Subject: Simple Horn Telescope Base Construction Guide
Memo: 34, Revision 5
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Summary: Simple Horn Radio Telescope Base Construction Guide

A horn radio telescope is your key to discovering the Milky Way! The telescope has several parts, including radio frequency receiver, telescope base, computer electronics and software. Here we describe the latest telescope base design. We've significantly reduced the weight, size and complexity of the horn telescope base. Here we list construction steps for the base.

Background

The West Virginia University Radio Astronomy Instrumentation Lab (WVURAIL) is a leader in bringing radio astronomy to the public. Though their guidance, they enable everyone to discover the immense size of our Milky Way Galaxy. The WVURAIL team of teachers and engineers enable everyone to find their place in the galaxy. The appendix of this memo has links to more background info and is a starting point for your research.

The horn telescope construction is described in LightWork Memo 32., ***Gather a Pail of Milky Way***. The computer setup is described in the installation guide associated with the Raspberry Pi operating system, that you download for quick setup (note the operating system file is big, 2.3 GBytes).

Figure 1: Completed horn radio telescope. The total height of the telescope is about 3 feet (1m). The fixed part is white and the tilting part is brown.

Base Components

The base has two major components, *first*, a fixed, but hinged, component which supports the horn and covers the telescope computer. The *second* component tilts the horn in elevation, allowing quick changes in the pointing angle. See **Figure 1**. The tilting part is 10 inches wide and 13.5 inches long.

The fixed and tilting parts are made out of wood. Only very basic woodworking skills are need to build them. The wooden base components are listed in **Table 1.** You can use a hand saw for all cutting, but you will need an electric drill.

The metal parts are 1) 4 door hinges, 2) three 3in, 1/4in bolts, 3) three 1/4 inch wing nuts and 4) ten 2.5in wood screws. Note that there is great flexibility in making the base, if you have different size spare pieces of wood, you can redesign you own base. If you do, please document your construction and add to the Lightwork memo series! The wooden parts I'm using are shown in **Figure 2.** The red ruler is 4 ft long.

Figure 2: Wooden parts for horn base. The Red 4 foot ruler is for scale. The most expensive part is the 16 by 48 inch shelf, plus two short 2x4s and 2 balusters.

Steps for building the Fixed Base

The first step is painting the 16x48 inch shelf and the 2x4 boards. After these has dried, divide the shelf into three equal parts, each 16x16 inches square. Draw lines and use a hand saw to cut the parts. See **Figure 3**. You now have two sides and the bottom of the base.

Cut the 2x4 board into two 2 foot lengths. Discard the remainder. These are the base legs. Place the 2x4 pieces parallel, on the ground, and separated by 14 inches.

Center the bottom piece on top of the 2x4s, mark points two inches from the edges of the bottom. Use a 1/8 inch drill bit and drill holes through the bottom to the legs. Screw the bottom onto the legs, with two screws on each leg.

Now prepare to add the 4 hinges, which will hold the sides in place. See **Figure 4**. When standing, the sides must be separated by 10 inches. For commonly available shelfs, they are 3/4 inches thick. So mark the mid-point of the bottom and draw, parallel to the first lines two more parallel lines, separated by 5.75 inches from the midpoint of the bottom. The hinges will be separated by 11.5 inches.

These hinges allow the base to be folded flat, for storage.

Draw the Protractors on the Sides

When you're making observations, you must know, and record. the elevation of the telescope, so that we can calculate where the telescope is pointed. To make this easier, we usually only point the fixed base either due North or South. Then we pick different elevation directions for each observation. Often we leave the telescope outside for one whole day, recording the signals from the sky. The next day we pick a different elevation to complete our experiment. To measure our positions, we will drill holes in both sides of the base.

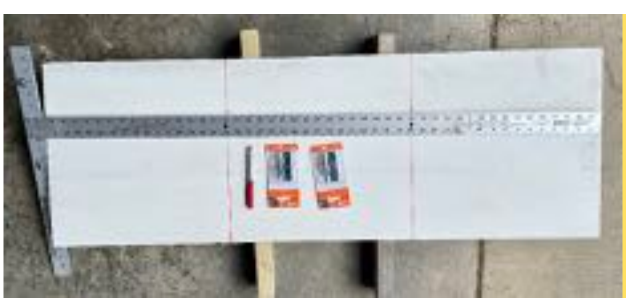


Figure 3: Prepare to cut painted shelf into 3. Draw two lines and cut with a hand saw. Door hinges are shown.

