



# Laboratory of Electronics Antennas and Telecommunications



## The Challenge of LoRaWan antenna Fabien Ferrero



# Outline

- Why antenna is important ? A practical example
- Antenna key parameters
- Low-cost Antenna Open Source project
- Micro-tracker Antenna Industrial project
- Conclusion and perspectives

# Antenna is important for communication range

- Smart Farming project in Pakistan
- Humidity sensors in a corn field
- Quart-wave antenna placed on a mast
- Communication range limited to 1 km ...



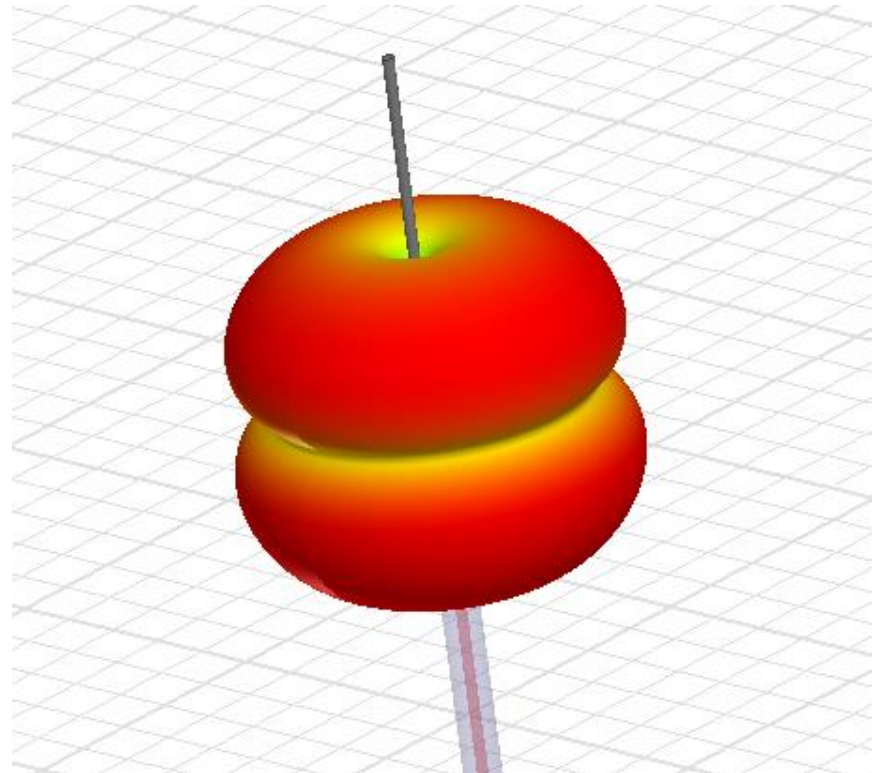
*project WaterSense UPPA/Nestlé*





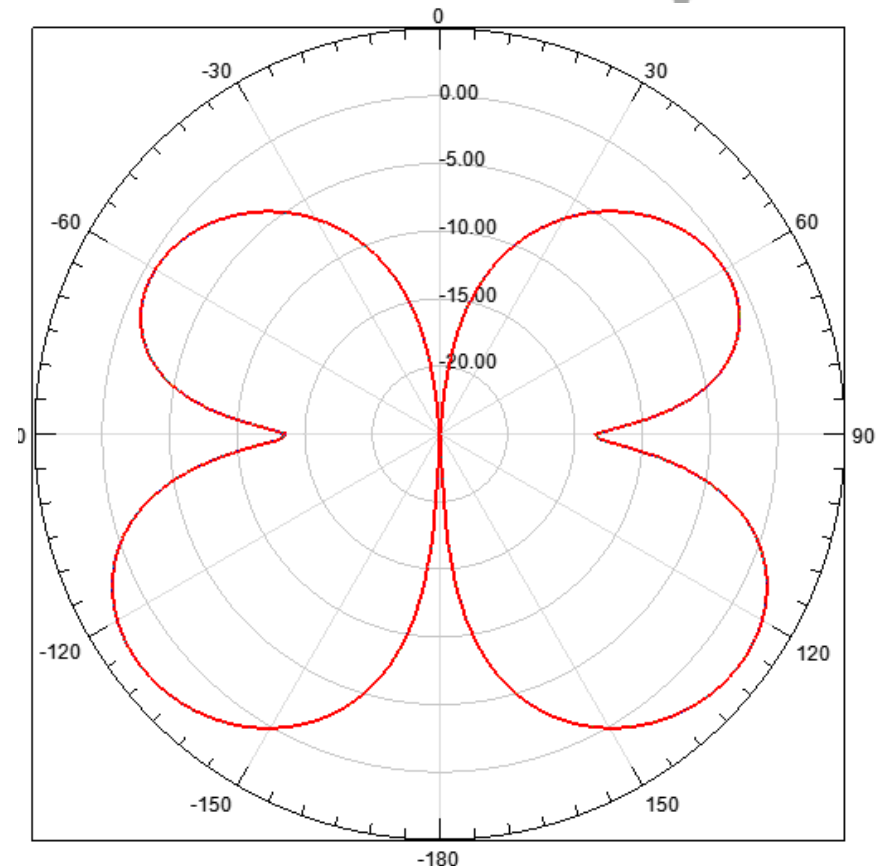
# Antenna is important for communication range

- Quarter-wave antenna need a ground plane
- EM simulation to analyse the radiation pattern



# Antenna is important for communication range

- Nulls in the radiation pattern
- Reduced Gain in the direction of the gateway (**-14 dBi**)
- Caused by current flowing on the shield on the coaxial cable
- The cable+antenna form an antenna array with destructive interference toward the horizon.
- Need to use a balanced antenna with a balun like a sleeve dipole



Total Gain Elevation plane

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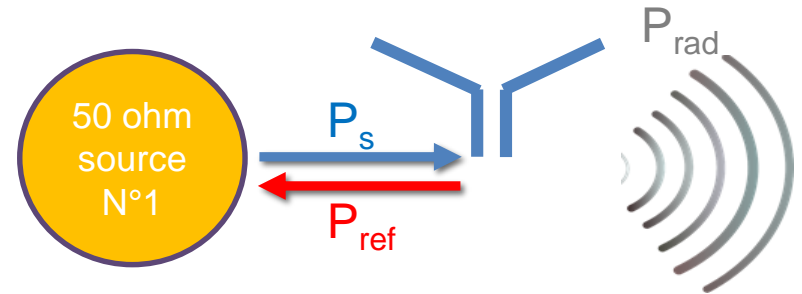
# Antenna performance indicator

## ■ Definition :

- $P_s$  : Power from the source
- $P_{ref}$  : Power reflected by the antenna
- $P_{rad}$  power radiated by the antenna

## ■ Antenna Performance Indicator

- Reflection coefficient
  - $S_{11}$  is usually plotted in dB scale
  - $S_{11}$  criteria from -10 dB to -6dB (90% to 75% transmitted power)
- Total Efficiency
  - Include **matching** and **radiation loss**
  - Can be plotted in linear or dB scale
  - 30-70% classically observed
- Gain
  - Include **matching**, **radiation loss** and **directivity**
  - Plotted in dBi



