LABORATOIRE D'ELECTRONIQUE
ANTENNES ET TELECOMMUNICATIONS

Laboratory of Electronics Antennas and Telecommunications

Antenna Radiation Measurement tutorial with Spectrum Analyser

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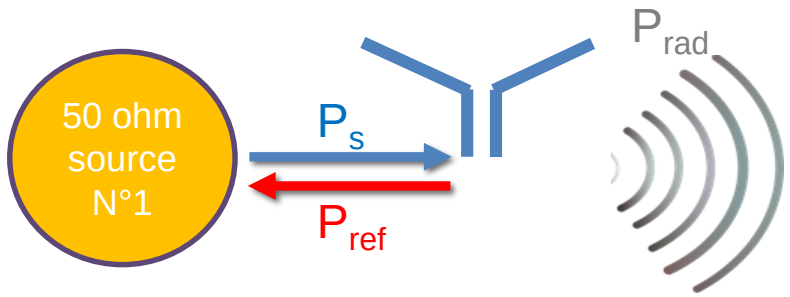
Antenna performance indicator

- 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



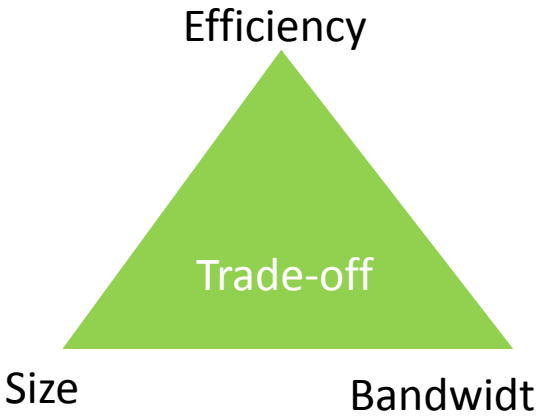
$$|S_{11}|^2 = P_{ref}/P_s$$

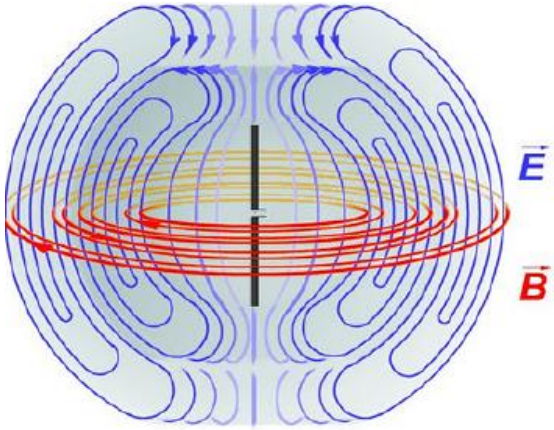
$$\eta_t = P_{rad}/P_s$$

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

Antenna key parameters

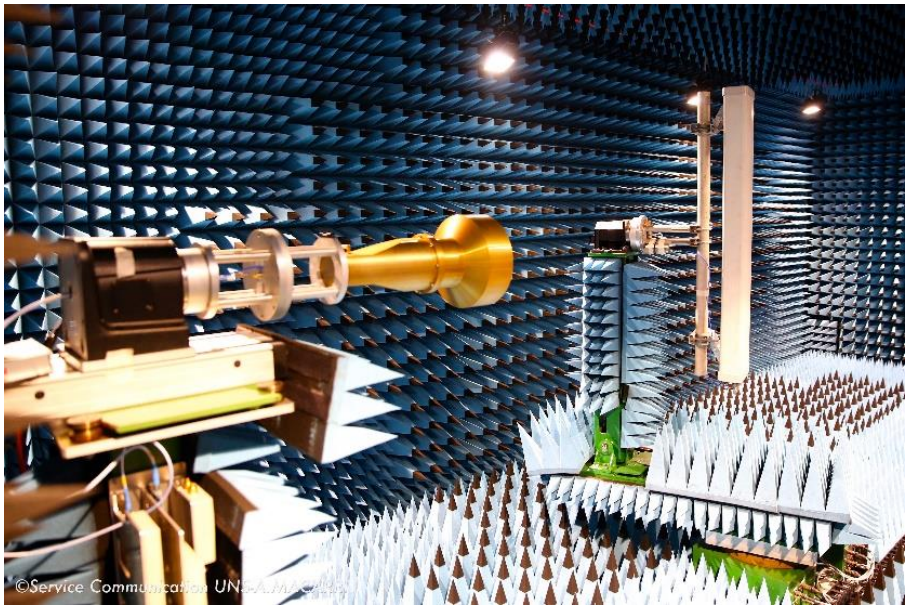
- Antenna is a resonnant structure :
  - Input impedance is changing with frequency
  - Limited frequency bandwidth
  - Miniature antenna can have a low efficiency due to metallic or dielectric losses
- Antenna is an open structure
  - Compare to electronic components, antenna is strongly influenced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

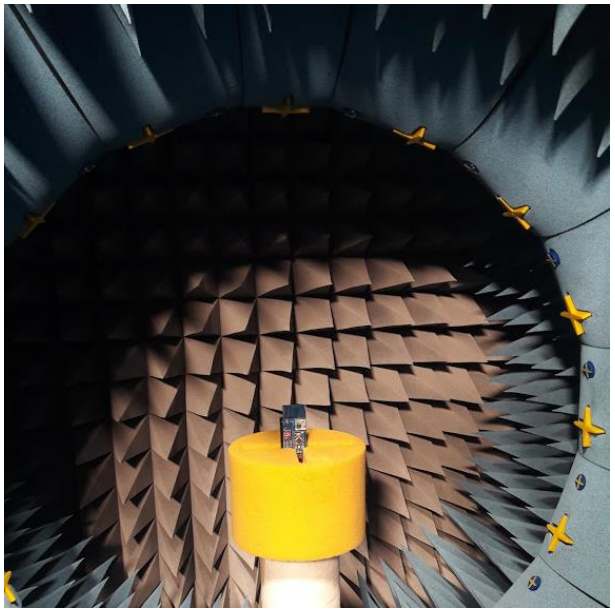




How to perform antenna radiation measurement ?

