Technical Note Volume 3, Number 1

The Evolution of JBL's Large Format Monitor Loudspeaker

Introduction:

Modern recording technology is presently driven by continuing improvements in digital signal processing and the demands of sound with picture. The coming of the DVD has changed the very nature of the studio environment, both physically and economically, resulting in more (but smaller) workspaces. JBL's response to these ongoing improvements is the DMS-1 digitally controlled monitoring system, a two-way design that makes use of new compression driver technology and high-performance cone transducers, resulting in distortion figures that are more typical of electronics than loudspeakers.

During the early eighties JBL pioneered the use of uniform coverage high frequency horns in studio monitors, producing the highly regarded Bi-Radial® systems. These systems were tailor made for the control rooms of that day, and the model 4425 and 4430 Bi-Radial monitors remain staples in the JBL line. They coexist with the newer designs, and this Technical Note will trace the engineering evolution from Bi-Radial monitors to the DMS family.

The Bi-Radials Revisited:

Background:

The JBL Bi-Radial monitors made use of state-of-the-art transducers of the early eighties, bringing JBL's SFG (Symmetrical Field Geometry) to new monitor design for the first time. What truly set the JBL Bi-Radials apart from earlier monitor designs was the use of a 90° by 90° uniform coverage HF horn that was crossed over with the LF transducer at the precise frequency at which the LF transducer's radiation angle matched that of the horn. The result of this was a system with horizontal and vertical patterns that began wide at low frequencies, progressively narrowing to 90 degrees, and remaining at that value to beyond 10 kHz. This can be seen in the beamwidth and DI plots for the 4425 and the 4430, shown respectively in Figures 1 and 2.

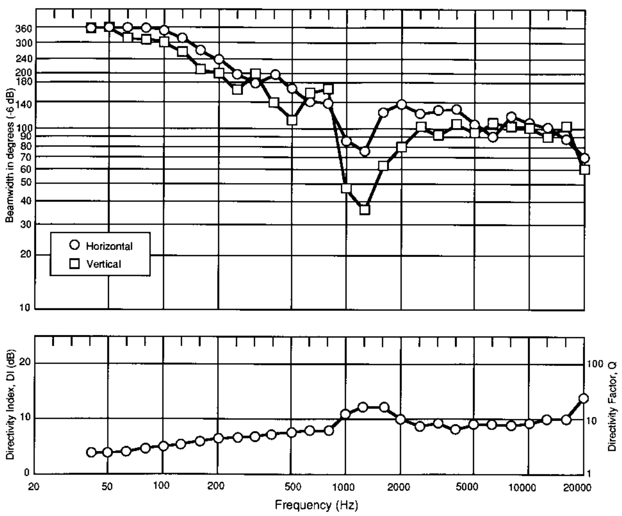

Figure 1. **Beamwidth (–6 dB) and DI for JBL 4425 monitor.**

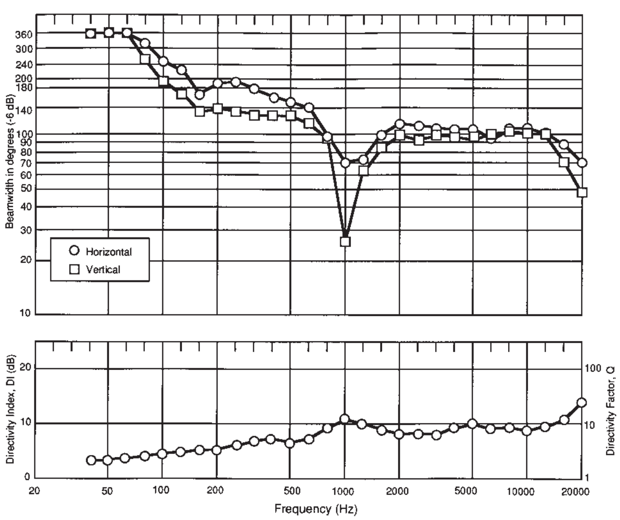

Figure 2. **Beamwidth (–6 dB) and DI for JBL 4430 monitor.**

In many control rooms of the eighties, the ratio of direct to reflected sound at the prime listening position was about unity, and absorption in the room was fairly uniform. A listener seated at the console in effect heard as much direct sound as reflected sound. In the Bi-Radial design, the direct field and the reflected field can be uniformly maintained above the transition to the horn, as can be seen from the nearly constant DI above 1 kHz. In practical terms, what this means is that, when the direct sound at the prime listening point has been equalized for some target response contour (house curve), the accompanying ensemble of reflections will also reflect that same contour over the frequency range of the horn. Typical monitor systems of the period had rather uneven DI's and the advantage of the Bi-Radial monitors over those systems shown through the progression of curves illustrated in Figure 3.

