Portable Base-Loaded Quarter-Wave Vertical Antennas

Discussion, Inspiration, Design Ideas, and How-To

Portable Base-Loaded Quarter-Wave Vertical Antennas

Jason Turnage – KO4NDP – Feb 11, 2023

Let’s Discuss

- What is a vertical antenna? What is loading it?
- Getting inspiration and ideas from various commercial products to get design ideas and other inspiration
  - Maybe you’ll find something you want to DIY, or maybe you’ll find something you just want to buy!
  - Full systems - Hand over some cash, get on the air
  - Antennas with no mounts - BYOM
  - A La Carte - DIY
- How to Design and Build a Single Band Coil
- Multi-band Tappable Coils

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Loaded Antenna Primer

If this ¼ wave antenna resonates at 7MHz

| ←—---------------- 10 m ----------------------→|

and this one resonates at 28MHz

|← 2.5m→|

The 2.5m (8ish’) one is more convenient than 10m (33ish’), how can we make it resonate at 7MHz? Or any other frequency (lower than 28MHz)?

Adding Inductance

https://www.electronics-notes.com/articles/basic_concepts/inductance/inductance-basics-tutorial.php

Inductance is the ability of an inductor to store energy and it does this in the magnetic field that is created by the flow of electrical current.

Energy is required to set up the magnetic field and this energy is released when the field falls.

As a result of the magnetic field associated with the current flow, inductors generate an opposing voltage proportional to the rate of change in current in a circuit.

By its very nature, an alternating waveform is changing all of the time. This means that the resulting magnetic field will always be changing, and there will always be an induced back EMF produced. The result of this is that the inductor impedes the flow of the alternating current through it as a result of the inductance.

—

In other words, the ever changing alternating current RF electrical field creates a magnetic field in the coil, which FIGHTS the flow of the current, "slowing it down", and making it take longer for a wave to get across, and essentially making the wire seem longer since it took longer to get from one side to the other.

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Full Antenna Systems

Entire packages. A single sum of money that'll get you:

- A vertical element of some kind (usually telescopic whip)
- A coil (or some kind of tuning circuit)
- Something to attach to (tripod, clamp, ground stake, mag mount, etc)
- Brackets if required
- Radials
- Coax (usually)
- A bag to put it all in

Everything you need to call the antenna system complete and get on the air without adding anything else

Buddistick PRO Deluxe 40m - 6m, 250W

$255 (with coax subtracted)

https://www.buddipole.com/budepa.html
Intended for elevated-above-the-ground use.
Comes with 1x 31’ radial wire that is intended to be used elevated 2` - 6’ above ground.

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Wolf River Coils

$150 - 180

TIA 80m-10m 100W SSB, 50W CW, 20W Dig

Silver Bullet 1000, 80 to 10 meters
Collapsible 102" Whip
Three 33' radials
with Mini Tripod 12" legs, 3 lb. 5 oz., 19" x 17"
with Mega Tripod 24" legs, 3 lb. 10 oz., 37" x 31"

Mega TIA 75m-10m 100W SSB, 50W CW, 20W Dig

Mega Mini TIA
Silver Bullet Mini
Mega Tripod
Collapsible 213" Whip
Three 33' radials
Footprint: 37" x 31"

Wolf River Coils

$125

SOTA Special 40m-10m

Silver Bullet Mini
40 to 10 meters
Mini Tripod
Collapsible 78" Whip
Three 33' radials
2 lb. 10 oz.
Footprint: 19" x 17"

Chelegance JPC-12 40m-6m, 100W

$210 (DX Eng), $100 (Aliexpress)

Center Loading Coil

As seen on Ham Radio Dude Next Level Portable Antenna Comms: JPC-12 Center Loaded Coil Antenna Review

https://www.aliexpress.us/item/2255801052641377.html

https://www.dxengineering.com/parts/nce-ch0010003

Chelegance MC-750 40m - 6m 100W

$250

40-6m
100W
Base/Ground Spike
7 MHz Coil
17 ft. Telescoping Whip (with screened markings for bands)
4x 11.48 ft Radials
Carrying Bag

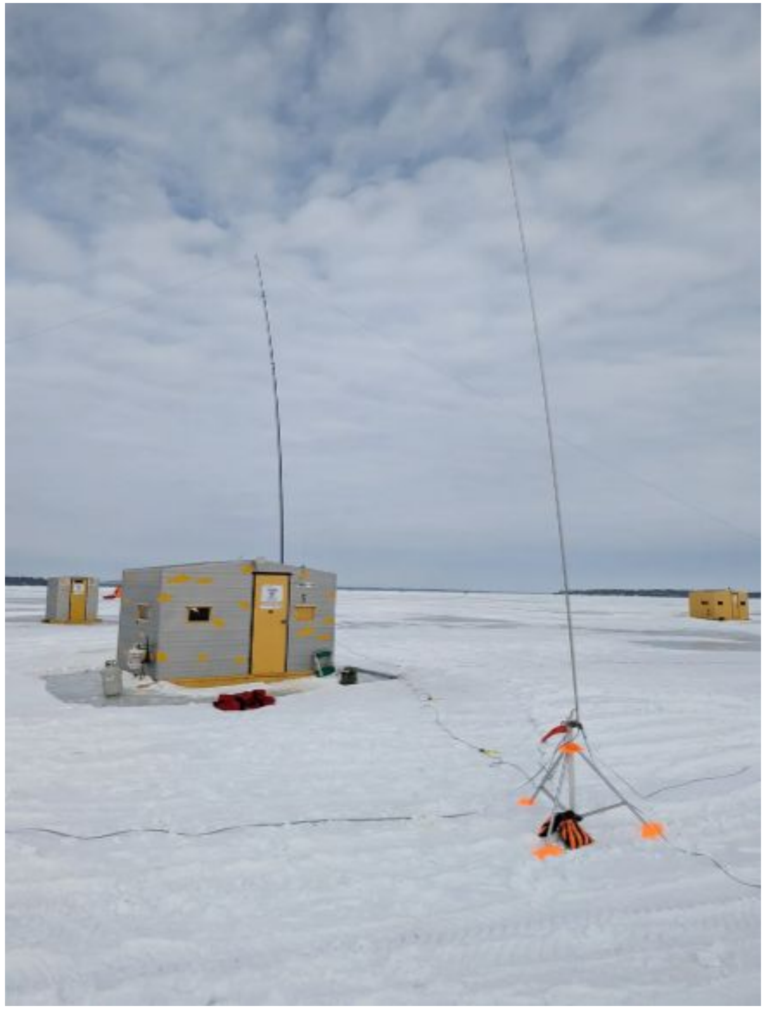
Used by Thomas K4SWL in
[New Year's Day POTA: New VK3IL Pressure Paddle, New FT-817/818 Narrow Filter, and New TPA-817 Pack Frame! | Q R P e r]

Chameleon MPAS 2.0 Micro 160m - 6m 50W CW 100W SSB

$600

Modular Portable Antenna System 2.0

- Vertical Whip configuration using one or both whips
- Horizontal Whip configuration for NVIS operations
- Sloper wire configuration
- Inverted “V” wire configuration
- Inverted “L” wire configuration
- NVIS wire configuration
- Balcony Rail mount using one or both whips
- Vehicle Mounted (Stationary use only)
- Man-Pack Vertical Whip configuration



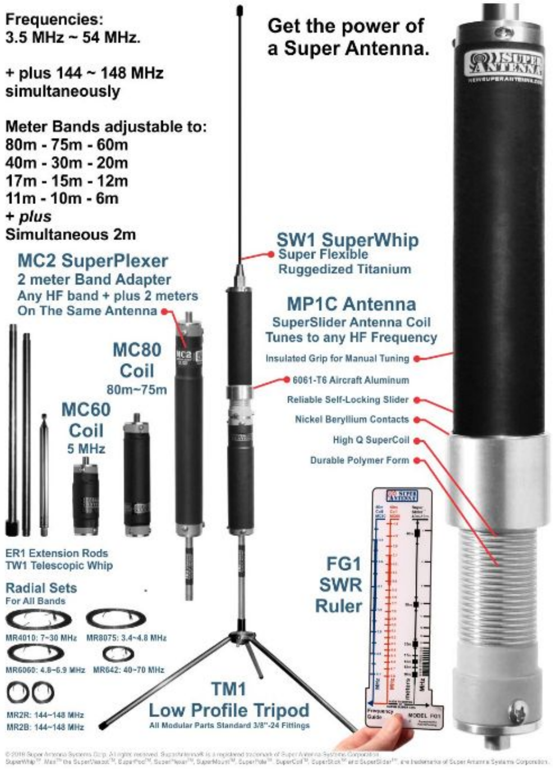
https://chameleonantenna.com/shop-here/ols/products/cha-mpas-modular-portable-antenna-system-20/v/CHA-MPAS-2-MICRO-BP

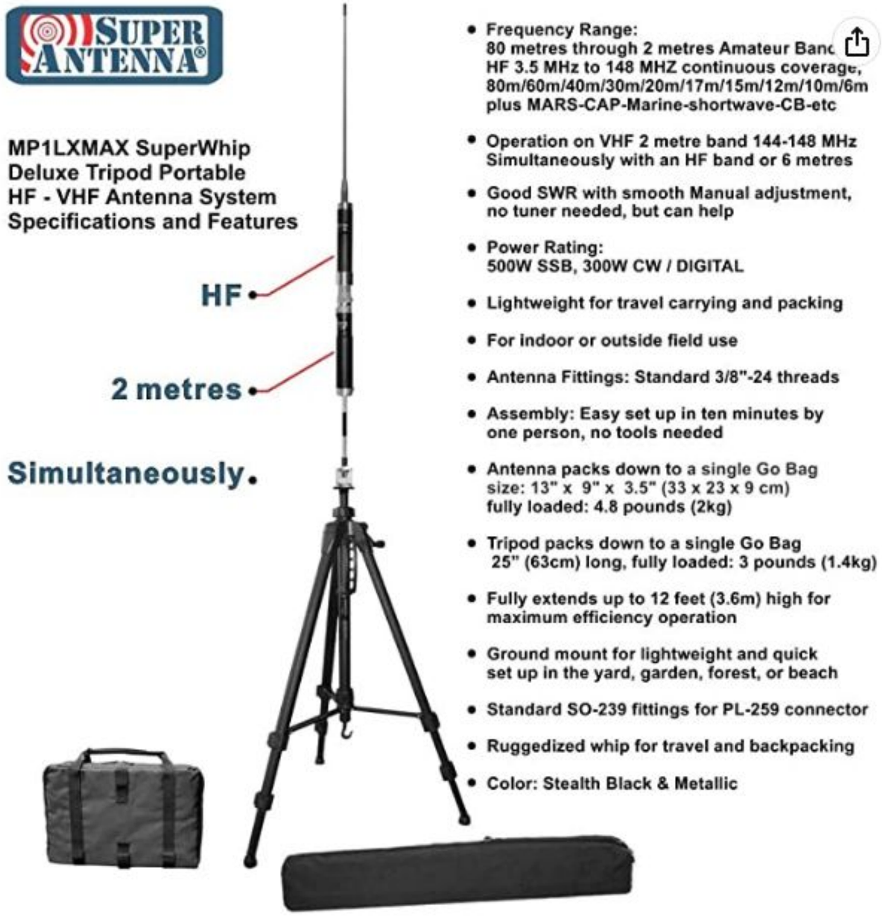
Super Antenna MP1*XMAX 80m - 6m & 2m

$700

500W SSB, 300W CW/DATA

Total extended height 12 feet (3.7m)
Antenna Collapsed Size: 12"
Tripod Collapsed Size: 25"
Go Bag Size: 13"x9"x3.5"





http://newsuperantenna.com/
https://www.amazon.com/superantenna
https://www.amazon.com/Super-Antenna-MP1LXMAX-80m-10m-Portable/dp/B07HMQ44W2

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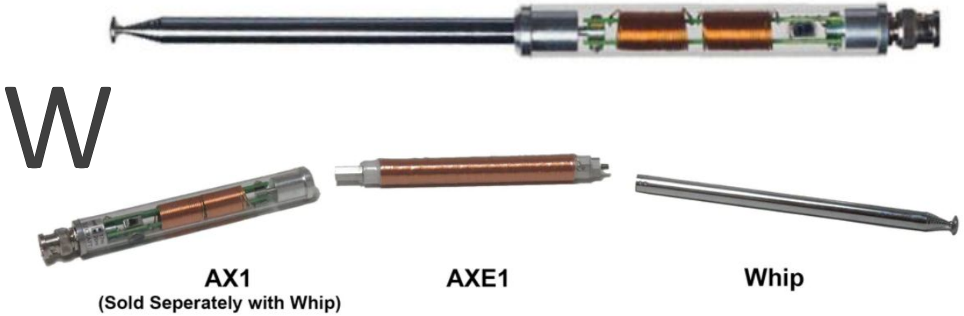

Elecraft AX1 20/17/15m 30W

$110

The AX1 is resonant on 20 meters in one switch position, while the other is designed for efficient 17 and 15-meter matching using an ATU.
Disassembles into two 6" (15 cm) pieces. (Three 6" pieces if you include the AXE1 40 m extender.)
Includes radial - 13 feet (4.0 m) long. Accessories: 40m AXE1 coil $60, bipod AXB1 $32, whip AXW1 $10, Tripod adapter AXT1 $25
Whip: 6” (15 cm) collapsed, 45” (115 cm) extended. Base: 6” (15 cm) long x 0.75” (19 mm) diameter.

https://elecraft.com/collections/ax-line-antennas/products/ax1-antenna
As seen in Thomas (K4SWL)’s videos
"Field Report: The Elecraft AX1's secret power? Speed of deployment”
He’s done a lot with the KX2 radio and AX1 antenna - search youtube:”K4SWL AX1”

Elecraft AX2 20m 15W

$80

Can be modified by user to tune anywhere from 20m to 6m (via soldering)

https://elecraft.com/products/ax2-minature-20-meter-whip-antenna

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Multi-band Fixed Coil Antennas

Not an entire kit. You'll get:

- A vertical element of some kind
- An electrically lengthening coil(s) OR LC circuit providing multiple band access

You'll need in addition:

- Something to attach to (tripod, clamp, ground stake, mag mount, etc)
- Brackets if required
- Radials
- Coax (usually)
- A bag to put it all in

For the option where you want an antenna but don't want to pay for a mounting solution.

