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Design, constructional aspects and first results of a solar radio spectrograph

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A solar radio spectrograph (SRS), constructed at our School of Physics to study the dynamic activities of the sun, is described. It consists of the following four parts: (i) antenna system, (ii) analog receiver system, (iii) control system, and (iv) data acquisition and recording system. The antenna system is a log periodic array with 8 dB gain and bandwidth of 50 MHz. The receiver system is a double stage superheterodyne receiver with a overall gain of 80 dB. The control system consists of IEEE 488 GPIB card and a PC to control the sweeping frequency synthesizer which is acting as one of the local oscillator in the receiver. The data acquisition and recording system include a hi-speed data acquisition card and a PC for acquiring the observed data and recording the same for the reproduction of the spectra. The spectrograph is acquiring observational data on solar radio bursts in the bandwidth of 30-80 MHz, which is quite important for understanding the physics of flares and bursts. Its calibration and reproduction of the observed results using it are also described.

1 Introduction

Scientists have been trying since 1950 to understand the radio spectrum of the sun using radiometers and spectrographs[1-5]. Because of the complexity in dynamic spectra of flares and bursts, the radio spectrum of the sun is not fully understood. Using the scanning radio spectrograph, one can bring out the interesting features of the dynamic sun. A low cost solar radio spectrograph[6,7] in the frequency range 30-80 MHz (Fig. 1) has been constructed at the School of Physics, Madurai Kamaraj University. It is mainly consisting of a wide band (30-80 MHz) log periodic antenna (LPA) to observe the transient radio emissions, a double stage superheterodyne receiver to process the RF signals, a controlling system to control the sweeping frequency synthesizer, and a high speed data acquisition system to acquire the data from the receiver. The control system and the data acquisition systems have been taken care of by an indigenously developed software. A PC/AT is employed to control the receiver and recording systems. The spectrograph has been calibrated using a noise generator and initial measurements have been done with a folded dipole antenna operating at 55 MHz and a LPA operating in the frequency range 30-80 MHz.

2 Antenna system

The log periodic antenna (LPA) has been chosen because of its large collecting area and wide bandwidth. A plane polarized LPA with a beam width of about 60° has been designed as given elsewhere[8] with a wide bandwidth (50 MHz) and a directive gain of 8 dB. The impedance of the antenna is 300 Ω and the collective area is 50 m^2 at 30 MHz. It consists of eight parallel dipoles whose lengths and spacings are logarithmically arranged in the end-fire pattern as shown in Fig. 2.

The design parameters such as scale factor, relative spacing factor, impedance, etc. are properly chosen so that they meet the specifications needed for a practically feasible LPA. The half of the apex angle is found to be 22° and the shortest and the longest elements are 0.7 m and 5 m respectively which determine the cutoff frequencies and hence the bandwidth. The various dimensions of the elements are given in Table 1.

The feed arrangement is done by the criss-cross method by a 300 Ω flat cable, as a two-conductor transmission line, which will balance the system by a separate BALUN. The feed is connected to the shortest elements in the array and the longest element side is terminated. The LPA is mounted at the terrace of the School of Physics. The weight and sturdiness of the LPA and the effect of wind loading have been taken into consideration while installing the antenna.

3 Analog receiver system

It is a double-stage superheterodyne receiver[9,10] (Fig. 3) which provides observing capability in the

