LABORATOIRE D'ELECTRONIQUE
ANTENNES ET TELECOMMUNICATIONS

Laboratory of Electronics Antennas and Telecommunications

Antenna tuning for your LoRaWAN device

Fabien Ferrero

https://github.com/FabienFerrero/Antenna_Radiation_Measurement

RF things

space Lacuna

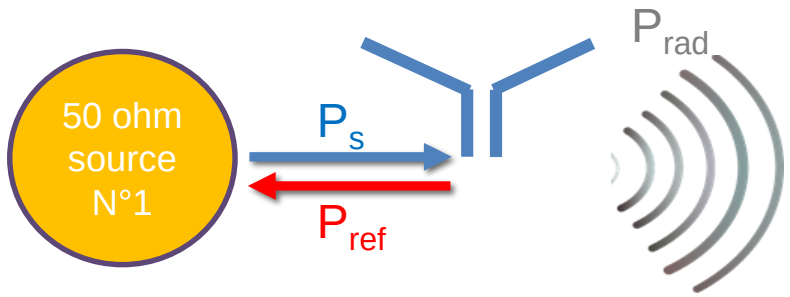
UNIVERSITÉ CÔTE D'AZUR

Outline

- Antenna Tuning
- Low Cost Vector Network Analyzer
- Inverted F Antenna
- UCA Antenna tuning
- Lacuna Space Antenna tuning
- Conclusion

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)
  - Total Efficiency
    - Include **matching** and **radiation loss**
    - Can be plotted in linear or dB scale
    - 30-70% classically observed
  - Gain
    - Include **matching**, **radiation loss** and **directivity**
    - Plotted in dBi
    - $U(\theta, \varphi)$ is the radiation intensity in a given direction



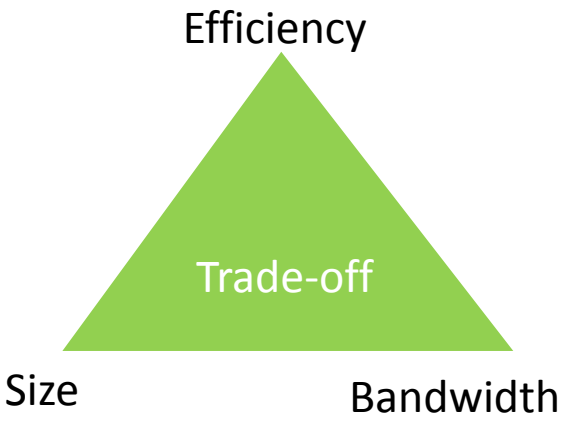
$$|S_{11}|^2 = P_{ref}/P_s$$

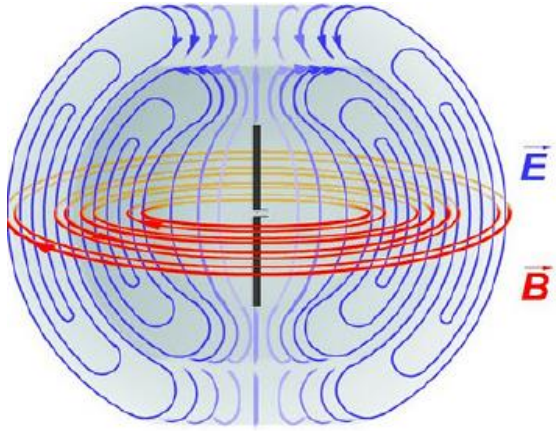
$$\eta_t = P_{rad}/P_s$$

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

Antenna key parameters

- Antenna is a resonnant structure :
  - Input impedance is changing with frequency
  - Limited frequency bandwidth
- 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

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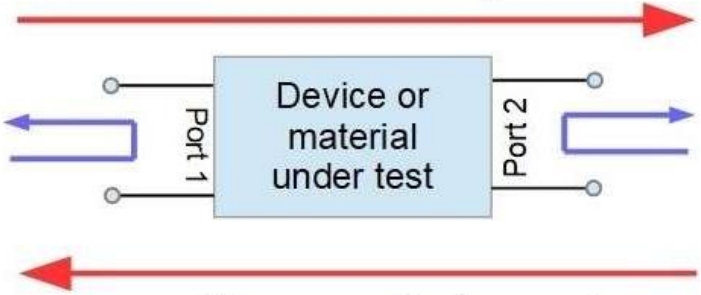
Vector Network Analyzer

- Vector Network Analyzer
  - RF Engineer best friend
  - Measure Reflection and transmission parameters at RF frequencies
  - Must be calibrated (SOLT)
  - Price for professional material from 10 to 300 k€

$$S21 = \frac{Wave\ transmited\ from\ port\ 2}{Wave\ inceident\ at\ port\ 1}$$

$$S11 = \frac{Wave\ reflected\ from\ port\ 1}{Wave\ incident\ at\ port\ 1}$$



$$S22 = \frac{Wave\ reflected\ at\ port\ 2}{Wave\ incendent\ at\ port\ 2}$$

$$S12 = \frac{Wave\ transmitted\ at\ port\ 1}{Wave\ incident\ at\ port\ 2}$$

Vector Network Analyzer

- Nano VNA
  - From 30 to 100$
  - Limited performance (50dB dynamic)
  - Battery powered
  - Must be calibrated (SOLT)
  - Enough for antenna measurements

$$S21 = \frac{Wave\ transmited\ from\ port\ 2}{Wave\ inceident\ at\ port\ 1}$$

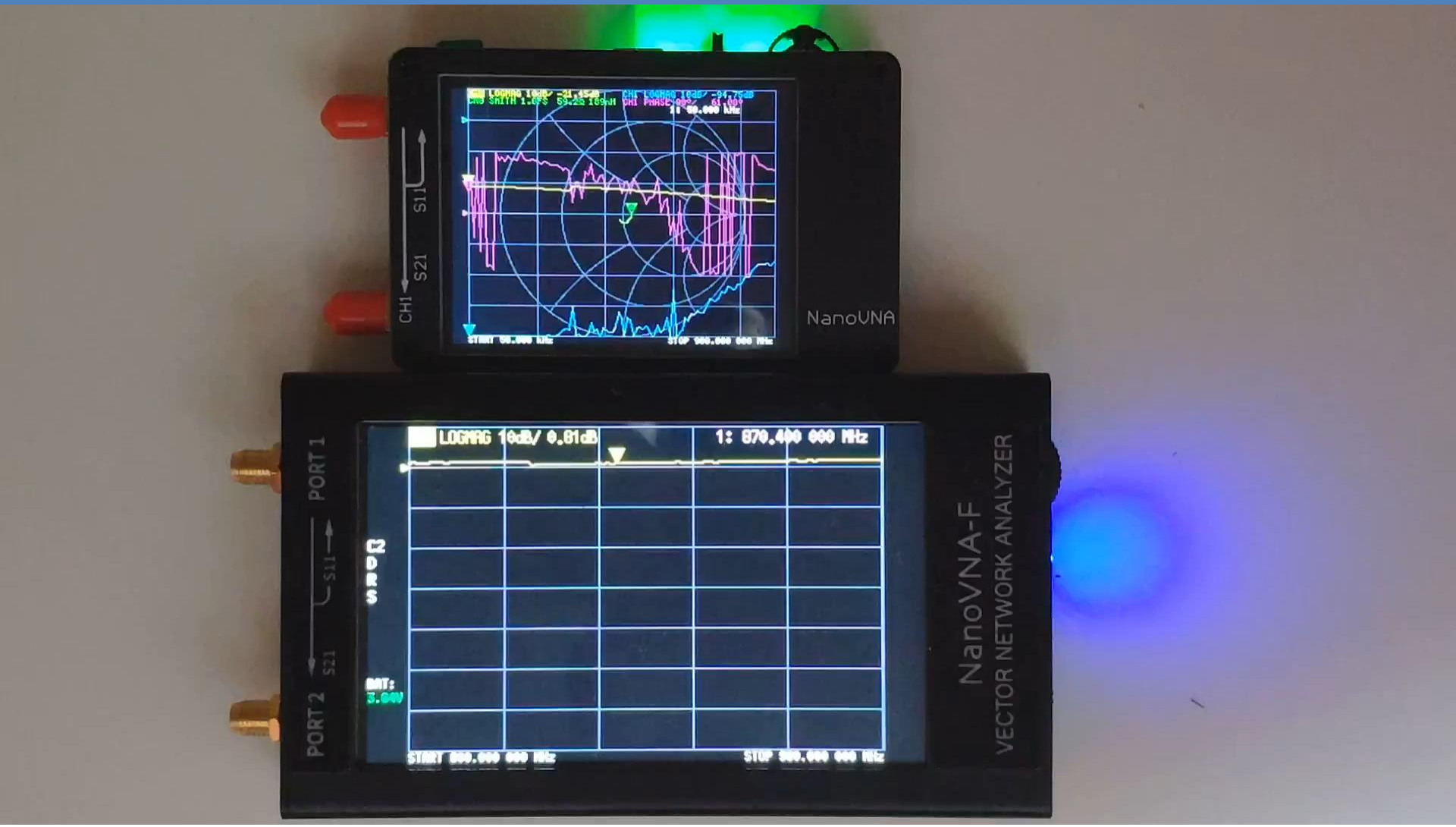
$$S11 = \frac{Wave\ reflected\ from\ port\ 1}{Wave\ incident\ at\ port\ 1}$$

Port 1 | Device or material under test | Port 2

$$S22 = \frac{Wave\ reflected\ at\ port\ 2}{Wave\ incendent\ at\ port\ 2}$$

$$S12 = \frac{Wave\ transmitted\ at\ port\ 1}{Wave\ incident\ at\ port\ 2}$$

Vector Network Analyzer



Vector Network Analyzer

- Nano VNA
  - Warning : Several version available !
    - 50KHz ~ 900 MHz or **50KHz ~ 1.5GHz**
    - 2.8" screen LCD (VNA-H) or 4.3 " screen LCD (VNA-F)
  - Code is open source and available on :

https://github.com/ttrftech/NanoVNA

  - NanoVNA v2.0 up to 3.5GHz is under development !

Vector Network Analyzer : calibration

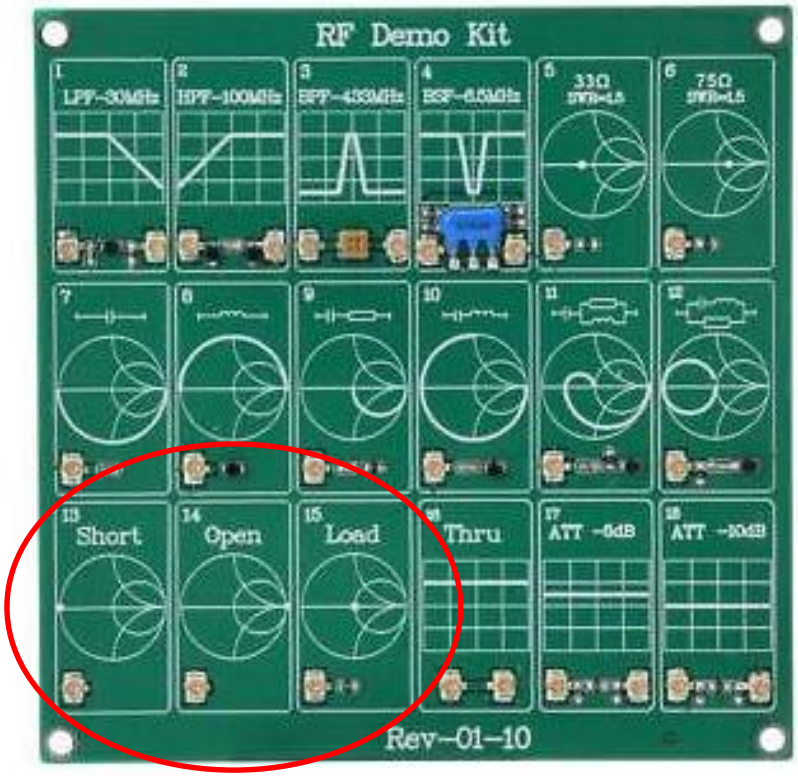
- Calibration
  - Before using the VNA, you have to calibrate it
  - Use Open, Short and Load (50 ohm)

For SMA Connector

Through Open Short Load

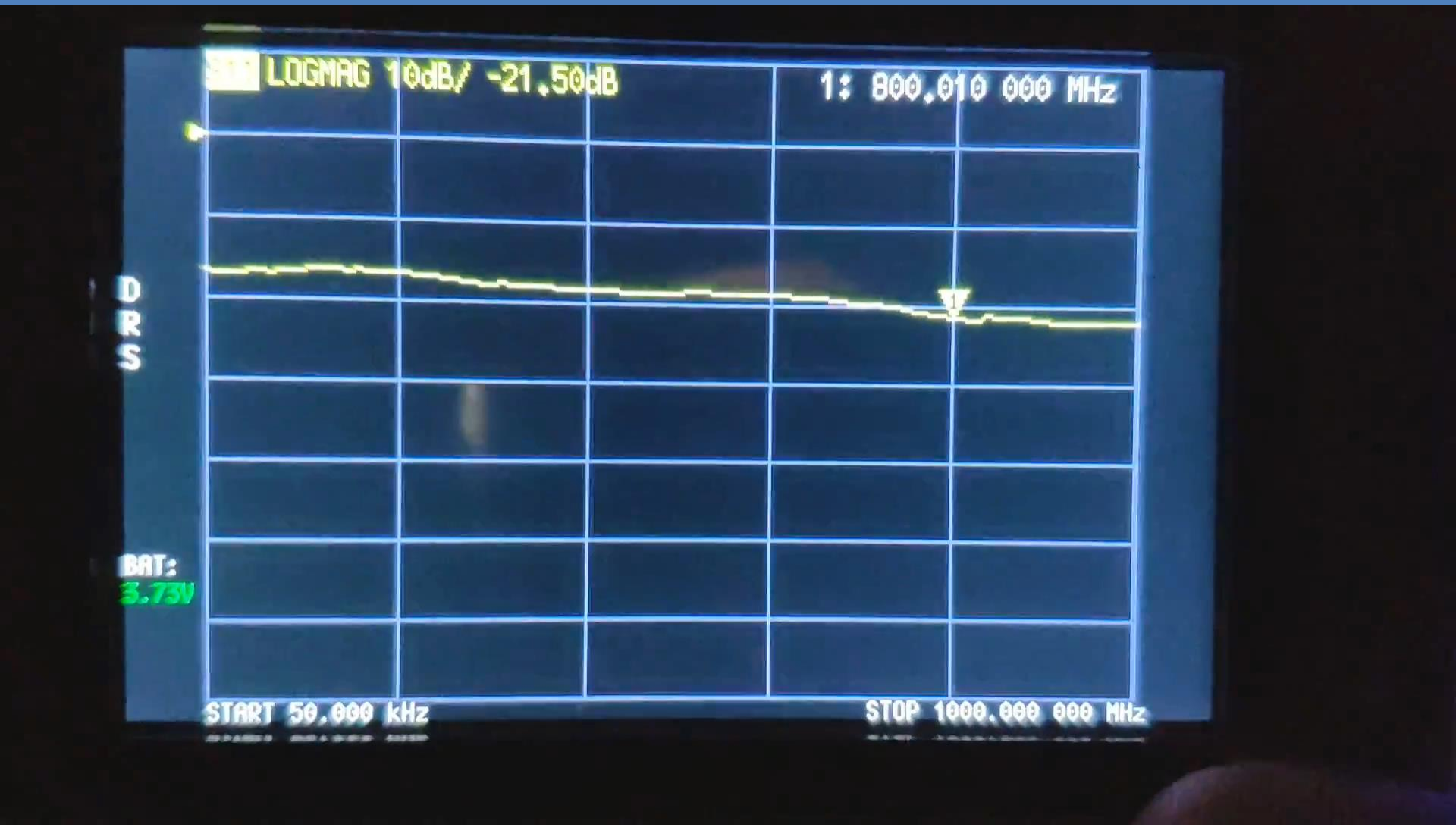
Vector Network Analyzer : calibration

- Calibration
  - Before using the VNA, you have to calibrate it
  - Use Open, Short and Load (50 ohm)