- 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)

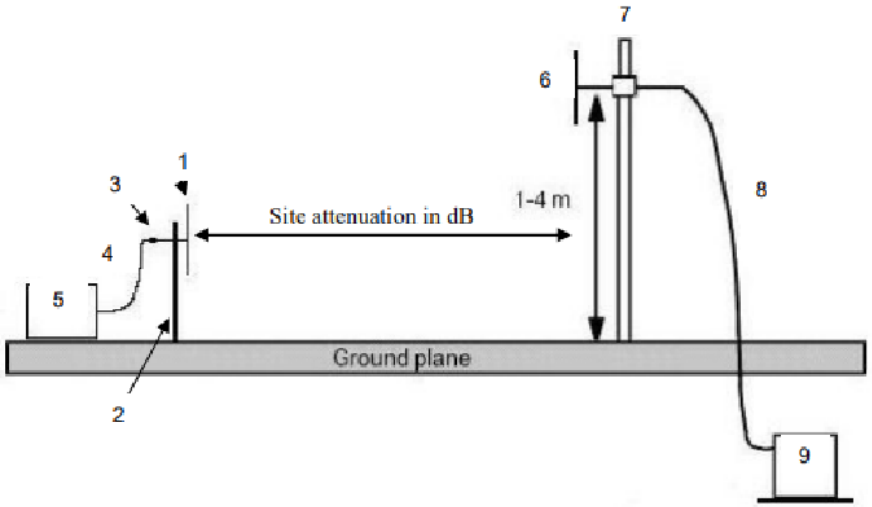


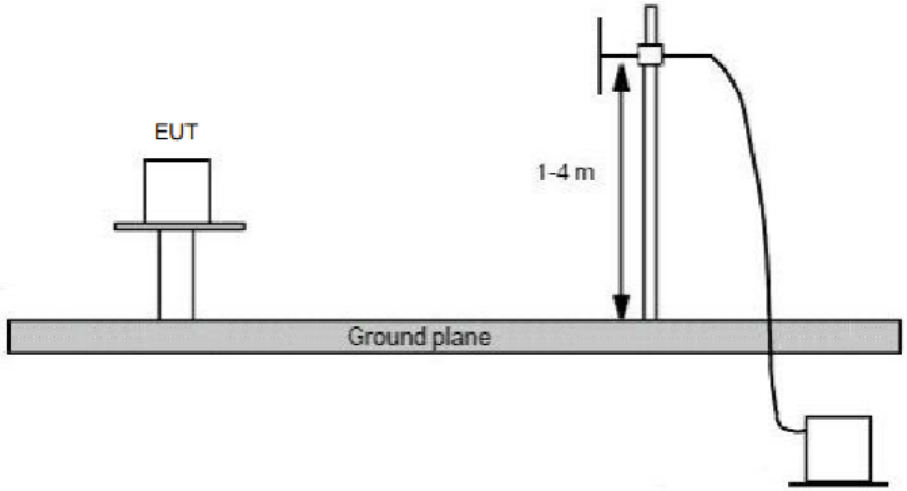


How to perform an antenna measurement ?

