

USER MANUAL / ASSEMBLY INSTRUCTIONS

CAL-AV Labs, Inc. 2D-40A

DUAL-DRIVEN ELEMENT 40 METER ANTENNA

DESCRIPTION:

The 2D-40A is a rotatable horizontal array of two full-size, closely spaced driven elements. Each element is about 70 feet long. The rear element is longer than the front. They are fed approximately 140 degrees out of phase, using a shielded phasing line that is inside the boom. The pattern is cardioid, with a free space forward gain of 6.5 dBi and a front-to-rear ratio of 20dB.

Matching and fine tuning is by means of hairpin transmission lines mounted along the underside of the boom near the feed point of each element. Both hairpins are adjustable.

The front hairpin is used to set minimum VSWR, which is specified as adjustable to 1.0:1 anywhere in the entire band. Adjustable element tip lengths set the intended operating frequency of the array. It is noteworthy that all four element tips are moved by the same amount for a frequency adjustment. The rear hairpin adjusts resonant frequency over a small range, approximately 70 kHz.

Feed connection is by means of an SO-239 UHF receptacle located in the RF neutral section of the forward hairpin. This patented feed, phasing, and matching system also functions as a wide band, high power balun. Also, because the elements are electrically connected to the boom at the neutral points of the hairpin sections, both a static drain and a dc path for lightning-induced EMP or direct-strike current are provided.

In no-ice conditions, wind survival is 100 mph. With 1/2 inch of ice loading on the elements, the wind survival is de-rated to 40 mph. Weight of the 2D-40A, including hardware, mounting, and matching accessories, is 163 pounds (74.1 kg). For more detailed information, including specifications, drawings, parts list, patterns and graphs, please see the appendices.

UNPACKING:

The 2D-40A is shipped in three cartons; two are about 7 feet long, and the third is about a 2-foot square.

Inspect cartons for any sign of shipping damage. Then open cartons and inspect the contents for hidden damage. Shipping damage is not a common occurrence, but it does happen. If damage is found, save the cartons and packing materials, and notify the carrier.

Remove contents and inventory for the following:

Carton 1:

1 of each of the following: Front, rear, boom and mast mounting plates

1 kit Mounting plate hardware.

2ea. Coupling sleeves, boom, 3.25" diameter by 17.75" long.
1 kit Coupling sleeve hardware.
1 assy. Phasing line, dual RG-213/U, approximately 18.5' long.
1 lot Rivets, closed end, three sizes in individual bags, incl. extras.
1 kit element hardware
1 kit Copper straps and hardware
4 ea. All-stainless hose clamps for mounting hairpins to boom
1 ea. Manual

Carton 2:

1 set Front element tubing
1 set Rear element tubing

Carton 3:

1 set Boom tubing
1 assy. Front hairpin
1 assy. Rear hairpin

Tools required:

Combination wrench, 9/16 inch

Combination wrench, 7/16 inch (2 required)

Phillips #2 screwdriver

Nut driver, 3/8 inch

Hand rivet tool, also known as "pop" or "blind" rivet tool. These are available from tool and hardware stores. Use the appropriate size nozzle for the size rivet being pulled.

Note: Riveting hand tools of the \$20-35 class are the minimum that will give satisfactory results when pulling the 5/32" rivets. For a much easier time, we recommend the Emhart (Pop) model A475. This 2-foot long tool will easily pull up to 1/4" rivets, and costs about \$125. To really make life really easy, particularly if you will be stacking antennas, pneumatic / hydraulic tools that run on 45 to 90 PSI air pressure are available from outlets like Harbor Freight for about \$75. All prices mentioned are approximate as of May 2002.

Two small bullet levels

A bridle, or trolley, if using a tram line, for lifting the assembled antenna

A hoisting line, 1/2 inch or larger diameter all-braided nylon

One or more "tag" lines, 3/16 inch or so, for control of the antenna while hoisting, if necessary

ASSEMBLY

ELEMENTS

This antenna has been sub-assembled at the factory and then disassembled for shipment. However, it is a good idea to check the measurements on the elements during assembly. The important measurements are those of the exposed lengths, that is, from the outer edge of an element component to the outer edge of the next larger one. The centermost element pieces (the ones that include the feed point terminals) are exposed for their entire length. Element exposed lengths can be found in APPENDIX C. The exposed lengths also appear in APPENDIX D, PARTS LIST.

Elements are stepwise tapered by using smaller diameter, thinner-walled tubing going from the center toward the tip. The first two joints of each half-element are bolted. Pieces farther out are swaged (at the last several inches farthest away from the center of the element) down to the outer diameter of the next smaller element piece. Sometimes the amount of size reduction due to the swage is just a few hundredths of an inch, however, the swage is visible. The tip pieces fit into the swaged and slotted ends of the next-to-last pieces, and are continuously adjustable for coarse frequency setting.

Element pieces have been marked for re-assembly with markings on both sides of each joint.

Note: Element naming and marking convention is as follows: Imagine that you are standing at the front of the boom looking toward the rear of the boom. When the beam is installed for operation (hairpins, element mounting plates, and elements below the boom), the front half-elements will have "A" markings to the left and "B" markings to the right. The rear half-elements will have "C" markings to the left, and "D" markings to the right.

The left front half-element begins with A1-A1 at the center fiberglass connecting piece, then A2-A2 at the next joint out, then A3-A3, and so on. The other half of the element begins with B1-B1, and is marked in a similar pattern. The rear element markings are C1 and D1 at the center.

Important Note: Be SURE to align the hand-marked legends on all joints.

Legends are hand-marked on both sides of every joint. There are three rows of rivets, only one of which has the legends.

The row with the legend is also the only row that has the small drain hole in line with it. All three rows will be perfectly aligned if and only if the legends are aligned.

Note: Elements are usually assembled as half elements, then are joined at the center prior to mounting them to the boom.

Prepare a sturdy table or bench for antenna assembly.

Unwrap black tape to release element pieces.

Note: Tape is best removed by unwinding. This will result in a minimum of tape residue on antenna elements. Tape residue on elements can be removed with mineral spirits or WD-40.

JOINING PIECES:

Except for the feed point, which is joined to the fiberglass, assemble joints as follows:

1. Clean any dirt, dust, or tape residue from the outer surface of the smaller diameter tubing to be joined. To the extent possible, also clean the inside surface of the larger tube. Tape residue may easily be removed with WD-40 or mineral spirits on a piece of rag or paper towel, then the residue of either of those solvents is removed with Acetone.
2. Use the supplied Scotch-Brite pad to clean the surface of the part of the tube to be mated. This cleaning will produce a uniform, matte finish.
3. Wipe down with Methyl Ethyl Ketone (MEK) (preferred) or Acetone. Either of these is available from most hardware stores in pint cans. Please read and understand the warnings on the container regarding use of these solvents.
4. Apply the supplied silicone grease, working it into the cleaned surface thoroughly. The amount of silicone grease needed is just enough to create a film between the two pieces of metal.

Note: The grease, which is an insulating dielectric, serves to prevent galling, to exclude moisture from between the metal pieces at points of contact, and to protect the electrical connection from oxidation. We recommend using pure, heavy silicone grease for this purpose. Contact between element pieces is between the aluminum. The grease will be forced from any areas where contact is made. But it will remain and protect the regions which are not in contact. Conductive materials in the grease are neither required nor desirable. Joint compounds containing copper, such as Penetrox B, should never be used for joining aluminum.

Note: Because freshly cleaned aluminum immediately begins to re-grow its protective oxide coating, it is important to apply the silicone grease within a few minutes of cleaning. For this reason, it may be necessary to clean, grease, and fasten just one or two joints at a time.

5. After treatment, assemble the pieces by sliding them together, with a rotary motion if necessary. Be careful not to allow any dirt or grit into the joint.
6. Carefully align the holes, hand-marked legend to legend. A tapered pin or small-diameter punch may be useful for the initial alignment of the holes. For riveted joints, place rivets in all holes before setting any of them. Then set them. Rivets will have from an easy slide fit to a snug fit. Excessive play indicates the wrong size rivet. Holes for the larger (5/32" diameter) rivets have the part number of the correct rivet to be used marked in red on the swaged portion of the tubing. The remaining smaller (1/8" diameter) holes all take AD-42H rivets.

