



# IC1301 -WiPE

## Wireless Power Transmission for Sustainable Electronics

- Ultra-low Cost  
Environmental Sensing  
with Scatter Radio and  
WIPE Opportunities

Aggelos Bletsas ([aggelos@telecom.tuc.gr](mailto:aggelos@telecom.tuc.gr))

Associate Professor

School of ECE, Technical Univ. of Crete



# Technical Univ. of Crete (TUC)



- 130 Faculty members:  
Electronic & Computer Engineering,  
Industrial Engineering,  
Environmental Engineering,  
Architecture,  
Mineral Resources Engineering.

- Technical Univ. of Crete is #1 in terms of citations per journal publication among all Universities in GREECE!  
(#2 was Univ. of Crete)

Source: National Documentation Center  
<http://report03.metrics.ekt.gr/el/index>

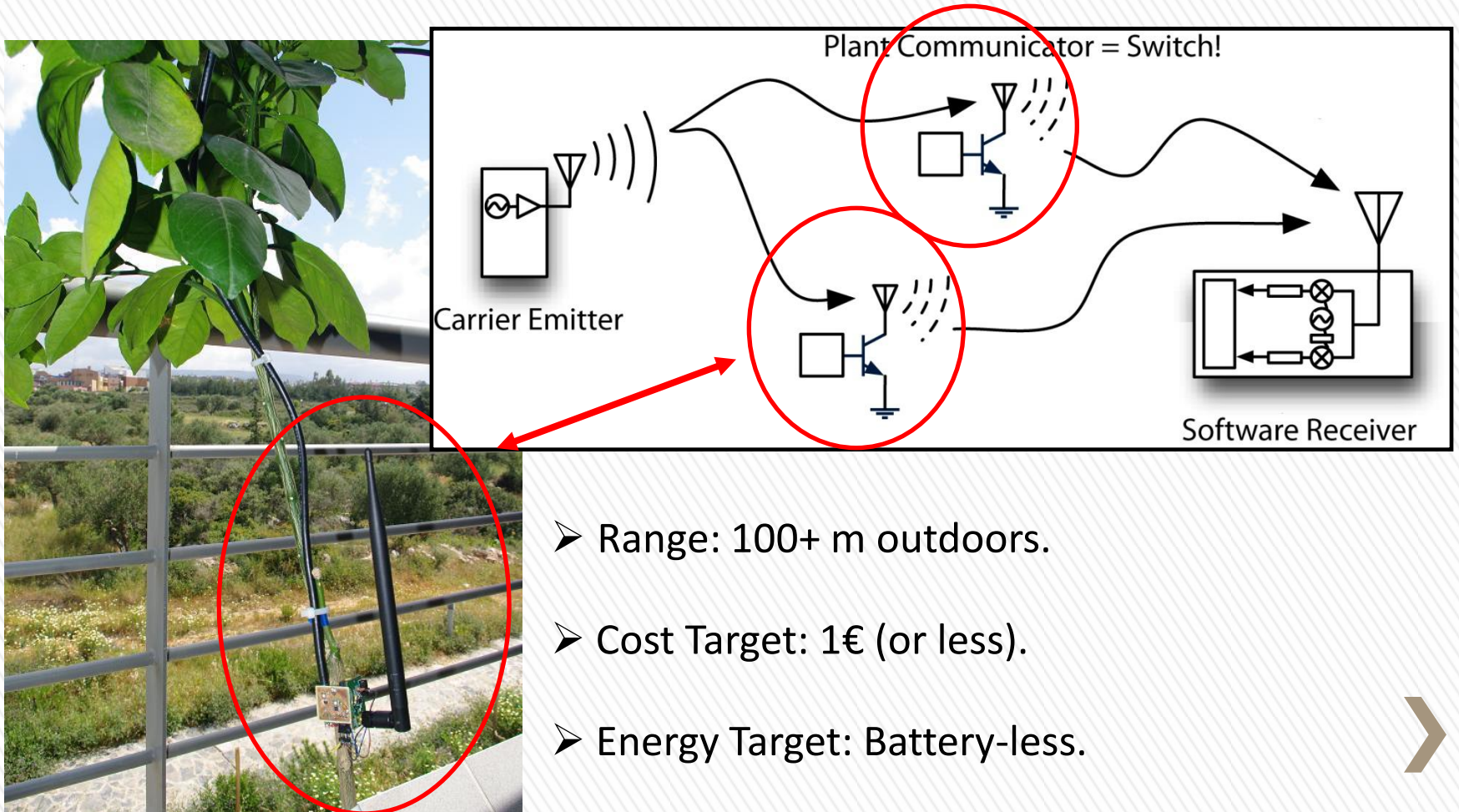




# Chania, Crete, Greece – Visit Us!



# Environmental Sensing with Scatter Radio



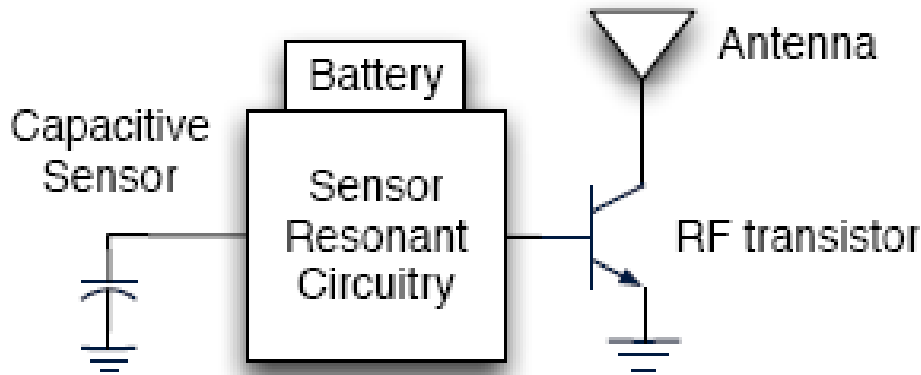
# Outline

- Environmental Humidity Sensing [1]
- “Plant is the sensor” Sensing
- RF Harvesting & WIPE Challenges





