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The Chinese Spectral Radioheliograph—CSRH

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Abstract A new Chinese radioheliograph project (CSRH) at multiple frequencies in the decimetric to centimeter wave range with ~100 antennas of 2–5 m is proposed. A prototype study of 2-element interferometer was tested for overall design. The site survey for the CSRH array is carried out and a radio quiet region in Inner Mongolia of China appears promising. As a first step, the CSRH in decimetric wave range with 40 antennas of 4.5 m is proposed. The progress about the project is introduced.

Keywords Solar corona · Solar radio emission · Instrumentation · Radio interferometry · Radioheliograph · Space weather

1 Introduction

The solar activities such as coronal mass ejections (CMEs), flares, and solar energetic particles (SEPs), etc., have great influence in the space weather studies. These activities are believed due to sudden energy release, particle acceleration, and/or transportation processes of the solar magnetic field. Radio bursts are prompt indicators of various solar activities. Therefore, radio observations provide important diagnosing tool on the related parameters, such as the magnetic field, electron density, plasma temperature, etc.

Imaging spectroscopy over centimeter and decimetric wavelength range are important for addressing fundamental problems of energy release, particle acceleration and particle transport (Bastien et al. 1998). Therefore a new instrument capable of true imaging spectroscopy, with high temporal, spatial, and spectral resolutions is required to meet this end (Gary and Keller 2004). The Chinese solar physics community had long been wishing to build a radioheliograph. Some pre-studies were carried out on proposals for radioheliograph in either centimeter-band (Hu et al. 1984) or millimeter-band (Fu et al. 1997), but none of

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these had been implemented. Following these lines, it was suggested to build a Chinese Spectral Radioheliograph (CSRH) in the decimetric to centimeter-wave range with a limited budget in the next few years (Yan et al. 2004). A prototype study of 2-element interferometer has been built and tested for overall design. The site survey for the CSRH array is carried out and a radio quiet region in Inner Mongolia of China appears promising.

2 CSRH SYSTEM

In order to understand the coronal dynamics, there is a strong need to have high spatial, temporal, and spectral resolutions in radio observations with CSRH or FASR (Bastian 2003; Vilmer 2006; Benz in press). The proposed specifications for the CSRH, as driven by scientific requirements, are shown in Table 1 (Yan et al. 2004). The system block diagram is shown in Fig. 1.

Table 1 The specifications of CSRH

Frequency range	$\sim$0.4–15 GHz (λ: $\sim$75–2 cm)
Frequency resolution	64 or 128 chan (I: 0.4–2 GHz)
	32 or 64 chan (II: 2–15 GHz)
Spatial resolution	1.3″–50″
Temporal resolution	$\sim$ < 100 ms (0.4–15 GHz)
Dynamic range	30 db (snapshot)
Polarizations	Dual circular L, R
Array	(40 $\times$ ϕ4.5 m + 60 $\times$ ϕ2m) parabolic antennas
Lmax	3 km
Field of view	0.6°–7°

