Bennington College Small Radio Telescope
Operations Manual

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with guidance from
MIT Haystack Observatory's
Haystack Small Radio Telescope Project

Table of Contents

1 Introduction

This manual serves as a guide following the work done at Bennington College during the spring of 2014 to build and operate a radio telescope, following the procedure laid out by MIT Haystack and their Small Radio Telescope (SRT) project. This manual contains information regarding both the hardware and software components of the project which should allow for a simple and successful build and operation of a SRT.

1.1 Disclaimer

Note that the procedure detailed in this document is a representation of the way we decided to build, assemble, and run the telescope, but it is not the only way to do it. The decisions made were based off of, but did have some variance from, the MIT documentation, so reading that alongside with this may be useful. Note also that while we tried to make our documentation as complete and thorough as possible, there is a chance that it is not complete as something small may have been missed along the way.

2 Considerations

2.1 Acquiring Parts

Many of the components required for this project are available through major suppliers, such as *Digi-Key*, *Mini-Circuits*, and *Mouser*. Many of the hardware should be available at your local hardware store, or online at a major hardware store's website. A few components are easier to find on Amazon or eBay, such as the cake pan used for the feed, but they may also be available at local retail stores. To get larger parts, such as the rotor, rotor controller, or dish, you can visit the manufacturer's website or find a retailer for what you need online. For our rotor and controller, we used products from *Spid Electronik* (http://www.spid.alpha.pl/english/01.php), and for our dish, *RF Hamdesign* (http://www.rfhamdesign.com/), though other options do exist.

2.2 Mounting the Dish

When choosing a location to mount the dish, it is best to have as few obstructions to the sky as possible. Care should also be taken to place the dish in a location with little RF interference. This means that when scoping out places where you want your dish to be, having a way to measure the RF interference would be helpful. Although you want as clear a view of the sky as possible, having a tree in range may be useful to act as an absorber during calibration.

There are a few options that you can consider when deciding how to mount your dish. The two options suggested by the MIT Haystack documentation are

1. Non-Penetrating Rood Mount
2. Concrete Pier

Our design follows neither of those paths; our dish is secured on a roof by a custom-built mount. Below are details on each of the three suggested methods so you can make a decision as to which mounting system will work best for you.

2.2.1 Non-Penetrating Roof Mount

Non-Penetrating Roof Mounts are ideal for flat areas, particularly roofs, paved areas, or flat fields, though they are not limited to these locations. Being non-penetrating, this method is the least permanent, as you are able to move the mount (and thus the dish) as needed. This option appears to have a large footprint, so it would be necessary to make sure you have the area required first. These mounts are available commercially. Below are links to some websites that sell them, as described in the MIT documentation

- http://www.skyvision.com/store/mi6012006.html
- http://www.orbitcommunications.com/cyberstore/cband/mounts.htm
- https://www.bairdmounts.com/

Since the mounts will be dependent on the dish size and may depend on project restrictions, it may be worthwhile to search for one that will best fit your needs.

2.2.2 Concrete Pier

Building a concrete pier mount is sturdy and reliable, if constructed properly, however it is also permanent. If this is the option you choose, take into consideration that soil mechanics vary widely, so the suggestions here (taken from MIT documentation) are just suggestions. You should speak to someone familiar with your local geography/weather to ensure your pier will be stable. Things to take into consideration:

- When digging the hole for the pier to be set in, be sure it goes below the frost line
- Taper the sides of the hole inward as the hole goes down. This will help provide additional stability
- Fill the bottom of the hole with gravel to improve drainage
- Make sure the pipe coming up from the concrete foundation is level as the concrete cures
- Allow enough time for the concrete to cure fully before applying too much weight to your mounting system

2.2.3 Custom Mount

We decided to build a mount to fit our needs, and it may be that this is the easiest option. The pros of this method is that your solution will work for your design and placement of the dish. Our design allowed us to use pre-existing structures, which simplified the mount a bit. If this method is chosen, it is likely everything will have to be custom built and designed, so be sure you have resources in place for this.

3 Parts List

3.1 LNA to Dongle Interface

PART	QTY	MANUFACTURER	COST
SMA-M Crimp Connector Straight	1	Amphenol/Connex	$5.95
LMR-400	100ft		$102.99
Type-F Male Crimp Connector	1	Amphenol/Connex	$4.95
In-Line Amplifier	1	Blonder Tongue	$8.22
BNC Female Jack to Type-F Male Plug	3		$10.99
BNC-M to BNC-M Patch Cable	3	Amphenol RF	$12.55
Power Injector	1	Channel Vision	$14.71
BNC-F to SMA-M Adapter	1	Vitelec / Emerson	$12.09
Bandpass Filter VBF-1445+	1	Mini-Circuits	$34.95
SMA-F to BNC-F Adapter	1	AIM-Cambridge / Emerson	$4.21
BNC-F to SMB Plug Adapter	1		$8.49
AC-to-DC Power Supply	1		$20.18
Breadboard	1	Vector Electronics	$5.75
DC Jack	1	CUI Inc	$1.00
F-Type Plug	1	Winchester Electronics	$4.16
Approximate Total:			**$251.19**

3.2 Feed & LNA

PART	QTY	MANUFACTURER	COST
Ultra Low Noise Amplifier ZX60-1614LN-S	1	Mini-Circuits	$149.95
Coaxial Bias-Tee ZFBT-4R2G-FT+	1	Mini-Circuits	$59.95
Coaxial Cable 086-6SM+	1	Mini-Circuits	$8.95
Coaxial Cable 086-4SM+	1	Mini-Circuits	$8.95
SMA-F to SMA-F Adapter SF-SF50+	1	Mini-Circuits	$4.95
SMA-F to Solder Pin Bulkhead Connector	1	Emerson	$8.06
SMA-M to SMA-M Right Angle Adapter	1	Amphenol Connex	$8.03
3M Adhesive Copper Foil Tape	1	3M	$30.49
22 Gauge Copper Wire	1	Jameco	$9.95
Semi-Rigid Coaxial Cable	1	Micro-Coax	$4.62
F-Type Male to BNC-F	1		$0.89
SMA-M to SMA-M Coupler	1		$7.49
DC Barrel Jack Connector	1	Digikey	$1.00

F-Type Plug Connector	1	Digikey	$4.16
Cap Screw 1/4-20x3.25″		McMaster-Carr	$4.29/10
Lock Washers, 6-32	4	McMaster-Carr	$1.69/10
Machine Screws, 6-32x1/2″	2	McMaster-Carr	$5.14/10
Machine Screws, 6-32x1″	4	McMaster-Carr	$7.43/10
Nuts, 6-32	14	McMaster-Carr	$1.16/100
Nuts, 1/4-20	1	McMaster-Carr	$3.95/50
Washers 1/4″	4	McMaster-Carr	$3.37/100
Styrofoam Rod 2.5″ x 24″	1		
Cake Pan 7″ x 3″	1		
O-Rings 7/32″ (inner diameter)	2	McMaster-Carr	$6.29/100
O-Rings 1/4″ (inner diameter)	2		
Approximate Total:			**$340.76**

3.3 Mount

PART	QTY	MANUFACTURER	COST
1.4″ (3' x 2') cold rolled steel plate	1		Scrap Metal
2 1/2″ (11') long steel pipe	1		Scrap Metal
1/8″ 2″ (6') angle iron	1		Scrap Metal
Spray Paint	1 - 3	Any	$4 - $12
Approximate Total:			**$4 - $12**

4 Tools List

4.1 Assembling the LNA and Feed

TOOL	DESCRIPTION
Soldering Iron & Solder	Solder components together
Wire Cutter/Stripper	Cut and strip wire
Screwdriver	Assemble box of LNA
Labeler	Label components of LNA
Hacksaw	Cut styrofoam
Measuring Tape	Measure styrofoam and helix position
Drill Press and 1/4″ Bit	Drill hole in styrofoam, LNA baseplate, cake pan, pc board
X-Acto Knife	Cut copper tape

Straight Edge	Cut copper tape
Pen/Marker	Mark position of helix
Electrical Tape	Insulate soldered connections

4.2 Assembling the Dish

TOOL	DESCRIPTION
Socket Wrench Set	Bolt arms to center plate
Hammer and Tap	Mark ends of ribs and outer band, makes drilling holes easier
Handheld Riveter/Rivets	Rivet the outer band, strips over mesh, arm brackets
Hacksaw/Bandsaw	Cut arms to length (if needed)
Power Drill + Drill Bit	Drill rivet holes for outer band, strips, and dish arms
Safety Gloves	For your fingers
Pliers	Useful for bending mesh when wrapping around edge
Tin Snips	Cut mesh
Pen/Marker	Mark hole locations, pre-drilling
Tape	Helps keep mesh pieces in place (optional)
Zip Ties	Secure the mesh to the outer band and ribs of the dish

4.3 Mounting the Dish

TOOL	DESCRIPTION
Socket Wrench + Socket Set	Bolt the rotor to the mount and the dish to the rotor
Ladder	Helps to reach top of mount (for rotor & dish placement)
Tap and Die	Minor adjustments to mounting plate (if needed)
Zip Ties	Bundle wires coming from rotor
Wrench/Adjustable Wrench	Attach rotor to the mount

4.4 Building a Custom Mount

TOOL	DESCRIPTION
Safety Glasses	To protect and serve your eyes

Welding Gloves	Protect your hands
Welding Helmets	So you don't go blind
Respirators	Lung protection
MIG Welder	Weld all pieces together
Grinder	Steel brush head for cleaning surfaces Carbide head for fabrication
Hydraulic Metal Band Saw	Cut pieces (e.g. the pipe)
Plasma Cutter	Cut steel sheet
C-Clamps/Vice	Hold components while welding and grinding
Roofing Square	Ensure squareness

4.5 Attaching Arms to Dish

TOOL	DESCRIPTION
Rivet Gun	Attach feed to arms and arm brackets to dish
Band Saw	Make custom brackets to attach cake pan to dish arms
Drill Press	Make custom brackets to attach cake pan to dish arms
5mm Crescent Wrench	Tighten arm-to-dish fasteners
Flexible Tape Measure	Space arm placement evenly around dish

4.6 Wiring the Rotor

TOOL	DESCRIPTION
Screwdriver (Phillips)	Remove cover plate of rotor
Utility Knife	Score plate edge to remove excess paint
Adjustable Wrench	Remove/Tighten water resistant wire caps
Small Screwdrivers (Phillips & Flathead)	Secure wires to the AZ / EL terminals
Soldering Iron + Solder	Tin the ends of the wire
Wire Strippers	Cut and strip the wires to use as terminal leads
Electrical Tape	Insulate wires

5 Installing SRTN Software

The original SRT source can be found on the MIT Haystack Observatory website http://www.haystack.mit.edu/edu/undergrad/srt/. This source (version 3) appears to work with ArchLinux and CentOS, and reportedly works on REHL (Red Hat Enterprise Linux). The source will not work immediately with Ubuntu, however a modified version of the source can be found at https://github.com/BenningtonCS/Telescope-2014, which will work on Ubuntu, as well as CentOS and ArchLinux (It may work with other linux- based operating systems, however, those listed are the only ones we have tested so far).

5.1 MIT Haystack Observatory SRT

The MIT Haystack Observatory SRT website includes the manuals, documentation, and program code. The code base we are looking at, SRT Source Code ver 3, can be found here:

http://www.haystack.mit.edu/edu/undergrad/srt/newsrtsource_ver3.tar.gz

5.2 Ubuntu

Note that these instructions were written for Ubuntu 12.10

```
$ lsb release -a
No LSB modules are available.
Distributor ID: Ubuntu
Description : Release :
Codename :
Ubuntu 12.10 12.10
quantal
```

5.2.1 Source Code

To get the source code, go to https://github.com/BenningtonCS/Telescope-2014 and download the repository. The source code exists in the srtnver3 folder of the repo.

5.2.2 Project Dependencies

In order to compile and run the program successfully, two libraries must be installed, gtk+-2.0, and libusb-1.0. This can be done using the command below:

```
$ sudo apt  get install libgtk2.0  dev libusb   1.0  0  dev
```

NOTE: If you are unable to download using `apt-get install`, try using the command `apt-get update` first, wait for all updates to be installed, and then retry the install command above.

5.2.3 Compiling

A script exists to compile the source code. To compile, run it:

```
$ ./srtnmake
```

A few warnings may appear, but the code should compile successfully, assuming the needed libraries were installed properly.

5.2.4 Running

To execute the program:

```
$./srtn
```

5.3 CentOS

These instructions were made using CentOS release 6.5 with kernel version:

```
$ uname -r
2.6.32-431.e16.x86_64
```

on a machine with an AMD processor.

5.3.1 Source Code

To get the source code, go to https://github.com/BenningtonCS/Telescope-2014 and download the repository. The source code exists in the srtnver3 folder of the repo.

5.3.2 Project Dependencies

From a clean install of CentOS, you will be missing some of the packages needed to run the software.

Getting sudo permissions

Before you do this though, you need to add your profile to the sudoers file, if you do not already have sudo permissions. To do this:

```
$ su
$ chmod +w /etc/sudoers
$ gedit /etc/sudoers
```

Down by the bottom of the file will be the line:

```
## Allow root to run any commands anywhere
root ALL=(ALL) ALL
```

Below this add the line ”xxx ALL=(ALL) ALL”, where xxx is the username logged in to the computer, in our case ’radiotelescope’

```
## Allow root to run any commands anywhere
root ALL=(ALL) ALL
radiotelescope ALL=(ALL) ALL
```

Save the file and exit gedit, then in the terminal, type exit to return to your user status:

```
[root@localhost radiotelescope]\# exit
exit
[radiotelescope@localhost ~]\$
```

Now your user account should have sudo permission, so we can now install package dependencies.