Note: The feed-point and the next 2 joints out are fastened with 1/4"-20 stainless bolts. Be sure that the gray, slotted plastic insulator sleeves that go on the element to either side of the feed point are installed before joining the element halves.

Note: Rivet holes are semi-random drilled. At the factory, the joint was correctly assembled; the first hole was drilled, a rivet installed, then the remaining holes drilled with the joined pieces unable to move relative to each other. Then, the one installed rivet was drilled out. This process results in holes that are as nearly-perfectly aligned as possible. With this process, every joint in the assembly is unique and must be reassembled with only the two original pieces. Be certain that joints are aligned with both hand-marked legends (e.g., A7-A7) lined up. If the holes do not match perfectly or very nearly so, then something is wrong, and the correct parts must be identified and used.

Note: There is an additional, much smaller hole in line with one of the three lines of rivet holes. It is a drain to keep water from accumulating at the joint. These drain holes must face downwards when the elements are installed for use.

Note: The elements are joined with either stainless bolts or closed-end rivets. The holes will be identified with red markings near them, on the end of the larger tubing. These markings will identify the correct fastener to use.

7. Clean, apply silicone grease, match markings and holes, and rivet, as outlined above, until both sides of each element have been assembled.

Note: If the antenna is to be painted, this is the time to paint the elements. Be sure to mask the feed point bolt areas and to slide the element tip pieces fully inside the next larger element tubing, so that the tip adjustments will be paint-free. After painting, inspect drain holes to make sure that none of them is plugged with paint. See APPENDIX F, "PAINTING INSTRUCTIONS".

8. Fasten the two element halves together, but do not tighten the bolts at this time. Make sure that the drain holes are all on the same side of the element when element halves are joined.

BOOM ASSEMBLY

Identify the 5-foot boom center piece, and place it on a table or bench for convenience. The center piece is the only 3" diameter tubing that is swaged at both ends. Place the boom center piece on the table with the handwritten instructions and legends facing up.

Note: For assembly purposes only, the boom is upside down with the hairpin matching sections and the elements above the boom. When the antenna is actually installed, the hairpin matching sections and the elements will be hanging below the boom, and the elastic stop nuts will be on the underside.

1. Apply silicone grease to the boom center piece swaged ends, and to the inside of the entire length of the boom coupler sleeves.
2. Slide the 3.25" diameter external coupling sleeves onto the ends, being sure to line up the legends, and install in each the two 4" long quarter-inch diameter bolts, using flat washers, finish side to the tubing, and elastic stop nuts. Tighten the nuts only enough to prevent loss at this time.

Note: Follow instructions on the coupler indicating location of the stop nuts. This will assure that the nuts will be below the boom when the antenna is in position for use. This is to make sure that even if a nut comes off, the bolt will remain in the coupler, and that the elastic material in the stop nut is not directly exposed to the sun.

3. Apply silicone grease to each boom end piece and slide it into the appropriately marked coupling sleeve. Install the bolts loosely as above.
4. Install the boom mounting plate at this time, with the plate under the boom, and with the nuts for the U-bolts left relatively loose. Place some soft material, for example, a piece of scrap carpet, under the boom mounting plate. This will help control the boom during assembly, and will allow rotation for the leveling operation to come a few steps later.

Note: The most popular mast diameter is 2.0" O.D. The mast plate supplied as standard with the 2D-40A is for this size mast. If necessary, a mast plate for other mast sizes can be supplied, or the supplied plate can be drilled to accommodate the necessary size of U-bolt for the different size mast. Contact the factory for custom mast plates.

5. Install the phasing line as follows:

Place the dual coaxial phasing line through the boom, being careful to clear those bolts already installed. Bolts can be removed and replaced one at a time to facilitate installation of the phasing line. Take care not to damage the cable when replacing the bolts.

ATTACHING THE BOOM TO ELEMENT MOUNTING PLATES

It is now necessary to provide adequate support of nearly the entire length of the boom, because you will be adding significant and uneven weight to the boom in the next steps. This can be accomplished with a long table or 3 sawhorses (one for the center plate to control rotation). The boom ends should protrude about 2 ft. beyond the ends of each support. This same support setup can be used for final assembly.

Notice that at one edge of the plate, there is a single 3/16" hole, which can be used to orient the plate for installation. When facing the boom, **which is now inverted for assembly**, and looking from the rear end toward the front end, that small hole and the edge that it is nearest, will be outboard, that is, nearer to you and the end of the boom, and the hole will be 3 inches to the left of the centerline of the boom. The imaginary centerline (in line with the boom) can also be identified by the two 1/4" diameter holes that lie along it. The foregoing is also true for the front end of the boom, where you will be looking from the front toward the rear.

Attach the aluminum rear element mounting plate to the boom as follows:

1. With the plate oriented as outlined above, install the U-bolts that attach the plate to the boom. These U-bolts will be installed through their saddle pieces, and then up through the element mounting plate, where each of the threaded legs of each U-bolt will receive a 3/8" split-ring lock washer, then a flanged 3/8" nut. Leave the nuts at the end of the threads at this time.
2. When all four U-bolts have been installed, turn the plate over, slide it onto the boom, with the saddles resting on the plate, while you lift and manipulate each U-bolt to get it over the end of the boom.
3. Once the boom tube is through the U-bolts and saddles, rotate the plate around the boom tube so that the plate is again above the boom, align the plate's two 1/4" diameter holes with those in the boom, and install the two 4.5" long, 1/4" bolts, with each bolt going first through the boom, then through the plate, where it receives a flat washer, then an elastic stop nut. This will put the nuts down and out of the sun when the beam is in use. Do not fully tighten the nuts at this time.
4. Now that you have gained experience using the lighter aluminum rear plate, install the heavier stainless steel plate for the front element.

Note: The weight difference of the mounting plates exactly offsets the difference in weight between the front and rear element. This produces an antenna that is weight-balanced at the center of the boom. This means that the mast attach point will also be at the center, for a wind-balanced boom, and that the antenna is torque-balanced as well. All this makes life much, much easier on the rotation system.

5. Mutually level the element mounting plates. This is most easily done with 2 people and two levels. The primary reason for having the elements mutually exactly level is appearance.

6. With one element mounting plate held level, using a small bullet level, check level on the other plate.
7. Twist one plate with respect to the other by grasping them and turning in opposite directions about the long axis of the boom. Now trial-tighten the twelve quarter-inch bolts, 4 in each of the two boom coupling sleeves, and 2 in each of the two element mounting plates, and recheck the level.
8. When the plates are mutually leveled, or as nearly so as you can get them, finish tightening the 1/4" diameter bolts. Do not tighten enough to distort the boom tubing out of round. Just touching the tubing, then another half turn would be fine.

ATTACHING THE HAIRPIN ASSEMBLIES

1. Attach the hairpin assemblies with 1/2 inch clearance between the insulating blocks (at the very end of each hairpin) and the boom-to-element mounting plate using the stainless hose clamps provided. Red markings indicate the location of the clamp strapping over the hairpin supports.
2. Install the copper straps to the hairpin assembly as follows:
 - a) Apply silicone grease to both sides of the smaller (3/16") hole end of each copper strap.
 - b) Fasten the copper straps to the welded tab at the end of each hairpin tube.
The order of hardware for the 10-24 stainless screws in the insulating block is as follows:
 - 1) The head of the screw is on the side of the insulating block that is closest to the element mounting plate.
 - 2) The screw goes through a flat washer, finish side to the plastic, except for one screw that passes through a ring terminal, then through a flat washer, finish side to the plastic.
 - 3) Each screw then protrudes through the plastic block and the welded tab.
 - 4) After the tab, there is a fender washer, copper strap, fender washer, split ring lock washer, and a nut.

Note: The copper straps must leave the insulating block parallel to each other and dressed straight up away from the boom. When the boom assembly is finally rotated into operating position, with the element mounting plates and hairpin assemblies below it, these straps will be pointing straight down. After the elements are attached to the boom in a later step, the straps will be bent toward the element with a gentle large radius bend to attach to the element feed points.

