# A square short loop antenna for 160-40m

## Building on his successful design from the early 1990s, the author gives his loop antenna a new lease of life

PHOTO 1: The refurbished loop for 160, 80 and 40m. The tuning unit is in the box at the top.

**INTRODUCTION.** After over twenty years of excellent activity, my square short loop antenna for the low bands (originally described in the February 1991 *RadCom*) needed extensive maintenance work. A new tuning unit was necessary and I adopted a different mechanical and electrical solution. I would like to share with you the work done, all details of the antenna and some on-air results. I also include some comparisons with other, conventional antennas.

**THE LOOP.** The loop is not circular but square shaped. This choice was made because it was impossible for me to bend the copper pipes into a circle – I don't have the specialised workshop equipment. I therefore decided on a square shape, which also simplified transporting the pipes to my home. Calculation shows that the square shape has slightly reduced radiation efficiency for a given length of tube, but it is the simplest mechanically. Other shapes (octagonal, hexagonal or pentagonal) are possible, but joining together the sides of the loop causes reduced efficiency unless specialised welding or mechanical techniques are used. Keeping ohmic losses very low is of paramount importance in building a short loop antenna. This is also the reason why copper is preferable to aluminium.

I decided to use copper tubing of 40mm diameter. This size is not so easily found; it is also possible to use 22mm tubing with reasonable radiation efficiency on the low bands.

For a true magnetic loop, the circumference must be one tenth of a wavelength or less in order to achieve constant current round the loop. A larger loop can also be used, with an increase in the radiation efficiency but some unpredictability in the polar diagram (because the loop then has a folded dipole mode in addition to the magnetic loop mode). The magnetic loop mode has maximum radiation in the plane of the loop (this is the mode used for direction finders), while the folded dipole mode has maximum radiation along the axis. As the loop circumference is increased above one tenth of a wavelength by raising the frequency, the folded dipole mode slowly takes over, until it is fully established when the circumference is one wavelength. With the present loop, with sides of 2.5m, pattern purity can be expected at 3.5MHz and below, while on 7MHz it will be more omnidirectional as a result of mixed-mode operation.

The feed uses inductive coupling and is based on RG8 or RG213 coaxial cable. **Figure 1** shows the complete antenna in diagrammatic form.

My loop has a total circumference of 10m including the capacitor connection cables. On 40m it has a circumference of a quarter wavelength. This length is not critical. The radiation efficiency is less at the lower frequencies. It is also possible to use the loop as a single-band antenna for the 40m band; in this case, the tuning capacitance required is small. The loop behaves as a magnetic loop on 160m and 80m and as a mixed-mode antenna on 40m.

**CONSTRUCTION.** The four sides must be connected by means of standard 90° copper elbows. Such components are normally used for water and gas installations and can be purchased from plumbing suppliers, as can the copper tubing.

It is preferable to solder the joints with a silver compound, also available in plumbing stores, using a good gas torch; great accuracy is required in doing this soldering operation to keep ohmic losses to a minimum. The ideal solution is a very high-temperature weld with oxy-acetylene, capable of melting copper and therefore with a perfect electrical continuity in the joints, but this is beyond the capabilities of the average radio amateur.

Another acceptable solution is to join the four elbows to the loop pipes by strong compression. This can be achieved by doing four longitudinal cuts 90° apart on each end of the elbows; the eight 'flaps' so obtained must be strongly

