Portable Magnetic Loop Antenna

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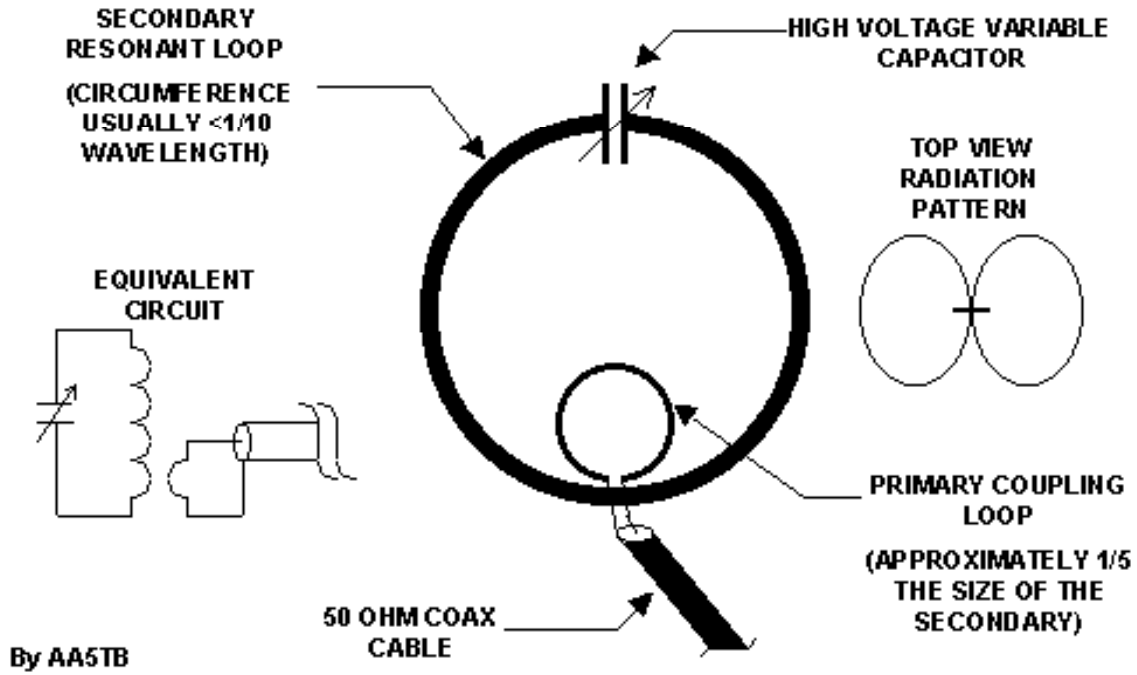
Overview

- Develop a ***Portable*** magnetic loop antenna for use on HF bands running QRP.
  - Portable and easy to deploy
  - Ideally run on the 40m through 10m bands
- For more theory and discussion try Steve Yates (AA5TB) website at: http://www.aa5tb.com/loop.html
- Design calculations were made with Steve's Excel spreadsheet also in the link above.

Components of a Magnetic Loop Antenna



- Loop length (circumference) should be >1/10 λ and <1/4 λ of the operating frequency.
- The larger the diameter of the loop & loop conductor, the greater the efficiency
- The small size and reasonable efficiency leads to a ***very*** narrow bandwidth

Danger: Hi-Voltage!

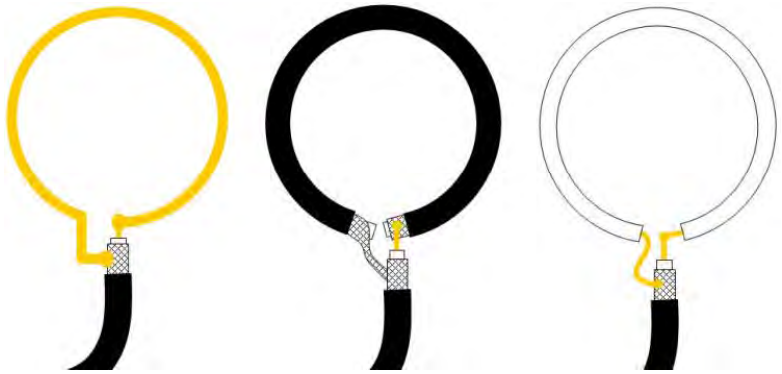
Caution!

Even at QRP Transmit levels there will be high voltage present in the loop:

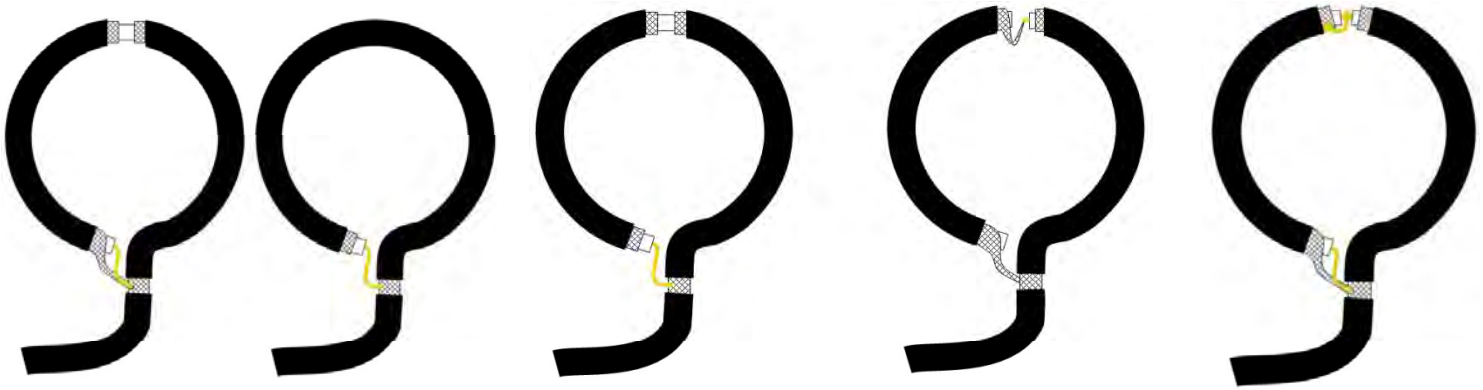
Power (W)	Loop Voltage (V)
5	920
20	1,800
100	4,100

Protect yourself and others from coming in contact with the loop when in operation!

