PROPERTIES OF VERY SHORT-DURATION SOLAR RADIO BURSTS

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Abstract

The characteristics of super-short time structures (SSSs) occurring in the metric solar type IV radio bursts are described. We focus on the frequency range 200-600 MHz, providing us the one-to-one identification of individual SSSs in single frequency recordings of the INAF-Trieste Astronomical Observatory and the spectral data of Artemis-IV (Greece) and AIP (Germany). The most important characteristic of SSSs is their duration which ranges at half power from 4 to 50 ms and is much shorter than generally expected for the bursts in the metric range. The analysis of the spectral and single-frequency data reveals a number of very different morphological categories: 1a) broad-band SSS pulses, 1b) broad-band drifting SSSs, 2a) narrow-band spike-like SSSs, 2b) narrow-band patch-like SSSs, 3) complex SSSs, consisting of the emission and absorption elements. Distribution of durations for all considered SSSs are compared with the distribution of spikes.

1 Introduction

For about 40 years spikes in the dm - range are considered to be the shortest known solar radio bursts [Benz, 1989; Fleishman and Mel'nikov, 1998 and references therein]. The duration of spikes increases with the decrease of the observing frequency, ranging from 3–4 ms at 3 GHz, to 110-150 ms at 200 MHz [Heszarosova et al., 2003; Guedel and Benz, 1990]. In this paper we show the existence and the characteristics of radio bursts, in the frequency range 200–600 MHz, with durations 2–10 times shorter than spikes. Hereafter we call these fast features super short structures (SSSs).

The aim is not only to report the existence of bursts shorter than spikes, but also to describe a whole palette of bursts in the time scale of spikes and shorter. Our analysis shows that it should not be presupposed SSSs are the shortest existing bursts, as it was considered for spikes up to now, but to regard them only as the shortest bursts we can presently record with now available technology.

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2 Observations

Starting data set are single frequency measurements recorded by the solar multichannel radiopolarimetric system of the INAF-Trieste Astronomical Observatory (MRPS) with 1 ms time resolution (in years 2000–2003). The solar origin of SSSs was confirmed by the identification of individual SSS bursts in the corresponding spectral recordings[1] of the solar radiospectrograph ARTHEMIS IV (University of Athens, Greece) and Tremsdorf (Astrophysical Institute Potsdam, Germany) sweep spectrographs with 10 ms and 100 ms time resolution respectively.

From the data set of 65 type IV bursts (hereafter "events"), comprising periodical fine structures, we selected 8 events abundant of SSSs. Spectral data show that different classes of SSSs exist through the whole dm-m range, but in this paper we focus on the frequency range 237–610 MHz.

3 Basic classification of SSSs

Due to morphological differences we divided the SSSs in the following categories:

- simple broad-band;
- simple narrow-band;
- complex SSSs.

All categories are in detail described elsewhere [Magdalenić et al., 2006], therefore we give here just a brief description.

Simple broad-band SSSs consist only of one type of features: in emission or in absorption. Two subclasses can be distinguished a) simple broad-band SSSs-pulses, and b) simple broad-band drifting SSSs. We found them in the frequency range of 200–500 MHz. Simple broad-band pulses are, in the 10 ms resolution dynamic spectra, instantaneous bursts of unmeasurable drift rate. Their bandwidth varies from pulse to pulse and is typically about $\triangle f$=100 MHz (Fig. 1). The duration of emission is the same over the whole frequency bandwidth, and at half power on average amounts to $d_{1/2} = 10$–20 ms. Simple broad-band drifting SSSs appear in the dynamic spectra as fuzzy drifting emission stripes (df/dt=400–1000 MHz/s). The bandwidth of broad-band drifting SSSs amounts to about $df \approx 100$ MHz (Fig. 1), and it is not changing much for the neighboring bursts. The duration varies from group to group, and it is on average $d_{1/2} = 30$–70 ms.

