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LETTERS

Solar Radio Bursts in the Period Oct. 22–Nov. 4, 2003 *

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Abstract A series of solar radio bursts were observed in AR NOAA 10486 with the Solar Broadband (1.1–7.6 GHz) Radio Spectrometers (SBRS of China). Here we analyze four significant events associated with CME events and strong X-ray flares that occurred on 2003 October 22, 26, 27, 29. The Oct. 26 event is a long duration event (LDE) with drift pulsation structure (DPS), narrowband dm-burst (DCIM), and more than seven types of Fine Structures (FSs); its time of the maximum flux (07:30 UT) is about half an hour later than the X-flare (06:54 UT).

Key words: Sun: flares — Sun: radio radiation — Sun: fine structures

1 INTRODUCTION

AR NOAA 10486 was the largest active region during the 23rd solar activity cycle. It moved into the visible solar disc on 2003 October 22, and moved out on Nov. 4. The sunspot size reached maximum on Oct. 29. During this time, many solar activity events occurred, including strong X-flare events (7 X-class, 20 M-class), CME, and other waveband events. Also many radio bursts were recorded with the SBRS (Solar Broadband Radio Spectrometer) of China. We analyzed these bursts and found a few complicated phenomena. One significant phenomenon is a DPS (Karlicky et al. 2001) which may be considered as a signature of dynamic magnetic reconnection and two-ribbon flares. Benz (1991), Isliker (1994) and Jiricka & Karlicky (2001) examined classifications of solar bursts. The data processing method we used was presented in Yan et al. (2001).

2 OBSERVATIONAL RESULTS

A total of 12 bursts were observed with the SBRS of China during Oct. 22–Nov. 4. Here we present four significant bursts associated with notable physical effects in the solar-terrestrial space environment. The bursts contained many FSs (fine structures) in 1.1–2.06 GHz range, some in 2.6–3.8 GHz range, and a few in 5.2–7.6 GHz range. In Table 1 SXR is the soft X-ray of GOES12; MAX (sfu) is the maximum flux at the given frequency. The peak flux frequency of the four events is higher than 5700 MHz. For gyromagnetic radiation, higher flux frequency goes with stronger magnetic field; so, here, a strong magnetic field of the source region is indicated.

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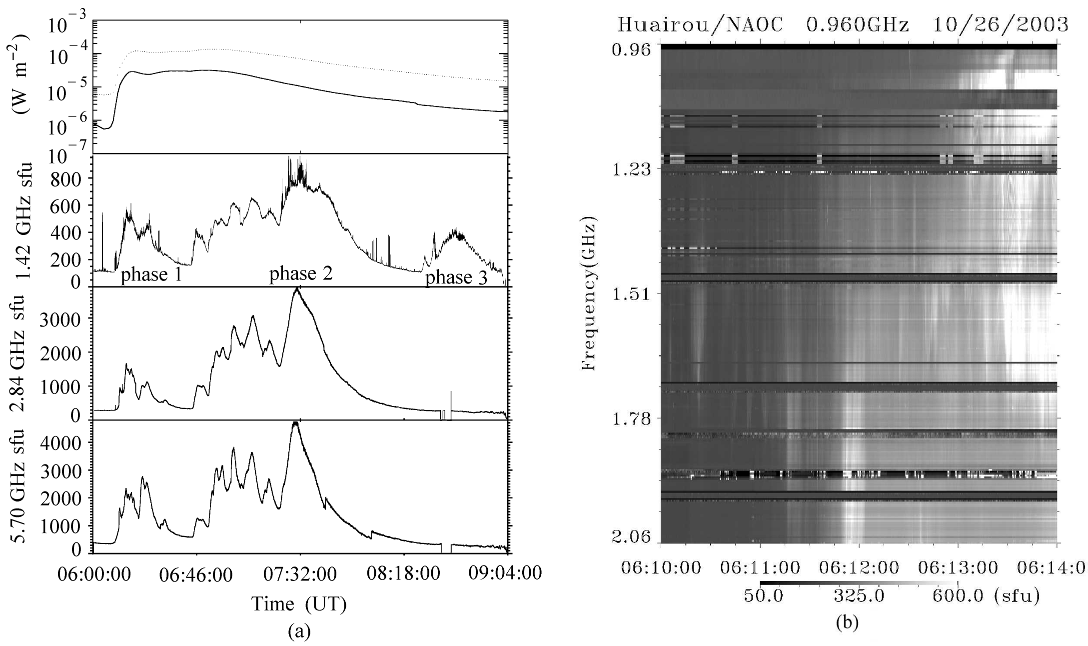

Fig. 1 (a) Time profile of solar radio event recorded by the SBRS of China. The profile of GOES12 SXR is in the top panel, where dashed line represents 0.1–0.8 nm, solid line represents 0.05–0.4 nm. (b) Spectrum of DPS. There is a group of ZPS in the top right corner.