3. The larger (1/4") hole end of each will be similarly greased and captured between fender washers on the bolts that are the feed point connections for the antenna element. This will be done after the elements are attached to the boom in a later step.

Note: If the antenna is to be painted, now is the time to paint the boom. However, if you do paint the boom at this time be sure to take steps to mask the hairpin assemblies and connecting straps so that they do **not** get painted. See APPENDIX F, "PAINTING INSTRUCTIONS".

FINAL ASSEMBLY

ATTACHING AND CONNECTING THE ELEMENTS

This procedure takes a space of 25 by 75 feet. This can be a driveway, rooftop, etc. Placing the boom on a couple of sturdy tables or sawhorses will make this assembly much easier. If absolutely necessary, it can also be done on a tower, with the boom vertical, and the plates and hairpins facing away from the tower.

1. Turn the boom over to its operating position, with plates and hairpins below it, and prepare to attach the elements.
2. Position the completed element so that it is centered directly under the boom to element mounting plate. The mounting plate should be resting on the element.
3. Position the gray slotted plastic element insulating sleeves, one to each side of the feed point bolts.
4. One at a time, place U-bolt saddles between mounting plate and gray slotted plastic element insulators and install U-bolts around element, through the clamp saddles, and up through the plate, using flanged nuts and lock washers. Do not tighten the U-bolt clamps yet.
5. When all 4 U-bolts have been installed, adjust element position as follows:
 - a) 2-inch visible section of fiberglass connector piece between B1 and A1 tubes should be centered on the mounting plate.
 - b) Adjust gray slotted plastic insulator sleeves so that they are centered under U-bolts.
 - c) Rotate element so that the rows of rivets aligned with the small drain holes will be along the bottom of the element. These holes should point straight down when the antenna is assembled and in its operating position. Note that the head of the feedpoint connection bolt should be nearest the element mounting plate with the bolt pointing straight down.
 - d) Tighten U-bolt nuts by alternating so that approximately an equal amount of U-bolt is visible on each side. Continue to tighten until lock washer is flat and then 1/2 turn more.

ATTACHING THE PHASING LINE

The following procedure applies to both ends of the phasing line:

1. Identify the single, shorter terminated wire coming out of the dual coaxial cable phasing line. This is the connection to the shields of the phasing lines.
2. Grease the terminal with silicone grease, then attach to the single small hole at the outer edge of the element to boom mounting plate using 10-24 hardware as follows: Pass the screw down through the plate. Follow below the plate with a flat washer, the terminal, another flat washer, a split ring lock washer, and a nut.

Note: The phasing line must be installed so that there is a 180 degree phase reversal in the connections to the elements. The ends of the phasing line have been color coded to facilitate making this connection correctly.

3. Identify the terminated twisted pair of the phasing line. The red coded terminal connects to the element feed point to your left as viewed facing the antenna looking down the boom. The uncoded terminal connects to the other side of the feed point. Using this procedure for each element results in the red coded terminals being connected to the opposite side of the feed point of the other element. This procedure provides the required reversed connection between the elements. See the schematic diagram in APPENDIX E, "OPERATIONAL NOTES".

The stainless 1/4-20 hex-head bolt head will be between the mounting plate and the element, with the bolt protruding downward when the element is in operating position. If it is not, make it so now. Verify that the drain holes in the element tubing will also be on the bottom side of the element when the antenna is in its operating position.

4. Install a flat washer, a split ring lock washer, and a nut on each bolt and tighten.
5. After the element is secured in place on the mounting plate, install the following hardware on each bolt in the following order:
 - a) a fender (large diameter) washer
 - b) the greased copper strap from the hairpin assembly
 - c) another fender washer
 - d) the correct terminal from the phasing line, greased and flat side to the fender washer
 - e) a flat washer, a split ring lock washer, and a nut.
6. Tighten the hardware for the feedpoint connection.

HAIRPIN AND ELEMENT LENGTH SETTINGS

Settings for the exposed length of the element tips and for the position of the adjustable shorts on the tuning and matching should be made at this time. See APPENDIX E, "OPERATIONAL NOTES", "Tune-up Procedures for the 2D-40A" to determine the proper dimensions to use for your intended mounting height.

This completes assembly of the antenna. Double check all joints and connections, then prepare the antenna for raising into position.

Be particularly careful with regard to working on towers and near power lines, either of which can and has caused injuries and fatalities. No part of the antenna or tower should ever be in a position such that it could come into contact with a power line in the event that it fell, slipped, etc.

Note: Use an adequate number of people, patience, common sense, and great care. These will get your new antenna into the sky without damage to it or to you!

If you are not experienced with installation of larger antennas, we strongly recommend that you get some very experienced help for the first few times. Then you can help newcomers.

Appendix A

Specifications for 2D-40A

Description: The 2D-40A is a 2-driven-element array for the 40-meter amateur band. It features full size elements, an internal phasing line, and an innovative integral BALUN feed system. This beam has gain comparable to a 2-element Yagi, and a front-to-rear ratio comparable to a 3-element Yagi.

Physical Specifications:

Materials:

Elements: Aluminum, 6061-T6.
Accessories: Aluminum, Steel, PVC, and Acrylic

Size:

Element Diameter: Elements taper from 2.500 inches to 0.375 inches
Element Overall length: Front, 66.2 feet Rear, 70.2 feet
Element sag: Front, 27.9 inches Rear, 30.6 inches
Turn Radius: 36 feet
Weight: 163 pounds, including mounting plates and hardware
Projected area: 16.8 square feet
Wind survival (no ice): 100MPH (85 Knots)

Electrical Specifications:

Operating Bandwidth:

For 2.6:1 VSWR: 295 kHz (36% of the range is below F_0 and 64% is above)
For 2.0:1 VSWR: 206 kHz (39% of the range is below F_0 and 61% is above)
For 1.4:1 VSWR: 94 kHz (45% of the range is below F_0 and 55% is above)

Minimum VSWR: Set to 1.0:1 at F_0

Gain: 6.5-dBi minimum (free space), 11.9 dBi (approximately - NEC2 model) when array tuned for $F_0 = 7.1$ MHz and mounted 70 ft (21 meters) above local earth.

Front to rear ratio: 20-dB minimum
Takeoff angle: 26.5 degrees
Vertical Beam width: 33 degrees -3dB 13 and 46 degrees
Horizontal Beam width: 74 degrees

Note: Please see APPENDIX B, 'PATTERNS AND GRAPHS" for more information.

Note: Cal-Av Labs, Inc. reserves the right to make and implement design improvements without notice.

Appendix B

PATTERNS AND GRAPHS

The following patterns are based on NEC-2 modeling. They do not represent measured patterns. However, both forward gain and relative response Front to Rear (F/R ratio) have been verified (for relatively clean sites) by antenna range field strength measurements. Patterns actually achieved in practice will be affected by many aspects of the actual site where the antenna is installed.

All patterns modeled over ground use 5 milliSiemens for earth conductivity and 13 for earth dielectric constant. We believe that this represents "average" ground conditions.

The modeling program used for the electrical modeling is EZNEC V2.0 by Roy Lewellen, W7EL. Very accurate EZNEC models for the 2D-40A are available for download from the Cal-Av Labs, Inc. website <www.cal-av.com>.

