

Build this Cheap and Easy Satellite Downlink Antenna

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Author's Note: *You've never seen an antenna constructed like this. You've never seen an antenna presented like this either. What follows 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 to painlessly acquire the 440 MHz downlink antenna needed to actually hear and work a satellite. I also had companion handouts for my designs of easy-to-build 2m uplink antennas. These handouts will be published later. For more background on how these handouts got started, see my article in the May/June 2005 issue of The AMSAT Journal titled "AMSAT at the Rochester Hamfest". Feel free to copy this handout and give it away at your next AMSAT presentation or*

hamfest. Also, it makes an excellent school, club or Boy Scout project.

Virtually no ham antenna article today lists all the materials, tools and specific building instructions so that a beginner can build it. As a result, only a well-equipped, skilled and experienced ham can hope to replicate those designs. In addition, many hams today don't have a machine shop or even a basement workshop or even power tools. So, after the 2005 Rochester hamfest, I put many months of thought into the design and presentation of an inexpensive, build-it-yourself satellite antenna which would remedy these issues. What emerged is presented here.

Introduction

Typical transmit power for an FM LEO

(Low Earth Orbit) satellite is only 250 to 500 milliwatts. With satellite to earth station distances of 400 to 2000 miles, receiving these kinds of signals adequately requires a gain antenna. So, I downlink the FM LEOs (AO-27, SO-50 and AO-51) with a homemade, handheld 440 MHz Yagi antenna. The electrical design for this antenna is from Cheap Yagi Antennas for VHF/UHF by Kent Britain, WA5VJB, (Google Cheap Yagi). I re-engineered the mechanical design to be super lightweight and super easy to build. I did this by inventing a foam board boom laminated with double-sided tape, aluminum wire antenna elements and no solder coax connections. Only a few simple hand tools are required. No power tools are required. And, I list all the tools and materials needed

