IGN Yebes Technology Development Center

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Abstract The activities in technical development related to geodetic VLBI done during 2014 at IGN Yebes Observatory were focused on different topics that are detailed below.

1 RAEGE Radio Telescopes

The RAEGE radio telescopes at Yebes and Santa María are fully assembled, and the Yebes radio telescope, "Jorge Juan", is now fully equipped with a tri-band receiver. On November 26, 2014, the 13.2-meter "Jorge Juan" radio telescope participated for the very first time in a geodetic S/X session together with our 40-meter radio telescope, confirming its first fringe detection. During 2014, the onsite work at the Santa María station have been focused on the infrastructures around the radio telescope (the control and power supply buildings). The receiver installation (a tri-band one) and the first light are planned for 2015.

2 LNA Development

During 2014, several Yebes-developed low noise cryogenic amplifiers at S, C, X, and Ka bands were allocated to equip VLBI receivers at Yebes Observatory, Azores, Ishioka (Japan), and Wettzell (BKG, Germany). The design for S-band has been transferred to the industry, and a Spanish company has produced the LNAs. X-band has benefited from the developments accomplished for ALMA IF, and presently 4-12 GHz amplifiers are being used as VLBI frontends. Ka-band amplifiers are the fruit of a long-term successful collaboration with the Fraunhofer IAF and the University of Cantabria; they include mGaAs MMICs with good cryogenic performance. A remarkable new development in Ka-band was made together with the ETH-Zurich in the framework of an ESA contract. The amplifier is a compact hybrid design with interchangeable I/O ports 2.9 mm coaxial or WR-28 waveguide. Its ETH HEMT transistors are based in InAs. This new material has shown exceptional performance with record noise temperatures of 10 K averaged in the 25.5—32.5 GHz band, extremely high gain, and very low power dissipation. Unfortunately, the availability of these experimental devices is currently very limited.

Finally, we are working towards an ultra-wideband amplifier covering the 2—14 GHz band, following two approaches: an MMIC-based version and a hybrid amplifier. The first hybrid units produced were tested with different transistors in the first stage. The best results, obtained with NGST transistors, yield average noise temperatures of 7.5 K. These devices are subject to severe export regulations and, for the moment, can only be used on our premises. We are devoting our best efforts to ensure a reliable source of low noise transistors for radio astronomy applications in Europe.

3 Tri-band (S/X/Ka) Receiver

A cryogenically cooled tri-band receiver has been successfully designed and developed. Currently three of these receivers have been built: two of them for the

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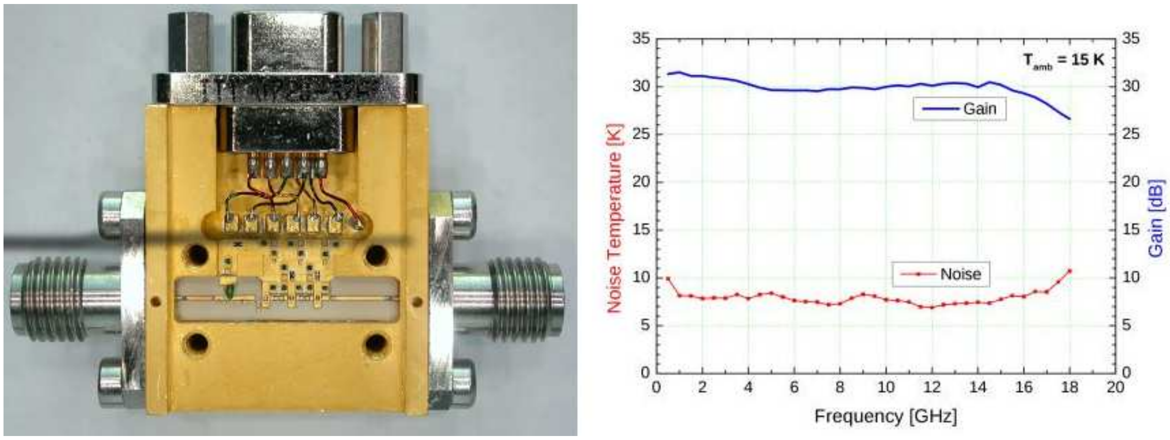

Fig. 1 2—14 GHz cryogenic amplifier picture, and noise and gain measurements at 15 K. InP NGST HEMT in the first stage.

