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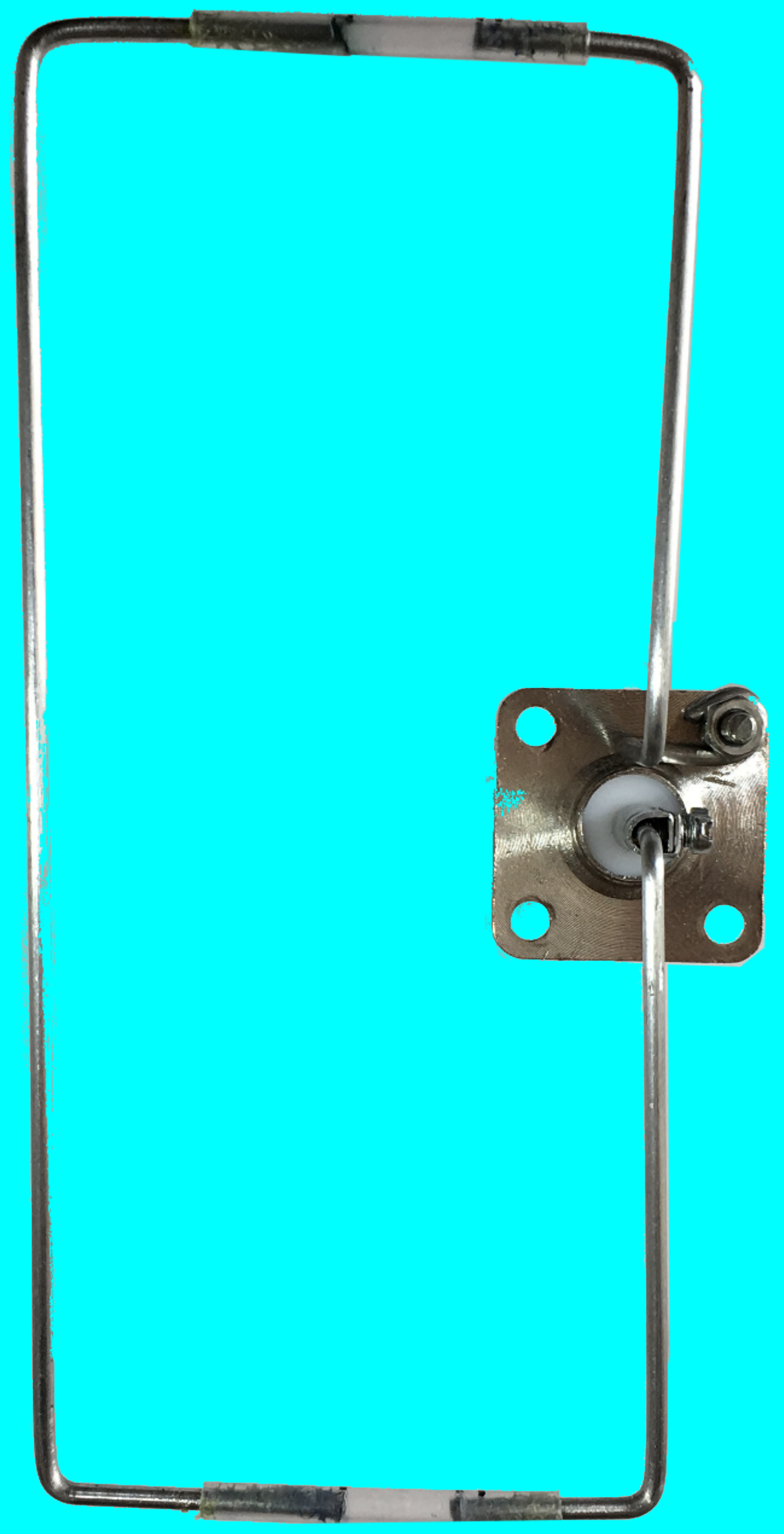
LORA / LORAWAN TUTORIAL 49

Moxon Antenna



v1.0.0

INTRO

- In this tutorial I will explain what a Moxon antenna is and how to build one.

ATTENTION

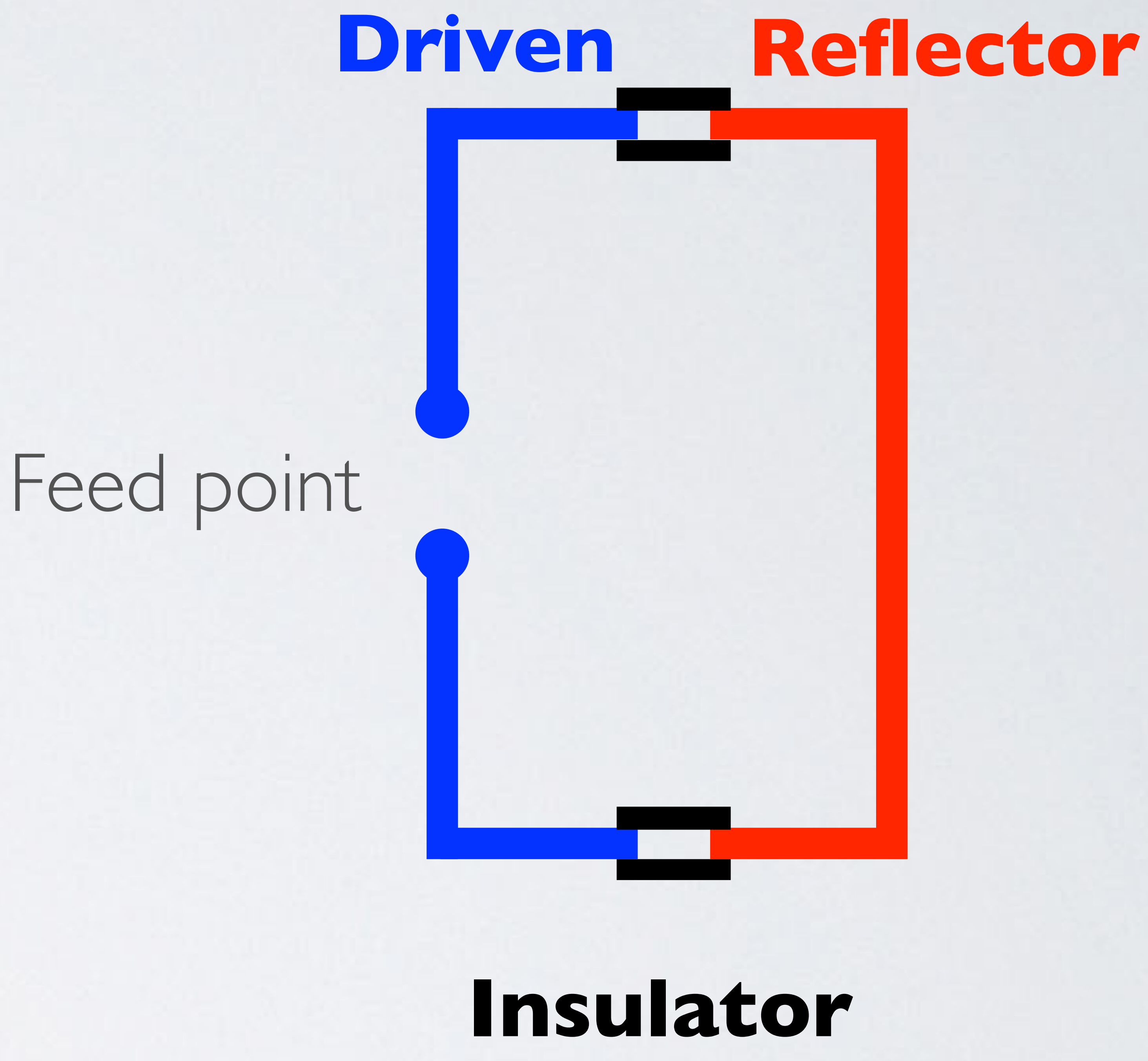
- **The antennas built in this tutorial are intended for test and educational purpose and should be used indoors.**

- **The antennas are constructed in such a way so it can be easily disassembled and its parts can be re-used in other antenna projects.**

- **The antennas are not properly constructed and the antenna performance can be improved by using better materials, parts or another way of construction.**

MOXON ANTENNA

- The Moxon antenna is a simple and mechanically robust two-element parasitic array antenna created by amateur radio operator Les Moxon.
- This directional antenna is equivalent to a two element Yagi-Uda antenna. It has a reflector and a driven element but no directors.
- The two elements are mechanically connected by two insulators.
- The antenna has a large beam width and a very good Front-To-Back ratio (tutorial 39).



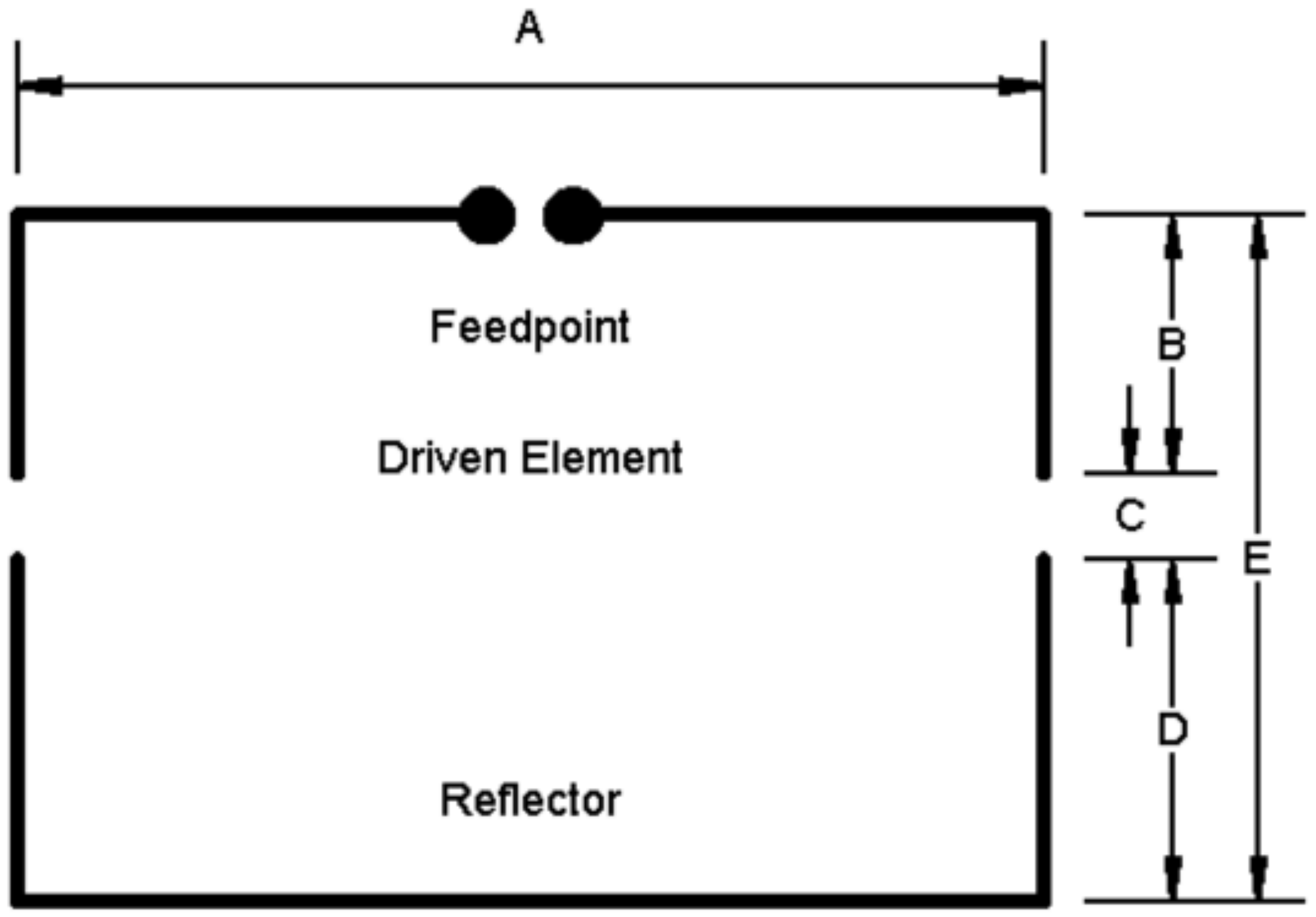
MOXON CALCULATOR

- To find the Moxon antenna dimensions you can use the following calculators:
  - Online calculator:
    http://tippete.net/cgi-bin/moxgen.pl
  - Windows program:
    https://ac6la.com/moxgen1.html
- I have tried both calculators and in MY situation, they both generate the same results.

MOXON CALCULATOR

Moxon Calculator

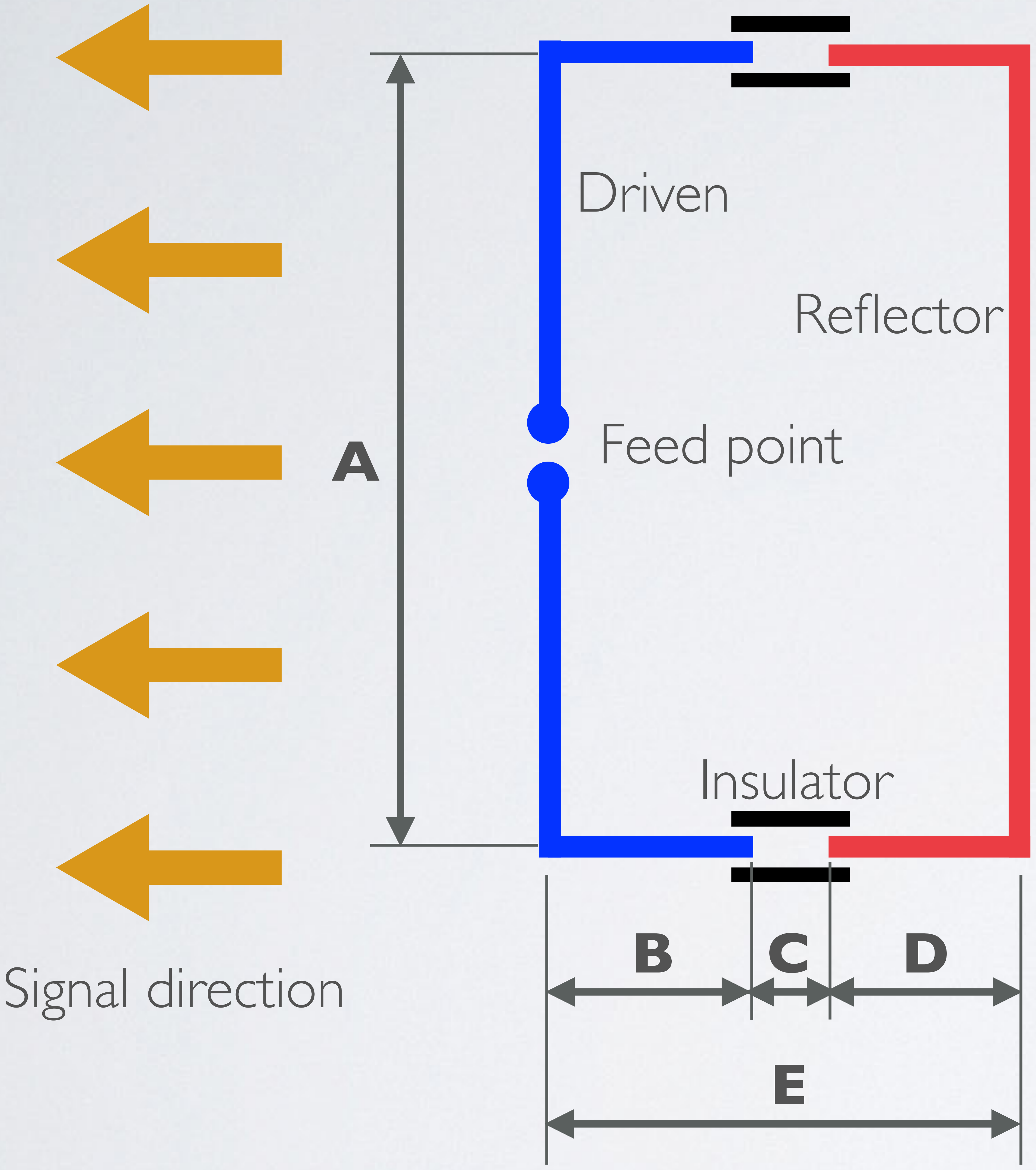
Dimension	Wavelengths	Feet	Inches	Meters	Millimeters
Frequency 868 MHz	1.0	1.133133	13.597592	0.345383	345.383065
Diameter 1.8 mm	0.005212	0.005905	0.070865	0.0018	1.8
A	0.340642	0.385993	4.631911	0.117652	117.651989
B	0.050184	0.056865	0.68238	0.017333	17.332662
C	0.009953	0.011278	0.135335	0.003438	3.437559
D	0.071703	0.081249	0.97499	0.024765	24.765036
E	0.13184	0.149392	1.792705	0.045535	45.535257



Generated by:

Windows program:
https://ac6la.com/moxgen1.html

MOXON ANTENNA



Frequency = 868 MHz
Wire diameter (d) = 1.8 mm

Parameter	Length (mm)
A	117.65
B	17.33
C	3.43
D	24.76
E	45.53

Note:
Keep the feed point gap as small as possible.

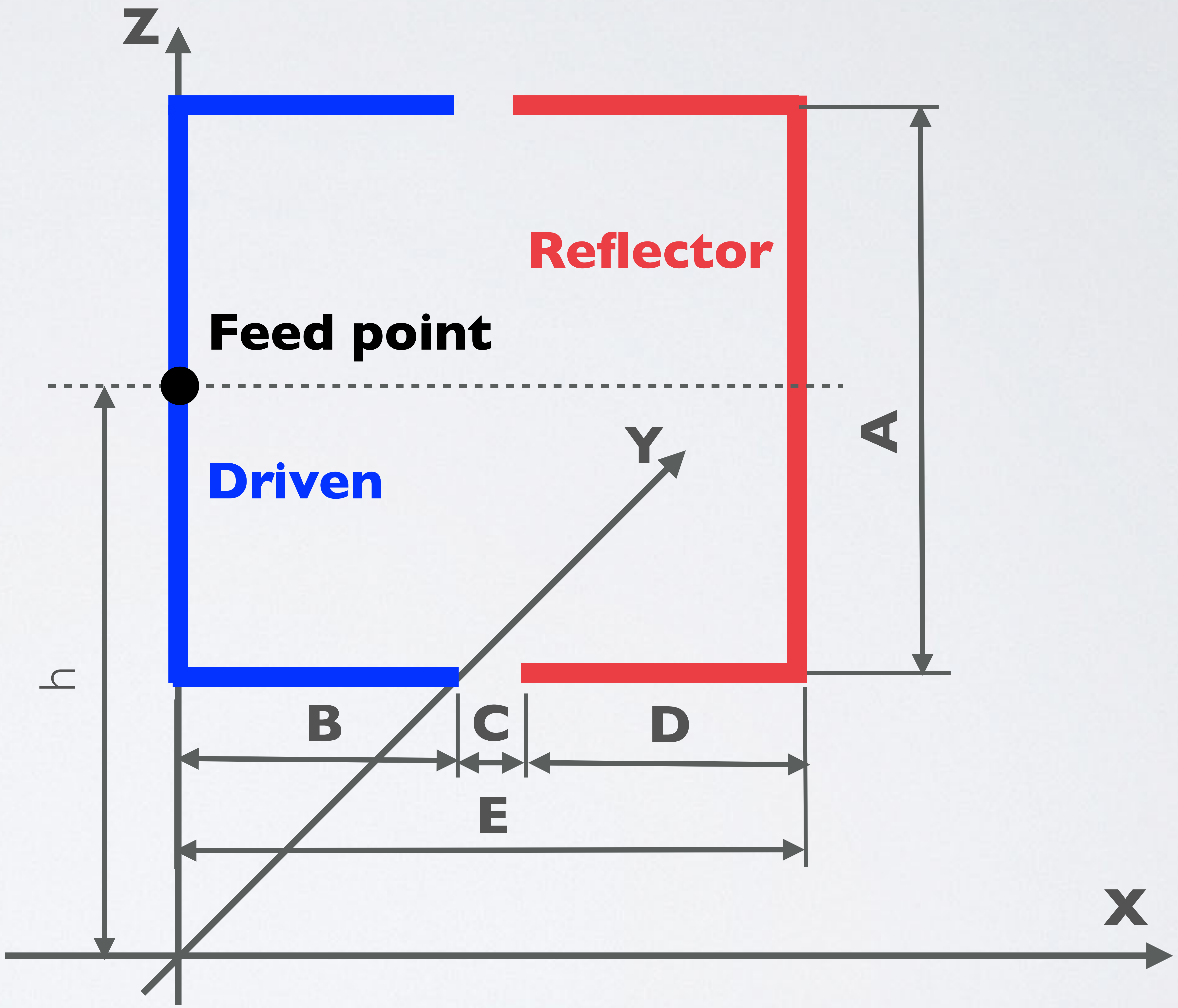
MOXON ANTENNA

- I have used the 4NEC2 antenna modelling software to verify the design.
- 4NEC2 card deck:
  https://www.mobilefish.com/download/lora/moxon_868mhz_4nec2.nec.txt

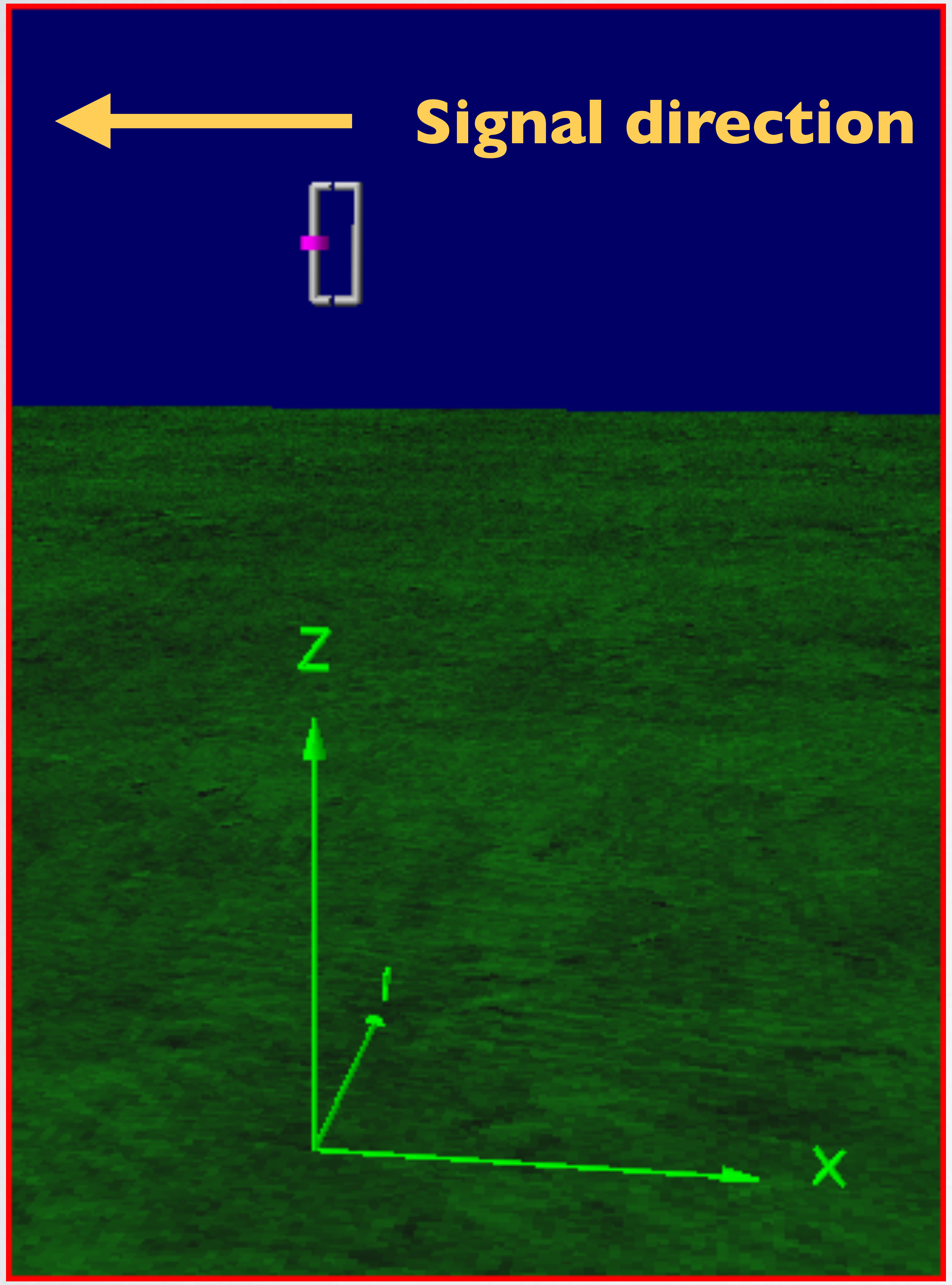
ANTENNA MODELLING NEC-2

- Moxon antenna
  f = 868 MHz
  wire diameter = 1.8 mm
  wire material: stainless steel
  height = 1 m
  Drawing not to scale