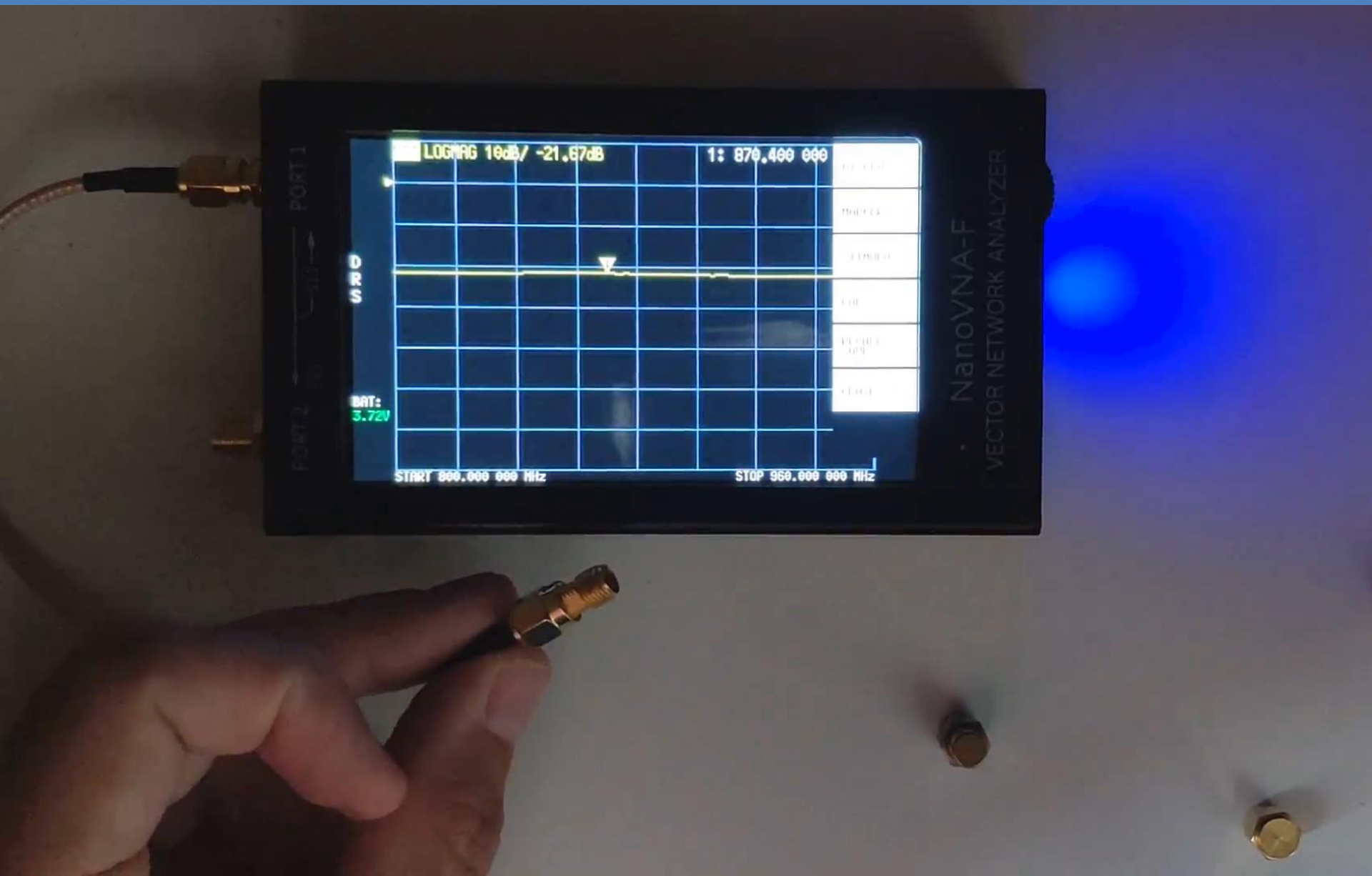


For UFL Connector

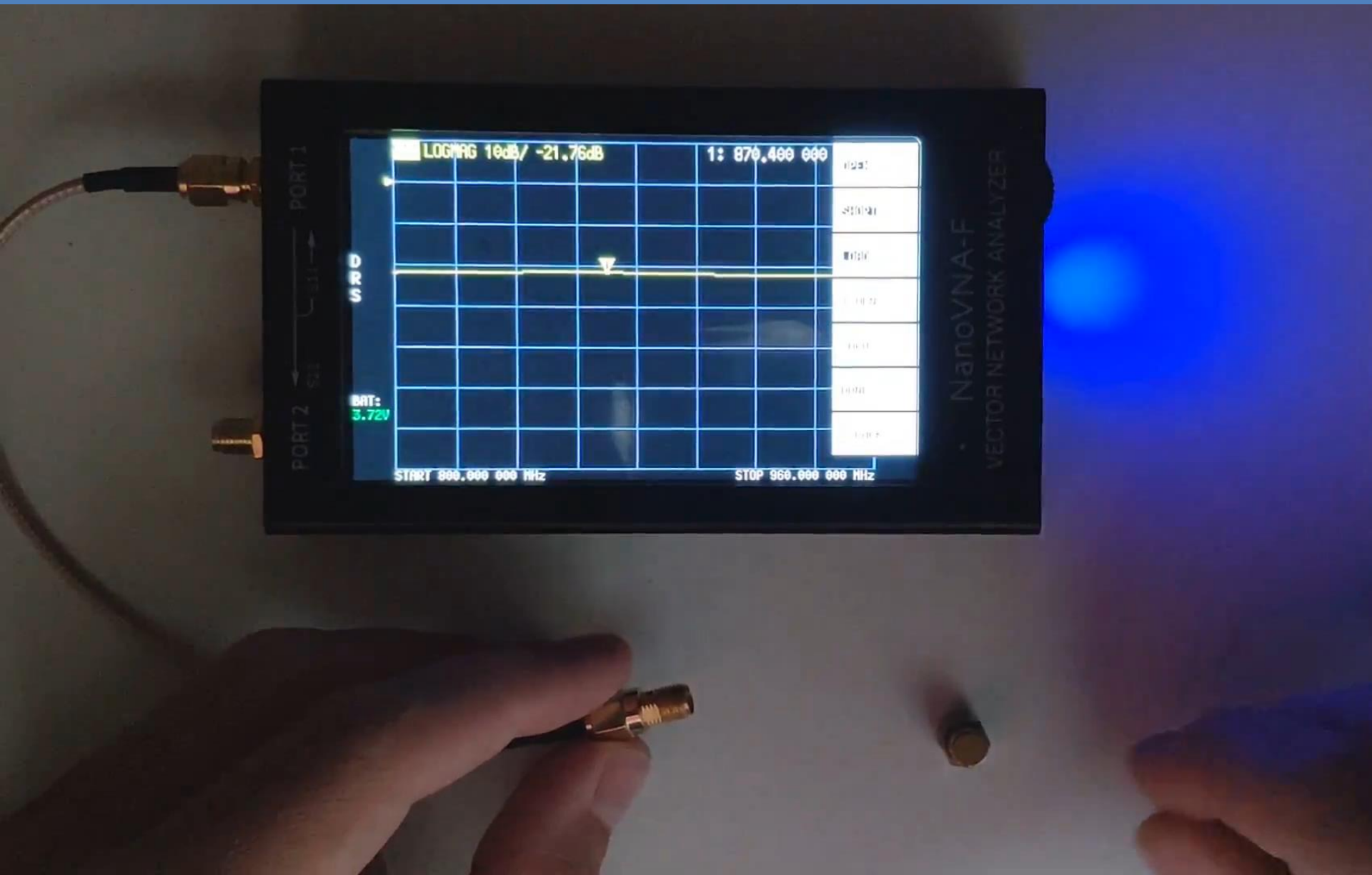
Vector Network Analyzer : calibration



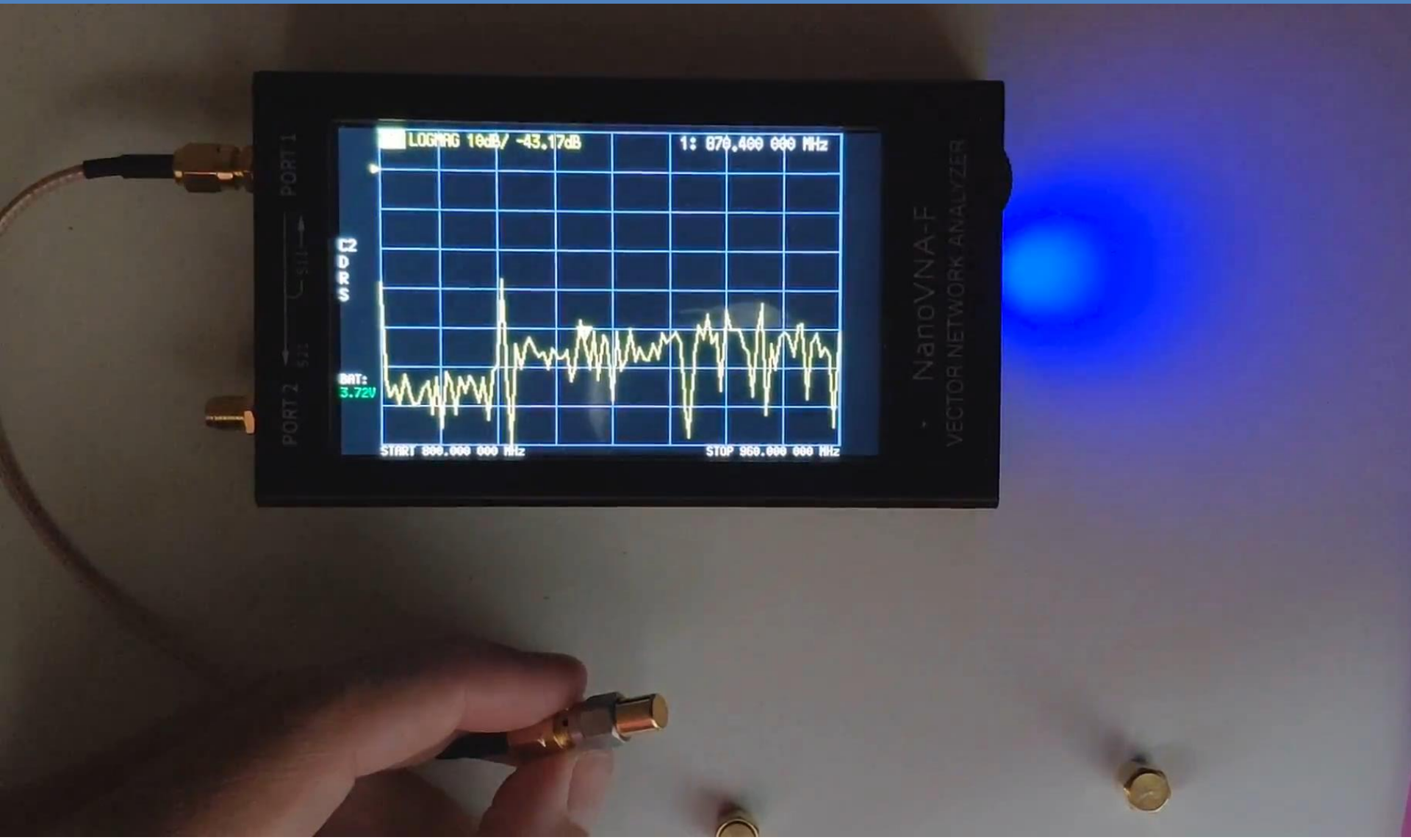
Vector Network Analyzer : calibration



Vector Network Analyzer : calibration



Vector Network Analyzer : calibration



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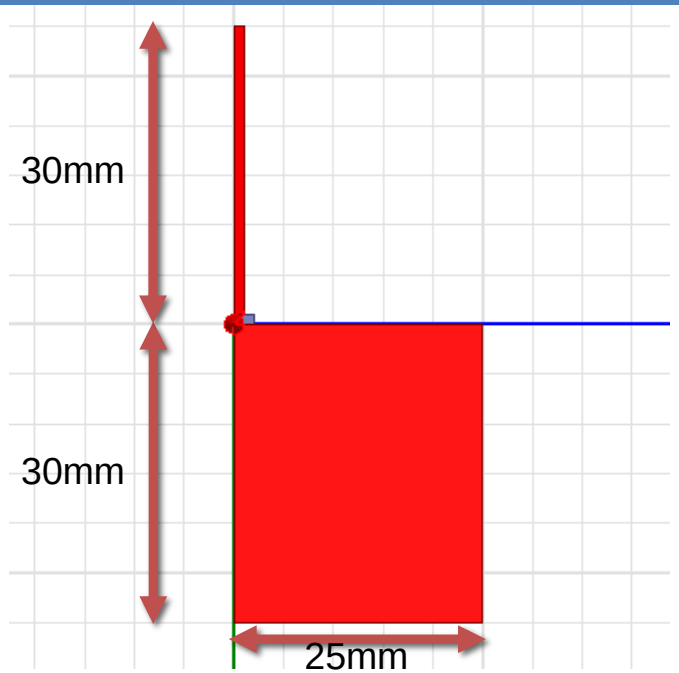
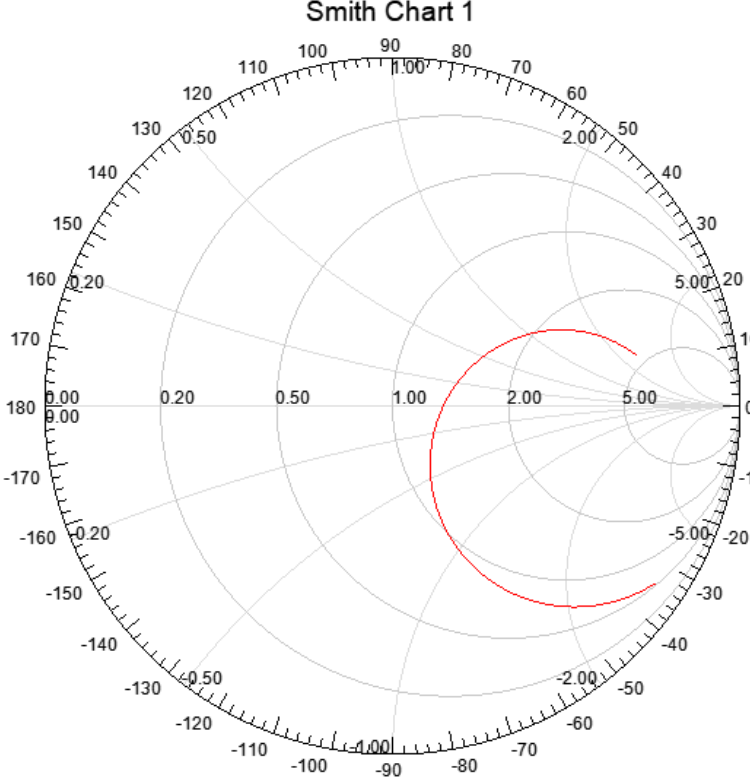
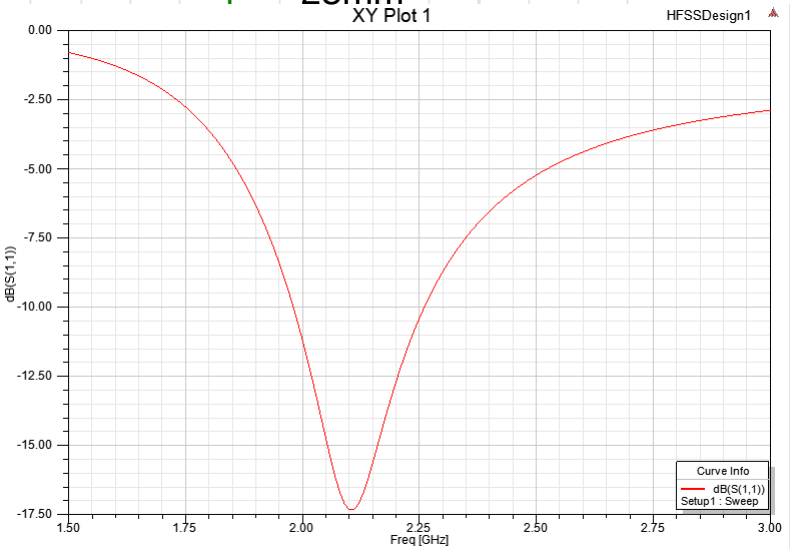
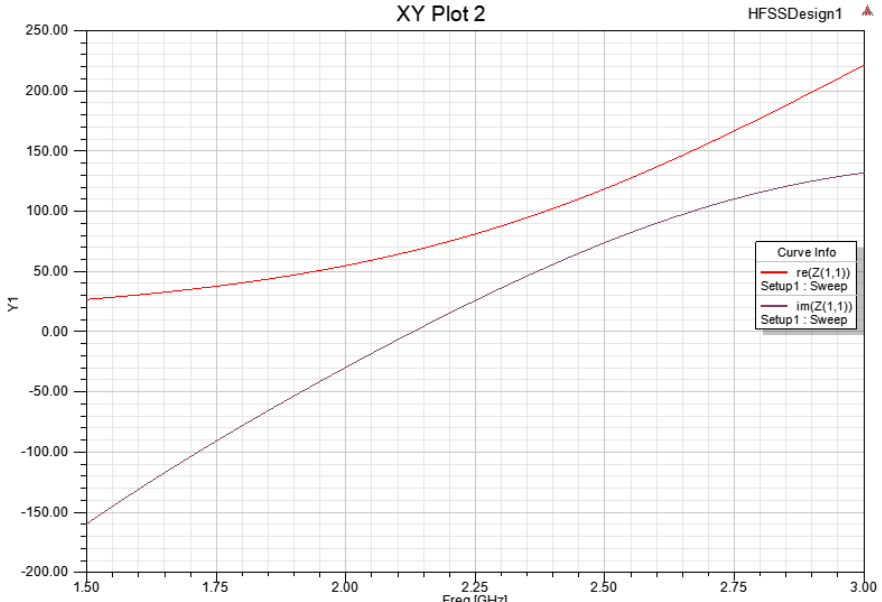
Monopole Antenna

