SOLAR MICROWAVE EMISSION IN ACTIVE REGIONS

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Abstract: Multi-frequency Observations of Solar Microwave bursts recorded during solar maximum period 1980-81 are analysed and compared with x-ray data for studying the nature of microwave emissions from active regions. Most of the microwave burst spectra showed that the spectral index below the peak frequency is always less than 2

The magneto-ionic conditions of the burst sources and the electron energies as obtained from these multi-frequency observations of the bursts showed that the centimetric and x-ray observations are satisfactorily explained, if the emitting regions are dense, hot and compact associated with strong magnetic fields of a few hundred gauss, suggesting that the thermal gyroresonance process is the most likely emission mechanism involved in the emission of microwave and x-ray radiations from the active regions of sun.

1 INTRODUCTION

The solar microwave bursts have been extensively studied by several investigators and established their characteristics (Kundu 1965). With the advent of the recent developments of high resolution radio interferometric techniques and space instruments, much work has been done on the structure of solar active regions (Kundu etal 1977; Pye etal 1978; Feldman and Doschek 1978; Lang and Willson 1980). The recent skylab x-ray and EUV data have provided an additional wealth of information on solar flare phenomenon. (Reeves etal 1976; Vorphal etal 1977). It has been realized that a coordinated study of centimetric and x-ray observations of solar flares are of particular important for understanding the physical mechanisms involved in the active regions of microwave emission (Schmahl 1980). The aim of this paper is to make such a comparative study of centimetric observations of active regions and the simultaneous x-ray observations carried out during solar maximum period 1980-81 in order to understand the emission mechanisms.

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2 MICROWAVE OBSERVATIONS AND SOURCE SPECTRA

The nature of these active regions can be investigated either by means of intensity and polarization measurements at several frequencies or by comparing radio measurements at a single frequency with simultaneous observations at other wavelengths (Kakinuma and Swarup 1962).

A first step in this direction is to construct a spectrum of a microwave burst from its multi-frequency radio observations and to make a statistical analysis of such spectra obtained from the study of a number of events recorded during solar maximum period. A statistical analysis of the low frequency part of microwave spectra makes it possible to estimate the importance of different obsorbing mechanisms and a better understanding of the physical conditions of the microwave source (Schoechlin and Magun 1979).

Microwave solar burst observations have been carried out simultaneously at frequencies of 2.8, 10 and 19 GHz. The 10 GHz microwave Dicke-type radiometer was operated at Japal-Rangapur Observatory of Osmania University and the other two at Physical Research Laboratory, Ahmedabad. These observations form a part of the international solar maximum year program for aolar flare studies. Fig. 1 shows simultaneious recordings at these frequencies of a typical solar burst observed on 4 JUNE 1980. These are compared with the x-ray data obtained from SMS mission and $H\alpha$ photographs. It is seen from the figure that the time of occurrance of x-ray burst is coinciding well with that of microwave bursts suggesting, that both the radiations are originating from the same solar active region.

The multifrequency observations of the microwave solar bursts carried out in India during the solar maximum period and the international Solar Geophysical data are used to construct radio spectra of the sources as shown in Fig. 2. A typical microwave spectrum is characterized by the parameters:
Spectral index α = d(log s)/d(log f) where s is flux in s.f.u. and f is frequency in MHz, maximum flux density s_{max} and the peak frequency f_{max} (Schoechlin and Magun 1979).

The magnetic fields associated with burst source and the electron energies involved in the production of microwave bursts are estimated from the source spectrum, since a radio specturm has a maximum at a frequency $f_{max} \gtrsim 4 f_H$, where f_H is the gyrofrequency (Takakura 1967). For the event of Fig. 1 the magnetic field strength of the source has been estimated as $\sim$500 gauss. The energy of electrons producing the microwave burst is $\gtrsim$1.5 MeV, which is mildly relativistic. The angular size of the burst source has been determined using the relation given by Kellerman (1966) and modified to solar conditions as

$$f_{max} = 24\ H^{1/5}\ (s_{max}/\varphi^2)^{2/5}$$

In the present case the source size $\varphi \approx 4$ arcsec.

