SKA array configuration studies – a guide for SKA site proposers

Configuration Simulations Task Force (CSTF)
January 2005 (section 3.4.2.3 modified 18 May 2005)

1. Background

On September 1, 2004, the International SKA Project Office (ISPO) released the document "Request for Proposals for Siting the SKA", referred to here as the Request for Proposals (RFP). In this document the ISPO set out the process by which consortia will bid to host the SKA, including a description of the criteria by which SKA site proposals will be judged and the information that Proposers will need to supply, as part of their proposals, against those criteria.

One of the areas that Proposers are required to address in detail is how well their site supports the overall layout and configuration of the SKA. The RFP broadly specifies the overall layout of the SKA as the percentage of collecting area that should be contained in various geographical areas. The RFP also specifies that Proposers need to consider two types of SKA configuration, one relevant to large-N, small-D (LNSD) concepts, and one relevant to small-N, large-D (SNLD) concepts. For siting purposes, the LNSD concepts can be taken to have twice as many stations as the SNLD concepts. The RFP outlines the basic type of array configuration that Proposers are expected to consider, based on logarithmic spiral arms originating at the array 'core'. Finally the RFP describes the tolerance allowed in individual station positions relative to the positions defined by a logarithmic spiral configuration.

The purpose of this document is to augment the RFP and clarify some statements that appear in that document, providing more detailed guidance on aspects of the array configuration work that Proposers are required to undertake. These guidelines are to be read in conjunction with the RFP. This document was produced by the Configuration Simulations Task Force (CSTF), a group convened by the ISPO as part of the Simulations Working Group (SimWG) following the 2004 International SKA Workshop in Penticton, Canada.

Proposers should note that specifications in the RFP concerning the division into LNSD and SNLD concepts and the number of stations to be assumed for both types of antenna concept are "for the purposes of siting", and the actual configuration parameters of the SKA when built may be quite different to these specifications.

These guidelines assume that "traditional" imaging and calibration techniques will be applied to data collected from the SKA to produce images of the radio sky.

2. Role of the CSTF and communication with the ISPO

In providing Proposers with detailed guidance on array configuration issues, the CSTF aims to have a uniformly informed proposal community, all equally well armed with the software required to address the site proposal process from an array configurations point of view.

The CSTF also aims to present the proposal teams with a set of specific issues that will be explored with regard to the evaluation of their proposed configurations, that they can specifically address in their proposals.

Finally, the CSTF wishes to make clear the process and the criteria by which the different proposals will be evaluated, from the array configurations point of view.

The CSTF reports to the ISPO Director via the SimWG. An evaluation of the proposed arrays will be made by the CSTF following the proposal deadline, as described below. A report written by the CSTF will summarise the advantages and disadvantages of each proposed configuration according to the specific criteria described in Section 3.4. This report will be submitted to the ISPO, who will then consider the report in the Site Evaluation Working Group (SEWG) and pass it to the Site Selection Advisory Committee (SSAC), an independent group convened by the ISSC to advise it on the final site decision. The CSTF report will not make any value judgments as to which proposed configuration (and therefore site) is the "best". The report will simply contain quantified comments on the facts relevant to each proposed array.

All communication on array configuration issues should be between the Proposers and the International Project Director. The International Project Director will consult the SimWG/CSTF if necessary. Proposers should note that the RFP states in section 1B8 that configurations under consideration by Proposers should first be tested for suitability by the SimWG prior to the Proposer adopting a final configuration for detailed consideration for submission in the Proposal.

In view of the proposal deadline of 31 December 2005, Proposers should submit their proposed configurations to the CSTF for comment no later than 30 September 2005.

3. Detailed guidelines for proposers

3.1 Array configurations

The SKA will have approximately 1 million square metres of effective collecting area distributed in a large number of small sized receptors (called large-N small-D [LNSD] concepts) or a small number of large size receptors (called small-N large-D [SNLD] concepts). For the purposes of configuration simulations for siting, it is assumed that the small receptors of the LNSD concepts are arranged as phased arrays in 125 stations. It is also assumed that for the SNLD concepts, 62 large receptors will be used. The footprint for a LNSD station is assumed to be an area of 200 m diameter. The footprint for a SNLD receptor is assumed to be an area of 400 m diameter. A schematic overview of SKA configurations is given in Figure 1 and Table 1.

Proposers are required to present two configurations for their site, one based on the LNSD concept and one based on the SNLD concept.

In recognition of the fact that most sites are expected to be able to accommodate the 1 km diameter core and the 5 km diameter central area for both LNSD and SNLD concepts, Proposers should consider the distribution of receptors in the core and central area to be fixed. Proposers should use the core and central area configurations specified in Appendix 2 at their reference latitude and longitude. The only modifications that Proposers are allowed to make to the core and central area configurations are: 1) translations of the entire configuration; 2) rotations of the entire configuration; and 3) reflections of the entire configuration through the reference latitude and longitude. Proposers must state in their proposal if they have employed any of these allowed modifications.

Several example arrays are given in section 3.2 below that illustrate the different constraints and requirements listed here. These example arrays can be used by Proposers as a starting point for their configuration simulations work.

Proposers should also base their estimates of construction costs for the core and central area on these fixed distributions of stations.

3.1.1 Core

The RFP states that 20% of the collecting area of the SKA is contained within an area of diameter 1 km (known as the ‘core’), with locations following a random Gaussian distribution. It transpires that the combination of 1 km core diameter, large station footprints, and a Gaussian distribution cannot be accommodated in the area available. A Gaussian distribution leads to large overlaps in the station footprints. This can be accommodated to some degree for some antenna concepts, but has severe difficulties for most others. In the example arrays, we assume no overlap of station footprints, taking the most conservative approach, given the uncertainty in the antenna technology to be chosen, and accept the fact that the core stations overflow the nominal core diameter even if packed as closely as possible. We believe this approach is acceptable at this stage of the configuration process.

It is assumed that, in the LNSD concept, the core will consist of 25 closely packed stations, and that a small number (5) of these stations will fall outside the 1 km diameter core area (core extends to approximately 1.4 km). Proposers should note that in the original LNSD concept, individual receptors are not grouped into stations. For the SNLD concepts, 12 closely packed stations will be located in the core, again with a number of stations (8) mainly falling outside the nominal core diameter (core extends to approximately 1.7 km diameter).

The mandatory fixed core and central area configurations for the LNSD and SNLD concepts are listed in Appendix 3.

3.1.2 Central area

For the purposes of these configuration simulations, it is also assumed that 32% of the collecting area of the SKA is contained within an annulus of inner diameter 1 km and outer diameter 5 km (known as the ‘central area’, co-centred with the core), with locations following a 5 arm symmetric logarithmic spiral. For the LNSD concepts, 40 stations will be located in the central area, 8 stations per arm. For the SNLD concepts, 20 receptors will be located in the central area, 4 receptors per arm.

3.1.3 Beyond the central area

For the purposes of these configuration simulations, it is assumed that 48% of the collecting area of the SKA is distributed on a series of logarithmic spiral arms extending from outside the central area (> 2.5 km from the reference latitude and longitude) to a distance from the reference latitude and longitude of at least 3000 km. For LNSD concepts, 60 stations will populate these arms. For the SNLD concepts, 30 receptors will populate these arms. Distance from the reference latitude and longitude refers to the projected distance, from the core to a remote station or receptor lying on a logarithmic spiral arm, in the plane that is tangent to the surface of the earth at the reference latitude and longitude.

The specifications of the logarithmic spiral arms between the radii of 2.5 km and >3000 km are not fixed, in contrast to the specifications for the core and central area. Proposers have the freedom to fully specify the array configuration on these scales, subject to a small number of constraints, as follows:

- The scale size of the logarithmic spiral arms will be such that 30 LNSD stations or 15 SNLD receptors will be located within 150 km of the reference latitude and longitude, and 30 LNSD stations or 15 SNLD receptors will be located between 150 km and at least 3000 km from the reference latitude and longitude.

- The locations of the stations or receptors defined by the particular logarithmic spiral equation adopted by the Proposers are nominal locations. Within a distance range from the reference latitude and longitude of 2.5 to150 km, Proposers have the freedom to move the positions of the stations or receptors from their nominal positions by up to 10% of the distance of the station or receptor from the reference latitude and longitude. This applies to the 30 LNSD or 15 SNLD stations in this distance range.

- Beyond 150 km from the reference latitude and longitude, Proposers have the freedom to move stations or receptors by any distance i.e. Proposers have complete freedom to position stations or receptors on these scales. However, adherence to the logarithmic spiral configuration adopted by the Proposers between 2.5 and 150 km from the reference longitude and latitude is desirable.

Proposers should note that they are not constrained to follow the logarithmic spiral configuration defined for the central area (3 or 5 equally spaced logarithmic spiral arms for SNLD and LNSD respectively, see next section) beyond the central area. Proposers have complete freedom to break the parameters of the logarithmic spiral arms beyond 2.5 km of the reference latitude and longitude. For instance, Proposers could choose any number of spiral arms, in a symmetric or asymmetric configuration, with any desired winding parameter. This freedom will allow Proposers to tailor arrays to their sites, taking into account, in particular, the large-scale geographical constraints.

