OVRO Solar Array Upgrades in Preparation for MAX 2000

Dale E. Gary
Center for Solar Physics, New Jersey Institute of Technology, Newark, NJ, USA
E-mail: dgary@njit.edu

and
Gordon J. Hurford
Space Sciences Lab, UC Berkeley, Berkeley, CA, USA

Abstract

Several significant changes to the OVRO Solar Array are underway in preparation for the coming solar maximum in the year 2000. The array currently consists of 5 antennas with a maximum baseline of about 670 m. By mid-2000, two additional antennas will be operating, with a maximum baseline of about 1250 m, nearly doubling the spatial resolution (to $5''$ at 10 GHz). The number of baselines recorded typically during the previous solar maximum was 7. A new data system, coupled with the additional antennas, will allow us to record 21 baselines for a factor of three improvement in imaging. The new data system, which is already in place, offers many additional advantages in ease of use of the data, as well as improved calibration. In concert with the HESSI (High Energy Solar Spectroscopic Imager) team, we plan to make the OVRO data and the IDL-based analysis software widely available via the World Wide Web. The current state of these improvements is discussed.

Key words: Sun: corona — Sun: active regions — intrumentation: interferometers — radio continuum

1. Introduction

The OVRO Solar Array has undergone steady improvements during the past two solar maxima. In 1980, it consisted of a single pair of 27-m antennas that were used for interferometry at 10.6 GHz, plus total power spectral measurements using the first frequency-agile receiver. Near the end of solar cycle 21, in 1984, the array was operating as an occasional three-element interferometer (using the OVRO 40-m antenna a few weeks per year as the third element) with all three antennas equipped with frequency-agile receivers. In 1989, one additional 2-m antenna had been designed and added to the array, using the existing third receiver, for full-time three-element operation. Just after the peak of solar cycle 22, in mid-1991, two additional 2-m antennas with frequency-agile receivers had been added, for full-time 5-element operation (Gary 1996).

In keeping with this tradition of steady improvements, additional upgrades are once again underway, to be completed by the time of the coming solar maximum in mid-2000. The main hardware improvement is the addition of two more 2-m antennas with frequency-agile receivers, for 7-element operation. However, many additional improvements are in store through a complete redesign of the computer and data system. These combined improvements will make the instrument much more powerful, user-friendly, and accessible for outside users. Here we describe the upgrade plans, current status, and the advantages that the new system will have over the present one.

2. Overview of Upgrade Plans

2.1. Hardware Upgrades

The main hardware upgrade is the addition of two more 2-m antennas to the array, bringing the total from 5 to 7. This brings the number of possible baselines from 10 to 21, but since during the previous maximum only 7 baselines (those involving at least one 27-m antenna) were recorded, the increase in number of actually recorded baselines is a factor of three. Both of the new antennas were obtained from the Solar Radio Burst Locator project (SRBL–see Hurford et al. 1996, and the paper by Hurford et al. in these proceedings), and were made available when that project changed from an equatorial design to a new, alt-azimuth mount design. Since the original equatorial design was based on the 2-m array antennas, these antennas are identical to the three 2-m antennas already in the array.

