A Simple, Effective Dual-Band Inverted-L Antenna

Classic ham-antenna types are classics for a reason: They've worked predictably and well for several generations of hams. Here's how to put such an antenna—the inverted L—to work on the low bands.

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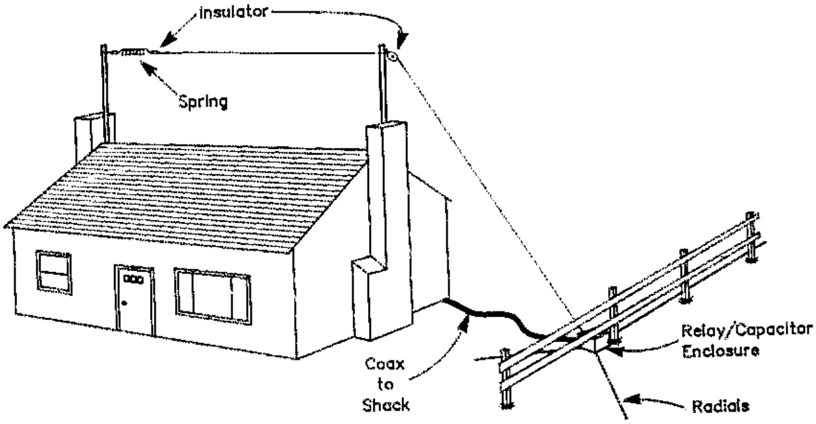

Building antennas is fun! These days, we purchase and operate sophisticated transceivers, but we still build many of our aerials. It satisfies us to create something that really "gets out." If only we each had several acres of tall trees...sigh. More often than not, though, we find ourselves crowded onto small city lots among neighbors who don't share our love for antennas. This presents quite a challenge, especially to low-band enthusiasts. What to do?

Build an inverted-L antenna! An 80-meter inverted L takes up only a quarter wavelength of horizontal space (64 feet) and can be built to blend into the background. You'll find it satisfying and it will work well on 40 meters, too. Inverted-L antennas are also easy on the pocketbook and use commonly available materials.

Background

Inverted-L antennas aren't new; they've been around for a long time. Most often they're used on 160 and 80 meters as an alternative to a 1/4-λ vertical where support height is scarce. They're proportioned according to this single guideline: make as much of the antenna as possible vertical and bend the rest over. Usually, 1/4-λ inverted Ls end up roughly 1/8 λ vertical and 1/8 λ horizontal (Fig 1A).

Fig 1B shows a variation on the basic inverted L. With its total wire length of 3/8 λ, this version offers several advantages over the quarter-wavelength configuration. Most importantly, the 3/8-λ antenna's radiation resistance and feed-point impedance are higher, which decreases the effect of ground losses.[1]

Because this antenna's maximum-current point occurs 1/8 λ above ground level (instead of *at* ground level, like the 1/4 λ version), the antenna can also "see out" beyond obstacles better than the shorter version. Computer simulations for a 3/8-λ 80-meter inverted L[2] reveal an essentially omnidirectional pattern with slight directivity (1.5 dB) in line with the horizontal wire and pointing away from the far end.[3] The takeoff angle is favorable for short- and medium-haul contacts (out to a few thousand miles).

A Free Band

What makes the 3/8-λ inverted L especially interesting is that it gives you decent performance at twice the fundamental frequency (that is, where the total antenna length is 3/4 λ—Fig 1C). You can build the antenna for 160 and 80 meters, 80 and 40 meters, and so forth. At twice the antenna's fundamental operating frequency, the antenna is resonant and has two current maxima: one at the feed point and another in the middle of the horizontal wire. The antenna acts essentially like a quarter-wave vertical end-feeding a horizontal half-wave dipole. The radiation pattern looks much like that of a dipole because the horizontal wire dominates the antenna's overall performance at moderate to high elevation angles, but the vertical wire contributes valuable low-angle radiation. At low elevation angles, the antenna has little directivity; at higher angles, the pattern more closely resembles the pattern of a dipole at the same height. At twice the antenna's lower operating frequency, this antenna works best for short- and medium-distance contacts, but I've worked my share of DX with it, too.