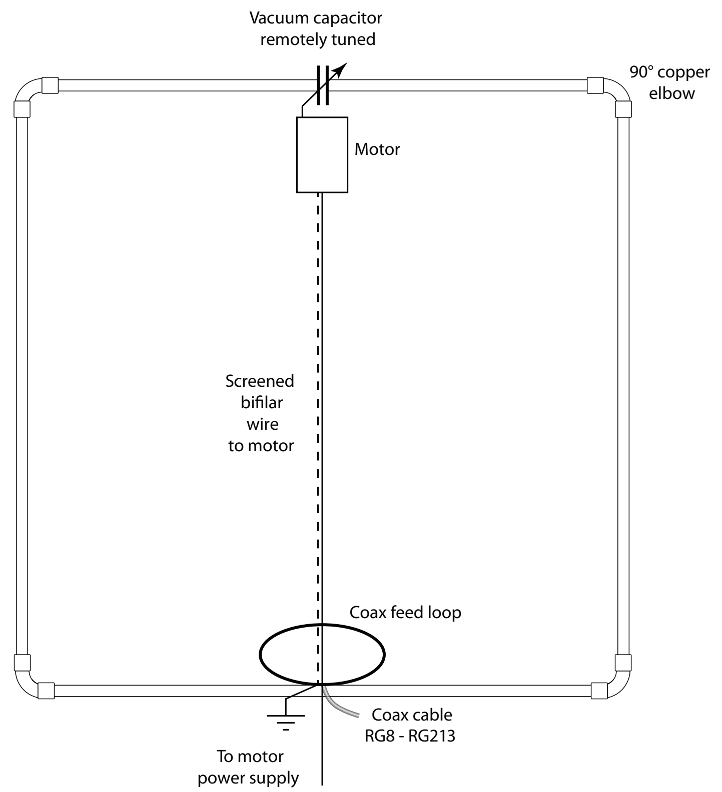


FIGURE 1: Diagram of the complete antenna.

PHOTO 2: Prototype loop pedestal mount, rotator and feed.

compressed against the loop pipe by mean of a couple of large stainless hose clamps tightened fiercely over such ends. The surfaces to be joined must be given a thorough cleaning first. Afterwards, the connections must be weather-protected by wrapping them in self-amalgamating tape. I adopted a similar compression method to connect the tuning unit cables to the loop frame, described later.

To keep the loop sides parallel, the soldering/fixing operation should be done on a flat surface. The top 'side' of the loop must be cut at the centre, with a gap of about 100mm; a bar of Teflon or strong plastic is inserted and held inside the two free ends of the loop by a through-bolt to keep the structure rigid.

**THE SUPPORTING MAST.** For the mast I used an old windsurfing fibreglass mast, reinforced for about 1m with a tapered wooden dowel inserted from the bottom. If you are living in an area where windsurfing is popular, it is easy to find a discarded mast at low cost which is still good for this purpose. Alternatively, a thick-walled strong plastic conventional tubing (of dark colour) can be used as a supporting mast.

The windsurfing mast idea was originally adopted to allow rotation of the loop. It was necessary to include at the top of the mast a bearing cap connected to three guys at 120°, which permitted free rotation of the loop. The length of the windsurfing mast I used was right for this purpose and it worked very well for years, but I found it is not really necessary to rotate loop. The antenna acts like a direction-finder on ground wave at the lower frequencies, where it is a true magnetic loop, but on sky waves at the higher frequencies, when the loop operates in mixed mode, it is practically omnidirectional. I leave it up to you to decide whether you want to make the loop rotatable.

The lower external end of the mast must be inserted inside a thick aluminium pipe,

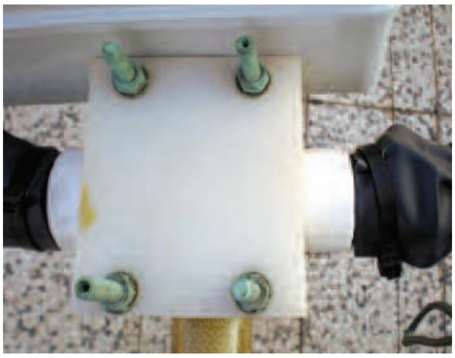

PHOTO 3: Detail of the Teflon bar connecting the loop frame ends.

bonded with epoxy glue and a through bolt. The length of this tube depends on the location - ground, roof, terrace etc. In my location, a flat roof, I adopted the pedestal solution shown in **Photo 2**. However the lower side of the loop should always be at a height of not less than 2m from the surface.

