Geofísica Internacional (2006), Vol. 45, Num. 4, pp. 271-276

Radio bursts of very short duration: Fine structure of solar flare emissions

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Received: October 25, 2005; accepted: May 31, 2006

RESUMEN

El propósito de este trabajo es el estudio de las estructuras temporales finas (radio-eventos con tiempo característico $t < 10^{-1}$ segundos) de la radioemisión solar. Las observaciones usadas fueron proporcionadas por el polarímetro multicanal de la Estación Basovizza del Observatorio Astronómico de Trieste en las frecuencias de 237, 327, y 408 MHz. Para este estudio fueron seleccionados dos casos de estudio en dependencia del diagrama del patrón de polarización. Fueron seleccionados los radio-eventos de febrero 8 y julio 9 de 1982, ambos asociados a destellos con emisión gamma. Se consideraron sólo eventos con más de 100 unidades de flujo solar. La relación entre la intensidad de los eventos impulsivos y la intensidad del continuo de la radioemisión en que ellos se presentan, fue analizada.

PALABRAS CLAVE: Radioemisión solar, diagrama de polarización, destellos cortos.

ABSTRACT

The fine time structure of sub-second radio events of solar flare emissions is described on the multichannel polarimeter of Station Basovizza at 237, 327, and 408 MHz frequencies. We selected the February 8 and July 9, 1982 solar radio bursts, both associated to gamma flares. We considered only events with more than 100 solar flux units. The relationship between the intensity of the impulsive radio events and the background radio emission is discussed.

KEY WORDS: Solar radio emission, polarization diagram, spikes.

INTRODUCTION

Solar flare radio emission includes spikes, pulsations, and dips of the emission intensity. Radio spikes are events with duration less than 10^{-1} s, exceptionally high temperature ($T_B \approx 10^{15}$ K) and narrow spectral width (2-15 MHz). Such events were reported first in meter wavelengths (Fleishman and Melnikov, 1998). Interest in this phenomenon of shortest characteristic time scale emission and narrowest spectral widths has grown rapidly.

Many individual events during the flare appear in groups with a total duration of the order of 1 minute (Benz, 1985). A single spike was interpreted as a microflare, and a large number of spikes during the flare led to the idea of energy release fragmentation. This fragmentation might be produced by intrinsic properties of the radio emission mechanism itself, or as a result of secondary fragmentation of the source structure (Fleishman and Melnikov, 1998). However, at present there is no theoretical model capable of reproducing all the features and temporal, spectral or spatial properties in solar radio spikes.

Polarization is a very important parameter in determining the probable origin, mechanism and dynamics of fine structure impulsive radio events. We present two cases related to solar gamma flares with different polarization behaviour. In one case (February 8, 1982), the fine structure polarization resembles the polarization of the background emission. In the July 9, 1982 event, the polarization characteristics of fine structure and background emission are different.

DATA

Records from the multichannel radiopolarimeter at Basovizza Station with 33 millisecond time resolution were provided by the INAF-Trieste Astronomical Observatory. The solar radio emissions on February 8 and July 9, 1982 were both associated with solar gamma flares (Vestrand *et al.*, 1999). The polarization diagrams of both events differ substantially. A polarization diagram plots right component polarization vs. left component polarization. In the case of the 8 February flare, background emissions of the event and the impulsive events themselves have the same polarization diagram (Figure 3). In the case of the flare of 9 July, impulsive events occur whose polarization diagram differs from the polarization diagram of the background emission (Figure 4). The frequencies and observation intervals are shown in Table 1. Only events with more than 100 solar flux units were considered.

Table 1

Dates, frequencies, and intervals of observations

Date	Frequencies	Intervals of observation
08 February 1982	237 MHZ, 327 MHz, 408 MHz	12:46:01 U.T. – 12:54:40 U.T.
09 July 1982	237 MHZ, 327 MHz, 408 MHz	07:35:01 U.T. – 07:40:43 U.T.

RESULTS AND DISCUSSION

Anti-spikes are millisecond dips of the radio emission intensity reported in the literature (e.g. Fleishman and Melnikov, 1998). For the 9 July 1982 flare we observed radio emission dips of very short duration (t ~ 0.2 s) only at 408 MHz, less than one second after the occurrence of the gamma event (Figure 1). These dips presented a very high proportion of right component polarization (Figure 2).

