# SMALL MAGNETIC LOOP ANTENNAS

Jerry Spring, VE6TL

May, 2022

# OUTLINE

- Introduction
- Advantages & Disadvantages
- Theory
- Building your own
- Commercial products
- Summary

# Introduction

- Main advantages are mitigating RFI and size/stealth
- Typically vertically oriented and rotated to null out unwanted signals When oriented horizontally, can behave like a vertical antenna
- Two main types:  active (RX only), passive (TX and/or RX)
    - Active mag loops contain wideband amplifiers and require no manual tuning.  Typically fed through Bias-T or batteries.  Used by SWLs or by hams for longer wavelength reception
    - Passive mag loops can be use for TX and RX, have very narrow bandwidth (tuned via variable capacitor) - popular with hams
- There are always trade-offs when comparing MLAs with wire antennas in terms of performance (radiation resistance, losses, noise cancellation, efficiency, etc.)

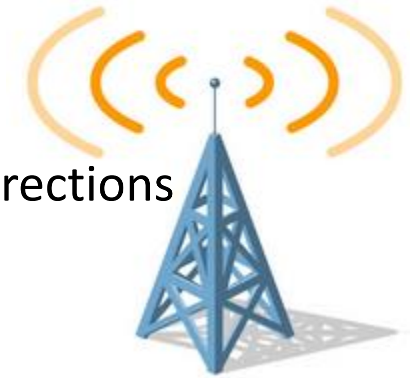
# Stealth

G4IZH - 5 band – in an attic

On a balcony

It pays to experiment!

# Antenna Theory 101

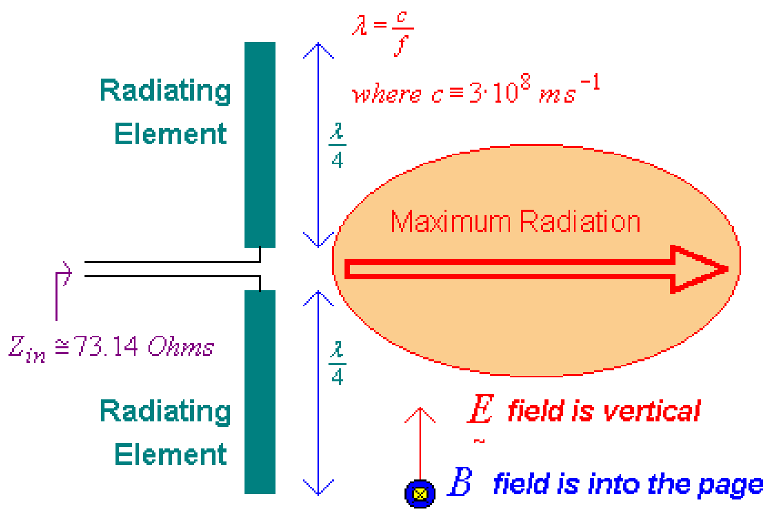


## Isotropic (Omni-Directional) Antenna:

- Transmits or receives radio signal energy equally in all directions
  - If lossless, will radiate over a sphere

## Half Wave "Dipole" Antenna:

- Consists of two "quarter wavelength" conductors placed end to end and fed in the middle.




The dipole antenna has relative gain of +2.15 dB over an isotropic antenna, as it has directivity

# Antenna Theory 101 Cont'd

## Short Dipole Antenna:

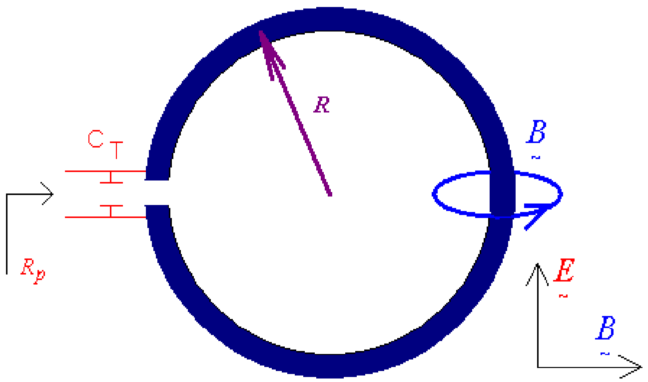
- When shorter than it's resonant length (< ½ λ), Z becomes capacitive. In order to "tune out" the $X_C$, you need to add $X_L$. We now have to worry about the "Q" of the antenna (broad or narrow).
- If the Q of the inductor = Q of the dipole antenna, the antenna efficiency will be 0.5 (receive or transmit). In other words, half of the energy will be lost in the inductor and half in the "radiation resistance" of the antenna.
- Matching an antenna with low radiation resistance to a 50 ohm impedance of a radio can lead to inefficiencies. Nearby metal objects can make things even worse (detuning).

**Conclusion:** **Shortened dipoles are less efficient than resonant ones and get even more inefficient the shorter they get relative to ½ λ.**

# Antenna Theory - SMLA

## Magnetic B Field Loop Antenna:

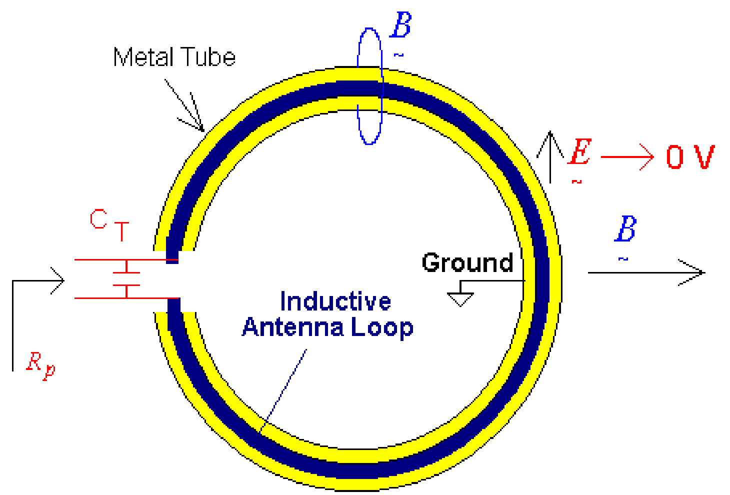
- Addresses many of the issues confronting the electrically short dipole
  - Physically small compared to λ
  - Has adequate radiation efficiency
  - Provides a reasonable impedance (can match to 50Ω)
  - Relatively immune to detuning effects caused by nearby objects




