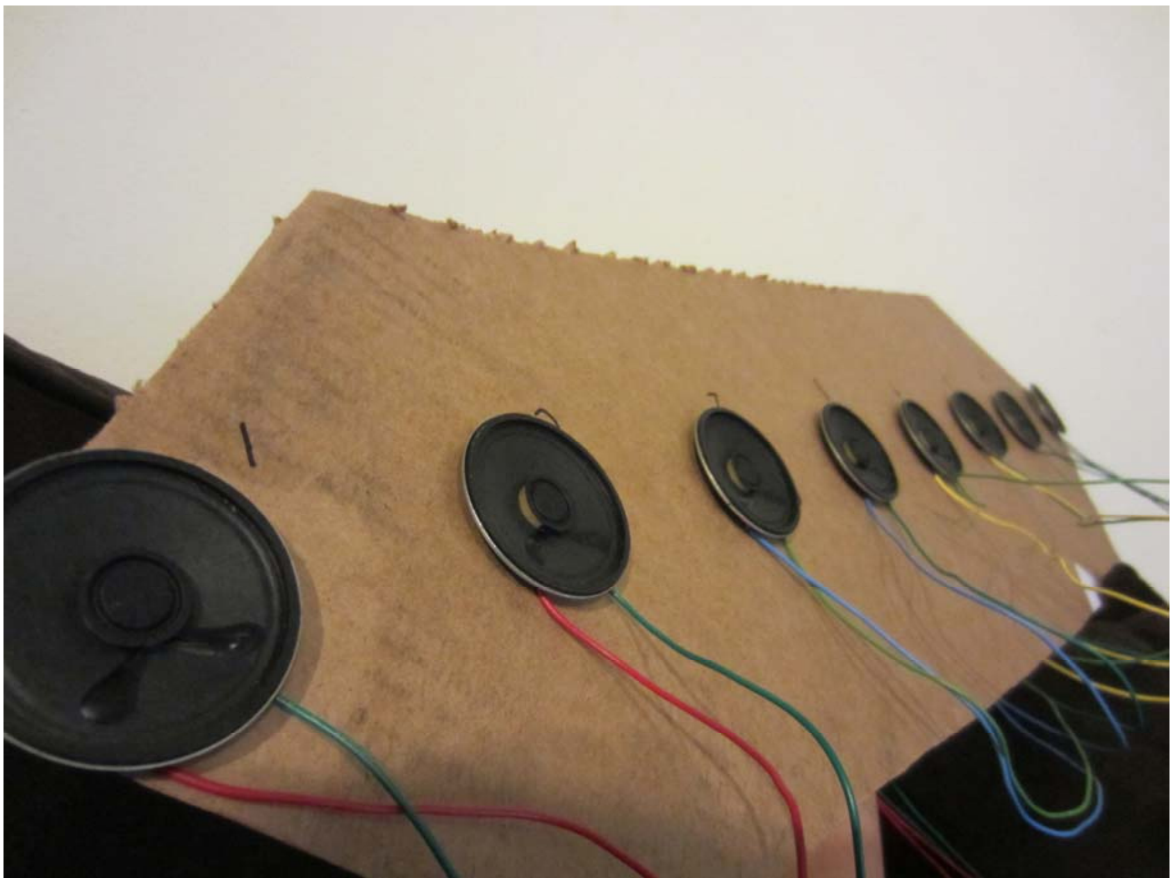
Sound Localizing Speaker Array



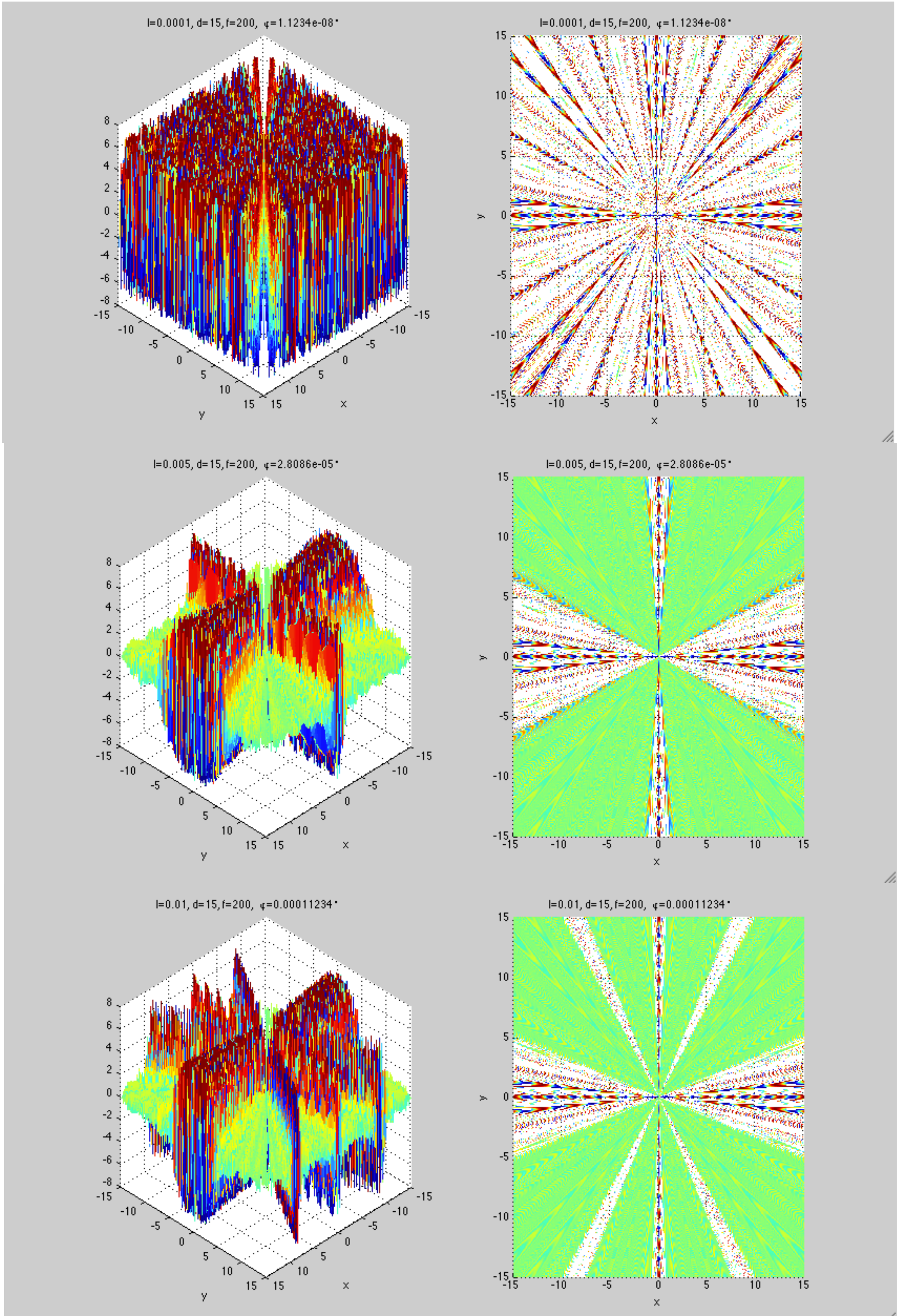
Michelle Ansai, Robby Regalbuto
Physics 406, Spring Semester 2013
Professor Errede

