Computer Control for Beam Antennas, Part 1

Give your station a smart, new twist.

by Ron Cole K4OND

If you are an experimenter, you have almost certainly seen bargain TV antenna rotators at hamfests and speculated about using them for ham antennas. You may have hesitated at buying an untested rotator even at five bucks. Hesitate and speculate no more! Those rotators work very well for lightweight VHF/UHF antennas, and can be easily fixed (in most cases). Furthermore, you don't even need to have the indoor control box to make them work. Even if you already own or plan to buy a heavy-duty rotator intended for ham use, most of the principles in this article still apply, and may save you some bucks on repairs when those units fail. This article will also show you how to do automated pointing and/or tracking, including how to control the antenna via a joystick. Although it is aimed primarily at the use of TV antenna rotators and UHF antennas for satellite communications, this article will also teach you a lot about how to take full control of other rotators. In Part I we will look at how typical rotators work, how to control them electrically, and how to read out the azimuth and/or elevation. In Part II we will extend the concepts to computer interfacing, automated pointing, and joystick control.

Rotator Basics

The rotator motor itself is a surprisingly small device, running at about 3600 rpm, and geared down to produce the final antenna speed of about 1 rpm or less. The motor power, supplied through the control cable, is usually about 40 VAC derived from a transformer in the control unit. There are actually three power connections to the motor. One of these is connected to one side of the 40 VAC winding; the other two control the direction of rotation. One of the big mysteries of rotators, direction control, is actually very simple (see Figure 1). A relatively large unpolarized capacitor (C1) is used to produce a phase shift between the other two motor power connections, and it is this phase shift which controls the direction of rotation. Thus, controlling direction only requires a switching of one side of the 40 VAC winding to one side or the other of the phase-shift capacitor. This is done inside the control unit as a part of the direction dial function. By the way, these capacitors are a high-failure-rate item: Almost every "bad rotator" I have found turned out to have a bad phase-shift capacitor. Fortunately, you can easily get a replacement at most appliance repair and electrical supply stores; they are known as "motor-run" capacitors. They come in a wide range of values and are rated at voltages well above the 40 VAC used in this application. All you have to do is find an approximate match to the one in your control unit; I have capacitors as much as 50% higher in value than the original one without any problems. Before I learned about motor-run capacitors I tried back-to-back electrolytics and those apparently will not work. While this experience is only based on TV rotators, it almost certainly applies to other rotators as well. It's the first place to look when your rotator won't rotate!

It's not enough to just control the direction of rotation, of course. You also need to get feedback on position (i.e., azimuth), and to stop the rotation when the desired position is reached. In most TV rotator controllers the position feedback is produced by an electromechanical coupling, driven by a solenoid. Refer again to Figure 1. Within the rotator housing, and as a part of the step-down gearing, a rotating cam is used to close the contacts of a switch. The cam is higher up in the gear train and rotates much faster than the antenna. It can produce switch closures for about every five degrees of antenna rotation (depending on the exact model). Each switch closure results in activating a