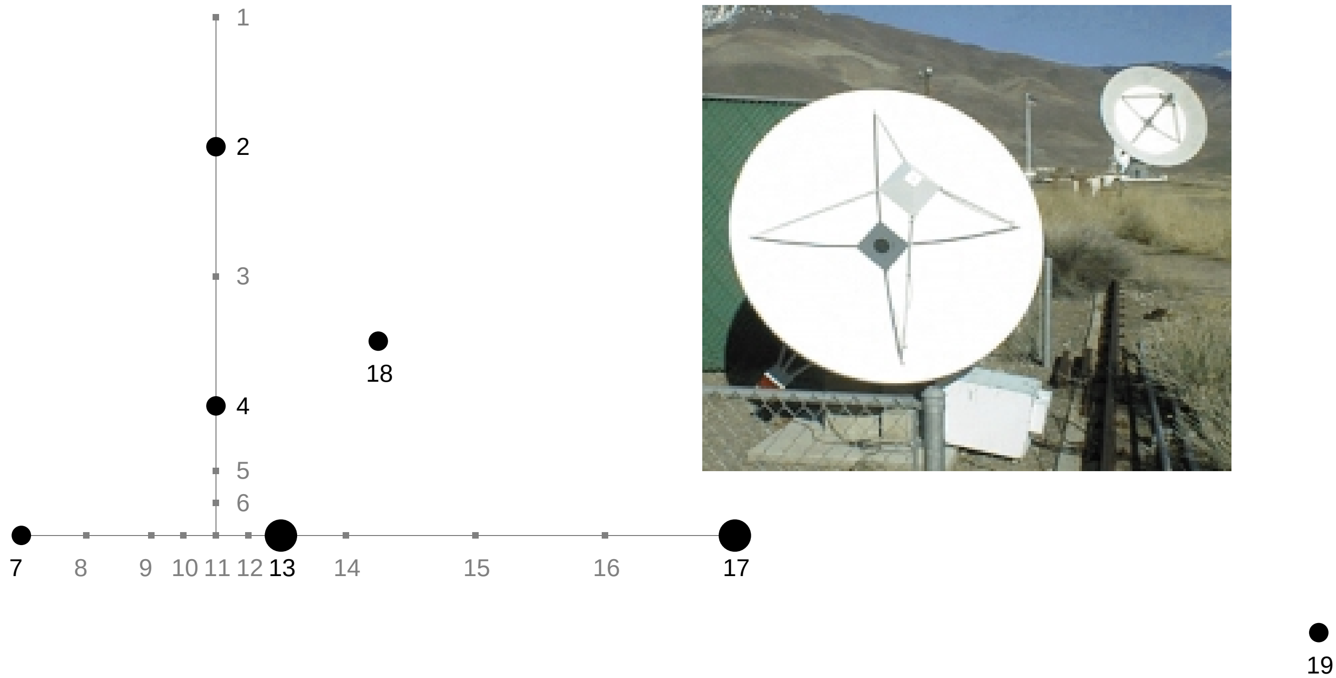

Fig. 1.. The array configuration of the current array (black circles shown at stations 2,4,7,13,17) and the sites of the two additional antennas at stations 18 and 19. The additional antennas will effectively triple the number of baselines for imaging, and double the east-west spatial resolution to 5″ at 10 GHz. The inset shows the view of the current array looking east from station 7.

The new array configuration is shown in Figure 1, where the current antennas in the array are shown along the original inverted-T rail system, and the new antennas are shown at new stations 18 and 19, well away from the rails. Station 18 gives additional small baselines for better imaging of large-scale features, while the distant station 19 doubles the east-west size of the array for a spatial resolution of 5″ at 10 GHz. Figure 2 shows the expected improvement in imaging for a model source distribution.

Additional planned hardware improvements include a phase-stabilization technique involving measurement of the round-trip phase changes in the 200 MHz reference signal between the control room and the receivers. This should allow us to essentially eliminate system phase variations, leaving only those due to the atmosphere.

2.2. Control System Upgrade

The hardware upgrades require significant new capability in the control system, to handle the additional complexity of the new antennas. A completely new PC-based computer system has been installed and has been operating since July 1998 in a hybrid mode, with the old computer still controlling the antennas and the new computer controlling the receivers and data recording. Shortly, the antenna control will be transferred to the new system as well. The control system is coded in FORTH, and uses many of the features of the SRBL system for much improved flexibility over the previous system. The advantages of the new system are:

- Allows handling of up to 8 elements (7 elements planned).
- Doubles the time resolution from 20 ms/sample to 10 ms/sample.
- Attenuation and fringe gain settings are frequency- and baseline-dependent to maximize signal-to-noise and avoid underflows, yet accomodate flux increases due to flares without saturation.
- Data are recorded to hard-disk, then transferred to CD-ROM, and are available in real time over the network.
- All instrument status is shown on a single display, with anomalies flagged in red.
- Monitoring/engineering data are recorded directly into the data stream.