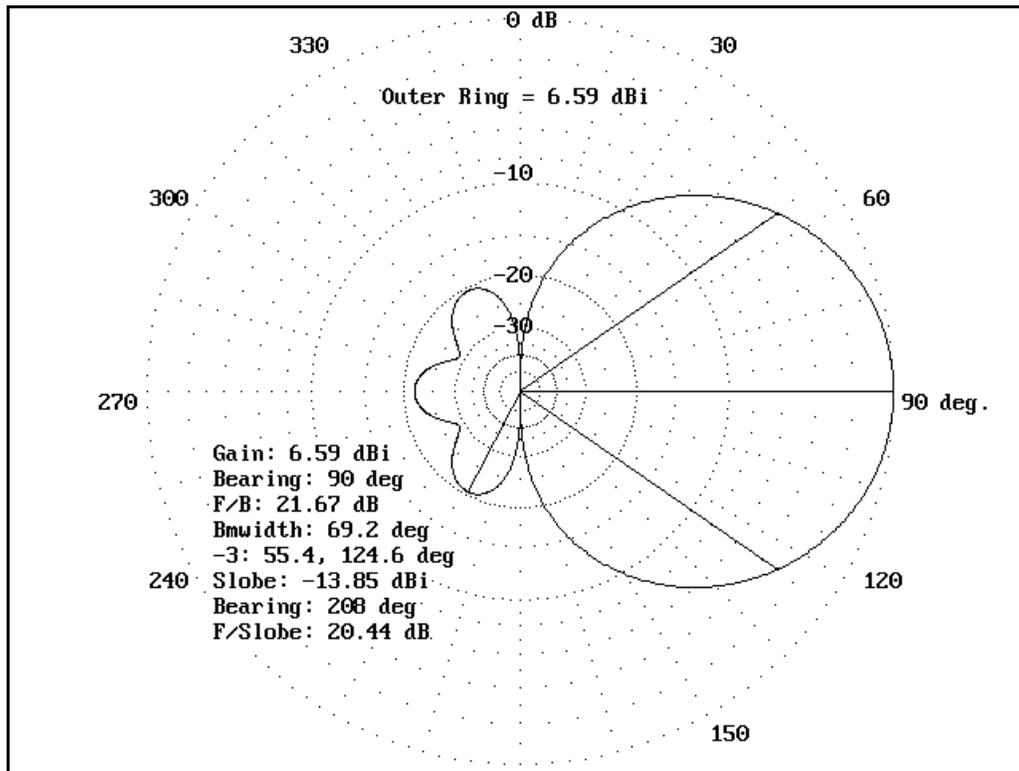


Figure 1-B

2D-40A Azimuth Plot
(antenna in free space)

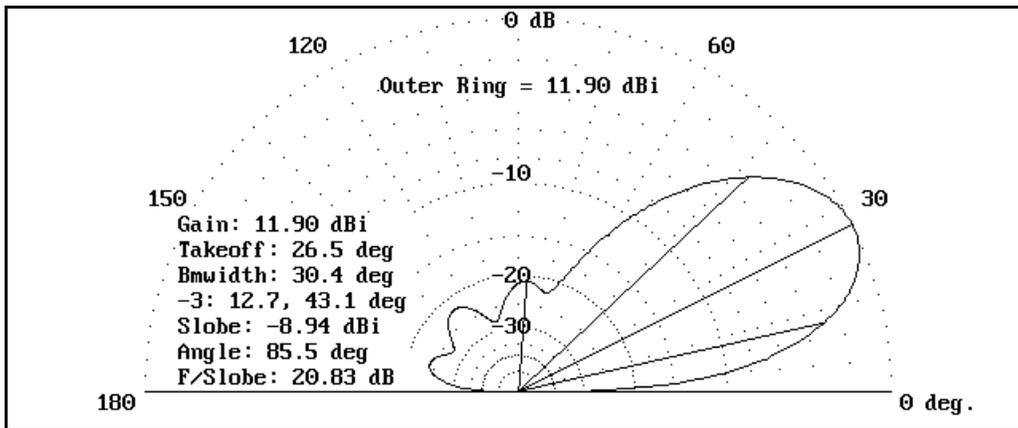


Figure 2-B

2D-40A Elevation Plot
 (antenna mounted 70 feet above earth)

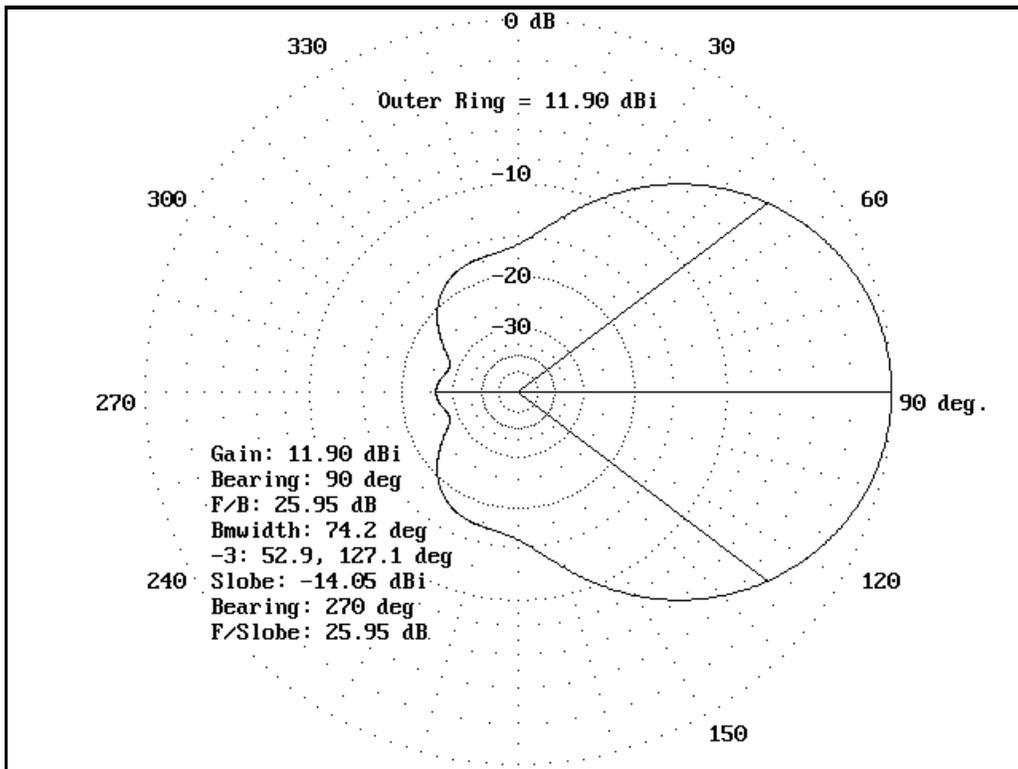


Figure 3-B

2D-40A Azimuth Plot
 (antenna mounted 70 feet above earth)

The following VSWR vs frequency plot was generated by the NEC-2 model. Actual measurements of real antennas in the field have typically reproduced the general shape of this curve. But the measured curves have shown a somewhat wider bandwidth between the 2:1 VSWR points. This is due to measurements being taken at the transmitter end of fairly long pieces of coax and to coupling of the antenna to the “stuff” in its near field region. This curve is shown here only to give some idea of the relative difference in rate of rise in SWR for frequencies below system resonance as compared to frequencies above system resonance.

