Product Reviews

November 2015

Product Reviews:

Mark J. Wilson, K1RO, k1ro@arrl.org

Yaesu FT-991 HF/VHF/UHF Transceiver

A multimode transceiver that plays well at home, in the car, or in the field.

Reviewed by Norm Fusaro, W3IZ
Assistant Manager, Field Services & Radiosport Department
w3iz@arrl.org

In 2002 Yaesu introduced the FT-897, quickly followed by the upgraded "D" model.[1] Well received by the amateur community, the FT-897 offered operators a grab-'n'-go 160 – 6 meter (100 W), 2 meter (50 W), and 70 centimeter (20 W) multimode radio in a compact package that fit nicely on a desktop, picnic table, or camper shelf. In fact, I remember needing to be "the first kid on the block" to have one of those gems. At the time, portable HF operating was growing in popularity. It increased significantly after the terrorist attacks on September 11, 2001, and again after the four hurricanes in the Southeast in 2004 and hurricane Katrina in 2005. Many hams began assembling "go-kits" and portable stations, and the Yaesu FT-897D remained a choice radio for this type of service for more than a dozen years.

The FT-897D has been discontinued and replaced by the subject of this review — the FT-991. Yaesu teased the crowd at the 2014 Ham Fair in Tokyo by displaying the FT-991 behind a glass showcase. Lucky for me, the Yaesu executives removed the glass case so I could examine the new transceiver more closely. I was intrigued by its touchscreen, bright display, and overall sharp appearance. Like everyone else in attendance, I was eager for its release to the amateur market.

Overview

Public service is just one of many reasons why an amateur might want a feature-packed, portable 100 W transceiver that is capable of HF, VHF, and UHF all-mode operation. The FT-991 is also a natural for anyone looking to set up a mobile station or take along an HF radio while traveling. The FT-991 could easily be the central transceiver in your home station, but don't expect it to outperform competition grade radios such as Yaesu's FTDX3000. The FT-991 does everything it was designed to do and does it all very well. We'll hit the highlights in this review, but it's well worth visiting Yaesu's website to download a copy of the manual and other documentation for an in-depth look at all of the features.

The FT-991 covers the 160 – 6 meter, 2 meter, and 70 centimeter bands. Modes of operation include SSB, FM, AM, and CW. It supports digital modes such as FSK RTTY, as well as PSK and other sound card digital modes. In addition to the more traditional modes, the FT-991 includes Yaesu's C4FM digital voice and data capability. It's also got many features we've come to expect in a modern transceiver, such as digital signal processing (DSP), selectable IF filters, automatic notch filter, CW keyer, and internal automatic antenna tuner for the 1.8 – 50 MHz bands.

The FT-991's rear panel (see Figure 1) has two antenna connectors, one for 160 – 6 meters and the other for 2 meters and

[1]R. Schetgen, KU7G, "FT-897 MF/HF/VHF/UHF All-Mode Transceiver," Product Review, *QST*, May 2003, pp 63 – 67.

Bottom Line

The Yaesu FT-991 can be the center of attention in a portable, mobile, or home station. Its many bands, modes, and features will provide endless hours of enjoyment exploring a wide variety of Amateur Radio activities.

Figure 1 — The FT-991's rear panel, showing available connections.

Key Measurements Summary

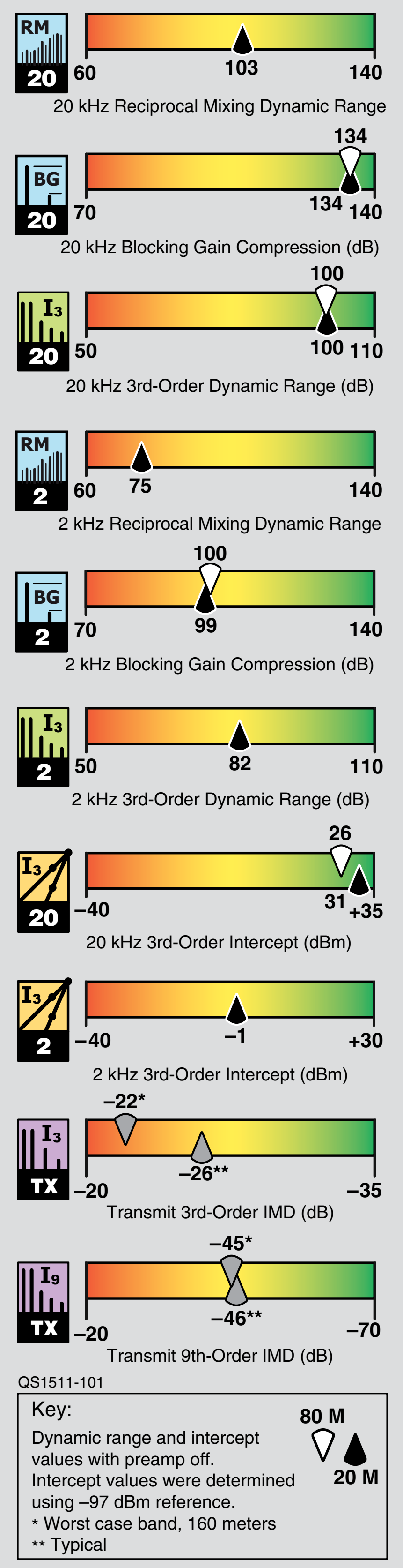


Table 1
Yaesu FT-991, serial number 4N020467

Manufacturer's Specifications	Measured in the ARRL Lab
Frequency coverage: Receive, 0.030 – 56, 118 –164, 420 – 470 MHz. Transmit, 1.8 – 54, 144 – 148, 430 – 450 MHz (amateur bands).	Receive and transmit, as specified.
Power requirements: 13.8 V dc ±15%. Receive, 1.8 A (no signal).Transmit, 23 A (HF/50 MHz, 100 W); 15 A (144/430 MHz, 50 W).	At 13.8 V dc: Receive, 1.58 A (max TFT and dimmer brightness, max volume, no signal); 840 mA (min TFT, min dimmer). Transmit, 6.8 A (min RF output), 19.6 A (max RF output, HF & 50 MHz, typical); 11 A (144 & 430 MHz).
Modes of operation: SSB, CW, AM, FM, C4FM, RTTY, data.	As specified.
Receiver	**Receiver Dynamic Testing**
CW sensitivity, 10 dB S+N/N, 2.4 kHz BW, amp 2 on: 0.158 µV (1.8 – 30 MHz), 0.125 µV (50 – 54 MHz), 0.11 µV (144 – 148, 430 – 450 MHz).	Noise floor (MDS), 3 kHz roofing filter, 500 Hz DSP bandwidth: *Preamp* *Off* *1* *2* 0.137 MHz –107 n/a –102 dBm 0.475 MHz –112 n/a –128 dBm 1.0 MHz –113 n/a –133 dBm 3.5 MHz –124 –136 –143 dBm 14 MHz –124 –136 –143 dBm 50 MHz –122 –133 –141 dBm 144 MHz n/a n/a –139 dBm 432 MHz n/a n/a –145 dBm
Noise figure: Not specified.	Preamp off/1/2: 14 MHz, 21/11/4 dB; 50 MHz; 25/14/6 dB. Preamp 2: 144 MHz, 6 dB; 432 MHz, 2 dB.
AM sensitivity, 10 dB S+N/N, 30% modulation, 400 Hz tone, 6 kHz BW, amp 2 on: 5 µV (0.5 – 1.8 MHz), 1.6 µV (1.8 – 30 MHz), 1.25 µV (50 – 54 MHz).	10 dB (S+N)/N, 1 kHz, 30% modulation, 6 kHz bandwidth: *Preamp* *Off* *1* *2* 1.02 MHz 14.6 n/a 1.23 µV 3.88 MHz 3.59 0.95 0.45 µV 50.4 MHz 6.09 1.43 0.59 µV 120 MHz n/a n/a 0.59 µV 144.4 MHz n/a n/a 0.52 µV 432 MHz n/a n/a 0.42 µV
FM sensitivity, 12 dB SINAD, 15 kHz BW, amp 2 on, 0.35 µV (28 – 30, 50 – 54 MHz), 0.18 µV (144 – 148, 430 – 450 MHz).	For 12 dB SINAD, 3 kHz deviation, 16 kHz bandwidth: *Preamp* *Off* *1* *2* 29 MHz 2.06 0.52 0.25 µV 52 MHz 2.51 0.62 0.25 µV 146 MHz n/a n/a 0.22 µV 162 MHz n/a n/a 0.18 µV 440 MHz n/a n/a 0.18 µV
Spectral sensitivity: Not specified.	Preamp off/1/2: –102/–111/–121 dBm
Blocking gain compression dynamic range: Not specified.	Blocking gain compression dynamic range, 3 kHz roofing filter, 500 Hz DSP BW: *20 kHz offset* *5/2 kHz offset* *Preamp off/1/2* *Preamp off* 3.5 MHz 134/138/133 dB 122/100 dB 14 MHz 134/137/132 dB 123/99 dB 50 MHz 117/115/110 dB 104/93 dB 144 MHz 122 dB (amp 2) 104/90 dB 432 MHz 117 dB (amp 2) 100/91 dB
Reciprocal mixing dynamic range: Not specified.	14 MHz, 20/5/2 kHz offset: 103/86/75 dB
ARRL Lab Two-Tone IMD Testing	See Table 2.
Second-order intercept point: Not specified.	Preamp off/1/2: 14 MHz, +65/+85/+81 dBm; 50 MHz, +93/+77/+77 dBm; 144 MHz, +41 dBm; 432 MHz, +73 dBm.
DSP noise reduction: Not specified.	15 dB.
Notch filter depth: Not specified.	Auto notch: >70 dB. Attack time: 100 ms, one or two tones.

Manufacturer's Specifications	Measured in the ARRL Lab
FM adjacent channel rejection: Not specified.	Preamp 2 on: 29 MHz, 60 dB; 52 MHz, 58 dB; 144 MHz, 65 dB; 432 MHz, 62 dB.
FM two-tone, third-order IMD dynamic range: Not specified.	20 kHz offset, preamp 2 on: 29 MHz, 58 dB*; 52 MHz, 57 dB*; 144 MHz, 65 dB*; 432 MHz, 62 dB*. 10 MHz offset: 29 MHz, 103 dB; 52 MHz, 94 dB; 144 MHz, 88 dB; 440 MHz, 79 dB.
S-meter sensitivity: Not specified.	S-9 signal, preamp off/1/2: 14 MHz, 122/33.1/8.3 µV; 50 MHz, 95.4/24.8/7.0 µV; 144 MHz, 10.3 µV; 432 MHz, 6.2 µV.
Squelch sensitivity: Amp 2 on, 0.35 µV (28 – 30 MHz), 0.125 µV (144 – 148, 430 – 450 MHz).	At threshold, preamp 2 on: FM, 29 MHz, 0.14 µV; 50 MHz, 0.17 µV; 144 MHz, 0.13 µV; 432 MHz, 0.11 µV.
Receiver audio output: 2.5 W into 4 W at 10% THD.	As specified. THD @ 1 V_{RMS}, 1.4%.
IF/audio response: Not specified.	Range at –6 dB points (bandwidth)**: CW (500 Hz): 345 – 840 Hz (495 Hz) Equivalent Rectangular BW, 497 Hz USB (2.4 kHz): 261 – 1925 Hz (1664 Hz) LSB (2.4 kHz): 260 – 1923 Hz (1663 Hz) AM (9 kHz): 56 – 2770 Hz (5428 Hz)
Spurious and image rejection: Not specified.	First IF rejection: 14 MHz, 88 dB; 50 MHz, 76 dB; 144 MHz, 79 dB; 432 MHz, 105 dB. Image rejection: 14 MHz, 91 dB; 50 MHz, 94 dB; 144 MHz, 88 dB; 432 MHz, 61 dB.
Transmitter	**Transmitter Dynamic Testing**
Power output: HF, 5 – 100 W (2 – 25 W AM). 144/432 MHz, 50 W.	1.8 – 30 MHz, 4.4 – 100 W typical (AM, 4.4 – 40 W); 50 MHz, 4 – 93 W (AM, 5 – 37 W); 144 MHz, 4 – 48 W (AM, 1.2 – 8 W); 432 MHz, 6 – 45 W.
RF output at minimum operating voltage. Not specified.	At 11.7 V dc: 89 W (HF), 47 W (144 MHz), 43 W, (430 MHz).
Spurious-signal and harmonic suppression: 1.8 – 30 MHz, ≥50 dB; 50 MHz, ≥63 dB; 144/432 MHz, ≥60 dB.	HF, 65 dB typical, 61 dB worst case (24.9 MHz); 50 MHz, 63 dB; 144 MHz, 61 dB; 440 MHz, 63 dB.
SSB carrier suppression: ≥ 50 dB.	>70 dB.
Undesired sideband suppression: ≥ 50 dB.	>70 dB.
Third-order intermodulation distortion (IMD) products: Not specified.	3rd/5th/7th/9th order, HF, 100 W PEP: –22/–32/–39/–45 dBc (worst case, 160 m) –26/–37/–41/–46 dBc (typical) 50 MHz: –21/–34/–40/–41 dBc 144 MHz: –24/–50/–43/–56 dBc 432 MHz: –28/–39/–40/<–44 dBc
CW keyer speed range: Not specified.	4 to 57 WPM, iambic Mode A and B.
CW keying characteristics: Not specified.	See Figures 2 and 3.
Transmit-receive turnaround time (PTT release to 50% audio output): Not specified.	S-9 signal, AGC fast, 39 ms (SSB); 4 ms (FM); 200 ms (C4FM).
Receive-transmit turnaround time (tx delay): Not specified.	SSB, 34 ms; FM, 25 ms; C4FM 26 ms.
Transmitted phase noise: Not specified.	See Figure 4.

Size (height, width, depth): 3.5 × 9.2 × 11.5 inches including protrusions. Weight: 9.5 lbs.

Price: $1550; FH-2 keypad, $100.

*Measurement was noise limited at the value indicated.
**Default values; bandwidth and frequency response are adjustable via DSP.

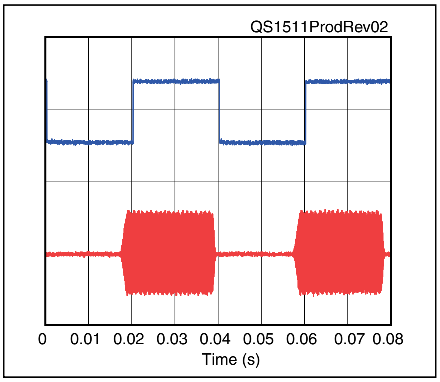


Figure 2 — CW keying waveform for the Yaesu FT-991 showing the first two dits in full-break-in (QSK) mode using external keying. Equivalent keying speed is 60 WPM. The upper trace is the actual key closure; the lower trace is the RF envelope. (Note that the first key closure starts at the left edge of the figure.) Horizontal divisions are 10 ms. The transceiver was being operated at 100 W output on the 14 MHz band.