Gabil GRA-7350T 80m - 6m, 130W

$130

https://smile.amazon.com/GRA-7350T-7-30MHz-Wideband-Telescopic-Portable/dp/B08H4CTJ1B

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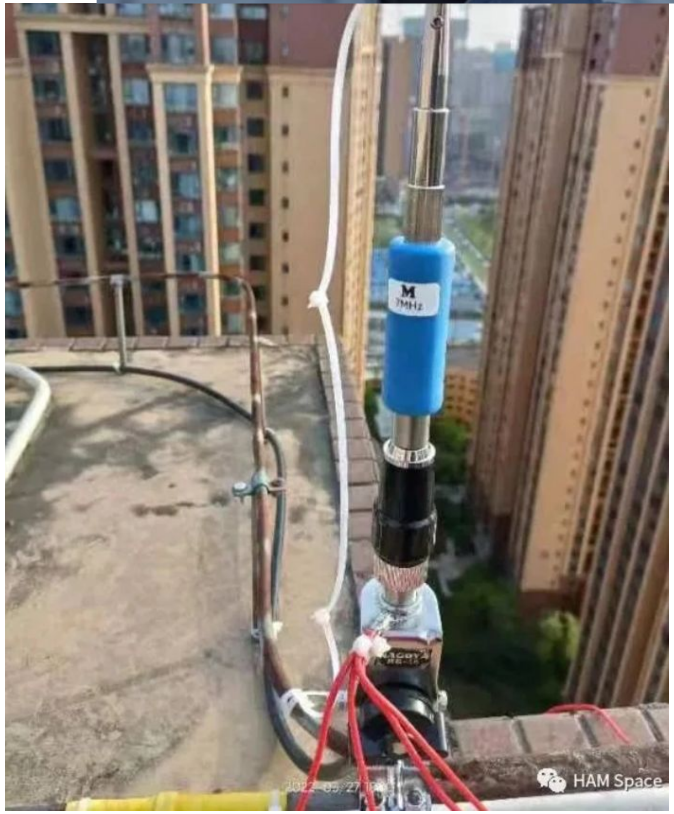
MA-01 40/20/15/10m 50w/100w

$62 (ships free - on a boat from China)

MA-01 7MHz/14MHz/21MHz/28MHz 50W-100W HF Shortwave Outdoor GP Portable Telescopic Antenna QRP For Ham Radio G90 IC-705
Note: M6 threaded



https://www.aliexpress.us/item/3256804401080673.html?gatewayAdapt=glo2usa4itemAdapt&_randl_shipto=US

As seen on Ham Radio Dude: The Power of Portable Ham Radio: Make a 4300 Mile Contact with the MA-01 Portable Antenna

Multi-band Tapped Coil Antennas

Not an entire kit. You'll get:

- A vertical element of some kind
- An electrically lengthening coil that's tappable to provide multi-band access

You'll need in addition:

- Something to attach to (tripod, clamp, ground stake, mag mount, etc)
- Brackets if required
- Radials
- Coax (usually)
- A bag to put it all in

For the option where you want an antenna but don't want to pay for a mounting solution.

Gabil GRA-1900T 160m - 6m, 120W

$108

https://smile.amazon.com/GRA-1900T-Multi-Band-1-8-50MHz-Telescopic-GABIL/dp/B095HBY2ML

Comet HFJ-350M “Toy Box” 160m - 6m 100W

$114

(per seller: 1.8MHz, 100W peak, 50W CW. At 3.5MHz, 75W SSB. At 7-50MHz, 100W SSB)

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https://smile.amazon.com/HFJ-350M-Original-Comet-Telescopic-Extension/dp/B08CYDC6C

MFJ 1699S (and 1699T) 10 band 80m-2m, 200W

$100

MFJ-1699S has PL-259 base, MFJ-1699T has a 3/8-24 stub base
Maximum height 49.5”.

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https://mfjenterprises.com/collections/antenna/products/mfj-1699s

MFJ 1899T 80m-6m, 25W

$120

QRP antenna
BNC
Maximum height 49.5”.

https://mfjenterprises.com/collections/antenna/products/mfj-1899t

Buddistick PRO - 40m-6m, 250W

$200

1/4-20

Intended for elevated-above-the-ground use. Comes with 1x 31’ radial wire that is intended to be used elevated 2` - 6’ above ground.

NOTE: Add 3x tripod legs for $57 more and it’s a whole system, aka PRO Deluxe

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https://www.buddipole.com/buddistick.html

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Mono-band Antennas

Not an entire kit. You'll get:

- A vertical element of some kind that has a coil built in to provide resonance on a single band

You'll need in addition:

- Something to attach to (tripod, clamp, ground stake, mag mount, etc)
- Radials (though you'll usually just use your car)

The most affordable option.

As cheap as these are, you can have several - one for each band.

MFJ Hamsticks 75m-10m, $25-40

$25-40

All 3/8-24, and rated to 250W

https://mfjenterprises.com/products/mfj-1610t (10m, $25)
https://mfjenterprises.com/products/mfj-1620t (20m, $30)
https://mfjenterprises.com/products/mfj-1640t (40m, $30)
https://mfjenterprises.com/products/mfj-1675t (75m, $40)

A La Carte

Complete Assemble-Yourself Solution.

Want to purchase part or all of the antenna solution individually?

Here are some ideas

Tripods

Gabil

$100-120

GRA-ULT01 MK2
$120-130
https://www.amazon.com/dp/B0BNKZDGFG

GRA-ULT01
6” collapsed, 4 ¾” - 2 ½’ open
https://www.amazon.com/GRA-ULT01-Lightweight-Portable-Connector-GRA-7350T/dp/B095RJCF89

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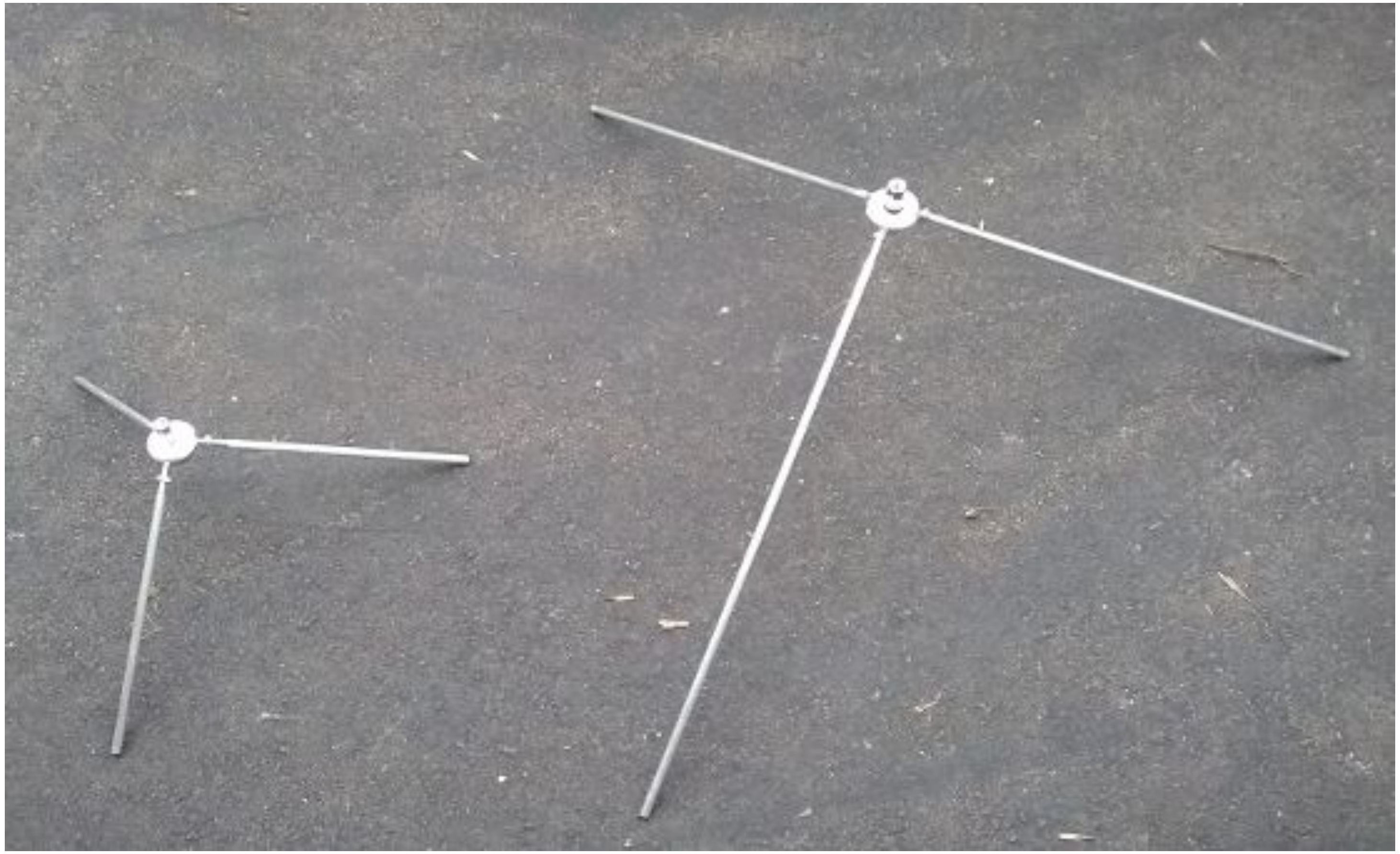
WRC

$42 (12" legs) - $62 (24" legs)

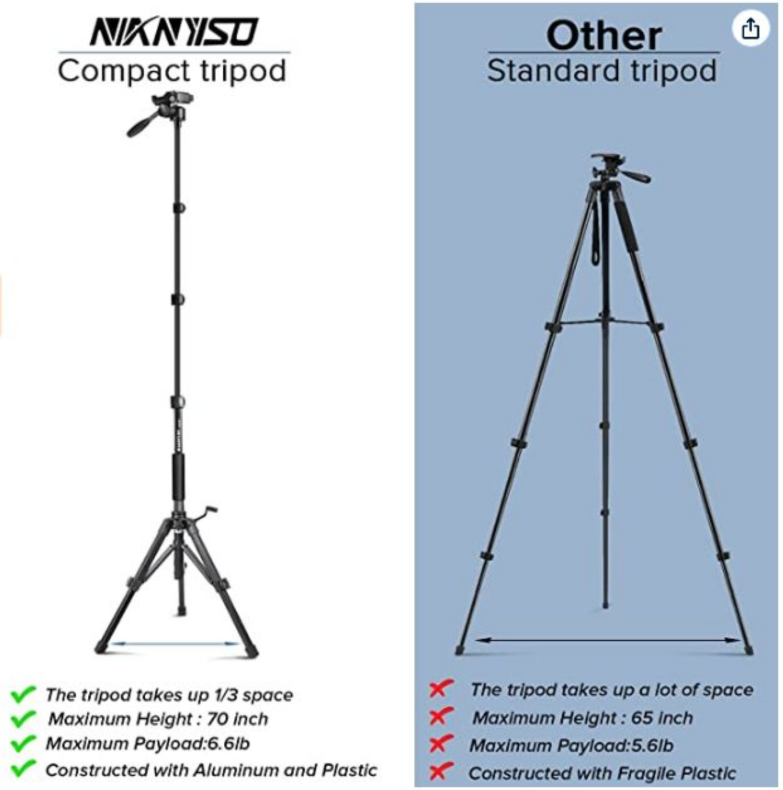


https://www.wolfrivercoils.com/order.html

NIANYISO (random Chinese on Amazon)

~$30-35

Tripod+monopod fully extended: 69”, tripod collapsed: 10.5”, monopod collapsed: 15.5”



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https://smile.amazon.com/gp/product/B07VD44X7C

Amazon Basics

$14

50” extended, collapsed: 16.5”

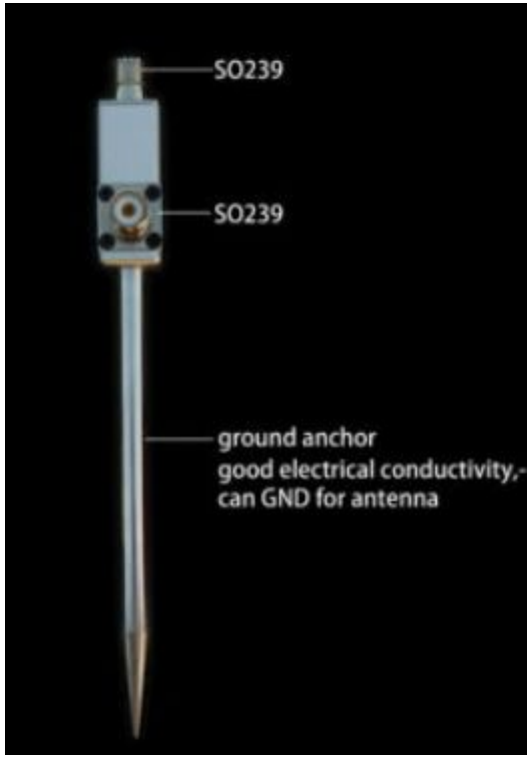
https://smile.amazon.com/dp/B00XI87KV8

Ground Spikes

bd7-maple

$38

As shown on HOA Ham on Youtube: https://www.youtube.com/watch?v=hKCGIeSIyBo



BNC to 3/8*24 https://www.ebay.com/itm/175545908527

SO239 https://www.ebay.com/itm/175371606096

SO239 to 3/8*24 https://www.ebay.com/itm/175545899912

Masts

BuddiPole

$85

$85, 22” collapsed, 9.5’ extended

https://www.buddipole.com/buddipolemast.html

SotaBeams

$47-73

Tactical Mini, 19.5’
$47 (ships from UK)
22” collapsed/packed
https://www.sotabeams.co.uk/tactical-mini-compact-ultra-portable-6-m-19-6-ft-mast/

