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Way Cool Rocket Project: Part 2

This 70cm rocketborne radio telemetry system is strictly for kids — NOT!

Part one of this series described the construction of a 433 MHz telemetry transmitter and receiver. Part two will describe construction of a 433 MHz telemetry receiving antenna and integration of the telemetry transmitter into the rocket payload section. Let's begin with construction of the telemetry receive antenna.

The telemetry receive antenna consists of two Astron Corporation Model 400-4 yagi antenna kits cut for 433 MHz operation, stacked vertically, and fed in phase. The Astron Model 400-4 kit can be purchased directly from Astron Corporation or from Ramsey Electronics as Ramsey #400-4. Specifications for the 4-element yagi indicate a forward gain of 7 dB, with a half-power beamwidth of about 30 degrees. With two antennas stacked for vertical polarization and fed in phase, the forward gain becomes 9.5 dB, with the vertical half power beamwidth reduced to about 15 degrees. In addition, the vertical capture area of the antenna is doubled. With only 80 milliwatts from the transmitter, we need all the gain and capture area that we can get to ensure solid copy of the telemetry signal. Vertical polarization of the receive antennas was selected to match the vertical polarization of the rocket-mounted transmit antenna. Because the rocket is in motion, the receive antenna must be able to follow the flight path to ensure positive reception of telemetry data. To accomplish this I created a fully steerable alt-azimuth antenna mount. **Photo A** shows the completed antenna array in tracking mode.

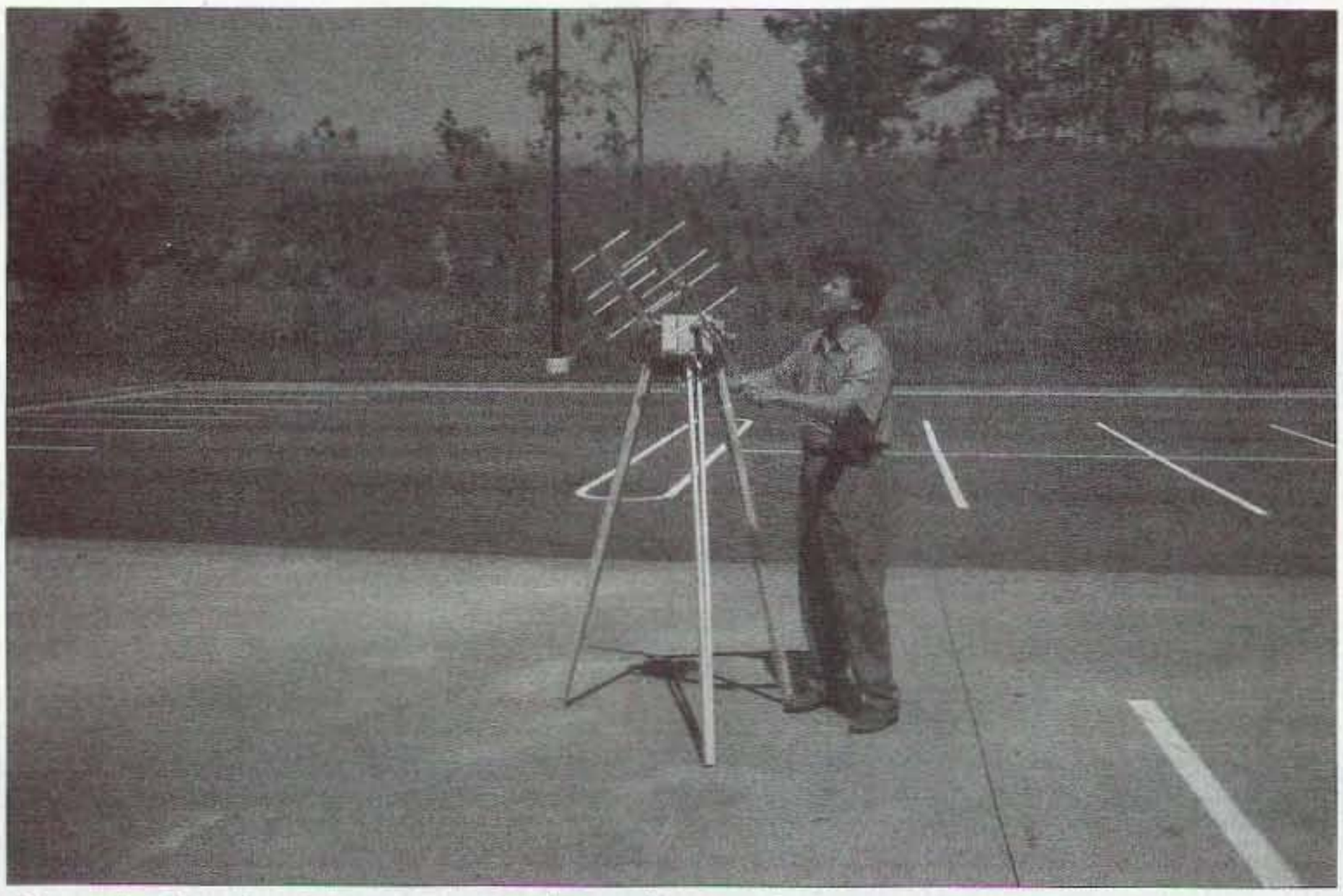

Photo A. *Completed antenna array in tracking mode.*

Building the antenna array begins with construction of the two 4-element yagi antennas. The Astron Model 400-4 is supplied as an undrilled aluminum boom with four sets of aluminum element material. (The driven element is preassembled but not cut to length.) Element mounting hardware is also supplied. Each element must be cut for the operating frequency. A chart is supplied with the kit that gives element dimensions and element spacing for specific frequencies. In addition to drilling the boom for the antenna elements, the boom must also be drilled for the mounting hardware and for an antenna counterweight. **Fig. 1** is a drawing of the antenna dimensions that I used in building the yagis for 433 MHz.