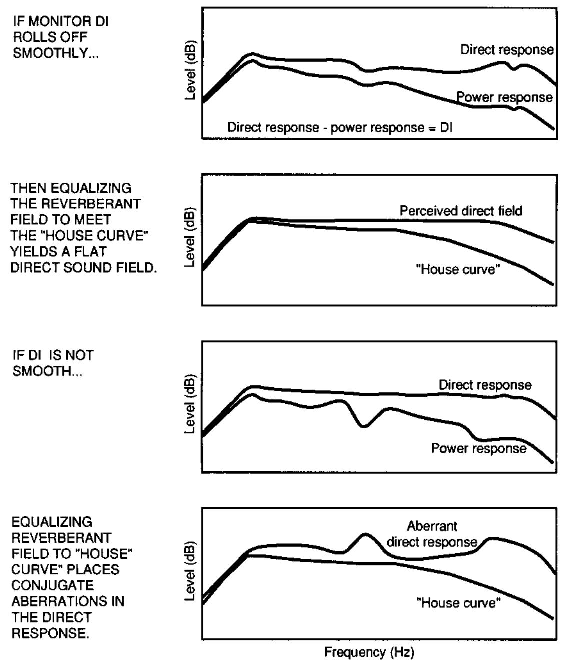

Figure 3. **Smooth versus irregular power response in the control room.**

<u>Maintaining the Desired Contour: Electrical or Acoustical Equalization?</u>

It is well known that HF compression drivers exhibit a –6 dB/octave falloff in response above their mass breakpoint. (See Technical Note volume 1, number 8) In most drivers, this occurs in the range of 3000 to 3500 Hz. If flat power response is desired above that frequency, then it will be necessary to boost the drive signal to the compression driver above the mass breakpoint.

Alternatively, if the horn's directional response is allowed to narrow with rising frequency, the effect of the rising DI will have the same effect on-axis as electrically boosting the signal to the horn. This was the philosophy dominant at the time JBL used acoustical lenses in monitor design
(e. g., the model series 4320, 4330, and 4340). The actual signal to the HF driver was maintained electrically flat, and the acoustical falloff above the mass breakpoint was effectively compensated for by the sharp rise in the axial DI of the horn/lens assembly. The effect was excellent for on-axis listening in a fairly dry acoustical setting, but in a normal control room, where reflections were significant, the sound texture was not uniform, even though the on-axis response was flat.

<u>Time Domain Response:</u>

Since the Bi-Radial monitors are 2-way designs, it is relatively easy to engineer them as minimum phase bandpass sections that will exhibit smooth time domain response along a specific vertical design axis. In the JBL 4430, these design details are shown in Figure 4A. Note that the preferred "launching angle" is about 10 degrees upward from a point midway between the frame of the LF transducer and the lower lip of the horn. Figure 4B shows the Blauert & Laws criteria for the audibility of group delay (timing) errors in loudspeakers. Note that the Bi-Radial monitors exhibit group delay well below the normal threshold of audibility.

The most stringent time domain test for a loudspeaker system is its capability for reproduction of square waves with fundamentals in the LF transducer range and most of the harmonics in the HF horn range. Figure 5 shows the excellent square wave response of the JBL Bi-Radial monitor model 4425.

