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SKA SA & MEERKAT Update

SQUARE KILOMETRE ARRAY (SKA) SOUTH AFRICA

SKA South Africa

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KAT-7 and the path to MeerKAT

Over the past months the MeerKAT project team have been developing the scope, specifications and development strategy for the MeerKAT. A four-person "drafting team" developed a MeerKAT document that mirrors the Draft SKA Specifications document that was produced over the same period by the "Tiger Team" set up by the SKA's International Site Selection Committee (ISSC) at its last meeting. MeerKAT Project Scientist Justin Jonas is a member of both the SKA Specifications Tiger Team and the MeerKAT drafting team, and so the two documents share synergies.

The Draft SKA Specifications document outlines various scenarios for the implementation of the various phases of the SKA. One scenario specifies the use of medium sized dishes (10 - 15 m) with "single-pixel wideband feeds" as the receptor for the SKA mid-frequency band (500 MHz - 3 GHz). The MeerKAT scope document specifies MeerKAT as a demonstrator for this SKA concept. The reference design specification for MeerKAT is an array of 80 12 m dishes with single-pixel wideband feeds covering the 500 MHz to 2.5 GHz frequency range. The receivers will be cryogenically cooled to achieve the best sensitivity possible. The array configuration will be centrally concentrated to provide good brightness temperature sensitivity, but will also extend out to nearly 10 km in order to provide sufficient resolution for optical cross-identification.

The MeerKAT scope document outlines the development path necessary to ensure that MeerKAT is implemented successfully, within budget, and on time. An important phase in this development path is the construction of the KAT-7 prototype array at the Karoo site. KAT-7 will primarily be an engineering test-bed, but it will also be capable of scientific observations and will be the first seven antennas of the full MeerKAT array.

The MeerKAT scope document is currently being reviewed, and will be made public once the review process is completed.

Astronomy Geographic Advantage Bill: One step closer

By Dr Adrian Tiplady, South African SKA Project Office, Johannesburg

South Africa's Astronomy Geographic Advantage (AGA) Bill took one step closer to being signed into law on Thursday, 13th September 2007, as it was approved and adopted by the National Assembly of the country. The last few months have seen a series of public hearings and stakeholder meetings to ensure that the bill is given the appropriate powers to ensure the protection of Astronomy Advantage Areas in South Africa's Northern Cape Province. These meetings, which led to case studies being undertaken with a number of operators of wireless communications networks in the Northern Cape, were very fruitful. They sought to find feasible solutions to re-engineer existing wireless communication infrastructure to be compatible with the operation of a major radio astronomy facility, as well as prevent the establishment of further infrastructure and other activities that could be detrimental to astronomy.

The AGA Bill aims to protect astronomy facilities across a wide range of wavelengths, from radio to optical and gamma-ray. This could see the establishment of frequency dependent protection areas hundreds of kilometres in extent. It is only through the excellent co-operation and support of the major stakeholders in South Africa that the progression of the AGA bill has been relatively smooth, and generally accepted as a necessity to protect South Africa's natural astronomical advantage.

MeerKAT prototype computing subsystem update

By Jasper Horrell, MeerKAT Project Office, Cape Town, September 2007

A large part of the recent focus has been to develop and integrate the complete software chain for the MeerKAT prototype (XDM) dish and engineering experiments. As of the end of August 2007, the software runs end-to-end in the laboratory using actual XDM computing hardware. This includes end-to-end facility monitoring and control using both web and scripted components, antenna control software with a simulated XDM dish, the data filler and data processing software, simulated RF and DSP subsystems, and simulated environmental monitoring.

Preliminary work on XDM integration with the real DSP subsystem has already commenced and lab integration with the other subsystems started in September 2007.

The CONRAD computing collaboration with the Australians is proceeding well with the codebase maturing in a number of areas such as the synthesis code for pipelined imaging and the various monitor and control components (also used in the XDM system as described above). Recently the CONRAD computing architecture, which is expected to be used for KAT-7 and MeerKAT, has also been given attention and international review (see www.conradsoftware.org).

Work continues in various areas to help in the KAT-7 and MeerKAT definitions. A particular focus at present is to determine the array configuration and unpack the science requirements in terms of engineering implications. As previously reported, the powerful array configuration design tool, known as AntConfig, is available from www.kat.ac.za.

