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Improvements to Host Country Radio Astronomy at Robledo: Another antenna, a new receiver, a new backend

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Abstract

NASA hosts three complexes worldwide built for spacecraft tracking, whose sensitive antennas are suitable for radio astronomy. Since more than a decade, INTA has managed guaranteed Spanish time at the complex located in Robledo de Chavela, in the frame of the Host Country Radio Astronomy (HCRA) program. Until now, the vast majority of the scientific results were achieved using a K-band (18 to 26 GHz) receiver, attached to the 70m antenna, and a narrow-band autocorrelator. In the recent years, we have undertaken two large instrumental projects: (1) the incorporation of a second antenna (34m in diameter), working in Q-band (38 to 50 GHz); and (2) the design and construction of a wideband backend, which may operate with both the Q- and K-band receivers, providing instantaneous bandwidths from 100 MHz to 6 GHz, and resolutions from 6 to 200 kHz. The new wideband backend is expanding the HCRA possibilities due its bandwidth, versatility, spectral resolution and stability of the baselines. Its IF processor splits each of the two circular-polarization signals, and downconverts them to four base-band channels, 1.5 GHz width. Two different frequencies may be tuned independently. Digitalisation is done through FPGA-based FFT spectrometers, which may be independently configured. Once end-to-end assembled, the commissioning of the new backend was done using the 34m antenna in Q-band. We report the main characteristics of both the antenna recently incorporated to HCRA, and the wideband backend.

1 Introduction

The Deep Space Network is a collection of three worldwide complexes built by NASA and run by JPL to provide support to the tracking of spacecrafts beyond the Moon. The Spanish complex, named Madrid Deep Space Communications Complex (MDSCC) hosts six antennas

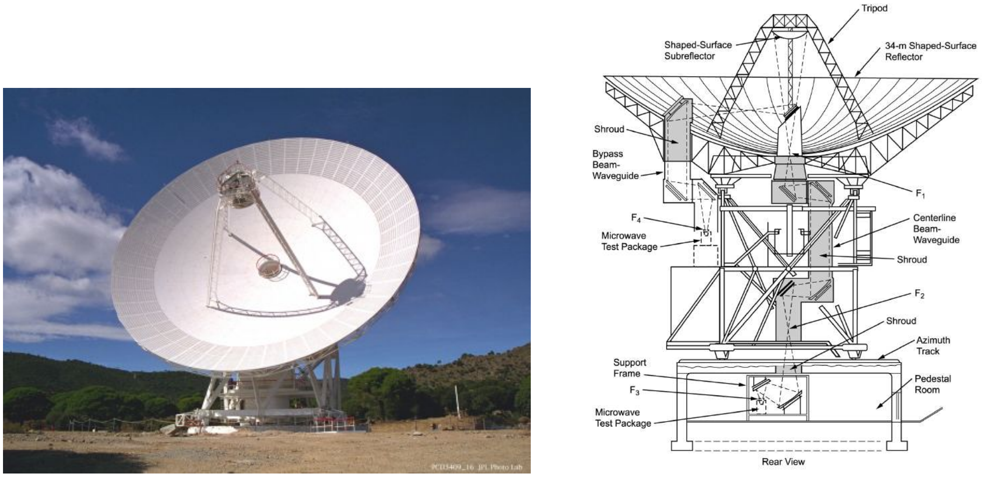


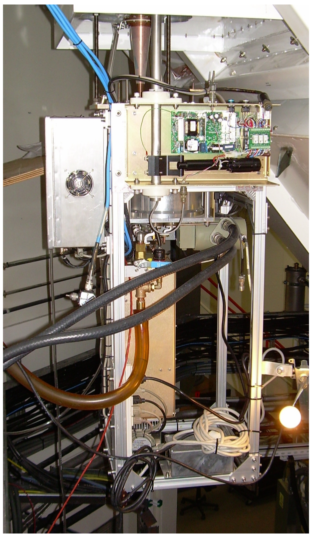
Figure 1: *Left panel:* Photograph of the DSS-54 antenna. *Right panel:* A beam waveguide schematic. (Credit: JPL)

having diameters between 26 and 70 m. The high aperture and sensitivity of the antennas permit them to work as excellent radio telescopes. By means of an international agreement, a percentage of the operational time of the MDSCC's antennas is offered to the Spanish community to do radio astronomical observations, in the frame of the "Host Country Radio Astronomy" program (HCRA).

