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NFC Hybrid Harvester for Battery-free Agricultural Sensor Nodes

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LEADERS IN IDEAS AND SOLUTIONS

RFID TA IEEE 2019

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What is the Problem?

- Applications: Microclimate monitoring
- Commercial WSN Sensor Nodes
  - BLE, LORA, Zigbee protocols
  - Cost and power constraints
- Necessity:
  - Scalability
  - Low cost
  - Low maintenance
- Solution:
  - Backscatter sensors nodes
  - Battery-less sensors
  - Easy fabricated -> Inkjet & 3D printed

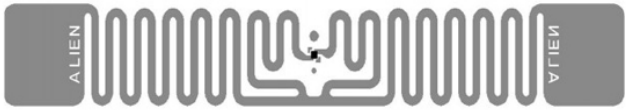
S. N. Daskalakis, J. Kimionis, A. Collado, M. M. Tentzeris and A. Georgiadis, Ambient FM Backscattering for Smart Agricultural Monitoring, in proc. IEEE MTT-S International Microwave Symposium (IMS), June 2017, Honolulu, Hawaii, USA.

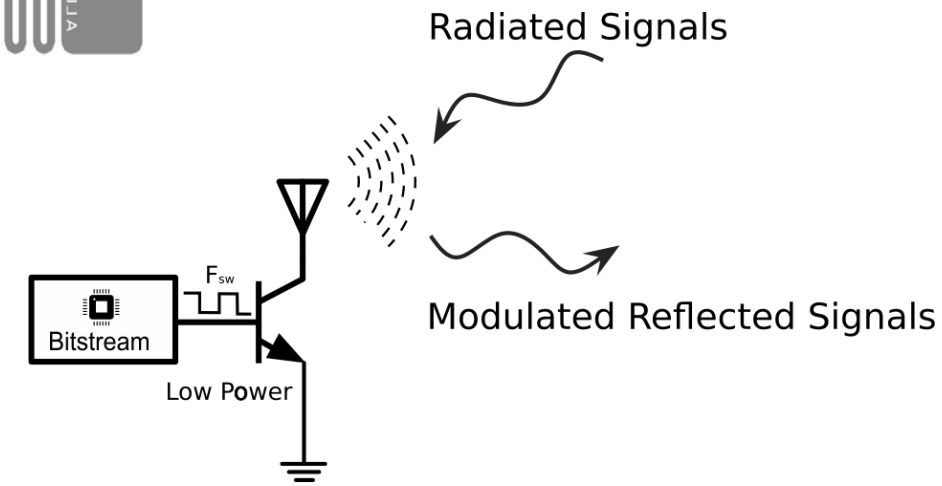
Backscatter Communication

Backscatter communication -> RFID tags

- Single transistor communication
- Antenna load switching @ F_{sw}
- µW power consumption!
- Low cost!

