QST

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ICOM IC-9700 VHF/UHF Multi-mode Transceiver

N6BT V-8 Vertical Dipole Antenna

mAT-Tuner mat-125E Automatic Antenna Tuner

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Product Review

Icom IC-9700 VHF/UHF Multimode Transceiver

Reviewed by Pascal Villeneuve, VA2PV
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The Icom IC-9700 all-mode tribander for 2 meters, 70 centimeters, and 23 centimeters is a game changer. It is based on SDR (software-defined radio) technology, with direct RF sampling on 2 meters and 70 centimeters. On 23 centimeters, it uses downconversion IF sampling.

There are many reasons why the ham community was very excited with this new transceiver. Here's a short list:

1 It's been a while since the last release of an all-mode VHF/UHF transceiver for our market.

2 This radio uses the latest SDR technology.

3 Lately, propagation on the HF bands has not been very good, and the higher bands are suddenly of interest.

4 It supports D-STAR digital-mode operation.

5 It can be used for EME (moonbounce), satellites, and terrestrial operation.

6 Its color touchscreen, spectrum scope, and waterfall give the IC-9700 a useful and modern user interface.

I was interested in this radio to replace my old all-mode multiband (HF/VHF/UHF) transceiver. I loved that radio, but it was 20-year-old technology, and I was using it only for VHF/UHF operation. As soon as I saw the IC-9700, I knew it was time to move on.

Overview

Physically, the IC-9700 is identical to the popular Icom IC-7300 HF and 6-meter transceiver, which I also own. Both radios have the same arrangement of buttons and controls, but many functions differ, and the rear panel is completely different.

This radio uses all modes on all three supported bands: SSB (LSB and USB), CW, RTTY, AM, FM, DATA (available when in SSB), D-STAR digital voice (DV), and digital data (DD, 1.2 GHz band only). On the 2-meter band, the maximum RF output is 100 W. It's 75 W on 70 centimeters and 10 W on 23 centimeters. It supports satellite operations with 99 satellite memory channels for both uplink and downlink frequencies (see the sidebar, "Using the IC-9700 on the Amateur Satellites").

In the middle of the IC-9700 front panel there's a 4.3-inch color display with a touchscreen, just like the IC-7300, and the navigation through the features and menus is very intuitive using this screen. You can use the integrated spectrum scope with a waterfall, with the span starting at 5 kHz up to 1 MHz. You can also display two views of the waveform of the transmitted or received signals. One **AUDIO SCOPE** view is similar to what you would see on a spectrum analyzer, and the other is similar to an oscilloscope (see Figures 1 and 2).

Bottom Line

The IC-9700 multimode transceiver brings direct-sampling SDR technology to VHF and UHF operation. It incorporates many features that operators have come to expect in HF transceivers and performs well on all modes.

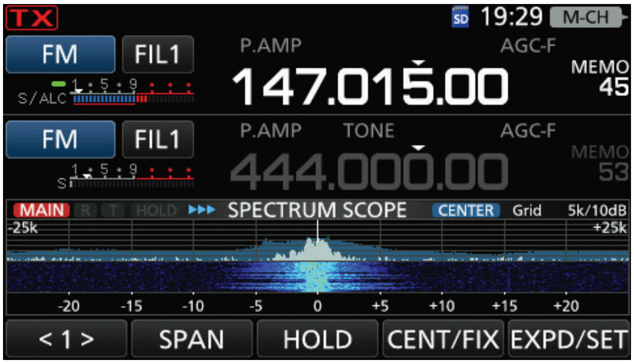


Figure 1 — The Icom IC-9700's expanded spectrum scope with waterfall.

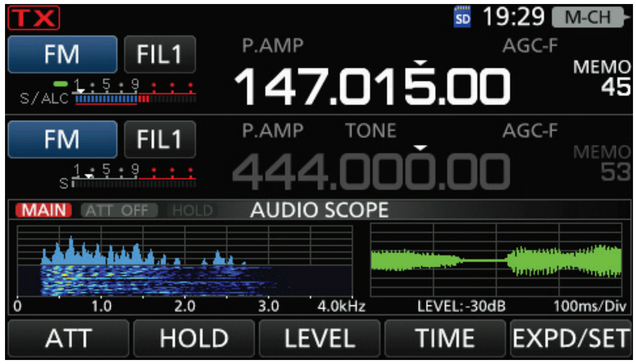


Figure 2 — The Icom IC-9700's audio scope.

The front panel offers many useful knobs and buttons for easy access when operating. There are two volume control knobs with concentric squelch/RF gain controls, one for each VFO. The large VFO knob is easy to use and is similar to a good HF transceiver. In addition to the usual buttons and knobs, there's an SD card slot to store your configurations, the D-STAR repeater list, and memory contents. It can also be used to upgrade the firmware. The radio comes equipped with a speech function for reading the frequency and the mode — very useful for those with vision issues.

The rear panel (see Figure 3) has three antenna ports. On VHF, it's an SO-239 connector, and on the two UHF bands, it's a female type-N connector. There's an ethernet LAN interface, allowing the radio to connect directly to the internet. It also has an integrated remote server, so you can use the Icom RS-BA1 remote software to operate remotely without having to leave a computer turned on in your station.

There is a USB (type-B) port that you can use to control the radio with a computer. The radio has an internal sound card, so interfacing this radio with a PC via the USB connection for digital modes — such as FT8, MSK144, or JT65 — is a piece of cake.

The SMA female connector is for a 10 MHz reference input (**REF IN**) that can be used with an external high-stability oscillator for frequency adjustment (more on this later). There is an accessory socket, a key jack, two 3.5-millimeter external speaker outputs (one for the main and one for the sub), a 13.8 V dc input socket, a CI-V jack for computer control, and another data jack.

In the box with the transceiver is a printed manual (available in English, French, and Spanish depending on the region). The included hand microphone has only two buttons on top, **UP** and **DN**, and no DTMF keypad. There's also a dc power cord, a plug for the CW key jack, and spare fuses.

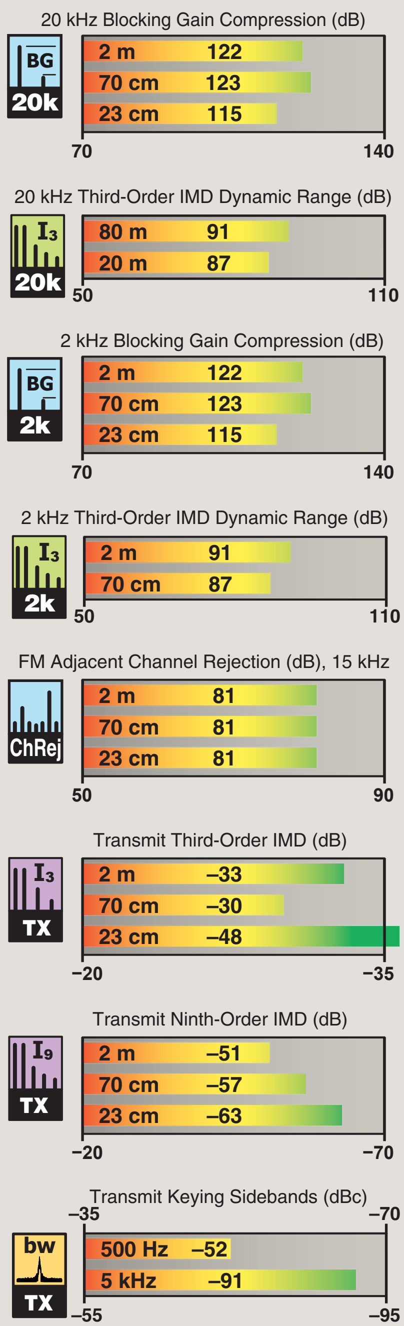
Features

The IC-9700 includes so many features that it's hard to cover everything in one review. But somehow the IC-9700 is very easy to operate, especially if you are already familiar with the Icom menus used in either the IC-7300 or the IC-7610. If we put aside the D-STAR repeater (DR) mode and the satellite operation, you could probably get by without reading the manual. But if you don't read the manual, you will miss many bells and whistles of this fine radio. You can download a PDF version of the basic manual and the advanced manual from Icom's website.

