The Prototype Experiments of Chinese Spectral Radioheliograph

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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 2-5m is carrying out in China. A prototype study of two elements has been carried out for CSRH overall design since 2004. This paper described the prototype system and some observed results.

1. Introduction

Imaging spectroscopy over centimeter and decimetric wavelength range are important for addressing fundamental problems of energy release, particle acceleration and particle transport (Bastian 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 & 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 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).

The CSRH will be a solar-dedicated radio interferometric array that will be optimized to carry out imaging spectroscopy of the Sun, to produce high spatial resolution (maximum 1.3”), high time resolution (<100ms) and high frequency resolution (about 1%) images of the Sun simultaneously at a wide range of frequencies (Yan et al., 2004).

A prototype study of two elements has been carried out for overall design since 2004 at Miyun radio observation station of NAOC.

2. Description of prototype instrumentations

The prototype system includes two 4.5m antennas, LNA (Low Noise Amplifier), Optical transmitter, Optical fiber, optical receiver, radio frequency receiver and digital correlator receiver.

The two antennas are in the E-W direction and the baseline is 8 m. The element antenna is an equatorial mounted mesh type parabolic dish with f/d ratio of 0.40. The left- and right-handed circular polarization signals are received by ANSERLIN (Annular Sector, Radiating-Line) feed in 1.2-1.8GHz range mounted at the prime focus of each dish. LNA with noise figure <1.5dB, gain ~48dB, gain stable$\pm$1dB and VSWR<1.2 in the above frequency range is connected to left-handed circular polarization port of feed. Optical transmitter and LNA are installed in a front-end box. The optical signal from each antenna is transmitted to the observation building located at a distance of 150m from antennas through a 200m long, phase-stable optical fiber. The outputs from optical receiver come into radio frequency receiver in observation room. The amplified RF signal is mixed with two local oscillator signals, then down-converted to a single sideband IF signal (10-200MHz). These signals are digitised using an 8bits, 400Msps digitizier, and then pass through a digital filter bank. These digital signals were recorded in disk after A/D conversion so that we can process them in different ways (such as different bits quantization, frequency channelization method, et.al.). Also, we can prove the result of correlator by processing the recorded data. Simultaneity, the signal come from each channel is mixed with different numeric local oscillator signal. Two channels of the correlator system are used in the prototype test. The signals from the two channels pass through delay lines and correlated with one-bit, two-level quantization. In delay adjustment unit, we have simultaneous 64 delay channel outputs within ±80 ns shift in order to analyze the results. We didn't insert fringe stopping device because of high enough sample frequency. In addition, if we need, we can add fringe stopping in data processing. This is one reason we recorded full-resolution data after A/D conversion.

The block diagram of this receiver system was shown in Figure 1.

