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Robots to improve satellite positioning accuracy in Australia

Sub-millimetre accuracy for global positioning

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Robots are used in many ways to improve our lives by doing things more precisely, efficiently and quickly. As of May 21st 2013, Geoscience Australia can now claim to have two AuScope Australian Geophysical Observing System (AGOS) funded robots which will improve the accuracy of satellite positioning in Australia.

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Introduction

Satellite positioning is increasingly ubiquitous. Global Positioning System (GPS) users can currently achieve 5 metre accuracy with a hand held device (for example, smartphone), but within the decade the accuracy is anticipated to increase to a few centimetres due to improvements in computational and modelling techniques, and exploiting Australia's geographic location. Australia is in the fortunate position to be one of the few regions in the world to see all the new and emerging Global Navigation Satellite Systems (GNSS), including Galileo (Europe), GPS III (USA), GLONASS (Russia), COMPASS (China) and other regional systems being developed by Japan and India. This will enable new geospatial applications in geoscience, intelligent transport, precision agriculture and industrial automation to emerge as well as opening a world of new possibilities for smartphone applications. Nevertheless, for this ambition to become reality, a number of advancements and developments are required to geodetic infrastructure, analysis and modelling.

Geoscience Australia's role

Geoscience Australia has a key role in enabling Australia's National Positioning capability by operating and analysing the data from a national network of permanent GNSS stations that both realise the national coordinate system (that is, the set of reference locations that define Australia's latitude and longitude) and support the determination of the precise orbits of the GNSS satellites, a key requirement of precise user positioning.

Centimetre accurate positioning with GNSS

The underlying signals transmitted by the GNSS satellites can be considered as repeating sine waves. Measurements of these waves are referred to as carrier phase observations and they differ from the range-to-satellite measurements that the current generation of smartphones use. Carrier phase observations enable the distance between the orbiting satellites and a user's receiver to be determined with centimetre accuracy and are subsequently used to compute the user's 3D position. The more accurate the range measurements are, the more accurately the user can compute their position.

Carrier phase observations have been used for two decades by surveyors to undertake relative centimetre-accurate positioning but limitations in communications, ground infrastructure and the expense of the receivers have meant that this capability has not transferred to the mass-consumer market. But this is set to change as the national GNSS network is supplemented with more sites with better communication links, high quality user receivers become cheaper and analysis techniques become more sophisticated.

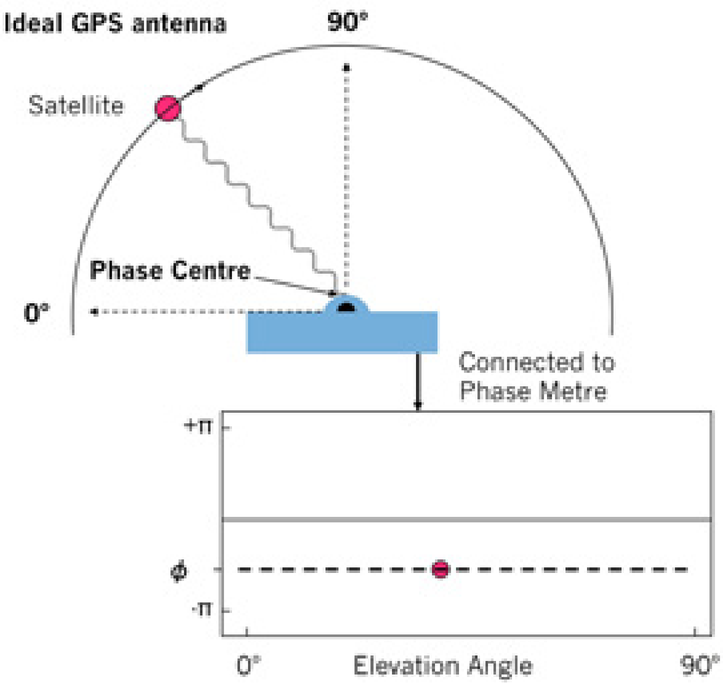

Figure 1: An ideal antenna, no bias (modifed from Gerry Mader).

