Technical Notes Vol. 1, No. 4

Constant Directivity Horns

I. Introduction:

In the last three years, constant directivity horns have virtually replaced the older radial and multi-cellular types in large-scale speech and music reinforcement systems. These devices are available from three domestic manufacturers: JBL's family of Bi-Radials, Altec's family of Mantarays, and EV's family of "White Horns".

While all of these horns succeed in their design aims, there are significant differences between them which contractors and consultants should be aware of, and it is the intent of this Technical Note to present comparative data on these devices in the most objective way.

More recently, JBL has introduced a line of Flat Front Bi-Radials, which effectively replace the corresponding older radials in the line. Since a number of users of the older models have been reluctant to give them up, we would like to present performance data on the old and new devices so that the advantages of the new models will be apparent. Additionally, we will present comparative data on the newer Altec and EV smaller horns which compare directly with JBL's new Flat Front Bi-Radials.

While most of our discussion will deal with the directional properties of these horns, we will comment as well on certain aspects of smoothness of frequency response and distortion.

II. The Large Horns:

The horns to be compared in this section are:

	JBL:	Altec:	EV:
90° x 40°:	2360A	MR94A	HR9040A
60° x 40°:	2365A	MR64A	HR6040A
40° x 20°:	2366A	MR42A	HR4020A

A. Details of Pattern Control:

While polar plots present the most complete directional data on horns, they take up considerable space and do not allow for easy comparisons.

More usually, we see plots of the horizontal and vertical nominal coverage angles, or the -6dB beamwidth, and directivity index (DI), vs. frequency. The beamwidth plots present information along the frontal normal on- and off-axis angles of the horn, while the DI plots tell us something about the pattern control integrated in all directions around the horn. The DI plot is an especially useful measure in assessing a horn's performance in a power-flat system.

We now show these plots for the 90° x 40° devices.

Figure 1: JBL 2360 Beamwidth & DI
Figure 2: Altec MR94 Beamwidth & DI
Figure 3: EV HR9040A Beamwidth & DI

The data presented in these figures is taken from that provided by the manufacturers' in their standard specification sheets. All three horns maintain excellent horizontal coverage. However, the vertical coverage varies considerably. The JBL 2360 maintains good coverage down to 500 Hz, while the Altec MR94 maintains similar coverage down to about 630 Hz. The EV HR9040 maintains its vertical pattern control only down to 1.25 kHz.

A comparison of the DI curves is instructive. The DI for the JBL 2360 is quite smooth from 500 Hz out to 12 kHz. This means that the horn can be used down to 500 Hz and maintain constant power response to that frequency. The Altec MR94A DI plot is at odds with their beamwidth data; the roll-off above 8 kHz is not reflected in any broadening of the horn's patterns above that frequency. EV's DI data for the HR9040A is consistent with their beamwidth data, and it shows that the horn would be a good performer down to only 1 kHz in a power flat system.

Moving on to the 60° x 40° devices, we show their beamwidth and DI plots.

Figure 4: JBL 2365 Beamwidth & DI
Figure 5: Altec MR64 Beamwidth & DI
Figure 6: EV HR6040A Beamwidth & DI

As was the case with the JBL 2360, the 2365 maintains good pattern control down to 500 Hz. The beamwidth is generally not as smooth as in the case of the 2360, but it is quite good out to beyond 10 kHz. The DI plot shows good uniformity from 500 Hz out to 12 kHz, indicating that it would perform well down to 500 Hz in a power-flat system.

The Altec MR64 is a good performer down to about 800 Hz and all the way out to 20 kHz. Again, as in the case of the MR94, the DI data does not agree with the beamwidth data, but the error seems to be smaller than in the case of the MR94.

The EV HR6040A maintains good vertical pattern control only down to about 1.25 kHz, although both horizontal and vertical pattern control are smooth out to 16 kHz. The fall-off in DI below 1.25 kHz is in agreement with the beamwidth data.

The beamwidth and DI data on the 40° x 20° drivers are shown in Figures 7, 8, and 9. The JBL 2366A maintains its horizontal pattern smoothly down to 630 Hz, while the Altec MR42A narrows in the 1 kHz region. The EV model holds its horizontal pattern down only to 1 kHz.

JBL's vertical pattern control is held down to 1 kHz, while the Altec and EV models begin to lose vertical control below 2 kHz.