Coupling Loops



Unshielded Coupling Loops



Shielded “Faraday” Coupling Loops

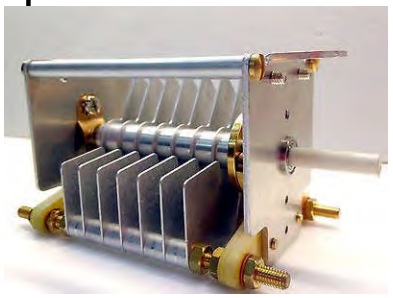
- Made from a piece of 50Ω RG-8X coax
- 1/5 diameter of main loop

Easy to Implement and good matching performance

Capacitor Selection

- Capacitor must be selected to meet the hi-voltage requirement and allow tuning in the operating bands.
  - Best choice is vacuum variable capacitor
    - High cost
    - Fragile
    - Bulky
    - Good in the 4-5kVrange

  - Air Variables
    - Need at least 25 mil plate separation for 20W operation
    - May introduce losses dependent on design.
      - Butterfly or split stator types the best
      - Many homebrew options



  - A length of coax
    - Good for fixed frequency operation

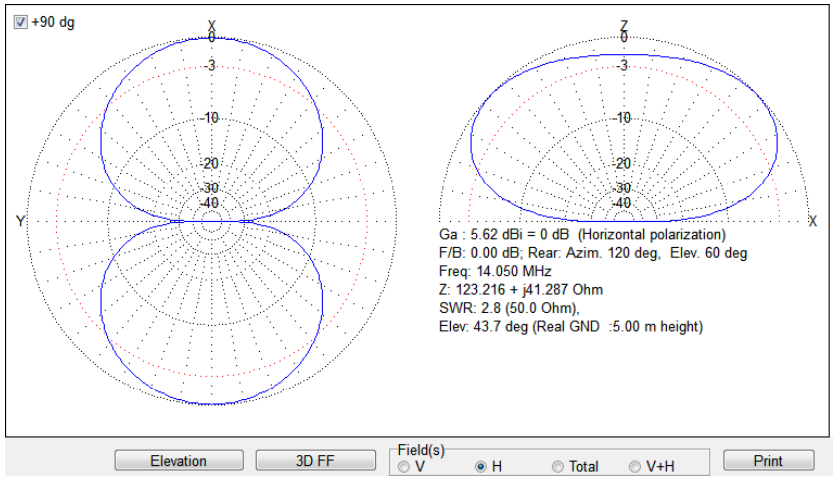
Pattern & Gain

In Vertical orientation:

- Needs to be a minimum of one loop diameter above ground; additional height provides no advantage.
- Exhibits a “donut” shaped pattern and with a 3.7dBi gain
- Keep it as clear as possible from metal structures
- Works at both high and low radiation angles

In Horizontal orientation:

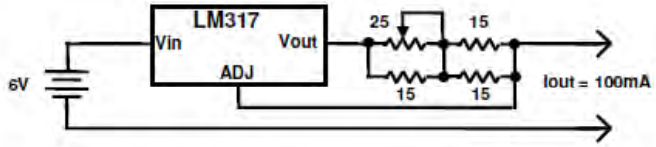
- Behaves as a dipole.
- Needs at least 1/4λ Height
- Loses directivity



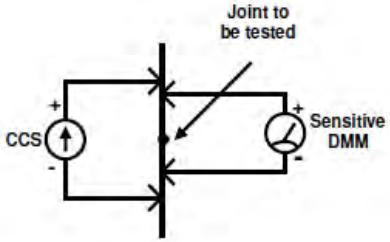
Vertical Pattern

Losses

Minimizing loss resistance in small transmitting loops is important. A simple constant current source is useful in measuring DC loss resistance in loop joints and connections in tuning capacitors.



N2CX – 100 mA Constant Current Source



Milliohm Measurements

Adjust pot for 100 ma into short circuit

Connect CCS to resistance under test – up to 10 ohms

Measure drop across resistance

Scale factor 0.1 mV = 1 milliohm

Thanks to N2CX for the method shown here!

- Measured 25 mOhms of loss in my antenna
- Impact:
  - Lowers efficiency
  - Widens bandwidth

Magnetic Loop Antenna Design Points

- The following pages show the design points for the magnetic loop using a 10 foot length of RG-213 coax.
  - RG-213 shield diameter is .314 inches
  - Using coax allows quick setup and take down of antenna and portability at the expense of efficiency.

40m Design Point

Design Frequency =	**7.000**MHz	
Loop Diameter =	**3.183**feet	**0.970**m
Conductor Diameter =	**0.314**inches	**7.976**mm
Added Loss Resistance =	**0.000**milliohms	
RF Power =	**20.000**Watts	

Calculated Results:

Bandwidth =	**9.573**kHz (-3 dB points)	
Efficiency =	**5.770**%	**-12.388**dB
Loop Area =	**7.958**ft²	**0.739**m²
Radiation Resistance =	**5.139**mΩ	
Total Loss Resistance =	**83.923**mΩ	
Loop Circumference =	**10.000**ft	**3.048**m
Wavelength Percentage =	**7.117**% λ	
Loop Inductance =	**2.961**µH	
Distributed Capacitance =	**8.200**pF	
Q (Quality Factor) =	**731.223**	
Tuning Capacitor =	**174.563**pF	
Capacitor Voltage =	**1380.148**V	
Minimum Plate Spacing =	**18.402**mils (1/1000 in)	**0.467**mm

