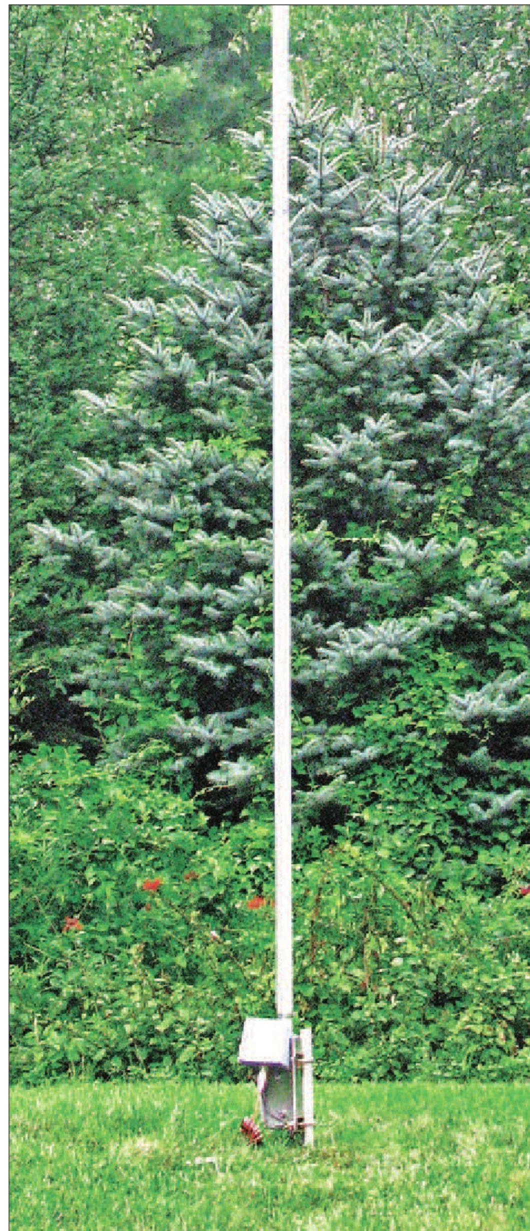
The 3/8-Wavelength Vertical — A Hidden Gem

This vertical antenna design is the third-place winner in the 2018 *QST* Antenna Design Competition.



Joe Reisert, W1JR

As the solar cycle rapidly winds down, the upper HF bands will be less available, but 20 meters will still be plenty active during the day. Many 20-meter operators are always looking for a small or stealthy antenna with good performance, and the ⅜-wavelength vertical antenna is a good candidate to fill that role.

When my son, Jim, AD1C, was first licensed, he built a homebrew receiver and 5 W transmitter for 40 meters. Later, he wanted a simple but efficient antenna. As I looked for a solution, the ⅜-wavelength vertical stood out. It is only about 50 feet in height on 40 meters. Because this vertical has a series impedance of about 200 Ω resistive, plus an inductive reactance of about 300 – 700 Ω, it is easily matched with a 4:1 step-up toroid transformer followed by a series matching capacitor. We strung up an approximately 50-foot wire in a nearby tree and four quarter-wavelength, ground-mounted radials to complete the installation and quickly matched the antenna. It worked quite well in contacting about 50 DXCC entities using Jim's 5 W.

Vertical Antenna Considerations

Ground planes are quite popular (see Figure 1). They are simple to construct and usually don't require matching networks, but do require some tie-down points. Elevated radials, however, can have several problems, including visibility and safety. The ends of the insulated radials are a high voltage point. A quarter-wavelength vertical with many radials on or near ground is also popular. For maximum efficiency, they require a minimum of 16 quarter-wavelength radials.[1] Performance often suffers from ground clutter near the base. The typical *EZNEC* modeled radiation pattern with a takeoff angle of 26° is shown in Figure 2.[2] The current distribution over the monopole is shown in Figure 3. Note that the region of highest current — the place where maximum radiation takes place — is at the bottom of the antenna.

