A 2-Meter Phased-Array Antenna

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Eighteen months ago a newly licensed Technician dropped by and asked for some advice on VHF antennas. My friend had limited funds, so his first creation was a simple 2-meter vertical installed atop an old 40-foot tower. He used this antenna to work 2-meter SSB with some success, despite the fact that his antenna was vertically polarized. (Most SSB enthusiasts use horizontal polarization. The signal loss caused by polarization "mismatch" can be substantial.) During his SSB explorations he routinely heard operators working stations up the coast over distances of 200 miles and more. He also heard them talking about "Yagis" and "quads."

Seeking to better his station, he visited again and asked me to explain antenna gain, directivity and polarization. Firing up the computer and my *EZNEC* software, we sat down together and designed a horizontally polarized, 12-element Yagi for 2 meters with a 17-foot boom. I wasn't sure if he was up to the task of building such a thing, but I was wrong.

Phaseuth Arun, AC6NX, arrived in the States 10 years ago from Cambodia with no trade skills. While doing odd jobs he read voraciously and, in the process, became a self-taught computer scientist. (He is now a system programmer and network specialist for a major corporation.) At the same time, Phaseuth was bitten by the ham bug. He jumped feet-first into the hobby, allowing nothing to stand in his way. Six months after I first met Phaseuth, he upgraded from Technician to Amateur Extra. So, I wasn't surprised when I heard that he had assembled and installed the home-brew Yagi on his tower. Shortly thereafter, AC6NX worked Hawaii with 150 W!

Basking in the glow of Phaseuth's enthusiasm, I thought it was time for *me* to do something. Two-meter SSB didn't interest me, but 2-meter FM did. I could have simply erected a vertically polarized Yagi for FM work, but I wanted to do something different—just for the pure fun of it. Many hams use ground plane antennas for omnidirectional coverage on VHF, but how many have ever tried two ground planes in a *phased array* to focus the radiation pattern in a particular direction? This phasing trick works well for verticals on the HF bands, but what about 2 meters? I decided to try!

Ask the Computer

I modeled my idea on the PC and found that if I fed the two ground planes 90° out of phase with each other and separated by a quarter wavelength, I could theoretically achieve 4.75 dBi of gain and a front-to-back ratio of about 40 dBi. That's an impressive amount of "focusing" for two ground planes, but could I do better? Sure enough, feeding the antennas 135° out of phase resulted in 6.29 dBi of gain, although the front-to-back ratio was somewhat reduced. I chose to go with the benefits of the 135° phase difference.

When I assembled and installed the phased array, I was pleasantly surprised to discover that the computer's predictions were very accurate. By aiming the antenna with a simple TV rotator, my effective range on 2-meter FM increased dramatically. When interfering signals became a problem, I was often able to turn the array slightly and reduce the offending signals a great deal. We're talking about taking a full-quieting FM signal and rendering it almost nonexistent!

The obvious question is, why build such a thing? Why not just use a Yagi on a rotator to achieve the same result? Not all hams have enough space for a 2-meter Yagi, especially if they intend to rotate it. My compact array is ideal for attic installations or any other environment where space is scarce. You get the benefits of a directional signal pattern—and the gain that comes with it—along with a small turning radius (less than 40 inches). Of course, building the array is also fun and educational!

Assembling the Ground Planes

Gather the parts you'll need to build the ground planes:

8	Ring terminals or long solder lugs
2	$^3/_{32}$-inch diameter brass tubes, 20 inches long
2	SO-239 chassis connectors
8	Radials, each 18 inches long (you can make these from stiff copper or aluminum wire)
8	Bolts, nuts and washers (4-40 × $^3/_8$ inch)

Solder the brass tubes into the SO-239 connectors (see **Figure 1**). Trim the tubes so that the total length from the flange of the SO-239 connector to the tip is $19^1/_4$ inches. Using the 4-40 × $^3/_8$-inch screws, nuts and washers, install four ring terminals into each of the four holes on the SO-239 connectors. Solder the radial wires to the ring terminals. Bend the radials down at 45° angles on both antennas.

