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Dynamic Real-time Soil Moisture Measurement

Requirements and Potentialities

Preliminary approaches for determining soil moisture were presented in [3]. Of the agrotechnical application possibilities, two fields can be differentiated. For the farmer a direct link of the measured value with machine control would be desirable. However, further data processing is of great interest to research. The ascertained measurement values at the current state of development of the measuring share are ± 5% of the gravimetrically identified moisture [1]. The mechanical penetration depth of the share nowadays is at least 7 cm.

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Keywords

Soil moisture, real time, Time Domain Reflectometry (TDR), TRIME

Since August 2002 the corporate research partners (University of Hohenheim; IMKO Mikromodultechnik) are working on the manifestation of a dynamic soil moisture sensor. After an identification of the factors on the dynamic moisture detection of soil, experiments about the variation of water content scenarios in altering conditions of fertilisation were conducted on varying soil types, in order to find out about influencing factors on TRIME technology (Time Domain Reflectometry with Intelligent Microelements) [2, 3]. After that, the frame for high frequency field and physical probe development had to be done. The research focus was, to adapt the high frequency measuring process to the sensor and vice versa in order to enable an optimal measuring field within the sensor. First trials discarded rotating disc sensors because of the appearing material conflict. Non metal material was either too much affected by the abrasive impact of soil or it was too brittle to resist the force of moving within the soil [4]. Furthermore the transceiving of the high frequency signal to the sampler unit could not be guaranteed at the demanded high standard for rotating probes. Therefore a solid sphenoid probe has been developed. Due to integrated measuring electronics and a 250 mm non-metal detection plate at the side of the probe, the probe grew to 500•30•160 mm (L•W•H). and 10,7 kg.

Measuring method

The integrated electronic measuring device is based on the TDR-approach, which consists of a signal generator, a sampler and the sensor plate itself. The signal generator is capable of producing a rapidly escalating voltage surge. Commonly used TDR instruments like the TRIME-EZ (IMKO) or the laboratory TDR instrument Tektronix Cabletester 1502 B generate a surge of 200 mV in a time of 20 ps (1 ps = 10^{-12} s). The voltage surge causes the propagation of an electromagnetic wave. The pulse propagates first within the probe and the insulated cable to the bare sensor plate. The wave pulse further spreads from the plate and comes into interaction with the surrounding soil. At the end of the detection plate, the pulse is being reflected and returns to the electronic measuring implements, where the interference of emitted and reflected pulse is recorded by a sampler. In this way the implemented electronic equipment is capable of reading the runtime of the electromagnetic pulse on the sensor plate.

Soil is to be described as a mixture of solid substrate, water and air. Molecules of water are strong dipoles, which align up within a given electromagnetic field. A medium characterised by this is called a dielectric. Dielectrics slow down the propagation speed of electromagnetic waves. This goes along with the finding that a TDR pulse propagates slower within a moist soil [5]. The most common TDR instruments scan the TDR curve point by point, detecting a current voltage past a defined time Δt, which is altered until the expressive part of the TDR signal has been scanned.

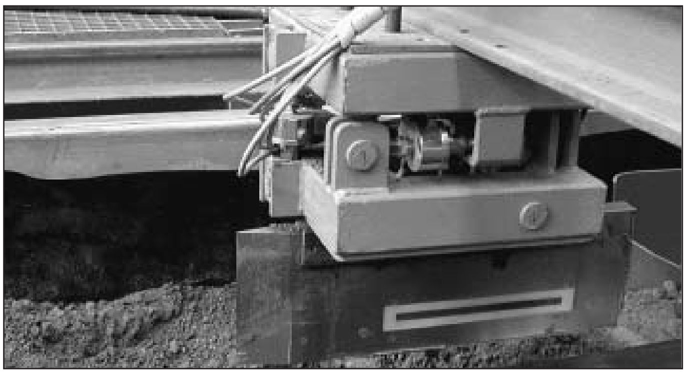

Fig. 1: Dynamic soil moisture probe within the soil bin; top: force measurement device

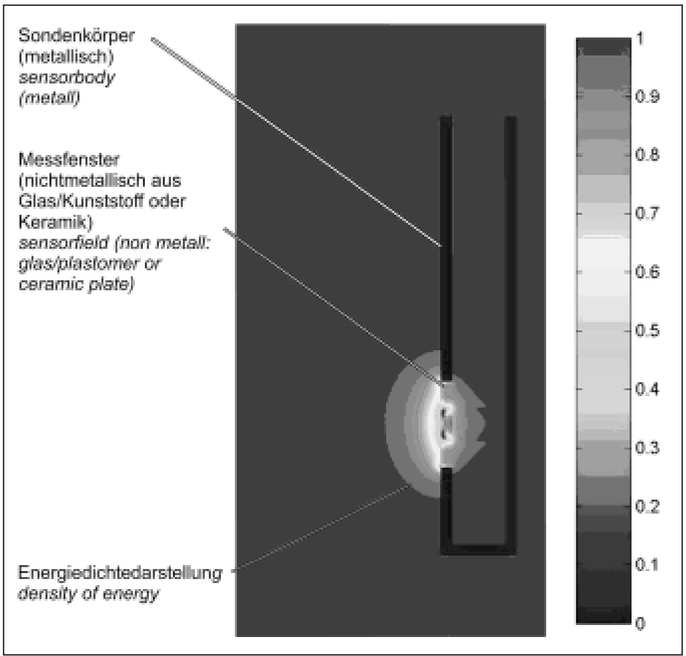

Fig. 2: Density of energy at the dynamic sensor at a dieelectrical permittivity of 20

Modification of TDR into TRIME

The TRIME process represents an ultra accurate stopwatch with a resolution of about 10 ps. TRIME gauges the past time until a certain grade of voltage is being exceeded. With the altering of the voltage grades, a part of the reflected part of the TDR curve is able to be scanned and therefore measured. This TDR reading simultaneously gives an assessment of the signal's quality. High ionic conductivity for example leads to a lowering of the signal's amplitude [6]. The TDR-scanning method gives a clear reading, even if ionic conductivity due to a high salt content appears.

Demands

An essential criterion for the layout of a dynamic probe is a steady soil sensor contact due to the limits of the aforementioned TDR method. For stationary readings the probes are carefully embedded within the surrounding soil [6]. For a dynamic measurement, the contact to the moving soil has to be guaranteed [3, 4], so the probe design has to be changed completely.

Setup

At this moment, the measuring setup of the dynamic detection of soil moisture, using TRIME technology, consists, beside the probe device itself, of a rope pulled carriage, allowing speeds up to 18 km/h in the soil bin. The soil bin's batch consists of a drainage layer of sand and gravel and a 35 cm thick cover layer of sandy substrate (density 2.4; compactness 1.1, porosity 58.2). The analogue measuring signal is recorded by means of the measuring card [DAQCard 6024E] and DASYLab. This data set contains the measuring duration, the position of the carriage in the soil bin, a triaxial force documentation at the measuring probe and the currently detected soil moisture. For the trials, moist spots were produced at random, which could be identified spatially exact and quantitative within a range of ± 5%. During sensor's progress through soil, forces are appearing proportional to the speed and the penetrating depth of the sensor. Appearing forces are to be considered while construction and planning the prototype sensor, in order not to risk the measuring setup and the prototype. Due to different function models, two possibilities of a realisation appear. On the one hand an opening of soil and the measuring itself are done by one instrument, consequently it has to be designed quite sturdy (*Fig. 1*). On the other hand a splitting of tasks (opening of the soil, a tight soil-sensor contact, measuring) could open alternative ways for a different sensor design. With that, the ability of integrating the sensor into already existing machines is growing. But there is demand for improvement by altering the sensor's form to fit into integrated systems.

The minor blade angle (up to 2°) serves for a better soil senor contact and does not produce transverse forces worth mentioning at speeds up to 4 m/s in the soil bin (Fig. 1). Draught force measurements of various farm equipment indicate a presumably higher force upon the probe's integrity under real field conditions [7]. The appearance of stones within the measuring field was already presented in detail in the LANDTECHNIK issue 3/2005. Consequently the singular and solid setup of the probe is established. A side-on collision of stones to the sensitive sensor plate means an endangering of the probe.

Simulation of the measuring field

The size of the measuring field plays a major role for the quality of the measurements. It is caused by the sensorís layout [3]. Beside the mechanical integrity of the probe, the size of the measuring field is the most important requirement for a successful measurement. By means of Maxwell2D, the energy of the electric field was simulated and further analysed by Matlab in order to describe the quantiles of energy. Thus, lines of equal energy, representing a certain percentage of the total field energy (e.g. 95%) were determined. Consequently the major part of the measuring field is characterised (*Fig. 2*).

The line of 95% field energy gives a good idea of the measuring field's real volume. With this, any change of the measuring field, caused by the water content of the soil or the shape of the sensor can be simulated and compared. *Figure 2* gives an overview of the measurement volume at an electrical permittivity of 20, which is equal to a soil moisture content of 34 Vol. %[8]. For this probe, a volume of 190 cm^3 is generated.

Outlook

Regarding a practical application of the innovative dynamic sensor-technique, there are clear chances of an online control of farm machinery. The afore mentioned measuring accuracy of ± 5 % generates the basis for the practical application. A link to existing BUS-ports is to be created in the progress of future research. A further development of probe design has to be forced forward, for an integration of the sensor into farm machinery becomes handy. Therefore a great contribution to environmental and resource protection can be achieved.

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