Foldable Mag Loop 40m-17m - PA0WIT

The small HF magnetic loop is made from standard aluminium profile purchased from a hardware store.
The six main sections are 67cm (26.4") long, this length maximises the number of pieces that can be cut from two 2.5m (8.25 ft) lengths of aluminium square tube.

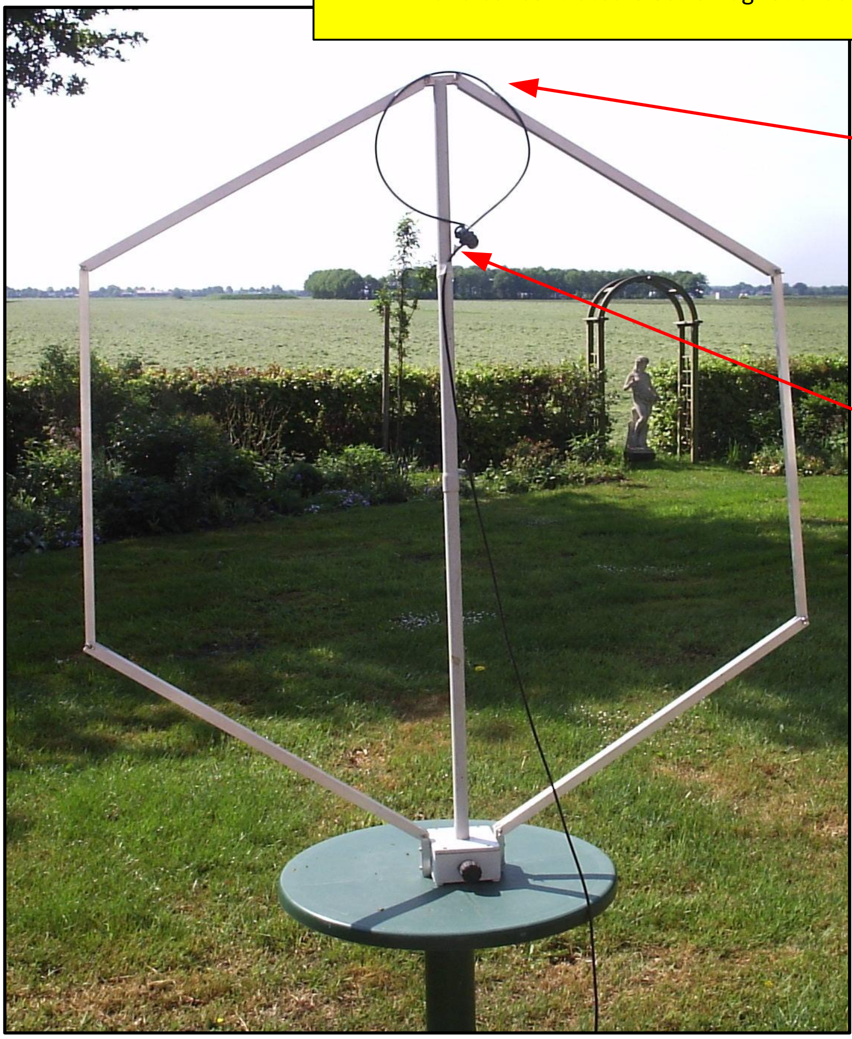
The square section tube 15mm X 15mm is used for the small 8cm (3.15") top section, the two short sections on the capacitor box and the two main vertical sections.

U profile channel - 15mmx15mm internally & 20 x20mm externally, is used for the four sloping sections. These interlock with the square section tube and it is important to have a tight fit when they are mated together. In some cases it may be necessary to use spacing washers. All the sections bolted together give the loop a total circumference of 414cm (163").

The Faraday coupling loop is made from 50 ohms coax and has a circumference of 20% of the main loop's circumference 414cm approx 83cm – cut this slightly longer and trim for best SWR,.

The split- stator 150pF tuning capacitor enables the loop to operate on 30m, 20m and 17m.

WARNING Even when fed at low power levels, small mag loop antennas produce very high voltages across the capacitor and concentrated electromagnetic radiation



Joints with wing-nuts

50 ohm Faraday Coupling Loop

My special thanks to G3YEU for helping me write this article and PA0WIT who made the antenna and allowed me to document it .