Parameter	Length (mm)
A	117.65
B	17.33
C	3.43
D	24.76
E	45.53

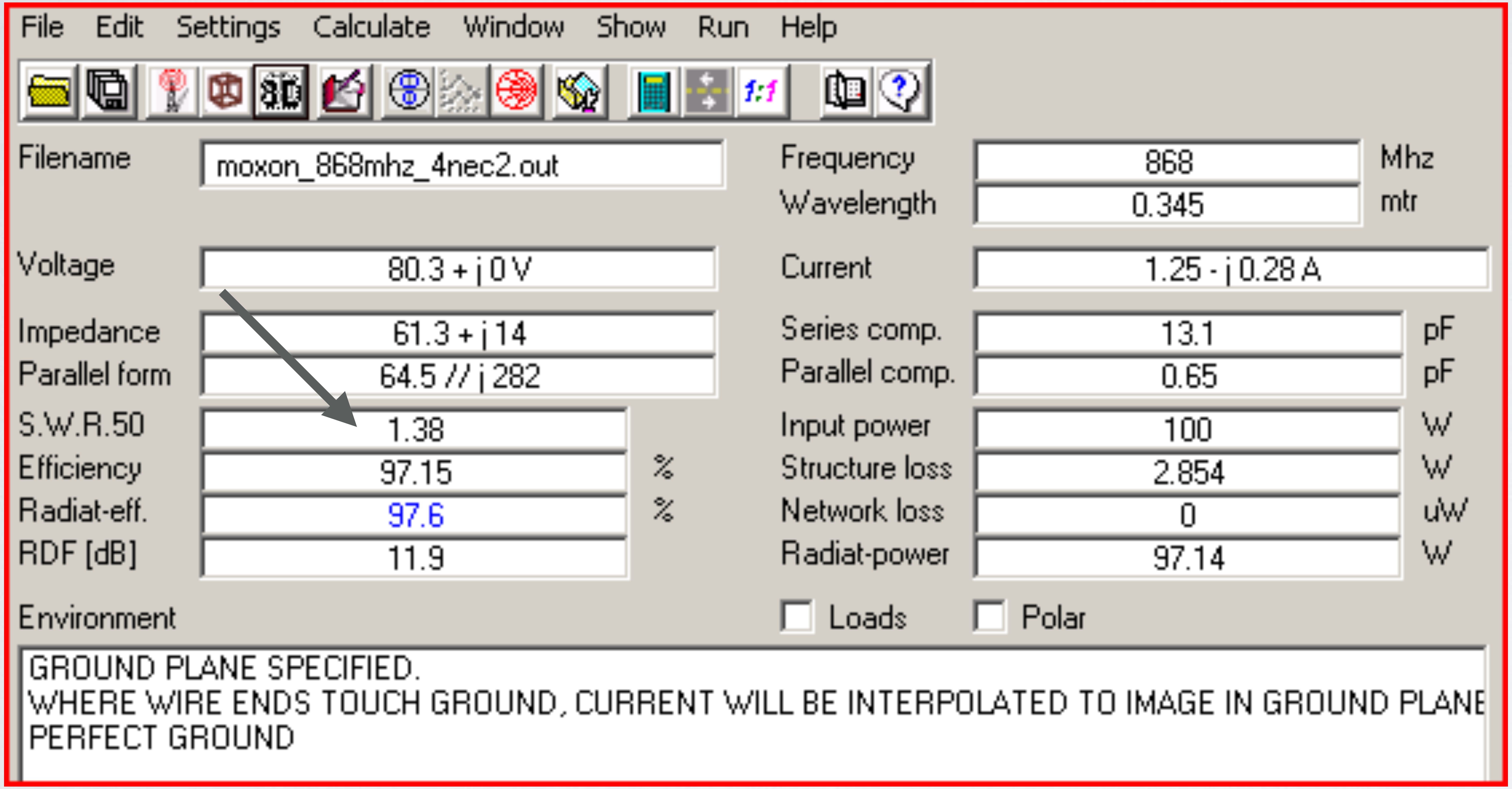


ANTENNA MODELLING NEC-2



Created in 4NEC2

ANTENNA MODELLING NEC-2

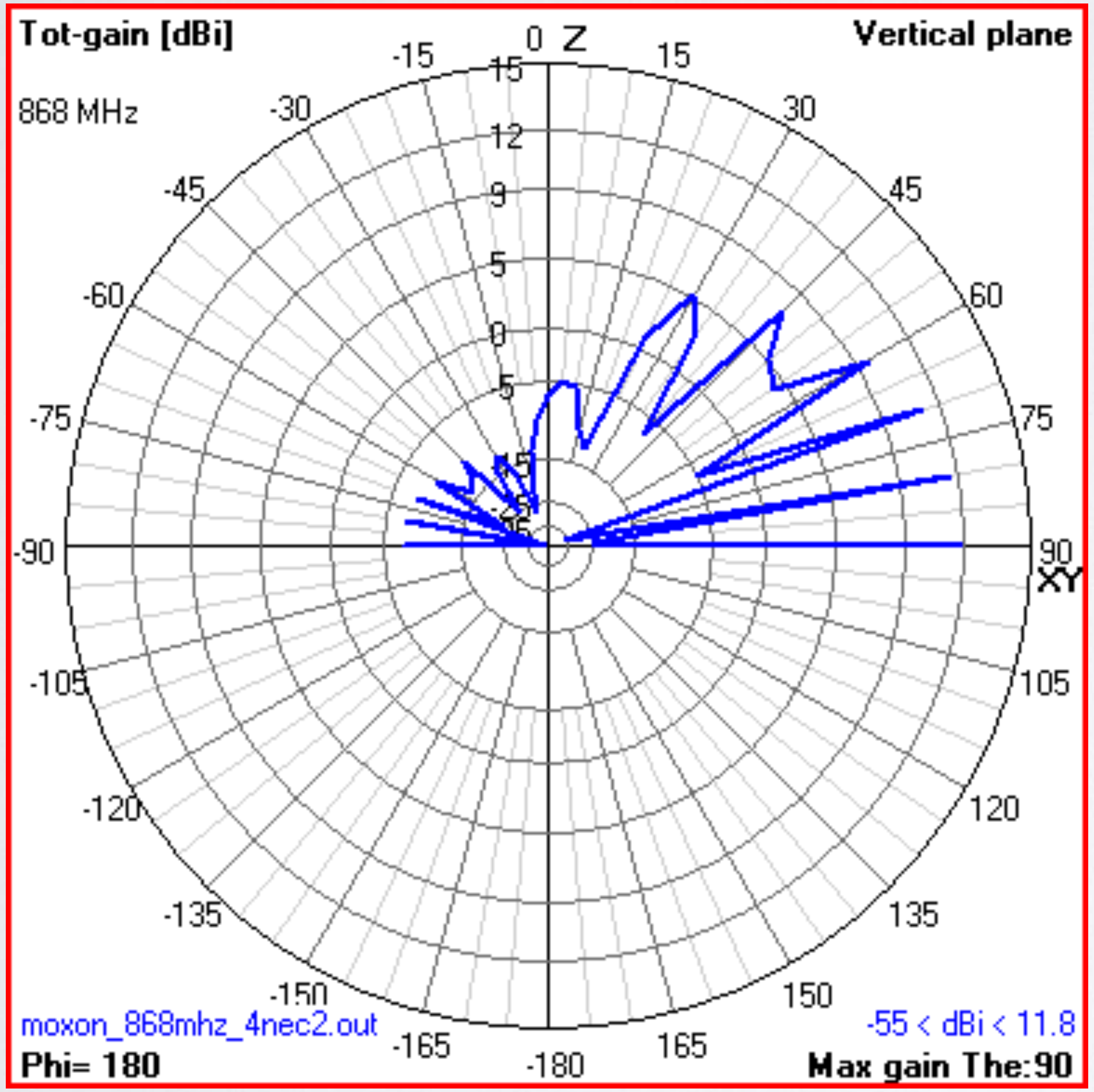


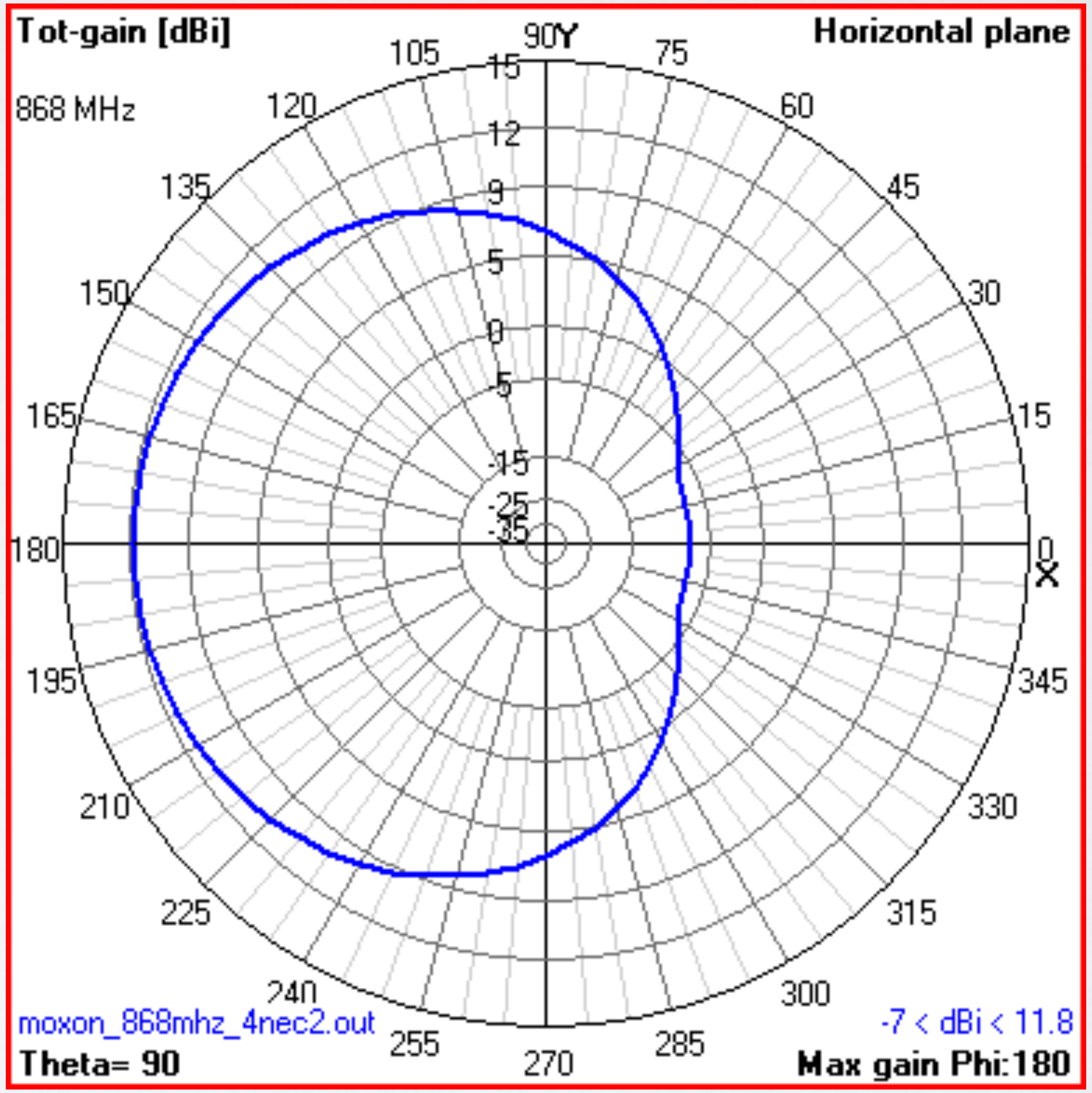
VSWR=1.38

Ground: **Perfect ground** (= perfectly conducting ground). Height: 1m above ground.

ANTENNA MODELLING NEC-2

- Ground: **Perfect ground** (= perfectly conducting ground)



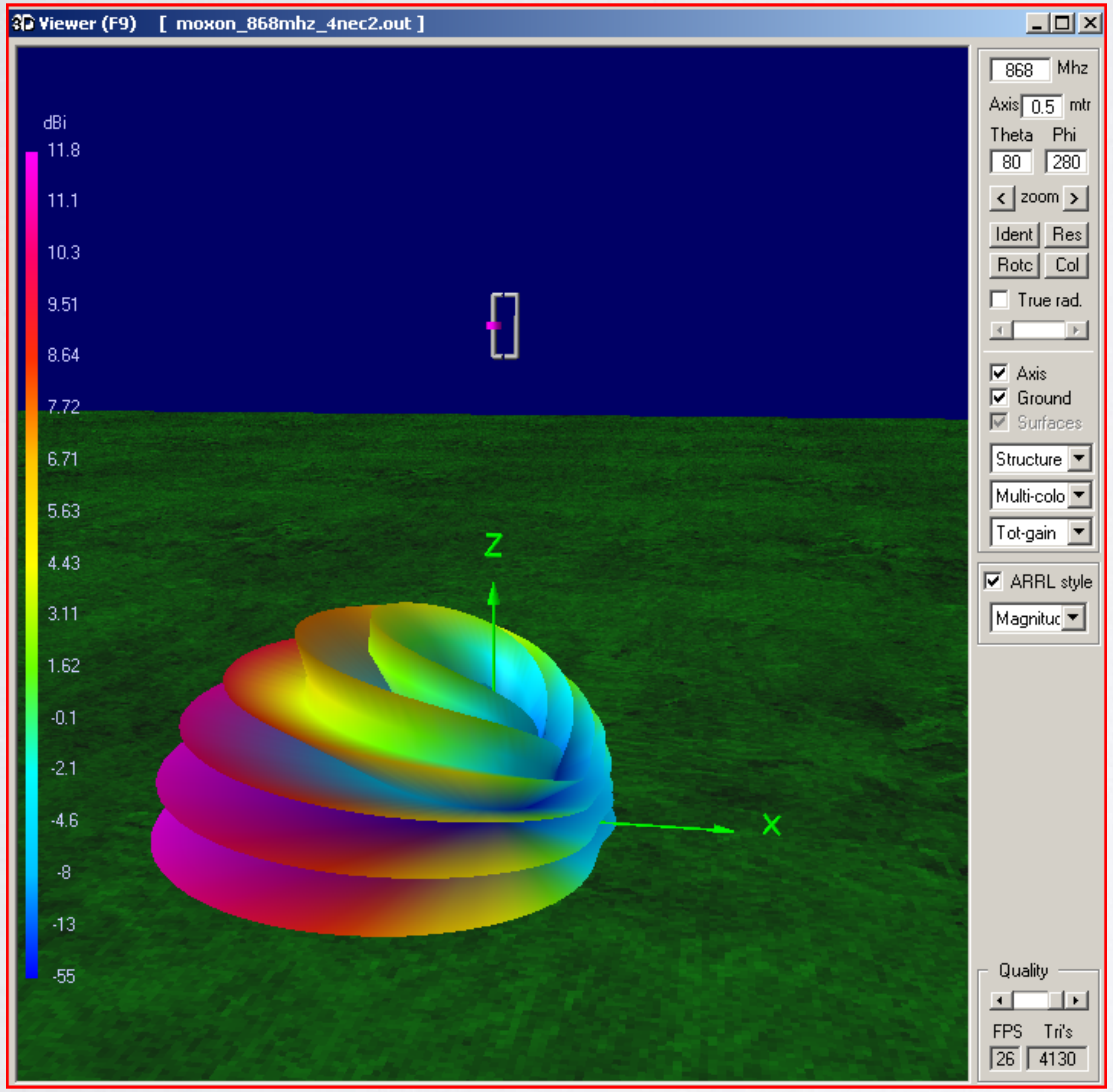


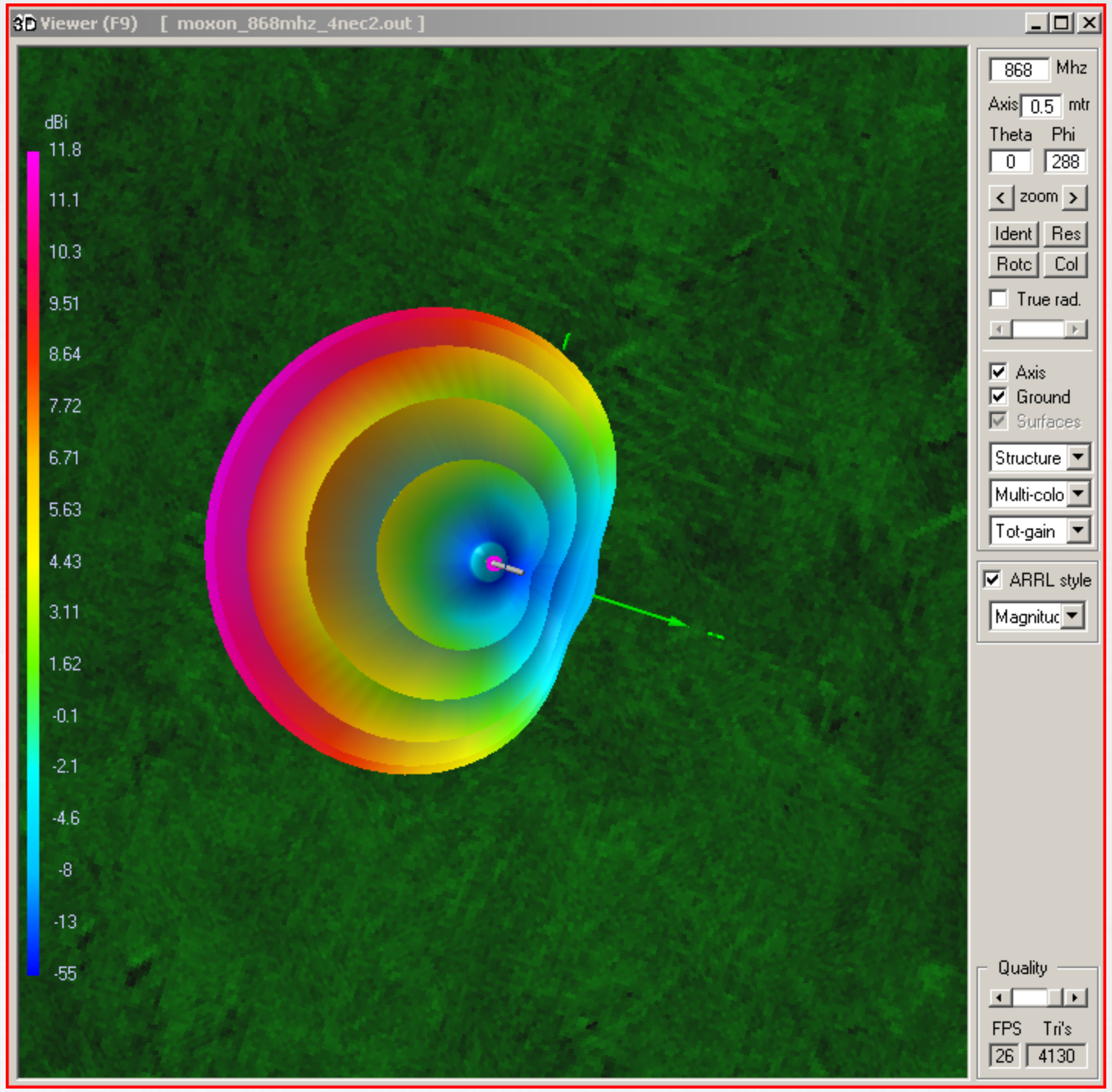
Height: 1m above ground

Max gain: 11.8 dBi @ Θ=90°

ANTENNA MODELLING NEC-2

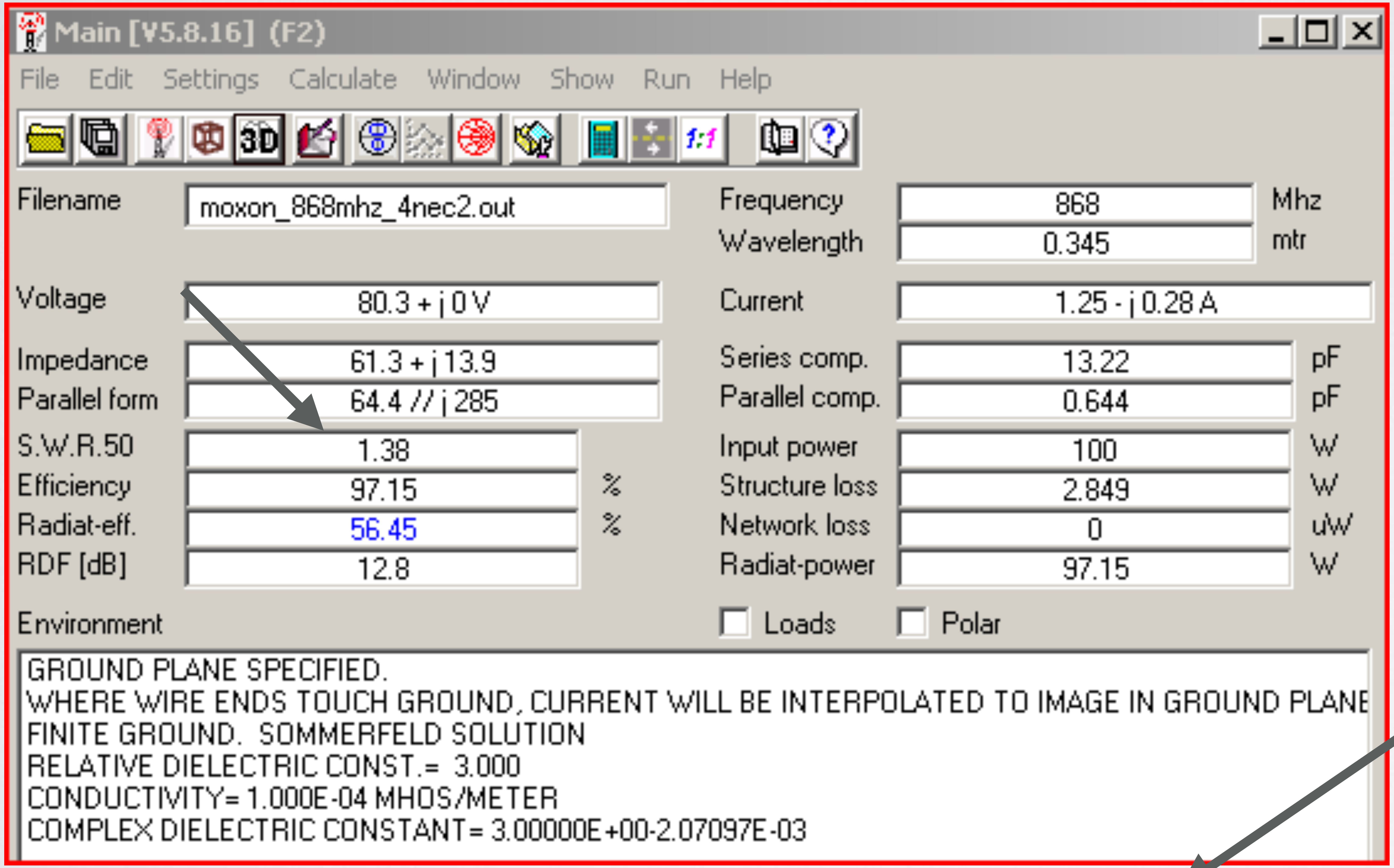
- Ground: **Perfect ground** (= perfectly conducting ground)





Height: 1m above ground

ANTENNA MODELLING NEC-2



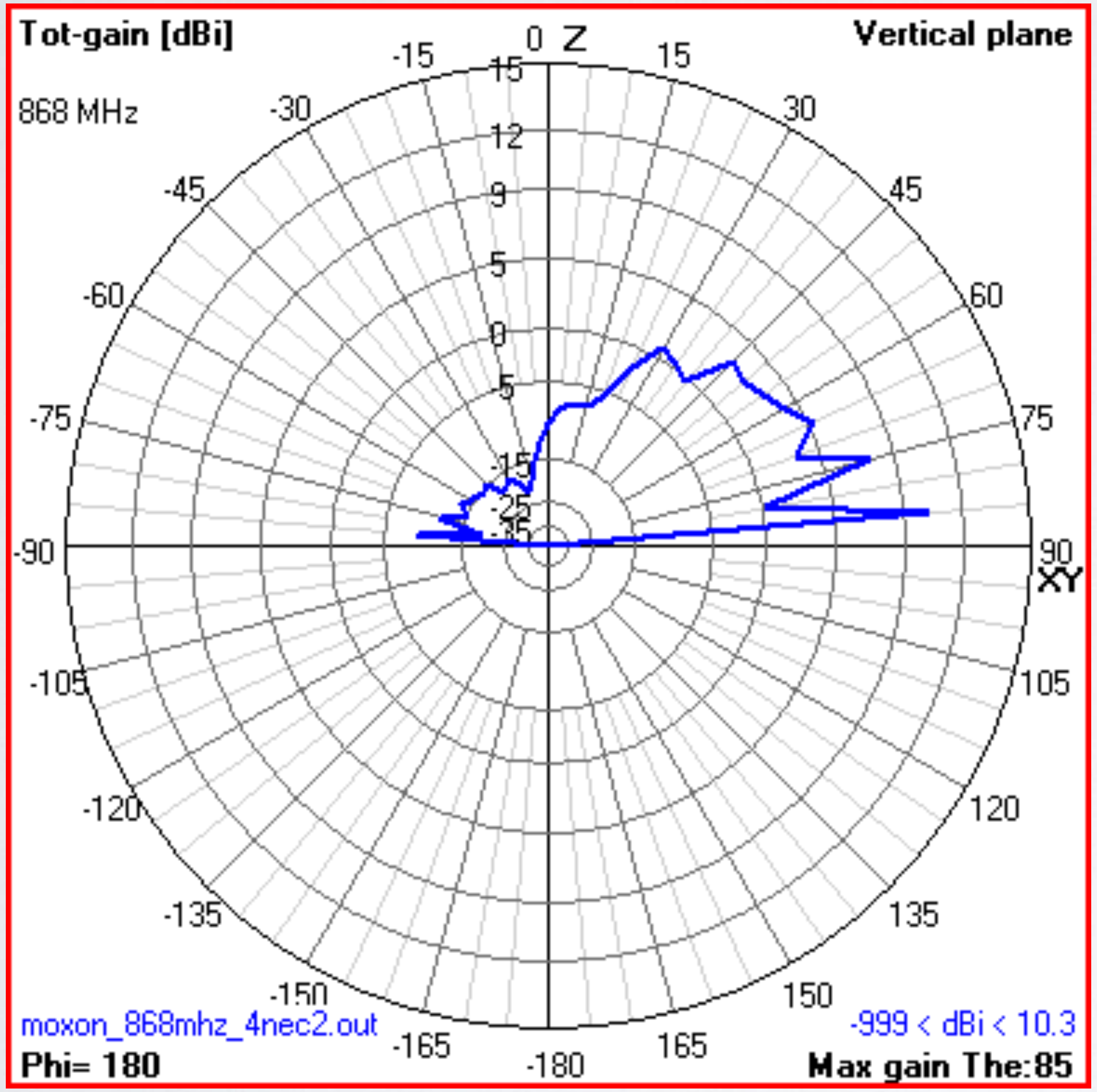
VSWR=1.38

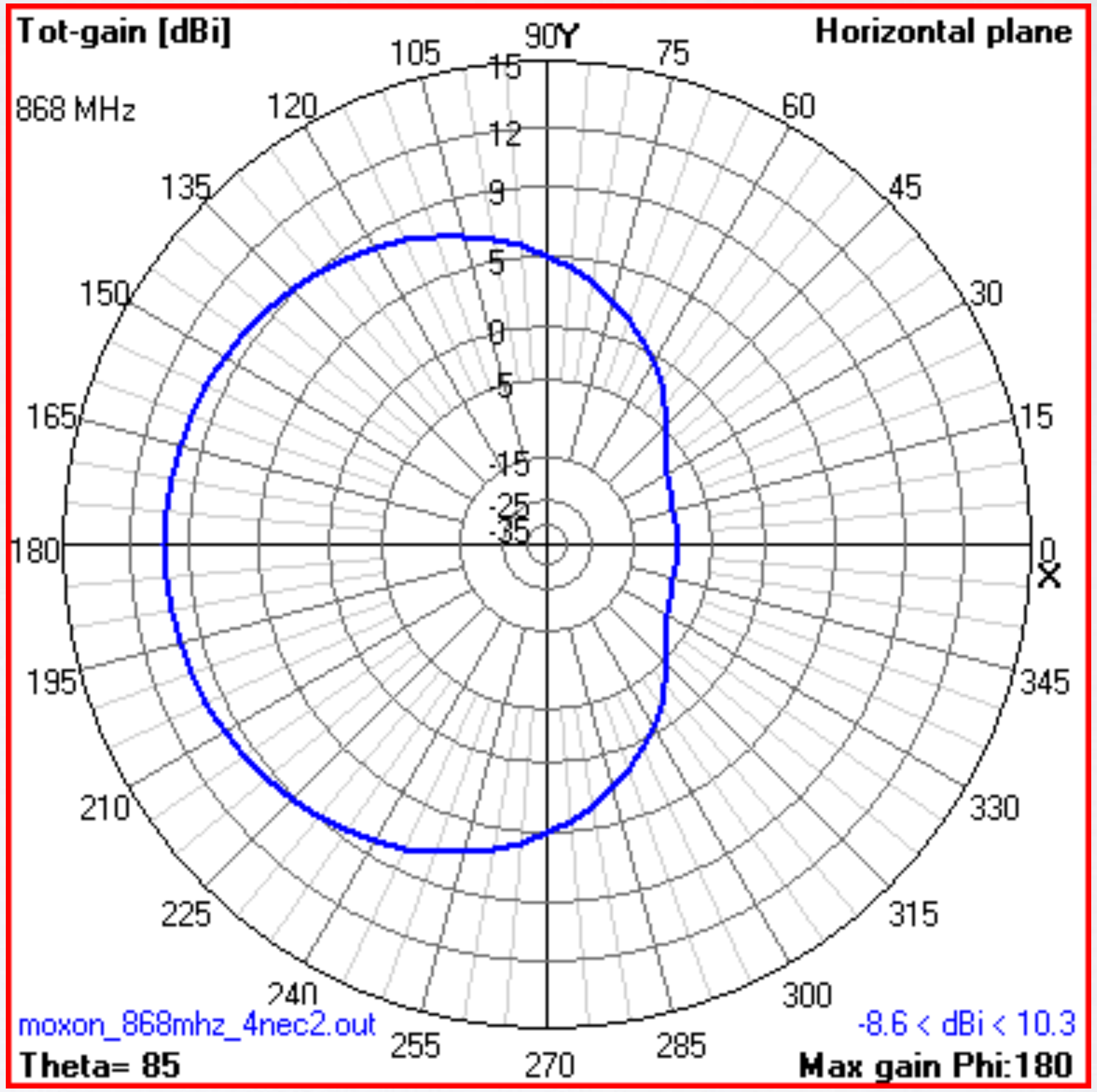
Change ground

Ground: **Real ground** Ground type: **City industrial area** Height: **1m above ground**

