The Horizontal Loop — An Effective Multipurpose Antenna

The horizontal loop need not be resonant and can work well in a number of ways

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It's been well documented that a large horizontal loop will perform well as an amateur radio antenna. It may also be one of the most misunderstood of antennas. Many hams believe a loop must be resonant on the lowest operating frequency to work well at the design and higher frequencies. The fact is, as I will show later, a loop need not be resonant at all to perform well.

One purpose of this article is to demonstrate how to use computer modeling to perfect a loop for one's needs and location. This paper is not an antenna modeling tutorial. Programs such as *EZNEC* and *NEC Win-Plus* are relatively inexpensive and readily available.[1,2] Thus, I assume readers have a sufficient working knowledge of their respective modeling program to allow modeling the antenna and ground conditions and will be able to interpret the program outputs. Those wishing to learn more should look at the excellent ARRL Antenna Modeling Course, authored by L.B. Cebik, W4RNL, (L.B.) or at least visit his Web site.[3,4]

The Misunderstood Loop

L.B. has written several excellent papers on loops that can also be found on his Web site.[5] These should be required reading for anyone contemplating building one. He points out two general misconceptions; the longer the loop the more the gain, and that the loop gives an omnidirectional pattern on all HF bands. The truth is that low angle gain is proportional to height — the higher the antenna, the higher the gain at low angles. Also, at higher than design frequencies, a loop is not omnidirectional. The loop radiation patterns and performance are affected by its shape and feed point location. The key parameters are shown in Figure 1.

[1]Notes appear on page 44.

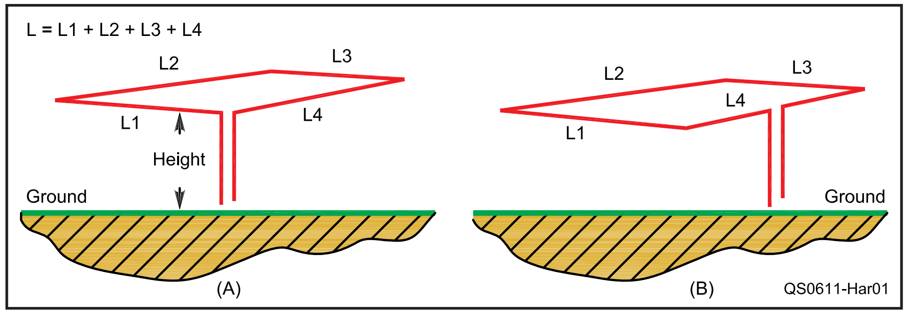

Figure 1 — At A, corner of angle-fed (AF) configuration showing key parameters. At B, center-fed (CF) configuration.

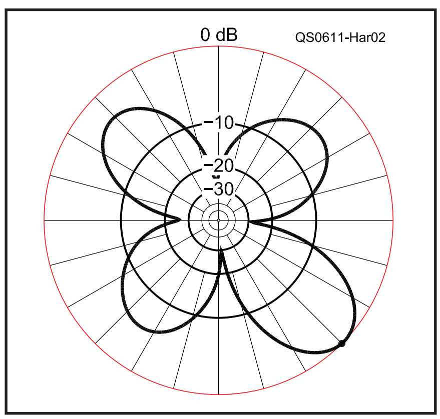

Figure 2 — Azimuth pattern of 300 foot loop on 14.2 MHz at elevation of 25°. Peak gain is 12.5 dBi.

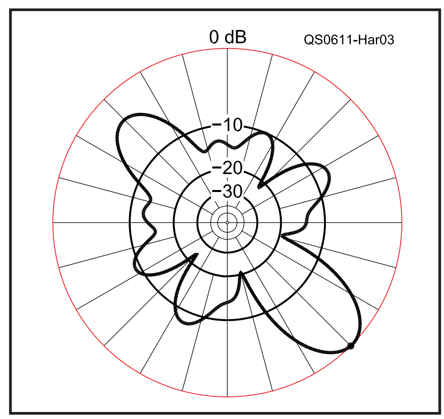

Figure 3 — Azimuth pattern of 320 foot loop on 14.2 MHz at elevation of 20°. Peak gain is 13.3 dBi.

