Having an antenna that's resonant across the entire 80-meter band is a challenge. Commercial antennas with integrated tuning units are expensive, but KA2C offers a compact and low-cost approach to "rolling your own" step-tuned 80-meter dipole or inverted vee.

An Inverted Vee for 80 Meters with Integrated Tuning

BY NELSON SOLLENBERGER,* KA2C

Antennas for 80 meters rarely cover the full band with low SWR, including full-size dipoles, inverted vees, and verticals. Many solutions to this problem are used by hams, including desktop manual and automatic antenna tuners, remote antenna tuners, antenna broad-banding techniques such as cage dipoles, manual adjustments such as adding/removing pieces of wire to shift antenna resonance within the band, and other techniques. SWR and antenna efficiency/performance are not tightly coupled and good antenna performance with high SWR is possible, while poor antenna performance with low SWR is also possible. But low SWR (an impedance-matched system) can be important for safe and efficient operation of transmitters and amplifiers. Low SWR also minimizes coax cable transmission loss. For high power operation, a matched impedance system at 50 ohms results in operating voltages of only a few hundred volts while unmatched conditions with high SWR can result in thousands of volts that may cause failures.

High performance HF antenna products sometimes include an integrated antenna tuning function. SteppIR is well known for including antenna tuning in its antennas, including 80 meters, based on adjusting the physical length of elements. OptiBeam offers an 80-meter rotatable dipole as well as 2-and 3-element Yagis with integrated tuning using relays and loading inductors at the center of the antenna elements to cover 80 meters in four band segments, and Array Solutions has provided 80-meter Yagi solutions with similar features. General-purpose remote antenna tuning units are available, but units capable of the full legal power limit cost $1,000 and up and are fairly large in size. But the use of integrated antenna tuning optimized and designed for low-cost full-size simple wire antennas appears uncommon for 80 meters. One exception is a simple 80-meter dipole with relay switched loading coils built into the antenna center unit available from Antennas-Amplifiers with two frequency selections for CW and SSB. Some hams have used relays and loading coils in some arrangements to provide an integrated tuning function.

This article describes a simple and low-cost inverted vee or dipole antenna for 80 meters with integrated tuning cov-

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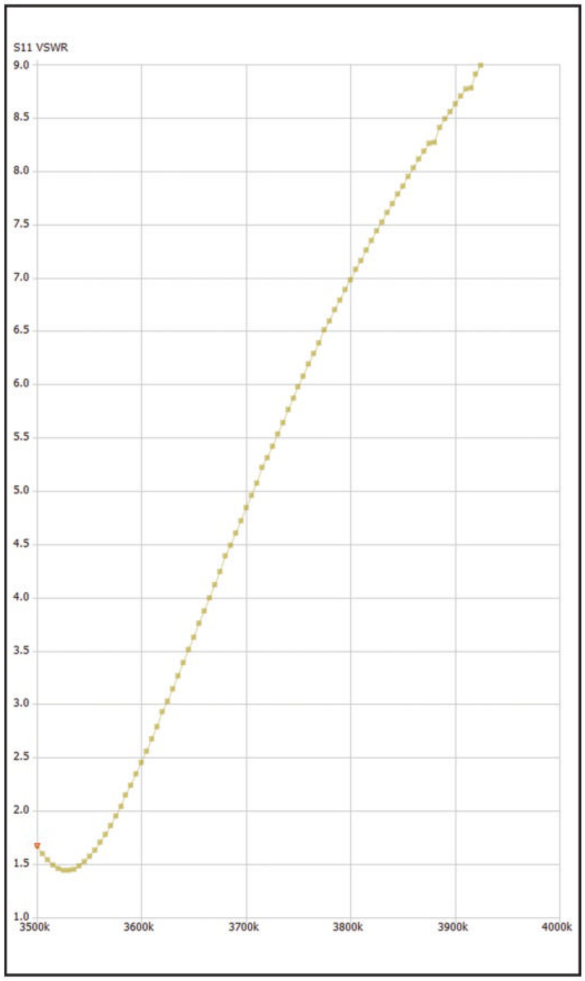

Figures 1-8: SWR plots using a nanoVNA for each of the eight switch positions of the integrated tuner, ranging from the bottom of the 80-meter band (Figure 1) to the top (Figure 8).

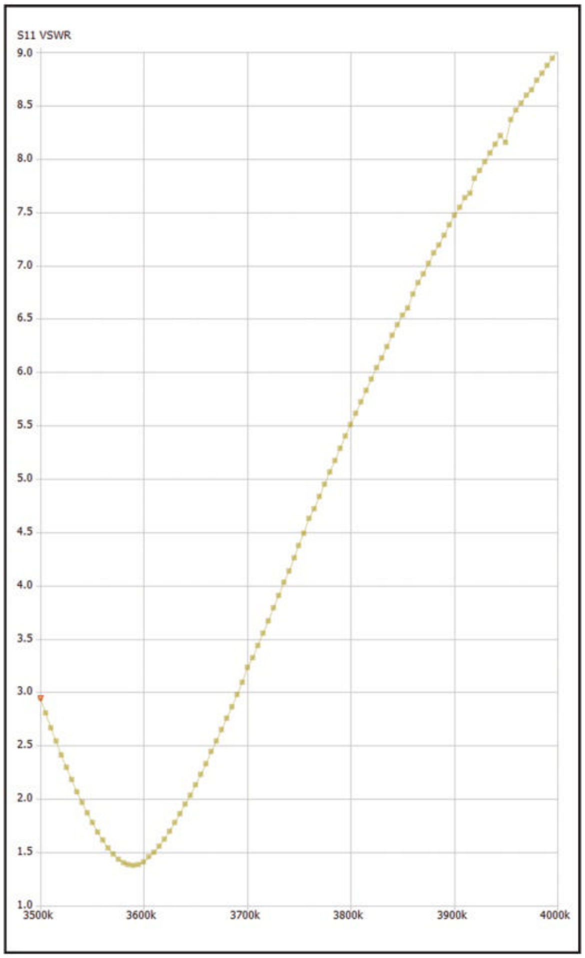

Figure 2.

