

Build This Cheap and Easy Satellite Uplink Antenna

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Author's Note: This is a companion article to my first article titled "Build This Cheap and Easy Satellite Downlink Antenna" published in the July/August 2006 AMSAT Journal. Please read my author's note at the beginning of the first article for additional background on this series. As before, this article is a revised copy of a free handout I developed for the AMSAT booth at the 2006 Rochester, NY hamfest. It is intended to enable non-satellite hams and students who will be the future satellite hams, to painlessly acquire the 146 MHz uplink antenna needed to actually work a satellite. Feel free to copy it and give it away, along with the "downlink antenna" handout, at your next AMSAT presentation or hamfest. Also, it makes an excellent school, club or Boy Scout project. But, before I get to the handout, I'd like to touch on a couple of points:

- (1) A school, a student or anyone can also use this 146 MHz uplink antenna to downlink (receive) voice and packet data signals from the ISS (International Space Station). The ISS worldwide downlink frequency for this is 145.800 MHz. A suitable 146MHz NBFM receiver may be found in a 2m Amateur Radio HT, 2m mobile transceiver, wide band receiver or police scanner. The suggestions for tracking and receiving a satellite in the "downlink antenna" article also apply generally to the ISS. If you have a ham license you can also uplink to the ISS with this antenna as well. At www.amsat.org, click on "Satellite Information", then click on "Amateur Satellite Status", then click on "ARISS" for ISS status and frequencies. Also, see www.issfanclub.com. For introductory info about working the ISS, see www.rac.ca/ariss/faqariss.htm and www.rac.ca/ariss/arisspak.htm.
- (2) A school, a student or anyone may be able to use this antenna to receive the signal from a future Suitsat mission, provided it transmits in the 2m band as it did before and its signal is strong enough. Most of the advice in note 1 above about receiving signals from the ISS will generally apply to SuitSat. If you're not familiar with SuitSat, Google "SuitSat" and "SuitSat-1".

Introduction

When I operate satellite portable, I uplink to the FM LEO (Low Earth Orbit) satellites (AO-27, SO-50 and AO-51) using a homemade handheld 146 MHz 3 element Yagi antenna. In the write up that follows, I'll show you how to build this inexpensive uplink antenna for yourself. If you're a satellite beginner, I recommend you start with handheld, portable antennas to avoid the expense and complication of purchasing Az/El (Azimuth and Elevation) rotators and fixed-station satellite antennas. Portability also gives you the flexibility to select and travel to an advantageous location for satellite operations if your home location is not so good.

Note there is a companion write-up titled "Build This Cheap and Easy Downlink Antenna". I will refer to this article, from time to time, as the "downlink antenna" article. You should build the downlink antenna first, and practice receiving satellite signals, before you build this uplink antenna. There is also a third article for building a cross boom with tripod which is tentatively titled "Build This Cross Boom For Your Cheap and Easy Satellite Antennas". If you find that this article is not available now, it will be soon. You'll need this cross boom and tripod to hold and separate your uplink and downlink antennas. If you can't locate copies of these other articles, see the instructions for e-mailing me at the end of this article. I'll either tell you where to find them or I'll send them to you.

Be advised that you need to possess a suitable Amateur Radio license to uplink

(transmit) to a satellite. To find out how to qualify for such a license, contact a local or national ham radio club, go to any hamfest, or visit www.arrl.org. In the United States, it's fairly easy and inexpensive, though perhaps time consuming, to study for and pass the test required to obtain the entry-level license needed.

Again, the electrical design for this antenna is from "Cheap Yagi Antennas for VHF/UHF" by Kent Britain, WA5VJB (Google "Cheap Yagi"). The mechanical construction and step-by-step presentation for this antenna is the same as in the downlink antenna article. If you built the downlink antenna, you can build this antenna. And finally, in step 57, I'll show you how to use this antenna to actually uplink to a real satellite. I think you'll be amazed by how well it works. See Photo 1.

Step-by-Step Instructions

1. Read these instructions all the way through to get an idea of what's involved. Pay particular attention to how tools are used in case you don't have one and can make a substitution with a tool you have.
2. Referring to the list of materials in Table 1, acquire the necessary materials. Note that the materials are exactly the same as those for the downlink antenna. You should have most of the materials you need left over from that project. However, for the 6-foot coax cable, it may be cheaper to purchase a 12-foot RG-58 coaxial jumper cable with BNC connectors on each end (Radio Shack #278-965). Cut the 12-foot cable in half and use one half for the downlink



Photo 1: The N2SPI Cheap and Easy Satellite Uplink Antenna.



