

SPECTRAL POLARIMETRIC OBSERVATIONS OF THE SUN BY THE VIRAC RT-32 RADIO TELESCOPE: FIRST RESULTS

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Received: 2012 November 13; accepted: 2012 November 28

Abstract. The article describes microwave observations of the Sun with the radio telescope RT-32 of the Ventspils International Radio Astronomy Center. The observations were performed using a multichannel spectral polarimeter for the 6.3–9.4 GHz frequency range. A set of 2D microwave emission maps of the Sun for the Stokes I and V parameters has been obtained and analyzed.

Key words: Sun: radio emission – instrumentation: polarimeters

1. INTRODUCTION

The very first observations of the Sun were realized with the radio telescope RT-32 of the Ventspils International Radio Astronomy Center (VIRAC) in 1998–1999 (Ozolinsh et al. 1998). A number of 2D solar microwave emission maps at the 2.5 cm wavelength have been obtained and the observations of active regions during the solar eclipse of 1999 were made. The main goal was to test technical abilities of the radio telescope after its restoration. These observations approved that this radio telescope has broad prospects to become a significant observational facility of the Sun allowing to solve many tasks of solar physics.

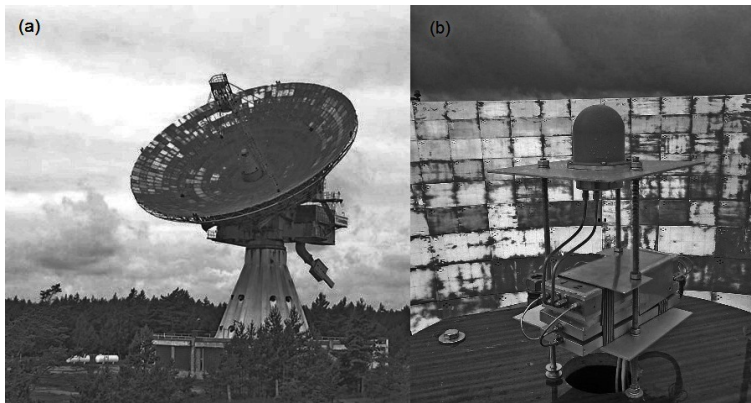


Fig. 1. Left panel: the VIRAC radio telescope RT-32. Right panel: the wide-band feed and UHF part of the spectral polarimeter installed in the secondary focus of the antenna.

The observational session of the Sun using the new multichannel spectral polarimeter was performed in July 2012. The equipment installed has the capability to observe simultaneously left and right circular polarizations of the solar microwave emission at 16 closely adjacent frequency bands within the range of 6.9–9.3 GHz (3.7–4.2 cm). As a result, a set of 2D maps for the Stokes I and V parameters of the solar microwave emission has been obtained.

2. INSTRUMENTATION

The radio telescope has been equipped with a set of wide-band feed, a multichannel spectral polarimeter and a software registration system (Figure 1). The wide-band feed has two flat helix antennas inside and is expected to receive left and right circular polarizations of microwave emission at 2–18 GHz frequency range.

The spectral polarimeter is assumed to be used for solar observations in order to solve modern problems of solar physics. Its frequency range is meant for observations of the microwave emission of the chromosphere – corona transient region and a lower corona. The separation of the frequency range into rather narrow bands allows to obtain a fine spectrum. This spectral polarimeter was designed and produced at the Special Astrophysical Observatory (SAO), Russia. It is very similar to the instrument working at the radio telescope RATAN 600 (Bogod 2011; Bogod et al. 2011).

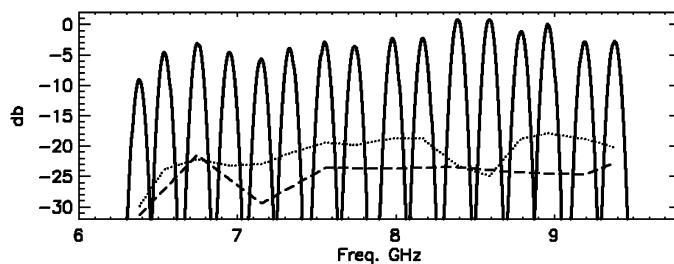


Fig. 2. Relative frequency response of the spectral polarimeter bands (solid lines), cross polarization interferences (dashed line) and system noise referred to antenna temperature of the quiet Sun (dotted line).