I. Introduction

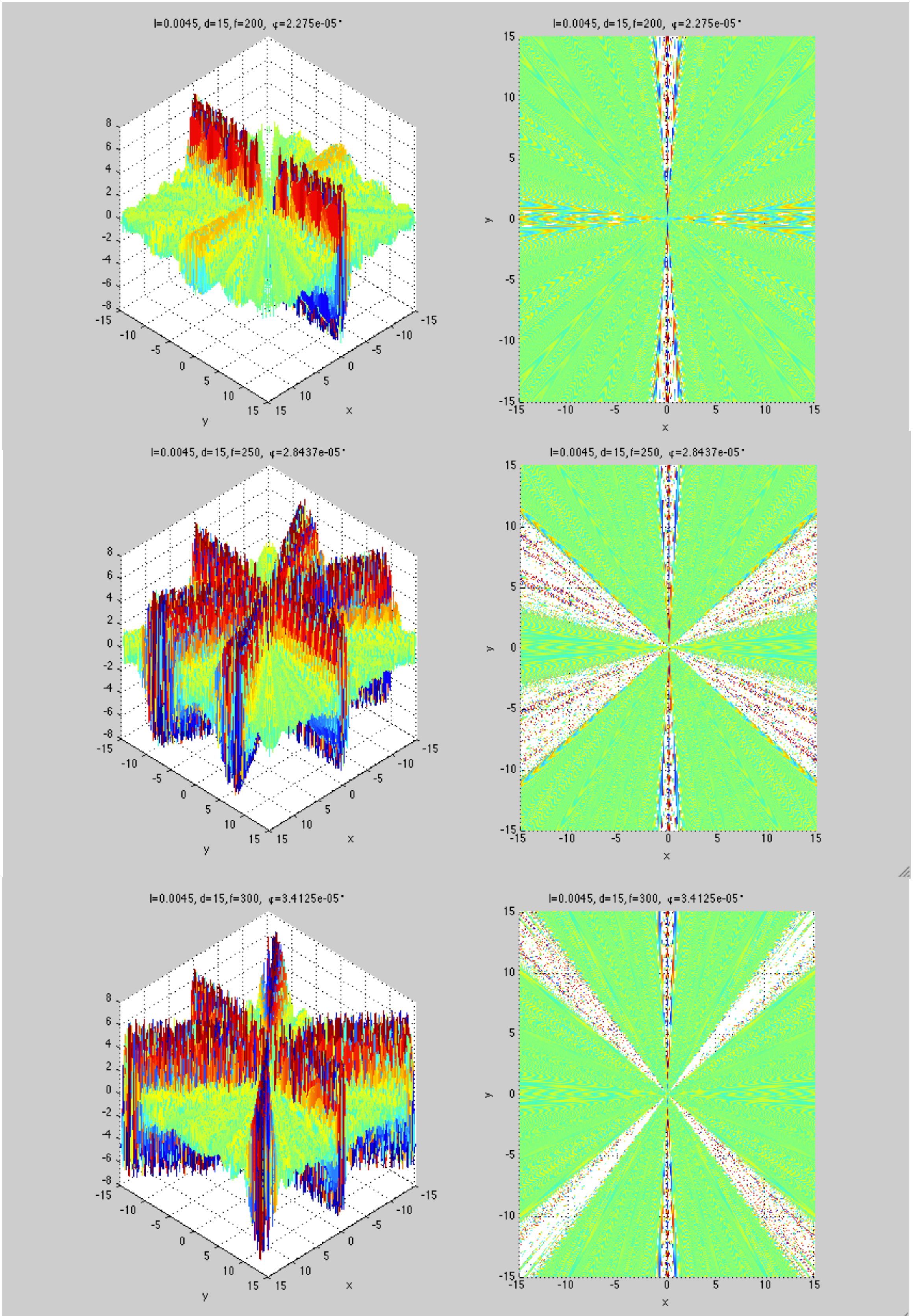
The Sound Localizing Speaker Array does exactly as its name implies. Using an array of speakers, sound played through each speaker acts constructively and destructively with every other speaker around it. By adjusting the relative phases of each of the speakers independently, it is possible to amplify and redirect the sound in a desirable fashion. The inspiration for this design came from a failed project idea we had tried to implement first, involving the use of parabolic dishes to take a quiet source and amplify it at long distances. Research for the first idea led us to find a number of sources citing the theory of relative phase manipulations and their outcomes. While our first goal seemed out of our reach and scope for this course, the second idea seemed like an appropriate and interesting endeavor. This report details the mathematical concepts, necessary materials, physical procedures, and end result data that came of our experimenting with this idea.

