Ambient Backscattering Sensor using FM Broadcasting for Low Cost and Low Power Wireless Applications

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Backscatter Communication Background

1. Low cost and low power sensing:

- Commercial WSN Radios → Cost and Power Constraints.

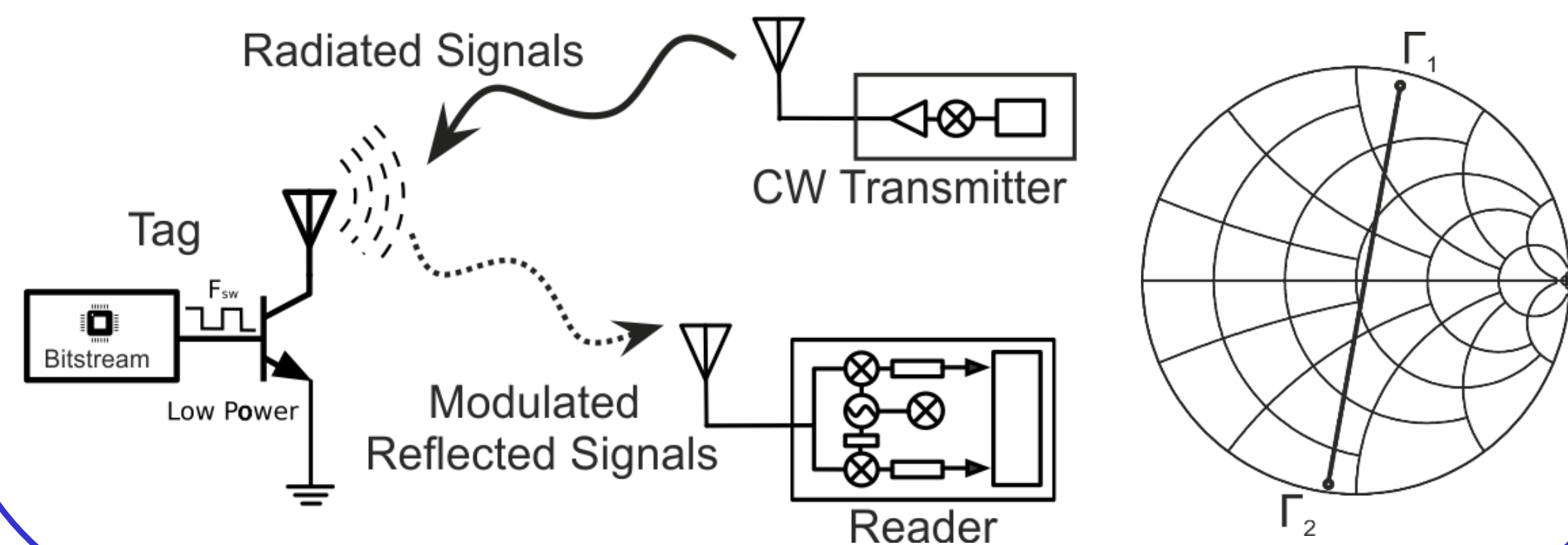- **"One Use" Environmental Sensors for Agricultural Applications.**

2. Necessity:

- Wireless communication!
- Low cost, scalability, ultra low power.

3. **Solution: Backscatter Radio → RFID technology**
- Antenna load switching @ F_{sw}.
- Single transistor (!) wireless communication.
- µW communication.

RFID TAG: ALN- Squiglette 9630

Novel RFID Tag for Agriculture

1. Measure temperature difference ($T_{leaf} - T_{air}$) → Related with water stress.

2. MSP430 MCU communication protocol development.
   - Backscatter ASK modulation (OOK with FM0 encoding).

3. Semi passive tags (Energy assisted).
   - Duty cycle, 9 hours, super-Cap operation.
   - MCU, Active mode: 126 µA at 2.3 V (1 MHz), Sleep Mode: 0.02 µA.
   - RF switch: < 1 µA at 2.75 V + sensors…

Sensor Board a)
LMT70A Sensors
MSP430FR5969 LaunchPad
0.1F Super Cap
FM Dipole Antenna

Dipole Arm 1
ADG902
Dipole Arm 2
RF 1 / RF 2
V_{DD}
CTRL
GND
MCU Dev board
F_{sw}
Bit stream

Inkjet-printed (photo paper substrate) "Clothes-pin" temperature sensor board and RF front end.

