INVESTIGATION OF DIFFRACTION PATTERN
OCcurring AT EARTH'S SURFACE FOR BACK
SCATTERING OF RADIO WAVES BY
INHOMOGENEITIES IN THE LOWER IONOSPHERE

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The characteristic dimensions have been measured for the diffraction pattern occurring at the
surface of the earth for back-scattering of radio waves by electron-concentration inhomogeneities in the upper part of the D-region of the ionosphere. Experiments were carried out
at 5.75 MHz with several transmitting antennas differing in radiation-pattern dimensions.
Signals were received by a space-diversity antenna system with a small base. Measurement
results show that the angular spectrum of radio wave scattering is basically concentrated within
angles $0 < \theta < 15^\circ$, and consequently the horizontal dimensions of the inhomogeneities exceed
the vertical ones. Sample determinations are given for rates of motion of inhomogeneities on
the basis of observations of back-scattered radio waves.

INTRODUCTION

Traditional methods of investigating inhomogeneities of the ionospheric plasma and their motions
by terrestrial radiophysics facilities are based on a study of the diffraction pattern occurring at the earth's
surface for reflection of radio waves from the ionosphere. One such approach is the back-scattering
method (viz, for example [1, 5]). In experimental technique and in the interpretation of the resulting data
this approach is very similar to the method of space-diversity reception with a small base. We shall
discuss the results of measurements of the characteristic dimensions for the diffraction pattern set up for
back-scattering of radio waves by inhomogeneities of the electron concentration in the upper portion of the
ionospheric D-region and shall consider questions pertaining to methods for measuring the rate of motion of
inhomogeneities in the lower ionosphere. The experimental results are analyzed on the basis of the
correlation relationships between the parameters of the scattering region and the radio waves back-scattering
field [3-5]. Let us recall these relationships. If there is motion of "frozen-in" inhomogeneities of the
ionospheric plasma at a constant horizontal velocity $\mathbf{v}$, then the space-time correlation coefficient $\rho(\mathbf{r}_0, \tau)$
for the amplitudes of back-scattered radio waves at the earth's surface is represented by the formula

$$
\rho(\mathbf{r}_0, \tau) \approx \frac{\left| \int_0^\infty \Phi_i \left( \frac{\mathbf{r}}{r} \right) K(r) \exp \left[ 2i k \left( \mathbf{v} \cdot \frac{\mathbf{r}_0}{2} - \frac{\mathbf{r}}{r} \right) \right] \frac{dr}{r^2} \right|^2}{\int_0^\infty \Phi_i \left( \frac{\mathbf{r}}{r} \right) K(r) dr^2},
$$

(1)

where $K(r) = f(r)/r^2$, $f(r/r) = f(\delta, \varphi)$ is the effective radiation pattern (for the field) of the antenna system
(product of the patterns of the transmitting and receiving antennas); $\mathbf{r}$ is a vector directed from the reception
point to the point of integration;

$$
\Phi_i \left( \frac{\mathbf{r}}{r} \right) = \frac{1}{2\pi} \int_0^{\infty} \Delta \sigma(r) \Delta \sigma(r + \eta) \exp \left[ -2i \frac{k_0}{r} (\eta \cdot \mathbf{r}) \right] d\eta,
$$


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Fig. 1

is the angular spectrum of radio wave scattering by inhomogeneities; \( k_0 = 2\pi/\lambda \), \( \lambda \) is the working wavelength; \( \delta \) and \( \varphi \) are polar coordinates. Expression (1) is valid on the assumption that the signal amplitudes are Rayleigh-distributed [6, 7, 11]; the conditions \( k_0 v \tau^2/\tau \ll 1 \) and \( k_0 r^2/\tau \ll 1 \) are satisfied; the index of refraction differs little from unity, and the mean square fluctuations in the dielectric constants, \( \Delta \varepsilon^2 \), do not depend on the altitude. It follows from (1) that the values of the time (\( \tau_C \)) and space (\( r_{0c} \)) correlation radii depend on which of the two functions, \( f^2(\tau/\tau) \) or \( \Phi_\varepsilon(\tau/\tau) \), is used for integration with respect to \( \delta \) and \( \varphi \).

Let us look at the possible relationships between the functions \( f^2(\tau/\tau) \) and \( \Phi_\varepsilon(\tau/\tau) \) and establish functional relationships for \( r_{0c} \) and \( \tau_C \).

We know [4, 11] that when the dimensions of the antenna radiation patterns are large, \( \delta_A \sim 1 \) (where \( \delta_A \) is the half-width of the pattern), while scattering takes place on isotropic inhomogeneities (\( \Phi_\varepsilon(\delta, \varphi) \) does not depend on \( \delta \) and \( \varphi \)), the space correlation decreases rapidly at scales of the order of the wavelength \( \lambda \). If scattering takes place at disk-shape inhomogeneities, however, and they are of Gaussian form

\[
(\varepsilon_\varepsilon(r) = \langle \Delta \varepsilon^2 \rangle \exp \left[-4(\eta_{x}^2 + 3\eta_{z}^2)/l^2\right] - 4(\eta_{z}^2/l^2)],
\]

where \( l \) and \( l_z \) are horizontal and vertical scale factors of the inhomogeneities, then when \( \delta_S = \lambda/(\pi l) \ll 1 \), we have the following relationship for the angular scattering spectrum;