International Square Kilometre Array Newsletter

Volume 3
October 2001

Our annual international SKA meeting, this year titled "The SKA: Defining the Future", was hosted at the University of California, Berkely and jointly sponsered by the US SKA Consortium, UC Berkeley and the SETI Institute. The meeting was very successful. The meeting presentations can be found at http://www.skatelescope.org/skaberkeley/ .

The twice-yearly ISSC meeting occured in the US this year, on 5 January at the Massachusetts Institute of Technology and on 27 July in association with the Berkeley meeting. The minutes of the MIT meeting are located on the SKA secretariat web site. At Berkeley we were joined by observers from South Africa and Japan. The next meeting of the ISSC will occur at Bologna on 17/18 of January. It will be preceded by a science workshop, "New Frontiers in Astrophysics: Square Kilometre Array ", aimed at refining the scientific drivers and technical specifications for the SKA.

Russ Taylor, Executive Secretary
International Square Kilometre Array Steering Committee

News from Australia

The Australian Government's announcement that it will fund an SKA demonstrator program has stimulated much activity within SKA groups. The funding will come via the Major National Research Facilities (MNRF) scheme and is about 85% of what the astronomy community requested in a joint Gemini/SKA proposal. Negotiations between bid proponents are continuing but the most likely outcome is an across-the-board scaling, implying that SKA programs totalling $US10M will be undertaken over the next five years.

At the recent Berkeley gathering the Australian team outlined programs focussing on construction of two SKA demonstrators, both of which will be integrated with existing radio telescopes. The Narrabri ATCA demonstrator will use either Luneburg Lenses or phased array receptors, while the Molonglo instrument will be based on the MOST east-west cylindrical reflector. Design studies for both instruments will be finished by the end of 2003 and the target is to have construction completed by 2005. The demonstrator work, together with SKA astronomy and engineering simulations to be undertaken by Swinburne University, will be co-ordinated by the recently-formed Australian SKA consortium. We plan to avoid R&D duplication and to collaborate with international colleagues in areas where productive research is already underway. More details of initial demonstrator proposals can be found in the Berkeley conference proceedings at http://www.skatelescope.org/skaberkeley/

The Berkeley proceedings also contain summaries of work in antenna, interference mitigation, site and outreach projects. Recent highlights include the delivery of initial artificial dielectric samples by our material science colleagues; the samples are currently being evaluated in RF tests. Characterization of the 0.9 m diameter Luneburg Lens obtained in collaboration with Russian radio astronomers is continuing, with near-field tests at 12 and 2 GHz being complete and outdoor tests about to begin. Indications are that the lens has excellent beam-forming properties and we expect to make accurate gain (and di-electric loss) measurements during the outdoor testing.

Analysis of the first Western Australian site test data is almost complete and summary reports are being compiled. Further site characterization at various inland Australain sites will begin next year and, to improve the sensitivity of the RFI measurement system, CSIRO has constructed an auto-correlator backend. This is currently being tested (Figure 1) and should be fully operational in early 2002. In related outreach work, we have obtained corporate and other sponsorship for a spectrum monitoring project designed for high school students. If a bid for associated Government funding is successful, city and country students at five or six locations will learn the value of the e.m. spectrum as a natural and commercial resource, and the value of radio quietness to astronomy and the SKA. Measurements will be made using scanning communications receivers interfaced to PCs. Data presentation and communication between participants will be via the internet. The success or otherwise of the outreach bid should be known by late October this year.

Returning to the newly-funded MNRF program, several additonal technology developments will be funded. A phased array antenna project will look at arrays in both primary receptor and focal surface array applications. We also expect to produce InP or SiGe MMIC receivers for the ATCA and Molonglo applications, and to look at photonic signal processing and distribution for the two demonstrators. Importantly, a new 2 GHz F/X correlator will be installed at the ATCA by 2005. It will incorporate interference mitigation machinery, will accommodate at least a small-scale multi-beaming interferometer option, and will demonstrate extensible architecture principles applicable to the SKA. The MNRF grant is not large given our ambitions and the next few months will see a process of careful planning and re-scoping now that we are in the position of being able to contribute still more effectively to the international SKA endeavour.

