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The Madurai solar radio spectrograph

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Abstract. A solar radio spectrograph has been constructed at our School of Physics to study the dynamic activities of the sun in metre wavelength which is quite important for understanding the physics of the outer solar corona. In this paper, the salient features of the spectrograph are highlighted and the current observations programmes and some of the observational results are described. The desirable improvements in the spectrograph before the next solar maximum and some of the theoretical aspects in connection with the coronal events attempted are summarised at the end.

Keywords: radio spectrograph - coronal emissions - observations

1. Introduction

The radio emissions of sun are an interesting feature in metric and decametric wavelengths (cf., McLean & Labrum 1985). The transient emissions have been identified for the association with various disturbances occurring in interplanetary medium (e.g., Gosling et al. 1976, Kundu 1990, Gopalswamy & Kundu 1989, Janardhan et al. 1996) and in earth's atmosphere (e.g., Gosling 1993; Hunduhasan 1994). Recently questions have been raised regarding the transient solar emissions and the association with interplanetary disturbances in IAU-154 held at NCRA, Pune, India. At present there are not many ground based instruments in the world to continuously monitor the sun in the meter-decametric wavelength range except the Gowribidanur Radio Heliograph (Subramanian et al. 1993) which is operated by IIA, Bangalore in India.

Considering this fact and to fill up the longitudinal gap in the ground based instruments to monitor the sun, a low cost solar radio spectrograph has been constructed with the assistance from Radio Astronomy Centre (RAC), TIFR, Ooty and Gowribidanur Radio Observatory, IIA, Bangalore. The digital data of the quiet sun and transient radio emissions are being recorded for further analysis. Recently on October 24, 1995, the solar eclipse has been observed using the spectrograph. It is also proposed to enhance the sensitivity of the spectrograph and to correlate the observational results with other observations such as Inter Planetary Scintillations (IPS), Geomagnetic disturbances, solar wind studies and white light observations at various places.

2. Radio Spectrograph

The spectrograph is located at Madurai Kamaraj University, Madurai (Latitude = 9°55' N, Longitude = 78°7' E). It mainly consists of a wide band (30-80 MHz) log periodic antenna (LPA) to observe the radio emissions, a double stage superheterodyne receiver (Shanmugaraju & Umapathy 1995a) with a swept frequency local oscillator, a controlling system to control the sweeping frequency synthesizer and a high speed data acquisition system to digitise the analog data and to record it in the computer. A PC/AT is employed to control the receiver and the recording system. The beam width of the telescope is 60° E-W and the collecting area is approximately $0.5\lambda^2$. The antenna is equatorially mounted (with 11° elevation) fixed type and the sun is being observed for 4 hours per day (± 2 hours from zenith) while sun transits the beam of the antenna. The local oscillator can be set to sweep the required band of frequency with optimum band width and sampling rate. The initial measurements and results have been reported elsewhere (Shanmugaraju & Umapathy 1996).

3. Observations and a few results

Regular observations of the solar radio emissions on a daily basis have been started from August 1995. Since burst emissions are transient in nature and not predictable in advance, the sun is continuously monitored. The broadness of the beam width of the antenna allows us to observe the sun for a minimum of four hours in a fixed position. Usually the bursts drift from high frequency to low frequency with various drift rates in a few seconds to a few minutes. So the spectrograph is made to scan from 30 MHz to 80 MHz by sweeping the local oscillator in steps of 0.1 MHz with a minimum sampling rate of 225 msecs. This sweeping is repeated until the observations come to an end.

On several days, the sky drift along with the sun has been taken which shows the increase and decrease in intensity contributed by the sun. For example, Fig. 1a, b show the clear intensity profiles of fixed frequency observations at 80 MHz and 75 MHz on 5 May 1996 and 4 August 1996 respectively while the sun transited the beam of the antenna. The small deviations in the base level amounting to a few rms may be due to instrumental gain variations, ground reflections, local interference, etc. The typical galactic plane drift obtained from the 24 hours observation of the radio sky is shown in Fig. 2. The peak coincides with the galactic center.

Fig. 3a and Fig. 3b show the radio spectrum at 50 MHz and 69 MHz while scanning the spectrograph 50-80 MHz on 4 June 1996. The individual frequency spectra have been obtained by demultiplexing the original data observed for 50-80 MHz. The declining phase during the initial period is due to the instability of the receiver.