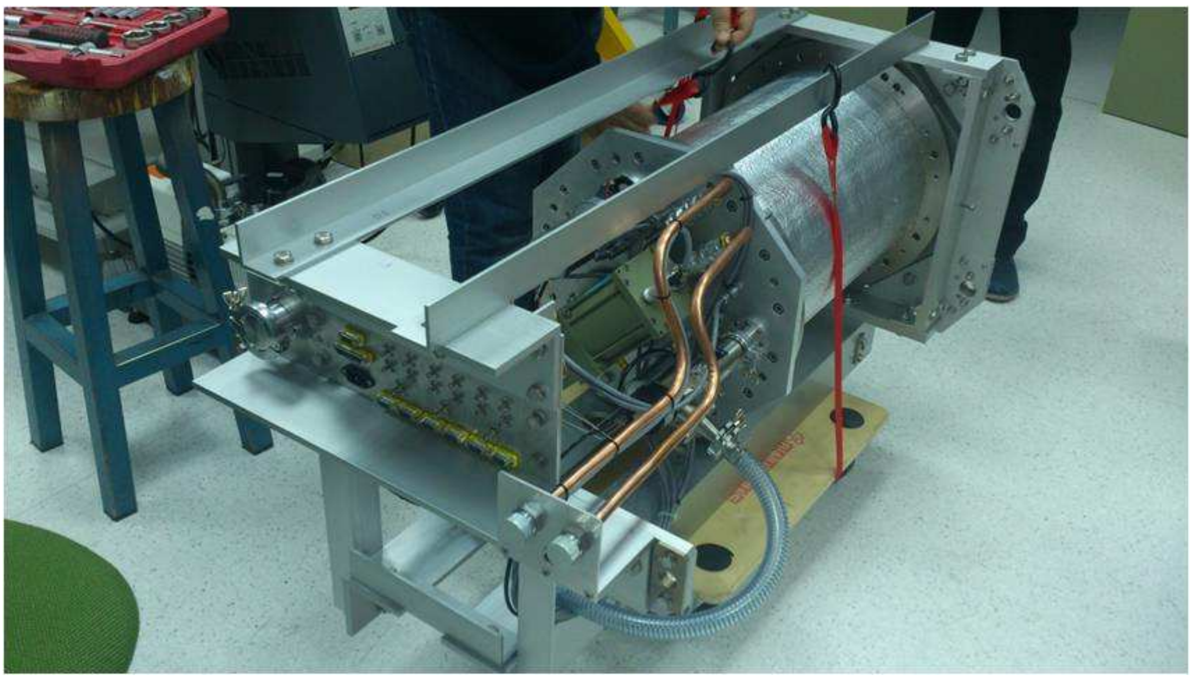

Fig. 2 Tri-band receiver installed in its frame positioner.

RAEGE radio telescopes in Yebes and Santa María, and one for the GSI's Ishioka station. This receiver allows simultaneous dual circular polarization observations at S, X, and Ka bands. The tri-band feed is actually made of three feeds in a coaxial arrangement. The S- and X-band feeds are fed by four symmetric ports at 90 degrees apart. The Ka-band feed output is a circular waveguide that interfaces to a septum polarizer-coupler developed in-house. The cryostat is built over a two-stage Sumitomo closed cycle refrigerator inside a cylindrical dewar made of steel with suitable multi-layer insulation. The LNAs and 90^{o} hybrid circuits are in-house designs developed at Yebes Labs. The averaged receiver noise temperatures are below 25 Kelvin. The receiver is fully integrated in a frame box positioner that facilitates the installation at the radio telescope feed cone.

4 Broadband Feed

In collaboration with the Carlos III University in Madrid, Yebes is developing an alternative broadband feed. The CQSA feed (Conical Quad-Spiral Array) is implemented as four elements, each one being a conical spiral antenna. The CQSA is double circular polarization with a symmetric pattern between 2 and 14 GHz. The phase center is not constant in the whole band, but its variation in the 4—14 GHz band is only one centimeter. The first prototype was made of titanium in order to assure the stiffness of the feed. The dimensions are 170 mm in height and 150 mm in diameter. The low conductivity of the titanium is compensated by a 10 micron silver plating layer. The feed has been measured in our anechoic chamber showing excellent performance. The RAEGE radio telescope performance has been simulated by means of PO software package GRASP and shows 70% aperture efficiency in the whole band. During the first months in 2015 the feed will be cooled, and the performance of the full receiver with our LNAs will be tested.

