2 – Way Loudspeaker

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1. Introduction

The objective of this project was to build a 2-way passive loudspeaker and test out the performance of it. My motivation of starting this project began from my personal hobby. I have always enjoyed listening to different kinds of speakers with different specifications and designs, and now I wanted to learn more about how everything works in detail. Also, I recently broke my speaker, so I wanted to give myself a try to build a loudspeaker, hoping the speaker would work at the end.

Because I have never built speakers, my main purpose was to learn each specific step for building a speaker and at the same time how Physics is applied into the speaker.

2. Overall Design

There were three important factors I had to consider: Design of the cabinet, which would be the base of the speaker, selections of drivers, which would be a woofer and a tweeter, and lastly, design of the crossover, which would depend on what kind of drivers I use. To begin building a speaker, I had to first decide whether the speaker cabinet should be a vented box or a closed box. Closed box speakers are usually made for car speakers and they produce tight, accurate bass and have a flat frequency response curve, but the sound is not as loud as ported box speakers. Vented boxes, or ported enclosures, have louder sound than closed box speakers. I decided to go with a vented design, because it can produce wider range of frequencies compare to sealed box. The shape of the speaker is decided to be a regular rectangular prism, because this is the most typical shape and I thought it would be the easiest shape to build for me since it was my first time making a cabinet.

3. Selection of Drivers / Crossover

For selecting drivers, I chose one woofer and a tweeter for each speaker cabinet. Certain models for drivers were selected depending on their Impedance and frequency response.

I. Dayton Audio RS150-8 6” Reference Woofer – Diameter with 6” was a perfect size for me since I did not want a huge or a too small speaker. This driver has a frequency response from 48 to 4200 Hz, which covers most of the low sounds. This means that when the sound with certain frequency is heard, this woofer can handle the frequency

between 48 and 4200 Hz. Impedance of this speaker is set to 8 ohms. Comparing to other drivers and considering the price, this driver was one of the best options I had. This driver had one of the lowest distortions and was the highest resolution driver series available.

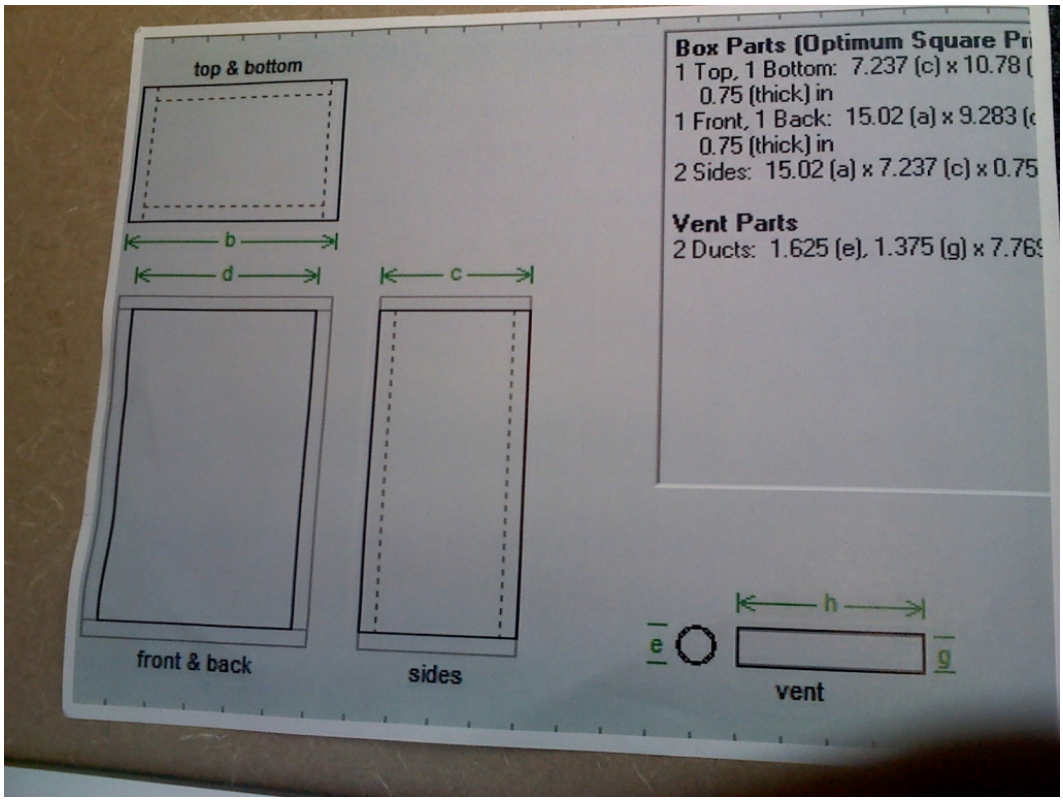
II. Tang Ban 28-847SD Shielded Neodymium Dome Tweeter – This is a 1" tweeter that has an impedance of 8 ohms and a frequency response of 1200-25,000Hz. It was very important to choose the tweeter with the same impedance as the woofer I chose to avoid the big volume difference between the woofer and the tweeter. For not very expensive price, this tweeter was my best option and it covers all the frequency range I need for the speaker, since 25,000 is the highest frequency a human ear can hear.