HCRA is managed and implemented under the responsibility of INTA, through the Centro de Astrobiología, one of their co-sponsored research centers. Until very recently, the vast majority of HCRA projects has been done using the K-band (18–26 GHz) receiver attached to DSS-63, the 70 m antenna.

In the recent years, important improvements are being implemented in HCRA, which give more chances and opportunities to the Spanish astronomy. A new high-efficiency antenna, 34 m in diameter, came into operation; a new Q-band (38–50 GHz) receiver was built and mounted on this antenna; and a state-of-the-art wideband backend was built and is currently used routinely in HCRA.

The mostly used bands (K and Q) allow the observation of several rotational transitions of important molecules, including water, ammonia, CCS, CS, SiO, and methanol, among others. It is possible to do research about star formation and evolution, Solar System studies, cold clouds, etc. The large instantaneous bandwidth now available, together with the high spectral resolution, permit the implementation of multiple line studies, spectroscopic surveys and extragalactic radio astronomy.



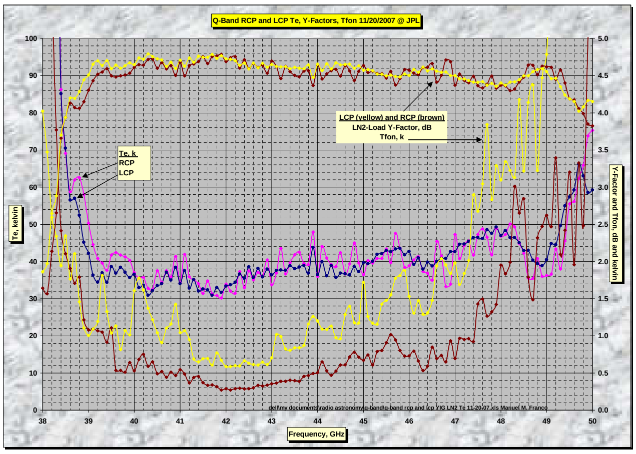


Figure 2: *Left panel:* Photograph of the Q-band receiver. *Right panel:* Chart of the receiver temperature and Y-factor. (Credit: JPL)

2 Developments and new facilities

2.1 The DSS-54 antenna

The DSS-54 is a beam waveguide (BWG) antenna which has a diameter of 34 m. In a BWG system, the feed horn and support equipment are placed in a stationary room (pedestal) below the antenna, and the signal is guided from the movable subreflector to the receiver using a system of reflecting mirrors. The Fig. 1 shows a photograph of the DSS-54 antenna, and a scheme of the signal path in a BWG antenna. The antenna has a velocity of 0.8 deg s^{-1} in azimuth. Its aperture efficiency is ~ 0.46 at 45 GHz.

2.2 The Q-band receiver

Designed and built at JPL, this new receiver was installed at the DSS-54 antenna in 2009. The band pass is from 38 to 50 GHz, although a better performance is obtained in the range from 39 to 49 GHz.

The Fig. 2 shows a photograph of the receiver installed at the pedestal room of the DSS-54 antenna; on the right, the figure also depicts a chart of the receiver temperature and Y-factor, for each polarization, as measured before final installation. Receiver temperature remains roughly constant around 40 K in most of the band pass.

The DSS-54 antenna with the Q-band receiver attached has a sensitivity of ~ 7 Jy/K. A local oscillator at 62 GHz is included in the receiver, which produces a signal output in the range from 12 to 24 GHz (inverted).

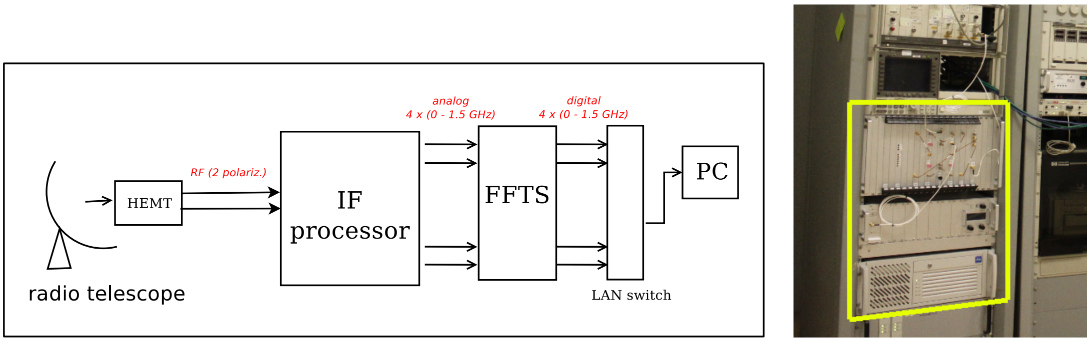


Figure 3: *Left panel:* A concept diagram of the wideband backend. *Right panel:* The backend installed. It is possible to see the IF processor, the FFT spectrometer and the PC which controls the observations.

