By Bob Reif, W1XP, Ralph Swick, KD1SM, and Stan Pozerski, KD1LE

The NVARC FoxFinder

Fox hunting is fun! This FoxFinder is a modern way to locate hidden two-meter transmitters. It's a project you can easily build yourself.

If you're active on 2 meters, you've certainly heard about "fox" (hidden transmitter) hunts. You may have even participated in them. Have you read Pete (N9SFX) Ostapchuk's article describing the fun you can have chasing foxes?[1] If so, you know something about the thrill experienced when you find that elusive fox, be it a person sitting in seclusion with an H-T, or a miniature automated fox disguised as a part of the natural landscape. Even if you don't dream of someday becoming an international athlete and representing your country in the Amateur Radio direction-finding competitions,[2] you can still combine an enjoyment of the outdoors with the thrill of a little friendly competition and the pleasure of exploring a nearby park or forest in search of a fox. The sport of fox hunting has practical spin-offs, too, as when you need to find a transmitter that's causing problems.

Anyone can find a hidden transmitter with an H-T and a portable Yagi and using body-fade techniques, but when you get close to the fox, simple equipment lets you down. H-Ts overload and body-fade techniques, even without an antenna on the H-T, can produce confusing results. In addition to receiver overload, signal reflections from buildings, trees and hills can lead you astray. Our Nashoba Valley Amateur Radio Club (NVARC) FoxFinder turns those last few hundred yards from a nightmare into a pleasure. If you're an active fox hunter, or are thinking about adding this skill to your list of accomplishments, you *need* the FoxFinder. It's a simple project, one you'll enjoy building!

Background

Several clubs in our central Massachusetts area regularly hide small, automated foxes. These foxes transmit a short message in voice or CW every three to five minutes. The transmitter our club uses is typically hidden in forests and conservation land, places in which you can be quite close to the fox and not see it. These are freestyle hunts—you can hunt alone or with a group. You also have the option to hunt whenever you want.

Over the years, many "sniffer" devices were designed to aid in locating hidden transmitters. We have used or observed many sniffers in action and found them lacking. Some designs have too many controls and require time-consuming adjustment during the hunt. Others have meters that are difficult to monitor as you stumble through the underbrush. Most designs lack the dynamic range to cover the last few hundred feet; others overload when close to a 5-W transmitter.

We were looking for a club project and fund-raiser. We wanted a small project that members could have fun assembling as a bag-of-parts kit. With these objectives in mind, we intensified our search for a suitable sniffer.

Designing a Sniffer

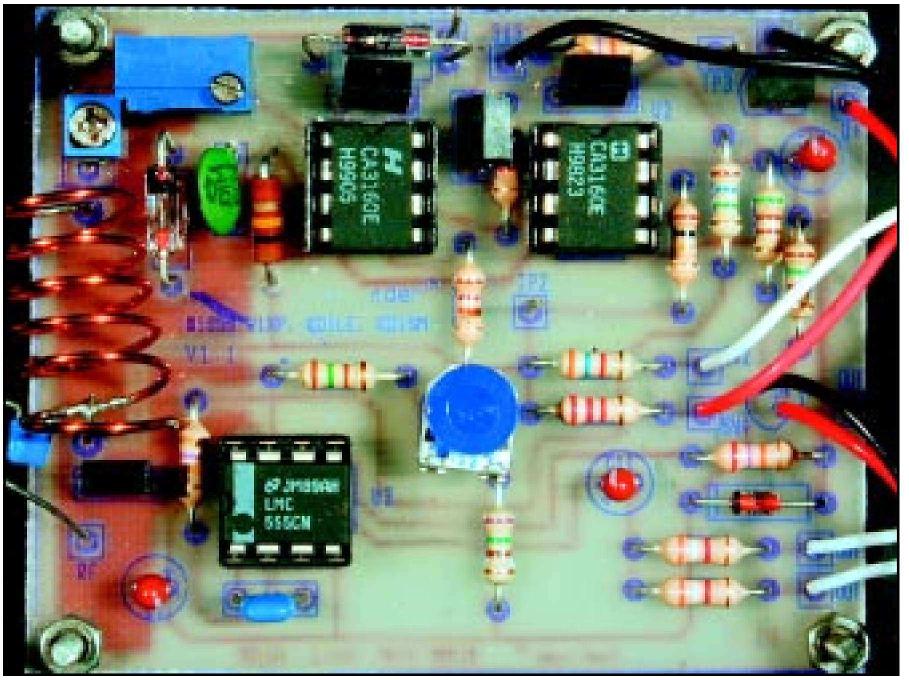
One Saturday afternoon after a morning's fox hunt, we were having lunch at a local fast-food emporium, lamenting for the umpteenth time that we'd once again spent a lot of time on the last few hundred feet of the hunt because we lacked a good sniffer. At that moment, we decided to either improve one of the existing sniffer designs or devise one of our own. On a napkin, we listed the requirements we considered necessary in a satisfactory sniffer.