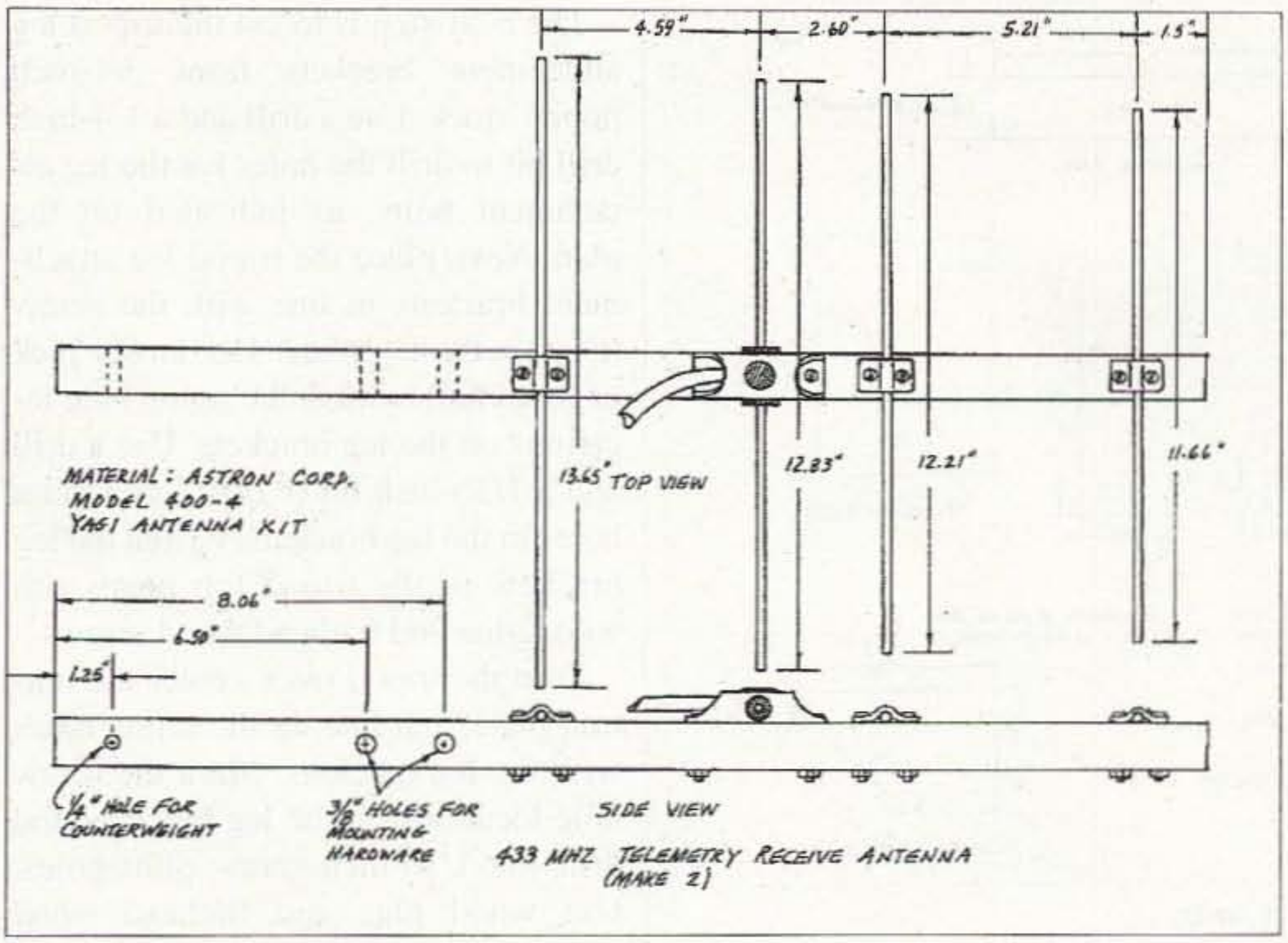

Fig. 1. Tracking antenna.

The antenna counterweights are 6-inch lengths of 1/2-inch-diameter soft steel rod. The counterweights are installed after the antennas are assembled and mounted. As a safety measure, these counterweight rods are wrapped with fluorescent red tape to prevent them being an eye hazard. Now that you have the two antennas assembled and drilled, set them aside and begin construction on the antenna mount.

The antenna mount

Three sub-assemblies are combined together to form the antenna mount. These three subassemblies are the tripod legs, tripod head, and elevation bearing box and azimuth bearing.

The tripod legs and tripod head are built first. **Fig. 2** is a dimensioned drawing of the tripod parts.

Cut six lengths of 1-1/2- x 3/4-inch clear pine to sixty inches (5 ft.). Each

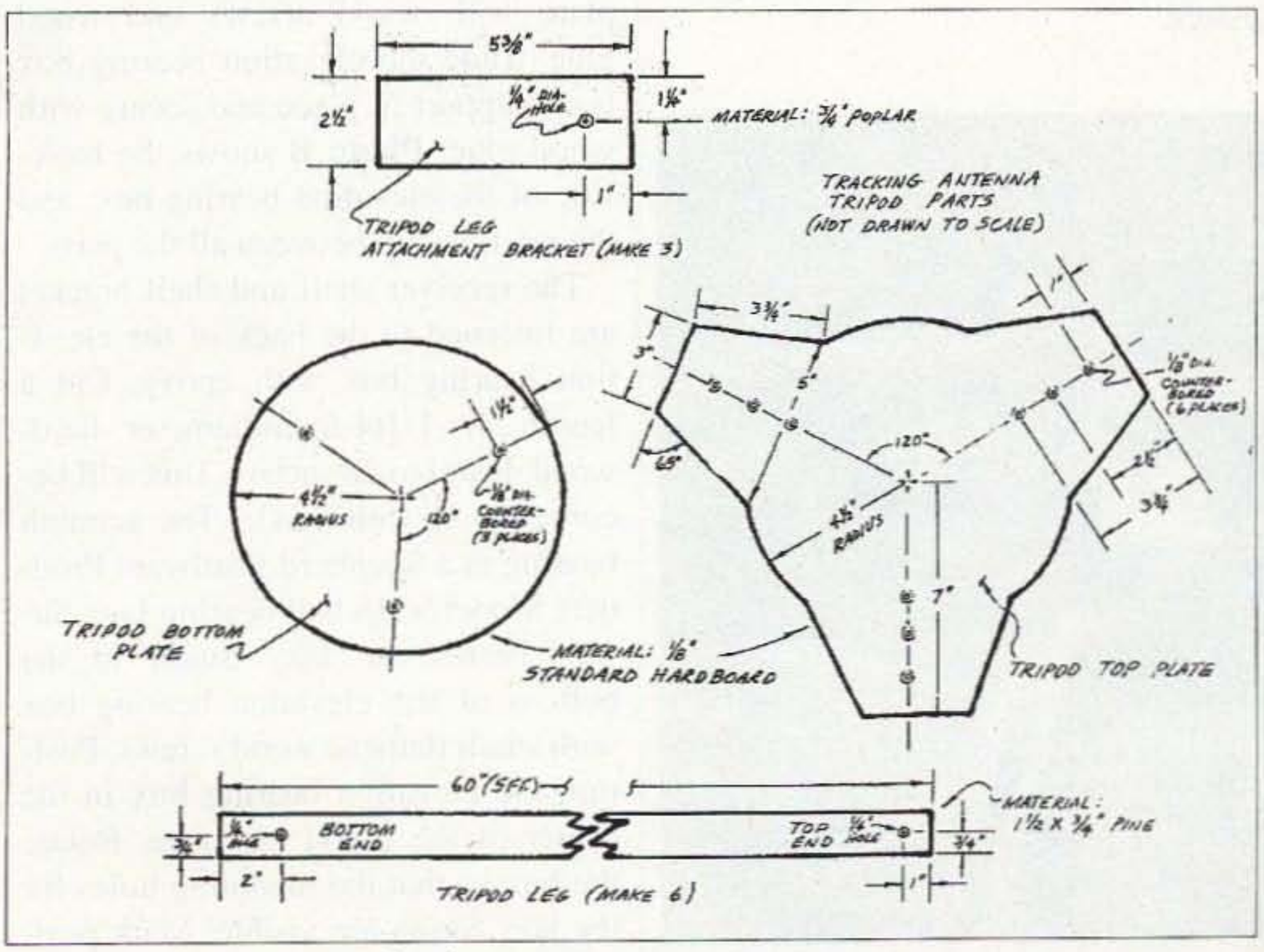

Fig. 2. Tracking antenna tripod parts.