The first step is to measure the position where we will place the bolts that will act as hinges for the tilting part of the base. Measure 1 inch from the top of the sides and 3 inches from the front edge. Drill a small hole, with a 1/8 inch drill bit. This will be the reference point of the arc you will draw. We are creating a big protractor, a device for measuring angles. This drilled location, coordinate 0,0, is the reference point for measuring angles.

Now find a ruler and drill two holes separated by 21cm (8.25 inches), the wavelength of neutral hydrogen. Make one hole big enough to allow the end of a marker to reach through.   Then drill a wood screw through the other hole, attaching it to the marked spot on the side of the fixed base.   See Figure 5. Then use a marker to draw an arc on the side.

Next print the protractor template (at 100%!!!, don't shrink to fit) to easily mark every 10 degrees of elevation. The template is in the Appendix and also at the WVURAIL Elevation Template link.

Remove the ruler and tape the template to the side, with the zero point at the elevation axis.   Next drill holes on either side of the elevation, separated by 1/2 inch, markings, from 0 to 90 degrees, in 10 degree steps.   Use a 1/8 inch drill bit first. After drilling all these holes, then get a bigger, 5/16 or 3/8, drill bit and re-drill all holes.   We'll point our telescope to different elevations, using a 1/4 inch bolt, to set the elevation

Also re-drill the reference point with the 5/16 drill bit. You can drill these holes on the other side too, but one bolt is enough to hold the telescope elevation in place.   You must re-drill the reference hole, 0,0 on both sides, with the bigger drill bit.

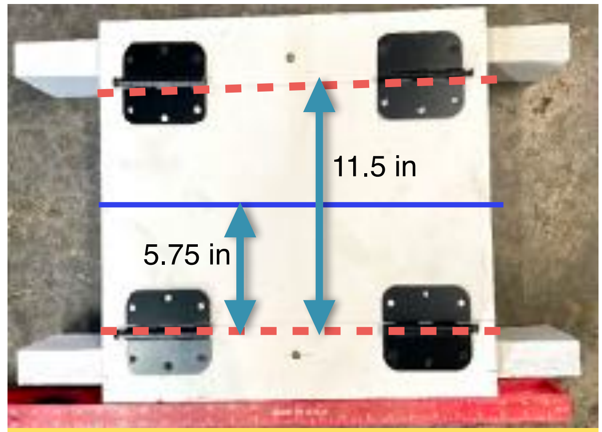


Figure 4: Placement of hinges on bottom. Measure from the center of the base 5.75 inches on either side, then attach hinges ***outside*** of these lines.

Figure 5: Make the protractors on one sides..The protractor template is taped in place and use an 1/8 inch drill bit to put two holes, separated by about a half inch.

Attach Sides to Hinges

The hinges usually come with screws. Align the sides with the front of the bottom. The sides should be inside the hinges on the base. Attach the first hinge with one screw on the front side of the base. The reference hole is in front of the sides. Then attach all the screws back hinge.   Complete this side by screwing the remaining screws to the front hinge.   Repeat for the other side.   When done, with the sides standing up, there should be 10 inches between the sides.

Build the Tilting Elevation Shelf

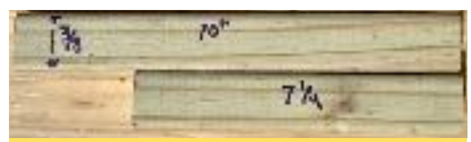
The metal radio telescope horn will be bolted to the tilting part of the base.   There are two common designs for the horn telescope, type A) with a rectangular (F-type) can and metal covered insulation sheets.   The other kind, type B), is built from two metal pails. These both have very similar sensitivity. This telescope tilt shelf design can accommodate either horn.

Figure 6: Cut the balusters into two 12 inch pieces and two 10 inch pieces.

For both types of horns, the side parts of the tilting shelf are 12 inches long, made from pressure treated balusters. (Balusters are used for the railings on steps and porches). These balusters are usually about 36 inches (1 m) long and are inexpensive (about $1.50 each, in 2024). Two balusters are needed, but you'll have plenty left over. See **Figure 6**. One cross piece is 10 inches long.   The 2nd cross piece is either 7.25 inches long, for type A) or 10 inches long for type B).

For both designs, drill 1/8 inch pilot holes 2 inches from the front of the side pieces.   Then drill a second hole 21cm from the first hole. The hole at 2 inches is for the elevation axis tilt. Then re-drill these holes with the 5/16 drill bit.   Make sure the 1/4 inch bolts easily slide into these holes.

