ANALYSIS OF THE EFFECT OF THE SHAPE OF THE RADIATION PATTERN ON THE ACCURACY OF AZIMUTH MEASUREMENTS BY THE MONOPULSE METHOD

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The effect of the shape of the radiation pattern of the difference channel of a monopulse antenna on the accuracy of angular-coordinate measurements is estimated. The least root mean square deviation is obtained using a radiation pattern with a Chebyshev amplitude distribution. Of the practical amplitude distributions a "parabola on a pedestal" of 0.1-0.316 is preferable.

To measure the azimuth of a target in a terrestrial radar system the simplest method of angular direction finding using the maximum of the radiation pattern is employed. Hence, to achieve acceptable measurement accuracy (the root mean square deviation of the results of measurements should not exceed 0.5°), the size of the antenna system in the horizontal place should amount to 80-90 wavelengths, i.e., more than 10 m for a radar system operating in the decimeter waveband [1, 2]. This leads to an increase in the weight of the mirror, which limits the azimuth scanning rate.

The monopulse method of determining the direction to a target has become widely used in radar. To determine the azimuth in a horizontal plane two overlapping radiation patterns are formed, displaced by an angle ±ψd from the equisignal direction, which, for a mirror antenna, is the focal axis of the mirror. The accuracy of measurements then depends on the slope of the direction-finding characteristic, which is determined by the slope of the radiation patterns generated in the direction in which they intersect [3]. As a rule, the radiation patterns generated intersect in the direction in which their slope is greatest, i.e., at the level of 0.707 of the radiation-pattern field strength. It is well known that the slope of the radiation pattern at a certain point can be found from its first derivative at this point [4]. Hence, the root mean square deviation of the measured value of the azimuth in the monopulse direction-finding method can be expressed as [4]:

\[
\sigma_a = F(\psi_d) / \sqrt{q} \left| \frac{dF(\psi)}{d\psi} \right|_{\psi = \psi_d},
\]

where q is the ratio of the signal energy to the spectral density of the noise (the signal/noise ratio), which can be taken to be equal to 30 for modern radar systems [2].

Since the radiation pattern field strength occurs in (1), the angle of deviation of the maxima of the radiation pattern from the equisignal direction is

\[
\psi_d = 0.707 \cdot 2 \psi_{0.707}.
\]

If the azimuth is measured by the amplitude method (from the maximum of the radiation pattern), the root mean square deviation can be represented by the formula [2]:

\[
\sigma_a = 2 \psi_{0.707} / \sqrt{q}. \tag{2}
\]
It can be seen from (1) and (2) that, other conditions being equal, the accuracy of the measurements depends on the shape of the radiation pattern. The purpose of this paper is to investigate the effect of the shape of the radiation pattern, i.e., the shape of the amplitude distribution in the antenna system, on the accuracy with which the azimuth can be measured by the monopulse and amplitude methods. The following distributions will be used as the amplitude distributions investigated:

a distribution in the form of a "cosine to the power \( n \) on a pedestal," in which the parameter \( n \) takes values of 1, 2, and 3,

\[
E(x) = \Delta + (1 - \Delta) \cos^n \left( \frac{x}{l_p} \right).
\]  

(3)

a distribution in the form of a "parabola to the power \( n \) on a pedestal," in which the parameter \( n \) takes the values 1 and 2,

\[
E(x) = \Delta - (1 - \Delta) \left( \frac{x^2}{2l_p^2} \right)^n.
\]  

(4)

where \( x \) is the coordinate along the aperture in the horizontal plane, \( l_p \) is the size of the antenna in the horizontal plane, taken in the calculations to be equal to 20 wavelengths, and \( \Delta \) is the relative amplitude of the field at the edges of the mirror, which, in the calculations, was taken to have the values 0, 0.1, 0.2, 0.316, 0.4, 0.5, 0.6, and 0.8;

the Dolph–Chebyshev (optimum) amplitude distribution with sidelobe levels of -20, -30, -40, and -50 dB:

\[
E_i = \sum_{q=1}^{N} (-1)^{N-q} \frac{2N(q+N-1)}{(q-1)(q+1)(N-q)!} \alpha_0^q.
\]  

(5)

where \( i \) is the number of the calculated point at which the field amplitude is determined, 31 calculated points \( (N = 31) \) were used, and \( \alpha_0 \) is a parameter-related to the sidelobe level \( \xi \).

Hence, from (3)-(5) we obtained the amplitudes of the field at the calculated points, from these we obtained the radiation pattern, and we then calculated its width and derivative.

The results of calculations, in the form of a curve of the root mean square deviation as a function of the relative current amplitude at the edges of the mirror are shown in Fig. 1. An analysis of these graphs enables us to draw the following conclusions:

1. When the relative field amplitude at the edges of the mirror increases, the slope of the radiation pattern generated increases and the accuracy increases; when \( \Delta > 0.6 \), no appreciable difference in accuracy between the amplitude distributions of a "cosine on a pedestal," a "cosine squared on a pedestal," and a "cosine cubed on a pedestal" is observed, since the amplitude distribution approaches a uniform distribution while the radiation pattern approaches a radiation pattern of the form \( \frac{(\sin x)}{x} \). This also holds with respect to an amplitude distribution in the form of a "parabola to the power \( n \) on a pedestal."

2. For amplitude distributions of the form of a "cosine to the power \( n \) on a pedestal," the radiation pattern corresponding to a "cosine on a pedestal" distribution has the least root mean square deviation, the accuracy decreases as the degree of the cosine increases, and in particular, for \( n = 3 \), the root mean square deviation is 1.5 times greater than for \( n = 1 \), while for \( n = 2 \) the root mean square deviation is 1.23 times greater than for \( n = 1 \).

3. When the relative field amplitude at the edges of the mirror increases, the accuracy of measurements of the azimuth by the monopulse method increases compared with the amplitude method; in particular, when \( 0.1 < \Delta < 0.316 \) the accuracy