



UC San Diego

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Electrical and Computer Engineering



ZenseTag: An RFID assisted Twin-Tag Single Antenna COTS Sensor Interface

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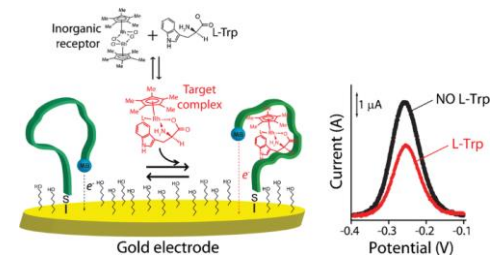
Ubiquitous sensing - Next wave of IoT



Ground Reaction Force



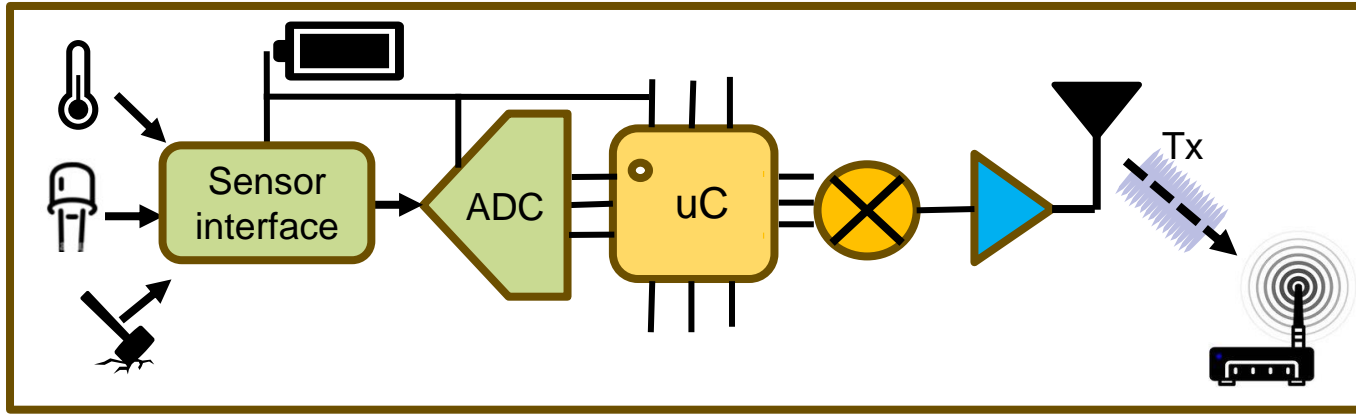
Sensing soil-moisture to automate irrigation



Biochemical sensors¹

Sensors enable continuous data collection for ubiquitous sensing.

Challenges of ubiquitous sensing: Batteries and bulk

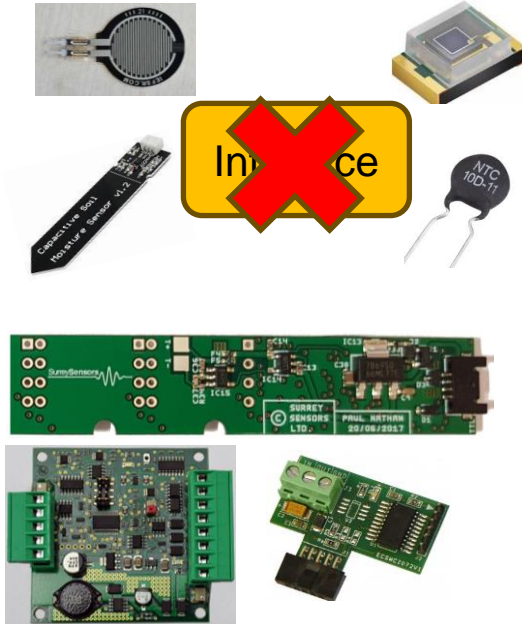


➤ Bulky Sensor interfaces with batteries!

- Need batteries/ energy harvesters.
- Rigid PCB with complex electronics to read sensors.

Sensor interfaces are bulky, rigid and need batteries!

Challenges of ubiquitous sensing: Sensor Interface



➤ A zoo of sensors to choose from! But. . .

- Every sensor outputs different voltage/ current!!
- Each sensor needs a unique interface!
- No universal sensor interface!

No universal interface for COTS sensors.

