Magnetic Loop Antennas for RDF, Receiving, Transmitting

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Hamfesters Radio Club

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Why Should You Care

- Because we love to build things
- Because learning something new will stave off dimension
- Because it is fun
- Do we really need a reason

Introduction

A **loop antenna** is a radio antenna consisting of a loop or coil of wire, tubing, or other electrical conductor usually fed by a balanced source or feeding a balanced load.

Within this physical description there are two distinct antenna types. The ***large self-resonant loop antenna has a circumference close to one wavelength*** of the operating frequency and so is resonant at that frequency.

This category also ***includes smaller loops 5% to 30% of a wavelength*** in circumference, which use a capacitor to make them resonant. These antennas are used for both transmission and reception.

In contrast, small loop antennas less than 1% of a wavelength in size are very inefficient radiators, and so are only used for reception.

An example is the ferrite (loopstick) antenna used in most AM broadcast radios.

Loop antennas have a dipole radiation pattern; ***they are most sensitive to radio waves in two broad lobes in opposite directions, 180° apart.*** Due to this directional pattern they are used for radio direction finding (RDF), to locate the position of a transmitter.

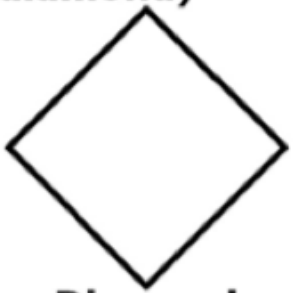
What Can I Do With Loop Antennas

- They were used substantially for Parks on the Air in 2017.
- They are often used for Summits on the Air (SOA).
- They can be used for winter or summer field day.
- If your transceiver has a receive input they can be used as receive antennas.
- If you have antenna restrictions they can easily be put up in an attack space.
- Loop antennas are fairly portable & can be used for ad-hoc operating.
- They are great for Radio Direction Finding (RDF) (aka Fox hunting).

Any symmetrical shape OK

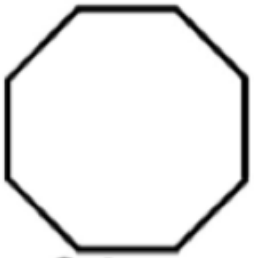
I will discuss square loops because they are the simplest mechanically (in the form on a diamond)

Square



Diamond

Triangle



Octagon

www.n6rk.com/loopantennas/pacificon.pdf

Loop antenna characteristics

- Same free space pattern as a short dipole
- Directivity factor 1.5 = 1.76 dB
- Sharp nulls (40 to 80 dB) broadside
- Much less affected by ground and nearby objects than dipole or vertical
- Low efficiency (~0.1 to 1%), about the same as a modest mobile whip
- Portable (no ground radials needed)

www.n6rk.com/loopantennas/pacificon.pdf

Youtupe Link

Youtube Link

Loop Antennas for Radio Direction Finding (RDF)

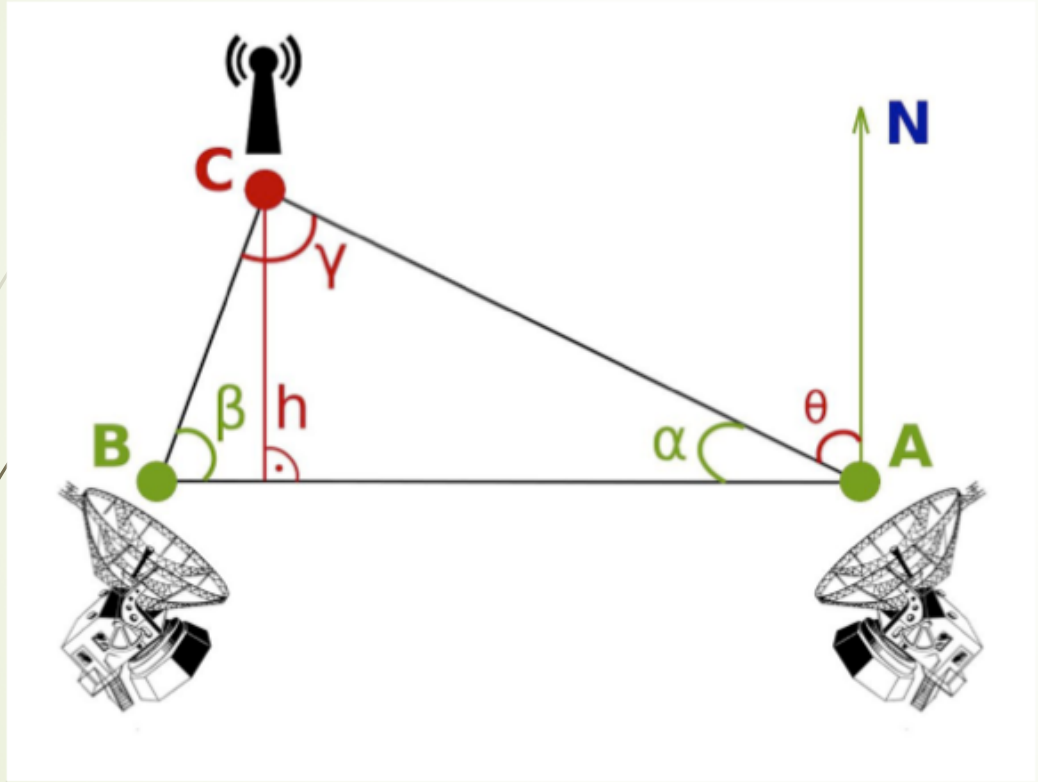
What do you need for RDF?