III. Eminence PXB2:1K6 Crossover – The function of the crossover is that it divides an input signal into two or more outputs of different ranges of frequencies, so tweeters and woofers will each get only the range of frequencies they were designed to play. From the drivers I chose, it is easy to notice that the frequency response of the tweeter and a woofer overlaps between 1200 – 4200 Hz. I needed a crossover that can balance out the two drivers, which has to have a crossover frequency of between 1200 – 4200Hz. Among various designs of crossover, I chose this model because it has a crossover frequency of 1,600Hz. Also, it is made for 2-way and 8 ohm drivers, so it was a perfect option for the drivers I chose.

Other than drivers and crossover, terminal, which connects the speaker with the amplifier, and port tubes were purchased. The size of the port tubes was chosen depending on the size of the vented hole, which was determined from Bass Box Pro program.

4. Box Dimension

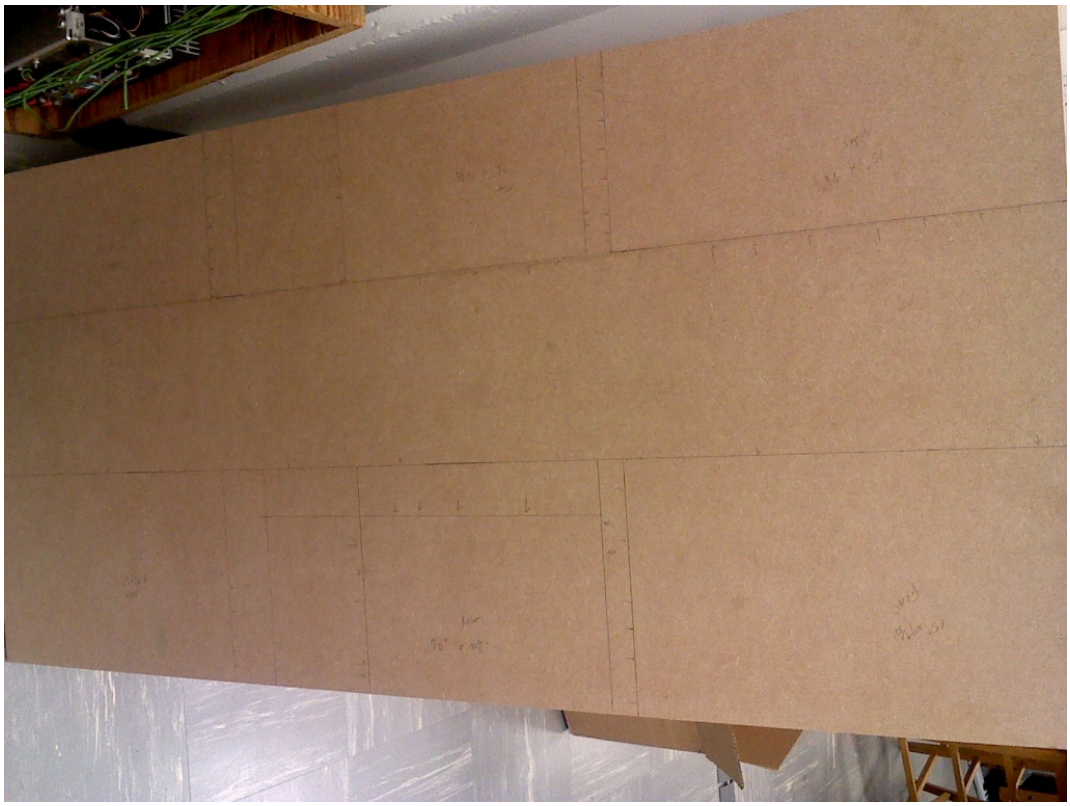
For the design of the cabinet, or enclosure design, I used the program called Bass-Box pro. It is a program that helps me determine the optimal internal / external volume of the cabinet and the dimensions of each side of the cabinet, depending on the size of the drivers. The depth and the width were set to golden ratio to minimize internal standing waves. The length of the vented parts was too long when only one vented hole was chosen, so I chose to make two vented holes, by dividing one long vented hole into two, in order to descrease the length of each one.

