Number 9 on your Feedback card

HOMING IN

Radio Direction Finding

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What's That Whirligig?

"Do you have a TV in your car?" Questions like that from passers-by are common when hams gather for hidden transmitter hunts, usually called foxhunts or T-hunts. The yagis and quads that most competitors in my area use for 2 meter radio direction finding (RDF) look a lot like television antennas, so they are big-time attention-getters. No one gets more stares than JaMi Smith KK6CU of Pasadena, California. His quad is long, tall, and continuously spinning at 40 rpm!

Last month's column showed how a display with a storage type cathode ray tube (CRT) gives far more useful RDF data than an S-meter when you're hunting with a beam. The concept, originally used on the ham bands by the late Jim Davis W6DTR, has been updated and improved by KK6CU. He motorized his antenna for continuous rotation and bearing readout.

This month you'll see how JaMi built up his system from inexpensive surplus components and read some hints to help ambitious RDFers build their own. You may not be able to make an exact duplicate but you can achieve the same results using hardware that's readily available, plus your own ingenuity.

It's Not Covert

JaMi supports his six-element quad with an A-frame almost three feet high (see Photo A). The frame sits atop a bicycle rack that is firmly attached to the rain gutter. Pillow blocks hold the 3/4-inch o.d. mast in two places, 21 inches apart, with the drive mechanism in between (see Photo B). The AC gearmotor turns at 72 rpm, coupled with a 13-inch belt to the 40 RPM mast.

Parking garage clearance? No problem. The A-frame lowers to the rear on hinges (see Photo C). The whole assembly adds only about a foot of height to the vehicle when lowered. JaMi says he's eyeing worm gear drives to automate the raise-lower function, but it's manual for now.

KK6CU's display unit is a Tektronix Model 603 medical monitor. It writes traces on the screen continuously until the ERASE button is pressed. When evaluating a storage oscilloscope for use in this application, look for external inputs on both left-right (x) and up-down (y) axes. Amplifiers for both axes must work at DC and have the same scale factors (volts per division).

JaMi uses a DC-to-AC inverter to power the CRT monitor, the motor, and a +/-15 volt DC power supply for the interface circuit. His 400-watt Tripp Lite square-wave inverter is not recommended for inductive motor loads, but the 50-watt motor and the 125-watt monitor have worked fine with it so far.

Electronic Trigonometry

A beam and receiver S-meter give signal strength information as a function of pointing direction (azimuth). This data is in "polar" form. You may remember from a math class that polar coordinates are represented by an angle (signified by the Greek letter theta) and the radius (r). The magnitude of r is proportional to signal strength.

To display polar data on an oscilloscope monitor, it must be converted to x and y axis voltages. The value of x equals r times the cosine of theta. The value of y equals r times the sine of theta. That means we need a device that outputs voltages proportional to the sine and cosine of the beam pointing angle.

Such a device exists: the sine-cosine potentiometer. You won't find one at your local parts store because they are used only in specialized applications such as servomechanisms and robotics. But try nearby surplus outlets—you might get lucky. JaMi found a good one for less than a dollar.

These pots have special windings that generate voltages proportional to the sine and cosine of the shaft angle when the pot is connected to equal positive and negative voltages. Several models are available from Servo Systems Corporation, 115 Main Road, PO Box 97, Montville NJ 07045-9299; telephone: (201) 335-1007, for a catalog. Prices range from $18.50 to $69.50 each. The minimum order is $30.