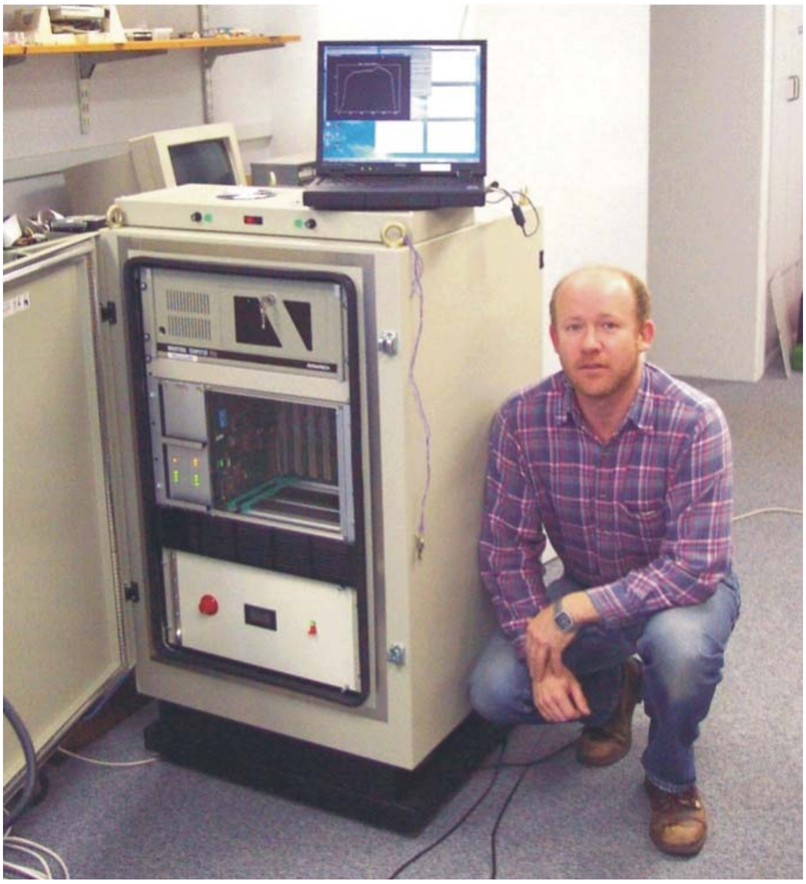

Figure 1 - ATNF engineer Mal Smith with part of the high-sensitivity RFI measurement system he has constructed for use in SKA site tests and observatory monitoring roles. The auto-correlator (centre unit in rack) has a maximum bandwidth of 64 MHz (at 62.5 kHz resolution). With

typical integration times, the correlator backend improves the measurement sensitivity by 20 dB or so relative to a sweeping spectrum analyser and signals around the -150 dBm level are easily detected.

Peter Hall, CSIRO

The Canadian Large Adaptive Reflector

Airborne Platform

Over the past year most of the development effort has been concentrated on theoretical modelling and field testing of the aerostat components of the Large Adaptive Reflector. A dual approach is critical to a thorough understanding of the behaviour of this system. The model permits us to test ideas without the expense of modifying hardware, and the actual tests verify the computer model and provide a guide as to what additional effects are important in modelling. Obviously, the testing is far more logistically difficult than the computer model, but both are equally important.

The simulation work is now centered at McGill University. Prof. Meyer Nahon along with Gabriele Gilardi (post-doc), and Casey Lambert (graduate student) have brought their numerical simulations to an advanced stage. They have now combined models of streamlined aerostats developed in the 1980's at the University of Toronto (J.D. DeLaurier) with their previous model of the multi-tethered cable system. Previously a spherical aerostat was assumed, which is still a serious option. The goal of this work is to create a reliable, verified simulator that can provide accurate predictions for a variety of scales and configurations.

Although we have to cope with a few months of delay, the field test of the aerostat is taking shape. The aerostat itself has been delivered in kit form, and is awaiting a bit more work on making a suitable assembly area. There is quite a lot of assembly and rigging to be done before it can be inflated with helium.

Figure 2. Inflation Test of Tail Section of the Aerostat that will be used for field tests in Penticton

A launching system was designed over the summer, and constructed at AMEC Dynamic Systems in Vancouver. When on the ground, the aerostat will be attached to a boom that can rotate with the wind. This is mounted on a modified flat-deck semi-trailer so that the launching point can be shifted to permit a variety of tether configurations to be tested.

