# Geodetic Italian VLBI: first tests

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**Abstract** First experiments of the Italian VLBI network (VITA) correlated in Bologna have involved the Medicina, Noto and Matera antennas. Although the scientific validity of these tests are yet to be proven, these experiments have served as a benchmark to verify a full, in-house, correlation pipeline, from the scheduling through the software correlation using DiFX to finally generating a geodetic database. A future inclusion of the Sardinia Radio Telescope, when geodetic receivers will be installed, will enhance the capability to plan *ad hoc* observations and strengthen the VITA network to became a basis for the definition of the national datum.

**Keywords** Italian VLBI network, software correlation.

## 1 Introduction

Since the installation of the DiFX software correlator by Deller et al. (2011) in 2012 there has been a growing interest in correlating and processing geodetic experiments in Italy. The pipeline for processing this kind of data has not been straightforward, particularly in the preparation of an observing schedule using the GSFC SKED Package (`http://vlbi.gsfc.nasa.gov/software\_sked.htm`) and gaining the skills to post-process data using the tools provided by the Haystack Observatory HOPS software (`http://www.haystack.mit.edu/tech/vlbi/hops.html`).

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**Fig. 1** Italian baselines - shortest 500 km - longest 900 km.

At present, the antennas involved in the experiments are Medicina, Noto and Matera. Each of them has different setup and available backends (see Table 1), including the newly acquired dBBC backends, which require manual editing of the vex files to ensure that the recorded data could be correlated. The fourth Italian antenna, the Sardinia Radio Telescope (SRT),

**Table 1** VLBI setup for Italian stations.

| Station | Backend | Recorder | Network |
|---|---|---|---|
| Medicina | dBBC | Mark5C | 10 Gbit |
| Noto | dBBC | Mark5B | 10 Gbit |
| Matera | VLBA | Mark5B | 512 Mbit |
| SRT | dBBC | Mark5C | - |

**Table 2** Correlator architecture.

| Machine | Cores | Storage | Connectivity |
|---|---|---|---|
| tank-mc | 8 | 50 TB | 10 Gbit network + 40 Gbit InfiniBand |
| tank-nt | 8 | 50 TB | 10 Gbit network + 40 Gbit InfiniBand |
| tank-srt | 8 | 50 TB | 10 Gbit network + 40 Gbit InfiniBand |

which owns state-of-the-art receivers and backends, including an active surface, has not planned to acquire standard geodetic S/X receivers yet, so it was not involved in this series of preliminary tests.

## 2 Correlation pipeline

All correlations were performed with DiFX correlation software installed in Bologna. The cluster architecture chosen to perform the correlation duties is composed of three storage and computational machines, and a software dedicated node. All the three aforementioned machines have the storage capacity of 50 TB composed by a 20 TB SATA disks RAID5 array and 30 TB SAS disks RAID5 array (see Table 2). Moreover, each node has a 10 Gbit network card and a dedicated 40 Gbit InfiniBand board for local interconnect. The aim of this architecture is to use each node for recording capabilities when not correlating data, avoiding the use and shipping of disk packs from the stations. The newly acquired dBBC backends have the possibility to stream data through the network at a peak velocity of 4 Gbit/s when coupled with a Fila10 G board, that acts as a formatter which encapsulates the data samples either in Mark5B mode or in VDIF mode. In these tests all the data were recoded using Mark5B or Mark5C at the stations, for safety, and subsequently sent through network connections to Bologna but, as numerous tests have proven, there is the possibility to directly stream and record data at the correlation facilities, in Bologna. Once data have been sent to the correlator, it was a matter of hours to perform fringe finding tasks and start the correlation process. For a classical 24-hours experiment, involving three antennas, it takes approximately 10 hours to process all the data. To make available database products for analysis some more time is required to process the correlation raw output into MarkIV file format and then finally to MarkIII database files getting rid of RFIs and correcting phase calibration in affected channels. The data is then ready to be processed by Calc/Solve software (`http://vlbi.gsfc.nasa.gov/software\_calc\_solve.htm`).

## 3 Italian VLBI network tests

In November 2013 there was a first short run of test involving the antennas of Medicina, Noto and Matera. It was unsuccessful due to a schedule problem happened in Matera, so it was only possible to correlate Medicina and Noto in this instance. Fringes were found but with no scientific use for a single baseline.

A second test was tried a month later, but this time the first half of the experiment was lost at Noto due to a failure at the recording system. Again a single correlated baseline was not enough to claim any valid scientific results.

The third trial has proven to be successful only in late 2015, though performed in March 2014. The main issue, lastly discovered, was a wrongly described setup in Noto. In fact, the schedule prepared with a not-up-to-date version of SKED still listed Noto as having a VLBA backend, whereas at the station it was decided to switch to the dBBC backend for that test. Retrieving the key information form the field system log, a new correlation process was set up to finally gather valid data for the three baselines.

## 4 First scientific outputs

The March 2014 experiment (called VI001) was shaped as an IVS standard EUROPE. Starting from the correlator output, the classical analysis steps have been performed: creation of the database with Dbedit, adding *apriori* information regarding sites, sources, models with Calc11, adding weather and cable information with Dbcal and performing group and phase delay ambiguities resolution and data editing with Solve. At the end, a typical solution of a small network, with 516 used observations for the 24-hours, was achieved with $\approx 60$ ps WRMS.

We have planned new observations in 2016, involving the three Italian geodetic antennas, that should be the beginning of a possible routine activity, creating a data set that can be combined with GNSS observations to contribute to the National Geodetic Reference Datum, to the ITRF and to study geophysical phenomena occurring in the Mediterranean area.

Particular care should be taken in the scheduling of the new experiments in order to optimize the number of the usable observations.

These observations will be used to study and plan future experiments in which the time and frequency standards can be given by an optical fiber link, so having a common clock at different VLBI stations.

## 5 Conclusions

The March 2014 geodetic VLBI test experiment (VI001), which involved the Medicina, Noto and Matera antennas, has proved the feasibility of a successful, in-house, correlation and analysis procedure.

The first tests marked the beginning of a progressive series of experiments planned to verify the validity of distributed time at the stations and the integration with the national GNSS network to contribute to the Geodetic Reference Datum.

A deeper integration of the correlation facilities could be forecasted, as the new VGOS system begins to be deployed and distributed correlation becomes a mean to ease the duties of the principal IVS correlators.

## References

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