9 Element Yagi for 2304 MHz

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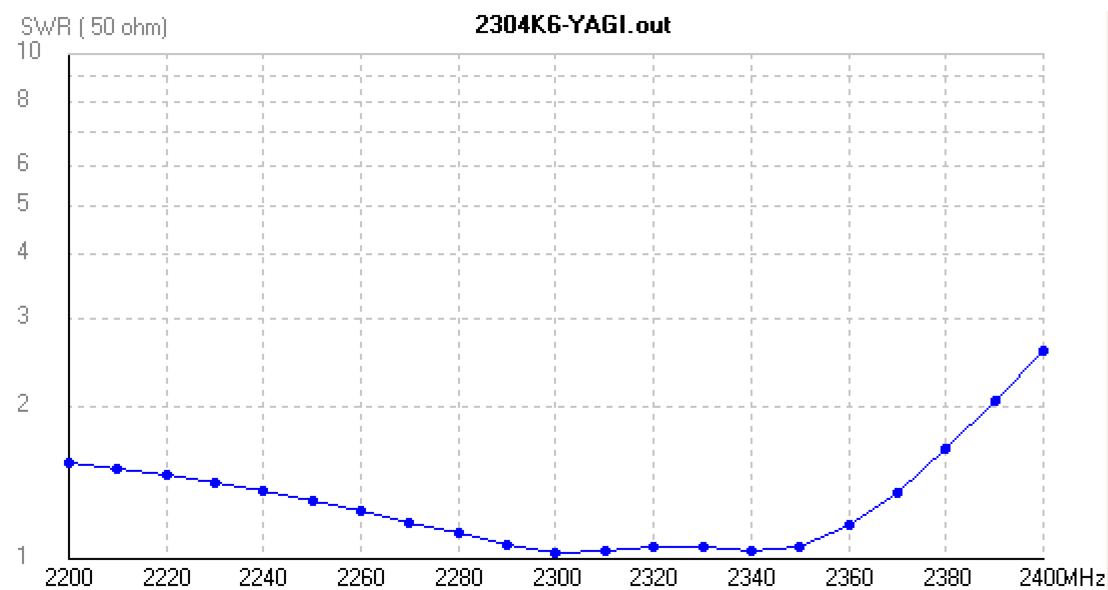
Design

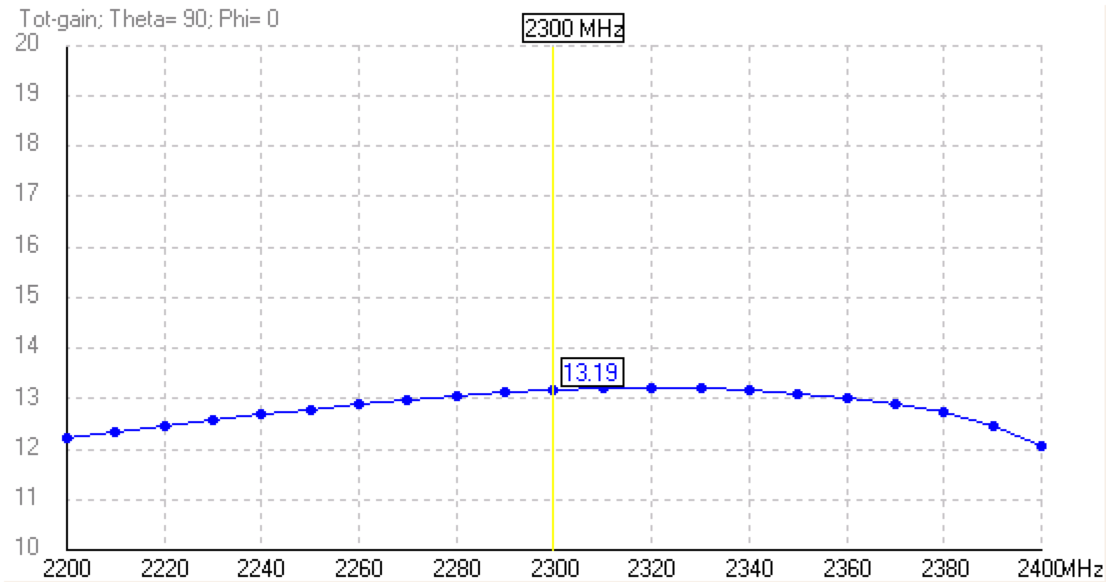
Dipole-based Yagi designs for 2304 MHz are rare, partly because they are a bit tricky to build and partly because the loop yagi has completely dominated this band in North America. There are a few 2320 MHz Yagi designs around from Europe. Wimo makes them commercially for the amateur market. An additional factor in popularity is the possible advantage loop yagis have in resistance to detuning from rain.

