

A Balanced, Everyday Approach to All-Band Bliss

Feed lines, antenna tuners, baluns, RFI, computer noise and all-band antennas—now there's a snake pit of potential conflict. After years of experimentation, the author has found the path to multiband nirvana.

For most of us, the Holy Grail of ham radio is antenna performance. It's often the key element in determining ham radio success and operating enjoyment. You can get by with a second-rate transceiver, a deep gravelly voice and even a severe lack of good looks and charm, but if you have an underperforming antenna, ham radio isn't nearly the fun it could be.

You've undoubtedly looked with longing, as I have, at magazine pictures that show fabulous contest "superstation" antenna farms, the few fortunate hams who have 350-foot towers festooned with big Yagis (or a smattering of 200-footers), the Northern California ham who has a dozen full-size rhombics strung between the tops of giant Sequoias, and so on.

After imagining an antenna system that qualifies as a navigation hazard, most of us will scale things down to the real matter at hand—how to put up an affordable, easy-to-build multiband antenna that works great and fits on an average-size lot. We're back to the search for the Holy Grail.

Horizontal Loop Antennas

What, you were expecting dipoles?

Although dipole antennas in all of their various shapes and configurations perform well, in my experience the *best* all-around multiband antenna is the horizontal loop. It's efficient, omnidirectional over most "real ground," it's quiet, it operates well on *all* HF frequencies above its design frequency (and even those below, as we'll see later), it fits on most lots and, contrary to tradition and many official-looking radiation pattern plots that can be found in various antenna manuals—can be an *outstanding* antenna for domestic and DX contacts alike.

As a kid I made my share of vertical loops/quads from bamboo poles and copper wire, but I didn't think about horizon-

tal loops until I read Dave Fischer, W7FB's life-changing article, "The Loop Skywire," in the November 1985 issue of *QST* (back when Dave signed W0MHS). Shown in Figure 1, the loop is simply a full-wavelength of wire cut for the lowest band of interest. Feed it with coax or ladder line (feed lines are discussed in detail later).

I had previously used quad loops and dipoles (G5RV-type and conventional). Sure, they *worked*—and they still do—but I had always thought something was lacking, and I had a secret hunch about the Loop Skywire.

Now, Fischer's First Rule of horizontal loop construction is to enclose as much area as possible within the confines of the loop. A circular loop is ideal, but a square loop is much more practical and doesn't suffer performance-wise. My lot could only accommodate a triangular "loop," which is pretty much the geometric limit of what you can get away with. If you make the loop any more elongated or constricted, it loses its "loop-like" qualities.

Although my most recent loop could have been cut for 40 meters, my property

and available skyhooks could contain a larger antenna (which should work better, especially on the low bands). It wasn't the 272 feet required for an 80-meter loop, but something in between. That's how I discovered another rule of thumb for building modern-day horizontal loops: Put up the largest possible horizontal loop your situation allows and forget about pruning it to resonance. The antenna tuner, which you'll need anyway for multiband operation, will take care of things.

Strung about 45 feet above the ground, I knew from past experience that my loop would be an excellent performer. Fed with 50 feet of RG-8 and my trusty old antenna tuner, the loop worked very well on 40 meters and up. As before, however, 80 and 160 were adequate, but just barely.

RFI was a big headache on the higher bands. In fact, 15 meters was almost impossible. Even at 5 W power levels, every key-down zapped the TV screen and all of the stereo and computer audio circuits in my office/shack. I had converted the garage to an office, and my shack is on the west wall. Just outside the wall is the base of my tower, which supports the feed point of the horizontal loop. Although the antenna itself is at least 50 feet from all of the PCs and consumer electronics, the feed line was in close proximity. The crud generated by three or four computers was also a headache and wiped out large chunks of the bands.

RFI

Despite the RFI and computer noise, I was pleased with the performance of the big loop.

I tried all of the standard RFI-fighting techniques. I made sure I had a good, short, low-impedance connection to an earth ground at my operating position. I installed ferrite cores and clamp-on chokes on seemingly endless numbers of audio and

Electronic Article References

If you're an ARRL Member, point your Web browser to the links below to access Adobe PDF versions of the articles I've referenced in the text.

