A Magnetic Loop Antenna for the Low Bands

(40,80 and 160 Metres)

by Roberto Craighero I1ARZ

THE GOOD RESULTS obtained with the loop antenna for 20m and above [1] persuaded me to try a similar antenna for 40m and below. My original intention was to build a circular antenna with a circumference of 10. 5m (corresponding to a quarter wavelength at 40m) to obtain maximum efficiency at 40m, and reduced performance on the lower bands. In my search for suitable copper tubing for the loop, I found some 40mm diameter pipe with a wall thickness of only 1mm, and thus very lightweight. However, as it was impossible to bend it without cracking or buckling the tube, I decided to design a square loop to overcome the bending problem. The radiating efficiency of a square loop is less than that of a circular one, but the constructional advantages in my case were compelling. This article describes the square loop I built, together with constructional details for a circular loop.

SIZE AND TYPE OF LOOP CONDUCTOR

FOR THE RANGE OF frequencies to be covered (1.8 - 7.2MHz), a large diameter copper pipe should be used, certainly no less than 25mm, and preferably 30 to 40mm. Aluminium tubing with diameters greater than 30mm could be used, but most amateurs do not have access to welding equipment needed to make reliable, low resistance connections to this material. To keep losses low, the loop should be carefully polished and given at least three coats of marine varnish before erection.

TUNING CAPACITOR

THIS IS THE MOST important part of a transmitting loop antenna, and every attempt must be made to obtain a good quality capacitor. The best (and most expensive) is a vacuum capacitor with a maximum value of around 1000pF and minimum of 7pF, which can sometimes be found on the surplus market. A unit rated at 7kV will operate safely with over 100W RF input power. Alternatively, a split stator or butterfly capacitor with double the nominal loop resonating capacitance can be used. This may not be practicable for operation on 160m, where around 1600pF per section would be needed.

PHYSICAL CHARACTERISTICS OF THE ANTENNA

THE SQUARE LOOP HAS sides of 2.50m, requiring 10m of tubing. The four corners are standard 90° copper elbows used for water or gas installations, and should ideally be brazed to the pipes. Alternatively, soft soldering with a gas torch will serve. All brazing or soldering should be carried out on a flat (concrete) floor

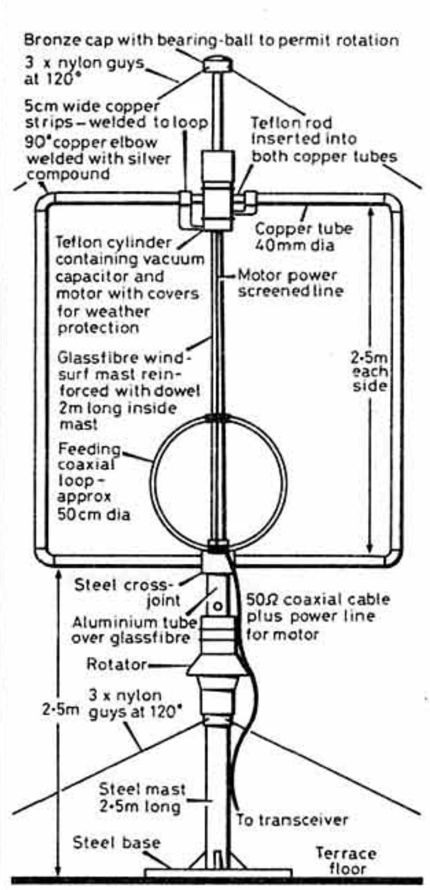

Fig 1: General arrangement of loop antenna system

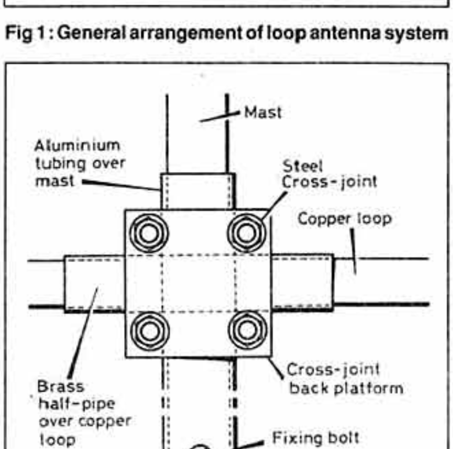

Fig 2: Detail of mast attachment, bottom of loop

to ensure that opposite loop sides remain parallel. A 100mm gap should be cut in the centre of the top pipe of the loop, and a bar of PTFE or Perspex should be inserted and locked in place with screws to stabilise the structure.