- Simplest MLA is a wire loop with AC current flowing in it. This generates both E and B fields. The inductance of the loop can be tuned out using a capacitor across the gap

# Antenna Theory - MLA

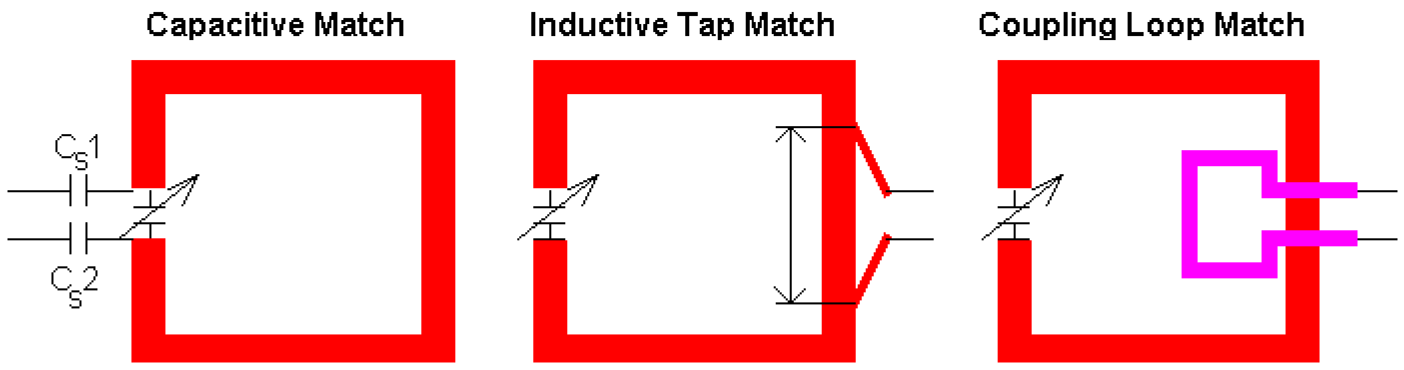
## Adding an electrostatic shield:




The physical area of the conductors may allow unwanted noise. Placing an electrostatic shield (metal tube) around the loop antenna can greatly reduce noise. A large diameter coaxial cable can reduce noise by grounding the shield.

# Antenna Theory - MLA

## Impedance Matching:



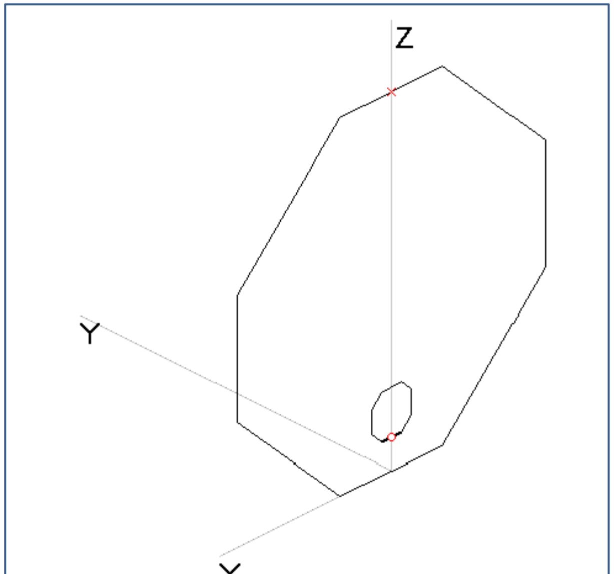

- **Capacitive match:** All 3 capacitors need to have high voltage ratings (KV) and provide a balanced 50 ohm impedance (may require balun). The variable capacitor should have a fine tune adjustment.
- **Inductive tap match:** Uses a segment of loop like an auto transformer, matching the effective parallel resistive component.
- **Coupled loop match:** Requires experimentation to optimize Z match as it is related to the relative areas of the two loops.

# Antenna Theory - SMLA

## Key Ideas for Small Loops (Steve Yates, AA5TB):

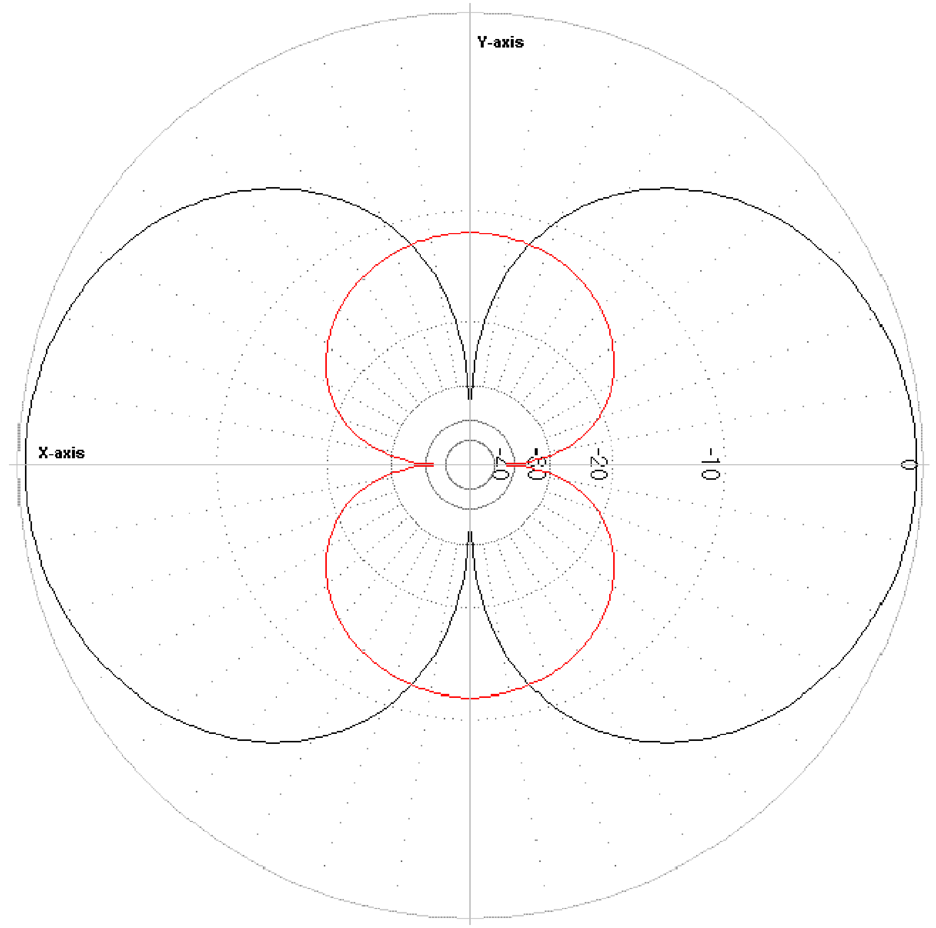
- Small loop antennas are magnetic antennas only in the near field (< λ)
- In the far field (> λ), RF is the same as for other antennas (E and B fields)
- In between 1/10 λ and λ, small loops respond more to the E field
- Since most of the near field component is magnetic, MLAs should be placed > 1/10 λ from ferrous objects – although many work well indoors
- MLAs attenuate local noise only if the offending source is in the near field AND if the source is truly of E field origin (e.g. nearby arcing power line)
- You cannot have a time varying E field without a time varying B field – and vice versa – which means far field noise is E and B noise together
- Small loop antennas usually have poorer SNR than larger antennas (> .25 λ)

