Designing and Constructing a Magnetic Loop Antenna

Presentation to the
Richmond Amateur Radio Club

- Many articles and video segments have been produced to demonstrate the use of magnetic loop antennas for amateur radio use.
- Ideally, a loop antenna is designed to be portable, easy to assemble, small enough to use when camping or operating in remote locations, and able to cover several bands.
- The drawback of most commercially available loop antennae is the price. They range anywhere from $300 to $500 according to advertising on the Internet and in catalogs.

- With the recent interest in UbitX and other QRP transceiver projects by members of this organization, it seemed useful to devise a well designed "do-it-yourself" magnetic loop antenna to be used with these low-power rigs.
- In the planning process for this project, we examined a multitude of videos and catalog cuts that were available, in the time frame we had available, with the objective of learning how these devices work, and what features are desirable or required in the construction of a good antenna.
- Here is what we found:

- There appear to be three major brands of commercially manufactured antennas of this type. There are other less advertised variations along with home brew versions as well. The Chameleon “P” which can be upgraded to a model “F” with additonal components; the Alpha Loop; and the HG-1 Precis seem to be the leading brands.
- In the info we observed, the Chameleon “P” seemed to be the best of the crop. The tripod supplied with the Chameleon is flimsy and subject to be blown over in even a mild wind, but the antenna itself seemed to have the best features. We therefore decided to build our “clone” based on that model.

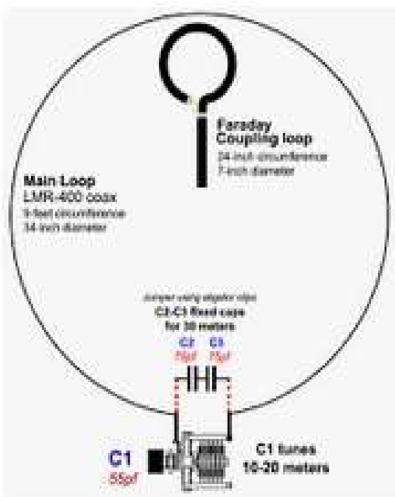
- For reference, here are views of the various styles of loop antennas we researched:

DELUXE HG-1 Precis...
preciserf.com · In stock

Building A Magnetic Loop Antenna |...
hackaday.com

Ciro Mazzoni Automati...
dxengineering.com · In st...

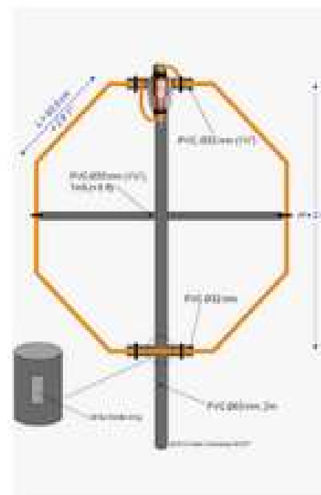
Alpha Loop QRP Mag...
radioworld.co.uk · In stock



Small Magnetic Loops - K5IJB

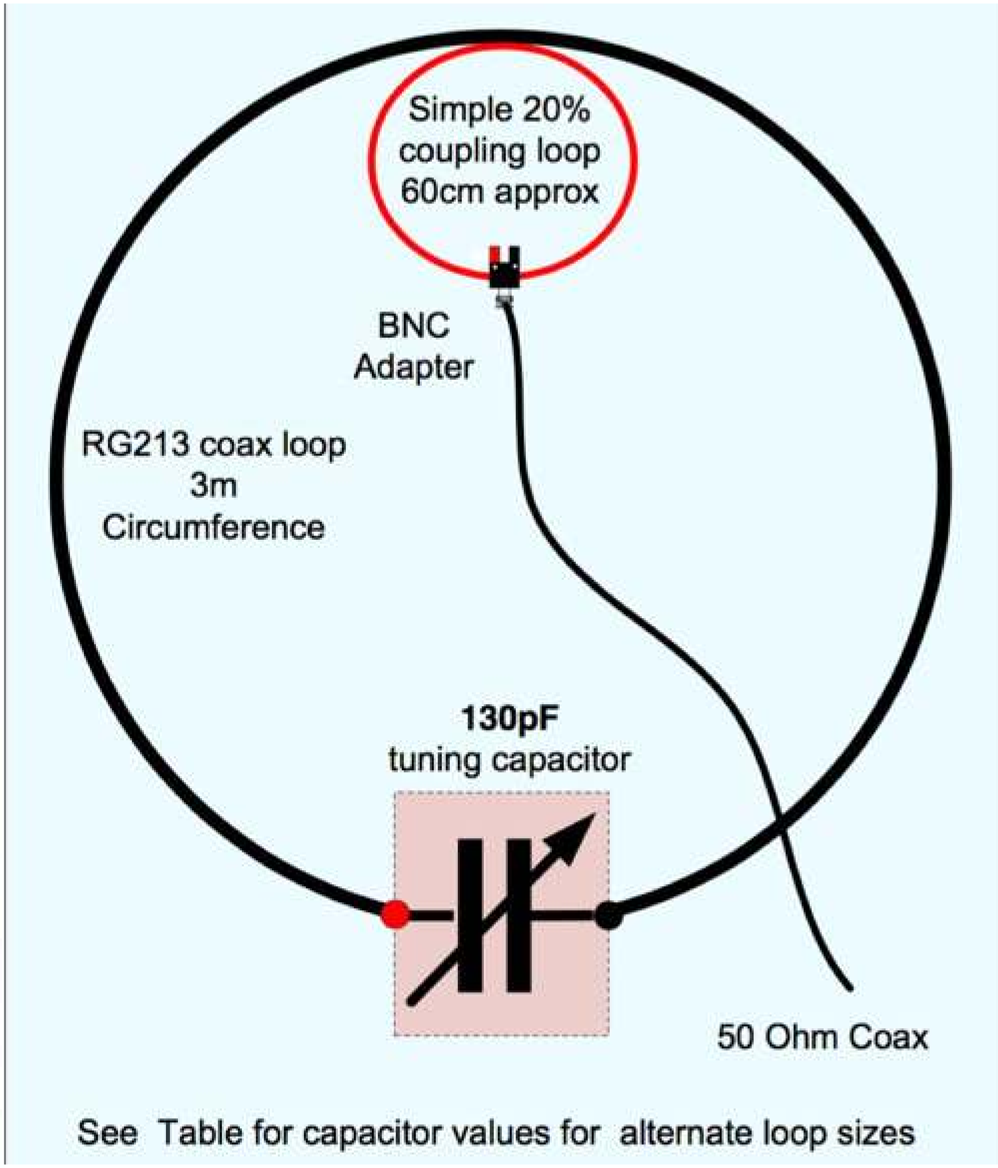
100 Watt 10-40M Magnetic Al...

Magnetic Loop Antenn...



80-20m Mag Loop

- What goes into creating a magnetic loop?



