LABORATOIRE D'ELECTRONIQUE
ANTENNES ET TELECOMMUNICATIONS

Laboratory of Electronics Antennas and Telecommunications

Antenna Radiation Measurement tutorial with Spectrum Analyser

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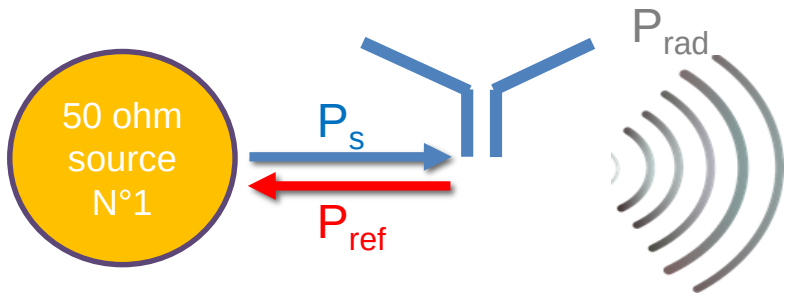
Antenna performance indicator

- 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



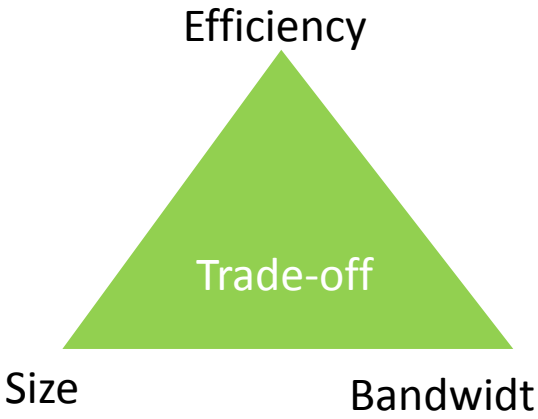
$$|S_{11}|^2 = P_{ref}/P_s$$

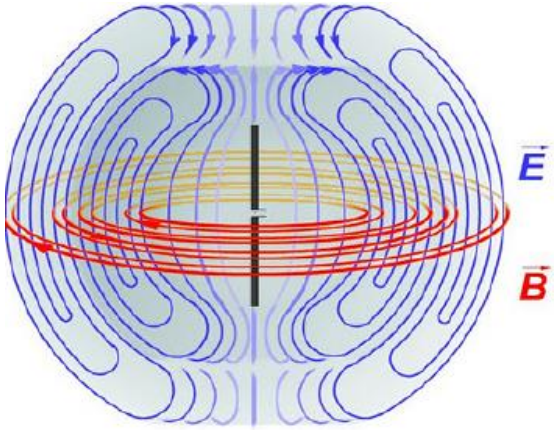
$$\eta_t = P_{rad}/P_s$$

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

Antenna key parameters

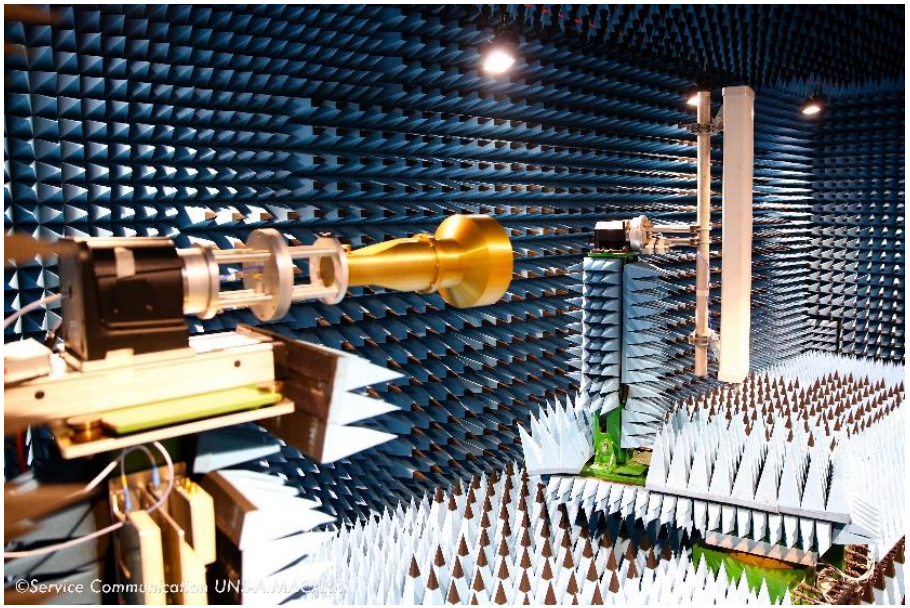
- Antenna is a resonnant structure :
  - Input impedance is changing with frequency
  - Limited frequency bandwidth
  - Miniature antenna can have a low efficiency due to metallic or dielectric losses
- Antenna is an open structure
  - Compare to electronic components, antenna is strongly influenced 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

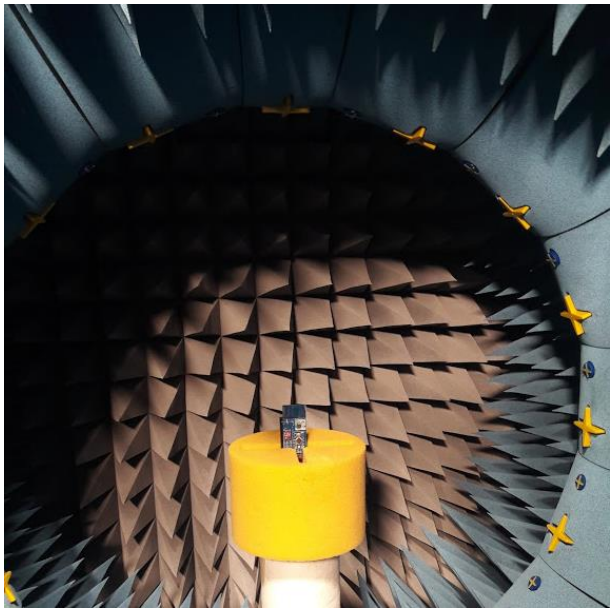




How to perform antenna radiation measurement ?

