi (433MHz or 2.4GHz). The components required to manufacture a sensor that measures a frequency shift as opposed to a change in amplitude at a fixed frequency are more complex but provide a superior result. The reason for this is demonstrated in figures 2 and 3.

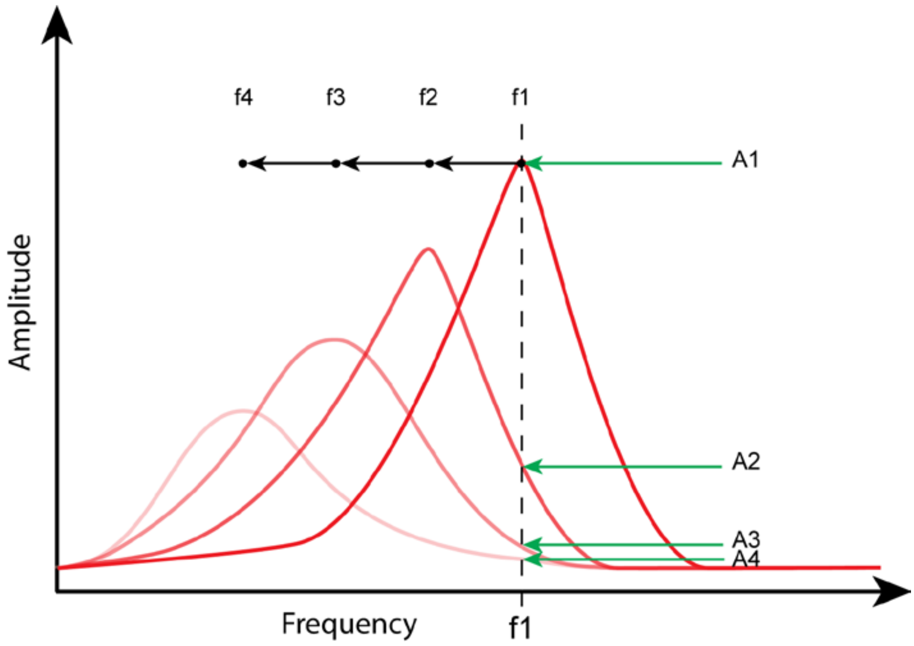

Figure 2: The Measurement

Figure 2 demonstrates the difference between a digital multi-frequency measurement and an analogue measurement at a fixed frequency (f1) of just the change in amplitude.

As the moisture increases the frequency shifts from f1 to f2, f3 and then f4. The shift between each is similar in magnitude. A sensor with a digital measurement technique will continually scan the frequency response and will track the equal changes in frequency as the material becomes wetter.

For the same moisture changes, a single frequency sensor simply measuring the change in the amplitude at frequency f1 will measure the changes from A1 to A2, A3 and then A4. It can be seen that the sensor progressively loses the ability to register a change in reading as the material becomes wetter. Typically, a good analogue sensor will lose the ability to register additional changes in moisture from about 12% onwards.

This not only effects the sensors ability to register changes in moisture above this level but it also means that the entire moisture curve lacks linearity as shown in figure 3.

