My Loop Antenna

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Outline

- Brief History
- Characteristics of Small Loop Antennas for HF
- My Loop for 40m – 15m
- Receive/Transmit Properties of Elect.-Small Loops
- Loop Equations
- Measuring Efficiency of a Loop or Vertical Antenna
- Evaluation of My Loop – Comparison to Verticals
- Conclusions - References

Brief History

- 1968 Lew McCoy W1ICP attempts using military small-loop antenna adapted for amateur applications

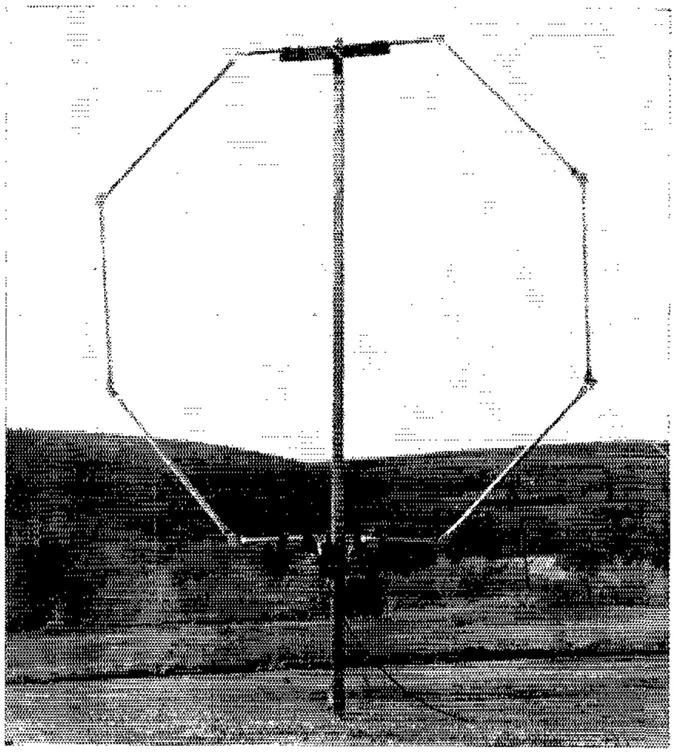


Fig. 2—The loop mounted on a guyed 2 x 3. The sides of the loop also were guyed as the antenna tended to be "floppy," in even light winds.

12-foot diameter loop

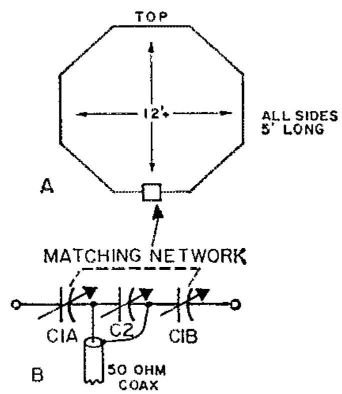


Fig. 1—A—Drawing of the octagonal loop; B—The matching network. In matching, a 50-ohm s.w.r. bridge is inserted in the coaxial line and the network adjusted to a 1-to-1 match.

C_{1A}, C_{1B}—Approximately 650 pf. per section, each section consisting of two 325 pf. variables in parallel.

C_2—Approximately 500 pf., two 250 pf. variables in parallel.

Capacitor matching

- Results from military – loop outperforms dipole over 2-5 MHz
- ***McCoy's results disappointing – loop is 3 S-units below dipole***
- Reason – losses in electrical/mechanical connections overwhelm *tiny radiation resistance*
- Military used very careful construction to achieve good results

Brief History (cont'd)

- Even earlier military applications have been documented

Schutzpolizei 1932

Balkans War 1942

Portable Army Radio Tested

The Princess Royal expresses interest in a new portable field radio transmitting and receiving set that was demonstrated by the Royal Corps of Signals at Aldershot, England.

A PORTABLE field radio transmitting and receiving set that operates while strapped to a soldier's back was satisfactorily tested by the Royal Corps of Signals at Aldershot, England. The device features a special loop-type antenna, standard earphones and a hand microphone. The power supply unit is self-contained.