- Circumference a bit low for 7MHz
- Requires 175pF of capacitance at high limit
- 5.8% efficiency with 9.5kHz Bandwidth

20m Design Point

Design Frequency =	**14.000** MHz	
Loop Diameter =	**3.183** feet	**0.970** m
Conductor Diameter =	**0.314** inches	**7.976** mm
Added Loss Resistance =	**0.000** milliohms	
RF Power =	**20.000** Watts	

Calculated Results:

Bandwidth =	**21.595** kHz (-3 dB points)	
Efficiency =	**40.927** %	**-3.880** dB
Loop Area =	**7.958** ft^2	**0.739** m^2
Radiation Resistance =	**82.226** mΩ	
Total Loss Resistance =	**118.684** mΩ	
Loop Circumference =	**10.000** ft	**3.048** m
Wavelength Percentage =	**14.234** % λ	
Loop Inductance =	**2.961** µH	
Distributed Capacitance =	**8.200** pF	
Q (Quality Factor) =	**648.289**	
Tuning Capacitor =	**43.641** pF	
Capacitor Voltage =	**1837.807** V	
Minimum Plate Spacing =	**24.504** mils (1/1000 in)	**0.622** mm

15m Design Point

Design Frequency =	**21.000**MHz	
Loop Diameter =	**3.183**feet	**0.970**m
Conductor Diameter =	**0.314**inches	**7.976**mm
Added Loss Resistance =	**0.000**milliohms	
RF Power =	**20.000**Watts	

Calculated Results:

Bandwidth =	**60.368**kHz (-3 dB points)	
Efficiency =	**74.118**%	**-1.301**dB
Loop Area =	**7.958**ft²	**0.739**m²
Radiation Resistance =	**416.269**mΩ	
Total Loss Resistance =	**145.358**mΩ	
Loop Circumference =	**10.000**ft	**3.048**m
Wavelength Percentage =	**21.351**% λ	
Loop Inductance =	**2.961**µH	
Distributed Capacitance =	**8.200**pF	
Q (Quality Factor) =	**347.868**	
Tuning Capacitor =	**19.396**pF	
Capacitor Voltage =	**1648.801**V	
Minimum Plate Spacing =	**21.984**mils (1/1000 in)	**0.558**mm

10m Design Point

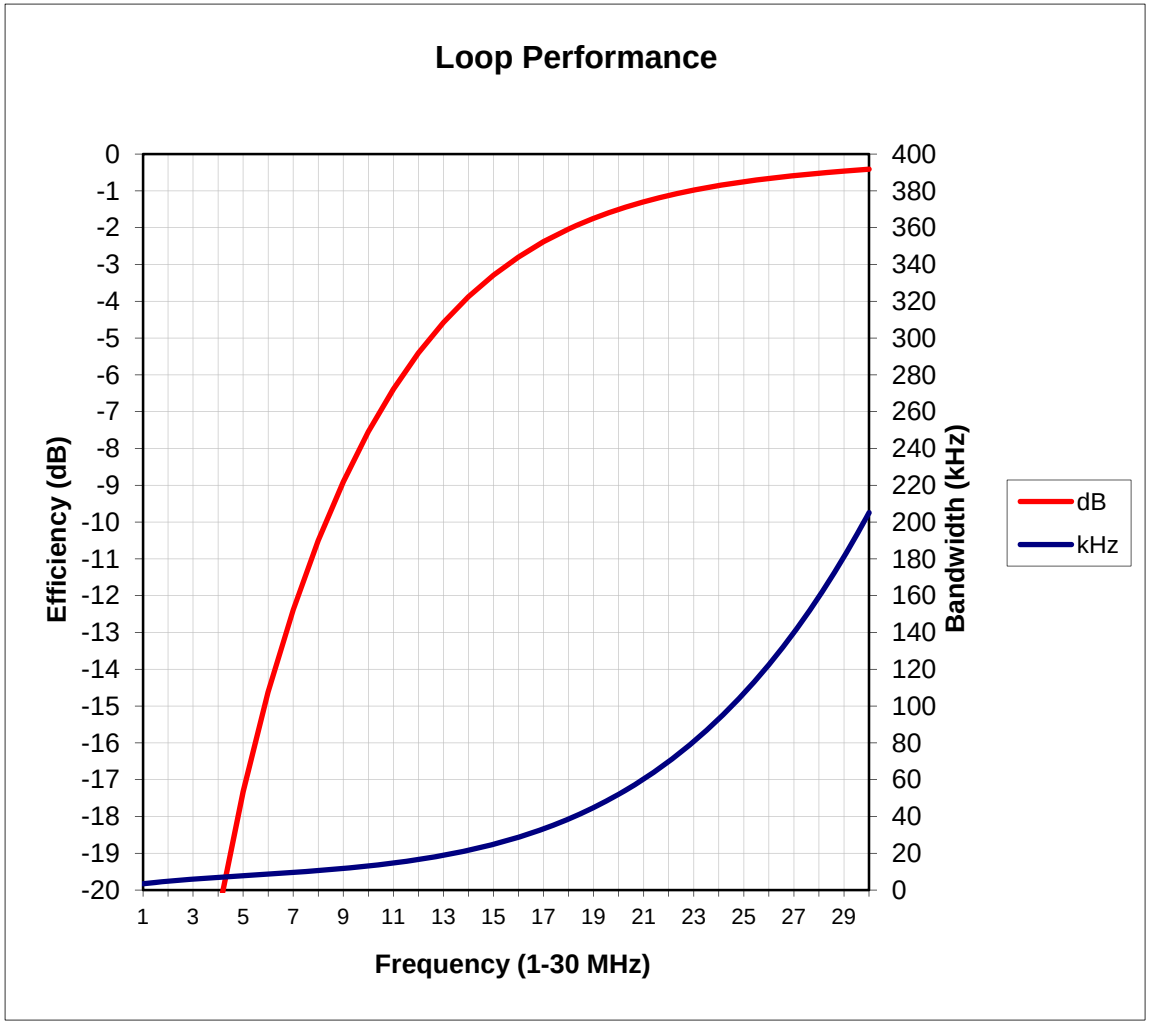
Design Frequency =	**28.500**MHz	
Loop Diameter =	**3.183**feet	**0.970**m
Conductor Diameter =	**0.314**inches	**7.976**mm
Added Loss Resistance =	**0.000**milliohms	
RF Power =	**20.000**Watts	