The Ground System

Because the inverted L is a modified end-fed vertical, the quality of the RF ground near the feed point influences its operation. It's therefore best to use as many radials as you can, based on the available space, following the guidelines given in *The ARRL Antenna Book*.[4] My ground-radial system is modest because of limited space, and tearing up the yard certainly wouldn't win me any points with my wife. I used an 8-foot ground rod (strategically located near a sprinkler) driven into moist soil at the feed point, and three odd-length radials. One is very long (over 100 feet) and snakes along a fence, and the others are less than 20 feet long. This ground system is far from ideal, but the antenna works.

Installing the Antenna

One of the nice things about inverted Ls is that they fit easily on most city lots. You can run the antenna from a chimney-mounted support (such as a TV mast) or tower to a tree in the yard. Or, you could run it between trees or push-up TV masts at opposite ends of the yard. The supports can be slender and lightweight because the wire's weight and wind load are small.

[1]Notes appear on p 41.

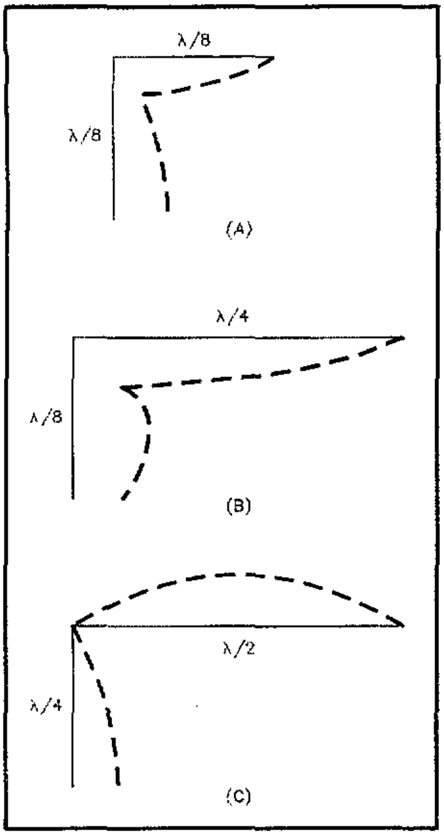

Fig 1—At A, the basic inverted L commonly used on the lower-frequency ham bands. The dotted line represents current distribution. The 3/8-wavelength inverted L shown at B features a more favorable current distribution. At twice the fundamental (C), the antenna at B acts as a 3/4-λ wire. Note the two current maxima. The antenna behaves like a quarter-wave vertical end-feeding a half-wave dipole.

Unlike center-fed dipoles, inverted Ls don't have heavy, unsightly coax hooked to the middle of the horizontal span. I use a pair of TV masts clamped to the chimneys located at the ends of my house to support my 3/8-λ inverted L (see the title drawing). The poles are painted sky blue and suspend insulated no. 16 stranded wire (also blue) at about 35 feet. Although the chimneys are only about 54 feet apart, the antenna works fine. I make up the difference in overall antenna length primarily by slightly angling the vertical wire away from the house. It's a good idea to space the wire's vertical section away from a building or conductive mast, even if the mast isn't grounded.

A box at the feed point firmly anchors the antenna wire at ground level, so install strain relief elsewhere in the system to keep swaying supports from breaking the wire. One popular technique often described in the literature[5] involves installing a small pulley, with a weight attached to the rope after it passes through the pulley, at the horizontal wire end opposite the feed point. As the supports sway, the weight keeps constant tension on the wire. At the top of the vertical section, the wire passes through one eye of a ceramic insulator. In my installation, a spring takes the place of the pulley and weight at the horizontal wire end opposite the feed point. Both techniques work well. My inverted L has survived seven winters so far, and is still going strong.