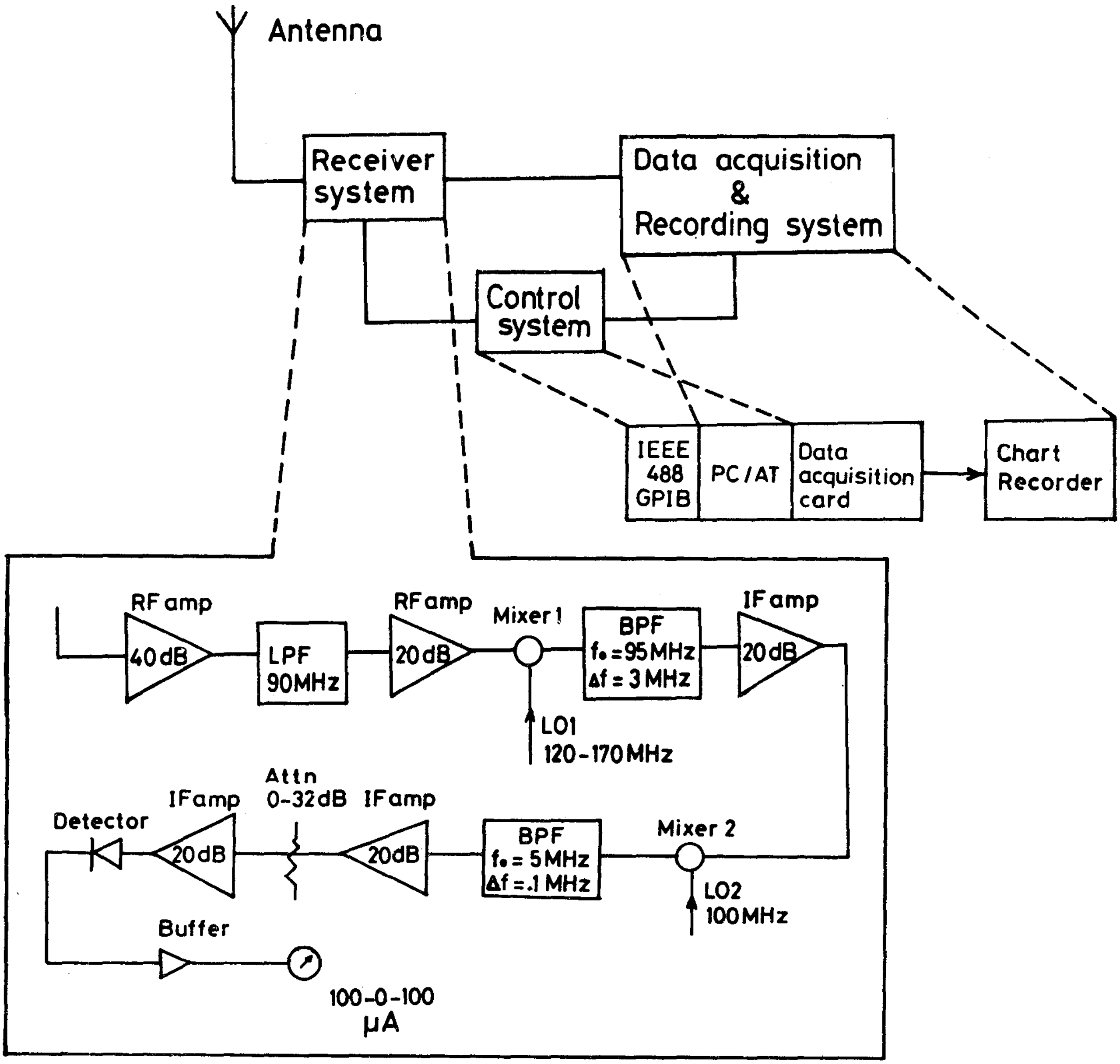

Fig. 1—Block diagram of the solar radio spectrograph.

frequency band 30-80 MHz. It has been constructed with the assistance of scientists and engineers of the Radio Astronomy Centre (TIFR), Ooty. The total gain of the receiver is around 80 dB. The main blocks of the receiver system are: (i) low pass filter, (ii) RF and IF amplifiers, (iii) band-pass fitlers, (iv) local oscillators, (v) mixers, and (vi) detector and a buffer. The following sections present the distinctive features of these different stages.

The RF signals received by the antenna are filtered out as desired using a fifth order Chebyshev low-pass filter having a cutoff frequency (f_0) of 90 MHz. It is designed using inductors and capacitors with a loss of 4 dB. The RF signals are amplified by a specially designed amplifier using two stages involving MAR-6 each having 20 dB gain which in turn will give 40 dB gain.

The first local oscillator (LO1, APLAB Model 2127) is made to sweep from 125 MHz to 175 MHz in steps of 0.1 MHz with a proper sampling rate. This is carried out by a controlling system installed in a PC/AT through an indigenously developed software. The power level of the signal is always kept constant at + 7 dBm.

In this receiver, the low intermediate frequency LO1-RF is only considered and it is transmitted by a 3rd order Butterworth band-pass filter[11] with characteristics of centre frequency of 95 MHz, bandwidth of 3 MHz and loss of 6 dB. The IF