For type A), can horn, cut the 2nd cross piece to 7.25 inches long. See **Figure 7**.



For type B), pail horn, we need to notch the cross pieces, so the pail will sit firmly in place. First mark the mid point of these cross pieces (at 5 inches) and hand saw 1/4 inch deep across the piece. Then mark 2.5 inches across the pieces on either side of the middle.

See **Figures 8 and 8.** The cutting can be done with a hand saw or a coping saw. It is not too hard, You'll have to experiment with the cutting. First cut across the board, then angle towards the center cut.

Figure 8: Profile of cuts to cross pieces.

The front cross piece is screwed to the sides with two 2.5 inch screws on each side. Pre-drill with the 1/8 inch bit, then screw in the wood screws. The balusters will crack if you do not pre-drill.

Figure 9: Hand saw the notch in the cross pieces.

For the type A) horn, the tilting shelf is flat, screw the rear cross piece in any place that is convenient, but make sure you do not cover up the hole for setting the elevation angle.

For the type B) horn, the rear cross piece is above the side pieces. This compensates for the fact that the pail is bigger on the top and the bottom, so the elevation axis will read approximately correct. With this base design, you should be able to set the elevation angle to within 1 to 2 degrees accuracy.

Figure 10: Pail Horn with tilting shelf. The pail will be bolted onto the front and rear pieces

Figure 11: The completed base with pail horn (type B) attached. Note the bolts are used as hinges for the angle reference and a 3rd bold is used to set the elevation angle. Oni, my dog and mascot, is enjoying the observations.

Conclusion

I hope you've found it is easy to build a horn radio telescope base. Because this base allows you to easily set the telescope pointing directions, I hope you can discover features of our Milky Way Galaxy.

Your horn telescope and software are sensitive enough to see our Galaxy. With 10 minutes of observations you can start to discover our galaxy. With your telescope, you can measure the Earth's motion around the Sun, measured relative to the Milky Way. You can also measure the drift of our Solar System within the Milky Way and estimate how fast we're orbiting the Milky Way.

We hope you will write up your discoveries and submit Lightwork memos. Email me if you have questions or suggestions for improvements. With a Radio Telescope, you'll always have ***Clear Skies***. See the Universe from your own back yard!

Thanks to my family and friends for their support for this project.

Appendix A: Background

Building your own horn radio telescope would be very difficult unless someone else wrote the software. Fortunately the people working on the Gnuradio Companion (GRC) provided a wonderful tool enabling Radio Astronomy. This software included in the Raspberry Pi operating system download. You can also download this yourself, for other types of computers, but installation might take some time. (see https://wiki.gnuradio.org/index.php/InstallingGR).

Figure 12: Students hunting the Milky Way with a horn radio telescope. They found it!

GRC is fun-to-use visual programming tool. There are many guides online for using different aspects of GRC (see https://wiki.gnuradio.org/index.php/GNURadioCompanion for instance). For background on Radio Astronomy see: https://www.cv.nrao.edu/course/astr534/Introradastro.html).

Dr. Jay Lockman provides an excellent video Great Course on Radio Astronomy[1]. He explains what we know about the invisible universe.

For a very short, and enjoyable, introduction to GRC take a look our Youtube "Nsf Listens" video (https://bit.ly/2HsFndr), staring Sophie de Saint Georges, Evan Smith and Glen Langston.

You can also see Glen Langston in a video with a horn radio telescope in operation!