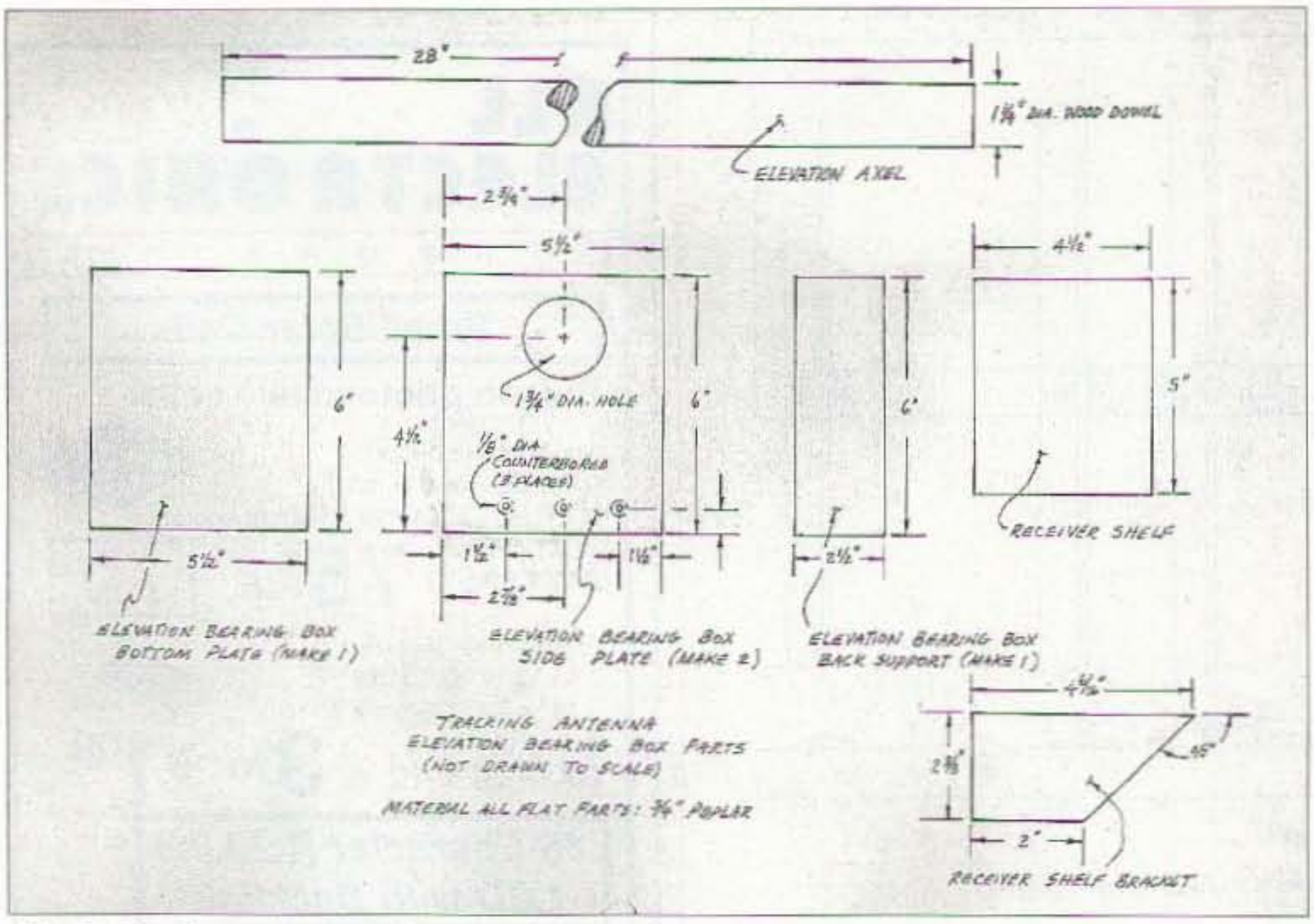

Fig. 3. *Tracking antenna elevation bearing box parts.*

tripod leg is made up of two of these five-foot members. Using the dimensioned drawing as a guide, mark the locations of the 1/4-inch holes on each end of the legs. Drill 1/4-inch holes at the top and bottom ends of each tripod leg at the measured locations. Fasten the bottom two members of each leg together with a 1/4-inch x 3-inch bolt. Loosely fasten the nut on each of the three bolts.

I elected to use 1/8-inch-thick standard hardboard as the material for the top and bottom plates on the tripod head. This material is inexpensive and easily worked. You can find this material at most home improvement centers. Once the top and bottom plates are cut to shape, use the dimensioned drawing to mark locations for the screw holes. Using a drill and a 1/8-inch drill bit, drill the nine screw holes in the tripod top plate and the three screw holes in the tripod bottom plate. Use a countersink bit to slightly counter bore these screw holes. This will ensure that the flathead wood screws to be used later will rest flat with the surface of the top and bottom plates.