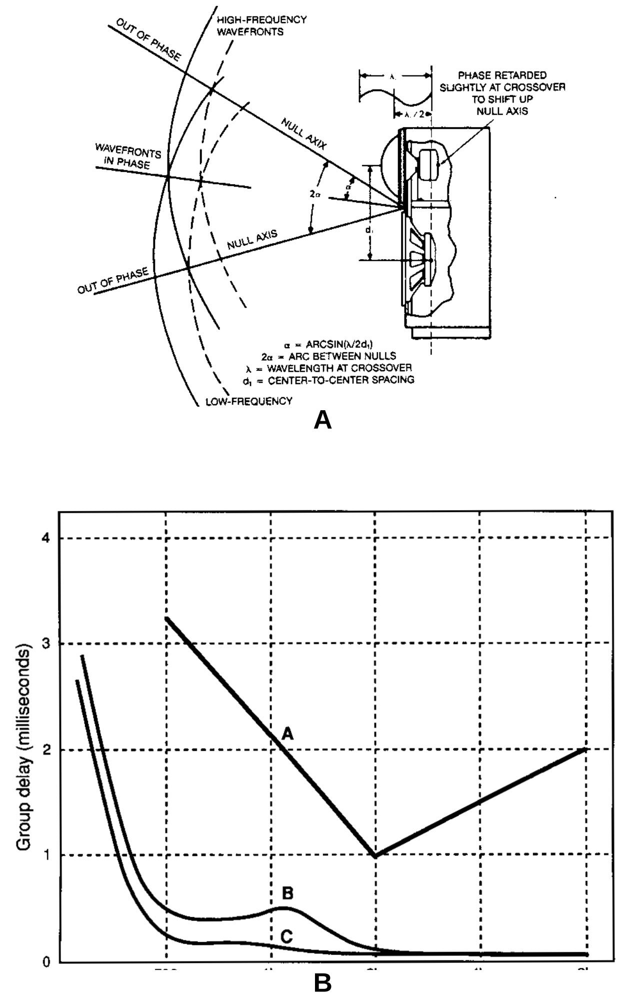

Figure 4. **Time domain response. Target vertical listening angle for JBL 4430 monitor (A); Blauert & Laws criteria for audibility of delay phenomena.**

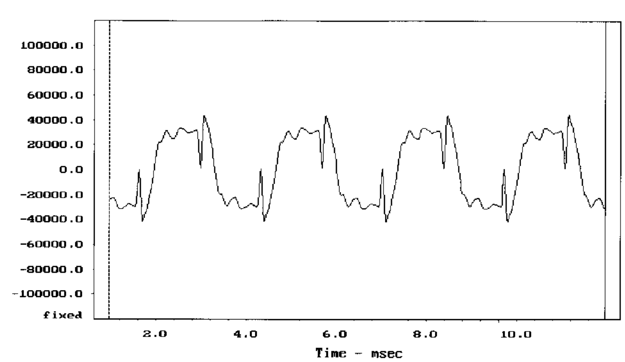

Figure 5. **Square wave response of the JBL 4425 at 365 Hz.**

Distortion:

JBL normally shows system distortion by plots of second and third harmonic distortion (raised 20 dB relative to the fundamental), at some reference power input and measured at 1 meter. For example, Figure 6 shows on-axis fundamental and distortion data for the 4425 with a nominal power input of 50 watts. This corresponds to a level at a distance of 1 meter of 107 dB Lp. At this elevated level, distortion in the range from 50 Hz to 5 kHz does not exceed a value of 3%. In the midrange from 160 Hz to 800 Hz, the distortion is below 1%.

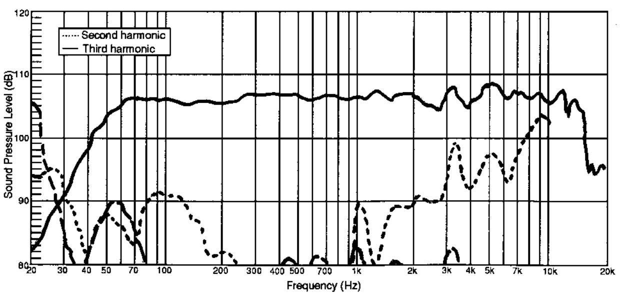

Figure 6. **Distortion for JBL 4425, 50 watts at 1 meter. (Distortion raised 20 dB)**

The model 4430 is designed around heavier duty hardware and can be driven to higher levels. Figure 7 shows this system operating with a nominal input of 50 watts, producing levels of 110 dB Lp at a distance of 1 meter. Here, the distortion remains around 1% from 160 Hz to 800 Hz, climbing to 3% at 6300 Hz.

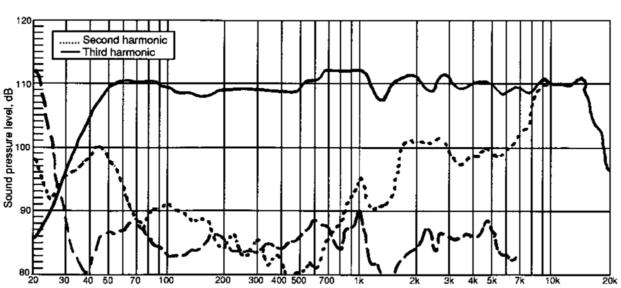

Figure 7. **Distortion (50 watts input at 1 meter) for JBL 4430. (Distortion raised 20 dB)**

Sine wave signals, especially at high levels and high frequencies, are particularly demanding on any loudspeaker system, and the curves shown here represent outstanding distortion performance for monitors of any design philosophy.

