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Observation of microwave radio sun during total solar eclipse on October 24, 1995 by Eastern Centre for Research in Astrophysics (ECRA)

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Abstract : Observations of the microwave radio emission from the sun in the C-band, at 4 GHz, have been made during the total solar eclipse of October 24, 1995 from the belt of totality at Diamond Harbour, 24-Parganas, West Bengal, by scientists of the Eastern Centre of Research in Astrophysics (ECRA) The results obtained from preliminary analyses of the data indicate that the ratio of the diameters of the radio sun to that of the optical sun is 1 04 and that the radio brightness distribution of the microwave sun is not uniform. Also, a prominent peak in the brightness distribution was found to be associated with an active region on the solar disk near a sunspot group, which was monitored by the Sky Watchers'Association, an amatuer society at Calcutta. The precision of the one dimensional radio map made from the records of the solar radio eclipse was 20", which is equivalent to that of a very large array (VLA), even though the antenna beamwidth is as large at 1.4° More detailed analyses and correlation of the results with H_α maps, magnetograms and 17 GHz solar map made in Japan are in progress and the results will be reported in due course.

Keywords : Solar eclipse, Radio observation

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1. Introduction

During a solar eclipse, the solar disc is eclipsed gradually. This allows mapping of the sun across the solar disc in one dimension along the track of the moon over the sun. We planned

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to observe the radio sun in the C-band, at 4 GHz, during the total solar eclipse on October 24, 1995 with a view to mapping of the sun in one dimension and also for estimating the diameter of the radio sun relative to that of the optical sun. Some of the interesting results obtained are presented in this rapid communication.

2. Equipment

A Radiotelescope at 4 GHz, based on a satellite TV Direct Reception System (DRS) was developed at the Institute of Radiophysics and Electronics, at the suggestion of Professor Govind Swarup, Director GMRT Project (TIFR). It uses a 12 ft parabolic dish antenna having a beamwidth 1.4°. The circuit diagram of the C-Band Radiotelescope is shown in Figure 1. LNA (Low noise amplifier) of the frontend is based on a 3-stage ultra low noise PHEMT amplifier MMIC chip ATF 35076, the Mixer is based on a matched Schottky diode

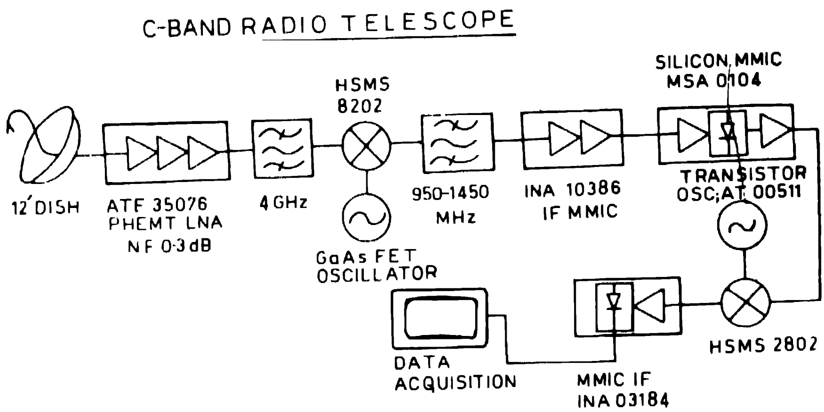

Figure 1. Circuit diagram of the C-band radio-telescope used to observe the solar eclipse on October 24, 1995.

pair HSMS 8202, whereas, the LO (Local oscillator) is based on GaAs FET (ATF 13786) dielectric resonator oscillator. Output of the mixer is amplified by MMIC IF amplifier INA 10386 and then fed to the L-band receiver and Data logger. The noise temperature of the receiving system is 28 K. The detector output indicating the solar noise power was recorded in a computer based data acquisition system as well as in a tape recorder to monitor the fall in the noise level during the eclipse. The rediotelescope is light weight and portable and, therefore, it could be easily shifted and installed in the track of totality at Diamond Harbour at the roof top of the Administrative building of the Subdivisional office at Diamond Harbour.

3. Observations

The central maximum of the antenna beam was arranged to track the sun during the total solar eclipse on the 24th October, 1995. Prior to the solar eclipse, solar scans were made by the antenna beam on several days preceding the date of the eclipse, for the purpose of calibrating the radiotelescope on non-eclipse days. For the same reason the observations were continued till one day after the eclipse as well. The receiving system was also calibrated by using a synthesized signal generator fed to the input of the receiver and controlling the output of the generator over the range of levels expected during the solar eclipse event. During the period of eclipse the sun was tracked step by step and the eclipse curve thus obtained is shown in Figure 2.