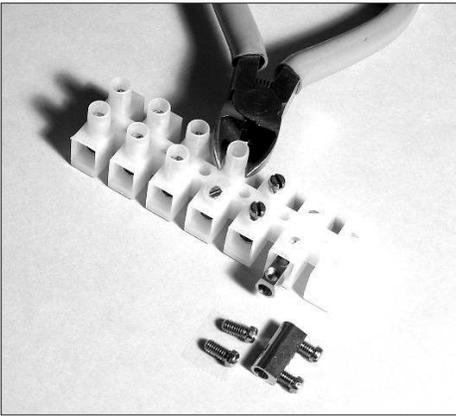


Photo 2: Terminal strip in various stages of disassembly.

antenna and the other half for the uplink antenna. Also, for the foam board, you may want to get the 30-inch by 40-inch size. You'll need this larger size later for the cross boom and Staples seems to be packaging this now as a 3-pack. With careful planning, you should be able to get a downlink antenna, an uplink antenna, a cross boom and then some out of a single 3-pack of 30 inch by 40 inch foam board. For other sources of aluminum wire, Google "aluminum ground wire".

- Referring to the list of tools in Table 2, make sure you have the necessary tools or suitable substitutes. Note that the tools required are exactly the same as those for the downlink antenna. However for the 36" straightedge, you may prefer to acquire and substitute a 4-foot carpenter's level. You'll need the carpenter's level to make the cross boom later. Position the smaller-width side of the level against the foam board when using it as a straight edge. Refer to the downlink antenna article for additional tool comments.

In the next 4 steps, liberate two wire-to-wire connectors from the Euro-style terminal strip. The wire-to-wire connector is the secret to the "N2SPI No-Solder Connection Method".

- Select a terminal on the Euro-style terminal strip and, using the flat 1/8" blade screwdriver, screw both screws in the terminal all the way in. Now, use the diagonal cutters to clip off the tops of both plastic screw towers just above the screw-heads. See Photo 2.
- Unscrew both screws until they fall out. Now, push the terminal's metal barrel out of the plastic housing.
- Now, re-install both screws into the barrel to complete the first wire-to-wire connector hereafter called a "connector".
- Repeat steps 4 through 6 to obtain a second connector. Then, set both connectors aside. They'll be used later to attach the coaxial cable to the antenna's driven element.

In the next 4 steps, make two 2 3/4 inch by 30 inch foam board strips for the side panels on the antenna boom.

- Position the foam-board so a 30-inch factory edge, hereafter called a factory edge, faces you. Place the two pine boards under the foam board so it is elevated and lies flat and steady. Adjust the combination square so 2-3/4 inches of the rule is sticking out of the attached head. Then, place the head of the combination square against the factory edge and, with the rule lying flat against the foam board, make two pencil marks, one 2-3/4 inches up the left side, and one 2-3/4 inches up the right side from the factory edge. Use the straight edge to draw a 30-inch line between the two marks. This general measuring procedure is hereafter called "using previous measuring methods".
- Now, place the first pine board under the line on the foam-board so as to act as a cutting board. Place the second pine board so the foam-board lies flat and steady.
- Be sure the X-Acto knife has a fresh, sharp blade. Now, carefully and

patiently (take your time), trace along the line with the tip of the X-Acto knife. At first, just penetrate the surface paper. Repeat, cutting a little deeper each time, and as you can, gently bend back the foam board to expose the cut. Finally, cut through to make a foam board strip, hereafter called a "strip". Using the pencil, lightly write "Factory Edge, Bottom" on the factory edge to make it the bottom edge. This general cutting procedure is hereafter called "using previous cutting methods".

- Repeat steps 8 through 10 to produce a second 2-3/4 inch by 30-inch strip, which includes the other factory edge. These two particular strips are hereafter called "side panels".

In the next step, make three 1-1/4 inch by 30-inch foam board strips for the inner core of the antenna boom.

- Using previous measuring and cutting methods, make three 1-1/4 inch by 30-inch strips. Note: (a) there're no more factory edges to locate, and (b) after each strip is cut, lightly write "Bottom" on its better 30-inch edge to make it the bottom edge.

