TIME PROFILE, DURATION AND POLARIZATION OF HIGH FREQUENCY SPIKES

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UDC 523.985.7-77
Conference paper

Abstract. We analysed a large data set of spikes observed at frequencies 1420 and 2695 MHz recorded with high time resolution by the Trieste Solar Radio System. Different types of analysis were performed in order to determine duration, polarization and time profiles of single spikes.

Key words: solar radio bursts - spikes

1. Introduction

Within solar radio bursts spikes present extreme characteristics like very high brightness temperature (about $10^{15}$ K), very short duration (less than 0.1 s) and very narrow bandwidth (relative emission frequency band is about 1%). They can be present in a very large spectral range (at least from 200 MHz to more than 3 GHz). They appear in groups (clouds) that last some seconds up to few minutes. Clouds of spikes are present during the lifetime of both, strong and also weak flares. Some develop in the early phase of flares, some others in the late one; this second possibility is rather
common during the evolution of strong flares. The most recent review was prepared by Fleishman & Mel’nikov (1998).

From the analysis of spikes recorded in the frequency range 360–1010 MHz, Güdel & Benz (1990) derived an empirical formula describing the duration of spikes as a function of frequency:

\[ d_2(\nu) = 0.02636 \left( \frac{\nu}{661} \right)^{-1.34} \text{s}, \]

where \( \nu \) is the observing frequency in MHz and \( d_2 \) the duration at half power.

Only few papers (Jin et al., 1986, Wang & Xie, 1999, and Wang et al., 2002) were dealing with spikes observed at frequencies higher than 1 GHz. The reported results are rather inconsistent and also do not match in a satisfactory way the values given by the quoted formula.

The generation mechanism of spikes is still uncertain. Theoretical emission models can be essentially divided into two groups that are based on either the plasma emission and acceleration processes or on electron-cyclotron maser emission (for reviews see Benz, 1986 and Fleishman & Mel’nikov 1998).

2. Data set

In the recent years the radiopolarimetric instruments of the Trieste Solar Radio System (TSRS) recorded many intervals of spikes with high time resolution (10 and 1 ms) at frequencies 1420 and 2695 MHz. The contemporaneous spectral data recorded at the Ondřejov Observatory confirmed the presence of such an activity. The initial motivation of our work was the evaluation of the duration of spikes at frequencies higher than 1 GHz, as the data reported in the literature are rather inconsistent with the ones that result from the formula by Güdel & Benz (1990).

In Figure 1 we report a short record with time resolution 10 ms (digitization rate 100 Hz) and the same interval with 10 times higher resolution (digitization rate 1000 Hz); it is very evident that a study regarding the characteristics of spikes must be based on data with the highest time resolution. Our selection criterion excluded spikes that undergo superposition and the rather weak ones evidently affected by noise. The aim of such a selection is to eliminate spurious results and obtain possibly a rather small
Figure 1: Same time interval representing a group of spikes in the L-channel: top – digitization rate 100 Hz, bottom – digitization rate 1000 Hz.

indetermination. We also studied the polarization and the time profile of single spikes.

3. Results

Figure 2 shows an example of a spike at 1420 MHz with its left- (L) and right-circular (R) component. As they are very similar, the polarization is about zero. It is possible to realize that the R signal is slightly delayed (0.3 ms). Figure 3 shows the R versus L contemporaneous data. Due to the delay, a loop is formed; as the R component is delayed the loop is formed in the anti-clock-wise (ACW) sense as the time is progressing.

At 1420 MHz ten groups of spikes were selected during July 20, 2000 and were divided in subsections. The polarization was practically zero and the mean duration (at half power) was 9.0 ms, which is in agreement with
the quoted formula.

At 2695 MHz some groups of spikes recorded during June 6, 2000 and March 28, 2001 revealed duration (at half power) in the range 3.7 – 4.6 ms, i.e. in accordance with the quoted formula. In some other groups the duration was slightly longer (5.0 ms or more). The polarization was different in the different time intervals and also varying during an interval. We were able to realize that the duration was independent from the polarization degree.

As important information should derive from time profiles, two types of analysis were performed. The first one regards the determination of the e-folding rise ($t_u$) and decay ($t_d$) times. We found that these values are quite similar (see Figure 4), the ratio of their mean values was generally about 0.93; i.e. spikes have a rather symmetrical form. The second analysis requires spikes showing very smooth increase and decrease of the time profile. Only few cases were used for such a purpose. Intervals during the lifetime of spikes were determined where the trend was exponential and this peculiarity was present not only in the descending part but sometimes also in the ascending one; the results were rather similar. The growth and the decay times resulted in the range 3.1 – 8.4 ms and the mean value was 5.0 ms. As the collisional absorption is function of the plasma temperature (proportional to $T^{-3/2}$), the result found in the descending exponential
trend was used for the coronal temperature estimation (range $2.7 \times 5.3 \times 10^6$ K; mean value $3.7 \times 10^6$ K).

4. Discussion and Conclusions

We realize that the Güdel & Benz (1990) formula that determines the duration of spikes in the range $360 - 1010$ MHz is practically valid also at higher frequencies: 1420 and 2695 MHz, even if some spikes at 2695 MHz last slightly longer. The values of the duration reported in the literature are quite different and the indetermination rather large (Jin et al., 1986, Wang & Xie, 1999, and Wang et al., 2002).

Important information about spikes is contained in their time profile, since the ascending and the decaying parts essentially correspond to the source instability evolution and the plasma wave absorptions, respectively. The mean characteristic times of the ascending and the decaying parts of spikes profiles are found to be comparable, even if the dispersion of values is quite broad. More detailed analysis on very smooth profiles provided that an exponential trend can be found not only in the decaying phase but also in the ascending part.
We derived that due to the nearly symmetrical form of spikes also the parameters that determine the time profile during the increasing and the decreasing part are quite similar. In particular from that trend the coronal temperature was derived (about $3.7 \times 10^6$ K).

The polarization can have different values and they can vary in time. The position of the flares associated with spikes was in all considered cases rather near the disk center. We realized also that the polarization does not influence the duration of spikes. That confirms the result obtained at lower frequencies (in particular at 327, 408 and 610 MHz) during an exceptionally strong and long lasting cloud of spikes (Zlobec & Karlický, 1998). For type I bursts it is known that they show depolarization and longer duration when their source is near the limb and the scattering, that is responsible for such changes, is localized far away from the source (Wentzel et al., 1986). As for spikes the trend is different, it is very probable that the change of polarization should be originated in the source itself, or very near it.

Acknowledgements

P.Z. acknowledges the support by the MIUR (Italian Ministry for University and Research) under COFIN 2000. H.M. and M.K. acknowledge the support from the grant IAA3003202 of the Academy of Sciences of the Czech Republic. A.V. acknowledges the support by the Austrian Science Fund (FWF project P13653 PHY).
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VREMENSKI PROFIL, TRAJANJE I POLARIZACIJA VISOKOFREKVENTNIH "SPIKE-OVA"

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UDK 523.985.7-77
Izlaganje sa znanstvenog skupa

Sažetak. Analiziran je velik skup podataka "spike-ova" opažanih Tršćanskim Sunčevim radio sustavom na frekvencijama od 1420 i 2695 MHz s velikim vremenskim razlučivanjem. Odredeni su vremenski profili, trajanje i polarizacija pojedinačnih "spike-ova".

Ključne riječi: Sunčevi prevale radio zračenja - "spike-ovi"