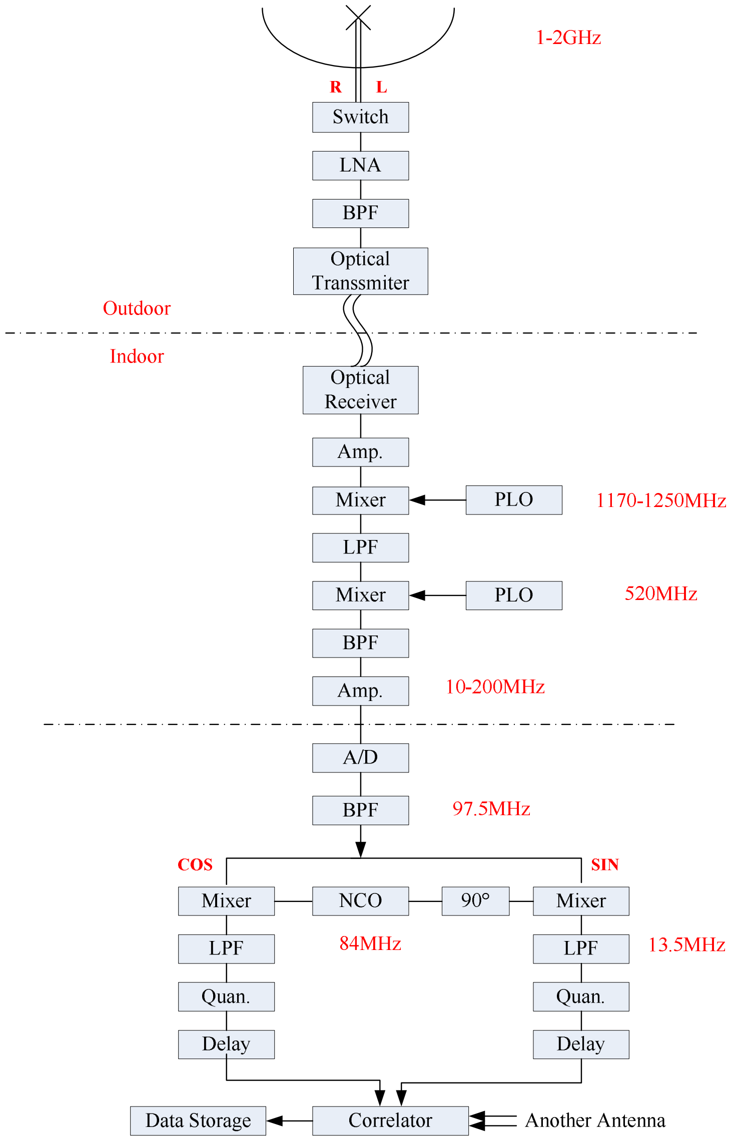

Figure 1, block diagram of prototype system

3. Observational results with two-element system

3.1 Observation of weather satellite

Before observing the sun, observation of weather satellite was carried out with two elements array at Miyun radio observation station (longitude 116.977° E, latitude 40.558° N) during July 2005.

The observing frequency was 1687.5MHz, and bandwidth was 5MHz. The first fringe was obtained by observation of satellite. We obtained very good correlated coefficient (>0.9) because the signal came from satellite is strong, compact enough and the satellite can be treated as a point source. This result corresponded well with theoretical analysis.

3.2 Observation of the quiet sun

We performed two days observation of the quiet sun using CSRH prototype system. The sun was tracked from 4:59UT to 7:49UT on July 7 2005, and observed data was recorded per 10 minutes. The other observation started at 1:45UT and ended at 5:00UT on July 8 2005, data was recorded per 5minutes.

Observed fringe obtained in the sun observation was shown in figuer2. Figure 2 described why the frequency of observed fringe is so low.