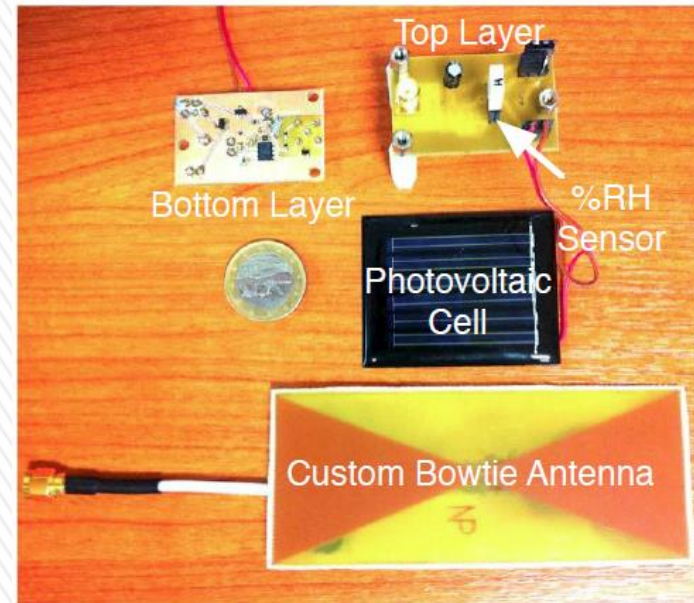
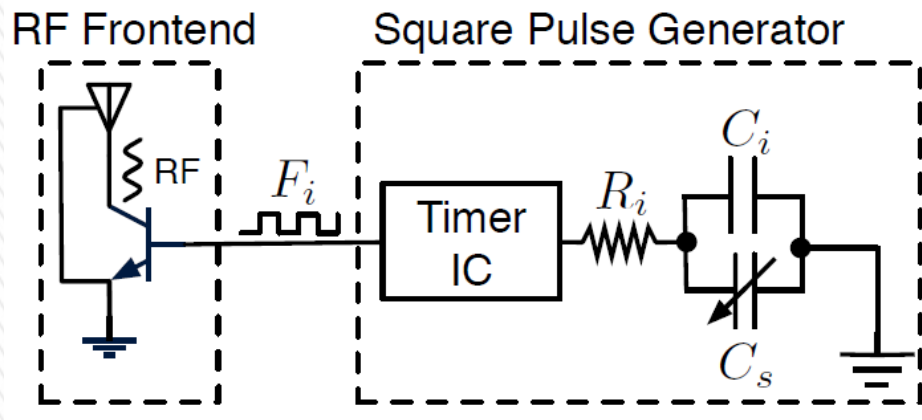
# Backscatter Humidity Sensing



- Principle: convert capacity changes to backscattered freq!
- Power Consumption: <math><1.6\text{ mWatt}</math> (ver 1), **220 $\mu$ Watt** (ver 3).
- Cost: ~3€ (quantity of 1)



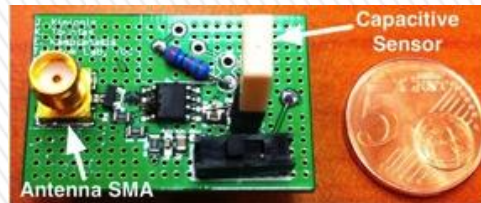
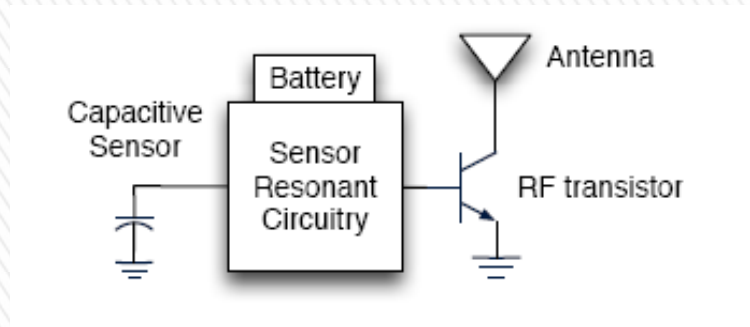
# Backscatter Humidity Sensing