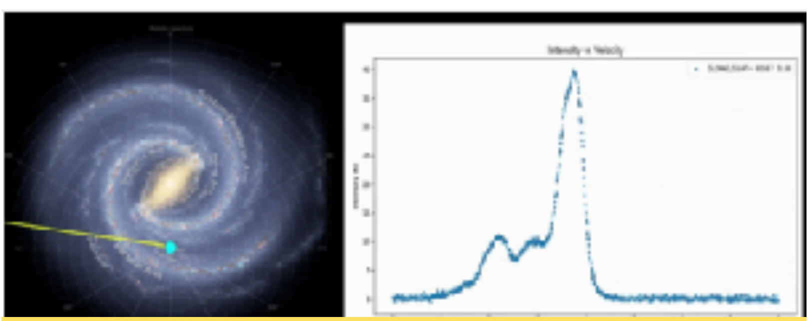
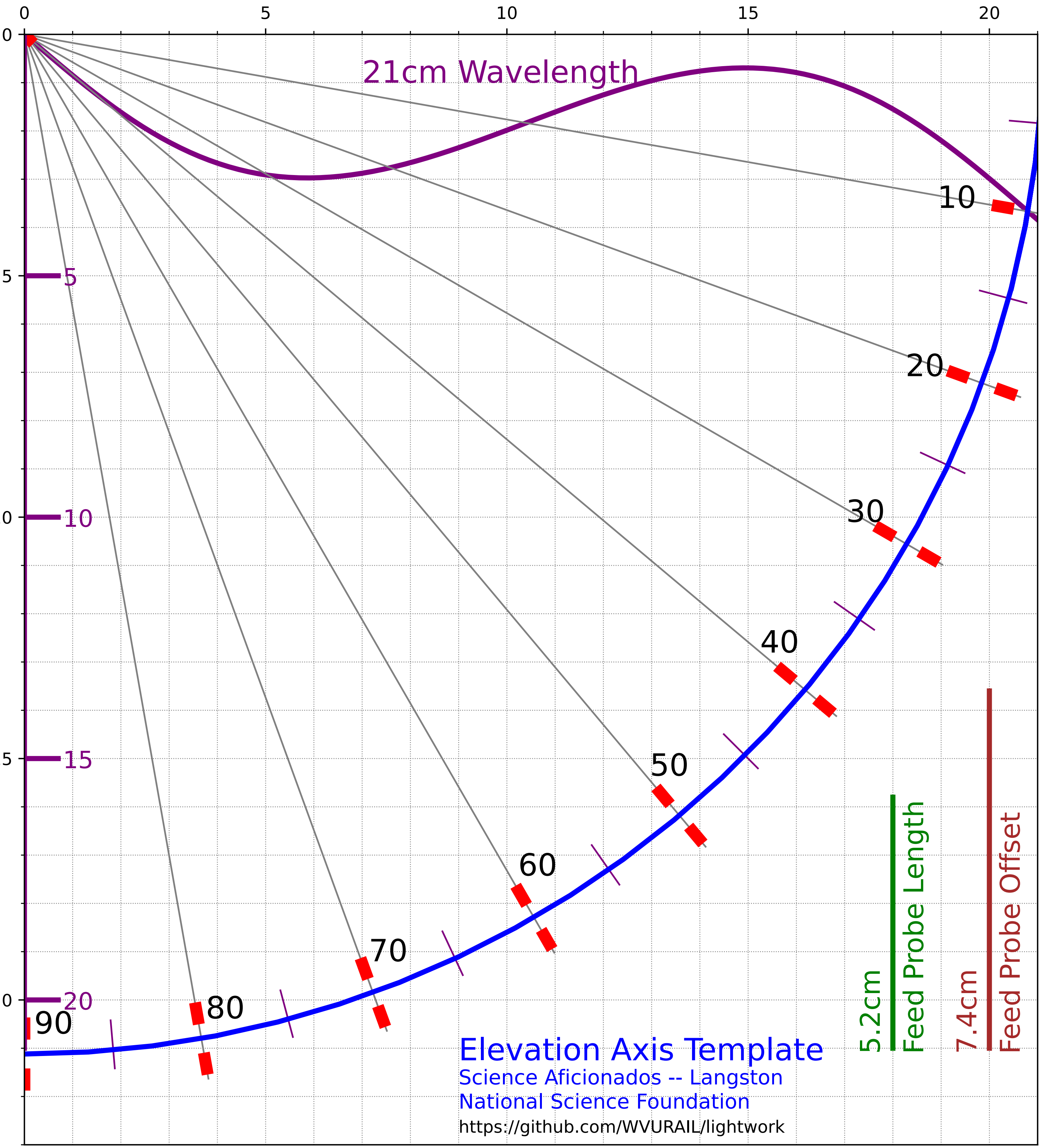


Figure 13: One observation with horn radio telescope. (left), shows hydrogen intensity on the Y axis versus speed on the X axis. On the right is the coordinate in the Milky Way. This coordinate was measured from the telescope azimuth, elevation and time of the observation.

After you've built the horn and base, you can setup for telescope to scan the Milky Way. Science teacher David Shultz as done great job of showing how peaks in the plot of horn observations find Milky Way spiral arms.

[1] https://www.thegreatcourses.com/courses/radio-astronomy-observing-the-invisible-universe.html


21cm Wavelength
10
20
30
40
50
60
70
80
90
5
10
15
20
5.2cm
Feed Probe Length
7.4cm
Feed Probe Offset
Elevation Axis Template
Science Aficionados -- Langston
National Science Foundation
https://github.com/WVURAIL/lightwork