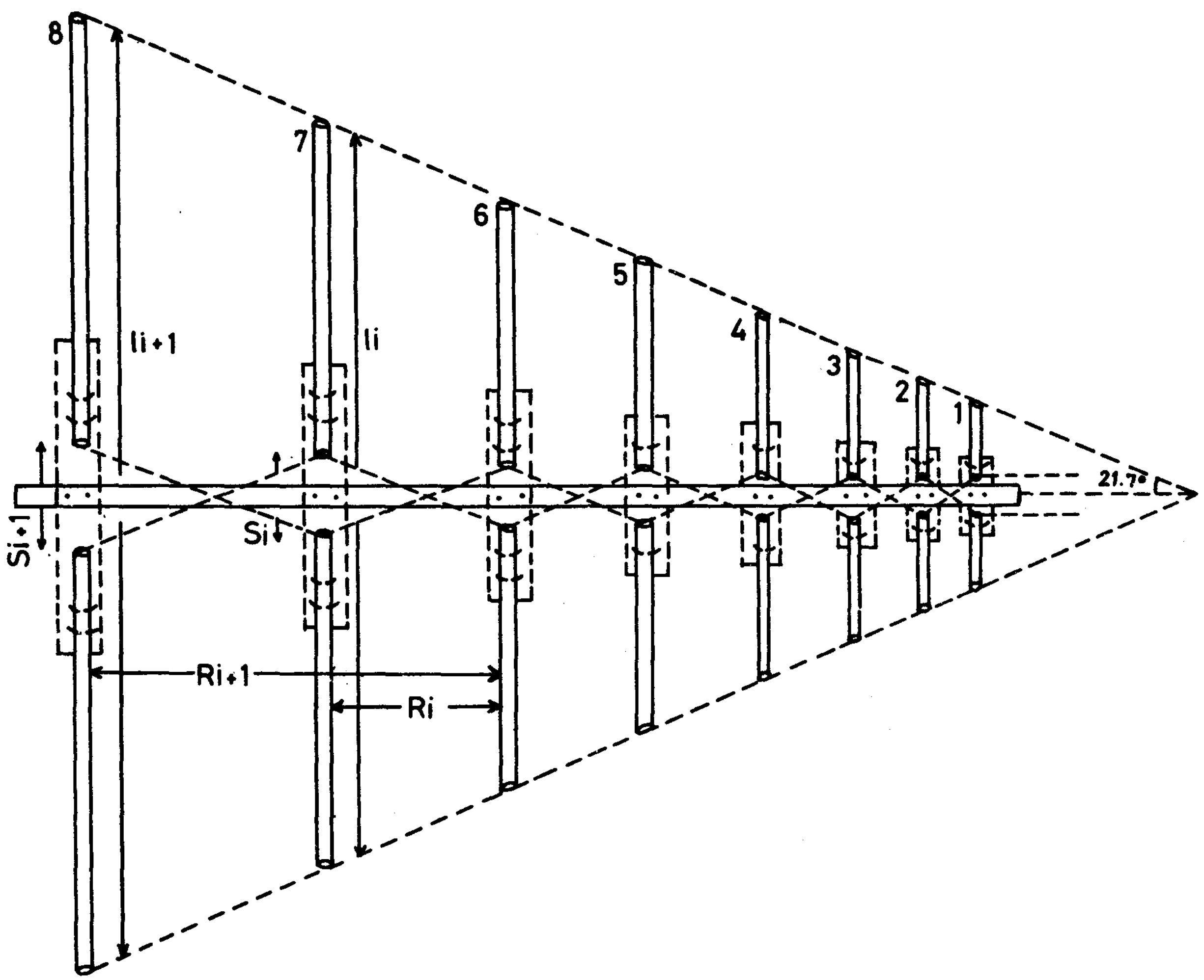

Fig. 2—Schematic diagram of the log periodic array (LPA) (S_i, spacing between dipole centres; l_i, length; and R_i, distance from bottom).

Table 1—Dimensions of the dipole elements

Dipole No. i	Length (l_i) m	Distance from the bottom (R_i) m	Spacing between dipole centres (S_i) cm
1	0.88	0.24	7.6
2	1.13	0.55	9.8
3	1.45	0.95	12.6
4	1.85	1.46	16.1
5	2.37	2.06	20.7
6	3.04	2.90	26.5
7	3.90	3.97	34.0
8	5.00	5.35	43.6

signals are further amplified by IF amplifiers at different places, as shown in Fig. 3, which determine the bandwidth and the frequency resolution of the receiver.

Even though the image frequency (high intermediate frequency) is rejected at the first band-pass filter, it is not fully bypassed[12]. So to reject this image frequency and to further lower conversion of the IF signals, the second stage of the superheterodyne receiver has been employed. This stage differs from the earlier stage in the construction of band-pass filters. The second local oscillator LO2 is a fixed frequency crystal oscillator (100 MHz). The second band-pass filter has characteristics of centre frequency of 5 MHz, bandwidth of 0.1 MHz and loss of 10 dB.

There is a square law detector (OA 79) by which the IF signals having the information of the RF signals are detected. This detector is followed by a buffer to increase the power level of the detected signals which has been designed using AD 517 and OP AMP 741. The continuous variation of the signals is monitored by a current meter (microammeter).

