LABORATOIRE D'ELECTRONIQUE
ANTENNES ET TELECOMMUNICATIONS

Laboratory of Electronics Antennas and Telecommunications

Antenna Radiation Measurement tutorial with Spectrum Analyser

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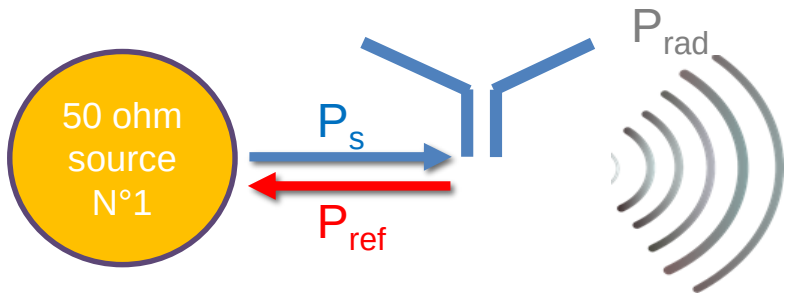
Antenna performance indicator

- 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



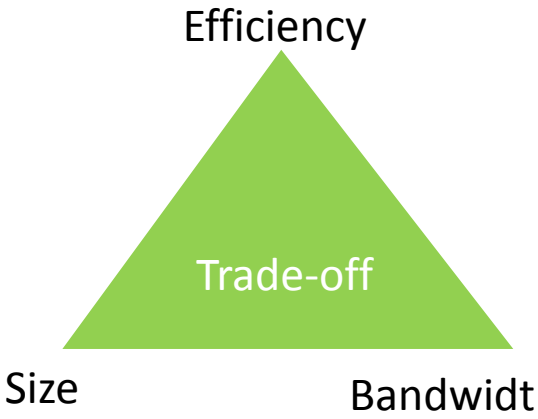
$$|S_{11}|^2 = P_{ref}/P_s$$

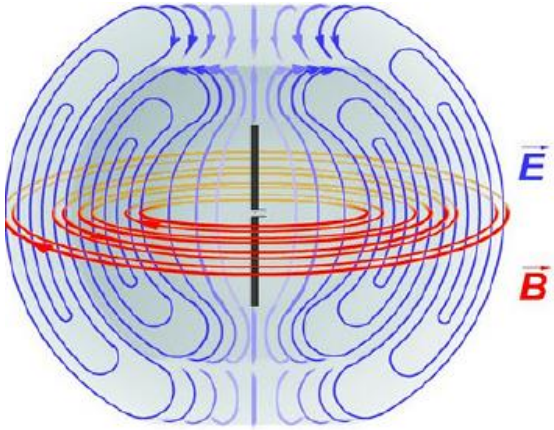
$$\eta_t = P_{rad}/P_s$$

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

Antenna key parameters

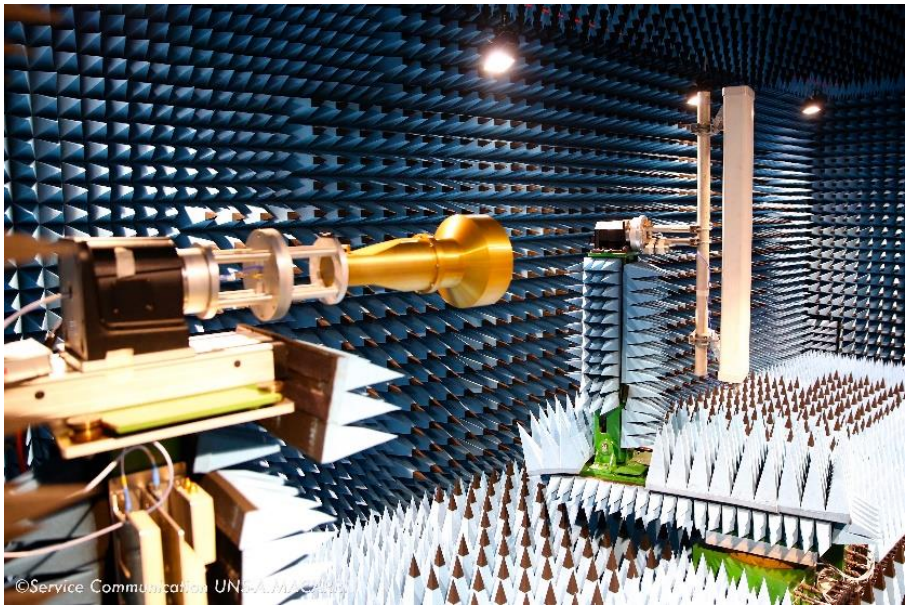
- Antenna is a resonnant structure :
  - Input impedance is changing with frequency
  - Limited frequency bandwidth
  - Miniature antenna can have a low efficiency due to metallic or dielectric losses
- Antenna is an open structure
  - Compare to electronic components, antenna is strongly influenced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

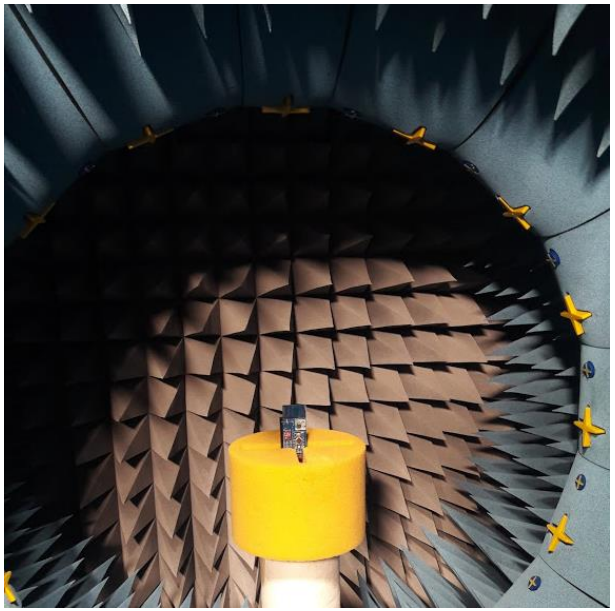




How to perform antenna radiation measurement ?

