Building UHF Yagis — A Practical Approach

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W6PQL treats us to a detailed photo essay on how he builds his well-designed UHF Yagi antennas.

The method of construction described here can be used on most UHF Yagis, and is especially useful for the 70, 33 and 23 cm bands. I make all my antennas with hand tools, hardware store aluminum and a simple common-sense process. I'll be describing the construction of a single Yagi, the basic building block for more complex arrays of multiple Yagis, such as the one shown in Figure 1.

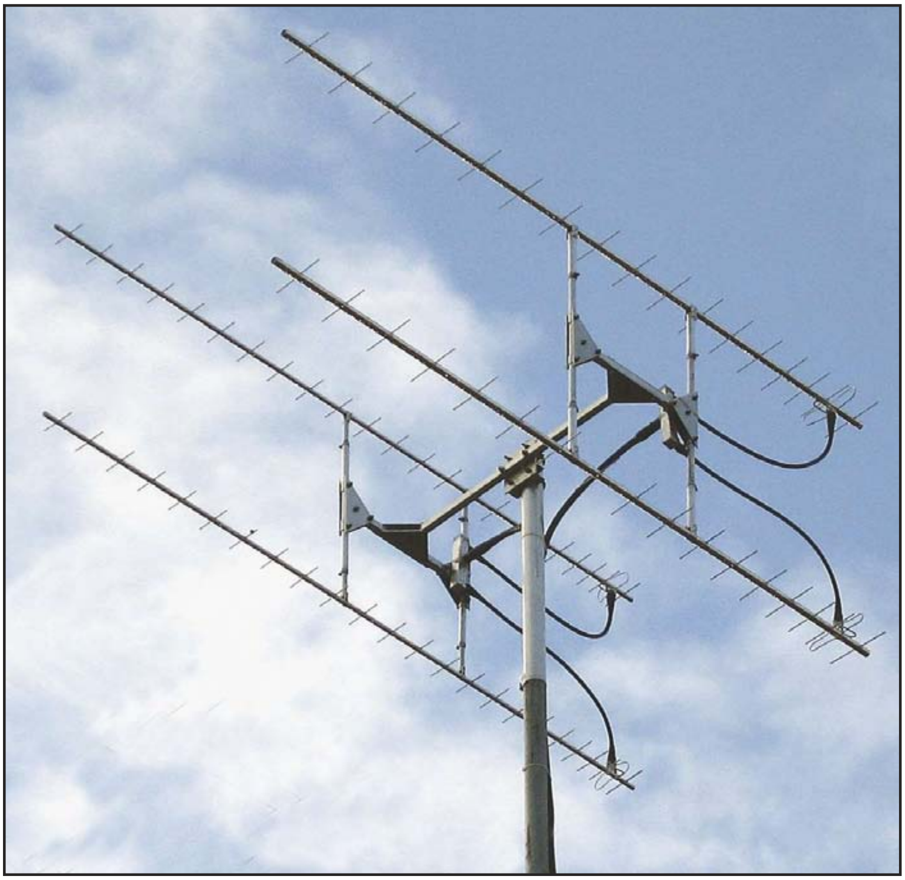


Figure 1 — Yagi pairs for 23 and 33 cm on 6-foot booms.

Freeware Tools

I like to use the DL6WU wideband Yagi designs whenever possible. A good design tool for this is the *Yagi Calculator* written by VK5DJ.[1] Figure 2A shows a printout I used for a 23 cm DL6WU Yagi built on a boom made from ½ inch outside diameter (OD) aluminum tubing with 0.058 inch thick walls. Figure 2B shows the radiation pattern for a 24 element 1296 MHz design. I also used the calculator to design several other antennas for 70, 33 and 23 cm. After building them, I tested them on an antenna range and found that the measured performance was very close to the expected results.