The category of *simple narrow-band SSSs* comprises bursts with bandwidth smaller than 20 MHz i.e. df/f=(4–7)%. The narrow-band SSSs are divided into a) spike-like SSSs and b) patch-like SSSs. Spike-like SSSs are the most frequent type of narrow-band SSSs in

[1] Intensity of the spectral recordings is "colour coded", but due to numerous procedures of image processing we use only the relative intensity I^*.

the frequency range 200–600 MHz. They are rather similar to "ordinary spikes" and, due to that, in lower time resolution records they could be erroneously classified as spikes. The durations of spike-like SSSs amount is in average 4–50 ms, and it does not seem to be frequency dependent, contrary to the duration of spikes [Guedel and Benz, 1990; Fleishman and Mel'nikov, 1998]. Various subclasses of patch-like SSSs with different spectral morphological "shape" exist, and we can divide them to dot-like, sail-like, and flag-like (Fig. 2). It is possible that more sub-categories exist, but since they are rather rare, we will not discuss them in more detail.

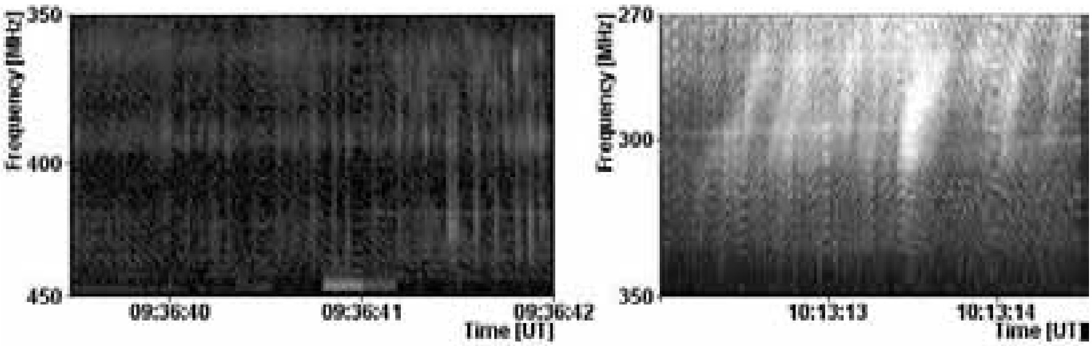

Figure 1: ARTHEMIS IV dynamic spectra of simple broad-band SSSs recorded on 15 April 2000. Left panel is showing SSS-pulses and right panel drifting SSSs.

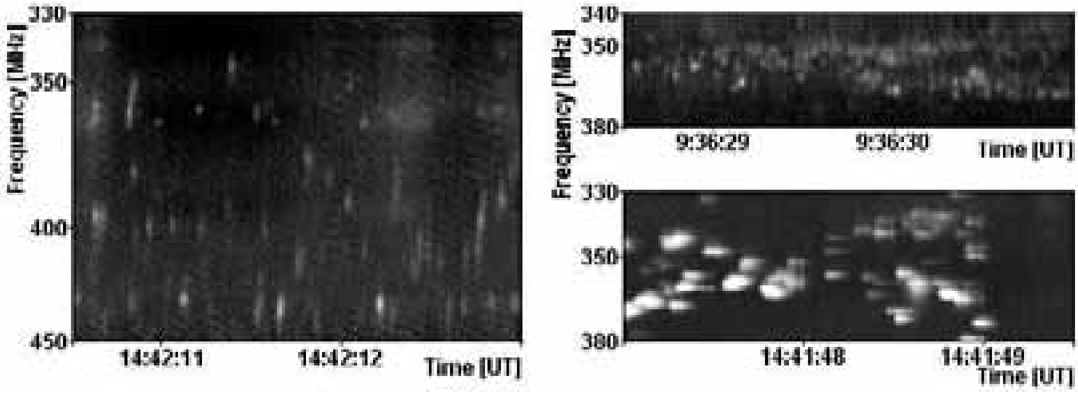

Figure 2: ARTHEMIS IV dynamic spectra of simple narrowband SSSs recorded on 15 April 2000. Left panel is showing spike-like SSSs, upper-right panel dot-like and lower-right panel flag-like SSSs.

The most distinct SSSs, in respect to the up to now known bursts, are the *complex SSSs*. Every individual burst consists of an emission and an absorption element. Two very distinctive sub-categories were found: a) tadpole-like SSSs and b) blinkers.