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

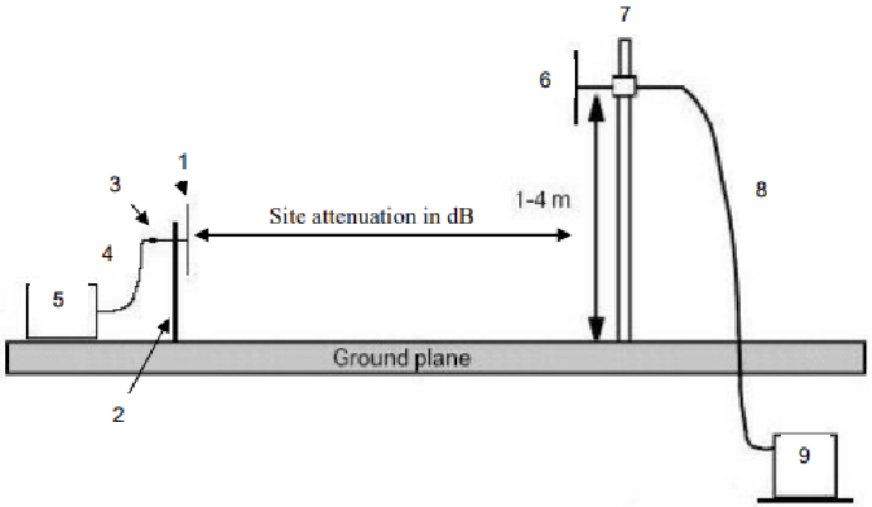


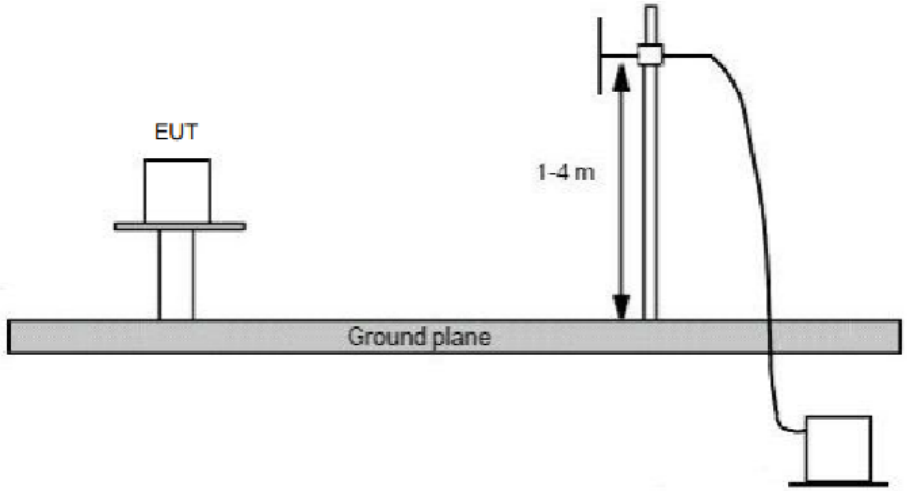


How to perform an antenna measurement ?

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

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



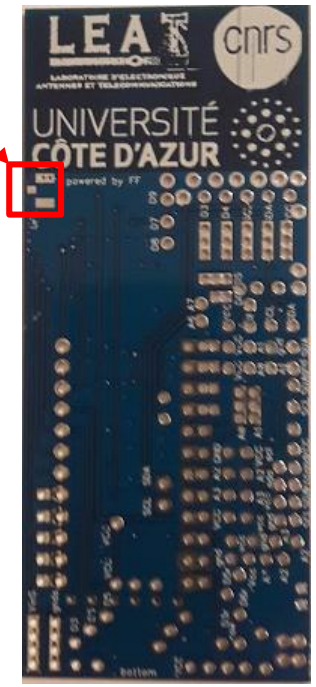


How to perform an antenna measurement ?

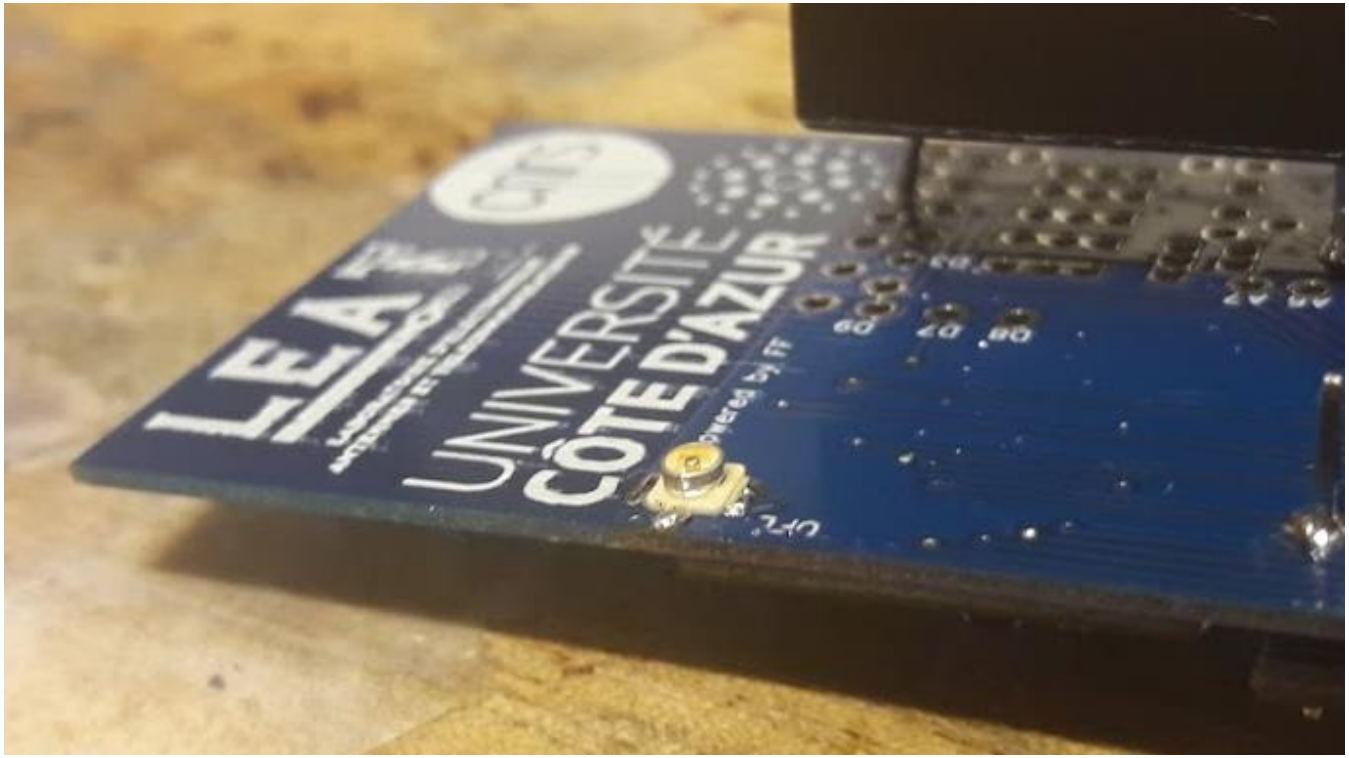
- Power source
- Reference antenna
- Anechoic chamber
- Spectrum analyser

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)

