FAST FINE STRUCTURE IN SOLAR MICROWAVE FLARES

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ABSTRACT

A preliminary account is presented of some characteristics of Fast Fine Structure, that is fine structure with time scales in the milli second range, and of the flare events in which they appear. Fast Fine Structure is found to be a fairly common phenomenon that could, but not necessarily does, appear in flare events of any importance occurring at any longitude. It may occur with any type of microwave burst (except most likely "Rise" and "Fall"). It appears more often in the more important events and it may last for only a few seconds up to many minutes. Fast Fine Structure may have any degree of circular polarization, apparently independent of its longitude position.

INTRODUCTION

In a flare on 11 April 1978 we discovered millisecond microwave spikes (figure 1), many of which had durations equal to or smaller than our time resolution of 20 ms (Slottje, 1978). A second flare with apparently similarly short lived fine structure, observed in the same month, suggested that these phenomena were not very rare. During about one year we tried to catch flare events to search them for fine structure. Unfortunately the fast magnetic recording system was not dedicated solar equipment and had to be lined up on each occasion. Consequently our collection of fine structure events is still small, yet some statistical features can be deduced. The present results are however necessarily preliminary.

THE INSTRUMENT

The observations were made with a double sideband receiver, sensitive to two bands of 12 MHz separated by 60 MHz around a central frequency of 2.65 GHz. Both left (L) and right (R) circularly polarized radiation

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were measured, with an effective time constant of 10 ms. The outputs were recorded on stripchart recorders allowing a resolution of about 100 ms, and, for full resolution, on magnetic tape with a sampling interval of 10 ms.

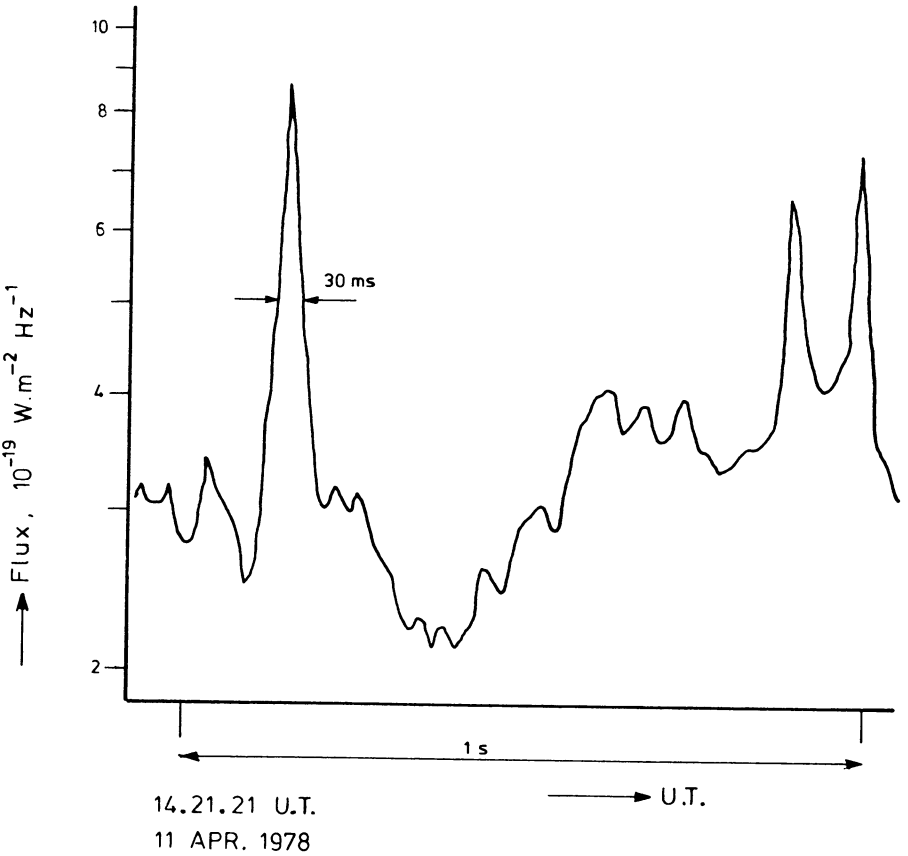

Figure 1 : Millisecond Spikes

THE OBSERVATIONS

For the present investigation we considered only fine structure with durations below 300 ms, which restricted our sample to 16 events. Subdivision in samples with fine structure durations below 100 ms, between 100 and 200, resp. 200 and 300 ms did not reveal any significant differences. Figure 2A gives the distribution of fine structure duration.

