Small Loop Antenna Systems for the 80m to 10m Amateur Bands

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1 Introduction

This article describes the development of two tunable antennas each consisting of three interconnected small loops and capable of providing excellent DX performance. The aerials are home-constructed, and located in a very small garden with a minimum of visual impact on the neighbours and are low enough in height to avoid the attention of UK planning authorities.

Illustration 1 shows a general view of two triple loop antennas. The LF Antenna is the size of a 10m cubical quad and covers 80m to 20m, whilst the HF Antenna, covering 40m to 10m, is similar in size to a 4m quad.

The experience gained in designing, building and testing these small loop arrays seems to support the common-sense notion that final results are most favourable when as much resonant copper is erected within as big a volume as possible. These guidelines probably apply to any type of antenna but are particularly important where height is lacking as in most small loop installations. EZNEC modelling of vertically polarised small loop arrays for the 80m to 10m bands suggests that low angle radiation DX gain is prejudiced when the array height approaches $\lambda/2$ and this factor should be considered when implementing arrays for the higher frequencies. The normal horizontal polarisation guideline of achieving the highest practicable antenna height seems not to apply for small vertically polarised loop installations.

Illustration 1: Foreground is HF and background is LF Triple Loop Antennas

2 Summary

For many years radio amateurs have reported that small loop antennas have been found capable of providing useful service on the HF bands, but little detailed performance data has been offered to support the observations and loop antennas have generally been relegated to Receive Only usage. The introduction of Joe Taylor's (K1JT) excellent WSPR software has provided a tool which allows accurate on-air measurements of station performance to be made. Comparative reports over lengthy periods of time against the range of antennas used by other stations can be assessed to aid in answering the long-debated question "do small loop antennas really work?".

In 2010 I commenced a project to investigate the performance of a series of small outdoor loop antennas compared against a conventional off-centre fed 132ft horizontal wire, using WSPR, and latterly EZNEC +5.0 antenna modelling software, as the investigation tools.

Early practical tests indicated that a marked improvement in performance for DX could be attained by using an array of small loops configured to use correctly phased currents and vertical polarisation, instead of the usual single loops.

This finding changed the scope of the investigation into refining the small loop array design to provide optimised DX performance.

Two years of WSPR observations on an array of two stacked 6ft diameter octagonal loops remotely tuned by a single vacuum variable capacitor showed that excellent WSPR DX and local contacts were possible using 5 watts of RF power at the antenna. This antenna covered the five bands 80m through to 20m. In general there appeared to be little consistent difference between the OCF antenna and the loop array, with QSB causing much greater changes in reported signal strengths than antenna type.

The most surprising observation was the excellent performance of the dual loop array on 80m where many two-way WSPR spots were exchanged with W amateurs through the winter months. Similarly many G to VK/ZL WSPR two-way spots were obtained on 20m with consistently good signal reports. These results showed that the small loop array could be a very serious antenna indeed. Whilst not competitive in absolute signal strength with the best high horizontal aerials or tall verticals over radial mats, the low radiation angle of the loop array produced DX spots under most reasonable band conditions at the present stage of the sunspot cycle.

The antenna design producing these results was then investigated using EZNEC +5.0, which is capable of modelling loop antennas, and the favourable low angle radiation characteristics were confirmed. The modelling software was then used to optimise the aerial design. Various loop array configurations were investigated until the final three-loop design emerged in the Spring of 2013.

The final LF Triple Loop aerial shown in Figure 1 is roughly the size of a 10m Cubical Quad antenna being a cube of three 7ft x 7.5ft square loops, 5.5ft wide, with a top height of only 13.5ft, tuned by a single 10 to 1000pF vacuum capacitor located under a plastic cover at the top of the array at 15ft. The array is mounted on a simple home-brew wooden mast which may be manually telescoped to bring the complete antenna down to a maximum height of 10ft for maintenance, adjustment or planning permission avoidance. The aerial covers 80m to 20m with measured limits of 2.6MHz to 14.8MHz.

Loop dimensions were chosen to give the largest array volume consistent with covering 20m at the HF end of the tuning range. This approach maximises the gain on all bands in the EZNEC model.

Having established satisfactory on-air performance of the LF Triple Loop a smaller version was designed to cover the higher frequency bands. This HF Triple Loop antenna is pictured in Figure 2. It covers 40m to 10m and is a cube of three 3ft x 3ft square loops, 3ft wide, with a top height of 9.75ft.

Loop dimensions were chosen to cover the 10m band at the top of the tuning range offered by a single 8 to 500pF vacuum capacitor. The overall tuning range of this antenna is 6.8MHz to 31MHz and in use this aerial is mounted on a Rotator.

The use of three loops in parallel on both antennas enables the circulating current to be shared evenly between the loops. The Q of the complete array is lower than that of a single loop resulting in lower loop currents and less sharp tuning besides producing lower RF voltages across the single tuning capacitor. The use of three larger loops replacing a single small loop for a given frequency significantly increases the radiation resistance of the antenna reducing the effect of resistive losses.

Losses are further minimised by the use of 22mm diameter plumbers copper tubing to form the loops, individual sections being joined by soft-soldered 90deg or 45 deg elbows. Whilst the copper tubing is fairly heavy and expensive it has the advantage of producing a solid integrated structure with a much lower RF loss than thinner tubing or wire. It may be preferable to use silver soldered joints but soft soldering appears to be satisfactory provided each joint is carefully made. It is vital to clean all parts initially, even with new copper components, then apply flux and solder using a gas torch in still weather conditions. Each joint should be double checked visually before erection since later detection of poor joints is difficult.

