Improving the Cushcraft A50-5S 6M Yagi with an Extended Boom and Optimized Design

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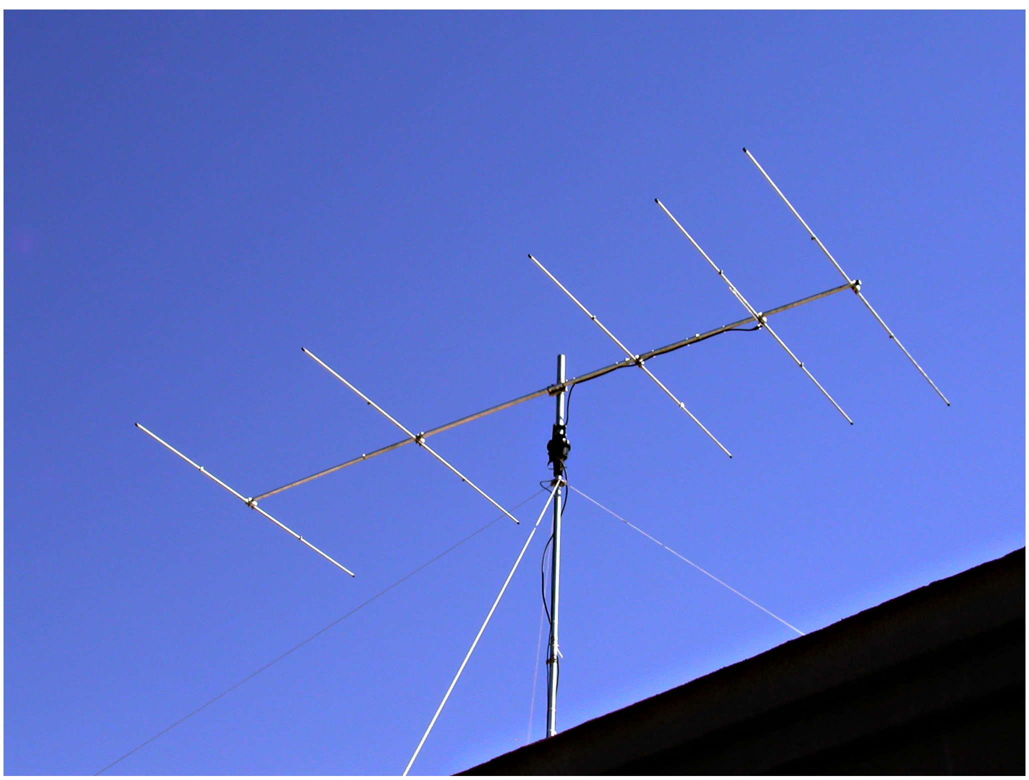
The Cushcraft A50-5S five-element yagi is one of the more popular manufactured 6M antennas available on the amateur market today. Assembled by the book, the A50-5S is virtually idiot-proof, and does a creditable job on the air.

After using it for a while, however, I felt the need to make some improvements in the design. The photo below shows the visible results of the improvement project described in this paper.



Design Criteria

In redesigning this antenna, I had three important criteria in mind:

- Lengthen the antenna's 12-foot boom to improve performance, but do so in a way that was simple, inexpensive, and wouldn't require any additional mechanical support.
- Optimize the design using yagi modeling software to maximize performance parameters, with special emphasis on improving the antenna's front-to-rear ratio.
- Minimize as much as practicable any increase in weight and wind loading.

These criteria were all met by the design described here.

Disassembly Notes

First, read the sidebar Thread Galling in Stainless Steel Fasteners. This is a serious problem that could affect your antenna if you don't take precautions to prevent it.

With a permanent black marker pen, mark each element assembly *before you remove it* with the letters "R" (Reflector), "DE" (Driven Element), "D1" (First Director), "D2" (Second Director), and "D3" (Third Director). Then carefully remove the elements from the boom assembly. When removing the Driven Element, take care not to bend or otherwise damage the gamma match assembly.

Store the U-bolts, washers, and nuts in a safe place.

Boom Modification

Using UPS-shippable parts that are readily available through catalog or website channels makes upgrading the A50-5S an easy project for anyone. In keeping with this ideal, it was decided to lengthen the boom using a standard 6-foot length of aluminum tubing ordered from Texas Towers. Longer lengths are available, of course, but are shipped only via motor express at increased cost. In addition, longer standard lengths would require cutting and/or extra mechanical support. The lengthened boom is 17.5 feet and is entirely self-supporting when used with the original Cushcraft elements.

