LABORATOIRE D'ELECTRONIQUE
ANTENNES ET TELECOMMUNICATIONS

Laboratory of Electronics Antennas and Telecommunications

Low-cost Antenna Radiation Measurement

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Outline

- Why antenna measurement are needed ?
- Antenna characteristics
- How to measure an antenna ?
- First solution with Spectrum Analyser
- Second solution with RSSI
- Conclusion and perspectives

Why do I need antenna measurement ?

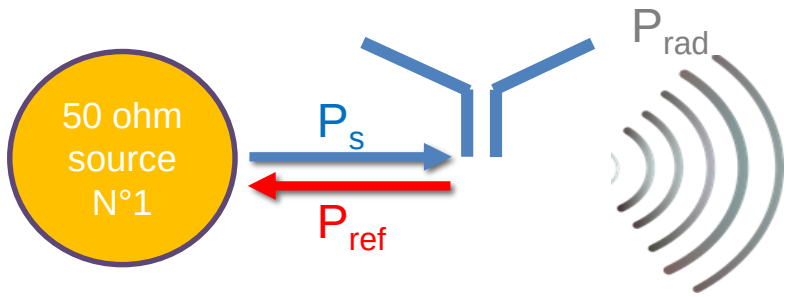
- To see if my antenna prototype work
- To optimize my antenna geometry or matching network
- To see if my antenna is sensitive to the environment
- To compare different antennas or to find an optimal position
- To verify if my device respect the certification

Why do I need antenna measurement ?

- To see if my antenna prototype works
  - Low accuracy
- To optimize my antenna geometry or matching network
  - Medium accuracy (relative measurement)
- To see if my antenna is sensitive to the environment
  - Medium accuracy (relative measurement)
- To compare different antennas or to find an optimal position
  - Medium accuracy (relative measurement)
- To verify if my device respect the certification
  - High accuracy (absolute results)

Antenna performance indicator

- Some definitions :
  - 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, polarization** and **directivity**
    - Plotted in dBi
    - $U(\theta, \varphi)$ is the radiation intensity in a given direction



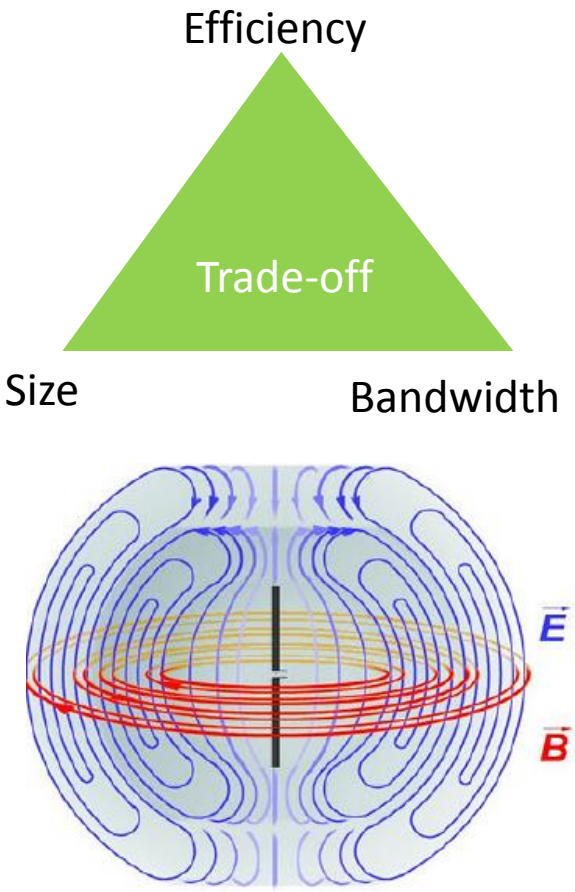
$$|S_{11}|^2 = P_{ref}/P_s$$

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

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

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

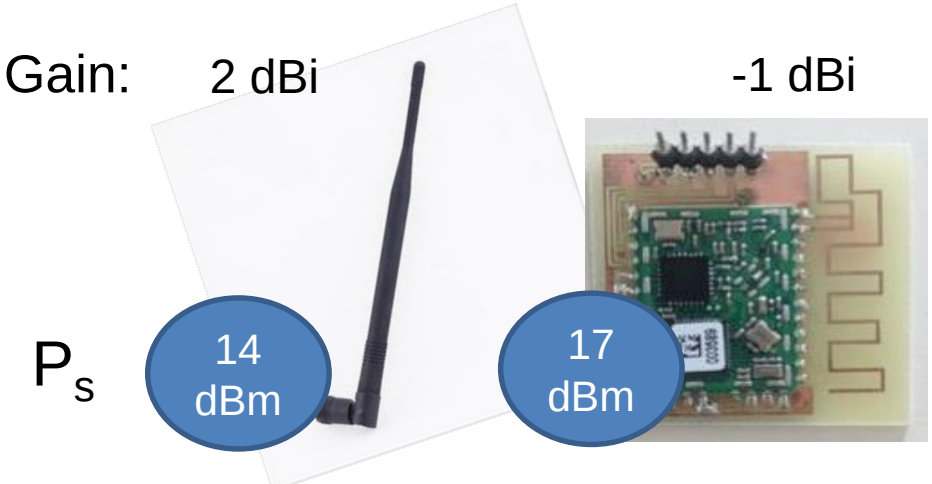


Certification process

- Regulators defines the maximum radiated power in Equivalent Radiated Power (ERP) -> I*n Europe : ERP @868MHz is* ***14 dBm***
  - **E**ffective **R**adiated **P**ower : amount of power applied to a half-wave dipole to give the same power density at a given point
  - **E**ffective **I**sotropic **R**adiated **P**ower : the reference is an isotropic radiator

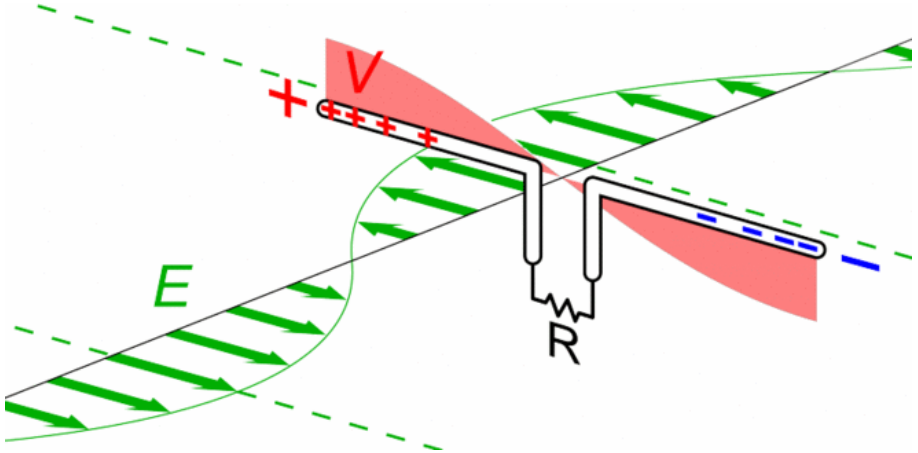
EIRP = ERP + 2 dB

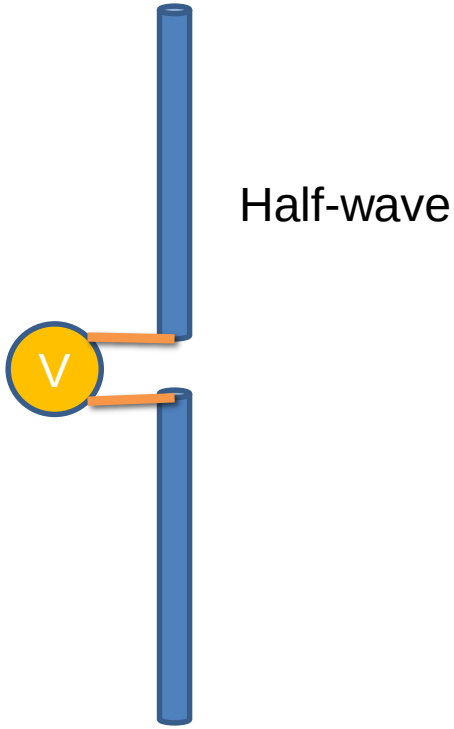
- Tested during the certification process for all signal harmonics (CW test mode)
- Some operator ask for a minimal gain performance (or give classifications)
- Certification process is (very) expensive



Effect of terminal chassis

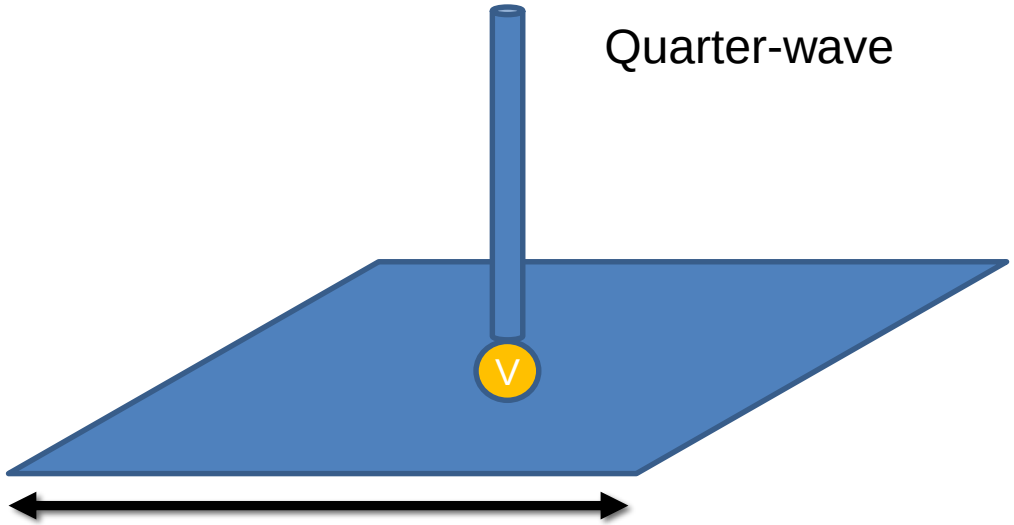
- Two type of antenna
  - Dual-pole : 2 parts contribute to the radiation (cable effect)
  - Single-pole with a large ground plane (cable OK)