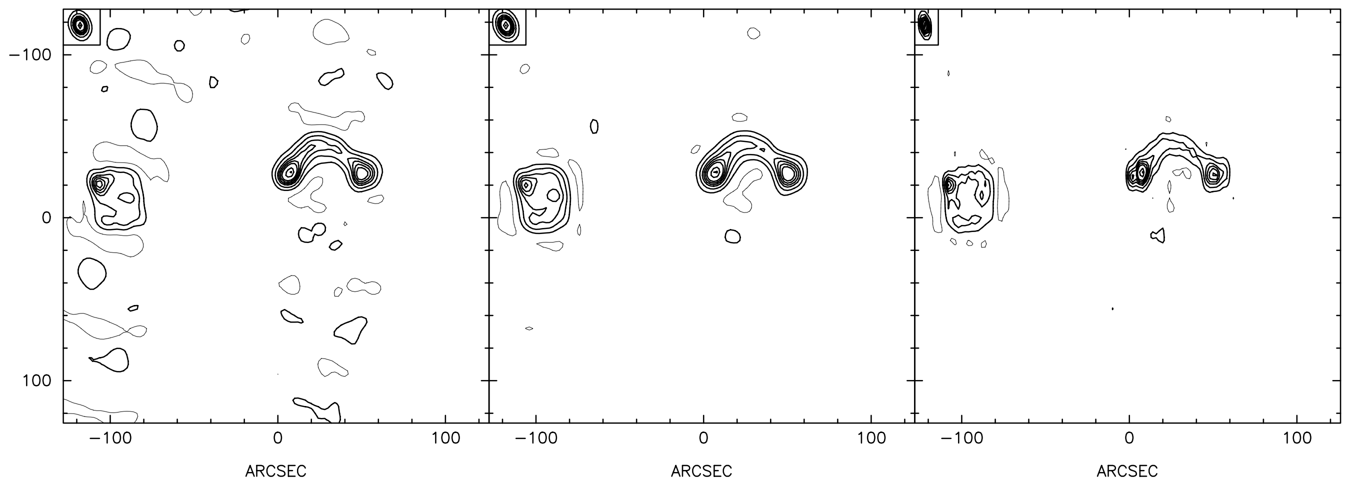

Fig. 2.. A model source sampled with *a*) the existing 5-element array, *b*) the array with one new element that adds short baselines, and *c*) the array with both new elements, for a total of 7 as planned. The 7th antenna will be about 1 km from the center of the array, for improved spatial resolution to 5″ at 10 GHz.

2.3. Data System Upgrade

Along with the control system, the data recording system and file structure has been completely redesigned. Previously, the data were recorded on magnetic tape and could not be examined in real time. Important monitoring information was either not available at all, or kept only in the form of computer hard-copy printout. There are three principle goals of the new data system: (i) to make the data easy to use and to share with the scientific community, (ii) to allow real-time monitoring of the data and the state of the system, and (iii) to make real-time data products available. Some advantages of the new system are:

- Records all baseline channels, and total power from all antennas.
- Provides for handling up to 8 elements (7 elements planned).
- Data are available in real time.
- Data files are self-contained, with all information placed within the data file for complete calibration and analysis of the data.
- Fully automated observing will be possible, for obtaining data at night (calibration data), on weekends, and other periods when no one is available on site.
- Remote control of the system for observing or system testing will be possible across the internet.
- The ultimate product of the analysis software will be a visibility file in UVFITS format, for use in AIPS or other standard software.

3. Current Status and Schedule for Completion

As of this writing, the daily data are being recorded with the new system, but the antenna control is not yet finished. The data files are not yet in final format, but the format has been fully defined and is being implemented in stages as appropriate. The initial goal is to recreate all of the capabilities of the original system, controlling 5 antennas/receivers but recording all 10 baselines. Once the computer system is successfully operating in this mode, additional capabilities including 7 element operation will be added.

The hardware development is proceeding concurrently with these software efforts. The two antennas are already in hand. The receivers are nearing completion, with all major machining and fabrication of circuit boards done. The first receiver should be ready for test by the end of the year, with the second following closely. The pad at station 18 is ready, and station 19 is now under construction. Additional cabling to both stations is needed, and we are planning to use fiber-optic cable for IF and control. To fully implement both antennas, both receiver and antenna control interfaces and additional multiplexing capability must be constructed. These items and the associated software effort should occupy us for an additional year, but by spring of the year 2000 we expect to be ready for testing the completed system. The goal is to have it working by mid-2000, near the scheduled time of launch of the HESSI mission.

Associated with these upgrades to the hardware and computer control/data system, we are also developing a data analysis package implemented in IDL, which will provide a user-friendly interface and allow even novice investigators to expertly calibrate and use the data for a set of standard data products such as total power spectra and light curves, as well as creating visibility databases for use in AIPS. We plan to include this package in the Solarsoft IDL library, and will work closely with the HESSI team (High-Energy Solar Spectroscopic Imager—Dennis et al. 1996) in defining common routines for handling the OVRO data within the HESSI software package. We have proposed to make the full OVRO database available on-line as part of the HESSI European Data Center (HEDC), so that OVRO Solar Array data and software will be a standard part of the HESSI data analysis system.

Finally, we are planning to make a number of real-time data products available on a daily basis via the World Wide Web. For example, calibrated total power spectra of bursts (or, alternatively, light curves at > 40 frequencies) will be available daily, including automatic detection and parameterization of radio transient brightenings. We will also produce a daily, interferometric active region spectral survey of each region on the disk. Such data will be available for planning of daily observations and/or observing campaigns, for which the extent of solar radio activity may provide important information that is currently unavailable. A database of such data taken over a year or more may also be useful in a statistical sense for assessing the radio spectrum as a predictor of flaring potential.

In conclusion, by the peak of the current solar maximum in mid-2000, the OVRO Solar Array will be operating as a 7-element interferometer array to produce better images and spectral diagnostics of the active and quiet corona that ever before. The data will be more flexible and better calibrated, and will be far easier to use due to the use of a self-contained data file format. The analysis software will be more complete, easier to use, and more widely available. The data itself will be widely available and completely open for anyone to use. We invite the solar community to make wide use of the data.

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