Kuncic and Robinson (1993) propose the existence of windows in the gyroresonant levels that allow the radio emission of the spikes. In this work we consider the possible influence of these windows in the appearance of the dips. Consider the following initial conditions:

Te ~ 5×10^6 K
L ~ 3×10^6 m
ω ~ 2p (0.4) $\times 10^9$ s^{-1}
(ωp/ω) ~ 0.1,

where Te is the background electronic temperature, L is the characteristic length of the magnetic field, ω is the observation frequency (408 MHz), and ωp is the plasma characteristic frequency. The angular dependence of the optical depth was calculated for the gyroresonant layer S = 2. A narrow window of only 1-3 degrees was allowed for the extraordinary waves and a window of some tens of degrees for the ordinary waves.

During the gamma event an increase of temperature of more than 10^7 K occurs. An increase by 2 orders of magnitude in the value of the optical depth at the angle limit of the window, thus producing a significant attenuation of the radio emission from that direction.

Thus the geometry of the problem is an important factor in the observation of the dips. Both active regions associated with spike activity are located far from the central meridian (N17 E73 and S13 W88). The directions between the magnetic field and the radio emission coming from the

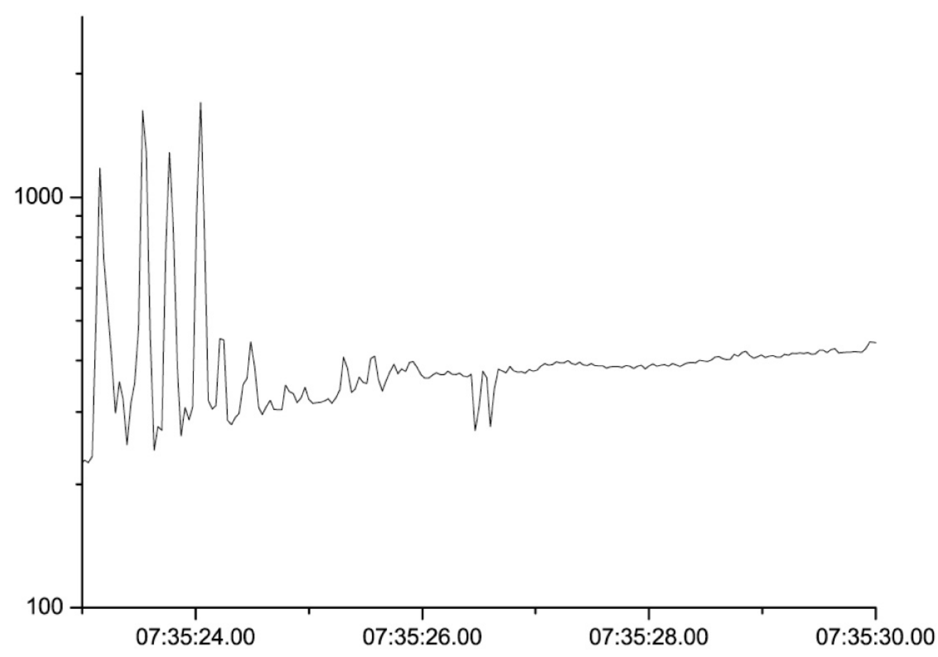

Fig. 1. Segment of the profile of the July 9, 1982 records in the frequency of 408 MHz. The dips can be observed in the interval between the 07:35:26 and the 07:35:27. Between 7:35:23 and 7:35:25 it can observed the radio emission associated to gamma event. In y-axis logarithm of solar flux units.