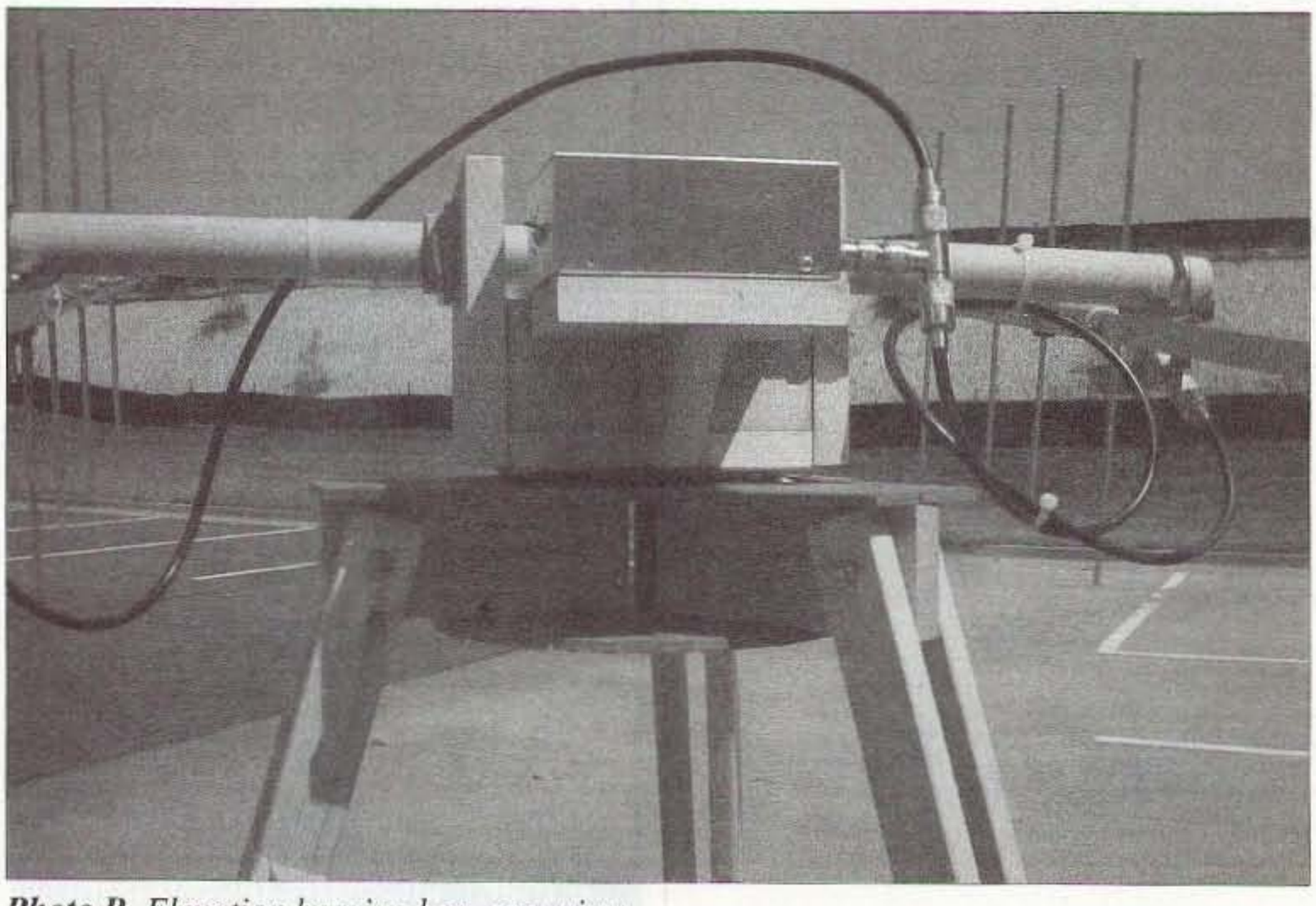

Photo B. *Elevation bearing box, rear view.*

The next step is to cut the tripod leg attachment brackets from 3/4-inch poplar stock. Use a drill and a 1/4-inch drill bit to drill the holes for the leg attachment bolts, as indicated on the plan. Next, place the tripod leg attachment brackets in line with the screw holes in the top plate. Use an ice pick or small nail to mark the screw hole locations on the leg brackets. Use a drill and a 1/16-inch bit to drill screw pilot holes in the leg brackets. Fasten the leg brackets to the tripod top plate with wood glue and flathead wood screws.

Turn the tripod over, center the bottom plate, and line up the screw holes with the leg brackets. Mark the screw hole locations on the leg brackets and drill the 1/16-inch screw pilot holes. Use wood glue and flathead wood screws to fasten the bottom plate to the tripod leg brackets. Set this assembly aside to dry.

The elevation bearing box is the next component of the antenna mount. **Fig. 3** is a dimensioned drawing of the parts for the elevation bearing box.

Start by cutting all the pieces for the bearing box. Make sure to make two of the side plates. I used 3/4-inch poplar for the bearing box, although the type of material is not critical. Mark and drill the holes in the side plates using information from the plans. Fasten the bearing box side plates to the bottom plate with wood screws and wood glue. Slide the elevation bearing box back support in place and secure with wood glue. **Photo B** shows the backside of the elevation bearing box, and the relationship between all the parts.

The receiver shelf and shelf bracket are fastened to the back of the elevation bearing box with epoxy. Cut a length of 1-1/4-inch-diameter hardwood dowel to 28 inches. This will become the elevation axle. The azimuth bearing is a Shepherd Hardware Products Model 9548 ball bearing lazy Susan. Fasten the lazy Susan to the bottom of the elevation bearing box with small flathead wood screws. Position the elevation bearing box in the center of the tripod top plate. Rotate the box so that the mounting holes for the lazy Susan are visible. Mark position of the lazy Susan mounting holes

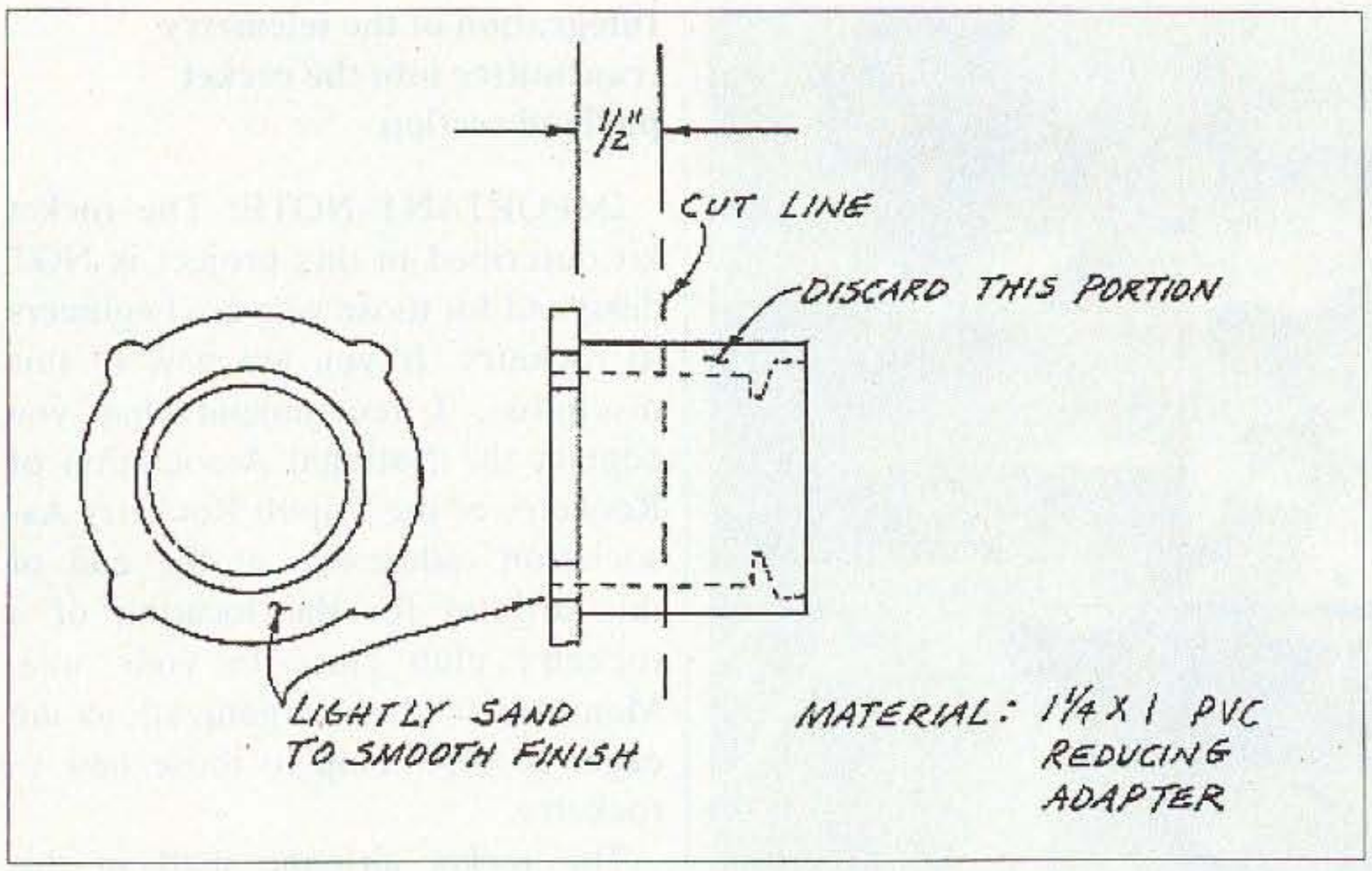

Fig. 4. *Elevation bearing detail.*

on the tripod top plate. You will find that one of the four lazy Susan mounting holes will line up with the position of a tripod leg bracket. A flathead wood screw should be used at this position. The remaining three mounting holes will use 6-32 x 1-inch machine screws and nuts.

