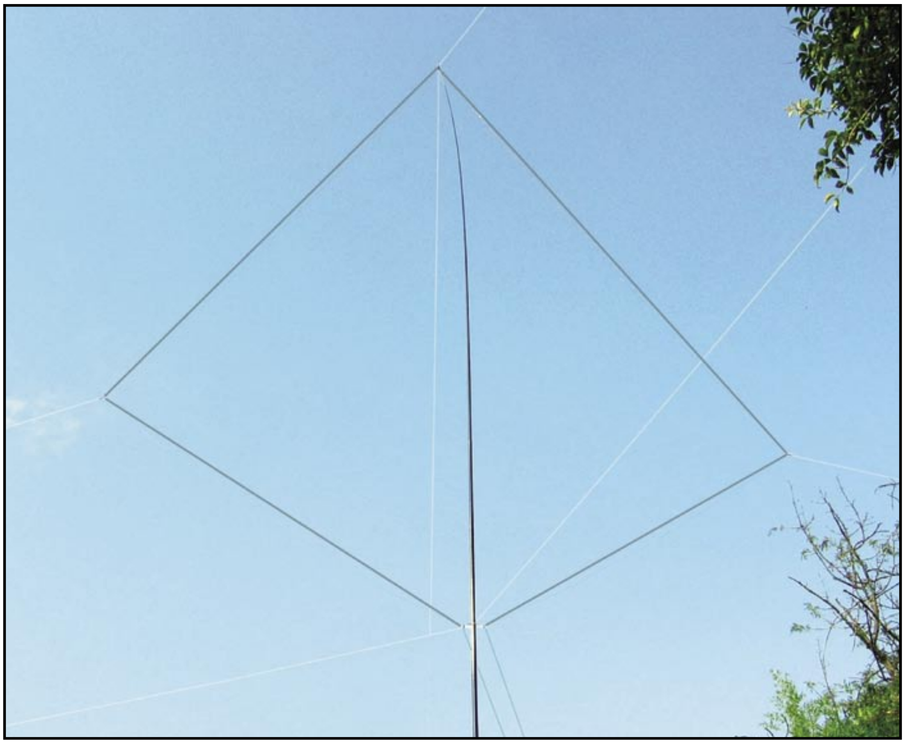
The Compact Quad Multiband HF Antenna

An easy to build loop with a simple matching section offers four band HF coverage.

Andrew Roos, ZS6AAA



When I relocated to Johannesburg I needed a new multiband HF antenna. Since I was staying in a rented house, a tower was out of the question, but fortunately my lovely wife had taken my not-so-subtle hints and given me a Spiderbeam 39 foot telescopic pole for my birthday.[1] The pole is much stiffer than a fishing rod, but still only suitable for a very lightweight antenna. This ruled out trap dipoles such as the W3DZZ, as the traps would have been too heavy. The garden, which measured only 66 × 46 feet, was too small to accommodate a G5RV. The location of the shack on the opposite side of the house from the garden made an open wire fed doublet impractical. I ruled out most of the standard multiband HF antennas and decided to develop my own.

A closed loop seemed to be a good starting point since loops are naturally resonant on all multiples of their fundamental frequency. This matches the harmonic relationships between the most popular amateur bands. They can be fed at the bottom of the loop, so the weight of the feed line does not have to be supported by the higher (and thinner) sections of the mast. Unfortunately, the 39 foot high mast was not tall enough to support a 40 meter 1 λ loop, and a 20 meter loop would only provide coverage of the 20 and 10 meter bands through the harmonic relationships. At this low point in the sunspot cycle, I also wanted to be able to work the 40 and 15 meter bands.