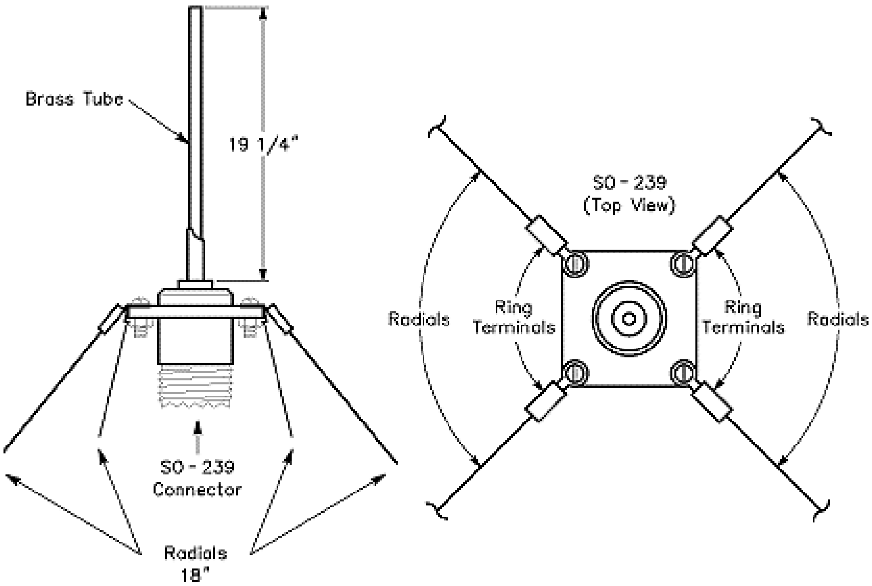


Figure 1—First you need to build two ground plane antennas as shown. Use brass tubes for the vertical radiators and stiff copper or aluminum wire for the radials. Ring terminals, screws and nuts secure the radials to the SO-239 chassis connectors.

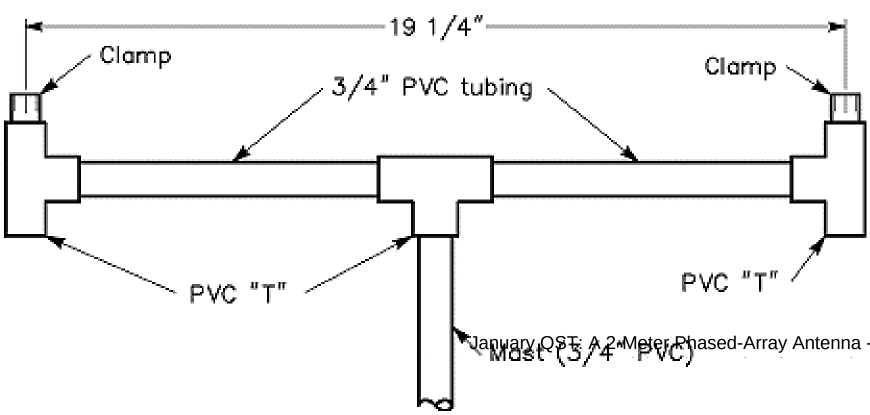
Now it's time to test and adjust each ground plane. Attach a piece of string or fishing line to the top of the brass tube (a little tape will do the trick) and suspend the antenna about six to eight feet above the floor or ground. Attach a length of coax (about 15 feet of RG-8X is fine) to the antenna and run it to a 2-meter transceiver and SWR meter. Measure the SWR at about 146 MHz and adjust for the lowest SWR by moving the radials up or down. If you've constructed the antennas properly, you should be able to adjust both for SWRs of less than 1.51.

Build the Boom

The boom is constructed from schedule-40 PVC tubing (see **Figure 2**). Take care to assemble it precisely. It's important to maintain the quarter-wavelength spacing between the ground planes.