Getting dependencies

The packages needed are gtk+2, gcc, and libusb. These can be acquired using the CentOS package manager, yum:

```
$ sudo yum install gtk2-devel gcc lubusb1-devel
```

If successful, you should now have all the packages you need to run the software.

5.3.3 Compiling

A script exists to compile the source code. To compile, run it:

```
$ ./srtnmake
```

5.3.4 Running

To execute the program:

```
$ ./srtn
```

5.4 Arch Linux

5.4.1 Source Code

To get the source code, go to https://github.com/BenningtonCS/Telescope-2014 and download the repository. The source code exists in the srtnver3 folder of the repo.

5.4.2 Project Dependencies

From a clean install of Archbang, there are a few necessary things missing, namely make and patch.

From the command line, run:

```
$ sudo pacman -S make patch
```

Unfortunately, the program will not run properly using a current version of gcc, so it is necessary to download and install gcc version 4.4. As gcc-4.4 is not in pac-man, gcc-4.4 must be downloaded from the AUR. You can find gcc-4.4 in the Arch User Repository (https://aur.archlinux.org/packages/gcc44/). Download the tar-ball (https://aur.archlinux.org/packages/gc/gcc44/gcc44.tar.gz). It should appear in your Downloads folder. You can untar it by using the command:

```
$ cd ~/Downloads
$ tar xzvf gcc44.tar.gz
```

then move into the new folder that was created.

```
$ cd gcc44
```

Use the command makepkg by itself to make the package.

```
$ makepkg
```

NOTE: It might be necessary to make the package as root. If this is the case, run:

```
$ sudo makepkg –asroot
```

As gcc is a large program, it might take a very long time to download. Once it's downloaded, run:

```
$ sudo pacman -U gcc44-4.4.7-6-x86_64.pkg.tar.xz
```

Once again, as gcc is a large program, this will take a long time to complete.

5.4.3 Compiling

First, you will need to edit the compiler script, srtnmake to make the script use gcc-4.4 instead of the default version.

```
$ nano srtnmake
```

Then, change *gcc* to *gcc-4.4*, save, and exit out of nano. You can now compile the software.

```
$ ./srtnmake
```

5.4.4 Running

To execute the program:

```
$ ./strn
```

5.5 Troubleshooting

5.5.1 Blacklisting the Driver

It may be necessary to blacklist the driver so it will not already be in use when we try to call on it:

```
$ sudo -i
# echo “blacklist dvb_usb_rtl28xxu” > /etc/modprobe.d/librtlsdr-
blacklist.conf
```

This will require a reboot before the effects can be seen:

```
$ sudo reboot
```

6 Using SRTN Software

The section above details how to install, compile, and run the software. Below are some tips/guidelines on how to use the software more effectively, including setting it up to work with the controller and the LNA/Feed/Dongle.

6.1 Configuration Options

The bulk of the configuration options for the software are found in the *srt.cat* file. The commands in this file are described in the help file, *srt.hlp*, which is accessible either through reading the file directly, or pressing the 'Help' button on the software UI when it is running.

6.2 Simulated Mode v. Unsimulated Mode

The *srt.cat* file contains options for

- SIMULATE ANTENNA
  - simulates antenna motion
- SIMULATE RECEIVER
  - simulates incoming data from the dongle
- SIMULATE FFT
  - simulates the fast-fourrier transform

To see if the software works initially, it may be prudent to simulate the receiver and antenna and run SRTN. This allows you to check if the software runs correctly without hardware dependencies. To receive data from the dongle, make sure the dongle is plugged into the computer, and comment out the SIMULATE RECIEVER command. Similarly, to use the controller via software, make sure the controller is plugged in to the computer and comment out the SIMULATE ANTENNA.

6.3 Setting Your Location

In the *srt.cat* file, under the LOCATION command, update the field with the name of your location, and the latitude and longitude.

7 RAS SPID Rotor

7.1 Setup

Documentation on how to set up the rotor and the controller can be found:

https://github.com/BenningtonCS/Telescope-2014/wiki/SPID-Antenna-Rotator-Setup---Getting-Started

Additional information can be found:

http://www.spid.alpha.pl/download/AlfaSpid_Rotator_RAS_EN.doc
http://www.spid.alpha.pl/download/rot2prog/RotorController_sat_A3.pdf
http://www.spid.alpha.pl/download/rot2prog/RotorController_sat_zas_A3.pdf

7.2 Wiring

Documentation for wiring the rotor can be found online. For the rotor we used, the documentation can be found off the manufacturer's website:

http://www.spid.alpha.pl/english/10.php

7.2.1 Tools Needed

- screwdriver (phillips)
- utility knife
- adjustable wrench
- small screwdrivers (phillips & flat- head)
- soldering iron
- solder
- electrical tape
- wire strippers

7.2.2 Instructions

The rotor we used was an Alpha Spid RAS rotor (http://www.spid.alpha.pl/english/11.php). These instructions are a guide to accessing the power/control terminals to the rotor in order to control it with our rotor controller (http://www.spid.alpha.pl/english/05.php).

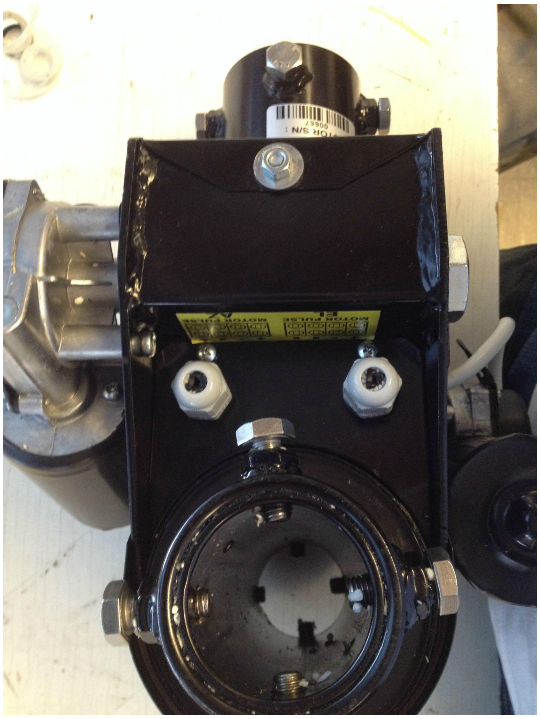


Figure 1: On the rotor, there is a plate with two screws and two waterproofed wire outputs. On the face next to the plate should be a sticker detailing the EL AZ wiring.

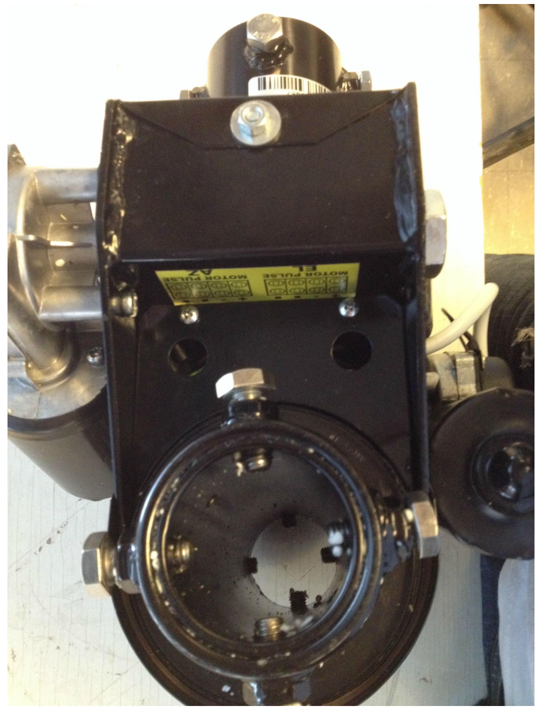


Figure 2: First, unscrew/remove the two waterproof outlets using the adjustable wrench and unscrew the two screws on the plate.

Figure 3: Note that the edge of the plate may be painted over, so use a utility knife to edge the plate. The first time you remove the plate, it may be difficult, so, using the back of a screwdriver, tap around the corners of the plate to loosen it.

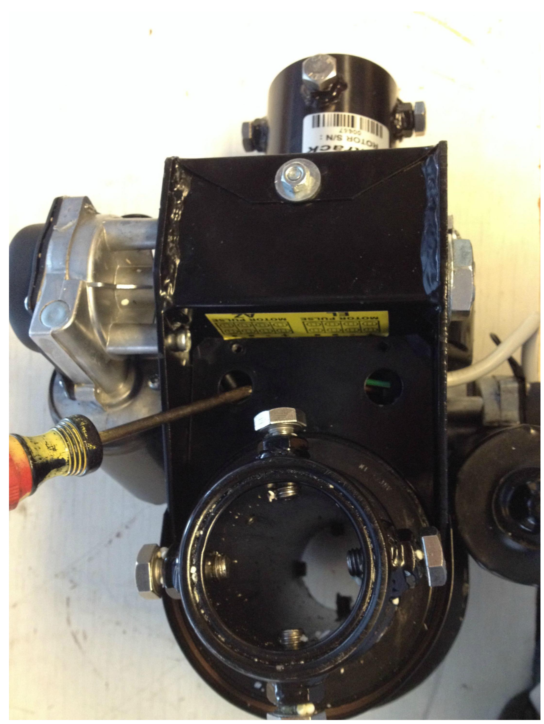


Figure 4: Using a screwdriver (or some other means of leverage), insert one end into a hole left from unscrewing the waterproof outlet, and carefully pry off the plate. This may take some time since the plate has a tight fit initially.

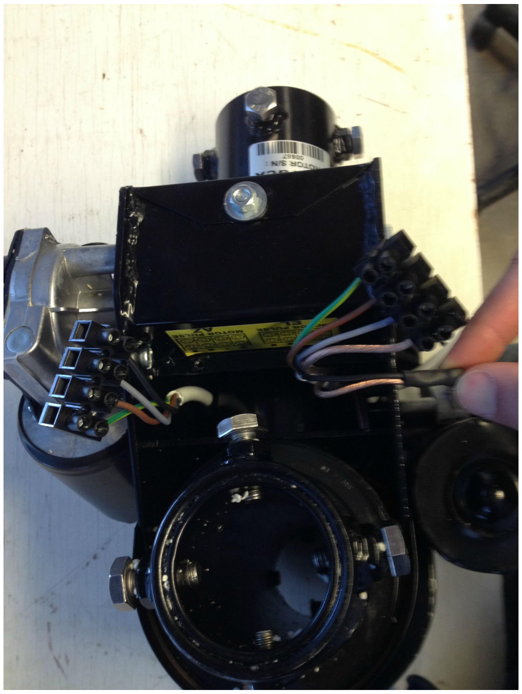


Figure 5: Underneath the plate are two wiring terminals, one for AZ and one for EL. (See the sticker on the rotor to determine which terminal corresponds to AZ and which corresponds to EL).

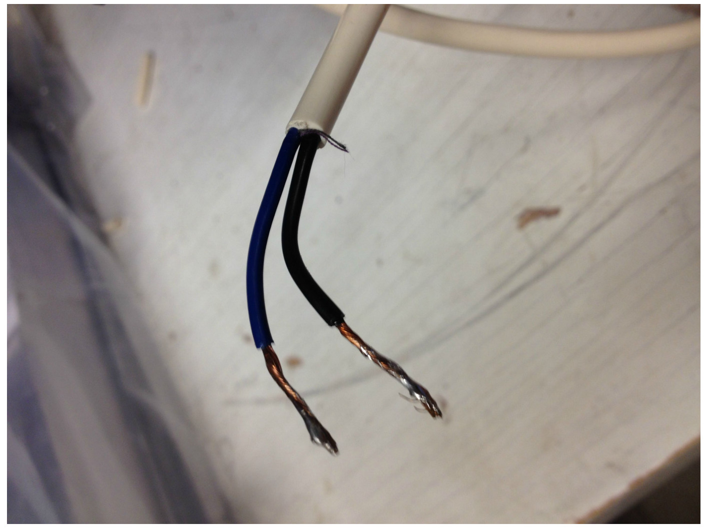


Figure 6: For testing purposes, a set of test cables were made, approx. 75 cm long. (Later, these wires were replaced with more permanent ones to fit our mounting strategy). Our test cables consisted of four cables, each cable containing two wires, so there were two cables per terminal, or four wires per terminal. The ends of the wires were stripped and tinned.

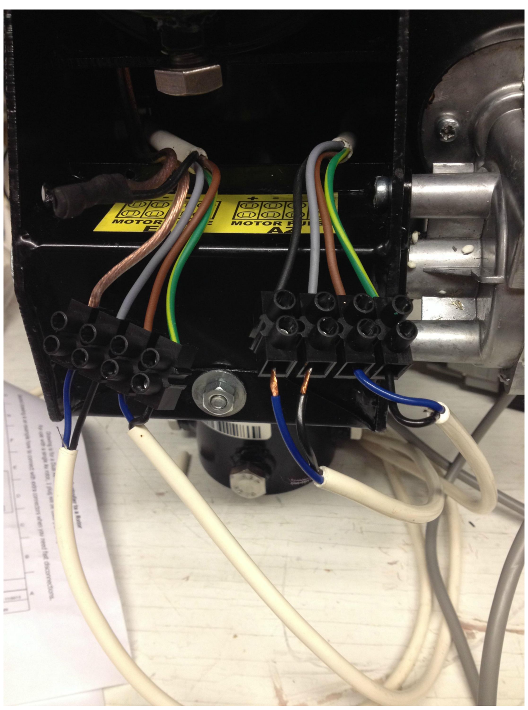


Figure 7: The ends of the wires were secured in their respective rotator terminal.