Thread Galling in Stainless Steel Fasteners

The hardware used on the A50-5S (but not the earlier A50-5) is stainless steel. This material doesn't corrode, and therefore maintains better RF electrical characteristics over time.

These advantages come at a price, however. Stainless steel bolts and nuts—especially if both are made from the exact same grade or formulation of stainless steel—are prone to *galling*, or seizing. Once the bolt and nut begin to gall, the friction between the threads quickly increases as the nut is turned, until they lock together in a bond that is, amazingly, stronger than the material itself.

Galling can be prevented by application of a good *anti-seize compound*, but Cushcraft didn't provide any with the A50-5S kit. Worse, they didn't even mention the fact in their assembly manual that stainless steel fasteners are extremely prone to galling, and that an anti-seize compound should be used when assembling them!

Therefore, it came as a complete shock to me when, upon disassembling my antenna, most of the U-bolts and nuts seized and froze. I ended up having to get a whole new set of U-bolts, washers, and nuts sent to me by Cushcraft under warranty.

What to Do If the Hardware Seizes Up

If one or more of the U-bolt nuts seize up while you are trying to remove them, your only recourse is to break the U-bolt (by cutting or twisting) and replace it and its nuts with new parts. *Even if you ultimately manage to remove the nut, never try to reuse stainless hardware that has manifested galling during disassembly.*

Unfortunately, the size of U-bolt Cushcraft uses is uncommon, especially in stainless steel. I was unable to find an exact size replacement in any hardware or home improvement store. Unless you have better luck finding them locally than I did, you will need to order replacements from Cushcraft or from McMaster-Carr (www.mcmaster.com). Using a U-bolt with different center-to-center spacing isn't an option, as the U-bolt is mounted through holes in each element. You must use the same size U-bolt Cushcraft uses.

How to Prevent Galling

Use any good anti-seize compound when assembling stainless steel bolts and nuts. You may not find anyone in a hardware or home improvement store who even knows what you're talking about, but all auto parts stores carry several types of it. You can also use Penetrox, which is sold by many amateur radio dealers like AES and HRO.

Apply it liberally to *all* the threads of the U-bolt. Don't miss any spots! My experience is that fingers work best for getting it evenly distributed over all the threads. Then, simply assemble the U-bolt, washers, and nuts as usual. You can wipe off any extreme excess of the stuff with a cloth after you're finished, but don't be overly diligent about this. You want the compound to remain on the threads all the way out to the end of the bolt, so that galling won't occur during the next disassembly.

Besides the aluminum tubing, the only extra parts required for the design are a couple of 1½" stainless steel hose clamps, available from any hardware or auto parts store. These are the same kind of clamp used in the original antenna by Cushcraft.

Figure 1 shows the boom modification graphically.

