November 1995 QST Volume 79, Number 11

The Four-Way DFer

There's been an unmodulated carrier on the repeater input for hours. You've got to find the source of the interference. With this VHF/UHF mobile radio-direction-finding (DFing) gear, you're prepared.

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Direction-finding involves two somewhat different activities: DFing on foot and DFing from a vehicle. Often, you must track the signal using a vehicle, then finish the hunt on foot. Whether on foot or in a vehicle, the primary problem you'll encounter when trying to locate the transmitter is *multipath reception*. Multipath reception involves receiving the same signal via more than one path, one signal from the true direction of the transmitter and others via reflected paths that may come from widely different directions. VHF and UHF signals bounce off almost any object and hide the true source of a signal. For example, if there's a large metal building north of you, a signal from the south may arrive from the north because the signal bounces off the building and back to you.

Multipath reception effects can be defeated by taking a number of readings from different positions and arriving at an average direction. While moving at road speeds in a vehicle, it's possible to take a number of readings from different positions and average them, and it's also possible to average a number of readings over a distance of travel by electronic means. The true bearing to the transmitter can usually be found by either method.

DFing equipment for use on foot is simpler than systems for use on a vehicle. While afoot, you can turn at will or easily rotate an antenna. Turning a vehicle while going down a street may result in a fender- bender if you're not careful.

The simplest DFing system to use while afoot consists of an S-meter-equipped hand-held receiver, and a small, hand-held Yagi with an attenuator in line between the antenna and receiver. The attenuator keeps the S meter from pinning. The direction in which the beam points when the strongest signal is received is the direction of the transmitter. Of course, you'll want to take readings at several locations at least a wavelength apart to obtain an average heading, as multipath reception can cause false readings in some locations.

Years Ago

David T. Geiser, WA2ANU, first described the simple device now commonly known as the "buzzbox."[1] Various commercial versions of the hand-held buzzbox system are available. Some systems indicate whether the signal is arriving from the left or right of your position. The only drawback to the buzzbox is that it's not as sensitive as a simple dipole and not nearly as sensitive as a beam.

You could take a buzzbox or Yagi/attenuator system in a car, stop periodically, get out and check the direction to the transmitter, then climb back in and drive off. Although this procedure works, it isn't very practical—it takes a long time to find the transmitter.

A Practical DFing System

In *73 Amateur Radio,*[2] Paul Bohrer, W9DUU, described a practical mobile DF system that uses the buzzbox switching network, but with a more complex processor that connects to the receiver audio output and indicates whether the signal is to the left or right of the receiver. Paul's system uses two mag-mount 1/4-λ antennas spaced less than 1/4 λ apart on the vehicle's roof. This results in a practical DF system for use in a vehicle as well as an improved system for use on foot.

But What about Front and Back?

The W9DUU left-right box is inexpensive to build, but it does not provide a front-to-back reading. With only a left-right reading, it's quite possible to drive past a transmitter. The box will read <right> if the transmitter is on the right as you approach the transmitter and continues to read <right> as you drive past it. Manual switching between two sets of antennas is not handy, and there may not be time for it if the transmitter is on for only a short time.

A Better Approach

An improvement to the left-right box is presented here. This left-right, front-back box (LRFB box) indicates whether the received signal is to the left or right *and* whether it is to the front or back of the receiver.

Four prototypes have been built and tested successfully. The location display consists of four LEDs arranged in a diamond pattern (see the title-page photo). When the top LED is on, the signal is coming from the front. When the top and right LEDs are on, the transmitter is between the front and the right. When only the right LED is on, the signal is dead to the right. When the bottom LED and right LED are on, the transmitter is to the right and to the back. The same pattern occurs around the clock. Therefore, four LEDs indicate eight directions. As most highways and streets have intersections that force a driver to choose moving straight ahead, right or left, the indication is sufficiently precise for practical transmitter hunting.

If the four-LED display is used alone, all parts can be obtained from your local Radio Shack store. Two zero-center 50-µA meters (50-0-50)—M1 and M2—can be used in addition to, or in place of, the LEDs, but Radio Shack does not stock such meters.

The LRFB box uses four mag-mount 1/4-λ antennas placed on the vehicle roof as shown in Figure 1. The whips in the mag mounts can be changed to 1/4-λ 440-MHz whips and the antennas placed closer together when switching from 144-MHz to 440-MHz operation.

Circuit Description

Refer to Figure 2. U2, a 555 timer, generates a string of square-wave pulses at pin 3. The pulse frequency is determined by the setting of R4. The pulses are fed to the clock input (pin 14) of U3, a 4017 decade counter. On the first pulse, a positive voltage appears at U3, pin 3. On receipt of the second pulse from U2, pin 3 of U3 goes to ground and a positive voltage appears on pin 2. This sequence continues on successive pulses from U2 as pins 3, 2, 4, 7, 10, 1, 5, 6, 9 and 11 go positive in succession.

D1 through D5, and D6 through D10, **OR** the pulses. The result is that TP3 goes positive on the first pulse from U2, while TP2 is at 0 V. The next pulse of U2 results in TP2 going positive and TP3 going to 0 V. This sequence repeats as the counter goes around to make pin 3 positive again, and recycles.

Antenna Switching

U2 and U3 produce alternating pulses at TP2 and TP3. If we wanted only to alternately turn on and off two antennas, we could use the pulses at TP2 and TP3. The design ensures that the pulses at TP2 are the same length as the pulses at TP3. For the LRFB box, however, we need to switch between the left-right antennas many times, then switch between the front-back antennas many times.

Pin 12 of U3, **CARRY OUT**, emits a pulse every time U3 counts through its cycle of 10 pulses. The carry pulses from U3 go to U4, pin 14, the clock input of that 4017 counter. As U4 cycles, its output pins pulse; those pulses are, in effect, directed by D11 through D20.