Tuning, Feeding and Adjusting the L

The inverted L can be easily matched to coax. For ease of explanation, I'll use the 80/40-meter version as an example. With a modest ground system, the antenna's feed-point impedance appears as roughly 100 Ω on both bands. If you use the dimensions given in Table 1, the antenna wire should be a tad long for resonance on 40 meters.

On 80 meters, the impedance is partially reactive, appearing as an inductor in series with about 100 Ω of resistance. Unlike 40 meters, though, the antenna's radiation resistance varies across the band (from about 70 Ω at 3.5 MHz to roughly 130 Ω at 4 MHz). To tune out the inductive reactance, you'll need to add a capacitor in series with the coax center conductor at the feed point (see Fig 2). I suggest that you use a variable capacitor to resonate the antenna at the frequency of interest. After doing this, you can replace the variable with a fixed capacitor, if you like. Should you choose to stick with the variable, protect it well against weather. Before sealing the feed-point box, toss in some moisture-absorbent material (desiccant).

You can make your own fixed-value, high-voltage, high-current capacitor from a piece of coax. For example, RG-8 (solid dielectric) exhibits 29.5 pF per foot and can withstand 4 kV at several amperes. Connect it by attaching one end of the inner conductor to the antenna and the braid (at the same end) to the feed system; leave the other end open. Start with about 4 feet of RG-8 and trim the coax for minimum SWR. (Make your cuts when you're *not* transmitting!) Other solid-dielectric cables (such as RG-58) are also suitable for this application; *The ARRL Handbook* gives capacitance per unit length in its table of coaxial-cable parameters.

Table 1
Recommended Wire Lengths and Capacitor Values*

Bands	*Vertical Length (ft)*	*Horizontal Length (ft)*	*Total Length (ft)*	*Series Capacitor*
80/40	32	64	96	≈100 pF
160/80	64	128	192	≈200 pF

*The total length is important, but the portions allocated to the vertical and horizontal members aren't critical.

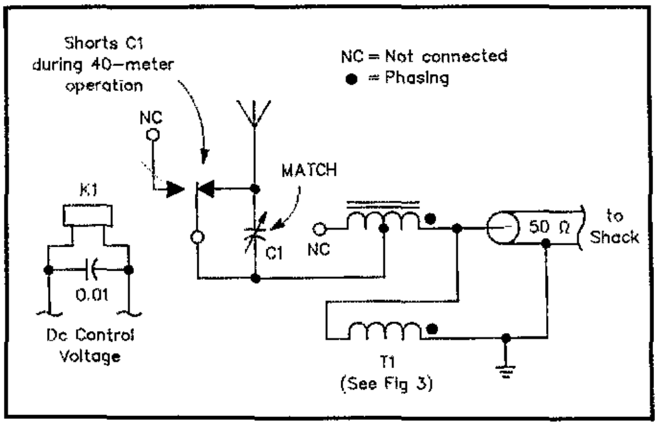

Fig 2—The resonating, impedance-matching, and band-switching circuitry required at the base of the inverted L, assuming a 50-Ω coaxial feed, no antenna tuner and a limited ground-radial system. See text for details and other feeding options. Fig 3 shows details of T1.

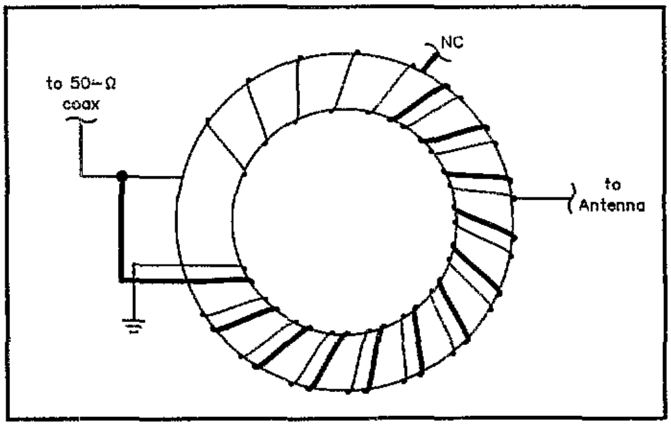

Fig 3—Winding details for constructing broadband bifilar transformer T1. You can use an Amidon FT-240-61, FT-240-43 or T-200-2 core; see note 9. The primary is 16 turns of no. 14 enameled wire, and the secondary is 10 turns of no. 14 enameled wire tapped at about the eighth turn from the feed-line end.

