

# Wide-Range Antenna Arrays For the Roanoke Doppler

And [Other Dopplers](#)

by Joe Moell KØOV

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Doppler units are the "weapon of choice" among mobile T-hunters in many parts of the country. They indicate the direction of incoming VHF signals on a circular ring of light-emitting diodes or a digital display. A doppler set updates bearings almost instantaneously, so even short carrier bursts can be tracked.

A doppler installation can be done quickly on just about any vehicle. It has a much lower profile than a RDF yagi or quad setup. The multi-element antenna assembly replaces your mobile whip. The control unit extracts direction information from a tone that the antenna set adds to the audio output of your VHF-FM transceiver or scanner.

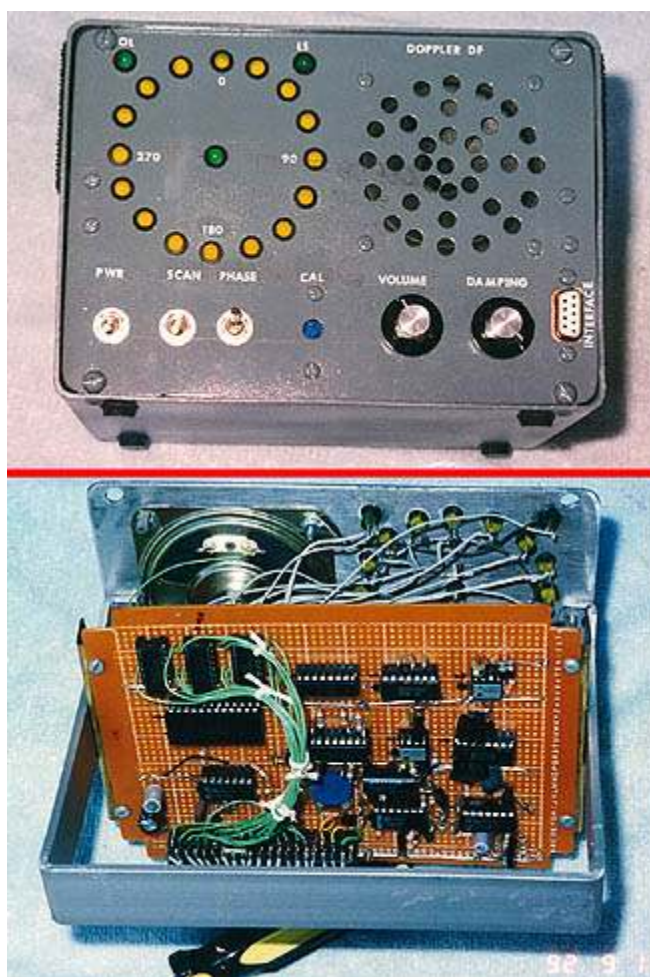
Excellent commercial doppler models are available for several hundred dollars, but you can build your own at a fraction of the cost. Today's most popular do-it-yourself doppler was originated by Chuck Tavaris N4FQ of Roanoke, Virginia. Tom Curlee WB6UZZ and I made enhancements and documented the design. We named it the Roanoke Doppler in honor of N4FQ's T-hunting grounds.

Complete plans for the Roanoke Doppler are in ["Transmitter Hunting---Radio Direction Finding Simplified"](#) by Moell and Curlee. One chapter in this book thoroughly discusses the theory of RDF using the doppler principle and gives much more information about techniques, advantages and disadvantages than space here allows.

The Roanoke Doppler has been built by hundreds of hams in many forms (see Photos 1 and 2 below). Several [independent suppliers](#) have made circuit boards and kits available for its controls and display. They are not affiliated with the book's authors or publisher, so contact them directly for information on their products.