Fortunately a loop which is N + $\lambda/2$ long is also resonant (the reactive component of its impedance is zero), although it has a very high impedance — as high as 50 kΩ for the $\lambda/2$ loop. This high resistive impedance can be transformed to a low impedance using a $\lambda/4$ matching section of the right characteristic impedance. To transform 50 kΩ to 50 Ω would require a matching section with a characteristic impedance (Z_0) of about 1600 Ω, which is not feasible. However a quarter-wave matching section with a Z_0 of 800 Ω (about the maximum practical impedance) would transform 50 kΩ to approximately 13 Ω, resulting in an SWR of 4:1 on 50 Ω coax. This is a very reasonable SWR for a multiband antenna, since it can be easily matched by most wide range antenna tuners and will not cause an unacceptably high loss in the coax. For example, if the antenna is fed by 100 feet of RG-213 at 7 MHz, then the matched loss would be about 0.6 dB, and an SWR of 4:1 would result in an additional loss of only 0.5 dB (10% of the transmitter power); while an SWR of 5:1 would result in an additional loss of 0.7 dB (15% of transmitter power) compared to a perfectly matched transmission line.[2]

The resulting design is a loop that is electrically 1 λ in the 20 meter band, fed by a matching section with a Z_0 of about 800 Ω that is $\lambda/2$ long in the 20 meter band.[3] In the 40 meter band the matching section is $\lambda/4$ long and transforms the high impedance of the loop to a low impedance that can be fed directly from 50 Ω coax. In the 20 meter band the $\lambda/2$ matching section has no effect, simply reflecting the 140 Ω impedance of the one-wavelength loop, for an SWR of about 3:1. In the 15 meter band, the matching section is ¾ λ long, and again transforms the high impedance of the 1½ λ loop to a low impedance, in this case close to 50 Ω. In the 10 meter band, the matching section is 1 λ long, so once again it simply reflects the low impedance of the loop, which is now 2 λ in circumference. The result is an acceptable match to 50 Ω coax with an SWR of 5:1 or less on the entire 40, 20 and 15 meter bands and on the bottom half of the 10 meter band. A 1:1 current (choke) balun should be used to connect the coax to the 800 Ω balanced matching section. The balun should perform

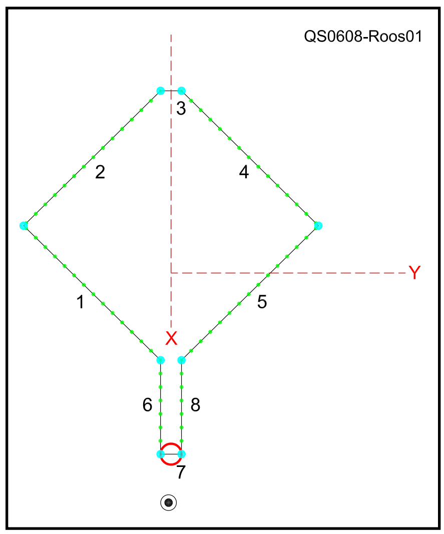


Figure 1 — Layout of compact quad loop.

[1]Notes are found on page 00.

well because the load impedance is low on all bands.

I investigated several different loop shapes using *EZNEC* antenna modeling software.[4] The best predicted performance was achieved with an apex-down delta loop. While this loop shape retains the cleanest pattern at the higher frequencies, it is not mechanically realizable with a single support. The best practical shape is the diamond quad as shown in Figure 1. The matching section runs horizontally along the X axis since, at 36 feet, it is too long to fit vertically below the loop on the 39 foot mast. If your configuration is supported by a 66 foot or taller mast, the matching section can be run down the mast, provided that adequate separation is maintained if the mast is conductive.

Construction

I used 18 gauge enameled copper wire for both the loop and the matching section since bare copper wire is hard to obtain in South Africa, and I didn't want the additional weight of PVC insulation. If you are able to obtain hard-drawn copper wire, it would be a better choice as it is stronger and less likely to stretch.

The antenna and matching section together require about 144 feet of wire — 72 for the loop, and 72 for the 36 foot long matching section. I suggest using a single continuous length of wire for both to avoid the requirement for a joint between the antenna and the matching section. Attach the center point of the wire to the top of the mast using a lightweight plastic insulator (such as those used in electric fences) secured with a couple of cable ties. The corners of the diamond are pulled away from the mast using 0.04 inch diameter monofilament nylon "builder's line" (100 pound test), also attached using lightweight insulators, which should be left free to slide over the antenna wire so they can find the position where the top and bottom halves of the antenna wire are under the same tension. Try to secure the other ends of the builder's line to elevated supports if possible — I used a drain pipe for one side and a telephone pole, that the telephone company had thoughtfully placed in the corner of the garden, for the other.

