The Status of RAEGE

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Abstract We describe the status of the RAEGE network reviewing each of the stations that compose it. The Observatory of Yebes station is equipped with a broadband receiver and it has been taking part in VGOS observations since mid 2016. Works to improve and minimize the impact of RFI are presented. Santa Maria station is currently running a tri-band receiver, whereas the first works to construct a 13.2-m telescope at Gran Canaria were initiated. We also review the activities of the Observatory of Yebes as a Technological Development Center for the IVS. These are mainly related to the construction of broadband receivers, a cable calibration system, RFI measurements, and a harwdare solution for converting linear to circular polarizaton in a broadband regime.

Keywords RAEGE, VGOS, broadband receivers, RFI, polarization

1 Introduction

RAEGE stands for Red Atlantica de Estaciones Geoespaciales and it is an array composed of four 13.2-m diameter VGOS radiotelescopes located in Spain and Portugal. There are already two telescopes built and in operation at the Observatory of Yebes (Spain) and on Santa Maria (Azores Islands, Portugal). Two more telescopes are foreseen for Gran Canaria (Canary Islands, Spain) by 2020 and for Flores (Azores Islands, Portugal) beyond 2021. The baseline distances range between 800 km and 2,300 km, with the longest one being East-West, very appropiate for UT1 studies.

RAEGE will be part of the global VGOS network since all its telescopes are fast moving, 12 degrees per second in azimuth and six degrees per second in elevation, and equipped with broadband cryogenic receivers.

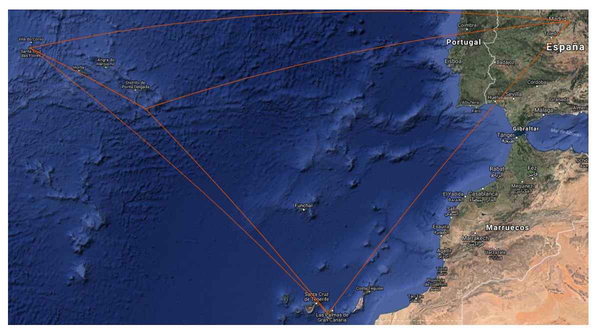

Fig. 1 RAEGE antennas and baselines depicted on a physical map. Already built and running telescopes: Yebes and Santa Maria. Its baseline is around 2,000 km long.

2 The Yebes 13.2-m RT

Currently the Yebes 13.2-m telescope is part of the CORE VGOS network and takes part in most of the tests performed since 2016. In 2016 the telescope was using two DBBC2s and a Mark6 as VLBI backends and recorder, respectively, and took part in 11 short observations. In 2017, the telescope started using four RDBE-Gs and took part in 24 24-hour observations. In 2018, the number of observations decreased due to a mechanical error at the telescope. VGOS observations have served to debug, correct, and optimize observa-

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tional procedures. Measures were taken to ensure the reliability of the operations avoiding the repetition of past errors.

The broadband receiver currently delivers an average system temperature of 50 K at 65 degrees elevation. Frequencies below 4 GHz are plagged with Radio Frequency Interference (RFI) causing an important increase of the system temperature, up to 100 K at some ranges (see Figure 2).

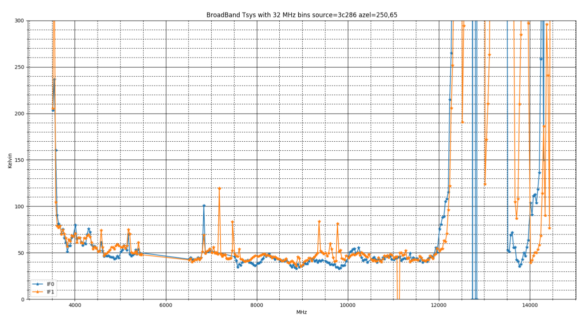

Fig. 2 System temperature for both polarizations at 250 degrees azimuth and 65 degrees elevation. It was obtained using a noise diode and while observing 3C286 under good weather conditions. The determination was done using a low band pass filter with a cut frequency of 12 GHz.

The frontend delivers two linear polarizations that are injected into an optical fiber module which transports the signals (1–14 GHz) to the backends room. Each polarized signal is then sent to a distribution module that amplifies and splits the input into four identical outputs that go into the up-down converter. The up-down converters follow the overall design by A. Rogers (2010) [6] and were developed and built at the Observatory of Yebes. Each up-down converter can be remotely commanded, allows to select the frequency input interval, and delivers the correct IF signal (0–500 MHz) to the RDBE-Gs. The digitized and packetized signal is directed towards the Mark6 after using a CX4-Optical-Fiber converter.