Aldershot, England 1937

Brief History (cont'd)

- Since McCoy's experiment, many hams have built highly performing "electrically-small" loops *(diameter ≈ one meter for HF operation – see examples next page)*

- With proper materials and construction techniques, the performance of small-loops becomes comparable to full size dipoles

- Advantages: much smaller footprint, works well a few feet off the ground (in vertical position), does not require radials or counterpoises

Brief History (cont'd)

alexloop.com

(see also QST Nov 2013 p. 67)

(much bigger loop)

AA5TB

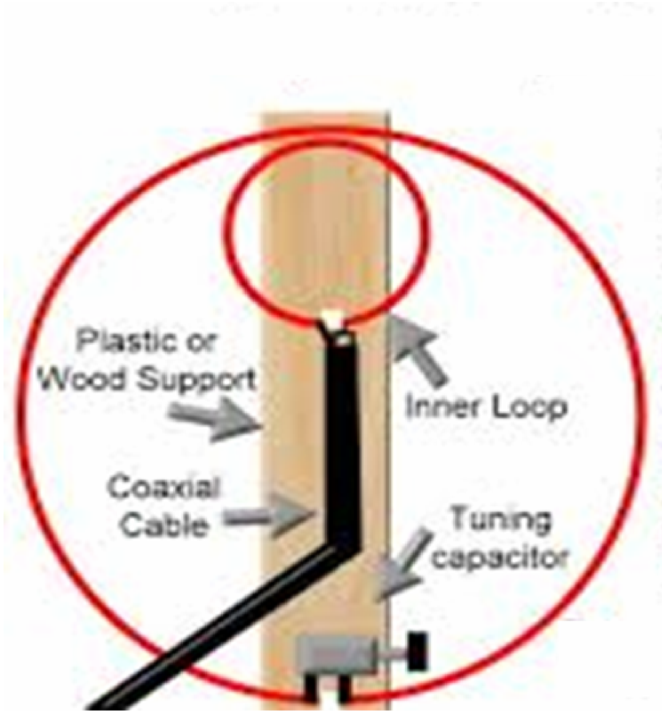
JL1BOH

Brief History (cont'd)