ALN- Squiglette 9630



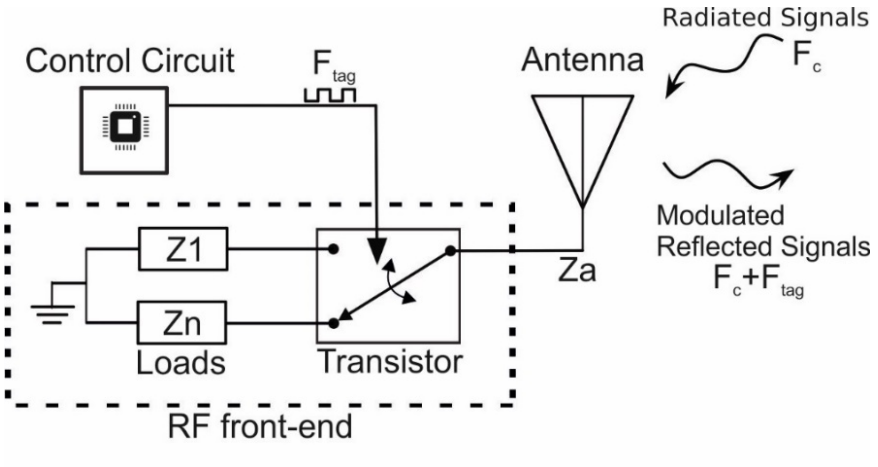


Backscatter Topology

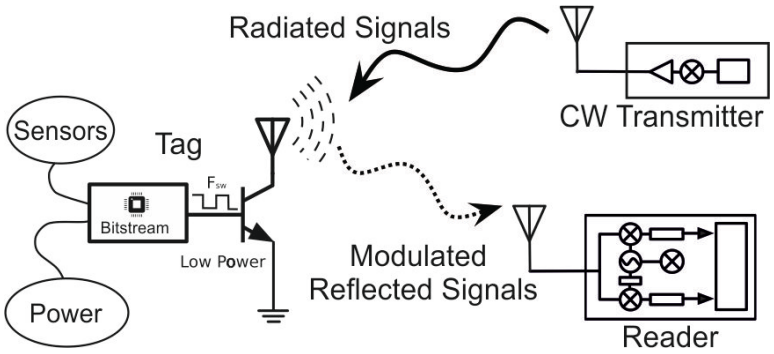
- Bistatic or monostatic architecture

- Emitter:
  - Dedicated CW transmitter
  - Ambient signals

- Reader:
  - Software defined radio

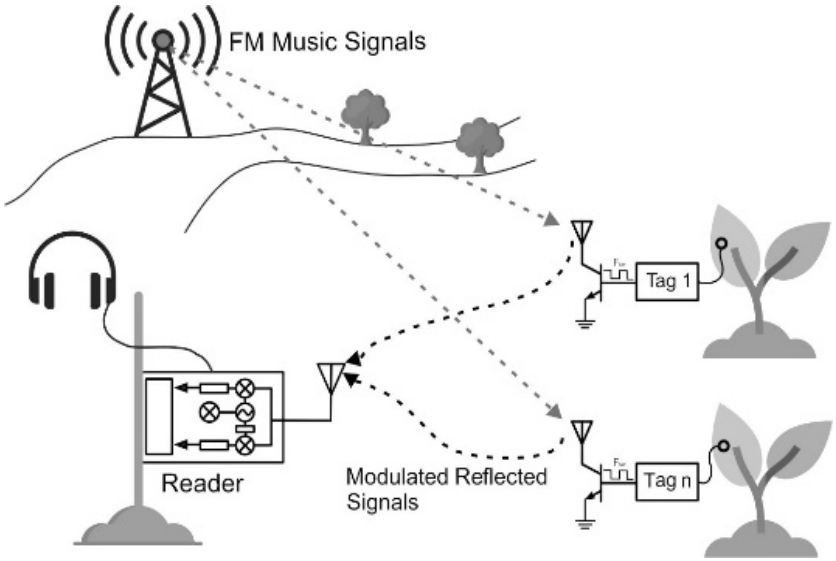


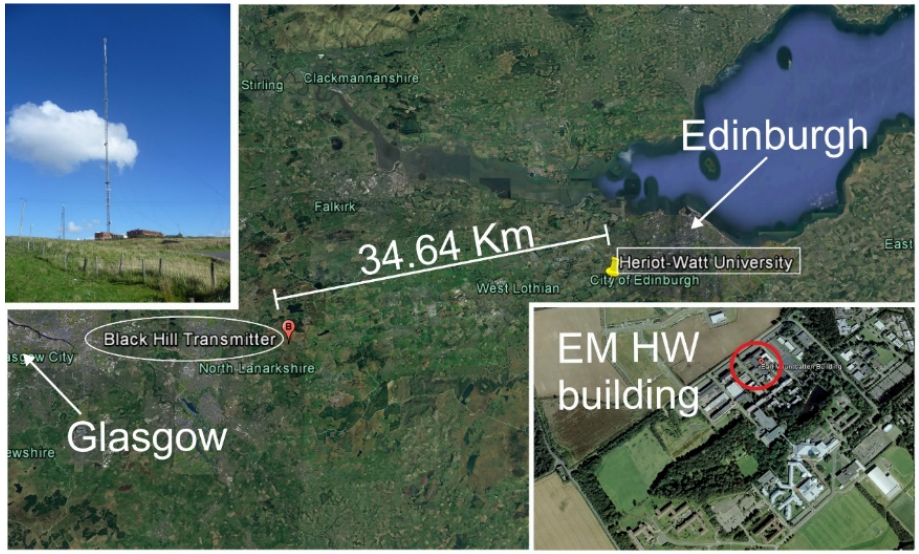
- Tag:
  - **Semi-passive (power source on tag -> extended comm. range)**
  - MCU (control unit) + Multiple sensors + Simple RF front-end



Ambient FM Backscatter

- Existing Transmitter
- Use Ambient FM Broadcast Signals
- Simple Scheme: only a receiver and a tag





BBC 95.8 MHz
Transmission power: 250 KW
Measured indoor max power: -60 dBm

S. N. Daskalakis, J. Kimionis, A Collado, G. Goussetis, M. M. Tentzeris and A. Georgiadis, Ambient Backscatterers using FM Broadcasting for Low Cost and Low Power Wireless Applications, IEEE Transactions on Microwave Theory and Techniques (TMTT), Vol. 65, No. 12, pp. 5251 - 5262, Nov. 2017.

