

Single Pole Antenna

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1.Introduction

Building a single pole antenna the most important step.

User will learn how to calculate ideal antenna then tune it to fit the real world condition. Such skill will later be used to build the dipole antenna (himself the base for a Yagi antenna).

The single pole antenna will then be expanded with an artificiel ground plane.

The single pole antenna with ground plane is used within the CanSat. Such antenna was tested to successfully transmit data over 4 Km.

Remarks

1.All antennas will be tuned with a VNA tool (eg: NanoVNA). Make sure you did read the chapter on VNA.

2.This chapter explains how to built antenna, not how to pack them into the CanSat.

2.Quarter Wavelength

Quarter wavelength antenna is the most simple to built.

It is reduced to a simple straight piece of wire pointing to the sky.

Its length is important to transmit a maximum power to the air. Too long or too short will reflect a part the power toward the emitter.

The great new about quarter wavelength is that an antenna cut near of the theoretical length will already offers some significant results but not over a large distance.

2.1.Presentation

Let's built two demonstration antennas with some salvaged material. The emitting element of one antenna will be made with stranded wire, the other with brass tube.

Unfortunately, the ordered connectors takes weeks to get delivered. As a consequence, connectors were salvaged from existing device to start testing antenna ASAP. That involves usage for RF-adapter with the VNA to perform the required measurement.

At 433 MHz, the standard RF connector is SMA.

The **female connector** sits on the **emitter board**.



Fig: SMA Female (emitter side)

The **male connector** is on the **antenna side**.



Fig: SMA male (antenna side)

2.2.433 MHz theoretical length

For a quarter wavelength antenna ($\lambda/4$ antenna), the final length must be divided by 4. This is why the formula contains a 4 at the denominator member.

$$L = c / (4 * \text{freq})$$

where:

- L is the length in meters
- C is the speed of light (in meter/sec).
- Freq is the frequency in hertz

For a 433 MHz antenna, the length is calculated like the following:

$$L = 300 * 10^6 / (4 * 433 * 10^6)$$

$$L = 0,1732\text{m}$$

$$L = 17,32\text{cm}$$

The theoretical length for a 433 MHz $\lambda/4$ antenna is 17,32cm.

2.3.Antenna 1 build

A RP-SMA connector was salvaged from a WiFi antenna. RP-SMA is used for higher frequencies (> GHz) where SMA is used for lower frequencies (like our 433 MHz antenna).

So measurement with VNA will involves RP-SMA-to-SMA adapter.

As shown on figure 1, only the core wire is made available on the connector (the ground braid is protected under shrink sleeve).



Fig 1: RP-SMA female connector salvaged from WiFi antenna

The stranded wire is cut at theoretical length then solder on the central wire of the connector.

A single copper wire can also be used. Initial length and tuning steps will stays the same.

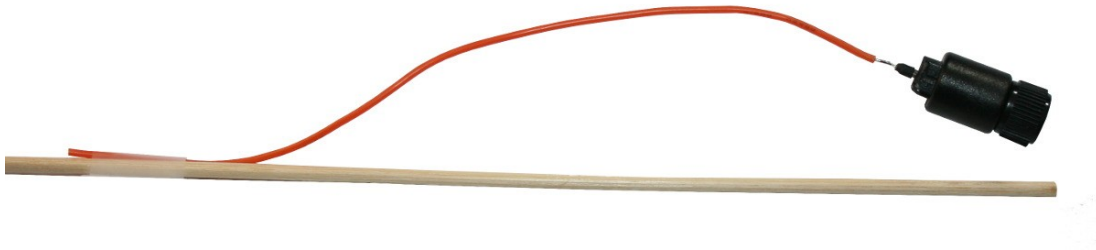


Fig 2: wire soldered on the connector

A piece of wood is used to keeps the wire as straight as possible during measurements.

Thank to a RP-SMA-to-SMA adapter, the antenna can be connected on the port 1 of the VNA measurement unit.

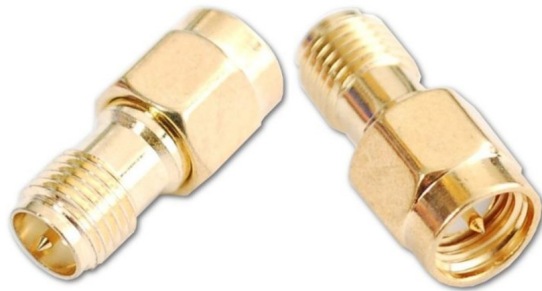


Fig 2b: example of RP-SMA-to-SMA adapter

2.4.Tuning antenna 1

Step 1: get closer

The initial measurement is a LOGMAG performed over the full measurement range.