- 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)

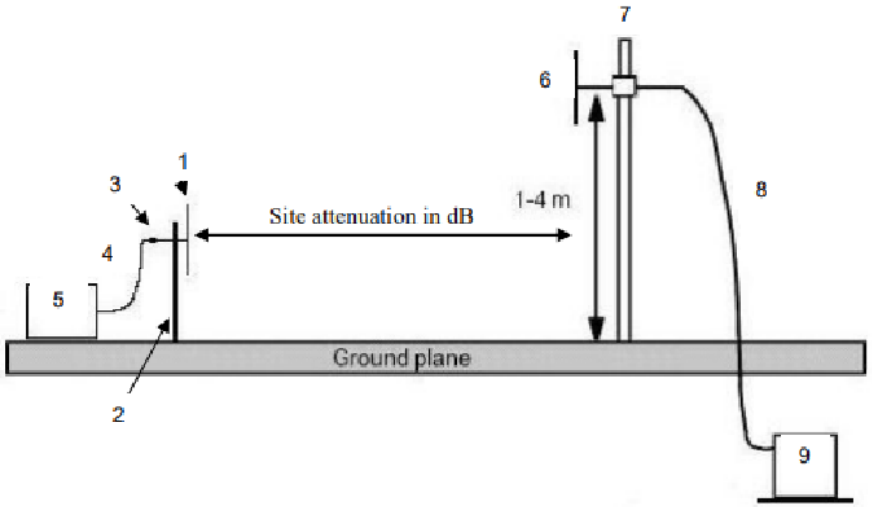


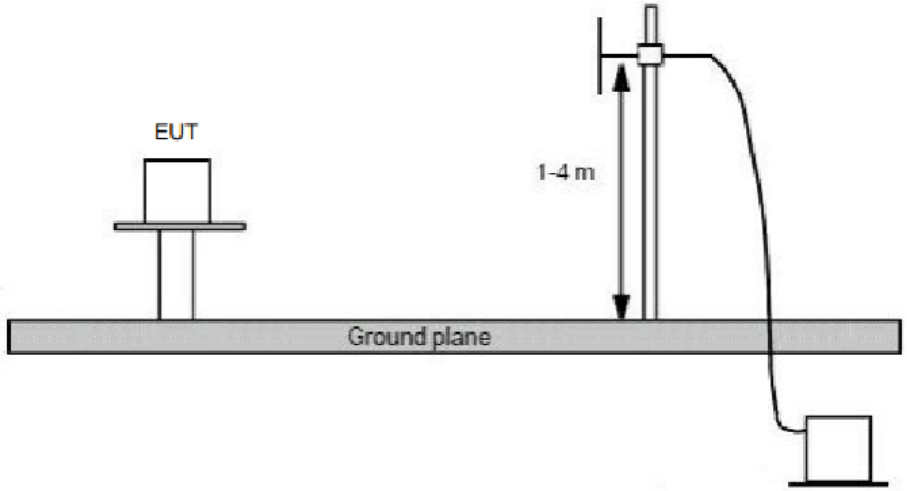


How to perform an antenna measurement ?

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

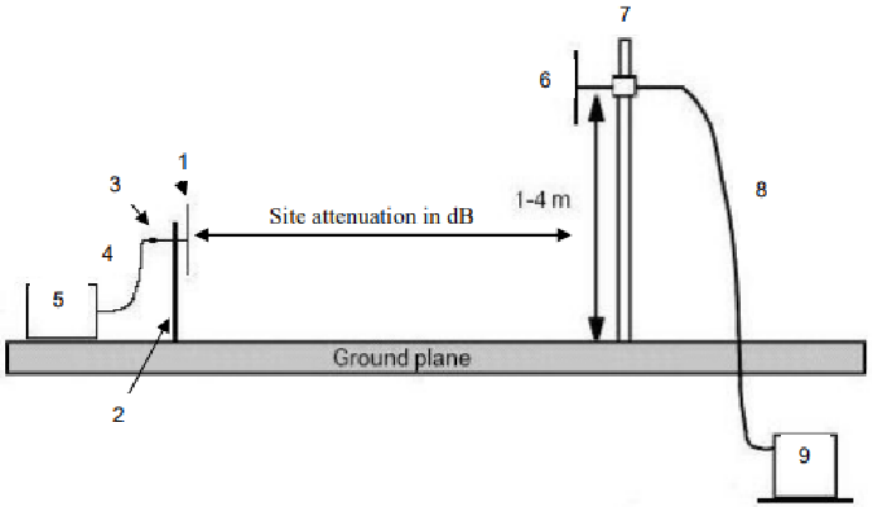


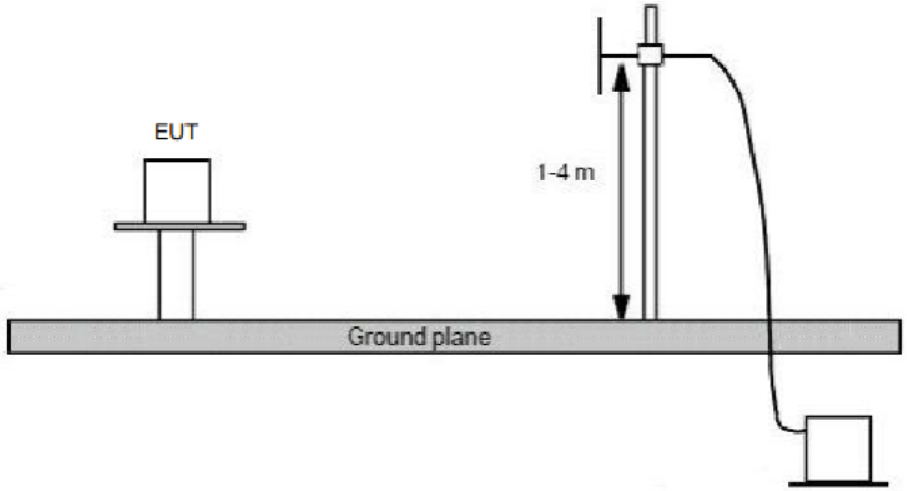


How to perform an antenna measurement ?

- 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)

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



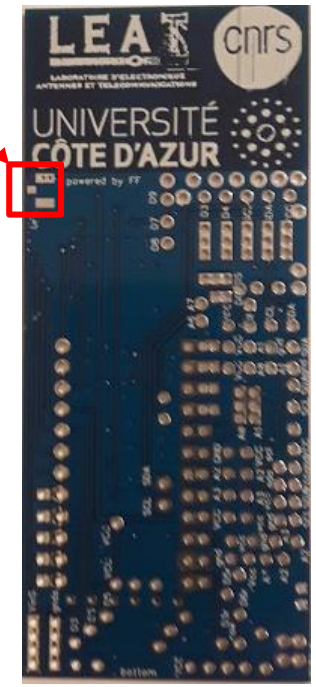


How to perform an antenna measurement ?