Challenges of ubiquitous sensing: Radio infrastructure



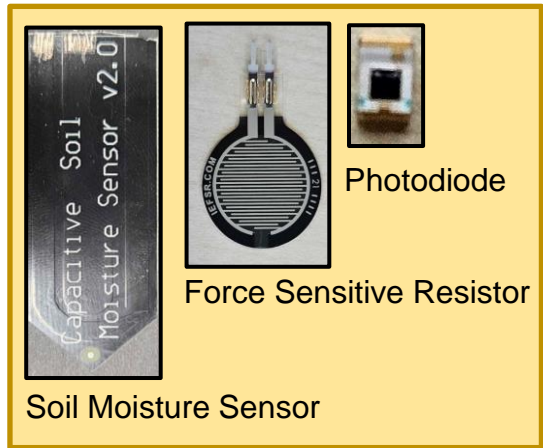
- So many commercial radio systems available!
 - None of which readily support battery-free sensor interfaces!
 - Passive sensing needs SDRs and custom waveforms.

No passive interface compatible with existing radios.

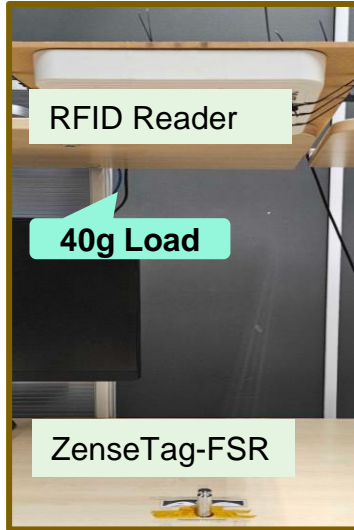
Current passive interfaces don't meet these needs:

Requirements
Universal Interface
Compact / Simple form factor
Compatible with existing radios
Reliable despite multipath
Realtime sensing

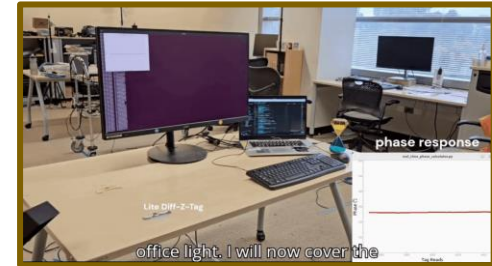
ZenseTag: Contributions



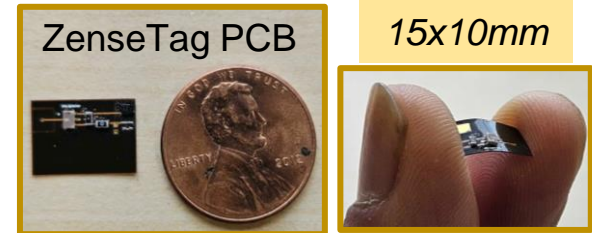
COTS Sensor Interface



Battery-Free/ commercial
RFID Compatible



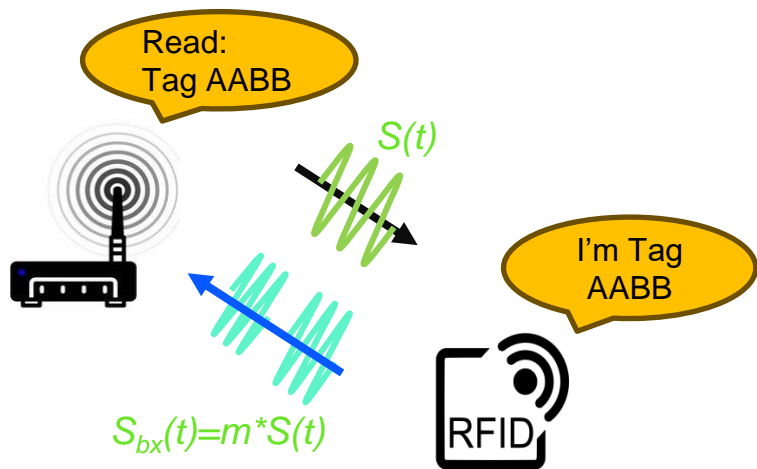
Robust and Realtime



Compact/ flexible form factor

ZenseTag: Battery-free, reliable sensor interface for
COTS sensors using commercial RFID.

Can RFID tags enable battery-free sensing?