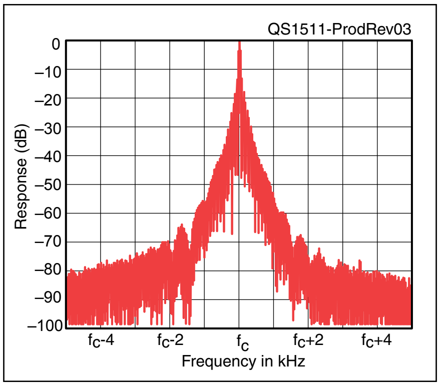


Figure 3 — Spectral display of the Yaesu FT-991 transmitter during keying sideband testing. Equivalent keying speed is 60 WPM using external keying. Spectrum analyzer resolution bandwidth is 10 Hz, and the sweep time is 30 seconds. The transmitter was being operated at 100 W PEP output on the 14 MHz 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 dB.

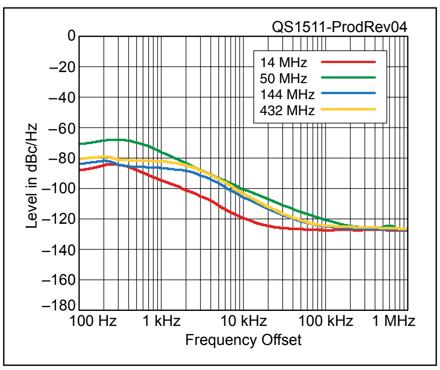
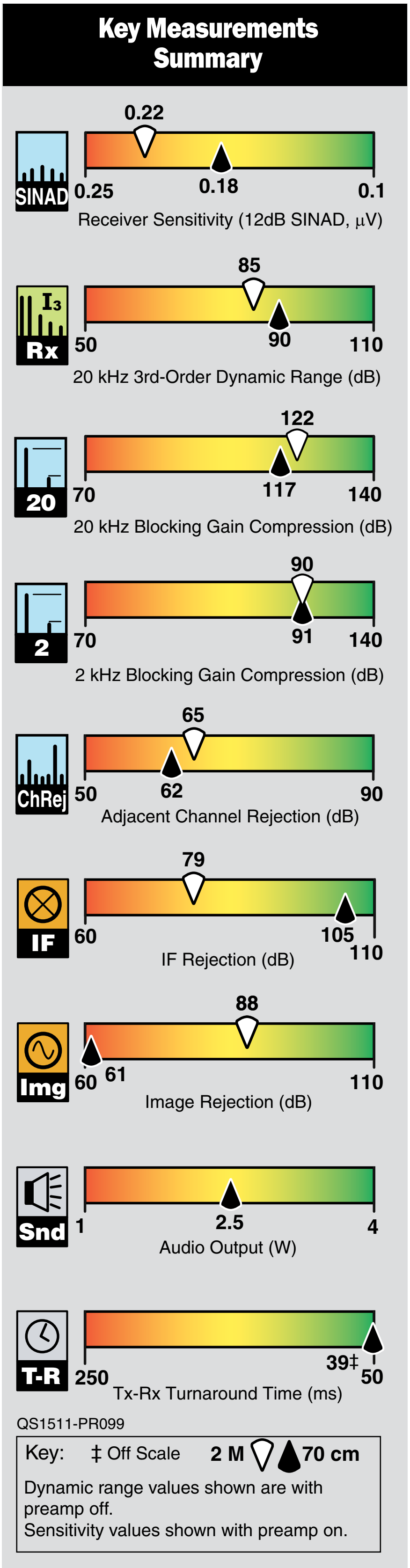


Figure 4 — Spectral display of the Yaesu FT-991 transmitter output during phase noise testing. Power output is 100 W on the 14 MHz band (red trace) and 50 MHz band (green trace), and 45 W on 144 MHz (blue trace) and 432 MHz (yellow trace). The carrier, off the left edge of the plot, is not shown. This plot shows composite transmitted noise 100 Hz to 1 MHz from the carrier. The reference level is 0 dBc, and the vertical scale is in dBc/Hz.



70 centimeters. The mini DIN jacks are for digital mode and antenna tuner/linear amplifier connections, while the RS-232 (DB-9) connector is for connecting an external GPS or computer. There's also a USB jack for computer control and data modes.

Out of the box, the first thing I noticed was that the lettering on all the controls was very bright compared to the transceiver that is normally on my operating desk. The white paint appeared to be illuminated under ordinary light. In previous transceiver reviews I had complained about poor visibility on front panels and was happy to see this improvement on the FT-991.

The main display is a full-color, 3.5-inch TFT LCD — and it's a touchscreen. The display is very bright and has good contrast to make viewing very comfortable on the eyes. The operator can adjust the screen brightness by using the menu.

The touchscreen is a nice addition to an amateur transceiver. It's similar to, but not quite like, the typical smartphone screen. I found that the touchscreen makes selecting features much faster than previous navigation schemes. When operating a particular mode, only the relevant menu items are active on the touchscreen. For example, the CW keyer settings are only active in CW mode. This prevents accidental changing of your favorite settings.

Receiver

I found the receiver to be very quiet and offer easy listening through headphones or the built-in speaker. The adjustable receiver audio filter allows some tailoring of the low and high cutoff frequencies separately for the SSB, CW AM, RTTY, and data modes.

The FT-991 includes two preamplifiers (AMP1, 10 dB and AMP2, 20 dB) for 1.8 – 50 MHz. As with other Yaesu models, there's an IPO (intercept point optimization) setting that bypasses the RF preamplifier. AMP1 is not available below 1.8 MHz, and only AMP2 is available at 144 and 430 MHz. There's also a 12 dB attenuator (ATT).

The FT-991 uses a 3 kHz roofing filter on SSB and CW, and a 15 kHz roofing filter for AM, FM, and C4FM.There's a NAR/WIDE button to quickly select DSP IF bandwidth. NAR can be set to 200 Hz – 1.8 kHz for SSB or 50 – 500 Hz for CW, RTTY, and data modes. WIDE can be set to 1.8 – 3 kHz for SSB and 500 Hz – 3 kHz for CW, RTTY, and data modes. AM is fixed at 6 kHz NAR or 9 kHz WIDE, and FM is 9 kHz or 16 kHz.

Other interference-fighting features include IF shift and variable IF width, an IF notch filter, and an automatic notch filter that will attack one or two tones. The auto-notch filter can be activated on CW (attacking desired CW signals), which may confuse some users. The CONTOUR filter allows you to set a peak or null in part of the receiver passband. For CW, the audio peak filter (APF) can help peak up a weak CW signal to separate it from background noise.

Digital noise reduction (DNR) offers 15 different noise reduction algorithms. The IF noise blanker (NB) is adjustable with three levels.

Voice Modes

Operating SSB on the FT-991 is very easy. One can turn on the transceiver, select SSB mode, key the mic, and talk. It does not require much effort to master some of the advanced SSB features.

The transmitted audio is very good using the factory default settings. The user has the option of enhancing the SSB or AM transmitted audio through the use of two parametric equalizers. With two equalizers you can set each one for specific operating conditions. In addition to the equalizer, there's an adjustable SSB speech processor.

SSB transmitted bandwidth is also adjustable. In addition to the default 300 – 2700 Hz setting, 400 – 2600, 200 – 2800, 100 – 2900, and 100 – 3000 Hz are available through menu settings.

During ARRL Lab testing (see Table 1), Senior Test Engineer Bob Allison, WB1GCM, noted that the typical third-order IMD products, only 26 dB below PEP on HF and 21 dB below PEP on 6 meters, could be better. For example, Yaesu's FTDX1200, reviewed in the January 2014 issue of *QST*, showed typical third-order IMD products an impressive 37 dB below PEP. Measurements shown in Table 1 were taken at full RF power output, with minimal ALC. Reducing RF power output by 20% improved the IMD performance. WB1GCM also noted that the FT-991's transmitted phase noise close to the carrier (see Figure 4) is higher than we like to see, particularly at 50 MHz and above.

I use a Heil Pro Set with the HC-6 microphone element. The Heil support page provides a good table of DSP settings for Yaesu radios. I always received excellent audio reports using the settings provided for the Heil microphone. You can use the FT-991's transmit monitor while making adjustments, but it's always a good idea to enlist some help on the air to confirm the best-sounding settings.

The transceiver includes a voice keyer that can store five messages of up to 20 seconds each. The voice memories can be controlled from the touchscreen or from the optional FH-2 keypad (more on this later).

With its coverage of the 28, 50, 144, and 430 MHz bands, the FT-991 includes a full set of features for analog FM and repeater operation. Automatic repeater shift makes operation simple, or you can set nonstandard splits manually. CTCSS encode/decode and DCS (digital code squelch) and tone squelch (opens the squelch when receiving the correct CTCSS tone) are controlled by menus.

Table 2
Yaesu FT-991, serial number 4N020467

ARRL Lab Two-Tone IMD Testing† (3 kHz roofing filter, 500 Hz DSP bandwidth)

Band/Preamp	*Spacing*	*IMD Level*	*Measured Input Level*	*Measured IMD DR*	*Calculated IP3*
3.5 MHz/Off	20 kHz	–24 dBm –15 dBm	–124 dBm –97 dBm	100 dB	+26 dBm +26 dBm
14 MHz/Off	20 kHz	–24 dBm –12 dBm 0 dBm	–124 dBm –97 dBm – 55 dBm	100 dB	+26 dBm +31 dBm +28 dBm
14 MHz/One	20 kHz	–36 dBm –21 dBm	–136 dBm –97 dBm	100 dB	+14 dBm +17 dBm
14 MHz/Two	20 kHz	–43 dBm –28 dBm	–143 dBm –97 dBm	100 dB	+7 dBm +7 dBm
14 MHz/Off	5 kHz	–24 dBm –11 dBm 0 dBm	–124 dBm –97 dBm –60 dBm	100 dB	+26 dBm +32 dBm +30 dBm
14 MHz/Off	2 kHz	–42 dBm –97 dBm 0 dBm	–124 dBm –36 dBm –27 dBm	82 dB	–1 dBm –5 dBm +13 dBm
50 MHz/Off	20 kHz	–22 dBm –12 dBm	–122 dBm –97 dBm	100 dB	+28 dBm +31 dBm
144 MHz/Two	20 kHz	–56 dBm –42 dBm	–141 dBm –97 dBm	85 dB	–13 dBm –14 dBm
432 MHz/Two	20 kHz	–55 dBm –41 dBm	–145 dBm –97 dBm	90 dB	–10 dBm –13 dBm

†ARRL Product Review testing includes Two-Tone IMD results at several signal levels. Two-Tone, Third-Order Dynamic Range figures comparable to previous reviews are shown on the first line in each group. The "IP3" column is the calculated Third-Order Intercept Point. Second-order intercept points were determined using –97 dBm reference.

C4FM Operation

Yaesu's System Fusion uses C4FM for digital voice and data providing superb clarity and the ability to send and receive data on the same voice channel. The FT-991 includes C4FM capabilities that are compatible with Yaesu's VHF/UHF FM transceivers and the growing number of System Fusion repeaters.

In the FT-991, a feature called Automatic Mode Selection allows the transceiver to detect C4FM and analog FM signals then automatically switch the transceiver's operating mode to match that of the incoming signal. This is useful in situations where the FT-991 may be the fixed station radio at an EOC (emergency operations center), for instance, and volunteers are in the field using a variety of C4FM or analog FM mobile and handheld radios. The command station can communicate with anyone in the field. With this scenario, volunteers and club members can upgrade to C4FM mobile and handheld radios as their budgets allow without disrupting service to the community.

For this review, I enlisted some volunteers using FM analog radios and Yaesu C4FM radios to demonstrate the flexibility of the FT-991 using a System Fusion repeater here in the Hartford, Connecticut, area. In the demonstration we used a Yaesu FT-1DR handheld, which has Automatic Mode Selection as well. It was interesting to make a mix of contacts through the repeater using C4FM voice or FM analog.

The FT-991 includes the Group Monitor (GM) function found on Yaesu's C4FM VHF/UHF FM transceivers. Position and distance can be displayed for up to 24 other stations with GM enabled that are within range. How does the FT-991 know its current location? Hook up a GPS receiver to the GPS/CAT jack on the rear panel.

In July 2015, Yaesu released an FT-991 firmware update that enables the FT-991 operator to connect to a WIRES-X — Wide-Coverage Internet Repeater Enhancement System — Node station and communicate through the WIRES-X VoIP (Voice over Internet Protocol) network, without the need for any additional accessories. WIRES-X is functionally similar to IRLP (including management via a central Internet server). I didn't test this new feature.

CW Operation

The FT-991 includes a versatile memory keyer, or you can use your favorite external keyer, computer software, or straight key. Note that if you use an external keyer, the front-panel KEY jack still requires a stereo phone plug (the ring is not connected). Semi break-in and full break-in (QSK) are available. In the Lab tests, the keying waveform (Figure 2) and keying sidebands (Figure 3) are acceptable.

The built-in keyer offers several different iambic modes, as well as a BUG mode (the keyer sends the dits, you form the dashes manually), plus an ACS mode with fixed character spacing. The keyer has five memories and can automatically insert serial numbers for contesting.

CW pitch is adjustable from 300 – 1050 Hz in 10 Hz steps. Like most current transceivers, the FT-991 offers assistance with tuning in ("zero beating") CW signals. Pressing the F(M-LIST) button and then touching ZIN on the LCD will automatically tune the received signal so that the transmit offset is correct. For manual tuning, you can touch SPOT on the LCD to generate a tone you can use to match the pitch of a received signal (and tune a little higher or lower than other stations calling in a pileup).

One thing noticeably missing is a CW tuning indicator, which is a useful visual aid when tuning a CW signal. Perhaps this is wishful thinking on my part, but maybe a future firmware upgrade can add this feature.

Digital Modes and Computer Interface

For RTTY or sound card digital modes such as PSK31 and JT65, traditional connections for FSK keying and sound card audio in and out are available from the RTTY/DATA jack on the rear panel. You can use those, or take advantage of the transceiver's USB port for computer control (CAT — computer aided transceiver) and for audio input and output to be used with sound card digital modes. The USB method eliminates the need for an external computer-to-radio interface, thus eliminating one more item from the go-bag.

Configuring the FT-991 for digital operation and CAT control through the USB port is fairly simple. The drivers are available to download from Yaesu's website at no additional charge. I installed the drivers, then I was able to quickly configure the radio to communicate with some popular contest and logging applications. I had had full control of the transceiver and was keying CW and FSK RTTY via the USB port of my laptop computer. Operating RTTY with the FT-991 was a pleasure. The transceiver's tuning is very smooth, making it easy to fine tune RTTY signals.

