Report on CTF visit to South Africa

Confidential

Report by R.P. Millenaar and R.C. Bolton – CTF
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Work on configurations by:
R.P. Millenaar (SPDO, CTF)
R.C. Bolton (UCam, CTF)
A. Tiplady (SKA Africa)
G. Nicholson (SKA Africa)
A. Fortescue (indep. consultant)
M. de Villiers (SKA Africa)

Further brief encounters with:
B. Fanaroff (SKA Africa)
T. Cheetham (SKA Africa)
B. Wallace (SKA Africa)

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Note: In the following text items in italics require action.
1 Purpose, principles, general discussions

The purpose is to discuss configuration specifics and to define a configuration for Southern Africa that maximises scientific performance whilst satisfying the masks and being mindful of access to optic-fibre and power infrastructure for the remote stations.

The configuration that optimises scientific performance is as specified in 3.1 below, and includes 5 spiral arms symmetrically distributed around 360 degrees with the winding parameter and placement of antennas along the arms as specified. These configuration parameters will be used on both candidate sites and the modifications required from the defined optimum configuration will be assessed.

Recent plans for the design of the configurations for the two site proponents were to design and evaluate more than one configuration; a “generic” and a “best” configuration, where the former would only be used for comparative cost evaluation and the latter would be the scientifically best possible, given the mask and other cost and terrain and interference related constraints. For practical reasons however it is now thought that it is not worthwhile to spend time and resources on a configuration that is unlikely to be built and would not enable an overall cost comparison between sites, and that therefore the generic configuration will not be considered. It is noted that the SSEC is yet to endorse this principle. The site proponent – Southern Africa – and the CTF will continue to work together on the design of the configuration that will be put forward for infrastructure costing by the SPDO and which will be considered in the site selection process.

The geographic and EMI masks have been produced by the South African team, according to the specifications that were established by the SPDO after a lengthy study involving both sites and the SPDO. It was found that the EMI buffer zones around the initial range of farmsteads in the area of interest (<180 km from the centre) did not offer free space to place antennas in the area, except for a relatively small patch in the middle where the farmsteads will be bought and brought under control of the site proponent. In order to proceed with the configuration designs it was agreed by the SSG and SSEC to reduce the buffer zones around farmsteads such that a configuration can be designed in areas not masked by other categories. For this purpose the South African team has supplied the CTF with a list of all farms in the area and a mask that does not contain the layer for the farmstead buffers. In this manner the design work can proceed and possible proximity of farmsteads to antennas is reflected in an EMI risk figure of merit. This procedure can be applied to Australia as well if deemed necessary or advantageous for the configuration design. At the same time the SPDO has requested and received comments on the process towards establishing the mask specifications for EMI from the Committee it installed for that purpose. The SPDO will adapt the specification in certain areas as suggested by the Committee.

It is noted that the list of farmsteads that was submitted to the SPDO, and which is used to identify those points of potential EMI, is a mix of surveyed and unsurveyed farmstead positions. This means that in the surveyed areas only farmsteads are included that are active. Inactive or abandoned farms were omitted. In unsurveyed areas all farmsteads were included in the list, regardless of whether they are active or not. This therefore represents a worst-case listing of farmsteads. It will be up to SKA Africa to defend the contents of the list and to fully describe the criteria that were applied for determining the classifications active and inactive. A document on this topic is expected of SKA Africa.

The RFI threshold masks specification effort (for intentional, licensed transmissions) has not yet come to a completion. The reference document has already been agreed, but now the propagation model and terrain databases to be used must be decided. There is the possibility that the configuration might change once the RFI masks become available, and that for the remote stations their locations cannot be fixed until the RFI analysis has been done. It is also recognised that once the SSG have determined weights for site selection criteria, and once infrastructure costs are better understood, that the configuration may be changed significantly.
The EMI and RFI arguments mentioned above may change the masks, and optimisations resulting from the establishment of the relative weights may give rise to further changes in the configurations. Therefore fine-tuning of the configurations, a process involving the site and SPDO, will be required once all the relevant information is in. It is anticipated that this will take place early 2011.

The report below aims to cover the events that took place, the work carried out and the discussions that were held, not necessarily in the same chronological order. A separate report detailing the results will be prepared.
2 Discussion of prior work done

The CTF has worked on aspects of the configurations for the SKA, addressing performance, scientific figures of merit and practical implementation via masks. A series of notes have been produced and circulated in the SKA community for comments and suggestions. Presentations of results of this work were given at various conferences and workshops. This has resulted in a specification document for the SKA configuration parameters [1]. Background for the shape of spiral layouts is found in [2].