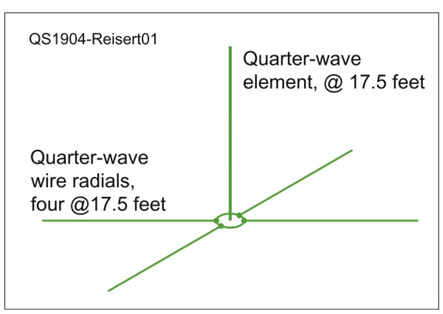


Figure 1 — Dimensions of a quarter-wave, ground-plane vertical antenna for 20 meters. The dimensions are similar for a ground-mounted version, but more radials are required.

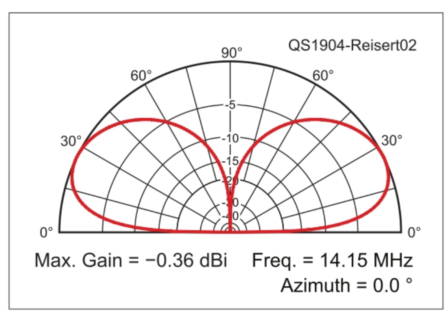


Figure 2 — Elevation pattern of a ground-mounted, quarter-wave antenna for 20 meters.

Table 1
Parts List for 20-Meter, ⅜-Wave Vertical Monopole

60 – 70 feet	#14 AWG PVC insulated wire for radials
1	Plastic electrical box for the matching network (see Figure 10)
2	Capacitors, ceramic disc NPO 20 pFd 1 – 2 kV, as required
1	Ferrite toroid core, T-240-61 2.4-inch OD
4 – 6 feet	#16 AWG PVC insulated twisted-pair wire for the toroid transformer
1	RF coaxial socket to match coax cable
Quantity	**Material (for tubing version only)**
5 – 6	Aluminum tubing 1 – 1.5 inches diameter, 5 – 6 feet long I used a surplus MFJ-1792 vertical antenna
1	Suitable base mount supported by around a 1-inch diameter stake
1	Base insulator
Quantity	**Material (for wire version only)**
2	Antenna insulators
26 feet	#12 AWG copper antenna wire

Meet the ⅜-Wave Vertical

The ⅜-wavelength vertical antenna (see Figure 4) is often an overlooked design. It has several advantages over the common quarter-wave vertical and just adds 50% to the height. Here are some advantages:

- It has a low takeoff angle of radiation at 23°, versus 26° for a ground-mounted, quarter-wave vertical (see Figure 5 and compare to Figure 2). This is a big advantage for working DX.
- It will work well even ground mounted because its maximum radiation point is ⅛ wavelength (about 8.7 feet at 20 meters) above the ground (see Figure 6). This is above the typical clutter present at ground level.
- It is easy to impedance match and, once matched, has a wide bandwidth with low SWR.
- Finally, it has a much higher radiation impedance. Therefore, four quarter-wavelength radials are all that is required for good performance.

Construction

This antenna can be easily constructed using either aluminum tubing or wire. I chose to modify a spare commercial vertical that I already had from a prior project. It had all the aluminum and hardware I needed, plus a good base and base insulator with tilt-over capability. It went together quickly (see Figure 7). Later, a wire equivalent was built at

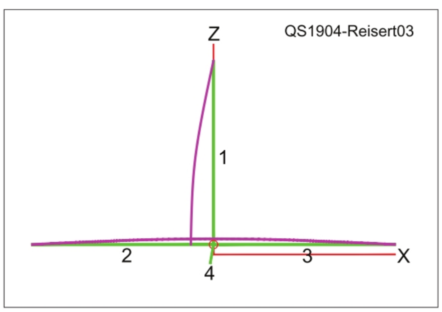


Figure 3 — Current distribution of a quarter-wavelength vertical monopole. Note that for the ground-mounted version, the maximum current and location of the maximum radiation are near the base, where nearby objects can diminish radiation.

