2 Way Loudspeakers

Michael Wojcik

Physics 406: 5/10/2013

Introduction:

I enjoy speaker building as a hobby and wanted to take things further with this course by pursuing a sort of loudspeaker design project. I have built a pair of *Overnight Sensations*, which are a DIY bookshelf speaker design by loudspeaker enthusiast Paul Carmody. I was financially limited in my design process, so I decided to first take measurements on the speaker enclosures I had already built per Paul Carmody's design specifications. Following this, I chose to redesign the speaker enclosures and attempt to use the same drivers and crossover networks and follow a folded horn design.

Initial Speakers – Overnight Sensations

The initial speakers I constructed some time ago were a pair of 2-way bookshelf loudspeakers designed by Paul Carmody. This design uses a Dayton ND20FA-6 tweeter and a HiVi B4N midbass woofer. This is a ported design that is estimated to have a 45-20,000 Hz frequency response. This specific design was chosen for a couple of reasons. Since this was to be my first speaker building project, I wanted to go with a reputable design where the risk I was taking in spending my time and money to build them was minimal. I also wanted a pair of smaller bookshelf speakers to specifically pair with my 1970's Panasonic technics receiver which has a power output of about 25 Watts per channel. After much research, I came across the Overnight Sensations. On his website, Paul Carmody actually posted the frequency response of these bookshelf speakers and they came across as a pretty good and relatively flat response over a 0 to 20 kHz range. This can be seen in Figure 1 in the appendix. Also, the handling power of these speakers was at about 25 Watts, which seemed to fit my receiver pretty well. A final large motivator for an undertaking such as this is also of course cost and these Overnight Sensations were initially estimated to cost about $250 to make (this estimate includes all electronic components, cabinet components and necessary tools).

When constructing the cabinets, I was limited with the tools I had at my disposal. The panels were as a result not perfectly square and a lot of the construction effort for the enclosures went into the post processing. This involved sealing the seams on the inside of the enclosure with a silicone sealant and painting the outside with a layer of fiberglass resin. It is important to have an air tight enclosure for loudspeakers because of the significant pressure changes caused by the woofer. Any small opening will result in the leakage of air which in turn causes small distortions in the sound and potential ‘squeaking’ noises as the air would leak through the tiny gaps.

During lab, I was able to take the speakers I had already built and measure the frequency response for the 0-2 kHz, 0-20 kHz and 0-50 kHz ranges. Figures 6-8 detail these frequency responses. As evidenced by Figures 6 and 7, we can see a pretty flat response between about 50 Hz to 16 kHz. The response begins to waver a bit between 16 kHz and 20 kHz. Past 27 kHz, the response drops pretty drastically. This matches the initial estimated response as noted online through the purchasing website (estimated response between 45 to 20,000 Hz). Some of the other peaks noted in the frequency response is most likely due to the noise in the room caused by the fluorescent lights and various other components in the building.

New Enclosure Designs- Transmission Line

For the rest of the semester, I wanted to take the Overnight Sensation speakers I had already built and design a new pair of enclosures. I was limited by financial funds, so I was planning on reusing the same midrange and tweeter and crossover network and simply create a new pair of enclosures. Because this was a school project, I had access to better tools and equipment. This inspired me to go for a fairly unconventional design that would otherwise be too difficult to make. I considered doing completely sealed enclosures or experimenting with different types of materials from which to make the cabinets. Ultimately, I decided on MDF as the material of choice. MDF, or medium density fiberboard, has been noted as one of the superior materials to use for speaker enclosures. This is because it has a great strength to rigidity ratio and is also good at damping the drivers’ vibrations. Other stiffer materials might resonate with the music more and would require more damping on the inside. Another reason for choosing MDF over other types of wood, is that it is not as prone to warping. MDF is essentially composed of highly compressed cardboard and glue. I did, however, decide to invest in sound isolating foam padding to lay the inside of the speaker enclosures.