Another way to construct your own high-voltage capacitor involves sandwiching a piece of picture-frame glass between two metal plates. Richard Plasencia, WØRPV, describes how to build a variable capacitor using this technique in *The ARRL Antenna Compendium*, Vol 2.[6]

Regardless of your choice of a series capacitor, remember that it must be able to withstand at least 1 kV and fairly high currents. Use 1-A/1-kV components for 100 W output and 4-A/4-kV parts for 1.5 kW. Receiving variables work fine. Transmitting variables are hard to come by these days from commercial sources; hamfests, electronic flea markets and surplus stores are your best bet if you don't have the right part in your junk box.[7]

Choosing a Feed Line

So far, so good. We now have a resonant two-band antenna—with a feed-point impedance near 100 Ω. What you do next depends on whether your station includes an antenna tuner. If you have a tuner, you're home free, because even if you use 50-Ω coax, the SWR on the line will be only 2:1 (higher off resonance, of course), which isn't enough to cause much additional line loss at these low frequencies. But consider the cable's breakdown voltage. Miniature RG-8 (such as Belden RG-8X and Radio Shack RG-8M) works fine at 100 W; solid-dielectric RG-8 is adequate for the kilowatt level—as long as you don't try to cover the entire 80-meter band with one setting of the series capacitor (more on this later).

Feed-line SWR can be minimized by using 75-Ω coax. In fact, 75-Ω cable is the best choice. Minimizing ground-system loss by improving the radial system makes the antenna a better match for 75-Ω coax by decreasing the feed-point impedance—another good reason to install the best radial system you can.

If you don't have a tuner but your rig has tube finals, you may be able to adjust the transmitter's output network to match the feed line. Pi-network output stages (like the one in my TS-820 and most other 6146-based rigs) can handle impedances above 50 Ω pretty well. You'll likely be able to connect the 75-Ω coax directly to such a rig without an antenna tuner. Trailing-edge technology can have its advantages!

Matching the Inverted L to Coaxial Cable

If your rig won't match the coax and you don't have an antenna tuner, use a matching transformer between the feed line and antenna. For single-band operation (80 or 40 meters), you can use an electrical 1/4-λ section of 75-Ω line, in series with the 50-Ω cable, to transform the ≈ 100 Ω feed-point impedance to 50 Ω at the end of that section. You can attach 50-Ω coax at that point or connect the matching section directly to the rig. This type of transformer is known as a *Q section*, a special case of the *series-section transformer. The ARRL Antenna Book*[8] describes these in more detail.

For dual-band operation, you'll need to either switch transformers when changing bands or construct a 2:1 (100:50 Ω) broadband transformer (Figs 2 and 3) that operates over your frequency range of interest. The easiest way to accomplish this is to wind a broadband transformer on a toroidal core. A 2-inch powdered-iron core or 2.4-inch ferrite core can handle the legal limit if properly applied. I see no problem with ferrite-core saturation at the 100-Ω impedance level using the recommended toroids. Wind the transformer as shown in Fig 3 using no. 14 enameled wire. A kit that includes everything you need for this application is available from Amidon Associates.[9] Although this transformer looks like a balun, it isn't. Both the input and output terminations of this transformer are unbalanced.

If you adjusted the antenna for resonance on the two bands, you need only adjust the transformer tap for minimum SWR at your rig. You should be able to cover the entire 40-meter band with an acceptable SWR, but 80 meters can only be covered in 175-kHz chunks (Fig 4). The best way to get around this is to make it easy to adjust the series capacitor, or switch in different capacitors. Fig 4B shows SWR curves representing two different capacitor values. Fig 5 shows my antenna's feed-point box, where the capacitors and shorting relay are mounted.