Figure 8: The free end was then soldered to a head which connects to the controller. When doing this, note the order of the wires. On the head, the pins are labeled 1-4, which will correspond sequentially to the wires coming from the terminal. Electrical tape was wrapped around the wire near the connection to ensure each pin and wire were isolated from one another. Stripping a small amount of wire on this end may diminish the need to wrap the connection in electrical tape.

Figure 9: The head was re-assembled and connected to the controller.

Figure 10: Once everything was secure and connected, the power supply and controller were turned on, with the mouse attached to the controller.

Adjusting the the controller to be in ’A’ (automatic mode, see the controller settings section below for a full list of controller options), we were able to control the rotor with the mouse. Note that in order for the controller to be given commands via the computer (serial), the controller *must* be in ’A’ mode.

7.3 Controller Settings

Full documentation can be found: (http://www.spid.alpha.pl/download/AlfaSpid_Rotator_RAS_EN.doc). Much of the documentation in this section was pulled directly from the source linked above.

7.3.1 RAS SPID rot2 Settings

In our setup, we are using the RAS SPID rot2 Rotator. We want to have our settings such that PS (program simulation) is configured to SP. If the mode is not SP, the controller will not work. With the rotor we are using (1 degree per pulse accuracy), we also want our rotor transmission, P, to be set to 1.0. To have the computer software or mouse control the rotor, the mode will need to be set to A (automatic). For more detailed information, see the ”Controller Setup” section, below.

7.3.2 Controller Reset

Since there are no mechanical limits in the rotor, it may be installed with the antenna pointing in any direction. There is no reason to locate “TRUE NORTH” until you are ready to calibrate the control box. Use the controller to position the antenna to physically point north, then reset the controller as follows:

- Turn the unit OFF.
- While holding the F button down, turn control unit back on.
- The display should then read 0.0 0.0

This feature can be used if, for any reason, the direction of the antenna becomes incorrect. This may be caused by antenna to mast slippage or incorrect initial alignment.

Important Note:

The SPID rotor will be set at the counter-clockwise end of its normal rotation range. Normal rotation range is in a clockwise direction for 360 degrees.

From the reset position, you can rotate counter-clockwise an additional 180 degrees in over-travel, as well 360 degrees clockwise, plus an additional 180 degrees into clockwise over-travel.

Counter-clockwise over-travel is indicated by a steady dot above the over-travel icon [<->]. [<->] Rotation past 359 degrees into the clockwise over-travel is indicated by a blinking dot above the over-travel icon.[<->]

Technical Note:

You will need to leave sufficient coax length to accommodate the additional 180 degrees of over-travel on each end of normal rotation. Failure to do so can cause damage to your coax and/or antennas.

7.3.3 Controller Operation

There are multiple modes of operation for the SPID controller. The two main modes, F and S are described below, along with all of their sub-modes.

F – Function Mode

The F button steps through the function menus. The leftmost character on the display indicates the function mode you are currently in.

(no letter) = Normal Operations Mode

> In Normal Operations Mode, the up, down, left, right buttons cause rotation as long as the buttons are pressed. Pressing S while in normal operations mode will take you to setup mode.

H = Half-Auto Mode

> In Half Auto Mode, the up, down, left, right buttons can be used to pre-select the desired beam heading. The heading displayed on the controller will rapidly change in the direction of desired rotation. Once the desired beam heading is shown on the display, release the key. Approximately 1/2 of a second after no key presses have been detected, the display will revert back to the actual beam heading, and rotation towards the desired heading will take place.

Pressing any key while in transit to the desired heading will cancel the action.

A = Auto Mode

In Auto Mode, the controller will respond to commands from control software running on an attached computer. The up, down, left, right buttons can still be used, but pressing of any of them will cause the data from the software to invalidate.

S – Setup Mode

The S button steps through the setup menu.

P = Rotor Transmission

This value defines the accuracy of rotator operation. 1.0 means operating with up to 1 degree per pulse from rotator accuracy.

PS = Program Simulation

Program Simulation allows the user to set the serial communication protocol used by the rotator. When set to emulate another brand of rotator, the Spid will respond to commands, and send responses back to the computer as if it were the rotator brand selected. If your favorite software supports a rotator, chances are, the Spid will be able to interface to your software. There are 2 modes available:

- PSSP = SPID
- PS 4A = Yaesu (GS232 protocol) (RS232: 600N1, 8 bits)

(data rate bound 600, 1 STOP bit, no even parity bit) Operating mode can be changed using left, right.

PH = Programmable High Limit

The Programmable High Limit is a user adjustable clockwise travel limit value. By reducing this value, the maximum clockwise rotation travel can be restricted. Use the buttons:

- *left* and *right* to adjust the azimuth value
- *up* and *down* to adjust the elevation value

PL = Programmable Low Limit

The Programmable Low Limit is a user adjustable counter-clockwise travel limit value. By increasing this value, the minimum counter-clockwise rotation travel can be restricted. Use the buttons:

- *left* and *right* to adjust the azimuth value,
- *up* and *down* to adjust the elevation value.

PP = Heading Adjust

This setting can be used to make minor heading adjustments without causing the rotator to turn. If you notice that the heading displayed on the controller to a known signal source is out by a few degrees, you can change the heading displayed on the LED readout to match the known heading, rather than having to turn back to North and reset the controller. These settings are made by *up*, *down*, *left*, *right* buttons.

7.4 Controller Setup

The antenna controller will likely need a bit of setup in order to work properly with the software. To properly set up the controller, three things must be done:

1. Make sure the controller has no limits set
2. Set the controller to SPID mode
3. Set the controller to Automatic mode so it is able to communicate with a computer via serial

7.4.1 Setting Limits

The easiest way to be sure there are no limits set on the controller is by doing a controller reset. To do this, turn off the controller, hold down the 'F' button, and while still holding down the button turn the controller on again.

Figure 11: To change the remaining settings, we will use the buttons on the controller, designated by the red arrows. (F, S, left, right, up, down)

If there are limits set, it is possible that when the software is run, a buffer overflow may occur, and that the GUI logic breaks, leading the program to be ineffective. If no radio data is being displayed on the UI and large values/NaN appear on the readout, having limits set is a potential cause.

7.4.2 Setting to SPID

In the controller's program simulation setting, two options are available, SPID or Yaesu. Since the controller we used is SPID, the controller should be set to SPID. To set, press the 'S' button until the readout says PS. Then, if the readout does not say PS SP, press the < or > arrows to change it to SP.

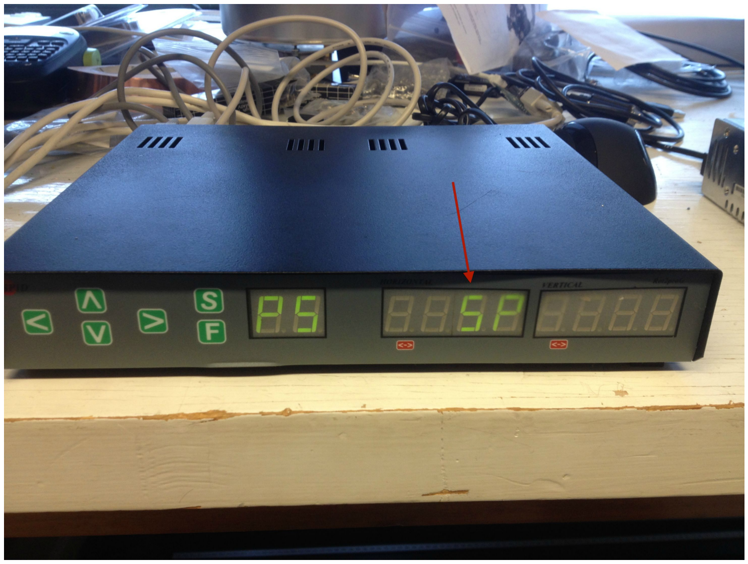


Figure 12: Controller set to SP mode (SPID mode)

If the controller is not in SPID mode, nothing will happen and the program may hang, as it is unable to communicate with the controller.

7.4.3 Setting to Automatic

In order for the computer to be able to communicate with the controller, it must be in automatic mode. To do this, you would press the 'F' button until an A shows up on the readout.

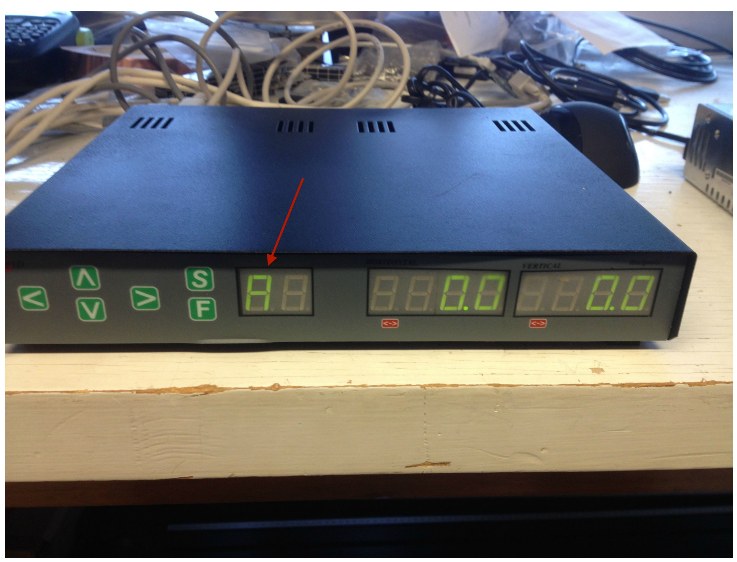


Figure 13: Controller readout in Automatic (A) mode

7.4.4 Controller Wiring

While the controller does not have many/complicated connections, and the documentation is fairly good for what connects where, below is a picture detailing our connection setup, for reference.

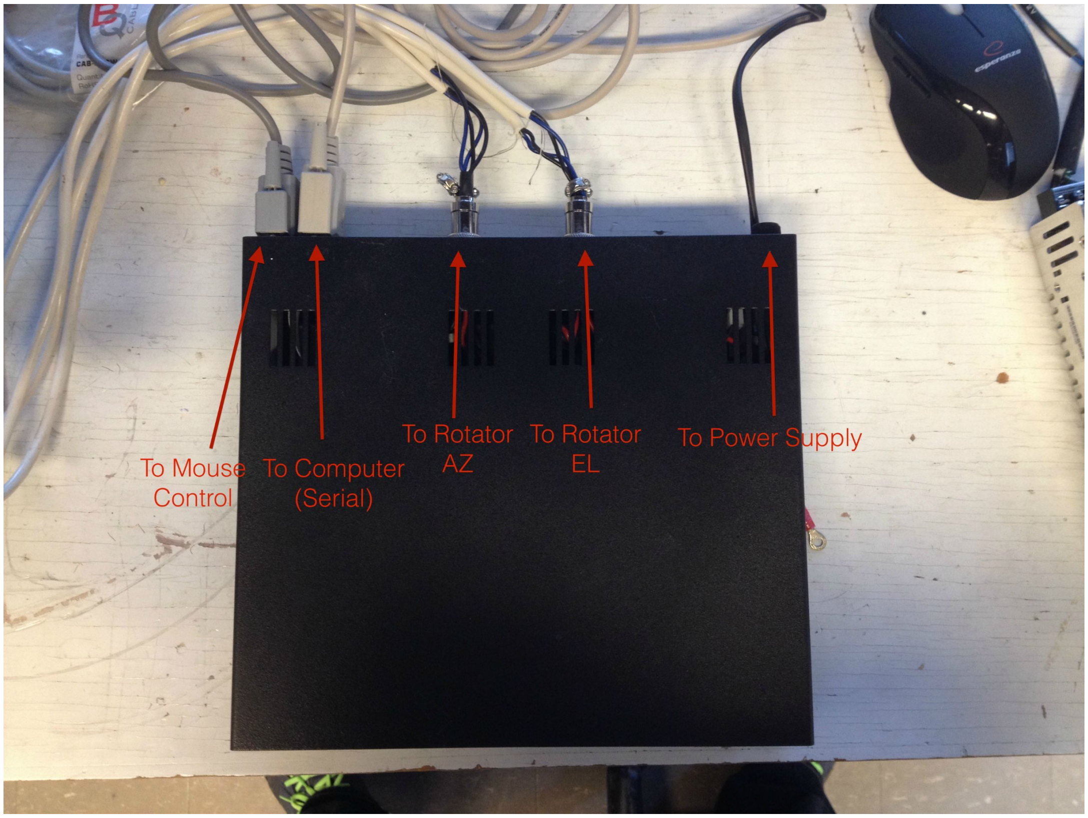


Figure 14: Controller wiring reference

8 Building Components

8.1 LNA

The LNA (low-noise amplifier) is housed in a watertight container mounted on the back of the receiver (cake pan). Housing it on the back allows for minimal additional block- age of the aperture. Within the container, the LNA itself consists of two ultra-low-noise amplifier modules, a band-pass filter, and a bias-tee to power the amplifiers.

