RAEGE Santa Maria: Station Overview

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Abstract The RAEGE station of Santa Maria is part of the RAEGE network (Atlantic Network of Geodynamic and Space Stations), a cooperation project established between the National Geographic Institute of Spain (IGN) and the Regional Government of the Azores. It is a unique project at a geodetic and geodynamic level, in which there is commitment to the construction and operation of four Fundamental Geodetic Stations, namely: Yebes and Gran Canaria stations in Spain and Flores and Santa Maria stations in the Azores, Portugal. Santa Maria has a radio telescope equipped with a triband receiver (S, X, and Ka bands) and has been operating as a regular station within the IVS R1 and R4 sessions since May 2021. For the past two years, the radio telescope infrastructure and signal chain underwent a series of maintenance procedures and improvements that are described in this contribution. Currently, the station has a team of ten people (and growing) distributed among IT, maintenance, administrative, science communication, and R&D tasks. An overview of the state of the art of Santa Maria and its plans, which include the installation of a broadband VGOS receiver in the second half of 2022, are presented.

Keywords RAEGE, VGOS, Azores, Yebes, core site

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1 Introduction

The RAEGE network (Portuguese/Spanish acronym for the Atlantic Network of Geodynamic and Space Stations) is a cooperation project between the National Geographic Institute of Spain (IGN) and the Regional Government of the Azores (RGA) [1]. It is a unique project at a geodetic and geodynamic level, in which there is commitment to the construction and operation of four Fundamental Geodetic Stations, namely: Yebes and Gran Canaria stations in Spain and Flores and Santa Maria stations in the Azores, Portugal. Out of these, the RAEGE sites of Yebes and Santa Maria are fully implemented.

In 2018, the RGA created Associação RAEGE Açores (RAEGE-Az) to a) manage, develop, and disseminate the RAEGE project in the Azores; b) set up a research and development infrastructure for space and space geodetic related activities, and c) communicate space science within the Azores [2]. This entity intends to establish human resources, knowledge, and experience in the Azores in areas relevant for the RAEGE project (i.e. geodesy, radio astronomy, astrometry, etc.), while allowing for greater agility in this project's management in this region.

Building on the work developed previously, a new team in place since 2020, supported by the experienced partners from Yebes Observatory, carried out a great number of corrective maintenance procedures and improvements that allowed for RAEGE Santa Maria to become a regular station in the IVS S/X legacy sessions since May 2021.

In this contribution we intend to present the station's current configuration and equipment, describe the problems found and the procedures used to solve them, detail the signal chain improvements developed in the past two years, and present the future prospects for the station.

2 Station Overview

The RAEGE station of Santa Maria has a team of ten people (and growing): one IT technician, two maintenance technicians, one administrative officer, one marketing and science communication officer, three engineers (electronics, telecommunications, and aerospace), one PhD astrophysicist for technical coordination and R&D project duties, and a station director, all based on Santa Maria island. Daily operations at this station comprise all the activities to ensure the supply of high-quality data for the network partners, technology development to support scientific challenges, and outreach activities.

The station has a 13.2-meter dish radio telescope (VGOS-like) equipped with a triband receiver designed by the Yebes Observatory. It is a low noise cryogenic receiver able to operate simultaneously in the S (2.2–2.7 GHz), X (7.5–9 GHz), and Ka (28–32 GHz) bands [3]. The Phase-Cal module injects tones shifted by 5 MHz. An active hydrogen maser generates the reference for the pulses and the local oscillators in the downconverters. The backend equipment is composed of a DBBC2 (Digital Base Band Converter) and two Mark 5b units for recording and transferring the sessions' data. Other than that, there is a relative gravimeter GRAVITON-EG installed since 2019, which has the purpose of gathering data to better understand which would be the most suitable gravimeter less prone to noise in an island environment. Also, there are two GNSS (Global Navigation Satellite System) stations, RAEG and AZSM, which are part of regional, national (both Portuguese and Spanish), and international networks (IGS, EUREF, EPOS, etc.). Finally, a seismograph Trillium 120 PA and a Silex accelerometer, designed by the IGN, are installed.