RFI is a severe problem at the Observatory of Yebes (OY), especially at lower frequency bands. Broadband receivers are specially vulnerable since the LNAs can saturate and cause non linear effects across the whole band. Fortunately this was not the case for the 13.2 m at Yebes, but there are issues with the optical fiber amplifiers that can break above 12 dBm. We have studied the environment of the OY with the broadband receiver and plotted the total power detected in the 2–12 GHz range across the sky. Figure 3 shows the distribution of power in a color diagram. Most of RFI happens at elevations below ten degrees and above 70 degrees. There are also some azimuths at which RFI is almost present at all elevations. The high power due to RFI led us to remove the amplifiers at ambient temperature after the cryostat and before the optical transceiver module to protect the latter but causing an increase in system temperature.

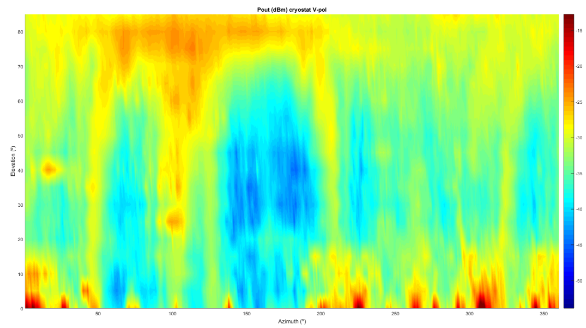

Fig. 3 Power in dBm from vertical polarization across the whole sky using the broadband receiver without filtering the data. The data are integrated between 2 and 12 GHz.

In order to decrease the system temperature and to keep at low level the RFI pollution, the output band from the amplifiers was split in two, above and below 4 GHz, and the amplifiers were reinstalled. In the band below 4 GHz a bandpass filter between 2 GHz and 2.35 GHz was installed and the signals from both bands were combined again before being injected into the optical fiber transceiver. The result of such combination is depicted in Figure 4 which shows a dramatic improvement resulting in strong RFI only below five degrees elevation and towards some selected azimuths. The average system temperature decreased from 70 K to below 50 K across the whole band. These results are part of a study on the RFI environment and mitigation by P. García (2018) [2].

A final iteration was used and the final setup consists in one amplifier per polarization after the cryogenic stage, a high pass band filter above 3 GHz, and a pin diode that limits the delivered output towards the optical fiber transceiver, keeping the linearity up to 6 dBm but limiting its maximum value to 10 dBm to protect all elements after. Figure 5 shows the final setup for the IF of the receiver.

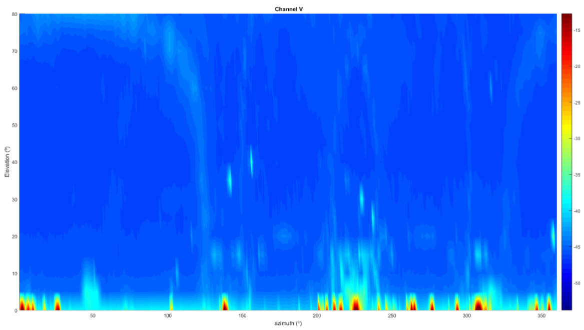

Fig. 4 Power in dBm from vertical polarization across the whole sky using the broadband receiver after filtering the data (see text for further details). The data are integrated between 4 and 12 GHz.

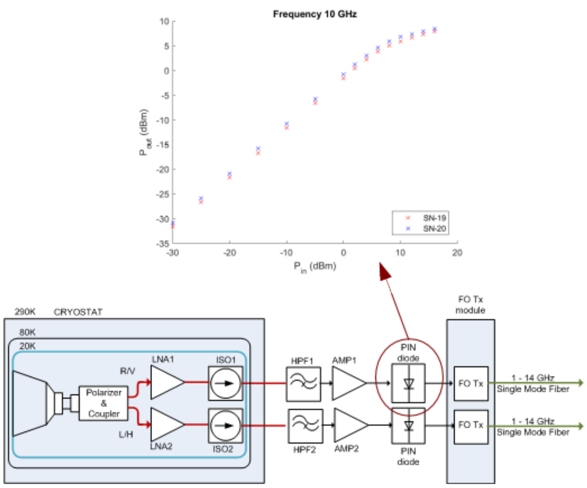

Fig. 5 Broadband receiver final setup. The high pass band filter has a cut frequency of 3 GHz. To avoid damaging the optical module, a diode pin that limits the current was installed. The curve with the response of the diode pin at 10 GHz is shown above.