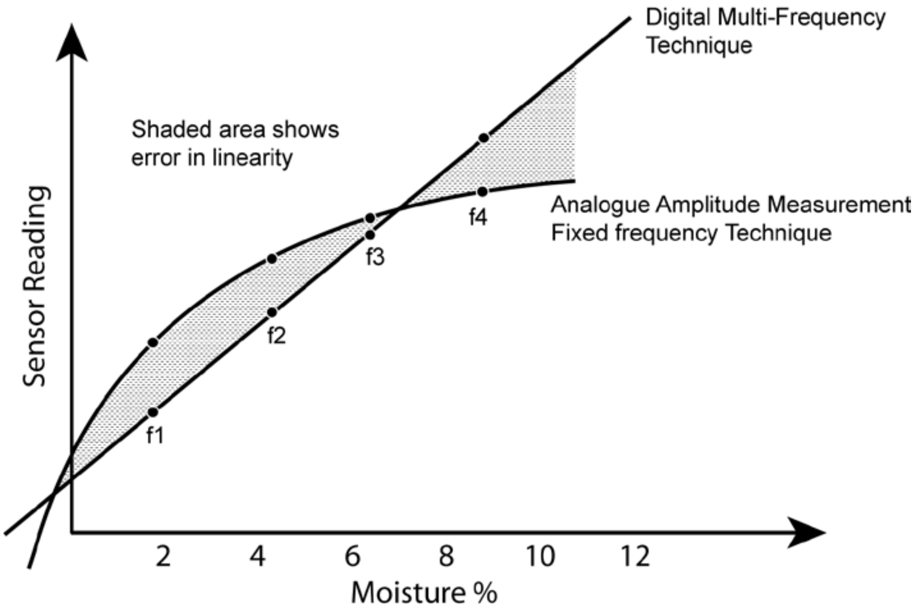

Figure 3: The effects of a non-linear measurement technique

Utilising a non-linear measurement technique requires the sensor reading to undergo significant mathematical manipulation in order to output what appears to be a linear response to changes in moisture.

A digital multi-frequency measurement has the ability to measure from 0% moisture through to material saturation while maintaining sensitivity and precision across the full working range. Admittedly, in the concrete industry this is not required. The benefits in accuracy around the 0% to 12% working are beneficial and noticeable when batching to tight quality and cost targets.

This also highlights a key difference between an analogue sensor that claims to be digital because it can process the signal and output a seemingly linear measurement and a sensor that uses a digital microwave moisture measurement technique that is inherently linear. The latter will overlay the linear response with subsequent processing to fine tune the curve and incorporate features such as on-board signal smoothing, alarms and averaging functions.

Accuracy Requires Calibration

Calibration is the process of defining the relationship between the change in the sensor response with the change in the moisture content of the material. This is required because each material will have its own electrical properties (dielectric properties) which effect the microwave field differently.

A good sensor should only require calibrating once for a given material. A poor quality sensor will require continual recalibrating due to errors. When well calibrated, an accurate and temperature stable moisture sensor should glide up and down the linear moisture line all year round.

However, a good sensor that is poorly calibrated or an unreliable sensor that is well calibrated may, for a short period perform well when operating at or around the moisture range to which it was calibrated. As the sensor moves away from this moisture range the reading will exhibit an ever increasing error. The same error will also exist for a sensor with an underlying non-linear measurement technique that is well calibrated.

For the demanding end-user, even a small calibration error can lead to large errors as the moisture varies even with an accurate sensor as shown in figure 4.

As appealing as it may be, leading manufacturers would agree that any claim made by a sensor manufacturer that their equipment does not require calibrating will lead to sub-optimal results in the field regardless of technical claims concerning the measurement technique of the sensor.

A well calibrated sensor that operates with a different calibration slope for coarse and fine sands of the same type of material is likely to be more accurate than a sensor that claims one calibration fits all.

Figure 4 shows the increasing inaccuracy arising from a either a very small calibration error or the assumption of the gradient of the calibration slope. At the point of calibration, between 2.5% and 3.5% moisture the sensor is reasonably accurate but as the working moisture range moves away from this range, perhaps with a changing season or a wet day, the error will progressively increase shown by the grey area which is the difference between the theoretically correct calibration and the one in use.

