REAL TIME SOLAR IMAGE PROCESSOR (RSIP) 
FOR THE $\lambda$ 8-cm RADIOHELIOGRAF AT TOYOKAWA

Masanori Nishio, Yoshio Tsukiji, Shoji Kobayashi 
Kiyoto Shibasaki and Shinzo Enome 
Toyokawa Observatory, Research Institute of Atmospheres, 
Nagoya University, Toyokawa, Aichi 442

Abstract

A description is given of the Real-time Solar Image Processor (RSIP). The system is a new back-end processor for the $\lambda$8-cm radioheliograph. By the introduction of the RSIP, the $\lambda$8-cm radioheliograph is changed from the swept-lobe type to the multi-correlator type. The RSIP can synthesize two-dimensional and one-dimensional images of the radio sun at the rate of 0.1 s/image and displays them in real time.

1. Introduction

The $\lambda$ 8-cm radioheliograph at Toyokawa has been operating since 1975 (Ishiguro et al., 1975). This system is a multi-element interferometer with T-shaped array of 3-m diameter paraboloids, which consists of 32+2 elements on the east-west baseline and of 16+2 elements on the north-south baseline. The baseline length is 437 m in the east-west direction and 217 m in the north-south direction, and the fundamental antenna spacing is 6.88 m. This system gives us two-dimensional brightness distributions of the radio sun and also one-dimensional east-west and north-south distributions with higher spatial resolution than two-dimensional observation. In this system, it takes about 40 s to obtain a two-dimensional image and 10 s to obtain an one-dimensional image.

In order to observe the radio bursts of fast time variation, we planned to improve the time resolution of the 8-cm radioheliograph, and a project to adapt the Real-time Solar Image Processor (RSIP) to this system has been started in 1983. By this improvement, it is possible to obtain two-dimensional and one-dimensional solar images at the rate of 0.1 s an image. Therefore, the time resolution is improved 400 times for the two-dimensional image and 100 times for the one-dimensional image. The RSIP consists of six parts, which are third IF, A/D converter, correlator, Fourier transformer, data storage system and image display. Presently, these parts have been installed and some experiments to check the performance of these parts are in progress. In this paper, we describe the outline of the RSIP.

2. Design principle and performance

The RSIP is designed to satisfy the following two requirements;
(1) to improve the time resolution of the $\lambda$ 8-cm radioheliograph up to 0.1 s/image without sacrificing the sensitivity, and
(2) to produce the solar images in real time.

In order to improve the time resolution, all correlations necessary to make an image and the correlation for the phase calibration are measured
in parallel. As a result, 1308 correlations are obtained simultaneously.
In order to produce the image in real time, the Fourier transform which
is used to obtain the solar images from the correlation data and some
arrangements to display the images are performed by hardware. In the
RSIP, the correlation data are recorded at the rate of 0.1 seconds an
image and the image data are displayed on a graphic terminal at the rate
of 10 seconds an image.

The frequency conversion of the input signal to the base-band signal
is performed by the double sideband mixer because it is possible to
perform the delay tracking and the phase tracking independently
(O'Sullivan, 1976). The correlators used in the RSIP are of one-bit type.
They are relatively insensitive to the amplitude variation of the input
signals and have a wide dynamic range to the amplitude. Therefore they
are suitable for the solar observations where large amplitude variations
occur comparing with that of the cosmic sources. The one-bit correlation
data can be converted to multi-bit correlation data by the Van Vleck's
correction (Van Vleck and Middleton, 1966). The expected performance of
the radioheliograph after this improvement is listed in table 1.

3. Outline of the system

The block diagram of the $\lambda$ 8-cm radioheliograph with the RSIP is
shown in figure 1, where the RSIP is enclosed by a dash-dotted line. The
outputs of the second IF of the radioheliograph system are fed into the
RSIP. At the third IF, input signals are amplified and frequency-

