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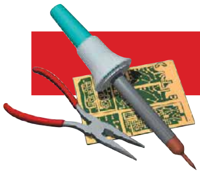

By Anthony Monteiro, AA2TX

Work OSCAR 40 with Cardboard-Box Antennas!

Are you interested in working the AMSAT-OSCAR 40 satellite but intimidated by the cost and complexity of the special antennas required? Parabolic dishes, axial-mode helices, circularly polarized Yagi arrays…NOT!

At a recent ARRL convention, several complaints were heard at the AMSAT booth from potential new OSCAR 40 satellite operators. Their concern was that a big, up-front commitment to antennas was required just to try this communications mode. Well, don't despair, potential satellite user…there's help around the corner; if you live near a grocery store, you're in luck! These antennas for working OSCAR 40 are made primarily out of cardboard cartons and aluminum foil and they are designed to be cheap and simple to build. There are no adjustments to make; no test equipment is required and you can leave the soldering iron off. Although they are made out of cardboard, these antennas are no paper tigers when it comes to performance. They perform like the typical antennas used by veteran OSCAR 40 operators.

OSCAR 40 is the satellite formerly known as Phase 3D and it carries lots of transmitters, receivers and transponders in its payload. While not all of these are functional, the mode U/S linear transponder is operating well and it facilitates the most popular operational mode. To access it, you'll need an S band (2.4 GHz) downlink antenna and a UHF (435 MHz) uplink antenna.

Downlink Antenna

OSCAR 40 is in a highly elliptical orbit that, at apogee, has a maximum range beyond 60,000 km. In order to hear the satellite at this distance, a high gain, low-noise antenna is needed. Eighteen to 20 dB of antenna gain is required to get the signal strength high enough to hear over your downconverter's front-end noise. The antenna must also have a clean radiation pattern with minimal side-lobes, coupled with an excellent front-to-back ratio. Otherwise, it will pick up thermal noise from the warm earth as well as interfering signals from cordless telephones and wireless networks that also operate on S band.

Parabolic dish antennas are by far the most popular type used to receive OSCAR 40. They provide the needed gain while maintaining a clean radiation pattern, but are tricky to set up and very sensitive to surface irregularities.

Fortunately, there is a type of antenna that can provide the needed gain and pattern but is much more forgiving of construction tolerances—the *pyramidal horn*, shown in Figure 1. The pyramidal horn looks a lot like a megaphone. If you have ever held a megaphone to your ear, you would have noticed how much louder sounds are through it. That is because the horn shape collects a lot more sound energy than your ear would by itself. The pyramidal horn works in much the same way. It collects lots of microwave signal energy and funnels it to a small antenna, called a probe, at the back of the horn. The probe then feeds the signal to your downconverter.

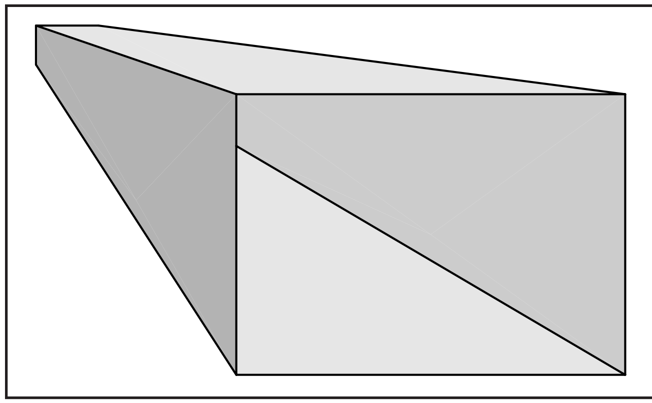

Figure 1—The basic pyramidal horn used for the downlink antenna.