Below are the steps we took to build the LNA for the SRT. To follow along with MIT's guide, see http://www.haystack.mit.edu/edu/undergrad/srt/pdf%20files/SRT_Hardware_Manual.pdf, beginning on page 5.

Figure 15: Attach the coupler (SMA-M to SMA-M) to the "in" side of the amplifier (Ultra Low Noise Amplifier ZX60-1 1614LN-S), then attach the bandpass filter (VBF-1445+) to the "out" side of the amplifier.

Figure 16: Connect the Coaxial Cable (086-4SM+) to the Bandpass Filter (VBF-1445+).

Figure 17: Connect the opposite end of the coaxial cable (086-4SM+) to the "in" side of a second Ultra Low Noise Amplifier (ZX60- 1 1614LN-S).

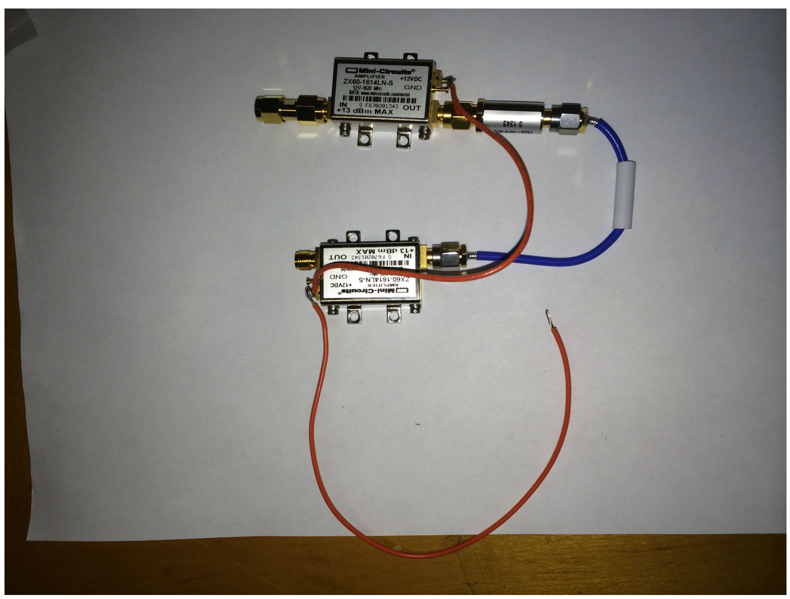


Figure 18: Cut two lengths of 22 gauge copper wire (15-20 cm). Solder one wire to both amplifiers (see picture). Solder other wire to the second Ultra Low Noise Amplifier.

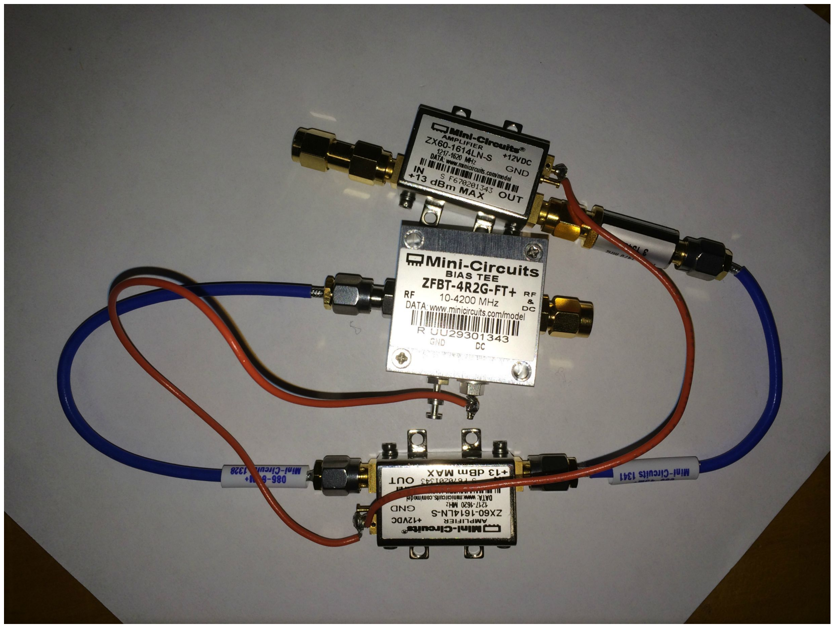


Figure 19: Solder the other end of the second wire to the 12 volt pin on the Coaxial Bias-Tee (ZFBT-4R2G-FT+). Connect "RF" side of the bias tee and "out" side of the second ultra low noise amplifier with Coaxial Cable (086-6SM+).

Figure 20: Place this group into the case, with coupler and "RF DC" side of the bias tee protruding from the holes.

Figure 21: Add rubber lining and case cover, label, and screw on cover.

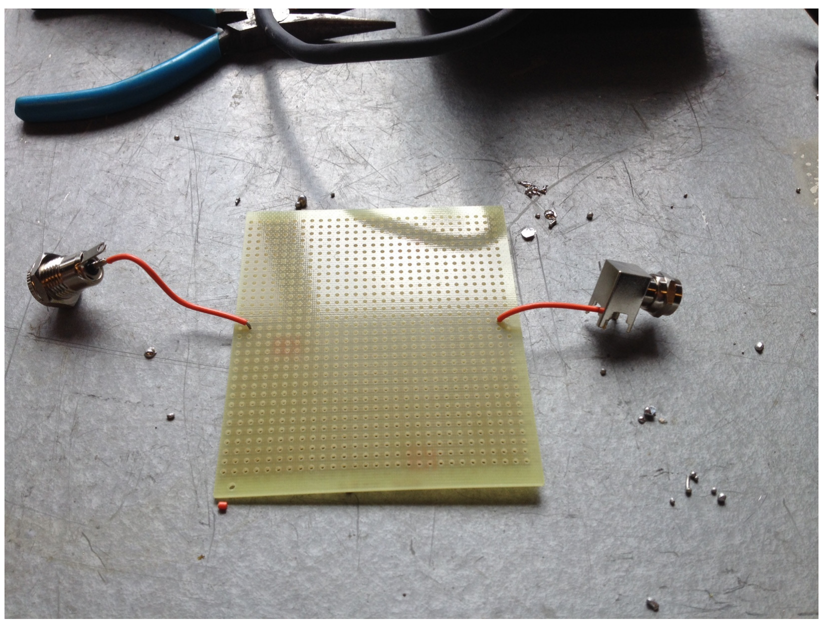


Figure 22: Assembly of dc jack connector to f type coax adapter. Solder middle pin of dc plug connector to perf board. Solder middle pin of f type plug connector to same conductive strip of perf board.

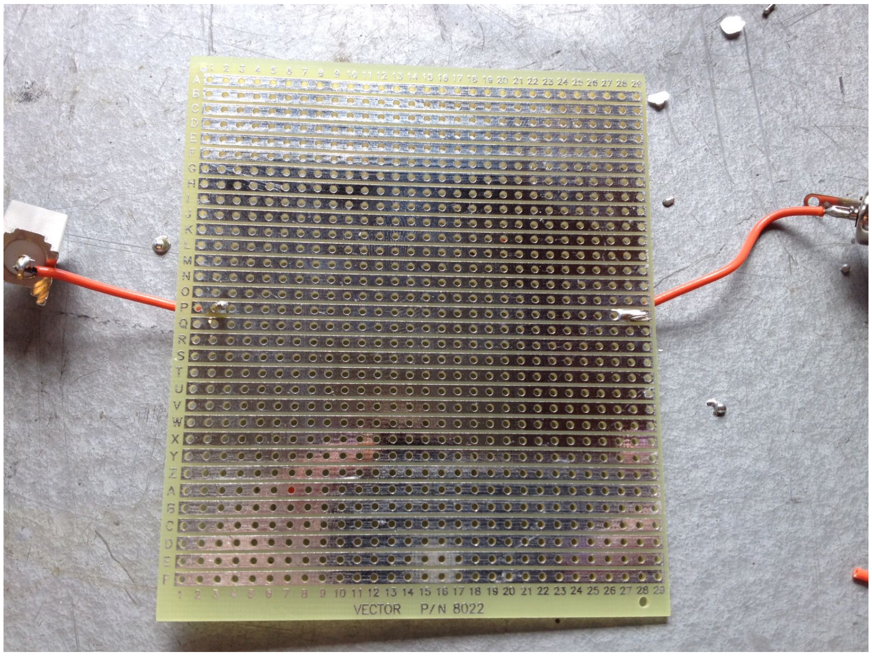


Figure 23: Under side.

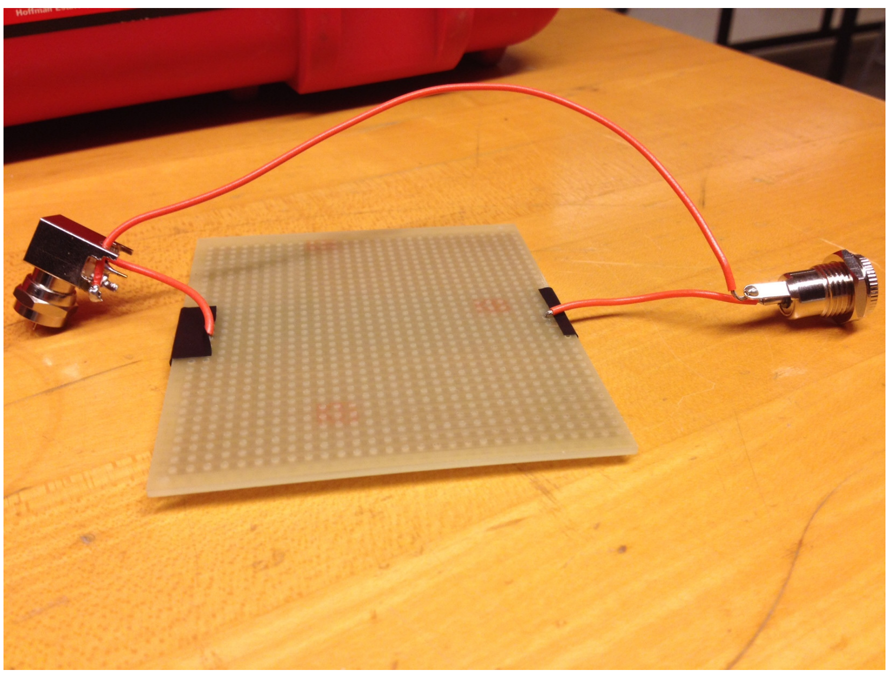


Figure 24: Solder ground pin on dc jack connector directly to one of the ground pins on the f type plug connector.