Power Compression:

Another look at system linearity is shown in power compression curves. Over time, high signal levels delivered to the monitors will cause heating of the voice coils. This produces an increase in resistance which results in a reduction of efficiency and a shifting of the LF response alignment. JBL customarily shows power compression by superimposing successively higher power curves upon one another, adjusting the levels so that the base values of the curves all match. When this is done, the degree of power compression is evident by simple inspection. Figure 8 shows families of power compression curves for the JBL 4425 (A) and 4430 (B) for inputs of 1, 10, and 100 watts.

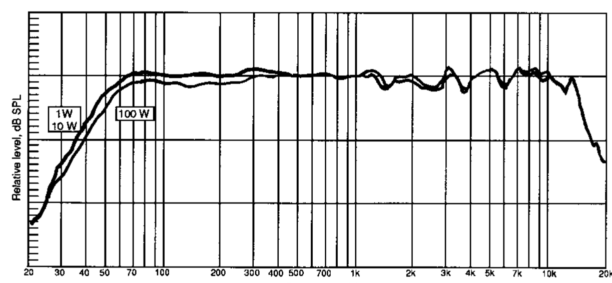

Figure 8A. **Power compression for JBL 4425 (inputs of 1, 10, and 100 watts)**

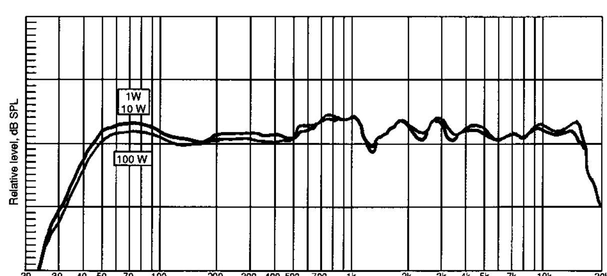

Figure 8B. **Power compression for JBL 4430 (inputs of 1, 10, and 100 watts)**

As seen here, both monitors have relatively low power compression. The 4425, with its 76 mm (3 in) diameter LF voice coil, has slightly more power compression at 100 watts than the 4430, with its 100 mm (4 in) diameter LF voice coil, and this is to be expected.

Enter the Digital Era: The JBL DMS-1:

By the early nineties significant changes were underway in the acoustical monitoring scene; among them were:

1. An increase in the ratio of small to large workspaces, with consequent greater acoustical absorption in those smaller spaces.

2. The requirement for advanced film and video postprocessing, with surround sound capability. This called for separate left, center, and right loudspeaker models for frontal presentation.

3. The requirement for lower distortion, to match the quality expectations generated by improved digital recording and processing.

4. The requirement for flat amplitude response (with minimum phase characteristics) over a passband from 40 Hz to 20 kHz.

JBL responded to these challenges through:

1. Use of the Coherent Wave™ large format phasing plug for extended HF response.

2. Use of a new family of rapid flare Optimized Aperture™ drivers and horns for lower HF distortion.

3. Use of neodymium-iron-boron magnets for high flux densities and for excellent magnetic shielding.

4. Use of advanced techniques for heat removal to reduce LF power compression.

5. Use of digital control electronics for basic frequency division, precise power response equalization, time domain alignment, and control room/environmental equalization.

<u>System Philosophy:</u>

JBL's aim in designing the DMS-1 was to provide a monitor system whose intrinsic linearity could easily be compared with its associated recording electronic systems. This is especially true at normal operating levels, where the distortion of the system is well below 1%.

The DMS-1 uses a vertically symmetrical in-line array in separate left and right models, as shown in Figure 9. The two LF transducers are mounted above and below the HF horn. For listening at fairly close quarters, this over-under placement of LF units produces LF localization at the HF horn itself, very much the way a coaxial design does. By necessity, the center channel baffle layout places the LF transducers horizontally below the HF horn.