Table 1 Parameters of the Bursts

Band	Date	Start(UT)	Max	End	MAX (sfu)	X-flare	FSs number
1420 MHz	Oct. 23	08:22:49	09:05:27	—	670		4–10
2840 MHz	23	08:21:55	09:05:30	—	1100		no
5700 MHz	23	08:21:20	08:40:47	—	4500		no
SXR	23	08:19	08:35	08:49		X5.4	
1420 MHz	Oct. 26	06:09:35	07:31:30	09:34:34	1000		>20
2840 MHz	26	06:09:40	07:30:20	09:04:01	3900		2
5700 MHz	26	06:08:00	07:29:48	09:04:05	4300		no
SXR	26	05:57	06:54	07:33		X1.2	
1420 MHz	Oct. 27	08:05:16	08:09:36	08:55:26	630		11–20
2840 MHz	27	07:58:40	08:21:25	08:55:09	980		4–10
5700 MHz	27	07:58:37	08:21:24	08:51:00	1500		no
SXR	27	07:51	08:33	09:24		M2.7	
1420 MHz	Oct. 29	04:26:50	04:57:10	05:21:30	470		4–10
2840 MHz	29	04:31:54	04:56:14	05:20:40	640		2
5700 MHz	29	04:09:57	04:56:12	05:43:18	920		no
SXR	29	04:08	05:11	05:54		M3.5	

The burst on Oct. 26 has a duration of more than 200 min (06:09–09:34 UT). It is a long duration event with three burst phases (Fig. 1a). Each phase has a multi-peak pulsation structure. The third phase (08:24–09:04 UT) was a DCIM. It produced the mass of high-energy particles which impacted on the solar-terrestrial space. At 5700 MHz the radiation flux reached its maximum (about 4300 sfu) at 07:29:48 UT. At the beginning of the burst (Fig. 1b), it is obvious that the pulsations drifted slowly from high frequency to low frequency. The mean frequency drift of this DPS is –3.7 MHz s^{-1}. After the DPS, a remarkable Zebra Pattern Structures (ZPS) occurred about 90 s before the first peak (06:14:56 UT). About 80 min later, another long duration ZPS occurred near the maximum peak (07:31:30 UT). The radio peak appeared about half an hour latter than the X-flare peak (06:54 UT). This phenomenon can be explained by the "thermal/nothermal" (TNT) model: the radio burst, which is produced by nonthermal electrons, is superposed on the burst associated with the SXR produced by thermal electrons.

3 FINE STRUCTURES

The Oct. 26 event contains more than seven types of FSs in the 1.1–2.06 GHz range, including ZPS, spikes, fibers, slowly drifting burst (SDB), fast drift burst (FDB), narrowband type III burst, V-structure burst, and some unclassified strange types.

1. ZPS: Nine ZPS were found during this event. The ZPS No.3 is significant (Fig. 2a). Table 2 lists the parameters of the ZPS. Here Δf is the frequency spacing between two stripes.

2. Narrowband spikes: Some groups of spikes were found. The prominent one (Fig. 2b) contained thousands of individual spikes in the 1.1–2.06 GHz range during 06:44:30–06:46:40 UT (130 s). The bandwidth of the individual was 4–72 MHz and the duration was 5–80 ms. Most of the narrowband spikes were strongly right-polarized. Some were accompanied by the ZPS No.9.

3. Fibers: Only one group of fibers was found. It contained hundreds of individual fibers in the 1.1–1.48 GHz range during 07:36:18–07:39:30 UT (190 s), with right polarization. It was also accompanied by the ZPS No.9. The mean interval between two fibers was 0.2 s. We can estimate there were nearly one thousand individual fibers in this group.

4. FDB: Many FDB were found. Prominent groups (Fig. 2b) appeared abundantly in 1.1–2.06 GHz range during 08:32:58–08:33:45 UT with strong right polarization. The frequency drift of the individual groups was changeable and fast ($\pm$9.0 GHz s^{-1}). The duration was 100–850 ms.

5. SDB: Many SDB were found. Their frequency drift slowly varied ($\pm$60 MHz s^{-1}). The special one occurred during 08:09:03–08:09:17 UT, with strong right polarization. It was accompanied by FDB.