- The Loop Skywire:
www.arrl.org/members-only/tis/info/pdf/8511020.pdf
- A Balanced Balanced Antenna Tuner: www.arrl.org/members-only/tis/info/pdf/9002028.pdf
- The Lure of the Ladder Line: www.arrl.org/tis/info/pdf/9312070.pdf
- Home-brew Your Own Inductors: www.arrl.org/members-only/tis/info/pdf/0107066.pdf

video cables. I installed ac line filters and connected some sensitive gear to the ac mains via an uninterruptible power supply, complete with RFI filtering, surge suppression and line conditioning.

I picked up a copy of *The ARRL RFI Book*, which is handy to have even if you're not besieged. I read up on common-mode interference, front-end overload, nonlinear rectification and even interference that's re-radiated by other affected components.

I disconnected dozens of speaker wires, audio and video leads, and coaxial TV cables. Is the RFI getting in through *this* wire or is it through *that* one? It was test, test, test—back and forth.

In the end, all of that poking and prodding made the RFI situation quite a bit better on all of the bands except 15 meters, which was still unusable.

Still, life was pretty good on 40, 30, 20 and 10 meters, and I was working lots of juicy DX and enjoying solid stateside ragchews.

Climbing the Ladder Line of Success

At this point I was feeding my loop through a standard antenna tuner and a 50-foot length of coax. I knew about open-wire line, TV twinlead and ladder line, but I'd never used the stuff to feed an antenna. Then I got wind of Steve Ford, WB8IMY's, excellent and eye-opening introduction to multiband antennas fed with 450-Ω ladder line. The article is "The

Lure of the Ladder Line," from the December 1993 issue of *QST*. It's also available to ARRL members in PDF format from *ARRLWeb* (www.arrl.org/).

Steve tells us how he dramatically improved the performance of his multiband dipole, formerly fed with coax and a tuner, by replacing the feed line with 450-Ω ladder line (see Figure 2). There it was in black and white: A key piece of antenna system wisdom that I'd been lacking for years.

In that article I discovered that the loss figures commonly attributed to coaxial cables of various sizes and compositions *are only accurate under low-SWR conditions*. As shown in Table 1, when the SWR on the coaxial feed line between your antenna tuner and your antenna's feed point is high—as it usually is when feeding antennas on frequencies at which they're not resonant—the signal losses in the coax can be staggering.

No wonder my antenna worked great at the design frequency and on all higher HF bands, but fell off on 80 and 160 meters. On those bands, even a 40-meter full-wave loop is physically small *and* the high SWR on the line between the tuner and the antenna wasted most of the power.

But look at the loss figures for the ladder line. They are a lot better, especially on the lower bands.

Baluns and Conventional Antenna Tuners

Unfortunately, using open-wire feed

lines isn't always as easy as simply swapping one cable type for another. Coaxial cables are unbalanced (which can make them vulnerable to common-mode RFI), and conventional antenna tuners are designed to handle them, so when they're matching coaxial cable loads, everything works out fine as long as the impedance at the tuner end of the feed line isn't too extreme.

Ladder-line and open-wire line are intended for balanced operation where equivalent currents flow through each of the two wires that make up the feed line. To accommodate balanced feed lines, conventional tuners almost always use a balun transformer at the tuner output to make the transition from balanced line to an unbalanced tuner network.

In a perfect world, this works pretty well and users can conveniently feed unbalanced and balanced loads without needing separate tuners. The problems arise when we consider how difficult it is to make a single balun that works well over a wide range of frequencies and power levels. In short, it's easy to build a tuner-output balun that works well on a single band or on a few adjacent bands, but when it

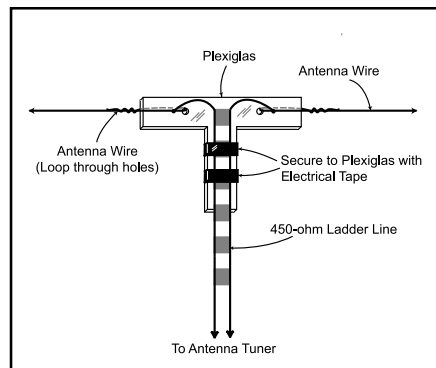


Figure 2—A dipole formerly fed with coax now has a ladder line feed.

