UC San Diego
JACOBS SCHOOL OF ENGINEERING
Electrical and Computer Engineering

WCSNG
Wireless Communications
Sensing and Networking

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

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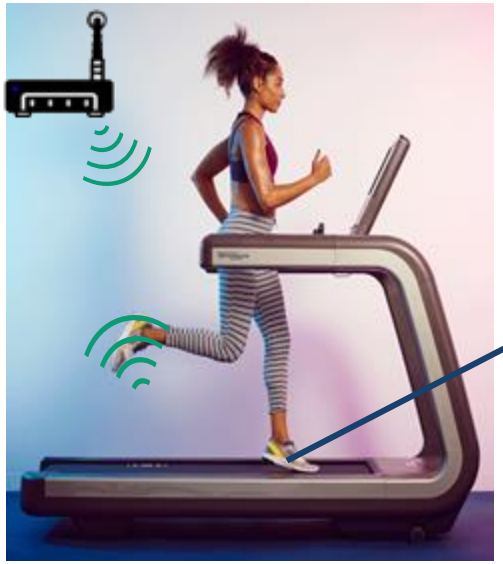
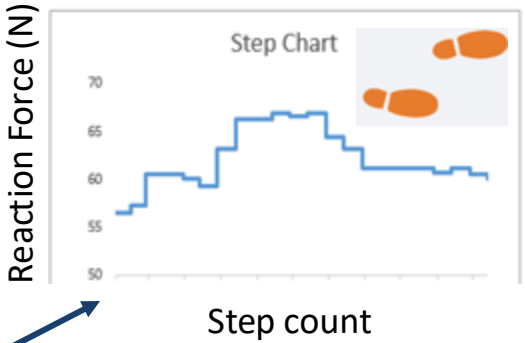
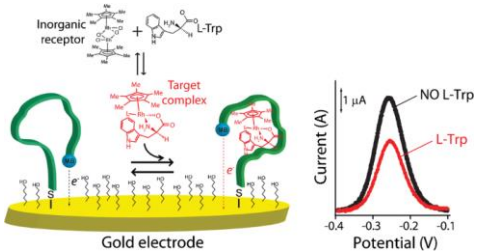
Ubiquitous sensing - Next wave of IoT





Ground Reaction Force

Sensing soil-moisture to automate irrigation

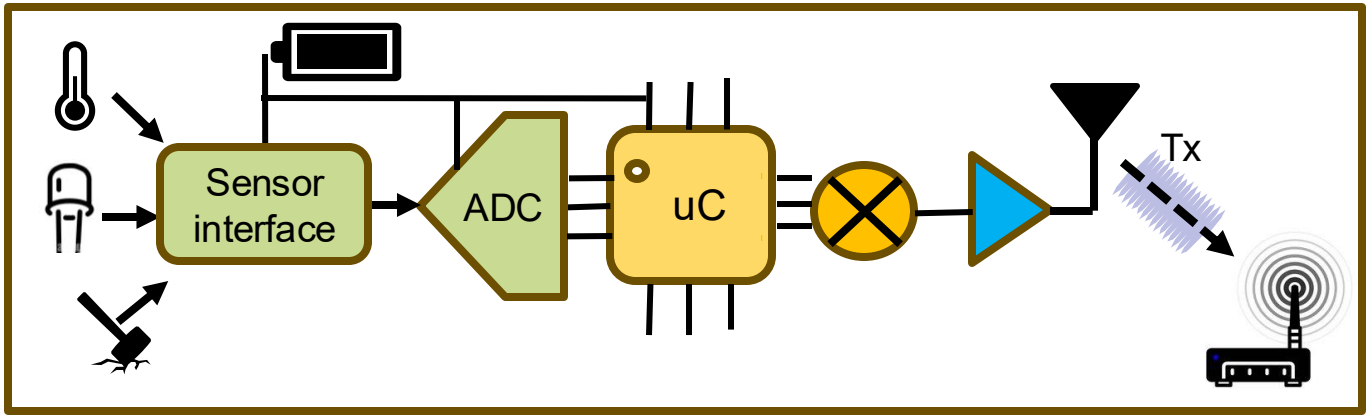


Biochemical sensors[1]

Sensors enable continuous data collection for ubiquitous sensing.

