A&A 375, 243–250 (2001)
DOI: 10.1051/0004-6361:20010782

Astronomy & Astrophysics

Global statistics of 0.8–2.0 GHz radio bursts and fine structures observed during 1992–2000 by the Ondřejov radiospectrograph

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Received 14 March 2001 / Accepted 28 May 2001

Abstract. 681 solar radio events observed by the Ondřejov 0.8–2.0 GHz radiospectrograph during 1992–2000 are analyzed and corresponding bursts and fine structures classified into ten different classes. A new rare type of fine structure with rapid frequency variation we called lace pattern was included. Drifting pulsation structures, observed usually at the beginning of the impulsive flare phase, were recognized among pulsations. Furthermore, a new sub-class of zebra patterns with many zebra lines (∼30) superimposed on fibers was identified. For all defined types of burst and fine structures basic characteristics of their parameters are presented. Distributions of various types of burst and fine structures in the years 1992–2000 in dependence on the changes of solar activity during the cycles 22 and 23, occurrences of studied types of burst in association with GOES class flares as well as their relationship to GOES flare maxima are shown. Finally, the association of the analyzed bursts with the metric type III bursts observed at Potsdam-Tremsdorf Observatory was studied.

Key words. plasmas – Sun: flares – Sun: radio radiation – methods: data analysis – methods: statistical

1. Introduction

In papers by Allaart et al. (1990), Bruggmann et al. (1990) and Isliker & Benz (1994) the first surveys of radio bursts and fine structures in the microwave range (4–8 GHz, 6–8.5 GHz and 1–3 GHz, respectively) were made. The double nature of the radio emission at frequencies above 1 GHz was recognized. While the featureless, broadband continua were considered to be generated by the incoherent gyrosynchrotron mechanism, the fine structures with narrowband features were connected with coherent plasma emission processes.

Based on our knowledge of conditions in the corona and the expectations of other authors (e.g. Bastian et al. 1998) the 0.8–2.0 GHz frequency range corresponds to frequencies at which the plasma emission from flare primary-energy release processes can be observed. Therefore observations in this range give us information about solar flares, especially about their primary processes.

The 0.8–2.0 GHz Ondřejov radiospectrograph (Jiřička et al. 1993) has been observing solar flare emissions since 1992. The time and frequency resolutions are 0.1 s and 5 MHz, respectively. In the period from June 1, 1992 till June 30, 2000 681 radio events were observed. All of them can be seen on the Ondřejov Solar Radio Astronomy Group WWW pages (http://sunkl.asu.cas.cz/~radio/) as images in GIF format.

In the following, based on phenomenological arguments, the observed bursts and fine structures are classified, their characteristics and parameters determined, and examples shown. The occurrence rates of different types of bursts and fine structures during the 8 years of observations are determined and compared with the phases of the solar cycle. Then, the occurrence of different types of radio bursts associated with GOES class flares and their start times in relation to GOES flare maxima are studied. Finally, in order to identify those bursts associated with particle beams, the association of 0.8–2.0 GHz bursts with metric type III bursts is studied.

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2. Classification

In every observed radio event (681 cases) some radio bursts and fine structures were found. These radio bursts and fine structures are classified into 10 different types. We tried to use the classification described by Isliker & Benz (1994), nevertheless there are some deviations due to new aspects of these bursts. In most flares (∼60%) only one type of radio burst is observed, but in many cases (∼40%) the flare is a combination of two or more types of radio bursts.

2.1. Continua

The broadband (>400 MHz), featureless radio emission lasting for 10 s or more is considered as continuum. An example of the continuum is shown in Fig. 1. In this event lasting 17 min (November 14, 1999) no other bursts or fine structures were observed. The bandwidth of this continuum is greater than 1.2 GHz.

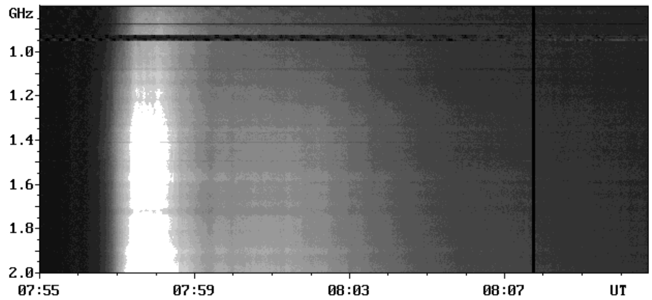

Fig. 1. Example of continuum (observed at Ondřejov on November 14, 1999).

In the studied period 1992–2000 368 events with continuum were recorded (see Table 3). For continua the following parameters were determined: time interval, frequency range, association with other types of radio bursts and fine structures (complexity of the event).