You'll need to know a few things before running *Yagi Calculator*, such as:

- operating frequency
- boom diameter
- element diameter
- number of directors
- are directors in direct contact with the boom or not?
- driven element diameter
- dipole gap at the feed point
- dipole height (for folded dipoles)
- balun design

You may have to change the number of directors to get the gain and beamwidth you want, or to fill up a given boom length. Armed with the information produced from the calculator, you can proceed to the next step.

Figure 3 shows all of the parasitic elements I prepared for four 23 cm Yagis on 48 inch booms that I used in a beacon array. It does help to organize the elements like this prior to attachment to the boom!

For material, I usually use ⅛ inch aluminum welding rod. It is inexpensive, easily cut to size with wire or bolt cutters and holds up well in weather. Once cut to size, you should trim the ends flat with a file.

I designed these antennas for full metal-to-metal contact between the boom and the parasitic elements. Be certain to keep that in mind when designing an antenna with whichever calculator you use.[2]

Drilling Straight Holes in a Round Boom

If you ever tried drilling straight holes through a round boom with hand tools, you probably wound up with elements sticking out of the boom in many different directions. It can be very frustrating trying to keep everything in a straight plane, but with the right method it can be easily done. Prepare the boom by cutting it to the proper length.

- Using a laundry marker, mark the end of the boom on opposite sides as shown in Figure 4. The tubing on the right is the piece you are working on.
- Tape the boom securely to a marking guide, positioning one of the end marks so that it almost touches the guide. I used another piece of tubing as a guide, but you can use almost anything that is straight, even a piece of wood.
- Place the tip of your marker in the joint between the boom and the guide, and mark a line down the entire length of the

[1]Notes appear on page 31.

boom. See Figure 5. You will probably need to tape the boom to the guide in several places to prevent the marker from forcing the boom away from the guide.

- Untape the boom from the guide. Rotate the boom to the opposite side using the other locating mark you made at the end of the boom as a reference. Retape the boom to the guide and mark a line down this side also.
- Now that you have both lines drawn, place tick marks on the lines (both sides of the boom) where the holes for the parasitic elements must be drilled. Measure from the end of the boom to each mark to elim-

ELEMENT LENGTHS AND SPACING
Reflector
118 mm long at boom position = 30 mm

Radiator
Single dipole 106 mm tip to tip at boom posn =75 mm
Folded dipole 108 mm tip to tip at boom posn =75 mm

Dir (no.)	Length (mm)	Spaced (mm)	Boom position (mm)	Gain (dBd)	Gain (dBi)
1	103	17	92	6.1	8.3
2	102	41	133	7.3	9.5
3	101	49	182	8.4	10.6
4	100	57	239	9.3	11.5
5	99	64	303	10.1	12.3
6	98	68	371	10.8	13.0
7	97	72	442	11.4	13.6
8	96	75	517	11.9	14.1
9	95	78	596	12.4	14.6
10	94	82	677	12.9	15.0
11	94	85	762	13.3	15.4
12	93	87	850	13.6	15.8
13	93	89	938	14.0	16.1
14	92	90	1028	14.3	16.4
15	92	91	1119	14.6	16.7
16	91	91	1210	14.8	17.0

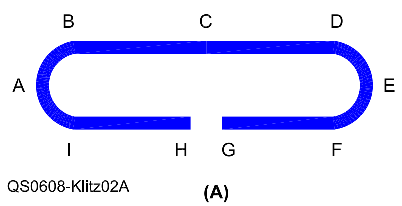
Director spacings are measured from the previous element
Tolerance for element lengths is +/- 1 mm

Boom position is the mounting point for each element as measured from the rear of the boom and includes the 30 mm overhang.The total boom length is 1240 mm including two overhangs

A half wave 4:1 balun uses 0.70 velocity factor RG-141 (PTFE) and is 79 mm long plus leads

Here are some construction details for a folded dipole

Measurements are taken from the inside of bends
Folded dipole length measured tip to tip = 108mm
Total rod length =236mm
Centre of rod=118mm
Distance HI=GF=32mm
Distance HA=GE=55mm
Distance HB=GD=79mm
Distance HC=GC=118mm
Gap at HG=15mm
Bend diameter BI=DF=30mm



