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Author: Rod Newkirk, W9BRD

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Honey, I Shrunk the Antenna!

Think small! Communicate with multiconductor miniature loop antennas.

By Rod Newkirk, W9BRD
3830 N Richmond St
Chicago, IL 60618

Great energy and ingenuity go into efforts to boost the effectiveness of compact transmitting antennas—compact meaning configurations with circumferences of $\frac{1}{4}$ wavelength or less. By this definition, a 40-meter design could be a square with 4-foot sides. In the following discussion, I depart slightly from the square. I prefer $3\frac{1}{2}$ feet high by $4\frac{1}{2}$ feet wide, suspended in the vertical plane, for convenience in my antenna's location.

The traditional small-loop approach is to insert capacitance in series with a one-turn loop, tune it to the desired frequency, and then attempt to feed power to it as efficiently as possible—no simple matter. The antenna's Q is astronomical, current and voltage are monstrous, bandwidth is razor sharp, and its radiation resistance is ridiculously low. This lossy situation can be improved by reducing the resistance of the loop material through the use of piping, foil, etc., but the resulting plumbers' nightmares are hardly worth the pains.

A more promising avenue toward practical, simple compact antennas would appear to be in the direction of varied configuration. The goal is to "cool" the system with better power distribution, and at the same time simplify the feed. For example, vast improvement in the key parameters is possible by application of the venerable "folded dipole"

technique. This can be done by adding one more turn, tuned identically, connecting the two turns *in series*, and re-resonating the antenna. Now, looking into one of the twin current nodes, the input impedance will have roughly quadrupled. The one-turn loop's skimpy 5 or 6 Ω rises to approximately 25 Ω . Adding yet another such turn doubles this to about 50 Ω —a convenient match to common coax. See Fig 1. As with the folded dipole, more than four turns are unprofitable; diminishing returns raise the input impedance little faster than ohmic resistance. Note that the tuning capacitances, each about 40 pF, must be kept nearly equal for overall system balance.

Increasing Multiturn Loop Efficiency

Lots of hams use small loops in situations where they can't erect a larger antenna. Making contacts with these antennas largely depends on high radiation efficiency. Here are some things you can do to increase efficiency and effectiveness of such antennas:

- Use large-diameter copper wire. Keep the copper surface clean. Tin-plated wire is noticeably worse than copper in this application because of skin effect—most of the RF travels in the tin, which is far lossier than copper at RF.

- Use low-loss capacitors. The key here is minimizing dielectric loss, which is most favorable in vacuum- and air-dielectric capacitors. You can also parallel several capacitors to decrease losses.

Increasing the wire size used in these loops raises the antenna Q, narrowing the bandwidth and increasing the voltages and currents present. For this reason, you may have to use higher-quality capacitors than those used in the experimental versions if you increase the wire size.

Remember that high voltages can exist on a multiturn loop antenna's wires at power levels of a few tens of watts or more. Thus, it's best to keep the antenna well away from other objects.—Roy Lewallen, W7EL, ARRL Technical Advisor

Construction techniques, conductor material, insulation and components now become less critical because voltage peaks and current nodes are distributed throughout the system. I use ordinary zip cord, two lengths entwined, giving four available turns.¹ For proper continuity, the four wires on each side of the loop are clearly tagged at alligator-clip connectors, top and bottom centers. For 7 MHz, one turn is left open (at top and bottom), but will become useful on the lower bands as discussed later. A more classy construction might feature braided hook-up wire of contrasting colors. Small cardboard spreaders at the clips keep adjacent capacitors separated.

Midget receiver-type capacitors are adequate for CW power output up to 100 watts. One of these should be conveniently variable, preferably a double-gang or split-stator type, for tweaking the system to the desired center frequency as indicated by a 1:1 SWR. At 7 MHz, each capacitance is about 40 pF in my antenna, so the old war-surplus Hammarlund APC midgets do nicely. Bandwidth can approach that of a normal linear dipole if a slightly higher center-frequency SWR is accepted by staggering-tuning.

¹Notes appear on page 39.