You'll need:

2 Lengths of $^{3}/_{4}$-inch diameter PVC tubing 8$^{1}/_{4}$ inches long
3 $^{3}/_{4}$-inch PVC Ts
2 Lengths of $^{3}/_{4}$-inch diameter PVC tubing 2 inches long
1 Tubing cutter (optional)
1 Can "purple primer" PVC cement
2 1-inch diameter stainless-steel hose clamps



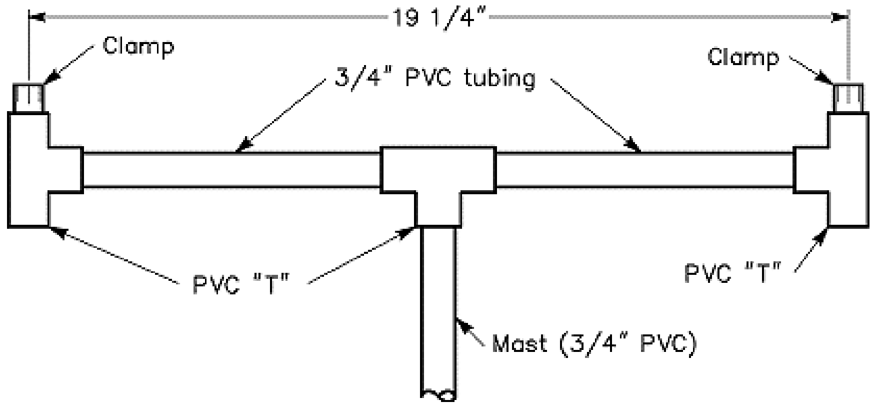


Figure 2—Assemble the boom using 3/4-inch diameter PVC tubing and Ts. Note that the distance is 19 1/4 inches between the center of one PVC "end T" and the other.

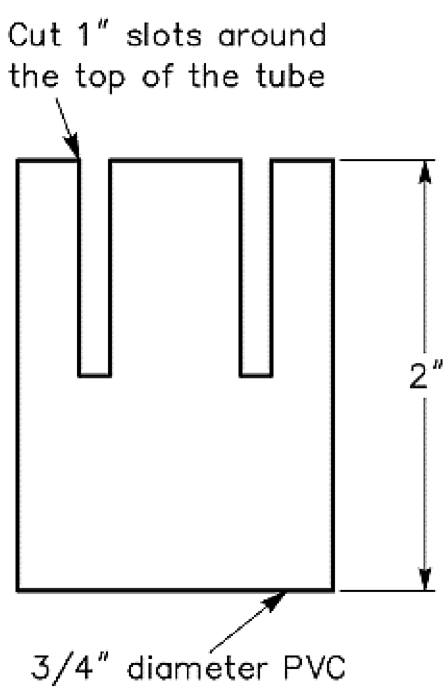
Don't use standard PVC cement. This stuff hardens so fast that you won't have time to adjust the fit. Be sure to get purple primer or equivalent. It sets up in 12 to 15 seconds, plenty of time for adjustments.

Sand the ends of both 8 1/4-inch tubes until they are smooth. "Dry fit" the entire boom by slipping on the vertical "end" Ts and then sliding both tubes to the horizontal "center" T. Measure for a total length of 19 1/4 inches between the centers of the end Ts. Sand or file the tubes as necessary to achieve the correct overall length.

Now disassemble your dry-fit boom and clean all joints, inside and out. Put a tube into a bench vise and clamp. Swab cement on either end of the tube (your choice!) and on the inside of one of the end Ts. Slide the center of the T onto the tube and quickly push it as far as it will go. Now do the same with the remaining 8 1/4-inch tube and T.

Clamp the center T horizontally into the bench vise. Slide both tube/T assemblies into the open ends of the T. Rotate the individual tubes so that their end Ts are properly aligned with each other. Using a marking pen, draw short, thick lines on the tubes where they meet the center T. Extend the lines a short distance onto the center T itself. Remove the tubes, prepare the tubes and center T with cement, and then reinsert. Quickly rotate the tubes so that the lines you just made with the marking pen match correctly.