In the next 3 steps, laminate the three 1 1/4 inch wide by 30 inch long strips to make the inner core of the boom.

- From one end of a 1-1/4 inch by 30-inch strip, lay down a first piece of double-sided tape near the top edge for the first 15 inches. Then cut neatly with the X-Acto knife. In a similar way, lay down another piece of double-sided tape along the remaining 15 inches of the top edge. Using the same procedure, lay down two consecutive pieces of double-sided tape along the bottom edge.
- Lay the first strip down on your worktable with the double-sided tape facing up. Then, take a second 1-1/4 inch by 30-inch strip, line up the bottom edges and one end of the two strips. Starting at the one end, progressively

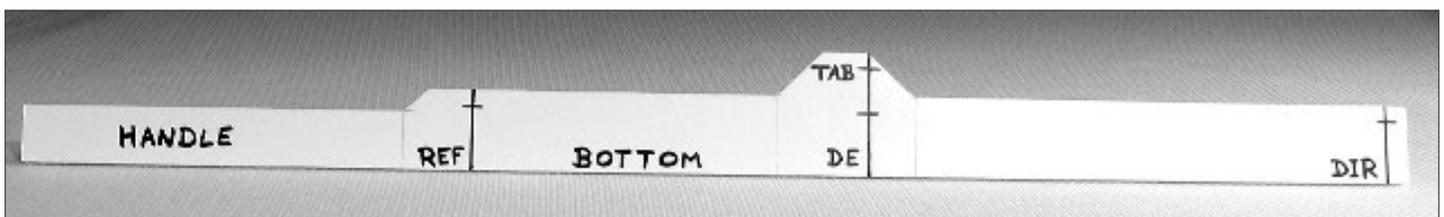


Photo 3: Side panel with element positions marked (markings made very dark for illustrative purposes).



press the second strip onto the first, keeping the bottom edges lined-up, until you're done. If strips are warped, combine the warp of one strip with and an opposite warp from the other strip, so they cancel out.

15. Repeat steps 13 and 14, hereafter called "using previous laminating methods", to laminate the third 1-1/4 inch by 30-inch strip together with the first two.

In the next 5 steps, cut the left side of a tab in the first side panel to accommodate the driven element hairpin wire.

16. Using the tape measure plus previous measuring methods, from the bottom left corner of a side panel, measure 16 inches to the right along the factory edge and make a first mark. Then, at this first mark, use the combination square to draw a line perpendicular to the factory edge and across the side panel. See Photo 3.

17. Now, from the factory edge, measure and make a second mark 1-3/4 inches up the perpendicular line just made in the step above.

18. Then, again from the factory edge, measure and make a third mark 1-3/4 inches up the left side of the side panel.

19. Use the straight edge to draw a 16-inch line from the third mark to the second mark. Place the combination square's 45 degree surface against the factory edge and extend and position the rule so you can draw a 45 degree line from the second mark to the right and up to the top edge of the side panel.

20. Using previous cutting methods, cut along the 16 inch and 45 degree lines making a curved transition at their junction. See Photo 3.

In the next 5 steps, cut the remaining right side of the tab in the first side panel.

21. Using previous measuring methods, from the bottom right corner of the same side panel as above, measure 11 inches to the left along the factory edge and make a first mark. Then, at this first mark, use the combination square to draw a line perpendicular to the factory edge and across the side panel.

22. Now, from the factory edge, measure and make a second mark 1-3/4 inches up the perpendicular line just made in the step above.

23. Then, again from the factory edge, measure and make a third mark 1-3/4 inches up the right side of the side panel.

24. Use the straight edge to draw an 11-inch line from the second mark to the third mark. Place the combination square's 45 degree surface against the factory edge and extend and position the rule so you can draw a 45 degree line from the second mark to the left and up to the top edge of the side panel.

25. Using previous cutting methods, cut along the 11 inch and 45 degree lines making a curved transition at their junction. See Photo 3.

In the next step, cut a tab in the second side panel.

26. Repeat steps 16 through 25 to cut an identical tab in the second side panel.

In the next 5 steps, cut a handle out of the first side panel.

27. Using previous measuring methods, from the bottom left corner of a side panel, measure 8 inches to the right along the factory edge and make a first mark. Then, at this first mark, use the combination square to draw a line perpendicular to the factory edge and across the side panel. See Photo 3.