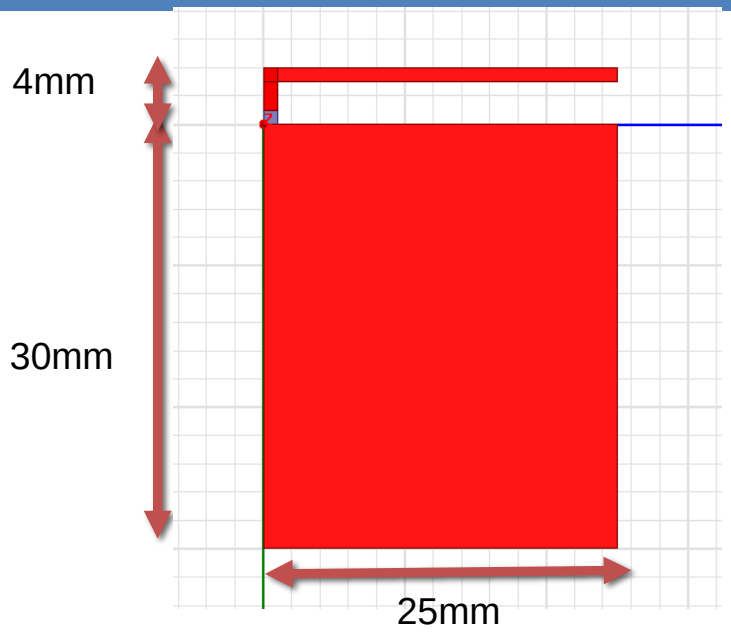


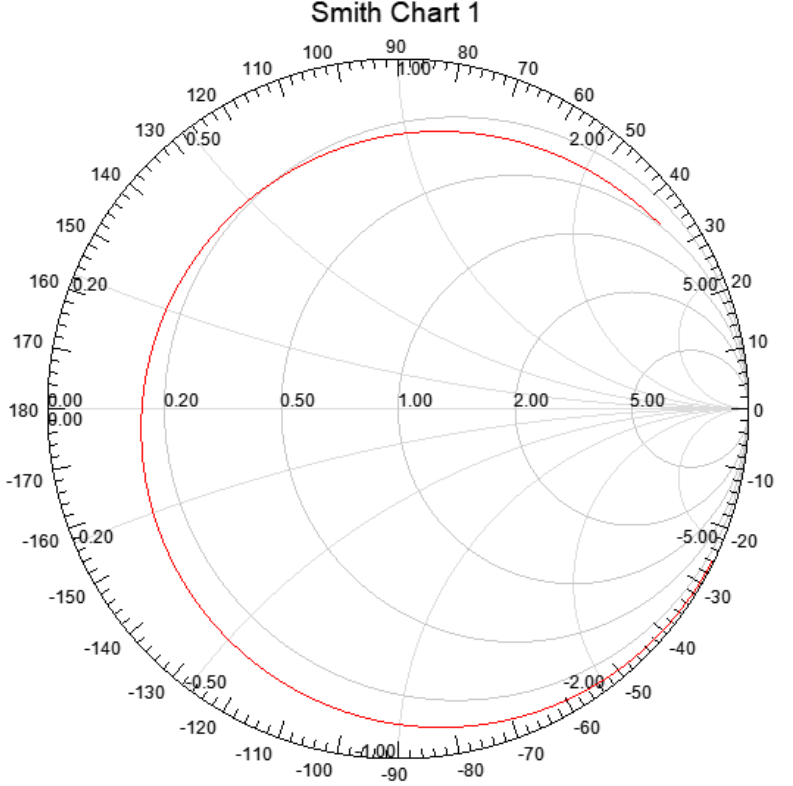


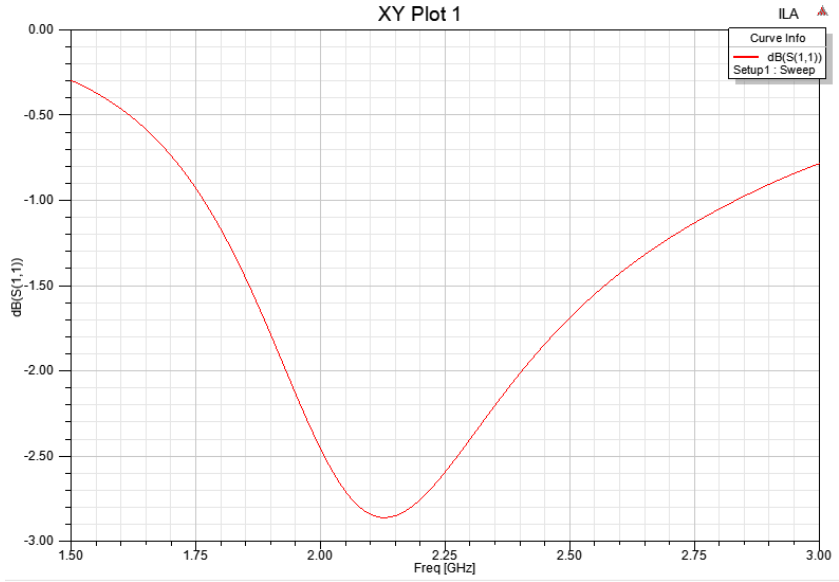


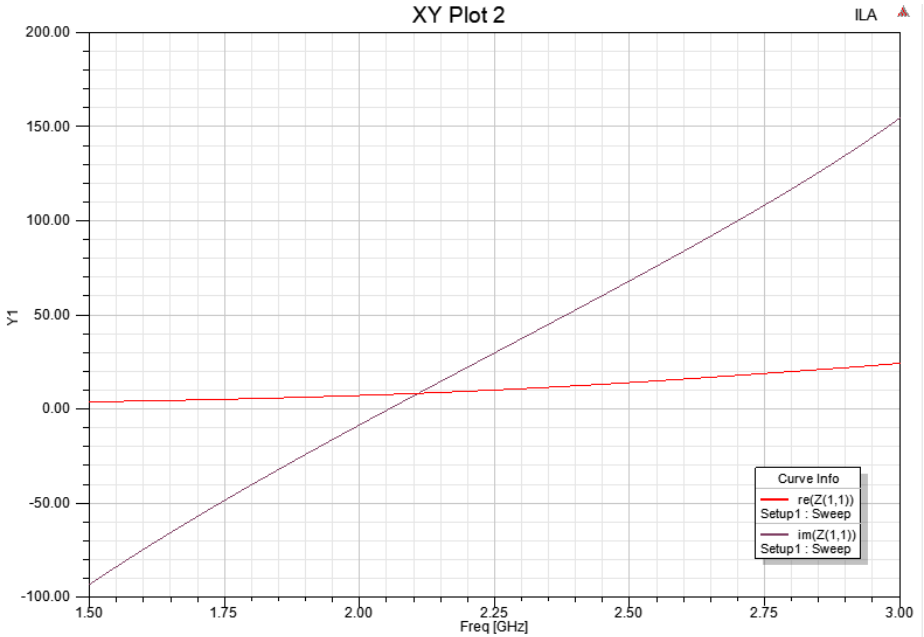


Inverted L Antenna







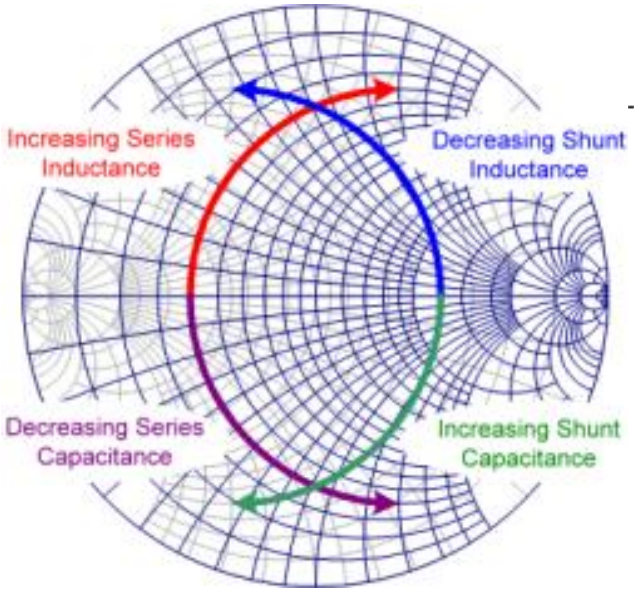


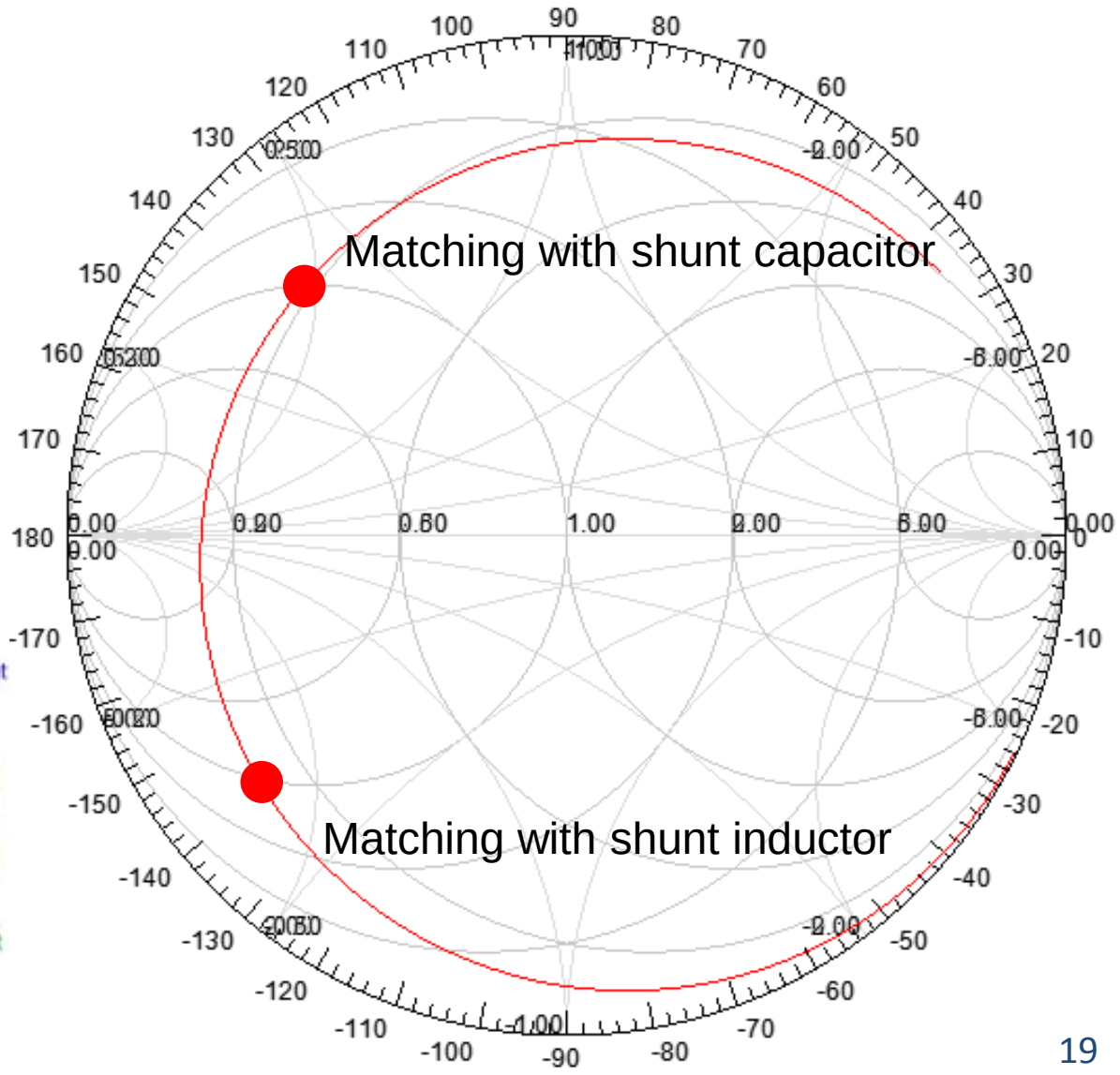
Inverted L Antenna

Additional matching needed

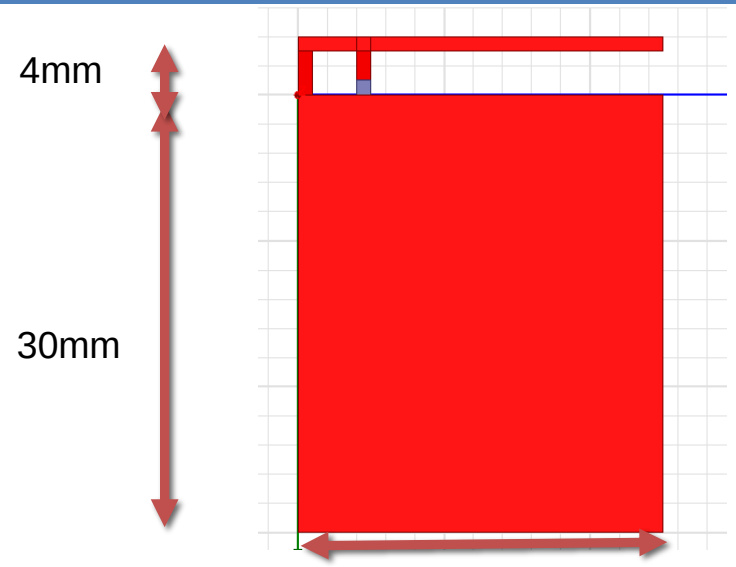
Passive components (inductor, capacitor) car be used

