Portable 2 Meter Yagi

Design and build an economical directional 2 meter beam antenna.

What is a Yagi Antenna?

- Directional antenna invented by Shintaro Uda in 1926.

- Since Uda was "only" a student, the professor, Hidetsugu Yagi, gets most of the credit.

- The full name is Yagi-Uda Antenna, but it is most commonly known simply as a Yagi.

- Antenna consists of a driven element, which is a dipole configuration, and one or more parasitic elements, i.e. reflector(s) and director(s).
  - The reflector is electrically longer than the driven element
  - The director is electrically shorter than the driven element

A Little Theory (very little)

- The longer reflector element is slightly inductive in nature.
  - This results in a current lagging the induced voltage.
  - The lagging current causes destructive interference between the waves, reducing the radiated power in that direction.
  - When arranged in a coplanar manner, there is very little benefit to having multiple reflectors.
- The shorter director element is slightly capacitive in nature.
  - This results in a current leading the induced voltage.
  - The leading current results in constructive interference between the waves.
  - Multiple directors will increase gain and directionality.

Design Criteria

- Overall length about 4 feet.

- Portable and easily assembled with minimal tools.

- Resonant at the lower portion of the band, about 145 MHz.
  - As you will see, I missed by a little—more on that later.

- Inexpensive with the use of readily obtainable materials.
  - Estimated cost around $30 or 40, depending on how much is sourced from your stash of spare parts (collection of junk).

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Idea Genesis

- I got the idea watching a YouTube video with John Portune W6NBC talking about an easily constructed Yagi.

- Big takeaways from the video:
  - Use fiberglass rod and aluminum foil tape for elements.
  - You don't need complex math and modeling programs to come up with a successful design.
  - The National Bureau of Standards published a document on Yagi Design with graphical methods for Yagi design. Very little math and no computers!

NBS Technical Note 688 on Reflector Spacing
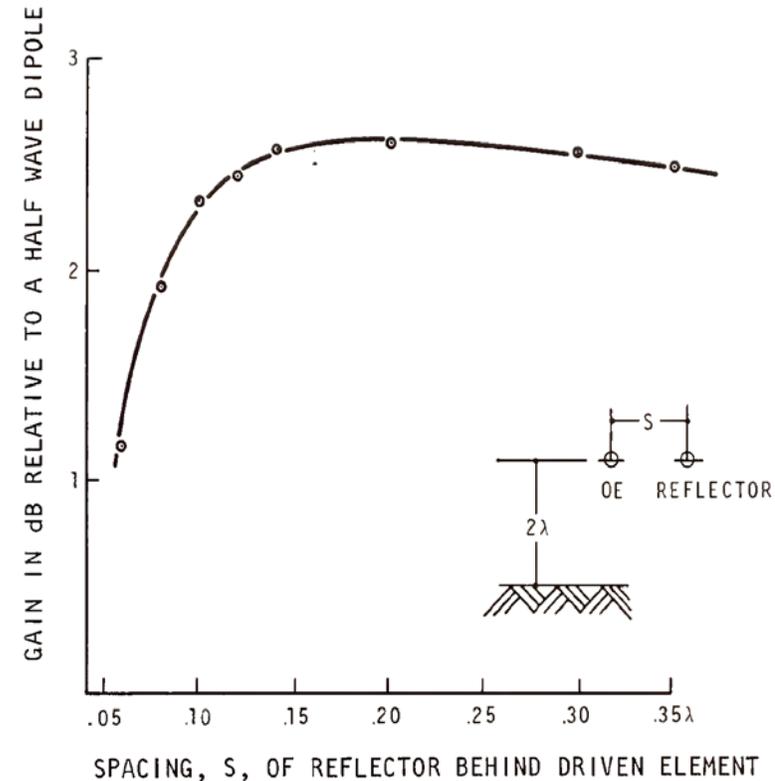
- Gain peaks at about 0.2λ reflector spacing