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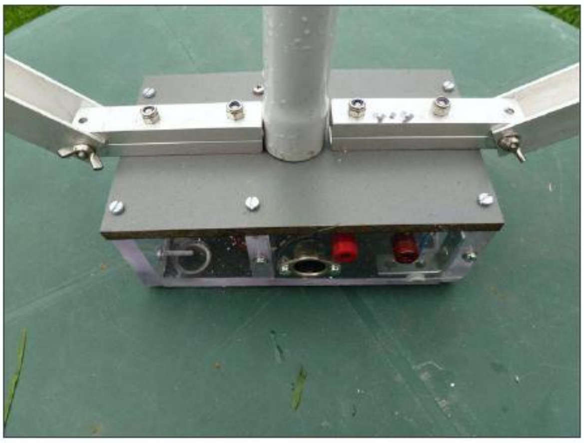
Foldable Mag Loop 40m-17m - PA0WIT



Close up photos of the various joints used to make the Foldable Mag Loop Antenna.
The bottom left photo shows the motorised capacitor installed at the base of the loop

Photos showing how the Foldable Loop is opened up into the operating hexagonal shape.

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Foldable Mag Loop 40m-17m - PA0WIT

The Top Photograph (Tuning Unit)

The small waterproof plastic box housing the small split stator tuning capacitor (with reduction gearing) enclosed, enabled me to work on 20m an 30m (&17m?)

The box also acts as the foot to support the mag loop's central plastic conduit tube .

The Centre Photograph

Shows the two short pieces of super-flex copper wire that form the connections to the two short square section aluminium profiles with the 150pF split stator tuning capacitor using stainless steel bolts. The super-flex wires are designed to carry the heavy currents that are developed in the small mag loop. A typical value for a 100 watt loop is in the region of 10 Amps. For QRP work this will be much lower.

The Lower Photograph

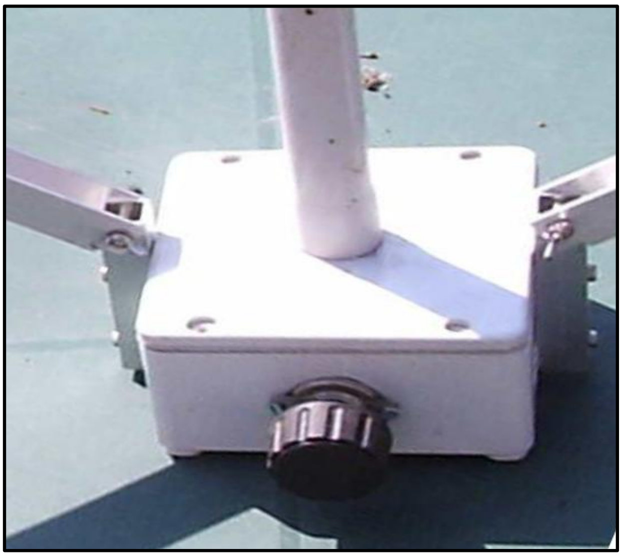
The motorised tuning unit uses a concentric capacitor from a German military tuning unit Type SEM25.

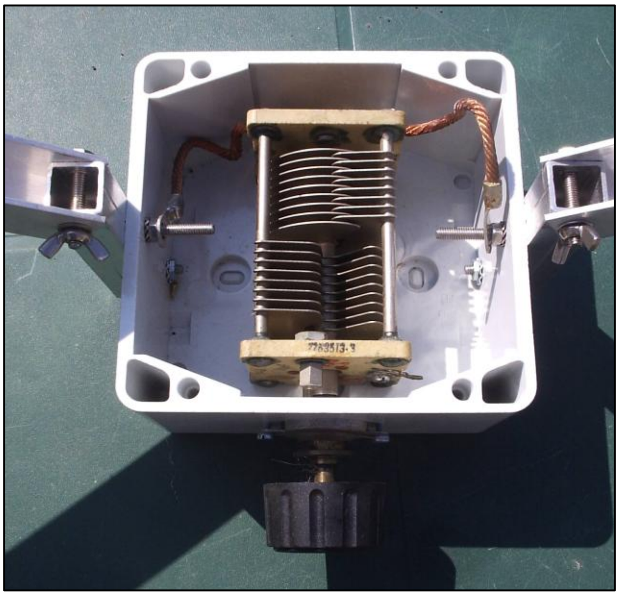
The spacing between the capacitor vanes in both capacitors are about 1mm and have I have not experienced any arcing sparking between the plates at 40W.

