New Zealand pathway towards Asia-Pacific
and global e-VLBI research and development

S Gulyaev¹, T Natusch¹, S Weston¹ and P Thomasson¹,²

¹Institute for Radio Astronomy and Space Research, Auckland University of
Technology, Private Bag 92006, Auckland, New Zealand
²The University of Manchester, Jodrell Bank Observatory, Macclesfield,
Cheshire SK11 9DL, U.K.

E-mail: Sergei Gulyaev <sergei.gulyaev@aut.ac.nz>

Abstract.
Over the past 3 years, Auckland University of Technology has established
the first radio astronomical observatory in New Zealand, which, because of
its remote geographic location, has quickly become a member of a number of
international VLBI networks, in particular the IVS and the LBA. Not only has
this added significantly to the observational power in the Pacific and Oceania,
but by utilising new fibre connections within New Zealand, and across the
Pacific and the Tasman Sea, the New Zealand radio telescopes have now
been linked to many in Australia, Asia and the Pacific. Recent astronomical
results are presented and plans for widening New Zealand participation in
Australasian, Asia-Pacific and global VLBI research and development are
outlined. Real-time e-VLBI is a vital part of New Zealand’s capability
development towards the SKA. The rapid and challenging establishment
of New Zealand radio astronomy can serve as a model for the engagement
in mega-Science and e-Science by resource-limited institutions and nations.
Perspectives for collaboration between New Zealand and Thailand in the field
of radio astronomy are included.

1. Introduction
The first radio astronomy undertaken in New Zealand was in the very early
pioneering days in 1948. John Bolton and Gordon Stanley, from CSIRO in
Australia, initially set up a cliff-top interferometer using the sea as a mirror,
first near Pakiri, ∼80 km north of Auckland on the east coast of North Island,
and then later at a World War II radar station near Piha, to the west of
Auckland. The interferometer operated at 100 MHz, and Bolton and Stanley
were able to locate for the first time the sources of radio waves from three
sources, Taurus A, Centaurus A and Virgo A, which were now seen to be outside
the solar system. This was probably the opening of a new window on the
Universe, but it was not until 2005 that further significant radio astronomy was
conducted in New Zealand. Brent Addis, a radio ‘ham’, had built a 6-m radio
telescope at Karaka (Figure 1(a)), to the south of Auckland, and this was used
at 1.6 GHz with the Australia Telescope Compact Array at Narrabri (ATCA) for
the first VLBI observations across the Tasman Sea by the newly formed group
Figure 1. (a) The Karaka 6-m telescope (b) First fringe from PKS 1921-231

Figure 2. (a) The Karaka 6-m telescope (b) First fringe from PKS 1921-231

| Manufacturer: | Patriot (Cobham) |
|---------------|------------------|
| Diameter:     | 12.1 m.          |
| System:       | Cassegrain       |
| Surface:      | 0.35 mm. (rms)   |
| Slewing:      | 5 deg/sec Azimuth|
|               | 1 deg/sec Elevation|
| Current Rxs.: | S/X- and L-Bands |
| H-maser       | Symmetricom, U.S.|
| VLBI Recorders: | Mk5+, Mk5C       |
|               | (9 chassis x 8 x 1 TB) |
| DBBC:         | Italy            |
| Net. Connectivity: | 1 Gbps international |

at Auckland University of Technology (AUT) and scientists at the Australia Telescope National Facility (ATNF).

Figure 1 (b) shows the first fringe from the radio telescope at 1.6 GHz. Since then, AUT has acquired a 12.1-m Cassegrain radio telescope manufactured by Patriot (See Figure 2 for its parameters and associated equipment), which has been sited in a radio-quiet zone (shown to be radio quiet by actual measurements) ∼55 km to the north of Auckland and a few kilometres to the south of Warkworth. It was officially opened on 8 October 2008. More recently, a former satellite-communications 30.5-m radio telescope on the same Warkworth site, and ∼200m from the 12-m antenna, has been taken over by AUT. This telescope, currently being upgraded, is capable of operations up to 40 GHz. So the Warkworth Observatory has come into being (Figure 3).
2. Network Connectivity
The introduction of the Kiwi Advanced Research and Education Network (KAREN) in 2005 and the linking into it of the Warkworth Observatory somewhat later has enabled data to be transferred between the Warkworth Observatory and Australia and the U.S.A, and onwards further to Europe and Japan at data rates of 1Gbps. Initial VLBI test observations between the 12-m telescope and Australian Long Baseline Array (LBA) telescopes in Australia have shown that New Zealand can contribute on a regular basis to LBA observations and a formal joining with the LBA was signed in 2010.

3. Australasian SKA and Trans-Tasman Collaboration
The introduction of the Australian Square Kilometre Array (SKA) Pathfinder telescopes (ASKAP) at the Murchison Radio Observatory in Western Australia and also the inclusion of the Warkworth 12-m telescope, has meant that the maximum baseline of the LBA has been extended to $\sim 5500\ km$ with a consequential improvement in both resolution and uvcoverage. Figures 4(a) and (b) show the results of observations of the Gigahertz Peaked Spectrum radio galaxy, PKS 1934-638, at 1.4 GHz with and without the ASKAP and Warkworth telescopes. It is interesting to note that were there to be a telescope in northern Thailand, the maximum length of baseline from an ASKAP antenna in Western Australia to this would be $\sim 4400\ km$, but in a much more NS direction. The uv-coverage of such an enhanced LBA array would improve significantly, not only from the point of view of the intermediate baseline lengths that would be generated, but also because of the considerably improved NS baselines.

For the above VLBI observations, data have been recorded on disc and correlated at a later time. For the successful operation of the SKA, ‘real-time’ correlation is essential, and this was achieved including the Warkworth 12-m telescope on 1st February 2011, when a real-time e-VLBI fringe at 1.4 GHz between it and the 22-m Mopra telescope in Australia was obtained. Somewhat later (June 2011), the first ‘real-time’ observations of the quasar, PKS 0637-752, using all of the LBA telescopes, including the ASKAP and Warkworth dishes were successfully made. Figure 4(c) shows the resulting image.
Figure 4. (a) PKS 1934-638 at 1.4 GHz (‘normal’ LBA)  
(b) PKS 1934-638 at 1.4 GHz (LBA+ASKAP+Warkworth)  
(c) PKS 0632-752 at 1.4 GHz (LBA+ASKAP+Warkworth) Credit: Steven Tingay

4. The International VLBI Service for Geodesy and Astrometry (IVS)
It has been long established that VLBI observations can contribute considerably to the study of the Earth’s crust and its movements, and a network of telescopes across the world has been established for these observations. The inclusion of a telescope in New Zealand, which is located in a very active region of the Earth’s surface, should be able to provide a significant contribution to the network. Following successful test VLBI observations at both S-Band and X-Band frequencies using the Warkworth 12-m telescope and a 32-m telescope at Tsukuba in Japan, the Warkworth 12-m telescope has now taken part on a regular basis in several observing sessions of this network since February 2011. It is also participating in the AuScope Project, an Australian geodetic research programme.

5. Conclusion
The observations showing the development of radio astronomy in New Zealand have clearly shown that:–
New Zealand has a strong observational basis for VLBI
New Zealand is capable of electronically transferring large amounts of data
New Zealand has excellent radio-quiet zones.

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