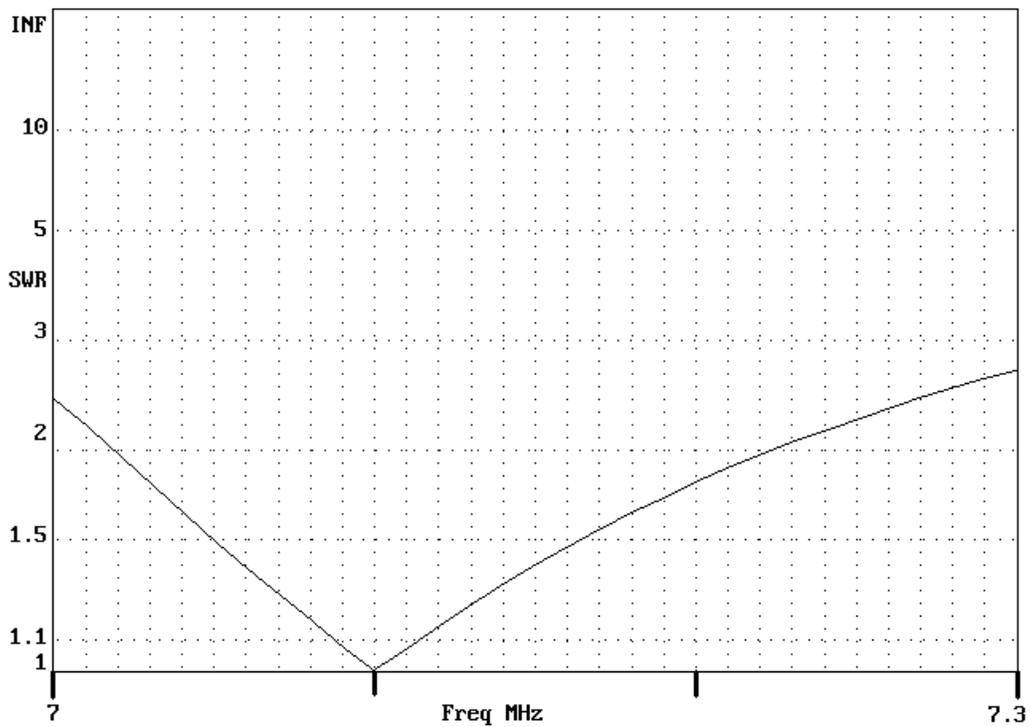
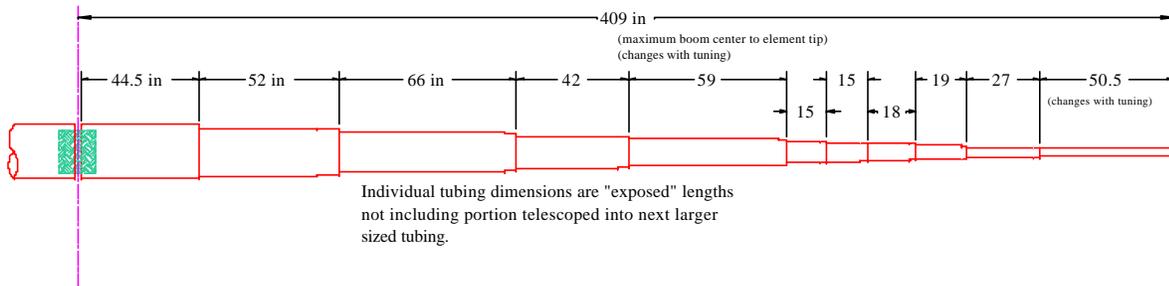


Figure 4-B

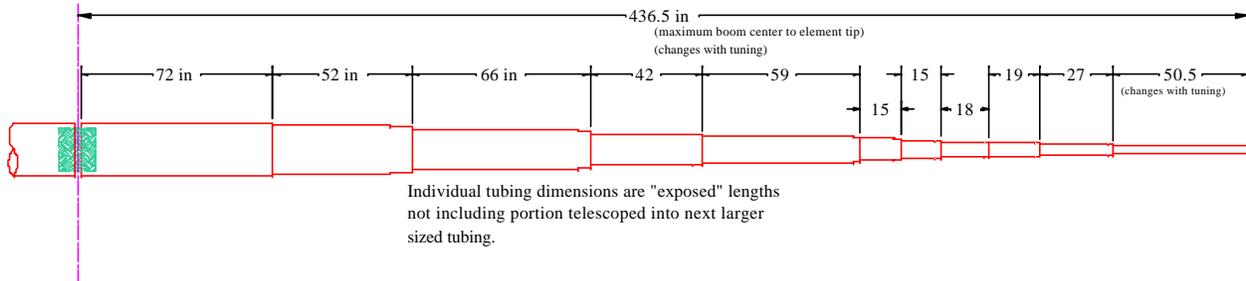
2D-40A Modeled VSWR curve
(antenna tuned for 7.1 MHz)

Appendix C

MECHANICAL DRAWINGS



2D-40A Front Element Overall Dimensions (element half length)



2D-40A Rear Element Overall Dimensions (element half length)

Appendix D

PARTS LIST

- 1 assy. BOOM, consisting of:
 - 1 assy. MOUNTING PLATE, BOOM-TO-MAST, CONSISTING OF:
 - 1 ea. Mounting Plate, Mast, DWG. No. 020218-001-0001
 - 4 assy. Clamp, 2", Stainless, ASSY/N MC9200SSA
 - 1 ea. Mounting Plate, Boom, DWG. No. 020215-001-0001
 - 4 assy. Clamp, 3", Stainless, ASSY/No. MC9300SS
 - 4 ea. Bolt, Hex head, 3/8-16 x 1", Stainless
 - 1 ea. Bolt, Hex head, 3/8-16 x 1.25", Stainless
 - 5 ea. Nut, 3/8-16, Stainless
 - 21 ea. Lock washer, split ring, 3/8", Stainless
 - 1 ea. BOOM CENTER TUBE,
3.00" dia., 6061-T6, 0.125 wall, 60" long, DWG. No. 020219-002-0001
 - 2 ea. BOOM END TUBE,
3.0" dia., 6061-T6, 0.125 wall, 72" long, DWG. 020221-002-0001
 - 2 ea. SLEEVE, BOOM EXTERNAL COUPLING,
3.25" DIA., 0.125 wall, 17.875" long, DWG. No. 020221-001-0001
 - 8 ea. Bolt, 1/4-20 by 4.00", stainless
 - 8 ea. Nut, elastic stop, 1/4-20, stainless
 - 8 ea. Washer, flat, AN 960C416", stainless
 - 1 assy. PLATE, FRONT ELEMENT MOUNTING, consisting of:
 - 1 ea. Plate, Elem. Mtg, Stainless, 0.375" thick, weight, 13.1 pounds, DWG. No. 001015-001-0001
 - 8 assy. Clamp, 3", Stainless, Assy No. MC9300SS
 - 16 ea. Washer, split-ring, 3/8", Stainless
 - 2 ea. Bolt, Hex, 1/4"-20 x 4.5" long, Stainless
 - 2 ea. Washer, Flat, 1/4"-20, AN-960C416, Stainless
 - 2 ea. Nut, Elastic Stop, 1/4"-20, Stainless
 - 1 assy. PLATE, REAR ELEMENT MOUNTING, consisting of:
 - 1 ea. Plate, Element Mtg. 6061-T6, 0.375" thick, weight, 4.75 pounds, DWG. No. 001015-002-0001
 - 8 assy. clamp, 3", stainless, Assy No. MC9300SS
 - 16 ea. Washer, split-ring, 3/8", stainless
 - 2 ea. Bolt, Hex, 1/4"-20 x 4.5" long, Stainless
 - 2 ea. Washer, Flat, 1/4"-20, AN-960C416, Stainless
 - 2 ea. Nut, Elastic Stop, 1/4"-20, Stainless
 - 1 assy. FRONT HAIRPIN, consisting of:
 - 1 assy. insulating bushing, consisting of:
 - 1 ea. Mtg. Bracket, Insulating Bushing
 - 1 ea. Lower bushing piece, acrylic, DWG. No. 020221-004-0001