Now the loop must be mechanically connected to the mast. The lower side of the loop is fixed with a steel crossover clamp. I suggest a clamp normally used on external scaffolding by builders. Such clamps accept pipes with a diameter up to 45mm and are not difficult to find. Between the clamp and the copper tubing there must be a 300mm long split brass tubing before the clamp is tightened. This avoids buckling of the copper tubing under stress (and possibly increases the overall diameter if the clamp is too large for the copper pipe employed).

The other side of the clamp must be tightened on the aluminium base pipe. An alternative method to fix the loop could be the classic system for connecting a Yagi boom to the mast, using U-bolts and a thick aluminium plate.

The top side of the loop must now be fixed to the mast. I used two U-bolts placed along the mast and a thick Teflon plate to keep in the centre insulated bar of the loop top side in place (see **Photo 3**). A simpler alternative method could be a strong binding made with self-amalgamating tape. Two crossed strong plastic clamps must be tightened over this binding for a safer fixture. Finally, everything is bonded with epoxy glue.

**THE TUNING UNIT.** As the old tuning unit was out of order I was compelled to make a new unit. I decided to build it inside a standard watertight plastic box normally used for external electric circuits. Such boxes are available in electrical supply stores.

Obviously the size of the box depends on the size of the capacitor, tuning motor and other small components. I suggest outlining the various components on a sheet of paper and drawing the ideal size of the box required. The height of the components must also be considered. You can then buy the closest size of box.

To build the unit, first prepare a Plexiglas board 3mm thick with the exact dimension of the inner bottom of the box, which will be the base for the whole unit. Trace the board centre line with a felt pen. This line must be strictly followed in placing and fixing the various components.

The first to be fixed is the tuning vacuum capacitor. I will describe my situation and you have to adapt it to your components. My capacitor is an Amperex vacuum ceramic capacitor of 7-1000pF, 7kV. It is kept in place by a large plastic clamp passing through the board and tight on top of the ceramic body of the capacitor. A square thick Teflon plate is inserted on the rotor shaft and fixed on the board by mean of two brass 90° angle brackets. This plate helps to keep the capacitor in place (see **Photo 4**). You must be very precise in drilling the rotor shaft hole in order to keep the capacitor shaft perfectly parallel to the track and at the right height, otherwise there are negative consequences. A brass ferrule with the correct diameter to permit a smooth shaft rotation must inserted in the Teflon plate hole and glued in place.

Now you can proceed to install the tuning motor. A small Plexiglas plate (the same type as the base board) must be prepared. A hole must be drilled to insert the motor shaft. Again great accuracy is required: the motor and the capacitor rotor shafts must be perfectly aligned. To do this more easily I suggest first fixing on the board two 90° angle brackets at the base keeping it temporarily on the main board in direct contact with the rotor shaft end, to determine the exact drilling point. Now you can fix the tuning motor to the board, but, before, you have to find the correct position on the base board, keeping in mind that a good quality flexible ceramic insulated ring must be inserted between the motor and rotor shafts (**Photo 5**). The rotor is RF-hot and must be very well insulated.

You can now drill the holes in the base board and tighten the nuts of the motor supporting base. Use stainless nuts, bolts and washers. With all the above operations completed, proceed to test the unit supplying power to the motor. Check this carefully: the rotation must be smooth, without any forcing, in both directions of rotation and with a quick change of direction.

For simplicity I did not include motor end-stop switches for the rotor, therefore I avoided such positions of the rotor both during tests and later during normal antenna use: the last tuning position must be remembered. I have used this method for a long time without problems. However, a simple empirical controlling system is to keep a milliammeter in series with the motor's power line in the shack. If the motor has difficulty in rotating, the current will increase suddenly. That's the clue that it must be stopped and the rotation direction changed.