NFC harvester (1/2)

Goal: design a battery-less sensor node for agriculture applications

Use NFC (Near Field Communication) technology for Communication & Energy harvesting.

- Operation frequency: 13.56 MHz
- Sensor node operates as a NFC tag-> "peer-to-peer" mode
- Battery-less mode
- With smartphone (reader) farmer can **power** and **securely read** device's identification (ID) number

Hybrid Solar/electromagnetic (EM) energy harvester:

- Solar radiation
  - Small solar panel
- NFC (Near Field Communication)
  - Harvesting energy from magnetic field induction between reader and tag antenna

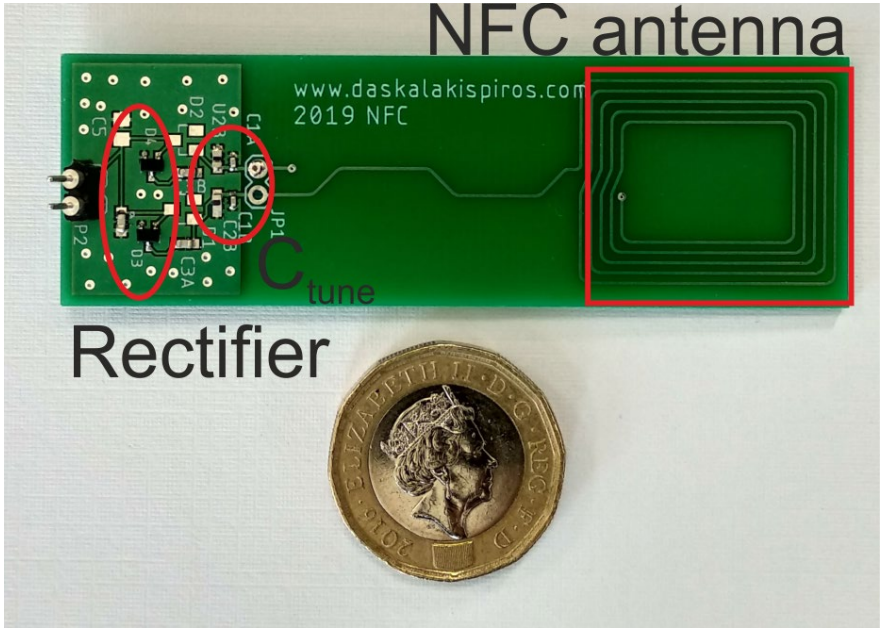
- Basic Components:

NFC antenna, NFC rectifier, combining/matching circuit, Solar panel, Boost Converter

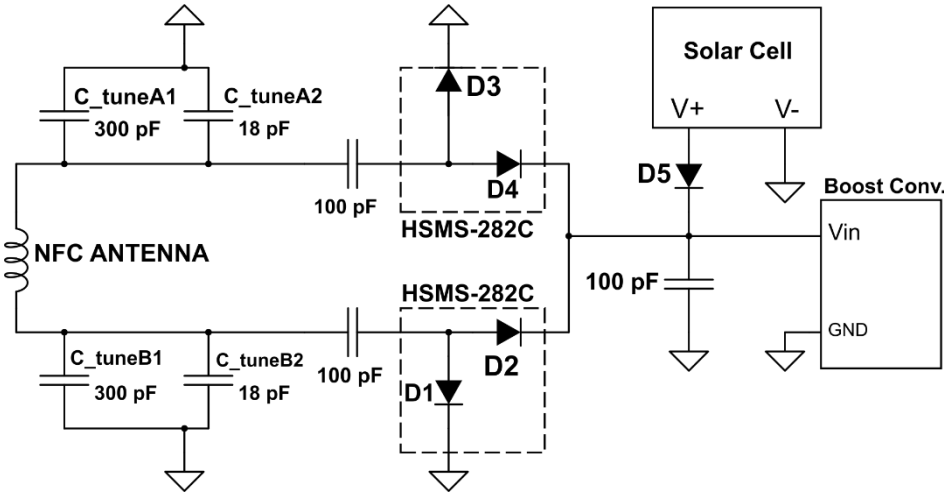
Rectifier Circuit Design

Full wave Rectenna (antenna + rectifier)

- 4 Avago HSMS-282C Schottky diodes (D1-D5)
- Nordic Semiconductor Coil NFC antenna
- Capacitor matching network (C_tuneA1, C_tuneA2, C_tuneB1, C_tuneB2,)
- Solar panel: Polycrystalline silicon board 45x45 mm (0.25 W, 5 V)
- Energy tank: 100 pF capacitor



Circuit



Low cost FR4 substrate (Er: 4.4, tand: 0.025)

