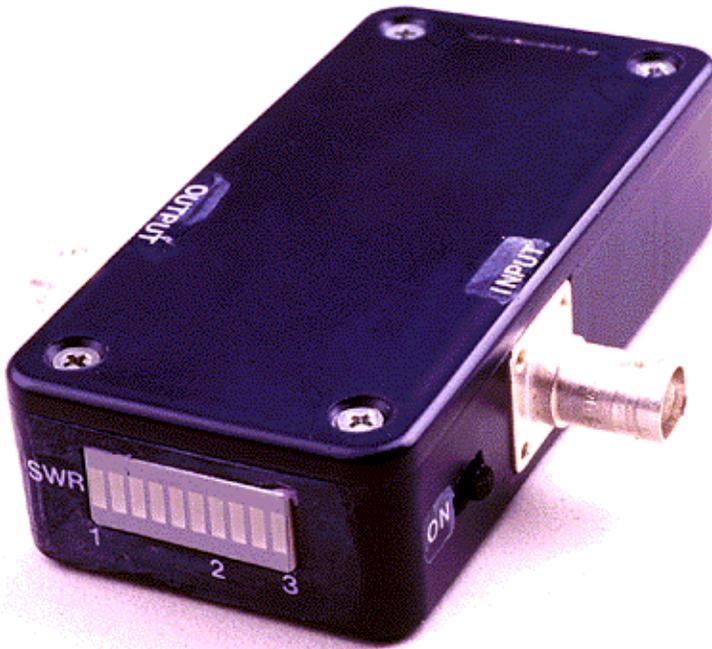# A Pocket-Size, Direct-Reading VHF SWR Meter

## This easy-to-build LED bargraph SWR meter goes with you anywhere.

By Bill VanRemmen, KA2WFJ

Here's a little SWR indicator that uses an LED array as the readout. Its microstripline directional coupler feeds a sample of the feed-line's forward and reflected waves to an LM3914 dot/bar display driver. [1] The driver lights an LED whose physical position in the array is proportional to the ratio of the forward and reflected signals. The uppermost LED lights when the SWR is 3:1 or higher, improving resolution in the lower SWR range. Microstripline design allows this circuit to be used at VHF and possibly higher.