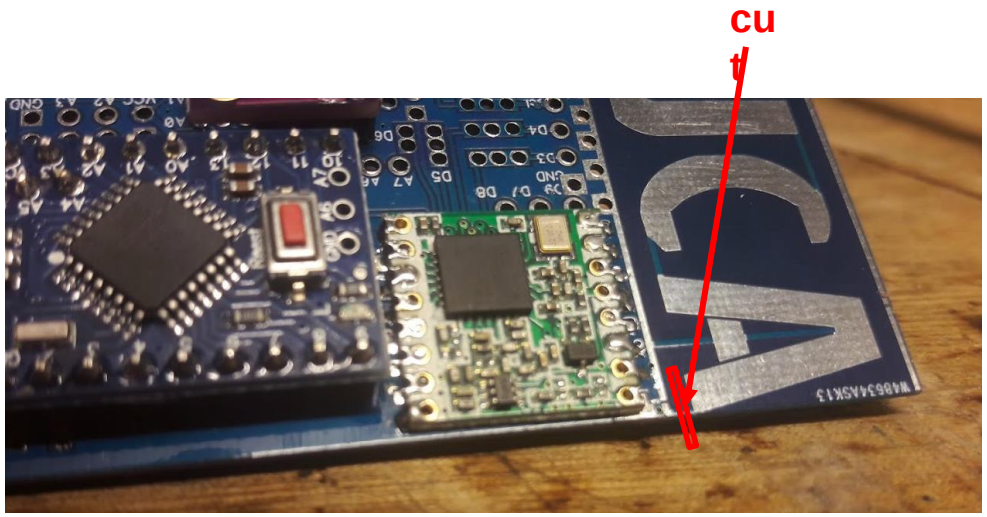


Adding a RF connector



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
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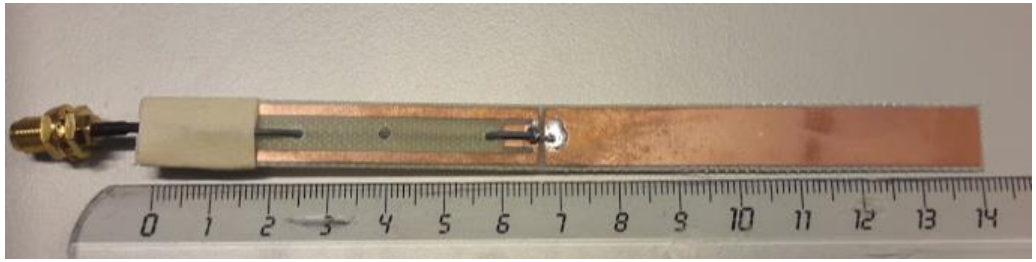
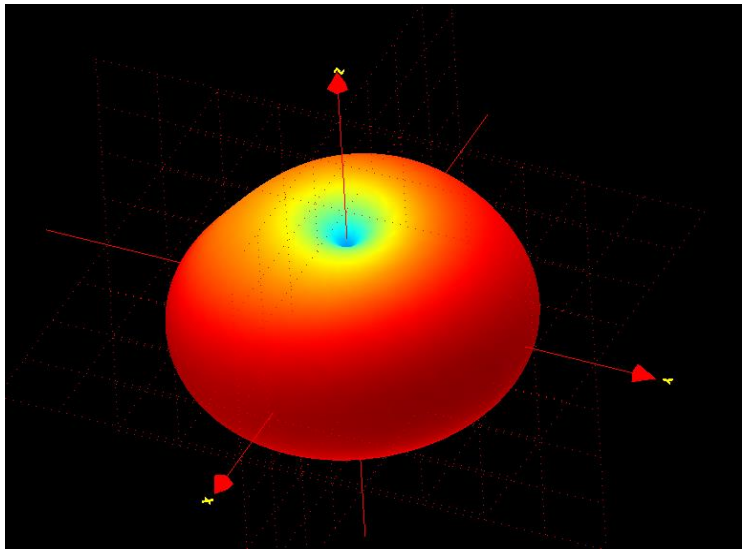
Can we reduce the price ?

Printed Sleeve dipole with coaxial cable

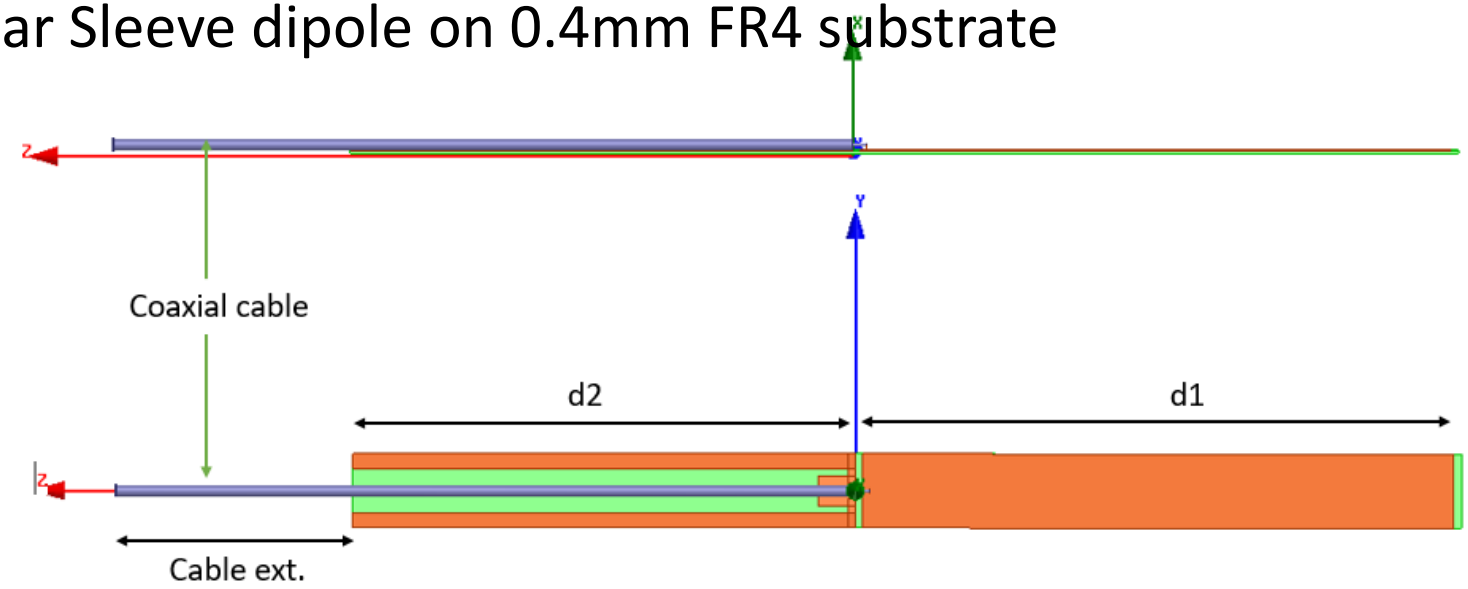
- Low cost 0.4mm FR4 Epoxy 140x15mm
- Low cost Small coaxial cable
- Integrated Balun for environment robustness
- Omnidirectional pattern
- Gain 2.5dBi
- Measured Efficiency 83%