ANTENNA MODELLING NEC-2

- Ground: **Real ground** Ground type: **City industrial area**



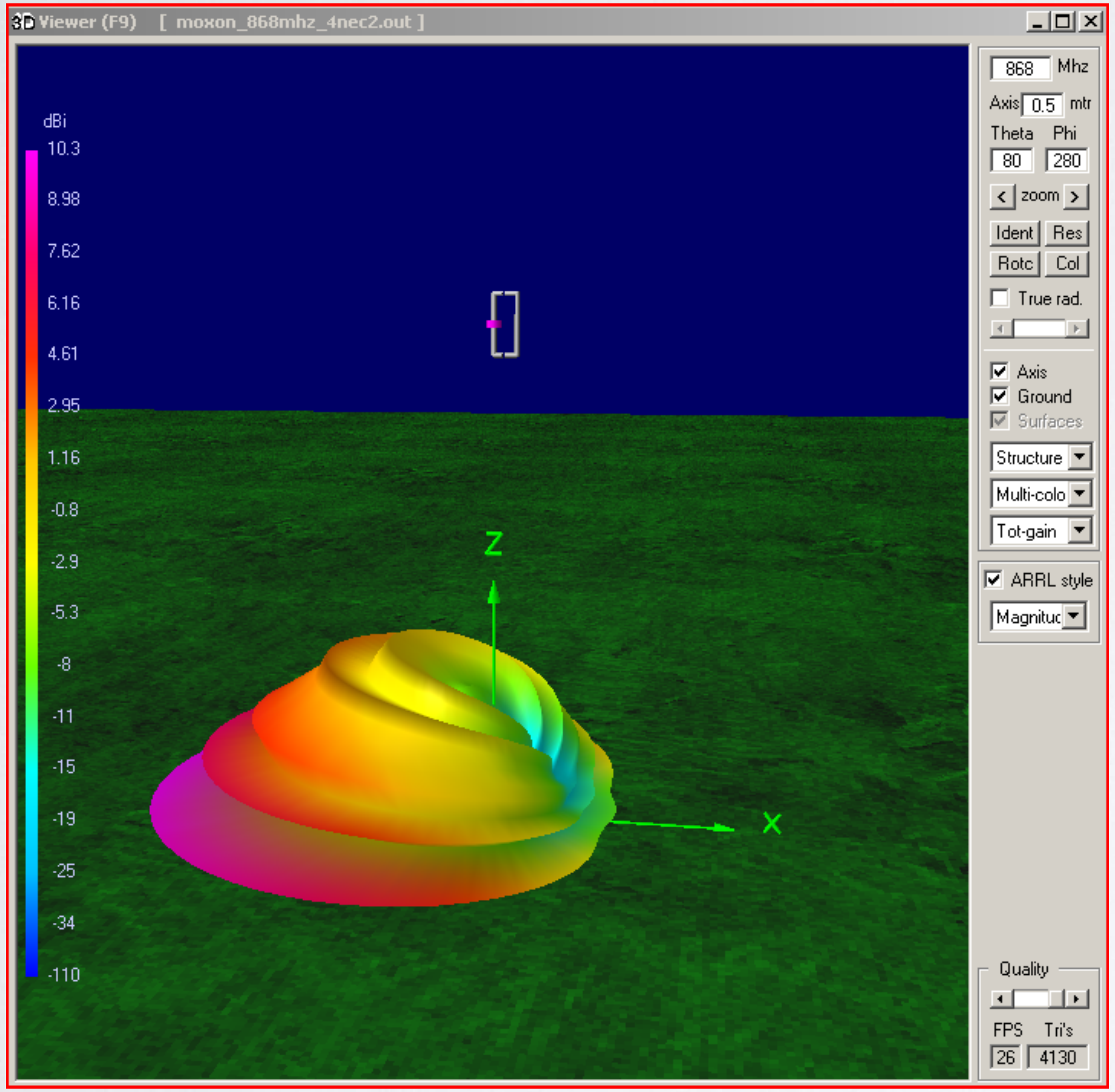


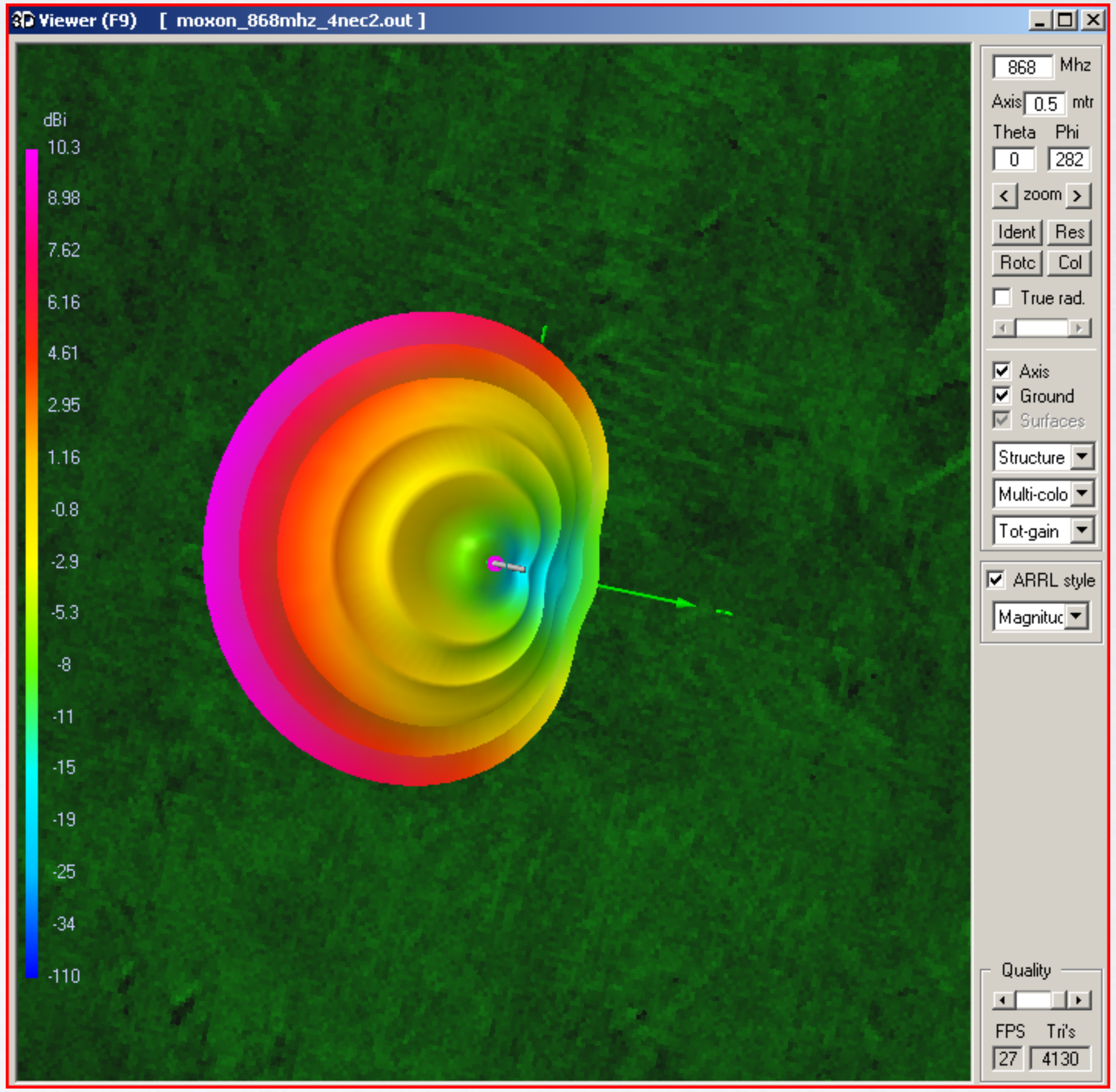
Height: 1m above ground

Max gain: 10.3 dBi @ Θ=85°

ANTENNA MODELLING NEC-2

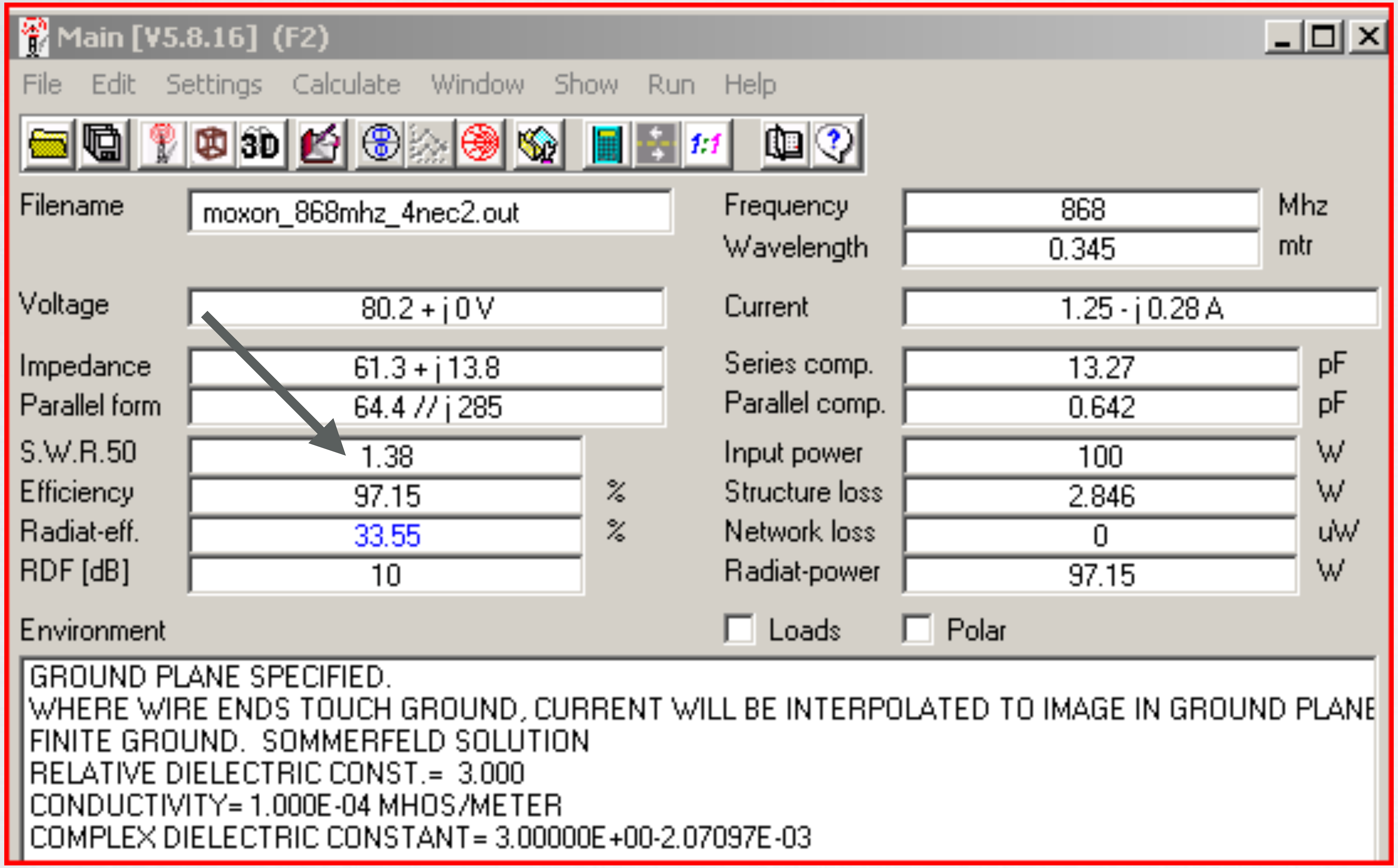
- Ground: **Real ground** Ground type: **City industrial area**





Height: 1m above ground

ANTENNA MODELLING NEC-2



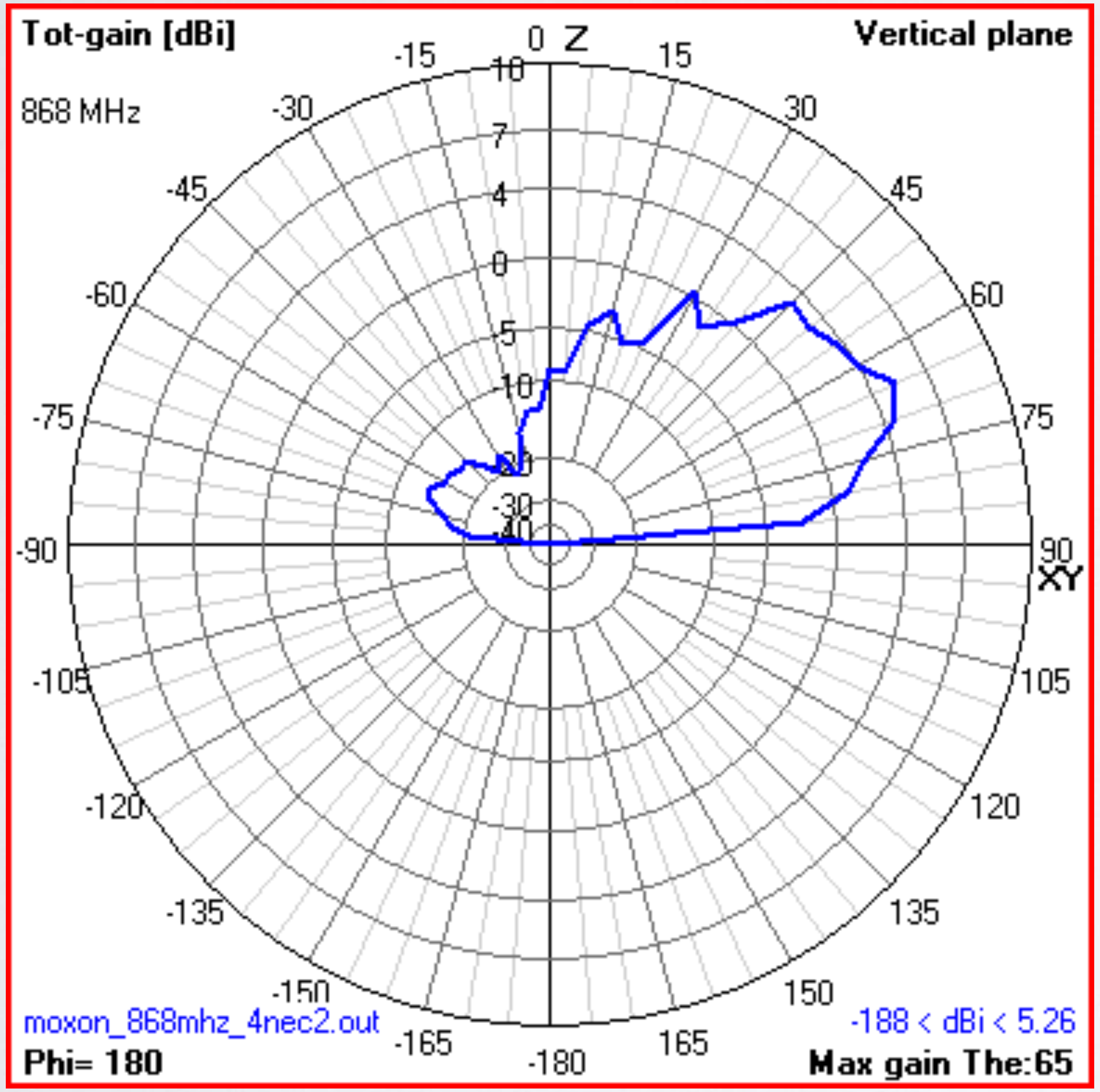
VSWR=1.38

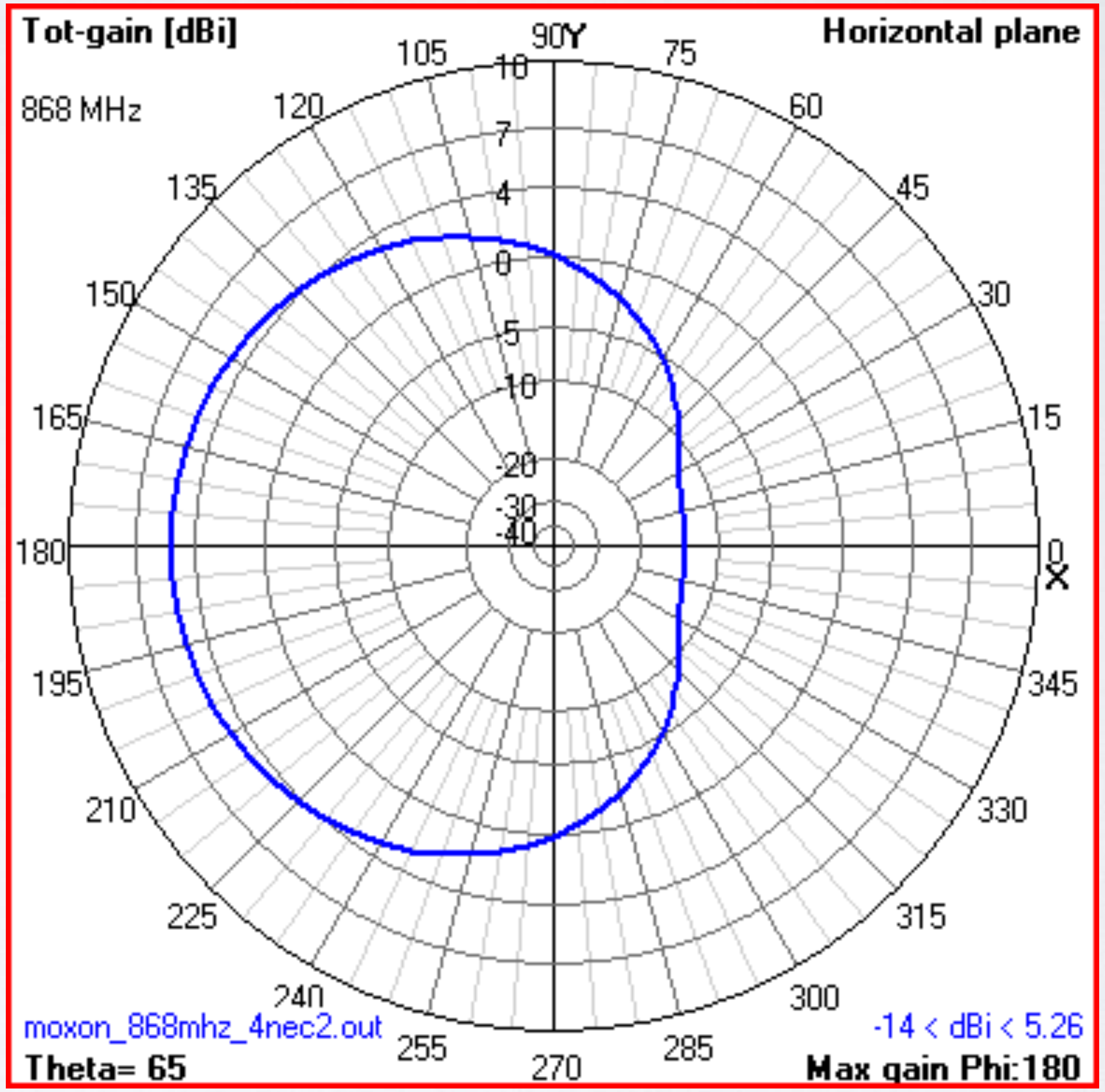
Change height

Ground: **Real ground** Ground type: **City industrial area** Height: **10m above ground**

ANTENNA MODELLING NEC-2

- Ground: **Real ground** Ground type: **City industrial area**





Height: 10m above ground

Max gain: 5.26 dBi @ Θ=65°

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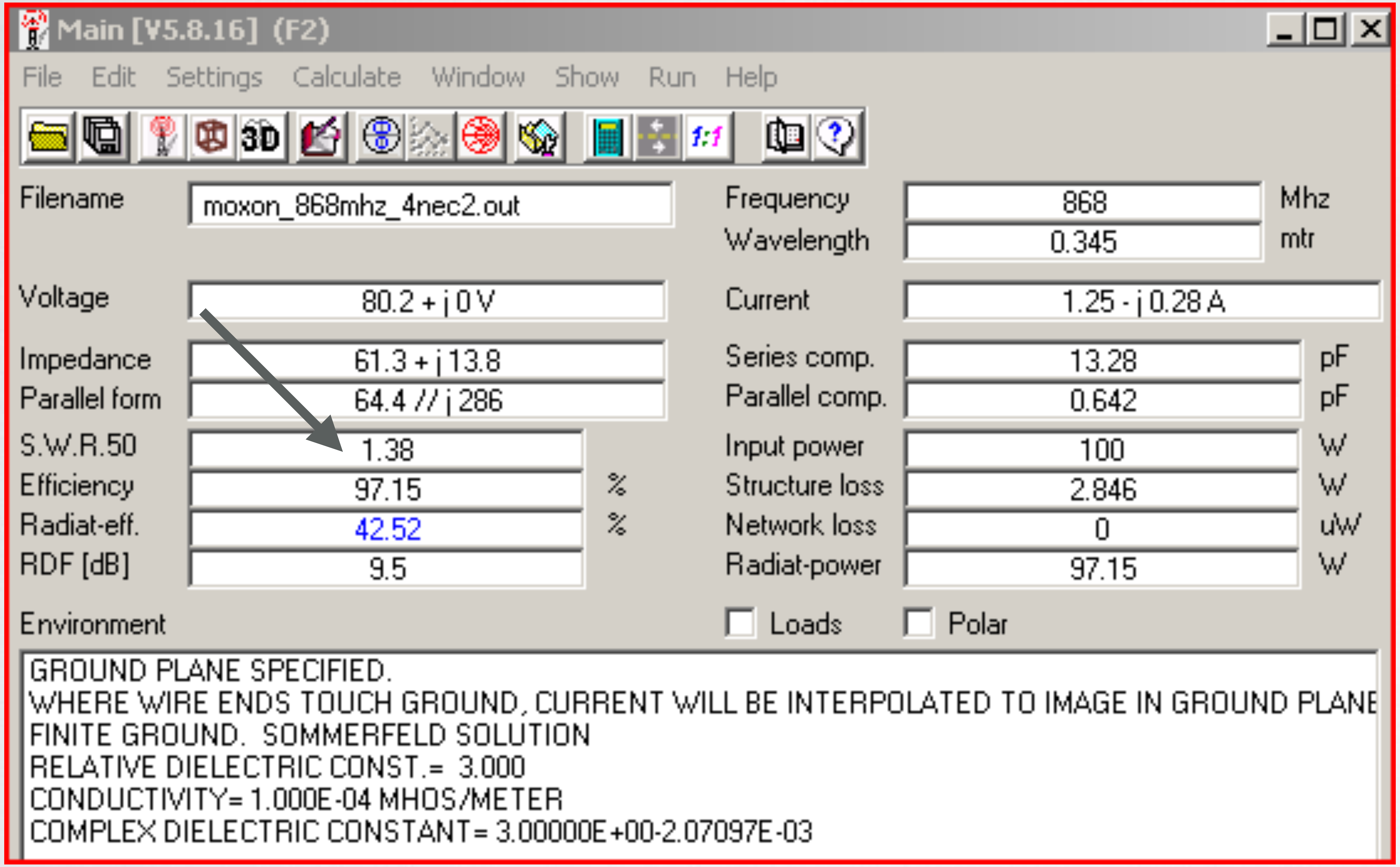
ANTENNA MODELLING NEC-2



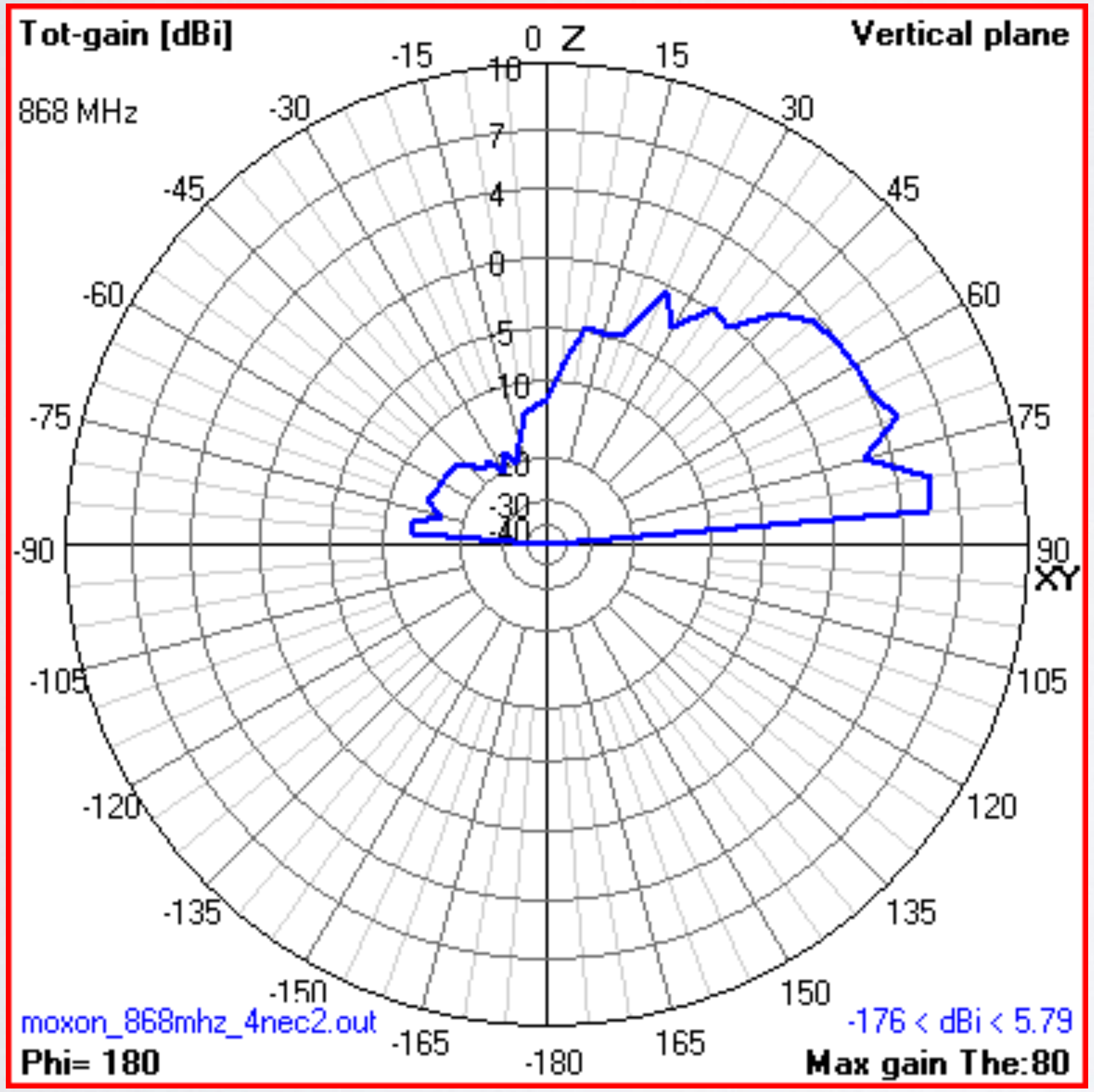
VSWR=1.38

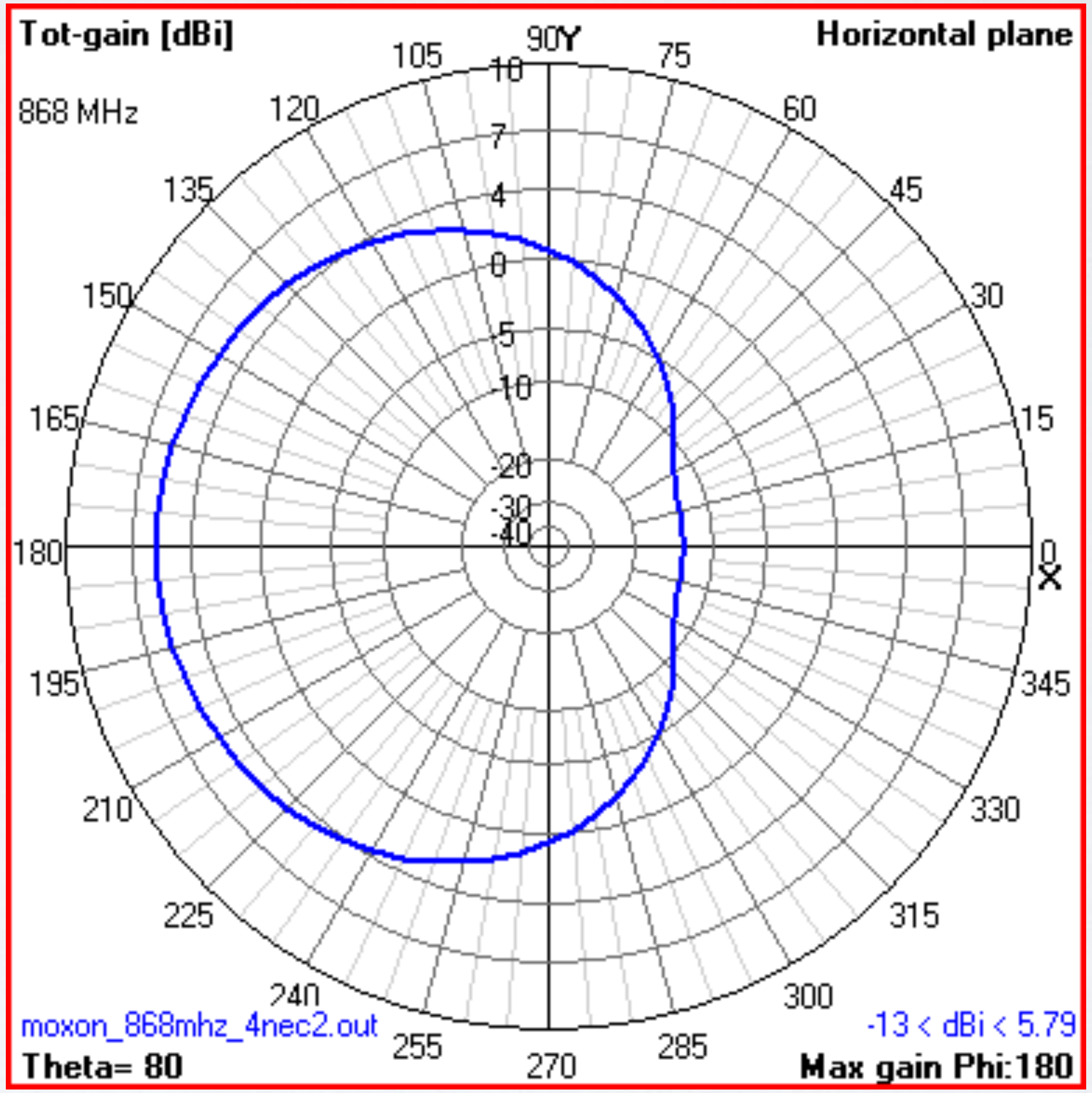
Change height

Ground: **Real ground** Ground type: **City industrial area** Height: **40m above ground**

ANTENNA MODELLING NEC-2

- Ground: **Real ground** Ground type: **City industrial area**





Height: 40m above ground

Max gain: 5.79 dBi @ Θ=80°

BUILD A MOXON ANTENNA

- Based on the 4NEC2 antenna design I have build the Moxon antenna.

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BUILD A MOXON ANTENNA

- Bill of materials
  - Type N female chassis mount 4-hole connector
    LxW: 2.5 x 2.5 cm / 1" x 1"
    Hole diameter: 3.5 mm / 0.137"
    Impedance: 50Ω
    Material: Metal alloy
    Cost: € 0.96

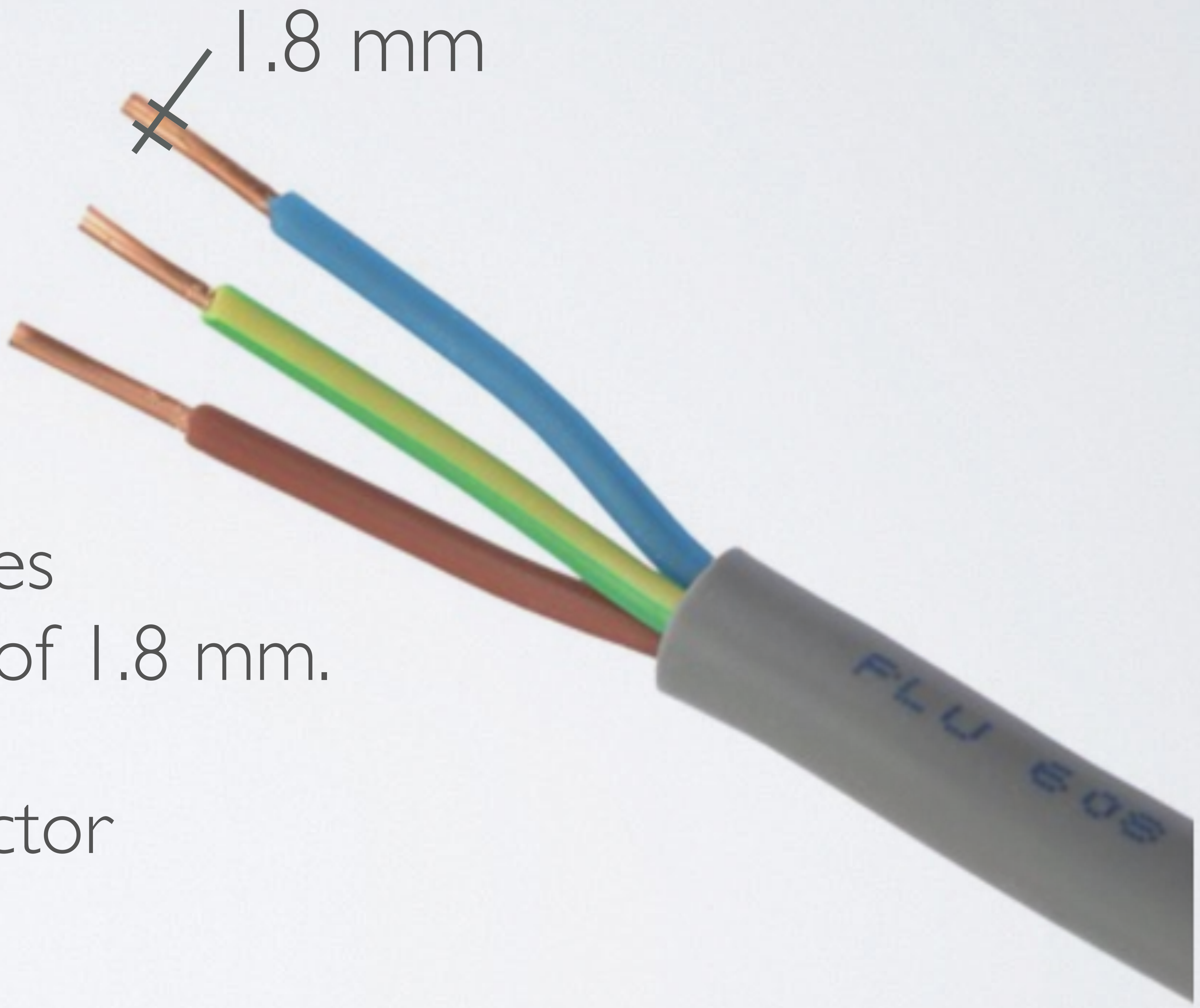
BUILD A MOXON ANTENNA

- Outdoor cable XMVK 3x2.5 mm^2 grey.
  The copper wire has a diameter of 1.8 mm.
  Only 1 meter is needed.
  Cost: € 1.75 per meter

- The electrical insulator can be easily removed using a Stanley knife.