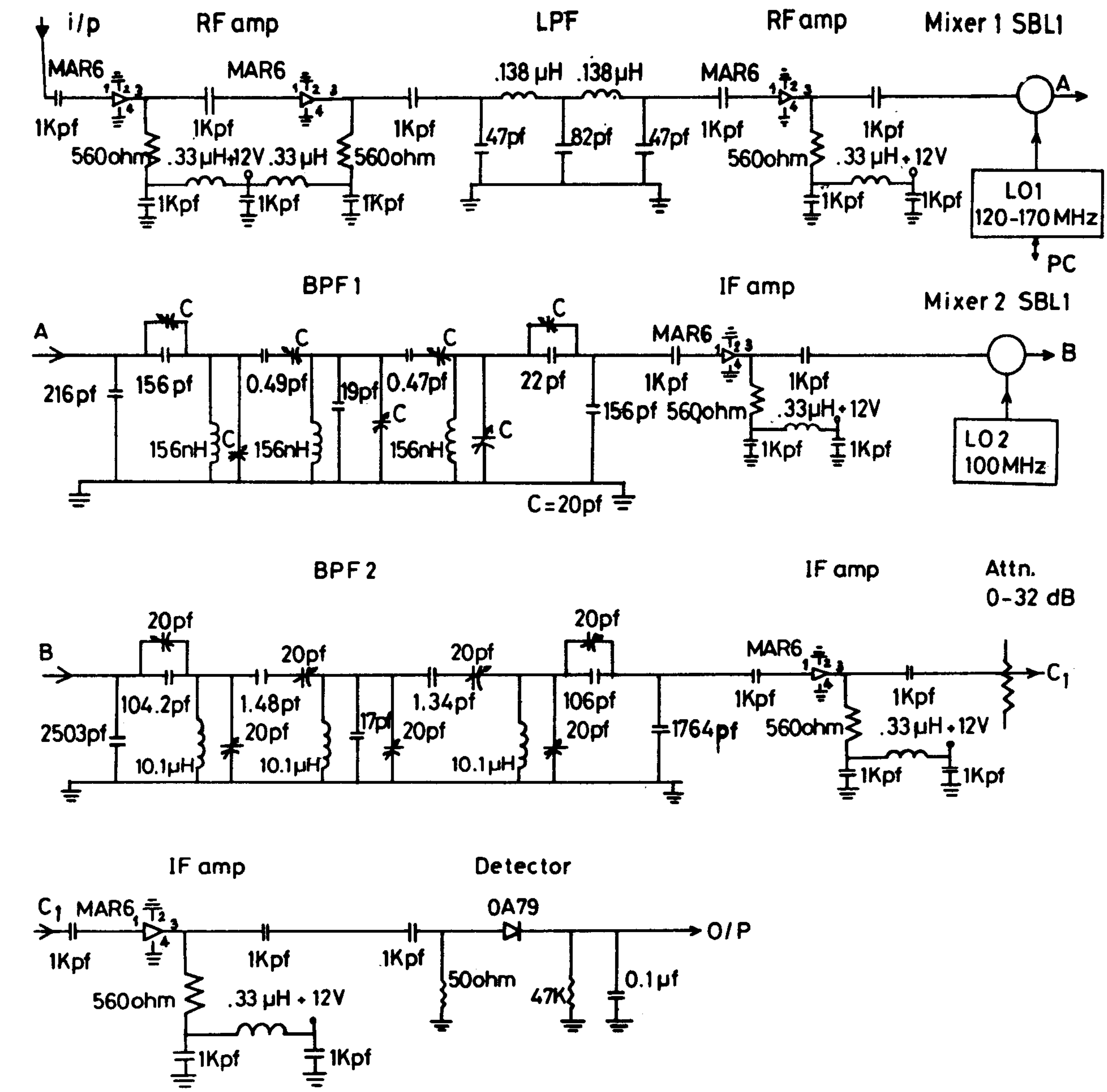

Fig. 3—Double stage superheterodyne receiver.

4 Controlling system

The sweeping frequency synthesizer (APLAB Model 2127) which has been used as the first local oscillator (LO1) in the spectrograph can be remote controlled by a controlling system. It includes IEEE 488 GPIB interfacing card and a PC/AT. Both operate as an asynchronous interlocking data exchange handshake mechanism.

The IEEE 488 interfacing card consists of eight data lines for sending the data such as frequency, level, etc., five interface management lines for sending the commands such as remote enable, service request, etc. and three transfer control lines for sending the asynchronous interlocking handshake.

First the sweeping frequency synthesizer, LO1, is made to activate in remote mode by transfering the remote enable signal. To generate any desired frequency and level etc., the values of the corresponding parameters have to be sent through the data lines strictly following the IEEE 488 standard commands.