Table 1
Downlink Antenna

Performance Specifications

Operating frequency	2.4 GHz (S band)
Return loss (SWR < 1.2:1)	> 23 dB @ 2.4 GHz
Gain	20 dBi
Polarization	Vertical
Elevation beamwidth	±9° at –3 dB
Azimuth beamwidth	±8° at –3 dB

List of Materials

(Quantity—2) Shipping carton, 16 × 22 × 22 inches of 1/8 inch cardboard
Roll of 18 inch wide aluminum foil
Roll of 2 inch wide clear packing tape
5/8 × 24 nut
1 5/8 inch length solid, bare #14 AWG copper wire

This OSCAR 40 downlink antenna was designed to have a gain of around 20 dBi, which is comparable to the 19-21 dBi gain of popular 2 foot dish antennas. It provides plenty of signal strength, even with the satellite at apogee. The complete technical specifications for the antenna are given in Table 1. Before starting construction on any of these antennas, it's a good idea to familiarize yourself with the tables, specifications and assembly details first—in order to understand the complete procedure.

Constructing the Downlink Antenna

As mentioned previously, the physical structure of the antenna is made of cardboard. A very inexpensive source of cardboard shipping cartons is the corner grocery store; these are generally free for the asking. The large size standard carton is around 16 × 22 × 22 inches and 1/8 inch thick. This is the size you ideally want, although the exact size is not critical. Two cartons are needed. One carton is cut up to make the horn panels and is covered with aluminum foil. The other carton is used to support the horn structure. Packing tape, the type used to wrap packages for mailing, holds everything together.

In order to eliminate the need for any connectors or soldering, the downconverter is directly mounted to the horn using a 5/8 × 24 nut. The nut fits the threads of the female N-connector on the downconverter. This size nut is supplied with single-hole, chassis-mount, coaxial connectors (N or UHF types) and other types of round connectors. If your junk box doesn't have one of these nuts, they are readily available new from coaxial connector suppliers for about 50 cents each.

The only other component required is a straight length of solid, bare, #14 AWG copper wire, used to make the coaxial coupling probe inserted into the center pin of the downconverter's female N-connector. You need to cut this as carefully as possible to 1 5/8 inches long. Since the diameter of #14 wire is the same as the center pin of a male N connector, it will fit snugly yet not deform or damage the connector on your downconverter. The complete list of materials is shown in Table 1.

To start construction, carefully unfold one of the cardboard cartons. If you have a carton sized differently than that specified, be sure that the resulting panel pieces have the correct dimensions. You will need all of the sides plus the top or bottom flaps of each side to make the horn panels as shown in Figure 2. Use the 22 inch wide sides to make the top and bottom horn panels and the 16 inch wide sides to make the two side panels. The top and bottom horn panels are the same, except that a 5/8 inch hole in the top panel will be used to mount the downconverter. Draw the horn panels on the cardboard as carefully as possible and then cut them out using either a utility knife or scissors. Be careful to make straight cuts and not bend or crimp the cardboard. After cutting out the horn panels, you may find it helpful to apply some tape along the edges or across the flat surfaces to strengthen them.

Apply the aluminum foil to one side of each horn panel, rolling it over the edges of the panel, and taping it snugly on the back to hold it in place. The foil needs to cover all of the edges of the cardboard panels. Do not tape over the foil on the edges of the panels; the edges of the foil must make electrical contact between panels.

The horn side panels are only 15¼ inches wide, so a single piece of 18 inch wide aluminum foil can be run lengthwise to cover the entire panel. The top and bottom panels are too wide for this, so instead, place one piece of foil across the front 20 inch edge and cover the remainder of the panel with a second piece. Leave an inch or so of overlap between the pieces. You do not need to tape them together. Carefully cut and push back the foil through the 5/8 inch hole in the top panel, again keeping tape off the edges of the hole so that good contact will be made with the connector.

After you have created the four panels, you need to tape them together. The easiest way to do this is to place all four panels on a flat surface, *foil side down*, and align the long edges together. Make sure to place the side panels between the top and bottom panels. This will then look like an unfolded, flat horn. The long edges are all 27 inches long, so all the panel lengths should match. You will be taping the three long sides that are touching. Separate the edges from each other by one cardboard thickness (±1/8 inch) using a scrap piece of cardboard for spacing and then tape the backs, *not the foil side*, of the panels together. This is important, as the long panel edges need to be one cardboard thickness from each other before folding, in order to make good electrical contact when the horn is assembled.

