Towards Internet of Underground Things (IOUT): Wireless Underground Communication Experiments using Software Defined Radios

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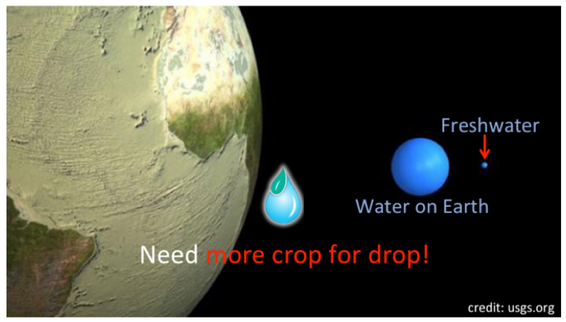
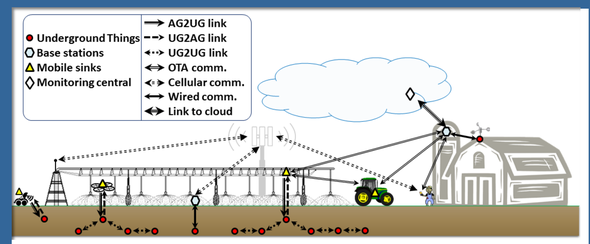
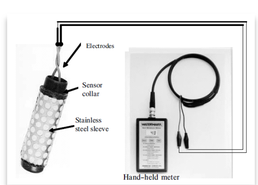


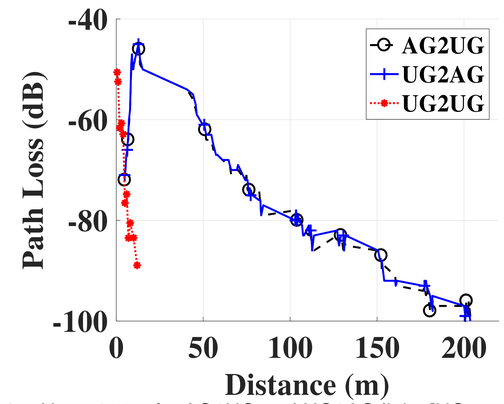
- Big blue sphere: Volume of all water compared to Earth's volume
- Not all water can be used for food production. Need freshwater (tiny blue sphere)
- This is a resource that does not necessarily increase
- Need solutions for more crop for drop



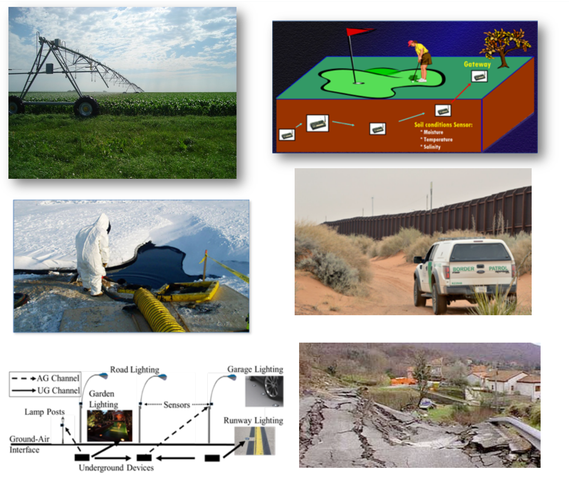
- IOUT represents autonomous devices that collect any relevant information about the Earth
- Enables complete autonomy on the field



- Up to 40% improvement in water use efficiency is possible
- in-situ soil water content measurements



- Up to 200m for AG2UG and UG2AG links [UG Antenna Patent - US Patent 9,532,118]
- Networking feasible when an AG link is involved
- UG2UG range is 12m
- Enhanced UG communication range is required for complete UG networking

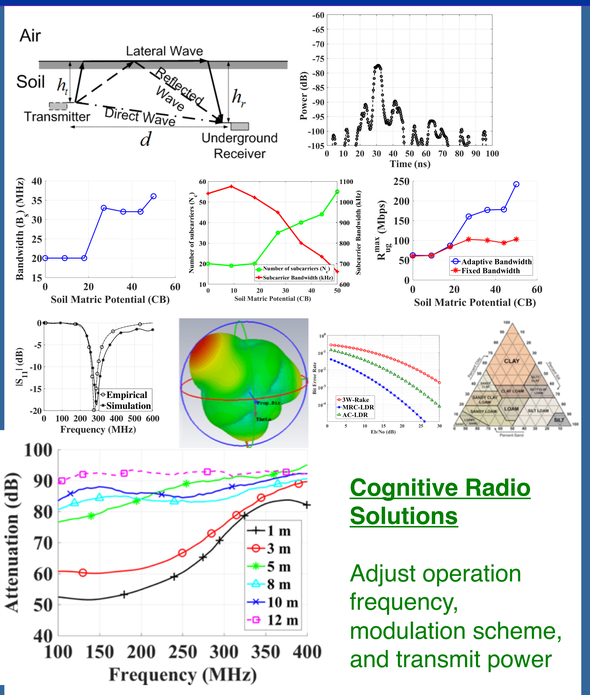


- Potential Applications in Precision Agriculture
- Infrastructure and environmental monitoring, Security,
- Earthquake and landslide monitoring, Border Patrol

Challenges in Underground Communications

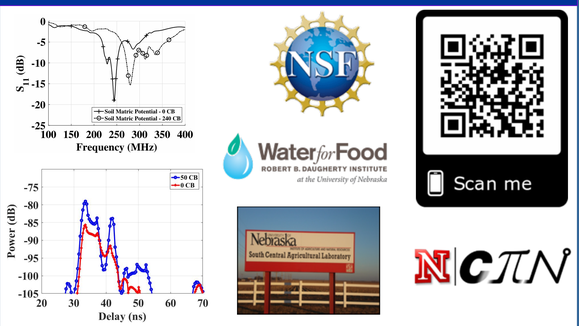
- An Indoor testbed in a Greenhouse
- Wooden box (2.5 x 1 m), 90 Cu-Ft Soil
- 12 Antennas, 3 Set – 4 Depths
- 50 cm - 1m T-R Distance,
- 16 Soil Moisture Sensors

- Software defined wireless underground communication field Testbed in South Central Agricultural Lab (SCAL)
- GNU Radio and N210 USRPs
- Dipole antennas buried at 20 cm depth at a distance of 50 cm in silty clay loam soil
- Transmitter-Receiver (TR) are synchronized by using a MIMO cable
- Transmit power:10 dBm
- The operation frequency range: 100MHz to 300MHz
- Cognitive radio experiments



Cognitive Radio Solutions

Adjust operation frequency, modulation scheme, and transmit power



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Water for Food
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- Underground Channel Models [BlackSeaCom13, Adhoc13, Globecom11, PhyCom10, PhyCom09]
- Error control [Globecom13]
- Network connectivity, transmit Power control [INFOCOM13]
- UAV-aided data harvesting [SECON12]
- System integration [Adhoc13, Adhoc11, CompNet11]
- UG OFDM [ICCCN16]
- Impulse response analysis [INFOCOM 16]
- Underground beamforming [INFOCOM 17]
- Internet of Underground Things [WF-IoT 18]
- UG Antenna Patent - [US Patent 9,532,118]