The instrument platform for the tests is receiving its final touches. The platform contains instruments for sensing air conditions (wind speed/direction, air temperature), tether loads, platform orientation (tilt and direction), and position. Position sensing will be measured using a specialized GPS system provided by the University of Calgary's Geomatics Engineering department. The platform was put together by a series of co-op students from the University of Victoria. It is now being completed, and will receive a "ground-test" in the next few weeks. This will entail a mock-up of the launch and tether arrangement, for which an overhead crane will replace the aerostat.

The test area, an 800-m diameter circle, has been cleared of fences. There is now a weather station, electrical power, communications, and a hangar where the aerostat assembly and other preparations for experiments will take place. There are many variables that affect timing, but we expect to be able to start the first tests in the next month.

Feed System

Although the Airborne Platform being assembled will not support a radio astronomy receiver, one of its larger successors will. We have been working on a focal plane phased array, and while fewer resources have been devoted to this, progress has been steady. As the basis for the system design, Bruce Veidt at DRAO has produced a end-to-end "block-diagram" model of a wide-band feed and beam-forming network. This includes an adaptation of the WIDAR sub-banding method to permit beams of constant angular size to be formed over a wide bandwidth. The focal-plane array required for the LAR is much simpler than a generalized phased-array system because it will not be electronically steered and thus phase-shifters will not be required. Beams in the sky will be formed by summing the outputs of groups of antennas and receivers with appropriate amplitude weighting. Multibeaming will be possible with separate summing networks that act upon the outputs of overlapping groups of elements.

Nevertheless, the number of receivers is very large, and new approaches to building receiver-arrays will be needed. Ed Reid, a graduate student from the University of Alberta, has started work at DRAO to look at the suitability of "Vivaldi" antennas for this purpose. His goal is to gain a full understanding of how to "match" them for low noise, and how their noise properties change when they are embedded in an array. Also important is that his designs can be implemented using low-weight techniques. He is beginning with computer simulations using a 3-D full-wave simulation program and will later examine promising candidates by measuring scale models. These tools are known to be accurate when using in the right hands, but computational loads are a strong practical limit to the solution of large problems.

Bruce is building room temperature low-noise amplifiers using commercial pHEMT devices. The goal with this work is to learn how to design amplifiers that are closely coupled to the radiating element. Eventually these devices will integrated near the feedpoint of the Vivaldi antennas that Ed develops.

Peter Dewdney, Herzberg Institute of Astrophysics

SKA Progress in China: Modeling FAST

There are two major achievements on FAST project since last issue of the newsletter. First, the actuated main reflector was tested successfully in Feb. 2001 in Shanghai by making a 1:3

scaled model. Four elementary panels can move up and down along the radius of a sphere to approach a parabolic surface. These feasibility studies were made by Tongji university in Shanghai, Nanjing astronomical instrument research institute under the contracts with the Beijing Astronomical Observatory (BAO, now the National Astronomical Observatories of China), with contributions by the NAOC. Some suggestions for modification were proposed by the experience from the Evaluating Committee and under serious consideration by our FAST Group. According to those suggestions, we started a new type design of the reflector element – pre-stressed back structure experiments on the reliability and life time of the main reflector.

Secondly, the cable-car focus driven system, one of the two key approaches for FAST feed supporting designs, reached its major goal by testing a scaled model of 1:25 in Tsinghua university. The trolly which carries the focus cabin is supported and driven by two cross sets of upward cables, and four down tied cables are applied to increase the stiffness of the structure. Positional accuracy of 3 mm was achieved on this model. Meanwhile a model of 1:10 for the secondary adjustable system - Stewart stabilizer was manufactured to meet the final pointing and tracking requirement. The new combined model, including the two adjustable systems, starts to be built up according to the similarity law, one year contract is made between Tsinghua university and the NAOC.

Another approach on feed support design is in progress in Xidian university in Xian to finalize a whole system (cable support designed by Xidian university and a stewart platform produced by Beijing institute of science and technology). The final check is expected to be completed late this year.

Some other aspects: the Science Case written in Chinese has been finalized at NAOC, the site survey report is completed, therefore the feasibility study of FAST as a key project of the Chinese Academy of Sciences will be ended up by this year.

FAST Group in China

News from the European Consortium

Meetings and workshops

The European SKA Consortium has now received financing for its meetings and workshops from the European Union. In the coming months two workshops of general interest are being planned:

(i) “New Frontiers in Astrophysics: the Square Kilometer Array” on 14 and 15 January, 2002, in Bologna, Italy. A one day meeting on 16 January will present the project to the wider Italian community. LOC chairperson for both is Franco Mantovani (fmantovani@ira.bo.cnr.it) and workshop information is available at www.ira.bo.cnr.it/~skawork/ .

