Solar physics with Chinese Spectral Radioheliograph

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Abstract

It is important to have imaging - spectroscopy over centimetric - decimetric wave range to address fundamental processes in the solar eruptive phenomena. The Chinese Spectral Radioheliograph (CSRH) is a solar-dedicated interferometric array with frequency from 0.4GHz to 15 GHz. There are 40 antennas with 400MHz to 2 GHz, and 60 antennas with 2 GHz to 15 GHz in this array. CSRH-I and CSRH-II, which include antennas, receivers, and correlators have already been established. This paper introduced the system, progress and current status of CSRH.

1. Introduction

Imaging spectroscopy of the sun over the centimetric and decimetric wavelength range is important for addressing fundamental problems of energy release, particle acceleration, and particle transport [1]. However, the available radio facilities are either with high time and spectral resolution but without spatial resolution, or with high time and spatial resolution but at only one or a few frequencies. The Nancay Radioheliograph in France observes the Sun only at several frequencies from 150MHz to 450MHz [2]. The Siberian Solar Radio Telescope in Russia at 5.7 GHz [3], and the Nobeyama Radioheliograph in Japan at 17 GHz and 34 GHz to observe the sun [4]. Therefore, there is an urgent need for a new powerful instrument which can obtain true imaging spectroscopy, along with high temporal, spatial, and spectral resolutions to meet this end [5]. Depending on some proposals and some pre-studies during the past 30 years, it was suggested to build a Chinese Spectral Radioheliograph (CSRH) in the decimeter to centimeter-wave range about 12 years ago in China[6, 7] .The CSRH being developed will be a solar dedicated radio interferometric array that will observe spectroscopic imaging of the Sun, with high spatial resolution, high time resolution, and high frequency resolution images of the Sun simultaneously in the decimeter to centimeter wave range [7]. It is expected to open new observational windows on solar flares and CMEs, and will be achieved by mapping the radio emission from unstable electron populations on the basic processes of energy release [8].

2. Description of CSRH

CSRH is built at Mingantu station of National Astronomical Observatories, Chinese Academic of Sciences. Its site in Inner Mongolia is about 400 km away from NAOC. There are two arrays, CHRH-I and CSRH-II. CSRH-I consists of 40 equatorial mounted parabolic antennas which diameter is 4.5m. Its frequency is from 0.4GHz to 2.0 GHz. CSRH-II consists of 60 equatorial mounted parabolic antennas, which diameter is 2m. Frequency is from 2.0 GHz to 15.0 GHz. The latitude and longitude

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coordinates of these arrays center is 115°15'1.8" east longitude, 42°12'42.6" north latitude, altitude is 1365 m. All of these 4.5 m and 2.0m antennas are arranged according to a three-arm spiral shape. The antenna arrangement is shown in figure 1. Some specifications of CSRH-I and CSRH-II are shown in table 1. A basic system block diagram of CSRH-I is shown in figure 2. The feed mounted at the prime focus of each dish with 0.4–2.0 GHz frequency range receives left and right-handed circular polarization signals which comes from a radio source. Microwave switch is connected to left and right-handed circular polarization ports of the feed by a short and stable cable. The output of switch connects to Low Noise Amplifier. Then the amplified signals were transmitted to optical signal. The optical transmitter, LNA, filter, attenuator and some control and monitor units are sealed in a temperature-controlled box, which mounted at the back panel of the feed. The optical signal from each antenna is transmitted to the control building by about 3400m long optical fiber cable. These fiber cables were buried in about 3m for maintaining a stable temperature during the observation time. The output signals from the optical receiver go into an analog receiver in the control room. After amplifier and filter, these signals are mixed with local oscillator signals, and down-converted to some single sideband IF signals which frequency are from 50MHz to 450MHz. These IF signals are digitized in AD converter, passed through a poly-phase filter bank, and divided to 16 base band channels. The bandwidth of each channel, from 1.5625 MHz, 3.125 MHz, 6.25 MHz, 12.5 MHz, and 25MHz, can be re-configured in control software before an observation. After this, 2-bits quantization and correlation with signals from other antennas were performed in digital receiver. The correlated data are stroed on a hard disk for off-line processing in computers. CSRH-II system is similar to CSRH-I, but there are two LNAs connected to left and right port of feed, then a microwave switch is connected to output of LNAs. The aim of this difference is to reduce the noise figure.

Table 1. CSRH specifications.

	CSRH-I	CSRH-II
Frequency range	0.4–2 GHz	2–15 GHz
Number of antennas	40	60
Antenna size	4.5 m	2 m
Maximum baseline	~3000 m	~3000 m
Minimum baseline	~8 m	~4 m
Frequency channels	64 channels	528 channels
Time resolution	25 ms	206.25 ms
Spatial resolution	10″.3–51″.6	10″.3–1″.4
Polarization	Left, Right	Left, Right

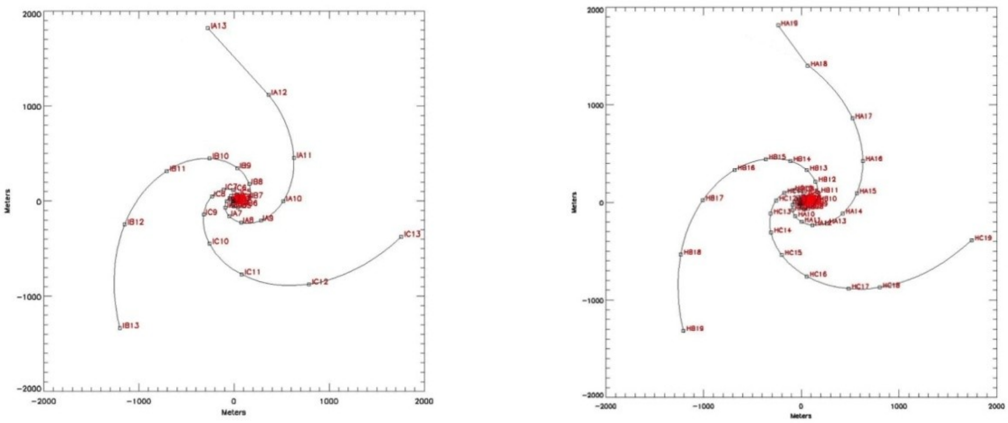

Fig.1, Antenna arrangement of CSRH-I and CSRH-II.