3 STATISTICAL ANALYSIS OF MICROWAVE SPECTRA

From the observations recorded by the above radiometers combined with that of solar geophysical data of 1980-81, about 60 active events have been analysed. The radio spectra of these events have been plotted similar to that in Fig. 1 and the corresponding statistical parameters of the Low frequency part of the spectra are determined, The distribution of spectral indicies as shown in Fig. 3 indicates the peak occurrence of α is in the range of 1.0 to 1.5. The most probable value of α has been estimated as 1.3.

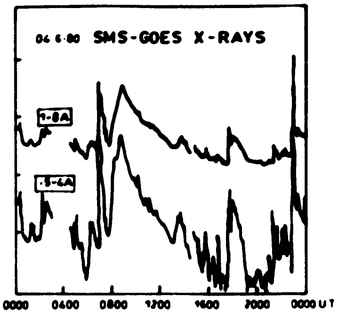
Following the method as discribed in section 2, the magetic fields of the energetic sources have been determined. Most of the sources are associated with magnetic fields in the range ~400 to 1000 gauss. The energy range of electrons is of the order of 1.5 to 2 MeV. The source sizes emitting the x-ray and microwave emissions are estimated as 4 - 8 arcsec with brightness temperatures in the range of 1 to 2 x 10^6K. The values of all these parameters as determined from radio spectra are in good agreement with high resolution measurements of the active regions of sun (Allissandrakis and Kundu 1975, Pick 1980, Velusamy and Kundu 1980).

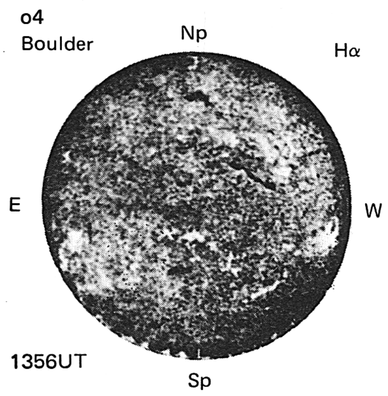
4 INTERPRETATION

The above estimations of the source parameters - the magnetic field strengths, electron energies, source sizes and brightness temperatures indicate that both the x-ray and microwave emissions can be satisfactorily explained, if the emitting regions are dense, hot and compact associated with magnetic fields of a few hundred gauss.

The estimated radio brightness temperature, 1 to 2 x 10^6K is of the same order of the maximum temperature of EUV and x-ray loops. The region with this temperature is optically thick and it cannot be explained due to thermal bremsstrahlung absorption. Hence, the source of absorption is mostly due to gyroresonance absorption(Zheleznyakov 1962, Kundu 1965) which satisfies the present estimation of magnetic fields from the condition $f_{max} = 4f_H$. This is in good agreement with the results obtained by Schmahl (1980) from simultaneous x-ray and centimetric observations of active regions, where he found that the 3rd and 4th harmonics are highly optically thick layers. The present low value of spectral index 1.3 may then be explained mainly due to this gyroresonance absorption.

Thus, it is concluded from the present estimated values of the magnetic fields, electron energies, spectral indicies, source sizes and brightness temperatures as obtained from the radio spectra of microwave bursts, points out to the thermal gyroresonance process as the most





