Yebes Observatory Report

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Abstract We describe the observations performed by the 40-m radio telescope and the VGOS 13-m radio telescope during the period 2019–2020 as part of the IVS network and the current status of the instrumentation for both instruments. We also present recent technical developments relevant for the IVS community and future plans within Yebes Observatory to keep the station as one of the most dynamic elements of the network.

1 General Information

The National Geographic Institute of Spain (Instituto Geográfico Nacional, Ministerio de Transportes, Movilidad y Agenda Urbana), has run geodetic VLBI programs at Yebes Observatory since 1995 and nowadays operates two radio telescopes on-site that contribute to the IVS. A 40-m radio telescope, station code "Ys", has been operating regularly since 2008. The 13.2-m VGOS-compatible antenna inaugurated in 2014 with code "Yj" (RAEGYEB) has been observing bi-weekly in the VGOS 24-hour sessions. Detailed information on RAEGE is available on the Web at http://www.raege.net/. IGN Yebes Observatory is also the reference station for the Spanish GNSS network and holds permanent facilities for gravimetry. Since 2014, IGN Yebes Observatory has been a Technology Development Center for the IVS. Activities are described in the corresponding contribution in this Biennial Report.

Yebes Observatory

Yebes Network Station

IVS 2019+2020 Biennial Report

2 Activities during the Past Two Years

In 2019, the 40-m radio telescope observed 23 IVS experiments, of which fifteen were of R4 type, two R1, four EURD, one CRF, and one EINT. The radio telescope also participated in one of the VITA experiments to explore remote clock distribution in VLBI experiments. The numbers were increased to a total of 37 in 2020, with 18 R4 sessions, 14 R1, three R&D sessions (mixed-mode observations), and two T2. Additionally, YEBES40M participated in five experiments of the RUA project. All the observations were successful except one, which was aborted due to mechanical failures in the antenna structure, and another three that were observed with minor errors.

Generally speaking, the antenna's sensitivity has remained in its nominal values, but internal investigation detected an internal source of RFI that has been present since the beginning of operations. The engineering group found a solution, and the new status has allowed the correlator to save one of the S-band channels that was being routinely eliminated from the post-processing.

The old meteorological station was replaced in the summer of 2019 with a MET4 station from Paroscientific. The wind sensor was also replaced with a Vaisala WXT532, without moving parts. The telescope has seen its storage capacity increased to 216 TB (there is an extra pool devoted exclusively to the EVN). Back in 2018, a thunderstorm hit the station and damaged the primary GPS antenna used for time synchronization, thus forcing to use the secondary GPS time system. After some time, replacement parts were acquired and verified, although we avoided to change again the master time reference, so we are still using a CNS Clock as primary GPS receiver. With regard to the GPS time synchronization, both the primary and the secondary receivers safely managed the GPS Week Rollover back in 2019.

Table 1 IVS observations participated by Yebes 40 m.

YEBES40M (Ys)	2019	2020
IVS-R1	2	14
IVS-R4	15	18
IVS-T2	0	2
EURD	4	0
R&D	0	3
CRF	1	0
EINT	1	0
Total	23	37

The 13.2-m VGOS-compatible telescope continued its participation in the VGOS-VO sessions. In 2019 this amounted to 23 sessions, and 25 in 2020. In addition, it observed 13 and 15 EU-VGOS experiments in 2019 and 2020, respectively. It has also participated in two out of the three R&D sessions in 2020, missing RD2006 because of an overcurrent in the cryogenics compressor. Luckily it caused minor damages as only a fuse needed to be replaced.

Several maintenance and upgrade operations affected the VGOS telescope during the past two years. The air conditioning system in the receiver cabin was modified in several phases during the summer of 2020 with the aim of reaching better stability and reducing the short-term fluctuations that can potentially damage the quality of the geodetic products. These tasks were included in the framework of the Cable Delay Measurement System (CDMS) upgrade, which allows the analysts to introduce ad-hoc corrections for each station to compensate for the systematic variations in the electrical length of the cable carrying the reference signal to the Phase-Cal Antenna Unit. The complete Ground Unit was replaced with a new version that incorporates a high resolution multi-meter and a Raspberry-Pi that reads the value. This is an intermediate step towards a new design based on a 24-bit ADC to increase the measurement resolution. The reference cable itself was also replaced with a different one with smaller temperature coefficient. Furthermore, this cable has been thermally isolated with an external foam layer.

The receiver is currently being under a second upgrade in the workshop, while the VGOS receiver built to be installed in Santa María (Azores, Portugal) is being used as a replacement in the meanwhile. A new QRFH that was optimized by the RF engineering group is to be installed, together with new cryo couplers characterized by 30 dB Insertion Loss to replace the current ones (20 dB IL). The receiver already underwent a first upgrade in November 2019, to replace the single amplifier channel with a balanced LNA, which was already in use for the other polarization. This configuration reduces significantly the Input Loss to the amplifier at the expense of a small increment in the receiver noise temperature. This new upgrade, which is intended to be installed on the telescope during the first half of 2021 will also allow to separate a Low Band (2.20–2.37 GHz) to allow legacy S/X observations. The current setup only allows observations in the frequency range of 3 to 12 GHz, limited in the lower side of the spectrum by the RFI environment.

Table 2 VGOS and EU-VGOS participations of RAEGYEB.

