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Drifting radio bursts and fine structures in the 0.8–7.6 GHz frequency range observed in the NOAA 9077 AR (July 10–14, 2000) solar flares

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Abstract. The 0.8–7.6 GHz global and detailed radio spectra of the four most intense flares observed in the NOAA 9077 active region (July 10–14, 2000) are presented. The radio bursts of these flares and their sequence reveal features indicative of topological similarities among the flares under study. The drifting pulsation structures were found to be the typical signatures of these flares. Furthermore, many other fine structures such as narrowband drifting lines, drifting harmonic structure with zebra patterns, drifting branches of narrowband dm-spikes, and structures with fast positively and negatively drifting bursts are shown in the context of the whole radio flares. Some of them were observed for the first time. The relationships among them and the resulting interpretations are summarized. The characteristic periods of the drifting pulsation structures and the magnetic field in the zebra radio source are determined.

Key words. Sun: activity – Sun: flares – Sun: radio radiation

1. Introduction

The NOAA 9077 active region appeared on the visible solar disc from July 7, 2000 till July 21, 2000. During its evolution, in the time interval of July 10–15, 2000 this active region was in the δ magnetic field configuration and strong flare activity in this region was recorded (3 X-class and 6 M-class solar flares). This period was very rich in interesting radio bursts and fine radio spectral structures, especially in the 0.8–7.6 GHz observing range. Moreover, the flares in this region were topologically similar. These events provide an opportunity to understand the role of some specific fine structures in the context of the whole flare process. For example, the drifting pulsation structure recorded recently at frequencies above 1 GHz (Kliem et al. 2000) are of special interest to us. According to our knowledge and to expectations of other authors (e.g. Bastian et al. 1998) the 0.8–7.6 GHz frequency range corresponds to frequencies at which the plasma emission from the flare primary-energy release processes can be observed. Therefore, using observations at these frequencies of the four most important flares (July 10, 21:42 UT, M5.7/2B; July 11, 13:10 UT, X1.1/2N; July 12, 10:37 UT, X1.9/2B; July 14, 10:24 UT, X5.7/3B) of the same active region NOAA 9077, we look for signatures of processes close to the primary energy release site. We are especially interested in those dynamic phenomena which induce shocks and beams and which are on the radio spectra indicated by frequency drifts (Kundu 1965; Krüger 1979; Bastian et al. 1998).

In the following, the radio observations of four NOAA 9077 AR flares are presented and some unique examples shown (for comparison in the 1–3 GHz range, see also the catalogue made by Isliker & Benz 1994). The radio spectra of these flares are then compared, looking for their typical aspects. Possible interpretations of the observed bursts are summarized, characteristic periods of the drifting pulsation structures determined and the magnetic field intensity estimation made. The roles of the analyzed radio bursts in the whole flare process are discussed.

2. Observations

The observations were performed by the Solar Radio Broadband Fast Dynamic Spectrometers (1–2, 2.6–3.8, and 5.2–7.6 GHz frequency range) at Huairou Solar Observing Station of Beijing Astronomical Observatory (Fu et al. 1995), and by the 0.8–2, 2–4.5 GHz radiospectrographs at the Ondřejov Observatory (Jiřička et al. 1993).

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2.1. The July 10, 2000 event

The July 10, 2000 flare classified as M5.7/2B was observed at 21:05 – Max 21:42 – 22:27 UT in the NOAA 9077 active region at position N19E49. Topologically the flare is a two-ribbon flare (Solar Image Index – Space Environment Center). In connection with this flare a coronal mass ejection and type II and type IV radio bursts were reported (NOAA Solar Events Report). At the Beijing Observatory this flare was observed at times after 21:57 UT, which means that the beginning of this flare was not observed. Nevertheless, a very strong radio burst was observed at 21:58-22:48 UT. It is in agreement with the 2.8 GHz Hiraiso observation showing the start of the flare impulsive phase at 22:00 UT. Just before this radio burst a drifting pulsation structure (DPS) in the 1.0–1.8 GHz frequency range at 21:59:36-21:59:47 UT was recorded (Fig. 1).