Cut two spacers measuring 8 × ¾ inches from a sheet of ¼ inch thick Perspex or any other good insulator. Drill 3⁄32 inch diameter holes ½ and ¾ inch from each end of the spacer, centered from side to side. One of the spacers will be used to hold the wires apart at the bottom of the loop. You can attach it to the mast using two heavy-duty cable ties arranged in a criss-cross pattern to hold the spacer horizontal. Feed the ends of the wire coming from the loop through the inner holes and then back through the outer holes, securing with cable ties. Figure 2 shows the assembly of the spacer.

The second Perspex spacer is used at the other end of the matching section to maintain the spacing between the two parallel wires. After being fed through the outer holes, around the back of the spacer and then back through the inner holes, the wires should be connected to the balanced terminals of the balun. I used a W2DU type balun (ferrite beads over a length of coax), but any 1:1 current (choke) balun will work. You can use cable ties to secure the wires to the spacer for strain relief, as shown in Figure 1. You may not need any intermediate spacers if you can tension the matching section sufficiently to keep the two wires parallel. However, if you live in a windy area, I suggest adding a few intermediate spacers made of lightweight plastic to prevent the spacing between the wires from being affected by the wind. The antenna can be fed via any length of 50 Ω coax connected to the unbalanced side of the balun.

The distance of 8 inches between the outer holes of the spacers sets the spacing for the open wire line that forms the matching section. The formula for the characteristic impedance of open wire line is:

$$Z_0 = 276\log(2D/d)$$

where D is the spacing between the wires, 8 inches, and d is the diameter of the wire, 0.0403 inches.[5] The calculated impedance is 717 Ω.

The exact shape of the loop is not critical. In my case, it looks more like an upside down kite than the square diamond shown in the lead photo, due to the locations of the available attachment points used to hold the sides of the loop. The important factor is for the loop to have as much internal area as possible — stay away from long thin loops that look more like a folded dipole, as this will compromise the performance.

The sides of the loop double as guys to support the mast. I added another two guy lines (also made of builder's line) at the top of the mast, as well as four guy lines at the bottom of the loop, which is about 13 feet off the ground. I consider this construction to be best suited to temporary use (in my case, for short-term use at a rented property; or perhaps for a field station or DXpedition, since the telescopic mast can be collapsed to less than 4 feet in length). For a permanent installation an aluminum mast, copper-clad steel wire and heavier nonmetallic guy wires should give many years of use under all weather conditions.

The lead photo shows the finished antenna. The photograph has been digitally enhanced to show the thin antenna wires, which would be almost invisible otherwise. You can clearly see the inverted kite shape of the loop, and the parallel wires of the matching section, which are attached to the Perspex spacer at the bottom of the loop. The other visible lines are guy wires. The total width of the antenna, from corner to corner, is only 26 feet, making it ideal for use in restricted spaces.

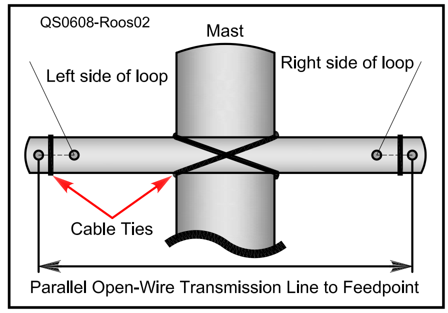


Figure 2 — Details of compact quad loop transmission line attachment.

Tuning the Antenna

You can tune the antenna by gradually shortening the matching section until an acceptable SWR is obtained on all bands. The minimum SWR will not necessarily coincide exactly for all bands, so you should tune it for a good compromise between the SWR on the different bands, rather than simply minimizing the SWR on a single band. Since the antenna is designed to be used with an antenna tuner, an SWR of 5:1 or less is adequate.