As a result, TP4 is positive during the first 50 pulses from U2 and TP5 is positive during the second 50 pulses of U2. Q1 through Q6 form a quad **AND** gate. They **AND** the pulses at TP4 and TP5 with the alternating pulses at TP2 and TP3 so that the result is a pulse at the base of Q9, followed by a pulse at the base of Q10, a pulse at the base of Q9, and so on. The pulses alternate 25 times between Q9 and Q10. Then, as TP4 goes to 0 V, TP5 rises from 0 V to some positive voltage and the alternating pulses appear at the bases of Q7 and Q8. The pulses alternately go to the bases of Q7 and

Q8 25 times. Then they alternate between the bases of Q9 and Q10 25 times. This pattern continues as long as the unit is in DF operation.

In Figure 3, two leads of a four-conductor-plus-ground cable to the antenna-switch board are connected to points A and B. The same pulses that turn Q7 and Q8 off and on turn on and off the left and right antennas. One of those two antennas is turned on and off in phase with Q7 and the other is turned on and off in phase with Q8. The **PHASE** switch, S3, determines which antenna is in phase with which transistor. Similarly, the two front/back antennas are turned on and off in phase with Q9 and Q10, and S4 determines which antenna is in phase with which transistor.

The pulses arriving at points A and B turn on and off the diodes connecting the coax of the left and right antennas to the receiver coax. This occurs 25 times, thereby switching the receiver between the left and right antennas 25 times. Similar switching then occurs between the front and the back antennas from pulses arriving at points C and D.

Detector Circuit

The detector circuit (Figure 2) starts with U5, a 741 op amp that amplifies the receiver's audio output. The audio is fed into R24 and R27, two 4.7-kΩ pots. The zero-center, 50-µA meters across R24 and R27 are optional. The meters, as well as the LEDs, indicate front/back and left/right. Such meters can be expensive unless you find surplus meters, and they're not really necessary.

When the left/right antennas are active, one end of R24 is grounded by Q7 and Q8 on each alternate pulse. If Q7 is conducting, Q8 is not conducting. On each pulse, one of the left/right antennas is turned on and one end of R24 is grounded. On the next pulse, the other left/right antenna is turned on and the other end of R24 is grounded. If there is a phase difference between the signal received by the left antenna and the signal received by the right antenna, a dc voltage is built up across R24. That voltage causes the quad comparator, U7 (see Figure 4) to turn on DS3 (red) or DS4 (green) L/R LEDs. If the optional left/right meter is installed, it deflects to indicate the direction as do the LEDs.

After 25 cycles, the left and right antennas are both turned off and the front and back antennas are cycled on and off 25 times with the same detection process, producing a voltage across R27 if there is a phase difference between the RF received by the front and the back antennas. That voltage across R27 causes quad comparator U6 to turn on DS1 or DS2.

C9 and C10, for the F/B detector, and C7 and C8, for the L/R detector, damp the voltage swings caused by multipath reception. To control damping, S2A and S2B switch the 4700-µF capacitors in or out of the circuit.[3] You want the greatest amount of damping when you drive through an area with a lot of multipath propagation (as from buildings); a lot of damping helps under those circumstances.

Construction

The prototype was built using a pad-per-hole Radio Shack board. However, a PC board makes construction a lot faster.[4] Except for the optional meters and the nonpolarized capacitors, most parts are available from Radio Shack.

First build the power supply so you can power the unit from your car or another 12-V source. Apply 12 V to the DFer and adjust R1 until U1's output is +9 V. (You can use a 9-V battery and omit the power-supply section, but you'd better take along a spare battery when you go DFing.)

Install U2 and its associated parts. Power up and turn on S1. A string of pulses should appear at TP1. If you have a frequency counter, set R4 for a pulse frequency of 2200 Hz at TP1. If you don't have a counter, connect a 0.1-µF capacitor from TP1 to headphones or a small speaker and set R4 for a tone of about 2 kHz. Later, you'll adjust the clock so the unit works with the passband of your receiver.

Turn off S1 and remove the power source. Install U3 and its diodes. Pin 12 of U3 need not be connected yet. Apply power and turn on S1. At TP2 and TP3, you should find alternating 1100-Hz pulses. If you have a dual-trace scope, you can see that the pulses alternate. If you have a single-trace scope, connect TP3 to TP2 and to the scope input and the trace will appear as a solid line as there is a pulse at either TP2 or TP3 at all times. If you don't have a scope, the tone in a speaker or earphones from TP2 or TP3 will sound half as high (about 1 kHz) as the tone at TP1.

Turn off S1. Install U4 and its diodes. Note that pin 12 of U3 is connected to pin 14 of U4. At TP4 and TP5, there

Turn off S1. Install U4 and its diodes. Note that pin 12 of U3 is connected to pin 14 of U4. At TP4 and TP5, there should be long pulses—five times longer than the pulses at TP1, and the pulses should alternate between TP4 and TP5. The pulse frequency should be about 44 Hz. Power down and turn off S1. Install the remaining circuit components. When you power up, 25 alternating pulses should appear at A and B, then 25 alternating pulses should appear at C and D. Use a scope to verify that.

If you're not using the optional panel meters, connect a voltmeter across R24 (**L/R BALANCE**), using the lowest dc-voltage range. Note that neither end of R24 is grounded. With no audio input, adjust R24 until there is no voltage across it. Do the same with R27 (**F/B BALANCE**). If you use the optional meters, adjust R24 and R27 so there's no current shown on either meter.