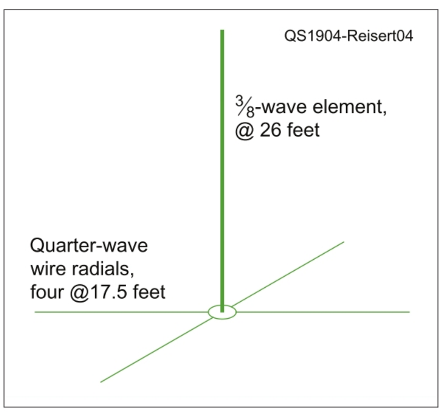


Figure 4 — The ⅜-wave vertical, a practical alternative to the quarter-wave, with some advantages.

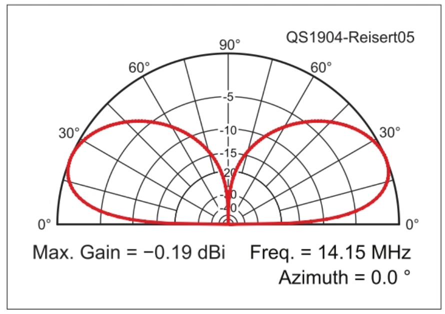


Figure 5 — Elevation pattern of a ground-mounted ⅜-wave antenna for 20 meters.

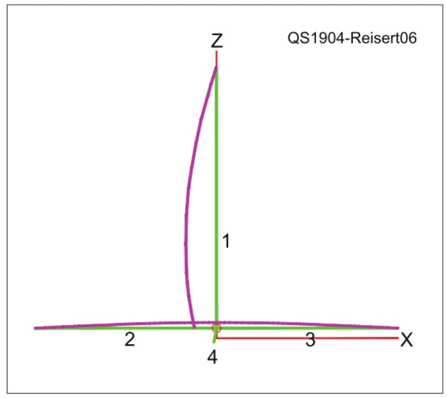


Figure 6 — Current distribution along the ⅜-wave monopole. Note the maximum current, so maximum radiation is ⅛ wavelength up from the base. This is about 8 feet for 20 meters.

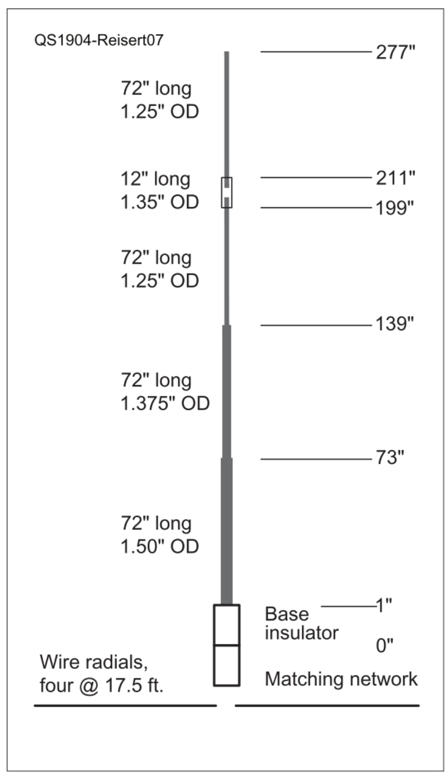


Figure 7 — Tubing construction for a ⅜-wavelength vertical antenna.

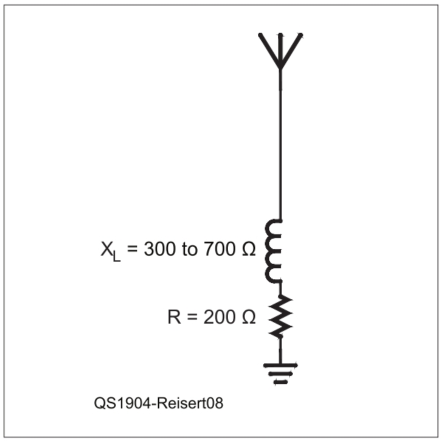


Figure 8 — Typical ⅜-wavelength antenna base feed impedance.