[1]https://doi.org/10.1007/s00216-019-01645-0

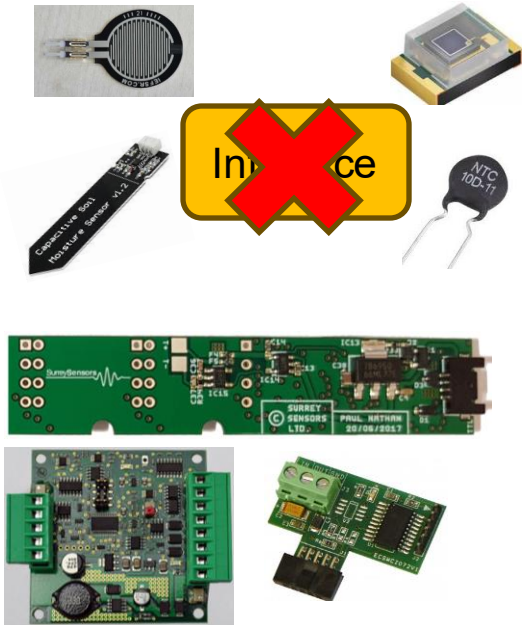
Challenges of ubiquitous sensing: Batteries and bulk



- 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	Digital Interfaces	Analog Interfaces	ZenseTag
Universal Interface	✗	✗	✓
Compact / Simple form factor	✗	✗	✓
Compatible with existing radios	✓	✗	✓
Reliable despite multipath	✓	✗	✓
Realtime sensing	✗	✓	✓

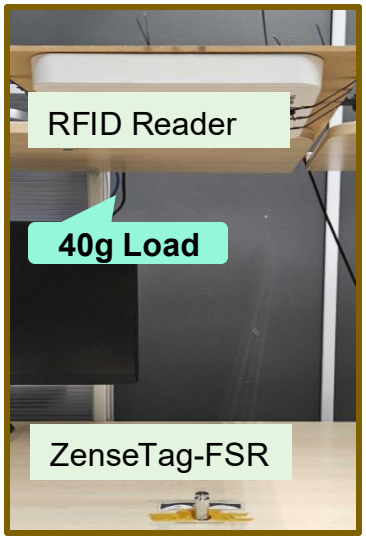
ZenseTag: Contributions

Soil Moisture Sensor

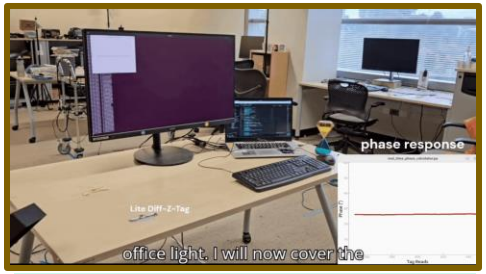
Force Sensitive Resistor

Photodiode

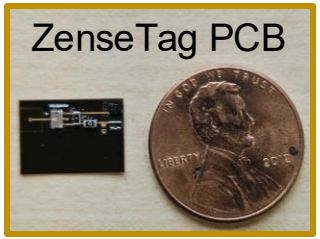
COTS Sensor Interface



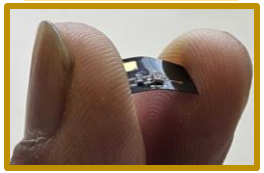
Battery-Free/ commercial RFID Compatible



Robust and Realtime



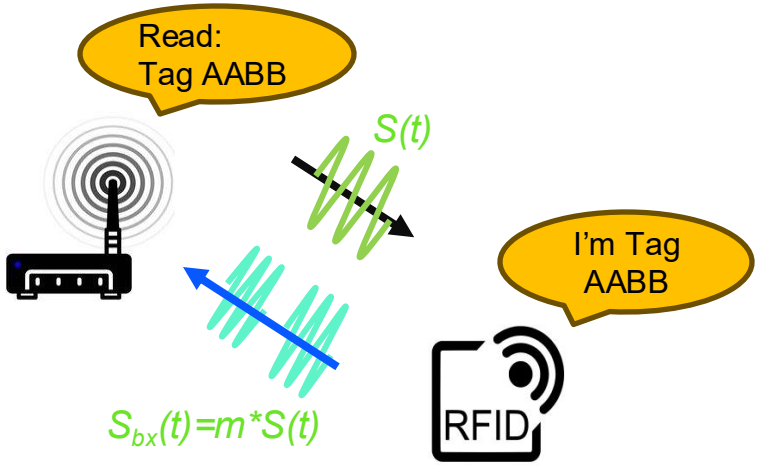
15x10mm



Compact/ flexible form factor

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

Can RFID tags enable battery-free sensing?