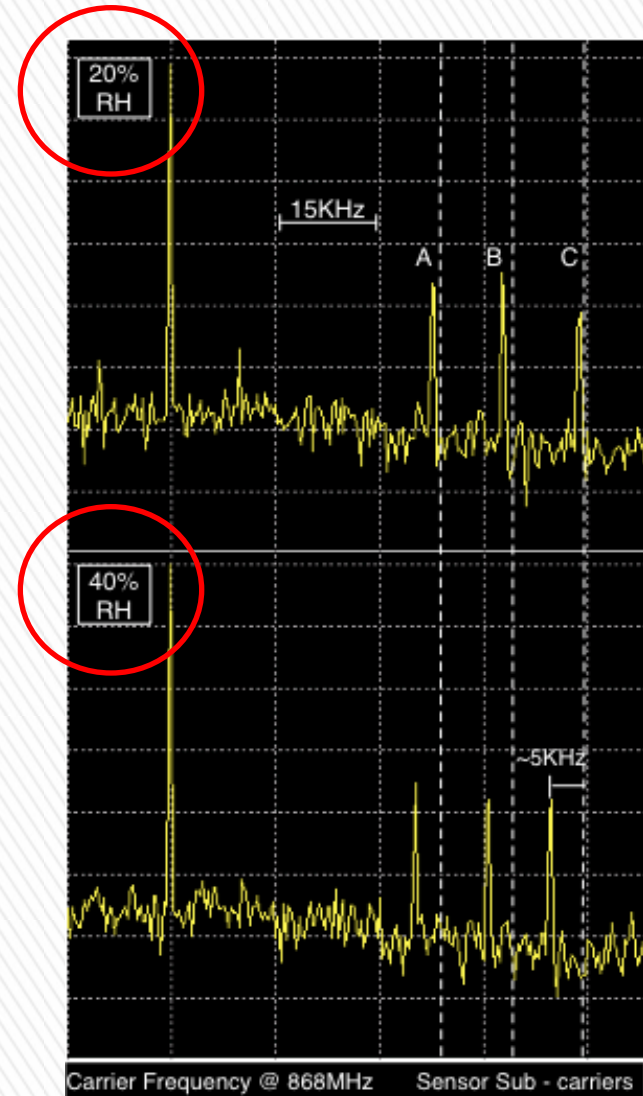
- Principle: convert capacity changes to backscattered freq!



# Backscatter Humidity Sensing (freq. domain)

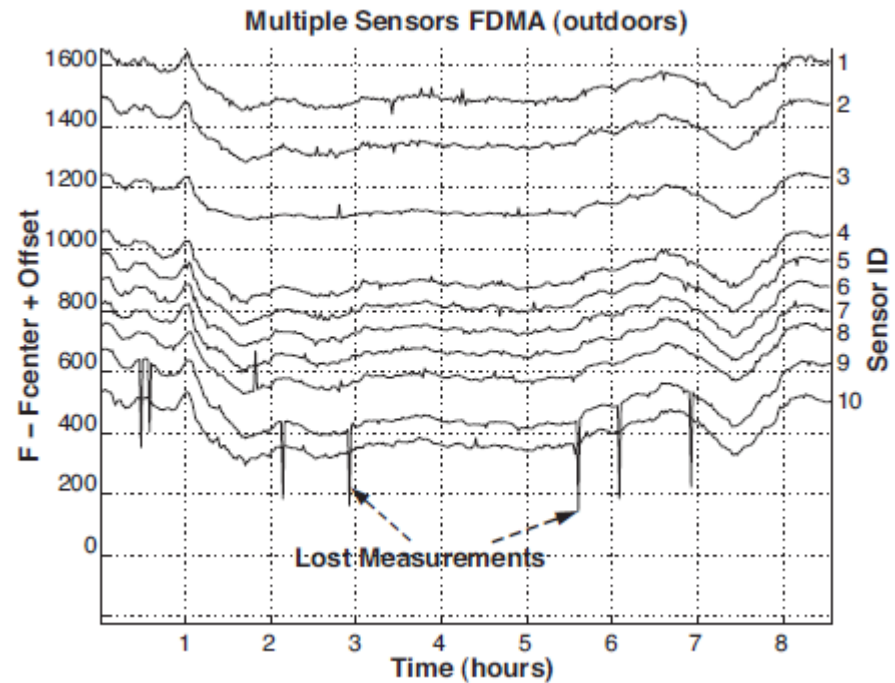
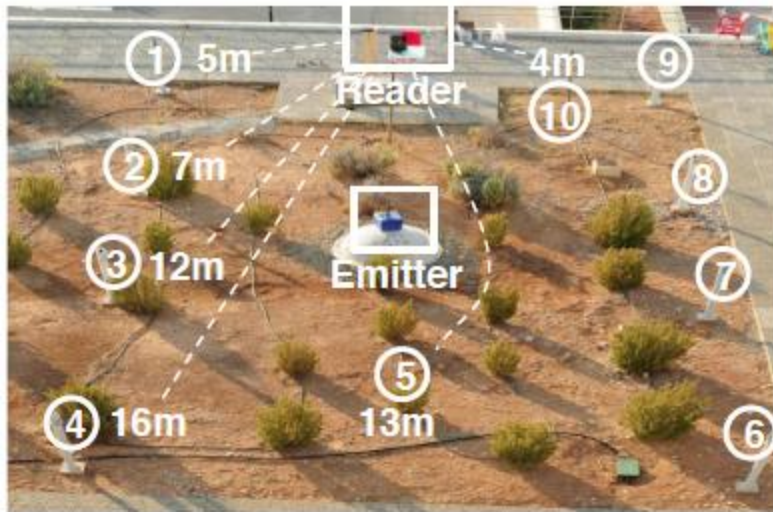


- Multiple sensors operating simultaneously (A, B and C depicted)!
- 2-5kHz per sensor; accuracy/bandwidth tradeoff.