Power down and assemble the rest of the circuit of Figure 4. With power applied, but with no audio input, adjust R31, 33, 42 and 44 so that the four LEDs (DS1 through DS4) are off. The objective of the following adjustments is to get the red and green LEDs to turn on with the same voltage amplitude, but opposite polarity, across R24. Move R24's wiper so a low positive voltage appears across R24, as indicated by the voltmeter connected across R24 or movement of the panel-meter needle. Adjust R44 (**LED ADJ 1A**) and R42 (**LED ADJ 1B**) so that the green LED (DS4) comes on when the voltage goes positive at one end of R24, but goes off when R24 is adjusted for 0 V across R24.

Next, adjust R24 for a slight negative-voltage indication and adjust R42 and R44 so that the red LED (DS3) comes on, but extinguishes when the voltage across R24 is 0 V. When you're done, adjusting R24's wiper slightly one way should illuminate the red LED. Both LEDs should be off when there's no voltage across R24; rotating R24's wiper slightly in the opposite direction should turn on the green LED.

Connect the voltmeter across R27 or use the panel meter as an indicator. With no audio input, adjust R27 so that there's no voltage across R27. Adjust R31 (**F/B LED ADJ 1A**) and R33 (**F/B LED 1B**) so that a F/B LED (DS1) is on when there is a slight positive voltage across R27 and the other F/B LED (DS2) is on when there is a negative voltage across R27.

Switch Board

Assemble the switch board for the four mag-mount antennas (see Figure 3). You can use half of a Radio Shack dual pad-per-hole PC board (RS 276-148) as a platform. Lead length is critical only on this board and in the length of the coax from the switching board to the antennas, so avoid wire-wrap construction here.

Feed Lines

The coax lines from the switch board to each of the four antennas *must be of equal length.*[5] The coax lengths should be long enough to permit each antenna to be placed slightly less than 1/4 λ from its counterpart, at the lowest frequency of operation. (There's a local belief that 27-1/2 inches is the best length. I used that length and it works, but other lengths might work as well.) An attempt to locate the switch board inside the vehicle and run equal-length 12-foot-long cables to the antennas failed. Keep the switch board on the vehicle's roof.

Use the same type of coax for all lines—that is, don't mix foam and polyethylene dielectric coax on the antenna lines. If the velocity factor of the lines is not equal, a phase shift in the signals will exist even when the transmitter is dead ahead and it will lead you astray.

Solder the coax from the antennas directly to the board—don't use connectors. From the switch board to the receiver, use 50-Ω coax of any type and length. Equip the receiver end of the line with a connector that mates with your receiver's antenna-input jack. Make the four-conductor shielded cable from the main DFer box to the switch board long enough to reach from the LRFB box's operating position to the roof of the car. Construct the antennas so that the whips can be changed easily for use on any frequency in which you're interested.

Mechanical Assembly

Mount the finished PC boards in a metal box (Radio Shack has some). You can follow the construction method used in the prototype (see the title photo and Figures 5 and 6), just ensure that R4 can be adjusted easily with a tuning tool from outside the box. A hole drilled in the box at the right point will suffice. Arrange the LEDs in a diamond pattern on the front panel, with the left LED (red) to the left, the right LED (green) on the right, and the front and back LEDs at the top and the bottom.

Wrap the switch board with tape to waterproof it, or place it in a watertight box. Arrange the mag-mount antennas on top of the vehicle in a diamond shape. The distance between each antenna pair should be less than 1/4 λ at the operating frequency. (In limiting the distance between antennas in a pair—F/B or L/R—to less than 1/4 λ, I am following W9DUU's experience.)

Final Adjustments

It's best to start on 2 meters. Install the 2-meter whips in the antenna bases. Mount the antennas on the top of your vehicle. Identify the left and right antenna bases with **L** and **R,** and mark the front and back antenna bases, too.

A good way to find out if the antennas are properly installed is to short either the left or right antenna with a clip lead from the whip to the metal base; the L/R meter will deflect one way and the left or right LED will light. If you short one of the front and back antennas with a clip lead, the front or back LED will come on. If you short one of the L/R antennas and it makes the meter go to the right, it does not mean you have the **PHASE** switch in the proper position. That depends on the relative phase determined by the number of audio stages in your receiver, each of which may contribute a shift of 180°.

Connect the coax from the switch board to your FM receiver. It must be an FM receiver; an AM VHF or AM aircraft receiver won't suffice. Connect the audio output of your 2-meter receiver to the LRFB box audio input. If you're using a transceiver, disable its transmit function by removing the mike. You don't want to transmit into the switch board!

Turn on the receiver and place the LRFB box in receive by setting S1 to the **RCV** position. Center R10. Only one of the antennas will be turned on and the DF operation will be disabled. Back off the squelch and notice that you hear the audio from the speaker of the LRFB box. Switch to an unused simplex channel. Have a friend with an H-T stand 20 feet or so in front of the vehicle. With the receiver in the car turned off, turn S1 to DF. The four LEDs should be off. If an LED lights, adjust R24 and R27 for zero voltage. If the LED is still on, readjust R31 and R33, or R42 and R44 as explained earlier. When all four LEDs are off with the antennas connected, no audio from the receiver and no RF input signal, you're ready. Turn on your receiver and have your friend transmit on the 2-meter frequency (simplex) that your receiver is set to. When he transmits, one or more of the LEDs should illuminate. Ignore the front/back LEDs, but check to see if the right or left LED is on. If the right LED is on and your friend is standing to the right of the center of the vehicle front, all is well. Have him walk back and forth in front of the vehicle and notice that when he is to the right, the green LED turns on, and when he's to the left, the red LED glows. If the indications are reversed, that is, if the LRFB box indicates left when your friend is to your right, reverse the position of **PHASE** switch S3.

When the L/R indicators are working properly, have your friend walk back and forth between a position 20 feet to the front and right of the car and a position 20 feet away to the rear and right of the car. The right LED should stay on, but the front LED should be on when the H-T is in front of the antennas, and the back LED should be on when the H-T is behind the antennas. If the front/back indications are reversed, reverse the position of **PHASE** switch S4.