The cube of loops is fed by UR67 coaxial cable via a 1:2 step-up transformer, converting the 50Ω feed impedance to 200Ω, coupled into a 3-sided triangular secondary feed loop of 8mm diameter copper tubing attached to one main outside loop at two points. This novel feed method, after proper spacing adjustment, can provide a SWR better than 1.2:1 over the complete frequency range of the aerial.

The top vacuum capacitor position is based upon EZNEC modelling which shows a distinct advantage in locating the capacitor at the top of the loop. Whilst a lower position would be much easier mechanically the low angle DX gain reduction in an optimised array would be significant.

The 5.7:1 frequency tuning range of the LF antenna means that the antenna type changes from a low impedance sharply tuned “small loop” array at the 80m end to a conventional antenna with a fairly flat frequency response and high radiation resistance at the 20m end.The frequency coverage of these antennas is so wide that at the HF end they do not satisfy the accepted criteria as a small loop with uniform current around each loop. Nevertheless the antennas work well in the real world so the inapplicability of small loop design formulae is merely an inconvenience.

The vacuum capacitor used in the array has a working voltage of 3kV. Higher working voltages are preferable especially if high RF power operation is contemplated. Conventionally WSPR mode uses powers of 5 watts or less, resulting in peak RF voltages well within the 3kV rating of the capacitor.

Measured loop and capacitor currents on both antennas and array Q calculated from field strength measurements are all lower than EZNEC predicted values implying lower gain, but on-air results are excellent. If the practical measurements are confirmed as accurate then higher RF powers can safely be used with the 3kV rated capacitor on this aerial. The accuracy of NEC-based model predictions for small loops has been questioned by some experts as being too pessimistic and WSPR results on the triple loop array appear to confirm these suggestions.

The performance of the array has been evaluated using WSPR over many months and the LF Triple Loop array has been confirmed to be superior to the early stacked dual version on all bands in its range. The stray capacitance across the vacuum capacitor is also lower on the triple loop design giving wider frequency coverage.

The high Q of Loop antennas and the associated sharp tuning necessitates the use of a very high resolution low loss tuning capacitor. The stepper motor, gearbox and vacuum variable capacitor employed on the LF Triple Loop array provides a step resolution of 0.1pF over the range 10 to 1000pF. This ensures that even at the lowest frequency the minimum SWR point may be reached in observable small steps when the stepper is running very slowly. There is inevitably a small amount of mechanical backlash but since the speed of stepper motors can be controlled over a wide range accurate tuning to the SWR null is easy and repeatable. Since fine tuning is essential near resonance a consequent disadvantage is the time required to tune over the whole capacitor range. On this array 'end to end' tuning at maximum motor speed requires about 30 seconds but this allows retuning to be accomplished and checked well within a 2 minute WSPR Transmit cycle time.

A useful additional facility has been developed providing automatic tuning of the antennas. The stepper motor drive circuits use the sensed SWR on the WSPR 5W transmission to control the motor speed down to zero at resonance. The motor direction is derived either from the station Icom IC756Pro DC output normally used for setting the band of an associated Linear Amplifier or external Antenna Tuner, or can be set manually. Recent upgrading of the transceiver to an IC7600 uses exactly the same system.

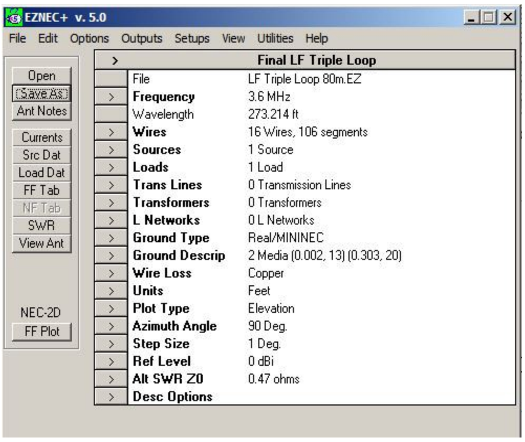
Illustration 3: HF Triple Loop at 9.75ft height

Illustration 4: Antenna telescoped down for maintenance

Illustration 5: View of Vacuum Capacitor connections to LF Triple Loop Antenna

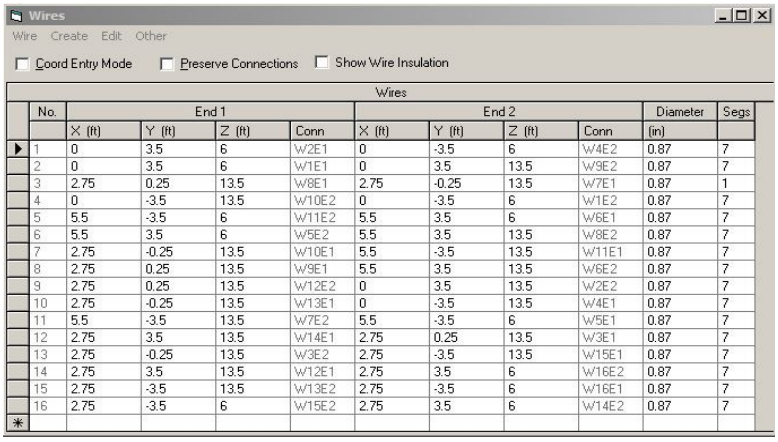
3. EZNEC Design Details

The details of the EZNEC +5.0 model are shown below. These include the physical construction and performance predictions. The EZNEC SWR plots are compared against the actual SWR measurements derived from a SARK110 Antenna Analyser.



