Acoustic Patents

By James Croft (Croft Acoustical)

The following loudspeaker-related patent was filed primarily under the Office of Patent and Trademarks classification 181 for acoustical devices and 381 for electrical-signal processing systems and HO4R for international patents. This also includes new patent applications that are published in the *Patent Application Journal*.

Directional Loudspeaker
Patent/Publication Number: EP3018915A1
Inventors: Koenraad August Jan Knaapen, Eric Van Duin, Martijn Gerardus Mensink, Kevin Ivan Kleine, George Ortega
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Number of Drawings: 5

Abstract from Patent

A directional loudspeaker is described for use in the mid-frequency range of the audio spectrum. The loudspeaker comprises: a housing comprising a front panel, side panels and a back panel, said housing comprising an acoustic resistive material; wherein at least one acoustic transducer is mounted to said front panel, said transducer being configured to drive a membrane for producing front waves at the front of said membrane and back waves at the back of said membrane; and, wherein one or more openings in said side panels, and, optionally, in said back panel allowing at least part of said back waves to exit said housing via said resistive material, said resistive material, said openings and said reflective back panel introducing for said back waves in the mid frequency range a phase delay, an attenuation and an amplitude such that an attenuation at the backside of said loudspeaker of 15dB or more of the mid-range frequencies is achieved.

Independent Claim

1. A directional loudspeaker for use in the mid frequency range of the audio spectrum comprising: a housing comprising a front panel, side panels and a back panel, said housing comprising an acoustic resistive material; wherein at least one acoustic transducer is mounted to said front panel, said transducer being configured to drive a membrane for producing front waves at the front of said membrane and back waves at the back of said membrane; and, wherein one or more openings in said side panels, and, optionally, in said back panel allowing at least part of said back waves to exit said housing via said resistive material, said resistive material, said openings and said reflective back panel introducing for said back waves in the mid frequency range a phase delay, an attenuation and an amplitude such that an attenuation at the backside of said loudspeaker of 15dB or more, preferably 20 dB or more, of the midrange frequencies is achieved.

Reviewer Comments

As an employee of Acoustic Research (AR) in the late 1960s, while measuring loudspeakers in 10 differently shaped and sized rooms, Roy Allison was intrigued by the occurrence of a consistent dip in the lower midrange (just above 200Hz) and mentioned it in an Audio Engineering Society (AES) paper with Robert Berkovitz, "The Sound Field in Home Listening Rooms" presented at the 39th Convention of the AES, October 12, 1970, exploring a wide range of issues relating to loudspeaker room interactions.

Discovering the work of Richard K. Cook and Richard V. Waterhouse from a decade earlier—"Interference Patterns in Reverberant Sound Fields," Journal of the Acoustic Society of America (JASA), Volume 27 (March 1955); "Output of a Sound Source in a Reverberation Chamber and Other Reflecting Environments," JASA, Volume 30 (January 1958); R. V. Waterhouse, and R.K. Cook, "Interference Patterns in Reverberant Sound Fields II," JASA, Volume 37 (March 1965)—and performing a set of confirming experiments, Allison found his answer, wrote his illuminating paper on boundary effects in loudspeaker design and placement, ("The Influence of Room Boundaries on Loudspeaker Power Output," JAES, Volume 22, June 1974). He then used the results as a basis for starting his new audio company, Allison Acoustics.

In simplified terms, the discovery was that for any boundary that was approximately a quarter of a wavelength from the output point of a loudspeaker transducer, there was an associated, resultant dip in the response of the loudspeaker. As can be seen in **Figure 1**, the effect starts with only a -1dB depression for a single boundary case, but additional boundaries cause a nonlinear increase, such that a two boundary case is -3dB and a worst-case scenario, of the loudspeaker being equidistant from a floor, front wall, and nearest sidewall reflection, the sum of the reduction in output could be on the order of an -11.5 dB cancellation of output near the quarter wavelength frequency, combined with a three boundary reinforcement reaching +9dB below that frequency, resulting in a 20dB swing in output, and this is before any environmental standing waves are introduced.