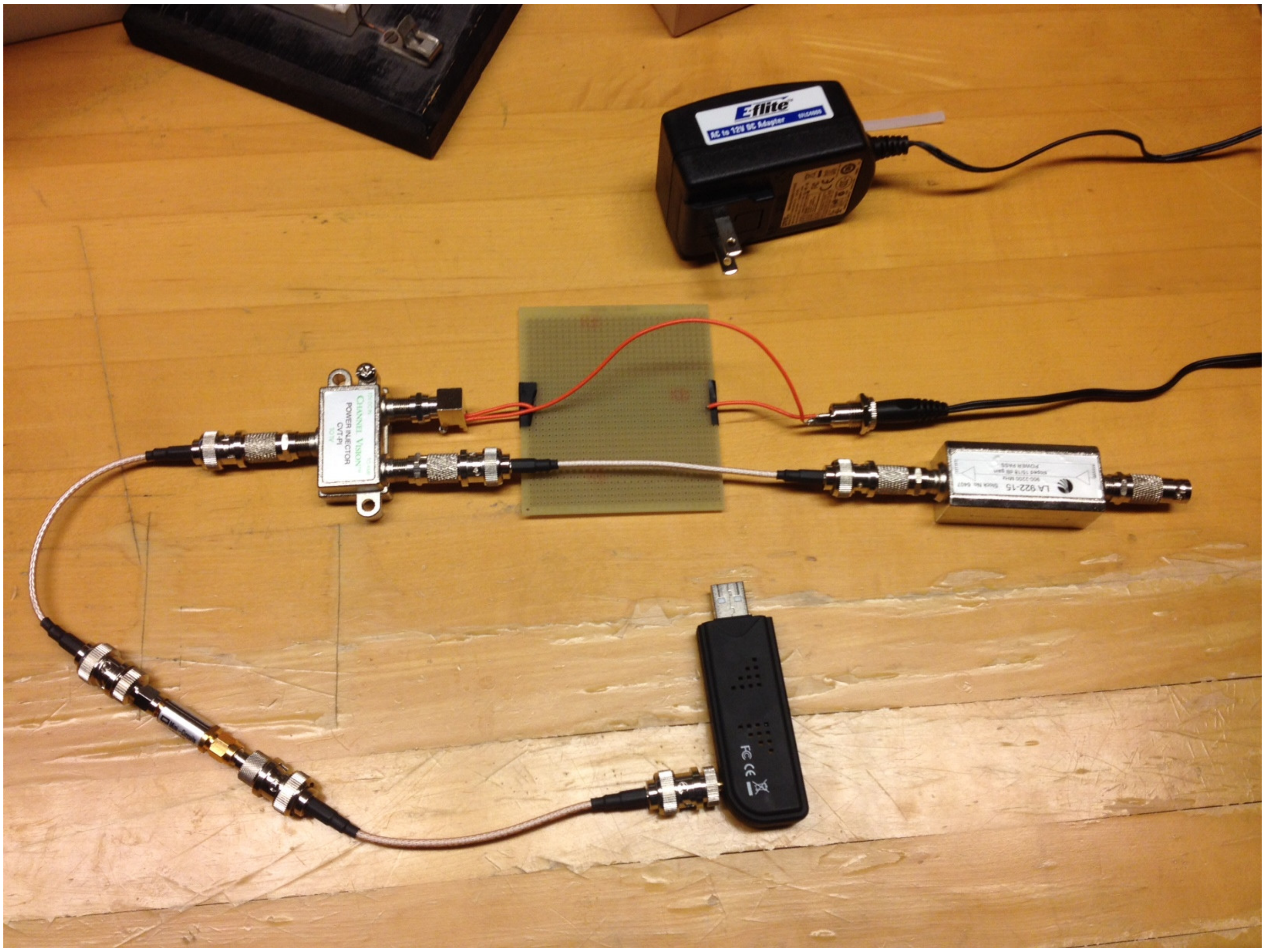
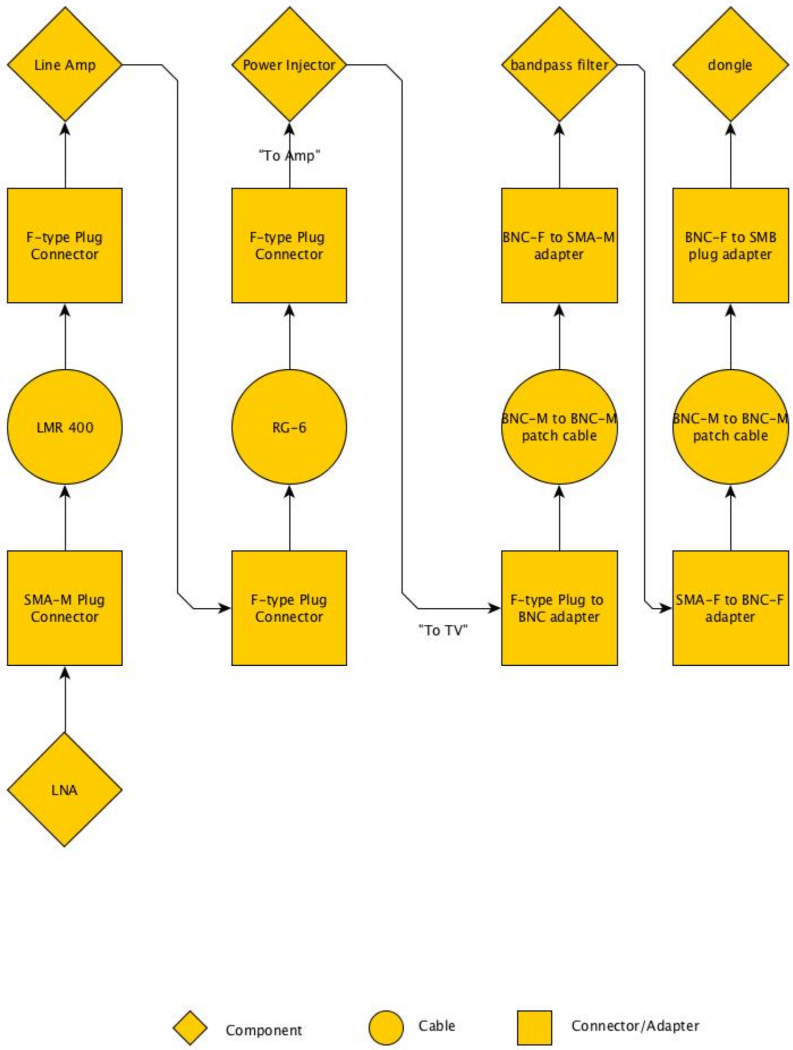


Figure 25: Back End b/t Dongle and LNA Put Together

8.2 LNA to Dongle Interface



8.2.1 Parts Needed

- 4 BNC jack (female) to BNC jack patch cables
- Line Amp
- Power Injector
- (DIY) DC plug (male) to F-type Plug adapter
- 1 SMA-M to BNC-M adapter
- 1 SMA-F to BNC-M adapter
- 5 F-type plug to BNC-M adapters
- Perf board/breadboard

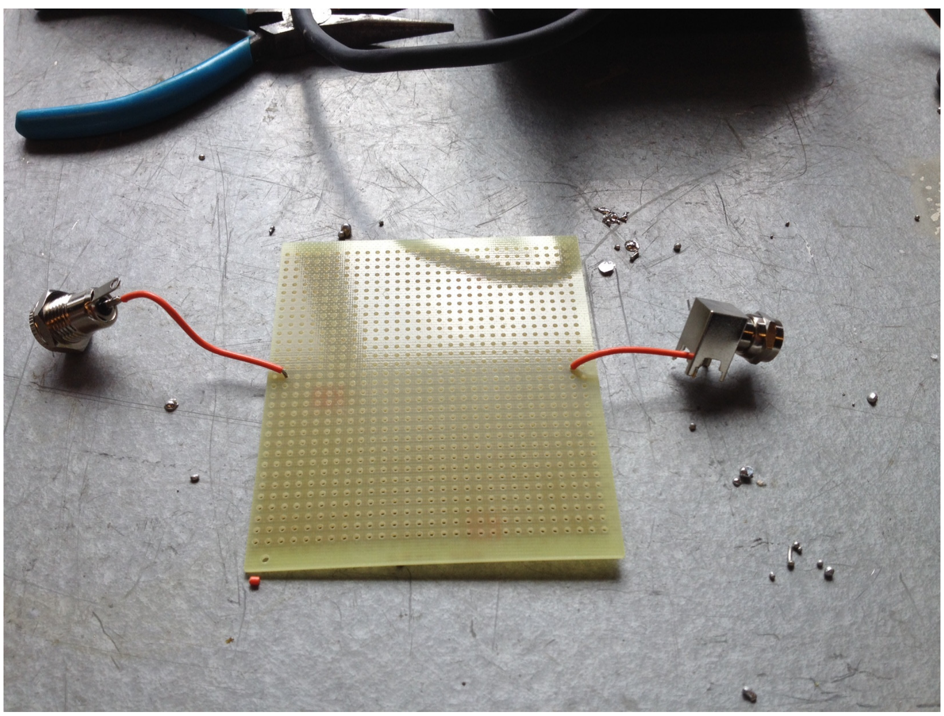
- 22-gauge copper wire
- DC-Barrel jack connector
- Right-angle F-type plug connector

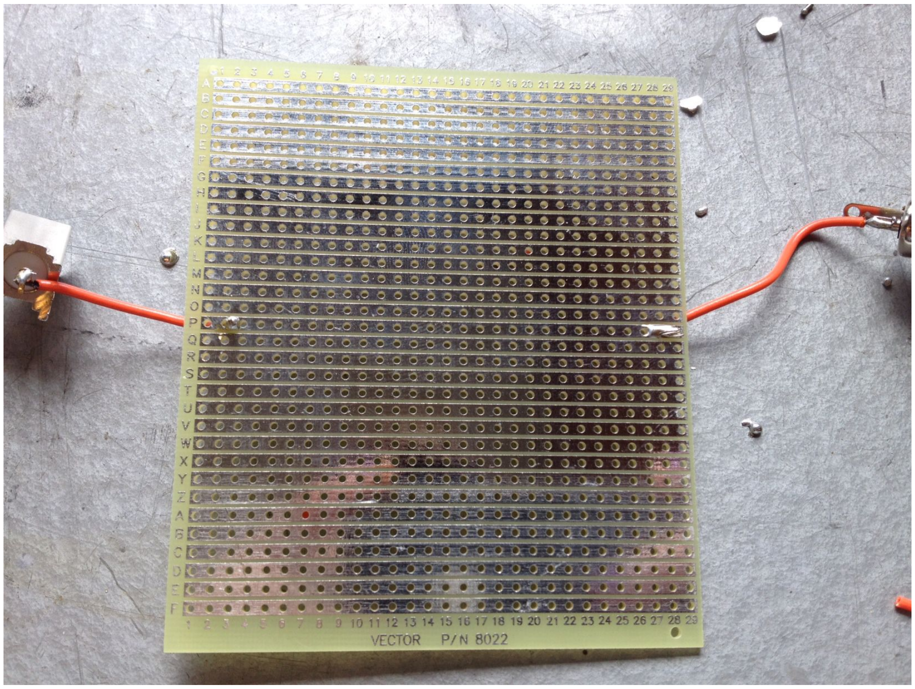
8.2.2 Tools Needed

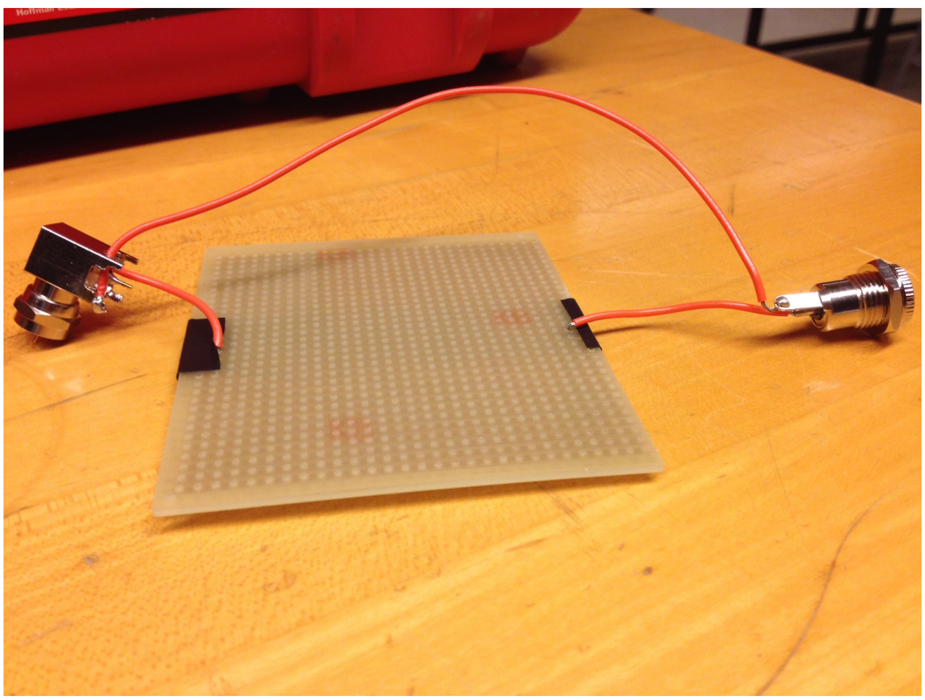
- Soldering Iron + Solder
- Wire Cutters/Strippers
- Electrical Tape

8.2.3 Building DC Barrel Jack to F-Type Plug Connector

- Assemble the perf board/breadboard, dc barrel jack connector, F-type plug connector, and copper wire.
- Solder middle pin of dc plug connector to perf board.
- Solder middle pin of f type plug connector to same conductive strip of perf board.
- Solder ground pin on dc jack connector directly to one of the ground pins on the f type plug connector.



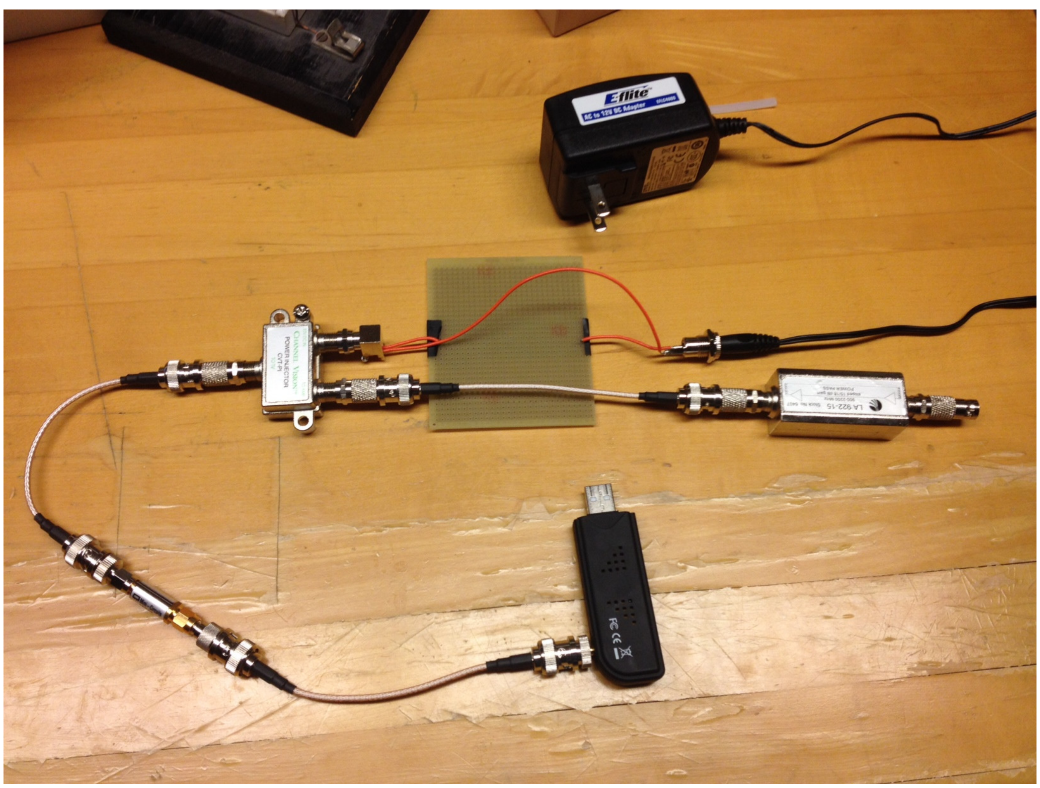




8.2.4 Assembly

- Attach one F type plug to BNC-M adapter to one end of one of the patch cables.
- To the other end of the patch cable, attach another F-type plug to BNC-M adapter.
- To the F-type side of the adapter, attach the ”in” side of the line amp.

