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The decameter spikes as a tool for the coronal plasma parameters diagnostics

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Abstract

The report is devoted to the analysis of the unusual event observed on 14 June 2012 in the frequency range 8–42 MHz. During this event the radiation flux changed stepwise two times. Assuming that these changes of radiation flux could be associated with the changes of the coronal plasma parameters (temperature, magnetic field) and using spikes as a tool for the determination of those parameters we traced how the temperature and magnetic field varied during the time of observations. According to the model proposed in the paper the magnetic field was about 1.9 G and the temperature varied in the range of $0.1 - 0.6 \times 10^6$ K at the heights 1.6–3.3 solar radii.

1. Introduction

Spikes are solar radio bursts which are usually observed during high solar activity in the wide frequency band from 8 GHz down to some MHz [1], [2]. Independently from the frequency band they have short durations ($\leq$1 s) and narrow frequency bandwidths (0.2–3 % of the observational frequency). The polarization of spikes is circular with the average value of about 25 %. The brightness temperature of the spikes is in the range $10^9 - 10^{15}$ K [1], [2]. Such morphological properties of the spikes make their identification simple and confident.

In this report the unusual event observed on 14 June 2012 in the frequency band 8–42 MHz is analyzed.

2. Observations

Three radio telescopes UTR-2 (Kharkov, Ukraine), URAN-2 (Poltava, Ukraine) and NDA (Nancay, France), were operated simultaneously on 14 June 2012. The observations with the radio telescopes UTR-2 and URAN-2 were performed with 100 ms time and 4 kHz frequency resolutions in the frequency band 8–32 MHz. The registration with the radio telescope NDA was carried out in the frequency band 28–42 MHz with time and frequency resolutions of 37 ms and 12 kHz respectively. The joint use of these radio telescopes allowed us to carry out the observations in the frequency band 8–42 MHz. The analyzed event was recorded in the time interval 04:45–16:00 UT on June 14, 2012. A storm of spikes was observed simultaneously with the storm of type III bursts and a type IV burst. During the observations the average radio emission flux changed stepwise two times from approximately 80 s.f.u. up to 20 s.f.u. in the time interval from 4:45 till 9:45 UT, and from 20 s.f.u. up to 1000 s.f.u. from 9:45 till 13:30 UT (Figure 1).

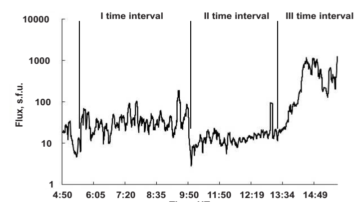

Figure 1: The time profile of the whole day of observations at frequency 28 MHz obtained with URAN-2.

We assumed that such variation of the flux can be related to the changes of the coronal plasma parameters. In the frame of the hypotheses that the spikes durations and bandwidths are determined by the temperature and magnetic field of the ambient plasma correspondingly [2], we checked whether and how the plasma parameters varied during the observation day. Clearly, we would like to understand the nature of these variations. Hence, the observations were divided into three time intervals (Figure 1). For each time interval we analyzed a large number of spikes. Thus for the first, second and third time intervals more than 500, 800 and 300 spikes were analyzed correspondingly.

3. Data analysis

The majority of spikes have durations of 0.4–1 s. The spikes durations decrease with the frequency and as a consequence also the rise and decay times, decreased during the day. In the present study we focused on the decay time (τ_d) of the spikes. Since the plasma mechanism of generation is considered as a possible mechanism of the spikes generation it is reasonable to assume that the decay time of spikes is defined by the life time of the Langmuir waves in the plasma i.e. by the particle collision time (τ_{coll}) [1]. The latter is determined by the temperature of the ambient plasma. If we assume that the $\tau_d \approx \tau_{coll}$, then, knowing the spike decay time we can estimate the temperature T of the coronal plasma:

$$T = 8 \times 10^3 f^{4/3} \tau_d^{2/3} \tag{1}$$

where f is the observing frequency.

During the first time interval the calculated coronal temperature was $\approx 0.1 - 0.6 \times 10^6$ K. During the second and third time intervals the temperature was found to be $\approx 0.2 - 0.43 \times 10^6$ K and $\approx 0.13 - 0.32 \times 10^6$ K respectively.

The instantaneous bandwidth of the decameter spike at the half maximum flux varies from 25±5.8 kHz at frequency 11 MHz to 80±17.2 kHz at frequency 40 MHz that is in average approximately 0.2 % of the central frequency. We noticed that the spike bandwidth linearly increases with the observing frequency:

$$\Delta f \propto Af \tag{2}$$

The coefficient A equals to 2.1×10^{-3}, 1.1×10^{-3} and 1.3×10^{-3} for the first, second and third time intervals respectively. Based on the ideas and assumptions proposed in [2] the magnetic field can be calculated using the formula:

$$B = \frac{\sqrt{2A} mc\omega_{pe}}{e \sin\theta} \tag{3}$$

where m and e are the mass and the charge of the electron, c is the speed of light, $\omega_{pe} = \sqrt{\frac{4\pi e^2 n}{m}}$ is the plasma frequency, and θ is the angle in which the electron beam is confined. If we suppose that the electron beam responsible for the generation of spikes is confined to some reasonable solid angle ($\theta = 15°$) [2], and knowing the coefficients A, we can determine the magnetic field B along the electron beam path. This yields that the magnetic field of the ambient plasma during the first, second, third time intervals amount about 2.2 G, 1.6 G, and 1.8 G correspondingly.

According to our analysis the decameter spike fluxes do not exceed 500 s.f.u. and in most cases they are even below 100 s.f.u. Such a high values of the flux lead to the high values of the brightness temperature $T_b = 10^9 - 10^{10}$ K that can be understood in the frames of plasma generation mechanism.

Based on the polarization data obtained with the radio telescope URAN-2 it was established that in the most cases the spikes polarization is circular and varies from 20 % up to 100 % with an average value of about 60 %.

4. Conclusion

In the present report we used decameter solar spikes as a tool for the determination of the coronal plasma parameters at heights 1.6–3.3 solar radii (in Newkirk empirical coronal model). We also traced the variation of the temperature T and magnetic field B in the course of the observation day. According to our analysis, the coronal temperature decreases during the day of observations. As a matter of fact, during the first, second and third time intervals the coronal temperatures were $\approx 0.1 - 0.6 \times 10^6$ K, $\approx 0.2 - 0.43 \times 10^6$ K and $\approx 0.13 - 0.32 \times 10^6$ K, respectively.

In this study we also found that the spike bandwidth linearly increases with the observational frequency. If we assume that the electron beam responsible for the generation of the spikes propagates within some average solid angle $\theta = 15°$, then the value of the magnetic field strength B varies in the range 1.6–2 G during the day. The magnetic field herein obtained is in good agreement with the results obtained by other authors.

References

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