Arm 1 / Arm 2
RF 1 / RF 2
ADG902
CTRL
MCU
GND
ADG902 RF Switch b)

Silver Nanoparticle Inks, Resolution: 20 µm – 50 µm

Radiated Signals
CW Transmitter
Tag
F_{sw}
Bitstream
Low Power
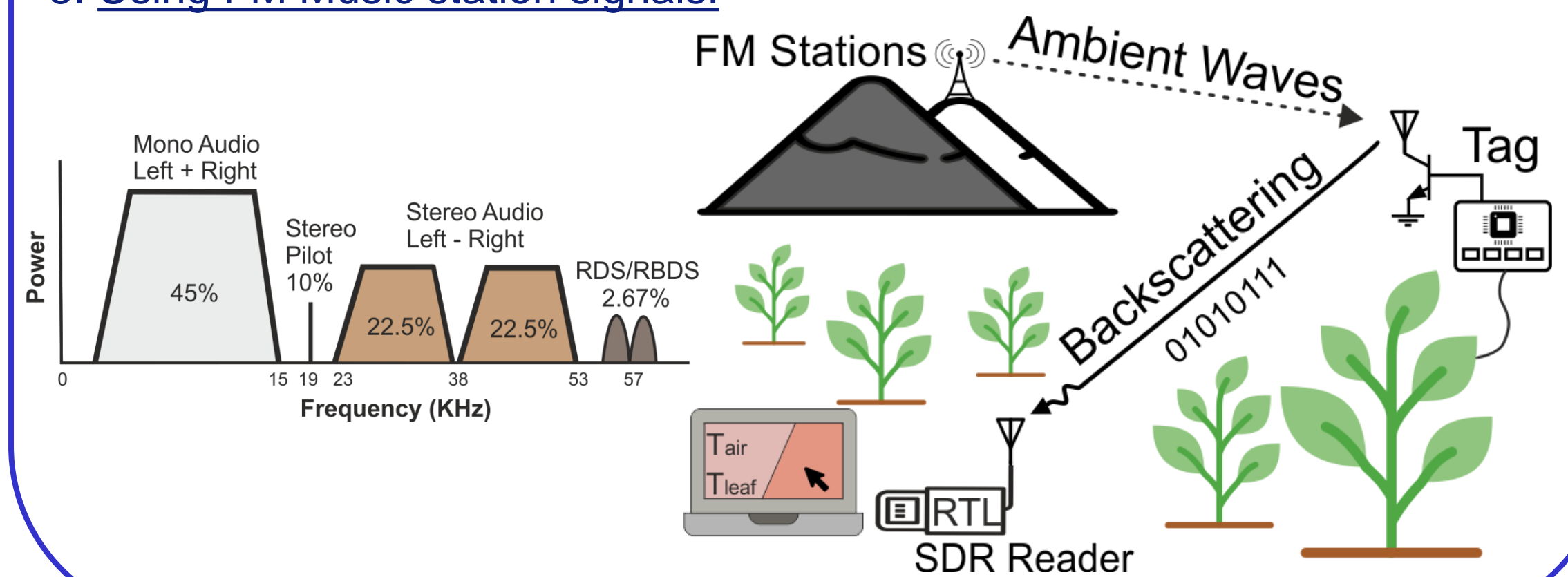Modulated Reflected Signals
Reader
Γ_1
Γ_2