	Final LF Triple Loop
File	LF Triple Loop 80m.EZ
Frequency	3.6 MHz
Wavelength	273.214 ft
Wires	16 Wires, 106 segments
Sources	1 Source
Loads	1 Load
Trans Lines	0 Transmission Lines
Transformers	0 Transformers
L Networks	0 L Networks
Ground Type	Real/MININEC
Ground Descrip	2 Media (0.002, 13) (0.303, 20)
Wire Loss	Copper
Units	Feet
Plot Type	Elevation
Azimuth Angle	90 Deg.
Step Size	1 Deg.
Ref Level	0 dBi
Alt SWR Z0	0.47 ohms
Desc Options	

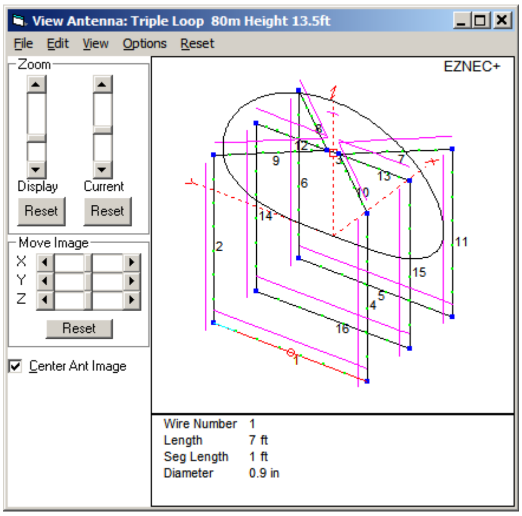
Table 1: EZNEC v 5.0 Model Main Parameters



☐ Coord Entry Mode ☐ Preserve Connections ☐ Show Wire Insulation

No.	End 1 X (ft)	End 1 Y (ft)	End 1 Z (ft)	End 1 Conn	End 2 X (ft)	End 2 Y (ft)	End 2 Z (ft)	End 2 Conn	Diameter (in)	Segs
1	0	3.5	6	W2E1	0	-3.5	6	W4E2	0.87	7
2	0	3.5	6	W1E1	0	3.5	13.5	W9E2	0.87	7
3	2.75	0.25	13.5	W8E1	2.75	-0.25	13.5	W7E1	0.87	1
4	0	-3.5	13.5	W10E2	0	-3.5	6	W1E2	0.87	7
5	5.5	-3.5	6	W11E2	5.5	3.5	6	W6E1	0.87	7
6	5.5	3.5	6	W5E2	5.5	3.5	13.5	W8E2	0.87	7
7	2.75	-0.25	13.5	W10E1	5.5	-3.5	13.5	W11E1	0.87	7
8	2.75	0.25	13.5	W9E1	5.5	3.5	13.5	W6E2	0.87	7
9	2.75	0.25	13.5	W12E2	0	3.5	13.5	W2E2	0.87	7
10	2.75	-0.25	13.5	W13E1	0	-3.5	13.5	W4E1	0.87	7
11	5.5	-3.5	13.5	W7E2	5.5	-3.5	6	W5E1	0.87	7
12	2.75	3.5	13.5	W14E1	2.75	0.25	13.5	W3E1	0.87	7
13	2.75	-0.25	13.5	W3E2	2.75	-3.5	13.5	W15E1	0.87	7
14	2.75	3.5	13.5	W12E1	2.75	3.5	6	W16E2	0.87	7
15	2.75	-3.5	13.5	W13E2	2.75	-3.5	6	W16E1	0.87	7
16	2.75	-3.5	6	W15E2	2.75	3.5	6	W14E2	0.87	7

Table 2: LF Triple Loop dimensions



Wire Number	1
Length	7 ft
Seg Length	1 ft
Diameter	0.9 in

Figure 1: Physical arrangement of three loops in LF Triple Loop Antenna

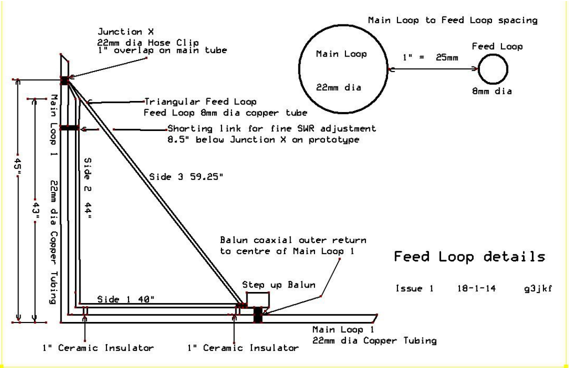


Figure 2: Secondary Triangular Feed Loop

In Figure 1 the pink lines indicate the relative current flowing in each tube. The direction of maximum radiation is in the plane of the loops. The radiation in the favoured direction shown is vertically polarised providing good DX performance at the low antenna height of 15ft max.

The wire (tubing) lengths and diameter shown in Table 2 apply to the cube of three loops shown in Figure 1 which also shows the elevation radiation pattern for 80m in the favoured azimuthal direction. The tuning capacitor (Load) is located in the centre of Wire 3 (W3), a nominal 6" section of 22mm copper tubing. This tube is divided into two 3" sections well insulated from each other by a pair of HV pyrex glass insulators as shown in Illustration 9. The capacitor is linked to the ends of W3 by two pairs of flexible thick copper braid and short sections of 22mm tubing. Two pairs of stainless steel hose clips tighten and secure the braids to W3. Note that the braid connections are as short as physically possible to minimise series resistance and inductance. The braids are the copper screens salvaged from scrap UR67 coaxial cable.

Although the EZNEC model shows the feed point at the centre of Wire 1, this position is arbitrary. In practise the coupling loop shown in Figure 2 carries a 1:2 step-up balun which transfers RF from the feed coax cable into the triangular secondary loop which is inductively and directly coupled into the 1st loop of the main aerial. Matching is optimised by small adjustments to the secondary loop spacing from the main loop and a moveable shorting block at the upper end. A spacing of 1" between tubing perimeters provided lowest SWR's circa 1.2:1 at resonance on each band on the prototype.