If you like, you can adjust the tap point on the toroid for your favorite 80-meter frequency. This will have an adverse, but minor, impact upon the minimum SWR on 40 meters.

If you're pruning the antenna and making feed-point adjustments with the aid of only an SWR meter, first adjust the total length for an SWR dip at your 40-meter frequency of interest. Then, adjust the capacitor for minimum SWR at your frequency of interest on 80 meters. You can further minimize (or trade off) SWR by choosing the optimum transformer tap. Remember, the transformer is there to reduce the SWR after you've resonated the antenna—it won't change the antenna's match frequency. Only pruning the wire and adjusting the series capacitor can do that.

Switching Bands

To switch bands, short the series capacitor (see Fig 2). You can do this manually or via a relay. I chose a relay because I don't like going outside with a flashlight on cold, rainy winter nights—numbs the fist, you know. Relay-contact spacing and size should be sufficient to handle at least the voltages and currents given for the series capacitor. (Large contacts are not necessary unless you run high power.) Ceramic relays work best for antenna

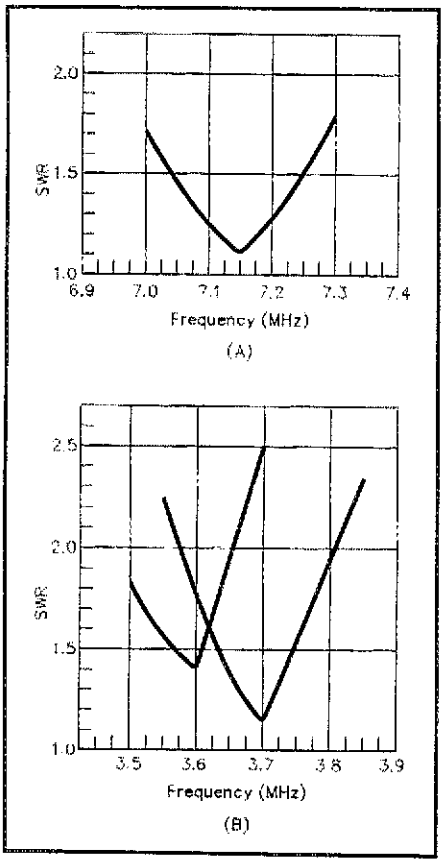

Fig 4—At A, 40-meter SWR curve using the network of Fig 2. At B, measured SWR curves for 80 meters using the same network. Curves representing two different series capacitor values are shown. A single capacitance value yields a 2:1 SWR bandwidth of approximately 175 kHz.

Fig 5—The feed-point enclosure for the dual-band inverted L at AE6C. Five high-voltage mica capacitors (at right) tune out the antenna's reactance at 80/75 meters.

switching, but they're hard to find. Hamfests, electronic flea markets and surplus stores are possible sources.[10] At the 100-W level, you can get by using plastic-insulated relays intended for line-voltage-switching applications. These are both easy to find and inexpensive.[11]

Adding 160 Meters to the 80/40-Meter L

When I want to work 160 meters, I insert a 15-μH loading coil in series with the feed point, and short the capacitor with a relay. Initially, I used a dip meter to establish resonance. The antenna's feed-point impedance is low on 160 meters (less than 20 Ω, including ground and coil loss) so if you usually use a 2:1 transformer to step 50-Ω coax impedance up to 100 Ω, bypass it. Connect the loading coil in series with the coax at the feed point. The line SWR will be high, but this shouldn't harm system performance because even a badly mismatched coaxial feed line has little loss at 160 meters. Of course, you'll need to use an antenna tuner. Alternatively, you could reverse the 2:1 transformer to step the coax impedance down closer to that of the antenna. I've never tried this, but it should work better than directly connecting the antenna to 50-Ω coax.