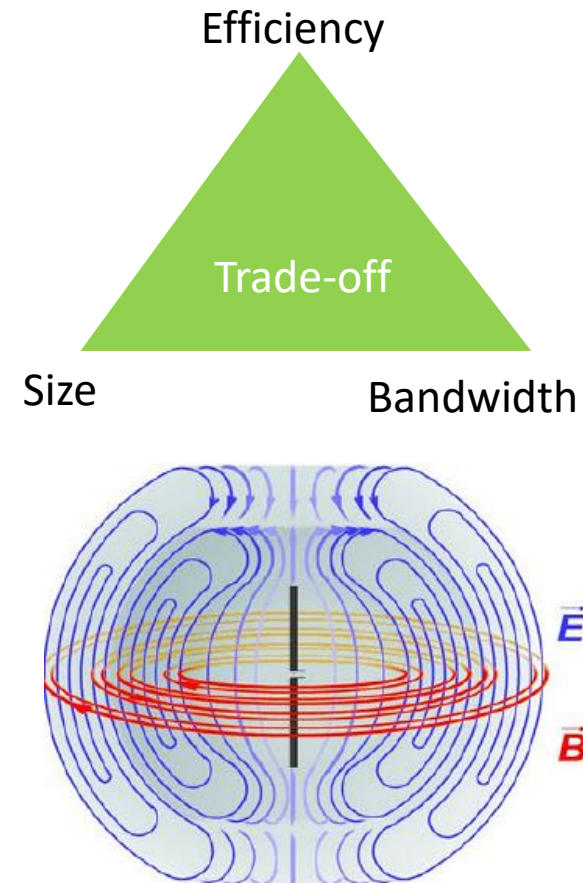
$$|S_{11}|^2 = P_{ref}/P_s$$

$$\eta_t = P_{rad}/P_s$$

$$G(\theta, \varphi) = \frac{G(\theta, \varphi)}{P_s/4\pi}$$

# Antenna key parameters

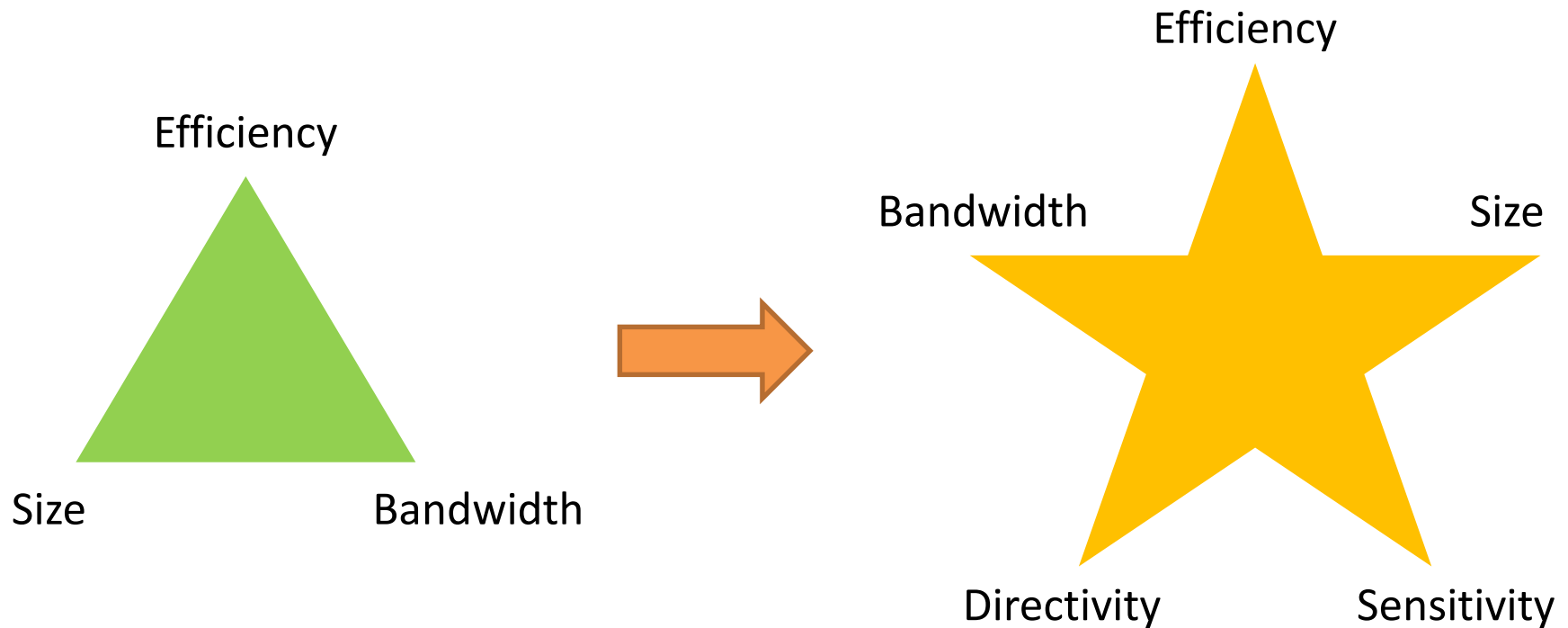
- Antenna is a resonant structure :
  - Input impedance is changing with frequency
  - Limited frequency bandwidth
  - Miniature antenna can have a low efficiency due to metallic or dielectric losses
- Antenna is an open structure
  - Compare to electronic components, antenna is strongly influenced by its surrounding environment
  - For integrated antenna, the electromagnetic wave is generated by the antenna and by the terminal ground plane
- Small antenna has to be carefully tuned





# Antenna key parameters

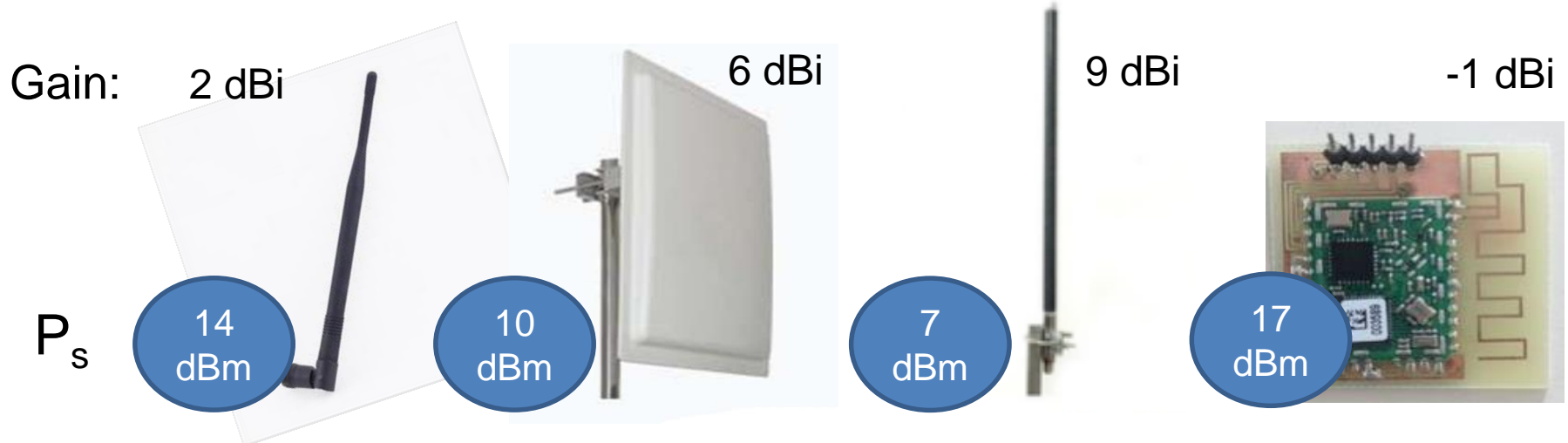
## Multidimensional Constraints



# How much can I radiate ?

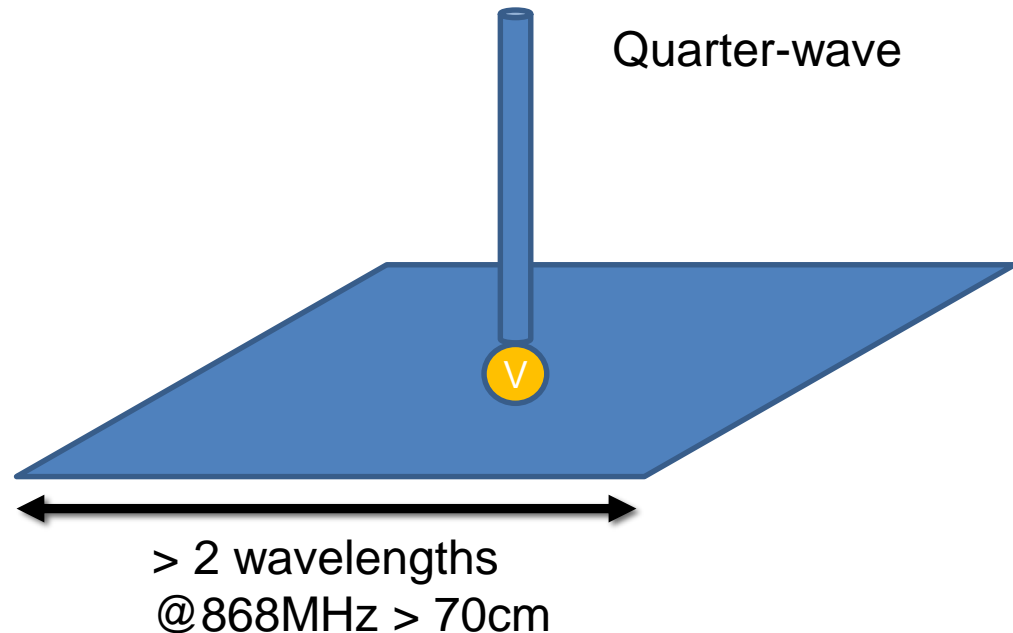
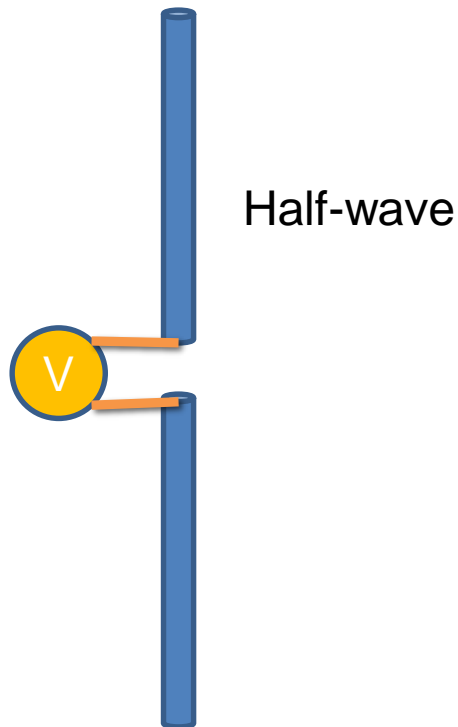
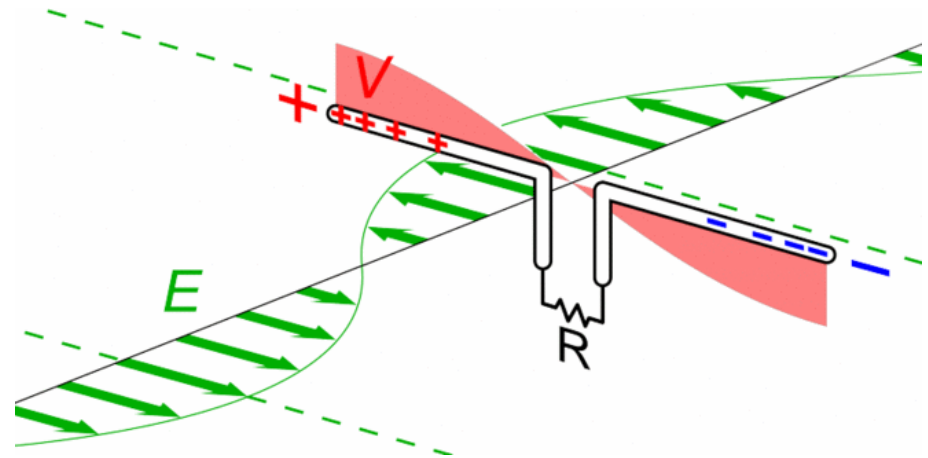
- Regulators defines the maximum radiated power in Equivalent Radiated Power (ERP)  
*In Europe : ERP @868MHz is **14 dBm***
- Effective Radiated Power** : amount of power applied to a half-wave dipole to give the same power density at a given point
- Effective Isotropic Radiated Power** : the reference is an isotropic radiator