With the large scope of work, the computing subsystem team of nine is currently looking to expand and jobs have been advertised with four positions available.

Progress update on the MeerKAT XDM Antenna Structure

By Willem Esterhuyse, MeerKAT project office, Cape Town

Fig 1: Theodolite and Photogrammetry measurements.

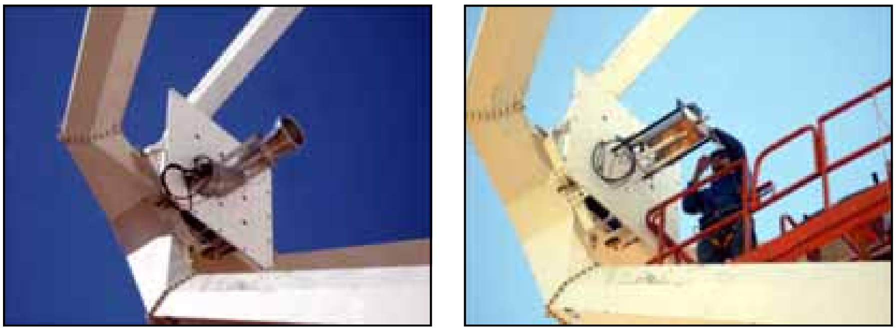


Fig 2: The 1.42 GHz (left) receiver fitted on the dish. On the right Pieter Stronkhorst is busy fitting the 12 GHz receiver.

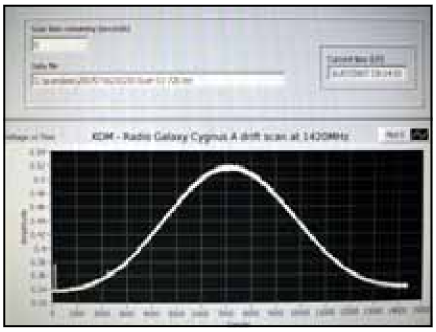


Fig 3: Typical scan of a radio source.

Fig 4: Optical pointing test.

The MeerKAT team has installed the last of the control system components on the MeerKAT prototype, and commissioned and tested the dish. A myriad of tests were performed, the most important of which were related to proof of the surface (accuracy and efficiency) and the pointing/tracking capability of the dish.

The surface was measured making use of photogrammetry as well as theodolites - the results from these two methods were consistent and therefore resulted in a high degree of confidence in the measurements.

Dr Mike Gaylard of HartRAO led the effort to build two receivers to test the flame-sprayed aluminum dish surface. The purpose was to test the efficiency of the antenna and check the integrity of the surface; as well as to verify the surface accuracy measurement results from the theodolites and photogrammetry.

Adriaan Peens-Hough from the System Engineering team performed the tests and analyzed the results. Right is typical scan of a radio source done with the XDM.

The conclusion from all these tests were that the flame sprayed surface performs very well, the surface accuracy is better than 2mm RMS (the original spec were 4mm RMS) and that the dish efficiency is as expected.

IST also performed a number of pointing and tracking tests in order to refine the pointing model. Right is an example of the tests (this was done optically).

The pointing and tracking performance of the antenna seems to be significantly better than the specified 0.04 deg. Some refinement on the pointing model will be done after the XDM receivers have been fitted, but overall the MeerKAT team is very happy with the performance of the dish. The better than specified surface accuracy and pointing performance will allow operation to higher frequencies than originally specified, which may be important to SKA, depending on the SKA science case. The XDM dish is essentially complete and will be signed off after the final documentation has been completed.

The rest of the year will be spent on changing the design of the prototype to that of 12m (as that is the likely size of the dishes); as well as to optimize the antenna structure for cost, since achieving the SKA cost target is the main remaining challenge.

Further test on MeerKAT prototype

By LJ du Toit, EMSS Antennas

The 15m reflector antenna of the MeerKAT at the Hartebeesthoek Radio Astronomy Observatory (HartRAO) will soon be configured for two interesting tests, both related to the unwanted multiple bounce of energy between the parabolic reflector surface (especially the area around the vertex) and the feed cluster package at prime focus.