DI data on the JBL and EV Models is consistent with the beamwidth data. The Altec DI data is at odds with their beamwidth data; specifically, a DI of 15 dB at 200 Hz is an obvious error.

B. Distortion and Frequency Response:

In general, the newer horns exhibit lower distortion than the older radials and multicells because they flare more rapidly. The older designs had fairly low flare rates, and while this may have increased their loading ability at low frequencies, it was at the expense of increased distortion throughout the frequency range.

The newer designs generally exhibit smoother frequency response contours than the older models, and this makes system equalization easier. We have noticed, however, that the Altec Mantarays, with their abrupt transitions from one conical flare to another, exhibit irregular frequency responses as compared to designs with smoother transitions.

C. Low-frequency Limitations:

The factors in horn design which determine pattern control are not necessarily related to those which determine the extent of low-frequency loading. Thus, it is possible for a horn to exhibit good pattern control down to, say, 500 Hz, but not exhibit adequate loading on the driver at that frequency. Obviously, such a horn would be of very limited use in that frequency range.

For the six horns we are discussing, the following data is taken from published specifications:

Horn Model:	Lowest Usable Frequency:	Lowest Recommended Crossover:
JBL 2360A	300 Hz	350 Hz
2365A	300 Hz	350 Hz
2366A	200 Hz	300 Hz
Altec MR94A	500 Hz	800 Hz
MR64A	500 Hz	800 Hz
MR42A	500 Hz	800 Hz
EV HR9040A	350 Hz	400 Hz
HR6040A	350 Hz	400 Hz
HR4020A	250 Hz	300 Hz

Both JBL and EV have similar low-frequency loading limitations. The Altec horns do not load down as low, and this is the result of their straight-wall, conical construction. Both the JBL and EV horns utilize exponential flares in their throats, and this enables them to load down to lower frequencies than is the case with the multiple conical flares.

We can also arbitrarily set low frequency limits on these horns based on loss of pattern control. Establishing a 1.5 factor(*) on the opening up of the nominal angle as being the useful limit, we have:

Horn Model:	Pattern Control Limits	
	Horizontal:	Vertical:
JBL 2360	200 Hz	500 Hz
2365	400 Hz	500 Hz
2366	630 Hz	1 kHz
Altec MR94	300 Hz	630 Hz
MR64	400 Hz	630 Hz
MR42	400 Hz	800 Hz
EV HR9040A	200 Hz	1.2 kHz
HR6040A	400 Hz	1.2 kHz
HR4020A	300 Hz	1.2 kHz

*No greater than 30° for 20° nominal
No greater than 60° for 40° nominal
No greater than 90° for 60° nominal
No greater than 135° for 90° nominal

One point is clear from an inspection of the data presented thus far, and that is that the JBL 2360 and 2365 horns are the only ones of the group that can be specified for use down to 500 Hz with negligible loss of both horizontal and vertical pattern control and with proper driver loading. Again, we stress that the data we have been examining is that provided by the manufacturers themselves on their own products.

III. The Small Horns:

A. A Quick Look at the Old Radials:

Most of the radial horns which were the workhorses of the professional sound business for decades were designed back in the forties and fifties. When viewed from above, they appear as sectors of a circle bounded by radii on the sides; when viewed from the side, they appear as a simple exponential flare, as shown in Figure 10 (A) and 10 (B). If the flare development in the throat is carefully derived, then the radial horn will exhibit quite even horizontal coverage. However, horizontal coverage at high frequencies is driver-size dependent. The larger throat drivers (49 mm or 2 inches) will show narrowing at high frequencies as compared with the 25 mm (1 inch) throat drivers.

Due to the exponential vertical cross-section, the vertical coverage will always be wide at low frequencies and narrow considerably with rising frequency. The "typical" beamwidth data of a radial is shown at Figure 10 (C), and the DI plot is shown at 10 (D).

Figure 10 (C) also shows a characteristic of all radials, mid-range narrowing in the horizontal plane. This happens at the wavelength which is approximately equal to the mouth width. Usually this will be in the 500 to 1000 Hz region, and the loss in coverage in that region is a problem.