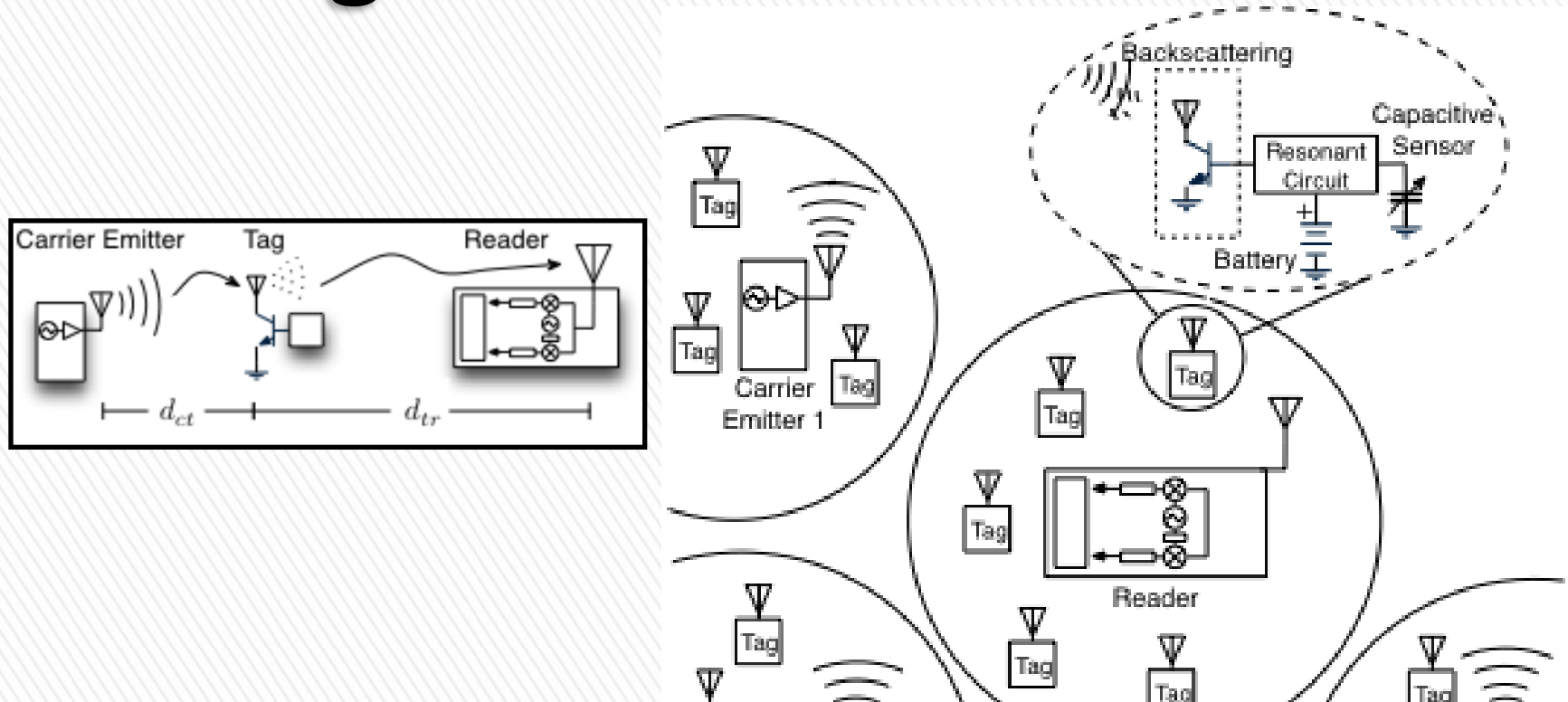
# Backscatter Humidity Sensing (time domain)



- time vs subcarrier frequency for 10 sensors, simultaneously operating.



# Backscatter Humidity Sensing



- Emitter-Sensor, Sensor-Reader Range: 10m, 50m (v1), 100m (v2)! (for 0.9 %RH RMS error @30 %RH)!
- New designs underway with further increased range!

# Outline

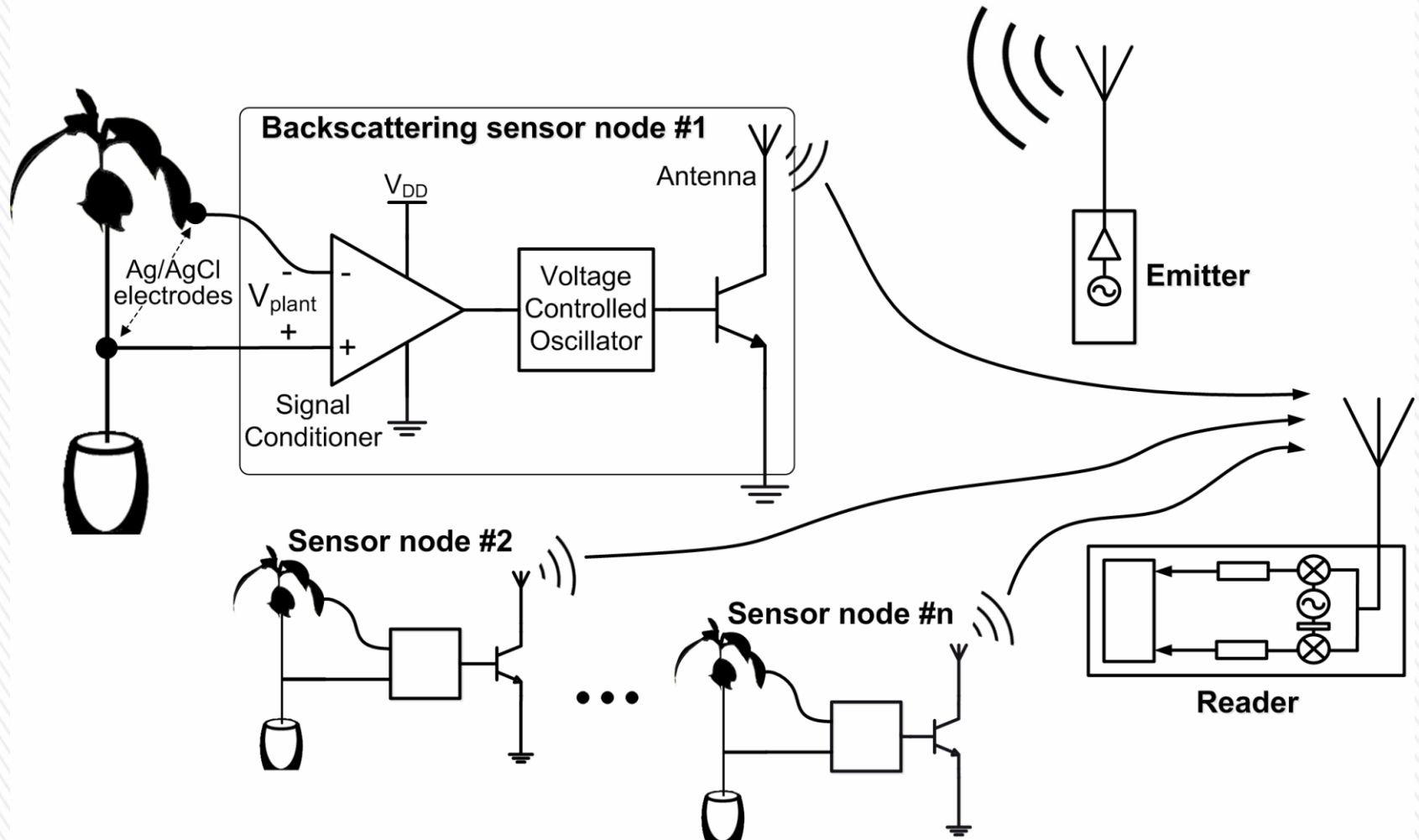
- Environmental Humidity Sensing
- “Plant is the sensor” Sensing [2]
- RF Harvesting & WIPE Challenges