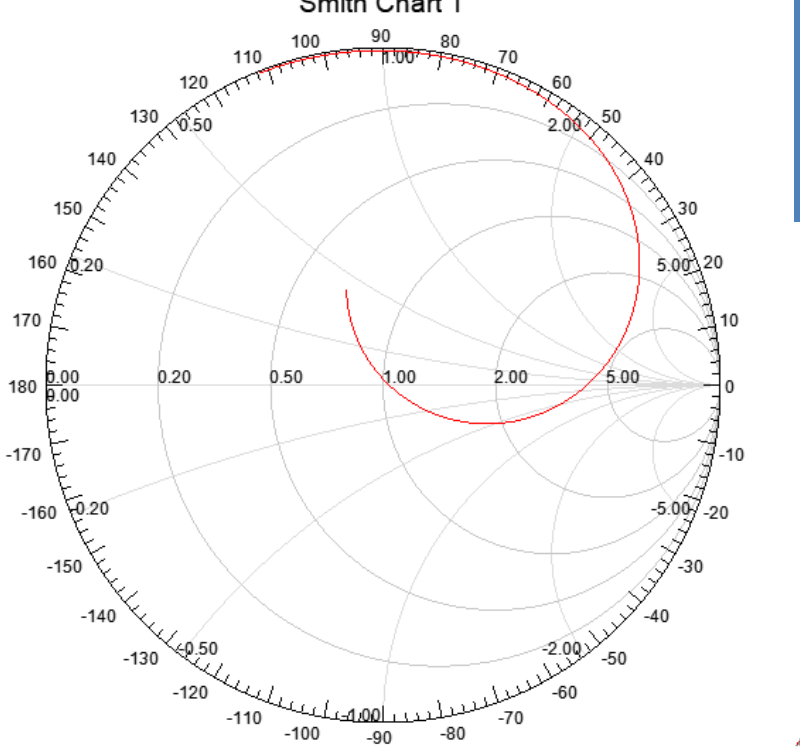
Stub can also be used

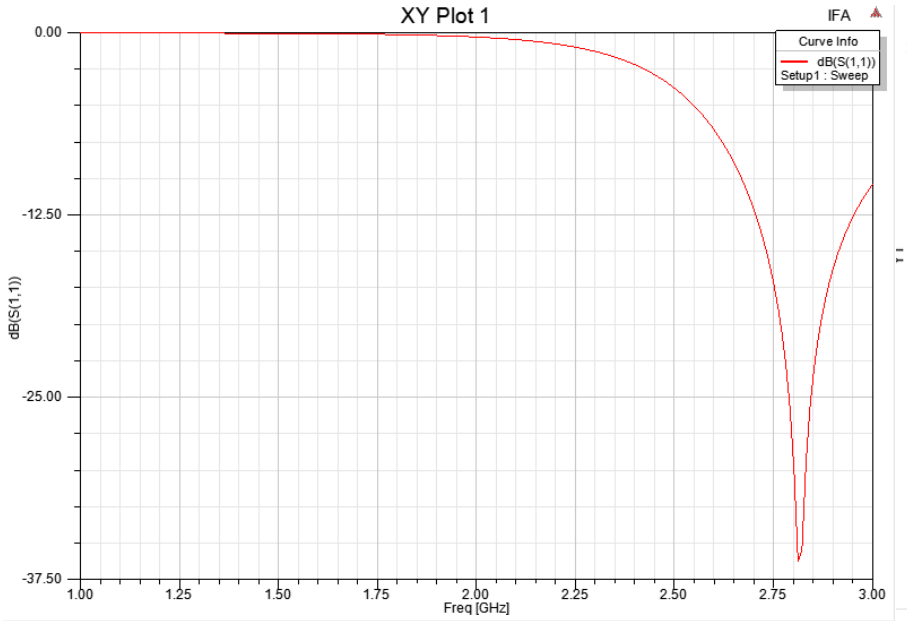


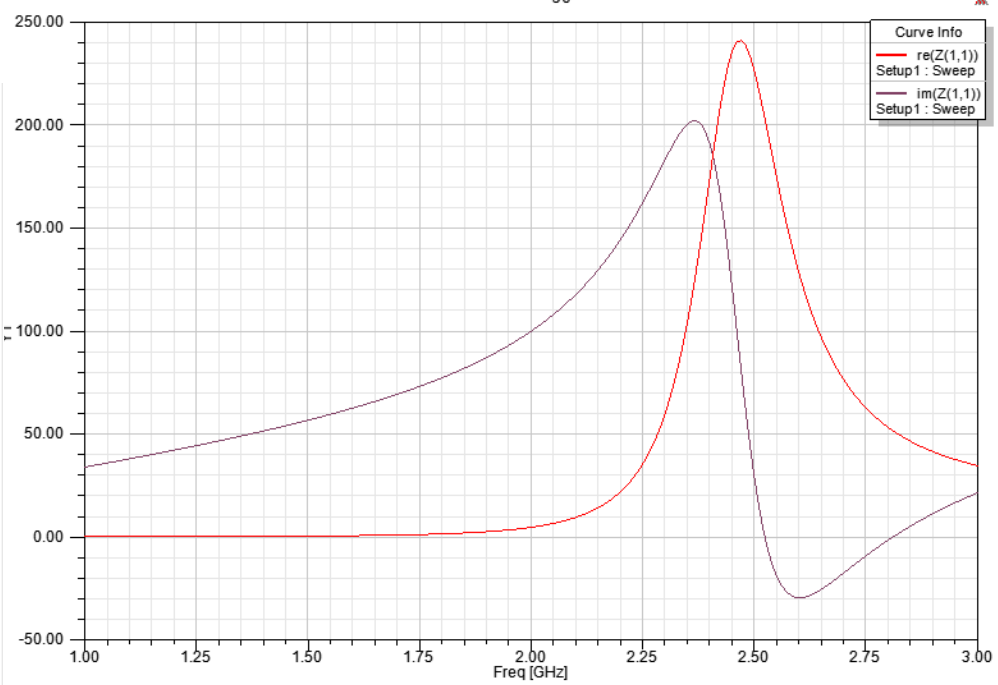


IFA: Inverted F Antenna









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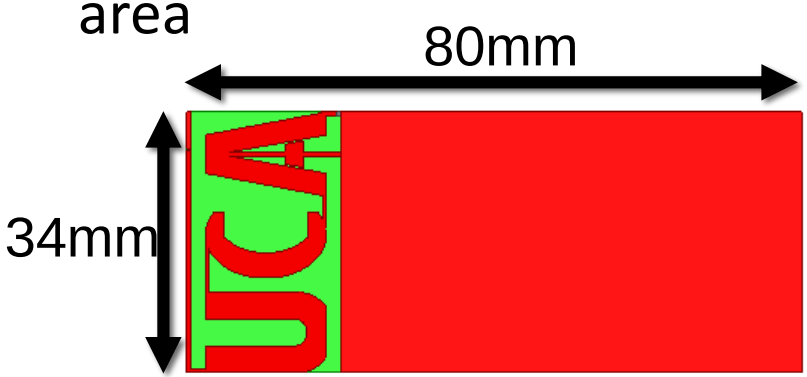
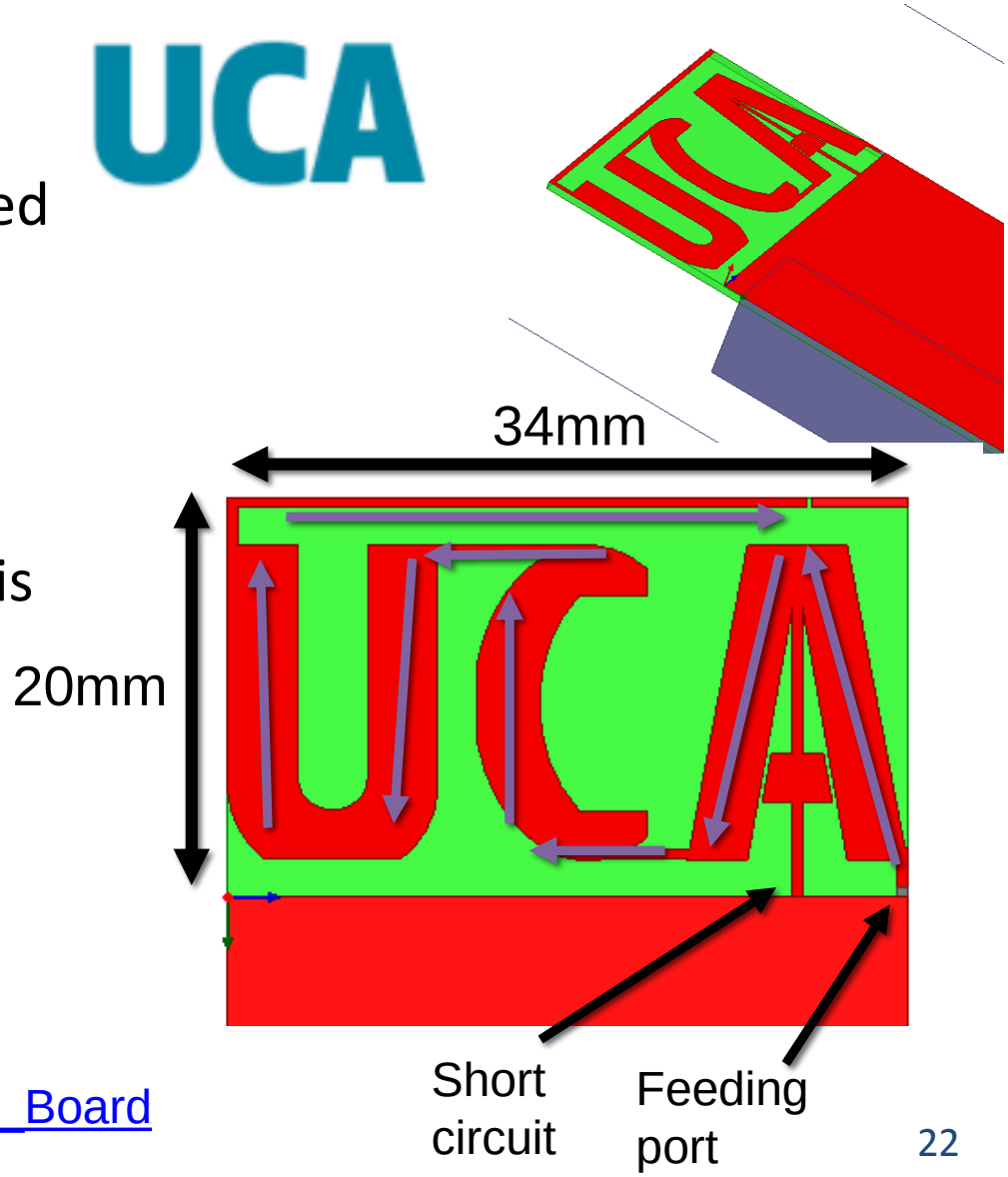
UCA Antenna layout