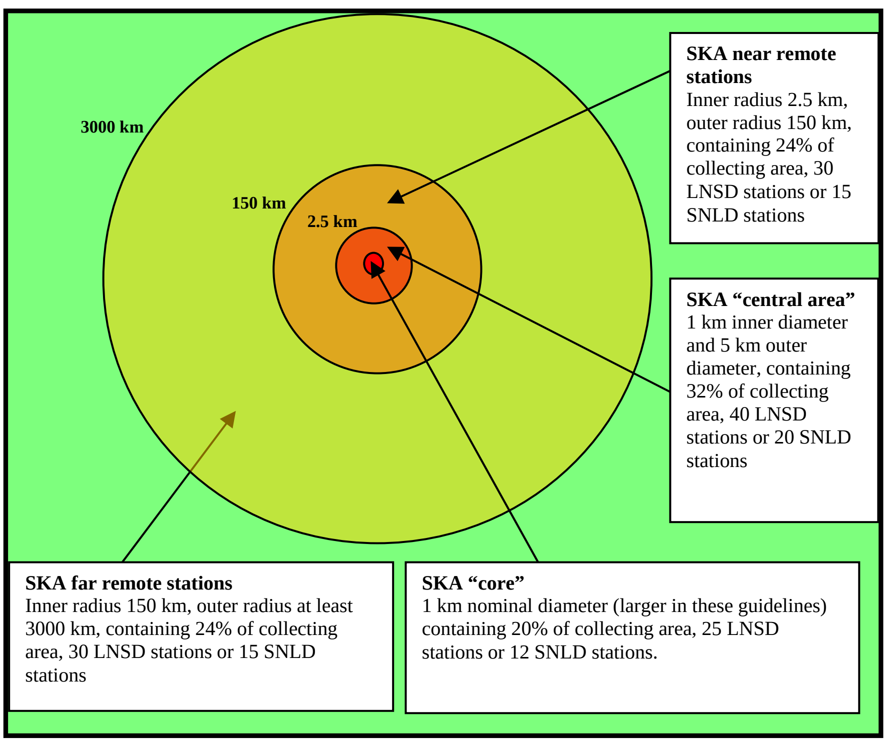

Figure 1: Schematic distribution of SKA collecting area as a function of distance from the reference longitude and latitude

Table 1 Summary of Array Regions

Region	Inner Radius (km)	Outer Radius (km)	Area (% of total)	LNSD (# stations)	SNLD (# stations)	LNSD Layout	SNLD Layout	Positional Freedom (% of distance to core)	Break in spiral parameters from previous region
Core	0	0.5	20	25	12	Close pack	Close pack	0	na
Central Area	0.5	2.5	32	40	20	5-arm symmetric log-spiral 8 stations per arm	5-arm symmetric log-spiral 4 stations per arm	0	na
Near Remote	2.5	150	24	30	15	Your log spiral	Your log spiral	10	yes
Far Remote	150	3000+	24	30	15	Your log spiral	Your log spiral	100	Your choice
Totals			100	125	62				

3.2 Example array configurations

3.2.1 LNSD asymmetric – 5 arm

Figure 2 shows an SKA array which utilizes the mandatory configuration given in Appendix 2 for an LNSD core and central area and a 5 arm asymmetric configuration beyond the central area.

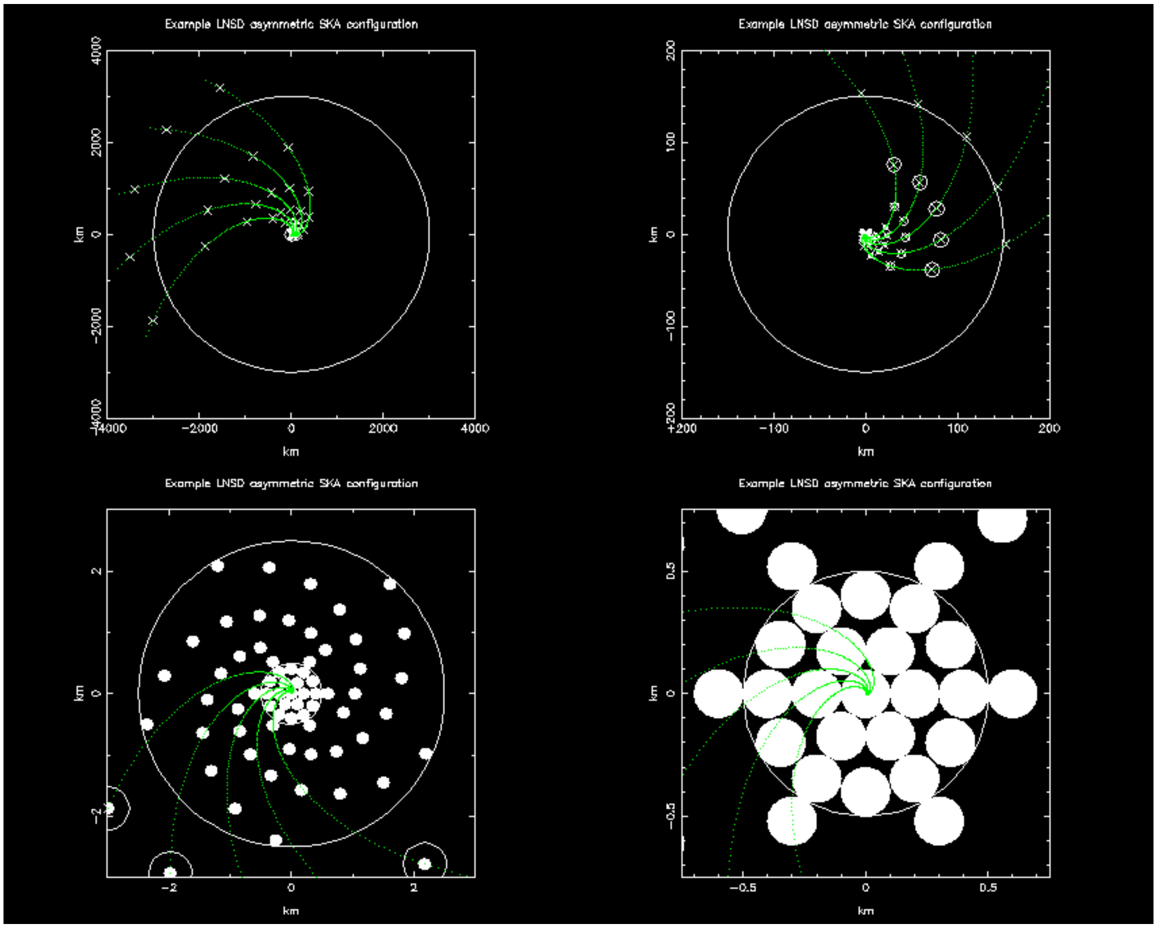

Figure 2: An example SKA configuration complying with the specifications listed in the RFP and this document. The four panels show the example configuration in a plane tangent to the earth at the reference latitude and longitude, on various spatial scales. **Bottom right:** the mandatory core distribution of stations, showing the 1 km core diameter and the 200 m diameter footprint assumed for the LNSD stations. There are 25 stations in the core. **Bottom left:** the mandatory central area distribution of stations in a five arm symmetric logarithmic spiral configuration, showing the 5 km diameter. There are 40 stations in the central area. Outside the 5 km diameter central area, the parameters of the central area logarithmic spiral configuration are broken. Five arms are retained but the configuration is now asymmetric and has a different winding parameter. The density of stations along the arms have been chosen to satisfy the collecting area specifications. **Top right:** station locations between the central area and the 150 km transition radius. 30 stations are located between the central area and the 150 km transition radius. **Top left:** station locations on the largest scales, showing the 3000 km minimum radius required by the RFP specifications. 30 stations lie beyond the 150 km transition radius. The data file giving the latitudes and longitudes of the station positions for this example is listed in Appendix 3. The 10% tolerance on station position is indicated, where applicable.

3.2.2 SNLD asymmetric – 3 arm

Figure 3 shows an SKA array which utilizes the mandatory configuration given in Appendix 2 for an SNLD core and central area and a 3 arm asymmetric configuration beyond the central area.