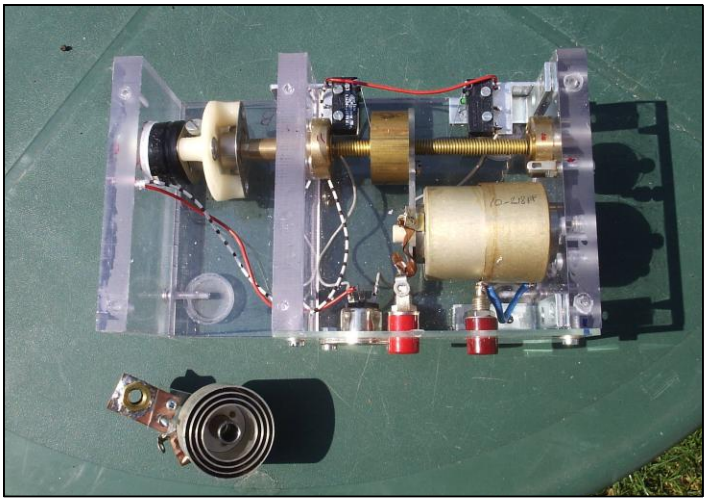
I have not yet had a chance to make many QSO's using the antenna standing on the desk next to the transceiver. But just to prove it worked OK, I made one QSO on 40m (HB) and another QSO on 20m (IK). They both replied right after my first call.

I welcome any comments my address is in QRZ.COM

Jan H. de Wit PA0WIT







The motorized drive:

The small 12V motor (black) on the left of the photo drives a friction coupling (white) connected to a threaded shaft. A brass cylinder with an attached arm is located on the shaft in order to control the rotor of the concentric capacitor.

The rotor section of a another concentric capacitor is shown under the motorized tuning unit. Motor travel is limited by two black micro switches, which are actuated by the brass cylinder touching them at each end of the direction of travel.

The red socket provide a means for connecting additional capacitance to tune the loop on 80m.

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Foldable Mag Loop 40m-17m - PA0WIT

Information For Designing Magnetic Loops

Table 1
Inductance Equations for Short Coils (Loop Antennas)

Triangle:

$$L(\mu H)=0.006N^2s\left[\ln\left(\frac{1.1547\,sN}{(N+1)\ell}\right)+0.65533+\frac{0.1348(N+1)\ell}{sN}\right]$$

Square:

$$L(\mu H)=0.008N^2s\left[\ln\left(\frac{1.4142\,sN}{(N+1)\ell}\right)+0.37942+\frac{0.3333(N+1)\ell}{sN}\right]$$

Hexagon:

$$L(\mu H)=0.012N^2s\left[\ln\left(\frac{2sN}{(N+1)\ell}\right)+0.65533+\frac{0.1348(N+1)\ell}{sN}\right]$$

Octagon:

$$L(\mu H)=0.016N^2s\left[\ln\left(\frac{2.613sN}{(N+1)\ell}\right)+0.75143+\frac{0.07153(N+1)\ell}{sN}\right]$$

where
- N = number of turns
- s = side length in cm
- l = coil length in cm

Note: In the case of single-turn coils, the diameter of the conductor should be used for ℓ.

Small Loop Equations for a Copper Loop

(circular loop assumed, results may vary with other shapes)

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: $\Delta f = (f\times10^{6})/Q = [(f_1-f_2)\times10^{6}]$