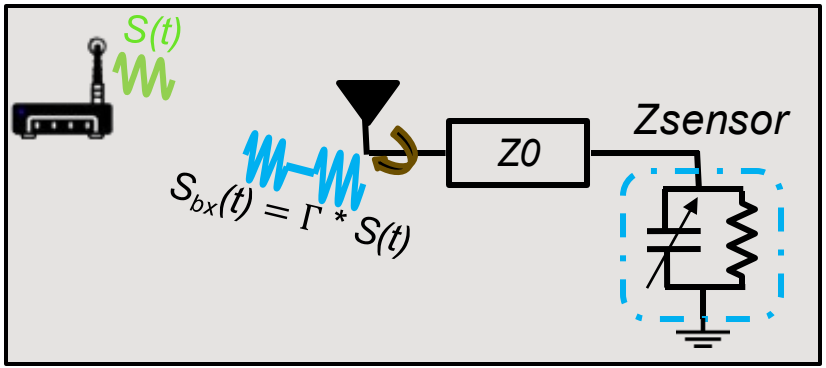


- RFID is a ubiquitous radio platform.
- RFID tags are passive/flexible and inexpensive
- RFID tags simply backscatter their digital ID.
- No inherent sensing capability.

Can we use the digital ID of Tags for sensing?

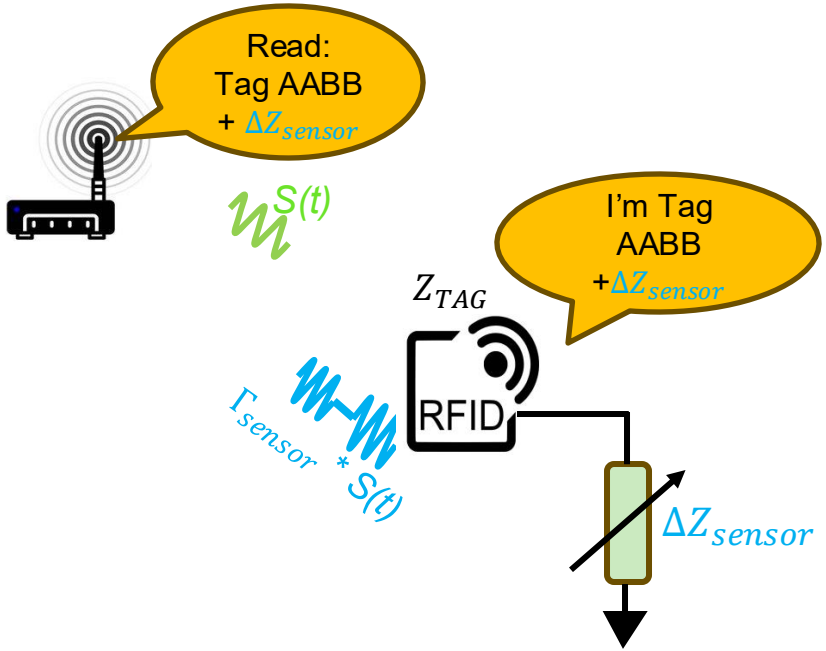
How to modulate RFID signal with sensor output?

$$Z_{sensor} = \frac{Vsensor(f)}{Isensor(f)}$$



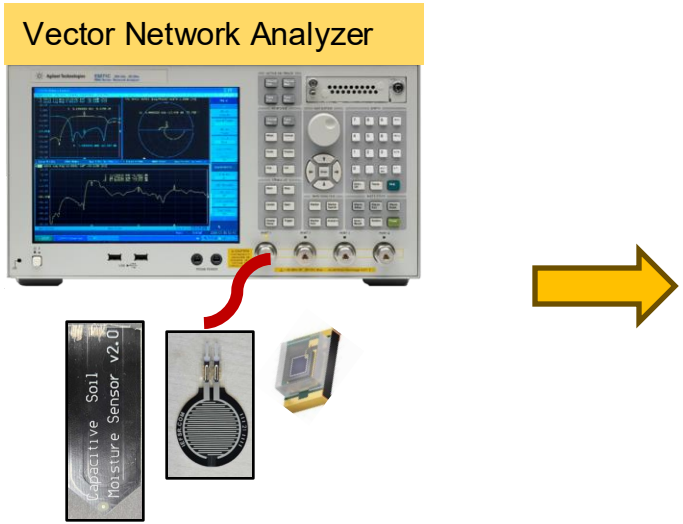
$$\Gamma = \frac{Zsensor - Z_0}{Zsensor + Z_0}$$