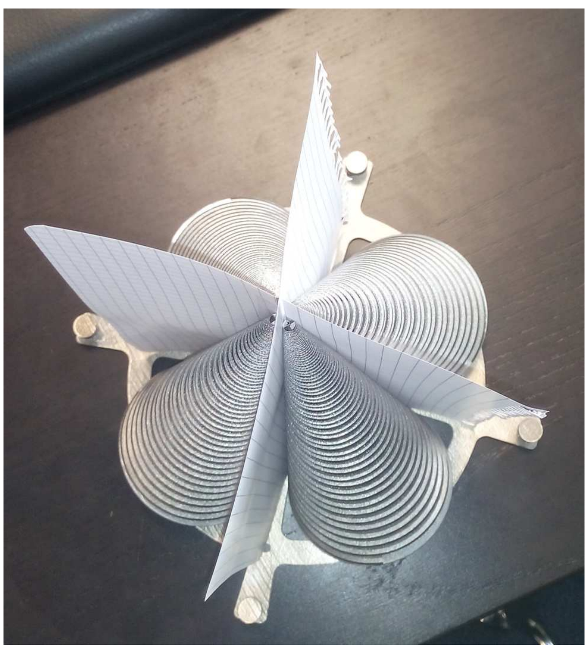

Fig. 3 CQSA feed prototype.

5 Control Software Development

During 2014 we worked on debugging the software for the control and monitoring of the 13-m RAEGE antenna in Yebes, as well as on characterizing the antenna. The work was oriented towards two different facets: single-dish observation and VLBI observations. We have investigated the RFI along the S, X, and Ka bands and its dependency on elevation and azimuth, finding that the RFI at S-band, although present, is less important in the 13-m than in the 40-m radio telescope. X-band seems to be a band almost free of RFI. Care was taken to avoid internal RFI sources inside the elevation cabin, where communication equipment and cables have been shielded.

We also determined pointing models for the antenna and the optimum focus using several sessions and following an iterative procedure. The noise diodes were calibrated using the atmosphere, and a hot load and gain curves at S, X, and Ka bands were determined while tracking sources from the horizon to zenith.

The connection between the Field System and the control system developed at Yebes is done via UDP sockets. Information from the weather station and the gps-maser comparison uses the same protocol. The Field System also transfers commands for the receivers: local oscillator frequency, attenuation, and noise diode on/off switching. Tests were performed to test the quality and the speed of the connectivity between both systems.

In August 2014, we received a DBBC2 equipped with four IFs/ADB2s/CORE2s to be used with the 13-m antenna. Once the equipment was configured and tested, we connected it to a Mark 5B+ recorder, and we performed a 24-hour VLBI session (R1656) with the 40-m telescope in parallel with the VLBA5 system. Fringes were found, and hence both the 13-m DBBC2 and the Mark 5B+ were validated.

OnOff sessions controlled by the Field System were also conducted to determine the SEFD of the telescope at S and X bands and to fine tune the calibration from the noise diodes. These tests were also important to debug the control software and the communication between the Field System and the local control system.

Finally, in November 2014, selected scans from an IVS session (R4663) were observed in parallel with the VLBA5 system connected to the 40-m telescope and the DBBC2 connected to the 13-m antenna. Fringes