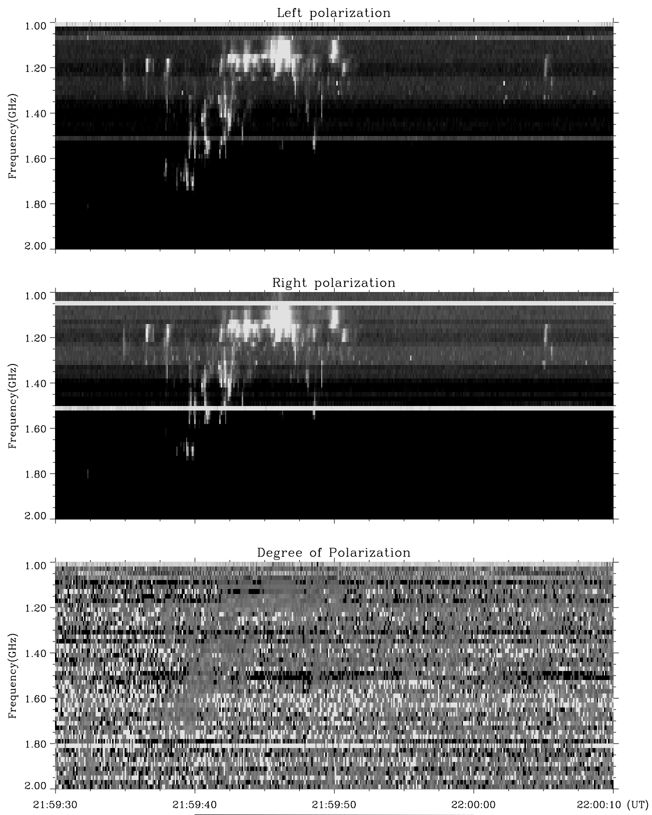

Fig. 1. The 1–2 GHz left and right polarization and degree of polarization radio spectra with drifting pulsation structure observed on July 10, 2000 by the Beijing radiospectrograph (the black colour in the degree of polarization spectrum corresponds to the right polarization)

The global mean frequency drift and instantaneous bandwidth of the DPS are -60 MHz s^{-1} and 200 MHz, respectively. The zero polarization of this DPS was found (Fig. 1, bottom part). Furthermore, prior to the DPS a group of fast positively and negatively drifting bursts (V-structure) was observed at 21:58:17.0-21:58:18.6 UT

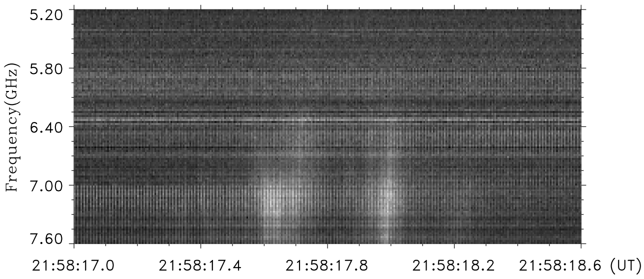

Fig. 2. The 5.2–7.6 GHz radio spectrum (right polarization) with a group of fast positively and negatively drifting bursts observed on July 10, 2000 by the Beijing radiospectrograph

in the 6.4–7.6 GHz range (Fig. 2). The frequency drifts of these fast drift bursts are in the 25– -60 GHz s^{-1} range.

2.2. The July 11, 2000 event

The July 11, 2000 flare classified as X1.1/2N was observed at 12:12 – Max 13:10 – 13:35 UT in the NOAA 9077 active region at position N18E27. Topologically the flare is a two-ribbon flare (Solar Image Index – Space Environment Center). In connection with this flare the a coronal mass ejection was reported (NOAA Solar Events Report). The flare impulsive phase recorded at 3 GHz consists of two pulses at 12:28 and 12:30 UT. The overview of the 1–2 GHz radio emission of this flare is shown in Fig. 3.

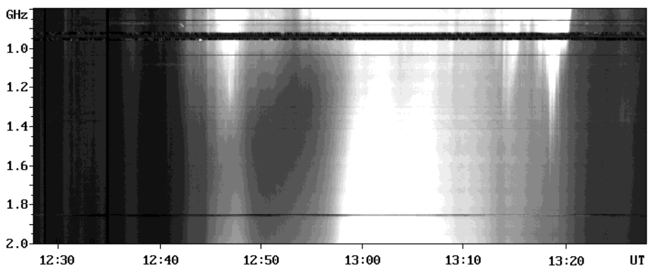

Fig. 3. The 0.8–2.0 GHz overview radio spectrum with drifting boundary of a continuum observed on July 11, 2000 by the Ondřejov radiospectrograph

At 12:28:38-12:28:50 UT in the 0.8–2.0 GHz range a weak drifting pulsation structure was observed. The mean drift and instantaneous bandwidth of this DPS are -50 MHz s^{-1} and 700 MHz, respectively. On higher frequencies drifting patches can be seen at 12:45:30-12:46:20 UT in the 2.7–3.2 GHz range (Fig. 4). Their mean drift is -30 MHz s^{-1}. Then the intensity of the radio burst was increasing and pulses of the radio emission were recorded at 12:43-12:50, 12:57-13:08, and 13:13-13:21 UT. Here, a continuum with drifting boundaries can be seen at 12:57:30-13:02:00 in the 1.0–2.0 GHz range, and at 13:04-13:07 UT in the 1.05–1.3 GHz range. Their frequency drifts are -3.7 and -1.4 MHz s^{-1}, respectively. With a higher time resolution these bursts reveal short-lasting pulsations (the characteristic period is $\sim$0.4 s) and occasional fiber bursts in the 0.8–1.0 GHz range. The drift