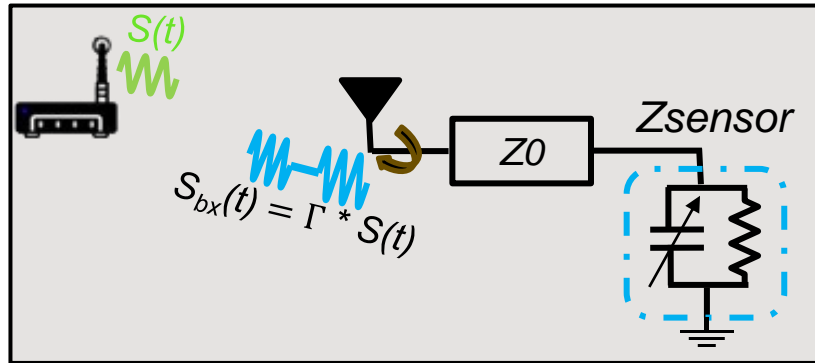


- RFID is a ubiquitous radio platform.
- RFID tags are passive/flexible and inexpensive
- RFID tags simply backscatter their digital ID.
- No inherent sensing capability.

Can we use the digital ID of Tags for sensing?

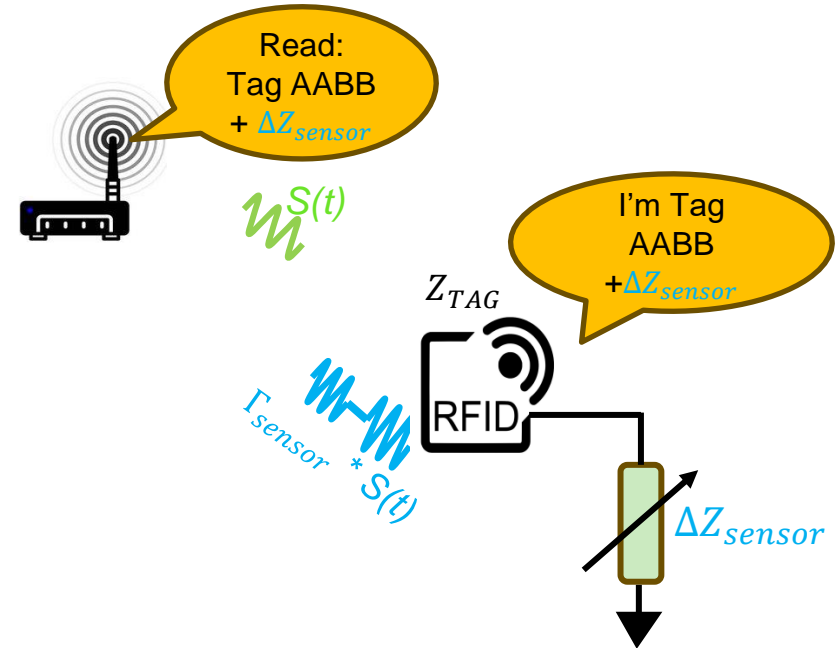
How to modulate RFID signal with sensor output?

$$Z_{\text{sensor}} = \frac{V_{\text{sensor}}(f)}{I_{\text{sensor}}(f)}$$



$$\Gamma = \frac{Z_{\text{sensor}} - Z_0}{Z_{\text{sensor}} + Z_0}$$

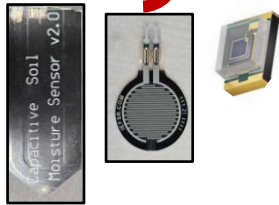
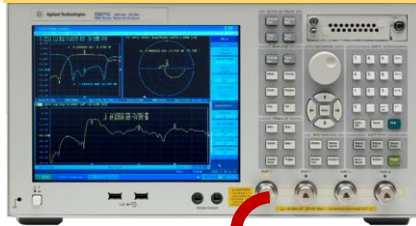
$$Z_0 \rightarrow Z_{\text{TAG}}$$



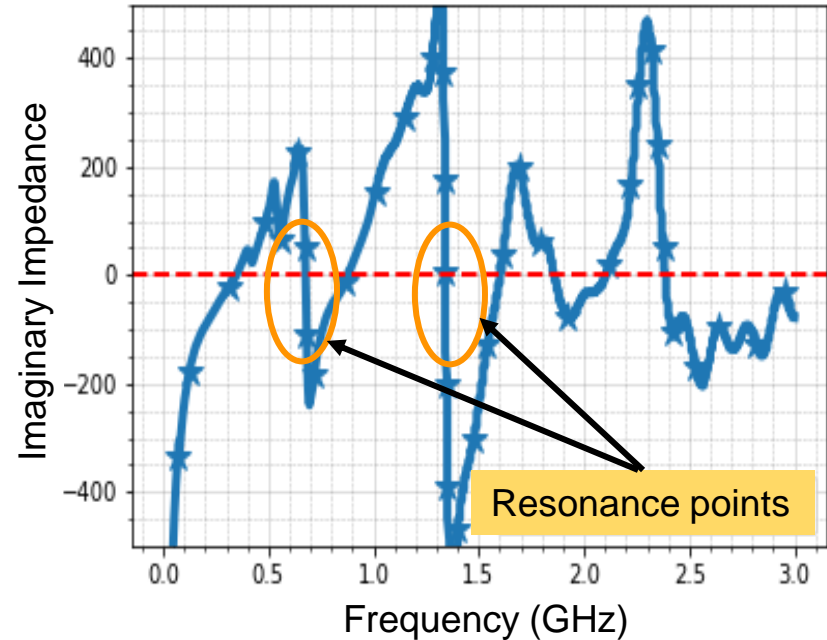
ZenseTag embeds sensor impedance into the tag digital ID.