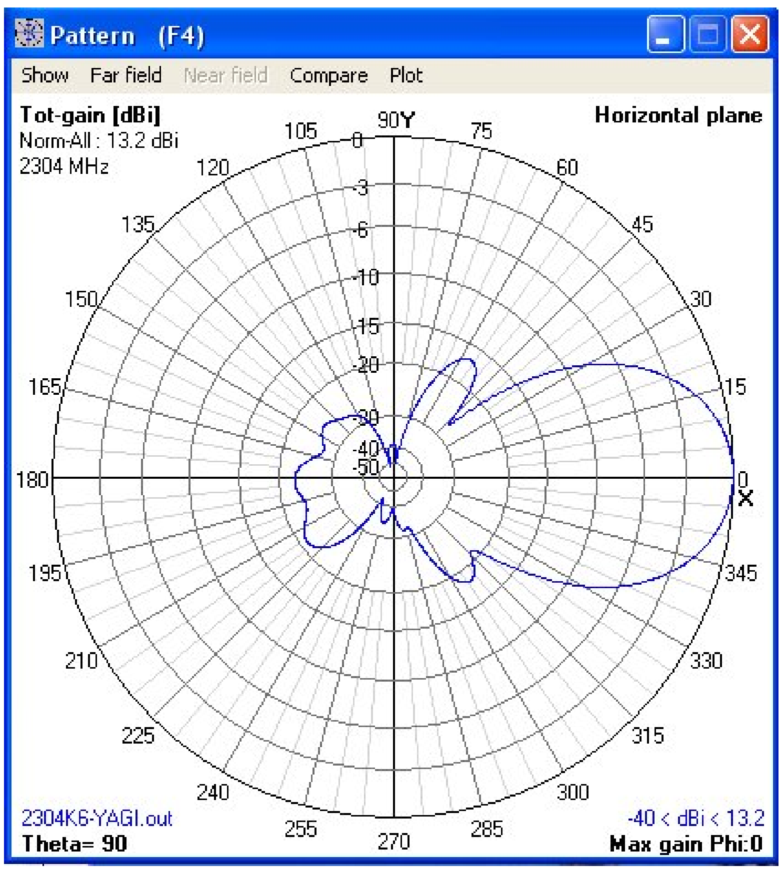
I wanted to design a small antenna for contest rover operation, for working local stations without having to put up a big antenna which would overwhelm my small car. I optimized a design using the NEC2 based simulation software 4NEC2 by Arne Voors, which can be downloaded free from the internet. This incorporates some features which are unusual in Yagi designs for the lower microwave bands

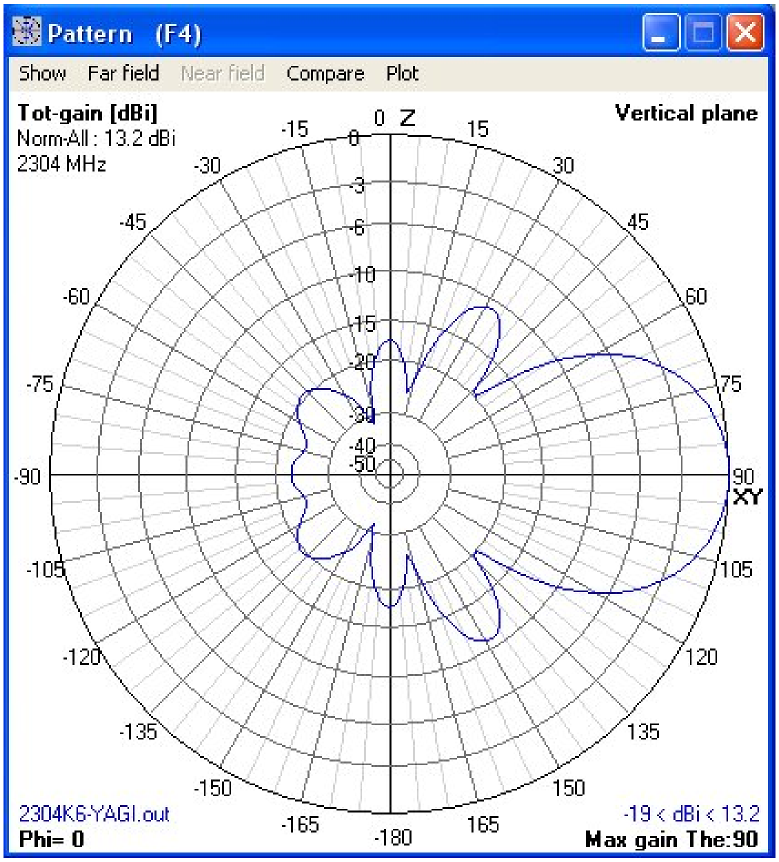
- The driven element is a centre-fed dipole (most designs use folded dipoles or loops).
- It has a wood boom.
- There is no explicit balun; the combination of the feed coax and the reflector element form a rudimentary balun to minimize current on the feedline behind the reflector.

