Technical Note, Volume 1, Number 21

JBL's New Optimized Aperture™ Horns and Low Distortion Drivers

Introduction:

Except in their initial historical development, high frequency horns and their associated compression drivers have normally been designed independently of each other. The reason is of course that drivers of a given exit diameter are normally expected to work with the appropriate family of horns, old and new. JBL's large format family of 100 mm (4 in) diaphragm drivers is a clear example of this. When the JBL 375 compression driver was designed during the fifties, it was based on the exit geometry of the original Western Electric 594 driver. Subsequent variations, such as the JBL 2441, 2445, and 2450 family all maintained the original exit geometry and were designed to work with four decades of horn hardware with 50 mm (2 in) throat diameter.

As part of JBL's ongoing research in horn/driver acoustic relationships, it became apparent that significant improvements could be made in non-linear performance at high output levels in horn systems if the exit geometry could be changed. Specifically, the generation of second and third harmonic distortion at high levels could be greatly reduced through a more rapid flare rate from the driver into the horn, and in order to do this both new drivers and new horns would have to be developed simultaneously.

JBL has embarked on such a program, and the driver models 2447 and 2451 have been developed. These are both 100 mm (4 in) diaphragm drivers with 38 mm (1.5 in) exit diameter. Three medium size format horn models 2352, 2353, and 2354, offering 90 by 40, 60 by 40, and 40 by 20 degree coverage, have been designed to work with these drivers. We have addressed the following points in the new coordinated designs:

1. Phasing plug coupled directly to the horn throat.
2. Lower distortion than earlier JBL and competitive combinations.
3. JBL's traditional 100 mm (4 in) titanium diaphragm integral to the design.
4. Excellent pattern control, extending down to the crossover range.
5. Consistent on-axis frequency response, model to model.

While much of this information is apparent from studying the product specification sheets, we have developed this Technical Note for the purpose of showing relevant competitive information on distortion and pattern control. We will present distortion measurements on three 90 by 40 degree horn/driver combinations and show beamwidth data on three combinations of 90 by 40 and 60 by 40 degree horns.

Background:

As discussed in JBL Technical Note Volume One, Number Eight, second harmonic distortion in horn/driver combinations is due to thermodynamic air overload and, for a given level and driving frequency, the distortion is inversely proportional to the design cutoff frequency of the horn. Actually, the exponential horn flare begins at the diaphragm and is initially established through the relatively short openings of the phasing plug. As shown in Figure 1 A, the older driver technology had a built-in coupler that provided a slow flare from the 38 mm (1.5 in) diameter of the phasing plug to the 50 mm (2 in) diameter at the driver's exit. The original reason for this was to allow internal space in the driver for relatively deep magnet structures or field coils.

Figure 1A. Old driver configuration.

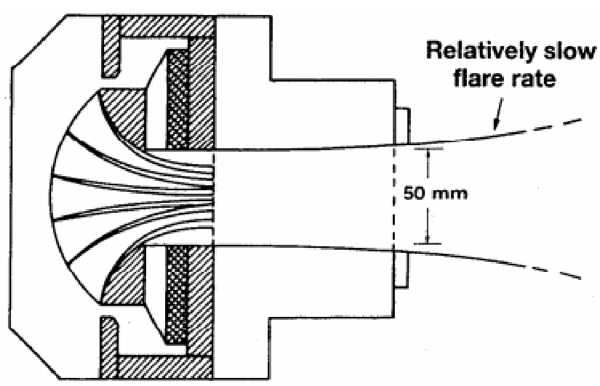
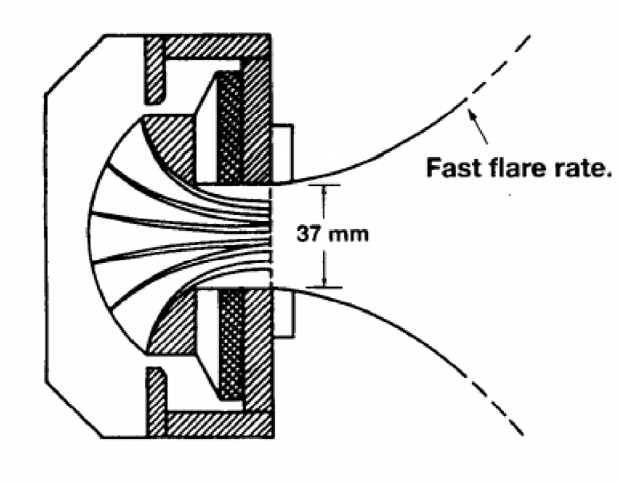


Figure 1B. New driver configuration.



