Technical Notes Volume 1, Number 11

Controlled Power Response: Its Importance in Sound Reinforcement System Design

Introduction:

Until the development in the last decade of uniform coverage HF horns and the general acceptance of ported LF systems, sound reinforcement relied on a venerable collection of hardware which had had its beginnings in the thirties. We all know these devices well: radial horns, multicellular horns, and vented horn LF enclosures. Their integration into early motion picture loudspeaker systems provided the basis of high-level sound reinforcement as it developed during the post-war years.

The early hardware had been designed to work with relatively small amplifiers, and power bandwidth was often sacrificed for efficiency. These early systems projected well on axis, but off-axis response tended to roll off at high frequencies. Further, LF response rolled off rather rapidly below 60 Hz.

The introduction of broad-band equalization in the late sixties probably helped as many systems as it harmed. Equalization was embraced by just about everybody, but few really understood exactly what was going on. Perhaps we can sum up the situation by saying that the general acceptance of equalization was evidence that there was something fundamentally wrong with most reinforcement systems.

An Analysis of Two Horns:

The essential difference between the old and the new hardware can be shown by examining, side by side, one of the older radial designs, the JBL 2350, and the newer JBL 2360 Constant-Coverage Bi-Radial™. Both horns are nominally rated 90-by-40 degrees in coverage, but that is about where the similarity ends.

In order to understand fully what happens when a horn and driver are matched, we will first take a look at the driver by itself. The driver's frequency response is normally shown on a plane wave tube (PWT). The PWT loads the driver smoothly over its operating frequency range, and the response we observe is a measure of its total acoustical power output as a function of frequency. Figure 1 shows the PWT curve for a JBL 2445 driver. Note that the response reaches a maximum in the 500-to-2000 Hz range, followed by a gentle 6 dB/octave roll-off above about 3500 Hz. This characteristic roll-off is inherent in all current HF compression drivers intended for wide-range application, and the reader is referred to JBL Technical Note Volume 1, Number 8, for more detailed information.

Figure 1. **PWT Measurement of HF Drivers**

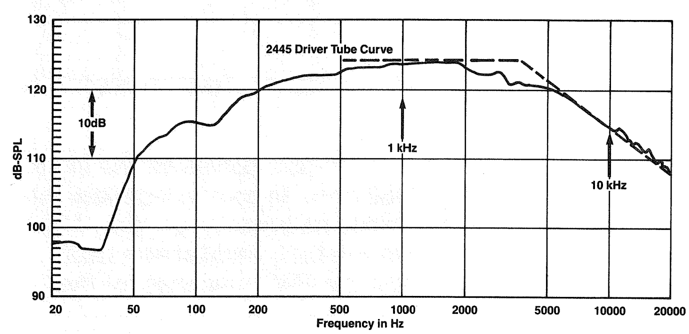
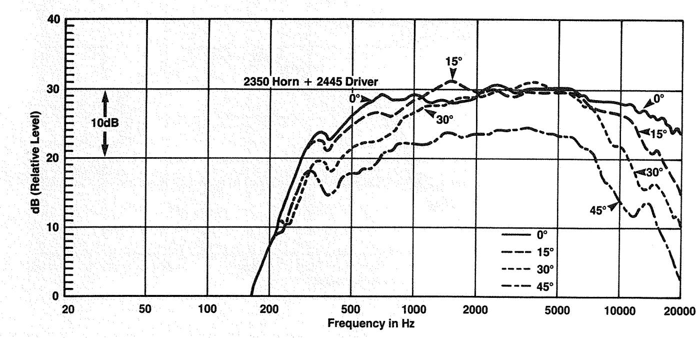


Figure 2 shows on- and off-axis response for the 2445 driver mounted on the 2350 horn. Examine the curves carefully, noting that the zero-degree curve is almost flat out to about 10 or 12 kHz. However, the off-axis curves show severe roll-off above 6 kHz.

Figure 2. **2441 Driver Mounted on 2350 Radial Horn**



The horn "beams" on axis, and the degree of beaming is virtually the sum of the PWT curve for the driver and the on-axis Directivity Index (DI) of the horn. The DI of a horn may be thought of as the on-axis "gain" in dB, relative to the same amount of acoustical power radiated equally in all directions. DI is related to the directivity factor, Q, by the equation:

$$DI = 10 \log Q$$

Figure 3 shows the summation of the PWT and DI curves, and it is a close match to the zero-degree curve shown in Figure 2.