28. Now, from the factory edge, measure and make a second mark 1-1/4 inches up the perpendicular line just made in the step above.

29. Then, again from the factory edge, measure and make a third mark 1-1/4 inches up the left side of the side panel.

30. Use the straight edge to draw an 8-inch line from the third mark to the second mark. Place the combination square's 45 degree surface against the factory edge and extend and position the rule so you can draw a 45 degree line from the second mark to the right and up to the top edge.

31. Using previous cutting methods, cut along the 8 inch and 45 degree lines making a curved transition at their junction. See Photo 3.

In the next step, cut a handle out of the second side panel.

32. Repeat steps 27 through 31 to cut an identical handle out of the second side panel. Note that both side panels now have a 1-3/4 inch wide end and a 1-1/4

inch narrow end.

In the next 4 steps, mark both side panels to show where the antenna elements will pass through.

33. Refer to Table 3. Use the combination square to measure along the top edge and make a mark 1/2 inch in from the wide end. This mark partially locates where the antenna's director element will go. Use the tape measure to measure along the top edge from the wide end and mark the remaining two element positions.

34. Now, at each marked element position on the top edge, use the combination square to draw a line perpendicular to the factory edge and across the side panel.

35. Then, re-adjust the combination square to measure and place a cross-mark on each perpendicular line at a point 1-3/8 inches up from the factory edge. At the driven element line only, make a second cross-mark 2-3/8 inches up from the factory edge. See Photo 3.

36. Repeat Steps 33 through 35 to mark the element holes for second side panel in the same way as the first, EXCEPT on the opposite side than the first. (i.e., the second side panel's markings are a mirror image of the first side panel's markings.)

In the next step, make element holes in the first side panel only.

37. Place the first side panel on a pine board and push the skewer partway through at an element location until it just barely pokes through. Make sure the skewer is perpendicular to the first side panel when you do this. Wiggle the skewer slightly if it helps. Then turn the side panel over and poke the skewer back through, all the way, to complete the hole. Do this for all four element holes.

In the next 2 steps, laminate the side panels to the inner core of the antenna's boom.

38. Position the first side panel so the element position markings are facing one side of the inner core. Now, using previous laminating methods, laminate the first side panel to the inner core.

39. Using previous laminating methods, laminate the second side panel to the other side of the inner core, AFTER lining-up the wide end(s) and bottom