The IC-9700 has two independent receivers (main and sub bands), and it can operate full duplex. There are two VFOs on each band, and I hope my next few sentences will not be too confusing as I can't use the usual terms V/U or U/V because there are two UHF bands in this radio (70 centimeters and 23 centi-

Figure 3 — The Icom IC-9700's rear panel.

Icom IC-9700
Key Measurements Summary



KEY: QS2001-PR141
Measurements with preamp off except adjacent channel measurements with preamp on.

Table 1
Icom IC-9700, serial number 12001802, Firmware V1.11

Manufacturer's Specifications	Measured in the ARRL Lab
Frequency coverage: Receive and transmit, 144 – 148, 430 – 450, 1,240 – 1,300 MHz.	Receive and transmit, as specified.
Power requirement: Transmit, <18 A, standby, 1.2 A (typical), <1.8 A maximum audio at 13.8 V dc (±15%).	At 13.8 V dc: Transmit, 144 MHz, 16 A; 432 MHz, 13 A; 1,296 MHz, 5 A. Receive, 1.6 A (max. lights, max. volume), 1.51 A (min. lights, max. volume). Standby, 1.2 A. Power off, 15 mA.
Modes of operation: SSB, CW, AM, FM, DV, DD, RTTY, digital.	As specified.
Receiver	**Receiver Dynamic Testing**
SSB/CW sensitivity (preamp on): <0.11 µV (<–126 dBm).	Noise floor (MDS), 500 Hz bandwidth: *Preamp* *Off* *On* 144 MHz –132 –145 dBm 432 MHz –133 –145 dBm 1,296 MHz –141 –145 dBm
Noise figure: Not specified.	Preamp off/on, 144 MHz, 15/2 dB; 432 MHz, 14/2 dB; 1,296 MHz, 6/2 dB.
AM sensitivity, 10 dB (S/N): <1.0 µV, preamp on.	10 dB (S+N)/N, 1 kHz tone, 30% modulation, 6 kHz BW: *Preamp* *Off* *On* 144 MHz 1.53 0.39 µV 432 MHz 1.38 0.39 µV 1,296 MHz 0.53 0.43 µV
FM sensitivity: 12 dB SINAD: <0.18 µV.	For 12 dB SINAD, 3 kHz deviation, 15 kHz BW: *Preamp* *Off* *On* 146 MHz 0.55 0.14 µV 440 MHz 0.55 0.14 µV 1,294 MHz 0.26 0.14 µV 7 kHz BW: 146 MHz 0.40 0.10 µV 432 MHz 0.40 0.11 µV 1,294 MHz 0.19 0.11 µV
Spectral sensitivity: Not specified.	Panadapter and waterfall, preamp off/on 144 MHz, –116/–135 dBm 432 MHz, –116/–136 dBm 1,296 MHz, –125/–135 dBm
ADC overload level: Not specified.	With preamp off/on: 144 MHz, –10/–27 dBm; 432 MHz, –10/–27 dBm; 1,296 MHz, –29/–37 dBm.
Blocking gain compression dynamic range: Not specified.	Blocking gain compression dynamic range, 500 Hz BW:† *20 kHz offset Preamp off/on* / *5/2 kHz offset Preamp off* 144 MHz 122/118 122/122 dB 432 MHz 123/118 123/123 dB 1,296 MHz >115/108 115/115 dB
Reciprocal mixing dynamic range: Not specified.	Not measured. Low-noise VHF and UHF oscillators not available.

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

Band/Preamp	*Spacing*	*Measured IMD Level*	*Measured Input Level*	*IMD DR*
144 MHz/off	20 kHz	–132 dBm –97 dBm	–41 dBm –22 dBm	91 dB
144 MHz/on	20 kHz	–145 dBm –97 dBm	–49 dBm –35 dBm	96 dB
144 MHz/off	5 kHz	–132 dBm –97 dBm	–41 dBm –25 dBm	91 dB
144 MHz/off	2 kHz	–132 dBm –97 dBm	–41 dBm –25 dBm	91 dB
432 MHz/off	20 kHz	–133 dBm –97 dBm	–46 dBm –24 dBm	87 dB
432 MHz/on	20 kHz	–145 dBm –97 dBm	–53 dBm –38 dBm	92 dB
432 MHz/off	5 kHz	–133 dBm –97 dBm	–45 dBm –24 dBm	88 dB
432 MHz/off	2 kHz	–133 dBm –97 dBm	–46 dBm –26 dBm	87 dB

