Technical Notes Vol. 1, No. 17

Measurement and Interpretation of Loudspeaker Polar Data: A Comparison of JBL Constant Coverage Bi-Radial™ Horns and EV HP Large Format Horns

Introduction:

Recent polar measurements of JBL and EV large format horns indicate that current data sheets from both manufacturers do not present accurate descriptions of the horns. EV's data sheets for their HP Series horns indicate −6 dB beamwidth control extending smoothly to 20 kHz in both horizontal and vertical planes. By comparison, the data sheets for the JBL large Bi-Radial horns indicate significant narrowing of beamwidth above 12.5 kHz in both planes. We reasoned that both JBL and EV horns should have similar horizontal dispersion, inasmuch as both devices have similar diffraction slot dimensions. Regarding vertical beamwidth control at high frequencies, the presence of horizontal vanes in the throat of the EV horns may cause significant performance differences. We will comment further on this point later.

We were thus prompted to make new measurements on both families of large horns, and the results may be summarized as follows:

1. High frequency beaming above 10 kHz is a problem in all horns. The diffraction slot in both 90° x 40° horns is not narrow enough to maintain full horizontal beamwidth at the highest frequencies. (Compare Figures 6 and 9.)

2. The JBL 2365A does, however, maintain full horizontal beamwidth at the highest frequencies, while the EV HP6040 does not. (Compare Figures 7 and 10.)

3. Clearly the worst performer in these tests was the EV HP4020 horn. There is no differentiation in horizontal and vertical pattern control below 2 kHz. By comparison, the JBL 2366A maintains clear differentiation down to 600 Hz. (Compare Figures 8 and 11.)

4. Overall, there appear to be no benefits in high frequency vertical pattern control due to the much touted vanes in the EV horns.

Test Conditions:

JBL engaged Summit Laboratories of Warner Springs, CA, to make independent comparative polar measurements under absolutely identical conditions, which were set as follows:

1. Outdoor ground plane conditions as shown in Figure 1. The measurement distance was 6 meters (20 feet) for the 90° x 40° and 60° x 40° horns and 10 meters (33 feet) for the 40 x 20 horns. The turntable was tilted so that the plane of rotation was exactly in line with the microphone. For horizontal data, rotation was about the diffraction slot; for vertical data, rotation was about the driver. The JBL 2450J driver was used for all tests.

2. The test signal was high-pass filtered pink noise with one-third octave filtering in the microphone return path. Pen writing speeds varied from 125 to 500 mm/s, consistent with frequency of measurement and horn rotation speed.

3. The test site was free of reflections and other disturbances. Tests were carried out during times of the day when wind velocity and thermal gradients were minimal. The symmetry of the plots indicates that reflections from nearby surfaces were virtually nonexistent.

4. High electrical and acoustical signal-to-noise ratios were maintained. At high frequencies, front-to-back level ratios were often in excess of 40 dB.

Summit Laboratories' measurements have subsequently been verified by free-field measurements made at the Technical University of Denmark.

Data Presentation:

The polar data is presented unretouched and reduced in diameter to 33%, which is about the minimum size which allows the user to identify clearly the one dB divisions. Horizontal and vertical sets are given, beginning at 500 Hz and proceeding upward on ISO one-third octave frequencies to 20 kHz. Data is presented in the following order:

Appendix I: JBL 2360A
Appendix II: EV HP9040
Appendix III: JBL 2365A
Appendix IV: EV HP6040
Appendix V: JBL 2366A
Appendix VI: EV HP4020

Derived Data Presentation:

As can be seen, polar data takes up a good deal of space, and most manufacturers routinely show derived data in the form of directivity index, directivity factor, −6 dB beamwidth plots in horizontal and vertical planes, and selected off-axis frequency response.

The general definition of beamwidth seems clear enough, and if the device under measurement has maximum sensitivity along its principal axis, decreasing monotonically away from that axis, as shown in Figure 2, then there is no question what the beamwidth is.

The matter becomes more complicated when the polar response is as shown in Figure 3. Here, the response is not maximum along the principal axis, but rises 3 dB at an angle about 5 degrees off-axis. The question becomes: should the beamwidth be established as the included angle at which the response is −3 dB (a total envelope of 6 dB), or should it be the −6 dB included angle relative to the on-axis value?

JBL has historically taken the former approach, defining beamwidth based on a total level variation of no more than 6 dB. Thus a beamwidth of 34 degrees, as indicated in Figure 3, is what JBL would consider accurate.

Others may take the approach of striking off the included angle at which response is −6 relative to the on-axis value, as we have shown in Figure 4. Here, the same polar data as used in Figure 3 yields a beamwidth of 47 degrees. The difference is quite significant.

Thus, published beamwidth data is subject to interpretation on the part of the manufacturer, and only a study of the original data will clarify the matter for the user.

JBL proposes the following:

"Beamwidth is defined as the largest included angle in the direction of the principal axis over which the axial response of a device does not vary by more than 6 dB. Readings are to be made in both horizontal and vertical planes, and all measurements should be made sufficiently far from the device so that inverse square level errors due to device rotation are minimal. All measurement conditions should be stated."

Reading polar data in the range from 500 Hz to about 2 kHz requires careful averaging, due to random variations in the test signal itself. Figure 5 shows how this is done. A line has been drawn through the center of the jagged response on the right side of the plot. Note that no tolerance is used in reading the averaged data. It is possible to reduce these data variations with a slower pen speed, but this requires a slower device rotation rate, increasing the measurement time.

Plots of directivity index and directivity factor can be arrived at by several methods. Integration over the entire sphere surrounding the device will give the most accurate value. The easiest way to do this is to make measurements of the device in a calibrated reverberant space and compare them with free field measurements.

Molloy's equation [1, 2] gives surprisingly accurate values at higher frequencies where the falloff of response outside the −6 dB limits is pronounced.

Where only horizontal and vertical polars have been taken, stepwise integration in those planes gives very accurate values [3].

In any event, manufacturers should carefully state all methods and assumptions used in generating derived data. JBL's published values of directivity index and directivity factor have been arrived at through stepwise integration in horizontal and vertical planes.

Conclusions:

As a summary of the polar data, we present beamwidth plots based on the definition given earlier. Figures 6, 7, and 8 show horizontal and vertical beamwidth plots for the JBL 2360A, 2365A, and 2366A horns, while Figures 9, 10, and 11 show this data for the EV HP9040, HP6040, and HP4020 horns.

Figures 12, 13, and 14 are taken directly from EV data sheets, and they indicate beamwidth performance for their three large horns which we have shown to be in error. For these reasons, we recommend that professional users check all manufacturers' specification sheets carefully, looking for inconsistencies. Never assume that derived data is accurate until you have verified it yourself. It will be JBL's position in the future to publish original unretouched polar data in a form which can be easily studied and interpreted by the user. Our specification sheets will continue to show derived directional information, including beamwidth plots, directivity plots, and frontal isobars.

We urge all consultants and professional dealers to study the attached polar data carefully. We believe you will agree with us that the EV horns are not as good in high-frequency beamwidth control as their data sheets indicate – and that JBL horns are better in this regard than the sheets have indicated.

References:

1. C. T Molloy, "Calculation of the Directivity Index for Various Types of Radiators," J. Acoustical Soc. Am., vol.20: 387-405 (1948)

2. G. Augspurger and J. Eargle, Sound System Design Reference Manual, JBL Incorporated (1986)

3. D. and C. Davis, Sound System Engineering, 2nd edition, Howard W. Sams, Indianapolis (1987) See page 117.

Polar turntable 6-10m (20-33 ft.)

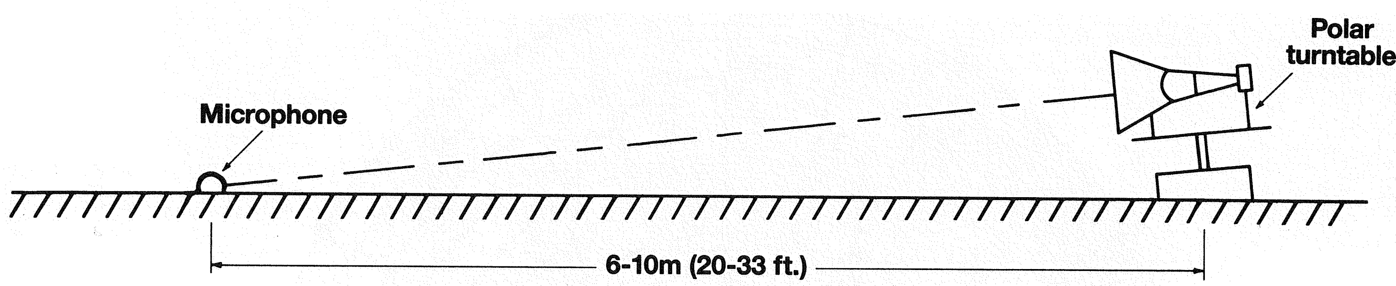


Figure 1. **Basic ground plane setup.**

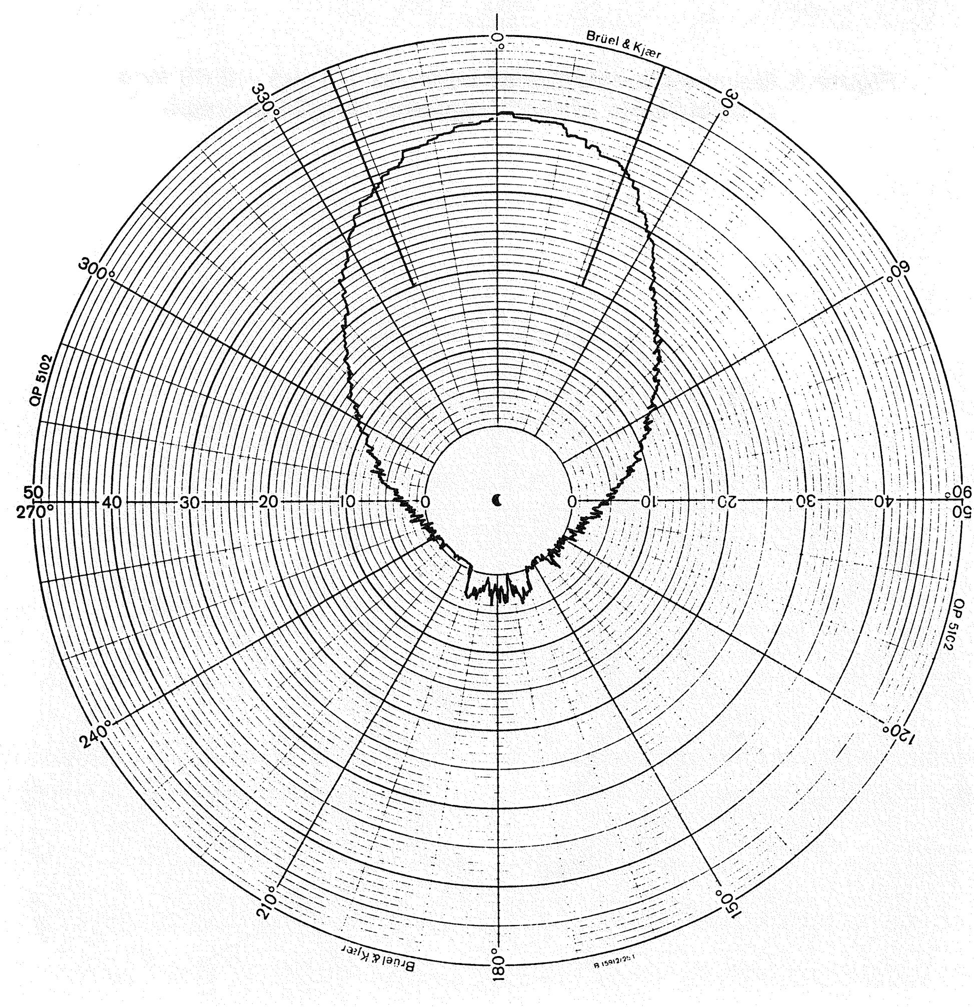


Figure 2. **−6 dB Beamwidth for a horn maximally sensitive on axis (approximately 45 degrees).**

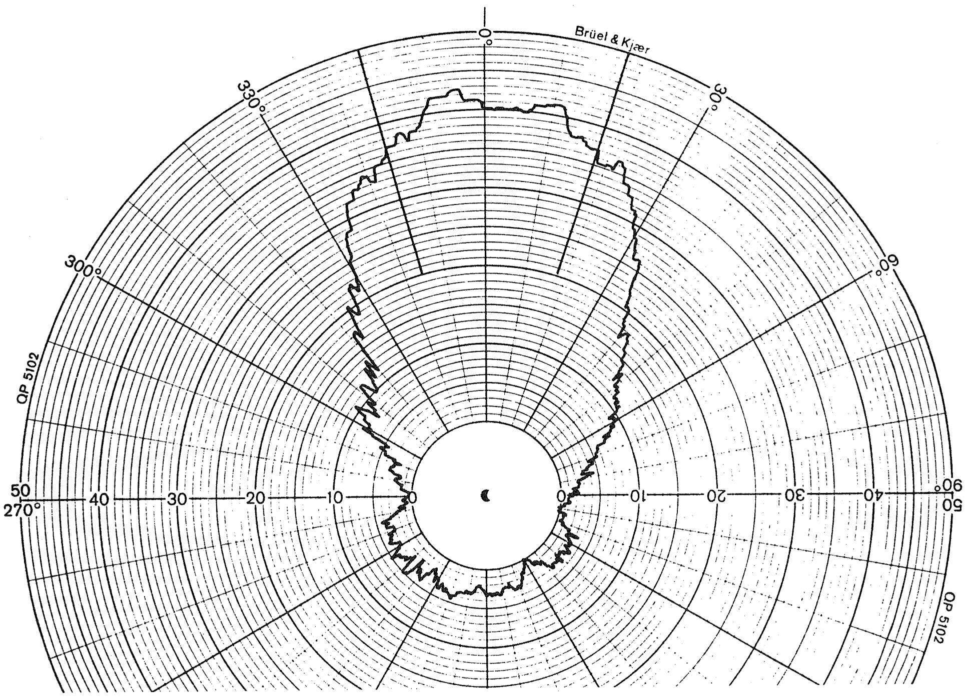


Figure 3. **Beamwidth established between +3 and −3 dB for a total envelope of 6 dB (approximately 34 degrees).**

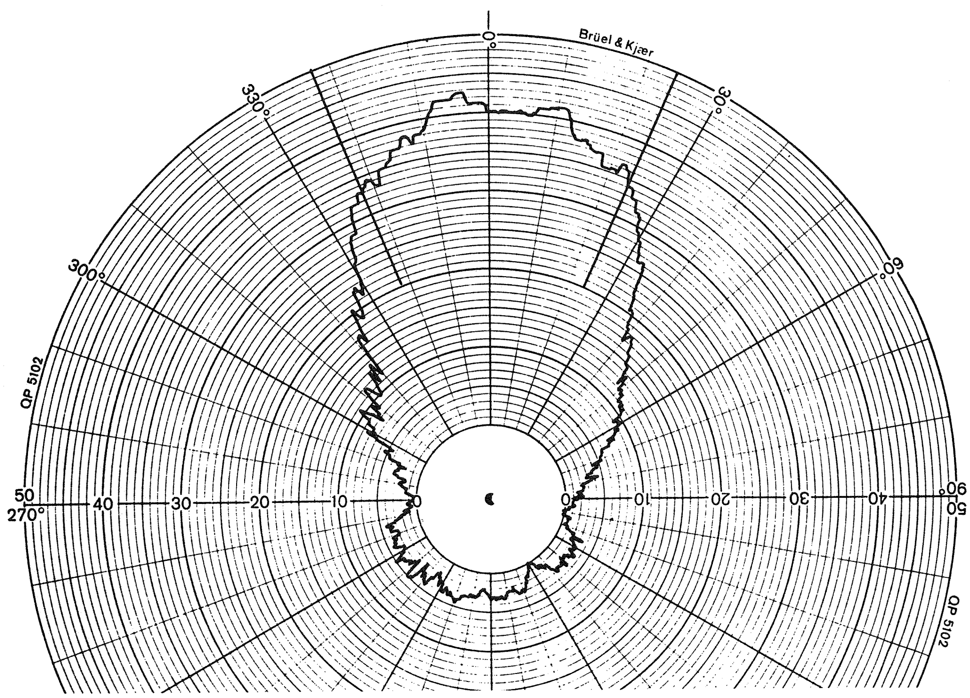


Figure 4. **Beamwidth established at −6 dB relative to on-axis value (approximately 47 degrees).**

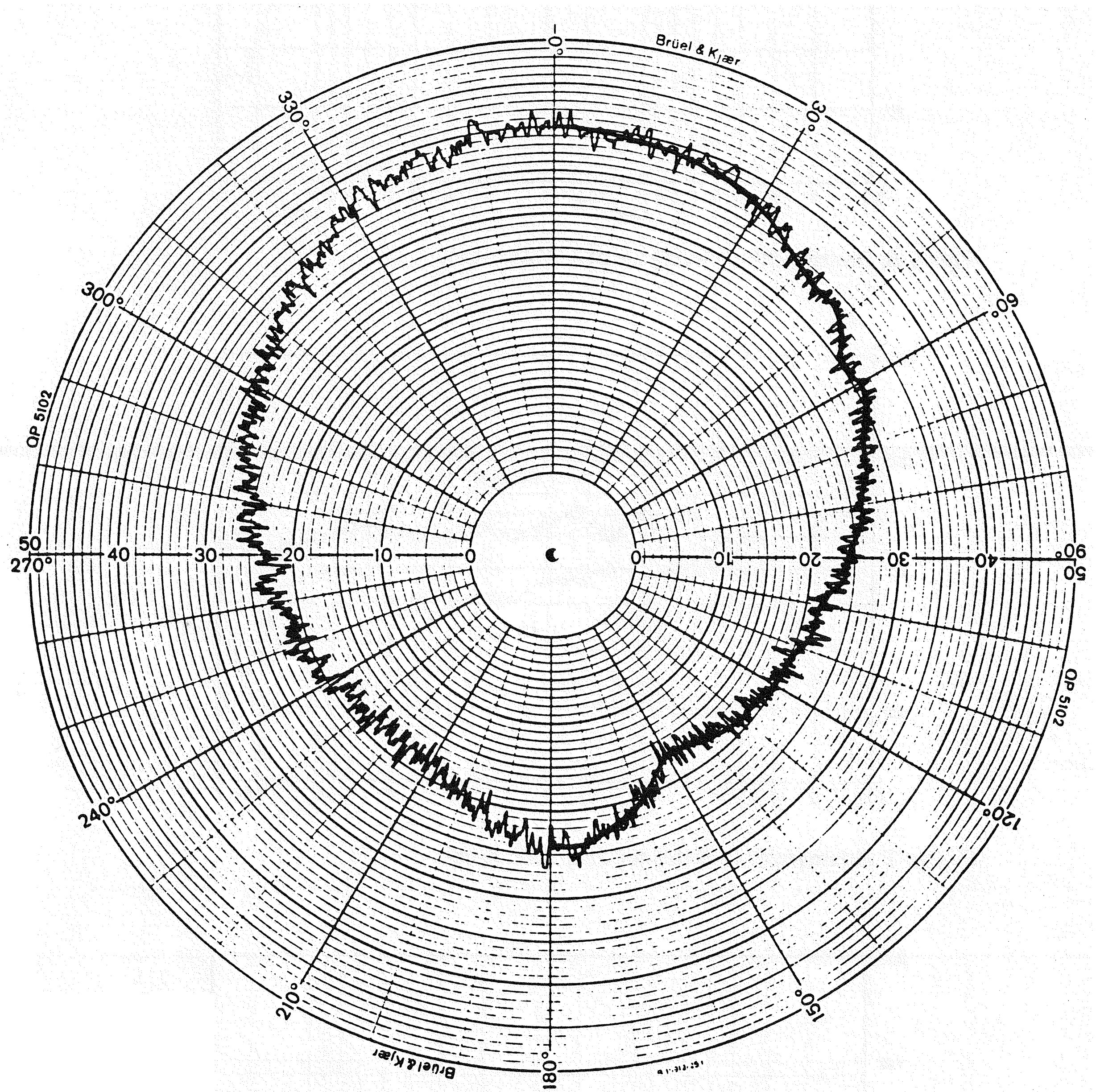


Figure 5. **Smoothing polar data prior to plotting.**

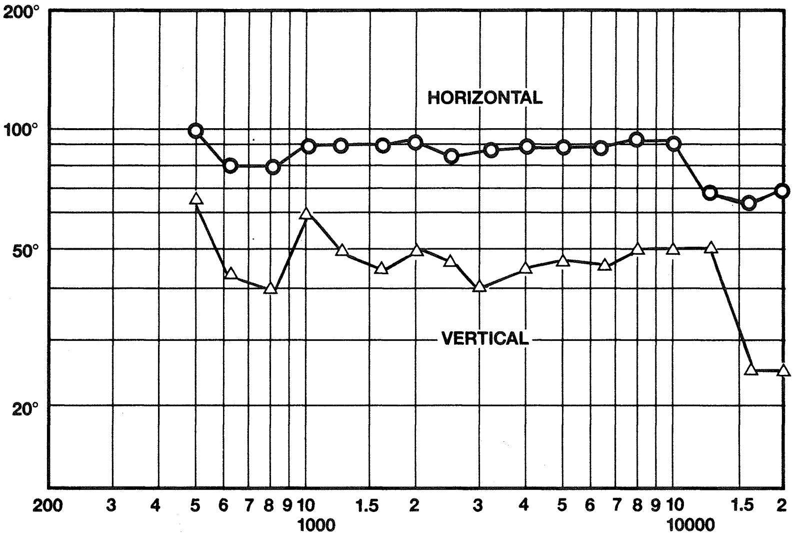


Figure 6. **Beamwidth (−6 dB) for JBL 2360 Horn.**

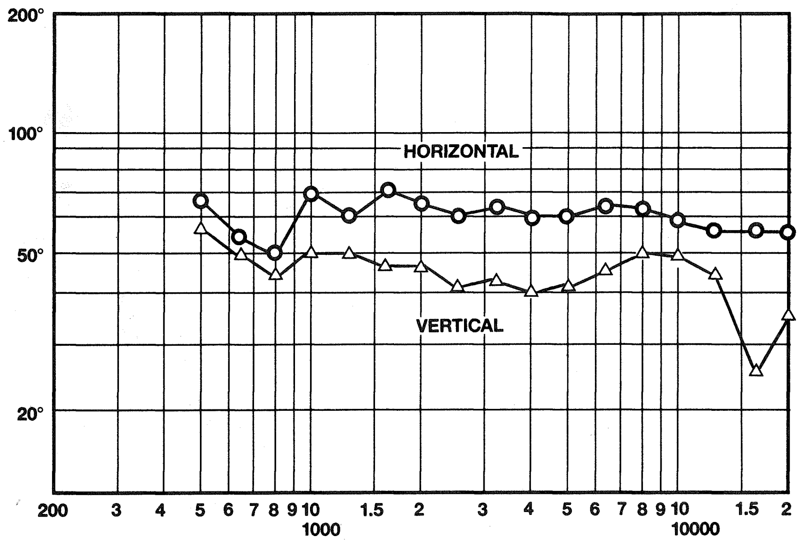


Figure 7. **Beamwidth (−6 dB) for JBL 2365 Horn.**

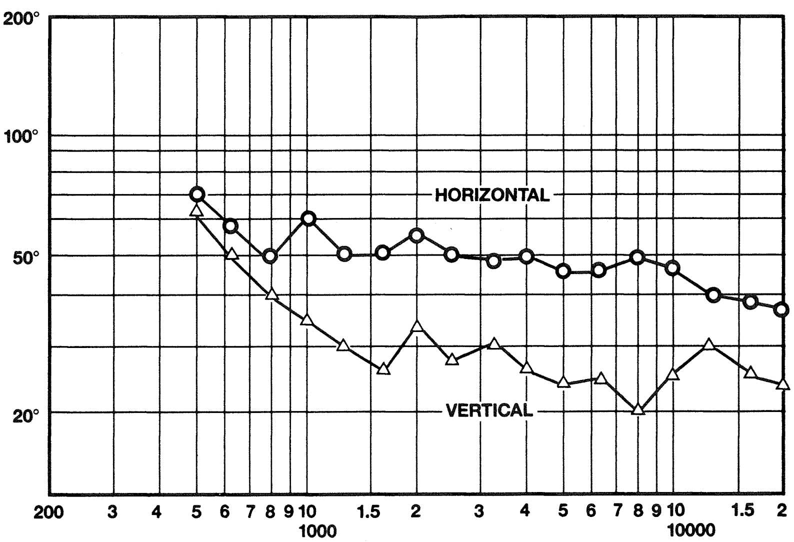


Figure 8. **Beamwidth (−6 dB) for JBL 2366 Horn.**

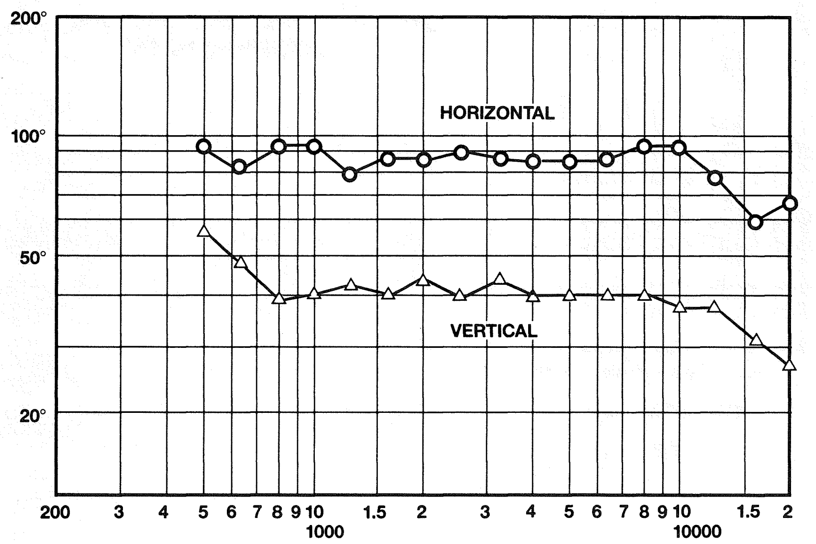


Figure 9. **Beamwidth (– 6 dB) for EV HP9040 Horn.**

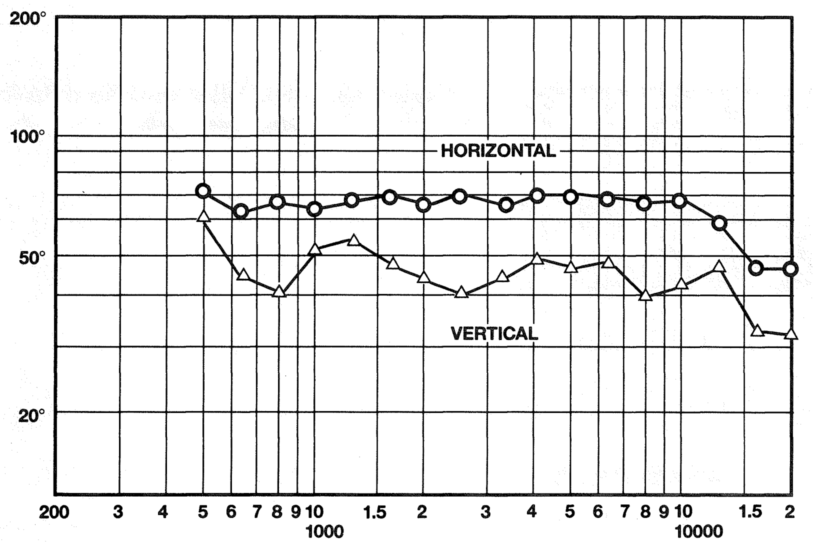


Figure 10. **Beamwidth (– 6 dB) for EV HP6040 Horn.**

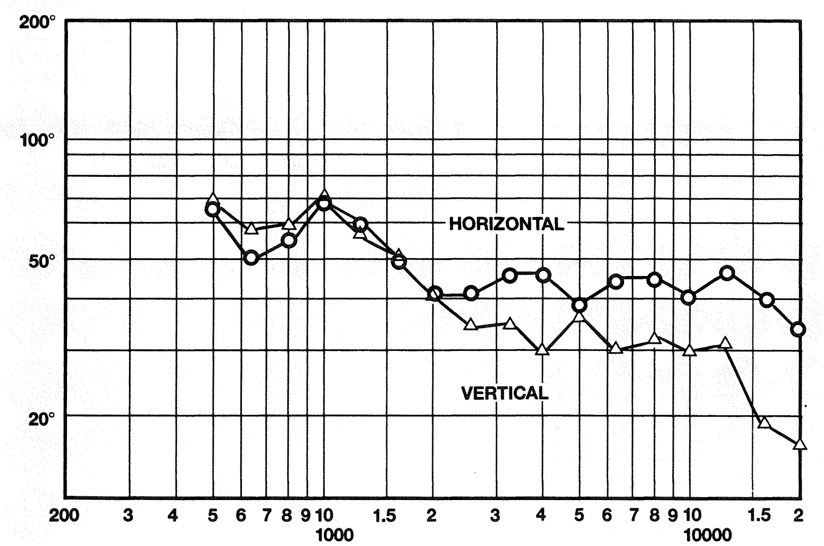


Figure 11. **Beamwidth (– 6 dB) for EV HP4020 Horn.**

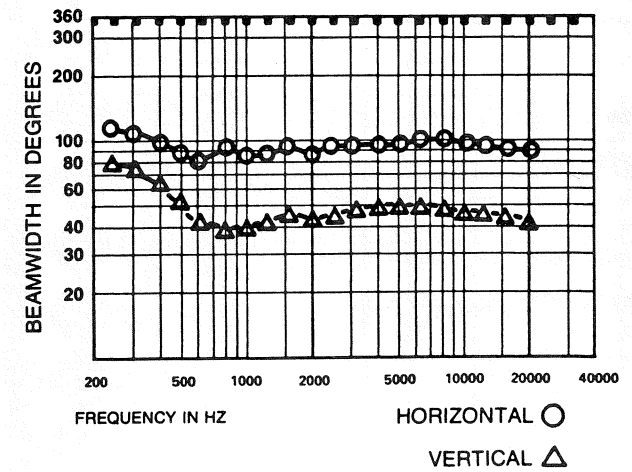


Figure 12. **−6 dB Beamwidth data for HP9040 Horn as published by EV.**

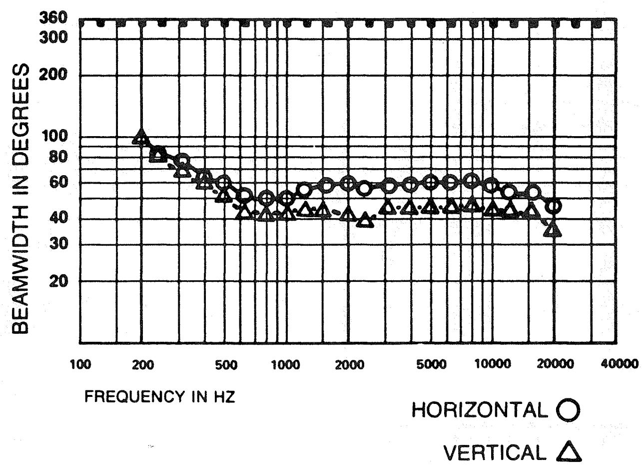


Figure 13. **−6 dB Beamwidth data for EV HP6040 Horn as published by EV.**

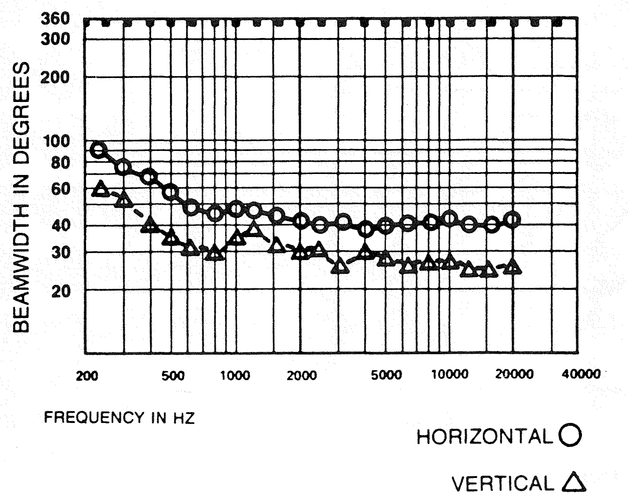
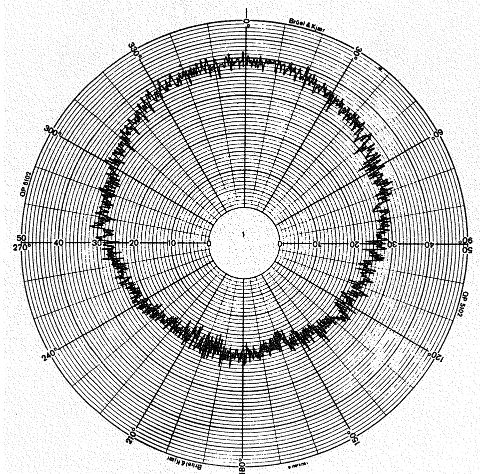
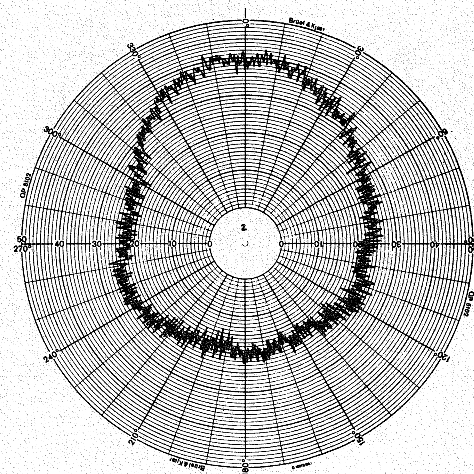


Figure 14. **−6 dB Beamwidth data for EV HP4020 Horn as published by EV.**

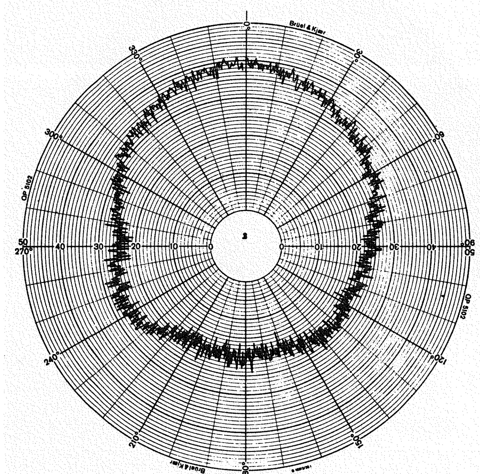
Appendix I: JBL 2360A



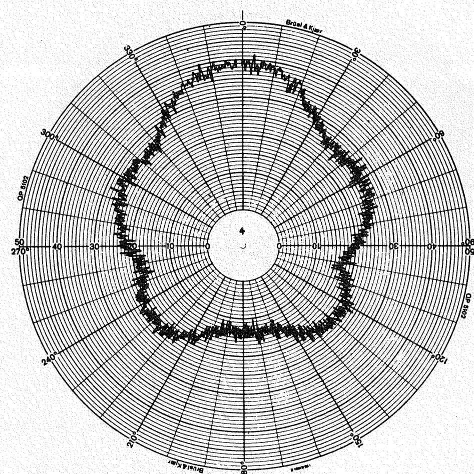
500 Hz, Hor.



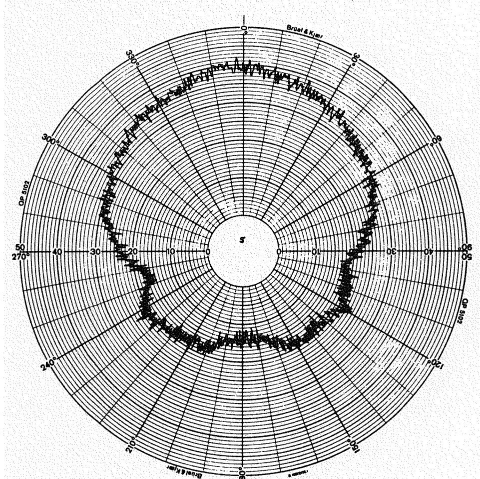
500 Hz, Vert.



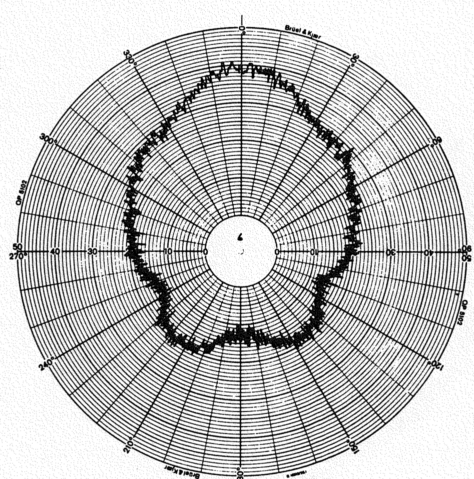
630 Hz, Hor.



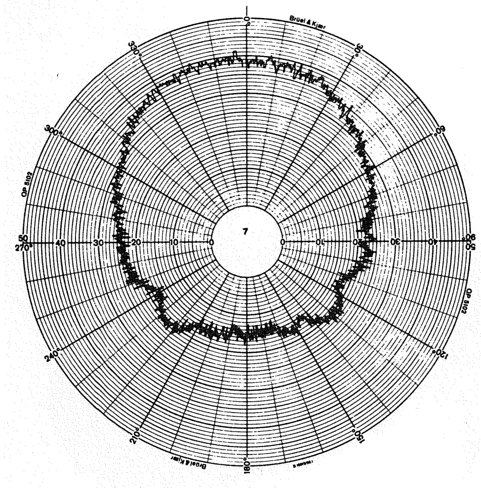
630 Hz, Vert.



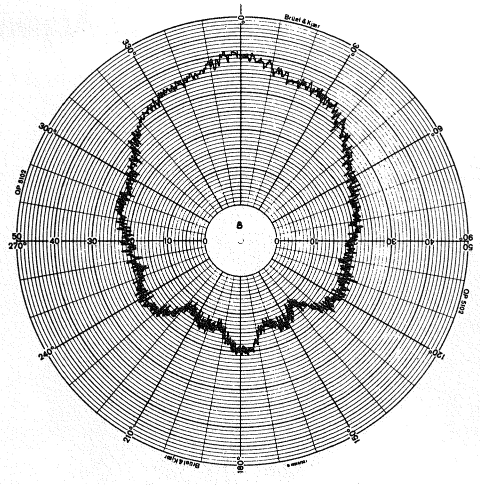
800 Hz, Hor.



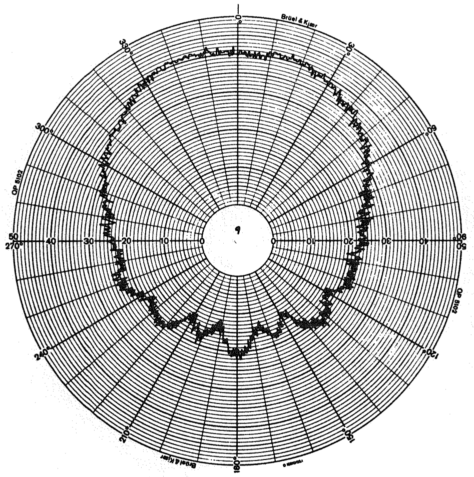
800 Hz, Vert.



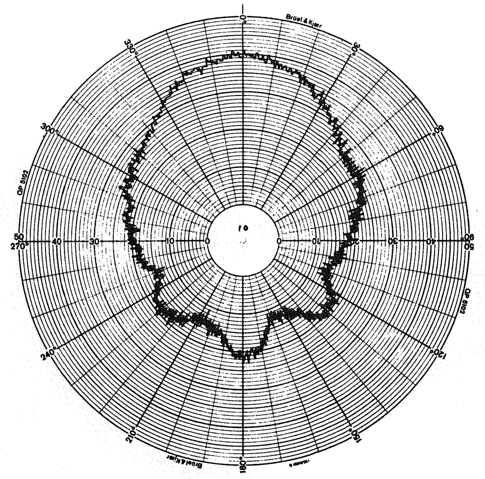
1 kHz, Hor.



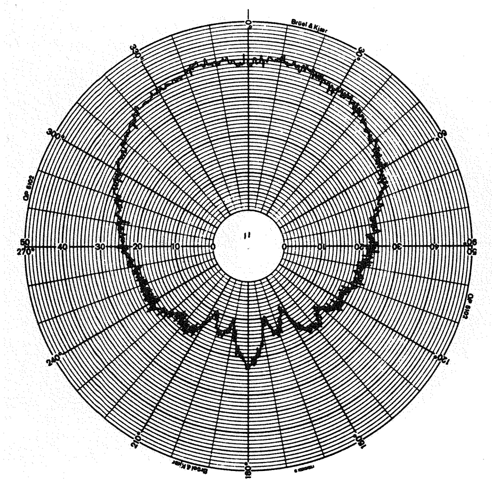
1 kHz, Vert.



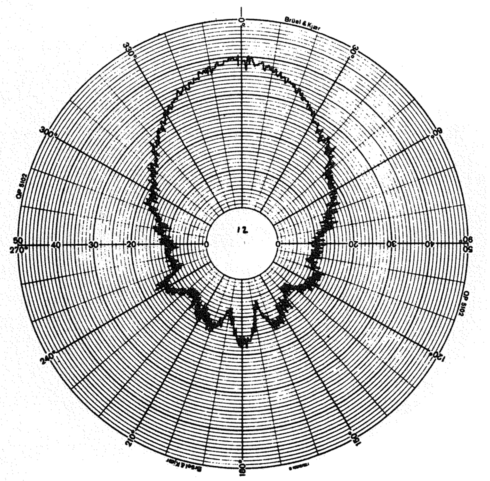
1.25 kHz, Hor.



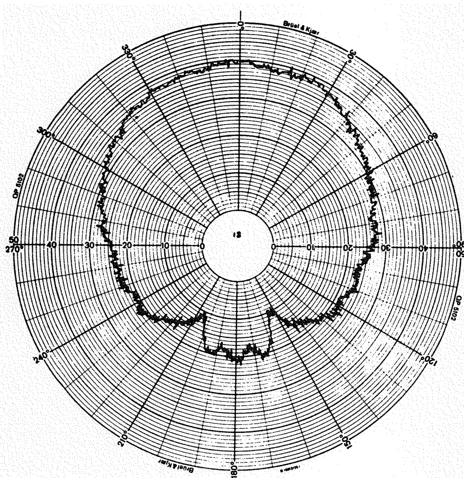
1.25 kHz, Vert.



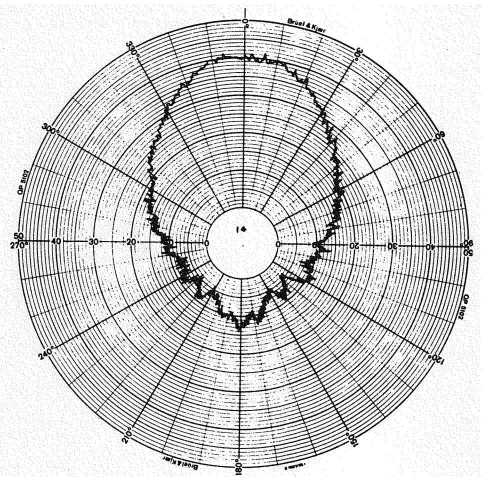
1.6 kHz, Hor.



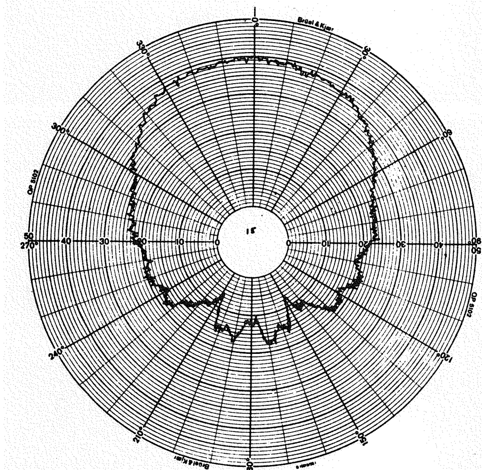
1.6 kHz, Vert.



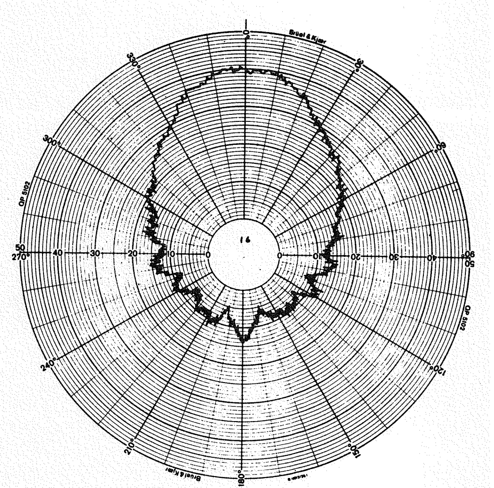
2 kHz, Hor.



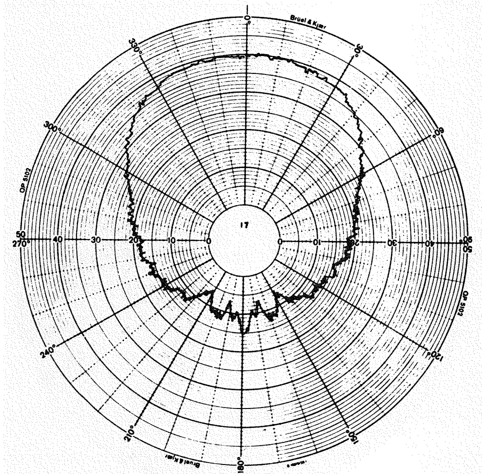
2 kHz, Vert.



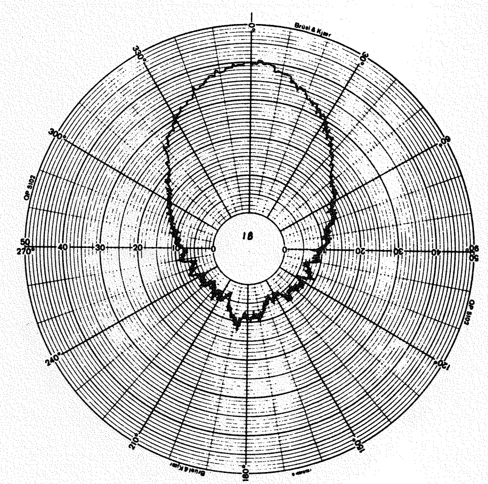
2.5 kHz, Hor.



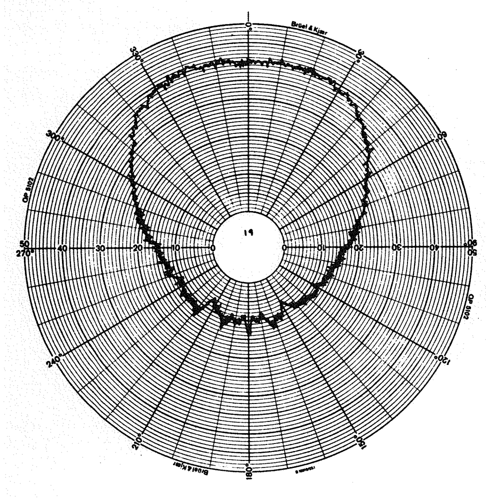
2.5 kHz, Vert.



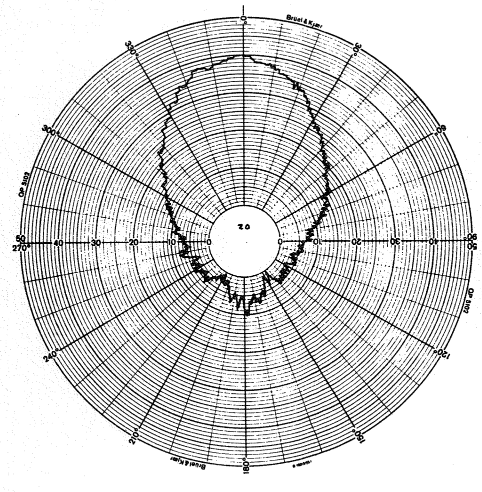
3.15 kHz, Hor.



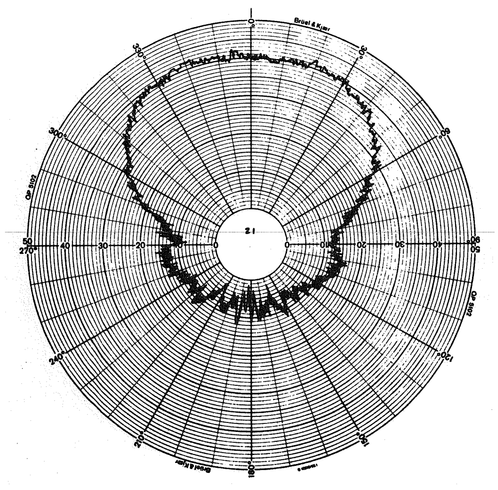
3.15 kHz, Vert.



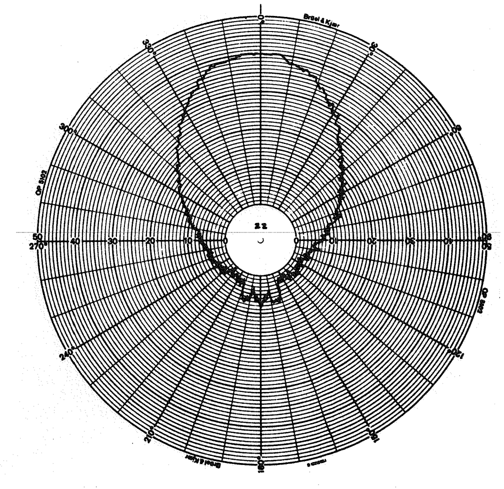
4 kHz, Hor.



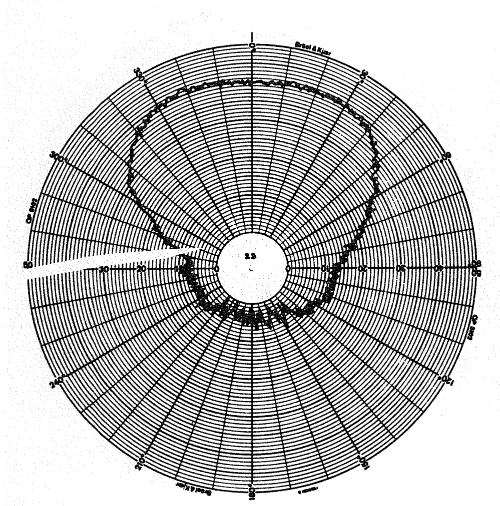
4 kHz, Vert.



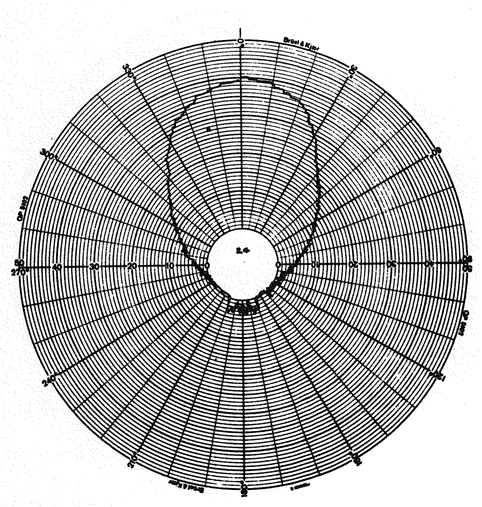
5 kHz, Hor.



5 kHz, Vert.

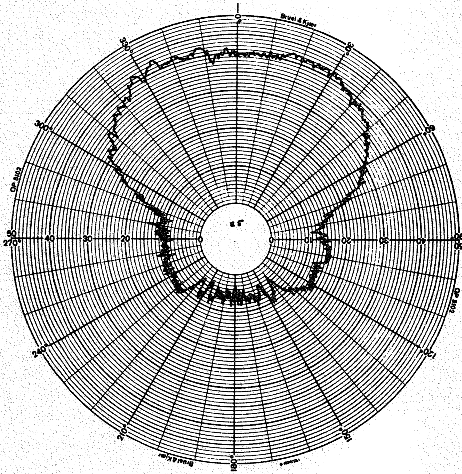


6.3 kHz, Hor.

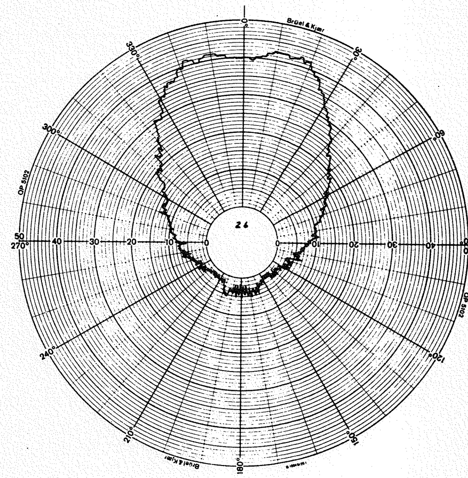


6.3 kHz, Vert.

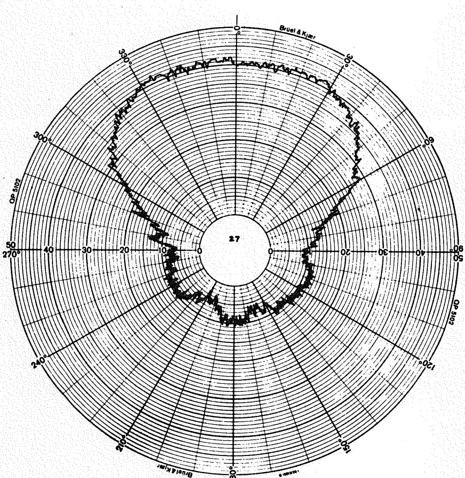
JBL 2360A



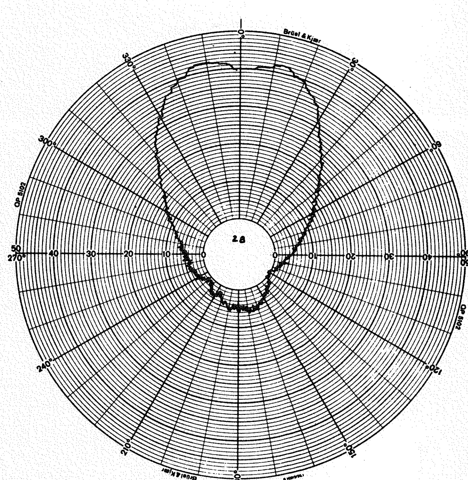
8 kHz, Hor.



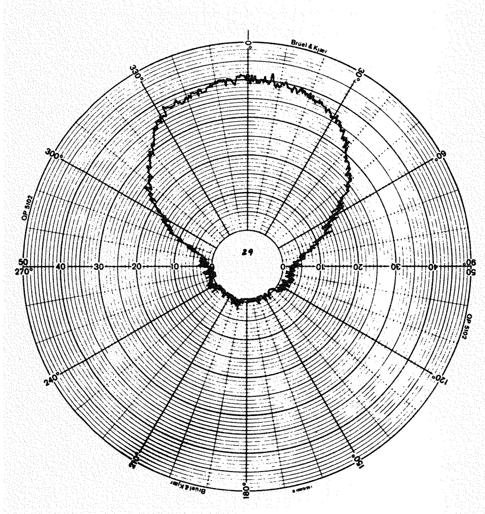
8 kHz, Vert.



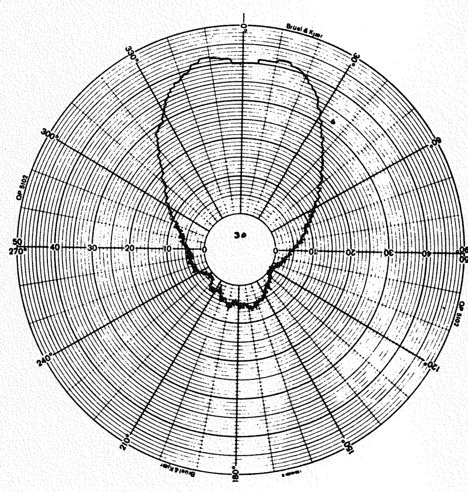
10 kHz, Hor.



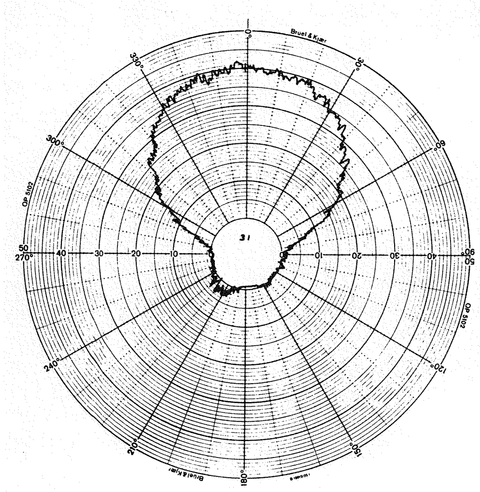
10 kHz, Vert.



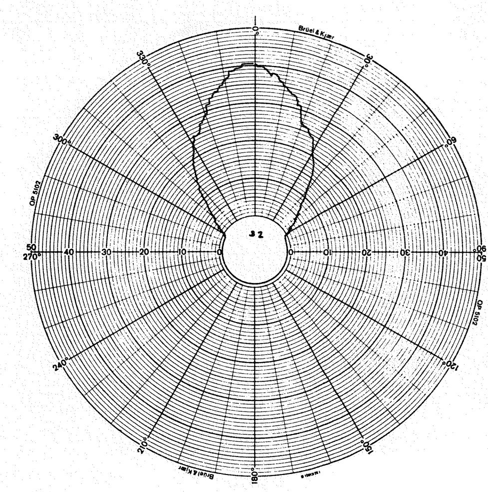
12.5 kHz, Hor.



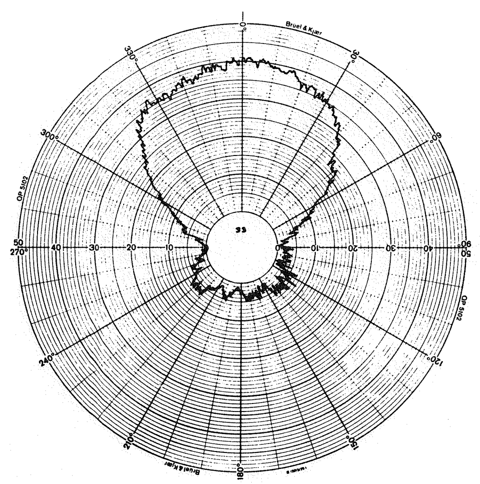
12.5 kHz, Vert.



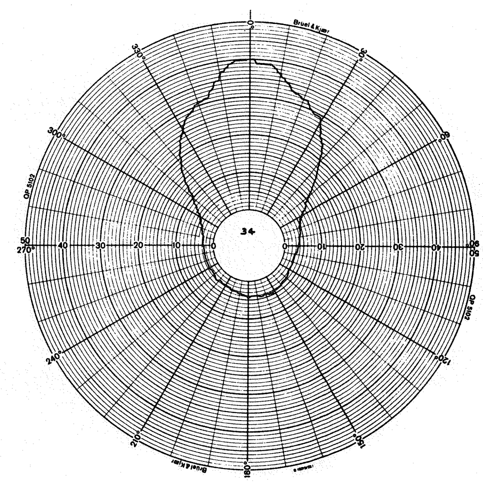
16 kHz, Hor.



16 kHz, Vert.

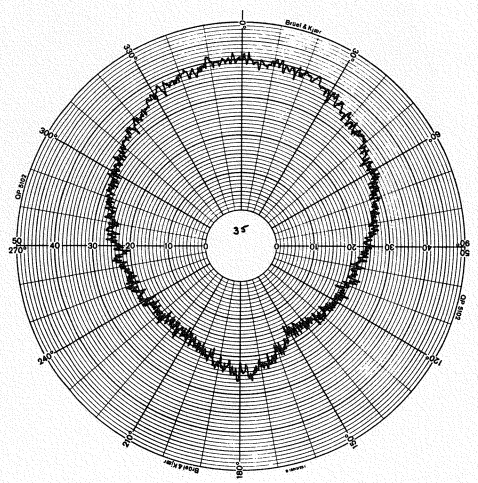


20 kHz, Hor.

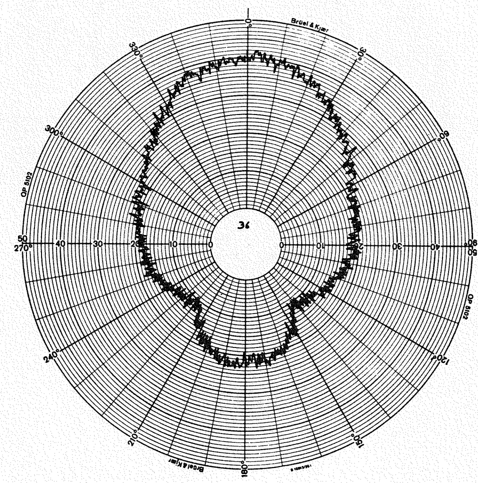


20 kHz, Vert.

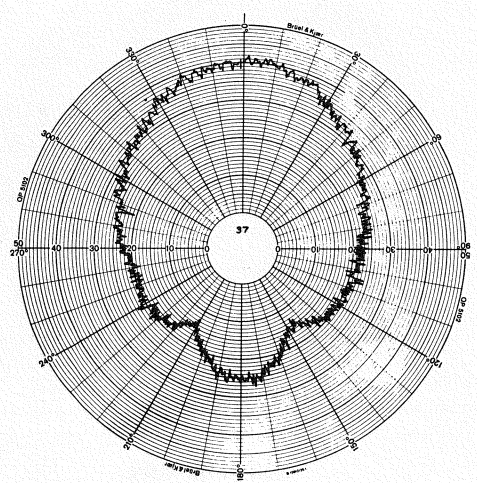
Appendix II: EV HP9040



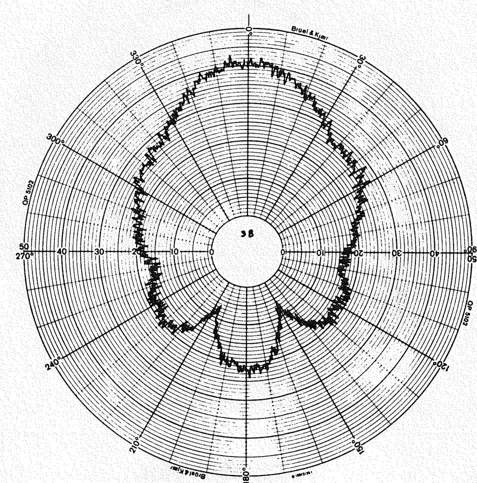
500 Hz, Hor.



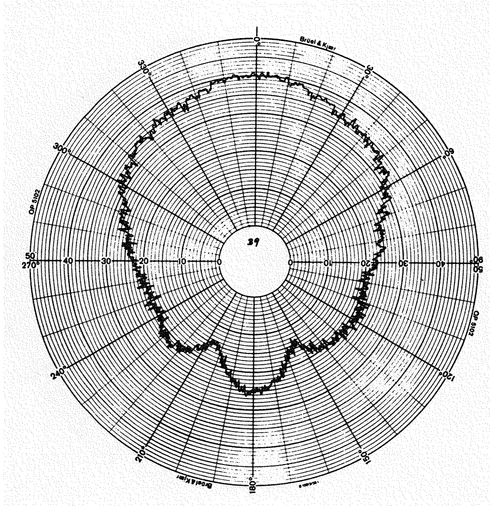
500 Hz, Vert.



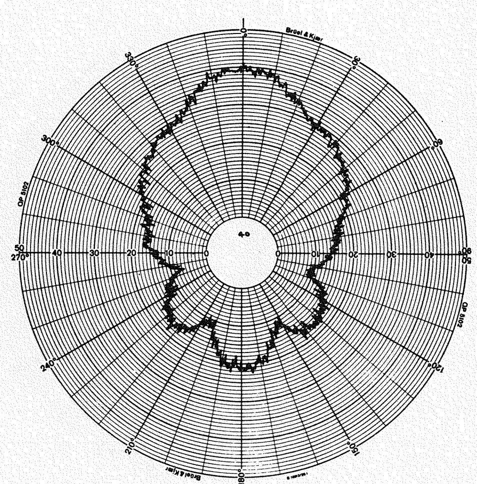
630 Hz, Hor.



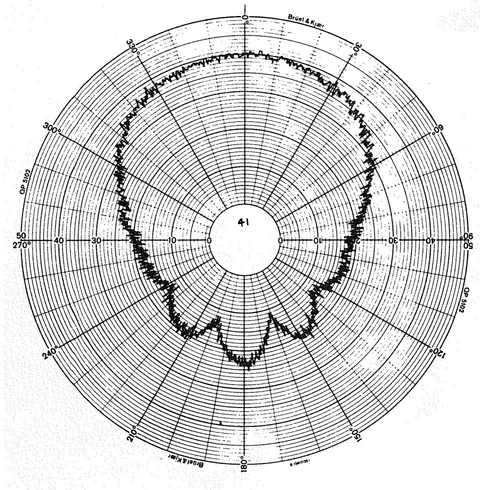
630 Hz, Vert.



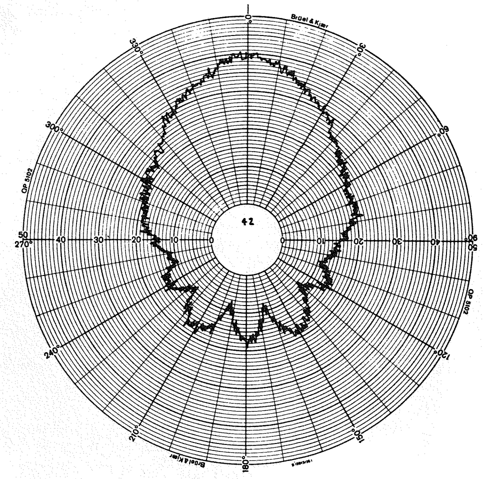
800 Hz, Hor.



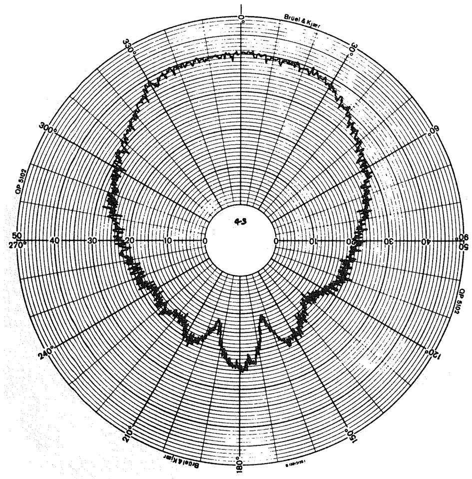
800 Hz, Vert.



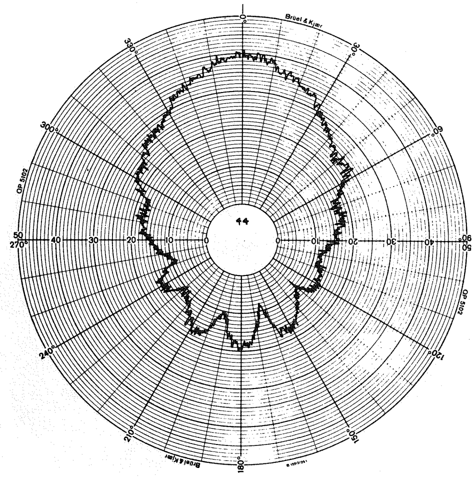
1 kHz, Hor.



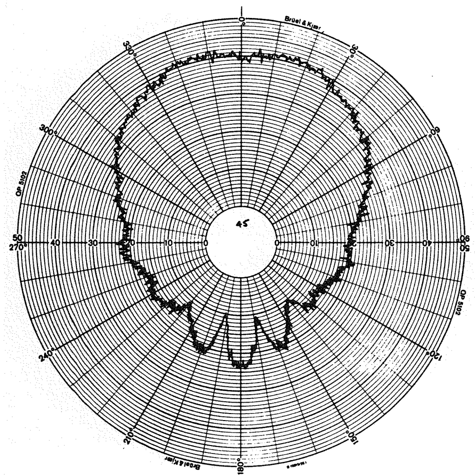
1 kHz, Vert.



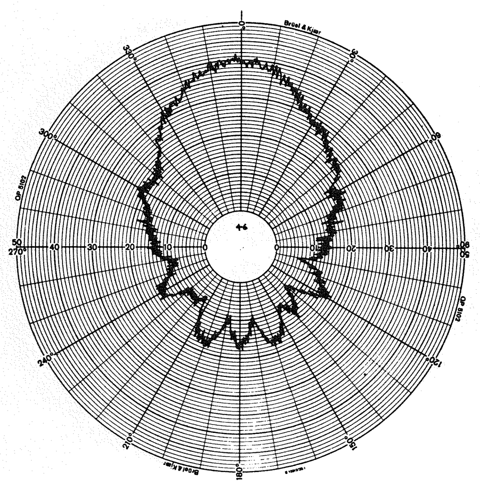
1.25 kHz, Hor.



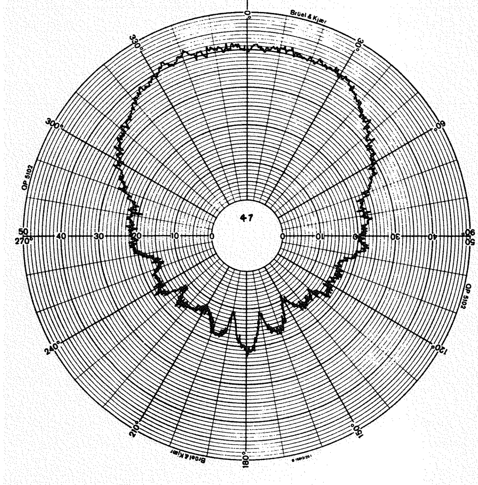
1.25 kHz, Vert.



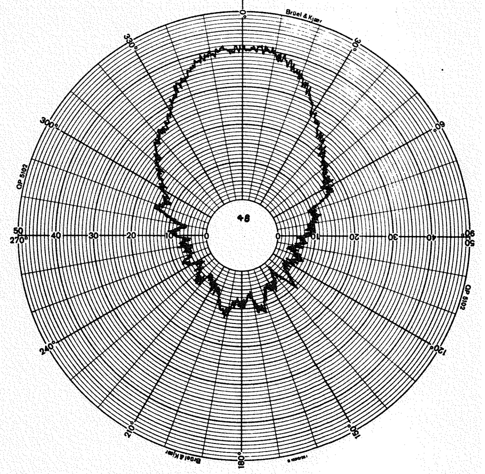
1.6 kHz, Hor.



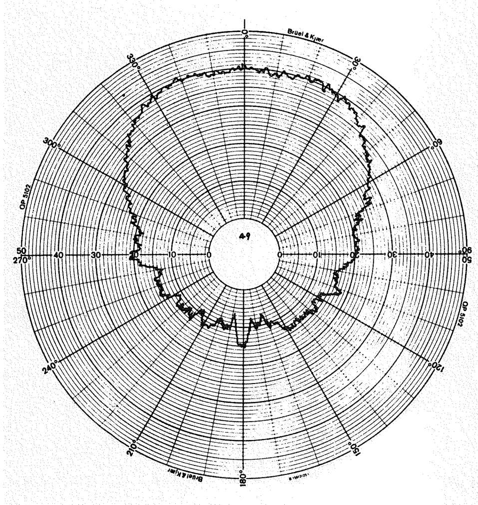
1.6 kHz, Vert.



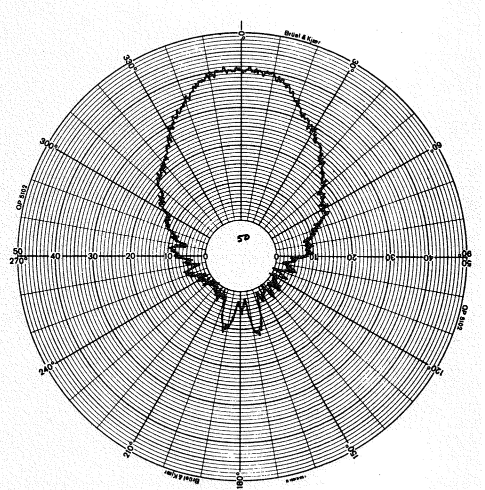
2 kHz, Hor.



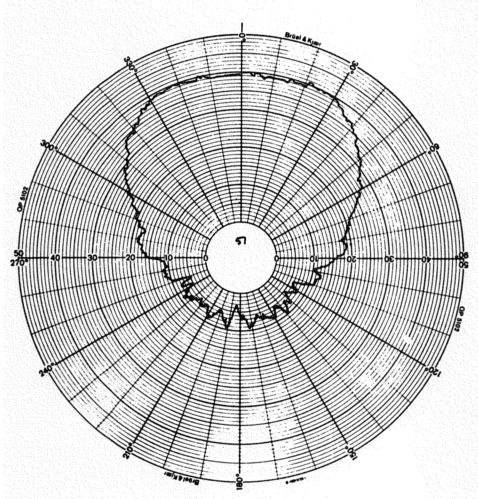
2 kHz, Vert.



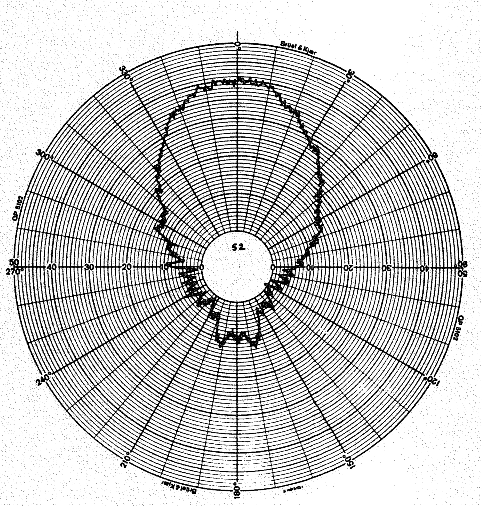
2.5 kHz, Hor.



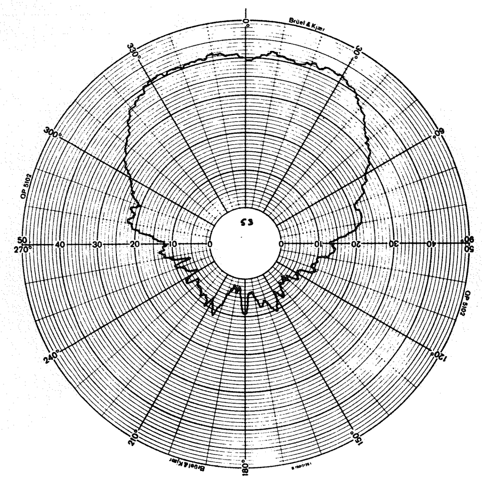
2.5 kHz, Vert.



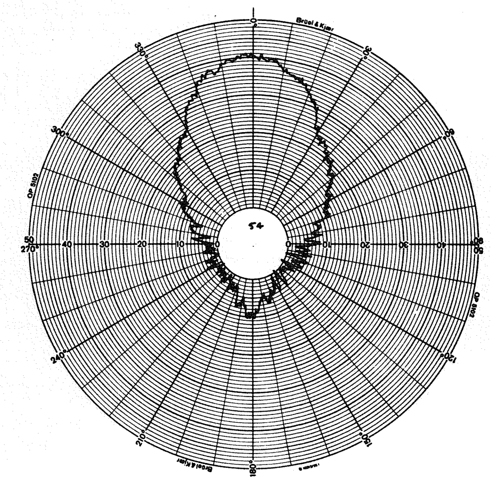
3.15 kHz, Hor.



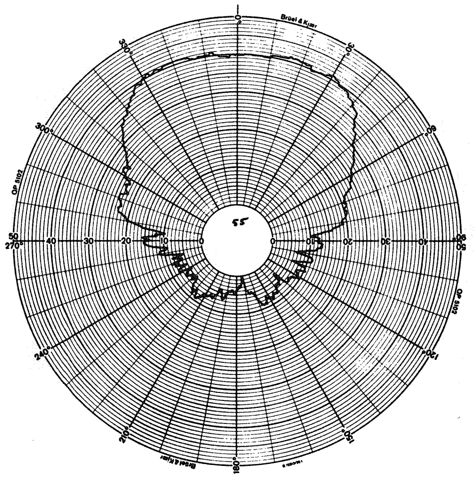
3.15 kHz, Vert.



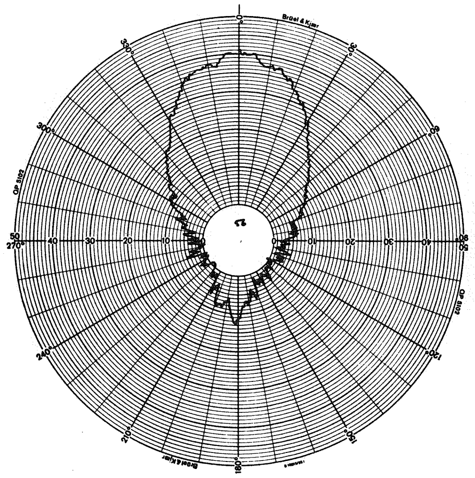
4 kHz, Hor.



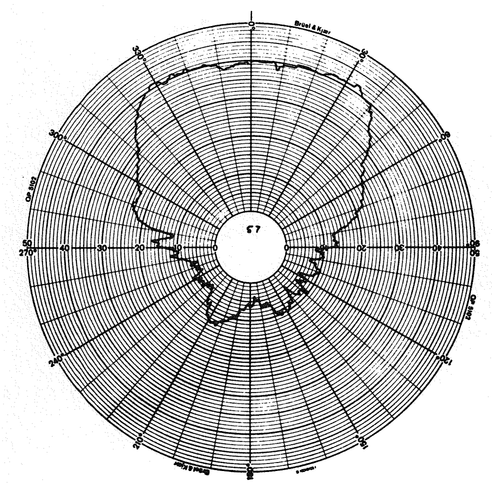
4 kHz, Vert.



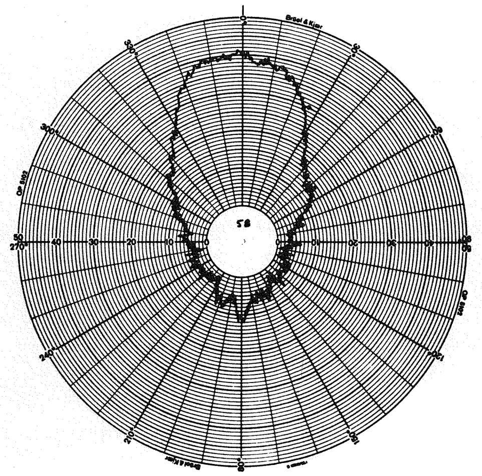
5 kHz, Hor.



5 kHz, Vert.

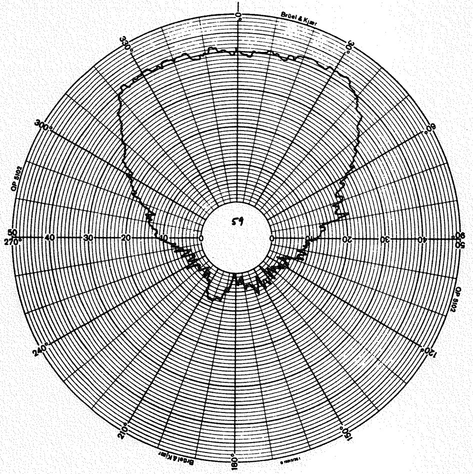


6.3 kHz, Hor.

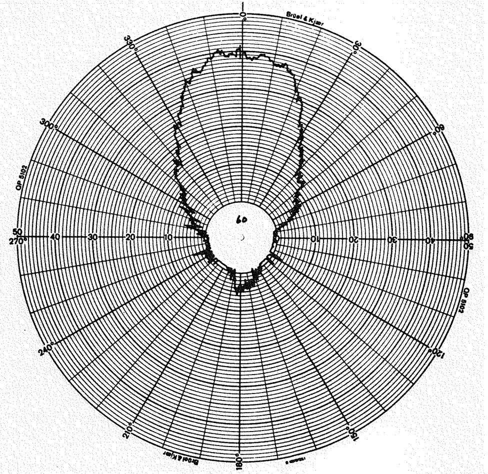


6.3 kHz, Vert.

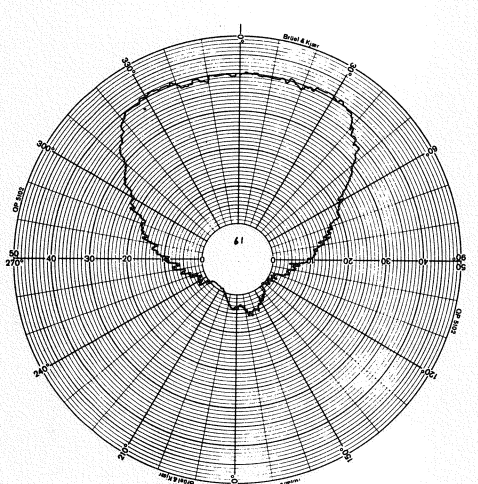
EV HP9040



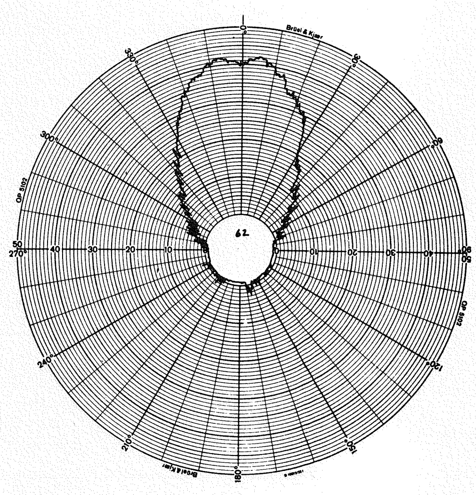
8 kHz, Hor.



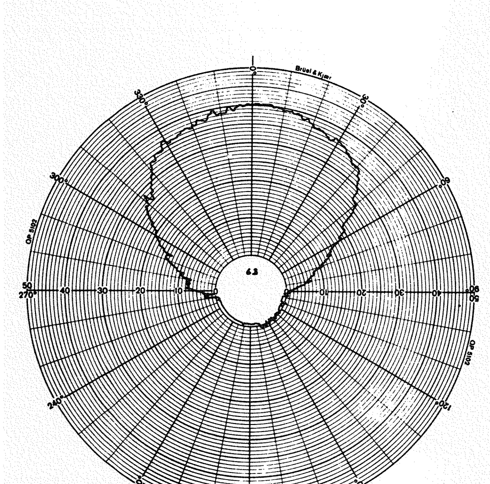
8 kHz, Vert.



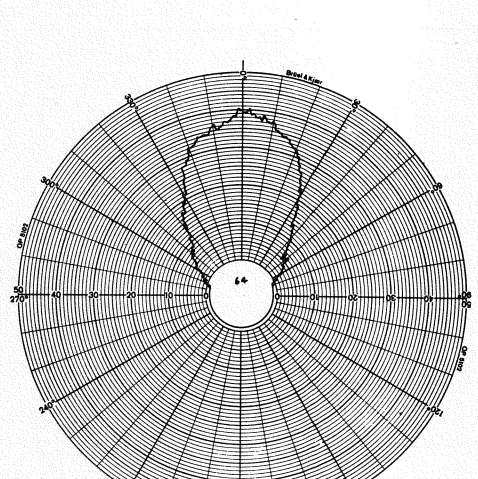
10 kHz, Hor.



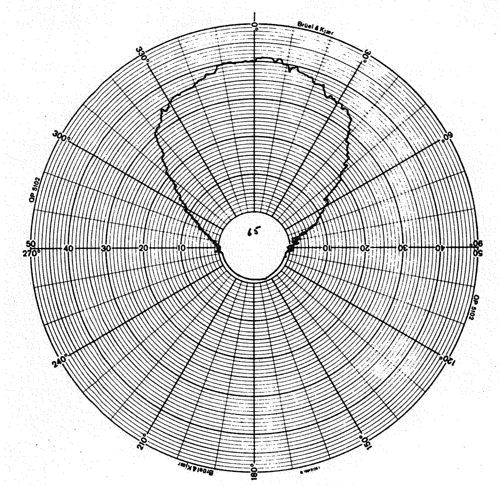
10 kHz, Vert.



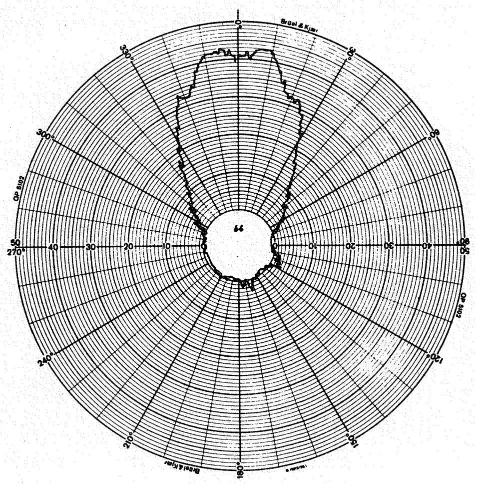
12.5 kHz, Hor.



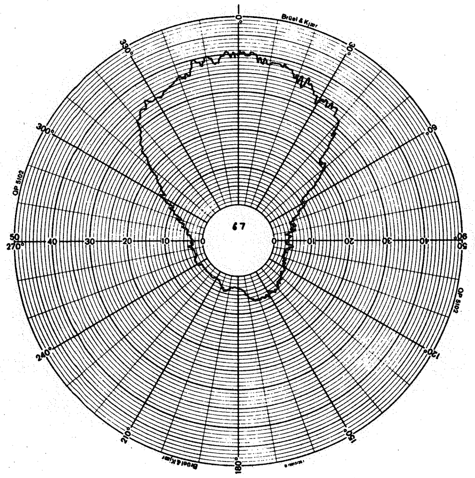
12.5 kHz, Vert.



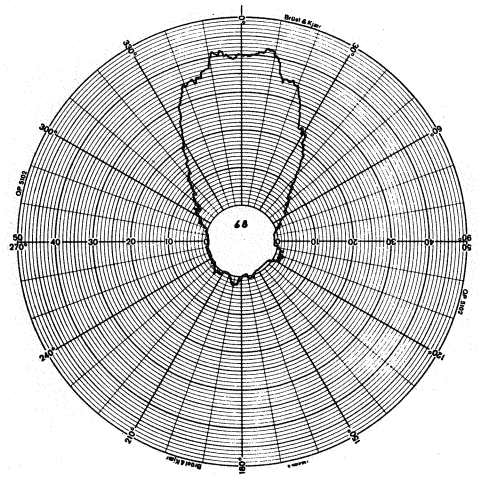
16 kHz, Hor.



16 kHz, Vert.

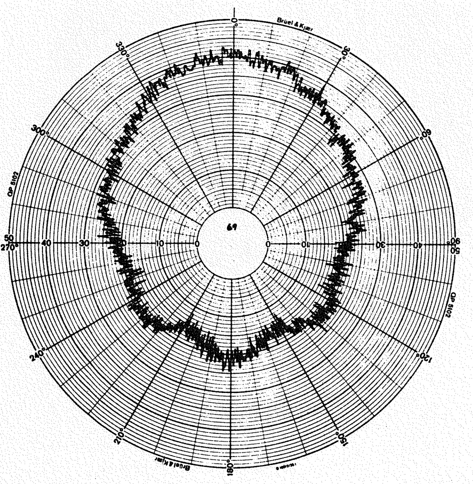


20 kHz, Hor.

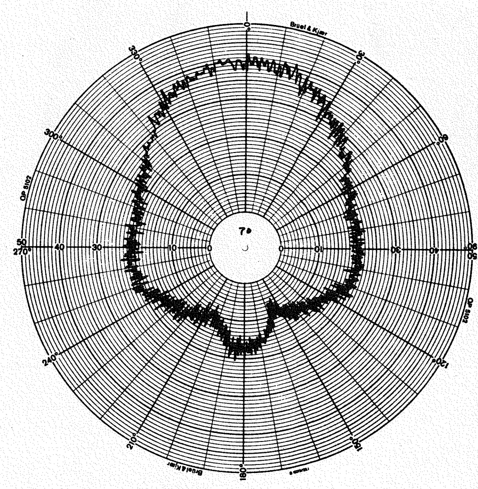


20 kHz, Vert.

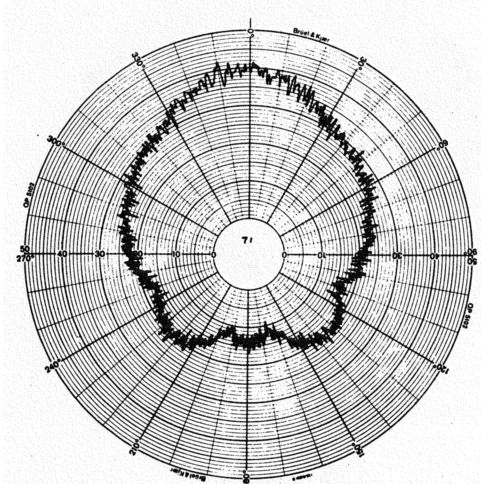
Appendix III: JBL 2365A



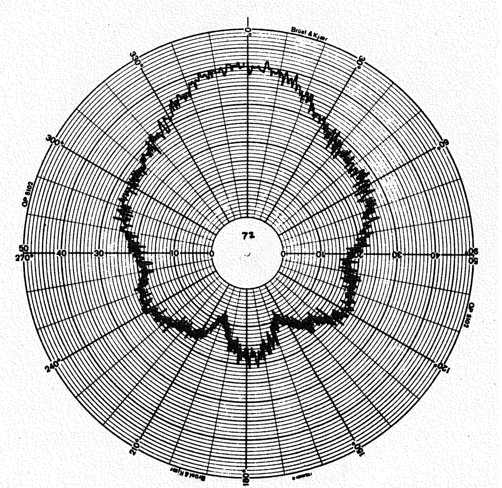
500 Hz, Hor.



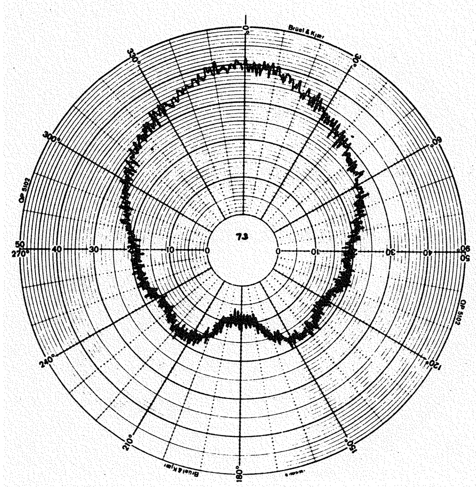
500 Hz, Vert.



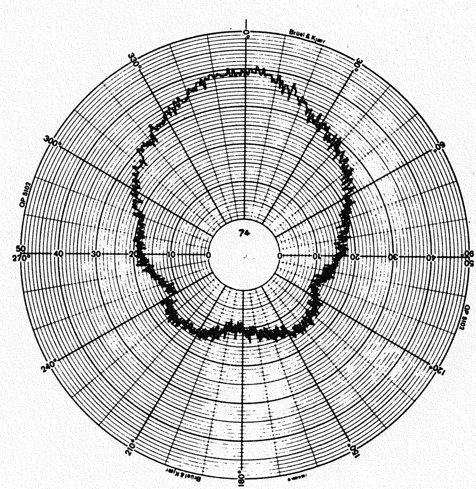
630 Hz, Hor.



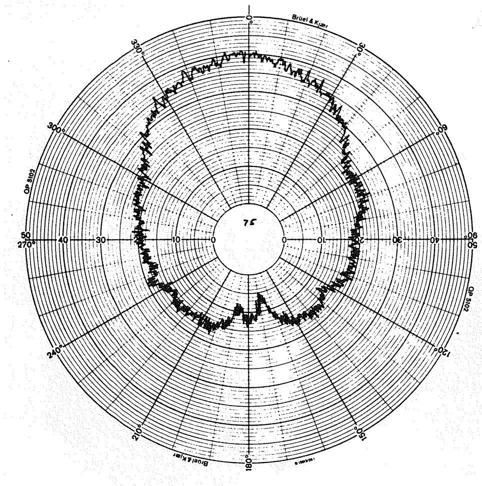
630 Hz, Vert.



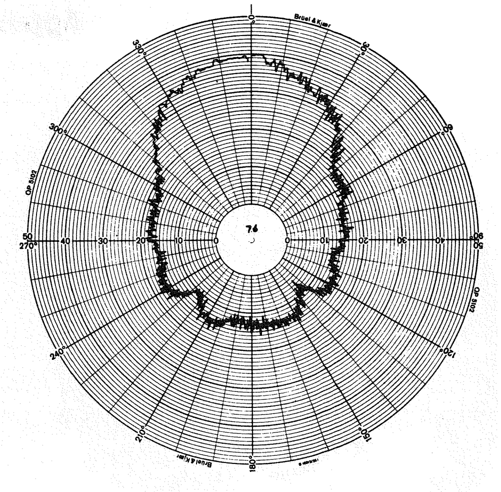
800 Hz, Hor.



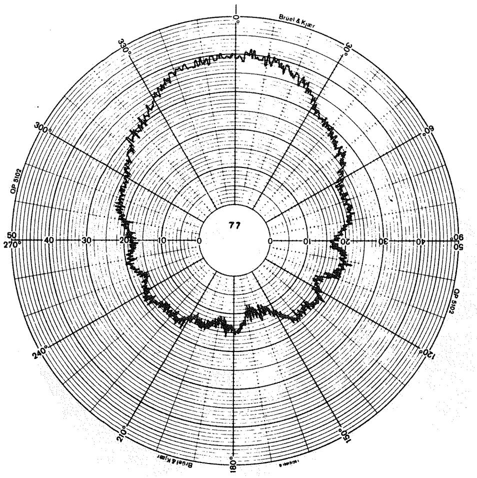
800 Hz, Vert.



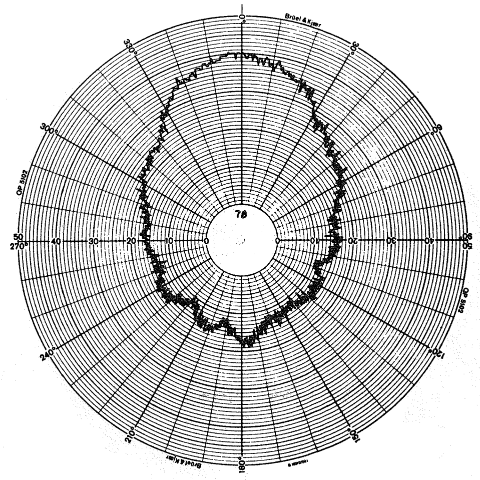
1 kHz, Hor.



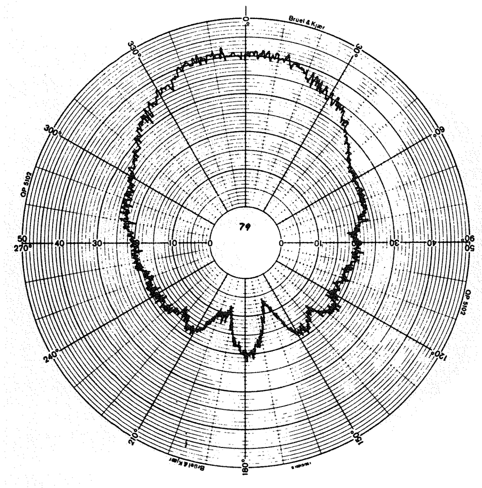
1 kHz, Vert.



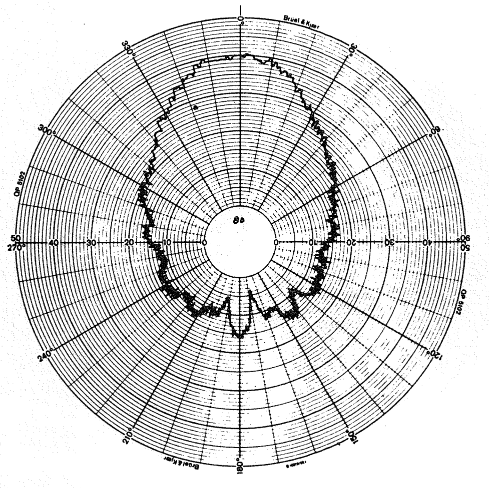
1.25 kHz, Hor.



1.25 kHz, Vert.

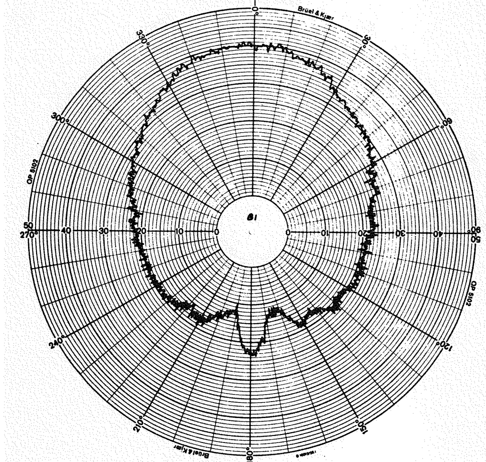


1.6 kHz, Hor.

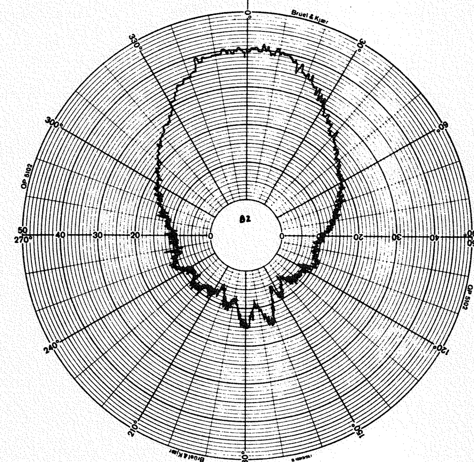


1.6 kHz, Vert.

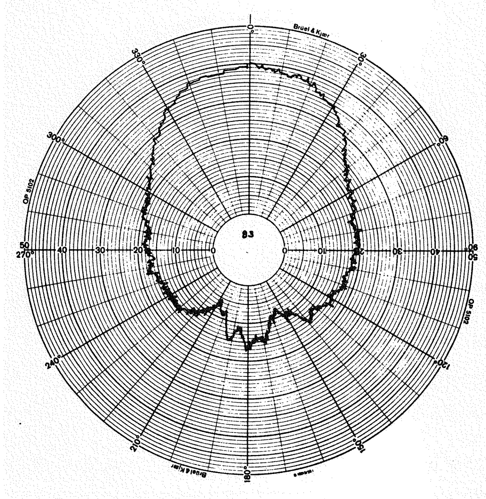
JBL 2365A



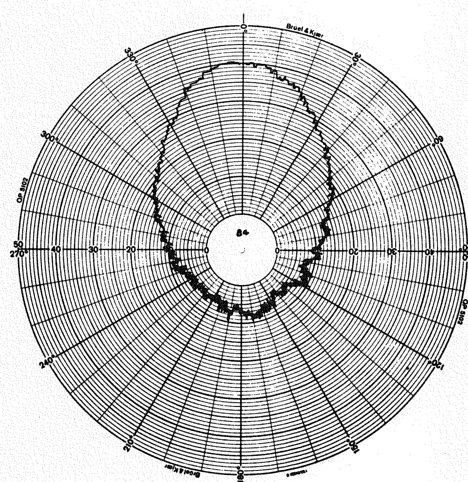
2 kHz, Hor.



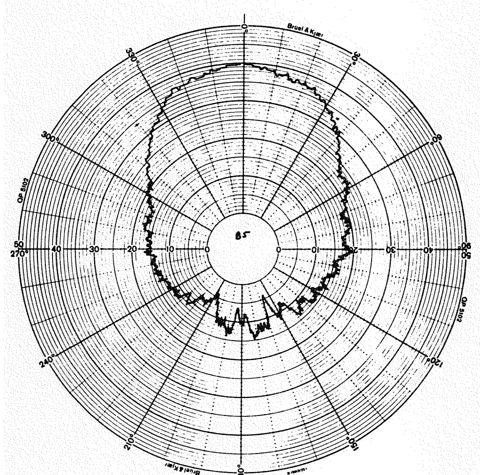
2 kHz, Vert.



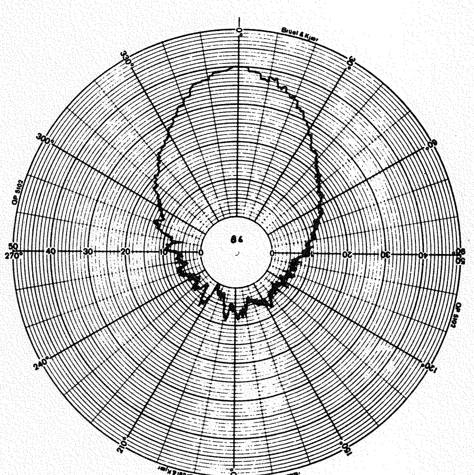
2.5 kHz, Hor.



2.5 kHz, Vert.

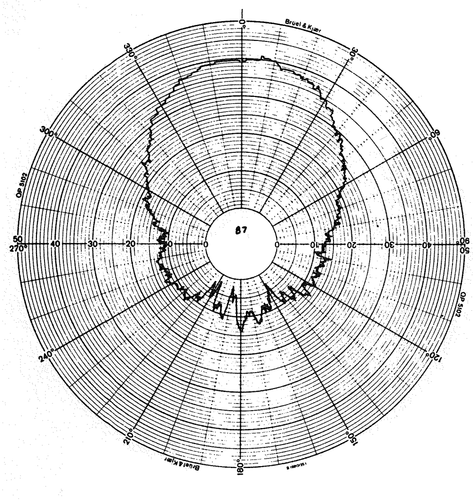


3.15 kHz, Hor.

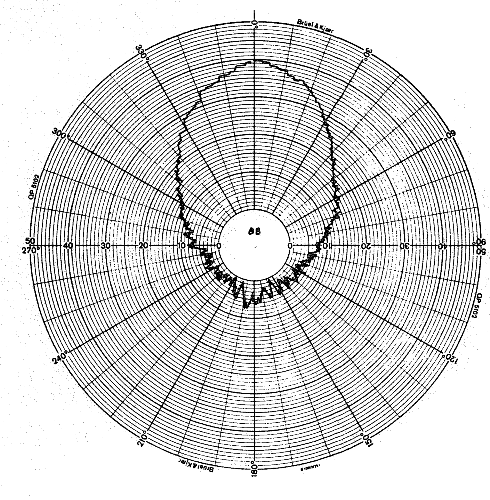


3.15 kHz, Vert.

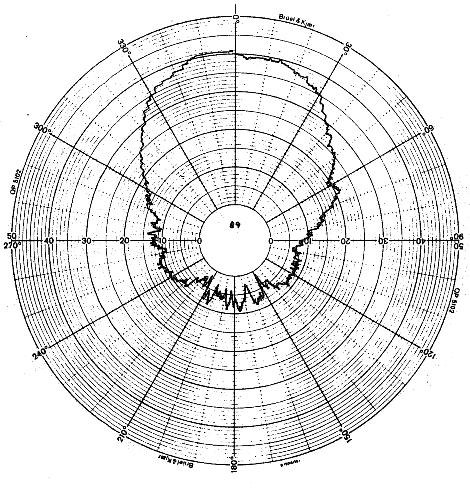
JBL 2365A



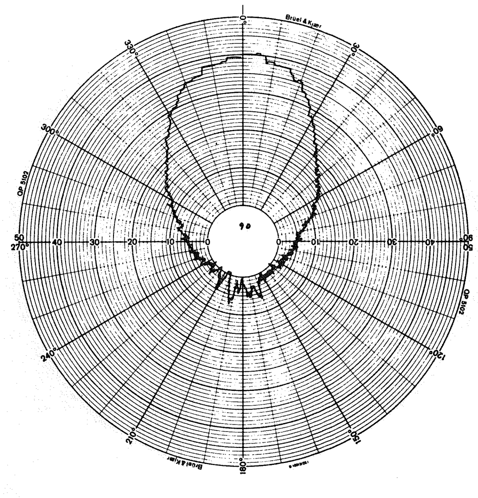
4 kHz, Hor.



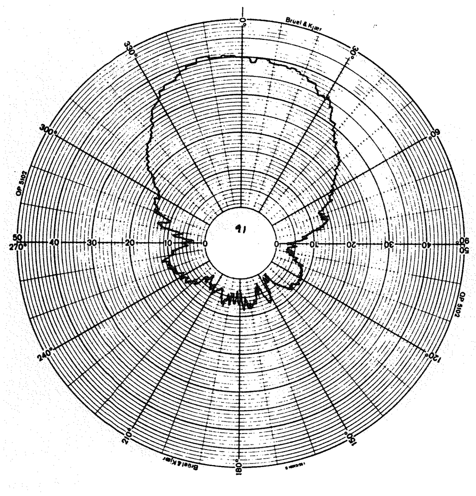
4 kHz, Vert.



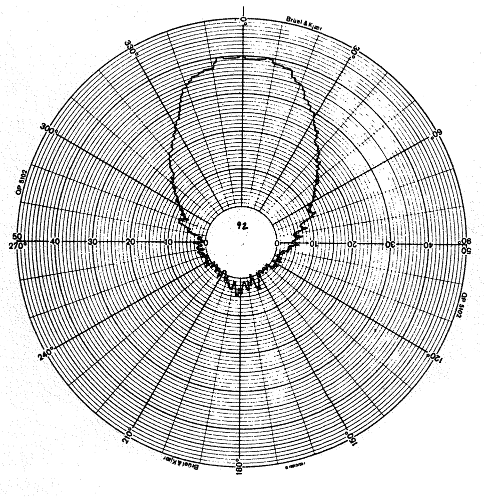
5 kHz, Hor.



5 kHz, Vert.

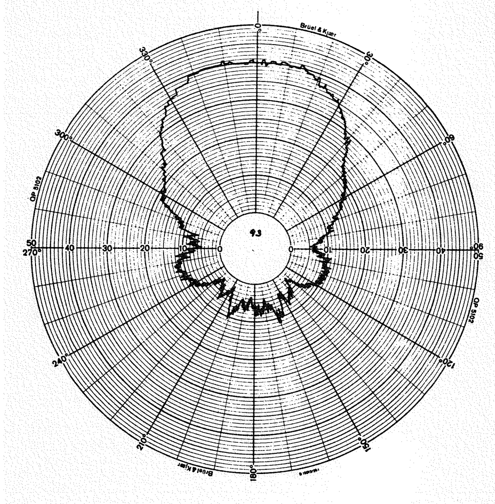


6.3 kHz, Hor.

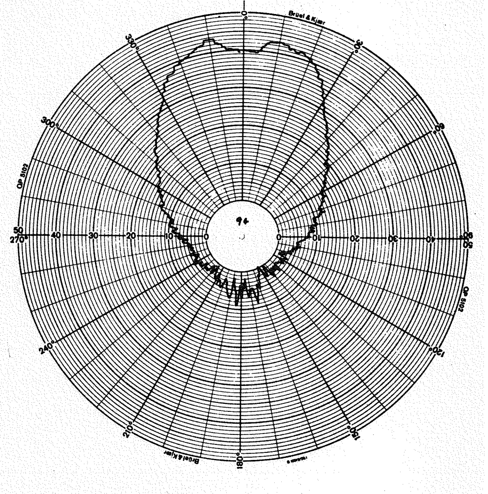


6.3 kHz, Vert.

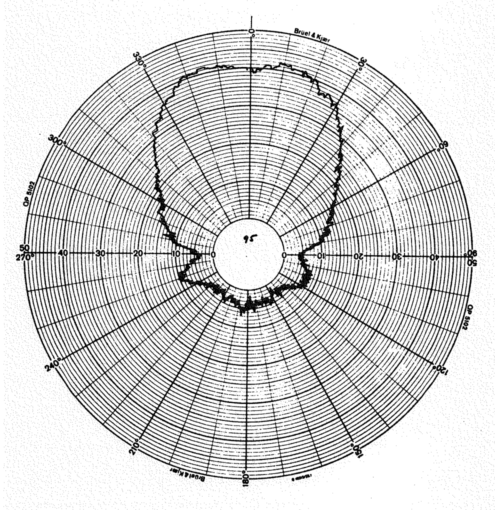
JBL 2365A



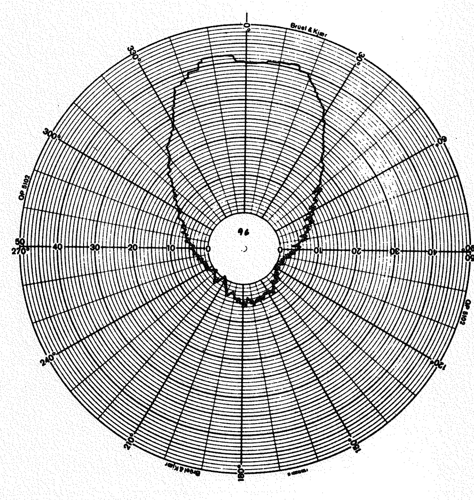
8 kHz, Hor.



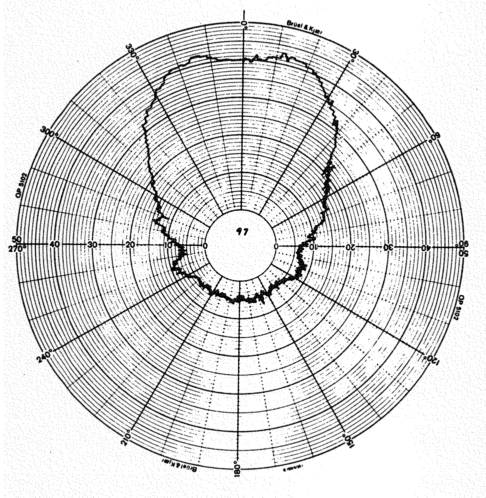
8 kHz, Vert.



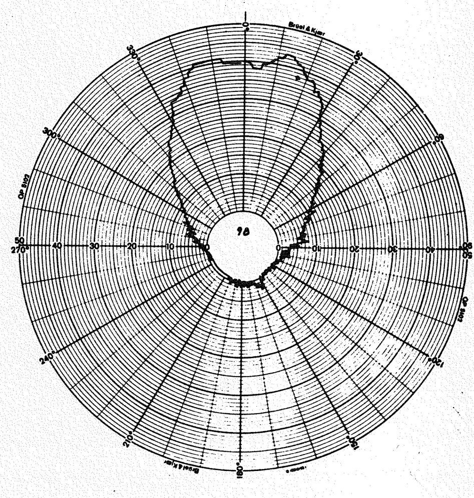
10 kHz, Hor.



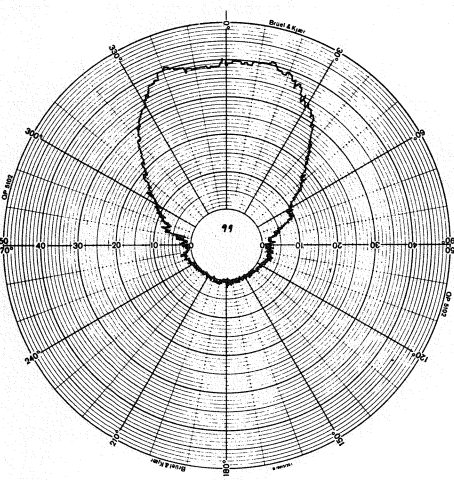
10 kHz, Vert.



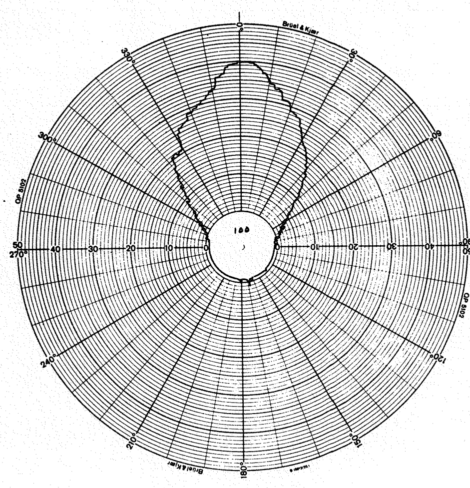
12.5 kHz, Hor.



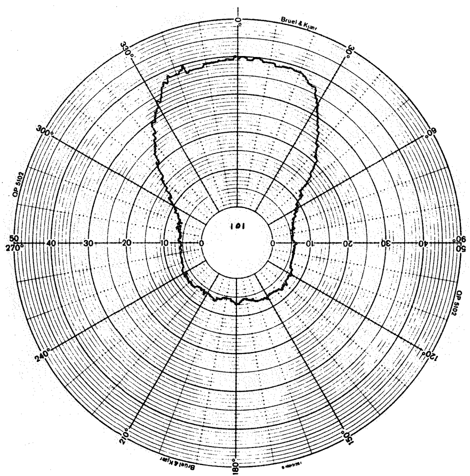
12.5 kHz, Vert.



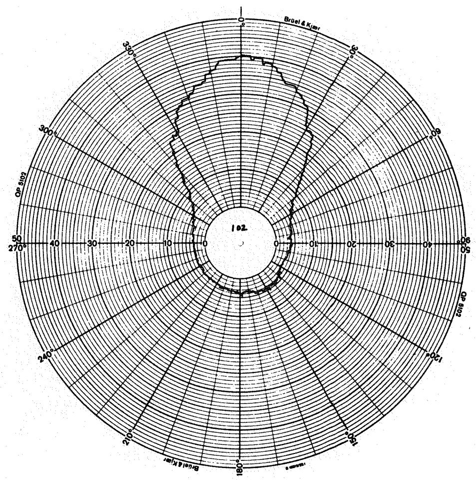
16 kHz, Hor.



16 kHz, Vert.

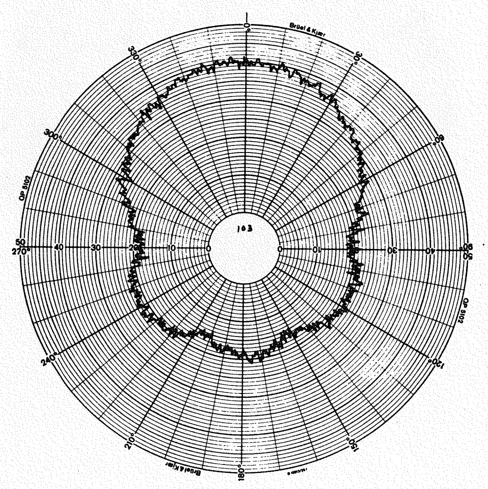


20 kHz, Hor.

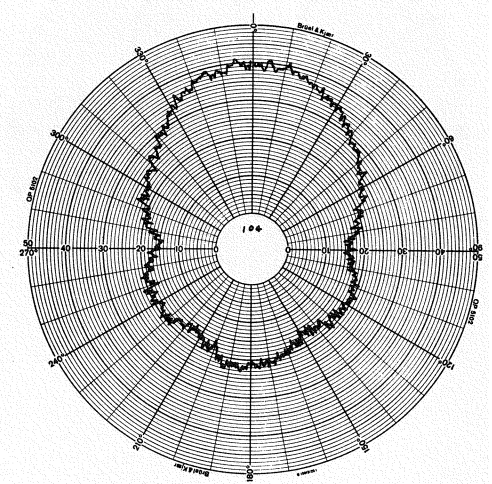


20 kHz, Vert.

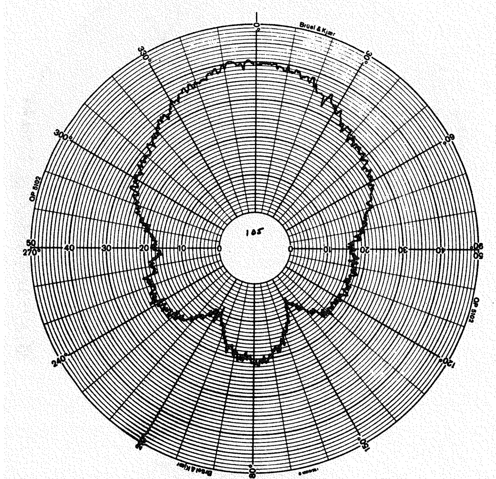
Appendix IV: EV HP6040



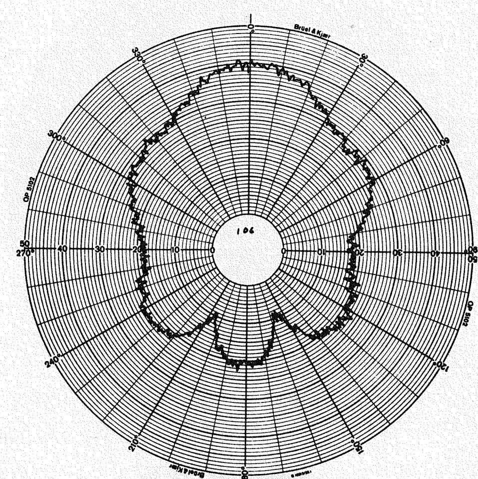
500 Hz, Hor.



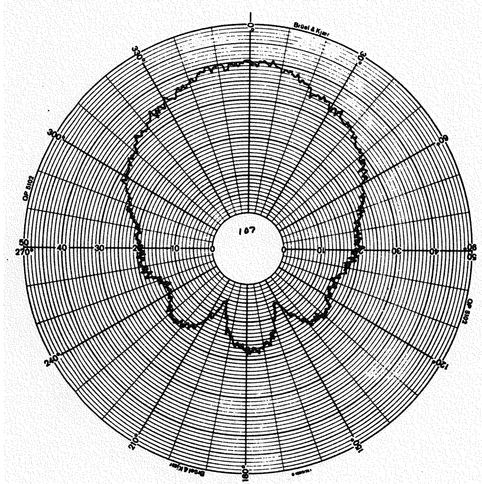
500 Hz, Vert.



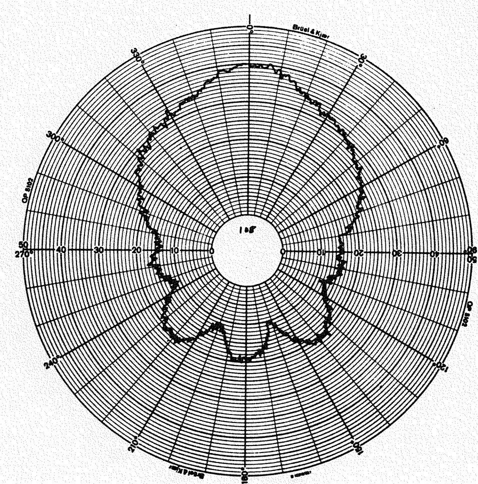
630 Hz, Hor.



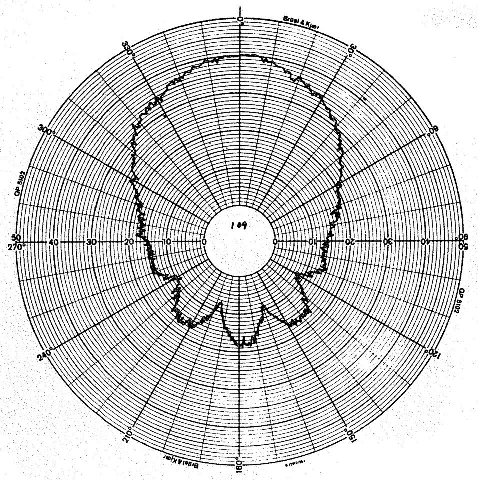
630 Hz, Vert.



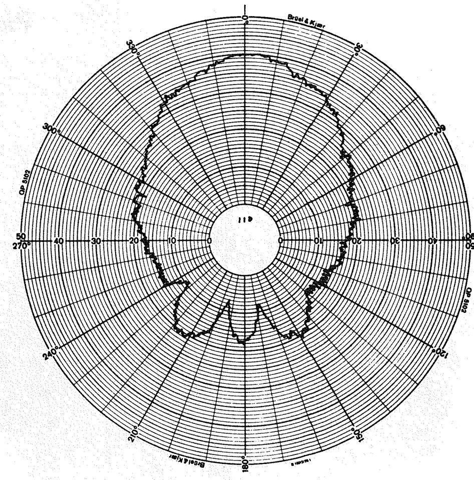
800 Hz, Hor.



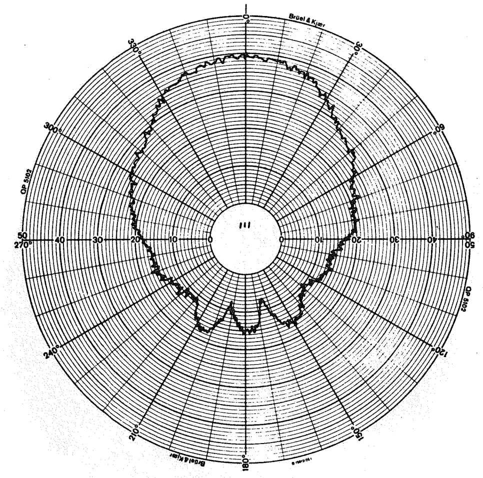
800 Hz, Vert.



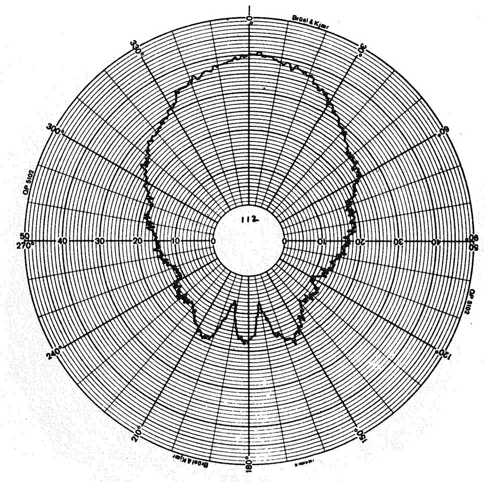
1 kHz, Hor.



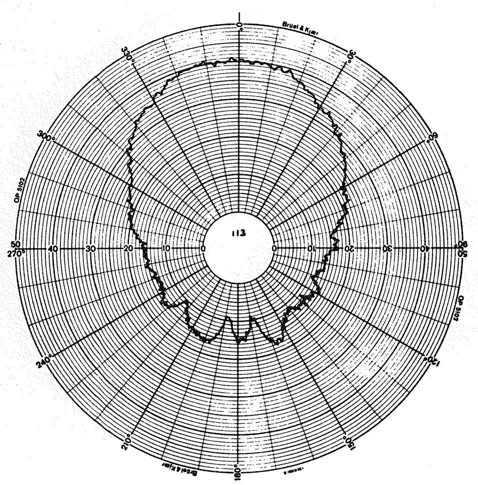
1 kHz, Vert.



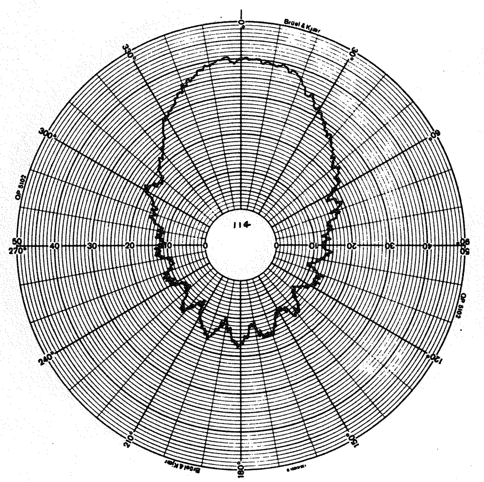
1.25 kHz, Hor.



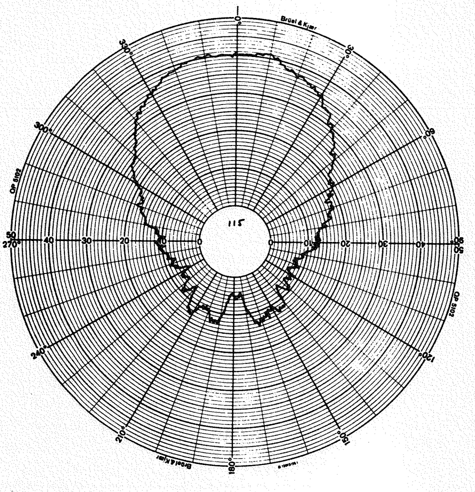
1.25 kHz, Vert.



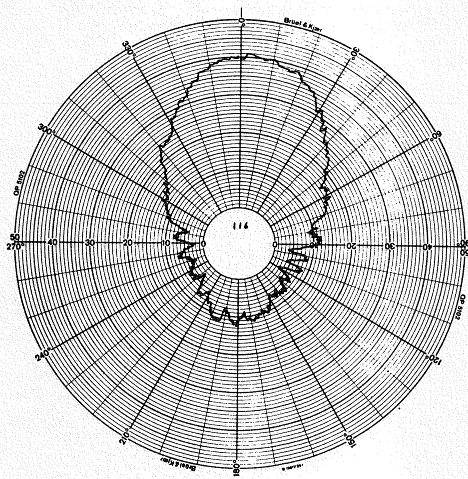
1.6 kHz, Hor.



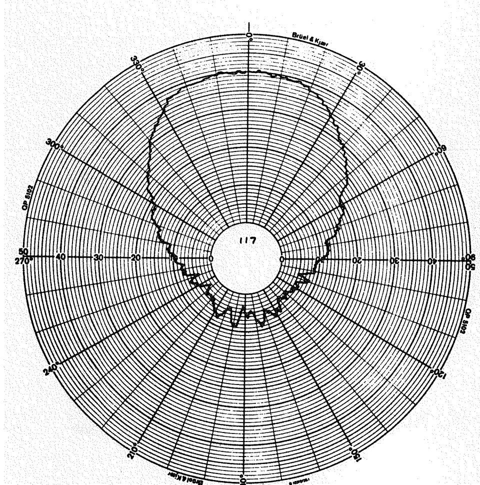
1.6 kHz, Vert.



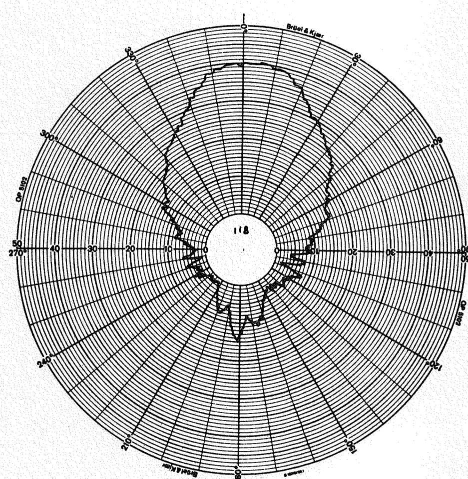
2 kHz, Hor.



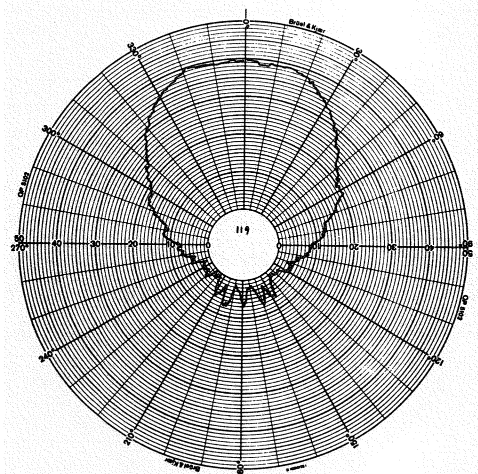
2 kHz, Vert.



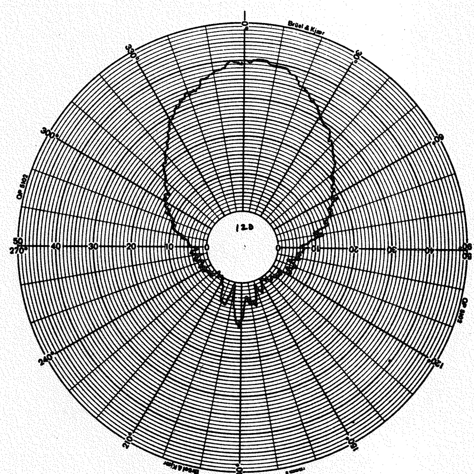
2.5 kHz, Hor.



2.5 kHz, Vert.

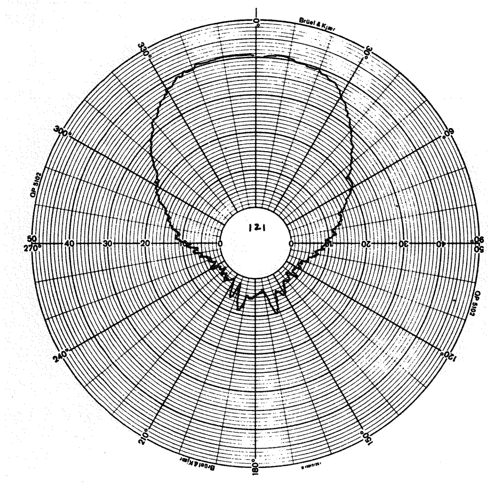


3.15 kHz, Hor.

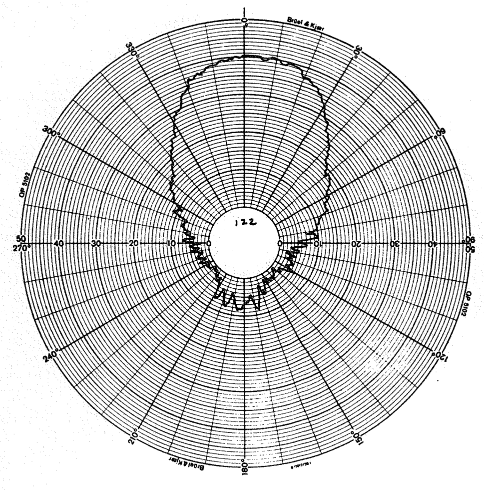


3.15 kHz, Vert.

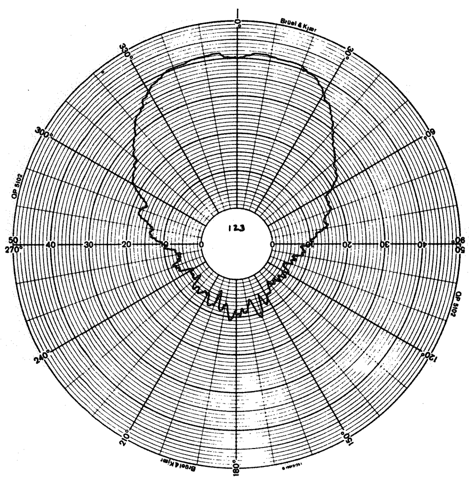
EV HP6040



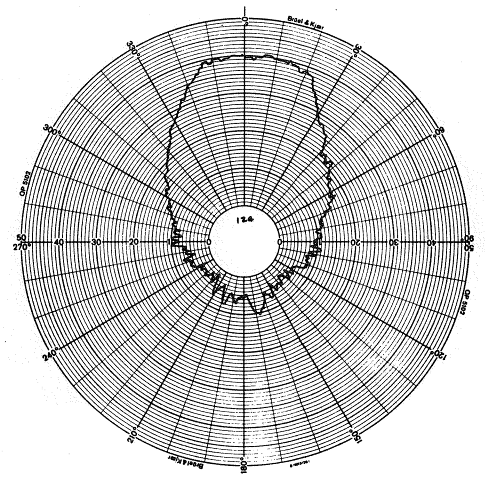
4 kHz, Hor.



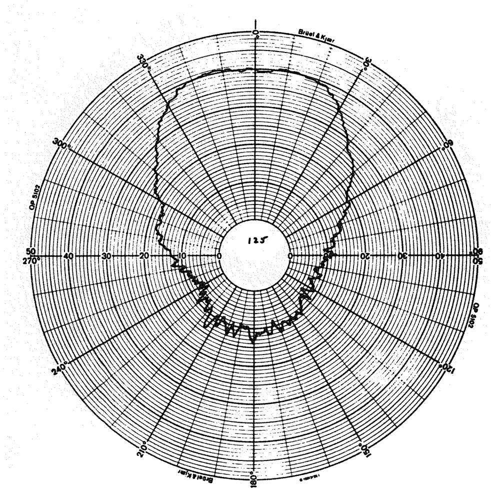
4 kHz, Vert.



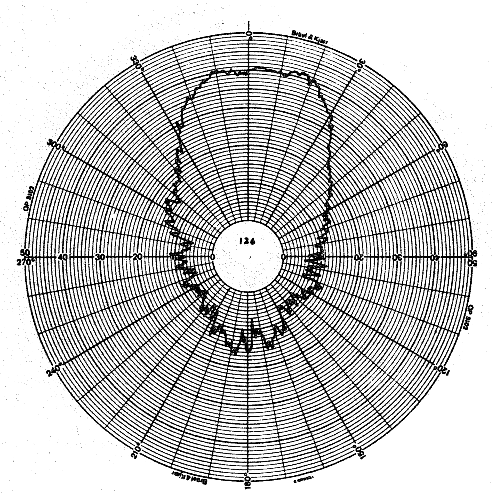
5 kHz, Hor.



5 kHz, Vert.

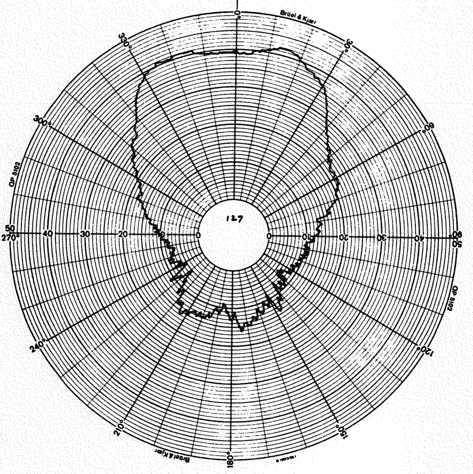


6.3 kHz, Hor.

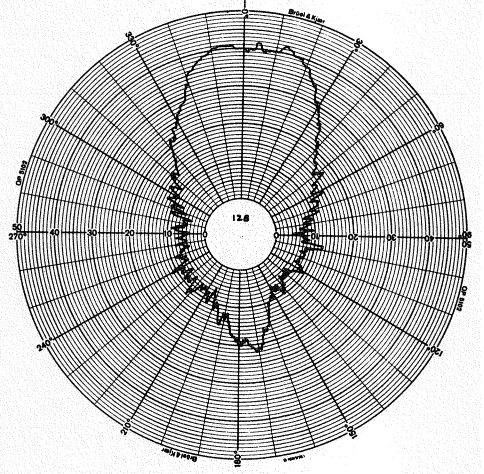


6.3 kHz, Vert.

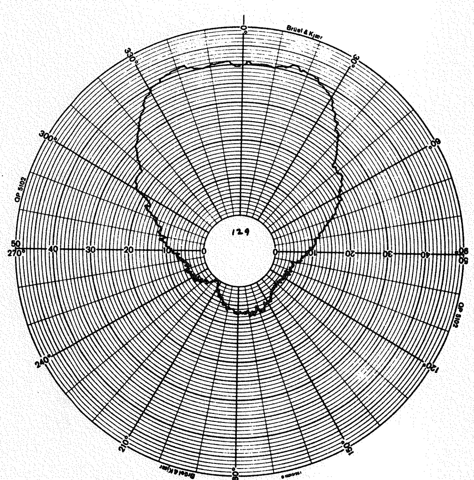
EV HP6040



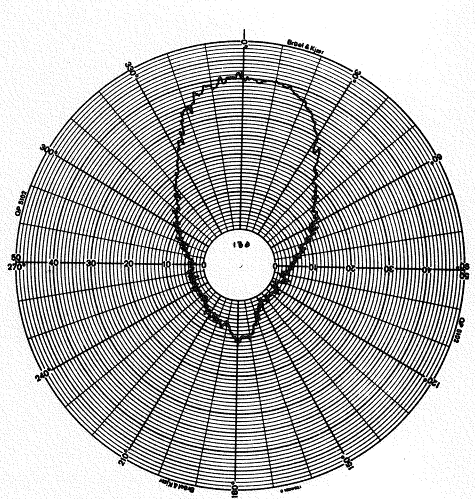
8 kHz, Hor.



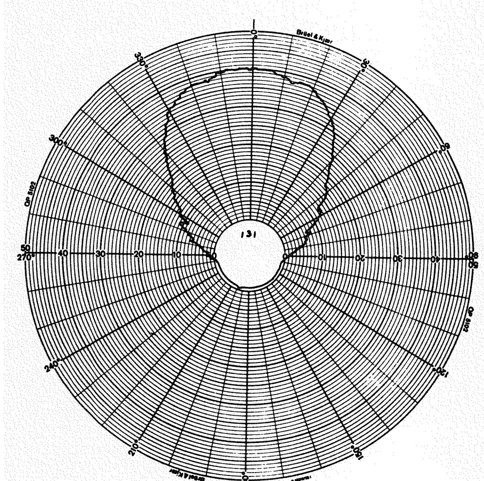
8 kHz, Vert.



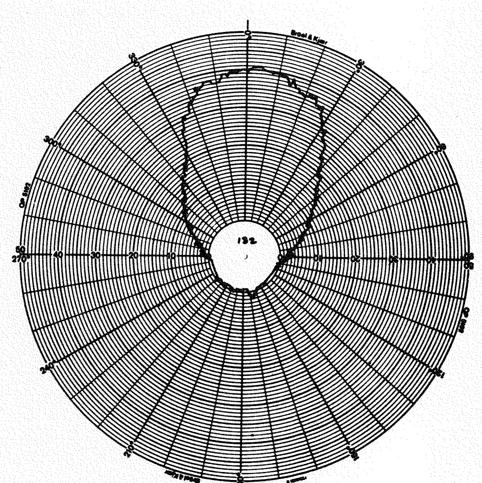
10 kHz, Hor.



10 kHz, Vert.

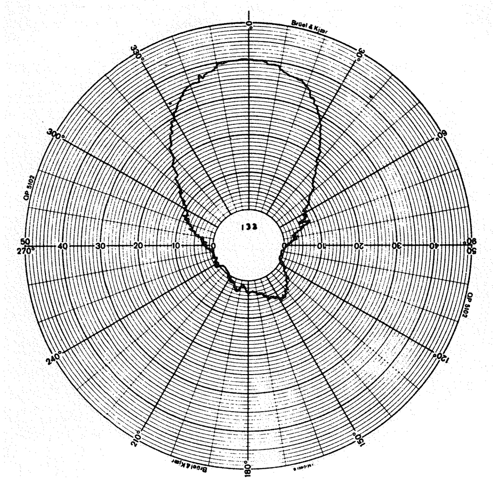


12.5 kHz, Hor.

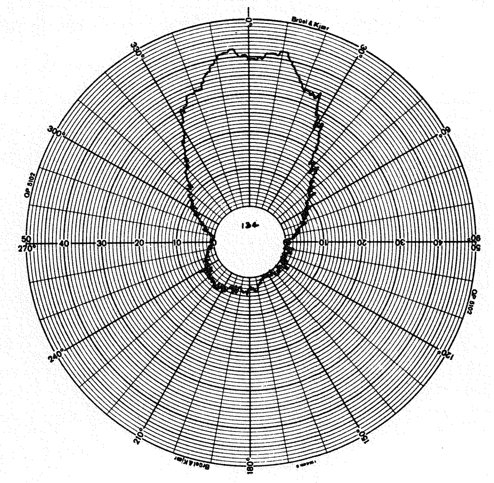


12.5 kHz, Vert.

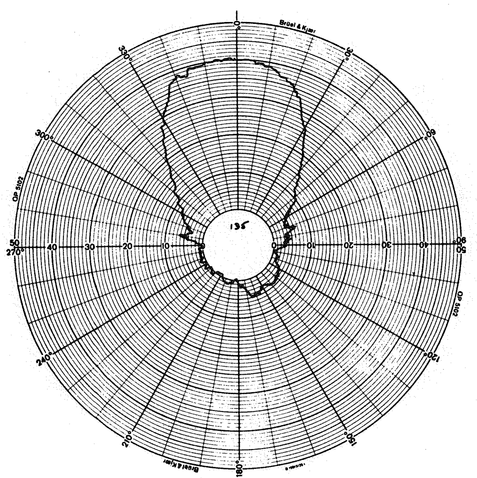
EV HP6040



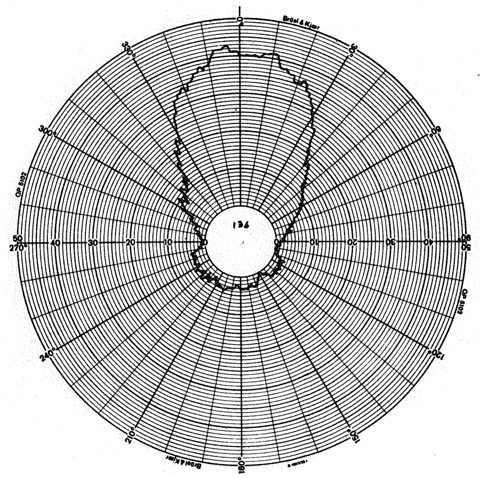
16 kHz, Hor.



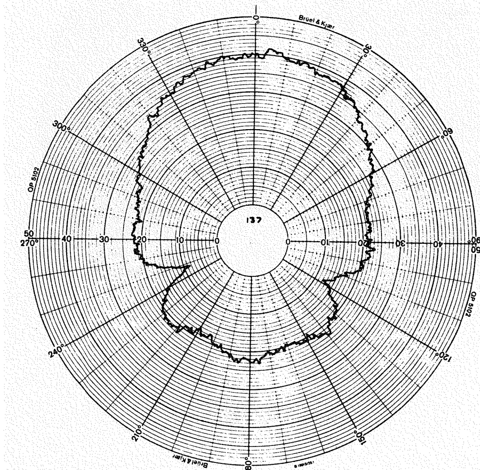
16 kHz, Vert.



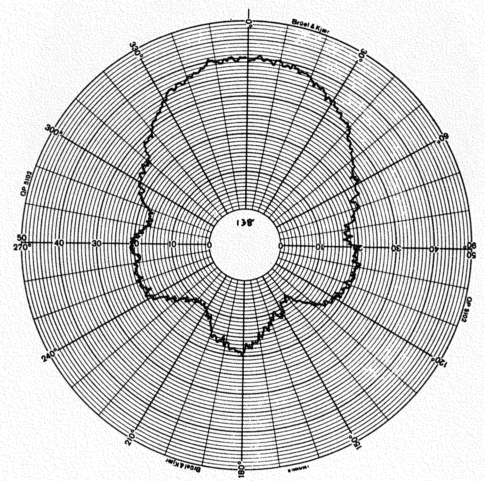
20 kHz, Hor.



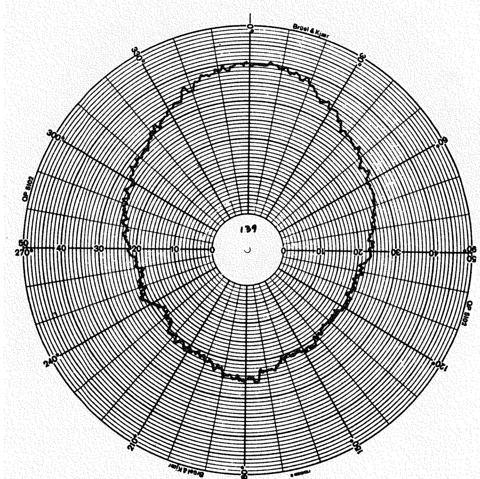
20 kHz, Vert.



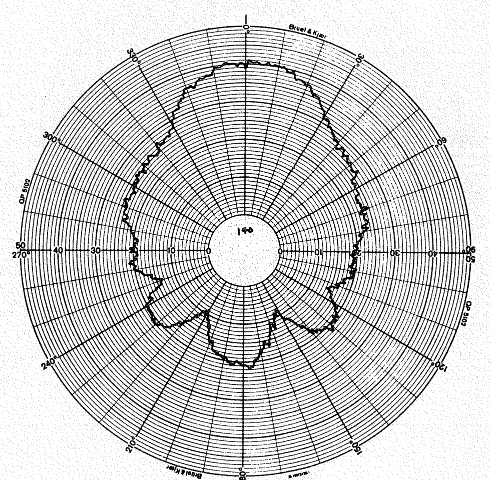
500 Hz, Hor.



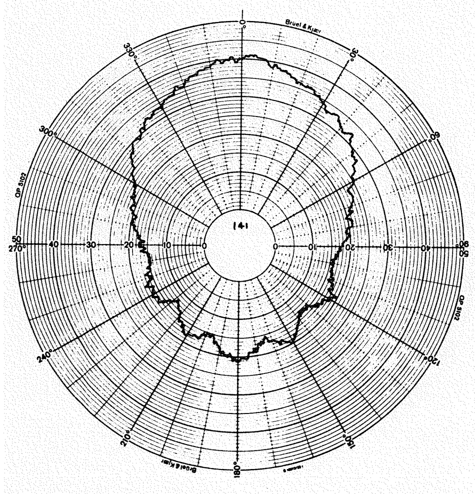
500 Hz, Vert.



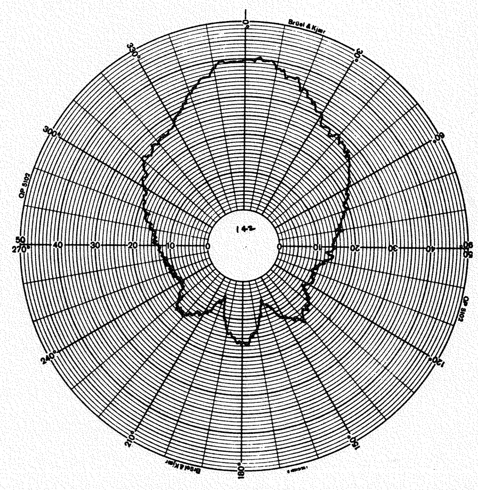
630 Hz, Hor.



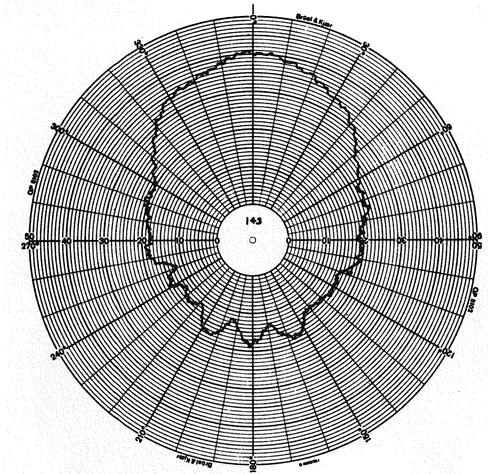
630 Hz, Vert.



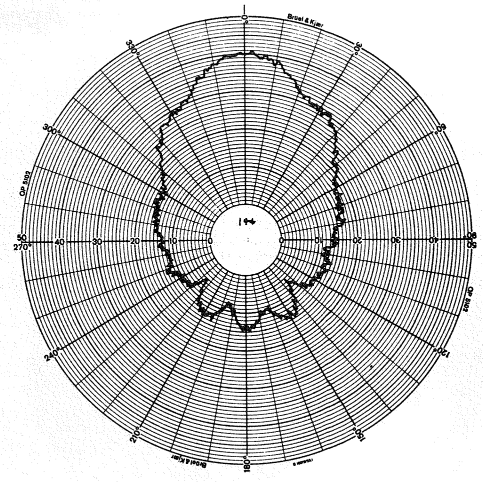
800 Hz, Hor.



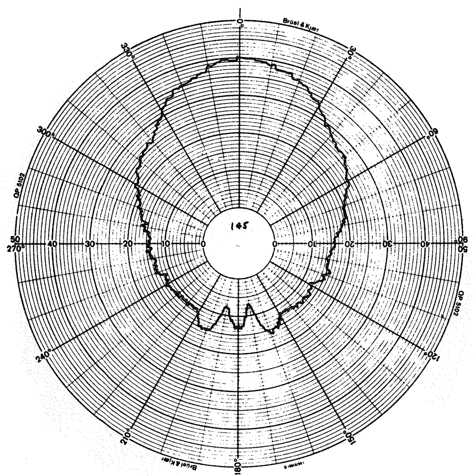
800 Hz, Vert.



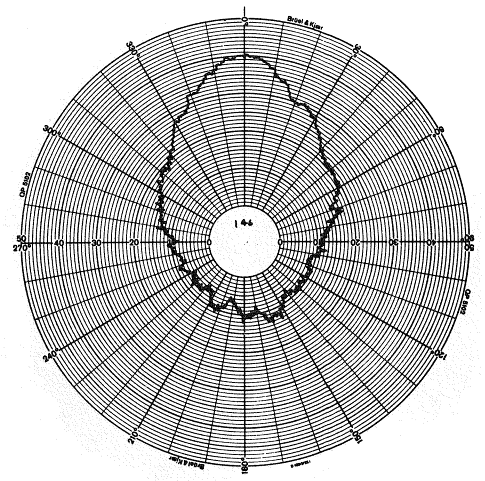
1 kHz, Hor.



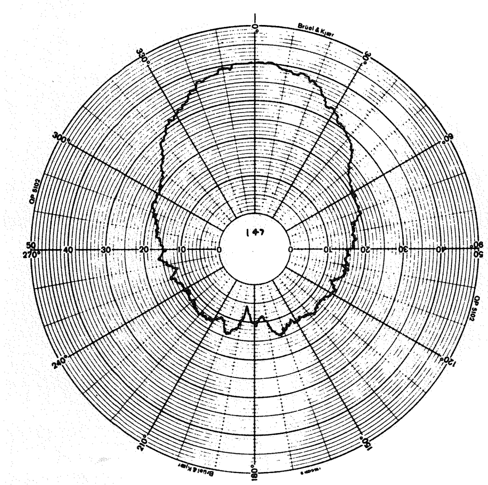
1 kHz, Vert.



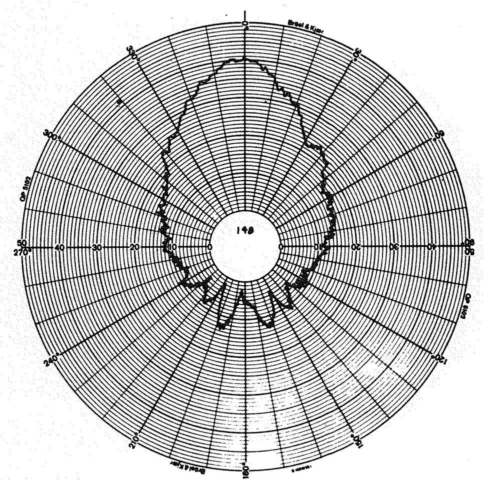
1.25 kHz, Hor.



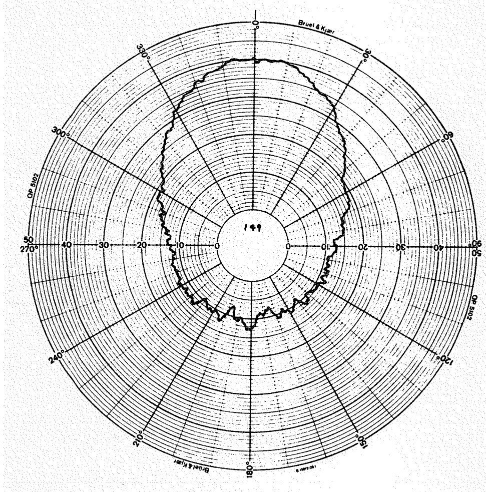
1.25 kHz, Vert.



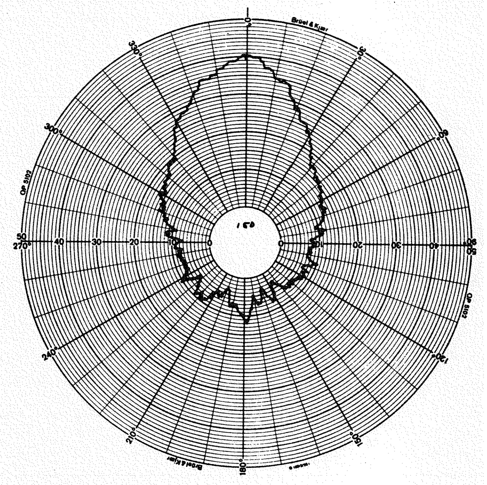
1.6 kHz, Hor.



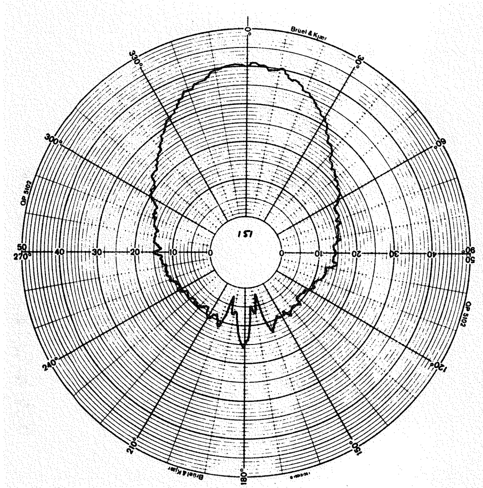
1.6 kHz, Vert.



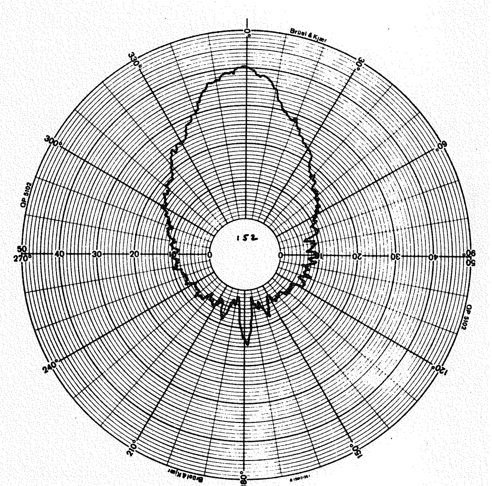
2 kHz, Hor.



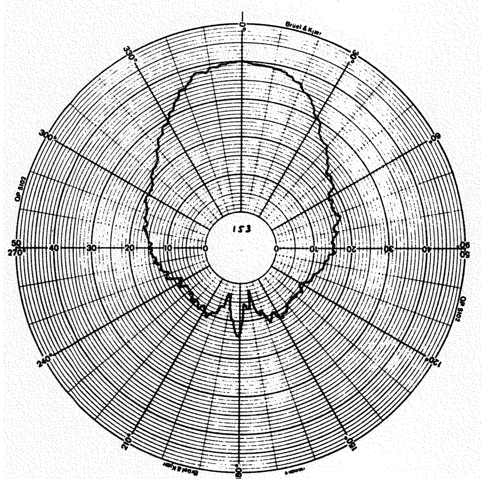
2 kHz, Vert.



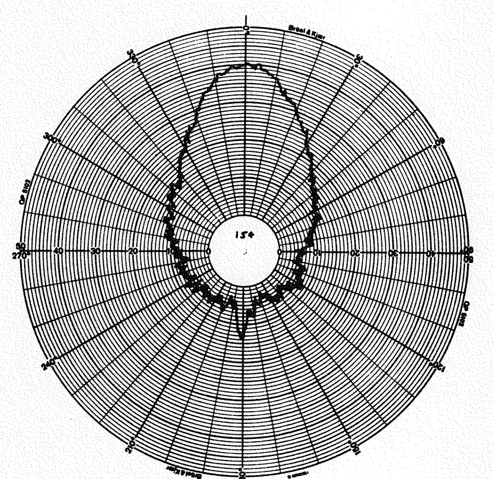
2.5 kHz, Hor.



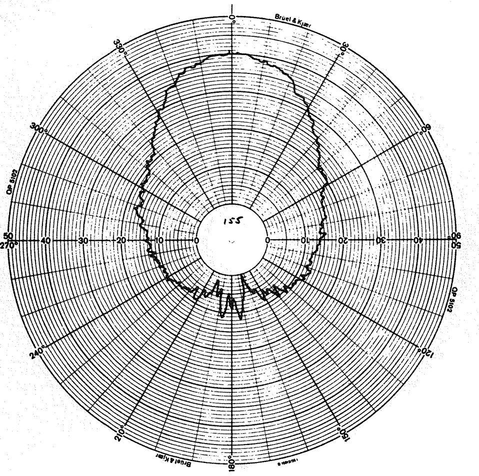
2.5 kHz, Vert.



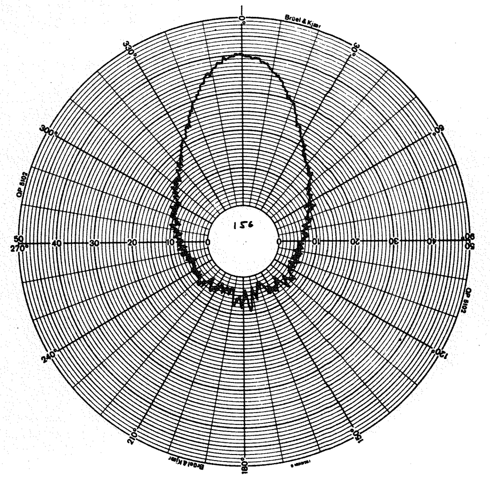
3.15 kHz, Hor.



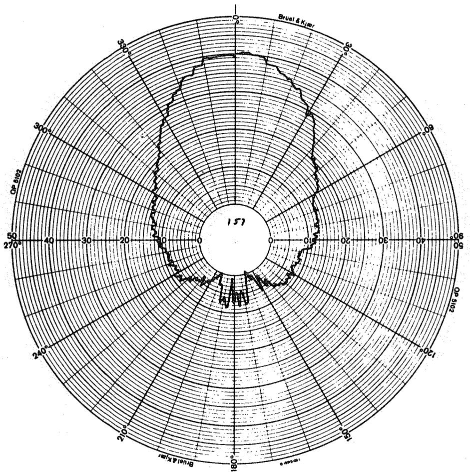
3.15 kHz, Vert.



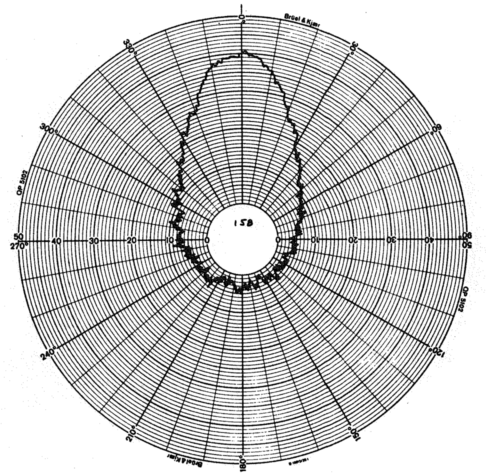
4 kHz, Hor.



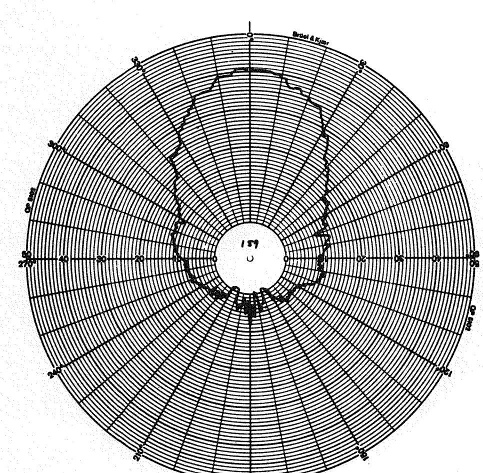
4 kHz, Vert.



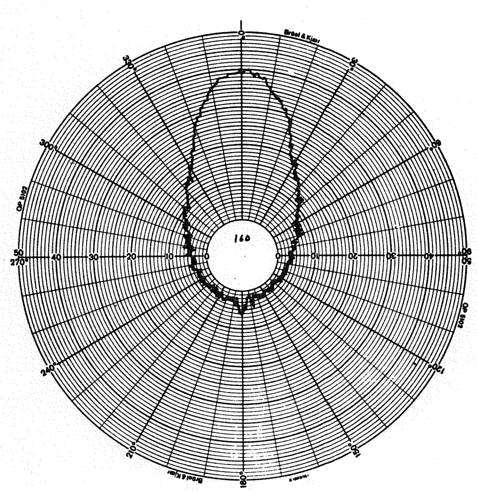
5 kHz, Hor.



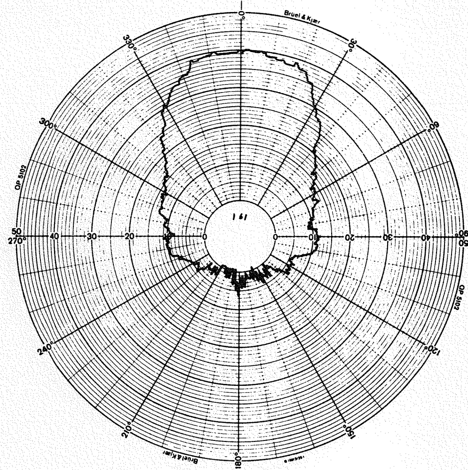
5 kHz, Vert.



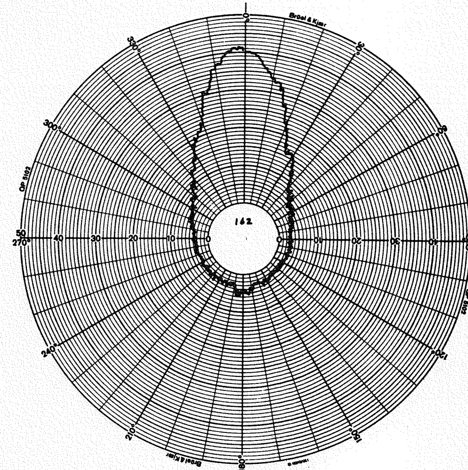
6.3 kHz, Hor.



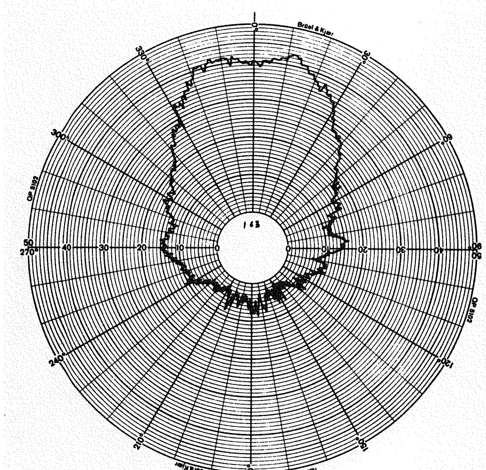
6.3 kHz, Vert.



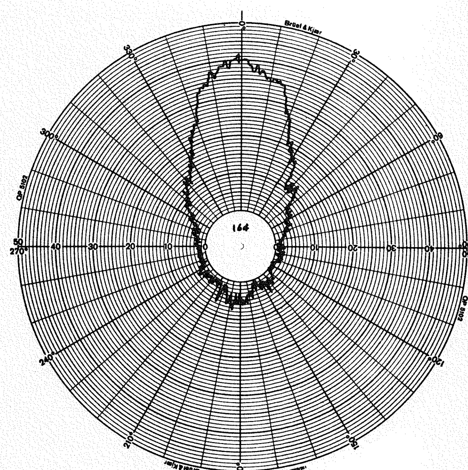
8 kHz, Hor.



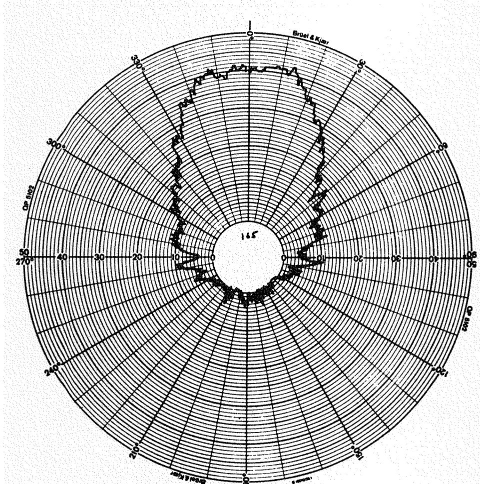
8 kHz, Vert.



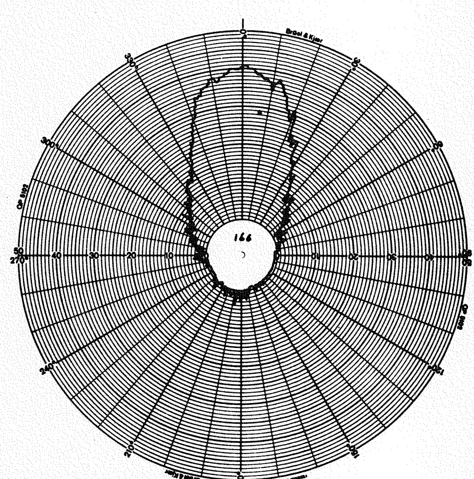
10 kHz, Hor.



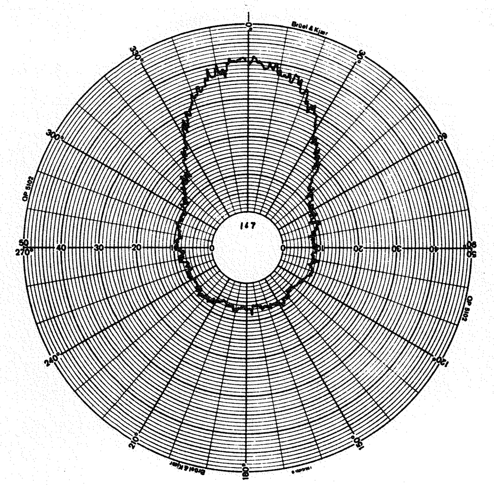
10 kHz, Vert.



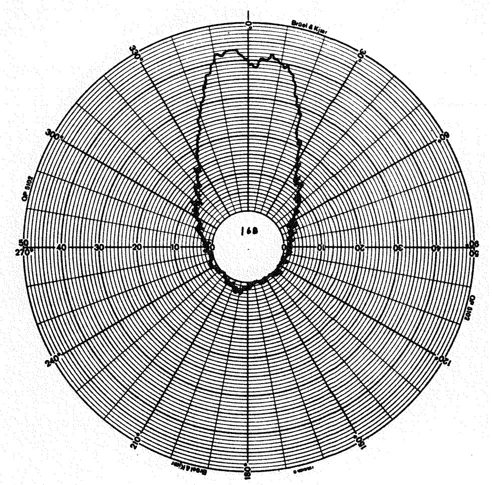
12.5 kHz, Hor.



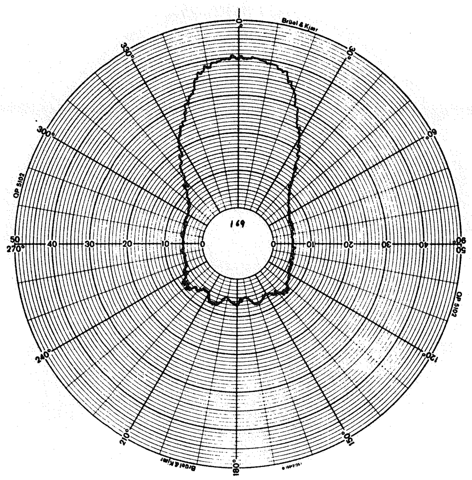
12.5 kHz, Vert.



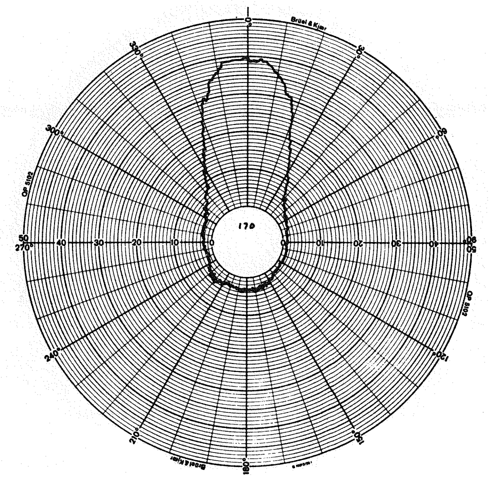
16 kHz, Hor.



16 kHz, Vert.

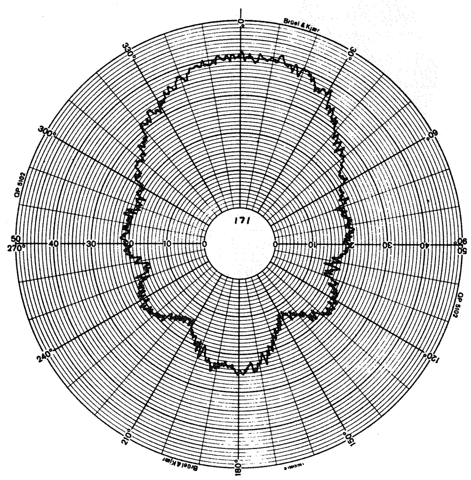


20 kHz, Hor.

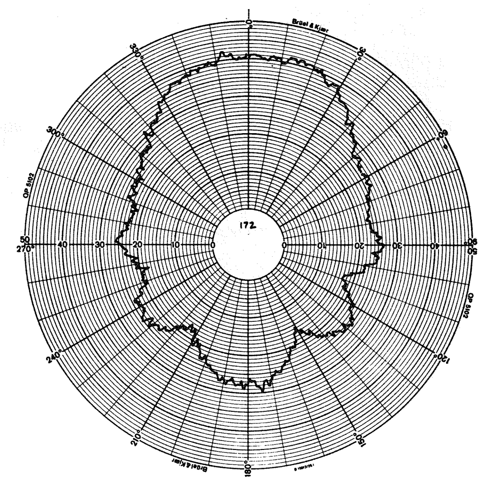


20 kHz, Vert.

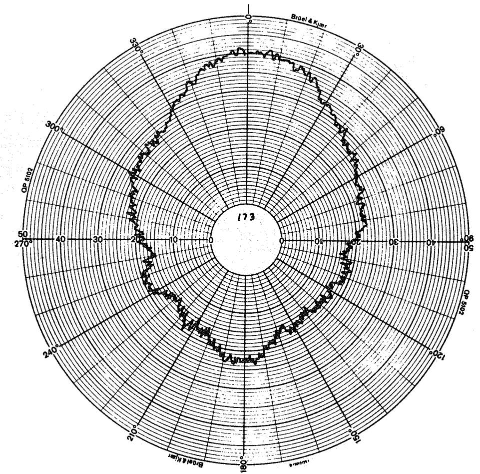
Appendix VI: EV HP4020



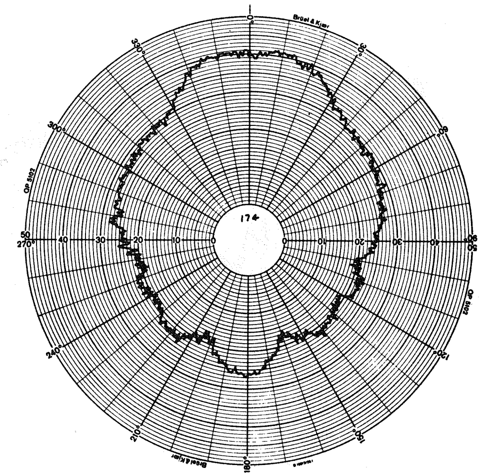
500 Hz, Hor.



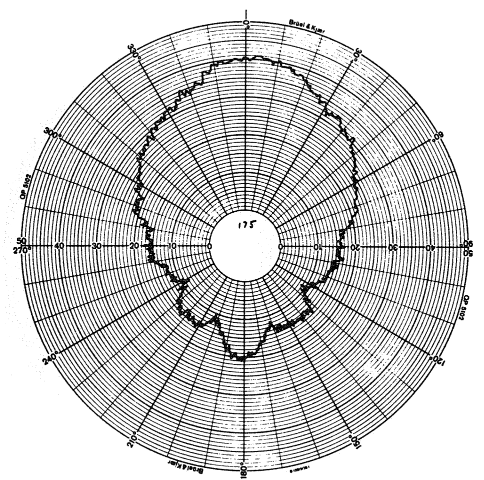
500 Hz, Vert.



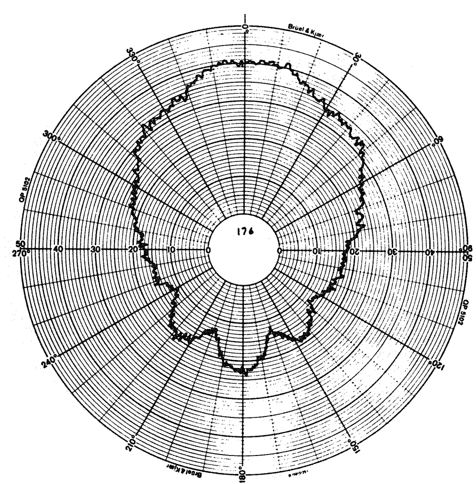
630 Hz, Hor.



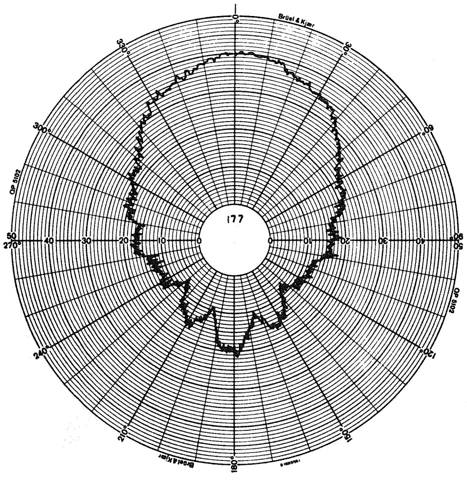
630 Hz, Vert.



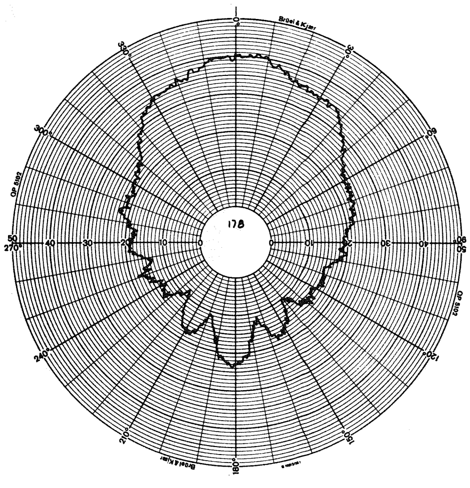
800 Hz, Hor.



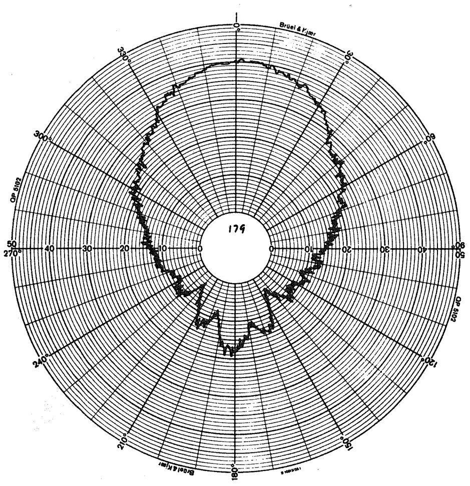
800 Hz, Vert.



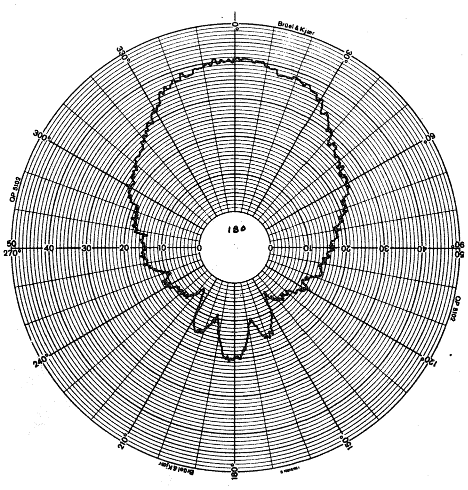
1 kHz, Hor.



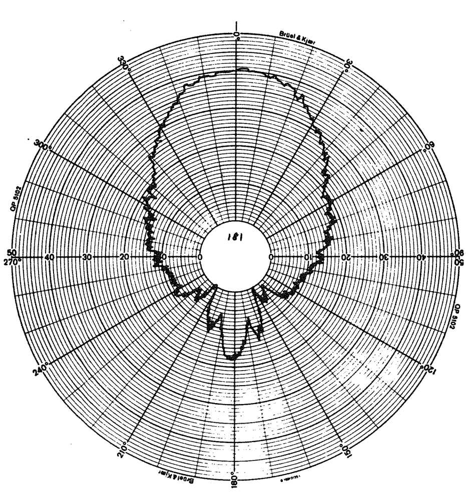
1 kHz, Vert.



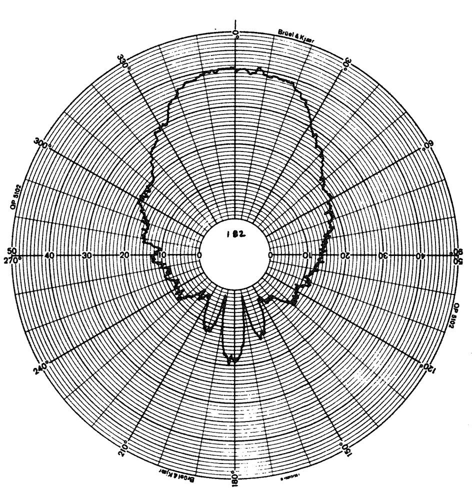
1.25 kHz, Hor.



1.25 kHz, Vert.

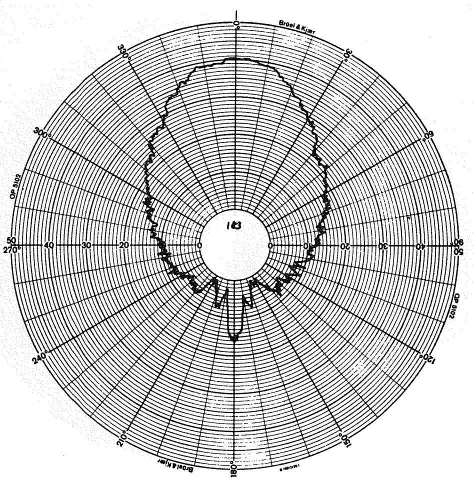


1.6 kHz, Hor.

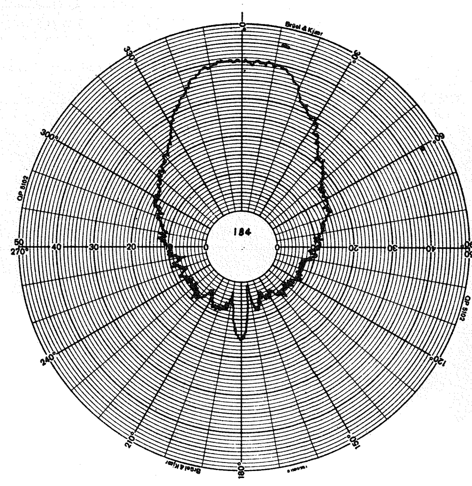


1.6 kHz, Vert.

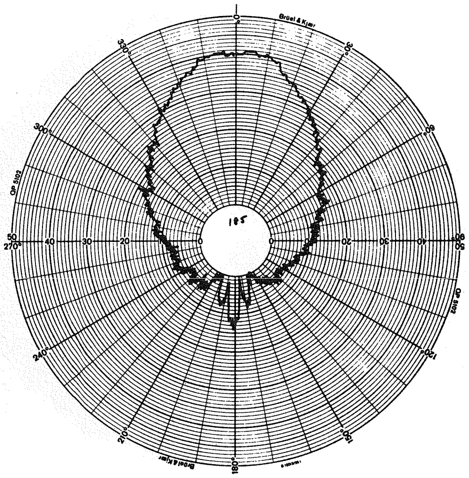
EV HP4020



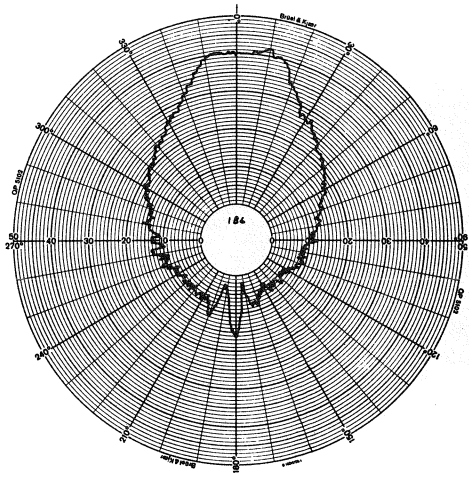
2 kHz, Hor.



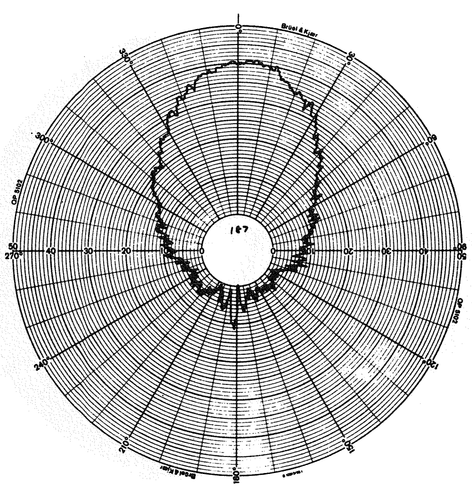
2 kHz, Vert.



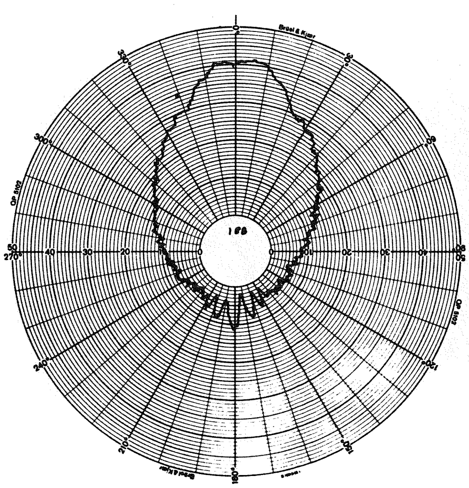
2.5 kHz, Hor.



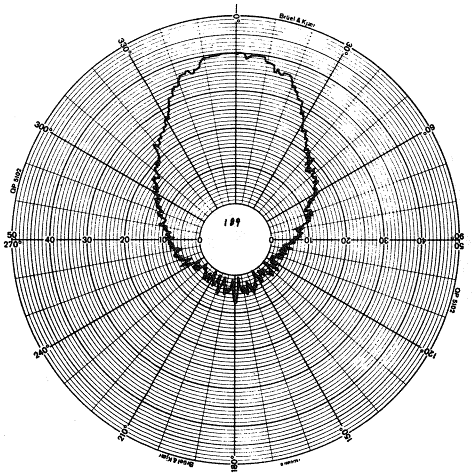
2.5 kHz, Vert.



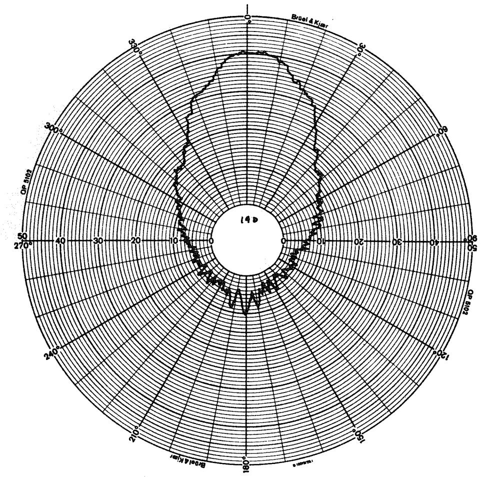
3.15 kHz, Hor.



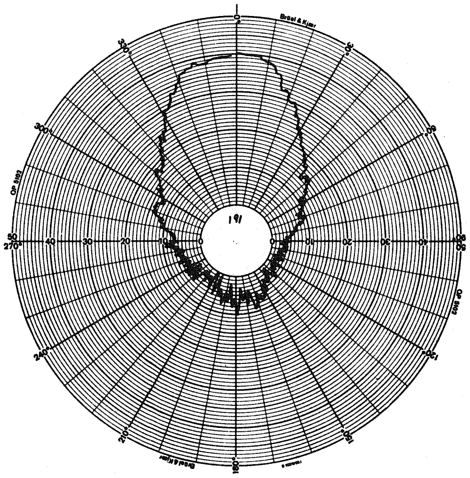
3.15 kHz, Vert.



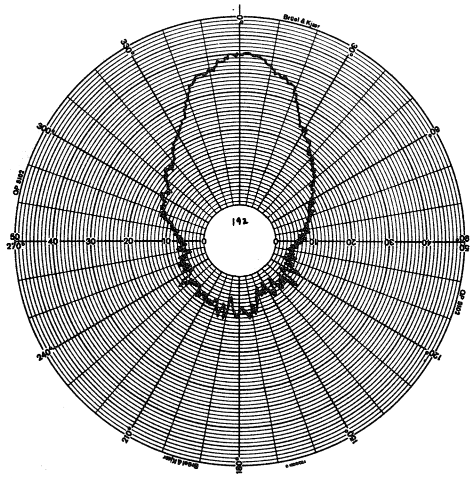
4 kHz, Hor.



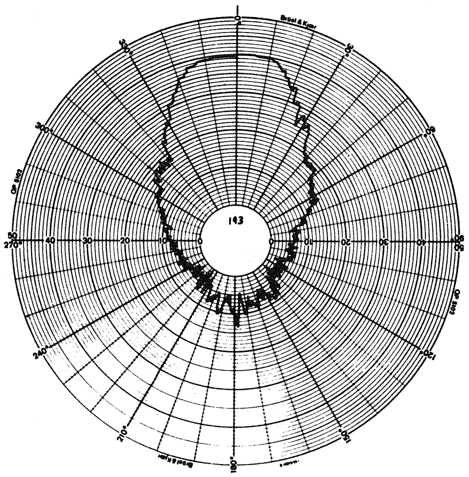
4 kHz, Vert.



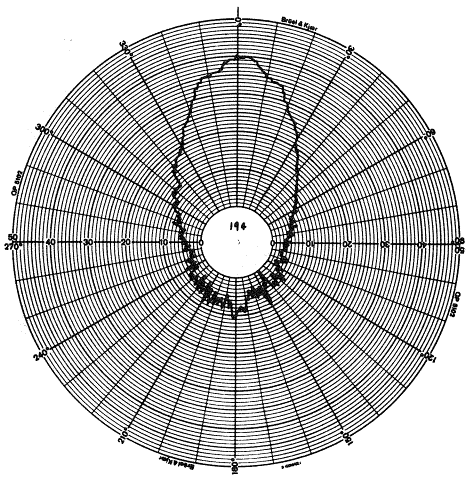
5 kHz, Hor.



5 kHz, Vert.

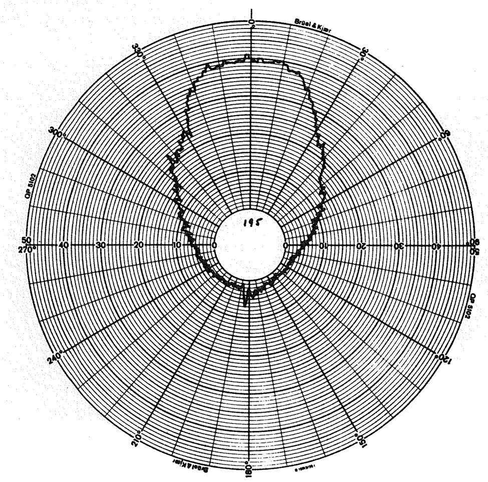


6.3 kHz, Hor.

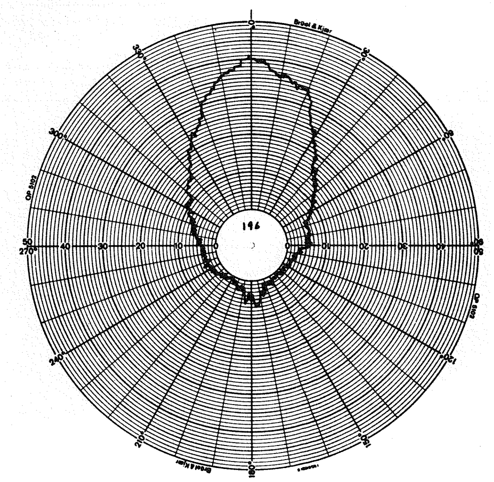


6.3 kHz, Vert.

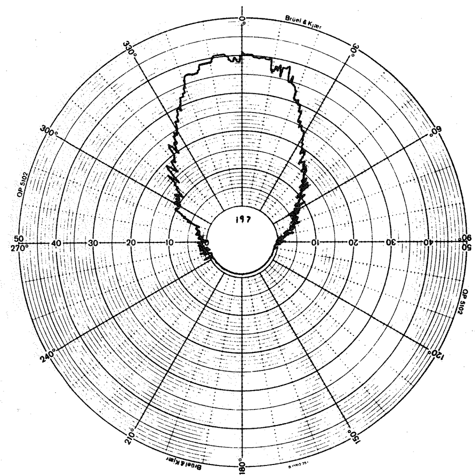
EV HP4020



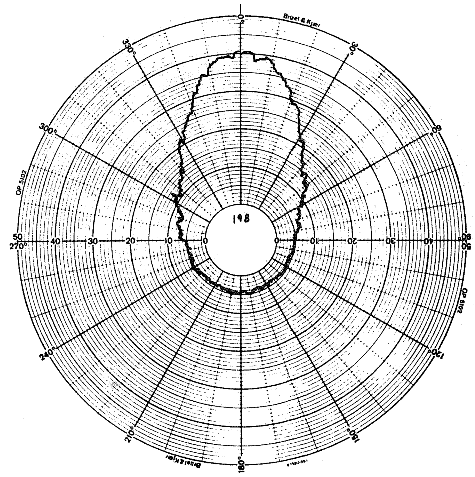
8 kHz, Hor.



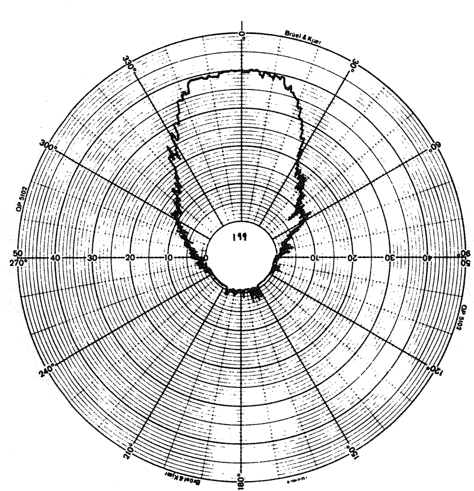
8 kHz, Vert.



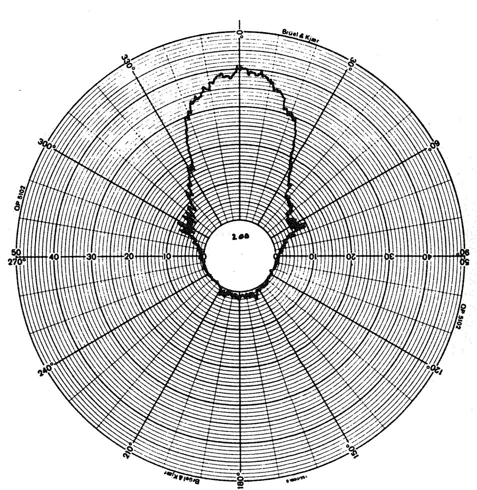
10 kHz, Hor.



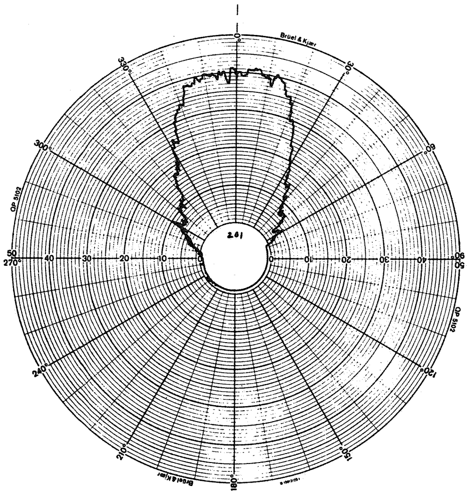
10 kHz, Vert.



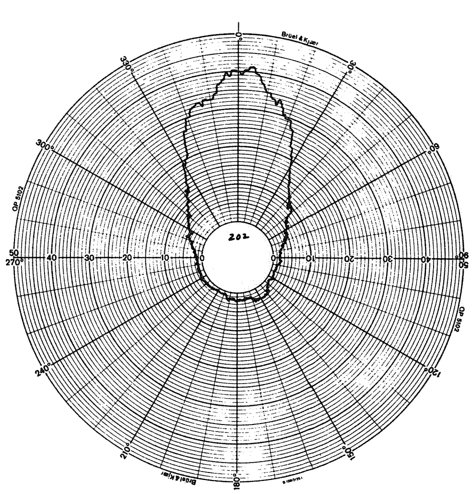
12.5 kHz, Hor.



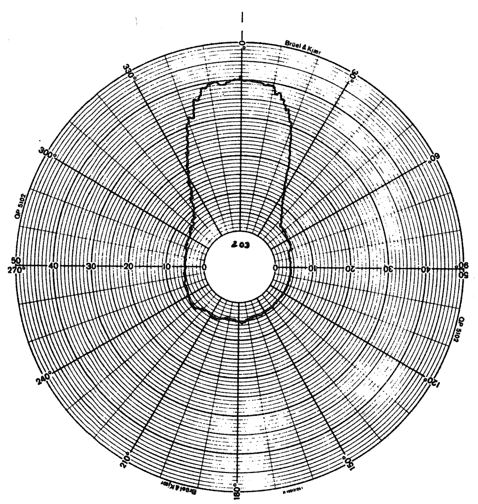
12.5 kHz, Vert.



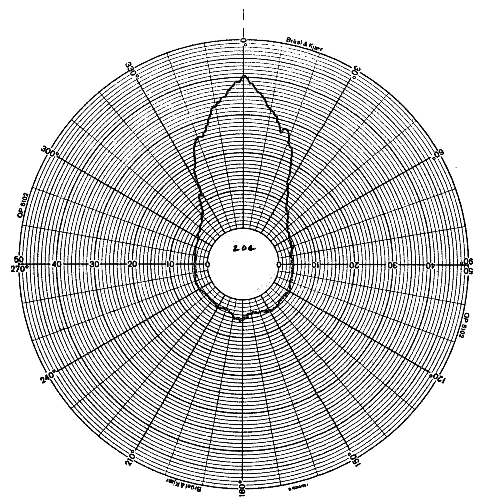
16 kHz, Hor.



16 kHz, Vert.



20 kHz, Hor.



20 kHz, Vert.

JBL

JBL Professional, 8500 Balboa Boulevard, P.O. Box 2200, Northridge, California 91329 U.S.A.