II. Phase Manipulation

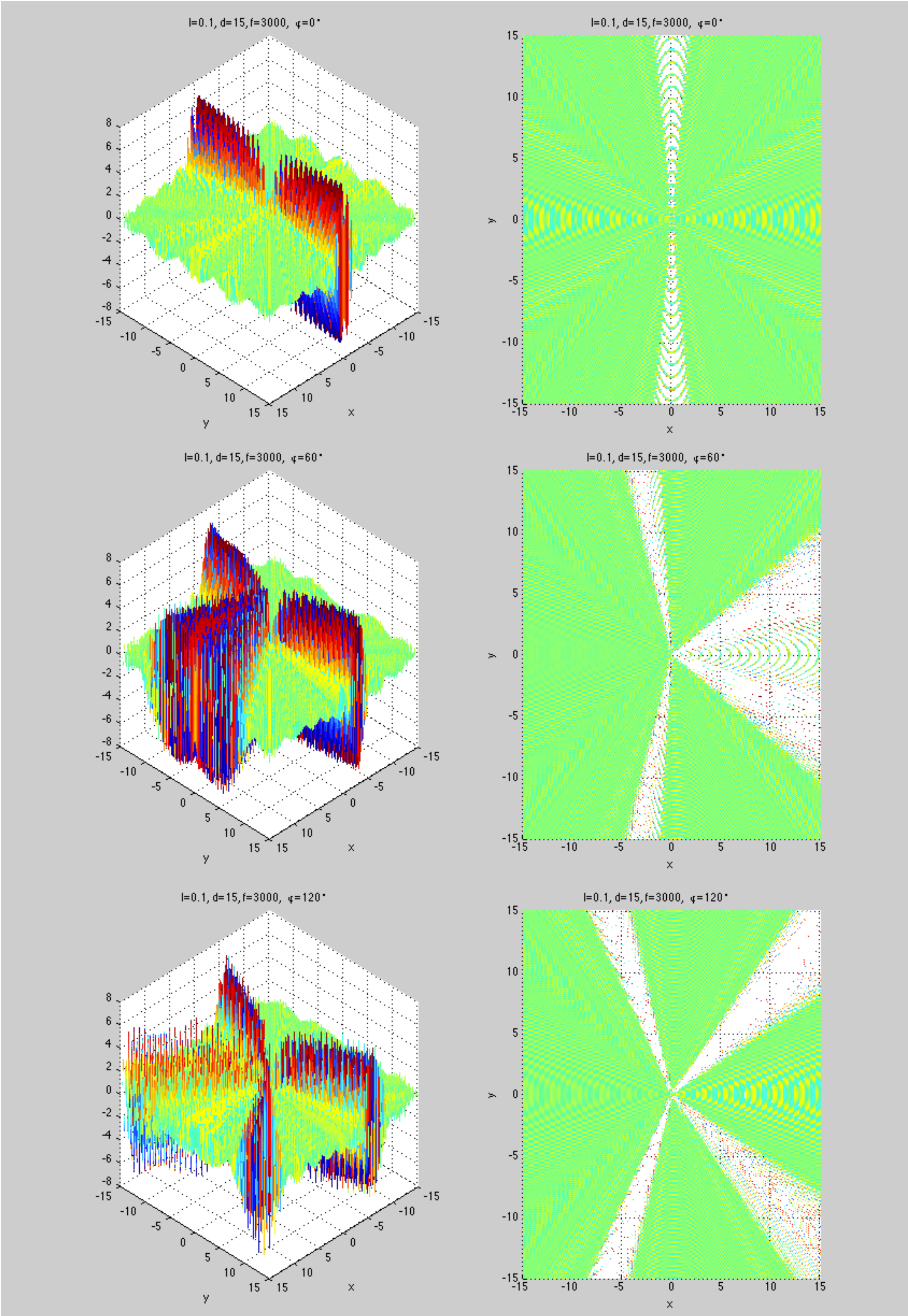
Before beginning any physical construction of the sound array, we wanted to make a preliminary proof-of-concept. To do this, we coded a sound array simulator in Matlab first, allowing us to adjust the number of speakers, the distance between the speakers, the frequencies of each speaker, and the phase offsets of each speaker as well. Using this, we were able to create animations that show the sound field relative to a sweep over a relevant range of any one of these parameters. Following are important or informative sound field images and their associated parameters.



