Laboratory of Electronics Antennas and Telecommunications

LABORATOIRE D'ELECTRONIQUE ANTENNES ET TELECOMMUNICATIONS

LP-WAN technology for Smarter Things : The antenna challenge

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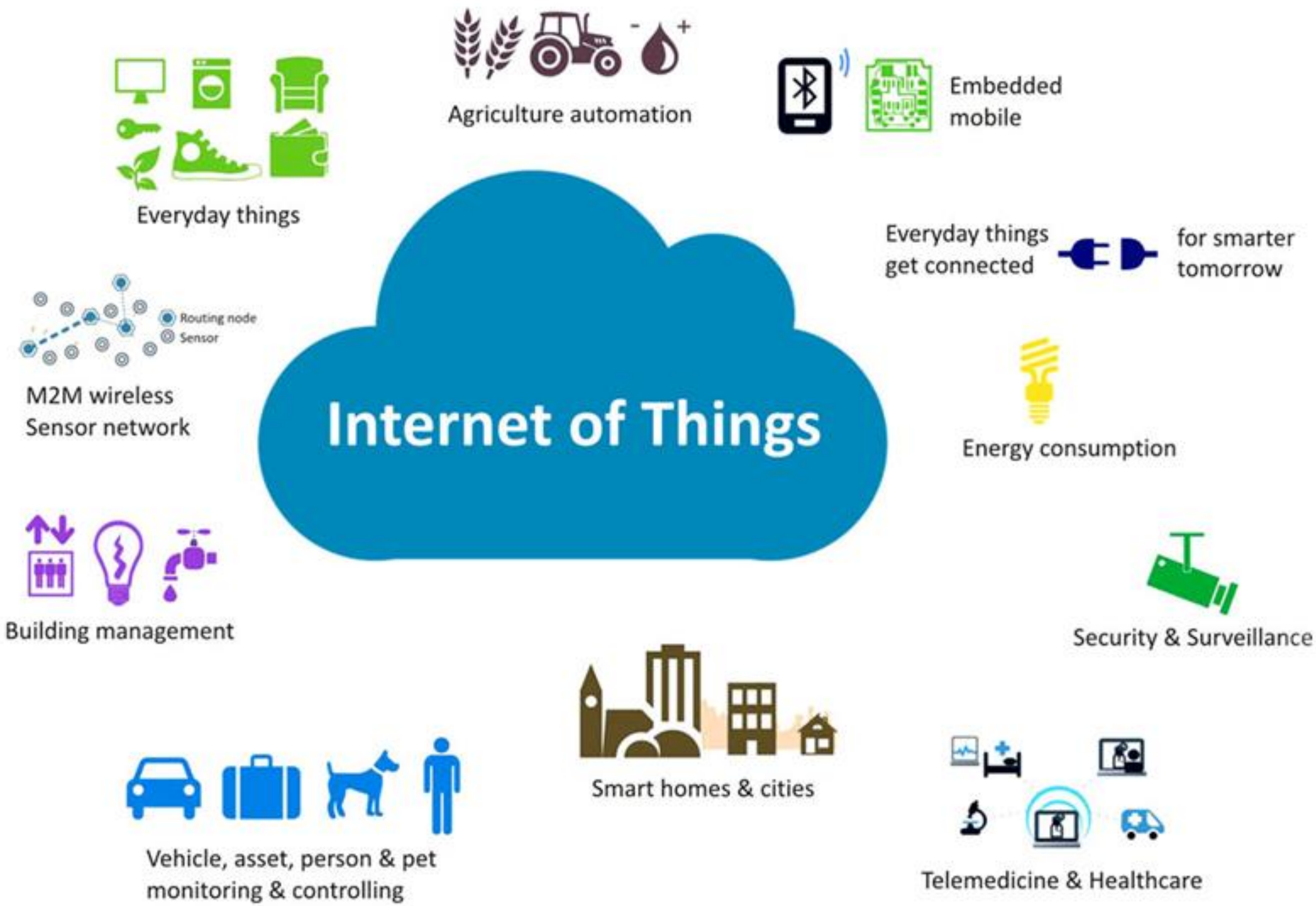
Outline

- LP-WAN Motivation
- Why antenna is important ? A practical example
- Antenna key parameters
- Low-cost Antenna Open Source project
- Micro-tracker Antenna Industrial project
- Da Nang/UCA : research perspectives
- Next Smart Campus Campaign

IoT opportunities : Potential market



IoT opportunities : Potential market

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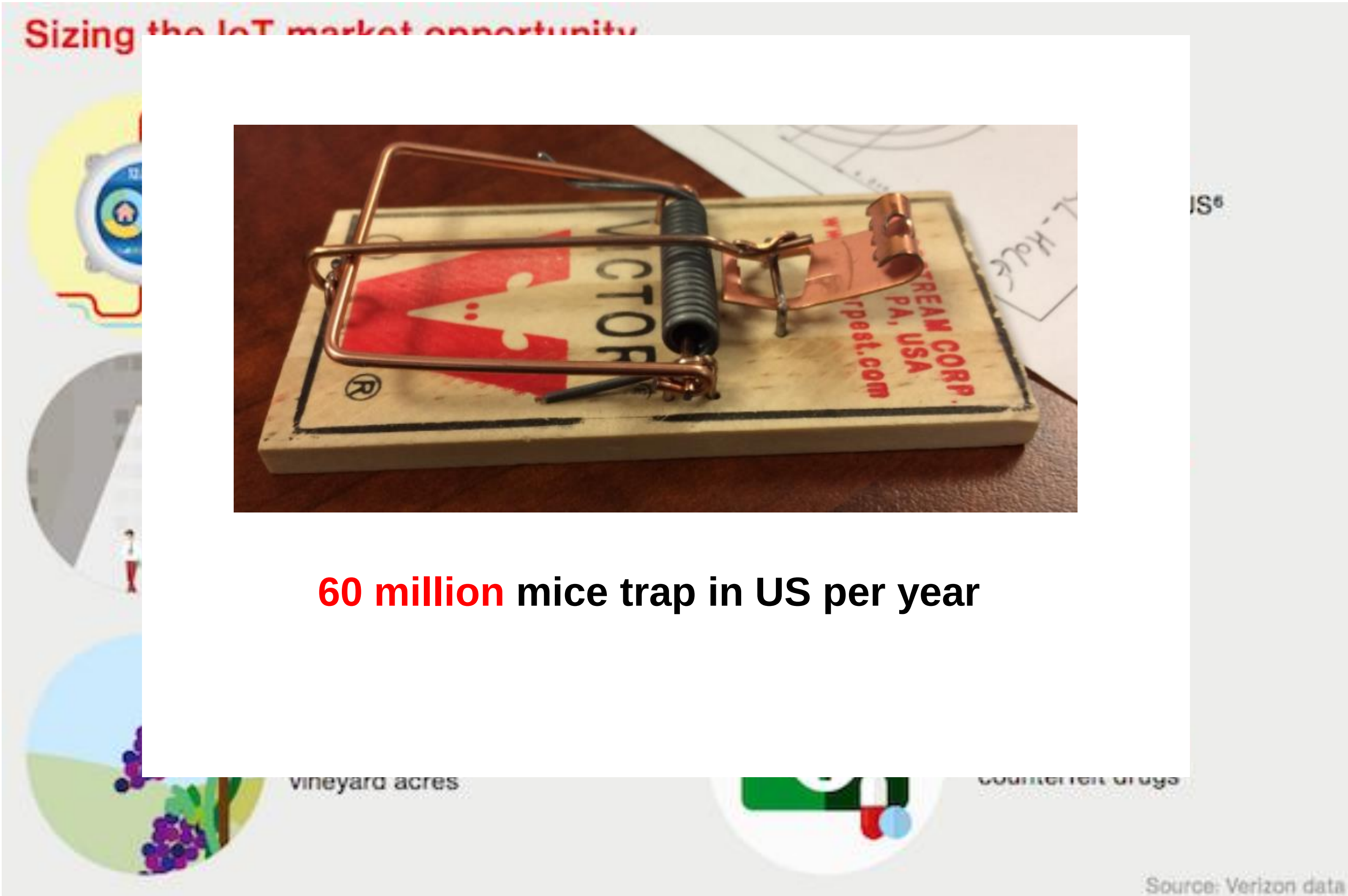
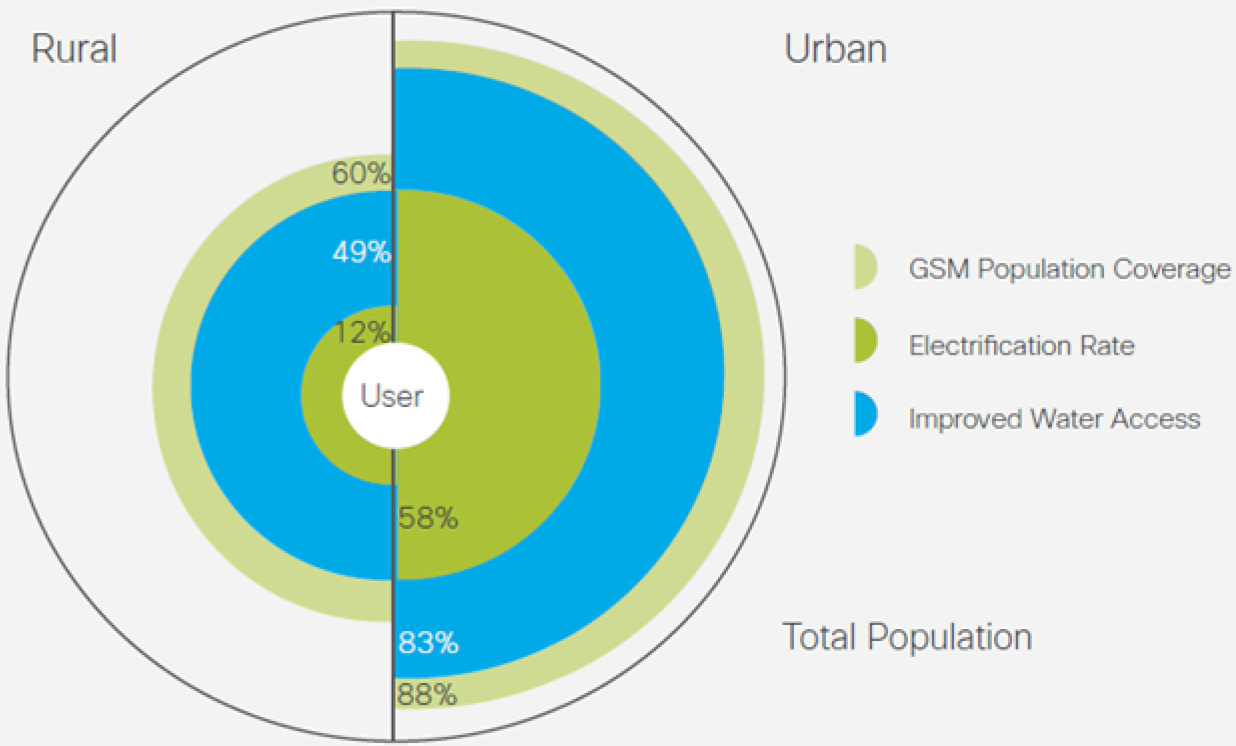