The relatively small size of the horn provides excellent 90° horizontal dispersion from 800 Hz to 12.5 kHz, narrowing to 60° at 20 kHz. The small vertical dimension of the horn's mouth also allows the LF transducers to be placed fairly close together in order to minimized vertical pattern lobing.

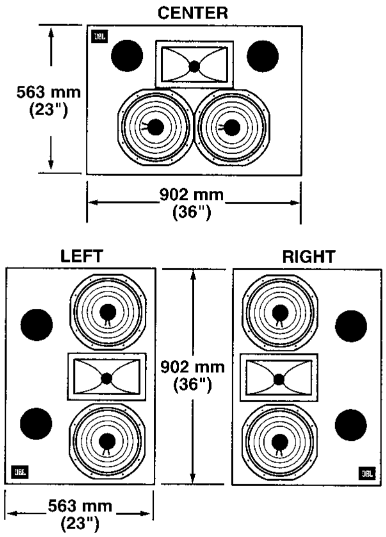

Figure 9. **Front views of left, center, and right models of JBL DMS-1 monitor system.**

However, the small vertical mouth dimension of the horn results in fairly wide vertical dispersion in the 1 to 2 kHz region, gradually narrowing to the 40-60° range at higher frequencies.

Figure 10 shows the –6 dB beamwidth and DI data for the system. Note that the DI is maintained at 10 dB, ± 1.5, from 500 Hz to 20 kHz. While the DMS-1 fulfills the same general requirement for equally smooth power and axial response as the Bi-Radials, the on-axis DI of the DMS-1 rise slightly from 1 kHz to 8 kHz, lessening to a slight degree the amount of electrical boost at higher frequencies needed for flat on-axis response, as compared with the 4430 Bi-Radial monitor.

Frequency Division and Power Response Equalization:

Frequency division and response equalization for flat on-axis response of the DMS-1 are shown in Figure 11. The curves shown here are programmed into the DSC-280 digital controller and are used to drive the power amplifier sections that are used for each loudspeaker. Each LF transducer is

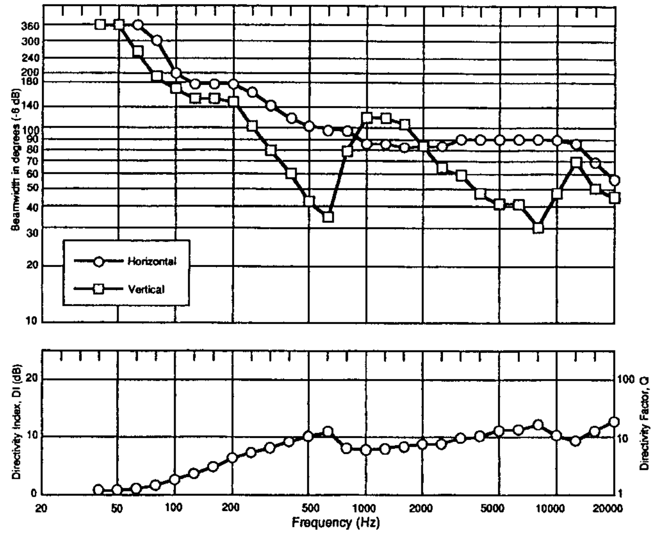

Figure 10. **Horizontal and vertical beamwidth (–6 dB) and directivity index for DMS-1.**

powered with up to 600 watts and the HF sections up to 200 watts. Figure 12 shows overall on-axis amplitude and phase response of the DMS-1.

Some users may prefer to use the JBL SMC 24 analog controller, a stereo unit which provides a Linkwitz-Riley 24-dB/octave crossover function at 1 kHz, basic HF power response equalization, and both HF and LF limiting. Limiting thresholds for both LF and HF can be set on the rear panel. When the SMC 24 controller is used, additional system equalization, may be necessary to fine tune the systems to the desired room reponse curve.

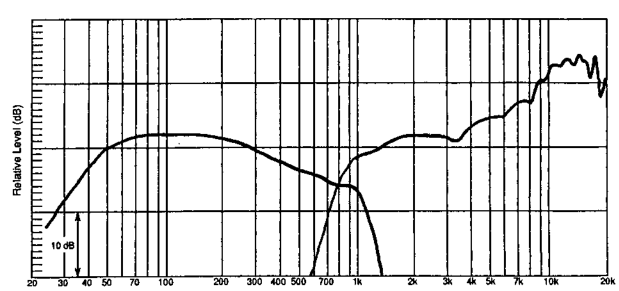

Figure 11. **Low and high frequency drive voltages for flat on-axis frequency response.**

Time Domain Response:

With the frequency response shown in Figure 12, it is no surprise that the square wave response of the DMS-1 is exemplary, as shown in Figure 13.

