Lab Notes - Limited Space Antennas

QST December 1992, pp. 85-86

Limited Space Antennas

Don't you wish you owned a monstrous tower with monoband Yagis for every amateur band from 40 meters through 70 cm? How about some sprawling 80- and 160-meter rhombics to round out the collection? Antenna farms like these exist only in the dreams of most hams. When it comes to antennas, the greatest obstacle isn't always cost, it's s-p-a-c-e! *ARRL Laboratory Engineer Zack Lau, KH6CP/1, has spent years grappling with the challenge of operating in limited-space environments. In this month's column Zack applies his expertise to solve some difficult problems.—WB8IMY*

Q: What is the smallest antenna I can buy that has lots of gain?

A: An optical telescope. A little 4-inch telescope has about 94 dBd of gain. An 8-inch telescope has 100 dBd of gain.

Q: I'm serious! I was thinking about the HF bands—something to put in my apartment. How much gain can I expect?

A: When squeezed into small apartments, most antennas will have no more than the same maximum gain as a dipole—0 dBd—less any losses. Losses can be relatively low in wood-frame buildings, and very high in concrete and steel structures. I've also heard bad things about stucco and wire mesh!

Q: How can I determine losses?

A: Try an antenna and see if it works! No kidding. It's sort of like measuring the loss of a windowpane by looking through it. There are usually too many factors involved to evaluate indoor antennas with theoretical models. It's quicker and less difficult to optimize indoor HF antennas empirically through trial and error.

Q: If I run 1500 watts to an indoor dipole, won't the fields around the antenna be awfully strong?

A: That's an understatement! (How's your fire and medical insurance?) I recommend using low power with indoor antennas. In fact, I suggest 5 watts output, though some folks run as much as 100 watts. While studies haven't conclusively linked low-level RF exposure to health problems, it's prudent to limit exposure if you can. If you're concerned about RF in your home, check Chapter 36 of the 1993 *ARRL Handbook*.

Q: But if I run low power to an indoor antenna, how can I compete with stations running 1500 watts to huge outdoor antennas?

A: You can't. However, *you can have lots of fun* with a modest setup. One of the challenges of radio is seeing what you can do with what you have. When you erect gigantic antennas and produce huge amounts of RF, you expect to work any station you want—and become gravely disappointed when you don't! This is hardly the best formula for enjoying Amateur Radio.

Q: Okay. I decided to try it your way. I set up a 20-meter dipole in the attic of my apartment building and carefully measured the wire lengths. Even so, the best SWR I can get is 4 to 1. What am I doing wrong?

A: Your antenna is probably being detuned by nearby objects. You could either vary the length of the antenna, or use an antenna tuner to reduce the SWR at the transmitter. A tuner makes a lot of sense if you can afford it. In many cases you'll be able to operate on several bands with the same antenna—even with a high SWR on the feed line.

On the downside, operating with a high SWR can result in considerable feed-line loss. When there is a mismatch at the antenna, a portion of the transmitted RF energy is reflected rather than radiated. This reflected RF travels back and forth many times between the antenna and the antenna tuner. The higher the SWR, the more trips are required to get rid of it—either in the form of heat in the feed line or radiation at the antenna. In good-quality feed line, many trips are possible before any loss is noticeable. By contrast, a poor feed line may dissipate most of the energy in a single trip!

Q: If the RF energy is making all those trips up and down the coax, won't my signal become distorted at the receiving end due to the delays?

A: You're forgetting how fast radio waves travel. For example, a radio wave zips through 16 feet of RG-213 coax in 49 nanoseconds. Even if it made 100 trips before finally being radiated, that's a delay of only 4.9 microseconds. The delay distortion that occurs is too small for anyone on the receiving end to detect. ATV (fast scan television) enthusiasts have some cause for concern, though. Delayed ATV signals appear as ghosts on TV screens.

Q: You were right about adjusting the length of my dipole. All it took was a little trimming and the SWR came right down. I'm running about 100 feet of coax to the antenna. I don't really need that much feed line, but I'm too lazy to cut it. Although the antenna tuner tunes easily, I get lousy signal reports. Is the tuner affecting my signal?

A: Not likely. The problem isn't the antenna tuner—it's your 100 feet of coax! An antenna tuner isn't a miracle worker. Putting it very simply, a tuner is a device that couples RF to the antenna system and reflects reflected power back to the antenna. It functions as an extension of the output tuning network in your transceiver.