FM Ambient Backscatter Communication

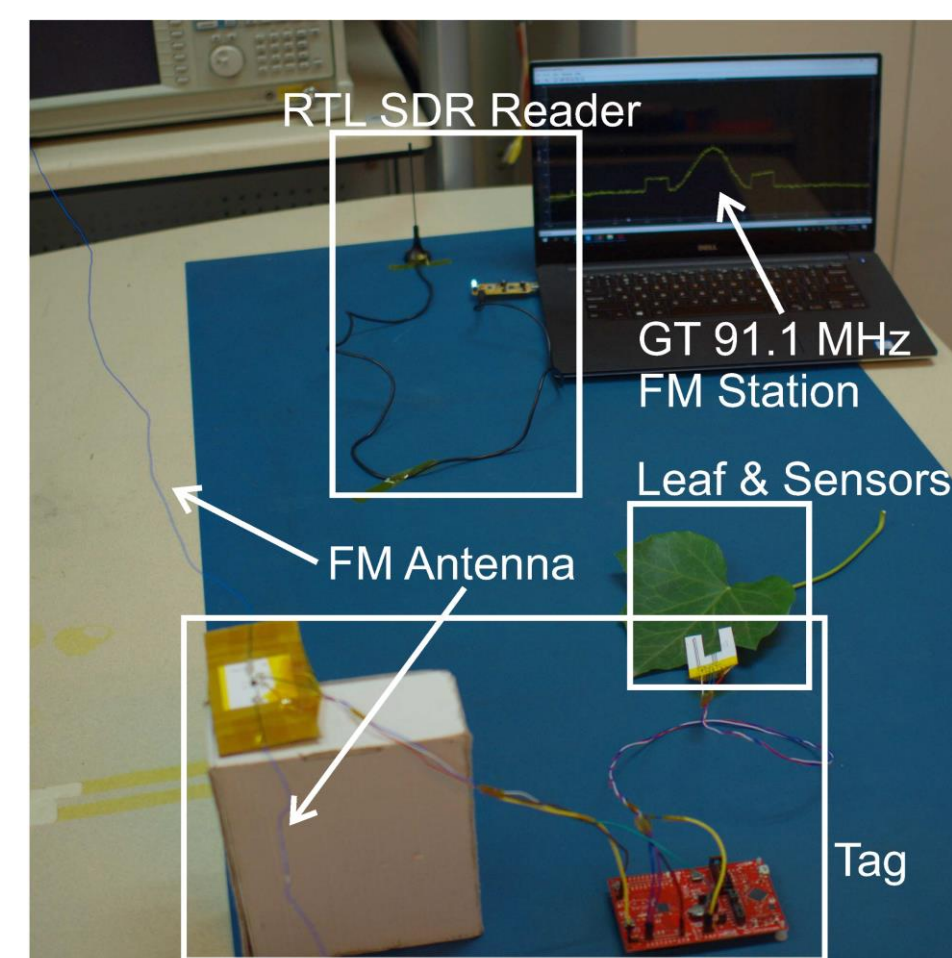1. Communication using reflected ambient signals.

2. Simplified communication scheme → only a **Receiver** and a **Tag**.

3. Using FM Music station signals:

Mono Audio Left + Right 45%
Stereo Pilot 10%
Stereo Audio Left - Right 22.5% 22.5%
RDS/RBDS 2.67%
Power
Frequency (KHz)
0 15 19 23 38 53 57