You need a very directional antenna.

A device for detecting the radio signal.

- In amateur radio RDF applications the signal detector is usually a receiver.
- It can also be a transceiver that you only use for receiving. Unmodified, commercially available portable or mobile receivers are generally quite satisfactory for signal detectors.
- A signal strength meter can be used close in to indicate signal strength when you get close.
- And at very close ranges a simple diode detector and dc micro-ammeter may suffice for the detector.

Triangulating with two RDF Antennas



Shielded Loop antenna for RDF

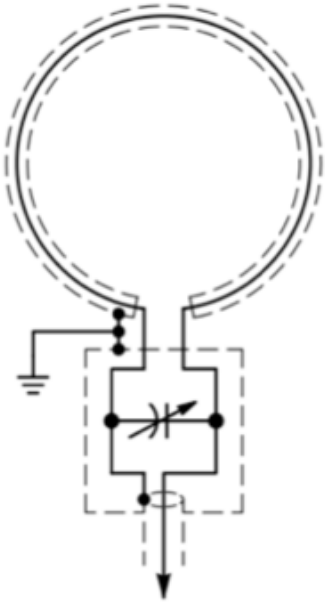


Fig 2—Shielded loop for direction finding. The ends of the shielding turn are not connected, to prevent shielding the loop from magnetic fields. The shield is effective against electric fields.

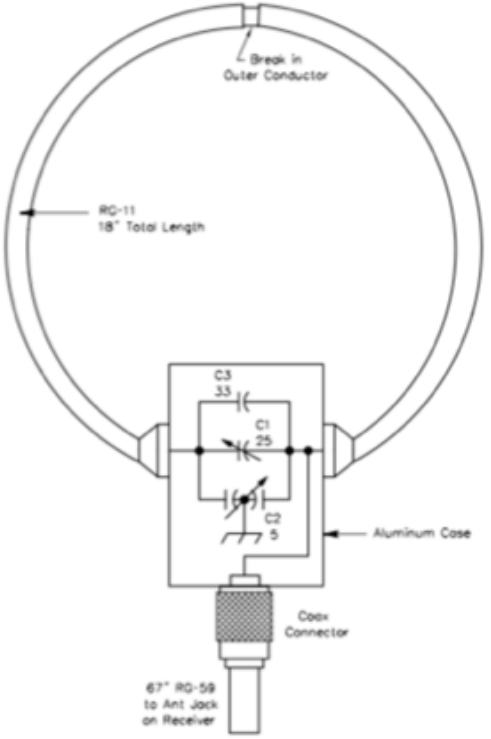
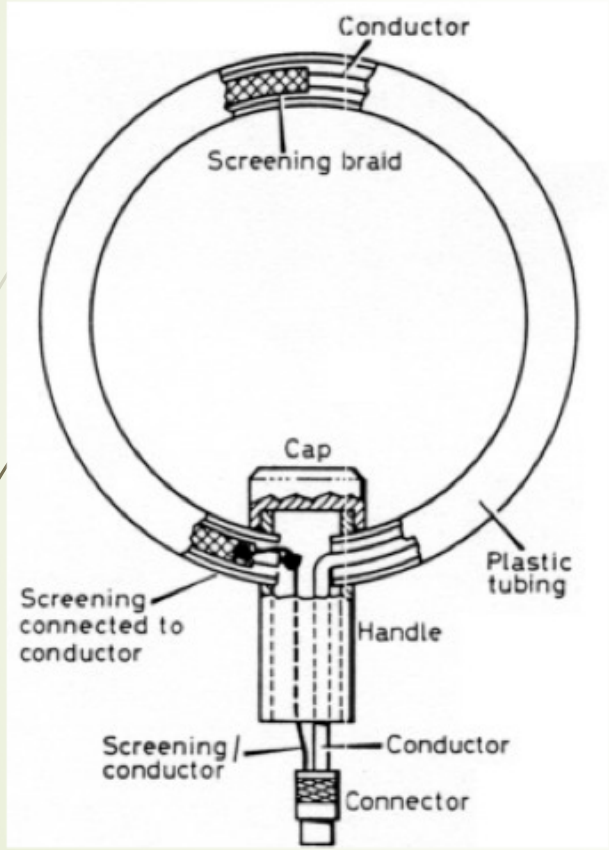


Fig 20—Sketch showing the constructional details of the 28-MHz RDF loop. The outer braid of the coax loop is broken at the center of the loop. The gap is covered with waterproof tape, and the entire assembly is given a coat of acrylic spray.