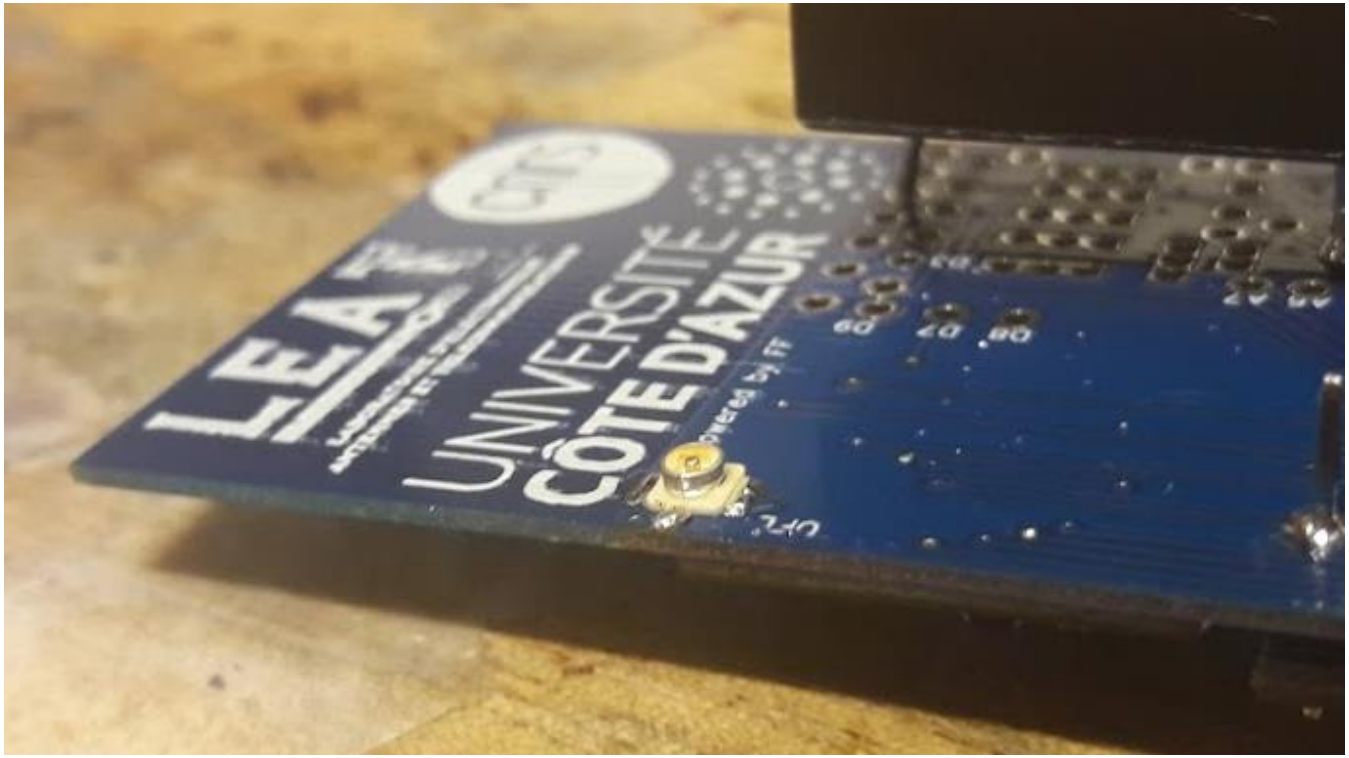
- Power source
- Reference antenna
- Anechoic chamber
- Spectrum analyser

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)

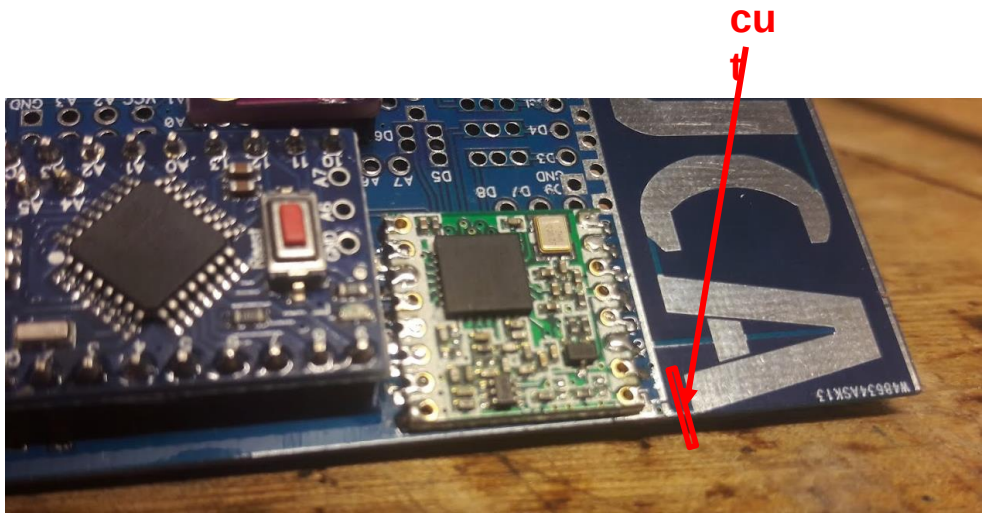


Adding a RF connector



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



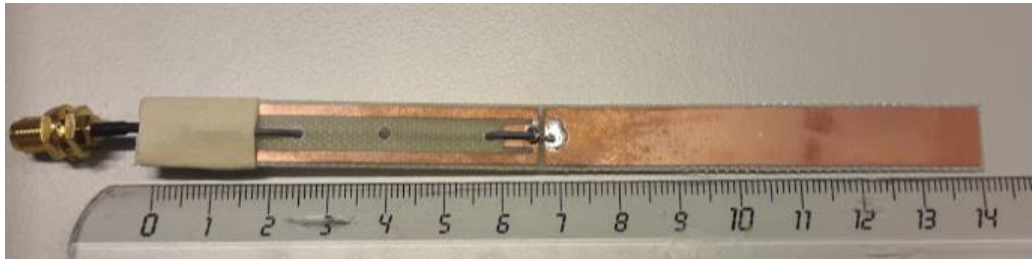
How to perform an antenna measurement ?

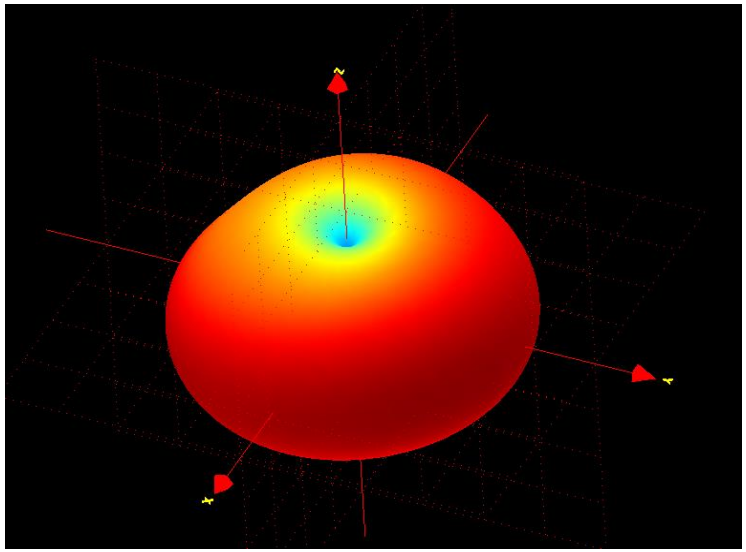
- Power source
- Reference antenna
- Anechoic chamber
- Spectrum analyser

Can we reduce the price ?

