The Green Bank Solar Radio Burst Spectrometer

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1 Introduction

Time-resolved radio spectroscopy of solar radio bursts – *dynamic spectroscopy* – has played an important role in identifying, studying, and understanding physical processes in the solar corona for more than fifty years. A resurgence of interest in radio spectroscopy has occurred in recent years as a result of its relevance to, and utility for, space weather studies, especially when used in combination with the wealth of space based instrumentation now available (e.g., SOHO, TRACE, RHESSI, WIND, ACE, and Ulysses).

Spectroscopic radio observations are used to study radio precursors of coronal mass ejections (CMEs), the shocks produced by blast waves and/or CMEs, particle acceleration in flares and CMEs; and energy release in flares. These studies rely on the availability of broadband spectroscopic records during times of interest. Surprisingly, support of ground based solar radio spectroscopy in western longitudes is sparse (Fig. 1). Available coverage is confined to swept-frequency radio spectrometers by the USAF/RSTN network operating between 25-180 MHz. These data are used for event reporting, but are generally unavailable for analysis.

We have embarked on a project to build high-performance spectrometers to address the need for high-quality broadband dynamic spectroscopy in western longitudes. The instrument will comprise two radio spectrometers that will together provide frequency coverage from 10-800 MHz. This ground-based facility will complement current and future space based spectrometers such as WIND/WAVES and STEREO/WAVES. Data from the spectrometers will be widely accessible for both basic research and programmatic purposes via a web interface.

We describe the site in Section 2, the instrument in section 3, data access and examples in Section 4, and briefly summarize future research and development efforts in Section 5.

2 The Instrument Site

The instrument is located at the National Radio Astronomy Observatory (NRAO) site in Green Bank, West Virginia. The Green Bank site (38º 26' N, 79º 49.5' W) is located in the National Radio Quiet Zone (NRQZ), a land area of approximately 33,000 km^2 established by the Federal Communications Commission in 1958 to minimize interfering radiation at radio frequencies. All frequency assignments for transmitters in the NRQZ are carefully coordinated and power density thresholds imposed. The Green Bank site therefore offers a relatively benign site for broadband radio spectroscopy from decimeter to decameter wavelengths.

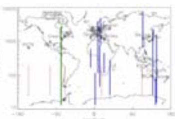


Fig. 1 Graphical summary of the present state of ground based solar-dedicated spectroscopic instrumentation around the world. Asterisks mark the locations of spectrometers. Vertical lines indicate the frequency range supported by a given observatory using the scale on the frequency axis to the left. Solid blue lines indicate those observatories where data are easily accessible via the web. The dashed red lines indicate those locations where this is not the case. The heavy solid green line indicates the location and eventual frequency range of the Green Bank spectrometers.

Fig. 2 View of the Low Frequency Spectrometer (left) and the 13.7 m antenna at Green Bank, WV. Upgrades in 2004 will replace the Erickson antenna with a crossed dipole that will be used in a balanced diplexer with a log-periodic antenna to cover a frequency range of 10-350 MHz. A spectrometer (Callisto) operating from 300-800 MHz will be deployed on the 13.7 m telescope.

3 Low Frequency Spectrometer

The Naval Research Laboratory (NRL) provided a dipole antenna, active balun preamplifier, HP spectrum analyzer, and associated software. The active balun preamp, located at the antenna terminals, buffers the impedance variation of the dipole with frequency. The dipole feeds the active balun preamp, from which signals are transmitted via coaxial cable to the spectrum analyzer. A Measurement Computing PCI-DAS1200 data acquisition (DAQ) card serves as the interface to the HP 8553B spectrum analyzer. An open source linux driver (Comedi) and user-space library (Comedilib) are used to control the DAQ card.