A Closer Look at a Loop Antenna for RDF



Multi-Turn Loop Antenna for RDF

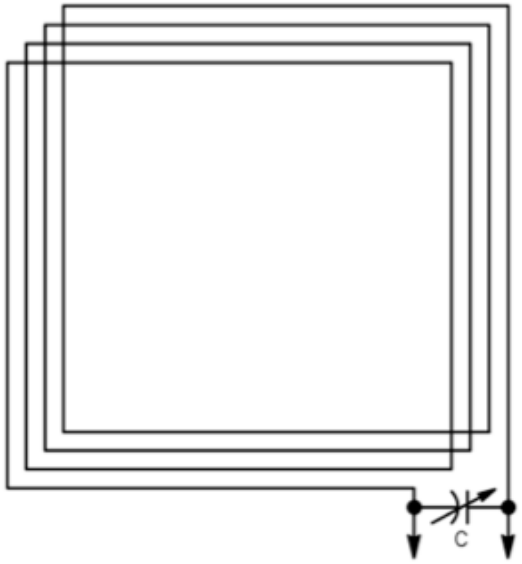
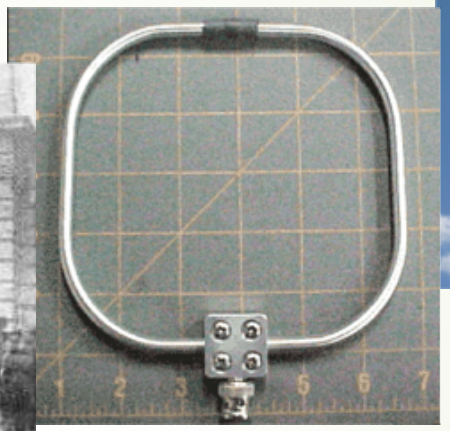


Fig 3—Small loop consisting of several turns of wire. The total conductor length is very much less than a wavelength. Maximum response is in the plane of the loop.

Design Characteristics of a RDF Loop Antenna

- It should be light weight.
- It should be small enough to be portable.
- It could be built as an octagon that uses couplings so it can be assembled in the field.
- If you operate stationary you should include a ground rod and #8 or larger grounding cable in your kit.
- If you operate mobile you need to consider how you will mount it on your vehicle.
  - A pickup truck with a tripod mounted on a sheet of plywood is an effective strategy.
  - A PVC pipe clamped between the underside of a car and its rough (protected by a blanket).
  - Back in 1964 Frank Spearman (From Frank's TV on SW Highway) took his side mirror off and rigged the mirror control to rotate the RDF antenna.
  - I have seen folks using a motorized rear bumper mount controlled with a remote control in the car or a Raspberry PI or other micro-controller.

Examples of RDF Loop Antennas



Purdue University sponsored Amelia Earhart's flight around the world ostensibly as a "flying laboratory." This photograph features the loop antenna that was mounted atop the Lockheed Electra 10E and configured with the Bendix RA-1 Manual Dirction Finder for evaluation. The loop was controlled by Earhart with a wheel inside the cockpit. After tuning in and identifying a station on the ground, the antenna was turned to detect a 'null', which indicated the 'bearing angle' to the station.

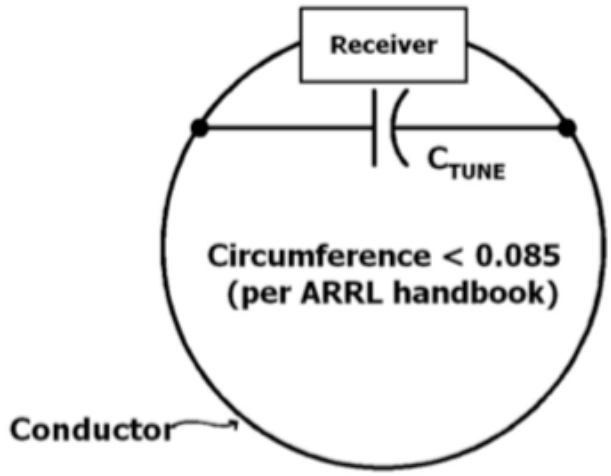
Applications

- Nulling power line noise, good for several S units
- Very useful for DF'ing power line noise
- Get bearing then walk to source using VHF gear to get actual pole
- Remote loop away from noise if you have the land
- Compare locations for noise using WWV(H) on 2.5 MHz as a beacon
- Null your own transmitter for SO2R

www.n6rk.com/loopantennas/pacificon.pdf

Loop Antennas for Receiving

The classic loop antenna



www.n6rk.com/loopantennas/pacificon.pdf

Why to use a receiving loop

- Can null interference (QRM or QRNN)
- Direction finding to locate QRNN
- Remote receiving antennas
- SO2R on the same band (160 meter contests, field day, SOSB, DXpeditions
- Although vertically polarized, may be quieter than a vertical

www.n6rk.com/loopantennas/pacificon.pdf

Design Characteristics of a Receiving Loop Antenna

- Follow Antenna best practices when planning your location
- They can be as small as an AM Antenna. 1% of the wavelength you wish to receive.
- They can be medium to large in size & have multiple loops to cover many different frequency ranges.
- Since you are not transmitting with them you don't need expensive air variable capacitors.
- They should be mounted on a non-metallic pole. Schedule 80 PVC works well for small to medium size loop antennas used for receiving.
- You can control them with a motor and some type of remote control. The motor shaft needs to be insulated (isolated) from the loop antenna by 18. to 24".

