VLBI – A new tool for geodesy in New Zealand

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Opening of the AUT radio telescope

On 8 October 2008 the Auckland University of Technology (AUT) opened its radio astronomical observatory near Warkworth, 60 km north of Auckland. The key structure in the observatory is a one million dollar 12 metre radio telescope. This is designed to collect radio signals from deep space objects such as quasars, radio galaxies, supernova remnants and areas of star formation. It will also be used for other applications such as measuring ozone in the atmosphere, and making geodetic measurements.

The Square Kilometre Array

The dish is a proof-of-concept scheme, designed to boost an Australia-New Zealand bid to build a $4 billion mega-science project to be known as the Square Kilometre Array (SKA). The core site of the Australasian bid will be in Western Australia, with radio telescope dishes spread across the continent.

Several sites are proposed in New Zealand, Warkworth and Ardmore in the North Island and Awarua and Rangiora in the South Island. A South African consortium is also on the shortlist to build the project. The winner will be chosen in 2011 by an independent scientific community panel called the International SKA Science and Engineering Committee.

The Australian-led bid would see 5,000 dishes built across Australia and New Zealand, working as one, virtual super radio telescope with a total satellite dish area of one square kilometre, the square kilometre array. In Australia, 36 dishes will soon go live in a $A150 million trial called the Australian SKA Pathfinder (ASKAP). If the Australia-New Zealand bid is successful, the aim is to have the full SKA operational by 2020. The SKA will be at least 50 times as sensitive as any radio telescope in existence today, allowing astronomers to look back billions of years, close to the time of the birth of the Universe.

What is geodetic VLBI

At the heart of AUT's dish will be a $300,000 atomic clock, necessary to provide the most accurate possible time-stamps. This enables the AUT observations to be correlated with those of other radio telescopes already operating around the world. The radio telescopes make very long baseline interferometry (VLBI), which can be used to measure precise distance or baseline between the radio telescopes and is an important tool used in space geodesy for establishing global reference frames.

VLBI is a geometric technique that measures the time difference between two or more Earth based radio telescope antennas of a radio wave-front emitted by a distant quasar

Data received at the antenna is combined with accurate timing information provided by the most accurate atomic clock, the hydrogen maser clock. By correlating the data from pairs of antennas the relative position of the antennas can be determined to a few millimetres and relative changes measured between the antennas can be used for crustal motion studies.

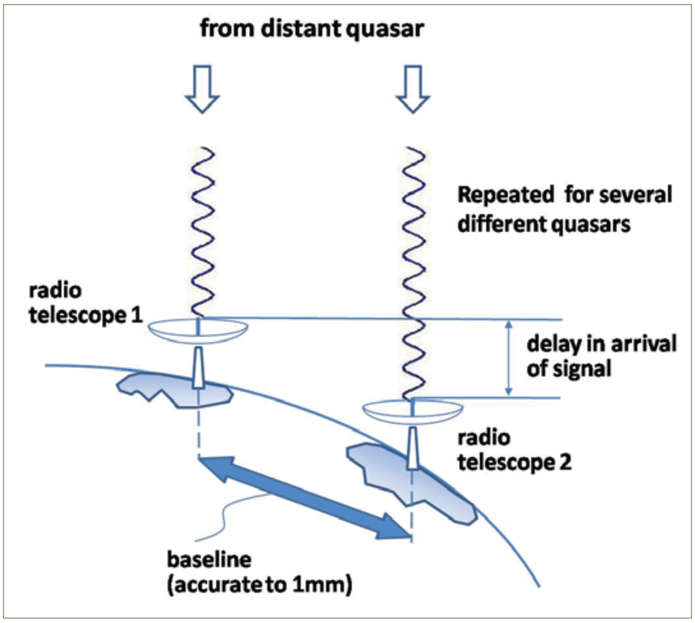
Southern Hemisphere expansion

Radio telescopes making geodetic VLBI measurements are located in 18 countries, now including New Zealand, and this latest telescope will help to expand the network in the southern hemisphere where it is particularly sparse. The geodetic International VLBI service has been operating since 1980 and currently provides accurate positions for more than 1000 quasars randomly distributed over the sky.

The 'constellation' of quasars reveals the natural fundamental reference frame in which our dynamic Earth rotates, wobbles or shifts its tectonic plates. Quasars – quasi-stellar objects – are both the most remote objects and therefore apparently immovable on the sky, and the strongest radio sources known in the universe. This makes them the only type of objects in the universe suitable for defining a highly accurate international celestial reference frame (ICRF). ICRF defines the instantaneous orientation of the Earth and provides the basis for spacecraft navigation.

VLBI is an important technique used in realisation of the international terrestrial reference frame (ITRF), a global reference frame upon which our national datum, NZGD2000, is based. The ITRF is geometrically connected to the ICRF via the Earth orientation parameters time series, which are determined primarily by the VLBI technique. It is VLBI that is capable of linking the ICRF and ITRF reference frames. At present, only two spatial geodetic techniques are used to measure the Earth radius as a scale parameter – VLBI and the satellite laser ranging (SLR).

Opening of the AUT radio telescope



Very long baseline interferometry (VLBI)

Determining global reference frames

The determination of accurate global reference frames requires measurements from a number of space geometric techniques. In addition to VLBI the following technologies are used –

- SLR measurements are particularly important for assisting with the accurate measurement of the Earth geocentre.
- Global navigation satellite systems (GNSS) such as GPS measurements are important as they are relatively cheap, and densify the geodetic network and are used for determining plate motions and crustal deformation studies
- Doppler orbit determination and radio-positioning integrated on satellite (DORIS) measurements are used to supplement GNSS measurements.

In determining global reference frames, Earth rotation and orientation parameters are measured using a combination GNSS, DORIS, SLR, VLBI. GNSS is used to measure in more detail Earth surface motions.

It is particularly important that the various technologies are co-located so that solutions from these can be combined to determine best global reference models. While internationally there are several hundred sites with sensors which contribute to global reference frame determinations, only 70 sites have two collocated sensors, 25 with three collocated sensors, and six with four collocated sensors.

LINZ's role in supporting the radio telescope and global geodesy

LINZ's traditional role in contributing to global reference frame determination is through its GNSS PositioNZ network. The PositioNZ network consisting of 33 GNSS continuous operating reference stations in New Zealand, one on the Chatham Islands and three in Antarctica. Data from several of these sites are forwarded to the international GPS service where they are incorporated into solutions used to determine GNSS satellite orbit and global reference frame determinations.

In November 2008 a new PositioNZ station was built at the AUT radio telescope site and an accurate tie will be made between the radio telescope antenna and GNSS antenna. Data from this site will also be forwarded to the international GPS service where it will be used to enhance global reference frames along with the data from the VLBI station.

The data will also contribute to an international association of geodesy initiative to establish a global geodetic observing system (GGOS). GGOS integrates different geodetic techniques, different models, and different approaches in order to achieve the required long-term consistency, reliability and understanding of geodetic, geodynamic and global change processes.

In our own small way, AUT and LINZ will be making a contribution to global geodesy. By combining data from the radio telescope with that from the PositioNZ station we will assist with enhancing the precision of global reference frames upon which we rely here in New Zealand for the definition of our national datum and spatial reference network. SQ