uW Backscatter Sensors for Low Cost Agricultural Wireless Sensor Networks

Spyridon Nektarios Daskalakis, Apostolos Georgiadis, George Goussetis and Manos M. Tenzteris

sd70@hw.ac.uk, apostolos.georgiadis@ieee.org, g.goussetis@hw.ac.uk, etentze@ece.gatech.edu

SCHOOL OF ENGINEERING & PHYSICAL SCIENCES, HERIOT-WATT UNIVERSITY, EDINBURGH, SCOTLAND, UNITED KINGDOM

Backscatter Communication Background

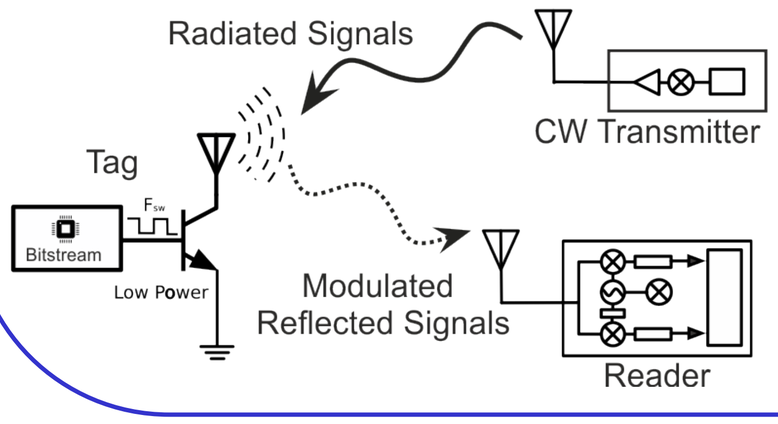
1. Low cost and low power sensing:

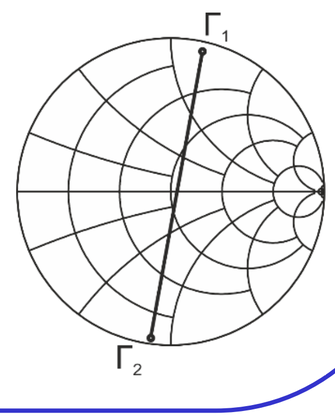
- Commercial WSN Radios → Cost and Power Constraints.
- **"One Use" Environmental Sensors for Agricultural Applications.**

2. Necessity:

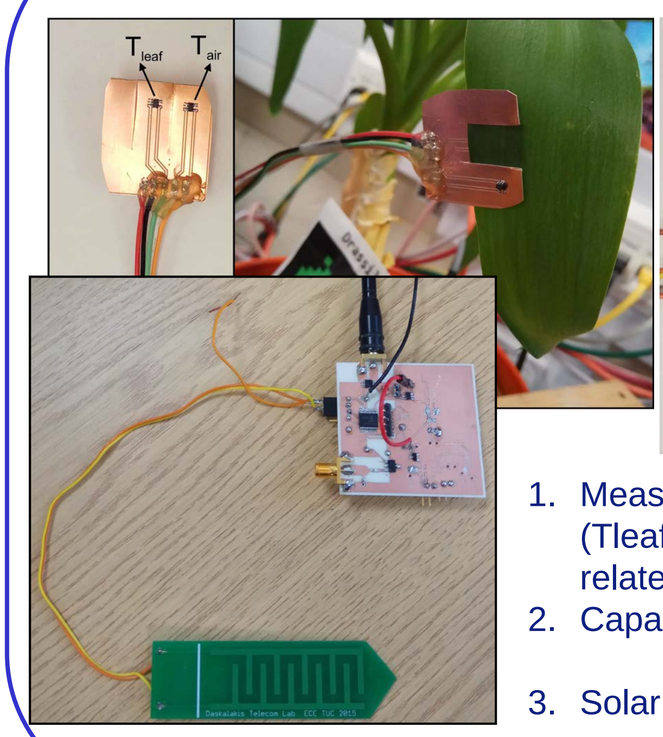
- Wireless communication!
- Low cost, scalability, ultra low power.