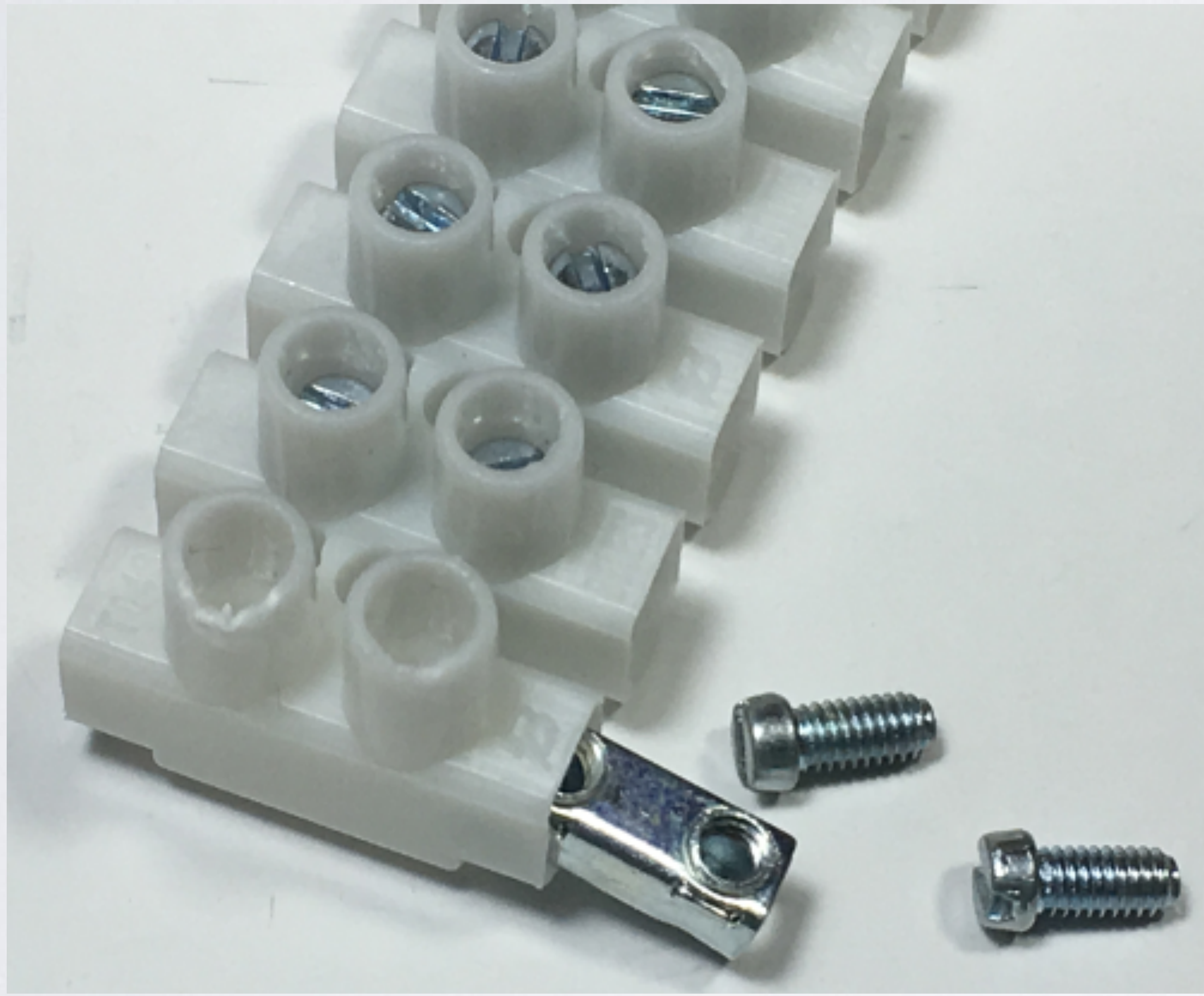
- Instead of copper wires I used umbrella wires (stainless steel) which also have a diameter of 1.8 mm.

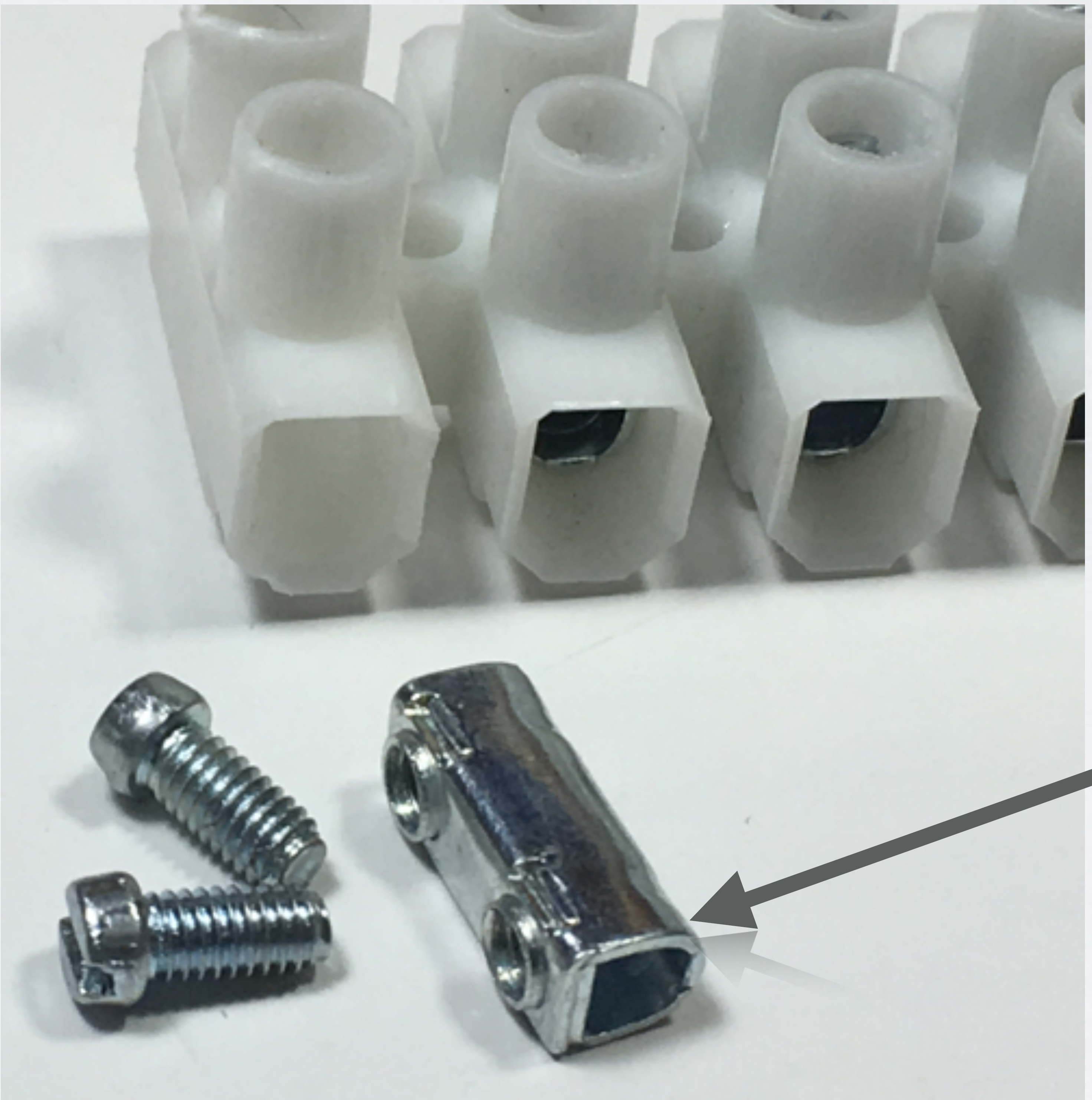
- With these umbrella wires I made the reflector and driven element.

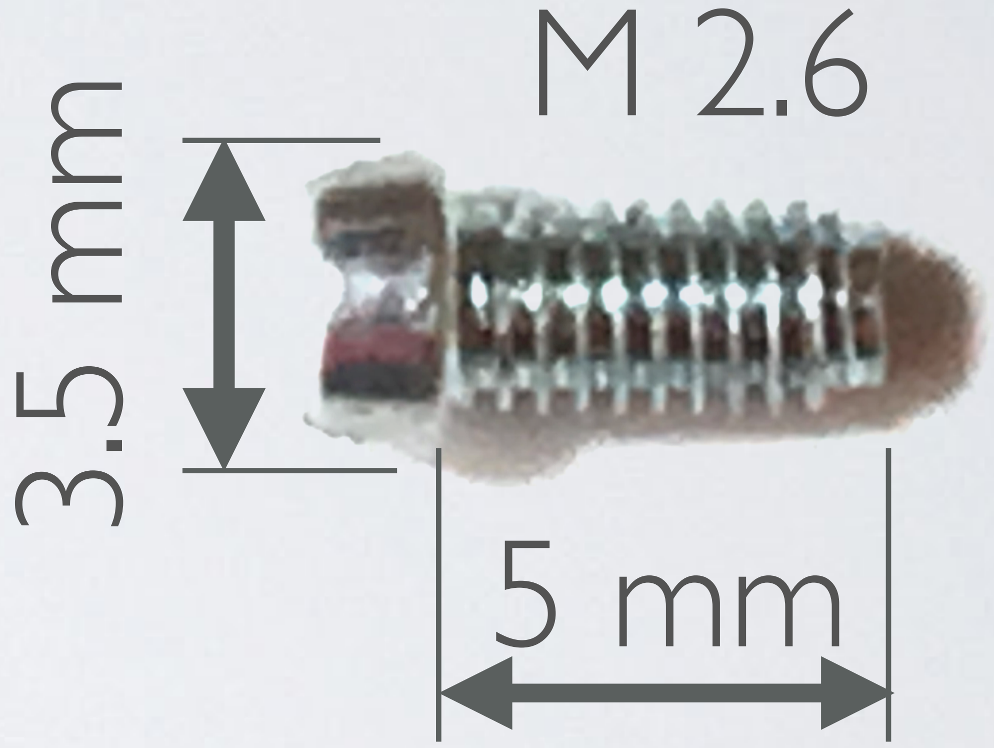


BUILD A MOXON ANTENNA

- Terminal strip block 1.5-4.0 mm^2
  To be used for wires with a diameter of 1.38 mm - 2.26 mm
  Cost: € 1.98 (2 strips, each strip has 12 terminals)

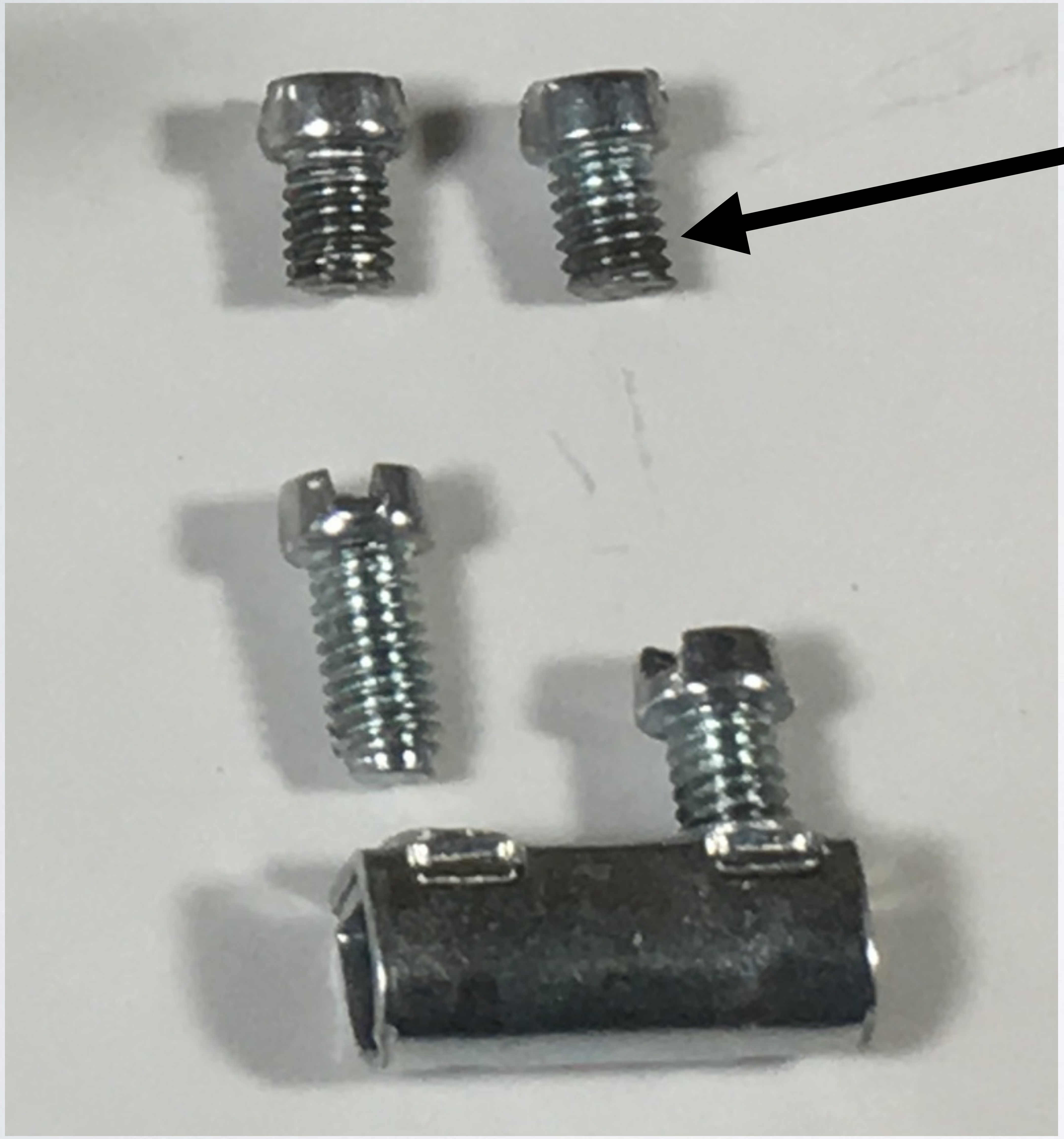




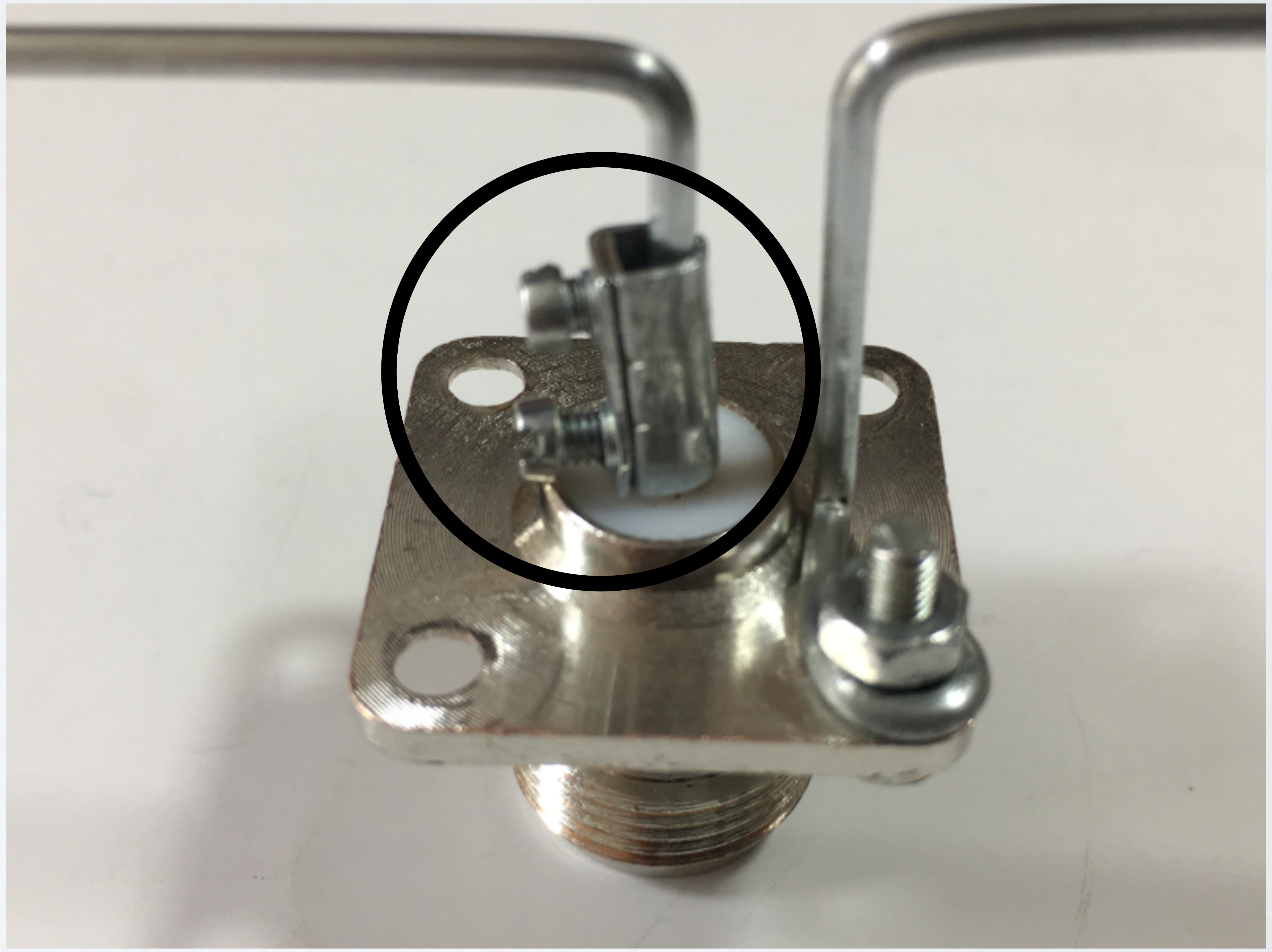


The terminals and screws are tiny.

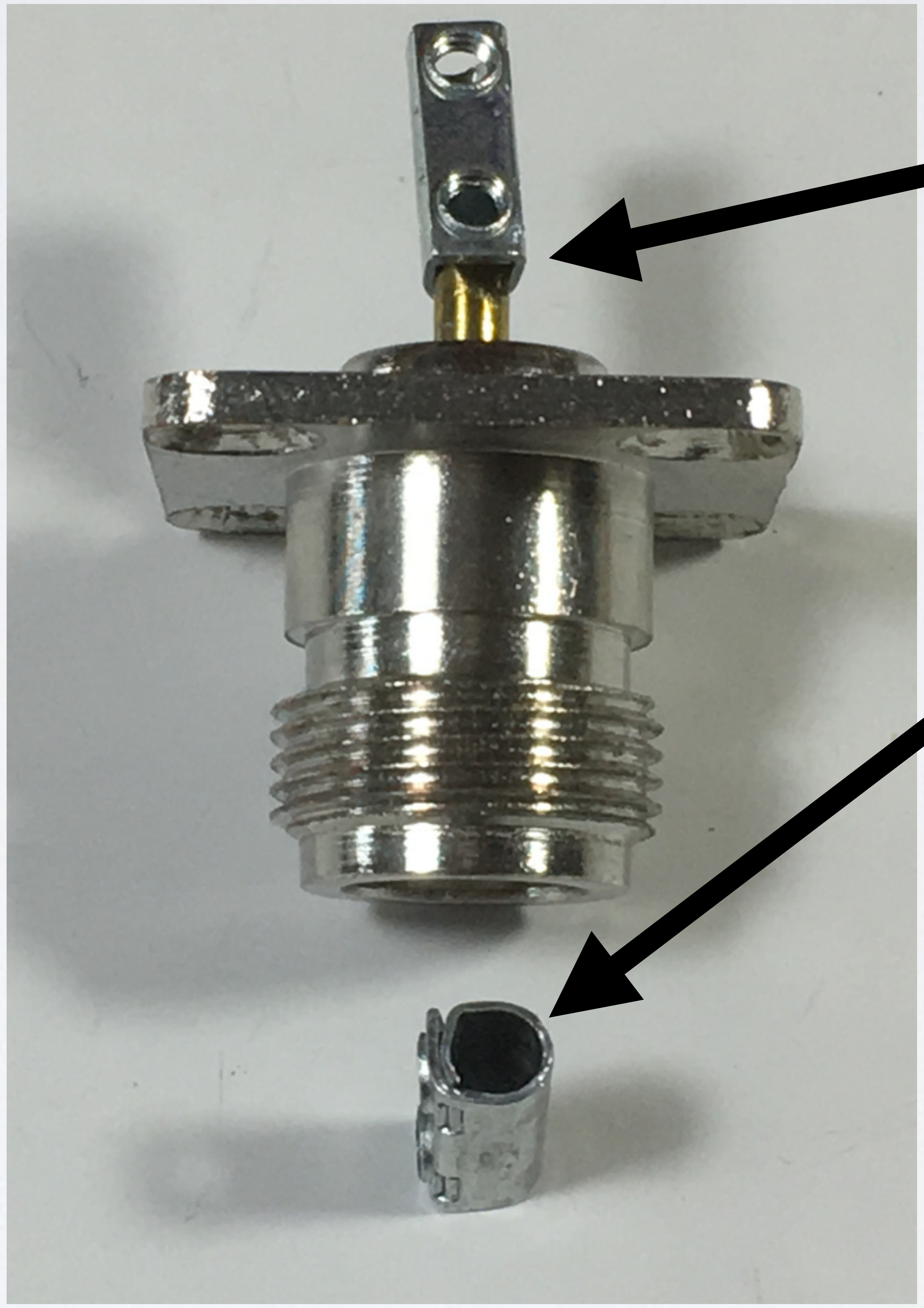
BUILD A MOXON ANTENNA



Cut the screws in half, so they will not stick out too much. Explained in tutorial 44.



BUILD A MOXON ANTENNA



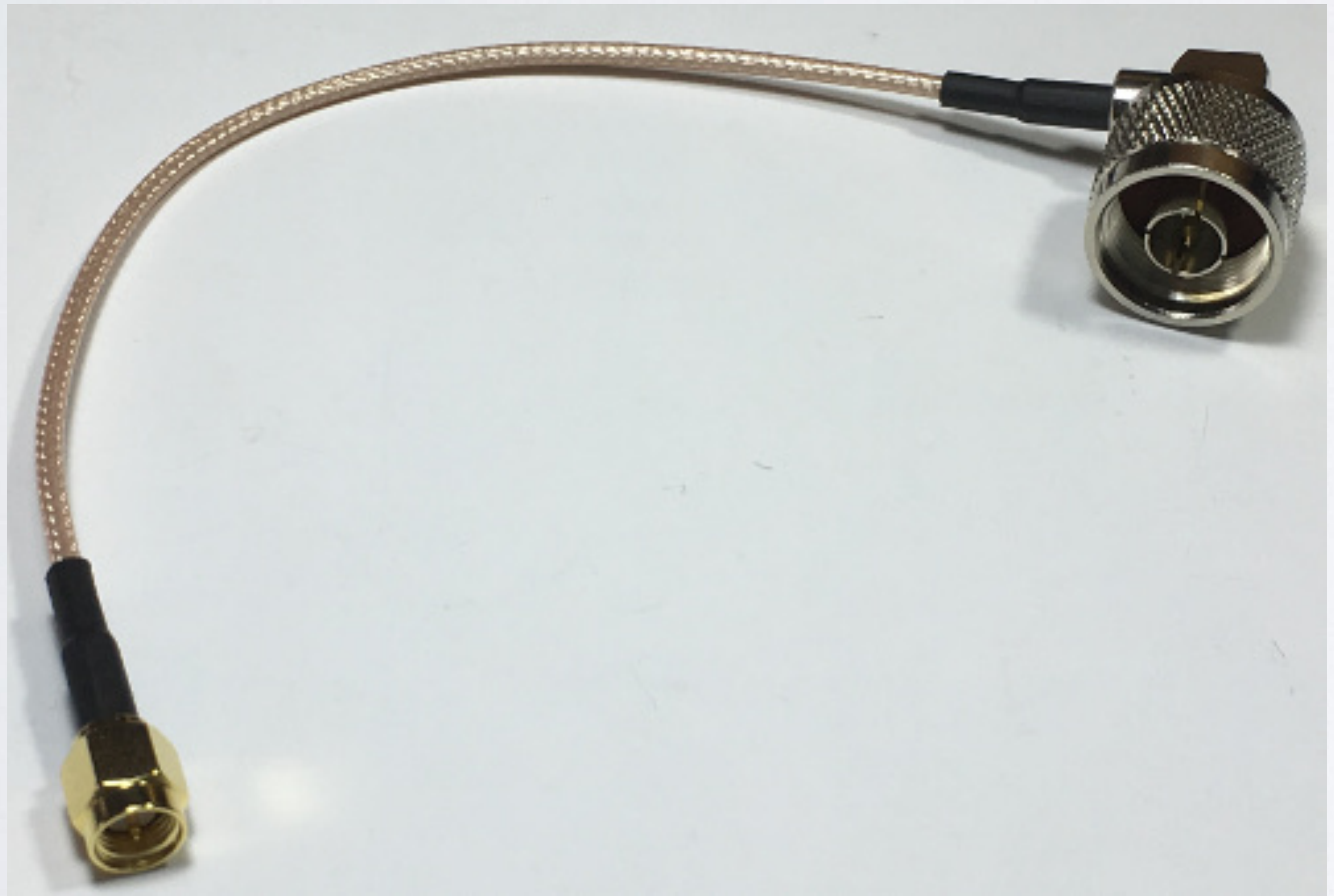
Terminal does not fit.

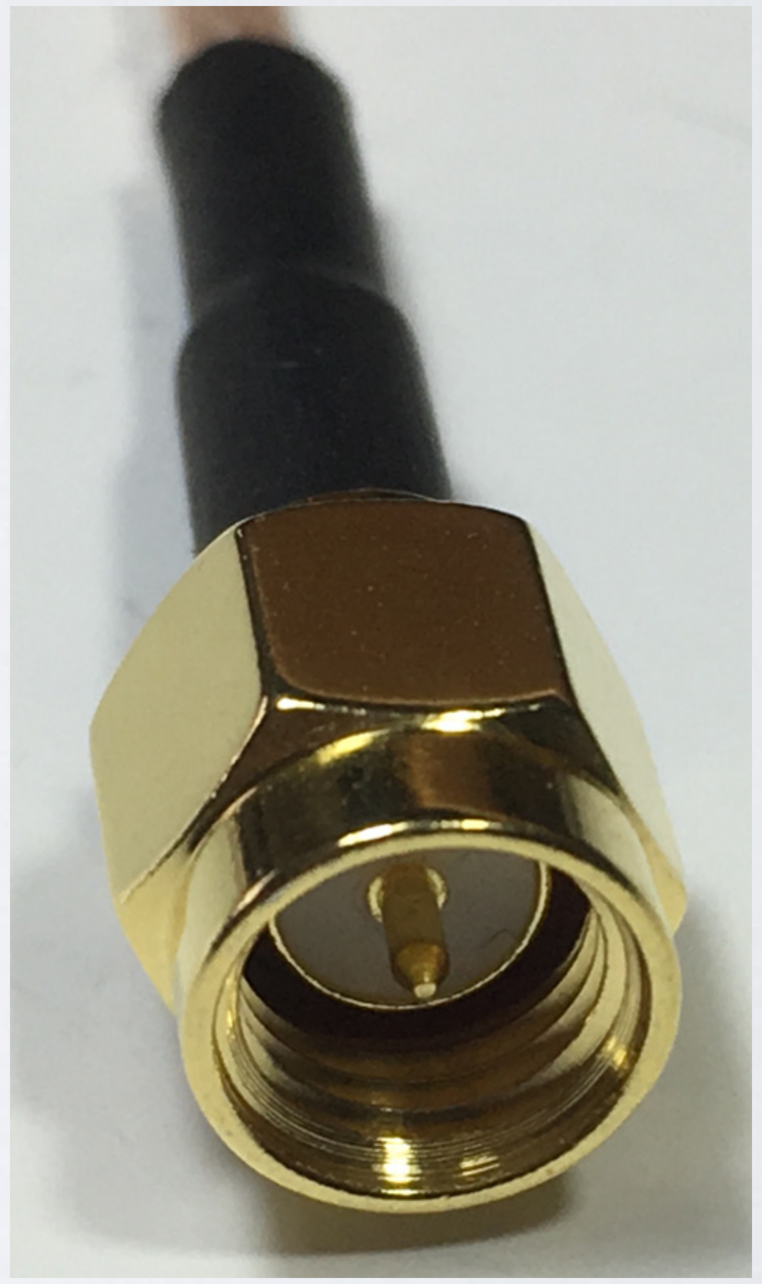
Enlarge the hole of a terminal.

Explained in tutorial 44.