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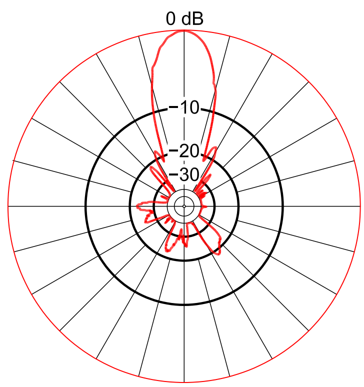
(A)

Gain estimated for E-Plane beamwidth and sidelobe levels ~ 16 dBd



(B)

Half Power Beamwidth = 22.7°
Front to Back Ratio = 25 dB
E-Plane

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Figure 2 — At A, portion of a printout from VK5DJ's *Yagi Calculator*. At B, polar pattern for 24 element DL6WU Yagi at 1296 MHz.

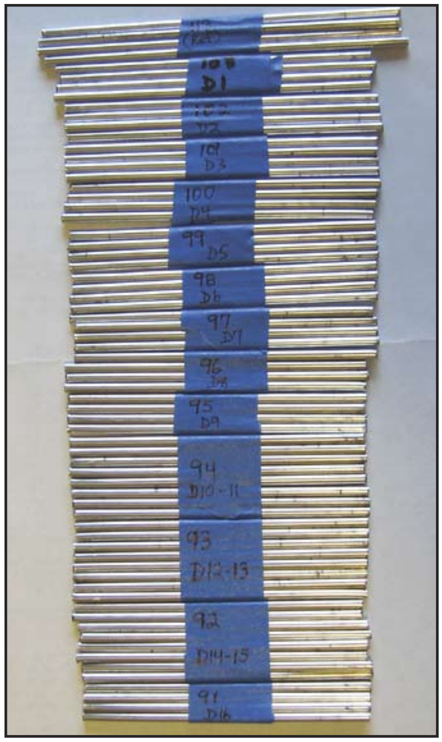

Figure 3 — Lineup of welding rod elements for four 23 cm Yagis, ready to be installed on booms.

Figure 4 — Setting up two aluminum booms for marking down the middle.

inate cumulative errors. See Figure 6.

- Finally, use a center punch to prep the locations (both sides) that will be drilled for the parasitic elements. If you are using ⅛ inch diameter elements, use a ⅛ inch drill bit.
- Drill the holes one side at a time. A common mistake is to drill all the way through the boom in one pass. This will almost always result in crooked elements unless you are using a drill press, and even then it's difficult to do properly that way.

Fastening the Elements to the Boom

- Hold the boom in a small vise as shown in Figure 7.
- Insert and center an element into the boom, beginning with the reflector. Use a small hammer and tap it through gently.
- Using a center punch, stake the boom next to the element in two places, preferably opposite one another. Stake the boom at a 45º angle toward the element as shown on the right, and at the 10:30 and 4:30 positions. See Figure 8 for a detail of what the staking dimples should look like.
- Stake the element on the other side of the boom as well.
- Attach the rest of the elements in a like manner.

If you did a good job with your humble hand tools, your antenna should look something like Figure 9.

You may find an element or two out of alignment with the others as you sight down the boom. It never goes perfectly. So, to adjust an element, grasp the end and bend it slightly to put it in alignment with the others. Looking closely, you might notice a slight "zig" in the alignment of the reflector on this antenna. I bent this into position after discovering it was just out of alignment with the first director. These small adjustments will not affect the performance of the antenna.

If you live in an environment in which corrosion is a problem (by the ocean, for example), a dab of latex paint covering the boom-to-element joints can be helpful, and will not detune the antenna.

Figure 5 — Marking two aluminum booms, using each as a guide for marking the other down the middle.

Figure 6 — One of the booms after marking.

