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TNRO*: A Beacon for Southeast Asia's VLBI Advancement and Role in Global VLBI Networks

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Abstract. National Astronomical Research Institute of Thailand (NARIT) initiated a national flagship project with the empyreal goal of capacity building and technology development through the construction of national radio telescopes for radio astronomy and geodesy in 2017. To achieve this, NARIT has established the Thai National Radio Astronomy Observatory (TNRO), in Chiangmai, the northern part of Thailand. At this observatory, two radio telescopes have been constructed: one is a 40-m Thai National Radio Telescope (TNRT) that is the largest telescope for radio astronomy in Southeast Asia with a wide frequency range of 0.3-115 GHz, and another one is a 13-m VGOS radio telescope as its co-location. Collaborating with VLBI arrays in the world, such as the European VLBI Network (EVN), these Thailand radio telescopes will drastically enhance the imaging quality and performance due to its unique geographical location. This advancement marks a significant step for both radio astronomy and geodetic VLBI studies. We here review the progress of TNRO, including the first Call for Proposals of the TNRT initiated in October 2023, and the preparations for VLBI observations, highlighted by the first fringe detection. The success of TNRO will be solid foundation to establish forthcoming regional VLBI networks, which are Thai National VLBI Array (TVA) and Southeast Asia VLBI Network (SEAVN) in collaboration with Indonesia, Malaysia, and Vietnam, then to accelerate the Global VLBI Alliance activities.

1. Introduction

Along with an essential probe of electromagnetic waves in the multi-messenger astronomy era, following the successful pathway of the 2.4-m optical telescope (Thai National Telescope) in the last decade, National Astronomical Research Institute of Thailand (NARIT: Public Organization) initiated a national flagship project in 2017 for development of radio astronomy and geodesy. This project was strongly motivated by the importance of the development by "Ourselves" in-house to achieve an empyreal goal of "Capacity building and technology development through radio astronomy and geodesy", via constructing national radio telescopes in Thailand.

NARIT has thus established the Thai National Radio Astronomy Observatory (TNRO) in Huai Hong Khrai Royal Development Study Centre, Doi Saket District, Chiangmai, in the northern part of Thailand since 2018. Given a radio quiet zone and low amount of water vapor on the basis of site investigations, this location is the best suitable site to build up radio telescopes covering low to high observable frequencies in Thailand, consisting of a 40-m Thai National Radio Telescope (TNRT, Figure 1 middle) and a 13-m VLBI Global Observing System (VGOS) radio telescope (Figure 1 right, TNRT co-location), with a visitor center to be opened to general public.

2. The 40-m Thai National Radio Telescope

The 40-m TNRT is located at latitude 18° 51′ 51.564″ N and longitude 99° 13′ 01.052″ E at 411.145 m above mean sea level, corresponding to geocentric coordinates (ITRF2014) (X, Y, Z) = (−967128.77, +5960055.19, +2049264.04) meter. Based on this location close to the equator, the TNRT is geographically accessible to both the Northern and Southern hemisphere. This is the largest telescope for radio astronomy in Southeast Asia. The TNRT was started to be built in 2018, based on the National Geographical Institute (IGN) 40-m Yebes telescope (López Fernández et al. 2006; de Vicente et al. 2006) with a classical Nasmyth-Cassegrain focus optics, but is

* Thai National Radio Astronomy Observatory

Fig. 1. The 40-m TNRT (middle) and 13-m VGOS radio telescope (right) at Thai National Radio Astronomy Observatory (TNRO) in Chiangmai, Thailand (Image credit: Left - NordNordWest in Wikipedia; Middle and right - TNRO/NARIT).

upgraded with the installation of a Tetrapod Head Unit at the prime focus. This upgrade enables the selection of either a receiver at the prime focus or the sub-reflector to be used for receivers installed at the Nasmyth focus in the receiver cabin. Given the specifications at the best performance: a pointing accuracy of 2 arcsec (no wind case) and a surface accuracy of 150 μm rms, we plan to install multiple receivers for this telescope from 300 MHz to 115 GHz.