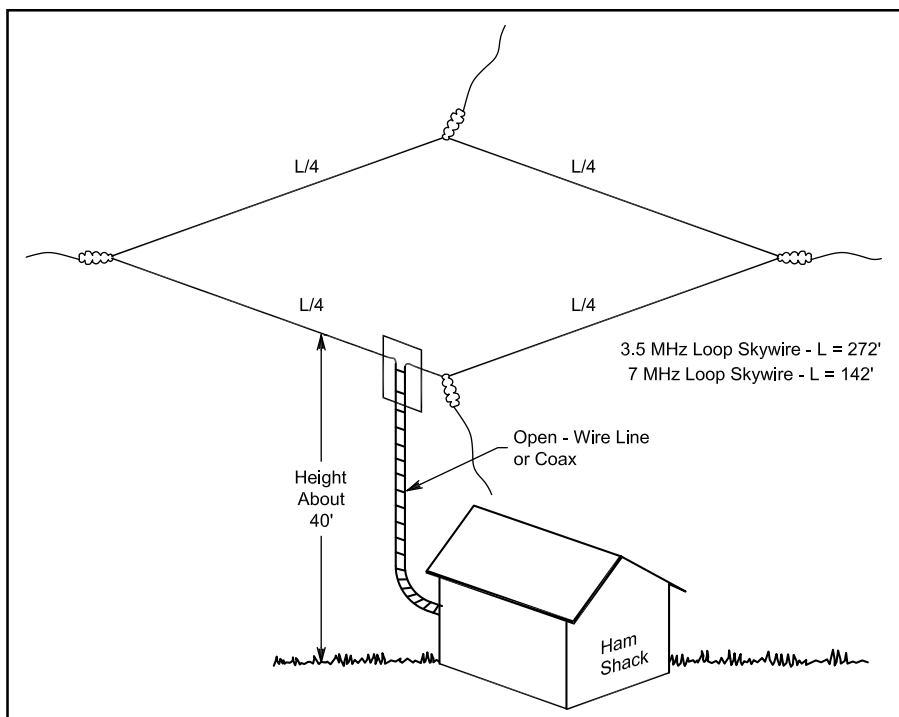


Figure 1—Put up the largest horizontal loop your lot can support while keeping the "loop" as square as possible. Don't worry about perfect symmetry. For size reference, values are shown for 80 and 40 meters. See the text for additional information.

Table 1

Loss Comparisons for Belden 8214 Coaxial Cable and 450-Ohm Ladder Line

Cable length: 50 feet.
Antenna: 66-foot dipole at 30 feet.
Calculated by Dean Straw, N6BV,
Senior Assistant Technical Editor.

Freq (MHz)	Loss (dB)	
	8214	Ladder Line
1.9	26.9	8.82
3.8	13.7	1.37
7.15	0.19	0.07
10.14	2.85	0.07
14.27	5.30	0.15
18.14	6.96	0.31
21.40	0.78	0.12
24.90	3.94	0.13
28.50	5.69	0.18

comes to a single dc-to-daylight tuner-output balun, things often don't work so well.

Also, because of where the balun resides in the tuner/antenna circuit, output-style baluns are often subject to extreme RF voltages, which can cause arcing, sparking, burning and other undesirable behavior. Output-style baluns also tend to have a tough time staying electrically balanced over a wide frequency range.

All of these factors combine to decrease the tuner's efficiency and increase power losses in the tuner and balun that are *in addition* to the losses of the feed line. Of course, all antenna tuners have some loss, and that loss tends to vary by frequency and load impedance. Matching extreme impedances usually means more loss.

Steve experienced this when feeding his 40-meter dipole with ladder line on 80 and 160 meters (extreme impedances for a 40-meter dipole). At anything more than just a few watts, his tuner would arc, snap, sizzle and pop. To operate on those bands he could run QRP or switch to an expensive megawatt tuner.

After a quick trip to the Twin Cities to fetch some ladder line, I dropped the feed point, made the switch to ladder line and hooked everything up to my time-tested—conventional—antenna tuner, making sure I connected the jumper wire that brought the output balun into the circuit.