If construction of a circular loop is contemplated, the diameter should be 3.40m, requiring 10.67m of tubing including the length of connection straps to the tuning capacitor. Form two half-loops, and join them at the base by brazing, so that only one joint is required. A PTFE or Perspex bar will be needed between the free ends (as for the square loop) to make the structure rigid.

THE SUPPORTING MAST AND PEDESTAL

THE GENERAL ARRANGEMENT of the loop antenna is shown in **Fig 1**. I support my loop with a discarded fiberglass windsurf board mast. The mast is reinforced with a 2m tapered wooden dowel inserted from the base. A thick-walled PVC tube could be used as an alternative support. The bottom of the loop is fastened to the mast by a stainless steel crossover clamp. The copper tube is protected from the clamp by 300mm of brass tubing, split and fitted over the loop tube before tightening. The mast is reinforced at the crossover with a sleeve of 60mm diameter, 3mm wall aluminium tubing, located by a bolt passed through the sleeve, mast and reinforcing dowel, and bonded to the mast by filling the gap with epoxy glue, (**Fig 2**). The mast is capped with a bearing fitted to take three guys at 120° intervals, arranged so that the mast and loop can rotate freely. The guys should be made from nylon or polypropylene rope. A similar system would be required to support a circular loop.

My loop is mounted on a flat roof on a very heavy circular steel base, to which is welded a 2.5m long, 60mm diameter steel mast which carries the rotator. This mast is kept in place by three equispaced thick nylon guys tensioned by turnbuckles. With this supporting structure the loop has survived very high winds without problems. Do not underestimate the weight and wind loading of a loop of this size!

THE LOOP FEEDING SYSTEM

THE BEST METHOD OF feeding is by inductive coupling with a small loop made from RG8 or RG213 coaxial cable as shown in **Fig 3**. The inner and outer of the cable are shorted together and connected to the outer at the base of the loop. The cable is cut at the top centre of the loop, and the inner of the driven side is connected to both inner and outer of the remaining part of the loop. The diameter of the coupling loop must be found by experiment, but should be about 500mm. Adjustment is easier if a slightly oversize loop is built, and symmetrically trimmed back at the top connection. The free cable end is terminated in a plug, which is connected to the end of the feeder via a barrel (socket to socket) connector. This avoids the need to braze a flange to the main loop, as described in my earlier article [1]. The connectors must be sealed and waterproofed, of course. The coupling loop is held in place by a copper strip soldered to the braid at the bottom of the coil. The strip is formed round the aluminium sleeve at the base of the support mast, and the ends pulled together by brass bolts run into nuts brazed or soldered to the strip, **Fig 4**. About 50mm of PVC tubing with a bore slightly larger than the cable should be slipped over one half of the loop before the ends are joined and the diameter adjusted for minimum VSWR. On completion of the adjustments (see below), the soldered joint should be carefully taped up to prevent moisture ingress, and the PVC tube slid over the joint to protect the tape. The top of the loop should be fastened to the mast with a plastic clamp.

THE TUNING MOTOR DRIVE AND FEED WIRING

THIS WAS DESCRIBED in detail in my original article [1], and an electronically controlled alternative was published in *Technical Topics*, November 1989, page 37 [2]. The latter has two errors; the motor is shown as 'meter' on the diagram, and the minimum motor voltage should be 3 to 4V, not 0. 75V. Richard Kelsall, G4FM, has sent me details of another method to drive the capacitor on a high band loop which he says, has the advantage of band selection by switch, rapid band changing, fine tuning within each band and direct indication of the band in use. Although I have not tried this myself, his circuit is reproduced in **Fig 5**, with his permission.

The motor feed wiring should be screened and secured to the support mast with plasic clips. The screens must be bonded to the motor body and to the grounding point at the centre bottom of the loop, and the motor leads must be bypassed with 10nF capacitors bonded to the motor body. Do not attempt to run the motor feedline through the tubing of the loop, as the radiation efficiency will be greatly reduced.

