Visiting the SARAO Carnarvon

IS Glass, SAAO.

It is not easy to arrange a visit to the SKA site in the Karoo at the best of times and is even more difficult at present due to the Covid-19 epidemic. The last time that I went there was in March 2014 with Maciej Soltynski and the late Tony Foley showed us around (*MNASSA* **73**, 46-51, 2014) On that occasion we drove the 640 km to Carnarvon and stayed over. This time I was fortunate enough to secure a place on the weekly chartered plane flight used by the engineering staff when travelling up from the headquarters in Cape Town. Katryn Rosie, an engineer with SAAO who worked formerly on the HERA project, showed us around. There is now a tarred air strip near the telescopes and the road to Carnarvon has also been tarred, so that access is much easier.

The Engineering and administrative headquarters are located about 19 km outside town and the telescopes are 72 km further on in the direction of Brandvlei.

We left Cape Town airport at 0730 on the Pilatus PC12 turboprop, capable of taking 7 or 8 passengers, and landed at the Observatory about 1½ hours later. We had to switch off our cellphones before arrival and were also not allowed to bring digital cameras on site. The pilot had to turn off many devices that might cause radio interference. As we came in to land it was thrilling to catch our first glimpses of the MeerKAT telescope dishes off to the side. The airstrip can be seen in Fig 1 to the NE of MeerKAT.

In 2014 construction had been at an early stage. The KAT (Karoo Array Telescope) with 7 dishes was in existence as was PAPER (Precision Array for Probing the Epoch of Re-ionisation). KAT is an experimental array used for testing out designs and training while PAPER has been dismantled after running for several years. Back then, the sites for the 64 MeerKAT dishes had been cleared and marked out and the Karoo Array Processor Building was being fitted with radiofrequency shielding.

Fig 1. Recent Google Earth view of the site, showing the major installations.

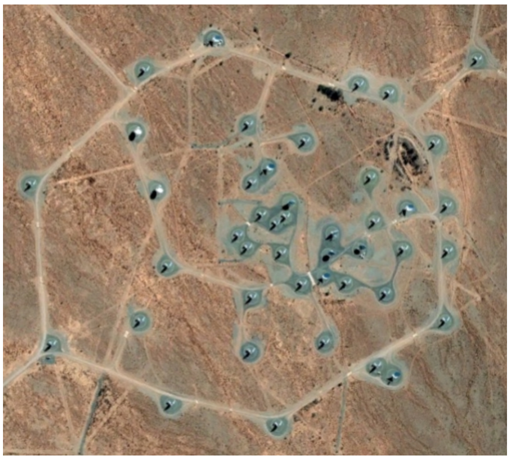


Fig 2. The central part of the MeerKAT array with about 60% of the dishes within a 1 km diameter circle (Google Earth).

Now, seven years later, the 64 antennas of MeerKAT are fully operational and quite a few impressive images and research papers have already come out.

The first receivers installed cover 1.0 to 1.75 GHz (30 cms to 17 cms wavelength – the so-called L-band). Ultimately there will be three interchangeable receivers on each antenna to give coverage from 0.5 to 14.5 GHz (60 cm to 2cm). These are on a turntable so that they can be rotated into the focus position as required. The dishes are 13.5 m diameter and have a combined accuracy (primary and secondary) of 0.6 mm to give about 1/40 wave rms at the shortest wavelengths. The surfaces of the reflectors have a number of small dots to assist in the alignment process.

Fig 3. A single MeerKAT antenna. The configuration is an offset Gregorian. The radio signals bounce off the big dish onto the smaller one and then into the receiver just below the small one. Two receivers can be seen on the turntable.
(Photo: S Burger, Engineering News).

MeerKAT is a wholly South African project at present but will soon be enhanced by the addition of 20 more antennas provided by the Max Planck Institute for Radio Astronomy. It will also form part of the Square Kilometre Array, an international project, during the next decade. (Wikipedia gives a good summary of the telescope and its programmes.)

HERA, on the other hand, is a collaborative project involving many international institutions.

The HERA (Hydrogen Epoch of Reionization Array) array has taken the place of PAPER and is, of course, much more sensitive. It will soon have 350 fixed dishes of 14m diameter, all but some outlying ones already constructed. It functions as an interferometer, scanning about 440 square degrees of the sky. The signals are fed through fibre optic cables to the Karoo Array Processor Building where they are processed, as are the MeerKAT ones.