Printed Sleeve dipole with coaxial cable

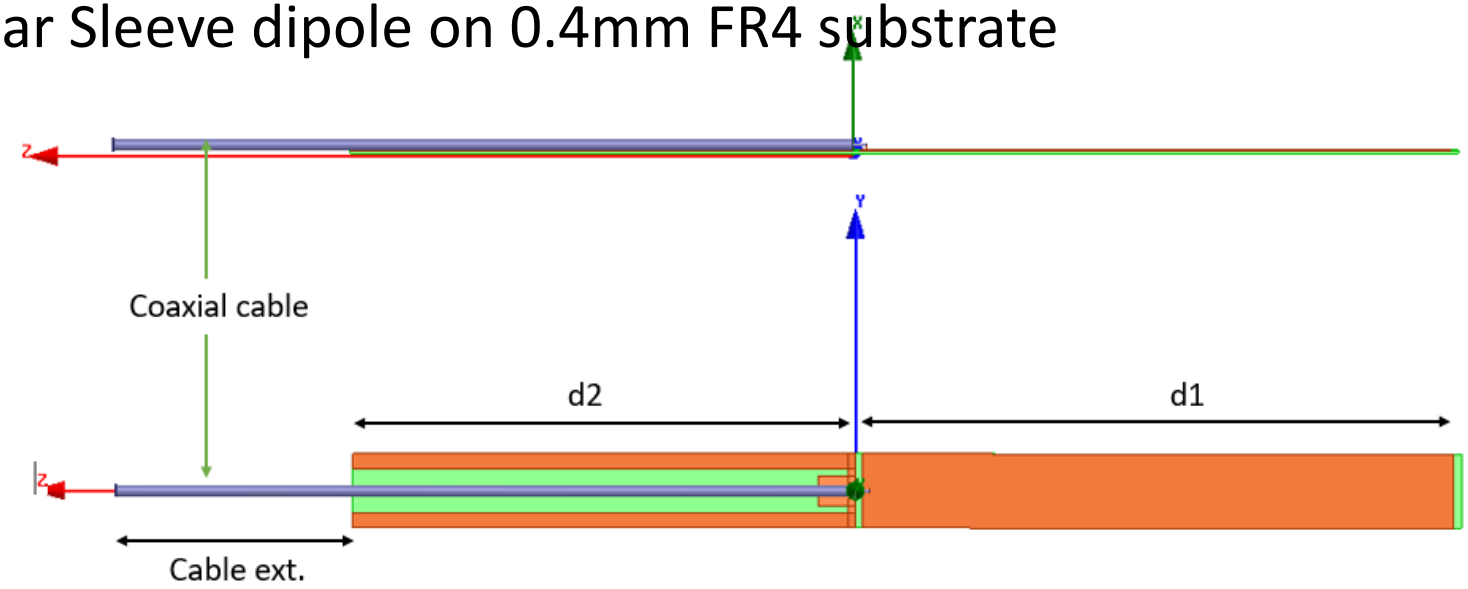
- Low cost 0.4mm FR4 Epoxy 140x15mm
- Low cost Small coaxial cable
- Integrated Balun for environment robustness
- Omnidirectional pattern
- Gain 2.5dBi
- Measured Efficiency 83%