60 million mice trap in US per year

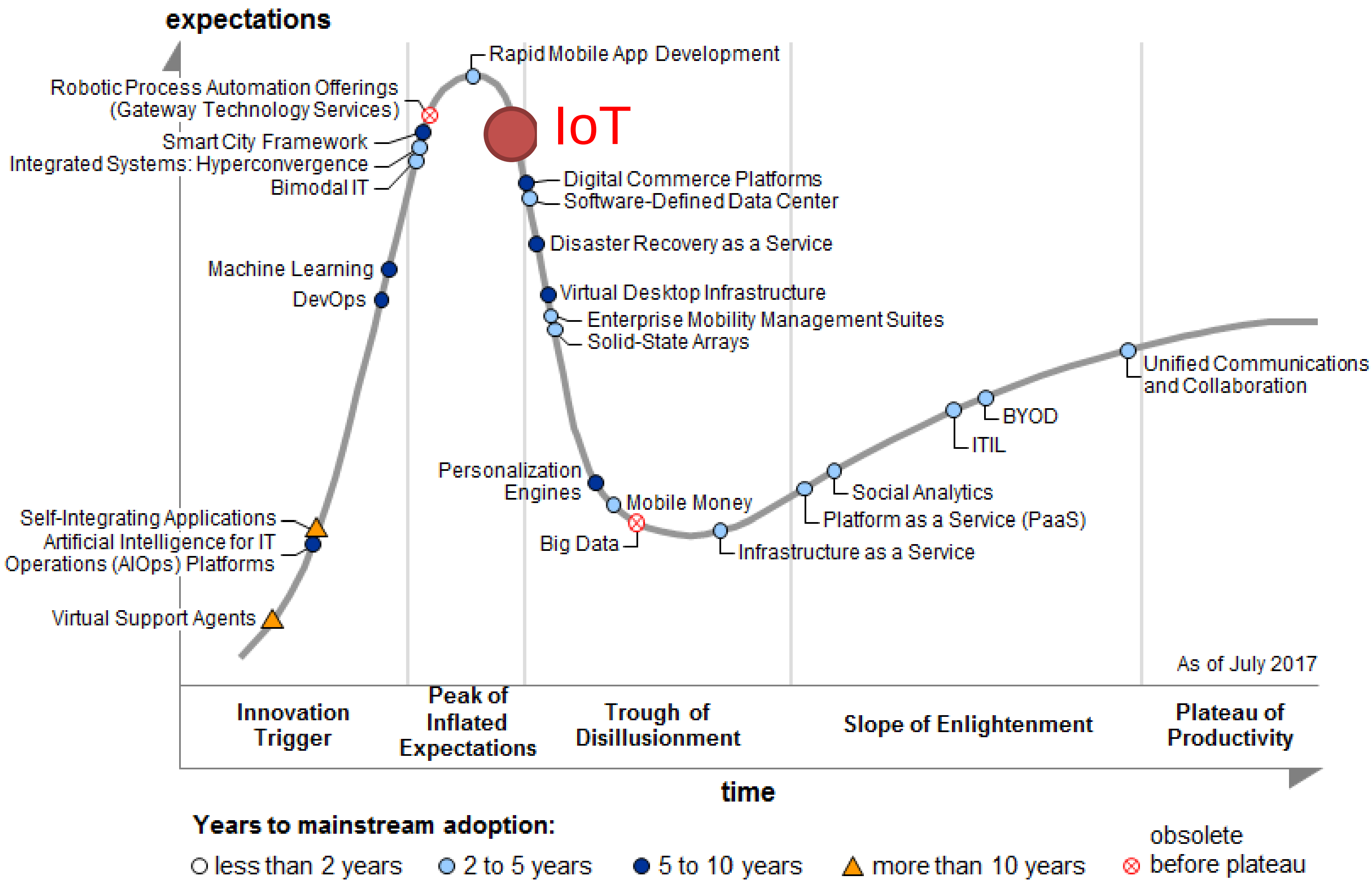
LP-WAN to improve energy and water access

Access to Energy, Water & GSM Population Coverage in Sub-Saharan Africa



Source: GSMA, "Sustainable Energy & Water Access through M2M Connectivity. http://www.gsma.com/mobilefordevelopment/wp-content/uploads/2013/01/Sustainable-Energy-and-Water-Access-through-M2M-Connectivity.pdf.

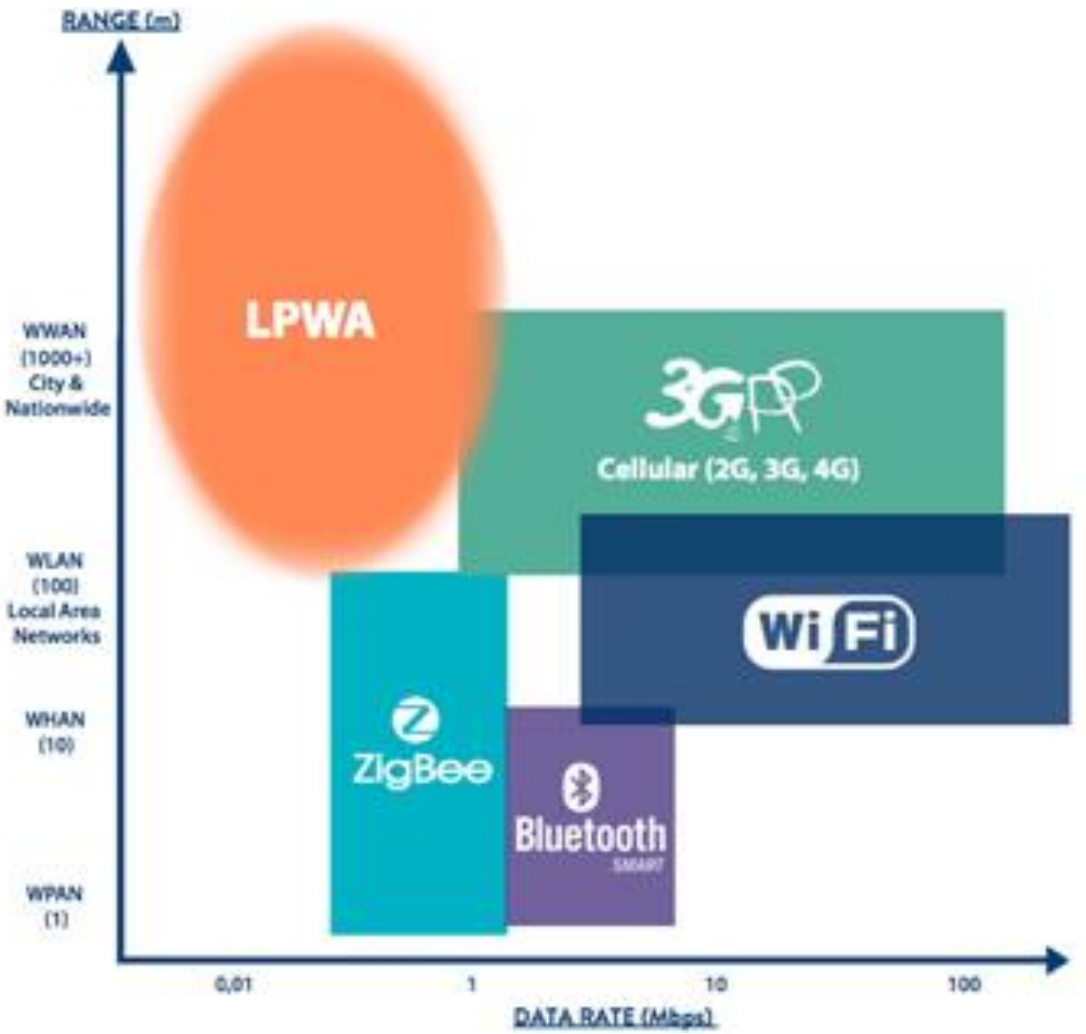
IoT opportunities : Hype cycle



LP-WAN technologies opportunities

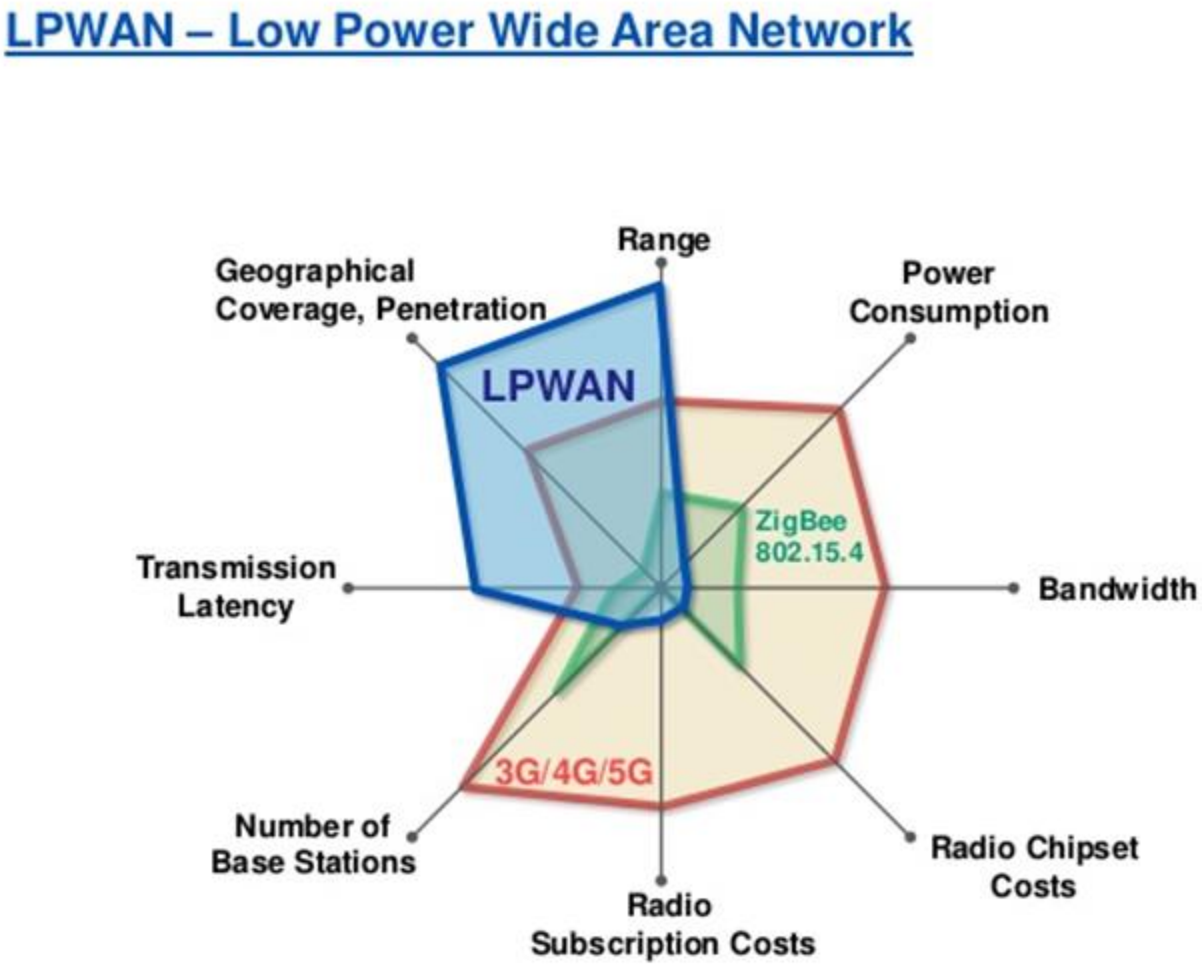
LP-WAN provides new capabilities :