The computer connection is also used to update the radio's firmware with new versions downloadable from the Yaesu website. Since we purchased the review unit, Yaesu has released several firmware updates to add features or improve performance.

I am very familiar with setting up this particular software/transceiver configuration, but anyone should be able to achieve positive results using the FT-991's manual and the logging software's documentation.

Other Features

Programming the memory channels of the FT-991 is fairly easy. Setting up duplex or split memories requires an extra step to save the transmit frequency. It took a few attempts to learn the button sequence to set the memory channels. It did not take much effort to program seven memory channels with the information to allow me to operate on amateur satellite SO-50, demonstrating the FT-991's versatility.

Figure 5 — The FT-991's display is crisp and conveys a lot of information about current operating parameters. The three rows of rectangular labels at the bottom of the screen are touch-sensitive buttons. The buttons change as different modes, features, or menus are selected.

Each band has three band-stacking registers that save all of the user settings. I like setting one register each for CW, SSB, and digital operation on each band. That makes mode switching very easy because personalized settings for each mode of operation stay locked into the band registry.

Yaesu offers an optional FH-2 keypad to program and control the built-in voice keyer and CW keyer memories. This is a nice accessory for day-to-day operation or for contest or DXpedition type operating. The popular *N1MM Logger* contest applications can be programmed to activate the FH-2 command by inserting a CAT instruction in the logging software's function configuration. This allows the operator to activate the messages stored in the transceiver by pressing the F1 – F4 keys on the logging computer's keyboard.

A built-in spectrum scope uses the lower half of the color TFT display. The scope can show a traditional spectrum display or a waterfall. The spectrum scope can be operated in the manual mode or using ASC (automatic spectrum scope) control. In the manual mode, touching SWEEP on the LCD activates the spectrum scope, mutes the transceiver audio, and displays a snapshot of the band activity on the screen. Using the transceiver's ASC function, the rig toggles between the spectrum scope and receive audio. I found this to be an annoying way to copy signals. Given the limited functionality of the spectrum scope, I don't think it can outperform a human tuning the dial and listening for signals. Considering all of the FT-991's other features and versatility, for me this limitation is not a deal breaker.

In the Field

To investigate the FT-991's portability, I set it up in our camper using the doublet antenna and auto tuner combination that I usually use from a campsite. Physically the transceiver fit nicely in the compact operating position and offered a comfortable view of all the controls.

The FT-991 performed well in the field. I was easily able to work any station I could hear and many stations responded to my calls. I should mention that the FT-991's antenna tuner works very well with coaxial fed antennas and impedances within its tuning range, but it is not designed to operate with the balanced line fed doublet that I use in the camper.

Final Thoughts

The FT-991 has a bright, easy-to-read display, is easy to operate, and interfaces easily with personal computers and popular Amateur Radio software applications. The color touchscreen is sharp and easy to read.

Chasing DX, collecting states or grid squares, using amateur satellites, working in traffic nets, public service, or operating from the campsite, the FT-991 is suitable for any operating environment.

Manufacturer: Yaesu USA, 6125 Phyllis Dr, Cypress, CA 90630; tel 714-827-7600; **www.yaesu.com**.

See the Digital Edition of *QST* for a video overview of the Yaesu FT-991 HF/VHF/UHF transceiver.

Icom IC-2730A Dual-Band FM Transceiver

Reviewed by Becky Schoenfeld, W1BXY
QST *Managing Editor*
w1bxy@arrl.org

As I write this review, it's summertime, and the livin' is easy. There's no better time to cruise around with a new mobile radio — in this case, Icom's dual-band IC-2730A. As a relatively new ham, this was my first experience with a mobile rig, and I was eager to try to make sense of it all. Fortunately, Icom has made it easy with this radio. The box contained a 90-page instruction manual, the radio body, the radio control head, the microphone, a connector cable, a dc power cable, a microphone hanger, and an extra 15 A fuse, but no mounting brackets. Several mounting bracket options are available at additional cost. (The IC-2730A Deluxe package includes the radio and an MBF-5 remote head mounting bracket.) I decided to get acquainted with the radio in the comfort of my home shack before taking it on the road.

The IC-2730A works on 2 meters and 70 centimeters, with three power levels on each band (50/15/5 W). It's got extended receive coverage outside the ham bands, including coverage of the AM aircraft band and the NOAA weather channels and weather alert. You can listen on both receivers at the same time — VHF/VHF, UHF/UHF, or VHF/UHF are all possible. Icom's optional VS-3 Bluetooth headset includes VOX capability for hands-free operation. Icom offers free programming software as a download from the web.

Getting the Lay of the Land

I wired up the IC-2730A to my switchmode power supply, snapped in the appropriate cables to connect the mic and the radio body to the control head, and turned on the radio to find that the front panel of the control head has a large, easy-to-read display (with adjustable brightness and contrast) with a simple white background. Being that this is a dual-band radio, the same pushbuttons (MAIN/BAND, V/MHZ/SCAN, MR/CALL) and knobs (VOL, DIAL, SQL) appear on each side of the display, for easy control of whichever band you're operating on. Four pushbuttons that control monitoring, power output, memory, and menus (MONI/DUP, LOW/DTMF, MW, MENU/LOCK) are located below the display. The layout of the controls is well-thought-out and uncomplicated — good qualities for a mobile radio, as the operator needs to be able to concentrate on driving. Once you get used to the layout, it's easy to find your way around the control head by touch.

The control head is about 5¾ × 1¾ × 1 inches, and though it is lightweight, the construction feels sturdy — a nice balance. The sizes of the buttons and knobs are thoughtfully designed for mobile operation — large enough for an operator to be able to find and use the desired button or knob, and spaced well enough apart that "fat-fingering" will be minimized. The pushbuttons and knobs have a satisfying amount of "weight" to them. There's no wobble to the pushbuttons, and they beep on a tone that corresponds with the band that you're on. The tones for the band on the left-hand side of the display are different from the tones on the right-hand side, and the tones for the main control pushbuttons at the bottom center of the control head shift to match the tone of the band you're operating on — all so you can keep your eye on the road! All the pushbuttons, including the power button, are multi-function, depending on whether you push or hold, and depending on which mode the radio is in.

The volume and squelch knobs rotate smoothly, and the tuning dial rotation is notched — not too wide, not too narrow;

> **Bottom Line**
>
> Rugged and easy to use, Icom's IC-2730A has all the features expected in an up-to-date analog FM VHF/UHF dual-band transceiver.

Table 3
Icom IC-2730A, serial number 05001768-9

Manufacturer's Specifications	Measured in ARRL Lab
Frequency coverage: Receive, 108 – 137 MHz (AM); 137 – 174, 375 – 550 MHz (FM). Transmit, 144 – 148, 430 – 450 MHz (FM).	Receive and transmit, as specified.
Modes: FM, FM-N	As specified.
Power requirements: Receive: ≤1.8 A (maximum audio), 1.2 A (standby). Transmit, ≤13.0 A (maximum) at 13.8 V dc ±15%.	At 13.8 V dc: Receive, 590 mA (both receivers at max audio, max lights, no signal), 572 mA (single receiver, max volume, max lights), 390 mA (standby, min lights). Transmit (hi/med/low): 146 MHz, 9.3/5.6/3.5 A 440 MHz, 9.6/4.9/3.1 A.
Receiver	**Receiver Dynamic Testing**
Sensitivity: FM, FM-N (12 dB SINAD), ≤0.18 µV for amateur bands, ≤0.32 µV (137 – 160 MHz, 400 – 500 MHz), 0.56 µV (160 – 174, 375 – 400, 500 – 550 MHz); AM, (10 dB S+N), ≤1 µV (118 – 136.99166 MHz).	FM (12 dB SINAD): 146 MHz, 0.13 µV, 162 MHz, 0.13 µV, 440 MHz, 0.13 µV; AM, (10 dB S+N/N): 0.46 µV.
FM two-tone, third-order IMD dynamic range: Not specified.	20 kHz offset: Receiver A, 146 MHz, 69 dB*; 440 MHz 69 dB*. Receiver B, 146 MHz, 68 dB*; 440 MHz, 71 dB. 10 MHz offset: 146 MHz, 83 dB; 440 MHz, 74 dB.
FM two-tone, second-order IMD dynamic range: Not specified.	Receiver A, 146 MHz, 80 dB; 440 MHz, 107 dB. Receiver B, 146 MHz, 80 dB; 440 MHz, 115 dB.
Adjacent-channel rejection: Not specified.	20 kHz offset: Receiver A, 146 MHz, 69 dB; 440 MHz, 69 dB. Receiver B, 146 MHz, 68 dB; 440 MHz, 73 dB.
Spurious response: Not specified.	IF rejection: Receiver A and B, 146 and 440 MHz, >135 dB. Image rejection: Receiver A, 146 MHz, 98 dB; 440 MHz, 73 dB. Receiver B, 146 MHz, 125 dB; 440 MHz, 83 dB.
Squelch sensitivity: 0.13 µV (threshold).	At threshold, 146 MHz, 0.08 µV, 4.02 µV (max); 440 MHz, 0.09 µV, 4.12 µV (max).
S-meter sensitivity: Not specified.	Full scale indication, 3.05 µV (144 MHz); 3.46 µV (440 MHz).
Audio output: ≥2 W at 10% THD into 8 Ω.	2.25 W at 10% THD. THD @ 1 V_{RMS}, 0.7%.
Transmitter	**Transmitter Dynamic Testing**
Power output: 50/15/5 W (hi/med/low).	Hi/med/low: 146 MHz, 47/14/4.3 W 440 MHz, 42/14/6.1 W.
RF output at minimum operating voltage: Not specified.	At 11.7 V dc: 144 MHz, 46/14/4.3 W, 440 MHz, 39/14/6.1 W.
Spurious signal and harmonic suppression: >60 dB.	146 MHz, 65 dB, 440 MHz, ≥70 dB. Meets FCC requirements.
Transmit-receive turnaround time (PTT release to 50% of full audio output): Not specified.	Squelch on, S-9 signal: 146 MHz, 130 ms; 440 MHz, 126 ms.
Receive-transmit turnaround time ("tx delay"): Not specified.	146 MHz, 69 ms; 440 MHz, 71 ms.

Size (height, width, depth): Control panel, 1.9 × 5.8 × 1.5 inches (including protrusions); rear chassis, 1.5 × 5.9 × 7.0 inches (including protrusions). Weight: Control panel, 5 oz; main chassis, 2.6 lbs.

Price: $340.

*Measurement was noise limited at the value indicated.

in fact, just right. In VFO mode, the tuning dial can be set to tune at your choice of 10 pre-selected step values ranging from 5 kHz to 50 kHz. In memory mode, the tuning dial runs through your memory channels. There's a mic jack on the right-hand side of the control head, and a jack on the back of the control head for connecting it to the main unit with the (included) connector cord.

The main unit is a compact chunk of radio and, like the control head, is relatively lightweight, yet sturdy. The front panel has a jack for the connector cord, as well as a mic jack. The rear panel is home to the antenna connector (the radio has a built-in duplexer, so you can use a 144 and 430 MHz dual-band antenna without needing an external duplexer), the cooling fan (which is adjustable via one of the menus), the 13.8 V dc power socket, and two jacks for external speakers.

The Icom IC-2730A comes with an Icom HM-207 microphone — the kind of microphone that has a keypad on it. The keypad is divided into two sections, with the upper section being nine control keys and the lower section being a traditional numeric keypad, plus a column of four additional control keys. As with the control head, the pushbuttons on the mic are laid out well, to reduce the likelihood of errors. The nine keys on the upper section of the mic duplicate some of the functions on the control head: the VFO/MR/LOCK key toggles between VFO and memory modes with a push, and toggles the lock function on and off when held; a pair of UP/DOWN keys change your frequency or memory channel, depending which mode you're in; the MAIN/DUAL key toggles between bands.

It's nice to have the option of performing these functions on the control head or on the mic that's right in your hand — especially while operating on the go. The remaining five buttons on the upper section of the mic are the HOME/CALL key, which you push to select your home channel, and hold down to toggle the call channel mode on and off; the F-1 and F-2 buttons, which can be programmed for a number of functions including squelch control, band or bank selection, scanning and skipping frequencies, changing the power level, selecting and transmitting tones, saving and selecting memories, and more; the ENT key, which enables you to set memories; and the CLR key, which takes you out of menu mode.

On the numeric part of the keypad, the numeral buttons do their usual thing. The asterisk key, aside from being an asterisk, is used to input a decimal point. Likewise, the pound key allows you to delete a number if you make an error, as well as enabling you to type a pound sign. The column of keys to the right of the numeric keypad, A, B, C, and D, control the volume (keys A and B) and squelch level (keys C and D) and also input DTMF codes.

Menus and Programming

And what about those menus? You access the menu tree by pressing the MENU/LOCK pushbutton on the control head, and using either of the main dials on the control head to move through the choices. In addition to the extensive "regular" menus, the IC-2730A also has "exmenu" mode for advanced settings, which are reviewed in the manual but discussed in further detail on the Icom website at **www.icom.co.jp/world/support/download/manual/pdf/IC-2730_Web_ENG_0.pdf**.

There are two ways to program frequencies in memory. If you're content to allow the radio to select a channel number for you, then it's a matter of pressing one button — the radio will write your desired frequency to a blank channel, and display that channel's number for you. It's up to you to remember it! If you'd prefer to select the channel number yourself, the process requires a couple of steps — selecting the channel number, and then specifically telling the radio to write to that channel — but it's still very simple to accomplish. You can manage the radio's 999 memory channels by categorizing them in any of the radio's 10 memory banks, which can be given custom names.

On the Air

My first contact with the '2730A was a simplex contact with Ernie, K1SEX, who was operating mobile about 8 miles south of my home station, where I was running the rig into the 2 meter vertical antenna on the roof of my house. Perfect signal reports were given both ways, with Ernie reporting "excellent audio and full quieting" from the '2730A. We parted ways with a promise that I would give Ernie a holler if I could hit the repeaters up in Vernon, Connecticut, about 19 miles from my home station.

This meant, of course, that my next task was to program the transceiver with the offsets for the Vernon repeaters. The radio's manual includes a very brief yet very clear basic description of repeater operation, which I greatly appreciated. I don't spend a great deal of time on repeaters, so this simple reminder about how they work was welcome as I prepared to try to hit the Vernon repeaters. As it turned out, programming the repeater offset and tone was simple — navigate to the appropriate menu (OFFSET and R TONE, respectively), twist the knob to your desired setting, hit one key to save, and you're in business. I was able to hit the Vernon repeaters on both high and low power on this radio — but I never did find Ernie again to tell him the good news.

