A Tri-band Cryogenic Receiver for VGOS Radio Telescopes

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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 compatibility with the 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 the LNAs. It also allows the characterization of radio telescope 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 can be seen in Figure 1. The largest feed is the S-band feed, 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 four symmetric ports 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 suitably combining the four port signals by means of microwave 180º and 90º hybrid circuits. The dimensions of the feed are 25 cm high and 20 cm in diameter, and it weighs 3 kg. The physical optic simulation of the feed, together with radio telescope reflectors, provides an aperture efficiency higher than 70% in all bands. Figure 2 shows the measured beam pattern for each band.

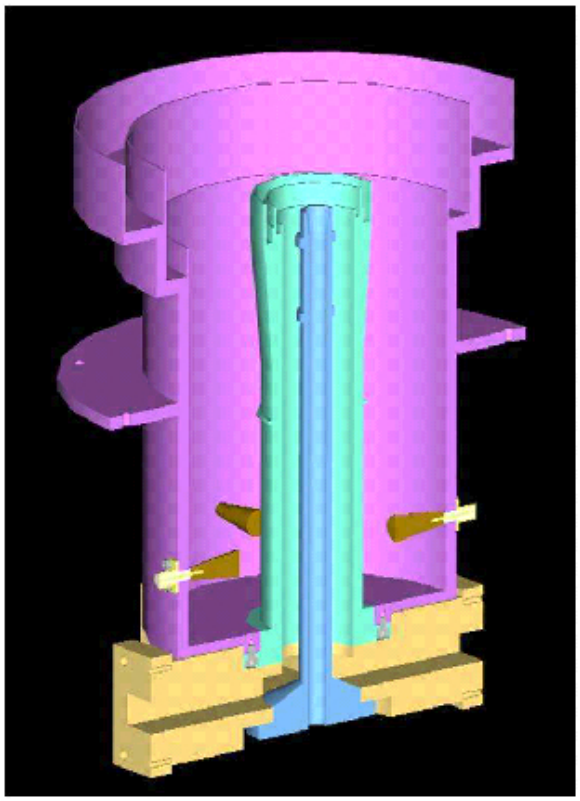

Fig. 1 Inside view of the tri-band feed (simulation).

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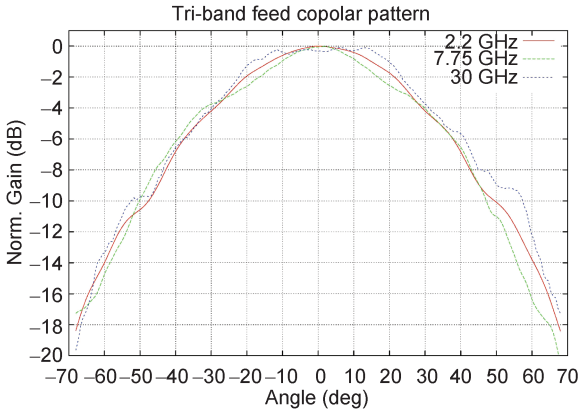

Fig. 2 Tri-band feed pattern.

2 The Cryostat

The cryostat is built over a two-stage Sumitomo closed-cycle refrigerator inside a cylindrical Dewar made of steel with suitable multi-layer insulation. The top and bottom cover plates are made of aluminum. In the top cover, an infrared filter and a mylar sheet act as a vacuum window and let the radiation go to the tri-band feed. In the bottom cover, there are all RF connectors for the 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.

The entire receiver has been assembled on a PVC structure that hold the different components: tri-band feed, the 180º and 90º 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} hPa and the cooling time is 12 hours, approximately.

3 Low Noise Amplifiers

The cryogenic low noise amplifiers and 90º hybrid circuits are in-house designs performed by Yebes Observatory laboratory. Figure 4 shows the Ka-band LNAs. The average LNA noise temperatures are < 6 Kelvin in S-band and X-band and < 21 Kelvin in Ka-band.

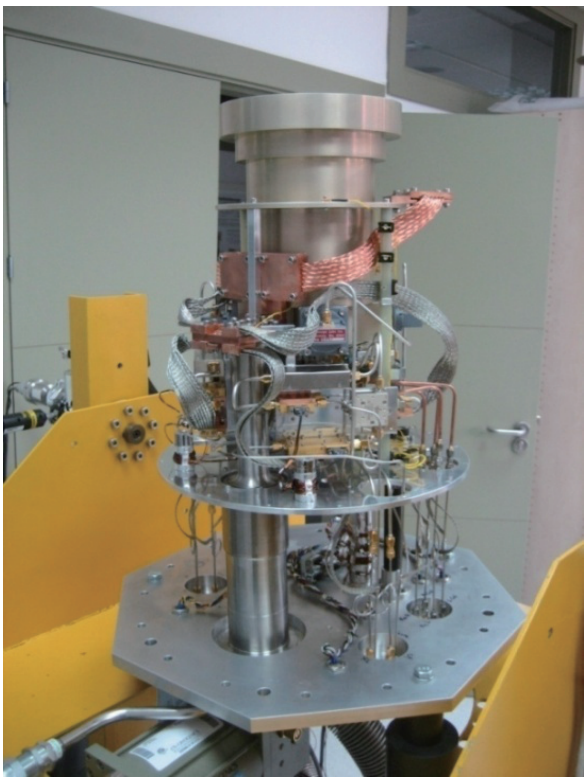

Fig. 3 Interior view of the tri-band receiver cryostat.