The motor is a small DC unit with sufficient torque to turn the capacitor rotor. It is driven

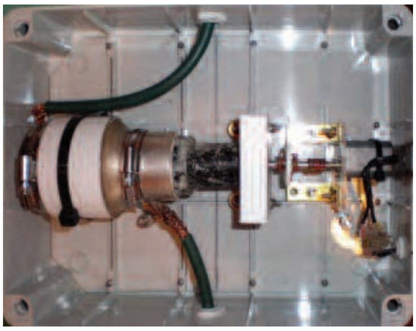

PHOTO 4: Inside the tuning unit. Note the Plexiglass sheet that acts as a chassis and the white Teflon block (see text).

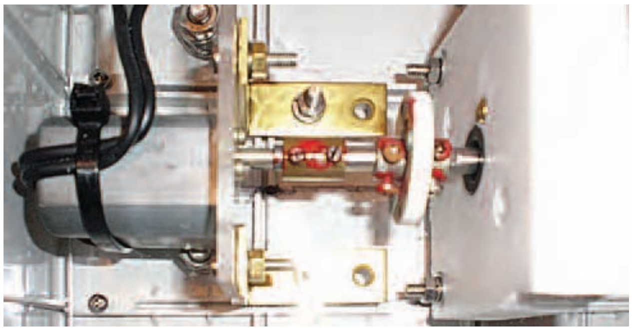

PHOTO 5: Detail of the coupling between motor (left) and capacitor shaft. Note the ceramic disc that insulates the motor from the (RF hot) vacuum capacitor shaft.

with variable voltage from 6 to 12V. Another important requirement is the rotation speed, which must not exceed 2-3 rpm, otherwise it will be impossible to tune the antenna (due to the very narrow bandwidth of the loop). If your motor is faster it is possible to add a reduction gear on the shaft like those used in the past for fine tuning of receivers. Of course you have to consider the extra space required when planning the unit. It is also important to be able to control the rotation speed by varying the supply voltage. Use a lower voltage for fine tuning and a higher voltage for changing bands. The power supply must be variable; a switch between voltages is OK but a continuously variable voltage control is preferable. The motor control circuit diagram is shown in **Figure 2**. I bought my motor at a rally after it was recovered from an old computer printer. Of course another good possibility is the web.

Proceed now to build the collar flange system to fix the box to the mast. Four stainless bolts (100mm long and 6mm diameter) were used. The top side of each bolt must be cut off. You need now four stainless steel collar flanges with the right dimensions to accept the outer diameter of the loop supporting mast. Such flanges are available in large hardware stores (see **Photo 6**). You must drill four holes on the back of the box to accept the bolts exactly. The holes must be drilled at the correct distance of the corresponding fixing holes of the collar flanges.

Now temporarily place the unit base inside the box and drill it using the box bottom holes as a guide; later, the bolts will also keep the board in place. Be careful during this drilling operation to avoid damage to the tuning capacitor and other components already in place on the board. Now take off the base and proceed to tighten the nuts on the bolts inside and outside the bottom of the box.

A few layers of Teflon tape normally used for watertight connections in plumbing work must be wound on to the four bolts where they pass through bottom of the box. Then insert from both box sides a flat washer, a lock washer and finally the nut, which is then tightened. All hardware must be stainless. I strongly recommend a water tightness check of the bolts. The test is very simple: put some weights inside the box and have it float on water for a few hours. You will easily verify if a perfect watertight seal has been achieved.

You can now finally put in place the unit board, tightening the nuts on the top side of the board, using a flat washer, lock washer and finally the nut.

The next step is connecting the vacuum capacitor to the loop ends. You'll need to prepare two lengths of coax cable (RG 214 or similar, with double shielding) about 1m long each. Remove the external jacket for about 250mm. Push the braid back against the jacket. Carefully open the inner copper foil, keeping it clear of the Teflon insulated inner conductor. Cut the inner away, gently flatten the copper foil, pull the braid back again and finally flatten it. You will obtain an excellent, flat, flexible conductor.