As shown on the figure 3, the cursor is placed into the first signal fall. The current antenna frequency is 330 MHz with -23 dB (excellent, almost all the power is sent to the air) but **frequency is wrong!**

Moving cursor to 433 MHz is near of 0 dB meaning that all the power is return to the emitter (and may destroy it).

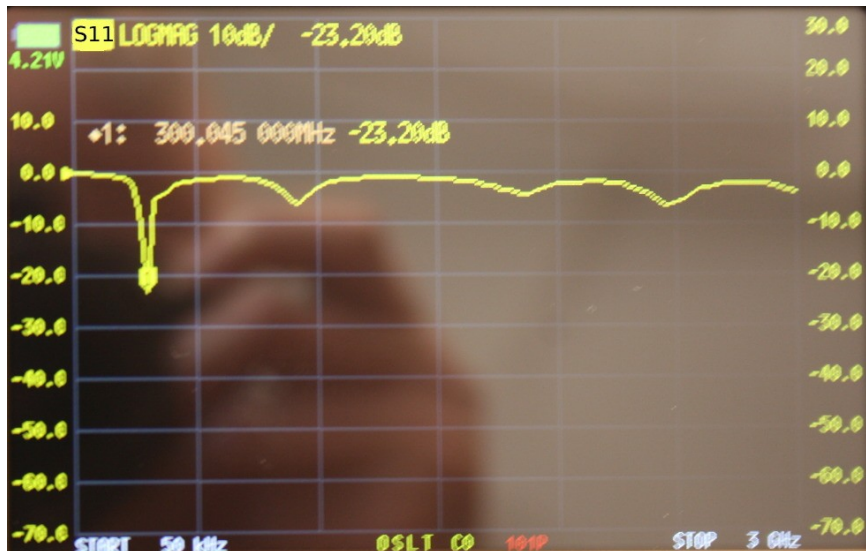


Fig 3: first LOGMAG measurement

Higher is the frequency and shorter the emitting element must be. As the frequency is lower than 433 MHz that means that emitting element is longer that the one for 433 MHz. We can shorten the wire.

Pick a diagonal cutter and cut a snip of wire at the end of antenna. The resonant frequency will move a bit to an higher frequency.



Fig 4: reduce length of antenna

Repeat the cut and measure operation until the frequency get close from the 400-430 MHz target. Do not go over because the full range measurement is not precise enough.

Step 2: fine tuning

Let's say we reached a frequency closer to 400-430 Mhz.

Now, the VNA frequency range (STIMULUS) can **be reduced and calibrated** for a range of 400 to 440 MHz (or so).

Now restart the measurement of the antenna with the cut smaller snip and measure for the fall in the curve to get closer and closer of 433 MHz.

The following figure shows an intermediate tuning step from 250 MHz to 450 MHz with a current antenna resonance at 338 MHz (-16 dB).



Fig 6: shorter frequency range measurement

Remind:

- LOGMAG value below -10 dB is a good start, -15 dB or lower would be best.
- Closer of the target frequency, switching to SWR view may be helpful (see NanoVNA chapter). **The SWR view may quickly inform you when tuning reach an acceptable stage.** SWR 1.9 → 1.5 is acceptable, SWR 1.5 → 1 are really great.

2.5. Antenna 2 build

The second antenna was build with a SMA female connector (see figure 7). Such connector is used onto an emitter board to connect antenna onto it... so, once again, a connector converter will be required to make the measurements with VNA.



Fig 7: SMA Female (emitter side)

The piece of **brass tube (1.5 mm external diameter)** is cut at the theoretical length.



Fig 8: brass tubes

Using a tube is not a problem! Indeed, at higher frequencies, the current does travel on the external side of the material (not the center) because of the “skin effect”.

Using a tube will work properly!

Because brass is made with copper, such material **can be solder with tin**.