Surprisingly, as with Waterhouse and Cook's earlier papers, from a loudspeaker design practice perspective, Allison's paper was generally ignored by the vast majority of the loudspeaker industry, a trend that continues to this

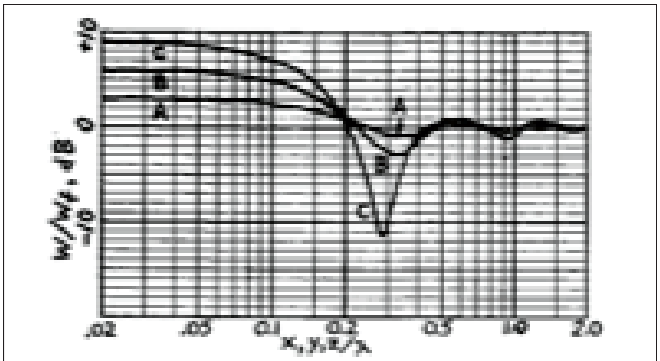

Figure 1: This graph shows the response of a loudspeaker equidistant from 1, 2, and 3 boundaries.

day. Only a very few local east coast competitors, primarily, Snell Acoustics, Boston Acoustics, and Acoustic Research addressed the issue in their products by creating work-a-rounds relative to the Allison patent, but even those brands have abandoned addressing the “Allison Effect.“

The two basic criteria established by Allison were that the center of a transducer emission point must be either, less than one-quarter wavelength from a boundary, or more than three-quarter wavelength from a boundary, over the entire operational band of the driver, if the cancellation effect was to be avoided. Additionally, if only one boundary was engaged, the cancellation error was only -1dB.

With those guidelines, Allison’s “best mode” solution to the problem required at least a three-way loudspeaker, with the woofer system boundary coupled to at least the front wall and floor, with the center of the woofer driver positioned within less than one-quarter wavelength of the two boundaries, all the way up to beyond its 350Hz crossover to a midrange driver. The midrange driver while placed up away from the floor, at ear level, was as closely coupled to the front wall as the woofer, transitioning through a quarter of a wavelength within its passband, but to only the single front wall boundary (only -1dB of error), while being greater than three-quarter wavelength from all other boundaries. The tweeter with a 3.7kHz crossover was more than three-quarter wavelength away from all boundaries. Alternative approaches from Allison, were to place the loudspeaker in a manner that diversified the distances to the front wall, sidewall, and floor, but in all cases placed the loudspeaker boundary coupled to at least the front wall of the listening environment.

This boundary coupling approach to loudspeaker placement, while being generally convenient and providing certain performance advantages when optimized, such as low frequency gain, has for the most part been rejected in the loudspeaker industry for high quality home audio systems. Among audiophiles, there tends to be a preference for loudspeakers to be floating out in the room, away from front wall and sidewall boundaries. Some of the reasons have to do with a perception of improved depth of field and three-dimensional imaging and avoidance of colorations caused by near boundaries relationships, particularly if the loudspeaker is not specifically designed for that type of placement.

Now more than 40 years later, with one form disclosed in the patent under review, there is a novel loudspeaker architecture evolving to address the room interaction issue in a new manner that provides an effective hybrid of minimizing undesirable boundary interactions while providing an effective, loudspeaker source placement in the room, away from the front wall boundary. This new configuration has three distinctly different design elements for covering each of three separate ranges; low frequencies (< 100Hz), lower midrange (100kHz to 1.2kHz), and the mid-high frequency range (above 1.2kHz).

The centerpiece of the patent is the midrange driver and enclosure system, which is a passive cardioid configuration with a forward firing midrange driver loaded into an enclosure with resistive, side-firing rectangular shaped ports shown as 1141 and 1144 in **Figure 2**. This structure may sound familiar as we have discussed similar passive cardioids systems in previous reviews, such as the “Subcardioid” alignment by David Gunness, reviewed in the February 2018 issue of *Voice Coil*, where we provided a lot of historical background for the cardioid concept.

In this current review, the disclosed architecture of the cardioid lower-midrange section is very similar to the original 1970 Bobby Beavers patent, US 3,722,616, “Directional Loudspeaker System” assigned to LTV Altec, Inc. This passive approach with side firing ports has also been refined by John Meyer, at Meyer Sound Laboratories, in US 8,428,284, “Loudspeaker with Passive Low Frequency Directional Control.”