Carbon 6, 19.5’
$47 (ships from UK)
17” collapsed/packed
https://www.sotabeams.co.uk/carbon-6-ultra-light-6-m-19-6-ft-mast/

SotaBeams Tactical 7000hds, 23’
$73 (ships from UK)
23” collapsed/packed
https://www.sotabeams.co.uk/tactical-7000hds-compact-heavy-duty-7-m-23-ft-mast/

SotaBeams Travel Mast, 32’
$73 (ships from UK)
26.5” collapsed/packed
https://www.sotabeams.co.uk/compact-light-weight-10-m-32-ft-travel-mast/

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Whips

Buddipole

$8-23, 5.5’ - 9.5’

Featherweight telescopic whip 72” $8.50
1/4-20, 13” to 72”
knurled base sleeve: $4.50 extra, 1/4-20 to 3/8-24 adapter: $3.50 extra
https://www.buddipole.com/fetewh.html

Standard telescopic whip, 66”
$16.50, 13” to 66”, 3/8-24, knurled base sleeve: $6.50 extra
https://www.buddipole.com/stainsteelte.html

Long telescopic whip, 9.5’
$23, 21” to 9.5’, 3/8-24, knurled base sleeve: $6.50 extra
https://www.buddipole.com/lotewh.html

MFJ

$30-80, 4.5’ - 16.75’

All 3/8-24:

MFJ-1979: $80, 16’9”, collapses to 27” <= 20m without loading
https://mfjenterprises.com/products/mfj-1979

MFJ-1977: $70, 12’, collapses to 26” <= 15m without coil
https://mfjenterprises.com/products/mfj-1977

MFJ-1974: $60, 8.2’, collapses to 24” <= 10m without coil
https://mfjenterprises.com/products/mfj-1974

MFJ-1972: $30, 4’6”, collapses to 27” <= 6m without coil
https://mfjenterprises.com/products/mfj-1972

WRC

$15-60, 6.5’ - 17+’

6’-6” - $15

8’-6” - $25

17’-9” - $60

https://www.wolfrivercoils.com/order.html

Coils

BuddiPole

$35-45

Buddipole Mini Coil 10-20m

$35, coil clips not included ($16.50 for 3)
https://www.buddipole.com/minicoil.html
https://www.buddipole.com/coilclips.html

Buddipole Coil 10-40m

$45, note the “set” is 2 coils, which is needed for a dipole. For a vertical you only need an single coil (“individual”)
Coil clips not included ($15 as an option on the page)
https://www.buddipole.com/bucoset.html

Buddipole Low Band Coil 80m

$35, coil clips not included ($16.50 for 3)
https://www.buddipole.com/lowbandcoil.html

WRC

$15-60, 6.5’ - 17+’

WRC Silver Bullet 1000 80m - 10m - $75

100 watts SSB, 50 watts CW and 20 watts in digital modes

WRC Silver Bullet Mini 40m - 10m - $55

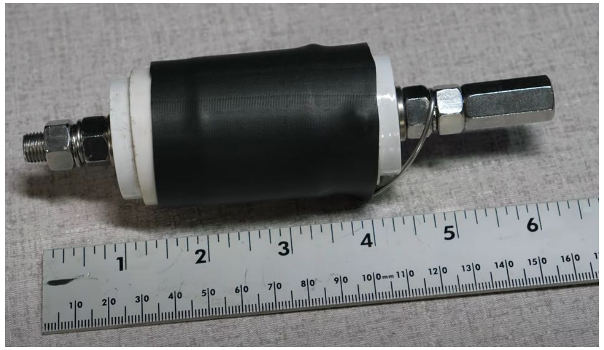
100 watts SSB, 50 watts CW and 20 watts in digital modes

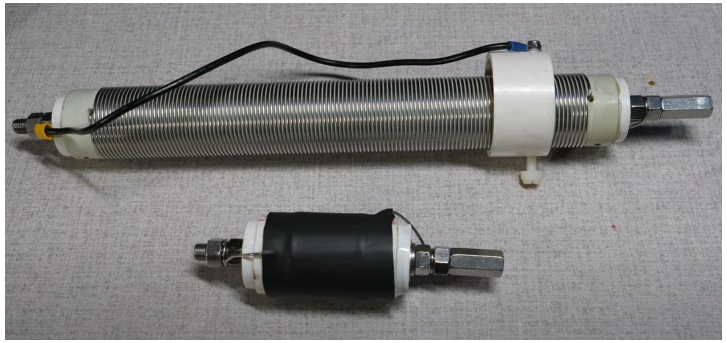
WRC Sporty Forty 40m - $30

Power: 75W digital, 100W CW & 200W SSB.
40m, pair with use 213 inch Collapsible Whip

- CW - whip full length.
- SSB - collapse whip 3-6”

20m - use only 213” whip, no coil
Note: You cannot use the Sporty Forty with a 102" whip.





https://www.wolfrivercoils.com/order.html

Misc

Miscellaneous Recommendations

BNTechGo Magnet Wire

Multiple options on Amazon - search “Bntechgo magnet wire” and look for the gauge and length you need. Example: $11.45, 28ga 4oz (527 feet), 22ga 4oz (122 feet)
https://smile.amazon.com/gp/product/B07DYF53ZN

Foto&Tech 1/4" to 3/8" Tripod Thread Adapters, 5

$7

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Designing a Single Band Tight Wound Coil

For this example, I'm going to make 4 assumptions:

- I'll be using the Buddipole Featherweight Telescopic Whip (https://www.buddipole.com/fetewh.html), which is 72" fully extended (6')
- Designing for 20m, the entire band from the bottom of CW portion to the upper end of SSB. (14.000 - 14.350)
- Using ¾" PVC as a coil former (1.05" dia as measured by my calipers). You may be flexible on this, having short amounts of a variety of sizes of PVC on hand. But it helps to narrow it down to a preferred size, with a "runner up" size or two to use if your preferred ends up with a coil being too long.
- Using ¾" PVC Tee for feed, and ¾" cap for whip mount. Both of these fittings allow for up to ⅞" of pipe slip into them (by my calipers). This is important for figuring out the former length.
- Using BNTechGo 22ga magnet wire https://smile.amazon.com/gp/product/B07DYF89T9) .027" dia with enamel, measured, .0253" without enamel

Parts

Coil:

PVC Caps (x2)

1” ¼”-20 bolts (x2)

¼” washers (x6)

¼” lock washers (x2)

¼” nuts (x2)

Connector:

PVC Tee

PVC Plugs (x3)

BNC Female panel mount

¼” rivnut

⅜” ring connector

Misc:

¼” to ⅜” thread adapter (connector to tripod)

¼” threaded coupler (coil to whip)

Overview of Steps

1. Find the element length
2. Decide what band it needs to tune
3. Understand the length you're replacing
4. Find out how much impedance is needed
5. Design the coil
6. Mark, cut, and bore the former
7. Wind it
8. Build the non-coil part of the coil
9. Tune
10. GOTA!

1. Find the Element Length

It is essential to know the length of the element (stinger, telescopic whip, wire, etc) before beginning to design the coil.

Know that in many cases (such as with a telescopic whip or wire with disconnection links) the length can be shortened, but to start the design you need the length at its full extension.

2. Decide what band it needs to tune

This is whatever band you'd like to use it for.

Note that a short antenna with a big coil will have a smaller bandwidth than a long antenna with a short (or no) coil.

A shortened antenna will likely only have a good match on a specific portion of most bands, with the rest tunable by shortening the whip (usually only an inch, maybe a few on a wide band). The 10m and 80m bands are large, though. 10m should be easily tunable across the band even though it's huge, because the element length requirement isn't much. 80m may be difficult, however, because it requires a much larger coil for a short antenna and the bandwidth is very small. With a short stinger, you may not be able to get the entire 80m band (at least not very good).

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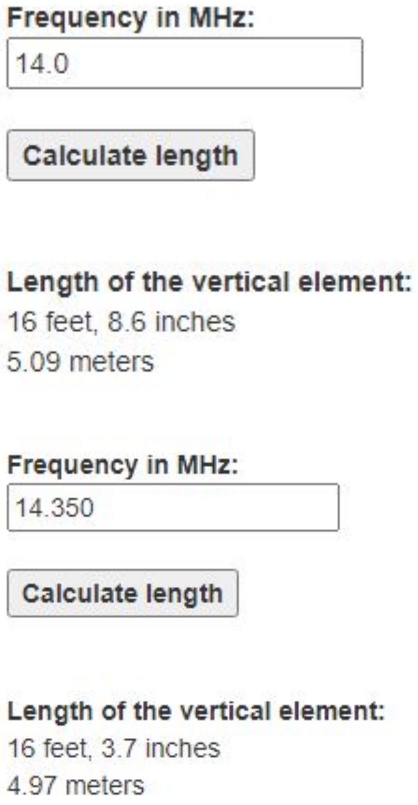
3. Understand the Length You’re Replacing

- Go to the Quarter-Wave Vertical Antenna Length Calculator
- Enter 14.000 in the textbox (for 14.0 MHz) and click the Calculate Length button
- So a 1/4 wave antenna with no coil needs to be 16’-8 ½” to resonate on 14.0MHz.
- Now enter 14.350 and click Calculate Length
- Only 16’-3 ½”.
- I just want to point out that the higher frequency requires a shorter antenna. This should be obvious when you think about it, but it’s an important piece of information.



3. Understand the Length You're Replacing

Note that we have 6' of telescopic whip AT ITS LONGEST. I emphasize that because remember it can be shortened.

So for the bottom (CW/digital) portion of the band, we need a coil that'll replace 16'-8 ½" - 6' = **10'-8 ½"** of length.
At the top of the phone portion, we only need to replace 16'-3 ½" - 6' = **10'-3 ½"** (5" shorter).

We'll design the coil for the bottom of the band. Then to tune up the band, simply shorten the whip (if you even need to). You know the length from the top to the bottom is a 5" difference.

Side note: It seems like you should be able to pull in the whip 5" to get there, but impedance doesn't work quite like that, it won't be exactly 5", but that's the ballpark.

4. Find out how much impedance is needed

Go to the Coil-Shortened Vertical Antenna Calculator to find how much impedance needs to be created to replace the 10+ feet of missing antenna element.

For our example, enter this:

Total height of antenna in feet

6

Distance from antenna base to the center of the coil in feet. (Enter "0" for a base loading coil.)

0

Diameter of the conductor in inches

.0253

Operating frequency in megahertz

14.0

Calculate

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4. Find out how much impedance is needed

Notes:

- 6’ is the length of the telescopic whip. The calculator is actually asking for the ENTIRE height. NOTE: in reality it will be more than this due to wire stub between the coax feeder and the coil, and between the coil and the whip. But we don’t know how much to put here yet, and it’s better to estimate short and build a bigger coil. You’re going to have to tune this coil, and it’s easier to remove winds from the coil than to add winds.
- 22 AWG copper is 0.64mm in dia, or 0.0253”
- You won’t want the coil + fully extended whip to be resonating on 14.0, half of its bandwidth will be wasted. But for an over-estimate, this is an appropriate frequency as it’s better to build too big to start with.

4. Find out how much impedance is needed

The results:

Results

The required inductance of the coil is 8.4 microhenries.

8.4 microhenries is not a lot at all! Note, the same calculation with a smaller diameter wire (28ga - 0.0126” dia) gives 9.2uH so a thicker wire will give us more impedance in a smaller area. Makes sense, but good to point out.

5. Design the coil

Now we need to turn this inductance into a coil design. There are multiple calculators to do this, I'm going to show 2.

