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Improving Sound Coherency Through the Implementation of Coaxial Drivers

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Abstract

In this article, I will be discussing my research into new forms of speaker technology-specifically within the realm of line array loudspeaker systems. The main objective of this is to try and implement line array technology into the home theater "audiophile" product market. This has previously been done, but at an immense cost for the consumer and the form factor of the speaker systems were very large. These reasons made these products readily unavailable to many consumers, which led towards the advent of the "soundbar" type systems that are very popular in homes today and can be had at a reasonably affordable price. With the products I'm developing, I can not only offer true line array technology at an attractive price to consumers but bring it into a much smaller form factor without sacrificing quality. For the first part of this paper we will discuss the technology with what are considered full range line array sources (operating from about 45 Hz – 20 KHz). For simplicity, these will be referred to as "top boxes" for the remainder of this paper. Commonly anything below 60 Hz is considered sub-bass and is handled exclusively by subwoofer speaker systems, which will be discussed in the second half of this paper.

I chose this topic as it is something I am very interested in but also something that I feel is very important. The main examples nfor acoustic spaces I use throughout this paper are a living room, and Biemesderfer Performance Hall located in the Winter Visual Performing Arts Center on Millersville University's campus. Both of these spaces present unique acoustical challenges such as:

-Living rooms are commonly small and square shaped, which are not ideal conditions for acoustics

-Speaker systems are normally placed in non-ideal locations in living rooms

-Biemesderfer, while it sounds amazing for a voice or piano unamplified, once you place loudspeakers in this space it "excites" all of these acoustic hotspots creating issues

-the existing speaker system in Biemesderfer is not providing sufficient audio coverage for the space

That being said, the audience for this paper is very specifically the Tell School of Music at Millersville University as well as people who are interested in upgrading the speaker systems in their homes to something that will work better given the acoustical challenges.

The main study in this research project is improving upon existing technologies in the audio world and manipulating them to be used in the manner I wish them to be. One of my personal heroes is Christian Heil, founder of the French loudspeaker manufacturer L'Acoustics. In the mid 90's he perfected the theories for line arrays touring applications that in this paper I am now building further upon. I am taking a different approach to his findings and taking line arrays into non-traditional situations to improve audio coherency for everyone.

DEFINING THE PROBLEM-POINT SOURCE VS. LINE SOURCE

In the audio world, you can generally break top box speaker systems into two generic types, point source and line source. The main differences between these two systems are the coverage pattern, directivity control of the coverage pattern, and how accurately the speaker system can "throw" sound over a certain distance while remaining consistent in amplitude, which we perceive as volume. Relating these constraints to point source speaker systems, they are very effective and controllable in the near field. The near field is where the sound is only dropping – 3 dB per doubling of distance whereas things are considered to be in the far field when sound drops – 6 dB per doubling of distance, this is all dependent on the individual drivers that make up the tested speaker system as well and cannot be generalized to a specific measurement. That being said, tested home speaker systems in the generic home consumer market are very inconsistent in their horizontal coverage. Since they are not always the highest quality drivers being used, their near field is a very short area and the -6 dB point occurs quickly. This becomes problematic in a rectangular shaped living room/home theater (Urban, Heil, Bauman).

Line source systems are on the positive side of these constraints, especially in their horizontal coverage and ability to have a larger area for the near field zone. Directivity of a speaker system can be difficult to control in lower to mid frequency sounds (20 Hz – 1 KHz) and is done through methods such as porting and phase plugs. High frequencies are extremely directional due to their shorter wavelength (frequency has an inverse relationship with wavelength- as frequency increases, wavelength decreases. Refer to Figure 1.1) and can be controlled in an easier manner through the use of waveguides (Heil, Urban).

FIGURE 1.1

Speed of sound (V) ~ 1130 ft/second
Frequency (F)
Wavelength (W) in ft
V/F= W

This is where there is a very hard line created between point source and line source systems. To be considered line source, the vertical dispersion pattern generally has to be 15° or less and the horizontal pattern is generally anywhere from 80°-140°. Some common point source coverage patterns are 60° x 60°, 70° x 70°, 80° x 120° etc. Especially in a small space such as a living room or home theater, conically wide coverage patterns (especially in the high frequency range) that are present in point source systems can result in comb filtering, which is constructive and destructive interference to a sound wave which can give audible "notches" in a speaker system as they are reacting to each other in the room of a defined space. Line source systems can be thought of as one infinite "ribbon" which is oscillating back and forth the exact same way the entire height of the "ribbon". This is advantageous as each driver along the length of that ribbon is identical and is designed to interact with each other. For example, a line array could be made up of 40 drivers over the height of the array but they are all considered to be one line array, or source and with point source designs they are made up of individual speakers in enclosures and are all considered to be individual sources stacked together to create a speaker system. To summarize, a line source system can be scaled to any height and only its vertical coverage will be affected, and a point source system will be effected in both its horizontal and vertical coverage if it is scaled down or up (Ureda).

