A Portable QRP CW Transceiver—*Part* 2[†]

When you finish building this transceiver, just bring it, batteries, a key and an antenna on your next outing, and you're set for lots of QRP fun!

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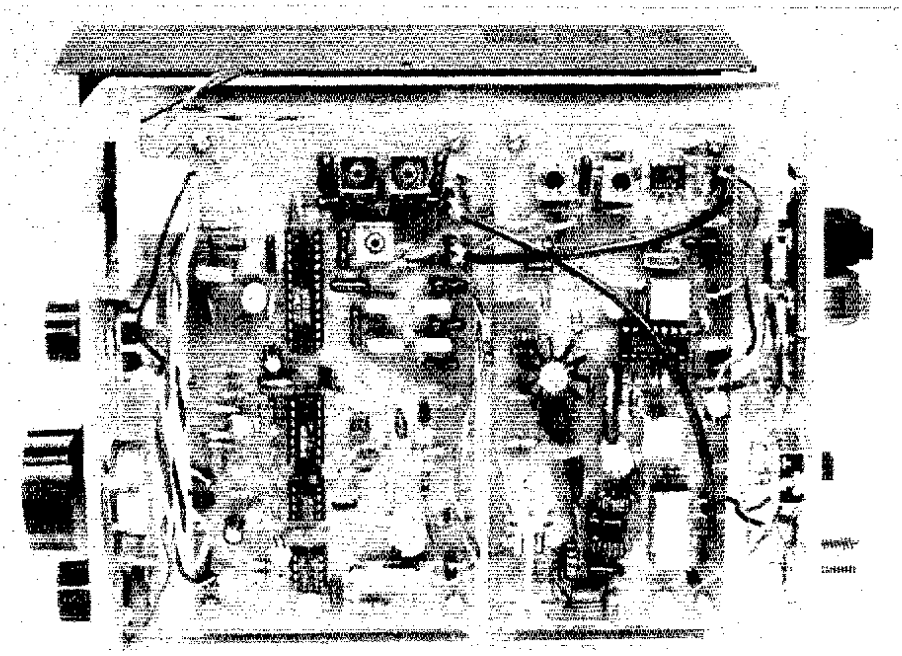


Last month we looked at the design and construction of the receiver portion of this 5-watt 20-meter transceiver. This month, I'll describe the transmitter section and how to interconnect the transmitter and receiver. The transmitter includes semi-QSK TR switching and CW-sidetone generation. As noted last month, I wanted the rig to be easy to build and readily available to other hams.[7] These priorities turned out to be the major part of the development effort: Designing a simple, stable and easy-to-align transmitter was harder than I thought it would be!

The Transmitter Circuit

Refer to Fig 3. Because the receiver is a superhet, on transmit, the VFO needs to be converted to the operating frequency, but offset by 800 Hz from the receiver frequency. To do this simply, I used an NE602 oscillator/mixer IC (U1) with an external crystal tuned to the center of the receiver's filter passband. (The crystal is from the same batch as those in the receiver filter and BFO; its frequency is adjusted by a series inductor and a trimmer in the feedback circuit.) U1 operates on Zener-regulated 6 V derived from a 12-V line that's switched by TR relay K1. This switching arrangement keeps the transmitter from delivering power until *after* the TR relay has been switched to the transmit position.

The mixer output contains the VFO and crystal frequencies and their sum and difference. A double-tuned filter after the mixer passes only the 14-MHz output. The NE602 is a low-level device, so the VFO input to U1, pin 1, is reduced with a series resistor. (If this was not done, the NE602 would generate substantial spurious signals.)

A typical problem in circuit design is impedance matching. This circuit has to match the very high impedance of the tuned circuits in the filter to the low impedance of the RF-amplification stages. Usually, this is done with tapped coils, link coupling, or another matching network. An FET source follower can also accomplish the task. I used yet another method: an IC video buffer.

Recently, op amps, buffers and other "low-frequency" ICs with bandwidths into the hundreds of megahertz have become available. I used one of these ICs, National Semiconductor's LM6321 (U2). This device has an input impedance of 5 MΩ and a very low output impedance. The LM6321's voltage gain is one, but it has plenty of current gain, and thus power gain. U2 requires almost no external parts: a pair of 1-MΩ resistors to bias the input, plus bypass and coupling capacitors, are all that's needed. A series resistor at the input minimizes this chip's tendency to oscillate with inductive inputs.