The first receivers installed for early sciences are the L-band (1.0–1.8 GHz, linear polarizations) and K-band (18–26.5 GHz, circular polarizations) receivers equipped with the Universal Software Backend (USB) and Effelsberg Direct Digitization (EDD) system enabling multiple observation modes[1]. These were developed in collaboration with Max Planck Institute for Radio Astronomy (MPIfR), while the Ku-band receiver (10.70–12.75 GHz) in using for microwave holography was developed in collaboration with Yebes Observatory, IGN (Lopez-Perez et al. 2014). The Telescope Control Software (TCS) is based on the ALMA Common Software and was also developed in collaboration with Yebes Observatory, IGN. The L-/Ku-bands and K-band receivers have been installed at the prime and the Nasmyth focuses, respectively.

Key Science Cases with TNRT: To prepare for launching the 40-m TNRT, a science working group was organized with world-wide collaborators to discuss key science cases achievable with TNRT for a wide-variety of research fields and the wide-coverage of observable frequencies: pulsar, fast radio burst, gravitational wave, star formation, galaxy, active galactic nucleus (AGN), evolved star, chemically peculiar star, maser, and geodesy. Based on an advantage for flexible operations as our own radio telescope and as being accessible to both the Northern and the Southern hemisphere, the key sciences as a single dish focuses on time-domain astronomy, which addresses exploration of transients / variability and achievement of high-cadence monitoring campaigns planned for known sources or as unbiased surveys for all the sky. These ideas were published as a white paper in arXiv website on 12 October 2022 (Jaroenjittichai et al. 2022). This was encouraged to achieve it through the first light of the TNRT in 2022 based on the detections of 21-cm HI emission, pulsar, and OH/H_2O masers in L-/K-bands.

The First Call for Proposals of TNRT, Cycle 0: To launch the TNRT for operations and science observations, the performance evaluations were achieved, particularly for the general engineering commissioning of the first phase of the L-band system. This consists of the beam-pattern measurement, the dynamic pointing tuning, establishment of the amplitude calibration with a noise-source, the aperture efficiency measurement with its dependence along elevation, the linearity and Allan variance evaluations, the Doppler correction, verification of the observing scanning modes, and bird's-eye view mapping of radio frequency interference (RFI) and the skyline at the site. All the results are publicized in the web-page for the first Call for Proposals of the 40-m TNRT with the L-band system in Resident Shared Risk Observing style (`https://indico.narit.or.th/event/197/`, see section "Status Report"), which was finally announced on 10th October 2023, TST 10 am as cycle 0, and the open-use observations in that cycle was completed in July 2024. The K-band receiver installed at the Nasmyth focus and its system on the TNRT is still under commissioning.