- To the ”out” side of the line amp, attach another F-type plug to BNC-M adapter.
- Attach another patch cable to the BNC side of the adapter.
- To the other end of the patch cable, attach another F-type plug to BNC-M adapter.
- Plug the F-type side of the adapter into the ”to amp” input on the Power Injector.
- Screw an F-type plug to BNC-M adapter onto the ”out” of the power injector.
- Attach another patch cable to the adapter.
- Onto the free side of the patch cable, screw on your SMA-M to BNC-M adapter.
- Attach the ”in” of the bandpass filter to the free (SMA-M) side of the adapter.
- To the ”out” of the BPF, screw in the SMA-F side of the SMA-F to BNC-M adapter.
- Attach another patch cable to the previous adapter.
- Attach the BNC-M to SMB-M adapter to the patch cable.
- Plug the SMB-M side of your adapter into the dongle.
- Into the ”12V DC IN” portion of the power injector, screw the F-type side of the dc plug to F type adapter
- Plug your 12V DC wall wart power supply into the DC Barrel Jack side of your DIY adapter.
- Plug dongle into computer.



8.3 Feed

The feed consists of a low-profile helical antenna contained within an aluminum cake pan. The helix is composed of copper tape wrapped around a polystyrene foam core, with a foil plate to match its impedance to that of the cable.

Below are the steps we took to build the LNA for the SRT. To follow along with MIT's guide, see http://www.haystack.mit.edu/edu/undergrad/srt/pdf%20files/SRT_Hardware_Manual.pdf, beginning on page 8.

8.3.1 Cutting Styrofoam Rod

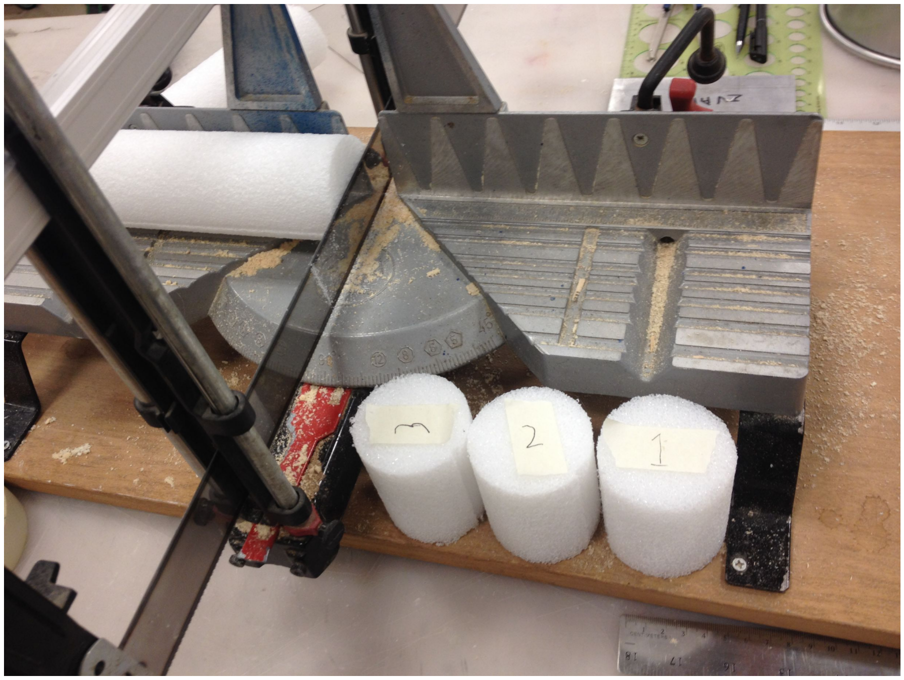


Figure 26: We used a hack saw in a jig to get perfectly straight cuts in the 2.5" Styrofoam rod. The Styrofoam was measured from multiple sides to determine the center. The rod we have ranges from 2 5/16" to 2 1/2" in diameter.

Figure 27: We used a drill press with a 1/4" bit. The Styrofoam was held by a vice on the drilling table. (The Styrofoam is a bit messy so we put down a rag under the vice) Note: we made three rods to provide room for error in the application and soldering of the copper tape later.

8.3.2 Drilling Aluminum LNA Base Plate

Figure 28: We put the plate in a vice which we secured on the drill press table with some heavy steel blocks.

8.3.3 Drilling Aluminum Cake Pan

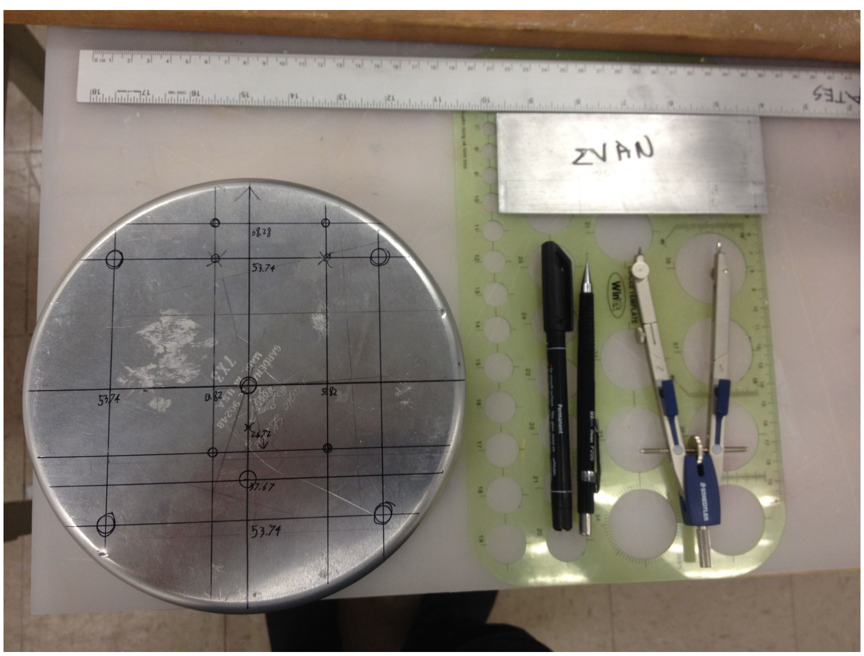


Figure 29: We made the measurements of the cake pan working out from the center which we found by transecting the circle and then making perpendicular rays from the center of each line cutting across the arc. This proved to be adequately precise.

Figure 30: The cake pan was more of a challenge to drill than the base plate as it was tricky to secure to the drill press table so we could make accurate holes. We ended up putting a 4" piece of angle iron on the pan and then clamping that down to the edges of the table.

Figure 31: Finished drilling

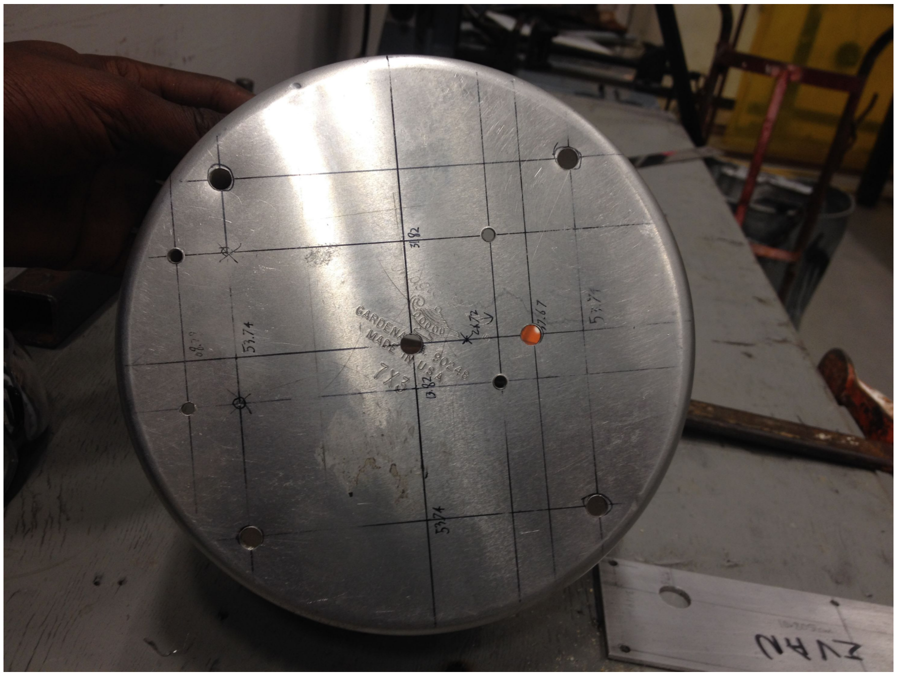
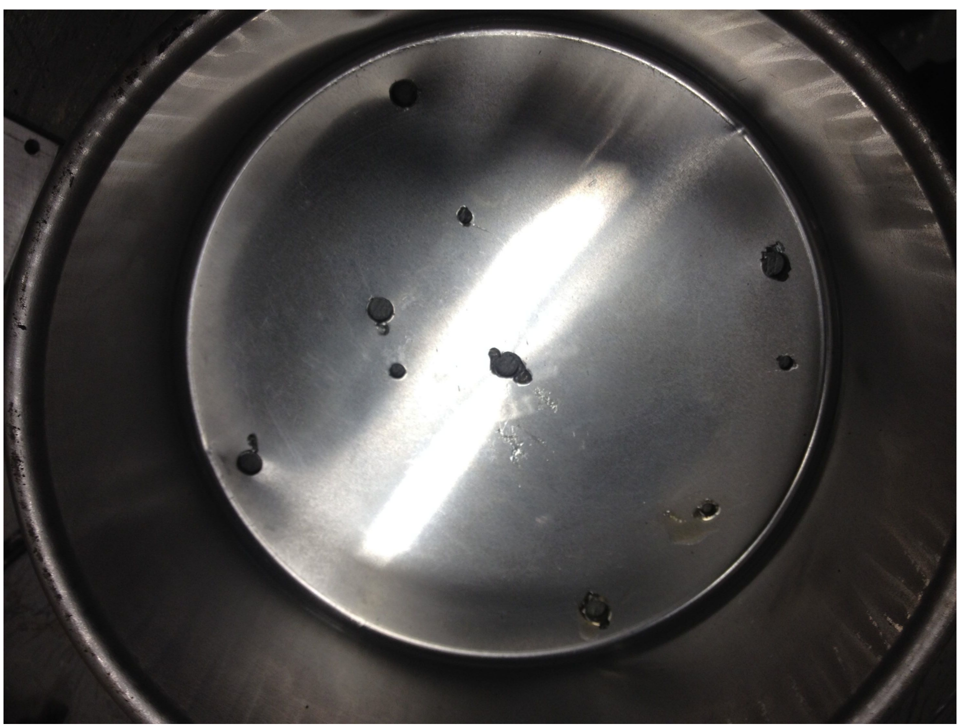


Figure 32: Finished drilling

8.3.4 Minor Concerns

The drilling instructions given by MIT are precise to a 100th of a millimeter. Having no access to a CNC machine, we used a drill press, which would have a precision closer to a 10^{th} of a millimeter. Given careful planning and drilling, this should be fine.



8.3.5 Making the Helical Antenna

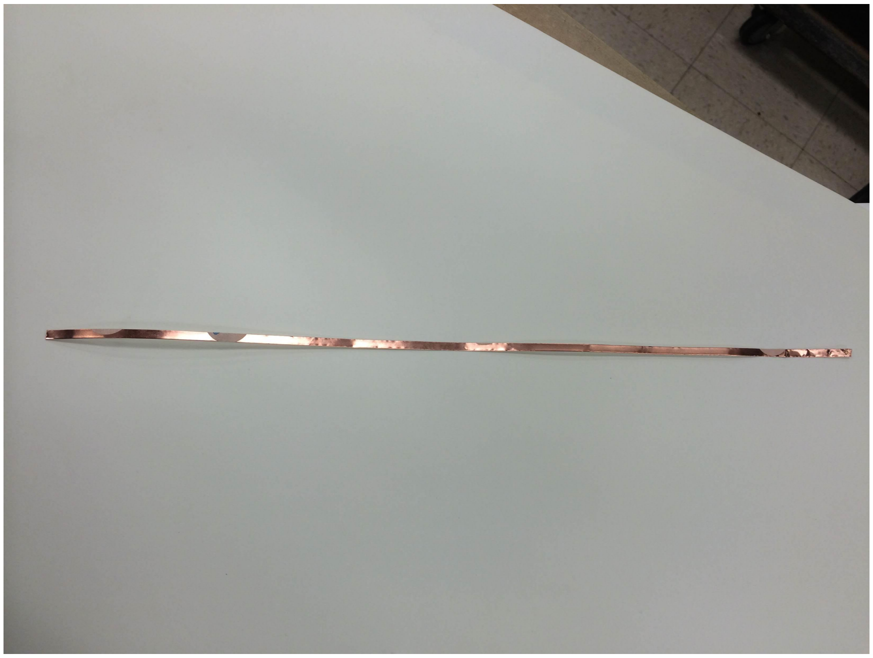


Figure 33: We cut out strips of copper tape with an X-acto knife and a straight edge.

