# OBSERVATORY REPORTS

## Australia Telescope Compact Array

### Technical developments and the MNRF upgrade

The ATNF, together with the University of Tasmania, is approaching completion on a set of substantial projects under the Commonwealth Government's Major National Research Facilities (MNRF) program, governed by a contract signed with the Government in February 1997. The contract provides $11M to:

- upgrade the Australia Telescope Compact Array to work at high (millimetre-wave) frequencies;
- extend the VLBI capabilities of both the ATNF and the University of Tasmania, and operate the University's Hobart and Ceduna Observatories as National Facilities;
- extend international collaboration in astronomy with funds administered by the ATNF, acting on advice from the Australian Academy of Science's National Committee for Astronomy; and
- perform strategic research on mitigating radio-frequency interference and on array technology for the next generation of radio telescopes.

Details of the MNRF program can be found at www.atnf.csiro.au/projects/mnrf/.

The upgraded telescopes of the ATNF and University of Tasmania will give Australian astronomers important new observational tools. In particular, the millimetre-wave upgrade of the Compact Array allows astronomers to image the signature emission from many cosmically important molecules active in southern hemisphere regions. The upgraded array will be able to work in a "tied-array" mode, which will give it a collecting area equivalent to a 50-m diameter millimetre-wave dish—an unusually powerful instrument.

During 2001, with various components of the MNRF upgrade being delivered, the Compact Array became a useful instrument at 12- and 3-mm wavelengths. The interim system was open to proposals during the May and September terms. The system, however, was an interim one, and proposals were on a shared risk basis and required an ATNF staff collaborator.

### New configurations

Part of the current Compact Array upgrade provides new antenna stations to support improved compact array configurations, ultimately using the new north spur to provide north – south baselines. The first new configuration to become available, the EW352 array, was scheduled during 3 – 24 October. This configuration, with its complementary partner EW367, replaces the 375-m array that was used for the last time on 12 July 2001. Outfitting all the new stations is progressing well, with observations using the north spur planned for mid-2002.

## New receivers

The 12- and 3-mm receivers are a key component of the high-frequency upgrade. An important feature of the high-frequency receivers is that they use MMIC (monolithic microwave integrated circuit) technology in the low-noise systems. In 1999 a decision was made to use indium phosphide (InP) MMICs for both the 12- and 3-mm receivers, rather than the gallium arsenide (GaAs) MMICs originally proposed for the 3-mm receiver. The InP MMICs will greatly increase the sensitivity of the array.

The high-frequency receivers are contained in a single multiband dewar, with the CSIRO-designed low-noise amplifiers operating at physical temperatures near 20 K. A substantial technology development program has resulted in the ATNF having the capacity to reliably bond wire connections to the tiny integrated-chips and to mount the devices in precision metal housings.

One of the highlights of the year was the installation of a new set of millimetre receivers. Three interim receiver packages, allowing observations at 3 and 12 mm, were installed on antennas 2, 3 and 4 of the Compact Array. As compared with the earlier prototype millimetre receivers, these are "broadband", dual polarization systems, and have improved system temperatures. Although they are broadband systems, the interim down conversion system means that observations are possible only in two sub-bands at each band. Possible observing ranges at 3 mm are 84,906 – 87,306 MHz, and 88,506 – 91,305 MHz. The 12-mm system can observe in the sub-bands 16,089 – 18,888 MHz and 20,089 – 22,488 MHz. At 12 mm, system calibration is achieved with noise diodes (improved noise diode systems with comparatively flat response over the band have been installed this year). To allow system calibration at 3 mm, a room temperature paddle can be switched in front of the feed horn.

## Local oscillator and signal distribution

The local oscillator (LO) in a synthesis telescope is the master reference signal to which all receivers are frequency-locked, and against which variations in signal phase (caused, for example, by structure in cosmic sources) are measured. The LO distribution must therefore be extremely stable. The new Compact Array LO distribution system is based on a "star" topology fibre optic network that uses an optical fibre connection from each of the antenna station posts to the Control Room.