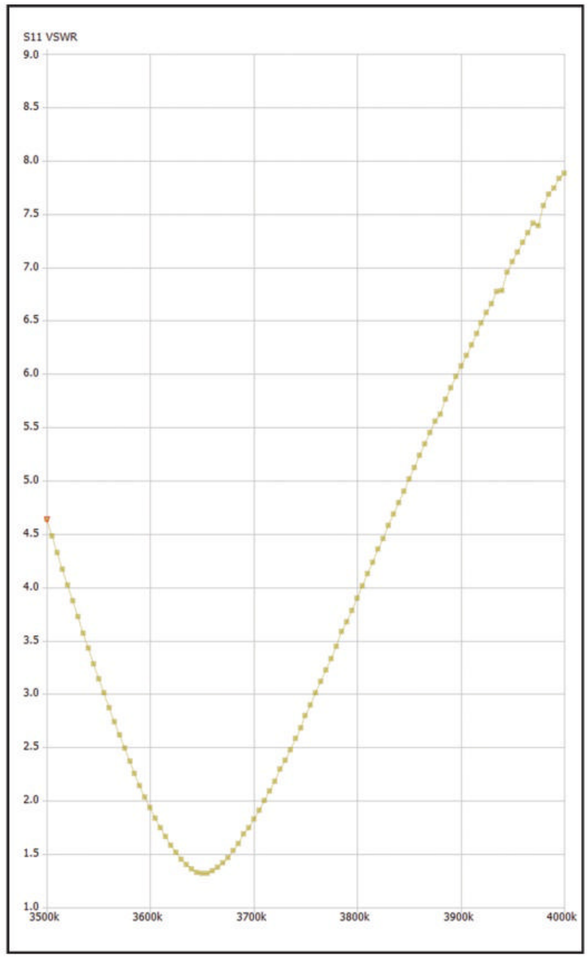

Figure 3.

ering 80 meters in eight frequency steps of about 70 kHz each at the full legal power limit, resulting in excellent matching across the entire band. Figures 1 through 8 show the measured SWRs for the 8 antenna tuning steps. When the best tuning step is selected, nearly all frequencies have an SWR below 1.5:1, with a few points showing an SWR between 1.5:1 and 1.7:1. A simple dipole or inverted vee for 80 meters typically has a 3:1 SWR bandwidth of only 250 to 300 kHz, and a 1.5:1 SWR bandwidth of less than 100 kHz.

This device is simple to build using only a few components. An antenna center box connects to a coaxial feedline going to the radio shack, and it replaces a balun or center insulator. In the center box, the signal goes first to an internal balun which provides an impedance matching function as well as a transition from unbalanced coax to a balanced circuit connecting to the two antenna elements of the inverted vee or dipole. The balun is followed by circuits containing three small low-cost relays to enable/disable three toroid inductors arranged in eight binary steps across the band to provide fine-tuning of the antenna. A printed circuit board from Far Circuits designed for a 1:6 remote antenna switch described in an April 2005 *QST* article by Bill Smith, KO4NR, was modified to mount three relays to appropriately enable/disable the three loading inductors. The largest inductor shifts the antenna resonance from the top of the band to near the middle of the band, and it is placed in series with one antenna element in the center box. The other two inductors, with values of about one-half and one-quarter of the largest inductor, are placed in series with the other element of the antenna. The two antenna wires are cut to resonant just below 4 MHz with no loading inductors enabled. In the radio shack, a control box contains only a 12 VDC power supply and a 3-pole 8-poition rotary switch connected with a 4-wire control cable to the center box of the inverted vee and the three relay coils plus ground. The control cable can be run alongside the coax for the inverted vee and attached with outdoor electrical tape or tie wraps.

By integrating the loading inductors for tuning with the antenna center unit directly on the antenna elements and with an internal balun, several advantages result. A separate antenna tuner or other tuning box is not required. The SWR is low for the complete station including the coax, antenna switches, filters and the rig and/or power amplifier for the entire 80-meter band. Tuning is very simple to control by selecting 1 of 8 sequential center frequencies with a rotary switch. The cost of the components is low to support operation at the full legal power limit of 1500 watts in the USA.

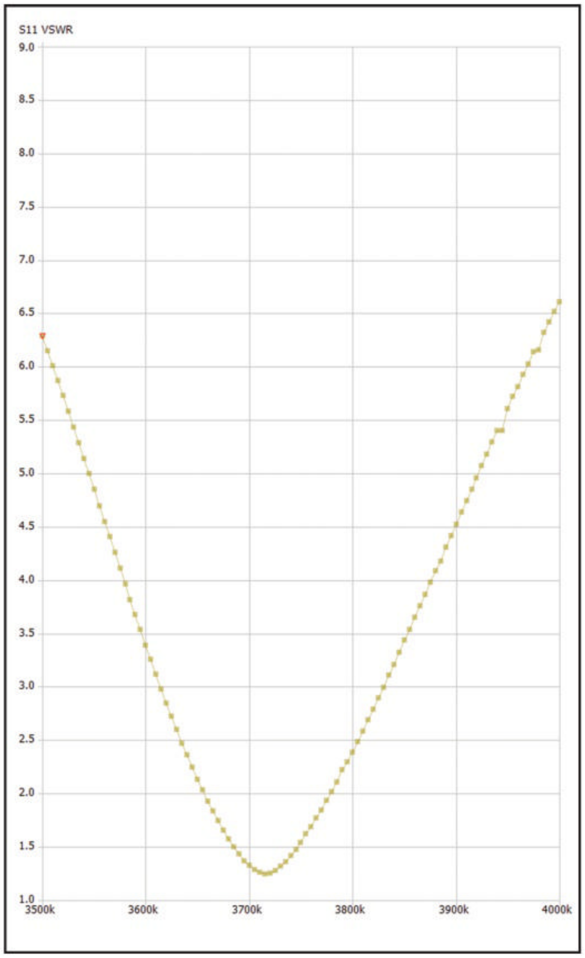

Figure 4.