- 1 ea. Upper bushing piece, acrylic, DWG. No. 020221-001-0001
- 4 ea. Screw, 10-24 x 1", Phillips pan head
- 8 ea. Washer, flat, stainless, AN-960C10
- 4 ea. Nut, elastic stop, 10-24, stainless
- 1 ea. Block, Insulating, acrylic, DWG. No. 020221-003-0001
 - 2 ea. Screw, 10-24 x 1" Stainless
 - 2 ea. Washer, flat, AN-960C10
 - 4 ea. Washer, flat, #10 x 0.625", .188 hole, \$\$, P/N 10N62FENS
 - 2 ea. Lock washer, split-ring, #10, Stainless
 - 2 ea. Nut, 10-24, Stainless
- 1 assy. Front hairpin line, welded, with 2 tubes, 0.375 dia. 50" long, with bracket for tubes and SO-239 connector, all 6061-T6. Includes int. BALUN
- 1 assy. Shorting Bar, consisting of:
 - 1 ea. Shorting Bar Machined block, DWG.000401-000-0001
 - 1 ea. Screw, 1/4"-20, Phillips flat head, 1 1/4 long, Stainless
 - 1 ea. Washer, lock, split-ring, 1/4", stainless
 - 1 ea. Nut, jam, 1/4"-20, Stainless
 - 1 ea. Shorting Bar Disc, DWG. 000401-000-0002
 - 1 ea. Washer, Flat, AN-960C416
 - 1 ea. Nut, Elastic Stop, 1/4"-20, Stainless
- 2 ea. Clamp, hose, all stainless, 71/95 mm, UPG P/N 4150
- 1 assy. REAR HAIRPIN, consisting of:
 - 1 assy. insulating bushing, consisting of:
 - 1 ea. Mtg. Bracket, Insulating bushing
 - 1 ea. Lower bushing piece, acrylic, DWG. No. 020221-004-0001
 - 1 ea. Upper bushing piece, acrylic, DWG. No. 020221-001-0001
 - 4 ea. Screw, 10-24 x 1", Phillips pan head
 - 8 ea. Washer, flat, stainless, AN-960C-10
 - 4 ea. Nut, elastic stop, 10-24, stainless
 - 1 ea. Block, Insulating, acrylic, DWG. No. 020221-003-0001
 - 2 ea. Screw, 10-24 x 1" Stainless
 - 2 ea. Washer, flat, AN-960C-10
 - 4 ea. Washer, flat, #10 x 0.625", .188 hole, \$\$, P/N 10N62FENS
 - 2 ea. Lock washer, split-ring, #10, Stainless
 - 2 ea. Nut, 10-24, Stainless
 - 1 assy. Rear hairpin, welded, with 2 tubes, 0.375 dia., 50" long, with bracket, all 6061-T6
 - 1 assy. Shorting Bar, consisting of:
 - 1 ea. Shorting Bar Machined block, DWG.000401-000-0001
 - 1 ea. Screw, 1/4"-20, Phillips flat head, 1 1/4" long, Stainless
 - 1 ea. Washer, lock, split-ring, 1/4", stainless
 - 1 ea. Nut, jam, 1/4"-20, Stainless
 - 1 ea. Shorting Bar Compression Disc, DWG. 000401-000-0002

- 1 ea. Washer, Flat, AN-960C416
- 1 ea. Nut, Elastic Stop, 1/4"-20, Stainless
- 2 ea. Clamp, hose, all stainless, 71/95 mm, UPG P/N 4150
- 2 kit, STRAP, CONNECTING, HAIRPIN TO ELEMENT, consisting of:
 - 2 ea. Strap, connecting, 0.625" wide, 8.5" long,
DWG. No. 020219-003-0001
 - 8 ea. Washer, flat, #10 x 0.750", .250" hole, \$\$, P/N 10N75FENS
 - 4 ea. Washer, flat, #10 x 0.625", .188" hole, \$\$, P/N 10N62FENS
 - 4 ea. Washer, lock, split ring, #10, stainless
 - 4 ea. Nut, 10-24, stainless

ELEMENTS

- 1 assy. FRONT ELEMENT, consisting of:
 - 2 ea. PVC insulator
 - 1 ea. Center ins. coupling, Fiberglas, 2.0" dia., 14"long, machined.
DWG. No. 020219-001-0001
 - 2 ea. Bolt, 1/4-20,3.5" long, hex head, stainless
 - 6 ea. Washer, flat, AN-960C-416, stainless
 - 2 ea. Washer, lock, split-ring, 1/4", stainless
 - 2 ea. Nut, 1/4-20, stainless
 - 2 ea. Tube Assy., 2.50" dia. 44.5"overall, all exposed, with 17.5" internal doubler,
DWG. No. 020506-001-0001
 - 2 ea. Tube, 2.25" dia., 0.125 wall, 58.75" overall, 52.0" exposed
 - 2 ea. Tube, 1.875" dia., 0.125 wall, 72.0" overall, 66.0" exposed
 - 2 ea. Tube, 1.50" dia., 0.095 wall, 47" overall, 42" exposed
 - 2 ea. Tube, 1.25" dia., 0.083 wall, 63.5" overall, 59" exposed
 - 2 ea. Tube, 1.00" dia., 0.049 wall, 18.5" overall, 15" exposed
 - 2 ea. Tube, 0.875" dia., 0.049 wall, 18.25" overall, 15" exposed
 - 2 ea. Tube, 0.75" dia., 0.049 wall, 21.0" overall, 18" exposed
 - 2 ea. Tube, 0.625" dia., 0.049 wall, 21.5" overall, 19" exposed
 - 2 ea. Tube, 0.50" dia., 0.049 wall, 29.5" overall, 27" exposed
 - 2 ea. Tube, 0.375" dia., 0.035 wall, 53.0" overall, adjustable
 - 4 ea. Clamp, hose, all-stainless, 7/32 - 5/8, P/N 41915
 - 4 ea. Bolt, 1/4-20, 3.5", stainless
 - 4 ea. Washer, flat, AN960C-416, stainless
 - 4 ea. Nut, elastic stop, 1/4-20, stainless
 - 72 ea. Rivet, closed end, Emhart AD55H, 5/32" dia.
 - 18 ea. Rivet, closed end, Emhart AD53H, 5/32" dia.
 - 72 ea. Rivet, closed end, Emhart AD42H, 1/8" dia.
- 1 assy. REAR ELEMENT, consisting of:
 - 2 ea. PVC insulator
 - 1 ea. Center ins. coupling, Fiberglas, 2.0" dia., 14"long,
DWG. No. 020219-001-0001
 - 2 ea. Bolt, 1/4-20,3.5" long, hex head, stainless

- 6 ea. Washer, flat, AN-960C-416, stainless
 - 2 ea. Washer, lock, split-ring, 1/4", stainless
 - 2 ea. Nut, 1/4-20, stainless
 - 2 ea. Tube Assy., 2.50" dia. 71.875" overall, all exposed, with 41" internal doubler, DWG. No. 020506-002-0001
 - 2 ea. Tube, 2.25" dia., 0.125 wall, 58.75" overall, 52.0" exposed
 - 2 ea. Tube, 1.875" dia., 0.125 wall, 72.0" overall, 66.0" exposed
 - 2 ea. Tube, 1.50" dia., 0.095 wall, 47" overall, 42" exposed
 - 2 ea. Tube, 1.25" dia., 0.083 wall, 63.5" overall, 59" exposed
 - 2 ea. Tube, 1.00" dia., 0.049 wall, 18.5" overall, 15" exposed
 - 2 ea. Tube, 0.875" dia., 0.049 wall, 18.25" overall, 15" exposed
 - 2 ea. Tube, 0.75" dia., 0.049 wall, 21.0" overall, 18" exposed
 - 2 ea. Tube, 0.625" dia., 0.049 wall, 21.5" overall, 19" exposed
 - 2 ea. Tube, 0.50" dia., 0.049 wall, 29.5" overall, 27" exposed
 - 2 ea. Tube, 0.375" dia., 0.035 wall, 53.0" overall, adjustable
 - 4 ea. Clamp, hose, all-stainless, 7/32 - 5/8, P/N 41915
 - 4 ea. Bolt, 1/4-20, 3.5", stainless
 - 4 ea. Washer, flat, AN960C-416, stainless
 - 4 ea. Nut, elastic stop, 1/4-20, stainless
 - 72 ea. Rivet, closed end, Emhart AD55H, 5/32" dia.
 - 18 ea. Rivet, closed end, Emhart AD53H, 5/32" dia.
 - 72 ea. Rivet, closed end, Emhart AD42H, 1/8" dia.
- 1 assy. PHASING LINE, consisting of:
- 1 ea. PHASING LINE ASSY., dual coaxial cable, 225" long, DWG. No. 020301-001-0001
 - 2 ea. Screw, 10-24, 1" long, Phillips pan head, stainless
 - 6 ea. Washer, flat, AN960-10, stainless
 - 2 ea. Washer, lock, split-ring, #10, stainless
 - 2 ea. Nut, hex, 10-24, stainless

Appendix E

OPERATIONAL NOTES

Feed System Description for the N7CL Array

The N7CL version of the two element driven array has been described incorrectly as being essentially an HB9CV antenna. While the N7CL driven array antenna is definitely in the same class of antenna as the HB9CV (also confused with the ZL-Special), the N7CL Array is not technically very similar to either of the above versions of the two element driven array. The primary differences are in the element lengths, element spacing, and the method of feeding and controlling the magnitude and phase of the current in the elements.