Effects of changing the speaker spacing (*l*)



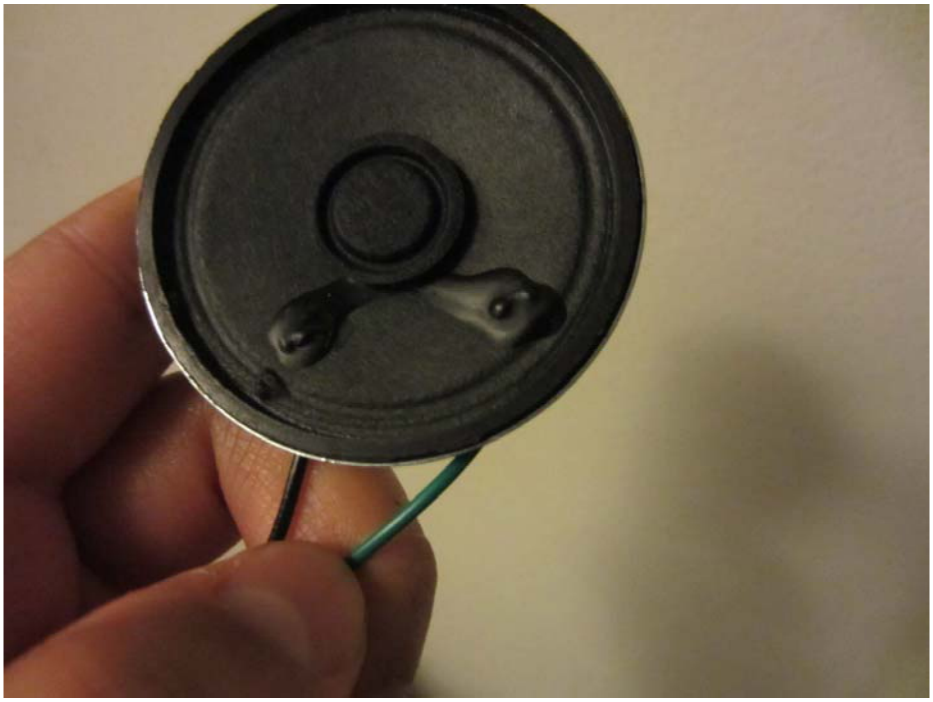
Effects of changing the frequency (f)