Half-wave

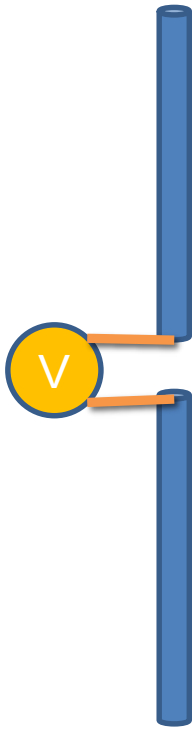
Quarter-wave



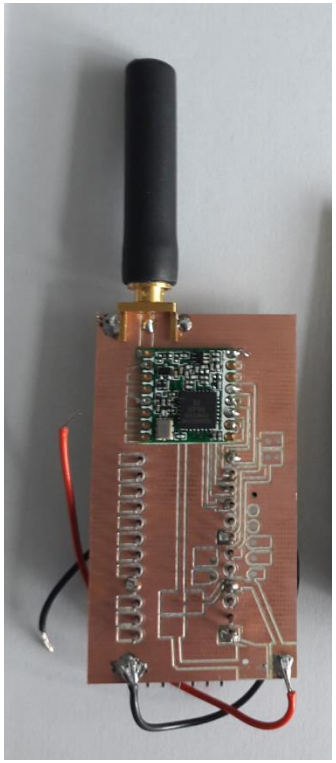
> 2 wavelengths
@868MHz > 70cm

Effect of terminal chassis

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

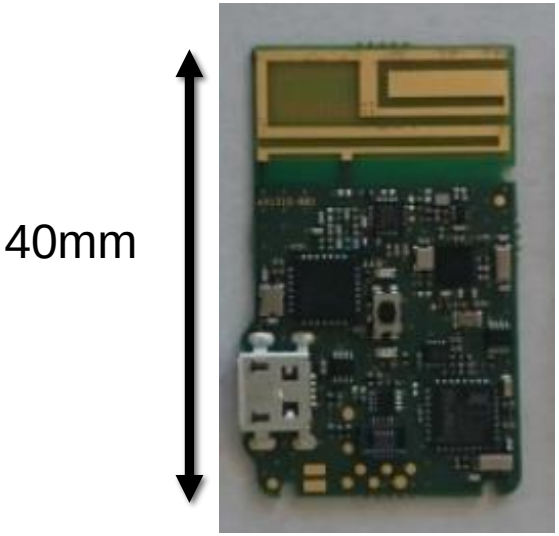


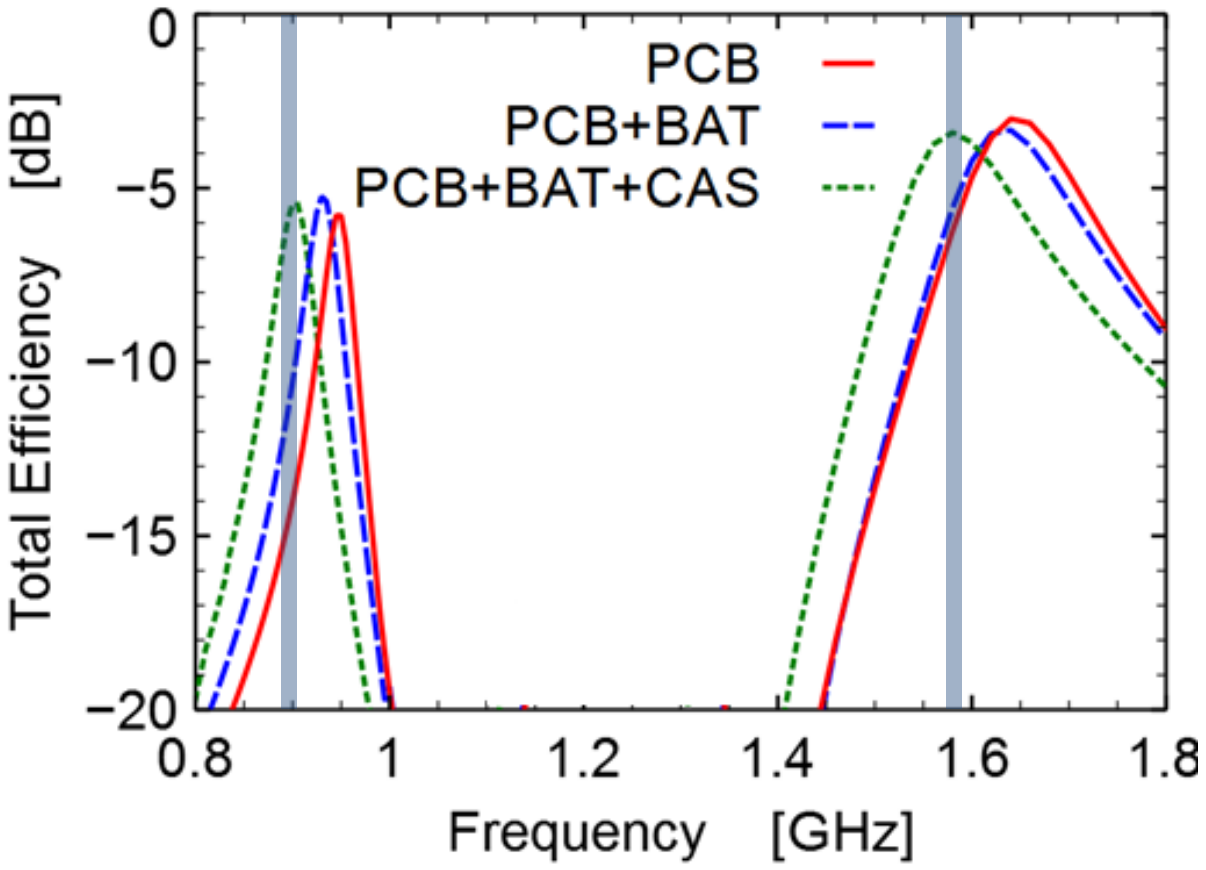
Half-wave



Effect of the environment

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

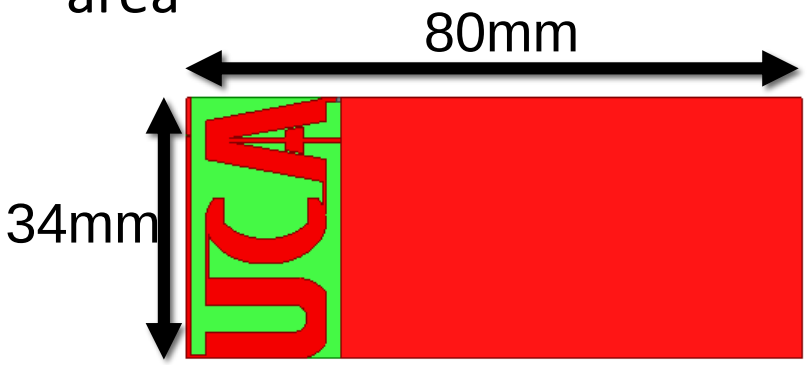


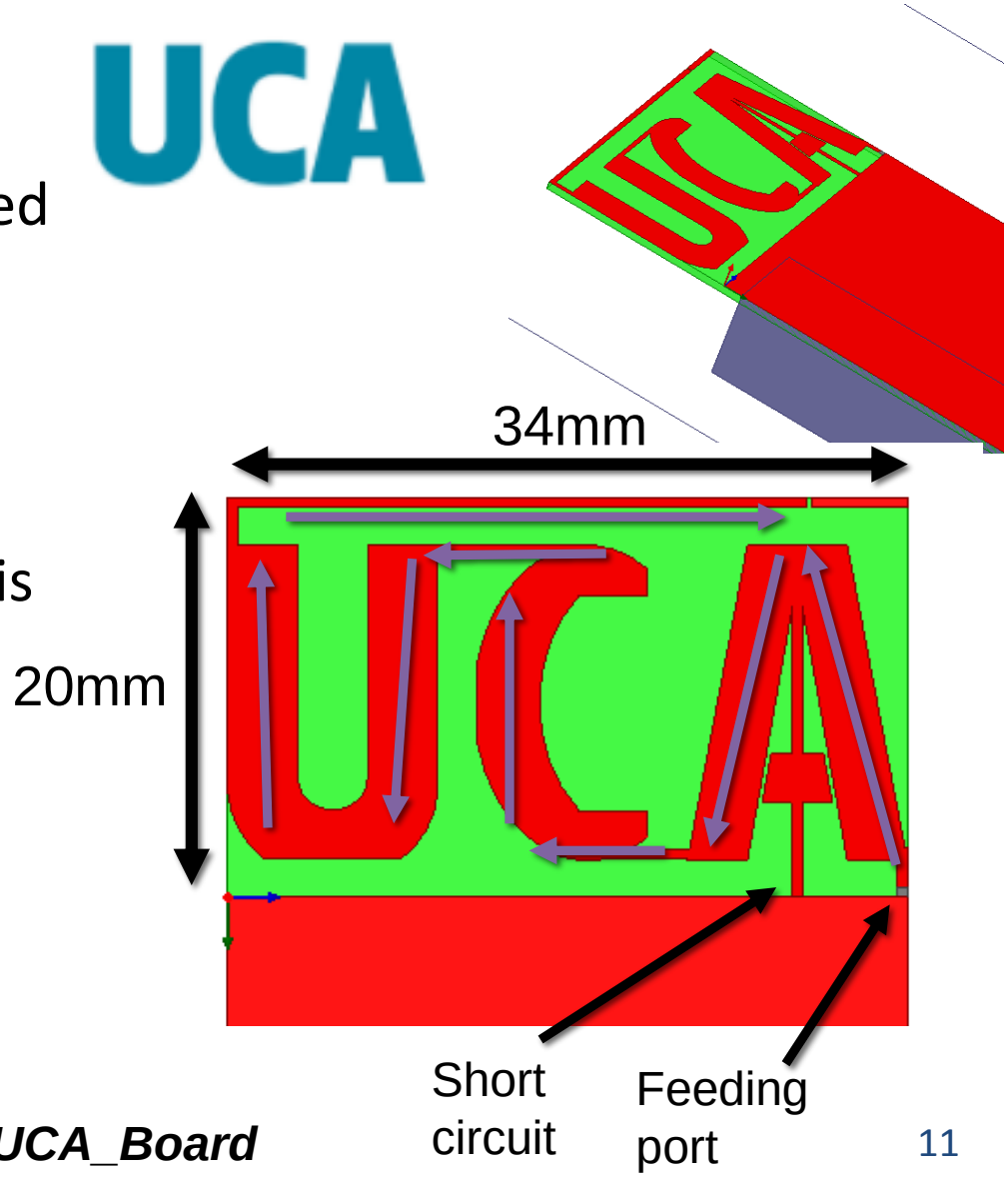


Small antenna have to be tuned

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

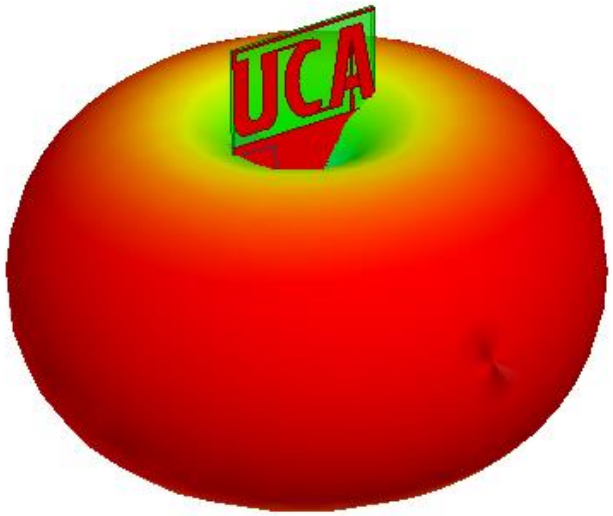




https://github.com/FabienFerrero/UCA_Board

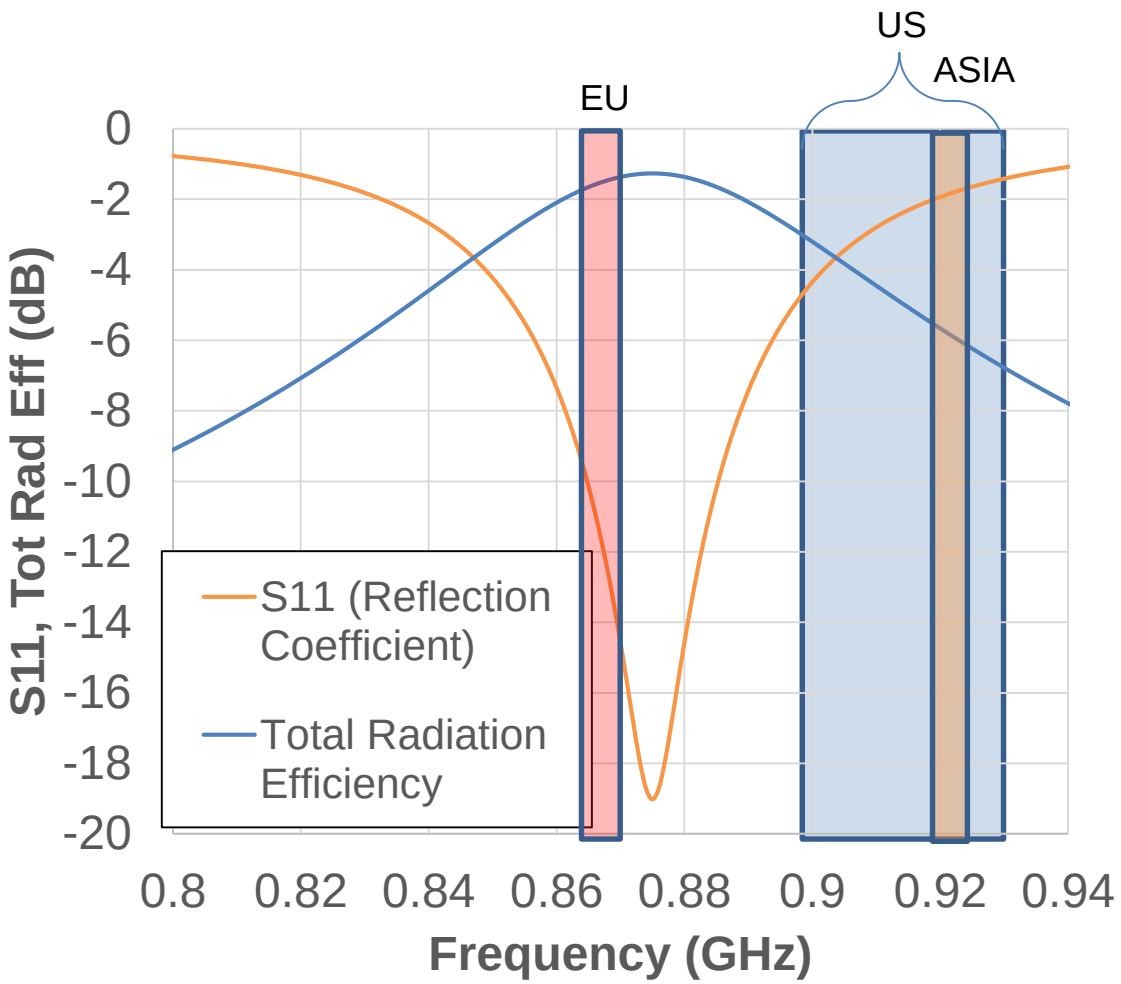
UCA Antenna tuned for EU band

- 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



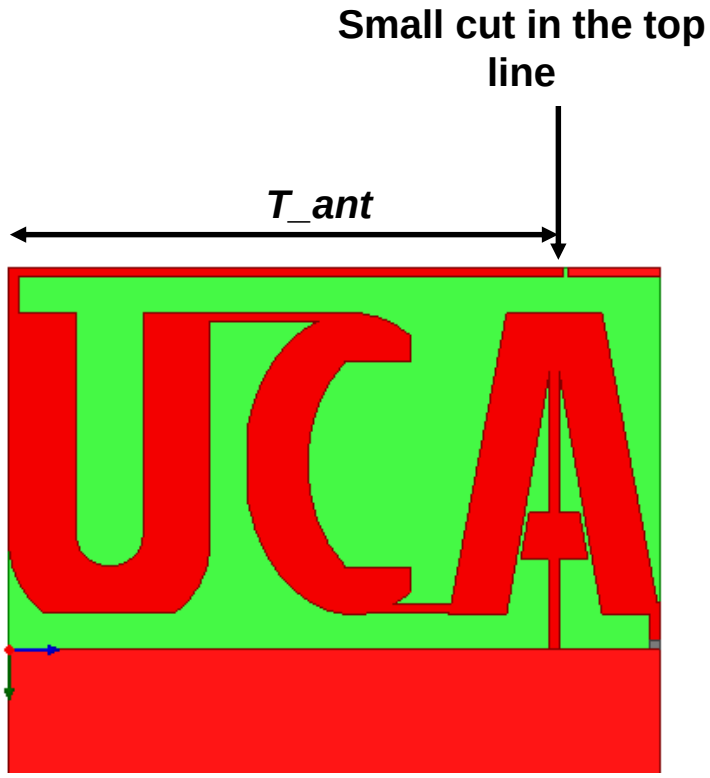
UCA Antenna tuned for EU band

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