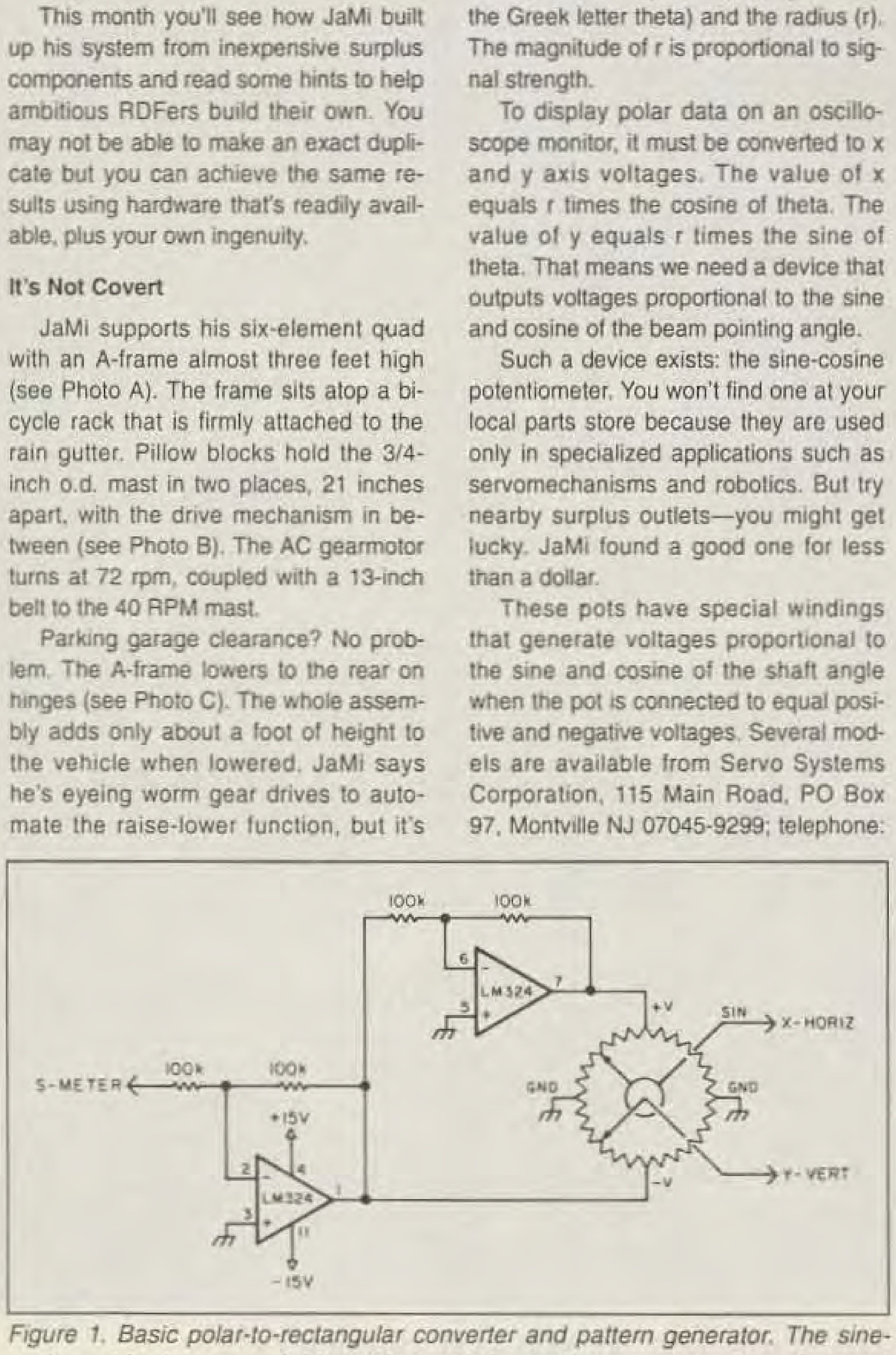

Figure 1. Basic polar-to-rectangular converter and pattern generator. The sine-cosine pot is shown as a bridge of four resistive sections and two wipers, but most units actually have a single tapped winding on a square board inside.

Photo A. Heads turn when JaMi Smith KK6CU goes on foxhunts with this array. It spins at 40 RPM and displays bearings on a storage oscilloscope.

If you can do so without damaging it, peek inside your sine-cosine pot to see if it is designed for rotation in a specific direction. Some units have the wiper arm configured to "pull" across the winding in one direction. If you rotate in the opposite direction, the wiper "pushes" across the winding and the pot will wear out quickly.

Use care mounting the pot on your antenna mast, particularly if it has a 1/8-inch diameter shaft. Allow a little side-to-side play so that damaging shear force is not applied to the shaft. But don't allow much rotational play, as that will cause bearing errors. JaMi supports the pot by the wiring harness, as shown in Photo D.

Figure 1 shows the polar to x-y conversion schematic. The op-amps operate near DC, so compensation is not critical. A 1458 dual op amp (RS 276-038) should work fine. JaMi used two sections of an LM324C (RS 276-1711).

Each stage inverts the S-meter output, so equal but opposite polarity "r" voltages are applied to the sine-cosine pot windings. Using two identical inverter stages assures symmetrical low impedance drive.

