RATAN-600 observations of solar cyclotron lines and their interpretation

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The data of multi frequency observations of AR 7962 on May 10–12, 1996 made in the range from 1.7 cm to 32 cm on reflective type radiotelescope RATAN 600 are given. A peculiarity of this sunspot-associated microwave source is the presence of a narrowband (line-like) feature at the wavelength about 8 cm overlapped on the background frequency spectrum of the active region. The relative linewidth is about 0.2 and peak intensity a twice exceeds the background radiation of sunspot-associated source. RATAN data are compared with Nobeyama radio maps at 1.7 cm on May 11-12, 1996: the line source seems to coincide with high frequency bright small size Nobeyama source. The life time 3 days and brightness temperature not more than a few million Kelvin make it possible to explain the observed feature as thermal cyclotron radiation from the source filled by the hot plasma.

Existence of line-like features in spectra of microwave sources attributed to cyclotron mechanism of generation, was predicted and expected, but observations face marked difficulties. According to theoretical analysis, individual cyclotron lines might be detectable in microwave spectra of active regions at gyrofrequency harmonics if specific distributions of physical parameters occur in the sources, for example, a neutral current sheet and/or magnetic field peak are present on the line of sight. A system of cyclotron lines is also expected in microwave spectrum of thermal radio emission from hot coronal loops and hot X-ray kernels responsible for so-called elementary flare bursts.

Two possible explanations of observed RATAN and Nobeyama sources are discussed. The first considers the origin of both radiations in one and the same source, most probably, hot kernel. The model of the kernel with static equilibrium plasma can be applied to our case: a small compact source with kinetic temperature $T_k \sim 3 \cdot 10^7 K$, electron density $N_e \sim 3 \cdot 10^{12} cm^{-3}$ and the size $L \sim 10^8 cm$ can provide the line-like emission at the wavelength about $8cm$ as the fourth harmonic of gyrofrequency in magnetic field about 300 G (for the sunspot with magnetic field at the photosphere $B_{ph} \simeq 2000G$ and the size of the order of $10^9 cm$ it means that the kernel was located at the height about $8 \cdot 10^8\, cm$). The high frequency Nobeyama source in this model is due to bremsstrahlung and, according to estimations, is quite explainable with above parameters.

Another possibility is to explain both sources by cyclotron radiation in inhomogeneous magnetic field. In this case the line is formed in a hot coronal loop rather high in the corona, while $1.7cm$ radiation is generated in the lower layers of the atmosphere above the active region: in the hot plasma the gyroresonance layer $s = 4$ can include markedly in the radiation at $1.7cm$ in magnetic field $B = 1500G$, but the line emission at $8cm$ can escape from a hot loop as the third-fourth harmonic in magnetic field about $300 - 400G$. The observed properties are fitted if $T_k \sim 10^7\, K,\ N_e \sim 10^9\, cm^{-3},\ L \sim 10^8\, cm$.