- 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)

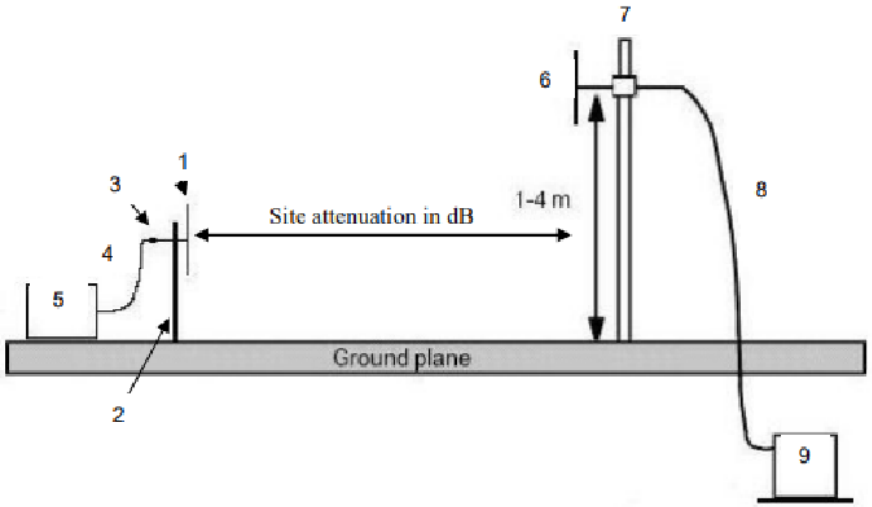


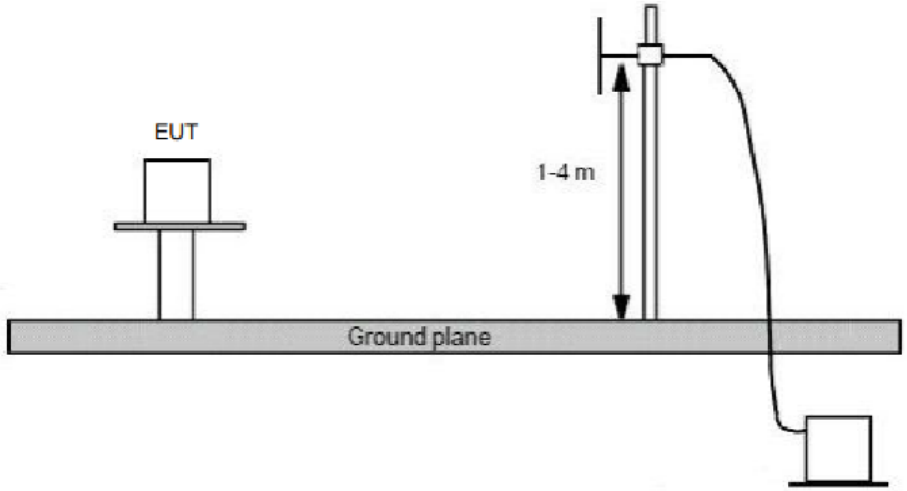


How to perform an antenna measurement ?

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

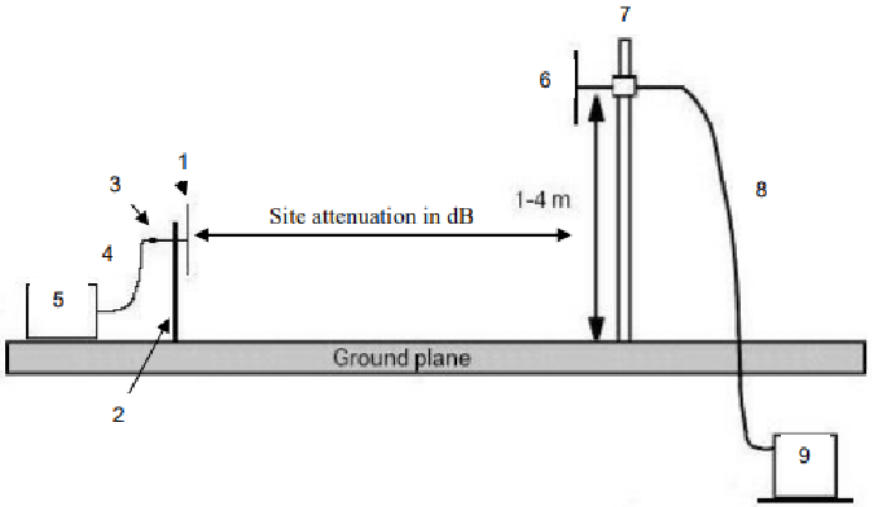


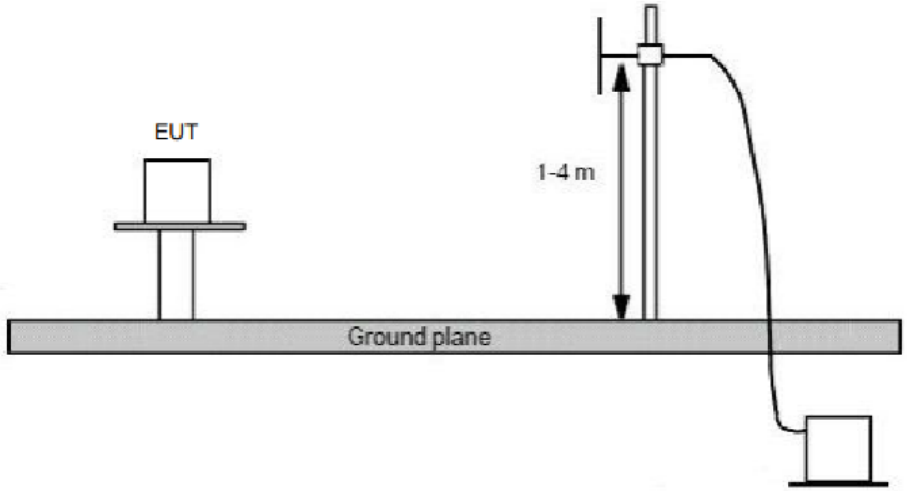


How to perform an antenna measurement ?