On the pot JaMi used, a Computer Instruments Company model 106-1, one inverter output goes to pin 1 and the other to pin 2. Sine and cosine outputs are pins 3 and 4. Two pins on this pot (5 and 6) are connected to signal ground. Yours may have only one ground pin, or it might have two separate sections, one for sine and one for cosine.

The S-meter input level and the gain of U1a are such that Jami gets full-size scope patterns with signals that barely move the receiver's S-meter. As he approaches the T and the traces go off the scope face, he adds RF attenuation between the antenna and the receiver to shrink the pattern.

A Cheap Joint

The next dilemma is getting the signal from the spinning antenna to the stationary receiver with minimum loss. Prices for coaxial rotary couplers (sometimes called "rotary joints") start at a budget-busting $450 each at specialty coax product suppliers like Pasternack Enterprises. Furthermore, they must be mounted to the bottom end of the mast, which is where the sine-cosine pot also needs to go.

KK6CU's solution was to make an in-line rotary coupler out of a two-element continuous-turning potentiometer. Two elements are needed because an insulated slip ring is required for the coax shield as well as for the center conductor. If you take the easy route and try to couple the shield through the bearing of the pot, you'll have a very noisy system.

It's simplest to convert a pot having a 1/4-inch diameter shaft. "Most continuous-turn pots, including this one, have