Now drill both side of the unit box at centre and mount the watertight cable glands of the correct diameter to accept the coax cable. Such glands are available in electrical stores. Introduce the coax cables to reach the rotor and stator terminals of the capacitor. Wind the flexible cable ends carefully on the capacitor rotor and stator terminals so as to nearly complete one turn. Now insert over each terminal a large stainless steel hose clamp and tighten it hard – see **Photo 7**.

Connect the tuning motor to the DC supply line. Drill the lower side of the box and mount another watertight connector of the correct size to accept a twin screened conductor of the same type used in audio systems. This cable must later be dressed along the mast and have a length of not less than one meter below the lower side of the loop. From this point to the shack a normal conductor can be used but at the joint point the screens of the audio type cable must be grounded. Solder the line to motor contact lugs and bypass with 10nF ceramic disc capacitors. Both screens are connected to motor body and capacitors. In the shack the line is connected to a DPDT toggle switch and to the power supply. The switch can be mounted on a small plastic box for easy operation.

PHOTO 6: Detail of the collar flange on the back of the tuning unit box.

The unit is now completed and it should be fixed on the upper part of the mast, close to the loop centre gap. To support the tuning-unit box, fix a short 90° aluminium angle bracket just under the lower side, kept in place by a stainless hose clamp on the mast.

Now clean and polish the loop ends very carefully: the copper must be shining, without any trace of oxidation. Both coax cables of the tuning unit are to be bent with a rather wide radius so that they can reach the ends of the loop from the lower side. Cut the cables to the correct length to obtain a flexible end, in the same way as for the capacitor connections. Wind two turns of the flexible cable flat ends over the loop ends (see **Photo 8**). Insert two stainless hose clamps for each side of the loop ends and tighten them over the flat terminals of the cables.

Now the connections must be weatherproofed with self-amalgamating tape, starting from where the coax touches the loop. Stretch the tape and apply it in a half-lapped fashion to form a void free joint. The degree of stretch is not critical. To provide additional weatherproofing, split a length of plastic (heatshrink) tubing of greater diameter than the hose clamps and place it over the self-amalgamating tape area. Make sure that the join overlaps and will be pointing downwards when the antenna is erected. Secure the tubing using several nylon ratchet

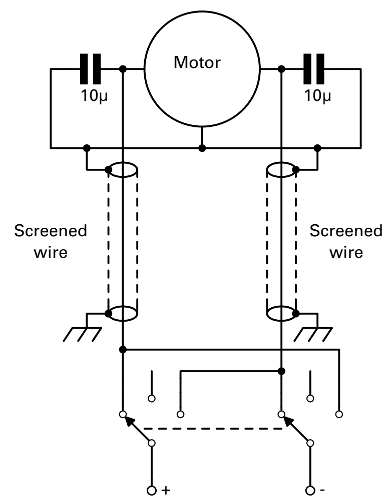


FIGURE 2: Motor control circuit.

PHOTO 7: Detail of the connections to the capacitor.

ties. It should look something like the right hand side of Photo 3.

Before closing the tuning unit watertight cover, make another test of the motor system by connecting the power supply at the end of the whole length of the feeding line. In closing the unit apply a thin layer of grease to the rubber fitting of the cover. Finally, apply at least two layers of marine grade varnish to the antenna: before this it is advisable to clean and polish the whole loop tubing; it should be shining without any trace of copper oxide. The mast and the tuning box should also be weather protected with the same varnish. Now the loop is ready to be put in place.

**GUYING.** Do not underestimate the weight and the wind-loading area of the antenna. A good guying system is required. I used three nylon guys at 120° from the top of the mast and another three guys from the upper part of the pedestal. The antenna survived for many years without problems, resisting gales very well. Use good nylon single wire and stainless turnbuckles for the correct tensioning.