The mean time duration of observed continua is 8.8 min. Their bandwidth is usually greater than the frequency range of the spectrograph (0.8–2.0 GHz), i.e. greater than 1.2 GHz. In most cases only the low-frequency part of the continuum appears in the 0.8–2.0 GHz spectrograph range. In 36% of cases the continua stand alone, i.e. they are not accompanied by other types of burst or fine structures. The remaining 64% of observed continua are a part of more complex events, accompanied by other types of burst and fine structures.

2.2. Pulsation

Series of pulses with frequency bandwidth ≥200 MHz lasting as a whole for more than 10 s are called pulsations. Some pulsations are almost periodic, but most of them are quasi-periodic. Within a pulsation, the parameters of individual pulses are similar. The characteristic periods of their repetitions are in the 0.1–2 s range. The frequency drift of pulses is infinite or very high, and thus not measurable.

Among the observed pulsations we found some with a slow global frequency drift. We call them the drifting pulsation structures (DPS). Examples of DPS are shown in Fig. 2, where the radio spectra of January 18, 1993 and August 18, 1998 events are presented. In the first case, observed at 13:01:00−13:02:00 UT in the 1.0–2.0 GHz frequency range, the duration and bandwidth of individual pulses are 0.3 s and 850 MHz, respectively. The characteristic period of the pulsation is about 0.3 s. The global drift is −30 MHz s^{-1}. In the August 18, 1998 event observed at 8:18:30−8:19:30 UT in the 0.8–1.5 GHz range, the duration and bandwidth of individual pulses are 0.5 s and 345 MHz, respectively. The characteristic period is about 0.4 s. The global drift of the DPS is variable within the interval of +25 − −21 MHz s^{-1}.

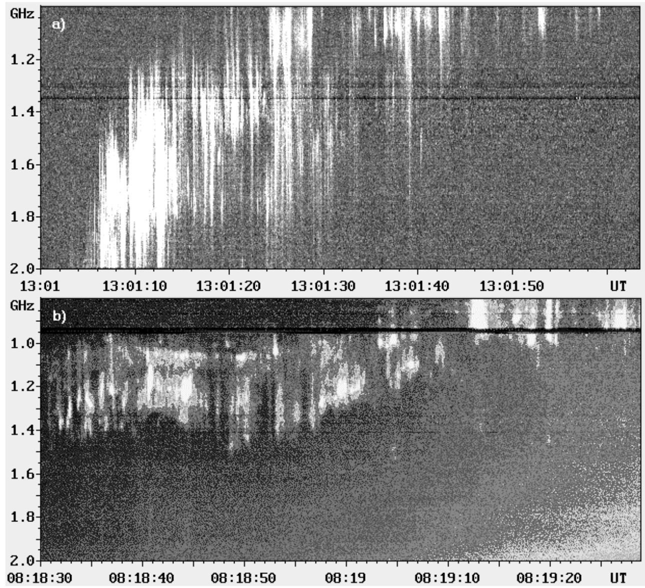

Fig. 2. Examples of drifting pulsation structures (DPS) (observed at Ondřejov **a)** on January 18, 1993 and **b)** on August 18, 1998).

In the studied period 1992–2000 92 events with pulsations were recorded (see Table 3). For the pulsations the following parameters were determined: time interval, frequency range, association with other types of radio bursts and fine structures (complexity of the event), for the DPS the global frequency drift, duration and bandwidth of individual pulses, and the characteristic period.

The mean time duration of these pulsations is 3.8 min. Their frequency range is usually greater than the 0.8–2.0 GHz frequency range of the spectrograph. Duration and bandwidth of individual pulses in pulsations and their mean repetition period were found to be 0.1–2.8 s and 200 −> 1200 MHz, and 0.3 s, respectively.

Among all events with pulsations 30 DPS structures were found, i.e. in 33% of cases. The histogram of global frequency drifts of DPS is shown in Fig. 3. The maximum and minimum of the drift is +80 and −67 MHz s^{-1}, respectively. The maximum of the histogram is for slow (i.e. <−20 MHz s^{-1}) negative drifts. Most of the DPS (47%) have negative drifts (see Fig. 2a), 13% of the DPS have positive ones. The remaining DPS have variable drifts (see Fig. 2b).

While 65% of pulsations appeared as single type, i.e. no other types were observed in corresponding events, the remaining 35% of pulsations are parts of more complex events.

