Selecting Paint for the Steppir Antenna

and the Effect of Painted PVC on RF

and why you should not buy a Steppir

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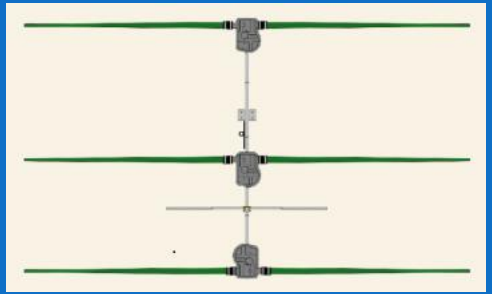
Rich Joerger
WB4EHG

What is a Steppir?

- A "Steppir" is a family of antennas that have the unique property of adjusting the physical length of the elements to match the frequency being used

- Normally antennas are cut to have their lowest SWR on a specific frequency, deviating from that frequency increases the SWR



Copper/Beryllium Tape

- Steppir uses stepper[1] motors to adjust the length of a copper/beryllium tape enclosed within a fiberglass tube

- Steppir antennas are available in a variety of types (Yagi, vertical, …)

[1]A stepper motor is a brushless DC motor that moves in discrete steps or precise angular movements controlled by electrical pulses

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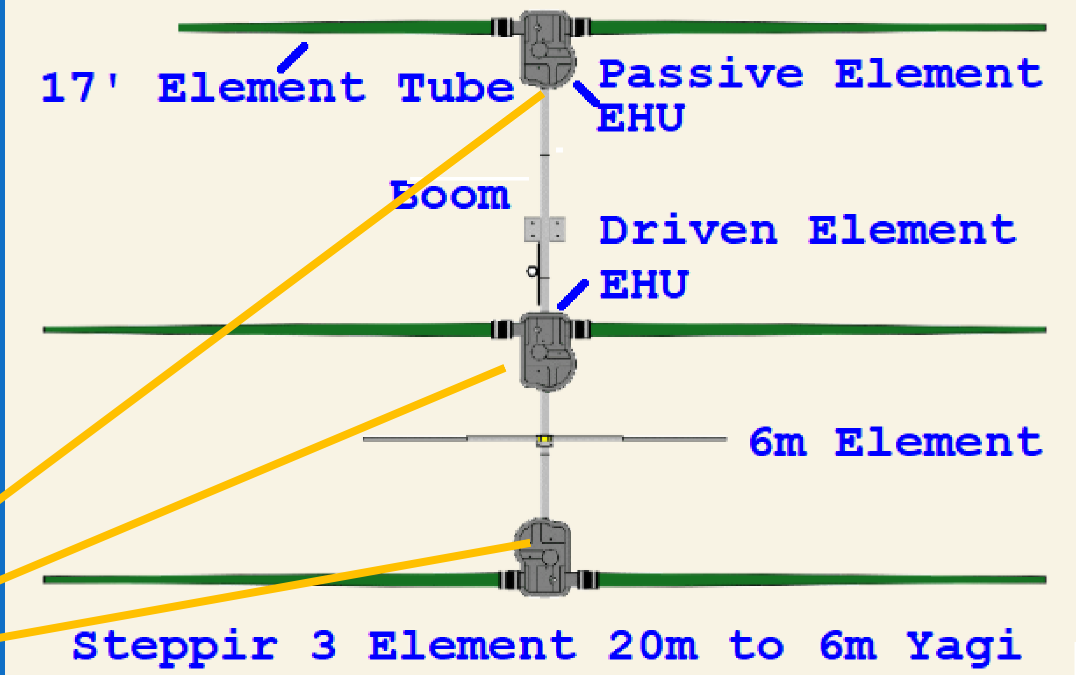
Steppir vs Yagi

- In the Steppir the EHU contains a step motor that unreels a copper/beryllium tape out the correct distance for the frequency it is set for

There's a microprocessor and driver ICs (susceptible to lightning) in here.