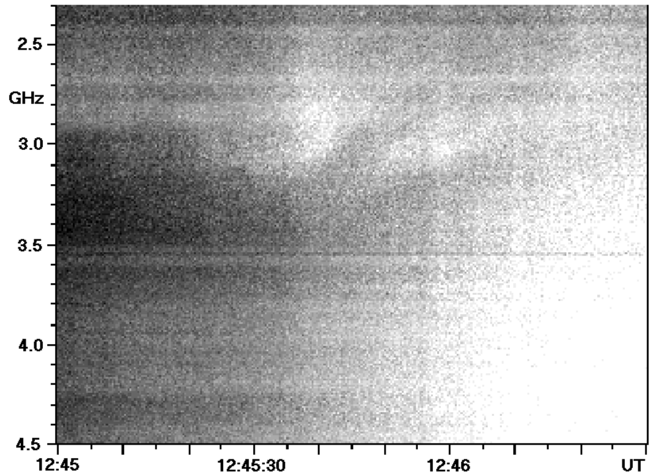

Fig. 4. The 2.0–4.5 GHz radio spectrum with drifting patches observed on July 11, 2000 by the Ondřejov radiospectrograph

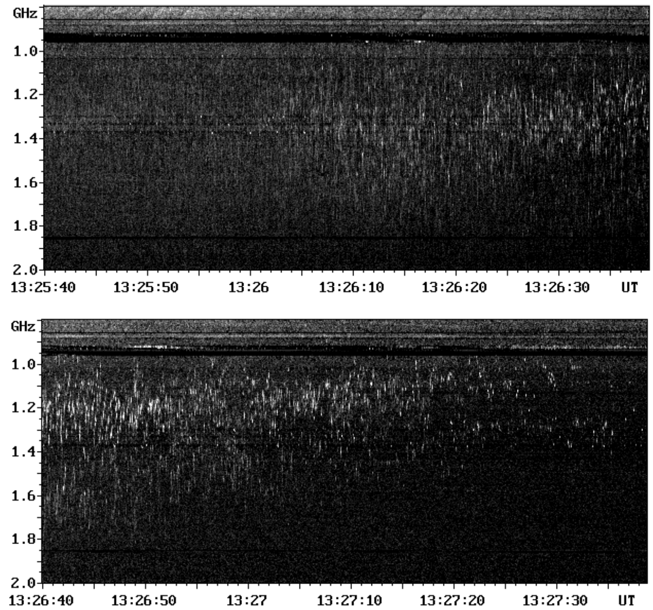

Fig. 5. The 0.8–2.0 GHz radio spectrum with drifting branches of narrowband dm-spikes observed on July 11, 2000 by the Ondřejov radiospectrograph

of the fiber bursts is -33 MHz s^{-1}. This part of flare ends with a group of narrowband dm-spikes at 13:25:40-13:27:40 UT, in the 1.0–1.8 GHz range (Fig. 5). As it can be seen, especially at the end, these spikes are organized in two branches (bandwidth $\sim$300 MHz), slowly drifting towards lower frequencies. The frequency drift of the branches is $\sim$$-6$ MHz s^{-1}.

2.3. The July 12, 2000 event

The July 12, 2000 flare classified as X1.9/2B was observed at 10:18 – Max 10:37 – 10:46 UT in the NOAA 9077 active region at position N17E27; its impulsive phase started at 10:30 UT (NOAA Solar Events Report). Topologically the flare is a two-ribbon flare (Hα Meudon Observatory image). The overview of the 1–4.5 GHz radio emission of this flare is shown in Fig. 6.

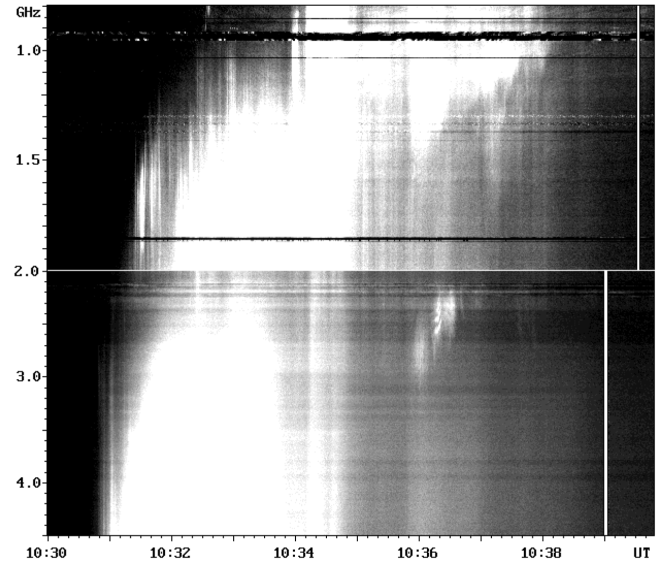

Fig. 6. The 0.8–4.5 GHz overview radio spectrum with a drifting pulsation structure observed on July 12, 2000 by the Ondřejov radiospectrographs

The radio emission of this flare started by a DPS (the durations of individual main pulses in the DPS are several tens of seconds) at 10:31-10:39 UT in the 0.8–4.5 GHz frequency range. The global frequency drift decreases with the frequency decrease. For example, in the 1.0–1.5 GHz range it is -5 MHz s^{-1} at the beginning of the DPS, and -3 MHz s^{-1} at its end. The instantaneous bandwidth of this DPS is greater than 1 GHz. The upper frequency part (2–4.5 GHz) of this DPS is similar to that of the 1–2 GHz continuum with drifting boundaries observed during the July 11, 2000 flare at 12:57:30-13:07:00 UT (see Fig. 3). At the maximum of the impulsive phase of this flare, at 10:34:10-10:35:05 UT, in the 0.8–1.8 GHz frequency range, a group of narrowband dm-spikes followed by a very narrowband drifting line was observed (Fig. 7).