(ii) “High-resolution (including VLBI) imaging with SKA” on 10 and 11 Dec in Bonn at MPIfR. Contacts for the organizers are Michael Garrett (garrett@jive.nl) and Richard Porcas (rporcas@mpi-bonn.mpg.de).

As an aid in publicizing the SKA, Peter Wilkinson at Jodrell Bank has developed generic SKA presentation material that is accessible over the internet. Version 1.0 is now complete and is available at via anonymous ftp at: ftp.jb.man.ac.uk, directory /pub/pnw (one PowerPoint file and 6 movies) or via the web at: http://www.jb.man.ac.uk/~pnw/files.html . Refinement and extension of the material will continue.

Europe-wide Future Planning

In response to a request for comment on proposed guidelines for the Research Infrastructures line of the EU's Sixth Framework Programme (2004-2007), an integrated initiative has been proposed involving (i) coupling the EVN telescopes to JIVE in Dwingeloo with high capacity fibers, (ii) participation in ALMA, (iii) developing plans for SKA in a global context, and (iv) evolving the initiative into a Council for Radio Astronomy in Europe to provide some of the functions that ESO provides in optical astronomy.

Technical R&D

Activities are currently concentrated at ASTRON in Dwingeloo, Jodrell Bank (JBO) in Manchester, IRA in Bologna, and TCfA in Torun. Very briefly, the main lines of work are given below.

Financing from the EU has recently been received jointly by these four groups for a coordinated development effort going by the name FARADAY. A main goal is to carry out R&D for producing phased array antenna systems for use at the foci of parabolic dish antennas. At the heart of the project is system integration using complex monolithic microwave integrated circuits (MMICs). The applications planned include cryogenic receivers in the 20-40 GHz band (InP technology) and phased arrays in the 2-5 GHz band (GaAs and SiGe technologies). In addition to the European partners, the ATNF is participating in the effort, which is planned to yield prototype arrays and feasibility studies for large production arrays.

The Jodrell Bank group is currently installing COBRA (Coherent Online Baseband Receiver for Astronomy). COBRA consists of a 182-node Beowulf PC cluster designed to handle, in the first instance, a dual polarisation 100 MHz signal from the Lovell Telescope. Its primary role will be to act as a sophisticated pulsar signal processing machine through coherently de-dispersing pulsar data. It can also operate in a spectroscopic mode and can be configured to find and remove RFI. It is hoped that COBRA is a prototype for future radio astronomy software receivers such as those that will be used for SKA.

In collaboration with the University of Birmingham, JBO was recently awarded a grant for the development of High Temperature Super-Conducting (HTSC) filters. These filters are being developed, in the first instance, for use in the L-band and UHF receivers on JBO and MERLIN telescopes with the aim of improving their survivability in the presence of strong RFI.

JBO staff have continued their development of prototype receiver/transmitter systems for the ALMA fibre-optics systems. This is an offshoot of the generic fibre-optics development in which JBO is involved, primarily for the e-MERLIN project. It is envisaged that both ALMA and e-MERLIN will use similar systems based on wavelength-division-multiplexing. The current design for e-MERLIN will result in 30 Gbps/telescope being transmitted to JBO over a few hundred kilometres; ALMA will require data transmission rates of 120 Gbps/telescope but over much smaller distances. Fibre-optics will naturally play a major role in the data transmission system of any conceivable SKA system.

As reported in previous Newsletters, the group at ASTRON has a long-term program to develop the technologies required for the wide-band phased array concept for SKA. In recent months this effort has focussed on completing the Thousand Element Array, THEA (Figure 3). THEA consists of 1024 receiving antenna elements and will be used as an outdoor phased-array system to detect (known) radio sources in the frequency band ranging from 600 to 1700 MHz in the presence of several strong RF Interfering (RFI) signals. The THEA phased-array system has various new features compared with conventional radio telescope designs: multi-beam operation, adaptive nulling, interference monitoring and reconfigurability of the sub-array units. THEA will also serve as a test-bed for new and advanced technologies that should lead to a higher level of integration and cost reduction. Examples are the use of a high-speed optical link (32 Gb/s) and a new multi-beam analogue beamformer with a high level of integration including the antenna elements.

