Soil Moisture Monitoring with LoRa Radios and UAVs

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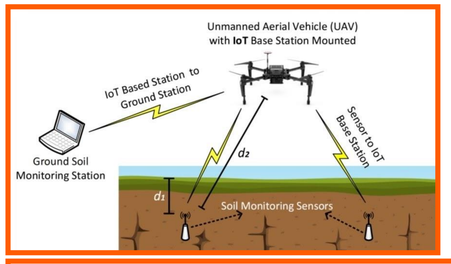


Introduction

Soil moisture levels are critically important to crop yields, yet they are often estimated based on experience, visible signs of stress in crops, and/or feel of soil. Soil moisture sensors add badly needed precision to watering but are often inconvenient for farmers due to reasons such as:

- They require wired power or regular battery maintenance
- The equipment (antennas and sensors) are partially located within crops above ground, creating obstacles for field equipment to avoid. [1]
- They have short signal range, require wired networking, or manual data retrieval. [2]

We present a low-power, fully wireless IoT solution that utilizes completely buried sensors and UAVs to measure, record, and convey soil moisture levels.

Importance

- According to a recent study by the US Department of Agriculture, only 89 of 78,531 farms use soil moisture monitoring to determine when to water crops. [3]
- Water usage in Oklahoma is quickly rising and must be managed more deliberately.
- According to the EPA, topsoil erosion is the leading cause of pollution of lakes and rivers. This erosion can be attributed to overuse of water, among other things. [4]
- The technology of this system can be applied to control and monitor the effectiveness of irrigation methods and to measure other important soil properties.

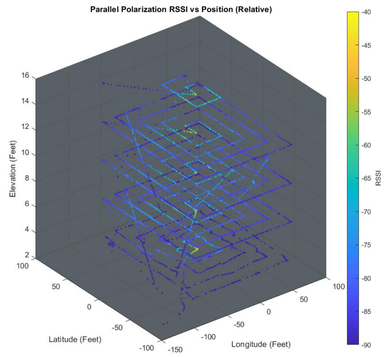
Research Goal, Method, and Results

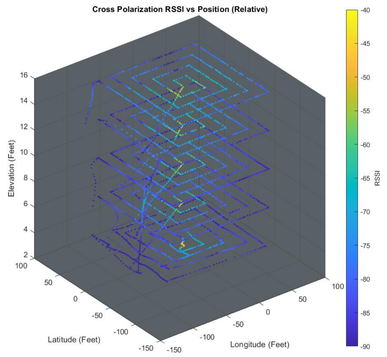
Goal:

- To determine if buried LoRa radios produce sufficiently strong signals in propagation through various soils to enable communication of soil moisture data to a UAV-based LoRa receiver hovering overhead, and to determine the communication link margins via determination of RSSI (received signal strength indicator).

Method:

- Buried LoRa radios convey soil sensor data wireless a short distance through the ground with very low power and excellent battery life.
- The UAV has a LoRa receiver as payload and visits each sensor to collect data.
- Soil sensors buried at 1 foot deep with antenna polarization recorded.
- Measurements validated with research grade sensor (Campbell Scientific Hydrosense II)
  - Soil moistures during measurements ranged from 3 feet to 15 feet.





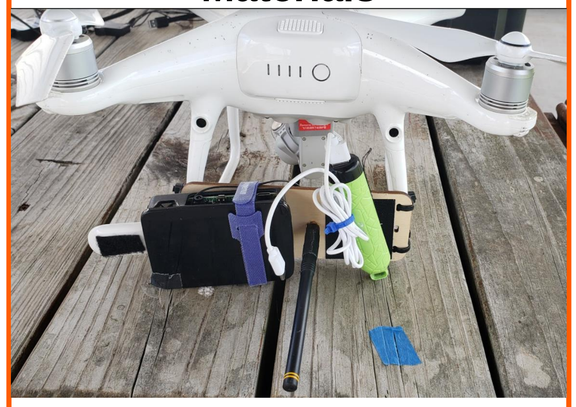
Parallel Polarization Tests

- The antenna mounted on the drone and the antenna mounted on the buried LoRa transmitter are parallel.
- 4,000+ RSSI measurements were collected at heights of 3, 6, 9, 12, and 15ft in an approximately 150 ft x 150 ft square centered on buried transmitter.
- RSSI indicate very usable communication is possible (RSSI > –80dB) at all heights, even out to transverse distances > 70ft.

Cross Polarization Tests

- The antenna mounted on the drone and the antenna mounted on the buried LoRa transmitter are perpendicular.
- 4000+ RSSI measurements were collected at heights of 3, 6, 9, 12, and 15ft, in an approximately 150 ft x150 ft square centered on buried transmitter.
- RSSI indicate very usable communication is possible (RSSI > –80dB) at all heights, even out to transverse distances > 70ft.

Materials



The system capitalizes on three major elements:

- The unmanned aerial vehicle (Phantom 4 UAV).
- Long Range wireless radios (LoRa)
- Capacitive style soil moisture sensors

Other equipment used in this research

- Raspberry Pi
- GPS Module
- USB Batteries

Conclusions

- The system behaves better than expected, exhibiting strong signal strengths at large transverse bounds and higher altitudes or heights.
- The RSSI values indicate a very large communication link margin is available, suggesting that crop cover should not adversely affect the system performance.
- The system is very insensitive to polarization misalignments.
- The system is robust, easy to set up and use, and easily adaptable to other sensing applications.
- With some protocol and hardware tuning, sensor battery life is expected to be on the scale of several months.
- The system operates at heights great enough to clear the height of any crops it may be used with.

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