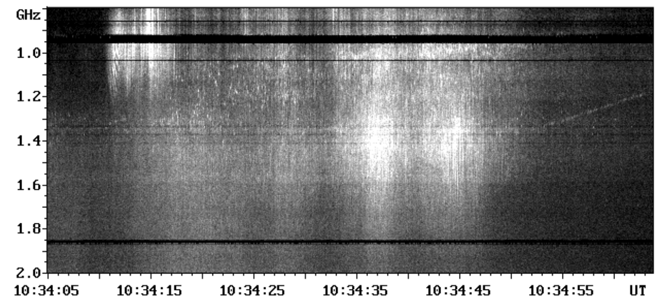

Fig. 7. The 0.8–2.0 GHz radio spectrum with a group of narrowband dm-spikes and a drifting line observed on July 12, 2000 by the Ondřejov radiospectrograph

The spikes are in this case organized in pulses (their duration is several seconds) and clouds; some of them are drifting. The unique drifting line with a narrow bandwidth (∼20 MHz) started at 10:34:53 UT, at 1.34 GHz and ended at 10:35:03 UT, at 1.2 GHz, i.e. its frequency drift is −14 MHz s^{-1}. Then, at 10:35:45-10:36:45 UT in the 2.2–3.0 GHz range and at 10:35:53-10:36:45 UT in the 1–1.4 GHz, i.e. in the harmonic ratio 1:2, two unique narrowband (∼300 MHz) drifting continua branches with drifting lines and zebra patterns were recognized (Fig. 8) (see also very narrowband line which connect zebra structures at 10:36:09-10:36:13 UT in the 2.7–2.9 GHz range).

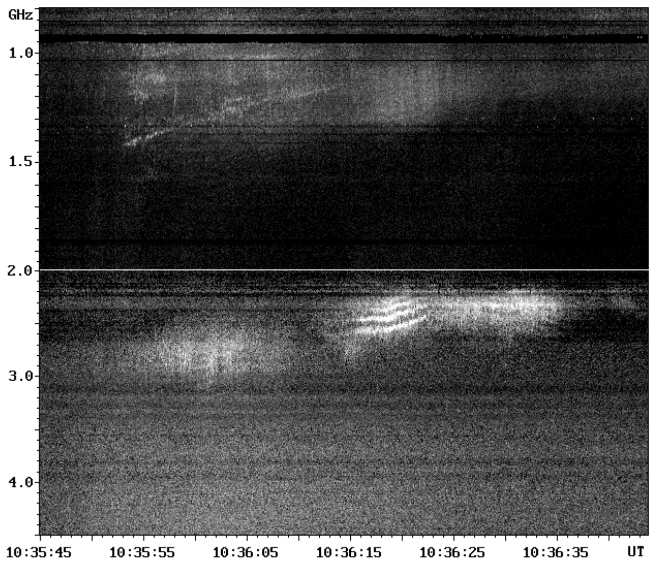

Fig. 8. The 0.8–4.5 GHz radio spectrum with a drifting zebra and drifting lines observed on July 12, 2000 by the Ondřejov radiospectrographs

The global mean drift is −6 MHz s^{-1} for the low frequency branch and −12 MHz s^{-1} for the harmonic branch, respectively, but some parts have faster drift, e.g. the line in the low frequency branch which started at 10:35:53 UT, 1.4 GHz and ended at 10:36:14 UT, 1.15 GHz (the drift is −12 MHz s^{-1}). Zebra patterns with two lines in the low frequency branch and with four distinct lines in the harmonic branch were found. In both cases these lines are drifting. It is important to note that the ratio of the zebra line frequencies decreases with the frequency decrease. At 10:36:20 UT, the frequencies of the zebra lines are f_1 = 2511 MHz, f_2 = 2398 MHz, f_3 = 2307 MHz, and f_4 = 2250 MHz. Thus, the ratios are: f_1/f_2 = 1.047, f_2/f_3 = 1.039, and f_3/f_4 = 1.025. After this phase of the flare another burst at 10:43-10:51 UT in the 1–2 GHz range consisting of broadband pulses (their duration is several tens of seconds) was observed. The flare ended with a group of narrowband dm-spikes at 10:53:30-10:54:30 UT in the 0.8–1.5 GHz range. On even higher frequencies the flare was accompanied by a broadband continuum in which a group of fast drifting type III-like bursts was found at 10:35:40-10:35:44 UT (i.e. just before the zebra pattern observation) in the 5.2–7.6 GHz frequency range (Fig. 9). Their frequency drift is −48 GHz s^{-1}.