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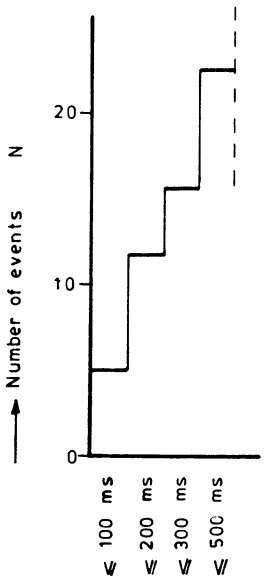
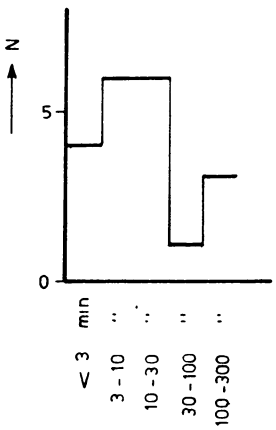


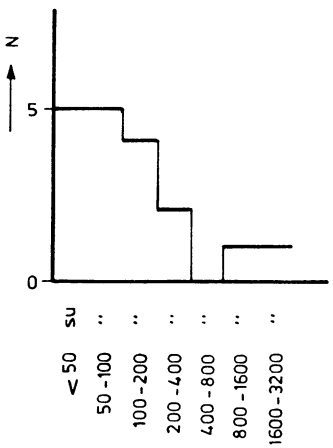
Events with spike duration

Fig. 2A



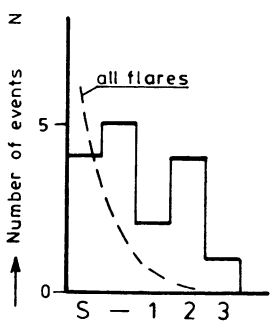
Duration of events

B



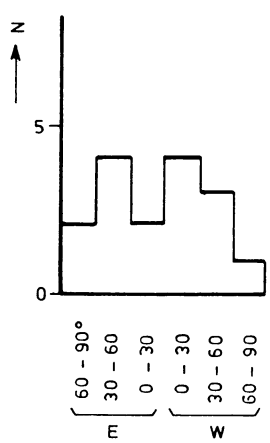
Maximum flux in Fast Fine Structure Events

C



H_α - flare importance

Fig. 3 A



H_α - flare longitude

B

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Fast fine structure appears in a large variety of bursts. Figure 2B shows that event durations up to 30 min are equally abundant. As the observational procedure, mentioned in the introduction, discriminated against short events, these may be underrepresented and the true distribution may be closer to that for all events, with and without fine structure. The distribution of maximum flux per event appears similar to that for all events (Figure 2C)

H-α importance. The distribution with H_α-flare importance, as reported in S.-G.D. (1978, 1979), is shown in figure 3A. We see that spikes may occur with flares of all importances, but that higher importances are stronger represented here than in the distribution for all flares. This result is similar to that for Type IV dm events with fine structure (Slottje, 1980).

Directivity. Some directivity may be present for fast fine structure events. No E-W asymmetry was found, but the longitude dependence might imply a half aperture angle of about 60°. Hence the radiation of the fine structure is not narrow beamed or there exists a wide range of beam orientations within the source (see figure 3B).

Polarization. We distinguished 100% polarization, L or R, partial polarization, l or r, and zero polarization, O, and grouped fine structure events accordingly (table 1). As in one event spikes of different polarization degree and sense may occur (even almost simultaneously!) the number of cases counted here is larger than 16. We notice that all polarizations do occur, without any appreciably different longitude dependence for L, R or O (see Table 1).

Table 1. Distribution of polarization.

