Do you need to measure soil moisture correctly and long-term stable or are rough estimates sufficient for your application?

Correct soil moisture measurement is a considerable challenge when it is planned not only to make rough estimations in soils but rather to record moisture measurements precise and long-term stable and to ensure verifiable compliance.
In applications with low requirements or in a time-limited project, perhaps rough estimations can be fulfilled with low cost capacitive or low tech TDR probes which still give a measurement result in any way. For higher demands and especially long run projects with the necessity of high precision measurement results, a use of precise sensors is indispensable. In data sheets (paper is patient) of many probe type manufacturers you often find information which do not represent the challenges transparently and objective for soil moisture measurements.

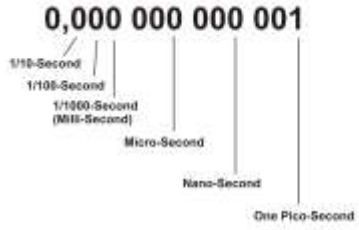
But why is the precise soil moisture measurement such a great challenge?

- Soil moisture probes should measure precise also in soils with higher salt contents. If a sensor measures instead 30% moisture suddenly 40% because the soil has a higher salt content due to a fertilization, then the sensor shows a considerable dependency due to conductivity.
- Precise soil moisture sensors should measure also higher moisture values. A clayey and loose soil can have up to 70% moisture content. If a capacitive sensor then shows only 30% to 40% because it cannot measure higher in general, then this should be taken into consideration.
- **Soil moisture sensors should measure long-term stable without drift.**
  With blank probe rods there is the danger of galvanic reactions and a seriously influence on the sensors reading. A removal from greater depths for a rod cleaning may cost much more as the sensor itself.
- TDR probes with multiplexers are limited with cable lengths. Coax-cables are exposed to wind and weather. If rain water covers a coax-cable and the moisture measurement values have deviations up to 5% due to a changed cable impedance, then this should be taken into consideration.
- Because soil types can be very inhomogeneous, soil moisture sensors should have a large measurement field. With a very small measurement field of a capacitive probe with e.g. 4 rods, the measurement field lies between the rods and therefore the result is not representative in inhomogeneous soils.
- Because soil types can be very different from sand to pure clay, soil moisture sensors should work with only one calibration curve and should show no strong dependency within wide soil type ranges.

The TRIME PICO-Series - Soil Moisture Sensors which provide to what they promise !

- Depending on sensor type, PICO probes have a large measurement field, up to 2 liters.
- The measurement range can cover up to 100% water, although here too, the range between 35% to 75% moisture is measured precise.
- The conductivity range cover up to 20dS/m.
- For most soils PICO probes are precise calibrated at delivery. For special applications, e.g. in pure clay the calibration curve can be changed within 15 different selections.
- **Very important:** PICO probes use coated and thus isolated rods which guarantee the non-appearance of galvanic accumulation along the rods. Thus PICO probes are suitable and **guarantee long-run installations** in terms of decades **without a measurement drift**.
- PICO rod probes and tube access probes are available for installation depths up to 50 meter (and longer if necessary).
- PICO probes measure moisture, conductivity and temperature. In addition the salt content of soils can be determined with the revolutionary TRIME method at 1GHz.
- PICO probes are suitable for sandy, organic and clayey soils. Even pure clay can be measured.
- Because the TDR electronic is housed directly inside the PICO probes, there are no restrictions concerning cable lengths and other faulty influences on the cable.
- PICO probes have rod lengths with a maximum of only 160mm. TDR probes with greater lengths up to 1 meter show considerable problems if there are different moisture layers inside the soil (e.g. upper layer 10% moisture, deeper layer 35% moisture).

Time Domain Measurement with the TDR Method



$$c = \frac{c_0}{\sqrt{\varepsilon \cdot \mu}} = \frac{2l}{t} \qquad t = \frac{2l}{c_0}\sqrt{\varepsilon_r}$$

c_0 = Light Speed ($3x10^8$ m/sec)
μ = 1 (magnetic Permeability)
ε = Dielectric Constant
t = Time Duration
$2l$ = Length of Radar line (back and forth)

With achieving of an accuracy of ±1 picosecond of a radar travel time, it was possible to use radar moisture probes for soil and industrial applications. The TDR principle (**T**ime-**D**omain-**R**eflectometry, also called cable radar) has become more and more established in the last 20 years as a new and precise measurement principle for challenging applications. With TDR a travel time (time domain measurement) of an electromagnetic radar pulse stands in relation to the dielectric constant ε which represents the water content in soil and other materials.

Points of comparison for PICO probes and capacitive probes

Topic	PICO probes	capacitive probes
Moisture measurement range	PICO probes can measure up to vol. 75% water content. The 1GHz TDR-technology guarantees best possible frequency spectra.	Dependent on probe type there are limitations at 35% maximum water content, caused by a too low frequency spectra. The imaginary part of Epsilon could be as high as the real part of Epsilon!
Soil type	Suitable for all types of soils, even pure clay can be measured precise as well as soils with very high mineral contents.	Considerable limitations in soil types, especially in clayey soils and soils with high mineral contents.
Long term stability	PICO probes use coated and thus isolated rods which guarantee the non-appearance of galvanic accumulation along the rods. **Soil moisture sensors should measure long-term stable without drift.**	With blank probe rods there is the danger of galvanic reactions and a seriously influence on the sensors reading. A removal from greater depths for a rod cleaning may cost much more as the sensor itself.
Calibration at commissioning	With a universal calibration, the PICO probes can be used for most common soils. Every probe can be set to an own calibration curve (1 of 15 different curves) for very special soils.	Considerable dependencies on soil type, caused by a too low frequency spectra. The imaginary part of Epsilon could be as high as the real part of Epsilon!
Bulk soil electrical conductivity, soil temperature	Virtually no dependencies; the electrical conductivity can be measured precisely at 1GHz.	Considerable dependencies on soil electrical conductivity, caused by a too low frequency spectra. The imaginary part of Epsilon could be as high as the real part of Epsilon!
Measurement field expansion	The large measurement field with two rods guarantees a representative measuring and is very important for representative results in heterogeneous soils.	Only a small measurement field is built between two or more very closely positioned rods. A larger stone between the rods influence the measurement value considerably.
Determination of salt concentration in soils	PICO probes measure the radar attenuation with the revolutionary 1GHz TRIME method, which allows a determination of salt contents in soils.	Not yet known

A new chapter of soil profile moisture measurement was opened with the innovative PICO probes and the revolutionary TRIME technology.

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