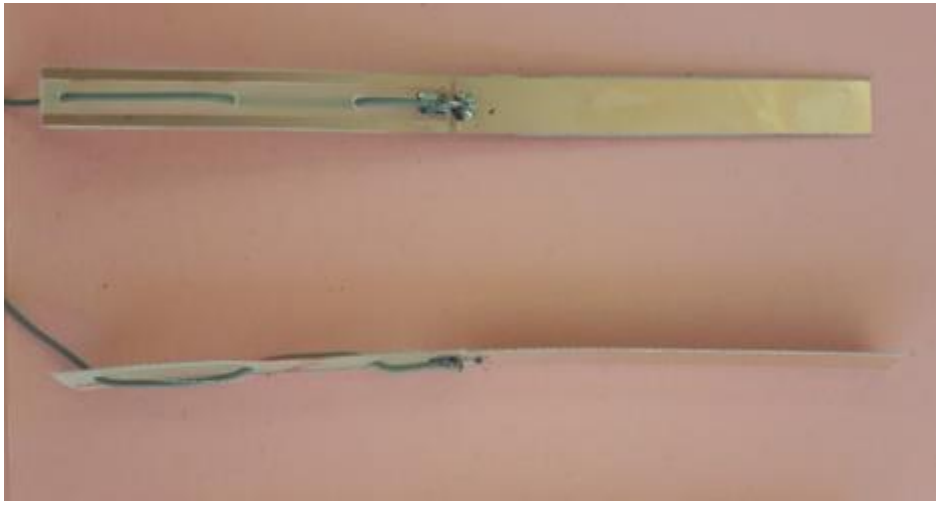




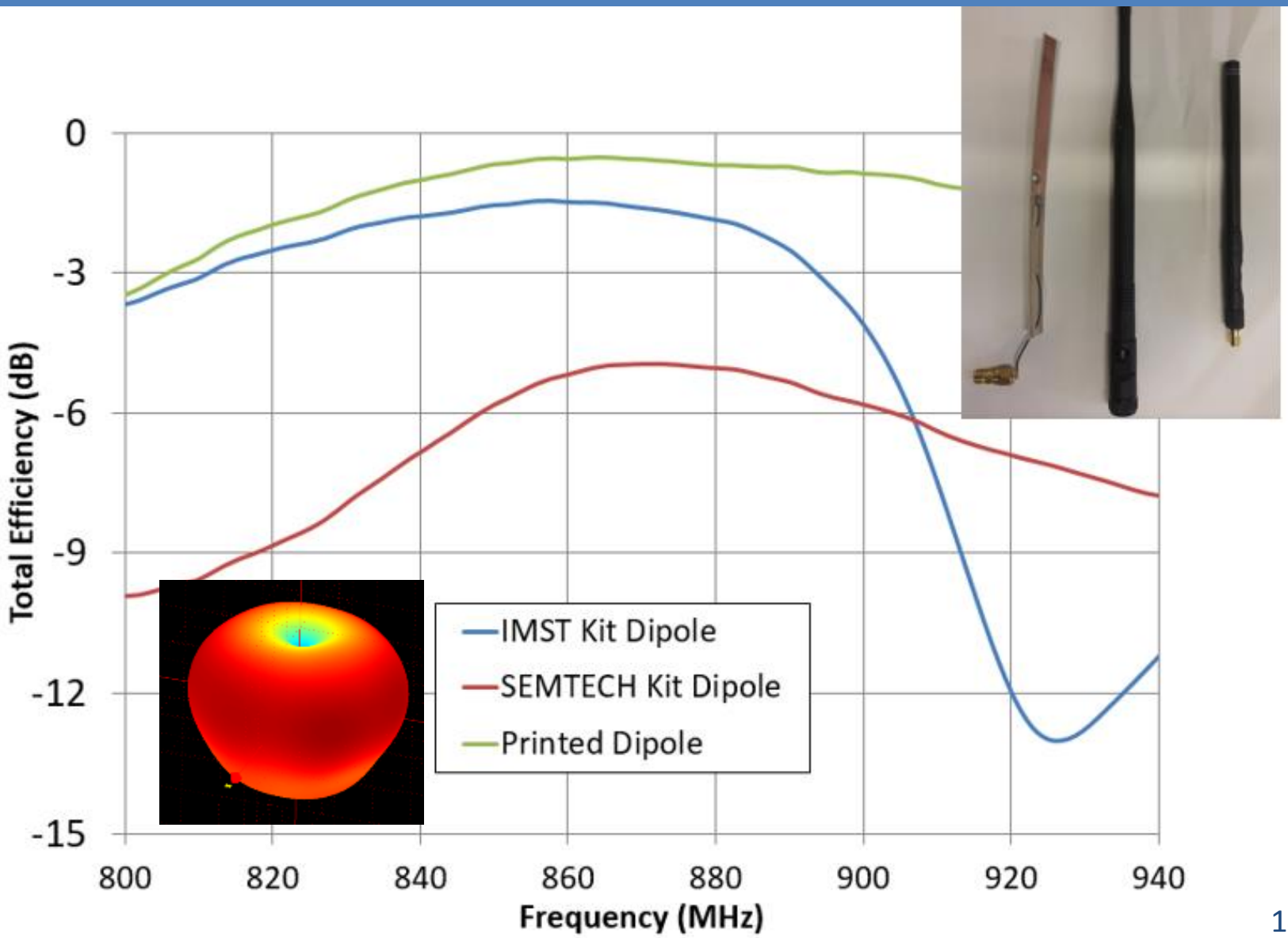
Half-wave dipole Antenna

- Planar Sleeve dipole on 0.4mm FR4 substrate



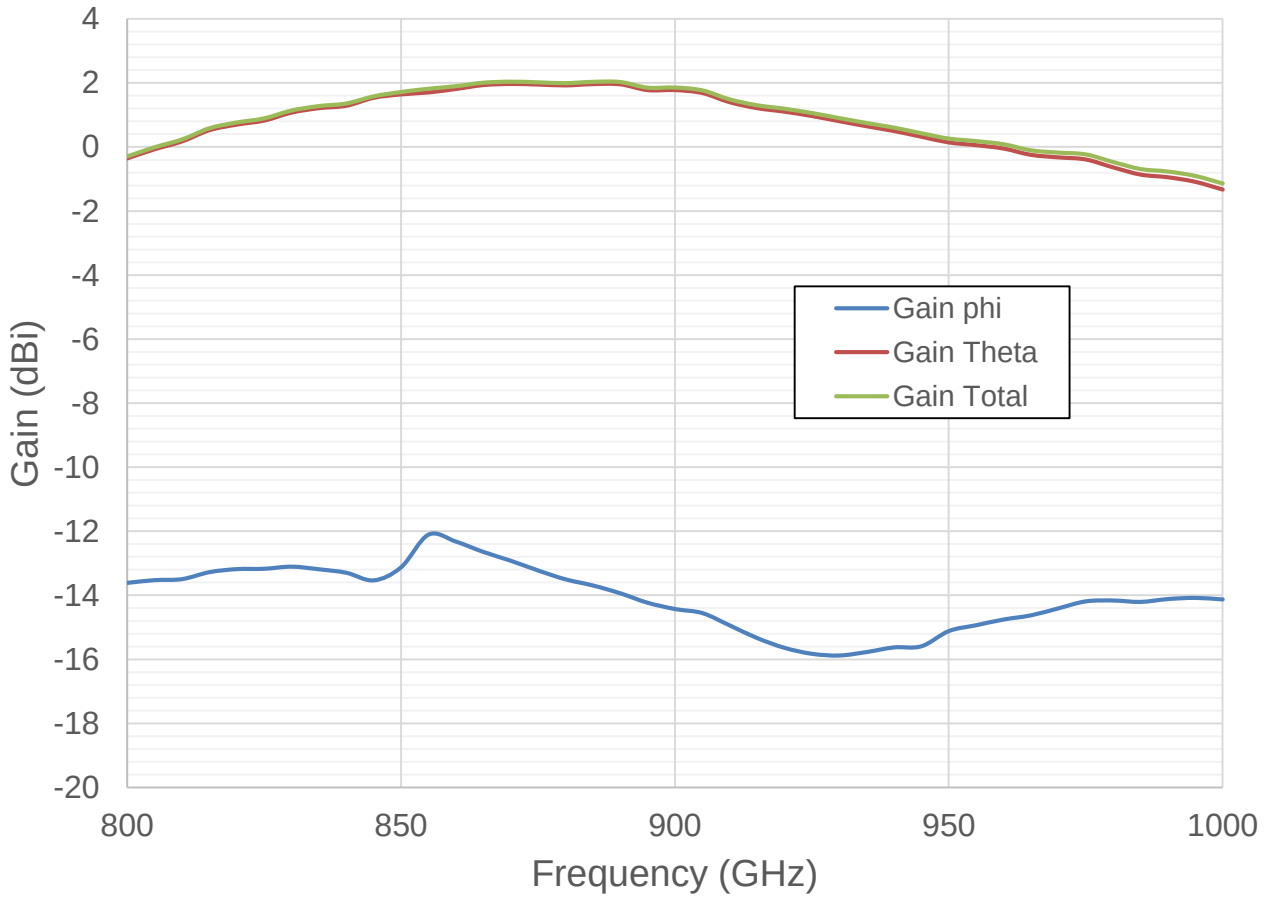


Comparison with on-the-shelf antenna



Printed Sleeve dipole with coaxial cable

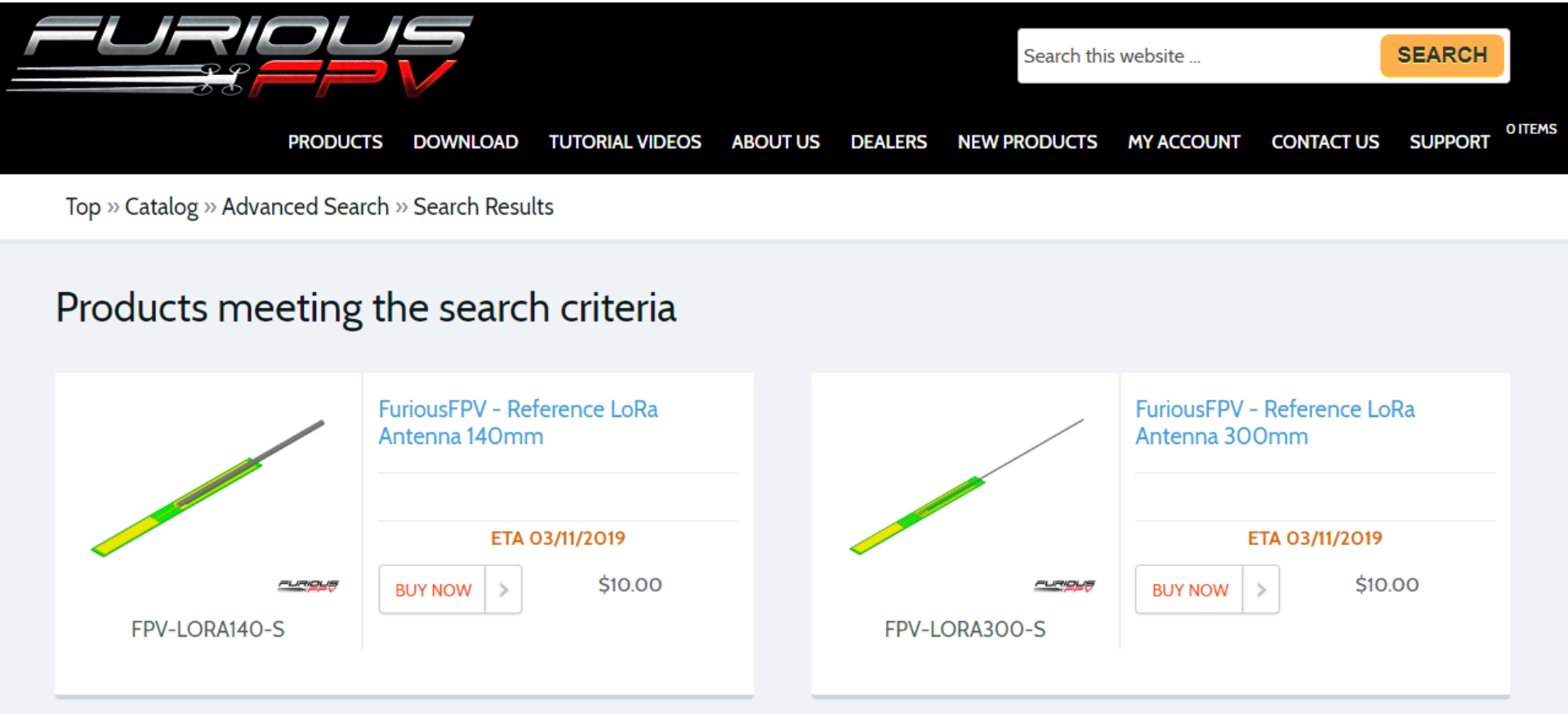
- Low cost 0.4mm FR4 Epoxy 140x15mm



