Observatory reports

Australia Telescope Compact Array

Array upgrades and developments

The primary development focus at the Compact Array for a number of years has been to upgrade the array to operate at high (millimetre-wave) frequencies, with two new observing bands at 12 and 3 mm. This upgrade has been funded under the Commonwealth Government's Major National Research Facilities program, under a contract signed in February 1997 (MNRF-1997).

The first millimetre-wave observations at the Compact Array were taken in November 2000 using two antennas on a single baseline. In 2001, interim 12- and 3-mm receiver packages were installed on antennas 2, 3 and 4 and the first millimetre images were obtained using data taken with these three antennas. Rather than extend the interim system to all antennas it was decided in 2002 to concentrate engineering development on the design and construction of the final systems. Installation of the final 12-mm receivers on all antennas is due in 2003 with the 3-mm systems expected to follow in 2004. Millimetre observing during 2002 continued to be available with three antennas and interim systems only.

As well as developing the new receiver packages, the millimetre upgrade requires a myriad of changes to the telescope hardware, software and operation. During 2002, considerable development work took place in these areas.

Dr Bob Sault, Officer-in-Charge at the Narrabri Paul Wild Observatory

New stations and array configurations

To optimise the Compact Array configurations (with antenna spacings up to several hundred metres) and to provide better arrays for high brightness sensitivity observations, nine new antenna stations have been constructed as part of the MNRF-1997 program. The new configuration include configuration EW214, which has a maximum spacing of 214 m, and two complementary configurations, EW352 and EW367, with maximum spacings of approximately 360 m. The millimetre upgrade also includes the construction of a north spur line, 214-m long with five antenna stations. This is intended for very compact configurations, and allows a reasonable Fourier coverage to be achieved in less than 12 hours. This is an important consideration at millimetre wavelengths where it is undesirable to observe sources at low elevations—at these wavelengths the data quality is reduced at low elevations due to increased atmospheric opacity and poorer phase stability.

Following the completion of optical fibre work on the new antenna stations in April 2002, several new array configurations, EW367, EW214, H75 and H168, were scheduled and successfully used during the June to October period. The reconfiguration to the H75 array, on 12 August 2002, was the first astronomical use of the new north spur.

Signal distribution

A major task of the MNRF-1997 program was the upgrade of the signal distribution system throughout the array as well as an upgrade of the local oscillator system. The upgraded signal paths use single-mode optical fibres, which replace copper wires, coaxial cables and multi-mode fibres.

The local oscillator system now distributes two frequency references: a low frequency one used at centimetre wavelengths and a high frequency one for use in conjunction with the new millimetre receiver packages.

The installation of the new single-mode optical fibre signal distribution system was completed mid-year. Fibre splicing work was completed on all antennas and to all station posts, as well as to a patch panel in the screened room. Upgraded fibre modems were installed to eliminate a synchronisation problem that had previously caused an occasional loss of data. Shortly thereafter all six antennas were switched over to regular operations using the new reference frequency distribution system. By the end of the year all signals, including time frame, ethernet communications and intermediate-frequency return data links, were running on the new fibres.

The one remaining task for the signal distribution system, making the high frequency local oscillator reference system tuneable, is due for completion in May 2003.

Antenna structure

The efficiency of the telescope antennas depends partly on the accuracy of their surfaces. At millimetre wavelengths the antenna optical surfaces need to be maintained within tolerances that are 10 times more stringent than at centimetre wavelengths. This is a challenging engineering requirement. The ATNF has an ongoing program to improve and monitor the surface accuracies of the antennas.

Two factors are important in achieving good beam efficiency and beam shape: firstly, the antenna surface panels must be set to within a specified tolerance; secondly, account must be made of the change in the gravitational deformation of the antennas as a function of elevation. The deformations of interest include changes to the main dish shape as well as movement of the subreflector and receiver package. During the year two studies were initiated to understand these issues.

A holographic image of the surface of antenna 2 was obtained using a 30 GHz geostationary satellite as a reference signal. This showed that the panels were aligned to an accuracy (rms) of 0.21 mm, with the poorest accuracy occurring in the innermost ring of panels.

One of the shortcomings of standard holography is that it uses geostationary satellite signals. This means that the holography is performed at a single, fixed elevation. An alternative method of surveying the antenna optical surfaces is by using photogrammetry. This is an advanced form of surveying where reflectors are placed at many points on an antenna surface. The three-dimensional positions of the reflectors can be deduced by photographing the surface and reflectors from many aspects. An advantage of photogrammetry is that it can be performed at arbitrary elevation, and so the gravitational effects on the antenna can be studied.