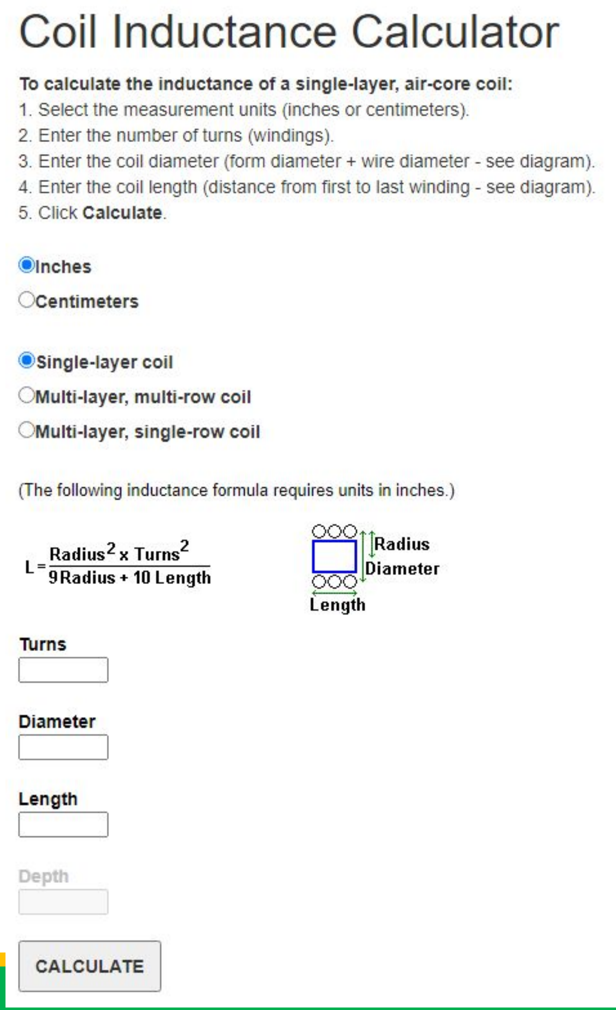
5a. 66pacific.com

5b. Hamwaves.com

5a. Design the coil (66pacific.com)

First let’s look at

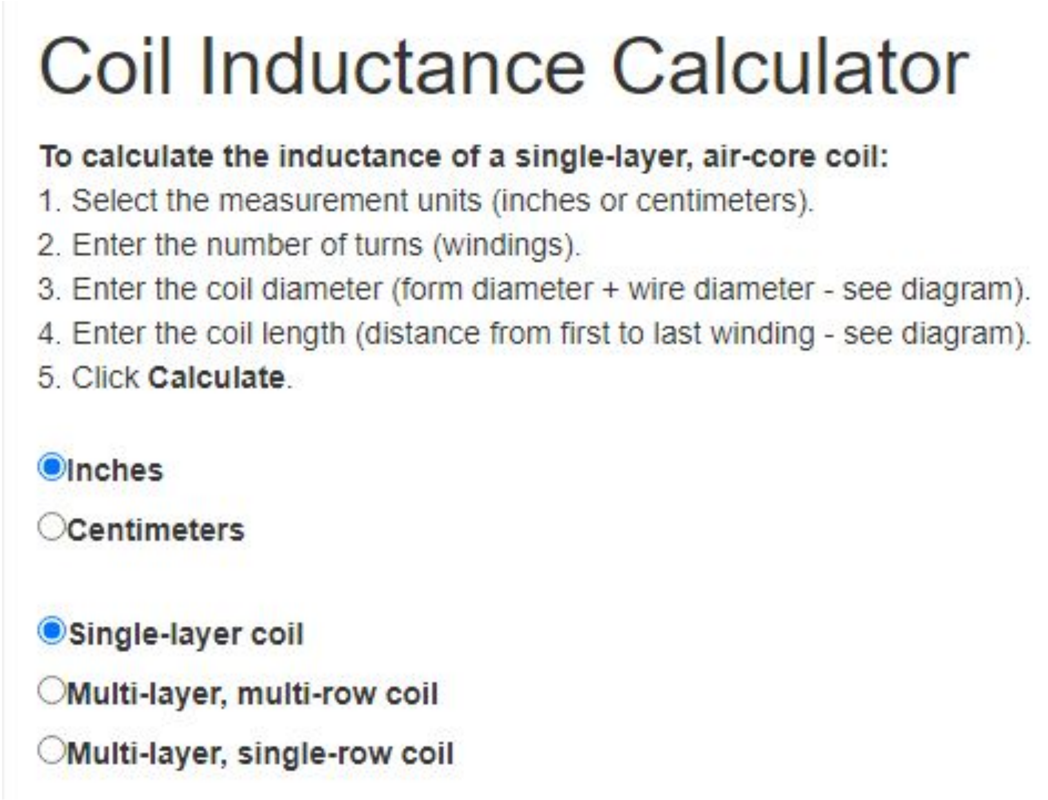
66pacific’s coil inductance calculator



5a. Design the coil (66pacific.com)

Because we’ve done everything so far in inches, and we’re looking for a SIMPLE coil design, choose

a) Inches
b) Single-layer Coil



5a. Design the coil (66pacific.com)

The only way to use this calculator is with a little trial-and-error experimentation.

- **Turns** - # of winds of the wire around the PVC former.
- **Diameter** - Diameter of the former (1.05” of PVC), plus Diameter of the wire with insulation (.027”). This is measuring from the center of one side of a wind to the center of the other side. ½(0.027”) + 1.05” + ½(0.027”) = 1.077”
- **Length** - Length of a tight-wound coil (no spacing between winds), the calculation is:
  - (# of turns + 1) * (dia of wire with insulation)

  So 5 turns of .027” dia wire will have a coil length of:

  6 * .027” = 0.162”

Try 5 turns and see that you get:

Turns
5

Diameter
1.077

Length
0.162

Result: Inductance = 1.1 microhenries

5a. Design the coil (66pacific.com)

Note: I hate that it asks for the Length. We don't know the length and we have to calculate it just to put it in the calculator. Don't calculators calculate? Much better would be to ask for spacing between winds (0 for tight wound coils), then it can calculate the length itself without asking us. But since it doesn't, we have to do this <u>for every change in # of Turns</u>.

5a. Design the coil (66pacific.com)

1.1 uH is not nearly enough. Let’s double the # of Turns

Turns

10

Diameter

1.077

Length

0.297

Result: Inductance = 3.7 microhenries

Still not there, but note that doubling the turns more than tripled the impedance. It’s not linear!
We need to find a # of turns & length that’ll give us 8.4uH, so keep going:

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5a. Design the coil (66pacific.com)

…

16 turns, 0.459” length = 7.9uH

17 turns, 0.486” length = **8.6uH**

- We want to go OVER the number we’re looking for.
- You may want to add even more turns (remember you can remove winds).
- But we’re already adding buffer with the length of the element by not including the stubs and coil, and by calculating below where we need to.
- So 17 turns is probably appropriate (and we’ll still need to remove one or two winds).

So there we go. **17 winds of 22ga wire on a ¾” PVC former, resulting in a .486” long coil.**

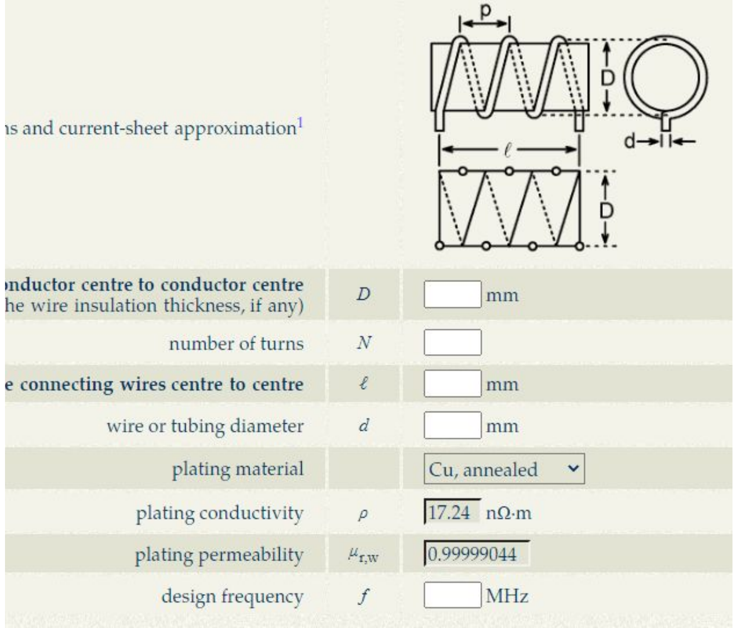
5b. Design the coil (Hamwaves.com)

Another calculator I like is hamwaves.com

[RF Inductance Calculator for Single-Layer Helical Round-Wire Coils]

What I like about this calculator:

- Inductance has a different effect at different frequencies which this accounts for but the 66pacific calculator does not
- This calculates and presents to you the length of wire you need for the coil (what a concept!)



This calculator works in metric, SAE-to-metric conversion:

1.05” = 26.67mm

0.027” = 0.6858mm

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WX4CAR

5b. Design the coil (Hamwaves.com)

- **D**: Mean dia of coil from wire center to wire center

  Former dia + 1x wire (w insul) = 26.67mm + 0.6858mm = 27.3558mm

- **l**: Length of coil (center of beginning to center of end)

  2 winds of coil: [|][|][|]

  Note the highlighted added up is 2x dia of insulated wire. So the length of coil (center to center) will be (# turns)*(dia of insulated wire)

- **d**: Wire/tubing diameter

  This is actually asking for dia of copper (minus insulation). 0.0253in (.6426mm) for this 22AWG. For enameled copper, we're talking about less than a couple thousandths of an inch of insulation

- **p**: Plating material and conductivity

  I'm leaving with defaults - annealed copper (because that's what I'm using) but if you're using something different you may want to change with this

- **f**: Design frequency (14.0)

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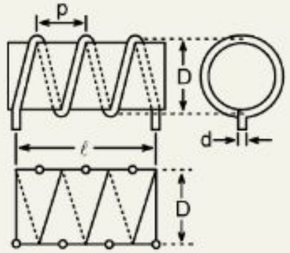
WX4CAR

5b. Design the coil (Hamwaves.com)

Our inputs:

D = 26.67mm (pvc dia) + 0.6858mm (½ of dia of insulated wire * 2) = 27.3558mm
N = 17 turns (# of turns from our last calculator)
l (little L) = 17 * (insulated dia of wire=0.6858mm) = 11.6586mm
d = 0.0253” = .6426mm (uninsulated wire)
f = 14.0, since i’m tuning for the bottom of 20m

Table 1: Input

round wire coil with dimensions and current-sheet approximation[1]		
mean diameter of the air core coil, **measured from conductor centre to conductor centre** (include the wire insulation thickness, if any)	D	27.355 mm
number of turns	N	17
length of the coil, **measured from the connecting wires centre to centre**	ℓ	11.658 mm
wire or tubing diameter	d	.6426 mm
plating material		Cu, annealed
plating conductivity	ρ	17.24 nΩ·m
plating permeability	$\mu_{r,w}$	0.99999044
design frequency	f	14.0 MHz

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5b. Design the coil (Hamwaves.com)

So according to this calculator, 17 turns may not be quite enough.

Not taking frequency into account, we got 8.5uH which is what the last calculator gave us.

But with frequency, we need a little more oomph to the coil.

Results

Table 6: Effective equivalent circ[uit]

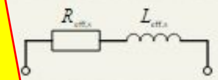
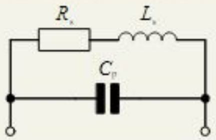
effective equivalent circuit		
effective series inductance **at the design frequency** from Corum's sheath helix **waveguide formula,** corrected for field non-uniformity and round wire[1,3,6,7]	$L_{eff,s}$	8.122 µH
effective series reactance of the round wire coil at the design frequency	$X_{eff,s}$	714.5 Ω
effective series AC resistance of the round wire coil at the design frequency[9]	$R_{eff,s}$	3.147 Ω
effective **unloaded** quality factor of the round wire coil at the design frequency	Q_{eff}	227

Table 7: Lumped equivalent circuit

lumped equivalent circuit		
frequency-independent series inductance from the current-sheet coil **geometrical formula,** corrected for field non-uniformity and round wire[1,3–6]	L_s	8.521 µH
series AC resistance of the round wire coil at the design frequency	R_s	3.464 Ω
parallel stray capacitance at the design frequency, from Corum's sheath helix **waveguide formula**[7]	C_p	-0.7 pF

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5b. Design the coil (Hamwaves.com)

Let's try 18. Same inputs, except N=18, and l=12.3444 (18 * 0.6858)

1 turn bumped it from 8.1 to 8.8uH. This leaves us in a little better spot, and it's just another turn.

WE'LL ALMOST DEFINITELY HAVE TO REMOVE THIS TURN (and one or two more). But it's better to have to remove turns than add them.

Table 6: Effective equivalent circuit

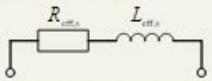
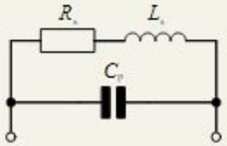
effective equivalent circuit		
effective series inductance **at the design frequency** from Corum's sheath helix **waveguide formula**, corrected for field non-uniformity and round wire[1,3,6,7]	$L_{eff,s}$	8.868 µH
effective series reactance of the round wire coil at the design frequency	$X_{eff,s}$	780.1 Ω
effective series AC resistance of the round wire coil at the design frequency[9]	$R_{eff,s}$	3.356 Ω
effective **unloaded** quality factor of the round wire coil at the design frequency	Q_{eff}	232

Table 7: Lumped equivalent circuit

lumped equivalent circuit		
frequency-independent series inductance from the current-sheet coil **geometrical formula**, corrected for field non-uniformity and round wire[1,3–6]	L_s	9.281 µH
series AC resistance of the round wire coil at the design frequency	R_s	3.675 Ω
parallel stray capacitance at the design frequency, from Corum's sheath helix **waveguide formula**[7]	C_p	-0.6 pF

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5b. Design the coil (Hamwaves.com)

Note also this section:

Table 4: Wire or tube conductor			
physical wire length	$\ell_{w,phys}$	1547.0	mm
effective wire length	$\ell_{w,eff}$	1527.4	mm
skin depth at the design frequency	δ_i	17.66	µm

With 18 winds, you’ll need **1547mm** of wire for the coil - 61”, a little over 5’.

Factor in a few extra inches above the coil and below, and you’ll do fine with 6 - 6.5’.

5. Design the coil (Summary)

With our 1.05” PVC former, and 22AWG magnet wire, to tune to the bottom of the 20m band, we’re going to build a coil that’s:

- 18 winds
- 0.48in long (12.3444mm)
- Use 5 feet of wire (61” - plus an extra 1-1.5’ to make connections)

… before removing winds to tune it.