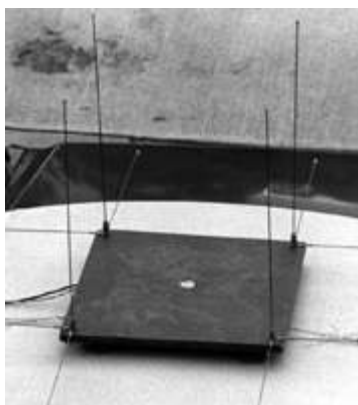
*Photo 1 (left). This Roanoke Doppler display box was built by Jerry Boyd WB8WFK of Albuquerque, NM. Note the 10-turn potentiometer and large dial for the calibration control. This allows him to log settings for each band. (Photo by WB8WFK)*



*Photo 2 (right). The Roanoke Doppler display circuits are designed for easy "homebrew" construction. Bill Briles W0OQC of Derby, KS built his on perforated prototyping board. Etched circuit boards are also available from several sources. (Photos by W0OQC)*

## A New Roanoke Switcher

The Roanoke Doppler antenna design in the book (see Photo 3 below) works well on strong two meter signals. I have used it on well over a hundred T-hunts. But it has room for improvement. The requirement for exact half-wavelengths of coax limits an array to a narrow frequency range (typically 5%). Furthermore, readers who have tried to scale the array for higher frequencies (such as the 70 centimeter band) have had disappointing results.



*Photo 3. The Roanoke Doppler antenna array described in [TRANSMITTER HUNTING](#) has four quarter-wavelength whips on a 20 X 20 inch metal plate with 8 radials to provide a ground plane under each whip.*

In 1994, I designed an improved switching system for the Roanoke Doppler and invited several T-hunters to build and test it. The new design (schematic in Figure 1 below) features series PIN diodes at each end of the coax lines to the four whips. This means that the coaxes can be any reasonable length, so long as the four lengths are equal. Coax lengths no longer limit the bandwidth of the array, so it is possible to use one array to cover tens of megahertz, limited only by array spacing and values of inductors and capacitors in the switcher.

(Why is it important to have diodes at each end of each coax? See [Homing In](#) for April 1995, which explains in detail the importance of controlling both the feedpoint impedance of switched-off whips and the impedance match at the common point.)