The convenient low-impedance output of the buffer drives a class-A 2N3866 driver amplifier (Q1) with negative feedback. I could have used a class-C stage here, but class-A operation allows higher gain, and the use of feedback ensures stable input and output impedances. Thus, the harmonics generated in this stage are not severe, and a simple broadband transformer (T1) can be used to couple it to the final stage. The driver and the preceding buffer stage are keyed, as explained later.

The final amplifier (Q2) uses the popular MRF475, a rugged NPN power transistor capable of 12 W output. I used other devices in this class in early versions of the transmitter, but I opted for an overrated final transistor that I knew could handle momentary shorts and opens at its output. All of us occasionally hook some outrageous load to a rig's antenna terminal!

At 5 W output, the collector-load impedance is close to 12 Ω, as determined by the general equation:

$$R_L = (V_{CE} - V_{SAT})^2 \div (2\ P_O) \quad \text{(Eq 2)}$$

Assuming a 12-V supply, $(V_{CE} - V_{SAT})$ is about 11 V. Thus, the impedance is 12.1 Ω, which can be easily and closely matched to 50 Ω by a 4:1 transformer. A five-pole low-pass filter at the output reduces the harmonic content to an acceptable level.

Control Circuits

Transmit/receive switching, keying cir-

[†] Part 1 of this article appeared in *QST*, Dec 1990, pp 44-47.

[7] PC boards and kits of parts for this project are available from A&A Engineering, 2521 W LaPalma, Unit K, Anaheim, CA 92801, tel 714-952-2114.