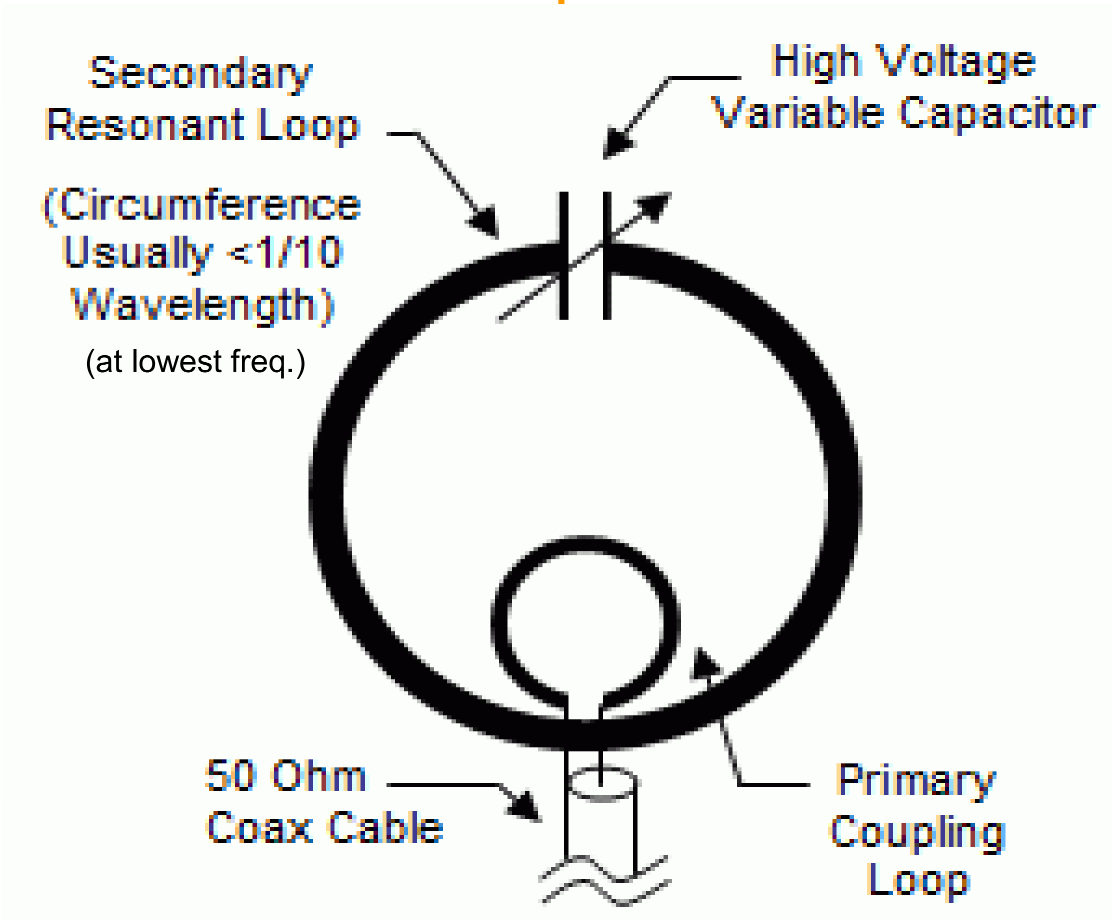
Alpha Loop

amateurradiostore.com (Alpha Antennas)

Characteristics of Small Loop Antennas for HF Operation



Mounting option with loop on top

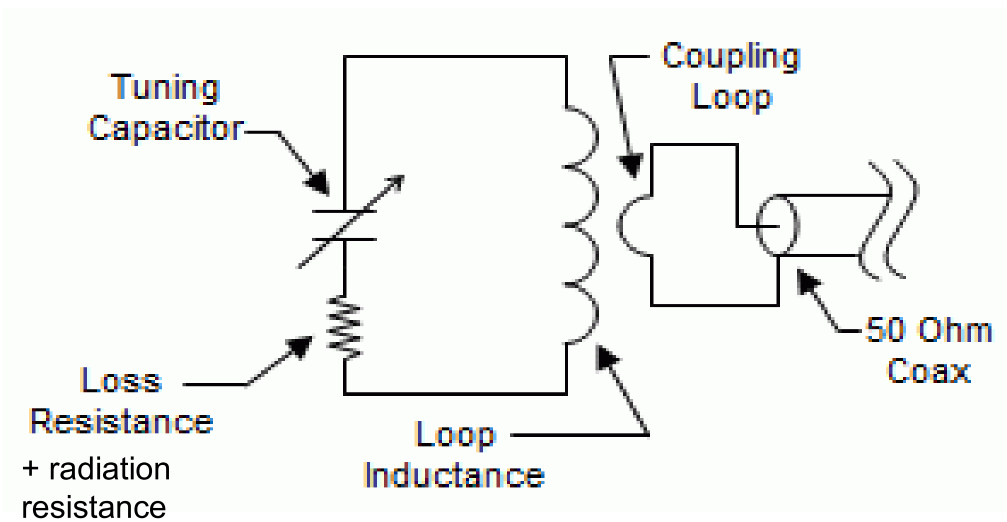


Mounting option with loop on bottom

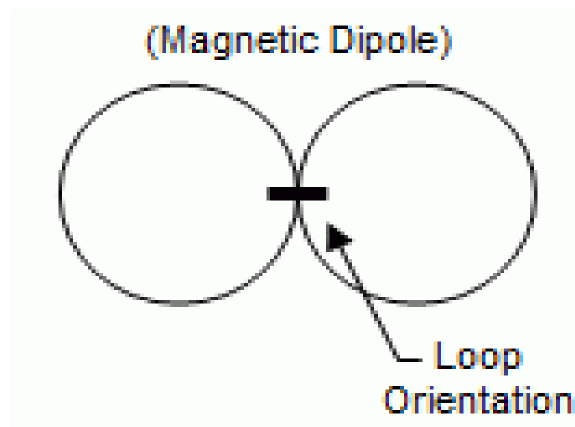
e.g. 40m band, C=4m=13 ft., d=1.27m=4.17 ft.