This is obviously a makeshift 160-meter aerial, but it works. On a good winter's night, I can work into the Midwest while running 100 W. If you've got the room, by all means put up the 80/160-meter version. It's impressive. Mitchell, KB6FPW, and I put one up in the pines last year on Field Day and cleaned out the 80-meter band with it. We didn't get a chance to exercise it on 160, though, because there was little activity. I'd love to hear from anyone who puts an 80/160-meter inverted L through its paces.

Conclusion

If you've read this far, you now realize that you no longer have an excuse to avoid the lower bands. As we slip farther down sunspot cycle 22, conditions and activity on 160, 80 and 40 meters will improve. Be there with an inverted L—and a good signal!

Notes

1This is because the antenna's feed-point impedance consists of *radiation resistance* (a constant for the antenna that represents the antenna's radiating load) and loss resistances. The higher the radiation resistance, the less toll loss resistance takes on antenna efficiency.

2I used an enhanced version of *MININEC* called *MN*, which is available from Brian Beezley, K6STI, 507½ Taylor St, Vista, CA 92084.

3J. Hall, ed, *The ARRL Antenna Book*, 15th Edition (Newington: ARRL, 1987), pp 6-11 to 6-12.

4*The ARRL Antenna Book*, pp 3-1 to 3-6 and 3-13 to 3-14.

5*The ARRL Antenna Book*, p 22-1.

6R. Plascencia, "Remotely Controlled Antenna Coupler," J. Hall, ed, *The ARRL Antenna Compendium*, Vol 2 (Newington: ARRL, 1989), pp 182-186.

7Fair Radio Sales (PO Box 1105, 1016 E Eureka St, Lima, OH 45802, tel 419-223-2196) currently carries two suitable variable capacitors: part no. C331/AM66 (17 to 212 pF with 0.04-in. spacing), $8; and part no. C-221/T-195 (13.5 to 77.8 pF [first section] and 17 to 99.6 pF [second section] with 0.094-in. spacing), $4.

8*The ARRL Antenna Book*, p 26-14.

9Amidon (2216 E Gladwick St, Dominguez Hills, CA 90220, tel 213-763-5770) carries a kit (part no. AB-200, $6) containing a T-200-2 core, and balun kit (p/n AB-240, $9) containing an FT-240-61 core. Both kits come with sufficient no. 14 high-voltage, high-temperature insulated wire for this application.

10Fair Radio (see note 7) currently carries several relays suitable for 100-W service: p/n PR80164 (5-A, 120-V ac contacts with 12-V dc coil), $2.50; p/n KR5737 (5-A, 115-V ac contacts with 115-V ac coil), $2.50. Fair Radio also carries a ceramic relay that appears capable of handling high power, although its contact spacing is not specified: p/n RY3/610 (10-A contacts, 115-V ac coil), $20.

11Radio Shack part nos. 275-206, 275-217 and 275-218 (1991 catalog, p 133) are suitable.

Dennis Monticelli was first licensed at age 15 in 1967. His Amateur Radio activities spurred his interest in electronics and led to his pursuit of a BSEE degree, which he earned from the University of California in 1974. Since graduating, Dennis has worked for National Semiconductor, first as an analog-integrated-circuit designer, where he's been involved in 20 patented circuit-design projects. He's presently Director of Voltage Regulator and Motion Control Products at National.

Dennis's favorite ham radio activities include home-brewing, HF DXing, QRP, antennas and CW. His other interests include woodworking, photography, and spending time with his family.

Strays

CELEBRITY NET

□ Walter Cronkite, Ronnie Milsap, Gary Schandling, Joe Walsh, Chet Atkins. How many famous (or semifamous) people are hams? Larry Junstrom, KN4UB, bass player for the band 38 Special, invites musicians, singers, actors, comedians, TV personalities and other entertainers interested in forming a net to contact him at 6834 Tom Thumb Dr, Jacksonville, FL 32210.