Table 1
Loop Performance by Shape and Feed Point

	Circular Loop		*Square Loop AF*		*Triangle Loop AF*		*Square Loop CF*		*Triangle Loop CF*	
	Gain (dBi)	*Elev*	*Gain (dBi)*	*Elev*	*Gain (dBi)*	*Elev*	*Gain (dBi)*	*Elev*	*Gain (dBi)*	*Elev*
1.9 MHz	3.93	90°	3.46	90°	2.88	90°	3.70	90°	2.67	90°
3.9 MHz	8.47	90°	8.13	90°	7.76	90°	8.23	90°	8.04	90°
7.2 MHz	7.76	50°	7.35	50°	7.98	45°	7.64	45°	7.30	45°
10.1 MHz	8.34	35°	10.68	35°	7.35	30°	8.17	35°	7.24	30°
14.2 MHz	10.44	25°	12.50	25°	11.27	25°	10.25	25°	8.50	25°
18.1 MHz	11.18	20°	14.03	20°	12.32	20°	11.40	20°	8.84	20°
21.2 MHz	10.16	15°	14.55	15°	12.42	15°	11.28	15°	8.29	15°
24.9 MHz	10.77	15°	13.69	15°	14.09	15°	10.58	15°	10.10	15°
28.5 MHz	11.39	15°	12.85	10°	13.84	10°	11.19	10°	12.66	10°

Is This Antenna For You?

The first step in our planning is to determine if a loop is the right antenna for your needs. If you are interested in 160 and 80 meter DX and can only erect a horizontal loop 30 to 50 feet off the ground, you may be better off with other choices. At those frequencies, and heights below λ/4 to λ/2, most radiation will go skyward, making the loop ideal for near vertical incidence skywave (NVIS) propagation out to distances of a few hundred miles. This provides reliable coverage for emergency and other medium range communications, but not for DX. They do perform well as DX antennas on the higher frequencies. The loop makes a fine antenna for the ham who has space for only one antenna. In my case, I already had very good antennas for 160 and 80 meters, but I wanted something that would perform as a backup for these bands and give me good DX performance on the higher bands. I was particularly interested in 20 and 17 meters.

A good rule of thumb is to start with a loop about 5 λ at the highest desired DX operating frequency. Therefore, using the usual formula for a 1 λ loop, 1005/freq (MHz), a 1 λ loop for 18.1 MHz would have a circumference of approximately 56 feet, so our model loop should be about 280 feet in circumference. I then modeled a square loop 40 feet above real/high accuracy ground with dimensions of 70 feet per side.[6] After some experimentation, I found a leg length of 75 feet with the feed source in a corner of the loop would produce the clean cloverleaf pattern shown in Figure 2 on 20 meters, which was what I desired. Any longer leg length would give more gain, but would make the antenna more bi-directional as shown in Figure 3. Such a pattern may meet your needs. What about other shapes and feed points? Table 1 gives a comparison of these, showing circular, square and triangle loops, with the square and triangle loops being fed in the corners (AF) and midway along a leg (CF).

The circular and triangle loops developed a more omnidirectional pattern on the lower bands, and if that is what one desires, then more experimentation with these types would be beneficial. For my purposes, the apex or corner fed square loop was the best. It gives nice performance on 80 through 30 meters and really shines on 20 and 17 meters. Looking at the figures for 10 meters, one might think it to be an excellent omnidirectional DX antenna. A close look at the actual azimuth pattern (Figure 4) shows that it has just about as many sharp nulls as gain lobes. Also, these lobes are relatively narrow. A windy day or varying atmospheric conditions can cause signals to fade in and out of the nulls. We want these nodes to be as broad as possible with the fewest nulls, so a frequency range of around 5:1 is the best range for a loop. For the DX enthusiast, a loop with a resonant frequency just below 7 MHz should perform well for 40 through 10 meters.