In the final upgraded system the original "daisy-chain" LO distribution to antennas (based on coaxial cables) will be replaced by dedicated optical fibres from the control building to each antenna station. Also, the digitised astronomical signals will be transmitted from each antenna using single-mode rather than the original multi-mode fibres, while dedicated single-mode fibres will also provide time signal and ethernet services to each antenna station. Work has continued with the connecting (splicing) of these fibres at each end. The 160-MHz LO reference is distributed to

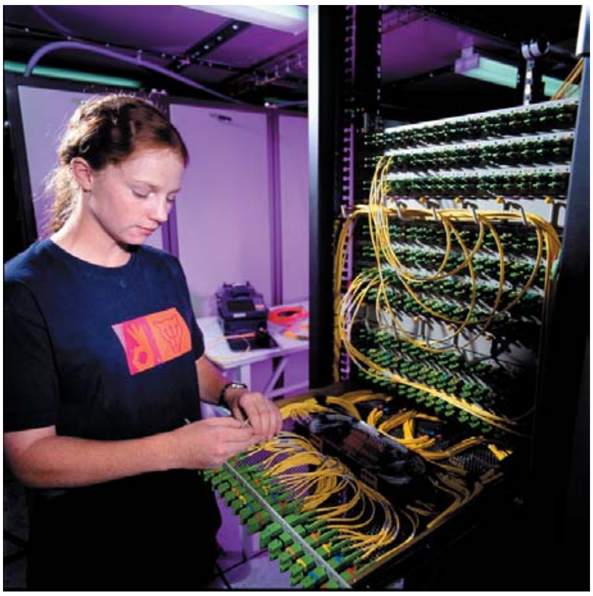


Photo: David Smyth

*Alison Ryan working on optical fibre connections for the local oscillator distribution network at the Compact Array.*

five of the six antennas on fibre, and a new high frequency reference (13 GHz) is distributed to the three antennas with new mm-wave receivers. Ethernet and time signals are now available on five antennas. Data transmission on single-mode fibres is possible on four of the six antennas.

An impetus for the new distribution system was the realization that phase noise injected into the system by the round-trip phase measurement system was causing significant (approximately 50%) decorrelation of the astronomical signal when observing at 3 mm. The new LO distribution system does not suffer from this flaw—amplitude decorrelation using this is measured at a few per cent, and may be a result of the atmosphere.

## Extra stations and the north spur

Under the MNRF program, four new stations have been built on the east – west track of the Compact Array, to give better short-spacing coverage. Extra funding from the CSIRO Capital Investment program has enabled the construction of a further five stations on a north spur line, 214-m long. This spur will let the array better cover the u-v plane when observing with high antenna elevations; these minimize atmospheric distortion at millimetre wavelengths.

The civil engineering component of these projects was completed in 2000 and, while delays have been experienced at Narrabri in cabling all stations, the new facilities will be available concurrently with the completion of the LO distribution system.

## Compact Array surface extensions

Five of the Compact Array antennas have been resurfaced with solid panels over their full 22-m diameter, doubling their sensitivity at 100 GHz. The antenna panels were adjusted in 1999 and measured to have an averaged rms surface accuracy of 0.25 mm.

During the 3-mm interferometry in November 2000, typical antenna efficiencies were still rather low and a pronounced coma lobe was evident in the beam patterns. However, subsequent adjustment of the antennas has led to improved efficiencies and clean beam patterns. At present, the overall antenna efficiencies are approaching 40% at 86 GHz, close to that expected with the originally specified surface accuracy of 0.15 mm.