The first test configuration will be an experiment where a circularly polarized floodlight illuminator is mounted at the reflector vertex, with its coupling to the horns at prime focus being the quantity of interest. This experiment is designed to evaluate the possible use of a single noise source to illuminate all the horns in the cluster simultaneously, for one-step calibration of all the receiver chains.

At present the cluster backplane is populated with only two out of a possible seven horns, and since the backplane had to make provision for lower frequency (larger) horns in future, it itself is larger than required for the present 1 414 - 1 670 MHz horns. The large and unpopulated flat part of the metallic surface introduces a large (triple-bounce) standing wave between it and the vertex of the paraboloid approximately 8m away, which degrades the smooth coupling that is required for successful noise calibration.

To reduce this standing wave (by reducing the flat surface area of the feed enclosure), conical covers have been designed and will be substituted for the five missing horns. The floodlight-to-horn coupling will be measured by network analyzer, and will be compared to the design values predicted by our EM analysis software, FEKO.

A computer model of the two horns and five conical covers is shown in Figure 1, and a prediction of the coupling follows in Figure 2. The expected reduction in the ripple, when the five covers are installed, can clearly be seen.

The second test configuration is aimed at normal radio astronomy operation, where a (double-bounce) standing wave will still be present. In this case the quantity of interest is the impedance mismatch of the horn at prime focus,

Figure 1: The five conical covers, two horns, feed cluster backplane (all in yellow), and top sections of the four struts (light blue) are shown on the left. A zoomed-out view is shown on the right, with the floodlight illuminator and deflector plate visible on the reflector surface vertex.

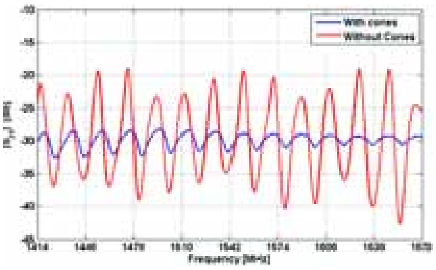


Figure 2: A numerical prediction of coupling between the floodlight illuminator and the center horn. The red trace is without the five conical covers present, and the blue trace is with them installed. The improvement (a smaller ripple in the coupling) is clearly visible, as well as the prediction that we will be within the required ± 2.5dB envelope.

Figure 3: The floodlight antenna cavity and deflector plate (with diameter ~1500mm).

which is strong indicator of the severity of the standing wave problem. To reduce this standing wave over the 17% test bandwidth a small deflector plate has been designed, which is mounted around the floodlight illuminator at the reflector vertex.

This deflector plate and floodlight antenna cavity is depicted in Figure 3, and primary horn mismatch measurements will again be made to validate our electromagnetic design as sound and sufficient.

Jocelyn Bell-Burnell in South Africa

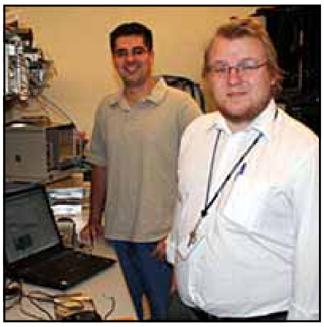
Professor Jocelyn Bell-Burnell (left) visited South Africa during July 2007 to deliver a number of presentations around the country. In the picture she is seen at the new MeerKAT prototype dish with Sarah Buchner (middle) and Sharmila Goedhart (right), staff members at the Hartebeestoek Radio Astronomy Observatory (HartRAO).

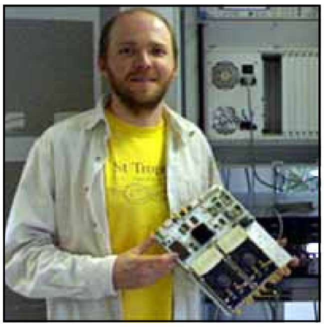
Professor Bell-Burnell discovered pulsars in 1967 whilst working on her PhD at Cambridge University. She visited South Africa as a guest of the South African Institute of Physics (SAIP) and of the HartRAO Visitors Programme.

At HartRAO, she presented a talk on "Women in Astronomy"; and also presented a public talk at the planetarium at the University of the Witwatersrand. Her plenary presentation during the SAIP annual conference was on "Pulsars and Extreme Physics". She spoke about the discovery of pulsars at the University of KwaZulu-Natal and at the new Astronomy Centre at the South African SKA Project Office in Rosebank, Johannesburg.