- 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

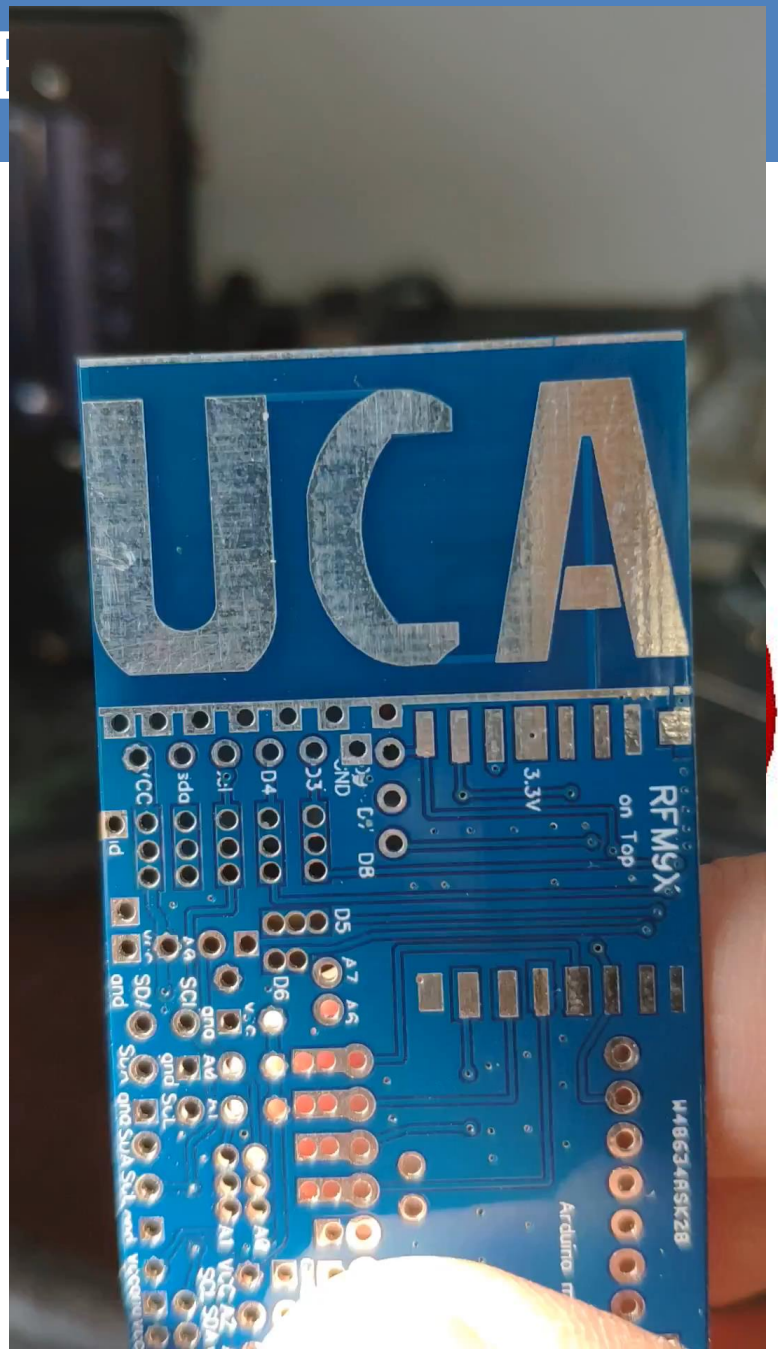




https://github.com/FabienFerrero/UCA_Board

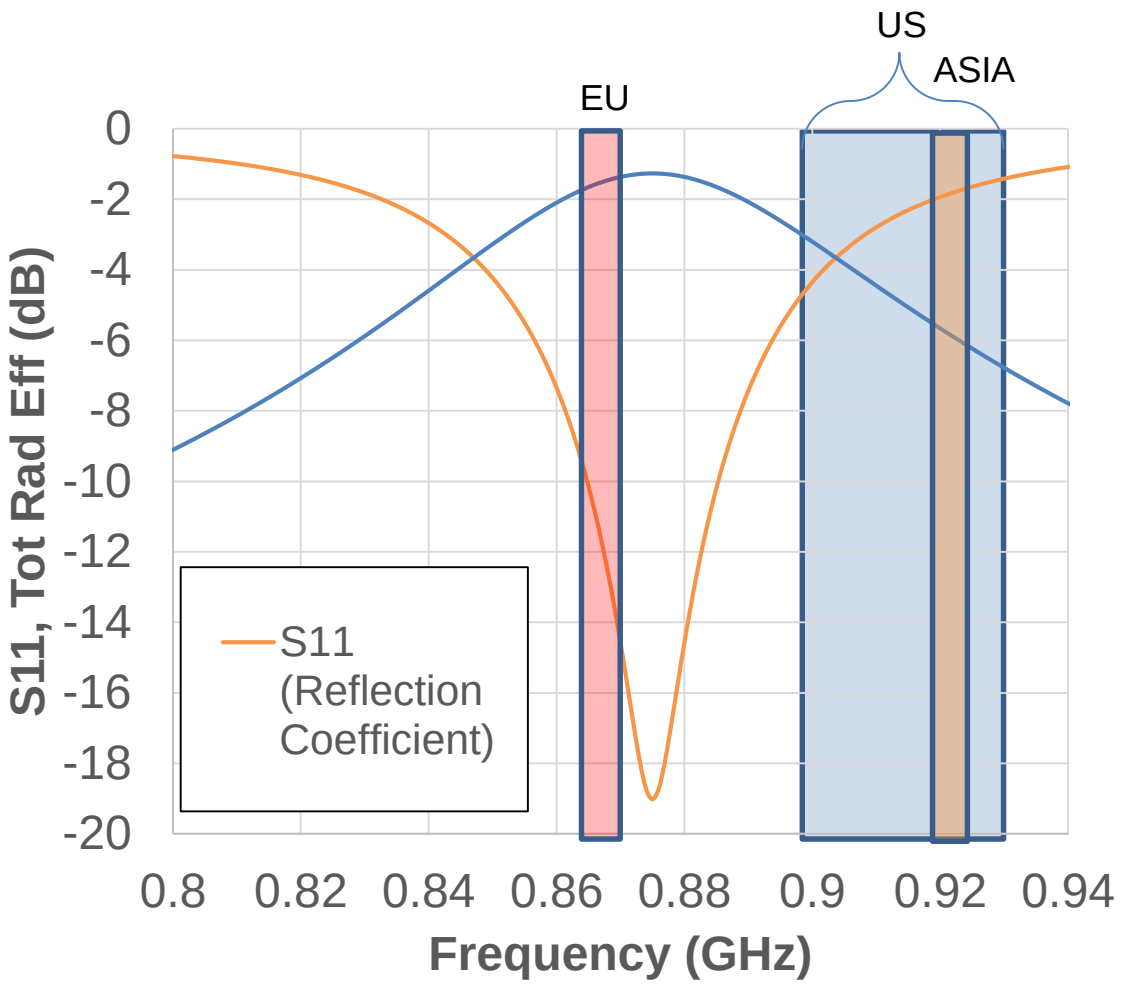
UCA Antenna tuned for E

- 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



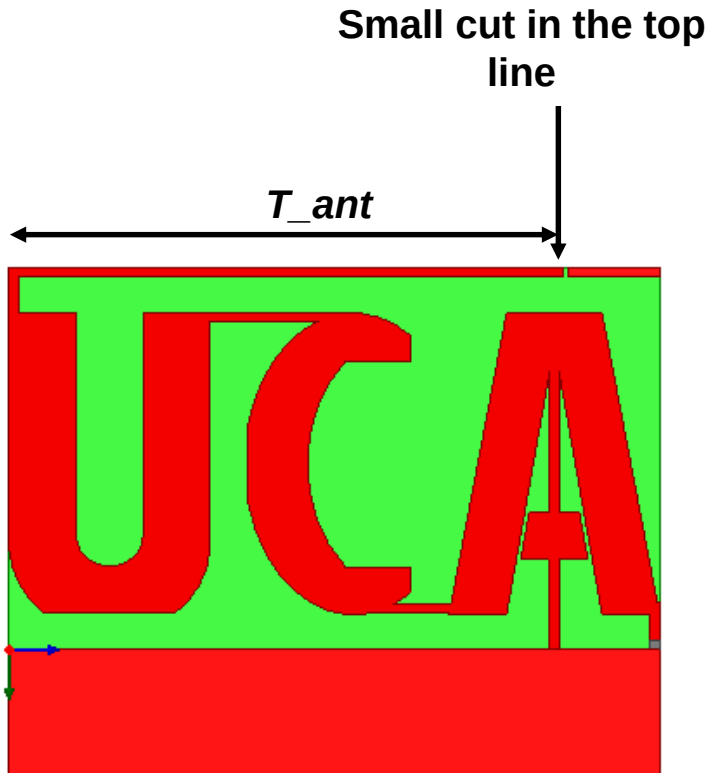
UCA Antenna tuned for EU band

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

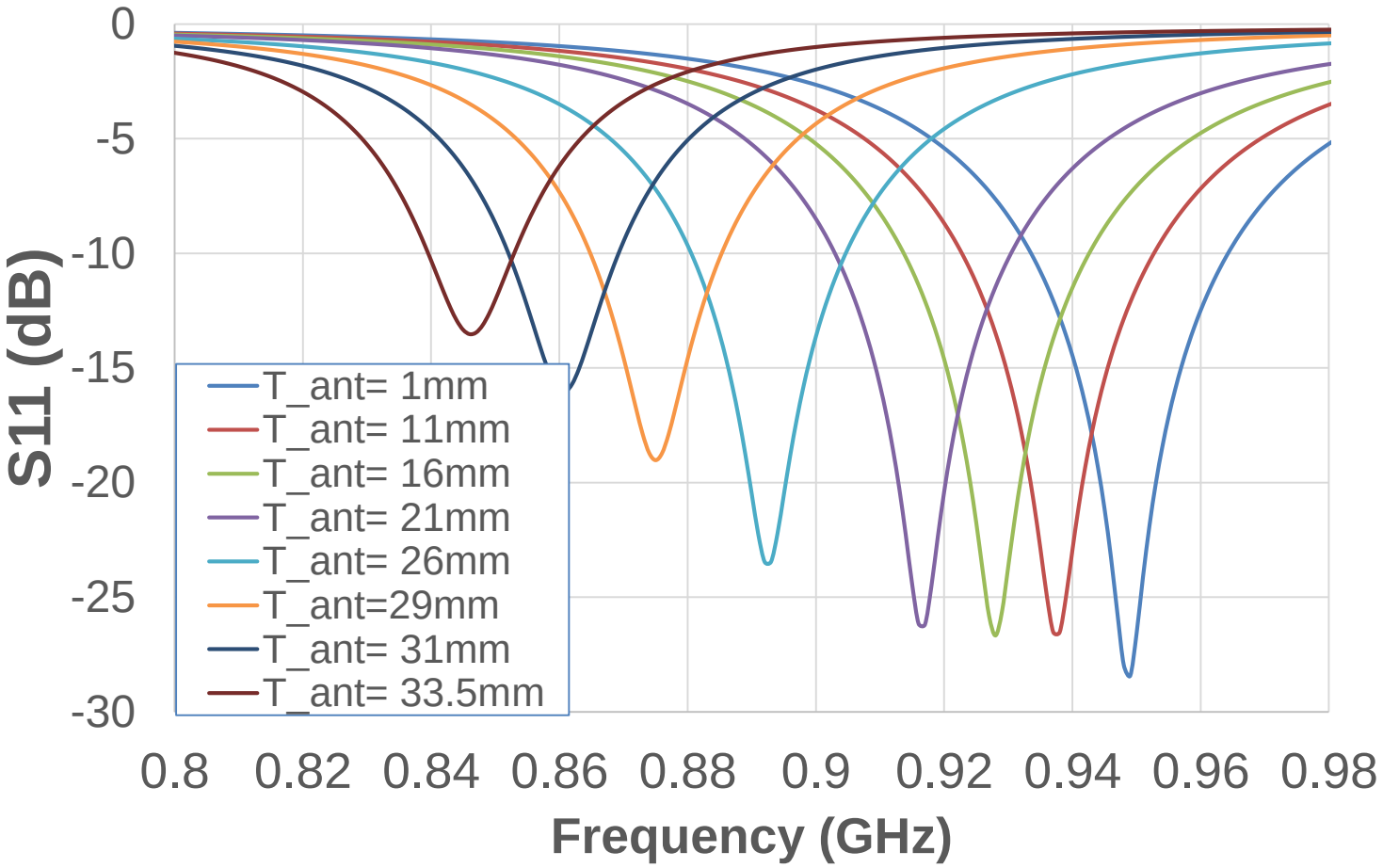


Antenna design

- 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