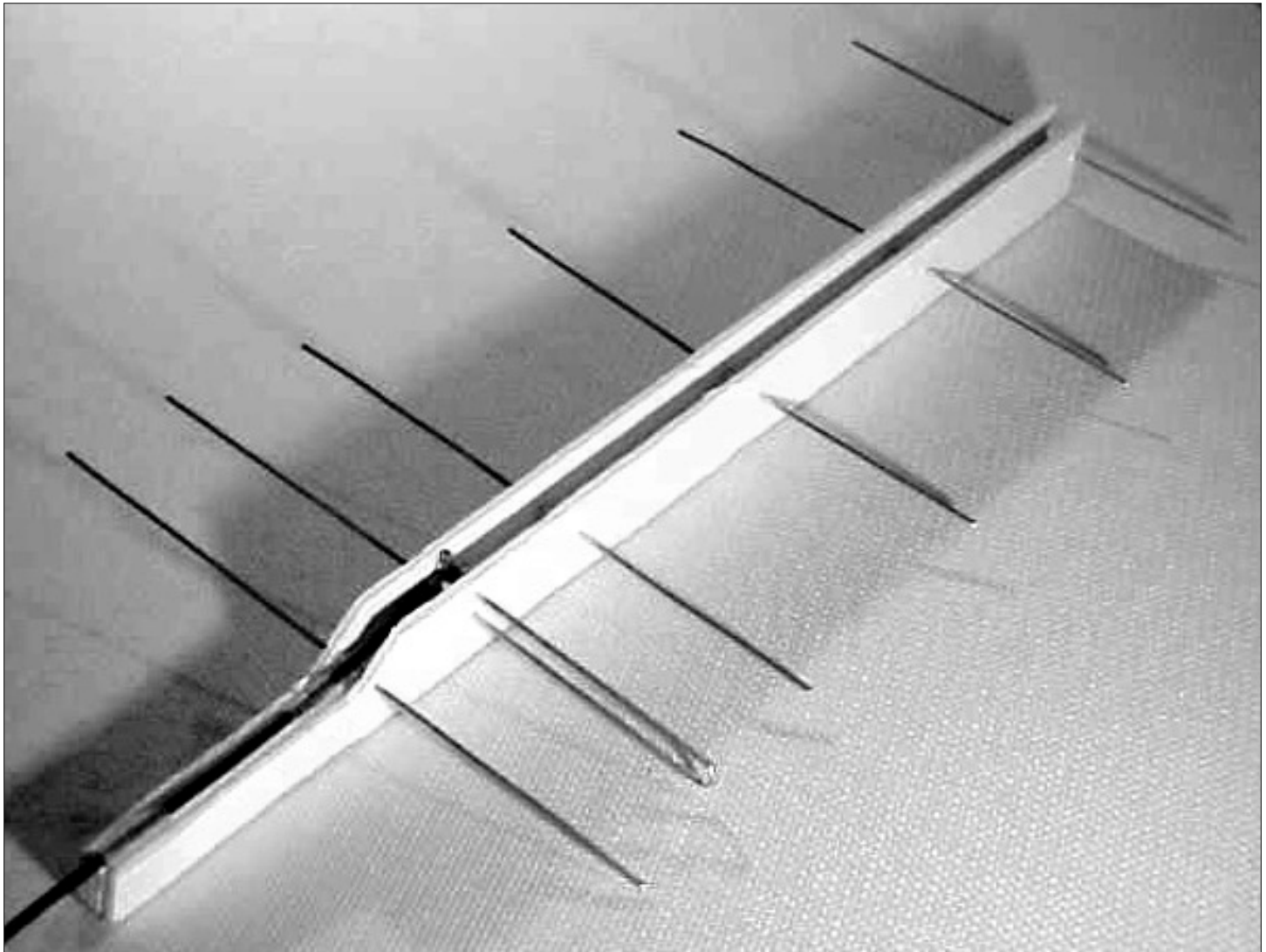


Figure 1: The N2SPI Cheap and Easy Satellite Downlink Antenna.