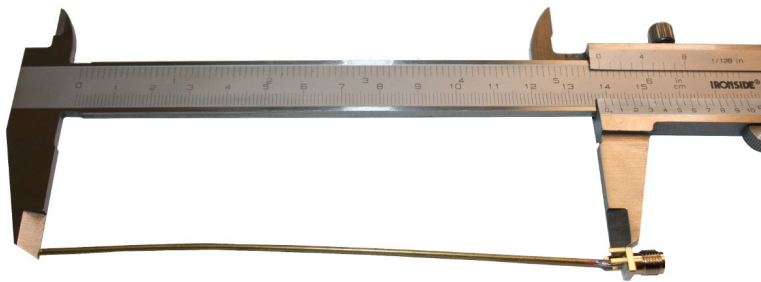


Fig 9: Solid wire solder on SMA connector

In this setup, the tube is soldered on the central pin of the SMA connector for tuning. Later, the tube can be un-soldered from the connector to solder it back on the final radio module.

2.6.Tuning antenna 2

The tuning procedure will be exactly the same as for the stranded wire.

The figure 10 below show that initial resonance frequency (the fall in LOGMAG) is set at 330 MHz. The resonance is 30 MHz higher with brass tube than with stranded wire. That clearly demonstrate that material and geometry does impact the antenna properties.



Fig 10: initial LOGMAG diagram of brass tube antenna

After tuning, **the final emitter element have a length of 13,4 cm**.

The antenna element can be de-solder from the connector then connected to the emitter board.

2.7.Common errors

When initially testing the antenna set, the results were not very amazing.

In my hurry I did completely forgot an elementary rule:

the emitting element must be perpendicular to the ground plane.



Fig 11: emitting element aligned with ground plane

The figure 11 here upper shows the emitting element solder on the emitter board.

The ground pads are visible on each side of the antenna solder spot. On properly designed PCB, a ground plane is usually used to connect all the GND points of the board and it should covers all the surface available between the traces. The ground plane is made of a thin layer of copper covering almost all the surface of the board (represented in violet).

Radio modules must be designed with ground plane!

For a correct assembly, the antenna (emitter element) should be mounted perpendicularly to the board. Communication would be quite better.

3. Quarter Wavelength with ground plane

3.1.Presentation

As the CanSat is flying in the sky, there is a lack of ground plane to balance the emitter element.

An efficient ground plane can be added to the emitter element (single pole). The ground plane is made with 3 additional elements positioned at specific positions and wired to the emitter ground.

- **Each ground plane element:** is longer of 5 cm compared to the real size of emitter element.
- **In horizontal plan:** each of the 3 ground plane elements must be positioned at 120° from the previous one.
- **In vertical plan:** each of the 3 ground plane element must be positioned at 120° from the emitting element (of 30° from horizontal plane).