Today, with very small, high energy neodymium magnets and thin profile ferrite magnets, we do not need that space. The overall depth of the driver can be significantly reduced, as shown in Figure 1 B, providing a relatively rapid flare into the throat of the horn.

By our calculations, the initial flare rate in the older driver design was approximately 160 Hz, reflecting the need to drive the very large horns that were used in early motion picture systems. Today, we can double or quadruple that flare rate, inasmuch as many horns are now intended for nominal crossover at 800 Hz.

Rapid flare rates offer an opportunity to make improvements in high frequency pattern control. Since the exit of the phasing plug is virtually at the apex of the horn, there is normally an excellent sight line into the phasing plug, even at the extremes of angular coverage; this is virtually a guarantee that high frequency signals will illuminate the entire wave guide and show little tendency to beam on axis.

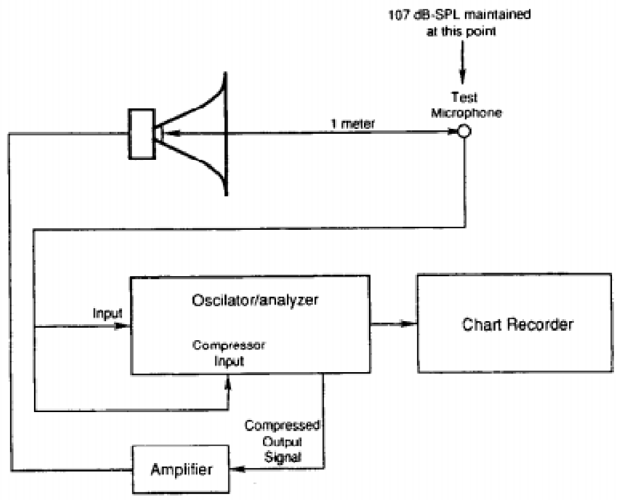
Distortion Measurements:

Figure 2 shows the basic setup for measuring second harmonic distortion. For these measurements, the output level at one meter from the diffraction slot of the horn was carefully maintained at 107 dB SPL through the use of the compressor in the B&K test gear. This level corresponds to 87 dB SPL at 10 meters (33 ft), and thus represents normal application of these horns. The action of the compressor simulates, on swept sine wave input signals, flat equalization of the system on axis, as would be the case in real world equalization practice for many applications. The total range of compression was about 15 dB.

The three horn/driver combinations used in these measurements were:

1. JBL 2380/2450
2. JBL 2352/2451
3. EV HP940/DH1A.

Figure 2. Block diagram of test setup for measuring distortion.

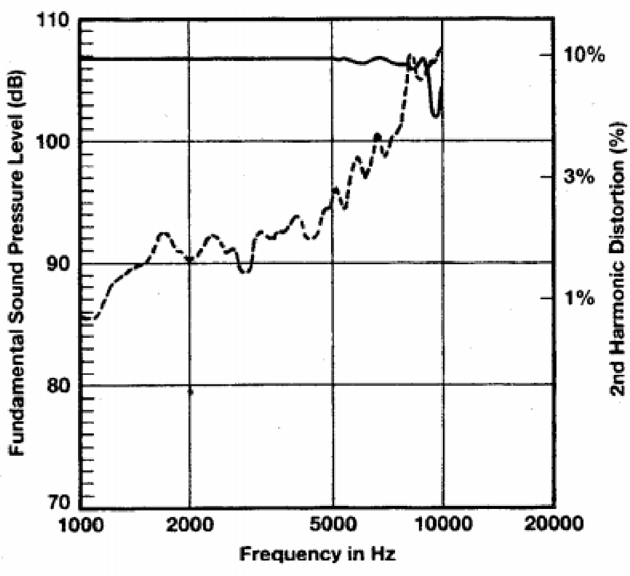


These systems are commercially equivalent in terms of nominal pattern control, and the horns are medium format in size. The use of the B&K compression circuitry enables a direct comparison of distortion, as a function of output level, to be made by inspection.

