1. Assembly Guide for EggNOGS


1.1. Special Thanks!

I want to give an extra special thanks to the following Halibut Electronics Patreon members who give at the Barefoot Level or above at the time this went to fabrication. You help keep the business running, with both your financial and emotional support. Thank you so much.

- AE0PQ Jordan
- WY8V San
- VE3BIC Andre
- W6MDX Tom
- AC7FD Tobias
- AE5X John
- KF5CLZ Dave
- K5IAG David
- VA3MW Mike
- KJ7OHF Lionel

1.2. Change Log

Date	Description
2024-05-02	First quick version for early testers
2024-07-31	v1.6 production run
2024-08-08	Product Launch

2. Table of Contents

3. Description

EggNOGS is a kit to help you build an "Egg Beater" antenna. (*)

Egg Beaters are an ideal, simple antenna for working satellites. They have a roughly hemispherical radiation pattern covering the entire sky, without the deep null straight up that vertical antennas have. They don't require rotors (azimuth and elevation) to keep a directional antenna pointed at the satellite as it moves through the sky. Egg Beaters are commonly used on simple satellite downlink stations, like those used on the SatNOGS network. (*)

An Egg Beater antenna. For use with SatNOGS. EggNOGS. You get it...

EggNOGS does the hardest part of building an Egg Beater: the 90° phasing loop. The phasing loop needs to be the same impedance as the two antennas (100Ω in this case), should be balanced like the two antennas, and should be shielded to prevent interactions with the mast, feed line, common mode current choke, etc.

> **"100Ω, balanced, shielded feed line is unobtanium."**
>
> --Smitty, trying to buy 100Ω, balanced, shielded feed line for EggNOGS

So EggNOGS uses the correct geometry on a circuit board to make a 100Ω, balanced, shielded 90° phasing loop. The Phasing Boards can be easily manufactured for any frequency. If your preferred frequency isn't already available, contact Halibut Electronics and we will make it for you.

* EggNOGS can be used to build more than just Egg Beater antennas, and will work with more than just SatNOGS. But far be it for me to pass up the name pun. It can be used to build any antenna that is fed in quadrature (two antennas 90° out of phase). See the Section on Aerial Loops for more details. It can also be used for transmitting at a moderate power level.

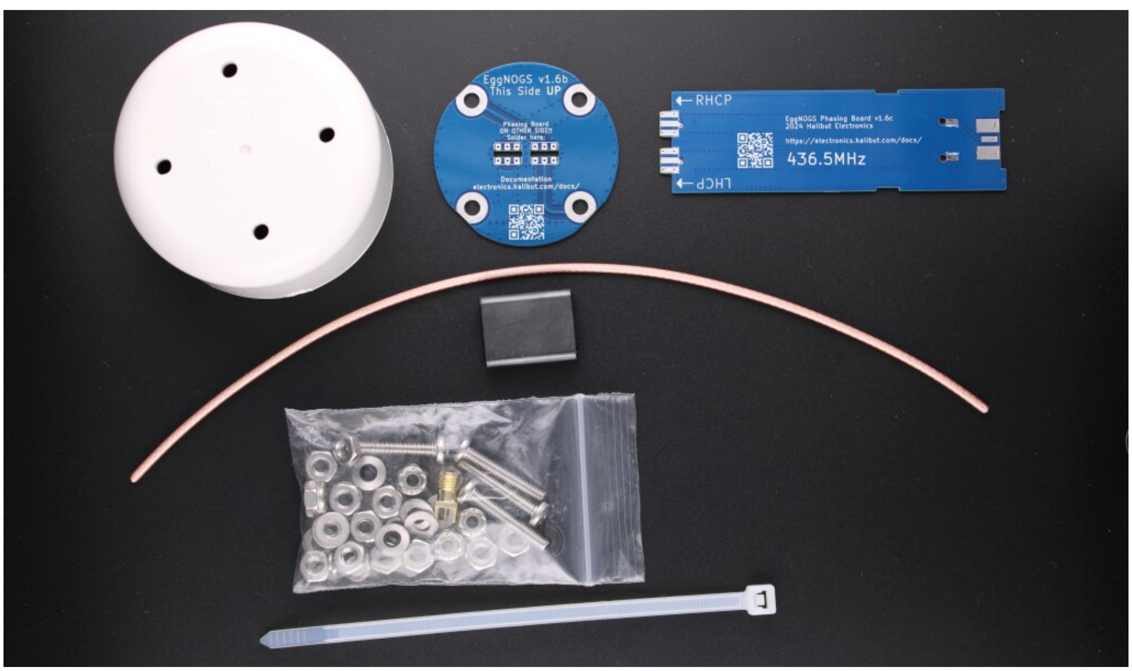
4. Assembly

Ok, let's build this thing.

4.1. Parts

The EggNOGS Kit provides the "unique" parts, the parts you can't pick-up at your local hardware store. You will provide the parts you *can* pick up locally.

4.1.1. Parts Provided



- Main Board: the circular board with four bolt holes around the edge

- Phasing Board: the rectangular board with "board edge" tabs on one end, and a spot for a coax connector on the other
- BN-43-3312 binocular ferrite core: the black/gray rectangular thing with two holes in it
- Short length of RG-316 cable: about 9in/24cm of orange colored coax cable, with no connectors on it
- A zip tie
- SMA PCB edge mount female socket (inside the bag of stainless steel hardware)
  - A BNC or Type F connector are available as optional upgrades
- Bag of stainless steel hardware: (Ok, yes, you can get this at your local hardware store. It's still included.)
  - 4x 1 inch, No. 8-32 screws, #2 philips head
  - 8x No. 8 flat washers
  - 4x No. 8 rubber sealing washers
  - 12x No. 8-32 nuts
  - 4x No. 8-32 nylon locking nuts
- 2in/50mm PVC cap, milled with 4 holes in the top

4.1.2. Parts You Provide

You must provide the following parts:

- Aerial loop material, and any connectors you want to use to connect to the No. 8 bolts
  - For UHF antennas, I use 14ga solid copper wire, stripped from household Romex wiring.
  - For larger antennas, you'll probably need something stiffer, or to provide a support (see below.)
- 2in/50mm PVC pipe for the mast, length to fit your deployment
  - Schedule 40 works well.
  - Schedule 80 (thicker than Schedule 40) is over-kill, and just makes the antenna heavier.
  - I haven't tried Schedule 20 (thinner than 40), but it might not be stiff enough to act as a mast.
- Ground Reflector, if needed
  - See the Aerial Loop design options below.
- Feed line, radio, etc.

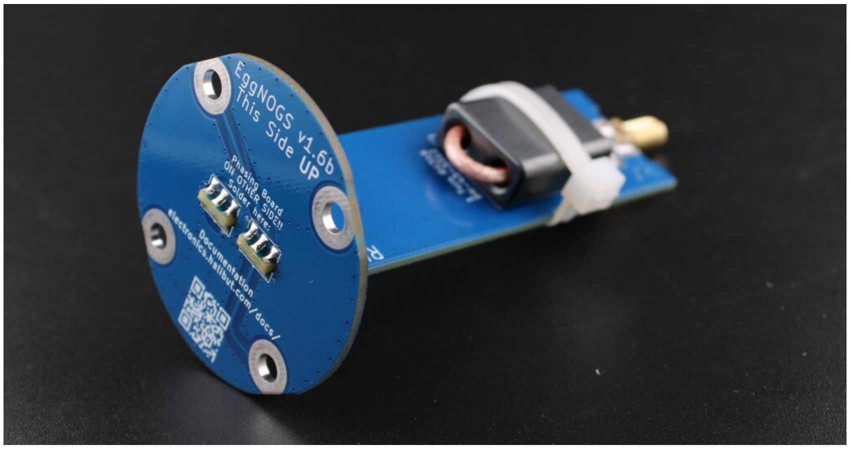
4.1.3. Tools

You'll need the following tools to build EggNOGS:

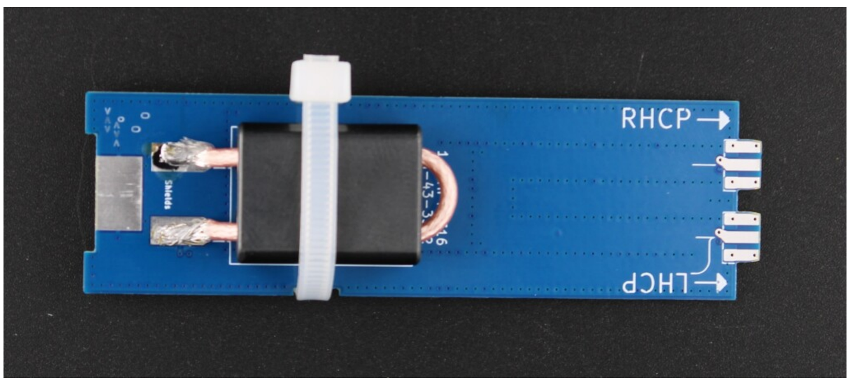
- Wire cutters
- Wire strippers, 14ga and 22ga. Or another way to strip RG316 coax.
- Soldering iron, and solder
  - Light weight/low wattage soldering irons will make this a challenge. A higher wattage iron will make soldering RF connectors a lot easier.
- No2 Philips head screw driver
- 11/32 inch nut driver or wrench

4.2. Board Assembly

This is what EggNOGS looks like inside the PVC cap:



4.2.1. Phasing Board and CMCC



The phasing board serves the following purposes:

- Feed point: You connect the feed line to the bottom of the phasing board.
- Common Mode Current Choke, aka Balun: The feed line is unbalanced, but the antenna is balanced. The CMCC Balun converts between the two, and prevents common mode currents on the feed line.
- Phasing loop: Inside the phasing board is a 1/4λ of shielded, impedance-matched, balanced feed line. This serves to feed the two aerial loops 90° out of phase.
  - This is why the phasing loop board is frequency specific. You must order the correct phasing board for your antenna's frequency range.
- Connects to main board: The two tabs at the top of the phasing board feed the RF to the main board.

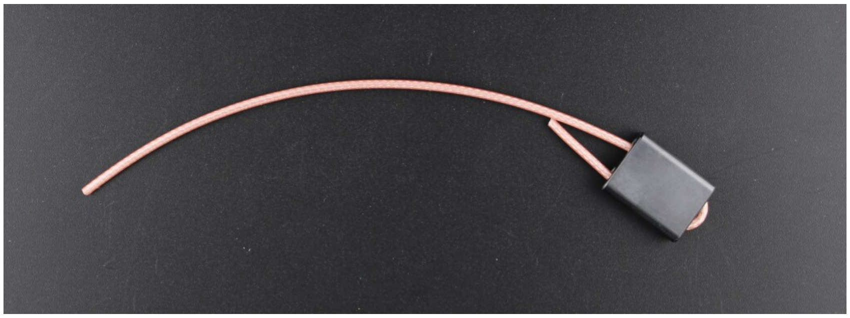
4.2.1.1. Common Mode Current Choke

The first step is to build the CMCC. It is made of a short length of RG316 coax fed through a BN-43-3312 ferrite core. This is the most compact and effective CMCC I've been able to find for operation at UHF and above.

> Challenge: In my opinion, this is the most challenging part of the build. This part is why EggNOGS is listed as an "Advanced Kit." Make sure you read these instructions entirely before you get started, and

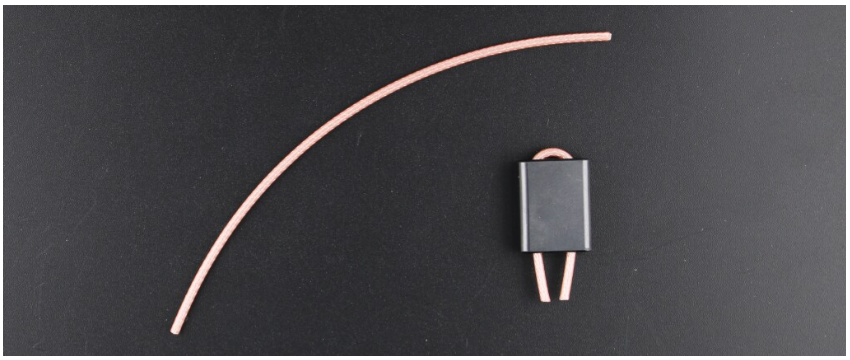
> understand what we're doing, and what it will look like when you're done.

- [ ] Hold the coax in a U shape, and feed both ends of the coax through the two holes on the ferrite core. Feed the coax all the way through the ferrite core so the bend in the coax is immediately adjacent to the core. It should look like this:



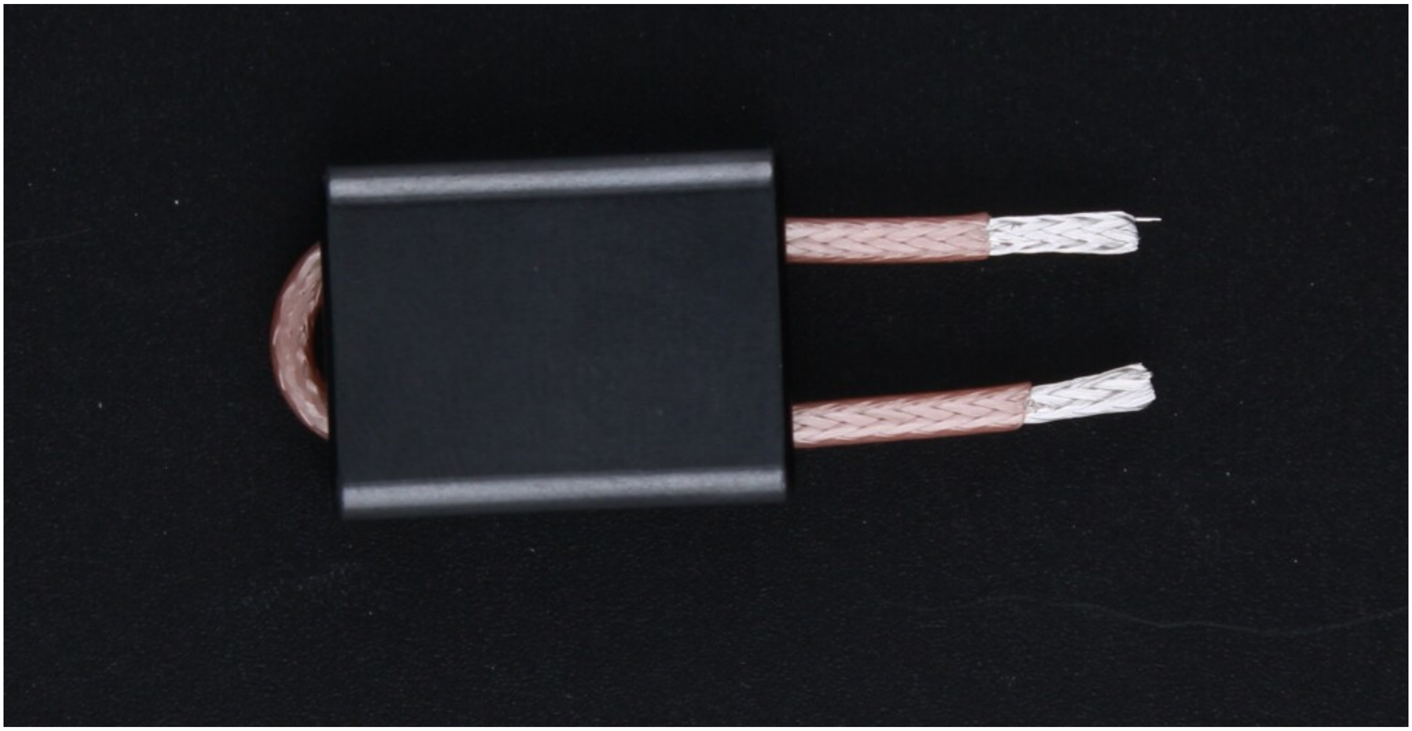
The kit comes with enough extra coax for two attempts at this. So leave all the extra on one end (like above) so when it is trimmed, you get it all in one chunk.

- [ ] Trim both ends of the coax so about 3/4 inch (2cm) is sticking out of the core.