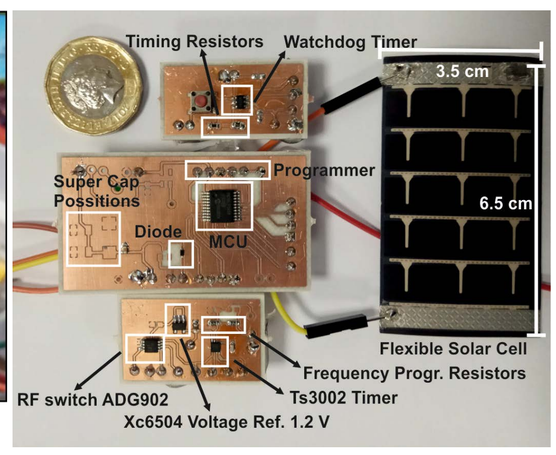
3. **Solution: Backscatter Radio → RFID technology**
- Antenna load switching @ F_{sw}.
- Single transistor (!) wireless communication.
- µWatt communication.





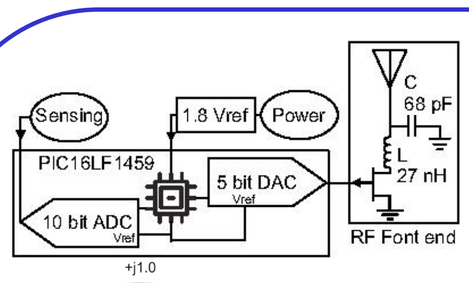
Low-Cost Batteryless Sensor Tags



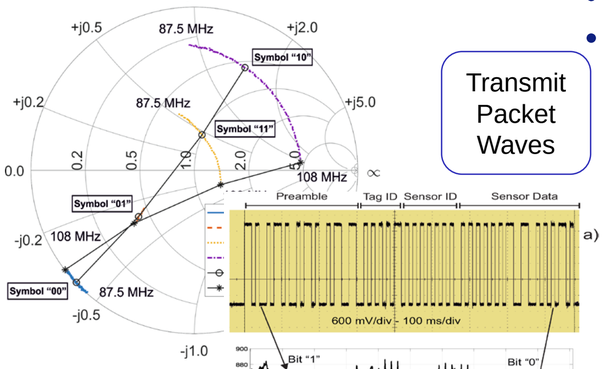


1. Measure temperature difference (Tleaf -Tair): Canopy temperature related with water stress.
2. Capacitive Soil Moisture Sensor.
3. Solar Powered + Super Cap.

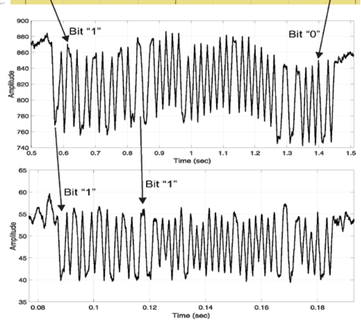
Modulation Techniques



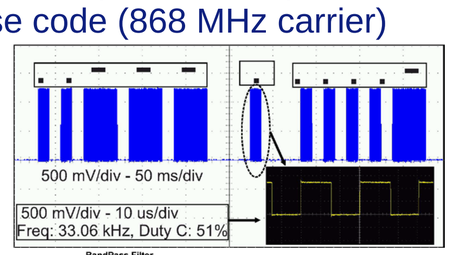
1. Spectrally efficient 4-PAM ambient FM backscattering.
2. No spectrally efficient 2-PAM
   - OOK FM0 (ambient FM)
   - Morse code (868 MHz carrier)