FIG. 1 GAIN IN dB OF A DIPOLE AND REFLECTOR FOR DIFFERENT SPACINGS BETWEEN ELEMENTS

NBS Technical Note 688 on Director Spacing

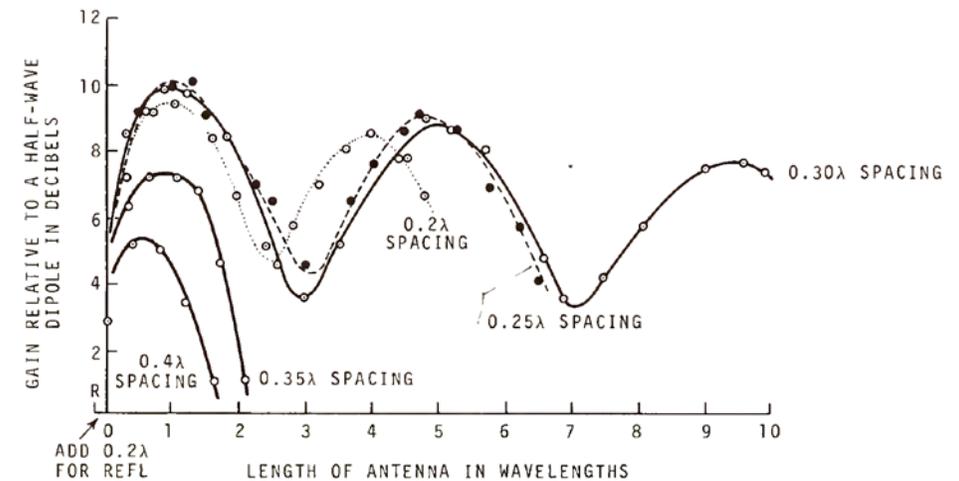- You can get pretty good results using 0.2λ spacing for directors too.

FIG. 6 GAIN OF A YAGI AS A FUNCTION OF LENGTH (NUMBER OF DIRECTORS) FOR DIFFERENT CONSTANT SPACINGS BETWEEN DIRECTORS OF LENGTH EQUAL TO 0.424λ

Simplified design criteria

- W6NBC simple design criteria:
  - Elements spaced evenly at 0.2λ
  - Reflector 5% longer than the driven element
  - Director(s) 5% shorter than the driven element
  - Use hairpin matching
- That's it!

Figure out the spacing

- Elements are to be spaced at 0.2λ.
  - Determine λ for the desired frequency (145 MHz).
  - λ = v/f
  - λ = 300 x 10^6 m/sec ÷ 145 x 10^6 Hz = 2.069 meters
  - 0.2λ = 0.2 x 2.069 meters = 0.414 meters
  - I prefer inches, so 0.414 meters x 39.37 inches/meter = 16.3 inches
- Space the elements at about 16.3 inches. 16 or 16-1/4 inches is going to be close enough.

Figure out the element length

- The driven element is just a dipole. A dipole should be $\lambda/2$ long. The actual length will be a little shorter than the calculated value.
  - From the previous calculation, λ = 2.069 meters.
  - $\lambda/2$ = 1.035 meters
  - Convert to inches 1.035 meters x 39.37 inches/meter = 40.7 inches
- The physical length will be less than the calculated length. The factor should be close to 90%, but I will use 95% to allow for trimming.
  - 40.7 inches x 95% = 38.67 inches. I will round up to 38-3/4 inches. You can always cut the element to make it shorter, but adding length is tough.
- Remember to make the reflector 5% longer!

# Materials

- (3) 5/16" diameter fiberglass driveway markers (Murdoch's) @ $3 each ➜ $9
- Roll aluminum foil tape 50 yard 2" x .003" (Harbor Freight) $7
- 8' 2 x 2 dimensional lumber (Home Depot) $3
- (2) 6-32 x 3/4" stainless steel screws, nuts, and washers $5 est.
- (2) crimp on ring lugs for 14-16 AWG (blue size) #6 screw.
- One or two feet of 12 or 14 AWG solid copper or aluminum wire for hairpin match
- Coax RG-8X or RG-58 and connector of your choice. It is a short run, so loss is not a major concern.

Construction Procedure

- Cut three elements to approximate length (about 100%, 95%, and 90% of λ/2).

- Wrap aluminum foil tape on each element.

- On the driven element, remove 1" of aluminum tape from the center.

- Drill two 0.140" diameter holes spaced 2" apart in the driven element. Use either a 9/64" or a number 28 drill bit.
  - Drilling perpendicular holes in a round rod can be difficult.
  - A drill press is highly recommended if you have access to one.