The HB9CV and the ZL-Special are typically fed and phased with high impedance open wire transmission line with a velocity factor in the high ninety percent range. Matching for the ZL-Special is by means of a shorted stub located some distance towards the generator from the antenna's feedpoint. "T" matches at each element are used in the HB9CV design. Element spacing for the original HB9CV is 0.125 wavelengths.

The Cal-Av LABS 2D series antennas incorporating the N7CL feed system have been issued U.S. Patent No. 6,411,264. This feed combines element stagger, shorted feedline stubs, and coax fed inside one arm of shorted open-wire transmission line stub to produce a feed system with the following characteristics:

1. Physical spacing of the elements significantly less than 0.125 wavelengths for increased forward gain and, conveniently, a more compact boom. The actual spacing used in the N7CL arrays produced by Cal-Av Labs, Inc. is 0.11 wavelengths. So the array is more properly characterized as a "close-spaced" driven array.
2. The feed system uses phasing line with a velocity factor in the 0.66 range. This permits the use of common coax to form the bulk of the phasing line. This allows the phasing lines to be placed inside a metallic boom.
3. The feed system permits setting the accuracy of the match to 50 ohm feedline and the array operating frequency independently using two separate adjustable "hairpin" shunt inductors.
4. These hairpin inductors are adjusted by sliding shorts. The arrangement of the hairpins on the boom brings the matching and tuning adjustments inboard towards the mast. This makes the adjustments reachable from a position on the antenna support tower. Thus final adjustments to the antenna can be easily made with the antenna in place on the tower while the antenna is mounted at its intended operating height above earth.
5. The array dimensions and feed system are configured so that the pattern optimization is coincident with system resonance and match to 50 ohms. When adjustment is made to the tuning hairpin to compensate the array for its mounted height, site clutter, etc., the good pattern characteristics of the array are maintained.

6. The design of the feed system rigidly enforces precise electrostatic balance for the array. Balance is maintained with regard both to the feedline connection and to the connection to the tower. This makes the antenna much quieter on receive and eliminates the need for a separate BALUN or coil of coax in the feedline to the transmitter. This balancing and matching scheme can handle virtually unlimited amounts of power (in amateur radio terms) without any non-linear effects or failure due to heating. It will "loaf" along at 5 kW CCS even on a full-carrier mode such as radio teletype.
7. The feed system connects the elements to local RF ground (the support boom) for low frequencies and DC. This feature permits the array to drain off static charges, survive lightning hits, and provide useful non-radiative top loading of the tower structure if required.
8. The feed system provides a high quality DC short across the feedpoint at the antenna end of the feedline.

A schematic representation of the N7CL feed system for the two element driven array is shown in Figure 1-E.

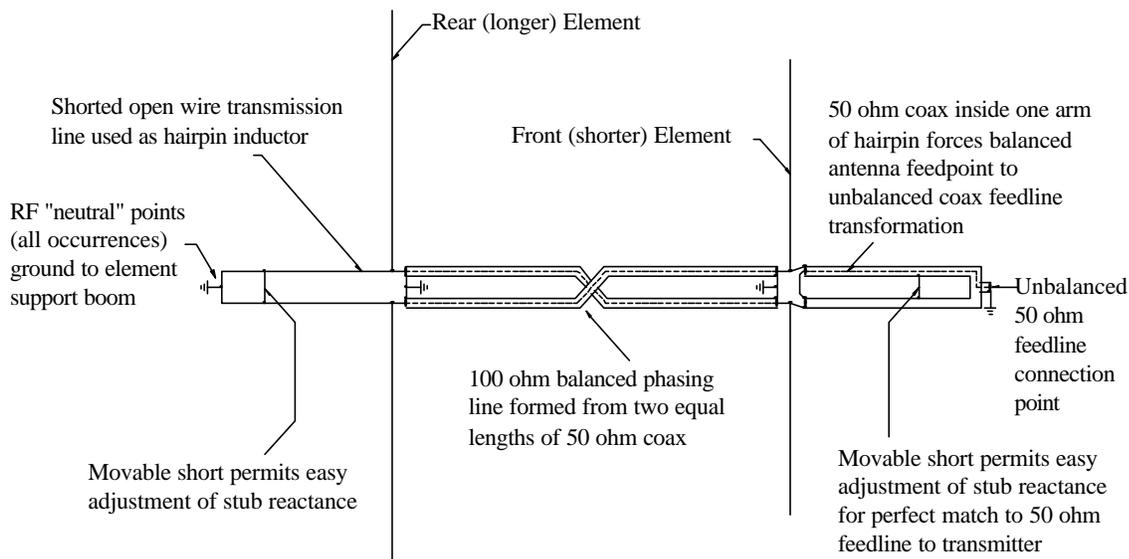


Figure 1-E

Tune-up Instructions for the Cal-Av Labs, Inc. Model 2D-40A Antenna

This manual contains tabular data on the tuning and matching stub shorting strap positions and element lengths for an antenna mounted at the minimum recommended height of 1/2 wavelength above local earth and additional data for antennas mounted at one wavelength. However, the local environment (ground constants, vegetation, site clutter, etc.) makes it impossible to predict **exactly** what you will find when you raise the antenna at your site. So you may need to make some minor adjustments "in place".

NOTE: The shorting strap on the transmission line stub attached to the front (shorter) element adjusts the array match to 50 ohms. This is the same assembly to which the coax feedline from the transceiver is attached.

The operating frequency of the array is adjusted primarily by adjusting the lengths of the elements. The element length is adjusted by changing the exposed length of the outermost "tip" sections. When changing the array operating frequency, **all four element tips should be adjusted by exactly the same amount**. A reasonable "sanity check" is to verify that all four tips are exactly equal length before raising the antenna.

Wherever referred to in this appendix, "element" lengths in inches are actually half-lengths. That is, the "element length" dimension refers to the distance from the end of the outside "tip" section of the element to the center of the boom (or half way across the 2-inch gap at the element feedpoint). "Tip" lengths refer to the exposed portion of the outermost 3/8-inch diameter element tube. "Tip" lengths will be given for settings and adjustments.

The tuning stub on the rear element sets the array reactance so that the pattern is optimized at the same frequency where the antenna feedpoint impedance is exactly 50 ohms. It should normally be set at the recommended length and not adjusted further.

However, if the array resonant frequency **must** be moved slightly, and the element tips **cannot** be reached for adjustment, the rear stub may be adjusted to move the array resonant frequency a **small** amount (approximately 70 kHz) without significantly degrading the pattern F/R characteristics.

Operating the antenna at a height above ground that is significantly different than 1/2 wavelength may necessitate an adjustment to the rear **tuning** stub to restore the antenna's excellent front to back ratio. Careful modeling of the proposed installation and consultation with the factory is recommended before proceeding with such an installation. A very accurate EZNEC (NEC2) model of the antenna is available for download from the Cal-Av Labs, Inc. web site <www.cal-av.com>.

Antenna Settings for 2D-40A Mounted at 70 feet (one half wavelength)

Frequency (MHz)	Delta (inches)	Tip Length (inches)
6.962	0	50.5
7.030	-5	45.5
7.099	-10	40.5
7.170	-15	35.5
7.241	-20	30.5
7.313	-25	25.5

Figure 2-E Tip Lengths vs Frequency (70 feet)

If the antenna is to be installed at this recommended minimum height of approximately 1/2 wavelength, the sliding shorts used to adjust tuning and matching for the array should be preset as follows:

The **tuning** (rear) shorting bar should be set to a distance of 22 inches back from the element end of the parallel line on which the shorting bar slides. Note that this distance is to the center of the shorting bar and does not include the length of the straps that connect the parallel tuning line to the element.

The **matching** (front) shorting bar should be set to a distance of 41.5 inches back from the element end of the parallel line on which the shorting bar slides. Note that this distance is to the center of the shorting bar and does not include the length of the straps that connect the parallel tuning line to the element.