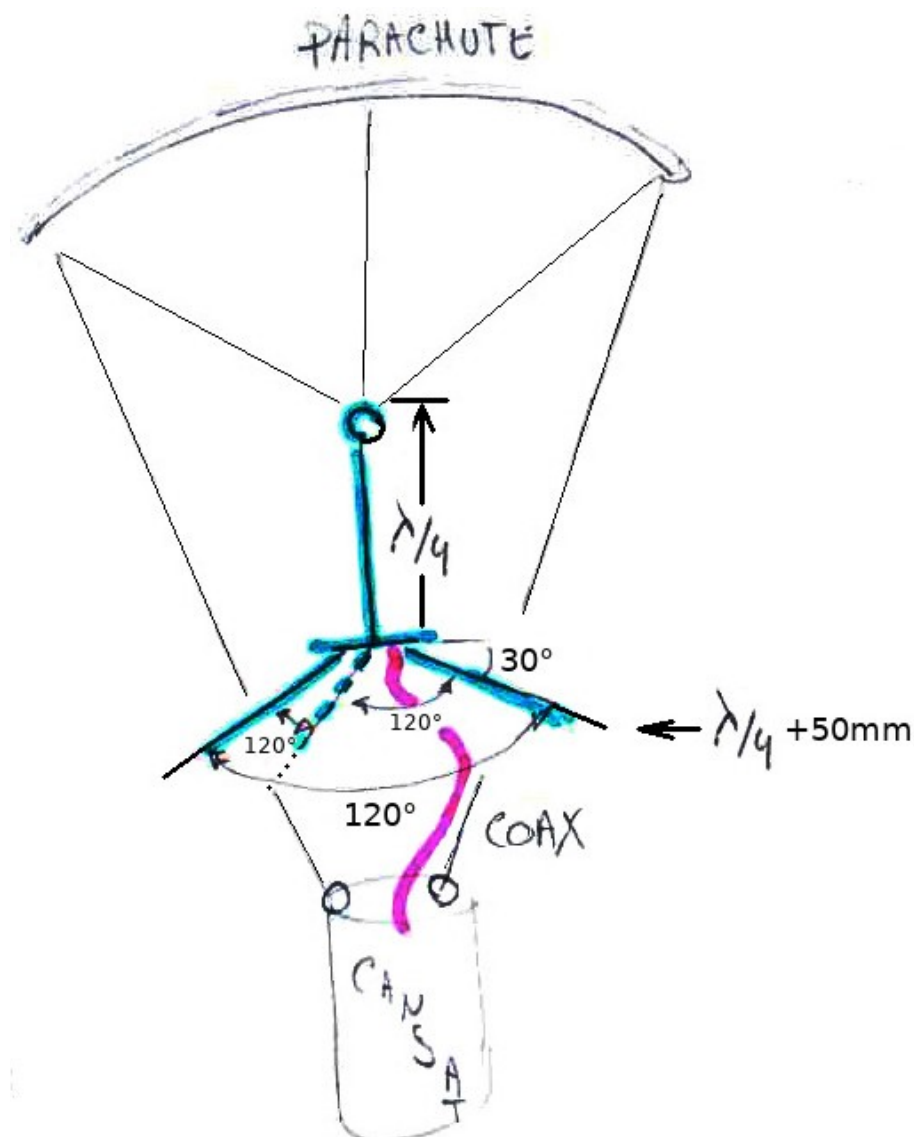


Fig 12: Emitter element + ground plane

According to radio amateur recommendations:

- The antenna should be placed under the parachute and **above the CanSat**.
- The emitter element can be made with stranded wire.
- The top of emitter can be terminated with an eyelet.

Warning: the eyelet is included within the length of emitter element! The antenna must be tuned with the eyelet.

3.2.Basic building

This section describes the build of a **basic ground plane** (experimental) antenna for testing purpose.

As the tuned emitter element does 13,4cm, the ground plane element should made $13,4 + 5 = 18,4\text{mm}$ (minimum).

By using 3 brass tube with sufficient length to have the required $18,4\text{mm}$ + some extra length to build a “base”. Use pliers to make the tube ending with a small hook.

As shown in figure 13, arrange the tube on a flat surface to build a triangle. Reserve a small space in the center to allow the connection of the emitter element.

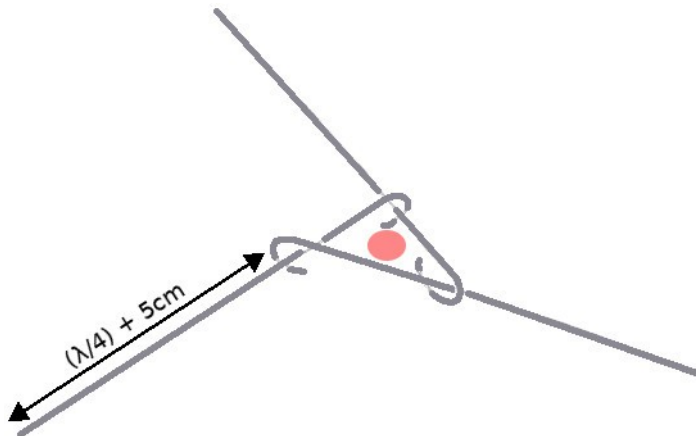


Fig 13: prepare the ground plane.

Use the pliers to firmly lock the hock then solder them right in place with tin.

As seen on the figure 14, the dielectric + core wire pass trough the ground plane. The emitting element is solder on the core wire (right after the ground plane).

The ground braid of the coaxial is soldered in multiple location under the ground plane



Fig 14: connecting the ground plane and emitting element

Finally, the antenna have been mechanically reinforced with some plastic and hot glue. Keeps in mind this may act as additional dielectric modifying the tuning!



Fig 15: reinforcing the ground plane

The final antenna set may look like the following.



Fig 16: final ground plane antenna assembly

3.3. Tuning antenna

Good practice implies to double check the antenna tuning after ground plane installation.