2.3. Isolated broadband pulses

A small group of broadband intermittent pulses lasting ≤10 s with frequency bandwidth >200 MHz we call

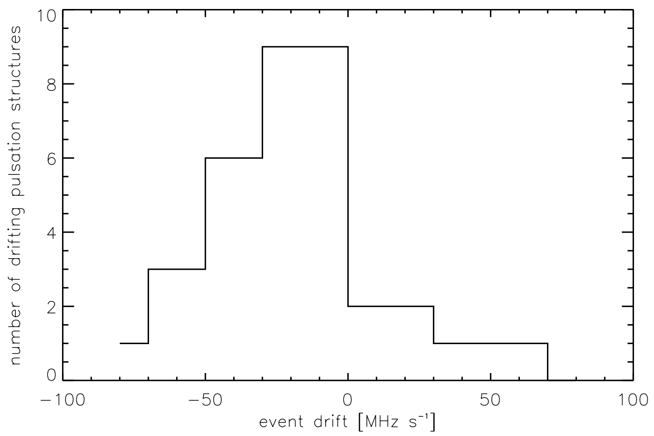

Fig. 3. Histogram of DPS global frequency drifts.

isolated broadband pulses. Their frequency drifts are infinite or very high, and thus not measurable. The parameters of individual isolated broadband pulses differ within the group.

An example of isolated broadband pulses is shown in Fig. 4, where the radio spectrum of March 12, 1999 event is presented. In this case, observed at 8:55:38–8:56:14 UT in the 800–1200 MHz frequency range, the duration and bandwidth of individual pulse are 1.9 s and 1200 MHz, respectively.

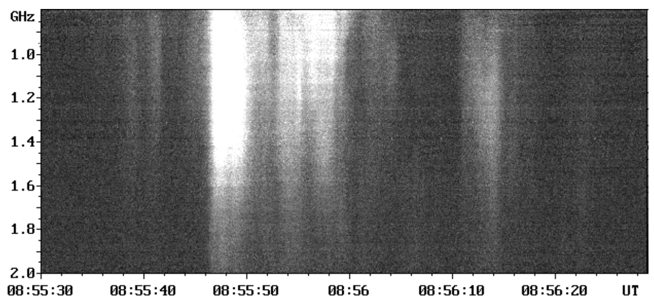

Fig. 4. Example of isolated broadband pulses (observed at Ondřejov on March 12, 1999).

In studied period of 1992–2000 230 events with isolated broadband pulses were recorded (see Table 3). For the observed isolated broadband pulses the following parameters were determined: time interval, frequency range, duration of individual pulses, bandwidth of individual pulses, and complexity of the event.

Mean time duration of a group of isolated broadband pulses is 1.7 min. Duration and bandwidth of individual pulses were found in the 0.1–4.0 s (exceptionally up to 9.0 s) and the 200 −> 1200 MHz ranges, respectively. Most (57%) of the broadband pulses appear as single case, while the remaining 43% are parts of more complex events.

2.4. Fast drift bursts

Short-lasting and fast drifting bursts with measurable drift ≥ ±100 MHz s^{-1} we call here fast drift bursts (FDB). They occur usually in a small group (the number of bursts is <10). The parameters of individual FDB within a group differ. According to their characteristics they are similar to the isolated broadband pulses, excepting the measurable frequency drift. Due to the time resolution of the radiospectrogram the upper limit for the measurable drift is about ±1000 MHz s^{-1}.

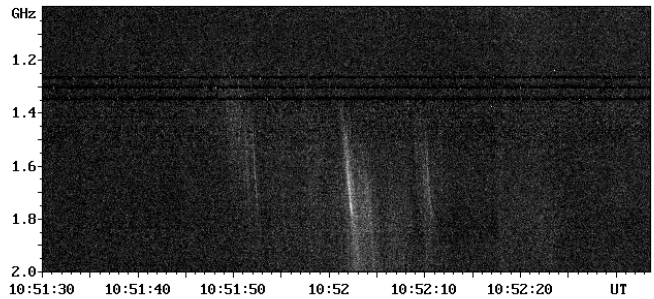

Fig. 5. Example of fast drift bursts (observed at Ondřejov on February 18, 1993).

In Fig. 5 you can see an example of typical fast drift bursts observed on February 18, 1993 at 10:51:51−10:52:10 UT in the 1360–2000 MHz frequency range. The duration and the frequency drift of an individual FDB is about 1.7 s and +370 MHz s^{-1}, respectively.

In the studied period of 1992–2000 48 events with fast drift bursts were recorded (see Table 3). For the recorded fast drift bursts the following parameters were determined: time interval, frequency range, duration of individual FDB, drift of individual FDB, and complexity of the event.

The mean time duration of a group of FDB is 36 s. Their bandwidth is usually smaller than 1.2 GHz. The duration of individual burst is in the 0.5–6.6 s interval. Most of these FDB (85%) have positive drifts (reverse drift bursts).

The fast drift bursts appear rarely as a single case (10% only), most of them (90%) are present in complex events with two or more types of burst (prevalently with pulses and pulsations).