Low-power and long communication range

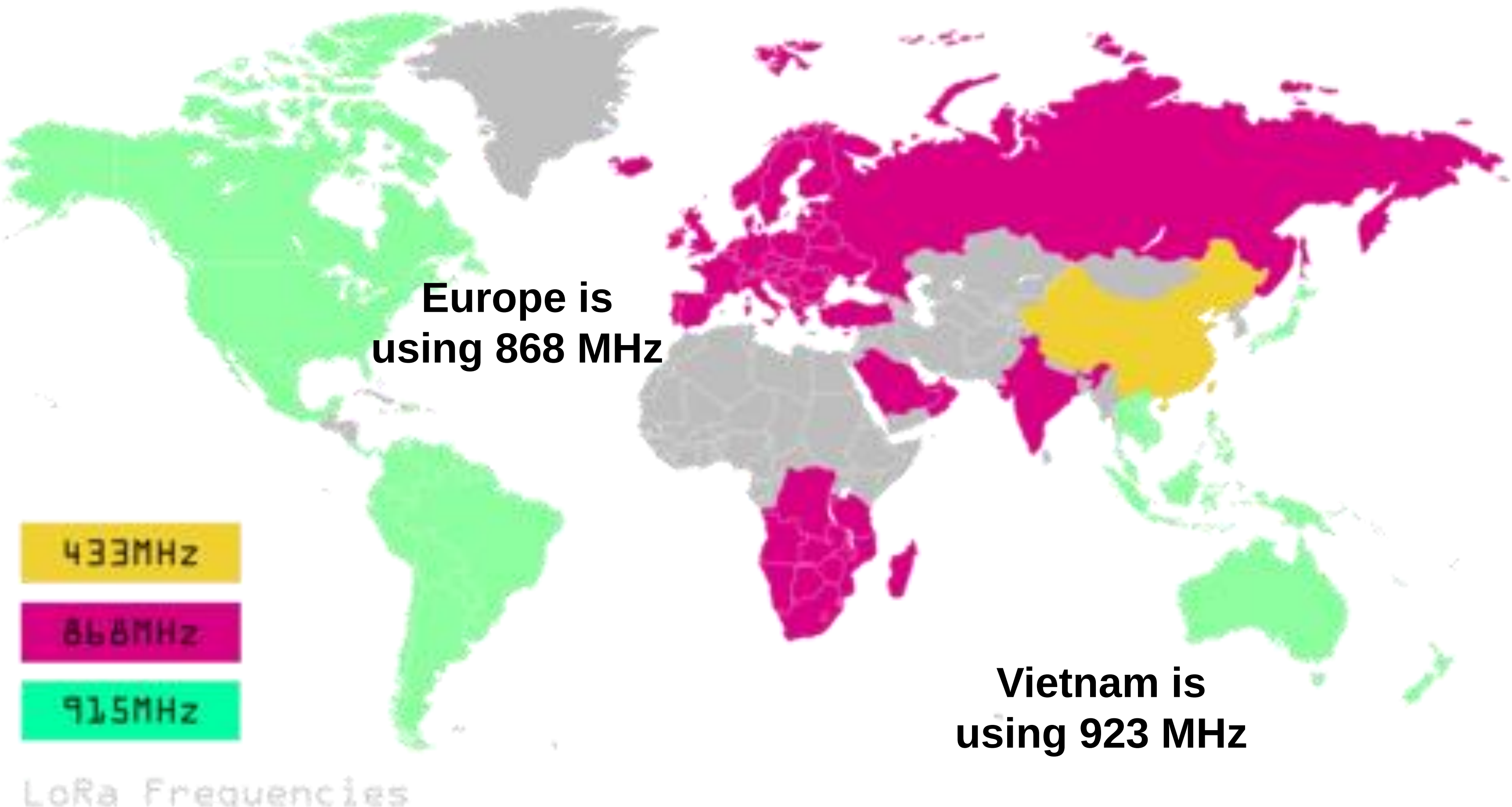


Power 1mW 10mW 100mW

LP-WAN technologies opportunities



LP-WAN ISM bands



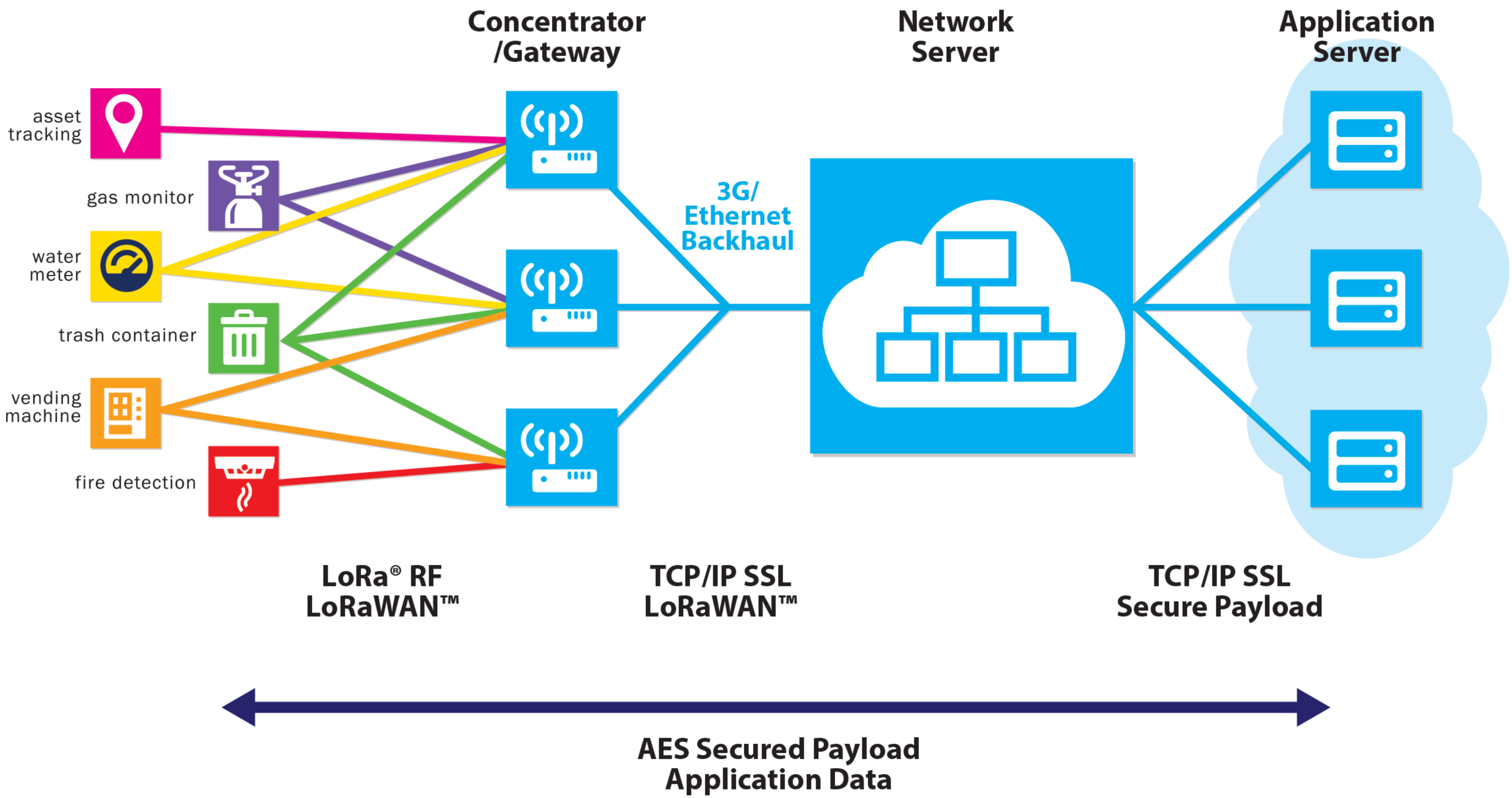
Europe is using 868 MHz

Vietnam is using 923 MHz

LP-WAN technologies comparison

	LoRa	SIGFOX	NB-IoT 3GPP
Range (km)	10km (suburban) 3-6km (urban)	30km (Rural) 10km (urban)	
Frequency Band (MHz)	Sub GHz (ISM)	868-900MHz (ISM)	Licensed LTE bands
Max. Coupling Loss	155dB		164dB
Modulation type	Chirp Spread Spectrum (CSS)	Ultra narrow band / GFSK / BPSK	LTE - OFDMA / SC-FDMA
Bandwidth	125 – 500 kHz	100 Hz	180 kHz
Datarate	300 bps – 50 kbps	100 bps	Up to 250 kbps (UL) – low latency
Max /message / day (Uplink)	Unlimited*	140 msg/day – 12bytesmax/msg	Unlimited (lice. Spectrum)
Max /message / day (Downlink)	Unlimited*	4 msg/day (8bytes max/msg)	Unlimited (lice. Spectrum)
Network density	+++ (ADR)	+	+++
Battery peak current	< 50 mA (14dBm)	< 50 mA (14dBm)	~300mA (@23dBm)
Average sensor autonomy	+++ (ADR)	++	+
Interference immunity	high	Low	Sensitive to downlink jamming
Native payload encryption	Yes	Proprietary	Yes
Able to create private networks	Yes	No	No
Location (w/o GPS)	Yes	No	M1 only, not deployed(**)
Commercial availability	Now	Now	Starting in 2017

LP-WAN network



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- Conclusion and perspectives

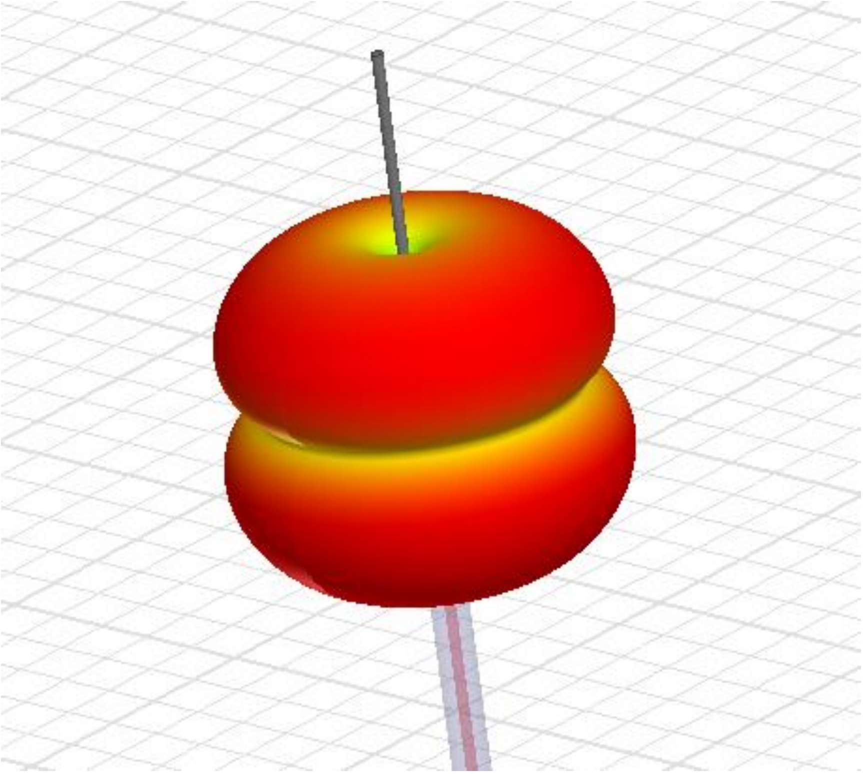
Antenna is important for communication range

- 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

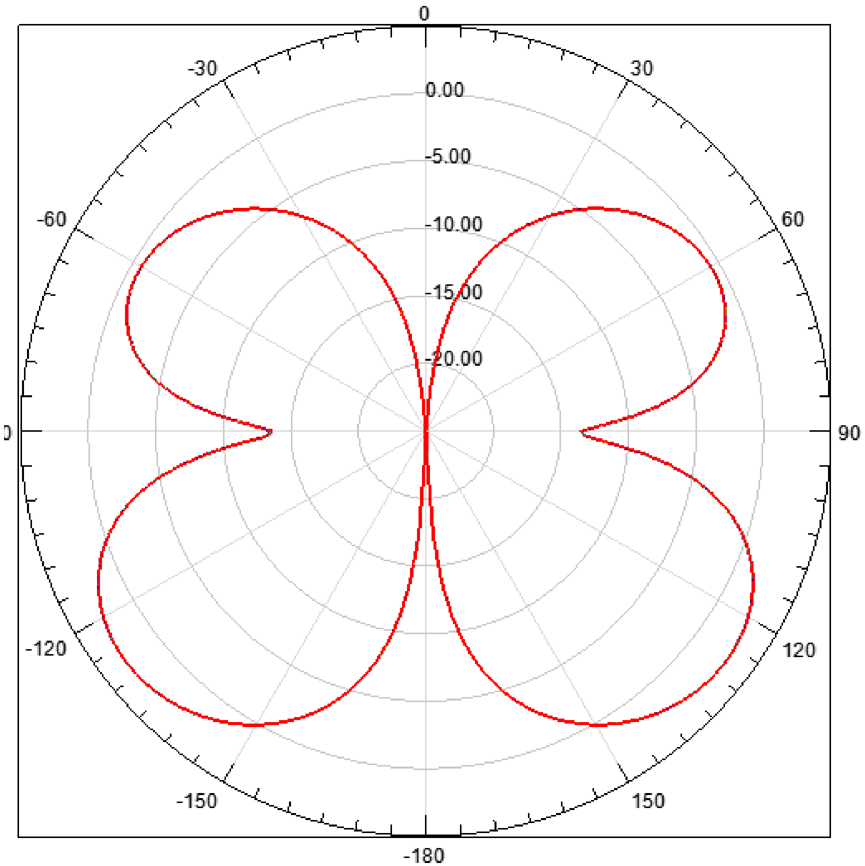
Antenna is important for communication range

- 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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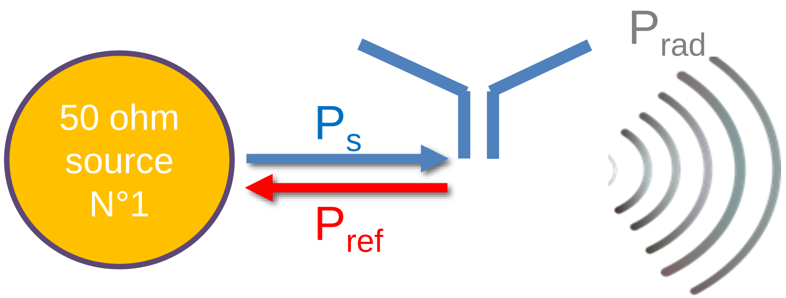
Antenna performance indicator

- 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)

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

  - Total Efficiency
    - Include **matching** and **radiation loss**
    - Can be plotted in linear or dB scale
    - 30-70% classically observed

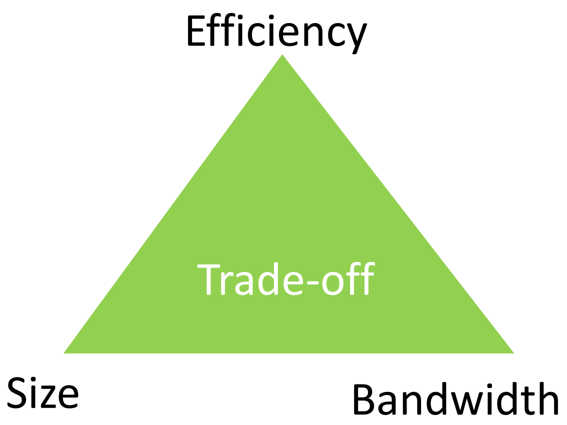
$$\eta_t = P_{rad}/P_s$$

  - Gain
    - Include **matching**, **radiation loss** and **directivity**
    - Plotted in dBi
    - $U(\theta,\varphi)$ is the radiation intensity in a given direction

