A tri-band cryogenic receiver for VGOS radio telescopes

José Antonio López–Pérez [1,2], José Antonio López–Fernández [1,2], Félix Tercero [1,2], Beatriz Vaquero [1,2], José Manuel Serna [1,2]

Abstract The Yebes Observatory has developed a world class tri-band (S/X/Ka) cryogenic receiver for VGOS radio telescopes. The main advantages of this receiver are the simultaneous S/X/Ka operation with dual circular polarization, the backward compatible with legacy VLBI stations, X/Ka VLBI measurements, the reduced feed size for cooling down to 15 Kelvin, and the easy cal signal injection in front of LNA's. It also allows characterization of radiotelescope pointing, tracking and gain at high frequencies (32 GHz).

Keywords VGOS, radio telescope, cryogenic receiver, instrumentation

1 The tri-band feed

The tri-band feed is actually made of three feeds in a coaxial arrangement, as it can be seen in Fig. 1. The larger feed is the S-band one, inside which the X-band feed is located. Finally, a conventional conical feed for Ka band is at the very center of the system. All feeds are working with the TE11 mode.

The S and X band feeds are fed by 4 symmetric ports at 90 degrees apart. These ports are of SMA connector type for S-band and WR-112 waveguide flange for X-band. The Ka-band feed output is a circular waveguide that interfaces to a septum polarizer-coupler developed in house to achieve dual circular polarization. In the S and X band, the dual circular polarization is achieved by the suitable combination of the four port signals by means of microwave 180º and 90º hybrid circuits. The dimensions of the feed are 25cm high and 20cm in diameter and it weighs 3 Kg. The physical optic simulation of the feed, together with radiotelescope reflectors, provides an aperture efficiency higher than 70% in all bands. Figure 2 shows the measured beam pattern for each band.

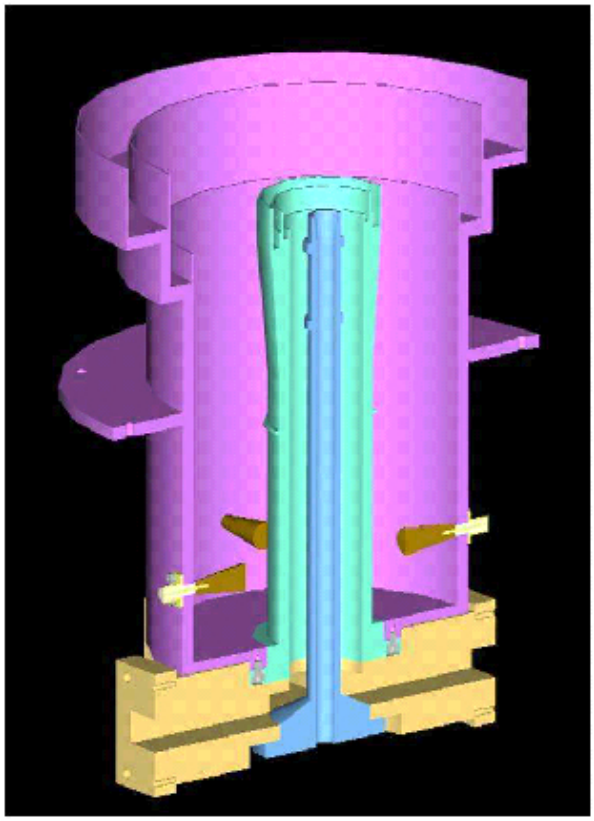

Fig. 1 Inside view of tri-band feed simulation.

1. Instituto Geográfico Nacional (IGN)
2. IGN Yebes Observatory

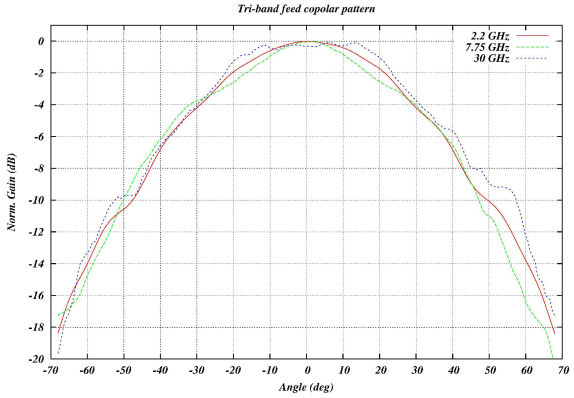

Fig. 2 Triband feed pattern.