Manufacturer's Specifications	Measured in the ARRL Lab
Second-order intercept point: Not specified.	Preamp off/on: 144 MHz, +87/+85 dBm 432 MHz, +79/+79 dBm
Noise reduction: Not specified.	CW, for S-5 noise level, up to 13 dB.
FM adjacent channel rejection: Not specified.	Preamp on, 15/7 kHz BW, 146 MHz, 81/85 dB; 440 MHz, 81/84 dB; 1,296 MHz, 81/83 dB.
FM two-tone third-order IMD dynamic range: Not specified.	20 kHz offset, preamp on: 146 MHz, 81 dB,* 440 MHz, 81 dB,* 1,294 MHz, 81 dB.* 10 MHz offset, preamp on: 146 MHz, 97 dB; 440 MHz, 92 dB; 1,294 MHz, 81 dB.
Squelch sensitivity: Not specified.	FM, preamp on, 146 MHz, 0.06 µV – 3.54 mV; 440 MHz, 0.08 µV – 3.16 mV; 1,294 MHz, 0.06 µV – 2.82 mV. SSB squelch, 1.26 – 19.9 mV.
S-meter sensitivity: Not specified.	S-9 signal, preamp off/on: 144 MHz, 13.8/3.63 µV 432 MHz, 12.2/3.16 µV 1,296 MHz, 4.51/2.48 µV Scaling: 3 dB per S-unit.
Notch filter depth: Not specified.	Tunable notch filter, 40 dB; auto notch, 50 dB; attack time 140 ms for one tone; 328 ms for two tones.
IF/audio response: Not specified.	Range at –6 dB points:‡ CW (500 Hz BW): 315 – 820 Hz; Equivalent Rectangular BW: 511 Hz; USB (2.4 kHz BW): 175 – 2,787 Hz; LSB (2.4 kHz BW): 175 –2,787 Hz; AM (9 kHz BW): 142 – 3,685 Hz.
Audio output: >2 W at 10% THD at 8 Ω.	2.3 W at 10% THD. 0.3% THD at 1 V_{RMS}.
Receive processing delay time: Not specified.	144 and 432 MHz, 8 ms; 1,296 MHz, 10 ms.
Transmitter	**Transmitter Dynamic Testing**
Power output: 144 MHz, 0.5 – 100 W; 432 MHz, 0.5 – 75 W; 1,296 MHz, 0.1 – 10 W. AM, 144 MHz, 0.125 – 25 W; 432 MHz, 0.125 – 18.75 W; 1,296 MHz, 0.025 – 2.5 W.	SSB, CW, FM: 144 MHz, 0.4 – 95 W; 432 MHz, 0.4 – 71 W; 1,296 MHz, 0.06 – 9.5 W. AM, 144 MHz, 0.08 – 21.5 W; 432 MHz, 0.02 – 20 W; 1,296 MHz, 0.02 – 2.5 W
Maximum RF power output at minimum specified operating voltage: Not specified.	At 11.7 V dc: 144 MHz, 73 W; 432 MHz, 57 W; 1,296, 7.8 W.
Spurious-signal and harmonic suppression: 144 MHz, >63 dB; 432 MHz > 61.5 dB; 1,296 MHz, >53 dB.	144 MHz, 70 dB; 432 MHz, >80 dB; 1,296 MHz, 64 dB. Complies with FCC emission standards.
Third-order intermodulation distortion (IMD) products: Not specified.	3rd/5th/7th/9th order, maximum PEP: 144 MHz, –33/–41/–48/–51 dB; 432 MHz, –30/–42/–59/–57 dB; 1,296 MHz, –48/–48/–52/–63 dB; At one-half of maximum PEP: 144 MHz, –38/–41/–48/–54 dB; 432 MHz, –43/–48/–52/–56 dB; 1,296 MHz, –45/–46/–55/–63 dB.
CW keyer speed range: Not specified.	6 to 48 WPM, iambic mode B.
CW keying characteristics: Not specified.	See Figures 4 and 5.
Transmit-receive turnaround time (PTT release to 50% of audio output): Not specified.	S-9 signal, AGC fast, SSB, 144 MHz, 35 ms; 432 MHz, 30 ms; 1,296 MHz, 40 ms; CW, full break-in, 144 MHz, 35 ms; 432 MHz, 35 ms; 1,296 MHz, 52 ms.
Receive-transmit turnaround time (TX delay): Not specified.	SSB, 70 ms; FM, 30 ms.
Transmit phase noise: Not specified.	See Figure 6.

Size (height, width, depth, including protrusions): 4.0 × 9.4 × 10.8 inches; weight, 10.4 pounds.
Second-order intercept points were determined using S-5 reference.

†Blocking dynamic range exceeds these values. No blocking was observed with up to +10 dBm signal at the antenna jack, the maximum level used in ARRL Lab testing.
††Best case third-order IMD dynamic range at 144 and 432 MHz; not tested at 1,296 MHz because test fixture is not rated above 500 MHz. See "Lab Notes."
*Measurement is noise limited at the value indicated.
‡Default values; bandwidth is adjustable.

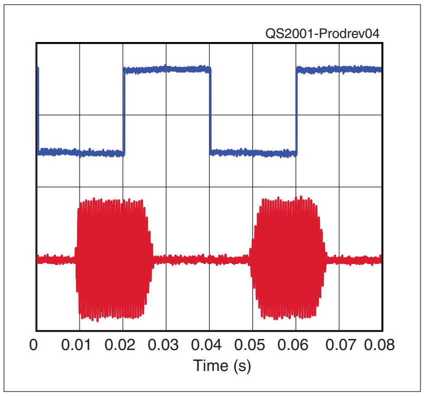


Figure 4 — CW keying waveform for the Icom IC-9700, showing the first two dits in full-break-in (QSK) mode using external keying and the default 4-millisecond rise time setting. Equivalent keying speed is 60 WPM. The upper trace is the actual key closure; the lower trace is the RF envelope. (Note that the first key closure starts at the left edge of the figure.) Horizontal divisions are 10 milliseconds. The transceiver was being operated at 100 W output on the 144 MHz band.

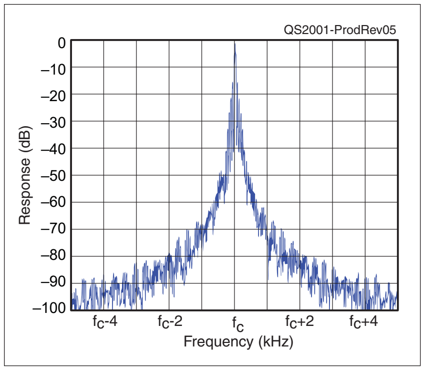


Figure 5 — Spectral display of the Icom IC-9700 transmitter during keying sideband testing. Equivalent keying speed is 60 WPM using external keying and the default 4-millisecond rise time setting. Spectrum analyzer resolution bandwidth is 10 Hz, and the sweep time is 30 seconds. The transmitter was being operated at 100 W PEP output on the 144 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.

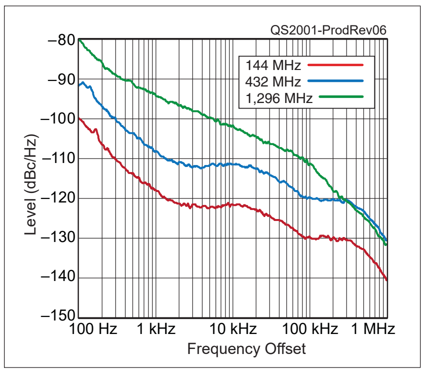


Figure 6 — Spectral display of the Icom IC-9700 transmitter output during phase-noise testing. Power output is 100 W on the 144 MHz band (red trace), 75 W on the 432 MHz band (blue trace), and 10 W on the 1,296 MHz band (green trace). The carrier, off the left edge of the plot, is not shown. This plot shows phase noise 100 Hz to 1 MHz from the carrier. The reference level is –80 dBc/Hz, and the vertical scale is 10 dB per division. The phase-noise at 30% of maximum output power is virtually identical to the full-power plot shown here on all three bands.

Using the IC-9700 for VHF/UHF DXing and Contesting

Jeff Klein, K1TEO

As an enthusiastic VHF operator and contester, I was excited about the introduction of the IC-9700 and was glad to have the chance to test drive one. In particular, I was intrigued by the SDR capabilities, as my two current main radios (TS-2000 and FT-736R) do not have the features included with the latest radios.