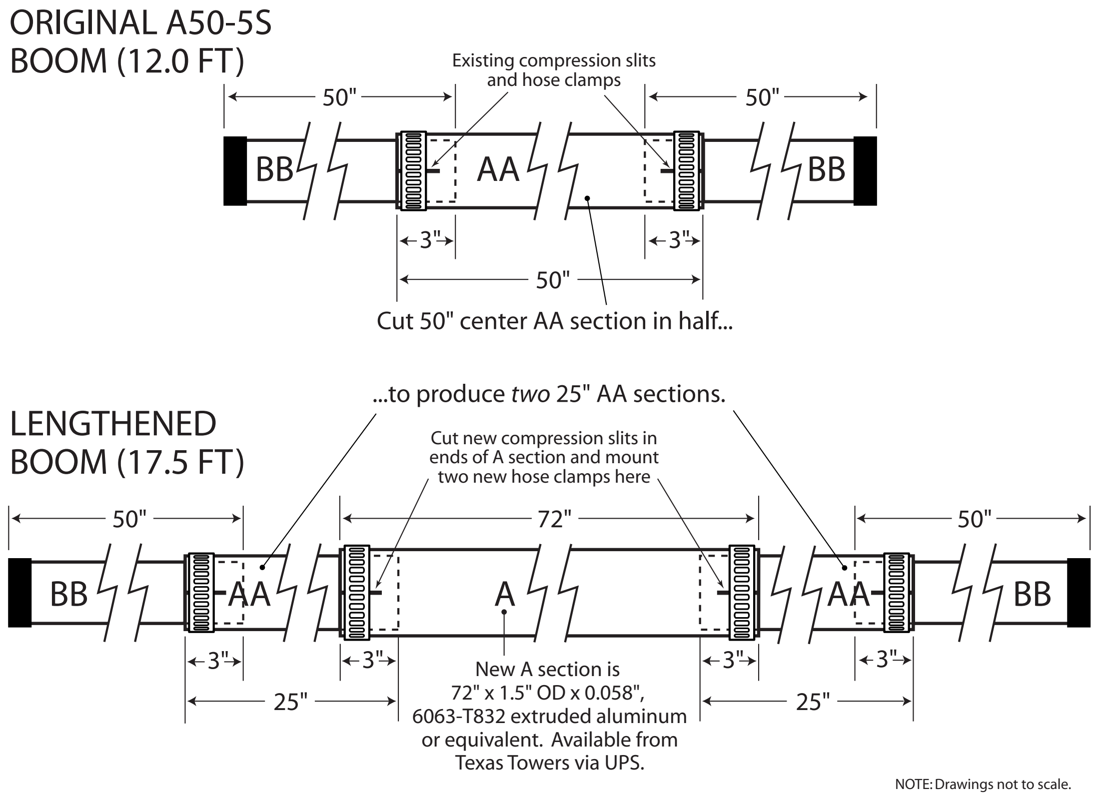


Figure 1: **Original and Lengthened Boom Assembly**

When halving the original boom center piece **AA**, it's important to measure accurately so that the 50" piece is cut into two equal-length pieces of 25" each. The tubing can be cut with a hacksaw or (if you have one) a pipe cutter.

With a hacksaw, cut compression slits in each end of the new boom center piece **A**. The slits should be around 1½" long.

Remove all burrs produced by the cuts with emery paper or file.

Assemble the boom as illustrated above, double-checking all measurements. Note that each nesting piece is inserted 3" into the larger mating piece. After assembly, measure to confirm that the overall length of the new boom is exactly 210" (17.5').

Element Length

Figure 2 shows the antenna's element positioning and *taper length*. The taper length is the distance the smaller-diameter tubing protrudes from the center **EA** section.

Reflector Element Length Caveats

There are a couple of "gotchas" regarding the new longer Reflector element:

- All the center **EA** sections are 48" long, but the outer nested tubing sections **EB** through **EF** are *not* all the same length. The outer tubing sections are identified in Figure 2. Especially if building this antenna from an unassembled A50-5S kit, it's important to correctly identify each outer element tubing section. The **EB** sections are the longest, and the **EF** sections are the shortest. These outer tubing sections *must be used for their designated elements*. Mixing them up could result in not having enough length available for some elements and excess length for others.

- In addition, reports from the field suggest that the older version of this antenna, the A50-5, uses **EB** sections that are 37 1/2" long, not 40 1/2" long as in the newer S version. Since the element taper length schedule in Figure 2 specifies a 37.5" extension for the **EB** sections, these shorter elements will not work because there is no nesting overlap. If attempting this modification on an old A50-5 yagi, remove and measure the **EB** tubing sections in the Reflector *before* ordering the aluminum for the boom. If they are not 40 1/2" long, then two six-foot sections of 5/8" tubing from the same tubing schedule (6063-T832) will also need to be ordered—unless you have a well-stocked aluminum bone-pile in your garage!

Adjusting to the New Dimensions

For each element, the length is adjusted by loosening the clamp on each end of the center section and sliding the smaller outer sections in or out to the desired dimension. Make exactly the same adjustment on both sides of the element. Measure carefully and double-check all measurements after retightening the clamps to ensure accuracy.