RAEGYEB (Yj)	2019	2020
VO obs	23	25
EV obs	13	15
Total	36	40

In 2020, a local tie survey was performed to update the data from the previous campaign in 2018, but the results are not publicly available yet. Within this project, a new script has been developed in Octave and Python to obtain the invariant reference point of both radio telescopes (13 m and 40 m) using targets on different parts of the antenna structures. Preliminary results allow to determine relative coordinates for both telescopes with a standard deviation of 0.1 mm. Additionally, an initial exploration of the relative coordinates of the 40-m and 13-m antennas by means of VLBI observations was also performed and compared with the local tie method. This project is to be continued in 2021.

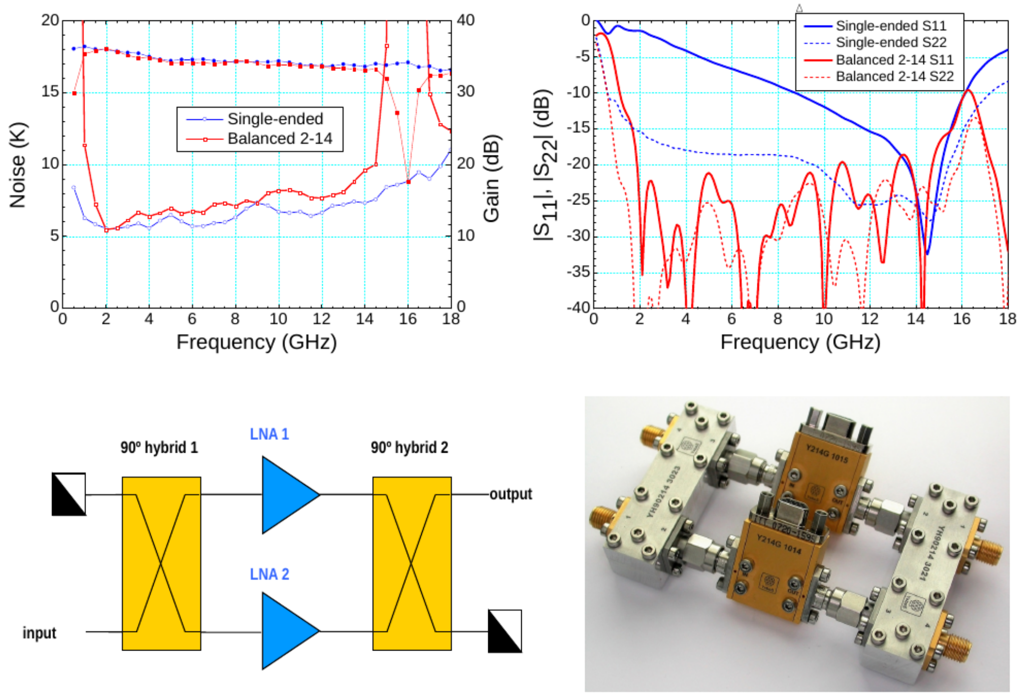

Fig. 1 The balanced LNA configuration developed at Yebes Observatory. Above: Noise and IL performance compared to single amplifier configuration. Below: schematic (left) and final built component (right).

3 Current Status

The observatory runs two active Hydrogen masers from T4-Science that provide the frequency references (5, 10, and 100 MHz and also 1PPS TTL signal) for all the electronics involved in VLBI operations, in a master-backup scheme. This same setup is also used to secure the GPS time synchronization by means of two GPS receivers (CNS Clock II and Symmetricom XLi, now Microsemi).

The 40-m is equipped with a simultaneous S/X receiver, C-band, W-band, and simultaneous K/Q. The W- and Q-band were built in Yebes labs during 2018 and commissioned on January 2019. All the receivers can record dual-circular polarization except W and Q which are linear, but lambda quarter plates are available for its use in circular polarization mode. Continuous calibration is available in the S/X, C, and K receiver using a noise diode driven by a 80 Hz signal generated in the backend. Q- and W-band observations can be calibrated with a hot-cold load system.

Since its first light, the 13.2-m VGOS-type telescope is equipped with four RDBE-G backends connected to a single Mark 6 unit. The frontend signal chain consists on a cryo-temperature QRFH feed connected to Yebes' own broadband receiver that sends the full 3 to 12 GHz band through an optical fiber link to four UDCs, each of them adapting a 512-MHz band in Nyquist zone 2 to be digitized by a RDBE-G. All the experiments since then were performed using this configuration, and the whole signal chain has shown good reliability, being able to run for months without human intervention other than routine monitoring operations.

YEBES40M is still involved in geodetic VLBI operations under the legacy network. RAEGYEB is doing bi-weekly observations within the emerging VGOS network.

4 Future Plans

The modifications to the VGOS receiver, that are currently being done at Yebes laboratories, are expected to be completed in the first trimester of the year and will give better sensitivity to the antenna. It is expected to have lower than 50 K receiver's equivalent noise temperature at any frequency from 2 to 14 GHz and well below 20 K above 6 GHz. The upgrades to the CDMS in 2020 had already demonstrated better stability in the cable length measurements, but we still expect further improvements when the final system is installed later in 2021. We also plan to deploy four R2DBEs which allow 1-GHz bandwidth and two IFs (polarizations) each, once the firmware is installed and tested.

During 2020, a DiFX correlator was installed in a small cluster for testing purposes. A couple of Very Short Baseline Interferometry sessions between YEBES40M and RAEGYEB were done and correlated to explore the pipeline, with promising results. That was the first step towards the design of a regular series of Local-Tie VLBI experiments to be started in 2021.

Finally, the observatory, as part of the national high-speed network for Investigation and Education (RedIRIS) in Spain, is upgrading the networking equipment to support a new 100-Gbps connection to the RedIRIS backbone, in view of higher bit rates for data transfer of wide bandwidth observations (over 1 GHz).

Acknowledgements

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References

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