The 4NEC2 model shows very low SWR (less than 1.1) from 2290-2350 MHz and a fairly flat gain with a peak of about 13.2 dBi a little above 2304 MHz (assuming perfectly conducting elements). When modelled using YA (from Brian Beezley, K6STI) the SWR is not as low but is around 1.3 or less from 2300-2340 MHz. I decided this was good enough and proceeded to build the antenna. The following plots show the predicted performance (SWR, gain and patterns for horizontal polarization) from 4NEC2.



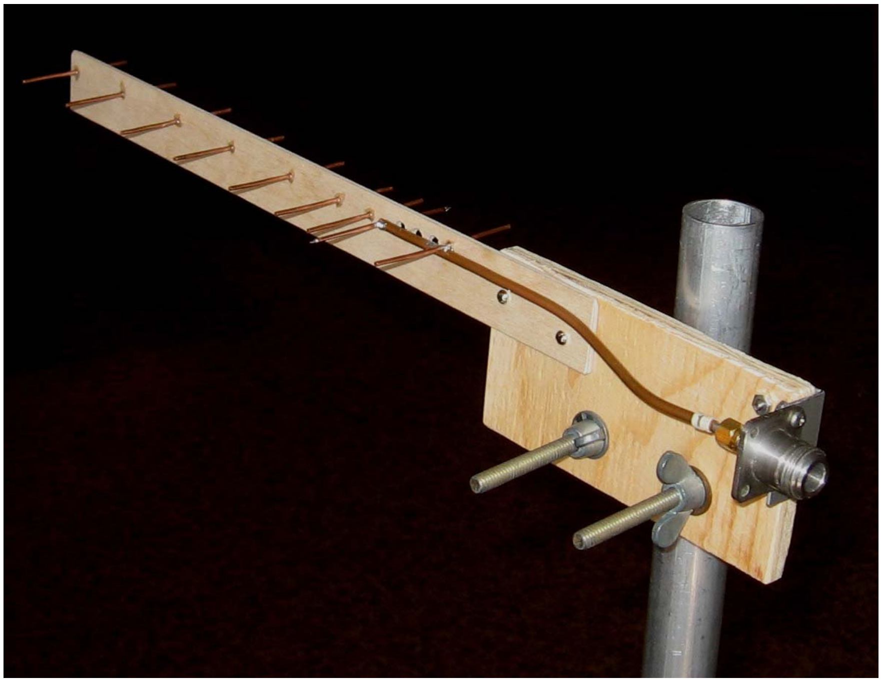

Tot-gain; Theta= 90; Phi= 0
2300 MHz
13.19
20
19
18
17
16
15
14
13
12
11
10
2200
2220
2240
2260
2280
2300
2320
2340
2360
2380
2400MHz


Pattern (F4)
Show
Far field
Near field
Compare
Plot
Tot-gain [dBi]
Norm-All : 13.2 dBi
2304 MHz
Horizontal plane
90Y
X
2304K6-YAGI.out
Theta= 90
-40 < dBi < 13.2
Max gain Phi:0



<u>Construction</u>

The following photo shows the assembled (but not quite finished) antenna.