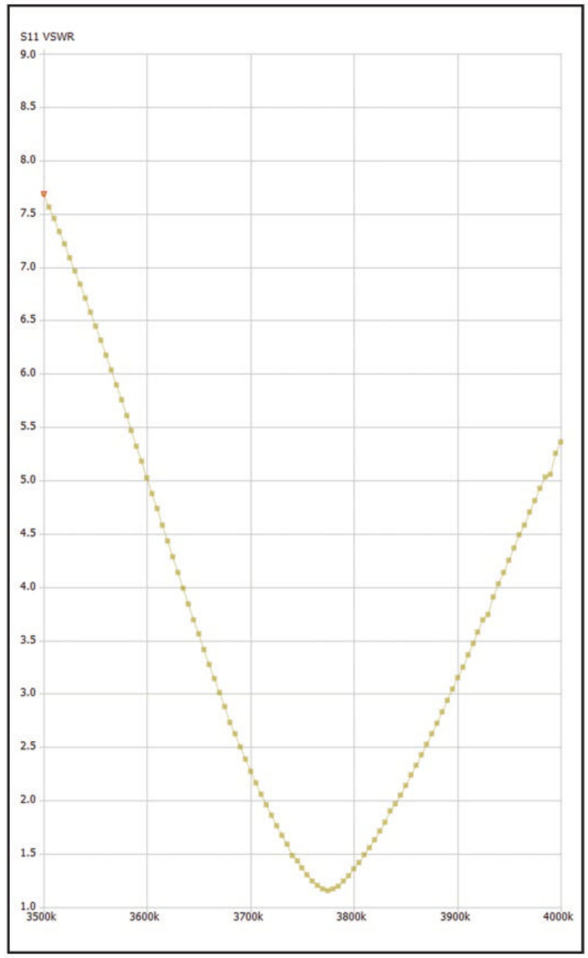

Figure 5.

While this design is for 80 meters, it could be scaled for 160 meters, which has a similar antenna bandwidth issue.

Precise matching of element lengths and of the loading with inductors of the two elements of an inverted vee or dipole is not necessary for the modest loading and frequency shifts required to tune across the 80-meter band for a dipole resonant at the top of the band. This is true because the impedance of a dipole changes slowly for small feed position offsets near the center of a resonant dipole. However, the radiation resistance of a shortened dipole decreases proportional to the square of the frequency, and this is the major side-effect of loading the antenna with inductance to lower the resonant frequency.

An inverted vee with the center at about 37 feet off the ground and the two ends at about 18 feet with elements of about 58 feet were used for the antenna. The modest height above ground and the inverted vee arrangement lower the impedance significantly from 73 ohms of an ideal resonant free space dipole. This resulted in a measured antenna resistance of about 40 ohms at 4.0 MHz (at resonance) going down to only 30 ohms at 3.5 MHz with loading. The SWR results show a minimal SWR very close to 1.0:1 at the top of the band, but rising to about 1.4:1 at the bottom of the band, which is consistent with the impedance results. With a higher antenna or with other arrangements, the antenna impedance may be different. The balun can be easily adjusted with more/fewer turns on the primary or secondary to provide a good match.

Antenna Center Unit and Tuning Inductors

A schematic diagram of the antenna center unit is shown in Figure 9, and Photo A shows its interior. The center unit is built in an outdoor electrical box by Zulkit, just 5.9 x 5.9 x 3.5 inches in size, which is mounted with the lid down in order to protect the circuits from any moisture which may enter the box. A few small 1/16" holes are drilled in the lid for drainage. A balun is placed at the input to the center unit using an FT240-43 toroid core with 8 turns of #14 solid copper enameled wire for an unbalanced primary and 7 turns of wire for the balanced secondary. This provides a 50- to 38-ohm impedance matching function as well as an unbalanced-to-balanced transition. The wires on the balun toroid core are secured with tie wraps at the start and ending turns and in the middle of the windings, and they are spaced to provide high RF voltage isolation with the primary and secondary windings interleaved.

The balun is mounted next to an SO-239 connector and connects to the SO-239 for the coax in the lid of the electrical box. Epoxy can be used to secure the balun but the con-

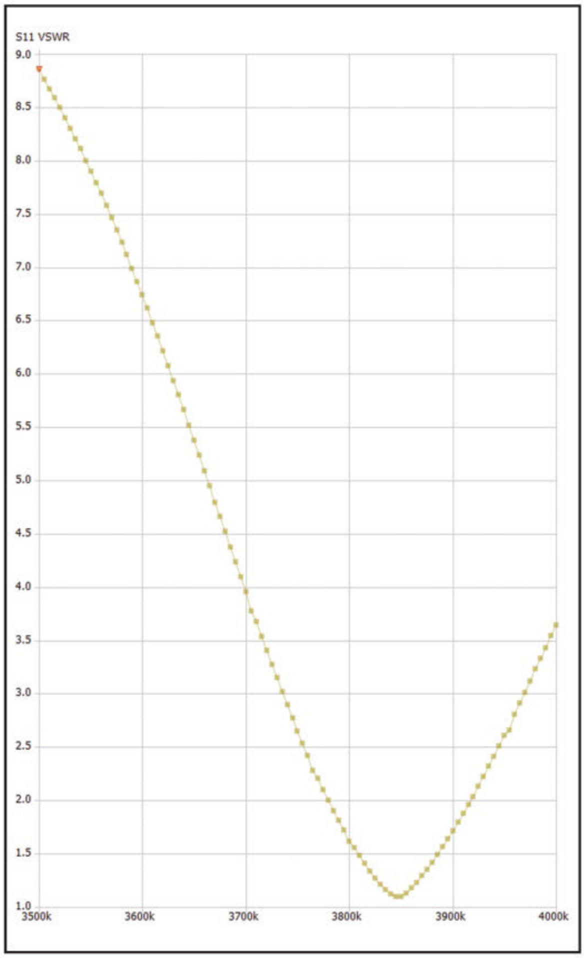

Figure 6.