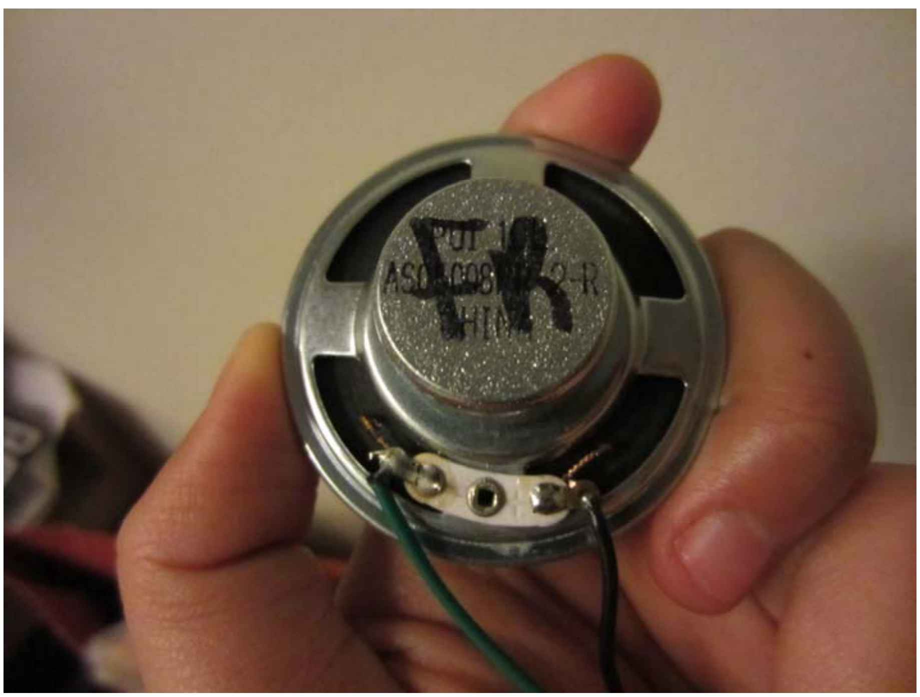


Demonstration of phase sweep (phi)

III. Materials

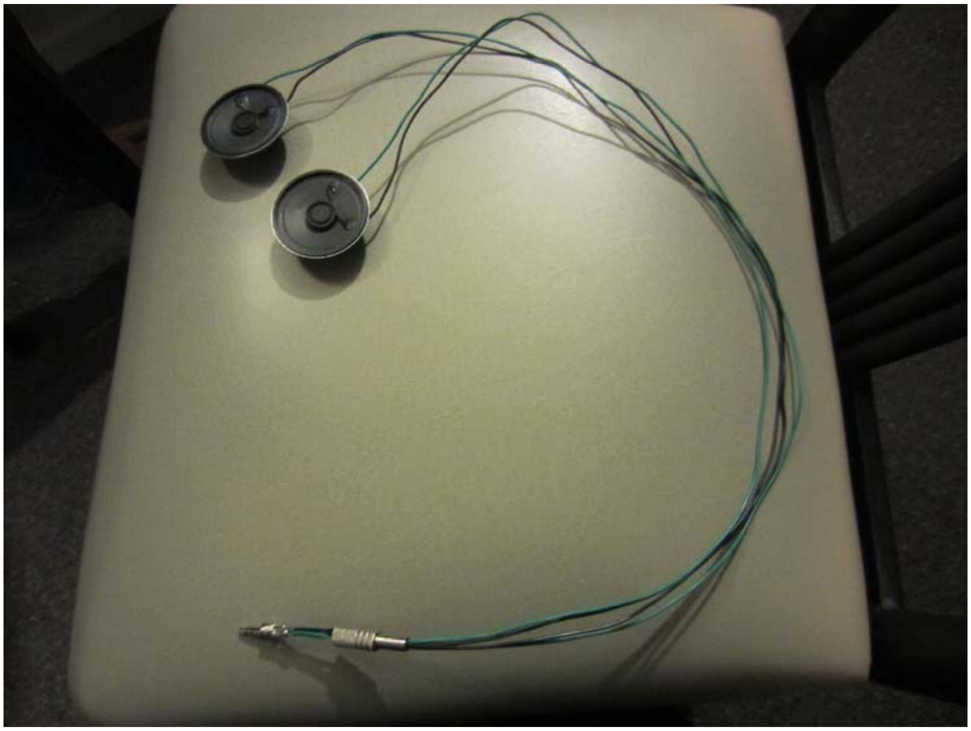
1. We started with eight basic speakers.