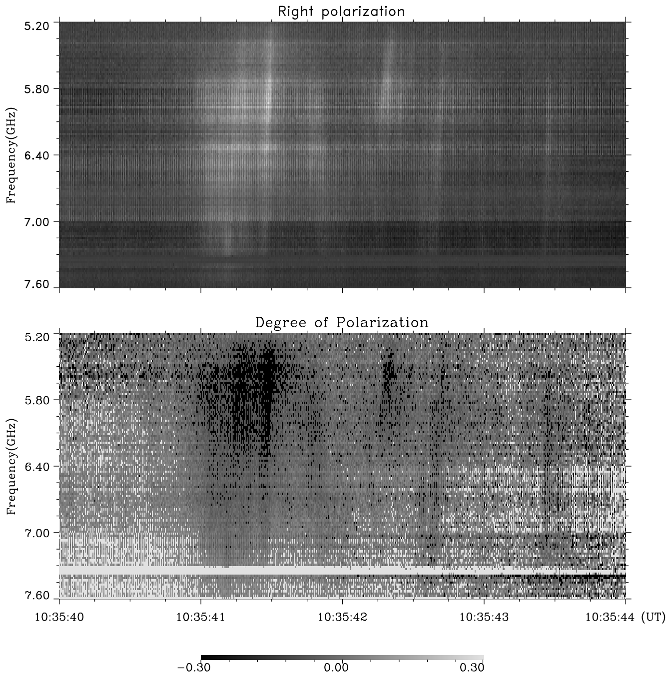

Fig. 9. The 5.2–7.6 GHz right polarization and degree of polarization radio spectra with fast drifting bursts observed on July 12, 2000 by the Beijing radiospectrograph (the black colour in the degree of polarization spectrum corresponds to the right polarization)

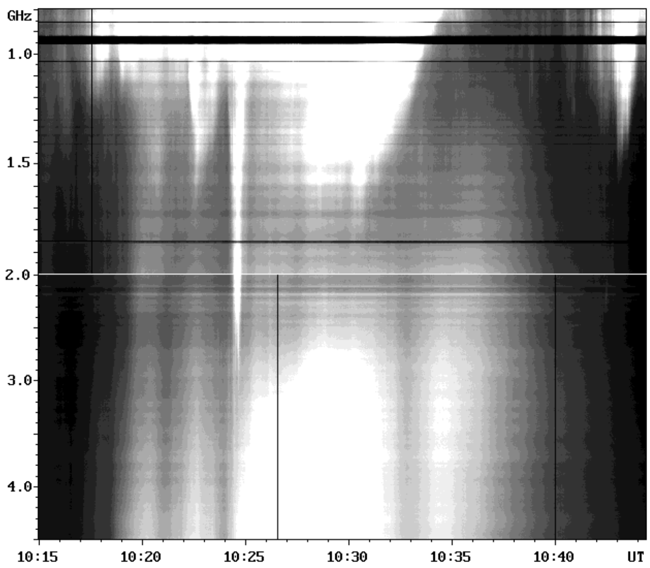

Fig. 10. The 0.8–4.5 GHz overview radio spectrum with a drifting continuum observed on July 14, 2000 by the Ondřejov radiospectrographs

2.4. The July 14, 2000 event

The July 14, 2000 flare classified as X5.7/3B was observed at 10:03 – Max 10:24 – 10:43 UT in the NOAA 9077 active region at position N22W07. Topologically the flare is a two-ribbon flare (Solar Image Index – Space Environment Center). In connection with this flare a coronal mass ejection, a type II burst, moving type IV radio bursts and relativistic protons were reported (NOAA Solar Events

Report). The overview of the 1.0–4.5 GHz radio emission of this flare is shown in Fig. 10.

The radio emission of this flare started at 10:05 UT by a broadband pulsations (0.8–4.5 GHz) intensity of which was increasing. Then at 10:24-10:25 UT in the 0.8–3.0 GHz range a fast drift burst was observed. Its drift was determined as -240 MHz s^{-1}. After this burst a drifting pulsation continuum appeared at 10:27-10:35 UT in the 0.8–1.5 GHz range. Its drift is -3.3 MHz s^{-1} and its instantaneous bandwidth is greater than 1 GHz. The upper frequency part (2.7–4.5 GHz, at 10:24:10:32 UT) of this DPS is similar to that of the 1–2 GHz continuum with drifting boundaries observed during the July 11, 2000 flare at 12:57:30-13:07:00 UT (see Fig. 3). The DPS was accompanied by a strong radio flux peak on 3 GHz at 10:25-10:33 UT (the flare impulsive phase). In the further phase two pulses were observed at 10:42-10:45 UT and 10:46-11:00 UT in the 0.8–1.5 and 0.8–1.7 GHz range, respectively. Both these pulses consisted of fiber bursts on lower frequencies, having frequency drifts in the -80 – -40 MHz s^{-1} range. Moreover, at the time of the first burst (10:42:08-10:42:40 UT), but on higher frequencies (2.0–2.4 GHz range), an interesting narrowband structure with fast positively and negatively drifting bursts was recorded (V-structure) (Fig. 11).