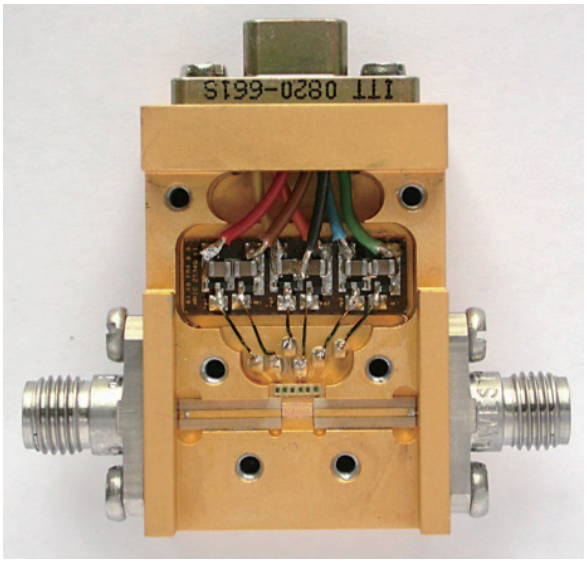

Fig. 4 Low noise amplifier (LNA) for Ka-band.

4 Measurements

The receiver noise temperature was measured for each frequency band with the Y-factor method. Microwave

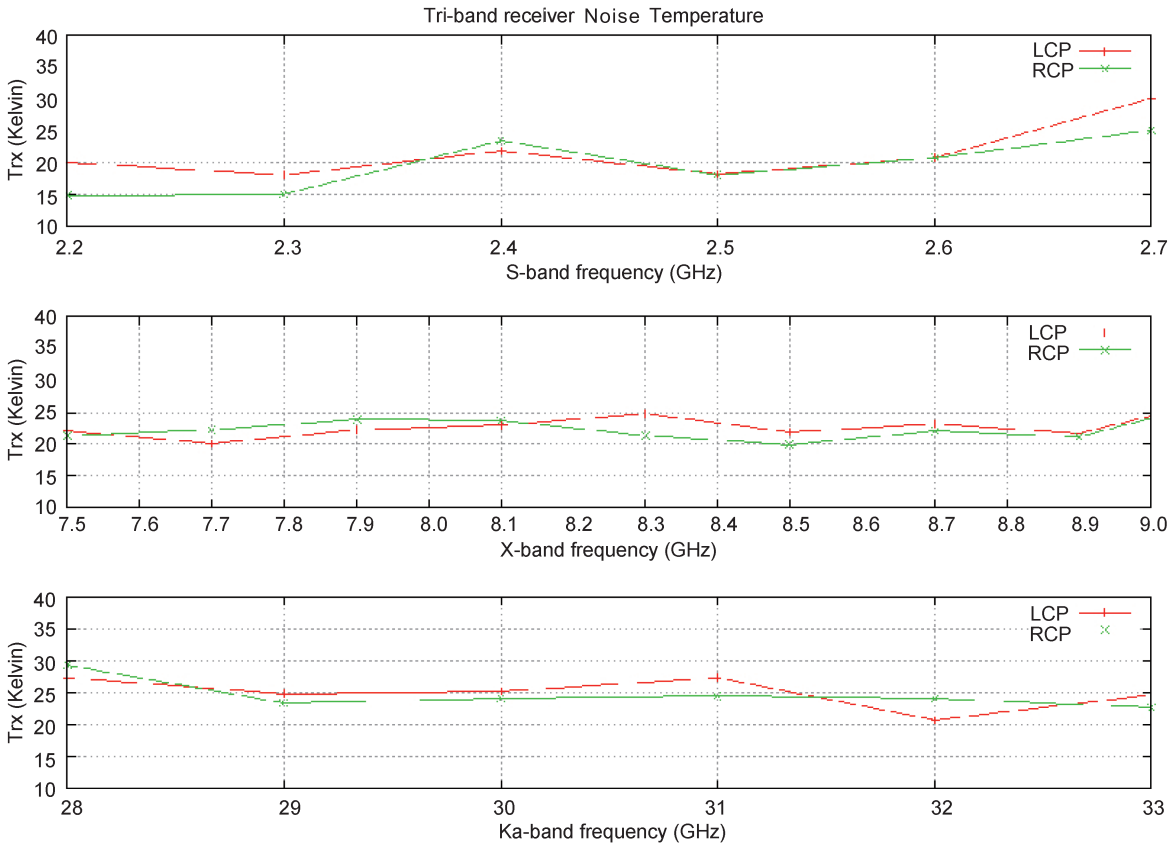

Fig. 5 Tri-band receiver noise temperature.

absorbers, dipped into liquid nitrogen and at room temperature, were used as calibration loads for the measurement. The results are plotted in Figure 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 VGOS radio telescopes 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 of the three RAEGE project radio telescopes (`http://www.raege.net/`) will be equipped with one tri-band receiver as described here. In addition, a tri-band receiver has been constructed at Yebes Observatory for the Geospatial Information Authority of Japan (GSI).

Acknowledgements

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