$Z_0 \rightarrow Z_{TAG}$

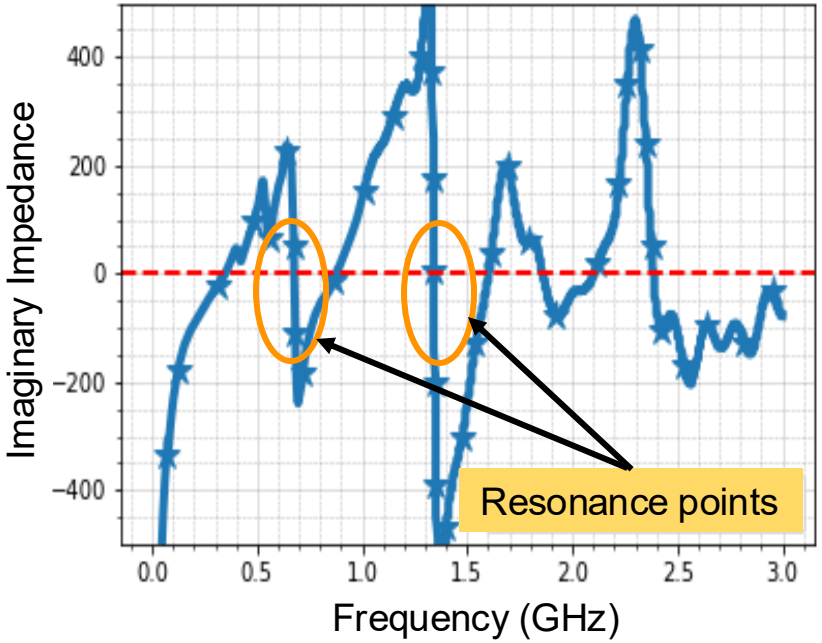


ZenseTag embeds sensor impedance into the tag digital ID.