Photo 1 and 2 show how to use a longer mast if you decide to make the antenna rotatable; a longer mast is required to obtain clearance of the guys for free rotation. The guys must of course be connected to a rolling bearing fixed on the mast top to permit rotation.

**FEEDING THE LOOP.** According to my experience, the best feeding method is by inductive symmetric coupling using RG8 or RG213 coaxial cable. I adopted the same design as that of the German commercial Loops AMA series by Christian Kaeferlein, DK5CZ, later followed also by Hans Wurtz, DL2EA and others.

This feeding loop has a particular symmetric configuration, shown in **Figure 3**. The correct circumference must be determined experimentally to obtain the lowest SWR. The length should be approximately 1/5 of the length of the main loop. The coax line forming the feed loop is open at top centre. The braid on the input side of the opening is unconnected. The inner conductor and braid on the other side of the opening are shorted and grounded together with the braid of the input side at the bottom. Affix the feed loop at the centre bottom of the main loop in the same plane and keep it close to the main loop conductor (see **Photo 9**).

Use two stainless steel hose clamps interconnected at 90° to keep the loop in place. Attach one clamp tightly to the aluminium pipe of the loop supporting mast. Screw the other clamp tightly to the lower terminal joint of the feed loop. **Figure 4** shows the general arrangement. This mounting system ensures that all the bottom parts of the main loop and feed loop are grounded. An efficient earth connection is very important to obtain a low SWR and good antenna performance.

I suggest the following procedure to determine the right dimension of the feed loop. Testing should be done at 80m, as this is the middle band. You will have to use the tuning capacitor to tune the loop to resonance at the test frequency.

Prepare a length of coax a bit longer than calculated. Form the loop, soldering the lower side connections. Fix a PL259 plug at the input end. Now determine the top side centre and remove jacket, braid and insulation for about 20mm, leaving the inner conductor intact. Make a temporary connection of braid of the output side and inner conductor at the top and put the feed loop in place. With an antenna analyser (or simply with a SWR bridge and a low power transceiver connected at the base of the antenna), check the SWR. Compress the feeding loop top side downward - you should see a reduction of the SWR. This confirms that the circumference is too long. Now cut the centre top side and symmetrically trim the feed loop length on both sides of the top opening, then reconnect the parts.

Proceed in this way until you find the best SWR. Normally you should obtain a 1:1 SWR in 40 and 80m, a bit higher on 160m. Finally, you can permanently fix the feed loop to the mast after protecting the top with self-amalgamating tape and a plastic clamp the feeding coax line (RG8 or RG213) and the tuning motor power line must be kept vertical for about 1m under the low side of the loop, otherwise these conductors will tend to be coupled to the main loop (with consequent difficulty in obtaining the lowest SWR).