***Figure 3.* Summation (A + B) of PWT Response of 2445 and DI of 2350 Horn On Axis. Compare Summation with 0° Curve of Figure 2.**

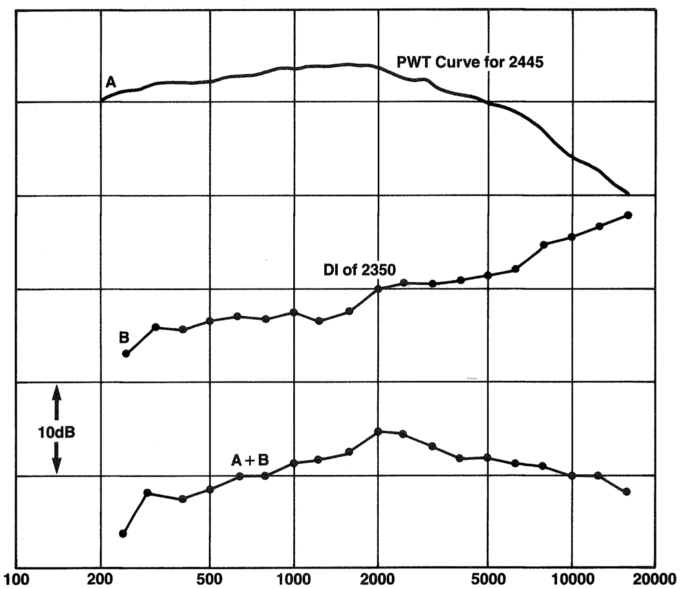


Figure 4 shows on- and off-axis curves for the 2445 driver mounted on the 2360 horn. In comparison with the 2350 horn, this model exhibits no beaming on axis. All of the on- and off-axis curves run fairly parallel with each other, and they all resemble the PWT response for the 2445 driver.

What these curves suggest is that we can equalize the driver's response, boosting it 6 dB/octave above 3.5 kHz, and attain relatively flat response for all on- and off-axis positions. This is shown in Figure 5.

***Figure 4.* 2445 Driver Mounted on 2360 Bi-Radial Horn**

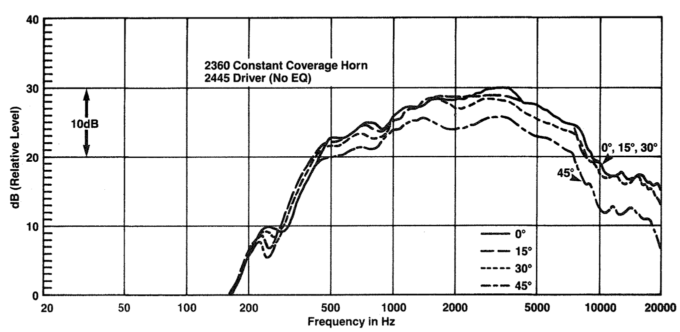
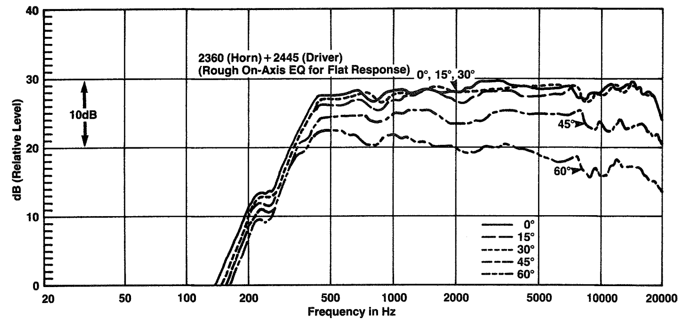
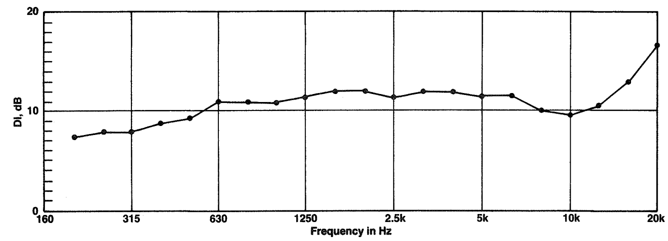


***Figure 5.* As in Figure 4, But Equalized**



As one would suspect, the on-axis DI for the 2360 is relatively flat, as shown in Figure 6, and this indicates that there is no HF narrowing except for frequencies well beyond 10 kHz.

***Figure 6.* DI for 2360 Bi-Radial Horn**



In general, a system with a relatively smooth on-axis DI can be equalized for flat power output over a wide frequency range. A system which has a rising on-axis DI cannot be successfully equalized, because the on-axis response will tend to rise at high frequencies.