## Pointing, optical alignment and the main reflector

During the year, a concerted effort was made to align the optics of the new millimetre systems so that, to first order, the pointing model and focus setting of the millimetre systems are the same as at centimetre wavelengths. With this now complete, second order effects related to the distortion/movement of the dish surface and subreflector position with elevation are being evaluated. These have an appreciable effect on the gain and efficiency of the dish. These issues are being investigated using a combination of modelling (ray tracing) and astronomical and mechanical measurements of the dishes.

In addition to "mechanical" aspects of the pointing model, an imbalance in the encoder electronics has been identified as the source of a periodic pointing error with amplitude of about five arcseconds. The offending circuitry in the millimetre antennas has been adjusted and the pointing error has improved markedly. Another contributor to pointing errors is related to the servo loop in the antenna control computer. Addressing this problem awaits the completion of the new antenna control computers.

Regardless of the accuracy of the pointing model and pointing hardware, at some level it is envisaged that to achieve the pointing specifications needed for mosaicing at 3-mm wavelengths, reference pointing will be needed. During the year, the reference pointing software has undergone significant development, to make it more robust, flexible and user friendly.

## Antenna control computers

The stringent demands of high-frequency observing, the expansion of Compact Array control and monitoring requirements, and concerns about the reliability of the present antenna control computers (ACCs) have combined to make delivery of new-generation ACCs a priority.

Work has continued for some time to develop object-oriented software to run in the new computers. Development work has also begun on the hardware interfaces between antenna systems and input/output devices in the new computers. In 2001, three prototype ACCs were installed in antennas 2, 3 and 4 in parallel with the original PDP11/73 machines. The new units are connected via the new fibre-based ethernet to the control computer network and are providing monitoring services for the new millimetre receiver packages. The ACCs are capable of driving an antenna and controlling the receivers and down conversion system to the point where autocorrelation spectra can be measured. It is envisaged that the old ACCs will be replaced in mid-2002.

## Millimetre weather

At 3-mm wavelength, the atmosphere will be a significant consideration in observing at the Compact Array. The first winter of using the millimetre system tended to confirm the old adage that it is not possible to judge observing conditions simply by looking out the window. During the September term, 15% of scheduled millimetre observing time was replaced with centimetre projects because of unsuitable weather.

In addition to phase errors, opacity and wind-related pointing errors, large fluctuations in both single-dish power and in interferometer amplitude have been identified with “anomalous refraction”, the effective wandering of the antenna primary beam caused by phase gradients across the 22-m aperture. The characteristics of this effect are being investigated.

A form of flexible scheduling, whereby millimetre and centimetre observing proposals can be interchanged depending on the weather, will be trialed in 2002.

Photo: David Smyth

*One of the new prototype receivers, in the upper vertex room of antenna 2, installed next to a large white 20-cm feed horn. The feed horn for the 12-mm waveband is in front of the 3-mm waveband (installed inside a vacuum dewar). A radio frequency absorber paddle can be seen above the two horns.*

## Atmospheric phase correction

At millimetre wavelengths, water vapour present in the atmosphere can cause significant distortion to the radio wavefront. A phase correction system is being developed to sense and correct the distortion. The phase correction system will use a room-temperature four-channel radiometer on each antenna, designed to detect water vapour emission while rejecting spurious emission from clouds or other sources. Each radiometer uses a separate horn which is mounted close to the astronomy horn; the offset between radiometer and astronomy horns is approximately five arcminutes.

In 2001, testing of two prototypes, using simple calibration of the radiometer output, has enabled the atmospheric phase to be reduced to the equivalent of 350 microns of path length. The aim had been to correct to about 100 microns. The dominant residual error is from 1/f noise originating in the radio frequency amplifiers of the radiometer. Errors with time scales greater than about three to five minutes dominate the error power. Work is progressing on switching schemes to reduce the 1/f noise of the system.