FM Stations
Ambient Waves
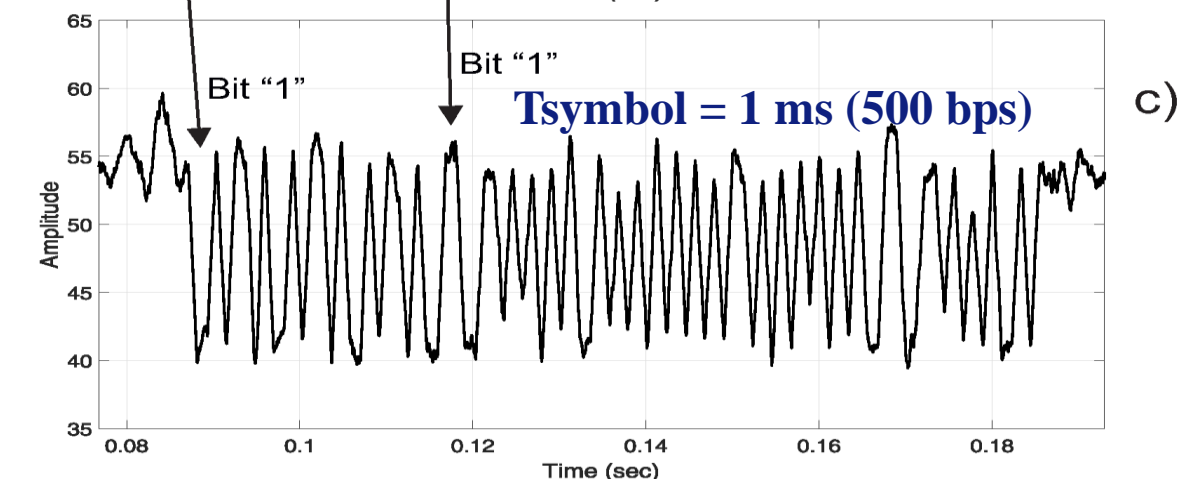Tag
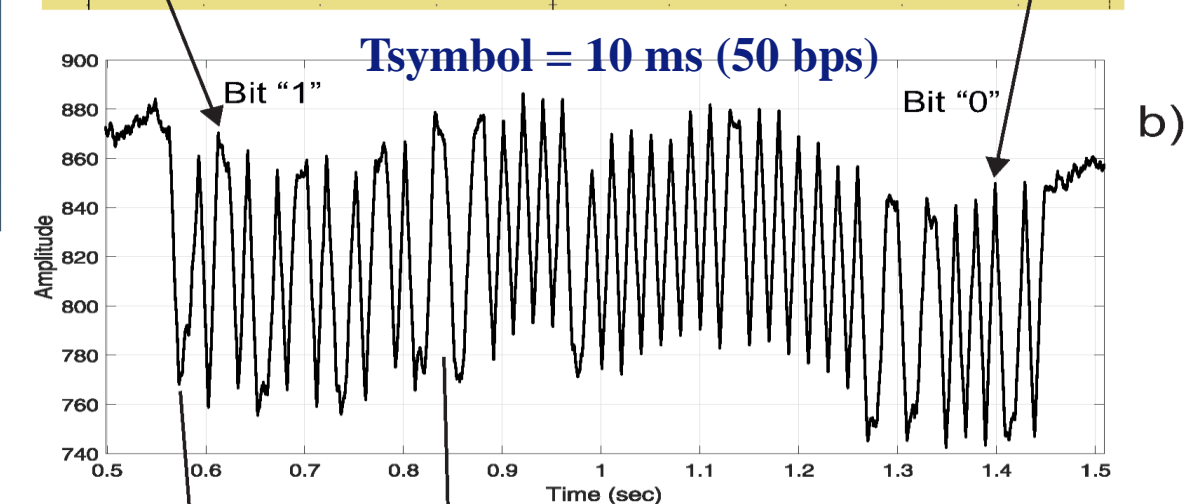