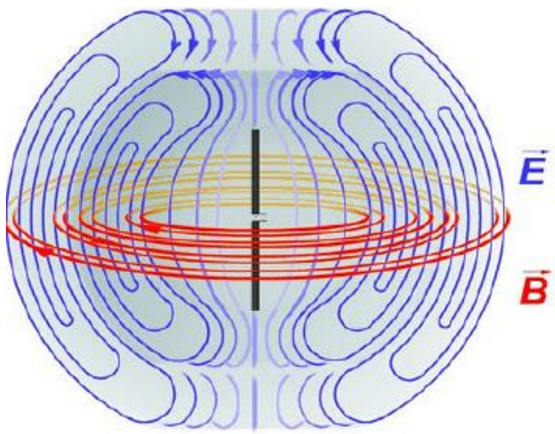
$$G(\theta,\varphi) = \frac{U(\theta,\varphi)}{P_s/4\pi}$$

Antenna key parameters

- Antenna is a resonnant structure :
  - Input impedance is changing with frequency
  - Limited frequency bandwidth
  - Miniature antenna can have a low efficiency due to metallic or dielectric losses



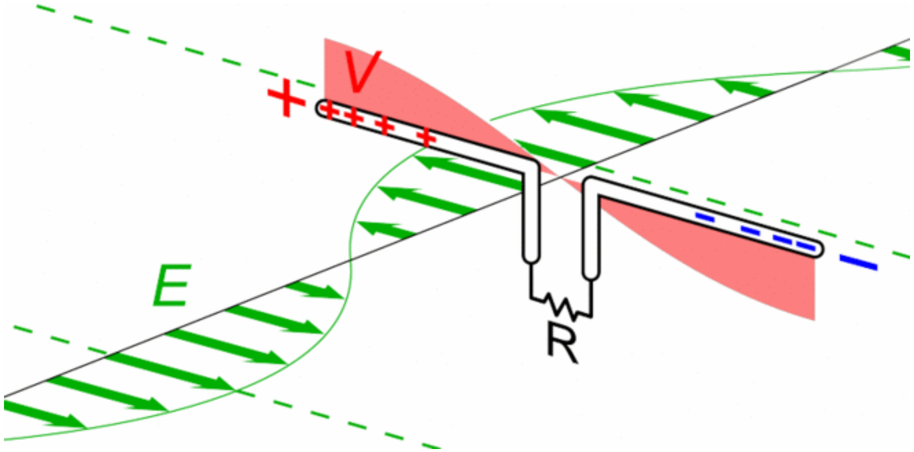
- Antenna is an open structure
  - Compare to electronic components, antenna is strongly influenced by its surrounding environment
  - For integrated antenna, the electromagnetic wave is generated by the antenna **and** by the terminal ground plane

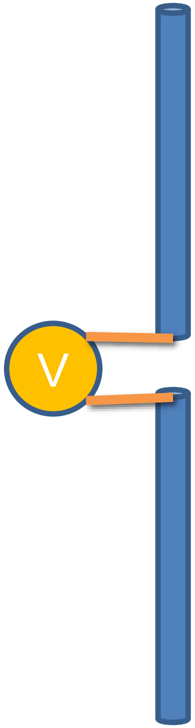


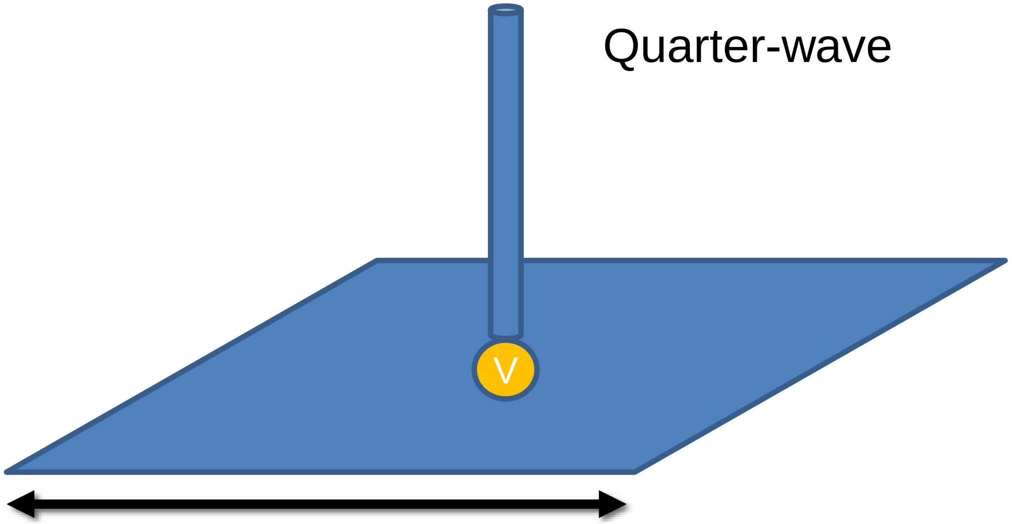
➢ Small antenna has to be carefully tuned