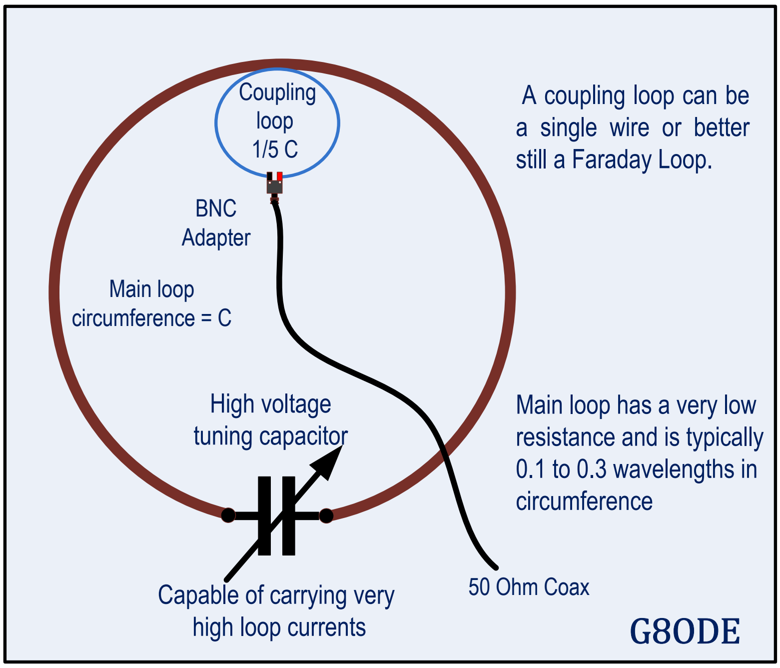
Distributed Capacity: pF: $C_D = 0.82S$

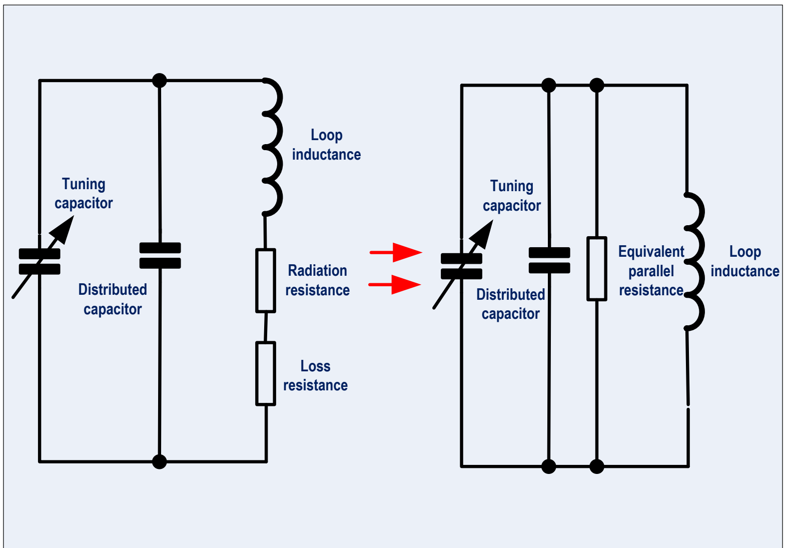
Capacitor Potential, Volts: $V_C = \sqrt{(PX_LQ)}$

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
- η = decimal value; dB = 10 $\log_{10}\eta$
- P = transmitter power, Watts

Ref. The American Radio Relay League, The ARRL Antenna Handbook, Small High Efficiency Loop Antennas for Transmitting, Publication No. 15, p. 5-14, Table 4, 1988



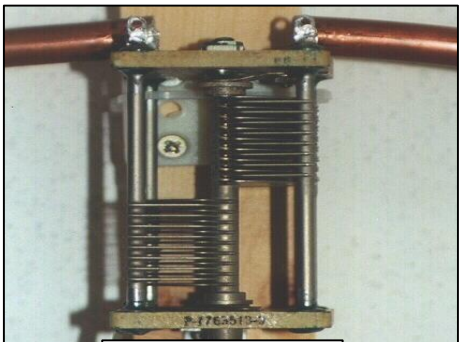


The series equivalent circuit and parallel equivalent circuit for the small loop antenna that are used in loop design calculators

Fortunately several Radio Hams have published small transmitting loop calculators on the web. The KI6GD loop calculator is an excellent example and results from this have been used tabulated on page 6.