2 The cryostat

The cryostat is built over a two-stage Sumitomo closed cycle refrigerator inside a cylindrical dewar made of steel with suitable multilayer insulation. Top and bottom cover plates are made of aluminum. In the top cover, an infrared filter and a mylar sheet act as vacuum window and let the radiation go to the tri-band feed. In the bottom cover, there are all the RF connectors for S/X/Ka output signals, vacuum flanges, pressure monitor, DC cabling and housekeeping connectors. Figure 3 shows the interior of the cryostat with the feed and components.

All the receiver has been assembled on a PVC structure that hold the different components: tri-band feed, the 180^o and 90^o hybrids, couplers for noise injection, microwave isolators and S/X LNAs. The Ka septum-type polarizer/coupler and LNAs are attached directly to the feed. Copper braids are used for the thermal connection between the cold stage and the components. The cold and intermediate stages cool down to 7 Kelvin and 37 Kelvin, respectively. The vacuum pressure reaches 10^{-6} mbars and the cooling time is 12 hours, approximately.

3 Low noise amplifiers

The cryogenic low noise amplifiers and 90^o hybrid circuits are in-house designs performed at Yebes Observatory laboratory. Figure 4 shows the Ka band LNAs.

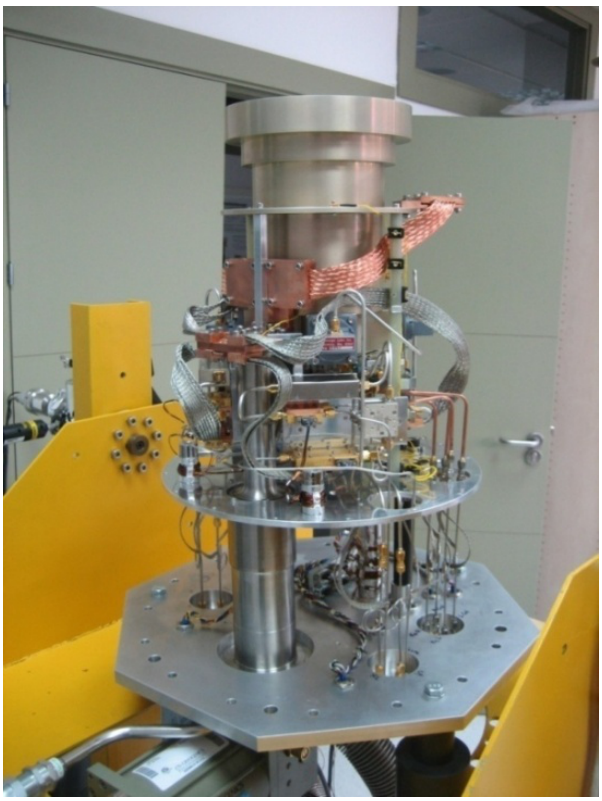

Fig. 3 Interior view of the tri-band receiver cryostat.

The average LNA noise temperatures are < 6 Kelvin in S-band and Xband and < 21 Kelvin in Ka-band.

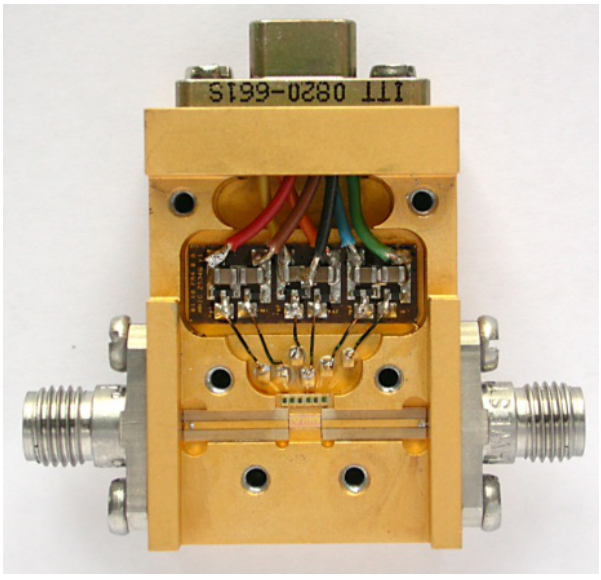

Fig. 4 Low noise amplifier (LNA) for Ka band.