A change to improve array symmetry is under investigation. The feed system is being transferred to the centre loop allowing the use of physically identical outer loops.

A major objective of achieving low SWR on every band is to facilitate automatic tuning of the vacuum capacitor. However the developed auto-tuning system is able to cope with resonance SWR's in excess of 2.0:1.

The Load vacuum capacitor assembly is built on a wooden base and housed in an inverted plastic kitchen waste bin with an open base where the braids drop down to the 22mm tubes on each side which connect to W3 as shown in Illustration 3. The waste bin is strengthened by creosoted wooden strips internally and externally to support the complete assembly which is screwed to the telescoping wooden mast. The stepper motor, gearbox, limit switches and 15way D Type cable connector are located above the capacitor. No problems due to water ingress have been experienced over several years of operation. Oxidisation of the copper tubing occurs and new methods of braid connection are being investigated to remove the possibility of increased joint resistance due to tarnishing.

Illustration 6 shows the vacuum capacitor employed in the LF Triple Loop Antenna. The capacitor was salvaged from a Collins 180L Antenna Tuner procured on ebay. The DC motor control originally used is too coarse for the small loop application where a capacitance resolution of 0.1pF is desirable for accurate tuning at the lowest frequency. The DC motor of the Collins Unit is replaced by a stepper motor. The modified vacuum capacitor assembly is shown with the stepper motor mounted on a new end plate with a pinion fitted on the shaft mating with the original gear wheel. Illustration 7 shows the stepper motor and vacuum capacitor assembly with additional end stop microswitches wired in parallel with the original sensors to improve reliability of end stop sensing.End stop sensing in the Collins 180L uses open relay contacts which break contact at maximum and minimum capacitance. These are augmented by a pair of added microswitches wired in parallel with the original contacts to overcome tarnishing and unreliable operation of the unprotected relay contacts. Both sets of contacts must be open circuit to action the relevant end stop process.

Illustration 6: Vacuum Capacitor from Collins 180L with modified motor and pinion.

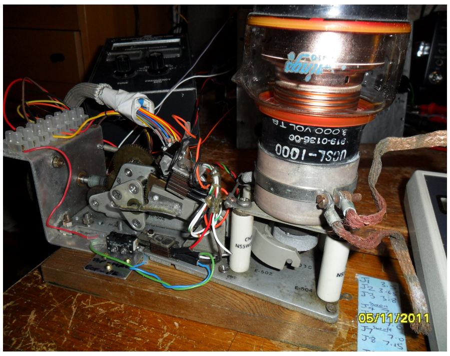


Illustration 7: Modified 180L Vacuum Capacitor assembly showing stepper motor pinion and additional end stop sensing.

Illustration 8 shows an alternative stepper motor assembly and gearbox. This unit houses an 8 to 500pF vacuum capacitor procured on ebay. It is used on the HF Triple Loop antenna.The home brew vacuum capacitor assembly employs a stepper motor type Fuji SM55-4830-A. The motor, pinion and plastic gears were obtained from www. alltronics.com in Santa Clara, CA. (ebay).

Illustration 8: Vacuum Capacitor Assembly with homebrew gearbox and stepper motor.

Illustration 9: Secondary Feed Loop and SWR adjustment Shorting Link

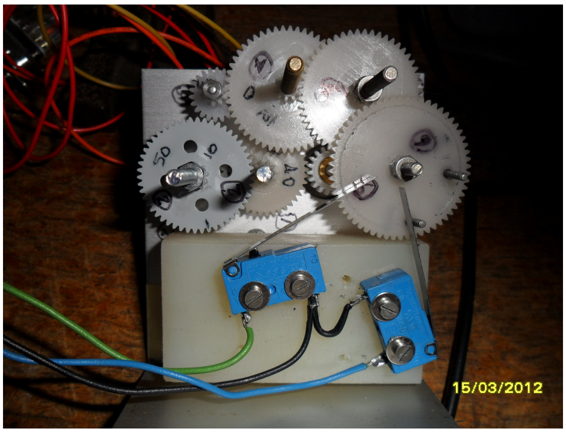


Illustration 10: Homebrew Stepper Motor Gearbox showing end stop sensing microswitches

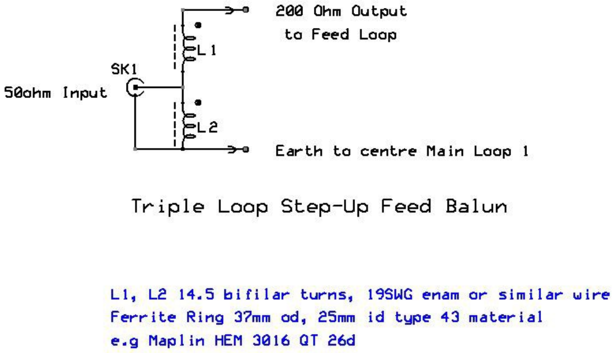


Figure 3: Triple Loop Feed Balun

The triangular Feed Loop shown in Figure 2, and Illustration 9 couples the 50Ω coaxial cable feeder into the 1st loop of the antenna via a 1:2 step up balun. The feeder outer is physically connected to the centre of the 1st loop which is at zero RF volts potential. The three loop structure is supported on four insulators adjacent to the tuning capacitor connections as shown in Illustration 11. These points are at high RF voltage and good insulation is vital. However the lower centre of each loop at nominal zero RF potential is simply supported on pyrex insulators tied to the wooden crossbeam using nylon fishing line. The cross beam bears the main weight of the antenna.