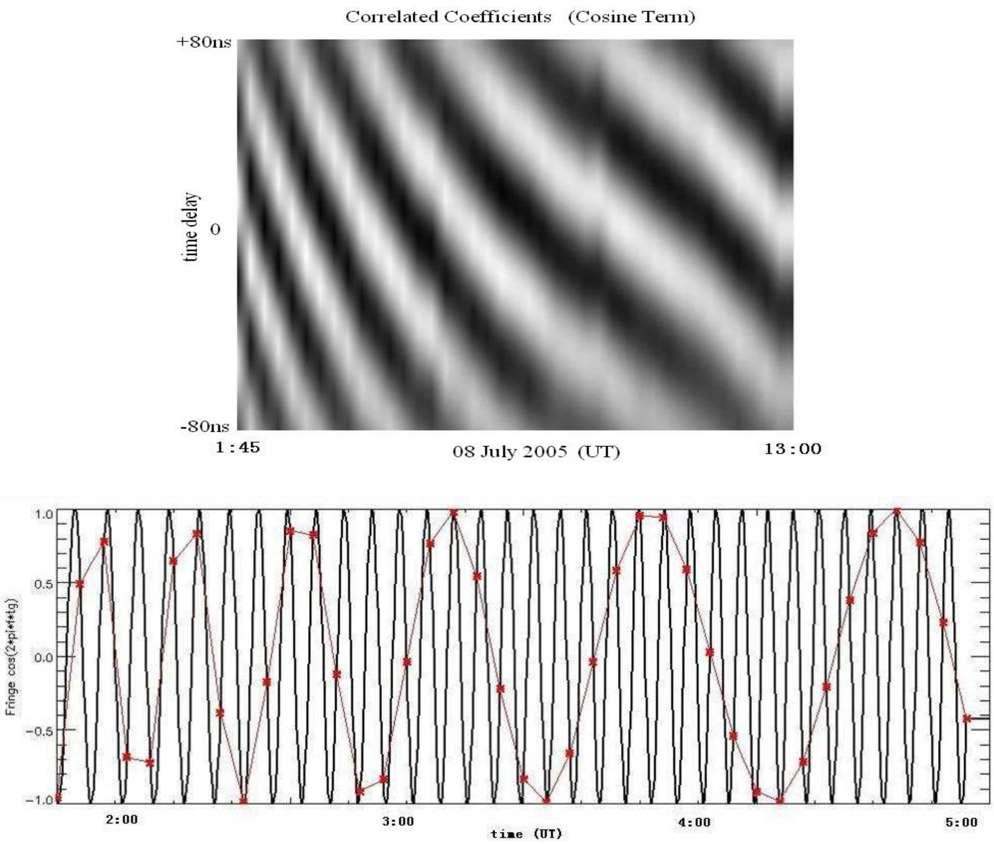

Figure 2, *Up panel:* Observed fringe variation in 64 channels at a cadence of ~5min with 8m short baseline.

Down panel: Simulated fringe without fringe stopping, red curve is fringe at a cadence of ~5min.

Generally, the quiet sun can be assumed as a uniformly bright disk in radio astronomy. Therefore, Fourier transform of uniform disk, which can be named as visibilities in interferometry, can be easily computed.

So, we computed the visibilities as the theoretical value to estimate observation of the sun with 2-element interferometer. In CSRH prototype experiments, correlated coefficients we observed is about 0.6~0.7. This value is in good agreement with the theoretical values.

As we all know that phase error is more important than amplitude error in modern interferometers, and phase errors are the dominant cause of poor imaging [Perley, 1999]. Also, phase error is hard to estimate in CSRH prototype system although we took observation of satellite as calibration data to correct system error.

If the sun is quiet in our observed duration, the difference between phase center of the 2-element interferometer and center of the sun is dominant cause of phase error. Furthermore, antenna position errors and pointing error must be considered in these experiments.

So, theoretical phase can be calculated according to observing time, observing site, source position if the errors (include antenna position error and pointing error) were assumed. Also, phase of visibilities can be derived from observed data. The difference between theoretical phase and observed phase is shown in Figure 3.

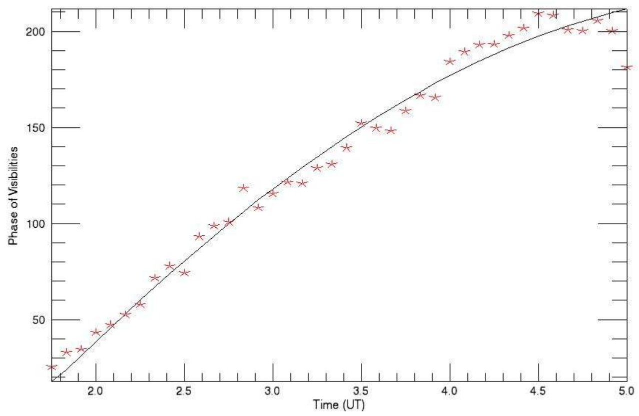

Figure 3, the phase change of visibility versus time deduced from observed data (star symbols) and the theoretic curve (the solid line) on 8 July 2005.

4. Summary

The prototype experiments of CSRH in L band have been successfully performed in 2005. All observed results are good agreement with theoretical values. There are some errors in receiver system, especially in antenna unit, although we design it carefully. But, these errors are predictable and can be estimated in data processing. Therefore, we think the errors in CSRH prototype system are reasonable.

Acknowledgments

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