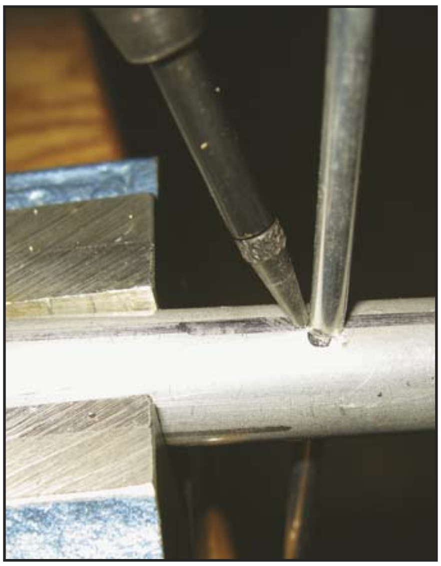

Figure 7 — "Dimpling" the boom to capture each element.

Figure 8 — Close-up of boom dimpling.

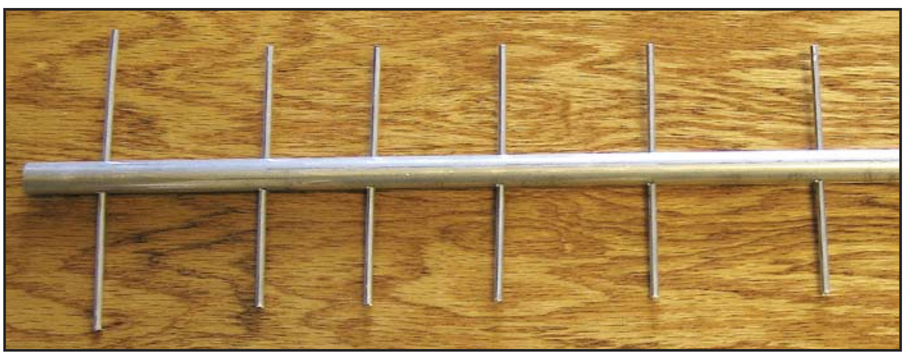

Figure 9 — Photo of Yagi with reflector and director elements installed.

Building the Driven Element

See Figure 10 for a view of the parts used in the driven element. You will need:

- One chassis-mount style N connector (at least two opposing mounting holes are needed), with Teflon insulation (not plastic).
- Two ½ to ¾ inch aluminum or brass spacers.
- 12 gauge copper wire for the folded dipole.
- A piece of UT-141 semi-rigid coax for the ½ λ balun.

The smooth part of a screwdriver handle makes a good form for bending both the balun and the dipole element. I usually wrap the barrel and threads of the N connector with several layers of paper, and hold it in a small vise. The paper protects the threads and slows heat loss to the vise while soldering.

Solder the shield of the UT-141 coax balun to the connector as shown in the close-up photo in Figure 11. Tin the solder cup of the N connector's center pin, and solder one end of the driven element dipole into it. Making a small bend into the cup with the wire is helpful.

Last, bend the center conductors of the balun under and around the ends of the dipole and solder as shown. Be careful to leave a small gap between the outer conductor of the balun and the ends of the dipole (about 2 mm).

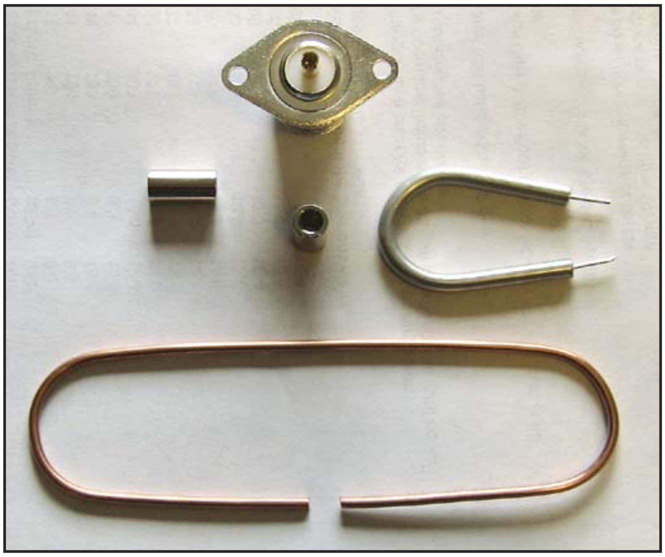

Figure 10 — Parts used to make folded dipole driven element.

