Pergamon
www.elsevier.nl/locate/asr

Adv. Space Res. Vol. 25, No. 9, pp. 1809–1812, 2000

Printed in Great Britain
0273-1177/00 $20.00 + 0.00

PII: S0273-1177(99)00591-8

BRAZILIAN DECIMETRIC ARRAY

H. S. Sawant[1], K. R. Subramanian[1*], E. Lüdke[2], J. H. A. Sobral[1], G. Swarup[3], F. C. R. Fernandes[1], R. R. Rosa[1], W. D. Gonzalez[1], and J. R. Cecatto[1]

[1]*National Institute for Space Research - INPE, C.P. 515, 12201-970 São José dos Campos, SP, Brazil*
[2]*Department of Physics, Federal Univ. of Santa Maria, Santa Maria, RS, Brazil*
[3]*Tata Institute of Fundamental Reasearch, Poona Univ. Campus, Ganeshkhind, Pune, 411 007, India*
*On leave from Indian Institute of Astrophysics, Koramangala, Bangalore - 560 034, India

ABSTRACT

A radio heliograph operating in the frequency range of 1200-1700 MHz is planned by INPE, Brazil, for investigations of time evolution of active regions, which will lead to better understanding of the physics of the flares energy release and particle acceleration, in order to suggest better criteria for the prediction of solar flares, Coronal Mass Ejections (CME), and solar terrestrial relations, such as geomagnetic storms and radio blackouts. In the first phase, the Brazilian Decimetric Array (BDA) will be a T shaped array 256 m by 144 m, consisting of 26 parabolic dish antennas of 4 m diameter. This array will produce full disk images of the sun with a spatial resolution of 3 by 5 arc minutes at 1420 MHz with a time resolution of 100 ms and sensitivity of ~ 10 Jy. In the second phase, in addition to the compact T array there will be 6 more 7 m diameter antennas on an East-West baseline of 2560 m to obtain higher spatial resolution and better sensitivity. Thus, finally this radioheliograph will have wide field of view and couple of arcsec spatial resolution and high time resolution (100 ms).

INTRODUCTION

Decimetric observations were carried out since 1960, however, for almost two decades they remained stagnant. SKYLAB soft X-rays observations (Sturrock, 1980) suggested that acceleration of the particles most likely occurring near the region where the decimetric plasma emission is emitted. This renewed interest in the decimetric observations. High time and spatial resolutions decimetric observations can significantly contribute to the understating of the physics of the flare energy release and particles acceleration.

For investigation of decimetric solar radio emission many radio spectrographs are in operation, including the high sensitivity, high time and frequency resolution digital spectrograph of INPE (Sawant *et al.*, 1996). However, there is lack of information on the location and size of the radio bursts at decimetric wavelengths. There are not many investigations of the regions from which decimetric radio bursts originate except very few observations made by VLA (Gopalswamy, 1995).

Thus, the data from the planned heliograph will also complement observations made by Nobeyama Radio Heliograph (Nishio *et al.*, 1995), at 17 GHz, Nancay Radio Heliograph (Radio heliograph group, 1993), at 160, 327 and 408 MHz and Gauribidanur Radio Heliograph (Subramanian *et al.*, 1994) operating in the frequency range of 40 - 150 MHz, and thus will be part of a world wide network for continuous monitoring of the solar radio emission and allow us to study the evolution of active regions.

ARRAY CONFIGURATION AND ANTENNA SYSTEM - PHASE I

In the first phase, the BDA will make full disk images of the sun in the Stokes parameter I in continuum with observing frequency tunable between 1200-1700 MHz. The T compact array (256 m in E-W direction and 144 m in S direction) (Figure 1), will be operating to obtain full disk solar images and will allow to produce images in a snap shot mode similar to the well known supersynthesis architecture proposed in early seventies (Thomspon *et al.*, 1980), Clark Lake TPT array (Erickson *et al.*, 1982; Sawant *et al.*, 1982, 1984;

Kundu et al., 1986) and used in Giant Metre-wave Radio Telescope (Swarup, 1990). The array will be located at Cachoeira Paulista, Brazil (44.7° W and 22.7° S).