General Description

This metering circuit uses an LM3914 (see **Figure 1**) with the forward voltage applied to the top of its internal resistive-divider network where the reference signal is normally applied. The reflected voltage is applied to the signal-input pin. Therefore, the display indicates the *ratio* of the two signals instead of their magnitude. Because the LM3914's internal divider network has a total resistance of 10 kΩ, an external 10-kΩ series resistor (R1) causes one-half of the forward voltage to appear at the top of the divider network, yielding a full-scale reading when the reflected voltage equals one-half of the forward voltage. This is equivalent to an SWR of 3:1. Indications higher than this are usually not instructive in amateur work beyond knowing that the SWR is much too high. If SWR measurements above 3:1 are desired, replace R1 with a jumper wire and recalibrate the markings on the front panel.
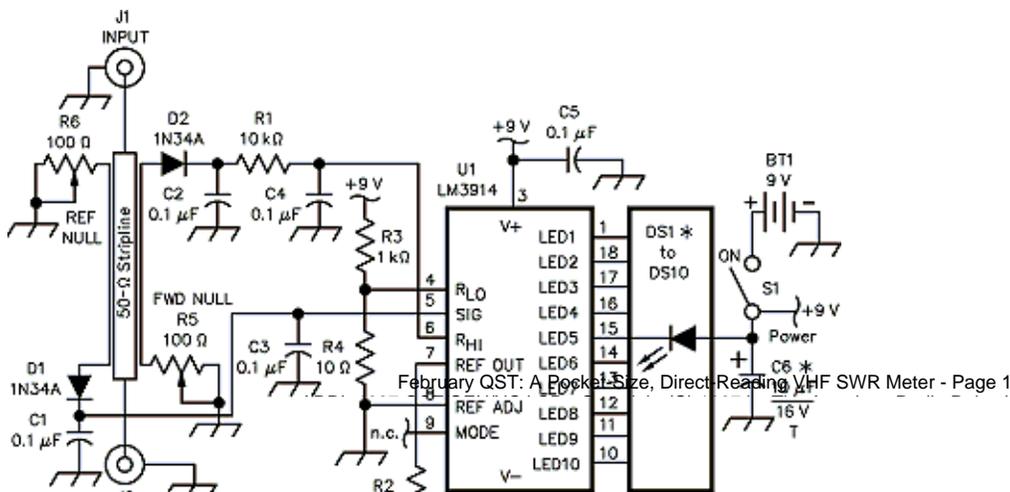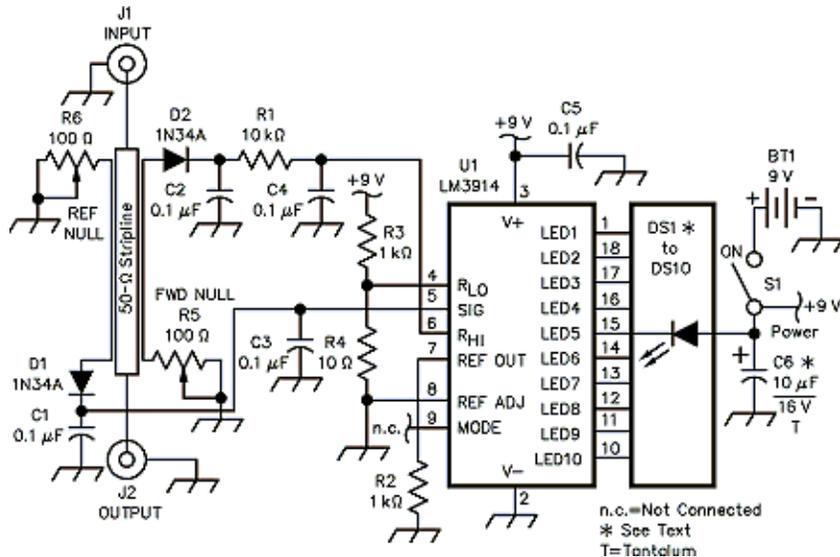
Figure 1—Schematic of the LED bargraph SWR meter. Unless otherwise specified, resistors are $1/4$-W, 5%-tolerance carbon-composition or film units. Suppliers key: DK= Digi-Key Corporation, 701 Brooks Ave South, Thief River Falls, MN 56701-0677, tel 800-344-4539; N=Newark Electronics, 4801 N Ravenswood Ave, Chicago, IL 60640-4496, tel 800-281-4320; RS = Radio Shack.

D1, D2—1N34A germanium diode; (RS 276-1123); see text

DS1-DS10—Individual LEDs, or a single 10-segment, tri-color LED bar graph (N 87F1693; this unit has separate anode and cathode connections for each LED); see text

J1, J2— UG-290A/U BNC connector; N 50F1443; DK ARF1062)

R5, R6—100-W trimmer potentiometer; see text

S1—SPST toggle or slide switch

U1—LM3914 dot/bar display driver

Misc: 18-pin DIP socket; 9-V battery clip; enclosure (Radio Shack 270-220)

R3 and R4 form a voltage divider that raises the voltage at the bottom of divider network to approximately 90 mV. This counteracts a slight offset voltage found at the input of the LM3914's signal buffer.

The LED array can be a single bar graph or a stack of 10 rectangular LEDs glued together. I suggest you use a multicolor array connected so that the green, yellow and red LEDs show low, medium and high SWR, respectively. Bar graphs have an advantage over homemade arrays in that the light from one LED segment does not leak into adjacent segments. Be certain that when the cathode connections are attached to the IC, the anode leads are above the component side of the board and that the first LED (probably a green one) is connected to pin 1.