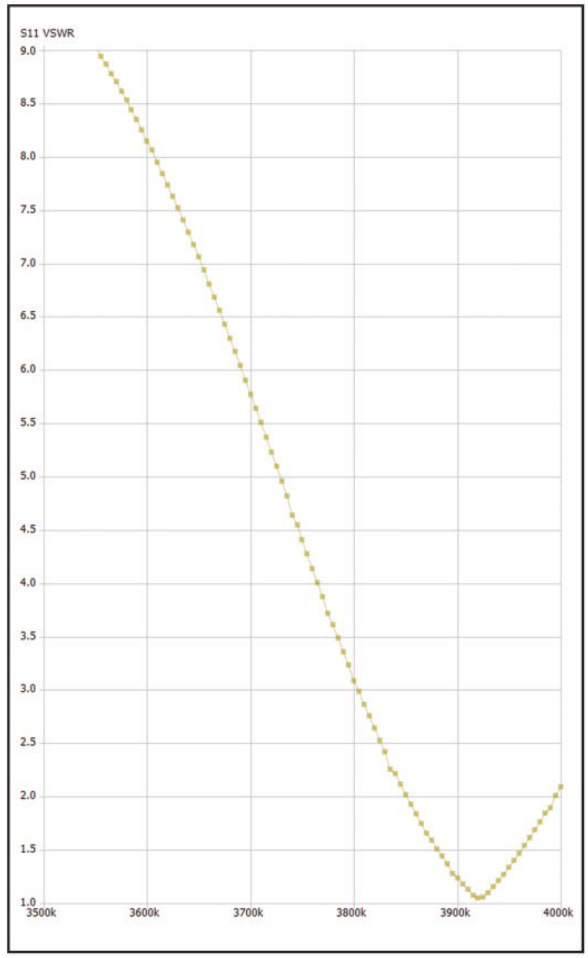

Figure 7.

nections to the SO-239 connector secure the balun fairly well. The balanced secondary of the balun connects to the toroid inductor loading elements in the main part of the electrical box with two #12 stranded copper insulated wires of about 6 inches in length. Those wires fold up into the lid beside the balun when the center box is closed and are guided into safe positions as it is closed to avoid contact with other parts in the box.

The PCB from Far Circuits contains an area for three relays on one side of the center and a similar area on the other side. One side of the PCB plus a small center area is cut off and discarded, leaving the area of the PCB for relays 1 to 3. The signal trace between output 3 and output 2 was cut with a Dremel® tool. The PCB grounds inactive relay outputs using the normally-closed relay connections, but that is not appropriate for this application, so those PCB connections to ground were removed by drilling out those holes with a 7/32-inch drill bit. Photo B shows the prepared PCB.

The three relays are Zettler AZ755s, and are also available from Far Circuits. Small eyelets are provided to place around each pin connecting to the relay contact prior to soldering to provide a good connection for the RC current.

In the first step, the three relays are mounted on the PCB; three small coil bypass surface mount caps, also provided by Far Circuits, are soldered to the PCB; and four hookup wires for the three relay coils plus ground with lengths of about 6 inches each are soldered to the PCB with the other ends unattached. This assembly is then turned upside down and attached to the center of the electrical box with epoxy on the relay tops with the four wires facing away from box lid hinges.

Next, a 4-connection terminal strip is attached with epoxy as shown in Photo A, and the four wires from the three relay coils plus ground are connected to one side of the terminal strip. The control cable connects later to the terminal strip.

The third step is to prepare the three toroid inductors. The inductors are 19, 12 and 8 turns of #14 enameled copper wire wound on T200-2 cores, providing calculated inductances of 4.33, 1.73 and 0.77 µH, not including pigtails, stray inductance and stray capacitance. Those factors increase the achieved circuit inductances, and EZNEC simulations of the antenna with three loading inductors to tune the antenna as desired produces values of 5.3, 2.7 and 1.4 µH.

The inductors are prepared with 6-inch pigtails. About 3/4-inch of enamel is stripped from the end of each pigtail. Also, 3/4-inch sections in the center of four pigtails are stripped to attach the two inputs from the balun and the two outputs to the wires which exit the center box to attach to the antenna elements. See Photo A and the schematic in Figure 9. The