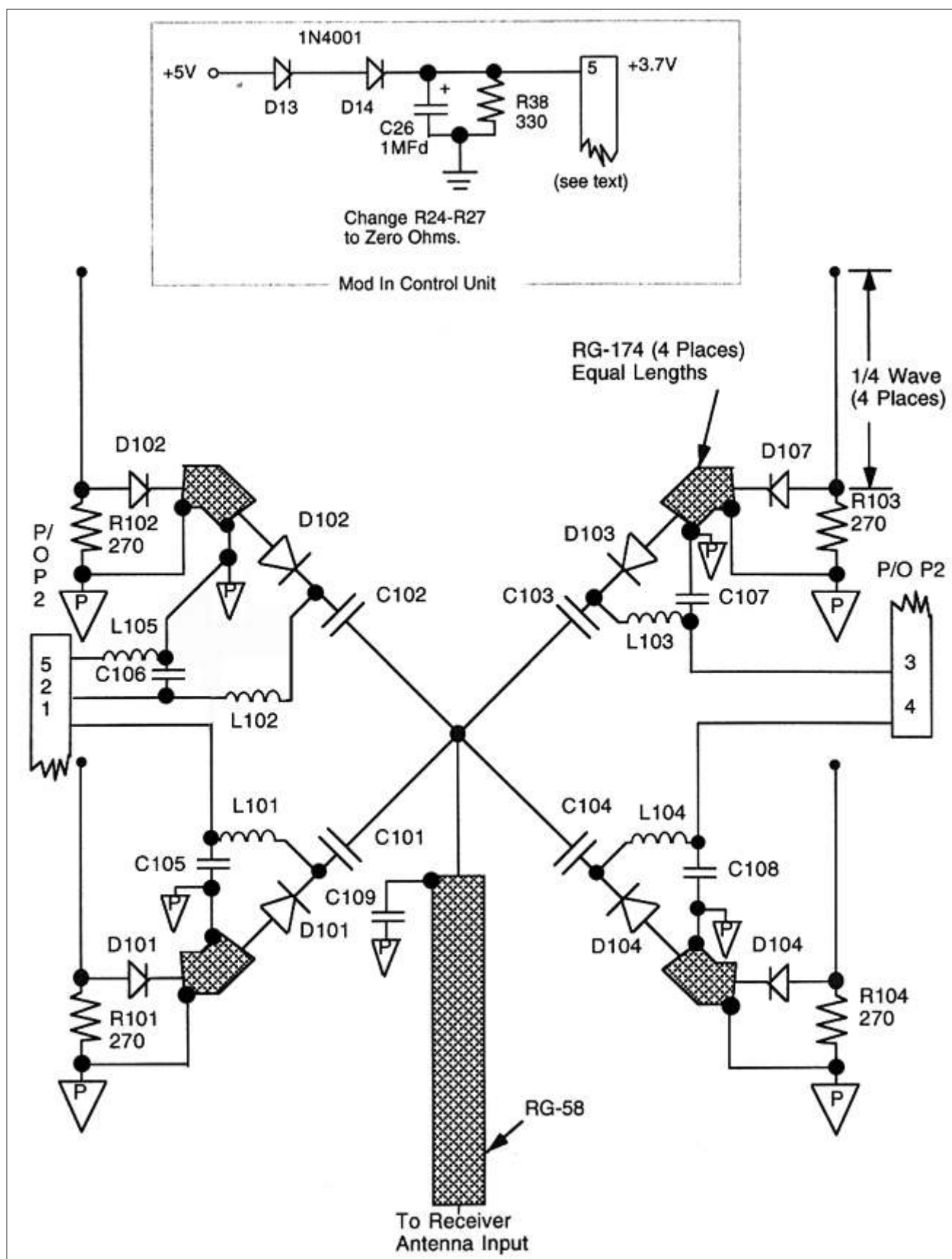


Figure 1. Schematic diagram of the new wideband switcher for the Roanoke Doppler. The P-in-a-triangle symbol denotes a connection to the ground plane sheet of the one-piece version. For the mag-mount version, the P-in-a-triangle points at the whip ends of the coaxes are connected to the magnets but remain insulated from the car body. Components values are for an array centered on two meters. All capacitors except C26 are

*680 picofarads. R101-R104 are 220 ohms. See text for data on D101-D108 and L101-L105.*

In the new Roanoke Doppler antenna switcher, PIN diodes receive more current drive in the ON state (7.5 mA), reducing loss. Diodes are reverse-biased when OFF to provide better isolation. The new switcher makes the Roanoke Doppler noticeably more sensitive. It gives bearings on weak signals that would have been masked by switching noise with the original antenna.

It's not hard to upgrade your present two-meter Roanoke Doppler switcher to use the new circuit. Most of the existing chokes and capacitors are unaffected. Just delete half of each two-section RG-174 coax line, put series PIN diodes at the end of each remaining line, add resistors at the antenna bases, then install L105 and C109. Note that the RG-174 lines to each whip are soldered to the plane at both ends, but the shield of the coax to the receiver connects to the plane through C109.

Changing from shunt to series RF diodes requires minor modifications in the control unit. The fifth wire in the control cable becomes a positive voltage source instead of a return connection. D13, D14, C26, and R38 set the potential on the counterpoise plane and radials at two diode drops below +5V (approximately +3.5V) instead of vehicle DC ground potential. If you fabricated the antenna unit as described in the book, using a copper-clad sheet on a wood base mounted with suction cups to insulate it from the car, DC on the sheet is not a problem.

Delete the 680 ohm drive resistors (R24-R27) in the control unit, replacing them with jumper wires. They are no longer needed because this function is performed by R101-R104 in the antenna unit. If your control unit has an A-suffix part at U5 (such as CD4049A or MC14049A), replace it with a B-suffix part to get adequate current drive.

I used Motorola MPN3401 PIN diodes at D101-D108. They are available by mail (see [Hardware Sources](#) page). Other suitable substitute PIN diodes are also listed on that page. Ordinary switching diodes are not recommended. (See the [Frequently Asked Questions](#) page for reasons.)