VACUUM CAPACITOR INSTALLATION

THE ARRANGEMENT I USED is shown in **Fig 6**. The aim is to keep the RF resistance to a minimum. Two brass bushings were made to fit the vacuum capacitor contacts exactly, each secured by at least three large screws bearing on the contacts. Do not try to solder to the capacitor directly, as you will break it. The loop connections are made with 50mm wide, 0. 5mm thick copper strips about 300mm long, which are brazed to the brass bushings prior to assembly. If possible, silver plate the straps and bushes to reduce the RF resistance. The capacitor is housed in a PTFE or Perspex tube with slots to clear the connecting straps, and is fixed in place by three

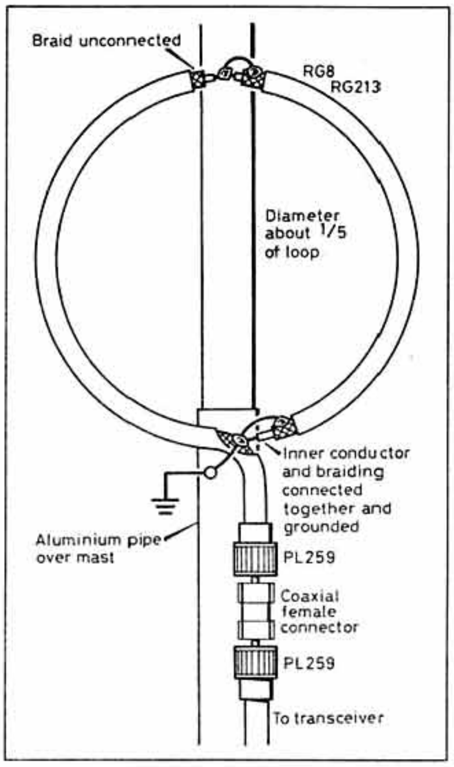

Fig 3: Detail of coupling loop

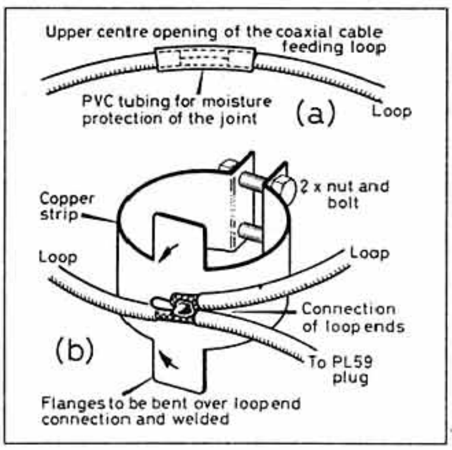

Fig 4: Detail of coupling loop fastening and sealing arrangements

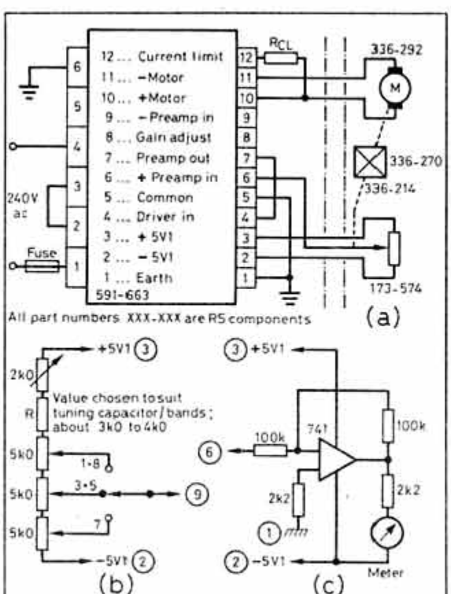

Fig 5: G4FM tuning drive circuit

equispaced screws through the tube bearing on each of the bushings. The ends of the tube are closed with PTFE or Perspex caps secured with self-tapping screws, the uppermost cap having a central hole to clear the capacitor drive shaft. Partial filling of the tube with silica-gel to absorb moisture will help to prevent oxidation of the silver-plated components. The upper cap carries the motor, reduction gear and the insulated shaft coupling in their own weatherproof housing. Cable and connecting strap entries should be sealed with silicone rubber compound. The assembly should be secured to the mast with two brass U-bolts, the closing bar being made from thick nylon or other plastic to avoid forming a 'shorted turn' round the capacitor (**Figs 7 and 8**). Alternatively, the assembly could be lashed to the mast with polypropylene rope secured with epoxy adhesive. The top of the main loop can be secured to the mast with brass bolts and a plastic bar in a similar fashion. Braze or solder the capacitor straps to the loop ends, removing the plastic spacer whilst this is carried out.

ADJUSTING THE ANTENNA FOR MINIMUM VSWR

THIS MUST BE CARRIED OUT with the antenna in its final position, with the coaxial feeder and the motor control line dressed vertically below the base of the loop for at least 1m, otherwise results will be unreliable. Fit an SWR meter in the feeder at the coupling loop; a second meter next to the transmitter is helpful in tuning to resonance. Do not use an antenna tuning unit for these tests.