3 Corrective Maintenance Activities

The environment in the Azores is quite extreme in terms of humidity levels (above 78% relative humidity on average annually) and in terms of salinity due to the islands' dimensions, orography, and exposure to oceanic winds. Thereby, this is an environment extremely prone to corrosion, which degrades all the materials (especially the metal structures) much faster than in continental areas. An effective maintenance program is essential to keep the infrastructure in satisfactory condition. In the past two years, some corrective maintenance interventions were needed to recover the radio telescope functionality. In 2019, the radio telescope spent most of the time in park position due to a problem with the Low Noise Amplifiers (LNA) of the receiver installed at that time. In the beginning of 2020, when the triband receiver was repaired and reinstalled, the main gears of the radio telescope were found to be completely dry with a considerable layer of corrosion (see Figure 1).

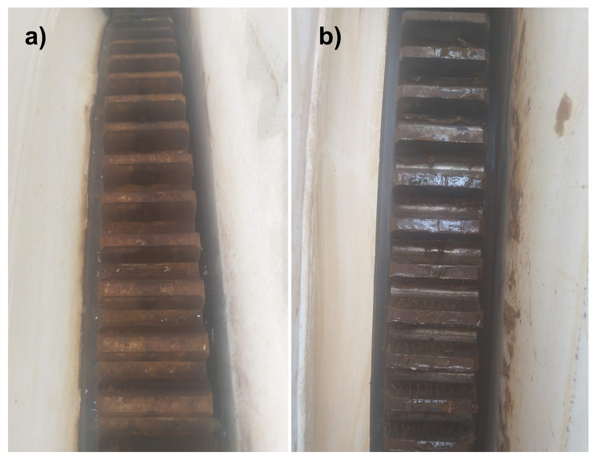

Fig. 1 Radio telescope main gears: a) before and b) after cleaning and lubrication.

Also, the automatic lubrication system in place (which works only with the motors running) wasn't supplying any grease to the lubrication gear wheels. These lubrication gear wheels are made of high-density polyurethane foam, and they are the greasing points of the system. They are critical for a correct lubrication process for both axis main gears. Due to the radio telescope's long stoppage time, these lubrication gear wheels were found completely dry and with cracks on some teeth (see Figure 2a). In two months, the accesses were opened, and all the main gears were cleaned and lubricated. It was decided to acquire a new standard of grease cartridges, to improve the pumping to the greasing points, and to replace all the lubrication gear wheels. Nowadays the system is regularly inspected to ensure that all main gears are in good condition and well-lubricated.

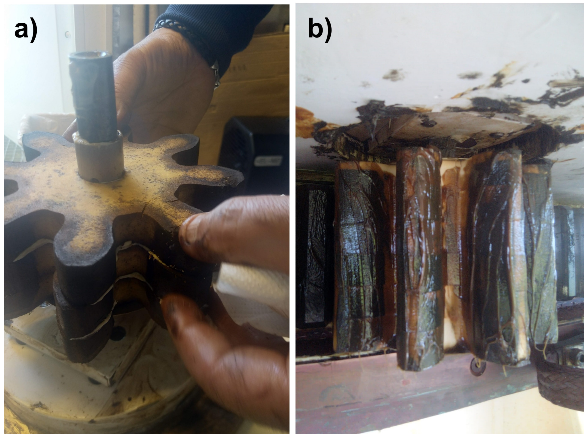

Fig. 2 Lubrication gear wheels: a) crack detail and b) after replacement by new parts.

Due to metal corrosion, several parts of the radio telescope had to be replaced by equivalent parts in stainless steel. Concerning this topic, the major intervention performed was the replacement of the servo-mechanism's container by a new one, in the beginning of 2021, as the floor started to collapse. The surrounding area had to be modified to improve the air flow on the structure and reduce condensation and zones with water accumulation. Every year from spring to early summer the radio telescope structure goes through a deep cleaning procedure to remove the moss that generally grows during winter, as well as general corrosion removal and repainting works.