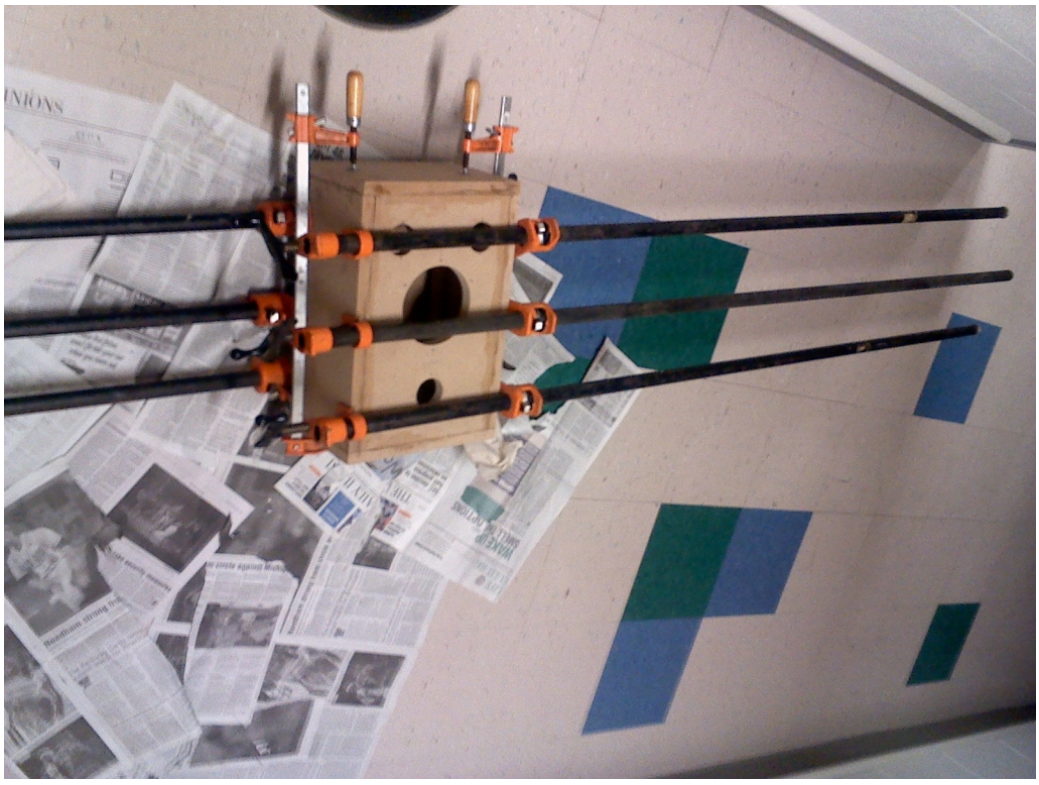


5. Cabinet Construction

One of the main features that the loudspeaker material must posses is a low amount of resonation, which means that vibrations should not be transmitted through the cabinet walls. Among various materials, wood was the best choice for my cabinet material. I chose Medium Density Fiberboard (MDF) for the material of the cabinet, because I wanted a material that is cheap and easy to buy. Among various wood materials, MDF is not a very good choice but it was the most accessible one for me. MDF is a type of fiberboard that is cheaper, more readily available, and more available in greater thickness than regular fiberboard.