Using the mask delivered by SKA Africa, see section 1, the CTF has produced a design for the dish core, the layout of the skirt and the intermediate area in agreement with this mask. This work is compared with the designs carried out by the SA team using the same parameters and documented in [3] (draft). We acknowledge the work done by the SA team in optimising the sense of rotation of the spiral arms and the location of the dish core with respect to the terrain constraints.

It is explained by the SA team that in order to provide required space in the central region of the site, out to about 15 km (CORRECT?), EMI impact in that area is planned to be mitigated by:
1) acquiring and vacating two rings of farmsteads around the centre, and
2) closing part of the road from Carnarvon to the R357 joining Brandsvlei and Van Wyksvlei, passing NE of the site. That section of road will then become an ‘observatory road’ and access will be limited.

When these farmsteads and this road are brought under management and control of SKA Africa the EMI bufferzones can be reduced to zero if appropriate measures are taken including vacating the farmsteads and blocking access to the road. It is thought that this becomes a realistic option by building a diversion route and by declaring an area around Losberg a Category 1 Special Nature Reserve. For the road diversion negotiations with the government need to be started up and negotiations with the South African National Parks Board (SANParks) already are underway.

For the current configuration design work it will be assumed that the effort to realise these two mitigating measures will be successful. It will be necessary that SKA Africa produces a document that fully describes the measures that free up the area to allow a configuration to be designed, and to include supporting documents issued by the South African authorities that show the nature, extent and timeline for the measures to be taken.
3 Configuration design

3.1 Summary of the specifications

The nominal parameters for the configuration in [1] can be condensed as:
- 3 ‘cores’ (Inner and Core regions), 5 km diameter each, edges separated by 1 km.
- 5 arm spirals conforming to the winding parameters given in [1] and [2].
- 3000 dishes total (~3000 km baseline)
- 1500 dishes in inner and core regions
- skirt region, annulus from inner region to 13 km radial distance with 350 individual dishes in 5 arms (70 dishes per arm)
- beyond the skirt to edge of intermediate area (180 km) clumps of dishes, 50 clumps total, or 10 clumps per arm, and with 11 dishes per clump (accounting for a total of 550 dishes in the region 13 km to 180 km)
- 25 remote stations (of 24 dishes each, for a total of 600 dishes)
(Summing these yields 1500+350+550+600=3000 dishes)

The prime target for the current exercise is to design the configuration for the dishes. The design of the ‘cores’ and inner arms (to 13 km from the cores) for the other technologies will follow the rules laid out in [1]. Beyond the outer boundary of the dish skirt (13 km from the centre of the dish core) all collector types will sit on the same locations as the dish clumps.

3.2 Core and Intermediate region

For this region we have the geographic and EMI masks. Noting the remarks about the masks in sections 1 and 0, and that constraints for RFI transmitter thresholds will affect the mask as soon as that information becomes available, the design exercise is done for:

The inner and core areas, where each of the three 5 km diameter areas are virtually unaffected by the mask. First task is to place the three cores such that the terrain allows this, satisfying the wish to keep the cores close together, but having a separation between the centres of cores of minimum 6 km. After evaluating two options the arrangement decided upon has a low hill in the middle of the three inner/core areas, named “Cronje Se Kop”, see Figure 1. In the analysis it was found that 1) the scientific figures of merit could not determine

Figure 1: Three core locations.
that one arrangement was better than the other and 2) to achieve a minimum distance of the core to the central processing facility, which is assumed to be situated behind the Losberg hill (mid bottom in the figure), close to the current position of the construction hall and other facilities for (Meer)KAT.

The locations for the three core centres are as follows (in degrees longitude and latitude):

<table>
<thead>
<tr>
<th>Core</th>
<th>Longitude</th>
<th>Latitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core 1</td>
<td>21.36617</td>
<td>-30.66010</td>
</tr>
<tr>
<td>Core 2</td>
<td>21.42691</td>
<td>-30.67843</td>
</tr>
<tr>
<td>Core 3</td>
<td>21.38586</td>
<td>-30.72104</td>
</tr>
</tbody>
</table>

It was noted that the proposed locations for cores 2 and 3 currently overlap the KAT7 and MeerKAT configurations. The latter configuration has not been finalised. This need not play a role for current work because these dishes and related infrastructure could be removed to make place for the SKA. Detailed placement of dishes in the inner/core area was not dealt with, as this plays no role for the purpose of the current exercise.