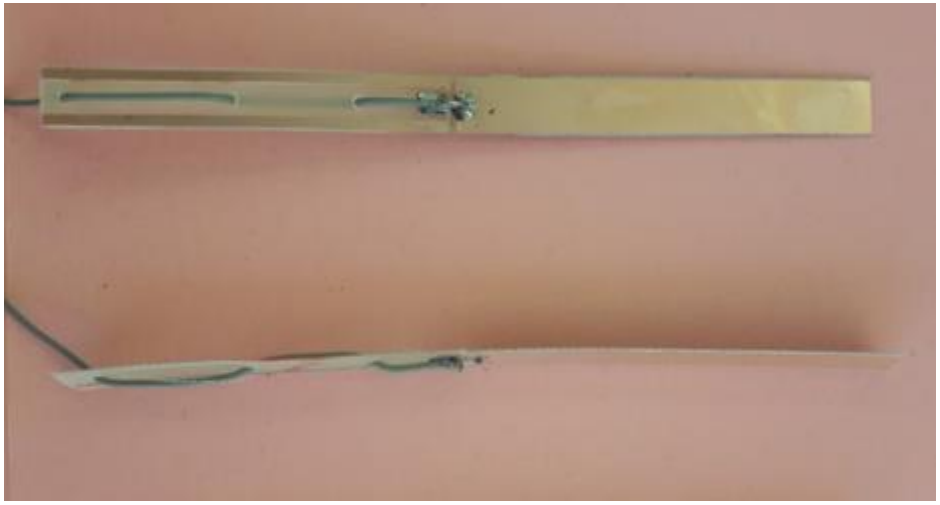




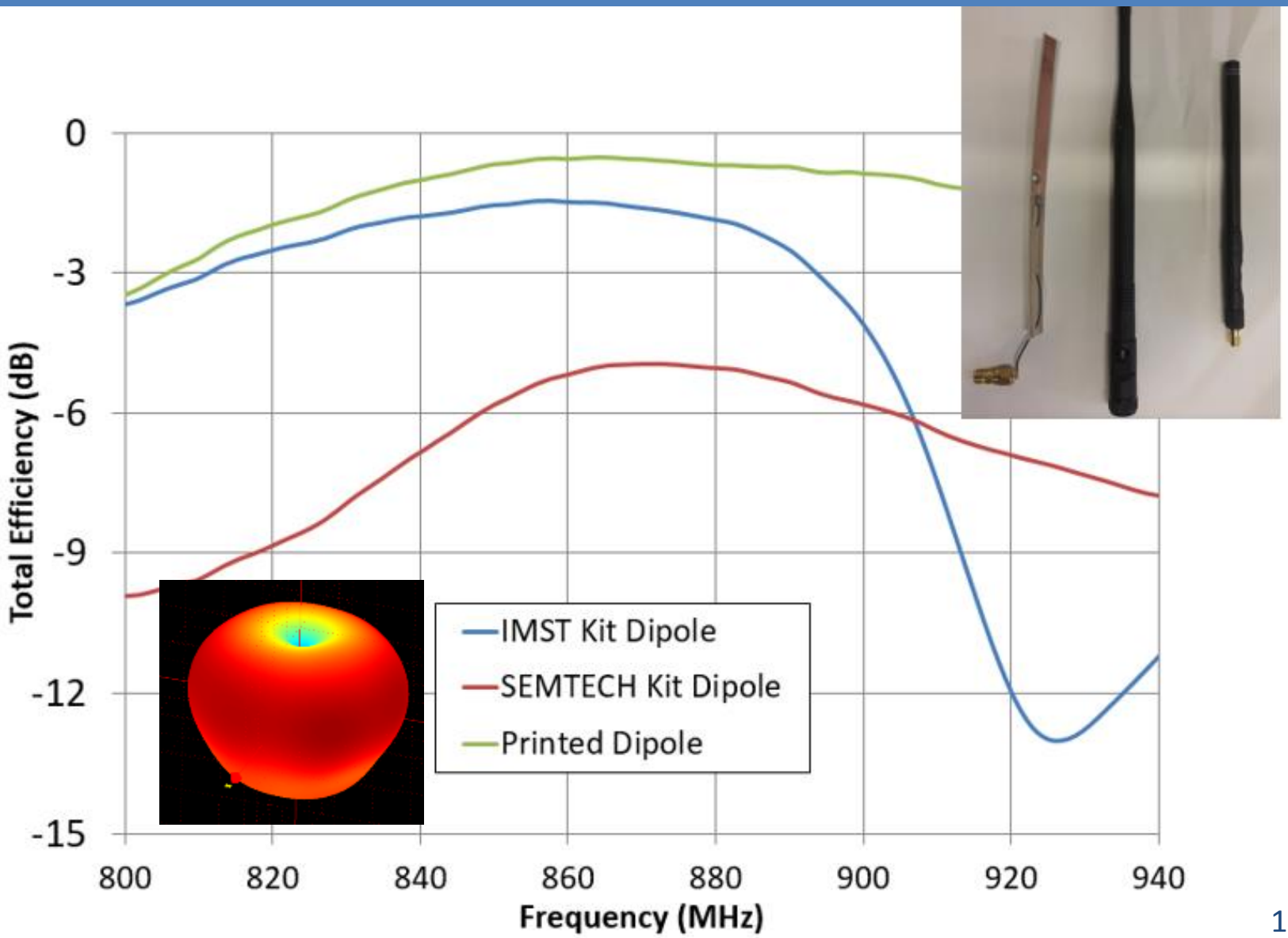
Half-wave dipole Antenna

- Planar Sleeve dipole on 0.4mm FR4 substrate



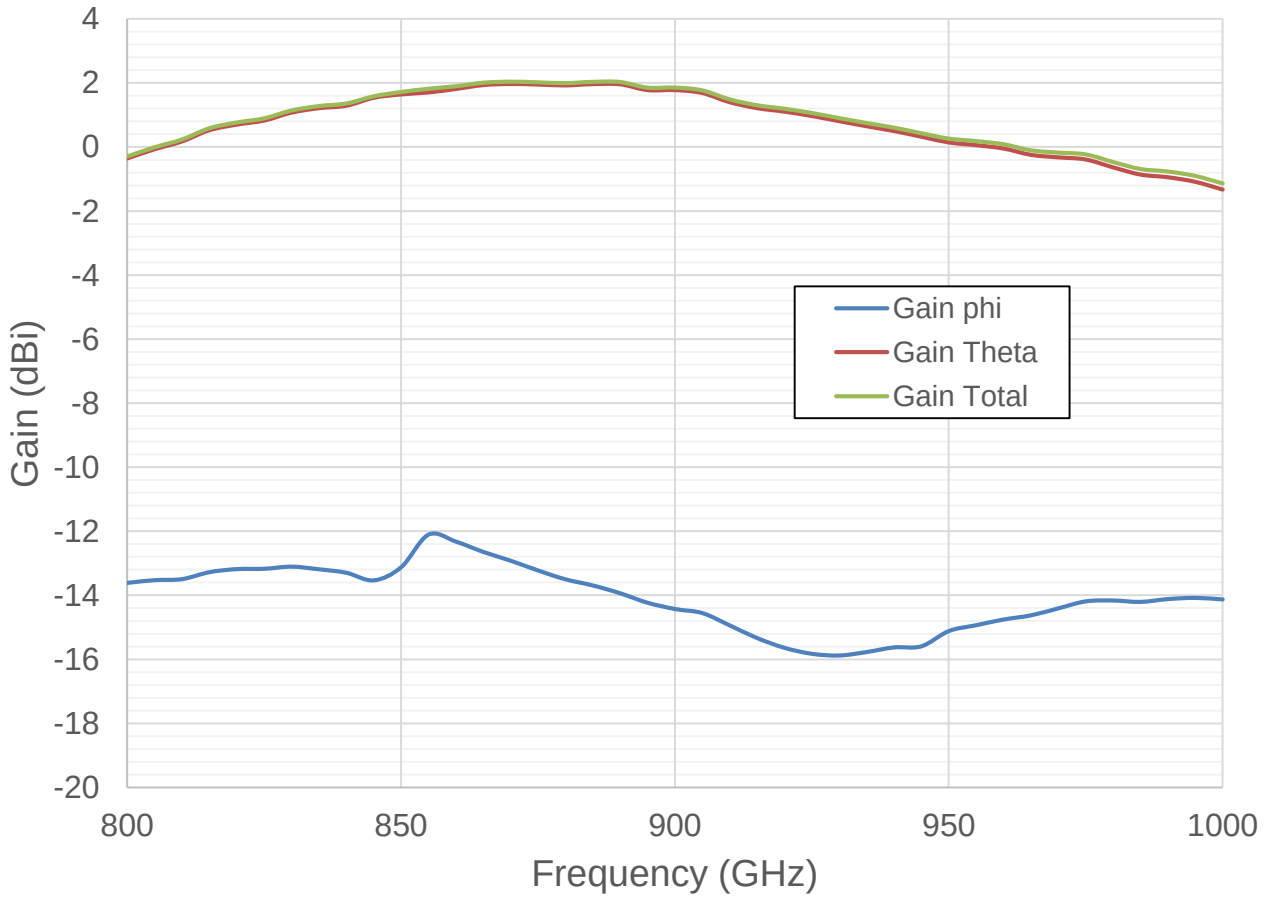


Comparison with on-the-shelf antenna



