Warkworth 12-m VLBI Station: WARK12M

Sergei Gulyaev, Tim Natusch, Stuart Weston, Neville Palmer, David Collett

Abstract

This report summarizes the geodetic VLBI activities in New Zealand in 2010. It provides geographical and technical details of WARK12M—the new IVS network station operated by the Institute for Radio Astronomy and Space Research (IRASR) of Auckland University of Technology (AUT). The details of the VLBI system installed in the station are outlined along with those of the co-located GNSS station. We report on the status of broadband connectivity and on the results of testing data transfer protocols; we investigate UDP protocols such as 'tsunami' and UDT and demonstrate that the UDT protocol is more efficient than 'tsunami' and 'ftp'. Overall, the station is fully equipped, connected, and ready to start participating in regular IVS observational sessions from the beginning of 2011.

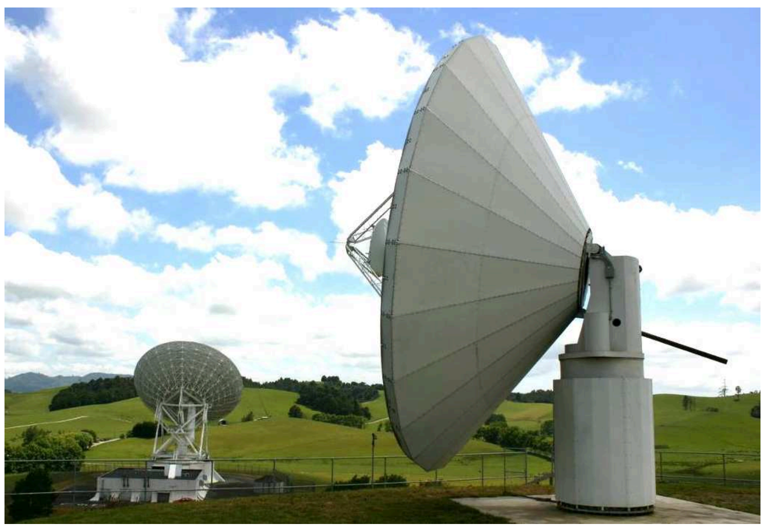

Figure 1. Warkworth 12-m (right) and Warkworth 30-m (left) antennas. Photo: Jordan Alexander

1. Introduction

The New Zealand 12-m radio telescope is located some 60 km north of the city of Auckland, near the township of Warkworth (see Figure 1). It was manufactured by Patriot Antenna Systems (now Cobham Antenna Systems), USA. The antenna specifications are provided in Table 1. The radio telescope is designed to operate at S and X bands and supplied with an S/X dual-band dual-polarization feed. The antenna is equipped with a digital base band converter (DBBC) developed by the Italian Institute of Radio Astronomy, a Symmetricom Active Hydrogen Maser MHM-2010 (75001-114), and a Mark 5B+ data recorder developed at MIT Haystack Observatory.

The support foundation for the antenna is a reinforced concrete pad that is 1.22 m thick by 6.7×6.7 meters square. The ground that the foundation is laid on consists of weathered sandstone/mudstone, i.e. of sedimentary origin, laid down in the Miocene period some 20 million years ago. The pedestal is essentially a steel cylinder of 2.5 m diameter. It supports the antenna elevation axis which is at a height of approximately 7.1 m above ground level. Apart from the pedestal,

Table 1. Specifications of the Warkworth 12-m antenna.

Antenna type	Dual-shaped Cassegrain
Manufacturer	Cobham/Patriot, USA
Main dish Diam.	12.1 m
Secondary refl. Diam.	1.8 m
Focal length	4.538 m
Surface accuracy	0.35 mm
Pointing accuracy	$18''$
Frequency range	1.4—43 GHz
Mount	alt-azimuth
Azimuth axis range	$90° \pm 270°$
Elevation axis range	4.5° to 88°
Azimuth axis max speed	5°/s
Elevation axis max speed	1°/s
Main dish F/D ratio:	0.375

all other components of the antenna (the reflector and feed support structure) are constructed of aluminium. The radio telescope is directly connected to the regional network KAREN (Kiwi Advanced Research and Education Network) [1].

In November 2010 Telecom New Zealand handed over to Auckland University of Technology its 30-meter Cassegrain wheel-and-track beam-waveguide antenna. It was manufactured in 1984 by Nippon Electric Corp., and since then it was used by Telecom NZ for communication between New Zealand and various Pacific Islands. The antenna is just 200 meters north of WARK12M (Figure 1). According to expert opinion, the antenna is in good state, and after conversion to a radio telescope, it has the potential to contribute to both astronomical and geodetic VLBI.

2. Antenna Position Survey

The reference point of a VLBI site is defined as the intersection of the azimuth and elevation axes of the telescope. A preliminary survey has been conducted in collaboration with the New Zealand Institute of Geological and Nuclear Sciences (GNS Science) and Land Information New Zealand (LINZ) to determine an initial estimate of the reference point of the VLBI site WARK12M (see details in [2]). A real-time kinematic (RTK) GPS method was used to derive the position with respect to the co-located GPS station WARK.

A co-located GPS station WARK was established in November 2008 at the radio telescope site and is one of 39 PositioNZ network stations in New Zealand [3]. All data received from the PositioNZ stations are processed to produce daily positions for each station in terms of ITRF2000. The RTK reference receiver was set up in an arbitrary location with clear sky view and was configured to record raw observations in addition to transmitting real-time corrections. The RTK station was later post-processed with respect to WARK, and all RTK rover-surveyed positions were subsequently adjusted relative to the updated reference position.

