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INSIDE PASSIVE CARDIOID LOUDSPEAKER TECHNOLOGY

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An application of a Fulcrum Acoustic FL283 passive subcardioid line array.

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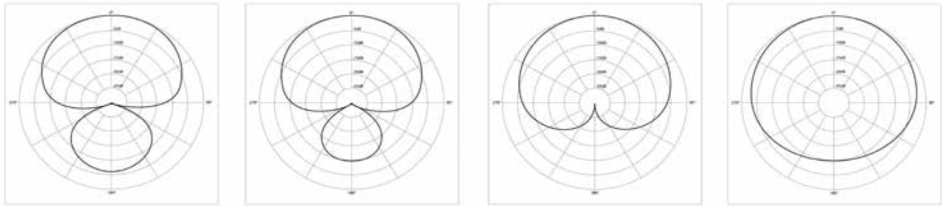
An approach for maintaining the directional pattern of high-powered subwoofers and loudspeakers *By David Gunness*

The ability to achieve low-frequency directional control — passively — has such obvious appeal that one might wonder why manufacturers haven't been doing it all along. Well, it isn't for want of trying, and in a sense, some already have.

For example, the classic open-back guitar cabinet is actually a passive figure-8 pattern loudspeaker. And in 1970, Bobby Beavers of Altec Lansing filed for a patent covering a passive cardioid loudspeaker. While the patent included all of the necessary design equations, no commercial product was ever produced under the patent. Presumably there were unresolved challenges in implementing a product.



The cardioid family, left to right: hypercardioid, supercardioid, cardioid, and subcardioid.

Various other passive cardioid patents have been awarded over the years, including in 1971 (Iding, for Philips Corp.), 1997 (Mizogushi, for Sony Corp.), and most recently in 2010 (John Meyer, et al.). What all of these attempts have in common is that they could only be implemented on a small scale which is to say, at not-very-low frequencies and not-very-high sound pressure levels.

Our approach, which is patent pending, addresses the problem of maintaining the directional pattern even when the total air flow is extreme, as it is in high powered subwoofers. The technology was first introduced in the FL283 passive subcardioid line array, followed by the FLS115 companion subwoofer and the CS118 stand-alone passive subcardioid sub. Most recently, the lineup has been further expanded to include the CS121, a 21-inch passive subcardioid sub.

Inner Workings

So, how does one produce a cardioid radiation pattern using only one source? To understand, let's look at how a cardioid subwoofer is produced using two sources: a forward facing cone loudspeaker varies from "nearly omnidirectional" at very low frequencies to "slightly directional" at the upper end of the frequency range typically covered by subwoofers.

To produce a cardioid pattern, add a second cone loudspeaker facing backward; EQ it to match the magnitude response of the forward facing cone at a point on the back axis of the loudspeaker (essentially a low-pass filter); add signal delay to the rear-facing loudspeaker until the phase response also matches at that point; and finally, invert the polarity of the rear-facing loudspeaker. The two sources will sharply cancel on the back axis, producing a standard cardioid pattern.

Next, progressively reduce the delay to produce a supercardioid (with a lobe on the back axis and a null at 109.5 degrees off axis) or a hypercardioid (with the null at 126.9 degrees off axis). Then increase the delay to produce a subcardioid, which has no sharp nulls but provides significant attenuation over the entire back hemisphere.

In short, the sound coming from the back of the box has to be inverted, low-pass filtered, and delayed, relative to the sound coming from the front of the box. With a single source, the polarity inversion is easy because the sound radiating from the back of a cone is opposite in polarity from the sound radiating from the front of the cone.

The low-pass filter and requisite delay can be achieved by way of a carefully balanced arrangement of acoustical elements. This is in fact the same way that a cardioid microphone works, except of course in reverse and on a much larger scale.

Several Advantages

Aside from the obvious advantage of requiring only one DSP channel and one amplifier channel, there are numerous other advantages to passive cardioid loudspeakers: higher efficiency, lower cost, cleaner sound in the back, and more control over the shape of the polar response.

Let's start with higher efficiency and lower cost. The maximum output of a passive cardioid is similar to the maximum output of an active cardioid using two of the same drivers, but it accomplishes it with half as many drivers, half as much amplifier power, and a simpler enclosure. As a result, passive cardioids are more efficient and much less expensive than active cardioids. Essentially, the rear radiation of the cone is used productively over a broader frequency range, providing everything that the second driver in an active cardioid provides.