Effect of terminal chassis

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

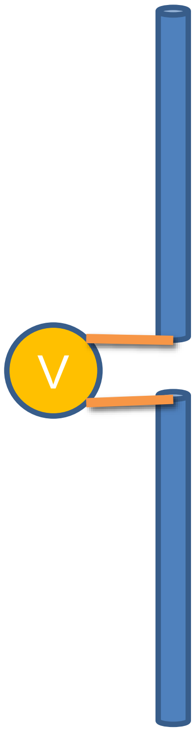




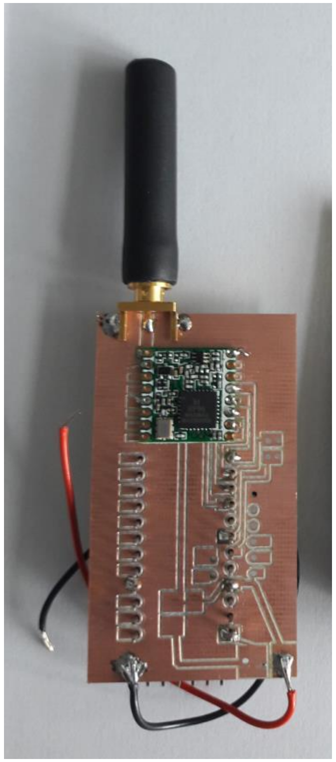


Effect of terminal chassis

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

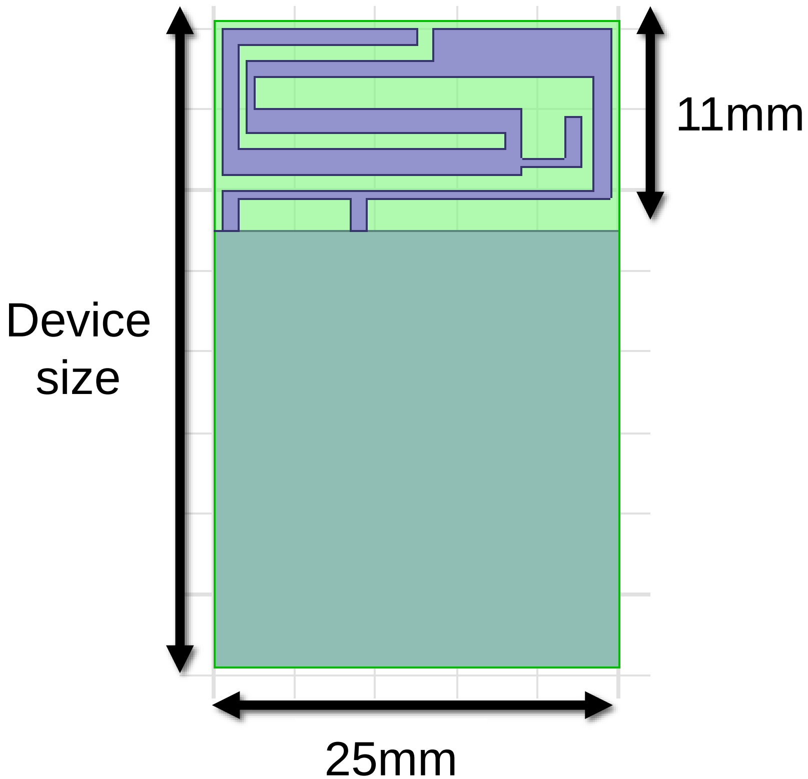


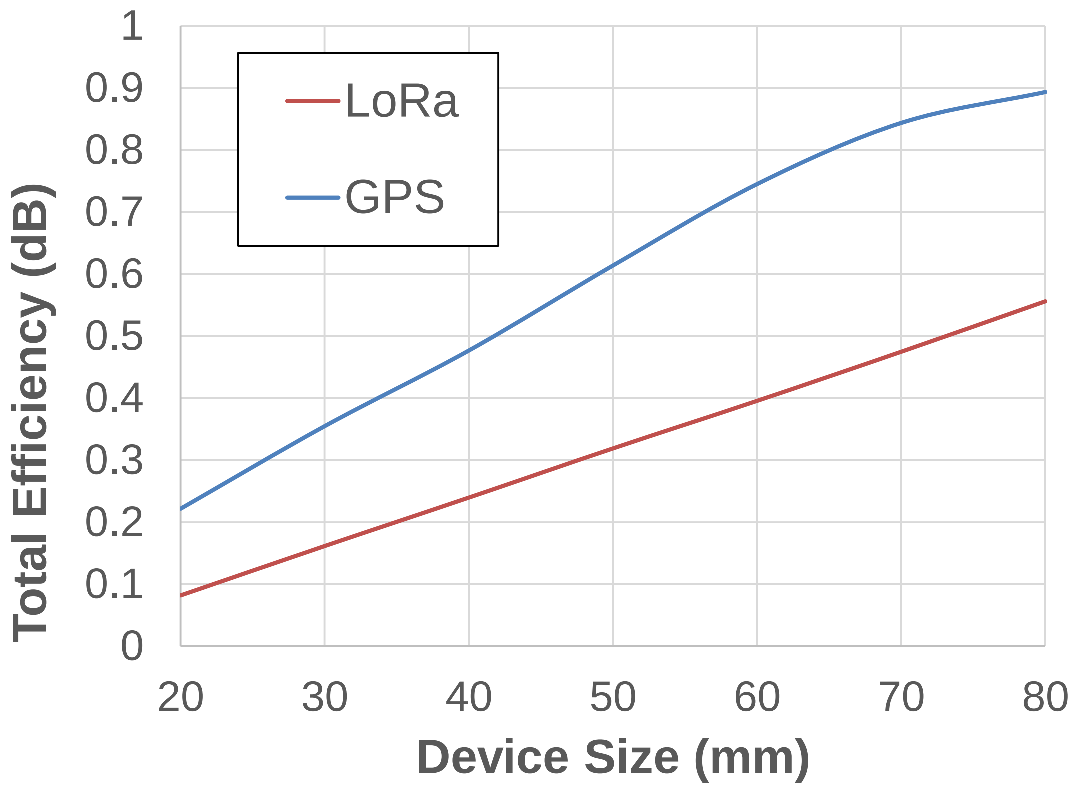
Half-wave



Effect of terminal chassis

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





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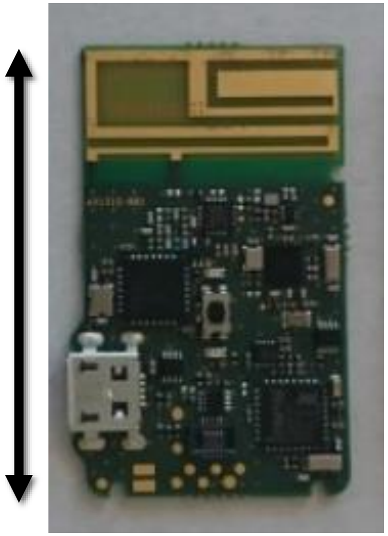
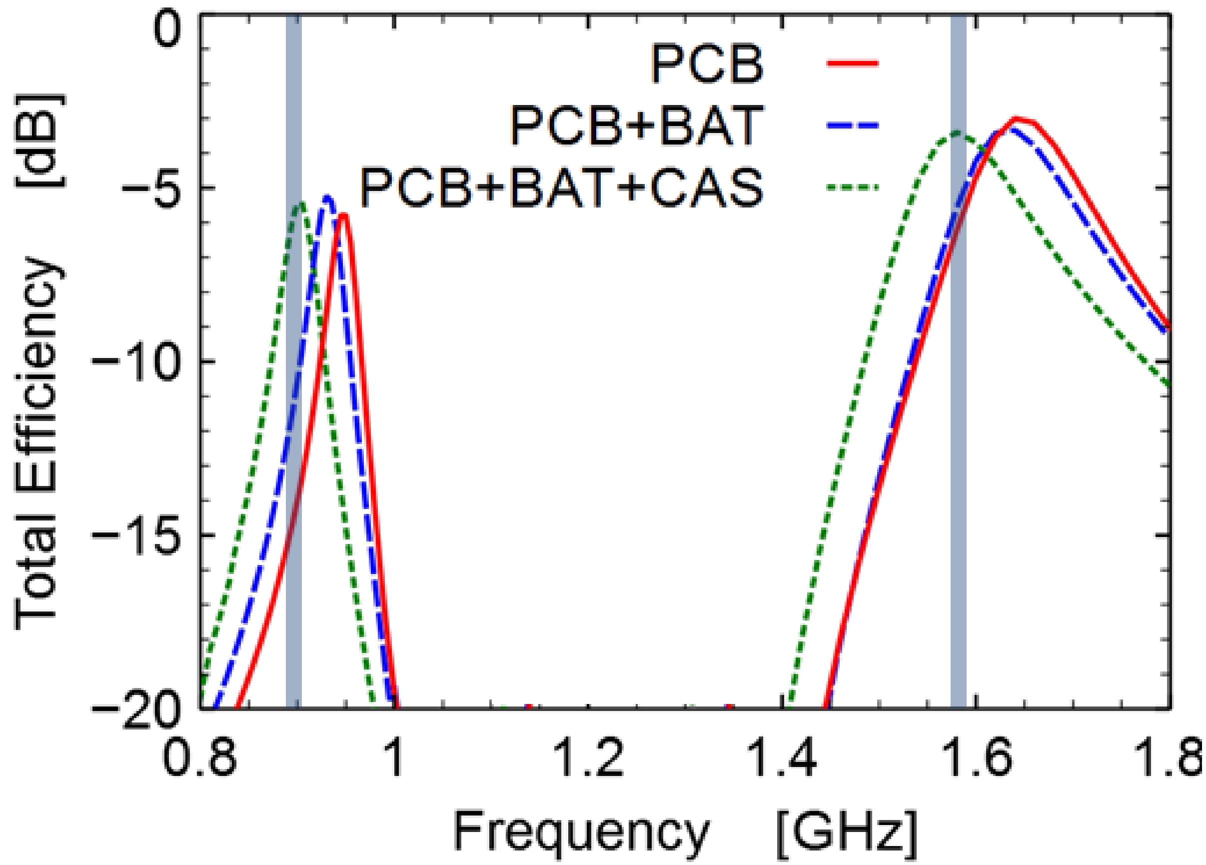
Effect of the environment

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

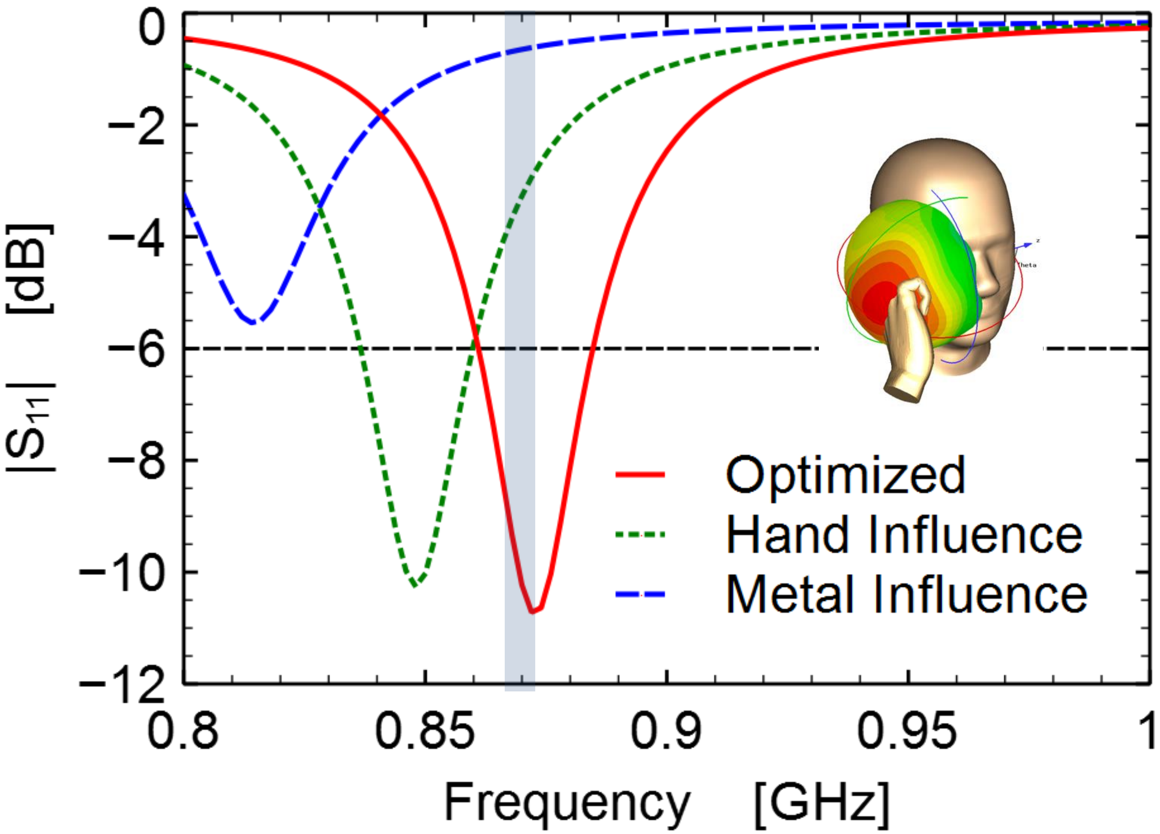
40mm





Effect of the environment

Antenna are also influenced by the surrounding environment



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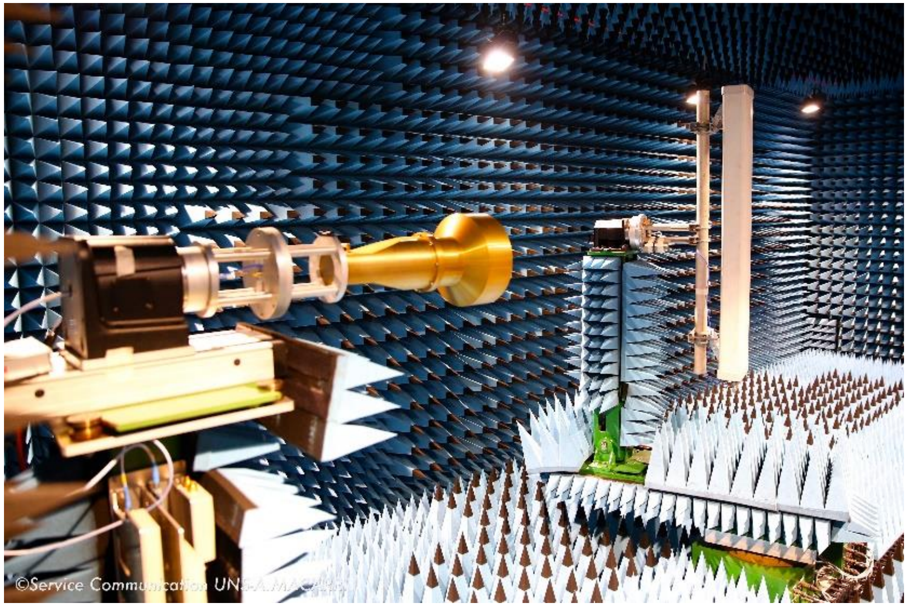
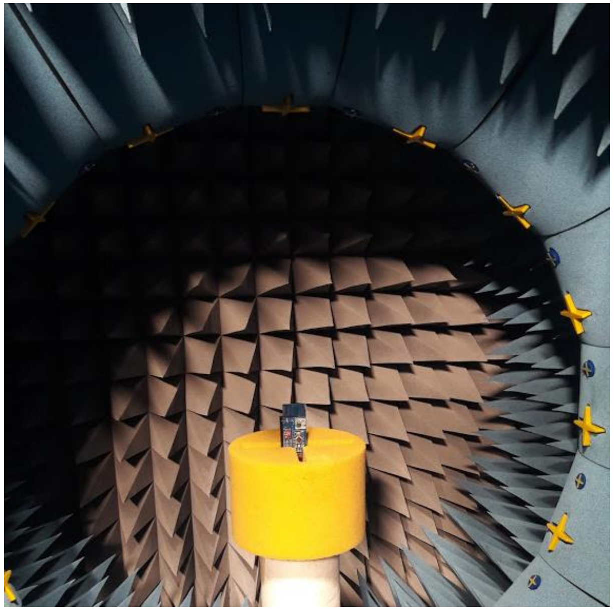
Antenna measurement

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





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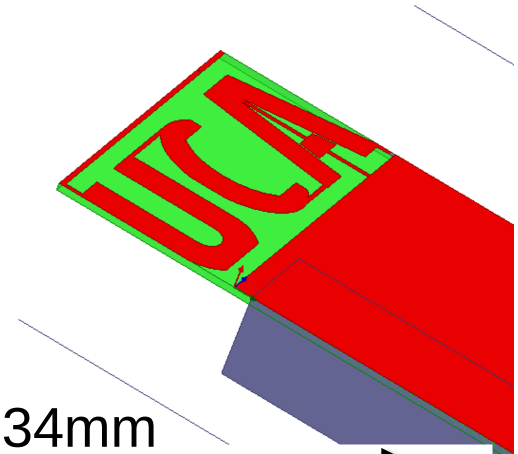
Design of cost efficient antenna @868MHz

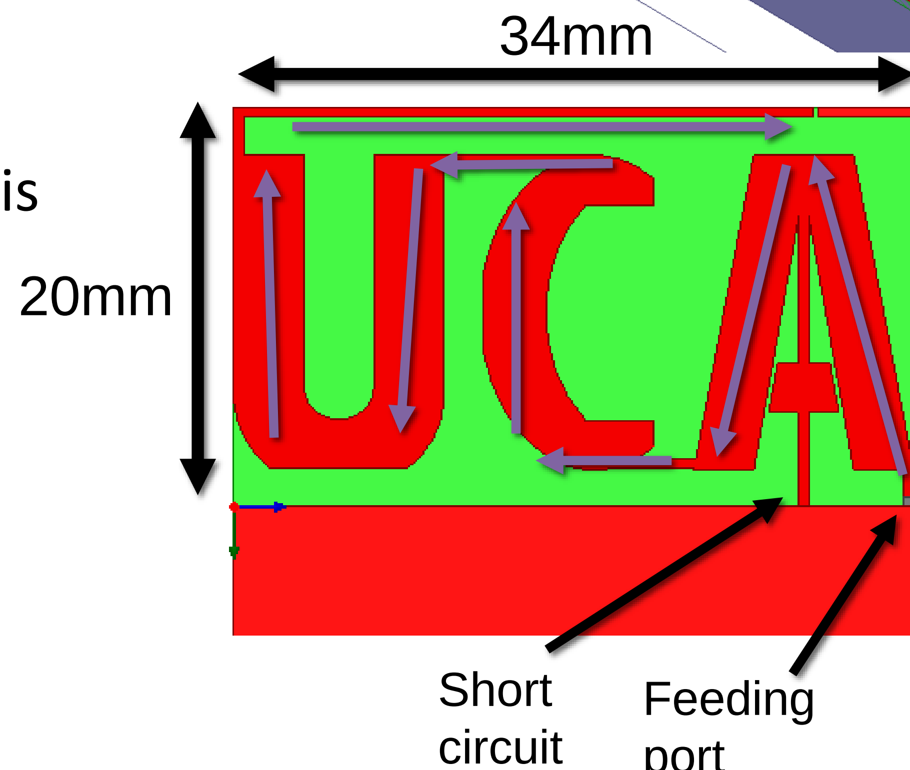
- LoRa collar for Cattle Rustling applications