On the Road

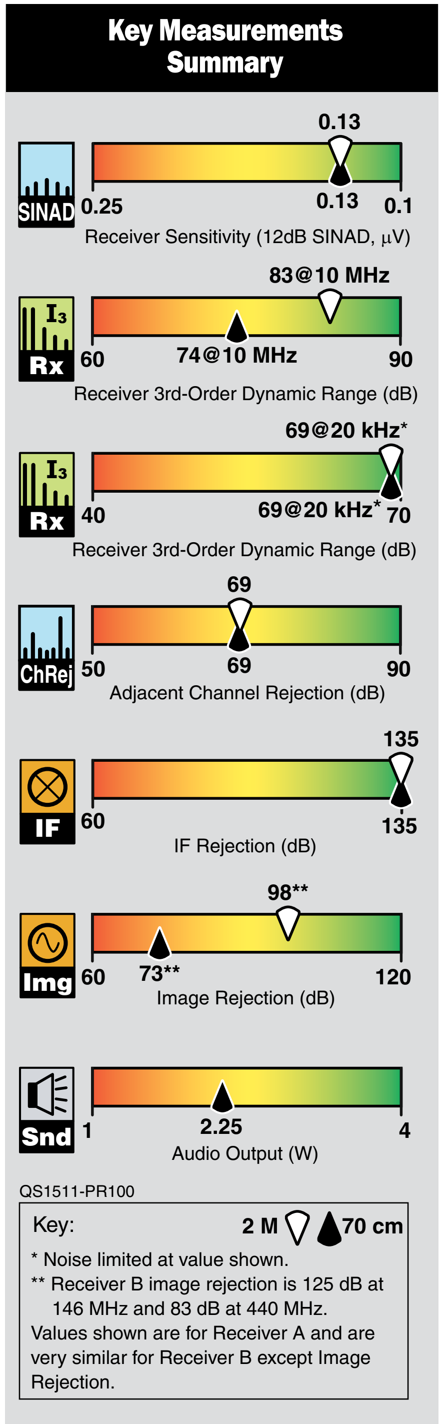
After my taste of success at home, it was time to take the IC-2730A on the road. I connected the radio to 13.8 V dc, put a simple mag-mount antenna on the roof of my Subaru Forester, and I was off. The radio performed admirably, just as it had at my home station. Because the radio was new to me, and because I'm new in general to the multitasking effort of driving while hamming, I pulled over a few times to unkink a setting or check a frequency. All of these "pullovers" were for operator-based concerns, rather than rig-based concerns, and I felt they were necessary for safety. Yes, mobile ham operating is protected by law, but your safety and the safety of people sharing the road with you should be paramount. You don't have to be a new ham to be distracted by your radio. Pull over if you need to!

For safer hands-free conversation, Icom offers an optional UT-133 Bluetooth interface that installs in the IC-2730A and other recent Icom mobiles. The UT-133 works with Icom's VS-3 Bluetooth headset, as well as headsets from other vendors.

In the Sky

Satellite operating was one of the first things I got into as a new ham, so of course I had to try out the IC-2730A on a satellite pass. My Elmer, Sean, KX9X, and I drove to a relatively high elevation and readied the rig for an SO-50 pass. This particular satellite requires a transmit tone, and setting the tone was a simple matter of two menu settings — one to make sure tones were activated, and another to set the proper tone.

The '2730A allows you to listen on both VFOs at once, and you can adjust the volume and squelch for each VFO, making this a convenient radio for satellite contacts.



Being able to hear your transmission on the satellite's downlink isn't a requirement for satellite contacts, but it's definitely a nice thing to have, and this radio makes that possible. With the radio set up to transmit on 2 meters while I was listening on 70 centimeters, I made six contacts via SO-50, from Maine to Virginia, and as far west as Ohio, all in the span of about 7 minutes.

In Summary

The Icom IC-2730A offers a quick learning curve, good ergonomics, and every function and feature you could want in a basic dual-band transceiver. It's solidly built and a good choice for home, portable, or mobile operation. Newer hams in particular will appreciate the ease of use and clear instructions.

Manufacturer: Icom America, 12421 Willows Road NE, Kirkland, WA 98034; tel 800-872-4266; fax: 425-454-1509; **www.icomamerica.com**.

See the Digital Edition of *QST* for a video overview of the Icom IC-2730A dual-band FM transceiver.

LNR Precision LD-5 QRP Transceiver

Reviewed by Chuck Skolaut, KØBOG
ARRL Field and Regulatory Correspondent
k0bog@arrl.org

The QRP world has seen the introduction of a number of new transceivers over the past year, either in kit form or assembled and ready to use right out of the box. One of the newest additions in the ready-to-use category is the LD-5 QRP transceiver available from LNR Precision. It covers 40, 30, 20, 17, and 15 meters. RF output power is adjustable, 5 W nominal. In addition to CW and SSB, the radio is capable of PSK, RTTY, and SSTV operation with a companion computer with sound card and software.

The LD-5 is actually an SDR in a box with switches and knobs, and so it offers quite a few features for a small transceiver, such as multiple bandwidth filters, noise blanker, notch filter, speech compressor, built-in CW keyer, and more. There are also some performance anomalies, as discussed in the accompanying sidebar, "Test Results from the ARRL Lab." It is possible to upgrade the firmware via the USB port. In fact, three revisions were downloaded during the review period.

There is a fairly comprehensive manual available online, featuring color illustrations. I might suggest printing it out in the landscape mode for easier viewing. The manual could do a better job of explaining some of the settings and connections, but you can figure it out from what's there and LNR responded quickly by e-mail to a few questions we had.

A Compact Package

The LD-5 is a bit larger than the previous QRP radios from LNR, but it still is very compact and sleek looking, at approximately 2.8 × 5.5 × 4.2 inches. It weighs in at just 19 ounces without the microphone. While this may not be classified strictly as a trail-friendly radio, it is still reasonably small enough to be taken in a backpack. The LD-5 may be powered by a 10.5 to 15 V dc power source and has polarity protection. The Lab measured the maximum current draw on transmit at 1.55 A, something to consider if you plan on taking it on a hiking trip and using strictly battery power.

> **Bottom Line**
>
> The LNR Precision LD-5 packs a lot of features into a tiny QRP transceiver capable of SSB, CW, and digital operation. It's got a few performance anomalies, but overall it is enjoyable and satisfying to use.

The front panel sports a highly legible LCD display with blue backlighting and the characters in white. The display backlight can be set to always be on, be on for 3 seconds whenever a switch or the encoder is activated, or it can be switched off to save 45 mA of current drain.

There are 13 pushbuttons for the various functions, along with the volume control and the main tuning knob. The buttons feel sturdy with a positive action. I like that the tuning knob features smooth tuning that reminds me of using a full-size rig — no detents as are often found in radios in this class. I also like the feet that swing down to allow you to tilt the unit for easy viewing. A clear plastic escutcheon provides good protection to the display and main tuning knob skirt area.

The key, mic, headphone, and line in/out connections (all 3.5 mm phone jacks) are on the left panel. The computer control (USB), antenna (BNC), PTT out (phono), dc power input jack (coaxial), and a speaker are on the right hand side. The built-in speaker is a nice plus in a compact transceiver such as this, if you should ever forget the earphones or want to keep accessories to a minimum while traveling. The line in/out jack is for connecting a computer sound card for digital modes.

Out of the Box

When I was first introduced to low power work, very simple radios such as the classic Tuna Tin 2 transmitter featured in *QST* were popular. It's amazing how far equipment technology has advanced in modern QRP radios.

For me, the most exciting part of checking out a new radio is actually using it in the shack. My first impression of the LD-5 was very good. The receiver seems very sensitive, with many signals heard on the active bands providing good copy on both SSB and CW. The display normally shows a signal strength reading on receive, and on transmit indicates power output or SWR depending on the menu setting. The controls are user friendly and I quickly became accustomed to the functions.

The LD-5 provides full band coverage on the five amateur bands it was designed for, but it does not provide continuous receive from 7 to 22 MHz, as one might think from first looking at the manual. Band selection is easy just by pushing the up or down arrow buttons. An updated manual on the LNR website describes a method to expand the receive-only capabilities to cover 80 and 160 meters.

The LD-5 has two VFOs, convenient for split frequency operation or jumping from one end of the band to the other after setting appropriate frequencies. Tuning past the band edge causes the coverage to loop back to the opposite band edge. For instance, tuning past 7.300 returns you to 7.000, a nice feature that gives you the opportunity to either tune back down the band or tune up from the bottom end.

Tuning steps are selectable — 10 Hz, 100 Hz, 1 kHz, and 10 kHz — either by pressing the STEP button or by pushing on the tuning knob. A small indicator on the display screen shows which step is engaged.

The radio features 100 memories that store frequency, mode, and other radio settings, providing plenty of storage for even the most ardent user. To store a frequency, first tune it in using either VFO. Set the mode and any other features you wish to store. Press MEMO, use the VFO knob to bring up the memory location you wish to store

Test Results from the ARRL Lab

The keying waveform plot in Figure 6 shows somewhat unusual behavior. Three dits were transmitted at 60 WPM for this plot, using the standard Product Review test setup and conditions. Upon keying the transmitter, there's a low-level artifact that precedes the first transmitted dit. The shape of the first dit indicates that full power output does not occur immediately at the beginning of this dit.

We found that at slower speeds, the artifact is not present, but the odd-shaped first dit remains. I investigated for possible on-air effects by asking *QST* Product Review Editor Mark Wilson, K1RO, to meet me on 40 meters during excellent band conditions. Mark gave a critical listen to the LD-5's CW signal, and could not hear any unwanted effects from the keying shape of this first dit. The transmitted signal sounded fine.

Figure 7 shows the output of the LD-5 during keying sideband testing. Usually the result is a single signal that tapers off into the spectrum analyzer's noise floor. As expected from the LD-5's soft keying waveform, this test shows rather narrow sidebands for the main signal. However, the main CW signal is accompanied by discrete spurious signals ±3 kHz of the fundamental frequency. The position of the "spurs" is dependent on the frequency of the LD-5's CW pitch control. In this case, the pitch was adjusted to 600 Hz with a result of four spurs appearing on each side of the carrier.

I suspect these spurs are present because CW is generated by an audio tone used to modulate the single sideband portion of the transmitter. The tone generator has harmonics, which are transmitted along with the desired signal. While this may look unusual, this method of keying has been used in the past with acceptable results. Note that the power of each spur is 46 dB or lower below the carrier, which translates to only 1.25 µW of power for the worst-case spur. K1RO could not detect any of the spurs during our on-air tests, even though signals were quite strong. The spurs could bother nearby stations if the LD-5 is used with an amplifier.

I had the opportunity to operate the LD-5 while staying in Dayton, Ohio, for the 2015 Hamvention. There was a tree in a convenient location outside my second-story hotel window, so I attached a thin 23-foot wire. Using a small LC antenna tuner and 23-foot counterpoise stretched across my hotel room, I managed to work stations several hundred miles distant on 40 and 30 meters, and a handful of European stations on 20 meters in CW mode, with good reports. It's a fun radio with a good-quality feel.
— Bob Allison, WB1GCM, ARRL Senior Test Engineer

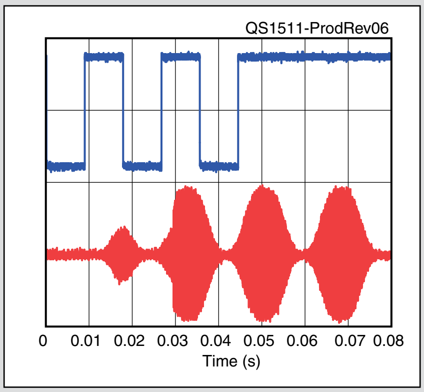


Figure 6 — CW keying waveform for the LNR Precision LD-5 showing the first three dits using external keying. Equivalent keying speed is 60 WPM. The upper trace is the actual key closure; the lower trace is the RF envelope. (Note that the first key closure starts at the left edge of the figure.) The low-level artifact before the first dit is not present at slower CW speeds — see the text above. Horizontal divisions are 10 ms. The transceiver was being operated at 5 W output on the 14 MHz band.

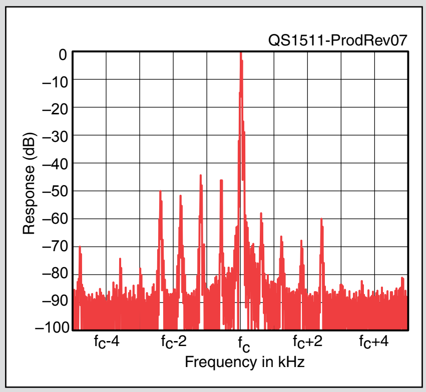


Figure 7 — Spectral display of the LNR Precision LD-5 transmitter during keying sideband testing. Equivalent keying speed is 60 WPM using external keying. Spectrum analyzer resolution bandwidth is 10 Hz, and the sweep time is 30 seconds. The transmitter was being operated at 5 W PEP output on the 14 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 dB.

(0 – 99), press the down-arrow button and press MEMO again. To recall a stored memory channel, press MEMO, tune the VFO dial to the desired memory location, press the up-arrow, and press MEMO again. This all sounds confusing, but it becomes second nature after you have entered in several memories.

Over 20 different settings are controlled in the menu. Just push to enter, select the desired setting with the up/down buttons, and push again to exit. For example, AGC is adjustable from a menu, as is CW pitch.

There are four bandwidth selections available for SSB and CW. Filters 1 – 3 for each mode are set at the factory. The ARRL Lab measured the CW filters at 800/500/200 Hz and the SSB filters at 2700/2400/2000 Hz. Filter #4 is user adjustable from a menu, 50 – 2400 Hz for CW and 250 – 3400 Hz for SSB.

The receiver includes a noise blanker and digital noise reduction. Both are adjustable over a wide range. The noise reduction works very well. It does add some distortion, but it greatly improves intelligibility, even when set to maximum (100).

A hand mic is included for SSB operation. The LD-5 offers some features found on full-size radios — VOX, a speech compressor, three-band transmit audio equalizer and transmit monitor. The mid-range for the equalizer worked best for casual QSOs. The high frequency setting added some punch for pileups or tough conditions, but did not sound as pleasing. WB1GCM experimented with the speech compressor. It adds some punch, and he found that a setting of 30 (range is 0 – 100) sounded the best with his voice. Bob also found the SSB notch filter effective against carriers.

Metering and Protection

You can check the power supply voltage by pressing the F (function) button and then the MENU button. This is very useful when operating on a battery supply. I did find that with the review unit, it sometimes took several attempts to switch back and forth.

The LD-5 has a built-in power meter and SWR indicator. Lab tests showed that for a 25 Ω resistive load (2:1 SWR), the LD-5 indicated 2.5:1 SWR. For a 100 Ω resistive load (also 2:1 SWR), it indicated 7.5.1. We contacted LNR Precision about this, and they replied that it is a known issue, but they did not have a solution. I would recommend using an external SWR meter for unknown antennas and for adjusting an antenna tuner.