2.5. Narrowband type III bursts

Narrowband type III bursts are defined here as a group (5–20) of short (∼1 s) narrowband (<200 MHz) fast drifting (>100 MHz s^{-1}) bursts. The parameters of individual bursts can differ considerably within a group. An example of this type of bursts is shown in Fig. 6, where the July 24, 1999 event observed at 11:21:07−11:21:43 UT in the 885–1570 MHz range is presented. The bandwidth of individual bursts is about 150 MHz.

In the studied period 1992–2000 106 events containing narrowband type III bursts were recorded (see Table 3). For the narrowband type III bursts the following parameters were determined: time interval, frequency range, bandwidth of individual burst, drift of individual burst, and complexity of the event.

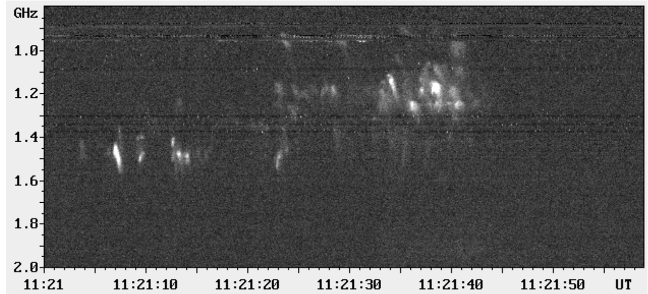

Fig. 6. Example of narrowband type III bursts (observed at Ondřejov on July 24, 1999).

The mean time duration of a group of this type of bursts is 1.5 min. Their frequency range is usually between 0.8–1.3 GHz, their bandwidth is in the 55–192 MHz range, and the mean frequency drift of individual bursts is 230 $\mathrm{MHz\,s^{-1}}$. 20% of all such events have global drift (the drift of the whole group), which was found to lie within the range +70 and −66 $\mathrm{MHz\,s^{-1}}$.

The narrowband type III bursts occur in 44% cases as single events, the rest are parts of more complex events. These bursts are sometimes observed at the very beginning of the flare (5% cases).

2.6. Slowly drifting bursts

The slowly drifting bursts are defined here as the bursts with a drift $<\pm 100$ $\mathrm{MHz\,s^{-1}}$. Prevalently they occur in a small group (the number of bursts less than 10). An example of this type of burst is shown in Fig. 7, where the September 23, 1998 event observed at 6:53:50−6:54:50 UT, in the 800–1800 MHz frequency range is presented. The duration and drift of individual bursts are 4.0 s and +55 $\mathrm{MHz\,s^{-1}}$, respectively.

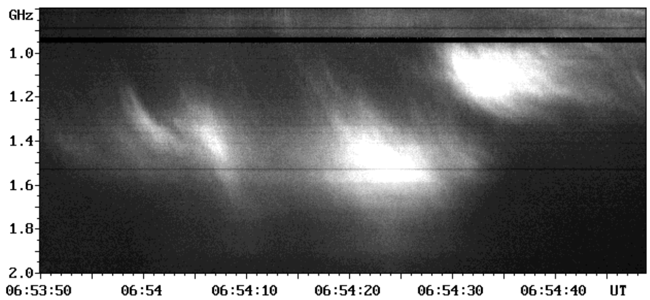

Fig. 7. Example of slowly drifting bursts (observed at Ondřejov on September 23, 1998).

In studied period 1992–2000 23 events with slowly drifting bursts were recorded (see Table 3). For the slowly drifting bursts the following parameters were determined: time interval, frequency range, duration of individual bursts, drift of individual bursts, and complexity of the event.

The mean time duration of these bursts is 32 s. They are observed in the whole frequency range of the radiospectrograph (0.8–2.0 GHz). The duration of individual bursts is in the 1.9–34.1 s range. From the 23 observed events 12 have negative and 11 positive drifts. Most of the slowly drifting bursts are observed during flares (91%) as parts of complex events.

2.7. Narrowband spikes

Narrowband spikes are defined here as a group of very short (≤0.1 s) narrowband (≤50 MHz) bursts. An example of narrowband spikes is shown in Fig. 8, where the September 12, 1997 event observed at 16:05:29−16:06:55 UT in the 1.0–2.0 GHz range is presented.

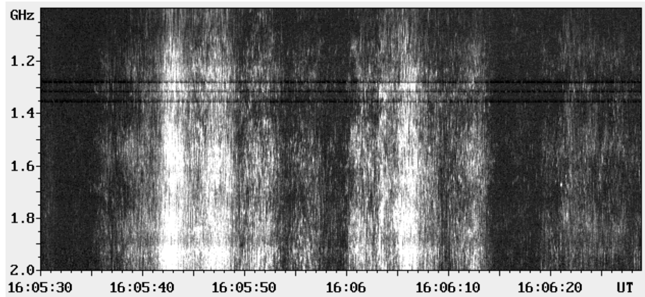

Fig. 8. Detailed view of narrowband spikes (observed at Ondřejov on September 12, 1997).