Modified 1-1/4- x 1-inch PVC reducer adapters are used as bearings for the elevation axle. **Fig. 4** is a drawing showing the modifications of the PVC adapters. You will need to make four of the modified adapters.

As shown in **Fig. 4**, the shank of each PVC adapter is cut down to a length of 1/2-inch. Make sure to remove any burrs with a small knife. The outside diameter of the PVC adapter is a little less than the 1-3/4-inch-diameter hole. Take two of the cut-down adapters and wrap masking tape around the outside surface of the 1/2-inch-long shank until it just fits into the 1-3/4-inch-diameter hole in the elevation bearing box side plate. Coat the inside surface of the 1-3/4-inch-diameter hole and the outside surface of the tape on the adapter with 5-minute epoxy and fit in place. Use care to not get any of the epoxy on the inside surface of the adapter. After the epoxy has set, slide the elevation axle into the PVC adapter bearings and center it with respect to the elevation bearing box. Slide one of the remaining prepared PVC adapters over one end of the elevation axle and bring up tight to the mounted bearing. Refer to **Photo B** to see this relationship between the bearing surfaces. While holding the prepared PVC adapter in place, use a drill and a 3/16-inch drill bit and drill through the PVC adapter and the axle. Slide a 5/32 x 2-1/2-inch cotter pin into the hole to hold the bearing in place. Repeat this procedure on the other end of the elevation axle. At this point, attach the leg assemblies to the leg brackets with 4-inch x 1/4-inch carriage bolts and nuts. Spread the tripod legs out so that the elevation bearing box is at a comfortable working height. The next step is to mount the antennas to the elevation axle.

Mounting the antennas

Radio Shack #15-826 U-bolt and clamp assemblies are used to mount the prepared antennas to the elevation axle. **Photo C** shows how the antenna is mounted to the elevation axle.

Make sure the driven element is directed outward (as shown in the photograph) and that the element is aligned with the end of the elevation axle. This will ensure proper spacing of the two antennas. Next, move the antennas so the booms are horizontal and insert the previously prepared lengths of steel rod into the rear open end of the boom. Adjust position of the steel rods until the antennas are balanced on the elevation axle. Mark this position on the

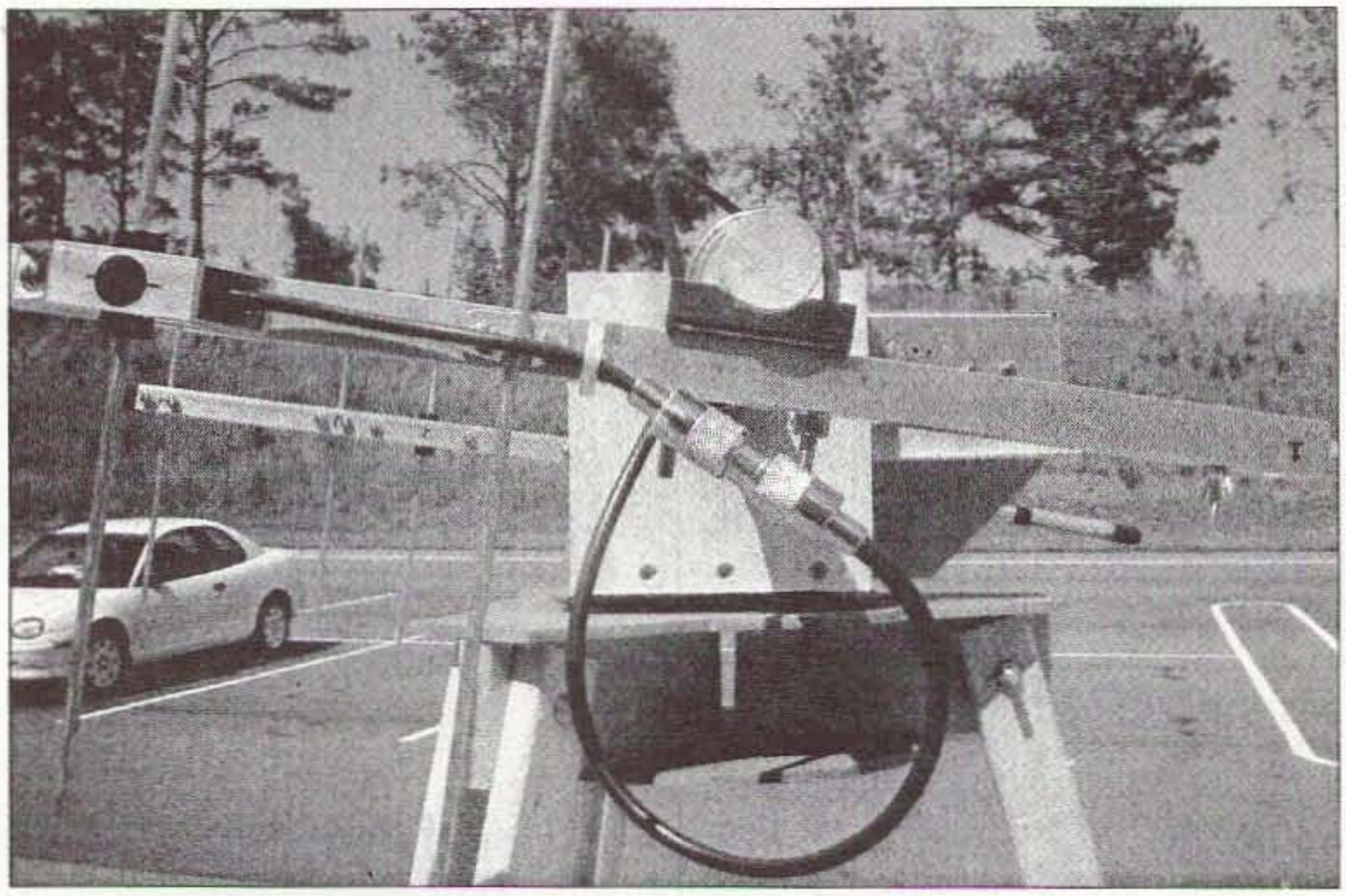

Photo C. Antenna mounted to elevation axle.

steel rod through the hole in the end of the antenna boom. Use a drill and 1/4-inch drill bit to drill a mounting hole through each of the steel rods at the marked locations. Install the steel rods into the rear end of the antenna booms with a 1/4-inch x 2-inch bolt and wing nut. The remaining step in antenna construction is fabrication of the coaxial cable phasing harness.

Building the phasing harness

Fig. 5 is a dimensioned drawing of the coaxial phasing harness.