Calculated Results:

Bandwidth =	**169.988**kHz (-3 dB points)	
Efficiency =	**89.292**%	**-0.492**dB
Loop Area =	**7.958**ft²	**0.739**m²
Radiation Resistance =	**1412.136**mΩ	
Total Loss Resistance =	**169.337**mΩ	
Loop Circumference =	**10.000**ft	**3.048**m
Wavelength Percentage =	**28.976**% λ	
Loop Inductance =	**2.961**µH	
Distributed Capacitance =	**8.200**pF	
Q (Quality Factor) =	**167.659**	
Tuning Capacitor =	**10.531**pF	
Capacitor Voltage =	**1333.481**V	
Minimum Plate Spacing =	**17.780**mils (1/1000 in)	**0.452**mm

- Circumference a bit high for 28MHz
- Requires 10.5pF of capacitance at high limit
- 89% efficiency with 169.9kHz Bandwidth

Loop performance vs. Frequency (assumes no additional Losses)



Design Decisions

- Use RG-213 coax for the loop
  - Cheap, flexible and reasonably large braid diameter (.314 inches)
  - Easy to swap coax for band changes
- Capacitor on hand will not meet frequency range with fixed loop
  - Use a 10 ft loop for 40-15m
    - Switch in a fixed 120pF silver mica capacitor to achieve tuning at 40m
  - Use a 6 ft loop for 15m-10m
    - Allow use of same capacitor at cost of some efficiency.

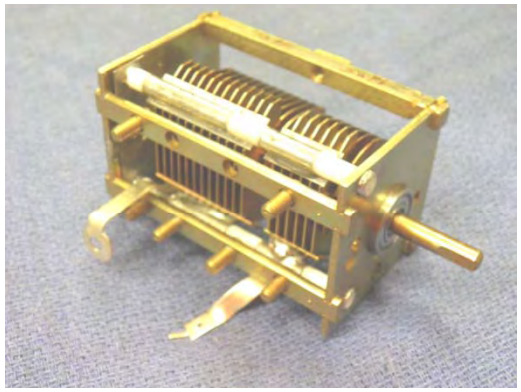
Bill of Materials & Costs

Item	Cost	Source
Air Variable Capacitor	$8.99	Ebay
RG-8X patch Cable (3ft)	$4.65	Ebay
RG-213 patch cable (10ft)	$17.96	Amazon
RG-213 patch cable (6ft)	$13.95	Amazon
UHF Panel Jacks (2x)	$4.38	Amazon
¾” Pipe Strap	$1.17	Home Depot
#10-32x3/4” machine screws	$1.18	Home Depot
4x4x2” Junction Box	$6.88	Home Depot
2ft x ¾” PVC Pipe (4x)	$6.28	Home Depot
¾” PVC Pipe Cross	$1.97	Home Depot
6:1 Shaft Reducer	$12.00	Xtal Set Society
Photo Tripod	$20.00	Walmart
¼” Fiberglass rod	$3.00	Ebay
Total	**$102.40**	

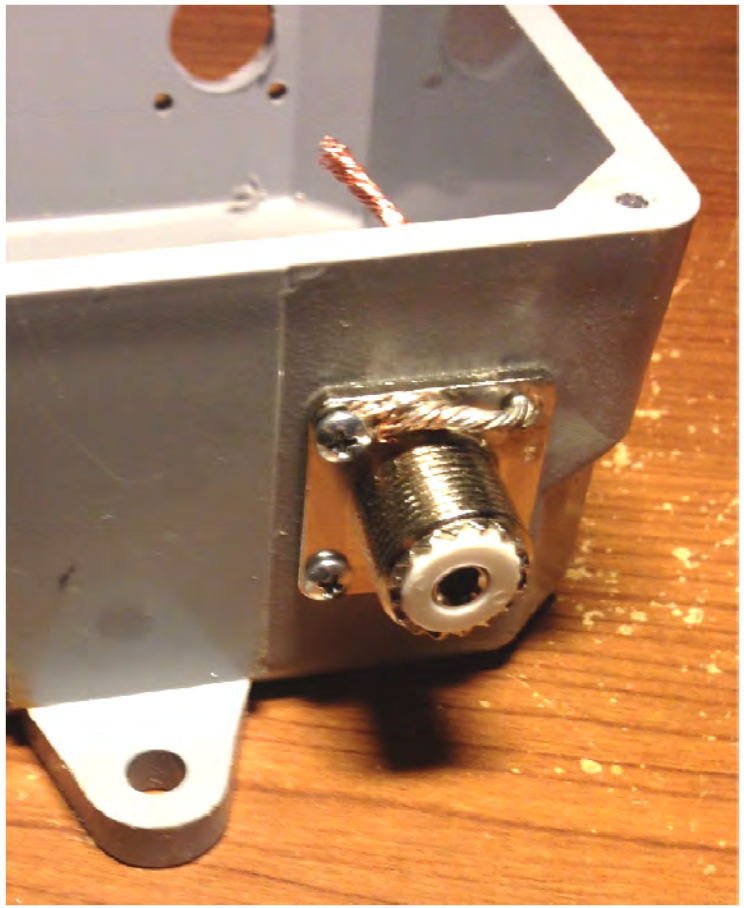
Construction

- Frame built from ¾” PVC pipe. Four 2’ sections of pipe on a central PVC cross.
- Frame supported on a standard camera tripod.
- 4”x4”x2” Plastic Junction box used to hold an air variable capacitor, the wiring and two chassis mount UHF connectors.
- Loop made from a 10 foot RG-213 patch cable for 40m thru 15m and a 6 for RG-213 patch cable for 15m thru 10m.
- 6:1 gear reducer mounted to capacitor shaft for easier tuning
- Junction box mounted to Lower PVC pipe section with metal strap.
- Fiberglass rod attached to capacitor for tuning
- Shielded “Faraday” coupling loop made from a RG-8X patch cable. Loop approximately 1/5 diameter of main loop.