The radio has built-in SWR protection, and the manual states that the radio will deliver full power into an SWR of 3:1 or less. At a greater mismatch, the protection circuit lowers the power output. The inaccurate SWR indicator causes a problem here. With both of the 2:1 SWR loads described above, the LD-5 reduced power to about 2.5 W. In summary: The LD-5 needs a very good SWR to deliver full power, so you will

Table 4
LNR Precision LD-5, serial number n/a

Frequency coverage: 7 – 22 MHz.	Receive and transmit, 7 – 7.3, 10 – 10.15, 14 – 14.350, 18.068 – 18.168, 21 – 21.45 MHz.
Power consumption: receive, 350 mA; transmit, 1 – 2 A (typical) at 10.5 – 15 V dc.	At 13.8 V dc: Receive, 485 mA (max display brightness, max volume, no signal), 440 mA (min display brightness, max volume). Transmit, 0.95 – 1.55 A (10 – 100 % transmit power).
Modes of operation: SSB, CW, digital.	As specified.
Receiver	**Receiver Dynamic Testing**
Sensitivity: 0.2 µV (–121 dBm) with preamp.	Noise floor (MDS), 500 Hz bandwidth: *Preamp off* / *Preamp on* 7.0 MHz: –125 dBm / –133 dBm 14 MHz: –125 dBm / –133 dBm 21 MHz: –124 dBm / –130 dBm
Noise figure: Not specified.	Preamp off/on: 14 MHz, 22/14 dB.
Blocking gain compression dynamic range: Not specified.	Blocking gain compression dynamic range, 500 Hz bandwidth: *20 kHz offset Preamp off/on* / *5/2 kHz offset Preamp off* 14 MHz: 117/111 dB* / 117/117 dB*
Reciprocal mixing dynamic range: Not specified.	14 MHz, 20/5/2 kHz offset: 112/105/104 dB.*

ARRL Lab Two-Tone IMD Testing** (500 Hz bandwidth)

Band/Preamp	*Spacing*	*Measured IMD Level*	*Input Level*	*Measured IMD DR*	*Calculated IP3*
14 MHz/Off	20 kHz	–125 dBm	–30 dBm	95 dB	+18 dBm
		–97 dBm	–21 dBm		+17 dBm
14 MHz/On	20 kHz	–133 dBm	–46 dBm	87 dB	+6 dBm
		–97 dBm	–33 dBm		–1 dBm
14 MHz/Off	5 kHz	–125 dBm	–35 dBm	90 dB	+10 dBm
		–97 dBm	–23 dBm		+14 dBm
14 MHz/Off	2 kHz	–125 dBm	–35 dBm	90 dB	+10 dBm
		–97 dBm	–23 dBm		+14 dBm

Second-order intercept point: Not specified.	Preamp off/on, 14 MHz, +43/+9 dBm; 21 MHz, +53/+52 dBm.
Notch filter depth: 6 – 40 dB.	0 – 35 dB.

Manufacturer's Specifications	Measured in the ARRL Lab
S-meter sensitivity: Not specified.	S-9 signal, preamp off/on: 14 MHz, 2.14 mV/385 µV.
Receiver audio output: 200 mW.	490 mW into 8 Ω. THD @ 1 V_{RMS}, 1.75%.
IF/audio response: Not specified.	Range at –6 dB points (bandwidth): CW (500 Hz): 360 – 850 Hz (490 Hz) Equivalent Rectangular BW: 496.5 Hz USB (2.4 kHz): 316 – 3690 Hz (2374 Hz) LSB (2.4 kHz): 314 – 2692 Hz (2378 Hz)
Image rejection: Not specified.	71 dB.
Transmitter	**Transmitter Dynamic Testing**
Power output: 3.5 – 8 W.	7 MHz, 0.25 – 3.4 W; 10.1 MHz, 0.5 – 5.6 W; 14 MHz, 0.6 – 5.3 W; 18.1 MHz, 0.5 – 4.7 W; 21 MHz, 0.6 – 5.1 W.
Spurious-signal and harmonic suppression: Not specified.	46 dB.† Complies with FCC emission standards.
SSB carrier suppression: Not specified.	52 dB.
Undesired sideband suppression: Not specified.	39 dB.
Third-order intermodulation distortion (IMD) products: Not specified.	3rd/5th/7th/9th order, 5 W PEP: –30/–39/–41/–52 dBc (worst case, 21 MHz) –35/–45/–52/–55 dBc (typical).
CW keyer speed range: Not specified.	4 to 52 WPM, iambic mode A or B.
CW keying characteristics: Not specified.	See Figures 6 and 7.
Transmit-receive turnaround time (PTT release to 50% audio output): Not specified.	S-9 signal, AGC fast, 71 ms.
Receive-transmit turnaround time (tx delay): Not specified.	82 ms.
Transmitted phase noise: Not specified.	See Figure 8.
Size (height, width, depth): 2.8 × 5.5 × 4.2 inches including protrusions. Weight: 1.25 lbs.	
Price: $575.	

*AGC could not be disabled. Blocking gain compression and reciprocal mixing were measured with AGC on.
**ARRL Product Review testing includes Two-Tone IMD results at several signal levels. Two-Tone, Third-Order Dynamic Range figures comparable to previous reviews are shown on the first line in each group. The "IP3" column is the calculated Third-Order Intercept Point. Second-order intercept points were determined using –97 dBm reference.
†Spurious emissions ±3 kHz from carrier in CW mode; harmonic output was significantly less.

probably need to add a small antenna tuner to your station to operate the LD-5 at full power into many typical antennas.

On the Air

How does the LD-5 work in the shack? I was very favorably impressed with its operation and had no trouble making CW and SSB contacts around the East Coast in a leisurely operating timeframe in the evenings on 40 meters. I also used it during Field Day to check the performance in crowded conditions, and I was impressed. My home testing was done using a basic 40 meter dipole only about 10 feet high. This likely closely duplicates portable operating conditions. WB1GCM loaned me a small antenna tuner, which I needed to use with my 40 meter dipole to get full output across the band.

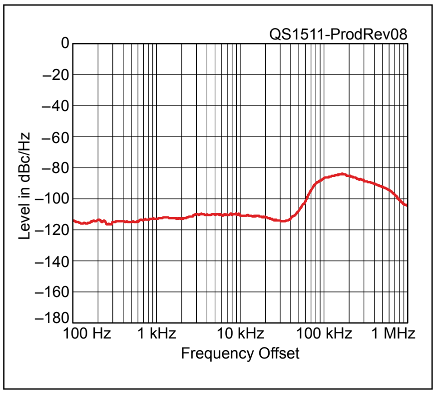


Figure 8 — Spectral display of the LNR Precision LD-5 transmitter output during phase noise testing. Power output is 5 W on the 14 MHz band. The carrier, off the left edge of the plot, is not shown. This plot shows composite transmitted noise 100 Hz to 1 MHz from the carrier. The reference level is 0 dBc, and the vertical scale is in dBc/Hz.

At lunch one day, WB1GCM and I enjoyed making stateside and DX contacts on 20 meter SSB using the Lab's SteppIR Yagi. We received good audio reports using the stock microphone.

The PRF/ATT (preamp/attenuator) button was useful for pulling in the weak ones or taming the overload from nearby W1AW transmissions. CW operation is semi break-in with adjustable delay.

All in all, I found it to be a very good performing radio — fun to operate, and worthy of consideration when considering equipment for low-power operation. I liked the physical design, especially the smooth tuning dial, and the radio appears to be durable.

I have long enjoyed QRP operation. It requires more patience, timing, and persistence but the resulting QSOs can be very satisfying. The enthusiasm of the QRP group is contagious, and new records for distance worked with low power levels are constantly being achieved. You too can work 500 or even 1000 miles using 1 W. Think outside of the box and give QRP a try, but be forewarned it can be addictive!

Manufacturer: LNR Precision, Randleman, NC 27317; tel 336-672-1818; **www.lnrprecision.com**.

Elecraft KSYN3A Synthesizer Upgrade for the K3 HF/VHF Transceiver

Reviewed by Joel R. Hallas, W1ZR
QST *Contributing Editor*
w1zr@arrl.org

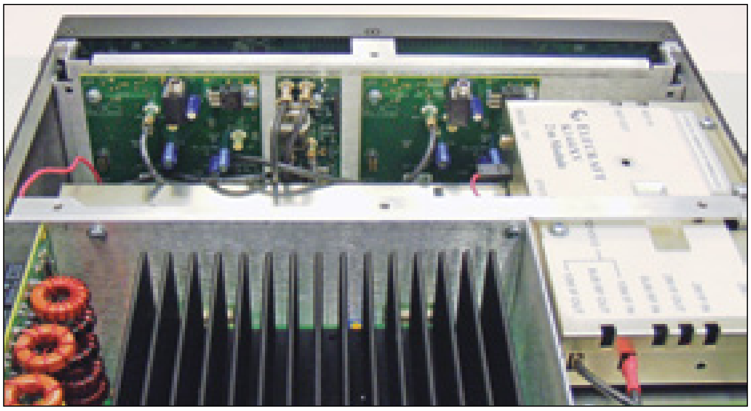


Figure 9 — Inside view from the rear of the author's dual-receiver 100 W K3 with new synthesizer boards installed.

One of the major benefits of an Elecraft K3 transceiver is that its modular architecture allows it to be expanded or upgraded as interests, technology, or finances change. We have reviewed two versions of the K3 in the past, a "bare bones" 10 W transceiver built from a kit, and a fairly well equipped 100 W version with a second receiver.[2, 3] Since those reviews, we have reviewed a number of additional options and now we will review a major hardware upgrade, the KSYN3A frequency synthesizer board (part number KSYN3AUPG).

When the K3 was introduced, it had one of the highest performance receivers and cleanest keying transmitters available at the time. While it is still as good now as it was then, since that time a number of transceivers have been made available with receivers that were better in the areas of close-in dynamic range — one of the key predictors of satisfactory operation in the presence of strong signals on adjacent channels.

According to Elecraft co-principal Wayne Burdick, N6KR, the new synthesizer came about because the design team found a way to dramatically reduce phase noise at close spacings. This can provide both improved receive and transmit performance. On the receive side, it prevents measurements from being noise limited, and also helps with reciprocal mixing dynamic range, often the limiting parameter. On transmit it makes the K3 signal even cleaner, particularly to those attempting to listen close to the K3 transmit frequency.

The new synthesizer has its own microcontroller to offload the main microcontroller during transmit-receive switching, resulting in less jitter in transmit-receive timing, making high-speed CW cleaner. This also provided an opportunity to add coverage of the upcoming 630 meter (472 – 479 kHz) band since the original synthesizer couldn't tune down that far. The new synthesizer tunes all the way down to 100 kHz and the transmitter can put out 1 mW on 630 meters as well.

In order to receive effectively on the lower frequencies, the K3 needs to have the general-coverage receive filter option (KBPF3) and the transverter interface option (KXV3) to allow connecting the antenna to the receive antenna (RX ANT IN) port or the transverter input (XVTR IN) port of the KXV3. The K3's regular antenna ports (ANT 1 or ANT 2) include a high-pass filter designed to eliminate strong broadcast signals that overload some receiver circuitry, but also attenuates desired signals in the new bands.

Any model of K3 transceiver shipped after January 23, 2015, (serial number 8801 or higher) comes equipped with the new synthesizers. If you have a second receiver installed in your K3, you will need a second KSYN3A for it.

Bottom Line

The Elecraft KSYN3A synthesizer upgrade for the K3 makes a dramatic improvement in local oscillator phase noise, resulting in improved receiver dynamic range and reduced transmit spurious output near the operating frequency.

Installing the Upgrade

The installation of the new board(s) is quite straightforward, and easier than many K3 modifications, since access is provided by just removing the K3's top cover. If a K144XV internal 2 meter transverter is installed, the stiffener bar will need to be removed and the transverter module shifted out of the way. Those with a single receiver have it particularly easy, because changing of a single board is all that is required. Not having the second receiver also provides additional visibility and connector access, but it isn't necessary to remove the second receiver if you have one.

The detailed instructions provide a number of cautions, especially that an electrostatic discharge (ESD) mat and wrist strap be used while handling the boards and that special care be taken to avoid losing two lockwashers into the radio's innards.

With a single receiver unit and no K144XV, the two synthesizer mounting screws are removed, the board unplugged, and the new one plugged in its place and new screws installed. One TMP terminated coax cable is shifted from the old to new board, and you're done. Having a K144XV with the optional reference phase lock adds one more cable.

In my K3, I have two receivers and the K144XV, so I had to do it all twice, as well as deal with an additional coax. The second receiver makes it a bit harder to get the second coax connector inserted, but it is, in my opinion, easier than removing the second receiver.

The whole operation took less than an hour and worked fine from the start. Figure 9 is an inside view of my K3 following the

[2]B. Prior, N7RR, "First Look: Elecraft K3 HF/6 Meter Transceiver," Product Review, *QST*, Apr 2008, pp 41 – 45.
[3]J. Hallas, W1ZR, "Elecraft K3/100 HF and 6 Meter Transceiver," Product Review, *QST*, Jan 2009, pp 43 – 49.

Table 5
Elecraft KSYN3A Synthesizer Upgrade for K3 — Receiver Tests

Test unit: Elecraft K3, s/n 431 with 400 Hz roofing filter and 400 Hz DSP bandwidth
Tests performed at 14.020 MHz before and after upgrade.

Minimum Discernible Signal (MDS)	
Before	*After*
Preamp off/on	*Preamp off/on*
–133/–139 dBm	–133/–139 dBm
MDS at 475 kHz (preamp off/on): –129/–122 dBm	
MDS at 137 kHz (preamp off): –44 dBm	
Blocking Gain Compression Dynamic Range	
Before	*After*
20 kHz offset	*20 kHz offset*
Preamp off/on	*Preamp off/on*
143/137 dB	143/138 dB
5/2 kHz offset	*5/2 kHz offset*
Preamp off	*Preamp off*
143/135 dB	143/143 dB
Reciprocal Mixing Dynamic Range	
Before	*After*
20/5/2 kHz offset	*20/5/2 kHz offset*
115/103/93 dB	119/118/115 dB
Two-Tone, Third-Order IMD Dynamic Range	
Before	*After*
20 kHz offset	*20 kHz offset*
Preamp off/on	*Preamp off/on*
106/102 dB	106/101 dB
5/2 kHz offset	*5/2 kHz offset*
Preamp off	*Preamp off*
106/103 dB	106/103 dB

change to the new boards, shown at the top of the photo, just inside the rear of the front panel.

Before and After Testing

My circa 2008 K3 was checked at Elecraft to get it up to snuff before we did a comparison of before-and-after measurements to make sure it was representative of current equipment. We tested the relevant performance parameters before and after the synthesizer replacement, with results shown in Table 5.