Foldable Mag Loop 40m-17m - PA0WIT

Tuning Capacitors

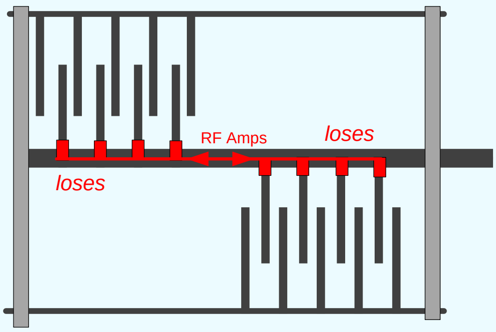


Split Stator

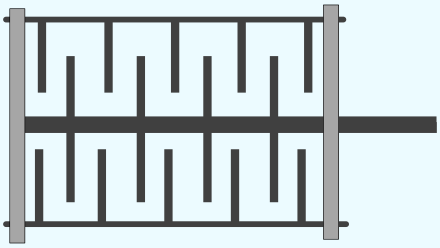
"Butterfly" Type

The Loop Tuning capacitors

Even with QRP power levels a couple of hundred volts can develop across the capacitor plates. An ordinary broadcast radio tuning capacitor with an air gap of 1mm equates to a breakdown voltage of about 1KV, it is suitable for about 15-20 watts, but you will require a 2mm gap for a power level of 100 watts or a vacuum variable capacitor.



Split Stator Capacitor – the two capacitors sections are series connected. Poor connections ■ between the shaft and vanes cause loses.
The capacitance halves & voltage rating doubles. Maximum rotation of the rotor is 180°.



Butterfly Capacitor – the vanes carry all the current – no flows in the shaft and therefore the loses are zero. However the rotor can move through a maximum angle of 90° relative to the stator

Standard radio two gang tuning capacitors have one of more sets of vanes mounted on insulators on a metal chassis, and the other set of moving vanes mounted on shaft connected to the chassis. These can be wired as a split stator capacitor by only wiring to the two stator banks.

However in a split stator capacitor the loop's current has to flow through the moving vanes and the shaft they are crimped on. This type of capacitor is not usually designed to carry the high currents that are encountered in Magnetic Loops, and can also be a problem if they are old and oxidised or dirty.

Professional high power loops use butterfly capacitors or high voltage vacuum capacitors for improved efficiency. Alternatively split stator capacitors that have a shaft brazed or welded to the vanes can be used.

For QRP or relatively low powers of 30-60 watts ordinary air spaced tuning capacitors can be used but will required additional insulation to protect the user from the high voltages (1kV or higher). An insulated shaft extension is needed to avoid hand capacitance affecting the tuning. Remote control motor tuning should be consider at the higher power to avoid radiation burns etc .

Surplus air-spaced capacitors can have contaminated brush contacts so may require a thorough cleaning before being put into service. If alcohols are used then ensure that all residues have completely evaporated as any sparking during operation can ignite any residual fumes.