## Interference

Radio frequency interference (RFI) remains a challenge for the Observatory. Interference from the Globalstar satellite phone constellation is becoming more problematic at the 13-cm band. This interference is caused by sidelobes of satellite-to-handset transmission. A predictor of the expected interference generated by the constellation (based on known satellite trajectories, antenna pointing centre and decorrelation effects) has been developed and made available as a Web-based tool. This allows astronomers to avoid unfavourable times for critical parts of an observation (e.g. delay setting or primary calibration).

A new RFI survey of the centimetre bands has been carried out. Additionally a survey of the 12-mm band found no RFI.

Work is progressing on post-correlation techniques, using a reference antenna, to remove interference from observations. This is still at an early, research, stage.

## Staff

Ben Reddall took a one-year leave-of-absence to take a position at the South Pole providing engineering support for the Degree Angular Scale Interferometer (DASI). Martin Oestreich moved from Sydney to Narrabri to take on the role of Electronics Group Leader. For the last two months of the year, Allan Day, who plays an important part in the Observatory cryogenic systems, also took leave-of-absence to work with the DASI group at the South Pole. During Allan Day's absence, Jock McFee assumed responsibility for the cryogenic systems.

Leigh Panton left the ATNF in early February for a new job on the Gold Coast utilising skills in fibre optics work gained during many months of working on the Compact Array in the "splicing caravan".

From February until the end of the year, the Officer-in-Charge (OIC), Dave McConnell, shared his time between being based at the ATNF headquarters in Marsfield, and at Narrabri. He spent roughly one week per month in Narrabri. The newly appointed Deputy OIC, Ron Beresford, acted for him in the day-to-day management of the Observatory during his absence. The OIC and Deputy were usually in daily contact, with each taking responsibility for different areas in running the Observatory. Dave McConnell stood down as OIC at the end of December and Bob Sault has been appointed as the Narrabri OIC from 1 January 2002.

After one year at the Observatory, Cliff Harvey resigned in September. Derek Aboltins joined the ATNF in December to take over Cliff's position in the Electronics Group.

After many years providing sterling service at the lodge to both visitors and staff, Chris Forbes resigned shortly before Christmas. Shaun James from the Electronics Group, also resigned shortly before Christmas, to take up a position with the Anglo-Australian Telescope at Siding Spring.

## Visits by the new CEO and by Australia's Chief Scientist

On 11 April 2001, the new Chief Executive Officer of CSIRO, Dr Geoff Garrett, made a brief visit to the Observatory. In a day which started with a visit to CSIRO's cotton research station at Myall Vale (Division of Plant Industry), Dr Garrett spent several hours inspecting the Compact Array and addressing staff.

On 5 November 2001, the Compact Array was visited by Robin Batterham (Australia's Chief Scientist), Martin Cole (President, Institute of Engineers) and Peter Jonson (Chairman, Melbourne Institute). After morning tea at the alidade level of an antenna, they had a site tour followed by lunch with the staff, before leaving for Siding Spring.

## Student visitors

As part of the collaboration between the ATNF and the Academia Sinica Institute of Astronomy and Astrophysics, Taiwanese student Cheng-Jiun Ma visited the Observatory for three months


*Sunset at the Compact Array*

starting in March to gain experience in practical radio astronomy. Working with Ravi Subrahmanyan and Bob Sault, Cheng-Jiun investigated anomalous refraction effects at 3 mm, evaluated the antenna tracking stability using an optical telescope mounted on a Compact Array antenna, and worked on data acquired from a short baseline interferometer with the aim of evaluating methods for rejecting cross-talk.

During the summer months, the Observatory hosted two pairs of vacation scholars. During the summer of 2000 – 2001, Elizabeth Claridge (University of Tasmania) worked with Steven Tingay on bent jets in extragalactic radio sources, and Tim Connors (University of Sydney) worked with Dave McConnell on radio emission from the globular cluster 47 Tucanae. During the summer of 2001 – 2002, vacation scholars Nicolai Grosse (Australian National University) worked with Steven Tingay on gamma-ray loud AGN, and Vicky Safouris (University of Sydney) studied the interstellar medium with Ravi Subrahmanyan.

