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REVERBERATION CORRECTION VALUES FOR TWO SPECIFIC ARRAYS.(U)
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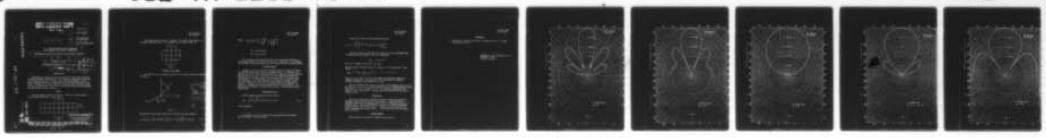

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U. S. NAVY UNDERWATER SOUND LABORATORY
FORT TRUMBULL, NEW LONDON, CONNECTICUT

(6) REVERBERATION CORRECTION VALUES FOR TWO SPECIFIC ARRAYS.

by

(10) Benjamin F. Cron

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INTRODUCTION

Experimental studies are often conducted to obtain the scattering strength of volume reverberation. The received reverberation level has to be corrected in order to obtain the scattering strength. One of these correction factors is determined by the intensity pattern of the array. The purpose of this study is to evaluate this correction factor for two specific arrays. The arrays are specified and the corresponding correction factors are obtained.

ARRAYS

The first array contains 20 squares. The side of each square is one half wavelength long. (See. Fig. 1).

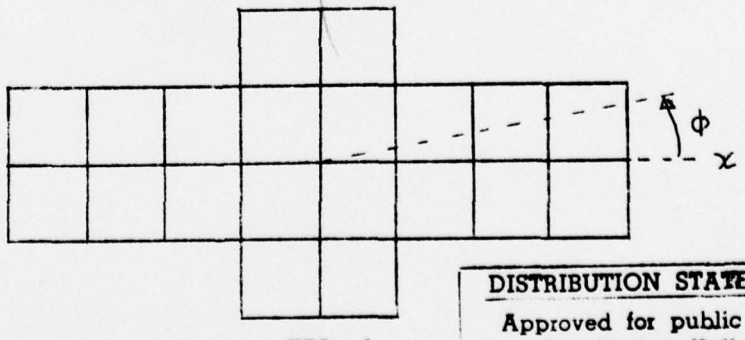

FIG. 1

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The second array contains 12 squares. The side of each square is one half wavelength long. The configuration is shown in Fig. 2.

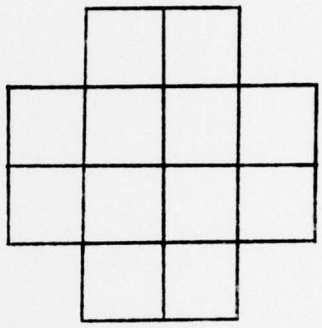

FIG. 2

PATTERN OF THE ARRAY

Let $I(\theta, \phi)$ be the intensity pattern of an array in the θ, ϕ directio
See Fig. 3.

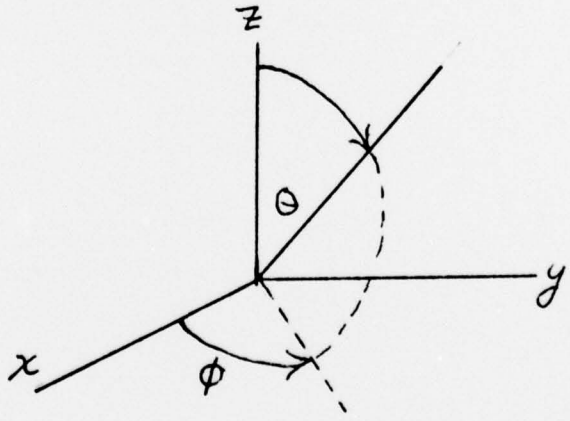

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FIG. 3

The pattern of the plane array may be obtained from the equation

$$I(\theta,\phi) = \left| \sum_i \exp\left[-j\frac{2\pi}{\lambda}(\alpha x_i + \beta y_i)\right] \right|^2 f(\theta,\phi) \qquad (1)$$