# Antenna Theory – Small Loop Model




Reference Diagram of a Small Loop Antenna

“Small loop antennas perform so well at very low heights (when mounted vertically) because in the extreme near field (less than 1/10 λ) most of the loop's field component is magnetic and magnetic losses in ordinary ground may be less then the dielectric losses that most antennas (i.e., dipoles) with a large electric field component are subject to.” – Steve Yates, AA5TB,




Pattern Viewed along Z-axis
Black - V-Pol
Red - H-Pol

# Antenna Theory - SMLA

## Design of Small Transmitting Loop:

You only get to choose two of the following parameters:

- Small size (in terms of wavelength)
- Efficiency
- Broadband

If you have built a wide bandwidth, small MLA, you have built a dummy load!

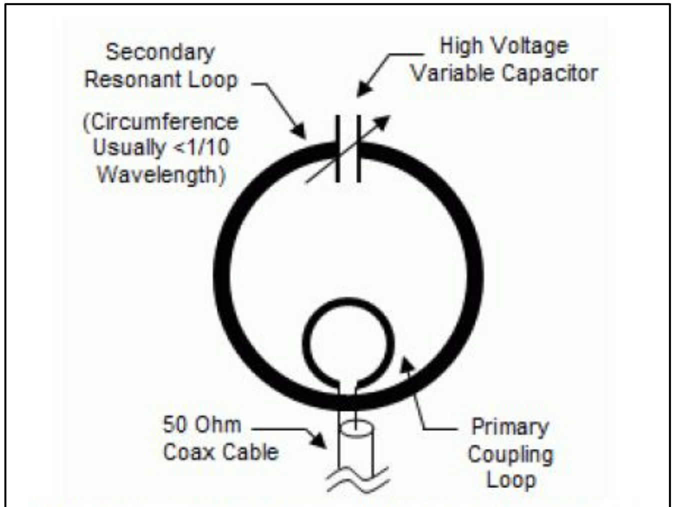
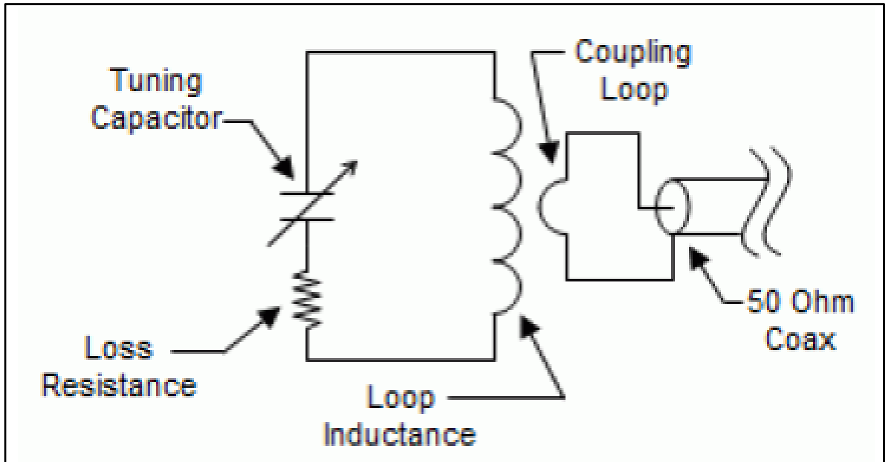
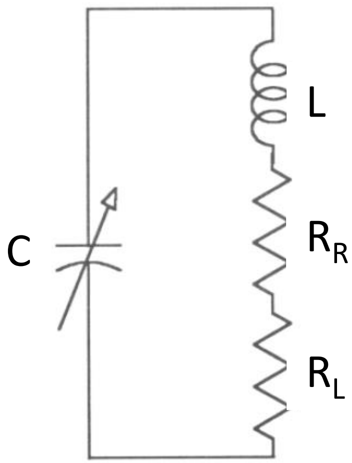



Diagram of a Small Loop Antenna




Equivalent Circuit

# Antenna Theory - MLA




<u>More on the equivalent circuit:</u>

L = Inductance of the loop
$R_R$ = Radiation Resistance
$R_L$ = Loss Resistance (heating)