## Narrabri Synthesis Imaging Workshop

The fifth ATNF Synthesis Imaging Workshop was very successfully held at the Observatory during the week of 24 – 28 September. This was the first one held since the flood-affected workshop in September 1988. There was an encouraging increase in attendance, with 35 post-graduates, 10 postdoctoral fellows and a few undergraduates. In addition about 30 speakers and other helpers attended the workshop. In comparison to previous workshops, the students included a larger fraction of those who were predominantly interested in wavelengths other than radio.

This workshop included two two-hour "practical sessions" and a site tour to complement the formal lectures and tutorials. During the practical sessions, the students were able to take part in activities such as observing, data analysis, working with a basic interferometer operating at 22 MHz, and using the antennas as single dishes at both millimetre and centimetre wavelengths. All the formal parts of the workshop were well rated by

the students, with the practical sessions, in particular, being highly successful. The presentations made at the workshop have been placed on the Web at
http://www.atnf.csiro.au/synthesis/talks.html

## Observatory improvements

A network connection has been installed to the Lodge. This will provide more facilities for monitoring the telescope operation while relaxing over a meal. The main staircase in the control building has been renovated to give a gentler angle. The former staircase was steep and failed to meet building regulations. A number of improvements were made to the grounds, including a new fence around the new car park at the Visitors Centre and the planting of an avenue of native shrubs along the path to the Lodge.

# Mopra

## Operations

During 2001 the use of Mopra continued to be restricted to VLBI and millimetre observations only. VLBI observations were taken as part of the Long Baseline Array (LBA) and in conjunction with the VLBI Space Observatory Program (VSOP) project. Although there were a small number of projects involving the 12-mm receiver, the bulk of the millimetre proposals used the 3-mm system. The millimetre observing was split between National Facility time and time given to the University of New South Wales (UNSW). This year was the final year of a three-year agreement with the UNSW, whereby the university was given access to the telescope during the winter months.




Photo: David Smyth

*A Compact Array antenna*

This was in exchange for financial support to re-surface the antenna in 1999 and for observing support for time allocated by the ATNF for National Facility use. This year 70 days were given to the UNSW for their use, and an additional 38 days were scheduled to outside observers as National Facility time. In total, 38% of the year was scheduled observing time or time allocated to the UNSW.

## Staff

In 2001 there were no permanent staff at Mopra. Engineering support was provided from Narrabri and Sydney. Observing support was provided either through the UNSW agreement, or by the ATNF VLBI group. Robina Otrupcek was employed on a casual basis to support space VLBI observations.

***Table 3*** *Mopra time use, 2001*

| Observing mode | days |
|---|---|
| National Facility time | 38.1 |
| UNSW time | 69.7 |
| VSOP | 10.0 |
| VLBI | 21.7 |
| **Total** | **139.5** |

## Mopra open day

As part of the annual Connabarabran "Festival of the Stars" weekend (which centres on Open Day at Siding Spring Mountain), Mopra was open to the public on 21 October. Ron Beresford gave approximately 100 visitors a brief tour of the telescope.

Photo: John Masterson

*The Mopra radio telescope, Coonabarabran*

# Parkes

## Performance and time use

The fraction of time scheduled for all observations in 2001 was 82%, unchanged from the previous year. It is expected that major maintenance works on the telescope will reduce this figure to closer to 70% in 2002.

The fraction of time lost to equipment faults in 2001 was 1.3%, a slight increase on the record low figure of 1.0% for 2000. The time lost due to bad weather (high winds) however was 2.8%, a doubling of the figure for the previous year. This increase reflected an abnormally windy year, particularly around the equinoxes, however improved monitoring of the wind speed and revised safe working practices also contributed.