BUILD A MOXON ANTENNA

- RF coaxial cable RG316, length 20 cm with type N male plug right angle to SMA male connector.
  Impedance: 50Ω
  Coax: RG316
  Cost: € 3.39



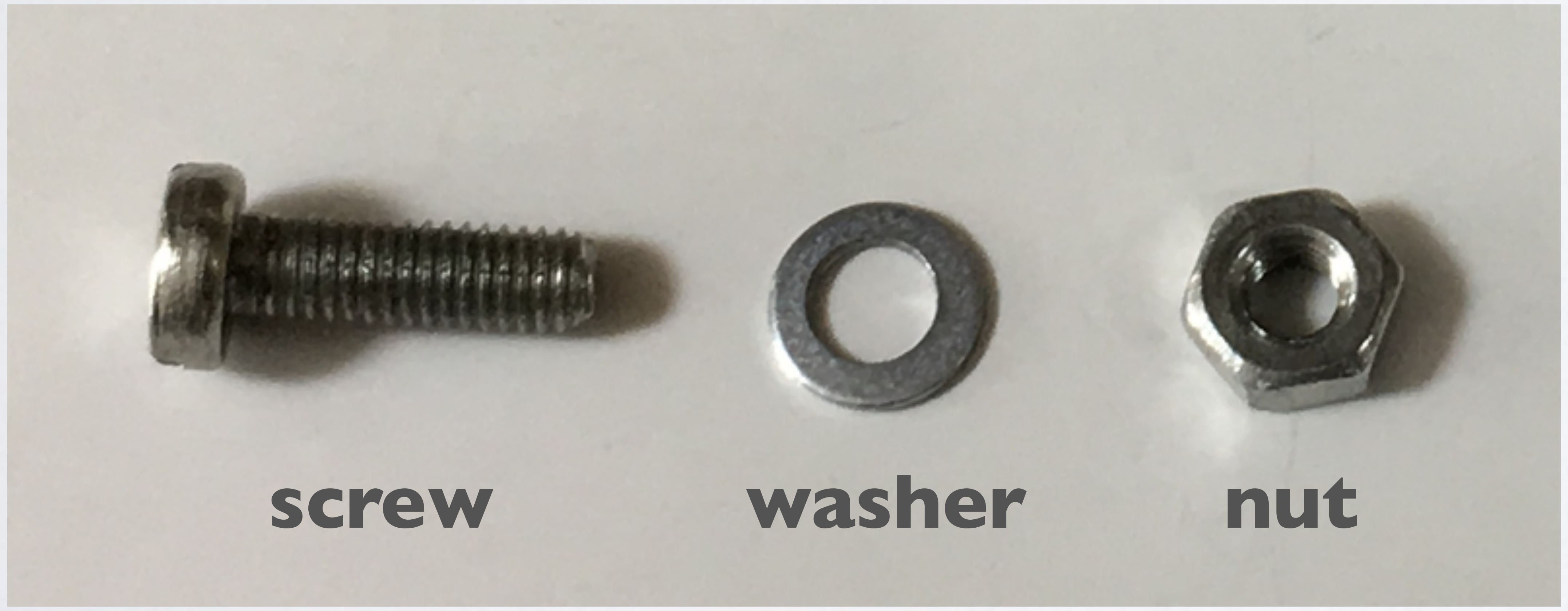


BUILD A MOXON ANTENNA

- Screw M3 x 8 mm (outer diameter, length)
  Cost: unknown

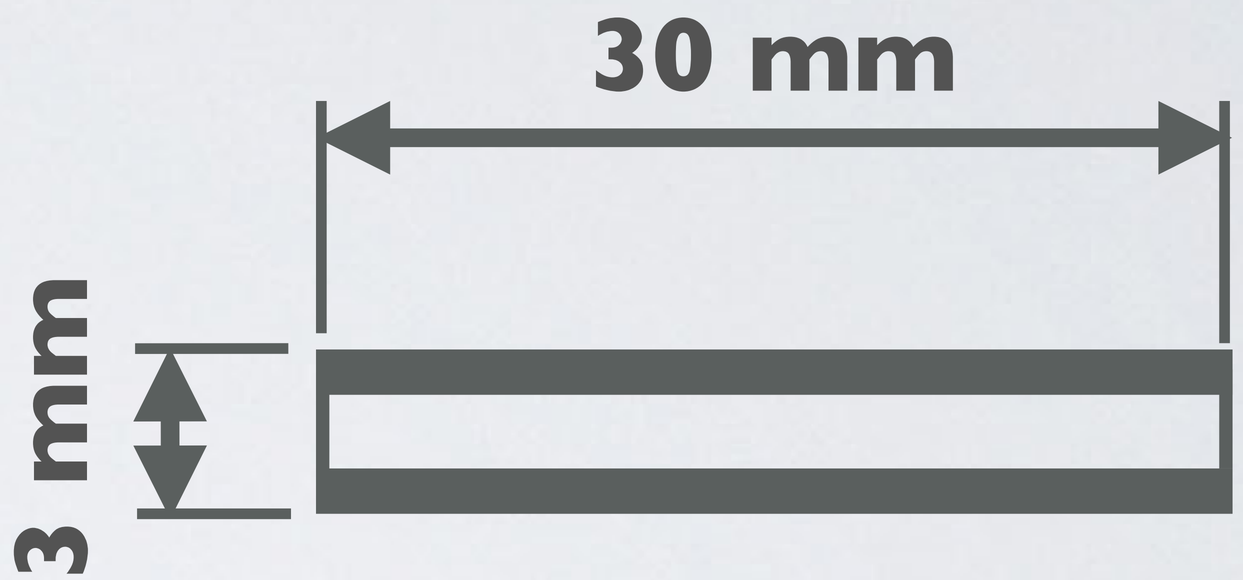
- Metal washer 5.8 x 3.3 x 0.5 mm (outer diameter, inner diameter, thickness)
  Cost: unknown

- Nut M3
  Cost: unknown



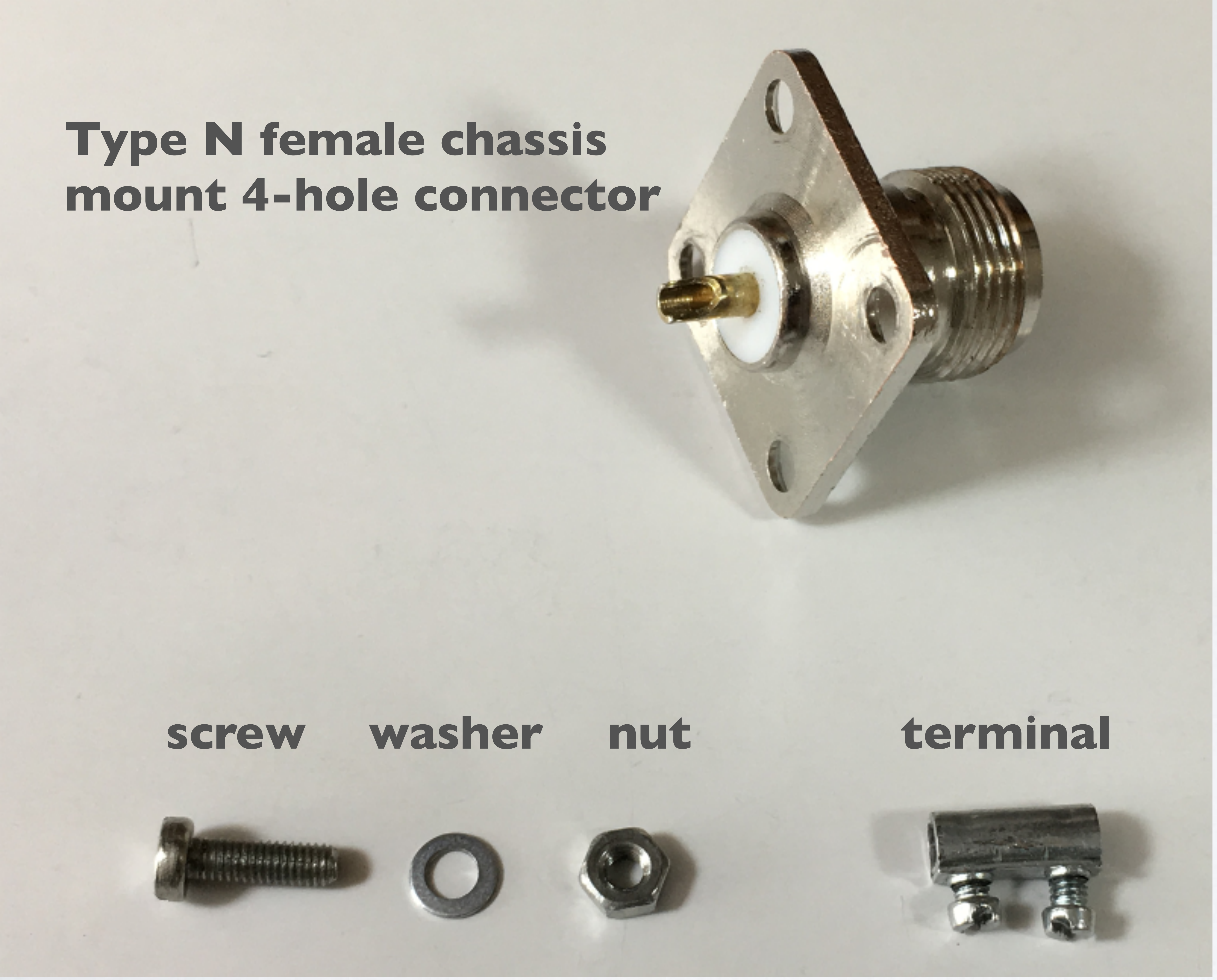
BUILD A MOXON ANTENNA

- Plastic pen ink reservoir.
  Outer diameter = 3 mm, inner diameter = 1.9 mm
  Cut 2 pieces, each has a length of 30 mm.
  Cost: unknown

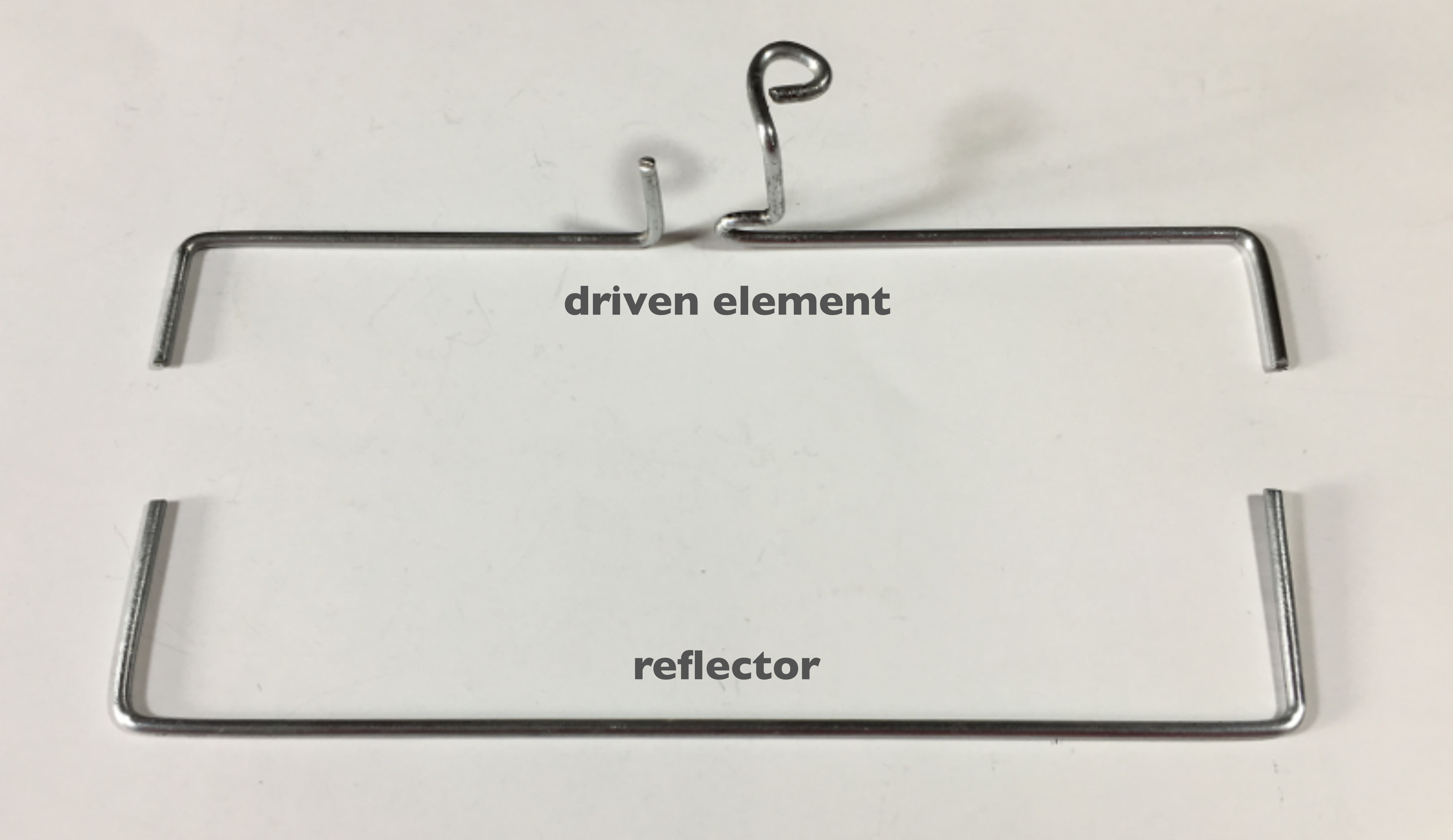


The plastic tube (insulator) will be used to mechanically connect the reflector element with the driven element.

BUILD A MOXON ANTENNA

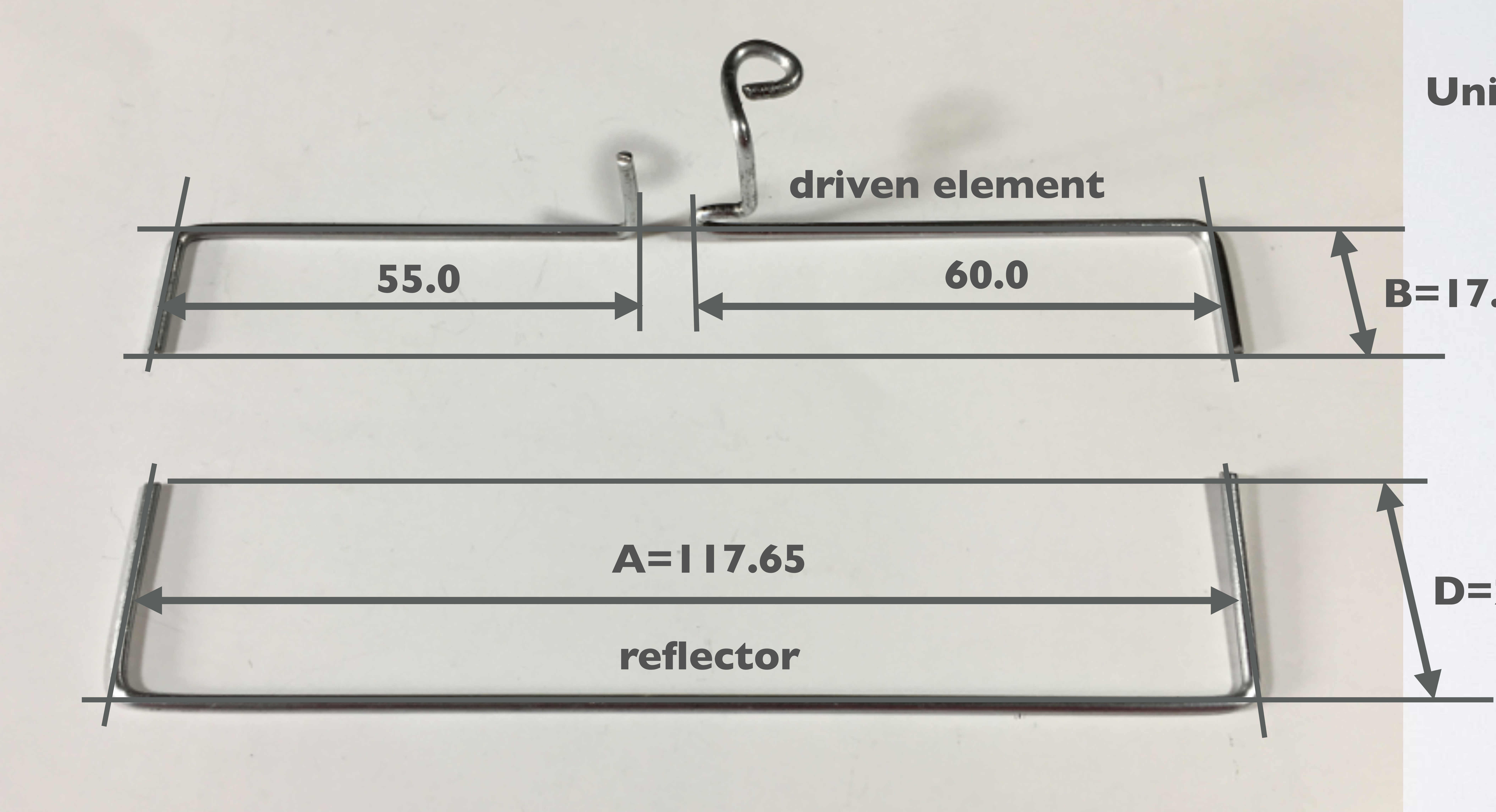


BUILD A MOXON ANTENNA



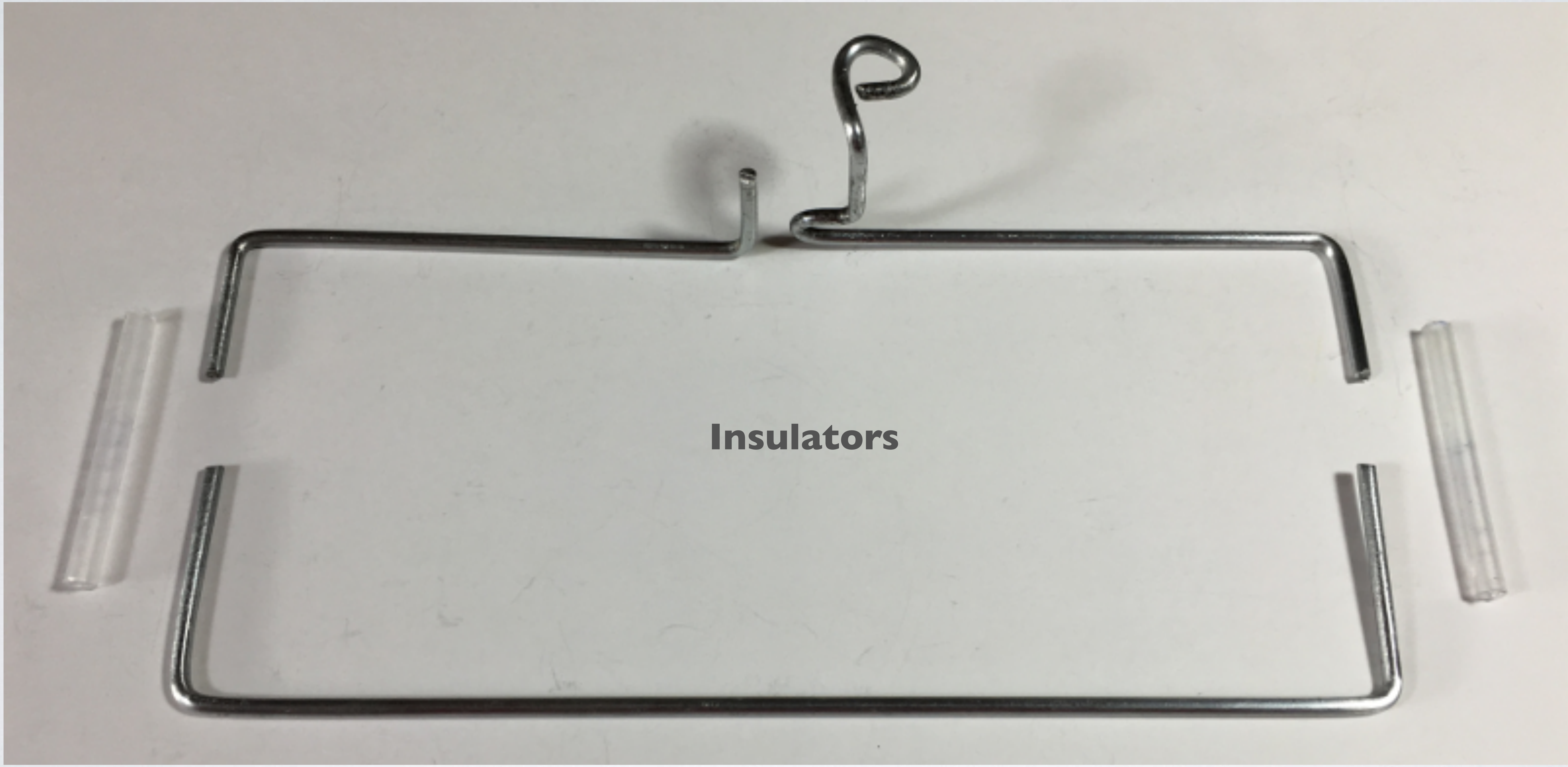
Bend the wires using pliers.