Power Response: A Definition:

The power response of a horn-driver combination, or of a full range system, is a measure of its total power output as a function of frequency. It is difficult to maintain absolutely flat power response over the entire frequency band, but over the range from, say, 250 Hz to 10 kHz, it can be maintained remarkably flat to within ± 2 dB.

Flat on-axis response is extremely important, since the axial response of a system determines the nature of first arrival sound at the listener. Power response, on the other hand, influences the nature of reverberant response in large enclosed spaces. For ultimate naturalness of response, both axial and power response should be as flat as can be—or at least run parallel with each other up to about 8 kHz.

When a system is equalized for flat on-axis response, its power response is proportional to the inverse of the system's DI. This is a fundamental relationship which we will observe several times in the remainder of this Technical Note.

Low-Frequency Enclosures:

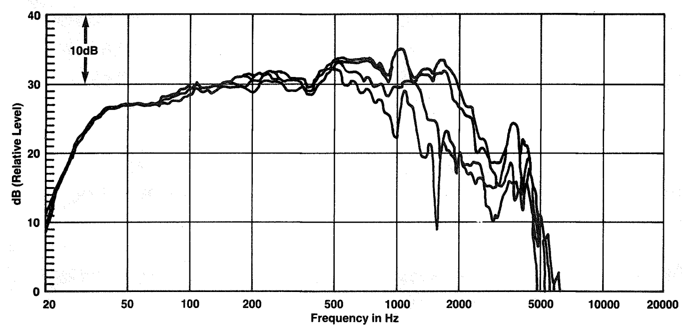
As in the case of HF horns, LF systems can be equalized for smoothest power response when their on- and off-axis curves are parallel running. Consider the set of on- and off-axis curves for the 4508 LF system, as shown in Figure 7A and B. The horizontal response is shown at A, and the vertical response at B.

In the horizontal plane, the system is remarkably smooth, both on- and off-axis, out to 500 Hz. In the vertical plane, the response shows off-axis fall-off beginning around 200 Hz. This is a consequence of mounting the two LF transducers in that plane, but the narrowing of vertical response does tend to match the vertical coverage of a 90-by-40 Bi-Radial horn, if the crossover is at 500 Hz.

By comparison, the horizontal and vertical on- and off-axis curves for the JBL 4550 are shown in Figure 8A and B. Here, both sets of curves indicate that the system's total power output is diminishing rapidly above 200 Hz, even though the zero-degree response is maintained fairly high out to about 700 Hz.

Figure 7. **Response, Horizontal (A) and Vertical (B), of 4508 at 0°, 15°, 30°, and 45° (Response Measured At Ground Plane).**

A



B

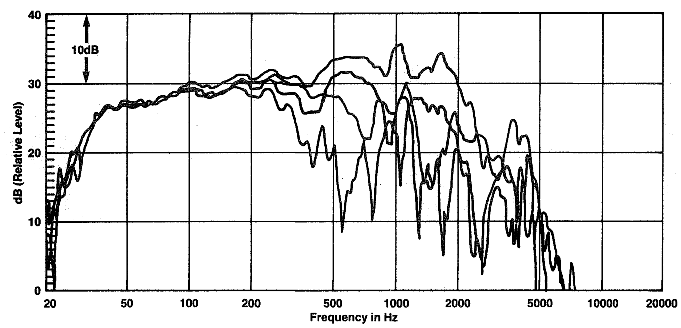
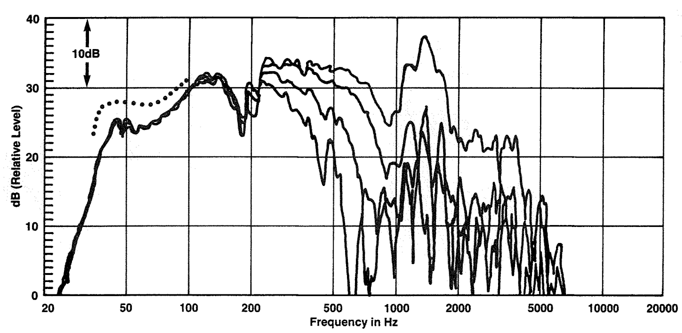
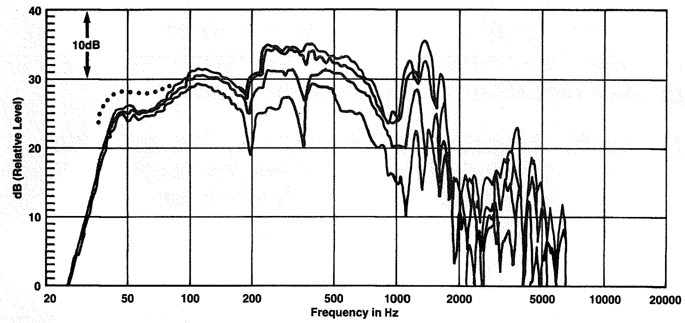