The primary antenna element used is a parabolic dish of 4 m diameter with a dual polarisation feed operating in the frequency range of 1200-1700 MHz at the prime focus which has the advantage that it can be used over the full frequency range of the reflector. The effective collecting area of each antenna is ~ 7.5 m^2 with an aperture efficiency of 60 %. The reflective surface will be wire mesh.

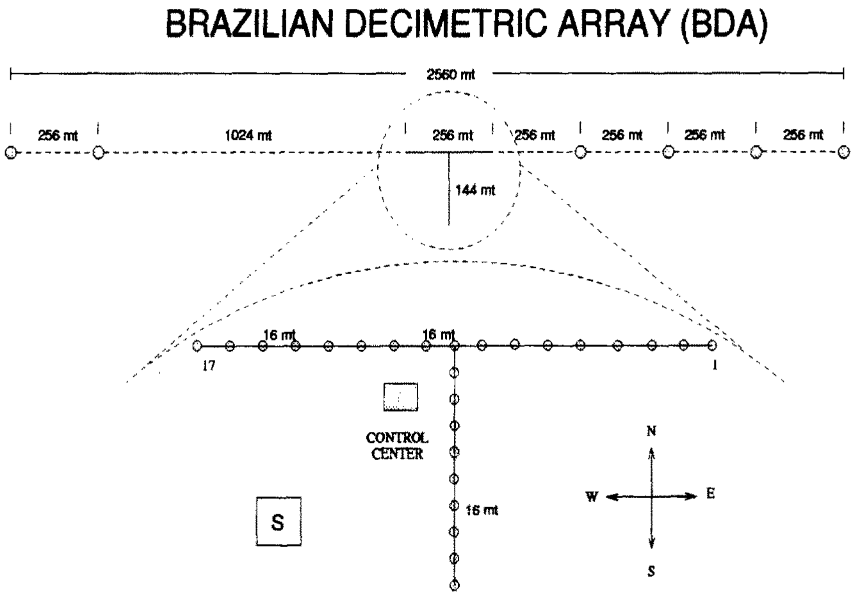

Fig. 1. Antenna location plan for the Brazilian Decimetric Array.

The half power beamwidth of the reflector is ~ 3 deg at 1420 MHz. Each antenna will be supported by a equatorial mount. Tracking of all antennas will follow the intended sky position with an accuracy better than 2 arc min. Each antenna will be fitted with a 12 bit incremental encoder with a non volatile memory. The drive system will track the sun for about ± 4 hrs around local noon and will take care of the wind torques on the antennas at 80 km/h which is the maximum operational wind speed at antenna height at Cachoeira Paulista.

FRONT END RECEIVER SYSTEM

At the front end the RF signal from each antenna will be amplified by a low noise (1.2 dB) tuned (1200-1700 MHz band) amplifier and passed through a band pass filter to eliminate the image band. The RF amplifiers and bandpass filters will be kept in a temperature controlled enclosure to minimise the phase and gain variations. The RF signal will be brought to the receiver box located at the base of the antenna by low loss cables. The receiver box will be buried at 1.5 m below the ground to keep the temperature variation minimum. The RF signal will be double converted into IF at 10 MHz with 2 MHz bandwidth and further amplified by video amplifier as shown in Figure 2. The IF signal will be modulated using Walsh function and send to the receiver building using low loss RF cable. The IF signal will be split into sine and cosine components using quadrature hybrids in the receiver building.

The local oscillator will be phase locked to a frequency standard and will employ modern phase locking techniques (Rhode, 1990) to compensate automatically the phase and frequency fluctuations from the local oscillator electronics and due to temperature variation of the cables. Multifrequency observations will be carried out by varying the frequency of the first LO. The IF signal will be phase coherent for digital correlation in single sideband one bit correlator which is sufficient for solar imaging. Programmable attenuators will keep the level of the signal within the range required for the correlator inputs. Calibration will be done using noise injected at the input of the receiver system using noise diodes.