Design equations: size, inductance

- Maximum size side = 0.02125 wavelength
- 10 ft at 2 MHz; 5 ft at 4 MHz
- ARRL Antenna Book inductance is wrong
- L=0.047 s log (1.18s/d)
- L=μH; s = side(in); d = conductor dia(in)
- Reactance of max size loop = 226Ω for s/d = 1000, independent of frequency
- Only weakly dependent on s/d

www.n6rk.com/loopantennas/pacificon.pdf

- Bandwidth (counterintuitively) is independent of size
- Tuning cap inversely proportional to loop width
- Gain increases 9 dB (theoretically) for doubling of loop width
- I observed more than +9 dB for full size loop on 160 meters (14 ft wide) vs 7 foot wide
- Doubling conductor diameter increases gain 3 dB, halves bandwidth
- Nulling still good on large loops

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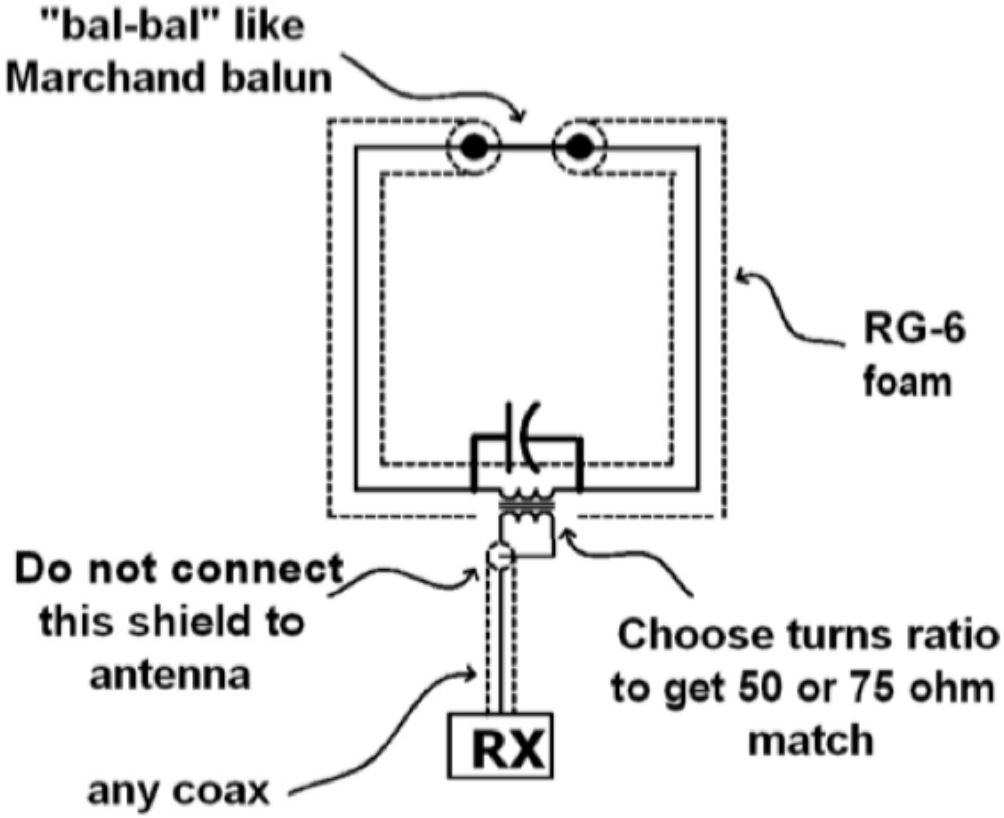
Complete design, fixed tuning



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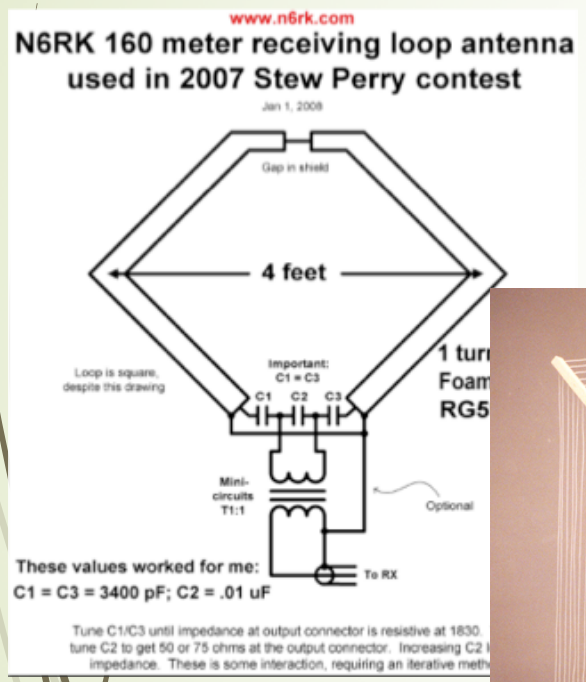
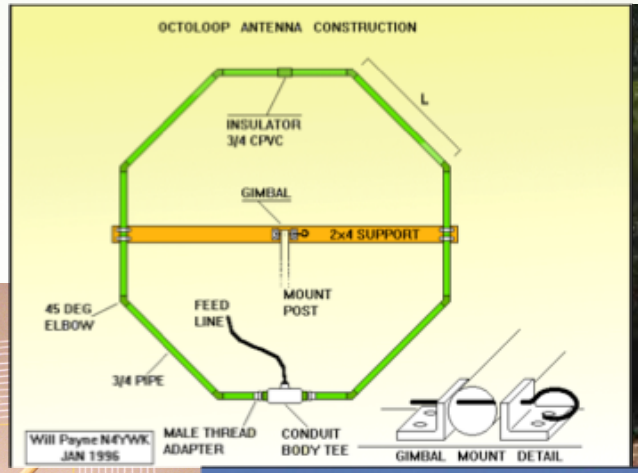
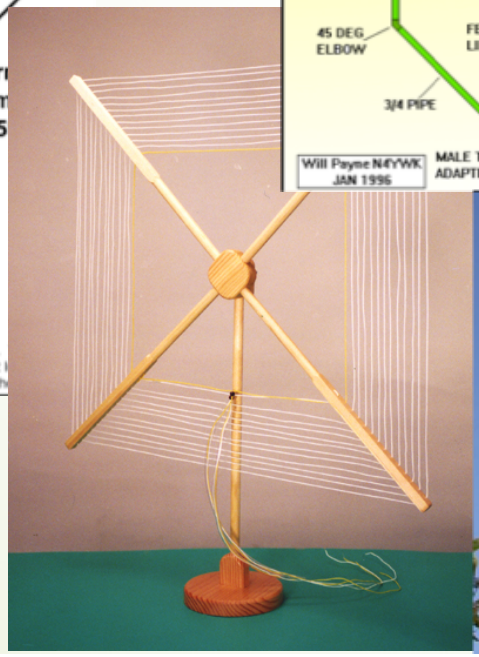
Examples of a Receiving Loop Antenna