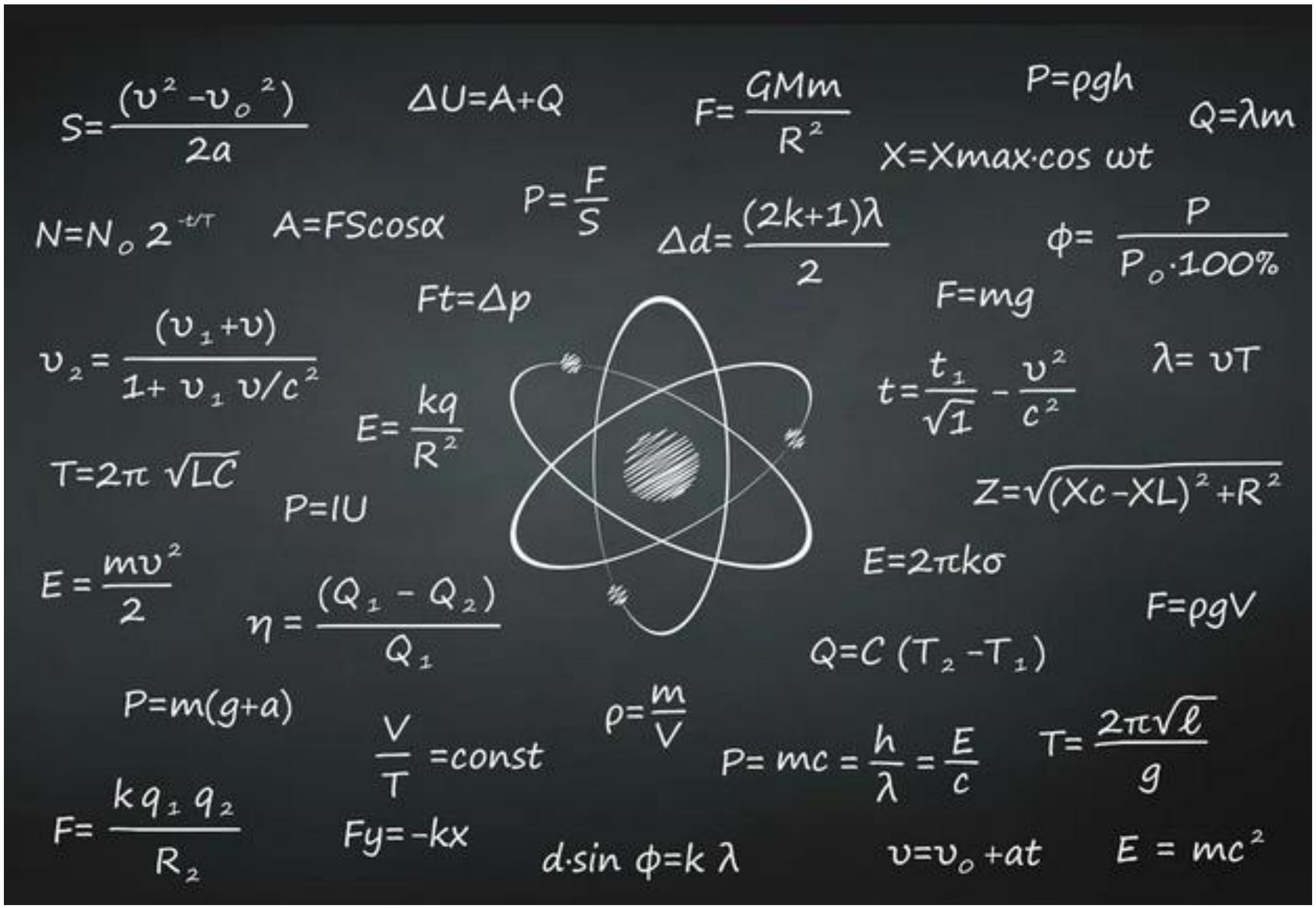

**But what is RADIATION RESISTANCE?**

"Radiation resistance is a hypothetical electrical analogy that allows a mathematical representation of resistance. Just as current flows through normal resistance and the resultant power is converted to heat, current through the radiation resistance results in power converted to electromagnetic radiation." – Ted Hart, W5QJR

- So for the loop antenna, we want to maximize radiation resistance and minimize loss resistance. This will result in maximized radiation efficiency.
- The loop will carry a large current and any sizeable $R_L$ can generate lots of heat. Also, C will handle voltages in KV, so must be large

# Antenna Theory - MLA

## Small Loop Equations



# The **Real Equations** for

## Small Copper Loop Antennas:

Radiation Resistance, Ohms: $R_R = (3.38\times10^{-8})(f^2A)^2$
Loss Resistance, Ohms: $R_L = (9.96\times10^{-4})(\sqrt{f})(S/d)$
Efficiency: $\eta = R_R/(R_R+R_L)$
Inductance, Henrys: $L = (1.9\times10^{-8})S[7.353\log_{10}(96S/\pi d)-6.386]$
Inductive Reactance, Ohms: $X_L = 2\pi f(L\times10^6)$
Tuning Capacitor, Farads: $C_T = 1/2\pi f(X_L\times10^6)$
Quality Factor: $Q = (f\times10^6)/\Delta f = X_L/2(R_R + R_L)$
Bandwidth, Hertz: $\Delta f = (f\times10^6)/Q = [(f_1-f_2)\times10^6]$
Distributed Capacity: pF: $C_D = 0.82S$
Capacitor Potential, Volts: $V_C = \sqrt{(PX_LQ)}$
Capacitor Voltage Rating: 75,000V/in

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

- Notice $R_R$ is proportional to the <u>fourth power</u> of freq and the <u>square</u> of the area of loop
- For most small loops $R_R$ is usually much less than 0.5 ohms
- To have a small value of $R_L$ , you need S/d to be small (note the units)

# Antenna Theory - MLA

## Gain:

“The small loop has a doughnut-shaped pattern with a gain of 1.72 dBi in free space, 7.32 dBi over a perfect reflector.  Over average ground, the loop has 0 dBi gain at high angles and 1.5 dBi at 30°.  With radials, the gain is 3 dBi at high angles and 5 dBi at 20°.

For comparison, a dipole mounted ¼ λ above average ground has a gain of 5.12 dBi and ¼ λ vertical with 120 wires each ¼ λ long in a counterpoise has a gain of 2 dBi over average ground. “  - Ted Hart, W5QJR

**A small loop antenna just a foot off the ground can provide adequate gain when compared to a vertical antenna or to a horizontal dipole mounted less than ¼ λ high.**

# Antenna Theory – Small Copper Loop

Example 1: 6’ diameter loop made of 5/8” OD copper tubing with 100W input power yields the following:

| F (MHz) | Efficiency % | Bandwidth (KHz) | Capacitor (pF) | Cap Voltage (KV) | Q | Resonant Circulating Current (A) |
|---|---|---|---|---|---|---|
| 3.5 | 4 | 4 | 560 | 2.5 | 803 | 31 |
| 7.1 | 43 | 10 | 113 | 3.7 | 701 | 19 |
| 14.1 | 89 | 75 | 29 | 2.7 | 185 | 7 |