Also on 24 October 1995, our spectrograph observed the solar eclipse in India among the very few radio observations. The observation is made using the non-trackable log periodic antenna in the frequency range 30-80 MHz. It is interesting to note from the intensity spectrum at individual frequencies that the size of the corona varies; lesser the radio frequency, bigger the size of the corona (Shanmugaraju & Umapathy 1997).

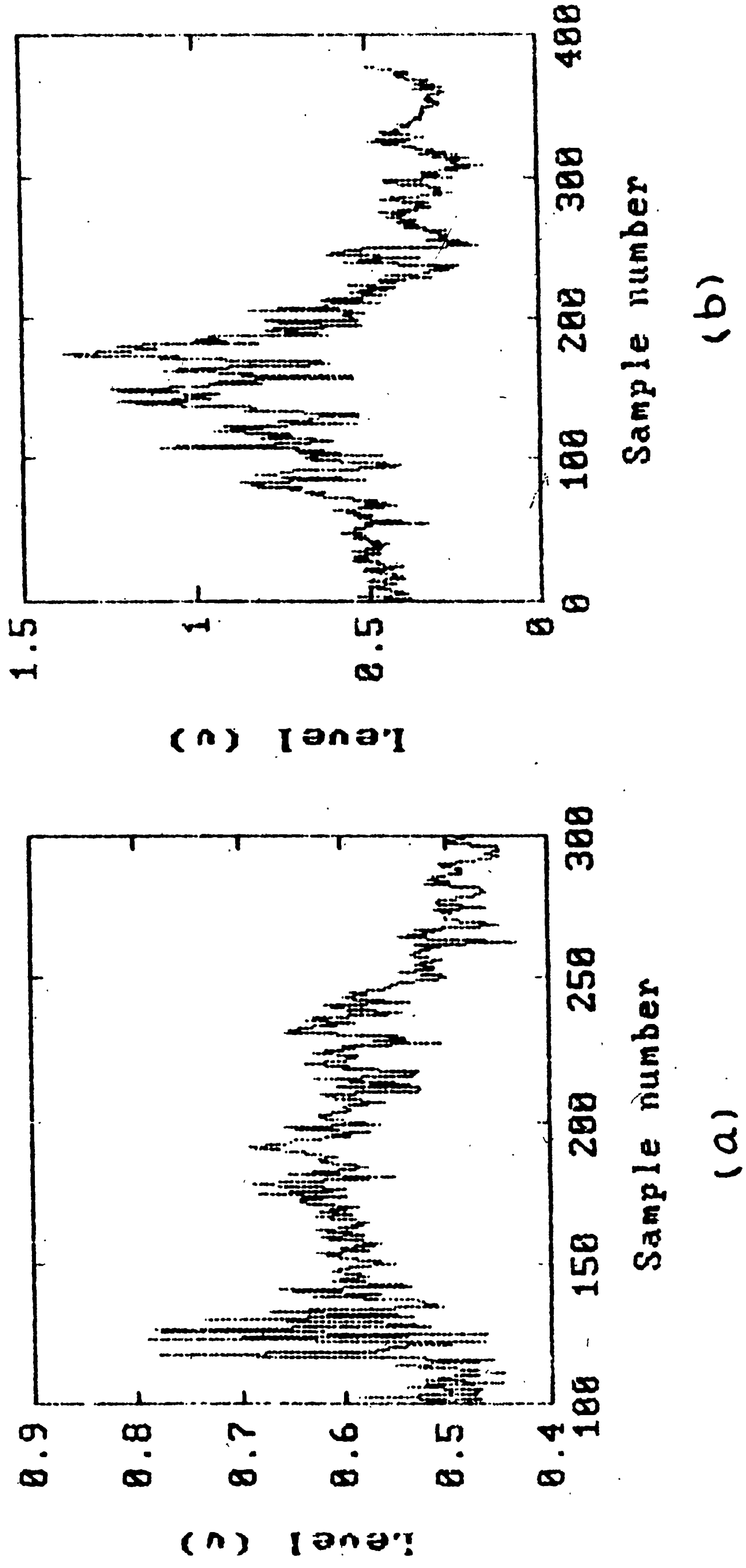

Figure 1. Fixed frequency observations of the sun. Intensity profile a) at 80 MHz on 22 May 1996 during 0505-0825 hrs UT b) at 75 MHz on 4 August 1996 during 0415-1015 hrs UT.