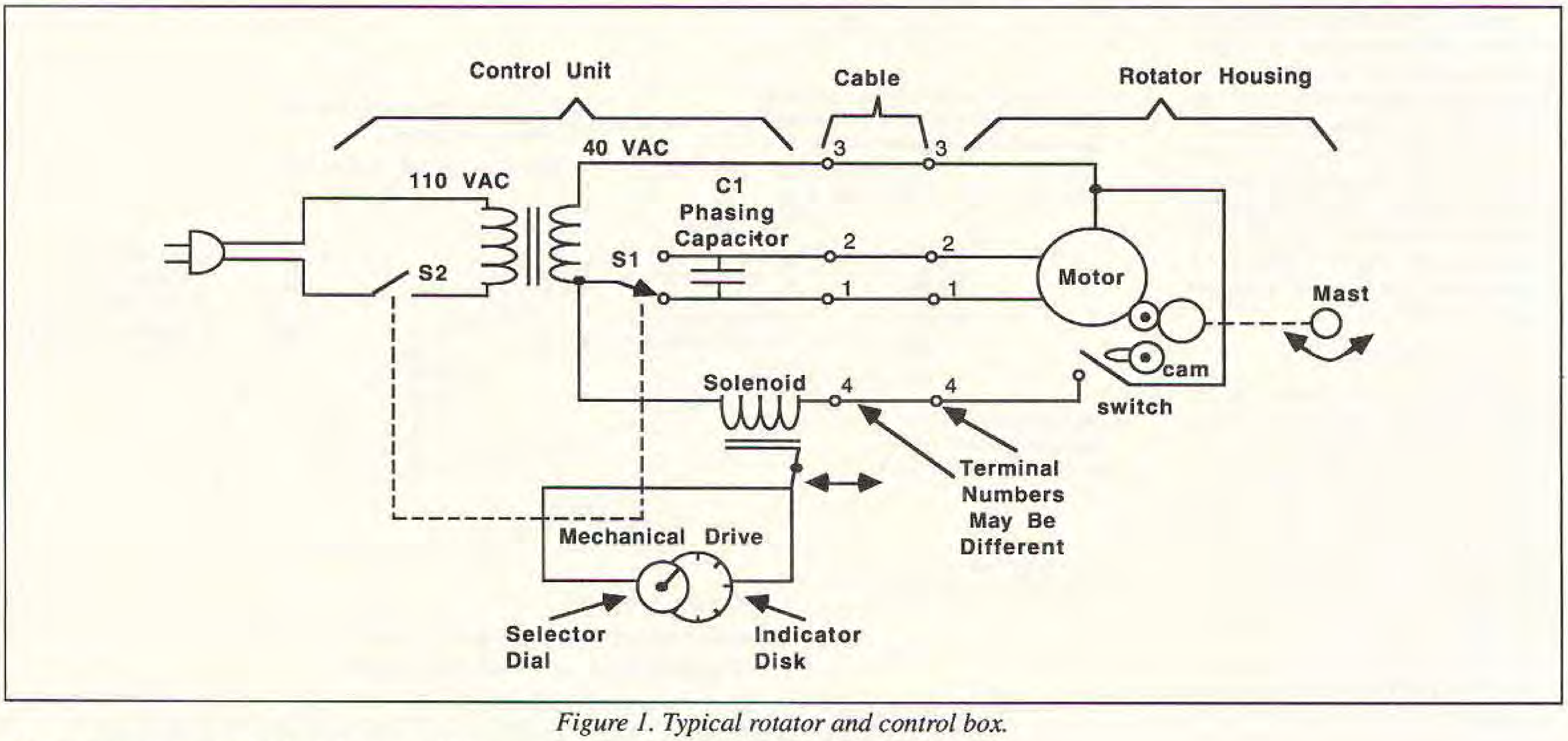

Figure 1. Typical rotator and control box.

solenoid in the control unit, and a mechanism connected to the solenoid turns the position indicator. (It is the firing of that solenoid which produces the typical "clack . . . clack . . ." sound when the rotator is turning.) A very messy set of mechanical and electrical components is used to cause the indication wheel to turn in the right direction, and to stop when the position indicator wheel is aligned with the direction dialed in by the user.

Another, and less common, type of position readout scheme involves using a second motor inside the control unit itself, and running exactly in parallel with the motor in the rotator on the mast. This second motor has a similar step-down gear train, but all it does is drive the position indicator wheel. Again, a mechanical or electrical scheme is used to detect when the two dials match, and stop the rotator. You can easily distinguish between these two types of rotator and control units. The first type (with a switch in the rotator) requires a four-wire control cable (three for the motor, one for the switch); the second type needs only three wires in the control cable.

Both of these types of position indicators are noisy and not easily adapted for any type of position readout other than the mechanical indicator dial. I have also found a few failures in the mechanisms which are virtually impossible to repair. Fortunately, we will soon see how the whole control box can be thrown away (except the 40 VAC power transformer and phase-shift capacitor).

There is one other feature of TV rotators which is important if your intended use is in a satellite antenna elevation system. This feature is the method for attaching the mast to the rotator. For easy adaptation to elevation use, you need to find a rotator which allows the mast to pass completely through the housing (see Photo A). You may have to do some searching to find one of these; they seem to be of older manufacture. All of the new rotators I have seen on the market are built so that the end of the mast rests on the rotator housing itself, or on a plate which is a molded part of the housing. If the latter type is the only one you can find, it may be possible to carefully cut the plate off and allow the mast to extend beyond the housing in both directions. This approach is necessary since the elevation rotator will normally be mounted at the top of the vertical mast, with a horizontal boom extending out both directions for the antennas themselves. (You may also want to use this type for an azimuth rotator, for the reason discussed below on using potentiometers for position readout.)

Photo A. K4OND's remote-controled rotating 2-meter yagi and 70 cm heilx antennas.

Now let's put together a better manual system, and one which is readily adapted to computer control.