Initially the main loop to feed loop spacing can be set to 1 inch as shown in Figure 2. During test after the capacitor has been adjusted for resonance indicated by a sharp SWR dip, the SWR may be adjusted by swinging the feed loop sideways by increments of 0.25 inch at the lower corner of the feed loop.

These adjustments are facilitated by repeated measurement runs using an Automatic Antenna Analyser since all bands are affected by each spacing change and an overall compromise setting needs to be established. However when the best overall spacing has been obtained a further adjustment may be made using a shorting link between the vertical feed loop section and the main loop as shown in Illustration 9.

On the prototype SWRs were refined from 1.3:1 down to 1.1:1 by optimal setting of the link. If the link is positioned approximately 2 inches from the bottom corner of the feed loop the SWR rises to about 2:1 on each band at resonance.

Since measurement of SWR and adjustments for matching, together with more radical experimental changes to the Triple Loop Antenna structure require many iterative measurements a simple method of easily achieving this has been developed.

A SARK 110 Antenna Analyser is positioned right at the antenna balun PL259 feed input. This is enclosed in a plastic bag to allow operation in rainy weather and has been calibrated to operate with a 6 inch long PL259 to BNC terminated cable which interfaces to the SARK Unit antenna cable.

The SARK 110 USB output connects to a Laptop PC operating under cover in a garden shed via a 30ft long USB cable. The Laptop operating under Windows XP runs SARKPlots software developed by Melchor Varela EA4FRB.This program controls the analyser operation and displays the outputs. Also running is TeamViewer 10.

The operating shack houses the complete station including an IC 7600, Loop Antenna Control Unit, local FS710H Power/SWR Meter, and switching to allow either of the Loop Antennas to be controlled and used on the transceiver. Also available is a remotely controlled Field Strength Meter located 50feet from the LF Triple Loop Antenna. A Desktop PC and large Monitor running under Win 7 provide WSPR Control and Display facilities when required. TeamViewer 10 software is also running.

When measurements are required a wireless link is established between the two computers using the standard non-commercial TeamViewer facility. This allows the Laptop to be completely operated remotely from the Desktop PC in the comfort of the shack where changes to the Loop tuning may be initiated with the resulting frequency and SWR/Xs change immediately plotted on the PC screen. Illustration 11 shows the remote display as transferred to the shack PC.

SARK Plots allows direct comparison of earlier stored responses against the current response, and accurate measurement of all the usual antenna RF parameters.

In practice an antenna configuration change is first examined on the Laptop SARK Plots display and any tweaking carried out for the single selected band. The shack PC is then used to provide SARK Plot responses for all the selectable bands with tuning provided by the Loop Antenna Control Unit adjacent to the PC. This setup allows a complete set of 5-band SWR/Xs responses to be produced and committed to memory in less than 30 minutes.

Frequency Control
Center 7,100,000
Span 200,000
Start 7,000,000
Stop 7,200,000
Presets

Cursor
☑ Enabled
Cursor: 7,098,425 Hz
VSWR: 1.04
Xs: 0.50
Impedance: 51.76 +j 0.50
VSWR: 1.04 :1

Left Y: VSWR
☐ Max 7,000,000 Hz 100.00
☑ Min 7,099,200 Hz 1.04

Markers
M1:
M2:
M3:
M4:7,100,000 Hz
VSWR: 1.07
Xs: -3.38

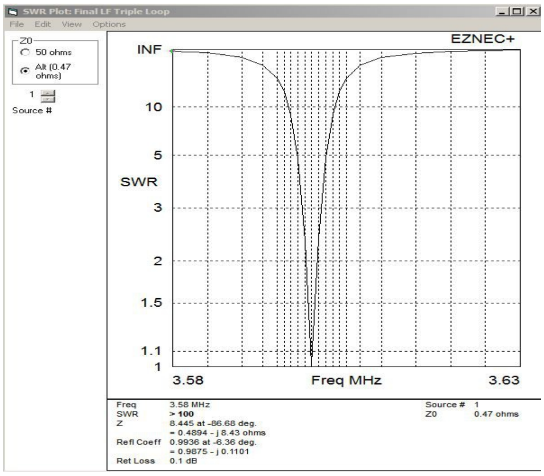
Illustration 11: TeamViewer display of remote SARK 110 SWR/Xs plot

Illustrations 12 and 13 show the general method of assembling a supporting top structure using standard 22mm 90º and 45º joints and Tee pieces. The pictured assembly shows a later improved structure used on the HF Triple Loop Antenna but it can equally be applied to the LF Triple Loop Antenna. It demonstrates the need for good insulation at the high voltage end of the loops across the capacitor connections. Also shown is the use of 22mm copper tubing elements links as close to the capacitor as possible to minimise connection resistance and inductance.

Illustration 12: HF Triple Loop Top support structure

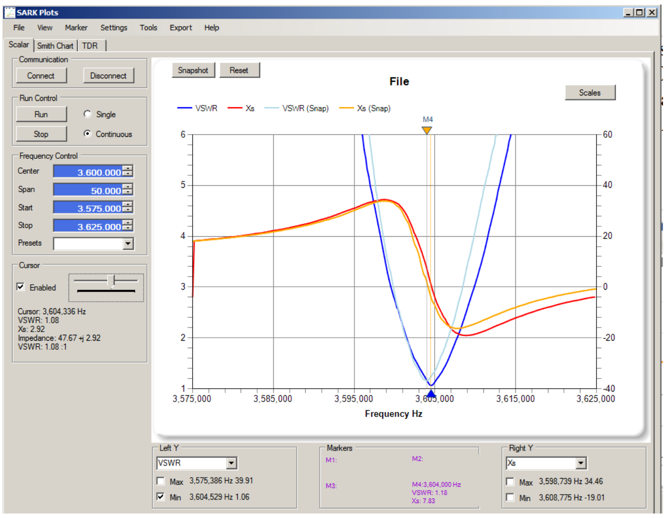
Illustration 13: Top of HF Triple Loop resonance check