With experience, I would now recommend:

1. To prepare the single pole antenna with an unfinished tuning (say stops around 420 MHz for a 433 MHz antenna)
2. Mount the ground plane based on current antenna length (+ 5cm).
3. Finish the antenna tuning to the target frequency.
4. Shorten the ground plane elements if needed (longer ground plane is not a problem).

3.4. Common error

Ground plane angle

The angles of the ground plane elements must be carefully respected (or positioned at the best).

The antenna impedance will vary with the position of the element. The impedance must be as close as possible of 50 Ohms to offer the best power emission.

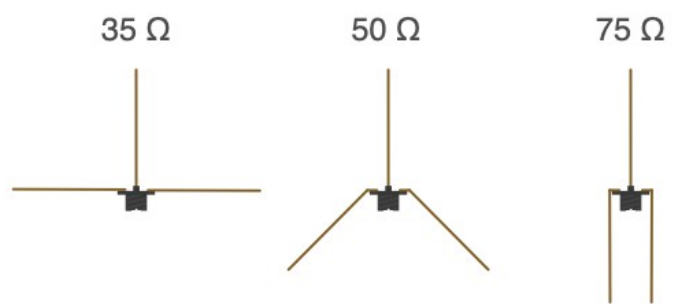


Fig 17: Ground plane impedance

Ground plane length

Element composing the ground plane must be longer than emitting element!

The additional should be at least 5cm!

Measurement conditions



**Keeps yourself away from VNA while doing measurement with ground plane antenna!
Your body will impact the results!**

Try to keeps the antenna suspended on the air while doing measurement.

3.5. Testing

This antenna have been successfully tested (as transmitter, 100mW) together with a Yagi antenna (as receiver) to transmit data up to 4 Km. Additional tests will be conducted for testing longer distances.

A clear line of sight is required!

The tests sessions for this antenna is documented online:

- <https://arduino103.blogspot.com/2025/08/cansat-rfm69hcx-et-communication-longue.html> (up to 2,2 Km).
- https://arduino103.blogspot.com/2025/08/cansat-rfm69hcx-et-communication-longue_26.html (up to 4 Km).

4. Tips and tricks

4.1. Stranded wire and Eyelet

The quarter wavelength antenna can be made with a piece of stranded wire ended with an eyelet.

The eyelet will be used to suspend the antenna in the air with the the parachute helps **keeping the emitting element straight toward the sky.**

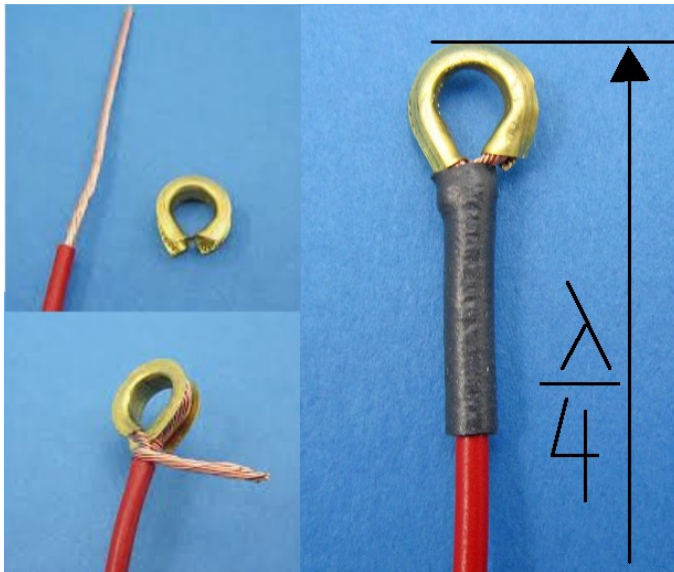


Fig 18: Eyelet with wire

Using silicon insulation wire are super flexible and will be more useful for working with parachute.

Keeps in mind that parachute opening will causes violent stresses in all the elements of the CanSat. This also imply the emitter element of the antenna and its ground plane.

The wire section, eyelet and connections points to the antenna connector will be the weak points to pay attention of.

4.2.Expandable ground plane

The professional tape measure is made of metal that magically get straight when released.



Fig 19: Tape measure

The meter is made with a metallic material covered with some polymer coating before getting the various information printed onto it.

Scrapping the polymer coating will expose the underlying metal allowing the electrical contact for building the ground plane.