A New Control System

It is trivially simple to construct a system to control motor direction and starting/stopping rotation. All it takes is the 40 VAC transformer, a good capacitor, and a center-off toggle switch (a good one is the Radio Shack #275-710, which is spring-loaded for the center-off position). See Figure 2. When you hook up the power wires to the rotator

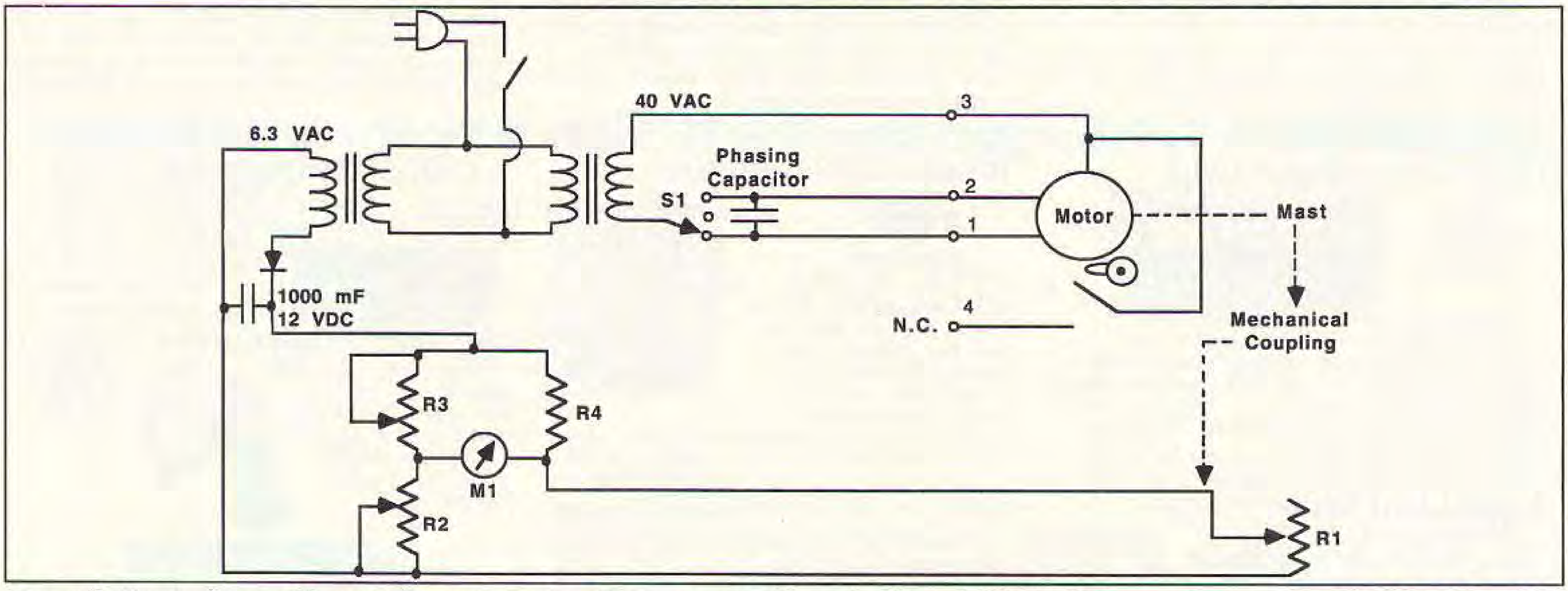

Figure 2. Simple "manual" controller and display. S1 is a center-off toggle. R1 and R2 should be equal, approximately 10k; R3 and R4 should be equal, approximately 5k. M1 should be 0-1 mA, up to 0-10 mA. If a less sensitive meter is used, decrease R1-R4. Adjust R2 and R3 for zero and full scale as R1 varies over its range. Duplicate the circuit if a second rotator is used.

motor, the only one which is critical is the lead which goes directly to one side of the 40 VAC transformer. The other two leads are completely interchangeable. The critical lead is usually marked "3" on the terminal strip on the rotator housing. If all else fails, just try different combinations until you find the right one; the motor will not be damaged by brief periods of wrong connections, it just won't run. The next part gets a lot more involved: how to get feedback on antenna position, and how to display it in an attractive way.