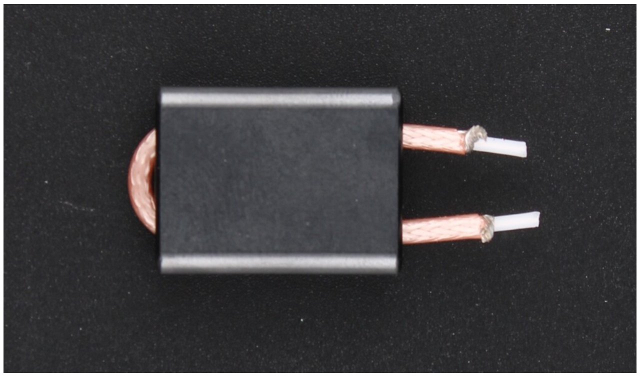
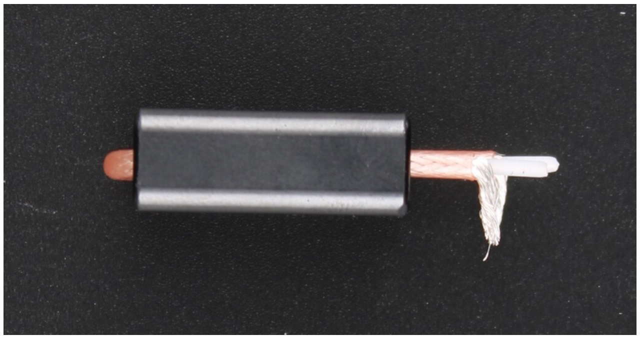


- [ ] Strip about 1/4 inch (8mm) of the outer jacket off both ends of RG-316.

> Tip: I've found that wire strippers with a circular cutting hole (not angular holes for multiple wire sizes, or straight blades on top and bottom) for 14ga wire works pretty well to cut the insulation. Carefully close the cutters on the cable, open them, rotate the coax a bit, close and open again, rotate a bit more, etc. This will cleanly cut the insulation around and make it easier to strip off. If it doesn't cut it all the way through, try 16ga, but be very careful.

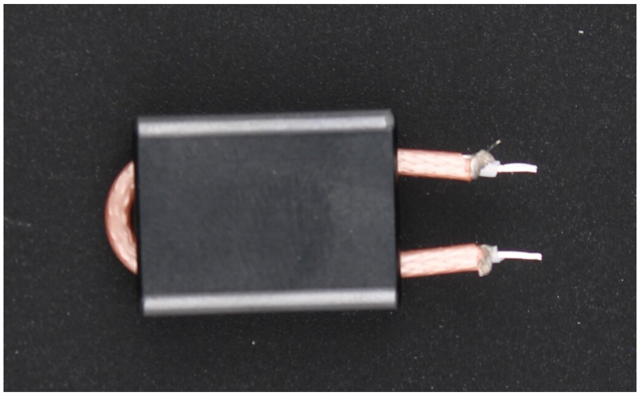
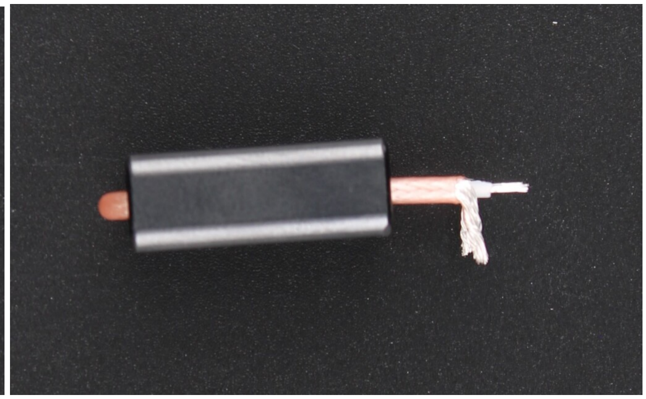


- [ ] Unwrap the shield from the center dielectric, pull it all to one side, and twist it so that it sticks out at a 90° angle from the coax, out the wide side of the ferrite core. Do this so both ends of the coax's shields are sticking out the same side of the ferrite core. The shield around the coax should be as flat as possible; you're going to insert the dielectric through the PCB, so the shield is flush against the PCB, and the center pin sticks out the other side. It should look like this:

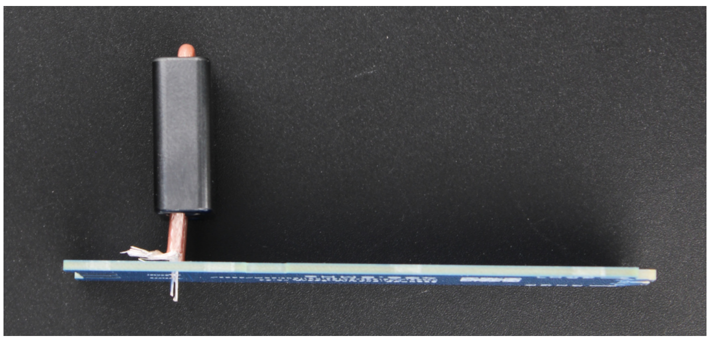
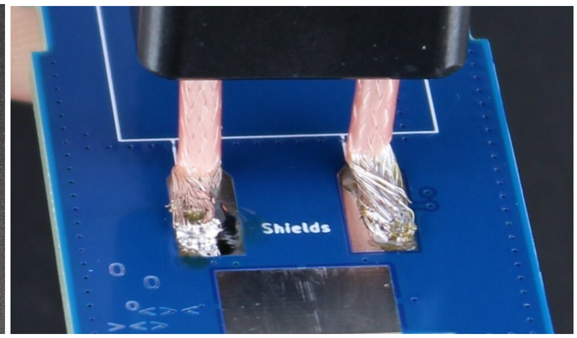
 

- [ ] Cut the dielectric about 1/16in (1.6mm) (the thickness of the PCB) above the shield you've just twisted together, then strip it off exposing the center conductor. Err on the side of leaving a bit more dielectric rather than less; make the dielectric sticking out of the shield longer, not shorter. But get as close to the thickness of the PCB as possible.

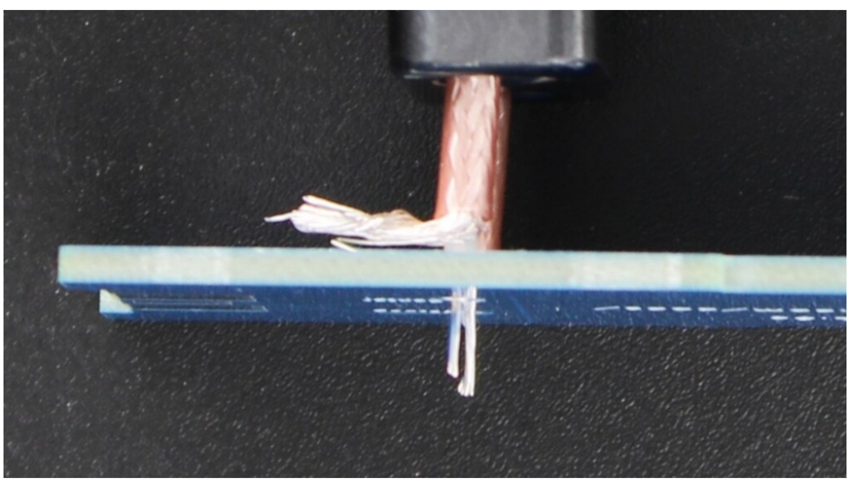
> Tip: Similar to the outer insulation, a 20ga to 22ga circular wire stripper works well here.

- [ ] Insert the whole CMCC assembly (ferrite core, RG-316 in a U shape through the holes, ends of the RG-316 trimmed as described above) into the two holes on the phasing board labeled "CMCC." Make sure the twisted-sticking-out shields line up with the two exposed pads labeled "Shield" on the PCB.