In the studied period 1992–2000 54 events with narrowband spikes were recorded (see Table 3). For the narrowband spikes the following parameters were determined: time interval, frequency range, bandwidth of individual spikes, harmonic structures of clouds of spikes, and complexity of the event.

The mean time duration of a cloud of spikes is 3.9 min. Their frequency range is usually between 0.8–1.3 GHz. Their minimum and maximum individual bandwidth is 5 and 50 MHz, respectively. The harmonic structure was observed at two events.

The narrowband spikes are in 39% of cases observed as single type events and in 61% cases as complex ones with two or more types of burst and fine structures present. In many cases the spikes are superimposed on broadband continua. The spikes are rarely observed at the beginning of a flare (2 cases only).

2.8. Fibers

Bursts with nearly regular repetition and with the frequency drift of about 100 $\mathrm{MHz\,s^{-1}}$ are called fibers. In most cases they are characterized by a change of the frequency drift.

An example of fibers is shown in Fig. 9 where the February 14, 1999 event observed at 12:11:45−12:12:45 UT in the 800–1540 MHz frequency range is presented. The total duration and total bandwidth are 5.7 s and 390 MHz, respectively. The duration on a specific frequency is about 0.5 s and the instantaneous bandwidth is 20 MHz for both emission lines and the absorption features. The drift of individual fiber is −69 $\mathrm{MHz\,s^{-1}}$, see also the change of drift of these fibers.

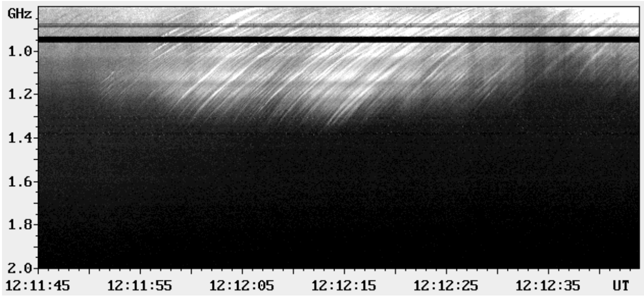

Fig. 9. Example of fibers (observed at Ondřejov on February 14, 1999).

In the studied period 1992–2000 35 events with fiber bursts were recorded (see Table 3). For the fibers the following parameters were determined: time interval, frequency range, duration of individual fiber, bandwidth of individual fiber, single frequency duration, instantaneous fiber bandwidth, emission-absorption frequency difference, drift of individual fiber, change of drift of fibers, and complexity of event.

The mean time duration of a group of fibers is 9.5 min. Their frequency range is usually between 0.8–1400 GHz. Parameters of observed fibers are shown in Table 1. Almost one half (49%) of fibre events show absorption.

Table 1. Fiber bursts parameters of 35 events. DF – duration of the individual fiber, BF – bandwidth of the individual fiber, FTT – fiber time thickness, FFT – fiber frequency thickness, FD – emission-absorption frequency difference, DR – frequency drift, Min – minimum value, Max – maximum value, Mean – mean value.

	DF [s]	BF [MHz]	FTT [s]	FFT [MHz]	FD [MHz]	DR [MHz s^{-1}]
Min	0.9	80	0.1	5	10	−21
Max	8.4	695	0.9	45	32	−220
Mean	4.0	273	0.4	16	19	−76

While 20% of observed fibres show constant frequency drift (at least within the observed frequency band), in most cases the drift of fibres changes (51% of observed fibres show negative change in drift and the remaining 29% show both negative and positive change in drift). In all cases the fibers are observed in complex events with two or more types of burst and fine structures present.

2.9. Zebras

Zebras are characterized by several emission lines, which maintain nearly regular distance to their neighbors. We recognize two types of zebras:

1. classical zebras (83%) which have small number of lines (9 on average), large line frequency spacings, and wavy appearance;
2. zebras superimposed on fibers (17%), which have larger number of lines (21 on average) and very small line frequency spacings.

An example of the normal zebra is shown in Fig. 10a where the May 2, 1998 event is presented with following parameters: number of lines = 9, duration = 4.7 s, bandwidth = 300 MHz, line spacing = 35 MHz. An example of zebras superimposed on fibers is shown in Fig. 10b where the November 23, 1998 event is presented with following parameters: number of lines = 39, zebra duration = 7.8 s, zebra bandwidth = 390 MHz, line spacing = 10 MHz.