where $$f(\theta, \phi) = \left(\frac{\sin \frac{\pi\alpha}{2}}{\frac{\pi\alpha}{2}} \; \frac{\sin \frac{\pi\beta}{2}}{\frac{\pi\beta}{2}} \right)^2$$

$$\alpha = \sin\theta \cos\phi$$

$$\beta = \sin\theta \cos\phi$$

x_i and y_i are the center positions of the squares referenced to the origin, which is the center of the array. Equation (1) is obtained by the usual Fraunhofer method for point sources and the product theorem.

PATTERN RESULTS

In Figs. 4, 5, 6 we show the intensity patterns versus θ for ϕ=0°, 44° and 90° respectively for the 20 element array. As expected, the pattern for ϕ = 0° (the plane containing the long axis) is narrower than the pattern for ϕ = 90°. In Figs. 7, 8, the intensity patterns are drawn for the 12 element array. The patterns for ϕ = 0° and ϕ = 90° are identical. It is interesting to note that the pattern for ϕ= 90° for this array is narrower than the corresponding 20 element array pattern. Along the y axis, the 12 element array has an aperture of about 2λ, whereas for the 20 element array it is more like λ. As more and more elements are added on the x axis, the effective aperture approaches λ.

CORRECTION FACTOR

Urick[1] defines a correction factor that is

$$\psi = \int_0^{2\pi} d\phi \int_0^{\pi/2} d\theta \, I^2(\theta, \phi) \sin\theta \, d\theta \qquad (2)$$

in our notation.

In equation (2), we consider only energy emitted and returned from one side of the plane array.

Equation (2) may be evaluated numerically by

$$\psi \simeq 4 \sum_{i=1}^{90} \sum_{j=1}^{90} I^2(\theta_i, \phi_j) \sin\theta_i \left(\frac{\pi}{180}\right)^2$$

The 8100 values of $I^2(\theta_i, \phi_j)$ were computed on the 1108 UNIVAC and the double sum was obtained. For the large array

$$\psi_{db} = -10.7 \text{ db}$$

For the 12 element array, $\psi_{db} = -8.2$ db.

Let us consider the small array as a square, 2λ on each side. From Urick[1]

$$\psi_{db} \simeq 10 \log_{10} \frac{\lambda^2}{4\pi a b} + 7.4 \quad , \quad \text{for } a, b >> \lambda$$

For $a = b = 2\lambda$, $\psi_{db} \simeq -9.6$ db. By using this equation instead of a computer computation, the correction factor and thus the computed scattering strength would differ by -1.4 db.

For 2° increments on θ and ϕ, the answer in ψ_{db} differed about 0.1 db. For $I(\theta, \phi) = 1$, for all θ and ϕ, equation 2 can be integrated analytically. The answer is $\psi_{db} = 10 \log_{10} (2\pi)$. The numerical integration was within .1 db of this answer. Accuracy could be increased by the use of Simpson's rule.

CONCLUSIONS

The use of large scale computers provides an excellent method for obtaining correction factors for reverberation. Urick provides approximate equations for configurations such as a rectangular array or a circular array. These approximations are good for given relationships between the size of the array and λ. The size of the array must be large, sometimes much larger, than λ. These conditions are not always met in practice.

ACKNOWLDGEMENT

This problem was stated by R. Martin and N. Fisch.

REFERENCES

1. "Principles of Underwater Sound for Engineers" by R. J. Urick, McGraw-Hill Book Co.