To Radio

The Controller gets the frequency from the radio, determines how many steps are needed and sends them over a 12 wire cable (4 wires for each motor) which is susceptible to lightning flashes



A close by lightning strike can couple into these cables

Damage to the antenna or controller can extend back to the radio

Balun for the DE which can arc when it get wet

Copper/Beryllium Tape

The tape can come off the reel and be bent/damaged

This is a lot of electronics and points of failure for the benefit of always having a perfect SWR

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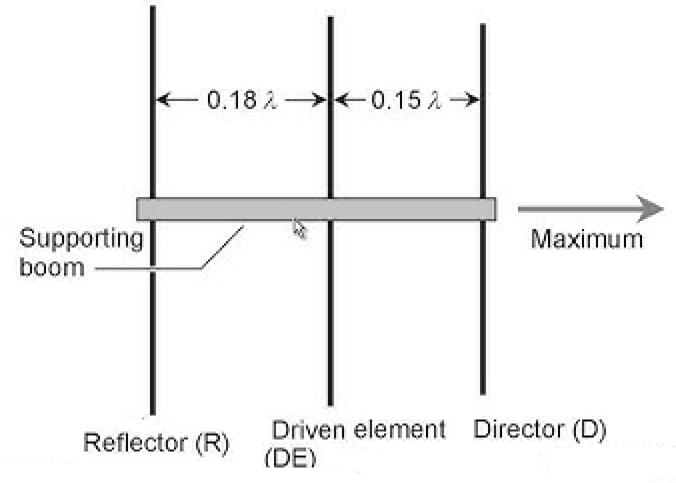
[1] A stepper motor is a brushless DC motor that moves in discrete steps or precise angular movements controlled by electrical pulses

Yagi-Uda – The "Normal" Directional Antenna

- ❑ It is directional antenna consisting of a single driven element and multiple parasitic elements: the front one is called the Director, the rear one is the Reflector



- ❑ To use multiple bands passive LC devices called "traps" are placed in the elements.
  - They act as filters to change the length of the element for different bands (they "trap" the RF)
- ❑ The Yagi does **not** provide a perfect SWR on every frequency.
  - You tune it for a part of the band CW or phone or center
- ❑ Yagi's are made by many companies.
- ❑ They are light weight and inexpensive compared to Steppir's
- ❑ They are available in many band combinations all the way up to UHF and higher
- ❑ More elements make them more directional

Since the elements are spaced a fraction of a wavelength, using the antenna on different bands becomes a compromise because the spacing is fixed

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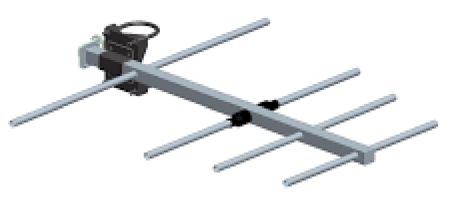
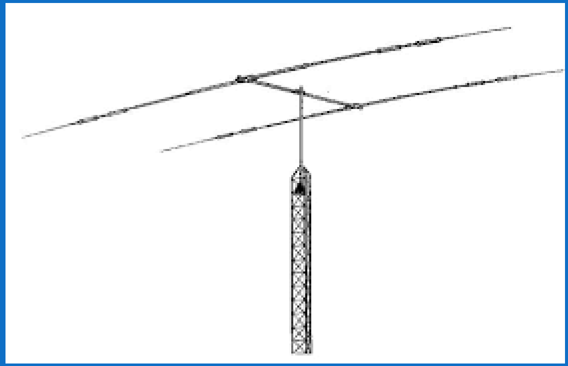
Some Example Yagi's





2 Element Yagi

This is a log periodic not a Yagi, it is a very wide band antenna. I'd rather have this than a Steppir

A UHF Yagi inside a VHF Yagi

10 Element VHF Yagi

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Why Would You Buy A Steppir?

- The SWR is always perfect for the frequency you are transmitting on
- Bragging rights – they are really cool

Why Wouldn't You Buy One?