3 The Santa Maria 13.2-m RT

The Santa Maria radiotelescope is currently equipped with a tri-band receiver. The first single dish successful observations were in July 2017 at S-, X-, and Ka-band. VLBI fringes were obtained at S- and X-band between Sm and Ys. The correlation was done at JIVE and repeated later at Yebes using a DiFX software correlator.

Current operations were paused for three months due to a hardware problem at the receiver, but observations have resumed in late August 2018 with legacy IVS observations and devoted observations at 2 and 8 GHz between Wettzell and Santa Maria to determine UT1. See Böhm et al. (2018) [1] in this same volume.

4 Gran Canaria and Flores Radio Telescopes

The 13.2-m radio telescope will be definitively installed at Gran Canaria island instead of being at Tenerife island, a location considered during the past years a potential site. The definitive location is at 1,100 meters above sea level in an enviromental protected area. Gran Canaria is an older and more stable island than Tenerife and thus probably a better fit for geodetic VLBI observations. Both of them are on the African plate.

Administrative work has started and it is foreseen that civil works will begin within the next months. Construction work is not allowed between March and September for enviromental reasons; therefore, the radio telescope will probably not be finished before 2020. The antenna is stored in a warehouse in Gran Canaria island, ready to be deployed when the site is ready. To ensure remote operations the IGN has signed an agreement with the technical University of Gran Canaria. The EVGA 2019 will take place in Gran Canaria in March 2019, on the premises of the University.

The status at Flores has not changed and there is no definitive site decided yet. Funds have not been secured by the Regional Government of Azores yet and there is still some preparation work to be performed first.

5 Technological Developments

The Observatory of Yebes is a Technological Development Center of the IVS and this section describes some of the activities performed during the last two years.

Within BRAND, a Radionet work package for developing a low frequency (1.5–15 GHz) broadband receiver, two of our engineers have measured the RFI environment at three EVN stations using portable equipment. Measurements were obtained between 1 and 18 GHz sweeping the whole horizon at different elevations. Spectra of RFI at each location were produced and they can be easily compared. This work has also interest for geodetic stations.

We have developed four cable and phase calibration systems composed of an antenna unit that generates pulses every 5 MHz and a ground unit which measures cable length variations with time. The design is based in the legacy design by A. Rogers [5] and it was implemented using printed circuit boards. Five more units will be built in the next year. Some of them will be delivered to BKG (Germany), FGI (Finland), and NMA (Norway). Improvements to the design using an ADC and some digital operations and filtering are already being considered and will be implemented in the next months. A prototype is being used at the Yebes 13.2-m radio telescope.

The Observatory of Yebes has installed and succesully tested a tri-band receiver at the two new NMA VGOS antennas in Ny-Ålesund. We installed the control system for the telescopes and performed the first single dish observations at both antennas remotely from Yebes. Three broadband receivers, two for NMA and one for FGI, are being built at our laboratories and it is foreseen to have them ready by 2019.

We have designed and are ready to develop a distribution module compatible with VLBI R2DBE and DBBC3 backends. The system creates four identical prefiltered outputs (4 GHz) per polarization prepared for a DBBC3 and six base bands at 2 GHz bandwidth following B. Petrachenko's proposal [4] prepared for the R2DBEs.

There has also been an important activity developing a hardware solution for the conversion between linear and circular polarization. It is well known that broadband receivers yield linear polarization. VGOS can work with linear polarizations at the correlator if both are present, but it requires a careful treatment of the data. A conversion to circular polarization at each station would ease the operations at the correlator. We have developed a solution for BRAND that has a direct application for VGOS. This solution requires the usage of hybrids and balanced Low Noise Amplifiers (LNAs). The hybrids were measured between 2 and 14 GHz and they deliver very good characteristics: low cross polarization (< 25 dB) and low phase errors ($<$ 4 degs). These excellent results strongly depend on the control of the relative lengths of the cables, which is feasible using special connectors whose electrical length is tunable. If this solution worked operationally, it could lead to broadband receivers which could be used for legacy observations. A report by García-Pérez (2018) [3] was delivered to the VGOS Technical Committee.

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