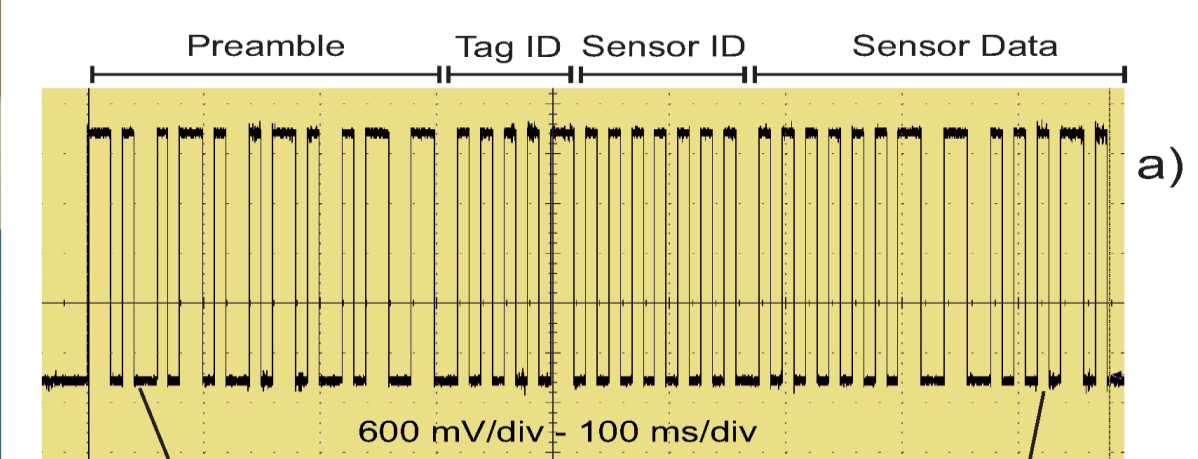Backscattering
01010111
T_{air}