While receiving a signal from your friend's H-T, adjust R4 for maximum deflection on any one of the two optional meters, or on a voltmeter (set on the lowest dc voltage range) connected across R24 or R27. Look for the maximum deflection of the meter needle as the meter swings both ways while the signal source moves from back to front or left to right (depending, of course, on which panel meter you're looking at or which resistor—R24 or R27—your voltmeter is across). The audio passband of FM receivers varies, and if you switch from an ICOM IC-27 to an ICOM IC-W2A, for example, you'll have to change U2's master clock frequency. You may encounter receivers that don't require readjusting R4, but such readjustment should be expected. When changing receivers, you may also need to change the position of **PHASE** switches S3 and S4. This may also be necessary when changing from UHF to VHF, or VHF to UHF on the same receiver, as the number of receiver stages (and, hence, the audio phase) may change from band to band.

Audio Level Adjustments

With meter damping (S2) off, adjust R10 so that you have full deflection of one of the two meters (or your multimeter) with the signal source at a 45° angle from the vehicle (halfway between ahead and right), and a reasonable audio level from the speaker. Turn the rig's volume control all the way up to ensure that the audio circuit doesn't overload. If it overloads, the meters won't deflect. From zero to full blast, the meter should deflect more and more (unless the signal is straight ahead or exactly left or right). If you're using an H-T, maximum deflection of the meter should occur before the volume control is 3/4 of maximum, or before the volume control is at 1/2 of maximum if you're using a mobile rig. If R10 is properly adjusted, turning the volume control to maximum won't cause the meter to fall back toward zero. If increasing the volume causes the meter to deflect less, then R10's setting is too high.

Now have your friend walk around the vehicle with the H-T transmitting and notice that the LEDs indicate the signal direction. On 2 meters in a clear field, the indications should be correct 80 or 90% of the time. The erroneous readings that occasionally occur are due to multipath propagation caused by the irregular shape of the vehicle. Slight adjustments in the positions of the L/R and F/B antennas may be necessary to make the zero points fall directly in front of the vehicle (neither left nor right LED on) and at the center of the antennas (neither front nor back LED on).

Try the same procedure on 440 MHz. You may have to flip the **PHASE** switches when you move to another band, even when using the same receiver. Remember that the total length of the 440-MHz antennas must be 1/4 λ or less, and the antennas must be placed less than 1/4 λ apart. The results on 440 MHz probably won't be as consistent as the results on 2 meters, as there is likely to be a lot more multipath propagation caused by the irregular shape of the vehicle.

Fox Hunting

Before heading out to find the fox,[6] check to be certain the LRFB box is working properly. Tune to the fox's frequency and drive off. Turning on the **DAMPING** switch stabilizes the indication as you drive along. Follow indications generated as you travel over the road or street. If an indication is constant for 15 or 20 seconds while you're moving down the road, it's probably the true direction to the fox. It's possible to have a reflection from a mountain over a long distance down the road, however. When you can hear the fox with no antenna, it's time to get out of the car, switch to the hand-held system and hunt for the fox on foot.

If you switch to a new receiver, you may have to readjust R4, **CLOCK FREQ**. That's because both receivers may not have the same audio bandwidth. WA9BVS forgot this while chasing a balloon with Dr Gary Stouder, N9MJC, and the results were comical. When chasing balloons with ham radio transmitters, the readings you get are likely to be confusing when the balloon is at a high angle with respect to the plane of the car top. Use a hand-held Yagi to verify the balloon location. Even with a simple buzzbox, you should be able to find a keyed transmitter. With the LRFB box, you can easily DF from a vehicle and do well in fox hunts and balloon chases.

Acknowledgments

Thanks to Greg Chaney, N9MOX, for help with several of the schematics. Thanks also to my wife, Joyce, N9NZJ, for putting up with the time I spent on this project, running around the car with an H-T on and driving in foxhunts. Finally, thanks to Paul Bohrer, W9DUU, for the basic design of the detector circuit and for building the second prototype.

Good luck DFing! Please drop me a card if you build an LRFB box and tell me of your experiences and success.

Malcolm C. Mallette was first licensed in 1962. He spends most of his radio time on ATV and SSTV, but also operates HF and VHF voice both mobile and at home. He is also involved in direction finding. A partner in the law firm of Krieg DeVault Alexander and Capehart, Malcolm spends most of his professional time in civil litigation.

See Feedback in December QST.

Notes

(1) David T. Geiser, WA2ANU, "Double-Ducky Direction Finder," *QST*, Jul 1981, pp 11-14.

(2) Paul Bohrer, W9DUU, "Foxhunt Radio Direction Finder," *73 Amateur Radio*, Jul 1990, pp 9-11.

(3) C7, C8, C9 and C10 are identified as non-polarized capacitors because a small reverse voltage can appear across the meter and capacitors when the system is in use. Standard polarized electrolytics have been used in an untold number of units using this circuit (the same detector circuit used in W9DUU's unit) without any known ill effects, however.

(4) A set of two PC boards is available from FAR Circuits, 18N640 Field Ct, Dundee, IL 60118-9269, tel 708-576-3540 (voice and fax). Price: $11 per set plus $1.50 shipping for two sets of boards. Visa and MasterCard accepted; minimum charge $20, or include a $2 service charge with orders of less than $20. Note: No component pads for C15 exist. Mount C15 between U2 pin 5 and ground on the bottom (foil) side of the board. A PC-board template package is available from the ARRL free of charge. Send your request for the MALLETTE 4-WAY DFER, along with a business size SASE, to the Technical Department Secretary, 225 Main St, Newington, CT 06111-1494.