- They are complicated: moving parts (motors and tape), electronics
- They are expensive ($Thousands) and heavy (~60lbs) An Aluminum Yagi is much lighter
- In September 2025 Steppir left the amateur market, making our existing antennas orphans without support. Just like MFJ did to their products.
- If you need part in the future, you have to depend on the used market

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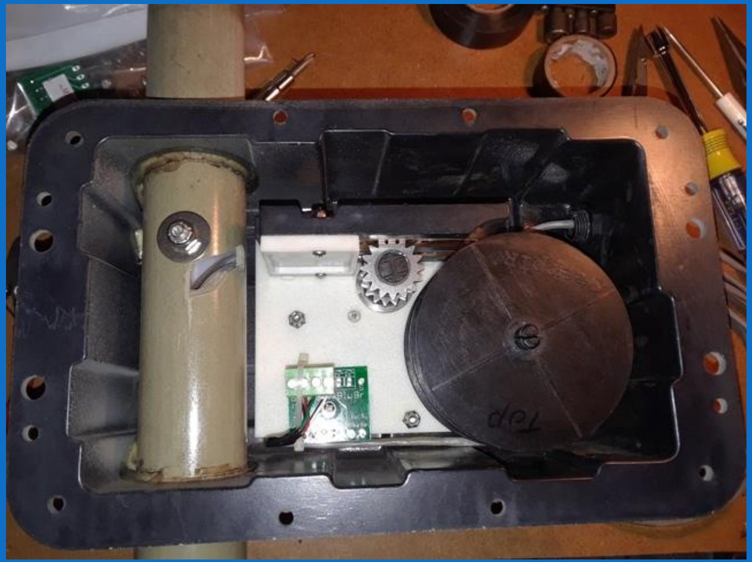
Back to My Steppir

- My Steppir developed a water leak, an easy fix after getting it on the ground, just replace the gasket (I bought spares). A Yagi's trap water holes can get blocked too.
  - I had to tilt the tower over, remove the fiberglass tubes and the EHU housing, clean the insides of the EHU, reassemble with a new gasket and remount on the mast. I examined everything when the antenna was on the ground.
- I found that the fiberglass tubes (6 tubes, each 17' long) were wearing from the weather

Fiberglass Element Tubes



Passive EHU

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Paint Them!

- Sounds simple enough
- Wait, some paint has metal in it – metal detunes antennas and absorbs RF energy
- OK, ask the manufacturer (who's leaving the market, no phone support) what paint to use
    - Rustoleum Hunter Green
        - Yeah, there are multiple versions with different uses and contents
- Since this thing uses electronics and motors and is heavy, if I paint it and get it in the air and it doesn't work, is it the paint or the electronics?
- Debugging will be difficult

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The Paint and How to Test It?

- I found three paints, each for different uses
  - 1. Satin Protective Enamel spray paint 376874
  - 2. High Performance Enamel spray paint 7538
  - 3. Marine Coat Topside brush paint 207007 (from ex-Steppir employee)

Fred suggested spraying them with lacquer, that would have saved a lot of time

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The Paint and How to Test It

- I devised an experiment where I made a VHF dipole and tested its SWR without PVC, with unpainted PVC, with PVC painted with each of the three paints, and finally with unpainted PVC wrapped in aluminum foil

- I used a rig expert AA-230 analyzer to plot the SWR on a graph since it could create plots on the computer screen that I could copy and paste into a report

- I didn't care what frequency the antenna was cut for and made no attempt to make it resonant on any frequency, I simply cut it for a convenient length to work with

- The photos below show the parts of the antenna. Next time I would add a screw below each of the solder lugs so that the copper wire is above the PVC (that is, it is floating in the housing)
  - It doesn't have to be sturdy, it's just for testing
  - It doesn't have to be pretty
  - It can be cut for any frequency easy to work with

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RigExpert® AA-230 ZOOM
Antenna and Cable analyzer up to 230 MHz

Applications

- Amateur radio
- Commercial radio

Use cases

- Rapid check-out of an antenna
- Tuning an antenna to resonance
- Comparing characteristics of an antenna before and after specific event (rain, hurricane, etc.)
- Making coaxial stubs or measuring Parameters
- Measuring capacitance or inductance of reactive loads

Main Features

- Color TFT display
- 6×3 keys on the waterproof keypad
- Factory calibrated
- Multilingual user friendly interface
- Built-in Helper at the push of a button
- USB connection to a personal computer

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The Antenna and the Tubes

The assembled dipole without PVC tubes. The wire is #4 copper normally used for grounding. It is very stiff and holds it shape. The height of the antenna is greater than 1 wavelength to reduce ground effect

Feed point from the side

Looking into the feed point from the side. I wanted the wire to float inside the PVC

The feed point from the top, the RG-213 coax is fed up the PVC mount

Putting a nut below the solder lug would have allowed the copper wire to float above the PVC