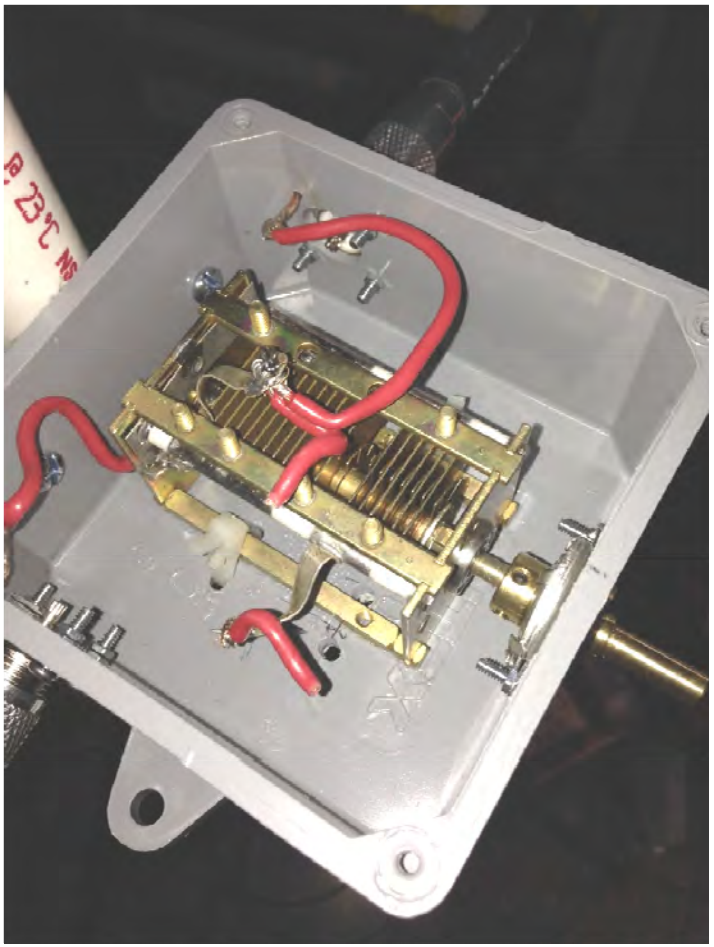
- Capacitor is a two gang air variable capacitor with a plate spacing of 0.025”
    - Gang #1: 7 – 65pF Used this gang only
    - Gang #2: 5 – 46pF
    - Readily available on Ebay