- Substitution or Pre-substitution method
  - Power source for the ref. ant. and AUT must be the same
  - First measurement Rx_{Cal} for calibration using a reference antenna
  - Second measurement Rx_{AUT} of the Antenna under Test (AUT)

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



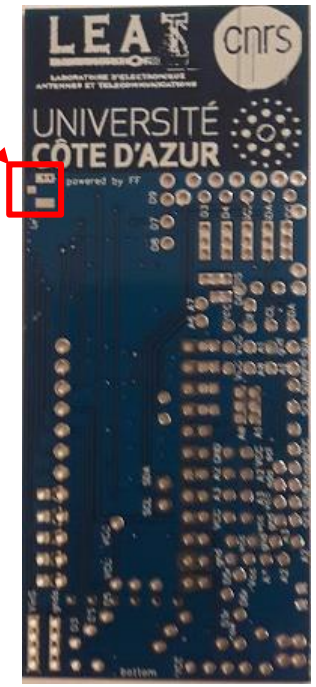


How to perform an antenna measurement ?

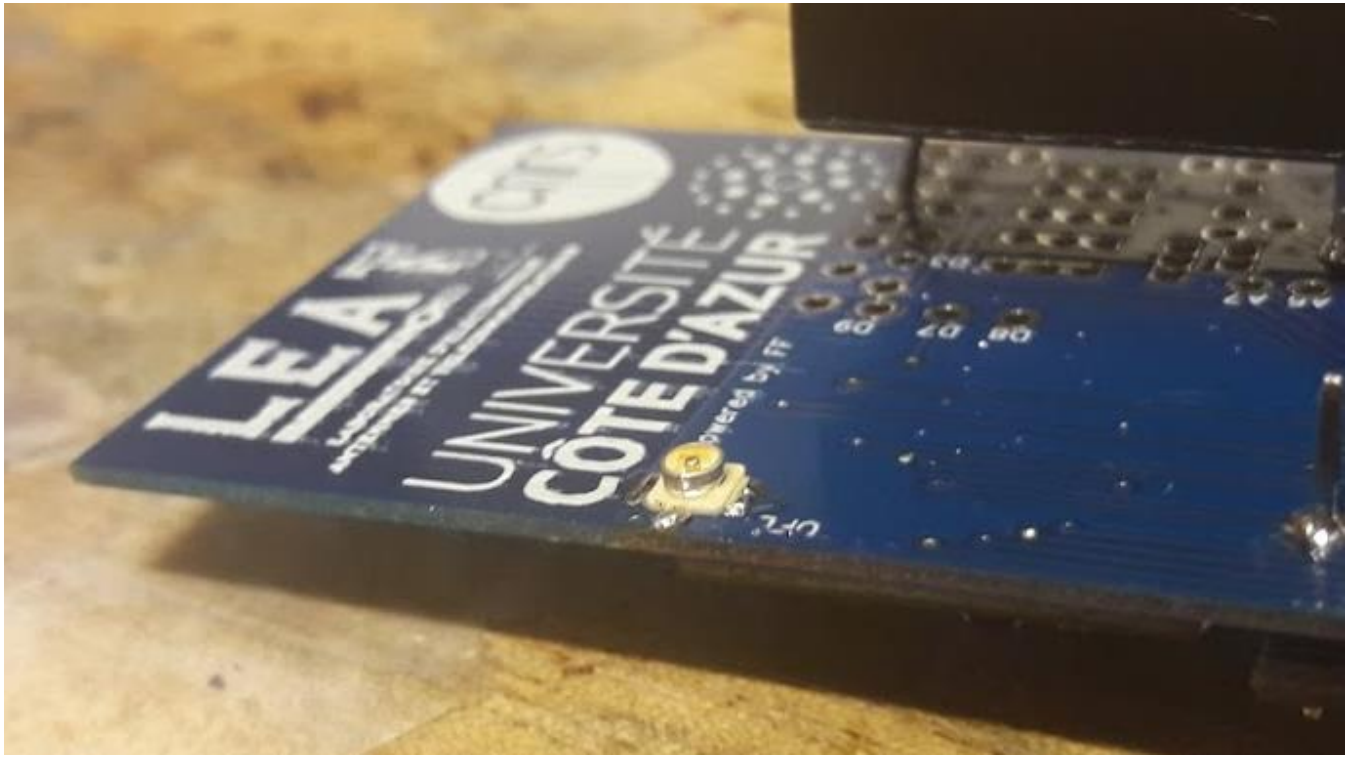
- Power source
- Reference antenna
- Anechoic chamber
- Spectrum analyser

Adding a RF connector

- Try to place a connector pad between module and antenna
- 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)