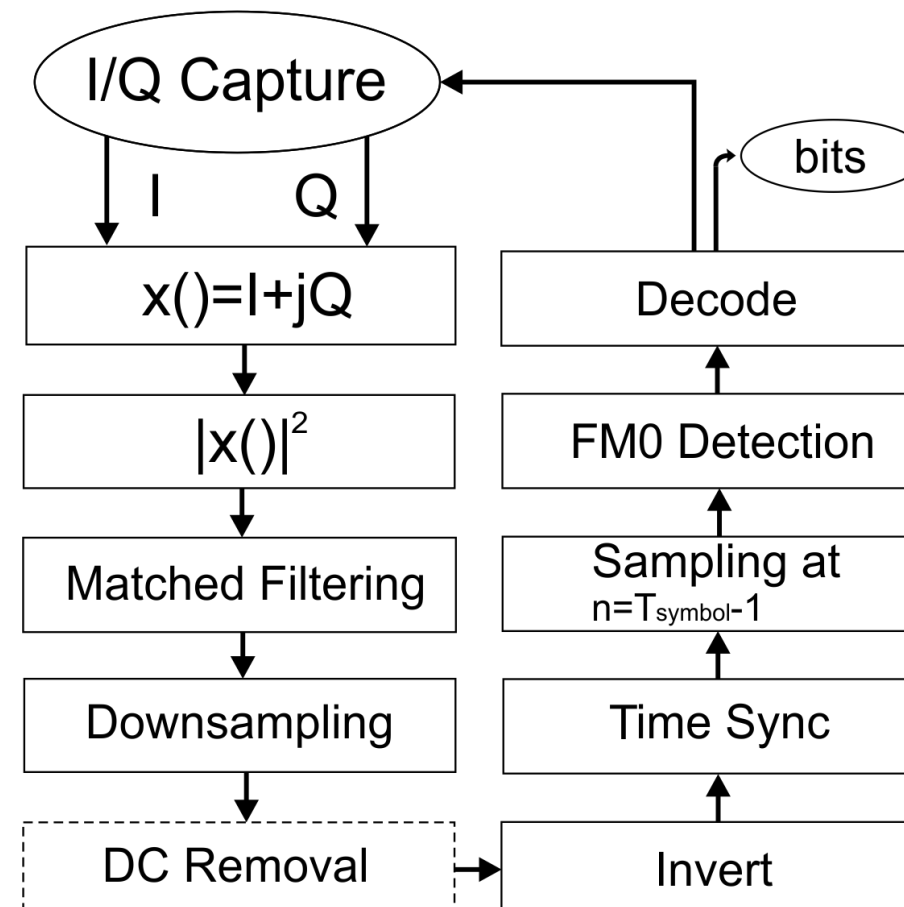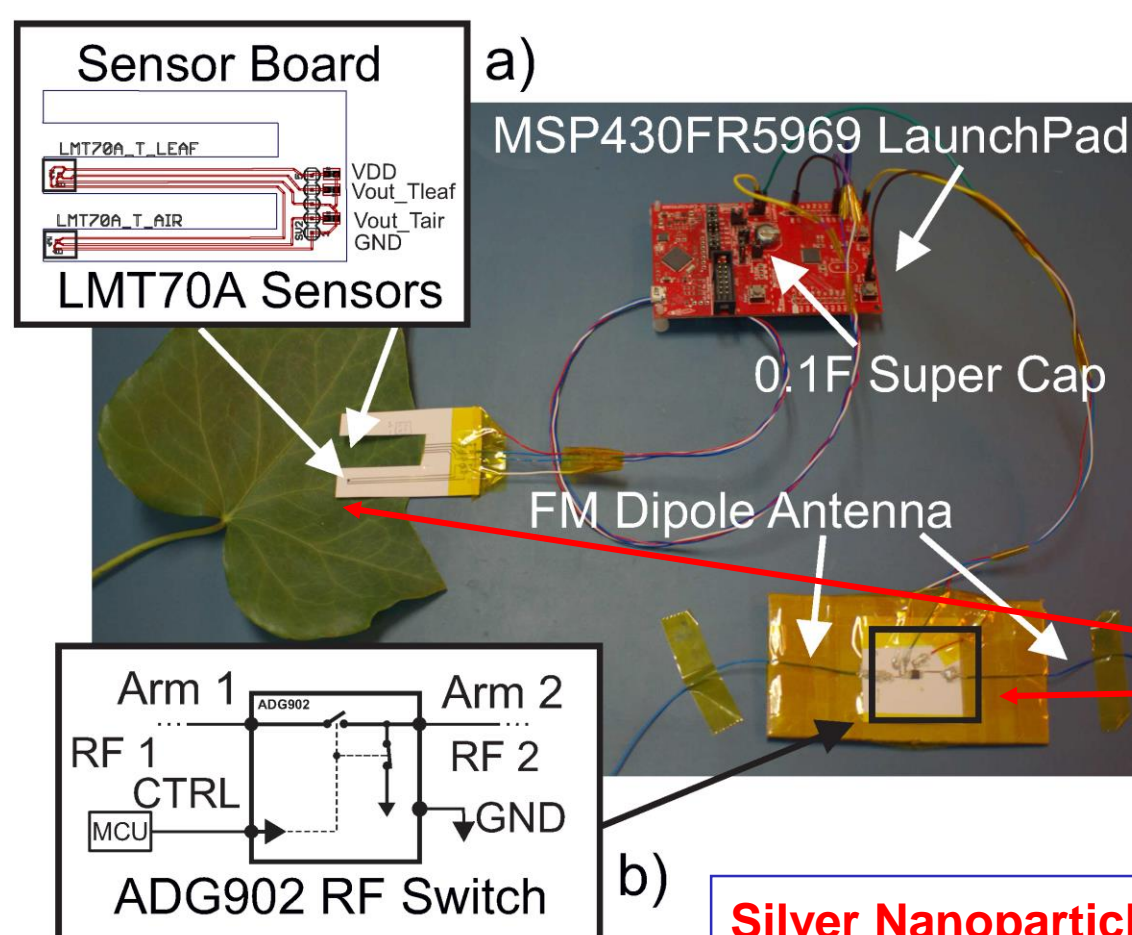