The UHF unit of the spectral polarimeter has the input switch for left and right circular polarizations, an internal calibration load, two frequency converters, a set of 16 band filters and quadratic detectors. The control unit of the spectral polarimeter has a set of fast A-to-D 24 bit converters and performs a multiplexing of input UHF and output LF signals during the cycle of measurements. The sampling frequency of measurements can be up to 100 Hz and each sample of the measurement consists of 32 subsamples. The information collected is sent periodically to the client application via LAN. So the spectral polarimeter provides a simultaneous measurement of antenna temperatures of solar microwave emission for both circular polarizations in 16 frequency bands.

Some frequency characteristics of the spectral polarimeter are presented in Figure 2. The set of band filters is used for both polarizations, so the frequency response of both polarization channels is the same. The system noise and cross polarization interferences are different from band to band but on the average do not exceed -20 db. Detectors of bands have the time constant less than 0.05 s. Ampli-

tude characteristics of bands are sufficiently linear and have a sufficient dynamic range for correct observations of local sources of the Sun. Other main parameters of the spectral polarimeter are: the frequency range 6.3–9.4 GHz (3.7–4.2 cm), the width of sub-band (half power) 80–100 MHz, the dynamic range (referred to antenna temperature of the quiet Sun) 24.2–30.9 db, the antenna pattern HPBW for VIRAC RT-32 5.2–3.5 arcmin. The software registration system receives and saves the samples of antenna temperature measurements to the file. Simultaneously it obtains and saves the precise time of each sample and the antenna position. The frequency of sampling is about 10 Hz.

3. OBSERVATIONS AND RESULTS

For obtaining 2D maps of the solar microwave emission the azimuthal scanning was used. During the scan the antenna moved azimuthally with the constant angular speed at the constant elevation. Each scan was sequentially shifted to the elevation from the center of the Sun by a half of the antenna pattern width. One full solar map observation consists of 30–32 scans and takes about 2 hours.

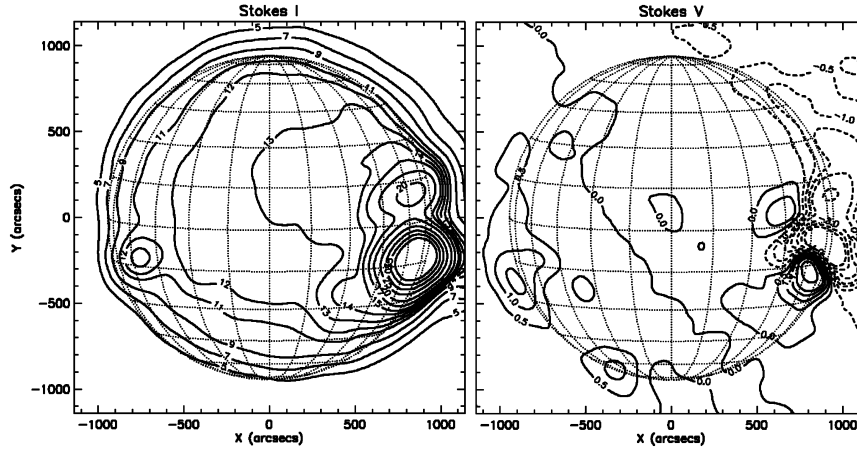


Fig. 3. Stokes I and V parameter maps of solar emission at 3.76 cm wavelength on 2012-07-17 UT 7:15. Levels are presented in 10^3 K. Solid lines on the Stokes V map are for right polarization, dashed lines are for left polarization.