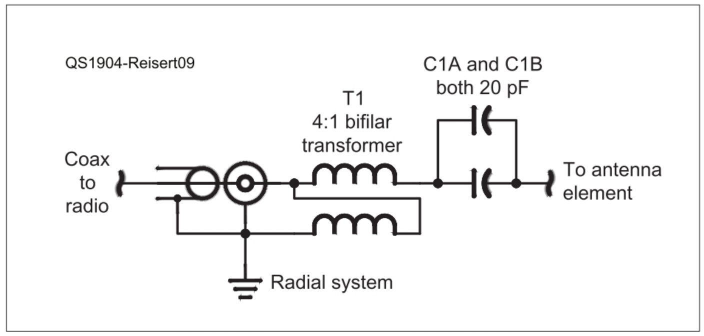


Figure 9 — Impedance-matching network for the ⅜-wavelength vertical. T1 is bifilar twisted pair #16 AWG PVC-covered wire, seven turns on T-240-61 2.4-inch outside diameter toroid. C1A and B are typically 20 pF, 2 kV ceramic disk capacitors. Lower voltage capacitors are useable for low-power operation.

the same location using ordinary seven-conductor #12 AWG copper antenna wire. It requires a top and bottom insulator and some higher structure such as a tree to hold it in place. It had a similar overall length.

Matching Network and Tuning

The ⅜-wavelength vertical antenna has a series impedance of approximately 200 Ω resistive with a series inductive reactance of 300 to 700 Ω (see Figure 8). Therefore, a 4:1 step-up transformer will match the resistive component, and a series capacitor tunes out the inductive reactance (see Figure 9). Typically, the required series capacitance is approximately 40 to 50 pF at 14 MHz and is not critical. A photo of a typical matching network in a 4 × 4 × 2 inch plastic box from an electrical supplier is shown in Figure 10.

The matching network is easy to use. Figure 11 shows a typical setup using an antenna analyzer to adjust for minimum SWR on the wire version of the antenna. Connect the ground side of the antenna connector to the on-ground radials. Connect the upper terminal to the bottom of the vertical tubing or wire. Next put in the specified capacitors or a ceramic (or equivalent) variable capacitor set to approximately 40 pF. Connect an SWR meter to the base.

Ground Radials

For optimum performance, ground radials are required on most vertical monopoles. They can be made of wire of any gauge or material. I recommend #14 AWG copper wire with a PVC covering because the makeup of the ground material will have little effect on long-term performance. The ⅜-wavelength vertical only requires four quarter-wave radials, which can be installed on the ground. The best length is a quarter-wavelength, or approximately 15 – 17 feet at 20 meters, but length is not critical.[3]

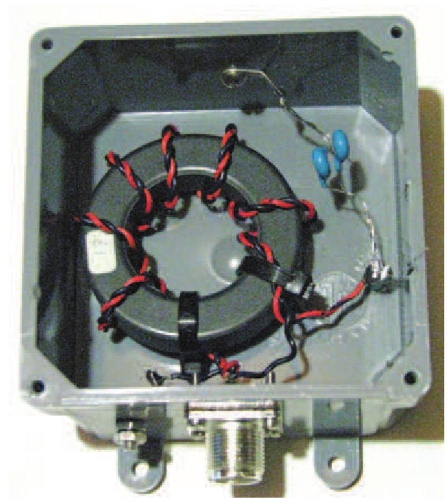


Figure 10 — Construction of impedance-matching network of Figure 9. The enclosure is a plastic electrical box.