$$\text{EIRP} = \text{ERP} + 2 \text{ dB}$$



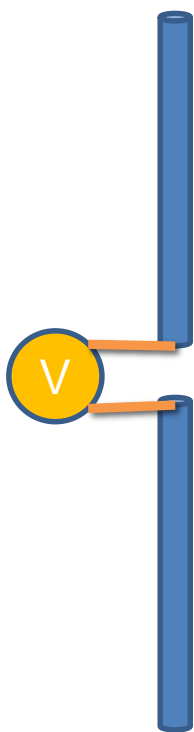
# Effect of terminal chassis

- Antennas can be:
  - Dual-pole : 2 parts will contribute to the radiation
  - Single-pole with a large ground plane

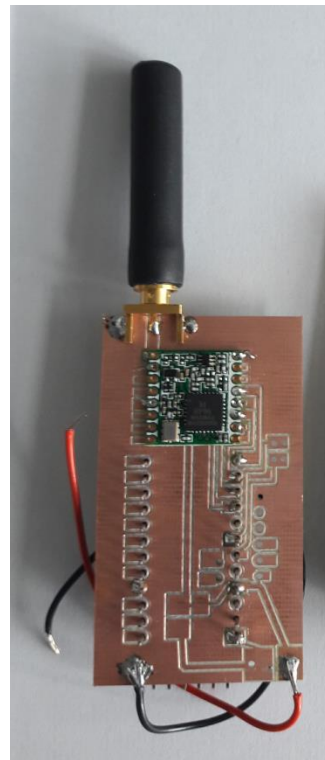


# Effect of terminal chassis

- In most of the case, you will have a dual-pole antenna

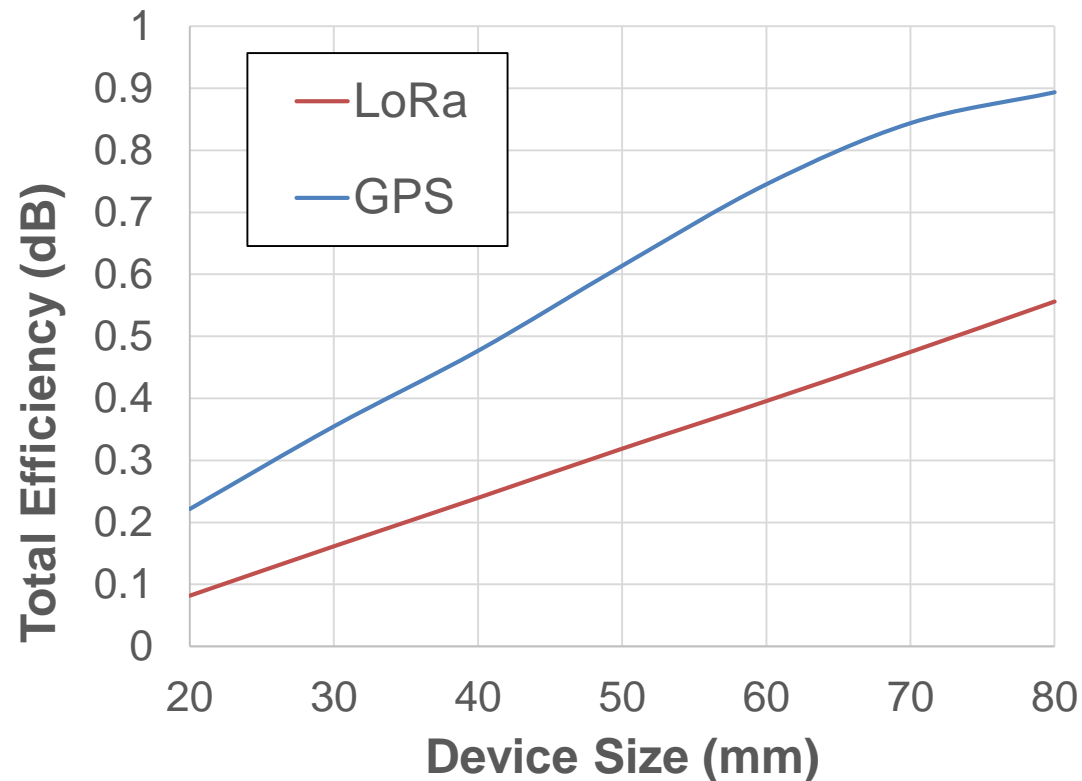
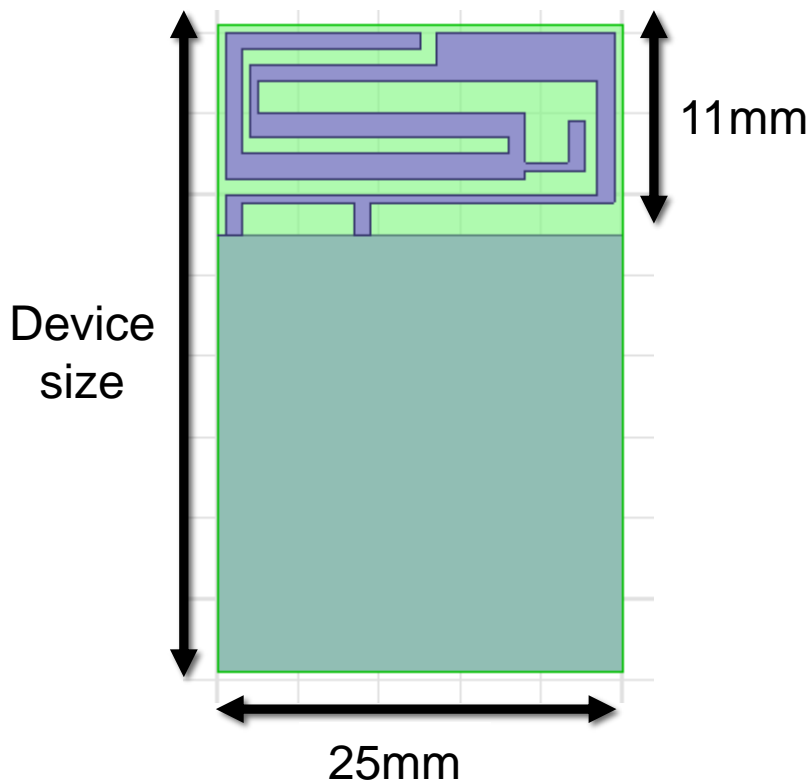