Matching

Matching Coil antenna with Rectifier

- Low frequency: with out simulation software
- Resonance frequency formula (13.56 MHz):

$$F_0 = \frac{1}{2\pi\sqrt{L_c(C_{IC} + C_p + C_{tune})}}.$$

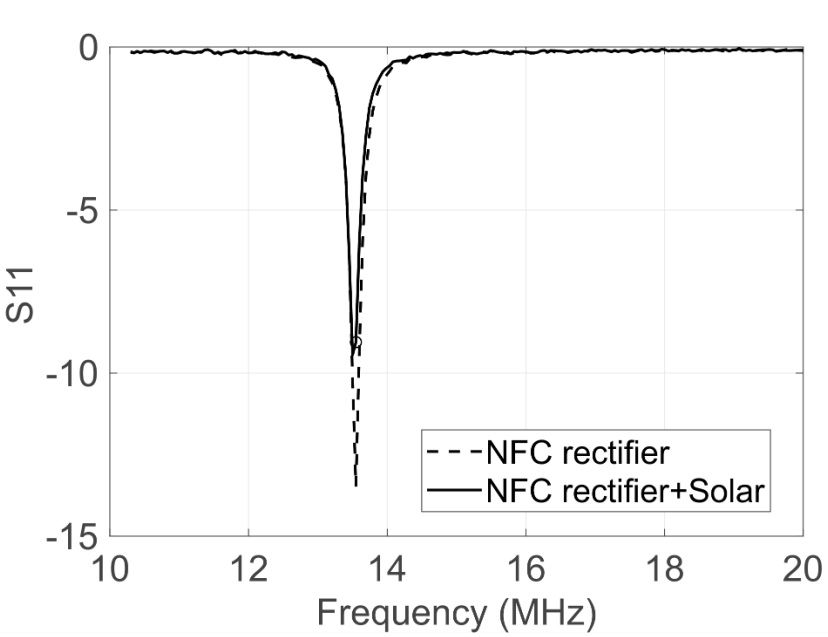
- L_c: Antenna inductance (918 nH)

Measured with VNA

- C_{IC}: Internal rectifier capacitance (4 pF)
- C_p : Layout parasitic capacitance

Find optimal C_{tune} caps (MATLAB script)

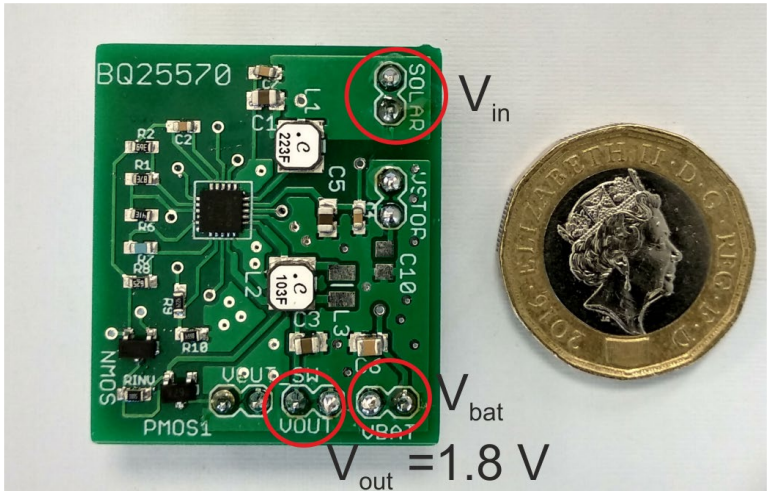
C_tuneA1, C_tuneB1: 300 pF
C_tuneA2, C_tuneB2: 18 pF
Validate the results with VNA