Loop Antennas for Transmitting (1 of 5)

Small Transmitting Loop Antenna Calculator

Small transmitting loop antennas, commonly called "magnetic loops" or "mag loops," can give surprisingly good performance when they are carefully designed and constructed. Although this online calculator is intended to assist with designing and building homemade, ham radio loop antennas for use in the HF bands, magnetic antennas have been constructed that function in the VHF or even the UHF frequencies.

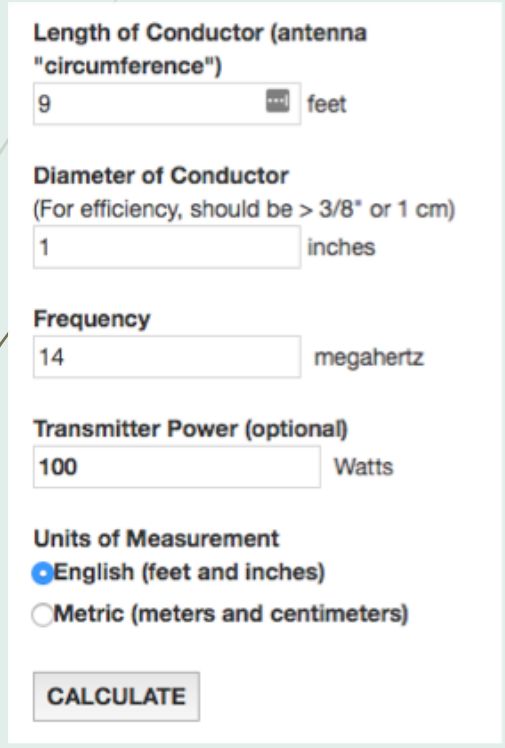
The most common material for home building small ham radio loop antennas is common copper plumbing pipe.

This calculator enables you to test the design of an octagonal loop antenna and to answer "what if" questions until you arrive at a design that meets your needs without a lot of experience in electronics.

You can find the calculator at the following link:
http://www.66pacific.com/calculators/small-transmitting-loop-antenna-calculator.aspx

Loop Antennas for Transmitting (2 of 5)

Lets try the calculator



To use the calculator:

1. Choose the units of measurement.

2. Enter the length of the antenna conductor, which is the distance around the loop. The length should be between 0.1 and 0.25 wavelength at the desired operating frequency.

3. **Enter the diameter of the conductor.**
Note: Small transmitting loops have very low radiation resistance and very high circulating current, so the diameter of the conductor must be large to assure reasonable efficiency around 1" for the HF bands.

4. Enter the frequency of operation.

5. Enter the transmitter power. This is optional, but it must be entered if you want to calculate the voltage at the capacitor and the circulating current.

6. Press Calculate.

…Another Xmit Example

Length of Conductor (antenna "circumference")

17 feet

Diameter of Conductor

(For efficiency, should be > 3/8" or 1 cm)

.5 inches

Frequency

14 megahertz

Transmitter Power (optional)

100 Watts

Units of Measurement

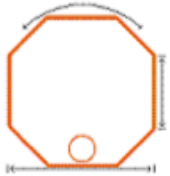
- (•) English (feet and inches)
- ( ) Metric (meters and centimeters)

CALCULATE

Antenna efficiency: 83% (-0.8 dB below 100%)
Antenna bandwidth: 64.5 kHz
Tuning Capacitance: 35 pF

Capacitor voltage: 2,648 volts RMS
Resonant circulating current: 8.20 A
Radiation resistance: 0.617 ohms
Loss Resistance: 0.127 ohms
Inductance: 3.67 microhenrys
Inductive Reactance: 323 ohms
Quality Factor (Q): 217
Distributed capacity: 14 pF

Antenna "circumference": 17 feet



Side length: 2.13 feet

Antenna diameter: 5.1 feet

Comments:

The specified conductor length of 17 feet is OK.