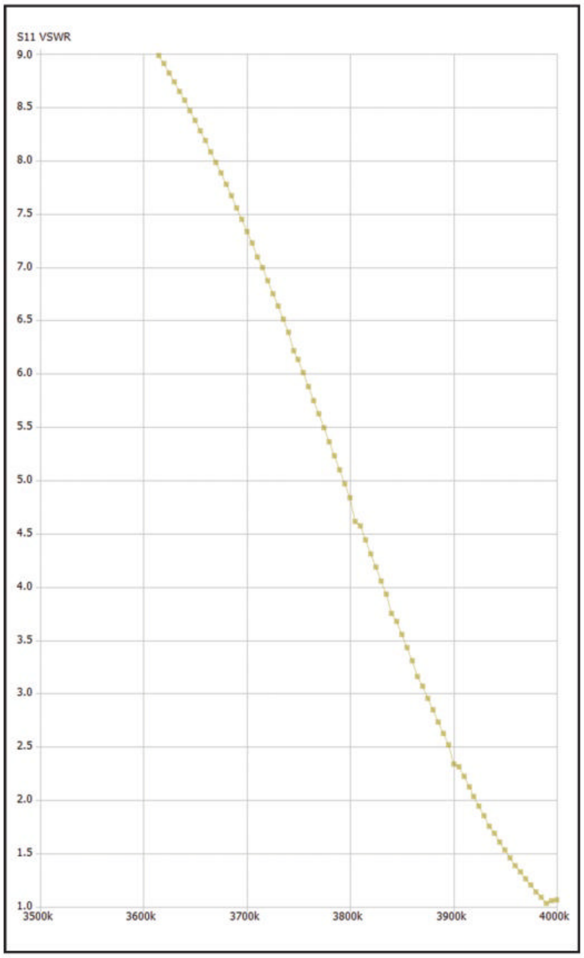

Figure 8.

three inductors are installed against three sides of the box and the pigtails are shaped so that the end sections align with the appropriate two pins for each connection to the relays (each signal connection to a relay uses two pins).

The spacing between the relay pins is modest, and joining the toroid inductor pigtail ends to the traces on the PCB requires some care. It is important to keep the gap as large as possible due to the RF voltages involved during operation. An 80-watt soldering iron with a chisel tip of about 1/2" width was used. First, lightly tin the bare end of each pigtail. Then with the wire shaped to meet the PCB trace, place it on the side away from the gap between the pins using needle nose pliers. With the chisel spanning the two pins and trace on the relay, reflow the solder and press the pigtail against the pins and PCB trace. To prevent heat damage, the 80-watt iron should be used sparingly and for a period just long enough to reflow the solder and allow the pigtail to be pressed into position and held until the solder is cooled and hardened.

Antenna Control Unit

A schematic for the antenna control unit is shown in Figure 10. It is very simple, containing a basic 12 VDC power supply with a fuse, and a 3-pole 8-position rotary switch. The rotary switch is wired to provide binary encoded 12 VDC to