Wrapping Tape on Elements

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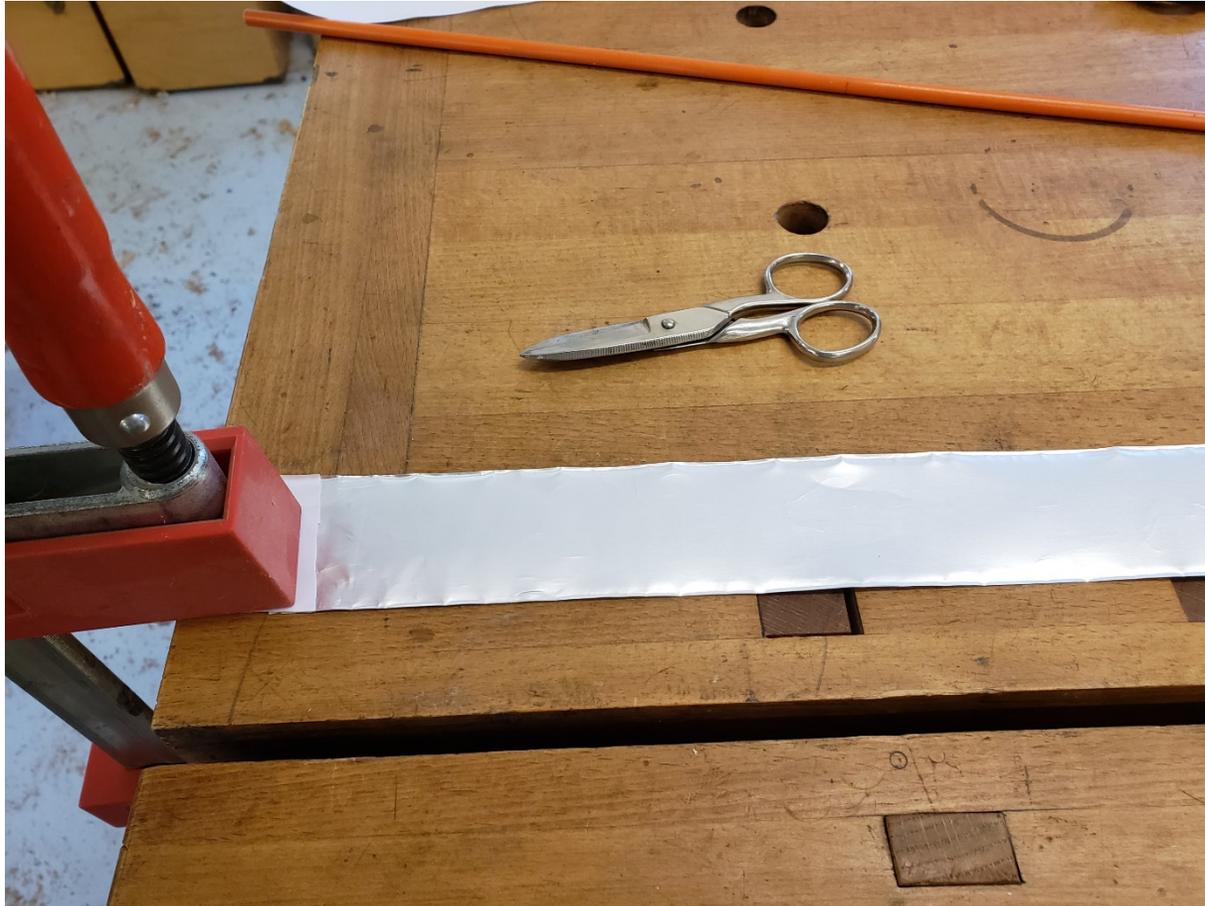
Driven Element Details