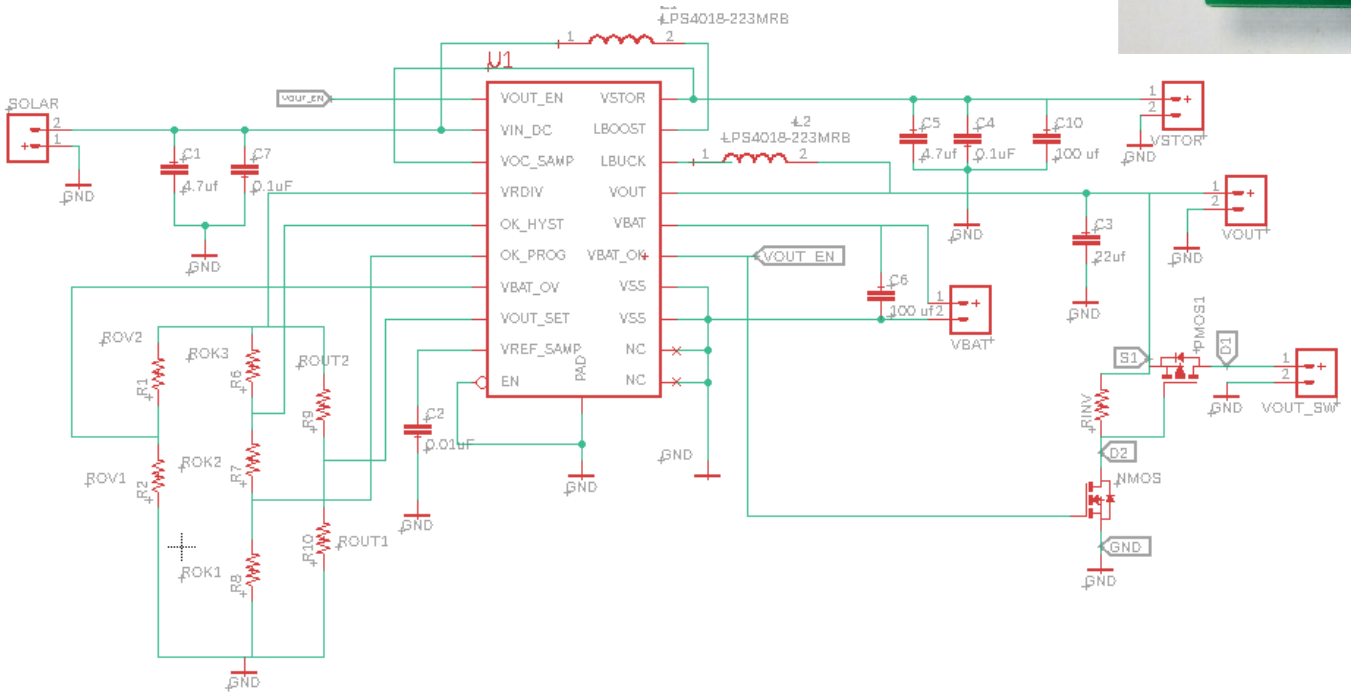


Boost Converter

Commercial Power management IC BQ25570

- Connected at the output of the rectifier
- Maximum power point tracking (MPPT)
- Fully programmable voltage thresholds with resistors
- Buck converter provides fixed output voltage: 1.8 V





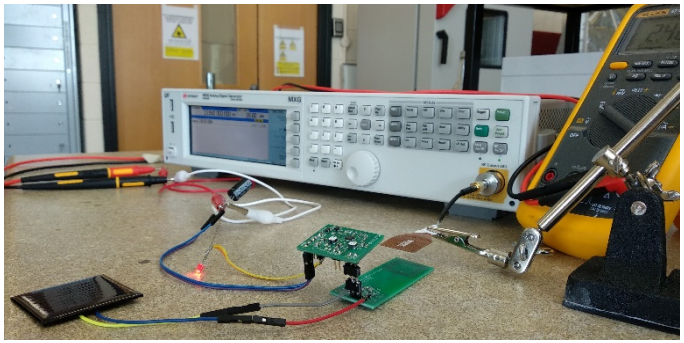
NFC harvester testing

Use for signal generator:

- Huawei P8 lite smartphone (with NFC communication)
  - ➢ 3 dBm periodic signal
- Signal generator