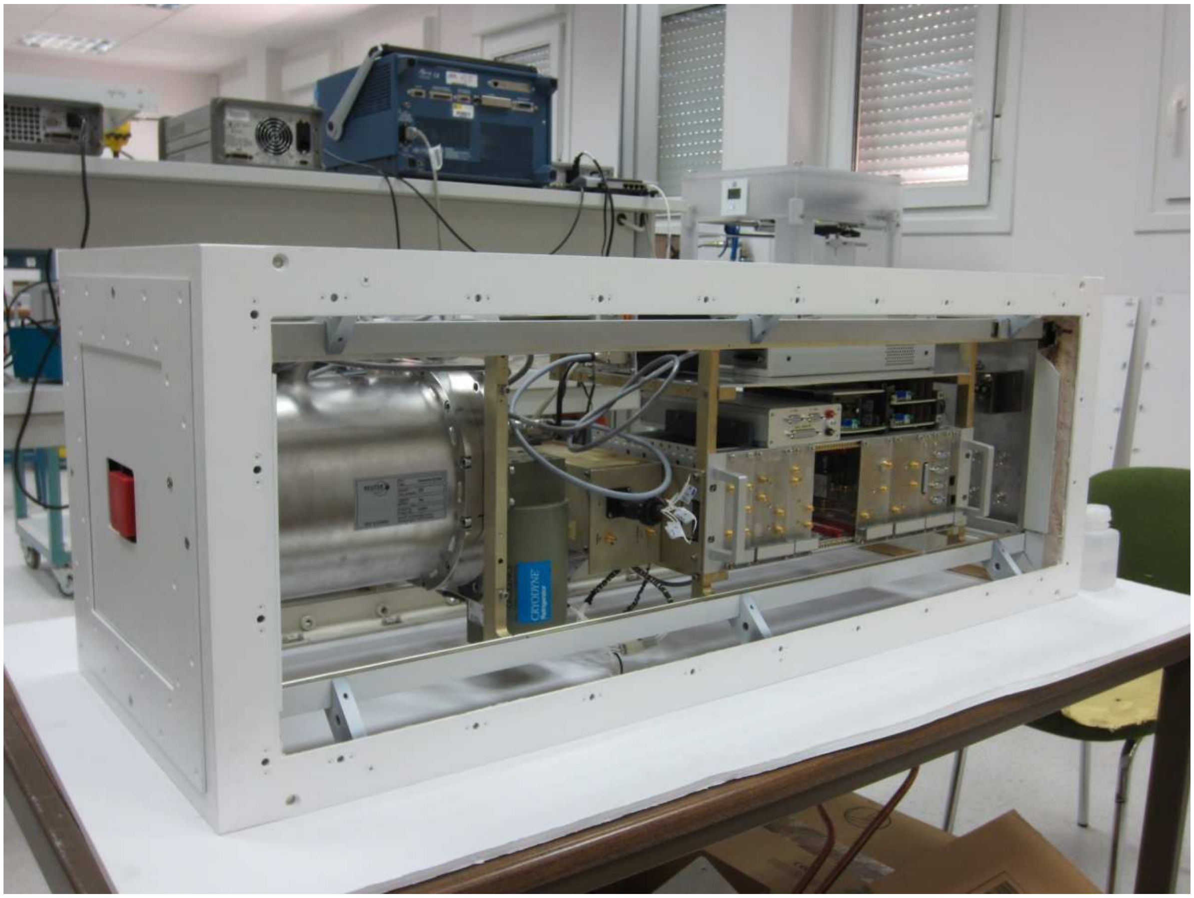

Fig. 4 O'Higgins receiver upgraded at Yebes.

were found at X-band. The lack of fringes at S-band was due to a problem with the signal from the IF.

Our near term goal is to have the 13 m be scheduled in 2015 as tagged along in some IVS sessions in which the 40-m antenna takes part. This will allow us to thoroughly test the whole receiving chain, detect problems, and correct them. It will also determine the position of the 13-m antenna and prepare the telescope for standard IVS observations. The midterm goal is to equip the antenna with a broadband receiving system and to start VGOS observations by the end of 2015.

6 S/X Receiver Activities

During 2014, several activities were carried out for the upgrade of cryogenic receivers belonging to BKG (Germany). One of the S/X Wettzell dewars was upgraded by fixing some bugs (vacuum leaks, multilayer insulation,...) that deteriorated the cryogenic performance. The O'Higgins station in Antarctica was also fully upgraded by installing new LNAs and a custom waveguide coupler designed and built in our labs. Several receiver modules such as the down converter, noise calibration, and LO's were also upgraded. The functionalities of the receiver (setting and monitoring output power level, LO's lock status, noise cal, phase cal, and LNAs bias) can be controlled via Ethernet, using a remote control system developed in our labs.

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