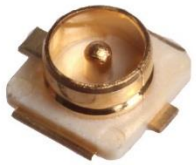


UCA Antenna tuning : Reflection coefficient

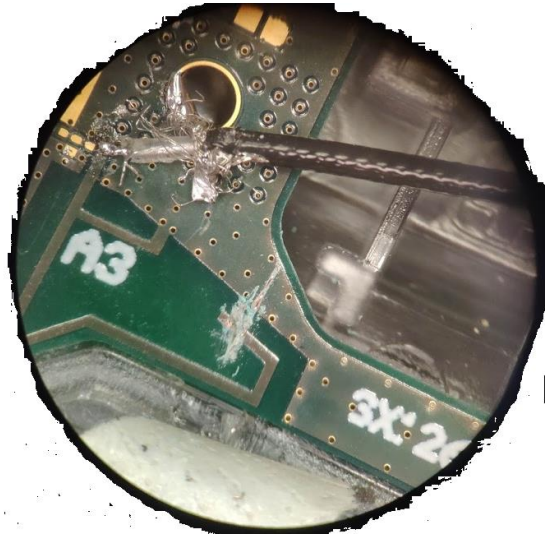


How to connect my antenna

- Best solution is to include a connector in your design, like UFL



- You can also directly solder the coaxial cable to the antenna patch



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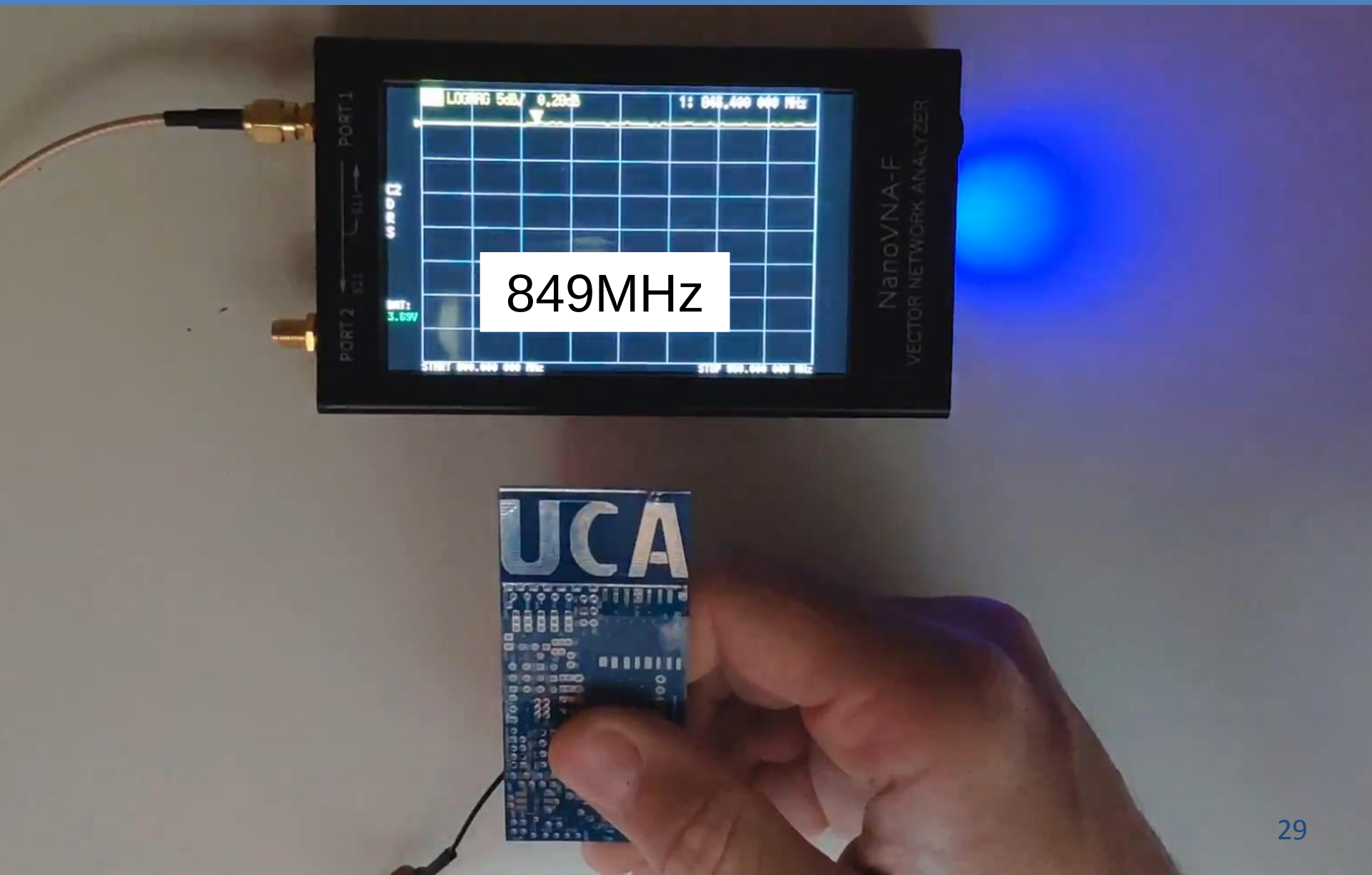
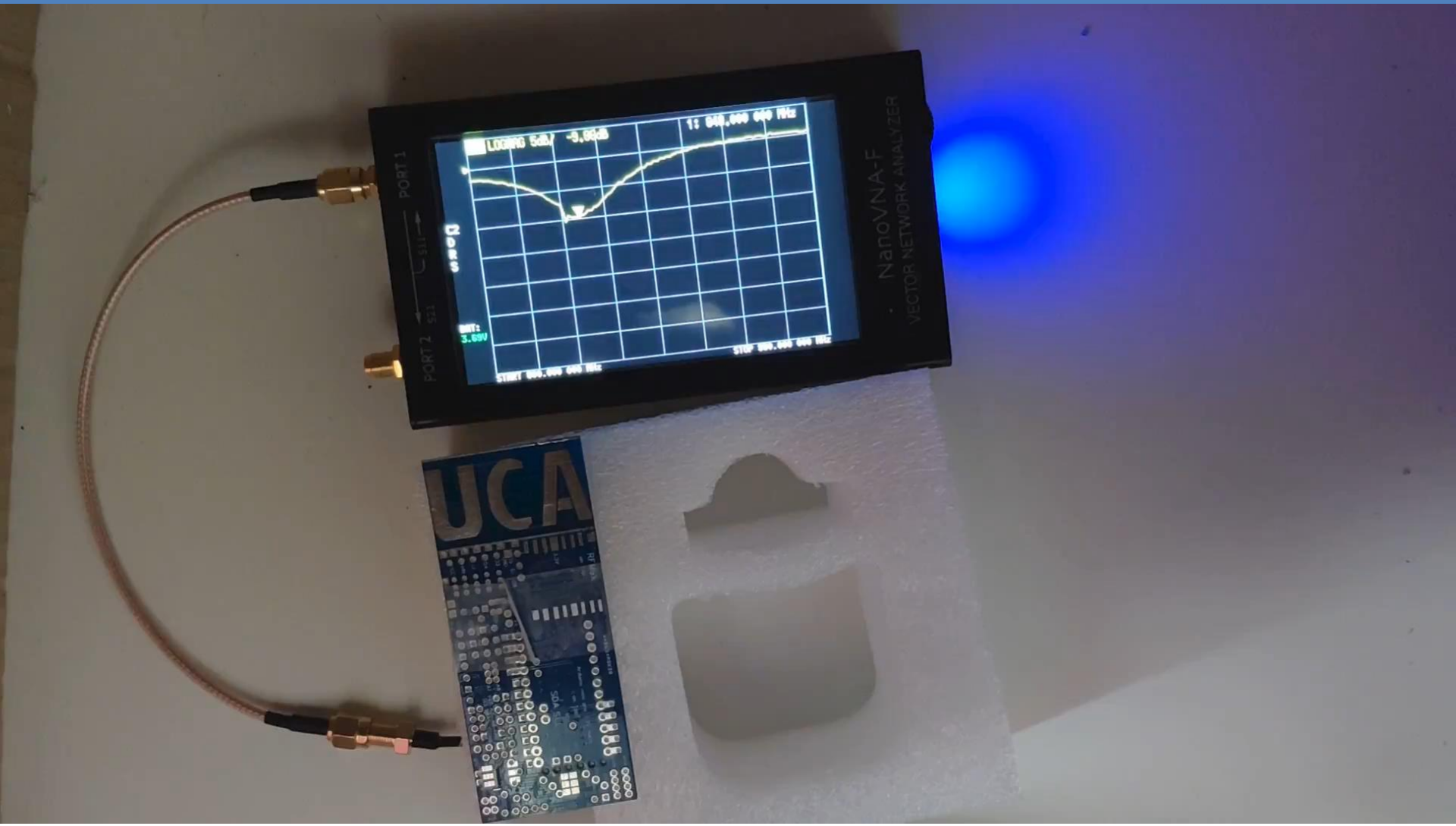
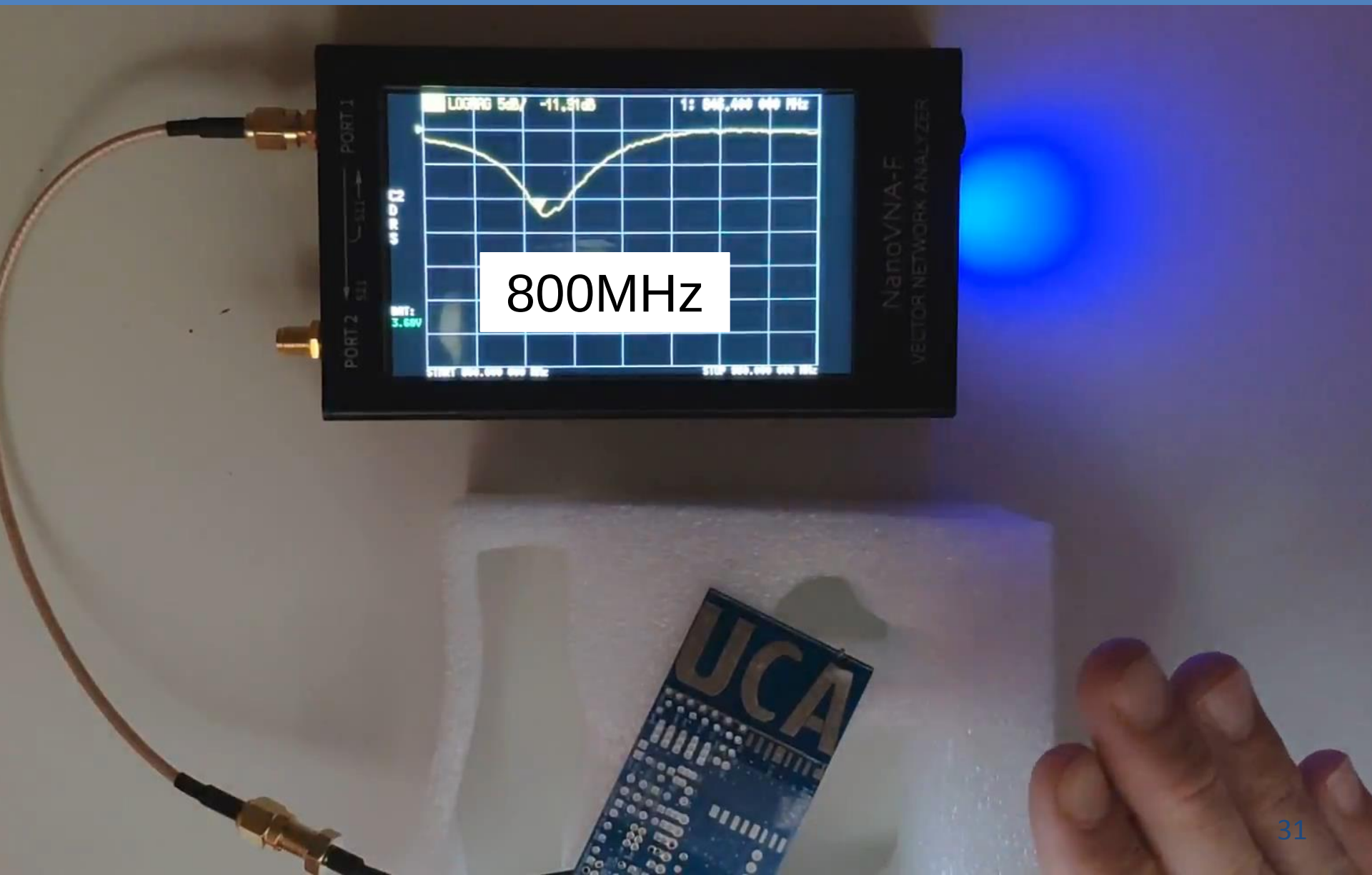
UCA Antenna tuning