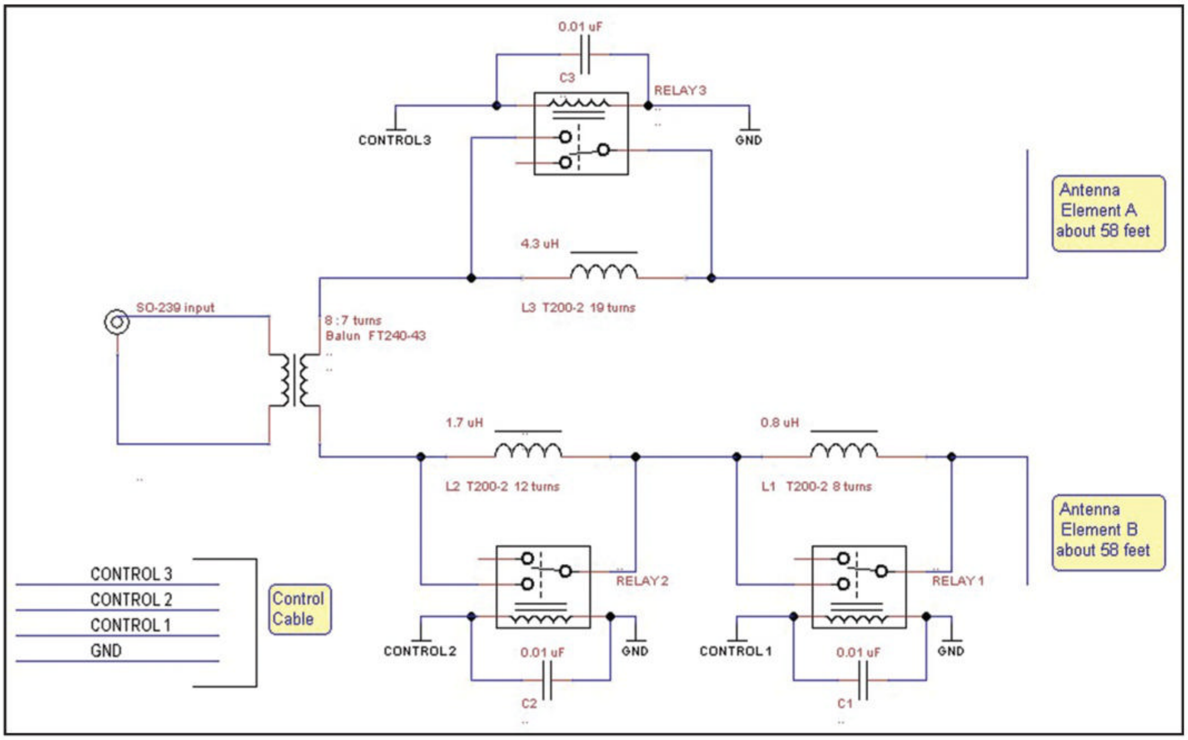

Figure 9. Schematic of the antenna center unit

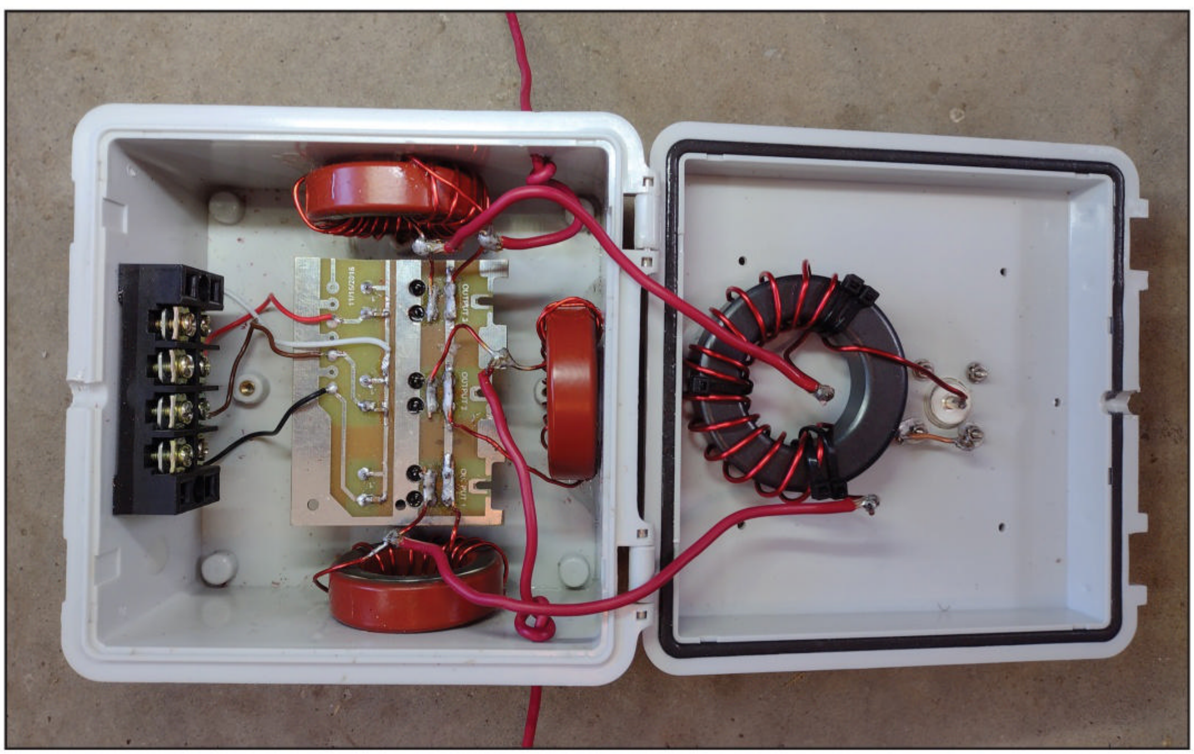

Photo A: Picture of the antenna center unit.

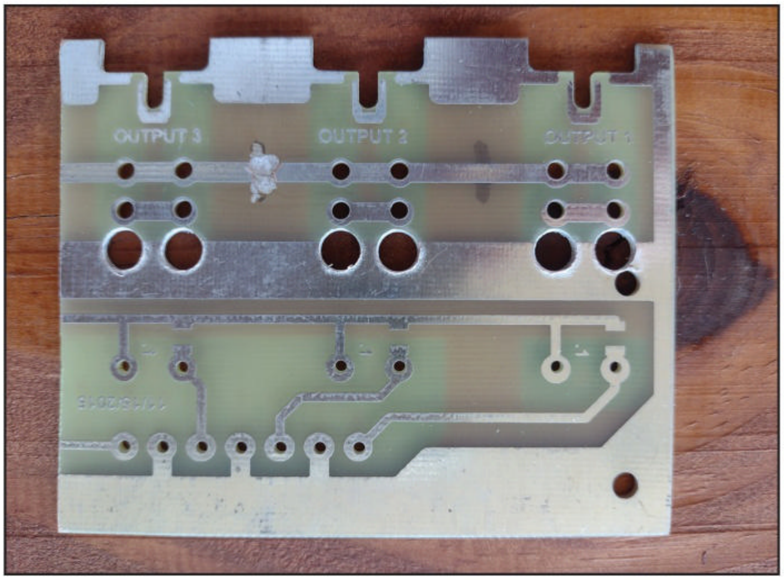

Photo B: The modified relay circuit board. See text for details.

the three relay coils in the antenna center unit. At the bottom of the 80-meter band, all three relays are inactive, resulting in open contacts for them, and the toroid inductors are active in the circuits providing loading to resonate the antenna near 3.5 MHz. At the top of the band, all three relays are active with 12 VDC connected to their coils, resulting in closed contacts for the relays, and the toroid inductors are shorted and inactive in the circuits to resonate the antenna near 4.0 MHz. When the antenna is installed, with the control box set to select a frequency near the top of the band, the antenna elements should be trimmed to tune the resonance to just below 4.0 MHz. A nanoVNA is convenient for tuning and measuring results.

The antenna control unit can be assembled in a small plastic electrical box or small electronics box and placed in a convenient spot on the station's operating table. The required rotary switch was found on Amazon for about $15. In