	L	l	O	r	R
$0-30^\circ$	2	2	2	1	2
$30-60^\circ$	4	-	4	-	1
$60-90^\circ$	1	-	1	1	-
Σ	7	2	7	2	3

Table 2. Relation of the dominant sense of polarization (L,R,O) with the hemisphere of the flare (N,S) or leading spot polarity.

presumed mode	correspondence with leading spot	
"O"	LN 4 RS 1	Σ "O"=5
"e"	LS 2 RN 2	Σ "e"=4
-	ON 2 OS 5	Σ = 7

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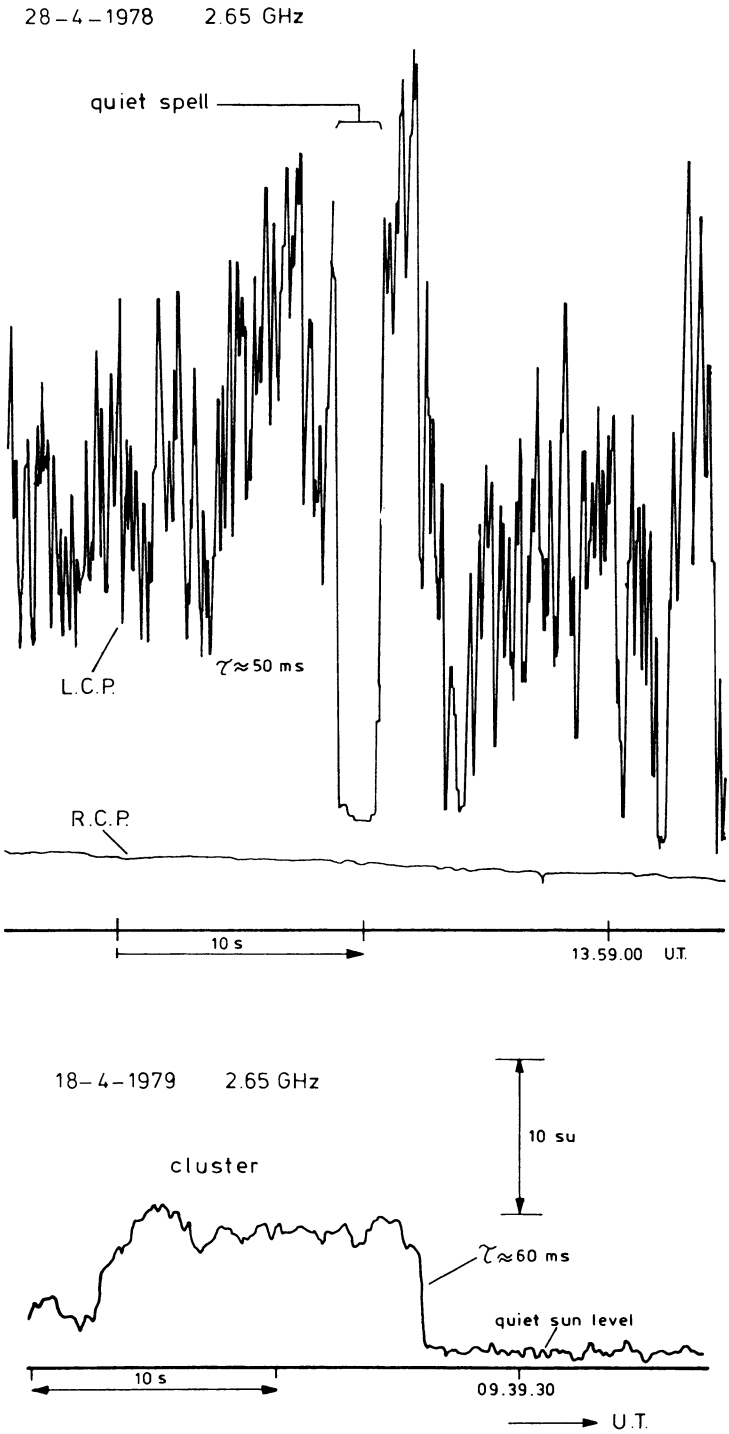