Figure 6 illustrates the EZNEC predicted SWR characteristic at 80m which shows 2:1 SWR points 1.7kHz apart and Antenna Impedance of 0.46 Ohms. Figure 7 shows the SARK 110 Antenna Analyser actual measured SWR on 80m at the antenna balun feed point showing 2:1 SWR bandwidth of approximately 6kHz and feed impedance as plotted in SARKPlots by Melchor Varela EA4FRB.



```
Freq       3.58 MHz                                   Source #   1
SWR        > 100                                      Z0         0.47 ohms
Z          8.445 at -86.68 deg.
           = 0.4894 - j 8.43 ohms
Refl Coeff 0.9936 at -6.36 deg.
           = 0.9875 - j 0.1101
Ret Loss   0.1 dB
```

Figure 6: EZNEC prediction of 80m SWR



○ Single
● Continuous

Center 3.600.000
Span 50.000
Start 3.575.000
Stop 3.625.000

☑ Enabled

Cursor: 3,604,336 Hz
VSWR: 1.08
Xs: 2.92
Impedance: 47.67 +j 2.92
VSWR: 1.08 :1

Left Y: VSWR
☐ Max 3,575,386 Hz 39.91
☑ Min 3,604,529 Hz 1.06

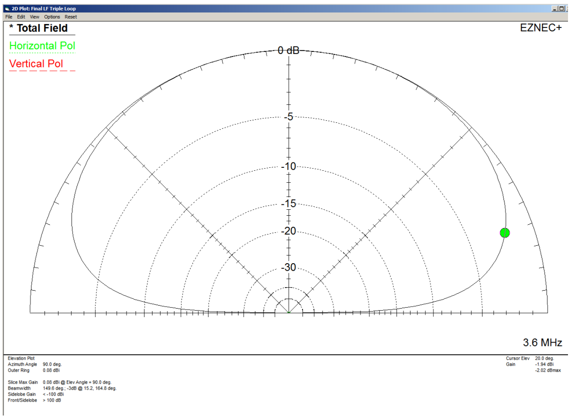
M1:
M2:
M3:
M4:3,604,000 Hz
VSWR: 1.18
Xs: 7.83

Right Y: Xs
☐ Max 3,598,739 Hz 34.46
☐ Min 3,608,775 Hz -19.01

Figure7: SARK 110 plot of 80m SWR and Xs at balun input

Figure 4 shows the EZNEC v5 prediction for the vertically polarised Elevation pattern of the LF Triple Loop Antenna on 80m. Quoted gain figures are derived from the pattern at 20° elevation angle.

Figure 5 illustrates the model predictions for the Tribase version of the LF Triple Loop Antenna on the five bands covered by the aerial. The maximum gain plot is 20m.



```
Elevation Plot                                                    Cursor Elev   20.0 deg.
Azimuth Angle    90.0 deg.                                        Gain          -1.94 dBi
Outer Ring       0.08 dBi                                                       -2.02 dBmax

Slice Max Gain   0.08 dBi @ Elev Angle = 90.0 deg.
Beamwidth        149.6 deg.; -3dB @ 15.2, 164.8 deg.
Sidelobe Gain    < -100 dBi
Front/Sidelobe   > 100 dB
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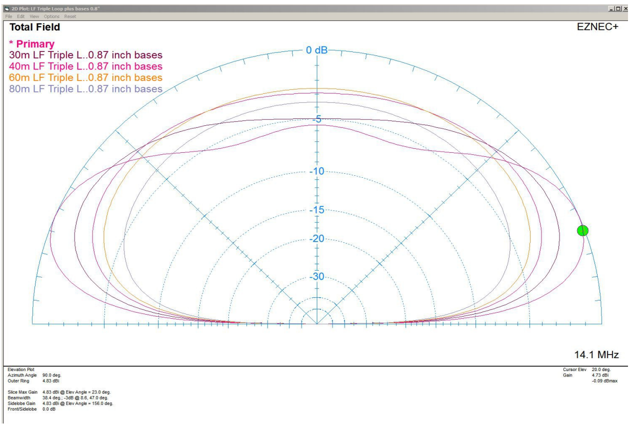
Figure 4 : EZNEC Triple Loop 80m Elevation Pattern



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Elevation Plot                                                    Cursor Elev   20.0 deg.
Azimuth Angle    90.0 deg.                                        Gain          4.73 dBi
Outer Ring       4.83 dBi                                                       -0.09 dBmax

Slice Max Gain   4.83 dBi @ Elev Angle = 23.0 deg.
Beamwidth        38.4 deg.; -3dB @ 8.6, 47.0 deg.
Sidelobe Gain    4.83 dBi @ Elev Angle = 156.0 deg.
Front/Sidelobe   0.0 dB
```

Figure 5 : EZNEC Tribase LF Triple Loop Elevation pattern predictions for five bands 20m to 80m

Appendix 1 Comparison of Small Loop configurations

The performance of various small loop configurations was evaluated using EZNEC +5.0 which is capable of modelling loop antennas. The original dual stacked array model was compared against other single and multiple loop designs using both parallel and series connected loops.

Whilst modelling showed that single loops could provide similar gains to a multi-loop design at the highest antenna frequency, the single loop impedance was less than 1/10 of the parallel multi-loop figure showing the need for a very low loss design to reach the modelled performance. Such low losses are practically unachievable.

It should be noted that at the higher frequencies for each antenna they are not strictly “small loops” and the formulae normally associated with small magnetic loop antennas do not apply.