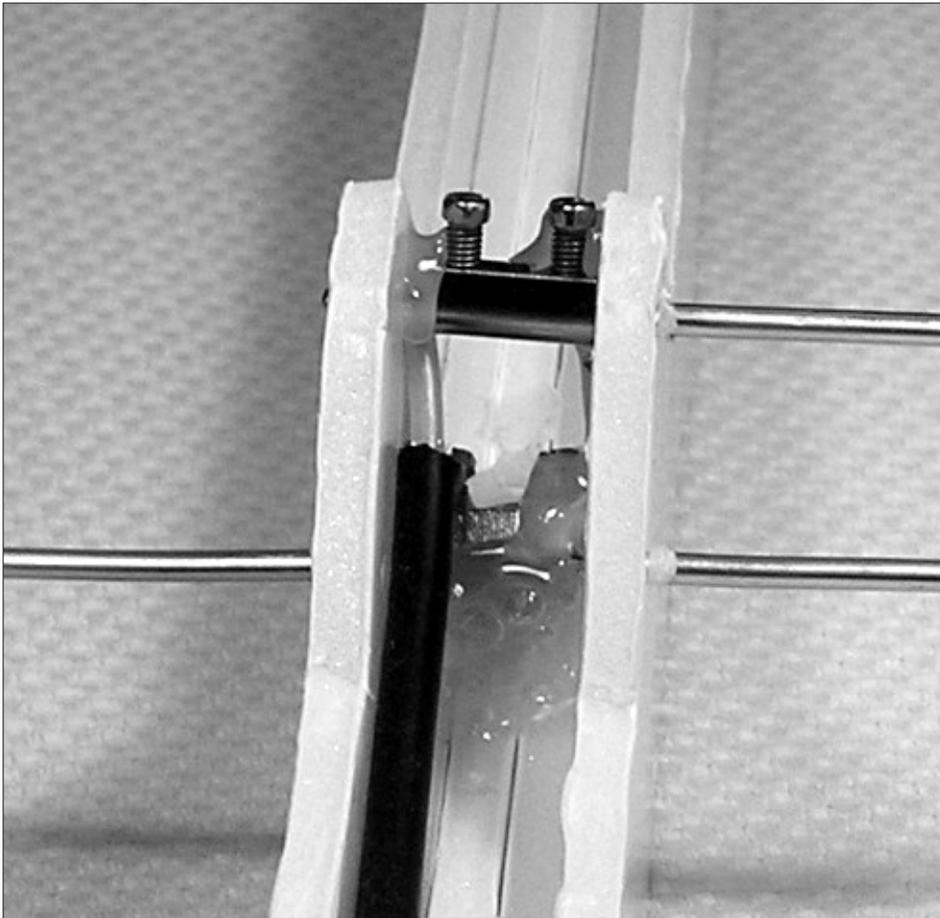


Photo 4: Driven element detail.

edge(s) of both side panels. Now, wrap the handle with one layer of clear packing tape.

In the next step, finish making the antenna element holes.

40. Re-push the skewer through the antenna's reflector element hole in the first side panel until it just touches the associated cross-mark on the second side panel. Use the combination square to verify the skewer is perpendicular with respect to the boom. If not, adjust the actual puncture point so the skewer is perpendicular to the boom. Then, using the method in step 37, make the hole. Repeat this until all four element holes in the second side panel are made.

In the next 4 steps, fabricate the antenna's driven element out of #8 AWG aluminum wire.

41. Straighten out a 60-inch length (hereafter called a "wire") from the #8 AWG aluminum ground wire. Use the tape measure and permanent marker to make a mark 20-1/2 inches in from a wire-end. At the mark, bend the wire around

a piece of 7/8 inch O.D. pipe or tubing until the short segment is parallel with the long segment. If you have nothing else, bend the wire around a "C" size flashlight battery. Re-bend, if necessary, until the two segments are spaced 1 inch apart. If the aluminum wire dirties your hands, wipe it down with paper towels dampened with a spray cleaner such as Windex.

42. Use the tape measure to measure 38-1/2 inches along the long segment starting from the bend. Mark and final-cut the wire here as follows: With the diagonal

cutters, cut the wire halfway, rotate the wire 90 degrees, and cut halfway again. Then bend the wire back and forth until it snaps in two. Use the mill file to bevel and smooth over the remaining rough and sharp edges. Use this method to get a smooth, rounded wire-end whenever a final-cut is called for.

43. Find the halfway point, or center, of the long segment. This should be $38\text{-}1/2 \text{ inches} / 2 = 19\text{-}1/4 \text{ inches}$. Now, get ready to make two marks, the first $5/8 \text{ inches}$ to the left, and the second $5/8 \text{ inches}$ to the right, of the center. To do this, measure and mark $19\text{-}1/4 \text{ inches} - 5/8 \text{ inches} = 18\text{-}5/8 \text{ inches}$ in from the bend, and also $18\text{-}5/8 \text{ inches}$ from the cut end. These marks will help you to center the element later.
44. Now, final-cut the short wire segment to $19\text{-}13/16 \text{ inches}$ measured from the bend.

In the next 4 steps, prepare the coaxial cable.

45. Take the RG-58 coaxial cable assembly (hereafter called the "cable") and use the diagonal cutters to cut off one of the BNC connectors so the remaining cable is about 6 feet long. Measure and mark the cable jacket 3 inches down from the cut end.
46. Be sure the X-Acto knife has a fresh, sharp blade. Place the cable on a pine board and gently roll it back and forth under the X-Acto knife to cut halfway through the jacket, all the way around, at the mark. Gently bend the jacket back to examine, and promote, the depth of the cut. Use a similar technique to slit the jacket from here up to the cable-end, cutting through the jacket only as you near the end. Now, pull the rest of the jacket apart and remove it.

Table 1: List of Materials

Qty Used	Material Description *	Example Source	Item Number **
1	"Elmer's" 20 inch x 30 inch Foam Board	Staples	245555
240"	1/2" wide "Scotch 665" Double Sided Tape	Staples	130500
36"	Clear Wide Cellophane Packing Tape	Staples	490802
144"	#8 AWG Aluminum Ground Wire	Radio Shack	15-035
1	Euro-style 12 mm Terminal Strip	Radio Shack	274-677
1	RG-58 Coax Jumper Cable, BNC to BNC, 6 Ft.	Radio Shack	278-964

* Name in "quotes" is the brand of product I used. Equivalents should be OK.