Figure 8. **Response, Horizontal (A) and Vertical (B), of 4550 at 0°, 15°, 30°, and 45°. (Dotted lines indicate ground plane equivalent low-frequency response.)**

A



B



Interaction With The Acoustical Environment:

If a full-range system is properly designed using the newer components, there are two related benefits:

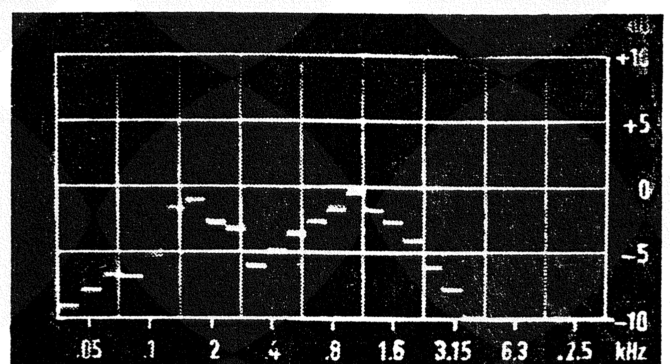
1. Listeners both on- and off-axis will perceive smooth first arrival sound.

2. All listeners will perceive a smooth reverberant spectrum, influenced basically by room boundary and air absorption as a function of frequency.

A third benefit often falls out as a result of the first two, and that is that little, if any, broadband equalization may be needed to adjust the system's overall response to match a given response contour.

We now present two examples of this. Figure 9 shows the response of a theater loudspeaker system as measured by Dolby Laboratories. The HF and LF components in this system were of the older type, and the curve, with its characteristic "camel back" shape, outlines the effective unequalized power response of the system. It is obvious that considerable one-third equalization was required to adjust the power response of this system to match the standard theater equalization contour. (See Reference 2 for a detailed discussion of this curve.)

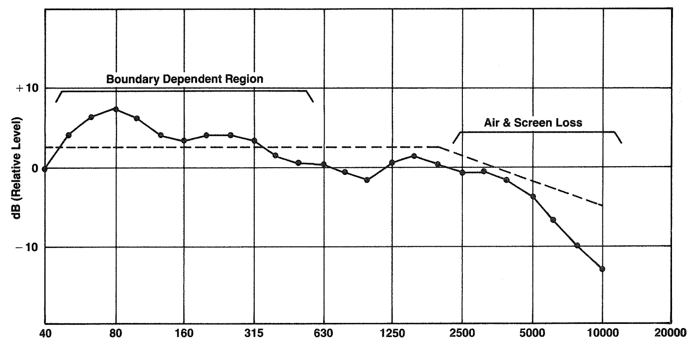
Figure 9. **Unequalized Response of Old-type Theater System (Dolby Data)**



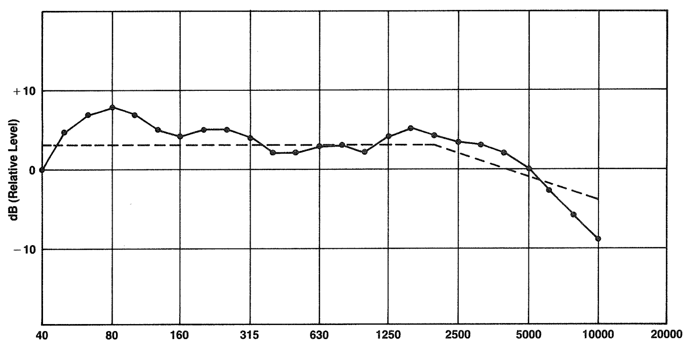
By comparison, Figure 10A shows the response of the center channel of the JBL system installed in the Goldwyn Theater of the Academy of Motion Picture Arts and Sciences. In this plot, the system was adjusted for flattest possible power response. Note that the curve, measured some two-thirds back in the house, matches the desired contour (dashed line) within +5/−6 dB from 40 Hz to 8 kHz. With a simple level adjustment of the HF section of +3 dB (as shown at B), the match above 500 Hz would be a remarkable one. (See Reference 1 for a detailed discussion of the Academy system.)