Tadpole-like SSSs are composed of a narrow-band emission patch on the high frequency side of the burst and an absorption component stretched towards lower frequencies (Fig.3). Drifting emission patch $df/dt = 60 \pm 10$ MHz s^{-1} is attached to the elongated dimmer absorption component of drift rate 1000 ± 400 MHz/s. The duration $d_{1/2}$ depends much on the frequency at which it is estimated, and it is in average about 50 ms for emission, and about 20 ms for absorption component. The tadpole like SSSs appear in the frequency range 250–370 MHz. To a certain degree, they remind to the tadpole bursts reported by Slottje [1972], but since there are also some distinguishable differences we named our SSSs tadpole-like.

Blinkers are drifting SSSs (in average −650 MHz/s) that consist of broad-band emission and broad-band absorption component. Each component extends to more than 100 MHz. We observed them in the frequency range 250–450 MHz, and it seems that the duration, $d_{1/2}$=30–40 ms, is approximately the same along the whole burst.

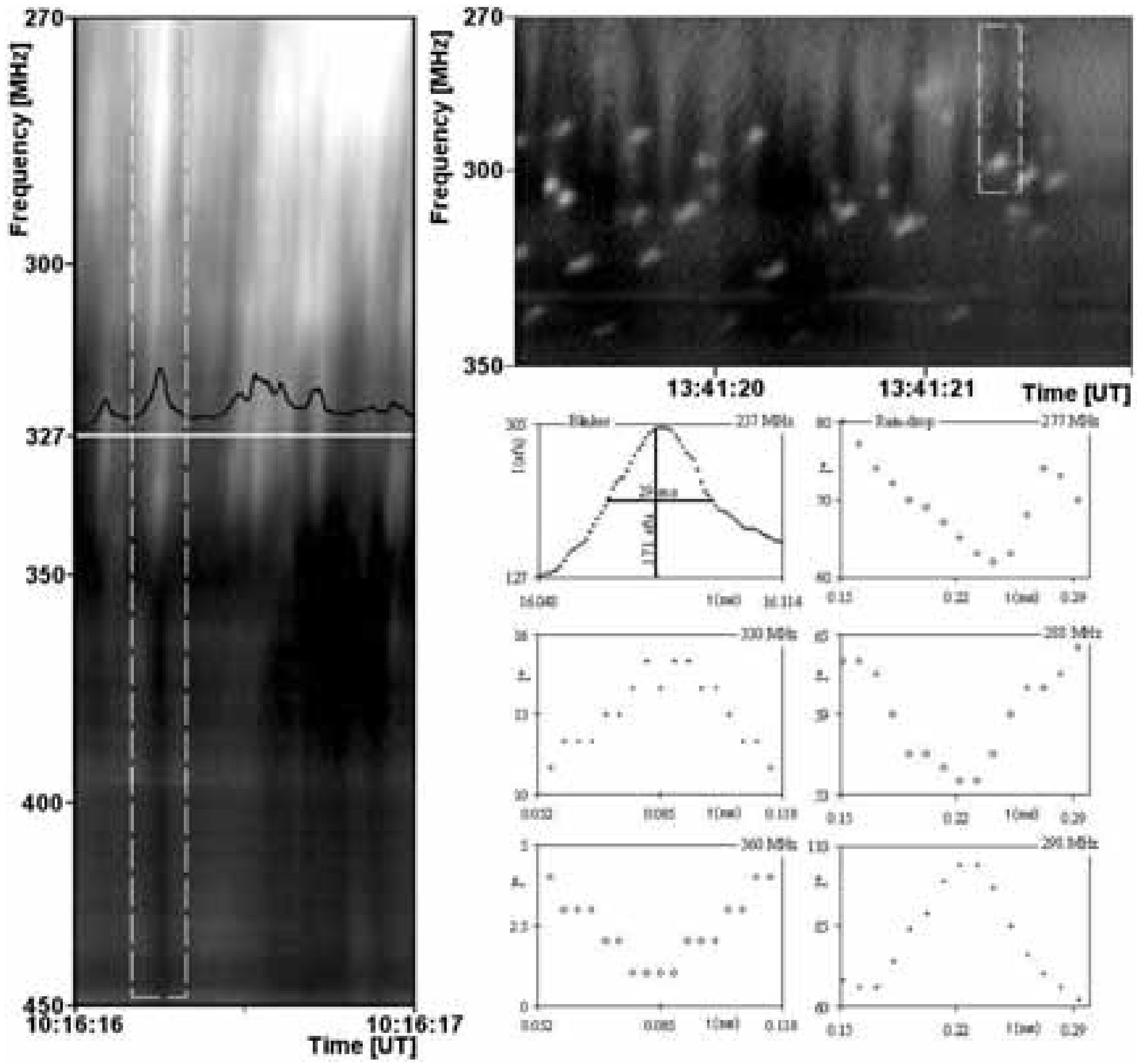

Figure 3: Complex SSSs recorded on 15 April 2000. Left panel shows blinkers and the upper right panel the rain-drop bursts. In the middle left panel the time profiles of the marked blinker at 327 MHz (single frequency data), 330 and 360 MHz (spectral cut) are shown. Time resolution is 1 and 10 ms, for single frequency record and spectral cuts respectively. In the middle right panel the time profiles of the marked rain-drop at 277 MHz, 288 and 298 MHz (spectral cuts) are shown.

4 Durations of the SSSs

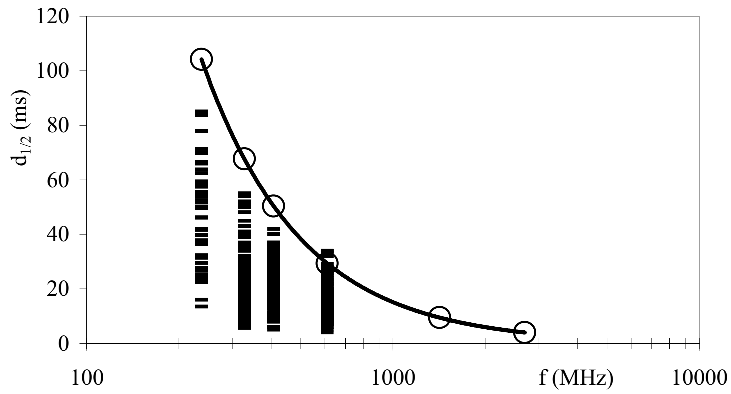

Figure 4: Durations of SSSs are shown as a function of observing frequency. Every dash represents the duration of a single SSS. Circles and curve represent the duration of spikes versus the observing frequency (obtained by Guedel and Benz [1990]).