As far as the actual enclosure design goes, a lot of research has led to transmission line designs for enclosures. An acoustic transmission line speaker enclosure, is a type of enclosure that has a labyrinth built within. When a driver emits sound by moving a cone back and forth, there is sound coming out from the front as well as the backside of the speaker. The sound coming out the back, however, is 90 degrees out of phase with the sound coming from the front. The labyrinth is then used to direct the sound coming out the rear of the driver through a path of a specific length. This length is typically equal to about ¼ the length of the wavelength of the driver's natural frequency. When the sound travels from the back of the cone, through the labyrinth, and finally out the port in the front of the box, it becomes in phase with the sound coming from the front of the driver. This then results in an amplified sound. Since I really enjoy the bass in much of the music I listen to, I was really interested in this type of design and wanted to get as much bass out of my 4 in woofer as possible.

There are a few different advantages to this transmission line design. First, this design can be used to minimize the mechanical impedance at lower frequencies. At the same time, this also reduces the energy coming out the back of the speaker and reduces distortion. By minimizing this distortion, we can maximize the acoustic output and minimize the negative acoustic effects of the driver.

Constructing these enclosures did prove to be a bit difficult. Although I learned a lot with the first pair of enclosures I made, this was a completely different design. For the transmission Line design with the midrange enclosure, I used the Bailey's Transmission Line calculator (found on http://www.mh-audio.nl/bailey_tml.asp) to determine the basic enclosure parameters:

Input Parameters:

Membrane Radius (Mr) = 5.08 cm

Driver Resonance Frequency (Fs) = 56 Hz

Enclosure Width Inside (Ew) = 12.7 cm

Resultant Enclosure Parameters:

Depth of the neck opening (Th) = 6.84 cm = 3.75 in

Depth of the mouth opening (Tm) = 4.51 cm = 1.77 in

Line Length (L) = 107.5 cm = 42 in

I then proceeded to use these output parameters to design these transmission line enclosures in Pro Engineer. This would facilitate the project greatly. I was able to use some of the tools I found in our RSO's shop to cut out panels that were fairly square. This setup that I used can be seen in Figure 9 and some of the completed panels can be seen in Figure 10. Figure 11 is a preliminary look of how the transmission line enclosure looks on the inside with some of the acoustic foam. It is not seen in this picture, but some acoustic damping filler was also put in to place behind the driver. The placement of the crossover was chosen to minimize negative effects on the sound waves going through the labyrinth.

In Figure 12 we can see the completed enclosure with rough dimensions below in the caption. Unfortunately, due to poor timing, I was unable to perform testing on these enclosures for their frequency response. Initial qualitative listening impressions are however quite positive. The use of the acoustic foam was helpful in damping and sealing some of the sides better because occasionally there seem to be some soft squeaking noises emerging from the enclosures. Sealing these enclosures with the fiberglass resin should take care of these problems. In the next couple weeks over the summer, I plan to seal the enclosures up well with fiberglass resin again and will apply a wood veneer to the outside for aesthetic reasons.

