Technology developments

Marsfield engineering developments

Executive Special Project

In December 1997 CSIRO's Chief Executive Officer, Dr Malcolm McIntosh, announced a number of projects to be undertaken by large research teams within CSIRO. One of these projects was a joint proposal of the ATNF and CTIP to develop high frequency integrated circuits for radio astronomy and telecommunications. The circuit designs are developed within ATNF and CTIP and are fabricated in the USA by the foundry TRW using their leading edge indium phosphide foundry process. Devices produced under the program include monolithic microwave integrated circuits (MMICs) and high-speed digitiser circuits.

This project was effectively completed with the delivery in April 2002 of the diced chips from the third and final TRW wafer fabrication run, labelled CSR15. As well as containing production quantities of proven MMIC designs from the initial CSR8 run from 2000, CSR15 also included a new design for a 3-mm band coplanar waveguide indium phosphide HEMT low noise amplifier. Initial tests indicate that this amplifier has the potential to extend the frequency coverage of the Compact Array 3-mm receivers to above 112 GHz.

The Executive Special Project has proved highly successful, not only in providing state-of-the-art components for a number of ATNF projects, but also in giving ATNF engineers the opportunity to develop expertise in the design of a wide range of high frequency MMICs.

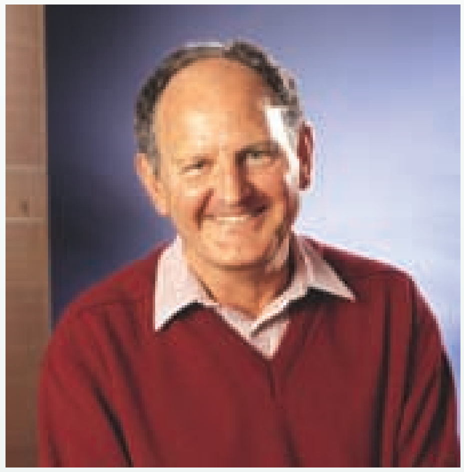

Photo: Kristen Clarke

Dr Warwick Wilson
Head, ATNF Engineering Development Group

12- and 3-mm receiver developments

A major effort was put into the detailed design of the final conversion systems for the new Compact Array 12-mm receivers. A new approach was taken in which significant sections of the system were integrated into modules combining a number of functions, with the aim of reducing packaging and cabling costs. Although this approach involved a significant learning curve in developing the basic techniques, the effort was considered to be worthwhile given the savings involved and the potential enhancements in performance and reliability offered for this and future projects.

As part of the upgrades to the 3-mm systems at the Compact Array, a new method of manufacturing the 3-mm feed horns, using precision machining rather than electro-forming, proved to be very successful and has significantly reduced the cost and complexity of manufacture.

A new design for a 3-mm OMT (orthomode transducer) polariser was completed. The design gives a significant improvement in performance over the commercial devices used in the 3-mm prototype receivers.

Local oscillator upgrade

As part of the Compact Array upgrade to operate at 3-mm wavelength, a new local oscillator (LO) chain is being developed to produce a reference near the observing frequency from the signal distributed from the central site. Two indium phosphide MMIC chips developed for this LO chain under the Special Executive Project were packaged and tested. These were a sideband separating mixer and a frequency doubler. In each case performance was shown to be well within specifications.

Three other components required for the 3-mm LO chain, a 25 – 50 GHz frequency doubler, a 50 GHz power amplifier and a 100 GHz power amplifier proved to be difficult to source from commercial suppliers. A gallium arsenide MMIC fabrication run with TRW was undertaken in July 2002 to address this problem. The designs for the power amplifiers were provided by CTIP, the doubler by ATNF. Wafers from this run were returned in October 2002. Initial on-wafer tests showed that the performance of the MMICs was probably adequate, although final results will not be available until the designs are packaged in early 2003. This development has significantly delayed the installation of the 3-mm systems, which is now unlikely to take place before mid-2004.

Parkes 10/50 cm receiver

Most of the mechanical design and manufacture of the 10/50 cm pulsar receiver was completed by the end of 2002. This included a dual frequency coaxial feed, designed by CTIP, which was successfully tested after integration with other ATNF designed components. A test installation to check the mechanical interface to the telescope will take place in early 2003.