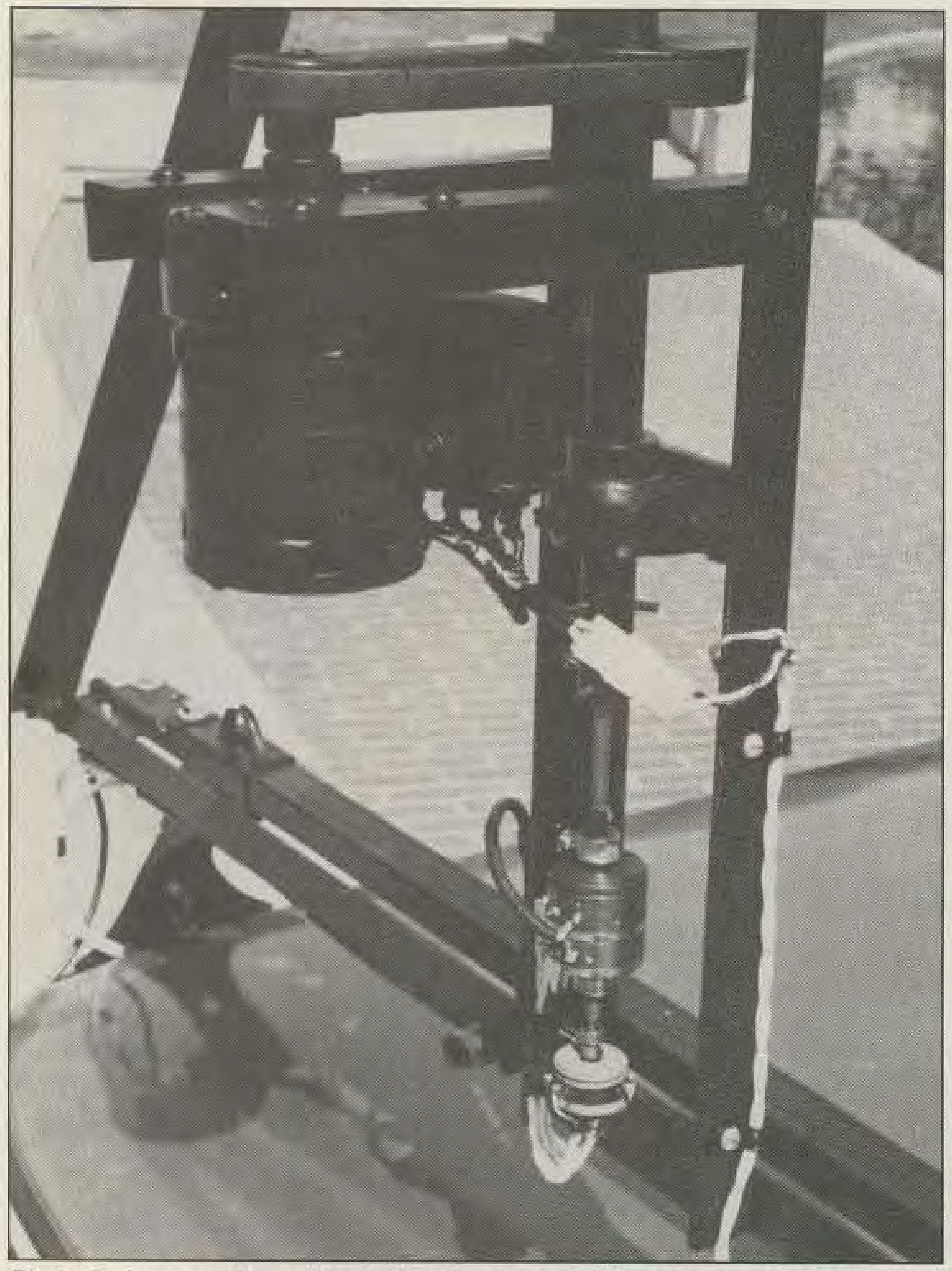

Photo B. A gearmotor and belt drive the mast, which rotates on two pillow block mounts. The antenna coax goes down the inside of the new brass shaft of the rotary coupler, located between the pulley and the sine-cosine pot.

