Number 57 on your Feedback card

Homing In

Radio Direction Finding

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Build the NorthScope

Sometimes hidden transmitter hunting (T-hunting) is easy. I get sharp, unambiguous bearings, drive directly to the hidden T on good streets through light traffic, and my passengers ask, "What's so hard about this?"

Or was I just daydreaming? Actually, it seems as if every time I take ride-alongs to demonstrate the fun of radio direction finding (RDF) contests, the hunt is extra difficult and I don't do as well as I would like. Of course, it wouldn't be fair to blame the passengers for upsetting my concentration. The fact is that there are wide variations in difficulty of T-hunts due to variations in signal level, polarization, terrain, and the surroundings of both the hidden T and the hunters. I'm always seeking out new ways to get the best bearings in the worst circumstances.

Most two-meter T-hunters in southern California use a yagi or quad of three to six elements on a mast extending vertically from the vehicle window or roof hole. They depend on the radio's S-meter to tell the direction of strongest signal as they rotate the mast by hand. An RF attenuator keeps the meter on scale when closing in. In urban areas where signals are constantly reflected from hills and buildings (multipath), the beam's sharp forward lobe can pick out each direct and reflected signal component. That's a major advantage of the beam method over a Doppler or dual-switched-dipole setup.

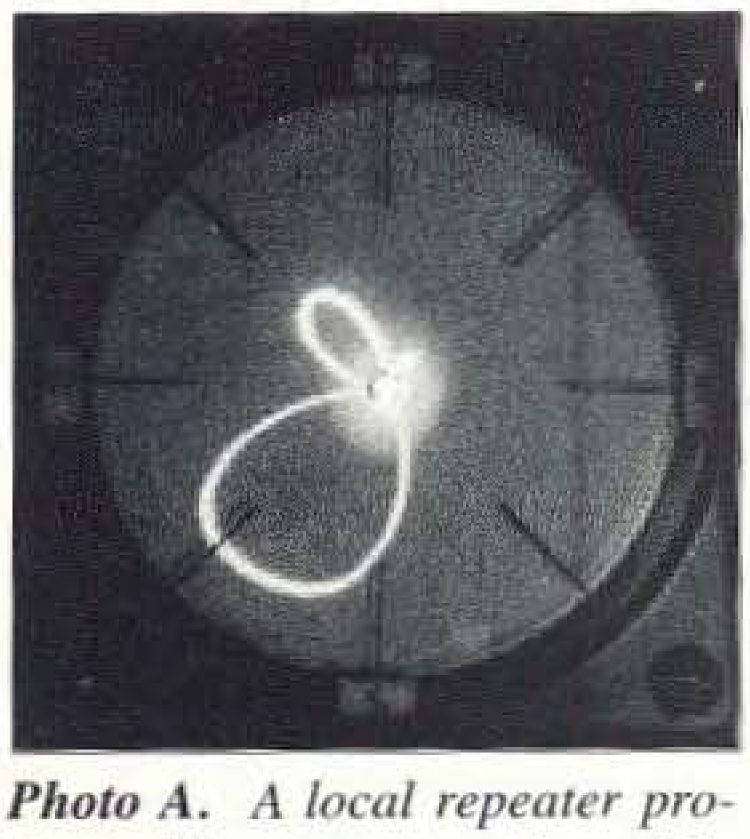

Photo A. A local repeater produces this pattern on the mobile quad and NorthScope. The main forward lobe at 220 degrees true is the direct signal. The second lobe at 320 degrees is reflected signal from nearby foothills.

The down side is that interpreting your beam's indications can be tricky and time consuming, slowing you down when speed is of the essence. Sometimes multipath, airplane flutter, and path blockage make the S-meter reading fluctuate constantly as you roll along. Getting an accurate bearing on the direct signal while ruling out reflected signal peaks under these circumstances is not an exact science. A few experienced T-hunters have improved their performance with polar-plot bearing displays of signal strength versus direction on a cathode-ray tube (CRT) or computer.

CRT bearing readouts featured in past "Homing In" columns include those of KK6CU (October and November 1992), NØMKJ (March 1994), and AB6OS/KA6SOX (November 1993). The screen shows signal strength versus direction from multiple sweeps of the antenna so the operator can "eyeball average" fluctuations resulting from motion. It is much easier to discern the most likely direct signal direction in a multipath environment with a polar display than it is with just an S-meter.