BUILD A MOXON ANTENNA

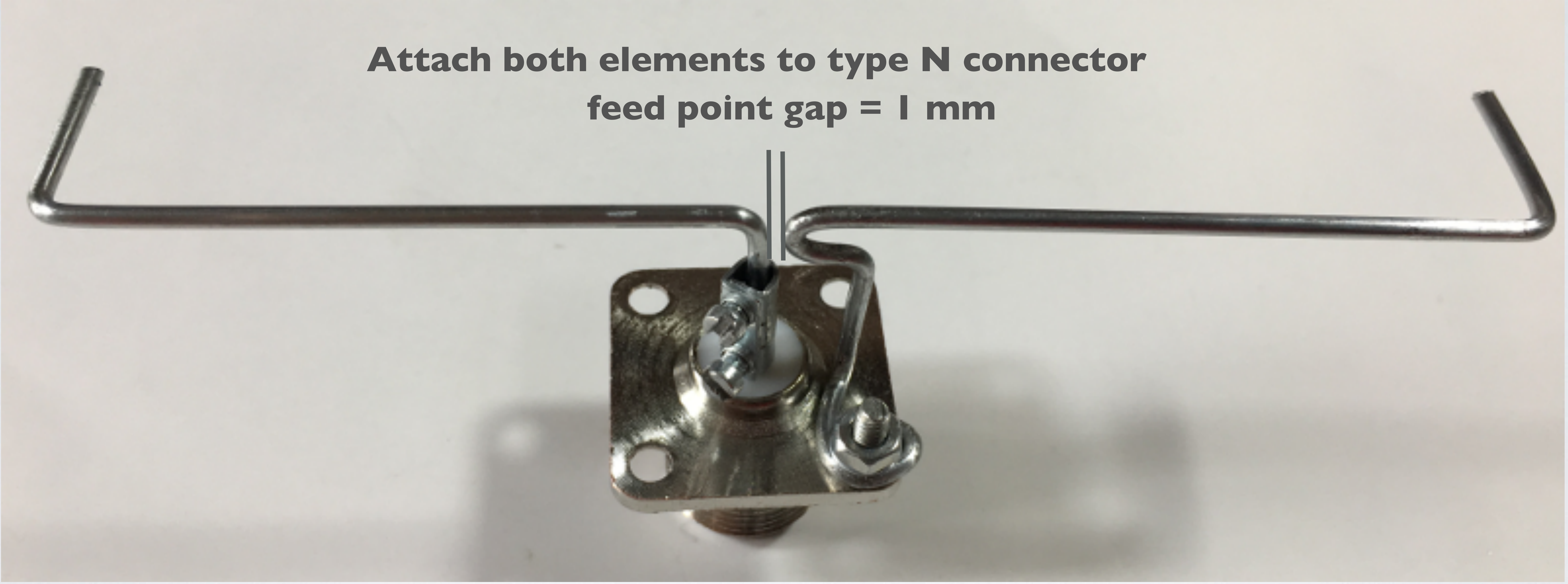


Units in mm

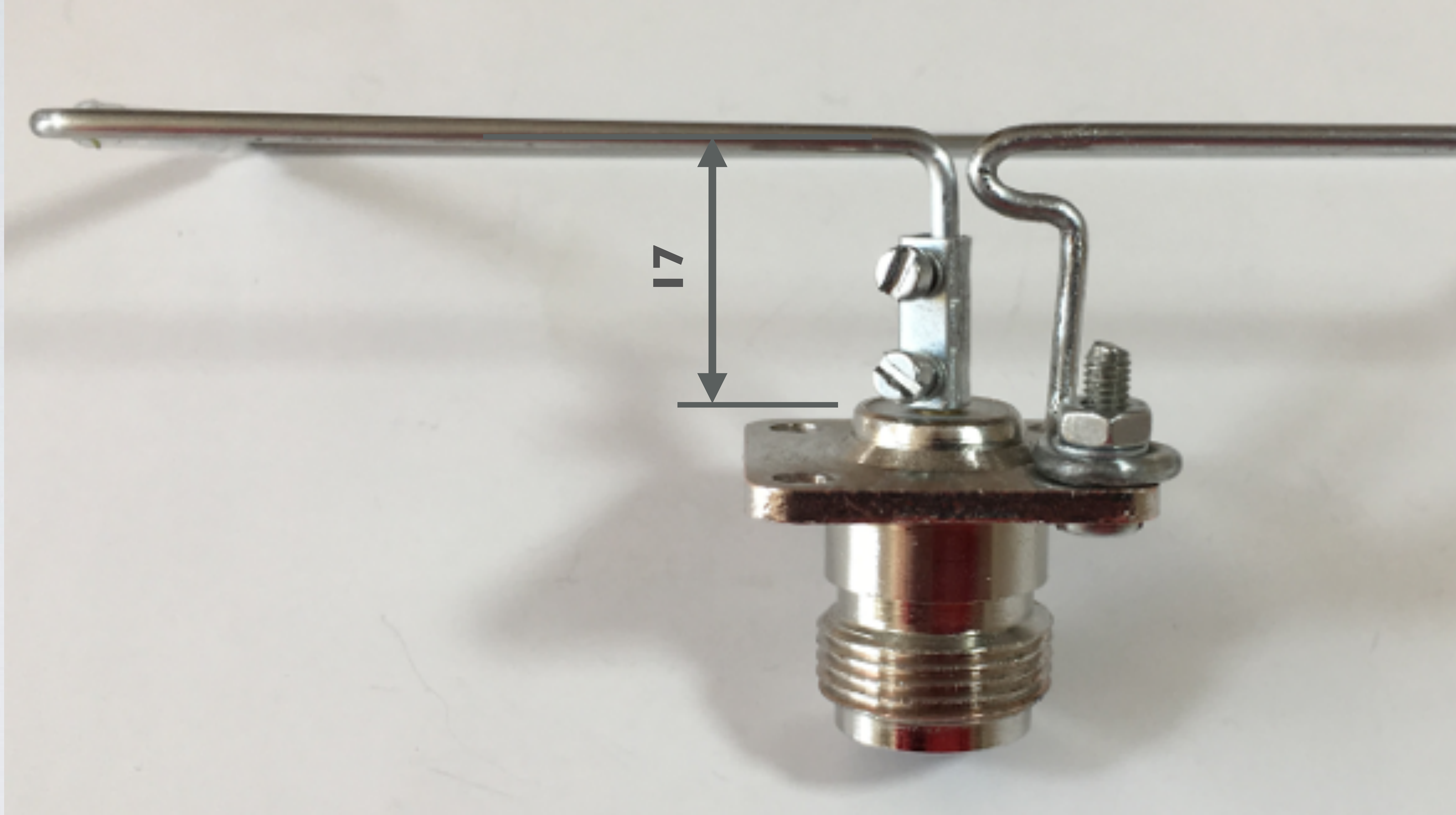
BUILD A MOXON ANTENNA



BUILD A MOXON ANTENNA



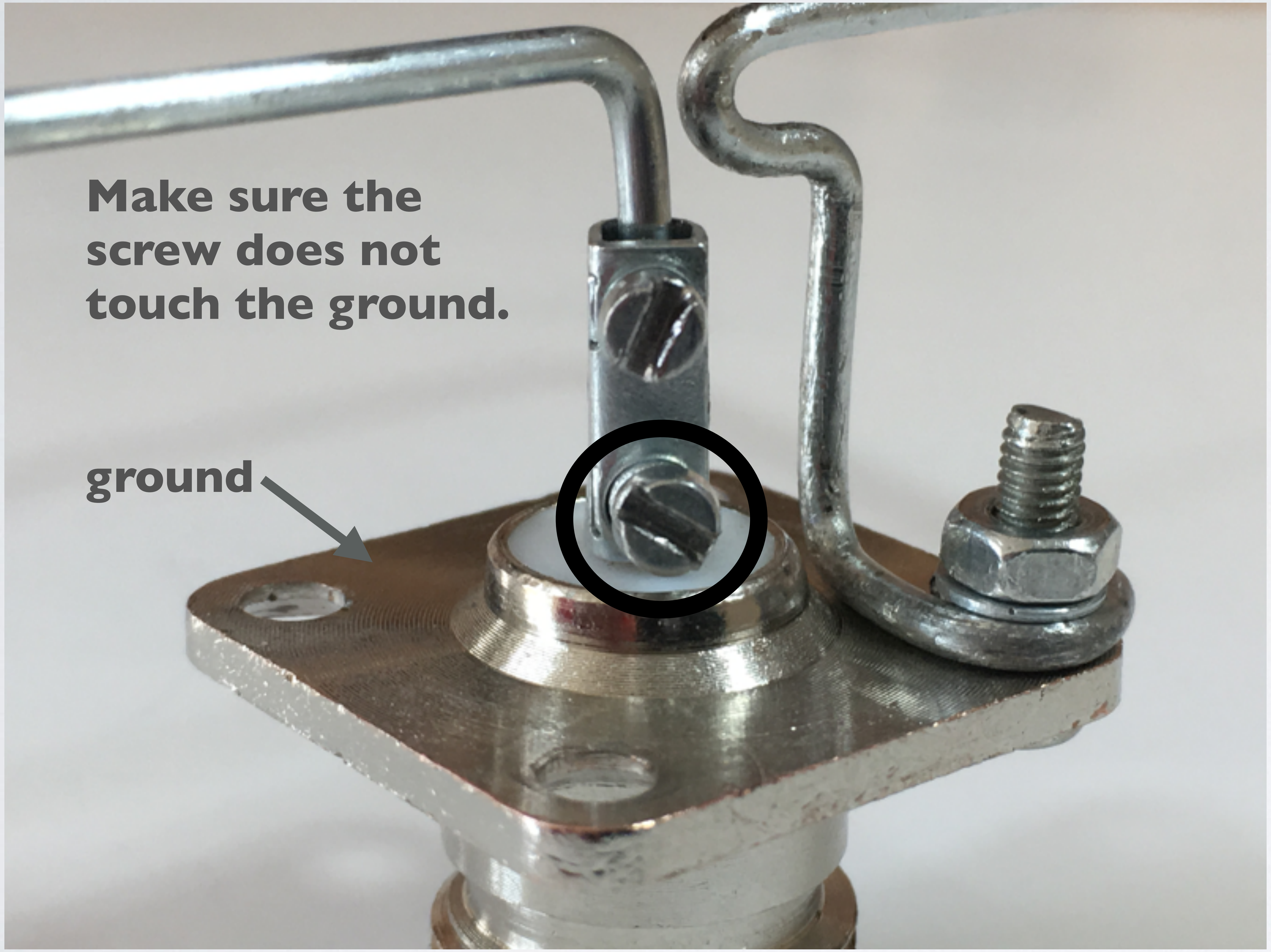
BUILD A MOXON ANTENNA



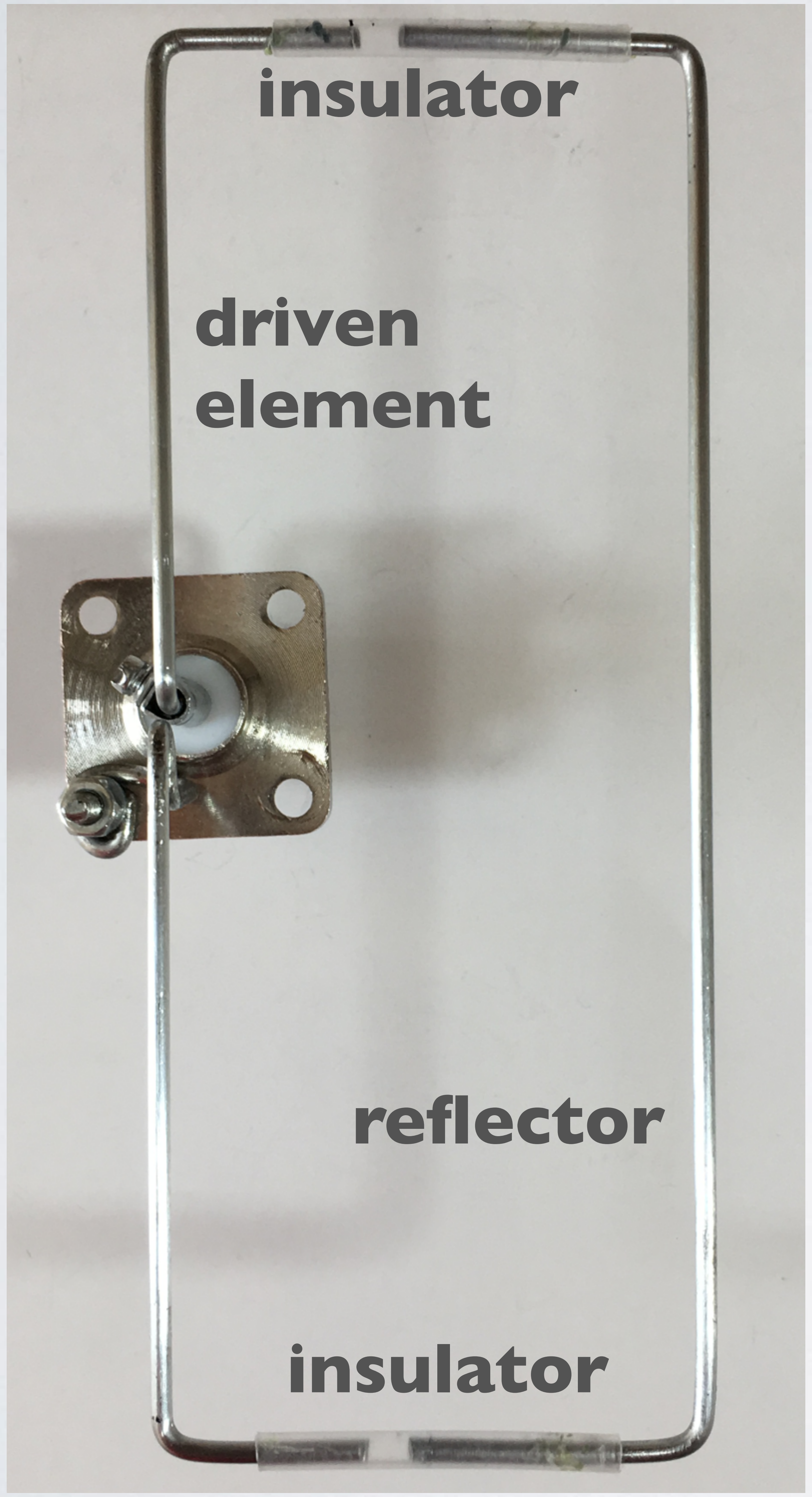
Units in mm

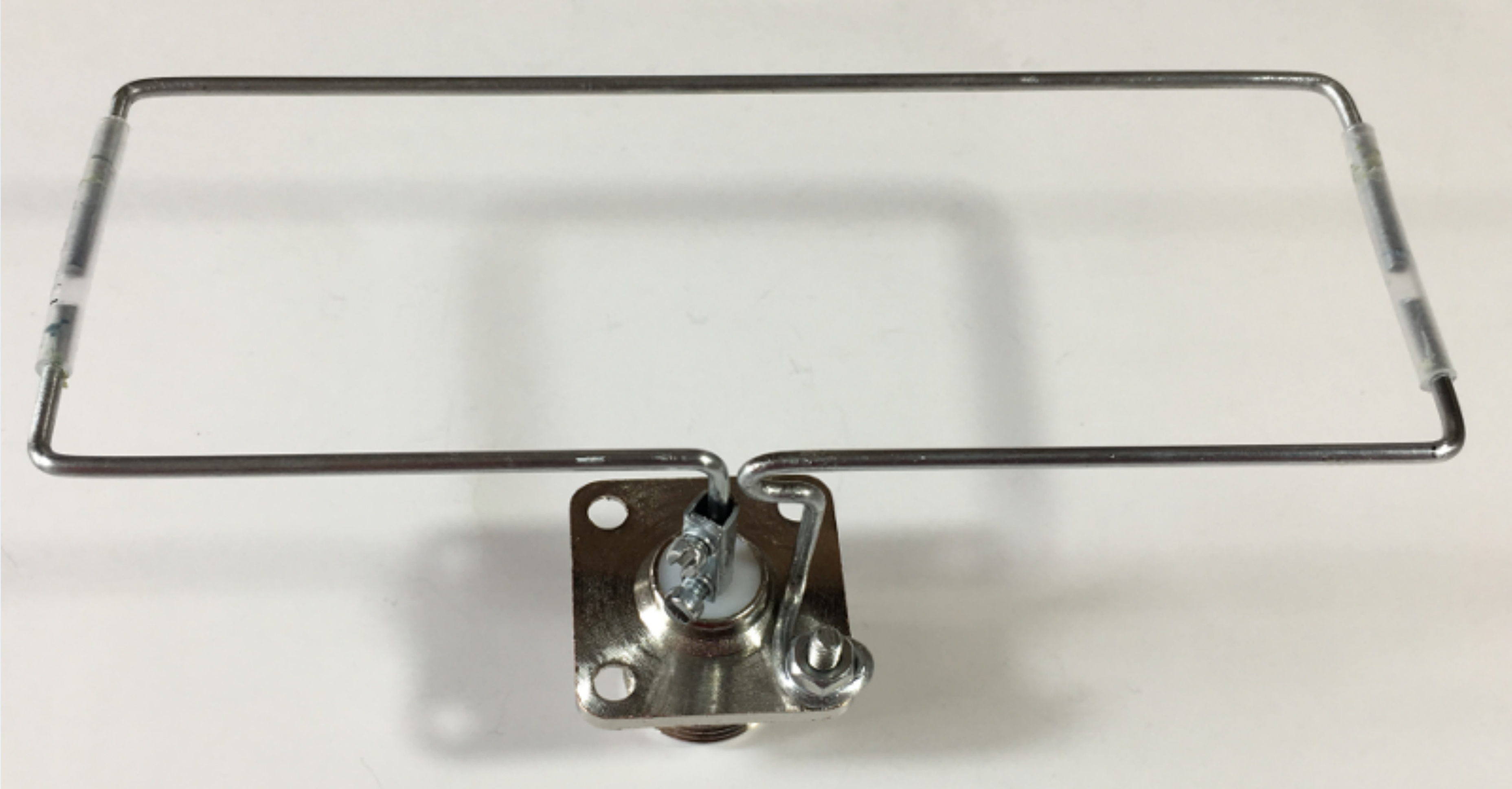
Do not make the height too large.

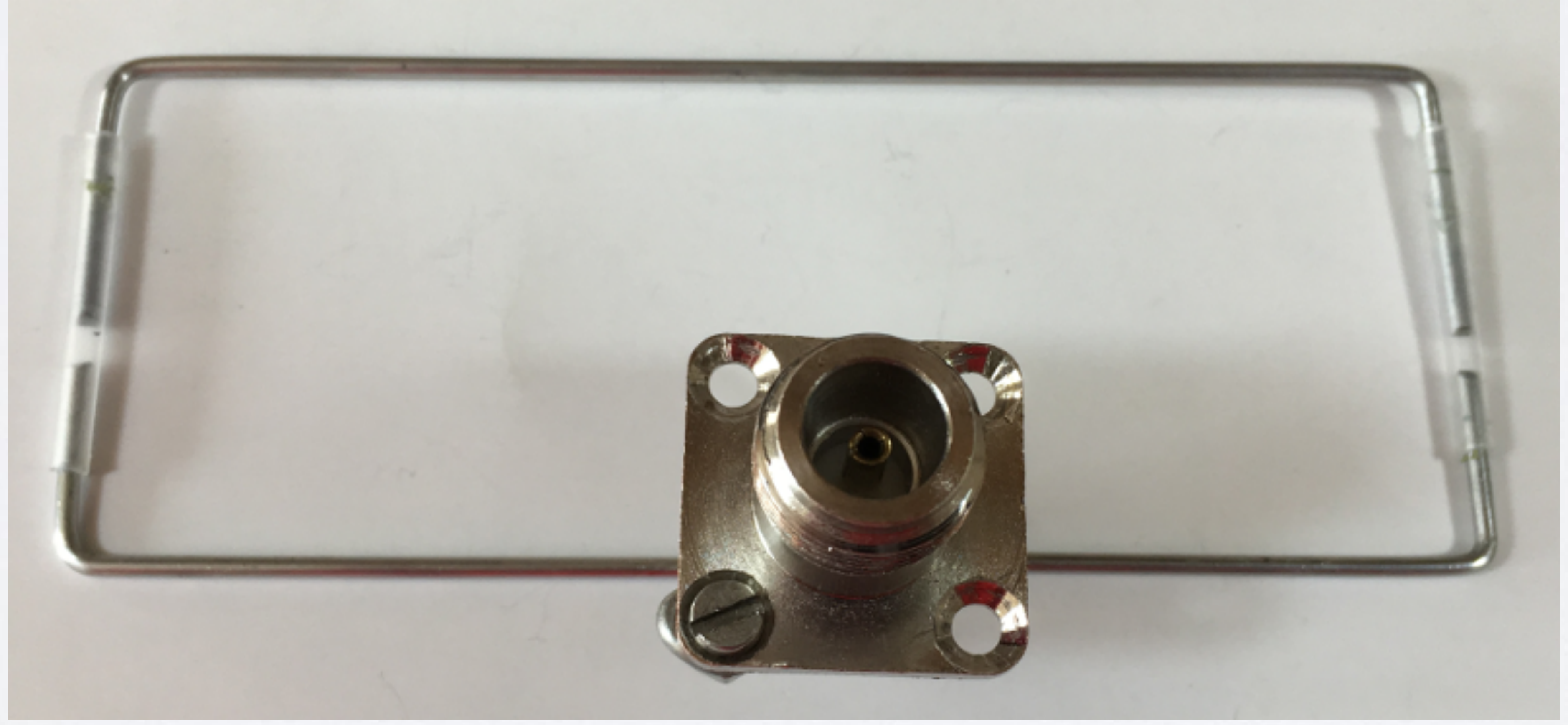
BUILD A MOXON ANTENNA

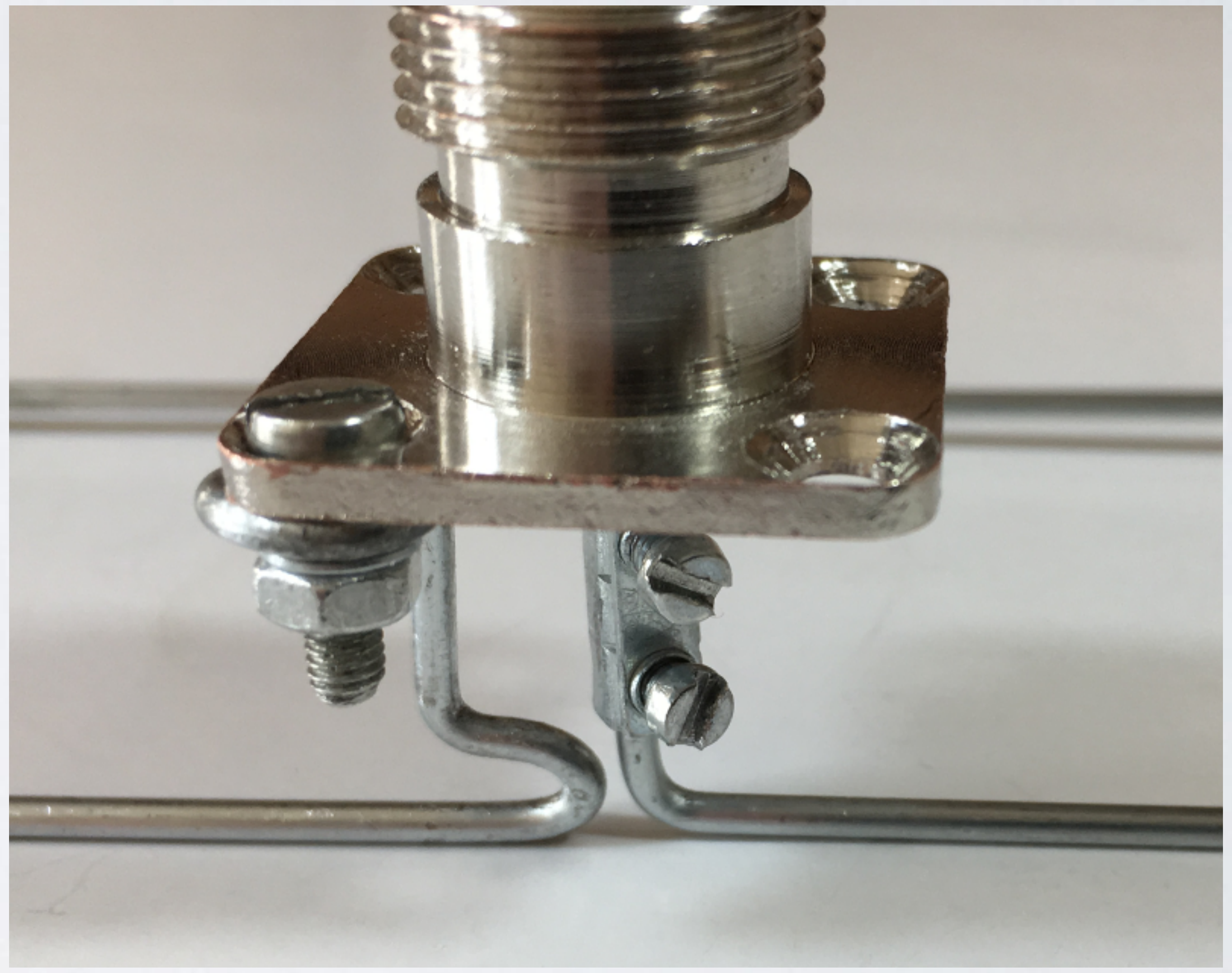


BUILD A MOXON ANTENNA



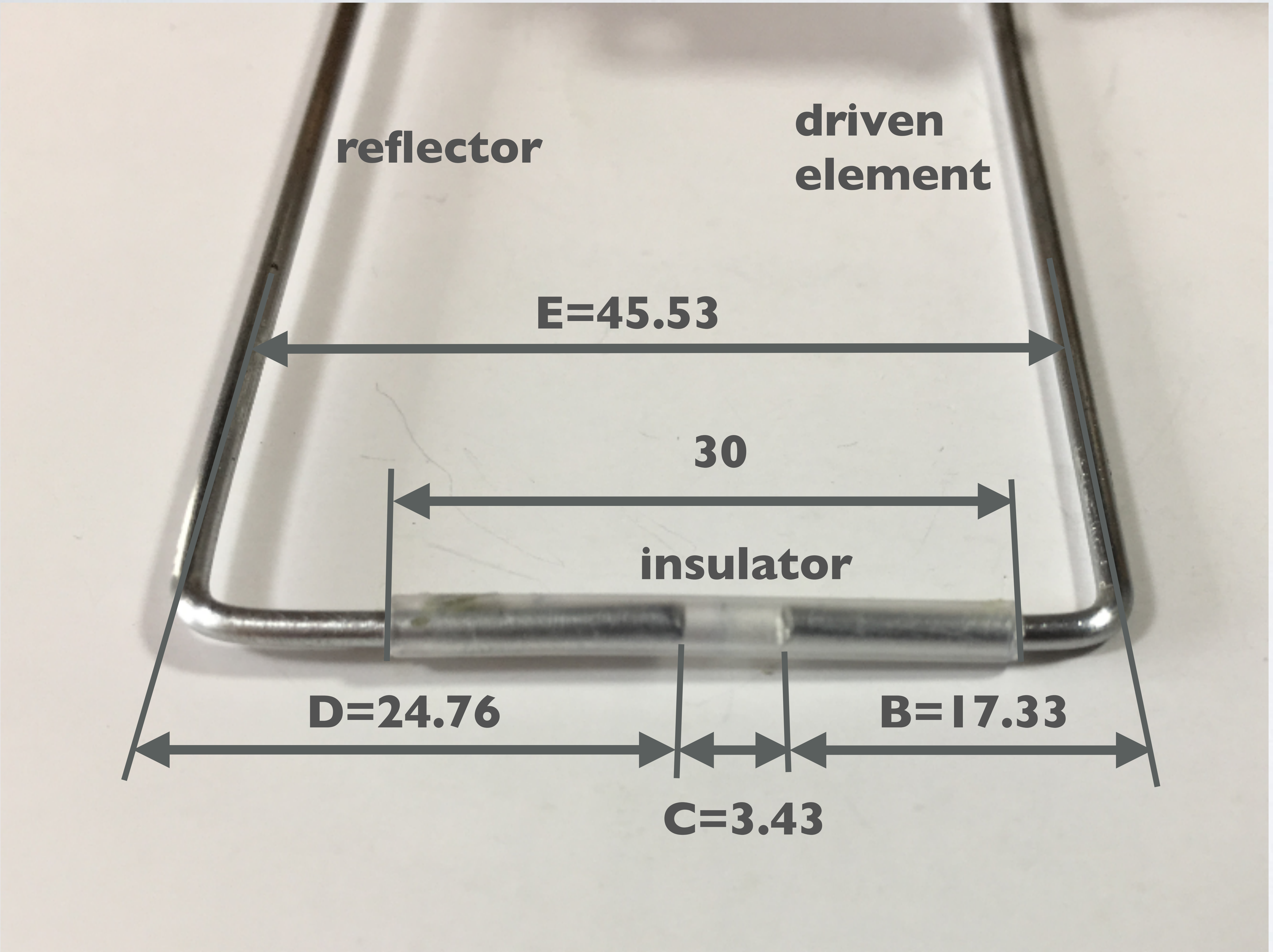






Attach reflector to driven element using insulators.

BUILD A MOXON ANTENNA



When using the antenna analyser the VSWR = 1.1

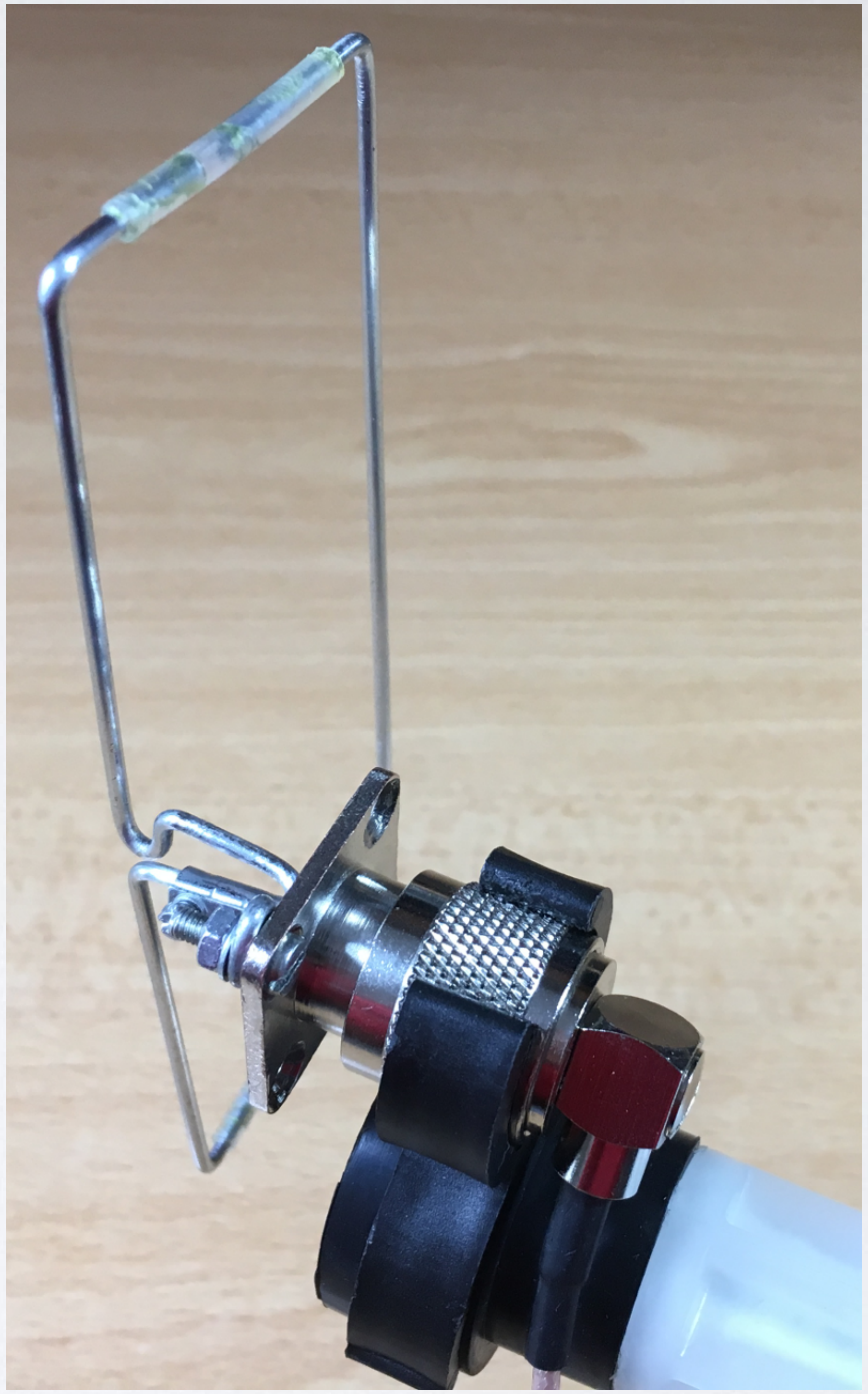
Use glue to attach insulator to reflector and driven element.

Units in mm

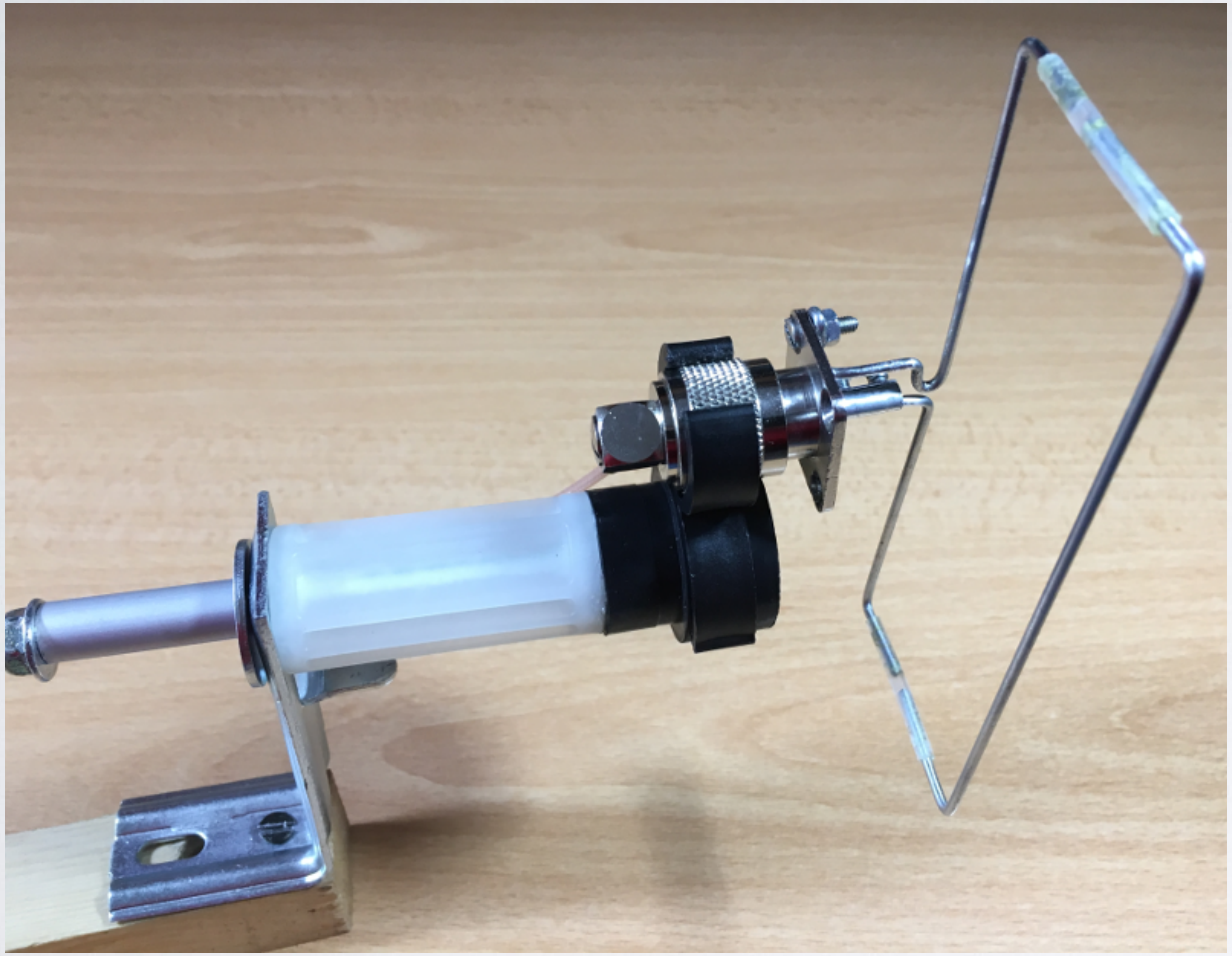
BUILD A MOXON ANTENNA

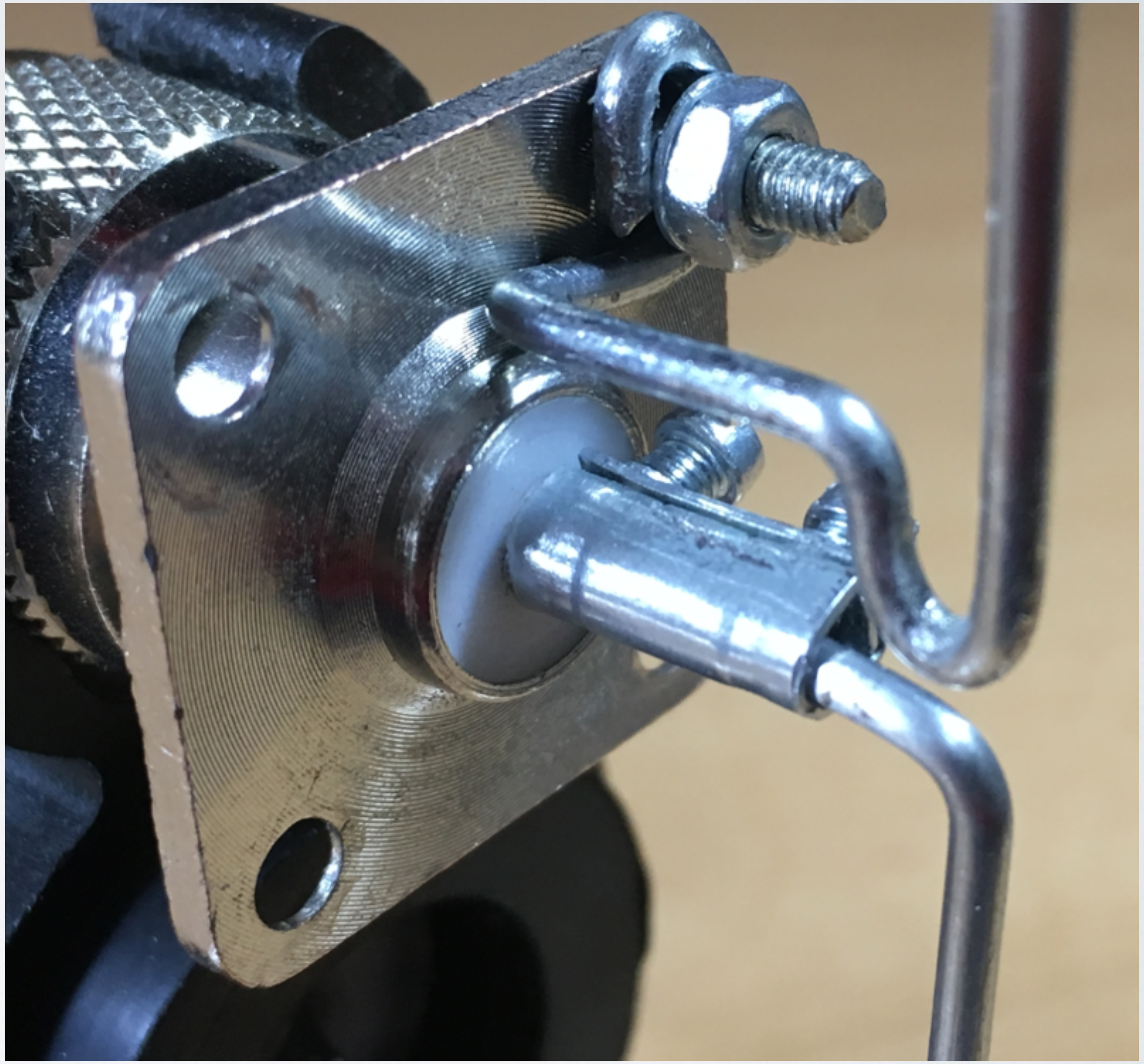
Bison Kit
Universal contact glue.
But this is not a good glue!
It does not glue to metal, for better attachment use a glue gun.