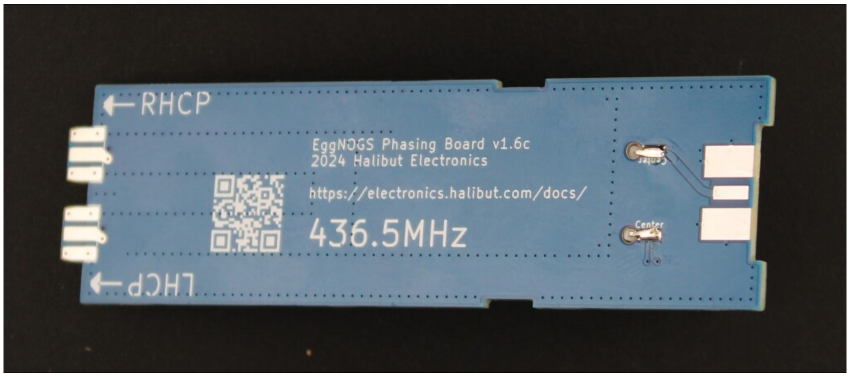



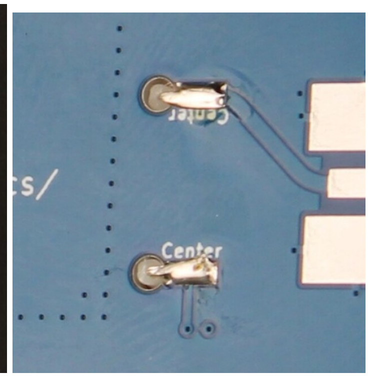
There should be about 3/8 to 1/2 inch (9 to 12mm) of exposed coax between the board and the ferrite core when you hold the ferrite core up away from the board -- enough to let the ferrite bend over against the board without crimping the coax. It should look like this:



- [ ] While holding the coax as close and tight to the board as possible, on the other side bend the center conductor over on to the exposed pad next to each one.

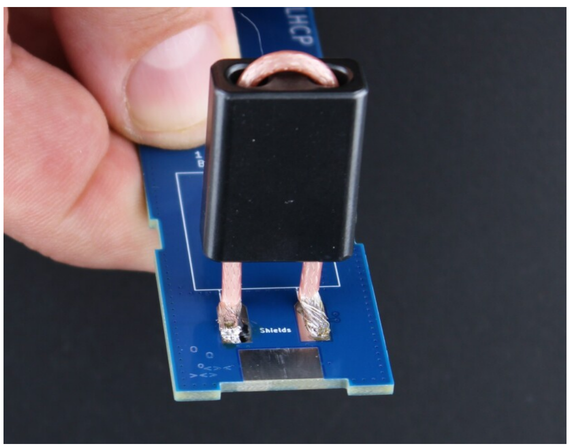
- [ ] Solder these two center pins to these pads. That should hold the assembly in place on the phasing board.

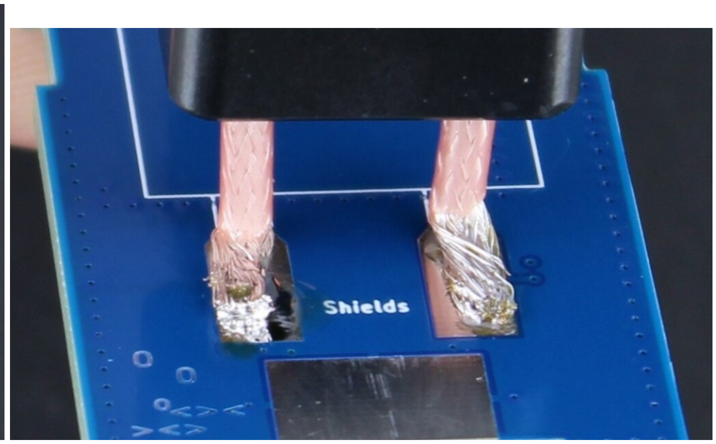




- [ ] Solder the shields to the two large pads.

> Warning: These shields are ELECTRICALLY DIFFERENT. Make sure to not short the shields to each other, or to the SMA/BNC connector shield. (That's a lie, one of them is the same as the RF connector, but it's easier to say "Don't short them" than it is to explain WHICH ONE must not be shorted.)

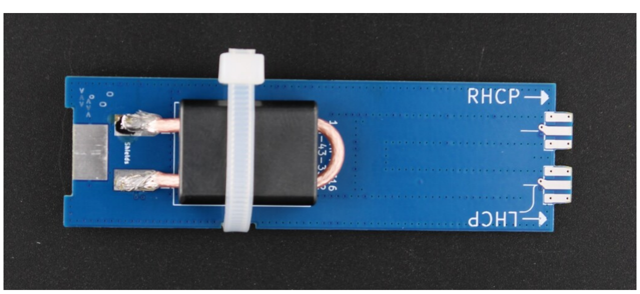


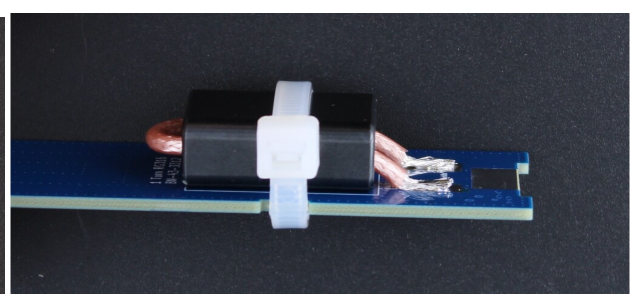


> Whew! You did it! That's the most difficult part of this whole build. Alright, let's keep going.

- [ ] Carefully rotate the ferrite core down against the phasing board, and strap it down using the provided zip tie.

This is your opportunity to adjust any lop-sided-ness of the U-bend in the coax, and make it more even.





4.2.1.2. SMA or BNC connector

If you purchased the optional BNC or Type-F connector, use that instead of the SMA below. The process for soldering it is the same, and the PCB outline will work for all three connectors.

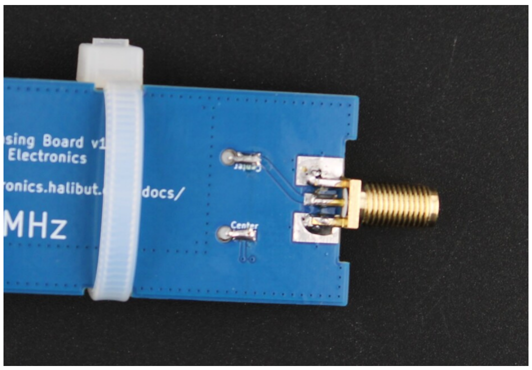
- [ ] Solder the SMA connector to the phasing board:

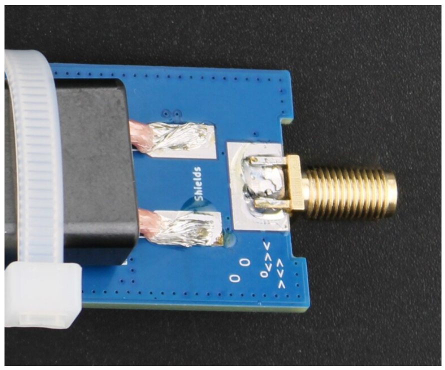
Solder the center pin first. Make sure that the center pin is over the center pin pad on the board. It's easier to reflow just the one pin while repositioning the whole connector to put it in place. Once you're happy with the positioning, solder all the shields to the board. Both top and bottom.

> Note: These connectors have a lot of thermal mass. If you've got more temperature on your soldering iron, now is the time to use it. Be patient, give it the time the solder needs to flow correctly.

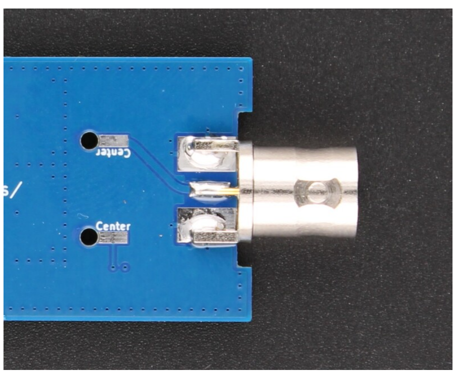
> Warning: The connector and board will both be VERY HOT during and after this process. Let it cool down before continuing.