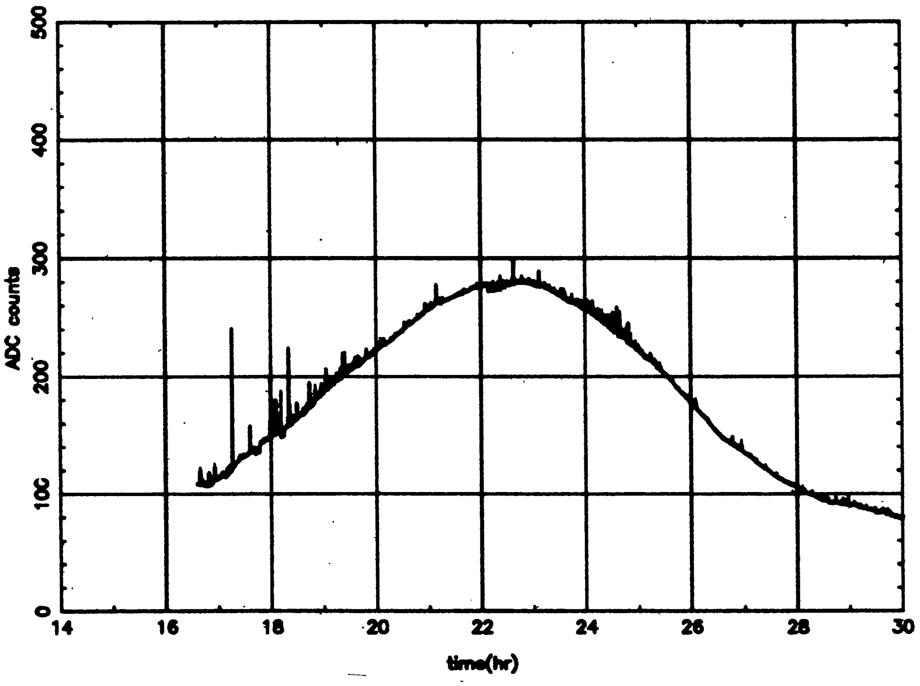

Figure 2. A typical galactic plane drift (after one minute averaging) observed using the single log periodic antenna at 60 MHz.

4. Desirable improvements and some theoretical investigations

From the previous observations and results, due to limitations in various parameters such as effective aperture (approximately $0.5\lambda^2$), minimum detectable flux density (approximately 1000 Jy at 80 MHz for one minute averaging), beam width (= 60^0 E-W) and large switching interval (=225 msec), only strong long living bursts (Type II and Type IV) are expected to be detected. Due to the fact that last one year was a solar minimum period and also due to the above limitations in the spectrograph, it may be difficult to detect the transient events during last year's observations. However, the recorded radio data are being analysed to identify the transient radio emissions.

Considering these facts, it is proposed to improve the spectrograph characteristics before the next solar maximum by increasing the sensitivity. This can be done by 1) adding a few more LPAs, 2) decreasing the switching time of the local oscillator, 3) increasing the integration time, etc.

It has been very well shown that these burst emissions are associated with Coronal Mass Ejections, also called "magnetic clouds" by some authors, (e.g., Burlaga 1988), Inter Planetary Disturbances (IPDs) and geomagnetic disturbances. Also various theoretical models put forward (e.g., Chen et al. 1995) have been proved by experimentally observed coronal emissions (e.g., Gopalswamy et al. 1994; Manoharan et al. 1996) and they are very closely matching the observations. So to strengthen the ideas, apart from the regular observations of the solar radio emissions, a few theoretical investigations have been initiated to bring out the association between various solar phenomena.