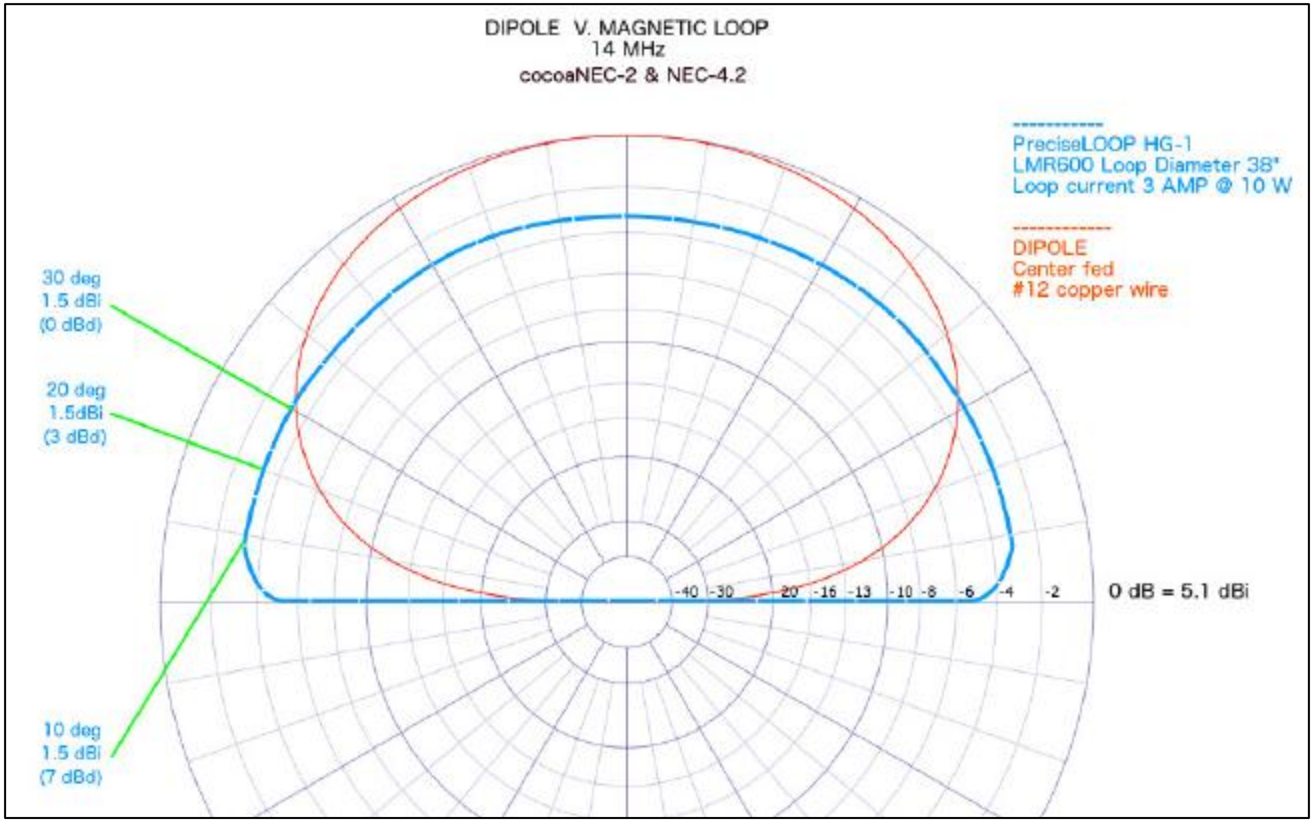
Example 2: 1’ diameter loop made of 5/8” OD copper tubing with 1W:

| F (MHz) | Efficiency % | Bandwidth (KHz) | Capacitor (pF) | Cap Voltage (KV) | Q | Resonant Circulating Current (A) |
|---|---|---|---|---|---|---|
| 145 | 82 | 575 | 21 | 0.115 | 252 | 2.2 |

Free online small loop antenna calculator:
https://www.66pacific.com/calculators/small-transmitting-loop-antenna-calculator.aspx

# Dipole Vs Magnetic Loop – Low Elevation

If mounted at low elevation, a MLA can exhibit lower takeoff angles (better DX) than a dipole (better than 6 dB)




20m Dipole at 15’ vs PreciseLoop HG-1 (US$535.00)

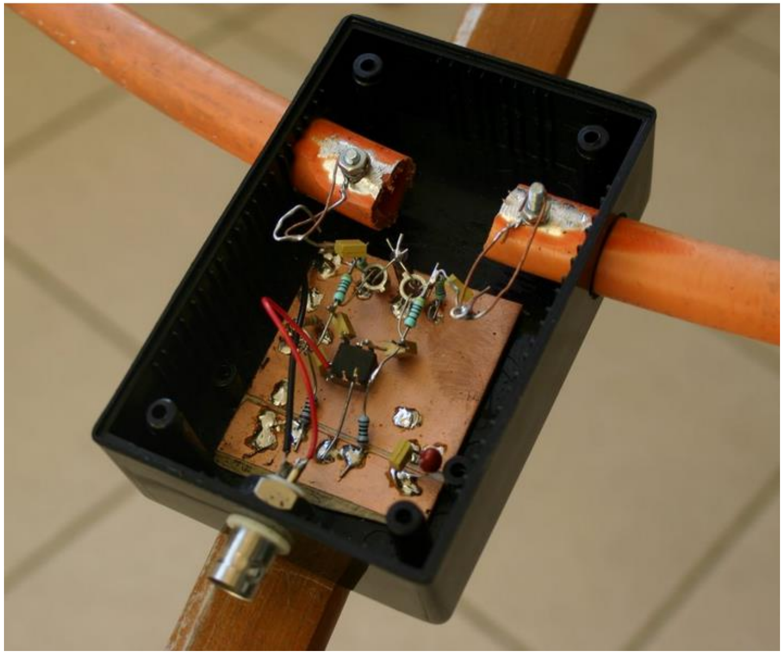
# Active Receiving Loops

## PRO:

- Broadband coverage using a small magnetic loop antenna with a preamplifier – often used by SWLers (100 kHz – 30 MHz)
- Takes advantage of noise reducing, directional property of magnetic loops
- Often out-performs active whip antennas for similar range of frequencies
- No tuning required

## CON:

- Must be placed clear of metal objects and not near transmitting antennas
- Easy to overload sensitive RF amplifier (expensive to replace)
- Typically do not come with bandpass filters in line with pre-amp (pre-amp amplifies entire spectrum)



# Active Receiving Loops - Commercial

**DX Engineering RF-PRO-1B - $549.99**

- Primary coverage range: 100 kHz to 30
- Very low IMD, 30 dB Low-Noise Preamplifier insures good performance in both strong and weak signal environments
- Up to 30 dB rejection of locally radiated noise compared to whip antennas
- Figure eight directivity provides deep nulls to further reduce interference
- Rejects power line noise
- No manual tuning necessary
- No Home Owners Association problems; low profile and works only 5 ft.
  above ground level
- Internal Transmit/Receive keying relay disconnects Antenna/Preamp from your receiver when transmitting

