Some Studies on Rare Types of Microwave Bursts

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Microwave bursts of rare types, viz. 'spike', 'rise', 'fall' and 'absorption', recorded by different solar observatories at and around 2800 MHz for a period of one decade (Jan. 1967-Dec. 1976) were examined. Important results obtained from this statistical investigation are: (i) most of the rare type of bursts have peak flux not more than 15 f.u., (ii) the percentage association of the bursts with flares increases with the increase of peak flux and also with the increase of rate of change of flux, (iii) burst-associated flares are mostly subflares, (iv) spectra of the peak flux (negative) and energy absorbed, for the 'absorption' type of bursts, generally show greater absorption at higher frequencies, (v) the bursts are mostly dominant in the declining phase of the solar cycle, and (vi) the percentage association of some types of bursts with flares varies more or less linearly with the number of bursts through the whole of the solar cycle studied.

1. Introduction

Microwave bursts which are in general characterized by their time profiles have been classified into thirty-one types (ESSA) based on a scheme of classification first introduced by Covington and Harvey. It is now fairly known that more than three-fourths of them are simple bursts and the remaining types of microwave bursts occur rather occasionally and may be called the infrequent or 'rare' types. Some of these rare bursts possess well defined and regular time profiles. These are: 'spike', 'rise', 'fall' and 'absorption'. Different properties and spectral nature of the commonly occurring microwave bursts and their association with Hα-flares are fairly known. However, similar comments cannot be made in connection with rare types of bursts. We are thus prompted to examine the various aspects of the above mentioned rare types of bursts, viz. their different properties, spectral nature, association with flares and sunspot numbers for a period of almost one solar cycle.

2. Data Analyzed

In the present investigation the major amount of data was obtained from the bursts recorded at 2800 MHz by the Algonquin Radio Observatory, Ottawa. In order to cover the non-observing periods of the Ottawa Observatory, microwave bursts recorded around 2800 MHz by other observatories, namely Crimea, Gorky, Berlin, Irkutsk, Manila, Nera, Sagamore Hill and Slough operating at 3100, 2950, 2920, 3100, 2695, 3000, 2695 and 2800 MHz respectively were also considered. Altogether 2181 rare events during the period Jan. 1967-Dec. 1976, published in the Solar Geophysical Data books issued by the ESSA, U.S.A., were critically examined. Flare data and Zurich relative sunspot numbers for each month were also obtained from the same data books. Burst-flare association has been assumed whenever they occurred within ± 5 min. Same burst reported by different observatories has been counted as one event.

Some of the information about the bursts, namely starting time, peak time, duration, peak and mean flux was collected from the data books mentioned earlier, while others namely rise time, rate of change of flux, energy excess, etc. were calculated therefrom.

3. Results

The results on the different types of the rare bursts are presented in the following.

3.1 'Spike' Events

A microwave burst which shows a rapid rise to a single peak followed by a rapid fall to the preburst level, with a very short duration is called a spike. Most of the spikes (812 in all) have been found to possess durations \( \leq 1 \) min and the energy excesses are very small. They attain peak flux even up to hundreds of flux units (1 f.u. = \( 10^{-22} \) W/m\(^2\)/Hz), but most of them have peak flux in the range 0-15 f.u. The percentage association of spikes with flares does not change appreciably with increasing peak flux of the spikes and it is maximum when the peak flux is in between 10 and 15 f.u. The percentage associa-
Table 1 — Percentage Association of Spikes with Flares

<table>
<thead>
<tr>
<th>Peak flux, f. u.</th>
<th>0-5</th>
<th>5-10</th>
<th>&gt; 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Association, %</td>
<td>30.8</td>
<td>34.8</td>
<td>41</td>
</tr>
<tr>
<td>(198)</td>
<td>(244)</td>
<td>(356)</td>
<td></td>
</tr>
</tbody>
</table>

The number of bursts is shown in parenthesis.

The overall percentage association is 36.7% only. Among the associated flares, about 91% are subflares, 50% are normal types and 20% are bright types.

3.2 ‘Rise’ Events

A moderate rise of flux in 5 to 30 min duration with no accompanying decline during the following hours is designated as rise only. The rise events belong to some gradual process and the maximum rise in flux in most of the cases has been found to lie between 0-4 f.u. Histograms in the upper half of Fig. 1 show the percentage distribution of the 1040 rise events for different values of peak flux. From Fig. 1, it is seen that the percentage of occurrences of spikes with flares for different values of peak flux is shown in Table 1.

Fig. 2 — Plots showing the rate of change of maximum flux values of the rise (●) and fall (○) events against the respective rise or fall time

<table>
<thead>
<tr>
<th>Peak flux range</th>
<th>0-2</th>
<th>2-4</th>
<th>&gt;4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rate of change of peak flux, f.u./min</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Association, %</td>
<td>14.6</td>
<td>25.6</td>
<td>26.8</td>
</tr>
<tr>
<td>(280)</td>
<td>(351)</td>
<td>(399)</td>
<td></td>
</tr>
</tbody>
</table>

The numbers in parenthesis indicate the number of bursts.