All major telescope systems performed well throughout the year, which the exception of the 3-cm (X-band) receiver, which failed during a VLBI run in November. Refurbishment of this receiver and the 1.3-cm (K-band) receiver will be a priority in 2002.

A subtle, nagging problem in the telescope's drive system causing it to occasionally stop driving was finally tracked down mid-year and fixed (with components costing less than a dollar). The drive system has since performed extremely reliably.

## User feedback

The Web-based user feedback system remains one of the Observatory's most important tools in maintaining successful Observatory operations and services. There were 34 responses from observers in 2001, close to the target figure of one report per observing team per session. Figure 10 (page 18) shows the user ratings on a scale of 1 – 10 in each of the categories included in the questionnaire.

Once again RFI emerges as the most salient single issue with many observers, and the Observatory is committed to maintaining mitigation of RFI as a high priority. The commissioning of the interfererence monitoring system (IMS), a sophisticated new system to monitor and identify interfering signals, and the construction of an anechoic room for characterizing new computers and other equipment, were both significant developments on this front in 2001.

## Major activities

The northern extensions to both the HI Parkes All-Sky Survey (HIPASS) and the Zone of Avoidance (ZOA) HI survey were completed towards the end of the year. A further extension of the ZOA survey to include the Galactic bulge will continue throughout 2002. Calibrated spectra for HIPASS have been released to the public domain, with the ZOA and northern extensions to follow in 2002. Observing programs with the narrowband multibeam system to confirm the statistical completeness of the main surveys are well progressed, with the large galaxy catalogues expected to be published also in 2002.

The Jodrell Bank-ATNF-Bologna Galactic pulsar survey is nearly complete. Follow-up timing observations will continue into 2002. The delay in completing the survey has been due entirely to its great success in finding many more pulsars than anticipated. More than half of all known pulsars have now been found at Parkes, with the number still growing.

Some smaller surveys have also achieved notable success in finding millisecond recycled pulsars away from the Galactic plane. The stability of these millisecond pulsars, matched by the Observatory's state-of-the-art timing system, is opening windows onto a number of hitherto inaccessible physical effects, and is maintaining the Observatory's position at the forefront of this research.

A new "common-view" GPS timing system has been commissioned at the Observatory, providing a second long-term stable comparison clock, independent of the conventional GPS receiver systems.