When building a speaker cabinet, it is very important to seal the cabinet so then no air can enter into the box. In order to increase the possibility of air tightness between each sides of the box and firmness of the overall box, long wood sticks were installed in each side of the box. There was a specific glue type called, gorilla glue, which was used throughout the gluing process. Gluing process had to be quick and thoroughly made, because it was important to place all the sides together before the glue dries up. Also, corners of each side have to be glued tightly so then there is no air going in and out through small gaps. To make sure there are no small gaps and the glue permeates into each corner, I left the cabinet for one day to let it dry after gluing is done. Clippers were placed on the cabinet for a better tightness of the cabinet.





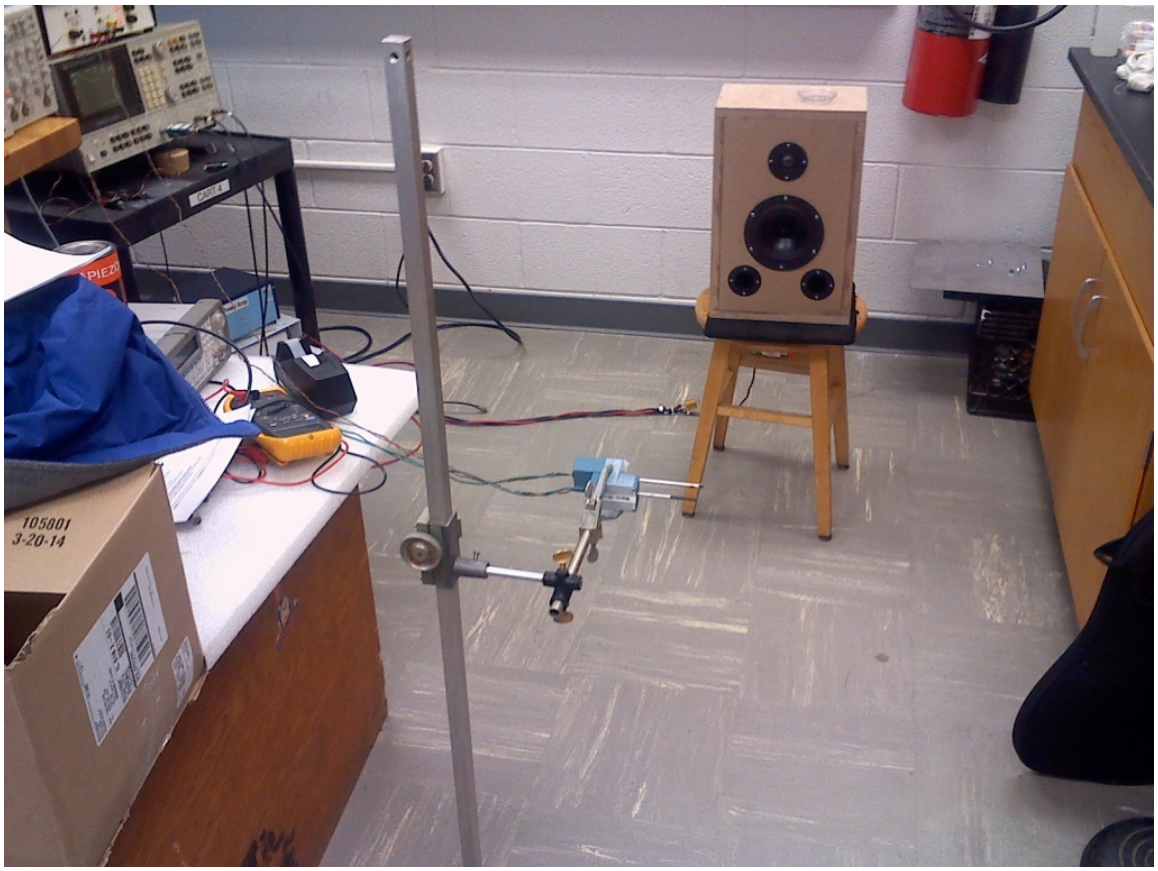
6. Driver Installation

From top to bottom, drivers were installed in the order of a tweeter, a woofer, and two ports at the bottom on the side of a woofer. Each driver is carefully placed so that it is placed symmetrically in the front. The location of the ports does not affect the sound performance significantly, so the ports were placed where I preferred. Installing parts into the cabinet had to be very carefully done with particular steps because the only way I could enter the inside of the cabinet and install all the parts inside was using a woofer hole. These are the steps I made:

First I had to solder the wires with tweeter then install the tweeter with screws. After installing the tweeter, I soldered all the wires for crossover and screwed the crossover inside the box with the wire coming out from the back of the box for the terminal. Then, a woofer and ports were installed and they were all screwed into the box as well.