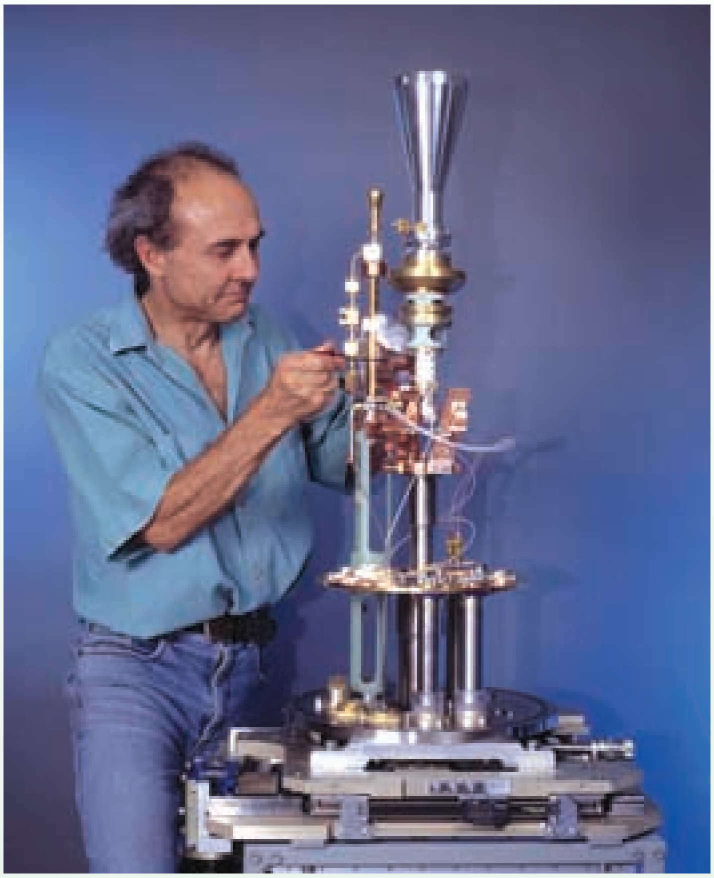

Photo: David Smyth

ATNF engineer Russell Bolton with the wideband-prototype 3-mm, and production-phase 12-mm receiver systems

FARADAY

The FARADAY project, funded by the European Union, is a co-operative program between the UK, The Netherlands, Poland, Italy and Australia that aims to produce prototypes of integrated focal plane arrays and to study large arrays for future implementation.

As part of the FARADAY collaboration, the ATNF acquired access to approximately 40% of an indium phosphide HEMT fabrication run to be undertaken at TRW in early 2003. Part of this allocation will be used to provide production quantities of previous designs developed under the Executive Special Project (page 57). In addition, a number of new designs were undertaken, both in response to immediate requirements, such as a 50 GHz frequency doubler for the 3-mm LO system, but also aimed at possible future requirements of a more speculative nature. The latter included a 60 – 90 GHz low noise amplifier and broadband low noise amplifiers in the 1 to 12 GHz range. The broadband low noise amplifiers were devised in the context of a possible future upgrade for the ATCA cm-wave systems.

A new 8 GHz bandwidth spectrometer for Mopra

In October 2002, the University of NSW was successful in obtaining funding from the ARC to enable the development of an 8 GHz spectrometer for the Mopra telescope. This will be a collaborative project, with UNSW, ATNF and Sydney and Monash Universities providing additional funding. The instrument will be built by ATNF using the polyphase digital filter bank designs being developed for the MNRF-2001 Compact Array broadband upgrade project. The system is planned to be installed and operating in mid-2004.

AMiBA prototype correlator

As part of a collaborative agreement between ATNF and ASIAA Taiwan, ATNF provided a prototype analogue correlator and data acquisition system to ASIAA for the two-element AMiBA CMB Prototype telescope. The correlator system was delivered to Taiwan in April. The prototype telescope was installed on Mauna Loa in September and first fringes were obtained in October 2002.

Arecibo 21-cm multibeam receiver

A contract with the National Astronomy and Ionisphere Center, USA (NAIC) was signed in April 2002 for the supply of a seven-beam 21-cm multibeam receiver for the Arecibo radio telescope. The receiver design will be an adaptation of the successful Parkes multibeam receiver. ATNF will supply the front-end receiver package, including the feed array, the cryogenic system, the low noise amplifiers and the receiver rotation mechanism. The design of the feed array has been subcontracted to CTIP. ATNF personnel attended a design review meeting at Arecibo in September 2002.

Photo: David Smyth

ATNF technical officer Pat Sykes with the Parkes 10/50cm receiver during its construction phase in Marsfield

MNRF-2001

In early 2001 the Government announced, as part of a new innovation statement, a new *Major National Research Facilities* program. The Australian astronomical community decided to combine their two highest priorities for future growth into one proposal for MNRF funding. These priorities, as identified by the Australian astronomical community in the report *Beyond 2000: The Way Ahead*, are additional access to the optical/infrared telescopes of the Gemini project and development of the SKA—the next-generation radio telescope. The MNRF-2001 proposal was submitted to AusIndustry in May 2001. On 21 August 2001, the Minister for Industry, Science, and Resources, Senator Nick Minchin, announced the allocation of A$155M under the MNRF-2001 program to 15 successful proposals. Of these the ATNF-led proposal was granted the largest single allocation, A$23.5M.