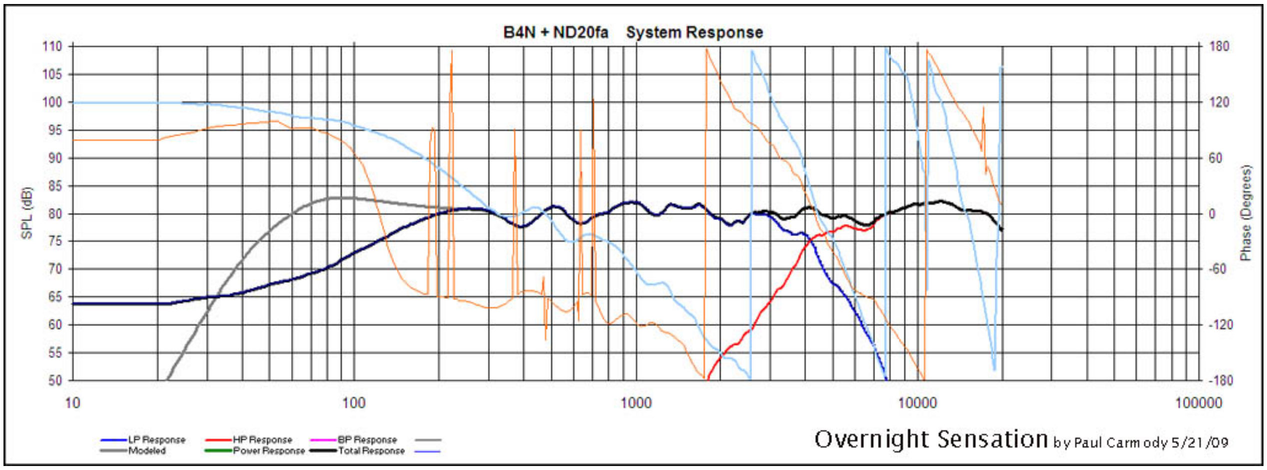

Figure 1: Frequency Response of Overnight Sensations as measured by Paul Carmody

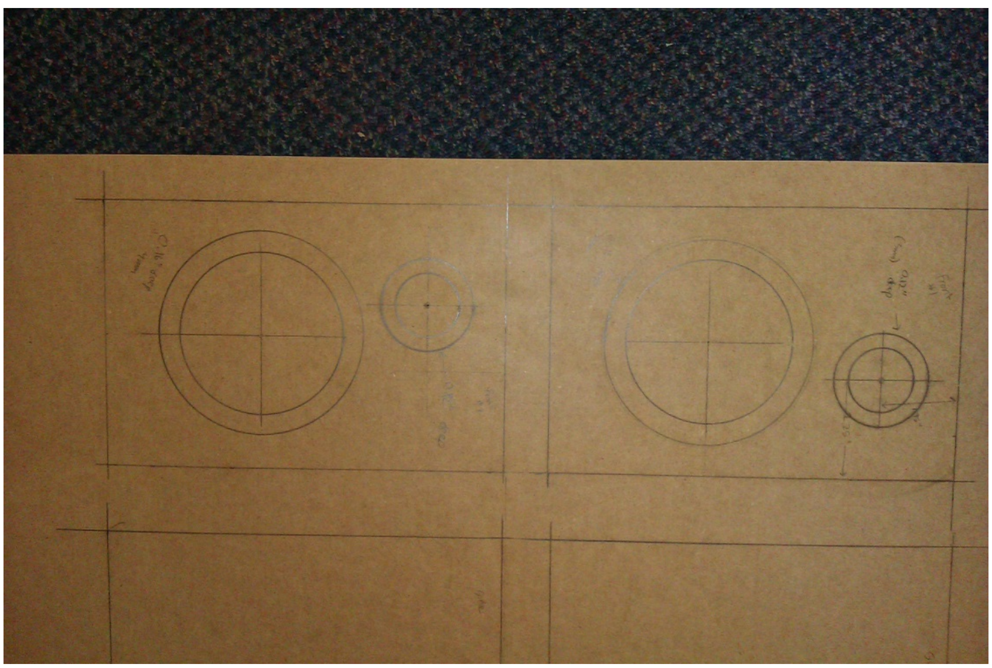

Figure 2: Original Cabinets drawn out on ½" MDF