ZenseTag: Direct-to-RF Interface of COTS sensors

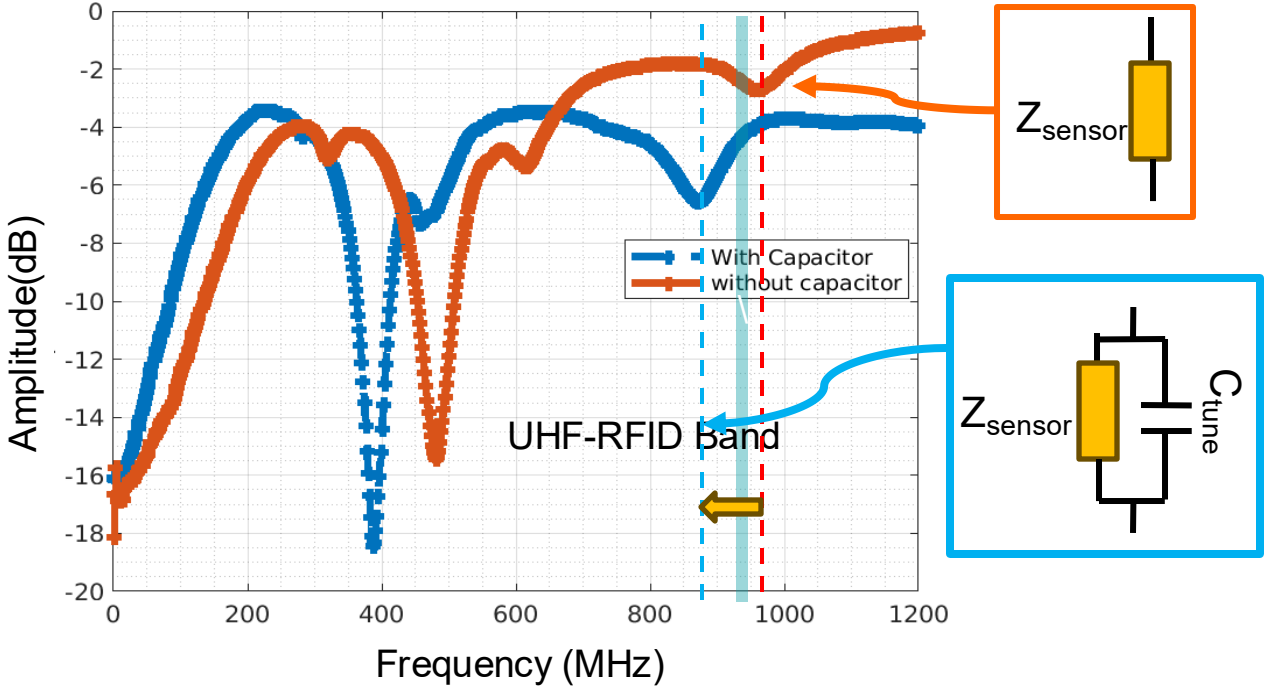


Profile Sensor Impedance $Z_{sense}(freq)$



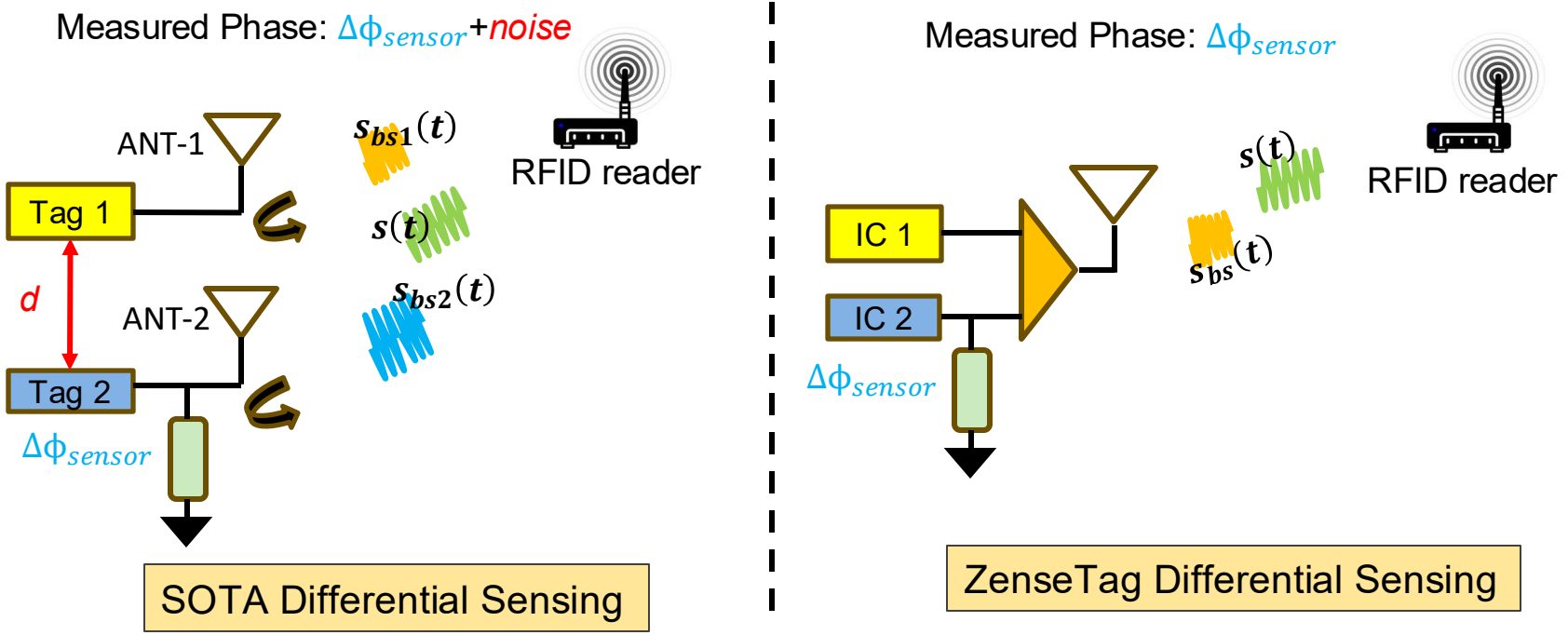
ZenseTag accurately profiles sensor impedance and tunes its resonance.