In your case, you're wasting a great deal of power heating 100 feet of coax with precious little radiated at the antenna! You'll never know this by the behavior of your antenna tuner, however. It happily matches your transceiver to this RF heating system and you're left wondering why you get such terrible signal reports. In this instance, a low SWR indication at your tuner doesn't add up to a terrific signal.

Q: An antenna tuner is a lot of money for my low-budget station. Are there cheaper alternatives?

A: Parts from old transmitters can often be fashioned into tuners. Some of the vintage rigs featured hefty output networks. Cannibalize the parts and they'll make great antenna tuners.

The cheapest antenna tuner for the higher HF bands can be made from two quarter-wavelength pieces of coax and three inductors made of #14 wire (see Fig 1). While I've played with this system in the lab, I haven't actually used it on the air since it's physically large on any band below 12 meters. (The system is similar to that used for microwave work. By placing three screws a quarter

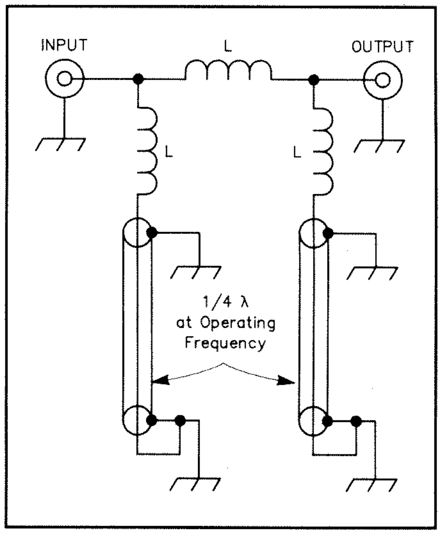

Fig 1—Here's a cheap antenna tuner design for single-band operation. The inductors (L) are wound with #14 wire. Their diameter and number of turns depends on the impedance of the antenna system you have in mind. In other words, you have to experiment! The 1/4-wave-length coax sections should be made from RG-213.

wavelength apart in a waveguide, you can match just about anything at a single frequency.) The losses might be a little higher than those you'll find in a conventional antenna tuner. The typical quality factor (Q) for coils is a tenth that of decent capacitors, but should still be acceptable if good coax such as RG-213 is used at 100 watts or less.

Q: When I shortened my coax, my carefully adjusted antenna went from a 1:1 to a 2:1 SWR. What happened?

A: The outside shield of the coax was functioning as part of the antenna. By shortening it, you effectively changed the antenna! You need to *decouple* the feed line from the antenna. If possible, bring the coax away from your dipole at a 90° angle. If the coax is running parallel to your antenna, RF coupling is likely to occur. In addition, try placing a *balun* in the feed line at the antenna. You'll see a number of baluns advertised in *QST*. Baluns decouple the feed line from the antenna but, like antenna tuners, they aren't cure-alls. You may need to experiment a bit to achieve maximum feed-line decoupling. (Try some ferrite beads on the coax, for example.)[1]

Q: Why don't they sell VHF/UHF antenna tuners?

A: They're available, but the market is awfully small since most VHF/UHF antennas are designed to present good loads to 50-Ω feed lines. Also, tuners usually give poor results at VHF/UHF. Operating at VHF/UHF with a high SWR almost always results in horrendous feed-line loss. Using an antenna tuner won't solve the problem, and manufacturers aren't inclined to sell products that don't provide much benefit. However, if you must have a 6-meter antenna tuner, it's possible to modify an existing HF unit by substituting smaller coils and capacitors.

Q: Does it matter which wire size I use for my antennas?

A: If you want to comply with the National Electrical code, yes. It specifies #14 hard-drawn copper wire for lengths under 150 feet. To make antennas nearly invisible, however, amateurs have successfully used wire as fine as #32 with monofilament fishing line as supports and insulators.

Q: Since my whole antenna system is indoors, do I really have to spend the extra money for high-quality connectors?

A: Probably not. Apartment-dwelling hams have been known to use clip-lead connectors with excellent results on HF—as long as the clip leads are reliable. I've seen a lot of shoddy ones with poorly crimped connections.

[1]R. Healy, "Feeding Dipole Antennas," *QST*, Jul 1991, pp 22-24.

Q: How about a small transmitting loop? Is it true that such an antenna will work as well as a full-size dipole?