Other major repairs consisted of the recovery of the positioning encoder system in the azimuth axis in the beginning of 2021. The system is composed of a large round tape and four encoder heads that read the tape marks at each axis of movement. The tape of the azimuth axis was found with scratches and with the marks faded in some areas, which caused the encoder heads to trigger errors at given radio telescope motion speeds. As no repair was possible, the encoder tape was replaced in a detailed procedure of installation and calibration. The source of the damages found on the tape was never truly understood.

The cable wrap is another system that needs to be inspected regularly for damages. After the rupture of the cable chain in the Yebes RAEGE antenna, an extensive assessment of the system in Santa Maria was made. It was found that in one of the extreme positions, the pins that support the wrap structure sometimes fail to hang the structure, and that could cause the rupture of the cable wrap chain. In order to ensure that the system behaves correctly, we were forced to limit the range of azimuth positions to 40°.

4 Signal Chain Improvements

The RAEGE station of Santa Maria began participating in the IVS S/X legacy sessions (R1 and R4) as a regular station from the end of May of 2021 to the present day with little interruption. The preparation of all signal chains to comply accordingly included the testing, updating, and debugging of all of the software of the different systems. The calibration of the DBBC and the pointing calibration sessions to determine the offsets and the gains in different sky positions, as well as all the works performed by the RAEGE team during the first months of operation (based on the correlators' and analysts' feedback), were vital to improve the quality of the data gathered by this station.

One of the improvements was to reduce the RFI (Radio Frequency Interference) detected on the channels. One of the sources was the radio telescope motor system injecting an 8 kHz tone through the electrical power supply line. On the DBBC channels, it was noticed that this tone only appeared with the active motors, and copies of it were being injected by the Phase-cal module on the receiver. To solve that, line filters were installed with the closest possible Phase-cal module. As a result, the tone disappeared.

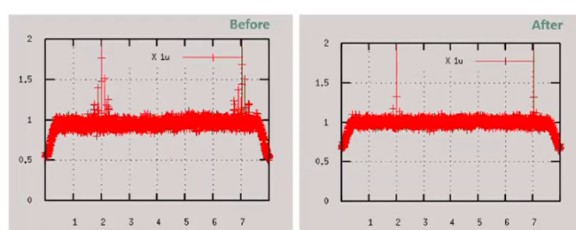

Fig. 3 RFI tones generated by the motors, before and after the installation of the line filters.

Another relevant RFI source was an external powerful link used by the civil protection with a carrier at around 2,274 MHz, which sits in one of the channels of interest for the R1 and R4 sessions. Because of that, this specific channel was being successively discarded from correlation. After several months of conversations with all the entities, mediated by the Portuguese Authority for Communication, it was possible to move the carrier outside the frequency range of interest, and the channel started to be considered for correlation from October 2021 onwards.

During the first six months of operation, the correlators reported Phase-cal tone amplitude instabilities in some sessions, leading to the need to apply manual phase-cal for correlation purposes and a significant number of non-detections in both bands. It was discovered that leakage from the signal generators, used as local oscillators in the downconverters, was the cause of the problem. First, we found anomalies in the cabling of the 5 MHz reference signal from the ground to the receiver cabin, which were provoking the signal generators to not lock to this external reference signal. Hereafter, it was also found that, as the signal generators didn't have internal cooling systems installed, and because there isn't much space in the receiver cart, the units stopped generating an RF signal as a protective measure when the internal temperature rose above a given level. To solve these issues, different cables for the reference signals were used, and the IGN organized a retrofit campaign to upgrade all the signal generators used in the different receivers, to install an internal cooling system. From that point, to monitor the system behavior, a status message is printed in the session log file, during each scan, illustrating the signal generators' actual conditions.