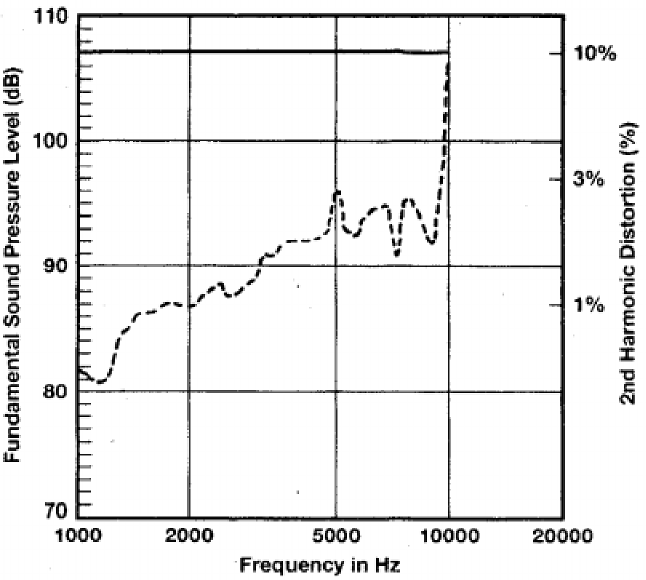
The JBL 2380/2450 combination is shown in Figure 3A. The compressed fundamental is shown as the solid line. Second harmonic distortion (dashed curve) has been raised 20 dB, and distortion percentage is indicated along the right axis of the graph. For this combination, second harmonic distortion lies between 1 % and 3% from 1 kHz to about 5.5 kHz. Between 5 kHz and 10 kHz it rises to a little over 10%.

Figure 3. Hom/Driver Distortion Measurements.

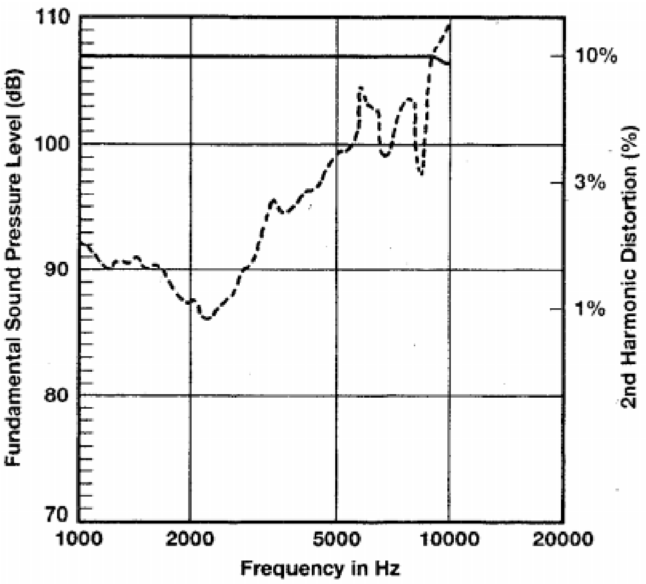
A. JBL 2380/24SO combination.



B. JBL 2352/2451 combination.



C. EV HP940/DH1A combination.



The JBL 2352/2451 combination is shown at 3B. Again, second harmonic distortion has been raised 20 dB. Here, midband distortion lies below 1 % up to about 2.5 kHz, reaching a value of 3% at about 9 kHz.

The EV HP940/DH1A combination is shown at 3C. Note the rise in distortion between 1 and 2 kHz; this appears to be due to mechanical suspension nonlinearity in the driver rather than to thermodynamic effects. In general, the distortion is significantly higher than that of either the JBL 2380/2450 or JBL 2352/2451 combination.

Beamwidth Measurements:

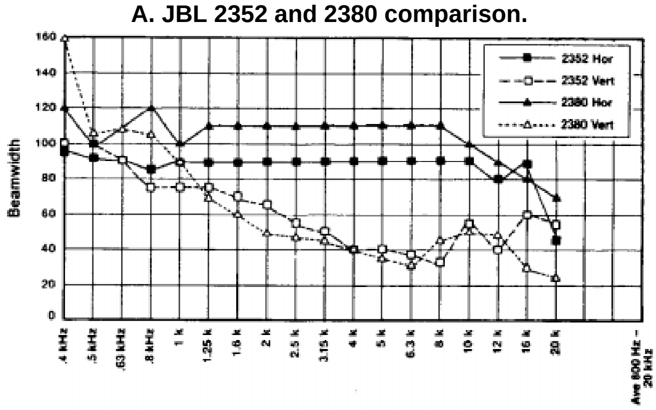
As a rule, JBL publishes beamwidth data plotted on a logarithmic vertical scale, since that scale relates inversely to directivity index. However, in Figures 4 and 5, a linear vertical scale is used for beamwidth measurements since it provides better resolution in the 80 to 120 degree range for ease in making competitive comparisons.

Figure 4 shows beamwidth performance versus frequency for the JBL 2352, as compared with the JBL2380 and the EV HP940. At 4A the new JBL 2352 is compared with the older JBL2380. While both horns have much in common, note that the horizontal beamwidth is virtually flat out to 16 kHz. Also, the pattern control in the 400 Hz to 1 kHz range is much smoother in the new horn.