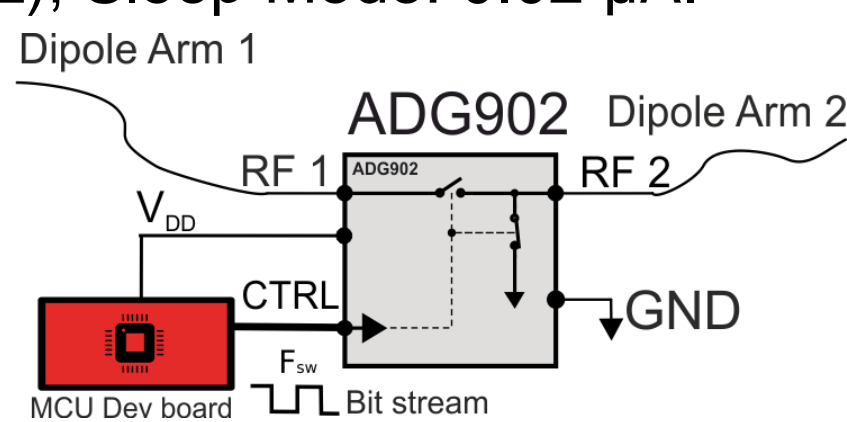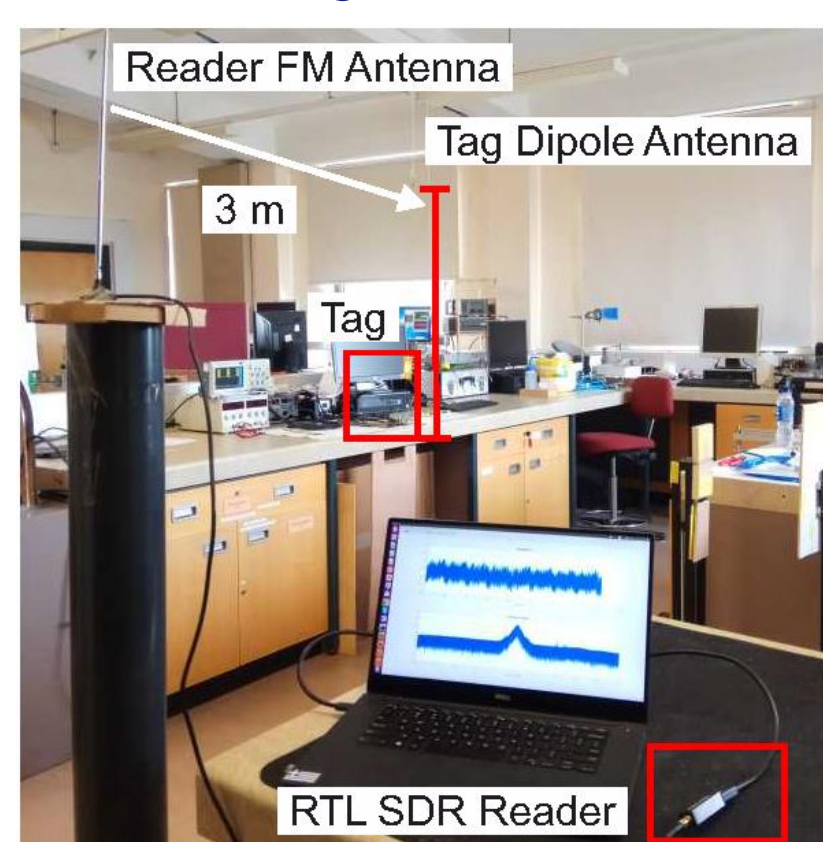T_{leaf}
RTL SDR Reader