Printed Sleeve dipole with coaxial cable

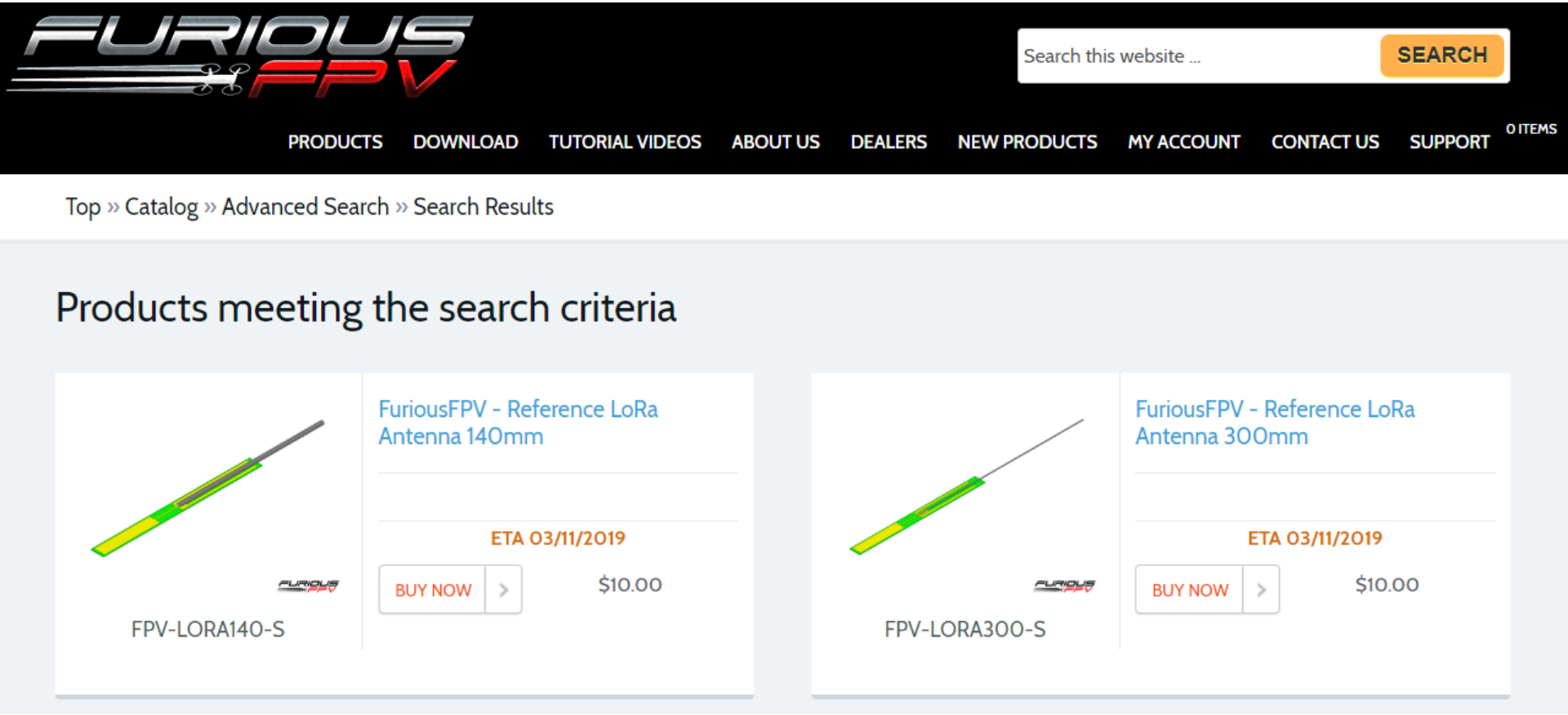
- Low cost 0.4mm FR4 Epoxy 140x15mm



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:

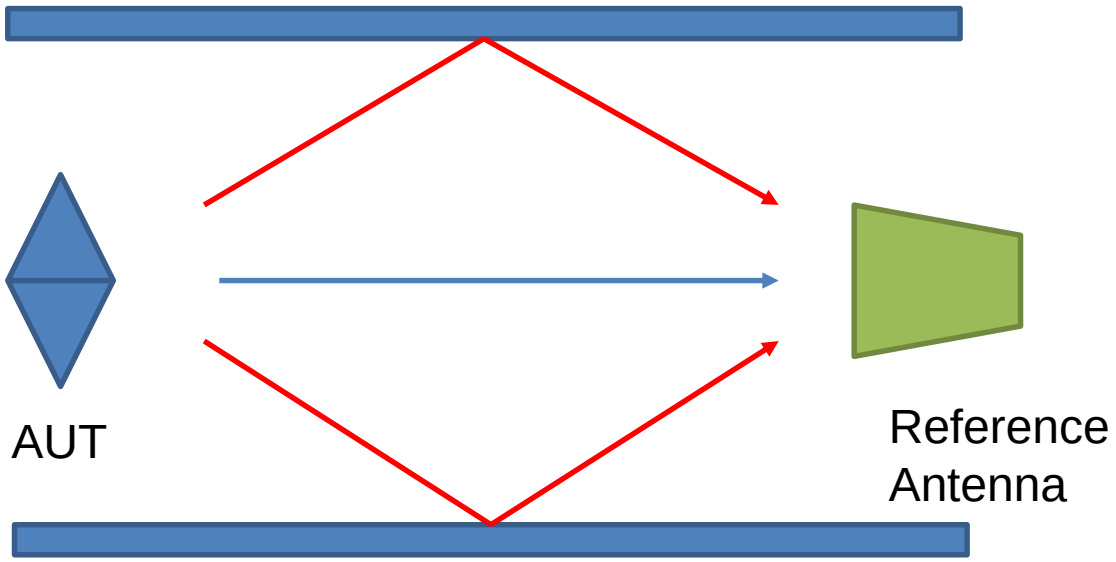
d1 is the largest dimension of the EUT/dipole after substitution (m);