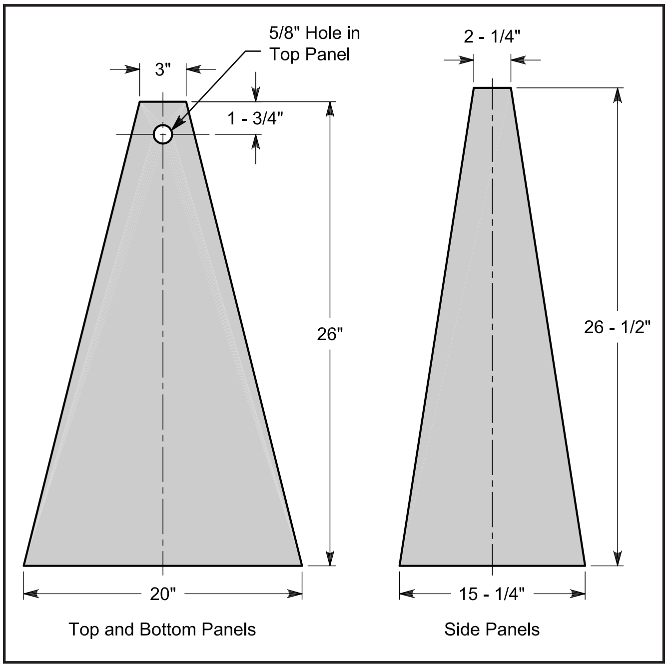

Figure 2—Dimensions for the downlink horn antenna panels.

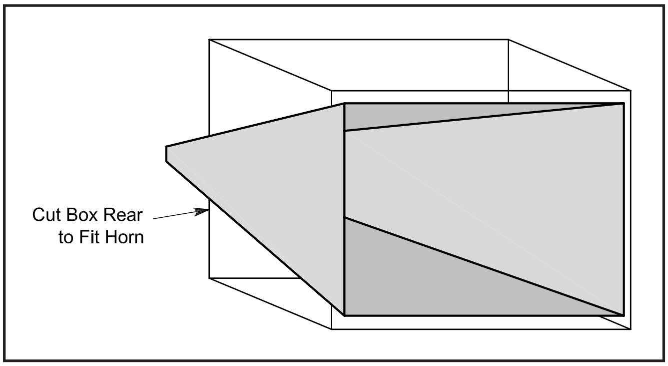

Figure 3—The final downlink antenna assembly showing how the horn fits into the supporting carton.

When the panels are taped together, carefully pick them up and fold them so the aluminum foil is on the inside. Form the pyramid shape, and tape the remaining edge tightly. When you form the pyramid, the cardboard on the edges will crush slightly, holding the aluminum foil covered edges together to make good electrical contact. After taping the fourth edge, hold the horn up to a light to see if there are any gaps between the edges. There will probably be a few. The design can tolerate linear gaps ¼ to ½ inch long without problems. Carefully use tape to pull the larger gaps together. If you have any really large gaps, patch them with foil and tape on the inside.

The remaining cardboard carton will be used to hold the horn, providing both structure and protection, as shown in Figure 3. The mouth of the horn will be centered in the supporting carton.

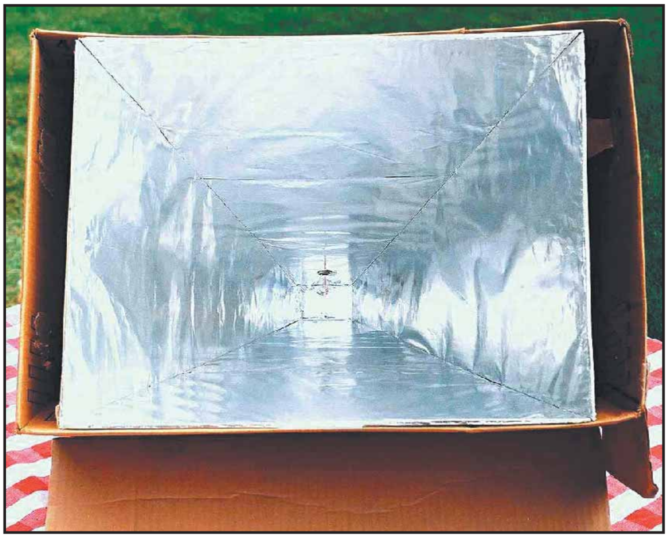

Figure 4—Front view of the downlink pyramidal horn showing how it is mounted in the support carton. Notice the coax probe at the back of the horn.