With high hopes, I keyed the rig and, as usual, the impressive audio thumps and TV screen blackouts began. I still felt the lure of the ladder line, and I was now making easy contacts on 80 and 160 meters—electrically goofy feed line and all. I was gaining ground, but because of the RFI, etc, operating wasn't convenient.

Autocoupler to the Rescue

The next remedy I tried didn't cure all ills, but it became a piece of "can't do without" gear. In preparation for portable operation at the lake, I acquired an SGC SG-231 autocoupler, a computerized, automatic supertuner that can match practically any load from 160 through 6 meters in the blink of an eye.

The SG-231 has no controls and is designed to be mounted outdoors, even in harsh environments. You supply the dc power to operate the innards and some RF from your rig and the '231 does the rest. Simply key the mike on whatever frequency and the autocoupler matches the load in a jiffy, remembering the tuning solution so when you return to a nearby frequency, the tuner matches the load in about a quarter of a second—fast.

This amazing piece of hardware, called an autocoupler by the manufacturer, is designed to be *mounted at the feed point of the antenna*. When mounted

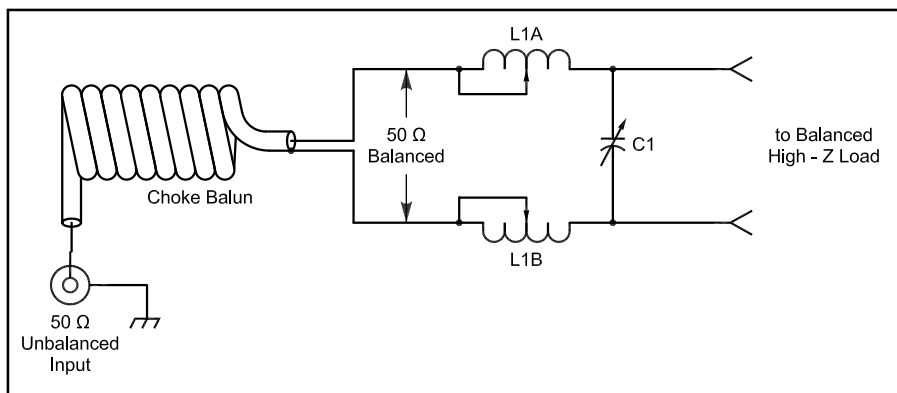


Figure 3—A simplified schematic of the balanced tuner as originally presented by Rich Measures, AG6K. The home-brew coaxial balun is on the input side of the network, which consists of two roller inductors that are adjusted in sync and a single variable capacitor. The capacitor, usually on the output side of the coils, can be moved to the input side to match some lower-impedance loads. Some builders use fixed, tapped inductors to save money. See the text and the References sidebar for more information.

in that fashion, the SG-231 matches the antenna to the 50-Ω impedance of the coax that runs from your rig to the tuner/feed point. Because the SWR on the cable between the tuner and the radio is low (matched), SWR losses are minimal and essentially of no concern.

The big problem for me was, I couldn't use the autocoupler at the lake if it was hanging 50 feet up in the air, precariously attached to my loop. And, even though it's designed for such service, I couldn't get myself to mount the coupler outside, exposed to the elements and those nasty Minnesota winters.

So, I snooped around on the Internet and saw that some ops were using their SGC tuners to feed balanced lines in a conventional sense (tuner in the shack, feeding a multiband antenna via 450-Ω ladder line).

I quickly connected the SG-231 to my rig and to my ladder line, fired it up and watched the magic happen with my own eyes. The autocoupler easily matched everything from 160 through 6 meters with the exception of a small chunk of 80 meters where the impedance at the shack end of the ladder line was probably weird.

I enjoyed using this arrangement for several years. It matched my loop, which is probably resonant at 5 MHz or so, in a snap, and RFI on 80 and 160 meters was pretty much eliminated. The 231 added tremendous convenience to the loop's superb performance.

The Final Balancing Act

Clearly, the horizontal loop, the ladder line and the autocoupler were working famously. I probably would have put up with the RFI/noise problems for a good long while if I hadn't run across a discussion during one of my late-night jaunts on 75 meters.