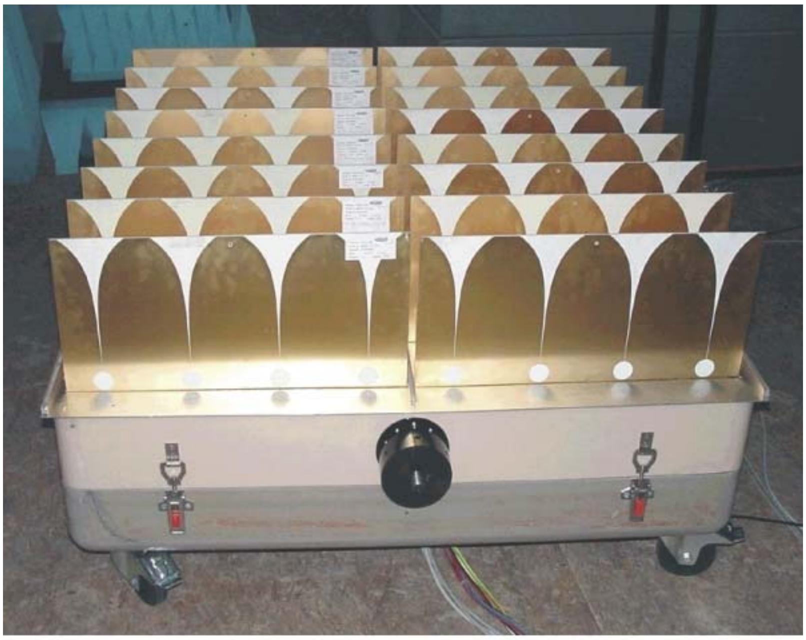

Figure 3. View of a Single THEA Tile with the radome removed.

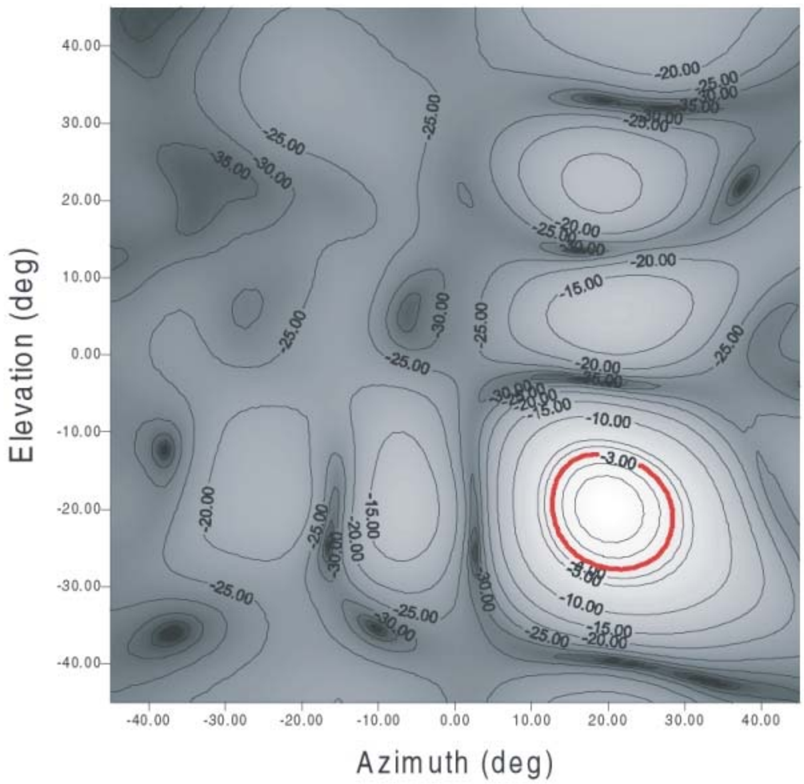

Figure 4. Measured far-field response of THEA steered to 20 degrees in azimuth and zenith angle.

LOFAR

The LOw Frequency ARray radio telescope project has received initial financing and is now aiming for first observations in 2006. A collaboration between ASTRON, M.I.T. and the U.S. Naval Research Laboratory, LOFAR will approach a square kilometer of collecting area at frequencies just above the ionospheric cut-off. It will test in an operational environment several of the key features of the wide-band phased array concept for SKA:

(i) multiple, independently pointed primary beams,
(ii) real-time interference suppression, and
(iii) on-line operation from geographically separated science operations centers.