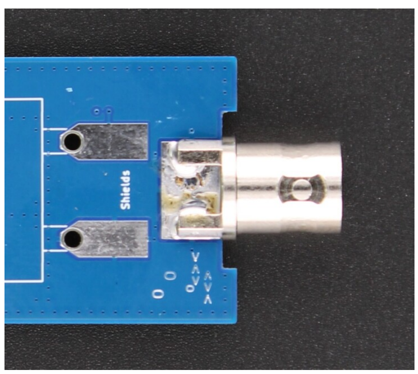
It should look like this when you're all done:



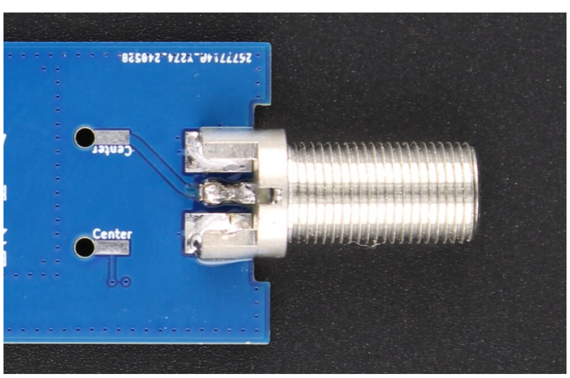


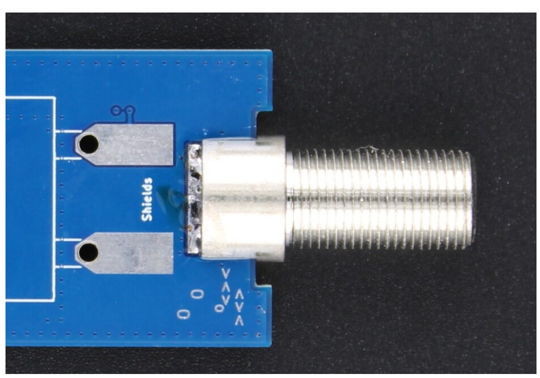
If you've upgraded to a BNC connector, this is what it'll look like when you're done:





And Type F. This is for folks who like to use low-loss, low-cost Cable TV RG6 for feed line:



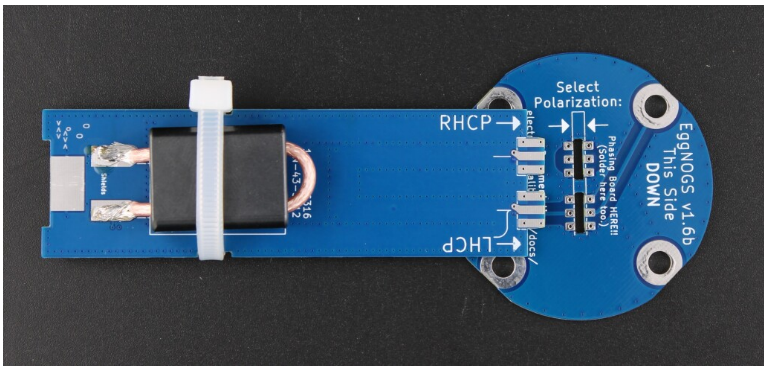


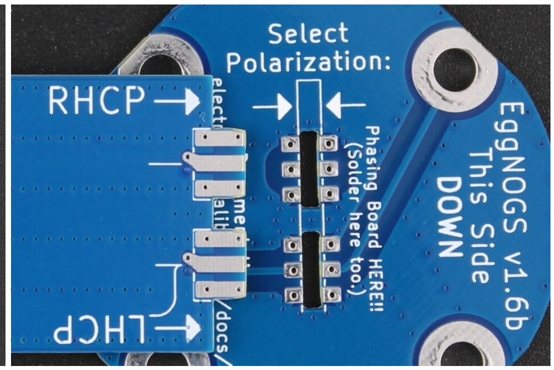
4.2.2. Main Board

> Oops: Pay no attention to the fact that these pictures don't show the feed point connector soldered. I took the pictures out of order.

- [ ] Choose whether you want your antenna to be Left Hand Circularly Polarized (LHCP) or Right Hand Circularly Polarized (RHCP).

> Note: Most ham satellites use Right Hand Circular Polarization. Unless you know you want to do otherwise, use RHCP. At low elevations the antenna will be horizontally polarized, not circularly, so it doesn't matter there. But the pattern becomes more circular as the elevation rises.





Pay attention to the main board's "This Side UP" and "This Side DOWN" text. The phasing board is inserted into the "This Side DOWN" side.

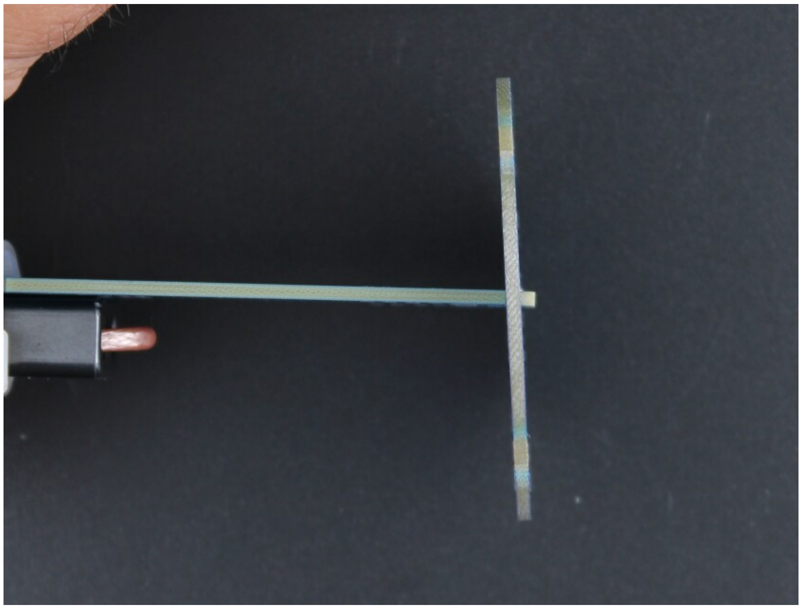
Note on the phasing board, the edges are labeled "LHCP" and "RHCP" with an arrow. Also note on the bottom of the main board the area labeled "Select Polarization." When inserting the phasing board into the main board, put the polarization you want next to the "Select Polarization" area, so the arrows line up.

- [ ] Insert the phasing board tabs into the slots on the *bottom* of the main board, paying attention to the polarization markings, and the "This Side UP/DOWN" markings.

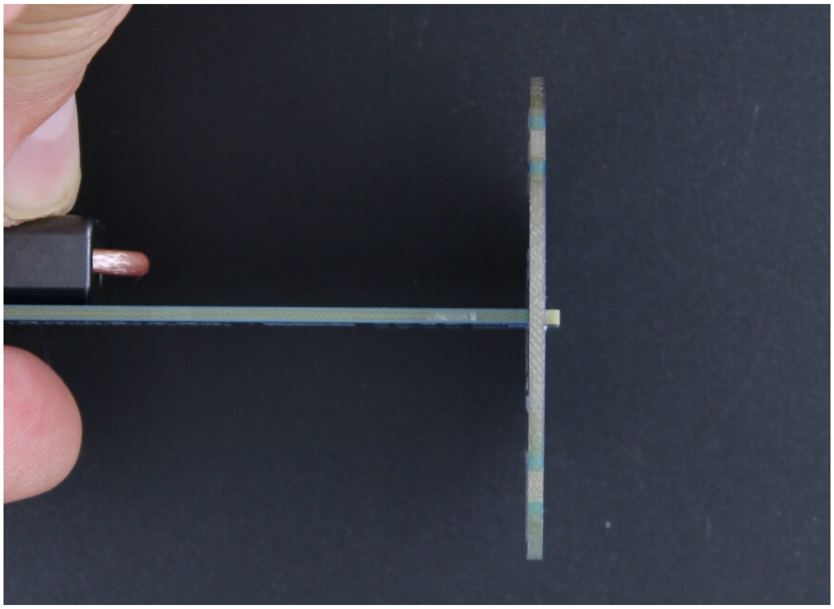
Note how the solder pads of the main board and phasing board line up and are at right angles to each other. When these are soldered, they will structurally hold the phasing board to the main board, and keep it straight.

- [ ] Carefully, holding the two boards at a right angle, tack solder together just one of the outer most pad joints.