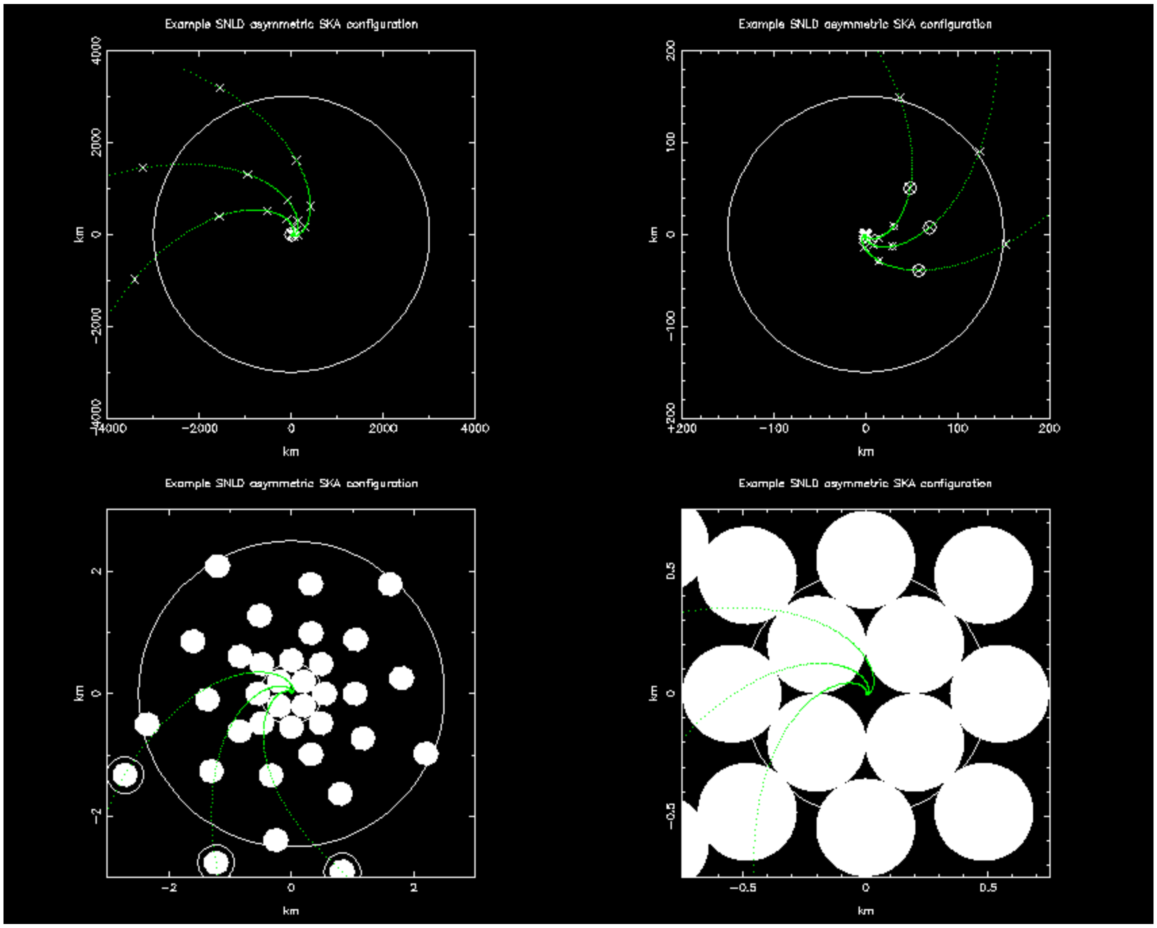

Figure 3: An example SKA configuration complying with the specifications listed in the RFP and this document. The four panels show the example configuration in a plane tangent to the earth at the reference latitude and longitude, on various spatial scales. **Bottom right:** the core distribution of stations, showing the 1 km core diameter and the 400 m diameter footprint assumed for the SNLD receptors. There are 12 stations in the core. **Bottom left:** the central area distribution of receptors in a three arm asymmetric logarithmic spiral configuration, showing the 5 km diameter. There are 20 stations in the central area. Outside the 5 km diameter central area, the parameters of the central area logarithmic spiral configuration are broken. Five arms are replaced with three, the configuration is now asymmetric, and a different winding parameter and density of stations along the arms have been chosen to satisfy the collecting area specifications. **Top right:** receptor locations between the central area and the 150 km transition radius. 15 stations are located between the central area and the 150 km transition radius. **Top left:** receptor locations on the largest scales, showing the 3000 km minimum radius required by the RFP specifications. There are 15 stations beyond the 150 km transition radius. The data file giving the latitudes and longitudes of the station positions for this example is listed in Appendix 3. The 10% tolerance on station position is indicated, where applicable.

3.2.3 LNSD symmetric – 5 arm

Figure 4 shows an SKA array which utilizes the mandatory configuration given in Appendix 2 for an LNSD core and central area and a 5 arm symmetric configuration beyond the central area.

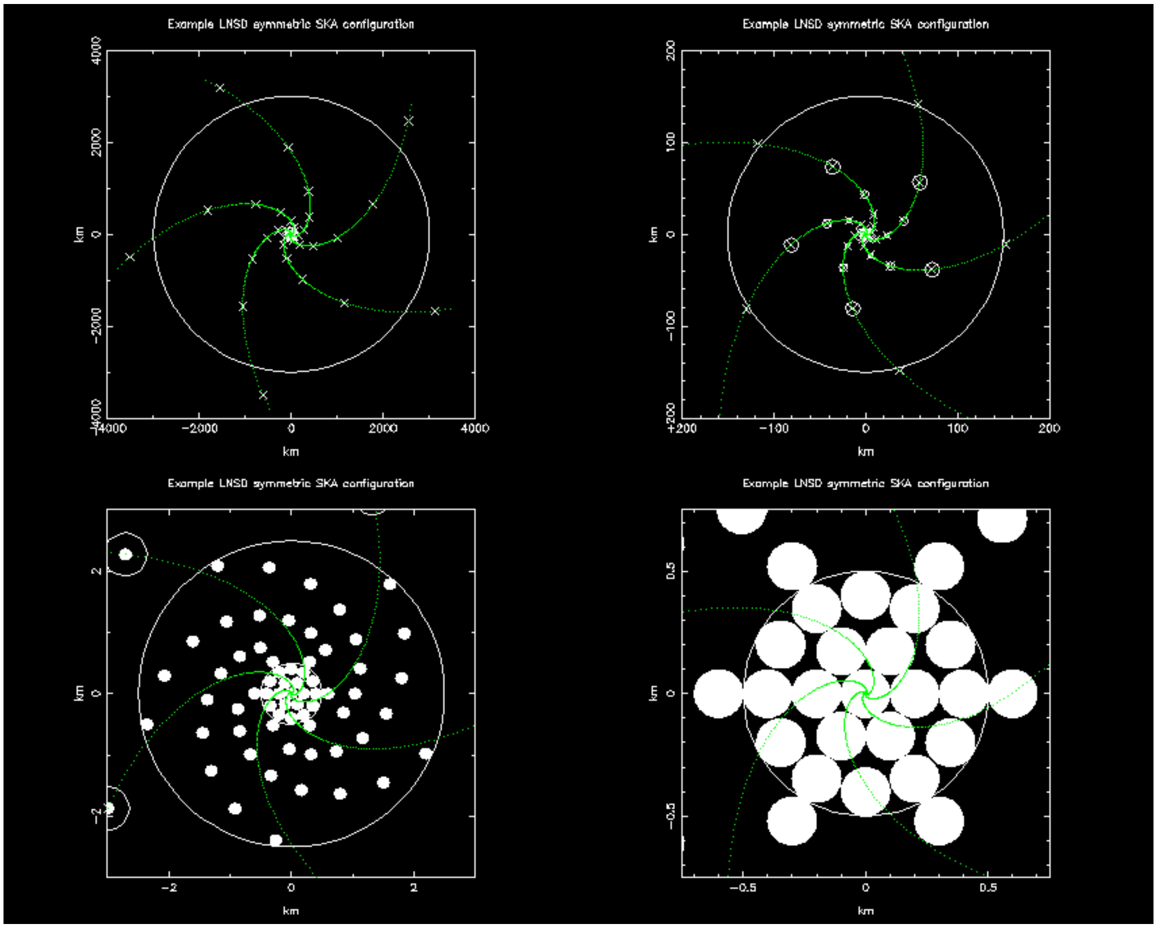

Figure 4: As for Figure 2, but for a symmetric five arm logarithmic spiral for distances from the core greater than 2.5 km. Configuration listing is in Appendix 3.

3.2.4 SNLD symmetric – 3 arm

Figure 5 shows an SKA array which utilizes the mandatory configuration given in Appendix 2 for an SNLD core and central area and a 3 arm symmetric configuration beyond the central area.

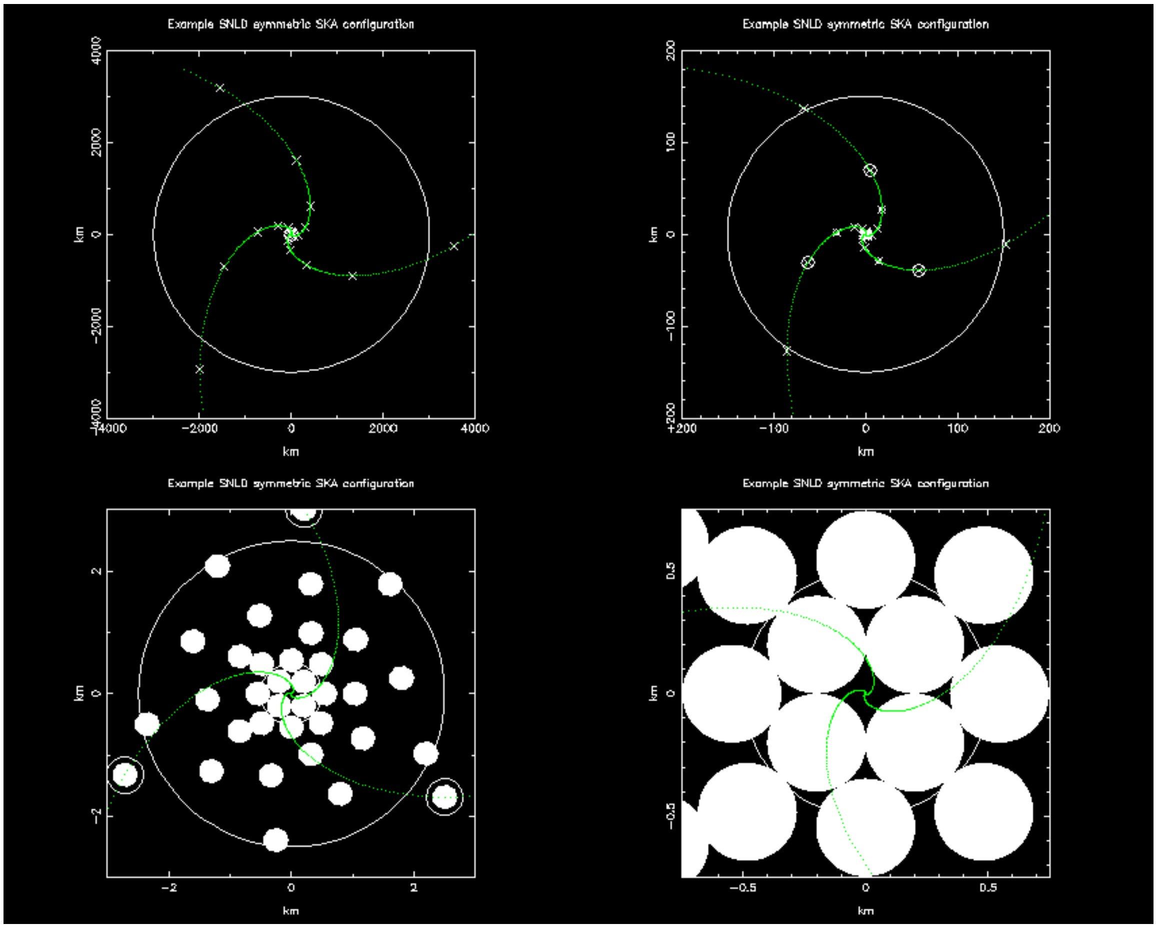

Figure 5: As for Figure 3 but for a three arm symmetric configuration. The configuration listing is in Appendix 3.