It had to be shirt-pocket size; that was on everybody's list. After some discussion, we decided to use an audible tone instead of a meter or LEDs as the signal-strength indicator; we wanted our eyes free to watch for other things—such as tiny transmitters! Besides, a meter would add to the project cost and LED displays use precious power and are difficult to read in bright sunlight. We wanted a minimum of controls that might get bumped out of adjustment while running through the woods. We even rejected the idea of a volume control. We opted for headphones instead of a speaker, both for privacy when hunting in a group and for extending battery life. The sniffer's usable range was a very important issue for us; several existing designs were lacking here. We wanted a range of 1000 feet when using a hand-held 3- or 4-element Yagi and a 2-W fox. The sniffer also had

[1]Notes appear on page 39.

to work with the same antenna at a distance of a couple of feet from the fox—some of our transmitters are quite well disguised!

After evaluating several approaches, we found a suitable RF detector that looked like it would meet the range requirement. The most difficult part was developing an interface between the detector and the audio oscillator. After building a breadboard unit, some field testing and some changes, we had a design that excited us. We chose a case size and laid out a PC board. At this point, we made a decision that changed the nature of the project. We determined that the fox-hunting community might want more than a bag-of-parts kit, especially since some of our associates are not expert scratch builders. So, we wrote an assembly/instruction manual complete with an alignment, operation and troubleshooting sections. This task proved to be bigger than we had ever imagined! Next, we developed templates for the enclosure and included photos. Then, several kits were built by other hams who critiqued the kit and the instructions. That led to PC-board and instruction-manual changes and the final products.



A completed PC board ready for installation.

The Result

How well does the FoxFinder work? Well, using a 4-element portable Yagi, foxes with power levels of 300 mW to 2 W can be detected within 500 feet and frequently at greater distances, depending on terrain and vegetation. The 1000-foot goal is achieved in open areas. Typically, if you have a no-antenna signal on your sensitive 2-meter H-T, the FoxFinder can detect the signal with the Yagi. Once you can hear the signal with the FoxFinder, you can follow the signal in the direction of the highest-pitch tone. The typical fox transmission we use is 30 seconds or less, but by rotating a handheld 3- or 4-element Yagi, you can quickly determine in which direction to move. If you're jogging down a trail, you can even tell if you're closing on the fox by the pitch change of the audio tone. If the pitch is higher, you moved in the right direction; if it is lower, you are farther away.

The FoxFinder is simple to operate. Other than the **POWER** switch, there's just one control: a three-position **RANGE** switch that gives you an indication of how close you are to the fox. You start with the **RANGE** switch in the most-sensitive position. As the tone pitch you hear increases, you move the switch to the next less-sensitive position and proceed. In the least-sensitive position, you can use the FoxFinder and a 4-element Yagi to get within several feet of a 5-W transmitter without overloading the FoxFinder. With the FoxFinder, you can literally walk right up to a hidden transmitter!

Theory of Operation

Refer to Figure 1. There are three main sections in the FoxFinder, centered on three ICs: the detector (U1), the amplifier (U2) and the voltage-controlled oscillator (VCO), U3. The circuit around U1 consists of a wide-dynamic-range detector using two 1N34 germanium diodes and a tuned circuit. U1 provides the feedback gain that compensates for the usual nonlinear behavior of the diode detector.[3] The tuned circuit provides rejection of out-of-band signals and a voltage step up. U1's input threshold is offset above ground by about 0.5 V. (The exact value of the threshold voltage is adjusted by R9 during final alignment.) The same offset voltage is applied to the second stage, U2. This "floating ground" is used to set the minimum VCO voltage described later. R12 on the offset-trim terminal of the diode detector is set during alignment to compensate for U1's input-offset voltage. The first stage is then adjusted in such a way that it compensates for the offset of the second stage. The forward voltage drops of D2 and D3 are matched at low currents to provide improved temperature stability. The resulting diode detector operates with a wide range of signal inputs from a few millivolts to about 5 V to provide the desired range performance.