The PVC cover tubes painted with 3 different greens and 1 pair wrapped in Aluminum foil

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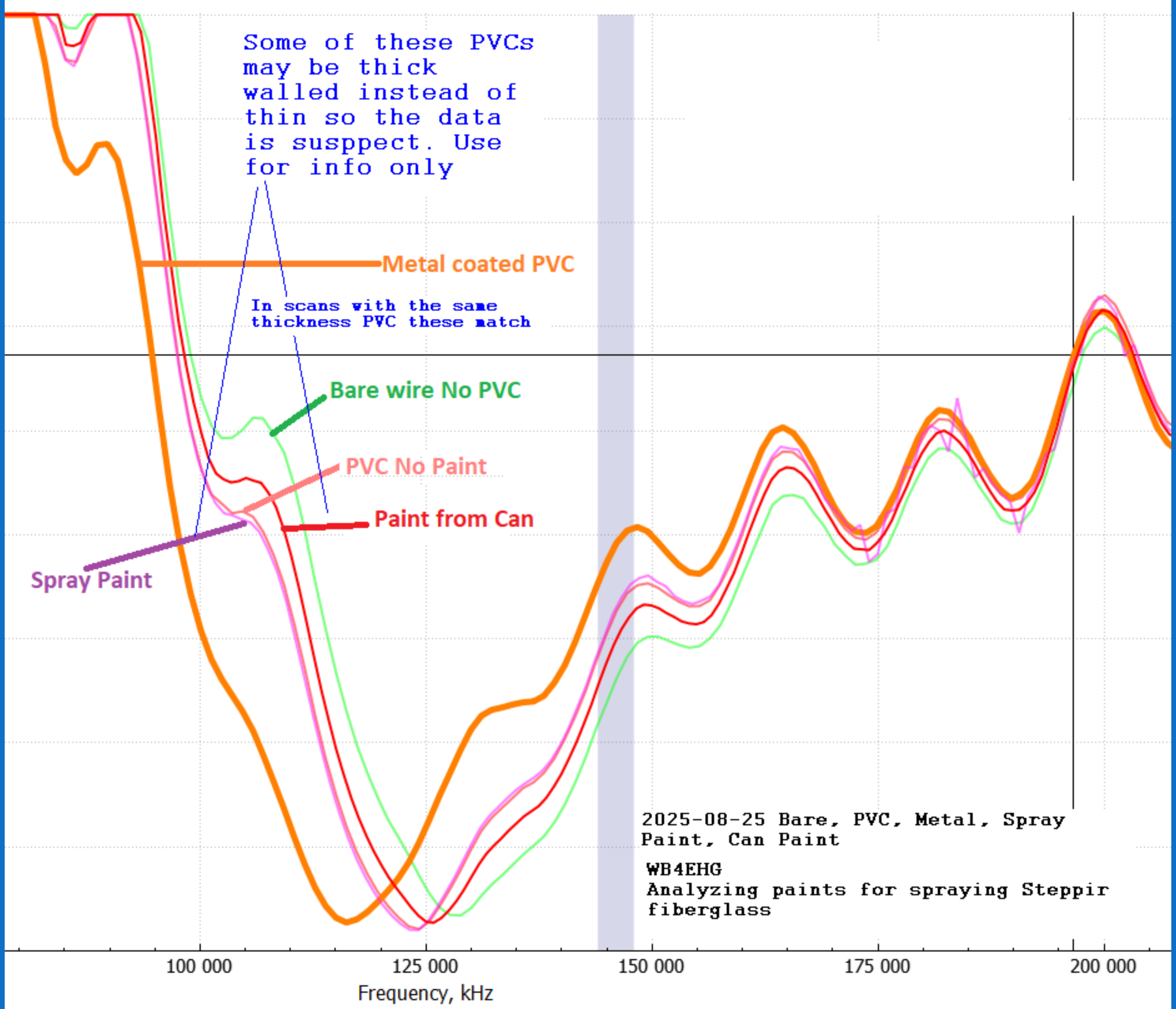
The First Test Run

- The graph shows frequency on the horizontal axis and SWR on the vertical
  - Lowest SWR is at the bottom
- Each color is a different PVC tube
- The resonant frequency is where the lowest SWR is, so at the bottom dip
- The uncovered PVC configuration has the highest resonant frequency
- The aluminum coated configuration has the lowest resonant frequency I'm surprised it resonated at all
- The two spray paints have the same result
- The brush paint has a higher SWR than the spray paint.
- But! This test is invalid. I discovered that I had a mixture of schedule 40 and 80 PVC. The thickness of the PVC was different!



