Detection of narrow spectral features using RASDR2 and the NRAO 20m telescope

P. Oxley, D. Fields[1], B. Vacaliuc[2], C. Lyster and F. Ghigo[3]
Tamke-Allan Observatory[4]
Roane State Community College
276 Patton Lane
Harriman, TN 37748

ABSTRACT

Identification and accurate spectral characterization of a narrow L-band spectral feature from a celestial source is a necessary first step in showing the importance of a Doppler (velocity-induced) frequency shift due to the Earth's rotation. This goal was mentioned at the 2014 SARA conference [1] [2]. With the assistance of NRAO staff, we have integrated RASDR2 [3] [4] with the NRAO 20m radio telescope [5] and have demonstrated detection of a suitable narrow spectral feature. Analysis of the complete 24h data set to show the spectral shift due to planetary Doppler shift will be discussed in a future paper.

RASDR2 was controlled by RASDRViewer software [2] running under Windows 7. RASDRViewer performed receiver control, FFT analysis, spectrum averaging, power monitoring and other functions. The local computer was connected via the Internet to a remote computer, with both computers running Remote Desktop. The remote computer or an adjacent laptop computer was also used to control the 20m radio telescope using SkyNet [6] [5].

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1 fieldsde@aol.com
2 Spallation Neutron Source (SNS); SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. Department of Energy.
3 National Radio Astronomy Observatory, Green Bank, WV.
4 www.roanestate.edu/TAO
5 Skynet is a world-wide network of astronomical telescopes operated by the University of North Carolina at Chapel Hill. The 20m telescope is located at the NRAO in Green Bank, WV and provides observations at 1.1 to 1.8 GHz and 8 to 10 GHz. The 20m receiver system is cryogenically cooled to provide high sensitivity radio images and spectra. See http://www.gb.nrao.edu/20m/index.htm

Identification of a narrow spectral feature for L-band studies

L-band signals hold significant interest within the amateur radio astronomy community. In particular, H1 signals offer significant technical and scientific challenges. As a prelude to analysis of L-band signals to show the importance of (relatively small) Doppler frequency shifts due to the Earth's rotation, we found it necessary to identify a narrow spectral feature. Most H1 clouds are significantly broadened by thermal effects.

Identification of a narrow L-band spectral feature from a celestial source is also a useful first step in measuring the frequency stability of a radio astronomy receiver, or determining small spectral shifts.

A cold dark cloud containing significant hydrogen was chosen for study. This cloud was located near Messier object M24 at coordinates RA=18:09:01.26 and DEC=-19:59:58.10 and contains a narrow hydrogen absorption line.

We choose to measure a narrow spectral feature over a period of roughly one day using the NRAO 20m radio telescope.

Usefulness of RASDR2 for narrow-band spectral measurements

The RASDR2 receiver is an optimal choice for resolving small frequency shifts because of its capability of having a very small spectral bin width (resolution). The SARA development of an SDR that is optimized for Radio Astronomy, RASDR and which is applicable to a wide variety of SARA projects, provides an integrated front end digital receiver package (RASDR2) and a software-driven desktop computer back end [3] [7]. The front end uses a computer chip containing the entire RF digital receiver chain and designated LMS6002d [8] [9]. The back end computer controls the front end hardware and permits the user to control receiver functions, display signals and perform analysis functions (averaging, computation of spectrograms, determination of power time-spectrum, and generating output files).

Signal processing permits dealing with low S/N data by averaging tens of thousands of spectra and presents data as spectral plots and data files, and metadata. Current RASDRviewer software [10] for the Windows OS, performs parameter optimizations, user control, spectral output, power characterization and output data formatting via a Graphical User Interface (GUI). This design evolution is based on the need to have widest possible data pipeline speed for radio astronomy applications, and to make this instrument available to SARA members in the near future [11]. The software was described at the SARA 2014 conference [2], together with examples of some initial applications [1].

Choosing RASDR2 Setup Parameters

A spectral bin width was chosen for FFT analysis using RASDRViewer, that was less than the expected Doppler shift from the Earth's rotation. This value is about Pi(13000km/24)(1h/3600s)(1.5MHz/316km/s) or about 0.002 MHz shift above and below the nominal frequency for a 12h period, at the equator. To resolve the 2 KHz shift, we selected an FFT bin bandwidth of 732 Hertz by specifying a sample density of 2048 samples per FFT frame and a sample rate of 1.5 (10^6) samples/second.

Experimental setup: integrating RASDR with the NRAO 20m radio telescope

The equipment configuration is shown in Fig. 1. RASDR2 was used to monitor the 1355-1430 MHz IF band from the NRAO 20m radio telescope. The observed input level was about -8 dBm. The RASDR2 local oscillator was locked to the NRAO frequency standard by connecting to a local 10 MHz reference.

Local RASDR2 control was via RASDRViewer software running on an adjacent dedicated PC. This computer was linked to a remote PC using the Remote Desktop program.