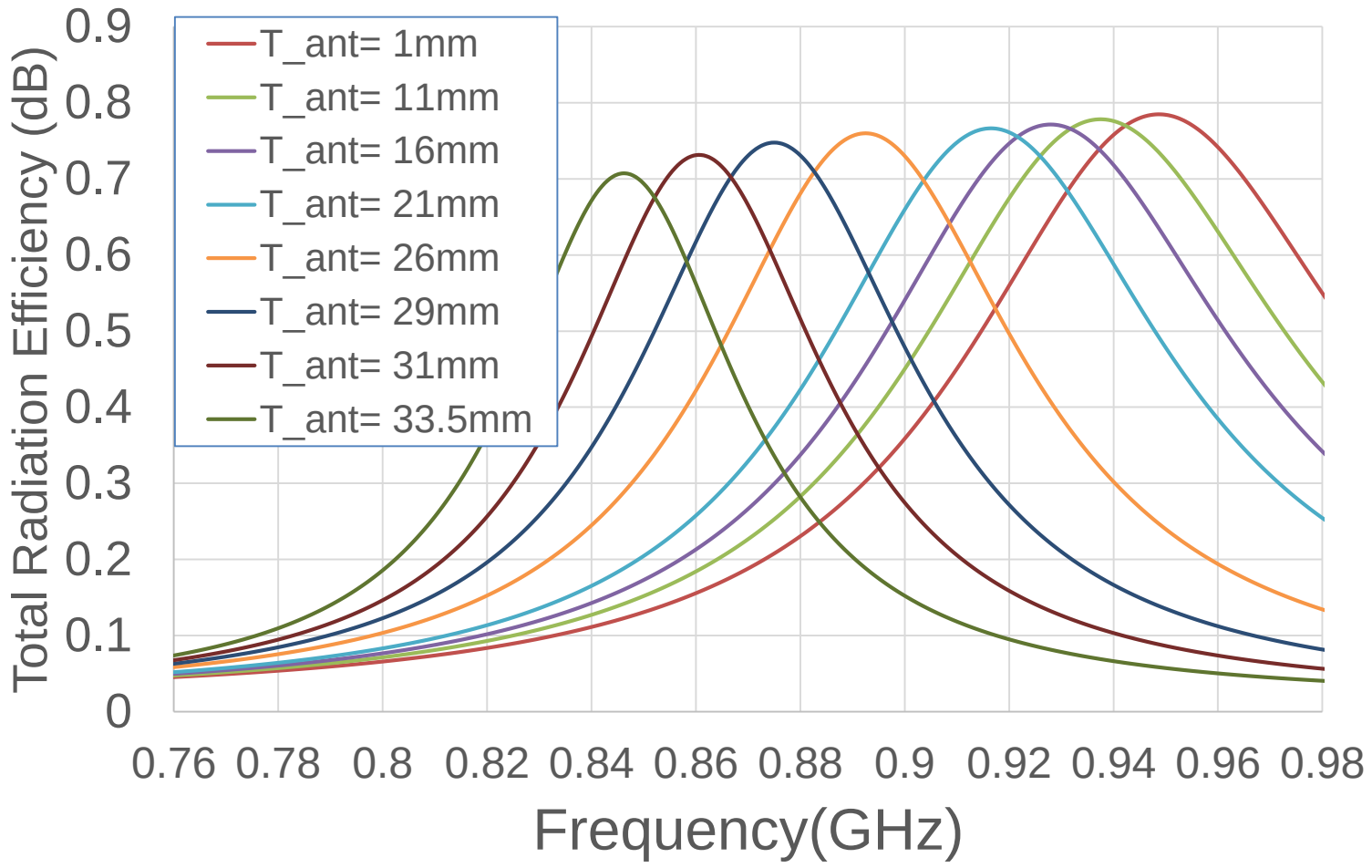


Antenna design

- 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

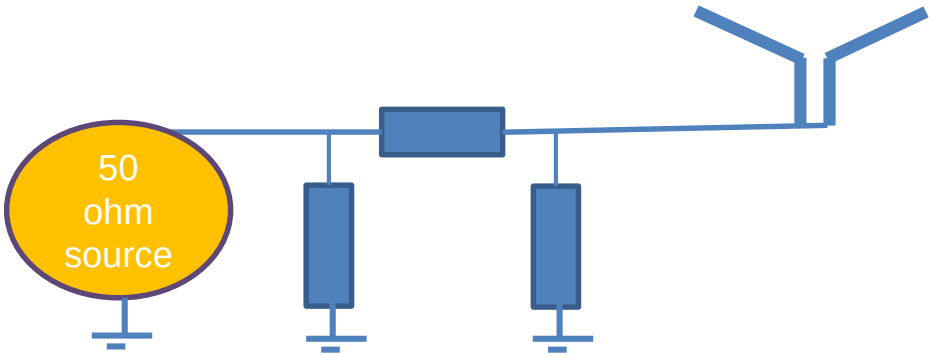


UCA Antenna : Linear Total Rad. Efficiency



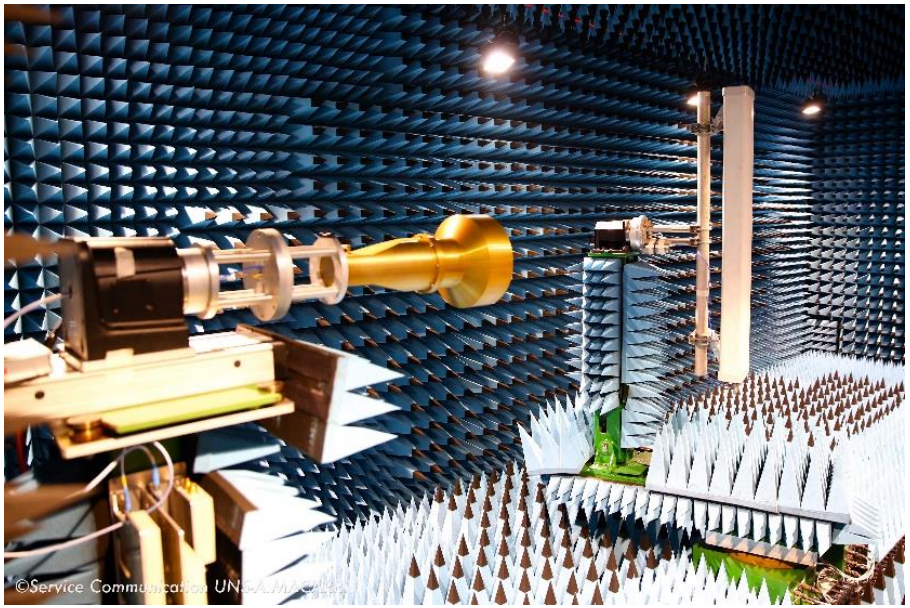
Classical issues with antenna and solutions

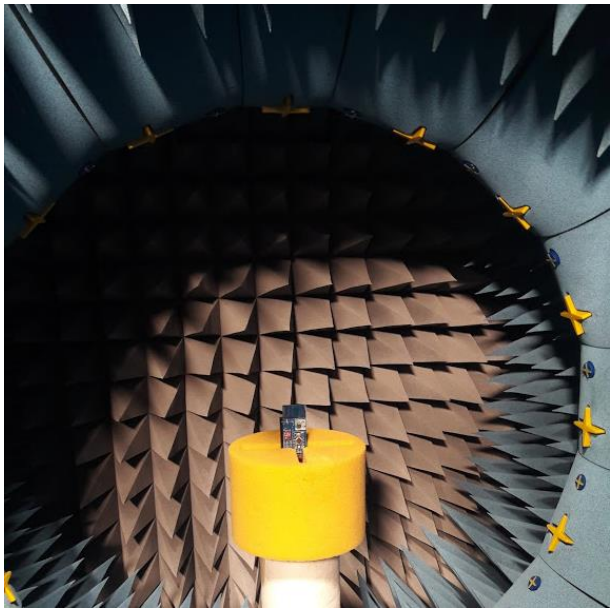
- Most of the time, your antenna won't be tuned at the wanted resonnance frequency
  - Usually, tuning antenna frequency is quite simple by changing the antenna geometry (length) and by changing the matching network
- Sometimes, you may have issue with the level of matching
  - Measurement with VNA is helpfull but effect of the cable has to be carrefully considered
  - **« Test and Try »** with gain measurement and matching network modification is the most secure solution
- Always add a PI matching network in front of your antenna
  - Use 0402 or 0603 package
  - Pay attention to component resonance frequency !