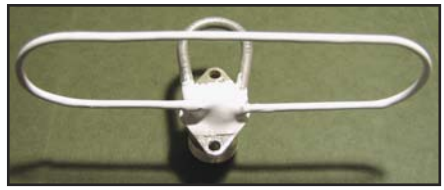

Figure 14 — Driven element after painting.

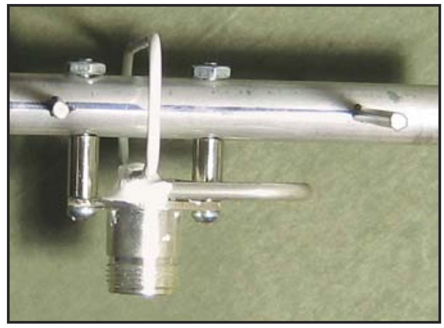

Figure 15 — Side view of the driven element mounted to the boom with spacers.

Figure 11 — Close-up of semi-rigid UT-141 coax used to make balun. It is connected to a Type N connector and the folded dipole driven element.

Figure 12 — Another view of the completed driven element.

Figure 13 — Close-up of the driven element showing epoxy used as weather protection.

Figure 16 — Side view of the finished Yagi. Note the element alignment

Your driven element should now look like Figure 12. Apply a generous coat of epoxy to the connections for strength and weatherproofing. See Figure 13. Not all epoxies are created equal, so be certain to test a cured lump in a microwave oven before using it on your antenna. Place your epoxy sample next to a cup of water in the microwave and cook for 30 seconds. If the epoxy becomes hot, try another brand. Just warm is okay. Apply a coat of white latex paint to cover the epoxy seal and the copper dipole. See Figure 14.

All that is left to do now is mount the driven element to the boom. For this I used ½ inch aluminum spacers and 6-32 machine screws. See Figure 15. Make certain you have the dipole placed at the correct distances from the reflector and first director before drilling the mounting holes in the boom.

Figure 16 shows the completed 4 foot boom antenna, held by my wife (this is as much of her as she would allow me to photograph). You may not need to tweak anything to minimize the SWR, but if you do need to, the SWR is affected by the shape or height of the folded dipole. You can also bend the ends of the folded dipole toward or away from the reflector as an additional adjustment. You should be able to get the SWR down below 1.2:1 at mid band and below 1.5:1 at the band edges.

Notes

[1]VK5DJ's Yagi calculator is available on his Web page at **vk5dj.mountgambier.org/Amateur_radio.html**.

[2]This is also discussed in detail in *The ARRL Antenna Book*. See p 18-30 and 18-31 in the 20th Edition. Available from the ARRL Bookstore for $39.95 plus shipping. Order number 9485. Telephone 860-594-0355 or toll-free in the US at 888-277-5289; **www.arrl.org/shop/**, **pubsales@arrl.org**.

Jim Klitzing, W6PQL, was first licensed in 1964 as WB6MYC. He has been a metrologist for both the US Air Force and Hewlett-Packard Company. He also designed, manufactured and sold a line of solid state VHF/UHF linear amplifiers. He is currently manager of engineering services at Agilent Laboratories in Palo Alto, California. Jim has always enjoyed building his own equipment, even going as far as making a 40 meter kW SSB/CW transceiver as well as various VHF through microwave transverters, amplifiers and test equipment. Currently antennas are his main interest. You can reach the author at 38105 Paseo Padre Ct, Fremont, CA 94536; **qrz@w6pql.com**.