At the lower frequencies covered by each antenna the reduced gain for the single loop against the multi-loop design approached 4dB plus any inevitable additional copper losses due to the 1/10 impedance ratio.

Multiple series-wired loops require much smaller tuning capacitance for a given frequency, or none if resonated by self-capacitance, and the area of the loop is smaller than the equivalent single loop, or multiple parallel loop array. The resultant gain and impedance reductions rendered this configuration impracticable.

Figure 1 illustrates the Gain and Impedance figures for an EZNEC calculated series of single small loop aerials compared against a new design HF Triple Loop Antenna, and the LF Triple Loop aerial described in this document. All loops are square to minimise the number of soldered joints in the construction.

Figure 2 shows the same series of aerials with calculated Gain and Tuning Capacitance plotted against frequency.

In the chart the single loop antennas are virtually self-resonant at the highest frequency. The loops are tuned by a capacitance of 10 to 15pF at the highest frequency except for the 40m Loop which is resonated by 30.9pF at 7.1MHz to achieve a practical loop size. All single loop aerial heights were selected to provide the highest gain at 20deg Elevation angle. Gain figures are plotted for all antennas at 20deg Elevation angle as a compromise radiation angle indicative of that needed for good DX performance. All antennas are modelled using 22mm (0.87inch) diameter copper tubing.

A useful increase in gain of approximately 1dB is achievable on all bands by use of three 22mm tubes in parallel as the base wire of each loop (W1, W5 and W16 in Figure 1).

EZNEC modelling appears inadequate to handle this tube configuration so an equivalent single tube of 66mm (2.6 inches) diameter, which has the same circumferential length as three parallel tubes, has been used in the model. This version of each antenna is referred to as the Tribase configuration.

All aerials are tuned at the middle of the top central horizontal tube since modelling indicates that this provides the best low angle radiation.

The Ground type used on all loop models is Real/Mininec for the authors location 1 mile from the sea on the UK south coast.

The modelled single loop and triple loop antenna details are summarised in Table A1 below:

Band	**Dimensions inches**	**Top Height ft**	**Single Loop Capacitance pf inc strays**	**Max Gain dBi**	**Max Impedance Ω and Band**
10m	32 x 32	8.5	10	3.5 @ 10m	0.6Ω @ 10m
12m	36 x 36	9.25	10.5	3.46 @ 12m	0.6Ω @ 12m
15m	44 x 44	10.9	11	3.43 @ 15m	0.67Ω @ 15m
17m	54 x 54	12.5	11	3.42 @ 17m	0.8Ω @ 17m
20m	72 x 72	15.25	12	3.34 @ 20m	0.92Ω @20m
30m	108 x 108	20.75	12.7	3.24 @ 30m	1.17Ω @30m
40m	120 x120	25	30.9	2.17 @ 40m	0.65Ω @ 40m
HF Triple Loop	36 x 36 x 36	9.75	18.6 to 514	3.95 @ 12m	**9.6 Ω @ 10m**
LF Triple Loop	84 x 90 x 66	13.5	31 to 1041	3.83 @ 20m	**15.5Ω @ 20m**
Tribase HF Triple Loop	37 x 37 x 36	9.75	18.6 to 514	5.47 @ 12m	**7.1Ω @ 10m**
Tribase LF Triple Loop	85 x 90 x 66	13.5	31 to 1041	4.73 @ 20m	**12.9Ω @ 20m**

Table A1: EZNEC derived data for square loop antennas

Square Loops Gain and Impedance

Figure A1 shows the Gain and Impedance of each type of aerial. It illustrates the good comparative gain of the triple loop arrays against the single loops at their optimum highest frequency, together with the desirable higher impedance of the triple loop arrays against the very low impedance of the single loops. The latter factor of the triple loop design provides much lower RF losses giving more flexibility of materials selection. Nevertheless the use of material such as 0.87inch diameter copper is essential to realise useful working DX gain on transmit. The Ground type used in the EZNEC models is Real/Mininec. Absolute Gain figures are representative only but all loop types use the same Ground characteristics so Relative Gains between all antennas should be realistic.

The predicted performance of two versions of each Triple Loop Antenna are shown.

The basic LF and HF Triple Loop Antennas use single 22mm (0.87inch) tubes for every part of each loop except for notional 0.5inch connections at the vacuum capacitor to represent the flexible copper braids.

Higher gain versions of the Triple Loop aerials are being tested. When EZNEC modelled these show a gain advantage in the region of 1dB. They use three closely-connected 22mm tubes to form the base of each loop. They are modelled as single tubes of 2.6inch diameter in the associated EZNEC model.