Figure 4B compares the JBL2352 with the EV HP940. The 2352 exhibits better control in the horizontal plane, while the EV HP940 horn exhibits smoother control in the vertical plane. Overall, the 2352 exhibits smoother pattern control in the 400 Hz to 1 kHz range.

Figure 4. -6 dB Beamwidth Measurements.

A. JBL 2352 and 2380 comparison.



B. JBL 2352 and EV HP940 comparison.

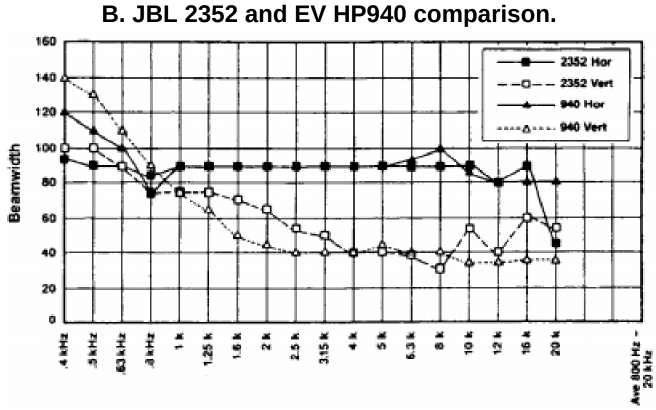
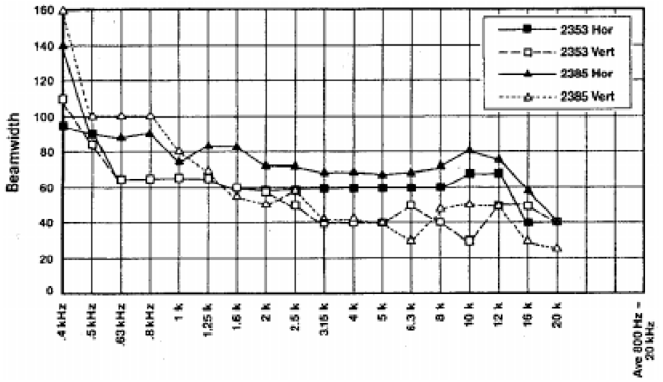


Figure 5 shows beamwidth performance versus frequency for the JBL 2353, as compared with the JBL 2385 and the EV HP640. At 5A the new JBL 2353 is compared with the older JBL2385. Note that the 2353's horizontal beamwidth follows its target 60degree response from 630 Hz to 12 kHz. Vertical pattern control is maintained from 2.5 kHz to 16 kHz within +10 degrees.

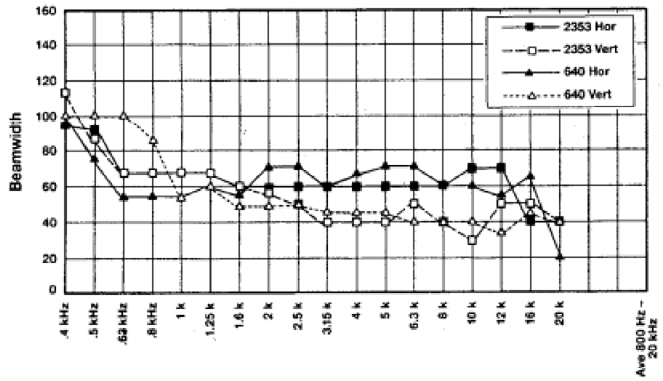
The JBL2353 and EV HP640 are compared in Figure 5B. Note that the 2353 exhibits horizontal pattern control that is within 10 degrees of the target 60 degrees from 630 Hz to 12 kHz. Both horns have roughly equivalent vertical pattern control. As with the 90 by 40 degree horn, note that the 2353 maintains better pattern control in the 500 Hz to 1 kHz range than either the older JBL2385 or the EV HP640.

Figure 5. -6 dB Beamwidth Measurements.

A. JBL 2353 and 2385 comparison.



B. JBL 2353 and EV HP640 comparison.



Conclusions:

JBL's new Optimized Aperture horns and their associated drivers offer a significant reduction in distortion when compared to all earlier JBL horns and all competitive models. These improvements in distortion have been attained with no loss of pattern control, as we can see when they are directly compared with the earlier JBL 2380 series Flat-Front Bi-Radial designs. In some cases the new horns offer better pattern control than the older Flat-Fronts. The combination of large diaphragm diameter and rapid flare exit geometry points the way for future development for all classes of horns.

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