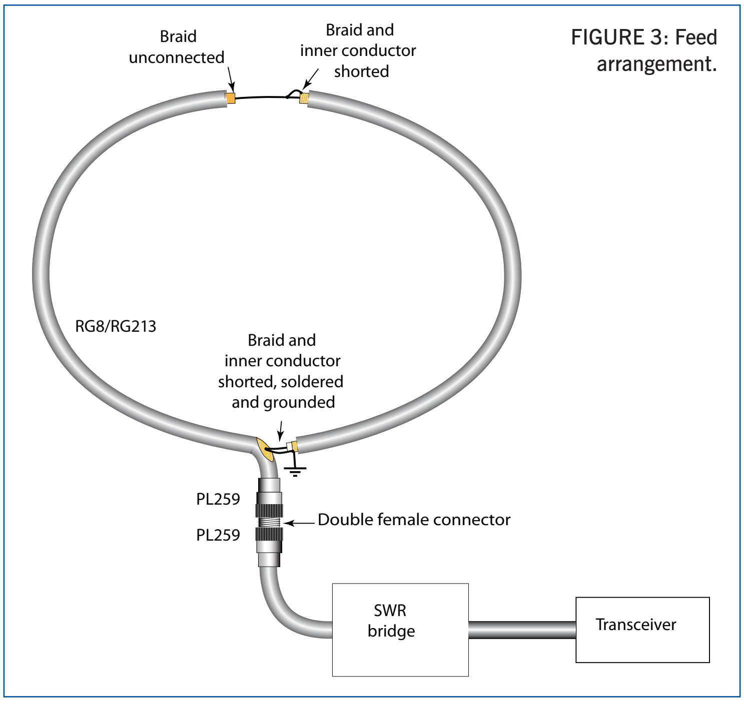


FIGURE 3: Feed arrangement.

**OPERATING THE LOOP.** To operate, bring the loop to resonance at the required frequency by operating the speed and polarity controls for the tuning motor. Do this operation at low power. The resonant point is reached when the SWR bridge meter shows a sharp dip: adjust the tuning to obtain the minimum reflected power. You can now increase the RF power; you may have to adjust the tuning again for the best SWR. It goes without saying that all the above operation must be done with the transceiver in tuning mode (CW or AM) to obtain a steady RF signal to read the SWR bridge meter. To avoid keeping the transceiver in the 'tune' position too long (and to minimise the radiated interference to other band users), it is most advisable to tune initially on receive (tune for maximum received noise) to bring the antenna close to the correct tuning point for transmission. With a little practice you will be able to do all tuning operations in a few seconds.

**LOOP RADIATION EFFICIENCY.** As I said at the beginning, an acceptable radiation efficiency for a short loop antenna depends on both a very low value for the ohmic losses of the system and from the shape and size of the loop. The radiation resistance of the antenna can be as low as a few milliohms. Bearing these parameters in mind, the ohmic loss is practically the only factor where it is possible to do something to improve the radiation efficiency.

Important factors are the quality and diameter of the conductor and the quality of the joints. Copper tubing of large diameter is important for good results as well as good quality in the joints, but the tuning capacitor must be considered the heart of the antenna.

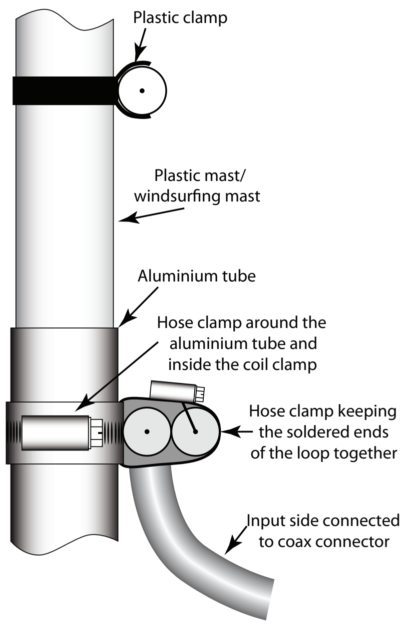


FIGURE 4: Mounting the feed.

For the low bands it is preferable to employ vacuum capacitors instead of conventional open capacitors, which are large and heavy because of the high capacitance required for such bands. The vacuum capacitor is certainly the most expensive part of the antenna, but with a good quality capacitor you are sure to obtain excellent results.

I suggest a research on the web to find such a component, as well trying rallies where acceptable prices can be found. Another important point is the RF power to be applied to the antenna. It is an intrinsic characteristic of small loops that *extremely* high RF voltages and currents are present. If you exceed the voltage limit you risk blowing up the capacitor in few seconds. Therefore forget the use of high power amplifiers, otherwise very, *very* high voltage capacitors are required. Such capacitors are rare and extremely expensive – and other insulation problems arise. The antenna gives good performance with the classic transceiver power of 100W. For this, the vacuum capacitor rating should be in the range of 5-8kV. The maximum capacitance should be about 1000pF if you intend to operate on Top Band, otherwise this value can be proportionally reduced.