Miniature (quarter-watt resistor sized) rf chokes typically have iron cores. The distributed capacitance of these chokes gives them self-resonant frequencies in the 75 MHz range. This is below two meters, so these chokes can act like capacitors instead of inductors there. Non-ferrous core chokes have self-resonant frequencies near 200 MHz, so be sure to use them in the switcher instead of iron-core chokes. For L101-L105, I recommend J. W. Miller #4602 (1.0 uH) or #4604 (1.5 uH), available at many local distributors or by mail from [Circuit Specialists](#) and [Ocean State Electronics](#). These chokes are about the size of a 1-watt resistor.

You can make your own 1 uH chokes on one-inch lengths of 3/16-inch diameter polystyrene rods. Wind 24 turns of AWG 26 enameled wire on the rod in a single layer, close-spaced. With the wire held in place with a bit of tape, cover the winding lightly with Q-Dope, a liquid polystyrene coating made by GC Electronics. It's best to use this substance outdoors to keep the shack fume-free. After the coating hardens, strip enamel from ends of the leads and install the choke.

If you are careful, you can make "air core" chokes without the rod. Wind the turns on the shaft of a 3/16-inch drill bit, hold down the ends of the winding, and brush on some Q-dope. When the coating dries, carefully slide the choke off the bit in one piece and install it. Covering the installed choke with more Q-dope will prevent it from peeling apart due to road shock and vibration. (Hint: Finished coils are fragile before the second coating. It's easier to strip enamel from the wire ends before winding instead of afterwards. It takes 19.5 inches of wire to make a 24-turn coil.)

## More Than Two Meters

Theoretically, the radius of rotation of a multi-whip doppler array (the distance along the ground plane from array center to any whip base) must be less than one quarter free-space wavelength at the frequency being received. This means that the four antenna square array pattern must not be more than 0.35 wavelength on a side. My experiments and those of others have shown that about 0.22 wavelength on a side is optimum.

Closer spacing increases mutual coupling between whips, which in turn increases undesirable amplitude directivity effects. Furthermore, it produces lower deviation of the doppler tone in the receiver, degrading the signal-to-noise performance. Wider spacing increases doppler tone deviation, which can be detrimental on some receivers, depending on their IF filter characteristics.

A 0.22 wavelength array works well over a +/-20 per cent frequency range. An 18-inch array like the one in the book covers 121 through 174 MHz. Bearing accuracy is unacceptable outside this range. Sensitivity is maximum near the resonant frequency of the quarter wavelength vertical whips.

Civil Air Patrol volunteers, Coast Guard Auxiliary members, and others interested in search and rescue can use this array on the 120 MHz aircraft band and the 160 MHz marine band. Keep in mind that Doppler processing works only with FM receivers. A scanner or marine set receives narrowband FM from 138 to 174 MHz, but most scanners and all transceivers have only AM detectors in the 120 Mhz aircraft band. They won't work with a doppler RDF set. Instead, you must use a receiver that features selectable narrowband FM mode for the aircraft band

Inductor and capacitor values in the switcher are not nearly as critical as whip length and spacing, so long as these components have self-resonant frequencies near the high end of the array operating range. Table 1 below gives array sizes and component values for doppler antennas centered on three UHF/VHF bands. For one-piece arrays on a metal plate, length of the corner radials extending from the whip base should equal the whip length. Turns data for inductors are for single-layer close-spaced chokes on 3/16-inch non-metallic forms, wound with AWG 26 enameled wire.

	VHF-High	UHF-Low	UHF-Mid
Design center (MHz)	146	224	440
Frequency range (MHz)	121 - 174	185 - 270	370 - 530
Whip length (inches)	19.25	12	6
Whip spacing (inches)	18	12	6
C101-C109 (picofarads)	680	470	220
L101-L105 (microhenries)	1.5	1.0	.47
Homemade choke turns	24	20	12
JW Miller choke	4604	4602	9230-12

*Table 1. Array and component data for the new Roanoke Doppler switcher for three popular bands.*

## Mag Mount Version

Some commercial doppler sets have individual magnetic-mount whip bases instead of a one-piece array. Coaxes from each whip go inside the vehicle to the switcher, located either in the center of the array or in the control/display box. One set of whip bases can be used over a very wide frequency range by placing them on the vehicle roof at appropriate spacing for the frequency of the hunt.