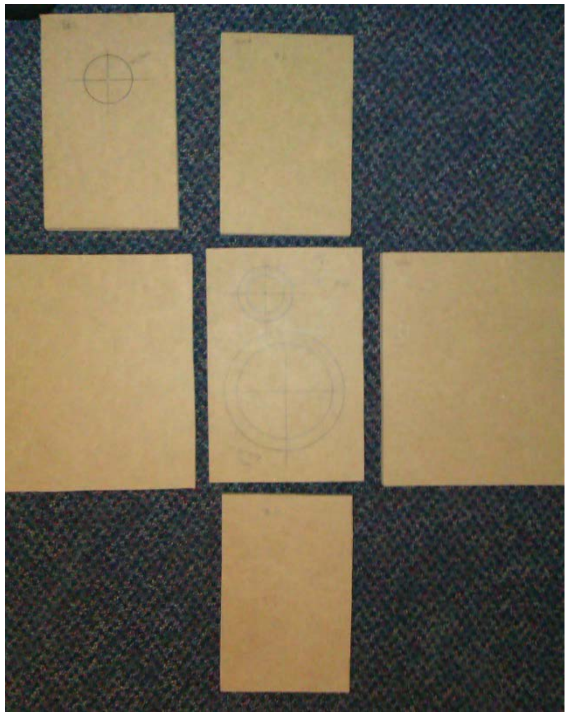

Figure 3: Single Panels cut ouf of MDF for original enclosures

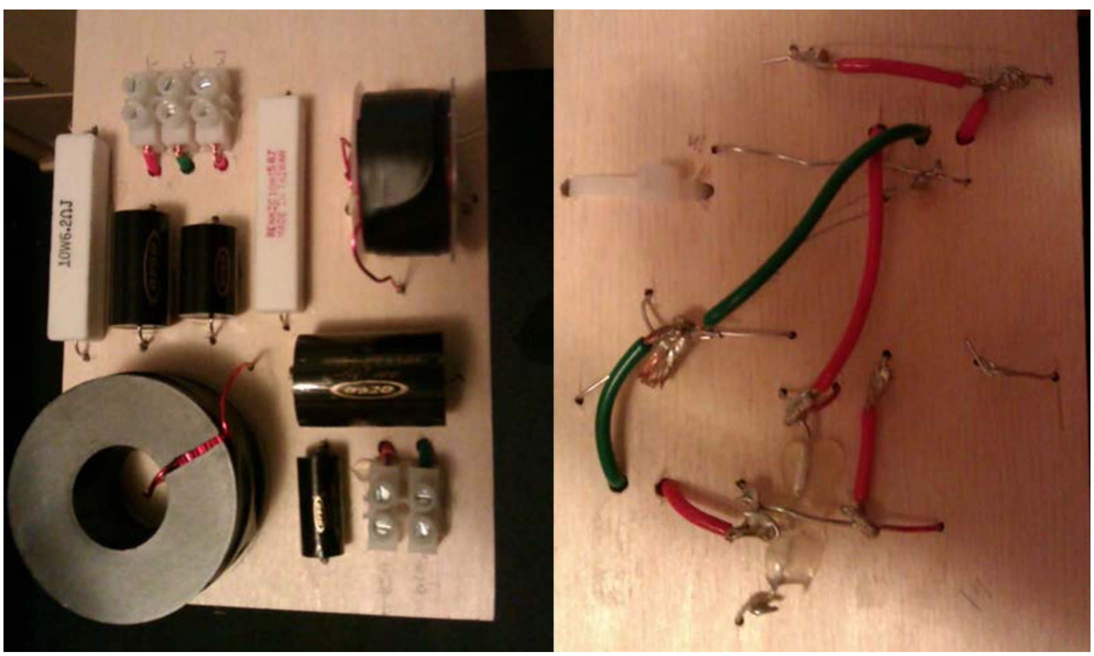

Figure 4: Crossover Network Soldered and attached to ¼” plywood