Analog Position Readout Concepts

These "analog" schemes involve mechanically coupling a potentiometer to the mast or boom. With the potentiometer turning in synchronism with the mast (or boom), you can use a meter to read voltage (or current) through the potentiometer, and calibrate the meter in terms of position. We have to find a way to accomplish this mechanical coupling. One of the problems you will find in the case of the azimuth rotator is that ordinary potentiometer shafts don't turn a full 360 degrees like the mast, so you will have to step the rotation down with different sized gears or belt pulleys, or go to a 10-turn potentiometer. I did find a set of gears which could fit into the rotator housing, in place of the cam which normally operates the solenoid-control switch. I brought the shaft out through a hole drilled in the housing and coupled it to a 10-turn potentiometer, but finding these parts was more pure dumb luck than anything else. It is certainly possible to use a rubber drive belt (such as can be found in VCR repair shops) passing around the mast and over a pulley attached to the potentiometer shaft, or maybe even a fairly large "rubber tire" wheel on the potentiometer shaft, mounting it so that the "tire" bears directly on the rotating mast.

A better scheme would be to find a fine-toothed gear which is a little larger than the mast; take the gear and a short section of mast to a machine shop and get them to cut a mast-sized hole through the center of the gear, and braze the gear onto the mast section. Simply insert the short mast section into the rotator, and add more mast sections as needed. Then, mount the potentiometer, with a matching gear, on the fixed portion of the rotator housing so that the gears mesh. Finally, if you can find one of the rotators which allow the mast to pass completely through the rotator, you can put a wooden plug into the very bottom end of the mast, drill a hole slightly less than 1/4" in the center of the plug, and force-fit a shaft into the plug. Then you can couple the pot to the shaft (through a step-down gear, or use a 10-turn pot). Obviously, some mechanical ingenuity is required in any of these methods.

For the elevation rotator, there is a simple scheme which works very well. This scheme involves attaching a potentiometer to the horizontal boom, with the shaft of the pot in line with the boom, then hanging a weight on the potentiometer shaft. As the boom rotates up and down, the weight turns the potentiometer shaft, producing the desired change of resistance. Since the elevation will normally be a maximum of 90 degrees (i.e., from horizontal to straight up), we don't even have to worry about exceeding the potentiometer shaft rotation limits. In my elevation system, I simply fastened a large coffee can to the underside of the boom, and mounted the potentiometer and weight inside the can for protection from weather and wind effects. This scheme, while very simple and effective, does have one drawback: As the boom is turning, the weight has a tendency to swing slightly, causing the meter needle to oscillate as well.