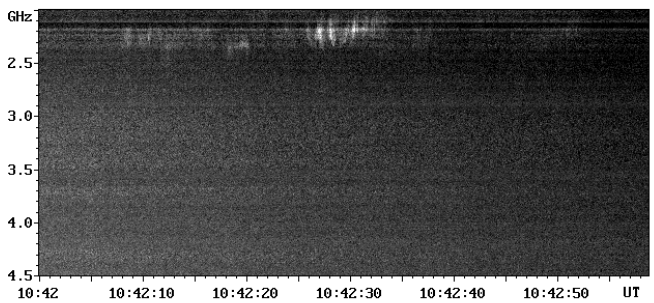

Fig. 11. The 2.0–4.5 GHz radio spectrum with a group of fast positively and negatively drifting bursts observed on July 14, 2000 by the Ondřejov radiospectrograph

The drifts were in the range -250–250 MHz s^{-1}. On even higher frequencies inside a broadband continuum two fine structures were found. At 10:18:53-10:19:00 UT the reverse drift bursts in the 5.2–7.6 GHz range were observed (their drift is 3.5 GHz s^{-1}) and then at 10:25:51-10:25:55 UT in the 5.2–7.6 GHz range a structure similar to that presented in Fig. 11 was found (V-structure) (Fig. 12). Once again a group of fast drifting bursts with positive and negative drifts can be seen. The drifts of these bursts are much higher, in the range -3–3 GHz s^{-1}. It is important to mention that this structure was observed during the formation of the drifting pulsation structure on lower frequencies.

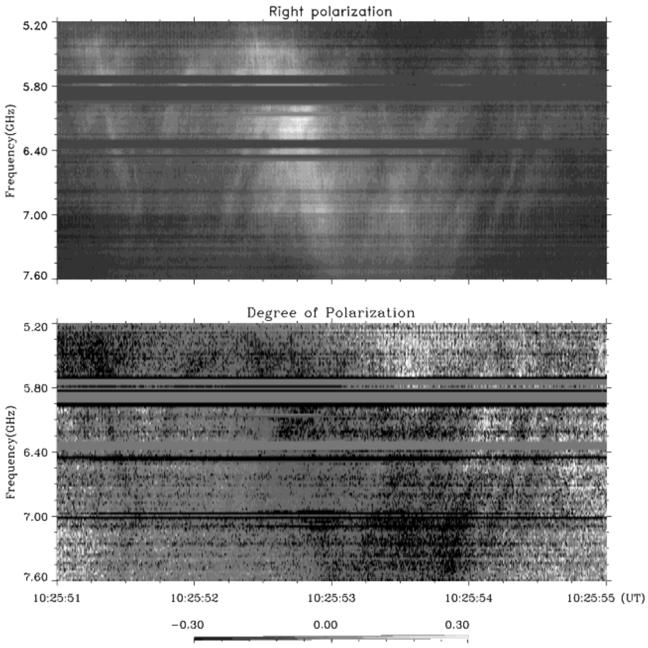

Fig. 12. The 5.2–7.6 GHz right polarization and degree of polarization radio spectra with a group of fast positively and negatively drifting bursts observed on July 14, 2000 by the Beijing radiospectrograph (the black colour in the degree of polarization spectrum corresponds to the right polarization)

2.5. Comparison of the radio spectra of the flares under study

At the beginning of impulsive phases of all presented flares, drifting pulsation structures with negative frequency drifts were observed. Thus these DPS can be considered as the typical feature of these types of flares. Their drifts and instantaneous bandwidths together with those of further observed drifting fine structures are summarized in Table 1. It can be seen that on higher frequencies the V-structures coincide (in time) with fine structures on lower frequencies. Furthermore, it was found that the high-frequency part of the DPS in the 2.0–4.5 GHz range at 10:31-10:33 UT, July 12, 2000 and at 10:24-10:32 UT, July 14, 2000 are similar to the 1–2 GHz continuum with drifting boundaries at 12:57:30-13:07:00 UT, July 11, 2000 flare.

2.6. Fourier analysis of the drifting pulsation structures

Time profiles on selected frequencies for two DPS structures (July 12 and 14, 2000) were analyzed by the Fourier method. The results are summarized in Table 2. In both cases the periodograms reveal the quasi-periodic character of these pulsations, in agreement with the DPS presented in the paper by Kliem et al. (2000).