Quick and simple way to install the loop as a manually tuned or fixed frequency auxiliary antenna

- There are four given factors:
- The smaller Faraday loop should be in alignment with the larger outer loop
- The loops should be as close to round as possible for normal operation on the bands that we desire. Optimum shape can vary.
- Precautions must be taken because of the high voltages that occur at the tuning mechanism. Precautions must also be taken to prevent unwanted radiation from the feed line, therefore ferrite chokes are needed.
- The antenna should be above the ground by at least its own height.

The intended design of a mag-loop can be checked with this simple spread sheet calculator that is available as an Excel file:

mag_loop_calculator.xls - OpenOffice Calc

File Edit View Insert Format Tools Data Window Help

B13 | 60

	A	B	C	D	E	F	G	H
1	**Yellow Values for Input**							
2	**Green Values for Output**							
3	**LC-Calculation:**							
4	Frequency:	1,000 kHz		Frequency:	1,000 kHz		Inductance:	169 μH
5	Capacity (incl. Parasitics):	150 pF		Inductance:	169 μH		Capacity:	150 pF
6								
7	**Necessary Inductance:**	**168.9 μH**		**Capacity:**	**150 pF**		**Frequency:**	**1,000 kHz**
8								
9								
10	**Coil-Calculation**							
11	μr:	1	(Air=1)					
12	Winding-Diameter D:	700 mm						
13	Length of Winding l:	60 mm	(form first to last turn)					
14	Shape of Winding:	Square						
15	Form factor of winding α:	0.09	l/D					
16	Turns:	10.14						
17	**Turns (rounded):**	**10**						
18								
19								
20	**Q-Factor Calculation:**							
21	Number of (Litz-) Wires:	90	(1=Single Wire/Tubing)					
22	(Single) Wire-Diameter:	0.10 mm						
23	Total Diameter incl. Isolation (5%) and Fill-factor for Litz-Wire (0,5):	1.99 mm						
24	Winding density η:	0.33	(=1 would be "touching turns"; if value is >1 increase the winding-diameter D!)					
25	Eff. Cross-sectional area A:	0.71 mm^2	(determins DC-Resistance)					
26	Specific Resistance ρ:	0.017 Ohms*mm^2/m	Copper: 0,017 Silver: 0,016 Aluminium: 0,0265 Brass:0,07 Steel: 0,12 Gold: 0,022					
27	Specific DC-Resistance:	24.1 mOhms/m	ρ/A					
28	DC-Resistance:	0.673 Ohms	ρ*l/A					
29	Skin-depth δ:	66 μm	Result only valid for non-iron metals (copper, aluminium, silver etc.)					SQR(2*ρ/(2*π*f*μ))
30	x:	0.76	d/2δ					
31	r/δ:	1.52						
32	Skin-Resistance Rskin:	0.75 Ohms	(already includes DC-Resistance!)					
33	Skin-factor (Rskin/Rdc):	1.11						
34	m:	0.97						
35	Φ:	1.21						

Should I

BUILD OR BUY?

A factor in the decision to build vs. buy is the total cost of the project. While the basic construction seems simple enough, building a well designed antenna, with the same features as the manufactured version, can cost slightly more than you might expect. Costs are, however, still substantially less than the store bought version in most cases

The antenna discussed herein cost under $150.00 to build, which is far less than the Chameleon's advertized price tag of $399.00.

If you have done the research and decided to construct your own Loop antenna, here are some components that you will need to obtain:

- A basic parts list includes:
- 1” x 1/8” 30” aluminum flat bar (available at hardware and home improvement stores.
- An SO-239 x 3/8 x 24 stud connector available from American Radio Supply, Inc. Addresses for parts suppliers are included in this presentation. Two additional SO-239 and PL-239 connectors are also required for the main loop and tuning unit
- A 15' length of LMR-400 coaxial cable. (Available from Pasternak Inc.)
- A dual gang variable capacitor with good plate spacing (>.5KV prefered) and a value of at least 365 uuf per section. Part # C-V365-X3 from Antique Radio Supply is what we used.

- A plastic or carbon fiber enclosure able to house a full-size dual-gang variable capacitor.
- A 10 foot length of RG-58U (small diameter) coax with PL-239 connectors installed.
- Four ferrite chokes and a length of 7/8” heat shrink tubing sufficent to cover the chokes.
- Mounting and support hardware, PVC fittings, brass screw insert, etc.
- Optional is a vernier reduction gear unit or a suitable motor drive for use with the tuning mechanism. We elected to use a vernier knob assembly that is commonly available from supply houses. (see supplier info)

The following problems were noted on some designs of commercial products:

The Alpha Loop tuning knob is located on the top of the tuner housing. Placing a hand on or near to the knob to adjust it, affects the tuning of the antenna. Ideally, this control should be located below the large loop rather than within its circumference.

Having the tuning knob on top also would allow dirt and water to enter the housing.

The neon tuning indicator on the Alpha is useless. When used with QRP level transmitters, the bulb doesn't even light.

- While the Chameleon antenna is the best of the three examined, its tripod base is under-sized for the height and weight of the total assembly. It is subject to fall over in even the slightest wind.
- We decided to use a good grade photographic tripod on our design, and therefore we made all mounting screws that interface with the tripod, the standard 1/4” x 20 threads-per-inch, that is found on most tripod camera mounts.

Some designs employed a coax ring for the Faraday loop. In the case of later Alpha models, the Faraday is LMR-400 coax with a “Tee” connector at the base. Other designs used a coax ring with the feed line directly soldered to the ring. This type of arrangement seems to be less than substantial in terms of the ability to keep the ring round. Having the feed line attached to the loop would also subject it to stress and breakage of the connections if the antenna is repeatedly disassembled and packed for transporting.

We therefore opted for a mechanically secure ring with an SO-239 coax feed line connector.