ZenseTag: Direct-to-RF Interface of COTS sensors

Vector Network Analyzer

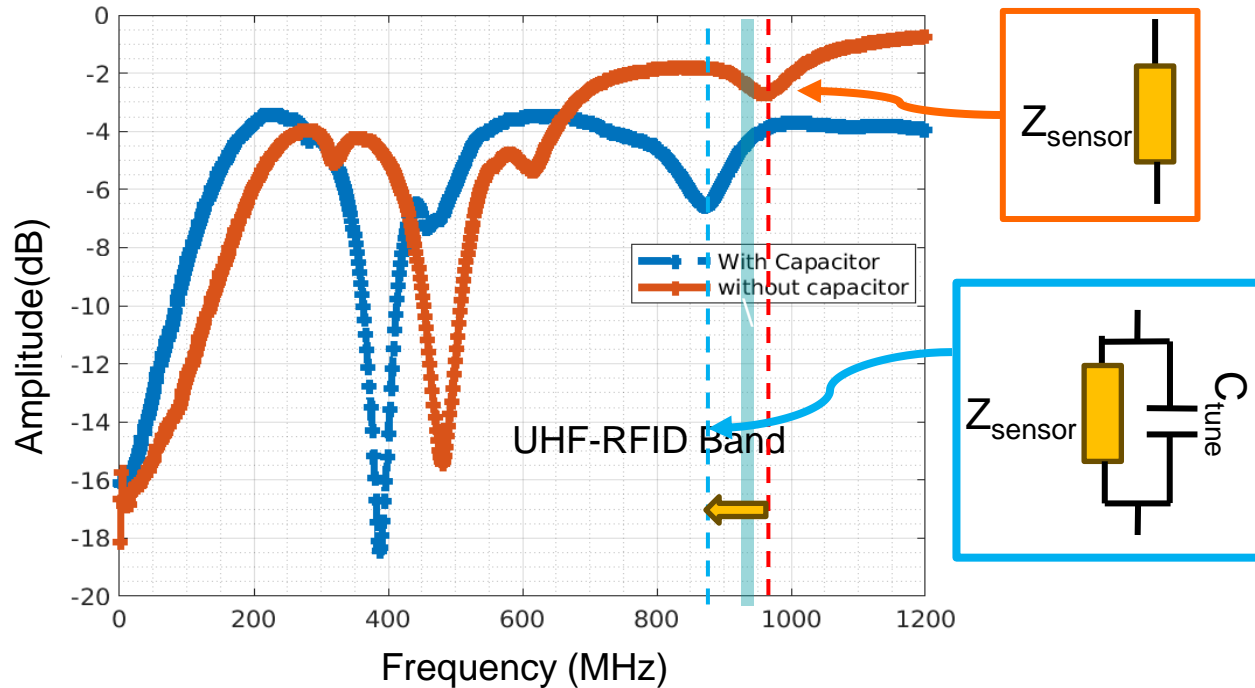


Profile Sensor Impedance $Z_{\text{sense}}(\text{freq})$



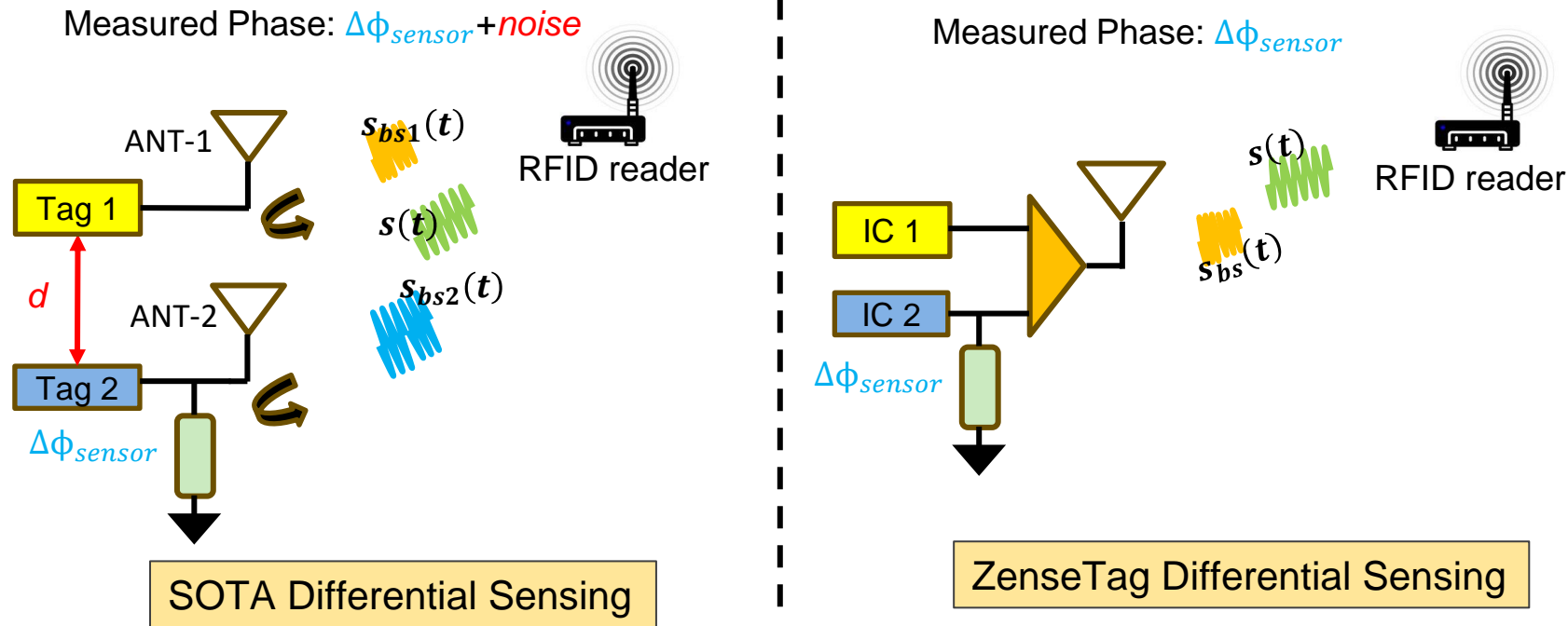