(5) For more on this subject, see Joe Moell, K0OV, "Homing In," *73 Amateur Radio Today*, Apr 1995, pp 68-73.

(6) For more information on direction finding, see *The ARRL Handbook*, (#4939) and *Transmitter Hunting: Radio Direction Finding Simplified*, by Joe Moell, K0OV, and Thomas Curlee, WB6UZZ (#2701). These books are available from your local dealer or can be ordered directly from ARRL. See the ARRL Publications Catalog elsewhere in this issue.

At the extreme left of the front panel is the VOLUME control. Immediately to the right is the **RCV/OFF/DF** center-off toggle switch, with the damping (**DMP**) control switch nearby. Four LEDs mounted in a diamond pattern indicate signal direction: front (yellow), right (green), back (orange) and left (red). The horizontally mounted zero-center meter indicates left/right signal reception, the vertically mounted meter displays front/back signal reception. A small speaker is mounted on the top cover.

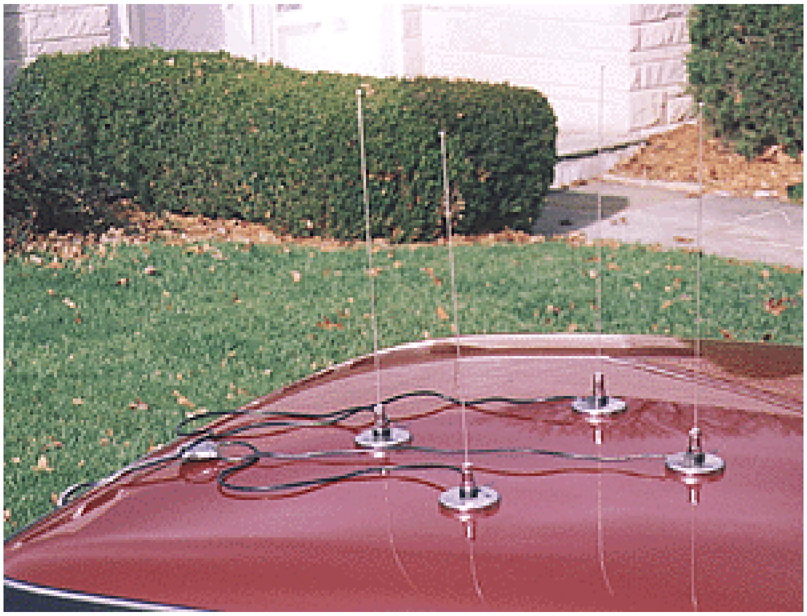

Figure 1—Placement of the four antennas on the author's car roof. The small object to the left of the antennas is the switch board.

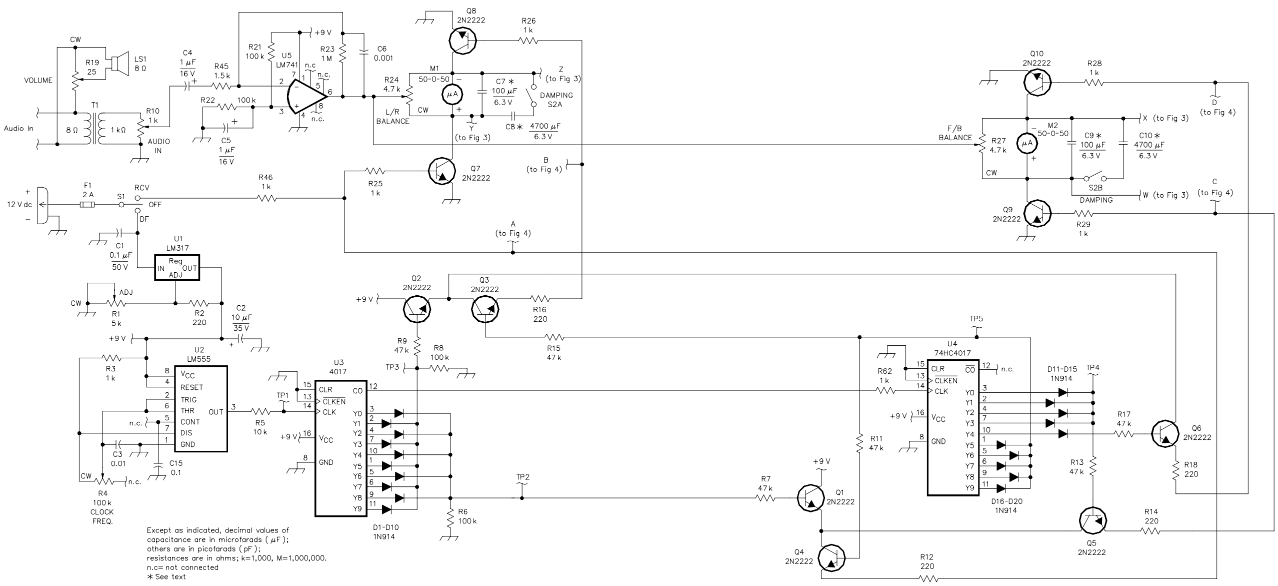

Figure 2—Unless otherwise specified, part numbers in parentheses are Radio Shack. All fixed-value resistors are 1/4-W, 5%-tolerance units. Equivalent parts can be substituted.

C1, C15—0.1-µF, 50-V (272-1069)

C2—10-µF, 35-V electrolytic capacitor (272-1025)

C3—0.01-µF, 25-V disc-ceramic capacitor (272-131)

C4, C5—1-µF, 16-V electrolytic capacitor (272-1434)

C6—0.001-µF, 25-V disc-ceramic capacitor (272-126)

C7, C9—100-µF, 6.3-V bipolar (nonpolarized) capacitor; see Note 3; Digi-Key P-1102, available from Digi-Key Corp, 701 Brooks Ave S, PO Box 677, Thief River Falls, MN 56701-0677, tel 800-344-4539, 218-681-6674; fax: 218-681-3880; Radio Shack stocks 100-µF, 35-V axial (272-1016) and radial-lead (272-1028) electrolytic capacitors.