ZenseTag: Tuning the resonance of sensors



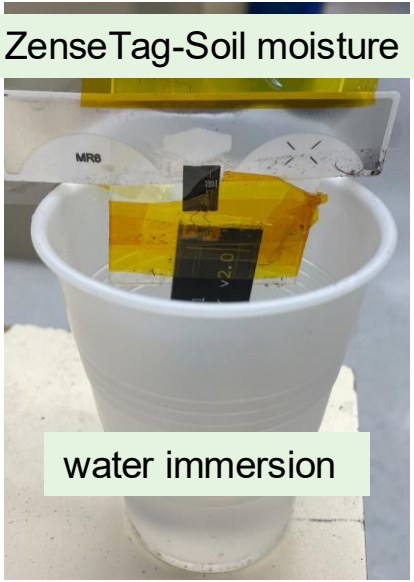
ZenseTag tunes Sensor Resonance close to RFID band.

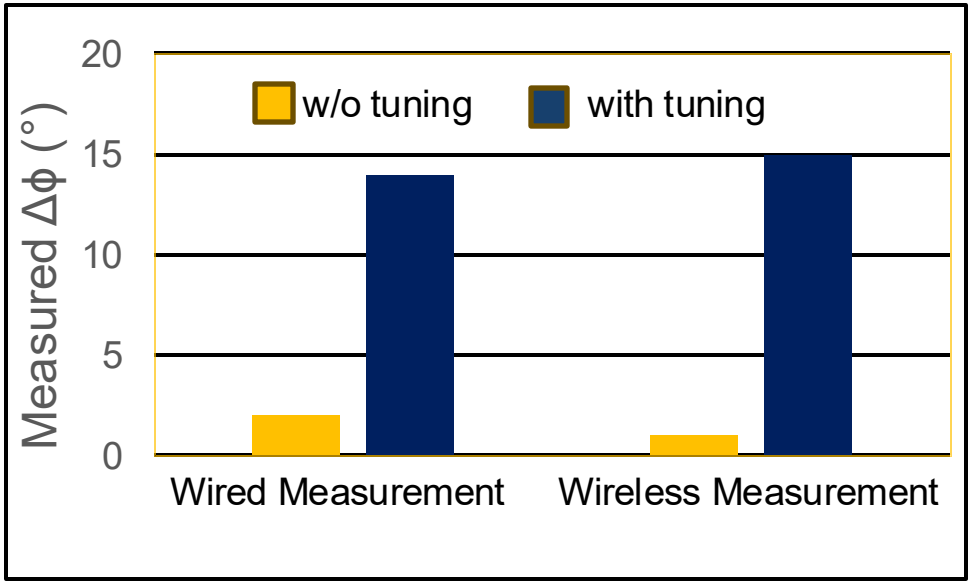
ZenseTag: Core Contributions



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

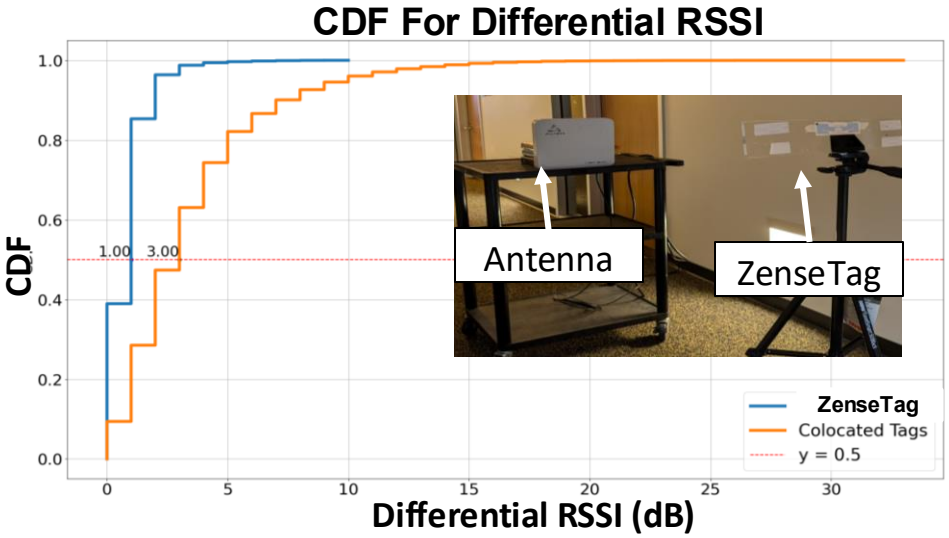
Benchmarks: Resonance-enhanced sensitivity