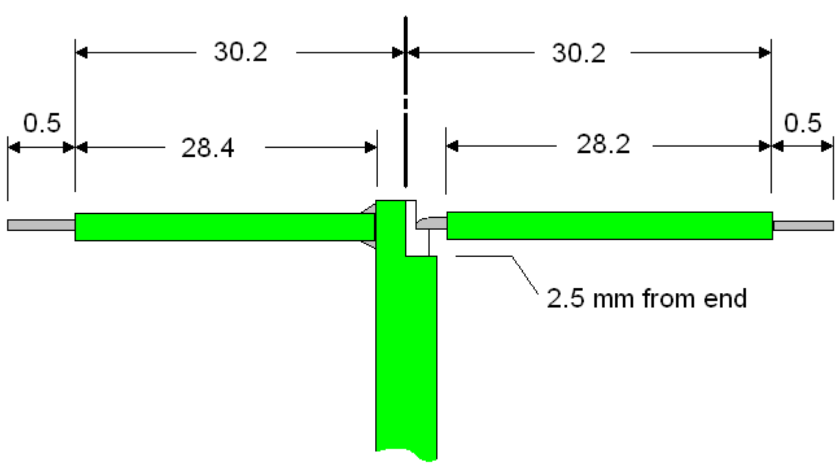


The boom is made from 1/8 inch plywood (cut to 1 x 12 inches) which I found at a craft supply store (Michael's). 1/16" diameter holes are drilled to take the elements (which have to be opened out a bit to take the parasitic elements, by pushing the drill bit against the sides of the holes). Three additional holes were drilled in the boom to reduce the loading effect of the wood on the feedline (forming part of the balun) between the driven element and the reflector. The boom is bolted at one end to a piece of thicker plywood which provides a location for the mast clamp and to mount the connector.

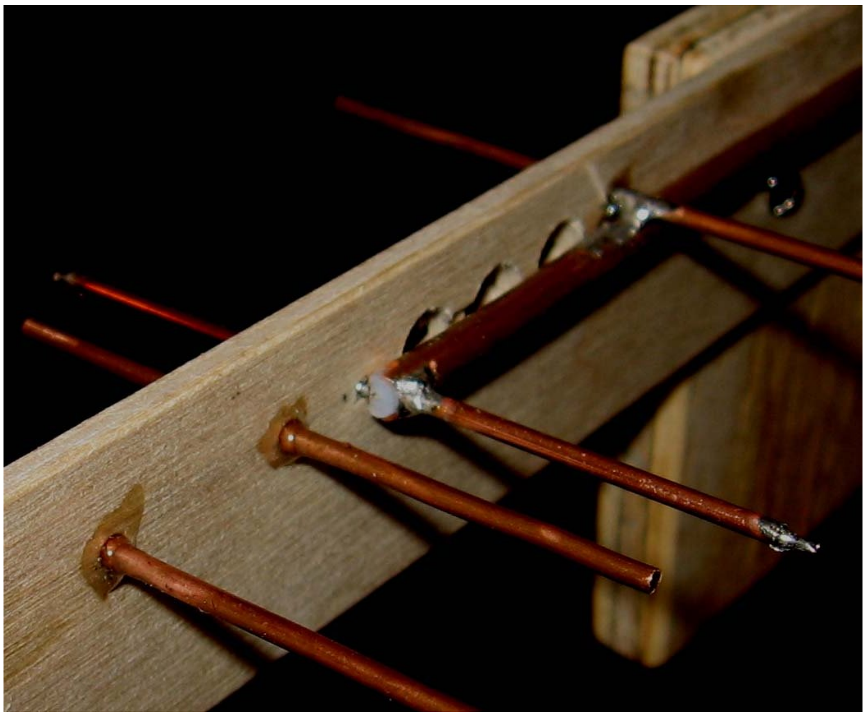
The parasitic elements are made from #14 AWG (1.63 mm diameter) bare copper wire, with the ends filed flat to adjust the lengths within about 0.03 mm of the dimensions given below, using a dial or digital caliper the check the length. The wire tends to bend while filing so it is useful to have a couple of steel plates handy for rolling the wire straight again when this happens. The reflector is filed about halfway though at the centre using a small round file about the same diameter as the 0.141" semi-rigid coax feedline. The element positions and lengths are given in the following table. These are the values used in the 4NEC2 model but with a length correction to account for the elements being solid rather than thin-wall tubing, which necessitates a reduction in length to take into account the capacitance of the ends of the elements. Probably there should be a "boom correction" for the reflector, but I did not take this additional step.

Element	**Position (mm)**	**Length (mm)**
Reflector	0 (offset 1.8 mm upwards)	60.6
Driven Element	32.5	60.4
Director 1	40.8	52.8
Director 2	58.0	53.6
Director 3	85.9	52.2
Director 4	121.8	51.2
Director 5	157.1	52.0
Director 6	195.3	52.4
Director 7	229.6	50.4