Despite their shortcomings, many designers appreciated the rising DI of the radials, inasmuch as it did not require much, if any, electrical equalization in order to get flat on-axis response. This advantage of course was bought at the expense of vertical coverage. The larger radials provided good loading down to 500 Hz, and sometimes below, because their exponential flare rates were relatively low.

B. The New Designs:

With the introduction of the new family of Flat Front Bi-Radials, JBL discontinued the models 2345, 2350 and 2355 radials. In each case, the new horn is smaller than the corresponding older model and exhibits improved coverage at high frequencies. While the new 2370 replaces the 2345 as a systems component, the 2380 and 2385, respectively, replace the 2350 and 2355 horns in the 90° x 40° and 60° x 40° categories.

Just as JBL has brought out a line of smaller horns based on new design principles, Altec and EV have brought out their own smaller horns. We will now compare these devices and see how they measure up to the old 2350 and 2355 radials.

First, we will look at the 90° x 40° devices.

Figure 11: JBL 2345 Beamwidth & DI
Figure 12: JBL 2370 Beamwidth & DI
Figure 13: JBL 2350 Beamwidth & DI
Figure 14: JBL 2380 Beamwidth & DI
Figure 15: Altec MR II 594 BW & DI
Figure 16: EV HR90 Beamwidth & DI

The 2345 was an excellent radial design, but the 2370 is more than a match for it in the areas of high-frequency pattern control, smoothness of frequency response, and distortion. Moving on to the 2350, we can see its limited horizontal coverage at high frequencies, due, as we stated earlier, to its larger throat diameter. This horn was designed in the early fifties as a theater component for Ampex. It was used with the old 2440 driver, whose response did not extend beyond 9 kHz, thus the pattern narrowing at high frequencies was probably not very noticeable.

All of the newer designs exhibit excellent horizontal control out to beyond 10 kHz. The frequency at which the vertical pattern meets that of the horizontal pattern is just about 1 kHz in every case. Above 3 kHz, the vertical coverage on these new models remains fairly constant. While all these new horns are quite comparable in their angular coverage performance, contractors and consultants are advised to assess their performance with their recommended high-frequency drivers in place, noting power handling and smoothness of response.

Now we will move on to the 60° x 40° devices.

Figure 17: JBL 2355 Beamwidth & DI
Figure 18: JBL 2385 Beamwidth & DI
Figure 19: Altec MR II 564 BW & DI
Figure 20: EV HR60 Beamwidth & DI

We can make many of the same observations with this set of horns as we did with the previous set. The JBL 2355 should not be missed by many designers, since the 2385 easily outperforms it. In all three of the competitive models, the vertical patterns have aberrations in smoothness; however, there appears to be nothing consistent in them.

The intended uses of these horns is in small reinforcement systems, as auxilliary elements in large arrays, and, especially in the case of the JBL Flat Fronts, for use in music reinforcement systems.

C. Low-frequency Limitations:

Below are the published lowest usable frequencies and the lowest recommended crossover frequencies for the small horns.

Horn Model:	Lowest Usable Frequency:	Lowest Recommended Crossover:
JBL 2350	350 Hz	500 Hz
2380	400 Hz	500 Hz
2355	350 Hz	500 Hz
2385	400 Hz	500 Hz
Altec MR II 594	500 Hz	500 Hz
MR II 564	500 Hz	500 Hz
EV HR90	500 Hz	800 Hz
HR60	500 Hz	800 Hz

Some comments are in order. Altec does not specify different frequency values for the lowest usable frequency and the lowest recommended crossover. Their single value is the one given here in both columns. EV states that their lowest recommended crossover frequencies are beamwidth limitations.

Let us now look at the low-frequency beamwidth limitations, assuming as we did before that an arbitrary limit is when the pattern control expands to approximately 1.5 times the nominal.

Horn Model:	Pattern Control Limits	
	Horizontal:	Vertical:
JBL 2350	300 Hz	2 kHz
2380	400 Hz	1.6 kHz
2355	400 Hz	2 kHz
2385	500 Hz	1.6 kHz
Altec MR II 594	500 Hz	1.6 kHz
MR II 564	1.2 kHz	1.6 kHz
EV HR90	500 Hz	2.5 kHz
HR60	630 Hz	2 kHz

This study of constant directivity horns, both large and small, is intended to help the contractor or consultant to sort out much of the confusion surrounding these devices. All of the data we have shown has been taken from manufacturer's specification sheets, and we have redrawn graphs so that comparisons can be made easily between similar models.