Here are my main observations after using the radio for several weeks:

- To get the IC-9700 operational, I needed to read the owner's manual and practice, although it would have been much easier if I were familiar with the IC-7300 or similar current HF transceiver. The touchscreen is nice, though I missed having traditional knobs for changing bands, modes, and other often-used features.
- I live in Connecticut, where there is a reasonable amount of VHF/UHF activity and many high-power stations. I was able to do A/B/C testing on my two radios versus the IC-9700 and found that the IC-9700 held up well with strong and clean nearby signals on the bands.
- I liked the band scope on this radio and found it helpful to locate stations on the bands. I found it most valuable during the August 222 MHz and Up contest, when I used the IC-9700 as the 144 MHz IF radio for some of my microwave transverters. While the frequency accuracy of microwave equipment has improved significantly over the last few years, there is still often some discrepancy between stations, especially on the bands above 2,304 MHz. Being able to see the signal from another station on the band was helpful in several cases, especially where the signal was particularly weak and difficult to hear in the noise. Unfortunately, because of some transverter issues on my end, I wasn't able to use the IC-9700 during the 10 GHz contest. I would expect that the ability to see weak signals when using the IC-9700 as an IF would be particularly valuable on the band.
- In VHF/UHF contests, there are a lot of unanswered CQs. I used the voice and CW keyers to set up messages for both modes. It was easy to do and worked well.
- I had a chance to use the FT8 and MSK144 digital modes with *WSJT-X* software on all three bands (2 meters and 70 and 23 centimeters). The biggest challenge I had was to get the settings right so the IC-9700 would talk to the *WSJT-X* software. At the time, I was not able to locate the required transceiver settings either online or from the documentation. Given the update to *WSJT-X* to include the IC-9700 in the **SETTINGS** menu, I had thought it would be straightforward. In the end, with the help of Bill, AA2UK, I was able to set up the transceiver correctly to work with *WSJT-X*.
- Once I got the IC-9700 and software working together, it worked well using the *WSJT-X* modes. The review radio had firmware version 1.11 installed, which addressed previously reported frequency stability issues. I had no problem making contacts using FT8 and MSK144 on all three bands, and I didn't note any frequency stability problems, even on 1,296 MHz. Likewise, I didn't observe any issues while using SSB and CW on all bands. Note that I only used the radio indoors and didn't use the radio with an external 10 MHz reference oscillator.

This is a very nice transceiver and it has a lot of capability. The band scope offers some real advantages on any band, but it's especially useful for a serious microwave operator when trying to find stations on the bands where frequency accuracy is still an issue.

Although I'm used to using radios with lots of knobs, I expect that, over time, I would get used to the touchscreen approach of the IC-9700. For my station, it would be a bonus if 6-meter operation were added, but this radio is a great way to get started on the weak-signal modes on 2 meters and 70 and 23 centimeters.

meters). Here are the possible main and subband combinations (top VFO listed first): 2 meters with 70 centimeters; 70 centimeters with 2 meters; 2 meters with 23 centimeters; 23 centimeters with 2 meters; 23 centimeters with 70 centimeters, and 70 centimeters with 23 centimeters. Notice that you can't set the main and sub receiver VFOs to the same band. You can still do split operation in the same band, as there are two VFOs per band. You can't mix all three bands when scanning memories or VFO frequencies, but you can scan two bands at a time using the main and subband VFOs. If you're confused with all those band descriptions, please watch the video review for a demonstration (see the YouTube video link provided). Finally, I didn't see information on how to do crossband repeater operation with this radio.

Now that we covered some of the things the radio doesn't do, you can assume that it does almost everything else. To get an idea of what's included, take most of the Icom ID-5100 dual-band mobile transceiver features (VHF/UHF, FM, D-STAR), then add many of the features of the Icom IC-7300 HF SDR transceiver, then the features of the Icom ID-1 (1.2 GHz transceiver), add some features of the Icom IC-7610 (IP+, LAN interface, RS-BA1 server), then add satellite operating capabilities and the D-STAR gateway modes, and you will have the IC-9700.

Lab Notes: Icom IC-9700

Bob Allison, WB1GCM,
ARRL Laboratory
Assistant Manager

With the ability to hear very weak signals, the Icom IC-9700 is well suited for satellite, EME, and terrestrial communications on the 2-meter, 70-centimeter, and 23-centimeter amateur bands. Enhanced sensitivity is sometimes attained at the expense of dynamic range — not so with the IC-9700. It has a third-order IMD dynamic range at 2 kHz spacing of 91 dB at 144 MHz and 87 dB at 432 MHz. One must also consider second-order IMD, where two strong signals at the antenna jack create a false signal on a frequency that is at the sum of the frequencies of the offending signals. This can happen in a spectrally dense environment where strong signals from transmitters for several radio services are physically located in one area, such as a mountaintop. The IC-9700 has a high second-order IMD dynamic range, making the receiver immune to intermodulation from all but the very strongest summation of signals.

Transmit quality is quite acceptable, with reasonably low transmit IMD. It is important to note that transmit IMD levels are lower at lower RF output levels. This is good to know when pairing up the IC-9700 with an RF power amplifier. An amplifier by itself contributes to the overall transmit IMD level. Please be sure not to overdrive an amplifier, as the transmit IMD products can get much higher than what constitutes good engineering practice. If the input to the amplifier is too high, the amplifier will operate in a non-linear state and cause splatter. Transmit phase-noise is reasonably low at 144 MHz and a bit higher on 432 MHz. It's higher than we'd like to see on 1,280 MHz, although we have not tested transmit phase-noise on any other 23-centimeter transceivers for comparison.

As discussed in the text, soon after the IC-9700 was released, some amateurs voiced concern about the transceiver's frequency stability, particularly during transmission of narrow bandwidth digital signals where a signal is not decoded at the receive end because of frequency drift of only a few hertz. Voice modes — and even CW — are not affected by such small changes of frequency. Icom made some changes to the firmware to improving frequency stability, and these were included in firmware version 1.11 that we used for testing.

To determine frequency drift, I simulated FT8 conditions during a contest or band opening, with the transmitter on at full power for 15 seconds, followed by 15 seconds in receive mode, and repeated this sequence for 30 minutes. Starting with IC-9700 at room temperature, I measured and logged the transmit frequency using our GPS-locked HP-5351B frequency counter during each transmission. The fan came on regularly during the 2-meter testing, but did not run during the 70- and 23-centimeter testing. As shown in Figure A, after 10 minutes of operation, frequency drift became negligible. Not shown in the chart is the amount of frequency drift within each transmission after warmup. My observation was the maximum frequency drift that occurred within each transmission during the initial 10-minute warmup was 2 Hz on the 23-centimeter band. After warmup, this drift per transmission was 1 Hz, or less. This is very reasonable, considering that the IC-9700 was not locked to an external high-stability frequency reference.

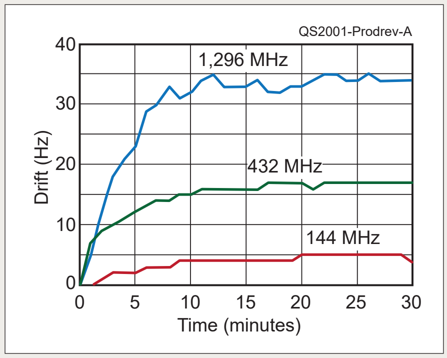


Figure A — IC-9700 frequency drift over 30-minute increments alternating 15 seconds on/off at full power.

Programming the Radio

You can download the *CS-9700* Windows programming software for free from the Icom website and start programming your radio. You can either use the USB port or the SD card to transfer the configuration into the radio. I prefer using an SD card reader with an SD card that I can move between the radio and computer. I started with a new SD card that I formatted with the radio, and then I saved the radio configuration even though I had not made any changes. I moved the SD card to my computer, loaded the saved file, and started building my configuration.

I also download the repeaters list for North America from the Icom website, then saved the .CSV data file into the correct directory of the SD card and imported the list when I inserted the SD card into the radio (see next section for more information). Keep in mind that the radio has a memory bank for each band, and you cannot mix them.