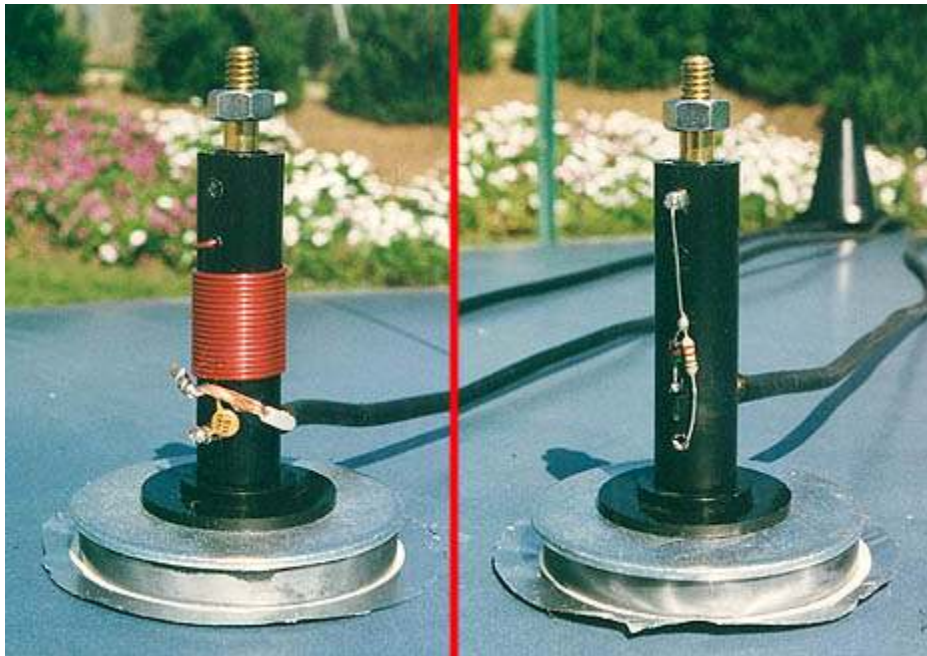
The requirement for exact dual quarter-wavelength coaxes between switcher and whips made it impossible to do this with the old Roanoke Doppler switcher. Coax lengths are not critical with the new switcher (so long as they are equal lengths). So a mag-mount antenna set is practical.

I built the prototype from inexpensive Citizens Band whips on sale at a local truck stop (see Photo 4 below). They are manufactured by Barjan Products (Model 300-102). The large bases make them easy to modify. The whip holder has a setscrew mount, so exchanging whips for band changes is simple. Other hams have used mag-mounts by MFJ, Lakeview and other suppliers.



*Photo 4. Magnetic-mount doppler whips can be placed quickly on any vehicle with a ferrous metal top and moved about to cover a wide range of frequencies.*

Photo 5B below shows modifications to the CB mounts. I removed the whip and holding nut, then carefully slit the bottom foil to remove the plastic base cover. Besides covering the magnet to prevent paint scratches, [the foil provides important capacitance coupling of RF to the ground plane \(vehicle body\)](#). As supplied, the foil is insulated from the magnet and coax shield with thin paper. This is important, because the coax shield is not DC-grounded with the new switcher.



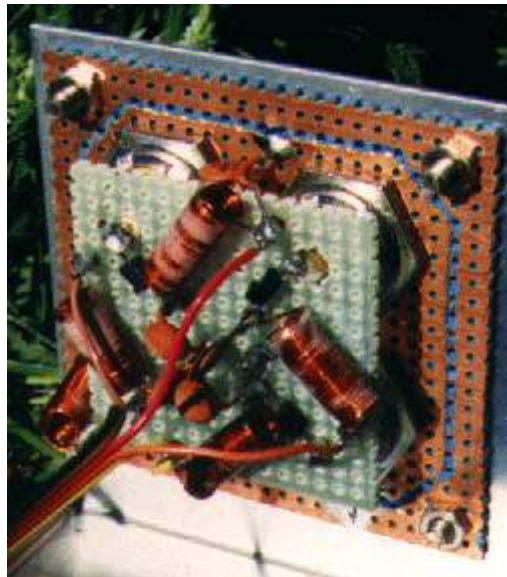
*Photo 5. At left, inside the base of the Barjan 11-meter antenna before modification. Note the white insulating paper between the magnet and the bottom foil. At right, the antenna base modified for doppler use. After taking the photo, I added electrical tape to prevent a short from the PIN diode cathode to the resistor lead.*

After unwinding the 11-meter loading coil and removing the matching capacitor, there is plenty of room to wire in a PIN diode and current limit resistor. To minimize loss, I shortened the 17-foot coax lines. Remember that for accurate bearings, all four line lengths must be exactly equal.