The specific aims of the MNRF-2001 program are to:

- **Increase Australia's share in the International Gemini Telescopes (currently 5%).** The MNRF funds will be used initially to purchase an additional share of Gemini. This program will not only provide Australian astronomers with a bigger share of Gemini observing time, but will also improve the capabilities of the Gemini telescopes, and advertise Australia's expertise in instrument building.

- **Develop enabling technologies for the SKA.** The ATNF is one of a consortium of major radio astronomy institutions in eleven countries now planning the world's next-generation large radio telescope, the SKA. This instrument's one million square metres of collecting area will make it 100 times as sensitive as the best present-day instruments: this area will be distributed across many hundreds, perhaps thousands, of kilometres in a location yet to be decided. Using a combination of technologies, the SKA will cover frequency ranges from 100 MHz to above 10 GHz. The SKA project is currently the world's largest radio astronomy initiative and will cost around A$2B. Construction of the instrument is expected to start by 2012.

  Australian SKA activities are coordinated through the Australian SKA Consortium Committee (ASKACC). This committee aims to provide a single interface between Australia and the international SKA project. To achieve this ASKACC coordinates SKA research and development within Australia, with the establishment of national working groups for different SKA activities. ASKACC also consults with the wider Australian astronomical community, promotes the SKA to the public and to Government and industry, and appoints Australia's members to the International SKA Steering Committee.

Compact Array broadband upgrade project

This project has the aim of developing new signal processsing technologies for the SKA and applying them in a significant upgrade of the Compact Array. The Compact Array will become, in effect, a test bed for SKA developments, but in so doing will profit from important extensions to its observational capabilities. In the short term, National Facility users will have access to a significantly enhanced instrument, while the longer term goals of the SKA are addressed.

The upgrade will increase the bandwidth of the Compact Array by a factor of 16 to a total of 8 GHz. A new polyphase digital filter bank structure will provide increased frequency resolution in a highly flexible format. This is a major upgrade to the Compact Array, replacing the existing frequency conversion systems, the samplers, the data transfer, the delay system and the correlator.

The Square Kilometre Array

The ATNF is a very active player in the international and Australian SKA consortiums and, in collaboration with Australian universities and other Divisions across CSIRO, is making major contributions to the design of the array in several key areas including the antenna elements, the receivers, signal processing, site investigations, array configurations and interference mitigation.

SKA antennas

Antennas are the highest profile components in the various SKA concept designs. The SKA goal is to have many simultaneous, widely separated beams which can be "placed" in different directions on the sky. Three types of antenna design are being considered in Australia. These involve Luneburg lens antennas, cylindrical reflectors, and phased-array antennas. In 2002, good progress continued to be made in a joint project between four CSIRO divisions (ATNF, CTIP, Molecular Science and Manufacturing Science & Technology) to investigate and develop composite, low-loss, dielectric material for use in Luneburg lenses and other electromagnetic engineering applications. The material is being developed primarily within CSIRO Manufacturing and Infrastructure Technology and a patent will be finalised by mid-2003. The current work on antenna prototype design will determine the choice of technology for Australian SKA demonstrator antennas; this choice will be made by mid-2004.

The ATNF is also contributing to the development of highly-integrated receiver solutions for the SKA and its demonstrator antennas. As part of this work, in 2002 the ATNF completed a design for an uncooled wideband GaAs MMIC low-noise amplifier. This has been delivered to international collaborators and will be used with SKA laboratory prototypes.

SKA site investigations

Radio frequency interference testing and site investigations at possible SKA sites remains high on the Australian agenda. Extensive tests have been carried out at the Mileura Station in Western Australia (ATNF Annual Report 2001). In December 2002, a first-round inspection and preliminary interference measurements were made at a potential SKA site near Murnpeowie, in outback South Australia. Radio frequency interference measurements have shown Murnepowie to be an excellent radio-quiet site although a detailed radio frequency interference survey using more sensitive equipment and analysis tools will need to be undertaken. Further site testing is also planned for a site in western New South Wales. The combined site investigations from these two sites and the well-characterised Mileura site in Western Australia will form part of the submission of an initial Australian SKA siting proposal during 2003.