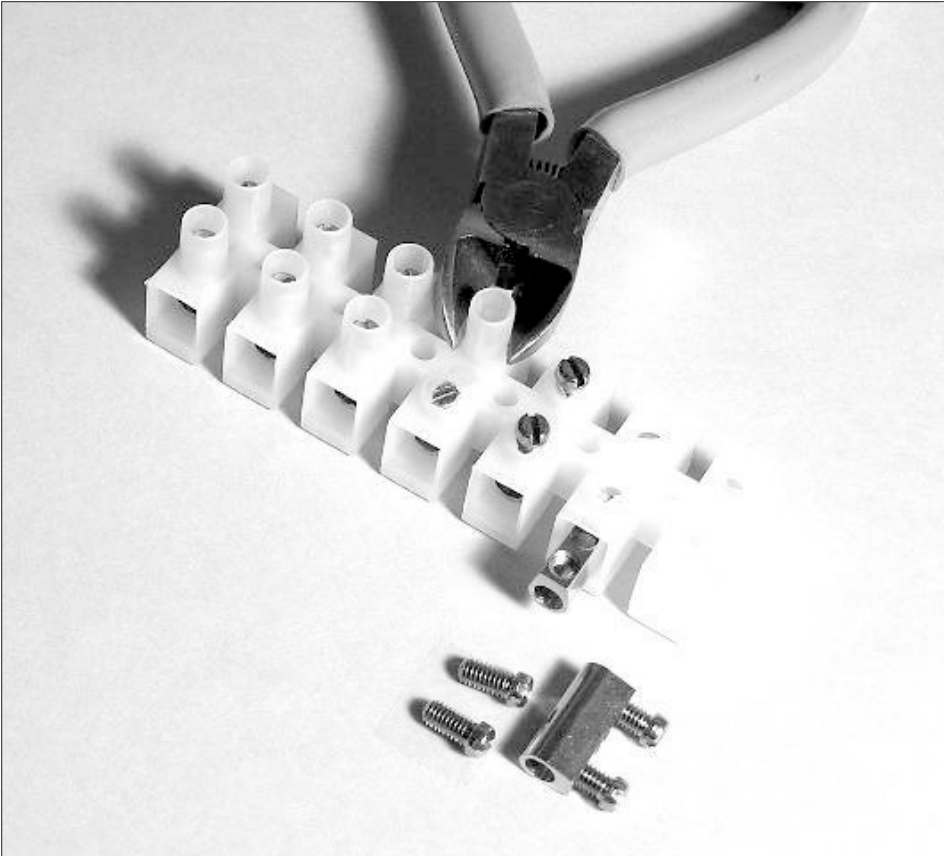


Figure 2: Terminal strip in various stages of disassembly.

and give detailed step-by-step instructions so that anyone can build this antenna. And finally, not only does this antenna receive the satellite signal from horizon to horizon; it's also light as a feather making it very easy to hold. See Figure 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 if you don't have some of them already.
- 3) Referring to the List of Tools in Table 2, make sure you have the necessary tools or suitable substitutes. If you aren't familiar with a particular tool look it up at www.sears.com or other tool supplier Web sites. The Sears tools shown are excellent but pricey. You may find less expensive equivalent tools at Home Depot, Wal-Mart, etc.

In the next three 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".

- 4) 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.
- 5) Unscrew both screws until they fall out. Now, push the terminal's metal barrel out of the plastic housing.
- 6) 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. See Figure 2.

In the next four steps, make two 2-1/4 inch by 30 inch foam board strips for the side panels on the antenna boom.

- 7) 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 2-1/4 inches of the rule (metal ruler part) 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 at 2-1/4 inches up the left side, and one 2-1/4 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".

- 8) 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.
- 9) 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). Write "bottom" on the factory edge to make it the bottom edge. This general cutting procedure is hereafter called "using previous cutting methods".
- 10) Repeat steps 7 through 9 to make a second 2-1/4 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.

- 11) Using previous measuring and cutting methods make three 1-1/4 inch by 30 inch strips. Note: (1) there are no more factory edges to locate, and (2) after each strip is cut, write "bottom" on its better, 30 inch edge to make it the bottom edge.

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

- 12) From one end of a 1-1/4 inch by 30 inch strip, lay down a first piece of double-side tape near the top edge for the first 15 inches. Then cut neatly with the X-Acto knife. In a similar way, lay down the remaining 15 inches of double-sided tape. Using the same procedure lay down a two pieces of double-side tape near the bottom edge.



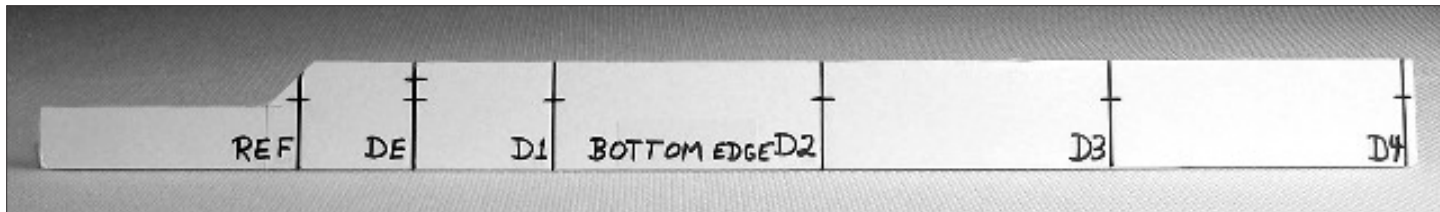


Figure 3: Side panel with element positions marked (markings made very dark for illustrative purposes).

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

14) Repeat Steps 12 and 13, 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 five steps, cut a handle out of one end of each side panel.

15) Using previous measuring methods, from the bottom left corner of a side panel, measure 5 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 across the panel.

16) Now, again from the left corner, measure and make a second mark 1-1/4 inches up the left side.