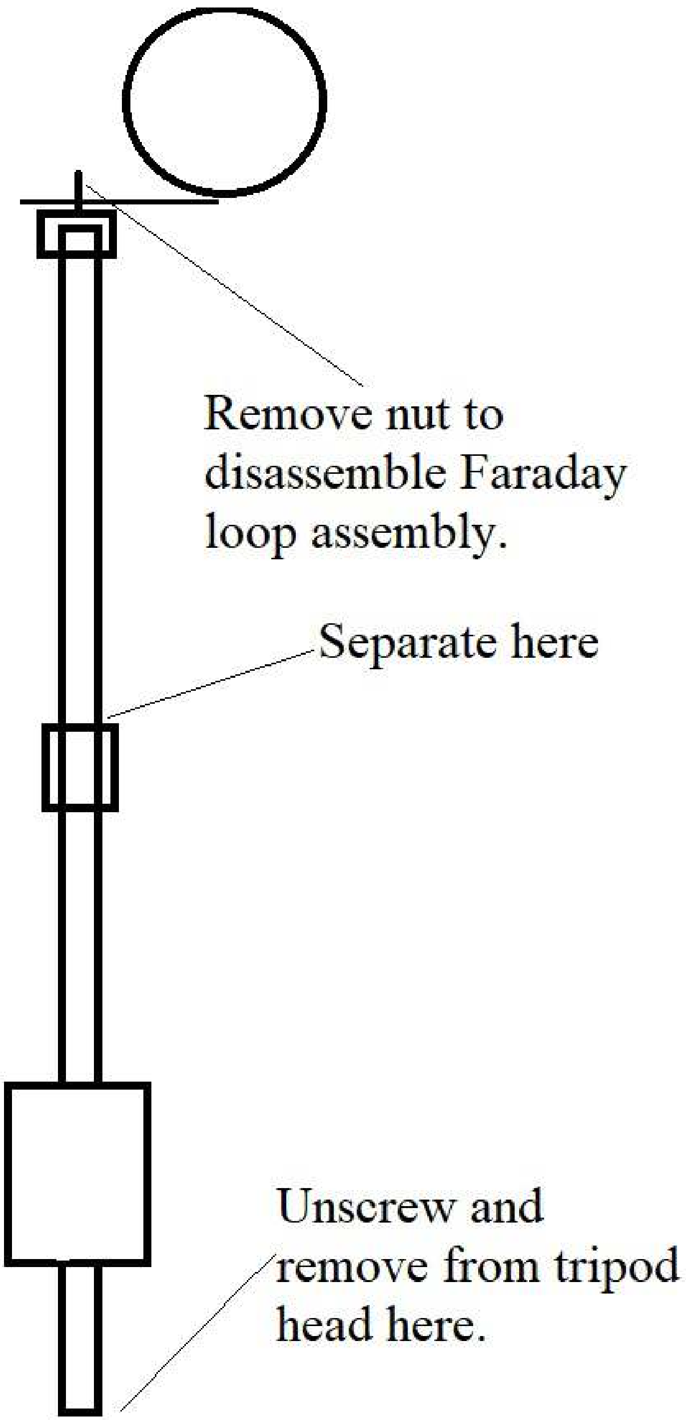
EASE OF ASSEMBLY AND DISASSEMBLY

The design is such that the PVC center mast can be disassembled by simply pulling the upper mast out of the sleeve that is in the middle of the mast.

The tuning unit can be removed by loosening the four 6-32 wing nuts that secure its hold-down straps to the mast.

The Faraday loop can be removed by removing the ¼ x 20 nut that secures its mounting tab at the top of the mast.

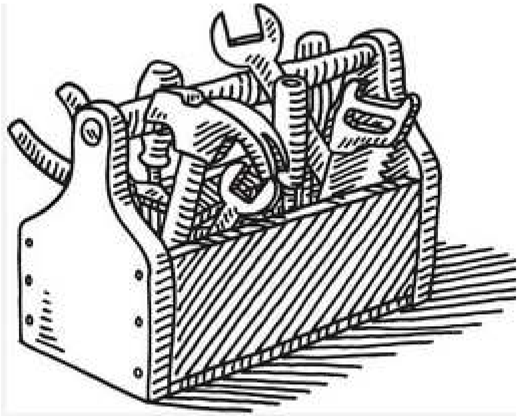
The large loop can be removed by unscrewing the two PL-239 plugs at the tuning unit.



The antenna breaks down into 6 sections for storage or transporting:

1. The tuning unit,
2. The lower mast section,
3. The upper mast section,
4. The Faraday Loop,
5. The LMR-400 main loop,
6. The 10' RG-58U feed line cable.

The user supplied photo tripod is not included in this list.

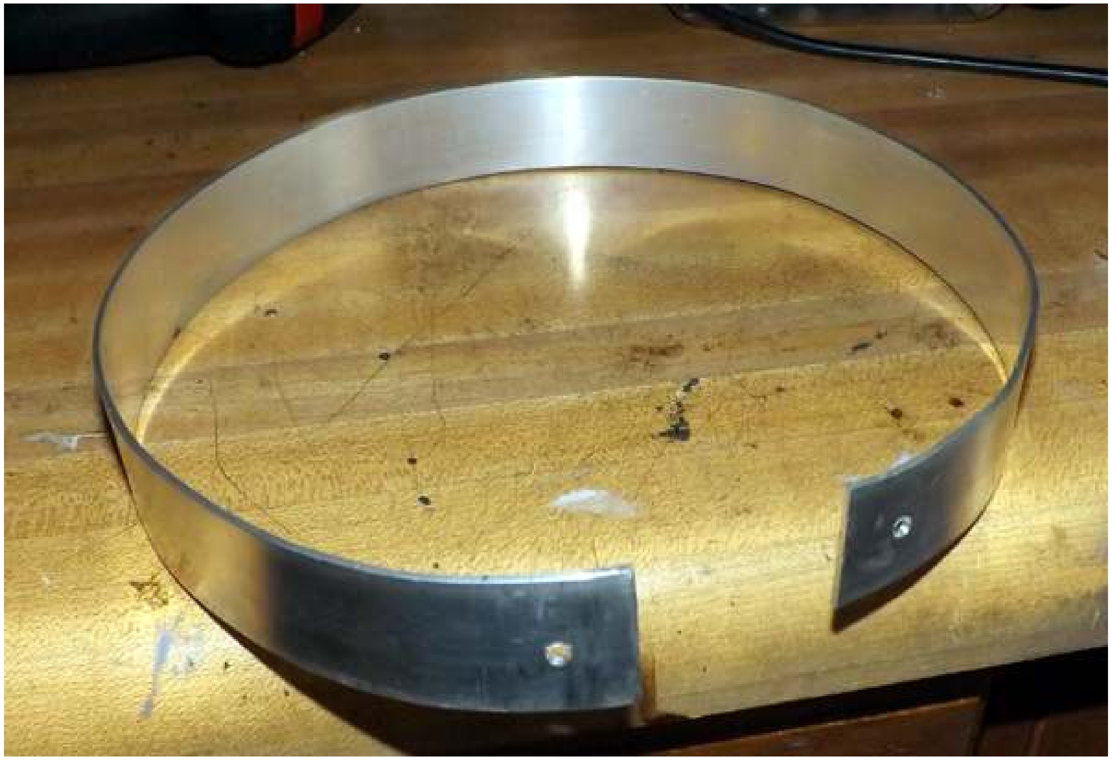


Now To The Shop!

CONSTRUCTION OF THE FARADAY LOOP AND MAST CAP

CONSTRUCTION

Building the Faraday Loop:



We started by cutting a piece of the 1” aluminum flat bar to a length of 23”.

We bent the bar around a 6” tomato sauce can. To smooth out irregularities, the metal was then heated slightly with a propane torch and formed into a perfect circle.

1/8” pilot holes were drilled 3/4” from each end.