Drill Press Setup
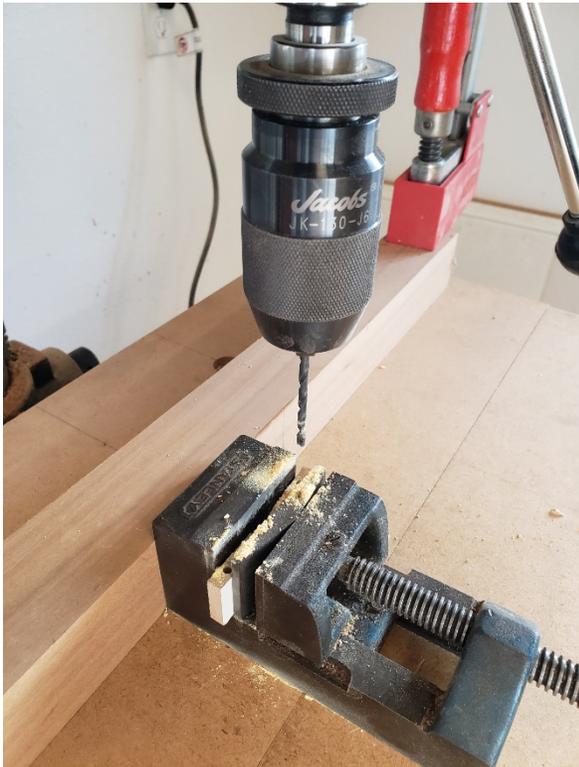

Holes in Driven Element

Mount Elements to Boom

- I wanted this to be portable, so I cut notches in the boom.

- I used heat-shrink tubing to mark the center and protect the aluminum tape.

- If you are building for station use, drill holes and fasten the elements with adhesive, e.g. RTV.

Feedline

- Strip the jacket from one end of the coaxial cable being careful not to nick the braid.

- Carefully "unbraid" the shield.

- I found a toothpick to be a useful tool for separating the braid.

- Prepare the cable to accept crimp lugs as shown in the photo.
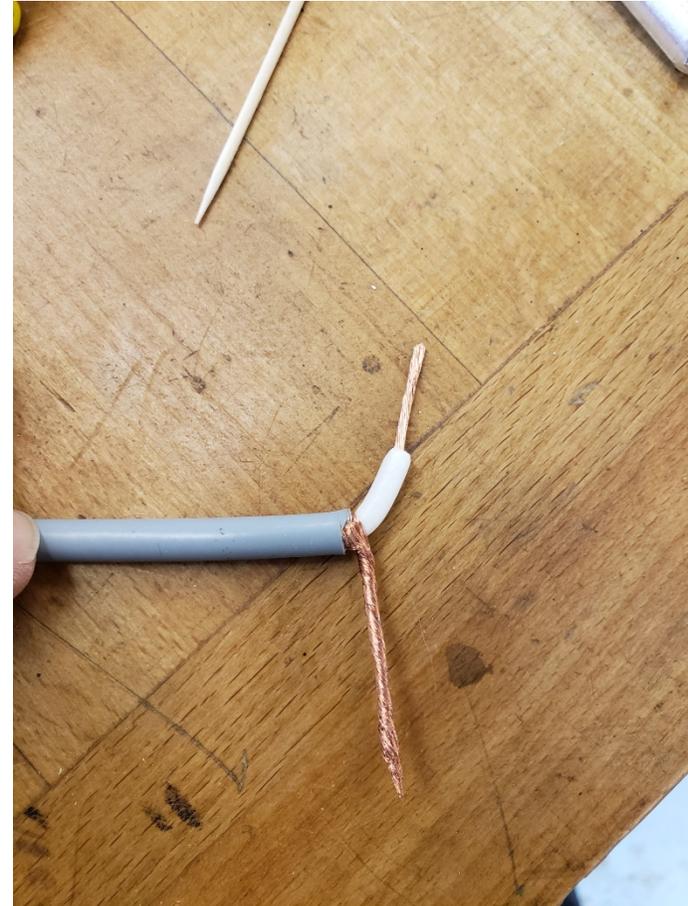
Feedpoint Detail

- Crimp lugs with #6 ring tongue on the feedline.

- If the antenna is for permanent installation, seal the ends of the feed line to prevent water ingress. Liquid electrical tape, Scotch 23 rubber tape, RTV sealant, etc. can be used.

Matching

- I used a "hairpin" matching stub as suggested in the John Portune article.

- The picture shows the matching section temporarily fastened so it could be adjusted for length.