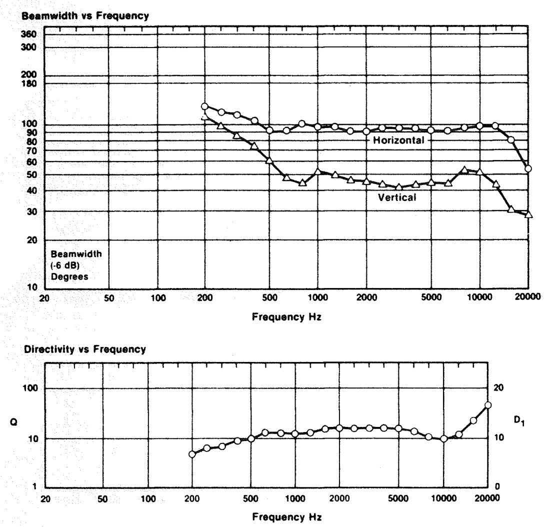

FIGURE 1. JBL 2360

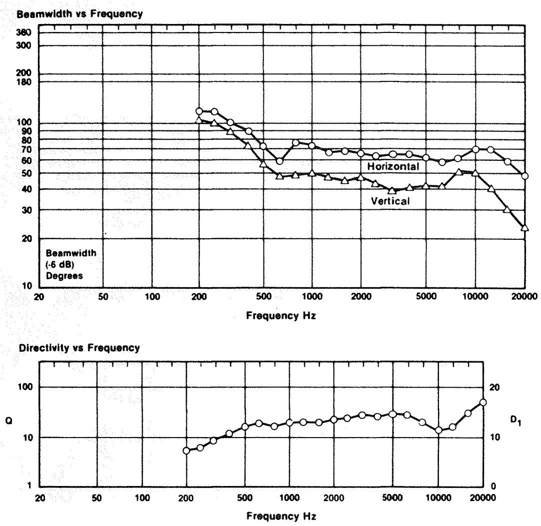

FIGURE 4. JBL 2365

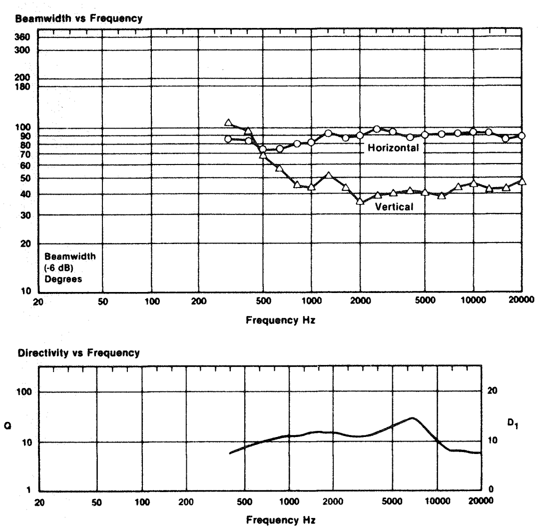

FIGURE 2. ALTEC MR94

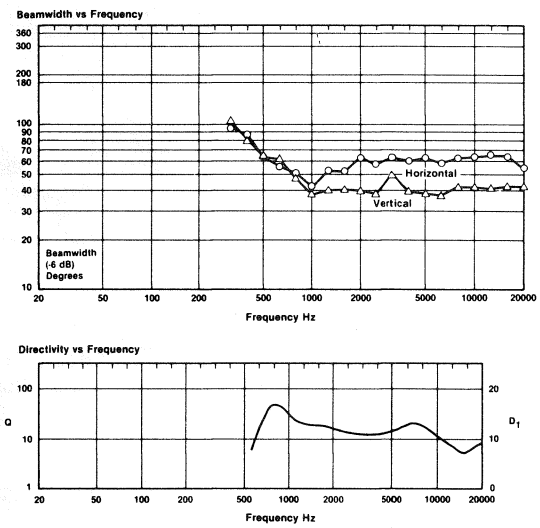

FIGURE 5. ALTEC MR64