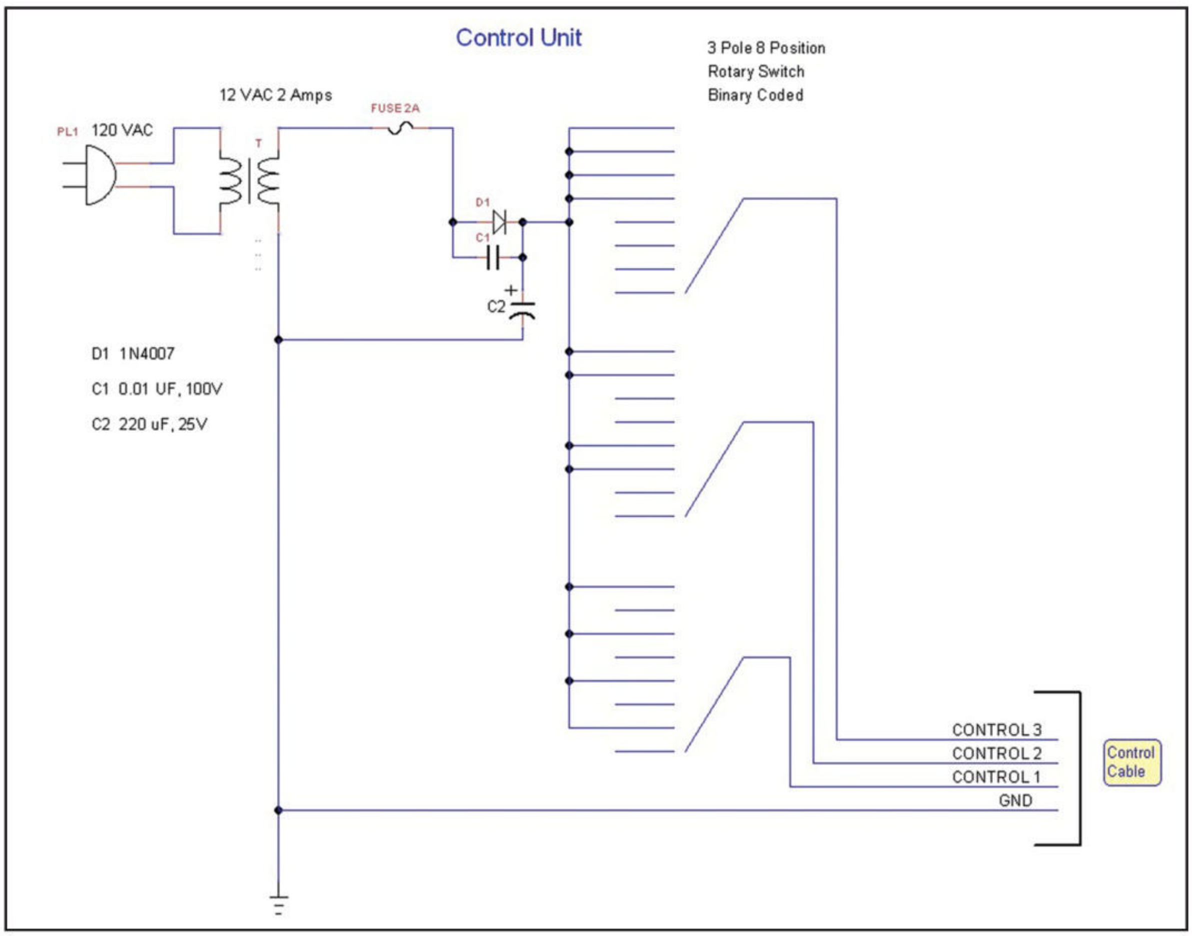

Figure 10: Schematic of the antenna control unit

some cases, 4-pole 8-position switches are available, which also work fine.

Tuning Relays

A number of manufacturers produce low-cost power relays in large volumes priced at several dollars in small quantities intended for usage as ON/OFF switches for 220/120 VAC power control. They typically support 16 to 20 amps of 50/60 Hz current with ratings of 4 to 5 KVA for power. These relays are very attractive for amateur radio usage, and they are commonly used in ham equipment such as remote antenna switches, remote antenna configuration switches and automatic antenna tuners. Specifications for these switches are rarely available for RF frequencies, but one key issue is that they are not used for hot switching of high-power RF. They are only switched when no RF power is present or with low power RF available such as during automatic antenna tuning.

What about their properties when high power RF is present and the relays are either open or closed? When the relays are closed, the key issue is RF current carrying capability. At 50 ohms, 1,500 watts (the legal limit of RF power for USA hams) results in a current of about 5.5 amps RMS. With these relays rated at 16 to 20 amps for 50/60 Hz AC, they have good margins for operations near 50 ohms at the legal limit for RF with the contacts closed, even with large de-rating factors.

These relays are intended for 220/120 VAC operations, so the breakdown voltage rating of open contacts is a question. The open contact breakdown voltage is typically specified at 1,000 VRMS for 50/60 Hz. Multiple sources suggest that this value should be de-rated by about a factor of 0.8 to 800 VRMS for HF frequencies and especially for 2 to 4 MHz. Please note that this value and de-rating factor are much different than contact voltage breaking values with current present while opening the relay contacts, which involves breaking a corona discharge as the contacts move from a closed to an open position. Contact voltage breaking values are substantially more frequency-dependent than open contact breakdown voltage values. For this reason, these relays should not change position when high power RF is present.

The RF current at 1500 watts of power for 40 ohms impedance is 6.1 amps. The largest loading inductor is about 5 µH, including stray inductance. That inductor then produces an RF voltage of 766 VRMS at 4 MHz, and the relay with open contacts must withstand voltage breakdown. An estimated rating for these relays at 4 MHz is 80% of the 60 Hz rating of 1000 VRMS or 800 volts, so the voltage rating of the relays is OK for 1500 watts of power. The antenna with integrated tuning was tested a few kHz from both the top and bottom of the band at about 900 watts without any problems. High duty cycle operation such as digital or RTTY modes near the legal power limit may lead to overheating of the balun or inductor toroid cores in this design, but SSB and typical CW operations should be fine at full power.