[1] `https://mpifr-bdg.pages.mpcdf.de/edd_documentation/`

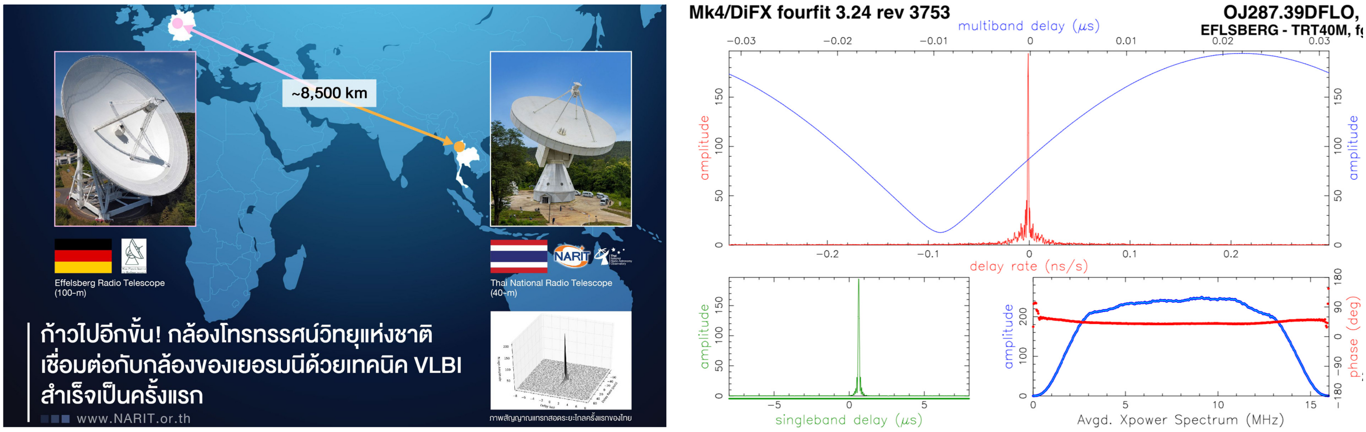

Fig. 2. Press-release entitled "Dawn of Radio Astronomy with Very Long Baseline Interferometry in Thailand" for success of the first VLBI fringe detection of the 40-m TNRT with the Effelsberg 100-m radio telescopes, in collaboration with MPIfR (Credit: NARIT and MPIfR). The right-hand panel presents one of the fringe detected in one of target continuum sources, OJ287, a BL Lac object type active galactic nucleus (Image Credit: J. Wagner, N. A. Esser, U. Bach, et al.).

Impacts on VLBI: The 40-m TNRT will be a powerful telescope for promoting any VLBI activities, such as European VLBI Network (EVN), East Asia VLBI Network (EAVN), Very Long Baseline Array (VLBA), Long Baseline Array (LBA), and so on. For any cases, TNRT contributes to improving the UV-coverage effectively due to its unique geographical location, by adding one of the longest baselines in unique directions as well as filling gaps in the coverages. The TNRT will thus enhance spatial angular resolution and imaging quality for a wide-range of frequencies for each VLBI array. The TNRT participation will thus enhance VLBI large programs, accelerate the synergy with essential projects in multi-messenger astronomy era, and achieve the first trial of Geodetic VLBI in Southeast Asia. As the significant first step to achieve this exciting enhancement, based on great collaboration with Max Planck colleagues in Germany, together with the 40-m telescope team at NARIT, we accomplished the first VLBI signal detection for the 40-m TNRT in L-band (1.658−1.674 GHz) on 16 May 2024 towards all of the four continuum quasar targets, in collaboration with MPIfR and their Effelsberg 100-m radio telescope (Figure 2). This milestone was officially announced through the press-release in web-pages of both institutes[2][3].

3. The 13-m VGOS radio telescopes in Thailand

As TNRT co-location in TNRO site, Chiangmai, one more another radio telescope of the 13-m VGOS was constructed in collaboration with Shanghai Astronomical Observatory (SHAO), Chinese Academy of Sciences (CAS), with its first fringe detection achieved in August 2024. This success is a great model case to build up the second VGOS telescope in Thailand with SHAO, and Walailak University in Nakhon Si Thammarat, the southern part of Thailand. This has been planned to launch towards the end of 2025. Moreover, the third VGOS station in Songkhla, also the southern part of Thailand, at a distance of 1,330 km from Chiangmai, will be realized together with an outsourcing company, towards the end of 2026. Meanwhile, IGN Yebes Observatory supported the receiver development, with excellent low noise temperatures better than 20 K across all the VGOS bands, arriving at NARIT in December 2023 already (de Vicente, Lopez-Perez, et al. in private communication). These VGOS stations covering both the Northern and Southern parts of Thailand allows extensive applications in geodesy and tectonic studies covering the two different Eurasian and Sunda plates in Southeast Asia.

4. Vision of Regional VLBI Networks

Thai National VLBI Array (TVA): In addition to these four radio telescopes, there are other possible candidate antennas available for radio astronomy in Thailand: telecommunication antennas with the diameter of 32-m at the campus of National Telecom Public Company Limited in Chonburi and Ubon Ratchathani, in the central and eastern parts of Thailand, via utilizing the antenna conversion technique (Fujisawa et al. 2002, 2022; Yonekura et al. 2016). Completing these plans will result in the establishment of Thai National VLBI Array (TVA: Figure 3 left) with a VLBI data correlation center, aiming to be launched since 2026 in C/X/Ku-bands.

Southeast Asian VLBI Network (SEAVN): The TVA will be the solid foundation for establishing a next regional VLBI network: Southeast Asian VLBI Network (SEAVN). The SEAVN will be achieved in collaboration with Institut Teknologi Bandung in Indonesia, Universiti Malaya in Malaysia, and Vietnam National Space Center

[2] https://www.narit.or.th/index.php/en-astronomy-news/4305-dawn-of-radio-astronomy