The duration of SSSs is considered to be their most important characteristic, therefore we performed more detailed analyses of this parameter using single frequency records. In 8 events related to different flares we analysed 40 SSSs at 237 MHz, 100 at 327 MHz, 180 at 408 MHz and 230 at 610 MHz. The durations of individual bursts shown in Fig. 4 are compared with the empirical relation for spikes $d_{1/2} = 0.02636\ (f/661)^{-(1.34\pm0.13)}$ obtained by Guedel and Benz [1990]. It is evident that the durations of SSSs are not following the empirical relation for spikes. Moreover, the duration of an SSS can be up to 10 times shorter than the duration of spikes at the corresponding frequency. The scatter of spikes duration at a given observing frequencies is very small [Guedel and Benz, 1990], and it is in Fig. 4. represented approximately by the dimension of circles. The large span of SSS durations is probably also the consequence of their different morphological characteristics (discussed in Section 3).

The comparison of the distributions of duration (Fig. 5) for spikes (obtained by Zlobec and Karlicky [1998], in the left panel, and derived from the relation of Guedel and Benz [1990], in the right panel) and for SSSs shows that these are different types of bursts.

5 Summary

Analysing fine structures in type IV bursts we have found new types of bursts with very short durations, and we named them SSSs. They are characterized by duration similar, but generally shorter than spikes at a given frequency (up to ten times). Another difference between the two types of bursts is their spectral appearance, therefore we distinguish few subclasses of SSSs. It is probable that even more classes exist, but they could not be properly resolved due to the insufficient spectral time/frequency resolution. The comparison of the distribution of durations of spikes and of SSSs confirm the existence of a whole palette of different types of short bursts in the time scale of spikes and shorter.