U2 is a switched-gain noninverting voltage amplifier. The three gain settings are selected by the **RANGE** switch. The voltage gain is about 23 in the **MAX** range position and just over one in the **MIN RANGE** position. This divides the FoxFinder's useful range into three overlapping segments. In the most sensitive position (**MAX**), the offset voltage is adjusted by R9 and the input offset is adjusted by R12, as stated earlier. When amplified by the high gain in the **MAX RANGE** position, this output is large enough to provide a voltage to the input of the audio-frequency VCO (U3) to produce a continuous low audio tone. Note that only the offset of the input above the threshold (a few millivolts), and not the full threshold offset, is amplified by the second-stage gain.

U3 is a CMOS timer IC. The VCO control voltage is the output of U2. This voltage charges C8 through R7 and R8 until a timing threshold voltage is reached. Then the timer changes state and discharges C8 through R8 until a lower timing threshold voltage is reached. At this point, the output switches again and the charging cycle starts over. The higher the control voltage, the more quickly the RC network charges and the higher the tone frequency.

To produce audio output, the VCO-input control voltage must be above the threshold of the 555 circuit. The input offset voltage of U1 and U2 achieve this voltage level without excessive gain or extremely large input signals. In the **MAX RANGE** position, the oscillator runs continuously, so that the smallest change in detected-signal level produces a pitch change, allowing detection of weak signals. The pulse output of U3 drives the headphones through C11 and current-lim-

