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Some Observed Results of Solar Radio Spectrometer at 4.5–7.5 GHz

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Abstract A new instrument of broadband solar radio spectrometer working at waveband 4.5–7.5 GHz was developed at Purple Mountain Observatory for Solar Maximum 23. Some new results of spectral observation have been obtained since August 1999. Two typical type IIIμ bursts with rich fine structures are presented and some interesting features discussed.

Key words: Sun: flares — Sun: radio radiation

1 INTRODUCTION

Solar radio type III bursts are characterized by narrow bandwidth, drifting emission frequency and harmonic structures, among other features (Suzuki & Dulk 1985). The observations suggest coherent emission and local plasma emission at its characteristic frequency excited by a source moving upward/downward along field lines. As an electron beam moves through the atmosphere, Langmiur waves will be generated and converted into escaping radiation at the fundamental and harmonic characteristic frequencies $\omega \approx \omega_p$, and $\omega \approx 2\omega_p$ by scattering or mode-mode coupling processes (Wild 1950a; Wild 1950b; Melrose 1980; Zheleznyakov 1970). The escaping emission frequency follows the variation of the exciting local plasma frequency, decreasing/increasing with time as the electron beam moves upward/downward, and leads to the observed normal/reverse drifting type III bursts. Such a picture is still accepted today. Both the fine structure and the form of the burst may be a reflection of the electron beam track and/or of the magnetic field configuration, thus possibly providing important diagnostics for the plasma in the flare regions and in the solar atmosphere. In particular, the range of the starting frequencies (which begin at almost the same time) for the opposite drifts and the bi-directional drifting structure contain information on the location of the acceleration region. Therefore, type III burst has been the only means of determining the location of the acceleration region (at least in one dimension), and that is very important for solar flare physics. In this paper, some interesting spectral events at waveband 4.5–7.5 GHz are presented. The observations are described in Section 2 and a discussion follows in Section 3.

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2 OBSERVATIONS

2.1 Instrument

The broadband solar radio spectrometer used is a multi-channel frequency-sensitive instrument. An instantaneous bandwidth of 600 MHz corresponds to 60 channels of 10 MHz each. The total bandwidth of 3 GHz is thus divided into 5 wavebands. The main performance parameters of the spectrometer are summarized as follows: instantaneous bandwidth 600 MHz, frequency coverage 3 GHz (4.5–7.5 GHz), sensitivity $\Delta I/I \leq 2\%$, frequency resolution 10 MHz, time resolution 1–5 ms, where I and ΔI are the signal received and minimum signal detected, respectively. Because the waveband can be chosen freely, the used time resolution varies from 1–5 ms for 1–5 wavebands.

2.2 Routine Observations

Since 1999 August, a daily patrol has been carried out and the patrol time is usually arranged from 00:30 to 08:00 UT. As a result, more than 100 solar microwave spectral events including some new spectral results were obtained. The observation can be made either in total or in partial waveband mode, but usually in the former. In this mode, the time resolution is 5 ms. A special program is developed for data analysis based on the IDL software. To show the new results of spectral observation, two typical microwave spectral events are presented bellow.

2.2.1 The event of 1999 August 25

The solar radio flare event on 1999-08-25 is a typical group of type IIIμ bursts. More than ten group of type IIIμ bursts can be discerned clearly (Fig. 1), and their bandwidths usually range from a few MHz to 1 GHz, but some reach ≥ 3 GHz. They drift in opposite directions, but predominantly in the positive direction at rates varying from one to a few tens GHz s^{-1}. Some of them contain rich fine structures, including fiber-like, V-shaped and necklace-like structures.