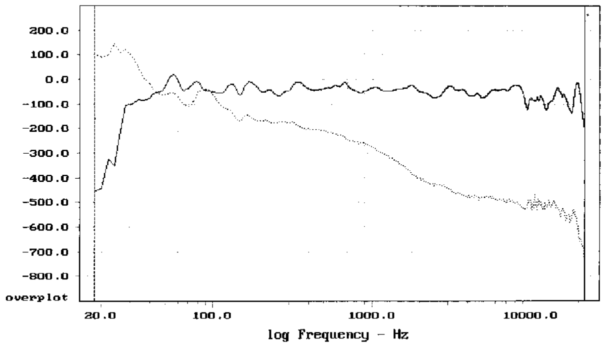

Figure 12. **On-axis amplitude and phase response of DMS-1. Amplitude shown by solid curve (5 dB per division); phase response shown by dotted curve (degrees shown on left scale).**

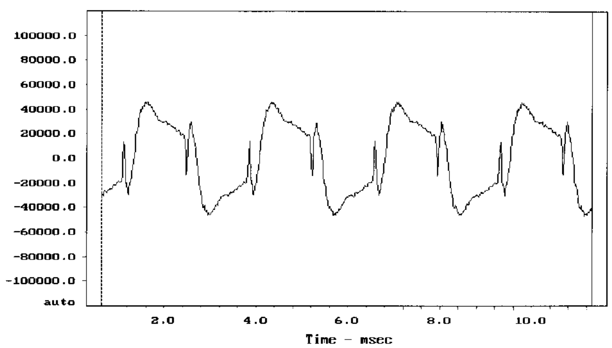

Figure 13. **Square wave response of JBL DMS-1 at 365 Hz.**

Distortion:

Figure 14 shows the second and third harmonic distortion (both raised 20 dB for ease in reading) for the DMS-1 driven to an output of 110 dB Lp measured at a distance of one meter. Note that second harmonic distortion at 10 kHz is no higher than 3%, a remarkably low value at these extremely high output levels. For the entire system, the distortion remains in the range of 1% or lower from 30 Hz to about 2500 Hz.

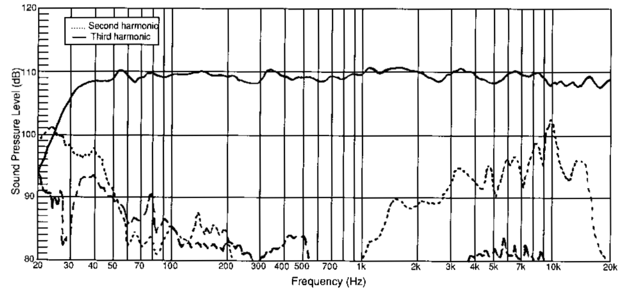

Figure 14. **DMS-1 2nd and 3rd harmonic distortion (+20 dB) for output level of 110 dB Lp at one meter.**

Conclusions:

The DMS-1 represents the best performance available today from any monitoring system in its class. Users invariably comment on the extremely smooth amplitude response of the system and its complete lack of listening fatigue over extended periods of use. Other users comment on the accuracy of imaging, both in stereo and in left-center-right applications. No compression driver system made by anyone can produce equivalent output levels with as low distortion.

Additional Reading:

1. J. Eargle and W. Gelow, "Performance of Horn Systems, Low-Frequency Cut-Off, Pattern Control, and Distortion Trade-Offs," presented at the Audio Engineering Society Convention, Los Angeles, November 1996, preprint number 4330.

2. JBL Technical Note, Volume 1, Number 8, "Characteristics of High-Frequency Compression Drivers."

3. JBL Technical Note, Volume 1, Number 21, "JBL's New Optimized Aperture(tm) Horns and Low Distortion Drivers."

4. JBL Technical Note, Volume 1, Number 22, "JBL's New Super Vented Gap(tm) Maximum Output Low Frequency Transducers."

References:

D. Smith, D. Keele, and J. Eargle, "Improvements in Monitor Loudspeakers," J. Audio Engineering Society, Volume 31, Number 6 (June 1983).

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