Figure 34: Then we measured marked the styrofoam rod at even intervals as specified by the manual to get a consistent helix with the tape.

Figure 35: Once the tape was applied we soldered on 26.25mmx13mm piece of copper tape for impedance matching section. Note: It is important to include an extra 3-4mm on the long side of the rectangle so that it can be attached to the helix.

Figure 36: In the process we melted some of the rod. This should be ok as long as the tape stays in a helix.

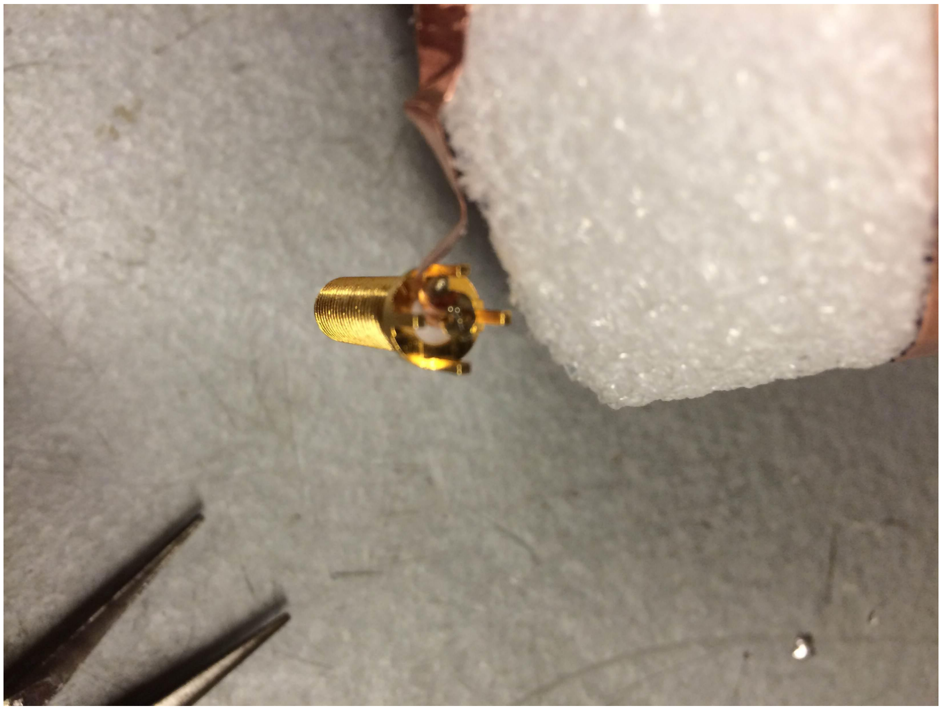


Figure 37: The we soldered the end of the helix to the SMA connector. MIT cut off some of the ground pins to make that easier. We left them on and it worked out the same.

8.3.6 Shaping the PC Board

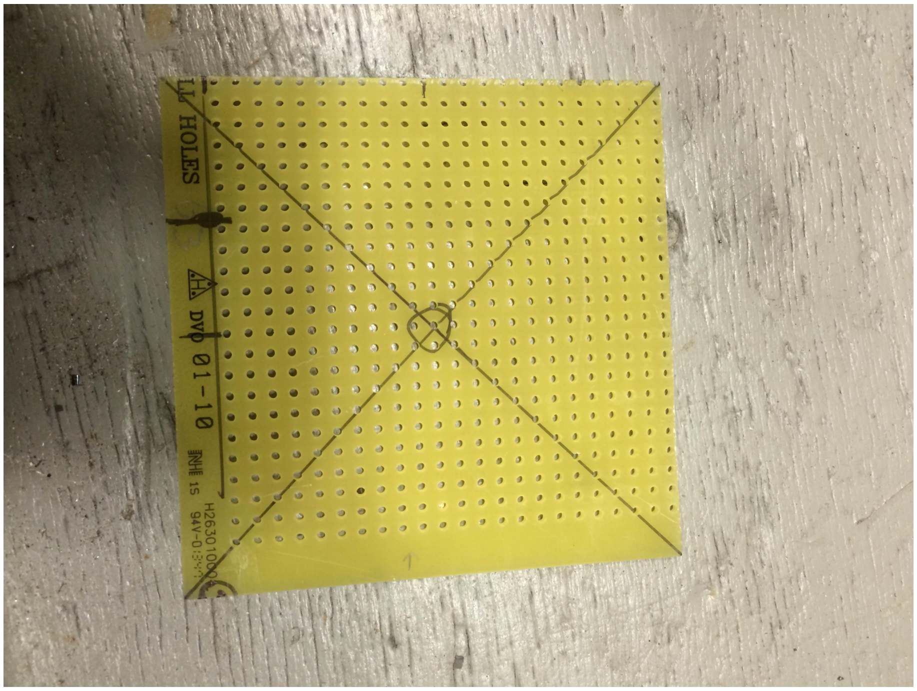


Figure 38: We cut the PC board into 63mm squares (We had enough PC board to make a couple back ups).

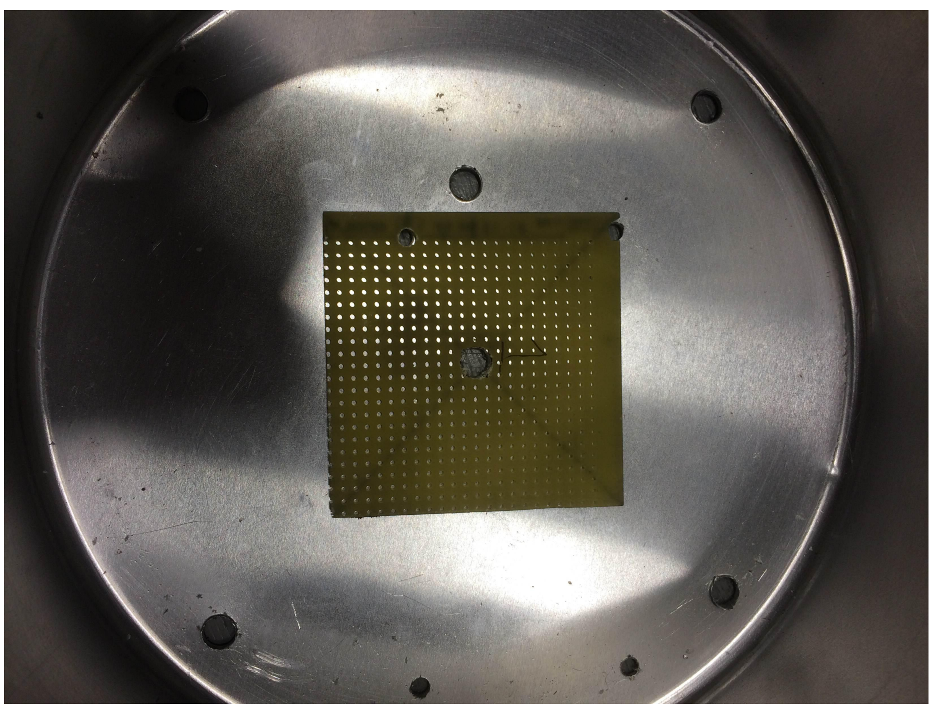
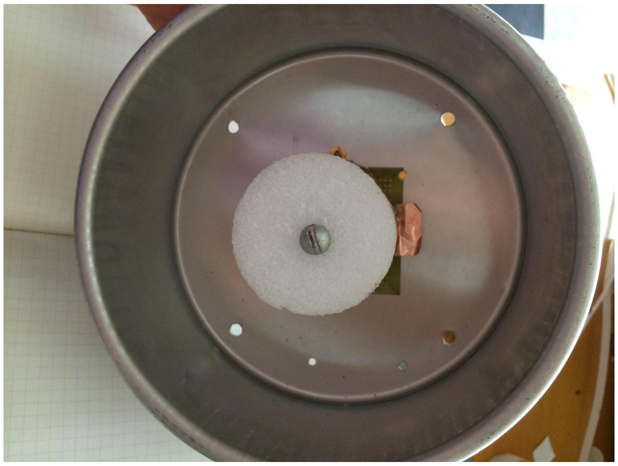
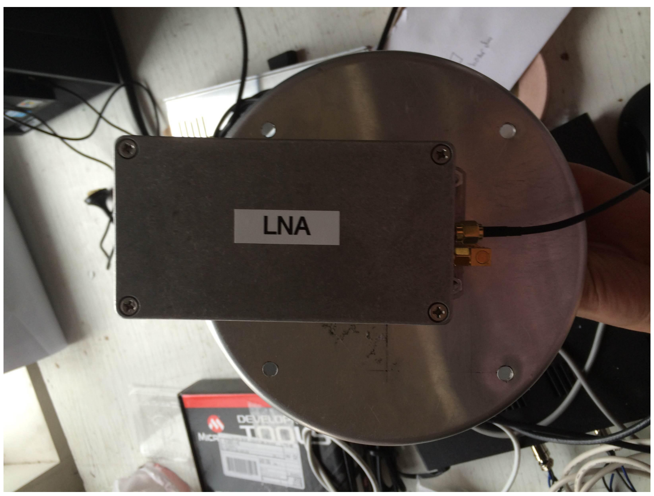


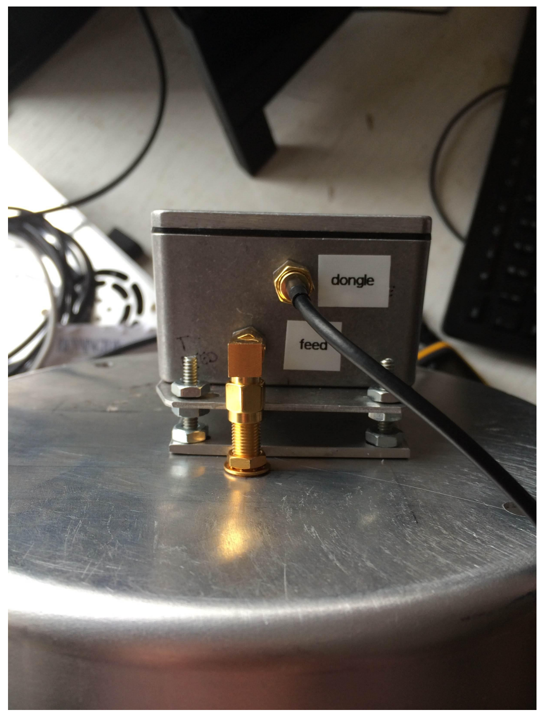
Figure 39: Then we drilled holes in it as specified by the manual using a drill press. It was relatively easy to secure the board in a vice for drilling.

8.3.7 Assembly

All the components were then bolted together.







8.4 Roof Mount

This section outlines the method we used for constructing our custom-designed dish mount. It was designed to use few materials, mostly scrap metal, and attaching the whole mount to pre-existing structures (in our case, a clerestory) on the roof of a building. Other options for roof mounts exist and not all methods will follow from what we have done below, but it may still be worthwhile to read through to get an idea of the process and the considerations made.

We used scrap metal to make our dish mount, so we started by cleaning the metal and cutting it to size. We plasma cut a 1.5’ x 3’ rectangle of 5 gauge steel (about 3/16” thick) and cleaned up the edges with a grinder.

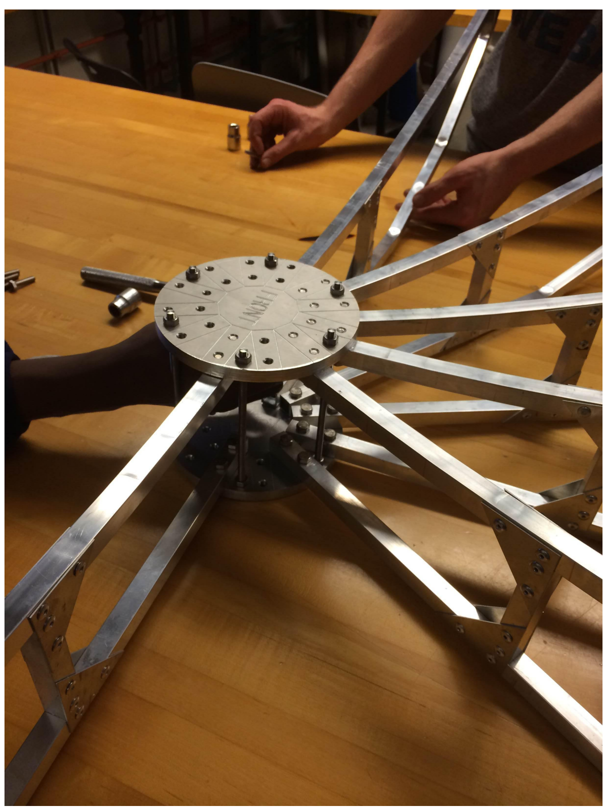
We cut an 11.5’ length of 2.5” (exterior diameter) pipe and cleaned in using a steel brush head on a grinder.