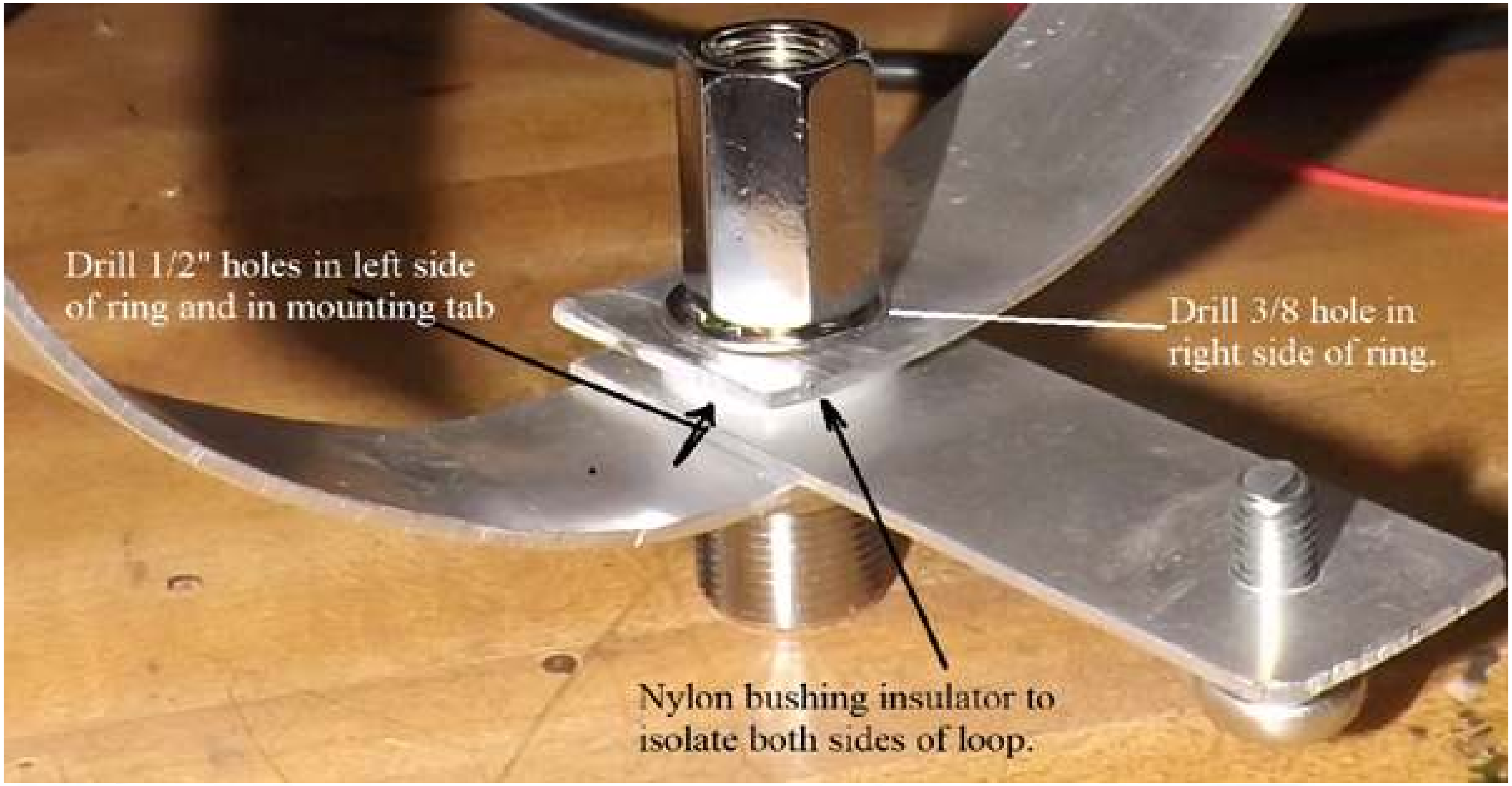
After heating, the ring and forming a circle, the ends were clamped with the pilot holes overlapping.

Next, we cut a 3-1/2" length of flat bar and tapped a ¼ x 20 threaded hole in one end and a 1/2" untapped hole in the other.

Next, the flat bar loop was drilled so as to produce a ½" hole in the left tip and a 3/8" hole in the right tip at the locations of the previously drilled pilot holes.

NOTE: For safety, it is advised that you clamp the metal securely when drilling the large diameter holes, or preferably clamp it in a drill press vice and use a drill press to drill the holes.

Install the SO-239 x 3/8 bushing as shown. Install the insulator washer so that the left side of the loop is connected to the connector shell, and the brass stud on the connector is connected to the right side of the loop.



The finished Faraday loop's diameter should be 6.9” (outside to outside) and should look like this:

The next component to fabricate is the mast 1" top cap which will have a fixed 1/4" x 20 screw to hold the Faraday loop. This is done by first tapping the center of the cap to accept a ¼ x 20 hex-head bolt. Stainless steel is recommended for all bolts on this project.

Partially screw the bolt into the tapped hole from inside the cap, letting the threads protrude from the outside top of the cap. Next, mix a small amount of 2 part Epoxy utility glue and carefully spoon it into the underside of the cap, being careful not to get it above 3/16" up the walls of the cap.

Next, tighten the bolt against the cap underside.

When the unit is completed and assembled, the mounting tab of the Faraday Loop will screw onto the stud protruding from the cap, and then a stainless nut and washer can be placed on the screw to secure it.

When the Faraday loop is mounted on the cap that forms the top of the antenna's mast, this is what you should have:

At this point, we should probably take look at the overall design of the antenna, and what we are trying to accomplish.