Several points on the rim of the main reflector were identified, and each point was measured several times with the RTK rover while the telescope was repositioned in elevation and azimuth between each measurement. The rover GPS antenna was mounted on a 0.5 m survey pole and was hand held for each measurement. For determination of the horizontal axis, the telescope azimuth axis was held fixed at $Az = 0°$. A point near the highest edge of the reflector was identified and measured with the telescope in four positions of elevation. This was repeated with a point on the edge of the reflector to one side of the telescope. Five positions of elevation were measured at this point. For determination of the vertical axis, the telescope elevation axis was held fixed at $El = 80°$. Three points around the edge of the reflector were identified, and three measurements of each identified point with the fixed telescope elevation and varying azimuths were conducted. The resulting points from these measurements describe two vertical circles of rotation which define the movable elevation axis and three horizontal circles of rotation which define the movable azimuthal axis. The coordinates for all subsequent calculations were retained as geocentric Cartesian coordinates to avoid any possibility of errors related to transformation of projection.

To determine the axes and their intersection point, the equation of a circle from three points was used to calculate all possible combinations of three observed points which define a circle of rotation. Mean values were taken for all horizontal axis definitions and all vertical axis definitions. The midpoint of the closest point of approach of each axis with the other was used as the final estimate of the point of intersection. The distance between the axes was calculated to be 24 mm. Based on the variation of results for different combinations of survey points, we estimate that the accuracy of the determined intersection point is within 0.1 m.

In summary, the following coordinates of the intersection of the azimuth and elevation axes for WARK12M were derived in terms of ITRF2000 at the epoch of the survey (March 2010):

$$
\begin{aligned}
X &= -5115324.5 \pm 0.1 \text{ m} \\
Y &= 477843.3 \pm 0.1 \text{ m} \\
Z &= -3767193.0 \pm 0.1 \text{ m}
\end{aligned}
$$

The radio telescope reference point coordinates will subsequently be re-determined to a higher accuracy with the use of a variety of terrestrial and GNSS survey techniques (e.g. [4]) and a more rigorous least squares analysis of the observations. Four geodetic survey monuments have been built within 15–20 m from the antenna pedestal for this purpose.

3. Network Connectivity and Data Transfer Protocols

In April 2010, the regional advanced network KAREN established a GigaPoP at the Warkworth Radio Astronomical Observatory, which provides a 1 Gbps international connectivity for the WARK12M radio telescope. Soon after the connection of WARK12M to KAREN, connectivity was achieved with a number of VLBI partners and correlation centers, including Bonn (Germany), CSIRO (Australia), JIVE (Netherlands), and Metsähovi (Finland).

Various network protocols were tested, such as ‘ftp’, ‘tsunami’ [5] and UDT [6]. The results of data transfer tests between the IRASR and the data processing center in Bonn are presented in Table 2. They were obtained by transferring an actual 16-bit VLBI file produced in observations with the 12-m radio telescope. It was transferred from IRASR’s IBM Blade server via the KAREN network using the default settings for each protocol with no tuning. Columns 1 and 2 show the protocol used and the amount of data sent in bytes, and columns 3 and 4 give the time it took to transfer the data and an average throughput rate (each test was repeated 5–10 times).

Table 2. Data transfer statistics: IRASR to Bonn.

Protocol	Bytes	Time (s)	Throughput (Mbps)
Ftp	65 G	8016	65
Tsunami	65 G	3466	151
UDT	65 G	1920	273

Table 2 clearly demonstrates the advantage of the UDT protocol over ‘tsunami’ and ‘ftp’. UDT is about two times faster than ‘tsunami’ and more than four times faster than the standard ‘ftp’ protocol. Tests were conducted repeatedly over several days and at different times resulting in slightly different average rates without changing the main conclusion that the UDT protocol is superior to ‘ftp’ and ‘tsunami’. In addition, UDT has an application programming interface (API) allowing easy integration with existing or future applications. Also, UDT is a better citizen on the network leaving bandwidth for TCP and other UDP protocols, a capability which is very important on a shared network such as KAREN.

A traceroute command from the AUT Blade server to the IP address in Bonn gave a route of 14 hops. Re-issuing this command repeatedly over several months showed that the route appears stable, without any changes. A high number of hops on the route (14) demonstrates the complexity of the path and explains why data transfers via protocols such as ‘ftp’ are not efficient.

In June 2010 file transfer tests to the correlator site at Curtin University, Perth were conducted. Using ‘tsunami’, a rate of 300 Mbps was achieved, while UDT was superior at 400 Mbps sustained throughput. In December 2010 the first e-VLBI tests from the Mark 5B recorder at the Warkworth Observatory to a server at CSIRO, Australia using UDP were conducted. The required data rate of 512 Mbps was achieved sustainably.

It is worth mentioning data transfer sessions conducted between Warkworth and Metsähovi in 2010. In August WARK12M participated in observations of the ESA’s Mars Express (MEX). First, data (86 GB) was transmitted to Metsähovi using ‘tsunami’; the next set of data (187 Gbytes) was sent to Metsähovi using UDT. Average rates sustained were 250 and 300 Mbps respectively.

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