Figure 4 : A quiet spell and a cluster

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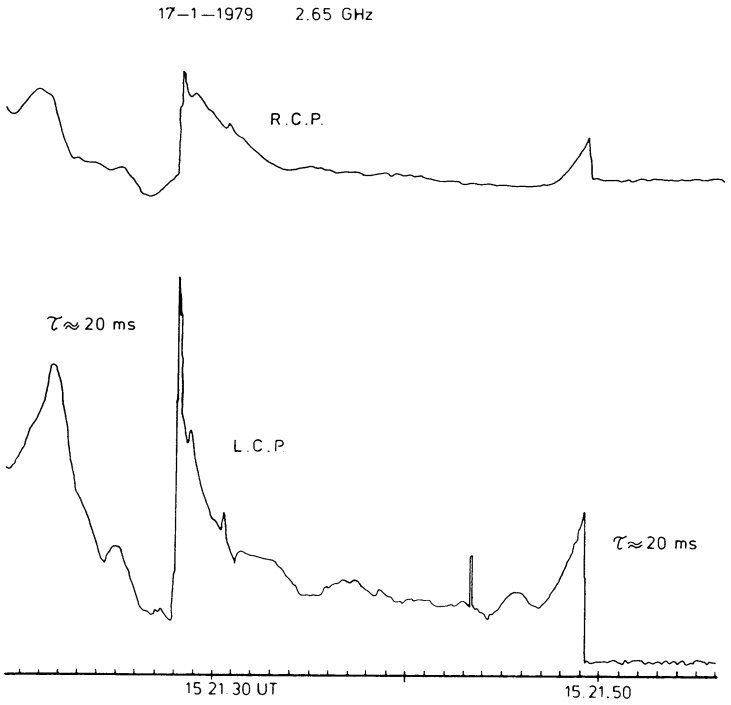
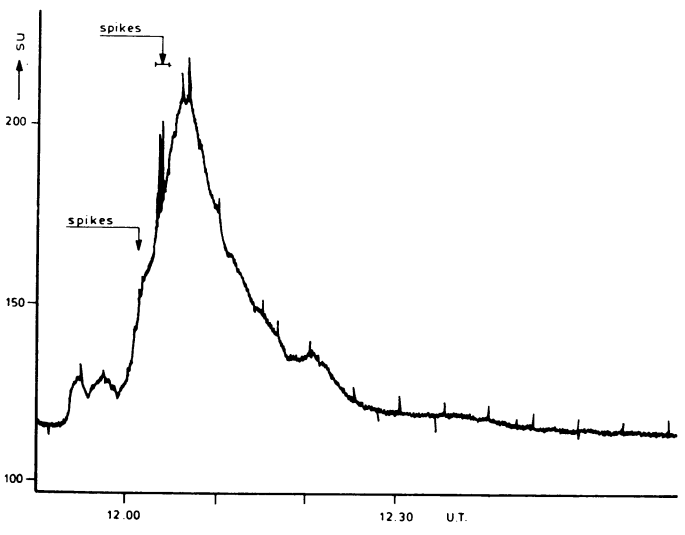


Figure 5 : Switch-on and switch-off structure



5 – 7 – 1978 2.65 GHz

Figure 6 : Smooth burst with sporadic fast fine structure

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Radiation mode. In an attempt to find the radiation mode we tested the so-called leading-spot-hypothesis. The results given in Table 2 show that this hypothesis is meaningless here, which is already clear despite the smalness of the sample. A similar result was obtained for Type IV dm events with fine structure (Slottje 1980). The question of the radiation mode can therefore only be solved by accurate measurements of radio positions and magnetograms.

Brightness Temperature. In the event of 11 April 1978 (Slottje, 1978) spikes were observed with brightness temperatures up to 10^{13} K (probably 10^{15} K). Such intense spikes have not been observed since but the event was one of the very few stronger ones in our collection.

Bandwidth. As we have presently only a single frequency receiver the bandwidth of fast fine structure can only roughly be deduced from responses on neighbouring frequencies at other stations. The event of 11 april 1978 showed a sharp high frequency cut-off (about 6 dB over 150 MHz, Slottje 1978). Another event, 17-1-1979, showed a probably even sharper cut-off. Roughly one could guess bandwidths in the order of a few hundreds of MHz.

Morphology. The most abundant fine structure is the simple spike (figure 1). Also short and sharply defined periods of quietness do occur as well as clusters of fine structure (figure 4). Occasionally a rather peculiar feature is observed, which we call switch-on and switch-off structure (Slottje, 1979) where the radiation is switched on in about 20 ms and decays very slowly afterwards, or a slowly rising flux level is suddenly switched off in a similarly short time (figure 5).

Abundances of spikes within events. The abundance of spikes within events may vary enormously. In a number of cases (e.g. 11 April 1978) hundreds of individual spikes appear, whereas in other cases (figure 6) only a few spikes show up on an otherwise smooth burst. Also within one event some impulsive phases may be devoid of fast fine structure, while others may be crowded (e.g. 11 April 1978).