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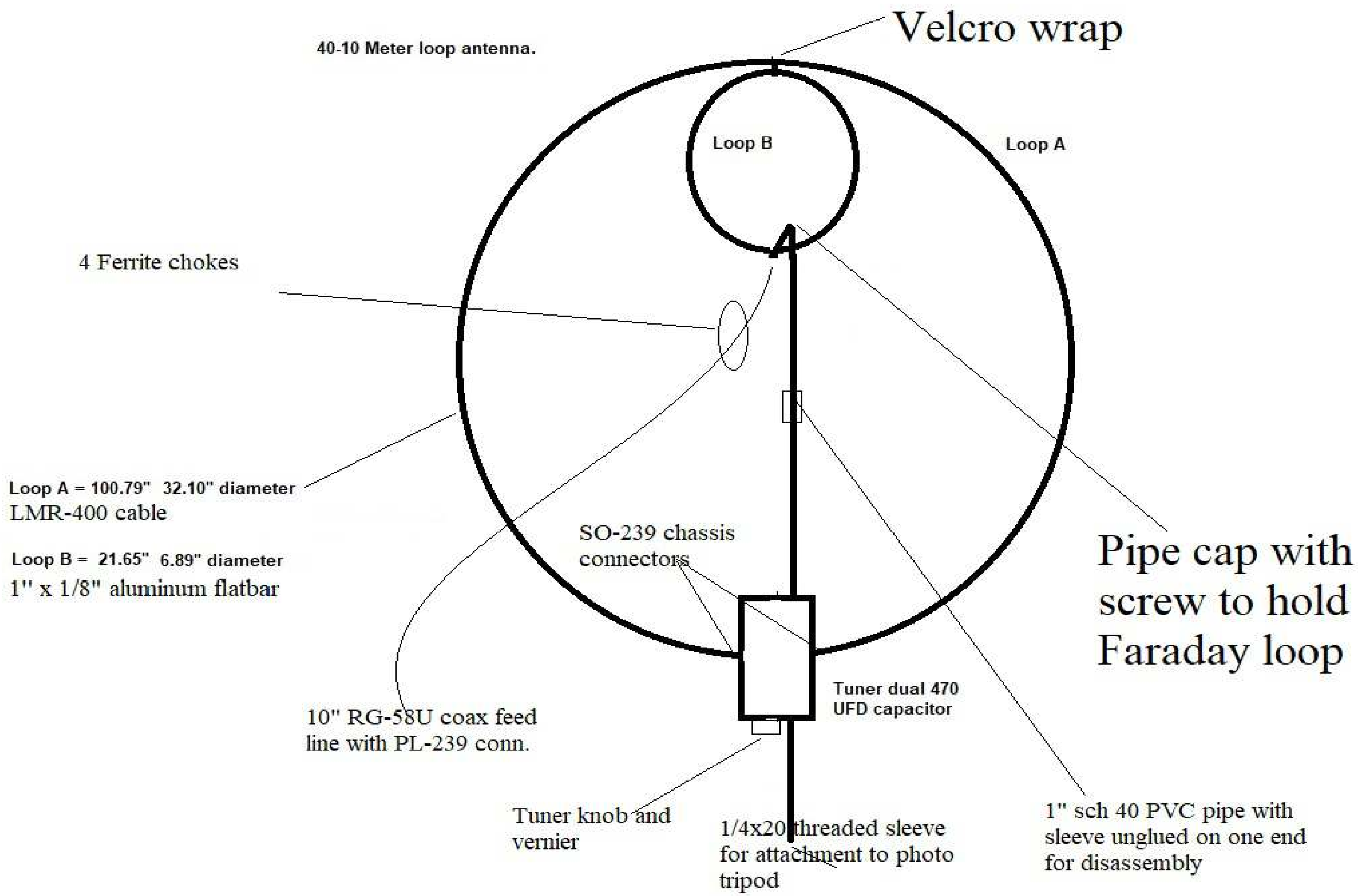
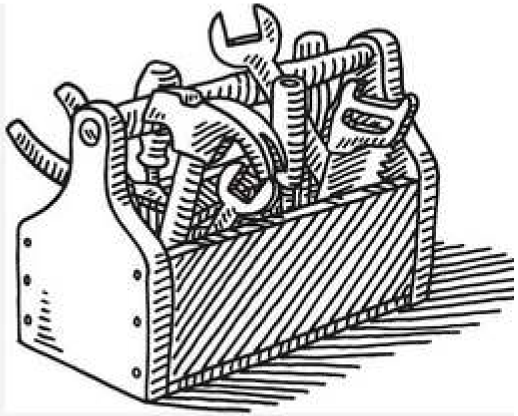




Next Step

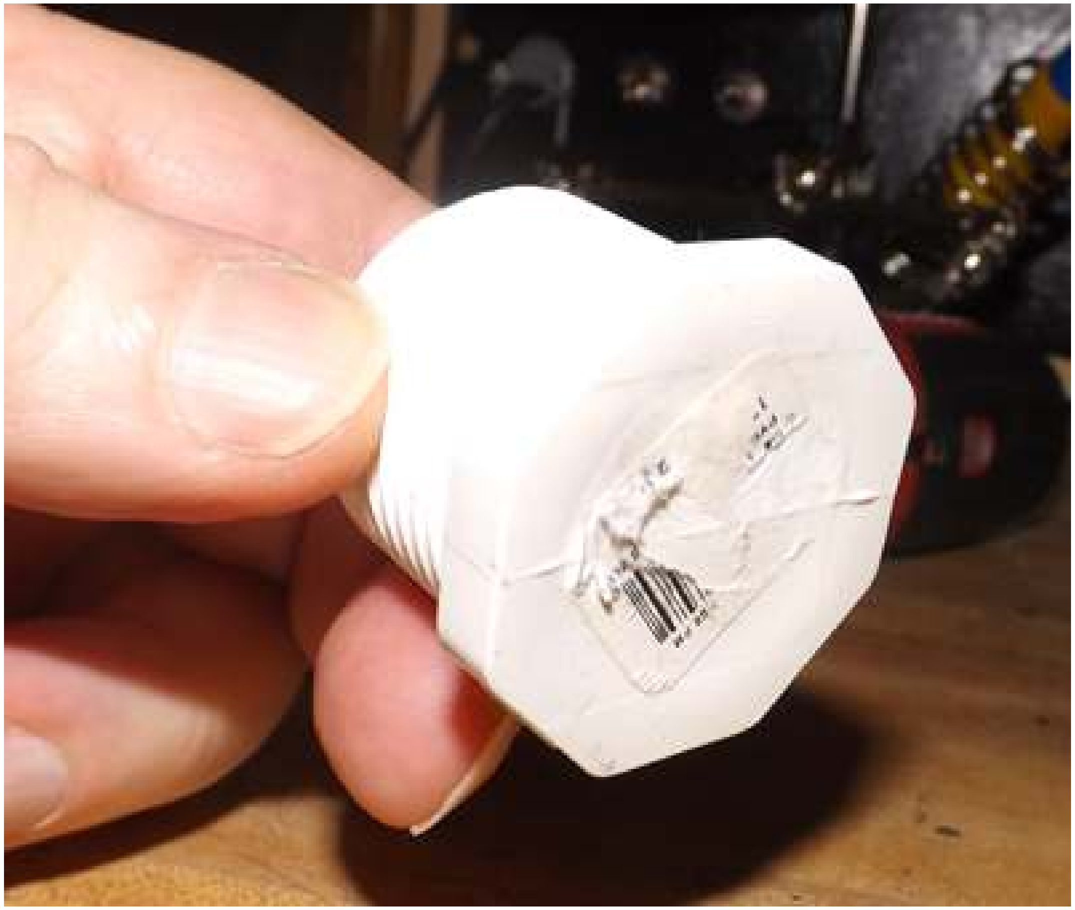
BUILDING THE MAST BASE

The next item to be constructed is the foot of the loop support arm that connects to a photographic tripod. Since we have elected to use PVC pipe as our support riser, it was necessary to develop a means to secure the end of the plastic pipe to the camera mount on a typical camera tripod.

Here is a description of the method we came up with, using PVC pipe fittings and a brass threaded insert.

First, the bottom of the fitting must have a generous flat surface to sit on the tripod's camera shelf.

A 1” pipe plug has a surface that is ample to sit securely on the tripod shelf.



The problem here is that the plastic at the top of the plug is not thick enough to prevent rocking.

The solution came in the form of a threaded brass insert that is designed to allow machine screws to be set into wood.