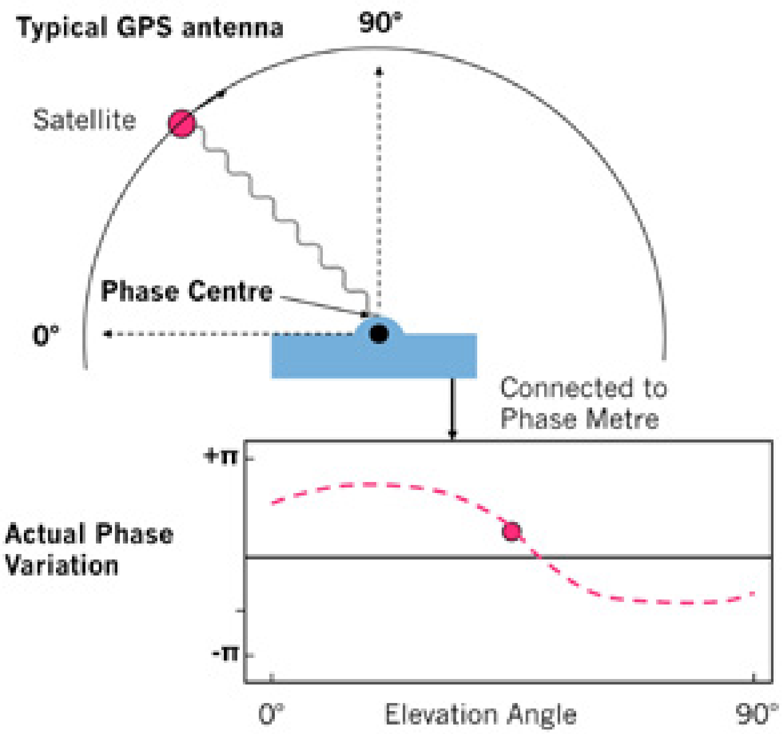

Figure 2: A typical antenna, with bias (modifed from Gerry Mader).

Modelling antenna biases

In the attempt to further improve positioning accuracy, the geodetic community have looked to each and every error source and have attempted to either eliminate or better model that error. GNSS antenna biases are one such error source. All GNSS antennas have small inconsistencies in their electronic components caused by the manufacturing process that currently limit their accuracy (compare Figure 1 and Figure 2). This is where the robots come in: they provide a means to investigate and develop models of the antenna biases. Essentially, antenna biases vary depending on the position of each satellite as they move across the skyline (that is, the satellite's azimuth and elevation). By rotating and tilting the GNSS antenna with a robot as it tracks the GNSS satellites, a highly accurate model of the antenna bias can be determined (Figure 3). By applying the models derived from the robotic system, these biases can be removed and the positional accuracy improved.

The GNSS research community have up until recently used generic antenna models for antenna types. However, with the ever growing accuracy requirements of GNSS users, individual antenna-specific modelling is necessary to further improve positioning accuracy. Antenna-specific models can only be derived using robotic calibration systems or prohibitively expensive anechoic chambers, neither of which was available to researchers in Australia, until now.

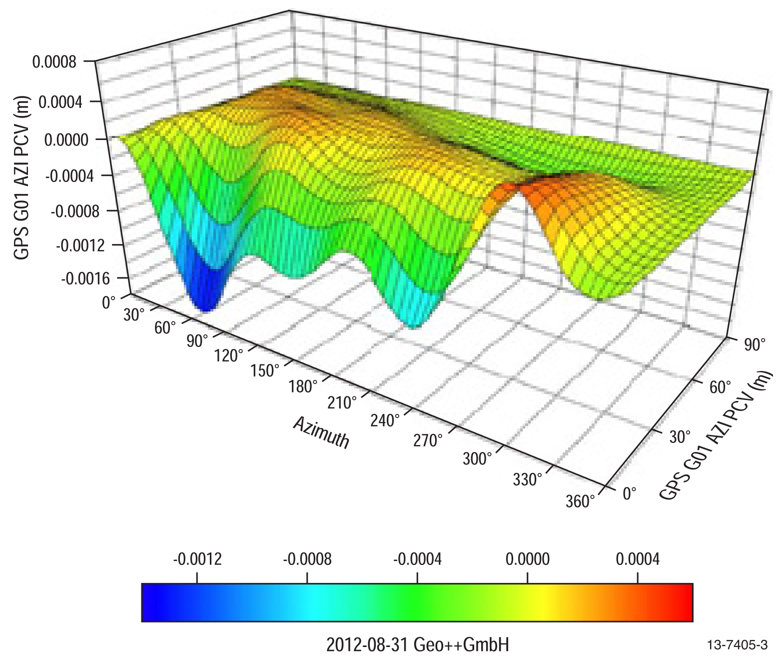

Figure 3: Antenna calibration solution plot.