How to perform antenna radiation measurement ?

- Accurate antenna measurement is difficult
- Cables have a large influence on the measurement
- Only consider Total Radiated Power (TRP) measurement (your device will be in Continuous Wave mode)





How to perform antenna radiation measurement ?

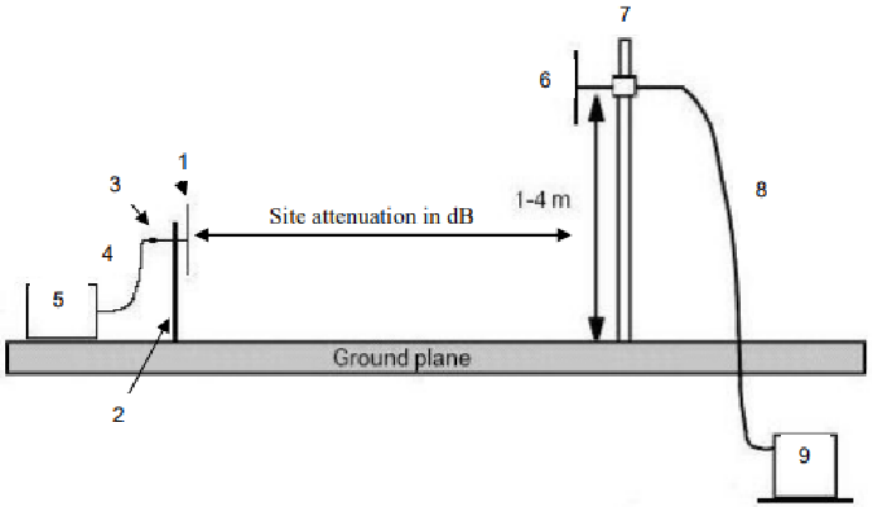
ETSI TS 103 052 V1.1.1 (2011-03)

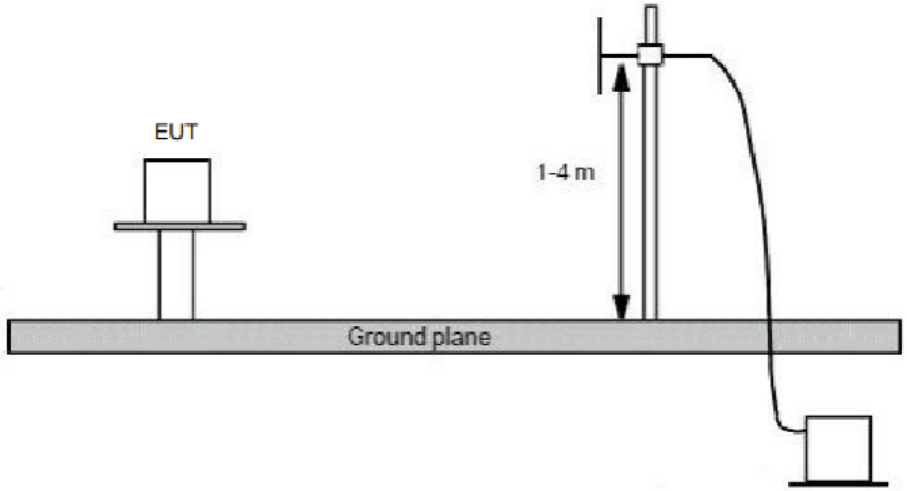
- Anechoic chamber
- 2 Reference antennas
- Power source
- Power measurement equipement (**Spectrum analyser** or power meter)

How to perform an antenna measurement ?

ETSI TS 103 052 V1.1.1 (2011-03)

- Anechoic chamber or open site
- Reference antenna : 1 & 6
- Power source : 5
- Power measurement equipement : 9

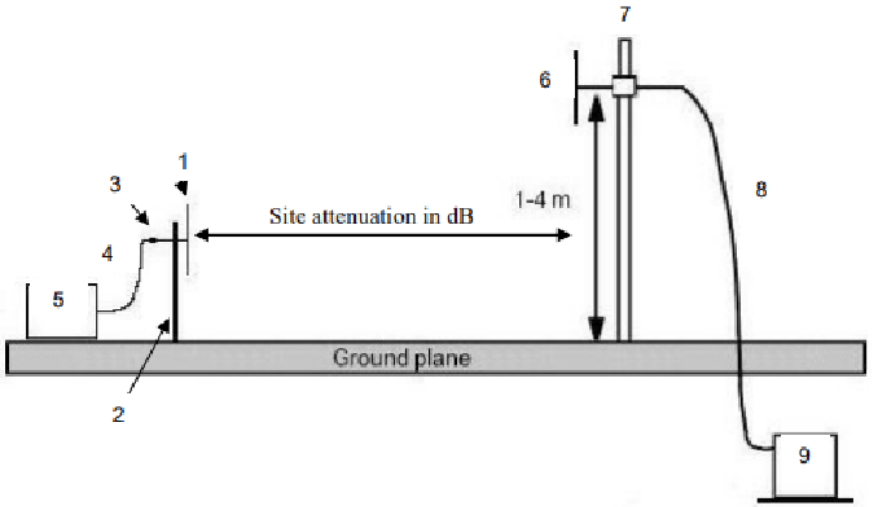


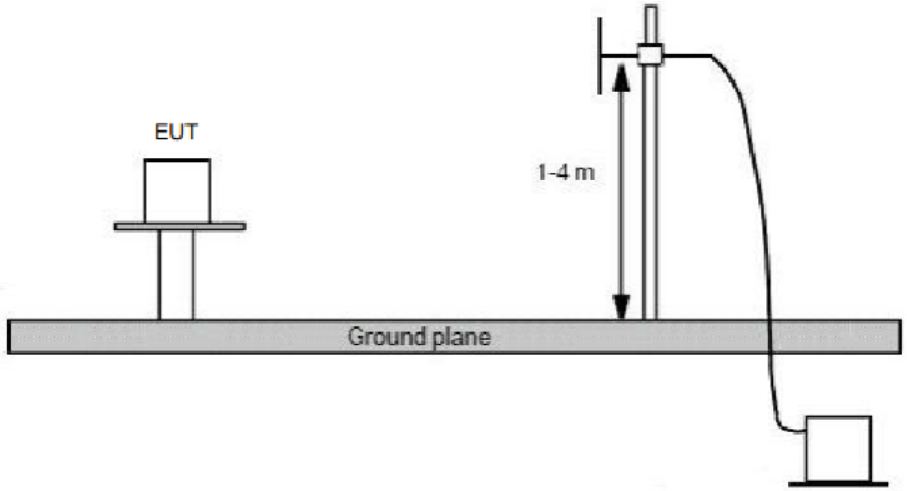


How to perform an antenna measurement ?

- Substitution or pre-substitution method
  - First measurement Rx_{Cal} for calibration using a reference antenna
  - Second measurement Rx_{AUT} of the Antenna under Test (AUT)

$$(Gain_{AUT})_{dBi} = (Rx_{AUT})_{dBm} - (Rx_{Cal})_{dBm} + (Gain_{Ref\ Ant})_{dBi}$$





How to perform an antenna measurement ?

- Anechoic chamber – 500 000 €
- Reference antenna – 3000 €
- Power source -20 000 €
- Spectrum analyser - 20 000 €

Can we reduce the price ?

How to perform an antenna measurement ?

- Miniature chamber – 50 000 €
- Reference antenna – 3000 €
- Power source -20 000 €
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DST200 from R&S

Can we reduce the price ?

How to perform an antenna measurement ?

- Anechoic chamber – 500 000 €
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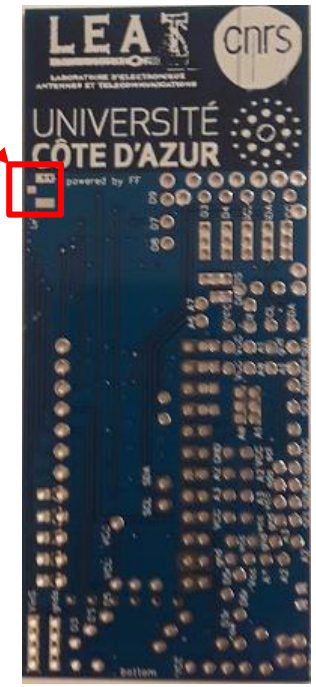
- ~~Power source -20 000 €~~
- Spectrum analyser - 20 000 €

My LoRa chip can transmit a continous wave !

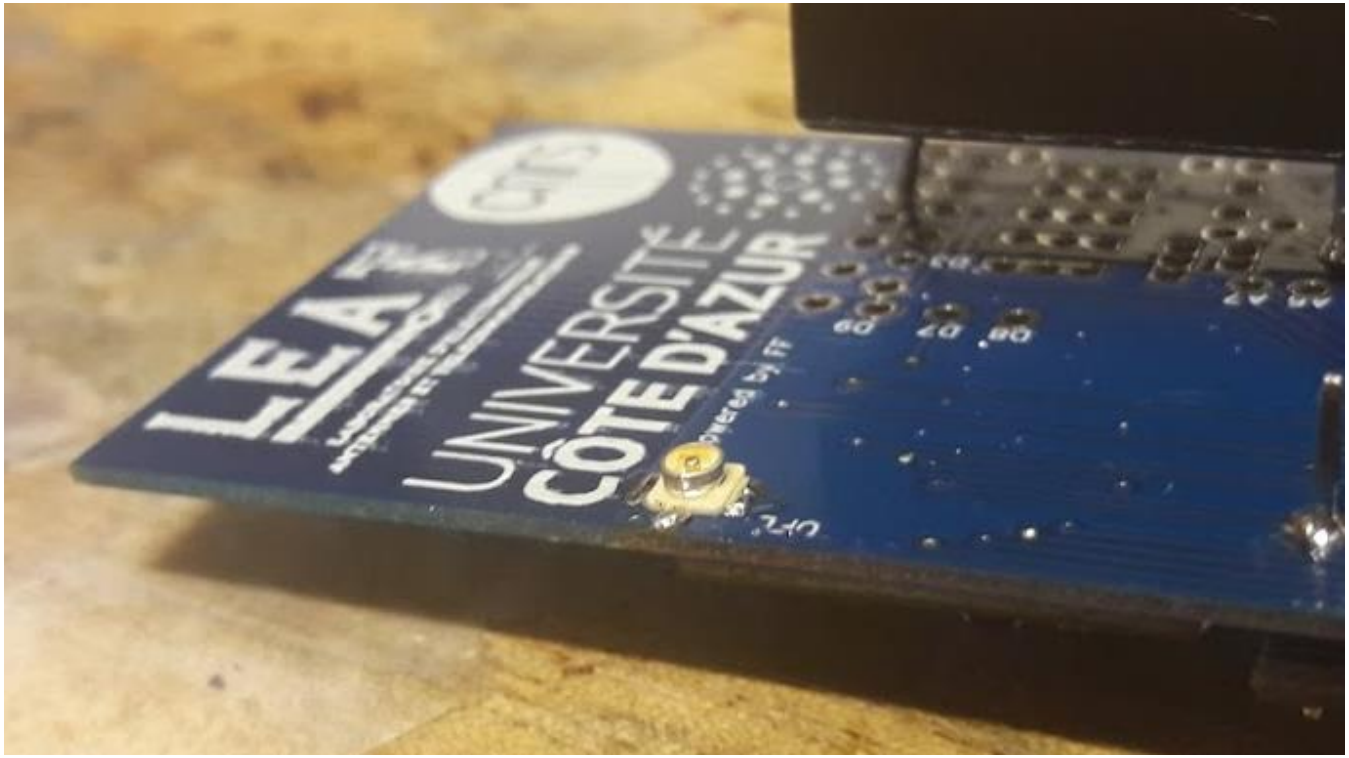
It is interesting to measure the exact output power of my module for a given configuration