Boost converter output connected with a 1000 pF cap

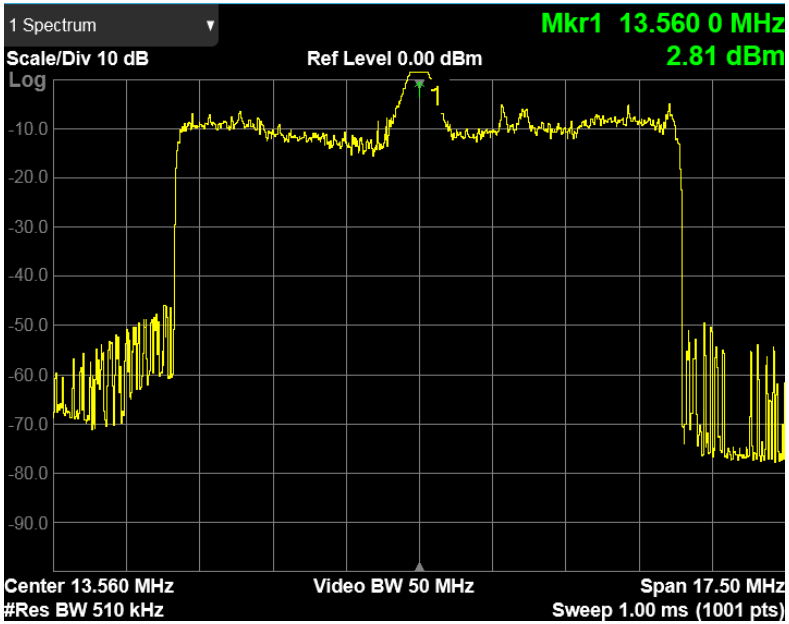
Use as Load a 20 mA LED

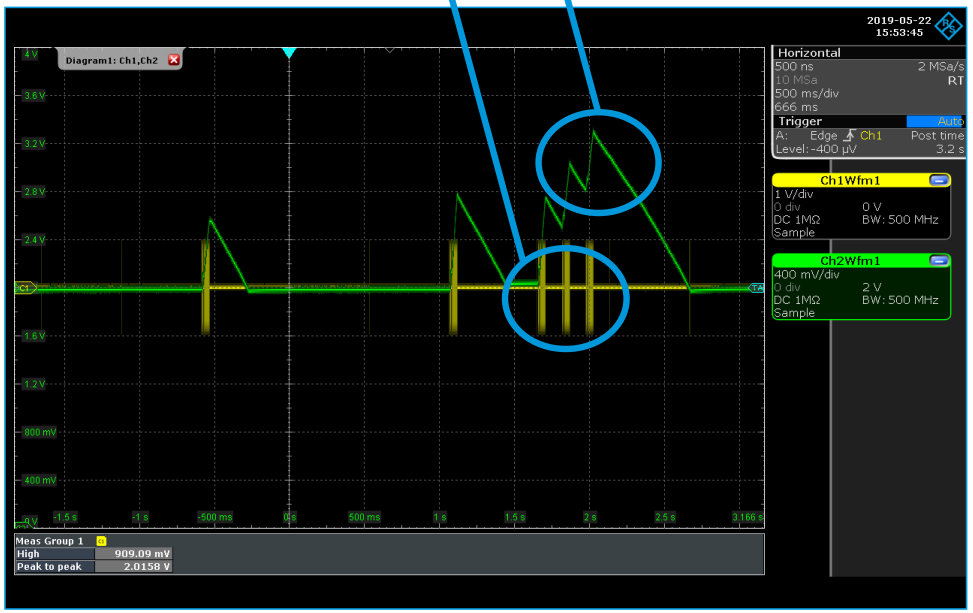


Voltage across the load

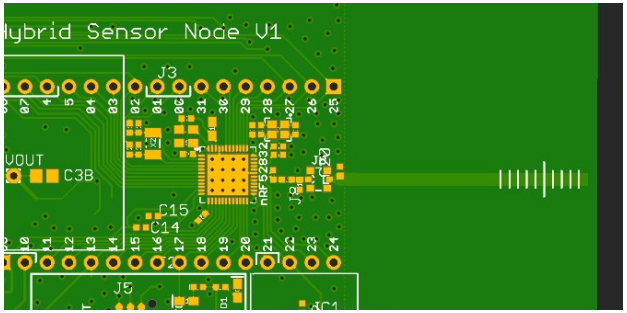
Smartphone NFC signal

Smartphone NFC signal “Max hold” reading





Hybrid Sensor Node



Printed Antenna…

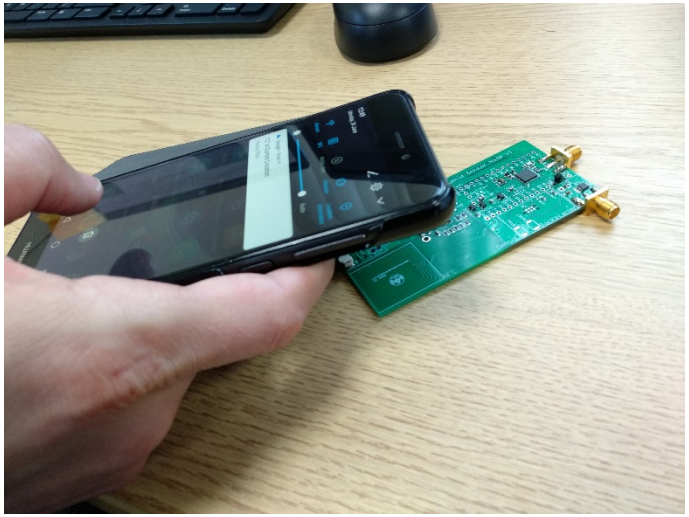
In progress…. For agriculture Apps!