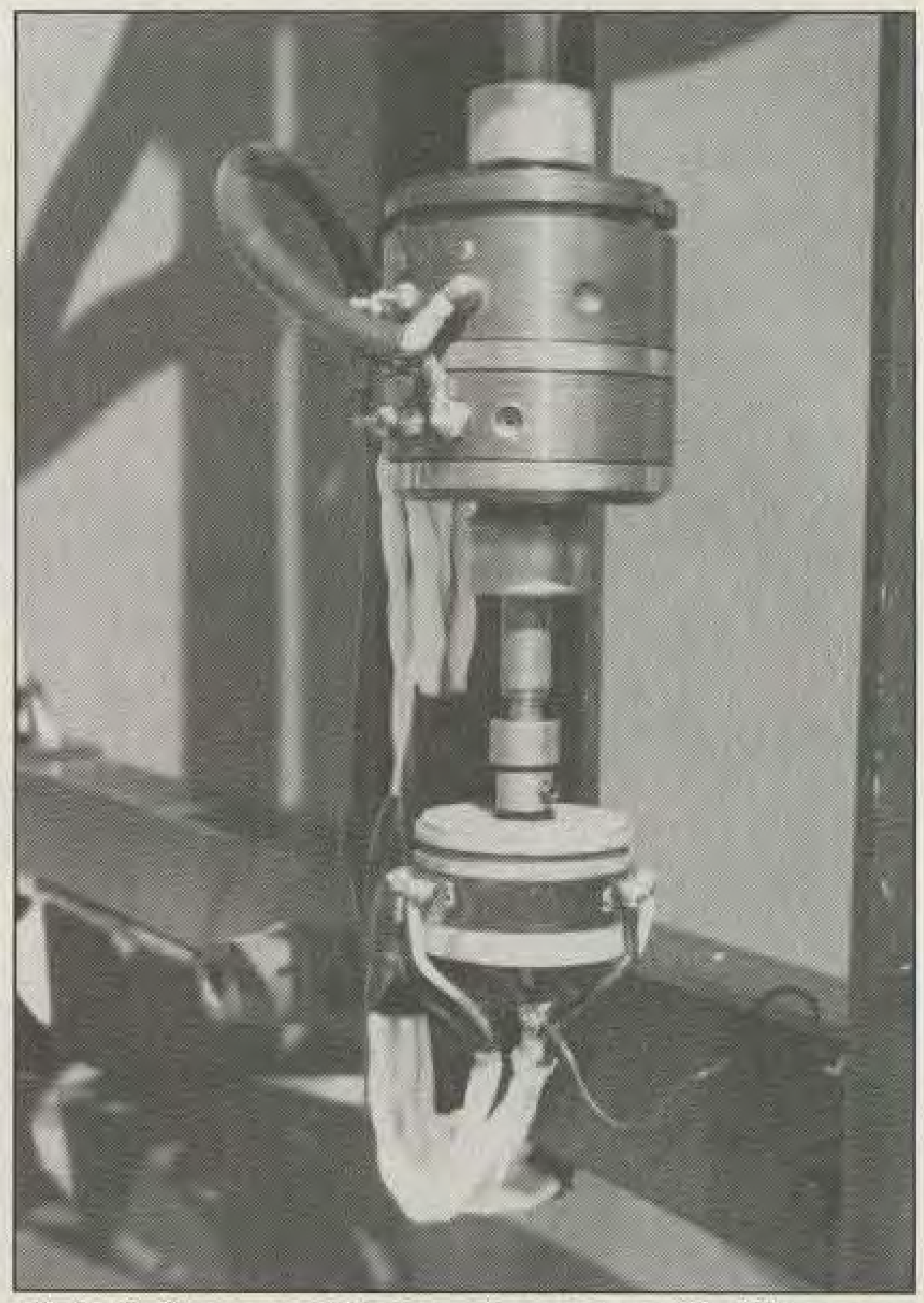

Photo D. Close-up of the two-stage pot modified into a coax rotary coupler (above) and the special sine-cosine pot (below) on the mast bottom.

some kind of insulated slip ring assembly bonded to the shaft," JaMi says. "I carefully disassembled it and put the shaft in a vise. Then I took a scribe and a little mallet and very gently chipped away the epoxy so that I could remove the two slip rings and their insulators intact from the shaft, which is discarded.

"I replaced the shaft with a piece of 1/4-inch o.d. hobby brass tubing, one foot long. I soldered a piece of 7/32-inch o.d. brass tubing inside the 1/4-inch tubing to reinforce it. I slid one of the slip rings on the tubing and bonded it in place; then I put the second one on, set for the same spacing as on the original shaft, and bonded it. The solderable connection points on the rings should face each other.

"After the glue set up, I used a rat-tail file to gently make a little slot in the tubes (forming an oval) between the slip rings, then deburred it. The coax from the antenna comes down the mast, into this tube, and out to the slip rings. Despite the higher loss, I recommend RG-178 teflon-dielectric coax. You can use RG-174 if you're very careful not to overheat it.

"By cutting a square end on the coax and curling it just a tiny bit, I could feed the coax down the hollow shaft and out through the oval hole. Then I stripped the shield and center conductor in the normal manner and soldered them to the slip ring rotors.

"I removed the windings to minimize stray capacitance. Finally, I reassembled the pot, making sure that the coax pigtails didn't protrude and interfere with anything inside the enclosure. The stationary coax connections (RG-58) go to the rotor terminals of two stages, as shown in the photo."

JaMi has some additional suggestions for anyone duplicating this conversion: "The original shaft probably had one or more C-rings to hold it in place. You may have to stack washers or shims onto the hollow brass shaft to maintain proper spacing and avoid end play.

"Lubricate the wiper to prevent noise and avoid excessive wear," he adds. "You'll need to re-lube it occasionally, so drill a 1/16-inch hole in the body. You can spray tuner lube through the hole as needed. The hole should be located where it will not allow easy water entry."

Photo C. JaMi can fold the entire antenna assembly down on the car top for low-clearance situations.

Safety First

When constructing and using an RDF system like this, keep safety in mind at all times. Use extra care in designing and building your motorized antenna. Mount the beam high enough that it can't strike someone standing next to the car. Fasten the frame securely to the vehicle—suction cups aren't good enough.

Pay close attention to balance, distribution of weight, and center of gravity. An antenna that breaks up or sheds pieces on the highway could injure someone following, or cause a serious accident. JaMi says he arranged for someone to serve as a spotter, trailing his car during initial tests to watch for mechanical instability in the antenna system.

There is also potential danger in the 120 volt AC power system. Carefully ground the chassis of the storage monitor and all other equipment to the vehicle frame. Do not leave AC terminals on the motor, or any other equipment exposed. Cover or tape them up. Don't use the system in wet weather unless you have a waterproof cover for the motor and other exposed AC-operated items.

A good engineer is never content with his or her creations. KK6CU is no exception; he's trying out new bells and whistles constantly. He has incorporated the x and y outputs from a Radio Shack fluxgate compass sensor through a switch to put a "north dot" on the CRT screen. When his rotatable screen-mounted protractor is aligned with the north dot, bearings are relative to north instead of relative to vehicle heading. He is working on new offset circuits to subtract the noise floor from the scope trace.

JaMi and I welcome your letters with questions on this unusual RDF scheme, but please enclose a self-addressed stamped envelope if you want a personal reply. 73