SELECTIVE ACOUSTIC ANTENNA

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Acoustic phase zone plates for focusing sound in air are described. The directional patterns and the amplitude-frequency characteristics are presented.

The strong nonatmospheric noise generated primarily by human activity makes it necessary to develop acoustic antennas with high noise immunity. One way to increase the noise immunity is to develop selective acoustic antennas, in particular, antennas based on zone plates.

A zone plate, blocking the path of a section of the front of a sound wave with corresponding even or odd Fresnel zones, was first proposed by Reyleigh and was first investigated by Pholman.[1] The basic properties of amplitude zone plates are described in detail in Ref. 2. It is much more difficult to develop an acoustic zone plate that reverses the phase in half of the zones. The reason for this lies in the fact that the acoustic impedance of any material is so high compared with that of air that the sound waves are almost completely reflected. A phase zone plate was developed under the direction of Professor Perkal'skis (Tomsk State University) based on the method proposed by W. Kock.[3] In this method the wave is forced to move between plates making an angle θ, so that the path traversed is increased by a factor of $1/\cos\theta$. The zone plate with phase reversal was fabricated with the help of a cross piece, on which three rings made from a brass tube were attached. Strips of sheet metal, which created an additional phase shift by 180° for waves traversing an inclined path between the strips, were soldered to the rings at an angle of 60°. The size of the rings was calculated for spherical waves with $\lambda = 32$ mm and for distances from the zone plate to the sound source and receiver equal to 1 m each. The radii of the central and subsequent Fresnel zones in this case are as follows: $R_0 = 126.7$ mm, $R_1 = 179.5$ mm, $R_2 = 220.3$ mm, $R_3 = 254.8$ mm, $R_4 = 285.4$ mm, $R_5 = 318$ mm, and $R_6 = 337$ mm. In this setup the phase shift is generated in the central, second, and fourth Fresnel zones. Experiments confirmed that a phase zone plate gives two times larger amplification than an amplitude zone plate. However the phase zone plate described above is not axisymmetric, and this causes the amplification to depend on the orientation. For this reason V.L. Larin built an axisymmetric zone plate.[4] The central part, corresponding to the central Fresnel zone, consisted of a system of truncated 120° cones. The other even zones consist of waveguides, formed by plates turned by the same small angle relative to one another. The length of the plates is determined from the condition

$$l - d = \frac{\lambda}{2} = \frac{\lambda}{2}(1/\cos\theta - 1) = 15 \text{ mm},$$

since the slope angle of the plates $\theta = 60°$ and the wavelength is equal to 32 mm. The width of the plates is determined by the dimensions of the Fresnel zones. The amplification obtained with an axisymmetric phase zone plate is 20% higher than in the case of a nonaxisymmetric plate.

An axisymmetric plate in which a phase lag of 180° is observed in the region of the 1, 3, and 5 Fresnel zones was also constructed. We also notet hat both plates operate equally efficiently when the direction of the waves is changed.

The axisymmetric zone plates described above can be used together with a 550 mm long conical horn with an aperture diameter of 450 mm. One or two rings with phase reversal, corresponding to even or odd Fresnel zones, are placed in the aperture.

The experimentally measured amplitude-frequency characteristics of the zone plates are presented in Fig 1. The aperture of the zone plates is equal to 450 mm.

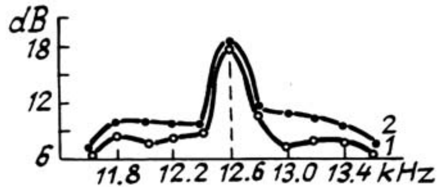

FIG. 1. The amplitude-frequency characteristics of the phase zone plates: 1) with phase reversal in the odd Fresnel zones and 2) with phase reversal in the even Fresnel zones.

The directional pattern of the antenna at 12.6 kHz is shown in Fig. 2. One can see from this figure that the phase reversal in the odd Fresnel zones gives somewhat better results than phase reversal in the even zones. This is explained by the fact that the central Fresnel zone makes the greatest contribution to the diffraction pattern on the axis of the zone plate and in the case of phase reversal in the even zones its effect is weakened by the waveguides.

The data presented in this paper show that the antenna described has a high immunity and can be used for performing different acoustic measurements in the presence of strong noise.

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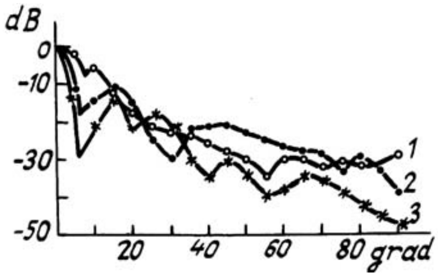

FIG. 2. Directional pattern of a selective acoustic antenna: 1) directional pattern of the horn; 2) directional pattern of an antenna with phase reversal in the even Fresnel zones; 3) same, but with phase reversal in the odd Fresnel zones.

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