Our robots

GNSS antenna calibration is a niche and highly specialised activity. Geoscience Australia is the home to one of five GNSS antenna calibration capabilities in the world and the only one in the southern hemisphere. The other four are at the National Geodetic Survey (Virginia, USA), University of Bonn (Bonn, Germany), SenB (Berlin, Germany), Geo++ (Hannover, Germany) and the Institute of Geodesy (IfE) (Hannover, Germany). The smaller of the two Geoscience Australia robots was purchased from Germany and its primary role will be to calibrate antennas prior to them being used in the field so the positions they record are free from antenna modelling bias. The larger of the two robots is unique to GNSS calibrations globally and will enable experiments to assess the impact of station and antenna design on positioning accuracy. Furthermore, it has a lifting capability large enough to support the calibration of GNSS satellite transmitters prior to launch and the speed and agility to replicate the movement a GNSS station would experience in an earthquake.

Improvements for science, industry and the public

Scientific and industrial GNSS users require high accuracy and integrity for applications to fields such as environmental monitoring, crustal motion, mining and construction. The improvements provided by absolute antenna modelling will allow these users to acquire positions an order of magnitude more accurately than they could of in the past.

A new national coordinate system

The current Australian geodetic datum, the Geocentric Datum of Australia 1994 (GDA94) was established in the 1990s, has relatively poor internal accuracy, weak linkages to the latest global coordinate system, and is 'frozen' at an epoch date of 1994. It will be unable to support the next generation of GNSS services and the many scientific endeavours that require accurate positioning, including sea level rise studies. The robotic calibration facility will enable an upgrade of Geoscience Australia's national GNSS network which will underpin an update of the Australian geodetic datum.

An improved understanding of earthquake hazard

Earthquakes in Australia occur after the long-term accumulation of strain on faults that is subsequently released. Over the last decade scientists have suggested that precise GNSS observations of crustal motion might provide insights into this seismic cycle. Towards this objective, Geoscience Australia, together with our State Government counterpart agencies, have established monitoring networks in the seismically active areas of Australia including the south-west seismic zone near Perth in Western Australia, the Flinders Ranges near Adelaide in South

Australia, and south-east Australia (Gippsland and Otway Basins). Geological evidence suggests that the deformation is likely to be small, perhaps as little as 0.1 mm/yr, and difficult to measure except over very long time spans. However, with improved GNSS antenna models the possibility of measuring deformation before an earthquake occurs may become a reality in time spans of several years. With this, an improved understanding of earthquake hazard in Australia will be achieved.

Figure 4: Robots are used to calibrate GNSS antennas and improve how accurately we can measure the dynamic Earth.

Sensing the atmosphere to improve weather forecasting

The Earth is surrounded by layers of gases held in place by the Earth's gravity field. Signals, such as those transmitted by GNSS, propagated from space, are delayed as they pass through the atmosphere. In the troposphere, the layer of atmosphere from the Earth's surface to approximately 20 kilometres altitude, the delay is proportional to temperature, pressure and humidity. The ionosphere, the layer of atmosphere from 50–1000 kilometres altitude, causes signal delays as a function of the frequency of the signal. The composition of both the troposphere and ionosphere vary both in space and time, and this variability currently limits the accuracy, speed and reliability of GNSS positioning. But it's not all bad news, and like a computer axial tomography (CAT) scan in medical science, the new GNSS signals and satellites can potentially be combined to provide a more complete 3D picture of the atmospheric delay as a function of time. Models that more completely remove the atmospheric delays will lead to improved accuracy, speed and reliability of positioning, and this ability to sense the atmosphere should ultimately lead to improved weather forecasting in Australia.

Construction process

Site selection and design for the antenna calibration facility began in the second half of 2011 with a number of site selection surveys to identify the best location for the facility on the grounds of Geoscience Australia. Ultimately, the location on the western side of the Geoscience Australia's support building was chosen as the preferred site because of its close connection to a power supply, good ground conditions and an unobstructed view to the north. This is important for GNSS users in the southern hemisphere because of GNSS satellite constellations; the majority of satellites are to the north of our location.

The construction of the facility was underway in January 2013 with Geoscience Australia managing the contractors. The facility includes the smaller Geo++ robot and larger industrial robot, an air-conditioned hut for the robot controller to operate the robots, a rubidium external frequency (high accuracy) clock, a continuously operating GNSS station, multiple GNSS receivers and web camera to monitor the calibrations.

The state-of-the-art Global Navigation Satellite System robotic antenna calibration facility was officially opened by the Minister for Science and Research, Senator Don Farrell, at Geoscience Australia on 20 May, 2013.

For more information

email: ausgeomail.com.au

Related articles and websites

Video footage of the robots and the launch by Senator Don Farrell

www.ga.gov.au/about-us/news-media/media/accuracy-for-global-positioning.html