3.3 Modification of arrays

3.3.1 Use of Geographical Information System (GIS) software

GIS software is a powerful tool for planning major infrastructure projects and is therefore an ideal tool to use for manipulations of SKA array configurations, where the interplay of station or receptor locations, data connections, existing infrastructure, topographical and geographical constraints, and other position-dependant constraints (such as the location of sources of RFI) is important.

From consultation with all proposal teams, it seems that the use of GIS software, in the form of the two most common packages, ArcGIS and Mapinfo, will be employed by each team at some level. We therefore adopt a simple format to specify array configurations that can easily be used with GIS software. The format specifying array configurations is as follows.

```
# This is a comment
# LNSD defined core + central area
# Long,                 Latitude,               El,   D,    Name
#
-0.000242824465431113,  -5.62169433363563e-06,  0,    100,  STA_NAME
0.000414049455969234,   -0.00206262897120304,   0,    100,  STA_NAME
-2.62465324567529e-05,  8.89886516320259e-05,   0,    100,  STA_NAME
-0.00214364680192602,   0.00681958508783194,    0,    100,  STA_NAME
.
.
.
.
.
```

The listings contain lines with five fields, comma separated. Comments are preceeded with a hash (#). Each line describes a single SKA station.

The first field is the longitude of the SKA station in decimal degrees (east of Greenwich is positive). The second field is the latitude of the SKA station in decimal degrees (north is positive). The third field is the elevation of the SKA station in metres. The fourth field is the effective diameter of the SKA station in metres. The fifth field is the name of the SKA station.

The configuration listings given in Appendices 2 and 3 adhere to this format.

3.4 Adherence to definitions (compliance) and Figures-of-merit (FOM) for proposed arrays

3.4.1 Adherence to definitions and specifications

The proposed arrays will need to adhere to the specifications on the distribution of collecting area as a function of distance and the tolerances on actual vs nominal locations of stations or receptors, as listed in this document. Figures 2 – 5 illustrate the type of analysis that will be made of the proposed arrays, identifying the locations of the stations or receptors and the distribution of collecting area in the various distance ranges, including the requirement that the maximum distance between core and outermost station(s) or receptor(s) be at least 3000 km. In Figures 2 – 5, the 10% tolerance on nominal station or receptor position in the distance range 2.5 to 150 km from the core is indicated.

Proposers will be required to present the list of nominal station or receptor positions, as defined by the logarithmic spiral configuration adopted by the proposers, in addition to the list of actual station or receptor positions (both in the format described in section 3) and a mathematical description of the receptor positions. Proposers should also present figures similar to those shown in Figures 2 - 5 that show graphically the differences between their logarithmic spiral configuration as defined mathematically and the actual station or receptor positions.

3.4.2 Figures of Merit

The following figures of merit will be calculated for the proposed configurations in order to measure their performance.

3.4.2.1 Sky visibility

The RFP defines visible sky as sky that is above the 30 degree elevation limit at all stations or receptors in the proposed array simultaneously for at least 4 hours in a 24 hour period. The visible sky for any given array will depend on the extremes of the east-west and north-south distribution of stations or receptors in the array and will be a function of declination.

Proposers should be aware that if the geography of their site has a significant effect on visible sky, they should note this in their proposal. For example, the existence of any geographic feature local to a station location that limits the minimum elevation to greater than the 30 degrees assumed (nearby mountain, station located in valley etc) should be noted, along with the elevation limit as a function of azimuth.

Figure 6 below illustrates the calculation of visible sky for the example array shown in Figure 2 above. Plots such as Figure 6 can be generated from files of the format described in section 3 via a PERL script that will be made available to proposers if requested. Proposers should include figures such as shown in Figure 6 as part of their proposals, as well as a graph of the time range visible to the array as a function of source declination, as illustrated in Figure 7 (this plot can also be generated via the PERL script).

Proposers should note that visible sky declination ranges that include equatorial regions have access to a much larger area of the total sky than declination ranges that are restricted to far north or far south declinations.

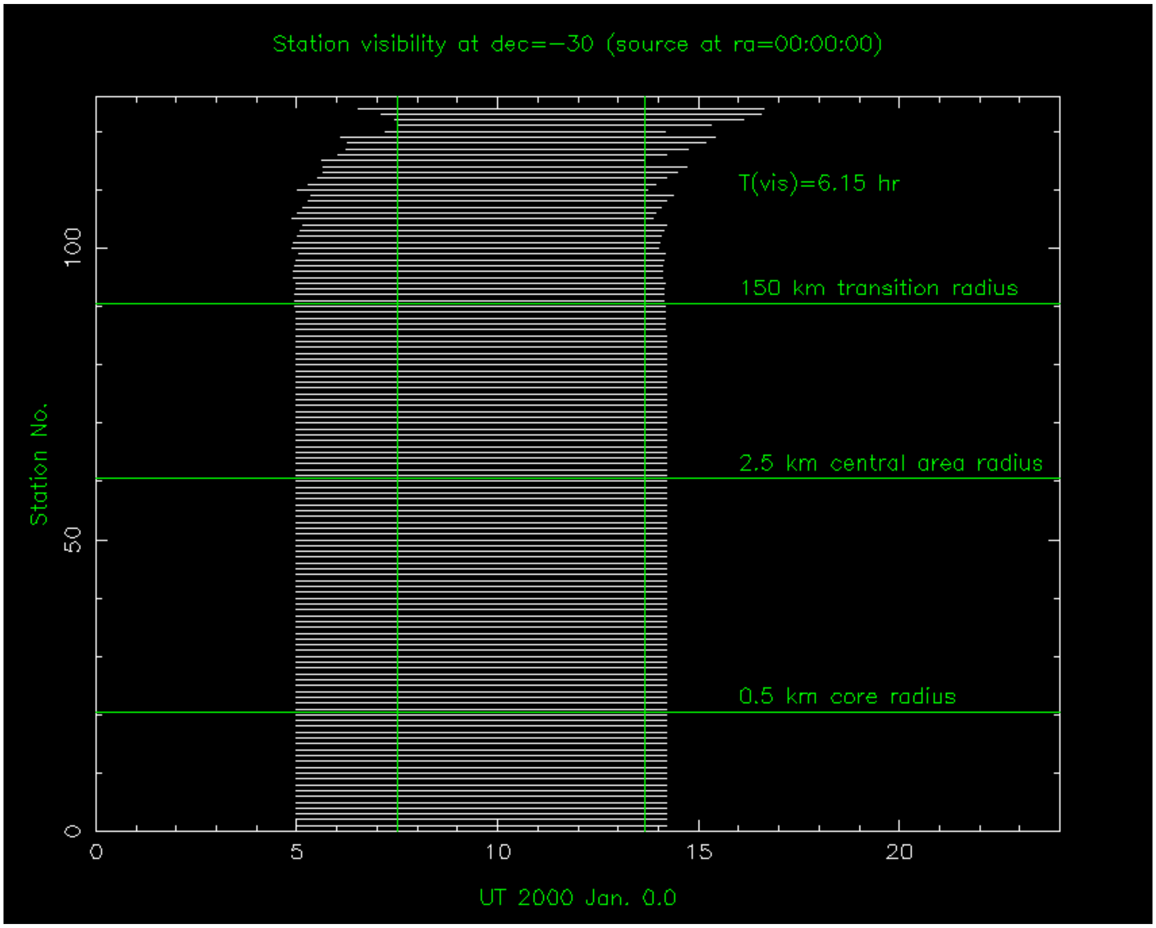

Figure 6: Example of the calculation of sky visibility for the array illustrated in Figure 2 at a reference latitude of -26.5 degrees and reference longitude of 117 degrees east of Greenwich. This Figure shows that there is 6.15 hours of sky visibility for a source at a declination of -30 degrees for this array configuration. The vertical axis is station or receptor number: increasing number relates to increasing distance from the reference latitude and longitude. The horizontal lines indicate various size scales of interest and the vertical lines indicate the time range over which a source at this declination will be visible to the entire array.