Finally, we have to insert two small PVC sleeves that will serve as holding clamps for our ground planes. Cut two 2-inch-long pieces of your 3/4-inch PVC tubing. Cut several 1-inch slots in the sleeves (see **Figure 3**). I used a hacksaw, then a wood saw to increase the width. Deburr the slots carefully. Slip the sleeves into the end Ts and check for a proper fit. About one inch of each sleeve should extend above the T. (Make sure you install the sleeves in the *top* ends of each T with the slotted portions protruding!) Cement them into place and, when the cement is dry, slip on the stainless steel hose clamps—but don't tighten them yet.



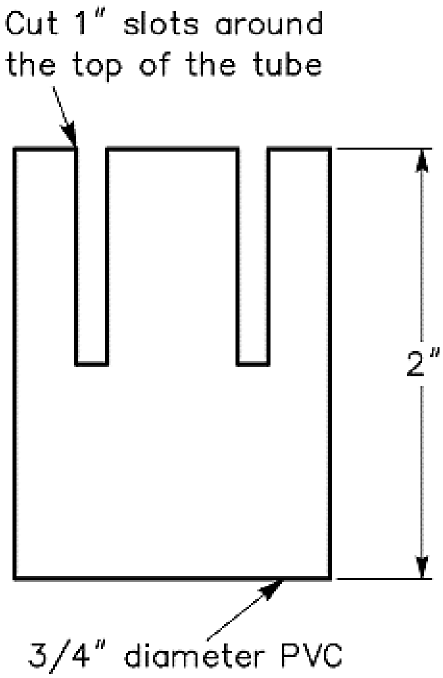
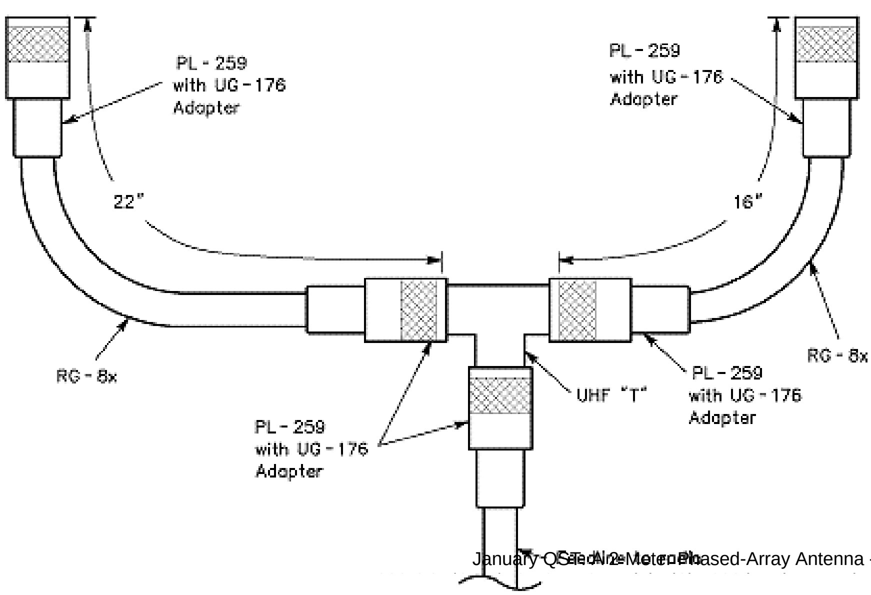


Figure 3—Make two clamps by cutting 1-inch slots into two 2-inch long, 3/4-inch diameter PVC tubes. When you tighten the steel hose clamps around these slots, they'll apply firm pressure to the PL-259 connectors, holding the ground planes in place.

This is a good time to cement a length of PVC tubing to the bottom of the center T so that you can attach the finished antenna to a mast. I used a 2-foot length of 3/4-inch PVC tubing.