The harness uses two sections of RG-6 75-ohm coax, each leg 37 inches in length. The first step, however is to attach a connector to the short length of coax from the antenna driven element. Cut this length of coax to 6 inches and attach a male coaxial connector. A coaxial barrel connector is used to join the phasing harness to each of the driven element connectors.

The photographs in this article show the details of mounting the phasing harness. This completes construction of the telemetry receive antenna array.

Integration of the telemetry transmitter into the rocket payload section

IMPORTANT NOTE: The rocket kit described in this project is NOT designed for those who are beginners to rocketry. If you are new to this discipline, I recommend that you contact the National Association of Rocketry or the Tripoli Rocketry Association (addresses at the end of this article) for the location of a rocketry club close to your area. Members of these organizations are eager to offer help to those new to rocketry.

The rocket airframe used in this project is the Vaughn Brothers Extreme 38 rocket kit. Construction of the rocket airframe is outside of the scope of this article. The kit should be built according to the instructions supplied with the kit with the exceptions detailed below. **Fig. 6** is a dimensioned drawing highlighting the modifications made to the payload section of the rocket kit.

The first modification to be made is to the nose cone. As detailed in **Fig. 6**, the rear portion of the nose cone is removed and discarded. With a 1/16-inch drill bit, drill two small holes 1/2-inch from the shoulder of the nose cone. This is the point at which the thermistor will be mounted. Insert the thermistor leads into the two small holes in the nose cone. Ensure a 1/32-inch air gap between the bottom of the thermistor and the nose cone surface. Place a small dab of epoxy over the thermistor leads on the inside of the nose cone to fix the thermistor in place.

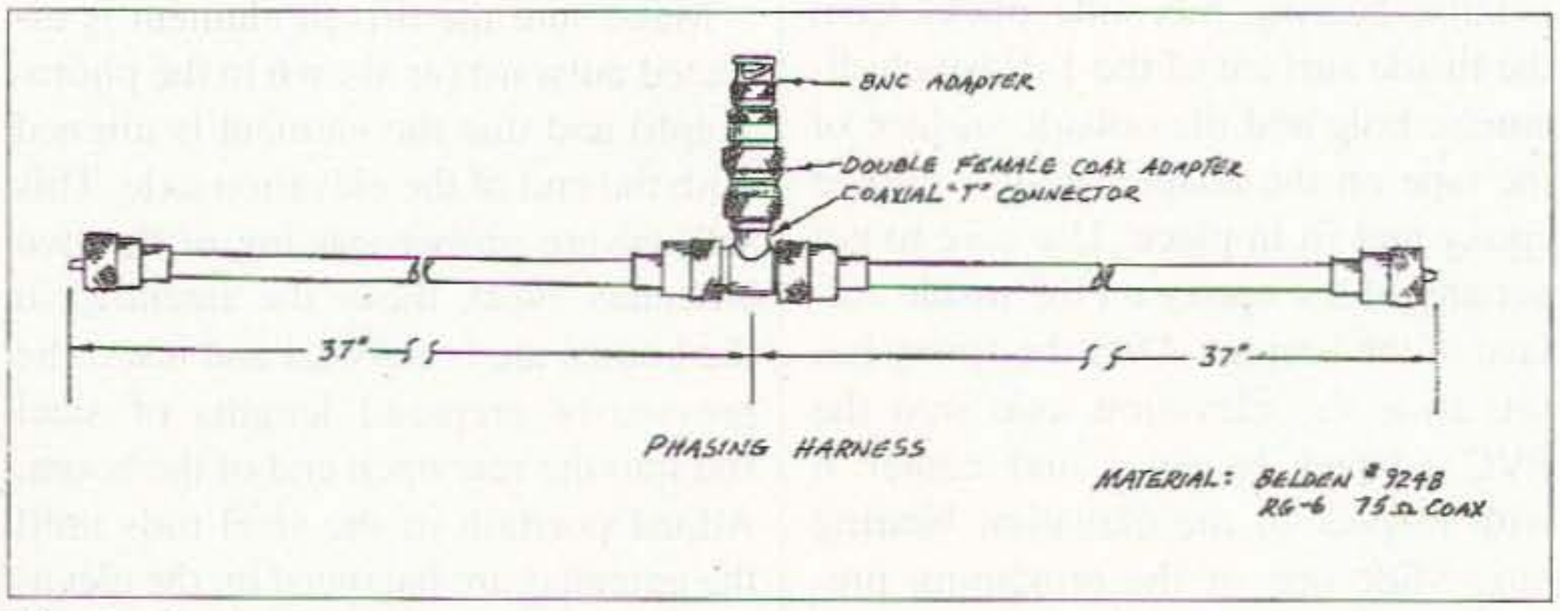

Fig. 5. Phasing harness.

Use the drawing in **Fig. 6** as a guide, and cut the thermistor shroud from a small sheet of .005-inch brass. Prepare three one-inch lengths of tinned number 22 solid copper wire. Solder these three wires to the brass shroud as shown in **Fig. 6**. Temporarily bend these wires out from the shroud and form the shroud over the thermistor. Make sure that the brass shroud will not touch the thermistor. Mark the three locations where the bent out wires touch the nose cone surface. Use a 1/32-inch drill bit to drill holes at the marked locations on the nose cone. Bend the shroud wires so they are pointing down and away from the shroud. Insert the shroud wires into the three holes. Bend the wires down from the inside of the nose cone to hold the shroud in place. Fix each shroud wire in place with a small dab of epoxy over each wire. Lay in an epoxy fillet at the shroud nose cone boundary. The shroud is used both to shield the thermistor from the sun and to protect it from flight-generated aerodynamic forces.