Usually bursts drift from high frequency to low frequency[13] with various drift rates in few seconds to few minutes. Using this spectrograph, the long-living (type II and type IV) bursts can be detected and occassionally type III as well. Here the frequency synthesizer, LO1, is made to sweep from 125 MHz to 175 MHz in steps of 0.1 MHz with optimum sampling rate. This sweeping can be repeated until the observation comes to an end. The above sequence of operations is being carried out by the indigenously developed software.

5 Data acquisition system and recording system

The data acquisition system is employed to acquire the data. The recording is done by a PC/AT as well as a chart recorder for further data analysis. The data acquisition system consists of one 16 channel-12 bit ADC for converting the analog signals into digital signals, three programmable timers to maintain the synchronization and 24 programmable digital I/O lines for providing data. The special features of this card are: conversion time, 10 μs; sampling rate, 100 k samples/s; and different modes of triggering the conversion.

The detected analog signals having the information about the input are digitized using this card by successive approximation method and then recorded. The radio emissions are transient in nature. Hence the sun is observed continuously and when the sun crosses the beam of LPA, the data are recorded for off-line analysis.

The sweeping of the LO1 and the data acquisition is synchronized so that the sampling of the particular frequency and the acquisition of data will be in synchronization. Since it is a 12 bit ADC and the data are read in two bytes (LSB and MSB), the four most significant bits of the MSB are to be masked and the data are read first by LSB followed by MSB and then should be combined to get the data. These sets of operations are being taken care by the indigenously developed software.

6 Scientific objectives

The burst emissions from the sun is an interesting feature at metre and decametre wavelengths. Since the last two decades, a lot of work has been done for understanding the association of these radio signatures with other phenomena like coronal mass ejections (CMEs)[14-16], geomagnetic disturbances[17,18], interplanetary shocks (IPSs) and solar wind studies[19], etc. Also the scattering theory[20,21] and the association of slowly varying components (SVCs) with sunspot rotations[22,23] are the unsolved problems in solar physics. Recently questions have been raised at the Colloquium IAU-154 at NCRA(TIFR), Pune (Ref. 24), regarding transient solar emissions and their association with interplanetary disturbances.

This spectrograph is being used in monitoring the sun continuously for the transient radio emissions in the frequency range 30-80 MHz. At present, due to limitations in various parameters such as effective aperture, minimum flux density and beam width, only the strong and long-living bursts (type II and type IV) are expected to be detected. Occasionally type III bursts can also be detected. The correlation studies of the observed data with other features like CMEs, IPSs and solar wind studies, geomagnetic disturbances; etc. will bring out the associationships. Observations of the dynamic spectra of the sun and these correlation studies are quite important for more clear understanding of the complex processes involved in the physics of solar flares and bursts.

7 Calibration and initial measurements

7.1 Calibration

The receiver has been calibrated using a specially designed noise generator and a 50 ohm terminator over the entire frequency range of 54-56 MHz. The corresponding intensity spectrum obtained is shown in Fig. 4. The power level of the noise source was varied from 31.5 dB to 15.5 dB (16 dB) for a fixed interval of time and it is found that the receiver is well responsible for the change in power level. The gain of the receiver is found almost constant for all frequencies. The flux density of the source was calculated by the off-line analysis software. The calibrating radio source (Cassiopeia A) will also be made observable for calibration later on. The calibration is being done once in a day using the noise source.

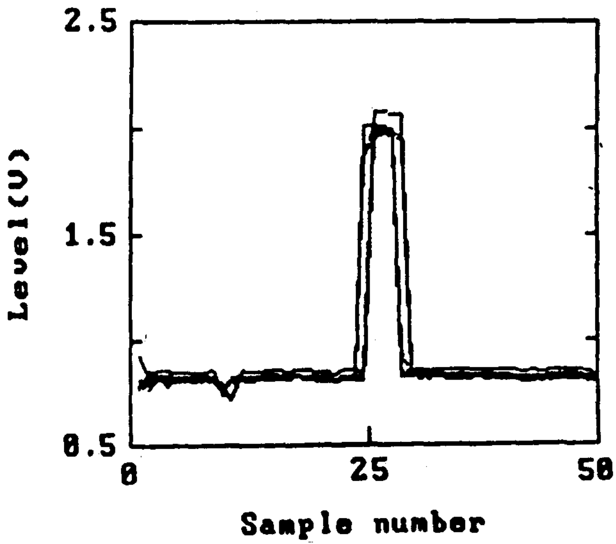

Fig. 4—Spectral presentation of the calibration of the spectrograph with the noise generator in the frequency range 54-56 MHz.