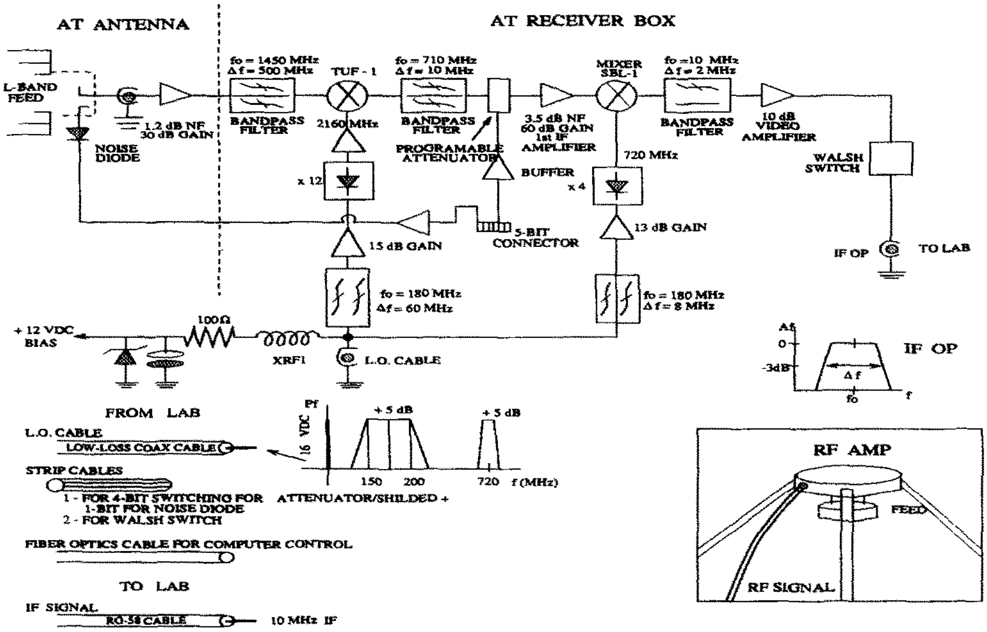

Fig. 2. A schematic diagram of the front end receiver system.

DIGITAL CORRELATOR SYSTEM

To permit simultaneous measurement of complex visibility function of 325 (n(n-1)/2 where n=26) interferometer baselines between the various antenna groups, a 650 channel one bit digital correlator (Weinreb, 1963) system is planned which obtains the real and imaginary parts of the complex visibilities for each antenna pair in the array. The IF signals will be quantized as 2 levels using zero cross detectors and over sampled at the rate of 10 MHz for finer time delay resolution to reduce the coherence loss to less than 2 %. The digital delay also will make a preliminary fringe rotation to correct for the delays in the wavefront due to the earth - sun system. The necessary delays will be implemented under the control of a computer with maximum value of 74 microseconds for EW antennas (for ± 4 hour tracking, 256 m baseline) and 34 microsenconds for South arm (for ± 45 degrees zenith angle coverage, 144 m baseline) in steps of 0.05 microseconds to reduce the coherence loss to less than 1.5 %. The correlator system will be built using custom built chips designed for Nobeyama radio heliograph (Nishio *et al.*, 1995). Each correlator chip can multiply signals from 4 antennas and can give 8 real multiplications One bit correlation results in the loss of amplitude information of measurement of fourier components. Therefore the signal strength including the receiver noise is measured for each antenna separately and stored in the buffer memory along with correlator data every 100 ms.

DATA ACQUISTION SYSTEM

The master computer at the control building will be a SUN work station ULTRA 1 which will read the correlation visibilities through a commercial VME - SCSI interface, apply preliminary corrections to the data by a C++ program written for UNIX/Solaris 2.5. The interferometer visibilities will be then stored in an Hexabyte tape in an NRAO Astronomical Image Processing Software (AIPS) readable standard FITS format. The master computer will also supply pointing tables to the slave computers at the antenna sites for antenna and receiver diagnosis. The fourier imaging to obtain the solar images will be done using procedures implemented in the AIPS software.