Adding a RF connector

- Try to place a connector footprint
- UFL are very small and easy to find
- Very important for debug !
- A UFL connector can be soldered on the bottom part of the board
- If you just solder the connector, the UFL will be in shunt with the existing « UCA » antenna
  - If you leave the UFL unconnected, your board will work as usual (the UFL effect is negligeable)
  - If you connect a load (antenna or spectrum) on the UFL, rougly half of the power will be captured by the UFL, and half part of the power will be radiated (and a part of the power will be reflected to the source)

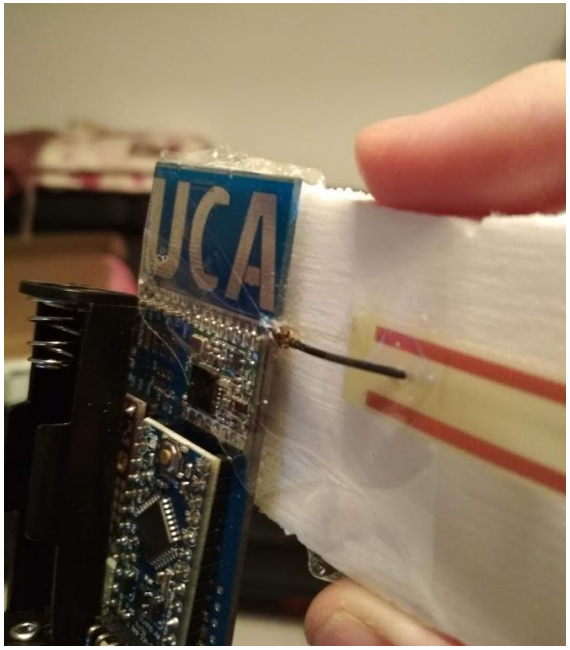


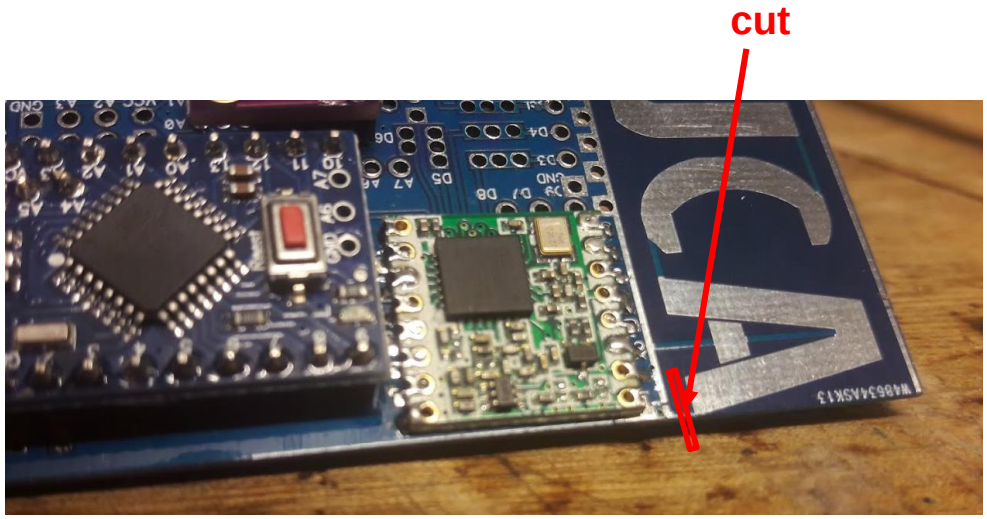
Adding a RF connector



Adding a RF connector

- To have 100% of the power on the UFL connector
  - You need to cut the antenna feeding line
  - You will be able to solder it again





How to perform an antenna measurement ?

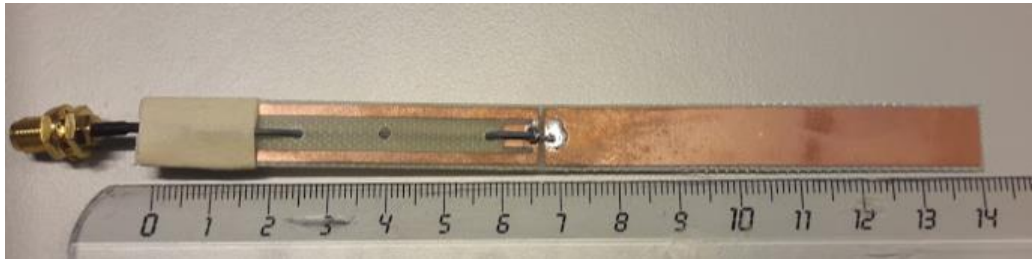
- Anechoic chamber – 500 000 €
- ~~Reference antenna – 3000 €~~
- ~~Power source -20 000 €~~
- Spectrum analyser - 20 000 €

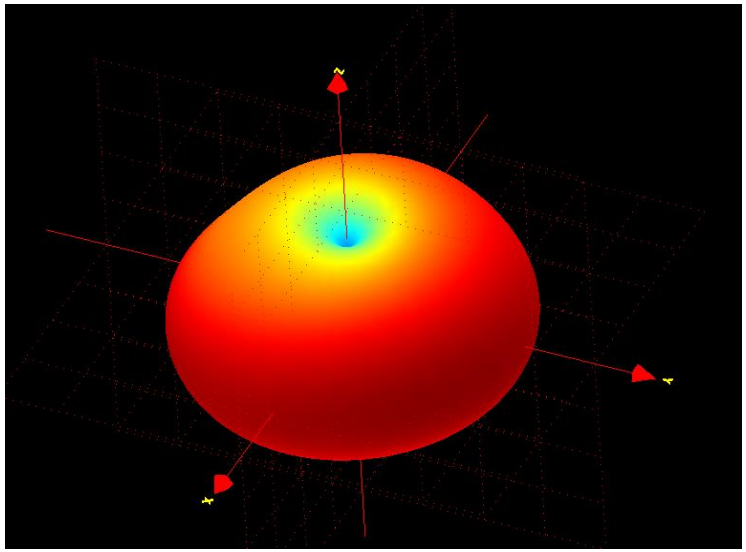
Can I use a low cost reference antenna ?

Can find some open source design or buy is cheap one

Printed Sleeve dipole with coaxial cable

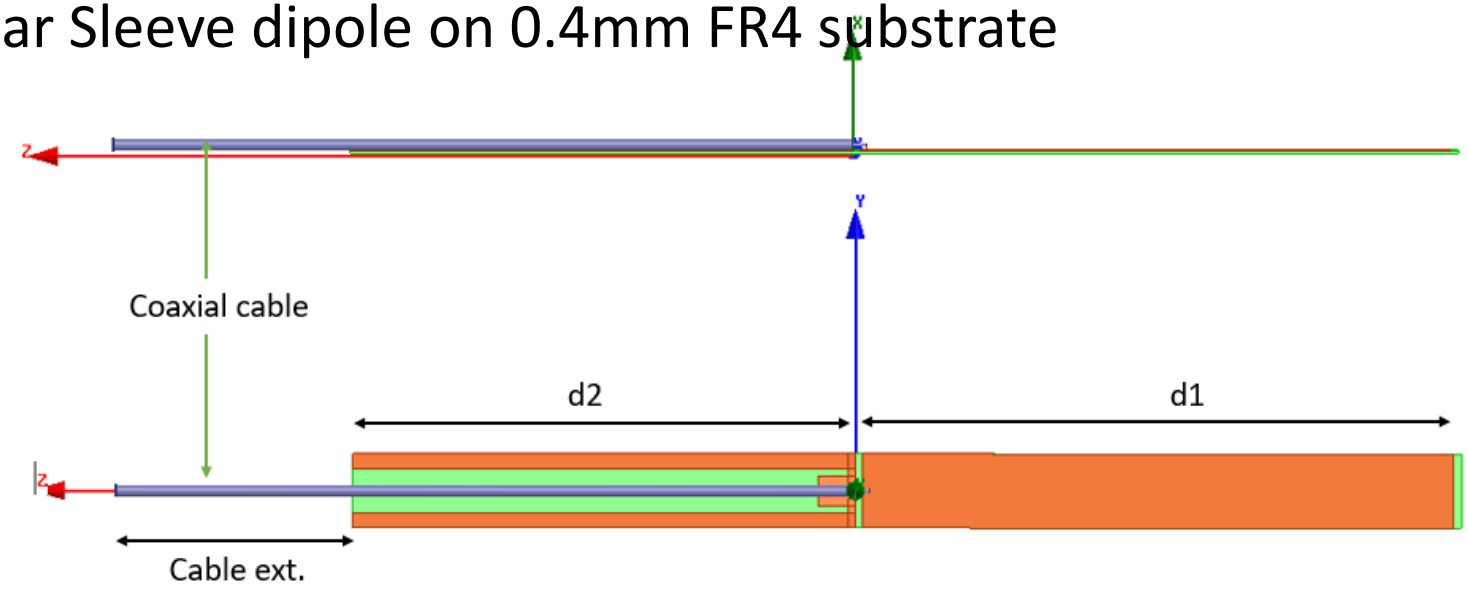
- Low cost 0.4mm FR4 Epoxy 140x15mm
- Low cost Small coaxial cable
- Integrated Balun for environment robustness
- Omnidirectional pattern
- Gain 2.5dBi
- Measured Efficiency 83%