Cut each vertical element to one-quarter wavelength, calculated with the standard formula  $L = 2808/F$  where  $L$  is element length in inches and  $F$  is frequency in MHz. For the antenna base of Photo 5 above, the feedpoint of the radiating element is the cathode end of the PIN diode. Taking into account the length of the whip base and the depth of the hole in the whip holder, the 3/32-inch diameter CB whip I used had to be cut to 16.9 inches to achieve an effective 19.25-inch quarter wavelength element for 146 MHz. I cut the leftover rods into whips for the 125 and 70 cm bands. You could also use 3/32-inch diameter welding rod (stainless steel or bronze) to make whips.

I mounted the switcher on the rear panel of the display unit in a 6 X 4 X 3 inch aluminum cabinet (LMB model CR-643), as described in the book (see Photo 6 below). Components are on a 2-1/2 inch square of perforated board, copper-clad on the interior side. The CB antennas came with PL-259 connectors, so I installed four SO-239 receptacles. For UHF, it might be better to convert to BNC fittings for minimum loss.



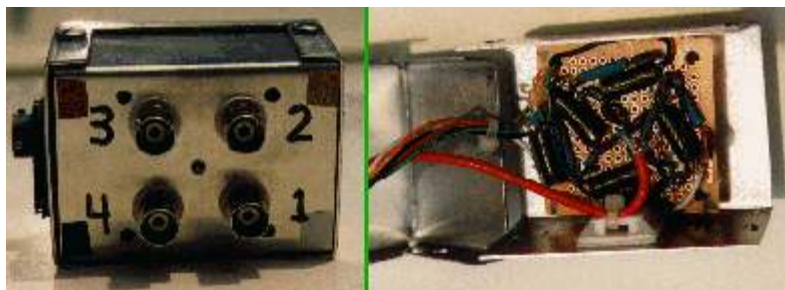


*Photo 6. KØOV's new Roanoke Doppler antenna switcher mounted on the back panel of the display box. The two display circuit boards and their connectors are not installed yet. A short length of RG-58 coax (not shown) ties the switcher common point to the BNC feedthrough adapter for connection to the VHF receiver.*

I used a Dremel Moto-tool (TM) as a router to insulate the center of the board where the four single-hole coax fittings mount. This part of the board floats at +3.7 volts DC, so use care to prevent the coax connectors from shorting to the box. A "nibbling tool" is an easy way to make a two-inch square hole in the rear panel to clear these connectors.

A 1-1/2 inch square piece of unclad perf-board fits over the center pins of the coax receptacles. Four capacitors (C101-C104), four PIN diodes (D101-D104) and four RF chokes mount on this board. C105-C108 connect between this board and the isolated return on the copper-clad board. Keep leads as short as possible on all these components and make sure the path length through D101-D104 and C101-C104 from common point to center conductor of each SO-239 is equal. Note the symmetry of the layout in Photo 6 above.

**UPDATE:** [FAR Circuits](#) now sells a [printed circuit board for this switcher](#) that is part of the board set for the Roanoke Doppler DF Set. There is an error in the marking on this board. [Click here for the correction.](#)



*Photo 7. The switcher for mag-mount antennas can be located near the array instead of in the display unit. N6QAB built his in an aluminum box. Use care to keep from shorting the +3.5 VDC RF return. (Photos by N6QAB)*