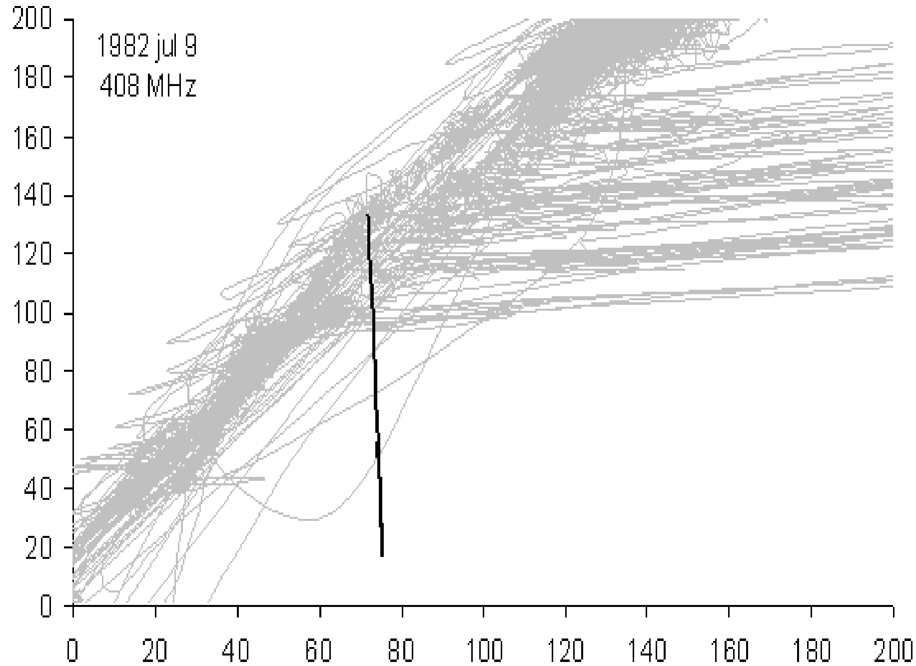

Fig. 2. Segment of the polarization diagram (right component polarization vs. left component polarization) of the July 9, 1982 records in the frequency of 408 MHz. The spiking activity associated to dips is marked with the arrow.

sources can be relatively wide. On the other hand, the magnetic field of the leader spot is generally better structured than the followers; thus its gyroresonant levels will also have a better structure. This could explain why the observed dips belong together with the active region located east of the central meridian (N17 E73).

A crucial unsolved problem is the possible relationship between impulsive, short-lived radio events and the background level. Fleishman *et al*. (2003) discuss a correlation between decimetric spike bursts vs. the microwave continuum.

In the present work one consideration is as follows. The polarization diagrams of the 8 February and 9 July 1982 events differ substantially. In the case of the 8 February event the background emission and the impulsive events have the same polarization diagram. The ratio of right component/ left component polarization is about 0.8 (Figure 3). In the case of the 9 July event there are impulsive events whose polarization diagram differs from the polarization diagram of the background emission (Figure 4). We examined the relationship between the intensity of impulsive events with a polarization diagram different from the background emission, and the intensity of the level of background emission on which they appear, and we found an inverse relationship (Figure 5).

Earlier work on a possible relationship between impulsive short-lived radio events and the microwave background had focused mainly on the cluster or group of spikes and the background level. In the present work we focus on the relationship between individual impulsive narrow band events and the microwave background continuum.

CONCLUSIONS

The results of an analysis of the impulsive events of very short duration (characteristic time $t < 10^{-1}$ s) associated with the radio emissions of February 8 and July 9, 1982 are presented. Several mechanisms could provide an explanation for millisecond radio events. Polarization characteristics of the solar millisecond radio events could be helpful to discriminate between them. We used the polarization diagram of the events, and we find that some spikes present a polarization behavior different from the background. This may be a very important clue to solve the problem about whether solar radio spikes form a homogeneous group, or contain subclasses as proposed by Fleishman and Melnikov (1998).

Another important aspect is the possible correlation between impulsive short-lived events and the background continuum on which they occur. We discuss the relationship