Characteristics of Small Loop Antennas for HF Operation

- Coupling loop ≈1/5 diameter of main loop for good impedance matching on all bands
- Antenna is narrowband, operating at resonance of loop L and tuning C
- Radiation resistance in series with loss res.; power divides between R_{rad} and R_{loss}
- Doughnut-shaped radiation pattern around loop
- Small loops operate in vertical position; virtually ground independent; elevation above ground can be low (few feet)



Equivalent circuit

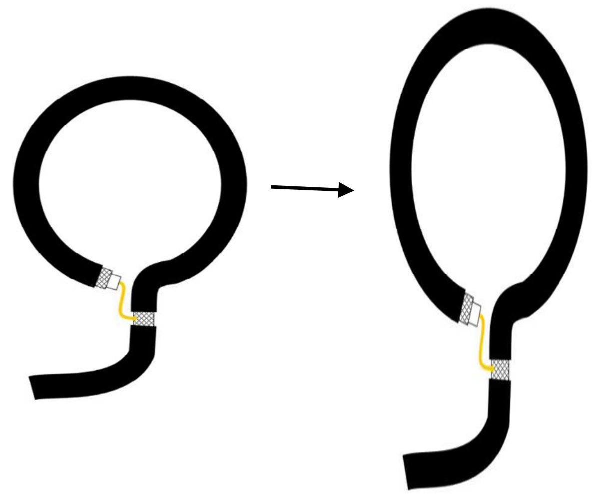


Radiation pattern

Characteristics of Small Loop Antennas for HF Operation

- Good match results with 1/5 diameter coupling loop, but *for best performance must adjust coupling* slightly for lowest SWR at resonance on lowest band used
- Easily done by rotating coupling loop (fixed loops) or compressing/elongating loop (coax coupling loops)

Rotating the coupling loop



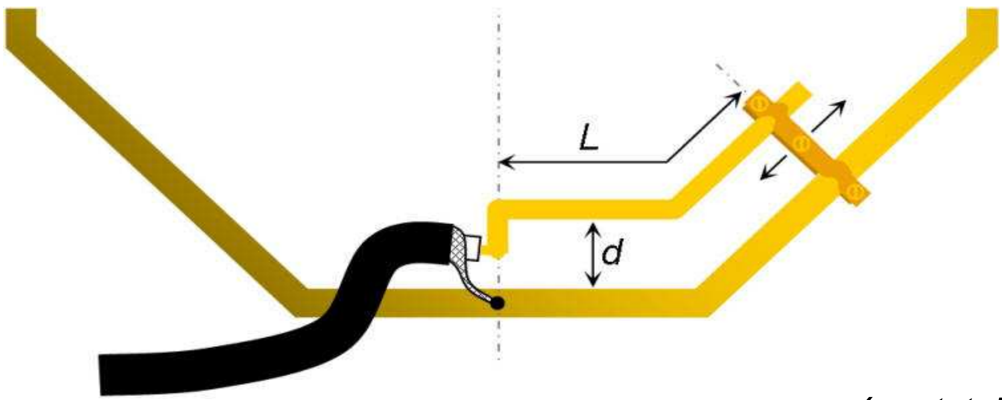
Elongating the coupling loop

Alternative to the Coupling Loop: Gamma Match

"The Gamma match is a tapped autotransformer with the coax feed braid connected to the loop's central neutral point (opposite the capacitor) and the centre conductor connected via the concentric adjustable Gamma tube to the point on the loop conductor where the voltage to current ratio matches 50 Ohms."