D-STAR Operation

The IC-9700 is compatible with the D-STAR digital voice (DV) and digital data (DD) mode. It performs just like any other dual-band D-STAR radio, but with extra capability. In addition to 23-centimeter-band (1.2 GHz) operation, Icom added the D-STAR repeater (DR) function that can be used on both the main and sub-bands simultaneously, and you can listen to two separate DV signals. If you have a 1.2 GHz D-STAR

Using the IC-9700 on the Amateur Satellites

Joe Carcia, NJ1Q
W1AW Station Manager

Those just starting out on amateur radio satellites may have tried the FM birds, such as AO-91, AO-92, or SO-50. You can make contacts on those satellites using a dual-band FM handheld with a simple hand-held 2-meter/70-centimeter Yagi. The IC-9700 offers a step up for those wanting to operate through the satellites using CW, SSB, or FM on Mode B (70 centimeters up/2 meters down), Mode J (2 meters up/70 centimeters down), or Mode L (23 centimeters up/70 centimeters down).

The IC-9700 has a dedicated **SATELLITE** mode. To select that mode, bring up the **MENU** display and press the **SATELLITE** icon for 1 second. This will copy the current frequency content to the satellite VFOs. The display will now revert to its **SATELLITE** mode display. The **TX** function drops to the **SUB** (lower) band, and **MAIN**, **NOR/REV**, and **SUB** buttons appear on the display.

Depending on the mode (B, J, L), the proper transmit and receive frequencies should be set first, noting that the **SUB** frequency becomes the **TRANSMIT** frequency in **SATELLITE** mode.

The **SATELLITE** mode allows for manual Doppler correction When running in **SATELLITE** mode, the user has the option of setting the tracking — a method of adjusting both the transmit and receive frequencies simultaneously with the tuning dial — via the **NOR/REV** button. In **NOR** (normal) mode, both the transmit and receive frequencies change in unison; if the transmit frequency goes up or down (in 10 Hz increments), the receive frequency does the same. In **REV** (reverse) mode, the transmit and receive frequencies change in opposition to each other; if one frequency goes up (in 10 Hz increments), the other frequency will go down accordingly. (Note that radio control available with some satellite tracking programs may allow for automatic Doppler adjustment.)

If the operator needs to adjust either the **MAIN** or **SUB** frequencies separately, then the corresponding **MAIN** or **SUB** button should be pressed. The button will turn orange, and the corresponding frequency will be underlined. Frequency changes to one VFO will not affect the other. To exit this function, press the button again.

In **SATELLITE** mode, the spectrum scope or audio scope can switch between the main or subbands by touching the **MAIN/SUB** indicator on the scope display.

On the Air

My first attempt at satellite activity was with one of the newer analog birds (Mode J). At first, I found the tracking (in normal mode) to be a little less effective than manually adjusting the uplink frequency myself. With the tracking in reverse, I observed my downlink signal audio kept up well with the uplink signal. However, I was also chasing myself around the band. When I tuned in a station calling CQ, I found that as I corrected for Doppler shift, I'd lose the station, because both frequencies were changing at the same rate. If the other station wasn't changing frequency at the same rate/step as I was, then I tuned right by their signal.

However, because the radio will operate full duplex (transmit on one band and receive on another at the same time), you can just operate without using **SATELLITE** mode and set the satellite transmit and receive frequencies accordingly. I chose to sit on a particular downlink frequency, and manually tune the uplink frequency, so my monitored downlink signal sounded stable. This is not meant to imply the tracking function isn't useful, rather it is a choice I make based on my experience and preferences.

Next up was one of the FM birds (Mode B) — see Figure B. Because the downlink was on 2 meters, I didn't have to worry as much about Doppler (at least for receive), and the IC-9700 has an AFC (auto frequency-control) feature to help compensate for Doppler shift in FM mode. I waited for TCA (time of closest approach) and set the uplink frequency accordingly. My first "CQ satellite" yielded an immediate response back. I proceeded to make two more contacts before the satellite dropped below where my antenna was oriented.

The audio for both SSB and FM was great. Received signals sounded clean and easy to copy, and I also received good signal reports. For both birds, I used an Arrow antenna mounted on a tripod. The antenna was oriented to the various birds' azimuth/elevation coordinates at TCA.

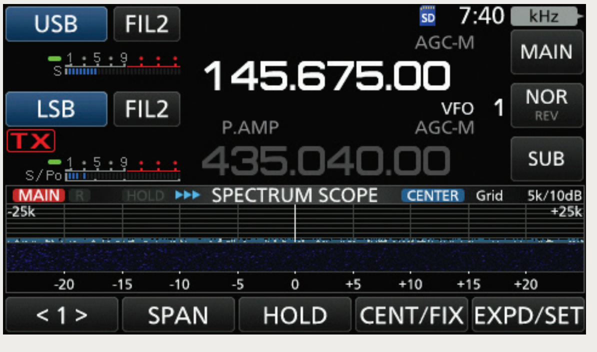


Figure B — The IC-9700 setup for Mode B satellite operation.

repeater with an internet gateway, you can use the DD mode to browse the internet through the repeater. If you set your GPS location coordinates into the radio (manually), you can use the DR mode to find the closest D-STAR repeater, and you can download the full North American list via the Icom website.

The radio's ethernet LAN interface can be configured using a dynamic IP address (DHCP), or you can set a static IP address if you need to do port forwarding for remote or DV gateway operations. That means you can use the radio directly in terminal mode or in access point mode, directly through the internet. Here's an example of the terminal mode. Let's say you are unable to reach a popular repeater located in another state on the air via RF. If the repeater gateway is compatible, you could connect to it via the internet and have a contact with your friends using the radio's mic and speaker — no PC or any extra gear is needed.

You could do exactly the same in access point mode using a D-STAR handheld and a simplex frequency on the IC-9700, so when it receives the RF from the handheld, it will uplink the information to a remote repeater via the internet. In other words, if there's no D-STAR repeater near you but you have an internet connection, you could still operate with D-STAR by using the integrated DV gateway function.

On the Air

I used the IC-9700 with my new antenna setup (see the "Diamond X6000A VHF/UHF Triband Antenna and MX3000N Triplexer" review in the December 2019 issue of *QST*). It outperformed my previous installation, to the point that I don't use the IC-9700's preamp on 2 meters — it's just too much. Compared to a dual-band mobile radio, the IC-9700 can pull weaker signals out of the noise. It's a totally different experience than I am used to, and it feels more like operating an HF radio. With a good antenna up high with 100 W on 2 meters and 75 W on 70 centimeters, I can reach those far away repeaters and can increase my coverage in simplex.

When the IC-9700 was first released, some users discovered that the frequency stability was not adequate for some digital mode operation using moonbounce (EME) or for some terrestrial digital-mode operation at UHF. Since the North American launch in April 2019, Icom has released a number of firmware upgrades, and the frequency stability has improved significantly. As noted in the sidebar, "Using the

Visit https://youtu.be/7EOPdwd8KK0 to see our review of the Icom IC-9700 VHF/UHF Multimode Transceiver on YouTube.

IC-9700 for VHF/UHF DXing and Contesting," Jeff Klein, K1TEO, had no trouble making SSB, CW, or FT8 contacts on VHF or UHF with version 1.11 firmware installed.