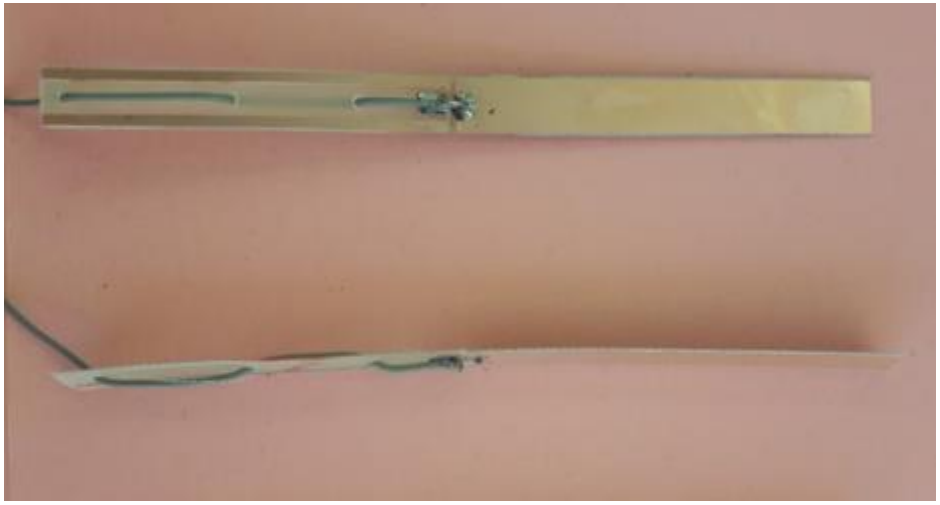




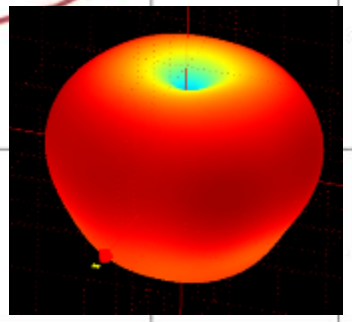
Half-wave dipole Antenna

- Planar Sleeve dipole on 0.4mm FR4 substrate



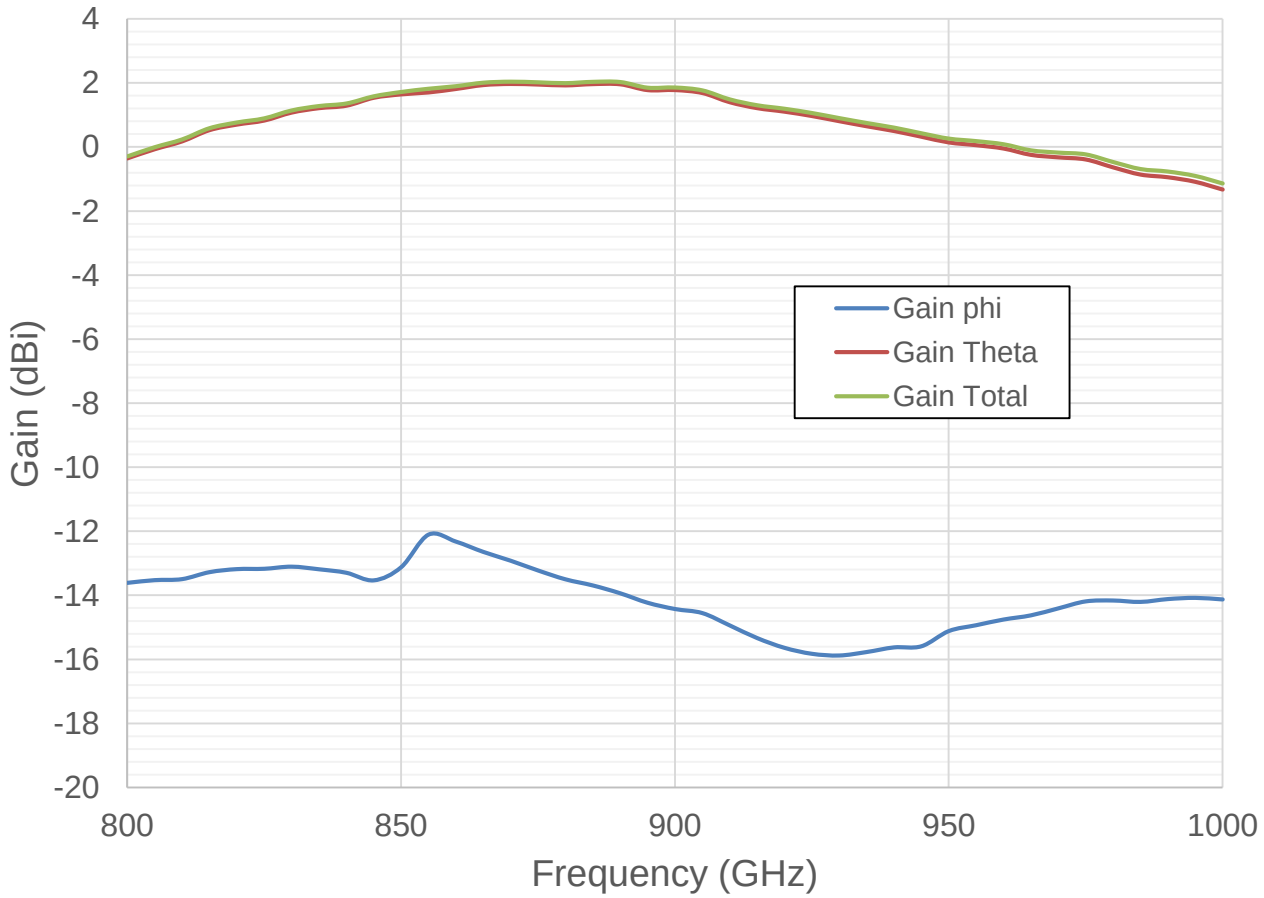


Comparison with on-the-shelf antenna



Printed Sleeve dipole with coaxial cable

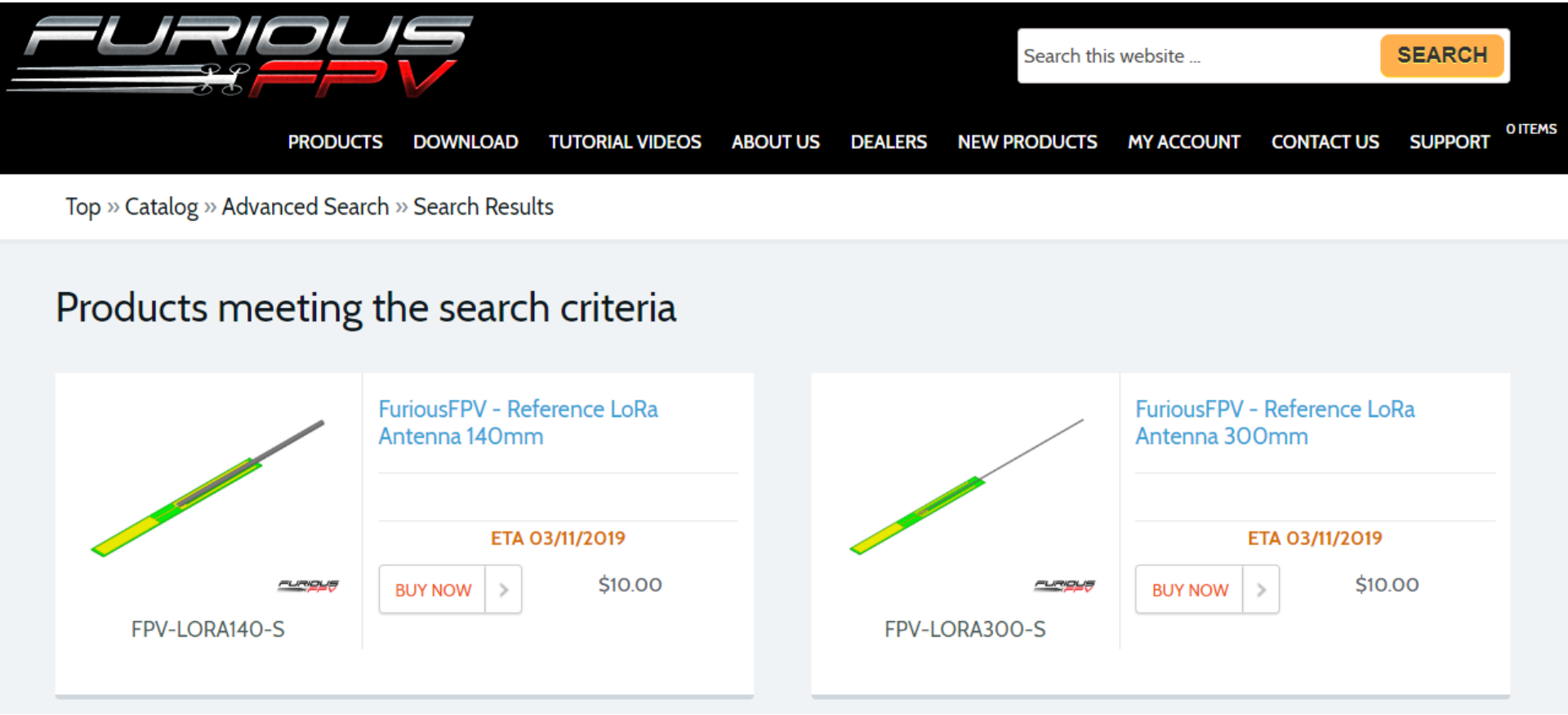
- Low cost 0.4mm FR4 Epoxy 140x15mm



Printed Sleeve dipole with coaxial cable

- Don’t want to fabricate it ? can just buy it !

https://furiousfpv.com/advanced_search_result.php?keywords=lora



How to perform an antenna measurement ?

- ~~Anechoic chamber – 500 000 €~~
- ~~Reference antenna – 3000 €~~
- ~~Power source -20 000 €~~
- Spectrum analyser - 20 000 €

Can we do measurement without anechoic chamber ?

Yes and No

How to perform an antenna measurement ?

ETSI TS 103 052 V1.1.1 (2011-03)

- Distance between antenna
- It shall be ensured that radiated measurements are tested in the far field.
- There is no clearly defined transition from near field to far field. The distance should be equal to or exceed:

$$\frac{2(d_1 + d_2)^2}{\lambda}$$

where:

d1 is the largest dimension of the EUT/dipole after substitution (m);

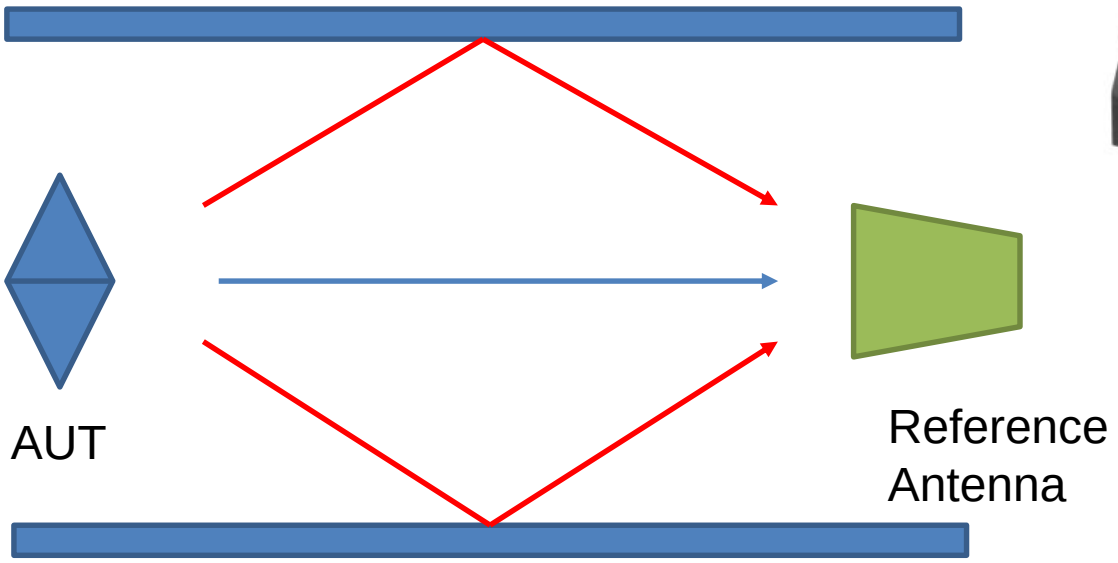
d2 is the largest dimension of the test antenna (m);

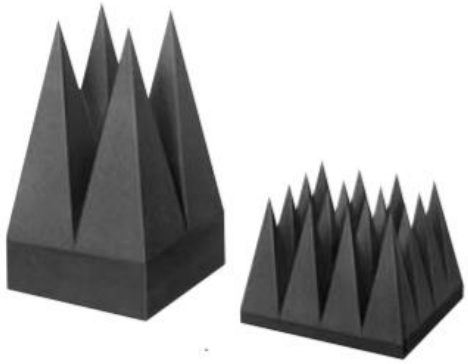
λ is the test frequency wavelength (m).

No anechoic chamber ?

Why do we need anechoic chamber or open site ?