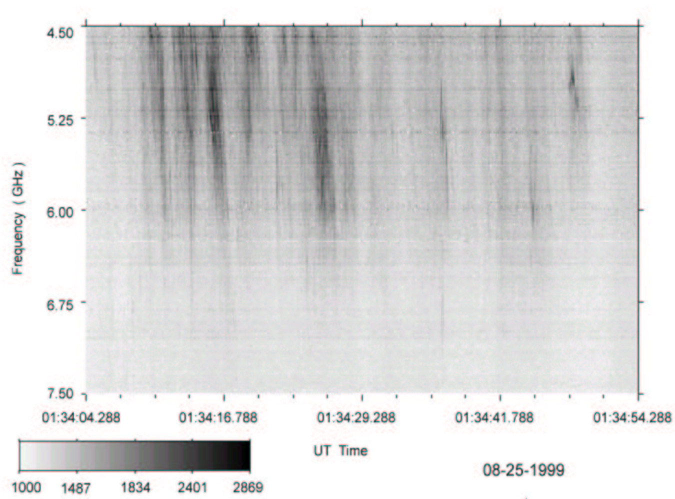

Fig. 1 Dynamic spectrogram of the type III burst on 1999 August 25

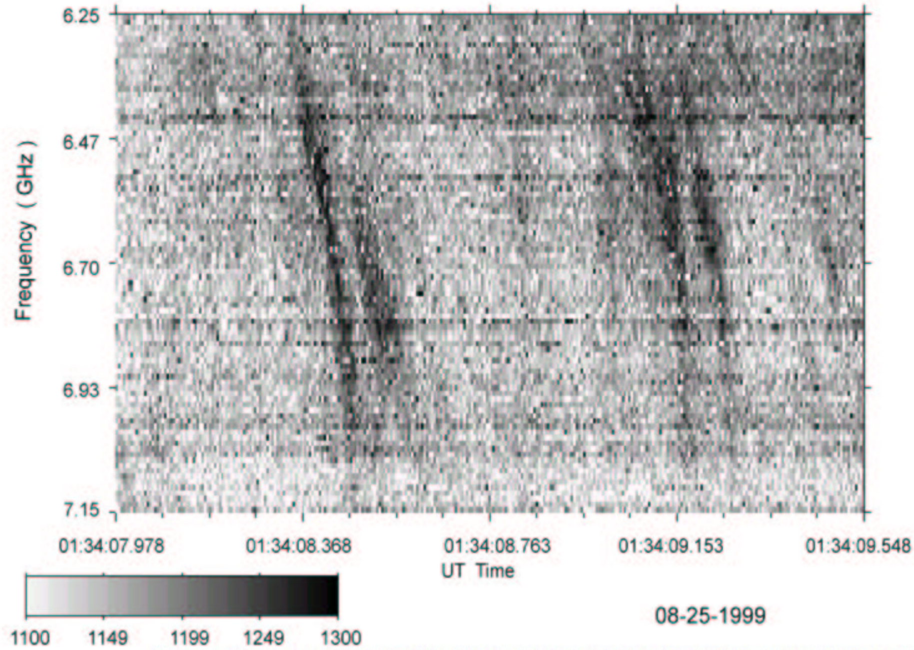

Fig. 2 Enlarged spectrogram of the fiber-like structures

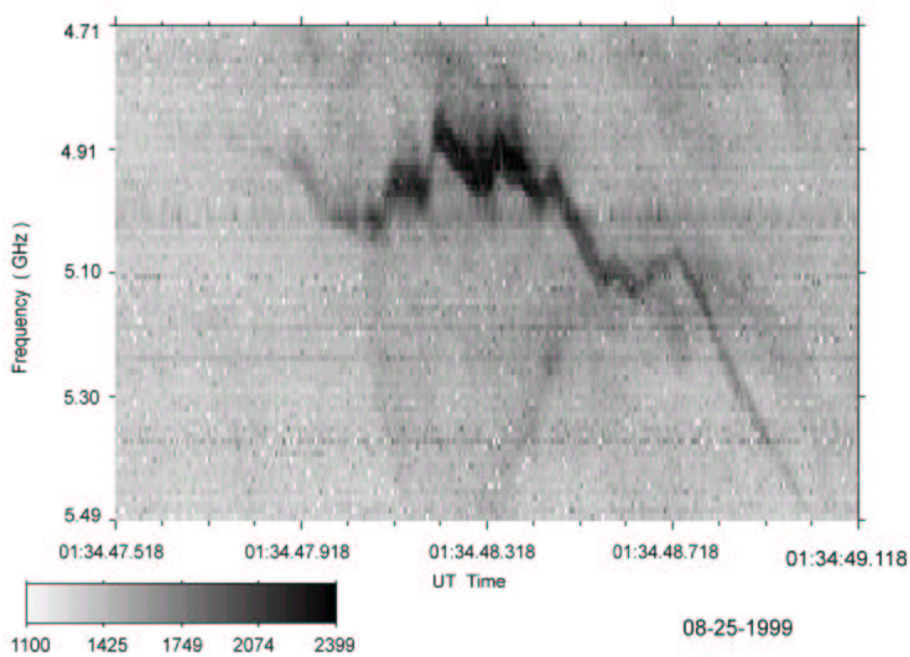

Fig. 3 Enlarged spectrogram of the M-shaped structures

The fine structures were reported in a preliminary form by Xu et al. (2000). A simple description for the fiber-like structure will be given again, and its enlarged dynamic spectrogram is shown in Fig. 2. The fiber structure is a phenomenon at meter-wavelength, we adopt this term only at the morphological level. In fact, the fiber-like structures at waveband of 4.5–7.5 GHz consist of two parallel drifting pairs drifting in the positive direction. The drifting rates measured at the more intensive parts of pairs are 5.595 and 5.356 GHz s^{-1} for the first and second pairs, respectively. Another interesting fine structure, the M-shaped feature, is shown in Fig. 3. It consists of two adjacent reverse type U structures, beginning at $\sim$ 01:34:47.787 UT, maximum at $\sim$ 01:34:48.218 UT and ending at $\sim$ 01:34:49.020 UT. Both frequency coverage and duration range from $\sim 4.8 - 5.1$ GHz and $\sim$ 600 ms to $\sim 5.05 - 5.49$ GHz and $\sim$ 450 ms for the first and second reverse type U structures, respectively. As seen from Fig. 3, there are several quasi-periodic reverse type U structures superposed on the first part with period of about 100 ms. The drifting rates are almost the same for the same drifting directions, but the normal drifting rate is faster than the reverse one.

2.2.2 The event on 1999 October 27

Another interesting spectral event is also a group of type IIIμ bursts, observed on 1999 October 27. Its time profile at 6.75 GHz is shown in Fig. 4. It is composed of three parts. Part 1 and part 2 are sub-impulsive bursts but part 3 is a main impulsive structure which consists of three complex impulses with tens of superposed spiky structures. Figure 5 is the expanded spectrogram of part 3 in Fig. 4. As shown by Fig. 5 there is a series of reverse-normal drifting belts, which contain many fast reverse or normal drifting structures with almost the same bandwidth of $\sim$ 1 GHz, and seem to form a time modulated drifting belt. The modulation period is about 0.7–0.9 s. The drifting rate of the belt is almost the same for the same drifting direction. For example, the drifting rate for the reverse drifting belts is about a few GHz s^{-1} but tens of GHz s^{-1} for the normal ones. These fine structures make this event a rare one.