SKA meetings

An international SKA meeting was held in Groningen, The Netherlands, in August 2002. A highlight of the meeting was the presentation and discussion of SKA concept proposals, or White Papers. Two White Papers were presented by the Australian SKA Consortium, one based on Luneburg lens antennas and the other describing a cylindrical reflector solution. Both proposals were "end-to-end" descriptions, giving representative designs from the antennas through to the data processing. Other Australian contributions included submissions on new receiver concepts and SKA data transport requirements. Several issues emerged from the discussions at Groningen. In particular it was evident that at present no single SKA antenna design meets all the project science goals. The available antenna designs provide for either high frequency observations (>20 GHz) or for observations taken using multiple fields of view, but not both. This issue is complex; the SKA science community is currently divided with some groups favouring high frequency observations and other groups favouring multiple fields of view. The Australian antenna designs may offer a compromise solution with options for observations at frequencies near 10 GHz using up to 10 beams.

An international SKA workshop will be held in Geraldton, Western Australia, in July 2003.

The Murnpeowie site in South Australia is one of several Australian sites being tested as a possible location for the SKA.

***Emu in the Sky* © 2002 Charmaine Green**

This painting, *Emu in the Sky*, by Charmaine Green, was commissioned by the ATNF in 2002 for the international SKA workshop to be held in Geraldton, Western Australia in July 2003. The original painting is acrylic on canvas.

Charmaine Green is a local member of the Marra Art Collective in Geraldton. The ATNF is working with the Marra Art Collective to produce parallel interpretations of the sky, presenting both the indigenous and astrophysics views together.

Warlu Time (story provided by Charmaine Green)

In our region the Yamaji people use the stars (seven sisters) and the Milky Way (emu image) to know when is time to go out for emu eggs. This is called Warlu Time.

This story refers to the fact that the obscuring dust clouds in the Milky Way make the shape of an emu. At a certain time of year, the emu shape appears to be sitting, and the local Aborigines, the Yamaji people, know that this is the time to collect emu eggs for eating. At Warlu time, the constellation of Pleiades (seven sisters) is low above the horizon.

Industry collaboration

The MNRF-2001 proposal includes industry partnerships with Advanced Powder Technologies Pty Ltd, CEA Technologies Pty Ltd and Dell Computers Pty Ltd. In 2002, a new partnership was established in a collaborative agreement with Connell Wagner Pty Ltd, one of Australia's largest engineering consultancies. This agreement provides additional SKA funds of $A0.5M for SKA research and development in 2003. Connell Wagner will contribute engineering resources in a variety of areas, including an engineering infrastructure study of possible SKA sites within Australia. In making the offer, Connell Wagner's NSW regional manager, Tony Barry, noted that the SKA will provide many opportunities for Australian engineering in coming years as well as leading to exciting achievements in radio astronomy. The new collaborative program will be directed by Steve Negus (Connell Wagner) and Peter Hall (ATNF).

Photo: Dietrich Georg and Engineers Australia Magazine

Connell Wagner Pty Ltd NSW Regional Manager Tony Barry (front left) and ATNF Director Ron Ekers (front right) sign the SKA collaborative agreement in December 2002. Standing: Steve Negus (Connell Wagner, left) and Peter Hall (ATNF).

LOFAR

LOFAR (LOw Frequency Array) is the first of the next-generation radio telescopes based on geographically distributed, but connected, systems of array stations. LOFAR is being designed to operate at frequencies from approximately 10 to 250 MHz and will be operational in initial form within the next five years. The LOFAR array will contain thousands of antennas distributed over a 400-km region. In many respects LOFAR is a low-frequency prototype version of the SKA, and is a direct step in the development of the SKA. However, the LOFAR antennas are designed to operate at lower frequencies and over much smaller bandwidths, allowing for simpler receiving systems than the SKA. LOFAR is expected to start initial operations around the time of the next solar minimum in 2006 – 2008, with an estimated cost of A$200M. Further information is available from the LOFAR website at www.lofar.org.

As a result of an initial White Paper submission in 2001, the international LOFAR Consortium short-listed inland Western Australia, along with two other sites (in the USA and The Netherlands), as a possible LOFAR site. The ATNF, in collaboration with the Government of Western Australia, submitted a second, more detailed, proposal in October 2002; this proposal outlined the many advantages of a location in Western Australia.

The scientific potential of LOFAR was discussed at a meeting held at the ATNF in December 2002: *Detecting the epoch of reionisation*. A second two-day meeting, *The low frequency Universe*, is scheduled for January 2003 at The University of Sydney.

In February 2003, a delegation from the LOFAR Consortium will visit Australia to discuss possible collaborations and Australian involvement with LOFAR. The delegation will also visit the potential site in Western Australia and will meet with the representatives of the Government of Western Australia, as well as advisers in the Australian Government. A decision on the location of a site for LOFAR is expected to be made by the end of 2003.