Threaded Inserts

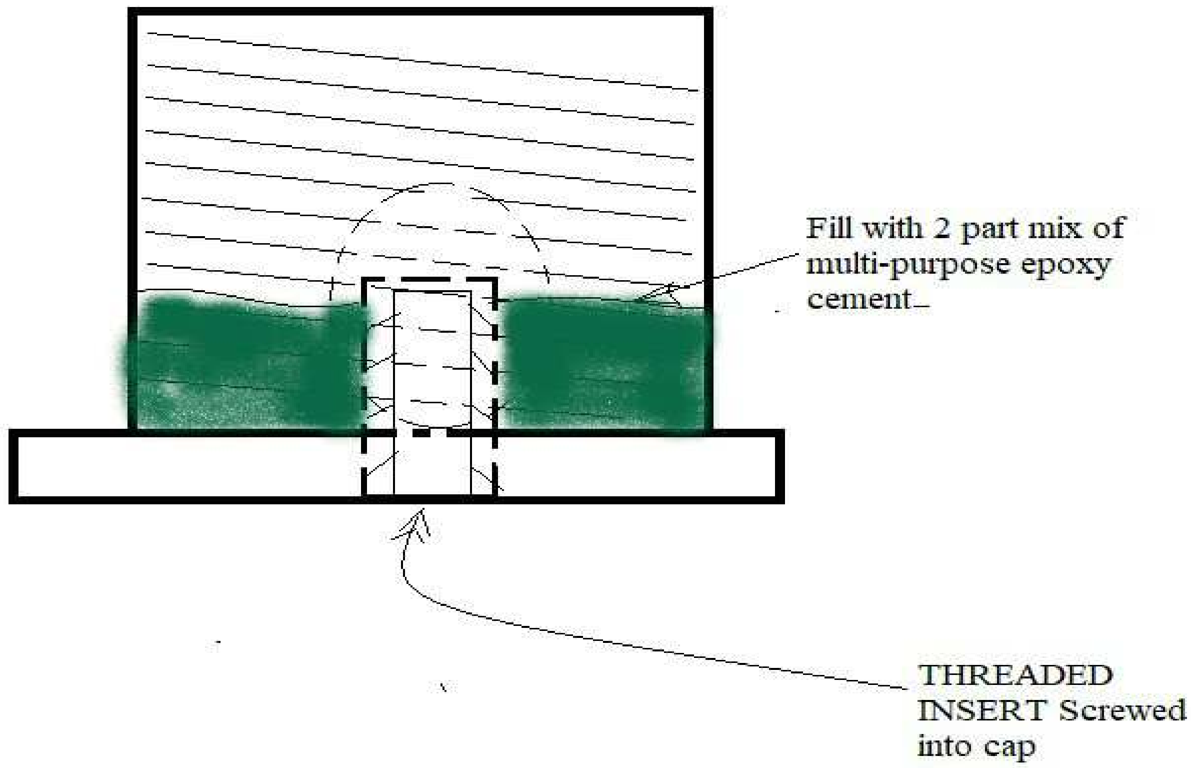
Use in new construction, replacement of stripped wood screws, or replacement of WurliTzer™ inserts. Allows for convenient, efficient, and frequent removal of chest parts. Bore 3/8" hole.

.453" OD x 1/2" L

	ID Thread	Material	Use	Drive Tool
7710.10	10-24	Brass		8246.10
7710.12	10-32	Brass		8246.10
7710.16	12-24	Plated Steel	WurliTzer™	8246.10
7710.20	1/4-20	Brass		8246.16

Here, Part 7710.20 provides the ¼ x 20 thread size needed to mate with tripod camera mounting screws.

Drill a 3/8” hole in the cap. Thread in the brass insert so that it is flush with the surface of the cap base as shown. A ¼ x 20 screw can be inserted into the insert, from the bottom, to insure that glue does not get into the inner threads. Next, pour epoxy mixture to partially fill bottom of cap.



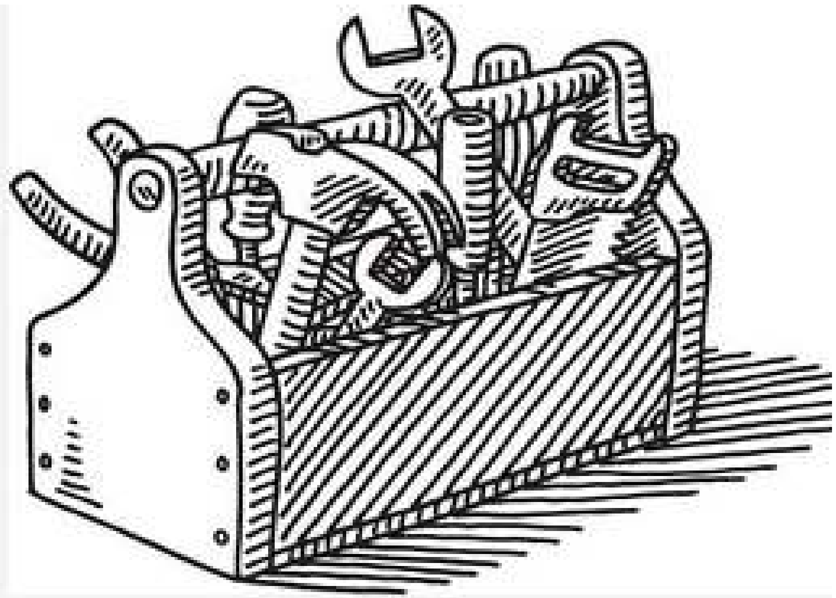
Before applying the epoxy mixture, insure that the insert is vertical in respect to the base of the cap, otherwise the antenna mast could lean off of 90 deg. vertical when mounted on the tripod.

If the insert is not vertical, you can carefully heat the top of the plastic cap with a small torch, and use a long 1/4” bolt or threaded rod to manipulate the insert so that it is at 90 degrees to the cap base. Allow the plastic to harden again before proceeding to the glue application.

If everything was done correctly, this is how your finished mast base should look:

The bolt shown in the insert is temporary to insure alignment of the brass insert. Epoxy glue has been poured into the cap to a level just below the top of the brass insert. The brass screw can be covered with a thin layer grease to insure that it can be removed in the event that any glue leaks onto the threads.

To complete this phase of the work, screw the finished mast base into the 1” PVC thread-to-sweat fitting that will ultimately attach to the bottom of the PVC pipe that forms the mast.



The next step will be construction of the

Tuning Unit

The tuning unit consists of a plastic box, a dual gang variable capacitor with a recommended value of 12-365 uuf per section, and two SO-239 female chassis connectors. A vernier or reduction device can be installed on the capacitor's shaft to facilitate critical tuning with greater than a 1:1 turns ratio. Even with QRP applications, the capacitor should be able to sustain RF voltages of between 500V and 1KV.

Today, it is almost impossible to find good mesh plate type variable capacitors of the value recommended, however the attached sheet shows a 3 x 365 capacitor that will allow the antenna to tune from 40-10 meters.

