ON THE PROBLEM OF POLARIZATION CHARACTERISTICS OF RADIO WAVES IN A RANDOMLY INHOMOGENEOUS MAGNETOACTIVE PLASMA

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Expressions for the Stokes parameters when radio waves propagate in a turbulent magnetoactive plasma have been obtained using a refractive scattering method. The problem of the spatial coherence of polarized radiation is considered. Expressions for the correlation functions and fluctuation dispersions of the Stokes parameters are found in the case of saturated wave field fluctuation. It is shown that the fluctuation of the circular polarized component will be observed in the received radiation even if the circular polarization is absent in the radiation that is incident on the magnetoactive plasma slab. A method is proposed to define the preference orientation of the magnetic field in the inhomogeneous layer of space plasma, which is based on the simultaneous measurement of the space correlation functions of the I, V Stokes parameter fluctuation and Faraday rotation of the radiation polarization plane from the source with known polarization characteristics.

The problems of radio emission polarization transfer in a magnetoactive plasma have been discussed in many papers (see [1, 2] and references therein). Much less attention has been given to the problem of the polarization of radio waves propagated in a randomly inhomogeneous plasma. Among the papers dealing with the latter problem we should mention [3] and [4] in which the Stokes parameters were calculated for radio waves propagated in a magnetoactive plasma with random inhomogeneities. Although the particular relationships [3, 4] for the Stokes parameters were obtained for almost the same conditions (for weakly gyrotropic and rarefied plasmas), the results reported in [3] and [4] differ considerably. Besides the difference in the calculation techniques used in [3] and [4], we also should mention the limits that were imposed on the characteristics of the medium in which the radio waves propagated (for example, the authors of [3] considered the case of plasma inhomogeneities with a Gaussian fluctuation correlation function while in [4] the phase fluctuations of normal modes on the screen were assumed to be identical). Therefore, it seems reasonable to consider once again the problem of the polarization of radio waves propagated in a randomly inhomogeneous magnetoactive plasma. We will use the method of refractive scattering of radio waves (RSRW) which is known to allow specific features of radio waves propagated in a turbulent medium with strong large-scale inhomogeneities to be studied by calculation of the statistical characteristics of radio waves behind the equivalent phase shield [5]. Furthermore, we consider the problem of space coherence of the polarized radiation propagated in a randomly inhomogeneous magnetoactive plasma. That problem was examined in [6] for the case of weak fluctuation of the wave field. Unlike [6], the RSRW method makes it possible to analyze the behavior of the correlation functions of the Stokes parameters in the mode of strong (saturated) fluctuation of the field. It will be shown below that in this formulation solving the problem of the space coherence of polarized radiation gives many interesting results concerning the propagation of polarized radiation in a space plasma.
Let a plane monochromatic wave of arbitrary polarization be normally incident (along the \( z \) axis) on a slab of homogeneous cold magnetoeactive plasma. The external magnetic field \( \vec{H}_0 \) lies in the \( yz \) plane and makes angle \( \alpha \) with the \( z \) axis. A turbulent phase shift is placed at the start of the slab (for \( z = 0 \)) to generate strong \( (s_{1,2}^2 \gg 1) \) large-scale \( (\Delta z \ll L_0) \) phase fluctuations of the normal waves \( (s_{1,2}^2 \) are the root-mean-square phase fluctuations of normal waves in the plasma, \( k_{1,2} \) are the wave numbers of the radiation, \( z \) is the distance from the start of the layer (shield) to the point of observation, and \( L_0 \) is the external scale of turbulence).

The complex field of two normal waves at the point of observation can be described by the following expression (cf. [4]):

\[
\vec{E}(z) = \vec{E}_1(z) + \vec{E}_2(z),
\]

\[
\vec{E}_{1,2}(z) \sim \int_{-\infty}^{\infty} d\vec{k}_\perp \, \vec{G}_{1,2}(\vec{k}_\perp) \exp[-i q^{1,2}(\vec{k}_\perp)z].
\]

Here, \( \vec{k}_\perp (\kappa_x, \kappa_y) \) is the wave vector in the \( xy \) plane, \( \vec{G}_{1,2}(\vec{k}_\perp) \) are the spatial spectra of the signal fields on the shield for two normal waves, and \( q^{1,2}(\vec{k}_\perp) \) are the longitudinal wave numbers of the normal waves. Using the approximation of small-angle scattering of radio waves by large-scale plasma inhomogeneities, we find [4]

\[
q^{1,2}(\vec{k}_\perp) \simeq q_0^{1,2} + q_1^{1,2} \kappa_y + \frac{q_2^{1,2} \kappa_y^2}{2k} + \frac{q_3^{1,2} \kappa_x^2}{2k}.
\]

For the case of a weakly gyrotrropic rarefied plasma \( (u, v \ll 1) \), which will be considered below (see also [3]), the parameters \( q \) in (2) are given by [2, 4]

\[
q_0^{1,2} \simeq k n_{1,2}(\alpha), \quad q_1^{1,2} \simeq \pm \frac{\sqrt{u} \sin \alpha}{2}, \quad q_2^{1,2} \simeq q_3^{1,2} \simeq \frac{\sqrt{u}}{2}(1 \mp \sqrt{u} \cos \alpha),
\]

where \( k = \omega/c, \omega = \omega_0^2/\omega^2, \omega_0 \) is the cyclotron frequency of electrons, \( \omega_0 \) is the Langmuir frequency of the electrons [2], and \( \omega \) is the circular frequency of the radiation. We find

\[
\vec{G}_{1,2}(\vec{k}_\perp) = \int_{-\infty}^{\infty} \vec{G}_{1,2}(\vec{k}_\perp') G_{1,2}(\vec{k}_\perp - \vec{k}_\perp') d\vec{k}_\perp',
\]

where \( \vec{G}_{1,2}(\vec{k}_\perp) = (2\pi)^{-2} \int_{-\infty}^{\infty} \exp\{i [s_{1,2}(z, y) - \vec{k}_\perp \vec{\rho}]\} d\vec{\rho} \) are the spatial spectra of the phase factors for normal wave fields on the shield, \( \vec{\rho}(z, y) \) is a vector in the \( xy \) plane, and \( \vec{C}_{1,2}(\vec{k}_\perp) \) are the vector amplitudes of the normal waves [2]. In the case of a phase shield with large-scale inhomogeneities we have

\[
\vec{C}_{1,2}(\vec{k}_\perp) \simeq \vec{C}_{01,2} \delta(\vec{k}_\perp),
\]

where \( \delta(\vec{k}_\perp) \) is a delta correlation function. The components of the vector \( \vec{C}_{01,2} \) can be described by the relations [2]

\[
C_{01x} = \frac{K_2 E_{ox} - E_{oy}}{K_2 - K_1}, \quad C_{02x} = \frac{E_{ox} - K_1 E_{oz}}{K_2 - K_1},
\]

\[
C_{01y} = K_1 C_{01x}, \quad C_{02y} = K_2 C_{02x}.
\]