Soil Moisture Wireless Sensor Network with Analog Scatter Radio, Low Power, Ultra-Low Cost, and Low Complexity

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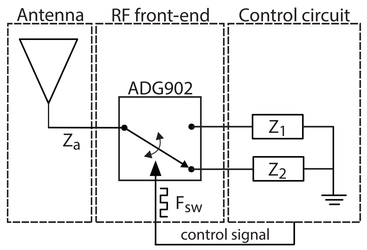
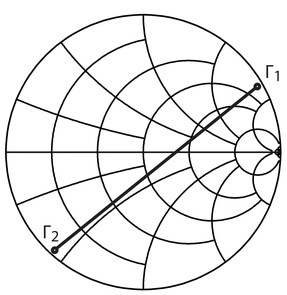
1. Introduction

- Precision agriculture applications:
  Environmental variables monitoring @ soil moisture.
- Necessity:
  - Classic WSN approaches > 1000 nodes!
    → Cost, Scalability, Power constraints.
- Ultra-large scale, ultra-low power, ultra-low cost environmental sensing.
- Solution: Bistatic Backscatter radio networks!

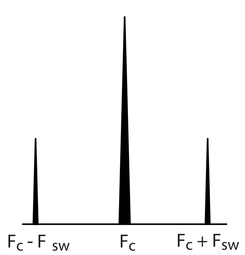
2. Scatter Radio Principle



Antenna S_{11} Parameters

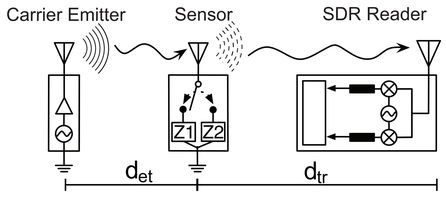


Frequency Spectrum



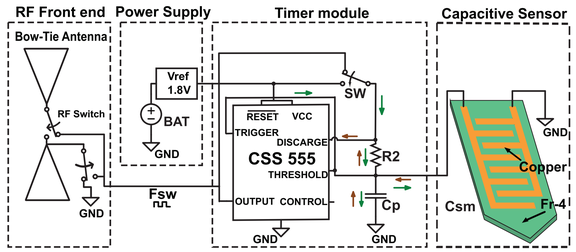
- Antenna load switching @ F_{sw}.
- When carrier with $F_c \rightarrow$ Subcarriers @$F_c \pm F_{sw}$.
- Single RF switch/transistor, μW communication! (RFIDs)

3. Topology Approach

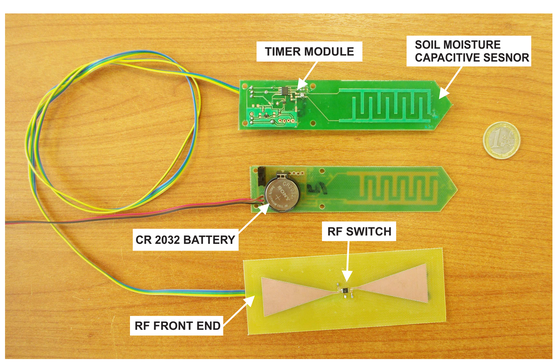


- Bistatic - dislocated topology.
- Semi passive tags (Energy assisted).
- Low-cost carrier emitter @ 868 Mhz.
- 1 Receiver low cost commercial software defined radio(RTL-SDR).
- Low bitrate (sensing)=> Ranges $\geq$ 100m!

4. Tag Implementation



- Capacitance to frequency converter
  - Timer IC 555 connected to a RC network (astable multi-vibrator mode).
- Custom (FR4) capacitive soil moisture sensor.
- Custom Bow tie antenna @ADG902 RF switch.
- Consuming μWs (CRC232 coin battery).
- Frequency modulation (FM) of soil moisture.

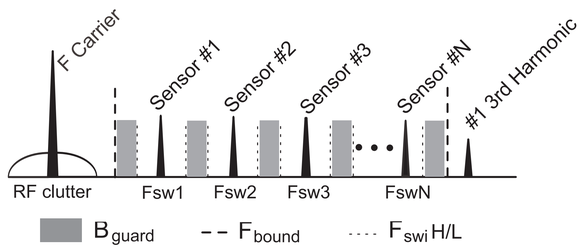


5. SDR Reader

- SDR RTL2832U USB dongle.
- Ebay cost: 6$.
- Single FFT receiver Algorithm: (i-th tag subcarrier frequency)

$$\hat{F}_i = \underset{F \in [F_{\mathrm{L}i}, F_{\mathrm{H}i}]}{\arg\max} |X(F)|^2. \quad (1)$$

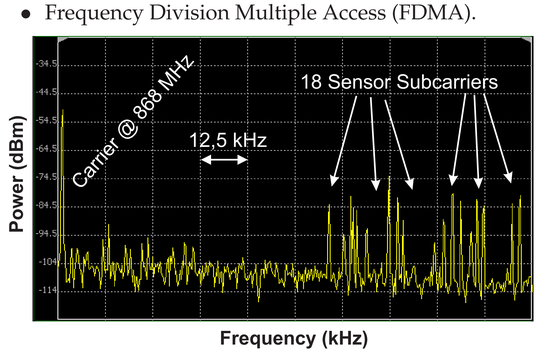
6. Sensor Network



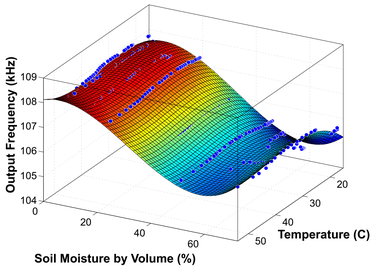
- BSN = Tags + medium access scheme.
- Unique R_{2i}, C_{pi}, different frequency bands.

$$F_{\mathrm{swi}} = \frac{1}{\ln(2)\ 2R_{2i}\ (C_{\mathrm{pi}} + C_{\mathrm{SM}})}, \quad (2)$$

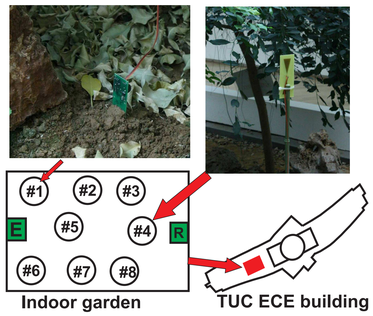
- Frequency Division Multiple Access (FDMA).

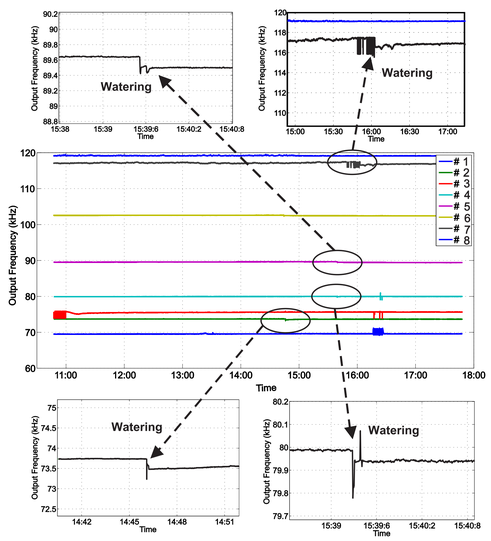


7. Sensor Calibration



8. 8 Hour Indoor Demo





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