Half-wave



# Effect of terminal chassis

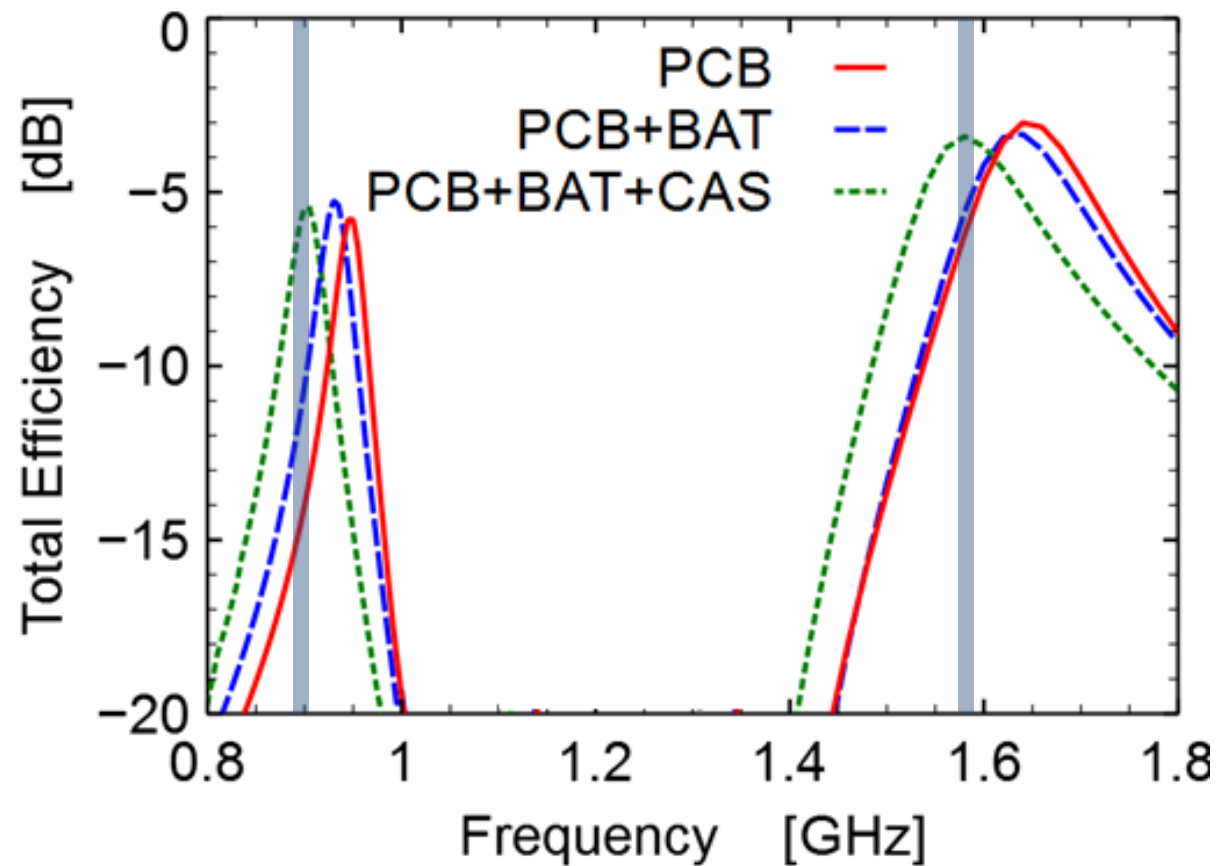
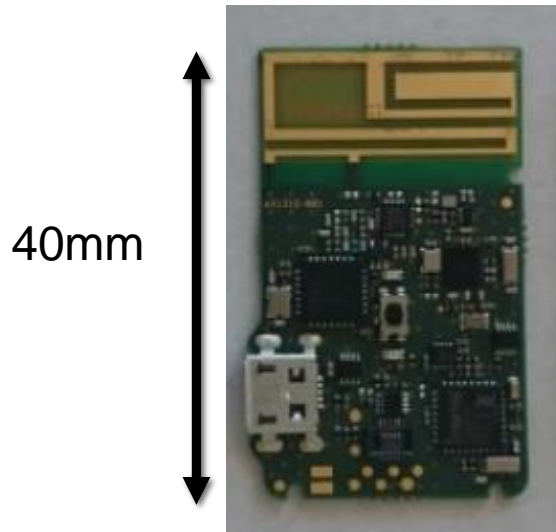
- LoRa (868MHz) and GPS (1575MHz) antenna on small terminal





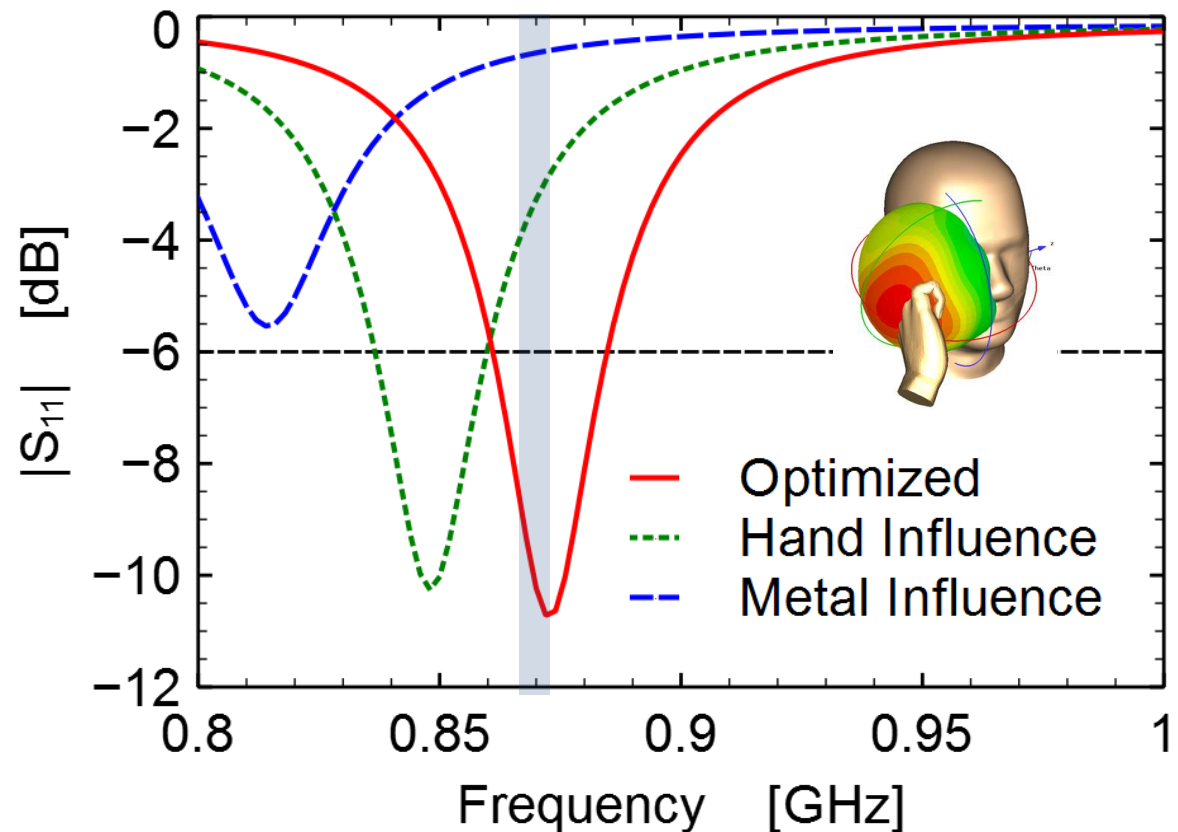
# Effect of the environment

Antenna are strongly influenced by the close environment like the battery or the terminal casing



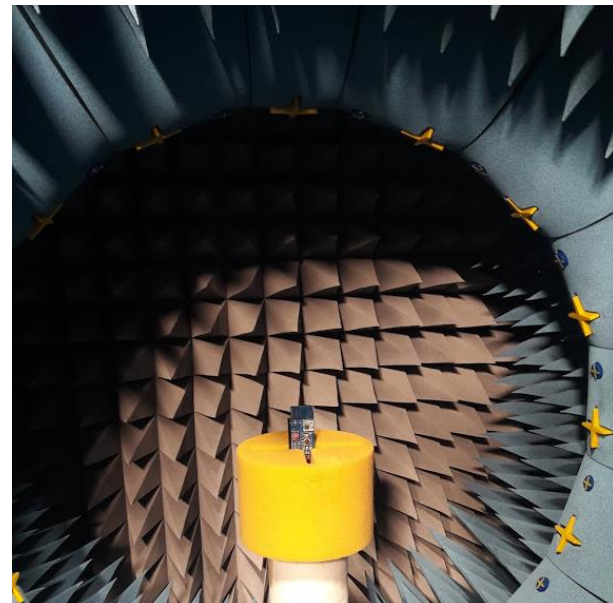
# Effect of the environment

Antenna are also influenced by the surrounding environment



# Antenna measurement

- Reliable antenna measurement is not an easy task
- Very hard to test antennas in a non-anechoic environment
- Cables has a large influence on the measurement
- Only Total Radiated Power (TRP) measurement can be trusted

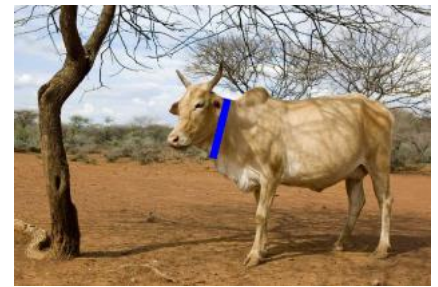


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# Design of cost efficient antenna @868MHz

- LoRa collar for Cattle Rustling applications
- Cost reduction
  - Remove RF connectors ( a SMA connector is 4\$)
  - Avoid external antenna (cost between 2 and 8 \$)
  - A PCB is needed for component integration
  - The cost for an extension of the PCB is negligible, so PCB integrated antenna is very cost efficient