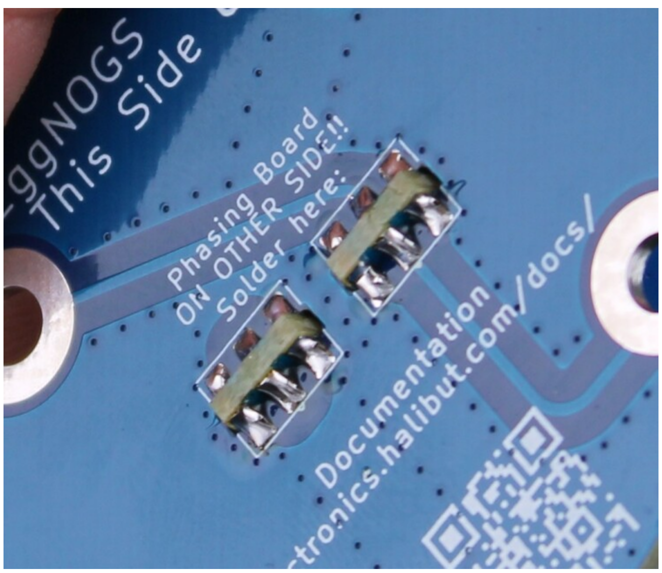
- [ ] Inspect the angle between the two boards. If necessary, reheat that solder joint and adjust the angle to make the boards as perpendicular as possible. For example, I re-did this joint:

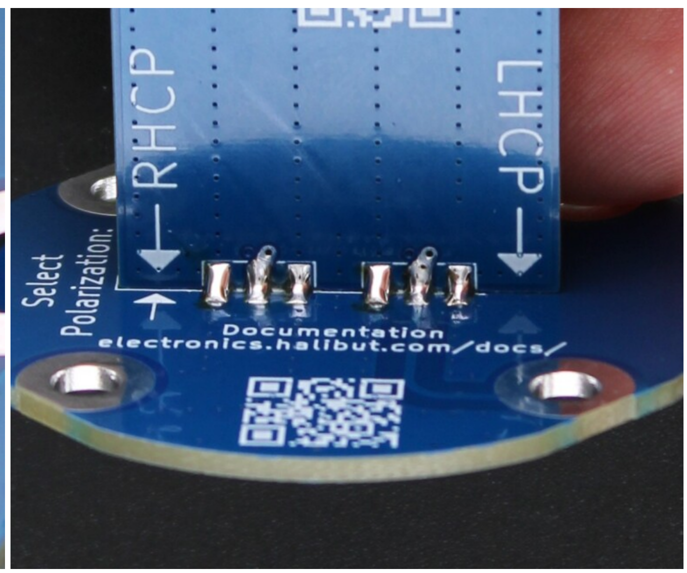


> Warning: Do NOT try to just bend the solder joint to be perpendicular, you'll lift a pad off the board. Ask me how I know. If your board angle needs adjustment, use your soldering iron to reheat that one pad's solder joint and adjust. Now is the only opportunity you'll have to fix this.
>
> It doesn't have to be perfect, but get it as close as you can to minimize off-axis forces from the feed line hanging down from the phasing board.



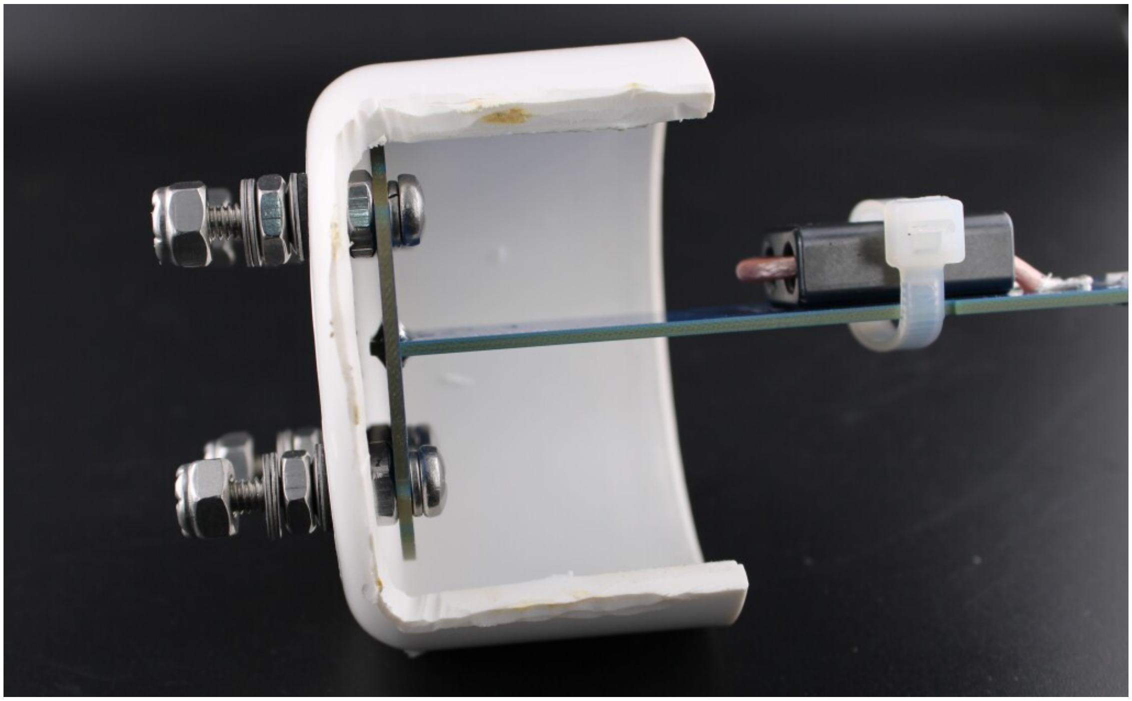
- [ ] Once you're happy with the angle between the two boards, solder the rest of the pad joints, on both top and bottom.





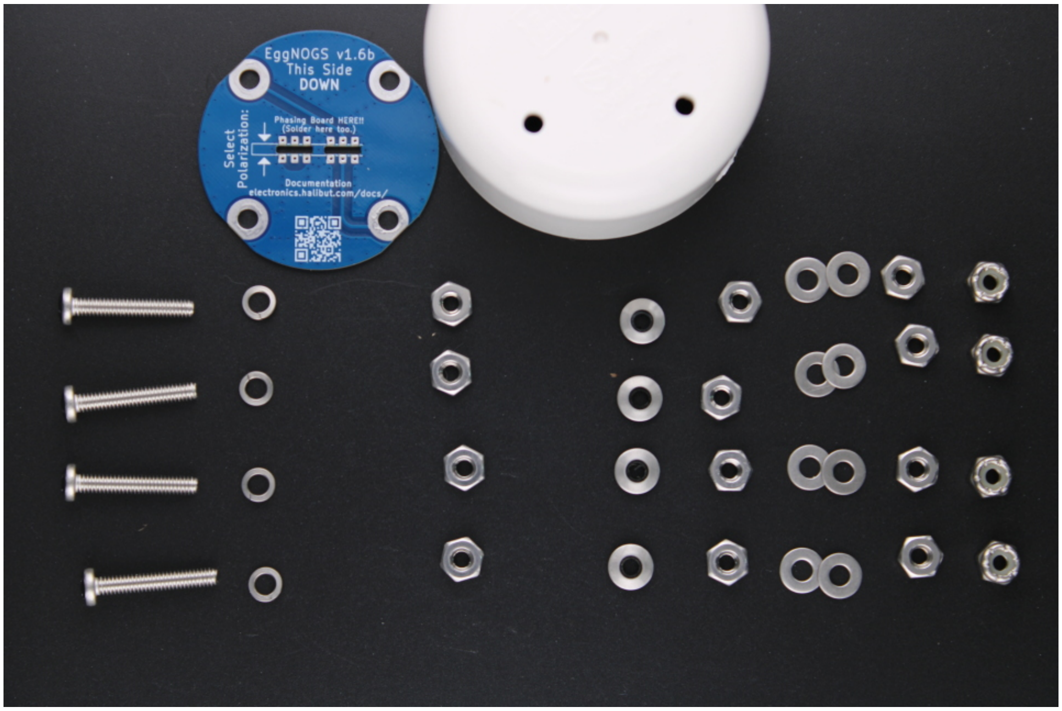
4.3. Structural Assembly

Now we'll mount the board assembly you just finished into the PVC cap and get it ready for connecting aerial loops. Through the magic of a Dremel Tool, I have a see-through PVC cap. This is what it will look like when we're done:



4.3.1. The full stack-up

Make sure you have all the parts. This picture shows all the parts in the order they will be installed. The Main Board is included in this photo to show where it goes in the stack up.