Figure 5: Completed Overnight Sensations in Original Speaker Enclosures

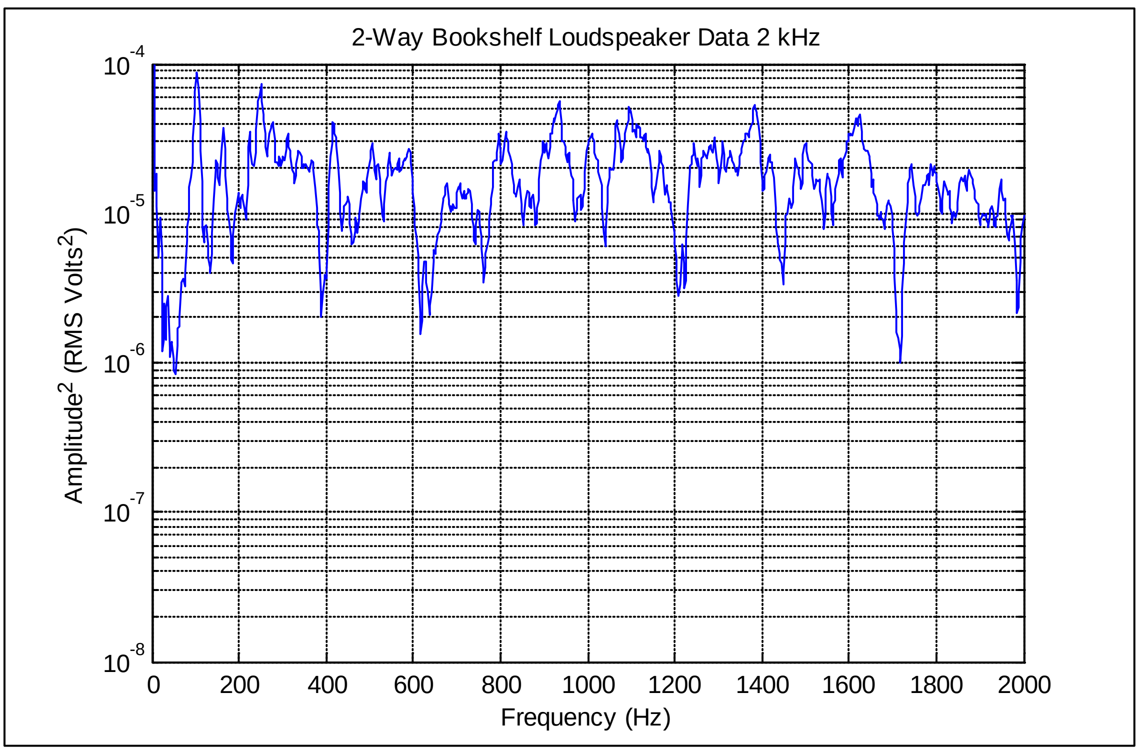

Figure 6: Frequency Response of Original Enclosures 2 kHz

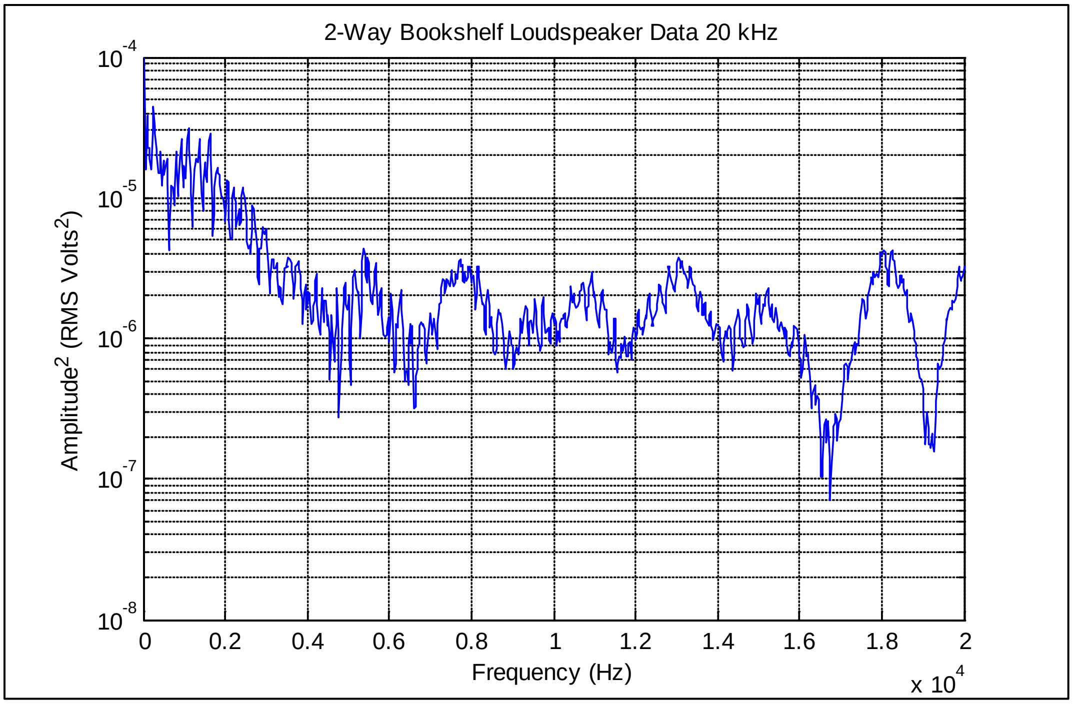