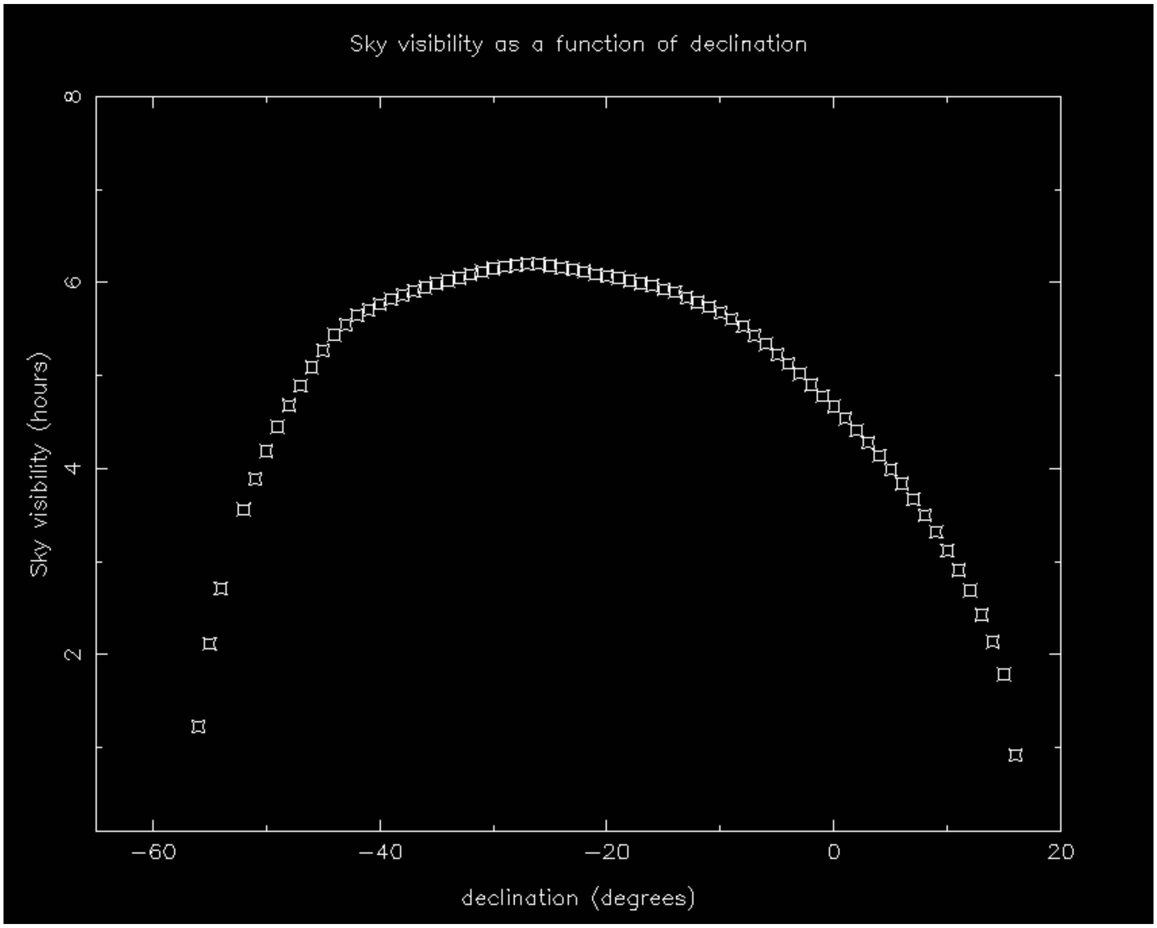

Figure 7: Calculation of the visible sky for the example configuration in Figure 2 (as described in Figure 6) as a function of source declination.

3.4.2.2 Visibility of key sources

The RFP requires proposers to show the extent of coverage of the proposed array for various key astronomically interesting sources. Following consultation with the SKA Science Working Group, the list of key astronomical sources that need to be considered by proposers comprises:

(a) At least two of the three nearest dark clouds: Taurus (RA = 04:20 ; DEC = +28), Ophiucus (RA = 17:05 ; DEC = -23), Chamaeleon (RA = 11:51 ; DEC = -78) [Key Science Program I]

(b) ~70% coverage of the inner Galaxy, including the Galactic Centre i.e. between Galactic longitudes -125 and +125 degrees [Key Science Programs I,II,III]

(c) ~20,000 square degrees of sky out of the Galactic Plane including the 'coldest' regions of sky i.e. for synchrotron emission (l,b) = (-150,+50) and (l,b) = (-130,-55) and for HI fluctuations (l,b) = (+150,+50) and (l,b) = (-135,-50) [Key Science Programs, IV and V]

The visibility of these key science targets can be assessed by comparison of their declinations or declination ranges to plots as shown in Figure 7. The proposers should demonstrate sky visibility for point (c) by providing the range in right ascension and declination that defines the 20,000 square degree area of interest, and indicate whether or not this region includes the galactic coordinates indicated above.

3.4.2.3 Opportunities for co-observation with major existing ground-based astronomical facilities

The RFP requires the Proposers to show the degree to which their proposed configuration will allow observations to be made of the same area of sky as available to major ground-based astronomical facilities at other wavelengths, either existing or under construction. This can be shown in the form of a table giving the range of common declination of these other facilities with the SKA.

In addition, an analysis should be made of the simultaneously visible sky with other large diameter radio telescopes that could be used to increase the maximum baseline of the SKA for high angular resolution observations. Space-based facilities should not be included since in most cases these facilities have a large amount of overlap with any earth-based location.

Proposers can show overlap with other large diameter radio telescopes by specifying the longitude and latitude of the facilities of interest in a file of the format given in section 3.3 and specifying this file as an argument when running the PERL script that produces the plots such as those in Figures 6 and 7. The PERL script will plot the existing facilities as if they were extra SKA stations, but in a different colour, to distinguish them from the SKA stations.

Proposers should name the facilities and comment on the overlap in the text of their proposal.

3.4.2.4 UV coverages

The gross properties of the uv plane coverage produced by the proposed SKA configurations will be a consideration when selecting the site for the SKA.

Since the proposers are asked to work with specifications that are “for the purposes of siting”, and the actual configuration parameters of the SKA when built may be quite different to these specifications, an evaluation of the uv coverages will be limited to the gross properties that are driven by 1) the length of the observation centred on source transit (snapshot, 1 hour, and 8 hour); 2) the declination of the source being observed (-90 to +90); and 3) the fractional bandwidth (single channel, 1% bandwidth, and 25% bandwidth). An example of such a uv coverage simulation within this parameter space is shown in Figure 8.

The figures of merit calculated for the uv coverages will be 1) the weight as a function of radius in the uv plane 2) the “circularity”of the uv coverage, 3) the percentage of empty uv cells as a function of radius in the uv plane. The figures of merit can be calculated via a PERL script which is available upon request.

The variation of weight as a function of position in the uv plane is represented as follows. The uv plane is partitioned into a series of annuli (100 for example) and each annulus is partitioned into a number of sectors (100 for example). This forms a radial grid on the uv plane. Within each grid cell the cell weight is calculated as the number of uv points multiplied by the collecting area per point and the observing time per point. Then in each annulus the mean and RMS values of the cell weights are calculated and plotted as a function of the radius of the annulus.

These plots immediately show the variability in the distribution of weights as a function of radius in the uv plane. An example set of such plots is shown in Figure 9, corresponding to the configuration shown in Figures 2 and 8.

The “circularity” parameter has been designed to reduce the information in plots such as Figure 8 into a few easily digestible numbers. The circularity is calculated as the average over annuli of the mean weight divided by the RMS variation around the mean. The circularity therefore gives an indication of the uniformity and degree of circular symmetry of the uv coverage. For example, a perfectly uniform and circular uv coverage will have identical mean weights and zero RMS in all radial grid cells. The circularity in this case will be infinite. For a uv coverage which has circular symmetry but varies smoothly in the radial direction, the mean weight will vary as a function of radius and the RMS at each radius will be non-zero. The circularity in this case will be finite but large.

In cases closer to reality, where the weights in the uv plane vary substantially in both the radial and azimuthal directions, the mean weight will vary significantly as a function of radius and the RMS at all radii will be large. The circularity for sparse arrays and short integration times will therefore be small.

Using the abovementioned PERL script the circularity can be calculated and tabulated as a function of source declination, integration time, and fractional bandwidth, for comparison between different proposed arrays.

The circularity, as measured, cannot capture all information relevant to a given uv coverage, since information is lost when averages are performed within the different annuli and over annuli. In particular, the circularity is only calculated over cells that contain data. A useful additional figure of merit to consider is therefore the percentage of cells populated with data as a function of radius in the uv plane. In addition, the overall percentage of cells that are filled (filling factor of the uv coverage) can be calculated. Both calculations are illustrated in Figure 9.

A useful comparison of the basic features of SKA-like uv coverages can be made, based on the plots shown in Figure 9.