Features:

- Communication: Bluetooth 4.2 + **Backscatter**+ NFC
- Battery free…**solar panel** & **Supercap** instead of battery
- Low cost **first** ***prototype***: ~20 USD/sensor node

Sensors:

- **Pheromone Sensor Interface**
- Temperature
- Humidity
- Atmospheric Pressure
- Photodiode
- Gyroscope
- Leaf Humidity



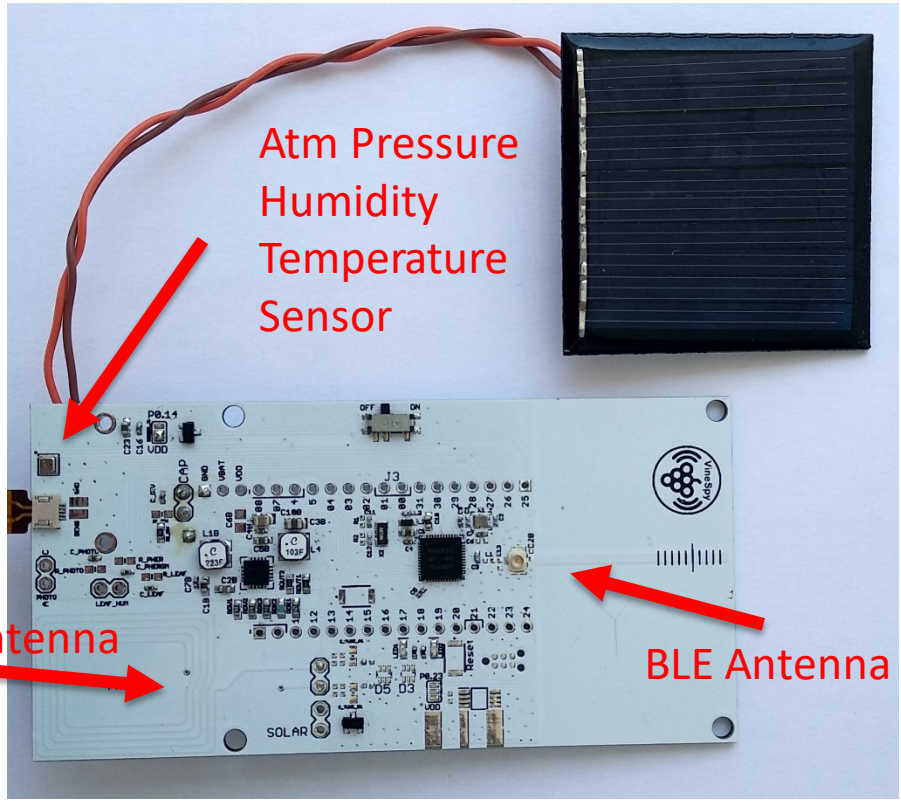
Charging with NFC…

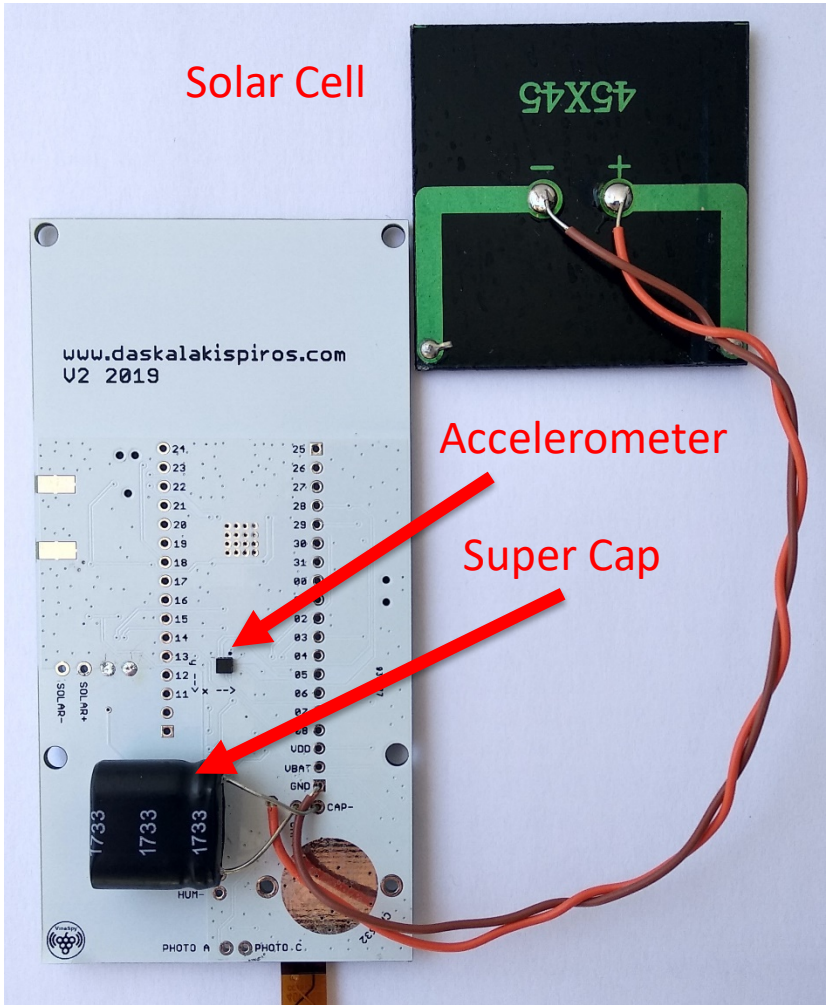
Hybrid Sensor Node Prototype

Extra features:

- Integrated NFC and BLE antenna on the same PCB (**FR4 substrate**)
- NFC wireless power Transfer Capability
- Low Power:

Continuous operation during the night

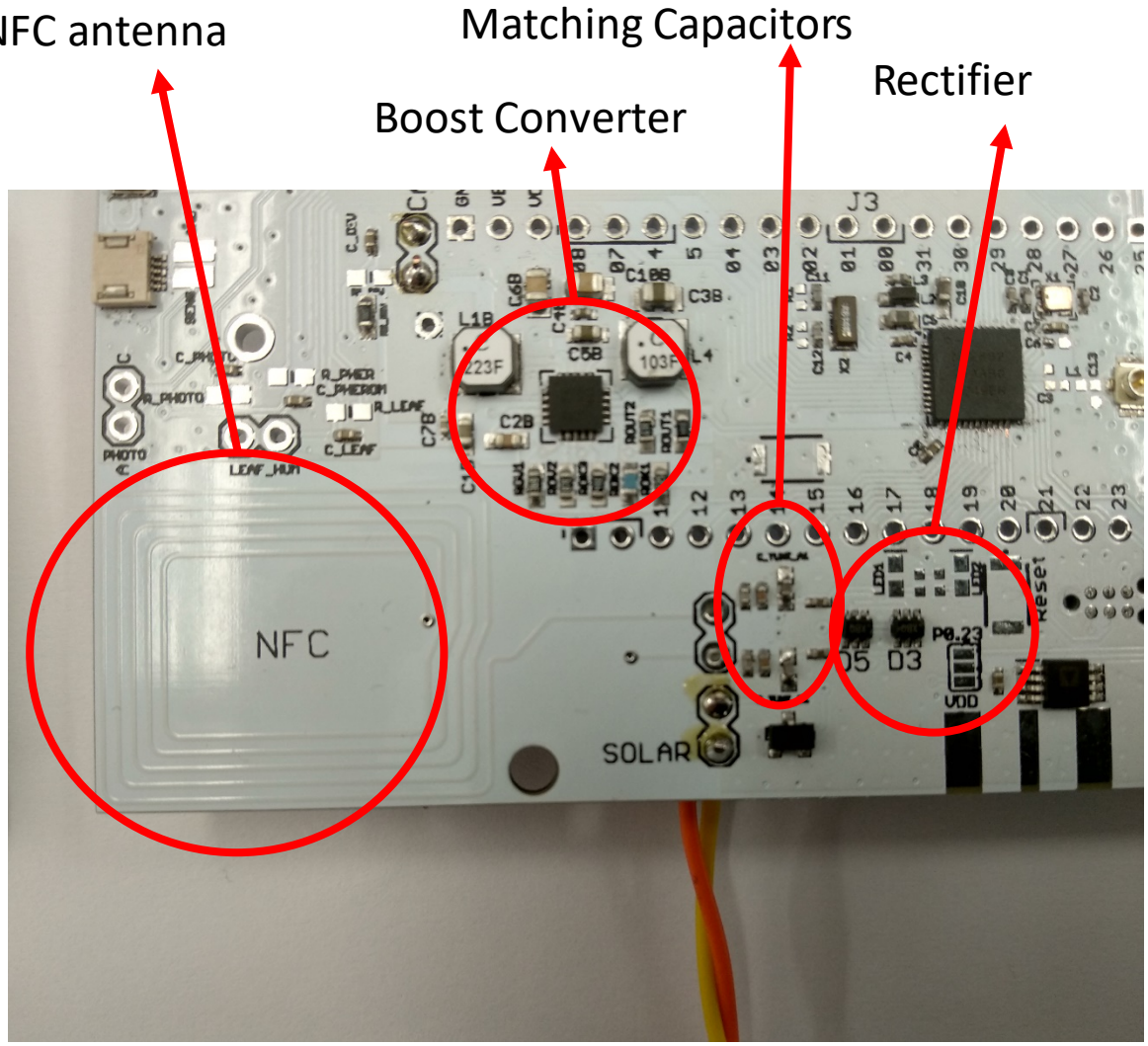




New version of NFC harvester

Integration in one board

- NFC antenna
- Boost Converter
- Solar panel
- Rectifier
  - new diode: SMS3923-081LF



Future Goal: Measurements + Extraction of Circuit Efficiency

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Thank you for your attention !

Questions ?

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