** Some Example Source Item Numbers come packaged in higher quantities than the quantity used.





Photo 5: Uplink antenna, cross boom and downlink antenna, ready for AMSAT's AO-51 Echo satellite.

47. Unbraid the shield wires until stopped by the new jacket end-point. Trim off half the shield wires and twist the remaining wires clockwise to form a 3-inch long, 18 AWG-size bare stranded wire shield conductor.
48. Cut the center conductor to a 2-inch length. In a way similar to step 46, cut the center conductor insulation halfway, all the way around, 1/2 inch down from the wire-end. Twist the insulation clockwise to complete the cut, then twist and pull it off. Similarly, remove another 1/2 inch, and then another. Use the 4" long nose pliers, as needed, to twist and pull-off the center insulation. In the end, the visible center conductor should have 1/2 inch of insulation remaining, and from there to wire-end, 1-1/2 inches of bare, clockwise-twisted wire.

In the next 3 steps, install the Driven Element, and attach coax using the "N2SPI No-Solder Connection Method".

49. Back-off the screws in both connectors, if necessary, until no screws are entering the wire chamber. Then, slide one connector over the coaxial cable shield conductor. Note that later in this step both the shield wire and the driven element wire should fit inside the connector. Locate the pair of holes in the side panel for the driven element's

long segment. Place the connector with the shield wire between these holes with its screws facing forward and tilted up. The coax shield should come out of the side of the connector opposite the first hole, which the driven element will pass through. Then, push the long element segment through the hole in the side panel and into the connector. As you're doing this, use the 4" long nose pliers, as needed, to position and hold things in place. See Photo 4.

50. Slide the other connector over the coax center conductor. Locate the pair of holes in the side panel to be used by the driven element's short segment. Place the connector installed on the center conductor between these holes with its screws facing up. The center conductor should be on the same side as the shield. Push the short segment through the side panel into the connector, while moving more of the long segment. Keep pushing the short segment through the connector until a little bit of it passes into the other side panel but doesn't extend beyond it. Having the short segment, as well as the long, held by both side panels considerably strengthens the attachment of the driven element to the boom. See Photo 4.
51. When the driven element is centered, and its hairpin is straight and not twisted,

and the pigtails between the coax and connector are 5/8 inch in length, tighten all screws. Apply a couple of dabs of hot-melt glue to hold the driven element in place, and then trim the excess wire with the X-Acto knife.

In the last 5 assembly steps, cut the remaining antenna elements out of the #8 AWG aluminum wire and install them.

52. Final-cut two 42-inch straightened lengths out of the #8 AWG aluminum wire.
 53. Refer to Table 3. From the final-cut end of a 42-inch wire, use the tape measure to carefully measure and mark the specified length of each element. Then final-cut each element. (i.e., both wire-ends receive the final-cut treatment.)
 54. In a way similar to step 43, find each element's center. Make two marks +/- 5/8 inches from the center of each element.
 55. Locate the pair of holes for each remaining antenna element in the side panels. Push each element through their pair of holes and then center them. Rotate the element wire while you push if it helps.
 56. Apply a dab of hot-melt glue to the middle of each element to hold it in place. When done, use hot-melt glue to secure the coax in a couple of places inside the boom. Then, use packing tape to secure the coax to the top of the handle.
- And finally, test your new satellite uplink antenna.

57. Test your new satellite antenna by using it to actually uplink to a satellite, say AMSAT's AO-51. See Photo 5. To do this:
 - a) First, consider how you'll handle your two satellite antennas, your downlink and now your new uplink antenna. You'll probably want to have a cross boom and tripod to hold these antennas. In the next article in this series, I'll explain how you can build this. See the introduction to this write up.
 - b) Connect your new uplink antenna to a 146 MHz NBFM transmitter. Such a transmitter can be found in a 2m HT (handheld transceiver) or a 2m mobile transceiver. Use whatever you have. If you use a mobile transceiver, switch the transmit power to a level you feel

is safe. Power your mobile transceiver with one of those 12 VDC power packs with attached automotive jumper cables. For most mobile transceivers, the power pack must be able to supply at least 10 amps, or so, though its cigarette lighter socket. Note that your 2m transceiver must be able to transmit a subaudible PL tone of 67 Hz to access AO-51. Personally, when I operate satellite-HT, I use an Icom IC-T2H Sport 2m HT (\$100 at www.aesham.com). For satellite-portable, I use a Yaesu FT-1802M 2m mobile transceiver (\$150 at www.aesham.com). Sometimes I wear a carpenter's tool belt, with several large pockets, to hold all my gear. Most of the time, a 5 watt 2m HT will work quite nicely provided AO-51 is at least several degrees above the horizon and there aren't a lot of stations vying for the single uplink frequency.