North-up is better

All of the above polar displays show signal directions relative to the vehicle's heading. That's fine when you're driving in a straight path and you know exactly which way you're going. But what about T-hunts that take you on winding roads in new housing developments or along desert washes in the middle of nowhere? How can you interpret the display accurately when it rotates as the vehicle turns?

Last month's "Homing In" showed how a fluxgate compass sensor on your mobile beam detects the mast's orientation with respect to true north. Why not combine the fluxgate sensor and CRT readout to produce a polar display of signal strength that is always relative to north, no matter which way you turn? In aviation terms, this is called a "north-up" display. I call mine the NorthScope.

For good "eyeball averaging," the CRT must display several rotations or sweeps of the RDF antenna at a time. An ordinary oscilloscope won't do—you need a storage-type oscilloscope or a high-persistence CRT like those in radar sets of the pre-computer era. The NorthScope trace of **Photo A** is typical for a strong signal with a small amount of multipath. The higher the beam's gain, the sharper and narrower the major lobe will be. Note that this pattern is consistent for every rotation of the antenna because the vehicle and source are stationary and there are no moving objects such as aircraft in the path.

The NorthScope is at its best in a difficult RF environment such as in **Photo B**. The large repeatable lobe identifies the most likely direct bearing to the T. Reflections and noise in other directions show up as a jumble of non-correlated traces after several rotations of the mast. If there are two or more keyed-down transmitters in different directions on the frequency simultaneously, the NorthScope can resolve bearings for each of them. Try that with a Doppler!

Sometimes the signal level flutters, making it hard to find a peak on the S-meter. Worse yet, imagine the S-meter bounce if the signal switches on and off every second or so. (It's legal on some hunts!) Under these conditions, turn the antenna slowly several times, find the peak on the polar display, then read the direction.

A CRT readout need not be a budget-breaker. Used storage scopes show up regularly at electronics surplus sales and swap meets. They aren't cheap, but if you're an experimenter, you will find other uses for one around the shack. Medical monitors such as the Tektronix Model 603 include waveform storage and are available on the surplus market at lower prices. Look for scopes and monitors that accept two analog inputs and have an X-Y mode, plus gain and position controls for each channel.

Laboratory scopes and medical monitors are designed to operate from household outlets. You will need a DC-to-AC step-up converter to adapt them to mobile use. PowerVerters™ by TrippLite are suitable and available in several wattage ratings. Be advised that the current drain of a storage scope or monitor can be substantial; a heavy-duty car battery is a good idea.

A simple interface

To connect the scope to the sin/cos fluxgate outputs (described last month) and draw a polar plot as the mast goes around, we need a circuit that varies the sine and cosine amplitudes in proportion to the incoming signal level. The analog multiplier, a little-known function block, is perfect for this task. Not to be confused with the more common analog multiplexer (which switches signals), the analog multiplier produces an output signal that is the exact product of two input signals. For instance, if one input is +2 volts and the other is +3 volts, the multiplier output is +6 volts.

