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**PhD course of National Interest in Technologies for
Fundamental Research in Physics and Astrophysics**

Annual report

Name and surname: Maida Anwar

Cycle and a.a.: 39th cycle /2024-2025

Supervisor: Federico Perini & Jacopo Nanni

- Research activity carried out during the year**

The PhD thesis is focused on the “Realization of Wide Band Radio Over Fiber Systems for the Downlink of INAF VLBI Antennas”, which aims to develop and implement high-performance links for the intermediate frequency (IF) downlinks of the Italian VLBI antennas. Initially, the project was focused on studying the link currently used at the Sardinia Radio Telescope (SRT). Following this, the goal has been to address and improve any identified issues to allow the installation of similar systems at both Medicina and Noto VLBI antennas. The project involves enhancements of the link dynamic range from architectural point of view and optical and RF components of the link: Mach-Zehnder Modulator (MZM), Photodetector (PD), Laser, Low Noise Amplifier and post-Amplifier.

During the second year, I focused my activity developing a MATLAB-based model of wideband optical fiber links. To validate this model, I conducted laboratory measurements but unfortunately only at low frequency (900MHz) because in the labs only low frequency components were available. The results of the validation of the model have been presented at the TECH-FPA PhD Retreat 2025.

Since the SRT link are already installed on the antenna, it was not possible to perform high-frequency (1–18 GHz) measurements directly on them. Therefore, I obtained the SRT link measurements and component data (from the company’s datasheets) for the components used in the SRT and used them in the model to match the results. Although data for one component (the PD) was missing, a reasonable response was still achieved. After this activity, I simulated several combinations of MZMs and PDs for the optical link, using their S21 parameters extracted from the data sheet for frequency dependency of all specifications e.g., insertion loss and V_{pi} of MZM and Responsivity of PD (the Laser used is the same of the SRT links because it was found good enough with low relative intensity noise value: $RIN \leq -160$ dB/Hz). Furthermore, I have been searching for suitable RF components (pre-



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and post-amplifiers) to ensure that the complete link satisfies the required performance.

The measurement activity on the 3-band receiver, due to the major upgrade of the Medicina VLBI dish, should start in the mid of October 2025 (Noto antenna is not available until mid 2026). The goal of this activity is to check, and eventually update, the RF specifications derived several years ago which were based only on simulations of the expected performances of the receivers. New optical components, whose suitability has been assessed using the MATLAB model, are expected to arrive by the end of 2025 (the orders are still ongoing). The components will first be characterized individually and then as part of the link. The characterization data of the individual components will then be used in the model to verify whether it works at high frequency. These components will be subsequently integrated with the RF blocks (pre- and post-amplifiers) to try to achieve full link specifications. Additionally, alternative architecture using dual-output MZM and balanced PD may be explored.

- **List of attended courses and passed exams**

- Sep-Dec: Attended course "**High Frequency Electronic Circuits M**", Cr 7.5, Exam Passed on Jan (addendum left)
- Sep-Dec : Attended the course "**Laboratory of Microwave Photonics T**", Cr 4, Exam passed on Jan (addendum left)
- 8-9April : Attended course "**Fundamental system engineering and project management for large scientific projects** ", Cr 1.5, Exam Passed

- **List of attended conferences,**

- **TECH-FPA PhD Retreat 2025**, February 17 - 21, 2025, Gran Sasso National Laboratory (LNGS), Assergi (L'Aquila)



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- **Sixth Workshop on Millimetre Astronomy in Italy**, 3 June 2025, Bologna
- **Towards high - performance mm - VLBI science operations with multi-band receivers**, Bologna (Italy), 28-31 October 2025
- **School**
- **SPEcialized Training in Technologies for Radio Astronomy**, September 15 to 19, 2025, INAF Radioastronomical Station of Medicina (Bologna)
- **The Bianca Garilli School, Scientific Communication in Astronomy , 3rd edition** October 12-17, 2025, Bertinoro, Bologna
- **List of published papers/proceedings**
Nill
- **Thesis title (even temporary)**
 - Design and Realization of wide band (1-18GHz) radio over fiber systems for the IF downlinks of INAF VLBI antennas

Date, 23/09/2025

Signature *Muhammad Anwar*

Seen, the supervisors