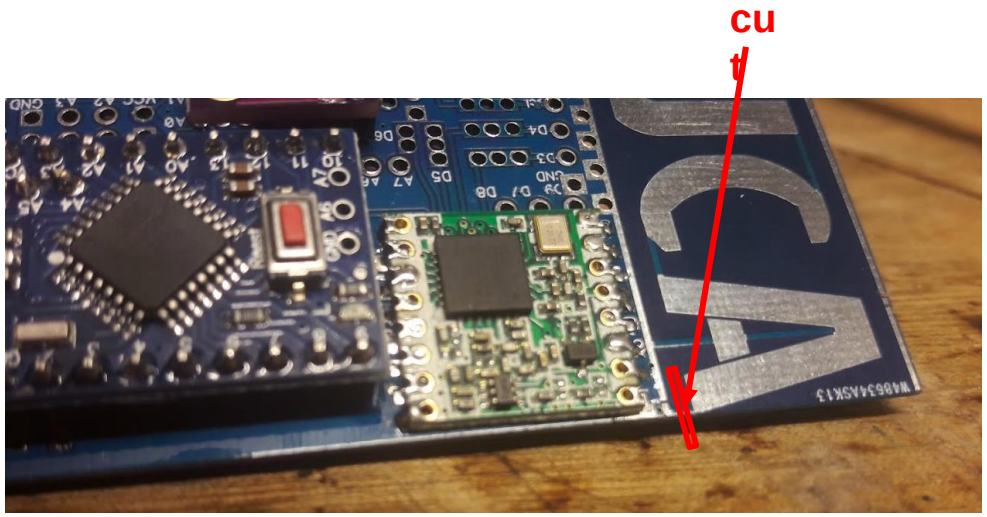


Adding a RF connector



Adding a RF connector

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



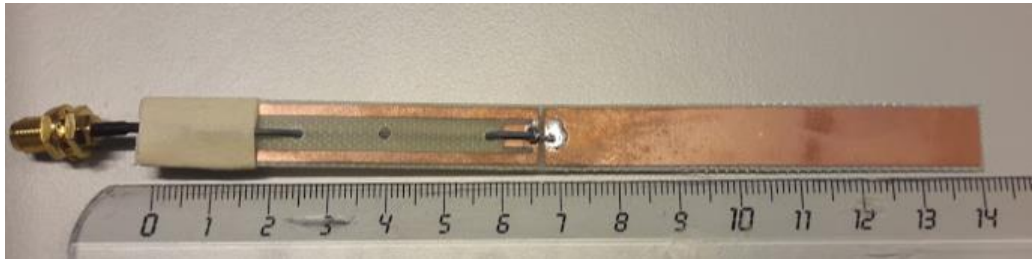
How to perform an antenna measurement ?

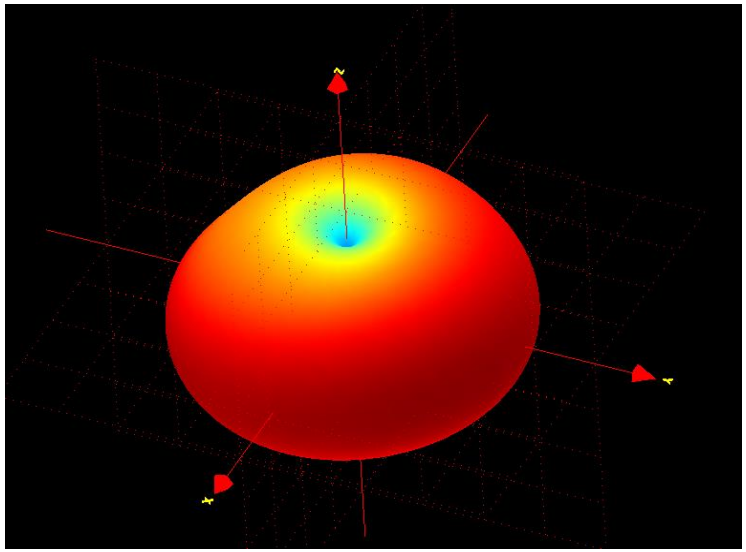
- Power source
- Reference antenna
- Anechoic chamber
- Spectrum analyser

Can we reduce the price ?

Printed Sleeve dipole with coaxial cable

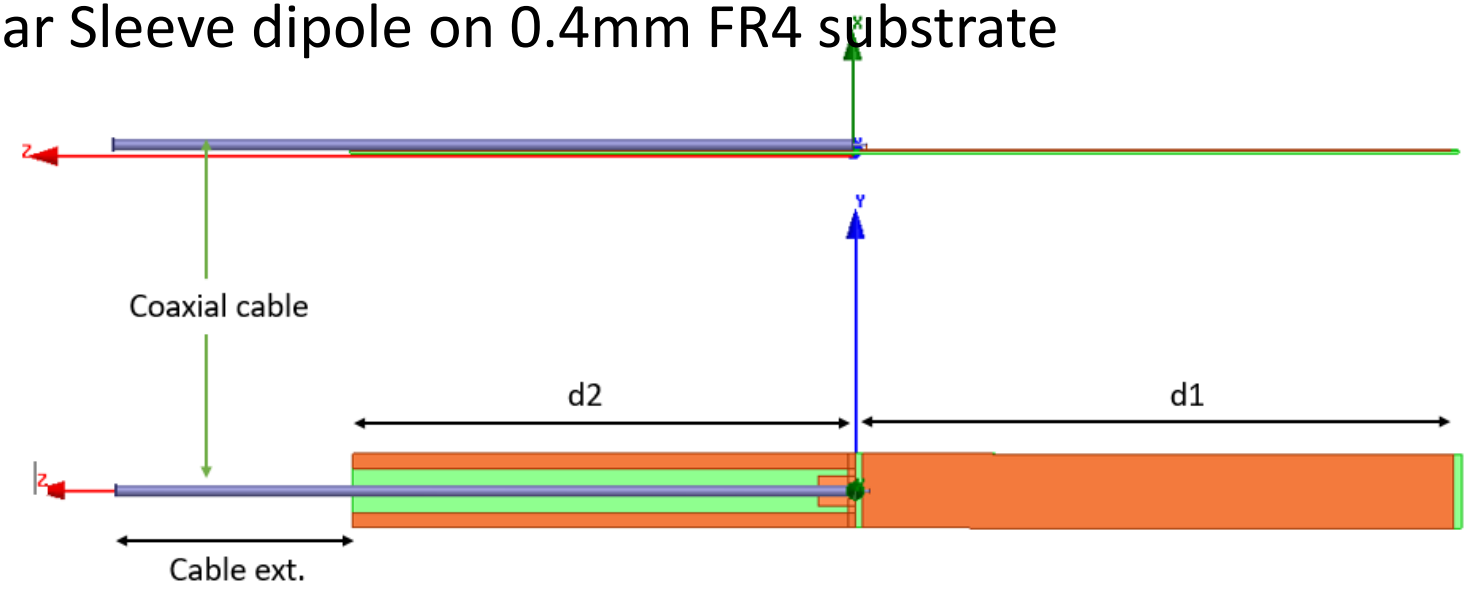
- Low cost 0.4mm FR4 Epoxy 140x15mm
- Low cost Small coaxial cable
- Integrated Balun for environment robustness
- Omnidirectional pattern
- Gain 2.5dBi
- Measured Efficiency 83%