ZenseTag accurately profiles sensor impedance and tunes its resonance.

ZenseTag: Tuning the resonance of sensors



ZenseTag tunes Sensor Resonance close to RFID band.

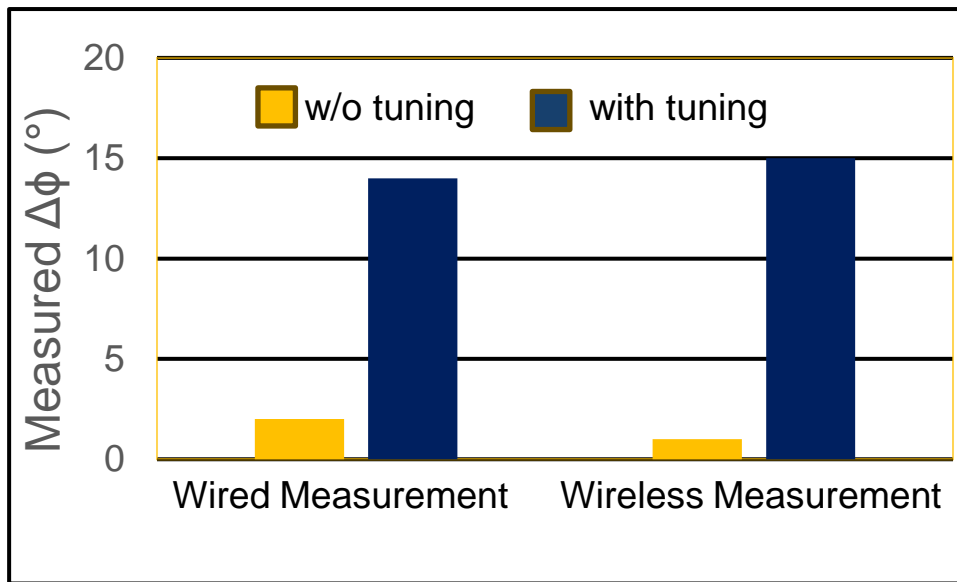
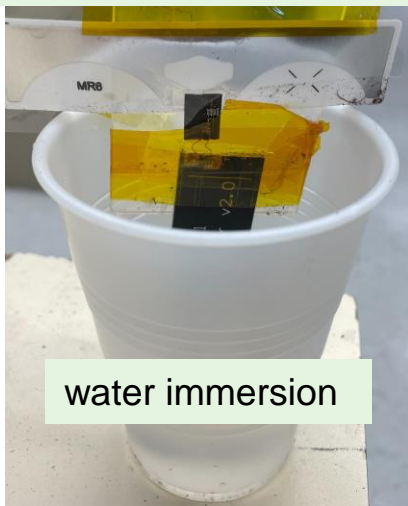
ZenseTag: Core Contributions