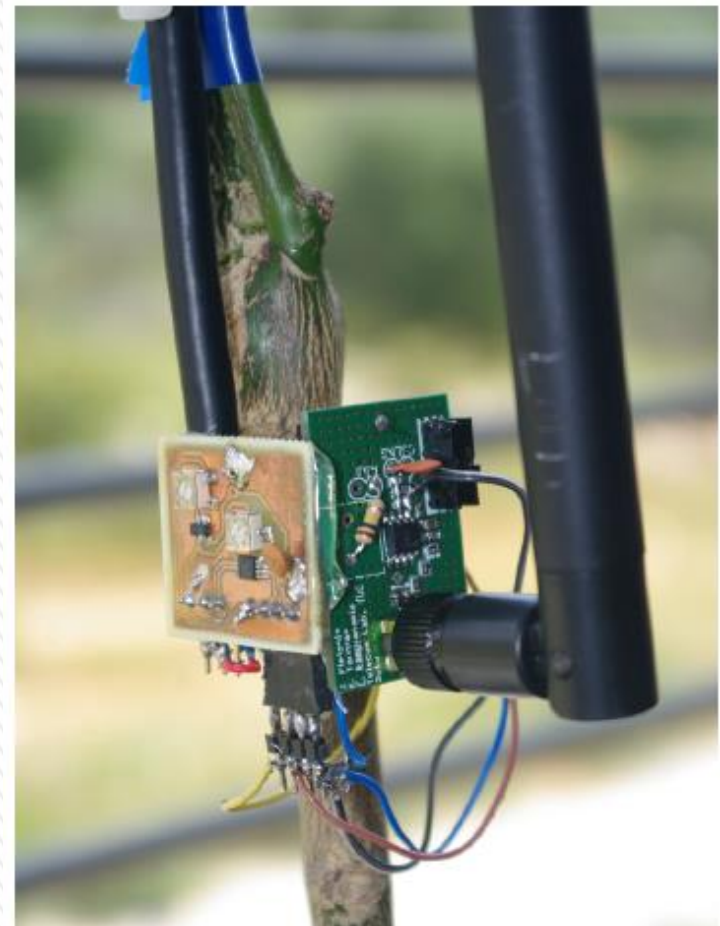
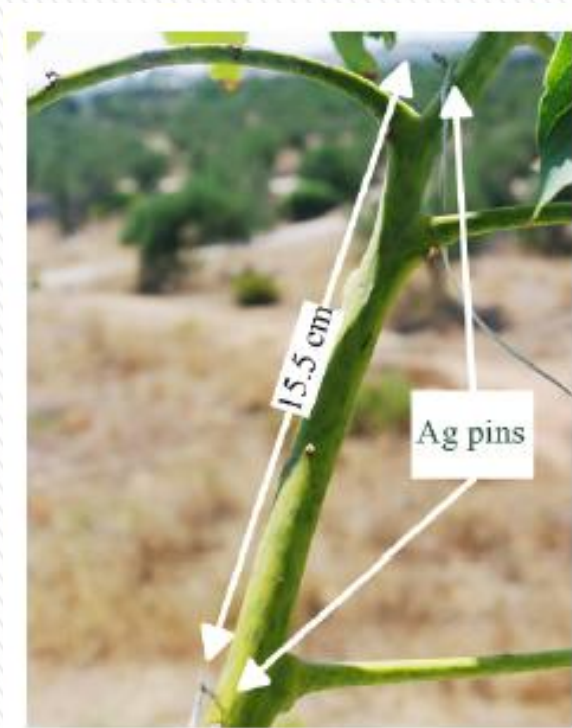