The length of the loop, 72 feet in circumference, should not have to be changed unless you are using wire with thick insulation, in which case the length of the loop will have to be reduced by about 2% to compensate for the dielectric effect of the insulation. In this case, disconnect the matching section from the loop, and first trim the loop for minimum SWR at 14.175 MHz. Then connect the matching section, and trim it for acceptable SWR on all bands.

Figure 3 shows the measured SWR of the Compact Quad on the 40, 20, 15 and 10 meter bands. I used a Palstar ZM-30 antenna analyzer with the ZM30-BT balanced transformer adapter to measure the SWR directly at the antenna feed point (the end of the matching section furthest from the loop). The antenna

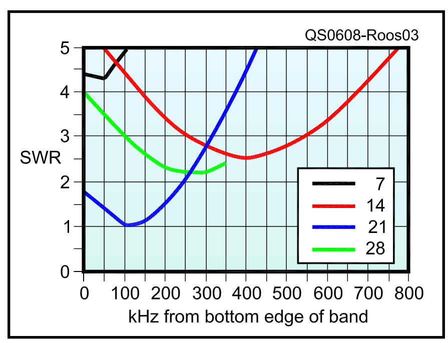


Figure 3 — Measured SWR of compact quad loop at end of matching section. 7 MHz in black, 14 MHz in red, 21 MHz in green, 28 MHz in blue. X axis is kHz from lower band edge.

covers the entire 40, 20 and 15m bands and about 700 kHz of the 10m band with an SWR of less than 5:1.When the SWR is measured from the shack it is slightly lower on all bands, due to the additional loss of the coax feed line, which is 25 meters of RG213.

I have used two antenna tuners with this antenna, the internal auto-tuner in my Kenwood TS-850S, and a Palstar AT1KM manual tuner, which I use when running with the linear. Both tuners have matched the antenna effortlessly on all frequencies that I have tried. Running up to 400 W CW (the maximum permitted in South Africa) I have not seen any signs of arcing, overheating or other problems in either the antenna or the balun, although if you are planning to use kilowatt power levels then you might consider using larger diameter wire.

Performance

Figure 4 shows the far-field elevation plots for frequencies of 7, 14, 21 and 28 MHz. The plots were calculated using the high accuracy (NEC Sommerfeld) ground model with a conductivity of 0.005 S/m and a dielectric constant of 13. The model included ohmic losses from copper wire with a diameter of 1 mm. The patterns at all frequencies were bidirectional, with only minor departures from bidirectional symmetry (typically less than 0.1 dB) caused by the very slight radiation from the matching section. All the patterns are referenced to the maximum gain plotted, which is 8.0 dBi at 21 MHz.

At 7 MHz the pattern is a squashed sphere that is virtually omnidirectional, with a maximum gain of 3.5 dBi at an elevation of 55°. The pattern at 14 MHz is a classic bean-shaped loop pattern, with a maximum gain of 6.5 dBi at 33°. The best DX performance is found at 21 MHz, where the maximum gain of 8.0 dBi occurs at an elevation angle of only 21°. At 28 MHz the pattern has a major lobe with a gain of 5.0 dBi at 39°, and a minor lobe with a gain of 1.1 dBi at 10°. While this is not perfect, the minor lobe should offer some good DX opportunities considering the relatively low power levels that are often required on the 10 meter band.

Figure 5 shows the azimuth patterns for an elevation angle of 10°, which is typical of the takeoff angle required for long-range communication. The plot scale is referenced to the maximum gain, 4.9 dBi at 21 MHz. As you can see, the pattern for 7 MHz is virtually omnidirectional. The direction of maximum radiation for 14 MHz and 21 MHz is perpendicular to the plane of the loop (along the X axis in Figure 1), while at 28 MHz it has a four lobed pattern with maximums at 42° from the X axis.