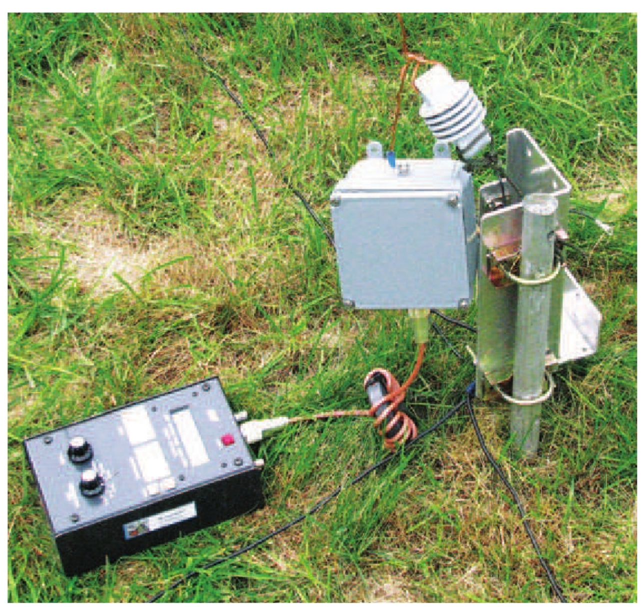


Figure 11 — An antenna analyzer is used in this typical test setup to adjust the matching of the antenna. The wire version is shown.

Manufacturer's Specifications	Measured in the ARRL Lab
FM two-tone, third-order IMD dynamic range: Not specified.	Preamp on: 20 kHz offset, 29 MHz, 59 dB;* 52 MHz, 66 dB.* 10 MHz offset, 114 dB; 52 MHz, 116 dB.
S-meter sensitivity: Not specified.	For S-9 signal, preamp off/on: 14 MHz, 65.2/10.0 µV; 50 MHz, 70.7/12.3 µV.
Squelch sensitivity: Not specified.	At threshold: Preamp on, FM, 29 MHz, 1.32 µV; 52 MHz, 1.35 µV. SSB, preamp off/on, 14 MHz, 0.66/0.11 µV.
Receiver processing delay time: Not specified.	116 ms.
Spurious and image rejection: IF rejection, 60 dB. Image rejection, 70 dB.	IF rejection: 14 MHz, 96 dB; 50 MHz, 86 dB. Image rejection: 14 MHz, 76 dB; 50 MHz, 69 dB.
IF/audio response: Not specified.	Range at –6 dB points:** CW (500 Hz BW): 492 – 822 Hz; SSB (2.4 kHz BW): 310 – 2,720 Hz; AM (6 kHz BW): 2 – 3,830 Hz.
Transmitter	**Transmitter Dynamic Testing**
Power output: 5 W (CW, SSB, FM); 1.5 W (AM).	At 13.8 V dc: HF, 0.5 to 5 W (typical CW, SSB, FM); 50 MHz, 0.4 to 3.7 W. At minimum operating voltage: HF, 4.75 W (typ.); 50 MHz, 3.7 W.
Spurious and harmonic suppression: 45 dB.	HF, 68 dB typical; 51 dB worst case (15 m); 50 MHz, 67 dB. Meets FCC requirements.
Third-order intermodulation distortion (IMD) products: Not specified.	3rd/5th/7th/9th order, 5 W PEP: –37/–43/–48/–51 dB (HF, typical) –26/–35/–44/–49 dB (worst case, 160 m) –36/–40/–45/–48 dB (50 MHz)
CW keyer range: 5 to 100 WPM.	Tested at 3.4 to 40 WPM, iambic modes A and B. See text.
CW keying characteristics: Not specified.	See Figures 2 and 3.
Transmit-receive turnaround time (PTT release to 50% audio output): Not specified.	SSB and CW, AGC fast, 214 ms.
Receive-transmit turnaround time (TX delay): Not specified.	SSB, 184 ms; FM, 29 MHz, 100 ms; 52 MHz, 122 ms.
Transmit phase noise: Not specified.	See Figure 4.
Size (height, width, depth): 2.0 × 7.1 × 3.8 inches (including protrusions); weight, 2.0 lbs.	