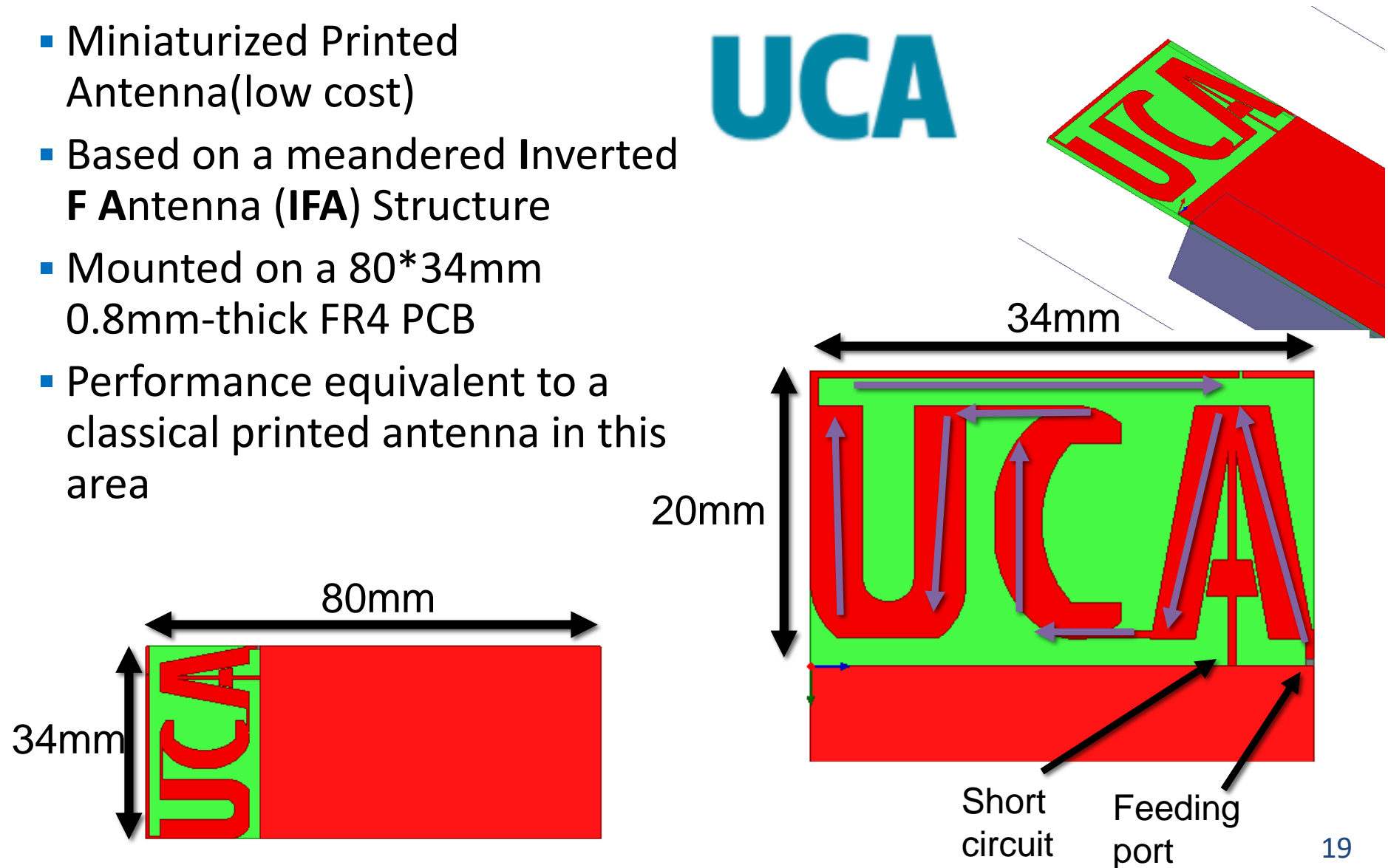




# UCA Antenna layout

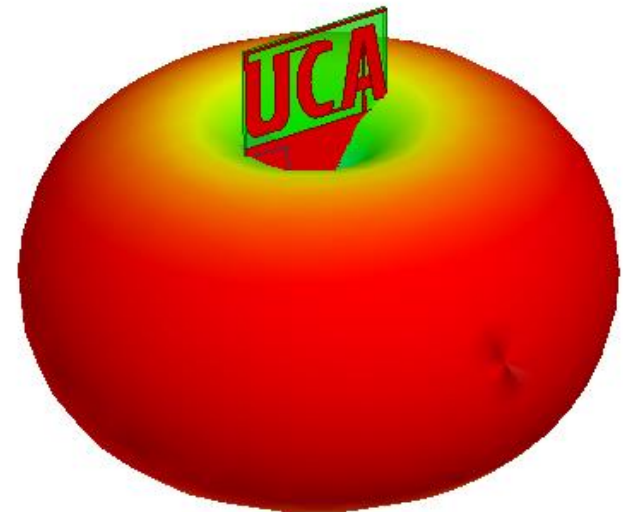
- Miniaturized Printed Antenna(low cost)
- Based on a meandered Inverted **F** Antenna (**IFA**) Structure
- Mounted on a 80\*34mm 0.8mm-thick FR4 PCB
- Performance equivalent to a classical printed antenna in this area

UCA



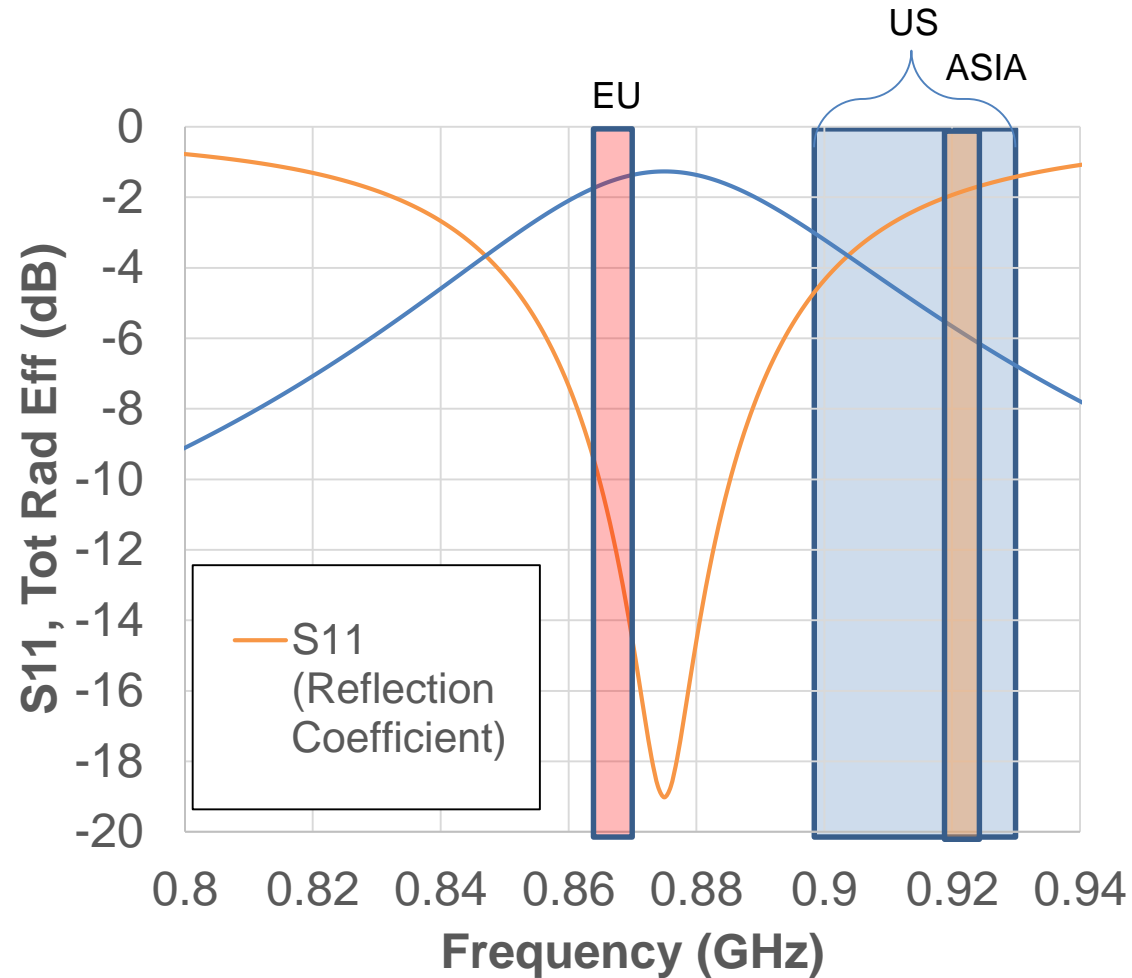
# UCA Antenna tuned for EU band

- Antenna simulation
  - Matched to 50 ohm
  - Bw = 30MHz (@-6dB )
  - -1.2 dB radiation efficiency (75%)
  - Dipole radiation pattern
  - 2.1 dBi peak directivity
  - 0.9 dBi peak Gain