The Phasing Harness

One way to feed two antennas out of phase is by varying the distance the RF energy must travel to reach each antenna. In our case, when the RF reaches the feed line T connector, it splits and travels on two separate paths to our ground planes (see **Figure 4**). This causes the RF to arrive at one ground plane well ahead of the other. As the ground planes radiate the energy, the phase differences that result from the different "arrival times" cause the signal to be canceled in some directions and reinforced in others. This creates the overall radiation pattern shown in **Figure 5**. Notice how it is focused in a particular direction. [The exact current amplitude and phase at each ground plane depends on the tuning of each element plus the exact velocity factor of the coax used. The change in gain is minor, but the depths of the side and back lobes may vary. The antenna will still work fine, however—*Ed.*]



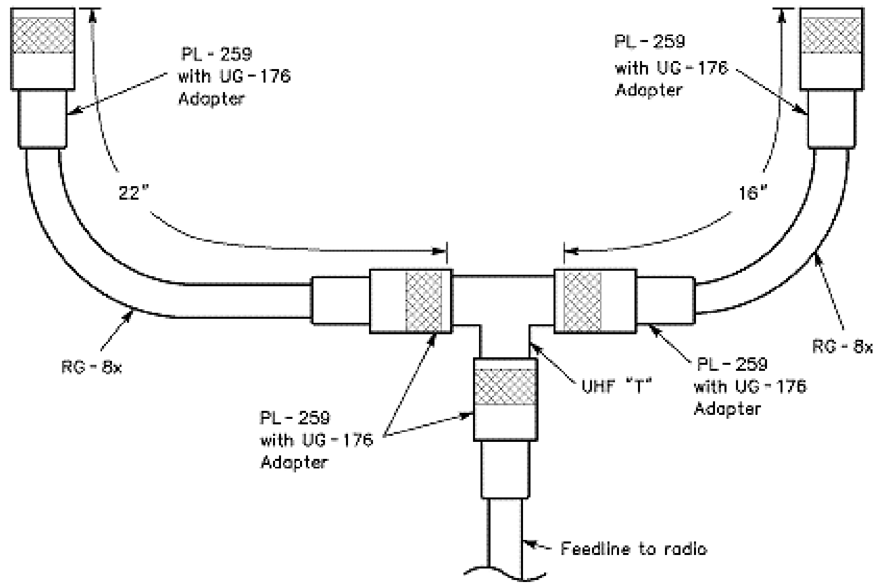


Figure 4—The phasing harness. The lengths of the individual phasing lines are critical and should be as precise as possible. The direction of radiation is toward the antenna connected to the *longest* line.

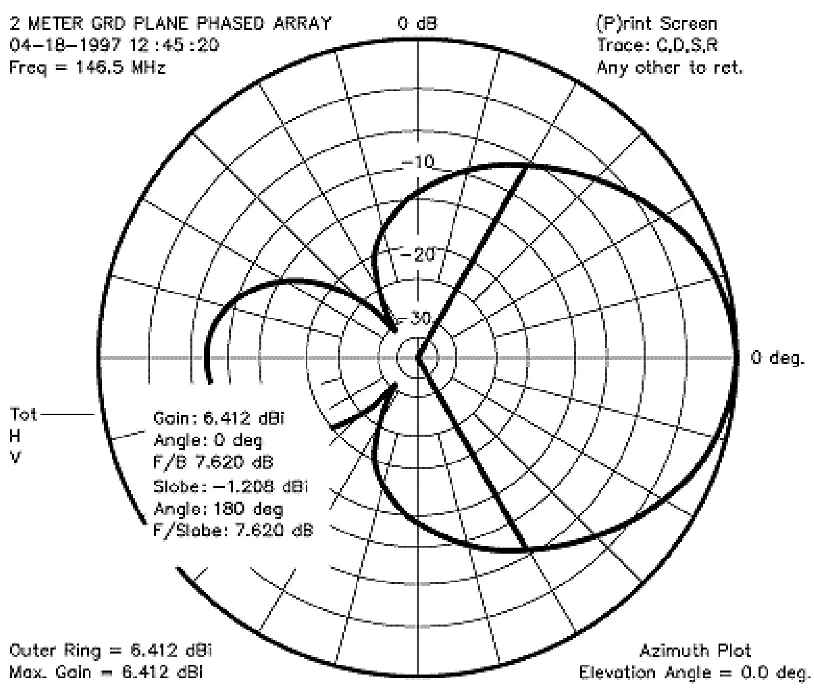


Figure 5—The theoretical radiation pattern of the 2-meter phased array, according to *EZNEC*.