17) Now, from the factory edge, measure and make a third mark 1-1/4 inches up the perpendicular line made in step 15. Then, use a straight edge to draw a 5 inch line from the second to third mark.

18) Place the 45 degree surface of combination square's head against the factory edge and extend and position the rule so you can draw a 45 degree line from the third mark to the right and up to the top edge. Using previous cutting methods cut along the 5 inch and 45 degree lines making a curved transition at their junction. See Figure 3.

19) Repeat steps 15 through 18 to cut a handle in the second side panel. Note that both side panels now have a 2-1/4 inch wide end and a 1-1/4 inch narrow end.

In the next three steps, mark both side

panels to show where the elements will pass through.

20) Refer to Table 3. Use the combination square to measure and mark on the top edge (non-factory edge) 1/4 inch in from the wide end. Now, use the tape measure to mark the remaining element positions along the top edge.

21) Now, at each marked element position, use the combination square to draw a line perpendicular to the factory edge (bottom edge) and across the side panel. Then, re-adjust the combination square to measure and place a cross-mark on each line at a point 1-3/8 inches up from the factory edge. At the driven element line only, make a second cross-mark 1-7/8 inches up from the factory edge. See Figure 3.

22) Repeat Steps 20 and 21 to mark the second side panel 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 holes for the elements in one side panel only.

23) Place the first side panel on a pine board and push the shish-kebab skewer partway through at an element location until it just barely pokes through. Wiggle the skewer, if it helps. Then turn the panel over and poke the skewer back through all the way to complete the hole. Do this for all seven element holes.

In the next three steps, laminate the side panels to the inner core, wrap the handle and finish making the element holes.

24) 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.

25) Using previous laminating methods laminate the second side panel to the other side of the inner core, after lining-up the wide end(s) of both side panels.

Then, wrap the handle with one layer of clear packing tape.

26) Re-push the skewer through the reflector element hole 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 new puncture point so the skewer is perpendicular to the boom, and using the method in Step 23, make the hole. Repeat this until all seven element holes in the second side panel are made.

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

27) Straighten out a 24 inch length (hereafter called a wire) from the #8 AWG aluminum ground wire. Use the combination square to measure and mark (with the permanent marker) 8 inches in from a wire-end. At the mark, bend the wire around a 3/8 inch diameter drill bit (if nothing else, remove the blade and use the X-Acto knife handle) until the short segment is parallel with the long segment and the two segments are spaced 1/2 inch apart. If the aluminum wire dirties your hands, wipe it down with paper towels dampened with a spray cleaner such as Windex.

28) Use the combination square to measure 13 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. 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 when a final cut is called for.

29) Find the halfway point, or center, of the long segment. This should be at 13 inches/2 = 6-1/2 inches from either end.