# Backscatter Sensing: Plant is the sensor!

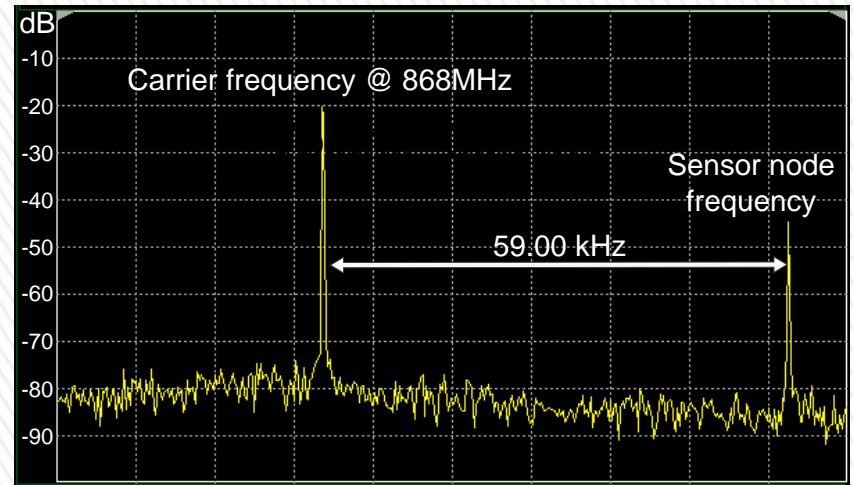
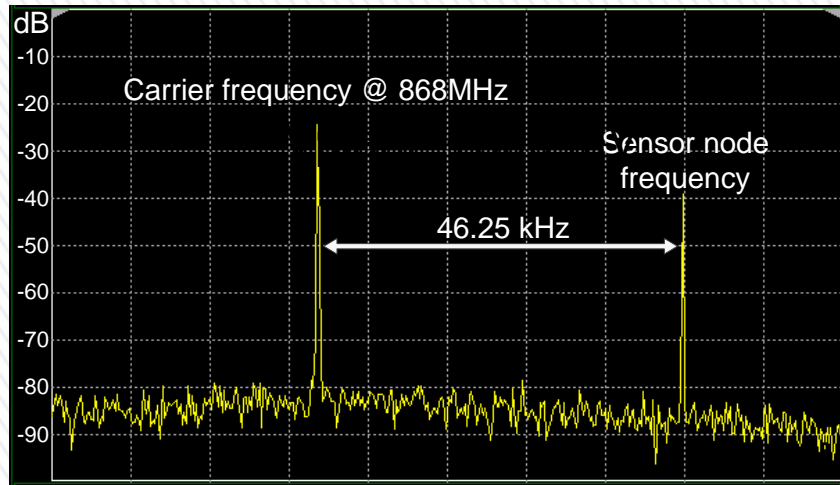
- Replace capacitor/timer circuit with a low-power VCO!



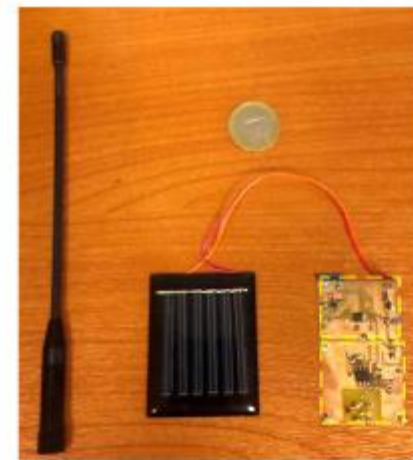
# Backscatter Sensing: Plant is the sensor!



# Backscatter Sensing: Plant is the sensor!



- Plant Voltage to freq. conversion.
- BW/sensor: 12.75kHz.
- Consumption: **240  $\mu$ Watt.**