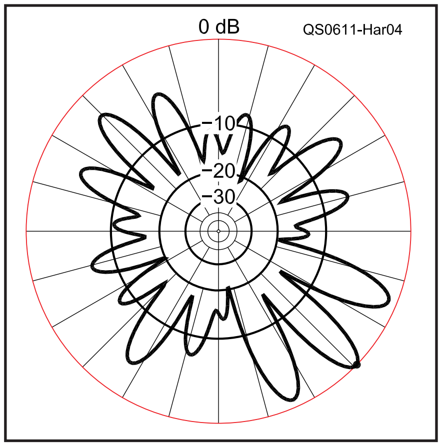

Figure 4 — Azimuth pattern of loop on 29 MHz at elevation of 10°. Peak gain is 12.6 dBi.

Optimizing the Antenna for Your Location

Now that we have a model of the kind of loop we want, the second step is to determine what size and shape loop we can erect. This means conducting a survey of one's antenna space. Take a long tape measure to the site and record distances to trees, towers, fences, other buildings, etc. Take this data and draw out a diagram of the maximum loop antenna possible. Once this is done, you can then attempt to fit your model into your actual location. If you have the supports in the right places, you are indeed fortunate. If not, don't be discouraged. The idea here is to utilize the modeling program, changing source point, shape, leg lengths, height (within limits of the overall yard dimensions), etc, until we have the best antenna for your location that will perform as well as possible on the bands you desire to operate.

Also play with adding loads (inductance and capacitance) at various points. For instance, adding an inductance may enhance performance on 160 meters, while adding a small capacitance may make it perform better on 80 meters. These components can also be utilized to "tame" the antenna on certain bands where matching is difficult. Nothing is sacred here, and playing with models certainly is easier than raising and lowering the loop many times!

One might ask why not erect a vertical loop, since this type of antenna only requires two supports and would seem to also generate good patterns on all bands? Well, as pointed out by W4RNL, loops have a strange behavior. At frequencies of twice design frequency and above, radiation is increasingly off the side of the antenna. Thus, on higher frequencies a vertical loop antenna would tend to radiate straight up and down! This is also why horizontal loops have lower radiation angle at higher frequencies.

Resonant vs Non-Resonant Loops

Now, let's deal with the issue of resonance. Table 2 compares performance of my loop against resonant 160 and 80 meter loops, as well as an inverted V. The non-resonant loop seems to be the better overall performer. One may ask, "What about SWR! Have you considered that? How are you going to feed this thing?" Well, first some basics. In his book, *Reflections*,[7] Maxwell states that all power fed into the transmission line (minus line loss) is absorbed by the load, regardless of the mismatch. Secondly, with open-wire tuned feed lines, we can ignore this mismatch at the junction of the feed line and the antenna, and all matching can be done at the transmitter itself.

One might think, "Isn't this bringing a high SWR (and problems) into the shack?" Well, Maxwell also tells us reflected power by itself is unimportant in determining how efficiently power is being delivered to an antenna. Put another way, if our antenna tuner can properly match the impedance of the input of the feed line, using open wire line, we can transfer just about all power to the antenna. Therefore, with a little planning, our loop can work on all amateur bands utilizing open line feeders and the proper tuner.