Event types and fast fine structure. Though in general fast fine structure shows up in impulsive bursts, this is not always the case (Figure 6 gives an example of a smooth burst with spikes), nor do impulsive bursts always show such fine structure. Figure 7 gives examples of impulsive bursts with and without fast fine structure.

Abundance of fast fine structure events. Clearly fast fine structure is a fairly common phenomenon. In our collection of events we found it in 30% of the cases. As we had to line up the fast recording on practically each occasion, we missed many short events and initial parts of longer events on our fast recordings. Hence the true fraction of events with fast fine structure might well be larger. On the other hand we did observe a number of events without any fast fine structure.

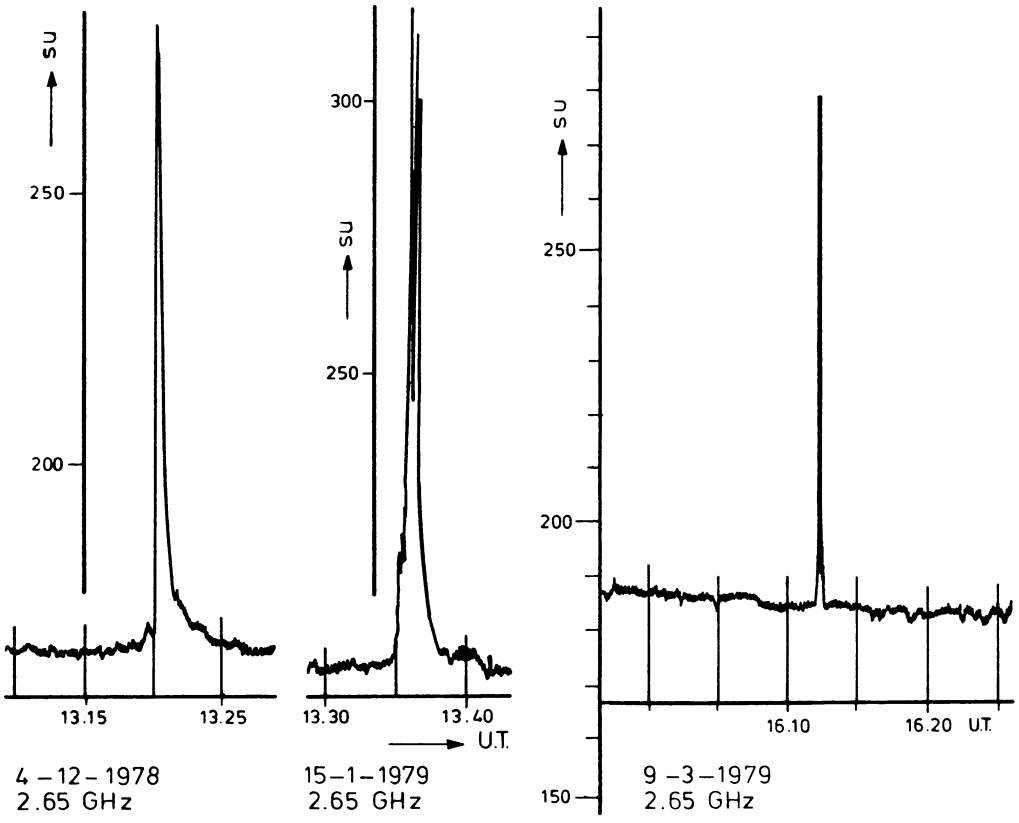

Figure 7 : Impulsive without (A) and with (B) fast fine structure

CONCLUSION.

Fast fine structure seems to be a common phenomenon that does not require very special conditions, but which does not necessarily show up with all flares. It may be present during the whole flare or only during a few seconds. The distinction between flares that do and those that do not show it is as yet obscure. Its investigation may shed light on interesting fundamental flare processes. Early 1980 we hope to operate a dedicated fast recording system for a systematic investigation of fast fine structure in microwave and decimetric wave bursts simultaneously down to 1 ms resolution.

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DISCUSSION

Achong: Have you been able to measure the frequency bandwidths of these fine structures?

Slottje: About 5 db reduction over 100 MHz. Bandwidths appear to be quite small.