---

**Table 1. Performance of the $\lambda$ 8-cm radioheliograph with the RSIP.**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observation frequency</td>
<td>3748.5 MHz (center frequency)</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>10 MHz</td>
</tr>
<tr>
<td>Observation time</td>
<td>meridian transit time + 3 hours</td>
</tr>
<tr>
<td>Field of view</td>
<td>40 arc min x 40 arc min</td>
</tr>
<tr>
<td>Observation mode</td>
<td>two-dimension</td>
</tr>
<tr>
<td>(Parallel obs.)</td>
<td>east-west one-dimension</td>
</tr>
<tr>
<td></td>
<td>north-south one-dimension</td>
</tr>
<tr>
<td></td>
<td>(phase error measurement)</td>
</tr>
<tr>
<td>Spatial resolution</td>
<td>2.5 x 2.5 arc min (two dimension)</td>
</tr>
<tr>
<td></td>
<td>38 arc sec (EW one dimension)</td>
</tr>
<tr>
<td></td>
<td>1.25 arc min (NS one dimension)</td>
</tr>
<tr>
<td>Max. time resolution</td>
<td>0.1 sec/2 maps (R and L polarization maps) #1</td>
</tr>
<tr>
<td>Minimum detectable flux density</td>
<td>0.08 s.f.u. (two dimension) #2</td>
</tr>
<tr>
<td></td>
<td>0.2 s.f.u. (EW one dimension)</td>
</tr>
<tr>
<td></td>
<td>0.3 s.f.u. (NS one dimension)</td>
</tr>
<tr>
<td>Polarization</td>
<td>R and L circular polarizations (time sharing by polarization switches)</td>
</tr>
<tr>
<td>Display speed</td>
<td>real time(10 s/image)</td>
</tr>
</tbody>
</table>

#1 greater than 40 s/image (two-dimension)
and 10 s/image (one-dimension) in the original system.

#2 1 s.f.u.(Solar Flux Unit)=$10^{-22}$ W m\(^{-2}\) Hz\(^{-1}\)
converted to base-band signals. This part consists of 52 modules corresponding to the number of the input channels. Each input signal is converted to two base-band signals orthogonal each other in order to obtain the real and the imaginary parts of the spatial frequency components simultaneously. The total gain in this part is 40 dB, and the output signal level of about -7 dBm can be obtained even when the solar activity is very low, which is corresponding to 0.1 V rms for 50-ohm output impedance. The bandwidth of the output base-band signal is 5 MHz.

Fig. 1. Block diagram of the λ 8-cm radioheliograph with the RSIP.
The 3rd IF is installed near the phase center of the antenna array, and other five parts of the RSIP are placed in the observation building about 200 m apart from the phase center. The output signals of the third IF are transmitted to the A/D converters through coaxial cables. At the A/D converter, the base-band signals are sampled and digitized to one-bit signals. The sampling frequency is twice the Nyquist sampling rate, that is 20 MHz. By two-times oversampling the degradation factor for the one-bit correlation can be decreased by 14% comparing with regular sampling (Bowers and Klingler, 1974). A level regulation circuit using the phase-locked loop (PLL) is attached to each A/D converter module in order to compensate the drift of the threshold level of the comparator (O'Sullivan, 1980). The relative propagation delays among the received signals are equalized at this point. The equalization of the delay is performed combining two types of digital delay lines, one is the fine step delay line with a delay step of 10 ns and the maximum delay time of 40 ns, and the other is the coarse delay line with a delay step of 50 ns and the maximum delay time of 1050 ns. The former has a function to shift the timing of sampling and the latter gives the delay to the sampled data. At the correlator, these one-bit digital signals are cross-correlated to obtain spatial frequency components of two-dimensional and one-dimensional solar images. This part consists of 2616 pre-scalers and a integration unit. Each pre-scaler is made by an exclusive OR circuit and a 16-bit binary counter. In the pre-scalers, one-bit correlation data with the integration time of 3 ms are produced. These data are read out through a bus-line in sequential manner and transmitted to the integration unit. The integration unit is made by a 12-bit adder, two RAM buffers and a Van Vleck correlation circuit. The output data of the pre-scalers are integrated for 0.1 s in this unit. The solar images are obtained by the Fourier transform of the output data of the correlators. T-shaped array samples spatial frequency components at Cartesian grid point, which is convenient to perform the Fast Fourier Transform (FFT). The solar images are displayed on a graphic terminal in order to monitor the solar activity in real time. On the other hand, the correlation data are stored on the data storage system for the off-line analysis. The correlation data is obtained at the rate of 60 kbytes/s and the total amount of the data is 1.3 Gbytes for 6 hours. We will reduce the amount of these data up to one reel of magnetic tape a day by adjusting the rate of data storage according to the solar activity.

References