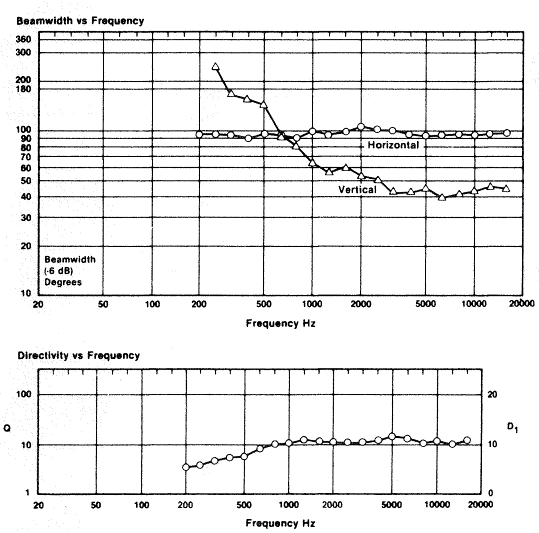

FIGURE 3. EV HR9040A

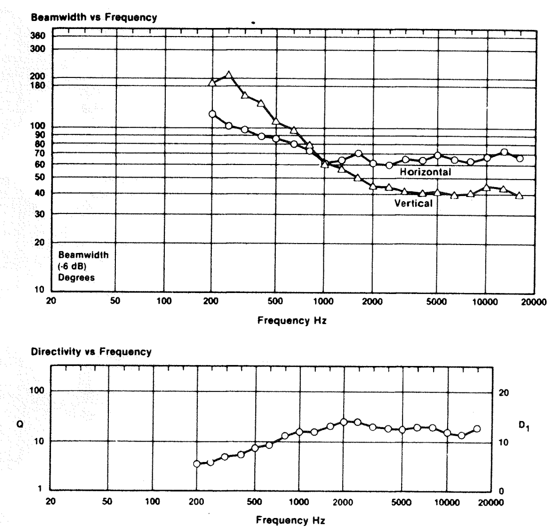

FIGURE 6. EV HR6040A

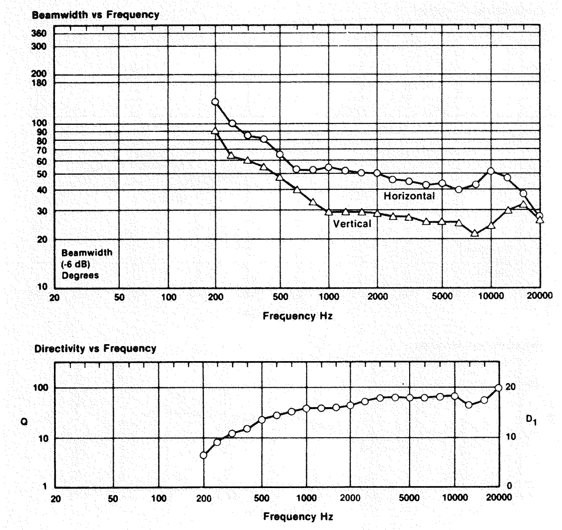

FIGURE 7. JBL 2366

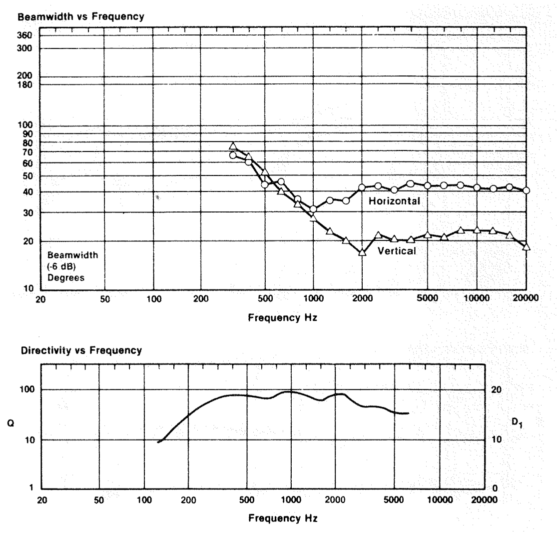

FIGURE 8. ALTEC MR42A

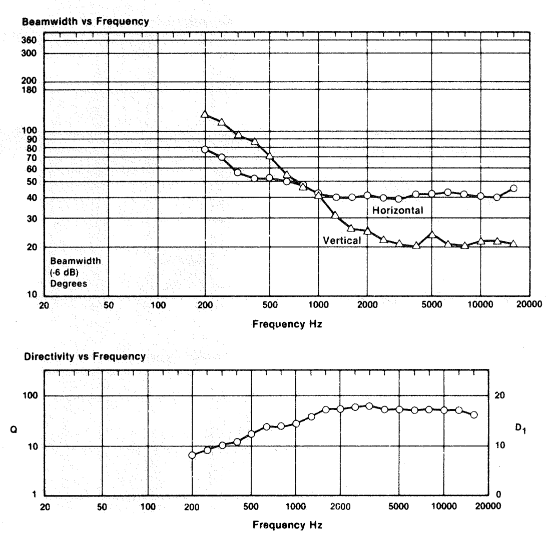