The algorithm of 2D map construction consists of the recalculation of horizontal coordinates of each sample to heliographic ones and composition of the regular grid of the Stokes I and V parameters.

Preliminary selected areas of the quiet Sun near the disk center were used for the brightness temperature calibration of the maps taking into account the known brightness temperatures of the microwave emission of the quiet Sun (Borovik et al. 1992).

Figure 3 presents a very typical example of ‘dirty’ Stokes I and V maps obtained. One can clearly see the polarized emission of the active regions NOAA 11519–11525 and a lot of artifacts as a result of the map composition procedure and antenna properties. As a set of simultaneous maps of the Sun at closely adjacent wavelengths has been obtained, a comparison of these maps is important

in order to evaluate a similarity of spectral polarimeter channels and the fidelity of the map composition algorithm. Figure 4 shows a number of Stokes I maps observed at different wavelengths and during close time period. This set of maps demonstrates the correct behavior of the channels for the quiet Sun and local sources.

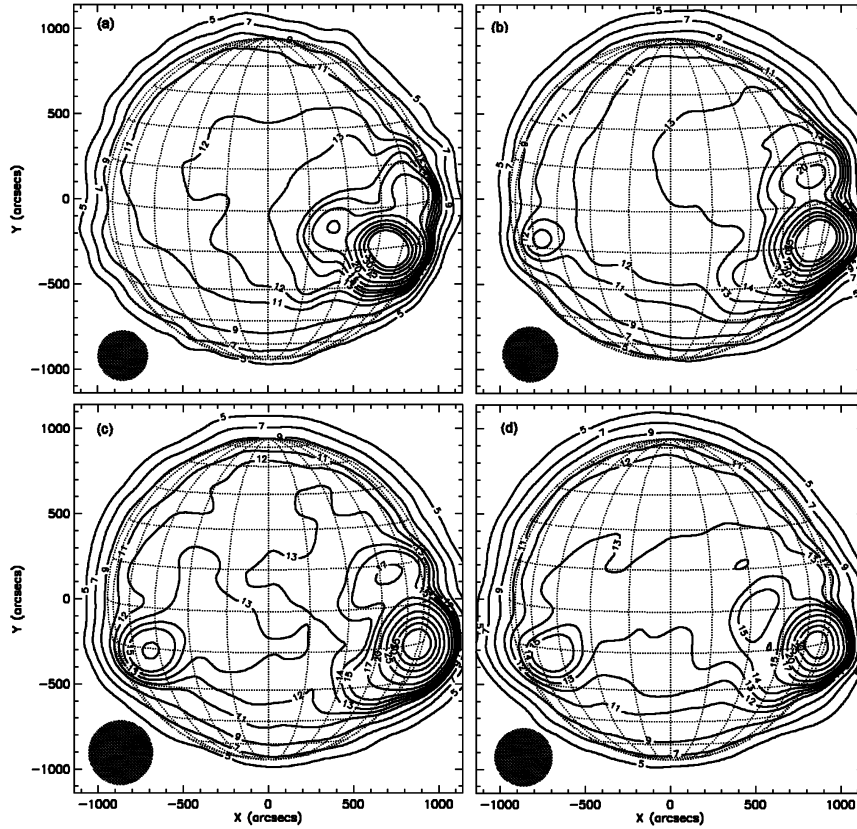


Fig. 4. Stokes I parameter maps of solar emission (a) at 3.41 cm on 2012-07-16, UT 14:18, (b) at 3.76 cm on 2012-07-17, UT 7:15, (c) at 4.44 cm on 2012-07-17, UT 9:10 and (d) at 3.97 cm on 2012-07-18, UT 13:30. Levels are presented in 10^3 K. Dark spots present the antenna pattern HPBW at the corresponding wavelengths.

The comparison of the ‘dirty’ Stokes I map of NOAA 11519–11521 group with the similar ‘cleaned’ maps obtained with of the Nobeyama Radio Heliograph (NoRH) and the Siberian Solar Radio Telescope (SSRT) at the same scale during the same time is shown in Figure 5. Obviously one can see that the results of solar observations are adequate but correct revelation of local sources needs a serious processing.