Table 2 — Percentage Association of Rise Events with Flares

<table>
<thead>
<tr>
<th>Peak flux range</th>
<th>0-2</th>
<th>2-4</th>
<th>&gt;4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rate of change of peak flux, f.u./min</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Association, %</td>
<td>14.1</td>
<td>30.6</td>
<td></td>
</tr>
<tr>
<td>(269)</td>
<td>(205)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The data on percentage association of the rise events with flares for different values of (a) peak flux and (b) rate of change of peak flux, are shown in Table 2.

![Fig. 2](image-url)
Table 3 — Percentage Association of Fall Events with Flares

<table>
<thead>
<tr>
<th>Peak flux range (-ve)</th>
<th>Rate of fall of flux</th>
<th>Association, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>f.u.</td>
<td>f.u./min</td>
<td></td>
</tr>
<tr>
<td>0-2</td>
<td>0-0'1</td>
<td>2'25</td>
</tr>
<tr>
<td>2-4</td>
<td>&gt;4</td>
<td>10'98</td>
</tr>
<tr>
<td>4-9</td>
<td>&gt;0'1</td>
<td>(89)</td>
</tr>
</tbody>
</table>

The numbers in parenthesis indicate the number of bursts.

3.3 'Fall' Events

The fall events are all characterized by a gradual decrease in flux to some minimum level without subsequent return to the preburst level with a moderate fall of flux for about one hour duration. Most of them possess negative peak flux \( \leq 6 \) f.u. Histograms of Fig. 1 give the percentage distribution of 242 fall events for different values of peak flux, showing the greatest percentage of occurrences in the range 0-2 f.u.

The time rate of change of flux of these bursts against their respective time of fall is shown by the hollow circles of Fig. 2. The diagram shows that the number of bursts having higher rate of change of flux and higher time of fall is scanty. The rate of change of flux in most of the cases is \( \leq 0'2 \) f.u./min.

The percentage association values with flares at different values of (a) peak flux and (b) rate of fall are shown in Table 3.

The percentage association of this type of bursts with flares increases with the increase of negative peak flux as well as with the increase of rate of fall of flux.

It is to be mentioned that the overall percentage association of this type of bursts with flares is 11'2% only. Among the associated flares, 67% are subflares and 14'8% belong to the normal and bright types respectively.

3.4 'Absorption' Events

A gradual decrease of flux density with a subsequent return to the preburst level is called an absorption event. Most of the absorption events, 87 in all, have durations ranging from 30 to 80 min, and the ratio of fall time of maximum absorption to duration of these bursts lies within 0'2 to 0'8 with an average value of 0'5 only. Most of them possess negative peak flux in the range 2-6 f.u. and the time rate of decrease of flux is of the order of 0'2 f.u./min. The data on percentage association of absorption events with flares at different values of (a) peak flux and (b) rate of absorption are shown in Table 4.

The percentage association of the absorption events with flares increases with the increase of negative peak flux and also with the increase of rate of absorption. It depends more upon the increase of negative peak flux than upon the rate of absorption.

It is to be noted that the overall percentage association is 29'9% only. Among the associated flares, about 96% are subflares, and 42% are normal types and 19'2% are bright types.

Some of the absorption events have been observed over a wide range of frequencies. For these, negative peak flux and energy absorbed at different frequencies were examined. Plots in Fig. 3 show the negative peak flux spectra thus obtained. Energy absorbed shows a similar trend of variation (negative) and hence is not separately shown. The peak flux in general, diminishes with increasing frequencies in all the spectra shown. It may be mentioned in this connection that spectral analyses could not be made for other rare types of microwave bursts, simply due to the fact that these were not observed over a wider range of discrete microwave frequencies.

3.5 Solar Cycle Variation of Rare Types of Bursts in Relation to Sunspot Numbers

In Fig. 4(a), the yearly average of Zurich relative sunspot numbers and the yearly average number of occurrences of the rare types of bursts have been...
plotted from 1967 to 1976; in Fig. 4(b), the variation of the yearly percentage association of these bursts with flares has been shown for the same period.

It is seen from Fig. 4(a) that the number of occurrences of spike, rise and fall events attain their maxima during the declining phase of the sunspot cycle (1972 for spike and 1974 for rise and fall events). In case of rise events there is a secondary maximum during the period of 1970. From Fig. 4(b), it is seen that the percentage association of the bursts with flares more or less varies linearly with the number of occurrences of the bursts excepting the fall type events. No comment is made regarding the absorption type events since their number is insufficient from statistical point of view.

References

Fig. 4 — Time variation of the occurrences of the bursts and the time variation of the percentage association of the bursts with flares [The curves I, II, III and IV stand for the variations of sunspot numbers, rise, spike and fall type events respectively.]