†Receiver tests with 500 Hz IF filter and 300 – 800 Hz audio filter.
*Measurements are noise limited at the value indicated.
**DSP is adjustable

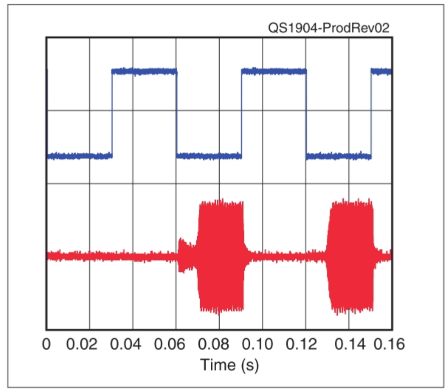


Figure 2 — CW keying waveform for the Xiegu X5105, showing the first two dits in full-break-in (QSK) mode using external keying and the default rise time setting. Equivalent keying speed is 40 WPM. The upper trace is the actual key closure; the lower trace is the RF envelope. (Note that the first key closure starts at the left edge of the figure.) Horizontal divisions are 10 ms. The transceiver was being operated at 5 W output on the 14 MHz band.

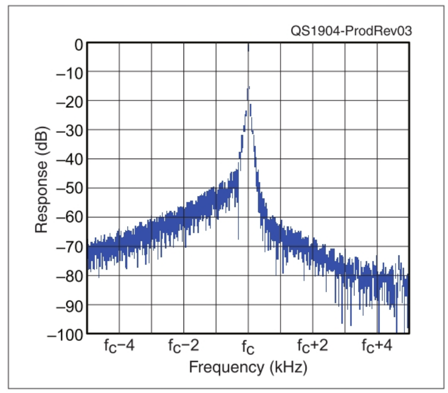


Figure 3 — Spectral display of the Xiegu X5105 transmitter during keying sideband testing. Equivalent keying speed is 40 WPM using external keying and the default rise time setting. Spectrum analyzer resolution bandwidth is 10 Hz, and the sweep time is 30 seconds. The transmitter was being operated at 5 W PEP output on the 14 MHz band, and this plot shows the transmitter output ±5 kHz from the carrier. The reference level is 0 dBc, and the vertical scale is in decibels.

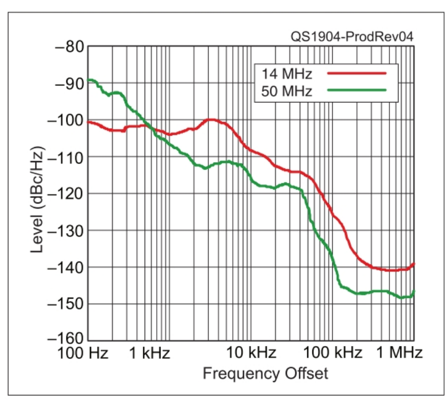


Figure 4 — Spectral display of the Xiegu X5105 transmitter output during phase-noise testing. Power output is 5 W on the 14 MHz band (red trace), and 3.7 W on the 50 MHz band (green trace). The carrier, off the left edge of the plot, is not shown. This plot shows composite transmitted noise 100 Hz to 1 MHz from the carrier. The reference level is –80 dBc/Hz, and the vertical scale is 10 dB per division.

The X5105 is an excellent semi-break-in performer if you leave the break-in delay set at the default 200 milliseconds.

Another CW issue is that glitch at the beginning of the first dit on any new transmission, as can be seen in Figure 2. This glitch does not reoccur until you pause long enough for the receiver to recover and then transmit again. However, I could not hear anything funny with that first dit when listening on an adjacent receiver. So this is more of an "observable on an oscilloscope" problem and not so much of a real-world problem.