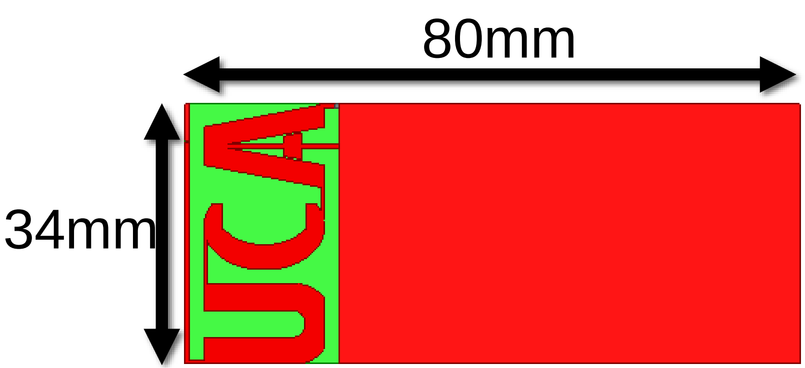
- Cost reduction
  - Remove RF connectors (a SMA connector is 4$)
  - Avoid external antenna (cost between 2 and 8 $)
  - A PCB is needed for component integration
  - The cost for an extension of the PCB is negligible, so PCB integrated antenna is very cost efficient