In February 2002, a photogrammetric examination was undertaken on antenna 2, for antenna elevations between 15 and 90 degrees. The results showed that the main antenna deformation at low elevations occurs in the main reflector surface, while the subreflector remains close to its design location. Additionally, analysis showed that the beam shape changes and gain/elevation effects implied by these deformations agreed with those observed astronomically. The gain loss and beam shape degradation can be recovered, however, with a two-axis adjustment to the axial and tilt motions of the subreflector. Following these findings, a study was initiated during the year to design a two-axis subreflector adjustment system.

Antenna control computers

The existing antenna control computers (PDP 11/73 machines) are showing their age in terms of reliability and their inflexibility in supporting the more stringent requirements needed for the new millimetre systems. As a consequence these computers are being replaced, and the control software rewritten using object-oriented programming. During 2002 all antennas were outfitted with the new hardware. The first interferometric observations using the new control software were achieved in March 2002 and the first scientific observations using the new computers were taken in September 2002.

Early morning at the Australia Telescope Compact Array

Photo: David Smyth

Millimetre operations

During the winter observing period from May to October 2002, the interim 12- and 3-mm systems on three antennas were offered to observers. Approximately 17% of the observations made use of the 3-mm systems. To optimise the antenna spacings and sky coverage the three antennas were "shuffled" in some array configurations, with the north spur used as a shunting yard. The initial millimetre observations provided essential testing of the array performance and system capabilities at mm-wavelengths whilst also enabling observers to gain millimetre-observing experience.

To provide some robustness against poor weather during millimetre observations, a flexible scheduling scheme was tried. In this scheme, a millimetre observing program was swapped with a program for observations at centimetre wavelengths when the weather was too poor to obtain good millimetre data. The millimetre program was then rescheduled a few days later.

An analysis of meteorological data from 1996 to 2002 showed that during the winter months the swap scheme was expected to improve the probability of observing in good weather from approximately 65% to 85%. In practice the swap scheme proved reasonably successful, with only three hours of millimetre observing lost due to poor weather. A total of six out of a possible 27 swaps were initiated. This was lower than expected from the weather analysis and reflected the extreme drought conditions experienced in the Narrabri region in 2002.

Compact Array wideband analogue correlator

With the advent of the millimetre receivers and the new single-mode optical fibres, it became feasible to develop a very wideband interferometer at the Compact Array. The major technical challenges were the transfer of broadband (up to 8 GHz) signals from the antennas to the central site and the development of a correlator to process these signals. Both of these challenges were met by resorting to purely analogue techniques. A broadband analogue signal transmission system was developed. This is capable of transferring the 4 to 12 GHz first intermediate-frequency signals from the millimetre receivers to the central site. The correlator used was the 4 GHz bandwidth analogue correlator developed by ATNF as part of the AMiBA prototype project. Eventually it is planned to replace this unit with a new analogue correlator capable of processing the full 4 to 12 GHz band.

The system was installed on the Compact Array in July 2002 as a survey instrument. It used a 30-m east-west baseline in the 12-mm band and operated as a transit instrument. This avoided the requirement for delay and phase tracking. The system was employed in September 2002 in a successful point source survey observation.

Compact Array data archive project

Since the start of operation of the Compact Array, almost all observations have been routinely archived. Although there are frequent requests for data from this archive, the archive is a valuable asset that is under-used. During 2002, an index of the list of files available in the archive was made available online. Together with the online "projects" and "positions" database, this has allowed archive requests to be more specific. In collaboration with CSIRO Mathematical and Information Sciences, work began to place the archive data online with access to be provided via a web-based interface. This process was well advanced by the end of 2002. In 2003 the archive facilities will be further improved by adding a data reduction front-end to the online archive, and by some integration of the archives with the developing Australian "virtual observatory" projects.

Observatory improvements

A significant amount of building work took place during the year to improve the site amenities. The receiver laboratory was extended so that all members of the Electronics Group, and their equipment, can be located in a single building. The reception area in the control building was renovated to make better use of available space, and to give a more welcoming entrance. Other significant jobs on site included refurbishing the men's bathroom in the Lodge, bringing some aspects of the control building and Visitors Centre up to current building safety standards, drainage work around the Lodge, replacing insect screens in many of the site houses and rebuilding a garage as a storage area.

Staff

A new systems scientist and three new staff members in the electronics group were appointed during 2002. Overall, staff numbers at Narrabri have increased by one person, with funding for a new postdoctoral position from Corporate CSIRO.

Mopra

Operations

Use of Mopra this year continued to be restricted to VLBI and millimetre observations. VLBI observations were taken as part of the Long Baseline Array as well as in conjunction with the VSOP project. The millimetre single-dish observations for all programs were taken using the 3-mm SIS receiver system. The millimetre observing time, scheduled in June – November 2002, was split between time allocated for National Facility observations (41 days) and time allocated to the University of New South Wales (71 days). In total, 39% of the year was used for National Facility and UNSW observations.