Figure 7: Frequency Response of Original Enclosures 20 kHz

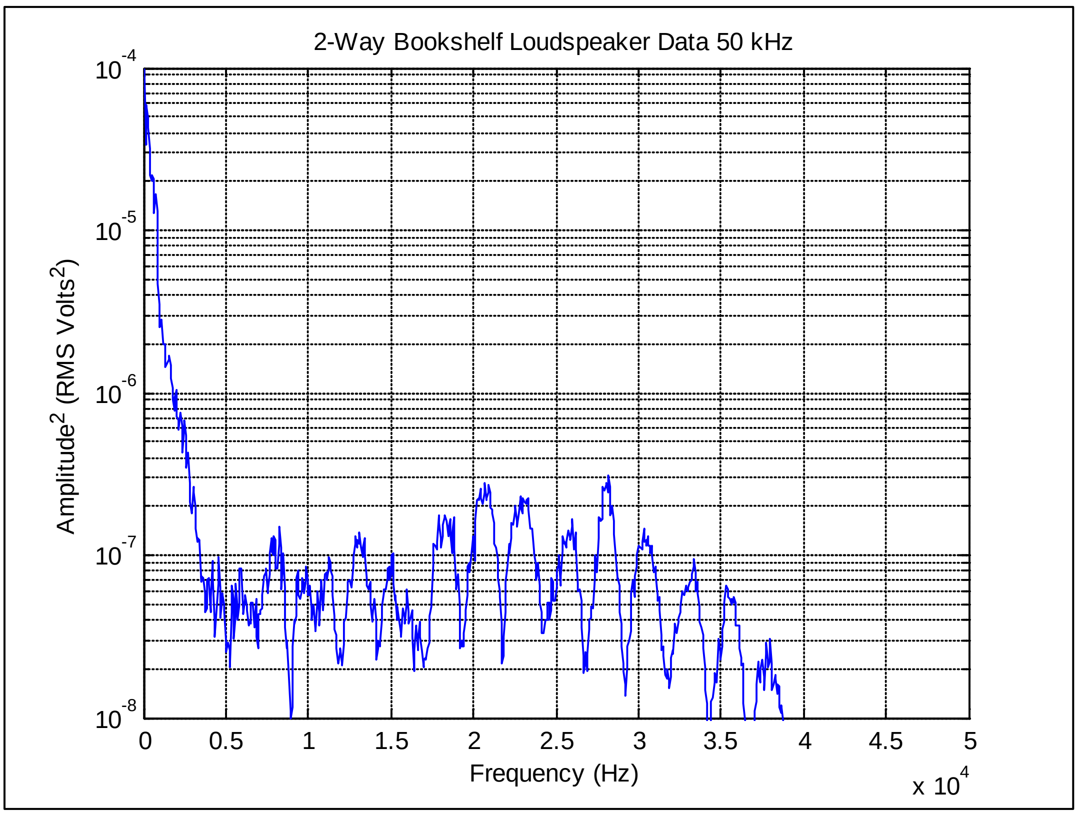

Figure 8: Frequency Response of Original Enclosures 50 kHz

Figure 9: Setup for Cutting the Panels in the MDF