- I found that it was not all that critical and ended up using a 2" wide x 3" long section.
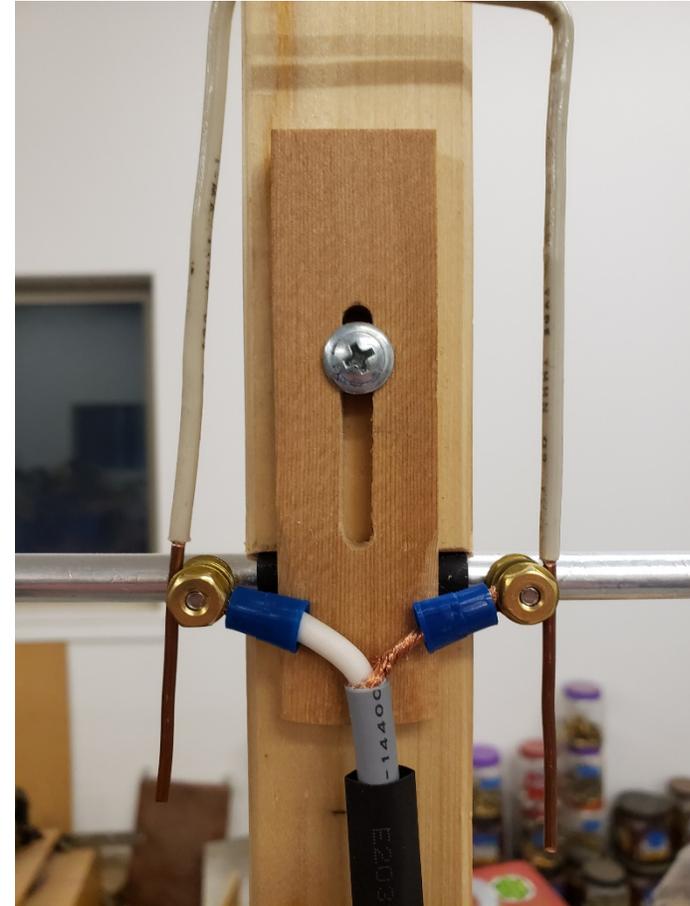
Hairpin Matching Stub

- Matching stub is #14 AWG copper

- This is a DC short circuit, but it has enough RF impedance in the 2 meter band to match the antenna impedance to the 50 ohm coaxial cable

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Trim the elements

- Using an antenna analyzer, trim the elements for desired frequency.
- I made the mistake of chasing the resonant frequency by trimming the driven element and not trimming the parasitic elements.
  - That's why best match is around 147 MHz
  - The parasitic elements have a greater effect than I thought.

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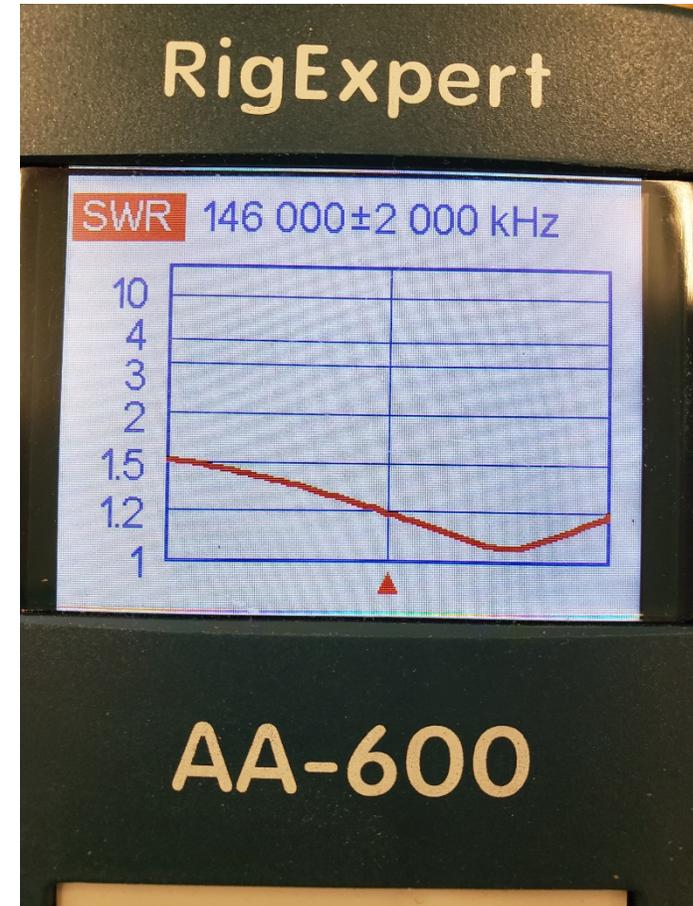
Completed Antenna Dissasembled