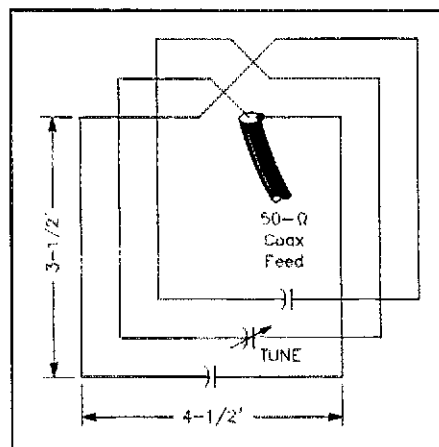


Fig 1—The three-turn loop antenna for 40 meters. Each capacitor is about 40 pF to resonate and match the antenna to a 50- Ω feed line.

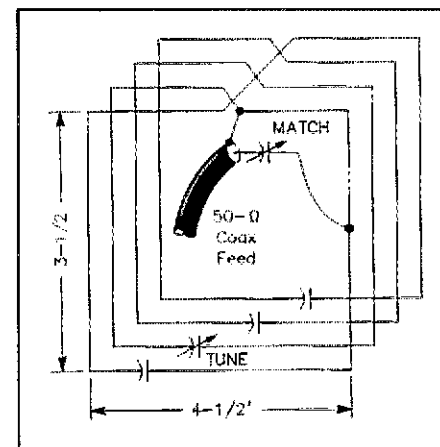


Fig 2—Extending the Fig 1 concept to 80 and 160 meters requires adding another turn to the antenna and increasing the capacitances. See the text for capacitor values.

The Ingredient Called *Belief*

Even though my busy family life keeps hamming time rare, the time I spend hamming has to be spent *right*. The idea isn't just to get on the air and contact anyone anywhere—that's too *easy*. The idea is to do something a hair off-the-wall and see if anyone shares the same orbit. So I'm one of those guys who calls CQ QRP for ten minutes at 10149.5 kHz even as game clogs the band's low end—someone who looks for (and *expects*) ragchews on 3560 at noon. And so I naturally was the guy to call a 5-watt, $3 \times 2 \times 1$ CQ at 7138 kHz at around 10 PM one night last fall when the broadcasters had long since muscled straight-thinking NovTechs off to safer terrain. And so I naturally was *of course* immediately answered by W9BRD.

It figures. We've worked on schedule many times before, but he—and I—he's the father; I'm the son—have never had to prearrange each new "first contact" after changes or station setup or locale. *Chance* is too facile a word for this, but then I haven't looked too hard for a better word, either. I don't need to; we just do our individual quirky things and click.

This time, we *both* had new setups: I'd just relocated the armful of gear constituting my "shack" to the bedroom and was talking to a low dipole through 100+ feet of mongrel coax; *he* was trying out an indoor, largely below-ground loop antenna—one of the versions shrunk in this article—with just a few tens of watts, tunneling past those steamroller broadcast signals as soundly as any medium-scale ham signal from Chicago.

Enjoying the magic of yet another first contact, I hardly gave his setup a second thought. But you may wonder if such antennas really work. Gooch's Paradox explains it thus: "RF gotta go *somewhere*." Seeking to soothe the linearless, towerless masses who toil with "only 100 watts," Newkirk's Tiresome Chant puts it, "Successful MF/HF radio communication may proceed at astoundingly low received-signal strengths." Reduced to generic essentials, it's this: The most important single factor in success with *whatever* you use is overcoming your own disbelief.—David Newkirk, WJ1Z

Excellent 40-meter results indicated that the same loop, dimensions unchanged, could have a shot at 80 meters. At 3.5 MHz, it becomes truly a miniloop, only $\frac{1}{6}$ wavelength in circumference. Adding the fourth turn (Fig 2) raises the feed impedance at a slightly higher rate than ohmic resistance, so I included it. Armed with a bargain bag of small 1-kV ceramic capacitors, I reached 3.6-MHz resonance with a value of 100 pF for

each of the four capacitances. One capacitor was then replaced with an old broadcast-style, two-gang 300-300-pF variable for tweaking. I measured the feed impedance, at the center of one of the four turns, at about 18Ω —well within the range of simple gamma matching. So another junk-box broadcast variable, three 350-pF gangs paralleled, was suspended at the loop's top center. Only about 650 pF was needed for a 1:1 match to coax after a 30-inch gamma lead was dangled to a tap at the center of one side of the feed turn. Then the system was tweakable over the entire 80-meter CW range. The remaining ceramic capacitors get slightly warm at 80 watts, which indicates significant power loss. These capacitors should be replaced with low-loss units for best performance, but I left them alone for my experiments. I easily contacted the East Coast and as far west as Arizona in the following few nights on the air.