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

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 $(Rx_{AUT})_{dBm}$

Spectrum analyzer

30 to 50 cm

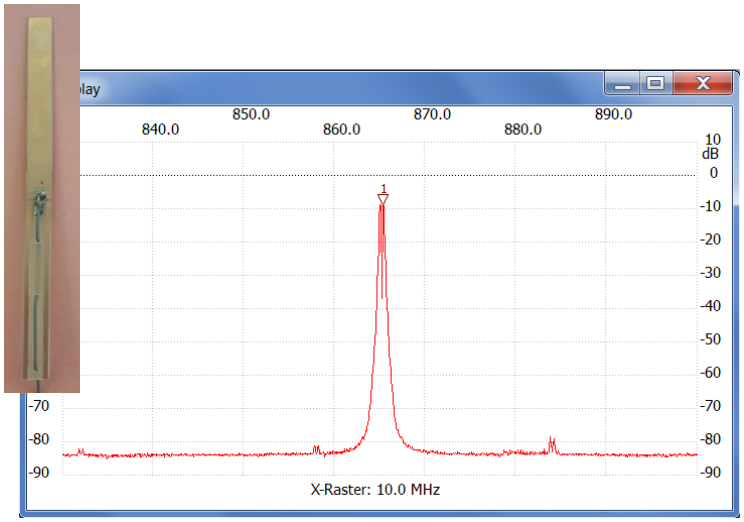
How to perform an antenna measurement ?

