Small Magnetic Loops: A Beginner’s Guide

“WOW! This is a very different antenna!”

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History

Balkan’s War in 1942

A 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.

Alder-shot England, November 1937
Full Size Loops

Driven Element (Overall FT) = \( \frac{1005}{f \text{ (MHz)}} \)

Reflector (Overall FT) = \( \frac{1030}{f \text{ (MHz)}} \)

\( f \) is in MHz.

QUAD

50 \( \Omega \) To Transmitter

52' 6" 52' 6"

64" 36' 11"

64' 2"
Full Size Loops

Diagram:

- L/4 segment on each arm
- 3.5 MHz Loop Skywire: L = 272'
- 7 MHz Loop Skywire: L = 142'
- Height: About 40'
- Open wire line
Nor the Mighty Rhombic Antenna

The two wires of the “V” must be fed out of phase for correct operation. A resonant line matching section is shown in the antenna fed through a nonresonant line. If the antenna wires are made multiples of a half-wave in length (use Equation 14-G for computing the length), the matching section will be closed at the free end. A stub can be connected across the resonant line to provide a match, as described in the preceding chapter.

THE RHOMBIC ANTENNA

The horizontal rhombic or “diamond” antenna is shown in Fig. 14-31. Like the “V,” it requires a great deal of space for erection, but it is capable of giving excellent gain and directivity.

Rhombic Antenna
From 1956 ARRL Handbook
Small Loop Antennas

- Known as a “magnetic loop” due to the fact that they work with the magnetic near-fields of the antenna (more on that in a bit)
- Small in comparison to the wavelength
  - Circumference less than $\lambda/10$
  - If multi-band, then the highest band drives size of the loop
- Smaller relative to wavelength means efficiency suffers
Electromagnetic Waves
(caused by either an alternating electric or magnetic field)

(a) Dipole antenna  (b) Monopole antenna  (c) Loop antenna

Electromagnetic Waves
(emitted by either an alternating electric or an magnetic field)
What the heck is “near-field”? 

Near and Far Fields from the Infinitesimal Dipole
What the heck is “near-field”? 

The trick is that within the near-field:
Electric (E-) field drops off with the cubic of the distance
Magnetic (H-) field drops off with the square of the distance
Therefore, within the near-field the magnetic field tends to dominate . . .
What the heck is “near-field”?
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**Near-field** through the collapsing electric and magnetic fields

**Far-field** through heat loss and the propagating EM wave
General Antenna Model

Efficiency = \( \frac{R_{\text{Radiation}}}{R_{\text{Ohmic}} + R_{\text{Radiation}}} \)

(a well-tuned and engineered dipole has an efficiency in the high 90%; while a good base-loaded, bumper-mounted 8-ft mobile antenna on 80M might be 10-20%)
Trade Offs

- Pick two: small, efficient, or broadband
  - Small = $< \lambda / 10$
  - Broad bandwidth = low Q
  - Low Q implies more resistive losses
- Transmitting small loops
  - Small + Efficient
- Receive-only small loops
  - Small + Broadband
- Full-wave loops
  - Efficient + Broadband

Where we are at . . .
The test antenna was the Chameleon CHA F-Loop, at 0.74 m (2.44 feet) diameter:

- SWR: 2:1  
  14.200 – 14.100  
  (or about 100 kHz) 
  20M full band is: 14.000 to 14.350 MHz

- SWR: 1.5:1  
  14.175 – 14.125  
  (or about 50 kHz)

https://www.qsl.net/kp4md/chafloop.htm
Parts

- **Resonant Loop**
  - Coax (uses shield and center typically connected together)
  - Metal tubes (larger diameter improves efficiency)
  - Minimizes resistive losses (radiation resistance is small, but large compared to loss resistance)
  - Circle is more area possible for given perimeter (but can be other shapes, e.g. octagon is common to ease formation of the metal tube)

- **Coupling Method**
  - Required as the impedance of the resonant loop is typically 2 to 10 ohms
    - Max impedance, max current, lowest voltage at coupling point
    - Lowest impedance, lowest current, max voltage is 180° away at the other side of the loop
  - Techniques: coupling loop (what we will show today), gamma match capacitive, ferrite
Parts (cont.)