UCA Antenna layout

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

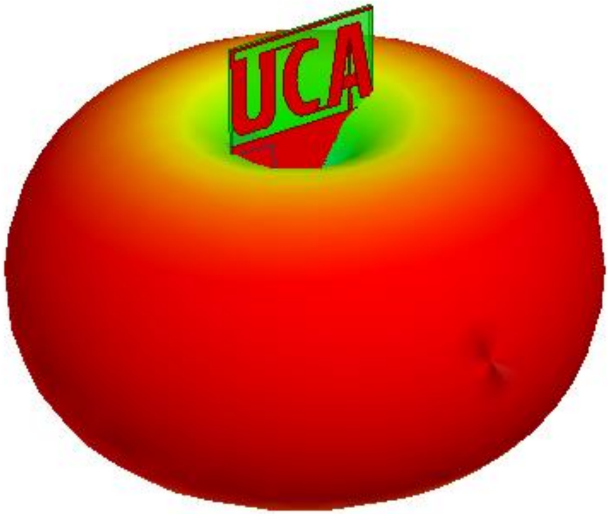






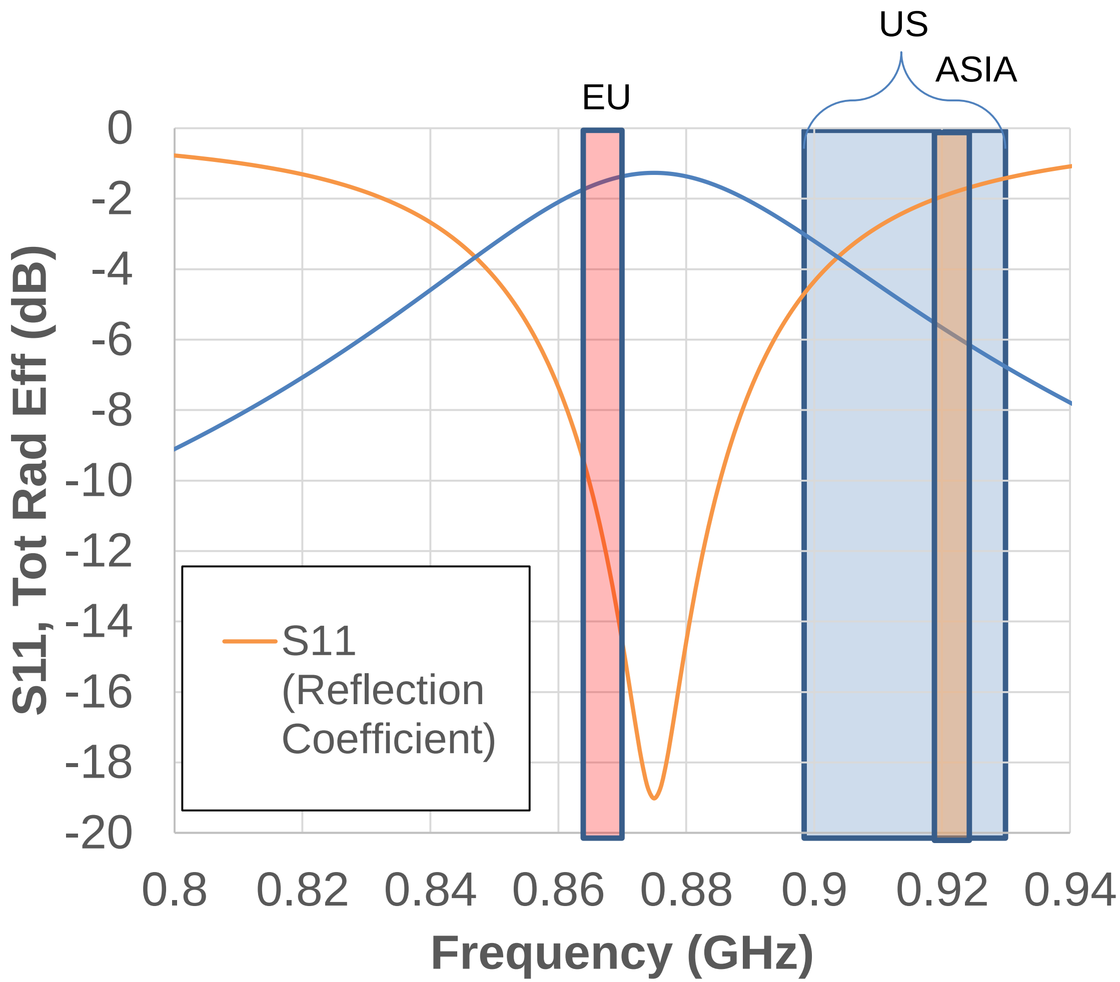
UCA Antenna tuned for EU band

- 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



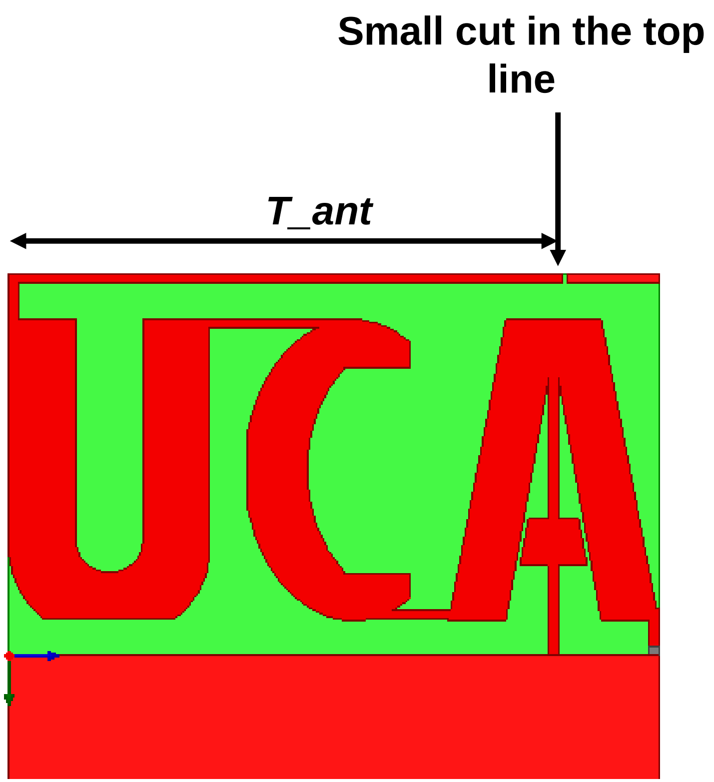
UCA Antenna tuned for EU band

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

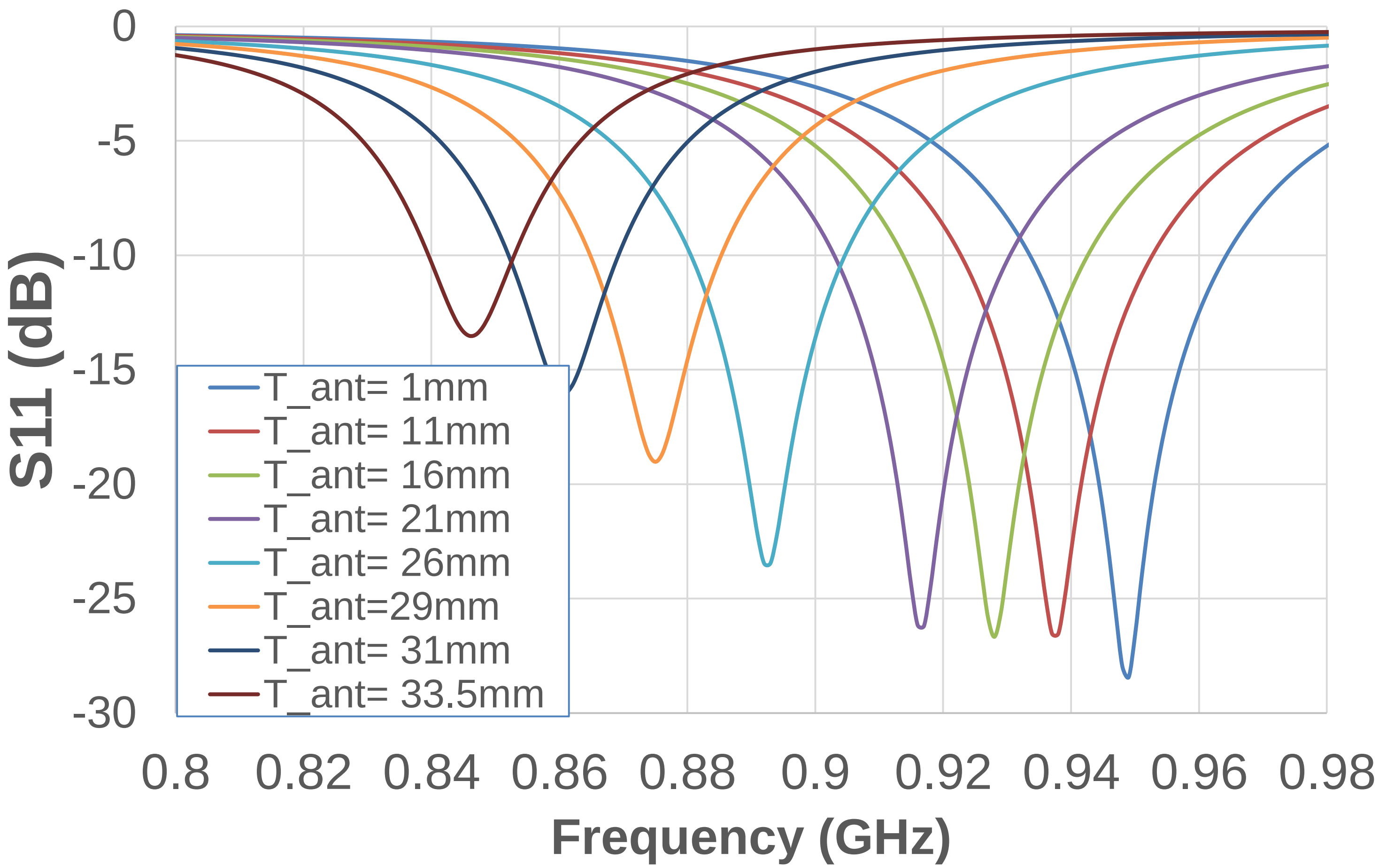


Antenna design

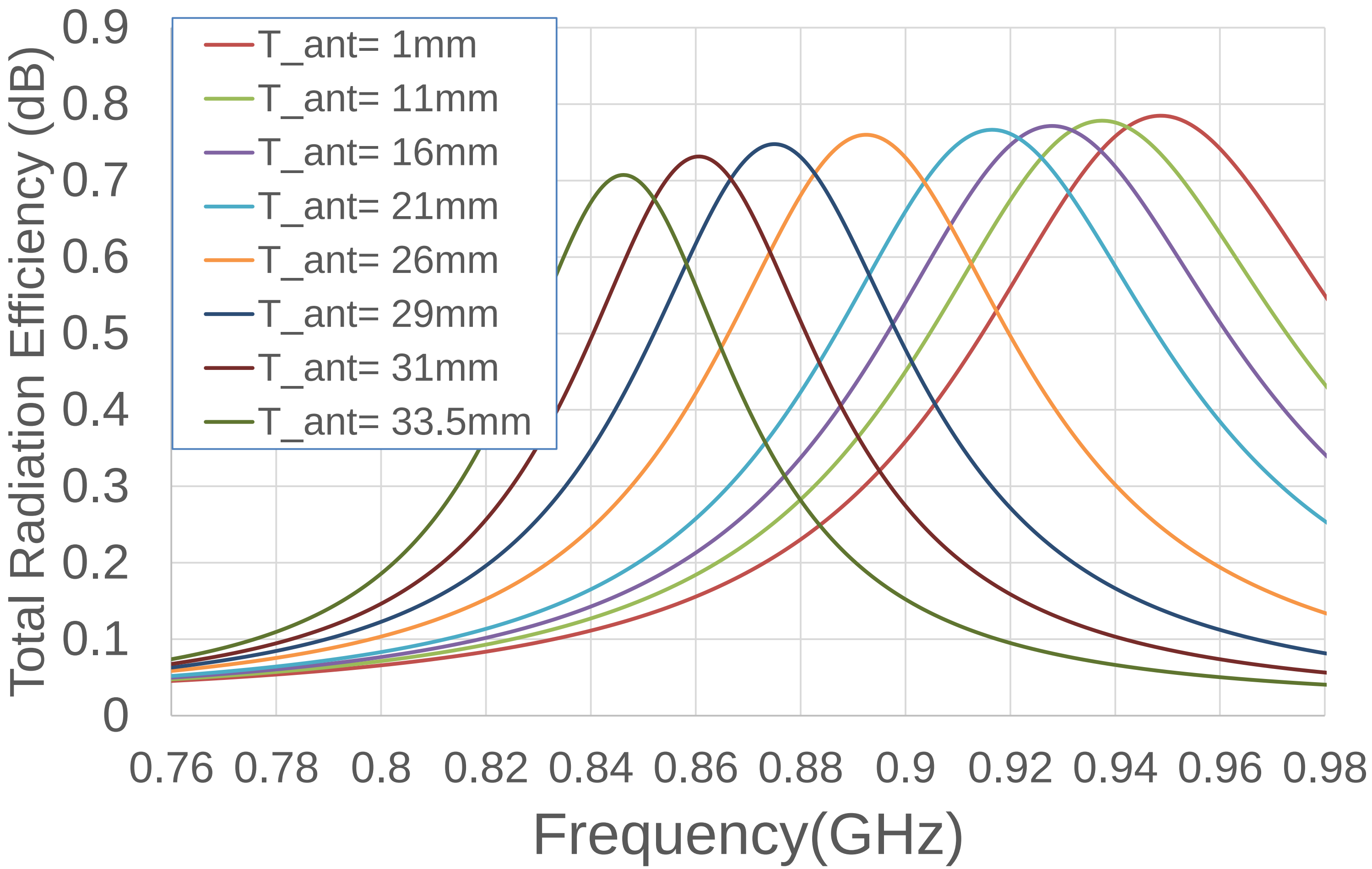
- The antenna shape can be easily tuned to different frequencies
  - The top line can be cut at different position to change the antenna trace length
  - *T_ant* parameter can be tuned from 0 to 34mm
  - Antenna resonance frequency can be tuned from 845 to 950MHz



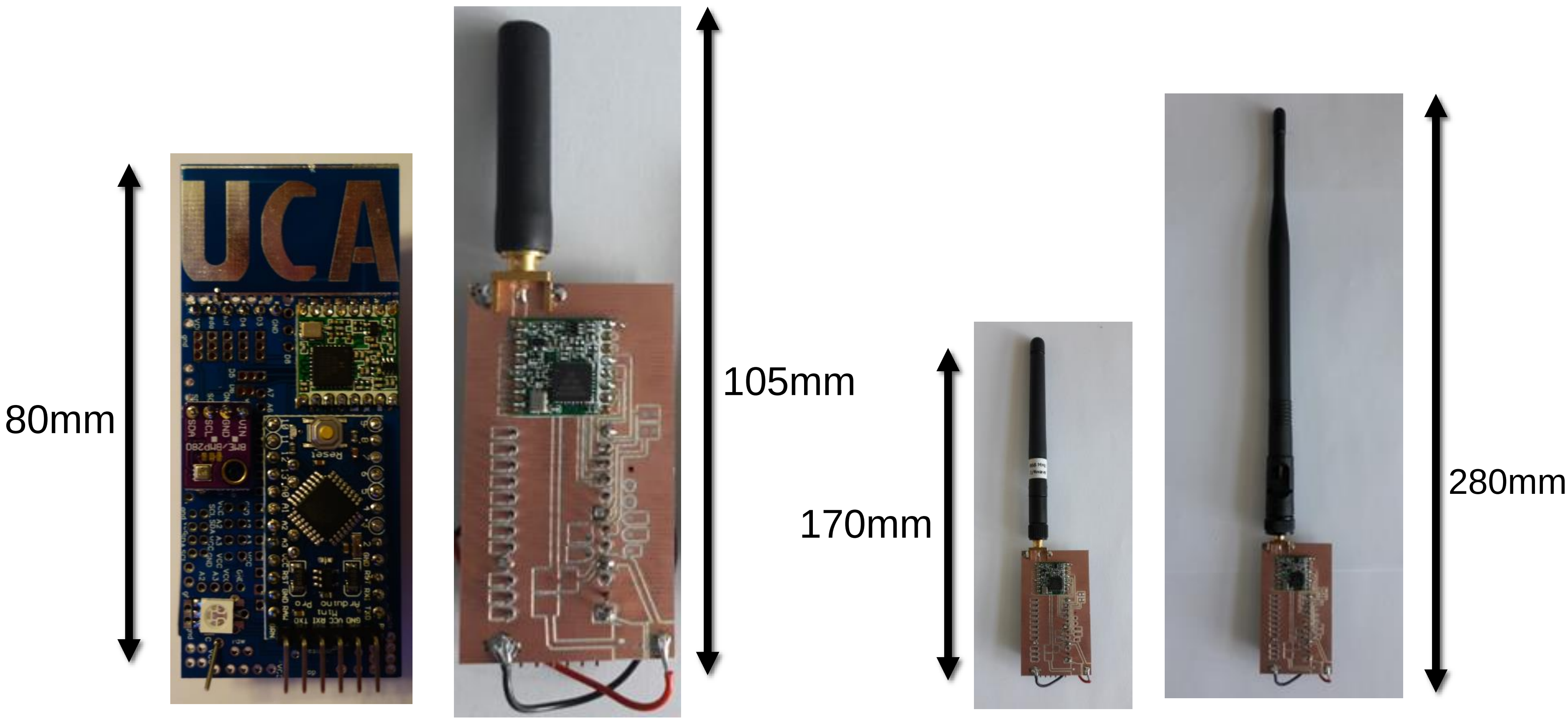
UCA Antenna tuning : Reflection coefficient



UCA Antenna : Linear Total Rad. Efficiency



Comparison with on-the-shelf antenna



UCA antenna

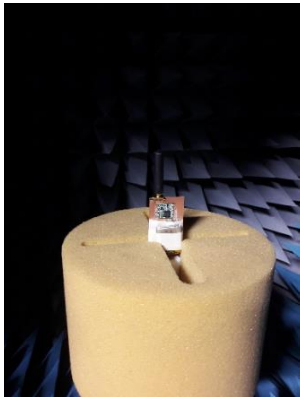
Short monopole

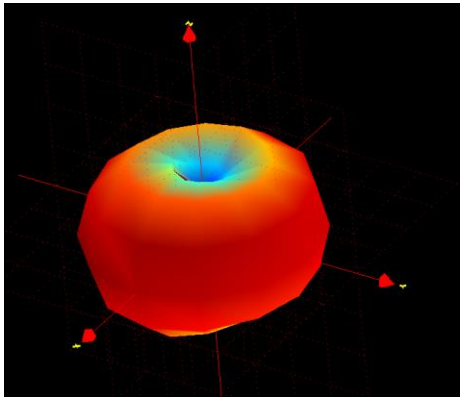
Quarter-wave monopole

half-wave dipole

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



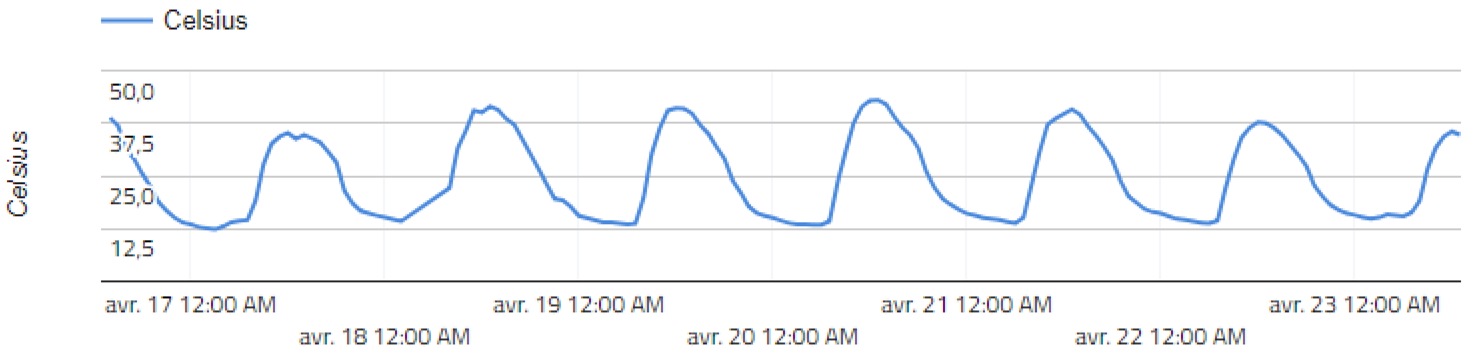


Antenna structure	EIRP (dBm)	Total efficiency	Max Dimension
Small monopole	14.7	74%	105 mm
Quarter-wave monop.	15.7	94%	170 mm
Half-wave dipole	13.9	61%	280 mm
UCA untuned	13.8	60%	80mm
UCA after tuning	14.8	76%	80mm

https://github.com/FabienFerrero/UCA_Board

Terminal Autonomy with a battery

- With a single AA Lithium battery
  - Measurement each 6mn (100mA peak)
  - Deep sleep between (10uA)
- Life time
  - 5 years
  - Parameters can be updated with downlink



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Micro-tracker Antenna Industrial project

- Specs
  - LoRa 868 or 915MHz
  - WiFi/BLE (2.4GHz)
  - GPS L1
  - Terminal size: 50*28mm²
- Proposed solution
  - Dual-band LoRa/GPS
  - SP4T to switch between LoRa Rx/Tx/Txboost and GPS.
  - WiFi/BLE antenna (2.4-2.48 GHz)

