PROPERTIES OF VERY SHORT DURATION SOLAR RADIO BURSTS

Jasmina Magdalenić1, B. Vršnak1, P. Zlobec2, and H. Aurass3

1Hvar Observatory, Faculty of Geodesy, Kačićeva 26, HR-10000 Zagreb, Croatia
2INAF-Trieste Astronomical Observatory, Via G.B. Tiepolo 11, I-34131 Trieste, Italy
3Astrophysical Institute Potsdam, D-14482 Potsdam, Germany

ABSTRACT

The characteristics of super-short structures (SSSs) occurring in the metric (200-600 MHz) solar type IV radio bursts are described. Their most important property is the short duration, which at half power, ranges from 4 to 60 ms. We present the properties of two groups of SSSs (events) related to flares in the same active region. Particularly of these SSSs is their spectral appearance; i.e. they form structured zebra pattern. Duration of the SSSs in both events, measured at high time resolution (1 ms) single frequency data (recorded at the Trieste Astronomical Observatory), is compared. Dependence of the SSS durations (4-30 ms) on observing frequency is discussed. We include also the analysis of the evolution of the radio source positions (obtained from the Nancay Radioheliograph). Similarities and differences in the two events are commented.

Key words: Sun; solar radio bursts.

1. INTRODUCTION

Radio spikes in the dm-wavelength range are considered to be the bursts of the shortest duration and the narrowest spectral width among all the types of solar radio emission. The dependence of the spike duration at half power $d_{1/2}$ on the observing frequency $f$, is expressed by the empirical relation $d_{1/2} = 0.02636(f/661)^{-1.342+0.13}$ (Güdel & Benz 1990).

However, Magdalenić et al. (2005, to be submitted) recently found very short bursts named super-short structures (hereafter SSSs) that occur in the metric (200-700 MHz) solar type IV radio bursts, and are significantly shorter than spikes. The duration of SSSs, at half power, ranges from 4 to 60 ms, and as we will show here, it is not necessarily frequency dependent.

The analysis of spectral data reveals a number of different morphological categories that are classified as: simple broad band, simple narrow-band, and complex SSSs. Here we discuss the subcategory of simple narrow-band SSSs named spike-like SSSs (morphologically most similar to spikes). We analyze the characteristics of two special SSS-abundant events related to homologous flares in the same active region. Particularly of these two events is that spike-like SSSs form zebra pattern. Structured zebra patterns, but with a longer duration of the substructures, at higher frequencies (2.6 - 3.8 GHz) had already been reported (Chernov et al. 2003). Here we focus on the analysis of the duration of the zebra substructures: spike-like SSSs.

2. DESCRIPTION OF EVENTS

For the analysis we use high time resolution single frequency data (1 ms) recorded by the Solar multichannel radioparametric system of the INAF-Trieste Astronomical Observatory (L-hand and R-hand circular polarizations, further on LCP and RCP). Spectral characteristics are inspected utilizing the dynamic spectra recorded by the Tremenfeld spectrograph of the Astrophysical Institute Potsdam (AIP). We include also the analysis of the evolution of the radio source positions (obtained from the Nancay Radioheliograph).

We analyze two events recorded on July 15, 2002. Both of the events (hereafter Event A and Event B) are related to SXR-flares from the same complex active region NOAA 30 (position N18 E01).

For every individual SSSs burst, the duration at half power was measured utilizing high time resolution (1 ms) single frequency data. SSSs consisting of several overlapping bursts, and noisy time profiles are not considered in the analysis.
2.1. Event A

The first time interval we analyzed is 11:40:30-11:48:30 UT. Single frequency recordings at 327 and 408 MHz are shown superposed on the AIP dynamic spectrum in Fig 1. The Event A was present during the rising phase of the related SXR C9.1 flare (beginning, maximum and end of the flare are 11:35-11:55-12:50 UT, respectively). In this event we considered altogether 260 SSSs at 327 MHz, and 304 SSSs at 408 MHz. Together with the fast SSSs in the first part of the Event A strong enhancements of the continuum that remind broad-band pulses were also recorded by Potsdam spectrograph. The SSSs appeared superposed both on weak (10 sfu) and on strong continuum (200-400 sfu). The intensity amplitudes (above continuum) of the SSSs are 2-3 times larger than the continuum itself.

Figure 2 shows changes of the SSS durations in time, at 327 and 408 MHz. For both observing frequencies we find that, during the first 350 s of the considered interval, all SSSs were of left circular polarization (further on LCP-SSSs). In the last 100 s the majority of SSSs were of right circular polarization (further on RCP-SSSs) and only few LCP-SSSs bursts were found. The SSSs showed different durations in these two subintervals. In the first 350 s we find that the durations of SSSs at 327 MHz were $d_{327} = 13 \pm 7$ ms, meanwhile at 408 MHz they were significantly shorter $d_{408} = 6 \pm 2$ ms. On the other hand, in the interval embracing the next 100 s, durations become significantly longer ($d_{327} = 20 \pm 9$, and $d_{408} = 17 \pm 8$ ms). Note that in the first subinterval the durations at 408 MHz were 2 times shorter than at 327 MHz (LCP-SSSs), whereas in the second subinterval the durations of RCP-SSSs were almost the same at both frequencies. Furthermore, we emphasize that the LCP-SSSs remained of comparable durations in both subintervals.

The different behavior of SSSs in the two subintervals is reflected also in the NRH radio source positions at 326 and 411 MHz (see Fig. 3). In the first subinterval (350 s) only one radio source was present, cospatial at 326 and 411 MHz ($x = -0.04; y = 0.22$). In the following 100 s, an additional radio source appeared ($x = -0.4; y = 0.28$). It is reasonable to conclude that the new radio source generated the SSSs of longer duration and different polarization, whereas the primary source remained the same over the whole period.

Figure 2. SSS durations at 327 and 408 MHz. Time interval is 11:40:30-11:48:30 UT.

Figure 3. Positions of the NRH radio sources during the first subinterval of 350 s (left panel). Additional radio source is visible during the second 100 s long, subinterval (right panel).
2.2. Event B

Event B comprises the time interval 13:59:25-14:00:55 UT, and it is, similar to Event A, simultaneous with the rising phase of the related subflare C3.6 (beginning, maximum and end of the flare are 13:45-14:04-14:15, respectively). Single frequency recordings at 327 and 408 MHz are shown superposed on the AIP dynamic spectrum in Fig. 4, and detail of the SSSs forming zebra pattern is shown in Fig. 5.

In this event we considered 375 SSSs at 327 MHz, and 305 SSSs at 408 MHz. The SSSs appeared, similar to the Event A, superposed both on weak (10 sfu) and on strong continuum (200-400 sfu). Intensity amplitudes (above continuum) of the SSSs are up to 6 times larger than the continuum, and in average larger that in Event A. Therefore, also zebra pattern and SSSs, in the dynamic spectrum, look more “emphasized” in comparison to the continuum (Fig. 5).

Contrary to the SSSs in the Event A, here all SSSs are of the same - left circular polarization (LCP-SSSs). The durations of LCP-SSSs are in average the same for both observing frequencies $d_{327,408} = 11 \pm 4$ min, and only small fluctuations exist during the whole interval (Fig. 6).

In this event there was only one, very stable NRH radio source having the same position ($x = -0.02; y = 0.22$) at both frequencies (327 and 411 MHz). Before the appearance of the SSSs three closely spaced sources were present. During the SSS interval, one of these sources became dominant, staying stable during the whole interval.