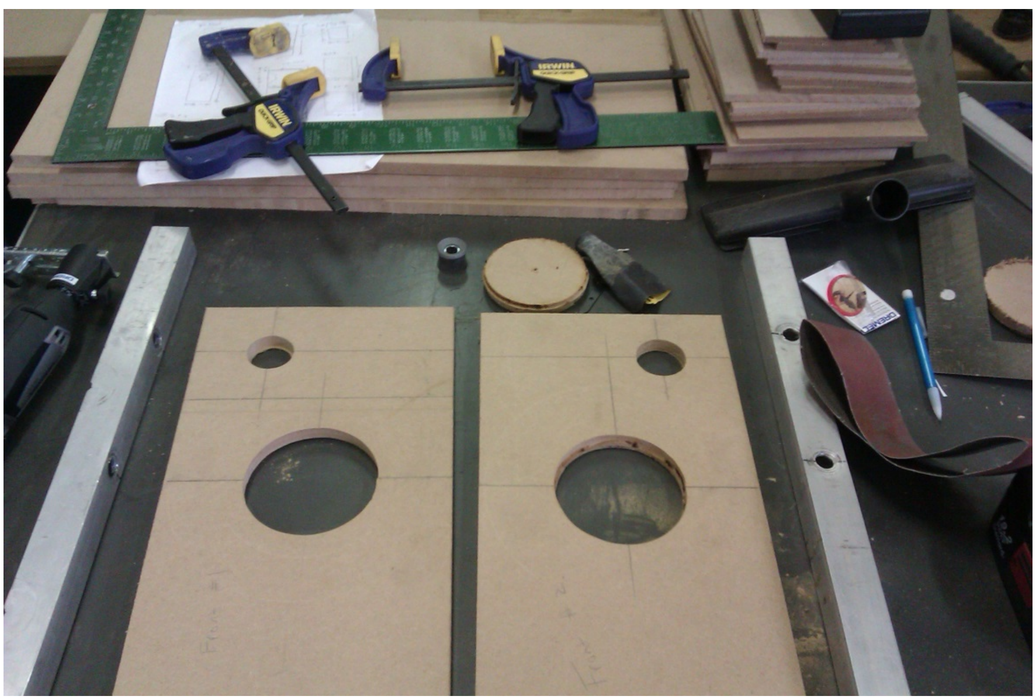

Figure 10: Front Panels Cut out from ½” MDF

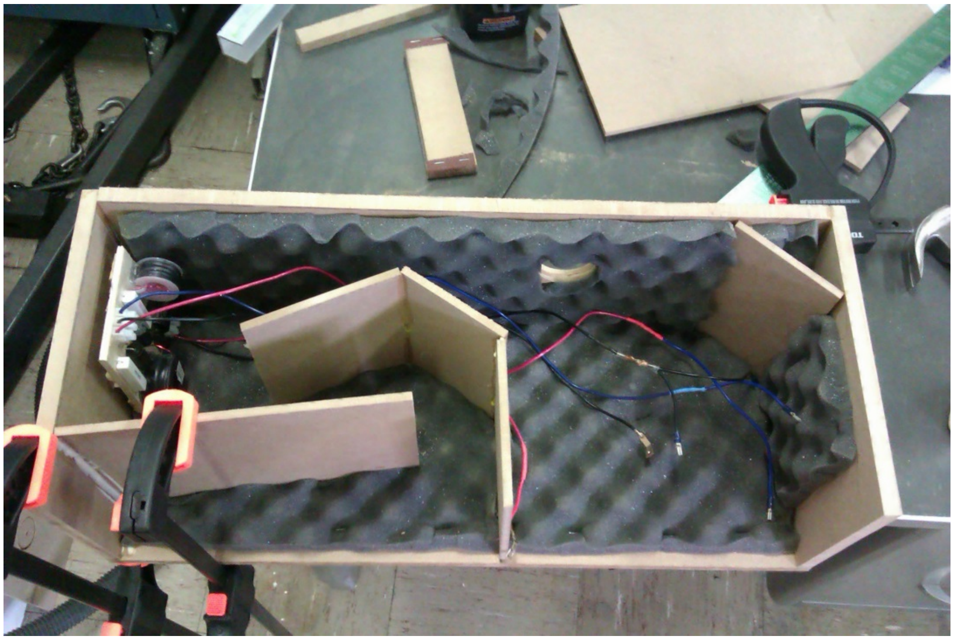

Figure 11: Transmission Line Path in Enclosure

Figure 12: Completed Enclosure (L x w x h = 10” x 8” x 24”)