For highest efficiency, the conductor length for a small transmitting loop antenna should be greater than 1/8 wavelength (greater than about 8.52 feet at the specified frequency of 14 MHz).

To avoid self-resonance, the conductor length for a small transmitting loop antenna should be less than 1/4 wavelength (less than about 17.0 feet at the specified frequency of 14 MHz).

Yet Another Xmit Loop Calculator

Small Magnetic Loop Diameter Calculations

Optimized - High Efficiency

Frequency F= (MHz)	144.0	MHz		
Minimum Diameter	3.1	inches	0.3	Feet
Maximum Diameter	6.2	inches	0.5	Feet
Minimum Length of Conductor	9.8	inches	0.8	Feet
Maximum Length of Conductor	19.5	inches	1.6	Feet

For the highest efficiency, the loop of a small transmitting loop antenna should be greater than a 1/8 wavelenght.

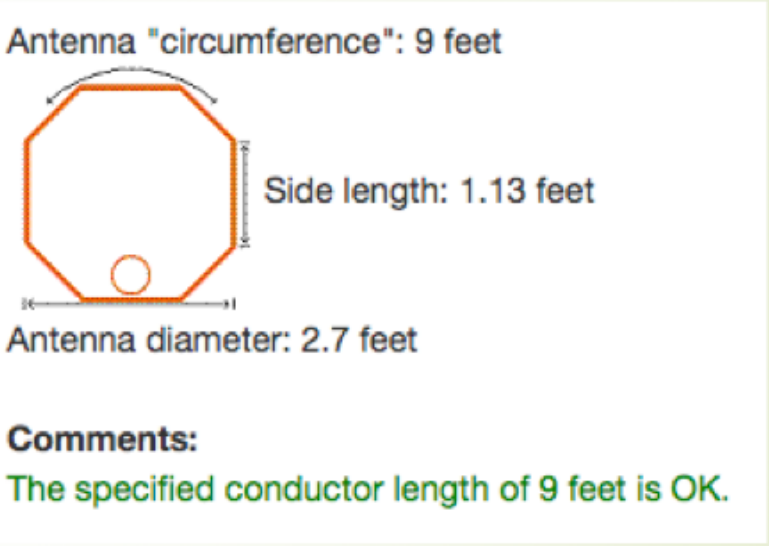
To avoid self-resonance, the loop of a small transmitting loop antenna should be less than a 1/4 wavelength.

http://www.wb5cxc.com/smallloop1.html

Loop Antennas for Transmitting (3 of 5)

Antenna efficiency: 59% (-2.3 dB below 100%)
Antenna bandwidth: 13.2 kHz
Tuning Capacitance: 65 pF

Capacitor voltage: 4,290 volts RMS
Resonant circulating current: 24.7 A
Radiation resistance: 0.048 ohms
Loss Resistance: 0.034 ohms
Inductance: 1.98 Mh
Inductive Reactance: 174 ohms
Quality Factor (Q): 1,059
Distributed capacity: 7 pF



Loop Antennas for Transmitting (4 of 5)

Conductor length should be between 8.52 and 17.0 feet at the specified frequency of 14 MHz.

For highest efficiency, the conductor length for a small transmitting loop antenna should be greater than 1/8 wavelength (greater than about 8.52 feet at the specified frequency of 14 MHz).

To avoid self-resonance, the conductor length for a small transmitting loop antenna should be less than 1/4 wavelength (less than about 17.0 feet at the specified frequency of 14 MHz).

Input Values:
Length of conductor: 9 feet
Diameter of conductor: 1 inches
Frequency: 14 MHz
Transmitter power: 100 watts

Loop Antennas for Transmitting (5 of 5)

Source:

The ARRL Antenna Book:
The Ultimate Reference for Amateur Radio Antennas, Transmission Lines And Propagation

References:

The ARRL Handbook for Radio Communications

Related Web Pages:

Design your own tuning capacitor
for use with this antenna with the Capacitance Calculator (Capacitor Design)

Design Characteristics of a Transmit Loop Antenna

- At higher transmit power levels you get very dangerous voltages and current in the loop.
- You can overcome this by using lower power when operating.
- A better approach is to use an Vacuum Air Variable Capacitor.
- If you use a motor to turn the capacitor remotely it must be insulated (isolated) from the capacitor by at least 18” to 24” using PVC, a doll rod, or some type of hard plastic tube.

Special Considerations for a Xmit Loop Antenna

- Most Xmit loops use a secondary coupling loop.
- They will normally have an isolated motor driven capacitor.
- You must insulate (isolate) the motor using a non-conductive rod or pipe. (PVC, dowel rod, …)
- You don't have to use a Vacuum Air Variable Capacitor as long as you operate a very low power 300mw to say 5W.