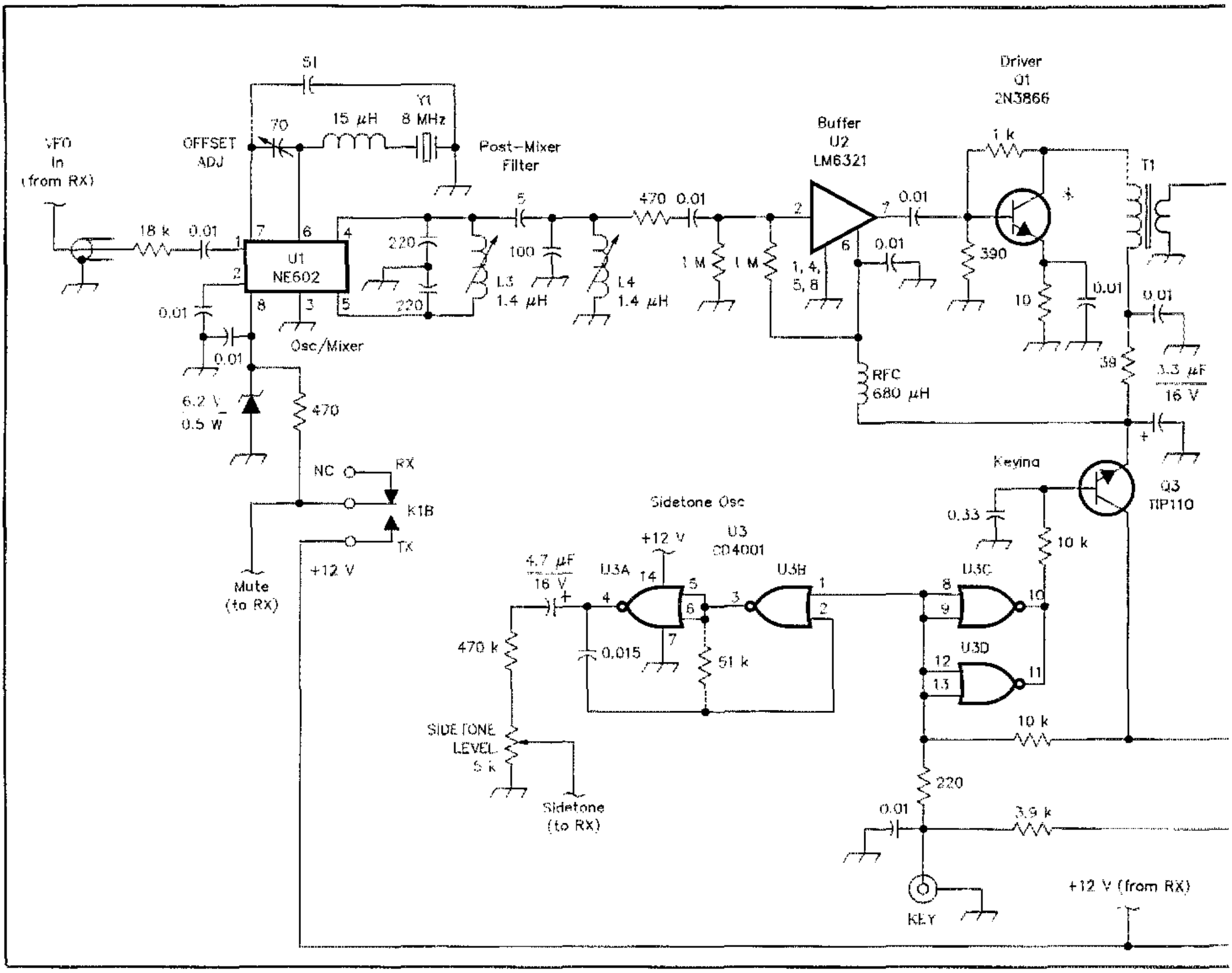


Fig 3—Circuit diagram of the transmitter (values shown are for 20-meter operation). See the text for information on winding the inductors.

cuitry and the sidetone oscillator are all on the transmitter board. TR switching is done by keying a 2N3906 transistor (Q4), which drives an RC network through a blocking diode. The rapidly charged RC network turns on Q5, pulling in the TR relay. The discharge time of the RC network is controlled by a trimmer pot, **DELAY**, that you can set for the desired hold-in time. The relay is a small DIP-outline DPDT unit. One set of contacts switches the antenna and the other feeds power to U1 and the receiver-muting circuit.

Keying begins with two sections of a 4001 CMOS quad NOR gate (U3). Its 12-V output drives a TIP110 Darlington power transistor (Q3) that switches dc to U2 and the 2N3866 driver stage. A series-R, shunt-C network to ground from the keying transistor's base shapes the keyed waveform. A photo of the rig's keyed output is shown in Fig 4.

The sidetone is generated in U3A and U3B, which form a keyed square-wave oscillator. I chose components that yield an 800-Hz note with a 12-V supply, which assists in zero-beating incoming signals. Some variation in pitch occurs with different 4001s and changing supply voltage. The oscillator's high output level is attenuated by a 470-kΩ resistor in series with the 5-kΩ **SIDETONE LEVEL** control.