- We want Free Space : No reflection (because of interferences)
- Try to analyze the possible origin for reflection and to limits as much as you can
- You can also buy some absorber to improve your test-bed (EM sheet, Pyramidal absorber)



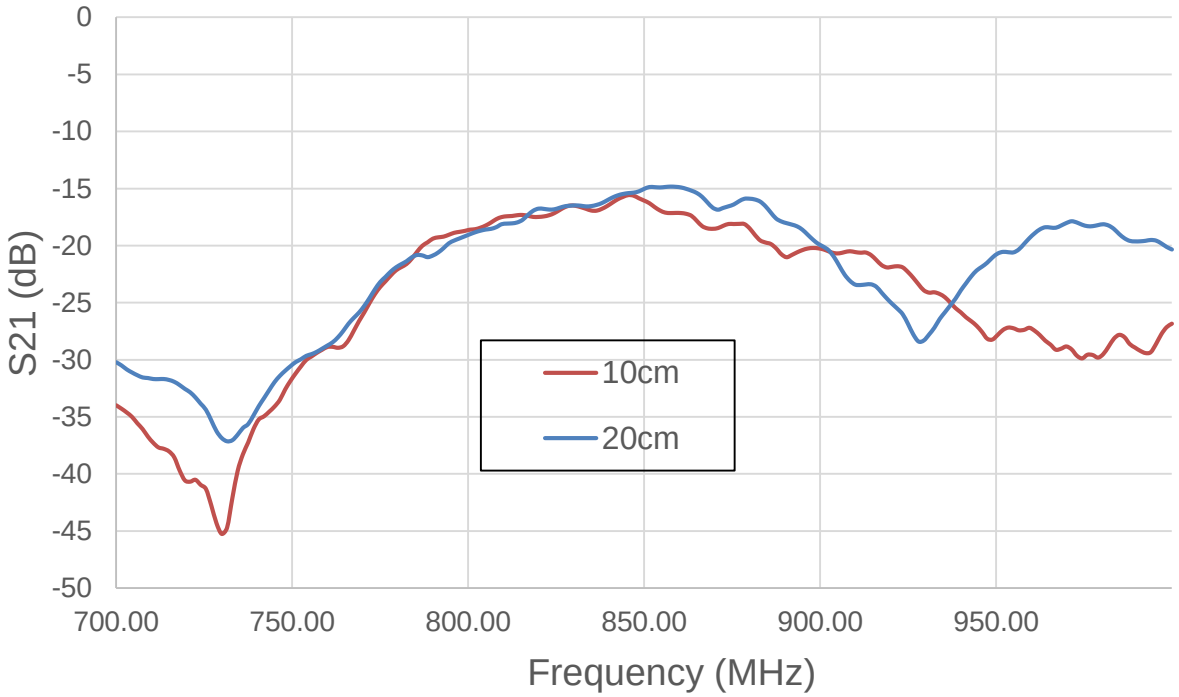


No anechoic chamber ?

- Transmission power versus frequency for different distances
- Measurement with VNA in a lab with walls, metal shelf, metal ceiling, etc

No anechoic chamber ?

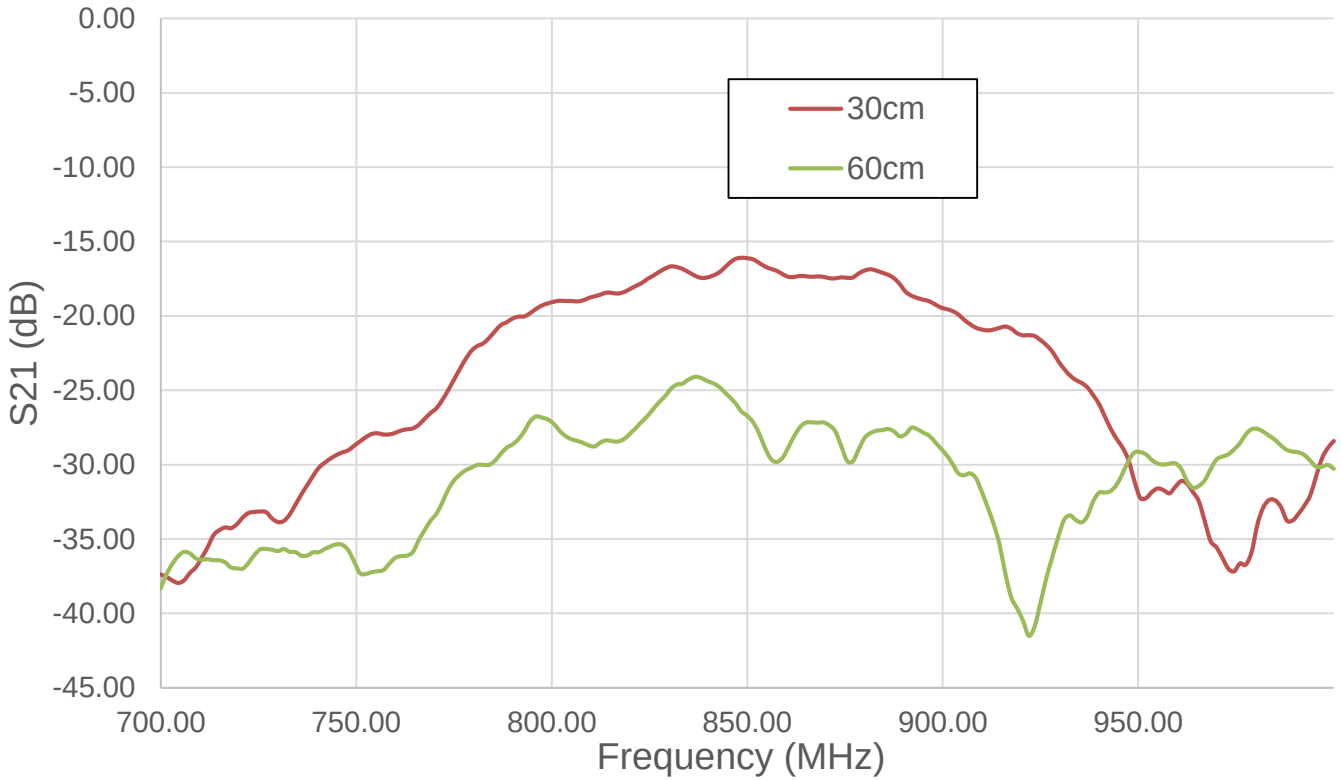
- Transmission power versus frequency for different distances



When antennas are two close, effect of near field

No anechoic chamber ?

- Transmission power versus frequency for different distances



When antennas are too far, multipath is too important

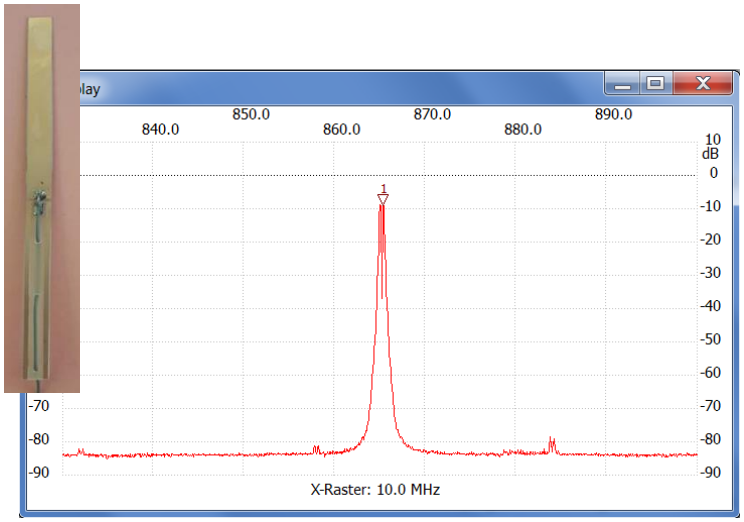
How to perform an antenna measurement ?

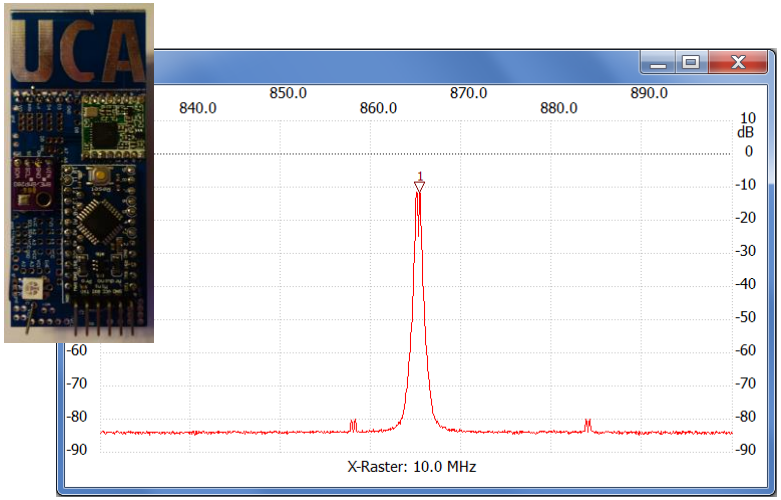
- ~~Anechoic chamber – 500 000 €~~
- ~~Reference antenna – 3000 €~~
- ~~Power source -20 000 €~~
- Spectrum analyzer - 20 000 €

Can we reduce the price ?

Summary

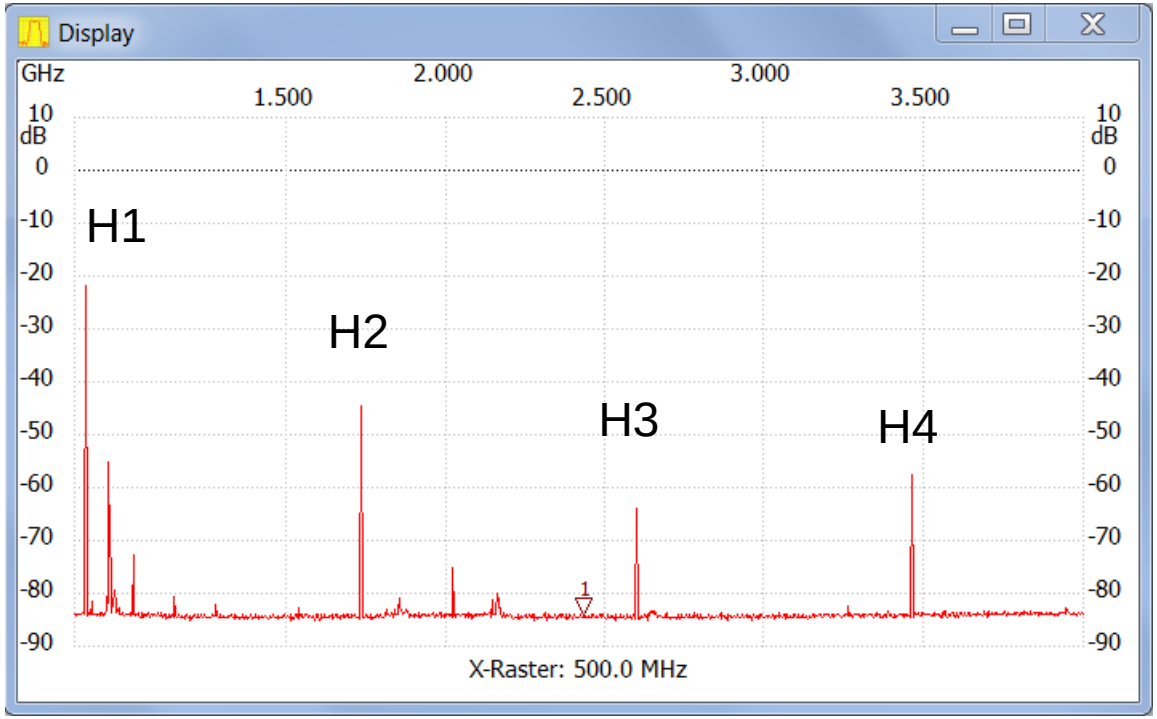
- Use CW mode of AUT
- Measure for a given distance with ref antenna
  - Exemple: $(Rx_{Cal})_{dBm}$ =-9.4dBm
- Measure for the same distance AUT
  - Exemple: $(Rx_{AUT})_{dBm}$ =-11.1dBm
- $At\ 865MHz, (Gain_{Ref\ Ant})_{dBi}$ = 2 dBi
- Then, $(Gain_{AUT})_{dBi}$ =-11.1+9.4+2= 0.3dBi
- Measured gain of this antenna at 865MHz is 1.1 dBi, so it is fair





How to perform an antenna measurement ?