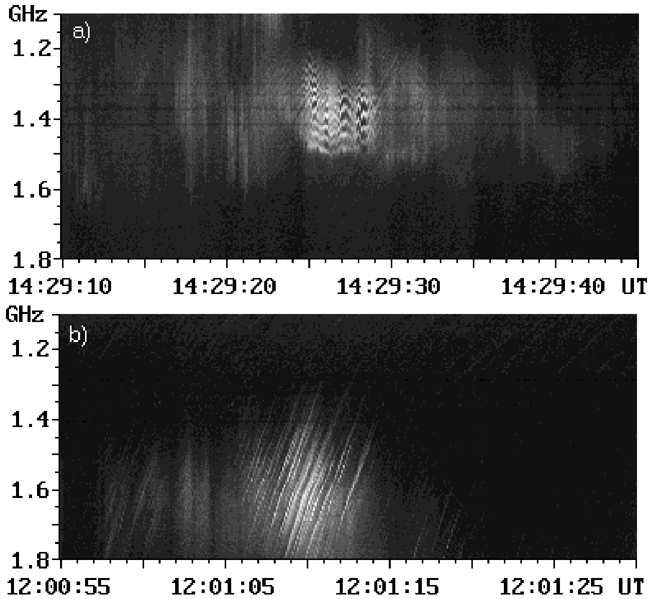

Fig. 10. Examples of zebra patterns: **a)** classical zebras (observed at Ondřejov on May 02, 1998) and **b)** zebras superimposed on fibers (observed at Ondřejov on November 23, 1998).

In the studied period 1992–2000 24 events with zebras were recorded (see Table 3). For the zebras the following parameters were determined: time interval, frequency range, duration of individual zebra, bandwidth of individual zebra, number of zebra lines, zebra line spacing, and complexity of the event. The statistics for individual parameters of zebras is shown in Table 2.

Table 2. Zebra parameters of the 24 observed cases. TB – total bandwidth, D – duration, NZL – number of zebra lines, FD – frequency difference between two neighboring zebra lines.

classical zebras				
	TB [MHz]	D [s]	NZL	FD [MHz]
Min	55	0.5	3	10
Max	440	38.1	29	70
Mean	256.5	7.1	9.7	28.3
zebras superimposed on fibers				
	TB [MHz]	D [s]	NZL	FD [MHz]
Min	230	0.6	5	10
Max	505	9.2	39	50
Mean	343.7	4.9	21.2	23.7

Table 3. Occurrences of various types of burst in the years 1992–2000.

Type of burst	1992	1993	1994	1995	1996	1997	1998	1999	2000	total
continua	25	42	5	5	10	13	109	90	69	368
pulsation	17	15	2	1	1	13	22	21	10	92
isolated broadband pulses	27	26	6	-	2	9	60	56	44	230
fast drift bursts	6	5	2	-	1	2	13	10	9	48
narrowband type III bursts	12	11	4	-	-	4	28	24	23	106
slowly drifting bursts	3	6	1	-	-	1	9	-	3	23
narrowband spikes	3	8	-	-	2	3	17	14	7	54
fibers	1	7	-	-	1	-	9	10	7	35
zebras	2	6	-	-	-	-	5	7	4	24
laces	-	1	-	-	-	-	4	3	1	9
sums of all types	96	127	20	6	17	35	276	235	177	989
number of events	68	78	13	5	11	23	170	174	139	681
mean complexity of event	1.4	1.6	1.5	1.2	1.5	1.5	1.6	1.3	1.3	1.4

2.10. Laces

We defined a new type of fine structure characterized by rapid frequency variations, both positive and negative. According to its appearance we called this structure "lace pattern". This phenomenon is rather rare, only 9 such cases were found in the whole studied interval 1992–2000. An example of this structure observed on August 17, 1999 at 15:07:30−15:08:30 UT in the 1–2 GHz frequency range is shown in Fig. 11.

It looks as a superposition of several bursts of this type. Their high-frequency ends are cut off sharply. They form lines (bandwidth of about 50 MHz) highly variable in their frequencies and intensities.

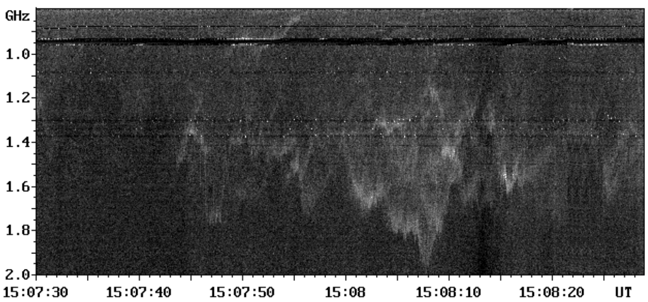

Fig. 11. Example of lace pattern (observed at Ondřejov on August 17, 1999).