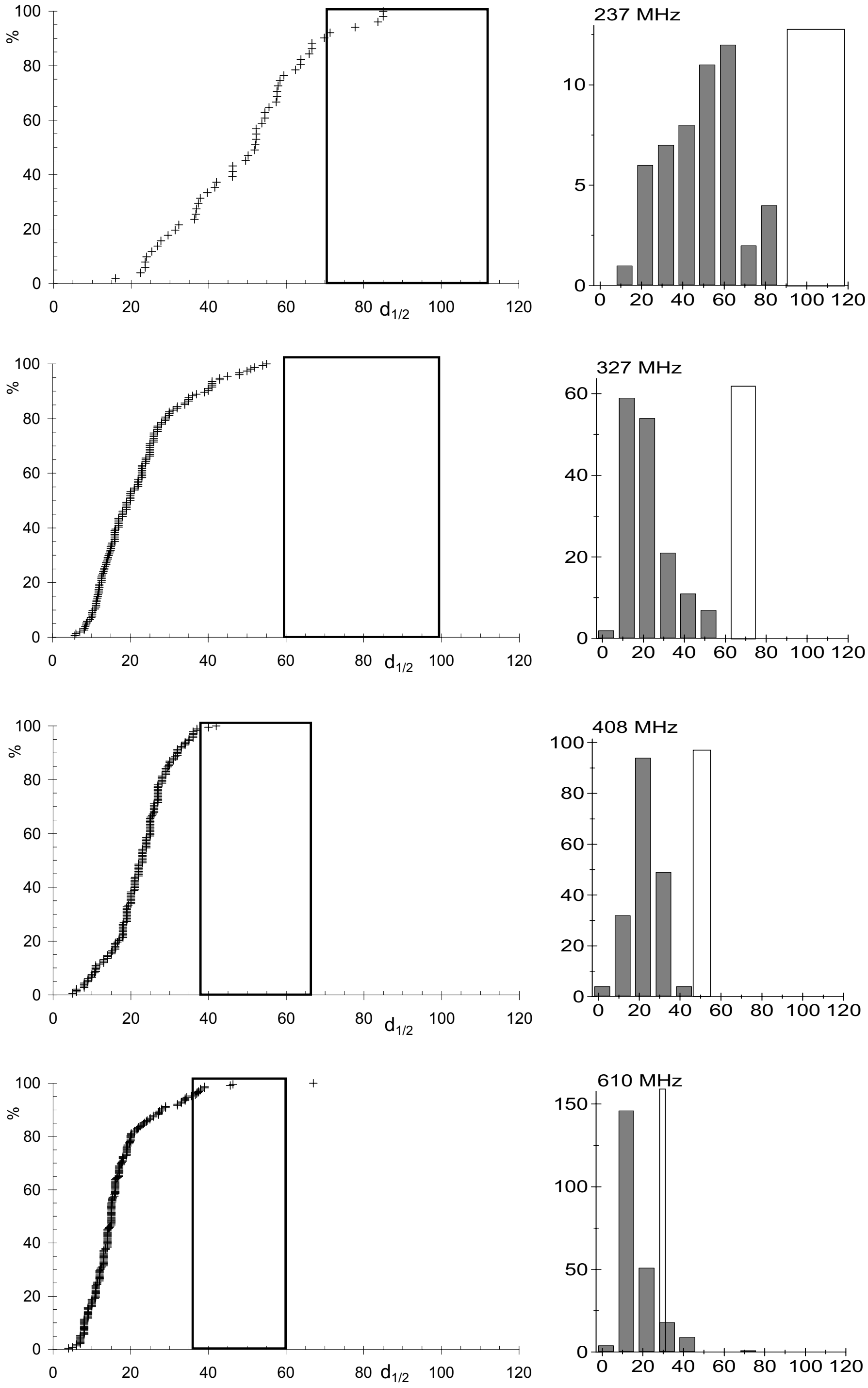

Figure 5: In the left panel we show cumulative distributions for SSSs (crosses) and spikes (white square) at frequencies 237, 327, 408, and 610 MHz. Distributions of spikes were obtained by Zlobec and Karlicky [1998]. In the right panel histograms of SSSs duration (gray) are compared with the duration of spikes (white square). Distributions of spikes are derived from the relation of Guedel and Benz [1990].

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