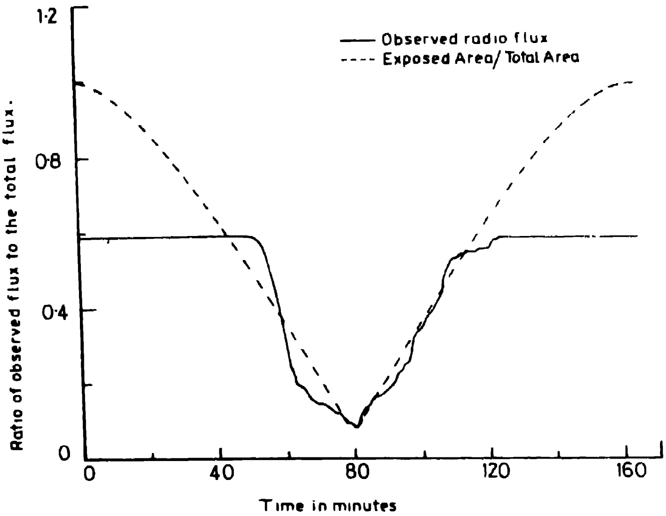

Figure 2. Eclipse curve showing the ratio of observed flux to the total flux against the time where the zero in the time scale gives the time of start for the solar eclipse The whole line curve gives the experimentally observed values, where as, the dotted line curve represents the theoretically estimated values

Geometry of the eclipse

After time 't' from the starting of eclipse, the exposed area is given as

$$A(t) = \pi R'^2 - \cos^{-1}\left(\frac{R' - vt}{R'}\right) R'^2 + \left(R' - vt\right) 2R'vt - v^2t^2$$

$$- \cos^{-1}\left(\frac{R - vt}{R}\right) R^2 + (R - vt)\, 2Rvt - v^2t^2 \qquad (1)$$

where $V = 2R'/T$,

R' is the radius of the radio sun and R is that of optical sun, T is the total time for eclipse.

We define relative Brightness function $B(t)$ as

$$B(t) = \frac{F(t + dt) - F(t)}{A(t + dt) - A(t)}, \qquad (2)$$

where $F(t)$ is the flux observed at any instant of time t.

Finally, we apply one dimensional image processing technique to produce a Solar map having a very high resolution in the East West direction.

Estimation of radio diameter

To estimate the diameter of the radio sun at 4 GHz, the following relation has been used based on the geometry during the totality of the eclipse :

$$\frac{\pi R'^2 - \pi R^2}{\pi R'^2} = \frac{\text{Solar radio flux at total eclipse}}{\text{Total Solar Radio flux}}. \quad (3)$$

Inserting the flux values in eq. (3) we obtain

$$R' \simeq 1.04\, R.$$

Hence, $$D' = 1.04\, D, \quad (4)$$

Where D' and D are the diameters of the radio sun and optical sun respectively.

4. Results of solar mapping

The data was analysed by a 486 computer and a plot of the brightness temperature distribution was made. From this one dimensional solar radiomap at 4 GHz as shown in Figure 3, it was clear that the solar radio brightness distribution is not uniform over the

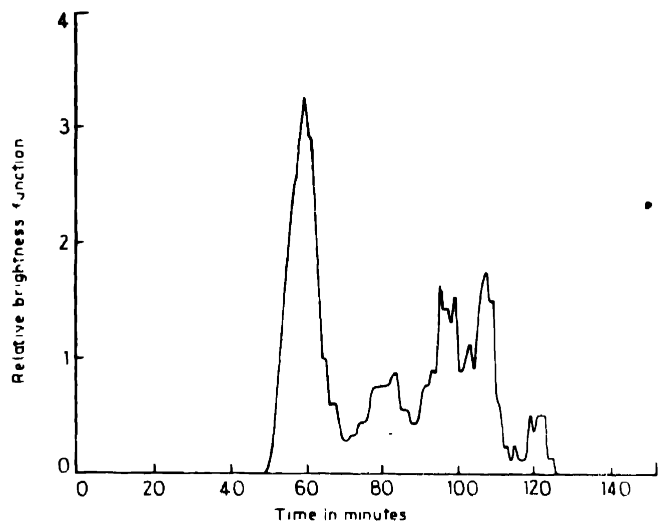

Figure 3. The curve shows the variation of the relative brightness with time for the whole eclipse period

solar disk, also indicating the presence of active centres. It is interesting to note that a sizeable peak in the brightness distribution on the right side of the map was found to be associated with that of the position a sunspot group observed by the Sky Watchers'Association, an amatuer astronomical society at Calcutta. The precision of the one dimensional radio mapping is 20" which is comparable to that of VLA, but realised with an antenna beam width as large as 1.4°, with a 12 ft parabolic dish antenna.

5. Discussion

The results obtained will be compared with solar H-alpha maps magnetograms and 17 GHz high resolution solar map obtained from Japan and the results obtained will be reported in due course. It may be mentioned here that similar low cost portable radiotelescopes have been developed in the S-band and are also planned to be developed in the L band and Ku band for installation at the ECRA centres at Kalyani University, and Darjeeling Hillstation of Bose Institute respectively, while another unit at S-band is under development by the Cotton College Centre at Guwahati. All these low cost radiotelescopes at different microwave bands may be distributed to more centres of activity of ECRA in due course for an integrated observations of the microwave sun over a wide microwave spectrum, as well as for the observations of multiwavelength radio bursts.

It may be mentioned here that during the present observations of the total solar eclipse, we were at sunspot minimum and therefore, no solar radio burst was expected. During the next total eclipse around 2000, we may plan to undertake a multiwavelength programme of observation of the radio eclipse, by bringing together all the portable microwave radiotelescopes into a common region of totality.

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