Engineering News
ALTEC
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1515 S. Manchester Avenue, Anaheim, California

TECHNICAL LETTER NO. 201-A

USEFUL DIRECTIVITY DATA FOR REVERBERANT SOUND FIELDS

By

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CALCULATION OF DIRECTIVITY FACTOR

The directivity factor (Q) of a loudspeaker is the ratio of the total power radiated by a hypothetical loudspeaker, having a uniform radiation pattern, to the given loudspeaker when each have identical symmetry on the principle axis of symmetry. Although the analytical calculation can be made for many simple models (1), most real loudspeakers deviate from mathematical models so that data must be taken for accurate results.

When the sound radiation pattern under examination can be considered to have radial symmetry about its pricinpal axis; i.e., a figure of revolution; the Q can be calculated from the following integral in Equation 1.

(Eq. 1)

$$Q = \frac{2}{\int_{0}^{\frac{\pi}{2}} \left[P_{(\theta)} \right]^{2} \sin\theta \, d\theta}$$

Where Q is the directivity factor

P_o is 1

θ is the polar angle

The graphical evaluation of this integral suggested by Bauer (2), has been used in reducing several hundred polar response curves to Qs, which are presented in the data sheets.

TEST SETUP

Polar response patterns were run on the various horns and low-frequency loudspeakers with the test setup shown in Figure 1. One third-octave band filtered pink noise was used as a test signal, except in the broadband measurements where a 500 Hz to 3000 Hz passband was obtained by using an ALTEC 9067B adjustable bandpass filter.

DATA PRESENTATION

Polar patterns were obtained in both horizontal and vertical orientations wherever possible. The integral (1) was obtained by graphical means from each polar plot and the resulting Q was plotted, as a function of frequency, for each loudspeaker. This was done for both horizontal and vertical polar data. This technique offers the important advantage of providing both integrated horizontal and vertical directivity information, as well as allowing a <u>mean</u> Q* figure to be calculated for the effective Q in a highly reverberant space. The mean Q figure used is a geometric mean based on the area of the rectangle formed by the horizontal and vertical coverage angles as expressed in Equation 2.

(Eq. 2)

$$\text{Mean } Q^* = \frac{\pi}{4} \sqrt{Q_H \cdot Q_V}$$

Where Mean Q is the mean directivity factor

Q_H is the apparent horizontal directivity factor

Q_V is the apparent vertical directivity factor

It is interesting to reverse this process and assign coverage angles to the loudspeakers, based on the concept that the total sound power radiated is through a rectangular window. These angles are indicated on the right margin of the "Q versus Frequency" curves and should be used to read a rough horizontal and vertical coverage from the Q_H and Q_V curves, respectively.

In addition to the "Q versus Frequency" curves, typical polar response patterns have been included for preferred horn-driver combinations at a 1/3-ocrave frequency band centered at 1000 Hz. These curves have been split in half to display both the horizontal and vertical polar response on one sheet. These curves are typical of several hundred that were recorded and that are on file for reference.

(1) Hopkins and Stryker, Procedures of I.E.E., March, 1948, P4.
(2) B.B. Baumzeiger (Bauer), J.A.S.A. No. 11, 1940, P477

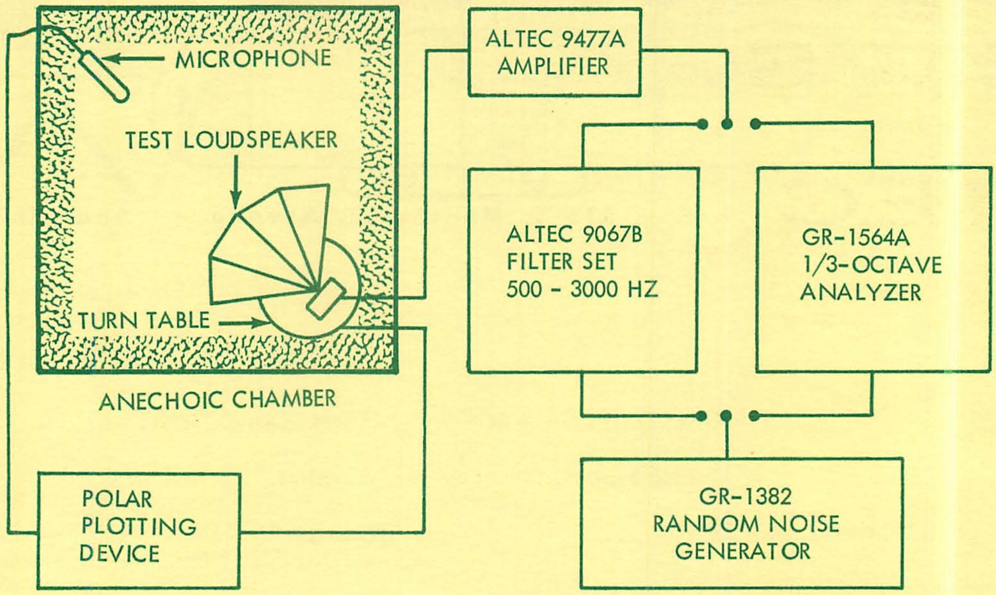
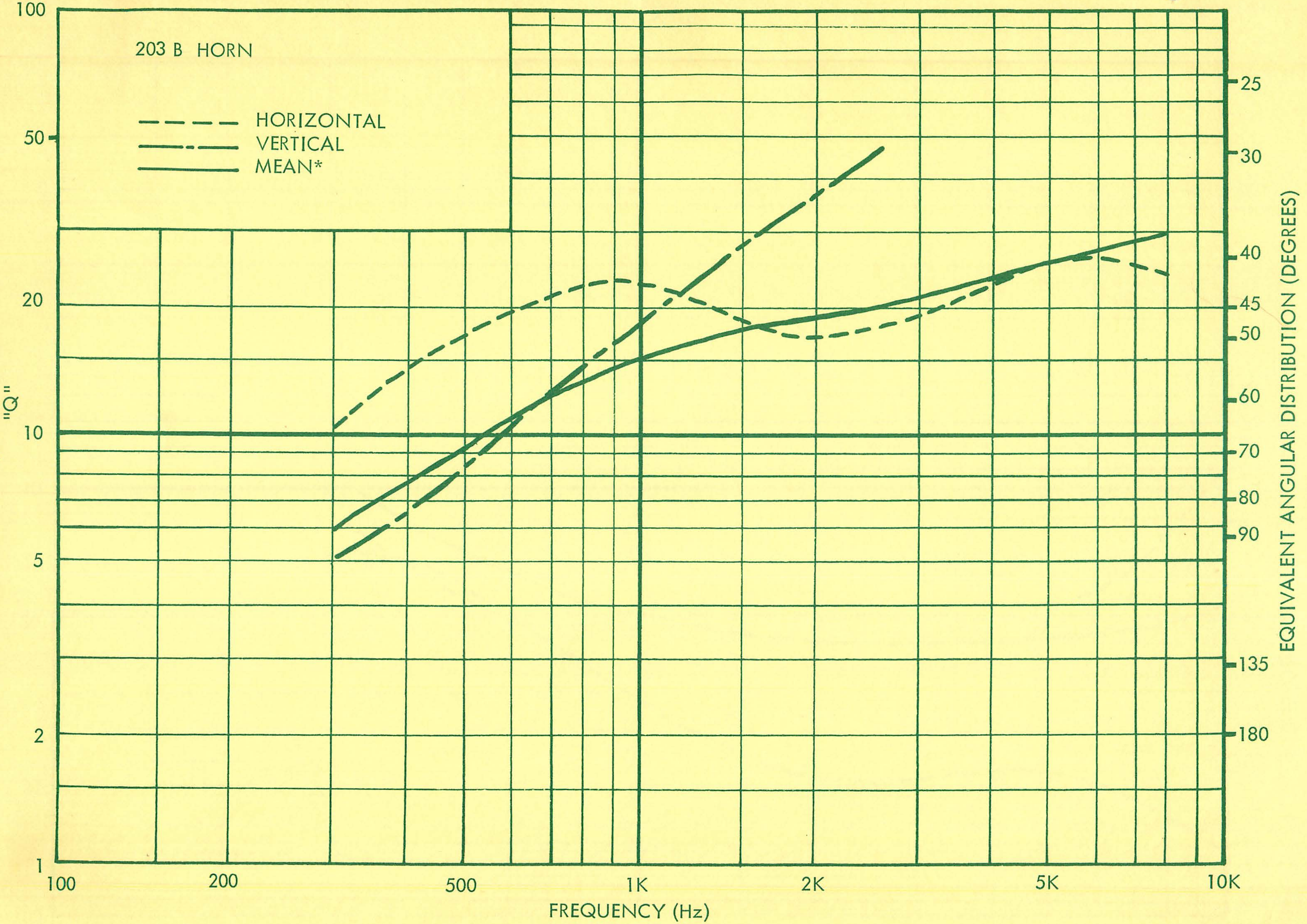
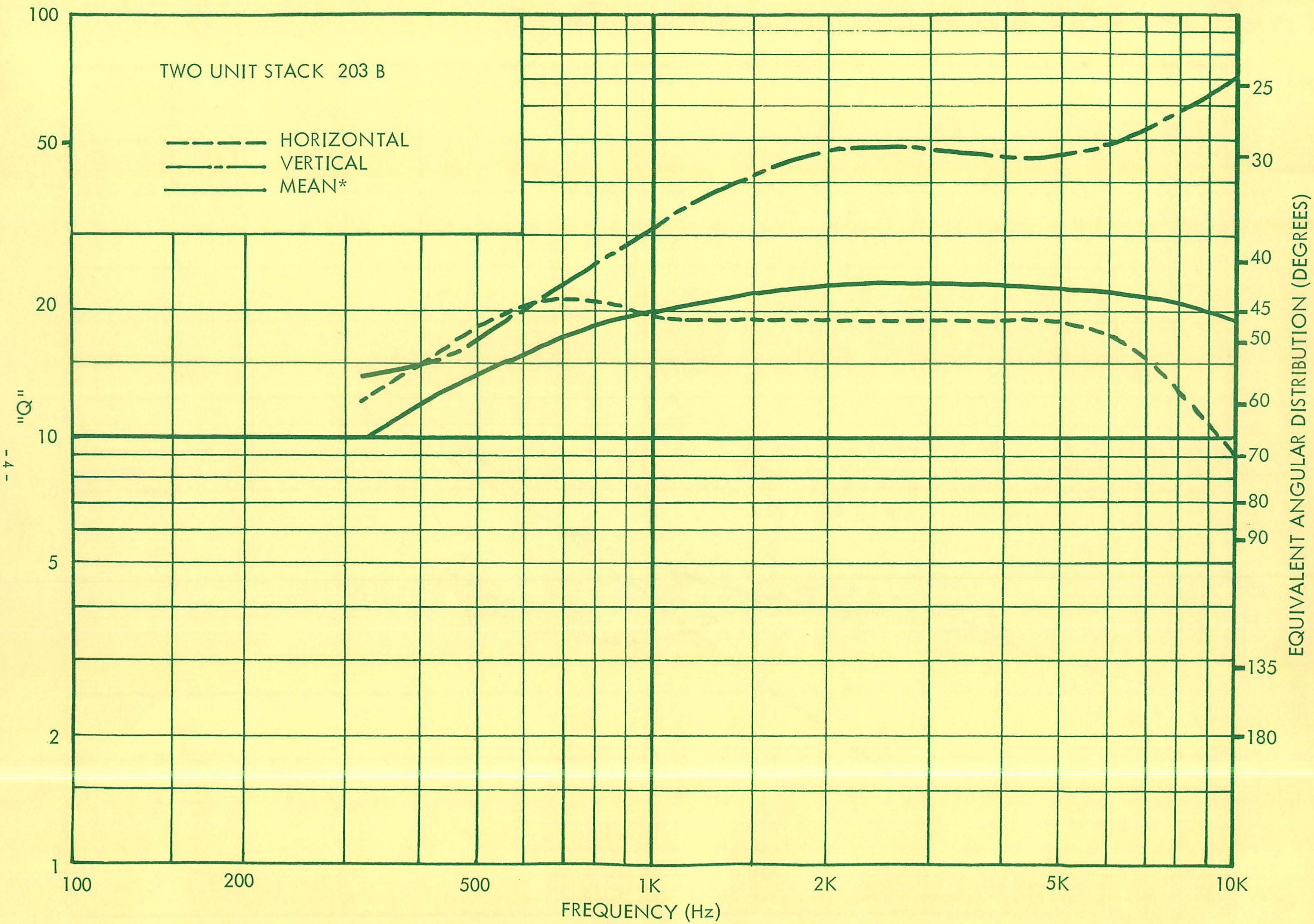
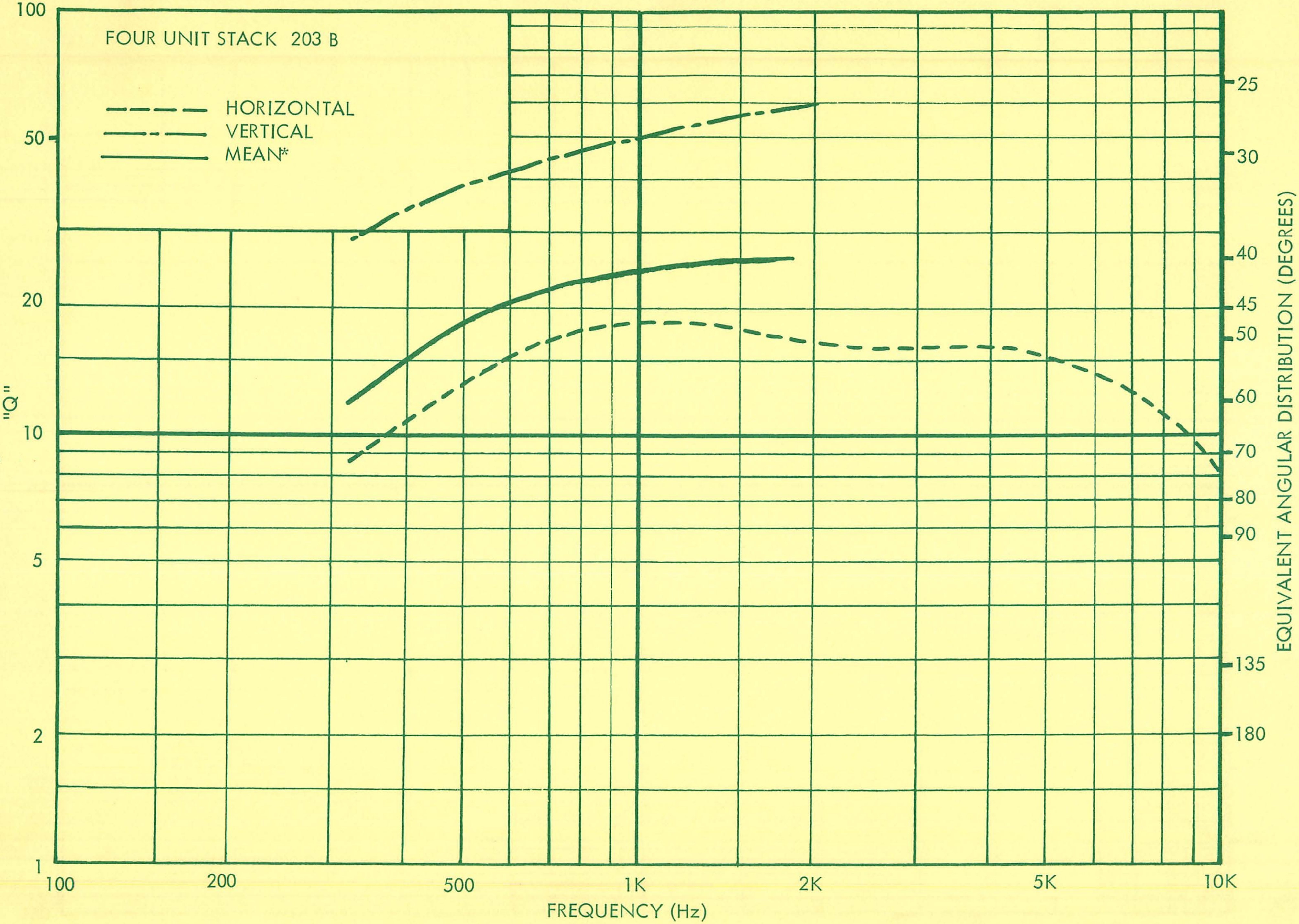


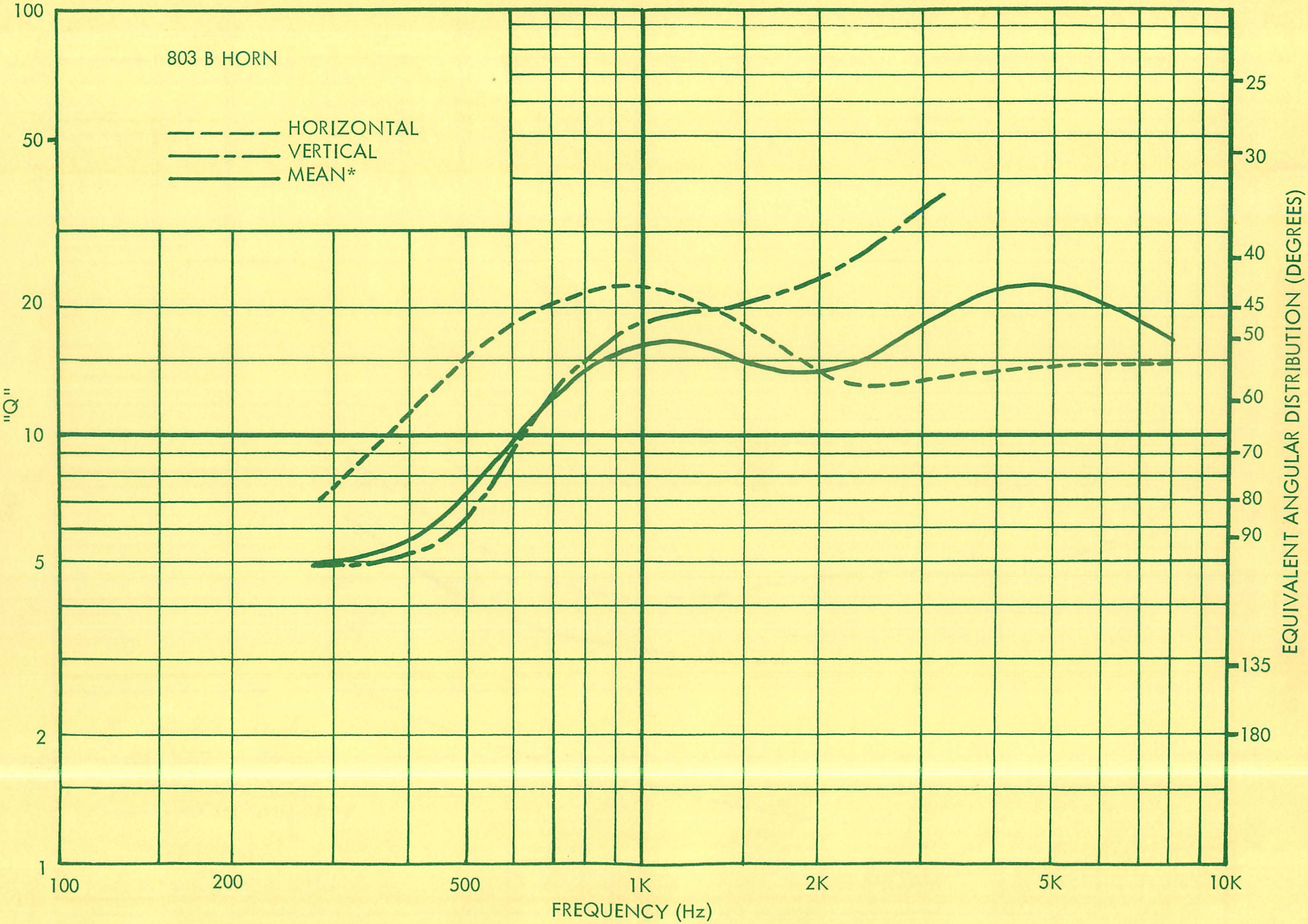
Figure 1. Test Setup for Measuring Polar Response Patterns

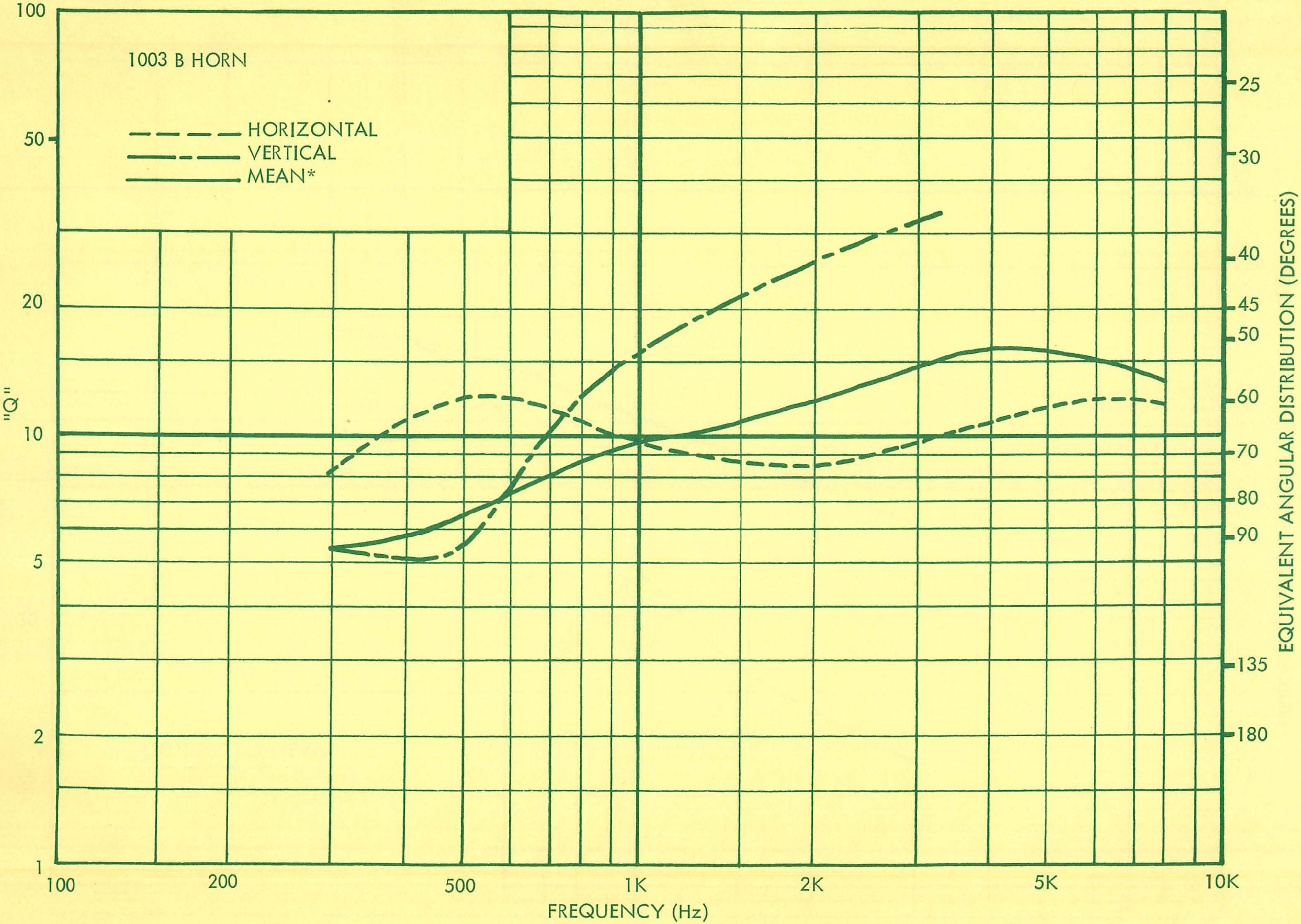

203 B HORN
HORIZONTAL
VERTICAL
MEAN*
"Q"
100
50
20
10
5
2
1
100
200
500
1K
2K
5K
10K
FREQUENCY (Hz)
EQUIVALENT ANGULAR DISTRIBUTION (DEGREES)
25
30
40
45
50
60
70
80
90
135
180

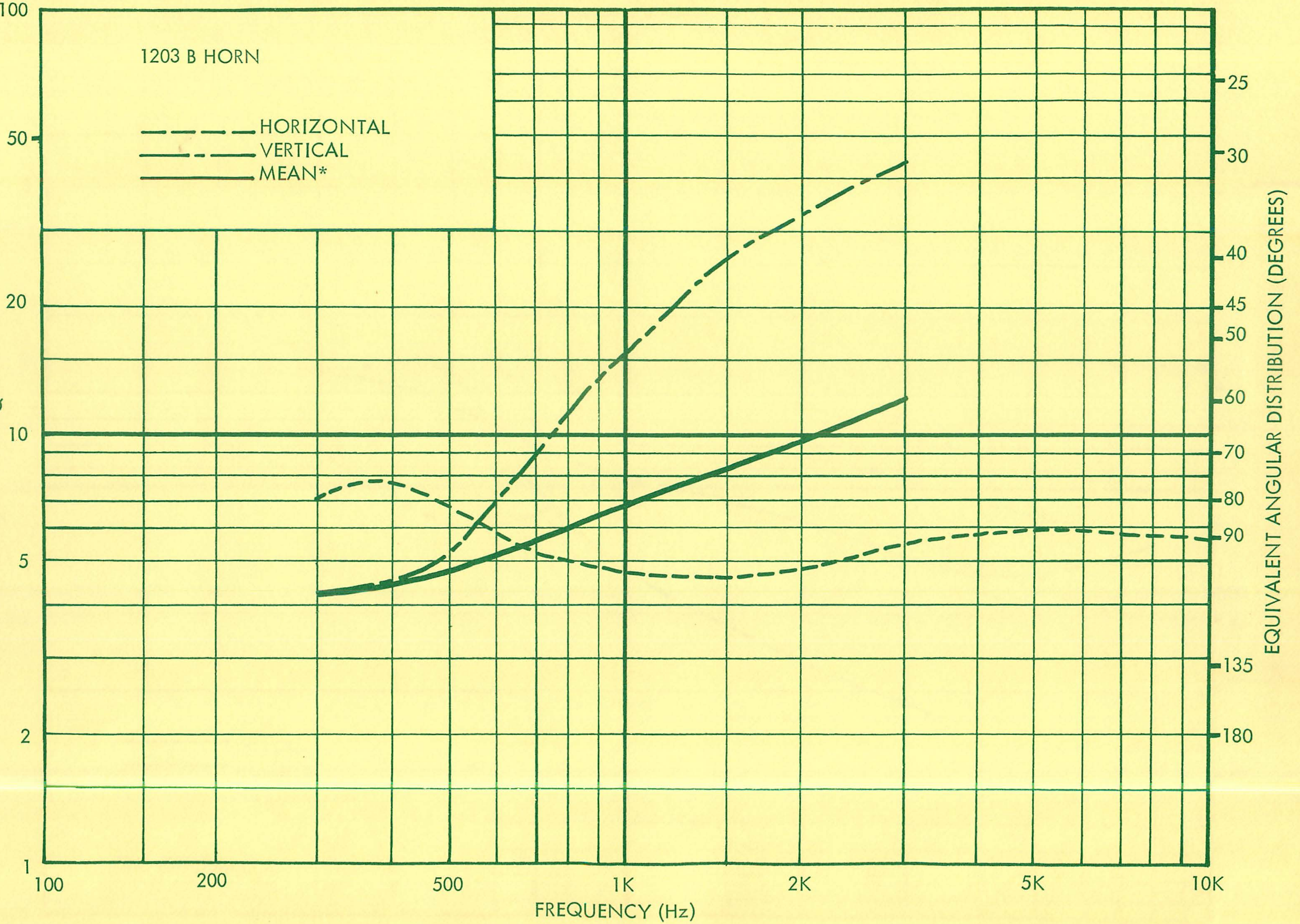

TWO UNIT STACK 203 B
HORIZONTAL
VERTICAL
MEAN*
"Q"
100
50
20
10
5
2
1
100
200
500
1K
2K
5K
10K
FREQUENCY (Hz)
EQUIVALENT ANGULAR DISTRIBUTION (DEGREES)
25
30
40
45
50
60
70
80
90
135
180

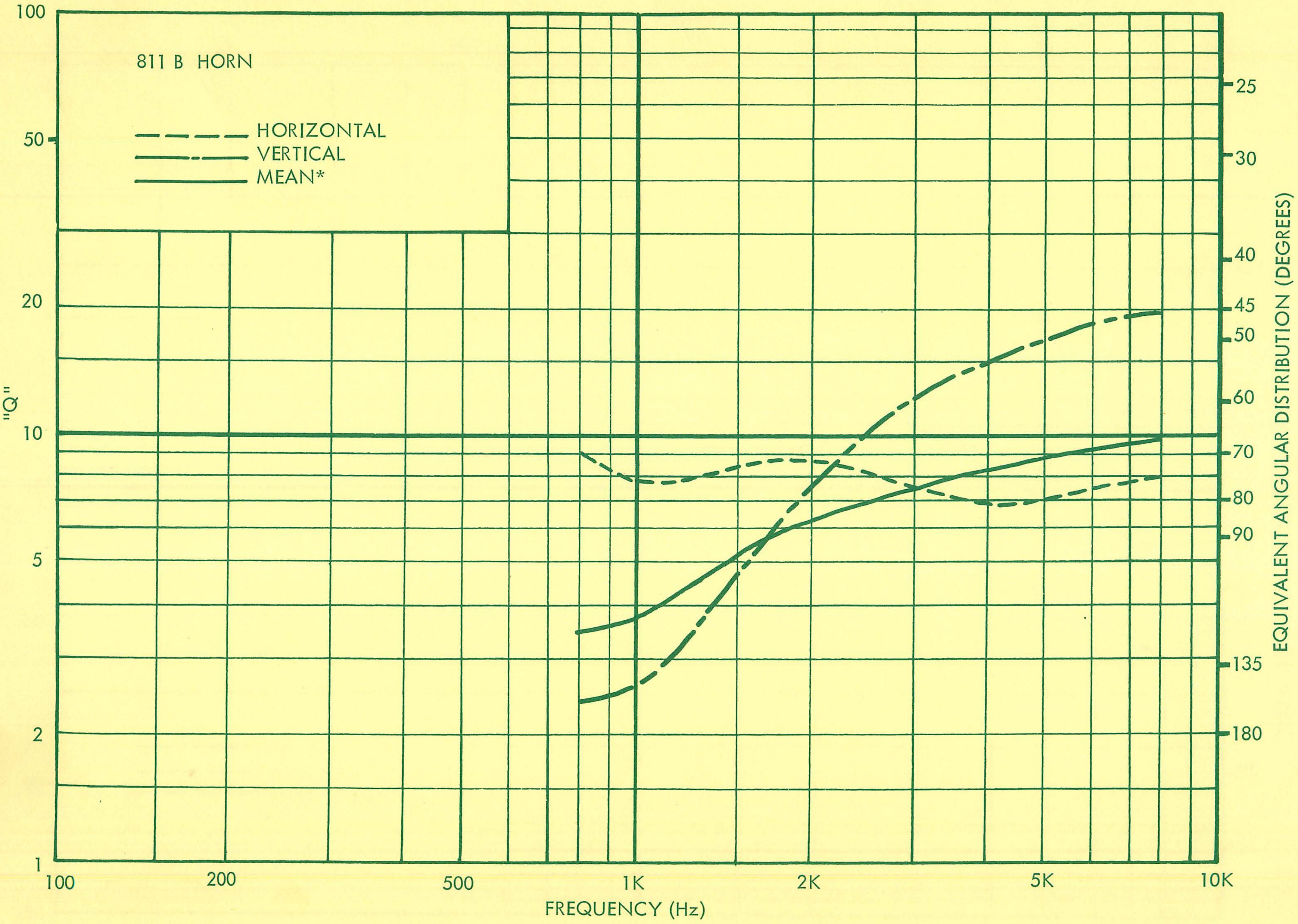


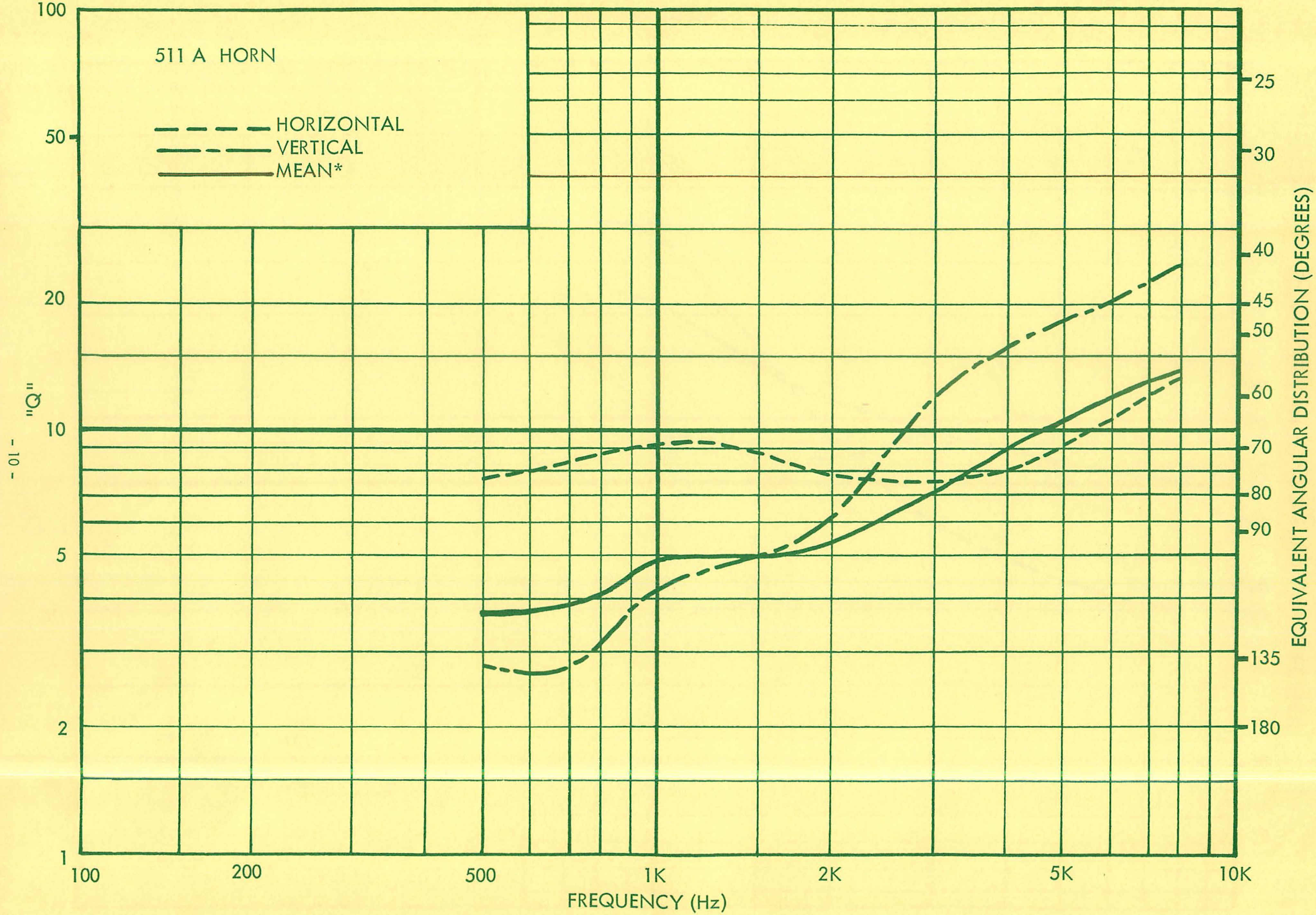
FOUR UNIT STACK 203 B
HORIZONTAL
VERTICAL
MEAN*
100
50
20
10
5
2
1
"Q"
25
30
40
45
50
60
70
80
90
135
180
EQUIVALENT ANGULAR DISTRIBUTION (DEGREES)
100
200
500
1K
2K
5K
10K
FREQUENCY (Hz)

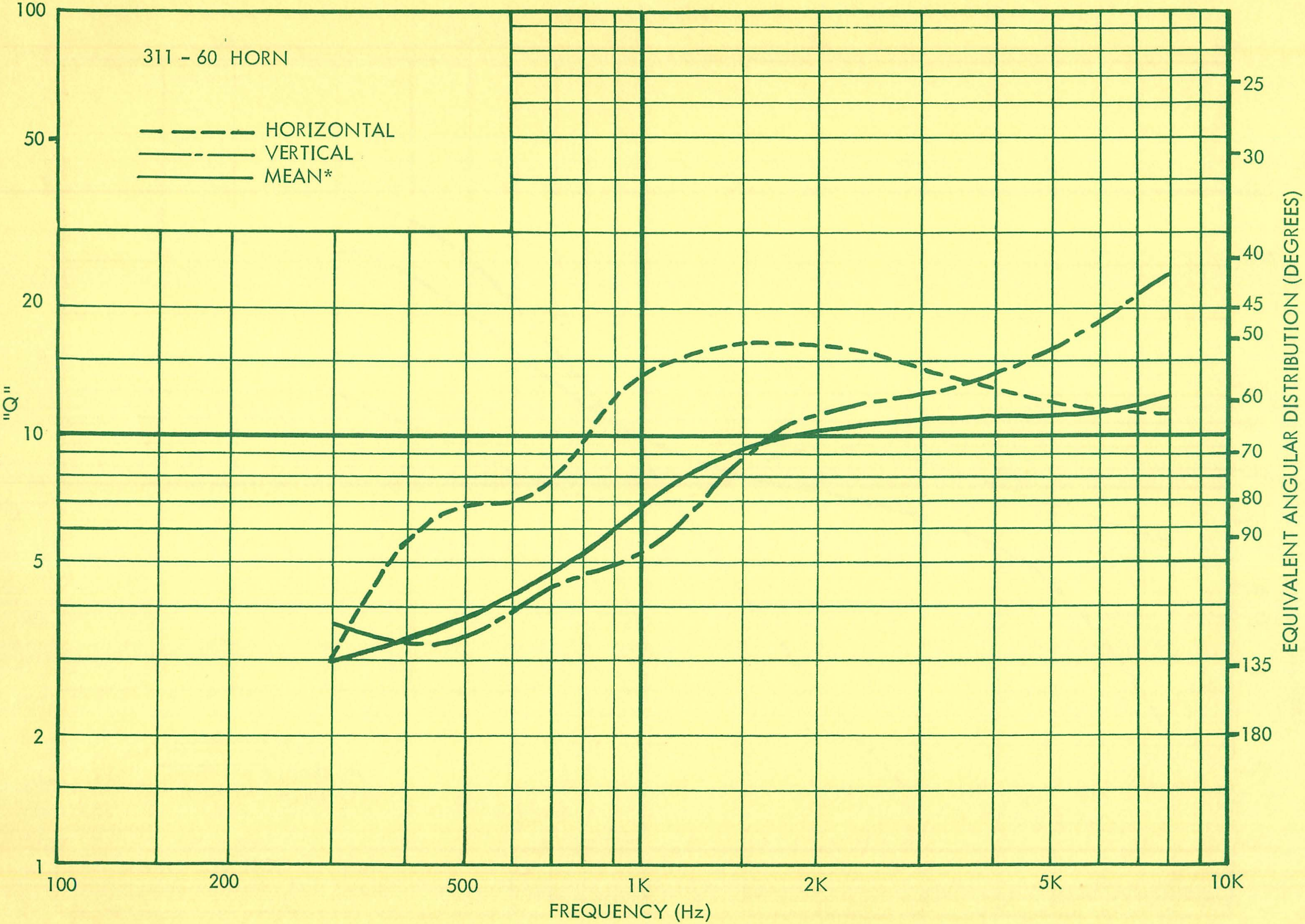

803 B HORN
HORIZONTAL
VERTICAL
MEAN*
"Q"
100
50
20
10
5
2
1
100
200
500
1K
2K
5K
10K
FREQUENCY (Hz)
EQUIVALENT ANGULAR DISTRIBUTION (DEGREES)
25
30
40
45
50
60
70
80
90
135
180

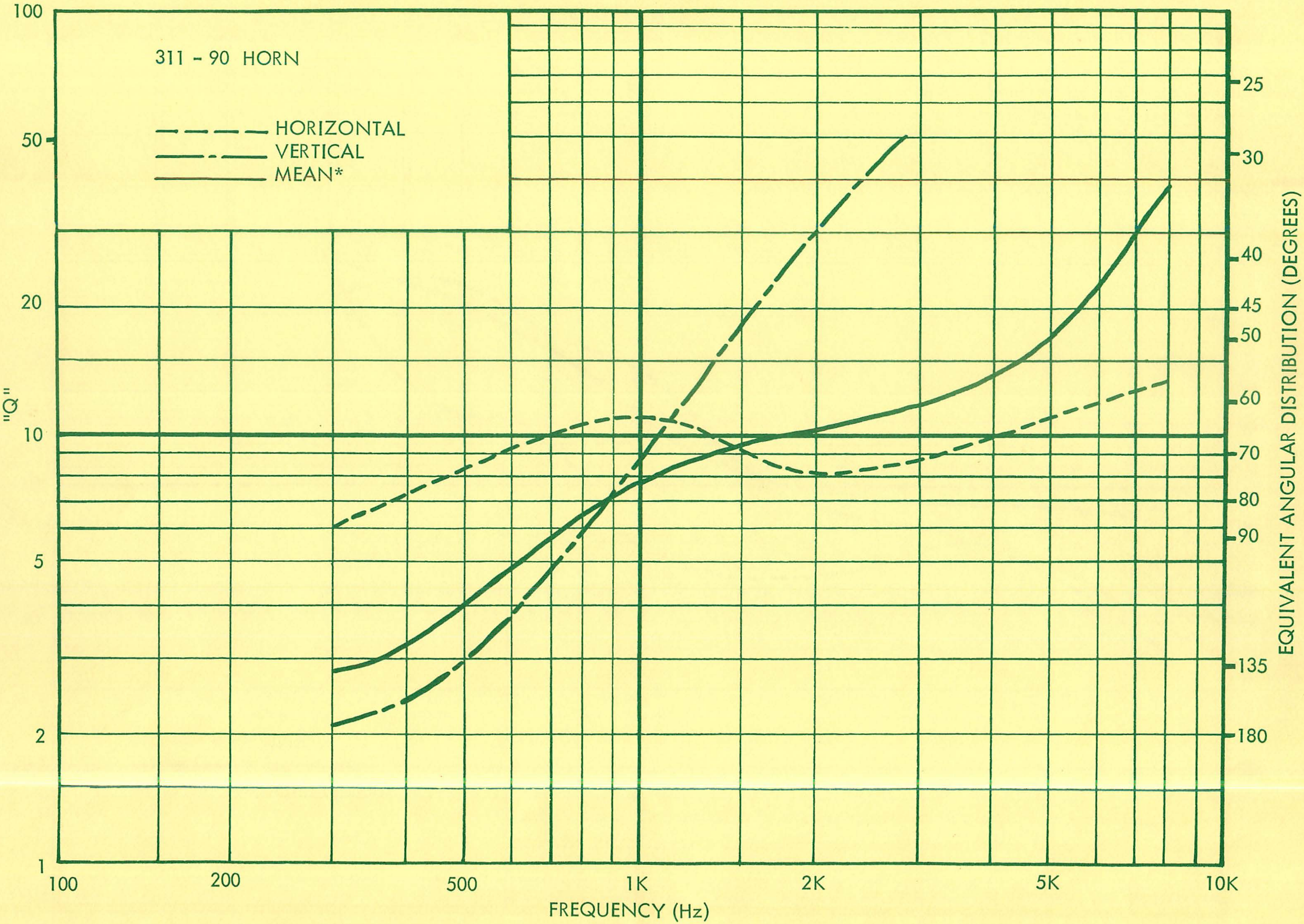

1003 B HORN
HORIZONTAL
VERTICAL
MEAN*
"Q"
100
50
20
10
5
2
1
25
30
40
45
50
60
70
80
90
135
180
EQUIVALENT ANGULAR DISTRIBUTION (DEGREES)
100
200
500
1K
2K
5K
10K
FREQUENCY (Hz)

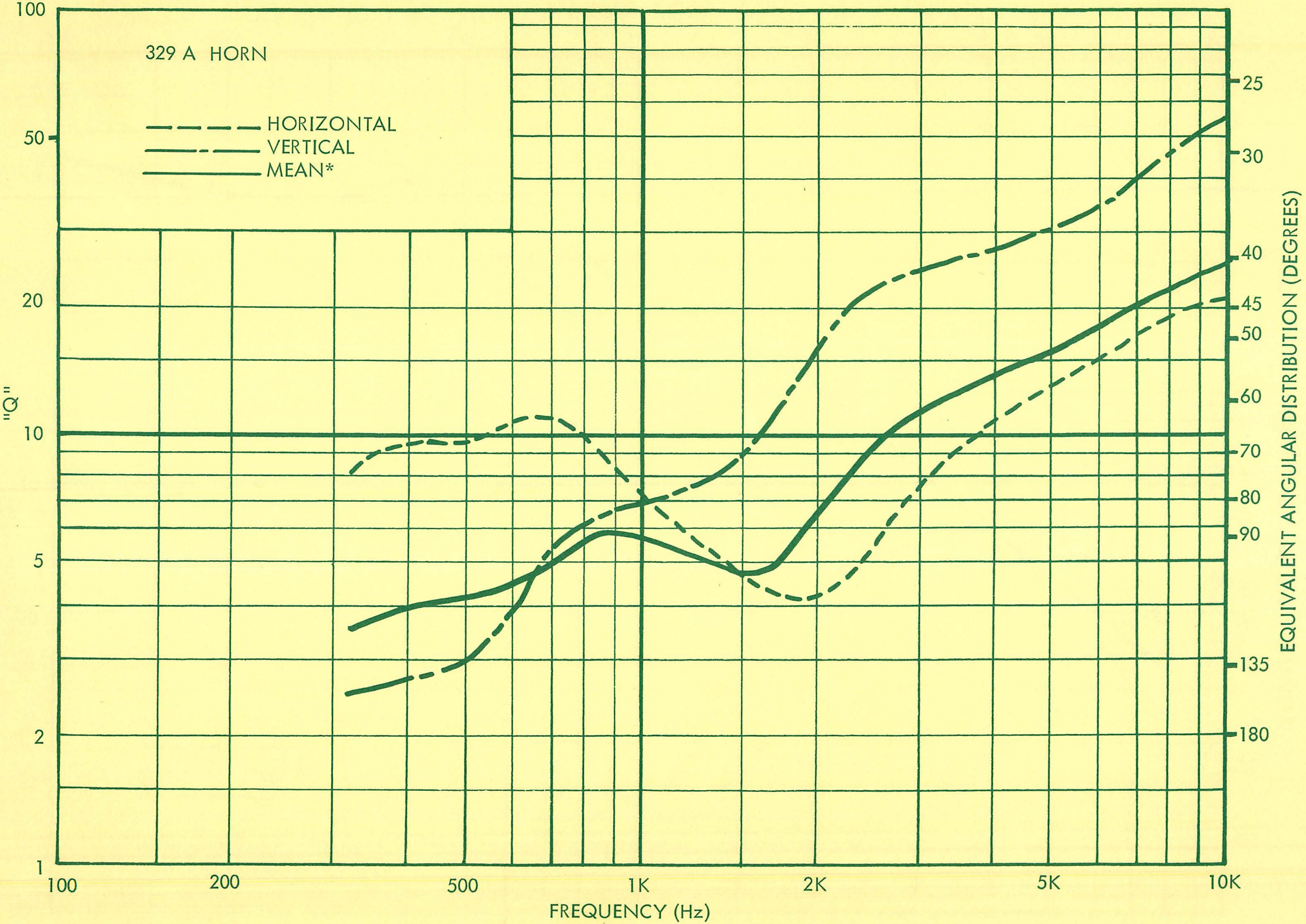

1203 B HORN
HORIZONTAL
VERTICAL
MEAN*
"Q"
100
50
20
10
5
2
1
100
200
500
1K
2K
5K
10K
FREQUENCY (Hz)
EQUIVALENT ANGULAR DISTRIBUTION (DEGREES)
25
30
40
45
50
60
70
80
90
135
180

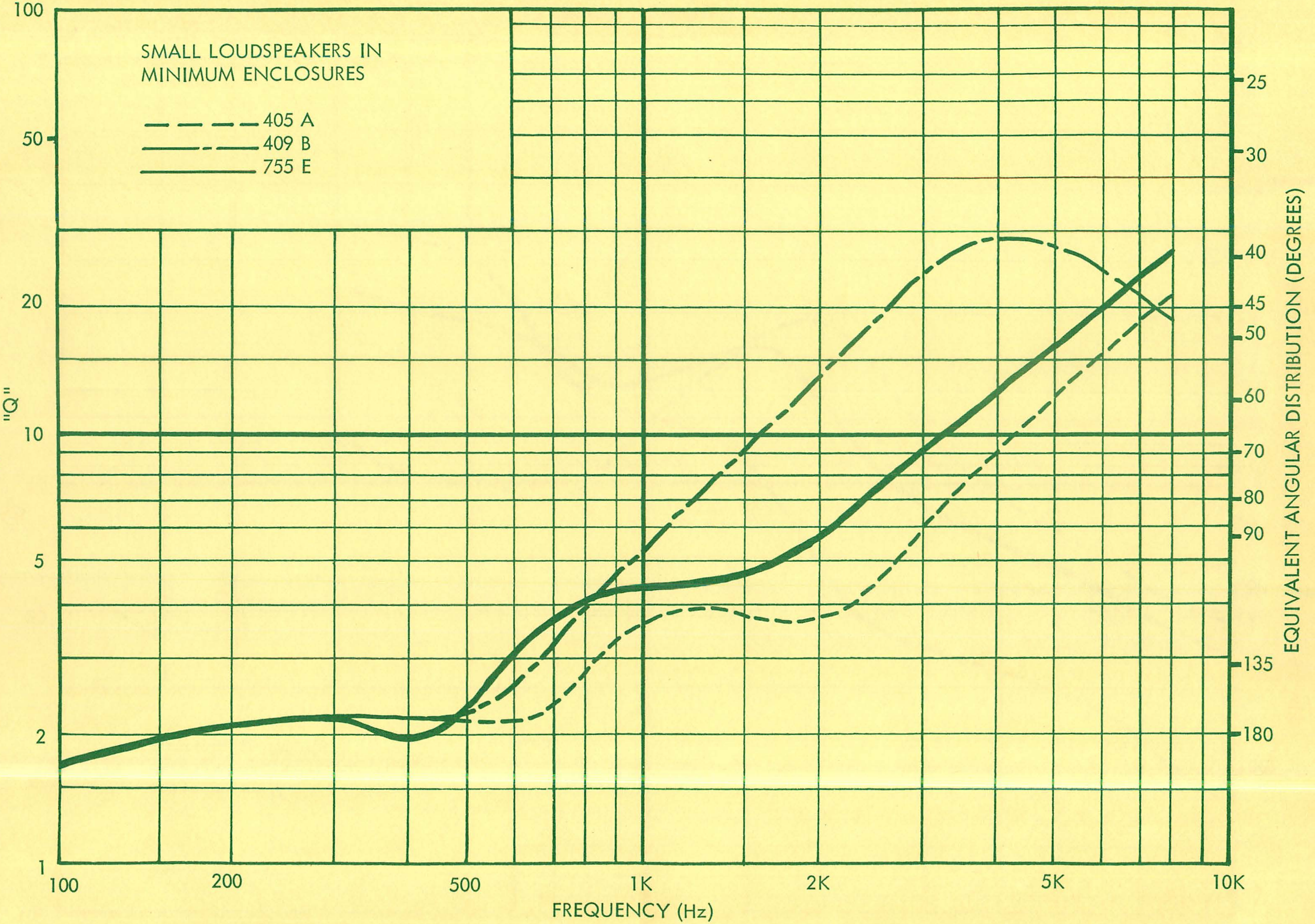

811 B HORN
HORIZONTAL
VERTICAL
MEAN*
"Q"
100
50
20
10
5
2
1
100
200
500
1K
2K
5K
10K
FREQUENCY (Hz)
EQUIVALENT ANGULAR DISTRIBUTION (DEGREES)
25
30
40
45
50
60
70
80
90
135
180

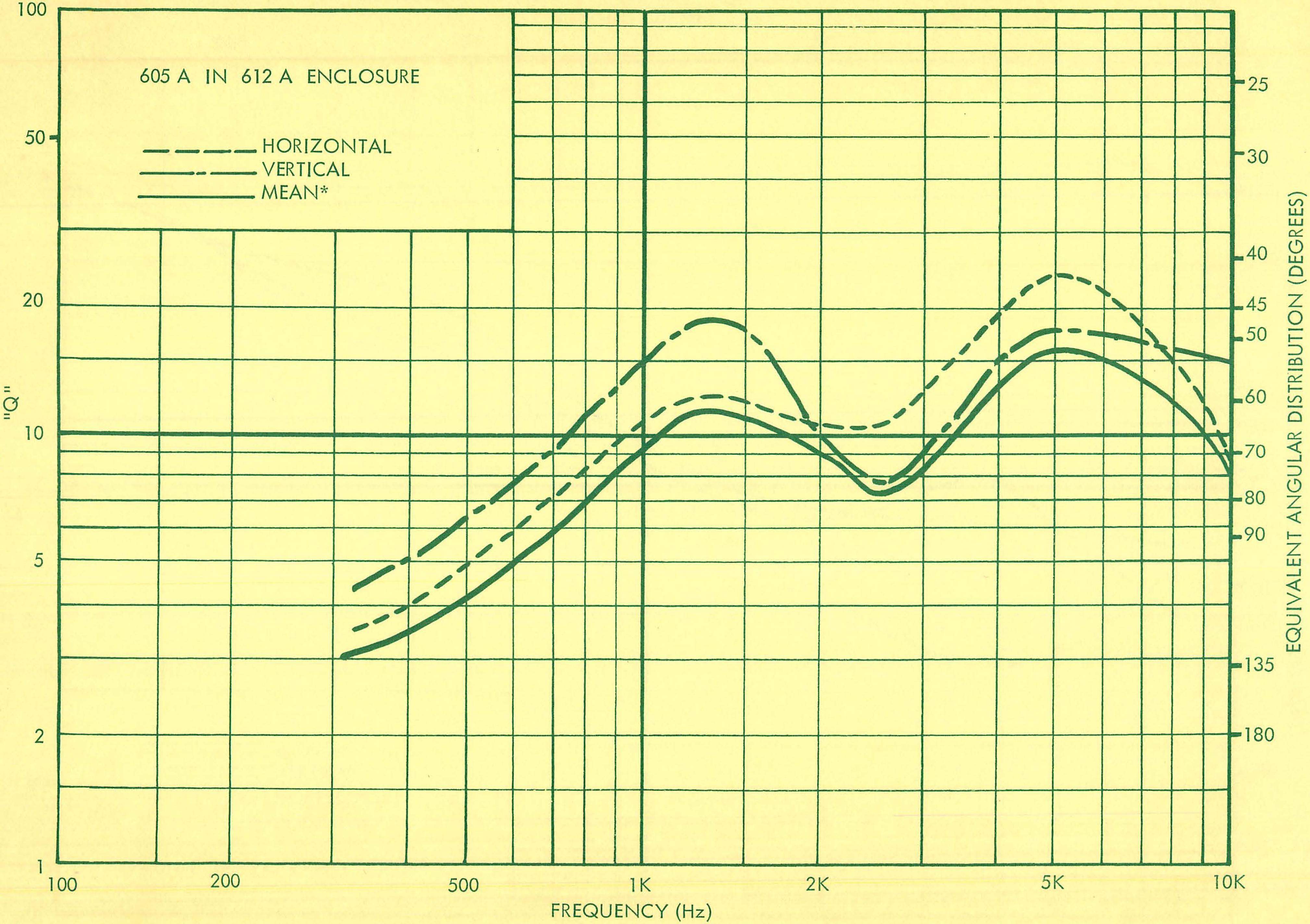

511 A HORN
HORIZONTAL
VERTICAL
MEAN*
"Q"
100
50
20
10
5
2
1
EQUIVALENT ANGULAR DISTRIBUTION (DEGREES)
25
30
40
45
50
60
70
80
90
135
180
100
200
500
1K
2K
5K
10K
FREQUENCY (Hz)

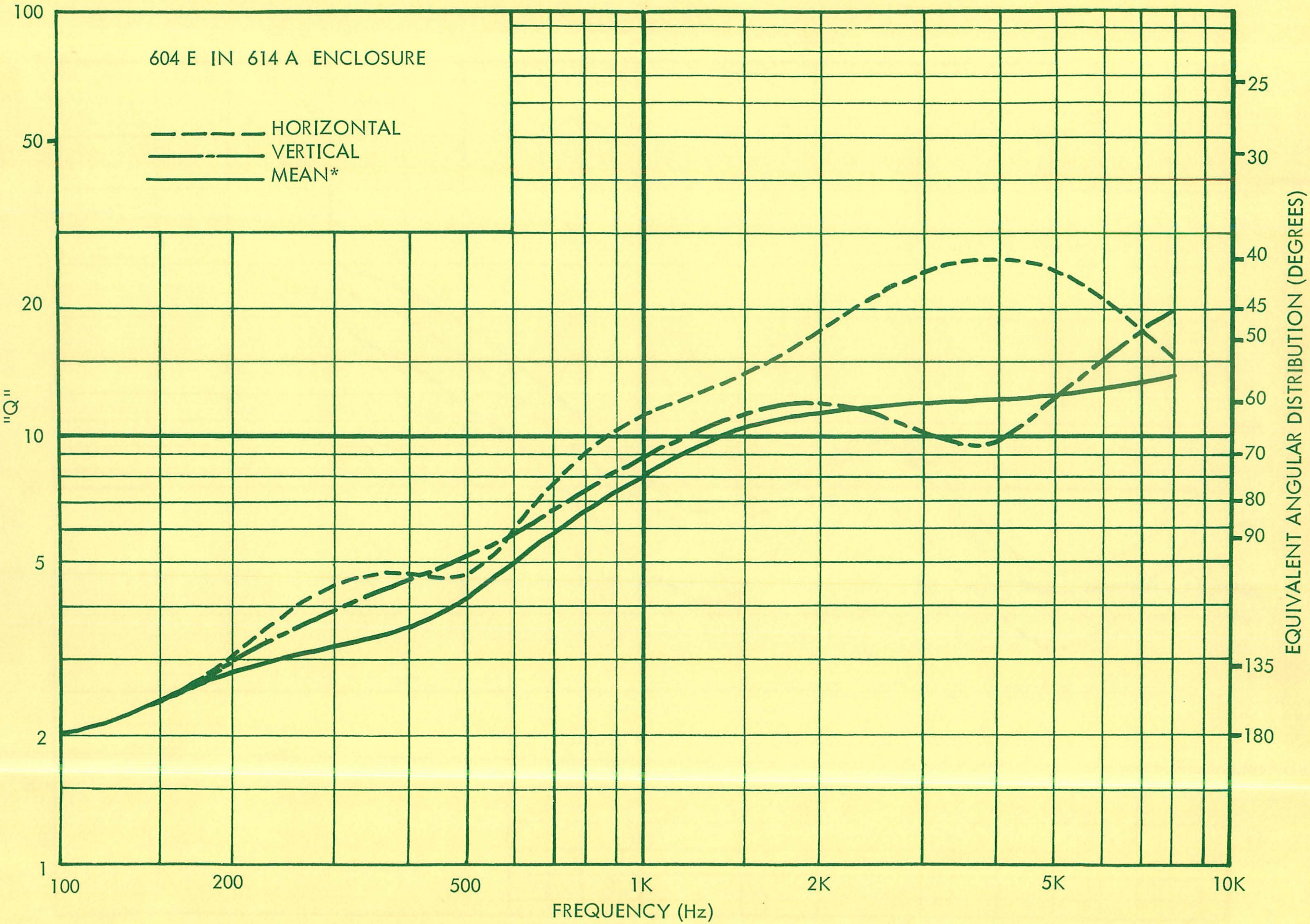

311 - 60 HORN
HORIZONTAL
VERTICAL
MEAN*
"Q"
100
50
20
10
5
2
1
100
200
500
1K
2K
5K
10K
FREQUENCY (Hz)
EQUIVALENT ANGULAR DISTRIBUTION (DEGREES)
25
30
40
45
50
60
70
80
90
135
180

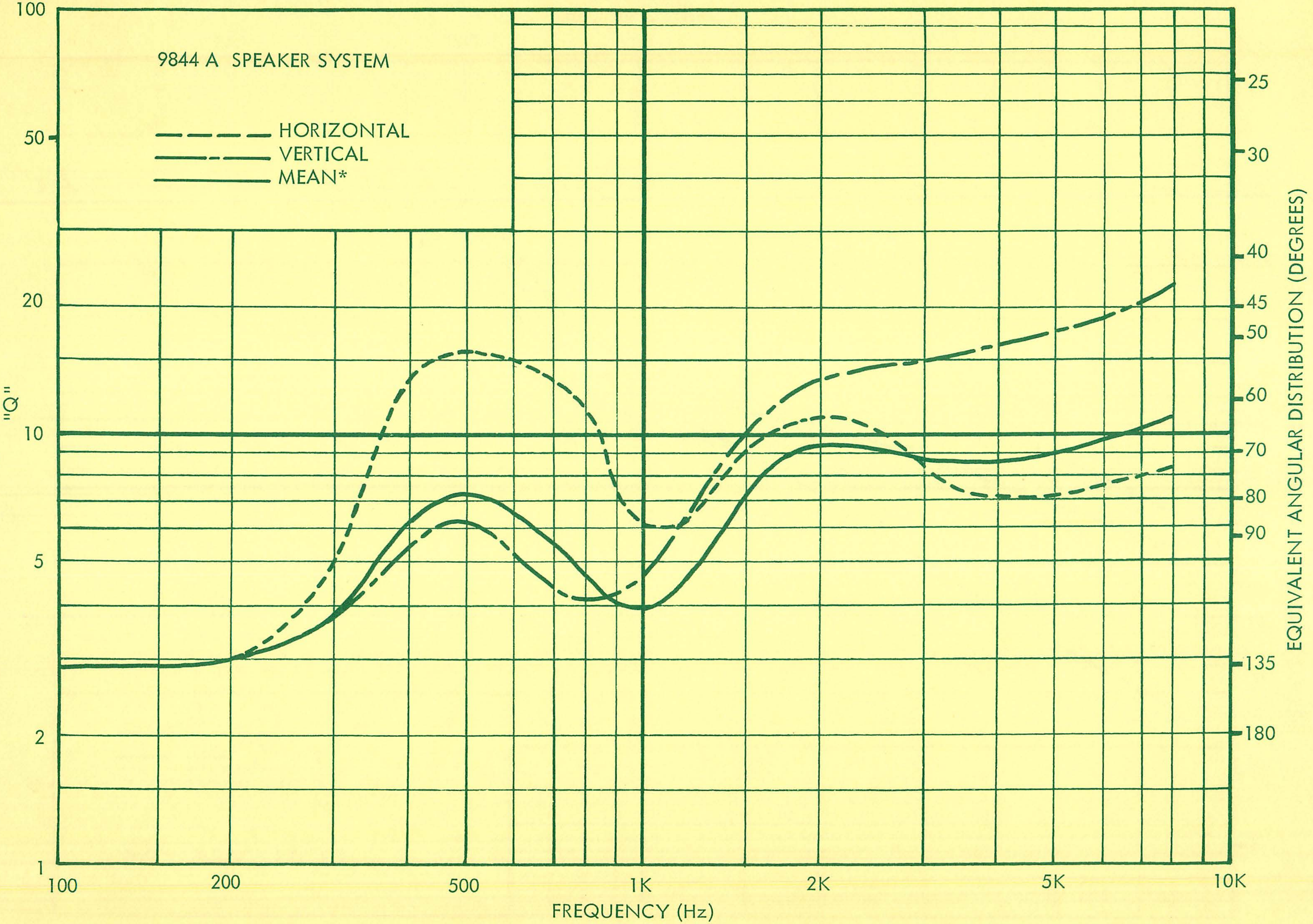

311 - 90 HORN
HORIZONTAL
VERTICAL
MEAN*
"Q"
100
50
20
10
5
2
1
100
200
500
1K
2K
5K
10K
FREQUENCY (Hz)
EQUIVALENT ANGULAR DISTRIBUTION (DEGREES)
25
30
40
45
50
60
70
80
90
135
180

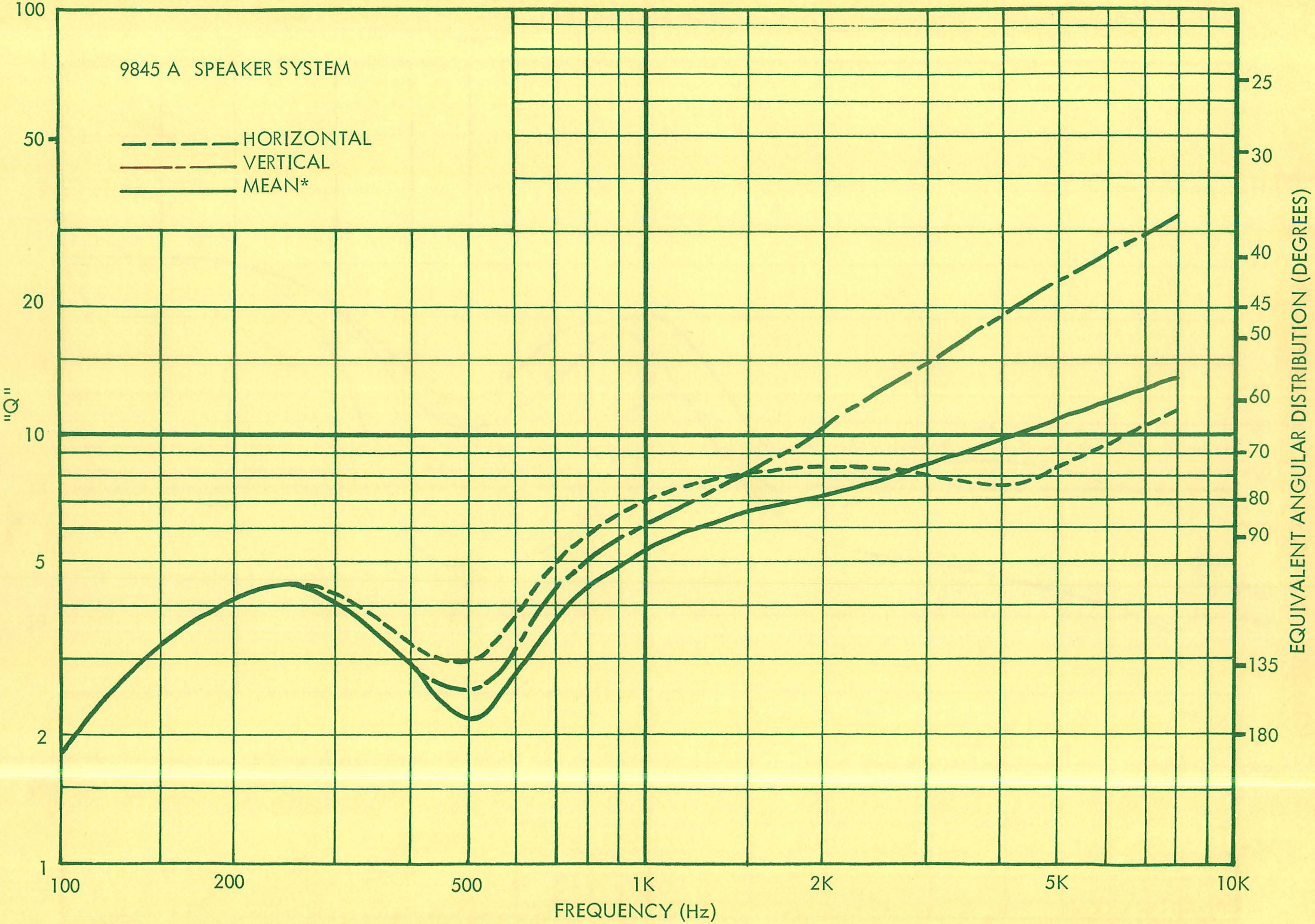

329 A HORN
HORIZONTAL
VERTICAL
MEAN*
"Q"
100
50
20
10
5
2
1
100
200
500
1K
2K
5K
10K
FREQUENCY (Hz)
EQUIVALENT ANGULAR DISTRIBUTION (DEGREES)
25
30
40
45
50
60
70
80
90
135
180


SMALL LOUDSPEAKERS IN
MINIMUM ENCLOSURES
405 A
409 B
755 E
"Q"
100
50
20
10
5
2
1
EQUIVALENT ANGULAR DISTRIBUTION (DEGREES)
25
30
40
45
50
60
70
80
90
135
180
100
200
500
1K
2K
5K
10K
FREQUENCY (Hz)

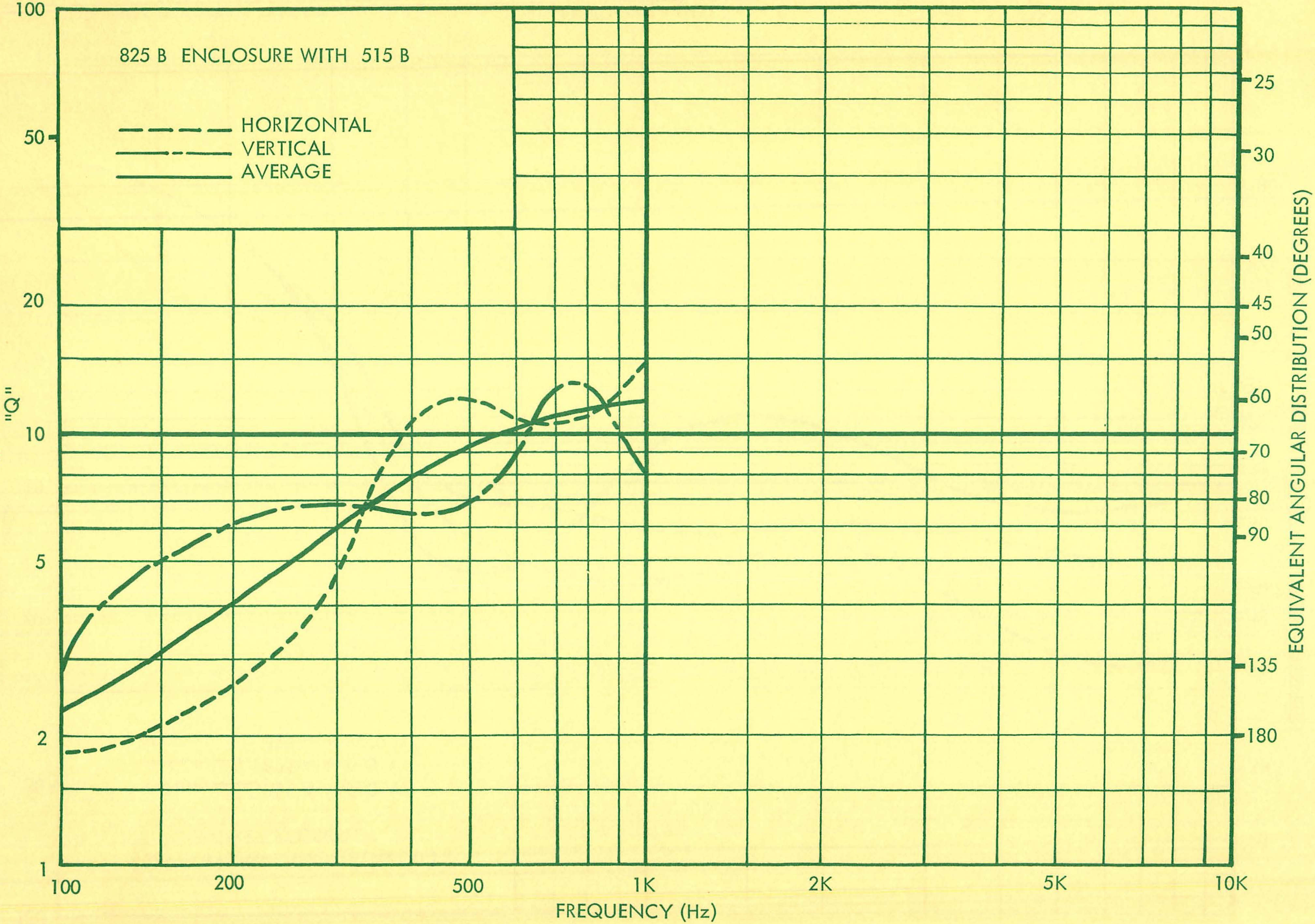

605 A IN 612 A ENCLOSURE
HORIZONTAL
VERTICAL
MEAN*
"Q"
100
50
20
10
5
2
1
EQUIVALENT ANGULAR DISTRIBUTION (DEGREES)
25
30
40
45
50
60
70
80
90
135
180
100
200
500
1K
2K
5K
10K
FREQUENCY (Hz)

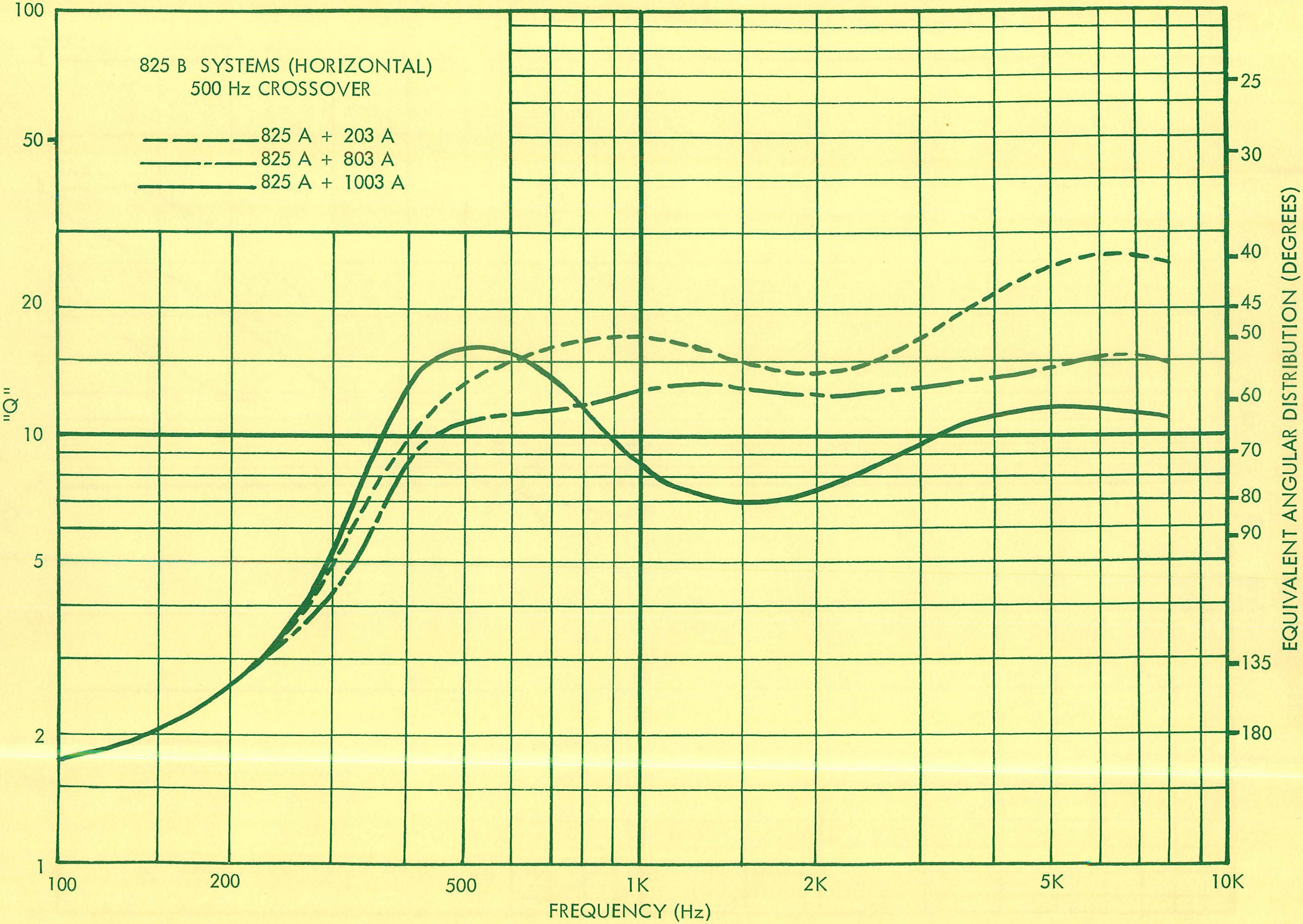

604 E IN 614 A ENCLOSURE
HORIZONTAL
VERTICAL
MEAN*
"Q"
100
50
20
10
5
2
1
100
200
500
1K
2K
5K
10K
FREQUENCY (Hz)
EQUIVALENT ANGULAR DISTRIBUTION (DEGREES)
25
30
40
45
50
60
70
80
90
135
180


9844 A SPEAKER SYSTEM
HORIZONTAL
VERTICAL
MEAN*
"Q"
100
50
20
10
5
2
1
EQUIVALENT ANGULAR DISTRIBUTION (DEGREES)
25
30
40
45
50
60
70
80
90
135
180
100
200
500
1K
2K
5K
10K
FREQUENCY (Hz)

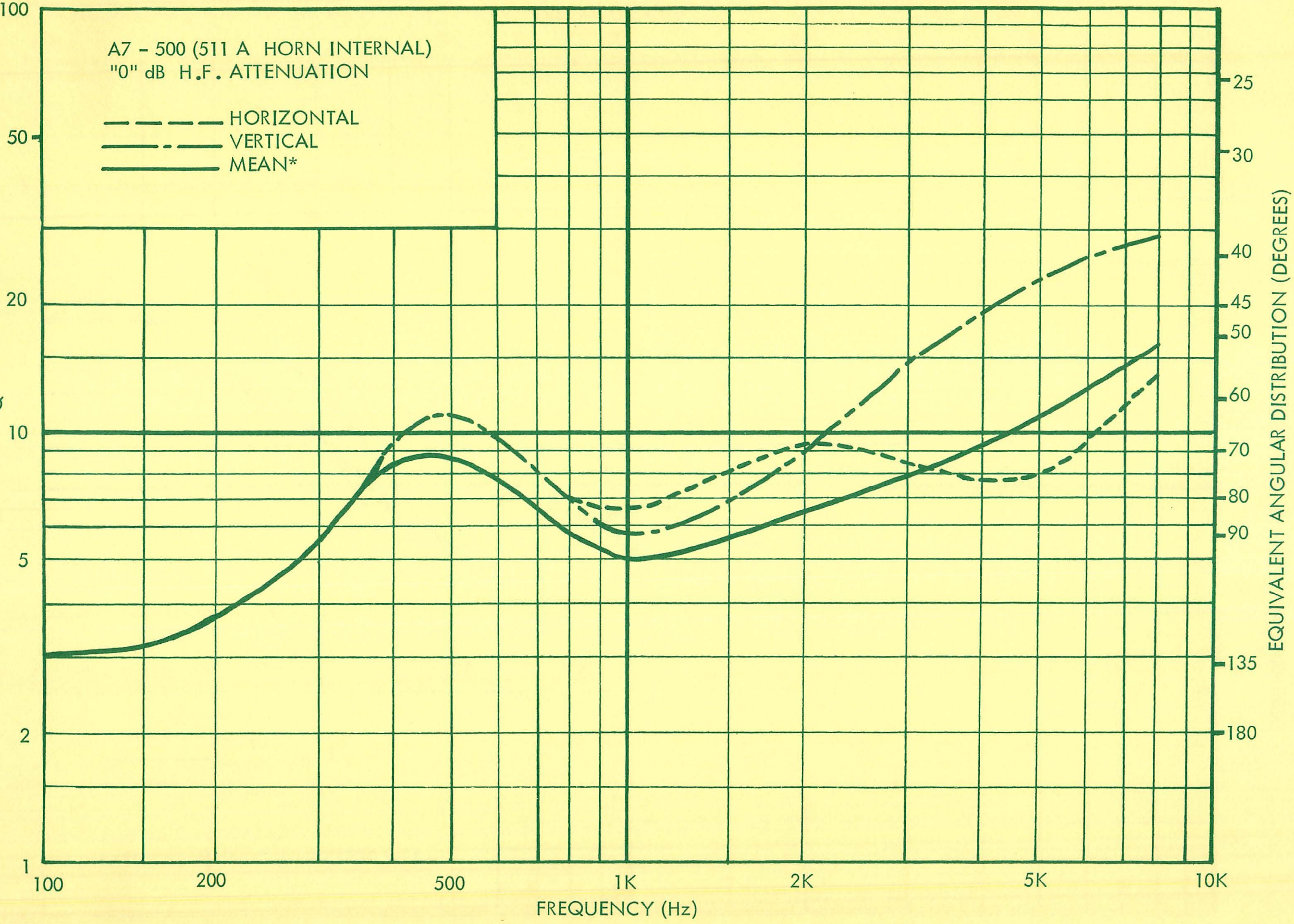


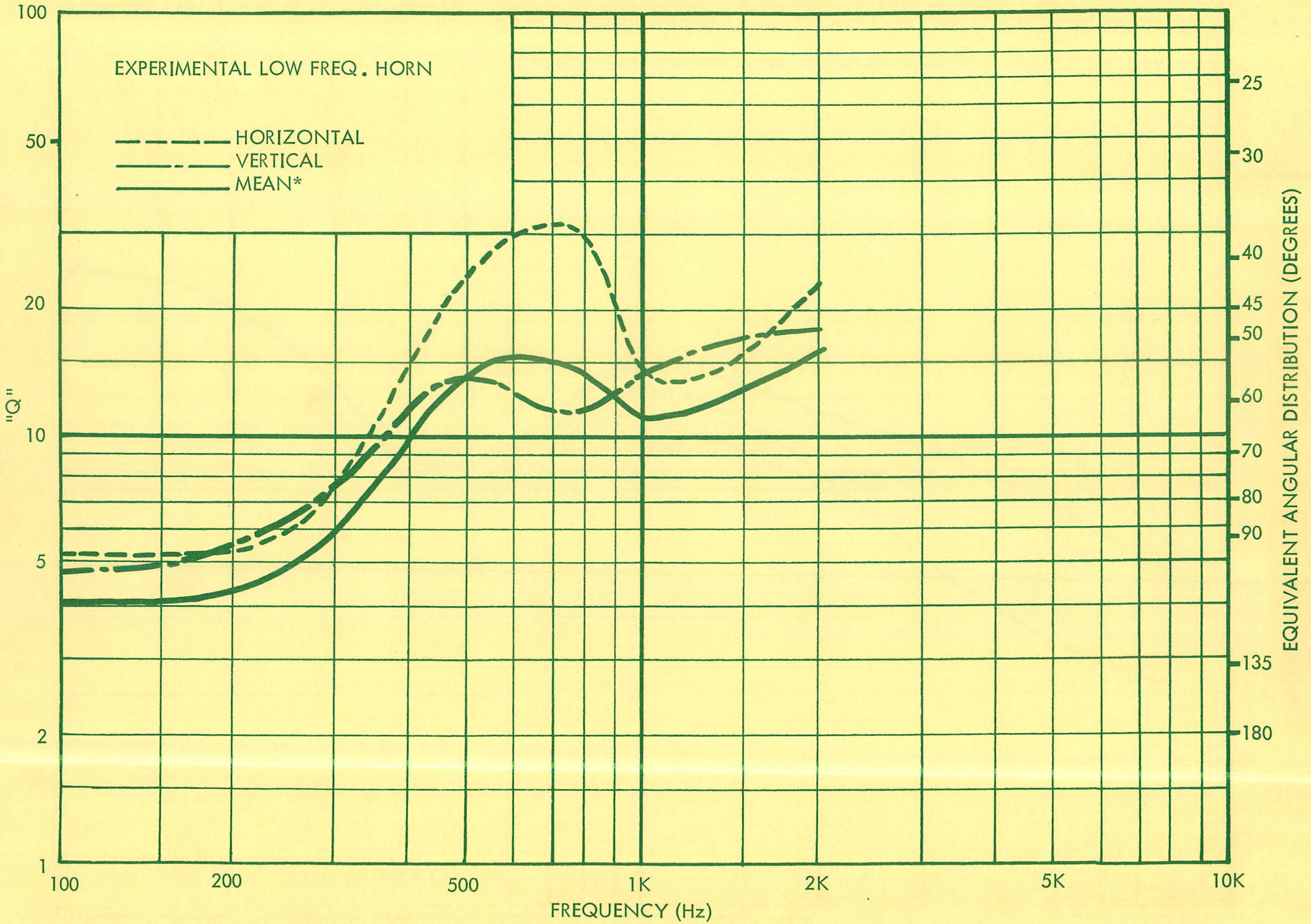
9845 A SPEAKER SYSTEM
HORIZONTAL
VERTICAL
MEAN*
"Q"
100
50
20
10
5
2
1
100
200
500
1K
2K
5K
10K
FREQUENCY (Hz)
EQUIVALENT ANGULAR DISTRIBUTION (DEGREES)
25
30
40
45
50
60
70
80
90
135
180


825 B ENCLOSURE WITH 515 B
HORIZONTAL
VERTICAL
AVERAGE
"Q"
100
50
20
10
5
2
1
EQUIVALENT ANGULAR DISTRIBUTION (DEGREES)
25
30
40
45
50
60
70
80
90
135
180
100
200
500
1K
2K
5K
10K
FREQUENCY (Hz)

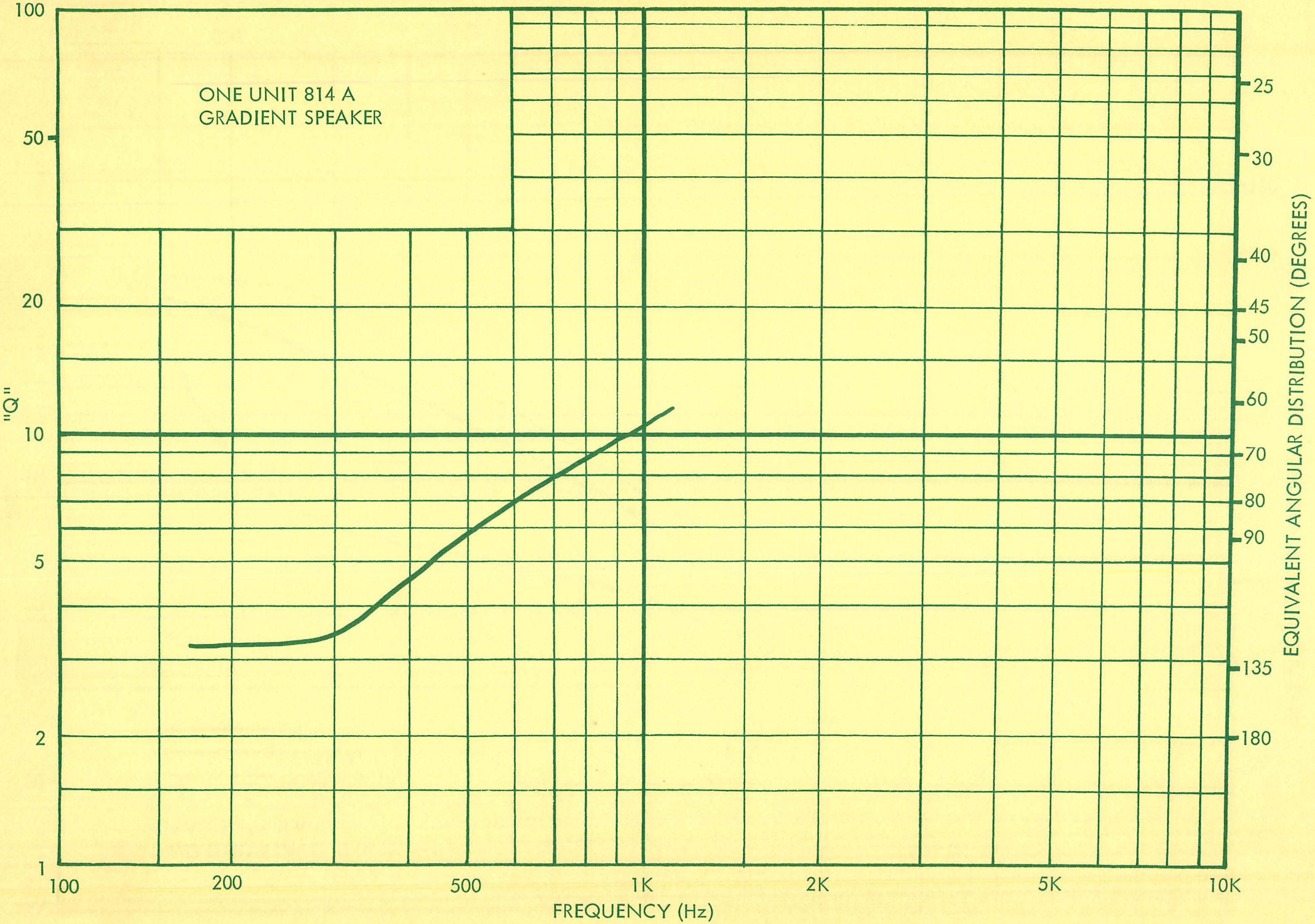


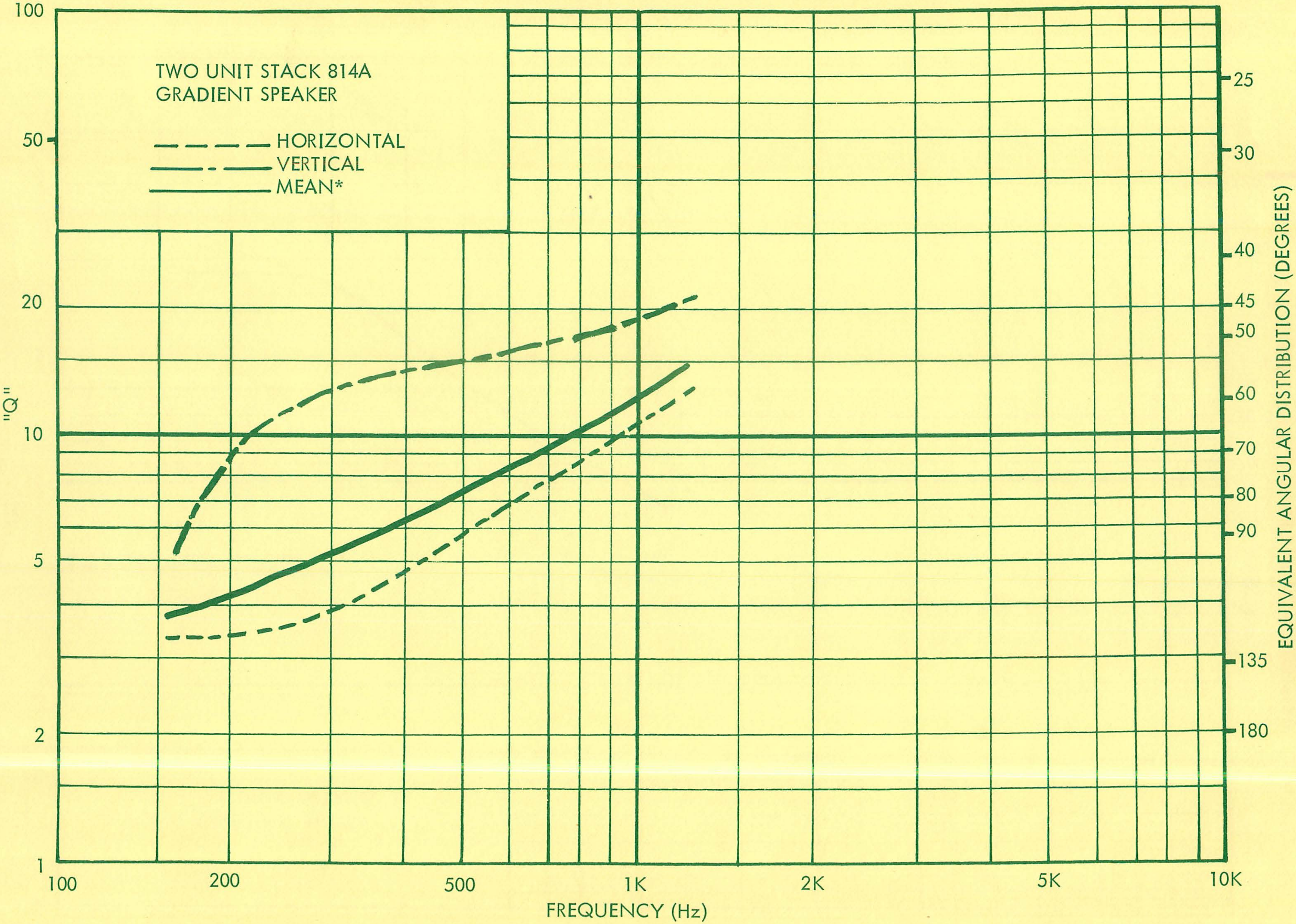
825 B SYSTEMS (HORIZONTAL)
500 Hz CROSSOVER
825 A + 203 A
825 A + 803 A
825 A + 1003 A
100
50
20
10
5
2
1
"Q"
25
30
40
45
50
60
70
80
90
135
180
EQUIVALENT ANGULAR DISTRIBUTION (DEGREES)
100
200
500
1K
2K
5K
10K
FREQUENCY (Hz)

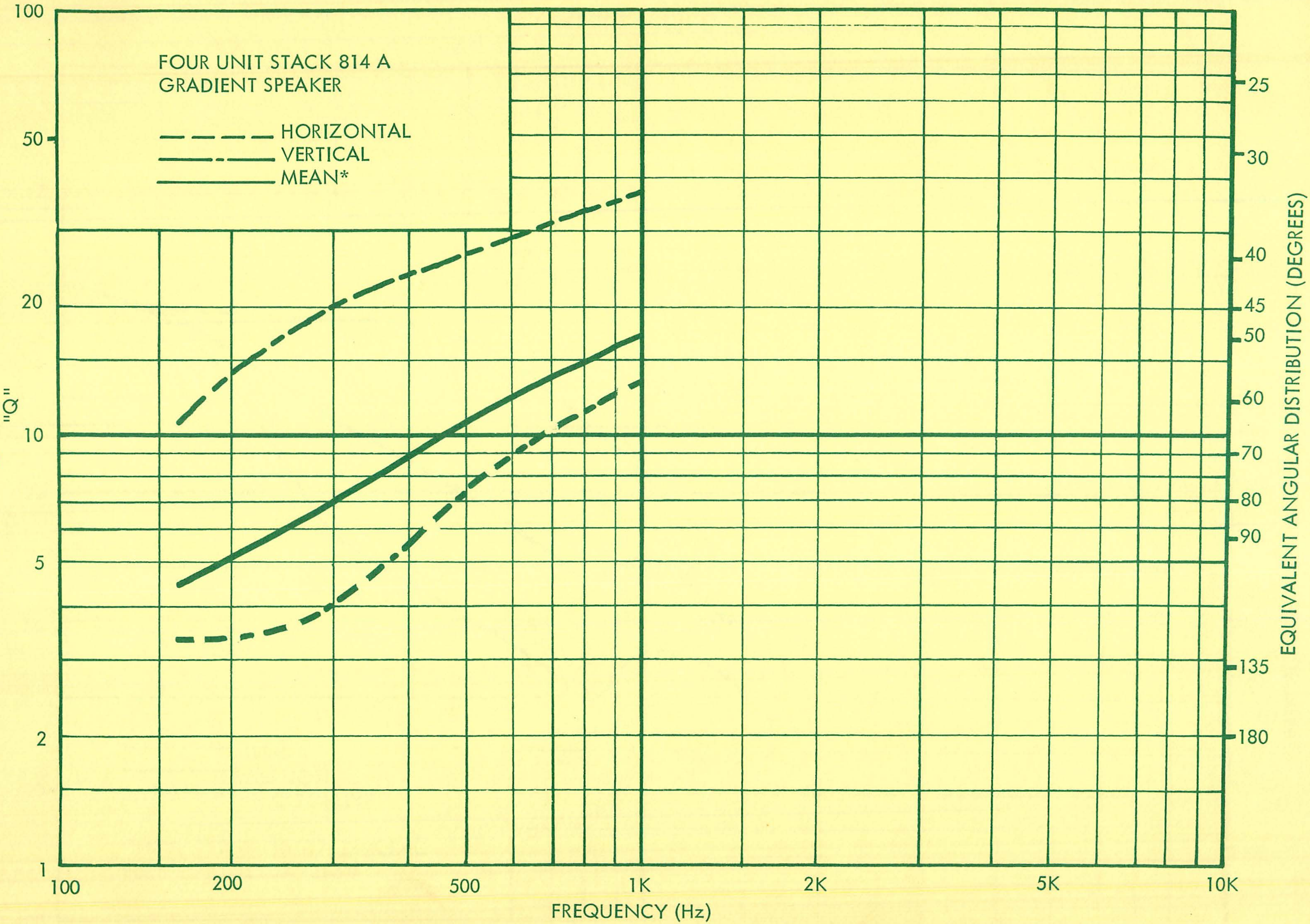

A7 - 500 (511 A HORN INTERNAL)
"0" dB H.F. ATTENUATION
HORIZONTAL
VERTICAL
MEAN*
"Q"
100
50
20
10
5
2
1
100
200
500
1K
2K
5K
10K
FREQUENCY (Hz)
EQUIVALENT ANGULAR DISTRIBUTION (DEGREES)
25
30
40
45
50
60
70
80
90
135
180



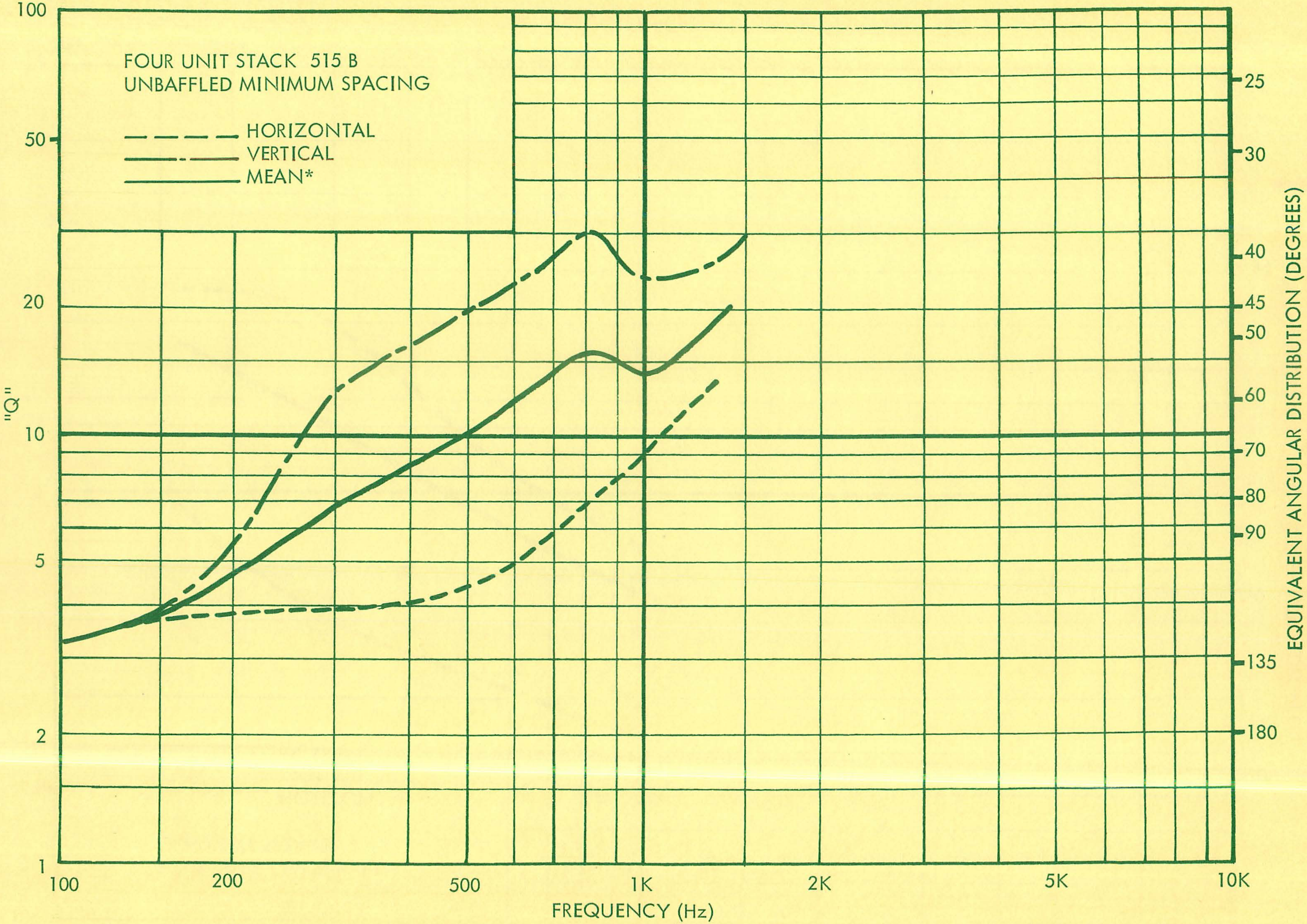
EXPERIMENTAL LOW FREQ. HORN
HORIZONTAL
VERTICAL
MEAN*
"Q"
100
50
20
10
5
2
1
100
200
500
1K
2K
5K
10K
FREQUENCY (Hz)
EQUIVALENT ANGULAR DISTRIBUTION (DEGREES)
25
30
40
45
50
60
70
80
90
135
180

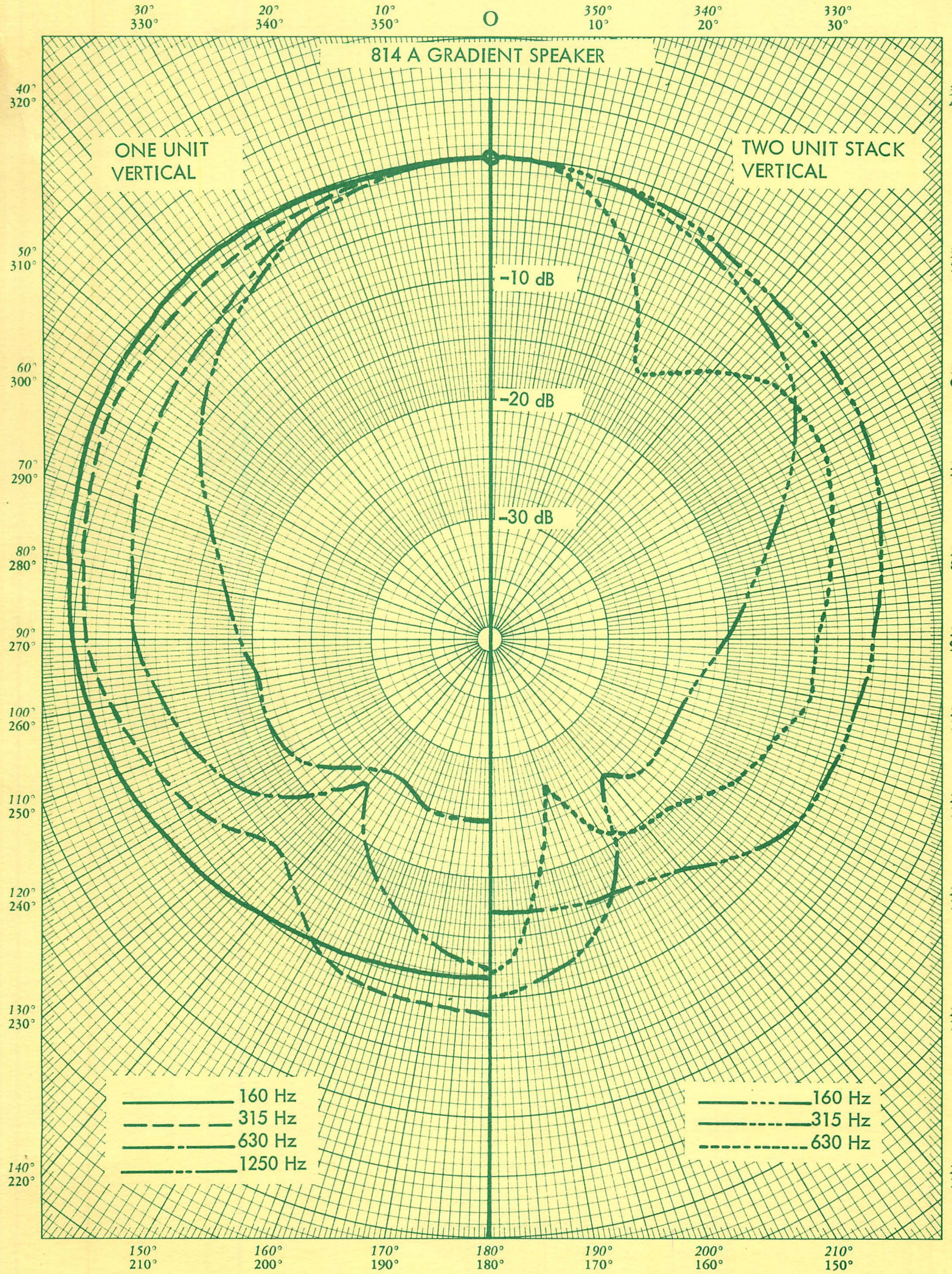

ONE UNIT 814 A
GRADIENT SPEAKER
"Q"
100
50
20
10
5
2
1
100
200
500
1K
2K
5K
10K
FREQUENCY (Hz)
EQUIVALENT ANGULAR DISTRIBUTION (DEGREES)
25
30
40
45
50
60
70
80
90
135
180


TWO UNIT STACK 814A
GRADIENT SPEAKER
HORIZONTAL
VERTICAL
MEAN*
"Q"
100
50
20
10
5
2
1
100
200
500
1K
2K
5K
10K
FREQUENCY (Hz)
EQUIVALENT ANGULAR DISTRIBUTION (DEGREES)
25
30
40
45
50
60
70
80
90
135
180

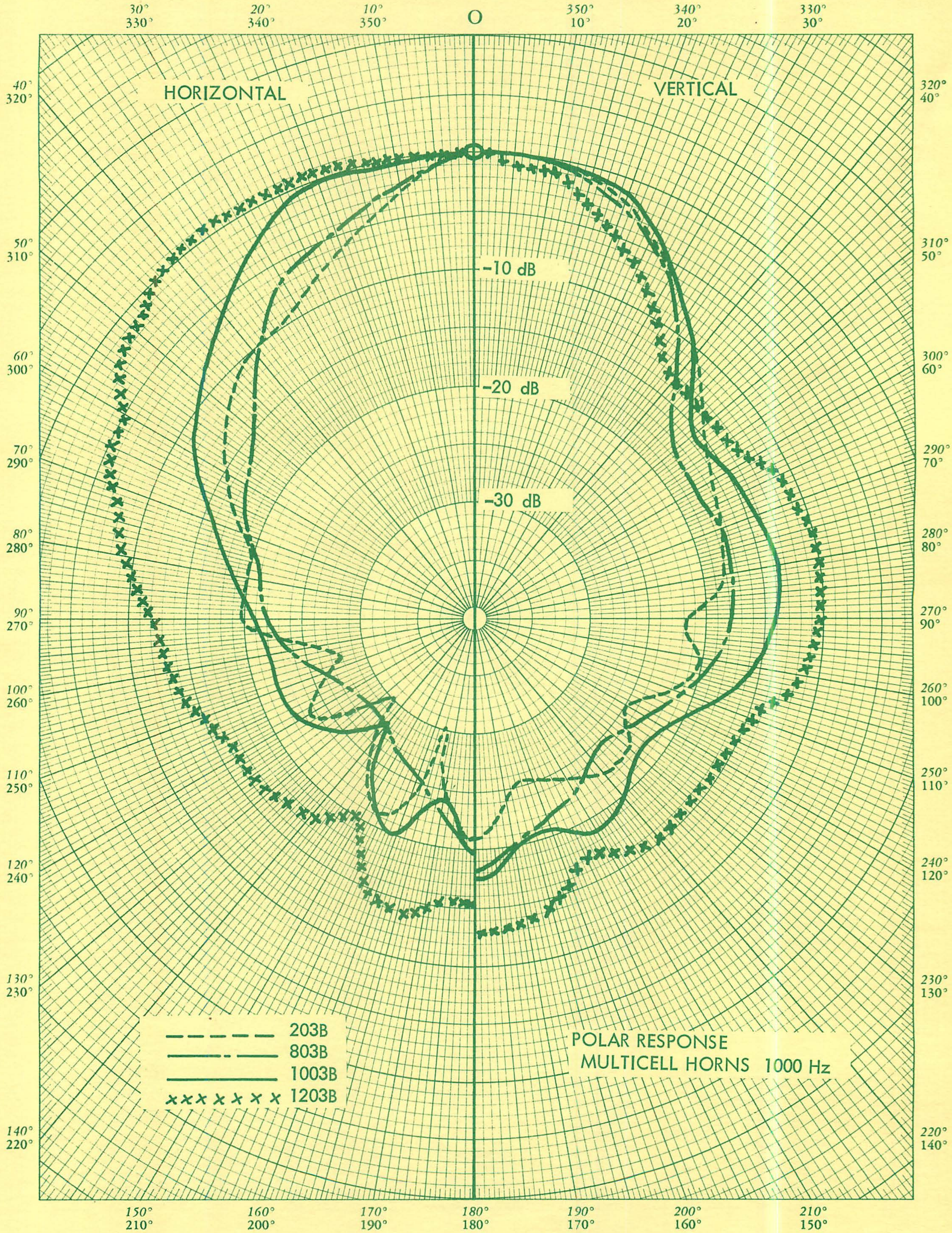


FOUR UNIT STACK 814 A
GRADIENT SPEAKER
HORIZONTAL
VERTICAL
MEAN*
"Q"
100
50
20
10
5
2
1
EQUIVALENT ANGULAR DISTRIBUTION (DEGREES)
25
30
40
45
50
60
70
80
90
135
180
100
200
500
1K
2K
5K
10K
FREQUENCY (Hz)

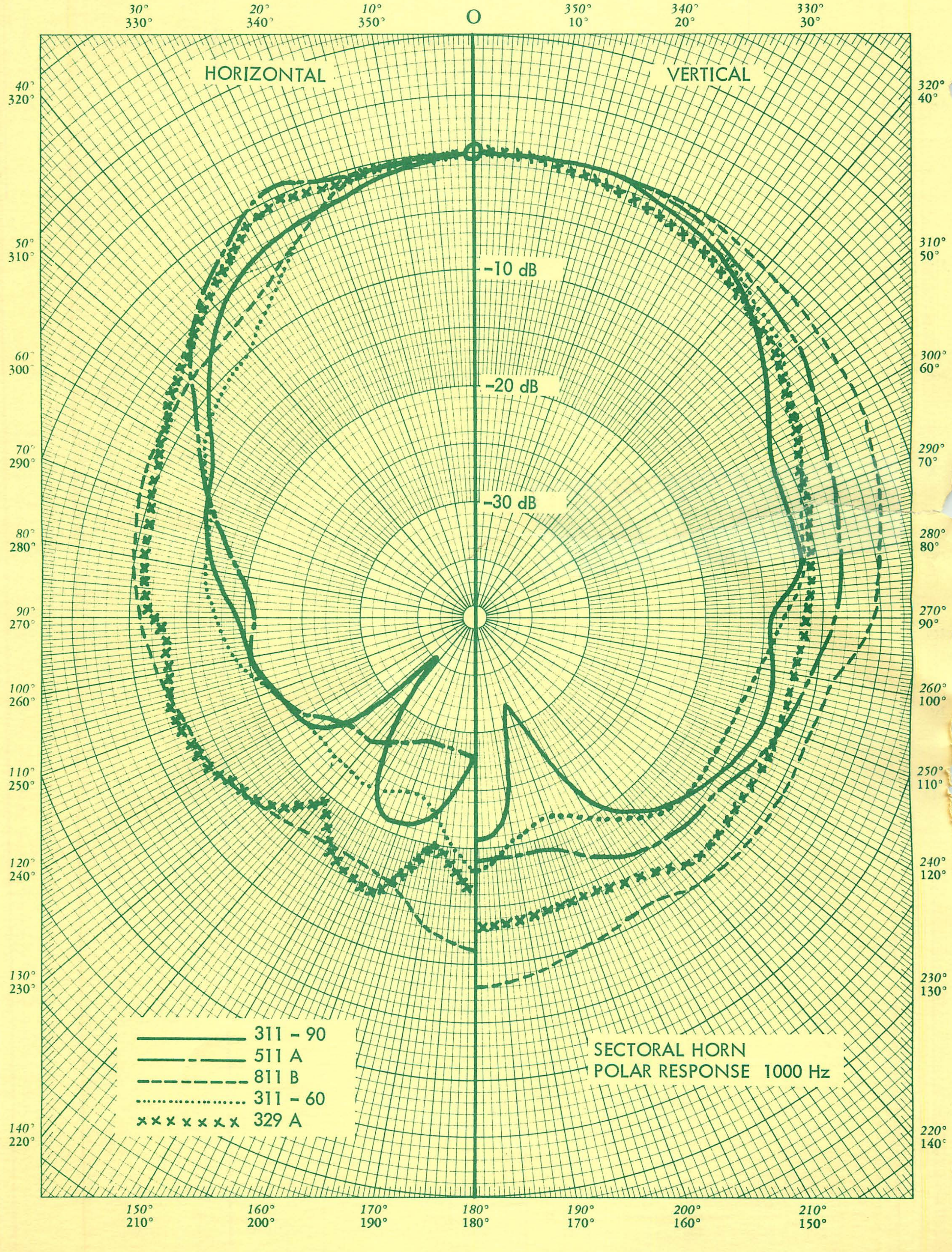

FOUR UNIT STACK 515 B
UNBAFFLED MINIMUM SPACING
HORIZONTAL
VERTICAL
MEAN*
"Q"
100
50
20
10
5
2
1
100
200
500
1K
2K
5K
10K
FREQUENCY (Hz)
EQUIVALENT ANGULAR DISTRIBUTION (DEGREES)
25
30
40
45
50
60
70
80
90
135
180

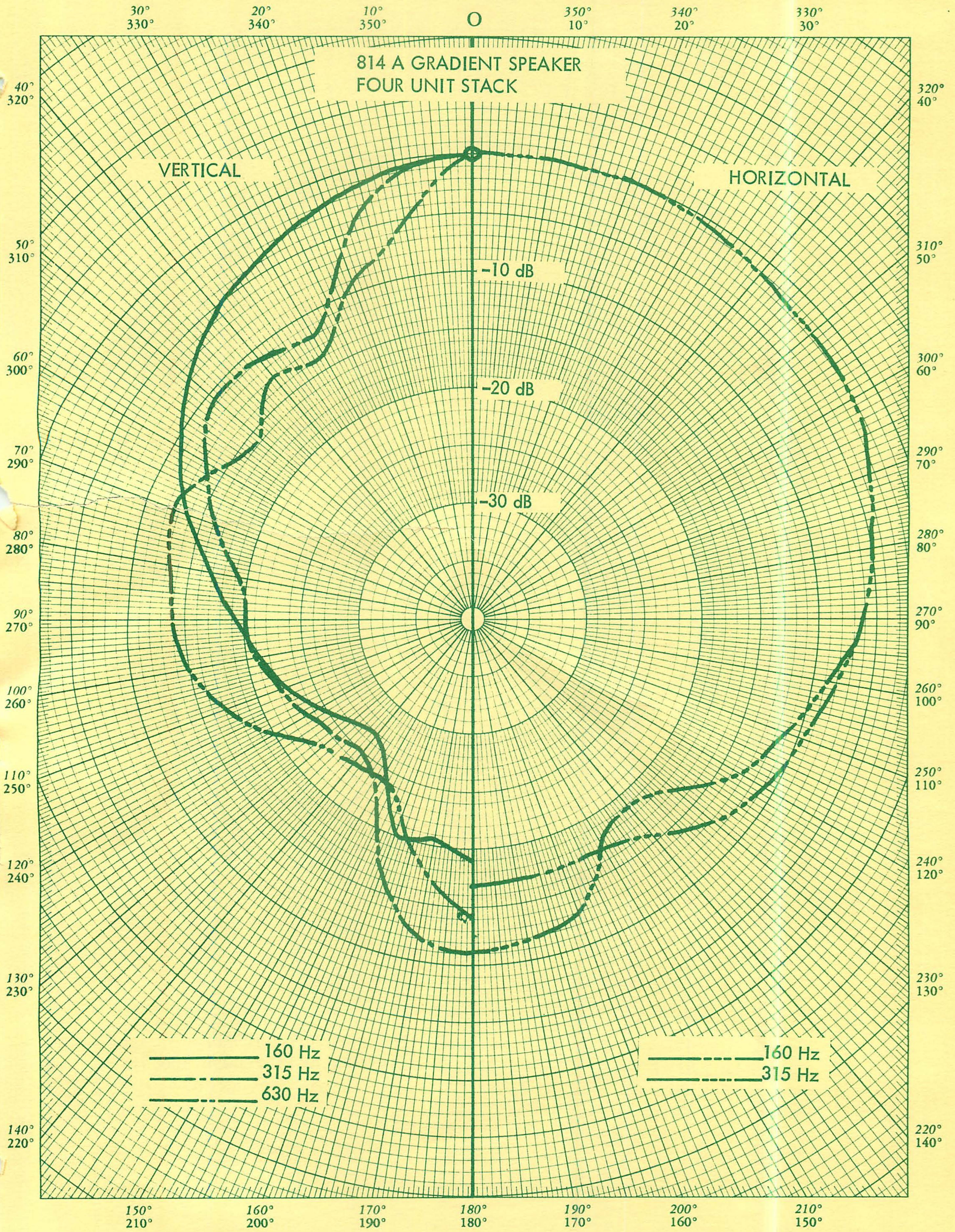


814 A GRADIENT SPEAKER
ONE UNIT VERTICAL
TWO UNIT STACK VERTICAL
-10 dB
-20 dB
-30 dB
160 Hz
315 Hz
630 Hz
1250 Hz
160 Hz
315 Hz
630 Hz
O
30° 330°
20° 340°
10° 350°
350° 10°
340° 20°
330° 30°
40° 320°
50° 310°
60° 300°
70° 290°
80° 280°
90° 270°
100° 260°
110° 250°
120° 240°
130° 230°
140° 220°
320° 40°
310° 50°
300° 60°
290° 70°
280° 80°
270° 90°
260° 100°
250° 110°
240° 120°
230° 130°
220° 140°
150° 210°
160° 200°
170° 190°
180° 180°
190° 170°
200° 160°
210° 150°

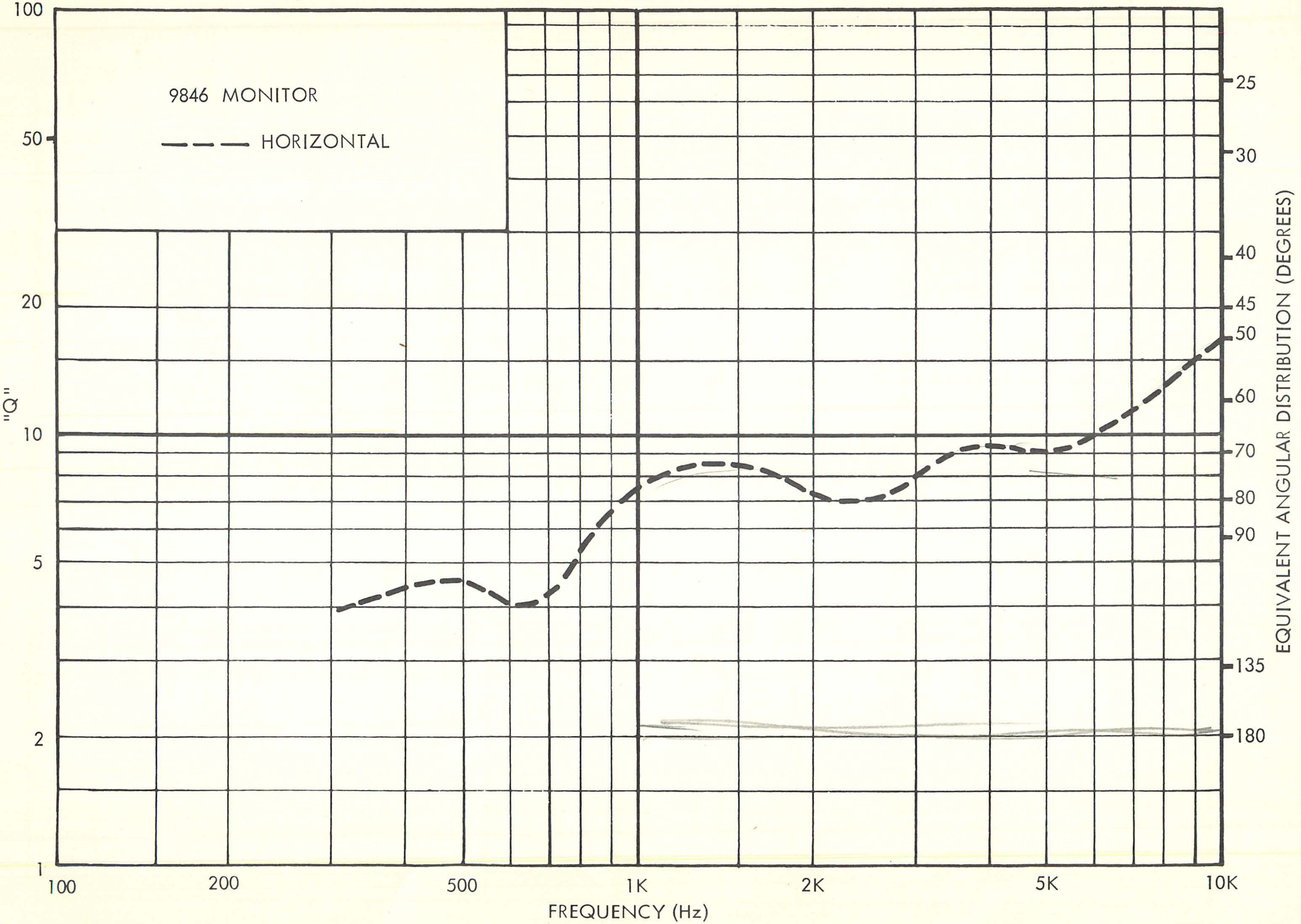


HORIZONTAL
VERTICAL
-10 dB
-20 dB
-30 dB
203B
803B
1003B
1203B
POLAR RESPONSE
MULTICELL HORNS 1000 Hz


HORIZONTAL
VERTICAL
-10 dB
-20 dB
-30 dB
311 - 90
511 A
811 B
311 - 60
329 A
SECTORAL HORN
POLAR RESPONSE 1000 Hz



814 A GRADIENT SPEAKER
FOUR UNIT STACK
VERTICAL
HORIZONTAL
O
-10 dB
-20 dB
-30 dB
160 Hz
315 Hz
630 Hz
160 Hz
315 Hz



9846 MONITOR
HORIZONTAL
"Q"
100
50
20
10
5
2
1
100
200
500
1K
2K
5K
10K
FREQUENCY (Hz)
EQUIVALENT ANGULAR DISTRIBUTION (DEGREES)
25
30
40
45
50
60
70
80
90
135
180