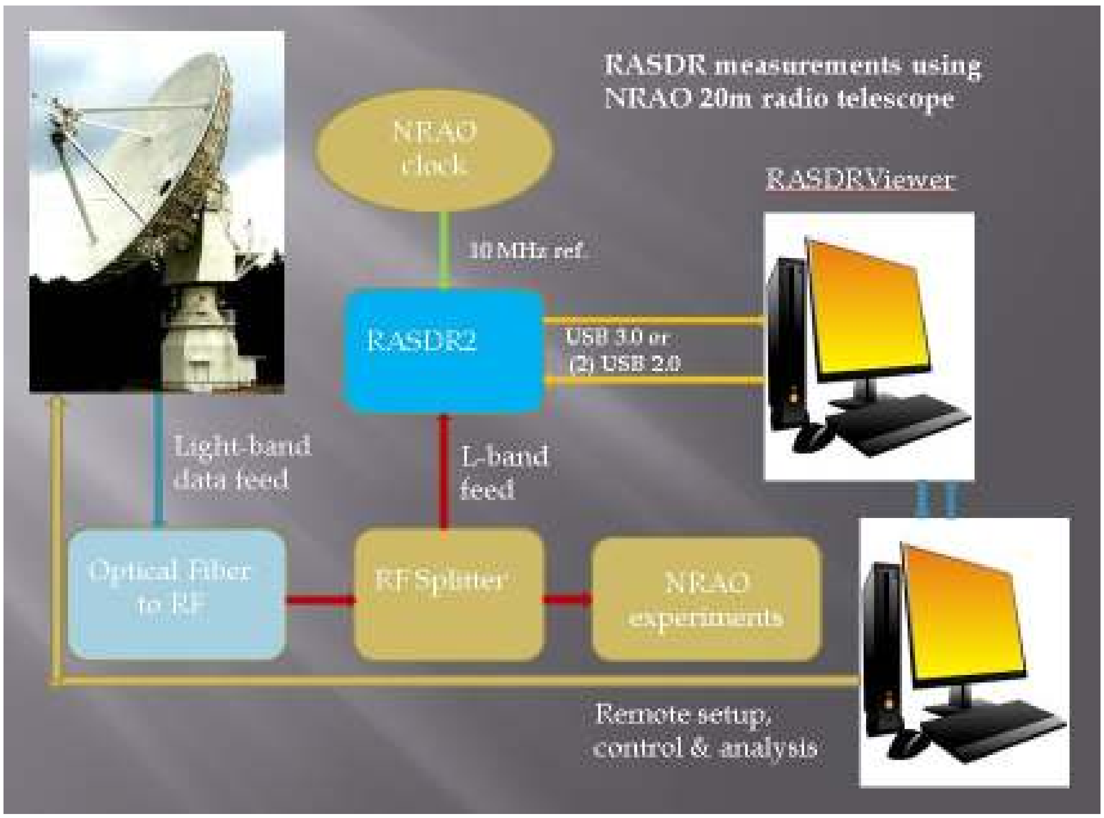

Figure 1. RASDR2 was integrated into the NRAO 20m system by monitoring the 20m output over the system data feed, and by locking RASDR2 to the NRAO clock via the 10MHz reference. RASDR2 control was via RASDRViewer running on a dedicated local computer, while remote operation was enabled using a second computer linked via Remote Desktop. The remote computer (or an associated laptop) was used to control the 20m telescope via SkyNet. (Scope photo by D. Fields)

Considerable difficulties were encountered in maintaining the connection between the local and remote PCs. These difficulties were traced to the data requirements of several simultaneous processes. The 5-y old PC functioned well running continuous FFT calculations after occasional windows housekeeping operations were suppressed. A greater challenge was to avoid extensive screen updates on the remote computer while data were being processed.

Results

Data were captured over a period exceeding 24h. The narrow cold-absorption spectral feature near M24, as shown in Fig. 2, was resolved.

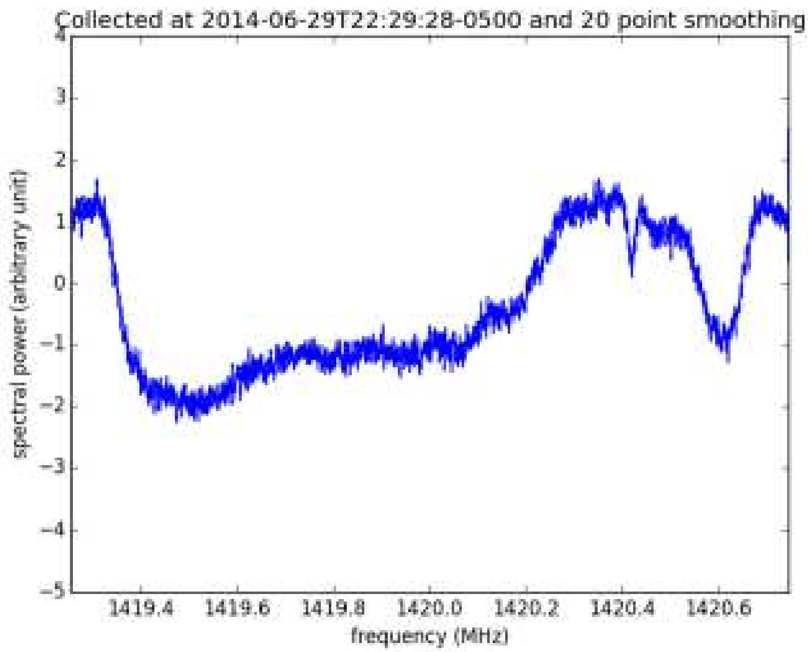

Figure 2. The narrow H1 absorption line (narrow notch in the peak, about 1420.4 MHz) was resolved at various times throughout the 24h observational period, as shown in this example plot.

Summary

The narrow H1 spectral feature is clearly identifiable and resolved, using RASDR2 to process data from the NRAO 20m telescope. Data have been collected near astronomical rising and setting of this celestial feature. Results from analysis of our complete data set will be discussed in a future paper.

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