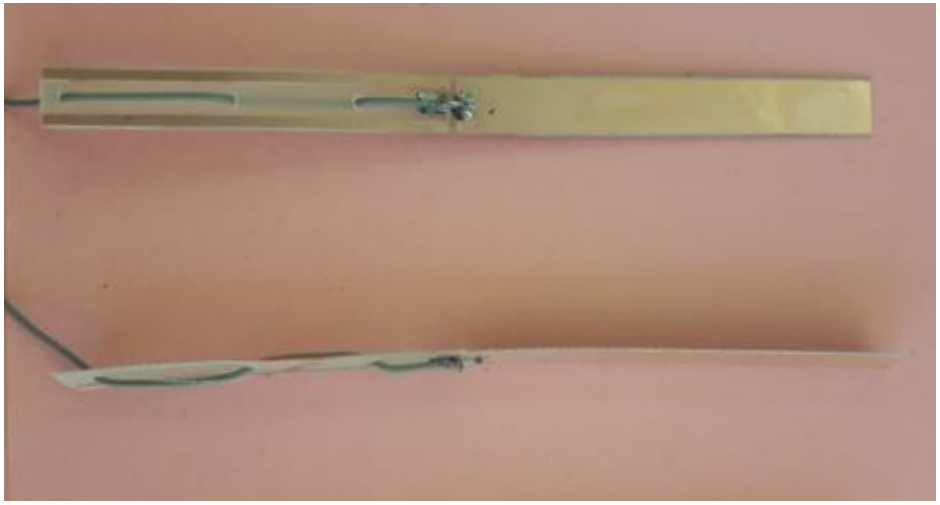




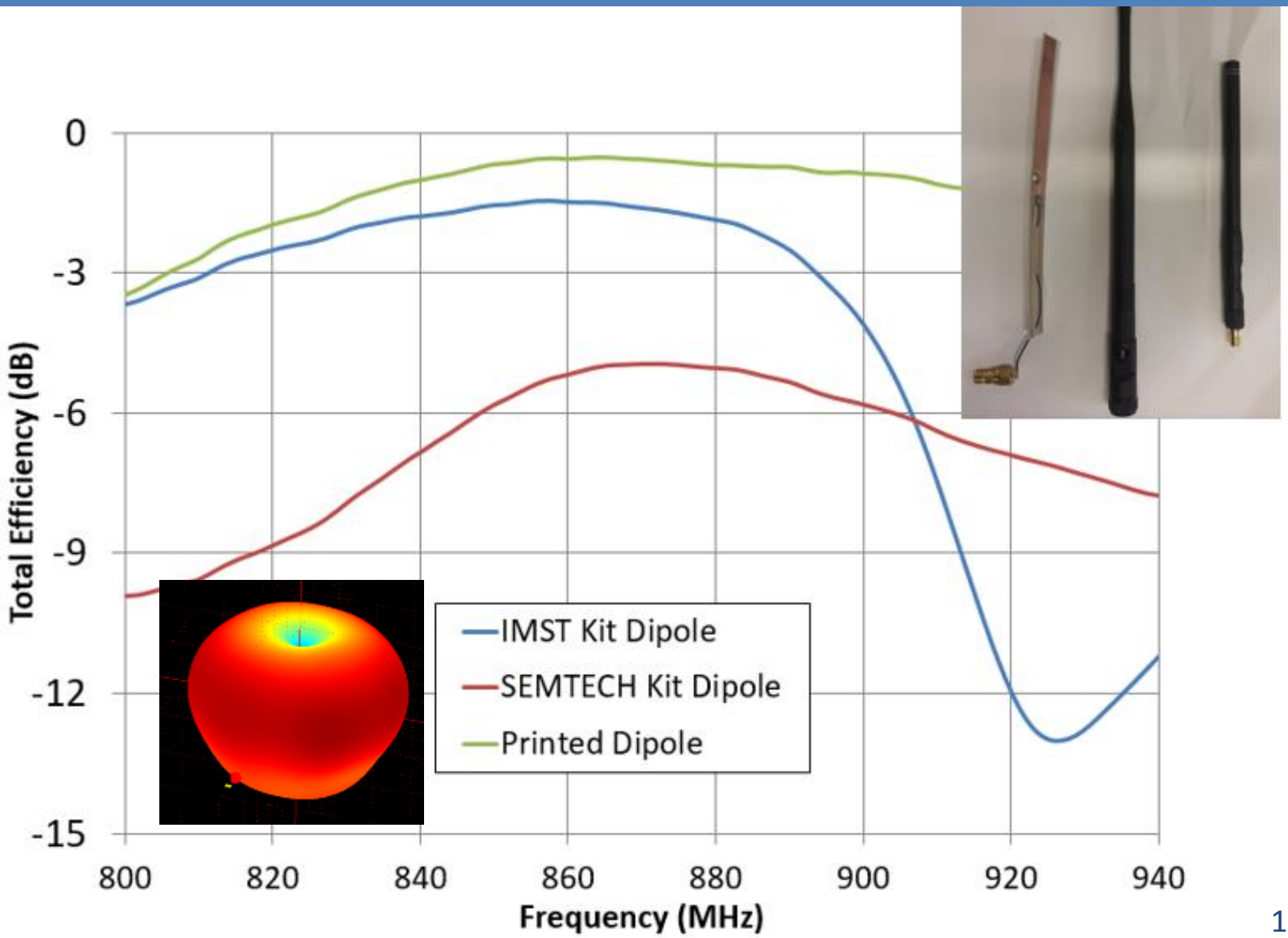
Half-wave dipole Antenna

- Planar Sleeve dipole on 0.4mm FR4 substrate



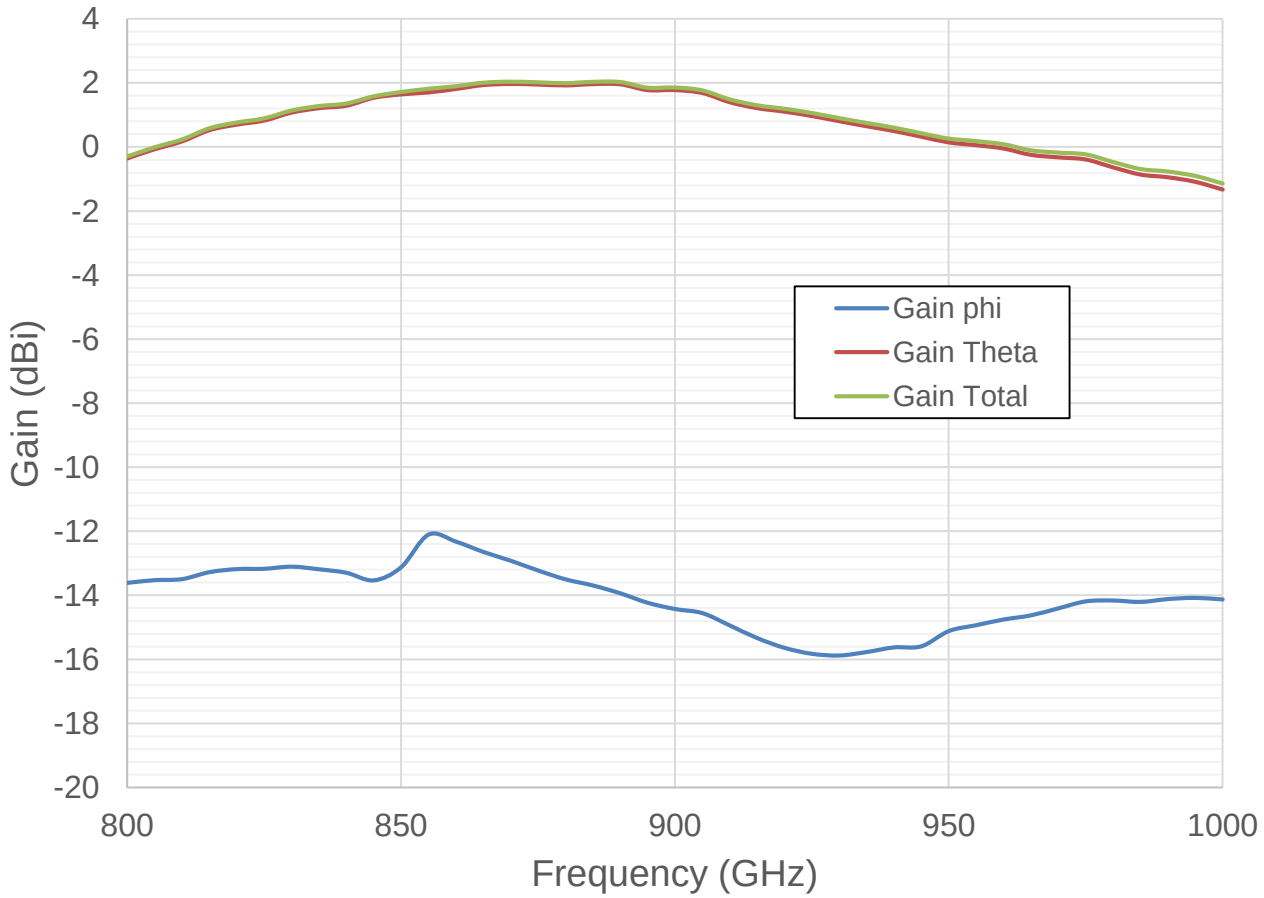


Comparison with on-the-shelf antenna



Printed Sleeve dipole with coaxial cable

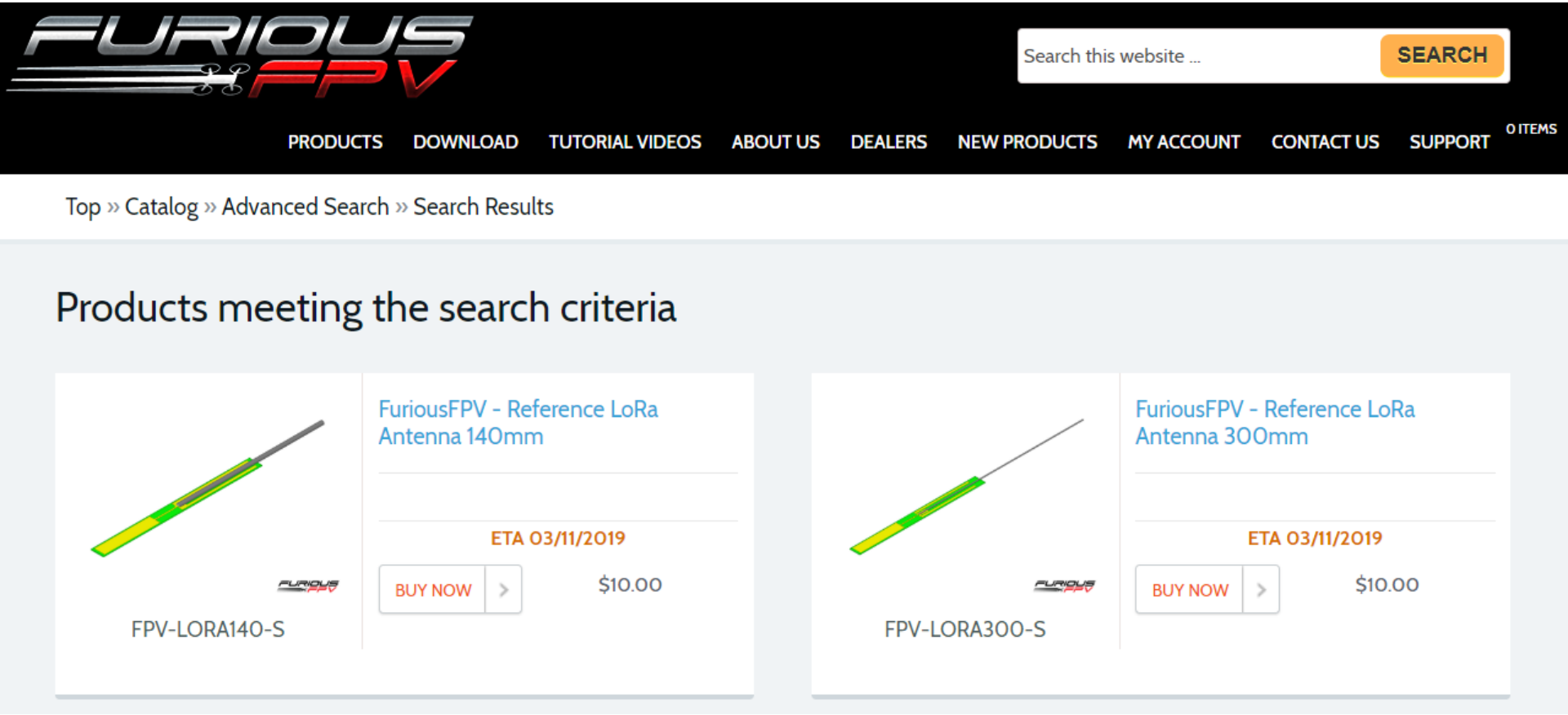
- Low cost 0.4mm FR4 Epoxy 140x15mm



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 ?

- Power source
- Reference antenna
- Anechoic chamber
- Spectrum analyser

Can we reduce the price ?

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:

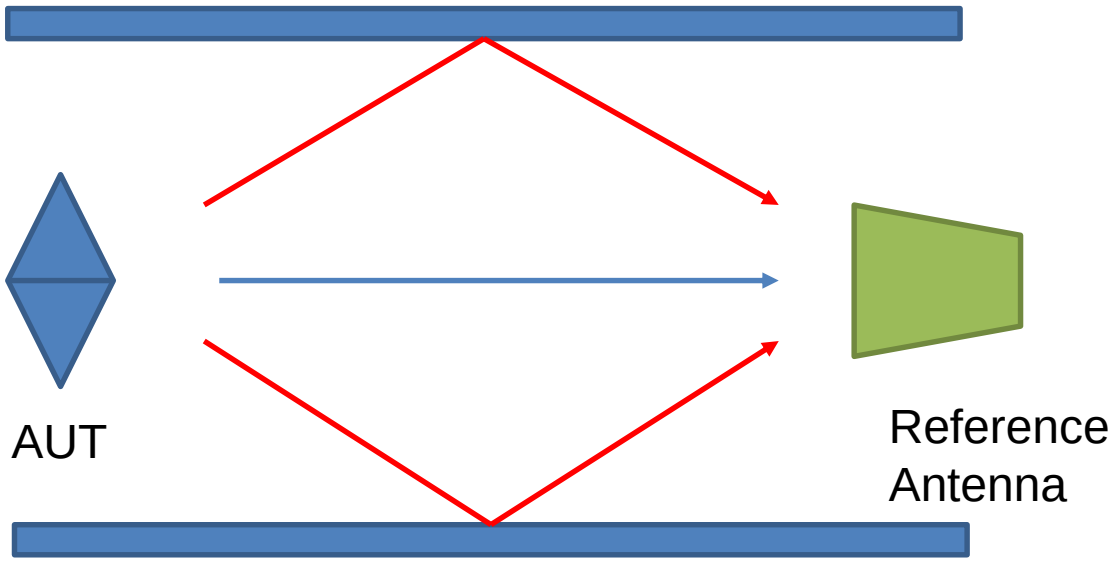
d1 is the largest dimension of the EUT/dipole after substitution (m);