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Research Associate

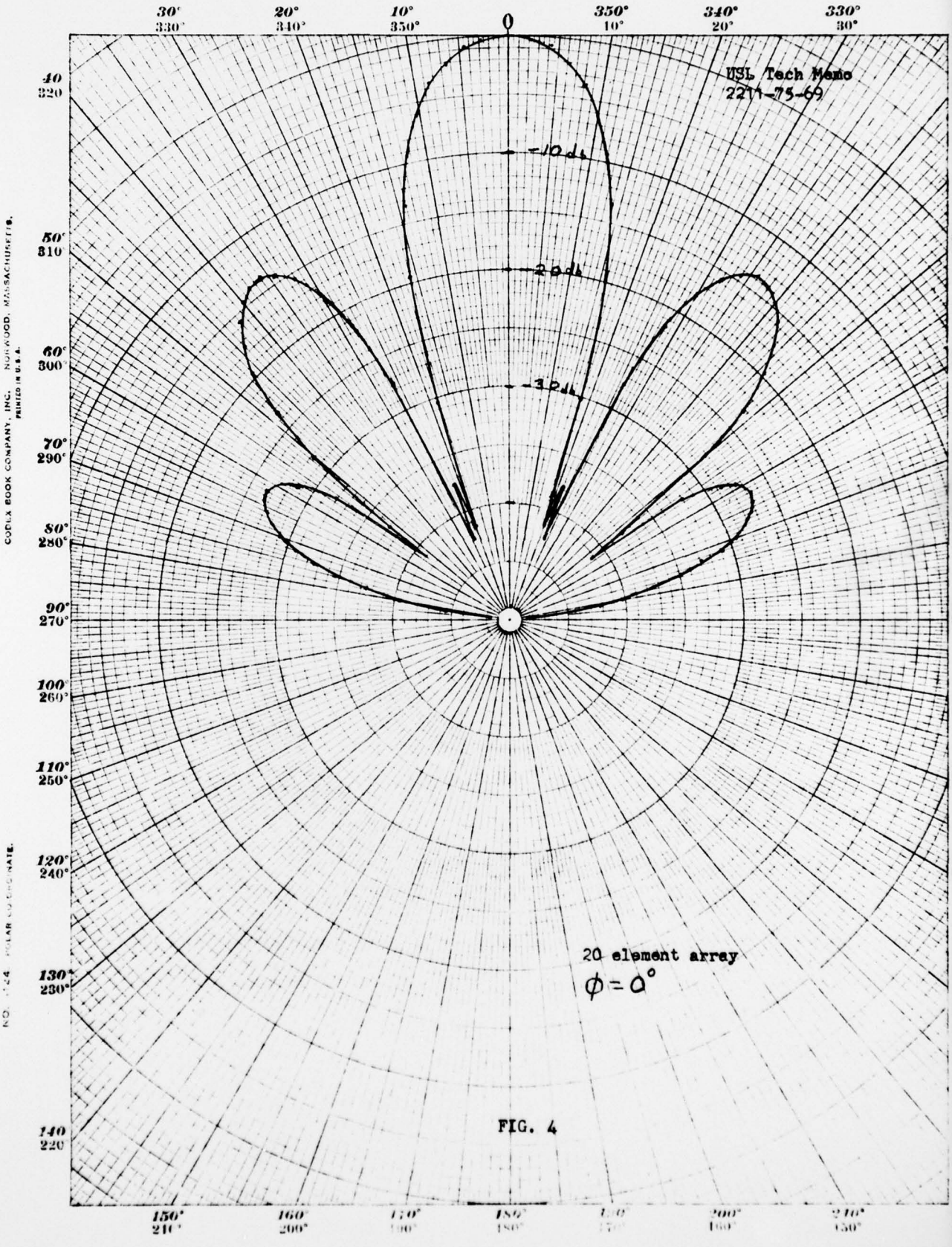

FIG. 4

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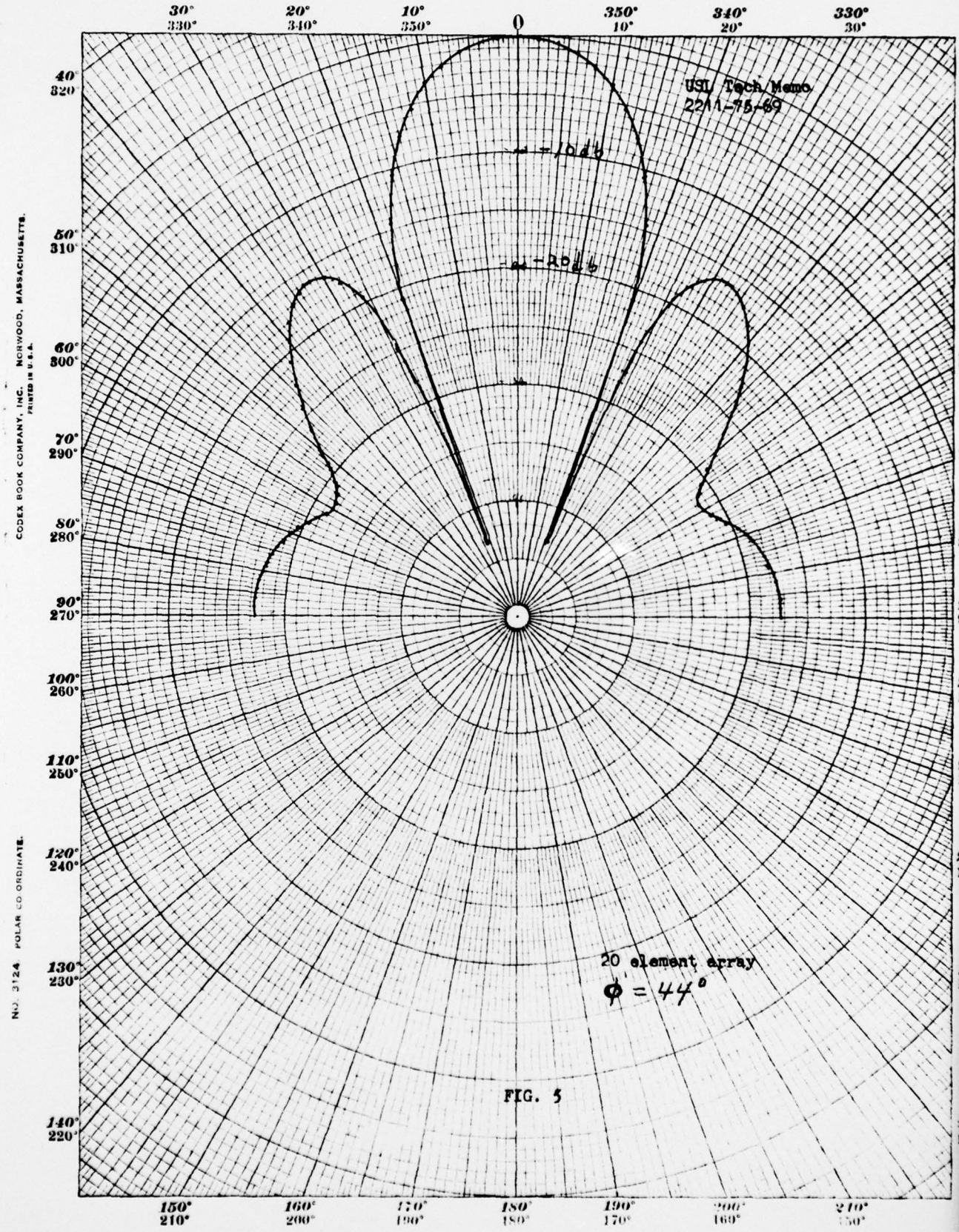

FIG. 5

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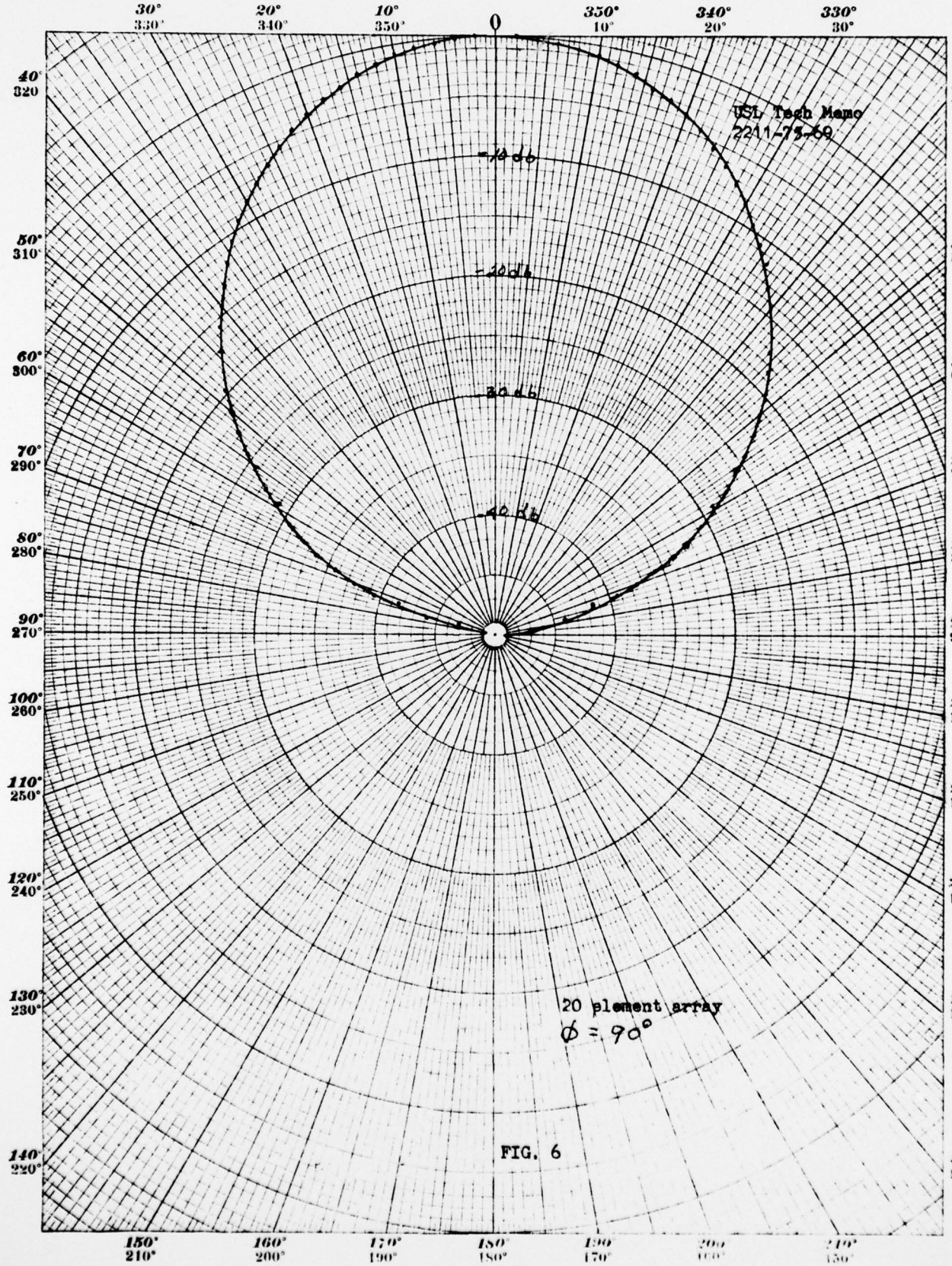
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-10 db
-20 db
-30 db
-40 db
20 element array
Ø = 90°

FIG. 6

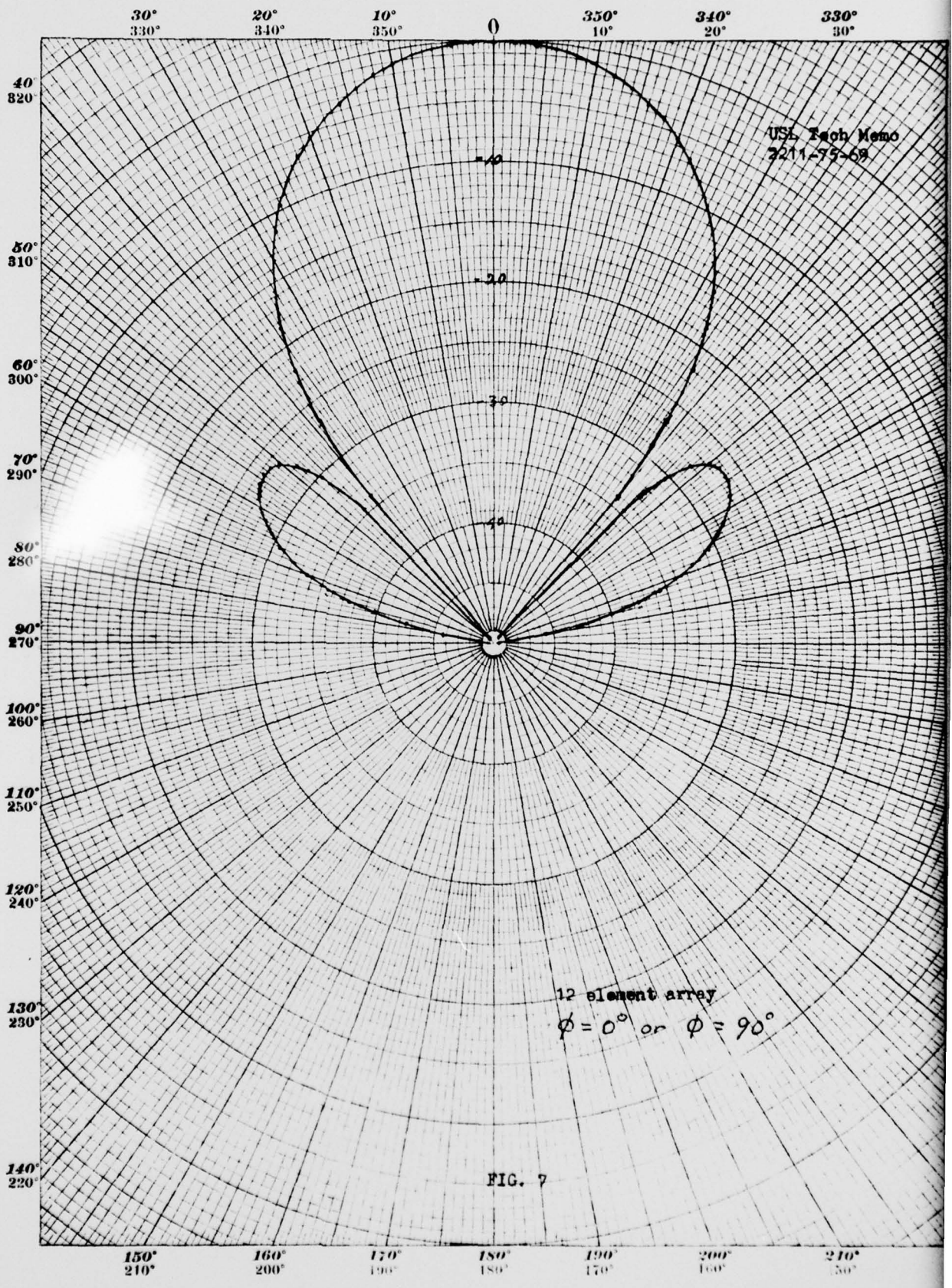

FIG. 7

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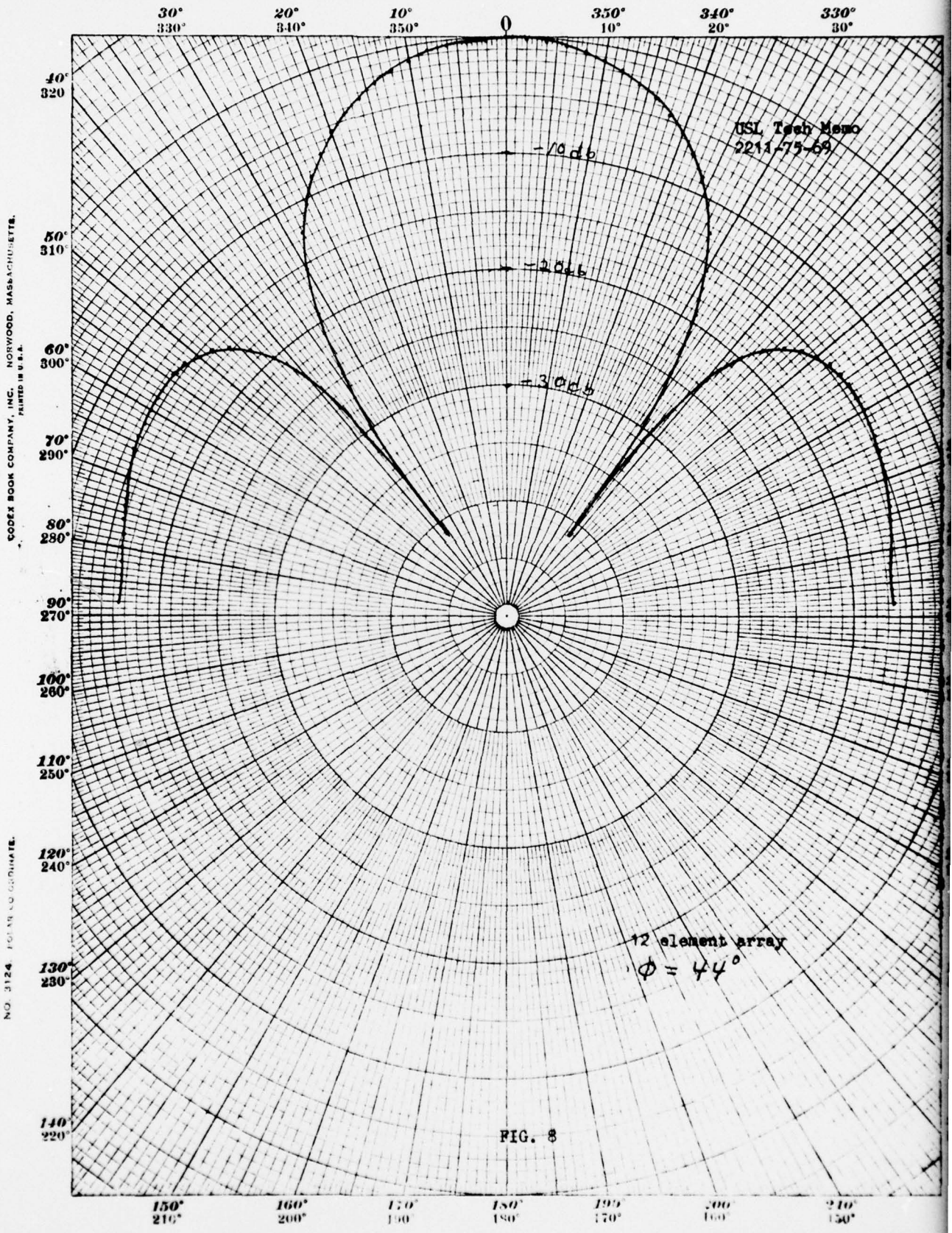
30° 330°
20° 340°
10° 350°
0
350° 10°
340° 20°
330° 30°
40° 320°
50° 310°
60° 300°
70° 290°
80° 280°
90° 270°
100° 260°
110° 250°
120° 240°
130° 230°
140° 220°
150° 210°
160° 200°
170° 190°
180°
190° 170°
200° 160°
210° 150°
-10 db
-20 db
-30 db
USL Tech Memo 2211-75-69
12 element array
$\phi = 44°$
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FIG. 8