FIGURE 9. EV HR4020A

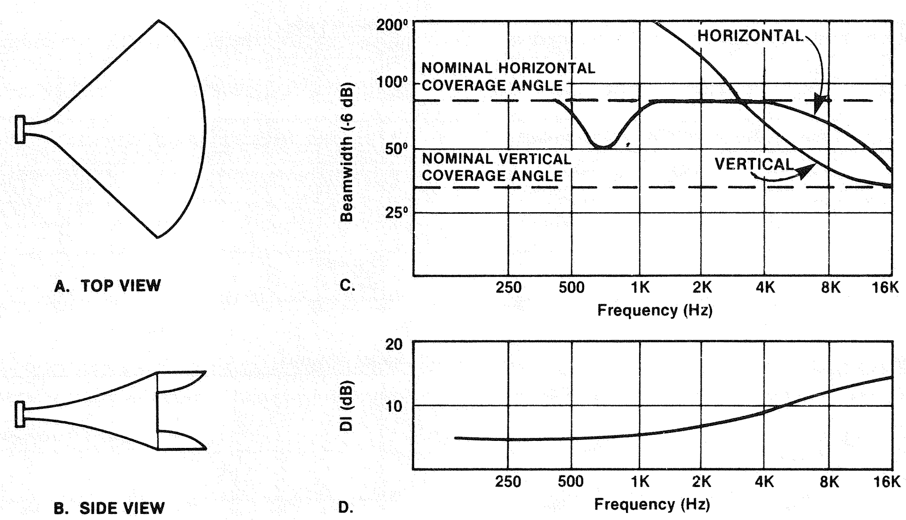

FIGURE 10. A TYPICAL RADIAL HORN

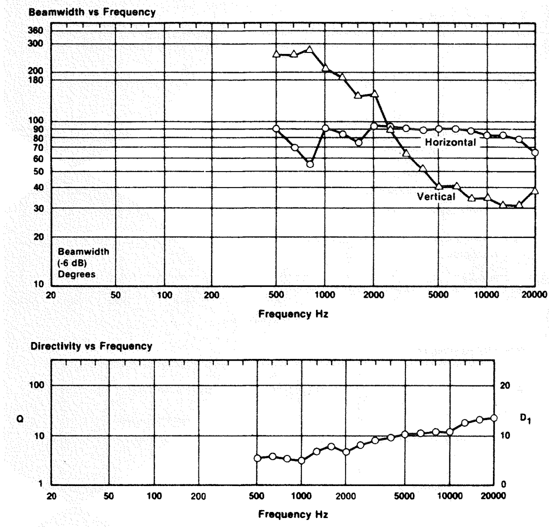

FIGURE 11. JBL 2345

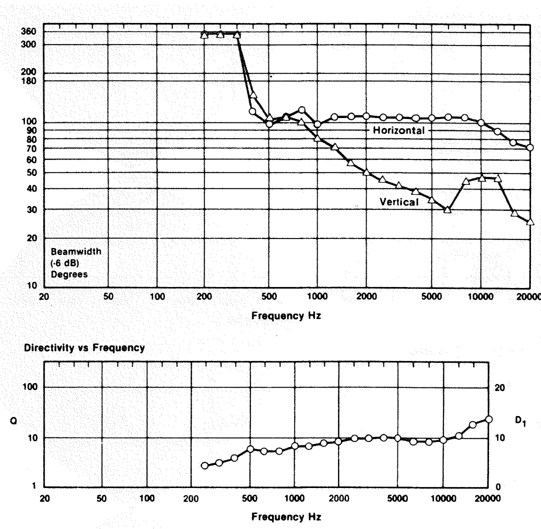

FIGURE 14. JBL 2380

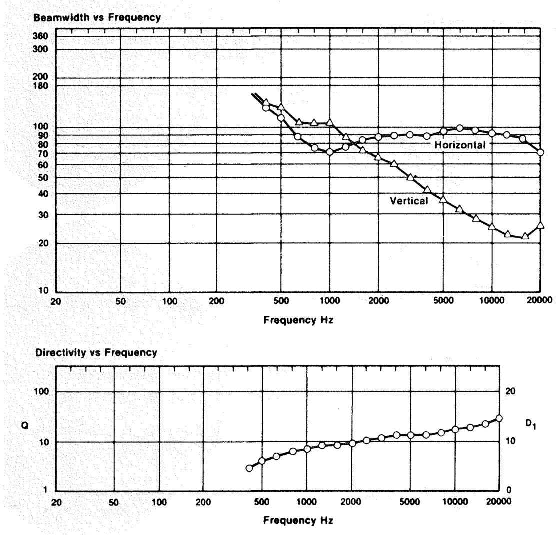