Has received excellent reviews on eHam.net

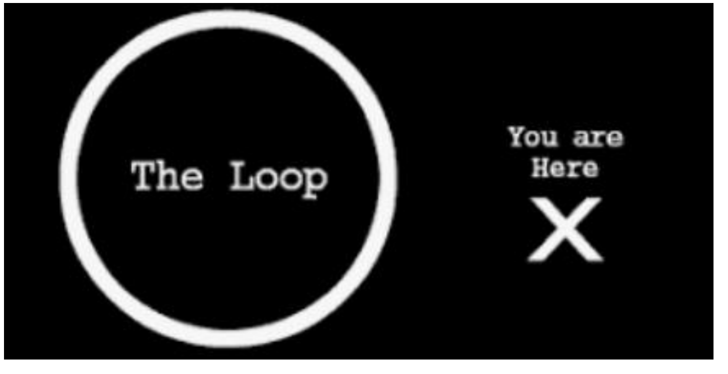
# Passive Receiving Loop

"Any good 80 or 160 meter DX operator will have a loop for receiving, and, in a high noise environment, a loop will hear much more than a big beam on the HF bands.  When compared to a vertical antenna, the loop is so quiet it is almost unbelievable." - Ted Hart, W5QJR

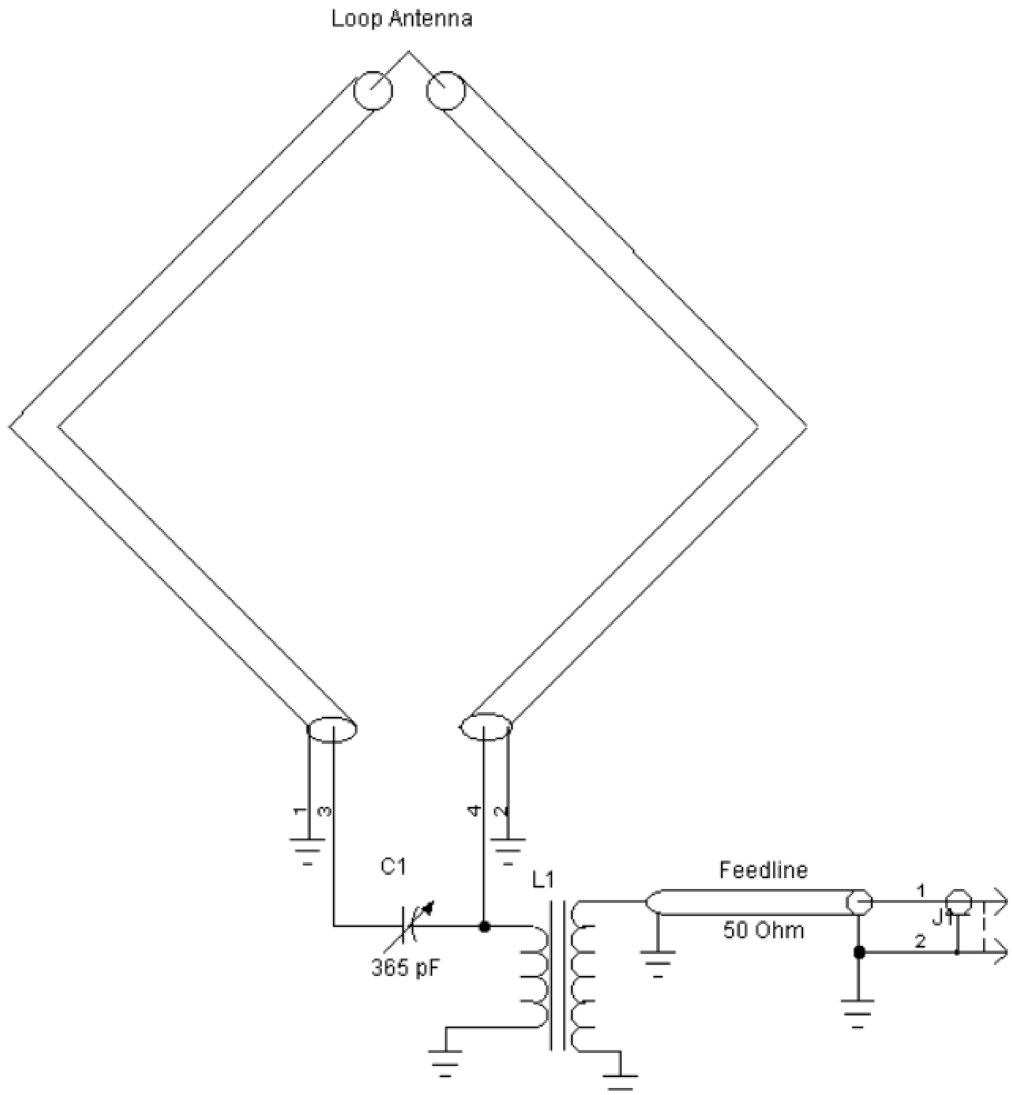
Courtesy:   Max, VE6RST

# Receiving Loop - Advantages

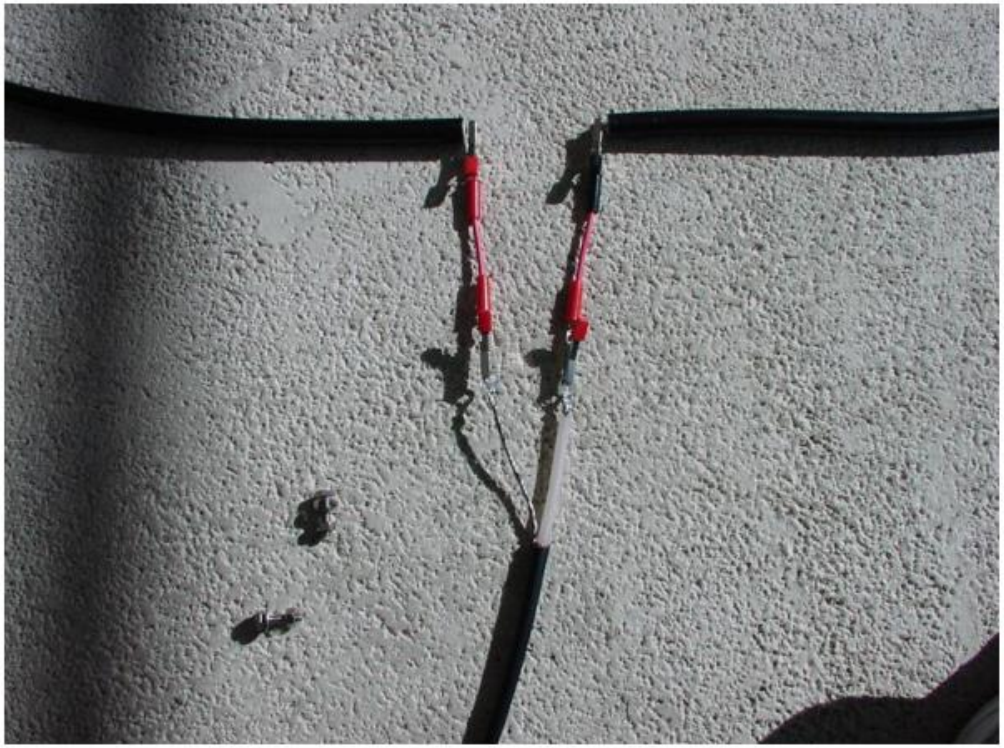
- As a general rule, the loop will produce a received SNR greater than 20 dB more than a horizontal dipole in a high noise environment, and another 6 dB or more compared to a vertical, since man-made noise is predominantly vertically polarized.
- A high-Q loop also acts as a narrow bandpass filter, reducing the amount of energy fed to the receiver’s front end.  This includes reducing energy from lightning in the area (static crashes).
- Performance is largely unaffected by height above ground.
- Efficiency is not a consideration as the main concern is SNR.



