CORONAL ENERGY RELEASE AND MAGNETIC FIELDS AT LOW SOLAR ACTIVITY

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ABSTRACT

Spatially resolved observations (angular resolution ≥ 17 arc seconds) of solar microwave emission obtained by the Siberian Solar Radio Telescope (SSRT) at 5.2 cm wavelength and soft X-ray observations by YOHKOH allow the detection of weak bursts from faint spotless active regions. Such bursts are rather rare and possibly forming a special class of solar events. The related coronal magnetic fields are estimated by means of model tests and compared with magnetographic observations. The question is raised how energy release can act at regions of low energy storage and whether these bursts can contribute to the understanding of elementary flare processes.

Key words: solar flares, radio emission.

1. INTRODUCTION

Solar microwave bursts develop as a brightening of pre-existing S-component sources or of parts of them in the plasma of solar coronal active regions (AR). Since the generation mechanisms of both, bursts and S-component, are governed by gyromagnetic radiation, the presence of coronal magnetic fields is a necessary precondition for the emission of both phenomena.

The energy source of S-component and microwave-burst emission is AR-plasma heating and flare-particle acceleration, respectively, addressed to magnetic energy release. In this way, coronal magnetic fields play a double role, viz. as driving and emitting agens. Nevertheless, the details of the driving process are scarcely understood. In particular the role of the emerging magnetic flux in competition with sheared magnetic fields is still controversially discussed (cf., e.g., Rust, Nakagawa, and Neupert, 1975; Švestka, 1976; Moore and Labonte, 1980).

Searching for the elementary process(es) of the energy release in the solar atmosphere, we are looking at the possibility of burst events occurring in weak fields, i.e. active regions without sunspots (or microwave S-component regions without spot component). From optical observations it is known that flares usually occur in well developed active regions and only about seven per cent of flares originate in spotless regions (Dodson and Hedeman, 1970). The occurrence of double-ribbon flares in spotless regions is rather exceptional (Rausaria, Aleem, and Raman; 1992). Another surprising fact is the recent detection of microwave burst radiation from a location outside active regions by VLA observations (Krucker et al., 1997).

The present study considers the occurrence of microwave bursts in faint spotless active regions without remarkable S-component emission which recently have been detected by the large Siberian Solar Radio Telescope (SSRT) in spotless active regions.

2. OBSERVATIONS

The microwave-burst observations considered here have been made by the cross-type Siberian Solar Radio Telescope (SSRT) operating at 5.2 cm wavelength (5.8 GHz). Each of the two interferometer arms (E-W and N-S) of the SSRT consist of 128 parabolic mirrors of 2.5 m diameter, equidistantly spaced at 4.9 m thus yielding a baseline of about 626 m (Smolkov et al., 1986).

The observations used in the present study are obtained by the E-W arm of the instrument scanning the solar disk with a fan-beam diagram where a sensitivity of about 0.05 sfu is achieved. The time and space resolution at local noon (about 05 UT) are 2 min 15 sec and 17 arcsec, respectively. The length of observation per day amounts to 6–10 hours, depending on the season. In the morning and evening hours the temporal and angular resolutions are reduced to about 3 min and 30 arcsec, respectively.

The radio observations will be compared with optical magnetograph and soft X-ray observations.

3. RADIO BURSTS FROM FAINT ACTIVE REGIONS

Checking the daily observations of the SSRT during the years 1993–1994, seven faint active regions have been selected, where microwave bursts emerged.
from regions with missing sunspot emission of the S-component. Inside these regions bursts have been observed which are listed in Table I. Four of the active regions were associated with weak chromospheric plages only, while the remaining three ones showed already pores or spots with an area less than 10 millionth of the solar half-sphere. The flare-less flux density measured from all these active regions did not exceed 1–1.5 sfu and the brightness temperature was about (1–3) × 10^5 K. The evolution appeared rather quiet. For illustration, scans of a characteristic burst are shown in Figure 1. The main observational parameters (flux, source diameter, brightness temperature, degree of polarization, duration, rise time, position on the Sun, maximum magnetic field strengths, and association with soft X-ray bursts, flares, and radio events) of the bursts from the selected regions are listed in Table I.

4. DISCUSSION

From Table I it can be concluded that the properties of all investigated microwave bursts are quite similar. The flux density S_e ranges between 0.5 and 0.8 sfu and hence is below the limit of detection of most of the usual patrol radio telescopes. The brightness temperature is T_b ≈ 2 × 10^5–10^6 K. The radio brightness shows only one peak and the angular size D is of the order 13–18 arc seconds or less. Furthermore, for all considered bursts a small degree of polarization p < 0.1 is characteristic. Because of the weakness, reports from other microwave-observing stations are missing. The duration of the events measured by the SSTR range between about 10 and 30 min. Associations with sunflares are sometimes visible.

