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On polarization of solar decameter spikes

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Abstract

In the present paper an analysis of the polarization properties of the solar decameter spikes is performed. We found that decameter spikes can possess both left and right circular polarization which changes from 0 up to 100% with an average value 50%.

1 Introduction

For more than one decade solar radio spikes attract attention of the researchers in the field of the solar radio astronomy. It is assumed that these bursts have high diagnostic potential for both source of emission generation and surroundings (coronal plasma) in which the emission is generated [1, 2]. Since 60th a great number of papers devoted to spikes in the different wavelength ranges have been published. In those articles the main spectral properties of the spikes and possible models of their generation were described in details. However, such parameter of spikes as polarization remained practically unattended. Nowadays polarization properties of the spikes well enough studied in the meter and decimeter wavelength ranges [3, 4, 5]. Depending on polarization degree solar spikes are divided into three groups: weakly polarized ones (polarization degree less than 20%); intermediately polarized (polarization between 20% and 80%); strongly polarized (polarization higher than 80%) [3]. In most cases spikes with intermediate polarization are observed. In the paper [5] it was shown that the degree of spikes polarization depends on location of the active region on the solar disk. Namely, the farer from the meridian is the active region the lower is the degree of polarization of associated spikes. In some cases the sense of spikes polarization and associated with them Type III and IV bursts is the same [6, 7] and in other cases the sense of polarization is opposite [5].
Until the relatively recent time the question concerning spikes polarization in the decameter wavelength range has not been studied. In the present paper the first results of analysis of spikes polarization in the frequency band 8 - 32 MHz are presented.

2 Observations

The spikes analyzed in the paper were observed on 14 June 2012 with URAN-2 radio telescope (Ukrainian Radio interferometer of the Academy of Science) in continuous frequency band 8 - 32 MHz with high time - frequency resolution 100 ms and 4 kHz respectively. URAN-2 consists of 512 elements in form of two orthogonal dipoles arranged at an angle 45° to the meridian and has an area of 28,000 m^2 [8]. Such configuration of the elements gives an opportunity to register simultaneously two linearly or two circularly polarized components of the signal. Registration and identification of spikes on the dynamic spectrum with URAN-2 became possible after equipment of the last with a receiver of new generation DSP-Z (Digital Spectra Polarimeter of Z modification) [9]. The part of the dynamic spectrum with storm of spikes simultaneously with storm of Type III bursts is presented on Figure 1. This storm lasted during all day of observations from 04:45 up to 16:00 UT [10]. The dynamic spectrum was recorded with URAN-2 coupled with new receiver DSP-Z.

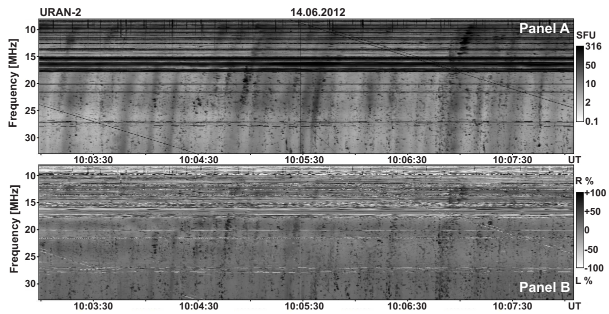

Figure 1. Storm of spikes bursts simultaneously with storm of Type III bursts recorded on 14 June 2012. Panel A represents power characteristics of the bursts and Panel B shows polarization one.

Spikes are fine structured bursts with duration and bandwidth in the decameter wavelength range about 1s and 60 kHz respectively [2]. On the Figure 1 spikes are dark spots chaotically located on the dynamic spectrum. Decameter Type III bursts on the dynamic spectrum appear as intense tracks drifting from high towards low frequencies. Duration of these bursts increases with observational frequency decrease. For example, at frequency 16 MHz duration of Type III bursts is about 10s [11].

3 Analysis of the observed data

For the analysis of polarization properties of the spikes we chose arbitrary 30 second intervals on the dynamic spectrum where influence of the accompanying bursts (Type IIIb, III, IV bursts) would be minimal. We measured the sense and the degree of polarization for more than 1500 spikes. According to statistical analysis spikes have high degree of circular polarization. On Figure 2 the histogram of spikes distribution on polarization is presented. As can be seen from the presented distribution spikes can have both left and right circular polarization. However, on this particular day the majority of analyzed spikes (approximately 96%) had right circular polarization. At the same time spikes with left circular polarization were not numerous only 4%. Such a numerical advantage on polarization may testify that most probably spikes with left and right circular polarization escaped from different active regions.

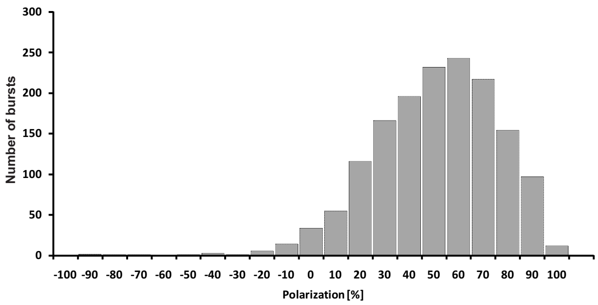

Figure 2. Histogram of spikes distribution on the polarization.