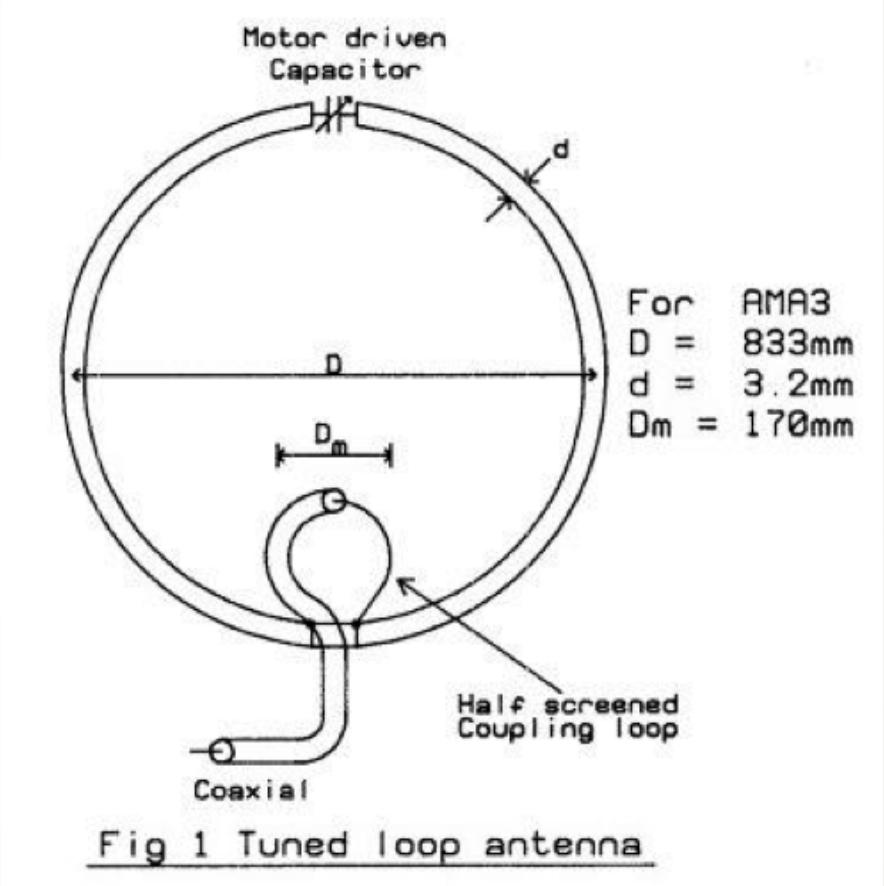


Fig 1 Tuned loop antenna

Vacuum Air Variable Capacitors

A Vacuum Air Variable Capacitor rated at 10K V and 0-500pF. Make sure that when you buy one to carefully checks the sellers reviews. You can expect to pay upwards to $125. Make sure there are no holes in the vacuum tube. Otherwise the inert gas wont be present.

Examples of Xmit Loop Antennas

A great garden decoration ☺

A close-up showing the mounted Vacuum Air Variable Capacitor and the PVC used to isolate the motor that tunes the capacitor.

Examples of Commercial Xmit Loop Antennas

DIY Materials for Loop Antennas

Schedule 40 or 80 PVC, PVC couplers, PVC cement, sand paper.

3/8” or larger Copper pipe and fittings. The bigger the better.
Copper fittings to create the desired shape if using copper pipe.

Coax cable. Again bigger is always better.

One or more fixed and variable tuning capacitors depending on your loop design.

An insulated support to mount your loop on (and potentially turn it). Wood, PVC, heavy plastic conduit.

SO-239 or N-Male depending on your design.

A plastic or metal box to mount your components in. Again depends on your design. Plastic is OK for RDF and RX loops, but metal is better for TX loops.

Misc. screws and other mounting hardware. Plastic zip ties,

Commercially Available Loop Antennas

From QRZ

MFJ has a line of small transmitting loop tuners. There is some technical information about RF exposure and loop sizes by frequency that I extracted from the MFJ manuals and posted in these articles for easy reference.

http://frrl.wordpress.com/2009/03/21/limited-space-antennas-the-small-transmitting-loop-antenna/

http://frrl.wordpress.com/2009/06/07/small-transmitting-loop-tuners-from-mfj/

KE9ZM, Jun 14, 2009

References

Loop antenna – Wikipedia
https://en.wikipedia.org/wiki/Loop_antenna

Small Transmitting Loop Antenna Calculator
http://www.66pacific.com/calculators/small-transmitting-loop-antenna-calculator.aspx

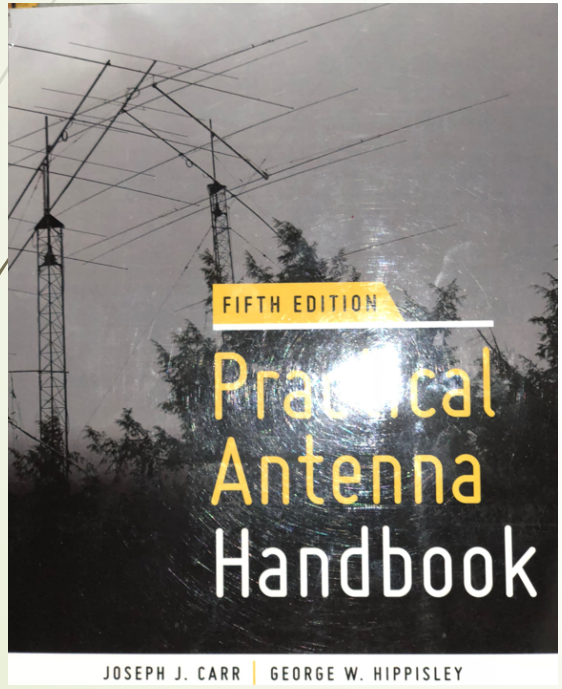
Portable Small Magnetic Loop for Transmitting
https://www.nonstopsystems.com/radio/frank_radio_antenna_magloop-small.htm