"The geometric parameters and the sliding shorting strap are *juggled empirically* to achieve a perfect 1:1 VSWR at loop resonance."

http://www.ahars.com.au/documents/the_underestimated_magnetic_loop_hf_antenna_vers%201.1.pdf .



(not tried by us)

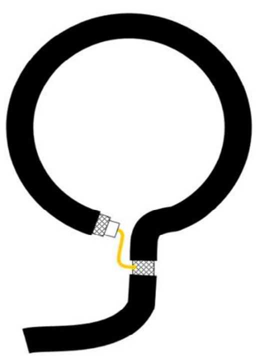
My Loop Antenna

Characteristics of Small Loop Antennas for HF Operation

- The tuning capacitor experiences very high voltage even at low power levels
- For my loop: 5W – 800v 50W – 2500v 100W – 3600v
- Must choose capacitor carefully
- Sliding contact to capacitor's rotor are lossy relative to the very small radiation resistance of loop antenna
- Preferred capacitors are butterfly, split stator, vacuum types

My Loop for 40m – 15m

- Main loop is LMR-400 coax (0.405” diam.)
- 3.67’ in diameter (1.12m)
- high power tuning capacitor taken from a 1.5kW capable MFJ antenna tuner
- Shielded coupling loop (RG-8X) for noise immunity



Receive Properties of Electrically-Small Loops

- Loop antenna is tuned to a resonance on receive by adjusting the tuning capacitor
- Atmospheric noise dominates over receiver noise at HF
- Tuning is narrowband, tending to limit received noise
- Gain of a loop may be lower than that of other antennas, but what matters is the signal-to noise *ratio*
- Small loop antenna can produce a signal-to-noise ratio that is oftentimes better than a dipole for the same band

Transmit Properties of Electrically-Small Loops

- **Small size** achieved by virtue of construction
- **High efficiency** achieved by proper loop design.
- Resulting **bandwidth is very narrow** in an efficient loop
- Small loop antennas can be almost as efficient as dipole antennas over 20m – 10m; over 160m – 30m performance within one S-unit
- High efficiency require larger construction (e.g. 1” copper tubing)
- Portable loops (e.g. coax loop) less efficient but comparable to other portable antenna solutions (e.g. short verticals)

Transmit efficiency: the percentage of power applied to the antenna which is transmitted into the air.

Transmit Properties of Electrically-Small Loops (cont'd)

- Radiation resistance R_{rad} : that part of the antenna's feedpoint resistance caused by the radiation of EM waves from the antenna

- R_{rad} is very small

- Ex: loop diam. 3.67 feet, loop conductor diam, 3 inches
  R_{rad} = 0.019 Ω (7 MHz)
  R_{rad} = 0.039 Ω (10.1 MHz)

- *Ideal* efficiency: 47% on 40m; 76% on 30m

- Loss due only to RF energy dissipated in the skin-depth of the loop conductor

- Actual efficiency will less because of contact resistance loss

Portable Loops – Evaluating Efficiency

- Goal: to build a *portable* loop: easily transportable and easy to set up
- Desired power handling ability 50W minimum CW (AlexLoop, Alpha Loop both rated at 10 watts CW)
- Will be less efficient than fixed-location loop with larger construction
- Will show that portable loop comparable in efficiency to other *small and portable* antennas

Loop Equations (Circular Copper Loop) (AA5TB)

Radiation Resistance, Ohms: $RR = (3.38\times10^{-8})(f^2A)^2$

Loss Resistance, Ohms: $RL = (9.96\times10^{-4})(\sqrt{f})(S/d)$ (skin resistance only)