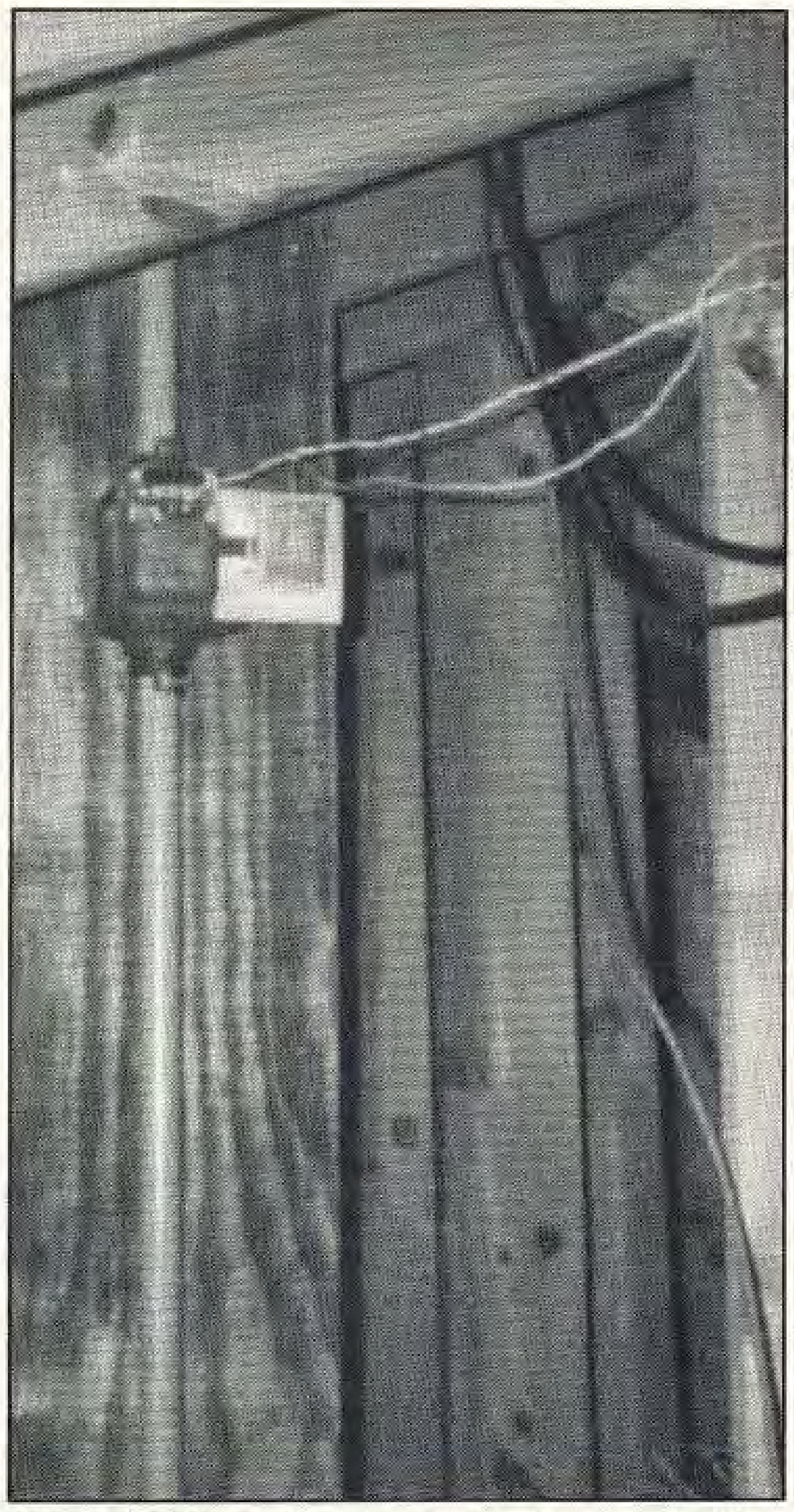

Photo B. The azimuth rotator is mounted between the rafters and the ceiling joists.

As shown in Figure 2, each sensor potentiometer is connected as one arm of a bridge circuit, with the 0-1 mA meter as the position indicator. Typical values for the bridge components are as listed in the figure, but many others will work, and you will probably have to do some "trial and error engineering" anyway to get the meter to deflect full scale as the sensor pot moves. Do this on the bench, before you mount the pots on the rotators!

Although it is possible to use other devices including rotary switches, or even to electronically count the closures of the solenoid control switch, using potentiometers for position sensors has a real advantage if you intend to go all the way to a computer-controlled system: You can read the potentiometers through "joystick" ports, and use software to convert the reading to an antenna position. (We will explore the concept in Part II of this article.)

Mechanical Assembly

Although this article is mostly about controlling rotators, a few words about rotator mounting may be of help when you build your system. If you used an azimuth rotator which allows the rotating mast to pass completely through the rotator housing, you can save some strain on the rotator by mounting it near the bottom of the mast and placing a bearing of some type under the mast bottom. In one such installation, I poured a small block of concrete in the ground, and stuck a three-foot section of mast near the center. The fixed portion of the rotator mounts on that short section. The rotating mast passes through the rotator, with the base of the mast resting on a ball-bearing mount salvaged from a heavy-duty caster assembly with the wheel removed. The bearing "bears" most of the weight of the mast. The concrete block is about a foot away from the wall of the shack; just below the eaves of the shack a support arm extends from the wall, fitting around the rotating mast just tight enough to provide support without clamping the rotation.

Another method, which worked very well, was to cut a hole in the roof of the shack for the mast (and using a rubber vent-pipe boot to prevent leaks). The azimuth rotator mounts on a vertical board between the rafters and the ceiling joists, and the mast rests on a bearing on a platform on top of the joists. (See Photo B.) The rotating mast protrudes through the roof only about six feet, but absolute height is not that significant when the satellites are more than a few degrees above the horizon. In both cases, the elevation rotator is mounted on an aluminum plate (an old rack panel) mounted to the vertical mast with U-bolts. Holes are drilled in the plate to accept the bolts on the elevation rotator which originally clamped the rotator to a vertical mast. You may be able to make out enough details in Photo A to see this scheme, as well as the 2 meter yagi and 70cm helix in my system, and the coffee can which holds the elevation potentiometer and weight. The two antennas are placed so as to balance the weight on the boom, including the counterweight protruding from the rear of the helix. Close attention to balance will go a long way towards preserving the life expectancy of the rotators.

That's it for Part I. We have seen how to control rotators, how to fix the most common problems with non-working rotators, how to get rid of the electromechanical control unit, and how to get electrical position readouts which are much easier to see than the dial on the original control unit. Is it worth the trouble? Maybe not if you only want to have manual control of your antenna position, but if you want to do computerized control and automatic positioning/tracking, the conversions described above are essential. In Part II we will expand the system to one which provides both manual and computer control, and even allows for the use of a joystick as the control device. 73