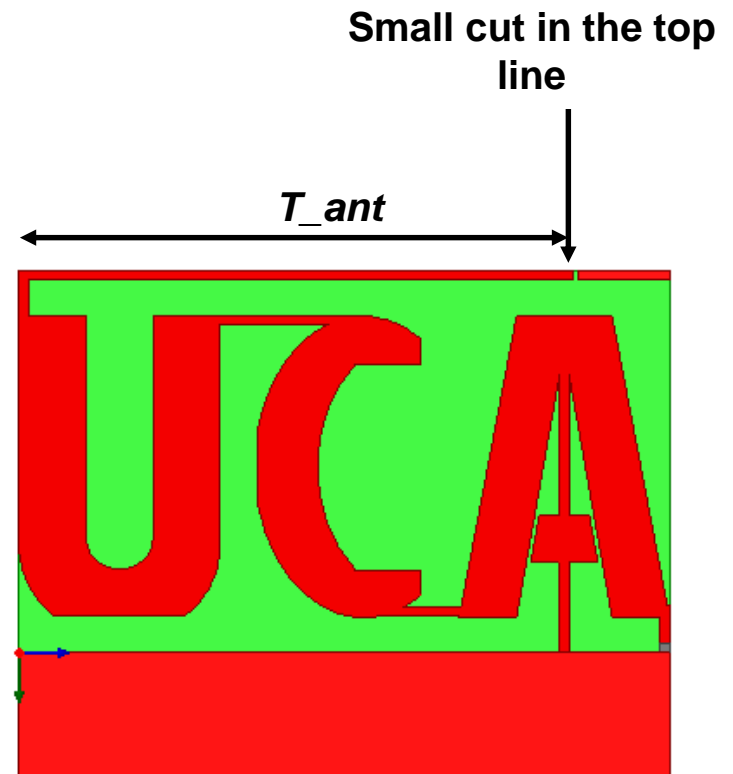
# UCA Antenna tuned for EU band

- Miniature antenna
  - Limited frequency bandwidth
  - If the antenna is matched for European band, the antenna has poor radiation performance in US and ASIA bands

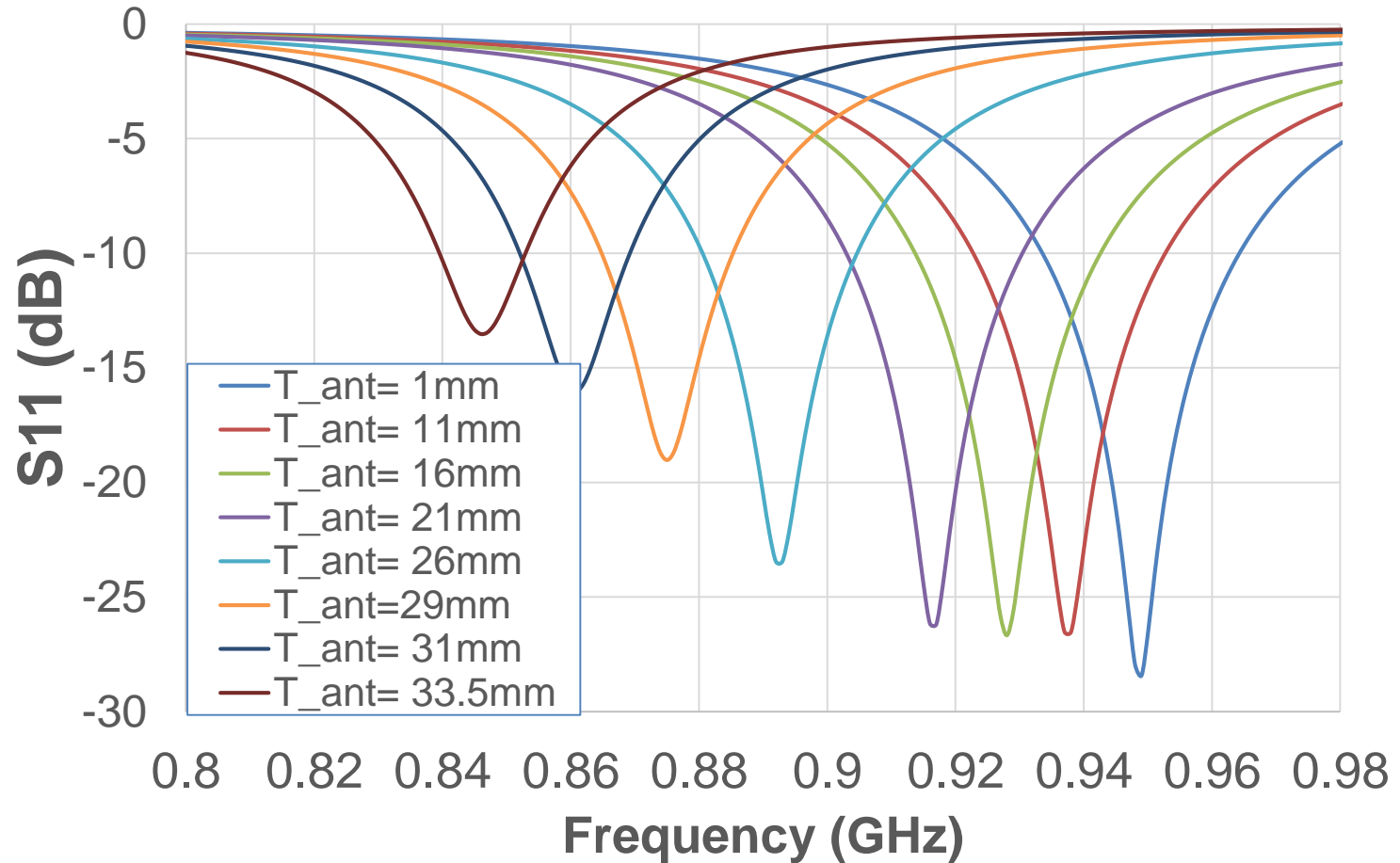


# Antenna design

- The antenna shape can be easily tuned to different frequencies
  - The top line can be cut at different position to change the antenna trace length
  - $T_{ant}$  parameter can be tuned from 0 to 34mm
  - Antenna resonance frequency can be tuned from 845 to 950MHz