All hardware is 18-8 stainless steel.

- 4x No 8-32 1 inch screws
- 4x No 8 split locking washers
- 12x No 8-32 "normal" nuts, in three different columns of that picture
- 4x No 8 rubber sealing washers
- 8x No 8 flat washers
- 4x Nylon locking nuts
- 1x Pre-drilled PVC cap

This is the full stack-up of the hardware. All four screw holes are identical.

From top to bottom:

- Nylon locking nut
    - The kit includes four extra "normal" nuts to use while building. Replace them with nylon locking nuts when deploying.
- Flat washer
- Aerial loop: a loop of copper wire, screw terminal, a hole drilled in aluminum stock, whatever you have
    - Not shown in the pictures here
- Flat washer
- Nut
- Rubber sealing washer
- PVC cap
- Nut
- Main board
- Split/locking washer

- Screw head

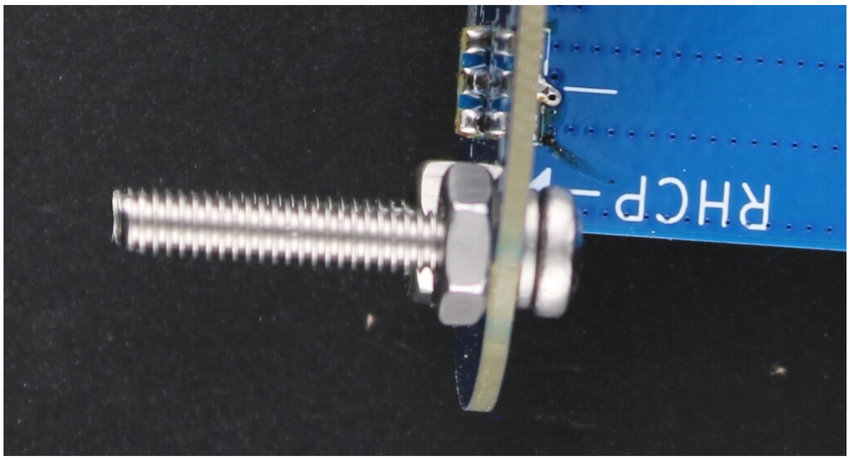
4.3.2. Step-by-step

The following instructions apply to all four screw holes.

- [ ] Slide a locking washer onto a screw.

- [ ] Insert the screw through a hole on the bottom of the main board, so that the long part of the screw sticks out the top of the board, opposite the phasing board.

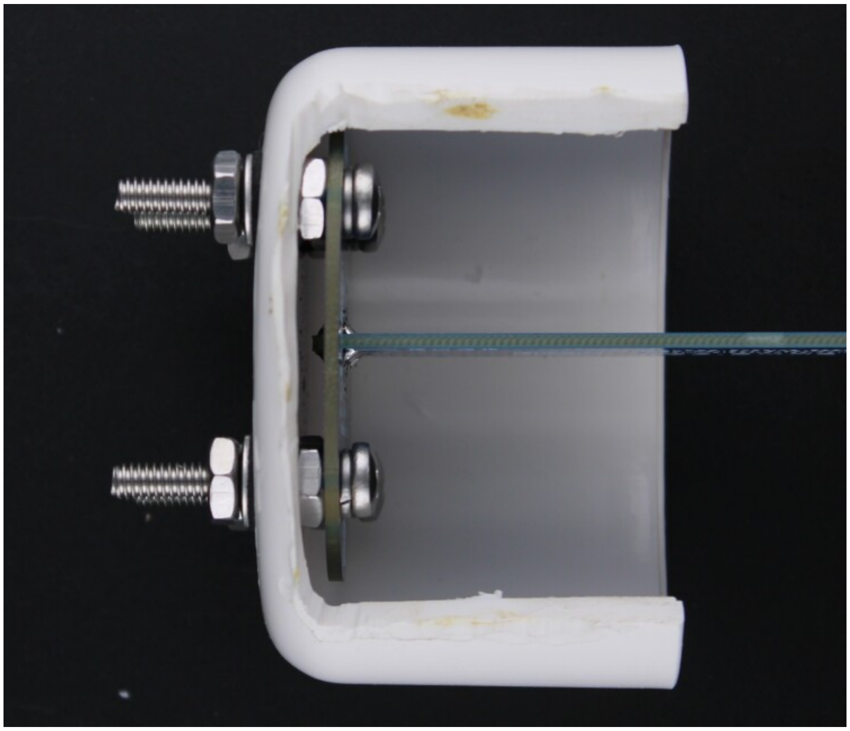
- [ ] Thread a nut onto the screw, tight enough to compress the split washer all the way. You don't want it getting lose, but don't crank it down hard enough to damage the board. It just needs to hold the screw in place on the main board, and space it out from the PVC on the cap a bit.



- [ ] Insert the main board assembly (with all four screws on it) into the INSIDE of the PVC cap, with the screws protruding through the holes to the outside. The holes should line up cleanly with the screws.

- [ ] Add a rubber sealing washer onto each screw. They take a little force to work down the screw.

- [ ] Thread a nut onto the screw, and tighten it down well to seal the washer, but don't crush it. This performs your weather sealing and structurally holds the EggNOGS assembly to the rest of the antenna.



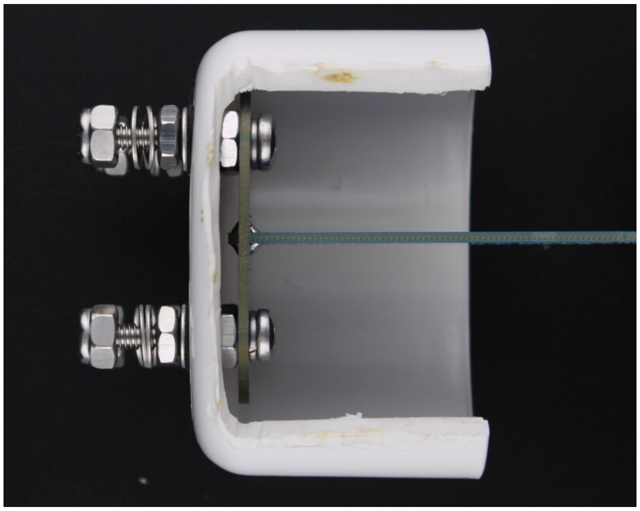
- [ ] Add a flat washer.

- [ ] Attach your aerial loops here (see section 5.1 below). If the connections on the aerial loops are closed (eg: ring terminals), you have to do this now. If they're open (eg: fork spade terminals, 180° turn of solid copper wire, etc.) then you can add them later.

- [ ] Add the last flat washer.

> Note: While building and tuning the antenna, use the last four normal non-locking nuts here. They're just easier to put on and take off as needed. When you're happy with the build and are ready to deploy, replace them with the included nylon locking nuts.

- [ ] Thread on the last nut (normal while building, or nylon locking when deploying). Once the aerial loops are attached, drive these down tightly.



4.4. CONGRATULATIONS!

That's the EggNOGS part of your new antenna! The rest of this document discusses building the rest of the antenna.

5. The Rest of the Build

This section describes the parts of the antenna that you provide. Nothing here is unique to EggNOGS. This document will link to other resources, rather than commit copyright infringement, or risk getting something wrong, or out of date.

The one exception to this is the K5OE Egg Beater II antenna design. This is the design I like the best, and Jerry, K5OE, has given me permission to include his design in these instructions. I'll still provide a link directly to his great materials.

5.1. Aerial Loops

There are several shapes and designs that can be used with EggNOGS. The simplest (and the namesake) is the Egg Beater antenna. But really, EggNOGS can be used to feed any quadrature phased antenna, where four elements need 0°, 90°, 180°, and 270° phases. It's optimized for 100Ω antennas (like the full-wave loop used in the Egg Beater), but works well for other antenna designs too.

If unsure which to build, I suggest starting with the K5OE Rectangular Egg Beater.