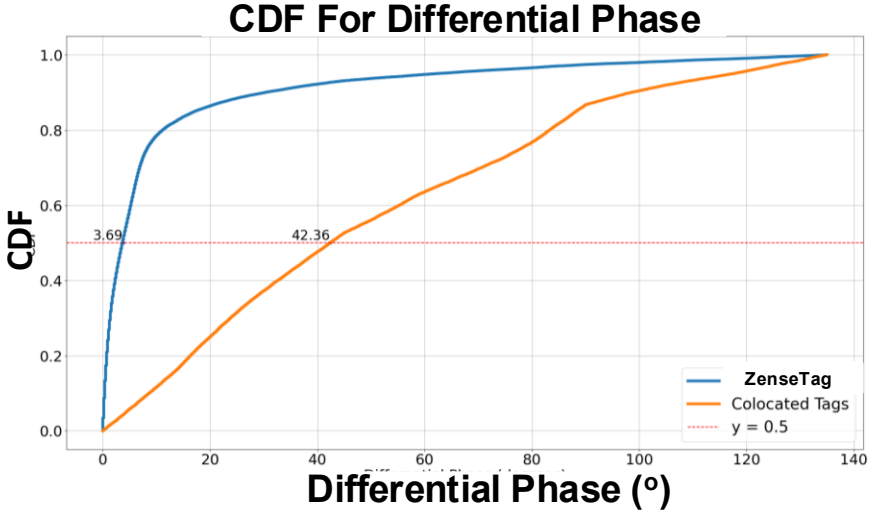




Tuning resonance achieves **7x** improvement in phase response of the sensor at RF