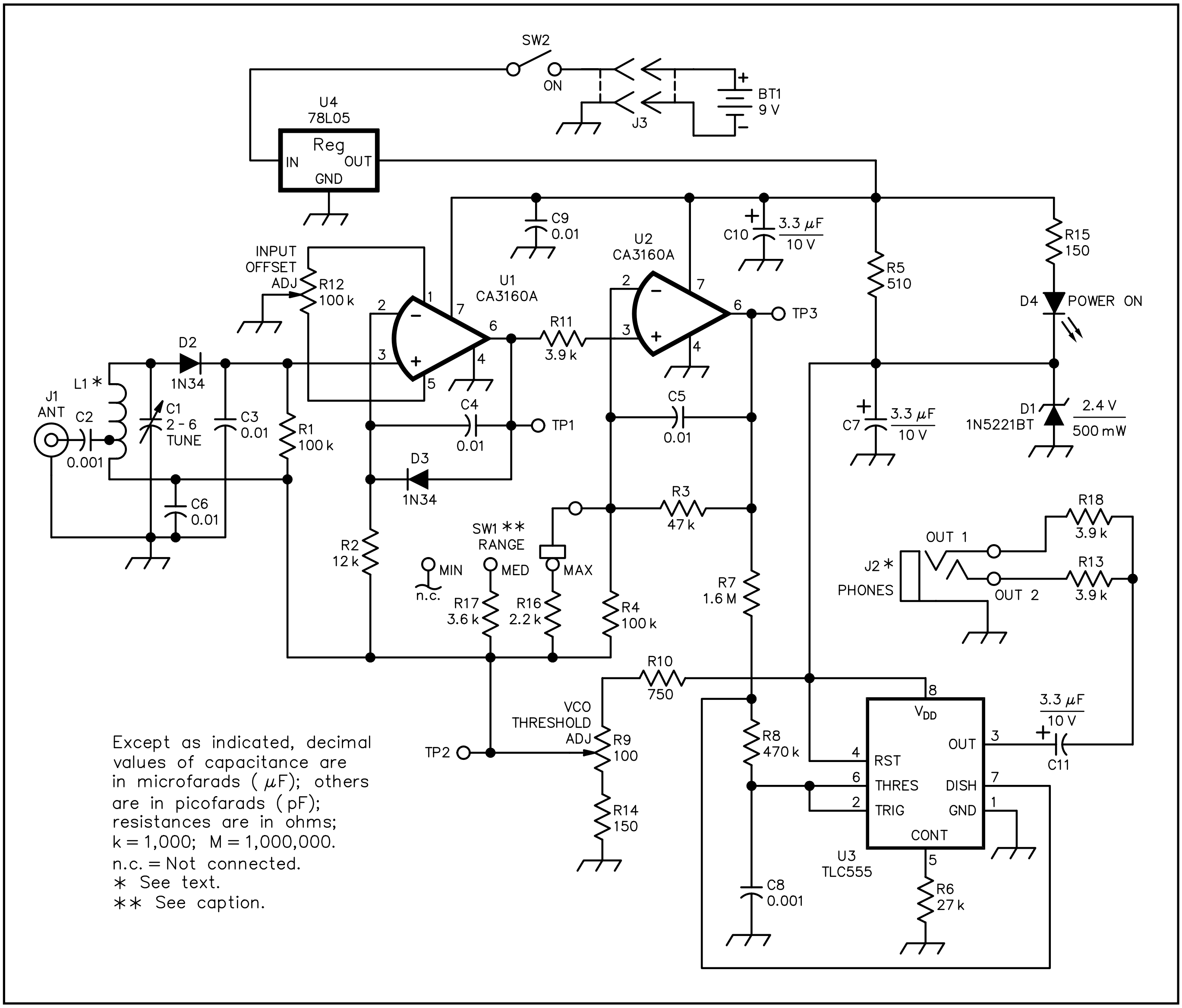


Figure 1—Schematic of the FoxFinder circuit. Unless otherwise specified, resistors are 1/4-W, 5%-tolerance carbon-composition or metal-film units. DK part numbers in parentheses are Digi-Key (Digi-Key Corp, 701 Brooks Ave S, Thief River Falls, MN 56701-0677; tel 800-344-4539, 218-681-6674, fax 218-681-3380; www.digikey.com**); RS part numbers are RadioShack (RadioShack.com, PO Box 1981, Fort Worth, TX 76101-1981; tel 800-843-7422; fax 800-813-0087;** www.radioshack.com**). Equivalent parts can be substituted; n.c. indicates no connection. (The designators for D4, SW1 and SW2 deviate from *QST* style.)**

C1—2-6-pF ceramic trimmer (DK SG1021)
C2, C8—0.001 μF, 50 V ceramic (DK P4937)
C3-C6, C9—0.01 μF, 50 V ceramic (DK P4922)
C7, C10, C11—3.3 μF, 10V tantalum (DK P2035)
D1—1N5221 2.4 V, 500 mW Zener (DK 1N5221BMSCT)
D2, D3—1N34A (RS 900-6232); component matching required, see text.
D4—Red LED (DK 160-1078)
J1—Chassis-mount BNC jack (DK ARFX1064)
J2—Chassis-mount, three-circuit (stereo), 3.5-mm jack (RS 910-0768)
J3—9-V battery connector (DK BS6I-HD)
L1—6 turns #21 wire wound on a 3/8-inch diam. form, with a total coil length of 1 inch; see text.
R9—100 Ω trimmer (DK 3306P-101)
R12—100 kΩ trimmer (DK CT9W104)
SW1—DP3P slide switch (DK SW334); one pole unused
SW2—SPST toggle (RS 900-6973)
U1, U2—CA3160AE (DK CA3160AE)
U4—UA78L05 (DK LM78L05ACZ)
U3—TLC555 or LMC555CN (DK LMC555CN)
Misc: 12 inches of #20 wire, hardware, PC board, 8-pin IC sockets (RS 900-5738), 1.1×2.4×4.4-inch (HWD) enclosure (DK HM103), slide-switch topper button (DK SW149)

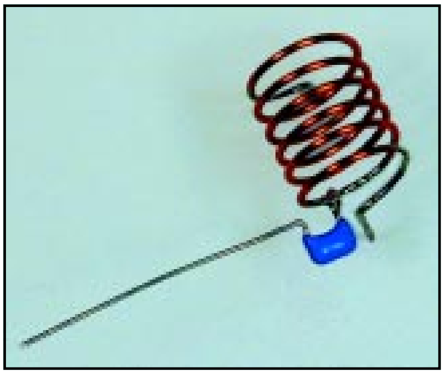
iting resistors R13 and R18. Having two current-limiting resistors in the circuit allows use of stereo or mono headphones; you can omit R18 if you intend to use only mono phones.

A regulated supply voltage from U4 provides circuit stability as the battery voltage changes over its useful life. Zener regulator D1 supplies voltage to the VCO and the threshold-adjusting circuit. LED D4 takes advantage of the current supply to D1 to provide a power-on indication without impacting the battery life. In typical use, a battery lasts longer than one year.