FIGURE 12. JBL 2370

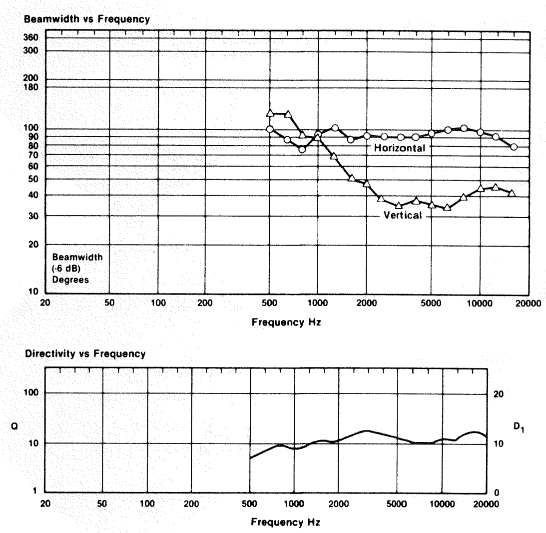

FIGURE 15. ALTEC MR II 594

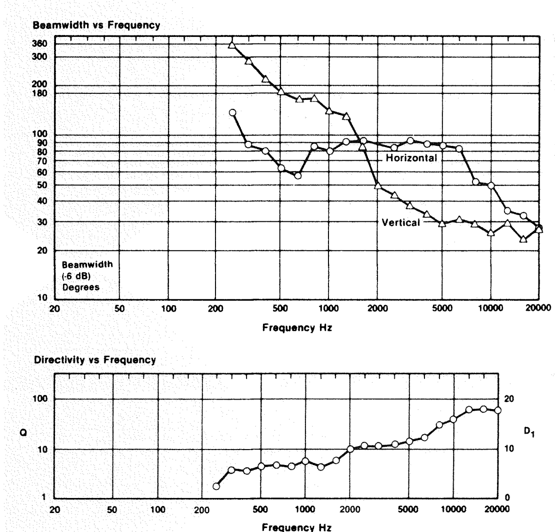

FIGURE 13. JBL 2350

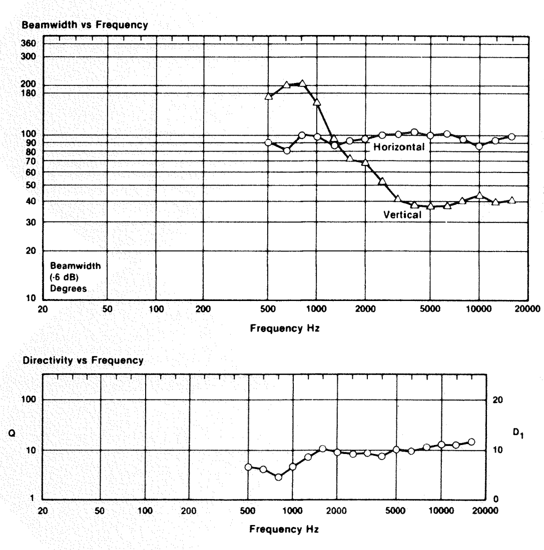

FIGURE 16. EV HR90

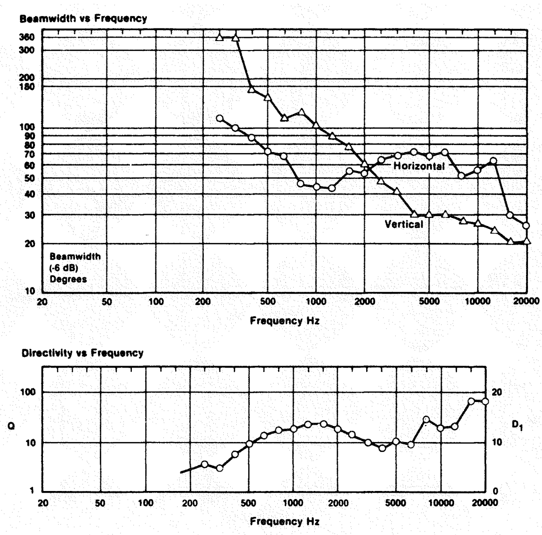