Home Products Capacitors

Capacitor - 3x365pF, Variable, 3 Section

Termination Style Solder Lugs/Tabs **Type** Variable

Three section, 365pF each. 3 ¼ long frame ¼" x 1" shaft. This capacitor is the largest condenser currently in production and can deliver a total capacitance of almost 1100 pF. Each section can be divided, creating a 6-section capacitor.

- Minimum capacitance per section: 10.3pF
- Maximum capacitance per section: 365.7pF
- Number of sections: 3
- Air gap: 0.0125 inches
- Maximum voltage: 600Vrms
- Counter-clockwise rotation

UPC/EAN: 841358109966

RoHS Compliant

View Product Measurements

Click to zoom in

Customer Images:

No Images yet! Submit a product image below!

Submit your own product image!

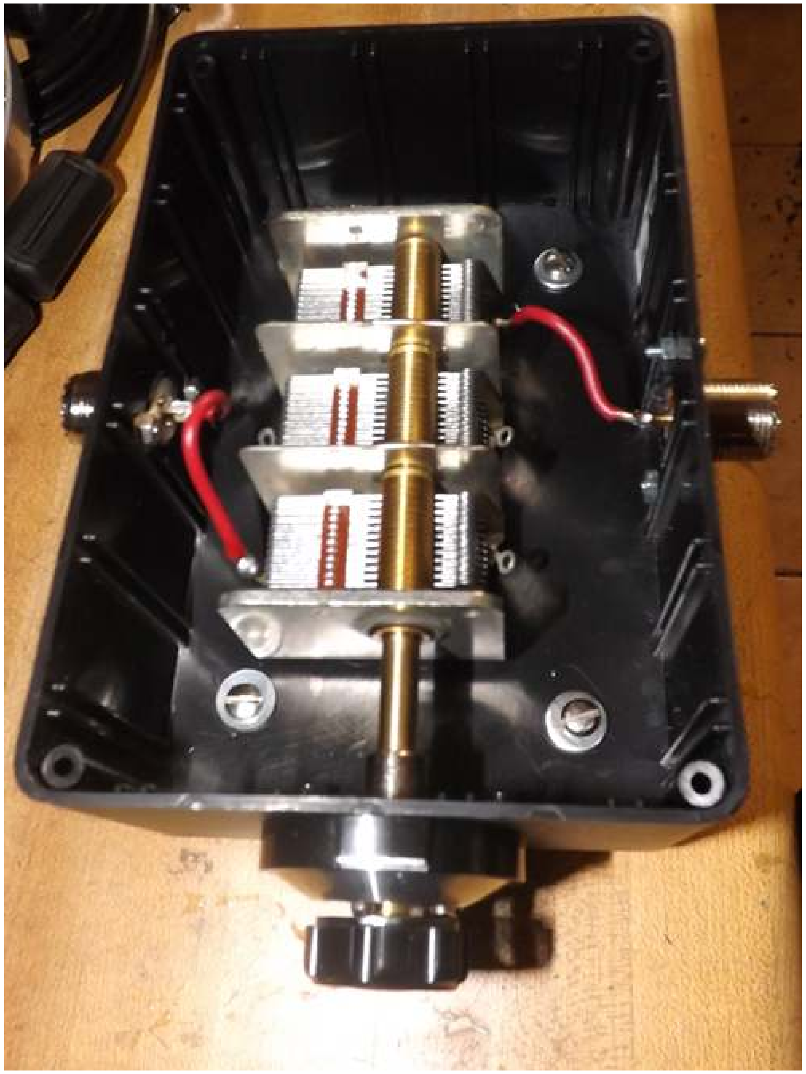
SKU: **C-V365-X3**
Item ID: **005318**
Price: $39.95
In stock

Quantity 1

Because of the anticipated problems with motor noise and an external power source being required for a motorized tuning drive, we opted for use of an 8:1 vernier as the tuning ratio reduction device.

The tuning unit is simple to build. These are the components needed:

This is how the tuner enclosure is prepared. It is helpful to make a template of the bottom of the capacitor for drilling accurate holes.

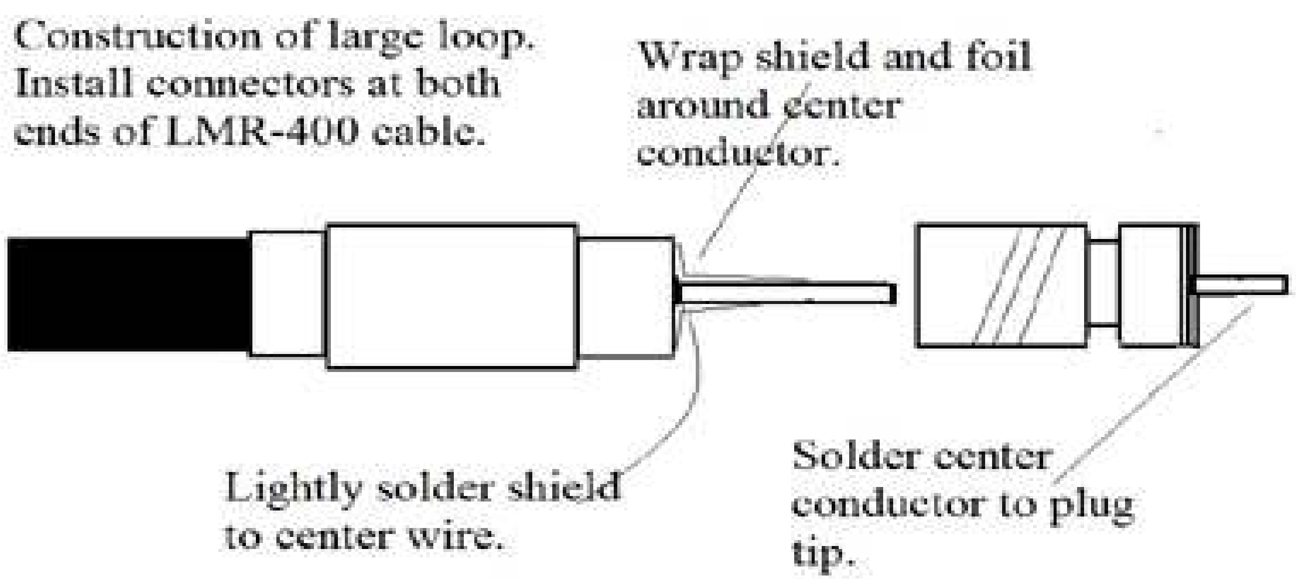


Contrary to conventional wisdom, the center and shell of the SO-239 connectors are shorted with grounding lugs. This is because both the shield and inner conductor of the LMR-400 cable are tied together to form the large loop.