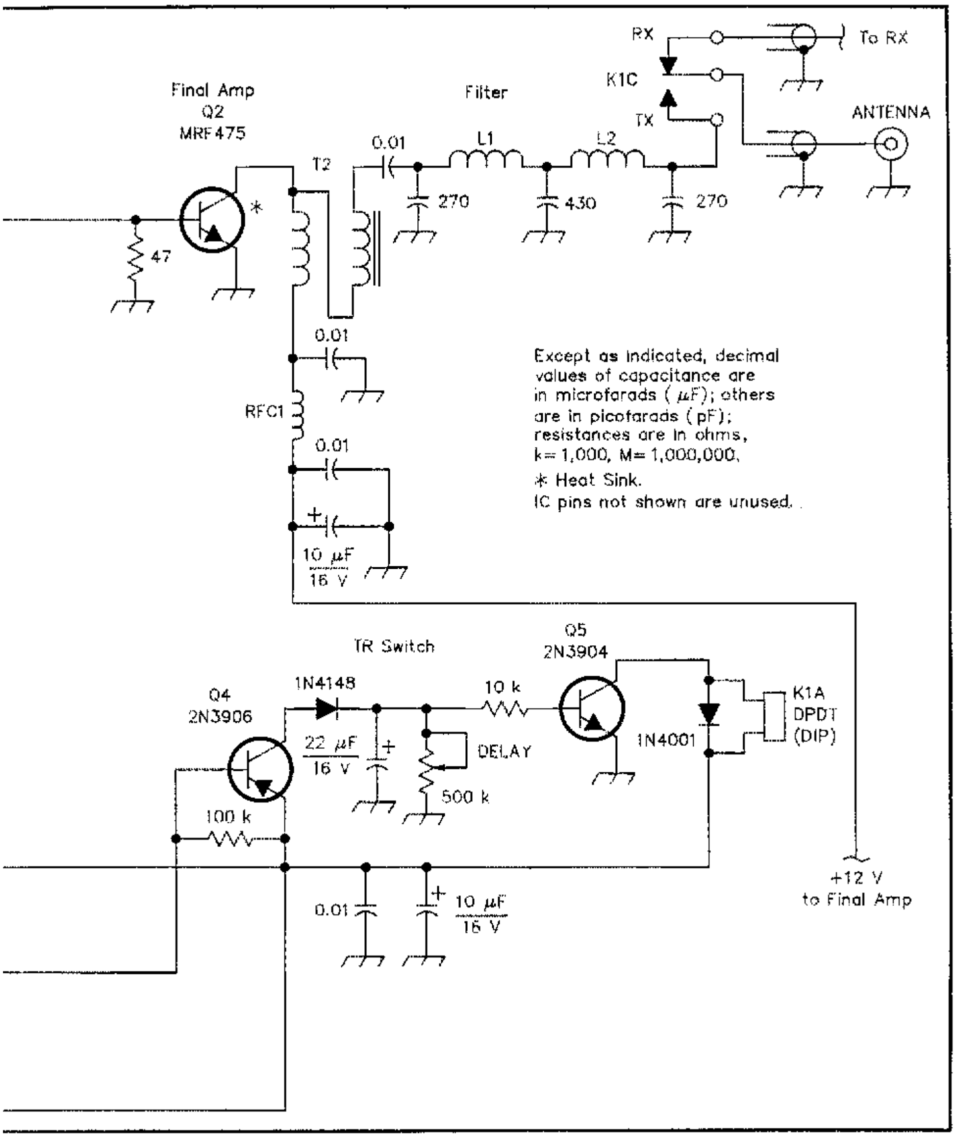
Coils and Transformers

The transmitter uses five inductors. Wind the driver-output transformer (T1) on a 43-material, ¼- × ¼-inch, two-hole balun core. The primary consists of three turns of no. 28 wire (the wire passes three times through each of the core's two holes). The secondary is a single turn "hairpin loop" of no. 24 wire. The power-amplifier RF choke (RFC1) is made of three turns of no. 24 wire on a large 73-material ferrite bead. The output transformer (T2) has eight bifilar turns of no. 28 wire on an FT-37-43 ferrite toroid. The two coils in the low-pass filter are identical: Each has 12 turns of no. 24 wire spaced evenly over the circumference of the T-37-2 powdered-iron toroid cores.

Construction

Transmitter assembly is straightforward, using common through-hole PC-board construction. As with all RF circuitry, keep component leads short and make good solder joints. A single-sided PC board with plenty of ground-plane area, combined with a compact but uncrowded layout, assures good stability.

The order of assembly is a bit more important with the transmitter than the receiver, as some larger components are used in the transmitter. Install U3's socket and the 0.01-µF bypass capacitors first. The driver- and final-stage output transformers, low-pass filter coils and ferrite-bead RF choke should go in next. The crystal, resistors, other capacitors and diodes can then be placed on the board. Then install the relay and shielded coils. You can solder in



Except as indicated, decimal values of capacitance are in microfarads (µF); others are in picofarads (pF); resistances are in ohms, k=1,000, M=1,000,000.
* Heat Sink.
IC pins not shown are unused.

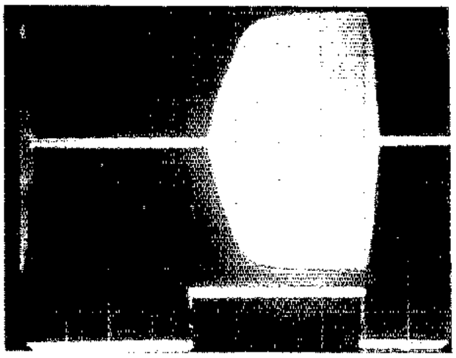


Fig 4—The QRP transceiver's keyed waveform. The upper trace is the RF envelope; the lower trace is the key closure. Each horizontal division is 5 ms. The transceiver was being operated at 6 W output.