Conclusions

Integrated tuning is found in some high performance HF antenna products such as those from SteppIR, Optibeam, Array Solutions and others, but low-cost solutions for simple wire antennas are generally not available. For hams, integrated antenna tuning is especially desirable on 80 and 160 meters. Using three low-cost power relays and three toroid inductors, it is possible to build inverted vee or dipole antenna center units providing eight tuning steps across the band while operating at high power. An 8-position rotary switch in a control unit provides for selecting eight operating center frequencies resulting in SWRs less than 1.5:1 for nearly all frequencies (with several points between 1.5 and 1.7:1. An internal balun in the antenna center unit improves impedance matching as well as balanced drive to the antenna using coax to connect the antenna center unit to the radio shack equipment. A 4-wire control cable parallels the coax. Only a few components are required for this antenna center unit with integrated tuning and for the control box, and this solution can be easily constructed at low cost by most hams.

announcements *(from page 30)*

TAMPA, FLORIDA — The TAMPA AMATEUR RADIO CLUB will hold the TarcFest from 7:00 a.m. to 1:00 p.m. on Saturday August 19 at the Tampa Amateur Radio Club, 7801 N. 22nd St. Contact: Bill Bode, N4WEB. Website: <http://www.hamclub.org>. Email: <n4web@hamclub.org>. Phone: (813) 382-9262. Talk-in 147.105+ PL 146.2. VE testing.

WINFIELD, INDIANA — The AMATEUR RADIO ASSOCIATION OF NEWTON COUNTY will hold the ARANCI Hamfest from 6:00 a.m. to 2:00 p.m. on Saturday August 19 at the Christ Presbyterian Church, 7416 E 109th Ave. Contact: Michael Swiader, KA9E. Website: <http://aranciradio.com>. Email: <ka9e@usa.com>. Phone: (815) 409-5070. Talk-in 444.250. VE testing.

CORTLAND, OHIO — The WARREN AMATEUR RADIO ASSOCIATION will hold the WARA Tailgate Swap Meet from 7:00 a.m. to noon on Sunday August 20 at the Mosquito Lake State Park, 1439 Wilson Sharpsville Rd (state route 305). Contact: Andrew Juchnowski, AB8MO. Website: <https://www.w8vtd.com/hamfest/>. Email: <hamfest@w8vtd.com>. Phone: (234) 238-2312. Talk-in 146.970- (100 Hz normally off).

MARLBOROUGH, MASSACHUSETTS — The FEMARA will hold the Northeast HamXposition, ARRL New England Division Convention times TBA from Thursday August 25 to Saturday August 27 at the Best Western Royal Plaza Hotel, 181 Boston Post Rd. Contact: Michael Raisbeck, K1TWF. Website: <https://hamxposition.org/>. Email: <k1twf@hamxposition.org>. Phone: (508) 574-5432. Talk-in 147.27/146.2, 223.94/103.5, 449.925/88.5. VE testing.

BARABOO, WISCONSIN — The YELLOW THUNDER AMATEUR RADIO CLUB will hold the Circus City Swapfest time TBA on Saturday August 26 at the Badger Steam and Gas Engine Club Property, E3347 Sand Road. Contact: Thomas Harrison, N9PQJ. Website: <http://yellowthunder.org/>. Email: <n9pqj@arrl.net>. Phone: (608) 963-0762. Talk-in 147.315 PL123.0. VE testing.

BREWSTER, MINNESOTA — The NORTHERN PLAINS REGIONAL RADIO COUNCIL will hold the Northern Plains Regional Radio Council Hamfest time TBA on Saturday August 26 at the Brewster American Legion Post, 825 3rd Avenue. Contact: Randy Donahue, WBØZSO. Website: <https://tinyurl.com/2s4ezbc3>. Email: <wbØzso@arrl.net>. Phone: (605) 610-9419. Talk-in 146.67 - 141.3.

DAVENPORT, IOWA — The DAVENPORT RADIO AMATEUR CLUB will hold the 52nd Annual Davenport Radio Amateur Club W0BXR Hamfest from 8:00 a.m. to 3:00 p.m. on Saturday August 26 at the Iowa Army National Guard, 5300 West Kimberly Road. Contact: Robert Kordick, KCØOYK. Website: <https://drac.club/>. Email: <KCØOYK@ARRL.NET>. Phone: (563) 324-4832. Talk-in 146.8800 -0.6 MHz PL 77hz. VE testing.

JOPLIN, MISSOURI — The JOPLIN AMATEUR RADIO CLUB, INC. will hold the Joplin Hamfest from 12:00 p.m. to 6:00 p.m. on Friday August 26 and from 8:00 a.m. to 2:00 p.m. on Saturday August 26 at the Joplin Family Worship Center, 5290 E 7th St. Contact: Jim Scott, WB0IYC. Website: <http://joplinhamfest.org/>. Email: <jim.scott@scottelectronic.com>. Phone: (417) 781-2211. Talk-in 147.210 MHz PL 91.5. VE testing.

MACEDON, NEW YORK — The RARA and RVHFG will hold the RocCityNet Hamfest starting 7:00 a.m. on Saturday August 26 at the Log Cabin Restaurant, 2445 W. Walworth Rd. Contact: Michael Happell, W3MJH. Website: <https://roccitynethamfest.com/>. Email: <mjhappell@gmail.com>. Phone: (585) 402-5235. Talk-in 145.110. VE testing.

BRIGHTON, COLORADO — The DENVER RADIO CLUB will hold the DRC Hamfest from 9:00 a.m. to 1:00 p.m. on Sunday August 27 at the Adams County Fairgrounds, 9755 Henderson Road. Contact: Gerry Villhauer, WØGV. Website: <https://wØtx.org/>. Email: <wØtx@wØtx.org>. Phone: (303) 467-0223. Talk-in 145.490 or 448.625 PL 100.0. VE testing.

NEW KENSINGTON, PENNSYLVANIA — The SKYVIEW RADIO SOCIETY will hold the Skyview Radio Society Swap N Shop from 8:00 a.m. to 1:00 p.m. on Sunday August 27 at the Skyview Radio Society Clubhouse, 2335 Turkey Ridge Rd. Contact: John Italiano, WA3KFS. Website: <http://www.skyviewradio.net/>. Email: <radiofreebob@gmail.com>. Phone: (724) 339-3821. Talk-in 146.640 131.8 PL.