[3] https://www.mpifr-bonn.mpg.de/announcements/2024/2

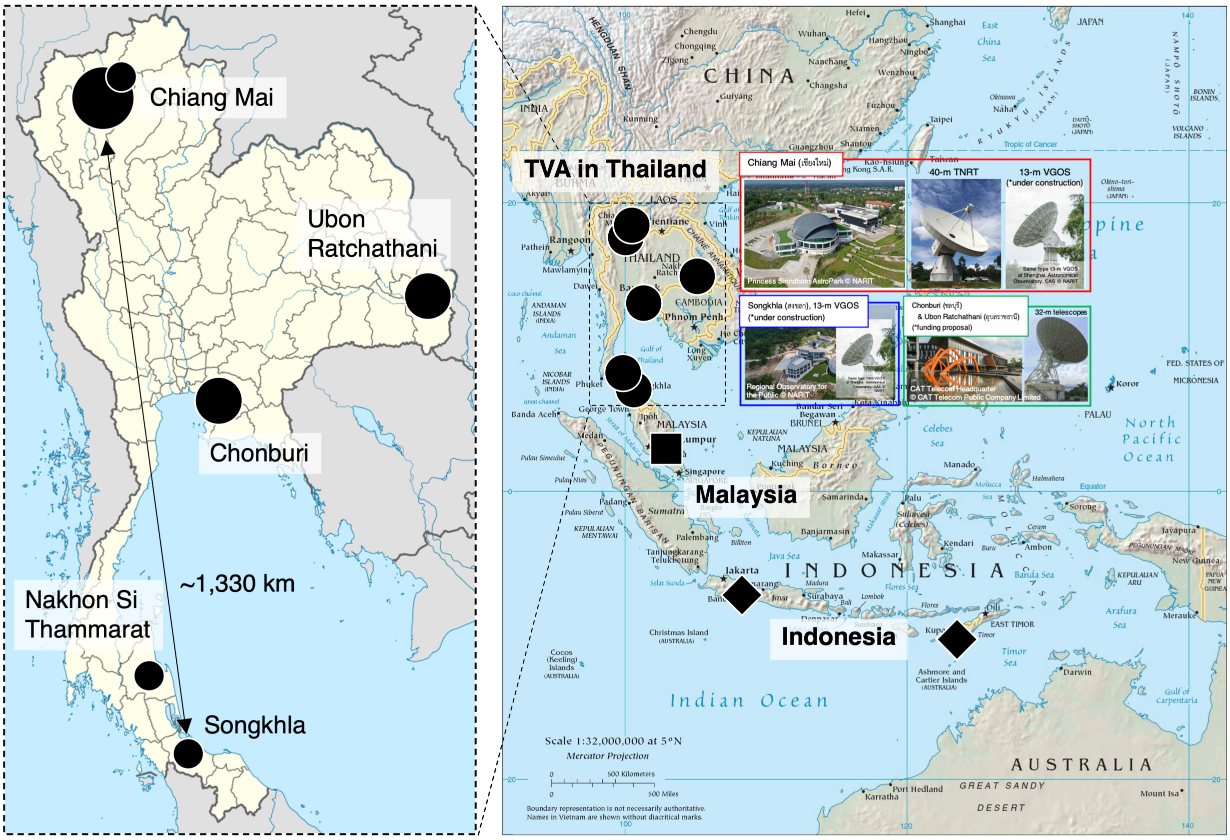

Fig. 3. Forthcoming regional VLBI networks: (Left) TVA. Each radio telescope is shown by circles with the size proportional to its diameters. (Right) SEAVN. Radio telescopes (including forthcomings) are shown by circle, diamond, and square symbols with its fixed sizes for in Thailand, Malaysia, and Indonesia, respectively. Image credit of backgrounds: Left - NordNordWest in Wikipedia; Right - Monedula, CIA World Factbook, Wikimedia.

in Vietnam. Considered their planning 3-4 radio telescopes, 8-9 stations in total combined with the TVA will constitute the initiation of SEAVN, as shown in Figure 3 (right).

The development of the SEAVN will enhance VLBI networks, bringing them to the next level, through the drastic upgrade of baseline lengths, imaging sensitivities, and the UV-coverages resulting in much better synthesized-beams and improved imaging qualities. In particular, this enhancement is notable for reconstructing the Asia-Pacific Telescope, by filling in severe uv-holes with the SEAVN telescopes located around the equator. These upgrades will result in the acceleration of an essential activity for the VLBI future led by the Global VLBI Alliance[4].

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[4] http://gvlbi.evlbi.org/welcome