My next inclination, as you may surmise, was to try the little gem on 160 meters. A four-foot-square transmitting loop for 1.8 MHz? I wasn't overly optimistic. Years of tinkering at W9BRD had failed to produce a decent indoor compact antenna, even of much larger size, for top-band work. But I dug into my bag of ceramics and gave it a go. The four-turn loop, now only $\frac{1}{32}$ wavelength in circumference, resonated at about 1.8 MHz with four 350-pF capacitors. One of these was replaced with an old broadcast-type 500-pF variable for tweaking the center frequency between 1.8 and 1.85 MHz. I double- and triple-checked the measured feed impedance— 16Ω . Now I knew it would work. The gamma-match SWR dipped to 1:1 at about 800 pF using the same lead, tap and broadcast capacitor as on 80 meters. Immediate solid 40-watt CW QSOs with WN9W, KC4WVW, WK9B and W4VZB were most gratifying.

Variations and the Higher Bands

If such a $\frac{1}{6}$ -wavelength loop can function at 80 meters, the same should be true at 20 meters. So I wound a 1-foot-square, three-turn model on a cardboard box, hung it on a wooden bulkhead, and resonated it to 14.050 MHz with three 50-pF ceramic capacitors. This time, instead of the usual fudging capacitor, I spaced the turns $1\frac{1}{2}$ inches apart. Center-frequency tweaking thus could be done by uniformly edging the turns away from or toward each other. This spacing approach works fine for box-wound loops, but for the lower bands, I prefer closewound zip cord. Input impedance turned out to be about 11Ω —I should have used a fourth turn—and gamma coupling worked okay, as on 80 and 160. The 1:1 feed-line dip occurred with a 120-pF series capacitor, with a gamma lead of 13 inches. In my installation, this antenna is no low-angle DX radiator, to be sure, but I've received S9 reports during many state-side QSOs. Anyone for a 3-inch-square 2-meter version?

Antennas smaller than necessary are interesting stunts that help prove a design. However, for the lowest HF bands I recommend the largest practicable circumference.

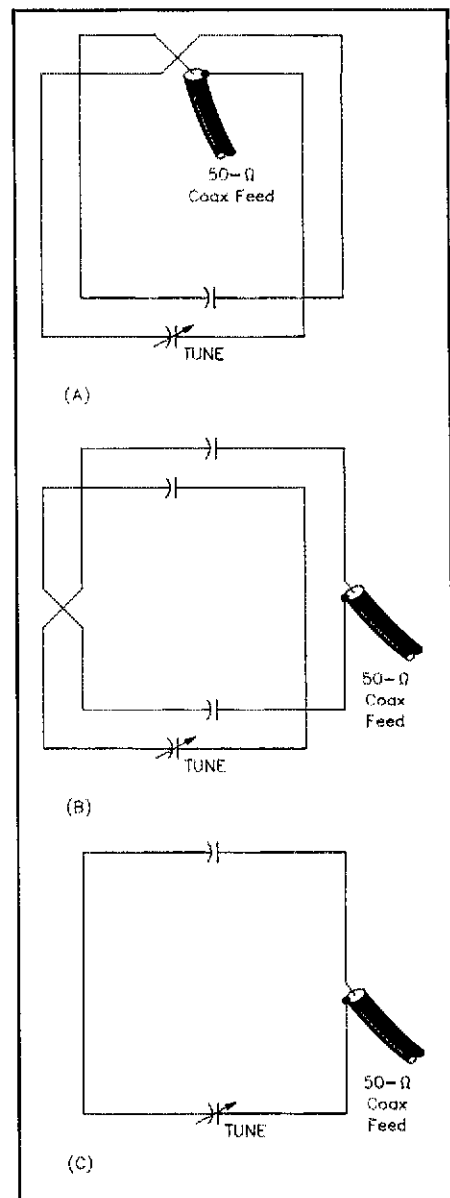
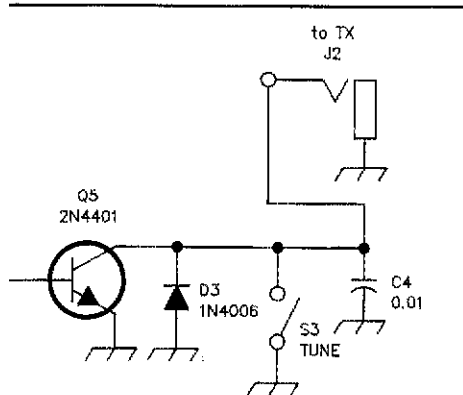