Custom Low Cost Receiver

- Receiver: low cost software defined radio → RTL SDR (Cost: 18$).
- Software: Linux + GNU Radio + MATLAB.
- Channel fluctuation → Bitrate and efficient filtering: Trade off.

RTL SDR Reader
GT 91.1 MHz FM Station
Leaf & Sensors
FM Antenna
Tag

I/Q Capture
I Q
bits
$x() = I + jQ$
Decode
$|x()|^2$
FM0 Detection
Matched Filtering
Sampling at $n = T_{symbol} - 1$
Downsampling
Time Sync
DC Removal
Invert

- Low bit rate communication.

Tag Packet Waves
Preamble | Tag ID | Sensor ID | Sensor Data
600 mV/div - 100 ms/div
a)

T_{symbol} = 10 ms (50 bps)
Bit "1"
Bit "0"
b)

T_{symbol} = 1 ms (500 bps)
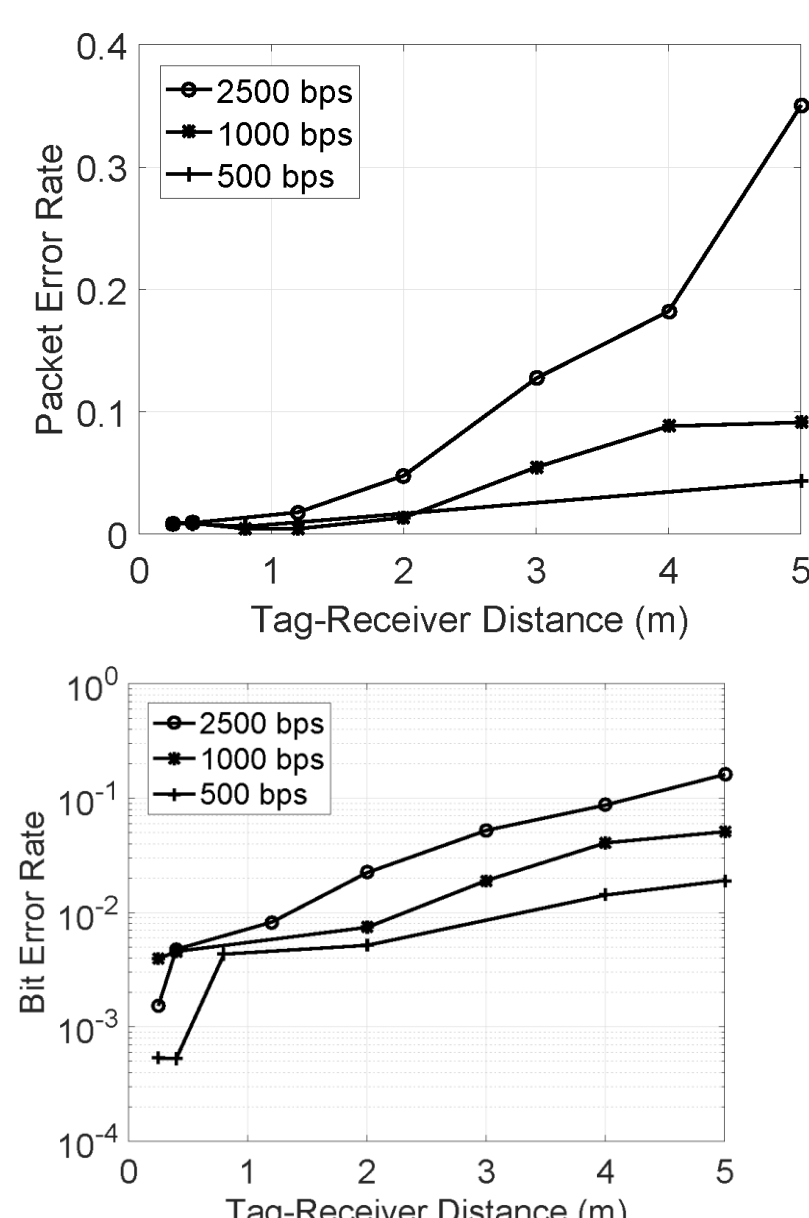Bit "1"
Bit "1"
c)

Received Packet Waves

Real Indoor Demo

1. GOAL: increase the "tag-reader" distance.

2. Edinburgh Heriot-Watt University Lab.

FM Station: BBC 95.8 MHz
Transmission power: 250 KW
Measured indoor max power: -51 dBm

Reader FM Antenna
Tag Dipole Antenna
3 m
Tag
RTL SDR Reader

Edinburgh
34.64 Km
Black Hill Transmitter
Heriot-Watt University
Glasgow
EM HW building

Packet Error Rate
2500 bps
1000 bps
500 bps
Tag-Receiver Distance (m)

Bit Error Rate
2500 bps
1000 bps
500 bps
Tag-Receiver Distance (m)

Future Work

1. Better RF Front-end → Increase Range.

2. Better MCU and Coding → Low Power.

3. High Order Modulation Techniques.

4. Ambient Solar & RF Energy Harvesting.

5. An "All in one" PCB on Paper Substrate.

6. Android Smartphone FM Receiver.

More info: www.daskalakispiros.com
First Registration Date: 01-Mar-2017