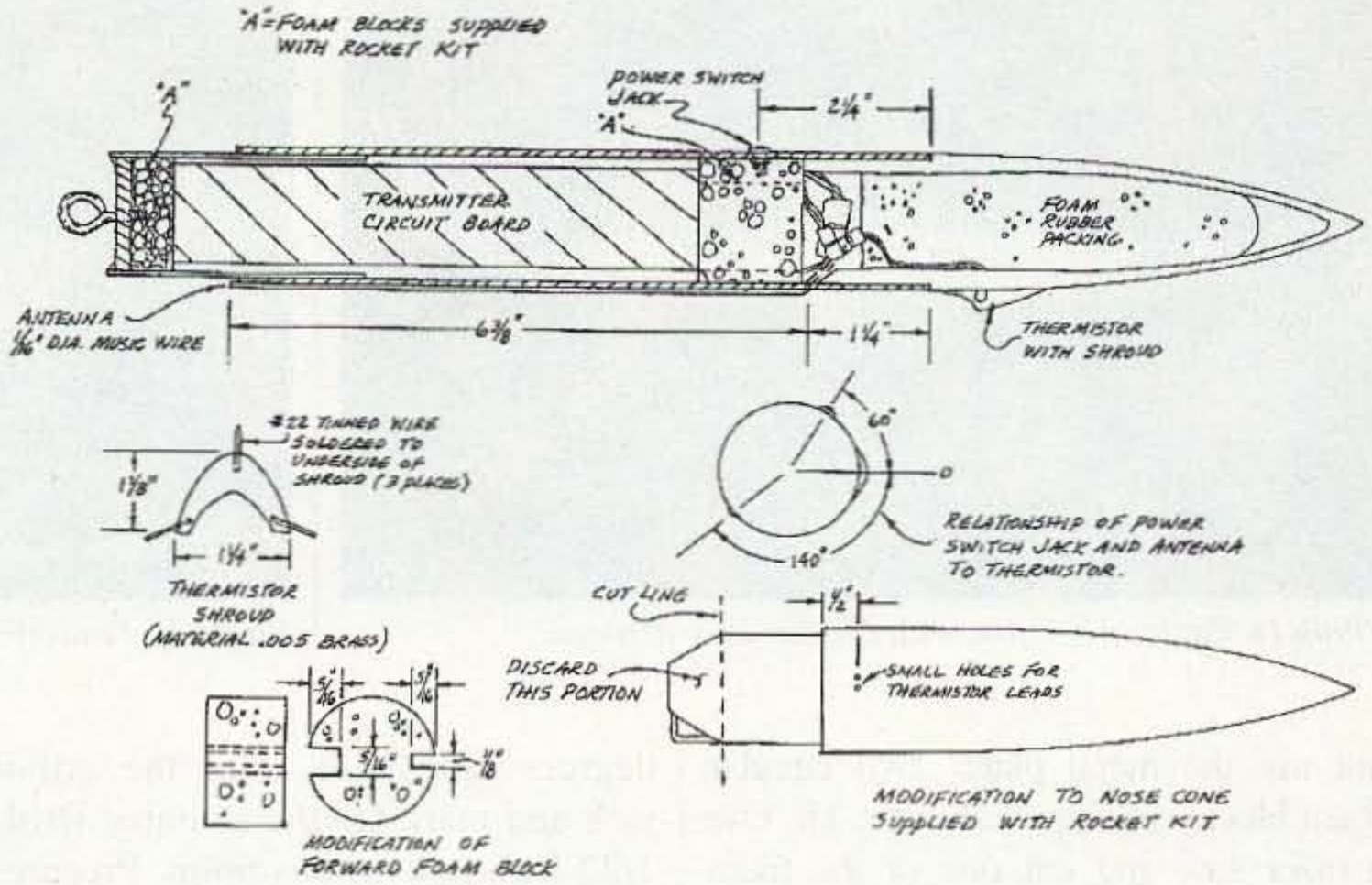

Fig. 6. Rocket assembly.

Prepare two lengths of stranded hookup wire, each 3 inches in length. Twist the two wires together. Solder a 2-pin Dean's connector to one end of the prepared two wires. Solder the free end of the wires to the thermistor leads inside the nose cone.

The Vaughn Brothers rocket kit is supplied with a mounting bracket and plate for an altimeter circuit. You will

Photo D. *Payload section, with arming jack in place.*

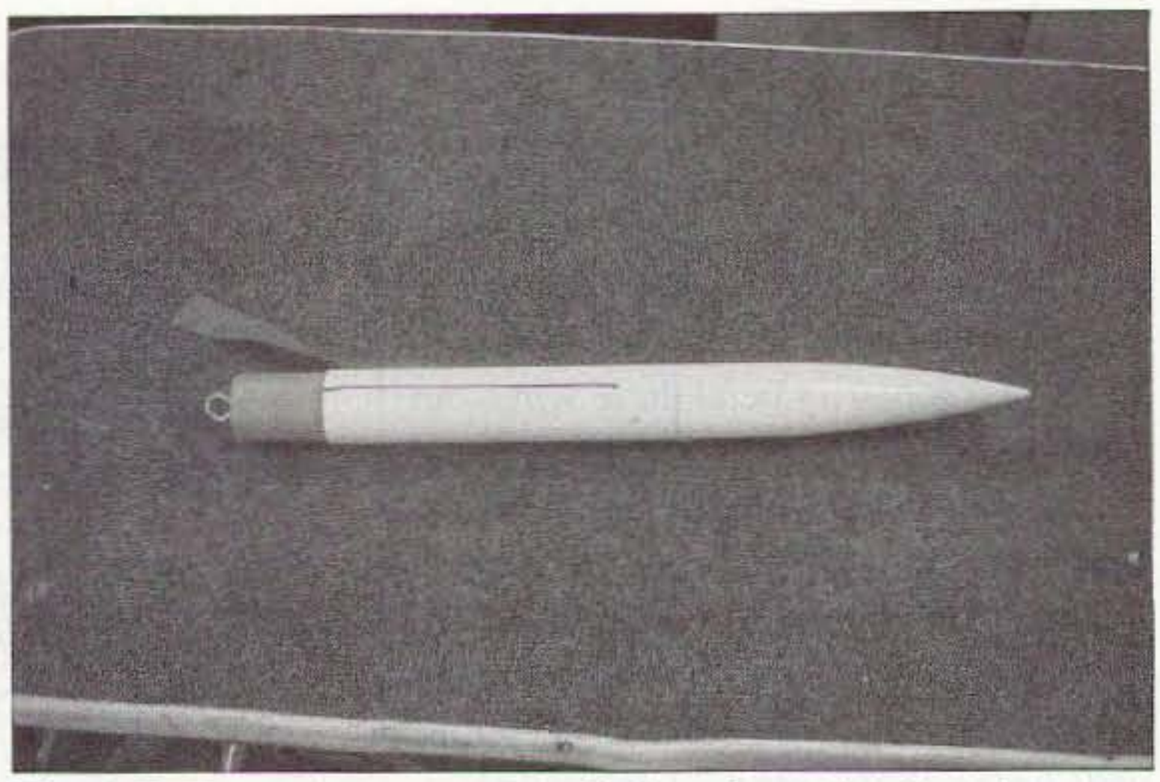

Photo E. *Transmit antenna installed on the payload section.*

not use the metal plate. Two circular foam blocks are supplied in the kit. Use a razor saw and cut one of the foam blocks in half. Modify the remaining foam block as shown in **Fig. 6**.

Build the payload section as detailed in the rocket kit instructions. When all the epoxy adhesive has fully set, push the one-half foam block you cut earlier to the bottom of the payload section. Measure 2-1/4 inches from the front edge of the payload section and mark the position of the mounting hole for the arming jack. Use the sharp point of a modeling knife to cut a 3/16-inch-diameter hole at the point marked for the arming jack. To make installation of the transmitter easier, I placed a two-conductor connector in series with the wires from the arming jack to the transmitter battery. **Photo D** shows the payload section with the arming jack in place.

Measure 1-1/4-inch from the front of the payload section at a point 200 degrees clockwise from the arming jack and mark for the antenna. Drill a 1/32-inch hole at this point. Prepare a two-inch length of stranded hookup wire by stripping 1/4-inch from each end and tinning the wire with solder. Next, cut a 6-3/4-inch length of 1/16-inch music wire. Use fine sandpaper and burnish 2 inches of one end of the music wire. Measure 3/8-inch from the burnished end of the wire. Use pliers to put a 40-degree bend in the wire at this point. Push the prepared music wire into the antenna hole in the payload section so that you have access to the short bent section of wire. Solder one end of the two-inch wire you prepared earlier to the bent section of music wire.

