SCINTILLATION OF CASSIOPEIA A FROM ARTIFICIAL IONOSPHERIC INHOMOGENEITIES AT 25, 240, AND 290 MHz


We present the result of observations of scintillation of the discrete radio source Cassiopeia A from artificial ionospheric inhomogeneities, and estimates of electron density fluctuations in the disturbed region.

It is well known that artificial electron density inhomogeneities are created in the ionospheric F layer under the influence of strong shortwave radiation (heating) [1-4]. The present work is a continuation of research described in [4], devoted to the study of scintillations of the discrete radio source Cassiopeia A from these artificial inhomogeneities.

Ionospheric heating was accomplished by either 4.6 MHz or 5.75 MHz radiation. There were several differences between the methods of the present experiment and that described in [4]. First, the transmitter power was increased to 200 kW. Second, the heating in a number of cases in 1977 was produced by a two-element interferometer with a spatial interference lobe period of 3 km at a height of 300 km and a directional envelope typically corresponding to the directional diagram of a single antenna, producing heating more quickly. Third, the radiation intensity from Cassiopeia A was simultaneously recorded at three points in the Gor'kii region: Zimenki (P1), Staraya Pustyn' (P2), and Vasil'sursk (P3); point P2 was located 66 km southwest of P1 [4], and point P3 was 100 km to the east of P1. Observations at P1 and P3 were made in 1976 and 1977 at a frequency of 25 MHz, while at P2 they were made at 25 and 240 MHz in 1976 and at 25 and 290 MHz in 1977.

Antenna rays of 12 wave dipoles were used for reception at 25 MHz, as in [4]. A fully steerable, 14-m-diameter parabolic radio telescope (RT-14) was used for observations at 240 MHz, while a 10-m telescope (RT-10) was used at 290 MHz. Dicke-switched receivers were used on the telescopes, which had a sensitivity of about 0.8 K with a 1-sec time constant. The antenna temperature of Cassiopeia A was 90 K at the RT-10 and 250 K at the RT-14. The radio telescopes enabled the reliable detection of intensity fluctuations in Cassiopeia A of typically 3-6 K. As an example, Fig. 1 shows a chart record for March 17, 1977, at a frequency of 290 MHz (the transmitter on time is defined by the striped band).

At P1 the speed and direction of motion of the inhomogeneities were also determined. Measurements of these parameters were carried out by spatially distributed reception of the radiation from Cassiopeia A, using three identical antennas at 25 MHz. The receiving stations formed a right triangle with legs 0.94 and 1.48 km. The speed and direction of motion of the inhomogeneities were determined by a similarity method.

Scintillation effects due to heating were observed most often at P1, which was below the center of the disturbed ionospheric region, and more strongly at P2, which was toward the edge of this region. However,
such effects were practically absent at P₃, which was located far from the disturbed region.

Scintillations were also observed on those days when heating was effected by the interferometer. We did not note any periodicity in the scintillations which might be associated with the working of the interferometer. This is apparently connected with washing out of the interference pattern by drift of the inhomogeneities (the drift time of inhomogeneities over a distance equal to the period of the interference pattern is 30-60 sec at typical drift speeds of 50-100 m/sec).

Ionospheric heating was accomplished in runs 7-14 min long. We determined the lag time τ₁ of effects with respect to the time the transmitter was turned on and the relaxation time τ_rel with respect to the time it was turned off, the speed and direction of motion of inhomogeneities (at P₁), the fluctuation frequency f₁ (or 1/T₁), and the value of the fluctuation index average over the run

\[ F = \langle (I - \bar{I})^2 / \bar{I} \rangle, \]  

(1)

where I is the radio intensity of the radiation received by the antenna.

The time lag varied from 0 to 9 min at P₁; in almost all cases, scintillations began later at P₂. Using data obtained at P₂ in February-March, 1976, we made a comparison of fluctuation frequencies f₁ with the rate of motion of inhomogeneities. The dependence of f₁ (sec⁻¹) on v (m/sec) is shown in Fig. 2; the points are apparently located in a sector bounded by the lines

\[ (f₁)_1 = 1.45 \cdot 10^{-4} v \]

and

\[ (f₁)_2 = 4.7 \cdot 10^{-4} v. \]

Figure 2 implies that the characteristic dimensions of inhomogeneities are in the range 2-7 km, and the most frequently occurring drift speeds of the inhomogeneities are 50-100 m/sec. The relaxation time at P₁ varied from 1 to 16 min. The scintillation relaxation time was determined by two factors: diffusion of inhomogeneities and their transport away from a fixed region. If we assume that the entire disturbed region moves with the speed measured at P₁, then the transport time of inhomogeneities τ_tr lies in the range 2 min to 30 min. Characteristic spreading times for inhomogeneities due to diffusion lie in this same range. (In diffusion time estimates τ_d ~ R_l²/4D_i, where D_i = κ(T_e + T_i)/Mν_i, and it has been assumed that T_e + T_i ~ 3500°, M ≈ 20, ν_i ~ 2, R_l = R_l / l, where l ~ 10 and R_l is on the order of 2-7 km; R_l is the longitudinal size of the inhomogeneities.) However, comparison of τ_rel and τ_tr, and also τ_rel and R²_l, showed no notable correlation between these values.

Values of the fluctuation index F differed substantially for scintillations observed simultaneously at different points and frequencies. For comparison, Table 1 shows data obtained on March 23 and 24, 1976 at P₁ (25 MHz) and at P₂ (25 and 240 MHz); T₁ is the mean fluctuation period.

<table>
<thead>
<tr>
<th>Date</th>
<th>Time of heating min</th>
<th>P₁</th>
<th>P₂</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>f₁ = 25 MHz</td>
<td>f₁ = 25 MHz</td>
<td>f₁ = 240 MHz</td>
</tr>
<tr>
<td></td>
<td>T₁</td>
<td>T₁</td>
<td>T₁</td>
</tr>
<tr>
<td>3-23-76</td>
<td>1051-1044</td>
<td>16,0</td>
<td>20 sec</td>
</tr>
<tr>
<td>3-24-76</td>
<td>1001-1014</td>
<td>18,6</td>
<td>150 sec</td>
</tr>
</tbody>
</table>

Figure 2