***Figure 10.* Response, A, of Academy Theater, When HF and LF Elements are Set for Flat Power Response. At B, HF System has Been Raised 3dB.**

A



B



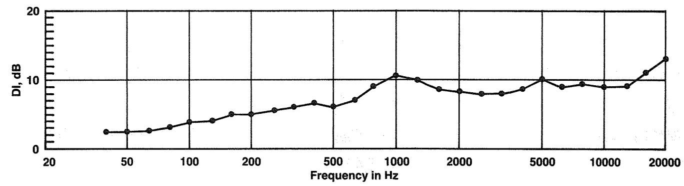
The degree of one-third octave equalization required to match the dashed line contour was quite small, as can be deduced from examining these curves.

In the recording studio, the engineer normally sits at a point where the ratio of direct to reflected sound can be nearly unity. While the integrity of the direct sound from the monitors is extremely important, the general spectrum of the reflected sound in the space will tend to track the inverse of the DI curve of the loudspeaker.

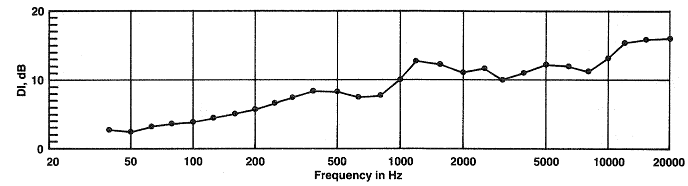
Figure 11 shows the DI curves for a pair of highly regarded studio monitors. The DI of the JBL 4430 is smooth within ± 2 dB from 400 Hz to 16 kHz, and we would expect the reflected spectrum in the control room to be relatively smooth. The DI of the UREI 813 is not as smooth; over the same frequency range, it exhibits a ± 4 dB variation. Consequently, this monitor should be specified for control room environments which are more absorptive than usual, so that level variations in the reflected sound are minimized. (See Reference 3 for additional discussion.)

***Figure 11.* DI Plots of JBL 4430 Monitor (A) and UREI 813 Monitor (B).**

A



B



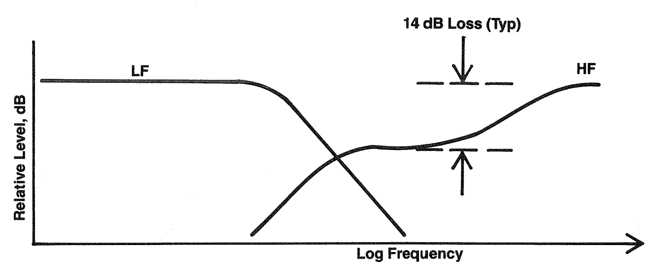
System Implementation:

JBL's passive 3100-series dividing networks have been redesigned to provide HF power response boosting. The function of the boost is shown in Figure 12A. Note that the HF driver can receive nearly full amplifier power at high frequencies. Care must be taken in system planning and layout so that driver power ratings are not exceeded.

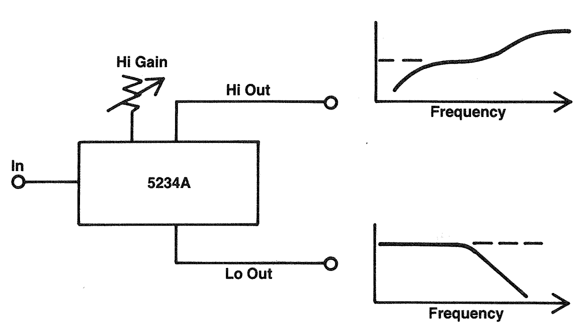
For biamping, the set-up shown at B is used. Plug-in cards for the 5234A are available with HF power response boost.

***Figure 12.* Power Response Correction in Networks; Passive (A) and Active (B)**

A



B



General Recommendations:

1. Unless there is a particular sonic requirement for one of the older vented horn LF enclosures, the simple ported enclosure will usually work better, and at lower cost to the user.

2. While the large Bi-Radial horns afford near perfect axial and power response, the Flat Front Bi-Radial™ horns should be considered for many applications. They exhibit horizontal coverage which is nearly as good as that of the larger Constant-Coverage Bi-Radials, with only slightly less pattern control in the vertical plane.

3. Most stock JBL systems designs have excellent axial and power response. In particular, the models 4660 and 4671 should be considered for many speech only applications.

References:

1. J. Eargle, J. Bonner, and D. Ross, "The Academy's New State-of-the-art Loudspeaker System," *Journal SMPTE*, Vol. 94, No. 6 (June 1985)

2. M. Engebretson and J. Eargle, "Cinema Sound Reproduction Systems," *Journal SMPTE*, Vol. 91, No. 11 (November 1982)

3. D. Smith, D. Keele, and J. Eargle, "Improvements in Monitor Loudspeaker Systems," Journal AES, Vol. 31, No. 6 (June 1983)

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