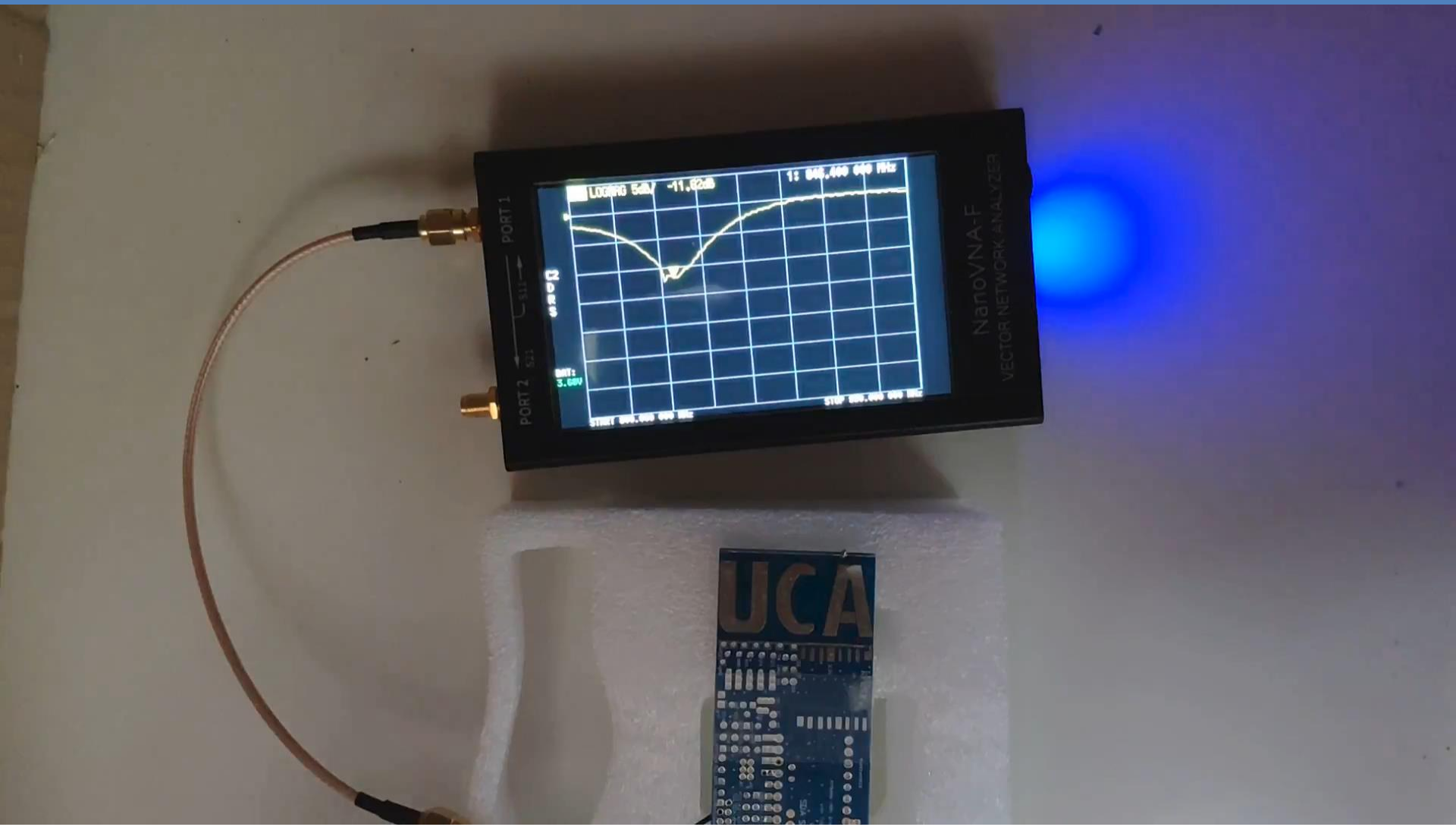
UCA Antenna : : effect of environment



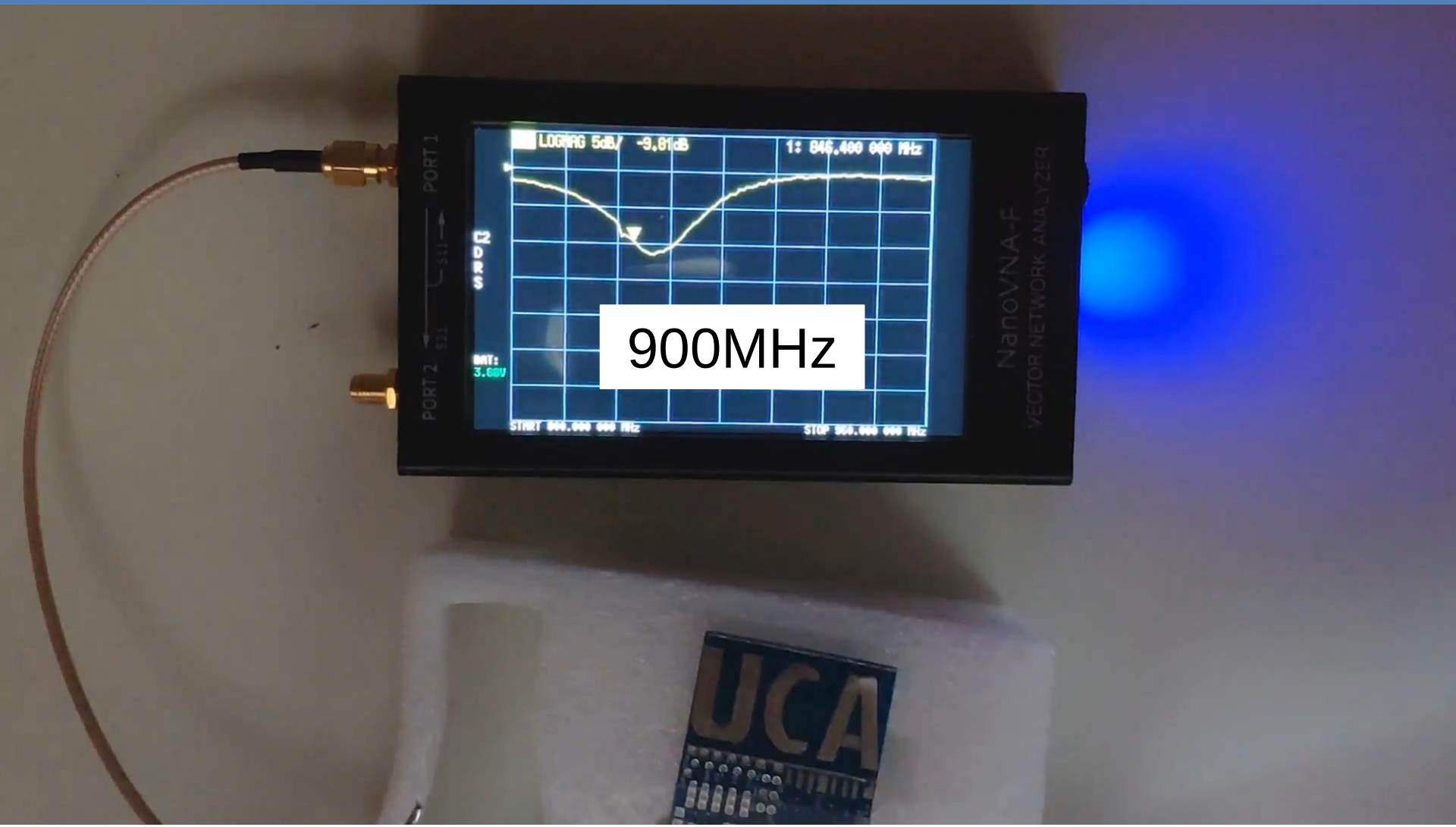
UCA Antenna : effect of environment



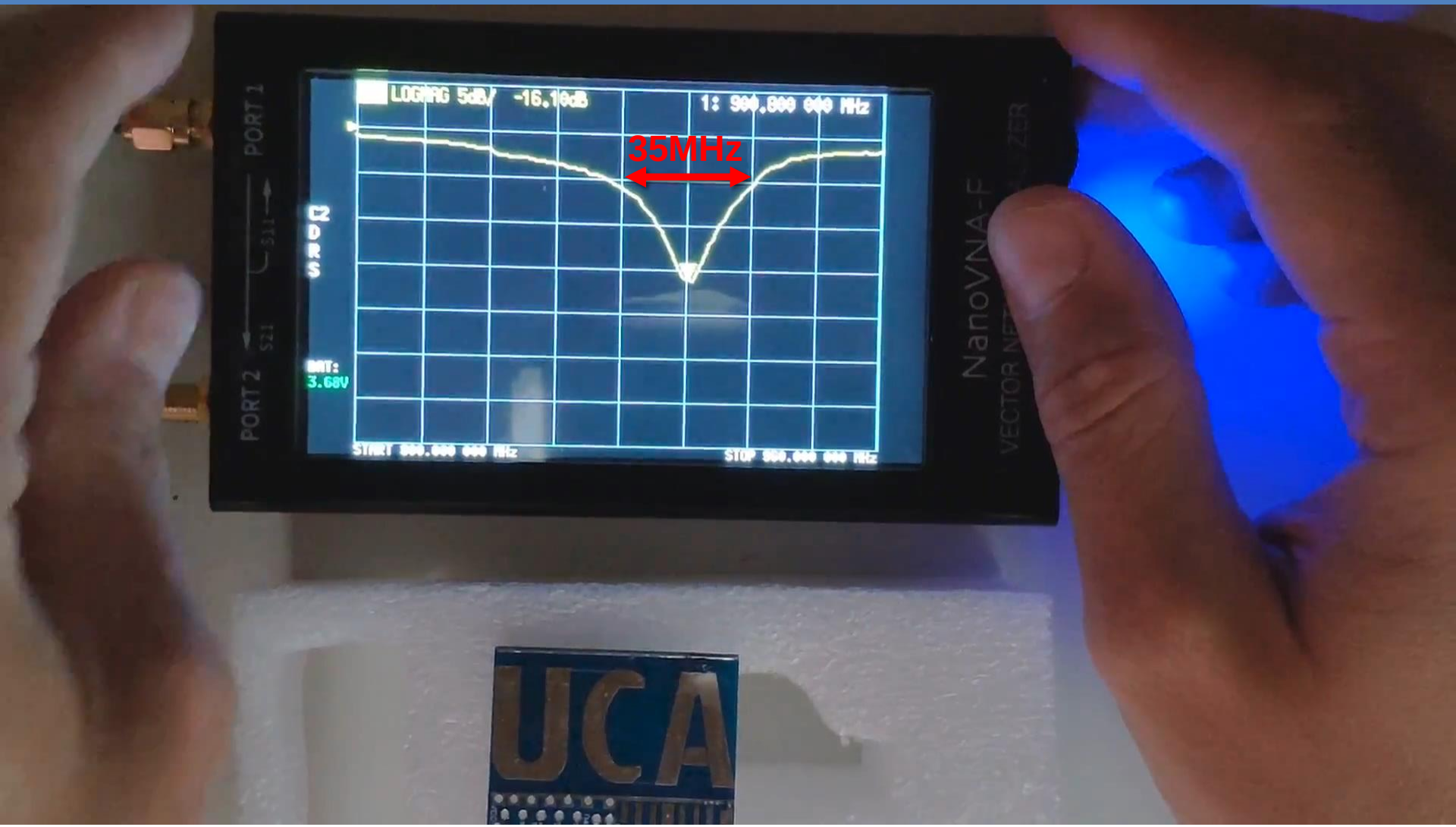
UCA Antenna tuning



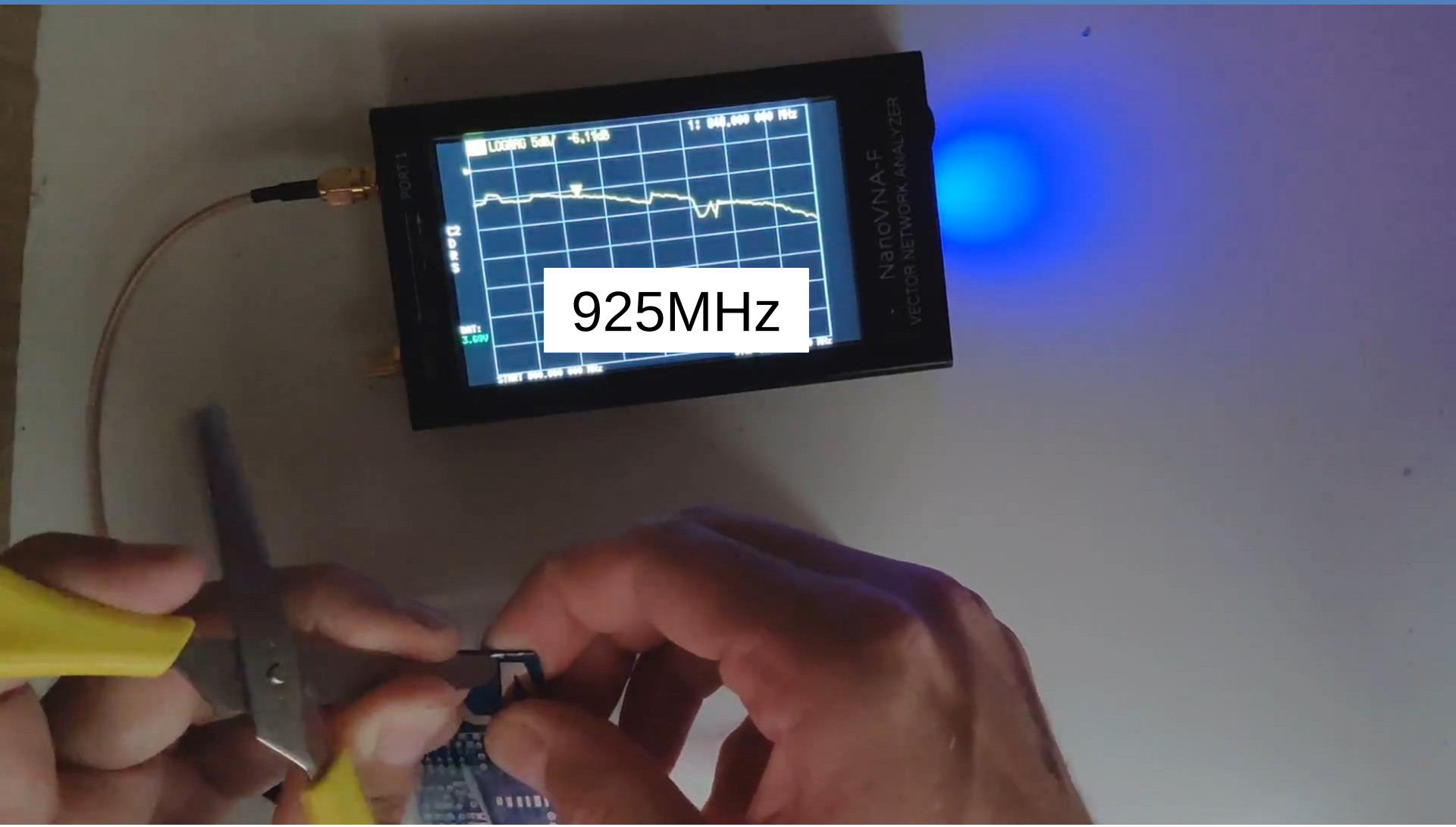
UCA Antenna tuning



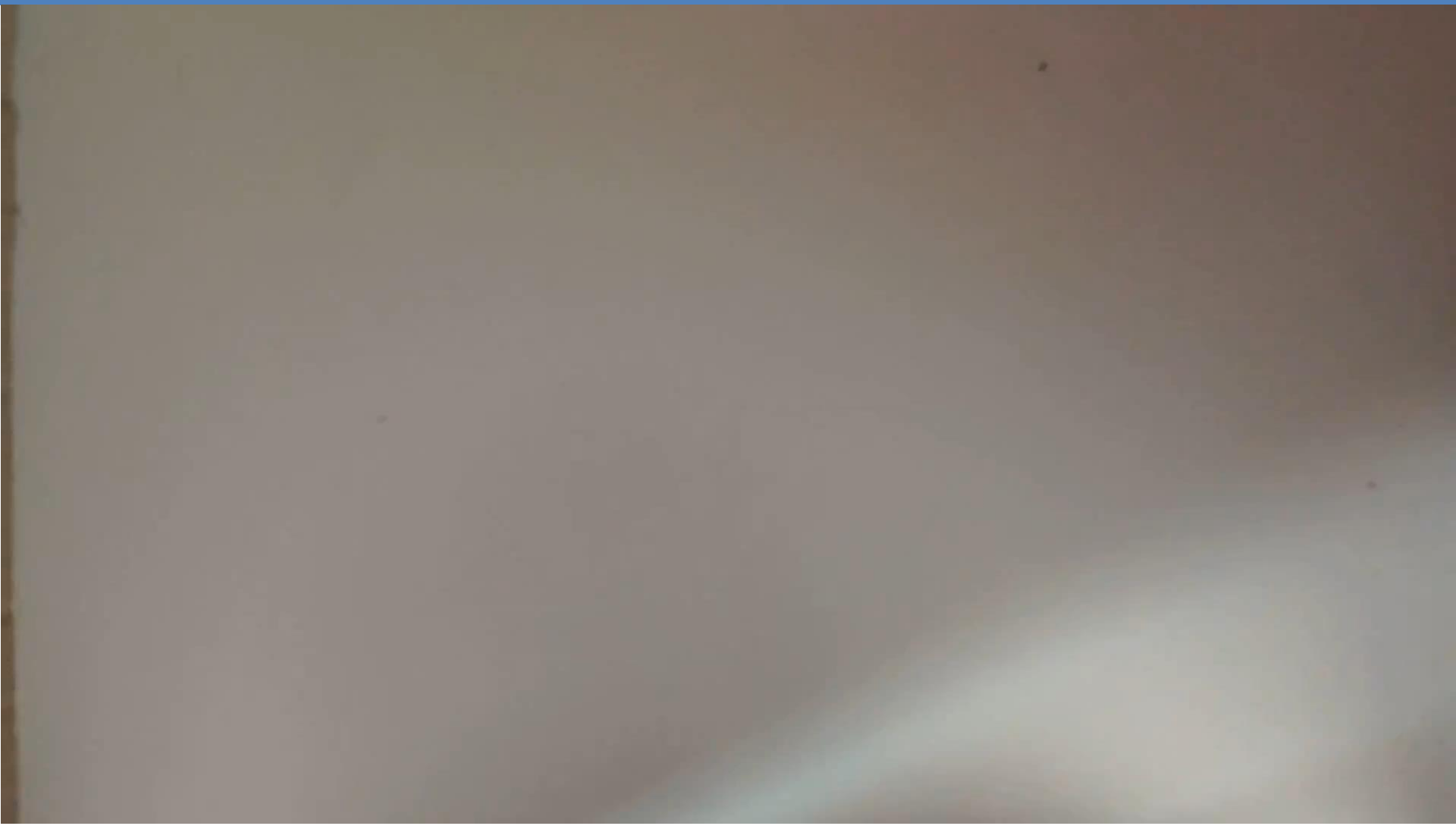
UCA Antenna tuning : Freq. Bandwidth



UCA Antenna tuning to US band



Antenna tuning with casing



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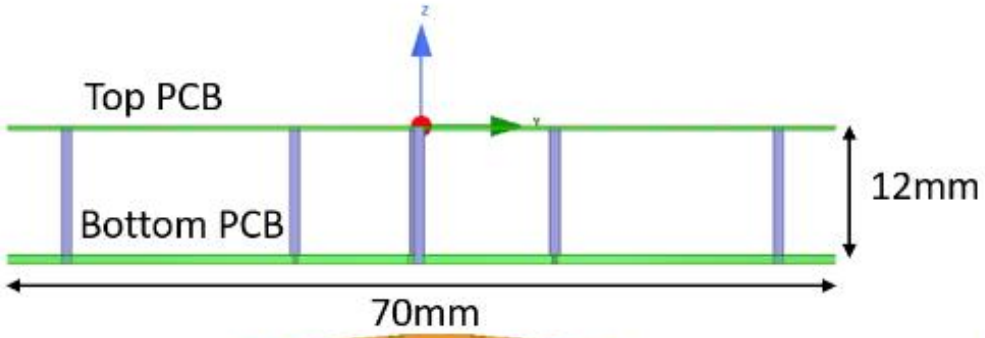
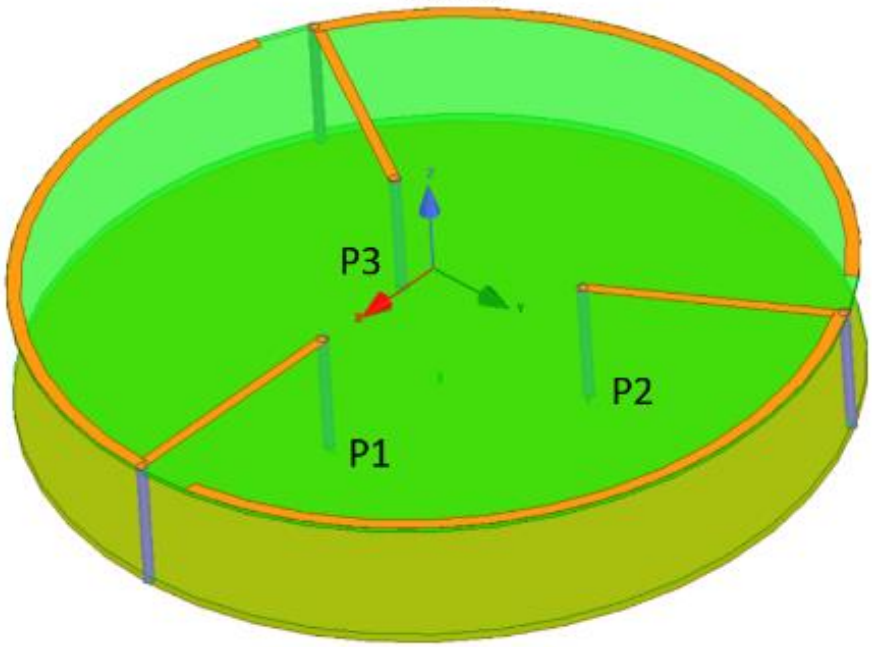
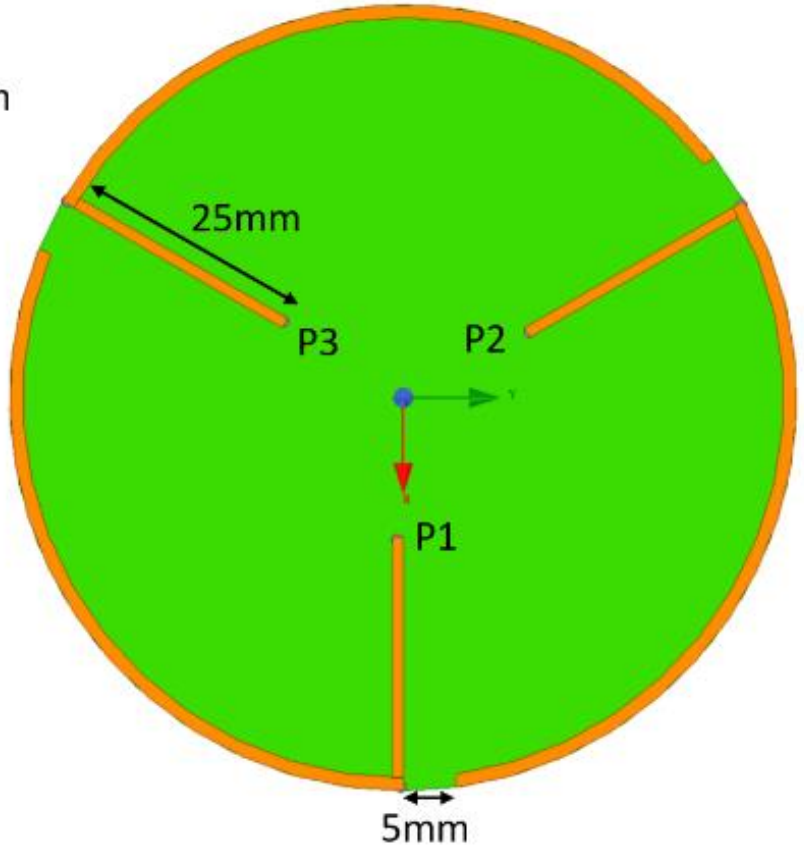
Tri-fillar antenna Radiating element