Since an antenna pattern size eliminates the common angular resolution of the map, a correct determination of local sources requires the initial distribution of solar emission brightness temperatures to be recovered. In addition, the antenna pattern of the VIRAC radio telescope RT-32 has the irregular side lobes caused

by some disadjustment of the secondary mirror (Abele et al. 2004). This disadjustment has not been corrected yet, and it has to be taken into account. The analysis of the features and the behavior of known recovering and ‘cleaning’ methods applied to solar maps shows that the generalized maximal entropy method is most suitable for the correct revelation of large-scale solar structures and small local sources even for this irregular antenna pattern (Bezrukov et al. 2009).

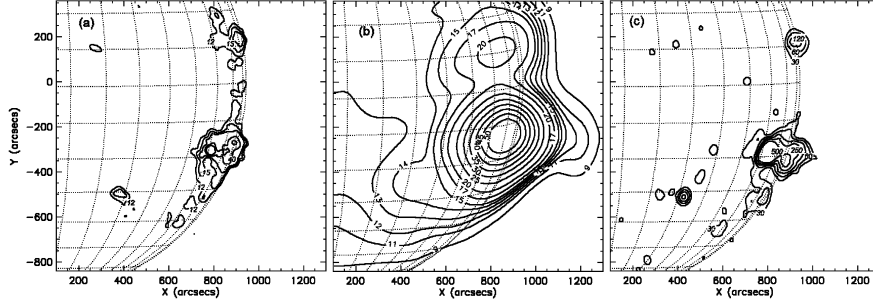


Fig. 5. The Stokes I parameter maps of NOAA 11519–11521 obtained with (a) NoRH at 1.76 cm on 2012-07-17 UT 6:05, (b) VIRAC RT-32 at 3.76 cm on 2012-07-17 UT 7:15, (c) SSRT at 5.2 cm on 2012-07-17 UT 2:44. Levels are presented in 10^3 K.

Taking into account system noises and cross polarization interferences of the spectral polarimeter, the precision of measurements of the antenna temperatures could be evaluated as 1% without processing of the ‘raw’ data and much better after it. A possible geometrical distortion of the map caused by measuring errors and the discretization of the antenna position sensors is negligible. The whole map could be shifted spatially to compensate the zero shifts of the antenna position sensors.

4. DISCUSSION AND CONCLUSION

The main purpose of the described solar spectral polarimetric observations was to test the used reception equipment, the methods and procedures of observations, the ‘raw’ data processing procedure and the algorithm of composition of microwave emission maps of the Sun. It is obvious that this goal is achieved, and the capability of VIRAC radio telescope RT-32 to perform adequate and valuable spectral polarimetric observations of the Sun has been approved.

A possibility of the VIRAC radio telescope to obtain a set of 2D maps at a number of closely adjacent wavelengths is significant and valuable for a common survey of the spatial locations and spectral behavior of solar local sources and large-scale structures. Taking into account a limited angular resolution of a ‘single dish’ radio telescope, the most effective observations of large-scale structures on the Sun are expected. The list of feasible tasks of solar physics to be solved on the base of spectral polarimetric observations on RT-32 have been discussed earlier (Bezrukov & Ryabov 2009). One of such tasks is the analysis of active regions associated with large isolated sunspots (Bezrukov et al. 2011). Spectral polarimetric observations of active regions of this kind could now be performed. A set of closely adjacent frequencies of the spectral polarimeter is an evident advantage for the observations of the fine spectral structures for revealing and analyzing of some possible current sheets of solar active regions (Kaverin et al. 1980).

Routine spectral polarimetric observations by means of VIRAC radio telescope RT-32 will give us more valuable information about the microwave emission of the Sun.

ACKNOWLEDGMENTS. This work is supported by the Latvian Council of Science, grant 11.1856

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