Hydrogen radiation has an un-redshifted wavelength of 21 cm and this telescope is designed to observe it when redshifted into the range 600 to 1200 cm, corresponding to z = 6 to 30. HERA's direct aim is to extract the large-scale structure of the primordial inter-galactic medium at different redshifts and provide more understanding of the very early Universe.

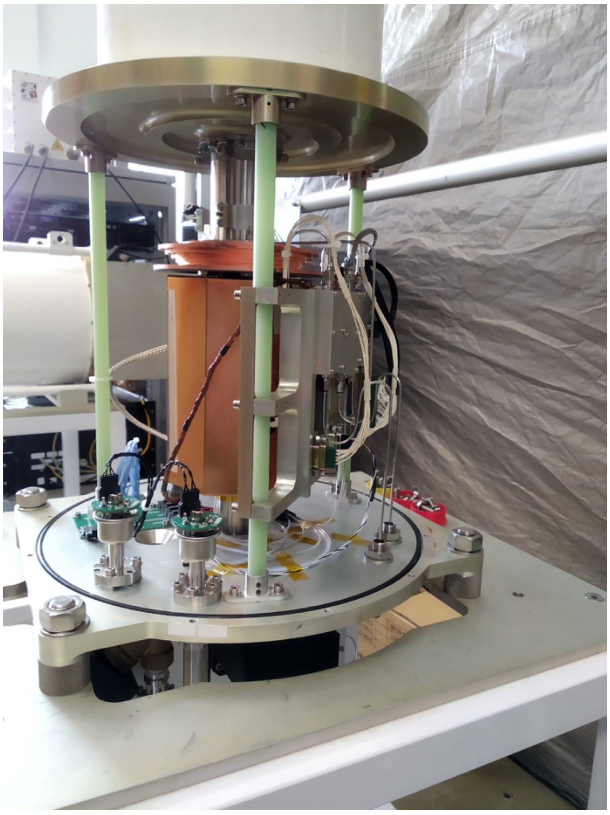
Fig 4. Google image of the HERA array.

The antennas are of much simpler construction than the MeerKAT ones since they are fixed and operate at much longer wavelengths.

Fig 5. Side view of the HERA array. The dish surface is constructed of wire birdcage netting and supported by ordinary PVC tubing and fittings.

The dishes originally focussed the radio waves onto simple dipole antennas to cater for two directions of linear polarisation, but these have been replaced by butterfly- shaped waveguides called "Vivaldi feeds" that offer much better sensitivity over a greater wavelength range than the dipoles.

The heart of the Observatory, where the signals from the individual antennas are combined and turned into images, is the Karoo Array Processor Building, located largely underground and behind an artificial hill formed by the excavated material. It has had to be highly shielded as the computers generate a tremendous amount of radio emission. In the same building are two atomic clocks that are needed to give the precise time reference data needed for combining the signals from the separate antennas to effectively make them into one large dish. On the same site are huge electrical generators to provide uninterruptable power. These are able of generating 4MW, to cater for the SKA, but at the moment the load is about 0.8MW.



The electronic and mechanical workshops needed to service and back up the equipment are located at Klerefontein so that personnel do not go to the antenna area unnecessarily. The figure shows one of the MeerKAT cryostats in the maintenance workshop at Klerefontein.

Fig 6. Each of the three bands on each of the 64 MeerKAT antennas requires a cryostat like this one to contain the critical low-noise part of the detector. On the focal plane turntable of each antenna are three cryostats and the digitising apparatus. High-pressure helium is fed from the telescope mount to power the expansion part of the Gifford-McMahon refrigerator, hidden behind the gold-plated shield in the centre. These were constructed by EMSS Antennas Stellenbosch (see www.emssantennas.com for further details).

Something that surprised me is that the operations at Carnarvon are purely engineering ones. In fact, I did not see any posters or pictures of the spectacular results that MeerKAT has obtained (though I admit that I did not visit every single building in the time available). It is not usually visited by astronomers except on ceremonial occasions! All the controlling of what the telescopes are doing scientifically is done from the Headquarters of SARAO in Observatory, Cape Town.

I would like to thank Kathryn Rosie for arranging my visit and the on-site technicians who patiently explained the various systems.

(reprinted from *MNASSA* **80**, 117, 2021)