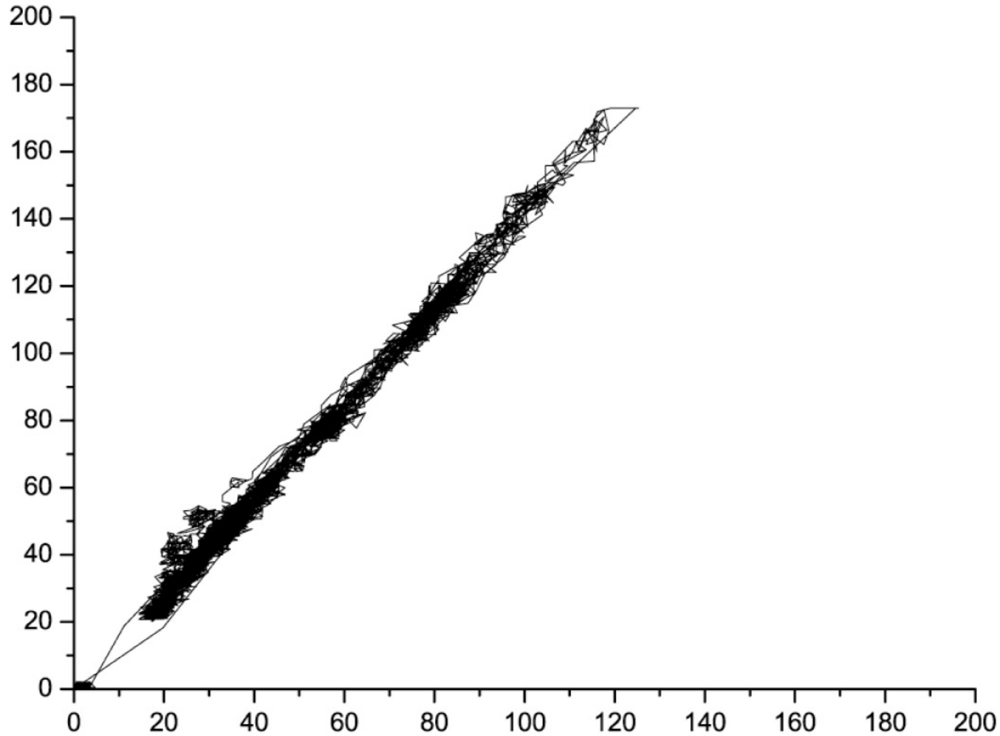

Fig. 3. Polarization diagram (right component polarization vs. left component polarization) of the February 8, 1982 records in the frequency of 408 MHz.

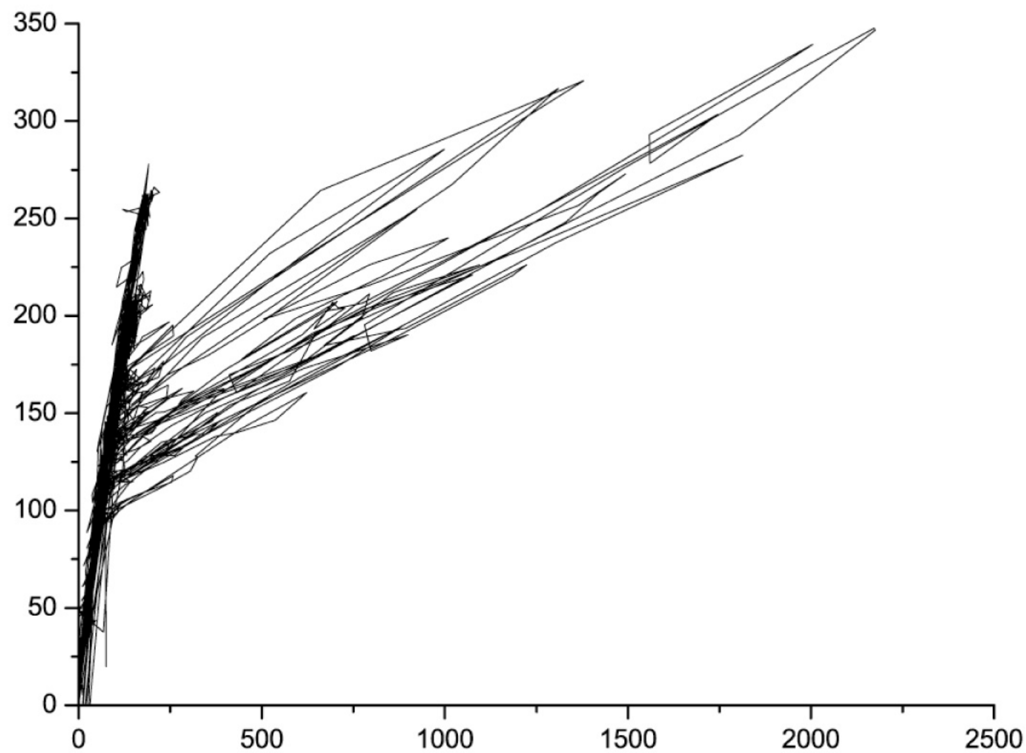

Fig. 4. Polarization diagram (right component polarization vs. left component polarization) of the July 9, 1982 records in the frequency of 408 MHz.