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:

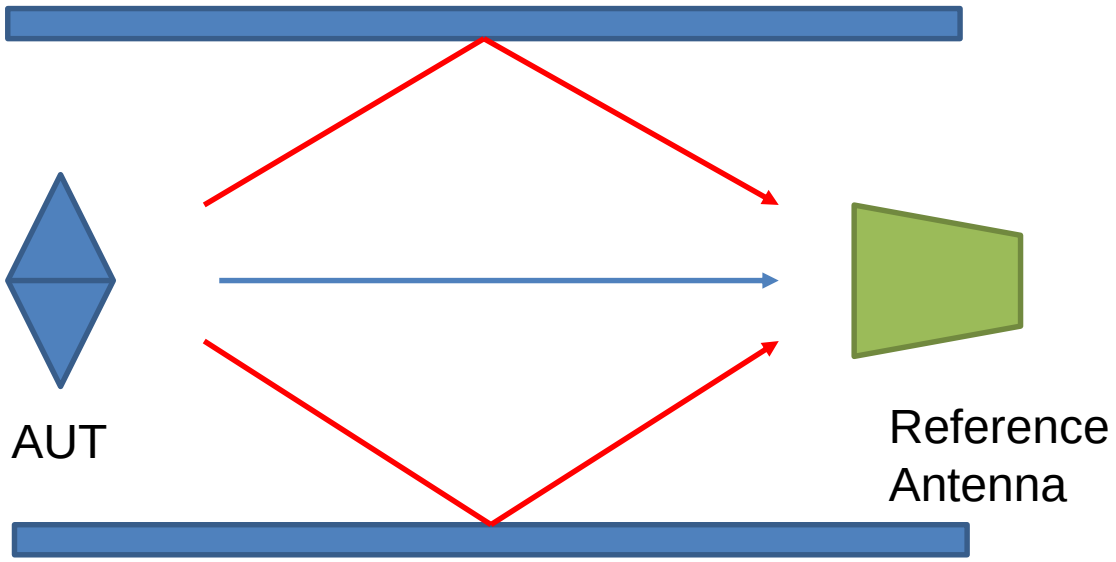
d1 is the largest dimension of the EUT/dipole after substitution (m);

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)

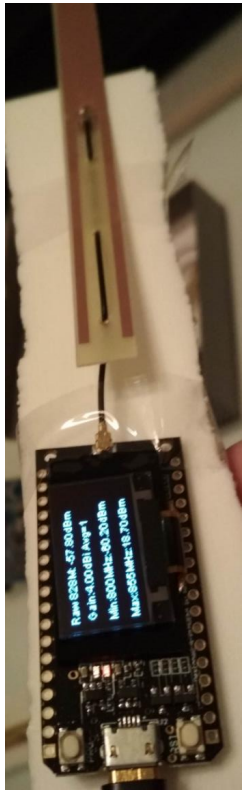


How to perform an antenna measurement ?

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

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 ?