3. Global statistics

In this chapter, occurrences of 10 defined types of radio bursts and fine structures as a function of various parameters for individual years (1992–2000) are presented:

- occurrences of individual types of burst (Table 3);
- occurrences of individual types of burst as a function of observed GOES flare classes (Table 4);
- numbers and percentages of individual types of burst occurring before the GOES soft X-ray flare maxima (Table 5);
- numbers and percentages of individual types of burst associated with metric type III bursts observed at the Potsdam-Tremsdorf Observatory (Table 6).

In Table 3 mean values (per year) of the coefficient of complexity of events, expressing the number of burst types per event, are added. Numbers are in the 1–2 range with a mean of 1.4 over the whole interval, which means that in most events only one type of burst or fine structure was observed. The events with more types of burst are less frequent. The effect of the solar cycle minimum on numbers of events and bursts is clearly identifiable. (Remark: in 1995, due to technical problem the observing interval was shorter roughly 3 times in comparison with other years therefore the numbers presented in the table should be multiply by 3.) The most frequent types are: continua, isolated broadband pulses, narrowband type III bursts, and pulsations. On the other hand, the newly defined lace pattern was observed on 9 occasions only.

Table 4. Occurrences of various types of burst as a function of the GOES flare classes during 1992–1999.

Type of Burst	X	M	C	B	total
continua	16	77	115	15	223
pulsation	6	19	20	4	49
isolated broadband pulses	4	28	84	16	132
fast drift bursts	1	6	19	4	30
narrowband type III bursts	7	19	30	4	60
slowly drifting bursts	2	6	6	1	15
narrowband spikes	3	12	19	3	37
fibers	2	5	7	-	14
zebras	1	4	5	-	10
laces	-	1	3	1	5
total	42	177	308	48	575

In Table 4 the distribution of various types of burst as a function of the observed GOES flare classes is shown. As can be seen the total number of bursts and fine structure is reduced in comparison with those in Table 3. This is due to the fact that GOES observations are not available

Table 5. Absolute numbers and (percentages) of various types of burst which occured before the GOES soft X-ray flare maxima in the years 1992–1999.

Type of Burst	1992 (%)	1993 (%)	1994 (%)	1995 (%)	1996 (%)	1997 (%)	1998 (%)	1999 (%)	sums (%)
continua	20 (80)	16 (38)	2 (40)	3 (60)	9 (50)	10 (77)	77 (71)	66 (73)	203 (68)
pulsation	8 (47)	4 (27)	-	1 (100)	1 (100)	2 (15)	12 (54)	6 (29)	34 (41)
pulses	14 (52)	11 (42)	4 (67)	-	2 (100)	6 (67)	41 (68)	32 (57)	110 (59)
FDB	3 (50)	2 (40)	2 (100)	-	1 (100)	1 (50)	8 (61)	7 (70)	24 (61)
type III	7 (58)	4 (36)	2 (50)	-	-	3 (75)	22 (79)	16 (67)	54 (65)
SDB	1 (33)	2 (33)	-	-	-	1 (100)	5 (56)	-	9 (45)
spikes	3 (100)	6 (75)	-	-	1 (50)	2 (67)	15 (88)	7 (50)	34 (72)
fibers	1 (100)	-	-	-	-	-	1 (11)	3 (30)	5 (18)
zebras	1 (50)	4 (67)	-	-	-	-	-	2 (29)	7 (35)
laces	-	1 (100)	-	-	-	-	1 (25)	2 (67)	4 (50)
total	58 (60)	50 (39)	10 (50)	4 (67)	14 (82)	25 (71)	182 (66)	141 (60)	484 (60)

Table 6. Absolute numbers and (percentages) of various types of burst associated with the metric type III bursts observed at the Potsdam-Tremsdorf Observatory in years 1992–2000.

Type of burst	1992 (%)	1993 (%)	1994 (%)	1995 (%)	1996 (%)	1997 (%)	1998 (%)	1999 (%)	2000 (%)	sums (%)
pulsation	3 (18)	4 (27)	-	-	-	2 (15)	7 (32)	6 (29)	7 (70)	29 (31)
pulses	6 (22)	5 (19)	3 (50)	-	1 (50)	2 (22)	26 (43)	13 (23)	13 (29)	69 (30)
FDB	1 (17)	2 (40)	-	-	1 (100)	-	4 (31)	2 (20)	2 (22)	12 (25)
type III	3 (25)	2 (18)	-	-	-	1 (25)	7 (25)	5 (21)	7 (30)	25 (24)
SDB	1 (33)	3 (50)	-	-	-	-	2 (22)	-	-	6 (26)
spikes	-	-	-	-	1 (50)	2 (67)	10 (59)	1 (7)	1 (14)	15 (28)
fibers	-	-	-	-	-	-	1 (11)	2 (20)	2 (29)	5 (14)
zebras	-	-	-	-	-	-	2 (40)	3 (43)	1 (25)	6 (25)
laces	-	-	-	-	-	-	2 (50)	-	-	2 (22)
total	14 (20)	16 (19)	3 (20)	-	3 (43)	7 (32)	61 (36)	32 (22)	33 (30)	169 (27)