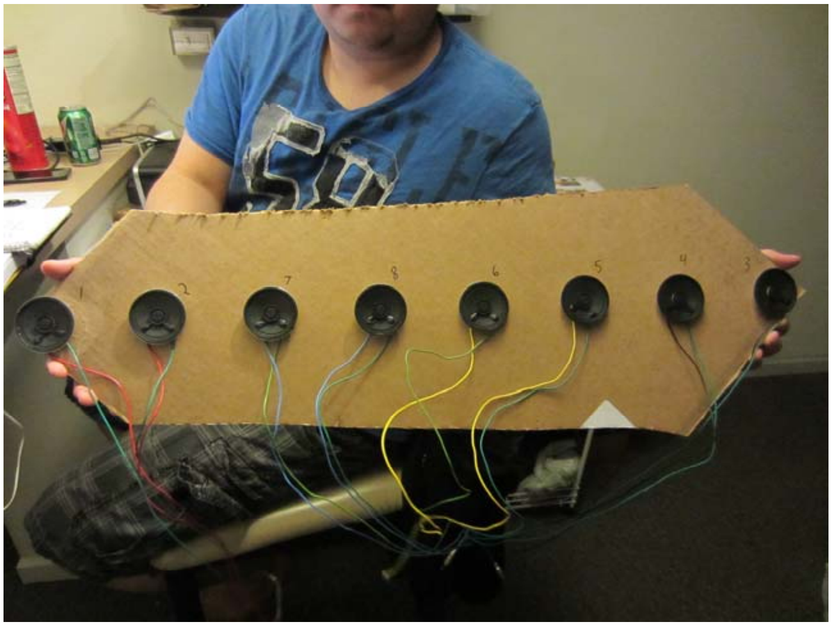


The speakers simply have a hot and a ground; we soldered two wires to the speakers as can be seen in the picture above.

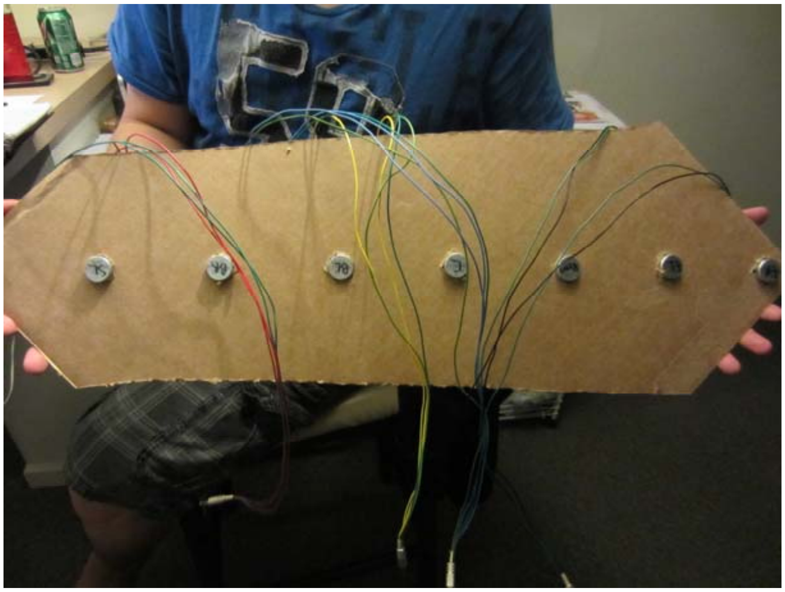
2. We then soldered on a 1/8th inch male jack connector to the speakers. There were two speakers for every jack: a left channel and a right channel for a total of four jacks for eight speakers.



3. After creating our speaker setup, we then chose a base in which to house the speakers. This took the form of one side of a cardboard box. We hand-drilled holes into it, each with a radius slightly smaller than the radius of the back of our speakers so a simple friction fit would keep them in place. We decided to have the holes be about 10cm apart from center to center. We then (unevenly) cut off a lot of the excess cardboard to make it simpler to carry. The final result is pictured below.



