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TULANCINGO-I: THE K BAND MEXICAN RADIOTELESCOPE

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RESUMEN

En este artículo presentamos un proyecto en proceso para la conversión de una antena de telecomunicaciones de 32 m de diámetro para investigación en astronomía. La antena está localizada cerca del poblado de Tulancingo, Hidalgo, en la parte central de México. Operando originalmente en la banda C, las pruebas de la superficie han demostrado que su superficie es útil hasta la banda K. Presentamos los resultados principales que avalan la realización de este proyecto.

ABSTRACT

In this paper, we present an ongoing initiative to convert a 32-meter diameter communication antenna into a radiotelescope for astronomy studies. The antenna is located in central México's state of Hidalgo at the town of Tulancingo. Originally operating at the C-band, its surface accuracy as been probed to be useful up to K-band. We present the main results that points to the feasibility of this project.

Key Words: Radiotelescopes — radio continuum:ISM — radio lines: General

1. INTRODUCTION

The Tulancingo earth station was constructed in Tulancingo, Hidalgo, México, as a part of a project to transmit the 1968 Summer Olympic Games worldwide. The design and construction of the antenna were managed by Mitsubishi Industries. It consists of a 32-m diameter, Cassegrain shaped, parabolic antenna located at then newly established Tulancingo ground station. The station was the principal satellite ground station in México used by the Mexican satellite communication network. From 1986 on, the site was managed by TELECOMM, a decentralized public institution that managed the telegraphic, satellite, and other telecommunication services. During almost 40 years of service, the antenna was maintained in optimal condition and was finally decommissioned in 2010.

The Tulancingo-I antenna (TUL-I) is now part of a project to convert the old satellite infrastructure into a radiotelescope capable of performing radio astronomical observations (Kurtz et al. 2022). The project began in 2018 as a collaboration between the National Autonomous University of México and the University of Oxford, through financial support from the Newton Fund (STFC-UKRI), in collaboration with TELECOMM, the Mexican Space Agency, and the State Government of Hidalgo. The goal of the project is to provide the Mexican research and a teaching community with infrastructure to train students in radio astronomy and carry out astronomical research. Figure 1 shows a photograph of the antenna and Table 1 presents the main characteristics of the telescope. Details of the antenna optical system can be found at Velazquez et al. (2022).

Fig. 1. The TUL-I antenna at Tulancingo earth station (Velazquez et al. 2022).

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TABLE 1

CHARACTERISTICS OF THE TUL-I ANTENNA

Specification	Description
Optical System	Cassegrain
Diameter	32 m
Focal length	9.6 m
Focal ratio	f/D=0.3
Diameter	2.8 m
Weight	350 tons
Angular Travel in Acimut	± 200°
Angular Travel in Elevation	0– 92°
Maximum velocity in Acimut	$1°s^{-1}$
Maximum velocity in Elevation	$1°s^{-1}$

The telescope will operate in the 1.4–24 GHz range (from L to K bands), both as a stand-alone facility and potentially as part of an international VLBI network. The extension to K-Band is particularly important for radio astronomical studies, because this band includes the water line at 22.235 GHz and the ammonia lines from 23.693 to 24.5 GHz. It would also allow the telescope to participate in the Third International Celestial Reference Frame project (ICRF-3) to determine the galactic acceleration and source positions at 8, 24, and 32 GHz (Charlot et al. 2020).

In this work we present a summary of the works that have been made in the antenna in order to turn it into a radiotelescope.

2. ANTENNA SURFACE

Initially, the TUL-I antenna operated in the C-band, ranging from 4 to 6 GHz. The initial goal was to find out if the antenna surface was good enough to work at K-band (24 GHz) for radio astronomy use. The characterization of the antenna surface was made by the Large Millimeter Telescope National Laboratory in 2020 (Gale 2020). The objective was to know the shape and errors of the main reflector, the subreflector and the tertiary reflector. It was found that the error of primary reflector at zenith (1.094 mm) and 60° elevation (1.305 mm).