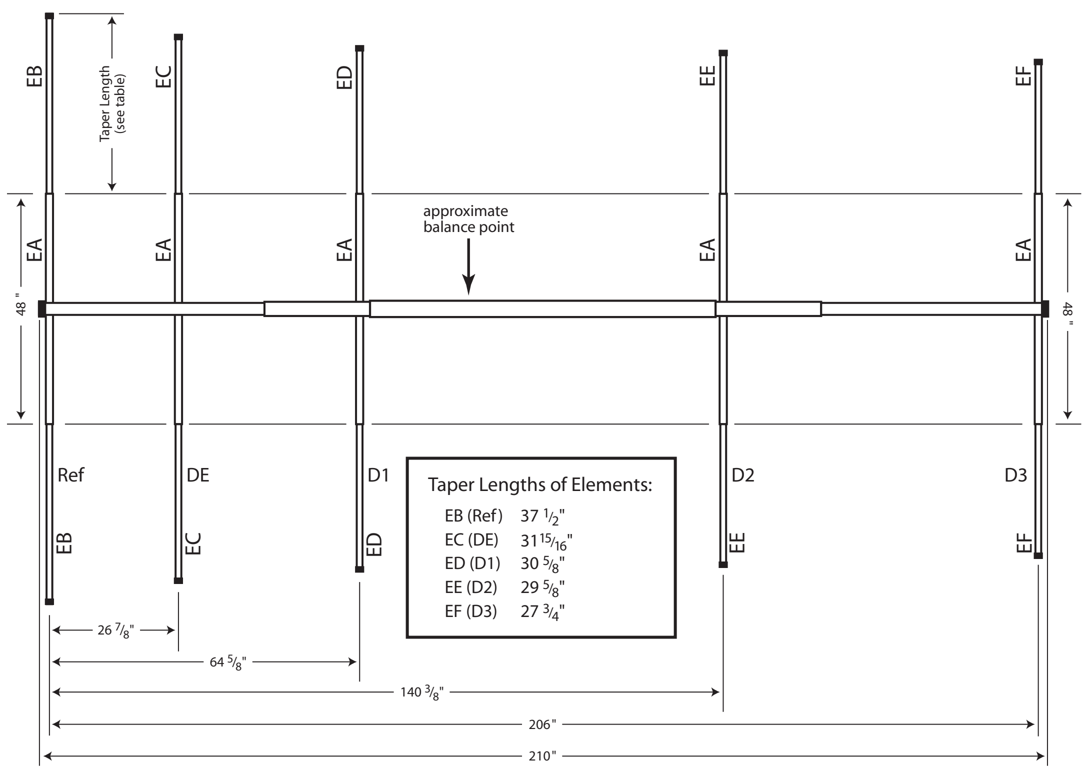


Figure 2: **Reassembled Antenna Dimensions**

Antenna Reassembly

Mounting the Elements to the Boom

Referring to Figure 2, attach the length-adjusted elements to the new boom according to the dimensions shown. *Use anti-seize compound on all U-bolt threads and nuts.* See the sidebar Thread Galling in Stainless Steel Fasteners, page 2, for more information.

Take note of the following requirements:

- All elements must be exactly perpendicular to the boom.
- All elements must lie in the same plane.

Accomplishing both these requirements usually takes some cut-and-try. The best procedure: Tighten each U-bolt clamp enough to produce some friction with the boom, but not so much that the element can't be moved with a little effort.

Because the gamma match is attached to the underside of the Driven Element, the most common approach is to assemble the antenna upside-down, with the elements resting on top of the boom and the gamma match protruding upwards. Assembling the antenna on a flat surface (like a concrete patio, driveway, or garage floor) helps keep the elements in the same plane while they're being attached and tightened.

Remove the boom end caps *before* mounting the elements, and attach the Reflector and Third Director such that the element center-lines are exactly 2" from the ends of the boom. (Note that the center-to-center distance from Reflector to Third Director is 206", while the length of the boom assembly is 210".) Then, measuring from the Reflector, attach the other elements.

Once all the elements have been attached and their spacing has been double-checked, start tightening them down one at a time, checking (and adjusting if necessary) the perpendicularity and planarity of each element. The U-bolts should hold the elements securely, but don't over-tighten the nuts. The boom tubing should not be visibly deformed by the tightened U-bolts.

After all the elements are finally tightened, you can push the end caps onto the boom ends as far as they will go.

Mounting the Boom-to-Mast Clamp

The mast must be attached to the boom at the antenna's *balance point* to minimize side-load stresses on the mast and rotator. Because of its element placement, the balance point for this antenna is not at the center of the boom. Determine the balance point experimentally by suspending the antenna clear of the ground at various locations along the boom. When the balance point is found, mark it clearly on the boom. It should be approximately at the location shown in Figure 2.(1)

Support the antenna by placing equal-size blocks or spacers under the elements so the antenna is flat and parallel to the ground, and the boom is elevated above ground by a foot or so.

1. Another consideration when mounting long yagis to a mast is *wind load asymmetry*—that is, the rotational torques created by wind blowing on the "aft" portion of the boom versus the "forward" portion of the boom. When a yagi is not mounted at the center of its boom, these torques are out of balance, and a rotational moment will be exerted on the rotator. While understanding this principle, I concluded after a bit of number-crunching that the antenna presented small enough a wind profile that this small net torque wouldn't create any problems, even with a lightweight non-braking rotator like the Yaesu G-450A. Experience with the antenna since its erection in wind gusts up to 60 MPH has borne this out.