In the past few months, one focus was the signal chain stability. During these months of operation, we found that the T_{sys} (System Temperature) measured varies a lot in the short term, even when observing the same reference source (such as TAU-A) successively at the same elevation. To confirm if the noise calibration diode was the reason for this issue, T_{sys} calibrations were compared with SEFD (System Equivalent Flux Density) calibrations carried out in sequence. Figure 4 presents T_{sys} and SEFD multiplied by a fix factor, just to be in the same scale, when the antenna is tracking TAU-A.

These tests were done only in X-band, where the RFI environment is more acceptable. Both curves present the same behavior (as the source is approaching the horizon, T_{sys} and SEFD rise), but the T_{sys} curve

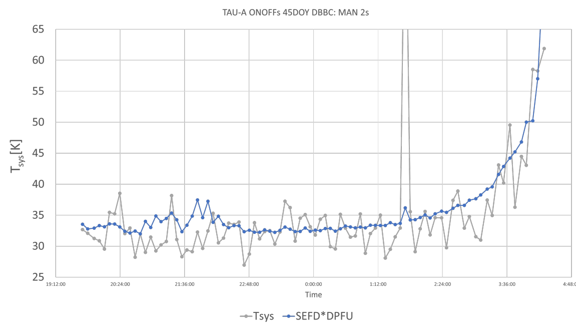

Fig. 4 System Temperature (gray) vs SEFD*DPFU (blue) measured observing TAU-A.

is noisier. At this point, two hypotheses could explain this effect: a) the noise calibration diode isn't stable or b) the sensitivity is limited and this is notable with the diode ($T_{cal} = 1.2\,\mathrm{K}$) and it isn't when tracking TAU-A (16 K approximately). To confirm this, the same test was done with a weaker source (3C84, with 50 Jy at X-band) as visible in Figure 5. Fluctuations in T_{sys} and SEFD are comparable, which suggests that gain stability is limiting the sensitivity, and this should be studied in more detail.

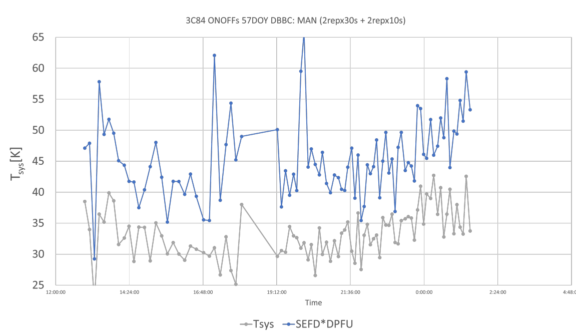

Fig. 5 System Temperature (gray) vs SEFD*DPFU (blue) measured observing 3C84.

5 Summary of IVS Operations

The RAEGE station of Santa Maria resumed operations on May 25, 2021. From that point on, the station has been participating regularly in the R1 and R4 S/X legacy sessions, and, in 2022, it is also scheduled in the

T2 and T2P sessions. The number of sessions in which the station participated is detailed in Table 1.

Table 1 IVS session summary from 2021-05-25 to 2022-03-31.

	R1	R4	T2	TOTAL
2021	29	27	–	56
2022	11	9	2	22

It must be noted that from the 90 sessions scheduled for Santa Maria to participate in from 2021-05-25 to 2022-03-31, 86.7% of them were indeed observed. From the observed sessions, 95% of the sessions were correlated. Concerning the correlators' statistics, the mean percentage of scheduled observations used per session was 68.7% for the Santa Maria data, which is considered as a successful performance.

6 Final Considerations

All the activities described in this contribution were performed by the Santa Maria station team in close collaboration with the staff from Yebes Observatory, as an expression of this RAEGE collaborative spirit across the Atlantic Ocean.

For 2022, as future major commitments for the RAEGE station of Santa Maria, all the RAEGE team is working to install a new Superconductive Gravimeter, to plan and build the GNSS–VLBI local tie pillar infrastructure, and to install a new VGOS broadband receiver, designed by Yebes Observatory, with all the corresponding backend equipment (Mark 6 and DBBC3), doing the best for the Santa Maria station to become a VGOS site by the end of 2022.

References

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