As expected, the performance parameters that tend to be limited by oscillator phase noise had the most dramatic changes. For receiver performance that is the reciprocal mixing dynamic range (RMDR), often the limiting factor in close in performance. The 2 kHz RMDR improved by 22 dB, to 115 dB at 2 kHz spacing — very impressive. In addition, all other 2 kHz spacing measures remained essentially the same or improved, with the blocking dynamic range increasing by 8 dB. It is important to note that these two parameters are those that can result from a single interfering signal, while the third-order dynamic range is only an issue with multiple interfering signals.

On the transmit side, the big news was the close in phase noise, often a major problem with multiple operators in the same band segment in close proximity, as happens in some contests and between neighbors with big stations. The transmitted phase noise on 20 meters at a spacing of 500 Hz was reduced by about 25 dB, while at 1 kHz it was down 12 dB. Figures 10 and 11 show the ARRL Lab transmitted phase noise data on 20 and 6 meters before and after the modification.

Expanded Frequency Coverage

Another big plus is the expansion of frequency coverage. The earlier synthesizers covered down to 500 kHz, which allowed coverage of the AM broadcast band (if the optional general coverage filter were added), as well as just down to the former marine CW calling and distress channel at 500 kHz. The new synthesizers cover down to 100 kHz.

With just the new synthesizers, general coverage module, and putting the antenna into one of the ports of the transverter module, the K3 will receive on the proposed 630 meter band with sensitivity comparable to that on other bands without the preamp, which is designed for higher frequencies. When 630 meter FCC operating authorization is received, Elecraft has announced plans to release a firmware revision that will permit transceive operation via the transverter ports at the 1 mW level. This means that an external amplifier and transmit receive antenna switching will be needed, but the K3 will then transmit and receive on 630 meters.

Because the original K3 design was not optimized for low frequency (LF) operation, it will take some modifications to the RF board and general coverage module for the transceiver to operate as well at the proposed 2200 meter band (135.7 – 137.8 kHz). Elecraft notes that current production K3s will leave the factory ready to go and that simple modification kits (part number KBPF3MDFT) are available for

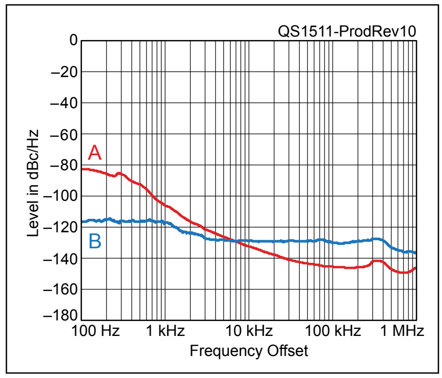


Figure 10 — Spectral display of the Elecraft K3 transmitter output during phase noise testing. Power output is 100 W on the 14 MHz band with the original synthesizer (line A) and after the synthesizer upgrade (line B). The carrier, off the left edge of the plot, is not shown. This plot shows composite transmitted noise 100 Hz to 1 MHz from the carrier. The reference level is 0 dBc, and the vertical scale is in dBc/Hz.

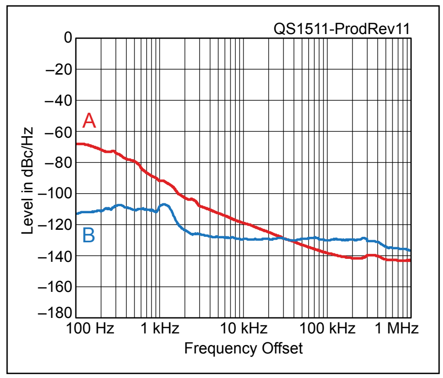


Figure 11 — Transmitted phase noise measurements for the K3 on the 50 MHz band with the original synthesizer (line A) and after the synthesizer upgrade (line B).

earlier transceivers. We did not install this modification, so the sensitivity at 137 kHz was quite low.

Documentation

Each KSYN3A synthesizer board comes with complete illustrated step-by-step installation instructions in a 19-page package. In addition, a single paragraph addendum is provided for the *K3 Operating Manual* that explains receiver operation below 500 kHz. I found the instructions complete and easy to follow. They are as lengthy as they are principally because Elecraft provides details for each K3 configuration that has different installation or cabling requirements. You can review the document on Elecraft's website.

Manufacturer: Elecraft, PO Box 69, Aptos, CA 95001; tel 831-662-8345; **www.elecraft.com**. Price: $220.

M² 6M-1K2 High-Power 6 Meter Amplifier

Reviewed by Jeff Klein, K1TEO
wa2teo@aol.com

About 5 years ago, M² Antenna Systems introduced a high-power solid state amplifier for 6 meters (model 6M-1000) capable of a full kilowatt of output. It was lightweight and small, making it usable both at home and for portable operations. Later they came out with a higher power 2 meter solid state amplifier called the 2M-1K2. I had a chance to review that amplifier and came away with a favorable opinion.[4] Now there is a 6 meter version that is similar to the 2 meter version in look and capabilities — the 6M-1K2. It is capable of delivering up to 1250 W of output, uses a 50 V dc supply that can be purchased integrated with the amplifier or added on separately, and — like its predecessor — is relatively lightweight and small.

Overview

The M² 6M-1K2 is a compact amplifier, measuring just 6 × 7.125 × 13.4 inches (height, width, depth) when set up without the optional internal power supply. When configured this way, it weighs 13 pounds. When the optional 2400 W switching power supply is integrated, the package grows to 9 inches tall and weighs 20.5 pounds. This makes it easy to use for DXpeditions or portable operation. We opted for the amplifier/power supply package for this review. In my station, it takes up about the same room as a desktop transceiver.

The amplifier uses a single Freescale LDMOSFET, an MRFE6VP61K25H, to generate power. The device can be driven to full output with about 5 W. Because most of us have transceivers that run significantly more power, M² has set the amplifier to be driven with 50 – 100 W of input by using a built-in attenuator to achieve the correct drive level.

To run the optional internal power supply, a 240 V connection with a 15 A maximum is required. If you want to use a different supply, it will need to provide 48 – 50 V dc at about 40 A.

[4]J. Klein, K1TEO, "M² 2M-1K2 High Power 2 Meter Amplifier," Product Review, *QST*, May 2013, pp 52 – 54.

Front Panel

The front of the amplifier has three switches and five lights that allow the operator to monitor and manage the status. The POWER switch controls the integrated power supply and turns on the 50 V dc. The amplifier can also be placed in or out of line using the READY switch.

The final switch on the front panel is to place the mode in or out of "JT mode." JT is shorthand for *WSJT*, the software commonly used for weak signal digital communications. In JT mode, the amplifier runs closer to Class C, operating cooler and more efficiently for high duty cycle modes such as *WSJT* and FM that don't require linear amplification. In JT mode, the rated output drops slightly as the drain current drops from the about 36 A to about 30 A.

Bottom Line

The M² 6M-1K2 is a quiet and easy way to run high power on 6 meters. It puts out near legal limit power and is compatible with most modern transceivers.

The amplifier is protected from both high SWR and overheating. If the SWR is greater than 2.5:1 at the output, the amplifier will shut down and the VSWR/TEMP LED on the front panel will illuminate. If this condition occurs, you can recycle the amplifier quickly by toggling the READY switch to reset the amplifier.

If the amplifier overheats, the same VSWR/TEMP LED will come on to indicate the fault. The instructions say that this condition is "very rare" and if it does occur you should let the amplifier cool for 30 minutes before trying to operate. My operating included several high-intensity periods where the amplifier was used at maximum power with continuous SSB or CW transmissions for up to 2 hours. I was curious to see how hot the amplifier got. The amplifier has two fans on the lower front panel to cool the internal power supply and two on top above the heat sink on the RF section. Though a little noisy (more on this later), they worked effectively to keep the amplifier cool. Even after lengthy usage the heat sink, accessible from the back of the unit, was no more than warm. My experience seems to confirm that under normal operating an overheating situation should be unusual.

Rear Panel Connections

The rear of the unit has two chassis-mounted N female connectors for the RF input and the RF output. As I noted in my earlier review of the M² 2 meter amplifier, neither connector is marked, though they are clearly shown in the instructions.

Keying the 6M-1K2 requires a path to ground through a phono jack on the rear of the unit. Keying the amplifier throws the built-in input and output relays. This is done with a built in 15 – 20 millisecond delay (per the instructions; ARRL Lab testing showed the delay to be 12 ms) to be sure the relays are closed before bias voltage is applied to the gates of the LDMOS device. This is a nice feature to help protect external preamps. In my case, I used my receive preamplifier without a sequencer and this delay did work to protect my preamplifier. I've damaged it in the past when I've used it without a sequencer with other amplifiers.

The other major connection on the back panel is for an external ac power cord when the amplifier includes the built-in power supply. Otherwise there are #10 AWG power leads to hook up an external 50 V supply.

There is also a terminal strip with a number of connections. Two of the screw terminals, connected at the factory, supply 28 V dc to the top cover fan. There is also a connection point for an external relay key return if the operator is keying external components. Another connection point supplies +13.6 V dc at 500 mA, convenient for hooking up external relays and preamps. In my case I didn't have a need to use any of these connections but they are nice features to have available.

A fuse is also accessible from the rear panel. It protects the internal regulator and components.

Documentation

The M² 6M-1K2 includes a 19-page printed manual that covers installation, a review of the features, and troubleshooting. It also includes a helpful overview of the theory of operation as well as block diagrams of the amplifier's components and one showing a typical installation. To assist with trouble-shooting there is a full schematic of the RF section and another of the control board. For those not familiar with *WSJT*, there is an addendum that provides information about the mode, use of the software, and references on how to obtain the software online.

The instructions are clearly written and should provide the information needed to get the amplifier on the air and help the user understand all of the available features.

Setup

Getting the 6M-1K2 on the air took just a few minutes. Since the test unit came with the built-in power supply, it was merely a matter of plugging in the ac cable that came with the amplifier to provide 240 V. As I already use an external amplifier on 6 meters, the next step was to move the coax from the transceiver to the M² amplifier and likewise move the amplifier output coax over as well. I key my current amplifier in the same way as the M² amplifier (ground to transmit) so once the RCA jack was connected I was basically good to go. That was the extent of the setup — simple and fast!

If you're not currently using a high power amplifier on 6 meters, be sure that anything connected to the output has an adequate power rating at this frequency. Coaxial jumpers, feed lines, wattmeters, antennas, and so on all need to be able to handle 1200 W or more.

Using the Amplifier

I drove the amplifier with my Kenwood TS-2000 transceiver which has a digital power indicator. I found that at about 80 – 85 W input from the transceiver I could achieve the maximum amplifier output as measured in my shack with a Bird wattmeter. I did not notice any significant difference on SSB or CW. The same was true when using *WSJT* with the amplifier in JT mode. Testing in the ARRL Lab (see Table 6 and Figure 13) showed that 90 – 100 W is needed for full output. It also shows that the amplifier output is only modestly different when running with JT mode switched on.

I have used several high-power solid state amplifiers and continue to enjoy the instant-

Table 6
M² 6M-1K2, serial number n/a

Manufacturer's Specifications	Measured in ARRL Lab
Frequency Range: 50 – 54 MHz.	As specified.
Power output: 1250 W PEP.	As specified.
Driving power required: 50 – 100 W.	90 to 100 W PEP for 1250 W PEP output. See Figure 13.
Spurious and harmonic suppression: >60 dB.	67 dB.
Third order intermodulation distortion (IMD): Not specified.	50 MHz, 3rd/5th/7th/9th: 29/42/46/51 dB below PEP.
TR switching time: Not specified.	Amplifier key to RF output: 12 ms; un-key to RF power off: 29 ms.
Primary power requirements: 180 – 264 V ac, 47– 63 Hz.	
Size (height, width, depth): 9.0 × 7.3 × 13.4 inches (including protrusions). Weight: 20.5 lbs.	
Price: $3299 with power supply; amplifier only, $2699.	

Figure 12 — The 6M-1K2 rear panel.

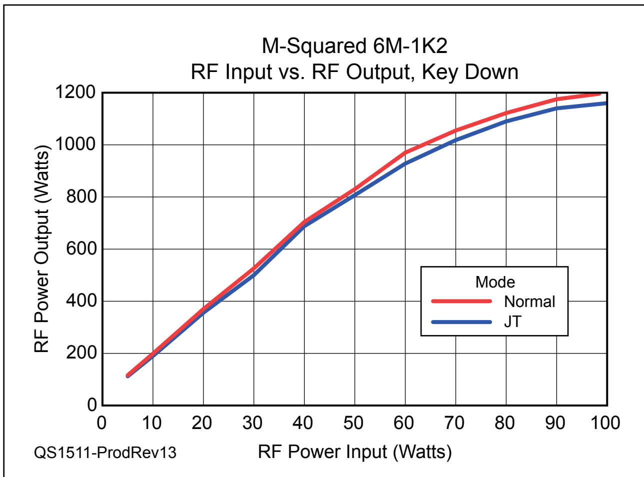


Figure 13 — Input versus output power for the 6M-1K2 in normal and JT modes.

on (no warm-up period) aspect. This amplifier is no exception — once the POWER and READY switches are thrown the amplifier is ready to use.

Once you turn the amplifier on, you will hear the lower fans come on immediately. They do so with some significant noise and then quickly drop to a lower level. However, during transmit, the fans speed up again to increase cooling, and the fans on the top of the amplifier come on as needed. In JT mode, the fan comes on as soon as the amplifier is keyed.

Operation

I had a chance to put the 6M-1K2 through its paces in several contests, including the Spring 6 Meter Sprint contest, the ARRL June VHF Contest, and the CQWW VHF Contest in July. I kept the amplifier at or near full power output in each event, and it performed flawlessly. Over-the-air reports were just what users would want — inline or out, my signal quality was the same. With its significant cooling capabilities, the amplifier was never more than slightly warm, even after extended periods of *WSJT* and CW operating.

If there was one minor concern, it was the amount of fan noise the amplifier generated. When transmitting, the fans tended to race and, though not loud, it was a bit distracting when I operated without headphones. I situated the amplifier on top of my existing 6 meter tube amplifier, close to my operating position and at about head height. That was convenient to allow me to easily use the existing input and output cables as well as the PTT line. That had some impact on the noise generated. If I was using this amplifier on an ongoing basis I would probably locate it farther away because there are no meters to monitor. As long as I have a power output meter in line and viewable, I can confirm the amplifier is working. Of course, it probably shouldn't be too far away if you want to switch to *WSJT* mode conveniently when desired. The amplifier switches to JT mode automatically after 5 seconds of continuous duty operation.

Final Thoughts

Overall, I would give the M² 6M-1K2 high marks for its performance. It delivered the power level as expected. Very importantly, it had a clean signal, something critical when operating with nearby stations at this power level. It was about as easy a setup as you would hope to have with a high-power amplifier. On top of that, it would have been very easy to take this setup portable. As with the 2 meter version, I came away with a highly favorable impression of this amplifier and think it would make a valuable addition for any serious 6 meter operator.