These two patents and the current patent under review have virtually identical layouts, but each has particular refinements for providing the desired directivity pattern. The Meyer device and the current patent specify a set of parameters and transfer function characteristic of the absorption material behind the driver, and the current patent discusses and illustrates the impact of the distance to the inner rear wall of the enclosure, shown as element 108 in Figure 2. The optimal attenuation of the rearward output is shown in the frequency response graph of **Figure 3** where, curve 204 represents the output in the forward 0-degree axis, and curves 206, 208, and 210 represent three distances of the internal rear wall 108 from the back of the midrange driver, with 206 being the shortest distance, 208 being the greatest distance and 210 representing a middle distance that can be seen to provide the greatest rearward attenuation.

Unfortunately, the inventors only state these as relative distances and don’t actually teach the optimal dimensions to realize the invention, which, as mentioned in previous reviews, does not tend to strictly meet the requirements for disclosure such that one skilled in the loudspeaker arts could reproduce the inventor’s best mode performance “without undue experimentation.” That said, these types of systems are difficult to simulate perfectly and tend to require a certain amount of empirical adjustment to reach optimization.

While the lower midrange structure

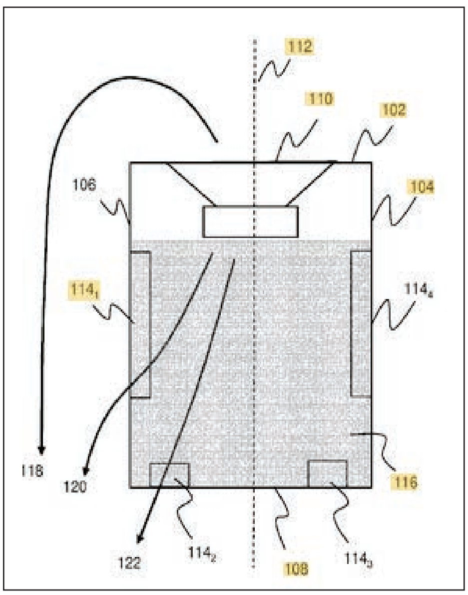

Figure 2: An enclosure of the invention is depicted with multiple output ports 114 and design sensitive internal back panel 108.

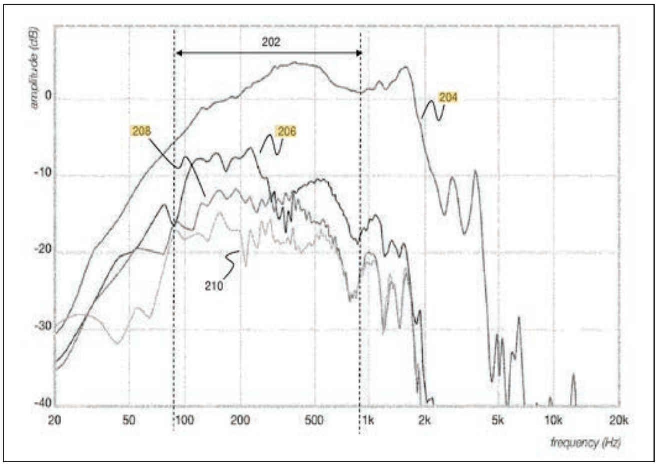

Figure 3: The rearward attenuation is shown for three positions 206,208, and 210 of the internal back panel 108.

realizes an optimized cardioid radiation pattern, for frequencies from just below 100Hz to approximately 1.2kHz, a tweeter driving a constant directivity waveguide is used above 1.2kHz to substantially match the polar pattern of the cardioid midrange system, achieving very well behaved, constant directivity above 400Hz and continuing to maintain good pattern control down to 100Hz, while substantially eliminating rearward radiation behind the loudspeaker to the front wall of the listening environment for all frequencies above 100Hz. This in itself is an admirable achievement, but the system also manages frequencies below 100Hz in a manner that effectively maintains the same directivity index over the full bandwidth of the system (**Figure 4**).