The guys in this roundtable were talk-

ing about how they'd built *balanced antenna tuners to feed their big horizontal loops with ladder line*. I knew I'd feel right at home chatting with these guys. They were spread out from the Carolinas to Arizona, and they were booming in on their own horizontal loop antennas. The guy from Carolina was running a kW and he sounded like a shortwave broadcast station.

The gist of our conversation centered around building a simplified version of the balanced antenna tuner detailed in, "A *Balanced Balanced Antenna Tuner*," by Rich Measures, AG6K, in the February 1990 issue of *QST* (available to ARRL members in PDF format from *ARRLWeb*).

The tuner uses a balanced L network instead of the conventional pi network employed by almost every commercial antenna tuner in service today (see Figure 3). The balanced L network can directly feed 450-Ω balanced lines while maintaining a high degree of electrical balance on each leg of the ladder line. It's this balance, I learned, that's critical in keeping the ladder line from radiating RF.

And instead of being at the tuner output, the balun is placed at the tuner's input, where baluns really do work over wide frequency ranges and where RF voltages and RF losses are minimal.

So what's the catch? Well, although the balanced L network could hardly be simpler, Rich's version requires two matched roller inductors, which are difficult to find and somewhat expensive, and a turns-counting dial.

Still, it was clear from reading Rich's article that using a balanced tuner with the balun on the input was the *proper* way of doing things for antennas fed with ladder line. So, I decided to build one and see for myself.

Thankfully, I had two brand-new roller inductors on hand. I'd purchased them

from MFJ several years ago when I was planning to build a pair of conventional antenna tuners. I also had a turns-counting dial I'd purchased almost 20 years earlier. The capacitor was a junkbox transmitting unit. The only parts I had to purchase were the sprockets (1/4-inch shaft size) and the toothed belt required to turn each roller inductor in sync. These cost only a few dollars from McMaster-Carr (www.mcmaster.com).

Building this tuner seemed like carpentry, with a little radio thrown in for good Measures (pun intended). The tuner is built on a piece of plywood with a wooden (or other non-conducting) front panel because the capacitor and inductor shafts are hot with RF. Building on metal would have required stand-off insulators and a lot of tedious wrangling. With wood it's a no brainer.

The only accommodation I made in my prototype is the use of banana posts and jacks to let me occasionally switch the capacitor from the output side of the coils to the input side to match balanced loads that are less than 50 Ω (most are greater than 50 Ω).

The thing went together in a couple of hours, and once I synchronized the roller inductors I replaced the autocoil with the balanced tuner. Figure 4 shows the completed tuner in all its glory.

Ahhh. The tuning was smoooooth, with no sharp, hard-to-find dips. It was also convenient because it had only two controls instead of the usual three. I methodically tuned up and down the bands with a 5-W signal and was pleased to notice that every spot on every band tuned up without a hassle, except for part of 75 meters—the same part that the SGC autocoil didn't like.

The other thing I almost forgot to notice was that—as if by divine decree—there was no more RFI. Anywhere. On any band. At any power output from 5 to 100 W. Not even the faintest of audio thumps could be heard in any of the many electronic goodies just three feet away from the tuner and the stub of ladder line that pokes through the wall.

But there's more. The computer noise was reduced by a good 80%. Now I could operate anywhere. The noise pickup problem that I'd made incremental progress on over the past few years was now virtually eliminated, and what remained was barely noticeable. I rushed to get on the air.

Because I was familiar with how well the horizontal loop works as a DX antenna, I wanted to really push the new setup to the edge. I tuned up on 30 meters with about 1.5 W showing on the QRP wattmeter. As I tuned to the low edge of the band I heard a nasty pileup. Underneath it all (and a few kHz down the band)