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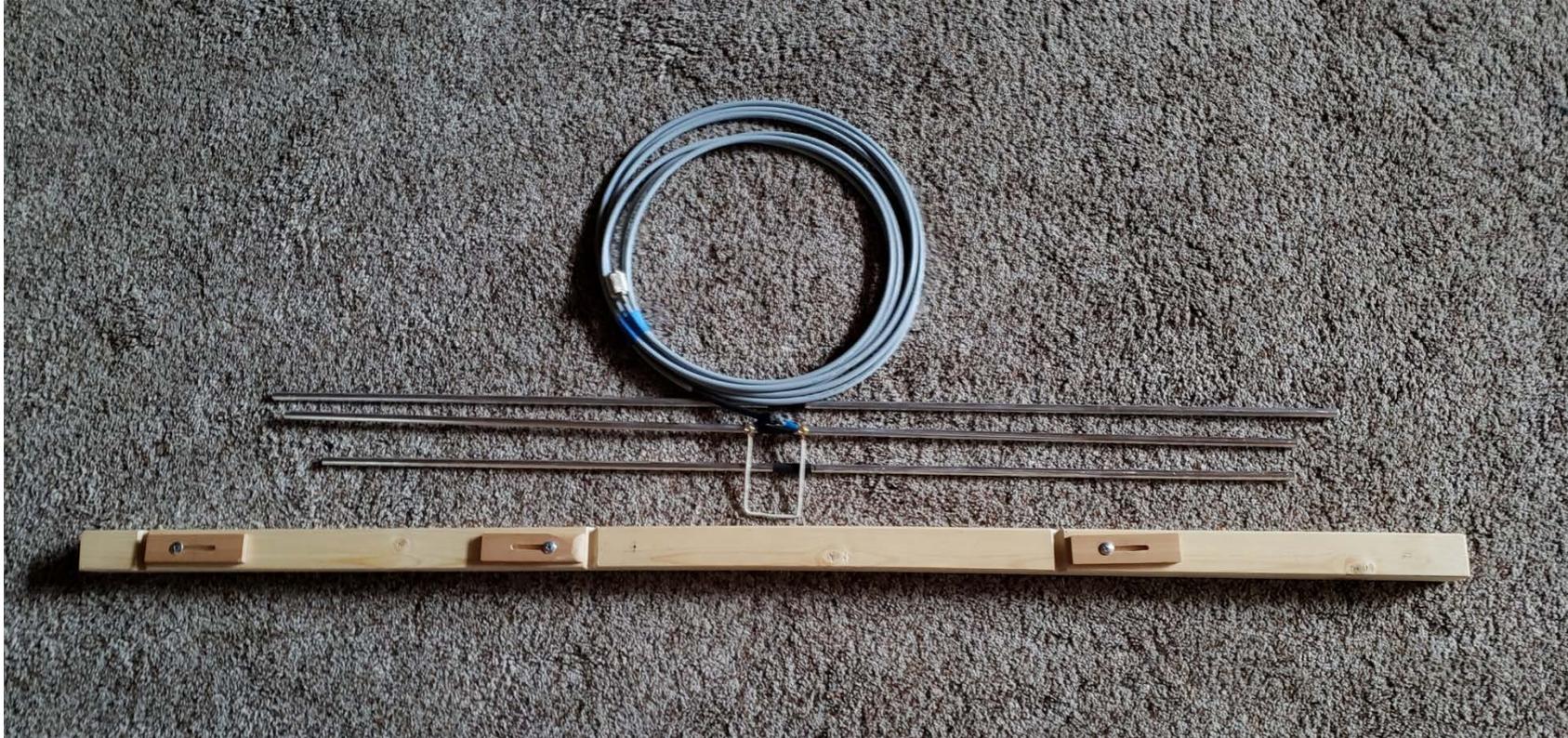
A Few Seconds Later. . . .

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Summary

- Designing and building a Yagi antenna is not that difficult.
- Space elements evenly at 0.2 λ.
- Make the reflector and director(s) 5% longer and 5% shorter respectively than the driven element.
- Impedance match before final trimming.
- Trim all the elements when adjusting frequency, not just the driven element.
- Proximity to ground and other objects makes a big difference in SWR and resonant frequency.

References

- John Portune video
  https://youtu.be/SKumu3twopc?si=dOGWm9XpRI73ba3V

- Yagi article in OTA Magazine January/February 2024 issue (requires ARRL membership to view).
  https://edition.pagesuite.com/html5/reader/production/default.aspx?pubname=&edid=5277f6f6-264a-4515-a057-c042539bb27d

- NBS 688 Yagi design document
  https://nvlpubs.nist.gov/nistpubs/Legacy/TN/nbstechnicalnote688.pdf