In addition to improving the stability with the internal oscillator, with firmware version 1.10, Icom added a new feature to make it easier to sync the internal oscillator to a GPS-disciplined oscillator or other high-stability external 10 MHz source connected to the **REF IN** jack on the rear panel. On the **REF ADJUST** screen in the **SET** menu, touch the **SYNC TO REF IN** button, and the radio will automatically adjust its internal reference frequency to match the high-stability source if one is connected. The manual notes that in an environment with sudden temperature changes, the transceiver may take longer to synchronize.

Conclusion

The amateur radio market is pretty small, so I'm always amazed when a manufacturer innovates for us. It must have taken many hours of development to put all that technology into one radio. It's expensive compared to a standard dual-band mobile radio, but this radio can do so much more. The main thing I like about this radio is that you can evolve from simple conversations on the local FM repeater to D-STAR digital operation, satellite operation, DXing, or contesting using SSB, CW, or digital modes (such as FT8 or MSK144). I think it's really worth the investment.

Manufacturer: Icom America, 12421 Willows Rd. NE, Kirkland, WA 98034; **www.icomamerica.com**. Price: IC-9700, $1,700; RC-28 remote USB encoder with tuning knob, $259; RS-BA1 remote-control software, $95.

N6BT V-8 Vertical Dipole for 80 – 10 Meters

Reviewed by Ward Silver, NØAX
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I have been a customer of Tom Schiller's, N6BT, innovative antenna designs since the Force 12 C-3 triband Yagi was introduced more than 20 years ago. I often use my ground-independent Bravo-7K portable vertical with consistent good results, so the new V-8 vertical dipole was a good opportunity to work with the latest evolution of the series.[1] You can find reviews of other earlier designs by N6BT in *QST* Product Reviews of the ZR-3 and Sigma-5 vertical dipoles and in my own *HF Vertical Performance — Test Methods & Results*.[2, 3, 4]

Overview

The V-8 antenna (see Figure 7) has a single vertical element with two horizontal resonator sections making a single horizontal element. The feed point is at the junction of the vertical and horizontal element (see Figure 8). The resonators actually form the bottom half of the dipole, making the antenna more of an inverted T.

When installed with the horizontal resonator sections at the recommended height above ground (4 feet, 6 inches) the total height is about 24 feet. The resonators extend symmetrically from 17 feet to 22 feet, 6 inches. The vertical section is installed at full length and any adjustments made to the resonators to compensate for ground type and height.

Construction is all aluminum tubing and stainless-steel hardware. The central feed point assembly (the Main Hub) is made of welded aluminum tubing and a fiberglass rod. The tubing segments are secured with stainless-steel hose clamps. The base consists of 18 inches of outdoor-rated PVC that is buried in the

Figure 7 — The V-8 installed in the author's backyard, as described in the instructions.

Bottom Line

The N6BT V-8 vertical antenna offers a multiband solution for portable operation or for home stations with limited space. It is easy to install, and although performance on the low bands is compromised by its short length, it is a good performer on the higher-frequency bands.

ground plus a 36-inch section of aluminum tubing that slides into it. The feed point assembly attaches to a section of aluminum tubing that slides into the base.

The antenna is represented as covering eight of the HF bands from 80 through 10 meters although it is not resonant on any of them. (Its natural resonance at the initial dimensions is just above 22 MHz.) Similar to the feed point of off-center-fed dipoles, the antenna is designed to present an impedance across the HF spectrum suitable for matching to 50 Ω by an antenna tuner at the base of the antenna. For multiband operation, you must use a tuner, and the only recommended location for it is at the feed point of the antenna.

Assembly and Installation

The antenna is shipped with the vertical element and both resonators telescoped to 3 feet and the hose clamps attached. There are no sections to sort out or mismatches to worry about — just loosen the clamps with a ¼-inch nutdriver or flat-blade screwdriver and extend each segment to the line marked on each. With the feed point section, base section, tuner, and roll of coax, the whole package will fit comfortably into a medium-size duffel for portable or go-kit use.

A 12- to 18-inch-deep hole is required for the PVC base, which is then secured by tamping in some dirt around it. For permanent installations, add some gravel to the bottom of the hole for drainage. Either dirt or concrete will hold the base securely. For portable use, N6BT suggests driving a stake into the ground, placing the aluminum base section over the stake, and guying the antenna.

Figure 8 — V-8 feed point assembly showing the beta- or hairpin-matching coil across the feed point.

Assuming the antenna is ground-mounted, the vertical section (a couple of pounds) is easy to lift and set in the feed point assembly, as are the resonators. If the antenna is used for temporary installations or if it must be taken down between operating periods, it is easy to loosen the clamps and lift the entire antenna out of the base. More conveniently, the elements can be removed from the feed point assembly, leaving the base in place, and reinstalled in a few minutes.

The beta- or hairpin-match inductor is connected across the feed point. A 2-foot length of RG-213 is provided to connect an autotuner output to the feed point, as shown in Figure 8. Your coaxial cable feed line from the station is then attached to the tuner. An RF choke in the coax to your station is recommended, as described in *The ARRL Handbook* or *ARRL Antenna Book.* Roof mounting may require adjustment in the resonator length for the tuner to achieve a match on all bands.

For permanent installations, anti-oxidation compounds, such as Penetrox or Noalox, should be applied where the element segments overlap and to feed point connections. The manufacturer discusses adding a ground screen to reduce loss in the soil and lower the overall radiation angle. The screen can be wires (not necessarily laid out radially) or mesh under the antenna and should not be connected to the resonator elements. A ground rod used for lightning protection can be connected to the screen. This would be effective for installations over soil with poor conductivity.

Impedance Matching and Adjustment

Because the feed point SWR of the antenna can be fairly high (see Figure 9A and 9B), a tuner should be located at the antenna whether it is automatic or manual. A tuner in the station will be able to provide a match to 50 Ω, but the resulting high SWR in the feed line will result in substantial losses, particularly on the 80-, 40-, and 30-meter bands (see the *ARRL Antenna Book*). I used an MFJ-994BRT weather-proof auto-tuner rated at 600 W during the evaluation of the antenna.

The high SWR presented by the V-8 on the lower HF bands, where it is electrically small, proved difficult to match and required some manual adjustment of the L and C values to obtain the best match as described below. An auto-tuner's tuning algorithms may arrive at values of L and C that result in an impedance match, but might have a very narrow bandwidth or not be in the lowest-loss combination. For that reason, be sure your auto-tuner has the ability to make manual adjustments of the L and C values, so you can obtain the widest bandwidth and lowest loss settings. A higher-power tuner will probably have lower loss components, as well (see *The ARRL Guide to Antenna Tuners*[5]). Plan for this step during your initial installation and setup. Using an antenna analyzer with a graphical display of SWR versus frequency makes this job a lot easier and quicker.