The science drivers for LOFAR cover an exceedingly broad range, from study of the epoch of re-ionisation to space weather and the origin of cosmic rays. Participation by individuals and groups in defining and planning the science program is open and is being organized through a separate LOFAR Science Consortium. European groups discussing substantial participation are the LOIS Consortium in Scandinavia and the SkyView Consortium in Germany and the Netherlands.
It may be possible that LOFAR can provide much of the desired capability being discussed for SKA for the lowest decade of frequencies, thereby reducing the total specified bandwidth for SKA itself to two decades.

Individuals and groups potentially interested in participating in one or another aspect of LOFAR are invited to contact the Project Scientist, Namir Kassim, lofar-scientist@rsd.nrl.navy.mil, and the Science Consortium secretary, Michiel van Haarlem, haarlem@astron.nl. Additional information about LOFAR may currently be found at web sites set up by the three collaborating institutes: http://www.lofar.nl/ , http://www.haystack.mit.edu/ , and http://LOFAR.nrl.navy.mil . Soon all project information will be consolidated at the web site www.lofar.org .

Harvey Butcher, ASTRON

South Africa sends a representative to the ISSC

Justin Jonas is completing a report on his visit to the SKA meetings in Berkeley which will be presented to the National Research Foundation (South Africa's primary research funding body) and the Department of Arts, Culture, Science and Technology (the responsible government ministry). The report will contain a motivation for funding of South African membership of the SKA consortium, and also for funding to carry out RFI surveys in remote areas of the country. The ISSC will be kept informed of the progress of this report.

Justin would like to thank the ISSC, the Berkeley conference orgainizers, and all the conference delegates for their hospitality and their inclusive attitude.

Justin Jonas, Rhodes University

Progress Report from the US SKA Consortium

The US SKA Consortium met four times during this past year; in Washington DC in September, at MIT in January, at the Harvard/Smithsonian Center for Astrophysics in April (during this meeting we held a one day SKA symposium for local scientists), and in Berkeley in July. At the urging of the NSF, consortium members prepared "*A Roadmap for the United States Development Efforts on the Square Kilometer Array*" and submitted it on March 15th. The intent of this document was to give the NSF some framework against which to assess any proposals involving SKA technology development. The US Decadal Review (*Astronomy and Astrophysics for the New Millennium*) had recommended SKA technology development at a level of $22M through the decade, one of twelve so-called moderate initiatives. While individual proposals to the NSF are always possible, the consortium members made the strategic decision that a combined, coordinated proposal had a better chance of success. The proposal preparation was led by Jim Cordes from Cornell University serving as the PI. On August 31st a multi-institutional proposal covering 3 years of technology development effort was submitted to the NSF ATI (Advanced Technology Initiative) program. It will be spring of 2002 before the fate of this proposal is decided. Of particular interest to the international community, that proposal included a request to fund the US share of a Project Manager for the International SKA Project Office during the first year, with funds for a Project Scientist and a Project Engineer being added in later years. As the result of prior proposals to the NSF MRI (Major Research Initiative) program, funding has been provided to build a correlator for LOFAR. Another proposal to build an imager for the ATA was not funded, and will be resubmitted at a future date.

Consortium members presented a number of papers describing work in progress trying to understand the benefits and challenges of a Large-N implementation for the SKA (where N refers to the number of stations). Roger Capallo concluded that a correlator (probably FX) for N=1000 is buildable with some combination of FPGAs and DSPs, though not yet affordable. A scientifically valuable data buffer for transients also looks feasible. The decade-long timescale for doubling software functionality is almost as much of a concern as the cost. Shep Doleman summarized current approaches and severe limitations to simulating Large-N performance (for N= 100, 200, and 400), as well as the first efforts to define a set of "benchmark observations" to be used in selecting a final SKA design. The first application of these simulation tools will be for LOFAR. Tim Cornwell argued that AIP++ was now a viable tool for detailed simulation studies, including the Large-N concept, but innovation in calibration and imaging algorithms lags significantly. Colin Lonsdale discussed the frequency dependent tradeoffs that are inherent in the current strawman science goals for the SKA. He concluded that the SKA is not one single instrument, and even so, cannot be all things for all scientists. Sandy Weinreb reported on work at JPL and Caltech concerning array requirements for space communications, gravitational distortion of hydroformed reflectors, and wideband low-noise receivers over a wide range of observational frequencies. Bryan Gaensler discussed the need for extreme polarization purity in the SKA (better than -40 dB) in order to permit polarimetry studies of the magnetized interstellar medium. Such studies would probe regions of low n and B, turbulence, and diffuse emission, while providing "instant" rotation measures and position angles