FIGURE 17. JBL 2355

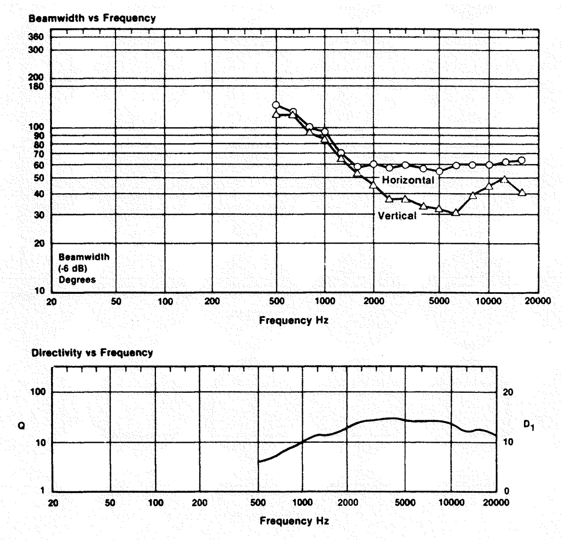

FIGURE 19. ALTEC MR II 564

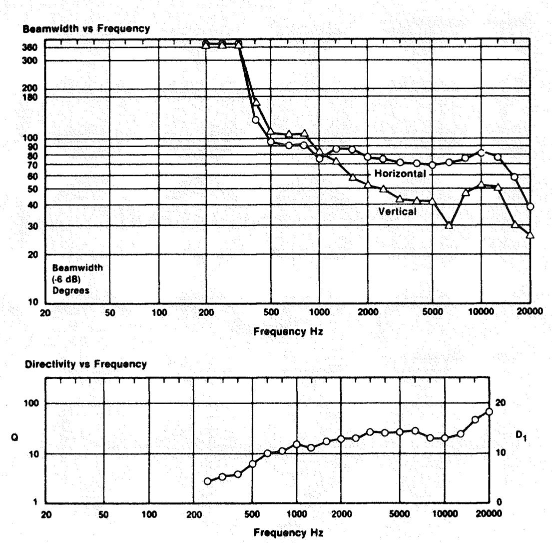

FIGURE 18. JBL 2385

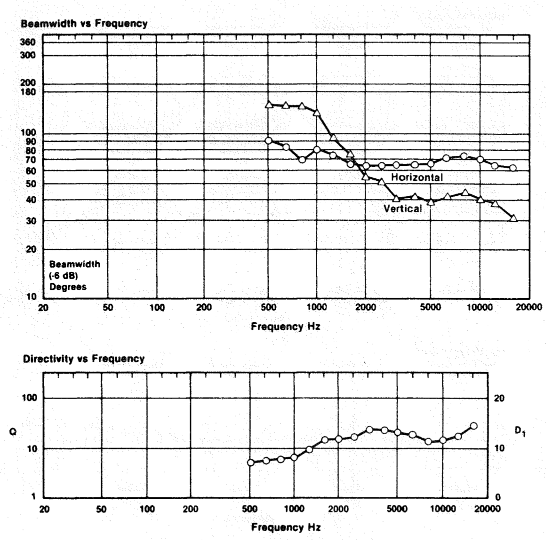

FIGURE 20. EV HR60

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