MeerKAT-Berkeley collaboration bearing fruit

The collaboration between the MeerKAT Digital Backend (DBE) team and the Center for Astronomy Signal Processing and Electronics Research (CASPER) at the University of California (UC), Berkeley, is producing its first results less than six months after the project started in earnest.





Left: Peter McMahon (front) and Jason Manley (back) working in the labs at the Berkeley Wireless Research Center. Right: Marc Welz, MeerKAT Lead Firmware Engineer, holding iBOB hardware in front of the DBE XDM rack.

The DBE team is currently using CASPER's iBOB hardware and software design tools and libraries to build a system for processing signals from the MeerKAT prototype dish. The teams are also working together to develop cutting edge instruments for future radio telescopes.

The CASPER team works closely with the Radio Astronomy Laboratory (RAL) in the Department of Astronomy at UC, Berkeley, who are building the Allen Telescope Array (ATA). This contact with the ATA project and other telescope projects around the world, including MeerKAT, ensures that CASPER continues to work on important projects that are of broad interest to digital back-end designers working on current and future radio telescopes.

The present generation iBOB board from CASPER, and the next-generation hardware ROACH (Reconfigurable Open Architecture Computing Hardware), are both designed specifically for digital processing of signals in radio telescopes. ROACH, currently under development through a collaboration of MeerKAT, CASPER and the NRAO (National Radio Astronomy Observatory in the USA), is set to deliver more than half a Teraop of processing power and up to four bidirectional 10 Gbit communication links. ROACH will provide the primary building block for digital signal processing systems in numerous next generation radio telescopes.

Skills development is essential for the success of MeerKAT. Currently the DBE team has two postgraduate electrical engineering students, both from the University of Cape Town, as year-long visitors at Berkeley. Jason Manley is working on building a 32-station dual polarization correlator. This is a key instrument in an array-based radio telescope such as MeerKAT, which essentially combines the signals from multiple antennas in such a way that a single image of the sky can be formed from its output. Peter McMahon is working on building a so-called "pulsar back-end" that MeerKAT will need to be able to search for and characterize pulsars. Peter is also working with other CASPER and MeerKAT engineers on high-level designs of possible architectures for high bandwidth correlators built using ROACH boards.

The South African MeerKAT project derives great benefit from this access to the engineers and scientists at CASPER, but also deliver benefits to its international partners. Dave George from the DSP team has already ported a much-needed driver for 10 Gigabit Ethernet for the iBOB to the CASPER library, while the work done by Francois Kapp as the lead design engineer on the ROACH board is crucial for its development. Jason and Peter's work will also certainly be useful to a variety of CASPER's partners, including NRAO at Green Bank and the ATA as well as for MeerKAT. Based on the successes and promise shown from the first six months of collaboration, we are looking forward to further collaboration with the CASPER team.

Attracting and nurturing top students via MeerKAT

Kim de Boer, South African SKA Project Office, Johannesburg

As part of its student recruitment efforts, the South African SKA project office produced a student recruitment poster for the MeerKAT project. The poster (download it at www.ska.ac.za) highlights the different skills and disciplines required for the science and engineering of building and operating a world-class radio telescope. The poster was distributed to all South African universities. Copies are available; contact kdeboer@ska.ac.za.

The annual South African SKA bursars' conference will take place from Monday 26 November 2007 to Friday 30 November 2007 at the South African Astronomical Observatory in Cape Town. The conference is an important networking and training event at many levels. It brings together the SKA/MeerKAT bursary holders, supervisors, potential supervisors and astronomers in southern Africa to network with each other and develop a community around MeerKAT, SKA and other radio astronomy initiatives. It also provides an opportunity for the MeerKAT team to interact with the local astronomy community. Students gain valuable experience by presenting their work to each other and the wider radio astronomy community.

New astronomy hub in Johannesburg

By Marina Joubert, for South African SKA Project Office

A new Astronomy Centre, consisting of offices, open-plan work stations, meetings rooms and an astronomy library, is now in full use at the SKA Offices in Rosebank, a suburb of Johannesburg.

