Directivity Control in Ceiling Loudspeakers

Technology Overview: Control Series Radiation Boundary Integrators

This paper explores how JBL—drawing on many decades of experience and innovation—extended professional levels of directivity control into the field of commercial in-ceiling loudspeakers.

Achieving uniform sound—both in volume and tonal balance—across a large area requires loudspeakers to perform consistently both on and off-axis. In other words, the loudspeaker should deliver the same tonal quality whether the listener is directly beneath it or off to the side. Listeners should not encounter areas where the sound is overly bright, dull, loud, or quiet.

Directivity control is a term used to describe the result of managing sound to provide some level of control over the coverage of a loudspeaker. Several different technologies can be used to exert varying levels of directivity control. "Constant Directivity" results from the highest degree of directivity control. Constant Directivity coverage delivers sound with very little or no change in the frequency response within the coverage zone. A Constant Directivity speaker has a beamwidth chart (showing coverage width by frequency) where every frequency (within the bandwidth of control) has the same (or close to the same) coverage.

The First Constant Directivity Loudspeaker

JBL's first constant directivity ceiling loudspeaker was introduced with the launch of the large-format JBL Control 300 Series. For this product line, JBL developed new drivers featuring a compression driver mounted coaxially behind the woofer (see Fig. 1). This innovative design uses the woofer's pole piece and cone as a constant directivity horn, delivering consistent tonal performance across the entire coverage area. While this design proved ideal for large-format loudspeakers—such as the AWC All-Weather Compact Speakers and the Control 200 Series—small-format drivers do not have large enough voice coils to enable constant directivity with this technology. A new solution was required.

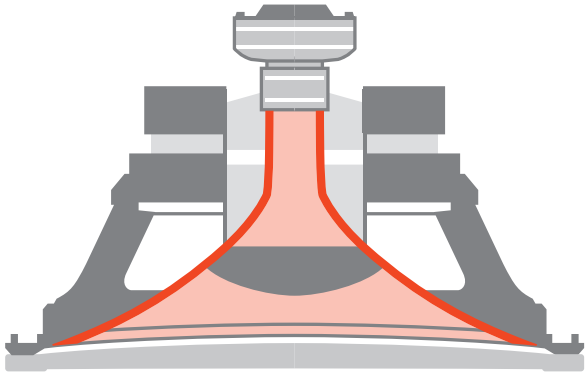

Fig. 1, JBL Control 300 cutaway, compression driver utilizing milled pole piece and cone for pattern control.

JBL Conical Radiation Boundary Integrator

To address this challenge, JBL engineers adapted the Radiation Boundary Integrator (RBI™) technology developed for the flagship VerTec™ and VTX™ tour-sound line arrays into something capable of delivering Constant Directivity in small-format ceiling speakers. This new technology is called "Conical RBI".

The Conical RBI design, which is utilized in JBL Control 400 Premium Coverage Series Speakers, incorporates two integrated baffles (see Fig. 2 and Fig 3). The first baffle, shown in turquoise, is a recessed panel that houses the woofer. This

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baffle design maximizes internal cabinet volume while ensuring optimal integration with the second baffle. Positioned in front of the woofer baffle is a full-width, conically-shaped baffle—shown in green—which supports the tweeter, functions as a waveguide, and utilizes RBI technology.

Fig. 2, JBL Control 445 Cutaway, Conical RBI™ design featuring two baffles.

Fig. 3, JBL Control 447C/T with Conical RBI technology.

JBL Coplanar Radiation Boundary Integrator

While the Conical RBI design provides the highest level of directivity control available for a small format ceiling loudspeaker, the complex tooling required for the three-dimensional baffles adds cost to the solution. The latest iteration of RBI, found in the JBL Control 400 Enhanced Coverage Series was designed to deliver many of the benefits of the Conical RBI at a lower cost.

The Coplanar RBI™ (CRBI™) utilizes a similar two baffle design as is found in Conical RBI loudspeakers, but rather than using a three-dimensional second baffle, the CRBI features a flat front baffle (see Fig. 4). Though the flat baffle does not provide quite the level of control as a conical design, many of the benefits, including a smoother transition between the woofer and tweeter, remain. The unique aperture design was created through extensive simulations and optimizations to deliver coverage consistency performance that far exceeds any competitive offering at a similar price point.

Fig. 4, JBL Control 426C/T 2D Front Baffle, with Coplanar RBI™ technology.