For the **intermediate area**, where individual dishes and clumped dishes must be placed, the preparatory work done by the CTF and SA was compared. The SKA Africa team had optimised the rotation and sense of the spiral arms to account for the terrain mask in the inner ~13km zone. The CTF then populated these arms with individual dishes and clumps of dishes. The effort concentrated next on making the positions agree with the mask. Dishes were nudged into available space fixing the radial distribution as much as possible, by changing the azimuthal distribution. At the same time the locations were checked for less desirable positions, for example avoiding the top of a hill, but also as far removed from farmsteads as possible. In most cases the new positions could remain in the same spiral arm and only in a few occasions had the positions been moved to different spiral arms. The result

![Figure 2: Dish positions in intermediate area (<180 km radius)](image)
of the dish positions after accounting for the mask and final terrain-based corrections is shown in Figure 2. The figure shows that the resulting configuration (blue diamonds) traces the 5 spirals, avoiding the roads in the mask, except directly North-East of the centre, where the road is anticipated to be closed, see section 2.

3.3 Remote stations

These are the stations beyond 180 km from the centre, where only dish locations are planned. There is no mask information; the station positions are to be designed in individually. It was agreed that it is advantageous the leave the remote station positions that were in the site bid of 2006 intact as much as possible, because of the work already done on these locations and the resulting information that is available. At the same time is was agreed that the argument of designing locations in agreement with the logarithmic radial distribution rule is a prime consideration in placing remote stations. This implied that a number of these bid locations had to be abandoned and new locations found. This work was undertaken and the resulting 25 stations were placed in radial bins and at locations that offer access to fibre and power, as far as can be determined at this point in time. It is noted that these locations will likely undergo refinements as more information on access becomes available. Another argument that was decided upon was to design a remote configuration with the required 25 stations to a maximum baseline of about 3000 km. That implied that some of the remote stations in the site bid will now be considered to be additional stations, part of an extended configuration.

![Figure 3: Remote stations in 25 radial bins](image)

Figure 3 shows the logarithmically spaced radial bins, in each of which one remote station should be placed. The figure also shows the 25 remote station positions that resulted after the work was finished. This involved a first assessment of the terrain, accessibility by roads and for fibre and power.

It was discussed that in the original RFP it was required to indicate how the SKA would tie in with existing VLBI networks. For that purpose the SA bid included long baseline stations in Ghana and Kenya. Concentrating the configuration in a 3000 km baseline area would not
include these remote stations. Therefore, as mentioned before, SA plans to propose additional stations beyond the 25 up to about 3000 km, which will be part of an extended configuration. It is requested by SA that the SPDO, SSEC and/or ASG produce a response or requirement on this issue. Figure 4 shows the nominal SKA configuration in red and blue, including the 25 stations up to about 3000 km baseline, plus the three additional stations for the extended configuration: Ghana, Kenya and Mauritius.

![Nominal and extended configuration](image)

Figure 4: Nominal and extended configuration

### 4 Aperture arrays

The two aperture arrays have neighbouring core locations and have stations that populate those core and inner regions, and have stations that fan out from those cores. It is in the interest of cost savings to co-allocate these stations and the dishes as soon as possible going out from the cores. During the design session the principles for designing the AA configurations were developed and results of these efforts were checked. Also conflicts with terrain and locations for receptors of the other technology types were resolved. The results are illustrated in Figure 5 and Figure 6, at different zoom levels.
Figure 5: Dish (blue), sparse AA (green) and dense AA (red) intermediate region

Figure 6: Dish (blue), sparse AA (green) and dense AA (red) core/inner regions
5 Further discussions

An assessment of the scientific merits of the final dish configuration was done, and how the performance compares with an unconstrained configuration. Initial results were discussed. The results of these assessments will be reported in a separate report. The same will be done for the Australian results.

In [3] G. Nicholson has introduced the idea to treat the EMI buffer zones for the masks in the intermediate region differently as has been agreed amongst the site proponents and SPDO so far. The idea centres on the point that the Radio Quiet Zone introduces zones of tolerable EMI related to RA769 (core), 15 dB less stringent from the core out to 180 km and 40 dB less stringent beyond that. These are step functions. It is argued that the 25 dB step from intermediate to remote area at 180 km is tapered. More importantly, it is argued that in the outer part of the intermediate zone, beyond about 50 km the separation between clumps becomes so large that this exceeds the largest VLBA baselines on which the 15 dB to 40 dB transition was based in RA769. The CTF agreed that this is an interesting viewpoint, which cannot be taken into consideration at this stage in the configuration design process, but which should be further studied. For this purpose G. Nicholson will submit a document on the way RA769 should be interpreted and applied to the RQZ in general and issue of EMI buffer zones in particular, to be considered by SPDO and both site proponents.
6 References