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The self-inversion of the sign of circular polarization in "halo" microwave sources

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Abstract. The experimental and theoretic investigation of the halo (a detail of local source structure genetically associated with an active region magnetosphere) is presented by the example of the AR 5200 (October, 1988). Accordingly to the high space resolution observations of RATAN-600 and SSRT the emission of this region was almost completely ($\approx 80\%$) consist of halo emission. The peculiarities of the observed halo spectrum and polarization with the model explaining these peculiarities are described. It is shown that the inversion phenomenon for the halo is strongly affected by the propagation conditions influence on the polarized emission inside the large source of this emission. The term 'self-inversion' is introduced for this effect. Maximum in the halo spectrum at the wavelengths 5–10 cm is clarified by the scattering and by the strong suppression of the emissivity of non-thermal electrons at these and more longer wavelengths.

1. Analyzes of observational data

By the example of the large active region (AR 5200, October, 1988) the concept about an emission of the halo (a detail of local source structure genetically connected with the AR magnetosphere) were precised on the base of the spectral polarization observations with the high space resolution (of RATAN-600 and SSRT). In case of AR 5200 the halo emission accounted $\approx 80\%$ of total AR emission. The halo (Korzhavin & Peterova 1992, Peterova 1994, Peterova 1997) is a large non-structured source of emission with sizes in order of the total AR, with the emission center above the division line of polarities of bipolar spot group. The spectrum of non-polarized emission allow to distinguish two components: the thermal part and non thermal one. The thermal free-free emission with the flat (or descending to the longer wavelengths) spectrum is observed at the wavelengths shorter then 2.7 cm. Starting from the wavelength ≈ 2.7 cm the non thermal addition with a very steep spectrum in range 3–5 cm and with a smoothed maximum at 7–10 cm becomes apparent.

The halo emission was polarized and shows the inversion of the sign of polarization with the shifting across the heliographic coordinates of AR. Approaching to the central meridian the distribution of the local source brightness becomes bipolar with both components corresponding to the sign of the magnetic field of the head and the tail of the AR parts, but no one coincides with the maximum of the nonpolarized emission. At the limbs the source became unipolar. This phenomenon of inversion for the halo could be explained by the influence to the polarized emission of propagation conditions inside the source of this emission as modeled below. The term of 'self-inversion' is introduced.

The investigations of the halo polarization is to be a further development of the conception of the polarization sign inversion in the local source emission. We propose to divide it in two parts: the inversion for the cyclotron emission sources observed at short part of spectrum (< 5 cm), and the self-inversion for halo governing the character of polarization at the longest wavelengths (> 5 cm).

2. Results of modeling and discussions

The model source is presented by a big coronal loop containing as the thermal electrons as the non-thermal ones with the exponential energy distribution. To model the polarized halo emission the effects of propagation through the QT-region of magnetic field were taken into account noticing that in the conditions of the big coronal loop there is a QT-region inside the source of emission. The model well explains the main characteristics of the phenomenon of the inversion for the halo. It is shown that the self-inversion effect strongly affects the character of the intensity distributions of polarized emission along the source. The observed characteristics of halo emission is simulated with the following parameters: the temperature of thermal electrons $T_e \approx 4 \cdot 10^6 K$, the density of thermal electrons $N_e \approx 10^9/\mathrm{cm}^3$, the density of non-thermal electrons $N_0 \approx 10^5/\mathrm{cm}^3$, the spectral index of non-thermal electrons $\delta = 3$–4, the magnetic field strength $H = 50$–400 Gs.

The scattering clarifies the presence of maximum in the halo flux spectrum at the wavelengths 5–10 cm due to the strong suppression of the emissivity of non-thermal electrons at these and more longer wavelengths (this is a region of opacity of halo matter due to scattering) and the steep part of halo spectrum in the diapason of half-opacity (3–5 cm) being, in fact, the total emission of halo and spot component, the last one is fuzzy due to scattering throughout the halo volume.

Setting aside as the problem of the sources and the mechanisms of generation of the high energy particles as the problem of their keeping and accumulation, we may to remark that in the case of R 5200 the coronal loop was leaning on a very fragmented structure at the photosphere level and, in fact, consisted of an amount of single loops. Between these single loops the favorite conditions could be realized for the formation of current sheets. Resistance instability of the current sheets, in their turn, could be the cause of generation of the hot particles filling this AR magnetosphere and making the halo so strong. This assumption was confirmed by RATAN-600 observations often revealing the diffuse brightening of radio emission above bunches of small spots and pores.

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