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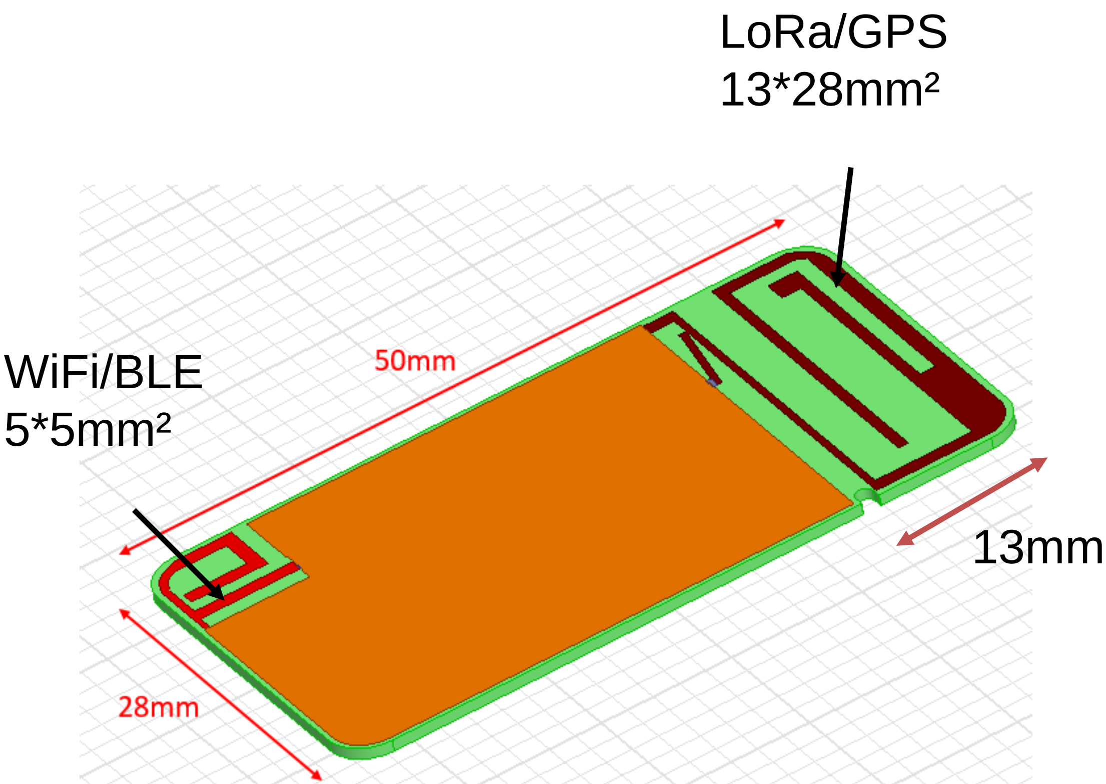
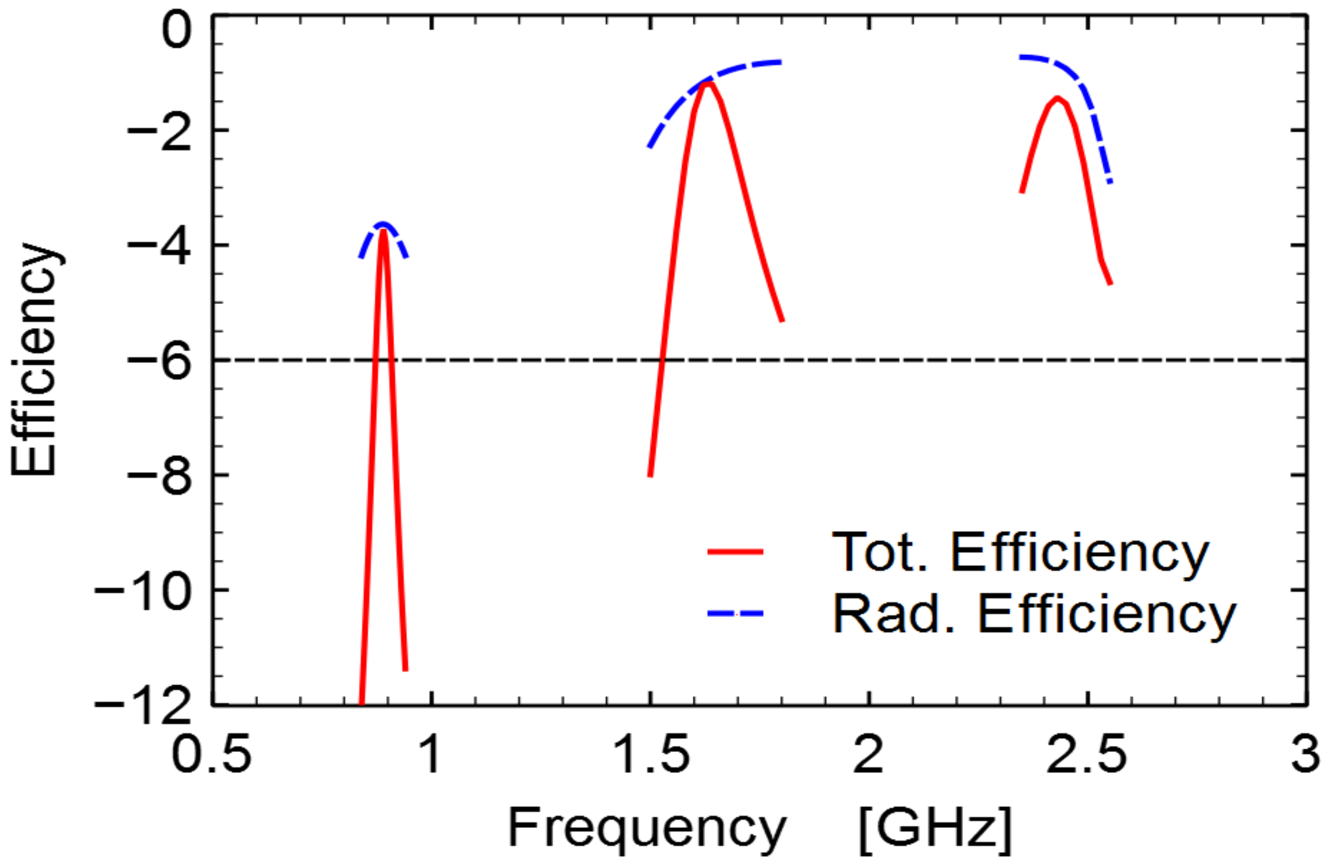
Micro-tracker Antenna Industrial project



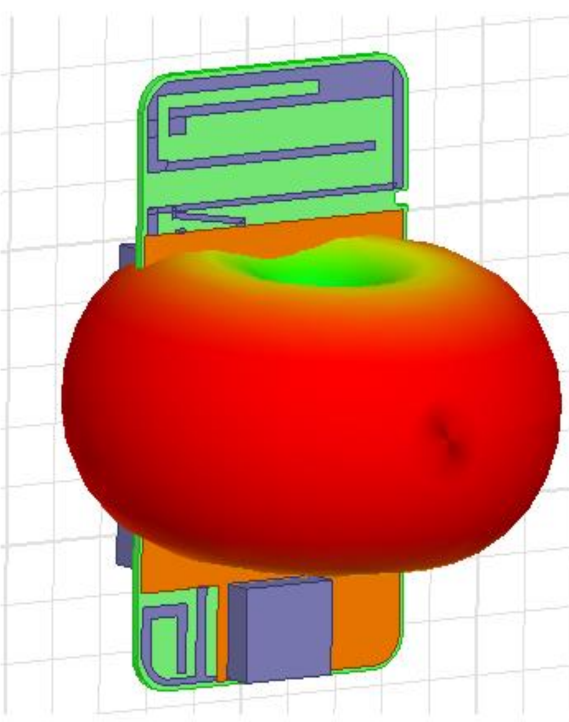
Micro-tracker Antenna Industrial project



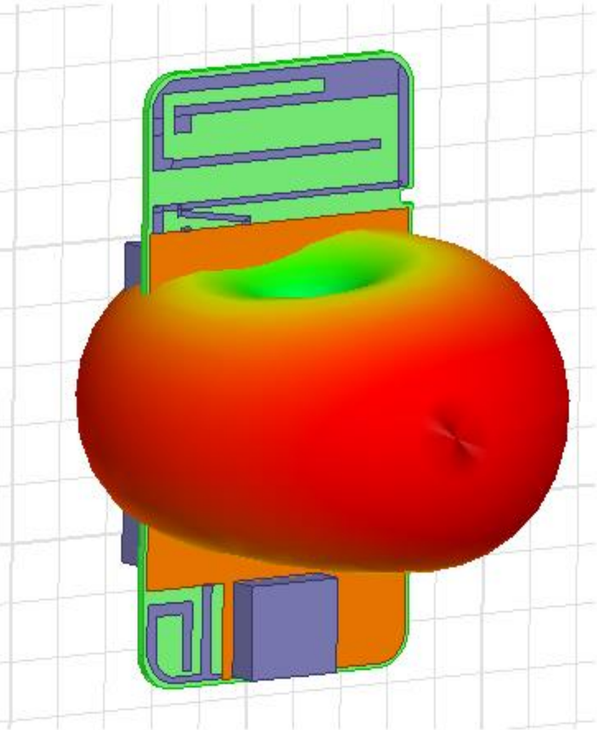
- Total Efficiency LoRa -4 dB (40%)
- Total Efficiency GPS -1.5 dB (70%)
- Total Efficiency WiFi/BLE -1.5 dB (70%)

Micro-tracker Antenna Industrial project

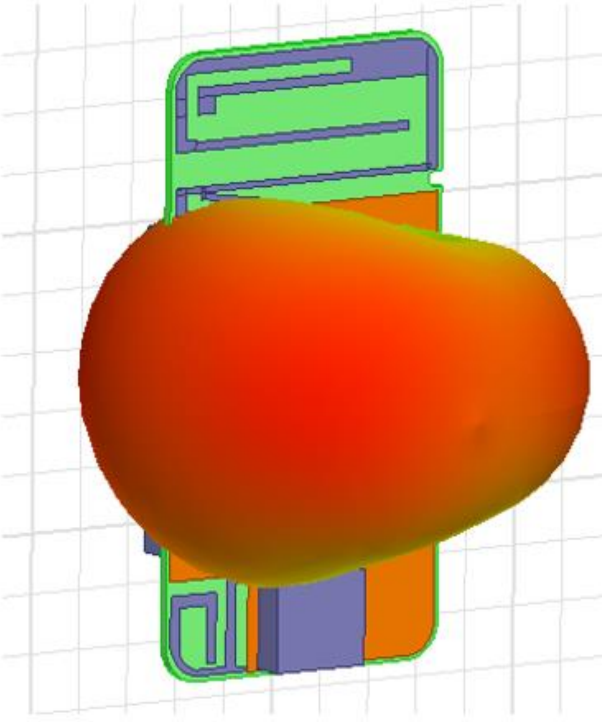
Radiation pattern



0.868 GHz



1.575 GHz

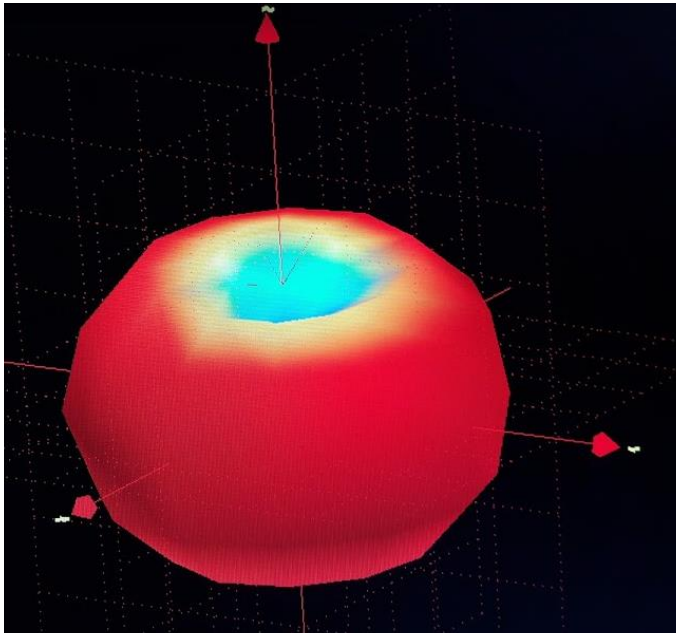


2.44 GHz

Micro-tracker Antenna Industrial project

Measurements :

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



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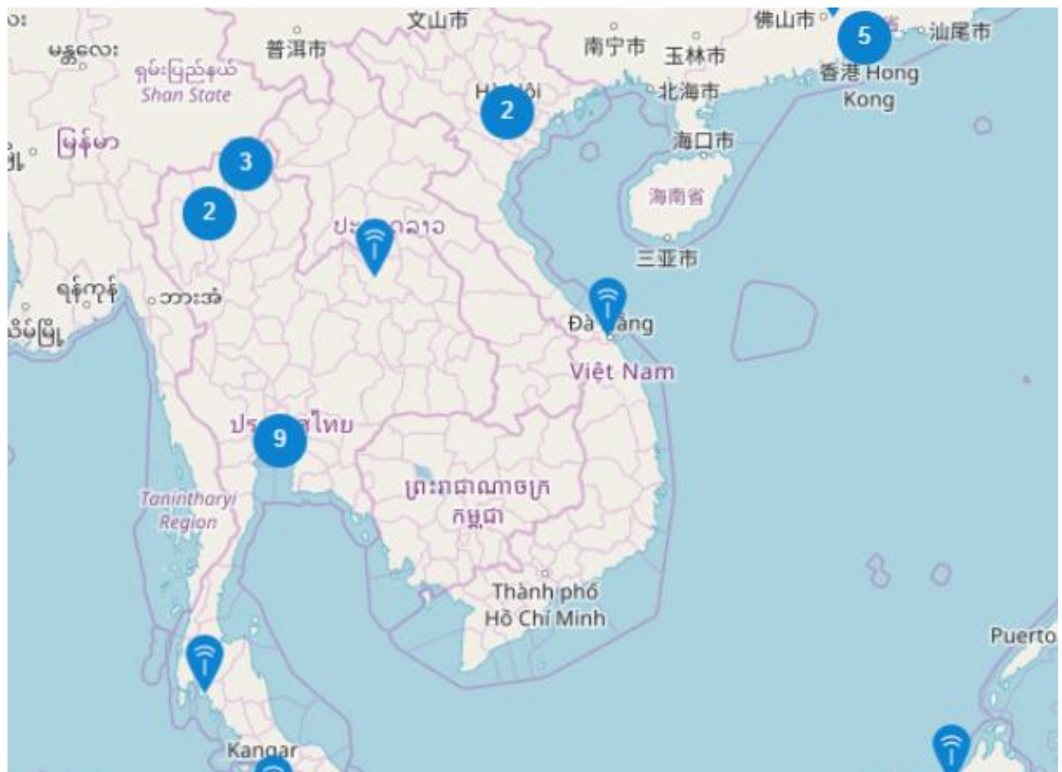
LoRaWAN in Da Nang

- Installation of LoRaWAN gateways in DUT and DNIIT
- Creation of a The Things Network Community



Da Nang/UCA : research perspectives

- Power management & Energy Harvesting
- Low-cost and low-power localization
- Advanced sensors for advanced applications
- Mix of LoRa, Bluetooth, Wifi, RFID, NFC, etc …
- Communication robustness and security

PAPIoT project -> MAVAK (MAng VAt-the Ket-noi)

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And Thanks to Leonardo Lizzi from UCA for contributing on most on this work

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