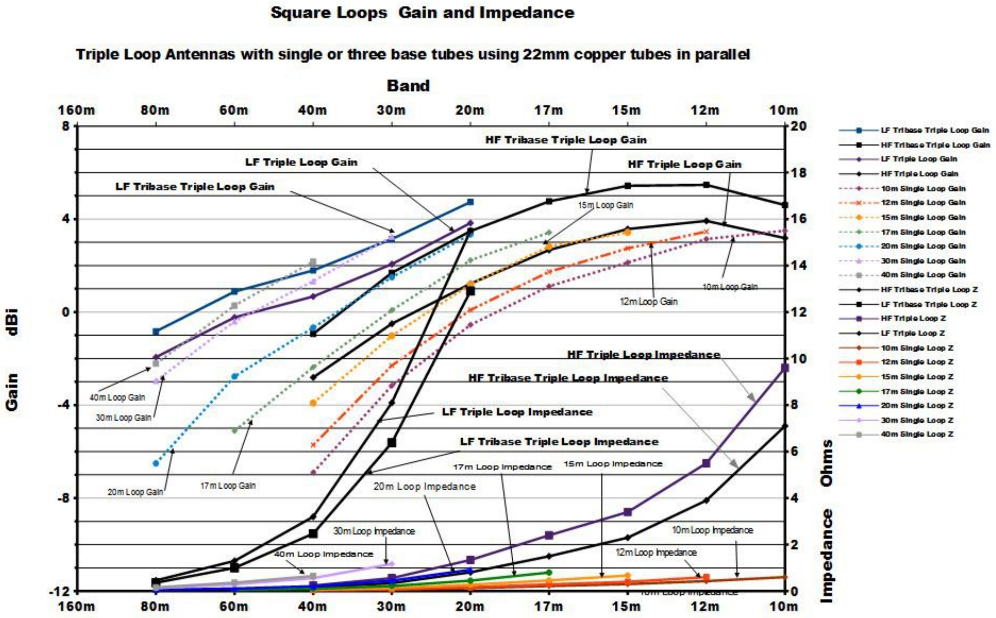

Figure A1: Chart showing Gain and Impedance for different Loop Antennas

Refer to the legends at RHS to identify each coloured plotted line. Gain dBi is shown at LHS with the Triple Loop plots as bold lines. The Impedance axis is at RHS with the much higher Triple Loop plots shown as bold lines.

Square Loops Gain and Capacitance

Figure A2 shows the Gain and tuning Capacitance required for each loop type. Each single loop is virtually self-resonant at its highest frequency where it exhibits the maximum gain. Loop height has also been selected to provide the highest gain at a low radiation angle for nominally best DX performance. The plots indicate the rapid fall-off in gain of the single loops as frequency is reduced compared to the higher impedance triple loop arrays. This loss characteristic would be even more severe with thinner tubing or lossier material. All plots assume zero resistive loss in the capacitor which is probably a reasonable assumption when using a vacuum capacitor but which might be unrealistic with less efficient tuning assemblies and connection methods.

The Gain and Impedance of the HF Triple Loop array on bands below 14.1MHz are shown for reference only since at these lower frequencies the LF Triple Loop array comes into use showing a gain advantage of 3 to 4dB. If a single antenna only is used the HF Triple Loop Antenna is capable of providing useful DX performance in spite of the lower gain. Additionally use of a Rotator on the smaller HF Triple Loop Antenna enables the array directivity to be used to boost signal reports.

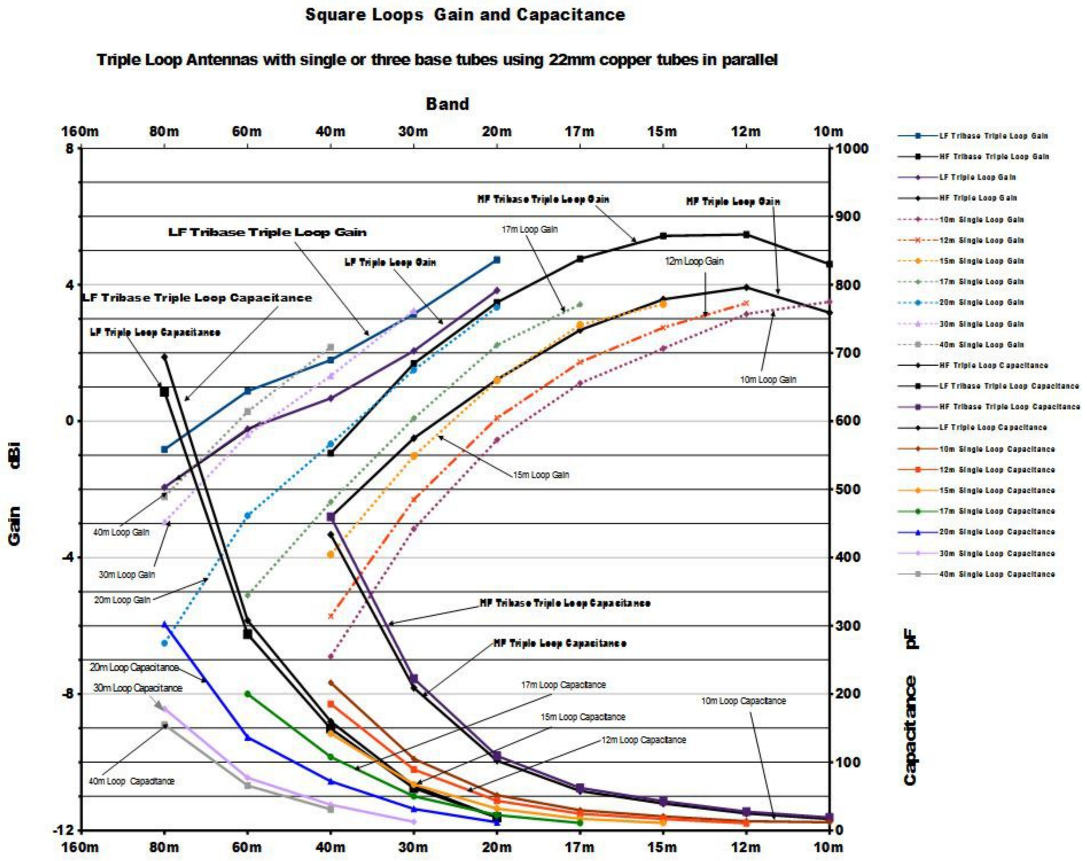

Figure A2 Square Loop - Gain and tuning Capacitance for different Loop Antennas

Refer to the legends at RHS to identify each coloured plotted line. Gain dBi is shown at LHS with the Triple Loop plots as heavy bold lines with icons. The Capacitance axis is at RHS with the Triple Loop plots shown as bold lines with icons.