Hα Photograph on 04.6.80

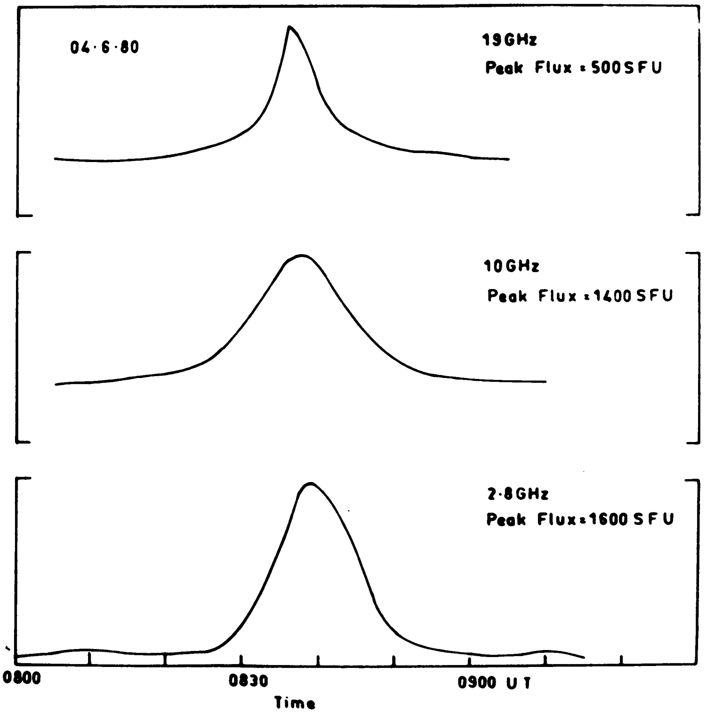


Fig.1 Intense solar microwave burst recorded at different frequencies and simultaneous X-ray observations

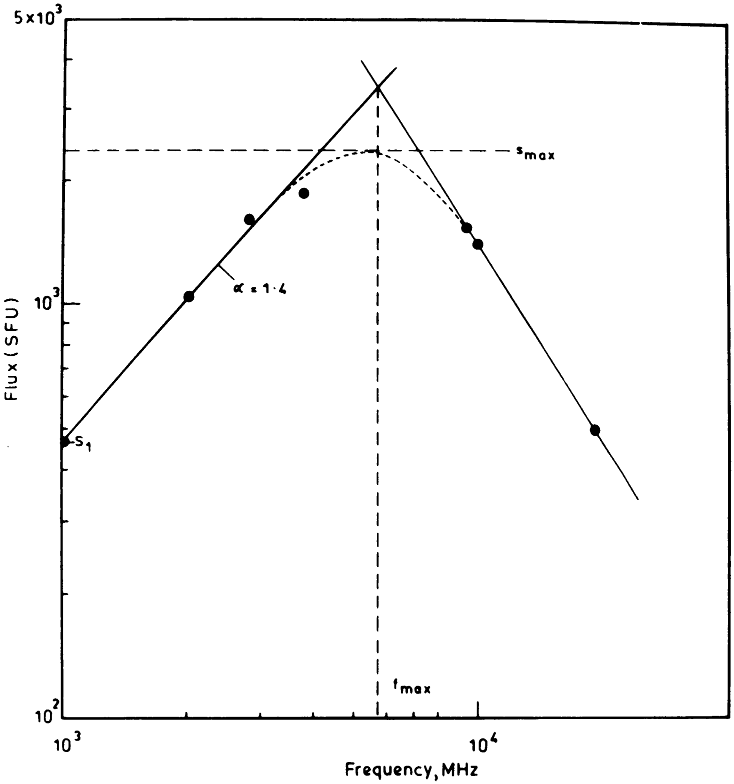


Fig.2 A Typical microwave spectrum of the burst observed on 4 June 1980 0840 UT

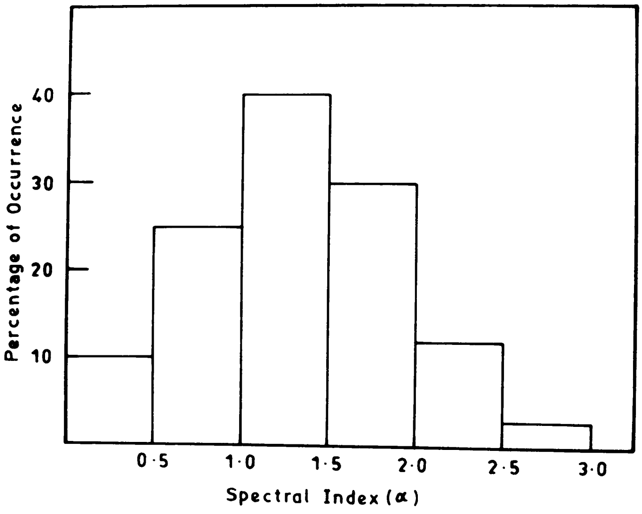


Fig.3 Distribution of spectral index

likely emission mechanism for the bright radio components associated with active regions.

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