Manufacturer: M² Antenna Systems, 4402 N Selland Ave, Fresno, CA 93722; tel 559-432-8873; **www.m2inc.com**.

SARK-110 Vector Impedance Antenna Analyzer

Reviewed by Phil Salas, AD5X
ad5x@arrl.net

The number and sophistication of antenna analyzers continue to increase at a rapid rate — so much so, that new antenna analyzers are popping into the market almost monthly! One of the newer entries is the SARK-110, a lab-grade vector impedance analyzer covering 100 kHz to 230 MHz in a package about the size of a smartphone! Designed by Melchor Varela, EA4FRB, the SARK-110

Bottom Line

The SARK-110 is a highly accurate antenna analyzer that will satisfy most antenna and home lab requirements.

is manufactured through the SEEED Studio (**www.seeedstudio.com**) and distributed in the US by SteppIR Antennas.

Basic Description

The SARK-110 arrived in a small box with an MCX-to-BNC adapter and an MCX-to-clip lead adapter. (An MCX-to-SMA adapter cable is included with units currently shipping, and the BNC and clip lead adapters are available as accessories.) The manual is only available online at EA4FRB's website, **www.sark110.com**.

A mini-USB port on the right side of the case allows connection to a personal computer for communication and battery charging (a USB A/mini B cable is included). An internal smart charger fully charges the 3.7 V, 1000 mAh Li-Po (lithium polymer) battery in about 3.5 hours.

The SARK-110's direct digital synthesizer covers the 0.1 – 230 MHz range with a frequency resolution of 1 Hz. As a true vector impedance instrument, it accurately resolves the resistive, capacitive, and inductive components of a load. Standard measurements include impedance, VSWR, reflection coefficient, and return loss. In addition to single-frequency measurements, linear, bi-linear, logarithmic, or bi-logarithmic frequency sweeps can be selected. Here are some of the key features:

- A transmission line addition/subtraction feature can be used to eliminate the effect of an interconnecting coaxial cable when making antenna measurements.
- For improved accuracy, the measurement reference plane can be precisely extended via Open/Short/Load calibration standards (not included — see the sidebar, "Calibration Loads for the SARK-110").
- A time domain reflectometer (TDR) mode can accurately determine a fault location in coax cables, as well as determining cable length.
- The single frequency measurement mode displays the impedance parameters as well as diagrams of RLC (resistor, inductor, capacitor) equivalent circuits.
- The graphical impedance mode displays impedance characteristics over a user-selected sweep range. This includes a graphical plot of two user-selectable parameters in a scalar chart, or the complex reflection coefficient in Smith Chart form for the more sophisticated user.
- The multiband mode permits the simultaneous display of four bands, which is ideal for tuning multiband resonant antennas.
- The SARK-110 can also operate as a signal generator for receiver testing. It outputs a sinusoidal RF signal with eight user-selectable amplitude levels between –73 dBm and –10 dBm. The –73 dBm setting is particularly useful, as it corresponds to the standard S-9 signal level.

Finally, while normally used standalone, the SARK-110 may be connected to a personal computer to provide additional data recording and analysis capabilities. An internal flash disk provides for the storage and recall of measured parameters, screenshots, analyzer configuration, and firmware updates. Screenshots are saved in BMP format with a single button push, making them easy to copy into documents.

Performance

Table 7 gives an overview of the SARK-110's capabilities. Note that there are few actual specifications published in the manual.

Table 8 displays the open-circuit output impedance of the SARK-110. This gives an indication of the impedance magnitude you can measure accurately as a function of frequency.

The frequency accuracy was excellent and drift was undetectable. Should the frequency not be exact, you can zero-beat the unit with WWV and adjust the SARK-110 frequency. The output power level is reasonably constant over the full frequency

Table 7
SARK-110, serial number n/a

Manufacturer's Specifications	Measured Performance
Frequency range: 0.1 – 230 MHz, continuous.	As specified.
SWR measurement range: Not specified.	100:1 maximum.
Impedance range: Not specified.	See text and Table 8.
Output power: –73 dBm to –10 dBm	User selectable. See Table 9.
Impedance and SWR accuracy: Not specified.	See Tables 10 and 11.
Drift: Not specified.	See text.
Harmonic and spurious suppression: Not specified.	3.5 MHz: 2nd –57 dB, 3rd >–60 dB 14 MHz: 2nd –57 dB, 3rd >–60 dB 28 MHz: 2nd –57 dB, 3rd >–60 dB 50 MHz: 2nd >–60 dB, 3rd >–60 dB 146 MHz: 2nd >–60 dB, 3rd >–60 dB* 222 MHz: 2nd >–60 dB, 3rd >–60 dB**
Power requirements: Internal 3.7 V 1000 mAh LiPo battery.	
Size (height, width, depth): 3.9 × 2.4 × 0.6 inches. Weight: 5 oz.	
Price: $389.	

*Spurious tone: 30 MHz above desired signal at –50 dBc.
**Spurious tone: 40 MHz above desired signal at –23 dBc.

Table 8
Open Circuit Output Impedance

Frequency (MHz)	Output Impedance (Ω)
1.8	33,000
3.5	22,300
7	14,300
14	8,300
28	4,500
50	975
146	971
220	633

Table 9
Output Power (dBm) vs frequency

Power measured with a NIST-traceable MiniCircuits PWR-6GHS+ power sensor.

Set Power (dBm)	------------------ Measured Power at Frequency (MHz) 1.8	3.5	7	14	28	50	144	222
–10	–9.24	–9.24	–9.26	–9.32	–9.41	–9.61	–10.66	–13.69
–23	–23.53	–23.53	–23.53	–23.60	–23.69	–23.88	–24.77	–27.45

range, making the SARK-110 accurate enough for receiver sensitivity testing when used with a good step attenuator. Table 9 tabulates the output power level versus frequency when set to –10 dBm and –23 dBm, measured with a MiniCircuits PWR-6GHS+ power sensor.[5]

Next I measured SWR and impedance accuracy. For this I used 4.8 dB and 3 dB microwave attenuators with open-circuit and short-circuit outputs so as to provide both low impedance and high impedance 2:1 and 3:1 SWR loads. The attenuators were measured with an Array Solutions VNAuhf vector network analyzer.[6] And because it is not uncommon for SWR measurements to become less accurate at very low and very high impedances, I also constructed 7.5 Ω (theoretically 6.67:1 SWR), and 400 Ω (theoretically 8:1 SWR) loads utilizing Caddock 15 W thick-film resistors (seen at the top of Figure 14A). The SARK-110 SWR measurements are tabulated in Table 10, compared to measurements made on an Array Solutions AIMuhf antenna analyzer.[7]

Finally, I constructed three complex loads that targeted 50 – *j*36 Ω for 50, 146, and 222 MHz. I chose 50 – *j*36 Ω as this theoretically also results in a 2:1 SWR. These complex loads consist of leaded capacitors and Caddock thick-film resistors. Figure 14A shows the three complex loads along the bottom, and the component side can be seen in Figure 14B. While not perfect, they are reasonably close to predicted performance in these frequency ranges, and are certainly adequate for measurement comparisons between the SARK-110 and the AIMuhf as shown in Table 11.

Calibration Loads for the SARK-110

The SARK-110 can be calibrated precisely to compensate for any stray reactance associated with external test fixtures, and to precisely calibrate out extension cables that go to your antenna or other load. And, in fact, the SARK-110 manual suggests that you recalibrate the instrument every once in a while. In order to calibrate the SARK-110 or a section of cable, you must use calibration loads consisting of an open, short, and a good 50 Ω resistive load. These loads are connected sequentially to the SARK-110 directly, or to the end of the test cable. The problem is that test loads are not provided with the SARK-100, and these types of calibration loads can be expensive. However, you can build your own calibration loads that will work quite well over the SARK-110's 230 MHz frequency range.

As our SARK-110 pendant cable terminated in a BNC female connector, I constructed calibration loads utilizing SMA-female-to-BNC-male adapters, an SMA short and an SMA 50 Ω load. For the open, an unterminated SMA-to-BNC adapter is used. (The MCX-to-SMA adapter cable shipping with current units will simplify this somewhat.) The calibration loads can be built for less than $20. While I elected to make three separate calibration loads, you can make the set even cheaper by purchasing a single SMA-to-BNC adapter and just screw on the SMA short and load, and leaving the adapter open during the calibration process. I used the following parts:

(3) SMA-F/BNC-M adapter, part no. 99-742 from **www.techcables.com**
(1) Amphenol SMA shorting cap, part no. 523-132331 from **www.mouser.com**
(1) Amphenol SMA 50 Ω termination, part no. 523-132360 from **www.mouser.com**

The most critical calibration item is the precision broadband 50 Ω termination. I measured the Amphenol SMA termination on an HP/Agilent 8722D vector network analyzer. The return loss exceeded 40 dB below 650 MHz when attached to the SMA-to-BNC adapter.

Of course, there is reference plane offset due to the adapters, which can contribute to some error. However, this error is very small at 230 MHz and below. Looking at the SMA-to-BNC adapters, it appears that the actual physical offset from the BNC connector to the SMA connector is 0.2 inches or less. The reference plane potential error at 230 MHz can be determined as follows:

Wavelength = 300/f(MHz) = 300/230 = 1.3 meters = 51.18 inches.

So the reference shift due to the adapter = 0.2/51.18 × 360 = 1.4 degrees at 230 MHz.

Figure A shows the final calibration loads.

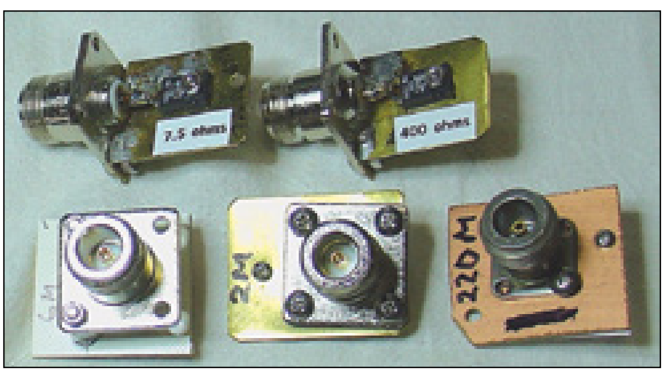
Figure A — Reviewer's open/short/50 Ω calibration loads

Using the SARK-110

I found the color display user interface to be very intuitive. Frankly, other than looking up the functions of the six top buttons (RUN/

[5]P. Salas, AD5X, "MiniCircuits PWR-6GHS+ USB Power Sensor," Product Review, *QST*, Feb 2011, pp 56 – 59.
[6]P. Salas, AD5X, "Array Solutions VNAuhf Vector Network Analyzer," Product Review, *QST*, Jul 2013, pp 49 – 50.
[7]H. W. Silver, NØAX, "Array Solutions AIMuhf Vector Impedance Analyzer," Product Review, *QST*, Nov 2012, pp 57 – 60.

(A)



(B)

Figure 14 — At A, the 7.5 Ω, 400 Ω and complex loads for 50, 146, and 222 MHz. At B, the component side of the three complex loads

Table 10
Resistive Load Measurements

Loads measured with the SARK-110 compared to the AIMuhf.
LoZ = low impedance resistive load. HiZ = high impedance resistive load.

Frequency (MHz)	2:1 SWR LoZ SARK/AIM	2:1 SWR HiZ SARK/AIM	3:1 SWR LoZ SARK/AIM	3:1 SWR HiZ SARK/AIM	7.5 Ω Load SARK/AIM	400 Ω Load SARK/AIM
1.8	2.01/2.02	2.04/2.02	3.14/3.18	3.04/2.99	6.65/6.77	8.11/7.94
3.5	2.01/2.02	2.04/2.02	3.14/3.17	3.04/2.98	6.67/6.78	8.11/7.93
7	2.00/2.01	2.05/2.02	3.14/3.17	3.04/2.99	6.64/6.78	8.11/7.94
14	2.00/2.00	2.05/2.02	3.14/3.16	3.04/2.99	6.65/6.76	8.11/7.96
28	2.01/2.00	2.07/2.02	3.14/3.14	3.06/3.00	6.68/6.73	8.15/7.97
50	2.03/2.00	2.09/2.03	3.18/3.13	3.09/2.99	6.63/6.79	8.19/7.91
146	1.99/1.99	1.99/2.01	3.05/3.13	2.96/2.99	6.96/7.11	7.75/7.62
222	1.97/1.97	1.99/2.01	2.89/3.14	2.92/2.96	6.42/7.28	7.25/7.25

HOLD, SELECT, SAVE SCREEN, SAVE CONFIGURATION, NAVIGATOR B, NAVIGATOR A), I really had no reason to use the manual.

Prior to using the SARK-110 for the first time, set up a folder for it on your computer.

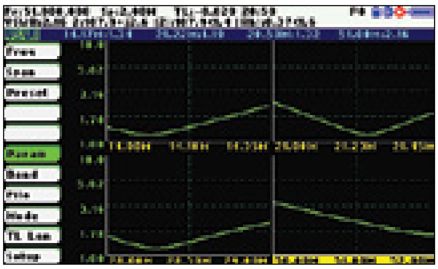


Figure 15 — Simultaneous displays of 20, 15, 10, and 6 meter bands on the reviewer's TH-1 antenna.

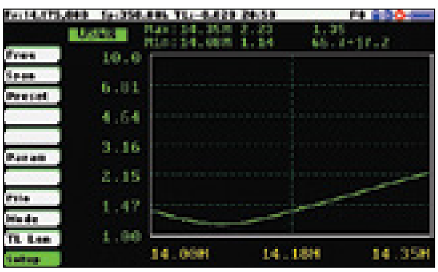


Figure 16 — 20 meter swept response.

Figure 17 — 20 meter single-frequency data.

Connect the SARK-110 to your computer with a USB A-to-Mini B cable and turn it on (the power button is on the right side). The SARK-110 will appear as a USB drive. Copy the factory calibration files ("detcalib.dat" and "oslcalib.dat") to your computer folder in case you corrupt these files at some future time.

Next, go to **www.SARK110.com**, select FILES, and download the latest firmware ZIP file to your SARK-110 folder. Unzip the "DFU" file and copy it to the SARK-110. Cycle the SARK-110 power while pressing the RUN/HOLD button and then follow the self-explanatory firmware update instructions on the SARK-110 display.

My main antenna is a HyGain TH-1 rotatable dipole consisting of a 20/15/10 meter trap dipole with a 6 meter fan dipole element. As the SARK-110 can plot four simultaneous curves, I started with this. I used a single sweep and saved the sweep using the SAVE SCREEN button. As you can see in Figure 15, my 6 meter section needs to be lengthened!

Figures 16 and 17 show the single-band and single frequency modes displaying 20 meter operation of my TH-1 antenna. A lot of data is available!