Construction

The microstripline directional coupler is made of a sandwich of two PC-board sections (see **Figure 2**). When constructed on a double thickness of $1/16$-inch glass-epoxy PC-board material, the 0.22-inch-wide strip presents a 50-Ω impedance. Two fine-wire pickup loops run between the strip and the groundplane.
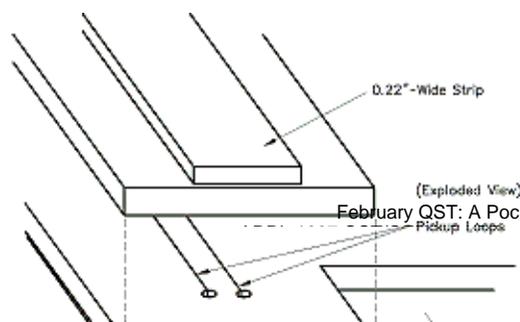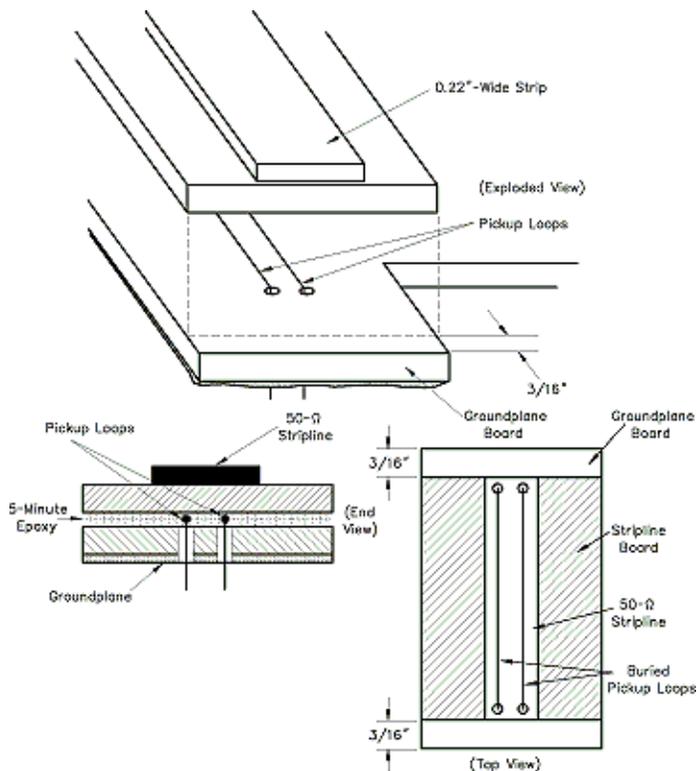
Figure 2—Assembly of the directional coupler PC-board elements.

The pick-up wire ends are terminated on the solder (foil) side of the board (see **Figure 3**) by 1N34A *germanium* (not silicon) diodes, 0.1-µF monolithic bypass capacitors (both items are available at Radio Shack) and (temporarily) by small 100-Ω trimmer potentiometers. Each pickup loop has a trimmer pot at one end and a diode-capacitor pair at the other. The trimmer pots are used to match the impedance of the pickup loop and are later replaced by suitable fixed-value resistors after the proper resistance value is determined.
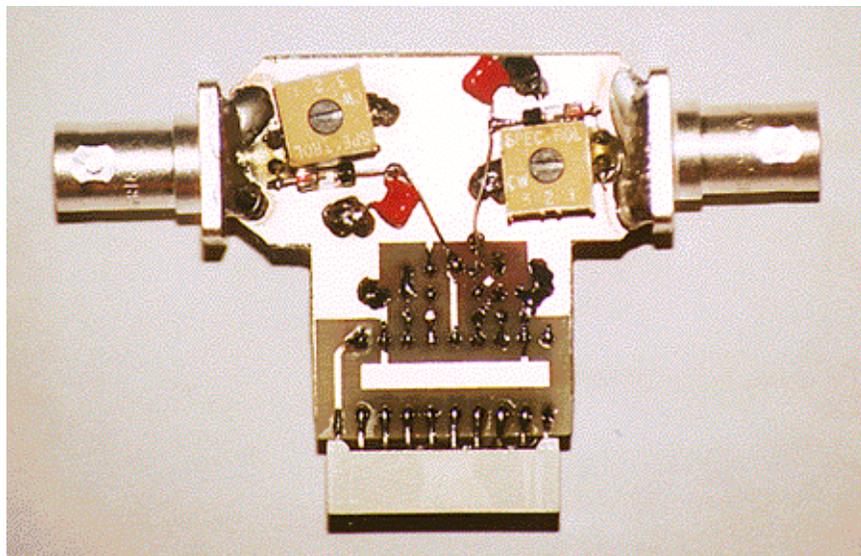

Figure 3—A close-up of the SWR meter subassembly before installation in the enclosure. The two rectangular objects behind each BNC connector are potentiometers that are replaced by fixed-value resistors (see text). Photo courtesy of Bill VanRammen, KA2WFJ.