- Harmonics can be also measured with this method
- But you need a reference antenna for the harmonics frequencies



How to perform an antenna measurement ?

- ~~Anechoic chamber – 500 000 €~~
- ~~Reference antenna – 3000 €~~
- ~~Power source -20 000 €~~
- ~~Spectrum analyser - 20 000 €~~

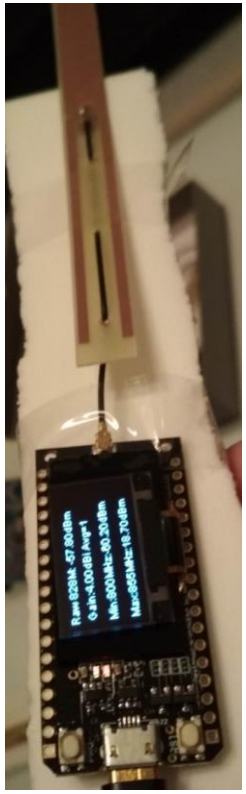
LoRa chip can provide RSSI

Can I use my LoRa chip as a receiver ?

Can be also sweep the frequency ?

How to perform an antenna measurement ?

A LoRa transmiter send a packet with the next frequency in the payload

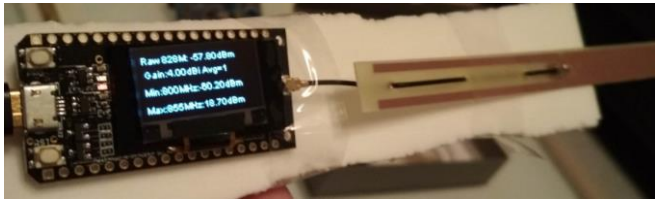


TTGO or Heltec board with OLED Screen

A LoRa receiver get the packet, decode the payload and move to the next frequency

How to perform an antenna measurement ?

Can we reduce the price ?

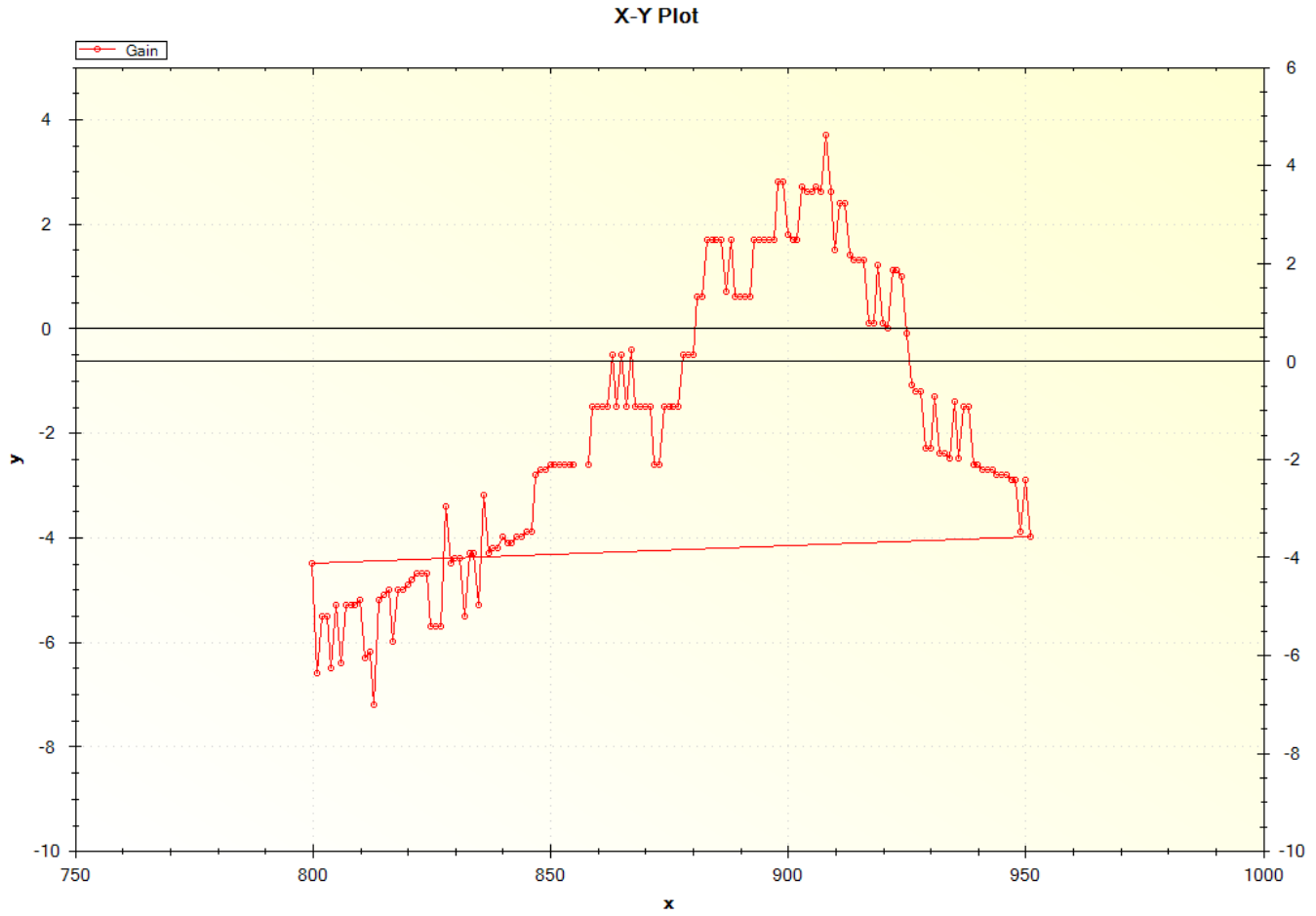


How to perform an antenna measurement ?

Measurement of 868MHz antenna
Sweep from 800 to 950 MHz

How to perform an antenna measurement ?

Measurement of 920 MHz antenna
Sweep from 800 to 950 MHz



Conclusion and perspective

- Can we do low-cost antenna radiation measurement ?
  - Yes and No, it depends on the accuracy you expect
  - Practice and know-how are essential
- Preliminary measurement can be realized to gain time
  - Some filtering can help
  - Repeat the same measurement for different distances
- Always consider uncertainty sources
- The more you invest, the more confident you will be in your measurement

REFERENCES

- Fabien Ferrero, CongDuc Pham, “Low Cost Antenna for IoT Deployment in Developing Country”, 12th European Conference on Antennas and Propagation (EuCAP 2018), 09/04/2018, London, Great Britain
- ETSI TS 103 052 V1.1.1 (2011-03)

Thanks to Christophe Danchesi and Stephane Boudaud from Abeeway for sharing the micro-tracker pictures

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

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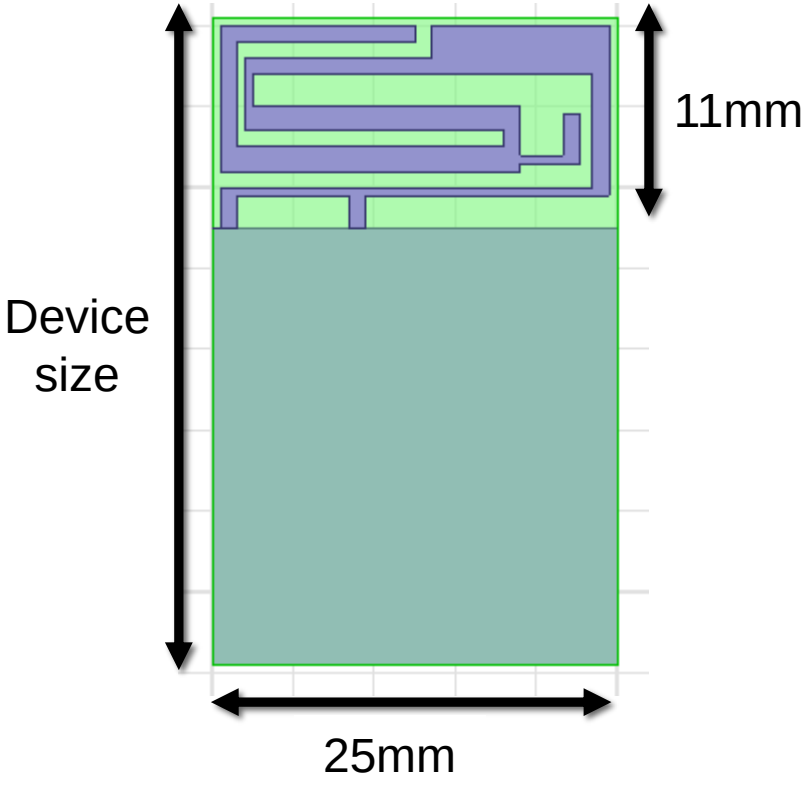
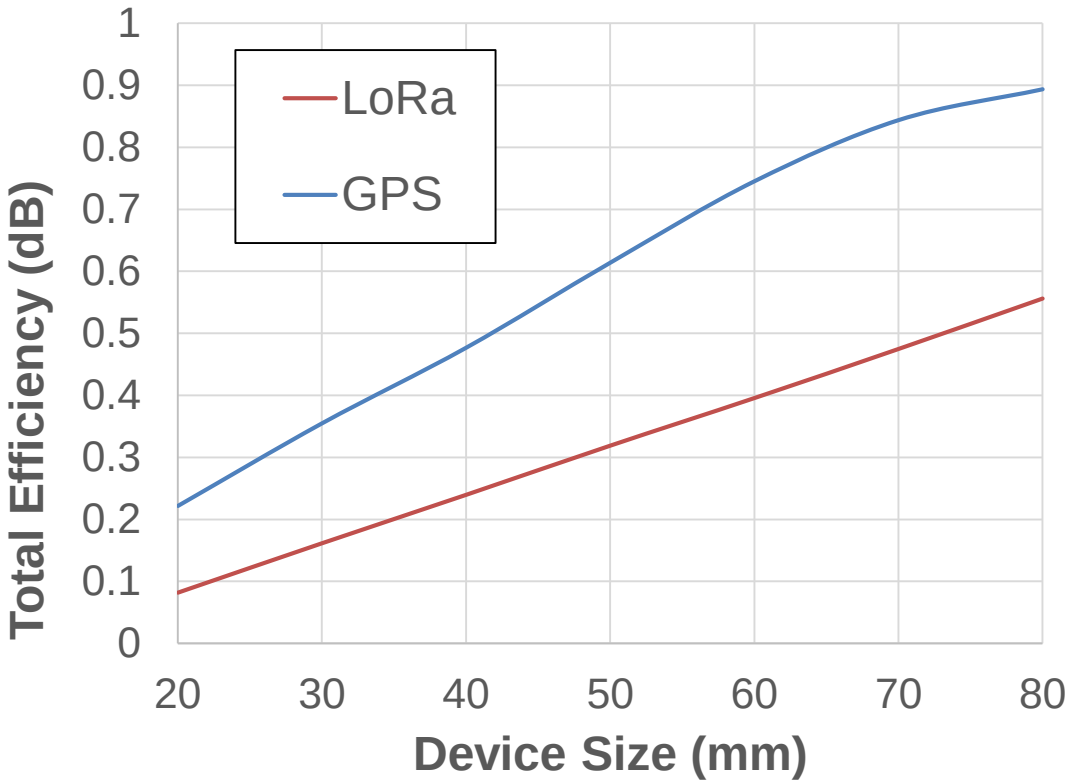
Back-up Slides

Effect of terminal chassis

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





abeeway
Smart geolocation technology

UCA Antenna tuning : Reflection coefficient