for all observed radio events. The maximum number of observed bursts correspond to the C-class of X-ray flares.

In Table 5 we tried to determine the time relation of observed bursts with the times of maximum of GOES soft X-ray emission. The table shows numbers and percentages (in comparison to the total numbers) of various types of burst which occur before the GOES soft X-ray flare maxima. For the radio bursts the time of their start was used. A high percentage means that most of the bursts are observed before the heating flare maxima.

Finally, we were looking for the association of observed high-frequency bursts with type III bursts observed in the metric range at the Potsdam-Tremsdorf Observatory (Solar Geophysical Data, Boulder, 1992–1999). We were interested to find out which bursts are thus associated with particle beams. An association was consider only in the case when the time interval of the high-frequency burst and the time interval of the metric type III radio burst overlapped.

4. Discussion and conclusions

In definitions of various types of burst and fine structures the phenomenological arguments were used. Nevertheless, it is highly probable that some types of burst are physically similar. For example, in analogy with metric type III bursts we believe that the following types belong to those generated by particle beams: isolated broadband pulses, fast drift bursts (FDB), and narrowband type III bursts. Moreover, due to the limited time resolution (100 ms) of our radiospectrograph high frequency drifts are not distinguishable, therefore some pulsations can be of the same physical origin. We tried to better distinguish individual types of burst, therefore we looked for the association of observed bursts with metric type III bursts (particle beams). Results partly confirmed our expectations that isolated broadband pulses, fast drift bursts (FDB), and narrowband type III bursts belong to the same group of bursts. On the other hand, there are many reasons why such an association does not exist, e.g. the closed magnetic field lines making the escape of beams to higher atmospheric layers impossible, gaps in observations, and so on.

Among all events with pulsations 30 drifting pulsation structures (DPS) were found, i.e. in 33% of observed cases. They are usually observed at the beginnings of impulsive flare phases. The maximum and minimum of the drift rates was found at +80 and −67 $\mathrm{MHz\,s^{-1}}$, respectively. Most of DPS have negative frequency drifts. The significance of DPS is given by the recent discovery (Kliem et al. 2000) that the DPS in the October 5, 1992 was associated with the plasmoid ejection (Ohyama & Shibata 1998). Furthermore, the DPS structures were observed during the most intense flares of this cycles (July 12 and 14, 2000 flares) (Karlický et al. 2001).

We recognized two types of zebras: a) classical zebras (83% of all cases) which have small number of lines (9 on average), large line frequency spacing, and wavy appearance, and b) zebras superimposed on fibers (17%), which have large number of lines (21 on average) and very small line frequency spacing. Though these two types of zebras can have similar physical origin, we think that at the present stage of knowledge about these phenomena this phenomenological division is useful.

It was also found that most of the events contain only one type of burst or fine structure. Events with more types of burst are less frequent. The effect of the solar cycle minimum on the number of events and bursts is well expressed, in Table 3 we can see decreasing number of bursts during the decay phase of the 22 solar cycle (1992–1996) as well as an increase in the 23 solar cycle (1997–2000). The most frequent types of events observed during 1992–2000 are: continua, isolated broadband pulses, narrowband type III bursts, and pulsations. On the other hand, only in 9 cases the fine structure with rapid frequency variations was found.

Furthermore, when comparing radio bursts with GOES data it was found that the maximum number of radio bursts are associated with the C-class of X-ray flares. The decrease of these numbers towards X and B classes can be explained by the flare number decrease for M and X flares and by the radio emission intensity decrease for B classes, respectively.

The comparison with GOES data shows that most of the bursts are observed before the soft X-ray flare maxima (flare heating maxima). It agrees with the general knowledge that the bursts above 1 GHz correspond in most cases to the impulsive phase of the flare which precedes the soft X-ray flare maxima. But it is important to note that sometimes, especially in prolonged flares, repetition of high frequency radio emission is observed.

Acknowledgements. This work was supported by the grants A3003003 and S1003006 of the Academy of Sciences of the Czech Republic, and the grant 205/00/1726 of the Grant Agency of the Czech republic under the key project K2043105.

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