Receiver is based on ESP32 + LoRa system
TTGO or Heltec with Oled Screen board are ok
Cost less than 10€

When the button is pushed, the calibration start with the reference antenna
Once it’s done, the system is calibrated a can measure AUT
On the screen, you can find the frequency with maximum and minimum gain

You can visualize the data using MegunoLink. This software can plot X-Y data

Exemple of measurement

- Calibration procedure
- Measurement

Setting-up Calibration device and Antenna Under Test

Connect your device with UFL cable to a reference antenna

Upload the code *DUT_Channel_Sounder_sender_workshop2.ino* to the reference device and Antenna under test

Setting-up Calibration device and Antenna Under Test

In *DUT_Channel_Sounder_sender_workshop2.ino :*

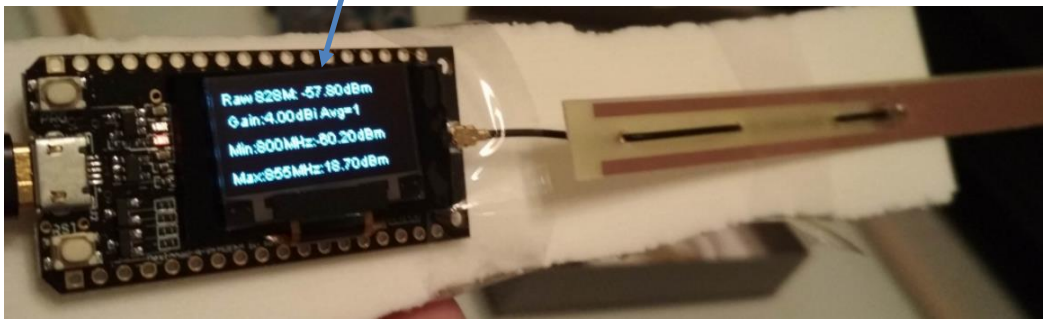
```
19
20  int counter = 0;
21  int avg = 1;
22  long freq_start = 800e6;
23  long freq_stop = 950e6;
24  long freq_step = 1e6;
```

You can choose the start and stop frequency, and the frequency step

Setting-up Receiver device

Connect the receiver device (TTGO board) with UFL cable to a reference antenna

Upload the code *LoRaOLED_Spectrumv3.ino* to the receiver device



Setting-up Receiver device

In *LoRaOLED_Spectrumv3.ino* code,

```
61  int ref_freq[] = {799e6, 850e6, 900e6, 950e6};
62  float ref_val[]={-3,17,18,3}; // Warning, all power values are in tenth of dB
```

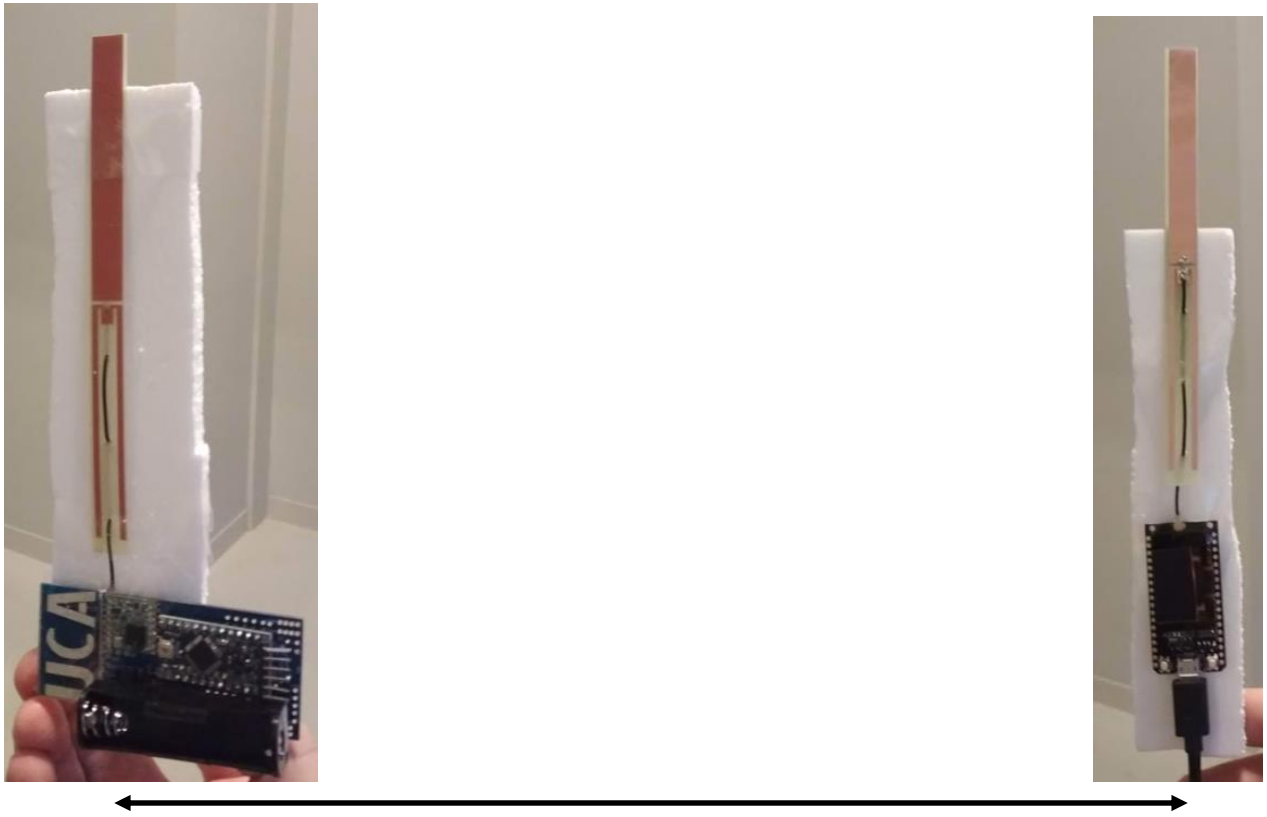
The gain versus frequency of the reference antenna is describe by linear approximation.