2.3 The wideband backend

A state-of-the-art, wideband backend was designed in 2009, built and fully assembled in September 2011. The first year of operation of the backend was done in combination with the Q-band receiver and the DSS-54 antenna, including a commissioning phase and normal operation.

The Fig. 3 depicts, on the left, the concept of the backend. A two-polarizations signal is the input of the IF processor, which is sensitive to the range 12–26 GHz. This range allows the backend to be useful for both the K- and Q-band receivers. Within the IF processor, each signal is divided in two different channels, and then translated to base band. The resulting output are four base band signals of 1.5 GHz width. These signals are later digitized by the FFT spectrometer. The FFT spectrometer is a FPGA-based array of boards capable to process the digitized signals at a rate of 3 Gb s^{-1}.

Three different resolutions and bandwidths are admitted by every FFT boards, and any combination of them are possible. The resolutions (bandwidths) possible to get are: 180 (1.5 GHz), 30 (500 MHz), and 6 kHz (100 MHz).

The right part of the Fig. 3 is a photograph of the backend installed at the pedestal room of DSS-54, near the Q-band receiver. A complete description of the backend was published by [2], together with the first astronomical results.

The backend is controlled by SDAI, a python-based software, already described by [3]. SDAI is on charge of the synchronization of the observations and the control of the backend, by tuning the synthesizers and driving the integration by the FFT spectrometer.

3 Astronomical results

All the new equipments were measured and tested accordingly. The DSS-54 antenna was characterized and checked, the Q-band receiver was tested at all frequencies, and different parts of the backend were checked separately. Once end-to-end assembled, commissioning

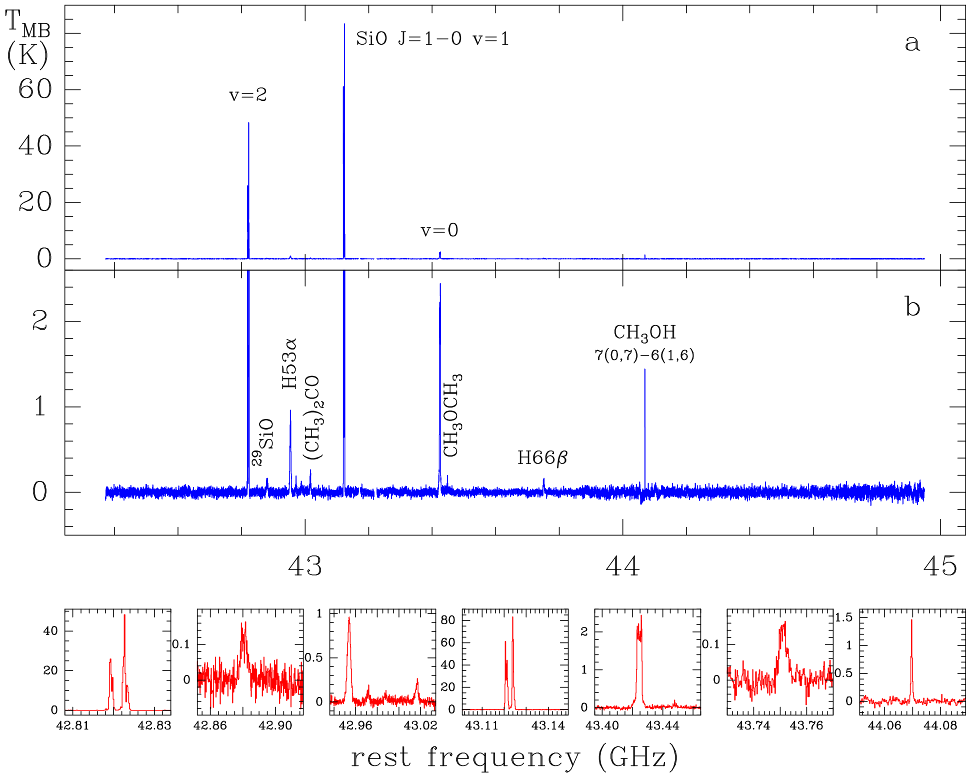


Figure 4: A spectrum of Orion KL at Q-band, obtained with the new wideband backend and the new receiver, attached to the DSS-54 antenna. Bandwidth is 2.6 GHz.

observations have been done, aiming to verify the functionality of all the backend features (stability, comparison between synthesizers, baseline quality, etc.) The commissioning observations and results are thoroughly detailed in [2].