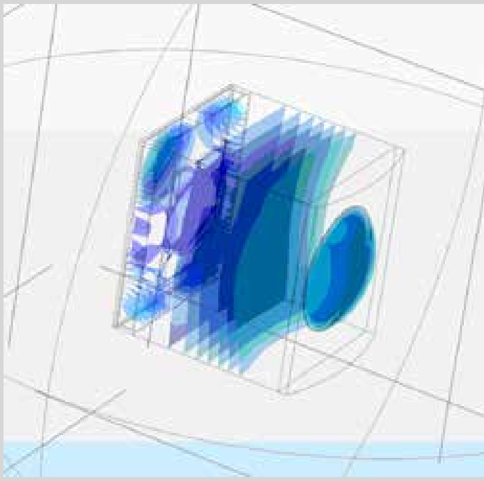
In an active cardioid, the two drivers receive different signals from their respective amplifiers; plus, no two drivers are exactly the same. As a result, distortion products produced by the front and rear drivers are not exactly the same, so the distortion doesn't entirely cancel in the back.

And, since the fundamental is much lower in the back, the distortion is significantly more audible than it would be for a non-cardioid loudspeaker. The technical term for this is "grunge;" active cardioids tend to sound grungy in the back at high levels.

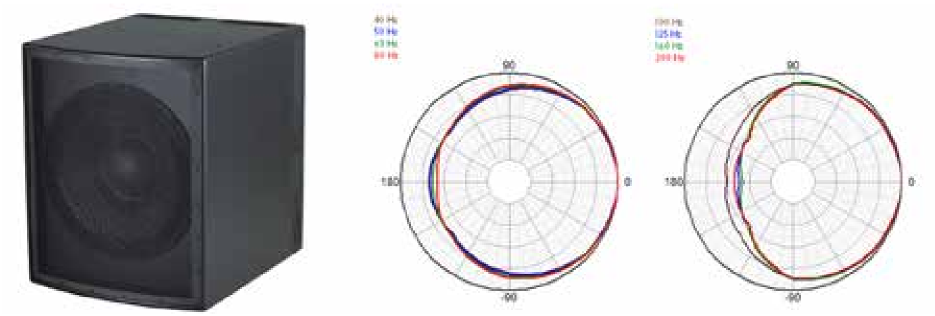
In a passive cardioid, both the front radiation and the back radiation are produced by the same cone. Any distortion originating at the driver is present in both the front and back radiation, so the distortion cancels in the back hemisphere just like the fundamental does. One of the surprising attributes of passive cardioids is that the sound behind the loudspeaker is cleaner than that of an active cardioid.

There are many variables in the implementation of a passive cardioid with which to adjust its performance. The rear radiation of a Fulcrum passive cardioid emanates from ports instead of an identical driver, and there is significant flexibility as to how those ports are implemented. The number of ports can be varied; their location can be adjusted; and their surface area, length, and even expansion can be adjusted.

And, to produce the desired shape of low-pass filter, there must be resistance in the ports — yet another variable. All of these variables affect the shape of the polar plots, so by carefully balancing all of them it is possible to achieve more consistent polar plots than is possible with an active cardioid.



Finite Element Analysis of the CS118 passive subwoofer's internal acoustical design.



The CS121 passive subwoofer and its subcardioid polar response.

Why Subcardioid?

There are several advantages to the subcardioid pattern. Of the four standard "cardioid" shapes, the subcardioid is the most efficient at low frequencies. The sharp nulls in the polar response of the other three shapes come with an efficiency penalty and they only affect a limited region of the sphere. By targeting consistent attenuation across the back hemisphere instead of trying to achieve a deep null somewhere, higher sensitivity can be maintained at low frequencies.

Above the cutoff frequency of the acoustical low-pass filter, the rear radiation ceases and the loudspeaker transitions from a subcardioid pattern to the natural directionality of a forward facing cone. The polar pattern of a forward facing cone in an enclosure is quite similar to a subcardioid pattern. Because of this and all of the variables that can be adjusted to subtly change the shape of a passive cardioid's polar response, a more consistent spectrum can be achieved over the entire sphere.

The bottom line is that this technology is applicable in a wide variety of sound reinforcement applications. As a result, it will be implemented in an expanding range of our products from this point forward.

DAVID GUNNESS *is vice president of research and development as well as lead product designer at Fulcrum Acoustic (fulcrum-acoustic.com), and he holds several patents for loudspeaker design.*

About Fulcrum Acoustic:
Founded in 2008, Fulcrum Acoustic is a professional loudspeaker manufacturer known for its unique approach to loudspeaker design. Employing the research of company co-founder David Gunness, Fulcrum Acoustic combines proprietary coaxial design and Temporal Equalization™ processing power to create the most powerful and versatile line of loudspeakers available.

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