> Warning: Be careful of designs that use different sized loops for each element, and don't use a 1/4λ phasing section of feed line. Those designs achieve the 90° phasing by making the loops reactive at the target frequency, Z=R+jX for one and Z=R-jX for the other. **EggNOGS will not work with those designs.**

5.1.1. K5OE Rectangular Egg Beater

Probably the best Egg Beater design I've seen is by Jerry, K5OE. His original document is here. All the pictures of a completed EggNOGS in this document are K5OE Egg Beaters.

The K5OE Egg Beater is two rectangular loops mounted at right angles to each other. The dimensions of those loops for different bands are given below, but the shorter sides of the rectangle are on the top and bottom, and the longer sides are on the, uhh, sides. EggNOGS attaches to the center of the bottom of the rectangles.

When forming the rectangles out of whatever material you're using, form the rectangles with the opening (the ends of the wire) in the center of the bottom.

TODO Picture of loop before trimming and stripping.

Lay the rectangle aerial loop down next to your EggNOGS, across opposite bolts, and mark where the bolts cross the bottom edge of the loop.

TODO Picture of loop laid on EggNOGS, showing the markings.

Strip the wire, or punch your hole, or however you plan to attach the aerial loop to EggNOGS. Attach it to EggNOGS, *without deforming the rectangle*. This means you may need to trim off some of the aerial loop, making the whole thing shorter. That's ok because there's about that same amount of length INSIDE EggNOGS.

If you're using solid core copper wire (like I do, and like shown in the pictures), strip the wire a bit past the bolt so it's exposed copper as it crosses the bolt. Then wrap the exposed copper wire 180° around the bolt, and trim any excess.

Once you have two such rectangular loops, connect them to opposing bolts on EggNOGS (not adjacent bolts) and tighten the nuts to hold everything in place.

TODO Picture of a close-up of the bolts and wires.

5.1.1.1. Dimensions of K5OE Egg Beater Antennas

Here are the dimensions of the K5OE Egg Beater antenna for different bands:

Band	Horizontal Top and Bottom	Vertical Sides
137.5MHz	21.4 inches / 54.3cm	26.1 inches / 66.4cm
145.9MHz	20.1 inches / 51.2cm	24.6 inches / 62.5cm
388.0MHz	7.57 inches / 19.2cm	9.26 inches / 23.5cm

Band	Horizontal Top and Bottom	Vertical Sides
401.0MHz	7.33 inches / 18.6cm	8.96 inches / 22.8cm
436.5MHz	6.73 inches / 17.1cm	8.23 inches / 20.9cm

5.1.1.2. Meta-Description of a K5OE Egg Beater Antenna

If you don't care about the derivation of those dimensions, feel free to skip this section.

The K5OE Egg Beater is two rectangular "full-wave" loops at right angles to each other. The rectangles have a 45:55 ratio between the top/botton, and sides, respectively.

The total length of the loop is "full-wave" in quotes because it's actually 10.7% longer than a full wavelength. Jerry tuned the size and shape of the loops to be as close to 100Ω resistive as possible; when two such loops are connected in parallel, they match directly to the 50Ω feed line.

Given that description, here's the math:

```
Length_topbottom_cm(Freq_MHz) = (.45/2)*(29970/Freq_MHz)*1.107
Length_sides_cm(Freq_MHz) = (.55/2)*(29970/Freq_MHz)*1.107
```

- `(.45/2)` or `(.55/2)` calculates the fraction of a wavelength for a given side.
- `(29970/Freq_MHz)` calculates the wavelength in centimeters.
- `1.107` accounts for the 10.7% longer total "full-wave" loop length.

Those can be minimized, and we can convert to inches too:

```
(.45/2)*29970*1.107 = 7464.8
Length_topbottom_cm(Freq_MHz) = 7464.8/Freq_MHz

(.55/2)*29970*1.107 = 9123.6
Length_sides_cm(Freq_MHz) = 9123.6/Freq_MHz

Length_inches(Length_cm) = Length_cm/2.54

7464.8/2.54 = 2938.9
Length_topbottom_in(Freq_MHz) = 2938.9/Freq_MHz

9123.6/2.54 = 3592.0
Length_sides_in(Freq_MHz) = 3592.0/Freq_MHz
```

So, element length as a function of frequency in MHz:

Length of which element	Unit	Function
Top and bottom	cm	**7464.8/Freq in MHz**
Sides	cm	**9123.6/Freq in MHz**
Top and bottom	inches	**2938.9/Freq in MHz**
Sides	inches	**3592.0/Freq in MHz**

5.1.2. Circular Egg Beater

Two full-wave circular loops mounted at right angles. This was the design that K5OE started with and improved (see above.) Unless you know otherwise, I'd recommend the rectangular design above.

https://qsl.net/k/kd7tww//Antennas/Antenne Eggbeater-Engl-Part1-Full.pdf


5.1.3. Turnstile

Two half wave dipoles mounted at right angles. Also called cross-dipoles, for obvious reasons.

https://www.tutorialspoint.com/antenna_theory/turnstile_antenna_theory.htm

https://en.wikipedia.org/wiki/Turnstile_antenna

5.1.4. Quadrifilar Helix

This is a more complex build, but apparently a very capable antenna. I haven't built one myself.

https://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=5399&context=smallsat

https://usradioguy.com/wp-content/uploads/2020/05/20200307-How-To-Build-A-QFH.pdf

5.2. Ground Reflector

EggNOGS is designed so that all the circuit boards and feed line fit inside the 2in/50mm PVC mast. You provide the PVC pipe; you can make it as long as appropriate for your deployment.

Egg Beater designs typically have a ground plane under the aerial loops (see design details above) to pull the lobes down to the horizon a bit. This gives more gain on the longer horizon path, at the expense of lower gain on the shorter overhead path. In my experience, I haven't noticed a strong difference between with- and without the ground reflector, but your mileage may vary.

Whether you deploy a ground reflector, and where you deploy it, is up to you and the specific antenna design you chose. EggNOGS as a product doesn't address the ground reflector at all.

5.3. Feed Line

Similarly to the mast and ground reflector, you provide the feed line. However, there are a few things to be aware of.

5.3.1. Keep the Feed Line Immobile

Structurally, the feed line hangs from the EggNOGS boards. The solder joints will hold a fair bit of weight, but I haven't tested this and can't tell you HOW MUCH weight it can hold. Besides, that depends entirely on how solid the solder joints are.

I suggest the following few things to minimize the chances of problems:

If your deployment has a long, heavy feed line, consider using a short, flexible jumper cable to connect EggNOGS to the heavy feed line, and attach the feed line to the support structure so that the support structure bears the weight of the cable.

No matter what feed line connects directly to EggNOGS, make sure it is immobile. Don't let it sway in the wind. This will prevent it from causing fatigue failures in the boards or solder joints.

A suggestion from a customer is: drill two holes into your PVC mast about 6 inches / 15cm below the feed point of the antenna. The holes need to be big enough to feed a zip-tie through them. Wrap the coax with 10-or-so turns of electrical tape, or foam, or some other way of distributing the load and not crimping the coax, and zip-tie the cable to the inside of the mast. Make sure you use a UV resistant zip-tie.

5.3.2. Critters and Weather

EggNOGS is weather tight at the top (to the degree you trust the rubber sealing washers anyway), but the bottom of the mast is still open to the elements, and to critters who see it as a wonderful place to build a nest.

Covering the lower end of your PVC mast is a good idea. You'll need a way to get the feed line out, so something formable like soft foam, or a rag, or steel wool (critters HATE the stuff.) Otherwise, another PVC cap with a hole and a grommet, or similar.

What ever you do, make sure it has a way for moisture to get out. If it's a solid bottom, drill a small weep hole for any condensed moisture to get out.

> **"Make it hard for water to get in, and easy to get out."**

> --Mike Walker, VA3MW, on the Ham Radio Workbench Podcast

6. Conclusion

If you have any questions, or run into any problems, don't hesitate to Contact Us:
https://electronics.halibut.com/contact/

If you would like an EggNOGS Phasing Board for a band we don't currently offer, please Contact Us and tell us what frequency. We can make it for you, and add it to our offerings.

I encourage you to join our Groups.io list: https://halibut-electronics.groups.io/

Again, thank you for your purchase of an EggNOGS antenna! I hope it gives you many QSOs of fun and excitement.

Cheers, 73 de N6MTS
-Mark