Foldable Mag Loop 40m-17m - PA0WIT

Small HF Mag Loop Antenna results using KI6GD Calculator program

	Copper Magnetic Loop			Aluminium Magnetic Loop		
Magnetic Loop Antenna Specifications	CIRCULAR	OCTAGONAL	SQUARE	CIRCULAR	OCTAGONAL	SQUARE
Loop Circumference	4.14 meters	4.14 meters	4.14 meters	4.14 meters	4.14 meters	4.14 meters
Conductor Diameter	15.00 mm	15.00 mm	15.00 mm	15.00 mm	15.00 mm	15.00 mm
Loop Diameter	1.3 meters	1.3 meters	1.0 meters	1.3 meters	1.3 meters	1.0 meters
Loop Area	4.5 meters²	4.2 meters²	3.5 meters²	4.5 meters²	4.2 meters²	3.5 meters²
Inductance	3.751 µH	3.751 µH	3.751 µH	3.751 µH	3.751 µH	3.751 µH
Input Power 30 watts	**7.1 MHz**			**7.1 MHz**		
Capacitor Value	122.8 pF	122.8 pF	122.8 pF	122.8 pF	122.8 pF	122.8 pF
Frequency	7.10 mHz	7.10 mHz	7.10 mHz	7.10 mHz	7.10 mHz	7.10 mHz
Conductor Wavelength	0.103 lamda	0.103 lamda	0.103 lamda	0.103 lamda	0.103 lamda	0.103 lamda
Bandwidth	**6.8 kHz**	**6.6 kHz**	**6.1 kHz**	**15.0 kHz**	**14.9 kHz**	**14.4 kHz**
Capacitor Voltage	**2.3 kV**	**2.3 kV**	**2.4 kV**	**1.5 kV**	**1.5 kV**	**1.6 kV**
Efficiency	**23.30%**	**21.40%**	**15.80%**	**10.40%**	**9.50%**	**6.70%**
Inductive Reactance	167.3 ohms	167.3 ohms	167.3 ohms	167.3 ohms	167.3 ohms	167.3 ohms
Loop Q Value	1051.8 Qres	1077.2 Qres	1154.7 Qres	472.1 Qres	477.2 Qres	491.8 Qres
Radiation Resistance	0.019 ohms	0.017 ohms	0.011 ohms	0.019 ohms	0.017 ohms	0.011 ohms
Resistance Loss	0.061 ohms	0.061 ohms	0.061 ohms	0.159 ohms	0.159 ohms	0.159 ohms
Input Power 30 watts	10.12 MHz			**10.12 MHz**		
Capacitor Value	54.8 pF	54.8 pF	54.8 pF	54.8 pF	54.8 pF	54.8 pF
Frequency	10.12 mHz	10.12 mHz	10.12 mHz	10.12 mHz	10.12 mHz	10.12 mHz
Conductor Wavelength	0.147 lamda	0.147 lamda	0.147 lamda	0.147 lamda	0.147 lamda	0.147 lamda
Bandwidth	**12.7 kHz**	**12.0 kHz**	**10.2 kHz**	**22.6 kHz**	**21.9 kHz**	**20.1 kHz**
Capacitor Voltage	**2.4 kV**	**2.5 kV**	**2.7 kV**	**1.8 kV**	**1.8 kV**	**1.9 kV**
Efficiency	**51.20%**	**48.50%**	**39.30%**	**28.70%**	**26.60%**	**19.90%**
Inductive Reactance	238.5 ohms	238.5 ohms	238.5 ohms	238.5 ohms	238.5 ohms	238.5 ohms
Loop Q Value	798.9 Qres	842.6 Qres	993.8 Qres	448.5 Qres	462.0 Qres	504.0 Qres
Radiation Resistance	0.076 ohms	0.069 ohms	0.047 ohms	0.076 ohms	0.069 ohms	0.047 ohms
Resistance Loss	0.073 ohms	0.073 ohms	0.073 ohms	0.189 ohms	0.189 ohms	0.189 ohms
Input Power 30 watts	**14.2 MHz**			**14.2 MHz**		
Capacitor Value	22.4 pF	22.4 pF	22.4 pF	22.4 pF	22.4 pF	22.4 pF
Frequency	14.20 mHz	14.20 mHz	14.20 mHz	14.20 mHz	14.20 mHz	14.20 mHz
Conductor Wavelength	0.206 lamda	0.206 lamda	0.206 lamda	0.206 lamda	0.206 lamda	0.206 lamda
Bandwidth	**32.5 kHz**	**29.9 kHz**	**22.8 kHz**	**44.2 kHz**	**41.6 kHz**	**34.5 kHz**
Capacitor Voltage	**2.1 kV**	**2.2 kV**	**2.5 kV**	**1.8 kV**	**1.9 kV**	**2.0 kV**
Efficiency	**77.40%**	**75.50%**	**67.90%**	**56.90%**	**54.30%**	**44.90%**
Inductive Reactance	334.7 ohms	334.7 ohms	334.7 ohms	334.7 ohms	334.7 ohms	334.7 ohms
Loop Q Value	437.5 Qres	474.7 Qres	622.0 Qres	321.4 Qres	341.1 Qres	411.0 Qres
Radiation Resistance	0.296 ohms	0.266 ohms	0.183 ohms	0.296 ohms	0.266 ohms	0.183 ohms
Resistance Loss	0.086 ohms	0.086 ohms	0.086 ohms	0.224 ohms	0.224 ohms	0.224 ohms
Input Power 30 watts	**18.12 MHz**			**18.12 MHz**		
Capacitor Value	9.4 pF	9.4 pF	9.4 pF	9.4 pF	9.4 pF	9.4 pF
Frequency	18.12 mHz	18.12 mHz	18.12 mHz	18.12 mHz	18.12 mHz	18.12 mHz
Conductor Wavelength	0.263 lamda	0.263 lamda	0.263 lamda	0.263 lamda	0.263 lamda	0.263 lamda
Bandwidth	**75.1 kHz**	**68.3 kHz**	**49.5 kHz**	**88.3 kHz**	**81.5 kHz**	**62.7 kHz**
Capacitor Voltage	**1.8kV**	**1.8kV**	**2.2kV**	**1.6kV**	**1.7kV**	**1.9kV**
Efficiency	**89.00%**	**87.90%**	**83.30%**	**75.60%**	**73.60%**	**65.70%**
Inductive Reactance	427.3 ohms	427.3 ohms	427.3 ohms	427.3 ohms	427.3 ohms	427.3 ohms
Loop Q Value	241.4 Qres	265.3 Qres	366.2 Qres	205.2 Qres	222.2 Qres	288.9 Qres
Radiation Resistance	0.788 ohms	0.708 ohms	0.486 ohms	0.788 ohms	0.708 ohms	0.486 ohms