From the histogram of spikes distribution on the polarization we can conclude that degree of polarization of spikes changes from 0 up to 100% with average value about 50% and 20% for the bursts with right and left polarization respectively. The former value is close to that obtained for the decameter Type IIIb bursts which were observed simultaneously with Type III bursts and composed so called IIIb-III pairs [11]. The mean value of Type IIIb bursts polarization is 40% - 60% depending on the time of observations. Also we found that spikes polarization does not depend on observational frequency and changes within interval 40% - 70%. It must be noted that as in the case of Type IIIb bursts in the majority of the cases (70%) the maximums of spikes polarization precede the maximums of emission fluxes (Figure 3). On the Figure 4 the histogram of distribution of time shifts between flux and polarization maxima is presented. The positive and negative values correspond to delay (in average 0.14s) and advance (about 0.25s) of flux maxima with respect to polarization maxima correspondingly.

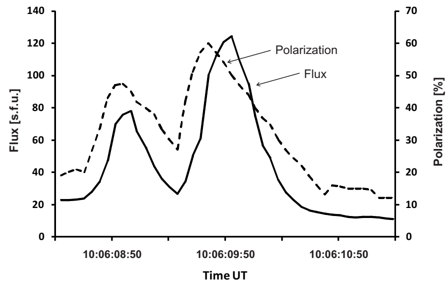

Figure 3. Power and polarization profiles of the spikes.

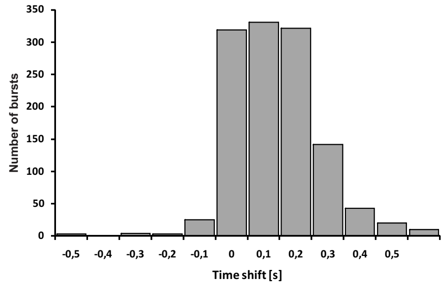

Figure 4. Histogram of distribution of time shifts between flux and polarization maxima.

4 Leading spot rule

Polarization properties of the spikes can be used to determine or refine their generation mechanism. Apparently from the polarization observations we can judge about preferred mode of emitted wave (ordinary or extraordinary). The "leading spot rule" is often used to determine the wave mode [4, 5]. In the frames of this rule it is assumed that flare happens above leading spot of the active region which in the majority of the cases dominate the trailing one. Thus the magnetic polarity of the leading spot determines direction of magnetic field of the emission source. Comparing measured degree of circular polarization of the bursts and direction of the magnetic field in the leading spot the mode of the wave can be determined. For example, if the emission has left (right) circular polarization and the magnetic field in the leading spot is directed toward the observer North (from observer South) then the leading spot rule suggests o-mode emission. In our case the majority of spikes (96%) had right circular polarization (see Figure 2). At the same time according to data from SDO satellite (Solar Dynamic Observatory) magnetic fields of the leading spots of the active regions NOAA 11504-11505 and NOAA 11507-11508 with which we associate the enhanced activity in the radio band were directed toward the observer North (Figure 5). Comparing spikes polarization and direction of the magnetic field we can conclude that most probably mode of the emitted wave corresponded to x-mode.
However, Type III bursts observed on this day had right circular polarization (see Figure 1). According to [5, 6] the emission of the Type III bursts corresponds to o-mode. To satisfy this statement the Type III bursts should be associated with active region NOAA 11506, where the magnetic

field in the leading spot was pointed from observer South (Figure 5). Since Type III bursts and spikes observed on this day have the same sense of circular polarization we may conclude that both types of bursts are emitted on o-mode and can be associated with the same AR NOAA 11506.

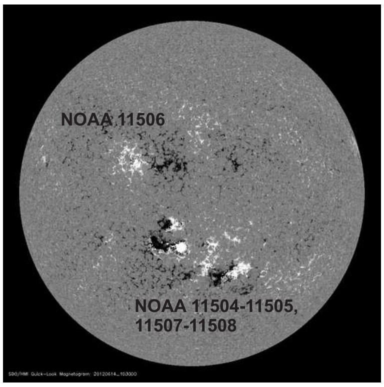

Figure 5. Magnetogram obtained with SDO satellite showing map of magnetic fields on the solar disk (black spots show direction of the magnetic field from observer and white toward observer). Taken from: https://www.nasa.gov/content/goddard/sdo-hmi-magnetogram/.

5 Conclusion

In the present article for the first time the analysis of the observational polarization properties of the decameter spikes was performed. It was shown that decameter spikes can have both left and right circular polarization. The degree of their polarization can vary from 0 up to 100% that observed in the case of high frequency spikes as well.

The sense and degree of polarization of decameter spikes agree well with those obtained for the decameter Type IIIb bursts. This fact can be additional evidence that spikes and striae, which form Type IIIb bursts, are the same type of the solar radio bursts [12].

Question concerning usage of the polarization of spikes for determination or confirmation of the possible model of their generation on this stage of our research remains open and needs further study.

6 Acknowledgements

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