3. Discussion

In the presented radio bursts and fine structures we can find several very interesting phenomena, especially

Table 1. Parameters of the observed drifting fine structures. The designations "(ib)" and "(tb)" mean the "Instantaneous Bandwidth" and "Total Bandwidth", respectively and "IPS" stands for "Impulsive Phase Start"

Flare	IPS [UT]	Type of Structure	Start Time [UT]	Frequency Range [GHz]	Drift [MHz s^{-1}]	Bandwidth [MHz]
July 10, 2000	22:00	V-structure	21:58:17	6.4–7.6	−60000, +25000	1200 (tb)
		DPS	21:59:36	1.0–1.8	−60	200 (ib)
July 11, 2000	12:28	weak DPS	12:28:38	0.8–2.0	−50	700 (ib)
		drifting patches	12:45:30	2.7–3.2	−30	300 (ib)
		fibers	12:46:16	0.8–1.0	−33	200 (tb)
		spike branches	13:26:40	1.0–1.8	−6	800 (tb)
July 12, 2000	10:30	DPS	10:31:00	0.8–4.5	−5	>1000 (ib)
		drifting line	10:34:53	1.34–1.2	−14	140 (tb)
		III-like bursts	10:35:40	5.2–7.6	−48000	>2400 (tb)
		harmonic zebra	10:35:45	1.0–3.0	−6– −12	2000 (tb)
July 14, 2000	10:25	RS bursts	10:18:53	5.2–7.6	+3500	∼2400 (tb)
		III-like burst	10:24:00	0.8–3.0	−240	>2200 (tb)
		V-structure	10:25:51	5.2–7.6	−3000, +3000	∼2400 (tb)
		DPS	10:27:00	0.8–1.5	−3.3	>1000 (ib)
		fibers	10:42:00	0.8–1,5	−80– −40	700 (tb)
		V-structure	10:42:08	2.0–2.4	−250, +250	400 (tb)

Table 2. Periods of drifting pulsation structures ("p" denotes the probability of the found period)

Flare	Frequency [GHz]	Time Interval [UT]	Period [s]	p [%]
July 12, 2000	1.3	10:32:00-10:36:00	3.24	89.8
			2.14	86.6
			1.56	82.8
			1.49	90.6
			1.42	88.4
			1.32	86.4
			1.06	78.7
July 14, 2000	1.4	10:28:00-10:32:00	9.23	76.3
			4.44	83.4
			1.52	76.3
			1.01	79.9

drifting pulsation structures, drifting patches, drifting harmonic structures with the zebra patterns, very narrowband drifting lines, drifting branches of narrowband dm-spikes, and structures with the fast positively and negatively drifting bursts (V-structures). In the following, we analyze these phenomena in more detail.

3.1. Drifting pulsation structures

Recently, in the paper by Kliem et al. (2000) the slowly negatively drifting pulsation structure (DPS) observed during the Oct. 5, 1992 flare plasmoid ejection (Ohyama & Shibata 1998) was presented and interpreted as the signature of the dynamic magnetic reconnection. The quasi-periodic radio flux pulsations were attributed to modulations of particle acceleration in the extended current sheet, thus representing repeated formation and subsequent coalescence of magnetic islands forming, feeding and launching a plasmoid. The same event was described also by Hori (1999). In our case the drifting DPSs are observed at the beginning of the flare impulsive phases. The DPSs have well-limited frequency bandwidths. In agreement with the paper by Kliem et al. (2000) this aspect can be explained in three possible ways: a) the radio pulses are generated by electron beams in the limited space between the ejected plasmoid and the underlying reconnected arch loops or b) the radio emission is generated by shocks formed at the region where the plasma reconnection outflow jets are stopped (just above underlying arch loops or below the ejected plasmoid) or c) the radio emission is generated inside a magnetically closed plasmoid. The slow negative drift of the whole DPS is in all these cases caused by the motion of the whole reconnection space and the plasmoid upwards to lower plasma densities. The drifting patches (Fig. 4) belong probably to the same group of fine structures.