KG4 QSLS

□ QSLs going to the KG4 bureau (Guantanamo Bay ARC) will no longer be forwarded to personnel who no longer reside in Guantanamo Bay. I still have a list of addresses for some of the operators. If you need a copy, write to me at Box 692, FPO New York, NY 09593-0055. Mail can still be sent to the KG4 bureau for KG4AM, KG4AN, KG4BD, KG4CO, KG4DD, KG4FD, KG4FG, KG4GB, KG4OM, KG4TG, KG4TM, KG4YL and any other operator presently active in Guantanamo Bay. KG4 2 × 1 call signs, ie, KG4W and KG4O, are not Guantanamo Bay call signs, they are stateside; QSL them via the W4 Bureau. Only KG 2 × 2 calls are in Guantanamo Bay. *—Douglas A. Donley, KG4DD, Guantanamo Bay, Cuba*

VK3 QSL BUREAU

□ The Wireless Institute of Australia (WIA) Victorian Division Inwards QSL Bureau is fully computerized and QSL cards are handled by paid staff. Cards are accepted for WIA members and nonmembers. VK3 Inwards QSL Bureau, Box 757G, GPO Melbourne 3001, Australia.

QST congratulates...

□ Leonard Kay, KB2R, who earned his PhD in electrical and computer engineering from the University of Massachusetts at Amherst. Kay says, "This is a big milestone for me and ham radio helped keep me sane through grad school." He's now an assistant professor at Northeastern University in Boston and is faculty advisor for the school's ARC. His research involves computer modeling and semiconductor devices.

□ The following amateurs on 50 years of League membership:

- Karl Gansler, W4PSG, Ft Pierce, FL
- George Russell, W2SJU, Gainesville, FL
- Paul Wilson, W4HHK, Collierville, TN
- Merle Turner, W3GF, Silver Springs, FL
- Charles Bookwalter, W8QJF, Mansfield, OH
- Robert Baird, W9NN, Cocoa Beach, FL
- Ulis Tucker, W4YRK, Auburndale, FL
- Elias "Bus" Etheridge, K4IX, Norfolk, VA
- Rex Hays, W7NP, Tacoma, WA
- Julius Hoffer, W1DL, Framingham, MA
- Tom Bohnsack, W6PEQ, Los Altos, CA
- David Jackson, W9BIX, Oak Lawn, IL
- William Jochimsen, K4ZK, Jensen Beach, FL
- Henry Nevrkla Jr, W3IQK, Pasadena, MD
- George Christofferson, K6MTZ, Los Altos, CA
- Emmett Freitas, AE6Z, San Jose, CA
- Bernard McKay, VE1LN, Yarmouth, NS
- Ralph Conly, N6VT, Sunnyvale, CA
- Donald Coeyman, W4RRK, Greensboro, NC
- Harry Mills, K4HU, Hendersonville, NC
- Herbert Klein, W2NCM, Brooklyn, NY
- Don Hawley, W4ZU, Orlando, FL
- Merritt Yancey, K6CDX, Downey, CA
- John Cale, W4GOV, Tallahassee, FL
- William Wesslund, WØBJ, N Platte, NE
- Wilbur Boyce, KD6JP, Arcadia, CA
- LeRoy Fry, W6LQN, Los Angeles, CA
- Alexander Newbold, W6MMG, Belmont, CA
- Arthur Schuessler, W9UUL, Roselle, IL
- Joe Speidel III, K4OYO, Clarksville, AR
- George Grey Jr, W2LOC, Cedar Grove, NJ
- Waldo Nason, W1LUG, Fitchburg, MA
- Cornelio Nouel, KG5B, Brownsville, TX
- Earl Reichman, W8NBK, Chillicothe, OH
- Homer Apple, W4HER, Burlington, NC
- Roy Belair, W3NX, Wilmington, DE
- Thomas Gibson, W3DJ, Joppa, MD
- J. Wesley Sammis, W2YRW, Haddonfield, NJ
- Joseph Duffin, W2ORA, Moorestown, NJ
- Selmer Sampson, W3QGE, Clarks Summit, PA