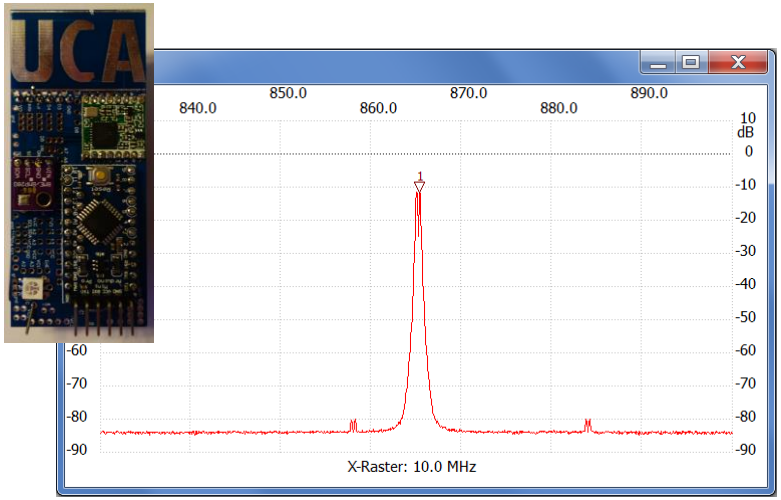
- Substitution or Pre-substitution method
  - First measurement Rx_{Cal} for calibration using a reference antenna
  - Second measurement Rx_{AUT} of the Antenna under Test (AUT)
  - Find the gain of the reference antenna at your measurement frequency (here 865MHz) -> $(Gain_{Ref\ Ant})_{dBi}$ = 2 dBi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

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

Summary

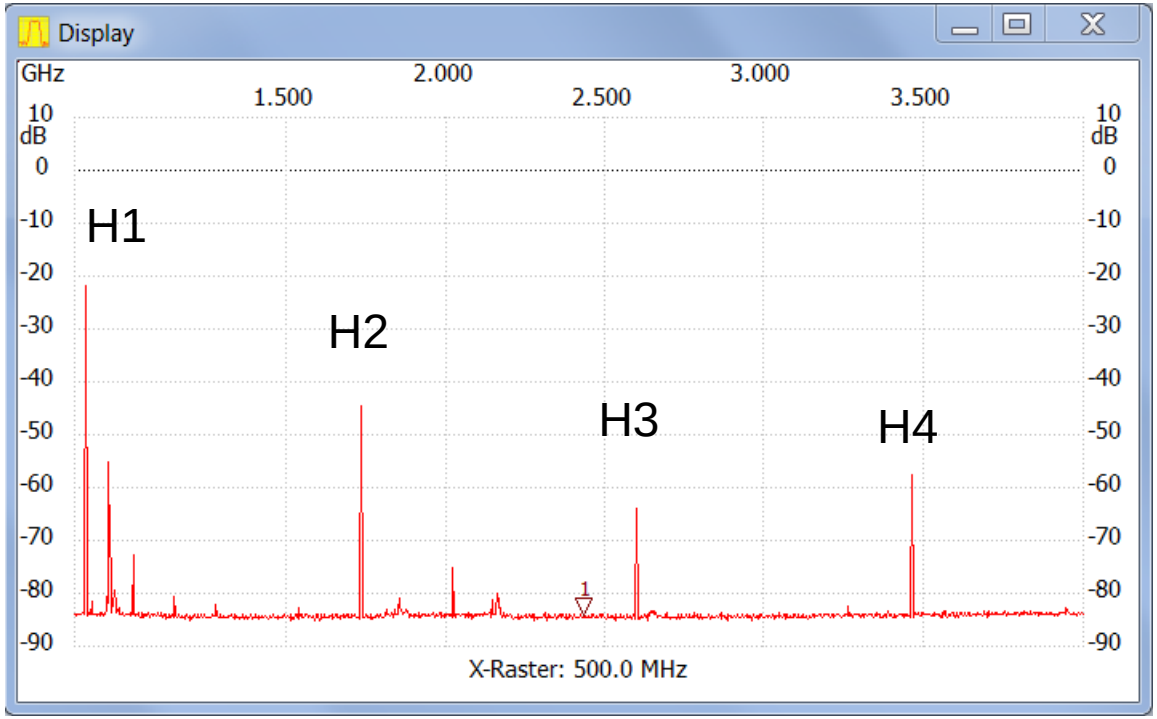
- Use CW mode of AUT
- Measure for a given distance with ref antenna
  - Exemple: $(Rx_{Cal})_{dBm}$ =-9.4dBm
- Measure for the same distance AUT
  - Exemple: $(Rx_{AUT})_{dBm}$ =-11.1dBm
- $At\ 865MHz, (Gain_{Ref\ Ant})_{dBi}$ = 2 dBi
- Then, $(Gain_{AUT})_{dBi}$ =-11.1+9.4+2= 0.3dBi
- Measured gain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



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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