3.2. The drifting harmonic structure with zebra pattern

A similar zebra structure was described for the first time in the papers by Ning et al. (2000 a,b) and explained by Ledenev et al. (2000). Here, this structure was observed for the first time with two harmonic branches. Due to the decrease of the frequency distance among the zebra lines with the frequency decrease and due to the observation of the zebra pattern in the harmonic branch, we interpret this structure in the same way as suggested by Ledenev et al. (2000) (see also Ledenev & Urbarz 1993). In this model an anisotropic beam, having temperatures $T_{\rm per}$ (perpendicular to the magnetic field B) much greater than $T_{\rm par}$ (parallel), is assumed. Such an anisotropic beam can be easily generated by a localized acceleration or/and heating when fast electrons along the B magnetic field escape from the acceleration space. This beam is unstable for the longitudinal waves having the frequency $\omega \sim (\omega_{\rm pe}^2 + \omega_{\rm Be}^2)^{1/2}$, if the resonance condition ($\omega = k_{\rm par} v_{\rm par} + s\omega_{\rm Be}$, where $k_{\rm par}$ and $v_{\rm par}$ are the k-wave vector and the electron velocity components parallel to B, and s is the number of the electron cyclotron harmonics) is fulfiled. Because the instability growth rate has a maximum for small $k_{\rm par}$, the resonance condition can be rewritten as $\omega \sim s\omega_{\rm Be}$, where $\omega \sim (\omega_{\rm pe}^2 + \omega_{\rm Be}^2)^{1/2}$. In such a case the unstable longitudinal waves are propagating nearly perpendicular to the magnetic field. The ratio for the adjacent harmonics can be expressed as $\omega_s/\omega_{s+1} \approx (s^3(s+2)/(s+1)^3(s-1))^{1/2}$, which gives the minimum values for the $\omega_2/\omega_3 \sim 1.09$, $\omega_3/\omega_4 \sim 1.03$, $\omega_4/\omega_5 \sim 1.01$ and so on. In our case, a zebra pattern with four lines was observed and the found ratios are: 1.047, 1.039, and 1.025. Therefore, we think that the highest frequency zebra line corresponds to the third harmonic. As observed, the zebra pattern is found in the harmonic branch, therefore the coalescence of two unstable longitudinal plasmons is assumed. Then we can write for the electron cyclotron frequency $\omega_{\rm Be} = \omega_{\rm el}/(2{\rm s})$, where $\omega_{\rm el}/(2\pi)$ is the frequency of observed zebra lines. Thus, for the third harmonic zebra line (f = 2511 MHz) the electron cyclotron frequency is $\omega_{\rm Be} = 2\pi f/(2.3)$, where f(MHz)= 2.8 H(G), and the magnetic field strength H in the zebra line radio source can be estimated as 150 G.

3.3. Very narrowband drifting lines

For this new feature there is no model. Nevertheless, similar narrowband drifting lines were observed also in the fundamental branch of the harmonic structure with zebra patterns. Based on this similarity we think that the very narrowband line is generated by the same process as the zebra pattern, but in this case due to specific conditions only one zebra line is generated. Thus, the model of Ledenev et al. (2000) valid for zebra pattern (see previous paragraph) can also be used in this case.

3.4. Narrowband dm-spikes

Three extended groups of narrowband dm-spikes were observed during the NOAA 9077 flares. One group was observed during the impulsive phase (the July 12, 2000 flare), two remaining in the later phases. In other papers (Karlický et al. 1996; Zlobec & Karlický 1998) it has been suggested that the narrowband dm-spikes are generated in the MHD turbulence of plasma reconnection outflows. This idea is in agreement with mechanism suggested for the DPS. Namely, during the July 12, 2000 flare, narrowband dm-spikes were observed within the DPS. On the other hand, the drifting branches of narrowband dm-spikes are probably connected with changes of plasma parameters in turbulent plasma outflows.

3.5. The group of fast positively and negatively drifting bursts (V-structure)

This structure was observed once at the beginning of a strong radio burst (the July 10, 2000 flare) at a time prior to the DPS on lower frequencies and twice during the July 14, 2000 flare: in the 5.2–7.6 GHz range at the start of the DPS on lower frequencies and in the 2.0–2.4 GHz range at the start of the intense pulse burst at lower frequencies. We think that these structures, mainly those with the same absolute values of the positive and negative drifts (two cases at the July 14, 2000 flare), manifest the electron beams propagating downwards as well as those reflected in the underlying magnetic mirrors and propagating upwards. The asymmetric case (bi-directional drift rates) observed during the July 10, 2000 event is probably more complicated.

4. Conclusions

The NOAA 9077 AR (July 10–14, 2000) solar flares were very rich in radio spectral fine structures. The variety of these structures in the 0.8–7.6 GHz frequency range was comparable with that observed, usually at lower frequencies, below 1 GHz (see e.g. Chernov et al. 1998). In all studied flares, the drifting pulsation structures were observed. Therefore, DPS can be considered as the typical signature of these types of flares (two-ribbon flares). In all cases the DPS drifts towards lower frequencies, expressing thus the upwards motion of the whole flare structure and the plasmoid ejection. The limited bandwidth of the DPS indicates that the DPS is generated in a limited space, maybe in the space between the ejected plasmoid and underlying arch loops, or in shocks formed at the regions where reconnection jets are stopped, or in a magnetically closed plasmoid. Three types of fine structures, which are probably connected with the magnetic field reconnection and the primary flare energy release processes, were recognized: the drifting pulsation structure associated with the plasmoid ejection, the narrowband dm-spikes with the MHD turbulence in the reconnection plasma outflows, and the harmonic structure with a zebra pattern, indicating the localized region with the anisotropic distribution function of accelerated electrons. In the July 12, 2000 flare all these structures were observed in the impulsive phase. Moreover, the narrowband dm-spikes and the harmonic structure with the zebra pattern were observed within the frequency bandwidth and time of the drifting pulsation structure. In three cases it was found that fine structures in the 1–2 GHz range coincide with the high-frequency structure of the fast positively and negatively drifting bursts. We designated this structure as "V-structure", which in our opinion expresses the mirroring of electron beams in underlying magnetic mirrors at times of increased flare process activity.

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