C8, C10—4700-µF, 6.3-V bipolar capacitor; see Note 3; (made of five 1000-µF, 6.3-V bipolar capacitors, Digi-Key P1106. Standard 1000-µF, 35-V radial and axial-lead electrolytic capacitors are available from Radio Shack; a 4700-µF, 35-V axial-lead electrolytic capacitor is also available (272-1022).

D1-D20—1N914 silicon switching diode (276-1620 or 276-1122)

F1—2-A fuse (270-1007)

LS1—8-Ω speaker (40-245)

M1, M2—Zero-center, 50-µA meter; optional—see text

Q1-Q10—MPS2222 or 2N2222 NPN silicon general-purpose transistors (276-2009)

R1, R24, R27—4.7 kΩ (271-281); note: many of the fixed-value resistors can be found in Radio Shack resistor assortment packages 271-308 and 271-312.

R2, R12, R14, R16, R18—220 Ω (271-1330)

R3, R25, R26, R28, R29—1 kΩ (271-1321)

R4—100-kΩ trimmer potentiometer (271-284)

R5—10 kΩ (271-1335)

R6, R8, R21, R22—100 kΩ (271-1347)

R7, R9, R11, R13, R15, R17—47 kΩ (271-1342)

R10—1-kΩ trimmer potentiometer (271-280)

R19—25-Ω panel-mount potentiometer (271-265A)

R23—1 MΩ (271-1134)

R45—1.5 kΩ (part of 271-312 assortment)

S1—SPDT, center-off switch (275-325)

S2—DPDT switch (275-626)

T1—8-Ω to 1-kΩ audio-output transformer (273-1380)

U1—LM317T, 1.5-A, three-terminal, adjustable voltage regulator (276-1778)

U2—555 timer (276-1723)

U3, U4—4017 decade counter (276-2417)

U5—LM741 op amp (276-007)

Misc: two 8-pin IC sockets (276-1995); two 16-pin IC sockets (276-1992); experimenter's PC board (276-148) or FAR Circuits PC board set (see Note 3); enclosure; four mag-mount antennas, four-conductor shielded cable; in-line fuse holder (270-1281).

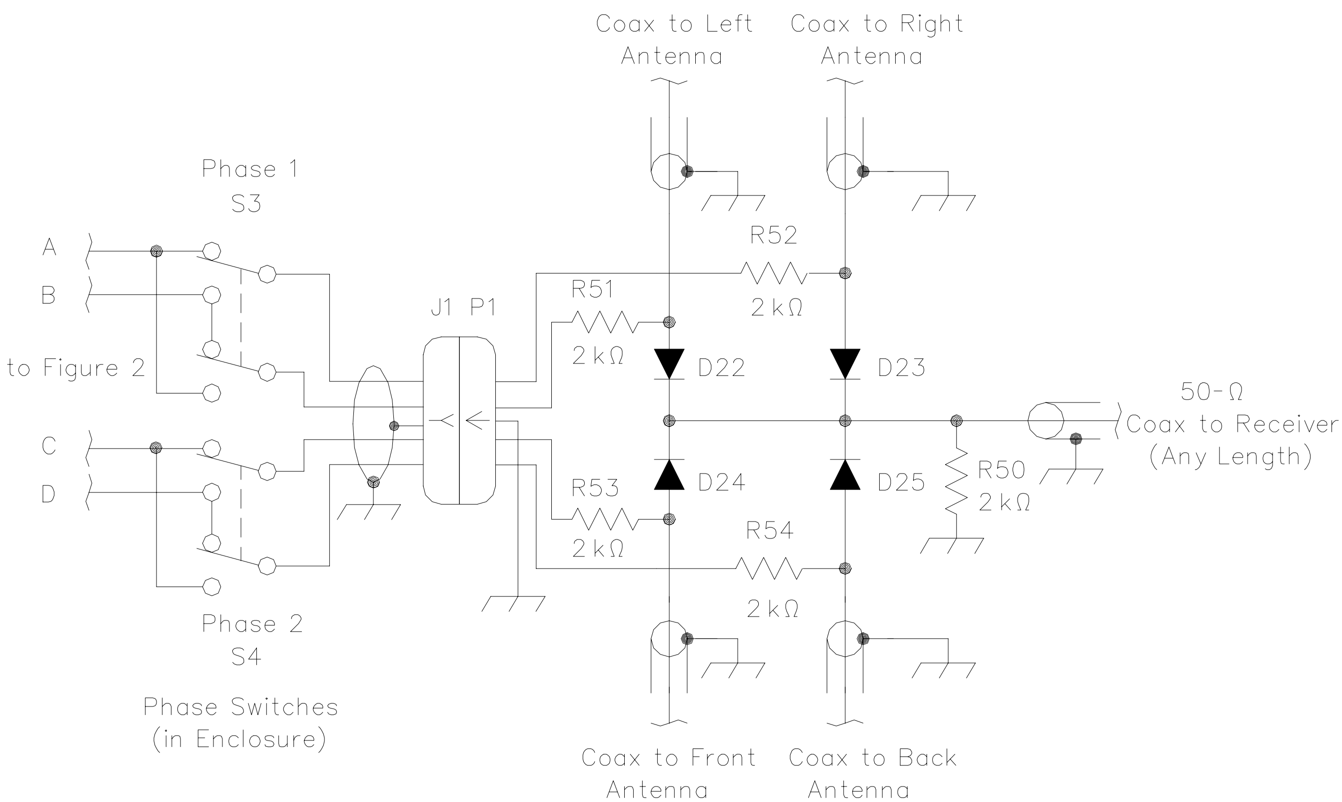

Figure 3—Schematic of the antenna switch board. Part numbers in parentheses are Radio Shack. All fixed-value resistors are 1/4-W, 5%-tolerance units. Equivalent parts can be substituted.