Prepare the U-bolts by applying anti-seize compound to all threads, and loosely attach the clamp plate to the boom. Using a carpenter's level, make the boom-to-mast clamp vertical while aligning its center-line with the balance point marked on the boom. Tighten the U-bolt nuts evenly.

The U-bolts provided with the Cushcraft boom-to-mast clamp are just large enough to accommodate the new 1½" boom center section, so you will get an even better fit with the new boom than with the original one.

Final Assembly and Tune-Up

The antenna can be tuned up in one of two ways:

- If you have a crank-up tower or some other way to elevate the antenna at least 20 feet above ground after each adjustment, you can tune the antenna in the normal horizontal position.
- If this is impossible or inconvenient, secure the antenna with non-conductive supports so that it is pointing straight up at the sky. The Reflector must be supported at least a foot above ground on a non-conductive object like a wooden chair or box, and the antenna should be well clear of any surrounding objects. (This is the method I used, and it worked extremely well.)

Tuning Tips

I applied an MFJ-259B Antenna Analyzer to the task of tweaking the antenna for best match and minimum reactance at the feed point.

There are three adjustments performed on a gamma-matched yagi's Driven Element that determine the balance of input resistance and inductive/capacitive reactance:

- The point on the Driven Element where the gamma rod shorting strap (Cushcraft item 69) is positioned. Refer to Figure 3, page 7.
- The amount of series capacitance presented by the coaxial capacitor built into the gamma rod. This is a function of the distance between the near end of the gamma tube (Cushcraft item **RM**) and the feed point—2 13/16" in the figure. Refer again to Figure 3. The shorter this dimension, the more series capacitance, and vice-versa.
- The length of the Driven Element. Refer to the taper length table in Figure 2.

The gamma match dimensions found to be ideal for a design frequency of 50.125 MHz are given here. The length of the Driven Element was shortened somewhat from the original design length provided by the computer model. The experimentally optimized Driven Element outer section taper length is reflected in Figure 2.

If there is a "logical" way of juggling these three adjustments with the MFJ-259B, I've never learned about it. In practice, all three of these variables were tweaked until the best combination was found. It took my partner and I about three hours of painstaking cut-and-try to come up with these dimensions, which in the end produced an ideal match—50Ω pure resistance, 0Ω reactance, at the design frequency.

NOTE: *Do not change the length of any of the four parasitic elements, or change the boom position of any of the five elements.*

You should at least start out constructing the antenna and gamma match using these dimensions. I have disassembled and reassembled this antenna in a different location since making these adjustments, and the reassembled yagi showed exactly the same flat resonance and 1:1 SWR that it had before it was taken apart. This is a good indication that the electrical properties of the antenna can be recreated during reassembly just by following the dimensions carefully.