# Receiving Loop – Build Your Own Using Coax

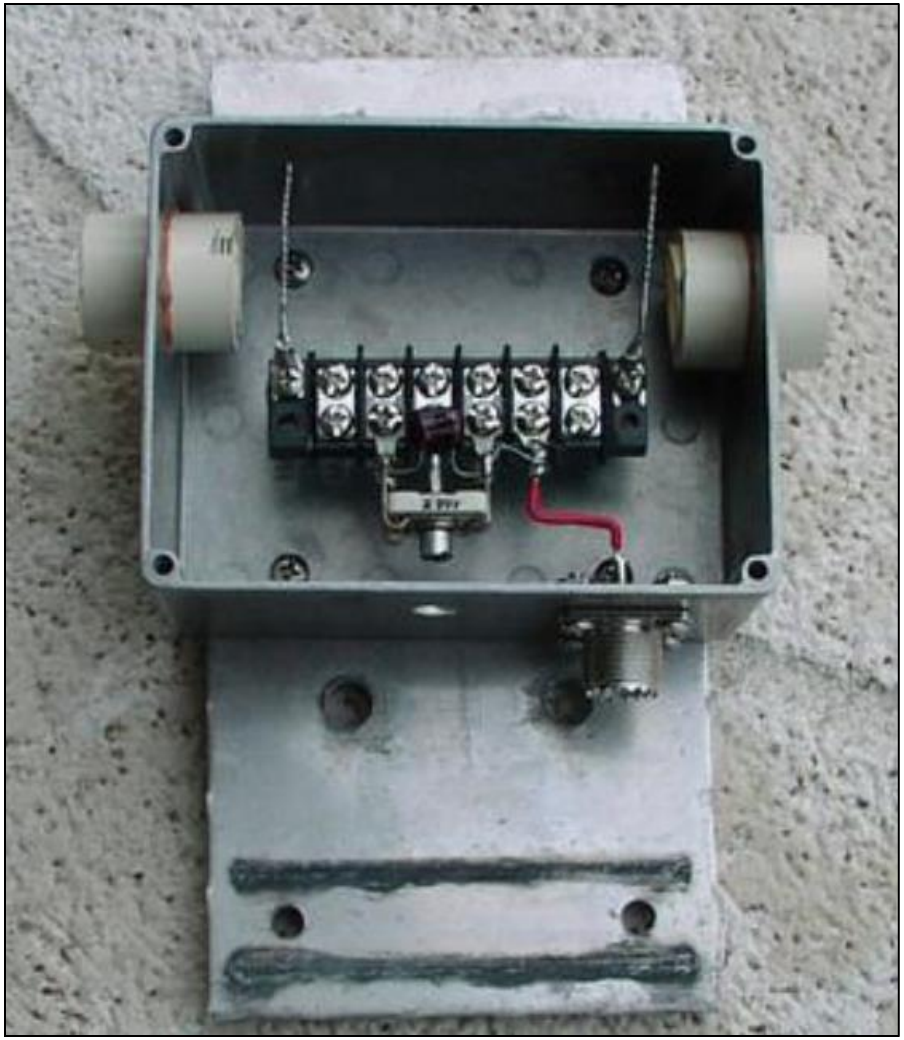


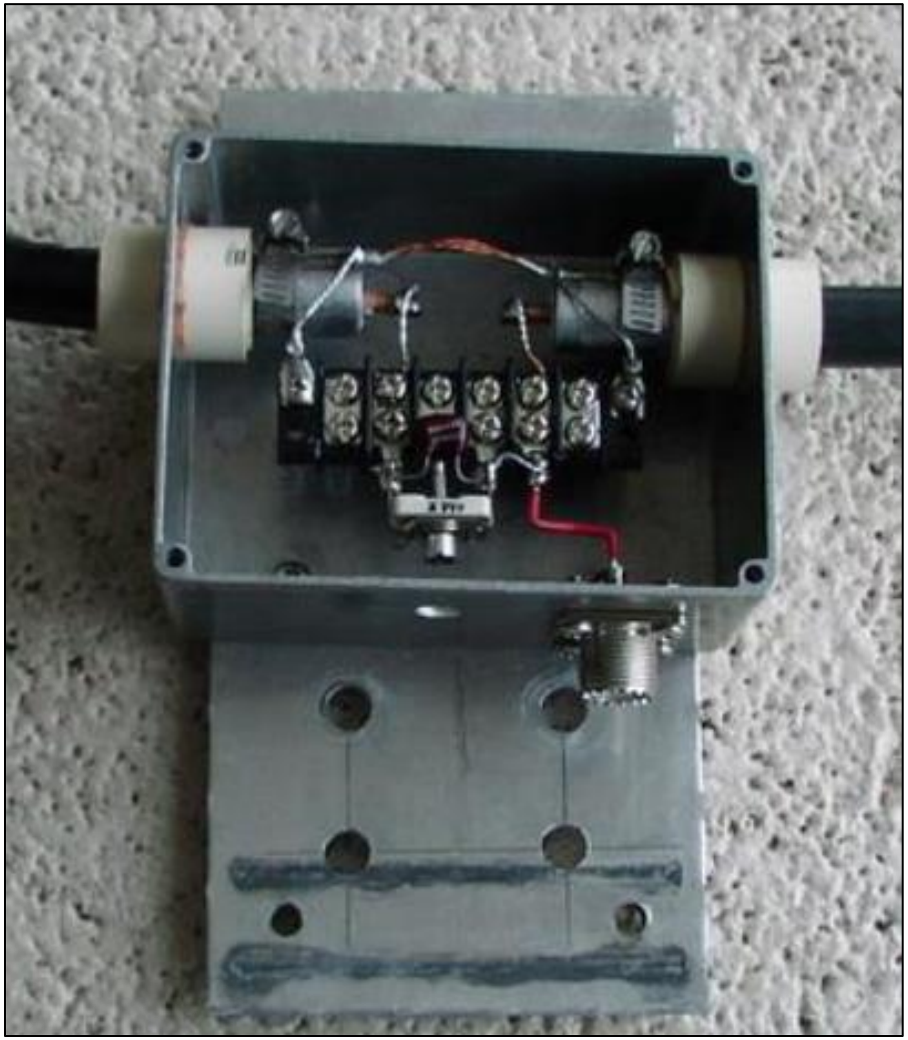
# Receiving Loop – Using Coax – Cont'd



Next step was to bare the center conductor at the bottom of the loop and make measurements with my MFJ-259B SWR Antenna analyzer. It is necessary to measure the SWR, XL, XC, R, C and L at the frequency that you want to center the SWR Bandwidth on. Keep the coax from the MFJ to the clip leads as short as possible .

# Receiving Loop – Using Coax – Cont'd





# Receiving Loop – Using Coax – Cont'd

The feed point impedance was measured to be 16 Ω.

With some experimentation, a toroid was added with 4:9 turns ratio that yielded:
$R = 51\ \Omega$,
$X_L = X_C = 9\ \Omega$,
SWR = 1.2,
F = 1.825 MHz

# Receiving Loop – Using Coax – Done

# Commercial MLAs


**MFJ MFJ-1788 - MFJ 1788 Super Hi-Q Loop Antennas**

Antenna, Super Hi-Q Loop, Remote Tuning Type, Horizontal, Omni-directional Small Loop, 150 W, 15-40 m, 110 V

**$719.95**

1

**Part Number:** MFJ-1788

★★★½☆ ( 12 )

Not in Stock

**Estimated USA Ship Date:** Aug 10, 2022

**Estimated International Ship Date:** Aug 11, 2022

(if ordered today)

Mixed reviews on eHam.net - "Prepare to rebuild it if you buy one"

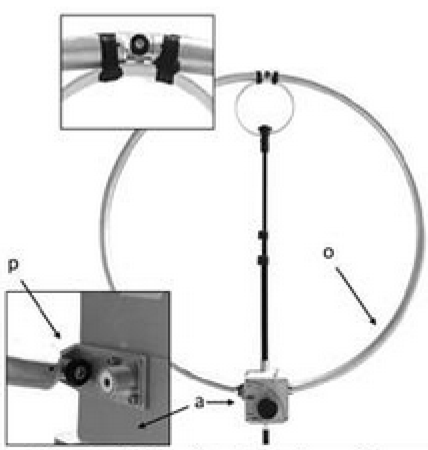



Plate 6. Rigid Radiator Loop Assembly.

**CHAMELEON ANTENNA FLOOP30PLUS - CHAMELEON 3.0 PLUS Portable HF Loop Antennas**

Antenna, Loop, Portable, 3.5-29.7 MHz, 25W SSB, 36 in. Two-section Aluminum Loop, Upgraded Tuning Box, 12 ft. RG-58A, Duffel Bag, Ea

**$649.99**

1

**Part Number:** CHA-FLOOP30PLUS

*Not Yet Reviewed*

Item is on Order

**Estimated USA Ship Date:** Jun 3, 2022

**Estimated International Ship Date:** Jun 6, 2022

(if ordered today)

No reviews in eHam.net

From DX Engineering Website