Fig 3—At A, the 30/20-meter loop; at B, the 15/17-meter version, and at C, the 10-meter variant.

For operators limited to indoor installations, floor-to-ceiling height is usually the limiting size factor. Thus, a cooler 7-foot by 9-foot job, requiring much smaller resonating capacitances, should be a natural for 80 and 160.

Incidentally, the configurations described are quite well balanced. Although in my tests the antennas were placed within tweaking distance of the operator, no shack RFI showed up on any band at the 80-watt level. Careful symmetry helps, notwithstanding the dangling gamma lead on 80 and 160. The coax feeder should run down and away from the top-center feed point, equidistant from the vertical sides. A balun or coaxial RF choke might seem applicable, but I found such isolation unnecessary. The directivity pattern for such a loop is the usual figure-8, with most

(continued on page 39)



Except as indicated, decimal values of capacitance are in microfarads (μF); others are in picofarads (pF); resistances are in ohms; k=1,000, M=1,000,000.

NC=Not Connected

close to the ultimate for manual CW keying. Even electric and electronic typewriter keys load the fingers more than this keyer does! CW will get easier only when someone perfects a voice-to-Morse converter. (With voice-recognition and computer technology already quite advanced, that may well be an idea just awaiting implementation. If you accomplish this, we at *QST* would like to know about it.—Ed.)

Notes

¹L. Cebik, "IROESK—An Infrared Optoelectronic Straight Key," *QST*, Feb 1992, pp 30-34.

²Back issues and photocopies are available from the ARRL. Contact the Technical Department Secretary at 203-666-1541; fax 203-665-7531.

³Because of the Curtis line-up change, and recognizing that many of the older chips are still available throughout the world, FAR Circuits makes available *three* PC boards. Two boards accommodate the circuits using the IR paddle input, one accepting the 16- and 18-pin ICs, the second is for the 20-pin IC. The third board is for a mechanical-paddle version of the 20-pin 8044ABM keyer *not described here*, but similar to the one in recent editions of *The ARRL Handbook*. PC-board pads are provided to allow access to *all* IC pins and incorporate all the features of a particular chip. PC boards are available from FAR Circuits 18N640 Field Ct, Dundee, IL 60118-9269. PC-board prices: 8044/8044AB, IR input, \$4.75; 8044ABM; mechanical-paddle input \$4.25. Please add \$1.50 for shipping.

PC-board templates, part-placement diagrams and a schematic of the unpublished paddle-input keyer are available from ARRL HQ. Please send a business-size SASE and address your request for the CEBIK IROESON KEYSER PC-BOARD TEMPLATE to: the Technical Department Secretary, ARRL, 225 Main St. Newington, CT 06111.

only be an artifact of the fairly tight quarters I created for keying. You may want to change the assembly design to suit your favorite keying posture.