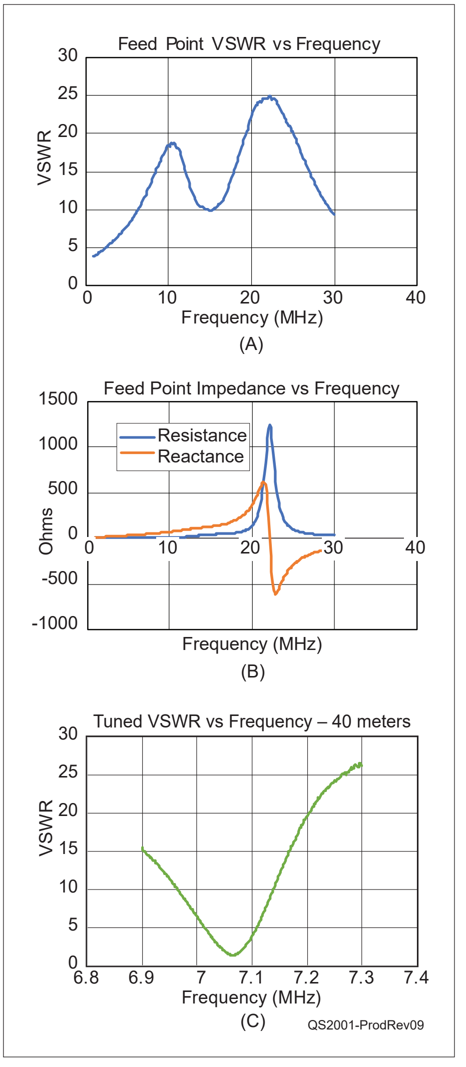

Figure 9 — Graph of SWR and impedance across the HF bands. The antenna exhibits a high-impedance parallel resonance just above the 15-meter band. The SWR when the antenna is tuned for 40-meter operation (C) shows a typical 3:1 bandwidth of about 60 kHz and a minimum SWR of 1.4:1.

Adjusting the length of the resonator elements (not the vertical element) may shift the feed point impedance to within the tuner's range. Height above ground and soil type and nearby conductors can all affect feed point impedance. In my situation, the antenna was installed over medium ground and no conducting surfaces or wires were within 30 feet. I adjusted the resonator lengths from 8 feet, 6 inches to 11 feet, 3 inches but did not see a dramatic effect on impedance on the 80-, 40-, or 30-meter bands, where the tuner had the most difficulty.

Low-Band Performance (80, 40, 30 Meters)

Initially, the auto-tuner had difficulty reducing SWR below 3:1 on 80 and 40 meters. This is not at all unusual when using electrically small antennas. A manual tuner was able to obtain a good match on all three bands.

I returned to the auto-tuner and used its manual L and C adjustment while watching the SWR on a graphical antenna analyzer and was able to set the auto-tuner for SWR less than 1.5:1 on all three bands. The auto-tuner stores settings in narrow ranges across the bands, so for a permanent installation, this might be time consuming during the initial setup but will greatly improve antenna system performance. Plan for this step during your initial installation and setup. Using an antenna analyzer with a graphical display of SWR versus frequency makes this job a lot easier and quicker. After tuning, the 3:1 SWR bandwidth was 35 kHz on 80 meters, 60 kHz on 40 meters (see Figure 9C), and the entire band on 30 meters.

On the air, the antenna was a good performer on 30 meters, even though it is about half size. I tested the antenna using the FT4 mode because of the consistent signal-to-noise (SNR) reports computed by the FT4 algorithm. On 30 meters, my signal seemed to be comparable to others from the middle of the US.

As the frequency dropped, so did my radiated signal. This is normal for antennas that are electrically small, particularly for a ground-mounted antenna, and by no means is it a design defect. On 40 meters, the antenna was hearing well, but making a contact took frequent repeats. On 80 meters, I was able to contact the strongest stations but not those with marginal signals. The antenna is about ⅛ the size of a full-size vertical on 80 meters, so this is not surprising.

Low-angle radiation from any vertical antenna is less effective on the lower-frequency bands for distances under about 1,000 miles, where high-angle radiation is more effective. Radiation patterns for the V-8 show the expected overhead null on all bands, so take that into account when using the antenna. From the middle of the US, stations from the East Coast, West Coast, and Caribbean were the easiest to work on 30 and 40 meters.

High-Band Performance (20 – 10 meters)

The V-8 really comes into its own on the higher bands, where it approaches or exceeds a quarter-wavelength in size. The auto-tuner was able to match the feed point impedance easily on all of these bands. (Adjusting the resonator length during low-band testing had the greatest effect on 17 meters at my location but that may not always be the case.) An SWR of 1.2:1 or less was obtained on all bands, and the tuner's memory settings allowed quick frequency changes when using the FT4 **TUNE** function or setting the radio to AM and transmitting an unmodulated carrier (followed by a message or transmission with your call sign).

Due to band conditions in the late summer and low solar flux, no contacts were made on 12 or 10 meters and only a couple on 15 meters. I made quite a few contacts on 17 and 20 meters, including with Europe, South America, and the Pacific. Received SNR was usually about average compared to what I saw other stations receiving, although those using beams or high power did a lot better, unsurprisingly. The effect of low-angle radiation was quite apparent when receiving signals from close to or within the skip zone. The antenna was performing normally and was at its most effective on these bands.

Availability and Support

The antenna's manufacturer, Next Generation Antennas, is a small company, so support and availability may be a concern, but Ham Radio Outlet has assured me they will maintain a stock of the antenna as long as it continues to sell. Regarding support, my anonymous questions and comments were addressed promptly and reasonably. The manual is in the style I expect from N6BT, with a lot of background and data about how the antenna works. Assembly instructions were fine, although I found a couple of places where the information wasn't entirely clear and made specific suggestions for improvement. Photos are provided for each step of the assembly process.

Recommendations and Summary

Because the V-8 is recommended for portable operating, I would really like to see a tripod mount similar to N6BT's Bravo series. This would probably require guying the antenna in windy areas but would be a lot more convenient than installing the PVC tube in the ground or having to drive in a stake, which may not be permitted in parks or public areas. The manufacturer is considering making some loading coils that would make the antenna easier to match on 80 and 40 meters.

The V-8 is an easy antenna to put up and take down, particularly for situations where an antenna can't be permanently installed, or where adequate supports aren't available for a more traditional horizontal antenna at reasonable heights, or if extensive ground systems can't be installed. The antenna is necessarily a compromise on its lower bands, which is typical of multiband, shortened antennas, but is a good performer as it becomes electrically longer.

Manufacturer: Tom Schiller, N6BT, Next Generation Antennas, Kingman, Arizona; **nextgeneration antennas.com.** Available only from Ham Radio Outlet, **www.hamradio.com**. Price: $349.

Notes

[1]W. Silver, NØAX, "Bravo-7K Portable Vertical Dipole," *QST,* Mar. 2012, pp. 52 – 53.

[2]The Force 12 ZR-3 Multiband Vertical is included in "Compact and Portable Antennas Roundup," Product Review, *QST,* Mar. 1998, pp. 74 – 75.

[3]"Force 12 Sigma-5 Five-Band Vertical Dipole Antenna," Product Review, *QST,* Oct. 2002, pp. 67 – 68.

[4]*HF Vertical Performance — Test Methods & Results* is available from Champion Radio Products, **championradio.com.**

[5]Available from the ARRL Store at **www.arrl.org/shop.**

mAT-Tuner mAT-125E Automatic Antenna Tuner

Reviewed by Steve Ford, WB8IMY
QST *Editor*
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As I lifted the mAT-125E automatic antenna tuner out of its box, I noticed something odd about the back panel. Rather than offering a dc power jack labeled **12 V** or something similar, the jack was labeled **CHARGER**. A glance at the instruction sheet revealed that the mAT-125E is powered by two rechargeable lithium batteries. A battery-powered antenna tuner is useful for portable as well as home-station applications.