# Commercial MLAs Continued

**AlexLoop HamPack Portable Magnetic Loop Antenna System**


3’ diameter
10M to 40 M – 25W PEP SSB Max
Or 10W FM/AM and Digital Max
Designed by Alex, PY1AHD

2 5-star reviews on eHam.net


Loop calculator says at max power on 40m, this antenna is 9% efficient, has a tuning capacitance of 272 pF @ 874Vrms and Q = 929. At 10m, it is 93% efficient with 700Vrms on 17pF capacitance with 2.1A circulating current.

From DX Engineering Website

# Commercial MLAs Continued

**Ciro Mazzoni Automatic Magnetic Loop Antennas**

$1,799.99

Antenna, Stealth Loop, 40-10 meters, Auto/Man. Tune w/incl. ATU 2.0+Keypad, Powder Coat Alum., 54 x 20 x10 in., 15.4 lbs., 125 W, 6.6-29.8 MHz, Each

No reviews in eHam.net

Intended to be placed on metal table or roof of a parked vehicle


From DX Engineering Website

# Summary – Small MLAs

- These antennas have their place:
  - Limited space for antennas
  - Small, lightweight, portable (SOTA/POTA, Fox hunting)
- Can be effective against man-made, vertically polarized **E** field noise
- TX/RX MLAs:
  - Maximize radiation resistance while minimizing loss resistance
  - More efficient for higher frequencies, larger diameter loop
  - Requires high voltage capacitor (cost, safety issues)
  - Need to be placed away from metallic objects
- RX MLAs:
  - Can be active (with broadband pre-amp) or passive
  - Passive loops don’t require high voltage capacitors
  - Can be mounted on rotator to null out local noise
  - Do not need to be high off the ground

# References

Dorrenberg, Frank, N4SPP, “My Small “Magnetic” Transmitting Loops for 80-20 MTRs”, https://www.nonstopsystems.com/radio/frank_radio_antenna_magloop.htm

Hart, Ted, W5QJR, “The Loop”, Second Edition, Franklin-Belle Publishers, Corpus Christi, TX, 1989. ISBN: 1-877992-75-5

Yates, Steve, AA5TB, “Small Transmitting Loop Antennas”, http://www.aa5tb.com/loop.html