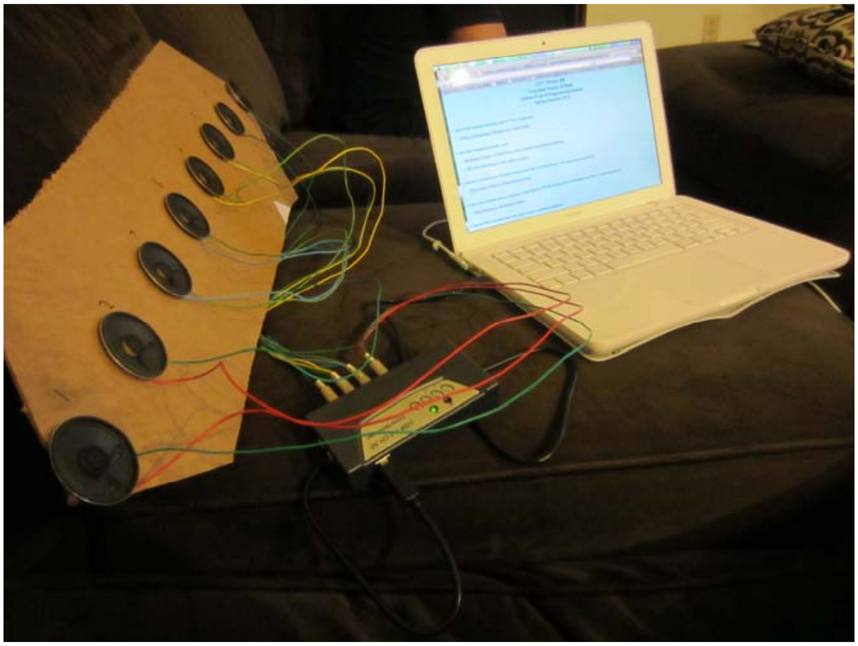
Front



Back

4. Once the array was set up, we then needed the necessary peripherals to play and manipulate eight-channel sound. We decided to use an audio 8 channel sound card with 7.1 surround sound. To create the sound files, we used a combination of Matlab and Audacity to create pure tones with different phase offsets and to route each sound file to the appropriate channel, respectively. Here is the sound card:

And here is the final setup:



IV. Using the Speaker Array

To use the speaker array in this setup, one simply has to play the eight-channel audio through some audio output software. For our purposes, we used VLC player, which supports the .flac files we were using.

For our project, we tried two experiments with the speaker array. The first was localization and amplification at a point directly in front of the face of the array. Like our simulation specifies, in order to do this, one simply needs to play the same sound out of the eight speakers with no phase offset between them at 10cm separation. This was our focus test.

The second experiment we tried was to create what we call a “sound lighthouse.” The effect of this recording would be to localize and amplify the sound coming out of the array such that the beam of greatest constructive interference moves radially around the array. A stationary listener located directly in front of the array will experience the sound “sweeping” over him periodically, thus a sonic analog to the effect of a common lighthouse. In order to do this, the offsets of the pure tones coming from each of the speakers should be multiples of each other, as in the first speaker is offset, the second is offset*2, the third is offset*3, and so on. By increasing the value of “offset” between 0 and 360 degrees over the course of a 20 second sound file a stationary listener would hear four sweeps.

V. Results

To measure the effects of the sound array, we needed to find a flat, open area where there wouldn’t be a lot of resonance from walls. We then tied the array to a stationary post and used a microphone and recording device to record the sound coming from the array at a number of locations. We later analyzed this data to determine the effectiveness of the localization. The data was spliced then analyzed in Matlab using its built in fast fourier transform. The test frequency was then measured for each setup. The results are shown in the table below:

Sound Intensities at Various Locations								
		Distance from Central Axis						
		Center	5 ft	10 ft	15 ft	20 ft	25 ft	30 ft
Distance from Post	15 ft	11.7	6.0	6.0	2.9	0	0	0
	20 ft	9.2	1.7	3.9	5.5	2.7	0	0
	30 ft	6.3	9.8	4.0	1.2	2.6	0.7	1.9

The data was somewhat conclusive, as the measurements taken closer to the center were certainly stronger than those further from the central beam of sound. That said, we did not have many opportunities to take measurements, so our data is limited.

VI. Conclusion

In conclusion, the principles behind the Sound Localizing Speaker Array held true in our experiments, both perceptually and through measurements. By creating relative offsets between the speakers at an arbitrary distance, we were able to localize the eight speakers' sound to a specific center beam using pure tones. Further considerations for this project would be to use more complex sounds instead of just single sine or square waves, or to try to implement this setup in real-time for more control.