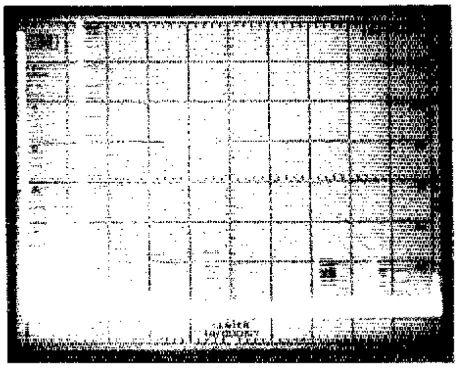


Fig 5—Spectrum analyzer display of the QRP transmitter's output. Horizontal divisions are each 10 MHz; vertical divisions are each 10 dB. Output power is approximately 6 W. All harmonics and spurious emissions are at least 42 dB below peak fundamental output. The transceiver complies with current FCC specifications for spectral purity for equipment in this power-output class and frequency range.

the connector pins for the power, antenna and control lines at any time.

Finally, install the transistors and ICs. For best performance, the NE602 and LM6321 should be soldered directly to the board—don't use sockets. The 2N3866 (Q1) uses a finned radial heat sink and should be mounted about 3/16 inch above the board to clear the surrounding components. The heat-sink fins should straddle the emitter-bypass capacitor. Solder Q2's heat sink into place, then mount the MRF475 to it with a mica insulator and heat-sink compound. After you've mounted and checked the device for shorts, solder in and trim the transistor leads.

Mount the board in the case on metal standoffs at each of its four corners. Like all transmitters, the board needs to be well-grounded to ensure stability. Most of the wires interconnecting the transmitter and receiver sections can be routed under the PC boards for neatest layout.

Alignment

An oscilloscope is the preferred test equipment for transmitter adjustments, but you can get satisfactory results with just a power indicator, such as a wattmeter or an RF-voltage probe. Begin checkout with the separate +12-V power to the final amplifier *disconnected.*

Keying the rig should mute the receiver and enable the sidetone. Adjust the sidetone-level control for the desired level. If the pitch is too high or low, increase or decrease the value of the 51-kΩ resistor between pins 2 and 3 of U3.

Temporarily disconnect the muting line. Keying should now produce two tones: the sidetone and the beat note between the receiver BFO and the transmitter-mixer crystal. Adjust the trimmer on the transmitter crystal to match the tone pitches as closely as possible. Reconnect the mute line.

If you have access to an oscilloscope, hook the probe to pin 7 of U2. With the transmitter keyed, adjust the two coils (L3 and L4) following the mixer for maximum level and the cleanest waveform. If this is not a smooth adjustment, make sure that all the components are installed with the shortest possible leads and that all solder joints are good. Repeat with the scope across the final-amplifier base resistor. (If you don't have an oscilloscope, move to the next step.)

Connect the power lead to the final amplifier. If possible, monitor the current in the supply lead to the rig. If you aren't using an oscilloscope, key the rig and adjust L3 and L4 for maximum power output. The peak may be quite broad, so adjust them carefully for the exact peak. The rig should draw between 0.8 and 1.25 A from

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equipment, but it is possible.

If you suspect your radio is overdeviating and you have an external microphone gain control, you're in luck. If there's no external control, consult the manual—there may be an internal control. If there's no internal control, you can use the TNC's internal AFSK level control.

After you've determined a method for adjusting the audio level between the TNC and your radio, consult the TNC manual for the audio-level calibration procedure. This involves putting the TNC in CALIBRATE mode and adjusting the audio level while you listen to the transmission (into a dummy load!) using your monitor receiver. Adjust the audio level until the transmitted audio just stops sounding louder, then reduce the audio level until the transmitted audio just starts to sound softer.

Conclusion

Packet radio is a lot of fun, and setting up your first station doesn't have to be difficult. I haven't covered a lot of the hardware variations you may encounter—all the possible combinations would fill at least one book! The ARRL publishes an excellent book, *Your Gateway to Packet Radio* by Stan Horzepa, WA1LOU, that covers these topics in more detail, and also provides a wealth of other information about packet radio. (See Stan's column Packet Perspective elsewhere in this issue.)

As with any Amateur Radio activity, your best resource is your local ham community. If you don't know anyone in a local club, drop a line to ARRL HQ and ask for information about clubs in your area. Shared experience from another "packeteer" can be worth a lot of reading and experimenting on your part.

Read your equipment manuals. There's a lot of information in the AEA PK-88 manual (so much that it may seem intimidating at first) but I learn something new every time I look through it.