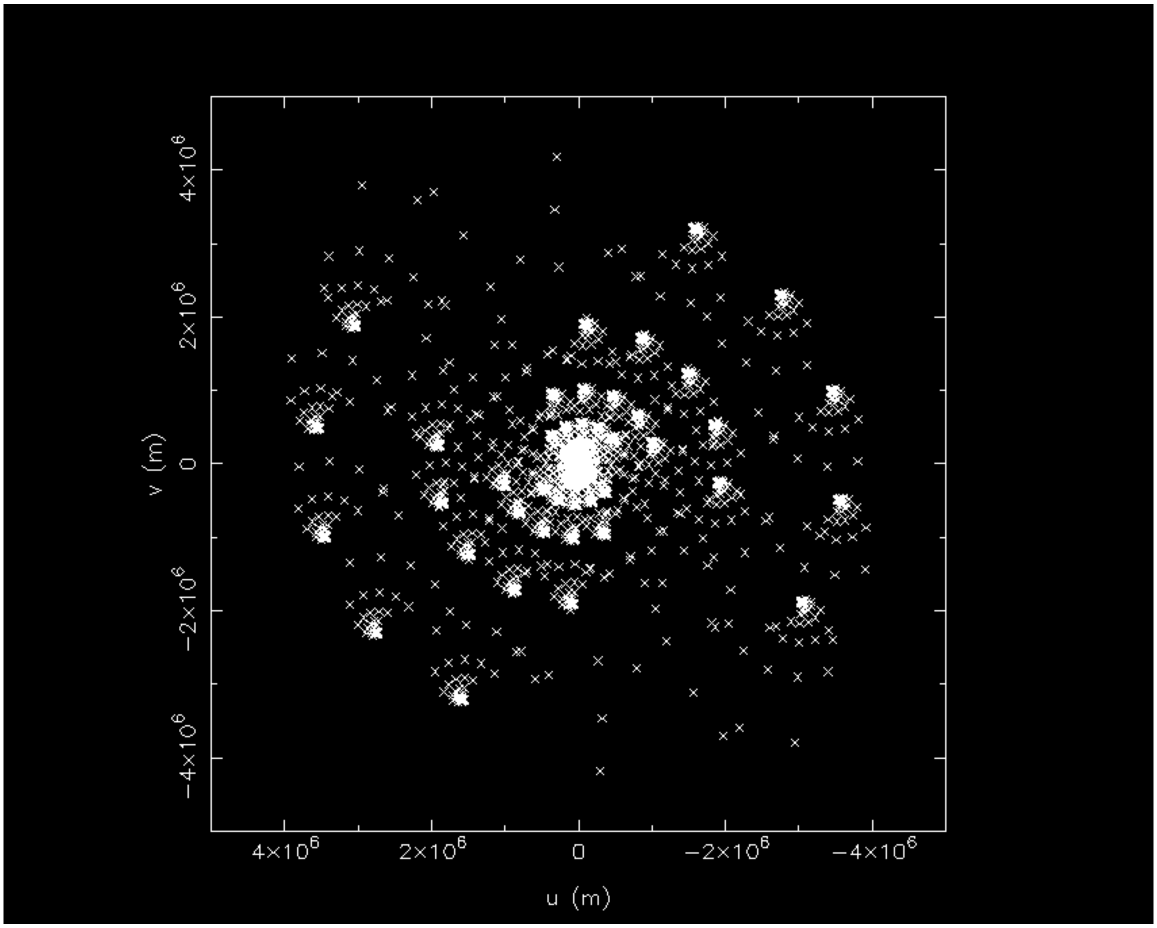

Figure 8: example uv coverage calculated for the configuration shown in Figure 2, at a reference latitude of -26.5 degrees and a reference longitude of 117 degrees east of Greenwich, for a source transiting the core at the zenith. A single frequency channel and a snapshot observation of 5 minutes duration were assumed.

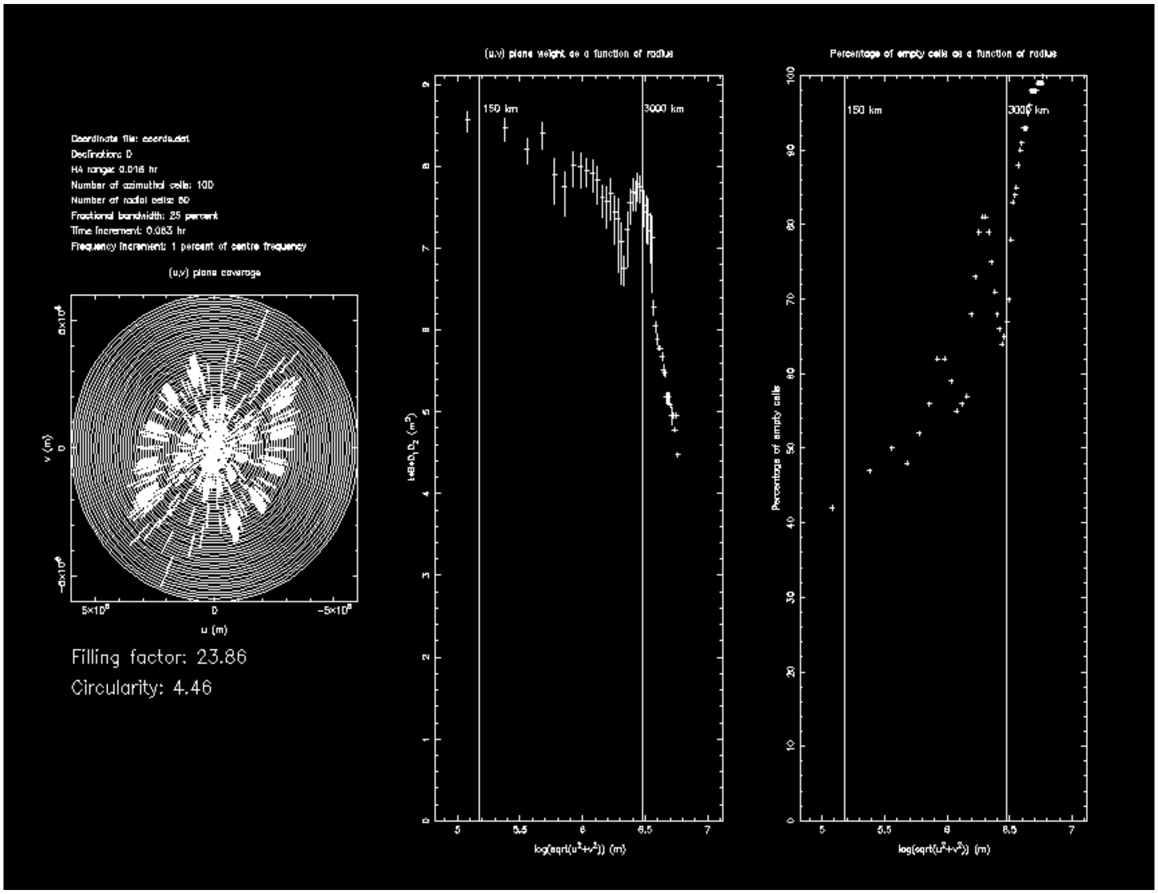

Figure 9: Plots of example calculations of uv coverage figures of merit for the example array in Figure 2. The left panel shows the uv coverage generated, along with parameter values used in the calculation. The uv coverage is plotted over the top of a set of annuli that are used to form a radial grid of cells (radial grid lines not shown). Values for the filling factor and circularity are shown. The middle panel shows the mean weight in the uv plane distributed as a function of radius – the vertical bars indicate +/- the RMS weight around the mean at each uv radius. The right panel shows the percentage of empty cells in the uv plane as a function of radius in the uv plane.

3.4.2.5 beam shape

The shape of the synthesized beam is also a figure of merit that can be calculated. The shape of the synthesized beam depends heavily on the form of weighting used in imaging. For example, in the case of configurations generated for the SKA site selection process, where 50% of the collecting area of the array is concentrated within a 5 km diameter area, and the distribution of this collecting area is identical for all proposers, a naturally weighted synthesized beam will be dominated by these short baselines in a very similar way for all proposed arrays. The placement of antennas on size scales that will discriminate between different sites (>few hundred km) will have little significant effect on a naturally weighted synthesized beam.

On the other hand, a uniformly weighted beam, which may be used for sidelobe suppression, maximum angular resolution, and identification of compact sources in confused fields, is sensitive to the placement of stations on distance scales that are likely to discriminate between proposed sites. However, the sensitivity of images produced using uniform weighting is non-optimal.

Robust weighting schemes can be used to take advantage of trade-offs between natural and uniform weighting and may be usefully applicable to SKA-like uv coverages. Robustly weighted beams can be calculated in software packages such as AIPS++.

For evaluation of the configurations, beams will be calculated using ROBUST=0 for sources at the northern and southern declination limits of the visible sky, for example as calculated in Figure 7. At these limits the integration time to be used in the calculation is, by the definition of visible sky, 4 hours (over the appropriate time range). The calculations will be made for both single channel bandwidth and a fractional bandwidth of 25%. A third calculation of the beam will be made, at the declination corresponding to the peak of the visible sky function, as calculated in Figure 7. The integration time (and time range) will be taken from the calculation of visible sky and again both single channel and 25% bandwidth will be used. The ellipticity of the half power point of the beam will be calculated and tabulated in each case, for comparison between proposed sites.

Further to the beam calculations based on long-track observations (greater than or equal to 4 hour duration), the beams will be calculated at the abovementioned declinations based on snapshot observations. Snapshot observations and snapshot uv coverages will be highly relevant to the SKA as a survey instrument.

Sidelobe statistics may also be tabulated for comparison for each of the calculated beams.

Appendix 1: CSTF membership

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Tim Cornwell (National Radio Astronomy Observatory, USA)
Catherine Cress (University of KwaZulu-Natal, South Africa)
Peter Dewdney (Dominion Radio Astrophysical Observatory, Canada)
Shep Doleman (MIT, USA)
Michael Garrett (Joint Institute for VLBI in Europe, The Netherlands)
Peter Hall (Project Engineer, International SKA Project)
Jasper Horrell (Saratoga Software, South Africa)
George Nicolson (Hartebeesthoek Radio Astronomy Observatory, South Africa)
Pramesh Rao (National Centre for Radio Astrophysics, India)
Steve Rawlings (Chair, Science Working Group)
Richard Schilizzi (Director, International SKA Project)
Yan Su (National Astronomical Observatories, China)
Yervant Terzian (Chair, Site Evaluation Working Group)
Maxim Voronkov (Australia Telescope Compact Array, Australia)
Craig Walker (National Radio Astronomy Observatory, USA)

Appendix 2: Defined core and central area configurations

The following listings give the defined core and central area configurations for LNSD and SNLD concepts that are described in the text for mandatory use by proposers. The format of the listings is also described in the text and is used by the FOM calculation software. These core plus central area configurations are centred at a longitude and latitude of (0,0). Proposers will need to translate them to their reference longitude and latitude.