Figure 5—Side view of the downlink pyramidal horn showing the elevation control supports and how the downconverter is attached to the horn. The downconverter is pulled forward by the tape to align the probe wire parallel to the rear surface of the horn.

The top and bottom panels of the horn are 15½ inches apart at the mouth and will fit nicely into the 16 inch wide opening on the carton.

The horn is about 25 inches deep from front to back, which is too long to fit inside the carton. Cut a hole in the bottom of the carton to allow the back of the horn to fit through the bottom. The hole should be in the center of the bottom of the carton and will need to be about 5 inches wide by 3¾ inches high. You will need to trim the hole to fit the horn.

Align the front of the horn flush with the open end of the carton and tape the top and bottom edges of the horn to the carton opening. There will be a gap between each horn side and the carton side. Secure the back part of the horn to the hole in the back of the carton with tape.

Now it is time to mount the downcon-verter. Cut four 2 × 2 inch pieces of cardboard from the left over scrap pieces and cut a ⅝ inch hole in each piece. These are stacked to make a mounting shim for the downconverter. Slip the shim over the N-connector on the downconverter. Next, take the 1⅝ inch piece of #14 AWG wire and gently push it into the center hole of the N connector until it will not go in any further. It should stick out 1¼ inches from the connector, making a probe. Do not bend the wire!

Being careful not to rip the aluminum foil in the hole, push the end of the N connector through the ⅝ inch hole in the top panel at the back end of the horn and secure the downconverter with the ⅝ × 24 nut. You will need to compress the cardboard shim a bit to do this. The top of the N connector should be just about flush with the top of the nut when it is secured. The springiness of the cardboard shim will hold the downconverter in the hole. The connector should not protrude very much into the horn.

The downconverter will still have a fair amount of play in the hole. Hold the downconverter so that the wire probe is parallel with the back plane of the horn and tape the downconverter in place. Finally, use a piece of aluminum foil to cover the back end of the horn and apply tape to hold it taut. Congratulations…your downlink antenna is complete! Figure 4 shows a front view of the completed pyramidal horn and Figure 5 is a side view.

Downlink Operation

The easiest way to test your new downlink antenna is to power-up the downconverter, point the antenna at the satellite and tune around for the beacon. You will need to know the position of AO-40 in order to point the antenna. There are many satellite tracking programs available, including some that are free, on AMSAT's Web site, **www.amsat.org/**; it's a good source for general information on satellites and tracking. Another useful Web site, specifically about AO-40, is **ao40.homestead.com/**.

The antenna has a beamwidth of around 17° in both azimuth and elevation, so pointing is not critical. Use a compass to set the antenna azimuth. You will need to include the magnetic declination in your area, which is the difference between compass north and true north.

For elevation control, it may be helpful to tape some additional pieces of scrap cardboard to tilt up the outer carton as can be seen in the photographs. You can also just prop up the carton with a heavy object. A protractor will be helpful for setting the elevation angle. A certain amount of trial and error will be needed to find the satellite beacon the first time but with a little experience this will be a snap. The satellite beacon is easy to hear and will be a very strong signal, even with the satellite at apogee.

After you find the beacon, you should tune around and listen for CW and SSB signals. You can get a good sense for how to operate on OSCAR 40 by monitoring contacts and nets that use the satellite.

Another activity you can try with your new antenna is decoding the satellite telemetry that is transmitted on the beacon. A convenient way to do this is by using the *ao40rcv* program (available free) at **www.qsl.net/ae4jy/ao40rcv.htm/**. This program uses a PC sound card to demodulate the signal, decode the telemetry and display the results on your PC screen. The program works well with the cardboard-box downlink antenna.

Uplink Antenna

Monitoring the satellite is entertaining, but once you listen a few times you will want to join in the fun and make your own contacts! In order to access the AO-40 satellite on the UHF uplink, an effective radiated power of 100 to 500 W is required.