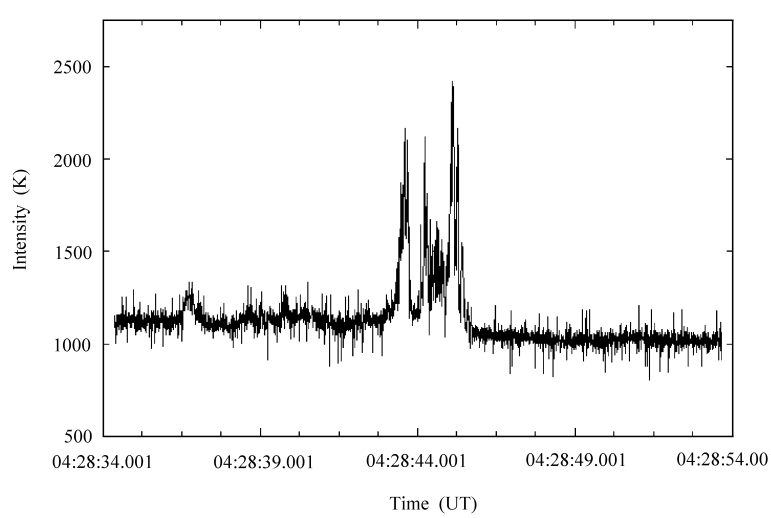

Fig. 4 Time profile of solar radio event on 1999 October 27 at 6.75 GHz

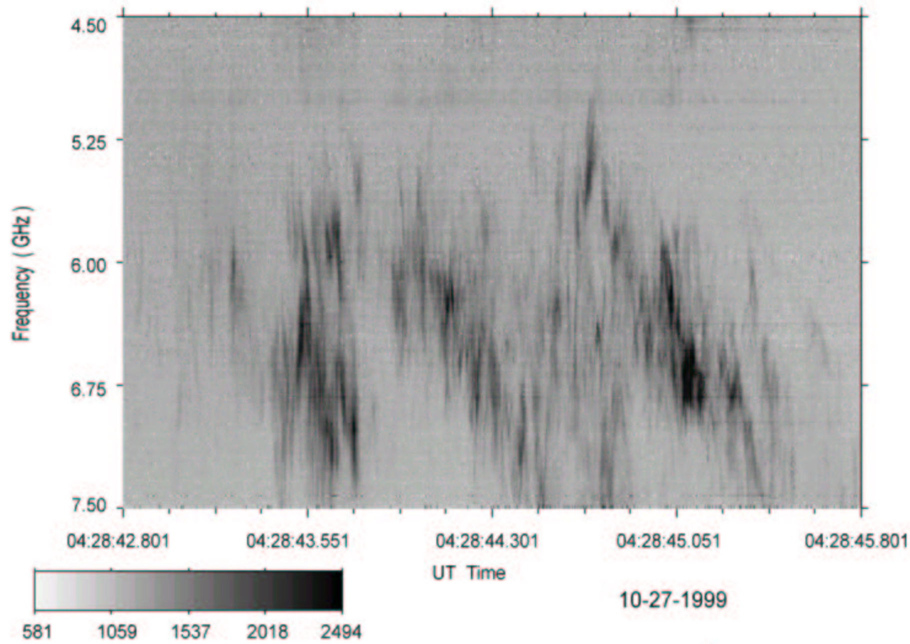

Fig. 5 Enlarged spectrogram of the type III burst on 1999 October 27

3 DISCUSSION

1. It is true that type III burst is much less at microwaves than at decimeter and meter waves based on our observations at 4.5–7.5 GHz. Because plasma emission at centimeter waveband is strongly absorbed by gyro-resonance or f-f absorption processes of lower plasma density layer with higher or lower temperature above the emission layer of cm waveband, the type III burst at shorter waveband (cm-waveband) is much more difficult to detect than that at longer waveband (decimeter and meter waveband). Although the type III burst at cm waveband is rare, its fine structure is much more complex than at the longer waveband if it occurs. This may be an indication that the magnetic field configuration is much more complex in the lower than in the higher corona since the type III burst and its fine structure reflect the electron beam path and the magnetic filed configuration.

2. Apart from the drifting in opposite directions but predominantly in the positive, the fast and slow drifting rates and the bunching etc. of the microwave type III bursts on 1999 August 25 agree well with the general characteristics of type III bursts reported formerly (Stahli & Benz 1987; Allaart 1990). The V-shaped, necklace-like structures etc. have been discussed by Xu et al. (2000). The new results, including the fiber-like, the M-shaped features and the drifting belt, are discussed below. The parallel drifting pairs are similar to fiber structure morphologically, but its emission mechanism is probably different. It may be caused by plasma emission at the same source region twice excited by electron beams in the same accelerating process.

3. The periodicities appearing in the M-shaped structure and drifting belts are different in both characteristic time scale and frequency range. The former may be generated from

MHD instability, such as pinch instability disturbed by Alfvén wave as electron beams pass through the top of a magnetic loop, and the latter may be a reflection of periodic electron beam acceleration caused by periodic reconnection of magnetic filed lines.

The above discussion centers only on some possibilities; other possibilities could not be excluded.

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