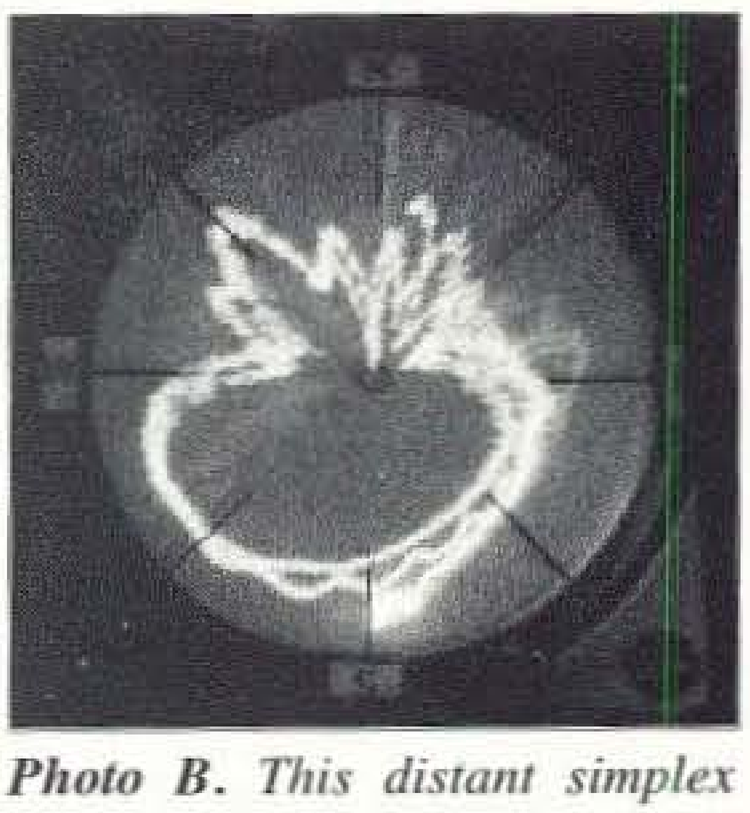

Photo B. This distant simplex signal is on the other side of a hill, so it has lots of multipath and airplane flutter. By viewing several overlaid sweeps with the NorthScope, it is clear that the most likely bearing is 235 degrees.

A four-quadrant multiplier takes into account the polarity of input signals. If A input is -2 volts and B input is +2 volts, output is -4 volts. Put in -1.5 volts and -2.0 volts to get +3.0 volts, and so forth. Typically, the product voltage is internally divided by a factor of 10. This makes sense when you consider that the result of 5 volts times 5 volts is too great for a circuit powered by a 15-volt source if the output is not scaled down.

Analog multiplier integrated circuits are inexpensive and ideal for modulators, wattmeters, voltage-controlled amplifiers, and automatic gain control stages. The major suppliers of these ICs are Analog Devices, Harris Semiconductors, and Motorola Semiconductors. Sin/cos signals swing positive and negative, while S-meter signals are positive. Therefore, the multiplier must operate in two of the four quadrants.

I chose the Motorola MC1495, available from nationwide distributors such as Newark Electronics. The dual-inline package (P suffix) is easiest for home builders to use, but it may be harder to find than the surface-mount (D suffix) package.

Fig. 1 is the fluxgate-to-monitor interface circuit schematic. There are separate analog multiplier ICs and operational amplifiers for the X and Y axes. All parts except the multipliers are available at local parts stores. They fit onto a few square inches of perforated board space (**Photo C**). Construction is simple, even without an etched circuit board. No ground plane is needed, but be sure to put the supply bypass capacitors close to the ICs. Mount S1 and R1 in convenient locations for adjustment during T-hunts.

Inputs of the multiplier ICs are differential amplifier stages. That's ideal for this application because the sin/cos outputs from the fluxgate compass vary positive and negative with respect to a +4.2-volt analog reference. By connecting multiplier inverting input pins to the analog reference, that relationship is preserved through the interface circuit and there is no need for a regulated negative voltage supply. U3A and U3B convert the differential outputs of the multiplier ICs to single-ended.