Push the music wire back through the antenna mounting hole so the 6-3/8-inch length lies alongside the payload section. Use a short length of masking tape to hold the antenna in place while you lay in epoxy fillets on each side of the wire to hold it in place. You may find it helpful to tack the antenna to the payload section with cyanoacrylate adhesive before using the epoxy. **Photo E** shows the transmit antenna installed on the payload section.

Solder a 2-pin Dean's connector to the free end of the 2-inch antenna wire. The next step is to install the transmitter circuit board into the payload section.

Insert the transmitter circuit board, battery end first, into the payload section. Use care to position the circuit board to clear the arming jack as you slide the circuit board into position. Slide the prepared forward foam block into place. The 5/16-inch slot in the foam block should just clear the arming jack. Dress the remaining wires from the transmitter circuit board through the 1/8-inch slot in the foam block. I used an additional piece of foam rubber as a forward block inside the nose cone. This ensures that, once the nose cone is fastened in place, the

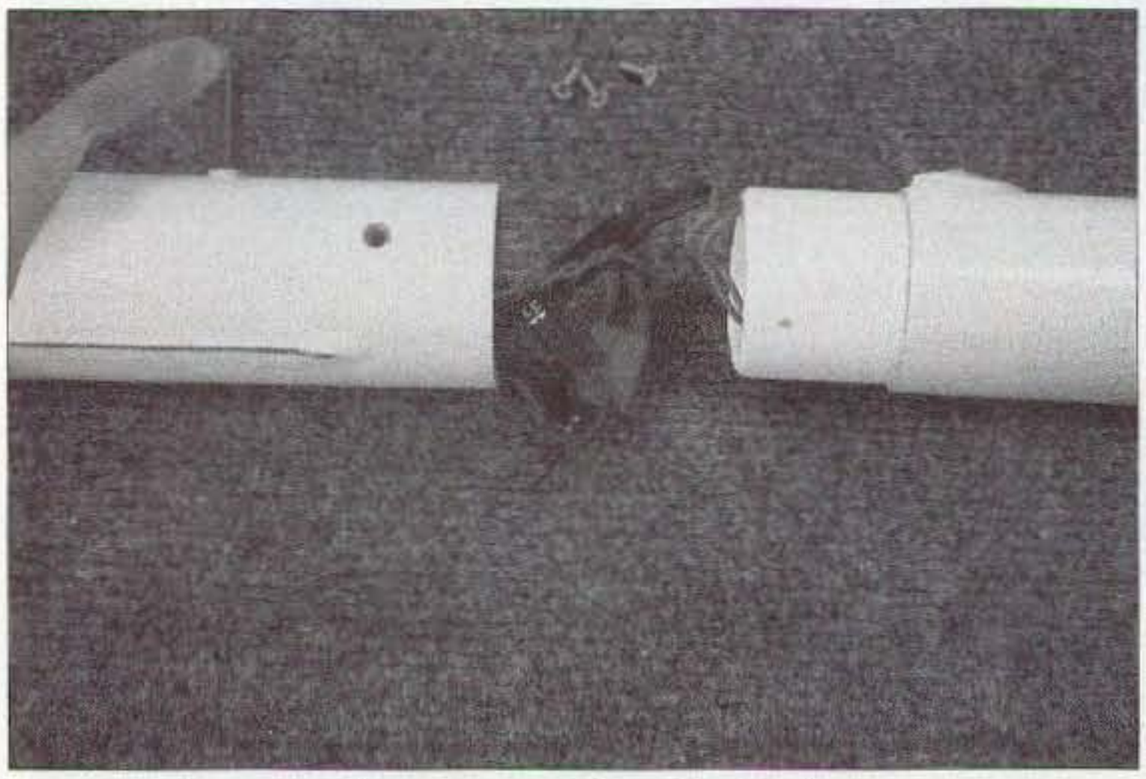

Photo F. *Antenna, thermistor, and arming jack connectors.*

Photo G. *Completed airframe in primer coat white.*

Qty.	Part
2	Astron 400-4 or Ramsey Electronics 400-4 yagi antenna kits
6	5 ft. lengths of 1-1/2 x 3/4 inch clear pine lumber
1	3 ft. x 3 ft. square piece of 1/8 inch standard hardboard
1	4 ft. section 5-1/2 x 3/4 inch poplar lumber
1	3 ft. section 3 x 3/4 inch poplar lumber
1	30 inch length 1-1/4 inch diam. hardwood dowel
3	3 inch x 1/4 inch carriage bolts with nuts
3	4 inch x 1/4 inch carriage bolts with nuts
3	6-32 machine screws with nuts
10	1-1/2 inch flathead wood screws
2	Radio Shack #15-826 U-bolt clamps
1	12 inch length 1/2 inch diam soft steel rod
4	1-1/4 inch x 1 inch PVC reducer adapter
1	8 ft. length Belden #9248 RG-6 75 ohm coaxial cable
6	UHF male coax cable connectors
2	UHF barrel double female coax connectors
1	UHF coax tee connector
1	UHF double female coax connector
1	UHF male-to-BNC male coax adapter

Table 1. Tracking antenna parts list.

transmitter circuit board will not shift under flight G-forces.

Connect the thermistor, antenna, and arming jack connectors, and then fasten the nose cone in place with the screws supplied in the rocket kit. Note: You may find it necessary to notch the bottom edge of the nose cone to clear the antenna wire on the inside of the payload section. I recommend placing an index mark on the junction between nose cone and payload section so proper alignment can be achieved later. **Photo F** shows the antenna, thermistor, and arming jack connectors.

Test the transmitter installation by turning on the receiver and then pulling the arming plug from the jack. If everything is working OK, you should hear tone pulses from the receiver. Reinstall the arming plug to turn off the transmitter. **Photo G** is a photograph of the completed airframe in primer coat white. The next article in this series will describe calibration of the thermistor temperature sensor, finishing the sounding rocket airframe, flight operations, data recovery, and implementation of the project with schools and youth groups.

ROCKET CONSTRUCTION NOTE: The rocket airframe has been built for launch from a tower, so no launch lugs have been installed. If you will be launching from a rod-type launcher, launch lugs will need to be installed on the airframe.

Qty.	Part
1	Vaughn Brothers Extreme 38 rocket kit
1	8 inch length 1/16 inch music wire
1	12 inch x 12 inch square section R/C packing foam rubber (available from hobby shops)
1	2 inch x 2 inch square sheet 0.005 brass (available from hobby shops)
1	6 inch length #22 tinned solid wire
1	Dean's Ultra Plug 2-pin power connector (available from hobby shops)
2	Dean's standard 2-pin connector (available from hobby shops)

Table 2. Airframe parts list.

Addresses

Vaughn Brothers Rocketry, 4575 Ross Drive, Paso Robles CA 93446; tel.: (805) 239-3818; fax: (805) 239-0292.

Astron Corporation, 22560 Glenn Drive, Suite 114, Sterling VA 20164; tel.: (703) 450-5517; fax: (703) 450-9753.

National Association of Rocketry, 1311 Edgewood Drive, Altoona WI 54720; [www.nar.org].

Tripoli Rocketry Association, Inc., P.O. Box 280, Bessemer AL 35021-0280; tel.: (205) 424-8357. 73