There we have it.

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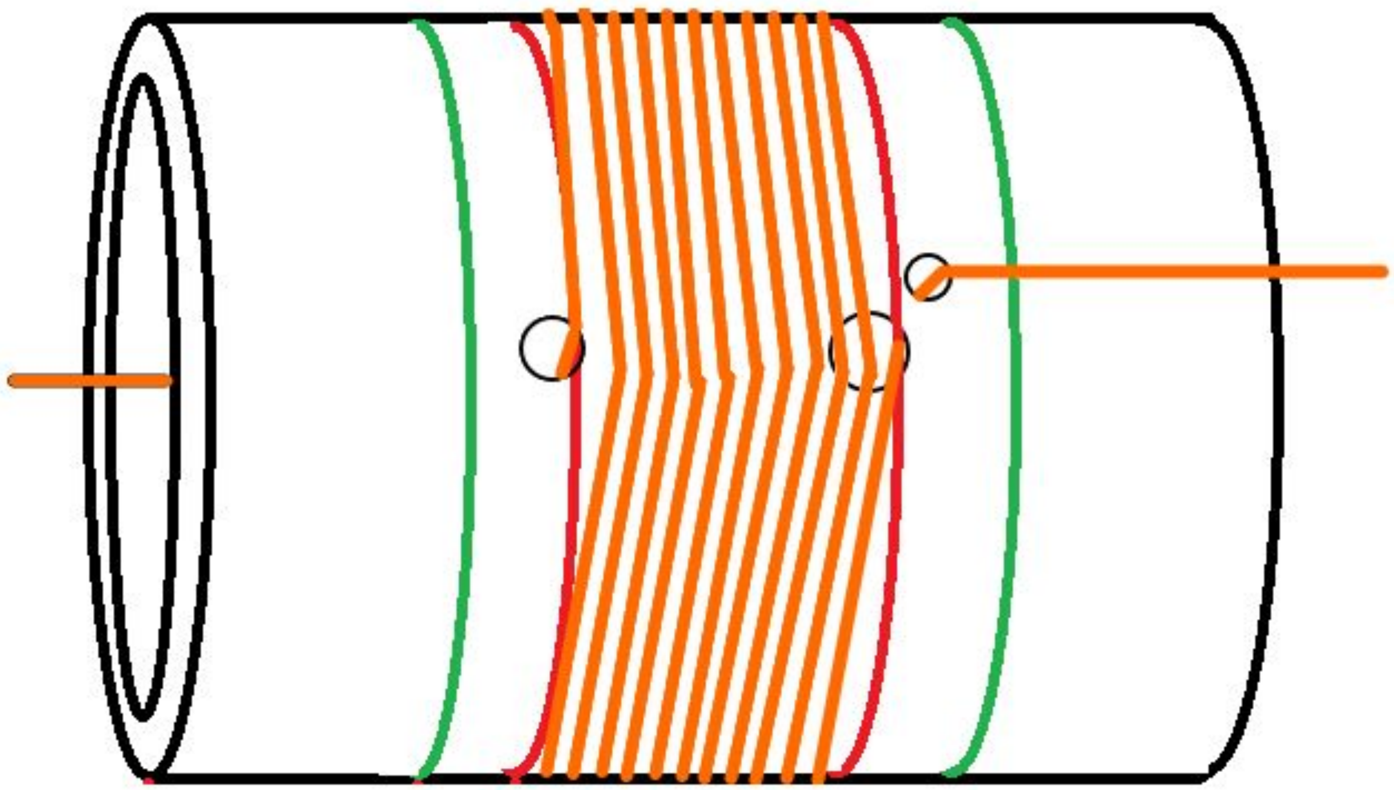
6. Mark, cut, and bore the former

Our goal:



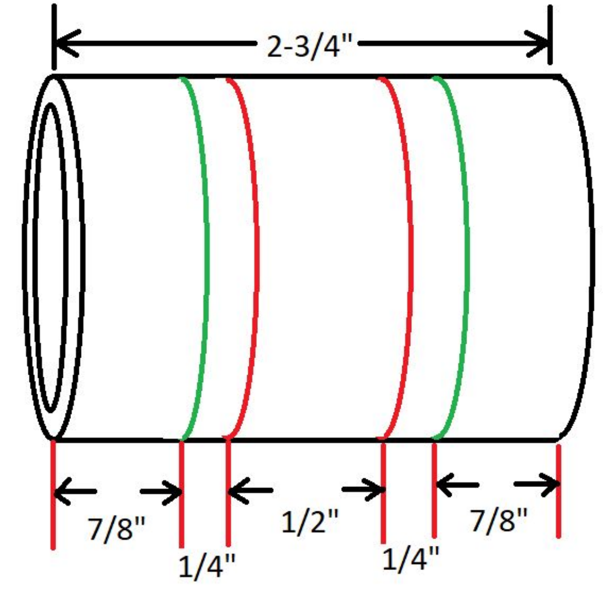
6. Mark, cut, and bore the former

The length of the coil we've designed here is 12.3444mm, or 0.486", a little under a half an inch (~31/64). Worrying about a high precision here will get you nowhere though.

Account for ⅞" that'll slip into the PVC fittings on each end.

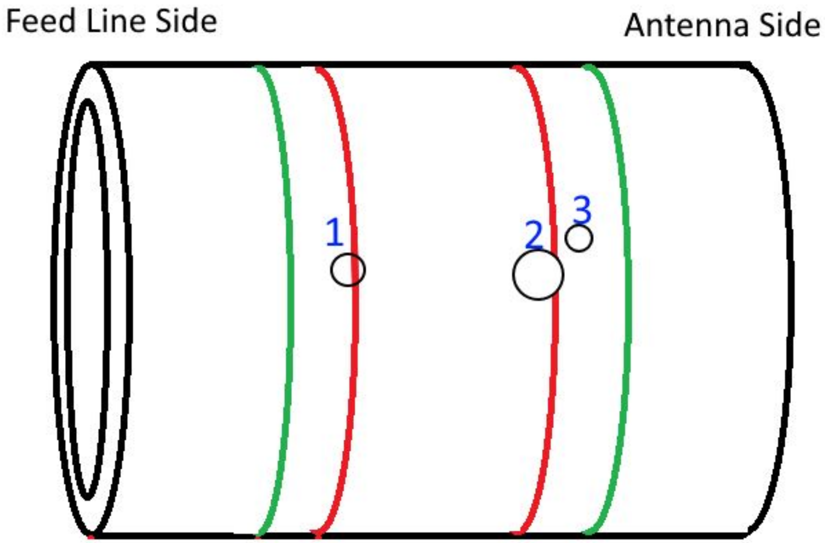
I recommend a ¼" buffer between the fitting and coil on each side.

You may want more, or less.



6. Mark, cut, and bore the former

- Brad point bit recommended, and a drill press
- Hole 1 should be on the red line. It can be a small hole.
- Hole 2 should be the only larger hole, and it should be inside the red lines, and only barely go over the red. Make it big enough so when removing several coils, there's still hole for them to go through.
- Hole 3 is another small hole, between green and red. Leave a gap between 2 and 3, enough that you don't accidentally break the bridge with the drill bit.



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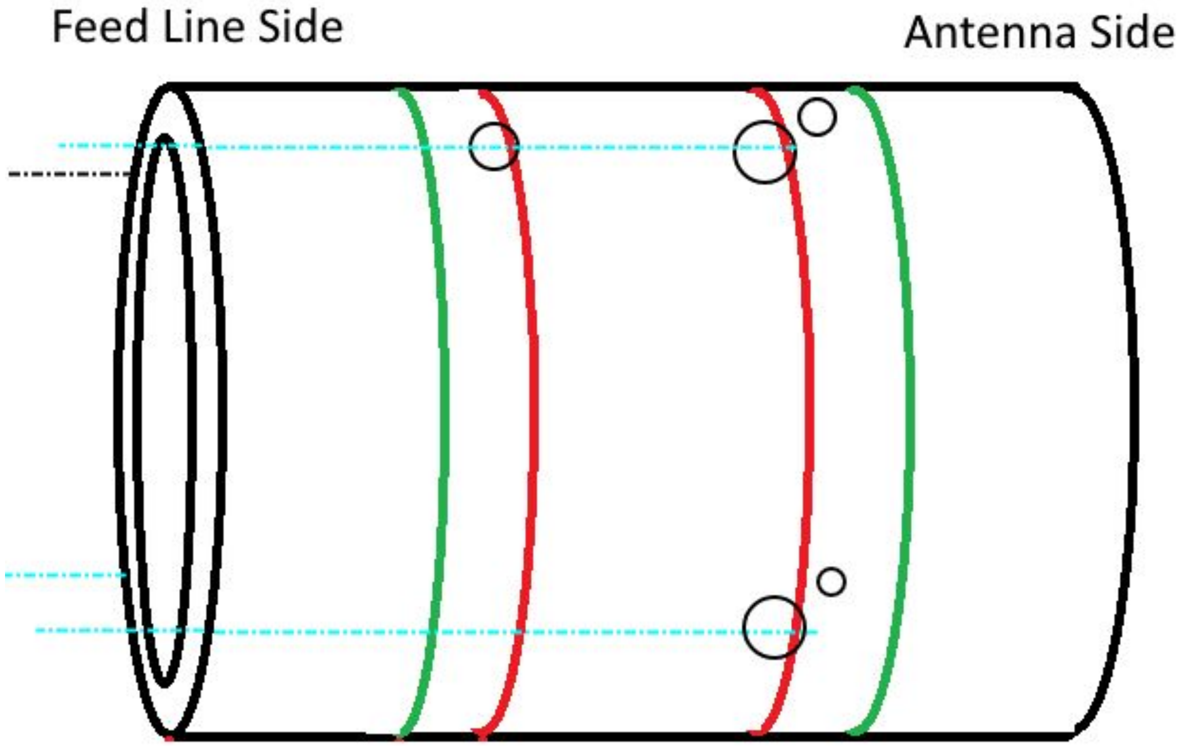
6. Mark, cut, and bore the former

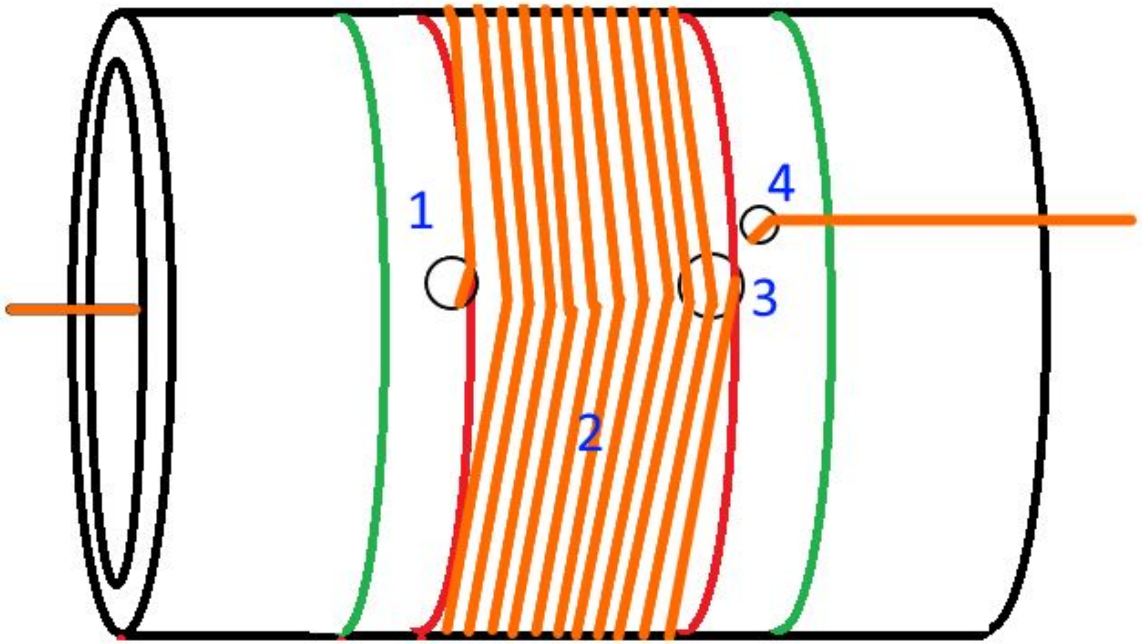
So you can remove coils ¼ turn at a time rather than 1 whole turn, repeat the exit hole pattern around the former, every 90 degrees:

Once you've drilled the holes, you are ready to cut the PVC to length. I recommend a miter saw (just please be careful - eyes and ears! and fingers away from the blade!)