This is accomplished by having a rear mounted subwoofer system that is optimized for frequencies below 100Hz (down to approximately 20Hz). While the output of the subwoofer is omnidirectional, when measured in the free-field, the use-model of the system is to place the loudspeaker system within approximately 24" of the front wall, which for all frequencies below 140Hz, this maintains a less than one-quarter wave spacing to the front wall, which means that effectively, the subwoofer radiation and the front wall reflection are in phase and act as a single sound source, such that the frequencies below 100Hz function as if the loudspeaker is boundary coupled and operating into a half-space environment. This means that the hemispherical wave front of the low frequency system has a directivity index comparable to the loudspeaker's upper range portion, allowing the complete system to function substantially as a full-range, constant directivity loudspeaker. By utilizing these three different system types for the three portions of the frequency range, the system essentially provides the effective boundary management of a boundary-coupled device, while placing the constant directivity midrange and high-frequency drivers a meter out into the room. As an additional optimization aspect of the system, the tweeter and midrange are delayed to substantially time-match the launch point of rear mounted subwoofer output. The loudspeaker effectively eliminates the problem of the front-wall being a secondary, delayed radiation and interference source.

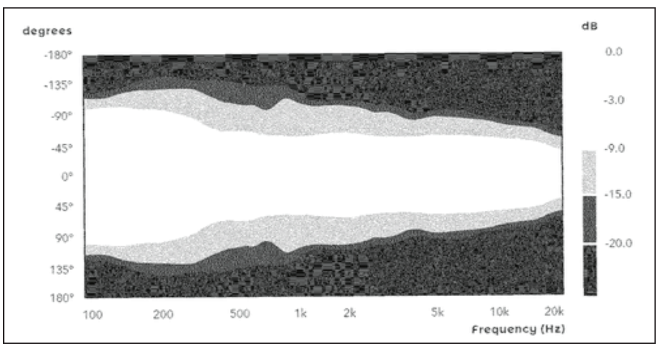

Figure 4: The wideband directivity pattern illustrates the behavior of the invention.

The name of the company that invented and developed the product based on this patent is "Dutch and Dutch" and the product is the model 8c. The concept of effective front wall and floor boundary coupling of the lowest frequency drivers along with constant, cardioid pattern control of the upper range systems, all active and DSP controlled, is an impressive piece of inventive engineering for effectively addressing real world design issues, and should set the stage for evolution of this system type by others. ***VC***

(Author's Note: For those interested readers, the one other new system that for the most part mirrors the same innovative design concepts, is the Kii Three, developed by Bruno Putzeys, also known for his advancements in Class-D amplifier development.)

Wavecor's FR070WA05 Aluminum Cone Full-Range 2.75" Driver

By Vance Dickason

Today, 2" to 3" diameter full-range drivers and woofers are without a doubt some of the most popular transducers in consumer electronics. They are finding broad application in soundbars, desktop speakers (e.g., Sonos products), smart speakers (e.g., Amazon Echo and Google Home), and portable Bluetooth speakers (e.g., the JBL Flip 4, Bose SoundLink Revolve, Logictech UE Boom, and a million others). With that as an inspiration, I received two drivers in that category for this month's Test Bench explications. In this first explication, I characterize the FR070WA05, a new 2.75" aluminum cone full-range driver from Wavecor (**Photo 1**).

This driver is built on a proprietary injection-molded polymer four-spoke frame. Like most contemporary drivers, the area below the spider mounting shelf is totally open for increased cooling. The cone assembly consists of a black anodized aluminum cone, with a 27mm diameter black anodized aluminum dust cap (directly coupled to the 26mm vented black non-conducting black fiberglass voice coil former), and suspended with a low loss (high Qm) NBR surround and a 45mm diameter flat Conex spider (damper). Powering the cone assembly is a dual neodymium motor with a copper cap shorting ring (Faraday shield) and a milled return cup with black emissive coating and 6mm diameter flared vent. Tinsel leads connect on one side of the cone to a pair of solderable gold-plated terminals.