Fig 4. The 350 MHz amplifier. The larger box contains the push-pull section of the

These elements were initially used to build a system similar to the Bruny Island Radio Spectrometer, which was designed, built, and operated by Bill Erickson on Bruny Island south of Hobart, Tasmania (http://fourier.phys.utas.edu.au/birs). A new amplifier was designed and fabricated at the Central Development Lab of the NRAO. The new version has a push-pull first stage followed by a 180-degree hybrid and a single-ended second stage. The amplifier has a gain of 14.5 dB ± 0.5 dB, is low-noise (175 K), and has excellent linearity and dynamic range. Total power dissipation is less than 1.5 watts (per polarization). This configuration will also be adopted for the 10-30 MHz amplifier (see Section 5). In addition, numerous improvements were implemented in software, leading to improved efficiency and performance.
The present configuration currently operates from approximately 1200-2300 UT each day. A frequency band from ~18-70 MHz frequency band is swept once per second, linearly sampling 1670 frequency channels, each with a bandwidth of 30 kHz.

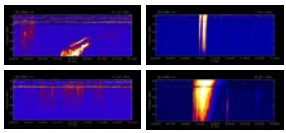


Fig. 3 Examples of spectra produced by the 18-70 MHz prototype instrument modeled after the BIRS instrument (Erickson ?). a) An example of type III radio bursts, produced by beams of suprathernal electrons; b) a storm of type III radio bursts; c) type III radio bursts followed by a type II radio bursts. Type II radio bursts are produced by a coronal shock; d) type III/V radio emission.

4 Data Access

The low frequency spectrometer was installed in Green Bank on January 7, 2004. Observations are available on a prototype web site from Jan 18 to the present at http://www.astro.umd.edu/~white/gb. A dedicated file server has been installed at the NRAO. After 1 June 2004 data the Green Bank Solar Radio Burst Spectrometer web site will be located at http://www.sunbeam.nrao.edu. The web site displays hourly summaries of spectroscopic data as well as an interface that allows users to specify and download data of interest. In future weeks, a near real time data display will be implemented.

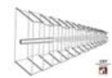
5 Instrument Upgrades and Expansions: 2004

A number of activities are underway in the current year that will greatly enhance the capability of GB/SRBS:

Upgrade of the Low Frequency Spectrometer to 10-350 MHz System

The current low frequency spectrometer will be upgraded to operate from 10-350 MHz by replacing the antenna and amplifier. The current antenna will be replaced by a crossed dipole operating from 10-30 MHz and a dual-polarization, trapezoidal element, log-periodic antenna operating from 25-350 MHz. CST Microwave Studio was used to perform the EM simulations for a first-order parameter optimization (Fig. 5) and we are now constructing antenna prototypes.

Fig. 5. Dual-polarization broadband antenna for use between 25-350 MHz. A scaled version will also be employed on the 13.7 m telescope for observations between 250-800 MHz.



The two antennas will be employed in a balanced diplexer. The RF from the 10-30 MHz antenna system is processed by a low pass filter (fc = 27 MHz) and the RF from the 25-350 MHz antenna system is processed by a high pass filter (fc=28 MHz). The output ports of the filters are combined using a broadband power combiner. A two-stage prototype amplifier has been developed at the NTC for use in the push-pull section of the new 350 MHz amplifier. This two-stage unit has gain=13 dB ± 0.5 dB and a noise temperature of 150 K. A rugged field unit consisting of a pair of these amplifiers in push-pull followed by a 180-degree hybrid and a single-ended stage (8.5 dB) is currently under construction. Total gain will be about 20 dB with under 1.5 watts of dissipation (per polarization).

Addition of a High Frequency Spectrometer

A. O. Benz and the Radio Astronomy and Plasma Physics group at the Swiss Institute of Technology (ETH/Zürich) have developed a flexible, low-cost spectrometer – Callisto – capable of operating between 47-850 MHz. Callisto is a frequency-agile spectrometer; the rate and sequence of frequency samples is therefore fully programmable. The frequency of a given sample can be tuned in steps 62.5 kHz. The channel bandwidth is 280 kHz. Callisto samples ~1000 channels s-1 in two polarization channels.

The Callisto spectrometer was delivered to the NRAO in April, 2004, and will be deployed on the NRAO 13.7 m antenna in Green Bank. The NRAO 13.7 m antenna was constructed in 1972 by Electronic Space Systems Corp. The surface was upgraded and realigned in 1992 as part of a general upgrade to use the antenna as a NASA ground station for Orbiting Very Long Baseline Interferometry. The antenna control system was designed for unattended operation and is therefore well-suited to perform the function as a solar-dedicated instrument. The antenna field of view is 4.5

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