Efficiency: $\eta = RR/(RR+RL)$

Inductance, Henrys: $L = (1.9\times10^{-8})S[7.353\log10(96S/\pi d)-6.386]$

Inductive Reactance, Ohms: $XL = 2\pi f(L\times10^{6})$

Tuning Capacitor, Farads: $CT = 1/2\pi f(XL\times10^{6})$

Quality Factor: $Q = (f\times10^{6})/\Delta f = XL/2(RR + RL)$

Bandwidth, Hertz: $\Delta f = (f\times10^{6})/Q = [(f1-f2)\times10^{6}]$

Distributed Capacity: pF: $CD = 0.82S$

Capacitor Potential, Volts: $VC = \sqrt{(PXLQ)}$

f = operating frequency, MHz
A = area of loop, square feet
S = conductor length, feet
d = conductor diameter, inches
η = decimal value; dB = 10 $\log_{10}\eta$
P = transmitter power, Watts

Loop Formulas

There is additional loss in the loop due to contact resistance. In the formulas, this loss is added to the skin resistance loss.

$$RL_{total} = R_{skin} + R_{contact}$$

To Measure The Efficiency of A Loop Antenna

- Measure the 2:1 SWR bandwidth B_{meas}
- Measure the loop dimensions
- **Guess at $R_{contact}$**
- Use the formulas to calculate the bandwidth BW_{calc}
- Iterate this process. We endeavor to improve our guess at each turn until the calculated bandwidth BW_{calc} agrees with the measured bandwidth BW_{meas}
- Very simple to do with AA5TB's Excel spreadsheet
- Once $BW_{calc} \approx BW_{meas}$, **we compute the actual antenna efficiency** via the formulas (spreadsheet).

To Measure The Efficiency of a *Vertical* Antenna

Phil Salas AD5DX shows how the **efficiency** of a vertical can be deduced from a knowledge of

- the loading coil inductance and placement
- the length of the antenna
- the ground resistance
- the 2:1 SWR bandwidth

We'll evaluate the efficiency of our loop antenna and compare it to the performance of various verticals

http://www.ad5x.com/images/Presentations/Antenna%20Efficiency.pdf

Evaluation of My Loop

- Main loop LMR-400 coax (0.405” diam.)
- LMR-600 coax (0.600” diam.) also tried
- Main loop 3.67’ in diameter (1.12m)
- Shielded coupling loop (RG-8X); 1/5 diam. of main loop
- Three different capacitors evaluated
- Metal tripod, PVC separates metal of tripod from loop
- PVC loop frame
- Used MFJ-259 antenna analyzer and MINI-60 SWR digital analyzer
- Frequency counter of MFJ-259 unreliable at resonance; had to use MINI-60 after initial tuning

Results for Verticals

Antenna	Dimension	Counterpoise	Band	2:1 SWR BW	Rad. Res. Ω	Loss Res.	Efficiency
Base-loaded vertical (AB2EW)	6.67' tall	Single wire, 25' long, on ground	40m	185 kHz	0.863	65.3Ω	1.3%
			30m	410 kHz	1.78	69.3Ω	2.5%
Base-loaded vertical (AB2EW)	15' tall	Single wire, λ/4 long, elevated 5'	40m	248 kHz	4.68	32.1Ω	12.7%
			30m	505 kHz	9.02	29.8Ω coil ground ↑	23.2%
Carolina Bug Catcher (Phil Salas)	7' tall	Typical good ground, (7-15Ω)	40m	30 kHz	2.45	8.9Ω ground, 7.9Ω coil	12.7%
Hamstick (Phil Salas' data)	7' tall	Typical good ground, (7-15Ω)	40m	50 kHz	2.45	8.9Ω ground, 20.5Ω coil	7.7%

Results for My Loop – MFJ High-Power Capacitor

Tuning Capacitor	Coax for Loop	Band	2:1 SWR BW kHz	Radiation Res. Ω	Total Loss Res. Ω *skin resistance + contact loss*	Max. Theor. Efficiency % *for zero contact loss*	Antenna Efficiency %
High-power	**LMR-400**	**40m**	16.3	0.0092	0.161	10.9	**5.4**
100W capacity	0.405" diam.)	**30m**	30	0.039	0.275	30.4	**12.5**
		20m	63	0.145	0.516	57.8	**22.0**
High-power	**LMR-600**	**40m**	15	0.0092	0.135	15.4	**6.4**
	(0.600" diam.)	**30m**	30.1	0.039	0.249	39.3	**13.6**
		20m	42.3	0.145	0.262	67.0	**35.7**