BUILD A MOXON ANTENNA

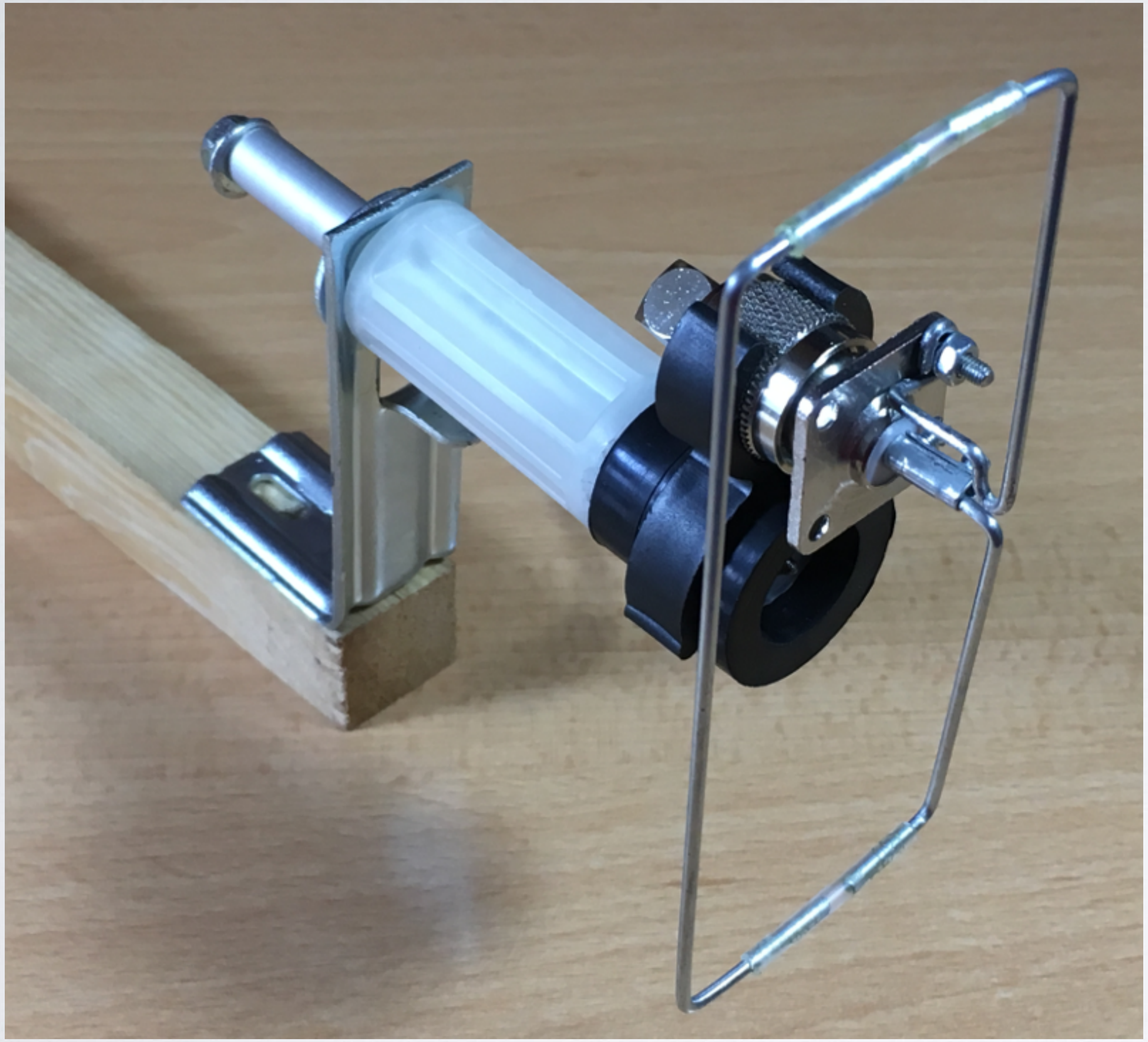


BUILD A MOXON ANTENNA





BUILD A MOXON ANTENNA

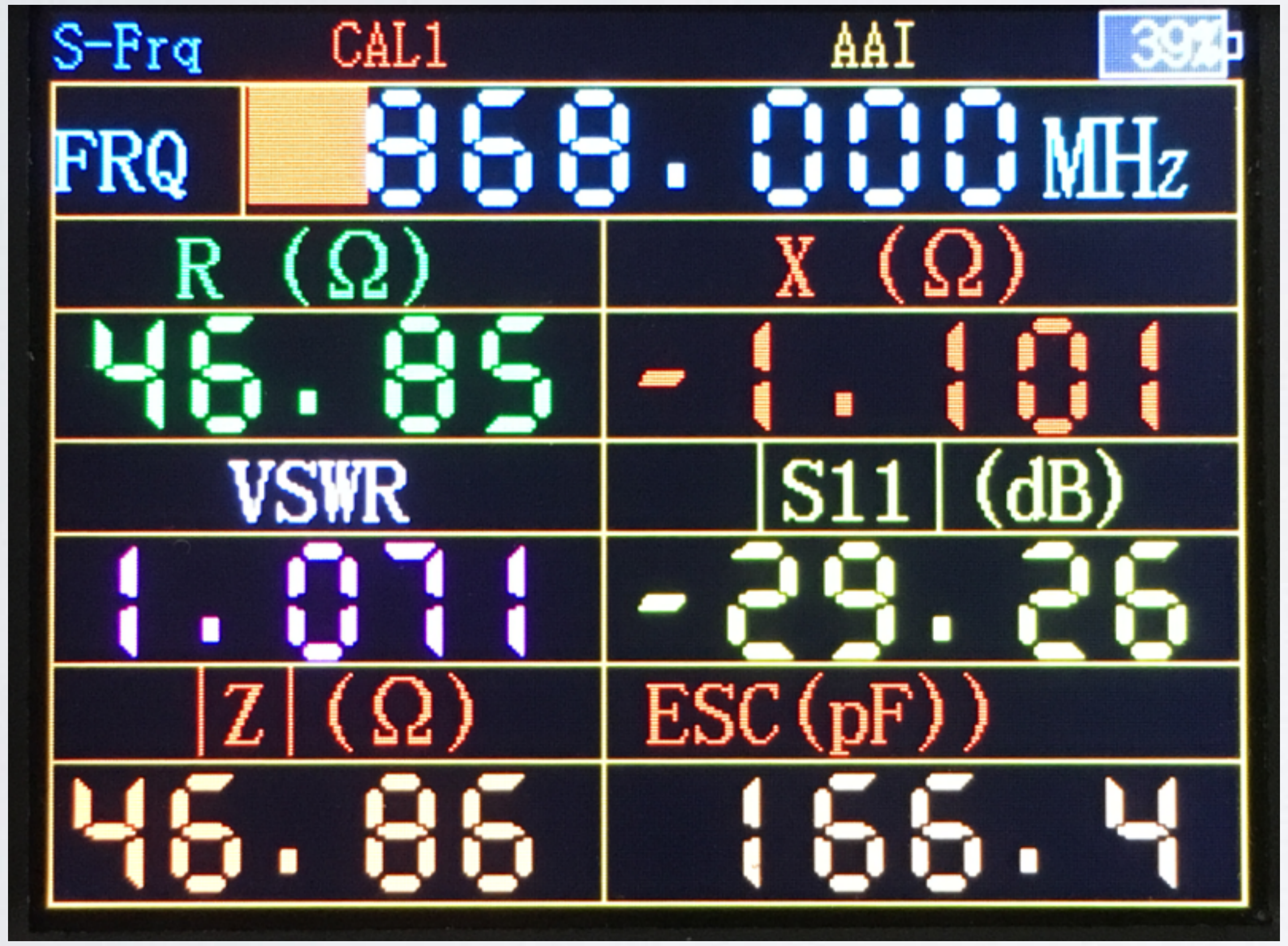


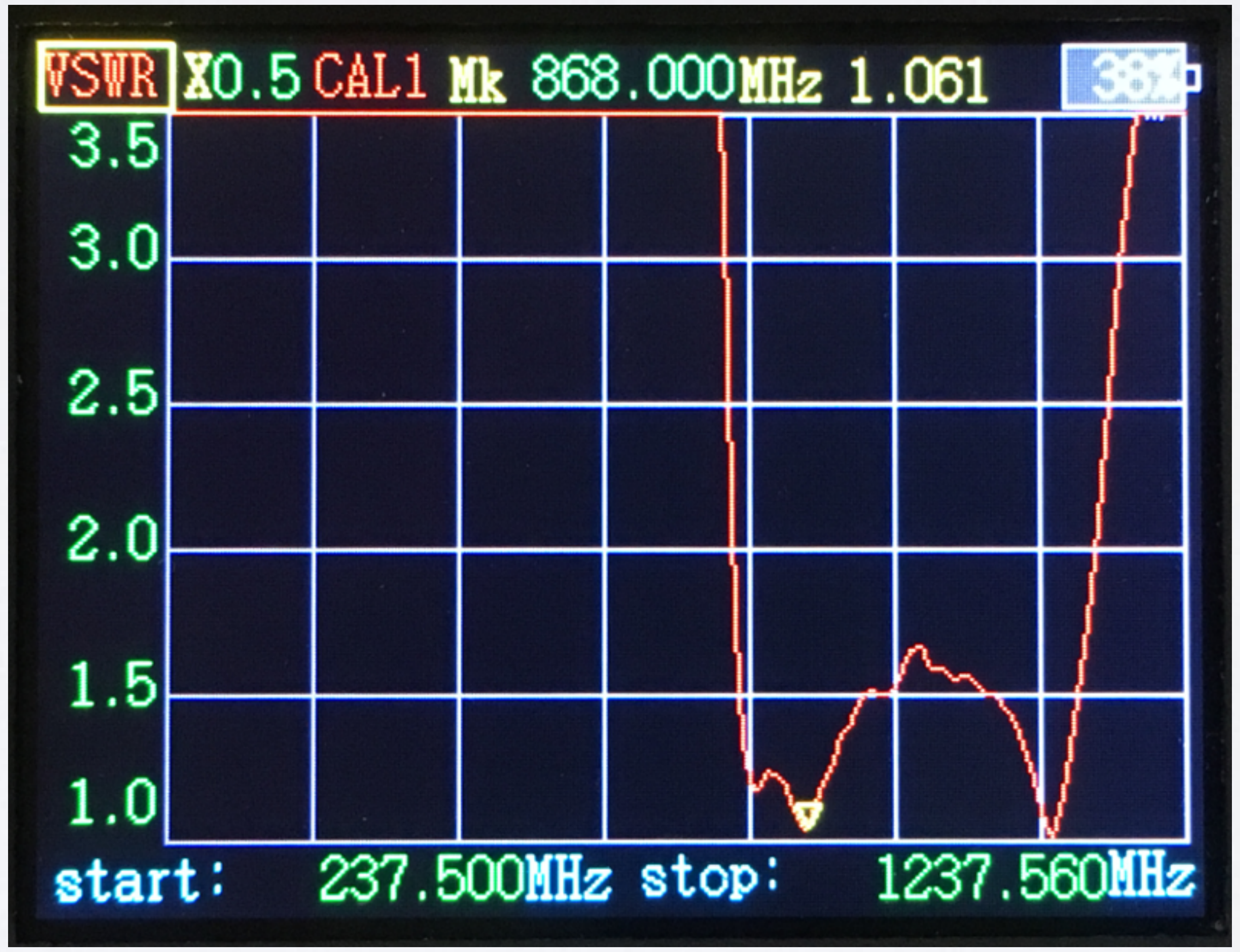
MOXON ANTENNA

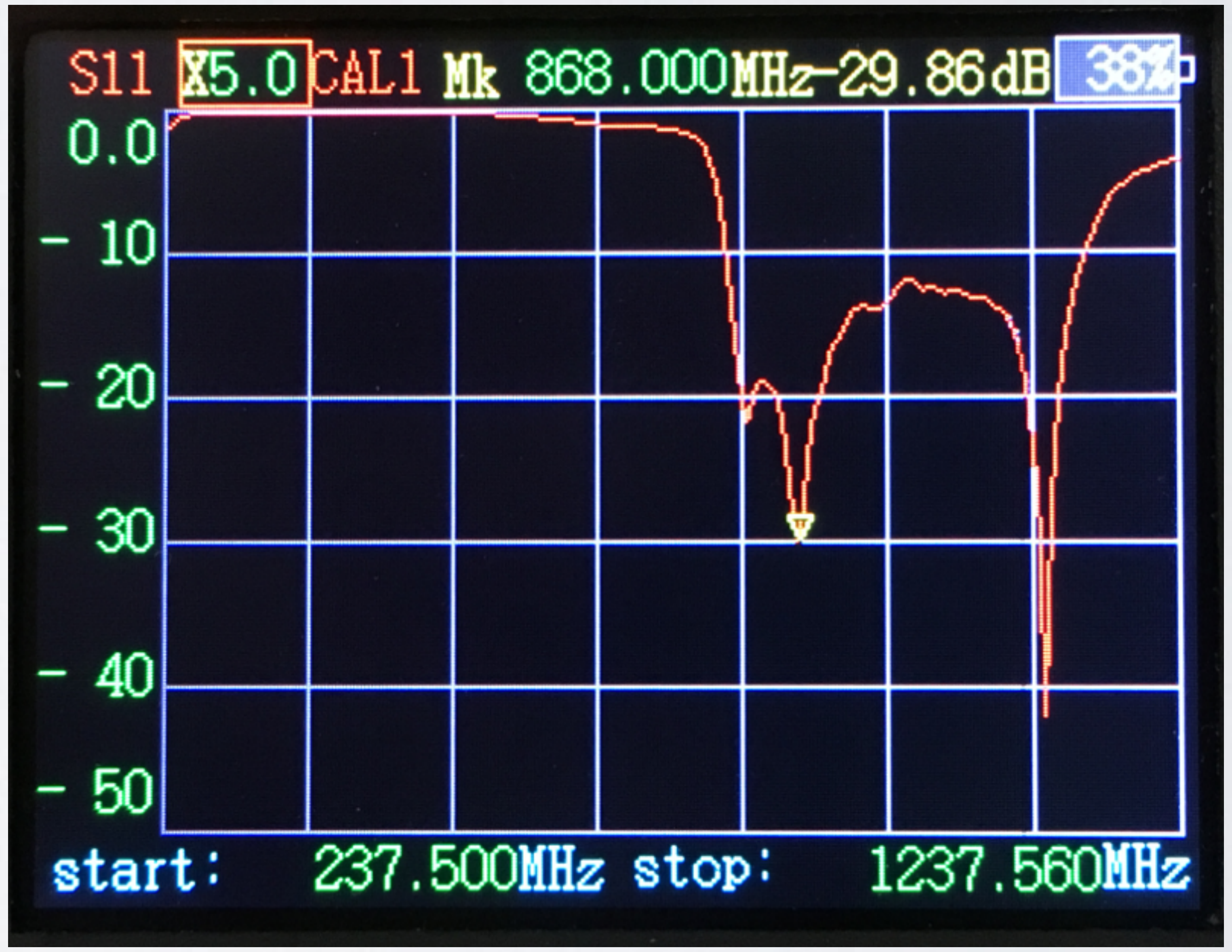
The antenna analyser with the Moxon antenna.

MEASURED ANTENNA PARAMETERS

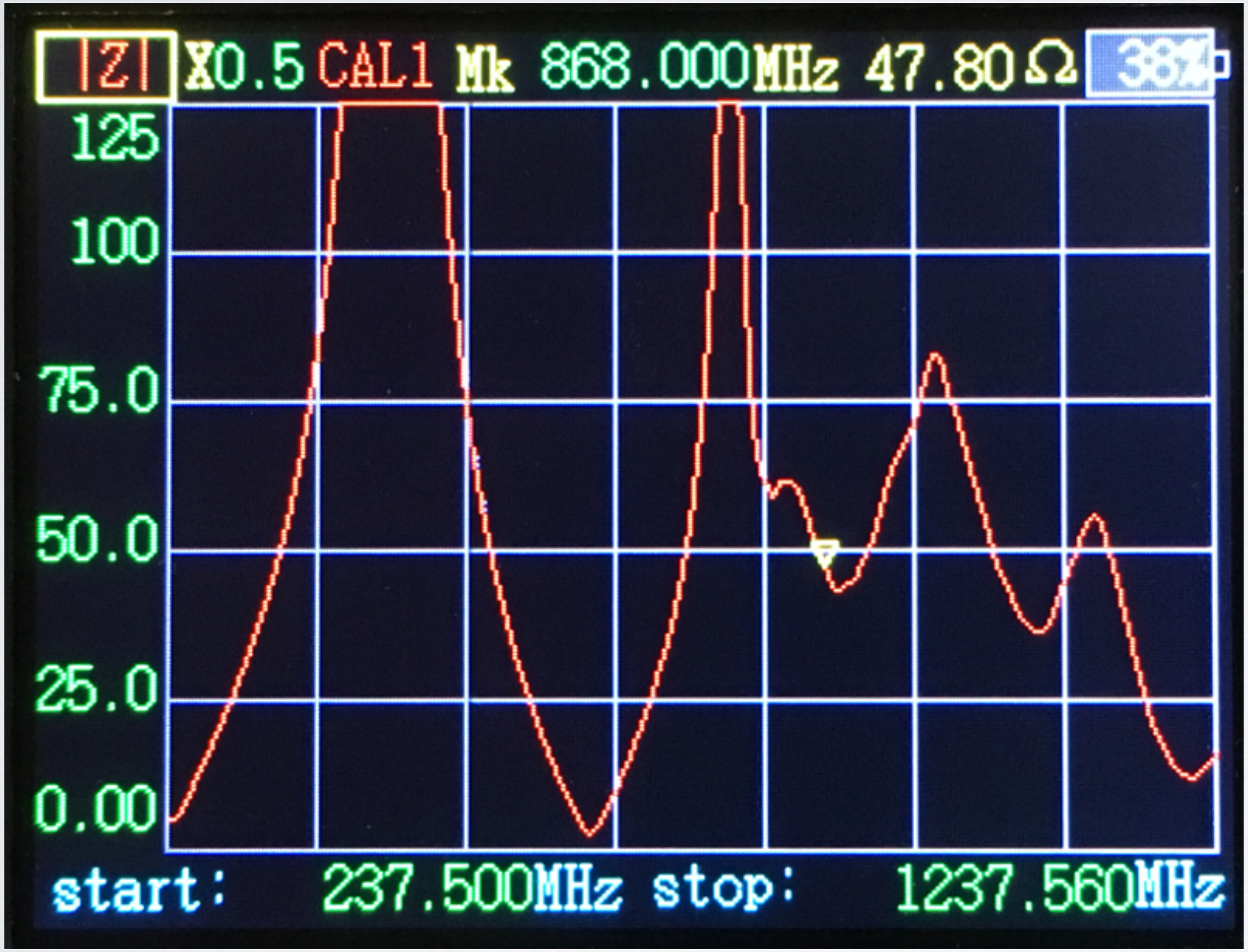
- Based on the Moxon design:
  VSWR ≈ 1.1 ← Good. It is < 2
  Z ≈ 47Ω ← Good. Should be approx. 50Ω
  S11 ≈ -29 dB







MEASURED ANTENNA PARAMETERS



ANTENNA PERFORMANCE TESTS

- How well does my self build Moxon antenna performs? To answer this question, two performance tests will be conducted.

- **Performance test A**:
  The Moxon antenna is attached to an end node, which is located inside a building, and transmit messages which will be received by nearby gateways in my area.
  In this test I am only interested which gateways were able to receive the transmitted sensor data. The test will be repeated using a sleeve dipole antenna.

- **Performance test B**:
  The Moxon antenna is attached to an end node and transmit messages which will be received by a dedicated gateway 6 meters away. Both devices are indoors.
  The average RSSI is calculated.
  The test will be repeated using a ½λ dipole antenna.

ANTENNA PERFORMANCE TESTS

- Performance test A and B are simple tests and will give me a **ROUGH INDICATION** how well my antenna performs compared to the dipole antenna.

- Both tests are conducted indoors which means the walls reflects the transmitted signals thus influencing the measurements.
  Therefore take the results with a grain of salt!

- A much better method to tell how your antenna actually performs in the real world, see this procedure: https://github.com/LoRaTracker/AntennaTesting

PERFORMANCE TEST A

- The Moxon antenna performance is compared with a sleeve dipole antenna. More information about sleeve dipole antennas, see tutorial 43.

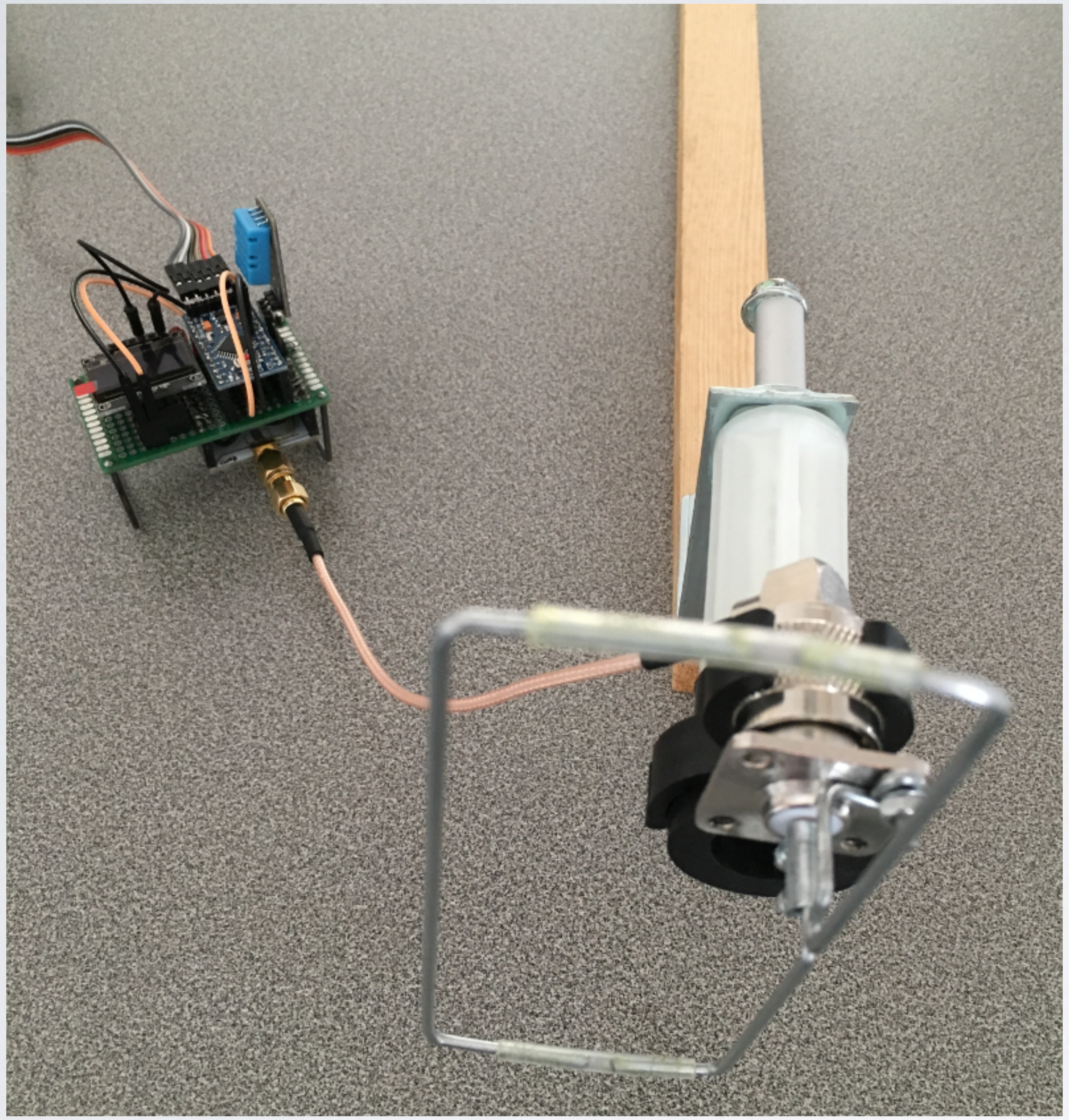
- For this test I am using the end node and antenna C as demonstrated in tutorial 33.

- More information about this end node, see: https://www.mobilefish.com/developer/lorawan/lorawan_quickguide_build_lora_node_rfm95_arduino_pro_mini.html

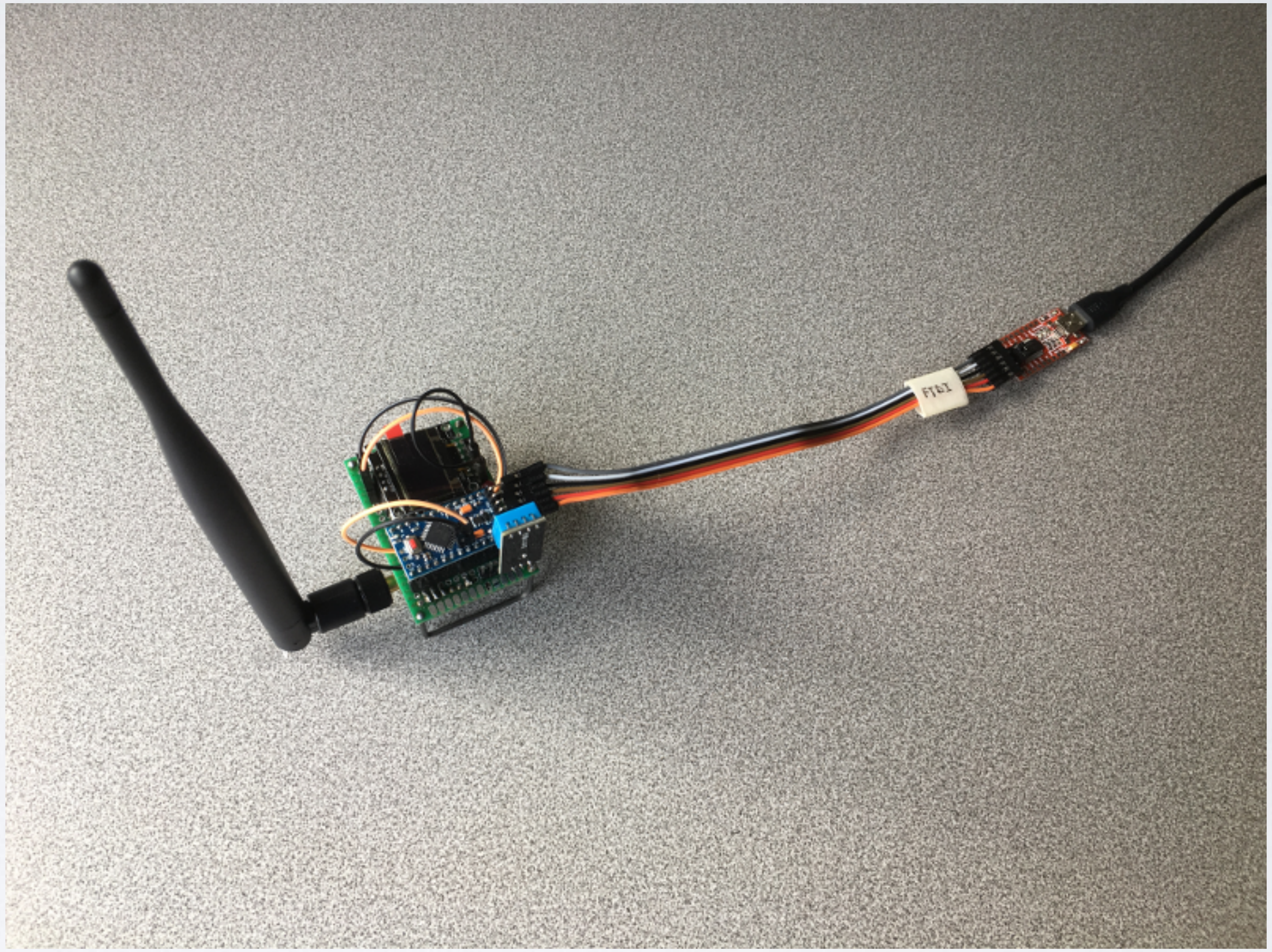
- The end node uses the MCCI LoRaWAN LMIC Library: https://github.com/mcci-catena/arduino-lmic

- The end node uses the following sketch: https://www.mobilefish.com/download/lora/ttn-otaa-pro-mini-sensors.ino.txt

PERFORMANCE TEST A

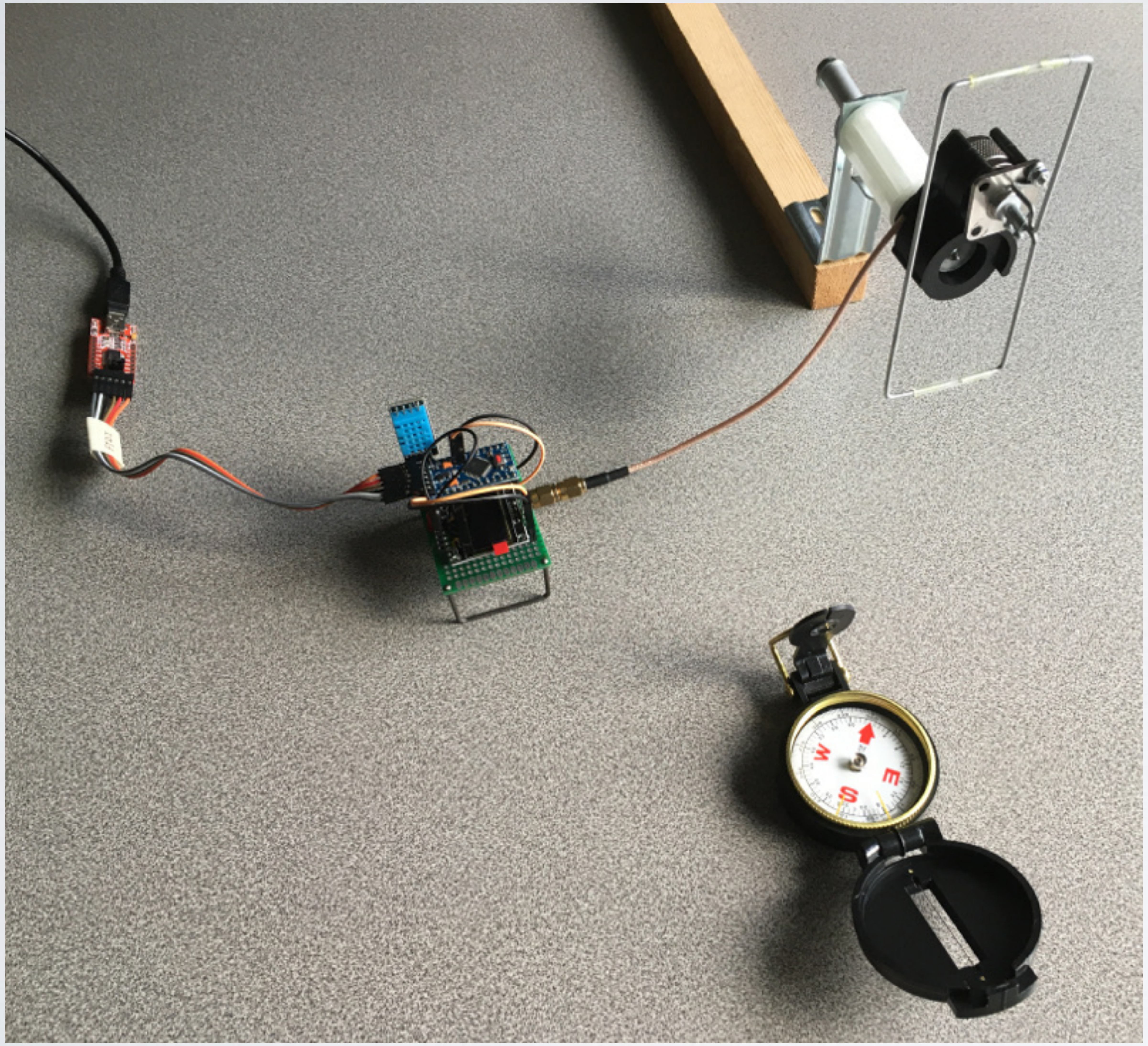


Moxon antenna + end node



Sleeve dipole + end node

PERFORMANCE TEST A



Use a compass to point the Moxon antenna to different directions.