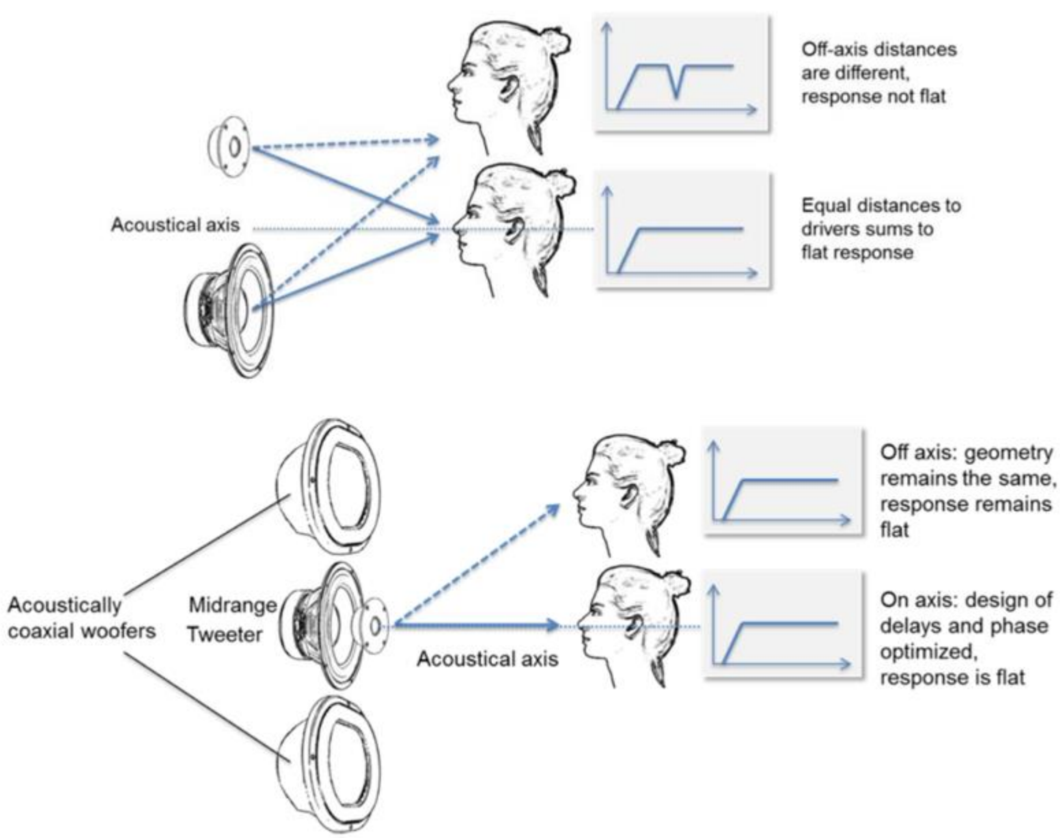
IMPLEMENTING COAXIAL DRIVERS INTO LINE SOURCES

A common problem as well with point source systems is that the drivers are displaced vertically across the front baffle of the enclosure, which in the near field can become very problematic as this not only creates comb filtering/phase issues for the single enclosure, but also drastically effects its interactions with other enclosures near it. The common solution to this is the coaxial driver. Coaxial drivers are literally as the word interprets, “existing on the same axis together”. This is done by mounting a high frequency compression driver in the apex/throat of a mid-frequency driver so they exist on the same vertical axis.

mid-frequency driver so they exist on the same vertical axis.