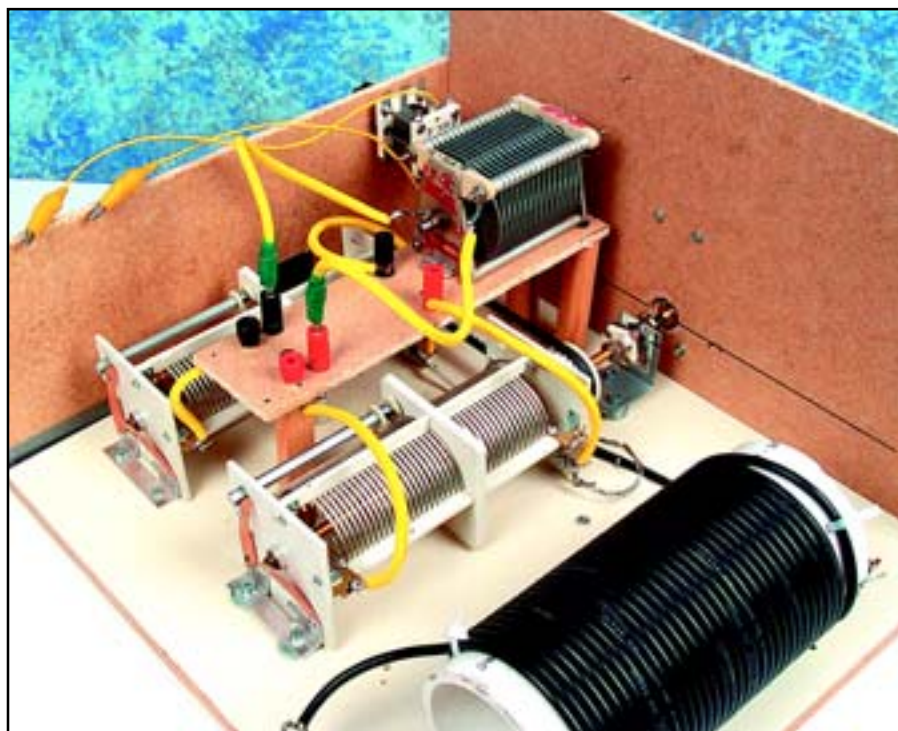


Figure 4—The parts layout of the author's balanced tuner. At the right is an easy-to-build, 160-10 meter coax balun. At the center is a pair of roller inductors and the front-panel tuning capacitor. The larger banana jacks allow the tuning capacitor to be switched from the input to the output side of the coils. The smaller banana jacks are for connecting the feed line. The smaller variable capacitor was added to facilitate testing. See the text and References sidebar for more information).

was 5U1A—a DXpedition to Niger, as I learned later. After re-remembering how to operate split, I jumped into the fray. It took me about 15 minutes to work through the pileup, but at that relatively low power level I was more than pleased (as I was the next night when I worked V51AS in Namibia on the same band).

After using the prototype tuner for a while I discovered a couple of minor things I need to iron out. The first is the funky part of 80 meters, which I hope to fix by lengthening the feed line. The second involves the wide tuning range I'm asking the L-network to accommodate.

Using the first capacitor I tried (a 15 to 300 pF unit) I can easily tune the bands from 160 through 20 meters, but there's apparently too much stray capacitance to match things on the higher bands. When I substitute a smaller capacitor I can tune 40 through 10, but not 80 and 160.

I think my eventual solution is to use the smaller capacitor and switch a fixed-value capacitor in parallel as needed, or to use the larger unit and switch a fixed C in series. My short-term solution, however, is to mount two tuning caps on the front panel and use their respective banana plugs to switch them in and out as necessary. Oh, the joys of breadboard construction.

The Path to Your Bliss

So, what have I/we learned so far?

(1) Horizontal loops are fabulous—if not the best—all-band non-resonant antennas. They noticeably outperform dipoles when used at frequencies above resonance and they're easier to match there as well (impedance wise). They're efficient, quiet and forgiving.

(2) As long as in-shack RFI and computer noise aren't part of your equation you can happily feed the loop with coax via a standard antenna tuner for use on the band of resonance and all HF bands above the fundamental frequency.

(3) If you want to operate your loop on bands below its fundamental frequency, you'll probably want to replace the coax with ladder line to minimize SWR losses in the feed line.

(4) In doing so you may discover firsthand that most conventional tuners don't work very well when feeding balanced lines, and that most tuner-output baluns don't keep things balanced over a wide range of frequencies.

If it isn't obvious by now, I'd like to offer my heartfelt thanks to Dave Fischer, W7FB; Steve Ford, WB8IMY; Rich Measures, AG6K, and the loopy guys on 75 meters.

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