Made on Epoxy FR4 substrate : Top is 0.4mm, Bottom is 0.8mm

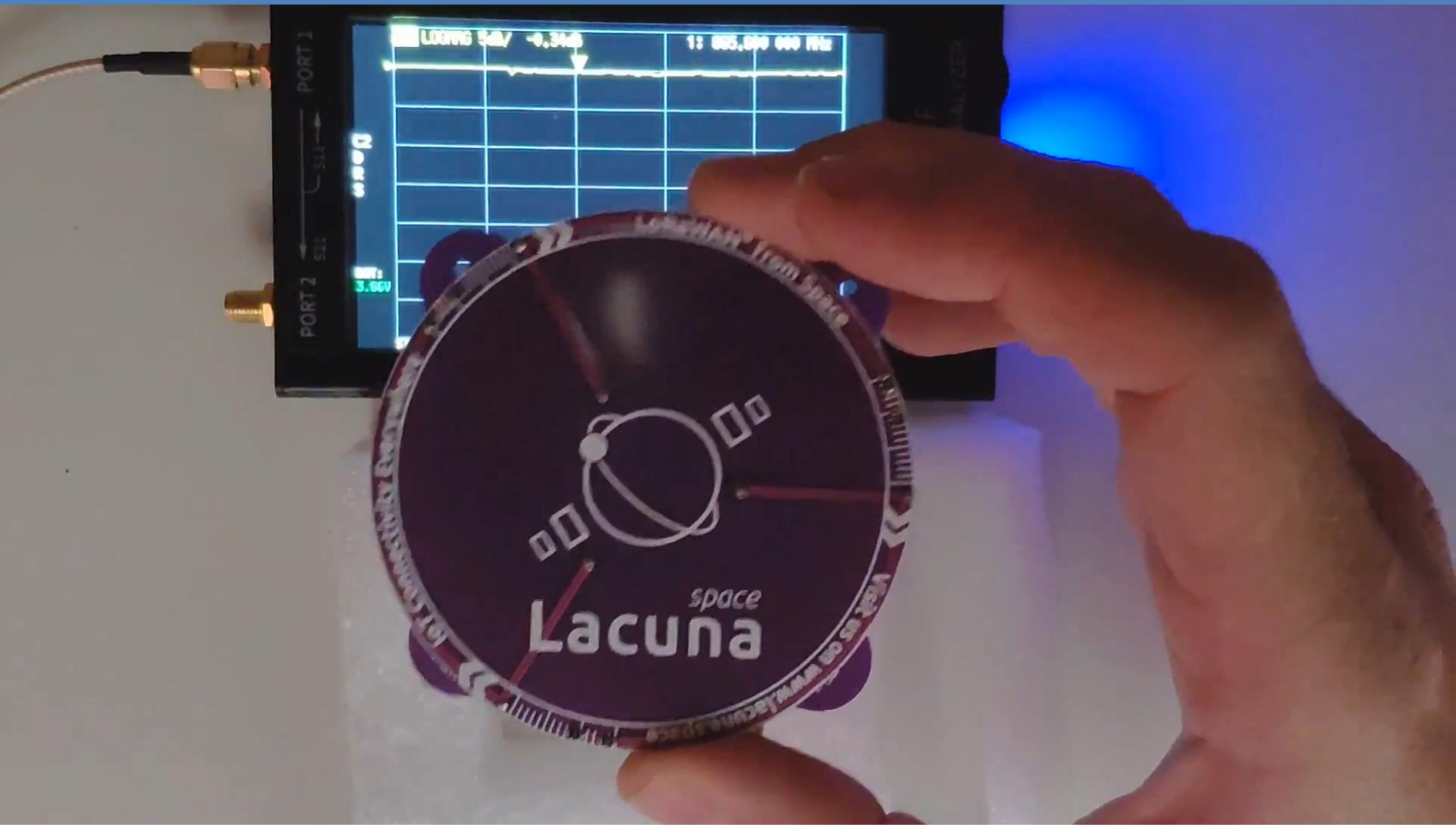




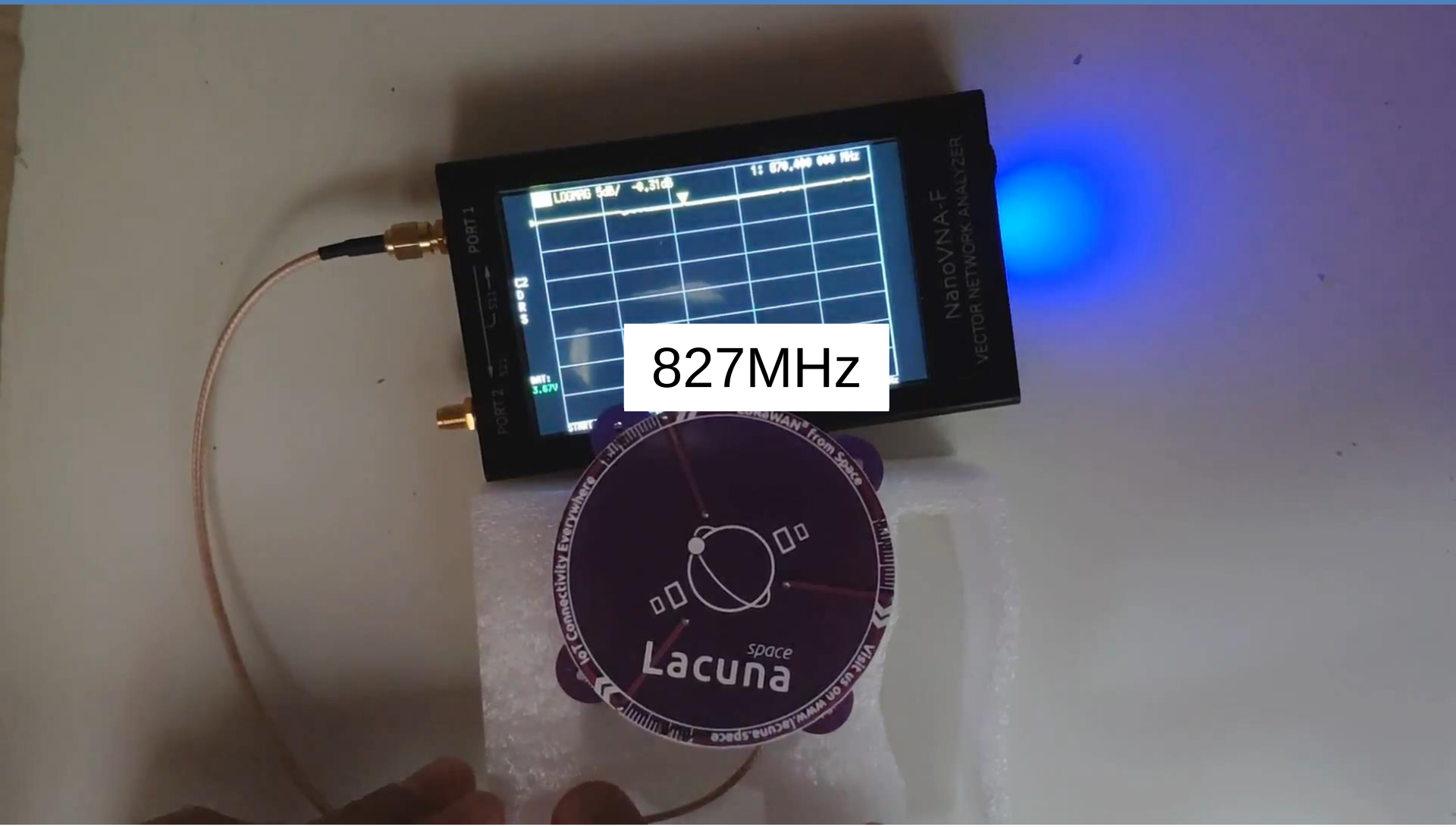


Tri-fillar antenna Radiating element

Tri-fillar antenna Radiating element



Tri-fillar antenna Radiating element



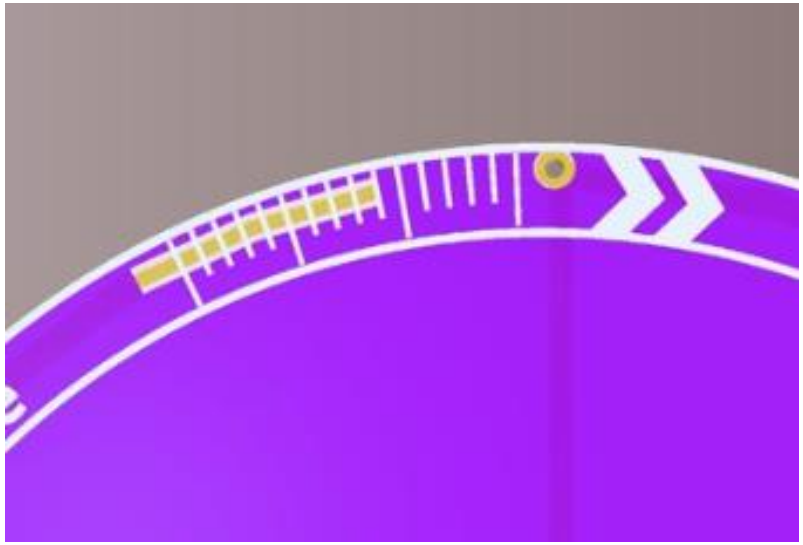
Tri-fillar antenna tuning

Tuning with 0ohm resistors

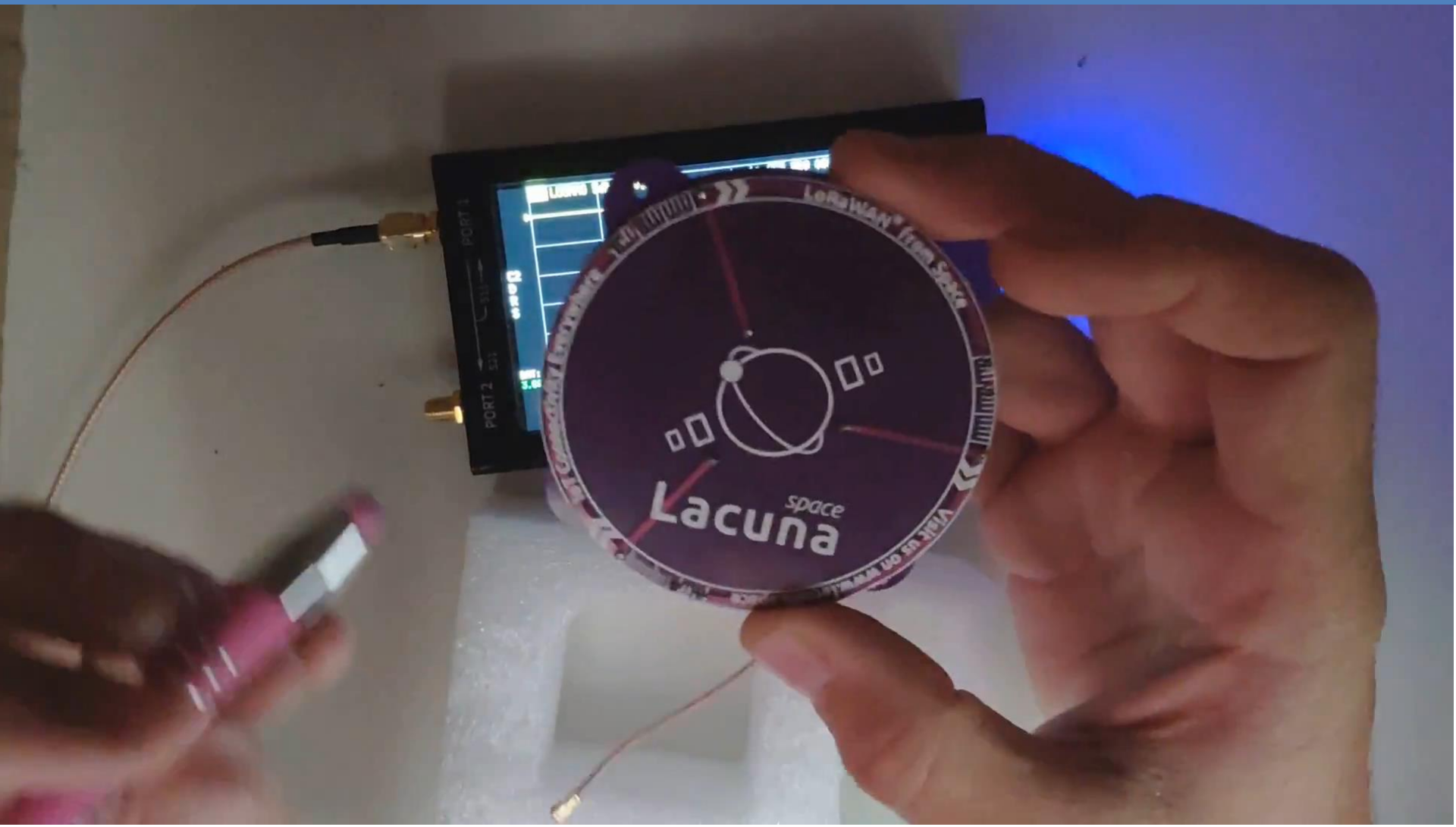
- Only discrete value
- Can use different packages
  0402, 0603, 0805
- Must be glued

Tuning with line length

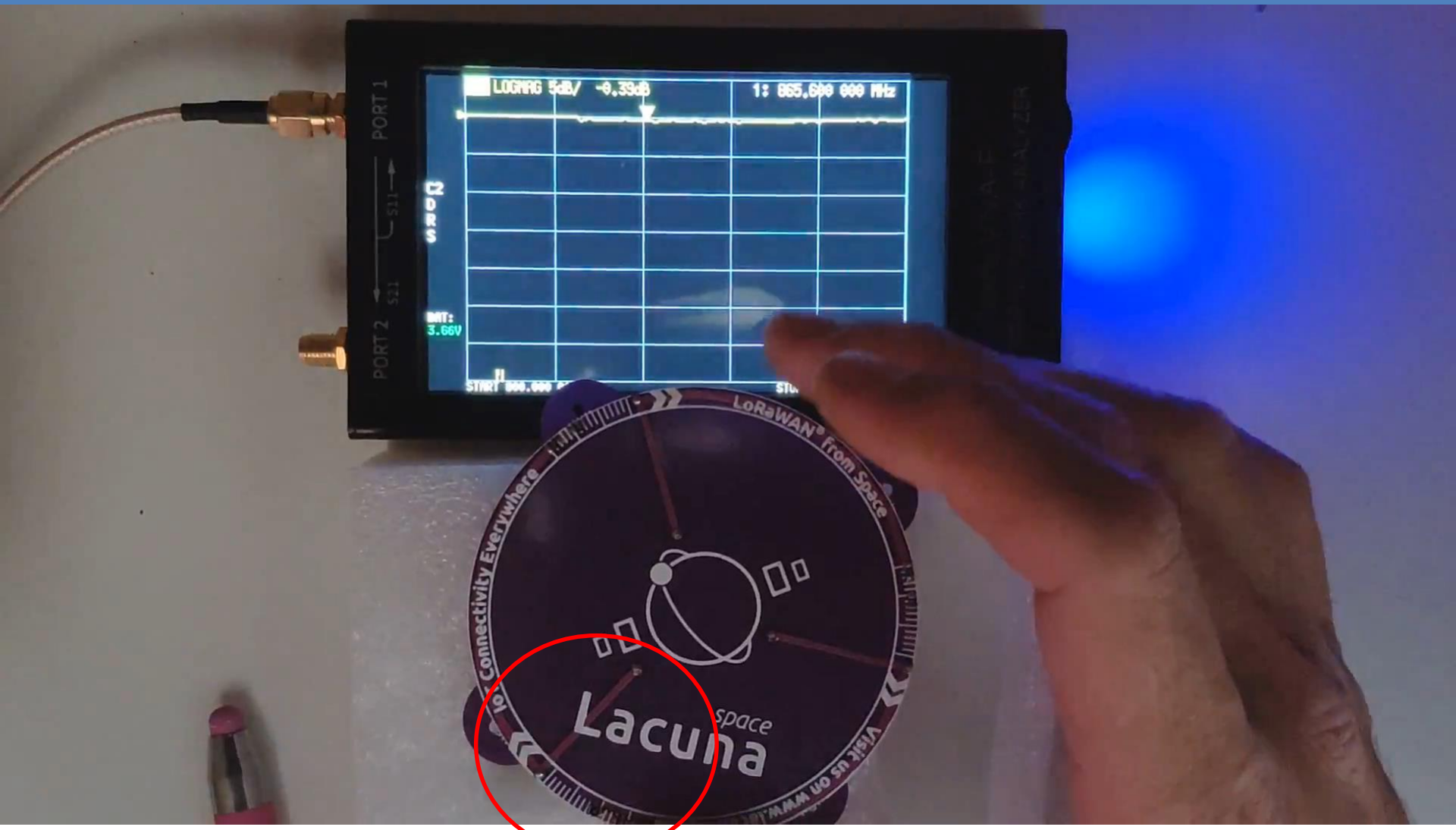
- Analog tuning !
- Available soon



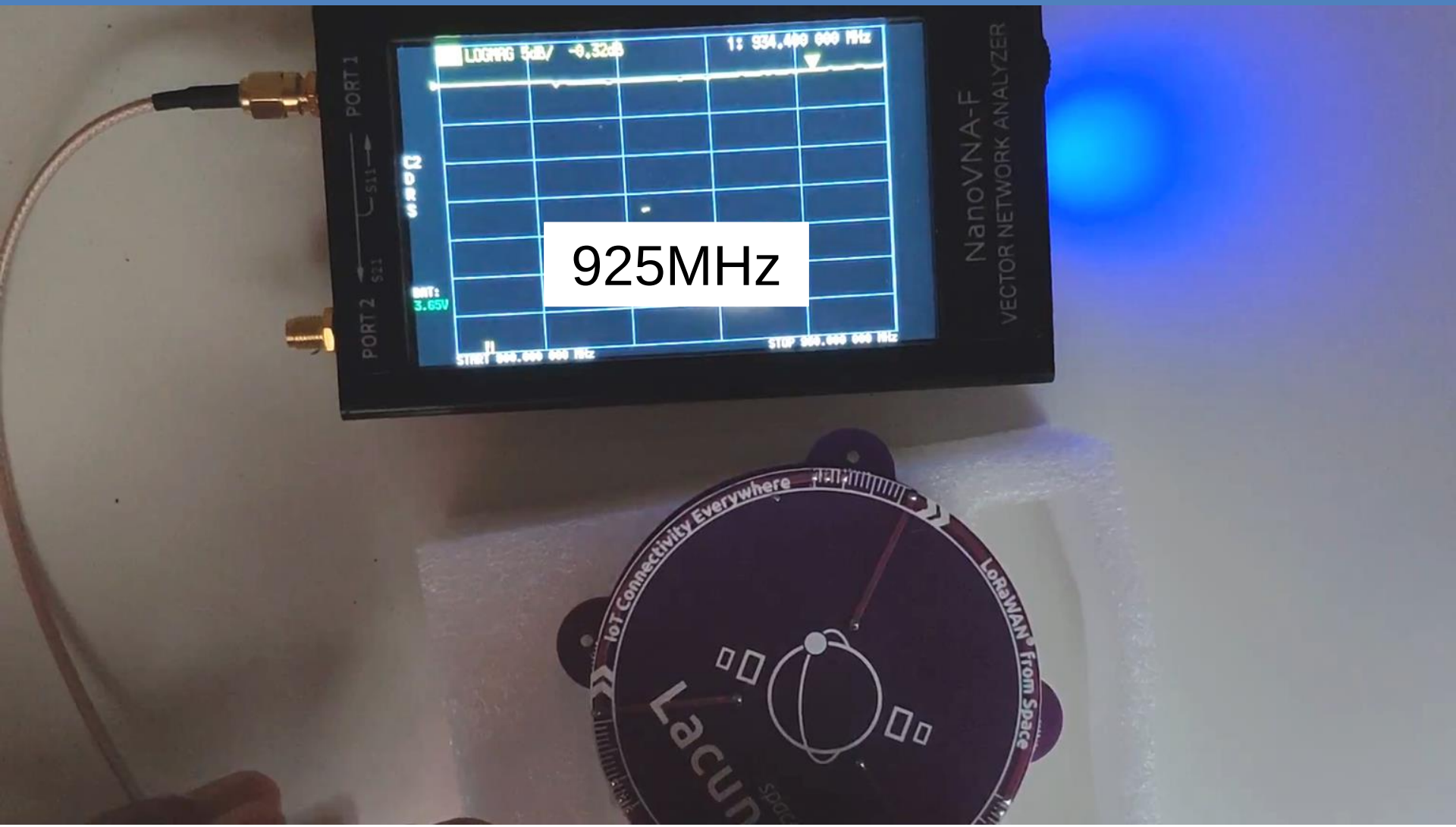
Tri-fillar antenna Radiating element



Tri-fillar antenna Radiating element



Tri-fillar antenna Radiating element



Outline

- Antenna Tuning
- Low Cost Vector Network Analyzer
- Inverted F Antenna
- UCA Antenna tuning
- Lacuna Space Antenna tuning
- Conclusion

Conclusion and Perspectives

- Testing and Tuning you antenna is always required (never trust datasheet)
- Nano-VNA is an affordable solution with sufficiant performance for antenna tuning
- VNA is a usefull tool to tune your antenna, but be carefull to cable effect
- VNA do not provide radiation efficiency, perform a radiation test to confirm your performance

https://github.com/FabienFerrero/Antenna_Radiation_Measurement

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Thanks a lot for TTN to organize this virtual conference

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