I have been very impressed with this little antenna. I managed 377 QSOs spread evenly between the 40, 20 and 15 meter bands while running 100 W in the 2006

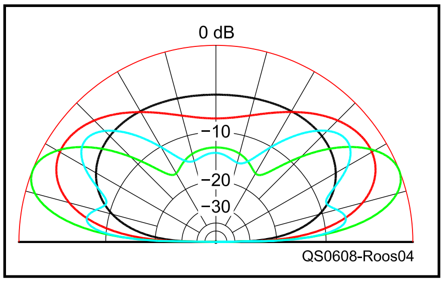


Figure 4 — *EZNEC* elevation pattern of compact quad loop model. 7.15 MHz in black, 14.15 MHz in red, 21.2 MHz in green, 28.2 MHz in blue.

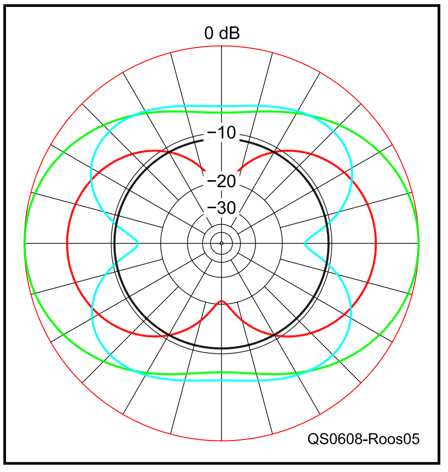


Figure 5 — *EZNEC* azimuth pattern of compact quad loop model at 10° elevation. 7.15 MHz in black, 14.15 MHz in red, 21.2 MHz in green, 28.2 MHz in blue.

ARRL International DX CW Contest. My 109 QSOs on 40 meters were a big improvement over the 41 contacts that I managed on the same band in the previous year's contest. This is especially gratifying, as this antenna is considerably smaller than the V beam that I used in 2005. Over the past few weeks I have managed to start small pileups of Asian and European stations almost every time I've called CQ on 40 meters. This surprised me as I struggled on this band with wire antennas from my previous location. I have also received many good reports on the 20 and 15 meter bands, running between 100 and 400 W, and have even made a couple of contacts on 10 meters despite low levels of solar activity. Of course my rented house feels more like home now that I can communicate with friends around the world.

If you have limited space, and need a small multiband HF antenna with good performance and a low visual profile, then why not try the Compact Quad?

Notes

[1]**www.spiderbeam.net**.

[2]*The ARRL Antenna Book*, 20th Edition, p 24-0, 2003. Available from your ARRL dealer or the ARRL Bookstore, ARRL order no. 9043. Telephone 860-594-0355, or toll-free in the US 888-277-5289; **www.arrl.org/shop/**; **pubsales@arrl.org**.

[3]I attempted to find references to similar designs on the Internet or in several reference works and antenna compendiums, without success while I was developing this antenna. I have since discovered, however, that Les Moxon, G6XN, mentions this arrangement in his excellent book *HF Antennas for All Locations*, 2nd edition, p 122. Available from The ARRL Bookstore, ARRL order no. 4300, Telephone 860-594-0355, or toll-free in the US 888-277-5789; **www.arrl.org/shop**; **pubsales@arrl.org**.

[4]*EZNEC* is available from Roy Lewallen, W7EL, at **www.eznec.com**.

[5]J. Kraus, W8JK (SK), *Antennas for All Applications*, 3rd Edition, McGraw Hill, 2002, p 891.

Andrew Roos has been a radio amateur since 2001. He initially was issued the call sign ZS1AN and now is ZS6AAA. He has Bachelor of Arts with Honours degree from Rhodes University. After 15 years in the software development industry, he recently accepted a position as a development engineer at a company that produces specialized antenna systems. Andrew is a past chairman of the Cape Town Amateur Radio Center and regularly teaches classes for the Radio Amateur Examination. You can reach him at **andrew.roos@mweb.co.za** *or PO Box 3294, Pinegowrie 2123, South Africa.*

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