FIGURE 1.2 (Mäkivirta)

If you look at a speaker from the front, you could think of this as replacing the area the dust cap exists at with a high frequency driver. This allows you to create a much more compact enclosure with less inherent issues than a standard point source design. Now, to implement this coaxial driver design into a line source design. By nature, coaxial drivers are a point source speaker as they either use the cone of the driver itself (the angle of this gets shallower as the speaker gets bigger i.e. a 15” driver would have a shallower cone to dust cap angle than a 5” driver) or a waveguide throat that is directly mounted to the high frequency driver with the paper cone existing around it. With my design, you can remove the waveguide that is a point source constriction and mount a waveguide to this driver that is a line array coverage pattern constriction. This allows line array enclosures to become extremely compact and achieve a greater phase coherency as the mid and high frequency drivers will be perfectly on the same axis (in traditional line arrays, these drivers are normally very close to being



perfectly on the same axis, but there is a slight difference that requires use of mid-frequency exit throats or phase plugs to be designed into the enclosure). An issue that is encountered with this is in a traditional line array design the high frequency drivers are normally 1" - 1.75". While the high frequency drivers mounted in a coaxial driver are this same measurement, the rest of the cone around it could be something like 5". The mathematical issue behind this is the driver positioning inside the cabinet and in relation to their waveguide. Obviously, two 1" drivers can be placed much closer together to be mounted to a waveguide than two 5" drivers. The solution to this is creating a waveguide that has a longer throat to compensate for the vertical displacement of the drivers, which just results in a longer, shallower rise on the vertical angle on the waveguide versus a steeper rise which would be on a shorter waveguide, although both still can achieve the same exit angle. Using these same theories, you could create a full range line source loudspeaker by using one coaxial driver (Mäkivirta). In general, across all speakers, as the cone diameter gets larger, so does the frequency response it can output, specifically correlating to its low frequency response. A general frequency response for a 12" driver would be 45 Hz – 2 KHz, and once you make that 12" coaxial, it can achieve full range frequency response as it would operate from 45 Hz – 20 KHz. In a more traditional enclosure design, you would normally need at bare minimum 3-4 drivers to achieve this type of frequency response. For obvious reasons, using a single coaxial driver could create a much more compact and lighter enclosure, which is highly desirable in all realms of audio ranging from home use to professional touring applications (Urban, Heil, Pignon).

SUBWOOFER APPLICATIONS AND IMPROVEMENTS

The term "line array subwoofer" is inherently an oxymoron, but the term is used to describe subwoofer systems which are designed to be used in conjunction with line array enclosures mostly due to their rigging components that allow them to be flown or ground stacked in touring applications. For a general consumer, a subwoofer designed to be used with a line array would be much too expensive and powerful for home use. What makes subwoofers interesting and somewhat challenging, especially in a small space, is that subwoofers are naturally omnidirectional. This is due to the frequencies that subwoofers output. The lower the frequency, the less directivity control you have over the frequency. So much of a subwoofer's sound, especially from company to company and what makes their product unique, comes down to the design of the enclosure itself and how it effects the sound of the subwoofer and controls the sound leaving the enclosure. This can be broken down into a few designs:

Sealed Box Enclosure: This is the most basic subwoofer enclosure design where it is essentially just a speaker mounted on the baffle and the rest of the cabinet is totally closed up.

Bass Reflex Enclosure: This is the next step up from a sealed box where there is a port tube/channel cut into the enclosure, not even mathematically calculated sometimes. This is done to relieve ambient pressure in the cabinet and create a perceived increase in low end energy. An issue with this design is that sometimes the port is not mathematically calculated and sound can leave the port out of phase with the sound leaving the speaker, which can cause cancellation at certain frequencies.

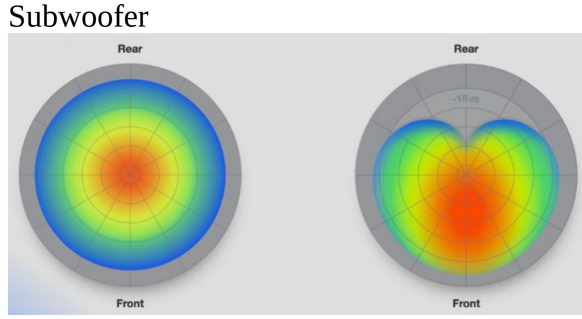
Transmission Line Enclosure: This design is the improvement upon the bass reflex where you create a port channel based on the wavelength of a desired frequency which you "tune" the cabinet to. This is normally based on a manufacturer recommended resonant frequency of their driver which will be loaded into the cabinet. You use the above mentioned wavelength formula to find the quarter wavelength of this frequency then using these numbers and the driver's dimensions to determine the dimensions of the port channel (Crutchfield).

After these design bases, you can delve into further designs of physically manipulating the angle and/or number of drivers in the enclosure to create certain coverage patterns such as omnidirectional (standard), cardioid, and hyper cardioid. You can also physically manipulate multiple subwoofer enclosure together in a sound field based on their locations in relation to each other using phase coherent manipulation.