7. Wind it

- On the feed line side, pass ~6" through hole #1, keep taught
- Wind 18 turns (#2). 1 time around is 1 turn. Keep the winds tight together
- At the end of the 18th turn, pass the remainder through hole #3
- Finally, come back out hole #4. You should have 6-12" left
- Consider adding some temporary tape to help hold it together



Congratulations, the coil part of this project is done

CHEROKEE AMATEUR RADIO SOCIETY WX4CAR

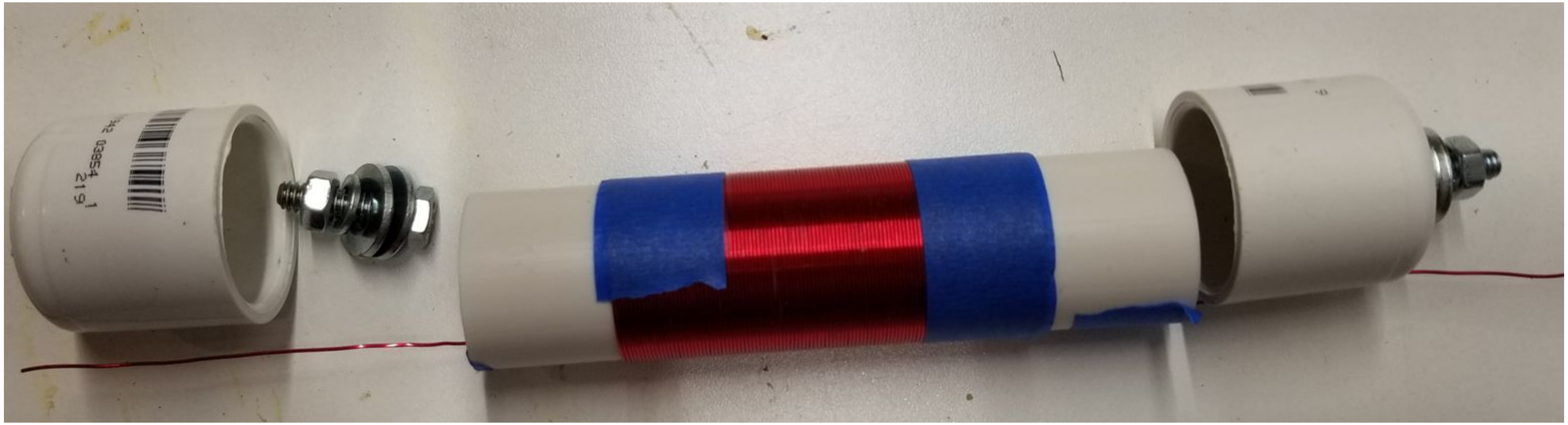
8. Build the non-coil part of the coil

I’m going for this - 2 PVC caps

The feed line end has a 1/4"-20 bolt with 2 washers on the inside that’ll clamp the wire

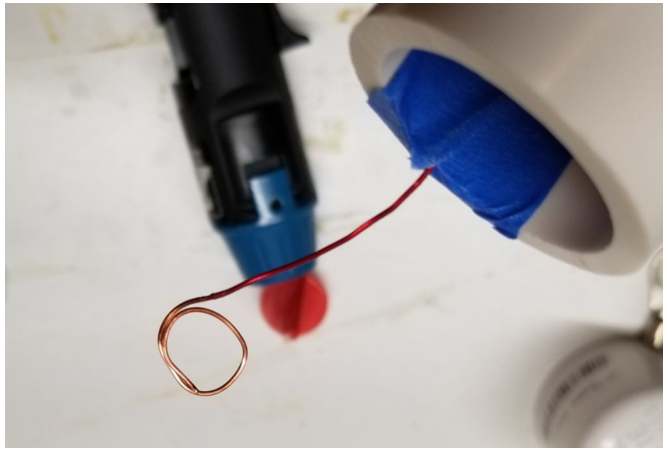
The antenna end also has a 1/4"-20 bolt, but 2 washers on the outside

Both will also have a washer opposite, plus a lock washer and nut



8. Build the non-coil part of the coil

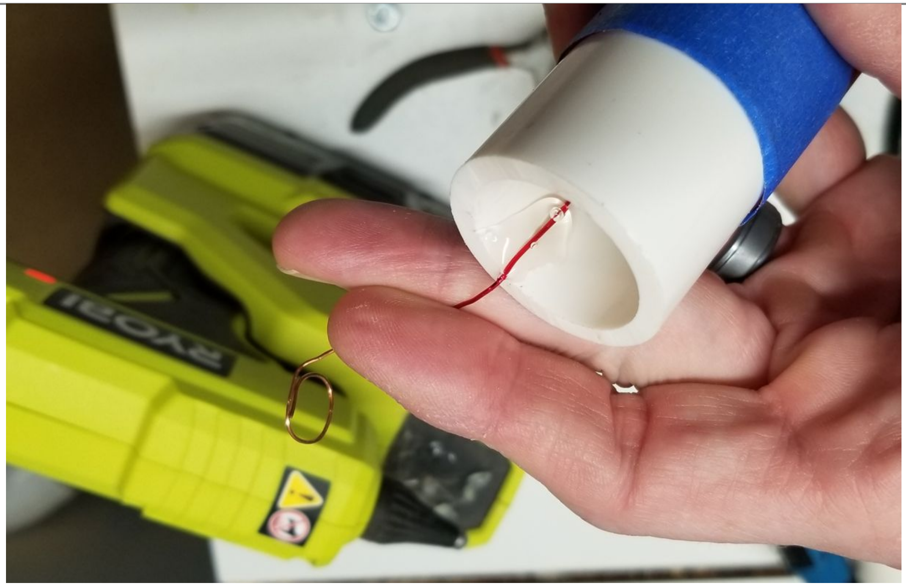
Find the amount of wire that'll get to the bottom of the inside of the cap, while letting the cap be perpendicular to the pipe. This will give you enough room to tighten the bolt.



Remove the enamel from the magnet wire. A butane torch is the best tool to use for this, enamel is turned to slag in about 2 seconds. Wipe off slag with steel wool, copper will be shiny. Finally wipe that with a cloth.

8. Build the non-coil part of the coil

A little hot glue will help keep everything together, while at the same time keep tension off parts that don't like tension.



Fit the clean wire between the two washers and fit in the PVC cap.

8. Build the non-coil part of the coil

On the antenna side of the coil,

strip the wire insulation and pass it between the washers for a mechanical bond

8. Build the non-coil part of the coil

Next build the connecting hub.

I used PVC plugs for all sides. These allow for a small profile. They're too curved on the inside though, so I bore them out with a Forstner bit. Then they have more diameter for a washer and more room for a socket to tighten the bolt.

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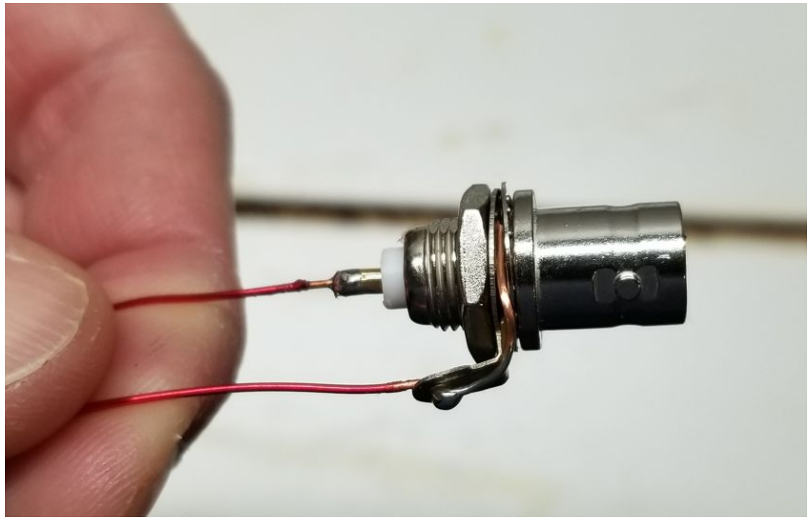
8. Build the non-coil part of the coil

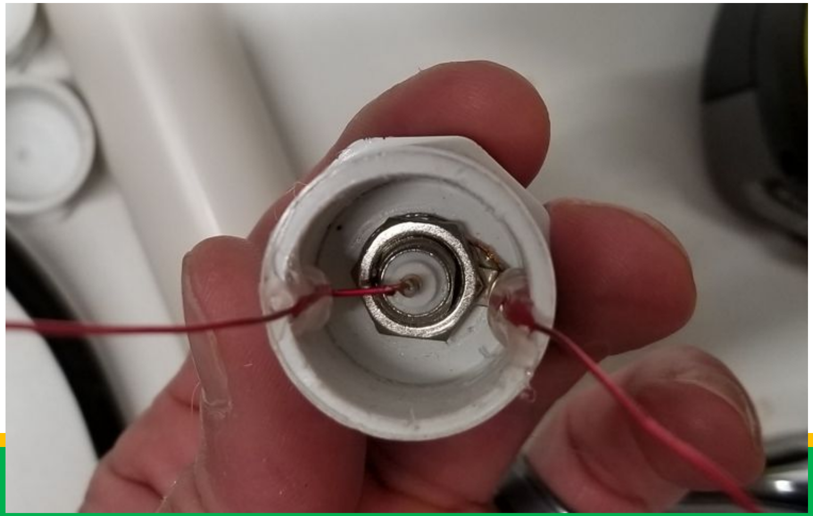
Drill ¼” hole for bolts to go through, and ⅜” holes for rivnut and BNC connector to go through. If you bored it out with a Forstner bit, you have a perfect center marker to use for a ¼” brad point bit and ⅜” Forstner bit.

8. Build the non-coil part of the coil

Next, build your BNC connector (or SO-239, whatever you're using). Tip: for the chassis mount ground connections that don't solder well (or at all, because they're not solderable material), use enough wire to go through the hole, and around the 2 washers. Separate it from the rest of the BNC assembly to solder, get it hot enough that it'll take solder whether it likes it or not. That'll give an "OK" connection, the mechanical connection between washers will provide the rest.

Put into place, tighten, and add a little hot glue for wire strain relief.





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8. Build the non-coil part of the coil

Tighten the BNC, feed the wire through the Tee

Mark a C and a G on the PVC,

C - indicating which is the center pin wire (going up to the antenna)

G - indicating which is the Ground/radials

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WX4CAR

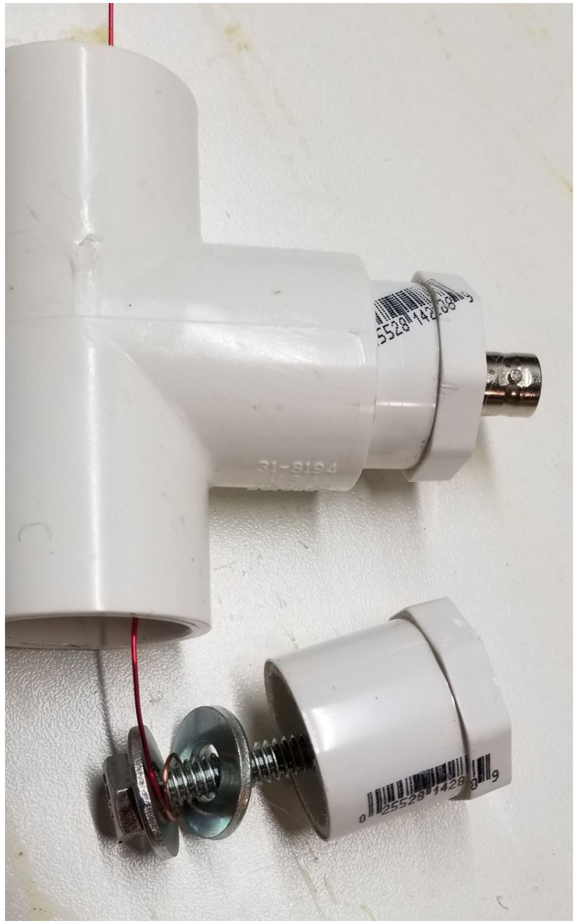
8. Build the non-coil part of the coil

Strip the insulation off the shield/radial/ground wire

Wrap it around bolt between the two inside washers

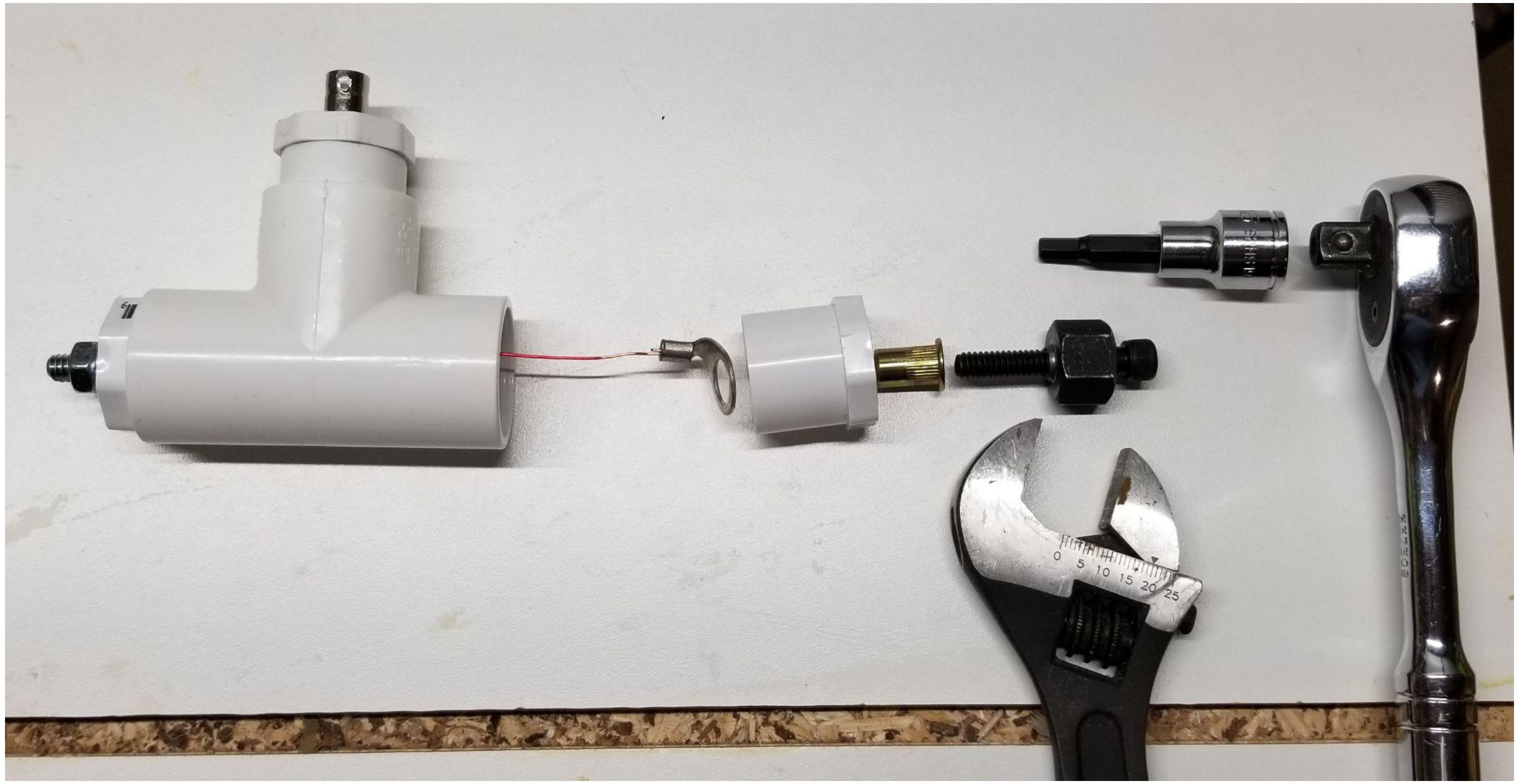
Outside are a washer, a ring connector (something to clip your radial set to), lock washer, and nut

Tighten



8. Build the non-coil part of the coil

I used a ¼” rivet nut (aka rivnut, nutsert) to connect the center pin element wire.