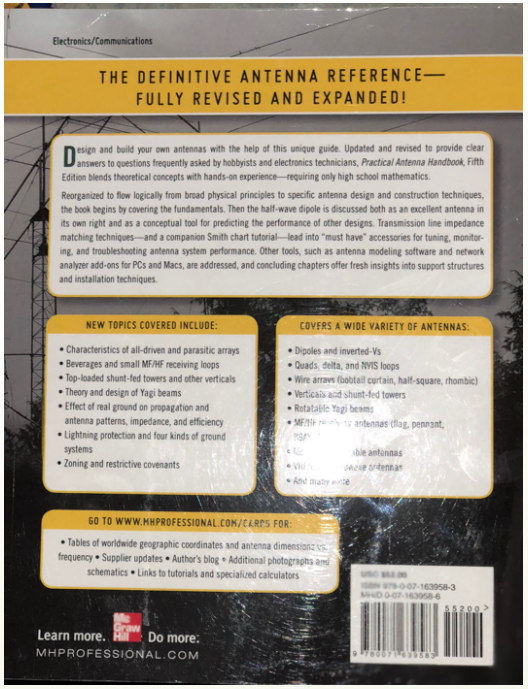
An excellent and very technical presentation on RX loops
http://www.n6rk.com/loopantennas/pacificon.pdf

A nice paper on loop antennas and RDF.
https://www.qrz.ru/schemes/contribute/arrl/chap14.pdf

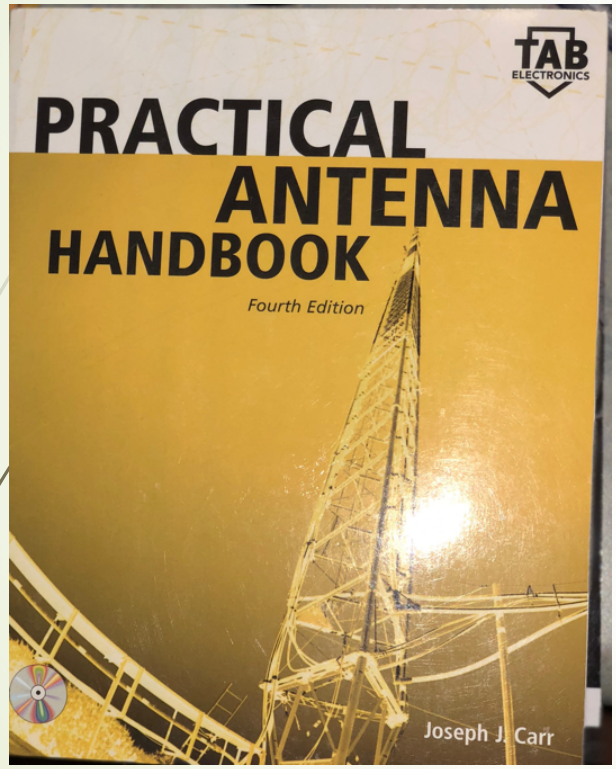
Suggested Reading (1 of 2)

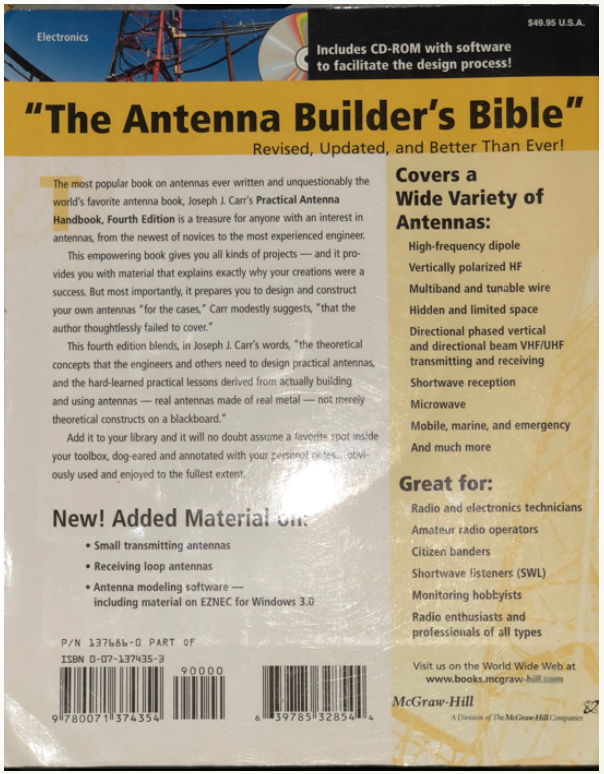
I picked up the following two books on Amazon used for $3 each plush $3.95 shipping cost. You can still periodically find these books used for a good price. You just have to look around. Both have great chapters on Magnetic Loop Antennas. Like the the ARRL Handbook there are significant differences between the book editions.





Suggested Reading (2 of 2)





??? Questions ???