Etch the circuit on $1/16$th-inch-thick (0.0625-inch) FR-4 or G-10 glass-epoxy board. This material has a dielectric constant of 4.6, so a 0.22-inch-wide strip with a separation of $1/8$ inch (0.125 inch) from the groundplane yields a characteristic impedance of 50 Ω. Drill all holes for component leads with an appropriately sized bit (a #65 works well). Center the holes for the pickup wires in the relief holes and drill them with a very fine bit so that they're just large enough to pass the wire. A #80 bit works well for #30 and smaller wire.

Once the pickup-loop holes are drilled, lay a steel ruler (or other straight edge) on the nonfoil side of the lower board and use a hobby knife to scribe grooves between the sets of pickup-loop holes. These grooves help the wire to lie straight when the PC-board sandwich is assembled.

Cut two 4-inch pieces of #30 or finer bare wire. Use bare wire—not enameled—because stripping enamel off the ends of these wires once they have been glued in place is likely to break them and ruin the board. You can use #30 wire-wrapping wire with its insulation removed if you're careful not to nick and weaken the wire. Insert the ends of these wires through two of the holes so an inch or so of wire protrudes from the foil side of the board, and apply a drop of five-minute epoxy to lock the wires in place. When the epoxy has cured, put the other ends of the wires through their holes, pull the wires snug so that they lie flat on the board, and apply another drop of five-minute epoxy to the board's foil side where the wires poke through. Apply a thin film of epoxy along the grooves to help keep the wires in place. To prevent the wires from springing loose, hold them snug and straight until the epoxy sets.

After the epoxy has cured, check the wires with an ohmmeter to be sure that they're not shorted to the groundplane. If all is well, epoxy the strip board over the pickup loops. Ensure that the strip board is centered accurately over the board's groundplane section, and that the pickup loops are directly under the strip. Use enough epoxy to guarantee a good bond, but not so much that the boards float or are separated appreciably.

The (upper) strip board is $3/8$ inch shorter than the (lower) groundplane board. This provides clearance for the BNC connector dielectric and aligns the connectors to place them directly in an "end-fire" configuration. Be sure that the length of exposed groundplane board is the same at each end.

Measure and match the forward voltage (VF) of the diodes you intend to use. This voltage should range between 0.2 and 0.3 V; the lower the better. Most modern multimeters can measure this voltage directly. The Radio Shack 1N34A diodes are sold as a package of 10; sort through them to find two that have a very close V_F. Be certain to get diodes with a clear-glass body and a black cathode band. Radio Shack "1N34A-type" diodes with opaque green or black-glass bodies tend to have widely varying forward voltage drops. If you intend to use this circuit at UHF or higher, consider replacing the 1N34As with diodes more suitable for use at those frequencies.

Assemble the pick-up section diodes, capacitors and trimmer potentiometers on the *foil* side of the main board and bring the diode leads to the rectangular pads (see **Figure 3**). The REFLECTED voltage pad is connected directly to the LM3914; the other pad is the FORWARD voltage connection. Be sure to ground the unused end and wiper connections of the trimmer pots.

Place the rest of the parts on the component side of the board. Use a socket for the LM3914. Pay particular attention to the LED-array polarity. Connect the cathodes of the array to the IC's board pads; the anode pins should rise above the component side of the board. Using a piece of bare wire, connect all the anode pins together; this is the LEDs' positive connection. Run a short piece of hook-up wire from this bus wire to the PC-board's +9-V pad. Connect the 9-V battery positive lead through ON/OFF switch S1 to the LED bus wire and attach the battery's negative lead to the board's groundplane at a convenient point. Connect a 10-µF tantalum capacitor between the LED bus wire and the board groundplane. During testing, I found this capacitor addition helpful and, although it's not absolutely necessary, it does help to keep the unit from reacting to stray RF currents. I recommend its use.

R2 sets the current for each of the LED segments at 12.5 mA. If this is not acceptable, the formula:

$$I_{LED}(mA) = 12.5 \div R2 \hspace{4cm} \text{(Eq 1)}$$

can be used to select another resistor value.