Several studies on techniques for RFI excision were presented. Steve Ellingson reported on experiments done with the Argus array of 7 quarter-wave monopoles at OSU to to find angles-of-arrival (including multipath) for mobile radios, and with another array of 7 compact spirals to identify LEOs using a multibeam "patroling" technique. Rick Fisher reported on studies of pulsed radar interference with the GBT, and concluded that multipath and poor clock standards make simple blanking techniques inadequate, but that more complicated algorithms that track pulses should work well. A poster by Rob Ackermann and Gerry Harp described the current state of the Rapid Prototyping Array for the ATA (the site of dinner one evening during the meeting) and the scope of the experimental and software development programs currently ongoing at that facility. Geoff Bower briefly described several different RFI excision experiments using the RPA that had been done by Fisher, Harp, Ackermann, Ellingson, and Mitchell. He presented details of his own experiments using Wiener Filters to adaptively remove satellite interference. At NRL, low-frequency (74 and 330 MHz) VLA observations are being used to develop tchniques for RFI excision that will have broad applications to both existing and future instruments (LOFAR, EVLA, and SKA). Discussions are also underway as to the extent that LOFAR prototype stations could be used as testbeds for RFI excision techniques.

A suite of papers and posters described other progress on the ATA. John Dreher presented the overview of the design, timeline, and current budget estimates extrapolated to the SKA. Ed Ackerman reported on the testing of three different options for the ATA wideband analog link between the antennas and the processing lab. Three types of system are under test; Mach-Zehnder Modulators (most expensive, proven track record), integrated Electro-Absorption modulators (mid cost, will work for the ATA if thermal stability is adequate), directly modulated VCSELs (cheapest, but not yet available at 1350 nm for the ATA --- these should be viable for the SKA). Douglas Bock described the tentatively selected configuration for the ATA that produces a round 78" beam at 1.4 GHz with peak, close-in sidelobes below 1%. He also discussed the GPS-aided surveying program underway at the site. Jack Welch summarize the design studies and tradeoffs that led to the selection of a 6.1 m primary (2.4 m secondary) offset Gregorian antenna design, and the current status of manufacturing by a hydroforming technique. Dave DeBoer outlined the current ATA signal path design that accommodates multiple, simultaneous backends for different science programs. Lynn Urry sketched the current plans for a radio astronomy imaging correlator, and Mike Davis provided an update on the implementation of a new generation of SETI backends for the independent ATA beams.

Rick Perley laid out the science goals and phases of the expanded VLA project (EVLA), illustrating how it will serve as one pathway and technology demonstrator for arriving at the eventual SKA. Sandy Weinreb and Larry D'Addario provided the participants with a preliminary cost equation in the form of a spreadsheet tool for estimating the eventual cost of the SKA in any implementation. This is now readily available on the web at http://www.skatelescope.org/ska_memos.shtml , and will be updated as system engineering studies progress. Dayton Jones highlighted a use of the SKA (or its DSN equivalent) for spacecraft tracking and planetary science. Putting the gain on the ground enables faster, better, cheaper missions with much higher return data rates, and greatly reduces the risk from navigational errors.

Since the July meeting, this last item has enjoyed a significant amount of attention. Strong support for a large array for the NASA deep space network (DSN) has developed at JPL and will add impetus to the US SKA effort. FY02 funds are expected from NASA for technology development (antennas and receivers), system design, and for liaison with other array projects. A plan for design and prototyping of a DSN array is under discussion. A small group (Sandy Weinreb, Peter Napier, and Lee King) visited the ATA antenna manufacturer, Andersen, in September to discuss manufacture of 6 to 12 meter antennas for the SKA, EVLA, and the DSN. The results were highly encouraging with regard to developing a 12m antenna with precision sufficient for 50 GHz operation and for construction of an on-site factory to circumvent the problems of transporting large one-piece hydroformed reflectors. And on the LOFAR front, considerable progress has been made (by NRAO and NRL personnel) in the past year in developing methods to compensate for ionospheric phase distortions. These phase distortions will be significant for SKA observations in the L band. In some (but probably not all) observing modes, multi-frequency observations will be capable of solving for the ionospheric phase exactly.

Jill Tarter, SETI Institute