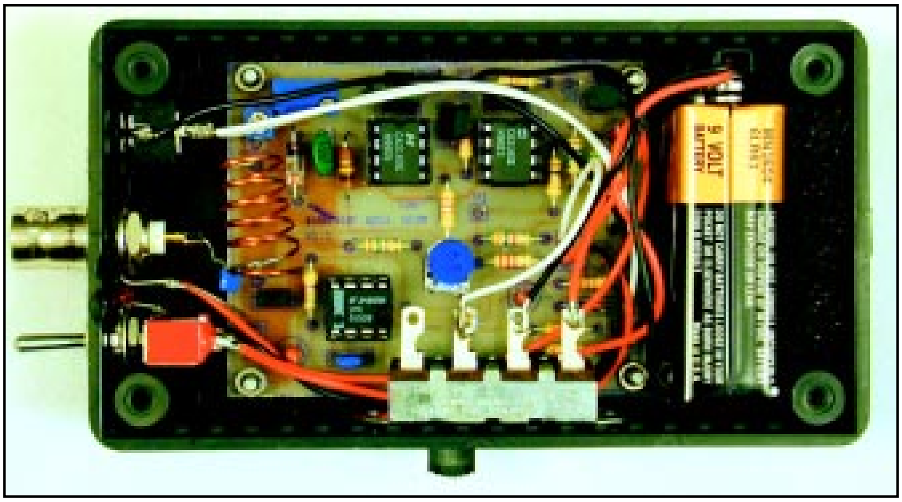
FoxFinder Construction

Now that you're convinced you want one, we'll tell you how to build your own. All components are readily available from the listed suppliers. A drilled and silk-screened PC board, with or without a complete set of parts, is available.[4]

Besides the usual good practice of keeping circuit connections short and direct, the only areas requiring attention are the coil and RF-detector wiring. Use short, direct leads for the coil, tuning capacitor,



L1 ready to go, complete with C2 tapped at 1 turn.



An inside view of the completed unit. J1, J2 and SW2 are to the left. The RANGE switch is at the bottom. One lug of the RANGE switch (MIN) is unconnected.

D2 and D3 and the connection to the coax connector. Be careful when soldering the RF-detector diodes: They are *germanium* diodes and more heat sensitive than silicon diodes. It is important that *germanium* diodes be used in the detector circuit. Silicon diodes such as 1N914s or 1N4148s are *not* suitable substitutes. RadioShack sells a package of 1N34 diodes (RS 276-1123). If you follow the schematic during construction and use the alignment procedure provided later, you should be able to easily duplicate the FoxFinder.

Case Selection

We selected a plastic case for its low cost and weight, and because metal boxes are darn cold to hold in the winter! The shielding qualities of a metal case are not required. The case must, however, be *opaque* because the typical 1N34 glass-encased diodes are light sensitive. Depending on your building skill and experience, you might want to consider using a slightly larger case than the one we chose so you have a bit more room for the parts. The layout shown in the photo is suggested for a "dead-bug" circuit as well, with the coil, RF detector diodes and IC located close to the tuning capacitor. The coil tap is at the end of the coil farthest from the diode connection.

The Coil

Wind the coil on a 3/8-inch form (a drill-bit shank or dowel). The wire need not be enameled, but if it isn't, you must use care to avoid shorting turns and ensure that nothing touches the coil to short it out. A tap point is needed one turn in from one end of the coil for attachment to the coupling capacitor. (If you use enameled wire for the coil, be sure to scrape off the enamel coating before soldering the connection.) While the coil is still on the form, spread the coil turns evenly to a width of one inch. Remove the form and mount the coil, making a direct connection from the end of the coil farthest from the tap point to the tuning capacitor, C1. Be sure to mount the tuning capacitor so you can adjust it later. Connect D2 between the coil and C3 with short, direct leads. We suggest building this part of the circuit on a small piece of copper-clad board even if you build the rest of the circuit on perf board.

Matching the Diodes

The 1N34 diodes should be matched to reduce temperature effects on the calibration. You can sort a group of diodes by connecting a 1-MΩ resistor in series with the diode (forward biased) across a 9-V battery. Using a voltmeter with millivolt resolution, measure the forward voltage drop across each diode and select two diodes having similar voltage drops. (It takes a few seconds for the voltage to stabilize after applying voltage to the diode.) You should be able to find two diodes that have voltage drops within a few millivolts of each other.

