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Culmination Project Reflection

My culmination project was research and exploration of subwoofer arrays through software prediction and actual measurements. The array designs were fundamental and simple to test for the purpose of observing the important aspects of multiple subwoofer relation in space, and no design was intended for a specific show or venue. However, exploration of the most basic acoustic properties of subwoofer arrays provided a deep insight into how these arrays respond in real space, comparing how the arrays behave in prediction software, measurement software, and how it is perceived by human ears.

The first process, which was the bulk of the project, was to research the different arrays, why they work, and design a simple setup to be predicted on the MAPP XT software. While there are countless number of different configurations with a design purpose for a specific venue or space, they are, more or less, combinations and fine adjustments of four simple ideas: endfire, gradient, stacked, and delayed horizontal. The principles are simply based on specifying placements so that destructive and constructive interference occurs at intended points, and each configuration provides different benefits depending on what needs to be achieved. These occurrences are specific to low frequency waves because of the large wavelengths that are much more forgiving in directivity than high frequencies. Achieving these effects in high frequency loudspeakers is not practical because of the demand of precise angle and distance. An important aspect discovered through research is that no perfect wave cancellation or combination can occur in all frequencies because of varying wavelengths. For example, to achieve a certain cancellation in one frequency in endfire or gradient pattern would mean that the opposite would occur in the doubling of the frequency, and results varying in the frequencies around it. If designing subwoofer arrays for an actual event, the priorities required should determine the optimal placements, while none being perfect.

The measurement process itself at Vorhees Theater consisted of two parts: setup and calibration of test environment, then running the measurement tests themselves. The first was the more time-consuming process with more required attention to details. The more carefully constructed test environment would result in a more accurate, coherent test results. As far as having the resources to seven, tested, matching microphones connected to SMAART software providing real-time measurements at same time was more than ideal. The microphones would stay at their respective places and not be touched for the entire duration of the test session. However, other environmental and resource factors were not as ideal.

The space itself at Vorhees Theater had problems, despite that predictions were made using the Vorhees Theater room acoustics. The theater was setting up for a show to happen within the same week, and many obstructions existed in space. Although low frequency waves have such high wave length and energy that it should travel around obstacles for the most part without problems, it was not ideal to have the possibility of unwanted variables in a test environment. Also, there were many small spaces, gaps, and mixture of wall materials that were too complex to be predicted using MAPP XT. One microphone position, placed at 50° arc 25' from source, was experiencing unforeseen wave cancellations that could be measured and heard. In all measurements, that specific microphone position would provide a biased response that was much lower than the prediction and relative to other microphones, and teach us that the bottom row, far stage-left seats were the worst seats in the house.

The lack of matching subwoofers were not ideal, as well. I had only access to two of the same models of Meyer subwoofers and found that they are slightly displaced in phase with each other. Although the third Meyer subwoofer would have similar enough impulse responses to the other two, loudspeakers that were built differently and sounded differently were not ideal. Three other EAW subwoofers, which had better matching responses to each other, were much different in frequency responses to the Meyer subwoofers and hard to be regarded as subwoofers based on their frequency response. They were used for measurements not listed on the culmination presentation that were left out for the significance of its findings versus the constraint on the amount of presentable materials. The availability of subwoofer choices, I believe, played the major role in real measurement discrepancies, because of the precise wave interactions and phase alignment required for the subwoofer arrays to behave as predicted.

The testing process itself was a big personal learning experience, as it was my first time seeing SMAART being used. There were difficulties in using SMAART with subwoofers, which I had known beforehand but did not realize the extent of its problems, because the impulse response for low frequency waves is not as easily read by the software, and SMAART would have difficulty in determining the direct sound impulse from the loudspeaker source. I have ideas now, if I were to repeat this process, to try to address this problem by raising the overall gain of the generated noise or tweaking the settings in the software. However, in the moment, we had to plug high frequency loudspeakers in place of subwoofers to try to read the correct delay timing for impulse response, which provided close enough values for the measurement to work but not ideal as there are nuanced behavioral differences of high frequency sound waves from low frequency sound waves in actual space filled with different gas compositions. It's hard to determine how that may have affected the measurements, but it is another uncontrolled variable that was introduced into the measurement.

Overall, I am both impressed yet disappointed in how the measurements resulted in comparison to the prediction. For the most part, the subwoofer arrays behaved as predicted in its frequency and phase response. Knowing the uncontrolled variables that were introduced in the measurement gives a feeling that a more precise measurement could have been conducted, and I hoped to see better wave cancellations in certain configurations. However, in the overall picture, the subwoofer arrays achieved what they were designed to do, and being able to hear the arrays' acoustic properties in actual space has given me another layer of perception to low frequency subwoofer placement and wave interactions. The learning experience through this project has been immense, in both technical aspects of using different software for real space applications as well as perceptive aspects of low frequency wave and space interactions, phase alignment, and wave interactions.