ZenseTag uses a single antenna to interface 2 ICs, for robust sensing

Benchmarks: Resonance-enhanced sensitivity

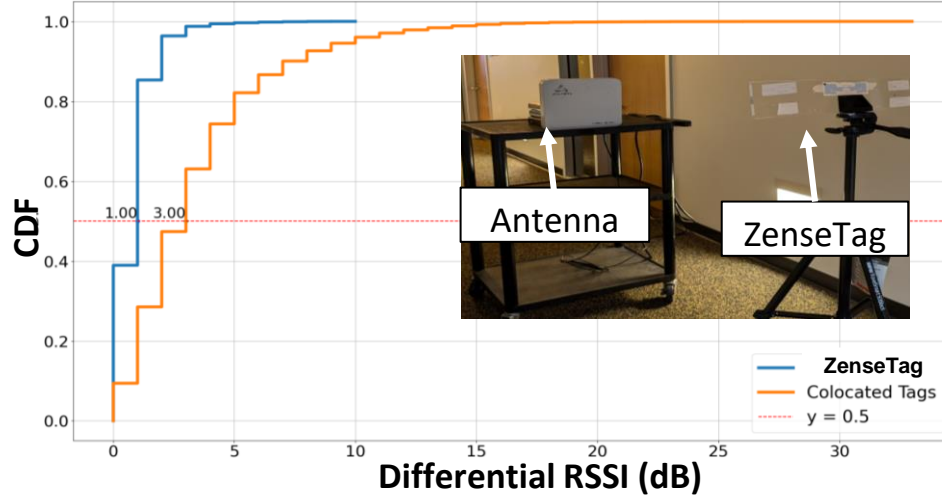
ZenseTag-Soil moisture



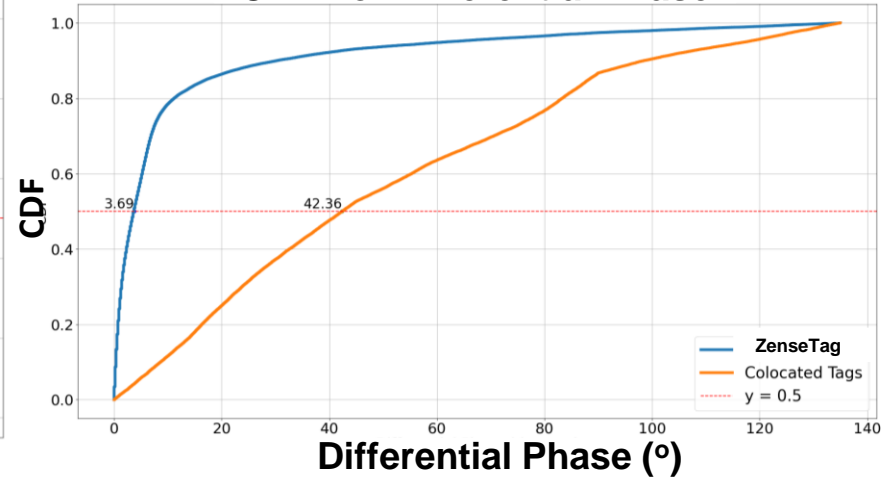
Tuning resonance achieves **7x** improvement in phase response of the sensor at RF