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

λ is the test frequency wavelength (m).

No anechoic chamber ?

- 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)



How to perform an antenna measurement ?

- Power source
- Reference antenna
- Anechoic chamber
- Spectrum analyser

Some lower cost Spectrum (refurbish) or on Aliexpress can be found for less than 100€

Setting-up Calibration device and Antenna Under Test

- Connect your device with UFL cable to a reference antenna
- Upload the code *Arduino_CW.ino* to the reference device and Antenna under test
- This code will generate a 14dBm continuous wave at 865MHz

Calibration of the set-up

Set-up the reference device and receiver device at a distance between 30 and 50 cm.
Measure the received power $(Rx_{Cal})_{dBm}$ on the Spectrum analyzer,

Spectrum analyzer

30 to 50 cm

AUT measurement

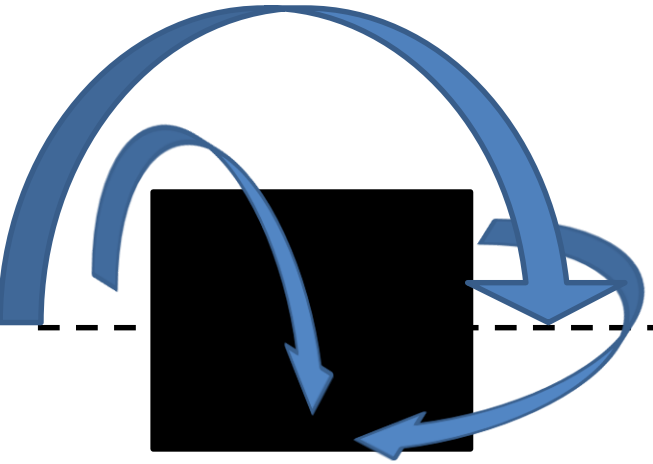
- Now you can replace the reference antenna by the Antenna Under Test.
- Measure again the power received $(Rx_{AUT})_{dBm}$
- Try to center the two antennas

Spectrum analyzer

30 to 50 cm

AUT measurement : black box

- If you measure a black box, and have no idea about antenna polarization and gain, try to rotate the AUT in any direction to find the maximum power