c) Even though this uplink antenna works very well, there will be times you won't be able to compete with the multitude of powerful home-based stations on AO-51, particularly on the weekends. The answer to this, in my opinion, is strategy. You need to pick a good time and location before attempting to work AO-51. For example, here in the northeast USA, I take my portable satellite station to a location with an excellent northern horizon. That way I can work AO-51 while it's over northern

Canada when only a few USA hams can access it. Such a location might be a hill with a good view to the north, or the south shore of a lake. Also, consider working AO-51 on a weekday morning when it's likely the congestion will be much reduced. Initially, whatever location and time you pick, be sure AO-51 will be in unobstructed sky for the interval that you intend to uplink to it.

- d) Once you've decided on an operating location, you'll need to be able to track AO-51. Everything in the downlink antenna article concerning tracking applies here. If you can hear AO-51, you can transmit to it. Refer to step 43 in the downlink antenna article for info on tracking. Note, however, that as you get more active on the satellites, you'll probably want to have your own tracking software to run on your PC. To purchase tracking software, click on "The AMSAT Store" at www.amsat.org. Personally, I use InstantTrack v1.50, which is available to AMSAT members for \$30, a bargain in my opinion.
- e) Check the AO-51 Schedule to make sure AO-51 is operating in V/U mode. If so, adjust your 2m FM transceiver to a transmit frequency of 145.920 MHz, the "V" uplink frequency. Don't forget to transmit the 67 Hz PL tone.
- f) When you've set up your portable satellite station at your chosen operating

location, and you're ready to uplink to AO-51, wait! Aim both your uplink and downlink antennas in the direction of AO-51 and listen for it first. A lot of interference is caused by operators who transmit to a satellite over and over when it's clear they can't hear the downlink. When you do hear AO-51's downlink, and there's a break in transmissions, transmit your call sign. If everything is working, you'll hear yourself on the downlink as you transmit. It's important that you hear yourself so you can determine if you're getting into the satellite clearly, or, if there's a problem. Because you can hear yourself while you transmit, it's important that you wear full-cup headphones. Otherwise, you'll create a different sort of interference with the squeal from your audio feedback. If you're receiving a clear signal from the satellite, but your uplink is noisy, try rotating your uplink antenna around its boom axis to maximize your signal into the satellite. Other FM satellites to try are AO-27 and SO-50.

In Conclusion...

If you need assistance building or using this satellite uplink antenna, or have other questions or comments, contact me at: n2spi@amsat.org. Please put the phrase "Satellite Uplink Antenna v2.0" somewhere on the email subject line. ☺

Table 2: List of Tools

Tool Description	Example Source	Item Number
16" Combination Square	Sears	00939681000
Small Tape Measure	Sears	00937396000
Flat 1/8" Blade Screwdriver	Sears	00941421000
6" Diagonal Cutters	Sears	00945075000
4" Long Nose Pliers	Sears	00945698000
Mill File	Sears	00931300000
"Sharpie" Ultra Fine Point Permanent Marker	Staples	498386
"X-Acto" Knife with #11 Blade	Staples	506998
"X-Acto" #11 Blade Refills	Staples	428300
Hot Melt Glue Gun with Glue Stick	Staples	508701
36" Straight Edge (Metal Yardstick)	Wal-Mart	
1/16" Square Shish-Kebab Skewer	Supermarket	
36" long Pine Boards, Qty = 2	Lumberyard	
Sharpened Pencil		

Table 3: Element Positions and Element Lengths for the 146 MHz Uplink Antenna

Antenna Element Name	Element Position from the "Wide End" (in inches)	Element Length* (in inches)
Director (DIR)	1/2	37
Driven Element (DE)	12	38-1/2
Reflector (REF)	20-1/2	41

* Try to cut the element length to within +/- 1/32 of an inch.