Wiring the rest of the circuit is easy. Mount the supply pin bypass capacitors close to their respective ICs. Be sure to provide suitable connection points (scraps of wire will do) for the three test points (TP1-TP3) so that they can be accessed easily without shorting to the surrounding components. The test points are used during alignment of the FoxFinder. Also ensure easy access to pots R9 and R12 for the alignment process.

Alignment

For the following procedure, you'll need a high-impedance digital or analog voltmeter and a 2-meter signal source (such as an H-T). If at anytime you do not obtain the expected results, you will have to troubleshoot the circuit. After fixing the problem, start the alignment procedure from the beginning.

1. Connect the battery and turn on the **POWER** switch. The LED should light indicating that power is applied.

As mentioned earlier, the 1N34 diodes are sensitive to bright light. During alignment, shade the diodes from any bright light; normal room lighting usually is okay. (This precaution is necessary only while adjusting R9 and R12.)

2. Place the **RANGE** switch in the **MAX** position. Connect the positive lead of a dc voltmeter to TP2 and connect the voltmeter's negative lead to the coax connector shell. (This is a handy place to make a ground connection.) Adjust R9 for a reading of +0.5 V. The exact value is not critical at this step; R9 will be readjusted in Step 3. Next, connect the voltmeter's positive lead to TP1 and connect the negative lead to TP2. Adjust R12 for an indication of about +7 mV. Again, the exact value isn't critical at this time, but you should be able to adjust this voltage through zero. It is important that the voltage be *positive*. If you can't get a level of +7mV, check for a wiring error, a defective component or an incorrectly installed component.

Move the voltmeter's positive lead from TP1 to TP3, leaving the negative lead on TP2. Ensure that the **RANGE** switch is in the **MAX** range position. Carefully adjust R12 for a dc voltage of +50 mV ±5 mV. Use the most sensitive voltmeter scale that is appropriate. Again, it is important that the voltage is *positive*. Remove the test leads.

3. Connect the positive voltmeter lead to TP1 and the negative lead to the coax connector ground shell. As a signal source, set up a 2-meter rig on a clear frequency with a low power-output level (100 mW to 1W). It is not necessary to

have an antenna on the FoxFinder. With the rig within a few feet of the FoxFinder, transmit and observe the voltage on the voltmeter. The voltage should increase in magnitude. It is the *increase* that is important. If the voltage increases in magnitude continue with the alignment. If the voltage *decreases*, it indicates that D2 is not installed properly. Unkey the rig, correct the problem and repeat the entire alignment procedure.

Connect the negative voltmeter lead to the cathode (banded) end of D3. Key the rig. The voltage measured this time should be well below 1 V. A voltage greater than 1 V indicates that D3 is either installed backward or defective. Correct this before proceeding, then repeat the entire alignment procedure. If everything tests correctly, remove the test leads and proceed to Step 4.

4. Plug a pair of headphones into headphone jack J2. With the rig unkeyed and the **RANGE** switch still in the **MAX** position, you should hear an audio tone in the headphones. If not, adjusting R9 should provide an audio tone in the headphones. While adjusting R9, note that at some point the tone becomes very low pitched and then oscillation stops. The correct adjustment of R9 is just beyond the point where oscillation starts with the **RANGE** switch in the **MAX** position. Moving the **RANGE** switch to the center position should stop the oscillation. This indicates a proper adjustment of the detection threshold.

5. RF alignment is next. Connect an antenna (a "rubber duck" will do) to the FoxFinder RF connector. Set the rig on a frequency close to the intended fox frequency and make a short transmission with the **RANGE** switch in the **MAX** position. The audio tone in the headphones should increase in pitch. With the help of an assistant, increase the separation between the rig and the FoxFinder so that the change in pitch is not too great when the rig is transmitting. Now, carefully adjust C1 for the highest pitch. This is the point of maximum sensitivity. Unkey the rig.

6. Turn off power to the FoxFinder and install the case cover. Assembly is complete and you can congratulate yourself on a job well done! As with any fine tool, you now need to practice using it. We are sure you will be pleased with your FoxFinder and will have many happy hours hunting with it.

Summary

Your FoxFinder is sure to add to your enjoyment of the great sport of hidden transmitter hunting! Our FoxFinders have saved us countless hours and given us confidence that we *can* find the elusive fox!