Photo 1: Wavecor's FR070WA05 2.75" aluminum cone full-range driver

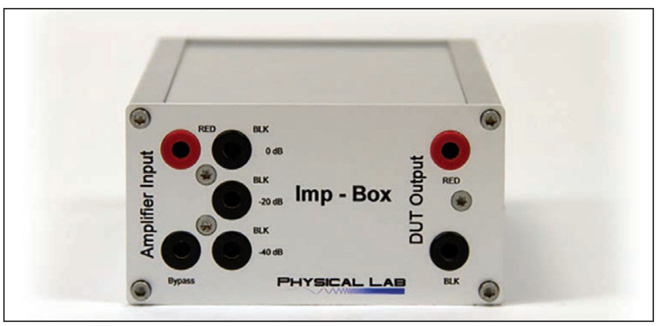

Photo 2: I used the Physical Lab IMP Box, which was provided to *Voice Coil* courtesy of Physical Lab, to take current and voltage measurements.

I began testing the FR070WA05 using the LinearX LMS analyzer and the Physical Lab IMP Box, which is shown in **Photo 2** and was provided to *Voice Coil* courtesy of Physical Lab. Please note that the Physical Lab IMP Box measures current and voltage measurements exactly the same as the LinearX VIBox, however, the LinearX VIBox is no longer available. This was used to create both voltage and admittance (current) curves with the driver clamped to

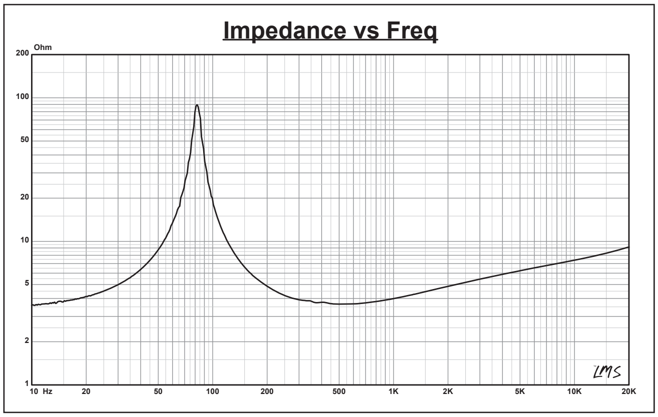

Figure 1: Wavecor FR070WA05 1V free-air impedance plot

	TSL Model		LTD Model		Factory
	Sample 1	Sample 2	Sample 1	Sample 2	
F_S	82.2Hz	80.2Hz	83.4Hz	83.4Hz	89Hz
R_{EVC}	3.19	3.22	3.19	3.22	3.4
Sd cm^2	20.4	20.4	20.4	20.4	22
Q_{MS}	12.31	12.78	14.03	13.13	12.6
Q_{ES}	0.41	0.39	0.52	0.44	0.49
Q_{TS}	0.40	0.38	0.50	0.43	0.47
V_{AS}	0.62 ltr	0.65 ltr	0.60 ltr	0.62 ltr	0.62 ltr
SPL 2.83 V	83.1dB	83.2dB	83.2dB	83.7dB	84dB
X_{MAX}	2.7mm	2.7mm	2.7mm	2.7mm	2.7mm

Table 1: Data comparison information for the Wavecor FR070WA05

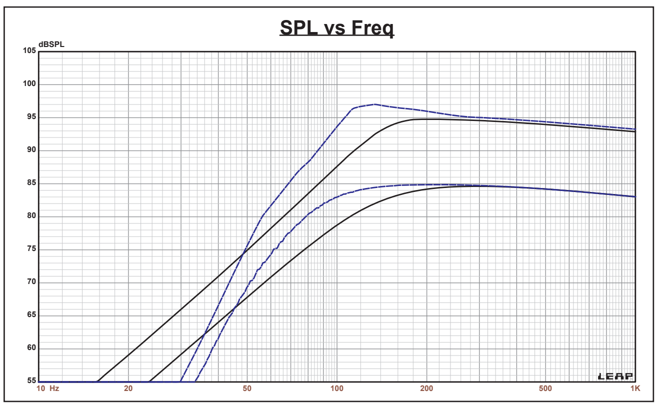

Figure 2: Wavecor FR070WA05 computer box simulations (black solid = sealed @ 2.83V; blue dash = vented @ 2.83V; black solid = sealed @ 11V; blue dash = vented @ 11V)