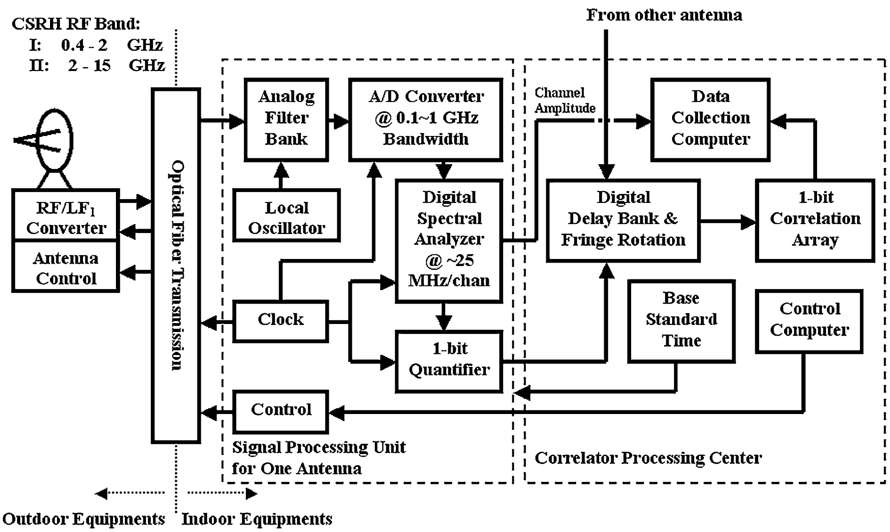

Fig. 1 CSRH System block diagram

2.1 Outdoor Equipments

As shown in Fig. 1, the outdoor equipments include antennas, wide-band feeds, LNAs, optic transmitters, optic fibers, control units, as well as power supplies, etc. It is considered that the RF signal in 0.4–15 GHz will be divided into 0.4–2 GHz (CSRH I), and 2–15 GHz (CSRH II) bands. The bands are then transmitted to the indoor unit by optical fibers. The array configuration is chosen as a self-similar spiral geometries and the design and development for wide-band feeds have been carried out with the performance evaluated (Wang et al. 2006). We have analyzed the blocking effect when two antennas are aligned in either east-west or north-south direction. It can be expected that about 8–10 h can be elapsed for observations in a day.

2.2 Indoor Equipments

The indoor equipments include optic receivers, analogous receivers, A/D converters, digital correlation receivers, LOs, monitors, computers, etc., as shown in Fig. 1. The signal of each band will be processed digitally. We plan to use a filter bank of 100 MHz (or up to 1 GHz) range for analog/digital converting. The sampled signal then go through a digital spectral analyzer of 4 (or 8) channels with 25 (or 12.5) MHz being bandwidth of each channel for CSRH I. Then we will correlate signals at a frequency point within each channel. For whole frequency coverage we will repeat above procedure. Therefore, we have repeating times and the whole channels. The signal from each 25/12.5 MHz but at a point frequency ($\sim$5 MHz) will be correlated with signals from other antennas. The delay compensation bank is estimated to be in the range of 10^4 with step of $\sim$1 ns. The number of complex correlators is 40(ant.) $\times$ 39/2 $\times$ 5(ch.) = 3,900 for CSRH I and 60(ant.) $\times$ 59/2 $\times$ 5(ch.) = 8,850 for CSRH II.

3 Prototype Study and Site Survey

The 2-element prototype system includes three 4.5 m antennas, 2 sets of 1.2–1.8 GHz feeds, LNAs, optical transmitters, optical fibers, optical receivers, RF receivers, and a digital correlator receiver. The experiment for short baseline of 8 m and long base line of $\sim$1 km had been done at Miyun Radio Astronomical Station of NAOC to validate the key technology design. Figure 2 shows the fringe variation obtained by the prototype experiment on 8 July 2005 when observing the Sun with 8 m baseline. For the experiment we have simultaneous 64 delay channel outputs within $\pm$80 ns shift in order to analyze the results. The deduced phase change of the visibility and the comparison with the theoretic results are also shown. It can be seen that the observed results are very promising, validating the development and the design of the prototype system.

The site survey for future location of the CSRH array is carried out and a radio quiet region in Inner Mongolia has been monitored. At moment the radio interference at the site is very low and it is expected to be protected for the CSRH project.

4 Summary

A radioheliograph with high temporal, spectral and spatial resolutions has been proposed. The key technology studies for CSRH have been conducted. The site survey and RFI

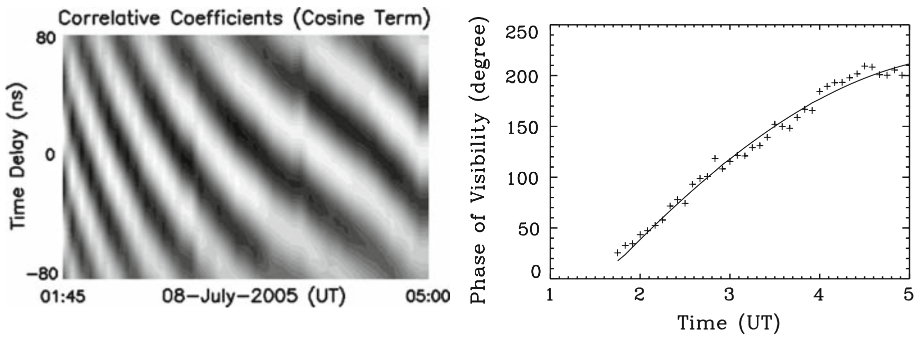

Fig. 2 *Left panel*: Observed fringe variation at an cadence of ~5-min with 8 m short baseline. *Right panel:* The phase change of visibility versus time deduced from the left panel data (plus symbols) and the theoretic curve (the solid line).

monitor for the CSRH array have been carried out. CSRH will play an important role in solar physics and space weather studies.

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