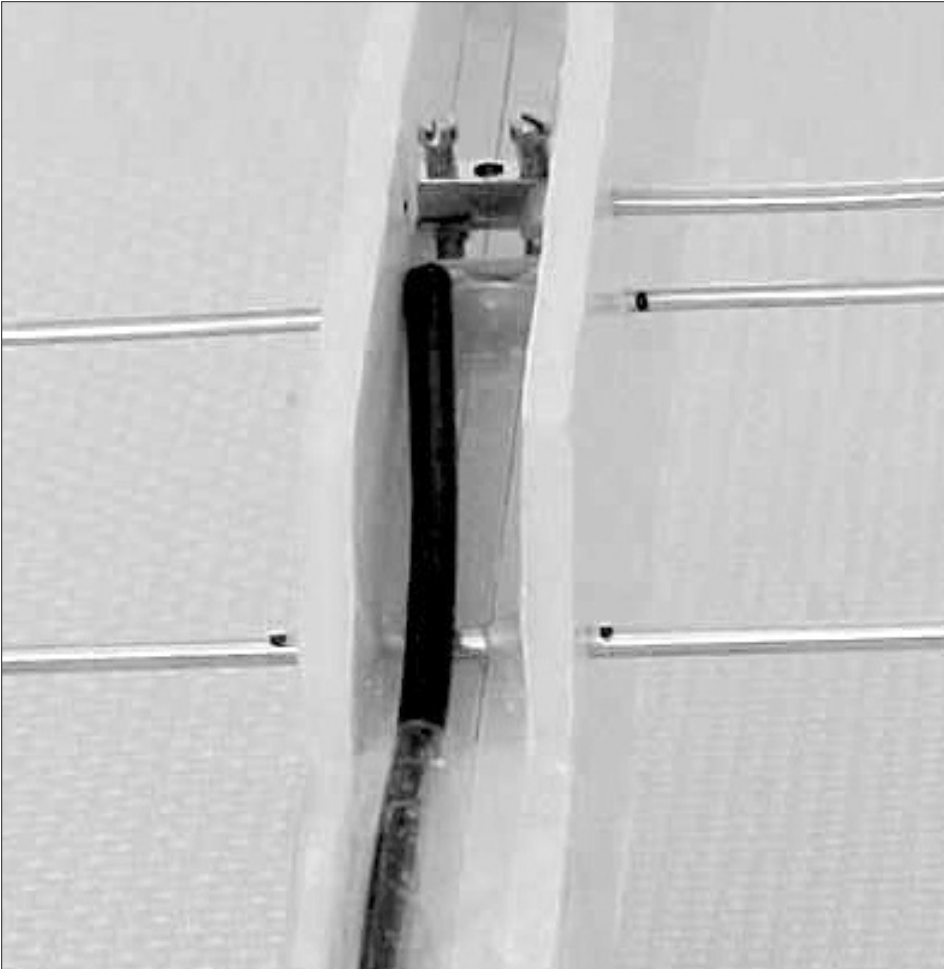


Figure 4: Driven element detail.

Now, get ready to make two marks, the first 5/8 inches to the left, and the second 5/8 inches to the right, of the center. Do this by adjusting the combination square to $6\text{-}1/2 - 5/8 = 5\text{-}7/8$ inches. Now, measure and mark 5-7/8 inches in from the bend and also 5-7/8 inches from the cut end. These marks will help you to center the element later.

- 30) In a way similar to Step 28, final cut the short wire segment to 7-1/16 inches measured from the bend.

In the next four steps, prepare the coaxial cable which will be the antenna's feed line.

- 31) Take the RG-58 coaxial cable assembly (hereafter called the cable) and use the diagonal cutters to cut off one of the BNC connectors. Measure and mark the cable jacket 3 inches down from the cut end.

- 32) 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 all the way through the jacket only as you near the end. Now, pull the rest of the jacket apart and remove it.

- 33) 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.

- 34) Cut the center conductor to a 1-3/4 inch length. In a way similar to Step 32 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 1/4 inch of insulation remaining, and from there to wire-end,

1-1/2 inches of bare, clockwise-twisted wire.

In the next three steps, install the driven element and attach the coaxial cable using the "N2SPI No-Solder Connection Method".

- 35) Use the flat 1/8" blade screwdriver to 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. Locate the pair of holes in the side panel for the driven element's long segment. Place the connector installed on 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 Figure 4.

- 36) 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 Figure 4.

- 37) When the driven element is centered, and its hairpin is straight and not twisted, and the pigtailed between the coax and connector are 3/8 inch in length, tighten all screws. Apply a couple of dabs of hot melt glue to hold the driven element in place. Then trim away the excess wire with the X-Acto knife.

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

- 38) Final cut five, 14 inch straightened lengths out of the #8 AWG aluminum wire.





Figure 5: The N2SPI Cheap and Easy Satellite Downlink Antenna in action.

- 39) Refer to Table 3. From the final cut end of a 14 inch wire, use the combination square to carefully measure and mark the specified length and then final cut each element, i.e., both wire ends receive the final cut treatment.
- 40) Similar to Step 29, find each element center. Make two marks +/- 5/8 inch from the center of each element.
- 41) 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.
- 42) Apply a dab of hot melt glue to the middle of each element to hold it in place. When done, use some clear packing tape to secure the coaxial cable to the top of the handle part of the boom. See Figure 4.