So, let's get to work on our phasing harness. You'll need:

4 PL-259 coaxial connectors
1 UHF female T connector
1 Three feet of RG-8X coaxial cable
2 UG-176 adaptors

It is important to maintain the correct lengths of the phasing lines. Cut one length of RG-8X coax to 16 inches. Cut another to 22 inches. Solder PL-259 connectors on both cables, but take care not to shorten their lengths in the process. Connect one end of each phasing line to the UHF T connector.

Final Assembly and Testing

Route the unconnected ends of your phasing lines through the bottoms of the end Ts on the antenna boom (see **Figure 6**). Screw the PL-259 connectors into the bottoms of your ground planes. Pull the coax and PL-259s down through the Ts until the antennas rest on the slotted sleeves. (You may need to rotate the antennas slightly to keep the radials from touching each other.) Tighten the hose clamps until they grip the PL-259s firmly. Use electrical tape to secure the coaxial T connector to the mast portion of your PVC tubing. Just allow the phasing lines to dangle in mid-air.

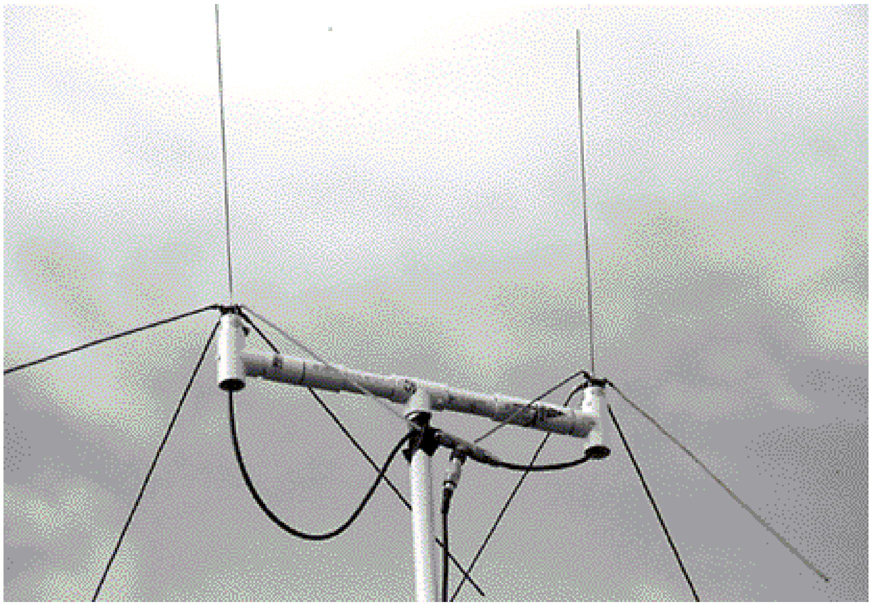


Figure 6—The assembled phased array antenna. Note how the two phasing lines reach the ground planes through the bottoms of the PVC T sections. The entire array radiates in the direction of the ground plane that's attached to the *longest* phasing line.

Install your antenna onto a mast or rotator, connect the main feed line to the bottom of the coaxial T connector and you're ready to go! The primary lobe of radiation will be in the direction of the ground plane that is attached to the longest cable of your phasing harness. Use your marking pen and draw an arrow on the boom to mark which direction your array is "pointing." This will be helpful when you install the antenna.

I installed my phased array on a rotator about 12 feet off the ground. After adjusting the radials a little for the best SWR (1.31 at 146 MHz) I was eager to get on the air. Using 300 mW I put a full-quieting signal into the Catalina Island repeater about 40 miles from my location. I increased my output to 30 W, turned the array, and worked a station *on simplex* in San Diego, 135 miles away! The longest contact so far was through a repeater near Paso Robles, about 200 miles distant.

I believe the 75° beamwidth and low angle of radiation are big factors in this array's performance. All it took was a $20 investment and about 3 hours of my time!

I would like to thank Phaseuth Arun, AC6NX, and Harry Amloian, KF6HBQ, for their help and encouragement.