Apply minimum power to the antenna and adjust the tuning motor for resonance. If the SWR is too high, try deforming the coupling loop slightly; if this does not produce desired results, change the size of the coupling loop. With a little patience, a VSWR below 1.5:1 can be obtained on all bands. I obtained VSWRs of 1. 5, 1. 2 and 1:1 on 40, 80 and 160m respectively. The transceiver load capacitor should be adjusted to the minimum capacitance that gives acceptable results.

LOOP PERFORMANCE

THE LOOP VSWR BANDWIDTH is very narrow. On 160m, I notice that although I obtain a 1:1 VSWR on tune-up, the SWR jumps to high values on SSB modulation peaks. This is not a problem when using CW, of course, due to the narrower bandwidth of this mode.

A rotator for turning the loop is preferable, but not essential. I notice different degrees of directivity according to propagation conditions, but the directivity seems greater for this loop than the high-band version. The maximum to minimum signal ratio for ground waves is about 18dB (3 S-points) in both transmission and reception tests.

The loop performs well, and I am well pleased with it. The performance is similar to a dipole a half-wave above the ground, and best reports are obtained on 40m where the efficiency is highest. I have worked several USA East Coast stations obtaining S9 report with 50W of RF power. Daytime reports for distances below 500km are usually 20 to 25dB over S9. The antenna is excellent for reception, as most man-made noise, static