Results for My Loop – Lafayette Capacitor

Tuning Capacitor	Coax for Loop	Band	2:1 SWR BW kHz	Radiation Res. Ω	Total Loss Res. Ω *skin resistance + contact loss*	Max. Theor. Efficiency % *for zero contact loss*	Antenna Efficiency %
Lafayette	**LMR-400**	**40m**	16	0.0092	0.159	10.9	**5.5**
(40W capacity)		**30m**	29.5	0.039	0.270	30.4	**12.7**
		20m	52	0.145	0.401	57.8	**26.6**
		17m	75	0.403	0.381	77.1	**51.5**
		15m	81	0.736	0.130	85.0	**85.0**
Lafayette	**LMR-600**	**40m**	15.2	0.0092	0.137	15.4	**6.3**
		30m	29	0.039	0.240	39.3	**14.1**
		20m	43	0.145	0.269	67.0	**35.1**
		17m	57	0.403	0.141	83.0	**74.0**
		15m	79	0.736	0.088	89.0	**89.0**

Results for My Loop – Hammarlund Capacitor

Tuning Capacitor	Coax for Loop	Band	2:1 SWR BW kHz	Radiation Res. Ω	Total Loss Res. Ω *skin resistance + contact loss*	Max. Theor. Efficiency % *for zero contact loss*	Antenna Efficiency %
Hammarlund	**LMR-400**	**20m**	51	0.145	0.391	57.8	**27.1**
(100W capacity)		**17m**	67	0.403	0.297	77.1	**57.8**
Hammarlund	**LMR-600**	**20m**	38	0.145	0.221	67.0	**39.6**
		17m	52	0.403	0.094	83.0	**81.0**

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High-power	**LMR-400**	**40m**	16.3	0.0092	0.161	10.9	**5.4**
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High-power	**LMR-600**	**40m**	15	0.0092	0.135	15.4	**6.4**
	(0.600” diam.)	**30m**	30.1	0.039	0.249	39.3	**13.6**
		20m	42.3	0.145	0.262	67.0	**35.7**
Lafayette	**LMR-400**	**40m**	16	0.0092	0.159	10.9	**5.5**
(40W capacity)		**30m**	29.5	0.039	0.270	30.4	**12.7**
		20m	52	0.145	0.401	57.8	**26.6**
		17m	75	0.403	0.381	77.1	**51.5**
		15m	81	0.736	0.130	85.0	**85.0**
Lafayette	**LMR-600**	**40m**	15.2	0.0092	0.137	15.4	**6.3**
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Hammarlund	**LMR-600**	**20m**	38	0.145	0.221	67.0	**39.6**
		17m	52	0.403	0.094	83.0	**81.0**

Summary and Conclusion

- Small portable loops provide excellent reception and good transmit efficiency in comparison to other portable antenna solutions
- Radials or counterpoises not required with loops
- Vertical loops work well at low elevations
- Bandwidth very narrow
- Very high voltages across tuning capacitor
- Very small radiation resistance requires great care in construction to avoid contact loss

DEMOS

- Voltage intensity around the loop
- AA5TB's Excel Spreadsheet

References

Many of the figures were taken from the websites below. Certain references also provide in depth discussions of loop antennas (and vertical antennas from ref. 3)

1. http://www.aa5tb.com/loop.html
2. http://26hs4316.wordpress.com/antenna-construction/magnetic-loops/
3. http://www.ad5x.com/images/Presentations/Antenna%20Efficiency.pdf
4. http://www.ahars.com.au/documents/the_underestimated_magnetic_loop_hf_antenna_vers%201.1.pdf .
5. http://www.nonstopsystems.com/radio/frank_radio_antenna_magloop.htm .
6. alexloop.com ($366 for portable loop antenna)
7. amateurradiostore.com ($300 for portable loop antenna)