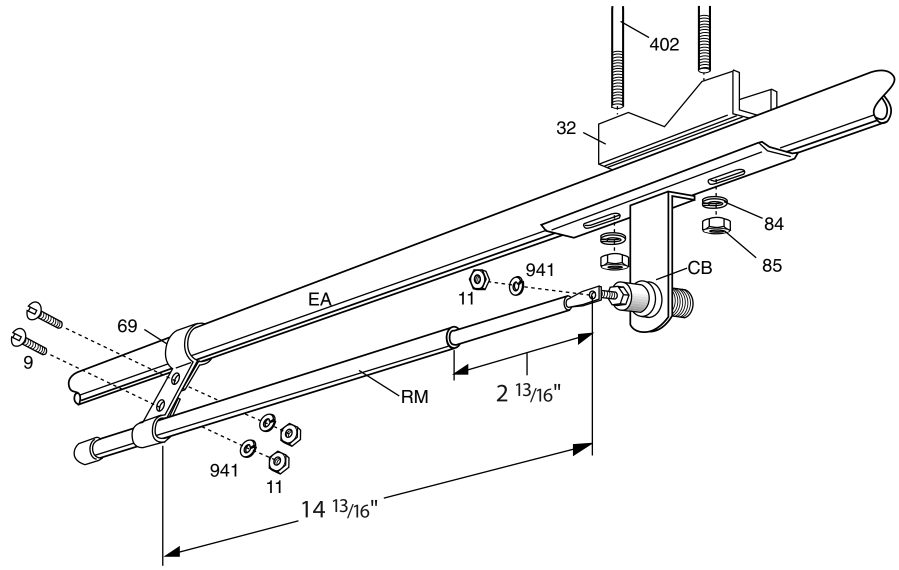


Figure 3: **Gamma Match Configuration Showing Adjustment Dimensions**

If the tuning of the antenna seems different after you put it up to its full operating height, then something was detuning it when it was in its “tune-up” position. You may want to do some more tweaking. How many times you’re willing to pull it down to tweak it, and put it back up to check it, is a function of how much of a perfectionist you are. At 50 MHz, though, assuming your rig is able to load fully into the antenna, any reasonable SWR (< 2.0:1) will not degrade your actual on-air performance in any way you can measure or hear.

At least, that’s what the engineers tell us. As for me, I’ll peak and tweak to get my antenna into perfect resonance every time.

How the Design Was Optimized

K6STI’s well-known Yagi Optimizer (YO) software, v7.58, was used to model and optimize the antenna design.(1)

I began by examining the A50-5S model that comes with YO 7.58. It seemed fairly nominal in terms of its setup parameters and trade-off settings (equal weighting applied to gain, front-to-rear, and SWR), so I decided to leave it as-is and change only the height-above-ground parameter. I set this for 32 ft., the height at which my antenna was mounted. This would give me a rough idea of what my radiation pattern should actually look like, assuming level terrain.

Azimuth and elevation field strength plots for both the original and modified antennas are shown in Figure 4 through Figure 7. A summary of the comparative parameters appears in Table 1.