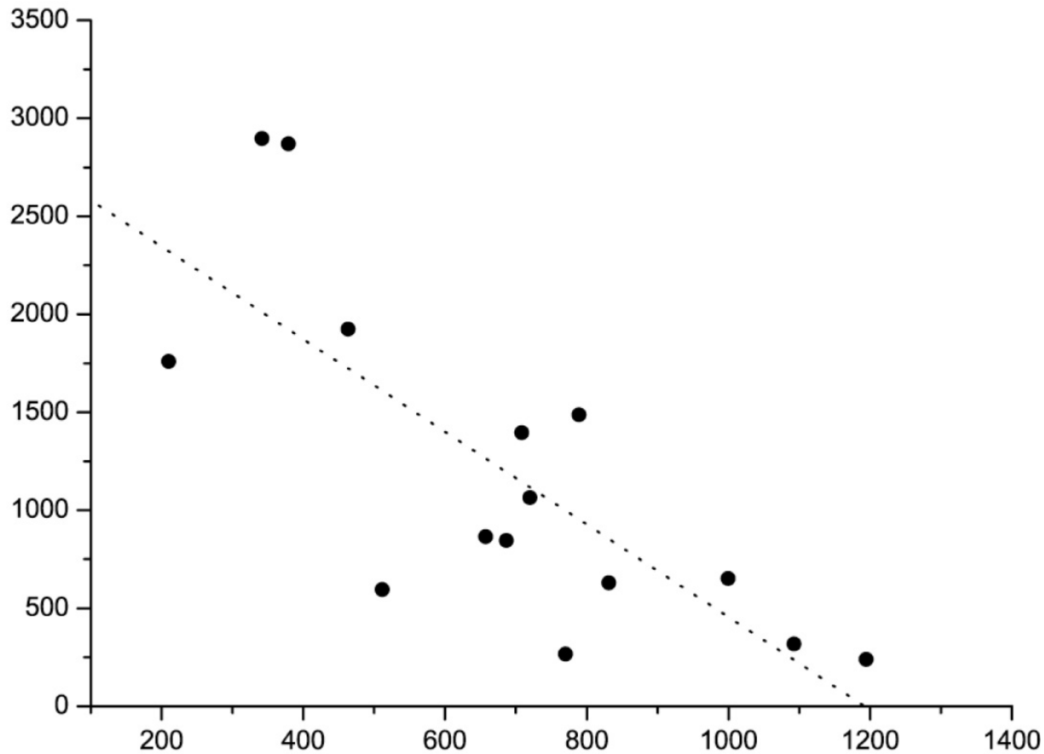

Fig. 5. Relationship between the intensities of the background radio emission (x-axis, in solar flux units) and the impulsive events (y-axis, in solar flux units) in the frequency of 327 MHz for the July 9, 1982 records.

between individual impulsive narrow-band events and the background continuum and we find an inverse relationship between the intensity of impulsive events with a polarization diagram different from the polarization diagram of the background emission, and the intensity of the level of background continuum emission on which they appear.

Spike flux is delayed by 2-5 s with respect to hard X-ray peaks (Aschwanden and Gudel, 1992). It is difficult to relate them to primary flare energy release sources (Fleishman *et al*., 2003). Instead we consider a probable interpretation of the relationship between the intensity of the impulsive radio events and the intensity of the background radio emission continuum in which they are inserted, as produced by different mechanisms of generation for background and spike radio emission.

If both mechanisms are powered by the same primary energy source, and if the spike mechanism has a growth index greater than the background one, early spikes could obtain much more energy than later one as the background mechanism extracts a significant part of the primary released energy.

In this hypothetical description, spikes cannot be used as a measure of primary energy source fragmentation. They would be the result of an emergence of new sources with a different generation mechanism.

ACKNOWLEDGEMENTS

The authors acknowledge INAF-Trieste Astronomical Observatory Basovizza Station staff for providing the data used in this work. We thank especially Dr. Paolo Zlobec for his comments and suggestions.

We also wish to thank the anonymous referees for improvement of this paper.

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