7. Measurements and Analysis

When one of the speakers was complete, frequency response of it was tested. To measure the frequency-domain performance of the speaker, a microphone was placed between the tweeter and a woofer, 1m away from the speaker. The speaker was connected with 50W power amp and a sine wave generator. The Electrical Magnetic and Acoustical performances of the speaker's measurements were made, and frequencies were varied so that each one is tested with 0-200Hz, 0-2,000 Hz, and 0-20K Hz. Following pictures are the results.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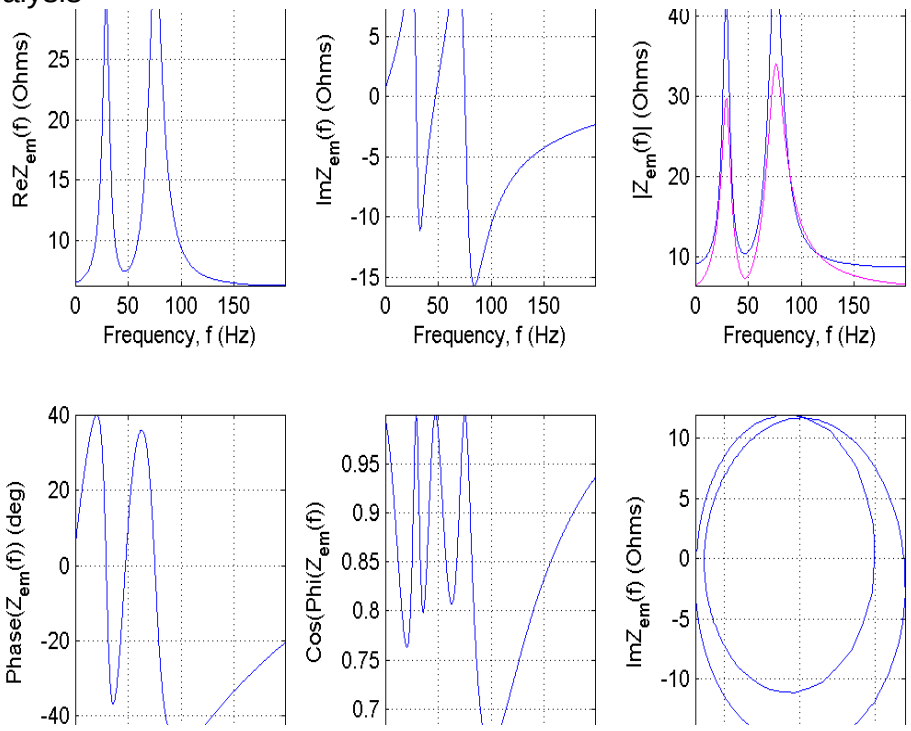
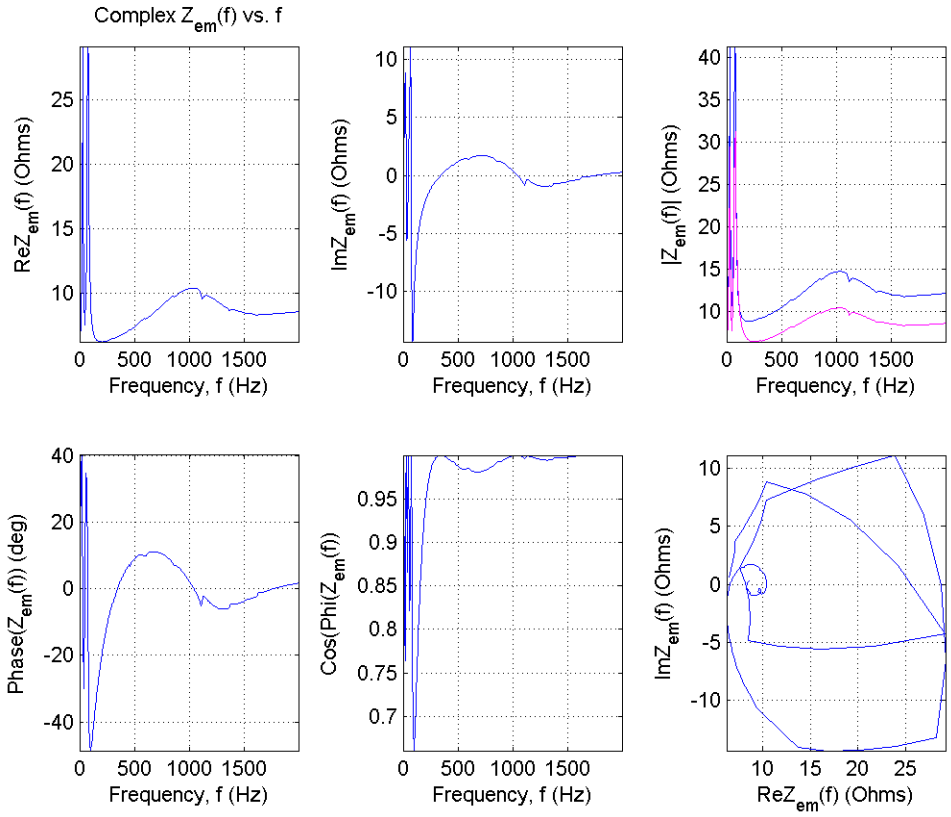
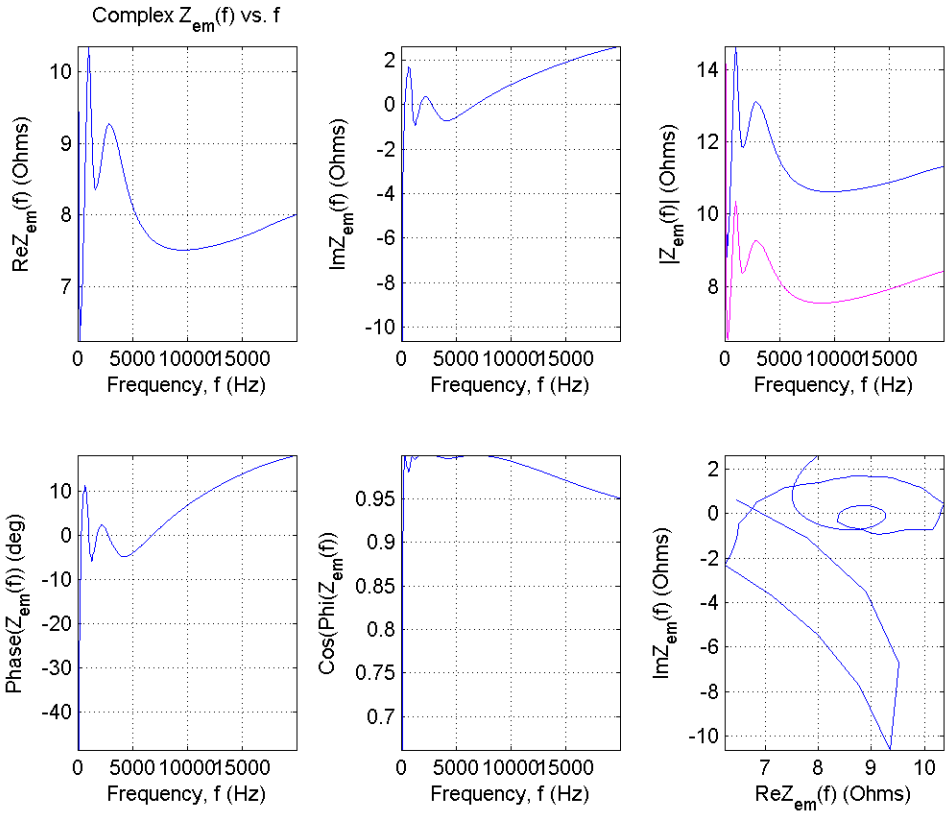
EM Analysis