Finally, spend a lot of time monitoring the packet channels. You'll pick up operating tricks from the other users. Packet isn't like any other operating mode; it may take a while to get the hang of it, but I know you'll have fun.

Thanks to Kenwood, ICOM and AEA for lending me the equipment used while writing this article.

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a 12.0-V supply, generating 3 to 8 W output. Output can be trimmed for best efficiency by squeezing and spreading the turns on low-pass filter coils L1 and L2 (this changes the impedance match). Output level can be adjusted by changing Q1's emitter resistor.

Transmitter Performance

The transmitter typically keys smoothly, with no significant shortening of the first dot. The sidetone is adjustable from quiet to earsplitting, and the TR turnaround can be set between near QSK and a sizable fraction of a second. Through many hours of operation, including contesting, I haven't experienced any glitches in operation.

Even when I've asked for critical reports, the on-the-air reports I've received have been good. The only difficulty has been erratic performance when the rig is operating into a high-SWR antenna. The stray RF that floats around under such conditions seems to create problems. No such problems occur when the rig feeds antenna systems with SWRs of 1.5:1 or better. Some antennas with 2:1 SWRs have worked well with the rig, but others have not.

The transmitter's spectral purity meets FCC requirements, as shown in Fig 5.

Conclusion

One lesson I learned from designing and building this rig is that home-brewing HF Amateur Radio equipment may be easier now than at any time in the past 20 years. Designing tube-type equipment was pretty straightforward, but in the years between then and now, working with individual transistors and discrete components was a lot for most radio amateurs to handle. Fortunately, integrated components and increasing familiarity with solid-state devices in general are making home-brewing more practical.

I'd like to thank my fellow members of the Arapahoe Radio Club for encouraging me to refine the design and construction of this rig into a reproducible form. Otherwise, it probably would have remained a one-time project. (Of course, I would have had a lot more spare time for other projects over the last year, too!) I hope you build and enjoy this little transceiver!

Gary Breed was first licensed at 12, in 1961, as WN9AYP. His first successful Amateur Radio construction project was a screen modulator to put his Knight T-50 on AM when he received his General ticket a year later. He has held an Extra Class license since 1971, and received his current call sign in 1977.

Gary is Editor of RF Design *magazine, a technical journal for design engineers, and supervises the editorial staffs of two other trade magazines. He is past president and Field Day Chairman of the Arapahoe Radio Club, many-time Field Day class 2A/3A champions, and is also active with the Mile High DX Association. Gary enjoys contesting (QRP and QRO), chasing DX and taking the portable rig described here on outings in the Rockies.*

New Products

VHF/UHF GROUNDPLANE ANTENNAS

☐ The Cellular Security Group offers three groundplane antennas based on a design in *The ARRL Handbook.* The elements of these rugged, preassembled antennas for the 144, 220 and 430-MHz bands are made from stainless steel, and the SO-239 feed points are protected from weather by a 6-inch PVC-pipe sleeve that doubles as a mounting mast. Price: all models, $29.95 postpaid in the continental US. (Massachusetts residents: Add 5% sales tax.) Options: 36-inch PVC-pipe mast, $5; N connector, $5. Antennas for other frequencies are also available. Cellular Security Group offers a product-lifetime money-back guarantee. For more information, contact Thomas Bernie, K0TB, Cellular Security Group, 4 Gerring Rd, Gloucester, MA 01930, tel 508-281-8892.—*NJ2L*

ROTATOR CONTROL-LINE PROTECTOR

☐ PolyPhaser Corporation, manufacturer of 450 lightning- and EMP-protection products, has introduced an EMP-rated protector for rotator control lines. Accepting and individually protecting up to eight lines, the model IS-RCT protects rotators and their control boxes. The IS-RCT is mounted in a water-resistant aluminum enclosure with bronze clamps and is designed for mounting on ½- to 2¼-inch tower legs.

Each protection circuit has a 35-V dc activation voltage and clamps spikes of up to 2000 A in 4 ns. Prices: IS-RCT-J1 (½- to 1¾-inch tower legs), $49.95; IS-RCT-J2 (1½- to 2¼-inch tower legs), $52.95. Manufacturer: PolyPhaser, PO Box 9000, Minden, NV 89423-9000, tel 800-325-7170 or 702-782-2511.—*NJ2L*