The PC board fits snugly into a Radio Shack 270-220 plastic box. I used 4-hole flange type BNC connectors. Other connectors should work so long as they have a $3/16$-inch spacing between the back of the flange and the point at which the center terminal exits the dielectric. The neck between the flange and the dielectric must be cut away parallel to one side of the flange (see **Figure 4**) so that the connector's dielectric lies flat against the substrate of the groundplane board when the flange is soldered to the groundplane. A hobby tool with a cut-off disk works well for this, but a hacksaw or a file can be used.
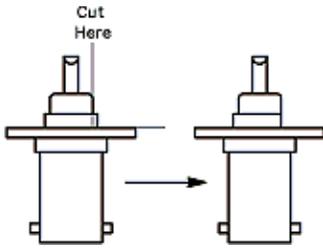
Cut
Here

Cut
Here
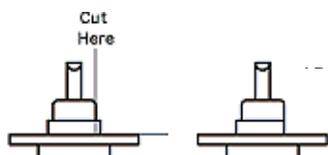
Figure 4—The metal neck at the back of the BNC connectors must have a section cut away to allow the dielectric to lie flat against the substrate of the groundplane board.

Solder the center terminal of each BNC connector to an end of the stripline, making sure that each connector's barrel points straight out from the stripline, and that the flanges press flush along the edge of the groundplane board. Run a fillet of solder between the groundplane and each connector's flange. Heat each connector sufficiently so that the solder wets to the metal to avoid a cold solder joint.

Using a nibbling tool, X-acto knife, hacksaw blade, file, or other appropriate tool, cut two $^{11}/_{16}$-inch square holes in the box to accept the BNC connector flanges. These holes allow the BNC connector flanges to slide snugly into the openings so that the metal of the connectors exactly replaces the plastic that was removed. Center these holes between the first and second sets of the box's internal PC-board guides at one end of the box, and open the holes at the top. If this is done properly, the square flanges will prevent the connectors from turning, and the pressure of the PC board against the inside of the box prevents lateral movement. This way, the board is held snugly in place without the need for mounting screws or glue. Some trimming of the PC-board corners may be necessary to permit the board to clear the box's internal PC-board guides and seat properly.

The box end closest to these holes is the front panel. If there are any blemishes in the case, plan the box orientation so that they are cut away or hidden. In the front end of the box, cut a rectangular hole to the exact dimensions of the LED array. Center this hole vertically and horizontally and make it a snug fit for the array to prevent it from moving about. In a convenient place, make a hole for the ON/OFF switch. Because the LED array and ON/OFF switch can be anything you have on hand, several factors determine the exact hole dimensions and positions for these parts. An inside view of the finished SWR meter is shown in **Figure 5**.
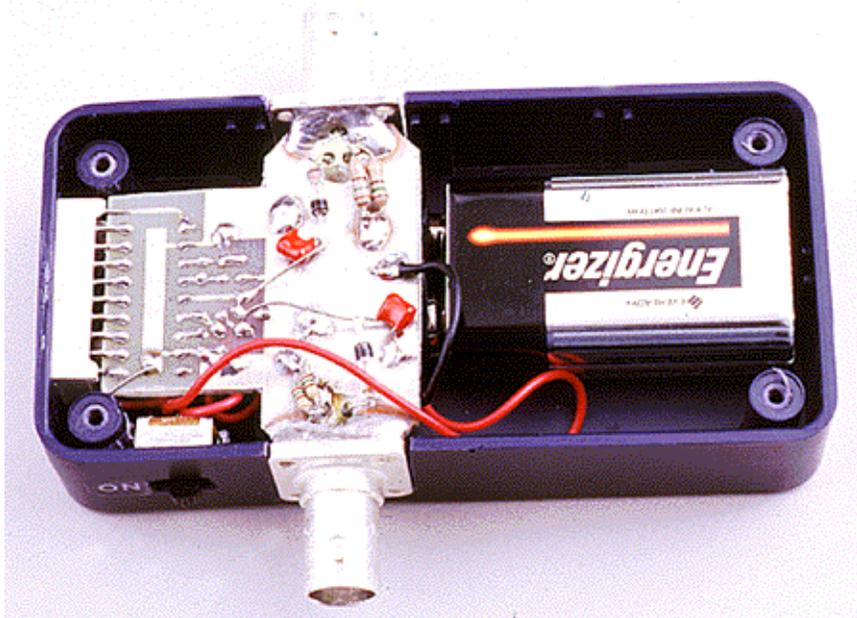