Tuning Box Construction

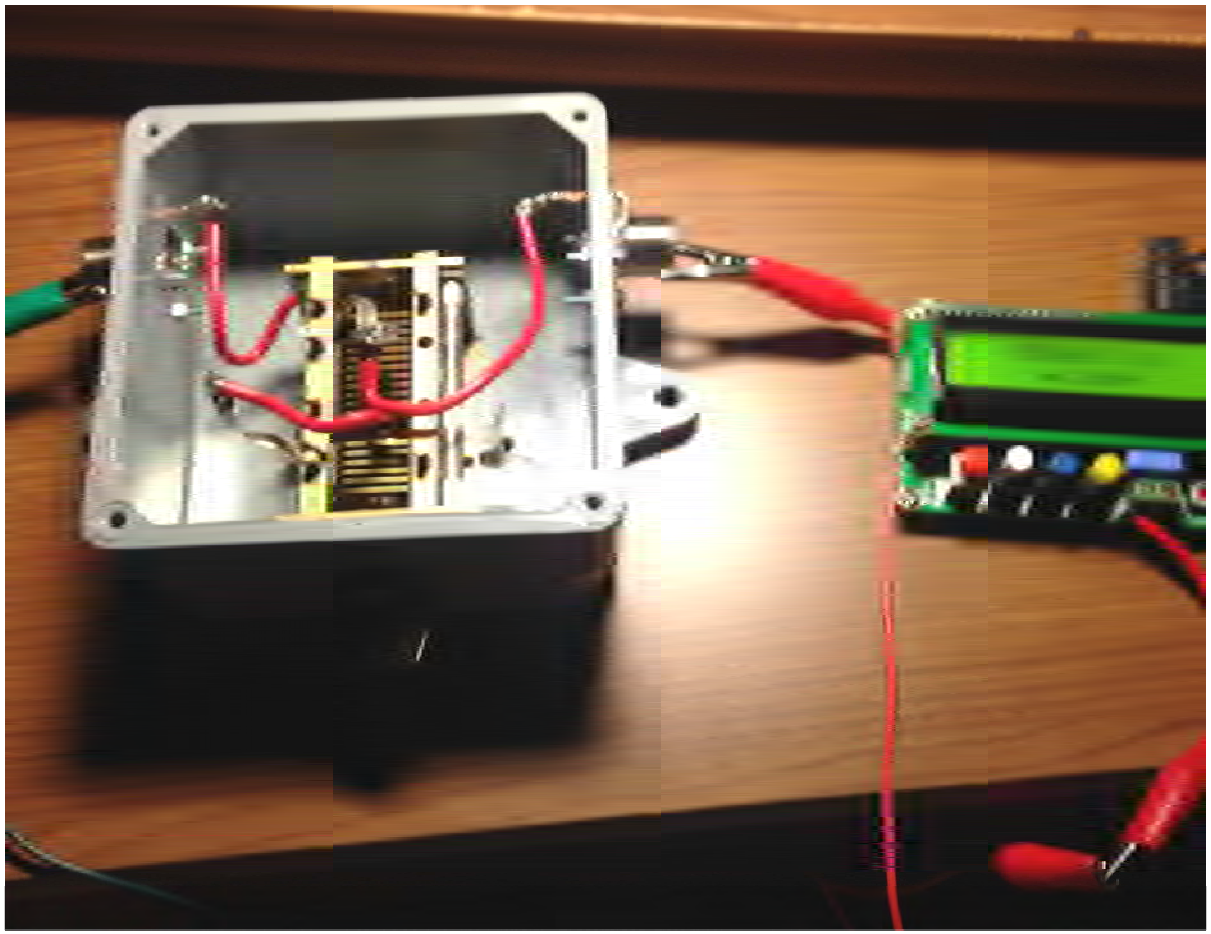


Install UHF Panel mount
Connectors with connection
to Solder braid



Wired box with 6:1 shaft reducer
and pipe clamp to PVC pipe

Testing Capacitance



Tuning Shaft

- Machined Aluminum coupler for non-metallic tuning shaft to capacitor
- Can also use small piece of rubber or silicone hose with cable ties or hose clamps.
- Tuning is manual with shaft about 3 feet long
- Wanna get fancy?
    - Try a motorized remote tuning project!

Assembly Sequence

1. Fully Open Tripod
2. Mount PVC with tuning box on tripod head (friction fit)
3. Install each of three arms on the PVC cross
4. Install loop coax to the cross. Use tape or wire ties to mark position.
5. Connect loop coax to tuning box
6. Install coupling loop to top of loop using Velcro cable ties
7. Install feedline coax to coupling loop and to radio
8. Install fiberglass rod to tuning shaft
9. Extend antenna to maximum tripod height

Antenna Deployed

Antenna configured for 40m thru 15m

Antenna configured for 15m thru 10m

- Note smaller arms for smaller loop

Portable Deployment

Bag Contains Antenna

Antenna deployed for 40m thru 15m
and directly connected to FT-817ND

Operation

1. Turn on transceiver and set operating band and frequency
2. Set power appropriate for your antenna (mine is 20W max)
3. Adjust tuning capacitor using the fiberglass rod until maximum receive noise is heard.
4. Apply a low power carrier and fine tune capacitor for minimum SWR
5. Make QSO's and have fun

- Depending on the band and antenna construction, It will require frequent retuning.
- Rotating the antenna provides some directionality and can null out some unwanted signals

Warning: Don't touch the loop when transmitting!
Hi Voltage present!

RF Exposure

Average Power at the Antenna	20 watts
Antenna Gain in dBi	3.7 dBi
Distance to the Area of Interest	3 feet 0.9144 metres
Frequency of Operation	29 MHz
Are Ground Reflections Calculated?	Yes
Estimated RF Power Density	1.1424 mW/cm^2

	Controlled Environment	**Uncontrolled Environment**
Maximum Permissible Exposure (MPE)	1.0752 mW/cm^2	0.219 mW/cm^2
Distance to Compliance From Centre of Antenna	3.1495 feet 0.96 metres	6.9807 feet 2.1277 metres
Does the Area of Interest Appear to be in Compliance?	no	no

Calculation Results

Average Power at the Antenna	100 watts
Antenna Gain in dBi	3.7 dBi
Distance to the Area of Interest	3 feet 0.9144 metres
Frequency of Operation	29 MHz
Are Ground Reflections Calculated?	Yes
Estimated RF Power Density	5.7117 mW/cm^2

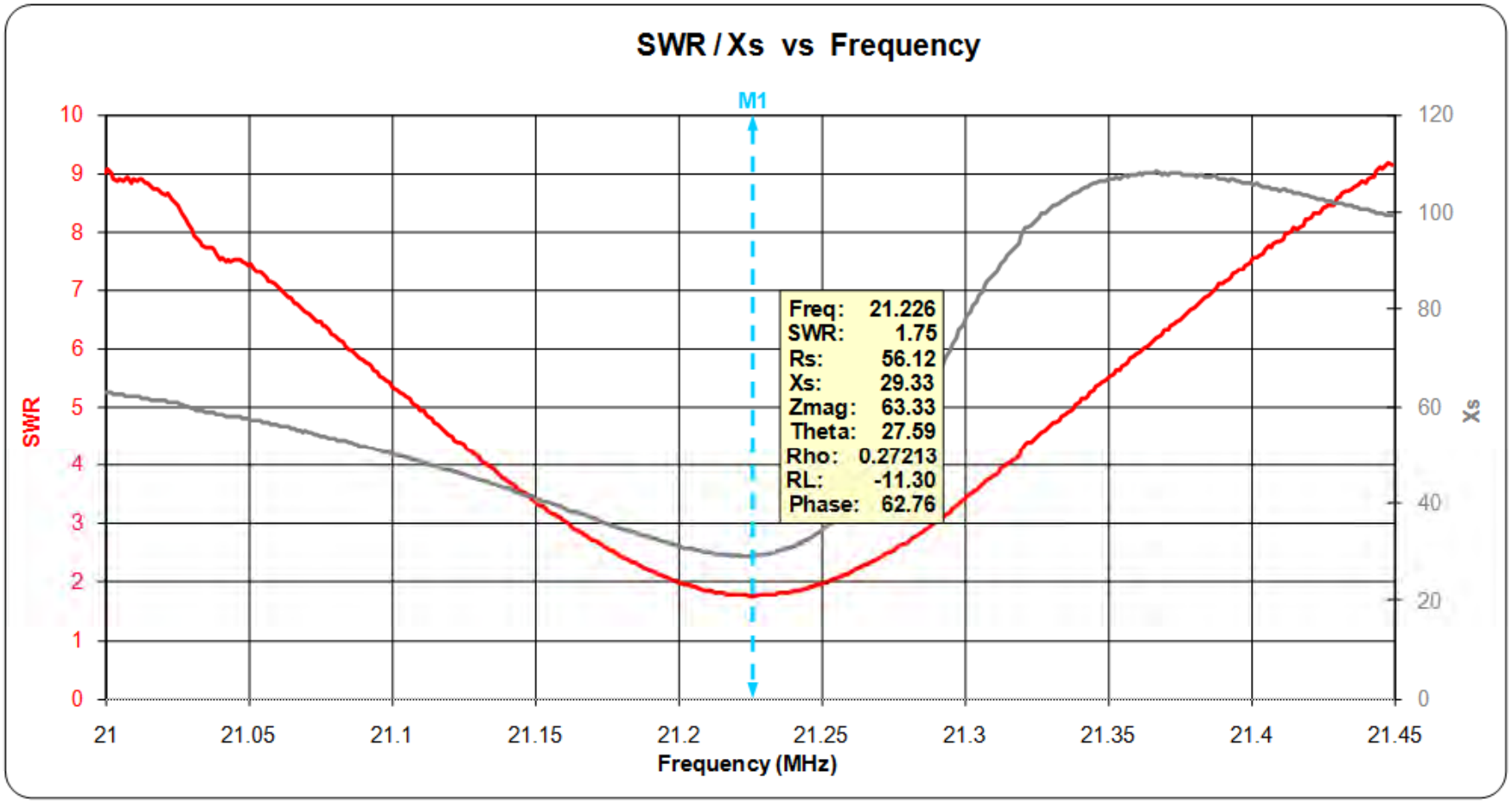
	Controlled Environment	**Uncontrolled Environment**
Maximum Permissible Exposure (MPE)	1.0752 mW/cm^2	0.219 mW/cm^2
Distance to Compliance From Centre of Antenna	6.9807 feet 2.1277 metres	15.5475 feet 4.7389 metres
Does the Area of Interest Appear to be in Compliance?	no	no