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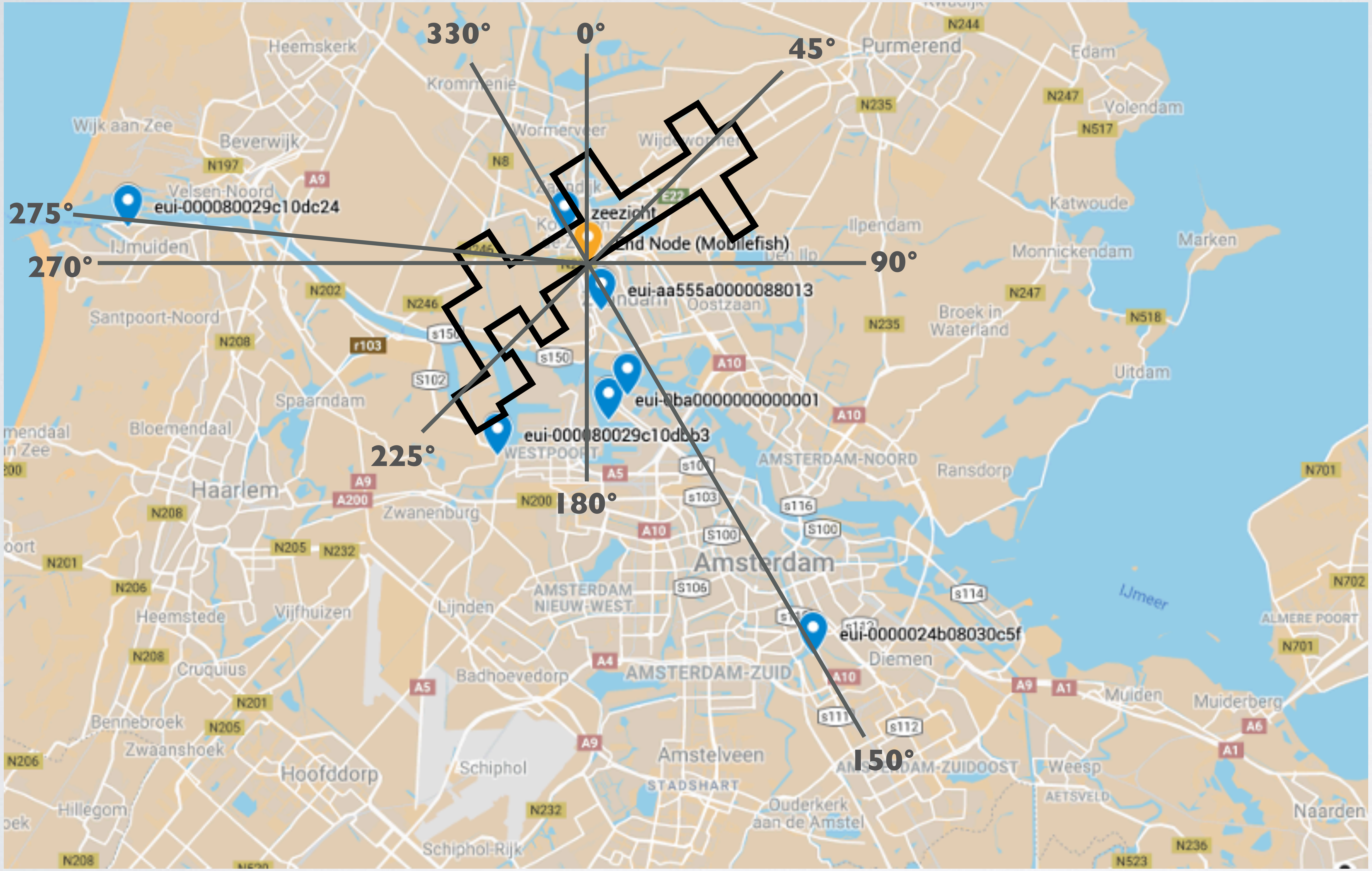
ANTENNA TEST SETUP



The building circumference.

The end node is placed inside the building in front of a window.

Two end node locations:

Location A, facing East and South. Altitude = ~11m

Location B, facing West and North. Altitude = ~11m

PERFORMANCE TEST A

- I have NOT modified the end node transmission power when using the Moxon antenna.

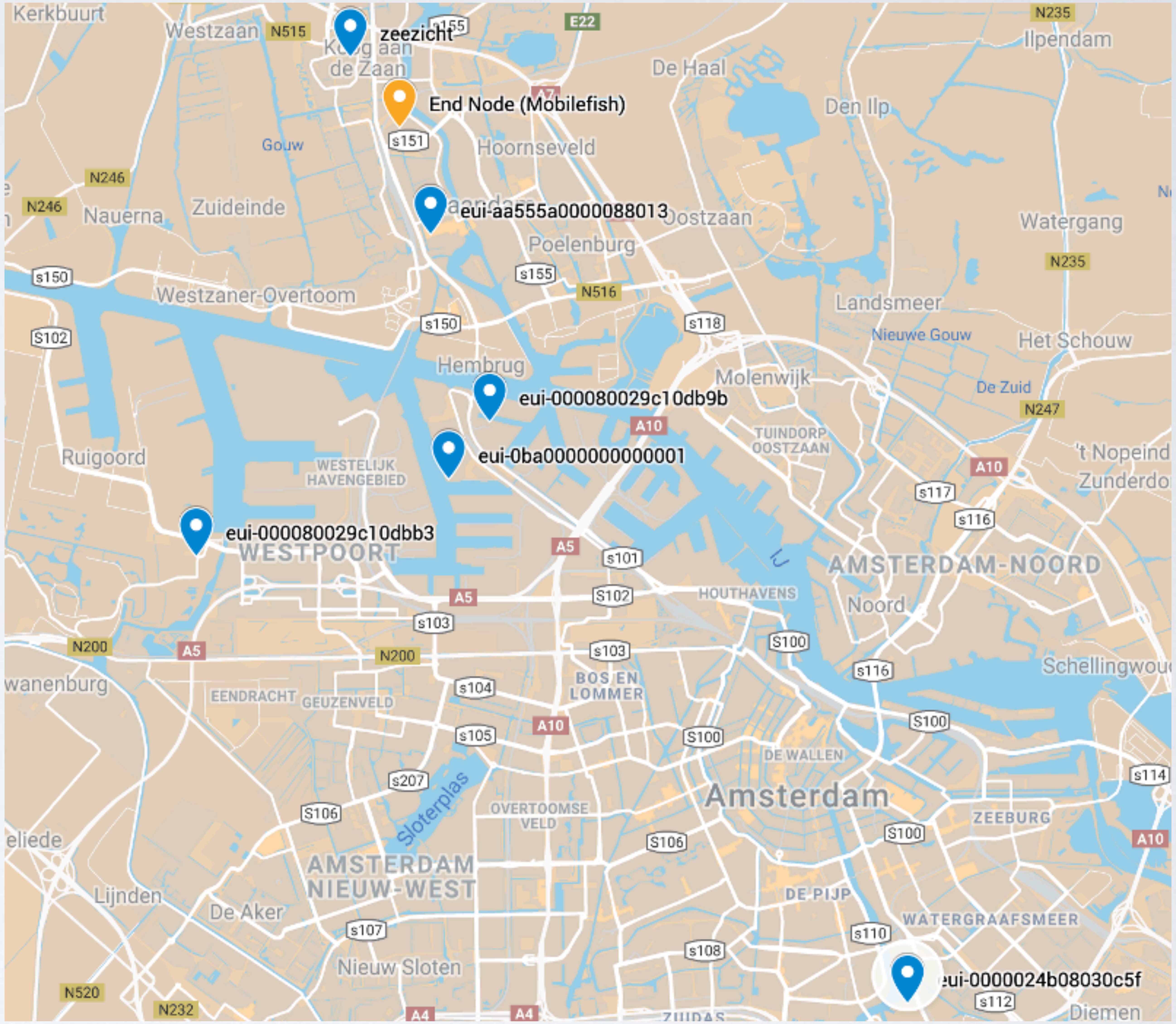
- In my area there are several gateways and I know that these gateways, which are connected to The Things Network, can receive my transmitted data.

- The Moxon antenna is attached to the end node at location A and transmits data.
  I have done the same with the sleeve dipole antenna.
  In both cases two messages per minute were transmitted.

- Both logged data can be found at:
  https://www.mobilefish.com/download/lora/moxon_test_results.txt

ANTENNA TEST RESULTS

- One or more gateways were able to receive my transmitted sensor data, see: https://drive.google.com/open?id=18SKbHVEIFHU6YjzYpgZL98vuHcmV4OPQ&usp=sharing



PERFORMANCE TEST A

- End node tx power = 14 dBm
  Data from: moxon_test_results.txt

Gateway	Distance from end device [km]	Altitude [m]	Sleeve dipole	Moxon
eui-7276ff000b031ebb	0.73	38		
eui-7276ff000b031d87	11.3	30		
eui-dca632fffe43df3e	0.458	10		
eui-000080029c10dc24	14.7	45		
eui-0ba0000000000001	5.03	20		
eui-aa555a0000088013	1.57	42		
eui-000080029c10db9b	4.36	30		
eui-60c5a8fffe760e60	4.15	30		

The Moxon antenna was pointed to different directions.

Green = Gateway has received the transmitted sensor data.

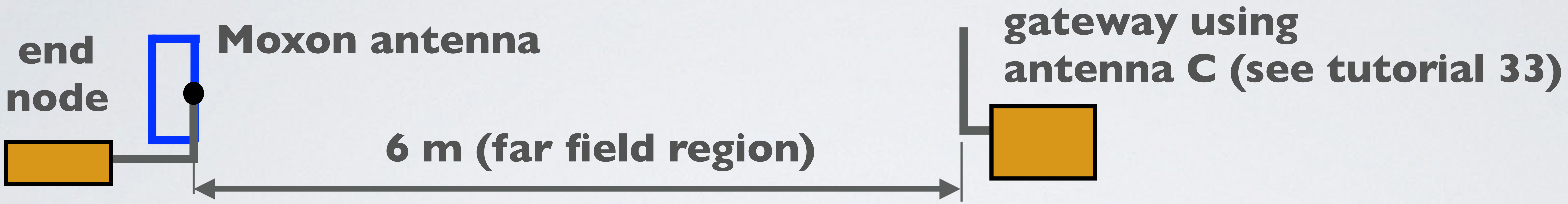
PERFORMANCE TEST B

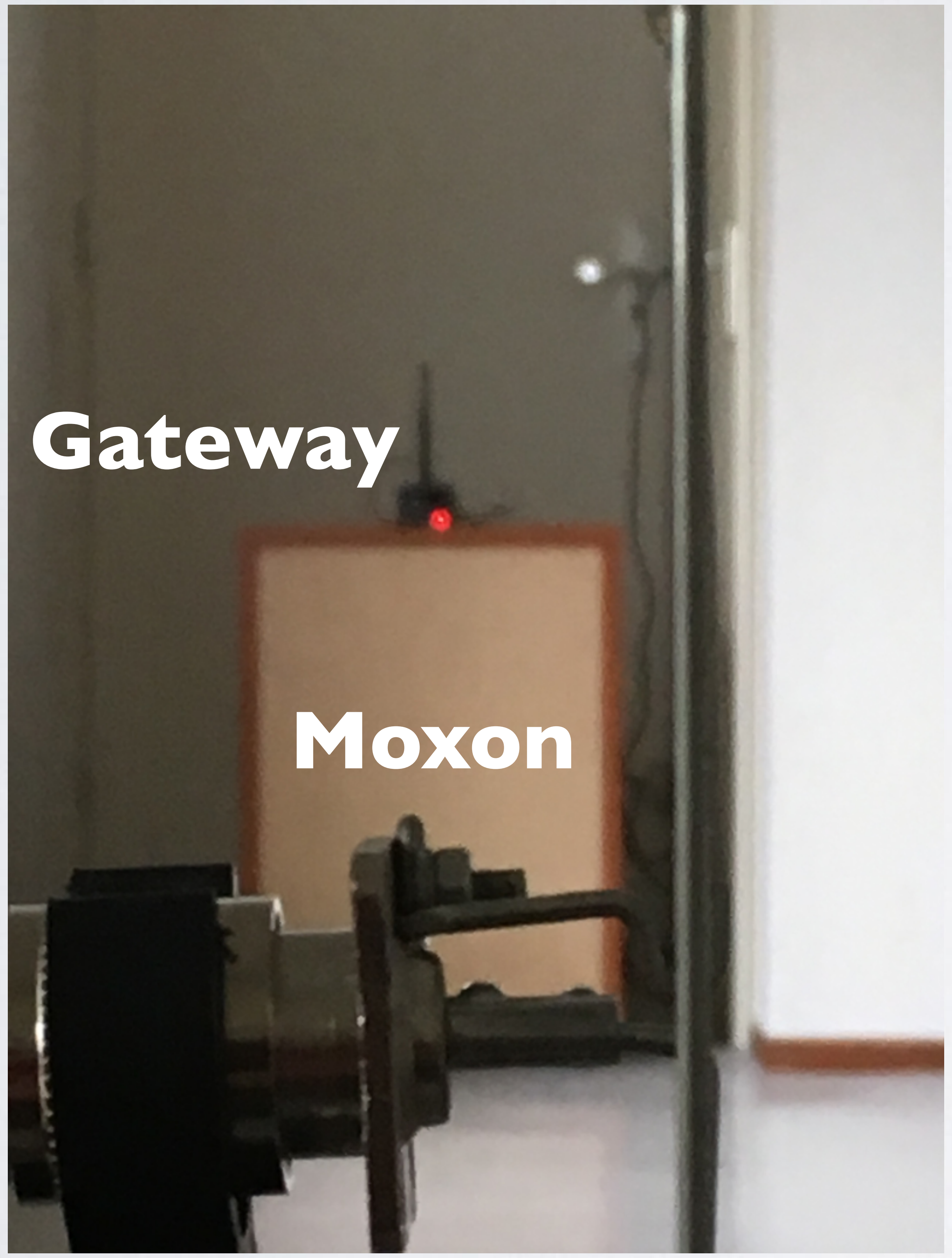
- Make sure you keep everything in your setup the same when switching from the Moxon antenna to the ½λ dipole antenna.

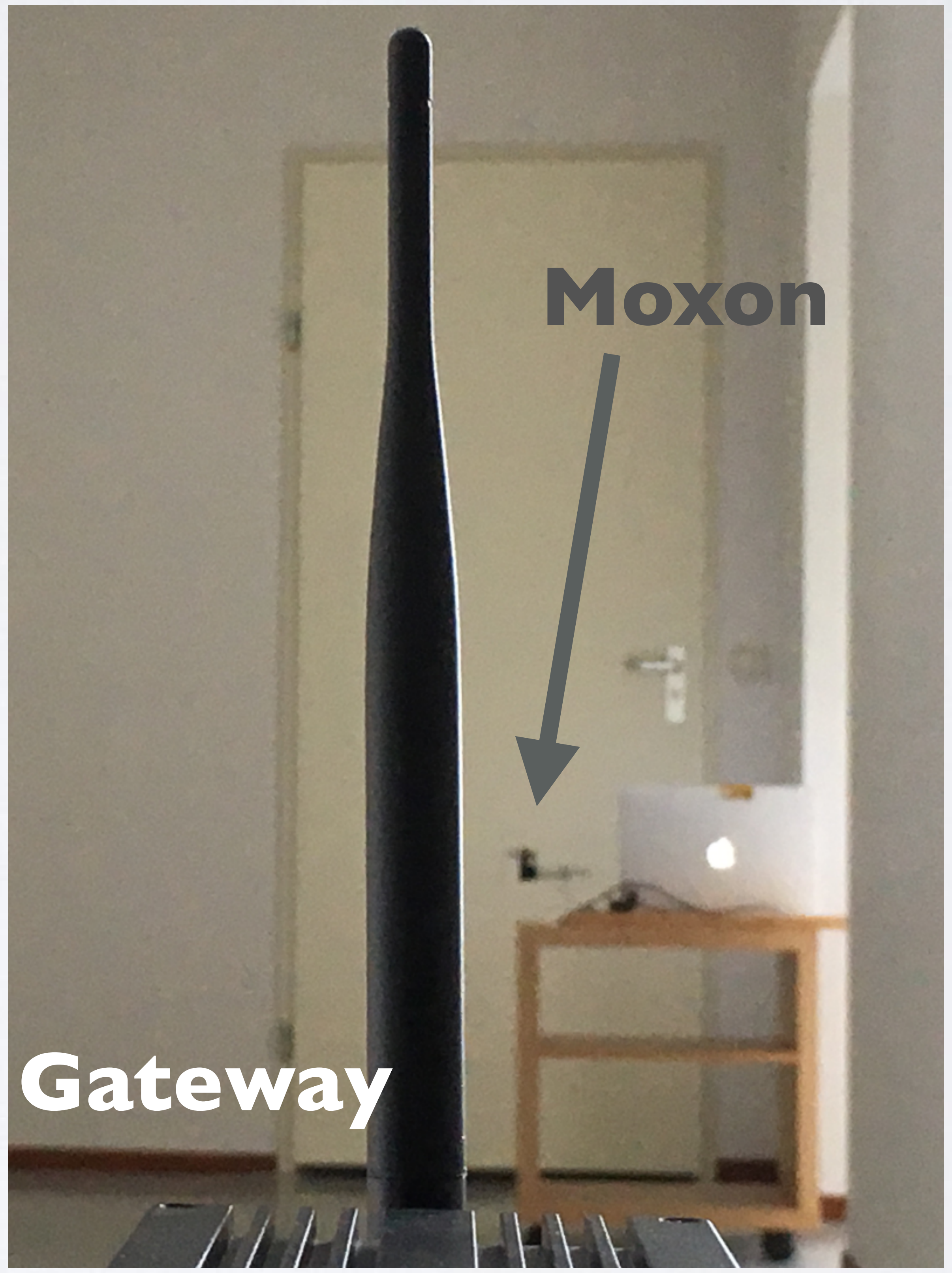
- A slight change can impact your measurements.

- - Do not change the height of the end node and the height of the gateway.
  - Do not change the distance between end node and the gateway.
  - Use the exact same end node and gateway.
  - Use the same coax cables and connectors.
  - During the measurements I did not stay in the same room.
  - The distance between transmitter and receiver should be > 4λ (Far field region)
    More information about near and far field, see tutorial 34.

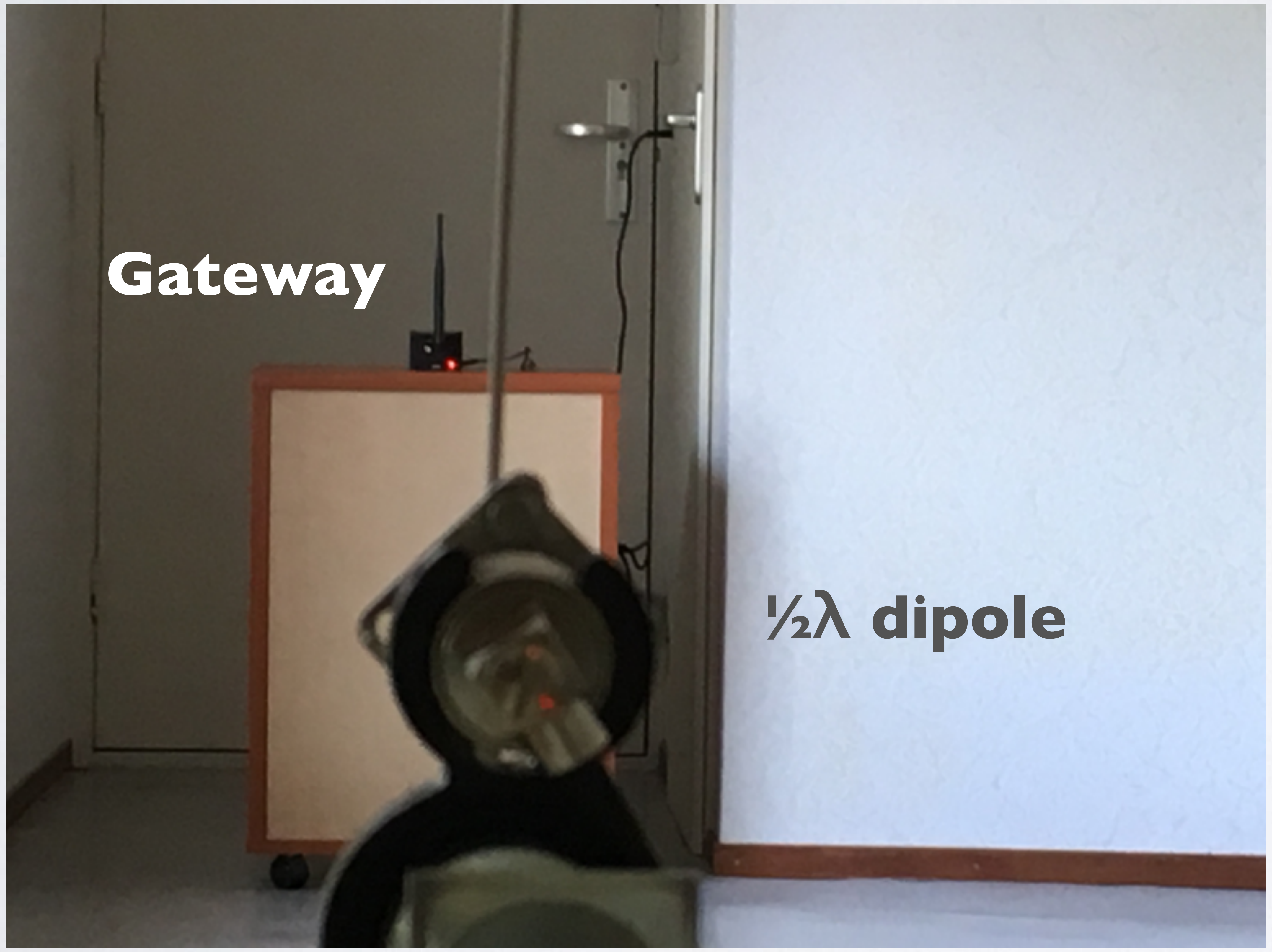
PERFORMANCE TEST B





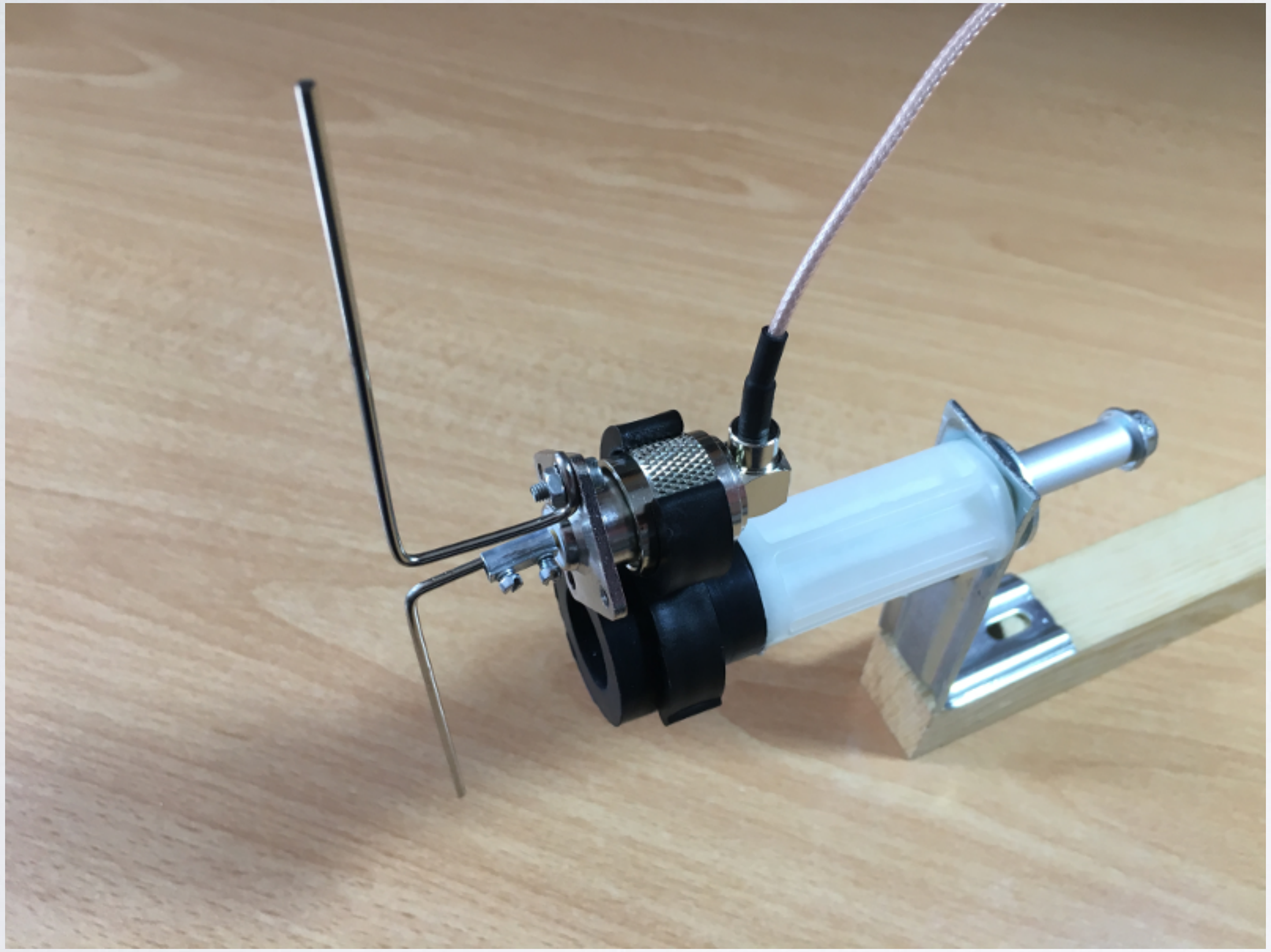


PERFORMANCE TEST B



PERFORMANCE TEST B

- This ½λ dipole antenna is used in this setup, see tutorial 41.



VSWR ≈ 1.1
Z ≈ 54Ω
S11 ≈ -27 dB

PERFORMANCE TEST B

- The logged data can be found at:
https://www.mobilefish.com/download/lora/moxon_antenna_gain.txt

- In both cases one message per minute were transmitted.

- The average RSSI when using the ½λ dipole antenna: -26.5 dBm
The average RSSI when using the Moxon antenna: -22.2 dBm

CONCLUSION

- Based on the average RSSI test results and the results from performance test A, the Moxon antenna performs better compared to the sleeve dipole antenna.
  …but…
  the Moxon antenna is a directional antenna, you need to point it to the correct direction. The sleeve dipole antenna is an omnidirectional antenna.