Figure 5—An inside view of the directional coupler discloses neat and compact assembly. In this prototype, two pairs of parallel-connected 150-W, $^1/_8$-W resistors replace trimmer potentiometers R5 and R6. Modified BNC connectors are held in rectangular slots cut in opposite sides of the box. A rectangular cutout in the front of the box secures the 10-LED bargraph. Between the front of the box and the INPUT BNC connector, a small rectangular slot accommodates a miniature ON/OFF

slide switch. Photo courtesy of Bill VanRammen, KA2WFJ

Adjustment

The BNC connector closest to the diode connected to the forward-voltage pad is the INPUT to the SWR meter (J1). The other connector is the OUTPUT (J2). Connect a 50-Ω nonreactive load through a short piece of 50-Ω coax to J2. Attach a high-impedance voltmeter to the reflected-voltage wire, and the output of your transmitter to the INPUT connector. While observing the reflected-voltage reading, apply power (at least 1 W at 2 meters). Adjust trimmer pot R6 near the INPUT connector (attached to the reflected-voltage pickup loop) until a voltage minimum is found. This is the match point for that loop. Reverse the transmitter and load connections and null the forward-voltage pickup loop with the other trimmer pot (R5). The adjustments should be noninteracting, but a couple iterations won't hurt.

Measure the resistance of the potentiometers and replace them with fixed-value resistors equal to the measured value. If you used 30-gauge wire, the resistance measured should be about 75 Ω. Two 150-Ω $^1/_8$-W resistors in parallel work well if single 75-Ω resistors are not available. Also, be certain to use *matched resistors* so that the resistance at the ends of the pickup loops is the same; otherwise, the meter will not be accurate. As with the diodes, it is best to measure the resistors and match them to within 0.5 Ω or better.

Take care when soldering and removing components attached to the pickup loops! If one of the wires breaks, the board will be ruined. If water-soluble flux solder (such as Hydro-X) is used, thoroughly deflux the board in a stream of very hot tap water. The residue from this flux is slightly conductive and mildly corrosive. It must be removed completely.

Press-on labels can be used to mark the LED segments with SWR values; **Table 1** shows the relationship. A coat of clear spray lacquer or nail polish helps protect the labels from damage.

Table 1—SWR Indication of each LED in the Array

LED	SWR
1	1.105
2	1.222
3	1.353
4	1.500
5	1.667
6	1.857
7	2.077
8	2.333
9	2.636
10	3

It's Ready to Go!

To use this SWR meter, simply connect your transmitter to the INPUT connector and the feed line to your antenna to the OUTPUT connector, turn on the meter and key your transmitter. Since there is no protection circuit in this design, keep the transmitter power low. A minimum of 1 W at 2 meters is recommended to provide a usable reading, and 25 W hasn't caused damage, though I recommend against using this circuit at higher power levels. No LED segments will light if the line is flat (1:1 SWR).

There is no "power-on" indicator in this circuit, although one could be added. Turning off the power when the unit is not in use extends battery life, although the LM3914 draws less than 10 mA when no LED segments are illuminated.

Summary

A *Postscript* file for the PC-board layout is available on the World Wide Web. [1] You are encouraged to make this file available to others. Be sure to print this board so that the lettering is legible when looking at the traces on the finished board. To accommodate different board-printing methods, right-reading and mirror-image versions are included. Use whichever one works with your process. A PC-board pattern designed for installation in a pager enclosure (now available from Radio Shack by special order, RSU 11453495) is included in the *Postscript* file if you prefer to use that case.

At the age of five, Bill VanRemmen, KA2WFJ, was given an Erector set, and has been playing with batteries, wires and things

ever since. First licensed in 1984 while attending the University of Rochester, he spent far too much time in the URARC Shack (K2ZWI), but still managed to earn a BS in electrical engineering. He was encouraged over the years by his parents, Bill Sr and Ruth; his uncle David Bell, WB2YCS; and his college Elmer, George Molnar, KF2T. Bill currently resides at 104 Mitchell Ln, Hamlin, NY 14464, with his wife Jennifer and three cats. You can reach Bill by e-mail at **billy@frontiernet.net**.

Notes

[1]The PC-board file for this project (MINISWR1.PS) can be retrieved from the author's Web site at **http://www.frontiernet.net/~billy/miniswr1/miniswr1.ps**, by ftp from **oak.oakland.edu**, dir **pub/hamradio/arrl**, and is available on the ARRL BBS: 860-594-0306. A PC-board template package is available for $2 for members, $4 for nonmembers. Send your request for the VANREMMEN MINISWR1 TEMPLATE to the Technical Department Secretary, ARRL, 225 Main St, Newington, CT 06111-1494.