The last issue has to do with the CW rise and fall times. Although the CW keying waveform has improved significantly since initial testing (see the "Lab Notes" sidebar), the rise time is only about 1.5 milliseconds, and the fall-time is even less. Typically, rise/fall times shorter than about 4 milliseconds lead to key clicks. As you can see in Figure 3, the keying sidebands are stronger below the intended frequency.

I cabled a sampled S-7 signal from the X5105 into a separate monitor receiver (an IC-706MKIIG with 500 Hz CW filter). Key clicks were noticeable up to

5 kHz below the X5105's transmit frequency, and 2 kHz above the transmit frequency with this quiet setup. As a comparison, when my Elecraft KX3 was connected into the same setup, I heard no key clicks.

Of course, with the typically low signal levels of QRP transmitters, the key clicks will fall below the normal band noise floor. During numerous contacts, I asked the receiving stations to tune off to the side, and they were unable to hear the clicks. Regardless of whether they can be heard or not, the key clicks contribute to the noise floor, and the problem will undoubtedly show up if an external amplifier is used. I hope that Xiegu will continue to improve the rise/fall times in a future firmware update.

Voice Operation

Speech compression is turned on and off via a soft key in the **FUNCTION** menu. Compression level and microphone gain are set in the **SYSTEM** menu. While there is no transmitter audio equalizer, the transmit audio is excellent, as monitored on a separate transceiver as well as on-the-air reports.

The default SSB filter bandwidth is 2.4 kHz, but you can select a 6 kHz bandwidth for receiving extended SSB (ESSB). You can also adjust the low- and high-pass receive. I found that the default receive audio passband response was very pleasant.

Lab Notes: Xiegu X5105 HF/6-Meter Transceiver

Bob Allison, WB1GCM, ARRL Lab Assistant Manager

The Xiegu X5105 is the first HF and 6-meter transceiver from China that we have tested with acceptable results at the ARRL Laboratory. These results didn't come easily, with much testing in the ARRL Lab and with great cooperation from US distributor MFJ and the manufacturer.

Initial testing in early 2018 showed that the X5105 had several issues. The CW keying had no shaping whatsoever, with resulting key clicks and a broad keying spectrum. It also transmitted high harmonic levels, with a total harmonic power greater than the fundamental power. It transmitted on all frequencies that it could receive on. MFJ worked with the manufacturer to clear up these issues and make the radio legal for use by US amateurs. The current X5105 reviewed here complies with FCC spurious emission suppression requirements and transmits only within the amateur bands, and these changes have been made in current production radios.

The X5105's receiver has adequate SSB and CW sensitivity; it can hear signals at or below a typical rural listening environment (about –120 dBm). FM sensitivity is also adequate, but AM sensitivity could be a bit better on 6 meters.

The lowest dynamic range at 2 kHz spacing is blocking at 58 dB, which is not great compared to current desktop radios. With the AGC off (our standard test condition), a single signal at –66 dBm (S-9 plus 7 dB), 2 kHz away, will start to lower the intended (tuned) signal's audio level. A stronger adjacent signal will significantly lower the audio level of the tuned signal. This may not be a problem during portable operation, but more of a problem when using a substantial antenna during good band conditions or if you live near other stations that are using the same band. Third-order IMD dynamic range and reciprocal mixing dynamic range are on par with other economy transceivers. Image and IF rejection are adequate.

The X5105's transmitter has reasonably low transmit audio IMD. The transmit phase noise is a bit high up to 11 kHz away from the transmitted signal, but not the highest we've seen in the Lab. As discussed in the text, the keying waveform lacks the fall time needed for narrow keying sidebands, but transmissions are free from audible key clicks. Because of the higher-than-normal keying sidebands and transmitted phase noise, I would not recommend using a power amplifier with the X5105.

Despite some shortfalls, radio amateurs should be able to enjoy using the Xiegu X5105 for portable operation at a park, beach, or picnic table in the backyard on a sunny day.