Summary

Kicking the "brass-and-spring" habit comes hard after many years. But in an age of labor-saving devices, IROESON may be

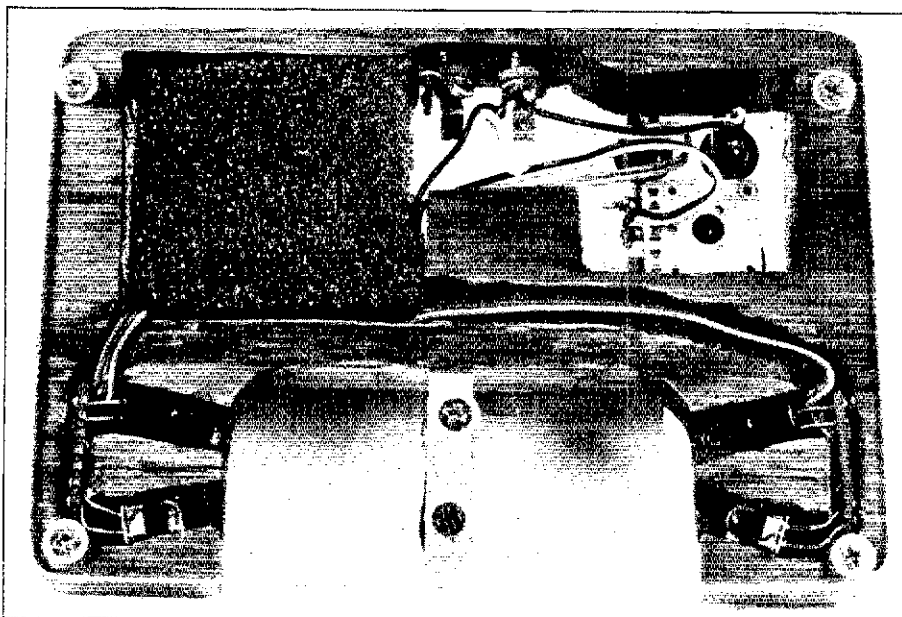


Fig 4—A bottom view of one of the prototype keyers. Note the channels for the wiring to the IR LEDs and phototransistors. Small pieces of perf board hold the LEDs and phototransistors in channels that are routed at an angle to the "paddle."

Honey, I Shrunk the Antenna!

(continued from page 35)

radiation in the plane of the loop. However, there will be sharp nulls perpendicular to the loop's plane, which you should take into account when placing your antenna.

My prime purpose here is to treat loops of $\frac{1}{8}$ -wavelength circumference or smaller, but you may desire to use the same $3\frac{1}{2}$ -foot by $4\frac{1}{2}$ -foot dimension on the higher HF bands, as I do. The hook-ups shown in Fig 3 perform well on 30 through 10 meters. Each provides a direct match to 50- Ω coax. True, almost any old piece of wire gets QSOs on 10.1 MHz and above, but a balanced loop radiator is hard to beat for indoor hamming. A few hints and observations:

- At 10.1 and 14 MHz (Fig 3A), just two turns are sufficient to reach a feed impedance of about 50 Ω . The two approximately 20-pF capacitance values are slightly higher for the 30-meter band.

- For 17 and 15 meters (Fig 3B), the loop must be made electrically smaller by splitting it symmetrically. Two split turns and four equal capacitances then bring a close 50- Ω match. Note that the feed point is moved to the center of one of the four vertical sides. Capacitances are in the 15-pF range.

- On 12 and 10 meters (Fig 3C), one split turn will suffice for a near-50- Ω match, with two capacitors of about 12 pF. Here, split-stator midgets can ease adjustment by minimizing hand capacitance, but it's a fancy junk box that includes them. The old APC midgets, whose rotors have little more mass than their stators, will maintain enough system balance.

Cautions and Conclusions

Like any indoor antenna, the loops I describe here generate substantial electromagnetic fields in operation. Thus, they have considerable potential to generate RFI. For this reason and to prudently avoid placing yourself or others in large RF fields, you should keep all antennas as far from consumer electronic devices and people as possible, and use the least RF power necessary to conduct the desired communications. The current editions of *The ARRL Handbook* and *The ARRL Antenna Book* cover this subject in more detail.²

A final comment: For overall results with compact antennas, like almost any skyhook, the higher above ground the better. In my case, radiation and reception strongly favor higher skywave propagation angles. All antenna configurations I describe here were tested and operated in a cellar ham shack, where half of the system is below ground level!

Notes

¹See the sidebar, "Increasing Multiturn Loop Efficiency," for some ideas on optimizing such an antenna's performance.

²See Chapter 36 of the *Handbook* and Chapter 1 of the *Antenna Book*.