<u>LNSD core plus central area configuration</u>

```
# This is a comment
# LNSD defined core + central area
# Long,                 Lat,                    El,   D,    Name
#
0,                      0,                      0,    100,  CORE-0
0.00179666916031584,    0,                      0,    100,  CORE-1
-0.00179666916031584,   0,                      0,    100,  CORE-2
0.00359333832239837,    0,                      0,    100,  CORE-3
-0.00359333832239837,   0,                      0,    100,  CORE-4
0.000898334580378758,   0.00155596130783336,    0,    100,  CORE-5
-0.000898334580378758,  0.00155596130783336,    0,    100,  CORE-6
0.000898334580378758,   -0.00155596130783336,   0,    100,  CORE-7
-0.000898334580378758,  -0.00155596130783336,   0,    100,  CORE-8
0.00179666916296587,    0.00311192261681421,    0,    100,  CORE-9
-0.00179666916296587,   0.00311192261681421,    0,    100,  CORE-10
0.00179666916296587,    -0.00311192261681421,   0,    100,  CORE-11
-0.00179666916296587,   -0.00311192261681421,   0,    100,  CORE-12
0,                      0.00359333832239837,    0,    100,  CORE-13
0,                      -0.0035933383223984,    0,    100,  CORE-14
0.00311192261834421,    0.00179666916031584,    0,    100,  CORE-15
-0.00311192261834421,   -0.00179666916031584,   0,    100,  CORE-16
-0.00311192261834421,   0.00179666916031584,    0,    100,  CORE-17
0.00311192261834421,    -0.00179666916031584,   0,    100,  CORE-18
0.00539000748801427,    0,                      0,    100,  CORE-19
0.00269500374996969,    0.00466788302975548,    0,    100,  CORE-20
-0.00269500374996969,   0.00466788302975548,    0,    100,  CORE-21
-0.00539000748801427,   0,                      0,    100,  CORE-22
0.00269500374996969,    -0.00466788302975548,   0,    100,  CORE-23
-0.00269500374996969,   -0.00466788302975548,   0,    100,  CORE-24
-0.000283775427006523,  -0.00812626494870506,   0,    100,  CENT-0
0.00764084580969595,    -0.00278104042891977,   0,    100,  CENT-1
0.00500607785545373,    0.00640748742633133,    0,    100,  CENT-2
-0.00454691957257493,   0.00674108544708608,    0,    100,  CENT-3
-0.00781622866556821,   -0.00224126749579257,   0,    100,  CENT-4
0.00288919554241276,    -0.00889202948140571,   0,    100,  CENT-5
0.00934963310047343,    -1.14496200499337e-17,  0,    100,  CENT-6
0.00288919554241278,    0.0088920294814057,     0,    100,  CENT-7
-0.00756401209264948,   0.0054955764348406,     0,    100,  CENT-8
-0.00756401209264949,   -0.00549557643484058,   0,    100,  CENT-9
0.00661874272531934,    -0.00847160428633477,   0,    100,  CENT-10
```

```
0.010102278460395,      0.0036769286337533,     0,     100,  CENT-11
-0.00037519123771547,   0.0107440711867414,     0,     100,  CENT-12
-0.0103341593902122,    0.00296327250213067,    0,     100,  CENT-13
-0.00601167055778671,   -0.00891266803629055,   0,     100,  CENT-14
0.0104831778438453,     -0.00655061648014342,   0,     100,  CENT-15
0.00946948667934615,    0.00794584269296427,    0,     100,  CENT-16
-0.00463071327360493,   0.011461417380083,      0,     100,  CENT-17
-0.012331424776639,     -0.000862297214629407,  0,     100,  CENT-18
-0.00299052647294755,   -0.0119943463782744,    0,     100,  CENT-19
0.0139032333721227,     -0.00295522345005189,   0,     100,  CENT-20
0.00710692004114442,    0.0123095463756352,     0,     100,  CENT-21
-0.00951091539436956,   0.0105629414962875,     0,     100,  CENT-22
-0.0129849888871181,    -0.0057812894618478,    0,     100,  CENT-23
0.00148575086822054,    -0.0141359749600231,    0,     100,  CENT-24
0.0161846437534262,     0.00227460331102306,    0,     100,  CENT-25
0.0028380537100366,     0.0160954019788586,     0,     100,  CENT-26
-0.0144306302226282,    0.0076729020672013,     0,     100,  CENT-27
-0.011756673692605,     -0.0113532875857553,    0,     100,  CENT-28
0.00716460645177037,    -0.0146896197713277,    0,     100,  CENT-29
0.0165929746637896,     0.00882264093500052,    0,     100,  CENT-30
-0.00326331926513029,   0.018507202566277,      0,     100,  CENT-31
-0.0186098166974192,    0.00261543912451038,    0,     100,  CENT-32
-0.00823818032243708,   -0.0168907722152089,    0,     100,  CENT-33
0.0135183416211969,     -0.0130545104105789,    0,     100,  CENT-34
0.0144590306334673,     0.0160583797829093,     0,     100,  CENT-35
-0.0108043412090372,    0.0187136671400135,     0,     100,  CENT-36
-0.0211364801539822,    -0.00449269743622899,   0,     100,  CENT-37
-0.00225872239200265,   -0.0214903070250911,    0,     100,  CENT-38
0.0197405131215547,     -0.00878904246160279,   0,     100,  CENT-39
```

<u>SNLD core plus central area configuration</u>

```
# This is a comment
# SNLD defined core + central area
# Longitude, Latitude, Elevation, Diameter, Name
-0.00179666916119919,   0.00179666916031584,    0,     140,  CORE-0
0.00179666916119919,    0.00179666916031584,    0,     140,  CORE-1
-0.00179666916119919,   -0.00179666916031584,   0,     140,  CORE-2
0.00179666916119919,    -0.00179666916031584,   0,     140,  CORE-3
0.00433754304756353,    0.00433754303513396,    0,     140,  CORE-4
-0.00433754304756353,   0.00433754303513396,    0,     140,  CORE-5
0.00433754304756353,    -0.00433754303513396,   0,     140,  CORE-6
-0.00433754304756353,   -0.00433754303513396,   0,     140,  CORE-7
0.00490859178131008,    0,                      0,     140,  CORE-8
-0.00490859178131008,   0,                      0,     140,  CORE-9
0,                      0.00490859178131008,    0,     140,  CORE-10
0,                      -0.00490859178131008,   0,     140,  CORE-11
0.00288919554241276,    -0.00889202948140571,   0,     140,  CENT-0
0.00934963310047343,    -1.14496200499337e-17,  0,     140,  CENT-1
0.00288919554241278,    0.0088920294814057,     0,     140,  CENT-2
-0.00756401209264948,   0.0054955764348406,     0,     140,  CENT-3
-0.00756401209264949,   -0.00549557643484058,   0,     140,  CENT-4
0.0104831778438453,     -0.00655061648014342,   0,     140,  CENT-5
0.00946948667934615,    0.00794584269296427,    0,     140,  CENT-6
-0.00463071327360493,   0.011461417380083,      0,     140,  CENT-7
-0.012331424776639,     -0.000862297214629407,  0,     140,  CENT-8
```

-0.00299052647294755,	-0.0119943463782744,	0,	140,	CENT-9
0.0161846437534262,	0.00227460331102306,	0,	140,	CENT-10
0.0028380537100366,	0.0160954019788586,	0,	140,	CENT-11
-0.0144306302226282,	0.0076729020672013,	0,	140,	CENT-12
-0.011756673692605,	-0.0113532875857553,	0,	140,	CENT-13
0.00716460645177037,	-0.0146896197713277,	0,	140,	CENT-14
0.0144590306334673,	0.0160583797829093,	0,	140,	CENT-15
-0.0108043412090372,	0.0187136671400135,	0,	140,	CENT-16
-0.0211364801539822,	-0.00449269743622899,	0,	140,	CENT-17
-0.00225872239200265,	-0.0214903070250911,	0,	140,	CENT-18
0.0197405131215547,	-0.00878904246160279,	0,	140,	CENT-19

Appendix 3: Listings for example arrays

These listings correspond to the example arrays given in this document.