Worst case RF exposure is on the higher frequencies. 20W is really exposure limit for operating portable and needs 3 feet minimum for safety

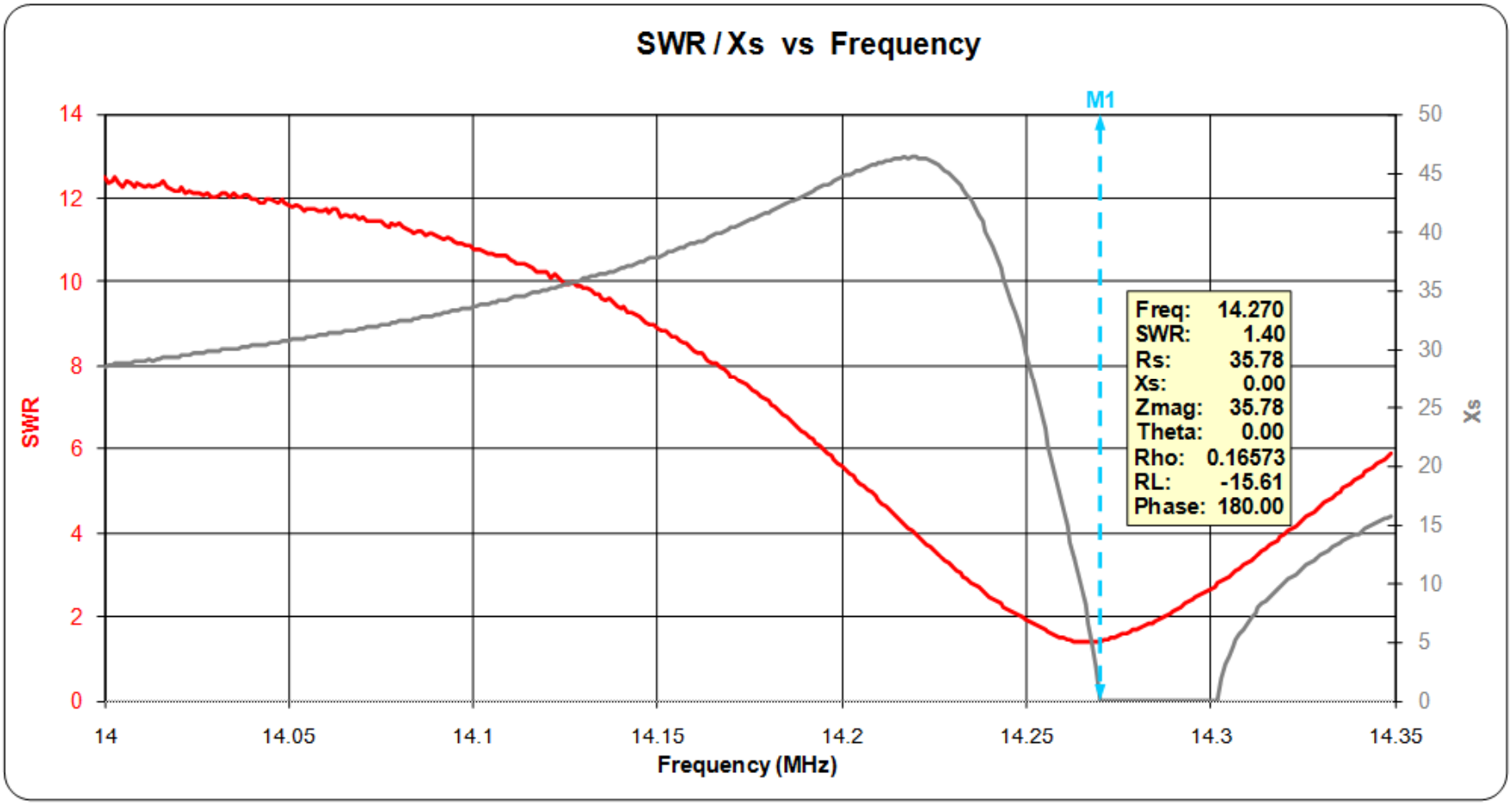
- Safest in the null facing the loop

Higher power means stay further away from the antenna…look into remote tuning!