Final Comments

The MCX connector is required due to the physical thickness of the SARK-110 (it's very thin). This is an excellent connector and it mates with a nice snap. However, the MCX connector is really only specified for about 500 connects/disconnects. So you may want to leave the MCX/BNC adapter cable connected most of the time to ensure a long life. While the SARK-110 is almost all screen, those of us with aging eyes may need a good pair of reading glasses to read all the information displayed.

The SARK-110 is a reasonably priced lab-grade antenna and component analyzer that can be an indispensable tool for most hams. As software and firmware updates are available at no charge, product obsolescence is really not an issue. I've only touched on the basic capabilities of this unit, so please investigate it further online.

US distributor: SteppIR Antennas Inc, 2112 – 116th Ave NE, Suite 1-5, Bellevue, WA 98004; tel 425-453-1910; **www.**

Table 11
Complex Load Measurements

Loads measured with the SARK-110 compared to the AIMuhf.

Frequency (MHz)	------ SARK-110 ------ SWR	Impedance (Ω)	--------- AIMuhf --------- SWR	Impedance (Ω)
50	2.01	48 – *j*35	1.94	47 – *j*33
146	1.81	44 – *j*28	1.80	45 – *j*28
222	1.80	39 – *j*24	1.76	42 – *j*25

Loads Measured:
89 pF in series with 50 Ω for 50 MHz
30 pF in series with 50 Ω for 146 MHz
20 pF in series with 50 Ω for 222 MHz

SCS Tracker/DSP TNC for HF APRS

Reviewed by Jerry Clement, VE6AB
stormchaser@shaw.ca

Like many other Amateur Radio operators, I use an APRS (Amateur Packet Reporting System) device in my mobile to access the VHF APRS network. There have been times when I wished for an APRS system that would keep me connected when I was out of range of the VHF APRS network, and with an HF transceiver already mounted in my mobile, I thought that possibly HF APRS could be the answer.

Until recently, APRS operation on HF has been done by ordinary HF packet (FSK 300 baud). With its small bandwidth, multipath propagation, phase shift, band noise, and other disturbances such as fading and constant fluctuating conditions, transmitting digital signals via HF can be problematic at best. As you already know, on HF it's a rare day that you have the equivalent of a noise-free, fully quieted frequency of the type you get on VHF.

While researching the various HF APRS options available to me, I discovered a system called Robust Packet Radio (RPR). RPR is a much more robust form of HF APRS, making it more likely for my packets to be delivered and heard by the various HF Gateways located worldwide and operating at the top end of the 30 meter band.

This system is available only through a hardware TNC built by Special Communications Systems (SCS) from Germany. SCS developed PACTOR, which is used by amateur and marine radio operators for FSK transfer of digital information over the HF bands. The SCS Tracker DSP/TNC reviewed can operate on all of the common conventional packet modes, plus Robust Packet Radio.

RPR has been designed to take advantage of the capabilities of digital signal processing (DSP) in order to obtain reliable communication over a less-than-perfect HF path. If you have only experienced traditional 300 baud FSK packet, RPR adds a whole new dimension.

A Nice Package

Once I had sourced and ordered an SCS Tracker DSP/TNC, and while I waited for the Tracker to arrive, I downloaded the manual from the SCS website, allowing me to familiarize myself with the workings of this device. I also downloaded the configuration software and drivers required so that I would be ready to go upon receiving the hardware.

Upon receiving the SCS Tracker/DSP TNC and getting my first look, I found it to be a nicely finished device with its all-metal housing and well laid out front and back panels. I was pleased with the screw terminals on the back panel (Figure 18), making it a simple procedure to connect the wiring without the use of any proprietary cable connectors. Another nice feature is the wiring diagram silkscreened on the bottom panel, allowing for the wiring hookups to be done without having to refer to the manual. The Tracker is a USB device, and included is the required USB cable that connects the Tracker to your computer for initial configuration before placing the Tracker into service.

The SCS Tracker/DSP TNC package includes a six-pin mini-DIN data cable that requires the installation of a matching connector on the pigtail end for connection to the data port of your HF transceiver. Included in the instructions with the Tracker are wiring diagrams for the majority of HF transceivers available in the marketplace. If you don't feel comfortable completing the wiring of the data cable, SCS offers optional completely finished cables.

With the Tracker connected to the data port of the Kenwood TS-480HX mounted in my mobile, I found that the default settings for the input and output levels of the radio's data port needed no further adjustments. Packets sent by the Tracker were decoded correctly by other robust packet stations listening on the HF APRS network.

The Tracker also needs to be connected to a bidirectional GPS receiver. I'm using a Garmin Montana in my mobile station.

With the SCS Tracker/DSP TNC installed and connected to the GPS receiver and TS-480HX, the Tracker is listening for packets being sent from other RPR stations on the network. Once the Tracker has

Bottom Line

The SCS Tracker/DSP TNC and Robust Packet Radio overcome some of the propagation challenges encountered when using packet radio on HF and greatly improve the performance of HF APRS operation.

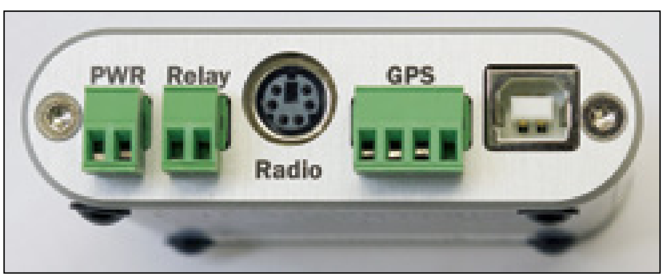


Figure 18 — The rear panel connections use screw terminals for power, relay, and GPS connections. The RADIO jack connects to the data port on an HF transceiver.

Robust Packet Radio — RPR

This overview of how robust packet works was adapted from an application note developed by Wavecom Elektronik AG.*

Ordinary amateur packet radio is not well adapted to the characteristics of the HF range. Robust Packet Radio, a data transmission mode designed by Special Communications Systems, is optimized to accommodate the characteristics of this frequency range, for example fading and multipath propagation (intersymbol interference).

Eight-carrier, pulse-shaped OFDM (orthogonal frequency division multiplex) is used. The audio center frequency is 1500 Hz and the carrier center spacing is 60 Hz (see Figure B). Dependent on the user data rate (200 or 600 bps before AX.25 protocol overhead) each carrier is DBPSK or DQPSK modulated at a constant rate of 50 bauds. The modulation type is automatically adapted to the propagation conditions.

Just like ordinary packet radio, the AX.25 protocol is utilized as the Layer 2 protocol. The payload of a packet can be up to 256 bytes, but the actual length depends on the amount of data to be sent and which one of the 25 different packet types is used. One type is used for connect-disconnect, and another 12 variable length types are used for each of the two user data rates.

Individual AX.25 packets are consolidated into multiframes, which contain only one CRC field (cyclic redundancy check — an error checking method) and one call sign field. This feature enhances throughput by approximately 30%. The decoder automatically detects the user data rate and the size of the transmitted packet and displays the result.

To make the transmission as robust as possible, several modifications have been applied to the AX.25-formatted data stream before transmission: The call signs are compressed with a special algorithm, the data stream is scrambled, redundancy is added, and the stream is interleaved over the full frame length using a robust, pseudo-random algorithm.

The packets are additionally protected by CRC. To ensure synchronization, each packet is led in with a 160 ms preamble of 64 DPSK symbols distributed across all eight carriers. The decoder output is divided into data and signaling information including call signs with SSID (Secondary Station ID), package identifier (PID), and AX.25 control word. Data may be displayed as US ITA5 or HEX. The PID specifies the Layer 3 protocol used.

*www.wavecom.ch/content/pdf/advanced_protocol_robust-packet.pdf

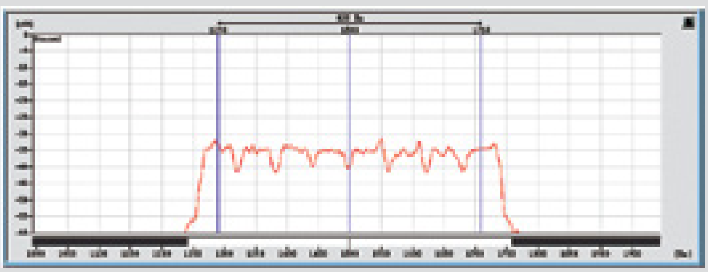


Figure B — Robust Packet Spectrum.

received and decoded any robust packet stations being received via the HF transceiver on 30 meters, the Tracker sends this data to the Garmin Montana. The Montana then saves this information in its waypoint list and places an APRS symbol (of your choosing) with included call sign on a map on its screen (Figure 19). When the next scheduled transmission by the Tracker is due to go out, it checks the 30 meter channel for any activity, and when the channel is clear, sends an APRS datagram.

On the Air

With the Tracker mounted in the radio stack of my mobile (see the cover of the September 2015 issue of *QST*), I made some comparisons to conventional packet using the Tracker operated in toggle mode, where I could use conventional 300 baud FSK packet running on one channel and robust packet running on the adjacent channel. More times than not, I found that all the packets being received on the robust packet channel were being decoded, while the conventional packet transmissions on the adjacent channel just flickered the DCD LED on the Tracker's front panel and were discarded due to errors present in the packet string.

The TS-480HX is capable of transmitting with 200 W output, so I experimented with different power levels. I found that although the packet string stood up well at all power levels, a setting of half the rated output proved to be more than adequate while operating RPR. Most transceivers run hotter when transmitting data modes than when operating in SSB, and so the cooling fans cycle on more often at the higher power level settings. With the power level set for 100 W, I rarely hear the transceiver fans come on. The SCS Tracker/DSP TNC and the Garmin Montana are proving to be a great combination as utilized with my Kenwood TS-480HX and dedicated 30 meter antenna that I designed and built for operating HF APRS, although any 30 meter antenna will work fine.

With HF APRS and the fact that you are potentially being heard across the world on the RPR 30 meter frequency of 10.147.30 MHz, it's critical that you set your path correctly, as you do not want to cause major congestion on the HF APRS network. Because I operate mobile and find myself traveling in areas of the Alberta Rockies with no services of any kind available, I set the path for APRS,WIDE1-1 increasing the potential for my mobile to be heard on the HF APRS network. With an RPR digipeater now located in Alberta, and several RPR mobiles normally located within 300 kilometers of my mobile, the chances are good that I can get help if required.

Although the Tracker can be used as strictly a tracking device, it can also be used in KISS mode with a computer running *UI-View* or *APRSIS/32* software, allowing the Tracker to be used as a bi-directional messaging device that decodes and places the beaconing RPR stations on the map. With *APRSIS/32* running on my netbook and connected to the Tracker, I found that I could keyboard message direct with other robust packet stations that were being received and decoded. This included a mobile-to-marine-mobile contact of 4500 kilometers that I made with Jeremy Allen, N1ZZZ, who was also using an SCS Tracker/DSP TNC along with a computer running *APRSIS/32* as he made his way through the Gulf of Mexico bound for Africa.

Figure 19 — The SCS Tracker/DSP TNC in the author's mobile station, with its companion Garmin Montana GPS receiver. The screen displays icons showing the locations of stations on the network.

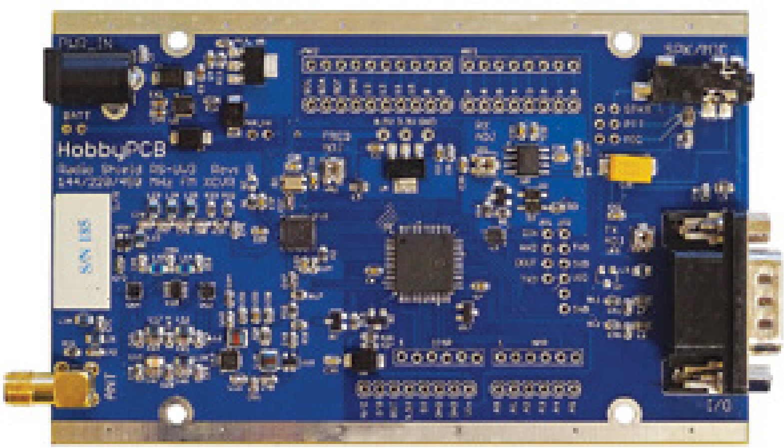
I am extremely pleased with how my mobile HF APRS RPR station keeps me connected as I go down roads less traveled in areas with no VHF APRS coverage. It is a pleasure to see the DCD LED on the front of my SCS Tracker light up upon hearing and successfully decoding beaconing stations on 30 meters, signals that are then sent to the Garmin Montana and placed on the map, keeping me informed and connected with other RPR stations on the robust packet network located across North America and other parts of the world.

Manufacturer: Special Communications Systems GmbH & Co. KG, Roentgenstr. 36, 63454 Hanau, Germany; **www.scs-ptc.com**. Distributed in North America by Farallon Electronics, 55 Belvedere St, San Rafael, CA 94901; tel 415 331 1924; **www.farallon.us** and White Squall Consulting, 608 Taylor Crescent, Ladysmith, BC V9G 1P8 Canada; tel 855-584-7369; **www.whitesquallconsulting.com**. Price: $350.

New Products

HobbyPCB RS-UV3 VHF/UHF Radio Module

The HobbyPCB RS-UV3 radio module is a 144/222/450 MHz FM transceiver board. The RS-UV3 supports multiple interfaces including microphone/speaker, line level audio (sound card), TTL serial control and Arduino shield connections. The RS-UV3 has a built-in battery charger and provides conditioned power for the Arduino controller. The RS-UV3 covers 144 – 148, 220 – 225, and 420 – 450 MHz with 200 mW RF output and receiver sensitivity of –120 dBm for 12 dB SINAD. Spurious emissions are –60 dBc or lower. Power requirements are 9.5 – 15 V dc at 100 mA on receive and 250 mA on transmit. The RS-UV3 is compatible with Arduino and Raspberry Pi boards as well as *Windows*, *Linux*, and *Mac OS*. It includes on board support for beacon, repeater, single channel voice, Echolink, APRS and packet radio applications. Price: $89.99. A speaker-mic ($15), dc power supply ($10), and triband flexible antenna ($15) are available. For more information, visit **www.hobbypcb.com**.



Ladder Snap Open Wire Feed Line Insulators from 73CNC.com

Ladder Snap spreaders from 73CNC.com and #14 AWG THHN copper wire from your local home improvement store can be used to make 600 Ω open wire feed line of any length. The Ladder Snap spreaders are made from UV stabilized Delrin. Assembly requires only pliers and a silicone spray for lubrication. Spreaders are available in white, black or tan. Price: 100 foot kit, $29.99; antenna center support insulator, $17.99. Other configurations are available. For more information, visit **www.73cnc.com**.

Feedback

In "The Long Road to Navassa" by Bob Allphin, K4UEE, published in the October 2015 issue of *QST*, the list of original founders of the KP1-5 Project omitted Glen Kesselring, KØJGH, and Garry Ritchie, W8OI. Jim Junkert, KØJUH, and Greg Golden were listed in error.