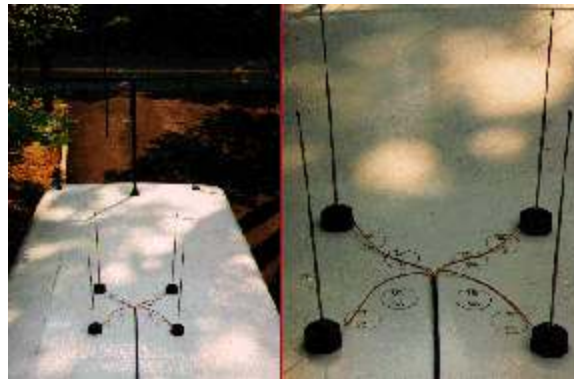
## Final Thoughts

Be sure that your array "rotates" in the proper direction and in proper sequence. I numbered the whips from 1 to 4 going clockwise (as viewed from above the car) beginning with the left front (LF). To minimize the

chance of installation error, I marked the whip bases, coax plugs, and box receptacles with location designators (LF, RF, RR, LR) instead of numbers.

Optimum spacing of the four array sides is given by the formula  $D = 2630/F$  where D is distance between adjacent whips in inches and F is received frequency in MHz. This distance is not critical, but use care to place the whips in a perfect square pattern on the roof and align the array sides parallel to the sides of the vehicle.

It's tedious to set out the mag-mount whips using just a ruler or tape measure. I made separate cardboard templates for optimum 146, 223, and 440 MHz spacing. Cutouts in the template corners match the whip bases. Emplacement is fast and misalignment is avoided with the templates. Once the whips are in place, I remove the template so it doesn't get rained on or blow away. Kevin Kelly N6QAB went a step further and marked the top of his vehicle with whip locations (see Photo 8 below).



*Photo 8. (Photos by N6QAB)*

When changing bands, check the bearing accuracy of your setup using a known signal source before setting out to find an unknown emitter. In my case, readjustment of the calibration control has not been necessary when whip length is within 20 per cent of resonance. On the other hand, using two meter whips on 224 MHz gives about 90 degrees bearing error. The presence of other VHF antennas on your vehicle may cause bearing error on some bands.

Fixed-site VHF doppler antennas usually use vertical dipoles instead of quarter-wavelength whips. Dipoles provide better RDF performance because inter-whip coupling through the ground plane is eliminated. Vertical dipoles are seldom seen on mobiles, because such an array is twice as tall and much less "stealthy" than a whip array. However, Vincent Fiscus KB7ADL built a 4-dipole two-meter array for his mobile (photos below) using this wide-range switcher and he says it works great.



*Photo 9. Vincent Fiscus KB7ADL built his two-meter Roanoke Doppler antenna using dipoles instead of quarter-wavelength whips. He reports that weak-signal and multipath performance is better. (Photos by KB7ADL)*

**This antenna system is suitable for other "hard switched" doppler sets** including the [Agrelo DFjr](#), which is no longer marketed. I use it regularly with a MicroFinder by AHHA! Solutions, which is also no longer on the market. It is important to note that whips are switched ON by taking the appropriate logic line LOW. The appropriate MicroFinder V2.0 antenna configuration command is:

**asw 4 1**

Note that the last character of the command is a letter "l" for LOW, not a numeral one. I obtained +5V from pin 5 of the Microfinder DB-9 antenna connector (always HIGH in the 4-antenna mode) to feed the diodes in the +3.7V source.

Similarly, this antenna system should work well with the [Montreal Doppler II by VE2EMM](#). (Select the "4-" antenna option.)

I haven't tried it, but this antenna system should be a good replacement for the [Dick Smith model K-6345](#) antenna set. The four logic signals from IC6 go to the four antenna logic lines. Since these lines swing positive and negative in the Dick Smith set, the +3.7V supply is not needed. Just connect the 3.7V input (pin 5 of connector in the schematic above) to circuit ground on the control display unit. You will need a 5-wire cable to the antenna unit instead of 4 wires as in the original Dick Smith set.

This antenna system is not suitable for use with "soft-switched" dopplers made by [Doppler Systems](#) of Arizona.

If you build this antenna system, please send [e-mail to k0ov@homingin.com](mailto:k0ov@homingin.com), letting me know what doppler display you have and how this antenna set works for you.

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