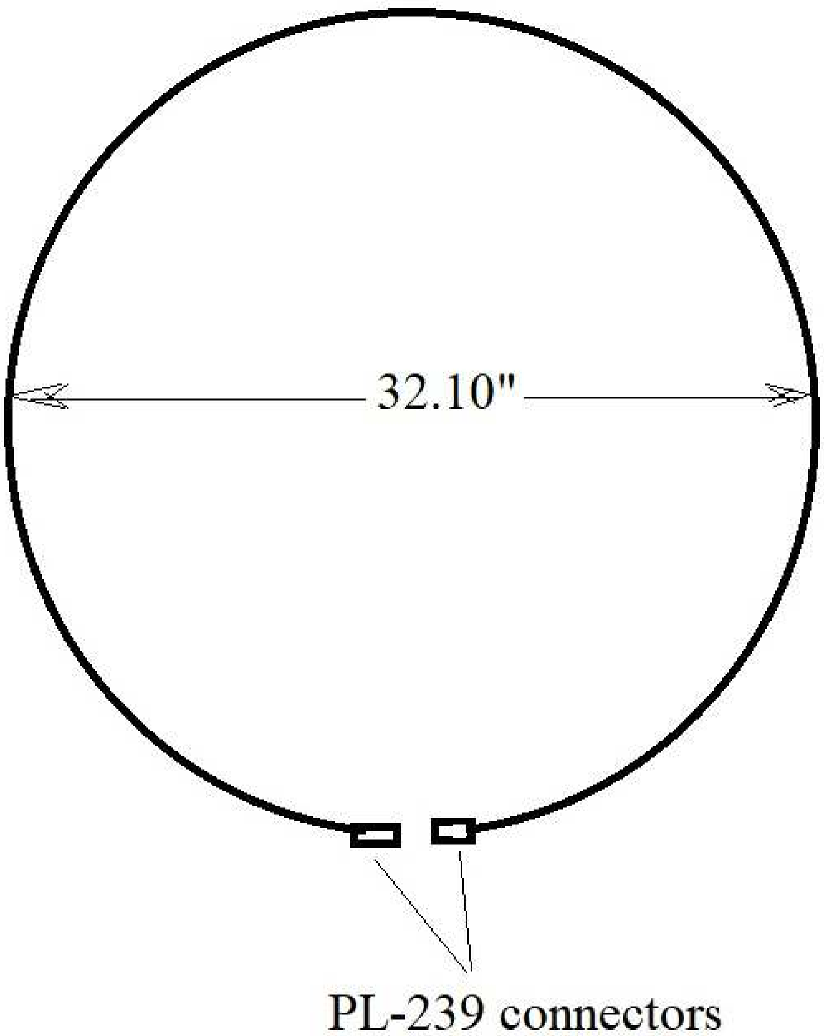
The order of assembly here was to measure the capacitor's shaft height and placement, and Install the vernier first. The holes for the capacitor mounting could then be drilled in order to avoid any offset in the placement.

There are four 1” bolts with washers and nuts that are installed through the back of the enclosure. These will be used to hold two straps and wing nuts that will secure the tuner to the PVC pole that supports the two loops.

Next, make up the LMR cable with the two PL-239 plugs. Remember that the shield and foil are wrapped around the center conductor so as to short the foil and shield to the center wire. Only the tip of the SO-239 connectors need to be soldered since both the tuning unit and the cable short the center and outer conductors.



The main loop should look like the example below.



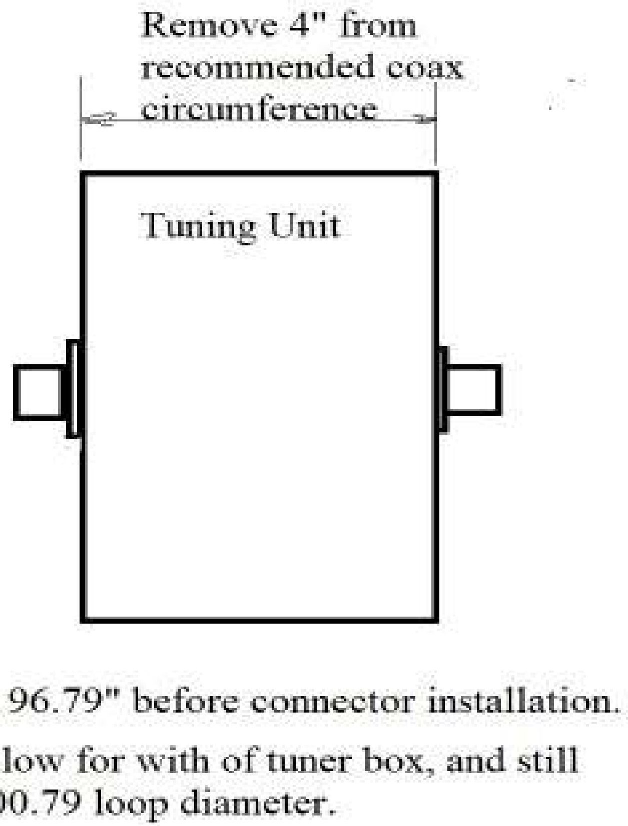
The overall circumfrence of the loop should Be 100.79”.

In figuring the length to cut the cable, be sure to reduce the length of the actual LMR cable by the width of the tuner enclosure, allowing for the portion of the wire that will inside the two connectors also.

This will require field measurements and cutting once the size of the enclosure and cable connectors are established.

We recommend installing one of the PL-239 connectors and then measuring the gap re-quired for the tuner box and the opposite connector.

The LMR-400 length of 100.79” should be reduced by 4” in order to compensate for the placement of the tuner in the loop.



FINAL ASSEMBLY

Preparation of the coax feedline:

Four ferrite chokes are to be installed on the RG-58U feedline, about 8” below the connector that connects to the Faraday Loop. Once the chokes are installed, they can be covered with 7/8” heat shrink tubing to protect them.

The final step is to assemble the PVC mast and attach the various components as indicated. This indicates how to install the tuner.

After measuring and cutting the LMR-400, and installing the connectors, the cable can be attached to the tuner in preparation for measuring the remaining section of the mast.

Now cut the top section of the mast to the proper height and install the Faraday loop assembly so that the top of the Faraday loop is even with the top of the main loop. Wrap the velcro to hold the tops of the two loops together.

Screw the antenna onto the tripod. You have now completed the construction process. Your finished antenna should resemble the one in the following photograph.

READY FOR FINAL TESTING

On the initial test, the SWR

On 40 meters was 1.5:1.

It was tested with similar SWR

readings on 20 and 15 meters

The reading on 10 meters was

1.1:1.

CONGRATULATIONS!!! You are now ready to test the antenna with a QRP radio.

Connect the antenna to the radio and select a band between 40 and 10 meters.

DO NOT TRANSMIT AT THIS POINT

Slowly tune the vernier until you notice a sharp rise in background noise. When you see or hear a peak, the antenna is likely tuned to resonance. Be sure you are tuned to the actual frequency and not a harmonic thereof. Use of an antenna analyzer, if available, is highly recommended, and SWR should always be checked before attempting to transmit for any length of time.

NOW FOR THE PROOF OF THE PUDDING

KEY UP YOUR RADIO AND WATCH OUT FOR SMOKE!

THE END