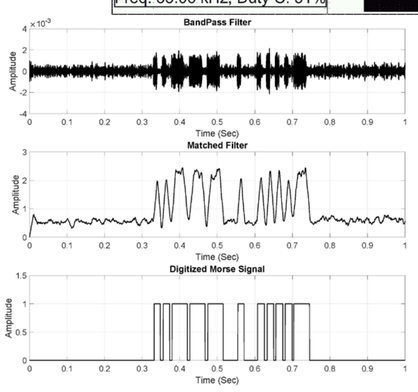


Transmit Packet Waves



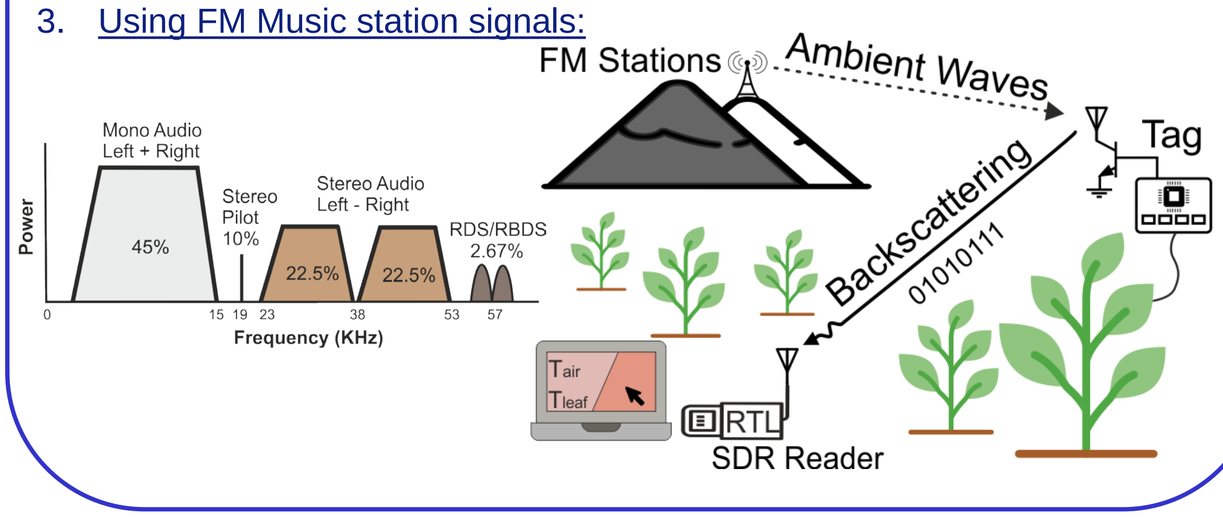
Received Packet Waves





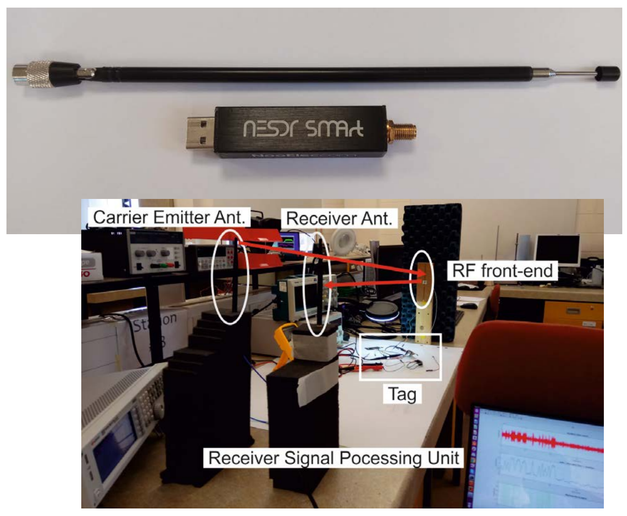
FM Ambient Backscatter Communication

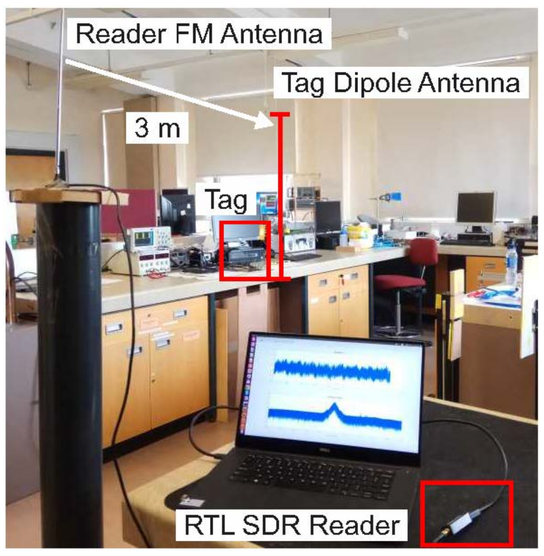
1. Communication using reflected ambient signals.
2. Simplified communication scheme → only a **Receiver** and a **Tag**.
3. Using FM Music station signals:

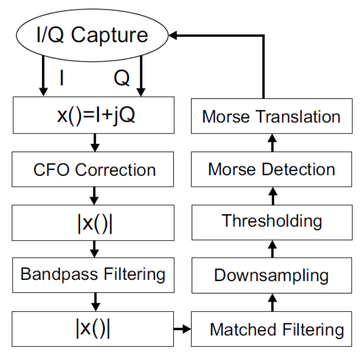


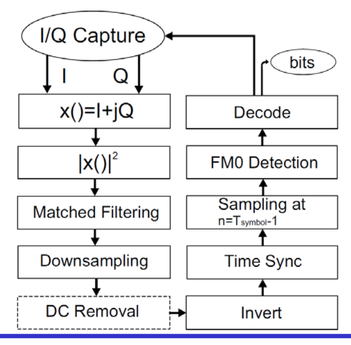
Custom Low Cost Receiver

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

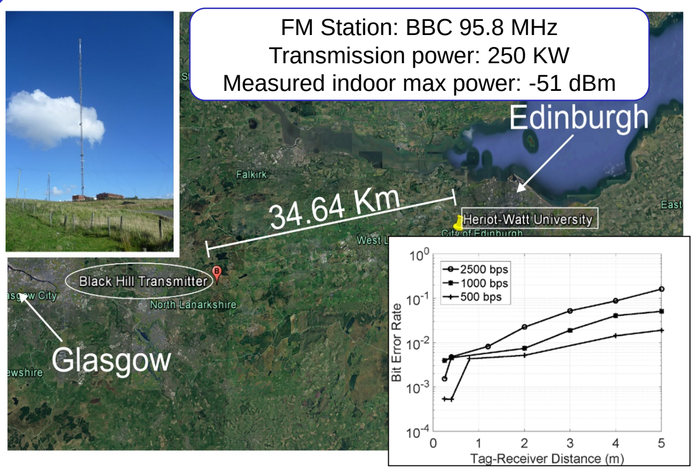








Indoor Demos & Future Work



- GOAL: increase the "tag-reader" distance.
- Edinburgh Heriot-Watt University lab.

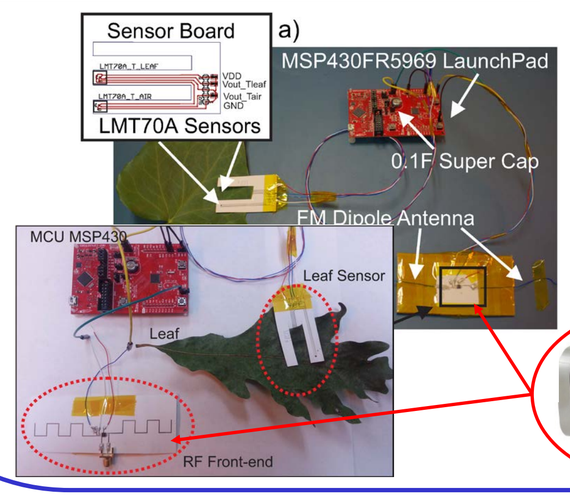
Future Goals:

1. Better RF front-end → Increase range.
2. Ambient solar & RF energy harvesting.
3. An "All in one" PCB on paper substrate.
4. Android smartphone FM receiver.

Tag Operation Mode @$V_{DD} = 1.8$ V	μA	Bit rate (bps)
Sleep: (no DAC, no ADC)	0.6	0
Active: OOK (no DAC, no ADC)	3.6	147
Active: OOK (no DAC, ADC)	220	147
Active: 4PAM (DAC, no ADC)	16	328
Active: 4PAM (DAC, ADC)	232	328

Use nanotechnology:

- **Flexible low cost substrates**
- **Nanoparticle conductive inks**
- **Easily fabricated tags**
- **Nanomaterial based passive sensors (e.g. gas, humidity)**



Silver Nanoparticle Inks, Resolution: 20 µm – 50 µm

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