Notes

[1]Pete Ostapchuk, N9SFX, "Fox Hunting is Practical and Fun!," *QST*, Oct 1998, pp 68-69.

[2]Dale Hunt, WB6BYU, "Amateur Radio Direction Finding—The 1998 IARU World Championships," *QST*, May 1999, pp 28-31.

[3]Roy Lewallen, W7EL, "A Simple and Accurate QRP Directional Wattmeter," *QST*, Feb 1990, pp 19-23, 36.

[4]Drilled, silk-screened PC boards and full kits (including a PC board, all parts, enclosure and an assembly manual) are available. Send all orders to the Nashoba Valley Amateur Radio Club, PO Box 900, Pepperell, MA 01463. Address any questions to **nvarc_n1nc@arrl.net**. Prices in the US: PC board, $10 postpaid; kit, $59.95 plus $5 shipping and handling. All US orders are shipped by First Class mail. Personal checks and money orders accepted for US orders. For shipments outside United States, payment must be in US currency by bank check or money order. PC board, $14 postpaid. For surface delivery of a kit, $59.95 plus $9 shipping and handling (expect a total of six to eight weeks delivery time). For kit air delivery, shipping and handling is $12, with an expected delivery time of two to three weeks.

First licensed in 1955 as KN9AQP, Bob Reif, W1XP, has been an active amateur ever since. He is an Extra Class license holder and an ARRL Life Member. In 1963 he earned his BSEE from Purdue University. After two years active duty in the US Army, Bob joined GTE in Waltham, Massachusetts, in 1966. During the next 30 years, he was involved in many areas of military communication: analog, RF and antenna design. Since retiring in 1994, Bob has spent more time enjoying Amateur Radio. During his 45-plus years as a ham, he has worked MF, HF, VHF, UHF and SHF to 10 GHz. Bob likes to design and build equipment and antennas. You can contact Bob at PO Box 363, Groton, MA 01450; **w1xp@arrl.net** *and* **nvarc_n1nc@arrl.net**.

Since the age of seven, Ralph Swick, KD1SM, has had a consuming interest in all things with wires and electrons. However, even with electronics as a hobby, it wasn't until his own son expressed interest in Amateur Radio that Ralph got his ticket. Ralph has BS degrees in physics and mathematics. His career involves designing computer software and protocols. Having worked in industry and academia, Ralph is presently on the research staff at the MIT Laboratory for Computer Science. You can contact Ralph at 113 Townsend Harbor Rd, Lunenburg, MA 01462; **kd1sm@arrl.net**.

Stan Pozerski, KD1LE, has been a ham since 1992 and holds an Amateur Extra license. He has a BS degree in computer systems with a minor in business management. For 25 years, Stan worked in defense industry electronics and industrial manufacturing. He now works as a network and systems administrator for the Mitsubishi Electric Research Laboratory. In addition to fox hunting, Stan enjoys mobile and fixed-station HF CW, and traffic handling. You can contact Stan at PO Box 527, Pepperell, MA 01463; **kd1le@amsat.org**.

Photos by the authors

NEW PRODUCTS

GPS/VHF MOBILE ANTENNA FROM ANTENEX

◊ Antenex Inc has recently made available a combination GPS/VHF antenna that should be well suited for APRS applications.

The Antenex Model GPSDVHF antenna consists of a compact cylindrically shaped base containing an active ceramic patch GPS receive antenna (power is supplied from your GPS receiver through the feed line). A tunable (138-148 MHz) $^{1}/_{4}$-λ 0.1-inch diameter stainless steel whip with a tapered shock spring base, finished in black chrome, is mounted on top.

The antenna system requires a $^{5}/_{8}$-inch mounting hole and is secured via a solid brass stud and a stainless steel jam nut.

The GPSDVHF comes with 14 feet of RG-174 for the GPS receiver and 14 feet of RG-58A/U for VHF. A crimp-on SMB connector and an N connector, for installation by the user, are provided.

For more information on the GPSDVHF and the entire line of Antenex antennas, antenna mounts and antenna related products, visit your favorite Amateur Radio equipment dealer or contact Antenex, 2000-205 Bloomingdale Rd, Glendale Heights, IL 60139; tel 800-323-3757 or 630-351-9007, fax 630-351-9009; **www.antenex.com**.