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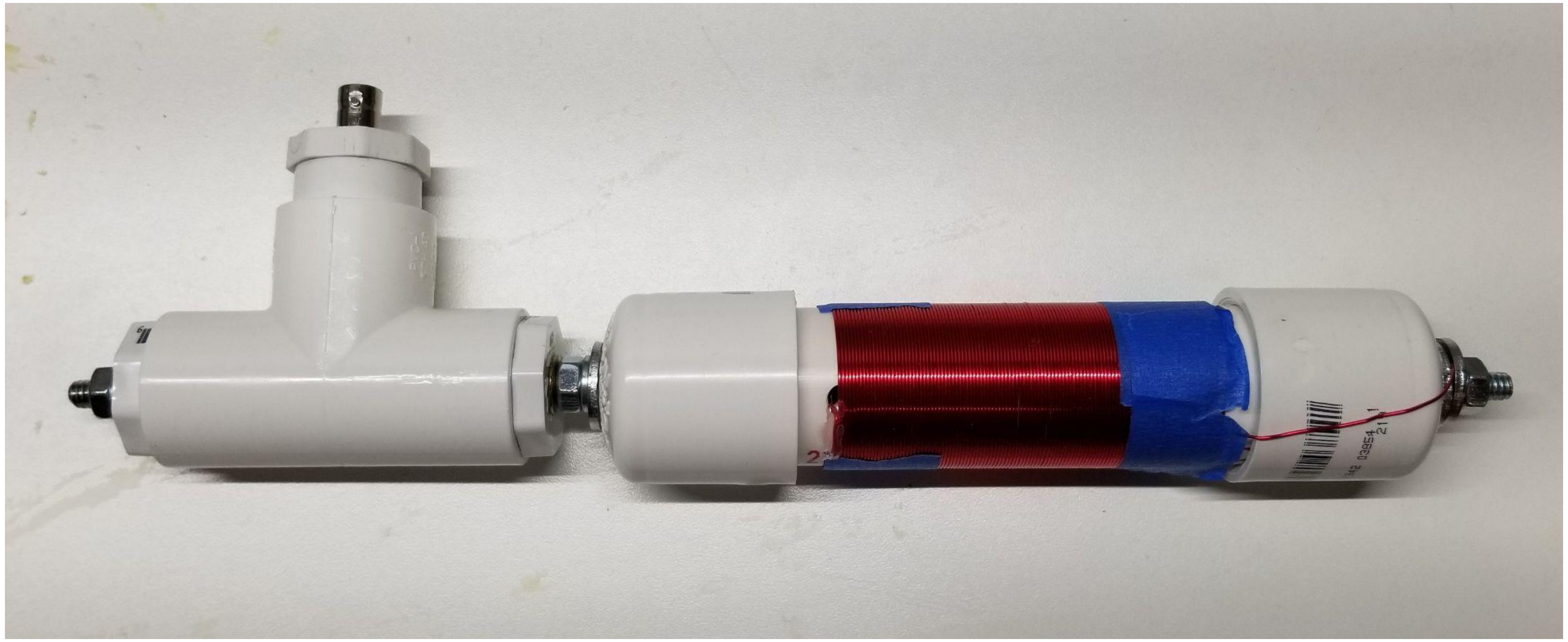
8. Build the non-coil part of the coil

Connect them. Everything is loose fit at this point, so have to be careful.

Attach a ¼” threaded coupling nut at the top coil bolt to accept the ¼” whip

This is ready to put on a tripod, add radials, and start tuning.



9. Tune

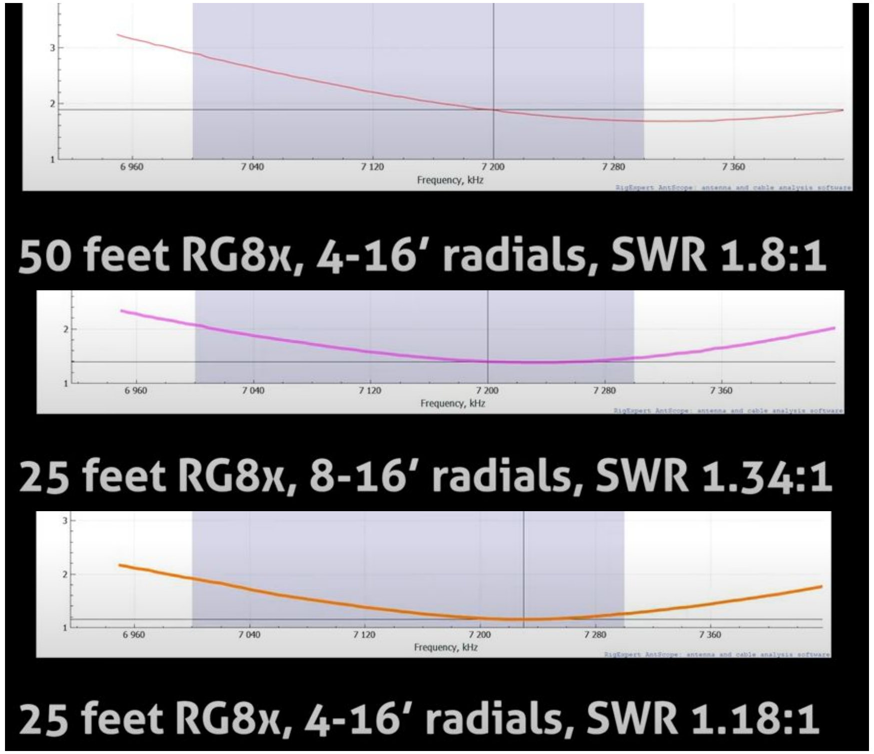
- Start by preparing the radials. General rules:
  - Coils installed directly on ground
    - will have multiple radial wires laid directly on ground - 16 minimum
    - typically shorter
    - aim for 2 wavelengths of total copper, or more
  - Coils elevated above ground will have fewer (even just 1) radial wire elevated above ground
    - length matters more than ground laid
    - recommend following Buddipole's radial length guide
    - have a length of wire on a spool or winder that's easy to extend/retract.

9. Tune

- For an elevated antenna/coil with an elevated radial, start with the radial longer than expected final length
- Measure resonance/SWR on an antenna analyzer/VNA
- If resonance point is below desired frequency, you have too many winds in the coil - remove some.
- For elevated radial - As you get closer to the desired resonance point, start adjusting the radial length/height and see how it affects the performance.
- Remember:
  - start small and see how much change is made
  - you can remove in ¼ turn increments
  - you can't add it back

9. Tune

Feed line length will also impact performance. KB9VBR tested various configurations of radials and coax length with his WRC Sporty Forty:



9. Tune

BuddiStick Pro recommended radial configuration

Use as a guide for your own

BAND	ARMS	COIL	COIL TAPS	RADIAL TAG COLOR	RADIAL LENGTH (INCHES)	WHIP LENGTH
40m	2	Y	39	Orange	362	Fully extended
20 m	2	Y	13	Blue	162	Fully extended
17 m	2	Y	9	Brown	119.25	6 sections minus 4 inches
15 m	2	Y	6	Red	110.25	Fully extended
12 m	2	Y	4	Yellow	95.5	Fully extended
10m	2	Y	2	Grey	81	Fully extended
6m	0	N	N/A	Black	42.5	5 sections

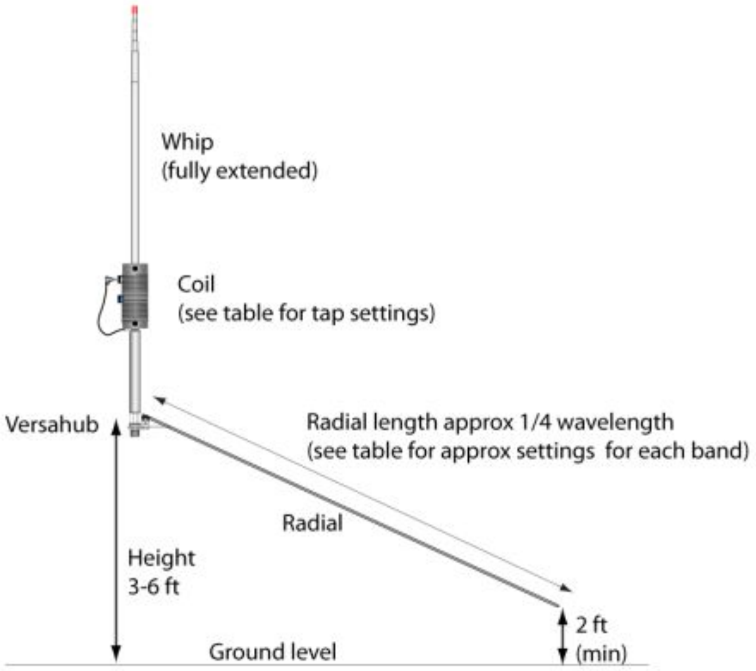


Figure 4 BUDDISTICK PRO Antenna Configuration

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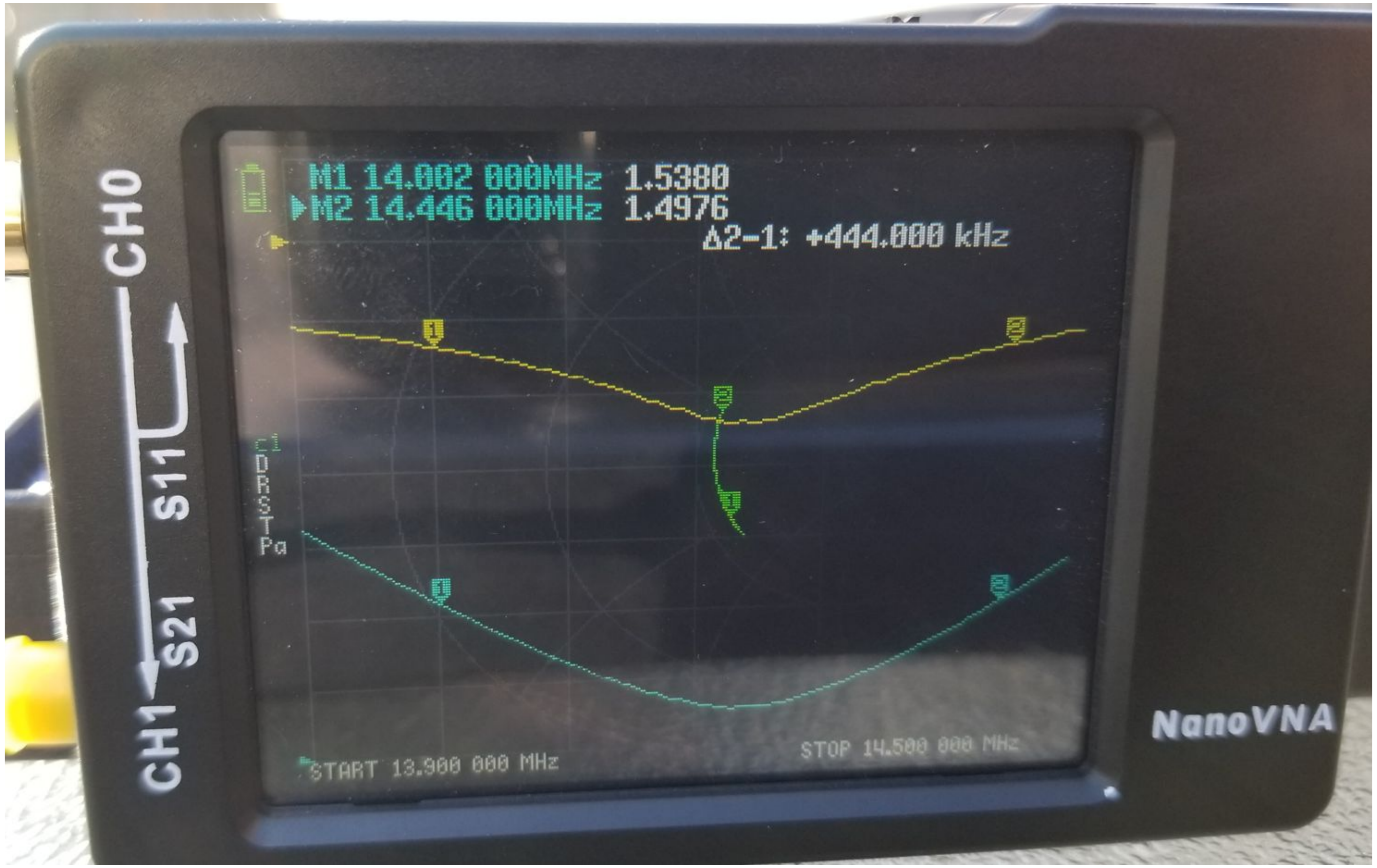
9. Tune

Goals….