The Centre is the brainchild of Professor Roy Booth, Director at the Hartebeesthoek Radio Astronomy Observatory (HartRAO). "My vision for the Centre is to concentrate our local astronomy education efforts in a vibrant hub for the two universities in Johannesburg, as well as for HartRAO staff and students," he says. "I hope that they will find a quiet place and the inspiration to study and write papers here, away from the work of operating the telescope."

The Rosebank area is a convenient and central meeting place. "It is imperative to get new senior and mid-level blood into South African Radio Astronomy and we trust that the Centre will facilitate this process," Professor Booth adds.

The combination of local, postgraduate university students, their lecturers and the HartRAO staff is perhaps the powerful motivation for the astronomy Centre. "Here we can mix practicing radio astronomers and their students with the more theoretical university people and begin adding a more experimental and data oriented approach to teaching and learning among the staff and students."

The Johannesburg Astronomy Centre will also provide a platform and home for the HartRAO Visitor Programme. International visitors will lecture at the Centre, but will also meet and mentor students informally. Professor Booth hopes that these visitors will "pass on the spirit of excitement of astronomical research and persuade the students to take up radio astronomy at a higher degree level".

Astronomy Career Weekend

By Kim de Boer, South African SKA Project Office, Johannesburg

During the weekend of 18 - 19 August 2007, eight Grade 12 students who have excelled at mathematics and physical science, participated in an Astronomy Career Weekend at the Hartebeesthoek Radio Astronomy Observatory (HartRAO). The learners were selected from the Department of Public Works' 2014 Youth Foundation Programme and the 2007 National Science and Technology Forum award winners.

The aim of the career weekend was to expose these students to the inner workings of an observatory and the jobs that astronomers, and engineers related to astronomy, do. We hoped that it would inspire some of them to consider pursuing such studies / careers. Their parents or guardians were also invited to attend so that they could also find out at first hand what the studies and career possibilities within physics and engineering are and assist the children in making a decision.

Staff members at HartRAO and the SKA South Africa Project Office joined forces to present a wide range of activities, including launching water rockets, using a sundial to tell the time, listening and talking to each other with parabolic whisper dishes, looking at sunspots and understanding the basics of radio astronomy using a simple receiver system. The activities illustrated physics' principles like: action and reaction, the effect of the Earth's tilt and orbit around the Sun, the principles of parabolic shaped antennae, the basics of radio receivers and the electromagnetic spectrum.

A presentation on astronomy introduced the learners to the scale of the universe, the immense amount of research needed to understand our universe and the South Africa's involvement in and commitment to building up astronomy in the country. Students used the 26m antenna to scan through the pulsar Vela at two different frequencies. Then, through a series of mathematical equations, the students determined the distance to the pulsar in light years. They also had the opportunity to assemble a mini-version of a radio astronomy receiving system. The students then had to calculate the correct dimensions of a source so that it produced a signal at a particular frequency.

We then held a discussion on the study paths for astronomy and electrical engineering, the value of a physics degree and the benefits of postgraduate studies. The students were also told about the opportunity of undergraduate bursaries for study in Physics and Electrical Engineering.

After sunset the students looked through an optical telescope at a variety of objects including Jupiter, Omega Centauri and The Jewel Box.

The students also visited the South African SKA office in Johannesburg. After watching the movie Contact, they participated in a lively science café (discussion session) with Dr Kent Cullers from SETI.

The students valued the opportunity to work with and talk to the astronomers and engineers, finding out from the about their own studies and career paths. Five of the students will be applying for an SKA undergraduate bursary.

Students at the base of the 26m radio telescope at HARTRAO (there are nine students in the photo because the sister

Students learning how to tell the time with a sundial.

Outreach to the Carnarvon Community

By Kim de Boer, South African SKA Project Office, Johannesburg

On Saturday 16 June 2007, the South African SKA/MeerKAT project exhibited at the "Carnarvon Fly In", an annual highlight on this community's social calendar.

Young and old from the town and surrounding farms gathered at the air field just outside the town to share in the excitement of local and visiting small aircraft.

Farmers, teachers, students and learners took the opportunity to find out more about the big telescope that will be built near their town and how this project could benefit the local community. The astronomy posters and other educational materials at the stand were very popular.

Seen at the "Carnavon Fly In" on 16 September 2007: Farmers, teachers and learners use the opportunity to find out everything they want to know about the SKA and MeerKAT.