This depends on the mode (CW or SSB) and distance to (or range of) the satellite. Remember that at apogee the range of the satellite can be over 60,000 km. Since the UHF output of a typical transceiver is only 10-50 W, a fair amount of gain is required of the uplink antenna.

Most OSCAR 40 operators use some form of Yagi antenna to get the required gain. A Yagi is, however, hard to construct out of cardboard! Instead, we use a dipole-fed corner reflector. The basic corner reflector antenna is shown in Figure 6.

Corner reflectors are simple to build and are very forgiving of mechanical tolerance errors. The gain of the corner reflector is mostly a function of its size. For more gain, just make it bigger! This means you can get started with a small and really simple corner reflector and make it bigger if you want better performance. With this in mind, two designs are presented here: a simple version and a larger, high-performance version.

The simple version is made from a single cardboard box and has about 9 dBi gain. When fed with 50 W, it will provide a solid SSB uplink signal to OSCAR 40 out to a 30,000-km range and a solid CW signal all the way out to apogee. This is a great way to get started on OSCAR 40, as the antenna is so easy to build.

The high-performance version provides over 14 dBi gain, equivalent to an 8 element optimized Yagi, and will provide solid SSB or CW signals all the way out to apogee. It uses the same construction style, but it is bigger; it takes longer to build, and it requires two to three cardboard boxes. The complete technical specifications for both versions of the uplink antennas are given in Table 2.

Constructing the Uplink Antennas

As with the downlink antenna, you can get all the cardboard you need from grocery store cardboard shipping cartons sized about 16 × 22 × 22 inches and 1/8 inch thick, although exact sizing isn't critical.

The dipole-feed is the same for both versions and is made from ¾ inch aluminum tubing and black PVC insert couplings of the type used in lawn sprinkler systems. The coupling is used as a center insulator for the dipole; two more are used on the ends to hold the dipole in place over the reflector. The dipole presents a 50 Ω impedance when used with the corner reflector. No balun transformer or other matching network is required.

A short length of RG-58 or RG-8X type coaxial cable with a suitable connector is used to connect the dipole to your transmitter. Most UHF transmitters have an N-connector. A premade jumper cable can be used…just cut off one end. A minimum of 5 feet of cable is required. The list of materials for the dipole feed can be found in Table 2.

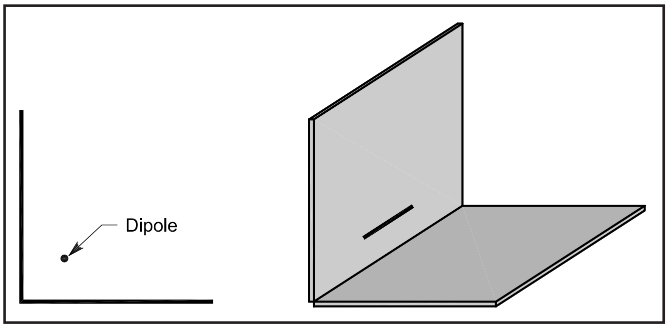

Figure 6—The basic corner reflector used for the uplink antenna. Note the dipole feed.

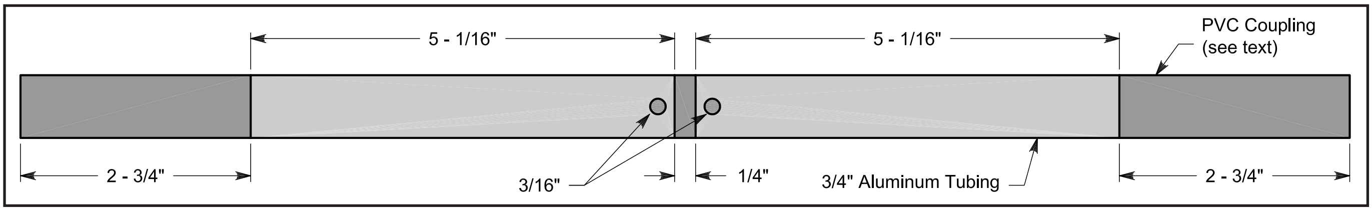

Figure 7—Dimensions for the corner reflector dipole feed.