Table 2
Loop Performance vs Resonant Antennas

	160 Meter Loop		*My Loop*		*80 Meter Loop*		*Inverted V*	
	Gain (dBi)	*Elev*	*Gain (dBi)*	*Elev*	*Gain (dBi)*	*Elev*	*Gain (dBi)*	*Elev*
1.9 MHz	6.72	90°	3.46	90°	1.64	90°	2.09	90°
3.9 MHz	5.69	55°	8.13	90°	7.88	90°	5.03	90°
7.2 MHz	9.65	40°	7.35	50°	6.54	50°	4.23	45°
10.1 MHz	12.09	25°	10.68	35°	9.51	40°	5.18	25°
14.2 MHz	12.05	20°	12.50	25°	10.96	25°	6.30	20°
18.1 MHz	12.98	20°	14.03	20°	13.89	20°	7.07	15°
21.2 MHz	14.43	15°	14.55	15°	14.11	15°	6.97	35°
24.9 MHz	13.48	10°	13.69	15°	14.61	15°	7.18	10°
28.5 MHz	14.55	10°	12.85	10°	14.25	10°	7.07	10°

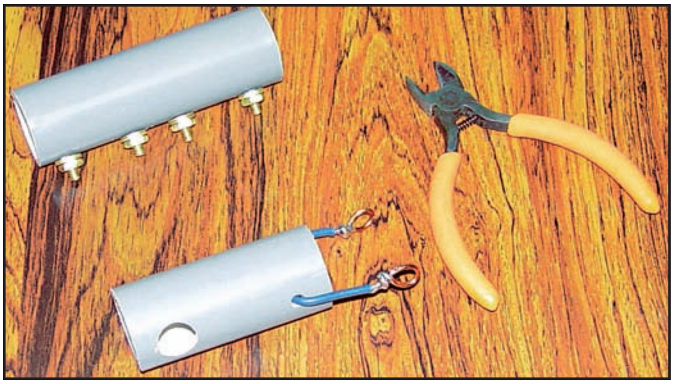

Figure 5 — PVC feed line and corner insulators.

Table 3
Antenna Z_0

	At Antenna	*At End 65 Ft. 450 Ω Line*
1.9 MHz	127.9 –*j*4282 Ω	2.029 –*j*310.1 Ω
3.9 MHz	230 +*j*691.1 Ω	71.72 –*j*160.5 Ω
7.2 MHz	188.3 +*j*475.3 Ω	286.2 +*j*619 Ω
10.1 MHz	313.3 +*j*0.03295 Ω	638.3 –*j*7.773 Ω
14.2 MHz	700.1 +*j*804.4 Ω	1620 +*j*424.2 Ω
18.1 MHz	2452 –*j*578.7 Ω	99.57 +*j*168.9 Ω
21.2 MHz	2280 +*j*609.2 Ω	737.4 –*j*1124 Ω
24.9 MHz	1579 –*j*1257 Ω	107.3 +*j*187.6 Ω
28.5 MHz	815.9 –*j*954.3 Ω	158.9 –*j*460.3 Ω

Tuner Considerations

We must consider the resistive and reactive components presented at the input of the feed line. Our tuner must be able to match these components of the line impedance (Z_0) to an unbalanced 50 Ω resistive load. Table 3 shows the impedances calculated by our modeling program for our loop at the antenna and at the end of 65 feet of 450 Ω transmission line. Here again, one can vary the line type, length, etc. to yield the best combinations for their location and needs. Using a 4:1 balun to a typical unbalanced tuner may work in some cases, but leaves a lot to be desired and will create a lot of problems. One needs a true balanced line tuner to match the antenna to the load properly.

It is not within the scope of this article to go into detail on the design and construction of such a tuner. *The ARRL Antenna Book*, *The ARRL Handbook*, and many other antenna journals have information on such a tuner. I personally prefer the tuner designed by AG6K using two variable inductors and a variable capacitor with a balun on the input side.[8] For those not willing to take the time and effort to design and build a tuner, there are several commercial tuners available.[9] The Palstar BT1500A is a commercial version of the A6GK tuner.[10] It is pricey but very well built, has an excellent metering system and is rated at 1500 W. MFJ has a balanced line tuner for a more attractive price that is rated at 300 W.[11] A surplus Johnson Matchbox should also work well, but likely won't provide a match on 30 meters.