Benchmarks: Multipath resilience

CDF For Differential RSSI



CDF For Differential Phase

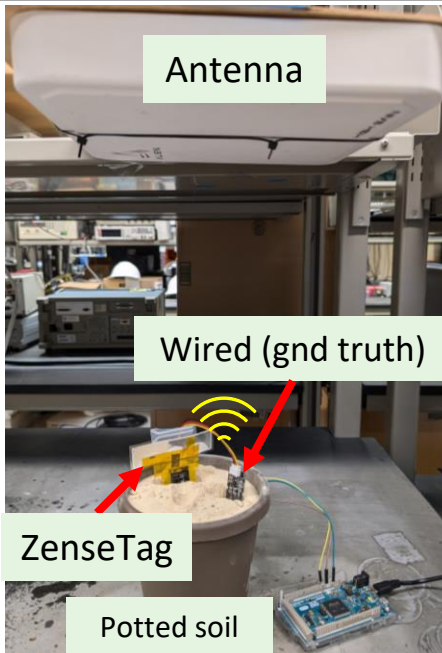


ZenseTag: >10x accurate phase estimate, +2dB accurate amplitude estimate

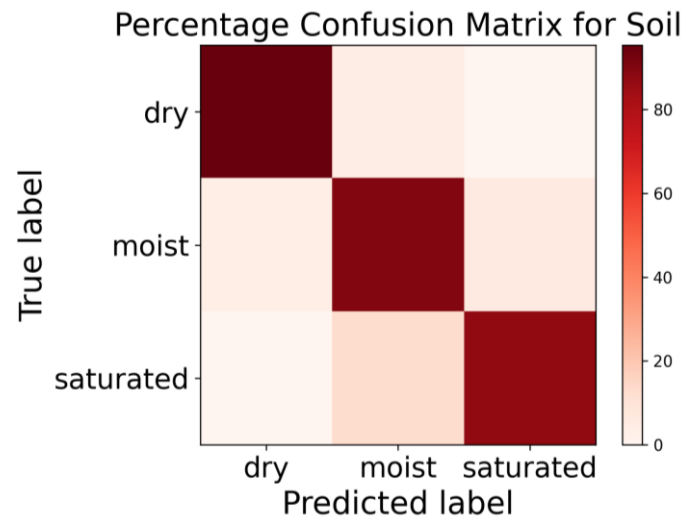
Evaluations: Sensing soil moisture



Outdoor measurement setup

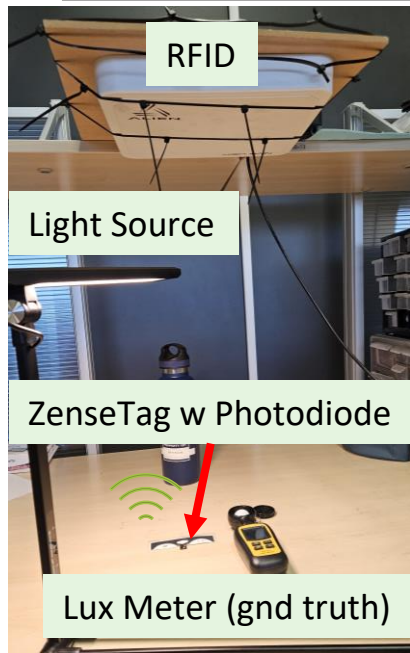


Indoor measurement setup

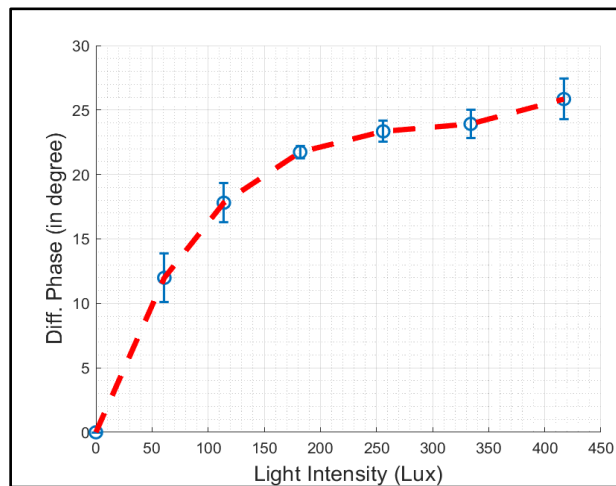


ZenseTag achieves **>93%** classification accuracy for soil moisture

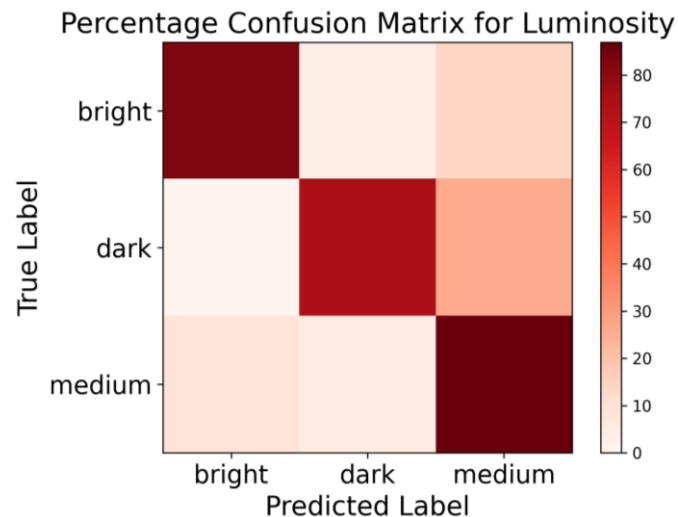
Evaluations: Sensing Light



Measurement setup



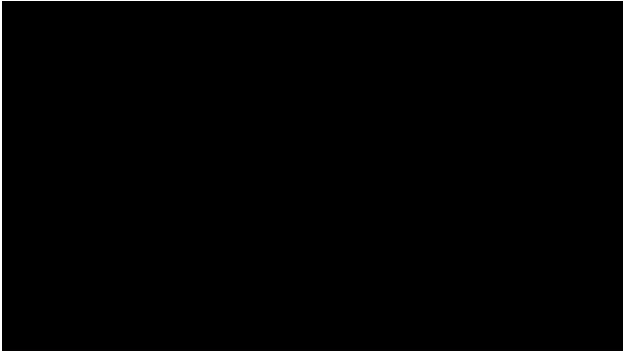