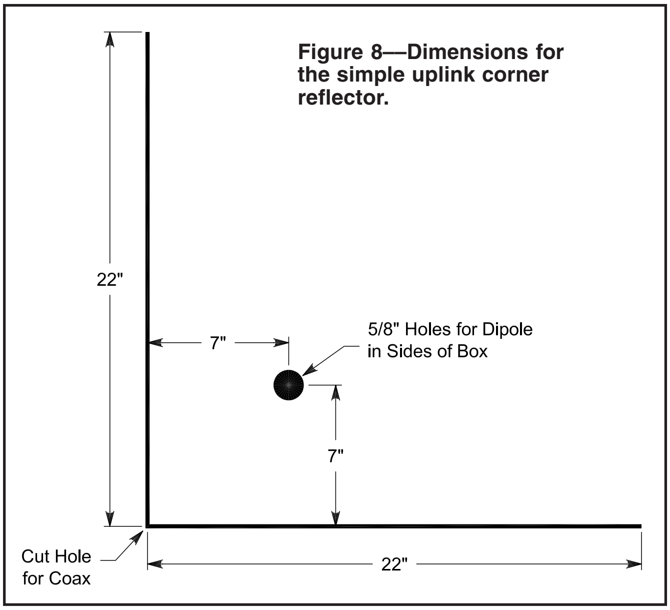

Figure 8—Dimensions for the simple uplink corner reflector.

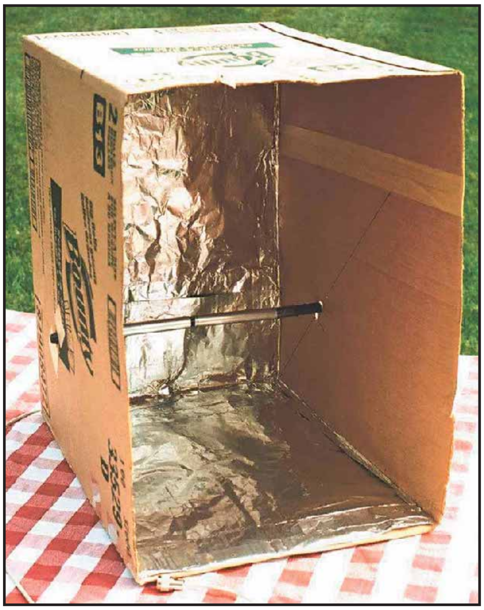

Figure 9—The completed simple uplink corner reflector.

Table 2
Uplink Antenna Specifications and Materials

Performance Specifications, Simple Version

Operating frequency	425-465 MHz
SWR	< 1.5:1
Reflector size	22 × 22 × 16 inches
Gain	9 dBi
Polarization	Horizontal
Elevation beamwidth	±13° at –1 dB; ±23° at –3 dB
Azimuth beamwidth	±26° at 1 dB; ±43° at 3 dB

Performance Specifications, High-Performance Version

Operating frequency	425-465 MHz
SWR	< 1.5:1
Reflector size	27 × 27 × 38 inches
Gain	14 dBi
Polarization	horizontal
Elevation beamwidth	±8° at –1 dB; ±13° at –3 dB
Azimuth beamwidth	±13° at 1 dB; ±24° at 3 dB

List of Materials

(Quantity 1-3) Cardboard carton, 16 × 22 × 22 inches of $\frac{1}{8}$ inch cardboard.
Roll of 18 inch wide aluminum foil.
Roll of 2 inch wide, clear packing tape.
12 inch length of ¾ inch aluminum tubing.
(Quantity 2) #8 × ½ inch sheet-metal screws.
(Quantity 3) ½ inch black PVC insert coupling.
5 ft length of RG-58 or RG-8X with N-connector and ½ inch leads.

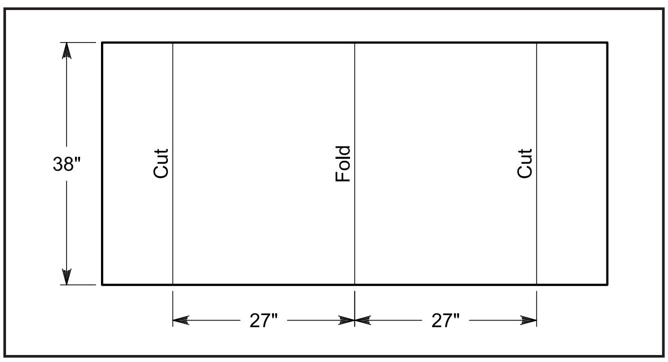

Figure 10—Cutting instructions for the high-performance corner reflector surfaces.