D22-D25—1N914 silicon switching diode (276-1620 or 276-1122)

J1—Six-pin female Molex connector (274-236 or 274-155)

P1—Six-pin male Molex connector (274-226 or 274-152)

R50-R54—2.2 kΩ (can be found in Radio Shack resistor assortment packages 271-308 and 271-312); also available in pack of five (271-1325)

S3, S4—DPDT switch (275-626)

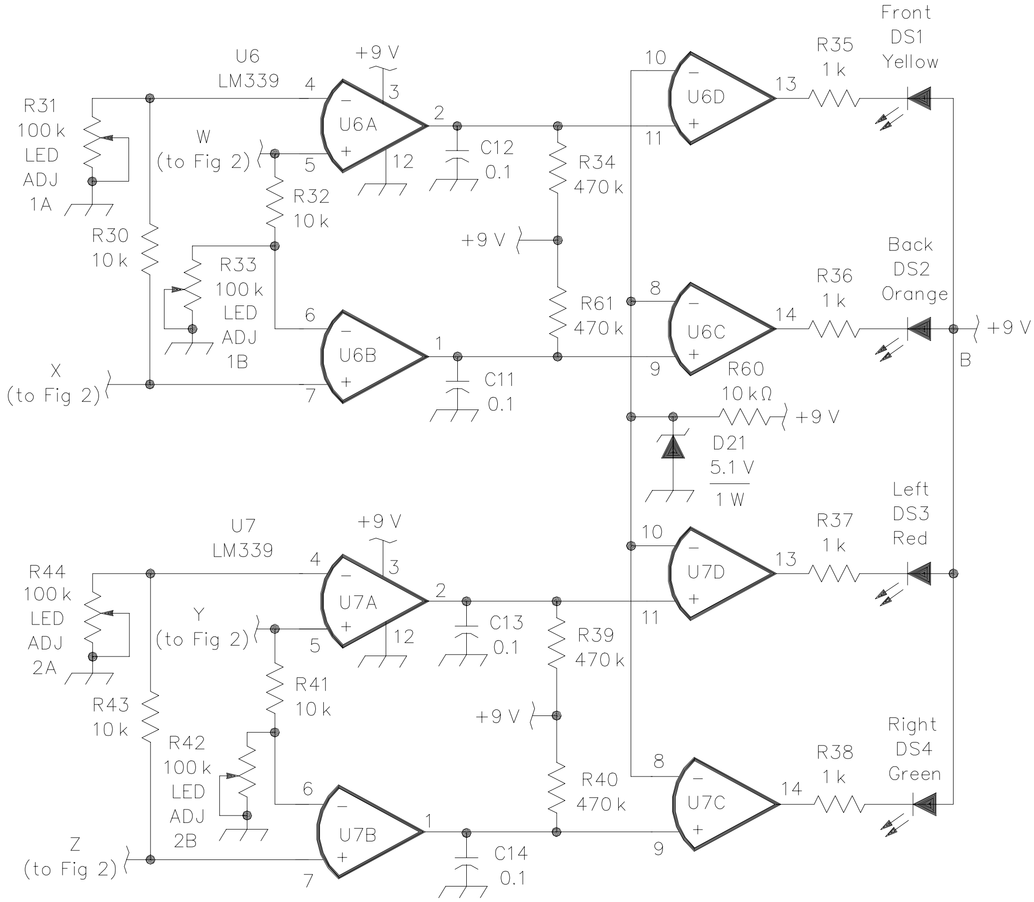

Figure 4—Schematic of the LED driver circuit. Part numbers in parentheses are Radio Shack. All fixed-value resistors are 1/4-W, 5%-tolerance units. Equivalent parts can be substituted.

C11-C14—0.1-µF, 25-V disc-ceramic capacitor (272-135)

D21—1N4733, 5.1-V, 1-W Zener diode (276-565)

DS1-DS4—LEDs; one each red (276-066); green (276-022); yellow (276-021); orange (276-012)

R30, R32, R41, R43—10 kΩ (271-1335)

R34, R39, R40, R61—470 kΩ (271-1354)

R35-R38—1 kΩ (271-1321)

R31, R33, R42, R44—100-kΩ trimmer potentiometer (271-284)

U6, U7—LM339 quad comparator (276-1712)

Misc: two 14-pin IC sockets (276-1999)