ReZem(f) (Ohms)
Frequency, f (Hz)
ImZem(f) (Ohms)
Frequency, f (Hz)
|Zem(f)| (Ohms)
Frequency, f (Hz)
Phase(Zem(f)) (deg)
Cos(Phi(Zem(f))
ImZem(f) (Ohms)

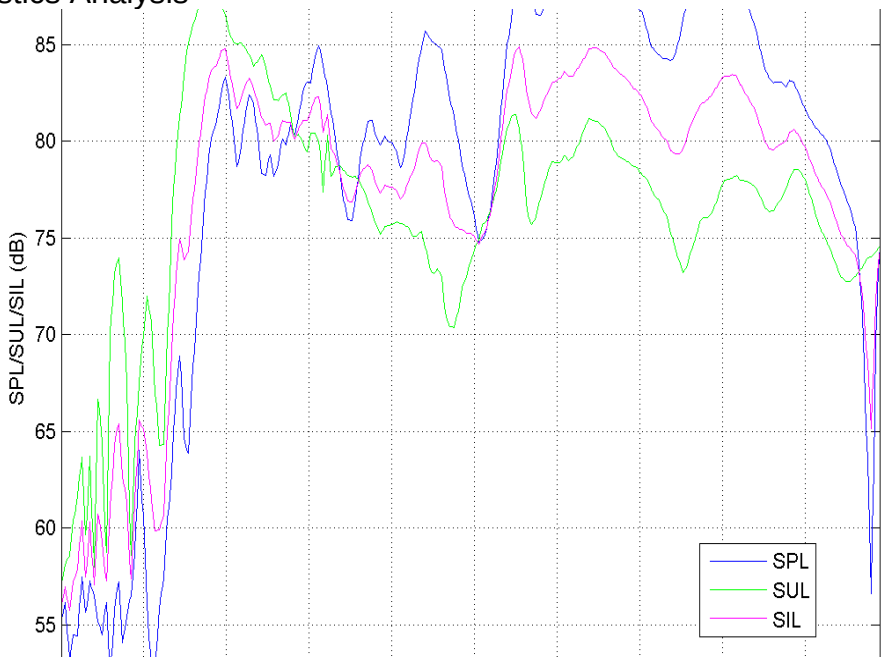
EM Analysis



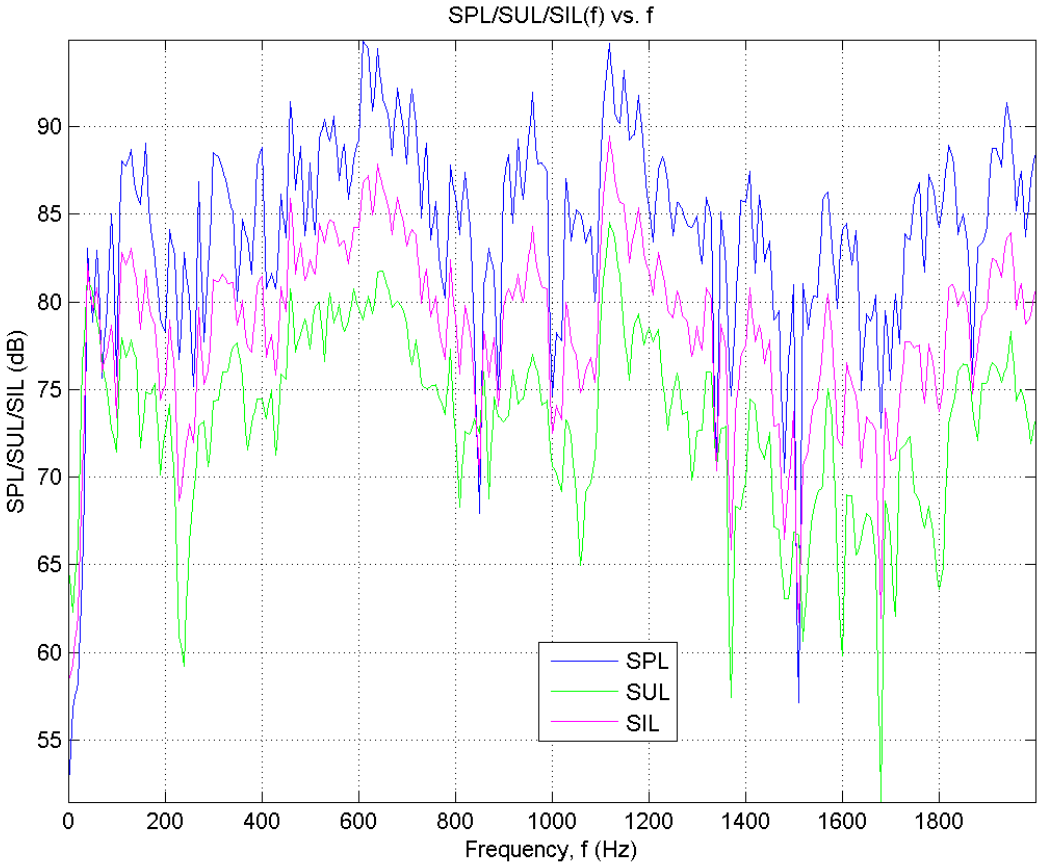
EM Analysis



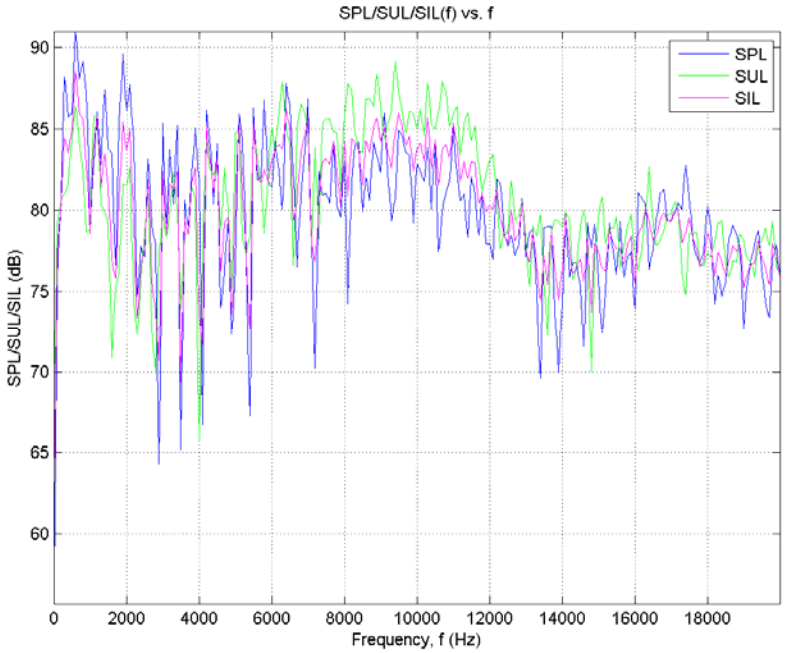
Acoustics Analysis



Acountics Analysis



Acoustics Analysis



The overall performance of the speaker came out great. In EM analysis graph, it is noticeable that there are two bumps, and the first bump is caused by the Helmholtz Resonance. Helmholtz resonance is a phenomenon that is caused by small open holes where air vibrates and causes frequency to vibrate as well. The vented cabinet act as a Helmholtz resonator because of the two vented holes. The EM analysis graphs show that the impedance eventually goes to 8 ohms, which is what I had to get as a result. The only small error that is noticeable is that the difference between theoretical and experimental value of the absolute value of the impedance vs frequency graph. This probably was caused by the error in matlab code, but it is not very significant considering the performance of the speaker.

Acoustical performance of the speaker was great as well. The graph shows the sound pressure level, sound particle velocity level, and sound intensity level. As frequency range increases, they all eventually overlap similarly, which shows that they all balance out. In person, the acoustical performance of the woofer was surprisingly good because the sound was loud and noticeable from very low frequency.

8. Conclusion

Overall, building a speaker from scratch was rather intersting. I learned that every measurements and procedures had to be done very accurtately and in order. There is one more speaker cabinet that needs to be finished. After finishing installing the drivers into it, I will be coloring the speaker cabinets to make it visually nicer. Eventually, it would be interesting for me to connect to the amplifier and try out the songs to test out the quality of sound when listening to daily music.