7.2 Initial measurements with folded dipole antenna

A half wavelength folded dipole antenna operating at 55 MHz has been utilized for the initial measurements. The voltage standing wave ratio (VSWR) for this antenna is measured as less than 2 in the frequency band 45-65 MHz. The observations have been made in the frequency range 54-56 MHz by sweeping the first local oscillator (LO1) in steps of 0.1 MHz with minimum switching time of 225 ms. The data acquired are for an integration time of 100 ms at each frequency. The spectrum as plotted (Fig. 5) shows that the amplitude is almost constant in the frequency range 54-56 MHz. Figure 6 shows the interference observed at 21.6 MHz in the known interference band 20-22 MHz using the same antenna. An attenuator is used to avoid the saturation of amplifiers.

7.3 First results using LPA

A log periodic antenna (LPA), specially designed for the Gowribidanur Radio Observatory, Indian Institute of Astrophysics, Bangalore, has been mounted at an elevation of 11° at the terrace of the School of Physics, Madurai Kamaraj University, for observation in the frequency band 30-80 MHz.

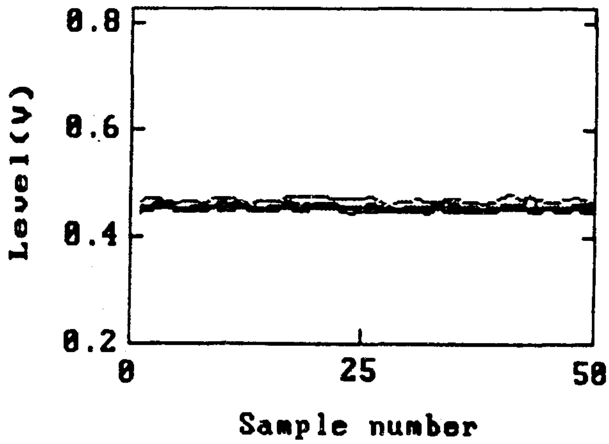

Fig. 5—Spectrum observed using folded dipole antenna in the frequency range 54-56 MHz.