Portable use also increases the potential for rough handling. To address that possibility, the rugged enclosure is a block of sleek, black aluminum with a minimalist approach to ergonomics. The front panel features an SWR indicator consisting of bright LEDs labeled **1.5**, **2**, and **3**, along with a fourth LED to indicate when the tuner is powered up. A set of pushbuttons controls semiautomatic and manual tuning functions. The back panel (see Figure 10) consists of little more than two SO-239 coaxial cable jacks (**RF IN** and **ANTENNA**), a ground post, and the **CHARGER** port.

Using the mAT-125E

The tuner is rated for use from 1.8 to 54 MHz and can work with impedance loads from 5 to 1,500 Ω. Designed to work with typical HF transceivers, the mAT-125E is rated for a maximum of 120 W PEP SSB or CW. If you plan to operate 100% duty-cycle modes, such as FT8 or RTTY, you'll need to reduce your transceiver output to 30 W or less.

Being battery powered makes the mAT-125E especially convenient to set up and use. You just connect the coaxial cables from your radio and antenna, and you're done. Tap the **PWR** button and the tuner comes to life with the bright glow of a green LED. If you do nothing for 3 minutes, the tuner will automatically shut down to conserve power. Because the mAT-125E uses latching relays, once it has found a match, there is no need for it to stay powered.

For HF operating, I presently use a 66-foot-long, inverted-**V** dipole antenna fed with 450 Ω windowed ladder line, a 4:1 balun, and a remote automatic antenna tuner. One hundred feet of low-loss coaxial cable snakes back to the transceiver at my station. The remote tuner can find an acceptable low-SWR match on frequencies from 40 to 6 meters.

I switched the remote tuner to the bypass mode and placed the mAT-125E in the line at my station. In this configuration, the tuner would encounter high SWR on most bands, which was exactly what I wanted. With my transceiver in the CW mode on 40 meters, I reduced its output to about 5 W and then closed the key. The mAT-125E instantly began tuning, its relays buzzing madly. Within about 2 seconds, it found a match that yielded an SWR of less than 1.5:1.

I went to other bands and conducted the same tests. Each time, the mAT-125E found a match within just a few seconds. The inductor/capacitor combinations

Bottom Line

The mAT-125E is a good companion for typical 100 W HF/6-meter transceivers. It's able to match a broad range of impedances, although loss increases at very low impedances.

Figure 10 — The mAT-125E rear panel and battery charger.

Table 2
mAT-TUNER mAT-125E Automatic Antenna Tuner

Manufacturer's Specifications

Frequency range: 1.8 – 54 MHz.

Power handling: 0.1 – 120 W SSB/CW; 30 W maximum with continuous digital modes; 100 W maximum above 50 MHz.

Matching range: 5 to 1,500 Ω.

Tuning time: 0.1 – 5 seconds for full tune cycle; 0.1 second to recall memories.

Power requirements: Internal rechargeable #18650 lithium batteries.

Size (height, width, depth): 1.8 × 5.2 × 8.1 inches; weight 2.2 lbs.

mAT-125E Resistive Load and Loss Testing in the ARRL Lab

Untuned Load		Power Loss (%) and Tuned SWR by Band (Meters)					
SWR	(Ω)	160	80	40	20	10	6*
9.1:1	5.5	36%	21%	18%	6%	16%	–
		2.1	1.4	1.5	1.4	1.3	1.4
7.4:1	6.8	28%	19%	18%	18%	4%	–
		1.8	1.3	1.2	1.1	1.2	1.4
3.8:1	13.1	10%	12%	13%	16%	18%	–
		1.1	1.1	1.2	1.1	1.9	1.4
2.0	25	4%	7%	8%	9%	14%	–
		1.1	1.0	1.0	1.1	1.2	1.6
1:1	50	2%	3%	3%	4%	6%	–
		1.0	1.0	1.0	1.1	1.0	1.1
2:1	100	14%	13%	10%	7%	2%	–
		1.7	1.9	1.9	1.9	1.6	1.1
4:1	200	1%	1%	1%	2%	1%	–
		1.0	1.1	1.0	1.2	1.8	1.3
8:1	400	2%	1%	1%	1%	1%	–
		1.2	1.1	1.0	1.1	1.4	1.2
16:1	800	17%	2%	2%	2%	2%	–
		2.2	1.2	1.1	1.3	1.4	1.5

*Our resistive load box is limited to a maximum frequency of 30 MHz and a maximum resistance of 800 Ω. Efficiency tests were not performed on 6 meters.

that result in an acceptable match at a given frequency are stored in one of 16,000 memory slots. So, when you return to that frequency, the mAT-125E will find the match almost instantaneously.

My final test presented the ultimate challenge: finding a match on 160 meters — a band on which my antenna was about 190 feet too short. As before, I reduced output and transmitted a continuous signal. The mAT-125E buzzed, hesitated, and then buzzed some more. Just as I thought it was about to give up, the buzzing ceased, and the **1.5** LED glowed green. The SWR meter on my transceiver agreed — the mAT-125E had found an impedance match that resulted in a 1.3:1 SWR.

I could have chosen to operate the mAT-125E in semiautomatic mode (initiating tuning myself rather than having the tuner respond to the RF from my radio), or even manual mode. I tried both modes, and they functioned well, but full auto is the most convenient, unless the tuner cannot find a match automatically. The tuner also offers a bypass mode.

Tuners and Loss

Tuners aren't panaceas for poor impedance matches and high SWRs. An antenna tuner makes it possible to dump the full output of your transceiver into the antenna system, nothing more. The SWR match the mAT-125E found for my transceiver on 160 meters existed only between the tuner and my radio. Beyond the tuner, the SWR remained unchanged, and so did the power loss from high SWR in the coaxial feed line.

Not only does the SWR between the tuner and the antenna cause loss, there is loss within the tuner itself. That's why the ARRL Laboratory always tests tuner efficiency. You'll see the test results in Table 2. Overall, the mAT-125E performed well, with the greatest efficiency (lowest loss) occurring with impedance loads greater than 25 Ω. The Lab recommends reducing power to 50 W or so with low-impedance loads.

Keep loss in mind when considering any antenna tuner that you intend to use at your operating position. If you're using a nonresonant antenna that presents a very high SWR, you can greatly reduce feed line loss by placing the antenna tuner outdoors at or near the feed point of the antenna. If a remote tuner is out of the question, be sure you are using low-loss cable to at least keep SWR loss at a minimum. With its battery-powered design, the mAT-125E would make a fine remote tuner, but it isn't designed for outdoor use.

That said, you could install the mAT-125E in a waterproof enclosure and still reap the remote benefits. Given the low current requirements when the tuner is in its resting state (which is most of the time), you may only need to recharge the batteries every few months.

The mAT-125E is intended for use with unbalanced feed lines, such as coaxial cable. If you want to use it with balanced lines (such as ladder line), you will need to purchase a balun and connect it to the tuner with a short length of coax — the shorter the better.

Manufacturer: Hengshui mAT-Tuner Communication Equipment Company, Hebei, China. Available from Vibroplex, 1001 N. Broadway St., Knoxville, TN 37917; **www.vibroplex.com**. Price: $164.95.