1. Sadly, I’ve been told that K6STI no longer markets or supports this software.

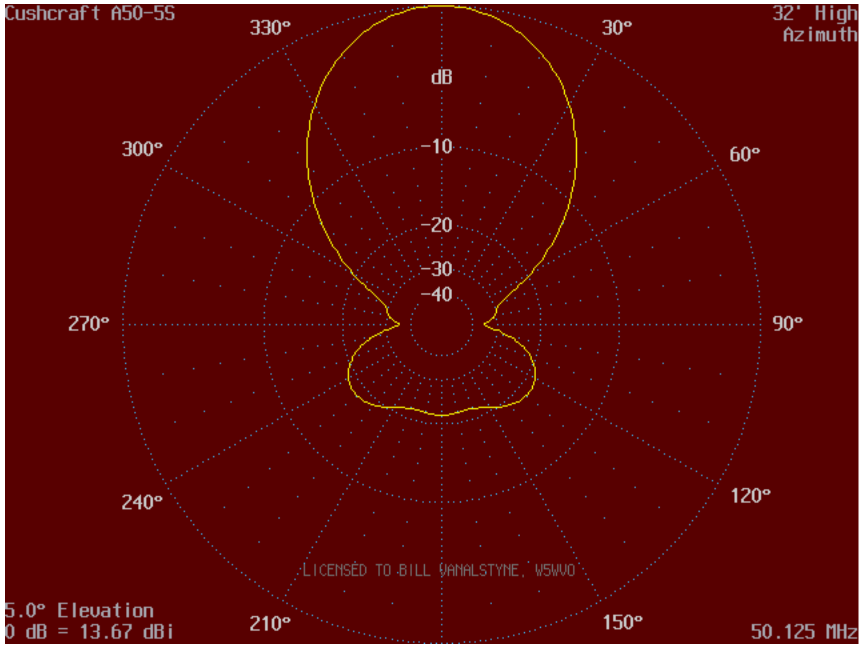


Figure 4: **Stock A50-5S Azimuth Plot**

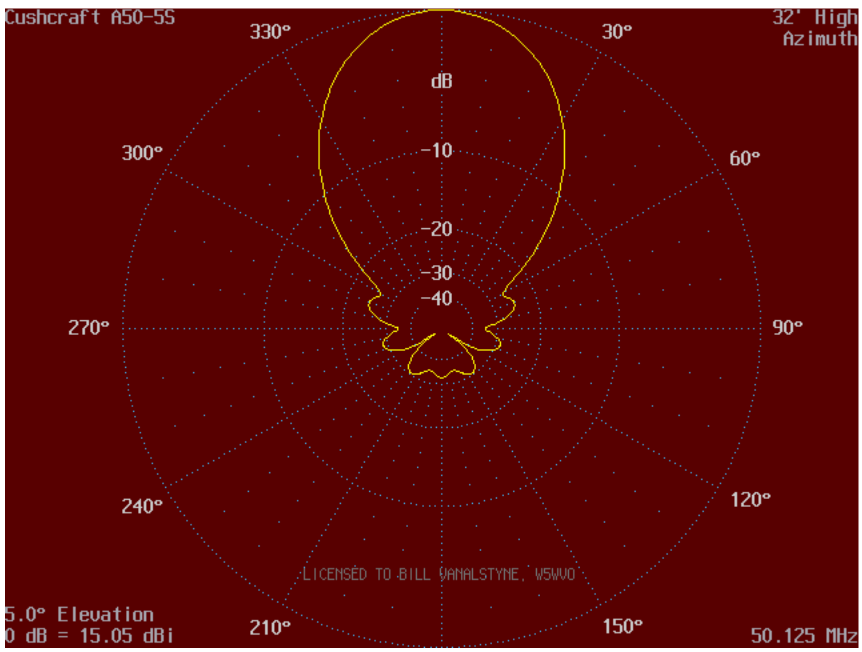


Figure 5: **Modified A50-5S Azimuth Plot**

Table 1: **Comparative Parameters from the YO Computer Models**

	Forward Gain(1)	Front-to-Rear Ratio(2)	Input Z	–3dB Beamwidth
Stock A50-5S (12′)	13.67 dBi	18.22 dB	31.5 – j5.2	54°
Modified (17.5′)	15.05 dBi	28.67 dB	15.7 – j0.4	46°

Notes:
1. Antenna at 32′ above ground. 5° elevation main lobe.
2. Front-to-rear ratio computed as average from 180° to 90° azimuth.