So how do all of these designs relate to my research and enclosure designs? With my research I have been heavily favoring a cardioid subwoofer design, but it becomes very interesting and expensive as normally you need multiple separate enclosures to achieve a cardioid configuration-but I am going to do it in a single enclosure. Cardioid is very desirable in a smaller space such as a home, home theater, or even movie theater and or production theater. This is due to the nature of a cardioid polar pattern which rejects from the back and uses that cancellation to provide more forward propulsion to the sound leaving the front of the enclosure. This is very advantageous in the types of spaces discussed as bass can easily become very overwhelming in small spaces due to two reasons-the Fletcher Munson curve, which states that humans do not hear frequencies equally and are less sensitive to low frequencies and very sensitive to high frequencies, and most rooms of this type are small squares (sometimes not even the full length of certain low frequencies' wavelengths) and bass acoustically builds up in square corners (Teach Me Audio). Plus, lots of people put their home theater system speakers right up against the wall or in the corner of the room, especially subwoofers systems. Using a cardioid configuration eliminates any reflections and buildups of bass that would normally occur in rooms of this size which creates a much clearer image in the low and allows the bass to be articulate and punchy instead of "woofy" and unclear. In applications such as a concert touring system with massive subwoofer systems, this is normally done by taking three subwoofers, flipping the physical direction of the middle one then flipping the phase of the loudspeaker in that enclosure. In a single enclosure, you have three drivers, two at the front of the cabinet facing forward and one at the back of the cabinet facing backwards, and then flip the phase of the one in the back of the cabinet and put a time delay on the front two so their sound "exits" at the same time as the back facing driver. This will effectively create a cardioid effect in a single enclosure cabinet which could be placed in a traditional home theater manner right up against the wall and have no detrimental effects on the sound quality of the room.

FIGURE 1.3

Traditional Subwoofer vs. Cardioid Subwoofer



(QSC Audio)

CONCLUSIONS & FINDINGS

While properly done mathematics don't lie when it comes to things like loudspeakers, especially new innovations in loudspeakers, people that are interested in buying these only want to see the math as a reassurance. The most important thing is that they want to hear the products. If the speakers you are selling don't sound good, you won't be selling many speakers. They also have to look good too if they're going to be sitting in your living room. These points lead into my design criteria. Take the CoAX CURVE for example, which is my flagship model. The main point of this box was to have a full range cabinet that will play nice with a subwoofer as an extension, but also satisfy the listener on its own. This cabinet also had to consist of coaxial drivers across the baffle, but these drivers had to be converted to line source by developing a different waveguide. With these as well as many other acoustical design and structural engineering issues, there was a ton of time spent into making this cabinet as effective as possible. The same goes for the C-SUB. This enclosure is actually 3 separate subwoofer enclosures built into one, to give total control over each of the 3 drivers in the cabinet, especially the cardioid one.

There have been many obstacles throughout the course of this project, and I have learned an immense amount of information and lessons as a result. Countless hours have been put into every step of the process, from research and design to testing of the finished product. I am very excited to show my work to others and get some more ears on my speakers.

References

"Fletcher Munson Curves." Teach Me Audio. November, 2018. https://www.teachmeaudio.com/recording/sound-reproduction/fletcher-munson-curves/

Heil, Christian, and Marcel Urban. "Sound Fields Radiated by Multiple Sound Sources Arrays." Heil Acoustics,/Audio Engineering Society. 1992. October, 2018.

Mäkivirta, A, J. Väisäsen, and I. Martikainen. "Design of an Acoustically Coaxial Three-Way Monitor." Genelec/Audio Engineering Society. 2014. October, 2018.

Mäkivirta, A, J. Väisäsen, and I. Martikainen. "Design of an Acoustically Coaxial Three-Way Monitor." Genelec/Audio Engineering Society. 2014. October, 2018. JPEG.

QSC Audio, https://www.qsc.com/nl/live-sound/products/loudspeakers/powered-subwoofers/ks212c/

"Subwoofer Enclosures." Crutchfield. November, 2018. https://www.crutchfield.com/S-2TPP9DDEZn0/learn/learningcenter/car/subwoofers_enclosures.html

Urban, Marcel, Christian Heil, C. Pignon, C. Combet, and P. Bauman. "The Distributed Edge Dipole (DED) Model for Cabinet Diffraction Effects." L'Acoustics/Audio Engineering Society. 2004. October, 2018.

Urban, Marcel, Christian Heil, and Paul Bauman. "Wavefront Sculpture Technology." L'Acoustics,/Audio Engineering Society. 2003. October, 2018.

Ureda, Mark S. "Pressure Response of Line Sources." JBL/Audio Engineering Society. 2002. October, 2018.

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