## Zenith drive repairs

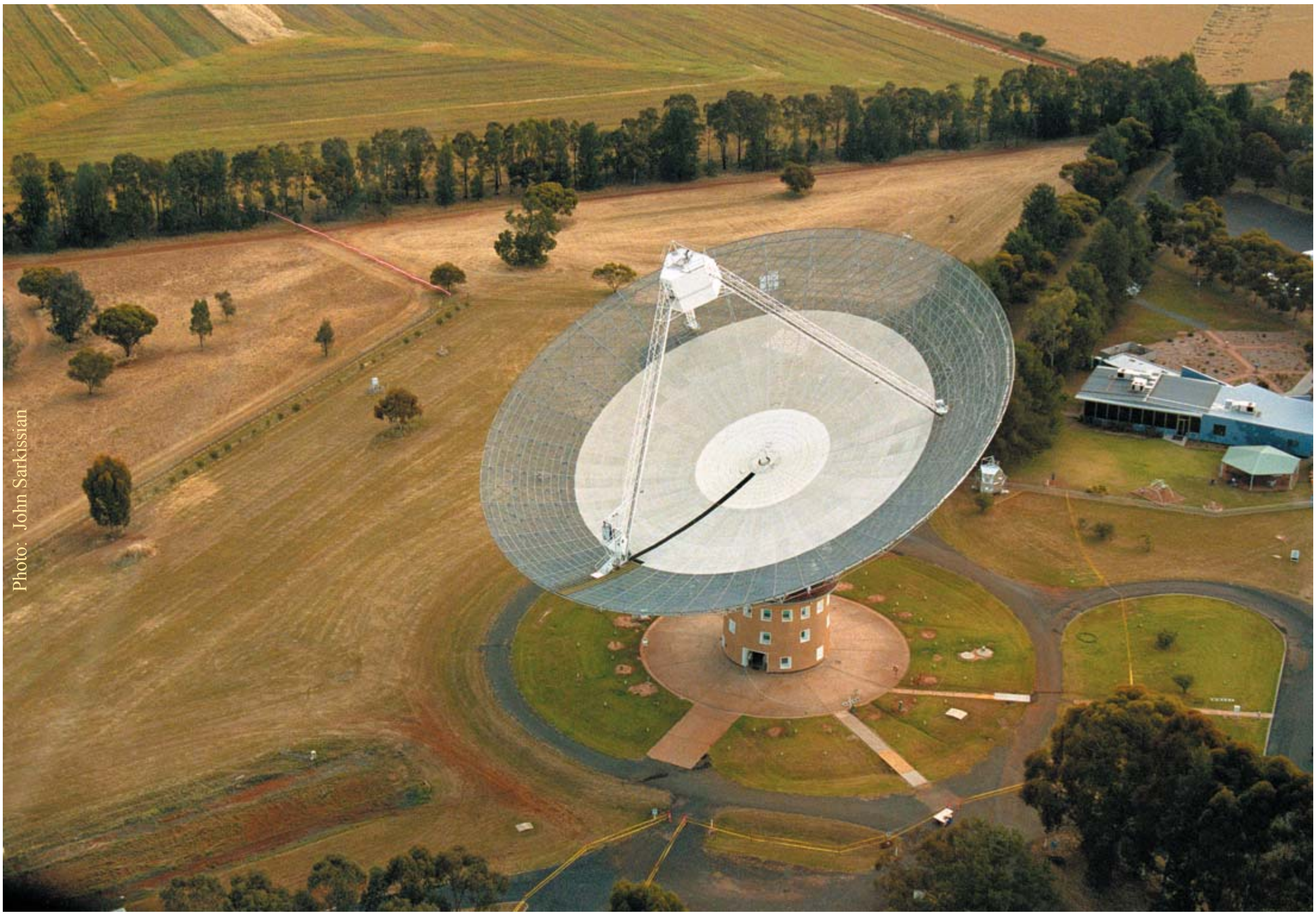
Preparations are underway to replace both zenith drive gearboxes and pinions, and to refurbish the rack gears in 2002. The drive systems have performed extremely well with minimal maintenance for the last 40 years, but are now nearing the end of their useful lives.

## New developments

The commissioning of a new GHz-bandwidth correlator in 2002 will significantly enhance both pulsar and spectral line observing capabilities. The new correlator is particularly well-matched to a new dual-frequency receiver tailored for pulsar timing, which will also be commissioned in 2002.

The Caltech-Parkes-Swinburne baseband data recorder (CPSR), will be upgraded with a several-fold increase in recording bandwidth, allowing precise timing observations to be extended to many more millisecond pulsar systems than is currently possible. Measurements made with the existing recorder have already set a new standard in pulsar timing accuracy.

Looking further ahead, a collaboration with Jodrell Bank to design a new multibeam receiver for Parkes has commenced. The new receiver will operate at 6.7 GHz to make a comprehensive survey of methanol molecular maser emission in the Milky Way and Magellanic Clouds.




*An aerial view of the Parkes radio telescope and surrounding land. The Parkes Visitors Centre is on the right-hand side of the image.*

# The Australian Long Baseline Array

## LBA astrometry project

A new postdoctoral position, funded by the United States Naval Observatory (USNO), started in late 2000 with the appointment of Dr Roopesh Ojha and allowed the commencement in 2001 of the joint ATNF-USNO collaborative astrometry program. This is a major and ambitious program over five years aiming to improve significantly the fundamental reference frame in the southern hemisphere. It consists of two distinct but complementary observational phases:

- VLBI imaging at 8.4 GHz using the LBA in its standard S2-recorder observing mode, to determine the structure of all radio sources observed in the VLBI astrometry program. Source structure is often the limiting factor in astrometric accuracy and the imaging will help achieve much more accurate astrometric positions by removing any residual structure effects. During 2001 four VLBI imaging sessions were scheduled under this program.