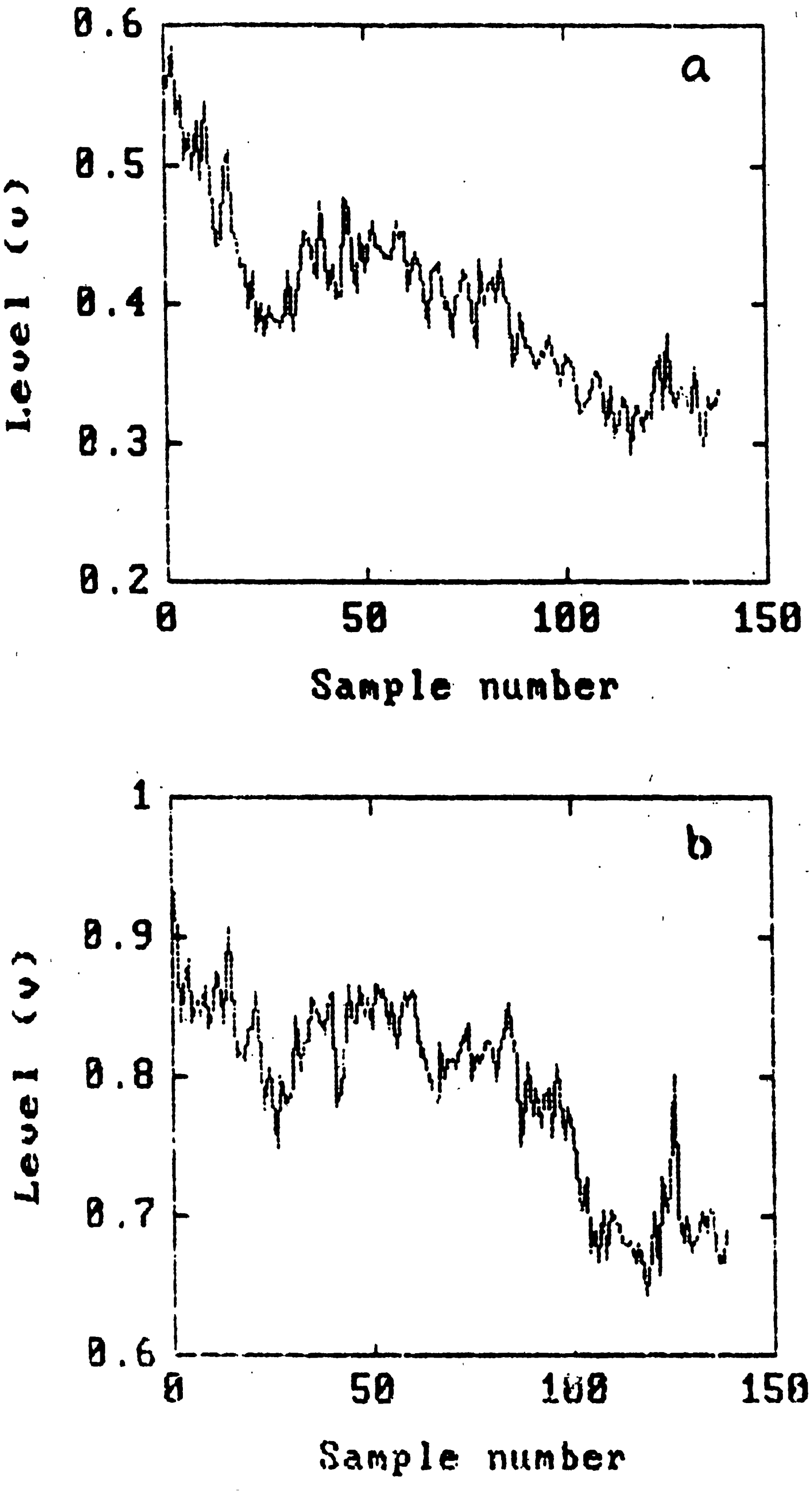

Figure 3. Spectra observed by sweeping the spectrograph from 50 MHz to 80 MHz on 4 June 1996 during 0452-1000 hrs UT. a) Spectrum obtained at 50 MHz b) spectrum obtained at 69 MHz.

Following the work done by Brown 1994, a hydrostatic equilibrium model for the intermediate temperature (10^5K < T < 10^6 K) solar coronal loops has been studied (Shanmugaraju & Umapathy 1995b) by choosing the appropriate equations describing the conservation of mass, momentum and energy along a flux tube with constant area of cross section. Also it is encouraging from the preliminary results of the model calculations on the coronal energy balance, that there exists a close relationship between magnetic flux tube divergence coronal heating and the properties of the solar wind. That is, when the flux tube divergence increases, the temperature and speed of the solar wind decreases as shown by Wang 1993.

5. Conclusion

A solar radio spectrograph operating at 30-80 MHz has been developed in our School of Physics. Some of the observational results have been reported. The sensitivity and the collecting area of the spectrograph hence to be increased to monitor the radio sun in the forthcoming solar maximum period. Any new results helpful in understanding of the bursts, CMEs, Inter Planetary Disturbances, geomagnetic disturbances, etc. will be reported in the subsequent communications.

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