M1 14.002 000MHz 1.5380
M2 14.446 000MHz 1.4976
Δ2-1: +444.000 kHz
CH0
S11
S21
CH1
START 13.900 000 MHz
STOP 14.500 000 MHz
NanoVNA

10. GOTA!

CHEROKEE AMATEUR RADIO SOCIETY

WX4CAR

Designing a Multi-Band Tappable Coil

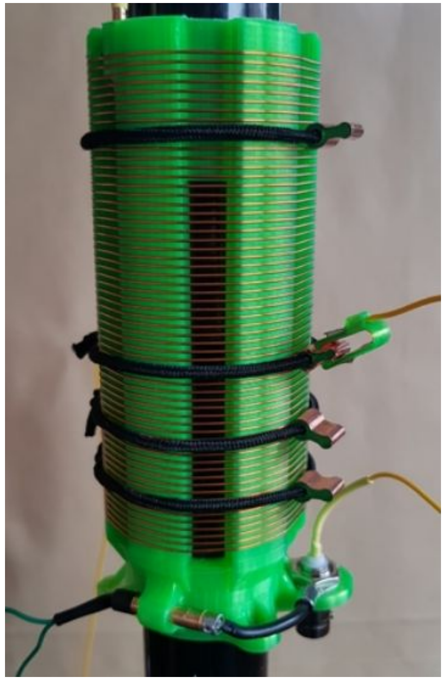
Same calculators and process as before, but with some changes…

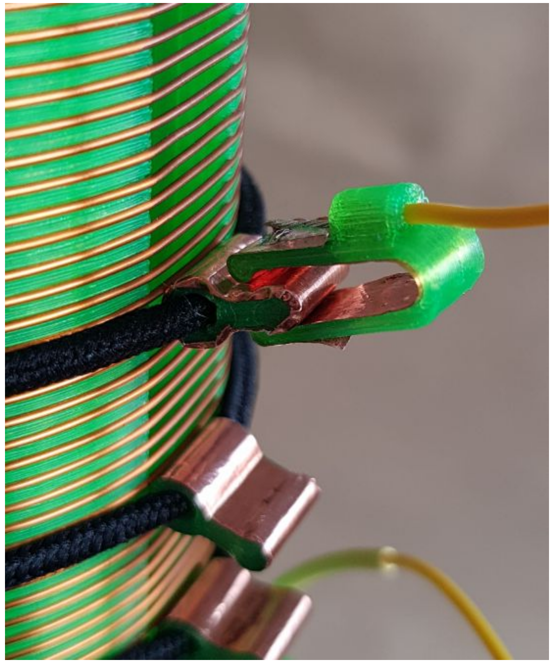
1) Use uninsulated wire
2) Full coil is lowest desired part of lowest desired band (want 80m CW? calculate for 3.500)
3) Space between coil winds
   a) Find the desired gap
   b) Factor that into the calculator when asked for coil length
      || || || = 3 winds + 2 gaps
4) Coil will only attach to one side - antenna or the feed point (usually antenna)
5) Other side will have a wire (or other mechanism) used to short out some or all of the coil, or bypass it altogether

Using an appropriate former for exact spacing

3D Printing can be very helpful here, along with some ingenuity

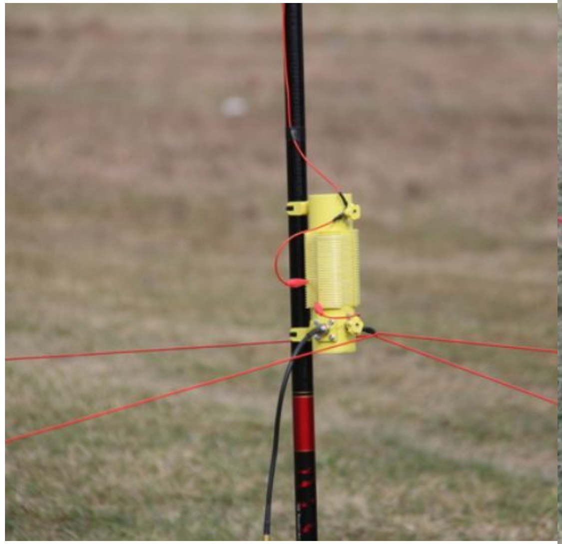
https://www.thingiverse.com/thing:4250441

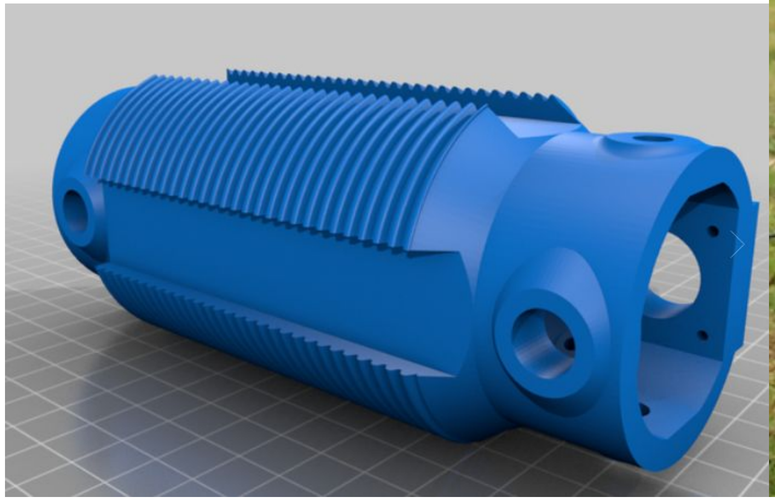




Using an appropriate former for exact spacing

https://www.thingiverse.com/thing:4525375
https://www.thingiverse.com/thing:2030237





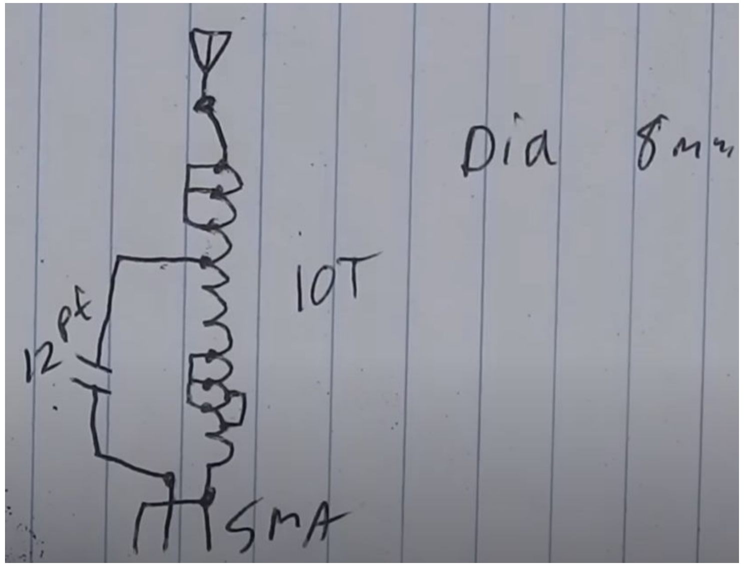

Miscellaneous Tidbits

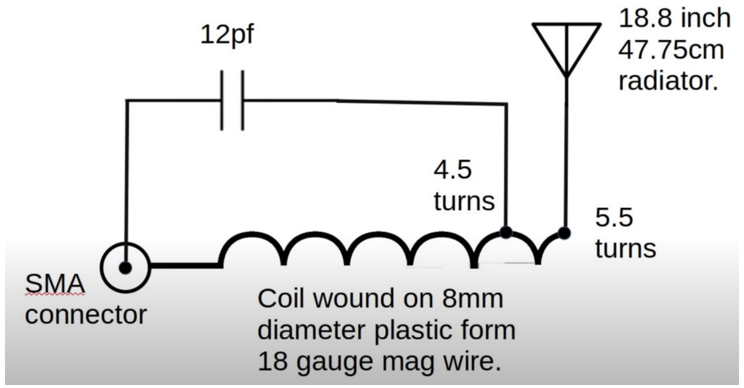
Tuned Circuits (LC) instead of Loading Coils (L)

LC Matching

Kevin Loughin took apart an ABBREE tactical VHF/UHF antenna

[Ham Radio - Tear down of the ABBREE tactical VHF/UHF antenna.]

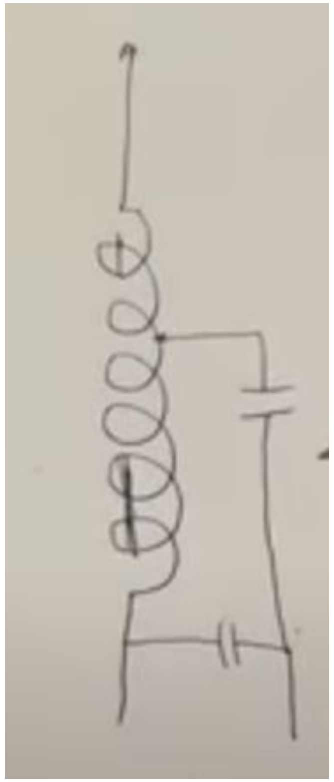




LC Matching

Mike-M0MSN took apart a Nagoya

[RADIO HAM: Antenna Autopsy NAGOYA MAG-77-EL teardown and repair.]



7pF

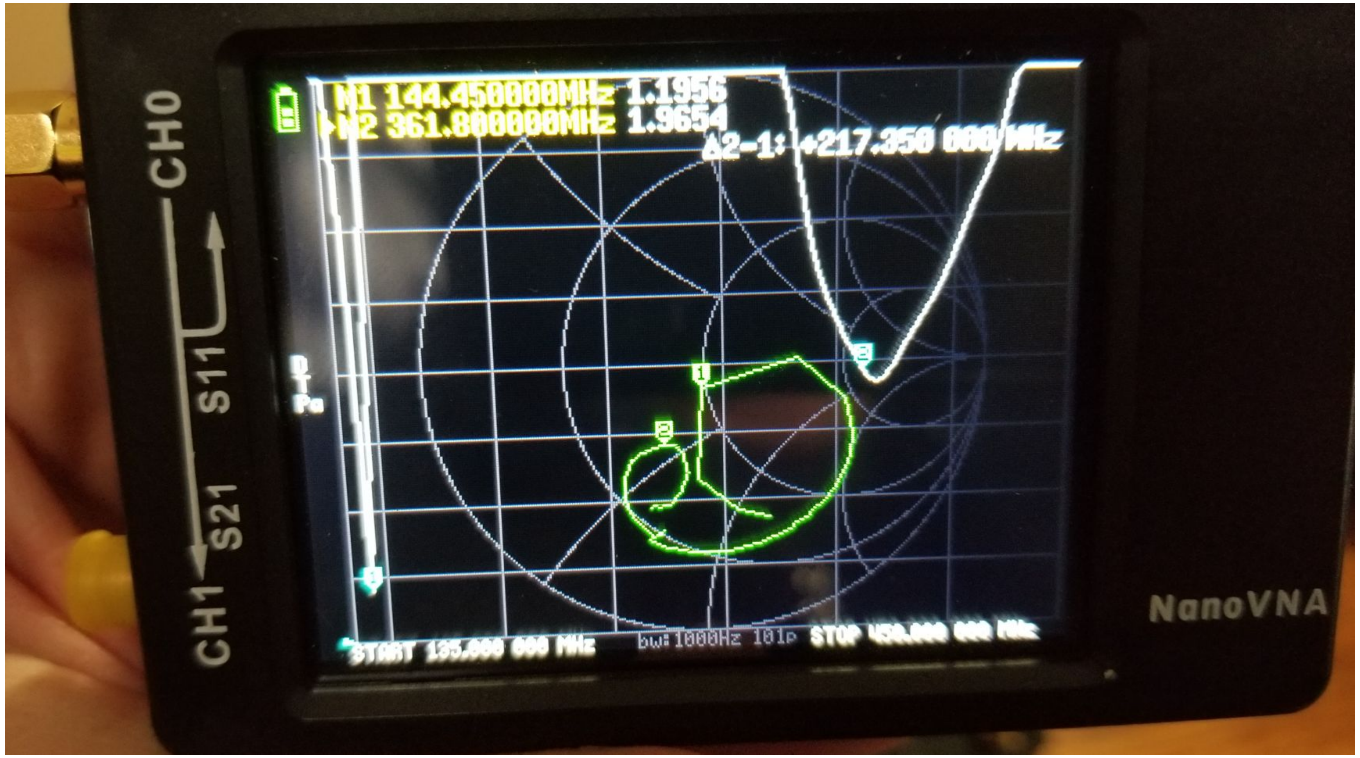
4pF

LC Matching

Inspecting on my own dual band Nagoya.

The Smith chart tells an interesting story and gives us clues as to the coil manufacture.

That the second dip is in the 360MHz range could likely be because it was calibrated at 135MHz, and going up to UHF is too broad of a sweep to be accurate.



Thanks for making it this far

… Slide #100 is a really long slide