- VLBI astrometry with standard MkIIIA/MKIV observations at S/X-bands to increase the number of astrometric sources in the south. Parkes and Hobart participate in these observations with other telescopes in the Asia Pacific region. During 2001 two sessions of such observations were performed.

The ATNF-USNO collaboration has also enabled the addition of the NASA Kokee Park antenna (Hawaii) as part of the LBA. An Australian S2 system was installed at Kokee in 2000 and the system has been successfully used during all observing sessions in 2001.

## VLBI polarization

Work also commenced in 2001 towards establishing full polarimetric VLBI observations with the LBA, primarily through the efforts of Dr Roopesh Ojha who has continued to work on the calibration of LBA polarimetric observations. A very successful one-day workshop on VLBI polarization was held in early 2001. All VLBI imaging observations in the astrometry program are now performed with full polarization measurements.

## Upgrades

The upgrades to the Hobart and Ceduna telescopes under the MNRF program were essentially completed during 2001.

New cooled receivers have been built and installed in the Hobart antenna. The new 21-cm receiver was used routinely for LBA observations and has provided much improved sensitivity. An innovative cooled receiver using a single dewar to house five bands at frequencies between 5 and 22 GHz has been built and tested. It will be commissioned on the telescope in 2002.

At Ceduna, the new 22-GHz receiver has been used in LBA observations, the pointing has been significantly improved, and the observing system has been streamlined for simpler and easier operations.

## VSOP

The radio astronomy satellite HALCA (Highly Advanced Laboratory for Communications and Astrophysics) was launched in February 1977. This satellite is used together with a global network of ground-based radio telescopes, for the VLBI Space Observatory Program.

Full VSOP observations continued throughout 2001 and involved the Compact Array, Mopra, Hobart and Ceduna antennas. Mopra was the most heavily used antenna with extensive support for general observing time VSOP observations as well as the mission-led VSOP survey program. NASA support for VSOP will cease in February 2002 and thus 2001 was the last year of full-scale VSOP operations. The VSOP survey program will continue in 2002 primarily using the Canadian S2 correlator and will include several southern hemisphere telescopes.

## Proposals and scheduling

There was strong proposal demand for the LBA in 2001, with an oversubscription rate of 2.0, slightly higher than the rate of 1.7 for the previous year. Proposals covered a wide range of areas, including polarimetry and high-resolution spectroscopy. A significant amount of time was scheduled for the new astrometric program. Access to the NASA Deep Space Network (DSN) Tidbinbilla telescopes continued to present problems with the effective scheduling of the LBA array, particularly for sensitive observations requiring the large 70-m antenna.

## Operations

There were four LBA observing sessions in 2001. Overall the LBA performed well and a summary is shown in Table 4 below. The overall success rate for the LBA in 2001 was 84%, the same rate as for 2000 but with a 45% increase in observing time. Many of the telescopes continued with success rates over 95%. However, single system failures at Parkes (receiver), Hobart (cryogenics) and Ceduna (hydrogen maser) led to significant time losses on these antennas with a corresponding loss in the overall array performance.

***Table 4*** Long Baseline Array observations, 2001

| Telescope | Parkes | Compact Array | Mopra | Hobart | Ceduna | Tidbinbilla | Hartebeesthoek | Kokee | LBA |
|---|---|---|---|---|---|---|---|---|---|
| hours observed | 525 | 529 | 524 | 400 | 359 | 32 | 122 | 70 | 574 |
| success rate % | 86 | 99 | 97 | 77 | 86 | 77 | 99 | 98 | 84 |