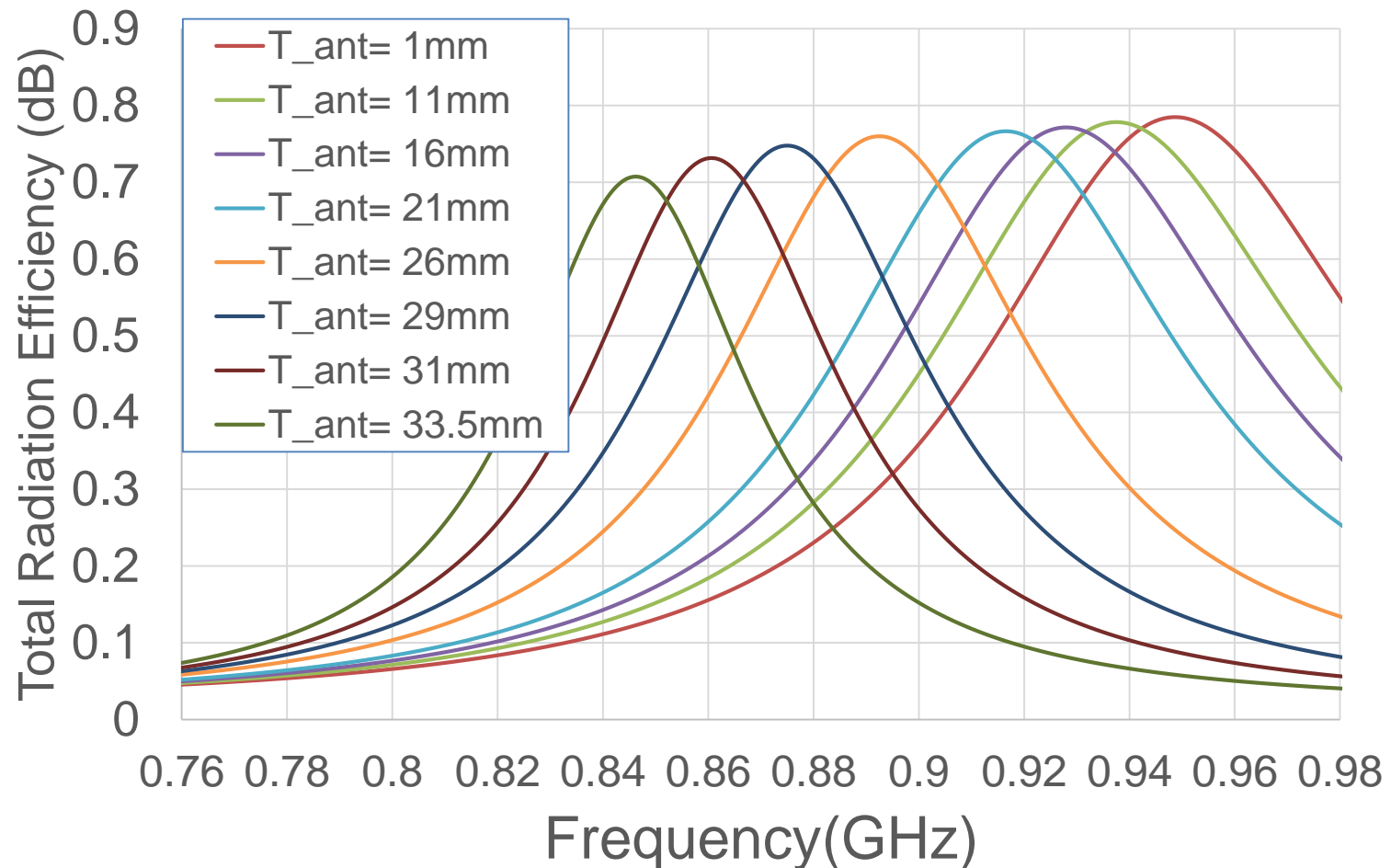


# UCA Antenna tuning : Reflection coefficient

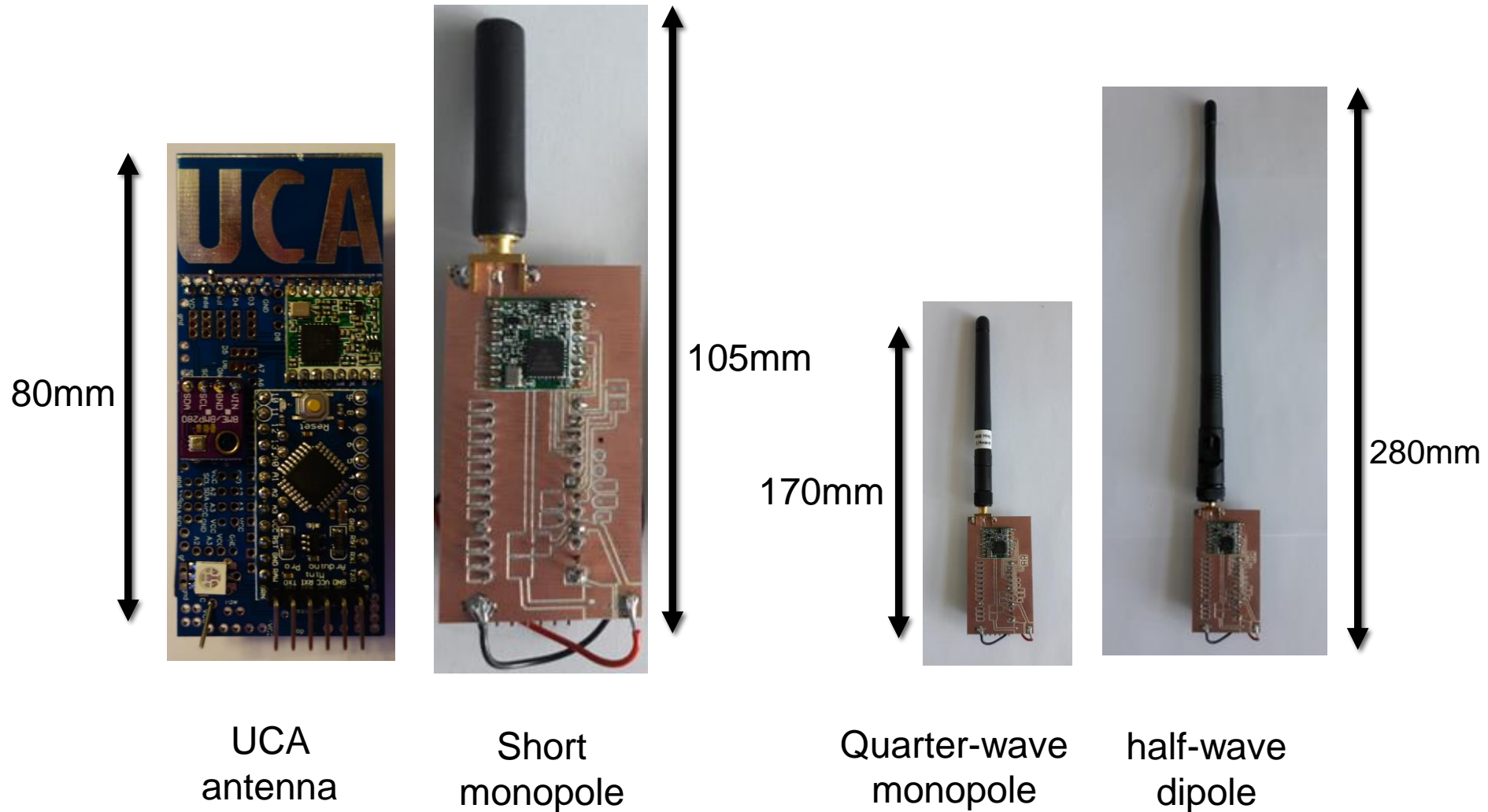




# UCA Antenna : Linear Total Rad. Efficiency

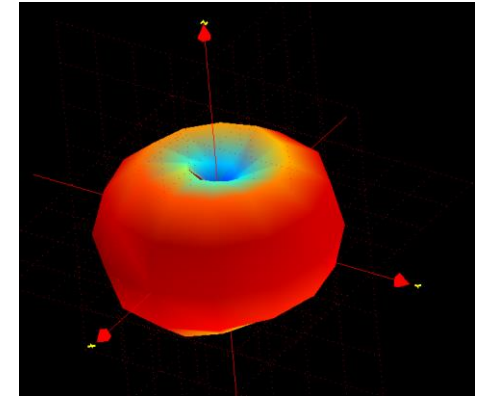


# Comparison with on-the-shelf antenna



# Comparison with on-the-shelf antenna

- Measurement on Satimo Starlab station
  - Continuous wave with 14 dBm power from RFM95W module
  - Efficiency calculated from the 3D antenna measurement



Antenna structure	TRP (dBm)	Total efficiency	Max Dimension
Small monopole	14.7	74%	105 mm
Quarter-wave monop.	15.7	94%	170 mm
Half-wave dipole	13.9	61%	280 mm
UCA untuned	13.8	60%	80mm
UCA after tuning	14.8	76%	80mm

[https://github.com/FabienFerrero/UCA\\_Board](https://github.com/FabienFerrero/UCA_Board)

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# Micro-tracker Antenna Industrial project

## ■ Specs

- LoRa 868 or 915MHz
- WiFi/BLE (2.4GHz)
- GPS L1
- Terminal size: 50\*28mm<sup>2</sup>

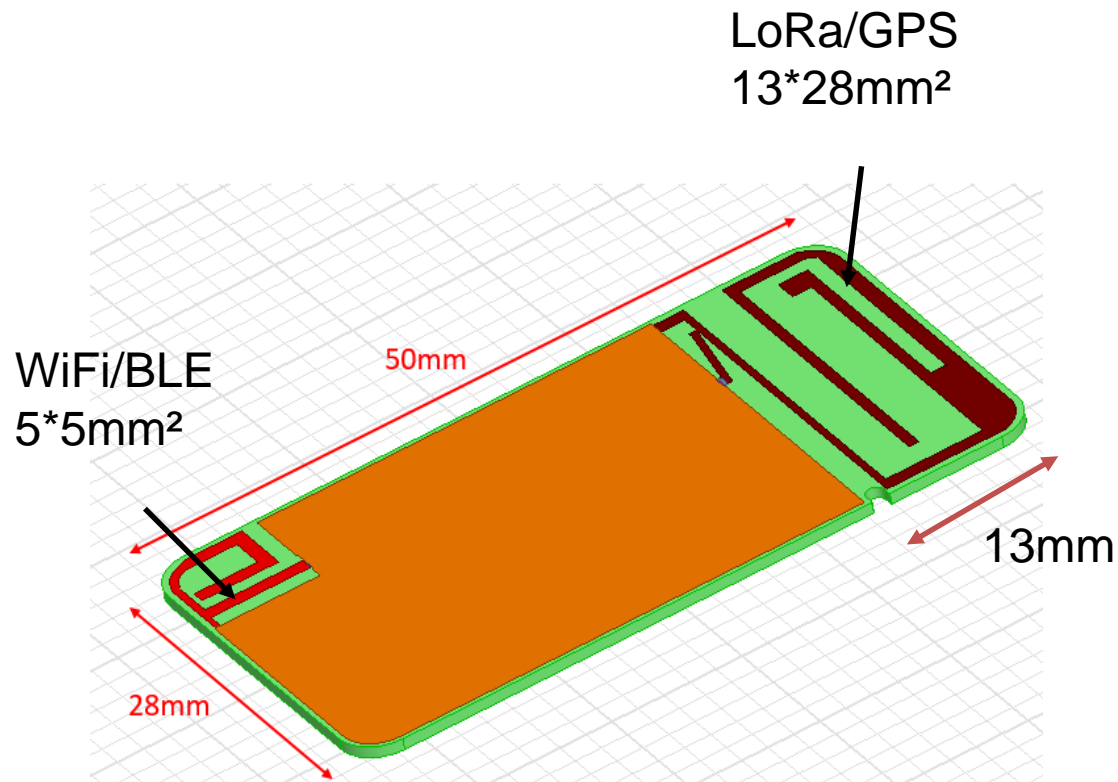
## ■ Proposed solution

- Dual-band LoRa/GPS
- SP4T to switch between LoRa Rx/Tx/Txboost and GPS.
- WiFi/BLE antenna (2.4-2.48 GHz)