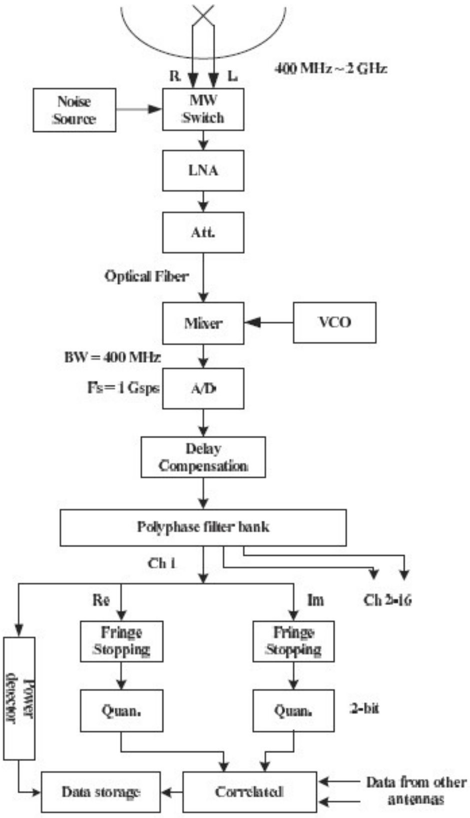

Fig.2, system block diagram of CSRH-I

Calibration

Some measurements and experiments have been carried out to test and calibrate the whole system. The geostationary satellite was treated as calibrator to calibrate observation of sun and Cygnus A. The precise location of each antenna and the delay of each baseline have been measured. The rms of measured delay is less than 1ns for each baseline, and it is very robust, as similar results obtained after multiple measurements pursued 1 year apart [9]. The circular - polarization degree was measured for polarization calibration. The circular polarization degree of a CSRH-I antenna element in the 400–2000MHz range, measured on 2012 August 13, which is <10% over 96.9% of the whole frequency band, and, <5% over 89.4% of the whole frequency band [8]. The average values of the phase closure of geostationary satellites observation are less than 3.0 degrees, and the rms of phase closure are less than 2.2 degrees during the 20 hours observation period [10].

Observations

During the period of test observation, some radio sources were observed including stationary satellite, GPS satellites, Cygnus A, quiet sun and burst. The first burst, associated with C1.5 class X-rays and observed by a 5-element system, was recorded at 07:59–08:20UT on 2010 November 12[11]. Observations of a geostationary satellite named Fengyun-2E, which was launched in 2004 and is stationed along the equator at 105 degrees east longitude, and some GPS satellites were carried out since 2010. Furthermore, satellite as calibrator, Cygnus A and sun were observed. Their images were obtained at corresponding frequency. An observation of sun on Jan. 2014 at 5:15UT was shown in fig. 3.

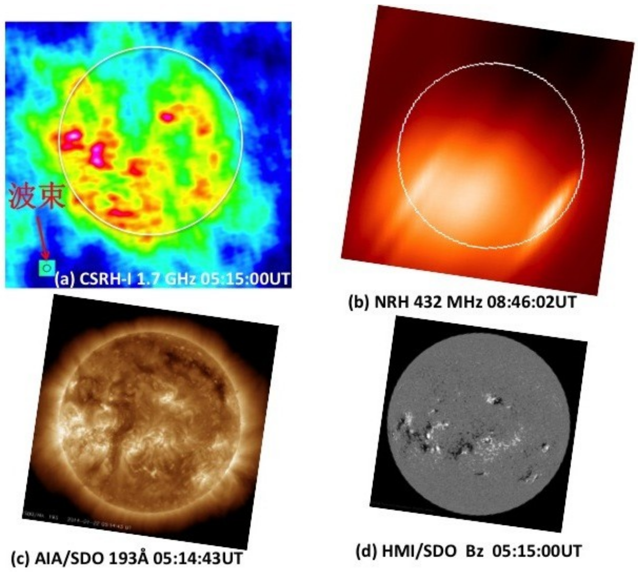

Fig.3 top left is CSRH-I observation of quiet sun with 60ms integration time on Jan. 2014 at 5:15UT, frequency is 1.7025GHz; top right is image observed by Nancay radioheliogpraph. Bottom left is image by AIA/SDO and bottom right is image by HMI/SDO.

Conclusion

Radio imaging spectroscopy is in its infancy and will open new observational windows on flares and CMEs, it will also provide coronal magnetograms. To reach this goal, CSRH project has been funded and construction was completed by the end of 2013. Calibration including antenna position measure, delay measurement, phase closure, polarization measurement has been carried out. For the test observations, the phase fringes for all baselines have been obtained; images of sun and Cygnus A have been observed. It is still for calibration and verification and it is expected to obtain solar maps in whole frequency band soon.

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