Loop Construction and Erection

Once we have decided on the final design, the next step is construction and erection of our loop. Use your favorite method of putting up rope at the support points, but there should be some method of strain relief at each support such as pulley-counterweights or springs. Loops take a lot of stress from wind and swaying supports. Many years' experience have taught me that in most areas, large loops need to be put up one leg at a time. Therefore, I recommend carefully measuring and cutting each leg of the loop.

Feed line and corner insulators can be fabricated from short lengths of PVC pipe, as shown in Figure 5. These should be spray painted to protect them from the sun. My feed line insulator has short internal jumpers running from the center terminals to the outside terminals. The corner insulators should be connected to the antenna legs by brass or stainless steel hardware.

Lay out the legs and insulators on the ground in the manner they will be part of the antenna. Connect the open wire line and the two extending legs to the feed line insulator and raise this up part of the way. Connect the next leg to one corner insulator. Keep working around the loop until all legs are up and connected and up in the air.

Measure out the proper length of open wire line, and route it along its path to the tuner. Open wire feed line is affected by nearby objects, especially metal objects such as gutters and other wires, so make every attempt to keep it free and clear. It should also be secured as much as possible to eliminate flopping and swaying around. I found 2 inch screw-in porcelain electric fence insulators very handy for making runs along the wall of the house.

There are many ways to run open wire line into the shack. Replacing a window pane with Plexiglas and drilling holes in it is one method. Another way is to run two short pieces of RG-8 coax with the center conductor of each coax connected to one of the open wire feeders. By connecting the shields together a shielded balanced line of twice the coax Z_0 is formed. Note that this transmission line will have the loss associated with the mismatched coax, so make the length of such a section as short as possible.

Final Thoughts

So there you have it. All the information needed to create that new station antenna that will suit your needs and location. Please remember modeling software is a great aid in discovering new high performance antennas, but it is not the absolute gospel. It can point us in the right direction and save a great deal of time in our quest for the "perfect" antenna, but its results need to be tested and verified.

One last thing: L.B. Cebik has stated, "The advantage of the [horizontal loop] will not show itself in any one contact or in a short period. Satisfaction with the antenna grows with time and changes in the propagation paths, a successful communication with almost everywhere shows up in the log." I couldn't agree more. I have enjoyed my loop for some time, and have worked many countries and received excellent signal reports.

Notes

[1]*EZNEC* is available from **www.eznec.com**.

[2]*NEC-Win Plus* is available from **www.nittany-scientific.com/plus/index.htm**.

[3]Information on ARRL modeling course available at **www.arrl.org/cce/courses.html**.

[4]**www.cebik.com**.

[5]For starters read "Horizontally Oriented, Horizontally Polarized Large Wire Loop Antennas" and "Horizontal Loops: How Big? How High? What Shape?"

[6]ASCII files of antenna models used in this article are available from the author.

[7]M. Walter Maxwell, W2DU, *Reflections: Transmission Lines and Antennas*, (Out of print). The entire text of *Reflections II* is available at **www.w2du.com**.

[8]R. Measures, AG6K, "A Balanced Balanced Line Tuner," *QST*, Feb 1990 (updated at **www.somis.org/bbat.html**).

[9]J. Hallas, W1ZR, "Product Review: A New Generation of Balanced Antenna Tuners," *QST*, Sep 2004, pp 60-66.

[10]Available from **www.palstar.com**.

[11]MFJ Enterprises **www.mfjenterprises.com**.

Scott M. Harwood, K4VWK, has been interested in radio since childhood. In the seventh grade he built a two tube regenerative receiver using #30 tubes as a science project. He obtained his Novice license in 1958 and has retained the same call for over 40 years. He now holds an Amateur Extra class license. After college and a tour in the USAF, Scott returned to Virginia where he now resides. An avid antenna experimenter, his main area of interest has been small portable antennas for 160 and 80 meters. He has given talks at local radio clubs on antennas, and has written articles for CQ *and* AntenneX *magazines. You can reach Scott at PO Box 523, Farmville, VA 23901 or at* **scotth@hsc.edu**.