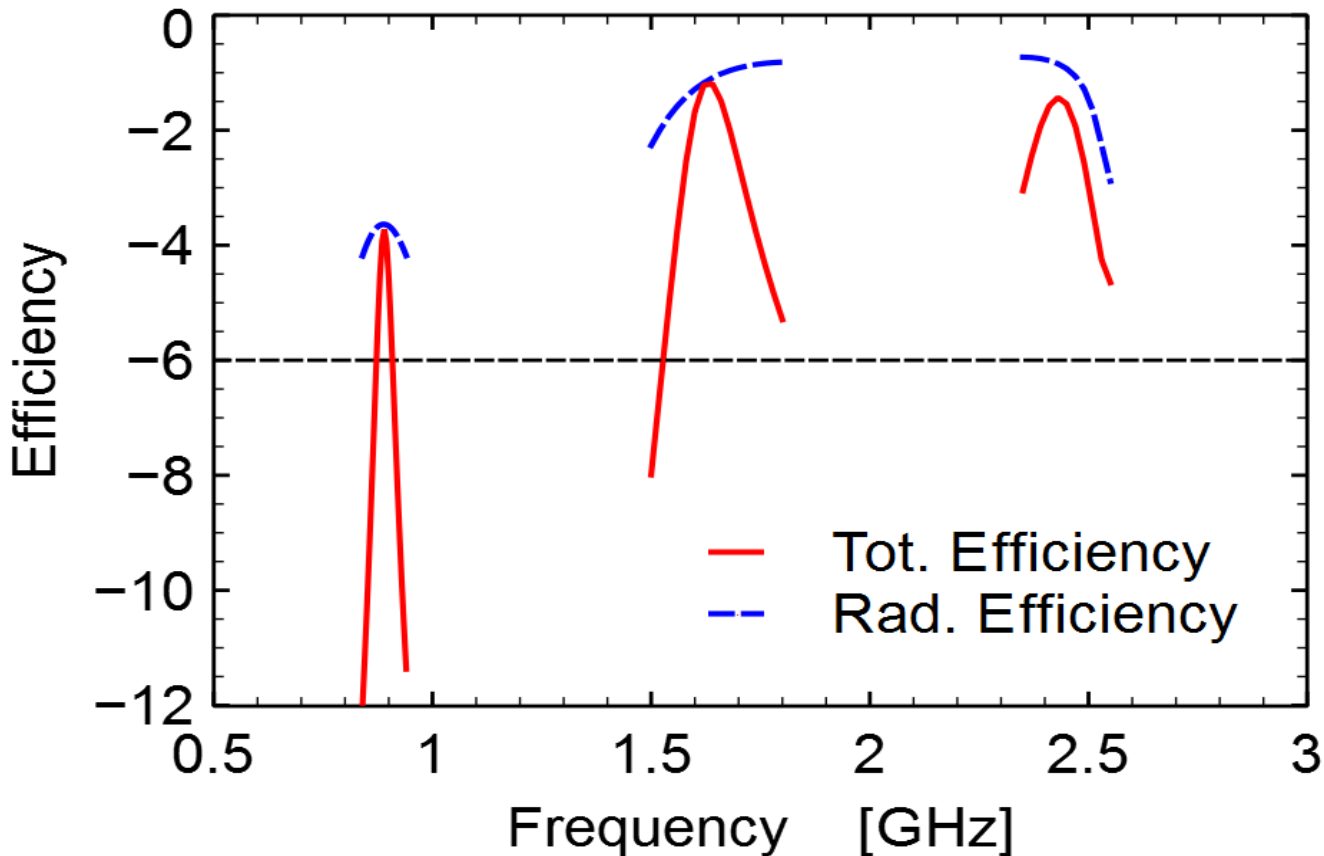




# Micro-tracker Antenna Industrial project



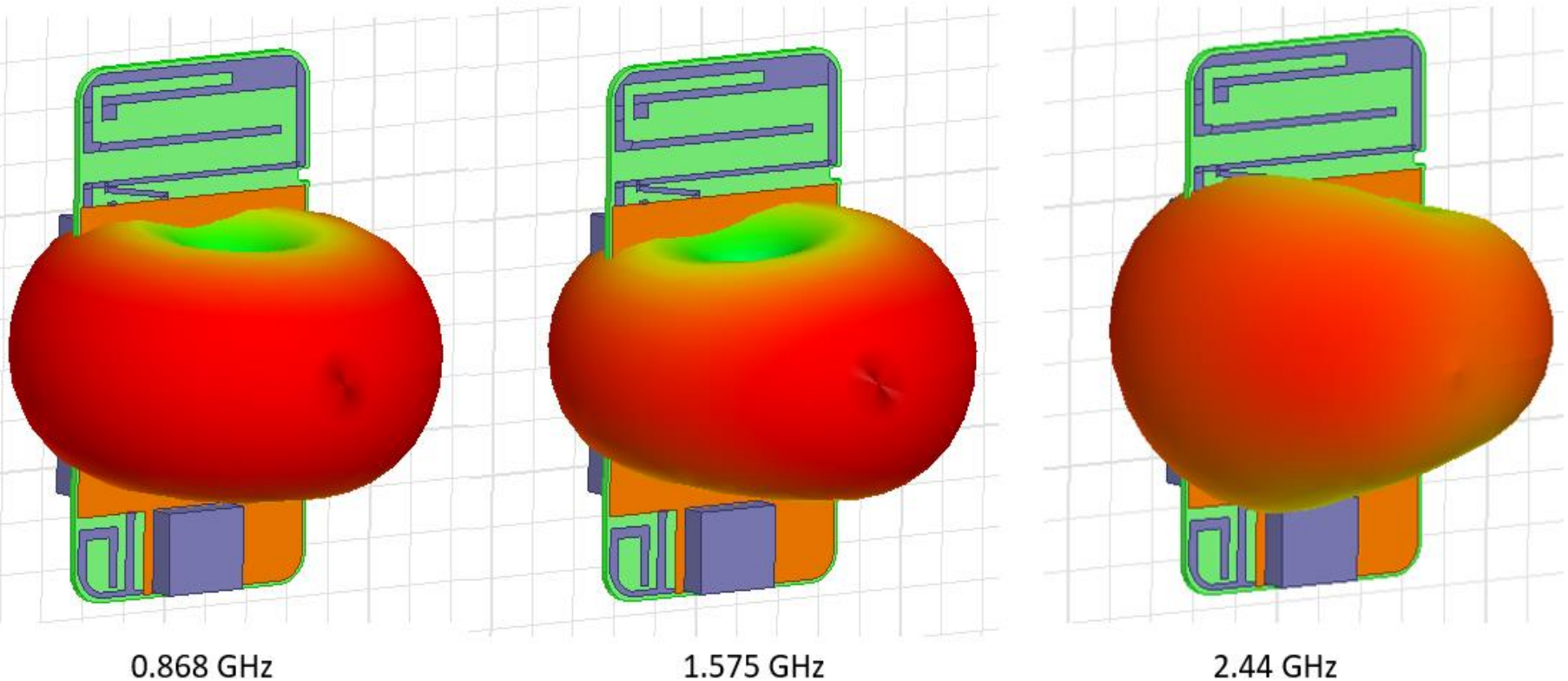
# Micro-tracker Antenna Industrial project



- Total Efficiency LoRa -4 dB (40%)
- Total Efficiency GPS -1.5 dB (70%)
- Total Efficiency WiFi/BLE -1.5 dB (70%)

# Micro-tracker Antenna Industrial project

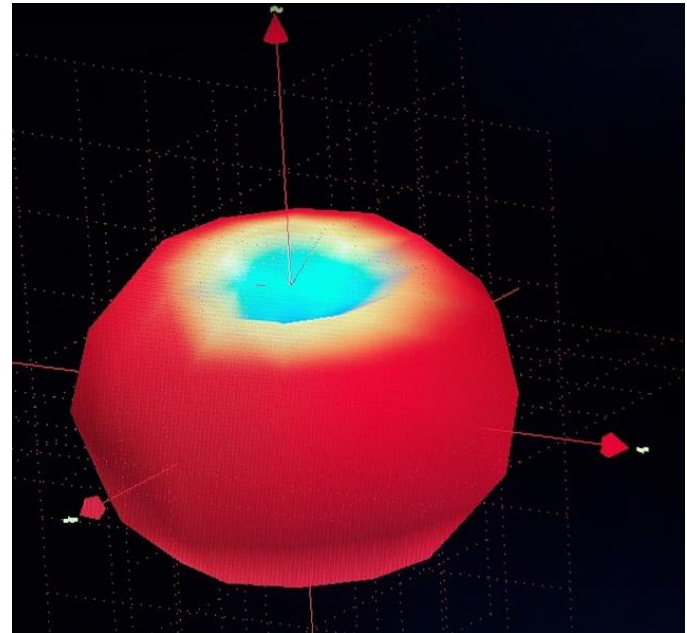
## Radiation pattern



# Micro-tracker Antenna Industrial project

## Measurements :

- LoRa : Peak Gain -1.5dB
- BLE/WiFi : Peak Gain 0.5dB
- GPS : Estimated at 0dB from anechoic chamber measurement with GPS protocol tester.



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# Conclusion and Perspectives

- Take care of your antenna, else your project might fail
- With a carefull design, antenna can be low-cost **and** good
- Advanced matching network can be used to enlarge bandwidth
- Reconfigurable antenna using RF switch can be a good solution to compensate environment effect or to add antenna diversity

# REFERENCES

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