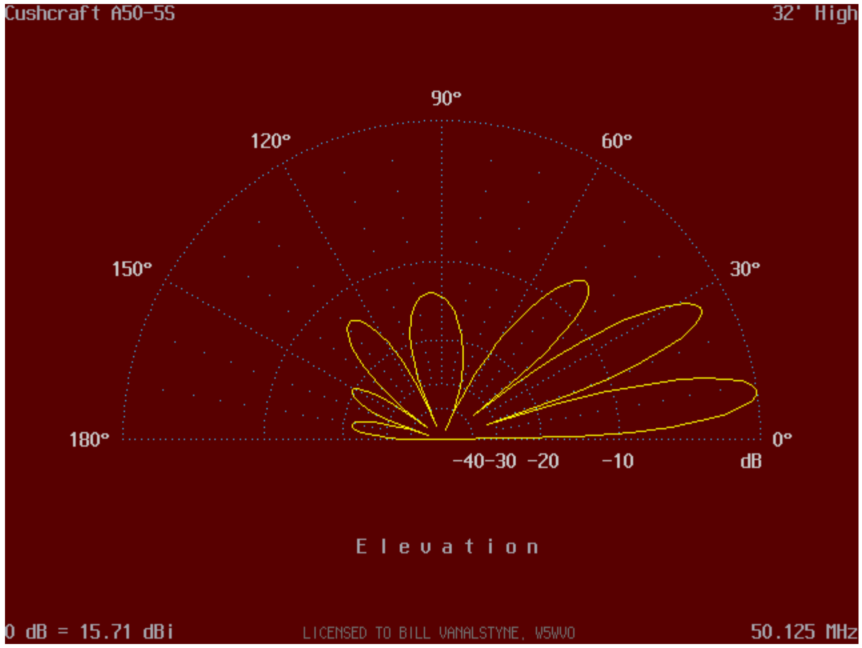


Figure 6: **Stock A50-5S Elevation Plot**

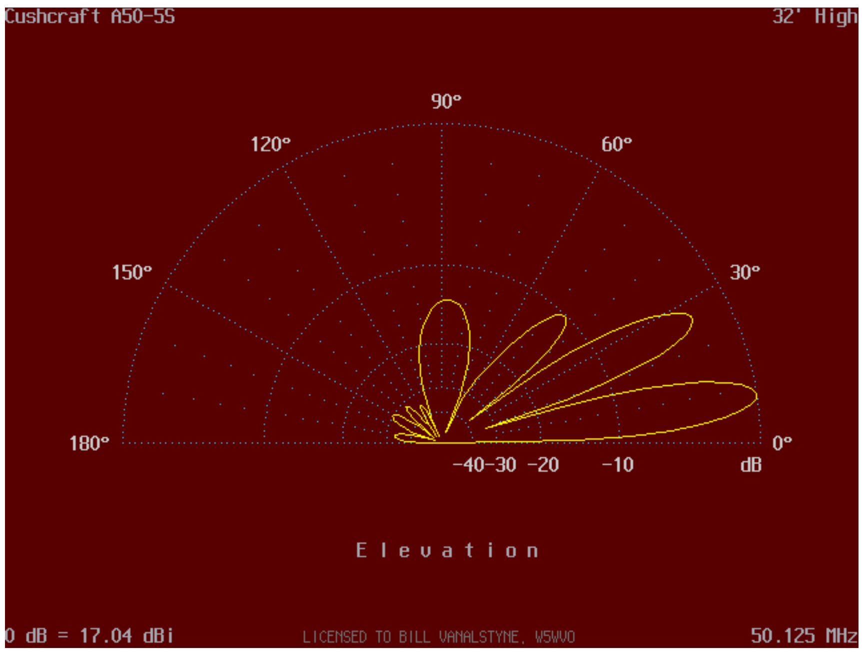


Figure 7: **Modified A50-5S Elevation Plot**

Future Enhancement—A Better Matching System?

Theoretically, the gamma match is a compromise any way you look at it. Because the Driven Element is excited off-center, common-mode currents can develop in the boom and coaxial feedline, and from there can be propagated to the mast, rotator control cable, etc.

This should be considered a practical fault, however, only if these currents cause an operational problem, such as RF feedback, RF in the shack, matching difficulties, severe pattern distortion, etc. [(1)]

Nevertheless, a properly constructed T-match or a hair-pin match would provide a balanced, centered feed to the Driven Element, eliminating the possibility of common-mode currents and the need for an RF choke in the feedline. Both these balanced matching systems are discussed in the *ARRL Antenna Book*.

On-the-Air Measurements and Performance

In terms of the design criteria discussed at the beginning of this paper, I certainly can't say that I can *hear* the extra dB-and-a-half of forward gain—but the antenna beamwidth "feels" sharper than it used to, and the front-to-rear appears to be every bit as impressive as the numbers and plots indicate it should be.

That said, doing meaningful on-the-air antenna measurement work here in Albuquerque is difficult. We live in the shadow of a 10,000-foot radio wave reflector called Sandia Crest. Local signals coming from the east have to climb over it; signals coming from the west bounce off of it. I can get a pretty reasonable local test path, however, by working with a station to the north or south of me.

Front-to-Rear Ratio

On-air checks were performed on two antennas modified according to this paper. The checks indicated that the front-to-back ratio is very close to that predicted by the computer model, with results in the range of 25–32 dB. These measurements were all made at 180° from the forward azimuth bearing of the test signals; no averaged 90°-180° front-to-rear assessments, as modeled by the YO software, have yet been made.

Forward Gain

Side-by-side forward gain comparisons between a modified and an unmodified A50-5S haven't been possible as yet, but forward gain appears to be at least as good as before the modification was done.

Physical Survivability

The antenna recently experienced a day of unusually high winds gusting in excess of 60 MPH with no damage to or rotation of elements on the boom.

Further Reports

If you do this modification project, please send a report of your experiences and on-air performance to the author at w5wvo@cybermesa.net.

1. I took preemptive action against these possibilities by installing a Radio Works T-4-Plus line isolator (RF choke) in the feedline right at the yagi's feed point. (This line isolator had not yet been installed when the photo on the first page was taken.) The T-4-Plus is specified to provide in excess of 4,000Ω of common-mode impedance at 50 MHz. I have had no problems with common-mode currents.

Revision History

The following table shows the revision history for this document.

Date	Version	Revision
10/29/03	1.0	Initial release.
11/24/03	1.1	• Table 1, page 8: Corrected –3 dB beamwidth numbers to 54° and 46° respectively. • Section On-the-Air Measurements and Performance, page 10: Revised and extended to provide more test data.
05/08/05	2.0	• Figure 2, page 4: Modified taper length of Driven Element. • Figure 3, page 7: Deleted "original" 50-5S gamma match illustration and added current dimensions to new illustration. • Revised and extended section Tuning Tips, page 6. • Minor copyedits throughout.
03/24/07	2.1	• Revised section Element Length, page 3 to warn that outer element tubing sections are not all the same length.
03/27/07	2.2	• Expanded section Element Length, page 3 to detail two potential problems with the Reflector element length. • Added footnote regarding availability of YO software. • Added reference to McMaster-Carr as a source for replacement U-bolts. • Updated format.