In those cases where associated X-ray bursts have been reported (by Yohkho, GOES), time and location of both, radio and X-ray signatures fall closely together, the intensity was rather weak (class B). In some rare cases correlated events at m-Dm waves are present.

The magnetic field derived from Kitt-Peak magnetograms is generally less than about 500 G in accordance with S-component model tests of microwave data. The bursts occurred typically in the middle of a short period of weak magnetic activity lasting only a few days. The occurrence of shear, i.e., of deviation angles from a potential field by the emergence of magnetic flux in a field of opposite polarity can be noted (cf. Hagyard et al., 1984).

5. CONCLUSIONS

The present study provides evidence for the occurrence of microwave bursts and related SXR bursts in weak spotless active regions. Because spectral radio data are yet missing, the nature of the measured microwave bursts can only be assumed: Preference for thermal emission can be given where plasma temperatures up to 10^7 K are resulting. In the case of gyromagnetic emission harmonic numbers (much) greater than 5 would be required. The magnetograms of the source areas confirm the impression that the magnitude of the magnetic field is less deciding than its gradients (shear, emerging flux) for the generation of instabilities leading to bursts and flare events. According to the duration and energy content, the events considered here are greater than anticipated "elementary flare" events (cf. de Jager and de Jonge 1978; Krüger et al., 1994).

ACKNOWLEDGMENTS

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4 September 1993, SSRT

![Solar optical disk and Burst](image)

**Figure 1.** Sequence of SSRT observations of a microwave burst on 4 September 1993 evolving in a weak active region.

**Table I**

Characteristics of microwave-burst radiation from spotless active regions

<table>
<thead>
<tr>
<th>Date</th>
<th>01.01.93</th>
<th>04.09.93</th>
<th>14.10.93</th>
<th>08.11.93</th>
<th>29.11.93</th>
<th>04.02.94</th>
<th>21.03.94</th>
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</thead>
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<tr>
<td>$t_s$ [UT]</td>
<td>05:00</td>
<td>07:15</td>
<td>06:30</td>
<td>06:35</td>
<td>07:30</td>
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<td>07:10</td>
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<tr>
<td>$S_v$ [sfu]</td>
<td>0.8</td>
<td>0.5</td>
<td>0.5</td>
<td>0.75</td>
<td>0.6</td>
<td>0.7</td>
<td>0.5</td>
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<tr>
<td>$D$ [arcsec]</td>
<td>$\lesssim 10''$</td>
<td>$\lesssim 10''$</td>
<td>$\sim 18''$</td>
<td>$\sim 18''$</td>
<td>$\sim 15''$</td>
<td>$\sim 15''$</td>
<td>20''</td>
</tr>
<tr>
<td>$T_b$ [K]</td>
<td>$8 \cdot 10^5 - 10^6$</td>
<td>$5 \cdot 10^5 - 10^6$</td>
<td>$2 \cdot 10^5$</td>
<td>$2.5 \cdot 10^5$</td>
<td>$4 \cdot 10^6$</td>
<td>$4 \cdot 10^6$</td>
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<tr>
<td>$p$ [%]</td>
<td>$\sim 0$</td>
<td>$\sim 0$</td>
<td>$&lt; 10$</td>
<td>$\sim 0$</td>
<td>$\sim 5$</td>
<td>$\sim 0$</td>
<td>$\sim 5$</td>
</tr>
<tr>
<td>$t_d$ [min]</td>
<td>10</td>
<td>30</td>
<td>12</td>
<td>12</td>
<td>35</td>
<td>10</td>
<td>$&lt; 15$</td>
</tr>
<tr>
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<td>2</td>
<td>2</td>
<td>6</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>?</td>
</tr>
<tr>
<td>AR</td>
<td>7576</td>
<td>SD213</td>
<td>SD230</td>
<td>[7623]</td>
<td>7662</td>
<td>7693</td>
<td></td>
</tr>
<tr>
<td>$B_{max}$ [G]</td>
<td>-250</td>
<td>-665</td>
<td>-472</td>
<td>-312</td>
<td>-327</td>
<td>-315</td>
<td></td>
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<tr>
<td>GOES</td>
<td>B 5.9</td>
<td>B 4.8</td>
<td>[B 3.8]</td>
<td>B 4.8</td>
<td>+200</td>
<td>+200</td>
<td></td>
</tr>
<tr>
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<td>SF</td>
<td>SF</td>
<td>[SF]</td>
<td>SF</td>
<td>SN</td>
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</tr>
<tr>
<td>Ass.</td>
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<td>type II</td>
<td>NS</td>
<td>SF</td>
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Figure 2. Photospheric magnetic-field configuration of the active region generating the burst of Figure 1 measured at Kitt Peak.