A simulation of the electromagnetic antenna patterns based on the results of the optical study were made by Velazquez et al. (2022). The electromagnetic analysis indicates that the antenna is capable of performing observations in the L, C, and X bands without systematic reductions in efficiency. On the other hand, at K-Band, the antenna can perform observations but is limited by rms errors presented at the main reflector surface (Velazquez et al. 2022).

3. TUL-I RECEIVERS

Currently, we have three receivers for use at the TUL-I radio telescope:

- L–Band receiver from the Instituto de Radioastronomía y Astrofísica (IRyA-UNAM);
- C–Band receiver from the University of Oxford (U-Oxford);
- K–Band receiver from the Hartebeesthoek Radio Astronomy Observatory (HartRAO).

The backend of the IRyA receiver is based on a Software-Defined Radio (SDR) (Dillinger, Mandani & Alonistoti 2003), while for the other two receivers, the backends are based on a Xilinx-Zynq®(Churiwala 2017). We intend to standardize all backends to a system based on a Radio Frequency System-on-Chip, known as RFSoC (Liu 2021). Table 2 provides a concise summary of the receiver characteristics that will be employed in the TUL-I radiotelescope.

As a part of this project, we are also developing a dual K-band radiometer at 20/25.5 GHz to measure atmospheric water vapor and to determine the path delay of electromagnetic signals (Claflin, Wu & Resch 1978). This radiometer will be installed at the TUL-I site and potential sites for the new antennas of the new generation Very Large Array (ngVLA) in Northern México to characterize this parameters at those sites.

4. ANTENNA MOTIONS

The Tulancingo I and II antennas have not been used for more than a decade. That causes many problems, such as oxidation of the building's metallic structures and antenna, damage to the concrete, oil leaks, etc. After initializing the project, there was a renewal of the lubrication systems and hydraulic pumps, new seals, and the cleaning of rust from gears, etc. These essential jobs were done before trying to move the antenna. The elevation and azimuth gears were in excellent condition, as the antennas did not move too much since they did not need to follow a geostationary satellite. Since the antenna pointed in a single direction in the sky, it was not equipped with a tracking system. Pointing of the antenna in azimuth and elevation was done by electric motors by pushing buttons on a handset.

The State of Hidalgo Government hired the company to install new servomotors, new encoders, and new control electronics for the antenna. Based on this system, we developed the control software for

TABLE 2

RECEIVERS FOR THE TUL-I ANTENNA

Institution	**Band**	**Freq. Range (MHz)**	**IF Badnwidth (MHZ)**	**Backend**	**Type**
IRyA-UNAM	L-Band	1,400–1,800	160	SDR	Room Temp.
Oxford	C-Band	4,000–8,500	4,000–8,500	Xilinx Zynq®	Cryogenic
HartRAO	K-Band	20,500-24,500	3,100–7,100	Xilinx Zynq®	Room Temp

the pointing and tracking of the alt-azimuth mount of the radiotelescope. We also design the user graphical interface for the user.

5. ANTENNA POINTING AND TRACKING TESTS

We will use a small optical telescope mounted on the antenna to look at stars to create the antenna pointing model (Carsltrom 2011; Magnum 2000; Magnum et al. 2006). We will use a telescope and camera to check how well the antenna is pointing and tracking. The direction in which the antenna points is determined by the astrometry of the optical images obtained by the camera(Ramos-Alcaraz, Alonso-Arévalo, & Nuñez-Alfonso 2023). This optical system will be also used for testing the rms tracking of the antenna.

Once the pointing of the antenna has been tested with the optical telescope, we will proceed to determine the offset between the optical axis and the radio axis of the antenna. This small optical telescope It may also be used as an offset guide for the radio telescope at night provided it has a large enough field of view (Assawaworrart & Padin 2012). It can also help in determining the flexure of the radio telescope mount and possible problems with the control system.

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