To construct the dipole-feed, cut two pieces of aluminum tubing with a pipe-cutter or a hacksaw, each $5\frac{1}{16}$ inches long. Push the two aluminum tubes onto one of the PVC insert couplings, leaving a ¼ inch gap in the center, as shown in Figure 7. This will require filing down the insert coupling using a grinding tool, a file, or coarse sandpaper. The tubes should fit snugly on the insert coupling. Note that the ¼ inch gap is a critical dimension, so measure this carefully.

With the tubes ¼ inch apart on the insert coupling, drill a $\frac{3}{16}$ inch diameter hole through the top of each aluminum tube and into the insert coupling, $\frac{1}{8}$ inch from the end of the tube. Insert a #8 sheet-metal screw and thread each hole, backing off two turns. Wrap the center conductor around one screw and the shield around the other and tighten. Make sure there are no short circuits. Push an insert coupling into the other end of each aluminum tube so it sticks out about 2¾ inches and tape it in place. Set this aside while making the reflector.

Simple Corner Reflector

The simple version of the antenna is made from a single cardboard box. The bottom and narrow side of the box should each be about 16 inches wide and 22 inches long. Cover the bottom and one of the narrow sides of the box with a single piece of aluminum foil and tape in place.

To mount the dipole, cut a $\frac{5}{8}$ inch hole on each side of the box, 7 inches from the bottom and 7 inches from the foil-covered side, as shown in Figure 8. Cut a hole in the center of the reflector for the coax. Mount the dipole by pushing the insert couplings through the holes in the sides of the box and hold it in place with tape. Push the coax connector and cable through the hole in the center of the reflector and tape the cable to the box to hold it in place. That's it! Your completed antenna should look like the photograph of Figure 9.

High-Performance Corner Reflector

The high-performance version of this antenna is just a bigger version of the simple one. The reflector sides are lengthened, from 22 inches long in the simple version, to 27 inches in this version. The reflector width is expanded from 16 to 38 inches wide. These dimensions are not critical; they were selected based on readily available cardboard box sizes.

To make the high-performance reflector, carefully unfold a 22 × 22 × 16 inch cardboard carton including the top and bottom flaps. This results in a piece of cardboard roughly 38 inches wide by 76 inches long with a fold in the center. Cut 11 inches from each end to make the piece 27 inches on each side of the fold. This will be the reflector surface shown in Figure 10. Cover it with aluminum foil and tape in place.

Flip the reflector over so the aluminum foil side is down. Using the leftover pieces of cardboard and tape, reinforce the reflector so it will hold its shape but make sure the center will still fold. Cut a hole in the center of the reflector surface for the coax connector.

Get another 22 × 22 × 16 inch cardboard box. Remove one of the narrow 22 × 16 inch sides and then cut the box in half down the long dimension, leaving two identical 8 inch wide corners. Bend the reflector surface along the centerfold, so the aluminum foil side is inside and tape it into the two corners to hold the corner reflector shape. You may need to do more reinforcing with cardboard and tape.

Finally, make a holder for the dipole out of cardboard and tape. The holder needs to position the dipole so it is held 7 inches from each of the reflector surfaces just as in the simple version. An easy way to do this is to cut out the corner from yet another box, punching holes in the sides to hold the PVC insulators and, in the bottom, for the coax connector. If you made the simple version first, just peel off the aluminum foil and cut the corner out with the dipole mounting holes already present. Mount the dipole in the holder and fasten with tape, as shown in Figure 11. Push the coax through the hole in the center of the reflector and again fasten with tape. When completed, the antenna should look like the one in Figures 11 and 12.