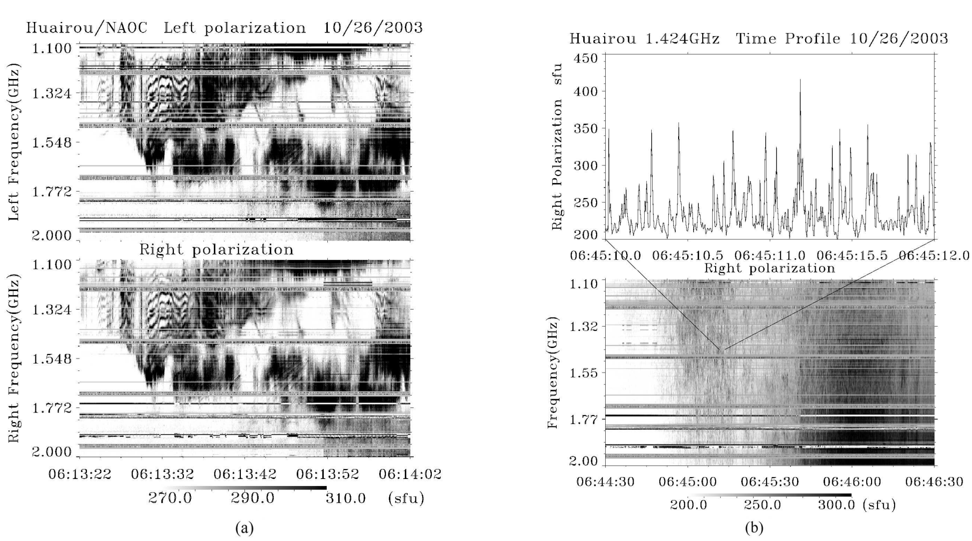

Fig. 2 (a) Spectrum of the ZPS No.3; (b) Spectrum of the spikes. Both were recorded by the SBRS of China.

6. Narrowband type III burst: Some bursts were found. The remarkable groups were in 1.1–1.62 GHz range during 06:37:55–06:37:57 UT, with left polarization. Their individual bandwidth was 80–540 MHz and their frequency drift was about –1.0 GHz s^{-1}.

7. V-structure: Some such bursts were found. The remarkable one emerged in 1.1–1.27 GHz range during 06:54:27–06:54:30 UT, with strong right polarization. It drifted first with FD of 127 MHz s^{-1}, then reversed at 06:54:28.9 UT, finally drifted with FD of –233 MHz s^{-1} till the end.

Table 2 Parameters of the ZPS

No.	Frequency (GHz)	Time (Duration)	Number	Δf (MHz)	Polarization	Intensity
1	1.66–1.86	06:10:52 (5 s)	3	36	—	mid
2	1.1–1.34	06:13:09 (6.2 s)	>4	44	—	weak
3	1.1–1.8	06:13:23 (22 s)	>13	44	—	strong
4	1.2–1.45	06:13:52 (2.8 s)	3	80	—	weak
5	1.1–1.47	06:13:56 (4.1 s)	3	68	—	mid
6	1.1–1.35	06:14:11 (17 s)	>5	44	—	strong
7	1.1–1.3	06:14:38 (7 s)	>5	40	—	mid
8	1.1–1.22	07:08:22 (7 s)	>4	28	L+	weak
9	1.1–1.5	07:31:22 (500 s)	>10	44	R+	strong

4 DISCUSSION AND CONCLUSIONS

The solar flares occurred at AR NOAA 10486 were very rich in FSs. The variety of the flares in 1.0–7.6 GHz range was comparable with that observed, usually at lower frequencies (< 2 GHz) (Chernov et al. 1998). Many types of FSs which are probably produced with magnetic reconnection and primary energy release processes in flares were recognized: DPS associated with plasmoid ejection, narrow-band dm-spikes with MHD turbulence in reconnection plasma outflows, and the harmonic structure of ZPS, indicating localized regions with anisotropic distribution of accelerated electrons. Moreover, it may be a plain evolving feature that a long duration event (Oct. 26) is with DPS at the beginning, ZPS near the maximum peak, and FDB or SDB in the decline phase.

Some conclusions are helpful for a better understanding of the role of some specific phenomena in the context of the whole flare process, and particle acceleration and energy conversion in the solar corona. 1. The long time delay between radio peak and SXR peak on Oct. 26 may be explained by the TNT model. However, the mechanism of producing the nonthermal electrons is still unknown. 2. FSs arose at dm-waveband (1.1–2.06 GHz) more often than cm-waveband (>3.0 GHz). Many FSs occurred not singly. Fibers or spikes associated with ZPS, while FDB or SDB associated with narrowband type III burst. Most of the FSs were with strong right polarization, but some without polarization and few with left polarization.

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