Each minor tick on the horizontal axis is 5 MHz

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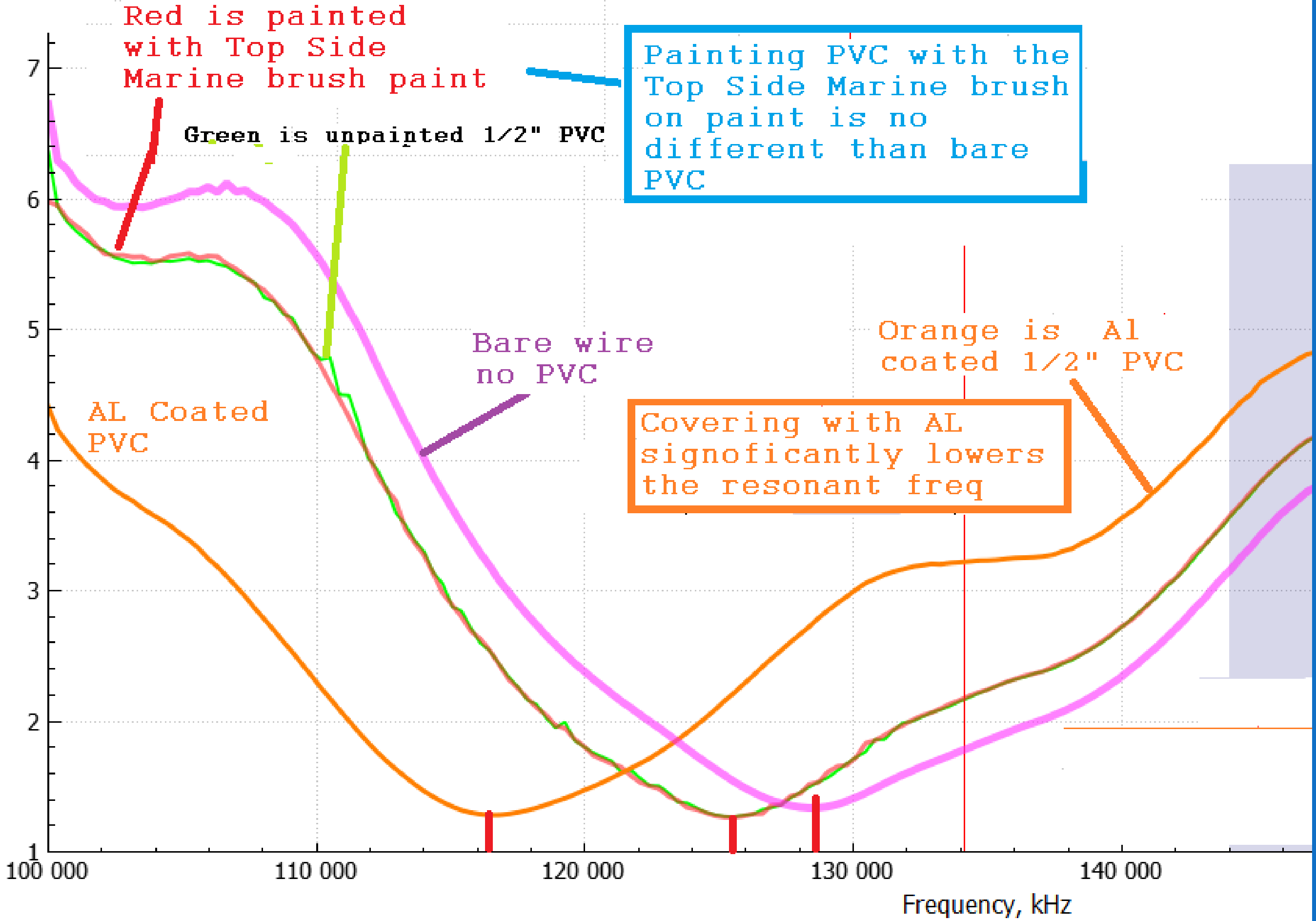
Moral: question everything