CALIBRATION

Since the observed interferometer visibilities differ from the true visibilities due to antenna based complex gain and correlator offset errors, they have to be corrected by calibration. Since the BDA has enough redundancy, redundant calibration will be used like Nobeyama (Nishio *et al.*, 1995) and Gauribidanur radio heliographs (Subramanian *et al.*, 1994) and Westerbork Synthesis Radio Telescope (Barrs *et al.*, 1973).

Specifications of BDA system in phase I is given in Table 1.

Table 1 . Specifications of BDA Phase I

ANTENNAS	
Diameter	4m
Field of view	3 deg at 1420 MHz
Feed	1200 - 1700 MHz
Tracking (maximum)	8 hrs
Zenith angle coverage	90 deg
ARRAY	
Number of antennas	26
Total collecting area	$\sim 200\ m^2$
Baseline	8 m to 240 m
Spatial resolution	3×5 arcmin at 1420 MHz
Sensitivity (2 MHz BW, 100 ms integration)	$\sim$ 10 Jy
RECEIVER SYSTEM	
Observing frequency	1200 - 1700 MHz
IF Bandwidth	2 MHz
Time resolution	100 ms
DIGITAL CORRELATOR SYSTEM	
Number of channels	650
Number of bits	1

CONCLUSIONS

The planned Brazilian Decimetric Array will be a powerful radioheliograph in the southern hemisphere for investigations of basic problems related to solar flares such as energy release and particle acceleration and CME for related space weather.

ACKNOWLEDGEMENTS

Thanks are due to Profs. K. Shibasaki and Ananthkrishanan, Dr. H. Nakajima, Dr. M. Nishio, Dr. R. Ramesh and Dr. T. Watanabe for suggestions leading to improvement of the design of BDA. One of us, K. R. Subramanian, is supported by CNPq under grant 30358-97/0. The participation of H. S. Sawant in the 32nd COSPAR Scientific Assembly was supported by FAPESP under grant 98/04282-9.

REFERENCES

Barrs, J. W. M., J. F. Van Der Bruggs, and J. L. Cassae, *Proc. IEEE*, **61**, 1258 (1973).
Erickson, W. C., M. J. Mahoney, and K. Erb, *ApJ S. Series*, **50**, 403 (1982).
Gopalswamy, N., *ApJ*, **435**, 892 (1995).
Kundu, M. R., T. E. Gergely, S. R. Kane, and H. S. Sawant, *Sol. Phys.*, **103**, 153 (1986).
Nancay Radio Heliograph group, *Adv. Space Res.*, **13**(9), 411 (1993).
Nishio, M., H. Nakajima, and S. Enome, *Kofu Symposium*, pp. 19 (1995).
Rhode, U. *Digital Phase Lockeded Loops, Theory and Applications*, John - Wiley & sons (1990).
Sawant, H. S., T. E. Gergely, and M. R. Kundu, *Sol. Phys.*, **77**, 249 (1982).
Sawant, H. S., J. H. A. Sobral, F. C. R. Fernandes, J. R. Cecatto, W. R. G. Day, J. A. C. F. Neri, E. M. B. Alonso, and A. Moraes, *Adv. Space Research*, **17**(4/5), 385 (1996).
Subramanian, K. R., M. S. Sundarajan, R. Ramesh, and C. V. Sastry, *STEP GBSC. News*, **4**, 13 (1994).
Swarup, G., *Indian Journal of Radio and Space Physics*, **43**, 31 (1990).
Thompson, A. R., B. C. Clark, C. M. Wade, and P. J. Napier, *ApJ. S. Series*, **44**, 151 (1980).
Weinreb, S. *MIT Technical Report*, **412** (1963).