**COMPARISON WITH CONVENTIONAL ANTENNAS.** When I began experimenting with the small loop, I was rather sceptical of the results to be achieved and I was motivated by curiosity rather than conviction. Soon I discovered the peculiarities of this antenna, which was quite different from other classic systems used during my long ham activity. I collected all possible information (very scarce at that time) to verify the real possibilities of this antenna and soon I wanted to compare the loop with conventional antennas.

One of the simplest systems for an average radio amateur to use to test an antenna is the

PHOTO 8: Using hose clamps to secure cables to the loop ends.

comparison method. This method is certainly not scientific but gives an indication of the performance of an unknown antenna relative to another, well known antenna. My conventional antenna was a classic monobander for 14MHz – a half wave dipole made in aluminium tubing, mounted on a telescopic mast 10m above my flat roof. The antenna to be compared was a 1m diameter loop of 22mm copper tubing, tuned with a motorised split stator capacitor. This loop was kept in place by a Black & Decker working table at about 1m above the floor of the flat roof of my house. The loop had a feeding coax cable of the same length of the dipole and both antennas presented a 1:1 SWR and the same orientation. The only difference was the polarisation: the loop was vertically polarised; the dipole, horizontal. In the shack, a switch permitted the quick switching of the two antennas.

I did tests with this setup for several months, operating both by day and night, with different propagation conditions, in transmit and receive mode – all without disclosing to my correspondents the type of antenna in use to avoid any possible 'psychological' influence. The power was less than 100W and the mode SSB. The test results were interesting. At a range of about 2000km the reports were practically the same, within a few dB. Sometimes the loop was better and sometimes slightly worse: on averaging the results I concluded that there was parity between the two antennas. For longer range (and in particular for DX) the dipole was definitely better, with differences between two or three S-points, nevertheless, I was able to make many contacts all over the world with this small loop.

Concerning the square loop for low bands, it was not possible to compare the antenna with a dipole without the space to erect such an antenna, but it compared with a vertical antenna for the 40m band. The results are very similar to the above. On relative short distance I constantly receive the same reports with the vertical antenna but in some instances the loop was better. Without too much effort I succeed also in transatlantic QSOs, showing a good radiation efficiency on this band, as expected. Reports at medium range are most of the time around S9.

On the 80m band no comparison was possible but the reports obtained are quite

PHOTO 9: The finished feed.

remarkable at 500km range, with figures between S9 and 20dB over 9. Also, Top Band surprised me very much. The calculated efficiency is quite low, as the loop is only 1/16 wavelength: nevertheless, I was able to make excellent contacts, mostly around 300km with reports of 10dB over 9. I had QSOs with almost all European countries. The bandwidth drops dramatically, reaching a value around 2kHz on 160m, making tuning critical: such operation must be done at a minimum motor speed. The people I worked were very surprised to learn of the type of antenna in use. In receiving mode the loop is excellent: it is possible to copy low signals without difficulties due to the antenna's low noise characteristics.

In any case it must be noted that on the low bands it is much more difficult to erect classic wire antennas half wave up over ground and, therefore, a good short loop can often win the competition because it is keeping an acceptable radiation efficiency at a very low level over ground due to the intrinsic magnetic characteristic of the antenna in the near field, which makes it less subject to ground losses.

**CONCLUSION.** In my opinion the short loop can be considered a good alternative when is impossible to erect efficient conventional antennas for the low bands. However, an efficient loop is not so easily built: you need excellent components and accurate mechanical and electrical handiwork; otherwise the risk of disappointment is high. Furthermore, it is rather annoying to have to tune the antenna every time you change the frequency by even a few kHz, but this can be also considered an advantage because the loop is acting as a filter on both transmit and receive. Another advantage is also that a loop this size may open the possibility of Top Band experiments, perhaps for the first time in your ham life, as happened to me.