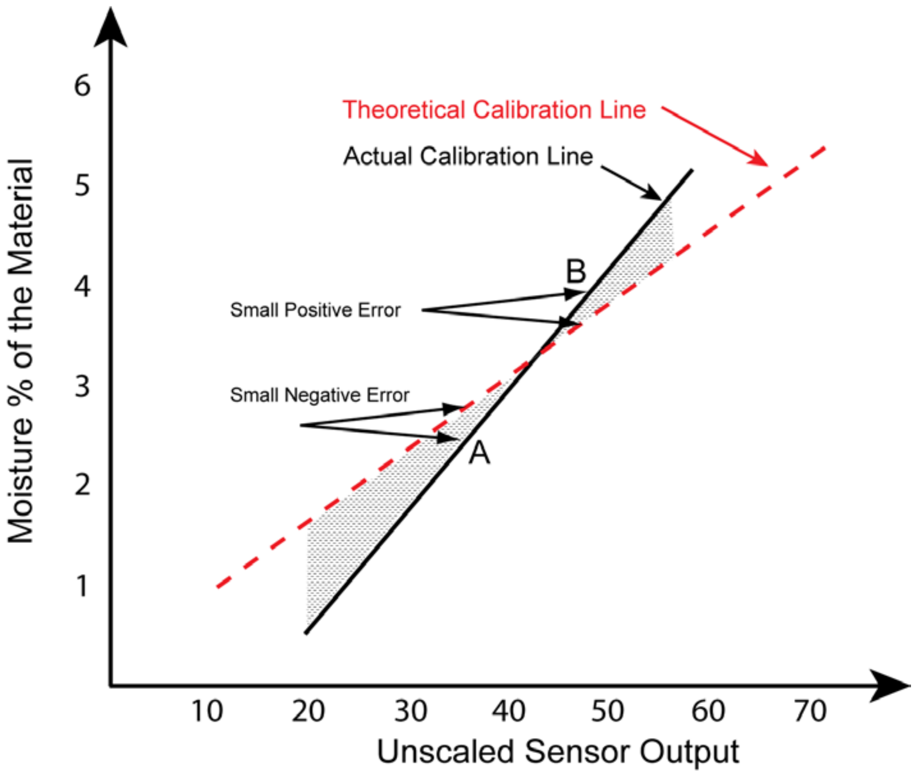

Figure 4: The effects of assuming a calibration slope

It is usual for moisture sensors measuring in the material bins to be calibrated to an absolute moisture percentage. Hydronix always recommends that the best and most failsafe method for calibrating a sensor is to use a multi-point technique such as that used in their Hydro-Com software, see figure 5.

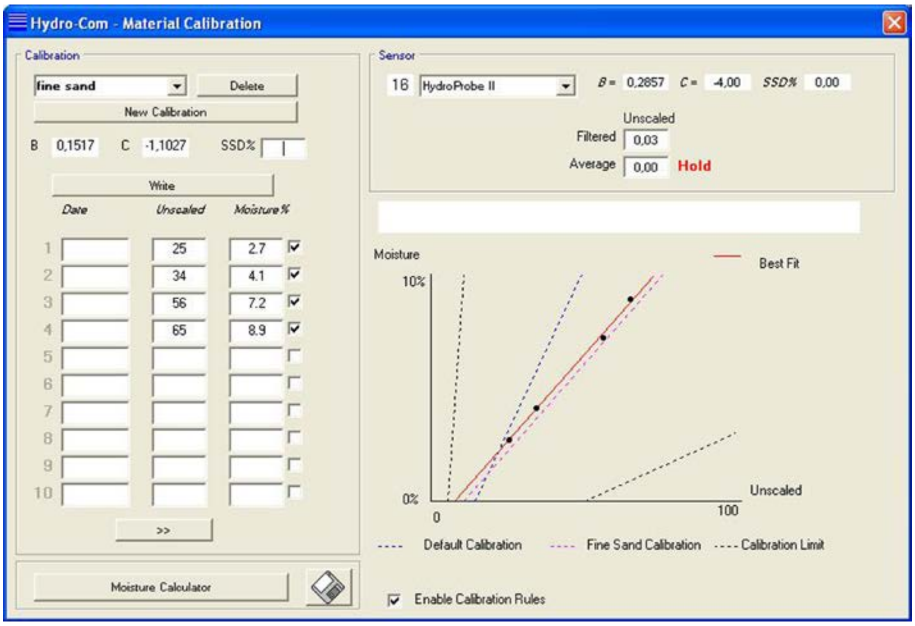

Figure 5: A multi-point calibration technique is recommended

Temperature Stability

When measuring in aggregates with a potentially steep calibration line, a small change in sensor readings will correspond to a large change in moisture readings. For this reason it is vital that the sensor readings remain stable with changes in temperature.

The electronic hardware in a good moisture sensor should be designed to remain indifferent to changes in temperature. Additionally, Hydronix has a software compensation algorithm that measures the temperature of the electronics and finely adjusts the sensor for any further compensation if it is required. Each sensor has a unique set of temperature coefficients calculated during the production stage which is stored in the sensors memory ensuring maximum stability for each individual unit.

To conclude

There are a variety of moisture measurement sensors available on the market, all of which claim to provide the best and most accurate results. It is well known that the microwave measurement technique provides the best results in the concrete industry. When choosing a sensor, you should ensure that it is fully temperature stable, and completely linear over the working range at which you wish to operate. A digital sensor utilising an underlying measurement technique that is capable of maintaining linearity from the absorption point (also known as S,S.D) to complete saturation by definition will give excellent accuracy limited only by the accuracy of the calibration.

The Hydronix range of sensors are supported in over 65 countries worldwide and our team of engineers is backed-up by our free global exchange program.

If you would like to know more about measuring moisture at your concrete plant, or using the latest microwave moisture measurement technology, contact Hydronix:

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