Digital Modes

The X5105 can be operated with a computer and sound card for FT8, RTTY, PSK, or any of the other popular digital modes. You will need to build or buy an interface cable with a mini-DIN eight-pin connector for the radio and appropriate connectors for your computer sound card. The interface connections are well documented in the X5105 user manual.

The X5105 does have a built-in receive modem, enabled via the **SYSTEM** menu, for copying PSK31 signals without using a computer.

When a PSK31 signal is centered on the display, the modem locks to it and begins displaying up to three lines of streaming text below the LCD screen. As PSK31 tuning is critical, the automatic frequency control (AFC) correction option can be turned on to ensure the decoder stays locked to the incoming signal.

Other Features

The X5105 can drive the internal speaker, an external speaker, or external headphones. When using headphones, press the **SPK** soft key in the **FUNCTION** menu to attenuate the audio output because the 600 mW normal speaker output is too high for headphones and your ears. A speaker or headphone icon appears on the screen, so you know which audio level mode is selected.

The X5105 receiver includes a preamp and attenuator. It also has an adjustable noise blanker and DSP noise reduction. Split-frequency operation is available, and the split operation can be set for the same band — or even different bands. There is even a scan receive mode that will sweep the selected band and graphically display band activity.

There are 100 memory channels available, each of which may be custom labeled. I used 10 of these for the five CW and five SSB center frequencies for 60 meters.

The X5105 accessory port (labeled **ATU**) provides dc voltage levels that may be used to drive remote band-switching devices, such as amplifiers and antenna switches. However, the well-documented voltages do not conform to any current band voltage standard, so you must create your own interface circuitry if you use external, non-Xiegu products.

Finally, the X5105 can plot SWR within any given ham band. This is a neat feature that makes tweaking a portable antenna easy in the field — no antenna analyzer needed. The default scan width is 100 kHz in 1 kHz steps (±50 kHz of center). Both the step spacing and center frequency are displayed. One complete scan requires about 15 seconds. Five scan width settings are available, each with 100 sampling points (100/200/300/400/500 kHz). The X5105 continuously scans until **QUIT** is pressed.

Conclusion

The Xiegu X5105 is a well-thought-out package that will interest the QRP operator. Everything needed is built in, including a lithium battery, so it is particularly easy to carry along on vacation or in the field. There are no options necessary, and no external devices to cable up for normal CW and SSB operation. Just connect your antenna and mic or key, and operate.

Manufacturer: Xiegu Technology Co. Ltd., **www.cqxiegu.com**. Distributed and supported in the US by MFJ Enterprises, 300 Industrial Park Rd., Starkville, MS 39759, **www.mfjenterprises.com**. Price: $600.

Visit https://youtu.be/QxVI2VPpaC4 to see our review of the Xiegu Communication X5105 HF/6-Meter QRP Transceiver on YouTube.

Antenna Disconnectors from Paradan and INRAD

Reviewed by Ward Silver, N0AX
QST *Contributing Editor*
n0ax@arrl.org

Bottom Line

These Paradan and INRAD antenna disconnect devices offer an easy way to automatically ensure that your antenna is disconnected from your radio when not in use, offering some protection against transients from nearby lightning strikes. For best results, careful attention to station grounding and bonding practices is required.

In the August 2014 issue of *QST*, Phil Salas, AD5X, described a feed line control box that included lightning and static discharge protection for his Elecraft KAT500 amplifier's three outputs.[1] Relays grounded the antenna lines when power was removed, and a gas discharge tube (GDT) acted as a voltage clamp for transients on the feed line when power was on. At the time, I thought it was a great idea to automatically protect the equipment outputs.

After I got serious about building my station in rural Missouri, where lightning is common, the idea of protecting the transceivers resurfaced. Operating the station by remote control is also something I want to do, and I am not at the station all the time to connect and disconnect cables. Lightning protectors are installed on all of the feed lines, but leaving the radios and amplifiers connected seemed too risky. Then I discovered the single-line INRAD Antenna Disconnect Actuator (DCA) and the