Uplink Operation

As shown in Table 3, the azimuth beamwidth of the uplink antennas is fairly wide, so the azimuth angle will usually not require frequent adjustment. Elevation positioning is even easier. With one of the reflector sides horizontal and the other one vertical, the antenna radiation pattern points up at about a 45° angle. To lower the radiation angle, raise the back of the antenna. Since the elevation beamwidth is quite high, it may be possible to set the antenna to an angle where no additional elevation positioning is required, depending upon your station location. For example, at my location in Massachusetts, setting the elevation angle to 20° provides good coverage for all AO-40 passes with no other elevation pointing. To set the angle to 20°, raise the back of the antenna until the bottom reflector

Figure 11—The completed high-performance corner reflector. Note how the box corners hold the reflectors and dipole feed in place. The rear legs set the antenna elevation to 20°—this gives good coverage at the author's latitude.

Figure 12—A close-up of the high-performance corner reflector dipole feed.

Figure 13—The complete satellite station with the tracking laptop, FT-847 transceiver, and both downlink and uplink antennas. [Recognize that key? It's a J-38 from 1944, bridging a gap of almost 60 years!–*Ed.*]

makes a 25° angle with the ground. This can be done by adding "legs" to the back of the high-performance antenna, as seen in the photograph of Figure 11. Locations that are closer to the equator will require a higher elevation angle.

On the Air

To transmit on the OSCAR 40 uplink you will need to first find your own downlink. This is not as hard as it sounds, after you have done it a couple of times. You need to find the beacon and then tune up or down 100 kHz or so to get away from the popular frequencies and not cause interference. Use your tracking program to tell you the downlink Doppler shift. The uplink shift is roughly one-sixth that of the downlink. Set your VFO to the uplink frequency and send a couple of Morse characters. Tune around your expected downlink frequency until you find the signal. You will need to adjust your transmit power until your signal is 10 dB weaker than the beacon. If the satellite is not all the way out at apogee, you will probably need to cut back the power quite a bit to prevent triggering LEILA (an uplink power limiting program that ensures that you are not putting an excessive signal into the satellite and thus reducing power available for other contacts). This is true for both versions of the antenna, as even the simple antenna has ample gain when the satellite range is less than 30,000 km.

For more information about working OSCAR 40, check AMSAT's Web site, **www.amsat.org/**. Steve Ford, WB8IMY, has written an excellent article on getting started with OSCAR 40.[1] It includes a list of satellite resources.

The author has used these antennas on several occasions on OSCAR 40. The complete station uses an AIDC-3731AA downconverter and a Yaesu FT-847 transceiver. A laptop computer running *Instant*Track and *Instant*Tune software is used to locate the satellite and auto-tune the FT-847.[2]

As you can see in Figure 13, the complete satellite station easily fits on a picnic table. The laptop computer and the FT-847 are in front of the downlink antenna and the simple version of the uplink antenna. The downconverter can be seen sticking up out of the back end of the downlink antenna and is connected to the FT-847 with a short piece of RG-6 coaxial cable. The uplink antenna is connected directly to the FT-847 UHF output. When the high-performance uplink antenna is used, it is set up next to the picnic table, on the ground.

Do these antennas really work? The answer is a resounding yes! With this simple arrangement, I made several dozen SSB and CW contacts through OSCAR 40. These included DX contacts when the satellite was over the Atlantic. Solid signals can be heard on the downlink antenna and good signal reports were received with both versions of the uplink antenna. Many ragchew sessions ensued when the author mentioned that his antennas were made of cardboard boxes covered with aluminum foil. I'll see you on the bird!

Notes

[1]S. Ford, WB8IMY, "OSCAR 40 on Mode U/S—No Excuses!," *QST*, Sep 2001, pp 38-41.

[2]*Instant*Track and *Instant*Tune are available from AMSAT at **www.amsat.org**.

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Tony Monteiro, AA2TX, has been a ham since 1973 and is a member of AMSAT, TAPR, ARRL and QCWA. Interested primarily in the technical aspects of Amateur Radio, he can often be found on the satellites. Tony was a member of the technical staff at Bell Laboratories and has held senior management positions at Cisco Systems and several high-tech start-ups. He can be reached at 25 Carriage Chase, North Andover, MA 01845; **aa2tx@amsat.org**.