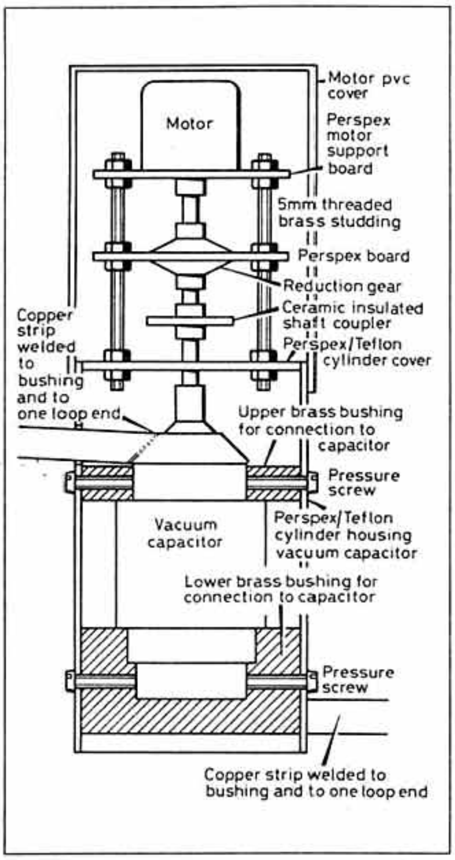

Fig 6: Vacuum capacitor housing and driving arrangement

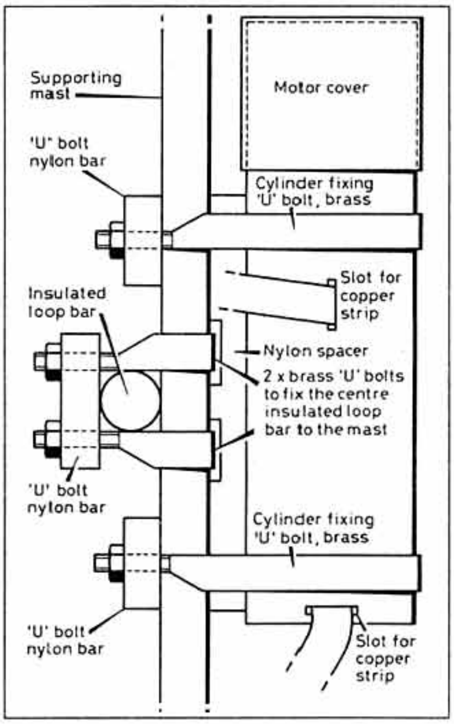

Fig 7: Vacuum capacitor mast mounting arrangement

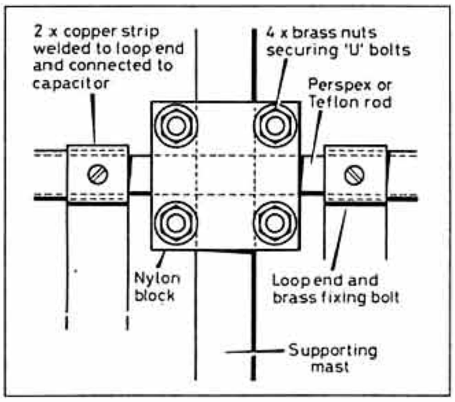

Fig 8: Detail of mast attachment, top of loop

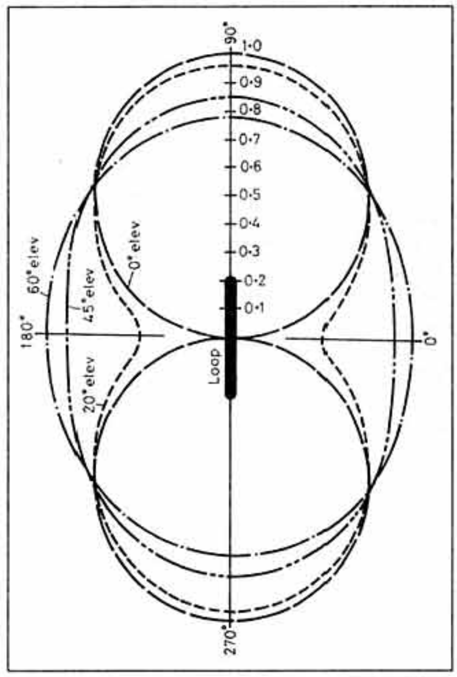

Fig 9: Radiation patterns

and splatter is greatly reduced because of the high selectivity, and you can hear weak signals that would otherwise be lost in the noise.

I was surprised at the performance on 160m, which I had not originally intended to try. The first QSO that I had with a station 500km away returned a report of 20dB over S9! I know from theoretical calculations that the efficiency of the loop is much less than 10% on this band, but I worked 13 countries in a couple of hours during an SSB CQ World Wide Contest with excellent reports. I had not been able to work 160m before because of lack of space for wire antennas for this band. For people unable to use large wire antennas, the loop, in my opinion, offers an alternative with good possibilities of satisfactory results.

TAILPIECE

A GOOD EARTH CONNECTION at the loop helps to ensure stable VSWR adjustments, and a groundplane beneath the loop, even if not connected to it, will increase the efficiency [4]. The use of monoband loops should be considered where possible, as the efficiency of a small loop is greatest when the circumference is a little less than one quarter wavelength, and declines quickly as the frequency decreases. The tuning range of a multiband loop should not exceed 2:1 for this reason.

The monoband loop offers other advantages as well:-

- Reduced Q factor and lower capacitor RF voltages.
- Wider bandwidth and less critical tuning, allowing higher tuning motor speeds.
- Smaller capacitor needed to resonate the loop.

For monoband operation, a smaller range, cheaper tuning capacitor can be used in parallel with a fixed capacitor. A good quality fixed capacitor is needed for transmission, but for powers up to 100W, a piece of RG8 cable (100pF/m) or copper clad printed circuit board [2] can be used. To avoid heating problems, several capacitors of equal value can be connected in parallel - the RF current is then divided between them.

The radiation pattern for the loop for different elevation angles is shown in **Fig 9**, and is suitable for DX, medium and short range operations.

The loop should be kept away from large conducting objects like fences, masts, pipes and cables, which affect radiation efficiency because of the currents induced in them. I would also discourage the use of the loop indoors close to the shack because of the risk of RF burns if touched, and the possible risks associated with long-term exposure to high RF (magnetic) fields.

The references below include new material not listed in the reading list at the end of my earlier article [1].

MAIN ELECTRICAL CHARACTERISTICS OF THE ANTENNA

		Square shape MHz			Circular shape MHz		
		7.0	3.5	1.8	7.0	3.5	1.8
Radiation resistance	Ohms	0.36	0.023	0.002	0.76	0.05	0.003
Conductor length	metres	10.0	10.67	10.67	10.67	10.67	10.67
Conductor diameter	mm	40	40	40	40	40	40
Conductor losses (copper tubing)	Ohms	0.058	0.04	0.03	0.05	0.04	0.03
Efficiency	%	88	36.5	6.3	93	53.5	10
Loop inductance	µH	8.2	8.2	8.2	9.6	9.6	9.6
Inductive reactance	Ohms	360	180	93	422	211	108
Q factor	Q	440	1454	1466	258	1187	1650
Theoretical bandwidth	kHz	15.9	2.4	1.23	27	3.0	1.09
Voltage across tuning capacitor (100 watts)	kV	4.0	5.1	3.7	3.3	5.0	4.2
Tuning capacitance	pF*	63	252	953	54	215	815

* Including length of the connection straps to tuning capacitor.
* When using split stator or butterfly capacitors this value must be doubled for each section.

REFERENCES

[1] R Craighero "Electrically Tuneable HF Loop" *Radio Communication*, February 1989 pp38-42

[2] *Radio Communication*, Nov. 1989

[3] *ARRL Antenna Book*, 15th Edition, 1988

[4] Ted Hart "The Convoluted Loop" *Ham Radio Magazine*, April 1989