- Tuning capacitor
  - Air variable, trombone, vacuum variable
  - Voltage breakdown point is a big selection factor (arc across and resulting pitting) — this is typically what drives the power limitations
  - Better implementations have reduction gearing to help with fine tuning
- Coupling point and the capacitor placed on opposite sides of the resonant loop
To get as strong coupling as possible, you typically bend the loops together.
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http://aa5tb.com/loop.html
Polarization

- Vertical (stand it up) – most common; does not need a ground plane; should be at least one diameter of the loop from the physical ground

- Horizontal (lay down) – can be done, but requires same above ground guidelines as a dipole, i.e. above $\frac{1}{4} \lambda$
Samples

- Thick piping (good efficiency)
- Gamma match at bottom for coupling
- Mechanical tuning capacitor at top
- Mount it on a mast
- Warning: Nulls come off the broadside of the antenna, so either be careful where it is positioned, or have a rotator to spin it to null out signals
Samples

- Double loop to give more electrical circumstance (better efficiency and lower frequencies, e.g. 40M, or 80M)
- Coupling loop hidden inside casing
- Horizontal polarization and omnidirectional
- Must be mounted high ( > \( \lambda / 4 \) )

Lots of turns possible!
Samples

- Mechanical adjustment of capacitor (top)
- High quality copper for good efficiency
- Remote tuning to capacitor mounted on back of mount
Pros and Cons

- Fast setup – no trees, tall masts, or radials needed
- Needs to be reachable for tuning, rotation (or use remote controlled motors)
- Low height OK
  - 1-2+ diameter above ground for vertical orientation
  - Horizontal orientation needs same height as dipole ( > λ/4 )
- Magnetic near-field means humans don’t mess with tuning as much
  - But works better away from large metal objects
  - Do not position the tuning knob so you have to reach into the loop to tune
    (at least one commercial vendor does this)
Tuning

- Do not blindly use antenna tuners – need to move the resonance point
- Listen to the noise floor, look at the S-meter, tune for maximum noise
- Using a pan adapters lets you tune visually – put the noise peak in the middle as the “wave” comes into your freq range
- Some vendors are starting to make products to assist, e.g. Alex Tune
- Follow-up with fine adjustments to SWR in radio tune mode
  - This is where having reduction gears on the capacitor helps a bunch, e.g. the P-Loop has a 6:1 gear reduction within its box
Summary: Why use a small mag loop?

- Excellent portability and efficiency
- It is a good DX antenna
  - Nulls are very sharp – broadside off the mag loop
  - In-line with the loop you get maximum propagation, and a good takeoff angle
- Use the high-Q (and the nulls) to:
  - Eliminate local QRM
  - Eliminate adjacent strong stations (particularly with SSB)
- Difficult to tune – not a good fit for “Search and Pounce”
- Great for fixed frequency uses, e.g. “Running”, SOTA, and for many digital modes, e.g. FT8, JBCALL, etc.
Commercial Offerings

- Alex loop – focus on portability $400
  http://www.alexloop.com/ also at:
  https://www.gigaparts.com/ph1ahd-alexloop-walkham.html

- Precise RF Loop – remote tuning and operation + portability $300-$450
  http://preciserf.com/

- Chameleon Antenna’s P-Loop (portable, coax) and F-Loop (semi-portable)
  https://www.dxengineering.com/parts/cha-floop-plus20
  $400-$500 depending on options

- Ciro Mazzoni Automatic Magnetic Loop Antennas
  https://www.dxengineering.com/parts/mzz-baby ($2K and up 😊)

- MFJ 1788 (fixed location) (see Dave Casler’s review and fixes) -- $500
  they also offer a $250 receive-only mag loop as well
References

- Presentation by Bob Fleck, W4RAX
  https://www.youtube.com/watch?v=yYbKrw8l6JU
  (used as the basis for this presentation)

- Several interesting presentations by Dave Casler, KEØOG
  https://www.youtube.com/watch?v=Klg-_vQYbfw
  https://www.youtube.com/watch?v=CgKzzyeM8lw
  https://www.youtube.com/watch?v=pZkKfHvyOjo

- Tuning a homebrew mag loop using a toroidal match
  https://www.youtube.com/watch?v=CpgwXNwCmm4

- Interesting visualizations of voltage and current flow in a mag loop
  https://www.youtube.com/watch?v=SUYI81dkEMA
Additional backup slides
Feeding your small mag loop
Add-on fixed capacitor physically snap’ed in for 40M coverage in parallel with the variable one.

Coupling Loop at the bottom.