Note the differences between copper and aluminium. As copper is the better conductor, resistive losses are smaller, the efficiency of a given loop is greater and results in a higher Q, which, in turn, produces much higher voltages across the capacitor. However, the higher the Q, the narrower the bandwidth. In addition, with an increase in frequency, the efficiency of the mag loop significantly improves.With a loop circumference of around 0.1λ, the efficiency is poor as can be seen from the calculated results above

Foldable Mag Loop 40m-17m - PA0WIT

RSARS

The Small Mag Loop's Characteristics:-

1. This loop is a parallel resonant circuit coupled with a smaller loop where D/d >20. The main loop's inductance is cancelled out by a capacitor, leaving a very low radiation resistance (Ra) is 0.018ohms @7.1Mhz & 0.76 ohms @18.1MHz. See note 5 &6
2. High Q (200-1000) and therefore low losses – almost all the RF is radiated.
3. The high Q causes very high voltages to develop across the tuning capacitor - > 2300v @ 30w RF.
4. the loop has a narrow bandwidth at the lower frequencies, e.g. 7KHz @7 MHz and 90kHz @18MHz.
   Below 10Mhz this helps to filter the TX output and on receive behaves like a pre-selector limiting the affects of static or strong adjacent channel signals from overloading the front end of the receiver.
5. The efficiency of the loop is η = (Ra / Ra + RL) x100 %
   where Ra = Radiation Resistance & RL = resistive loses in loop & capacitor. – at 7MHZ η=21.4 %
6. The losses (RL) can be minimised by using large diameter copper tube or aluminium and by using a high quality capacitor designed for loops e.g. butterfly capacitor. RL also affects the "Q" of the loop and hence its bandwidth. If the losses are too small the "Q" becomes very large and bandwidth can fall to around 1KHz and be too narrow for AM or SSB..

OPERATION

The efficiency of the small loop antenna improves when it is elevated slightly. At very low heights, close coupling to the ground can cause detuning. Energy absorbed from the near field changes the effective load the transmitter sees and the SWR will also change.

Practical experience for vertical oriented small loops has shown that an operational height equal to half the diameter of the loop antenna helps to reduce detuning and excess ground losses.

For operation on 14 MHz and higher frequencies, with the loop at table top heights the loop's ground losses are minimal, and the efficiency approaches that of a full size dipole at the same frequency. For the 7 MHz band and lower, ground losses become more of a problem, so elevated operation (i.e. from a second or higher floor) can result in improved performance.

Acknowledgements

KI6GD Magnetic Loop Antenna Calculator version 1.6 copyright 2003
Down loaded from http://www.standpipe.com/w2bri/software.htm

Further reading

PA3CJN loop http://combotec.com/projects/magloop-HF/magloop2.html
AA5TB web site -- this site has more links.

EA5XQ web site http://www.qsl.net/ea5xq/ea5xqpre_magneticloop.html -- this site has more links.