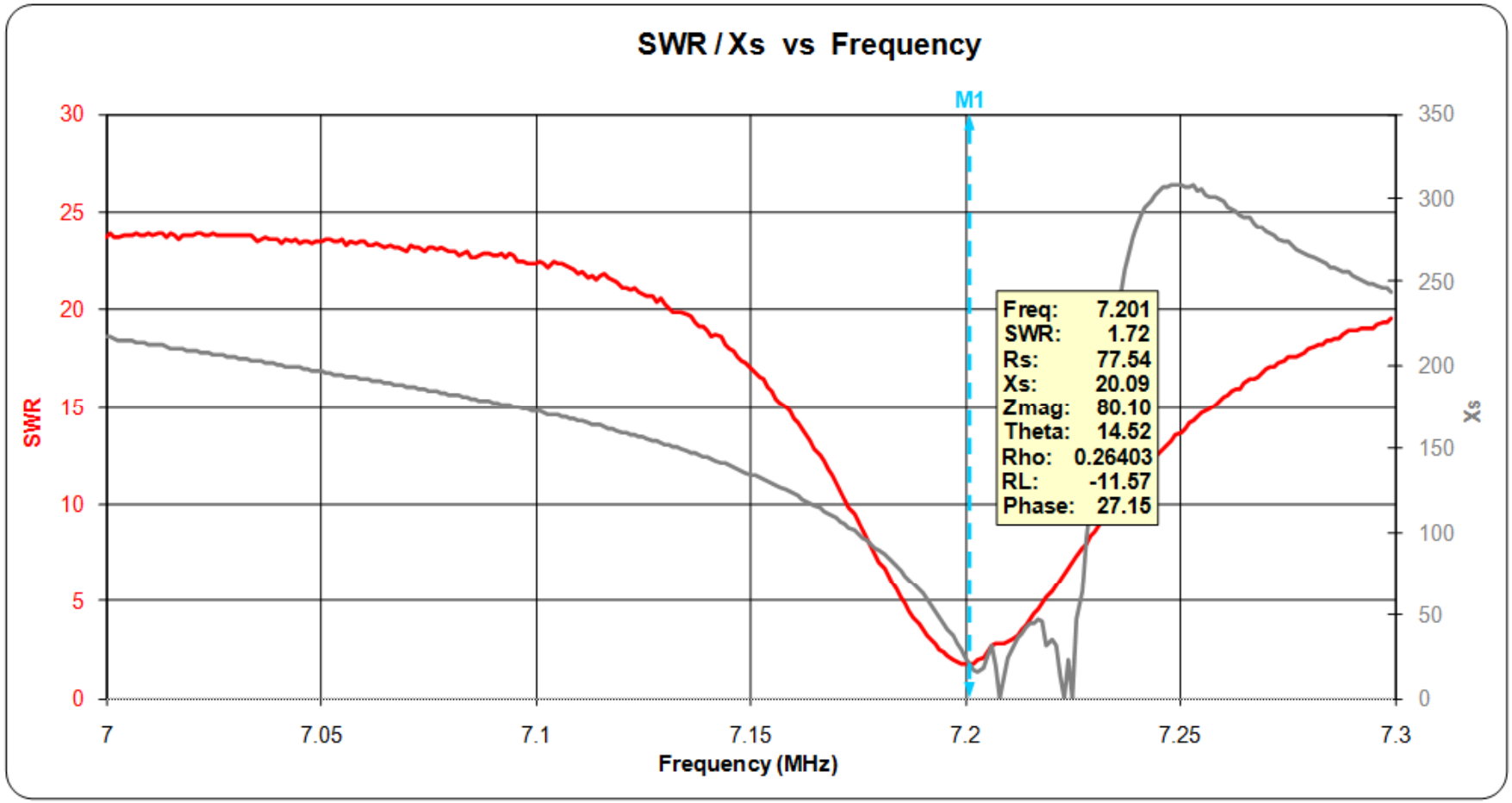
15m Frequency Sweep



20m Frequency Sweep



40m Frequency Sweep
120pF capacitor in parallel



Stations worked During Initial Testing

Band	Power	Indoors?	Contacts
10m	20W		CT, Puerto Rico
12m	30W	X	Chile
15m	5W		Argentina, Guatemala, Spain, Azores
17m	20W		Venezuela
20m	5W	X	Mexico, Guatemala, Czech Republic, Bosnia Herzegovina, CA, NY, VA, MD, IN
20m	5W		Belgium, MT, KS, VA

No contacts made yet on 40m

Magnetic Loop vs. End Fed Vertical

- A 30 foot vertical end fed wire with a 9:1 matchbox, 30 ft of coax feedline counterpoise and autotuner was compared to the magnetic loop antenna through an A/B switch with 5W SSB.
    - A contact in WA state gave a 53 signal report with no noticeable change in signal strength or quality between the two antennas.

Magnetic Loop vs. End Fed Vertical

The Portable Magnetic loop antenna exhibited:

1. Easy setup (less than 5 minutes)
2. Low receive noise
3. Some directionality
4. No External tuner required (tuner built in to antenna)

For the 30 ft End Fed Vertical:

1. Easy band change from 80m thru 10m using the external autotuner
2. Can run higher power than current Mag loop
3. Broadband: generally does not require retuning within the band.

The ease of setup swings my preference to the Magnetic Loop Antenna for portable use.

Conclusions

- Basic design goal of an easily deployed, portable HF antenna was accomplished
- Trick is finding a suitable capacitor and keeping connection losses low
- Easy to build and low cost
- Performs very well even with design compromises.
- Can be used indoors with good results on low power

- Future work:
  - Make a 40m contact!
    - Test as an NVIS antenna on 40m
  - Build my own air variable capacitor to support 50W operation
  - Evaluate with short radials
  - Try this as a loop (6” x 8 ft dryer duct):

Thank You!!!

Questions?