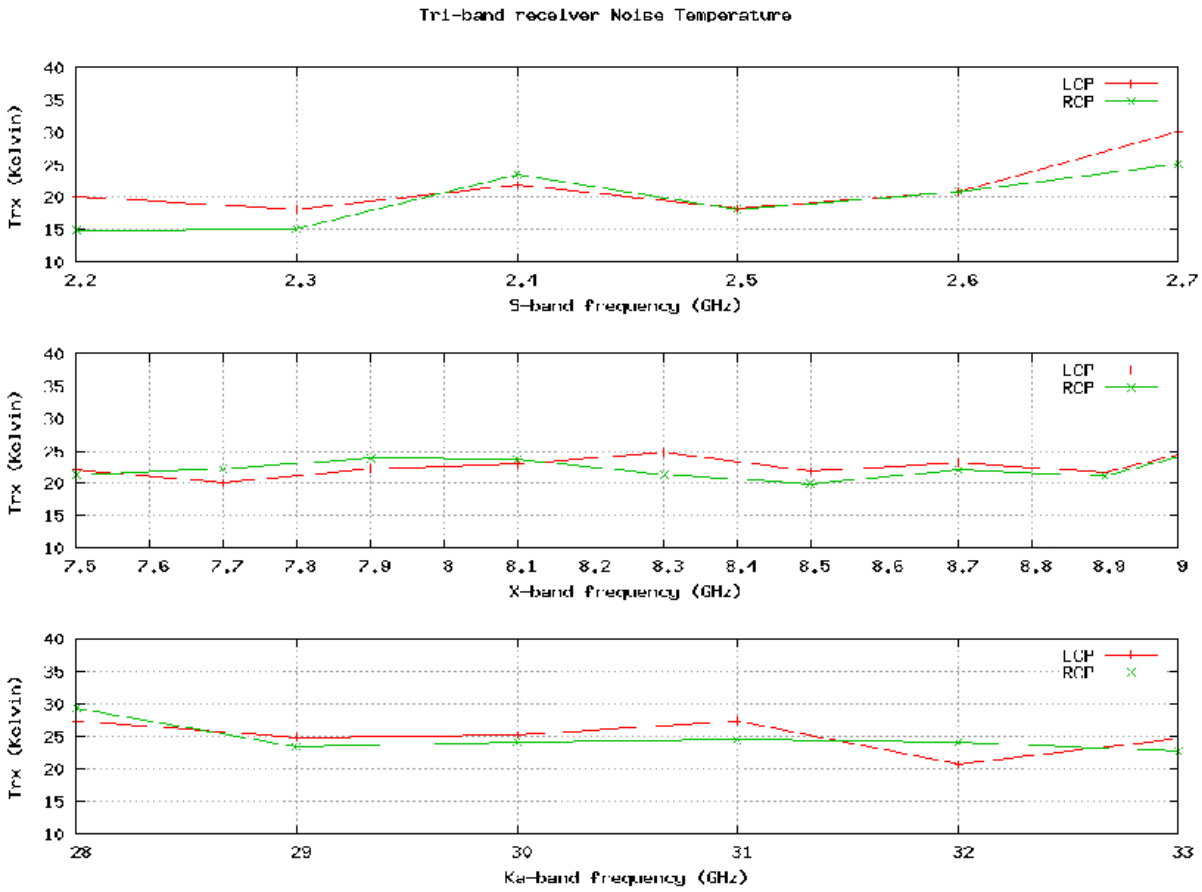

Fig. 5 Tri-band receiver noise temperature.

4 Measurements

The receiver noise temperature has been measured for each frequency band with the Y-factor method. Microwave absorber dipped into liquid nitrogen and at room temperature were used as calibration loads for the measurement. The results are plotted in Fig. 5. The average receiver noise temperatures are 21 Kelvin in S-band, 23 Kelvin in X-band and 25 Kelvin in Ka-band.

5 Conclusions

A cryogenically cooled tri-band receiver for VLBI2010 radiotelescopes has been successfully designed and developed at Yebes Observatory (IGN CDT). The main advantages of this receiver have been mentioned in the introduction section. Each one of the three RAEGE project radiotelescopes (`http://www.raege.net/`) will be equipped with one tri-band receiver as described here. In addition a tri-band receiver has been constructed in Yebes Observatory for the Geospatial Information Authority of Japan (GSI).

Acknowledgements

This work has been supported by the project FIS2012-38160 of the Spanish Ministry of Economy and Competivity.