Spectrum analyzer

30 to 50 cm

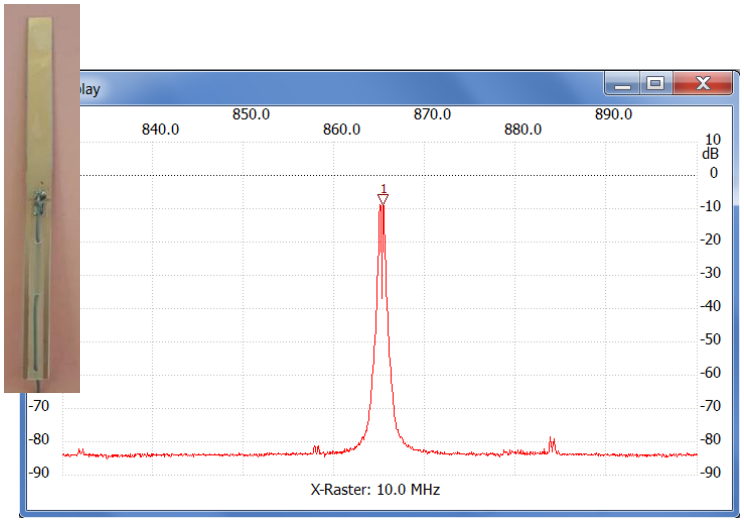
How to perform an antenna measurement ?

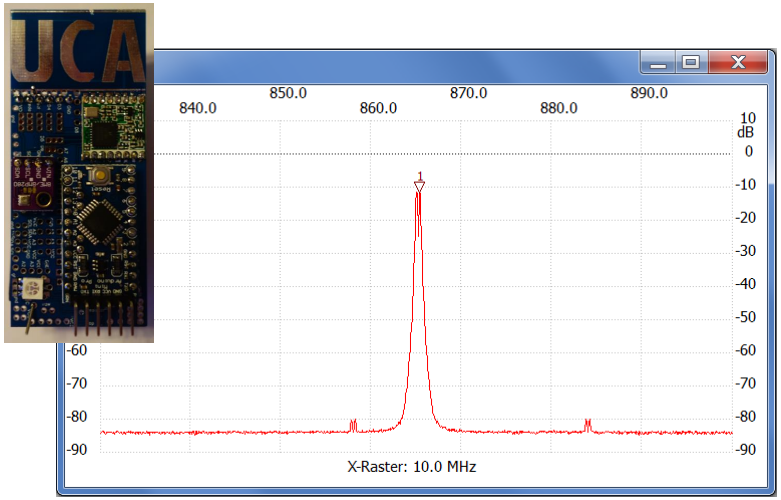
- Substitution or Pre-substitution method
  - First measurement Rx_{Cal} for calibration using a reference antenna
  - Second measurement Rx_{AUT} of the Antenna under Test (AUT)
  - Find the gain of the reference antenna at your measurement frequency (here 865MHz) -> $(Gain_{Ref\ Ant})_{dBi}$ = 2 dBi
  - You can now calculate the gain of your antenna

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

Exemple

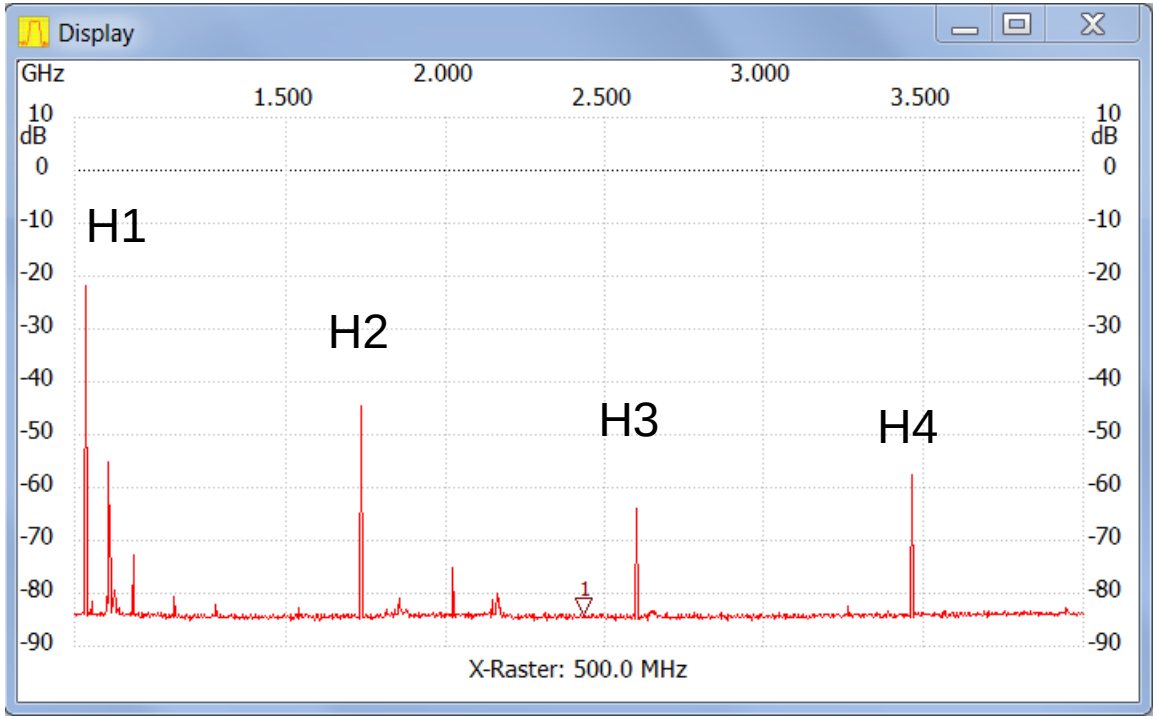
- Use CW mode of AUT
- Measure for a given distance with ref antenna
  - Exemple: $(Rx_{Cal})_{dBm}$ =-9.4dBm
- Measure for the same distance AUT
  - Exemple: $(Rx_{AUT})_{dBm}$ =-11.1dBm
- $At\ 865MHz, (Gain_{Ref\ Ant})_{dBi}$ = 2 dBi
- Then, $(Gain_{AUT})_{dBi}$ =-11.1+9.4+2= 0.3dBi
- Measured gain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



Conclusion

- 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 distance
- Always consider uncertainty sources
- The more you invest, the more confident you will be in your measurement

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