← Signal-conditioning unit

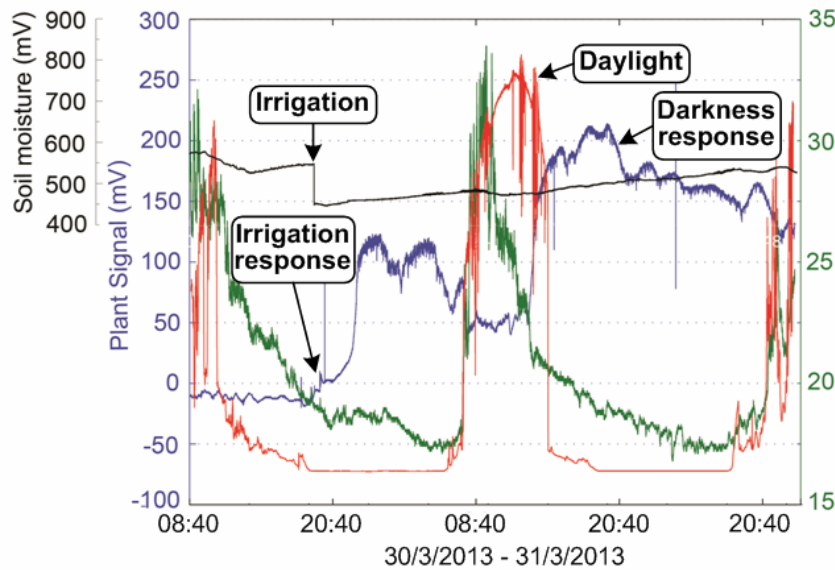
← Voltage Controlled Oscillator

↑ Antenna    ↑ Solar panel    ↑ Sensor node

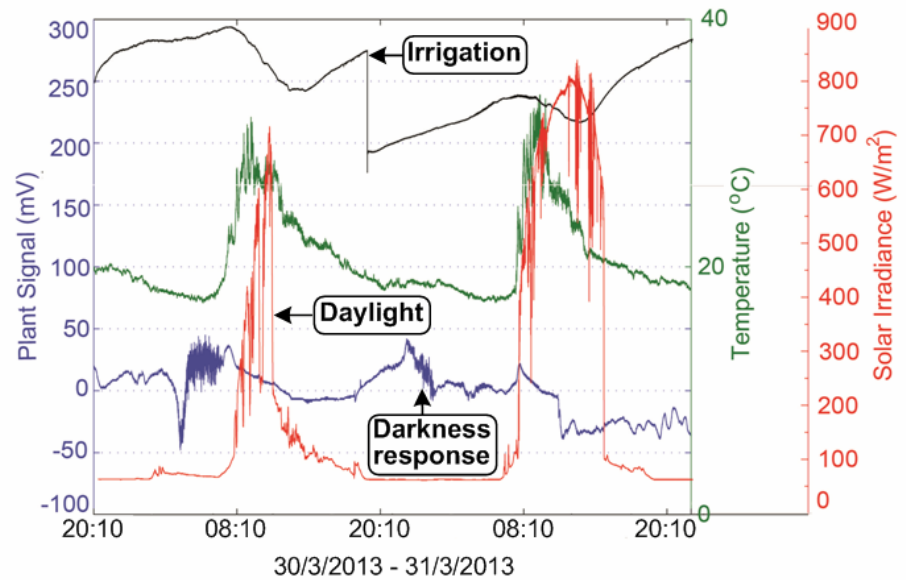


# Backscatter Sensing: Plant is the sensor!

Avocado tree



Orange tree



- Plant voltage is correlated with environmental conditions and soil moisture.
- 2-days data...

# Greenhouse Deployment



**Blaise** Backscatter Networks for Large-Scale

WSN Monitoring   WSN Administration   Notifications Center   About Project   Contact Us

From: 03/04/2014 12:01 AM   Show: Humidity Sensors: Time Interval   Auto-refresh: 30 sec   REFRESH  
Until: 03/04/2014 07:54 PM   Export: Measurements to CSV   Call of WSN: All

**WSN Map: Deployed sensors for environmental sensing**

WSN Map   WSN Sensor List

The screenshot shows a web interface for monitoring a WSN. On the left, a map displays the layout of the greenhouse with various sensor locations marked by icons. On the right, a line graph titled "Humidity VS. TIME of Environmental Sensors" plots humidity (%) on the y-axis (ranging from 45 to 105) against time on the x-axis (ranging from 00:00 to 20:00). Two data series are shown: Sensor - 5 (orange line) and Sensor - 6 (grey line). Both sensors show a significant drop in humidity starting around 08:00, with Sensor - 5 reaching a minimum of approximately 50% and Sensor - 6 reaching approximately 55% before both begin to recover.

... and reporting to a web site, real time!



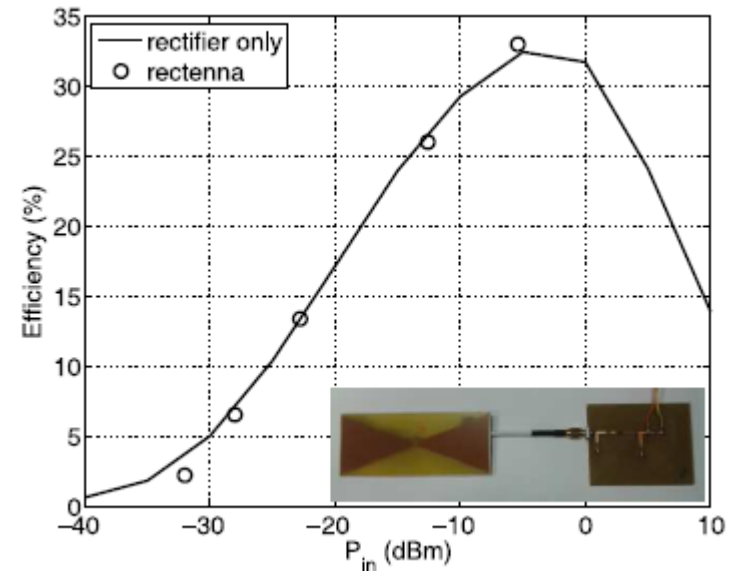
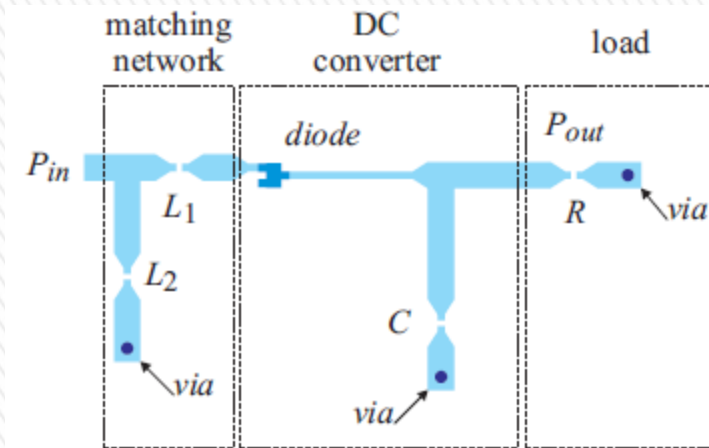
# Outline

- Environmental Humidity Sensing
- “Plant is the sensor” Sensing
- RF Harvesting [3] [4]  
& WIPE Opportunities