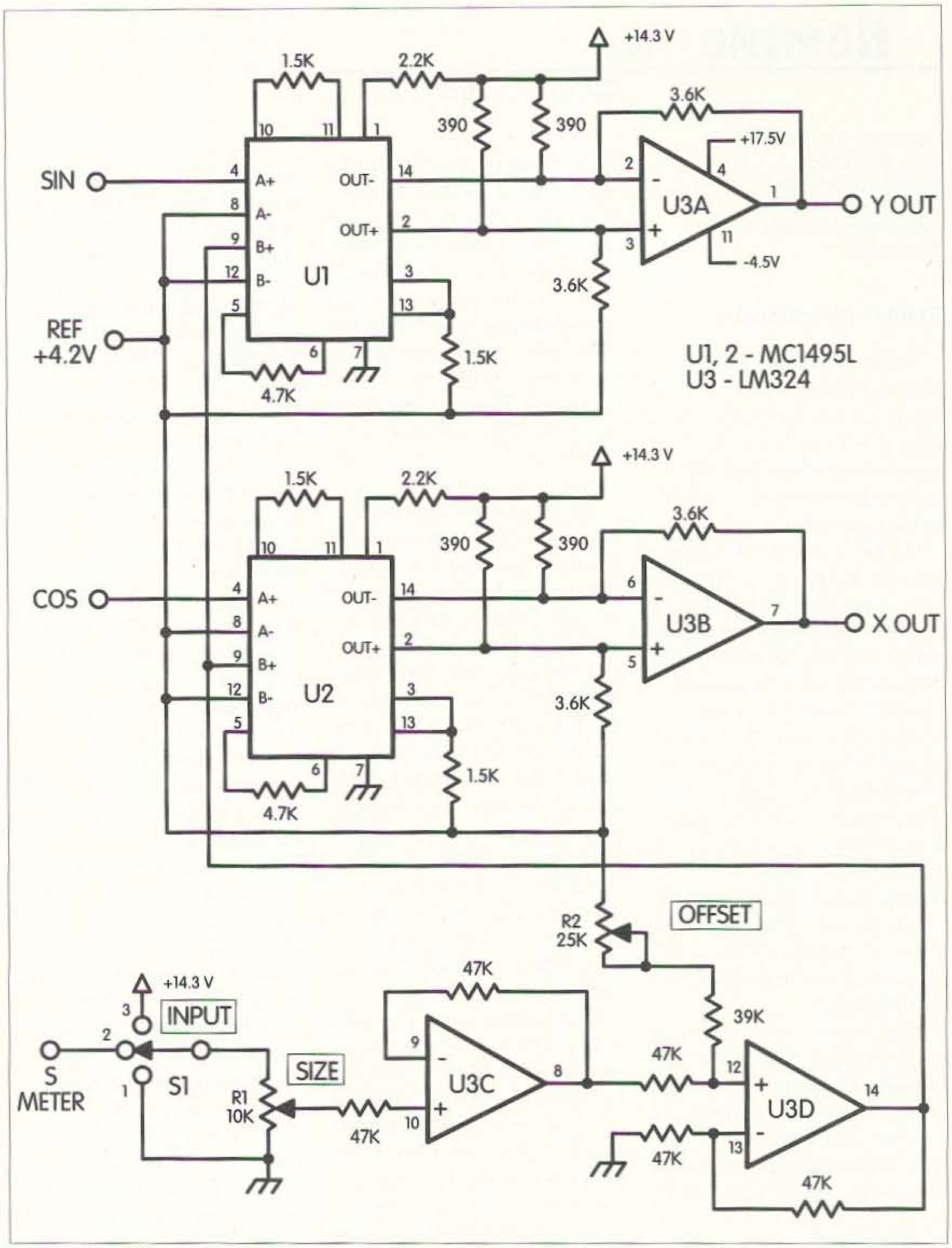

Fig. 1. Schematic of the interface circuit that combines fluxgate compass and S-meter signals to drive a north-up CRT display. Resistors are in ohms and capacitances are in microfarads unless otherwise noted.

My receiver's S-meter tapoff circuit is described in Chapter 5 of the book *TRANSMITTER HUNTING—Radio Direction Finding Simplified* (available from *73*'s Radio Bookshop). It includes an operational amplifier to drive an analog panel meter atop the dashboard. The op-amp output in that circuit goes from zero to +10 volts full scale and connects to the point marked S-METER in **Fig. 1**. U3A is a voltage follower stage with unity gain; U3B adds 4.2 volts to the S-meter voltage as required by the differential analog multiplier inputs.

To ensure sufficient headroom in the multiplier and avoid waveform clipping under all input conditions, use care in choosing supply voltages for the interface circuit. The positive supply to the MC1495 ICs should be regulated. Supplies for the LM324 quad op-amp can be unregulated. The LM324 positive supply (pin 4) range is +15.8 to +20 volts; negative supply (pin 11) can be -1.5 to -12 volts. Look for places to tap off these supply voltages within your monitor.

Tune-up is easy

A few simple alignment steps are required to set up the NorthScope for the first time. Connect all the assemblies and install the fluxgate sensor on your antenna mast. Set the focus control on your monitor for a minimum-size spot. Keep the