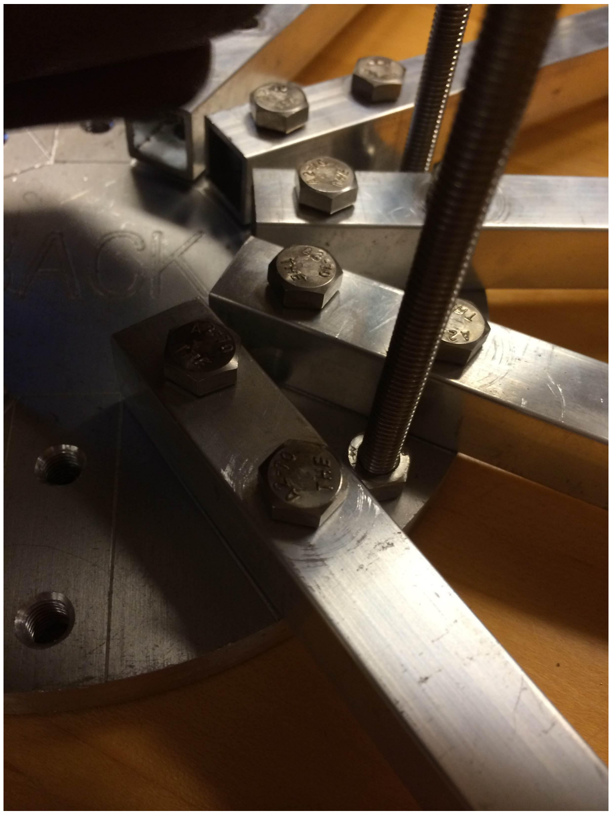
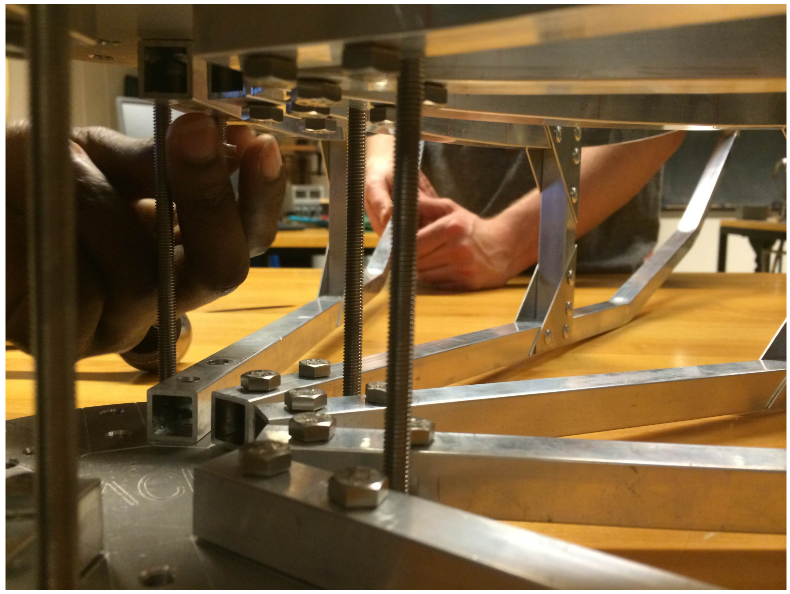
We then MIG welded the pipe to the plate. We reinforced the weld with a couple extra beads because most of the force in the system will be directed to this point. Keeping the roof mount square is essential.

We reinforced the base of the mount with angle iron to better support the weight.

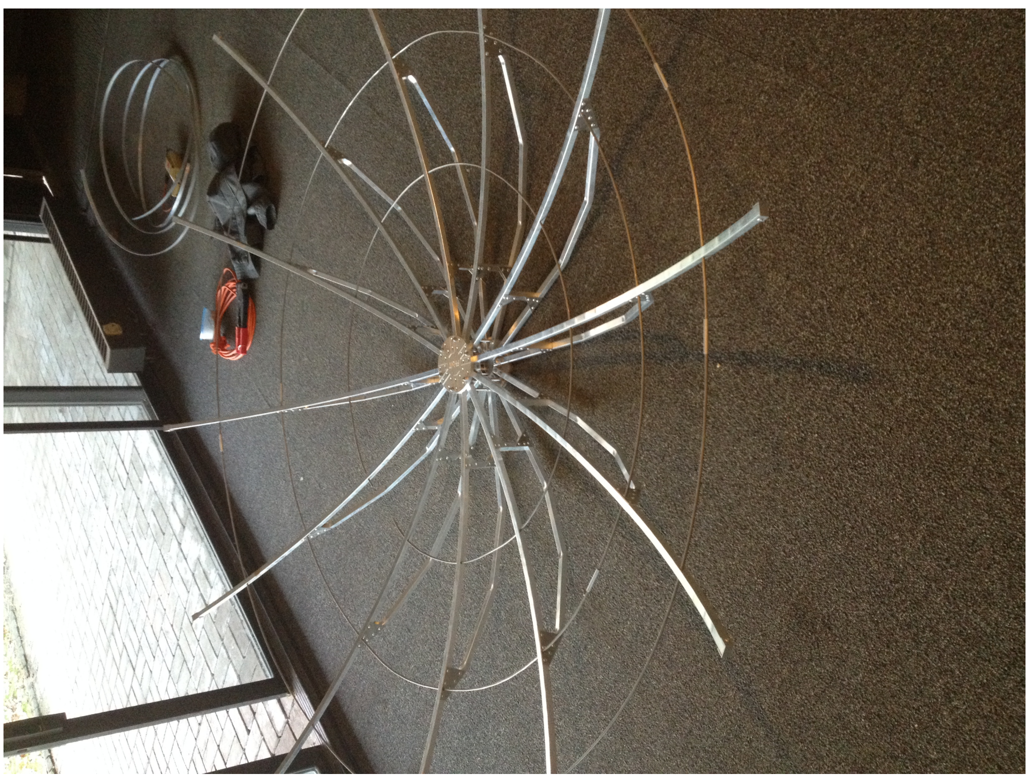
8.5 Dish

We bolted together the central plates, trying to make sure they are parallel to each other. We also bolted on half of the dish arms to test the accuracy of the central plate constuction.

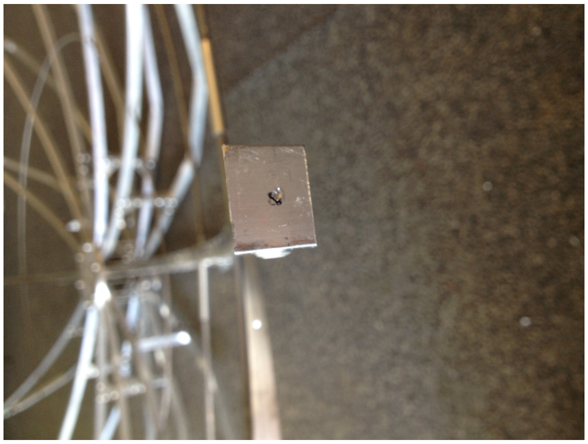


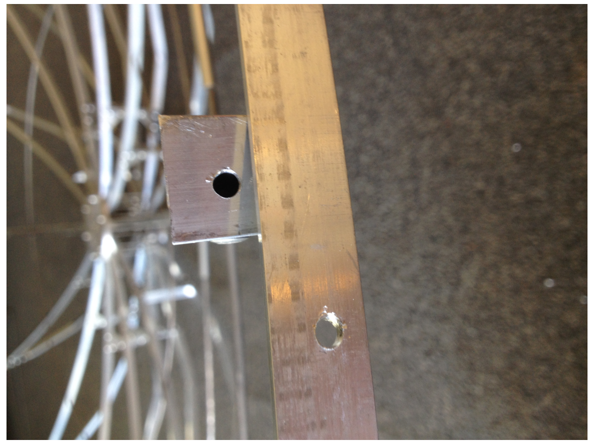



Once the ribs are put together and the support rings are in place, we are ready to put on the outer band.



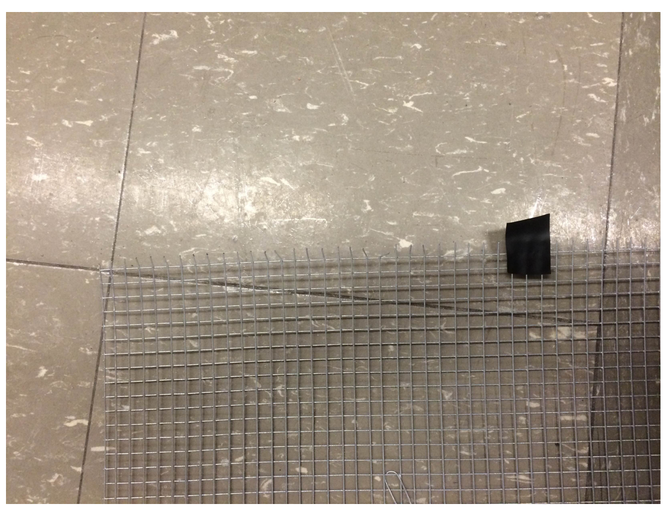
To do this, a hammer and tap were used to make dents in the end of the rib and the band. A power drill was used to cut holes from the dents, so the band and rib could be riveted together.

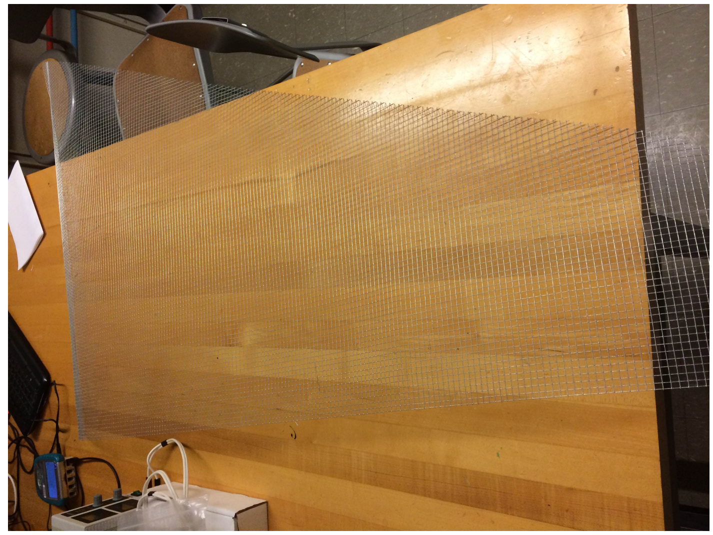




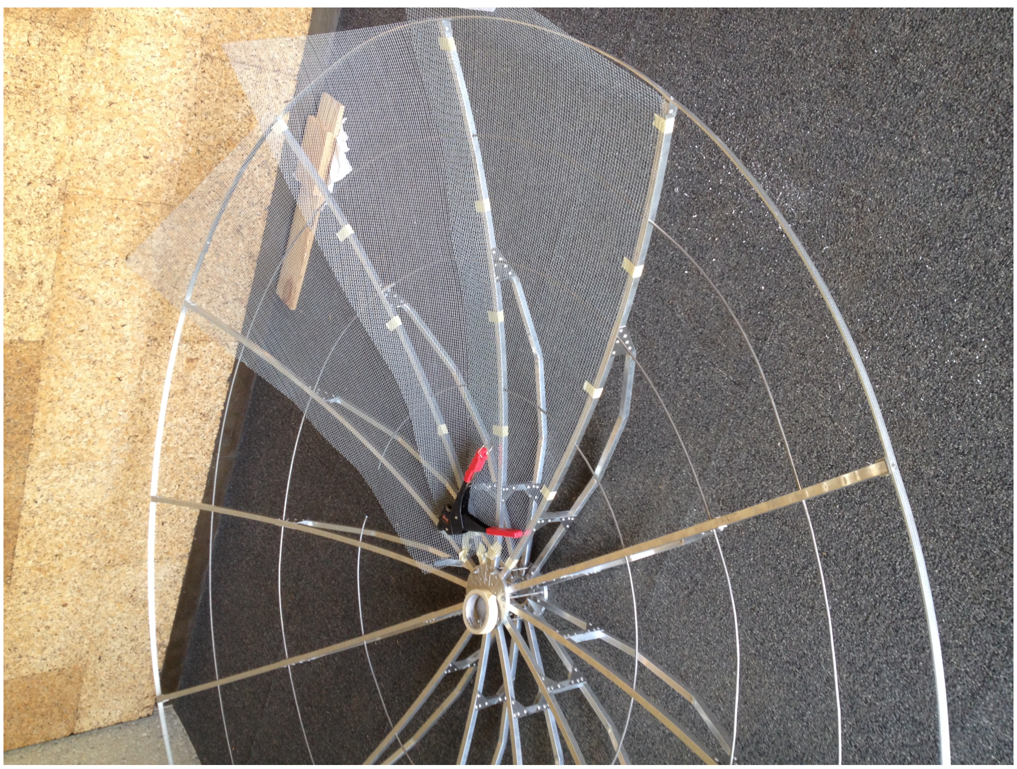
The process of tapping, drilling, and riveting was repeated for each of the 12 ribs of the dish. Once complete, the support rings were put in place. While the ends of the support rings should be crimped together, we did not, since they seemed secure enough without crimping.

With the support rings in place, the mesh is ready to be added. The first stage: cut the mesh to size.





After the mesh was cut to specification, it was laid out on the skeleton of the dish to make sure there was enough material and that it was cut properly.



After verifying the measurements of the cut material, all the sheets were secured to the skeleton, one at a time. One end of a sheet was secured to a rib using tape, while the other end was trimmed down to be flush with the next rib.


Figure 40: Trimming excess mesh to align with a rib

The next sheet is placed on top of the end of the first sheet so they are overlapping, and a strip with pre-drilled holes (part of the kit) were lined up on top of the rib. Holes were drilled through the rib in alignment with the holes in the wire strip.

The strip, with the overlapping pieces of mesh underneath, was riveted to the rib.

This process was repeated until all the mesh was fixed to the dish.

The outer edges were trimmed, leaving about ¼" to ½" mesh past the outer band (enough to wrap around the band a bit).

It was wrapped around the band, and secured using zip ties (~ 4 per section).