Staff

There are no permanent staff at Mopra. Most of the engineering support is provided from Narrabri and Sydney. In 2002 an arrangement was established with the Anglo-Australian Observatory to provide limited engineering support at short notice. This allowed for a more timely response to minor problems at the observatory. Additionally three people in the Mopra area were employed on a casual basis to support VSOP observations and to perform housekeeping functions.

During the 3-mm observing season, visiting astronomers were supported by a UNSW-funded "Friend of the Telescope" and two ATNF-funded casual observing assistants. At the end of 2002, a Mopra operations scientist was appointed. This position will be stationed in Narrabri, but with a focus on assisting with Mopra operations and upgrades.

Photo: University of New South Wales

The Mopra antenna, with Siding Spring Mountain and part of Mopra Rock in the background. The smaller antenna is used for 12 GHz holographic measurement of the main dish surface.

Parkes

Performance and time use

The fraction of time scheduled for all observations in 2002 was 82.0%, unchanged from the two previous years. This was better than expected, given a lengthy maintenance shutdown during September and October for telescope refurbishment. Some additional time for observations was made possible by scheduling night-time observing during the shutdown for a specialised zenith-strip HI survey (HIPARK).

The fraction of time lost to equipment faults in 2002 was 1.4%, a slight increase on the previous year. However, an extraordinary period of bad weather towards the end of the year resulted in a total time lost due to high winds of 3.8%, significantly higher than in any recent year.

There were no outstanding technical problems with any important telescope systems. Minor problems with the heavily-used multibeam receiver continued, culminating in a failure of one of the 26 channels. A refurbishment of this receiver is planned for 2003.

User feedback

The web-based user feedback and fault reporting systems is an essential tool for the successful operations at the observatory. In total, 26 user feedback responses were received in 2002, slightly lower than for the previous year (34), in part due to the lengthy maintenance shutdown. The responses received were generally very positive, with radio frequency interference again emerging as the single most important issue flagged by observers. Considerable resources are now committed each year to identifying, and where possible eliminating, sources of interference.

Elevation drive refurbishment

The telescope had a shutdown period of six weeks in September – October 2002 to allow time for major refurbishment of the elevation drive system. All moving parts in the two elevation gearboxes, many of them original, were replaced and the two large sector gears were reground by hand into the correct figure. This was only the second occasion in the 40 year life of the telescope that the gearboxes had been removed.

Dr John Reynolds, Officer-in-Charge at the Parkes Observatory

The Parkes radio telescope

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This work went extremely smoothly and the new systems should give many more years of useful life to the telescope. During the shutdown period, the nights were put to good use by observing a narrow strip of the sky repeatedly, with the telescope parked and pointed at the zenith. The aim of this project is to create an extemely sensitive image of neutral hydrogen emission.

Major activities

The Parkes multibeam pulsar survey, a major survey of the Galactic plane using the 20-cm multibeam receiver and dedicated pulsar filter banks, was nominally completed on 14 March 2002. This survey, a collaboration between Jodrell Bank, ATNF and the University of Bologna, commenced in 1997 and has been one of the observatory's principal research activities in the intervening five years.

The success of the survey has exceeded all expectations, with the discovery of more than 600 new pulsars and another 100 or so expected to be revealed when the data are reprocessed. The survey will then have roughly doubled the number of pulsars known, with around two thirds of all known pulsars discovered with the Parkes telescope. Follow-up observations of the newly-discovered pulsars will continue well into 2003.

A new-generation baseband recording system was commissioned late in the year. Known as CPSR2 (Caltech Parkes Swinburne Recorder 2), the new system is an order of magnitude leap forward in baseband recording technology, capable of recording a data rate of one Gigabit per second for sustained periods. The new system extends the very precise pulsar timing measurements currently being made to a much larger number of fainter pulsars, and maintains Parkes' leading international position in this area.

The wide-bandwidth, high time-resolution correlator, initially installed at Parkes in April 2002, produced its first pulsar spectrum in October 2002. This instrument will eventually provide bandwidths up to 2 GHz with up to 1,024 frequency channels and full polarisation capability. By the end of 2002 the correlator was operating somewhat below its ultimate capability, but upgrades to be installed in early 2003 should redress this situation. This instrument will become the main observatory "workhorse" for pulsar timing, where sensitivity and polarisation are more critical than high time resolution.

A collaborative project with the Urumqi Astronomical Observatory in China reached a very successful conclusion in August with the commissioning of a cryogenically-cooled 18-cm receiver on the Urumqi telescope. ATNF staff travelled to China to assist in the installation.