If you use a different reference antenna, you should update these tables

The measurement is plotted in MegunoLink format

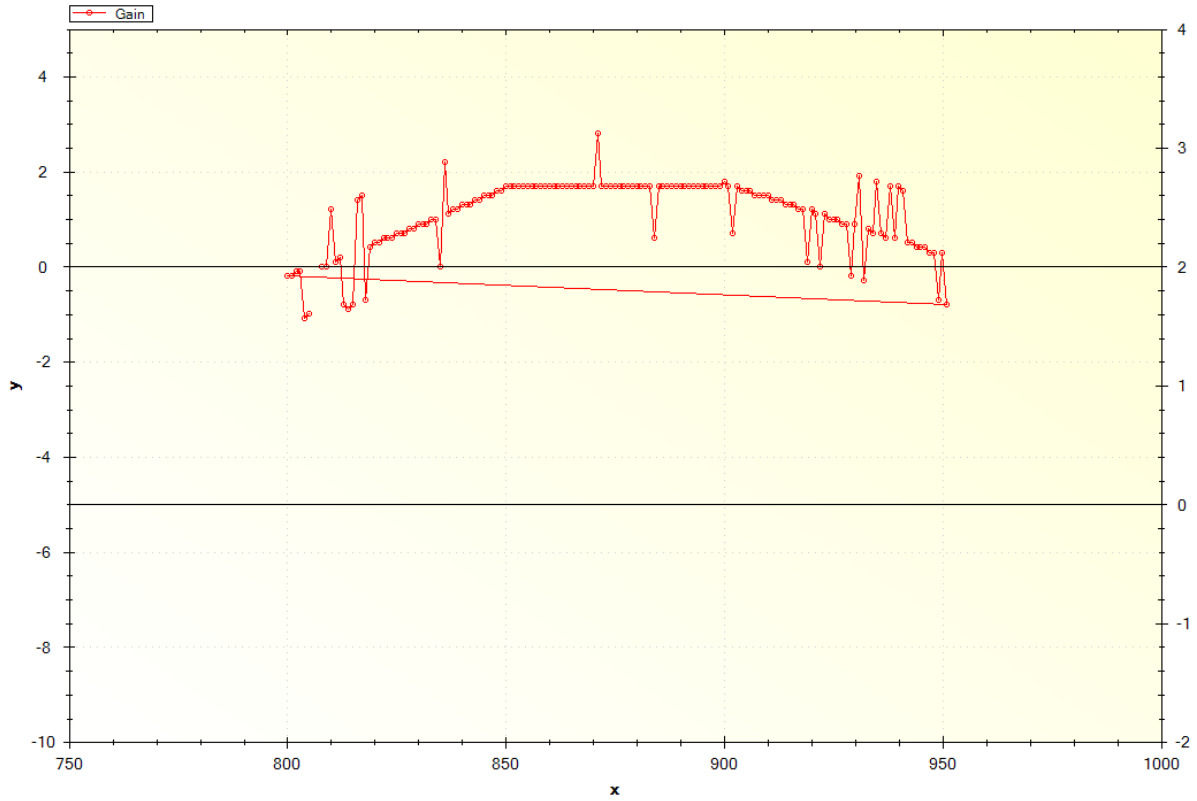
Setting-up Receiver device

Set-up the reference device and receiver device at a distance between 30 and 50 cm.
Push the button, the calibration start with the reference antenna.
Wait for the complete scan between 800 and 950MHz



How to perform an antenna measurement ?

Once it’s done, the system is calibrated.
The system will continue to scan but you should find the gain of the reference antenna
On MegunoLink you can visualize the plot, choose X-Y plot, connect to your serial port with 115200 bauds, in parameters set the maximum number of point to 151 (950-800MHz with 1MHz step)



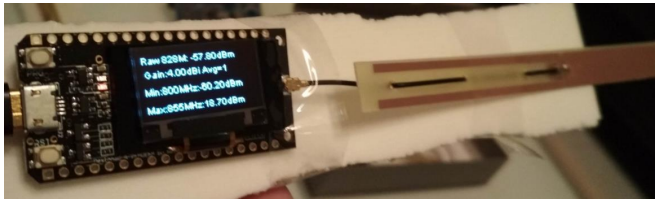
Setting-up Receiver device

- Now you can replace the reference antenna by the Antenna Under Test.
- Try to place it exactly at the same position

30 to 50 cm

How to perform an antenna measurement ?

Exemple of DIY measurement at home, use box as antenna holder

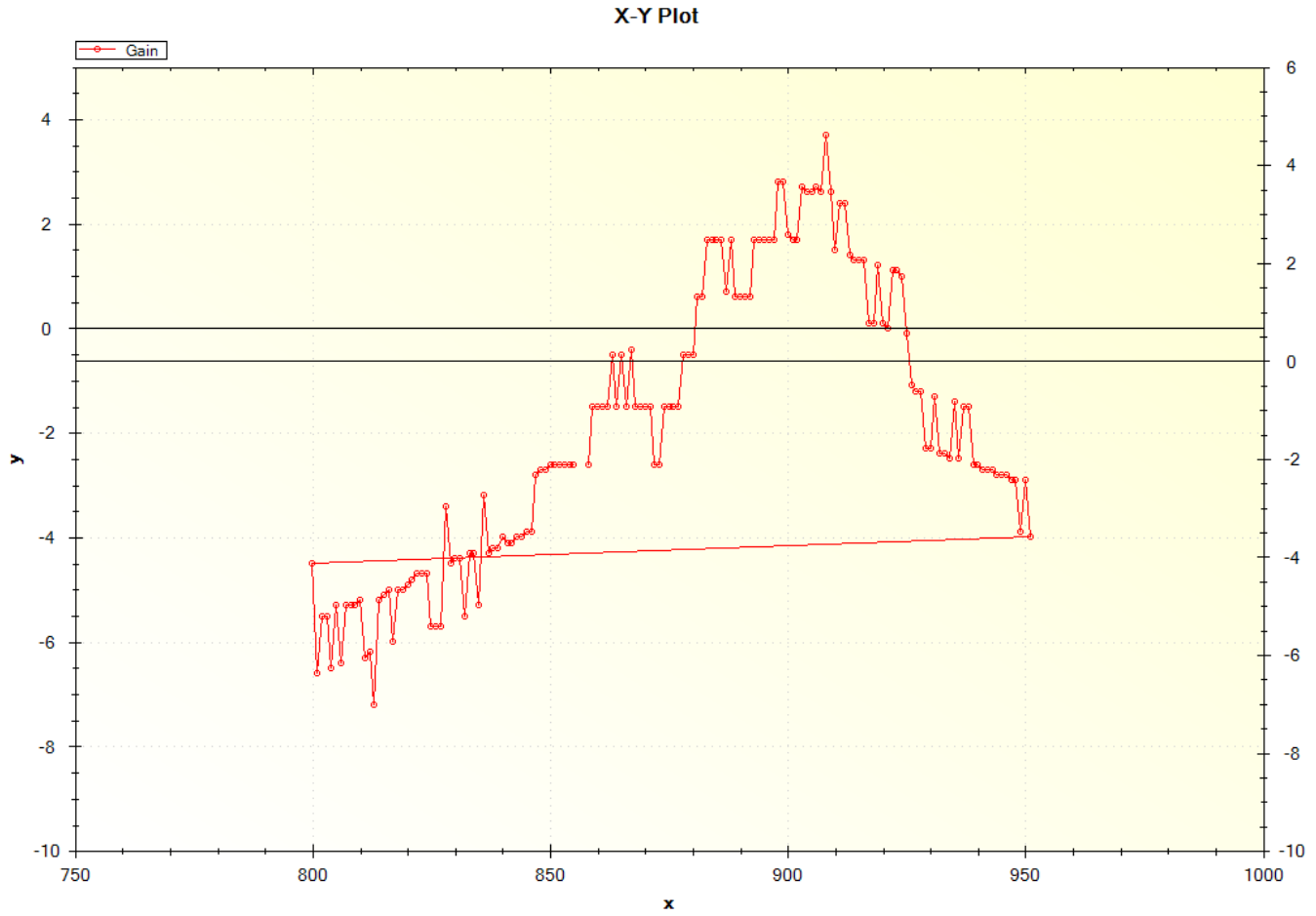


How to perform an antenna measurement ?

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

- 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