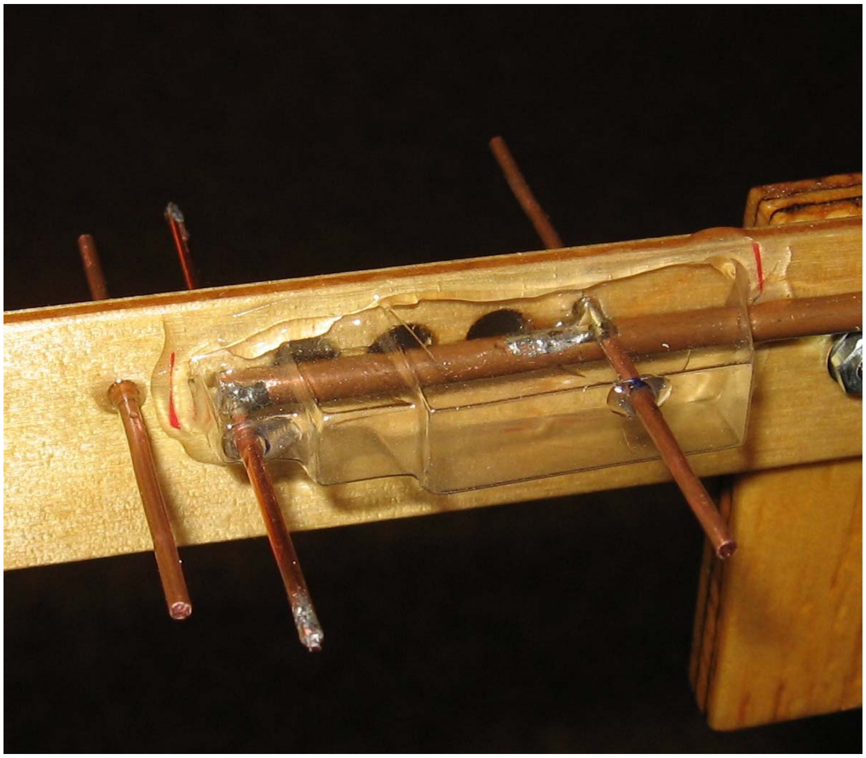
The driven element, reflector and feedline are assembled as a unit as follows. First the 0.141" semi-rigid (RG-402/U or UT-141) feed coax is prepared. The piece I used had an SMA plug on one end, requiring the use of an adapter to get a rugged N-type interface. At the other end cut the shield off about 10 mm from the end (dimension is not critical). This can be done by deeply scoring around the shield with a knife and then breaking off the shield, or with a small saw. Also cut the insulation flush with the cut end of the shield. Now, file the shield off over one half of the circumference of the cable, for a length of about 2.5 mm. With a sharp knife slice off a piece of the insulation so the inner conductor can be bent over as shown in the following sketch.



The driven element is made up of two pieces of brass tubing (1/16" O.D., 0.014" wall, made by K&L and available in good hobby shops) as shown in the sketch. One piece is slipped over the bent inner conductor and soldered in place while the other is soldered to the coax shield on the opposite side. I ended up needing to tune the driven element a bit to get the best match. The final version has pieces of #21 AWG (0.7 mm diameter) wire soldered into the outer ends of the tubing, protruding about 0.5 mm on each side. This is an odd wire size – I used some clipped off component leads. #20 wire should fit and give about the same results. The reflector is soldered to the feedline (with the filed out indentation against the coax) 32.5 mm from the driven element (measured between the centres of the two elements). The following photo shows a close-up of the feed assembly.



The feed assembly is positioned with the driven element half connected to the inner conductor pushed through the hole in the boom. This way the hole does not have to accommodate the large blob of solder on the other side of the coax. You will probably have to open out the reflector hole in the boom as the chances of getting the spacing of the holes and the spacing between the driven element and reflector exactly the same is pretty low. Once all the elements are inserted in their respective holes in the boom they are held in place with glue (I used 5 minute epoxy). I did not epoxy the coax side of the driven element. The directors are all offset a bit (compared to being centred on the boom) so that they are centred with respect to the feed coax. Some additional epoxy was used to hold the coax to the rear of the boom, enabling the coax to contribute significantly to the boom stiffness. The wood parts were given a couple of coats of varnish. Finally, the feedpoint and the holes in the boom were weatherproofed (hopefully !) by epoxying a piece cut from a blister pack over the driven element and reflector (with holes punched with a sharp point for those elements to pass through), and another small piece of flat plastic over the holes in the boom on the opposite side. The following photo shows the blister pack piece.



<u>Results</u>

I measured an SWR of about 1.3 at 2304 MHz (18 dB return loss). Adding the small wire inserts at the ends of the driven element brought the SWR down just slightly. This SWR is as predicted by YA, but not as good as predicted by 4NEC2.

Some very crude indoor range tests at 2304.1 MHz (in my living room !) indicate that the Yagi had about 5 dB gain over a tomato puree can horn, which seems about right. The horizontal plane -3 dB beamwidth was measured at 37 degrees, compared to 39 degrees from 4NEC2 and the beamwidth between the first pattern nulls was measured at 82 degrees, compared to 87 degrees from 4NEC2.