Two examples of the first astronomical results attained with the new system are shown in Figs. 4 and 5, where wideband spectra of Orion KL and Sgr B2(M), respectively, are shown. Several projects were lately observed, and are currently under preparation. One of the first new results with this new system has been recently published by [1].

4 Concluding remarks

With the improvements implemented in the very recent years, a new era of the HCRA in Robledo is starting. The new facilities open new spectral windows and allow the observation of several GHz of instantaneous bandwidth. These changes not only increase the efficiency of HCRA, but also allow the astronomical community to tackle new scientific cases, such as spectral surveys and extragalactic radio astronomy. After an initial internal pool, results are being published.

Several upgrades are still possible to increase the efficiency of the HCRA program. The

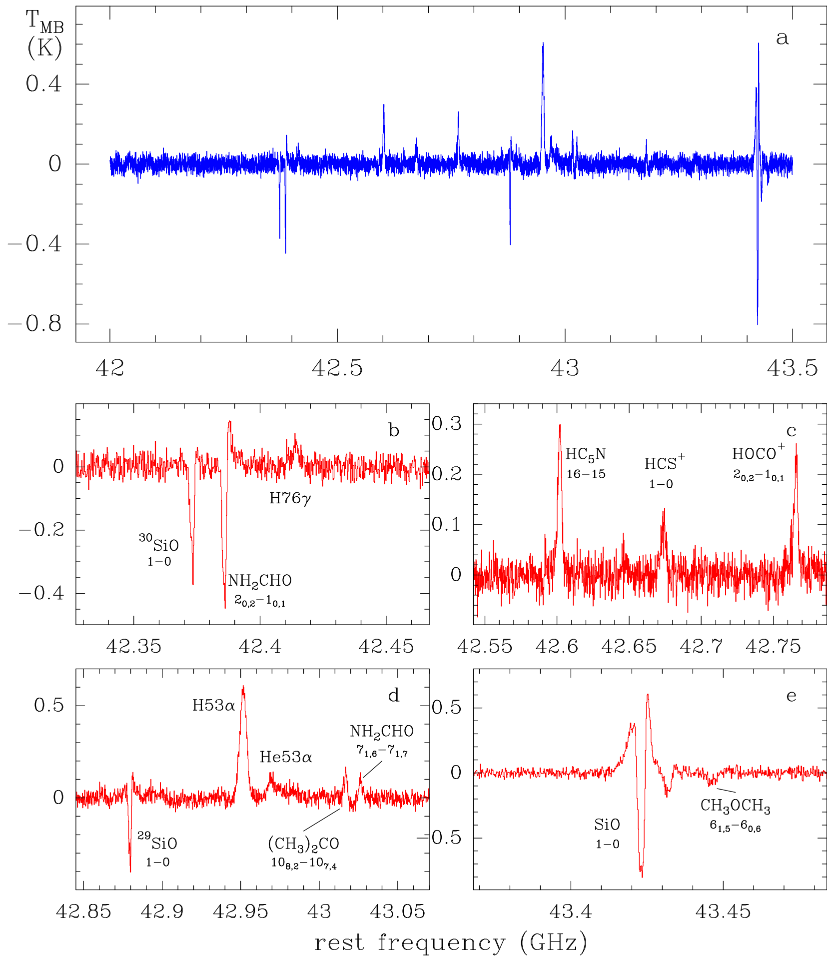


Figure 5: A spectrum of Sgr B2(M) at *Q*-band, obtained with the new wideband backend and the new receiver, attached to the DSS-54 antenna. This spectrum, of 1.5 GHz of bandwidth, was obtained after only 20 minutes of integration time.

installation of new post-amplifiers are planned to improve the quality of the band pass. With the ongoing installation of optical fiber between the DSS-63 antenna (70 m in diameter) and the pedestal room of DSS-54, the simultaneous availability of both antennas will be possible, which will result in a better use of the available time. The recent acquisition of a third and fourth FFT boards has doubled the instantaneous bandwidth, up to 6 GHz.

References

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