Broadband Imaging Spectroscopy with the Solar Radio Telescope

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Abstract. On 17–20 April, 1995, a workshop was held in San Juan Capistrano, California. The purpose of the workshop, which was attended by more than 40 scientists from the US and around the world, was to discuss the science that could be done with a solar-dedicated radio synthesis telescope, and to discuss the design constraints imposed by the science envisioned. Special attention was also given to nighttime uses for the instrument. We summarize the “strawman” concept for the instrument here.

1. Introduction

Using large aperture synthesis radio telescopes like the WSRT and the VLA, improved understanding of a variety of solar phenomena has been gained over the past 15–20 years. However, since these instruments are optimized for observing cosmic sources, and are in any case only available to solar observers for a relatively small amount of time each year, progress has been slow. With the upgrade of the OVRO Solar Array (Gary 1996) and the construction of the NRO radioheliograph at Nobeyama, Japan (Nakajima et al. 1993), solar-dedicated interferometric instruments are now producing valuable data on a routine ba-
sis. Nevertheless, neither instrument allows full exploitation of the information inherent in solar radio emission. What is need is a solar-dedicated broadband imaging spectrometer optimized for solar imaging over the microwave spectral band. The NRO radioheliograph operates at only one frequency (17 GHz), although it will soon be upgraded to support 34 GHz as well. The OVRO Solar Array, while frequency agile between 1–18 GHz, has only 5 antenna elements and, as a consequence, has a limited imaging capability. The time has come to consider the design and construction of a solar-dedicated array. At a recent workshop in San Juan Capistrano, California, the scientific justification for such an instrument was considered and, in light of scientific concerns, a strawman instrumental concept was developed. Details may be found in a document edited by Gary & Bastian (1995).

The instrument design calls for a frequency-agile synthesis telescope capable of performing broadband imaging spectroscopy and polarimetry on timescales of ~ 1 s. It will be composed of 3 large (~ 25 m) elements and ~ 20 small (2 m) elements outfitted with feeds and receivers operating between 300 MHz and 26 GHz. Furthermore, the large elements may be outfitted with a backend for high-time and high-frequency resolution decimetric spectroscopy.

The instrument will revolutionize solar groundbased observing. It will be the only instrument, space- or groundbased, capable of producing high-quality images of energetic and nonthermal phenomena over a broad range of energies. Phenomena for which the array will potentially have a major impact on our understanding include solar flares, erupting filaments and prominences, and coronal mass ejections. The array will also have excellent sensitivity for quiet Sun studies, including high-resolution imaging spectroscopy of the solar chromosphere, coronal magnetography in solar active regions, and high-resolution studies of the formation and evolution of filaments and prominences.

While solar-dedicated by day, the instrument will possess unique capabilities for observing cosmic sources at night, and on a “target-of-opportunity” basis during the day. The 3 large elements, which are needed for calibration of the small antennas, can be designed for cosmic work, with broadband spectral capabilities and sensitivity comparable to that of the present-day VLA. Such a three-element system would offer opportunities for longterm monitoring projects, broadband spectroscopy of transient sources (e.g., novae, active stars, scintillating sources), and a rapid response to new sources of interest (e.g., super-novae, gamma-ray bursts).

2. The Strawman Concept

The primary goal of the project is to design and construct an instrument which fully exploits solar microwave emission as a diagnostic of energetic processes on the Sun. This requires an instrument which simultaneously fulfills the requirements for i) high-dynamic range imaging; ii) arcsecond angular resolution; iii) a full-disk field of view at most frequencies; iv) good absolute positional accuracy; v) high time resolution (< 1 sec); vi) near- instantaneous spectral coverage over a broad range of frequencies (0.5–26 GHz) with moderate spectral resolution (~ 5%); vii) support of polarimetry. Discussion to date has lead to the following strawman concept:
An interferometric array composed of $3 \times 25$ m antennas and $\sim 20 \times 2$ m antennas

- Large elements for astronomical calibration, high resolution solar spectroscopy, cosmic observations; small elements for solar imaging
- $2^\prime$ angular resolution @ 20 GHz (1.5 km baseline)
- Emphasis on good brightness sensitivity (short baselines)
- Exploit frequency synthesis

Solar-dedicated during daylight hours

- Instrument calibrated before and after observing day
- Large elements available for cosmic observing at night; much of the day as well

Core frequency range: 0.5–26 GHz

- High frequency options: sample between 18-40 GHz; support 80-115 GHz
- Low frequency options: support spectroscopic observations on large elements at frequencies 100–500 MHz

Support dual circular polarization measurements

- IF transmission and correlator technology available now
- 500 MHz/IF; optical fiber
- Broadband spectroscopy performed via frequency multiplex (50 freq./sec)
- High resolution spectroscopy based on backend IF

References