Italy INAF Analysis Center

Monia Negusini, Roberto Ricci, Matteo Stagni

Abstract This report summarizes the activity of the INAF VLBI Analysis Center. Our Analysis Center is located in Bologna, Italy and belongs to the Institute of Radio Astronomy (IRA), which is part of the National Institute for Astrophysics (INAF). The IRA runs the observatories of Medicina and Noto, where two 32-m twin VLBI AZ-EL telescopes are located. This report contains the AC's VLBI data analysis activities and illustrates the latest experiments, involving the Italian antennas and correlator, carried out in the last two years.

1 Current Status and Activity

Following the installation of the DiFX software correlator DiFX in 2012 in Bologna, there have been a number of experiments to test the correlation pipeline for geodesy. These VLBI experiments were performed at first on the single baseline Medicina–Noto and subsequently extended to Matera after seeking a collaboration with ASI, which manages the antenna facility. The VITA (ITAlian Vlbi network) project was launched as a national pilot project, obtaining observing time at the stations and successful experiments.

In these last years the group has been involved in the IQB (Italian Quantum Backbone) development, in collaboration with INRiM (National Institute of Metrology), which set up a distributed time and frequency optical link to some scientific and commercial facilities, such as the Milan financial District, the Medicina Radioastronomical Observatory, the Italian Laboratory for Non-linear Spectroscopy (LENS) in Florence, the Telespazio Facility in the Fucino Plain, where one of the main stations of the European Galileo satellite network for global navigation is located, and the National Institute of Optics in Pozzuli, to finally reach the Matera Center for Space Geodesy.

In 2021, our group continued a series of VLBI experiments aimed at the characterization of atomic clock synchronization and frequency transfer.

On January 11, 2021 the Medicina antenna took part in a 24-hour rapid session (R1981) in which the clock frequency reference was shared with the Matera antenna via the Italian Quantum Backbone fiber link infrastructure [1]. The data of the participating antennas were correlated by both the Bologna and the Bonn DiFX correlators and locally analyzed via νSolve to extract clock model information.

On February 13 and 24, 2021 the Medicina antenna was part of a VLBI experiment in which all of the four Italian antennas observed a few extragalactic sources at 8.4 GHz. A particular frequency set-up was chosen so that both Matera and the Sardinia Radio Telescope could take part in the runs. SRT, in particular, used a narrow-band (40 MHz) receiver operated by the Italian Space Agency for satellite tracking that overlaps with the geodetic X-band frequency range. The data of two six-hour runs were correlated by the Bologna DiFX correlator, fringe fitted, and analyzed using the software package AIPS. The February 13^{th} experiment was performed with Medicina and Matera operating in common-clock mode, whereas the February 24^{th} experiment had all the antennas operating with their local clocks. The statistics on the observed phase stability were extracted and the clock frequency contribution

Istituto di Radioastronomia INAF, Bologna

INAF Analysis Center

IVS 2021+2022 Biennial Report

characterized. Preliminary results were presented at the EVN mini-symposium in July 2021 [2].

New efforts to compare optical atomic clock frequencies at intercontinental distances via VLBI/GPS techniques were undertaken with a new Italian-Korean collaboration, after the completion of the Italian-Japanese project involving transportable small broadband dishes, whose scientific achievements were detailed in publications [3] and [4]. As a first step of the Italian-Korean collaboration the frequencies of the INRiM Ytterbium optical clock and the KRISS Ytterbium optical clock were compared in a 24-hour K-band geodetic VLBI experiment in December 2021 involving six antennas, where the Medicina and Sejong antennas were connected via optical fiber to the INRiM and KRISS, respectively, hosting their optical clocks. In 2022 the data were correlated by the Bologna DiFX correlator and analyzed via νSolve. Future optical clock frequency comparison will make use of the Korean-designed Compact Triple-band Receiver to be also installed in 2023/24 on the Italian antennas as part of a major infrastructure upgrade.

2 Data Analysis and Results

The IRA started to analyze VLBI geodetic databases in 1989, using the Calc/Solve package on an HP workstation, first located at the Medicina observatory and later at the Bologna headquarters. Since 2007, Linux workstations have been set up for the migration of all the VLBI data analysis, and Mark 5 Calc/Solve has been installed. During the last years, our Analysis Center had some inner problems, and we did not participate regularly in the IVS activities. However, we continued to update the catalog, and we installed and tested the latest releases of Calc/Solve and νSolve.

References

1. C. Clivati *et al*. Common-clock very long baseline interferometry using a coherent optical fiber link, *Optica*, 7, 1031-1037, https://doi.org/10.1364/OPTICA.393356, 2020
2. R. Ricci, M. Negusini, F. Perini *et al*. VLBI experiments with the dissemination of a common clock via coherent optical fiber link, *European VLBI Network Mini-Symposium and Users' Meeting 2021*, https://doi.org/10.22323/1.399.0029, 2021
3. M. Sekido, K. Takefuji, H. Ujihara *et al*. A broadband VLBI system using transportable stations for geodesy and metrology: an alternative approach to the VGOS concept, *J. Geodesy*, 95, 41, https://doi.org/10.1007/s00190-021-01479-8, 2021
4. M. Pizzocaro, M. Sekido, K. Takefuji *et al*. Intercontinental comparison of optical atomic clocks through very long baseline interferometry, *Nat. Phys.*, 17, 223–227, https://doi.org/10.1038/s41567-020-01038-6, 2021