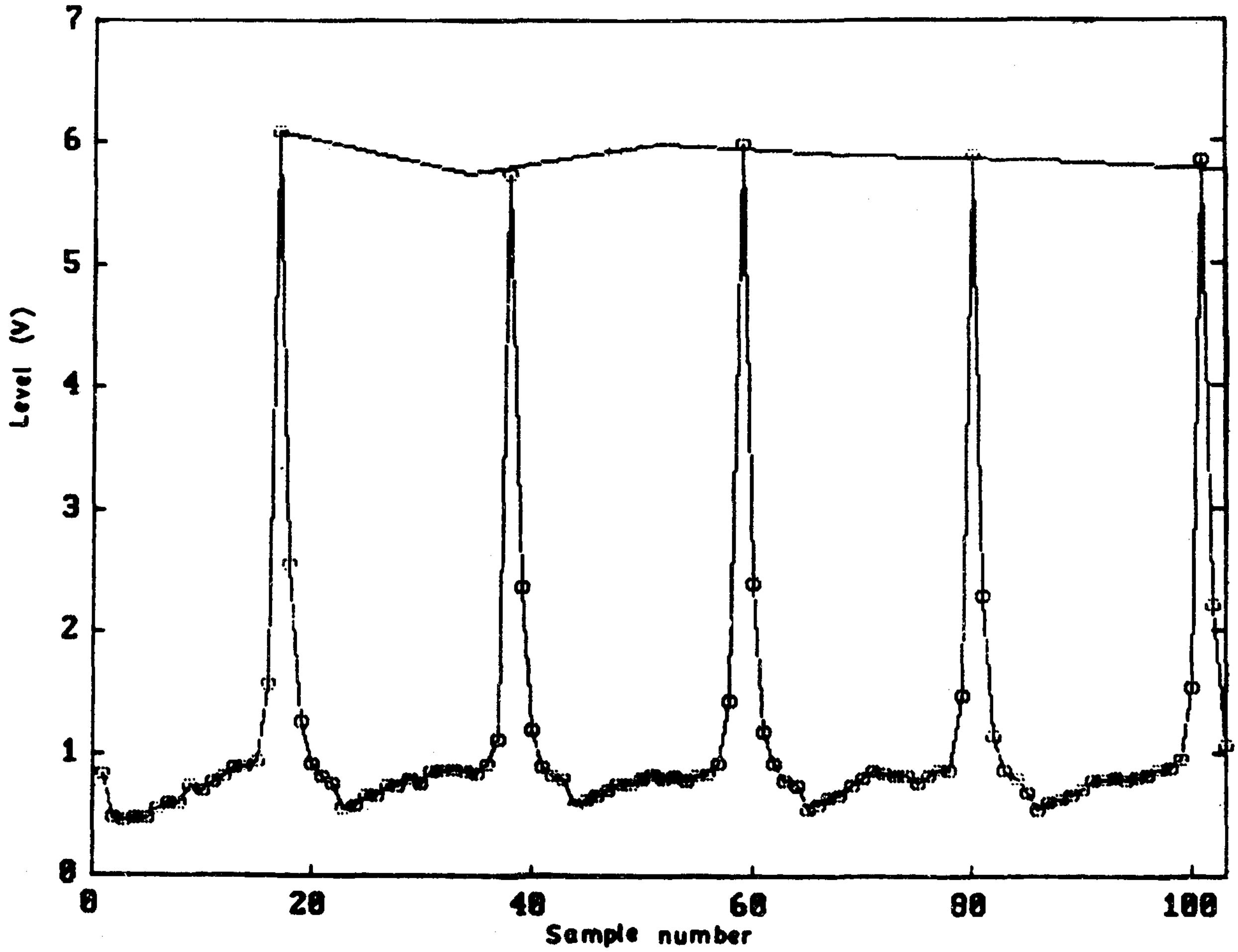

Fig. 6—Strong interference at 21.6 MHz observed using folded dipole antenna, seen in 5 sweeps from 20-22 MHz.

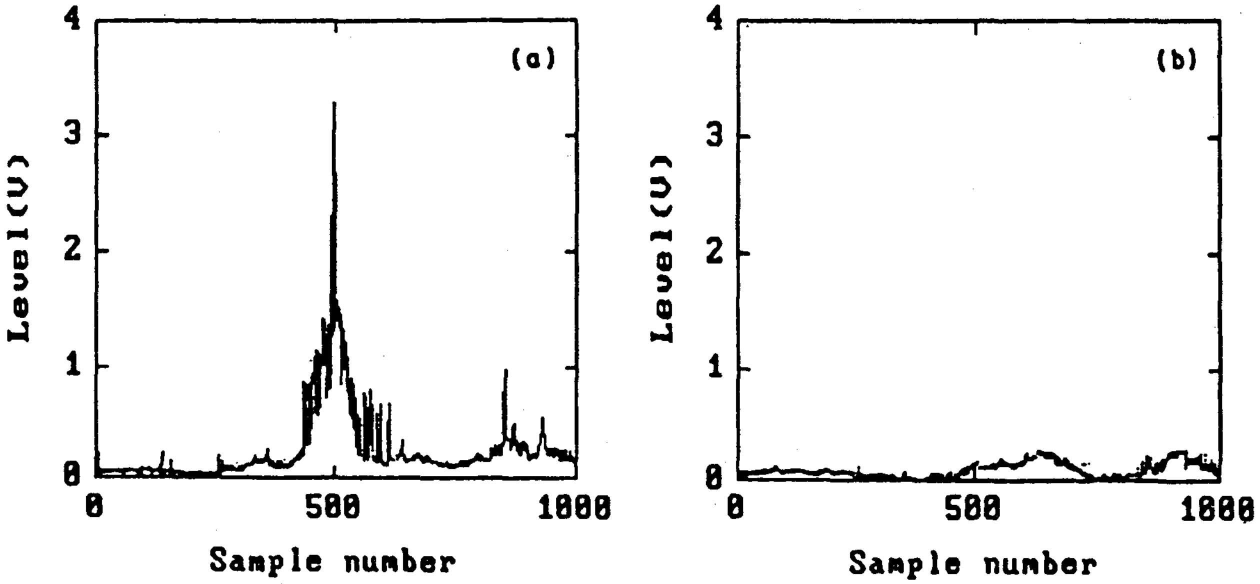

Fig. 7—Spectra observed using LPA in the frequency band 30-80 MHz (a) when there is a transmission of signals at 55 MHz, and (b) when there is no transmission of signals at 55 MHz.