The Final Test Run using PVC with the same thickness

- The resonant frequency is where the lowest SWR is (at the bottom dip)
- The uncovered PVC has the highest resonant frequency (pink) as expected
- The aluminum covered PVC has the lowest resonant frequency (orange)
- The brush paint has the same SWR as the spray paints AND AS THE UNPAINTED PVC, so it doesn't matter which paint I use
- The lowest SWR doesn't change (much)
- Why does covering the antenna with PVC reduce the resonant frequency? Future slide
- This analysis does not determine if the amount of radiated power is reduced by the PVC



Final test run. Covering with PVC lowers the resonant freq. Covering with aluminum foil lowers it the most. Painting with either spray paint or the brush on paint has the same effect so

Each minor tick on the horizontal axis is 2 MHz

Yes, I used PVC to model a fiberglass antenna. PVC is readily available and easy to work with. Remember that the goal was to test the paint.

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You can use PVC to Shorten an Antenna (equations are from Copilot)

1. You need to know the Permittivity factor (E_r) of the PVC

   You may find it on-line for PVC as 3 to 4 or just 4.06, I found it both ways. The range of 3 to 4 doesn't help much, that is broad

2. If you know the resonant frequency of the dipole outside and inside the PVC you can calculate Permittivity factor E_r of the PVC and use it #3 below[3]

   $\mathbf{E_r = (F_0 / F_1)^2}$ $\mathbf{E_r}$ = $(128.3/125.6)^2$ = 1.0215 --- That's not much help

   where F_0 is the resonant frequency of the dipole length in free space
   F_1 is the resonant frequency of the dipole length in PVC
   E_r is the Permittivity factor

E_r should be close to 2

This result makes me question the measurements which means doing it again specifically to answer this question

3. For the dipole I made where the top of the center section is open, you have to calculate the Permittivity factor of the combined open and covered parts and then apply that to that value to your antenna. Remember that the feed point is always in PVC.

   $L_1 = L_0 / \sqrt{E_r}$

   where L_0 is the dipole length in free space
   where L_1 is the dipole length in PVC
   where Er is the Permittivity factor you calculated

E_r : this assumes the dielectric loading is dominant and the antenna is sufficiently surrounded by the material.

4. Or you can use the measure – cut – measure – cut method.

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Why does covering the antenna with PVC change the resonant frequency? [MS Copilot AI analysis]

- **Dielectric Loading**
  - PVC has a relative permittivity (ε_r) typically between 2.5 and 4.0.
    - When the antenna is surrounded by PVC, the effective dielectric constant of the medium around the radiating element increases.
  - This slows down the propagation velocity of the electromagnetic wave, which increases the electrical length of the antenna.
  - Result: The antenna behaves as if it's longer than it physically is, lowering the resonant frequency.

- **Field Confinement**
  - The PVC tube confines the near-field region, especially the capacitive field around the antenna.
  - This alters the capacitance per unit length, again increasing electrical length.
  - Think of it like adding a sleeve of lossy dielectric around a transmission line—it shifts the impedance and phase velocity.

- **Material Thickness and Proximity**
  - The thicker the PVC and the closer it hugs the dipole, the stronger the detuning effect.
  - If the antenna is centered inside a wide tube, the effect is milder. But if it's snug, the dielectric loading is more pronounced.

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Permittivity for This Antenna

If the legs of a dipole antenna are shortened by **5%**, that implies the **effective wavelength** is reduced due to the **dielectric loading** of the enclosure. We can estimate the **relative permittivity (ε_r)** using the relationship between wavelength in free space and wavelength in the dielectric:

For a dielectric-loaded antenna: completely

L_loaded = L_free × $(1 / \sqrt{\varepsilon_r})$

If the antenna legs are shortened by 5%, then: L_loaded = 0.95 × L_free

Solving for ε_r: $0.95 = 1 / \sqrt{\varepsilon_r}$

$\sqrt{\varepsilon_r} = 1 / 0.95 \approx 1.0526$

$\varepsilon_r \approx (1.0526)^2 \approx 1.108$

Estimated relative permittivity (ε_r) ≈ 1.11

This is a very low dielectric constant, consistent with lightweight plastics or thin-walled PVC with significant air gaps

This analysis was done by MS Copilot.