Photo: John Sarkissian

One of the cleaned Parkes radio telescope zenith axis racks. The racks were cleaned prior to a dye being applied that highlighted the elevated regions on the rack teeth for later grinding.

Photo: John Sarkissian

One of the new zenith axis gears, manufactured by Crown Engineering of Brisbane.

The new receiver is the first cryogenic receiver to be installed on the 25-metre Urumqi telecope, and was constructed at Parkes by local staff working with two visiting Chinese engineers.

NASA Mars tracking support

An agreement with CTIP, acting on behalf of NASA, for the upgrade and use of Parkes for support of NASA spacecraft tracking in 2003/4 was signed in August 2002. The major components of this agreement are:

- An upgrade of the surface of the Parkes antenna providing new panels in the 44 to 54 m diameter range.
- Provision of a new 8.4 GHz receiver.
- Antenna acceptance testing.
- Up to nine hours per day tracking in the period September 2003 to March 2004.

A contract for the supply of the panels was signed in August with Sydney Engineering and installation of the new panels is scheduled in March 2003. The design and manufacture of the receiver is proceeding. The feed was manufactured and successfully tested in October. Of the other components, the design is complete and manufacture is proceeding. The total value of the contract is approximately A$3M.

Future developments

In addition to the NASA-related work, a new receiver specifically designed for pulsar timing observations will be commissioned in the second half of 2003. Work on this project has proceeded more slowly than expected, owing to commitments in other areas, such as the NASA contract.

Photo: John Sarkissian

Robert Semlitzky (centre), Senior Project Engineer with Svenska Kullager Föreningen (SKF) Australia, Steve Broadhurst (right) and Jon Crocker (left) replacing one of the bearings of the zenith axis gears.

The Australian Long Baseline Array

LBA report 2002

The Australian Long Baseline Array (LBA) operates as a very long baseline interferometer (VLBI) array utilising most radio telescopes around Australia. It includes all the ATNF antennas (Parkes, Mopra, Compact Array), the Hobart and Ceduna antennas of the University of Tasmania, and antennas of NASA's Canberra Deep Space Communications Complex at Tidbinbilla. It also frequently operates in collaboration with overseas antennas, especially the Hartebeesthoek antenna in South Africa and the Kokee Park antenna in Hawaii.

22 GHz operations

In 2002 a technical problem with the 22 GHz receiver system on the 70-m Tidbinbilla antenna was resolved and the telescope became available for extremely sensitive observations in the 12-mm (22 GHz) observing band. The new 22 GHz facilities greatly enhanced the operation of the LBA network in this band. Tidbinbilla is now the most sensitive radio telescope in the southern hemisphere for observations at 22 GHz.

A large proportion of LBA observations during May – August 2002 were at 22 GHz, utilising the Compact Array, Mopra, Parkes, Tidbinbilla, Hobart and Ceduna. A new observing mode was tried successfully for one project. In this mode, two water maser lines were recorded simultaneously, and the system switched around four pairs of spectral lines. In addition, spectral line data were recorded at the Compact Array and autocorrelations were recorded at all telescopes.

Towards the end of 2002, arrangements were put in place for a fraction of time on the Tidbinbilla 70-m antenna to be allocated for single-dish observations. This time, provided under a Host Country agreement with NASA, will be used in a service observing mode for spectroscopic observations. This new facility was advertised to the Australian and international community with service observations expected to start in the first observing term of 2003.

VSOP

The VSOP satellite continued to operate into its sixth year. However, NASA support was discontinued in February 2002 and operation continued only at the Penticton and Mitaka correlators. The main VSOP program has been the mission-led survey of active galactic nuclei and this has been done using primarily S2 data recording systems. Mopra and Hobart have been the main ground antennas. Operations in 2002 involved one or two short observations (up to six hours) per week with these antennas. The Mopra antenna provided reduced support for VSOP during the southern winter months because of commitments to millimetre observing. Continued VSOP support is contingent on the scientific case been approved each term by the ATNF Time Assignment Committee.

Proposals and scheduling

There was continued strong proposal demand for the LBA in 2002, with an effective over-subscription rate of about two, similar to previous years. A significant amount of time was scheduled for the ATNF-USNO astrometric program. However, access to the Tidbinbilla facilities remains difficult, especially for the 70-m antenna.

Operations

There were three major LBA observing sessions in 2002, with an allocation as usual of one week per term. Overall the LBA achieved an 89% success rate, a 5% improvement on the previous two years. Most of the telescopes continued with success rates over 97%. However, a single system failure of a motor drive at Ceduna led to significant time losses in one session and affected the overall array performance.