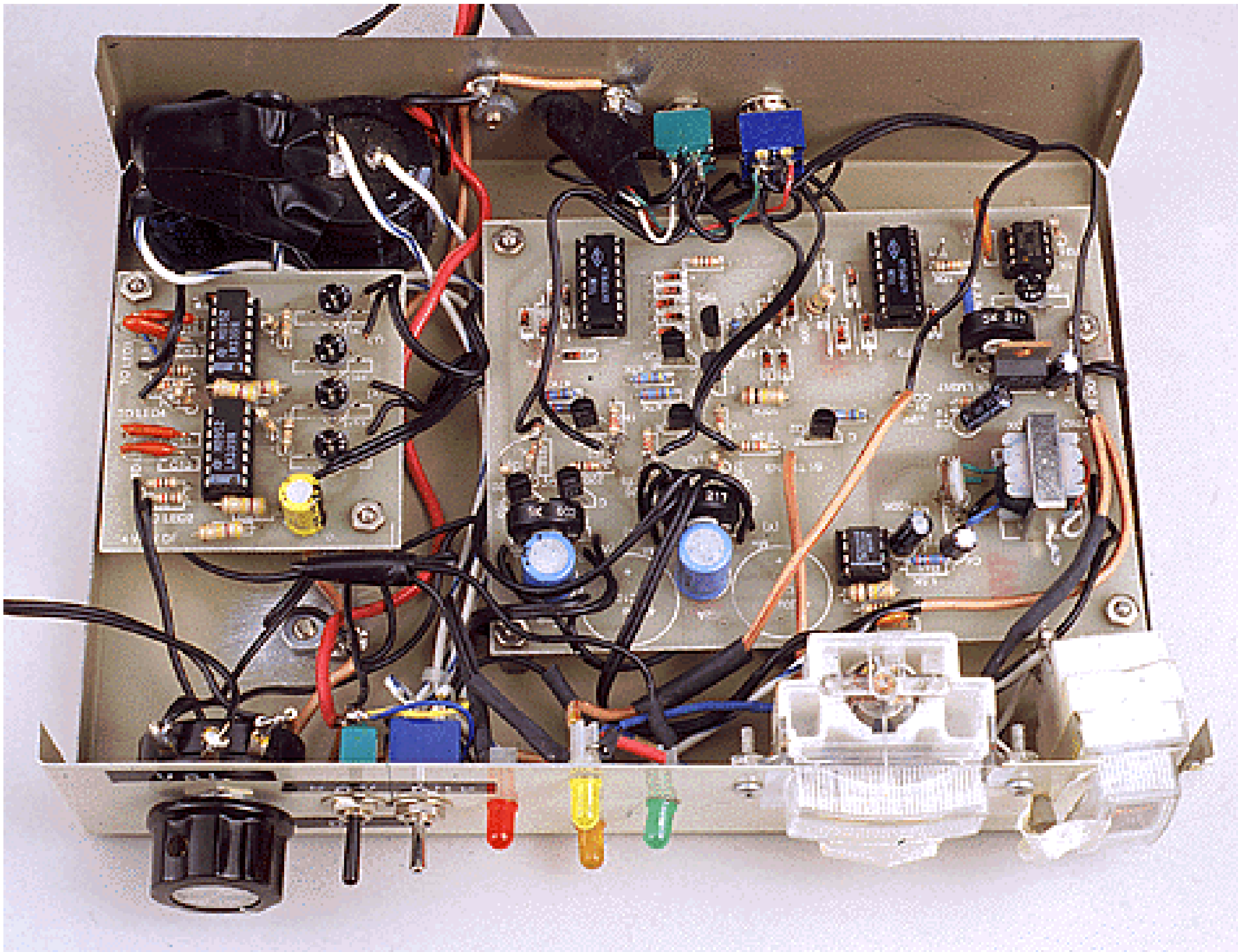

Figure 5—An inside view of one DF unit built into a 2×8×5-3/4-inch (HWD) box. Because of the height restriction, the two 4700-µF damping capacitors (C8 and C10) are not mounted on the PC board, but near the rear panel behind the smaller of the two PC boards. One of the 4700-µF damping capacitors is a standard electrolytic, the other is a parallel combination of five 1000-µF, 6.3-V bipolar (nonpolarized) capacitors wrapped in electrical tape (see Note 3).

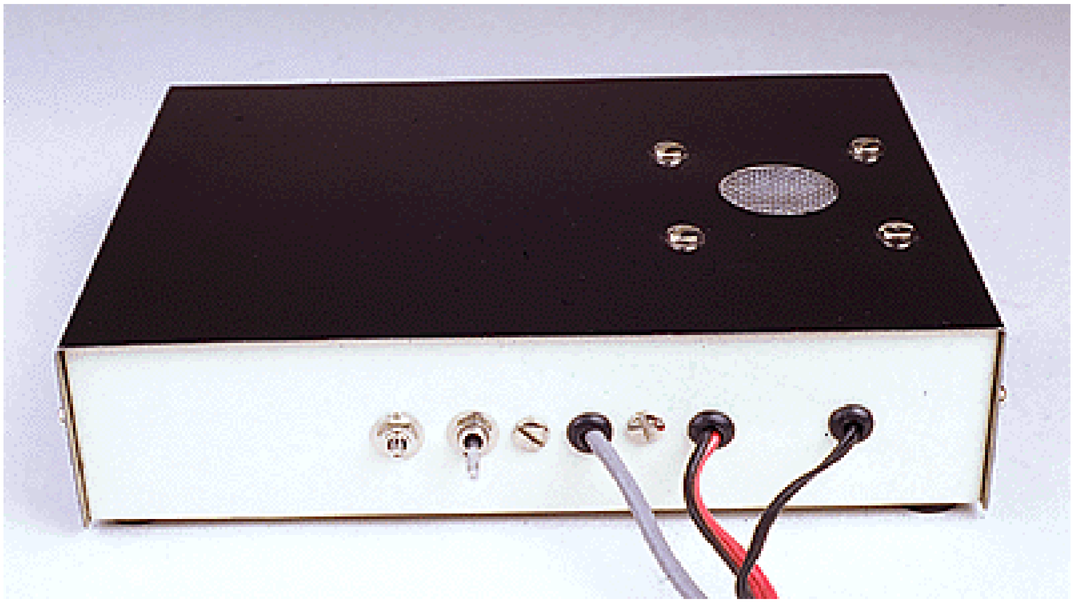

Figure 6—The rear panel of the DF unit supports the two DPDT **PHASE** toggle switches. Grommets in the panel holes allow abrasion-free passage of the antenna, dc-power and audio cables. The dc power cord is outfitted with an inline fuse holder and a male Jones plug. A six-pin female Molex connector (five pins are used) feeds the four antennas. The audio-input cable is terminated in a 1/8-inch diameter male plug.