Calibration curve



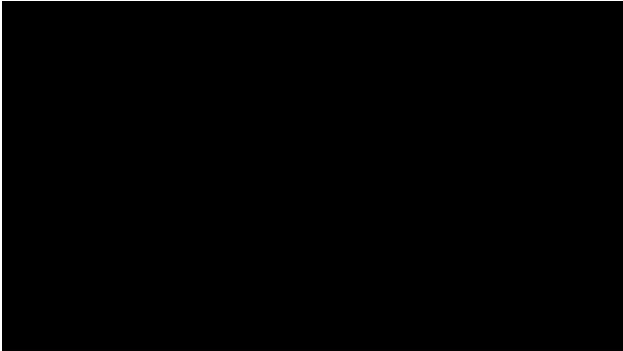
Results

ZenseTag achieves **>85%** classification accuracy for light intensity

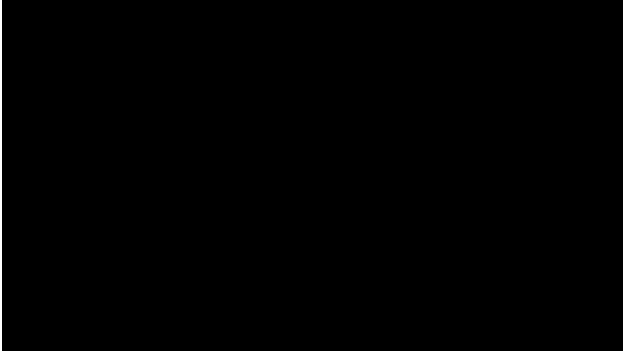
Evaluations: Demonstrations



ZenseTag-Luminosity
Sensor



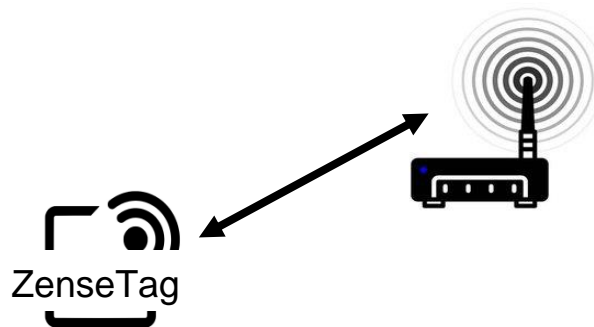
ZenseTag-Contact
Force Sensor



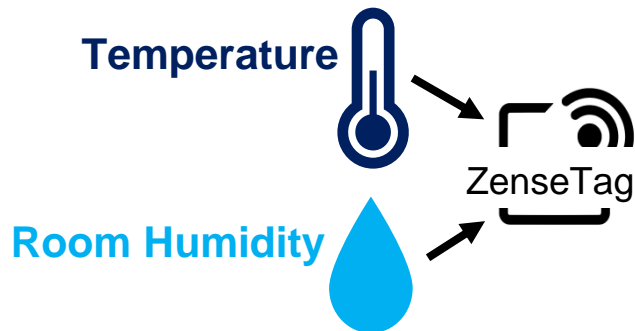
ZenseTag-Soil
Moisture Sensor

ZenseTag enables sensing in real-time using COTS sensors

Future Directions



Improve sensing range



Additional Sensor Interfaces



Compatibility with portable readers

Thank you!

Please read our paper here:

