Examining the Effectiveness of Commercial RFID Tags as Soil Moisture Sensors

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Abstract

Currently available soil volumetric water content (VWC) sensors have several drawbacks that pose certain challenges for implementation on large scale for farms. Such issues include cost, scalability, maintenance, wires running through fields, and single-spot resolution. The development of a passive soil moisture sensing system utilizing Radio Frequency Identification (RFID) would allay many of these issues. The type of passive RFID tags discussed in this paper currently cost between 8 to 15 cents retail per tag when purchased in bulk. An incredibly cheap, scalable, low-maintenance, wireless, high-resolution system for sensing soil moisture would be possible if such tags were introduced into the agricultural world. This paper discusses both the use cases as well as examines one implementation of the tags. In 2015, RFID tag manufacturer SmarTrac started selling RFID moisture sensing tags for use in the automotive industry to detect leaks during quality assurance. We place those tags in soil at a depth of 4 inches and compared the moisture levels sensed by the RFID tags with the relative permittivity (εr) of the soil as measured by an industry-standard probe. Using an equation derived by Topp et al, we converted to VWC. We tested this over a wide range of moisture conditions and found a statistically significant, correlational relationship between the sensor values from the RFID tags and the probe's measurement of εr. We also identified a possible function for mapping vales from the RFID tag to the probe bounded by a reasonable margin of error.

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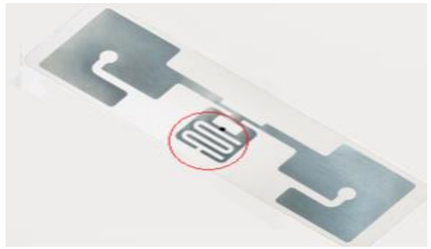
Abstract

- Current soil moisture sensors have several drawbacks such as high costs, poor scalability, and poor mobility
- An incredibly cheap, low-maintenance, wireless, high-resolution system for sensing soil moisture would be possible using RFID tags
- The RFID tags discussed here, SmarTrac's Dogbone, have been used in many industries and are commercially available at a cost of 12¢ per tag[1]



Close up of SmarTrac's Dogbone RFID tag with the moisture sensitive area circled in red.

Methods

The RFID tags measure moisture indirectly from the electrical permittivity (ε_r) of their environment.[1] By comparing their sensor values to an industry standard Decagon 5TM capacitance probe, a model can be created mapping the RIFD tag's sensor value to soil moisture.

For the tests, both the RFID tag and 5TM probe were buried 4 in deep in a homogenous mixture of sandy loam soil. Data from the RFID tag and 5TM probe were read for 5 minute intervals multiple times at a given moisture level.

Soil was measured with a range of ε_r from 10 to 18. This corresponded to the soil being dry (ε_r of 10 or VWC of 18.8%) to practically saturated (ε_r of 18 or VWC of 32%).

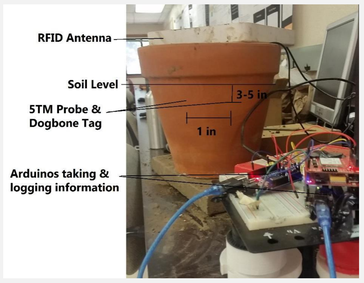
A protective "Shield Sandwich" for the tags made out of two pieces of 1mm 3D printed ABS and HIPS plastic. Theoretically, creating shields varying thickness could allow for changing a tag's sensing range to be centered around a chosen level of VWC.

Scan this QR Code to learn more about this project

Image of the RFID Sandwich shield.