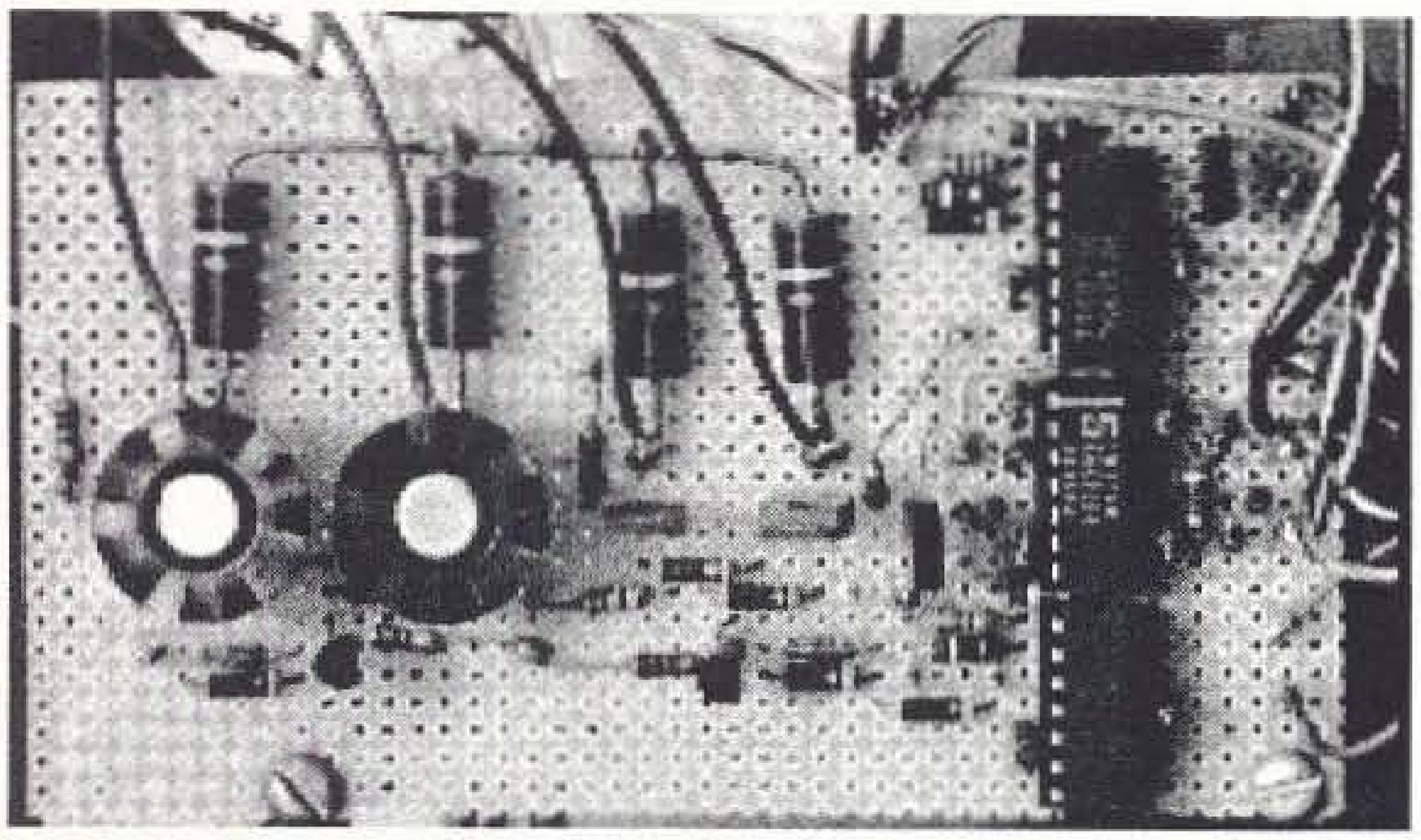

Photo C. The three ICs and associated resistors on the right side of this perforated board are the fluxgate/S-meter interface components. The rest of the board holds CRT deflection amplifiers for the home-built monitor.

brightness control as low as practical to avoid burning the phosphor screen of the scope. X and Y channel sensitivity settings should be about one volt per division, depending on your screen size.

Turn SIZE control R1 on the interface to zero. Set input switch S1 to SPOT (position1). Set the X and Y position controls on your scope to center the spot on the screen. Turn the mast and sensor around 360 degrees; the spot should not move. If it does, adjust OFFSET control R2 until the spot does not move as the mast turns. Now re-center the spot, if necessary, with the position controls.

Set S1 to CIRCLE (position 3). Adjust the SIZE control to move the spot about an inch toward the edge of the screen. Rotate the mast/sensor and adjust the X and Y gain controls and the two screwdriver-adjusted potentiometers on the left side of the fluxgate compass display for a perfect circular pattern around the center spot position. The E-W and N-S pots on the fluxgate equalize the left-right and top-bottom voltage swings such that positive excursions equal negative excursions for each axis. This makes the circle trace exactly over the spot (see **Fig. 2**). If the circle is elliptical instead of round, adjust the X and Y channel gains as appropriate.

Set S1 to TRACE (position 2). With your receiver tuned to an active repeater and enough RF attenuation that the S-meter does not peg, swing the beam around and adjust the SIZE control for a trace similar to **Photo A**. There is plenty of gain in the S-meter channel, so you can get a full-size trace even if the incoming signal only moves the S-meter to quarter-scale.