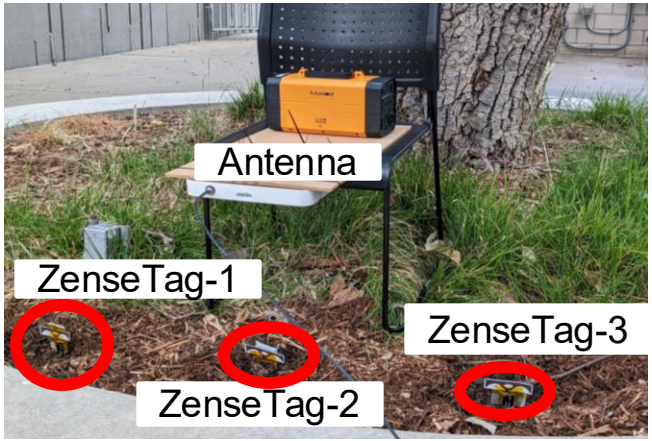
Benchmarks: Multipath resilience



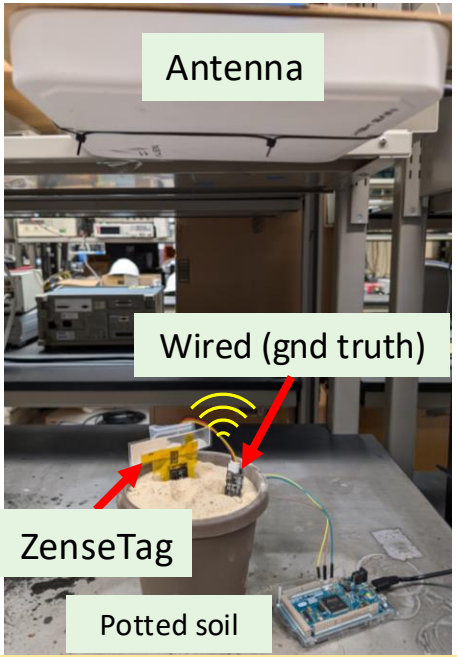


ZenseTag: **>10x accurate** phase estimate, **+2dB accurate** amplitude estimate

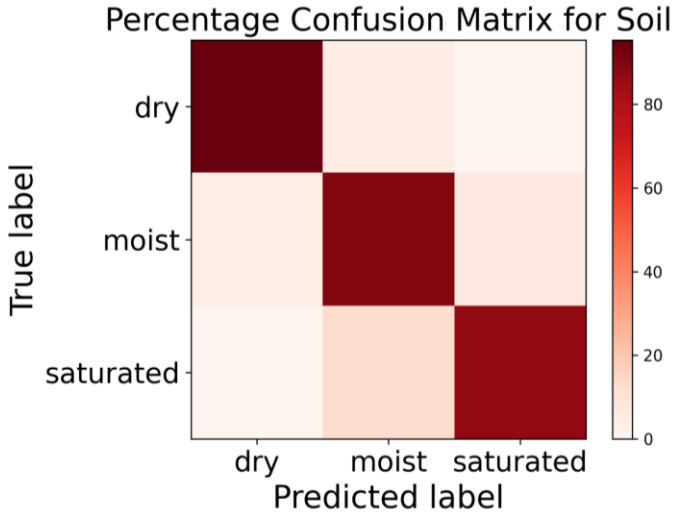
Evaluations: Sensing soil moisture



Outdoor measurement setup



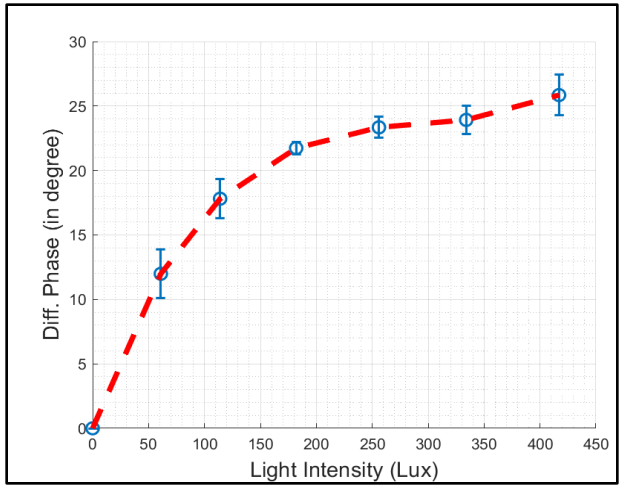
Indoor measurement setup



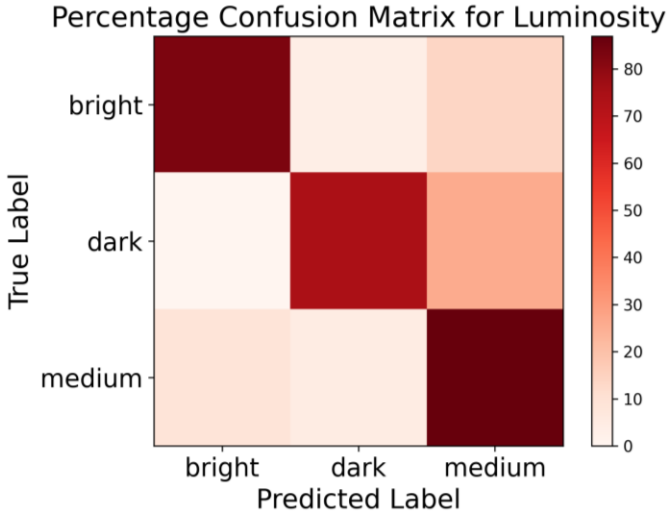
ZenseTag achieves **>93%** classification accuracy for soil moisture

Evaluations: Sensing Light

Measurement setup



Calibration curve



Results

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

Evaluations: Demonstrations

[redacted]

ZenseTag-Luminosity Sensor

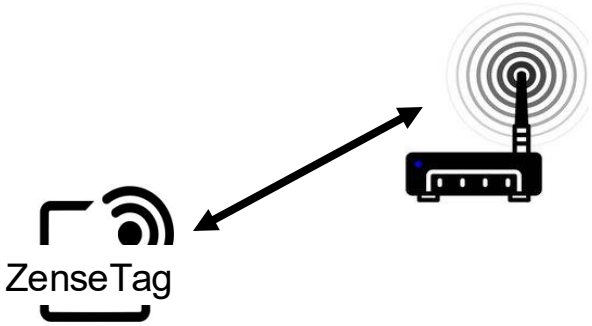
[redacted]

ZenseTag-Contact Force Sensor

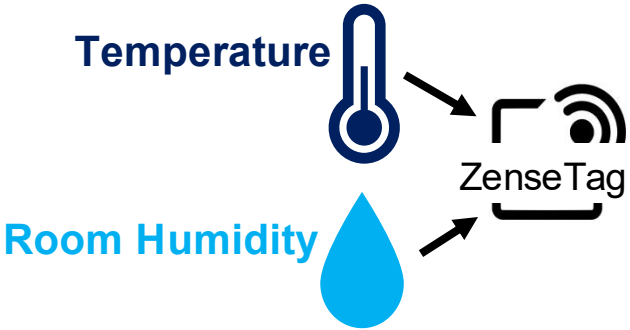
ZenseTag-Soil Moisture Sensor

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: