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SIGNAL-TO-NOISE GAIN OF AN IDEALIZED ARRAY PATTERN AS A FUNCTIO--ETC(U)
APR 62 M C KARAMARGIN, B F CRON
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Signal-To-Noise Gain of an Idealized Array Pattern as a Function of Major Lobe Width

by

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Abstract

An idealized receiving pattern is hypothesized. For this pattern, the directivity ratio is fixed to a constant value. Thus the minor lobe is decreased when the major lobe is broadened. The signal-to-noise gain for isotropic noise does not change as the major lobe is broadened. However, the signal-to-noise gain does change if the noise is directional surface noise. For the conditions examined, increasing the width of the major lobe results in an increase of signal-to-noise ratio.

Geometry

Consider the following idealized array pattern. The major lobe is constant in a region θ_1 to θ_2 in a plane and the response is equal to I_B. The minor lobe is constant and equal to I_A in the remaining region. In figure 1, we have a cross section of the idealized three directional pattern.

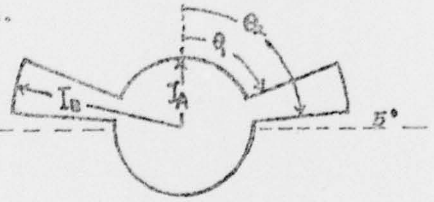

Figure I

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Let the depth of the ocean be 4 kyds and let the frequency be monochromatic and equal to 4 KC. Let the major beam be 5° from the horizontal.

Math Analysis

Let us find the relation between I_A and I_B for a fixed directivity ration as a function of major beam width.

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D.R. = I_B/I_{AV} where I_B is the maximum intensity received and I_{AV} is the intensity averaged over all directions. Let us draw an arbitrary sphere of radius r about the center of the array and consider spherical coordinates. Then

$$I_{AV} = \frac{I_B 2\pi r^2 (\cos\theta_1 - \cos\theta_2) + I_A\left[4\pi r^2 - 2\pi r^2(\cos\theta_1 - \cos\theta_2)\right]}{4\pi r^2}$$

Let us set D.R. = K

Then

$$I_A = \frac{I_B\left[1 - \frac{K}{2}(\cos\theta_1 - \cos\theta_2)\right]}{K\left[1 + \frac{1}{2}(\cos\theta_2 - \cos\theta_1)\right]}$$

Thus for major beam widths of 5°, 10° and 15° ($\theta_2 - \theta_1$), and for a given K, we can find the relationship between I_A and I_B. For all these cases, the signal-to-noise gain will be the same if the noise is isotropic. We will now investigate the signal-to-noise gain for the case of directional sufrace noise.

Surface Noise

Consider surface noise which is directional in the direction and radiates independently in the azimuthal direction. We will consider attenuation and spherical spreading. Let the directionality of the intensity of the radiated source be $\cos^m\theta$. Then the intensity received at the array due to one noise source is

$$\cos^m\theta \exp{-\alpha r}/r^2$$

where $\cos^m\theta$ is the directional property of noise, $\exp{-\alpha r}$ is the attenuation factor, r^2 is the spherical spreading factor.

$$\alpha = 0.17 \ln 10$$

Let us now assume that there is one noise source per unit area. Then in a ring of noise sources the energy received on the major beam is

$$I_B \cos^m\theta \frac{\exp{-\alpha r}}{r^2} 2\pi x\, dx$$

Figure 2

By changing variables

$$I_{B\ \text{received}} = 2\pi(\alpha D)^m \int_{y_1}^{y_2} \frac{\exp -y}{y^{m+1}}\, dy \qquad I_{A\ \text{received}} = 2\pi I_A(\alpha D)^m \int_{y_0}^{y_2} \frac{\exp -y}{y^{m+1}}\, dy$$

where

$$y_0 = \alpha D$$

$$y_1 = \alpha D/\cos\theta_1$$

$$y_2 = \alpha D/\cos\theta_2$$

The region from $\theta = \theta_2$ to $\theta = \pi/2$ has been disregarded since it will be the same form in all three cases of comparison.

Using a directivity ratio of K = 10 and varying the beam width, it is found that as the major lobe increases, the total received noise decreases. The same is true for a K= 5. The cos θ and $\cos^2\theta$ directionality of the noise is compared.

It is interesting to compute the received intensity as a function of direction. For a $\cos^m\theta$ directionality of the noise, the received intensity in the angle $d\theta\, d\phi$ is

$$\cos^{m-1} \sin\theta \exp - \alpha D \sec\theta$$

For cos θ and $\cos^2\theta$ noise sources, the received intensity is given in graph 2.

Conclusions

For the idealized conditions shown, increasing the major beam width results in a lower noise input and in a larger signal-to-noise ratio. Since this increase is on the order of 18 db, it is worthwhile computing the gains for more realistic situations. From graph 2 we see the received intensity as a function of direction. For this type of situation, the minor lobes should be placed at the maximum intensity and the major lobe at the small received intensity.

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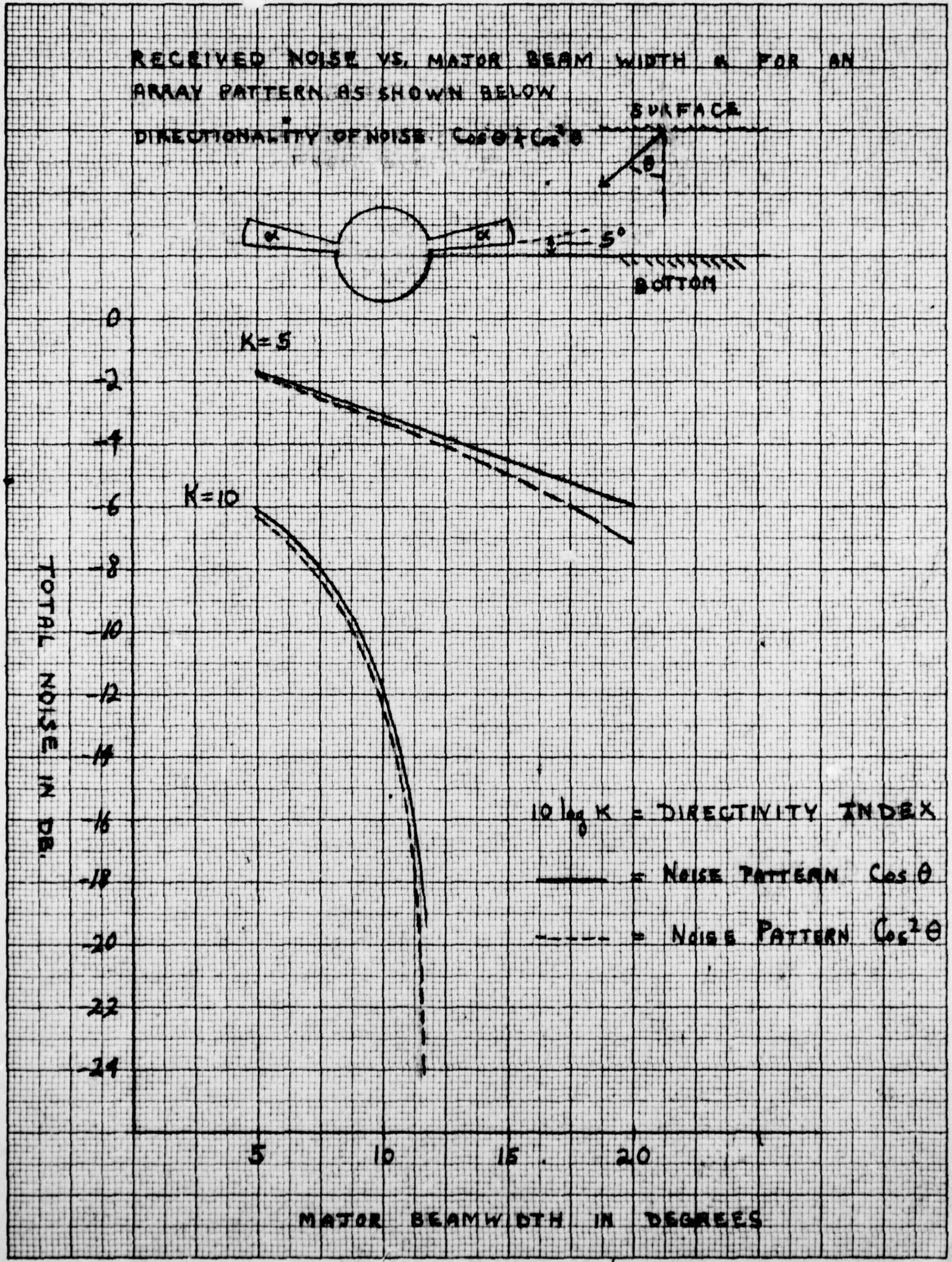
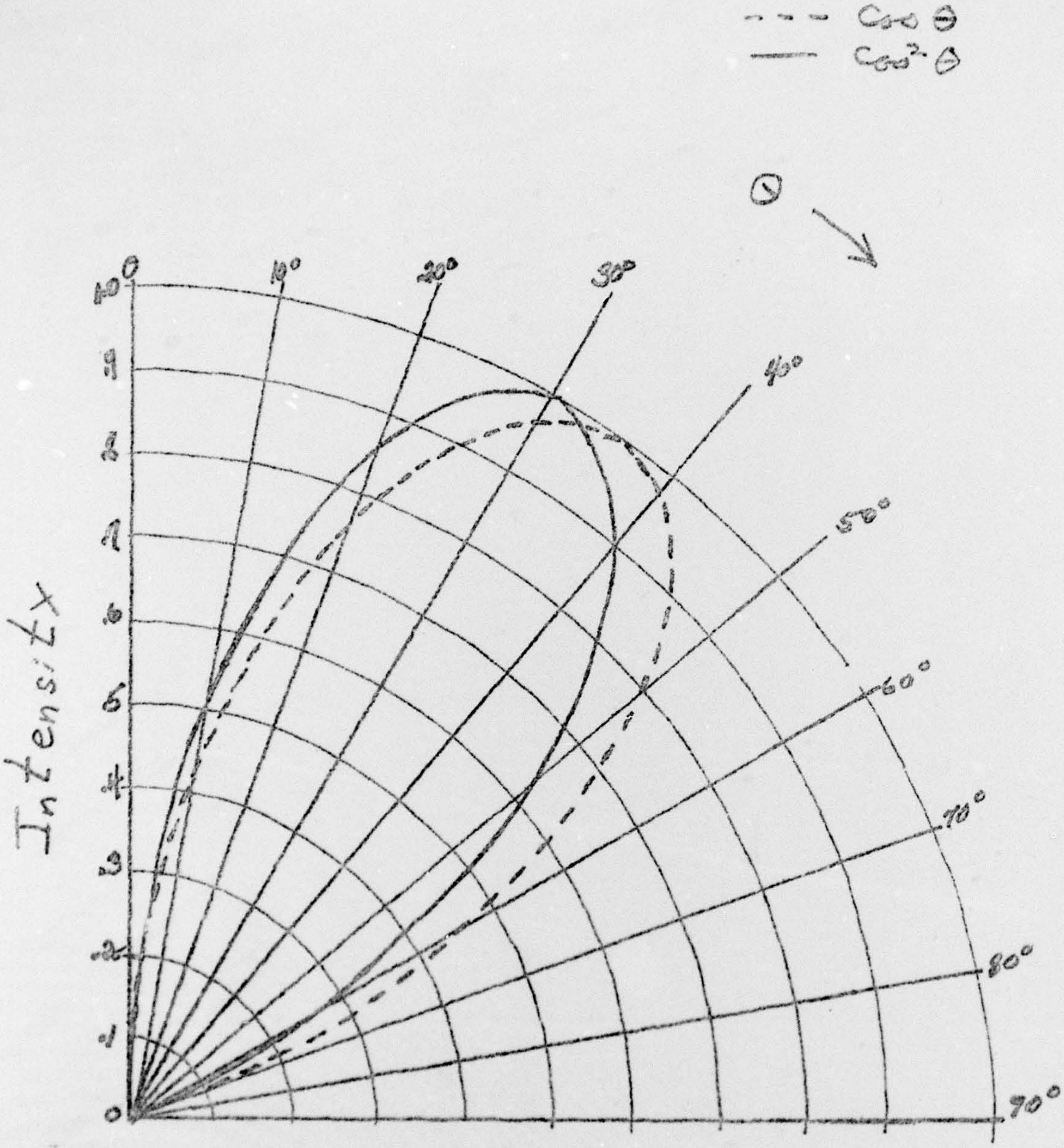
1. R. J. Urick - "Some Directional Properties of Deep-Water Ambient Noise" NRL Report 3796 dtd 16 Jan. 1951



RECEIVED NOISE VS. MAJOR BEAM WIDTH α FOR AN ARRAY PATTERN AS SHOWN BELOW

DIRECTIONALITY OF NOISE $\cos\theta$ & $\cos^2\theta$

GRAPH I



Received Intensity in an Angle dφ dθ
As a Function of Direction
Graph 2.