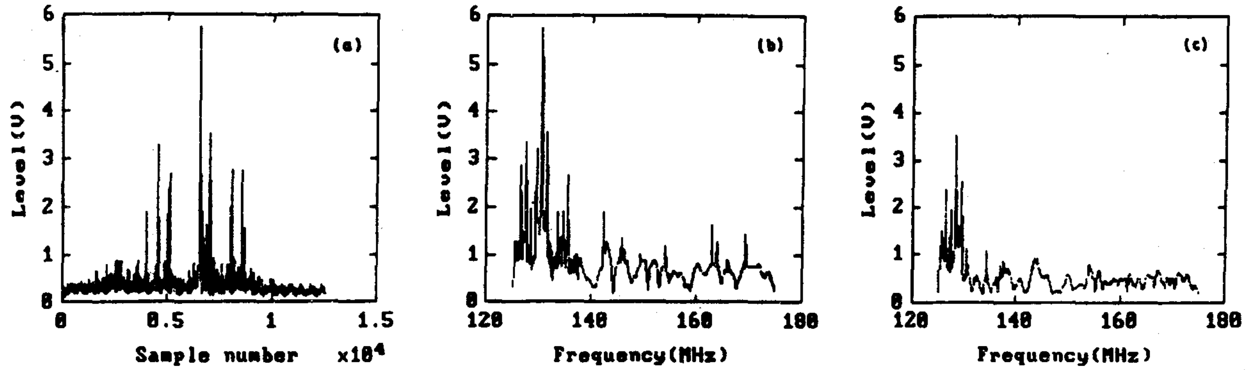

Fig. 8—Spectra observed using LPA in the frequency band 30-80 MHz (a) a type II burst on 13 July 1995 during 0649-0844 hrs UT, (b) 6th sweep showing a maximum peak at 130.4 MHz (RF=35.4 MHz) at 0719 hrs UT, and (c) 7th sweep showing a maximum peak at 128.4 MHz (RF=33.4 MHz) at 0721 hrs UT.

For the transmission of signals at 55 MHz using a known source through a dipole antenna, the signals are received by LPA and the spectrum obtained is shown in Fig.7(a) with a peak at 55 MHz. Figure 7(b) gives the spectrum showing no peak when there is no transmission of the signals.

Regular observations of the dynamic activities of the sun are being made since April 1995. At present, observations are made when sun crosses the beam in the frequency band 30-80 MHz using the static LPA. The whole frequency band is divided into 500 channels with 0.1 MHz band width and each channel is observed for 225 ms. The sun and the background have been observed for a period of months and small deviations in the level found. This may be due to instrumental gain variations, thermal variations, ground reflections, etc.

Type II burst on 13 *July* 1995

On 13 July 1995 during 0649-0844 hrs UT, we observed quite a few peaks over and above the threshold of 1 V as shown in Fig. 8(a). During this period in the 6th sweep of LO1 (125-175 MHz), we observed many peaks in the band of LO1 (125-135 MHz) [Fig. 8(b)]. We noticed that a peak with maximum output level of 6 V (nearly 20 dB enhancement from the baseline) is situated at LO1 (130.4 MHz). Typically type II bursts occur in the frequency range 20-100 MHz (p. 337 of Ref. 13). Subsequently in the 7th sweep of LO1, as shown in Fig. 8(c), we further noticed that the peak is drifted towards lower frequency and the drift rate is nearly 0.02 MHz/s. Typically type II bursts last for minutes and they drift towards lower frequency with drift rate 0.25 MHz/s (p. 8 of Ref. 13). On the days previous and subse-

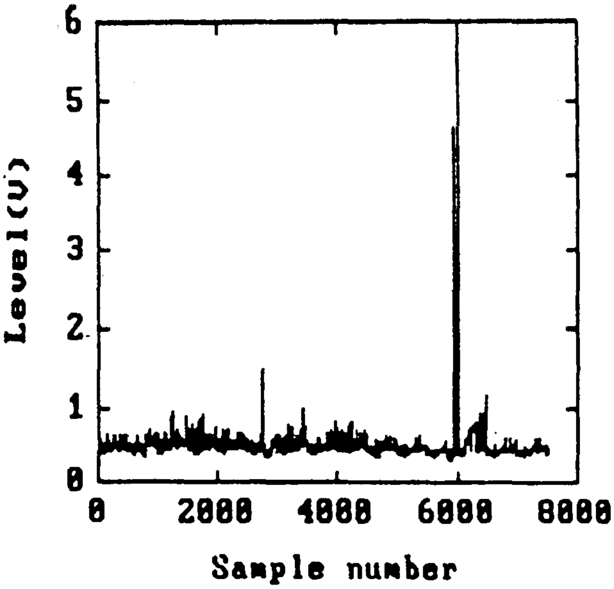

Fig. 9—Spectra showing the strong interference at 79.7 MHz on 1 Aug. 1995 during 0543-0805hrs UT.

quent to 13 July 1995, there were no changes or enhancements in the baseline. Hence we attribute the above feature to a type II burst.

Further, we have been cautious for any local interference. For example, on 1 Aug. 1995 during 0543-0805 hrs UT we noticed a single peak with an enhancement of 6 V over and above the threshold of nearly 1 V in one particular sweep No. 12 out of 60 sweeps made during 0543-0805 hrs UT. The spectrum is shown in Fig. 9. There were no peaks observed in the previous and subsequent sweeps in a total of 60 sweeps. Hence this may be attributed to some unidentified sudden interference which may be local or may be a burst!

The sun is being observed continuously using the above spectrograph and any new results helpful in the understanding of the flares and bursts, CMEs, geomagnetic disturbances, interplanetary shocks, etc. will be reported in subsequent communications.

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