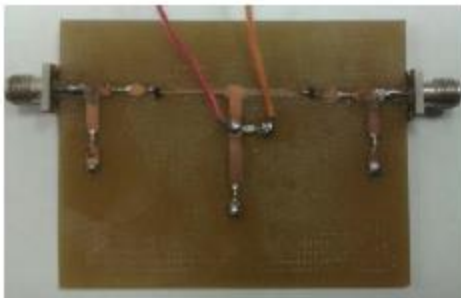
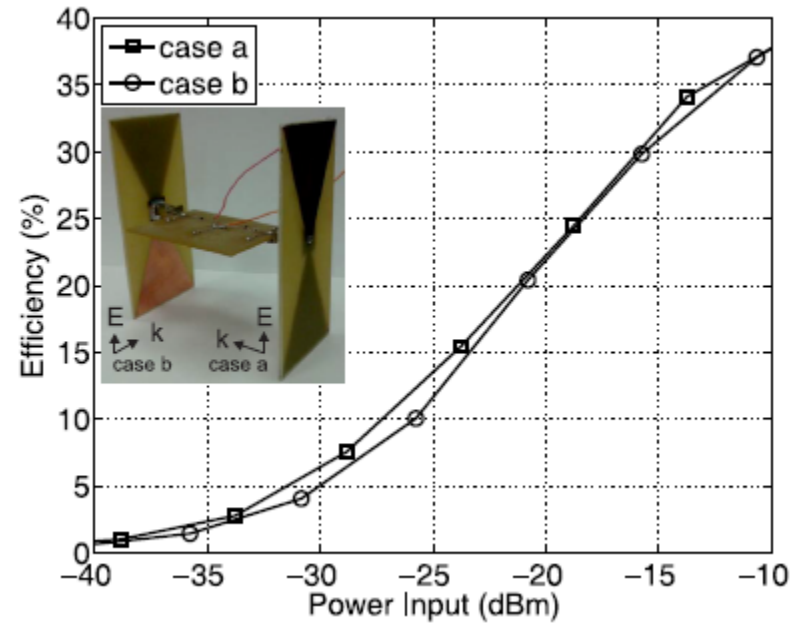
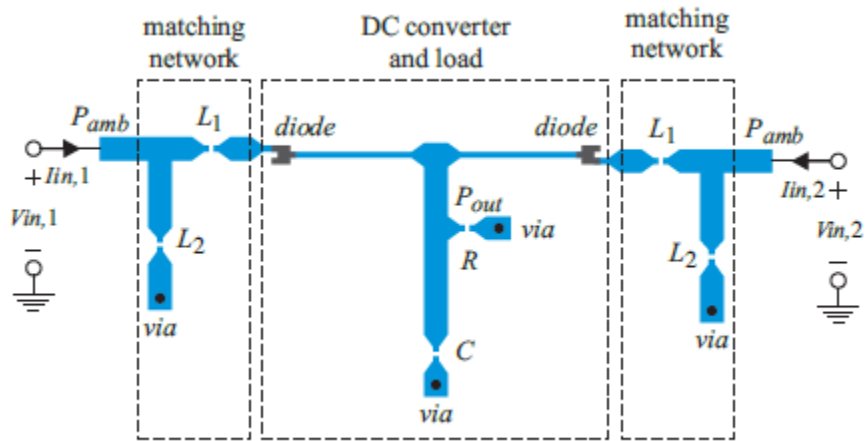
# (Low-cost) FR4 microstrip Rectenna



- Efficiency @ -10dBm input: 30%
- Efficiency @ -20dBm input: 17%



# (Low-cost) FR4 microstrip Rectenna Grid



- Similar efficiency but larger harvested power:  
 -8.7 dBm at load @ -30 dBm/cm<sup>2</sup>  
 -33.7 dBm at load @ -50 dBm/cm<sup>2</sup>

# WIPE Opportunities

- ❑ (+) ...environmental sensing = ULTRA LOW duty-cycle (100msec/60secs)!
- ❑ (-)...need to operate in smaller ambient RF density...
- ❑ (+) ...can trade harvesting efficiency with sensitivity...
- ❑ (+-)...perhaps, hybrid modes with RF harvesting need to be exploited (solar, thermal, wind etc)!
- ❑ (+++)...need you!



# References

- [1] E. Kampianakis, I. Kimionis, K. Tountas, C. Konstantopoulos, E. Koutroulis, A. Bletsas, "Backscatter Sensor Network for Extended Ranges and Low Cost with Frequency Modulators: Application on Wireless Humidity Sensing", IEEE Sensors, November 2013, Baltimore, USA. **Selected as one of the best papers of the conference.**
- [2] C. Konstantopoulos, E. Kampianakis, E. Koutroulis and A. Bletsas, "Wireless Sensor Node for Backscattering Electrical Signals Generated by Plants", IEEE Sensors, November 2013, Baltimore, USA.
- [3] S. D. Assimonis and A. Bletsas, "Energy Harvesting with a Low-Cost and High Efficiency Rectenna for Low-Power Input", IEEE Radio Wireless Week Conference, January 2014, Newport Beach CA, USA.
- [4] S. D. Assimonis, S. N. Daskalakis, and A. Bletsas, "Efficient RF Harvesting for Low-Power Input with Low-Cost 3D Rectenna Grid", submitted to European Microwave 2014.





# <http://blase.tuc.gr>

Thank you!



This work was supported by the **ERC-04-BLASE** project (“Backscatter Networks for Large-scale Environmental Sensing”), executed in the context of the Education & Lifelong Learning Program of General Secretariat for Research & Technology (GSRT) and funded through European Union-European Social Fund and national funds.