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Coaxial Design Improvements

Many lower cost ceiling loudspeaker designs feature a tweeter coaxially mounted to the end of a post, extended some distance in front of the woofer. JBL improves upon this design by introducing a pattern control device to the tweeter that narrows the dispersion at certain frequencies while broadening it at others. This device also tends to reduce the unwanted wraparound of the high frequencies and their reflection off the low frequency cone (which happens out of time-sync), resulting in better sound quality. This innovation, used in the JBL Control 400 Standard Coverage Series — provides a level of directivity control without a significant increase in cost (see Fig. 5).

Fig. 5, JBL Control 416C/T, featuring a pattern control device on tweeter.

Illustrating Performance

RBI™ and CRBI™ technologies represent a substantial advancement in ceiling loudspeaker engineering, delivering measurably superior directivity control compared to conventional designs. Their performance benefits are validated through beamwidth analysis across models with and without these innovations. As illustrated in Figure 6, the JBL Control 426C/T (CRBI™) and Control 447C/T (RBI™) are benchmarked against a Control 416C/T ceiling loudspeaker.

Though the 416C/T itself provides a more consistent sound character than most traditional ceiling speakers, from 2 kHz to 10kHz—a frequency range critical for speech intelligibility—both RBI™ and CRBI™ models demonstrate significantly improved beamwidth consistency.

This consistency in the coverage pattern ensures a uniform frequency response across the coverage area. Listeners will experience consistent, even sound, both in volume and tonal balance, whether they are directly under a speaker, off to the side, or moving throughout the coverage area.

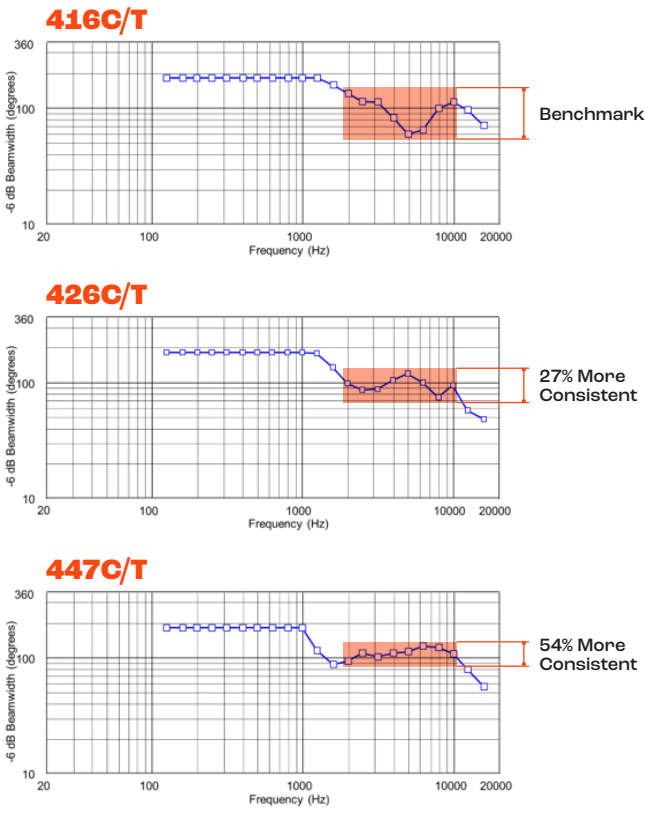

Fig. 6, Beamwidth Comparison Chart.

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For system integrators, the improved consistency delivers two more key benefits.

First, it can reduce the total number of loudspeakers required to achieve uniform tonal coverage, as each unit performs more consistently across its designated area. For example, modeling a room with 14 foot high ceilings using JBL's Distributed System Design (DSD) software, shows that similar levels of coverage consistency can be achieved by installing Control 416C/Ts at 13 foot intervals, Control 426C/Ts at 15 foot intervals, or Control 447C/Ts at 18 foot intervals. The cost savings of installing fewer speakers can be significant.

Second, enhanced tonal consistency simplifies and streamlines the system tuning process. When individual loudspeakers maintain uniform tonal quality throughout their coverage, there is no longer a need to add extra loudspeakers solely to compensate for poor sound performance. Additionally, global equalization across a multi-loudspeaker system becomes more straightforward and effective. In contrast, systems built with loudspeakers that exhibit uneven tonal characteristics often require additional units and force integrators to make difficult compromises during system tuning.

Conclusion

JBL's development of the Conical Radiation Boundary Integrator and Coplanar Radiation Boundary Integrator marks a significant advancement in commercial ceiling loudspeaker design. These innovations not only enhance the listening experience for end users—eliminating volume and tonal inconsistencies—but also simplify the installation and tuning process for system integrators. The result is a more consistent, high-quality sound reinforcement solution that elevates the standard for commercial audio environments.

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