Materials

- 2 Arduino UNOs
- Sparkfun SD logger Shield
- M6E Nano RFID Reader Shield
- Alien ALR-8698 High Gain Antenna
- Smartrac Dogbone RFID tag with "Shield Sandwich"
- Decagon 5TM soil moisture sensor

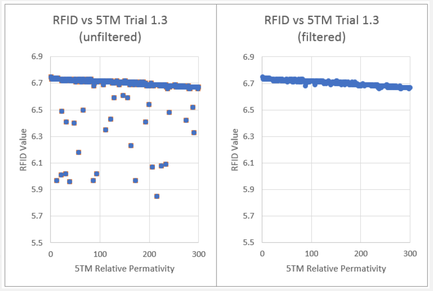


Graphic of the experimental setup

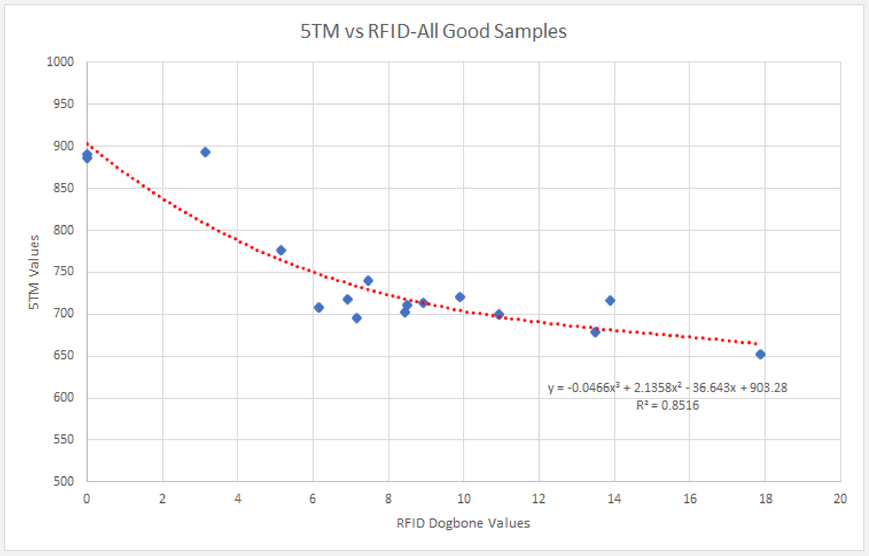
Experimental Results

It was realized that the Decagon 5TM moisture probe generated a significant amount of noise. This noise was effectively filtered by a moving median filter.

It is believed that electromagnetic interference between the RFID reader and 5TM probe was the source of this noise and, therefore, filtering it did not alter the relationship between the RFID and 5TM.



Visualizing the results of the electromagnetic noise filter



Results of experiment. Successful trials shown only. Possible model for relating RFID values to the 5TMs measurements of ε_r is shown in red

Of the 22 trials originally conducted, 5 were found to be outliers fitting and were removed before the final model was created. These outliers were randomly distributed and were determined to be caused by soil imperfections such as a small rock or air pocket near either of the sensors. A third-degree polynomial seems to be the best fit for the data model, however a first degree linear fit was used to find the final equation.

Conclusion

- Between the RFID sensor and 5TM, there was shown to be a statistically significant trend of an R^2 of 0.85 for a third degree polynomial.
- The experiments presented support the original hypothesis that the Dogbone RIFD tags can be used as a soil moisture sensor.
- RFID tag sensor value to VWC was empirically determined to be with an error less than 10%[2]

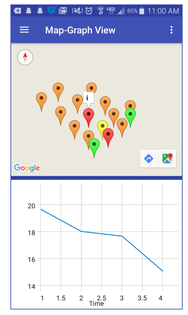
$$f(x) = -8.82803\times10^{-8}x^3 - 2.47337*10^{-5}x^3 - 3.88447*10^{-3}x + 0.306477$$

Further Development

Collecting data from tags buried under a 10m radius center pivot irrigator. There were 18 total tags buried in this field.

We constructed a portable version of the RFID reader device field testing at Hermiston Agricultural Research Center. Using a companion phone app, we were able to record the change in soil moisture as a center pivot irrigation arm passed over the buried tags and overlay that data onto Google Maps.

The RFID system used in this way can be used to recognize over-watering to improve irrigation practices. It's estimated that farmers over-water their fields by 20%[3]. In the USA, this results in 5 billion gallons of water wasted every day.



Screenshot from the app used during field trial

Acknowledgements and References:

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