And finally, test your new satellite downlink antenna.

- 43) Test your new antenna by using it to actually receive a satellite's signal, say AMSAT's AO-51 downlink. See Figure 5. To do this:
 - a) Determine when AO-51 is in line-of-sight range of your location. For example, go to www.heavens-above.com, select your location under Anonymous Users, and navigate to radio amateur satellites. Then look for start and end times for AO-Echo (AO-51) passes. After a start time, AO-51 will rise in the sky until it reaches a maximum altitude and then start to fall. Note that Heavens Above gives you the "time", "Alt." and "Az." for the maximum altitude. Click on these terms for an explanation.
 - b) To use the time based pass information successfully, you'll need to be able

to tell time accurately. Verify your wristwatch, or other timepiece, against the official United States time, which you'll find at <http://tf.nist.gov>.

- c) To determine if AO-51 is in a suitable mode, go to www.amsat.org, click on Amateur Satellite Status and then click on the AO-51 Schedule to make sure the U downlink (435.300 MHz) is active.
- d) To receive AO-51, connect your new antenna to a UHF narrow band FM receiver, preferably with tuning steps of 5 KHz or less, and tune it to 435.300 MHz. This receiver can be most any Amateur Radio 440 MHz HT, 440 MHz mobile transceiver, wide band receiver or police scanner. Personally, I use an Alinco DJ-S40T pocket sized UHF HT for my FM downlink receiver (\$90 at www.aesham.com). Also, a low noise 440 MHz receive preamp can improve reception considerably. I use a Hamtronics LNK-450 preamp (\$60 at www.hamtronics.com). I rig up two 9 volt battery clips in series (Radio Shack #274-324) to power the LNK-450 from two 9 volt batteries. Also, full cup headphones will help you hear AO-51's signal more clearly and will be a must when you transmit on the uplink. I use Vanco HF-24RS scanner headphones (\$20 at www.aesham.com).
- e) Initially, take your antenna and receiver

outside to a location where you can aim your antenna by hand toward AO-51 when it will be in unobstructed sky at, or near, a maximum altitude of 30 degrees or more. Wave the antenna around in general direction of the satellite and rotate it around the boom axis until you hear the strongest signal.

- f) And finally, you will hear AO-51 at exactly 435.300 MHz when it is at, or near, maximum altitude. But at other times in the pass, because of Doppler frequency shift, you'll have to tune somewhere between 435.290 to 435.310 MHz to find the clearest reception.
- g) Other satellites to listen for are AO-27 and SO-50 (a.k.a. SAUDISAT 1C), which both downlink on 436.795 MHz. Check www.amsat.org for their status and characteristics. Also, if you prefer, you can use the online satellite pass predictions at www.amsat.org.

In Conclusion ...

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



Table 1: List of Materials

Quantity Used	Material Description *	Example Source	Item No. **
1	"Elmer's" 20 inch x 30 inch Foam Board	Staples	245555
240"	"Scotch 665" Permanent Double Sided Tape	Staples	130500
36"	Clear Wide Cellophane Packing Tape	Staples	490802
94"	#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. Equivalentents should be OK.

** Some Example Item Numbers come packaged in higher quantities than Qty Used.



Table 2: List of Tools

Tool Description	Source	Item Number
16" Combination Square	Sears	00939681000
Small Tape Measure	Sears	00939697000
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 (see Steps 7 and 8)	Lumberyard	
Sharpened Pencil		

Table 3: Element positions and element lengths for the 440 MHz antenna.

Antenna Element Name	Element Position from the Wide End (in inches)	Element Length * (in inches)
Director 4 (D4)	1/4	11
Director 3 (D3)	6-3/4	12
Director 2 (D2)	13	12
Director 1 (D1)	18-3/4	12-3/8
Driven Element (DE)	21-3/4	13
Reflector (REF)	24-1/4	13-3/8

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