OH7SV 80m Loop http://www.dxzone.com/cgi-bin/dir/jump2.cgi?ID=9508

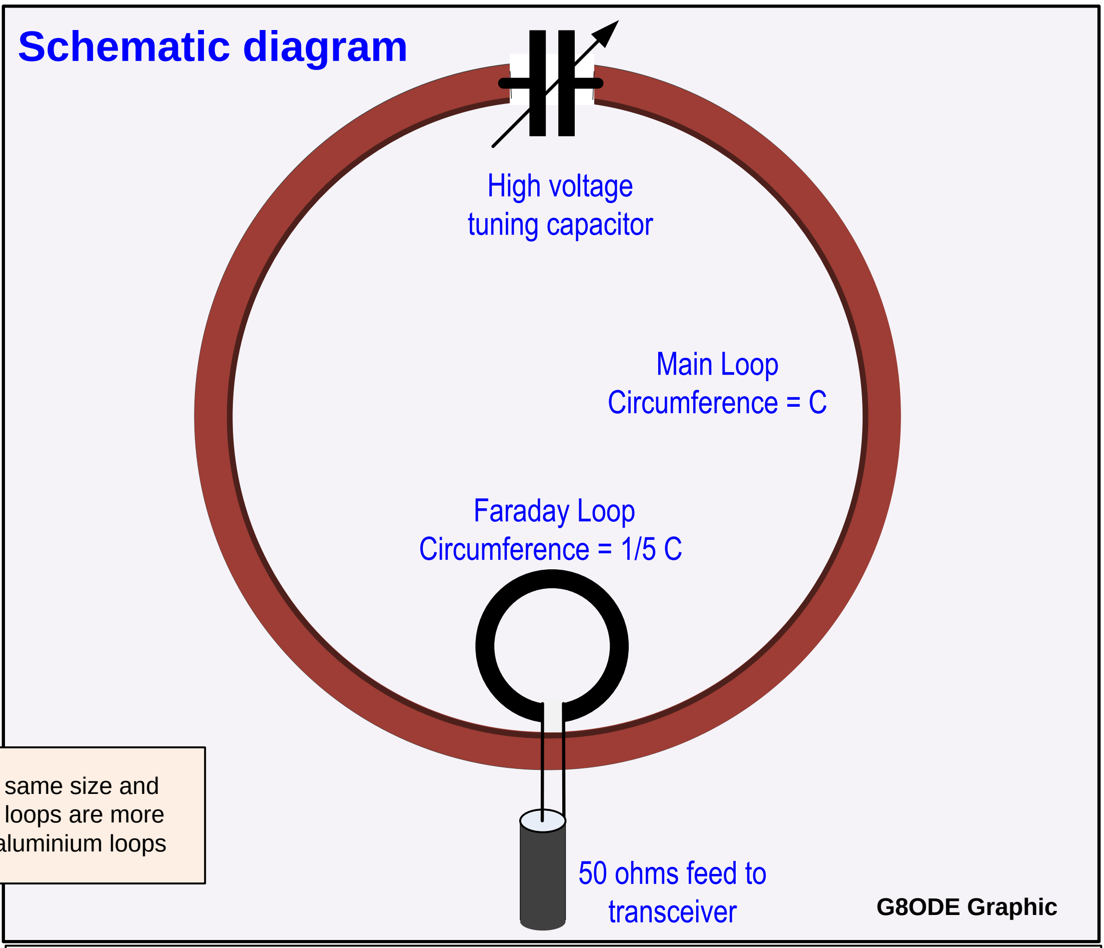
Foldable Mag Loop 40m-17m - PA0WIT

RSARS

COUPLING A SMALL MAG LOOP

The easiest way to feed the loop is with a simple coaxial shielded Faraday loop that is 1/5 (20%) of the main loops circumference . This can be made from coax RG213 or RG8 as shown in the diagram. The Faraday loop will provide a VSWR match of 1.1 and is less prone to noise pickup than a gamma match.

The correct position for the Faraday loop is directly opposite the tuning capacitor, which is the electrical neutral point of the loop. Ideally, the capacitor should be as far away from the ground as possible, i.e. at the top of the loop, in order to reduce ground effects. However, in practice, as long as the main loop is at least a loop diameter above the ground the capacitor can be placed at the bottom as in this design. This distance also reduces the ground absorption effects that will change the impedance of the loop.



Note: For the same size and shape copper loops are more efficient than aluminium loops

The more usual position of the Faraday coupling loop
This has no bearing on the performance or efficiency of the loop.

The main loop is a single turn coil, the inductance of which is brought to resonance at the desired frequency of operation by the tuning capacitor. The coil acts as a radiator and the capacitor and coil together form a parallel tuned circuit. The current distribution is evenly distributed in the whole loop with very high voltages developing across the tuning capacitor because of the main loop's low losses and the resulting very high "Q" and, with careful design, the loop radiates most of the applied RF power as there are few losses.

The main loop is normally inductively coupled to the transceiver with a smaller loop. This does not have to be a shielded Faraday coaxial loop as shown in the diagram. A simple single wire loop will work but will also pick electric fields from local QRN sources. In either case the coupling loop needs to be 5 times smaller than the main loop. The same ratio is used when the loop’s shape is a octagon, hexagon or square . But it’s a good idea to cut slightly bigger and trim to get the SWR to 1:1.