All of the above settings apply only to an antenna which has fixed element half-lengths (center of boom to end of element **without the tip section installed**) of 358.5 inches for the front element and 386 inches for the rear element. Some prototype and early production antennas were produced with element dimensions that differ from those shown above. If your antenna's element half-lengths **not including the adjustable tip section** differ from these values, please consult the factory.

We recommend that you use the element tip length settings shown in figure 2-E and the hairpin settings shown above as a starting point. Once the antenna is installed, you should find that when set to the factory recommended settings the array SWR approaches 1 to 1 at some frequency very near the one for which you set the element length. Since the performance of the array doesn't change significantly over the entire 2:1 SWR range (and somewhat beyond 2:1 on the high frequency side), the exact location of the minimum point may not cause you to wish to take the effort move it.

However, if you wish to achieve perfection at some particular frequency, here is the procedure to completely optimize the antenna for operation on a particular frequency:

1. If the minimum SWR is low enough to make you happy, proceed to step 6 below. If not, then adjust the matching (front) stub for minimum SWR as indicated in the subsequent steps.
2. First, find the frequency of minimum SWR (don't worry about the frequency where this occurs yet).
3. Then, adjust the shorting strap location on the **matching** (front) stub to minimize the SWR at that frequency.
4. Find the new frequency where the minimum SWR occurs (this should **NOT** be far removed from the original minimum SWR frequency).
5. Repeat steps 2 and 3 above until you have the array minimum SWR set to 1.0 to 1 at some frequency. Further adjustment of the **matching** (front) stub will not be necessary.
6. If you can arrange to reach the element tips for adjustment, then adjust the element lengths (all four tips by the same amount) to bring the minimum SWR point to the desired frequency. The 2D-40A antenna will move about 14 kHz per inch of element tip length change. As you might expect, the resonant frequency of the array will rise with shortening element lengths.
7. If you absolutely **cannot** arrange to reach the element tips for adjustment (and the required frequency excursion is less than one percent), then move the shorting bar on the rear **tuning** stub to bring the antenna resonant frequency to the desired point. However, if the frequency change is larger than one percent, please consider resetting the element lengths if at all possible. The 2D-40A antenna will move its resonant frequency by approximately 6 kHz per inch of **tuning** (rear) stub length change. Shortening the stub raises the resonant frequency.

NOTE: Pattern degradation due to moving the **tuning** (rear) stub length away from the recommended setting is not symmetrical. Lowering the antenna's resonant frequency by changing the **tuning** (rear) stub length will degrade the front to rear performance much more significantly than raising the resonant frequency will. If the constraints of the installation will prohibit adjustment of the element tip lengths for tuning, it is better to err on the low side when selecting the target frequency during antenna assembly.

Antenna Settings for 2D-40A Mounted at 140 feet (one full wavelength)

Frequency (MHz)	Delta (inches)	Tip Length (inches)
6.948	0	50.5
7.015	-5	45.5
7.084	-10	40.5
7.154	-15	35.5
7.224	-20	30.5
7.296	-25	25.5

Fig 3-E Tip Lengths vs Frequency (140 Feet)

If the antenna is to be installed at this height (approximately one wavelength), the sliding shorts used to adjust tuning and matching for the array should be preset as follows:

The **tuning** (rear) shorting bar should be set to a distance of 25.3 inches back from the element end of the parallel line on which the shorting bar slides. Note that this distance is to the center of the shorting bar and does not include the length of the straps that connect the parallel tuning line to the element.

The **matching** (front) shorting bar should be set to a distance of 39.75 inches back from the element end of the parallel line on which the shorting bar slides. Note that this distance is to the center of the shorting bar and does not include the length of the straps that connect the parallel tuning line to the element.

All of the above adjustments apply only to an antenna which has element half-lengths (center of boom to end of element **without the tip installed**) of 358.5 inches for the front element and 386 inches for the rear element. If your antenna's element half-lengths **not including the adjustable tip section** differ from these values, please consult the factory.

The tune-up procedure to use for an antenna mounted at 140 feet is exactly the same as shown above for 70 feet. But the starting settings for the tuning shorts and the element lengths for a particular frequency should be taken from Figure 3-E rather than from Figure 2-E.

Appendix F

PAINTING INSTRUCTIONS

GENERAL:

Should you paint your antenna? We think so, but it's your decision. Here are the facts:

OPERATIONAL EFFECTS:

Nil; a thin dielectric coating (paint) between the metal and the air does cause changes, but they would be very difficult to measure for antennas of this size. A slight reduction in precipitation static may be noticed.

ADVANTAGES:

There are two primary advantages to painting an antenna:

First, its visual impact is mitigated, because the recommended paint is flat, eliminating the "glint" associated with aluminum, even so called low-glare treatments. Further, the recommended paint is very close to the color and gray-scale of power company pole-mounted transformers and modern insulators; this results in it not being too dark against a light sky, nor too light against a dark sky.

Second, the antenna is protected from weathering, particularly if its surrounding area is subject to contaminants that would attack aluminum (ocean air, acid rain, etc.).

Other advantages include: cleaner handling (bare aluminum can be really dirty stuff), protection and easy-to-disassemble locking of mounting hardware, protection of cables, BALUNs, etc. from the effects of sunlight, and as mentioned above, some reduction of static from raindrops.

DISADVANTAGES:

Labor and cost of painting materials

MATERIALS REQUIRED:

1. "Scotch-Brite" pad, general-purpose hand pad, maroon. Available from auto painting and abrasives companies and larger hardware stores
2. Clean soft rags or paper towels
3. Acetone or Methyl-Ethyl-Ketone (MEK) (latter recommended)
4. Light Gray Primer, Rust-Oleum No. 2081, available at Home Depot, large hardware stores, and some paint stores. There are no recommended substitutes at this time.

BACKGROUND:

1. This primer is light gray, a color that is being used more and more for power-pole insulators, transformers, etc., for looking less obtrusive against an average sky.
2. Read instructions on paint can thoroughly; disregard the part about surface preparation, which was written for steel automotive bodies. This particular primer

has some very nice attributes. Among them are that it can easily be removed with acetone, even after it is dry, and that it is very easy to touch up, while wet, after it's dry, or days later. It will oxidize a bit after years in the sun; even then, it can be cleaned with an MEK-dampened rag, just enough to remove dirt and some of the oxidized paint, and then repainted. We recommend two coats, at least 15 minutes time between coats.

NOTE: If the background for the antenna will be land or foliage, we recommend "Krylon Olive Drab Camouflage Paint", number 8143, over the primer.

SURFACE PREPARATION:

1. In this case, the surfaces to be painted are new plated steel hardware, stainless steel, and aluminum plate and tubing.
2. The hardware can just be wiped down with MEK and allowed to dry before painting.
3. The aluminum plates should be cleaned with Scotch-Brite to a dull, uniform finish, then washed with MEK until no more aluminum residue shows on the cleaning towel. Then hang the plate using a piece of wire and paint it.
4. The elements are prepared for painting after assembly. A complete element may be prepared for painting and then painted before attachment to the boom. Balance it on a stepladder step so that it is about chest high. Wipe the element down with a rag dampened with MEK. Be sure to remove any silicone grease residue. Be careful not to let the MEK drain into the joints. Clean the exposed surfaces of the entire element using a Scotch-Brite pad. Clean to produce a uniform, matte finish. Then wipe down with MEK until no more aluminum residue shows on the cleaning towel.
5. The boom and all its parts, including brackets and matching lines, are cleaned in the same manner as the elements. Mask the feed point connector and the matching lines. No paint should touch the metal where the sliding short will be used for adjustments.

PAINTING:

1. Follow the instructions (other than for surface preparation) on the can. Be sure to use several even, light sprays, close enough to produce a wet (shiny) coat, but not so thick that it runs. Touch-up can be at any time. A second coat is recommended at least 15 minutes after the first.
2. For elements, a good approach is to spray one side, then the other. When dry enough to handle, rotate the element 90 degrees and spray each side in the new position (what were the top and the bottom).
3. Paint the boom in a manner similar to the elements, however, mask off any connections that will be made after the elements are attached, as well as the feed point connector and the tuning stub tubes.