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Effect of PVC on Signal Strength

- **The PVC tube will have a minimal attenuation in HF, VHF and UHF**
  - Standard white schedule 40 PVC is generally transparent to RF below a few GHz.
  - It does not significantly absorb or block signals in the HF/VHF/UHF range
  - White PVC is preferred; gray, black or ABS variants may contain carbon or additives that increase RF loss
    - To test, put a piece in the microwave, if it warms up then it absorbs RF, so don’t use it

This analysis was done by MS Copilot.

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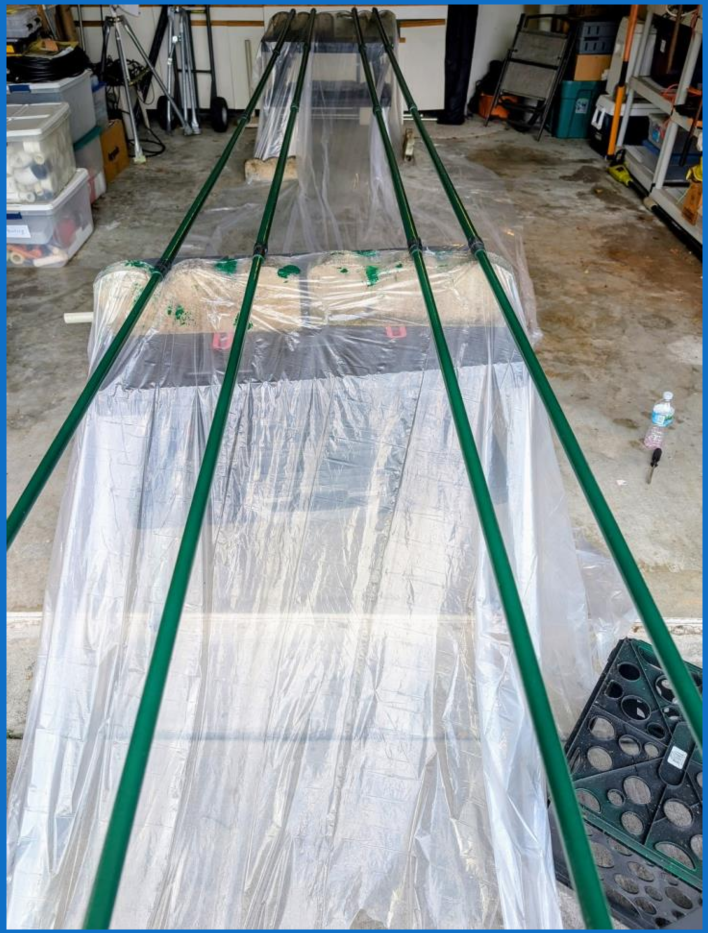
Painting the Fiberglass Tubes

Rust-Oleum
Deep Green # 207007
Marine Coatings
Topside Paint



The fiberglass tubes were stored with the open ends covered with painters tape to keep bugs and lizards from getting inside

I painted the fiberglass tubes with the brush-on paint using foam rollers.
The tubes were lightly sanded and cleaned with acetone. To keep the tubes from rolling around on the drop plastic I placed scalloped edging bricks so that the shrink tubed joints were in the valley of the bricks. The paint did not go on smoothly so I kept applying the paint and turning the tubes. They got a 2^{nd} coat the next day.

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The Result

- **Getting the Steppir reassembled is harder than you think.**
  - Before mounting the EHU on the mast I performed the motor test which runs a few inches of the tape out so you can tell if the motors are wired correctly.
  - After mounting the EHU on the mast (serious effort to seal everything to keep water out) I again performed the motor test which worked. To the right is what happens when you hit the wrong button and tape tries to tune to 10m.
  - Insert the tubes into the rubber booties and the EHU, use hose clamps and lots of 3M tape and ty-wraps to keep the water out.
  - Once again try the motor test, the controller will complain if there is a problem
  - Un-tarp the rotator (wrapped in tarp to keep the water out while it was on its side)
  - Layout the cables (3 antennas on the tower + rotator control, Steppir control)

- **To be clear, none of this would be necessary if this was an aluminum Yagi antenna.**

- **The first contacts were Greenland and Iceland**

- **The SWR is good on all bands but slightly different than before**

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