A: Well, it's only comparable to a full-size antenna in a similar location. If I shielded both of them within a house or apartment, I wouldn't expect either to work all that well.

Loops can be quite efficient if their losses are kept to a minimum through the use of thick tubing for the radiators and low-loss capacitors for the matching networks. Low-loss variable capacitors are often expensive, though. Even if money isn't a problem, small loop antennas aren't practical at 80 and 160 meters where the bandwidth of an *efficient* loop can become too narrow to pass an SSB signal!

Q: Is there an antenna that offers high angles of radiation on 80 and 40 meters and low angles on the higher bands for DX work?

A: An antenna that meets this requirement is the full-wave horizontal loop. Unfortunately, an 80-meter loop is about 70 feet on a side, by no means a small antenna. If you only operate on 40 through 10 meters, a 40-meter loop may be feasible depending on the size of your dwelling. Or, you could use a vertical loop for the higher bands and a short horizontal dipole and an antenna tuner for the lower bands. An antenna popular among novice hams in New Zealand is a loop of wire wrapped around the house! I haven't tried it, but it would make a pretty invisible antenna, especially if you put it up just prior to painting your home.

Q: I'm on the 10th floor of an apartment building. How do I get a ground?

A: Are you sure you need one? (I can't think of any satellite stations that are grounded to the earth!) If you absolutely must have a ground because of stray-RF problems, 15 to 20 square feet of sheet metal on a concrete floor works about as well as anything else. It acts as a lossy ground, getting rid of stray RF.

You might also try a 1/4-wave *counterpoise* wire attached to the ground lug on your rig. You'll need a wire for every band on which you experience grounding-related problems. However, this approach can backfire. The counterpoise wires might also act as antennas, radiating even more RF into your apartment. Even wide copper straps are bound to be good radiators unless they're placed near lossy materials such as concrete.

Q: Can I use the sheet-metal ground for my long wire antenna?

A: You could, but much of your power may end up as heat. You're better off with balanced antennas, though people have effectively used long wires in limited-space environments (high-rise buildings in particular). When working against poor grounds, much of your signal is lost as heat. Even so, the remainder that *is* radiated may be adequate if the wire is 100 feet up!

Q: I just heard a DX station using a trap vertical at a beach-front location. His signal was terrific! I use a vertical too, but my signal wasn't nearly as good on his end. Why?

A: The quality of the ground determines how well a vertical performs at low angles of radiation—the lower the angle the better for DX! Sand saturated by salt water is a terrific ground plane for verticals.

The ideal ground plane for HF verticals should extend for hundreds, if not thousands, of feet around the antenna. The DX station you heard is operating in a near-ideal environment (in more ways than one!). Some hams try placing copper screens under their verticals, but it doesn't offer much improvement. Unless you can move to a tropical island or seaside resort, you can only work with what you have available.

Q: The trap vertical I bought seems to work, but I can't adjust the SWR to 1:1 on all bands. Should I be concerned?

A: No. Many designers find it a challenge to build an efficient antenna that exhibits an SWR under 2:1 on all HF bands. The easiest way to reduce the SWR is by increasing the losses, either by putting in a resistor or using lossy matching techniques. The classic double-bazooka antenna uses the latter—the coaxial stubs increase the bandwidth by making the antenna convert RF into heat! The acceptability of these techniques is subject to much debate and we don't have space to cover it here. If I were you, I'd use an antenna tuner and stop worrying about the SWR.

Q: I'd prefer to use a multiband trap antenna so I won't need an antenna tuner. What are the disadvantages of doing so?

A: Traps generally reduce the bandwidth of the antenna and limit power-handling capability. In most antenna designs, they're the weak link in the system. For multiband HF operating, I prefer an antenna with a minimum of weak links—no traps or baluns. This allows experimentation with an antenna tuner to determine which bands the antenna will work on.

Try a coax-fed dipole and "force feed" it via an antenna tuner. Make the antenna as long as practical. Use good-quality coax and keep it as short as you can. You may even want to try feeding your dipole with 450-ohm *ladder line* since, compared to coax, open-wire feed line has extremely low loss at HF. The SWR may be quite high on some bands, but don't let it bother you. Use your tuner to couple the RF to the antenna system and most of it *will* be radiated.

We welcome your suggestions for topics to be discussed in *Lab Notes*, but we are unable to provide individual replies. Please send your comments or suggestions to: Lab Notes, ARRL, 225 Main St, Newington, CT 06111. QST