Notice that the reflection lobe in **Photo A** is quite sharp but the major lobe is broad at the outside. This is caused by nonlinearity in my receiver's S-meter circuits. Normally this is not a problem, but I can get a sharper lobe if needed by adding RF attenuation to the receiver and turning up the SIZE control to compensate. It should also be possible to add nonlinear devices such as diodes to the feedback path of U1A to make that stage an antilog amplifier; I have not tried this yet.

While the north-up display could be used with a motorized mast like the displays of KK6CU and others, I prefer turning the mast by hand. Not only does it simplify the project (no slip rings for the coax and sin/cos signals), it also makes it easier to find the exact direction of signal peaks as displayed on the scope. I can rock the beam back and forth until I'm satisfied that I have found the optimum bearing. This is particularly helpful when there is airplane flutter or rapid amplitude changes due to keying or high modulation levels.

I have enjoyed building several oscilloscopes over the years so I decided to make my own monitor/display for the NorthScope. By modifying a commonly available "boat anchor" scope and raiding the junk box, the cost was under $100. The monitor draws about as much as a typical mobile receiver, so I don't worry about draining the car battery. Next month's "Homing In" will have all the monitor details and some thoughts on computerizing the NorthScope. Meanwhile, keep sending your T-hunting news and column suggestions via E-mail or my post office box. Thank you!

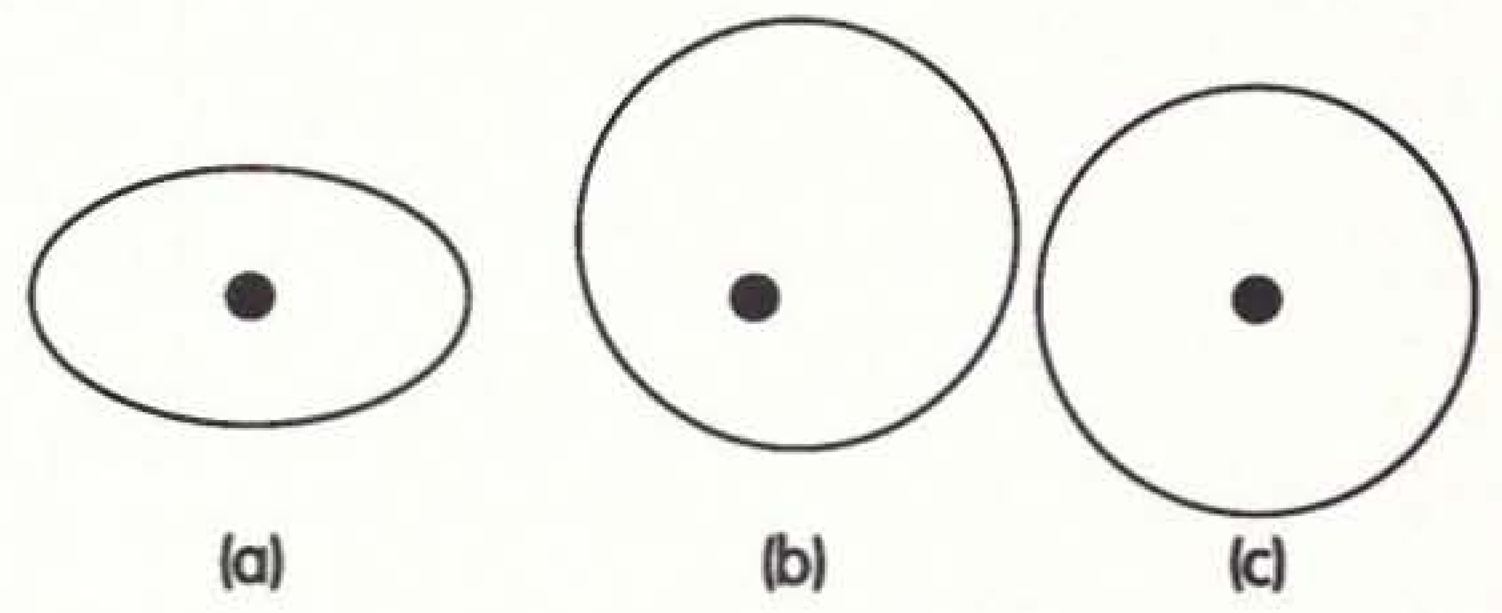

Fig. 2. At (a), unequal horizontal and vertical gain. At (b), offset due to misadjusted E-W and N-S controls. At (c), a perfect circle in proper position.