<u>LNSD 5 arm asymmetric array (Figure 2)</u>

```
# This is a comment
# LNSD defined core + central area
# Long,                 Lat,                    El,    D,     Name
#
0,                      0,                      0,     100,   CORE-0
0.00179666916031584,    0,                      0,     100,   CORE-1
-0.00179666916031584,   0,                      0,     100,   CORE-2
0.00359333832239837,    0,                      0,     100,   CORE-3
-0.00359333832239837,   0,                      0,     100,   CORE-4
0.000898334580378758,   0.00155596130783336,    0,     100,   CORE-5
-0.000898334580378758,  0.00155596130783336,    0,     100,   CORE-6
0.000898334580378758,   -0.00155596130783336,   0,     100,   CORE-7
-0.000898334580378758,  -0.00155596130783336,   0,     100,   CORE-8
0.00179666916296587,    0.00311192261681421,    0,     100,   CORE-9
-0.00179666916296587,   0.00311192261681421,    0,     100,   CORE-10
0.00179666916296587,    -0.00311192261681421,   0,     100,   CORE-11
-0.00179666916296587,   -0.00311192261681421,   0,     100,   CORE-12
0,                      0.00359333832239837,    0,     100,   CORE-13
0,                      -0.0035933383223984,    0,     100,   CORE-14
0.00311192261834421,    0.00179666916031584,    0,     100,   CORE-15
-0.00311192261834421,   -0.00179666916031584,   0,     100,   CORE-16
-0.00311192261834421,   0.00179666916031584,    0,     100,   CORE-17
0.00311192261834421,    -0.00179666916031584,   0,     100,   CORE-18
0.00539000748801427,    0,                      0,     100,   CORE-19
0.00269500374996969,    0.00466788302975548,    0,     100,   CORE-20
-0.00269500374996969,   0.00466788302975548,    0,     100,   CORE-21
-0.00539000748801427,   0,                      0,     100,   CORE-22
0.00269500374996969,    -0.00466788302975548,   0,     100,   CORE-23
-0.00269500374996969,   -0.00466788302975548,   0,     100,   CORE-24
-0.000283775427006523,  -0.00812626494870506,   0,     100,   CENT-0
0.00764084580969595,    -0.00278104042891977,   0,     100,   CENT-1
0.00500607785545373,    0.00640748742633133,    0,     100,   CENT-2
-0.00454691957257493,   0.00674108544708608,    0,     100,   CENT-3
-0.00781622866556821,   -0.00224126749579257,   0,     100,   CENT-4
0.00288919554241276,    -0.00889202948140571,   0,     100,   CENT-5
0.00934963310047343,    -1.14496200499337e-17,  0,     100,   CENT-6
0.00288919554241278,    0.0088920294814057,     0,     100,   CENT-7
-0.00756401209264948,   0.0054955764348406,     0,     100,   CENT-8
-0.00756401209264949,   -0.00549557643484058,   0,     100,   CENT-9
0.00661874272531934,    -0.00847160428633477,   0,     100,   CENT-10
0.010102278460395,      0.0036769286337533,     0,     100,   CENT-11
-0.00037519123771547,   0.0107440711867414,     0,     100,   CENT-12
-0.0103341593902122,    0.00296327250213067,    0,     100,   CENT-13
-0.00601167055778671,   -0.00891266803629055,   0,     100,   CENT-14
0.0104831778438453,     -0.00655061648014342,   0,     100,   CENT-15
0.00946948667934615,    0.00794584269296427,    0,     100,   CENT-16
-0.00463071327360493,   0.011461417380083,      0,     100,   CENT-17
```

```
-0.012331424776639,     -0.000862297214629407,  0,    100,  CENT-18
-0.00299052647294755,   -0.0119943463782744,    0,    100,  CENT-19
0.0139032333721227,     -0.00295522345005189,   0,    100,  CENT-20
0.00710692004114442,    0.0123095463756352,     0,    100,  CENT-21
-0.00951091539436956,   0.0105629414962875,     0,    100,  CENT-22
-0.0129849888871181,    -0.0057812894618478,    0,    100,  CENT-23
0.00148575086822054,    -0.0141359749600231,    0,    100,  CENT-24
0.0161846437534262,     0.00227460331102306,    0,    100,  CENT-25
0.0028380537100366,     0.0160954019788586,     0,    100,  CENT-26
-0.0144306302226282,    0.0076729020672013,     0,    100,  CENT-27
-0.011756673692605,     -0.0113532875857553,    0,    100,  CENT-28
0.00716460645177037,    -0.0146896197713277,    0,    100,  CENT-29
0.0165929746637896,     0.00882264093500052,    0,    100,  CENT-30
-0.00326331926513029,   0.018507202566277,      0,    100,  CENT-31
-0.0186098166974192,    0.00261543912451038,    0,    100,  CENT-32
-0.00823818032243708,   -0.0168907722152089,    0,    100,  CENT-33
0.0135183416211969,     -0.0130545104105789,    0,    100,  CENT-34
0.0144590306334673,     0.0160583797829093,     0,    100,  CENT-35
-0.0108043412090372,    0.0187136671400135,     0,    100,  CENT-36
-0.0211364801539822,    -0.00449269743622899,   0,    100,  CENT-37
-0.00225872239200265,   -0.0214903070250911,    0,    100,  CENT-38
0.0197405131215547,     -0.00878904246160279,   0,    100,  CENT-39
-0.0269353407917602,    -0.0168310678399118,    0,    100,  OUT-0
-0.0177608464882262,    -0.0263315354956908,    0,    100,  OUT-1
-0.0055153395127514,    -0.0312790415520039,    0,    100,  OUT-2
0.00768382026146014,    -0.030818116736983,     0,    100,  OUT-3
0.0195543770491324,     -0.0250284591989358,    0,    100,  OUT-4
-0.0332919369978106,    -0.0493573113725475,    0,    100,  OUT-5
-0.0103382656372458,    -0.0586311971713571,    0,    100,  OUT-6
0.0144029890105343,     -0.0577672135270508,    0,    100,  OUT-7
0.0366538316776,        -0.0469147514587033,    0,    100,  OUT-8
0.0525668879412629,     -0.0279503039731609,    0,    100,  OUT-9
-0.0193786507266387,    -0.109901652672741,     0,    100,  OUT-10
0.0269978056362923,     -0.108282151170985,     0,    100,  OUT-11
0.0687060675949318,     -0.0879396661695577,    0,    100,  OUT-12
0.0985343873232972,     -0.0523916226554985,    0,    100,  OUT-13
0.111325220785456,      -0.00778461283243149,   0,    100,  OUT-14
0.0506064329978128,     -0.202970441139741,     0,    100,  OUT-15
0.128786965534754,      -0.164839205269607,     0,    100,  OUT-16
0.184698805090015,      -0.098205830425081,     0,    100,  OUT-17
0.208674572676093,      -0.0145919150260911,    0,    100,  OUT-18
0.196568885693447,      0.0715450458395649,     0,    100,  OUT-19
0.241408533817723,      -0.30898492320968,      0,    100,  OUT-20
0.346212585102561,      -0.184082743238218,     0,    100,  OUT-21
0.391153528613967,      -0.0273519046933908,    0,    100,  OUT-22
0.368462283357979,      0.134108134312172,      0,    100,  OUT-23
0.282061487095162,      0.272380459750696,      0,    100,  OUT-24
0.648978634662979,      -0.345056510853085,     0,    100,  OUT-25
0.733214639679743,      -0.0512699491543855,    0,    100,  OUT-26
0.690683092802094,      0.251380385710503,      0,    100,  OUT-27
0.528732258310002,      0.510570045015457,      0,    100,  OUT-28
0.275350658593953,      0.681482033661528,      0,    100,  OUT-29
1.3744743419983,        -0.0961033005401496,    0,    100,  REM-0
1.29476529019792,       0.471205294257924,      0,    100,  REM-1
0.991219705704699,      0.957072970350971,      0,    100,  REM-2
0.516229516152395,      1.27748386991625,       0,    100,  REM-3
-0.0480948117436098,    1.3769898779171,        0,    100,  REM-4
```

```
2.42770680575767,       0.883278661577965,      0,     100,  REM-5
1.85888321265986,       1.79420104959972,       0,     100,  REM-6
0.968287888469344,      2.39508649595571,       0,     100,  REM-7
-0.0902171774699261,    2.5817321584955,        0,     100,  REM-8
-1.13306747275263,      2.32170959655118,       0,     100,  REM-9
3.49024618625907,       3.36453476899044,       0,     100,  REM-10
1.81923609750219,       4.49277980347018,       0,     100,  REM-11
-0.169542087283596,     4.84347269772343,       0,     100,  REM-12
-2.128637528275,        4.35494385303548,       0,     100,  REM-13
-3.71624198387499,      3.11304442028673,       0,     100,  REM-14
3.43833643732577,       8.44341802646415,       0,     100,  REM-15
-0.320707673637881,     9.10635799767426,       0,     100,  REM-16
-4.02181953105843,      8.18308469612642,       0,     100,  REM-17
-7.00450635187936,      5.84251439788713,       0,     100,  REM-18
-8.76456265332944,      2.50181667874405,       0,     100,  REM-19
-0.621566273798893,     17.2574491546163,       0,     100,  REM-20
-7.75997638002987,      15.4741700742881,       0,     100,  REM-21
-13.3944580337073,      11.0000175287957,       0,     100,  REM-22
-16.637004164102,       4.69330222928319,       0,     100,  REM-23
-17.1101030917353,      -2.36773768017676,      0,     100,  REM-24
-16.3603091706194,      30.0074264453148,       0,     100,  MAX-0
-27.1576400409257,      20.9567816664626,       0,     100,  MAX-1
-32.7704706117689,      8.82237538378423,       0,     100,  MAX-2
-33.5504070214281,      -4.4414038534658,       0,     100,  MAX-3
-29.5927293585186,      -17.1491893307046,      0,     100,  MAX-4
```

<u>LNSD 5 arm symmetric array (Figure 4)</u>

```
# This is a comment
# LNSD defined core + central area
# Long,                 Lat,                    El,    D,    Name
#
0,                      0,                      0,     100,  CORE-0
0.00179666916031584,    0,                      0,     100,  CORE-1
-0.00179666916031584,   0,                      0,     100,  CORE-2
0.00359333832239837,    0,                      0,     100,  CORE-3
-0.00359333832239837,   0,                      0,     100,  CORE-4
0.000898334580378758,   0.00155596130783336,    0,     100,  CORE-5
-0.000898334580378758,  0.00155596130783336,    0,     100,  CORE-6
0.000898334580378758,   -0.00155596130783336,   0,     100,  CORE-7
-0.000898334580378758,  -0.00155596130783336,   0,     100,  CORE-8
0.00179666916296587,    0.00311192261681421,    0,     100,  CORE-9
-0.00179666916296587,   0.00311192261681421,    0,     100,  CORE-10
0.00179666916296587,    -0.00311192261681421,   0,     100,  CORE-11
-0.00179666916296587,   -0.00311192261681421,   0,     100,  CORE-12
0,                      0.00359333832239837,    0,     100,  CORE-13
0,                      -0.0035933383223984,    0,     100,  CORE-14
0.00311192261834421,    0.00179666916031584,    0,     100,  CORE-15
-0.00311192261834421,   -0.00179666916031584,   0,     100,  CORE-16
-0.00311192261834421,   0.00179666916031584,    0,     100,  CORE-17
0.00311192261834421,    -0.00179666916031584,   0,     100,  CORE-18
0.00539000748801427,    0,                      0,     100,  CORE-19
0.00269500374996969,    0.00466788302975548,    0,     100,  CORE-20
-0.00269500374996969,   0.00466788302975548,    0,     100,  CORE-21
-0.00539000748801427,   0,                      0,     100,  CORE-22
0.00269500374996969,    -0.00466788302975548,   0,     100,  CORE-23
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-0.00269500374996969,	-0.00466788302975548,	0,	100,	CORE-24
-0.000283775427006523,	-0.00812626494870506,	0,	100,	CENT-0
0.00764084580969595,	-0.00278104042891977,	0,	100,	CENT-1
0.00500607785545373,	0.00640748742633133,	0,	100,	CENT-2
-0.00454691957257493,	0.00674108544708608,	0,	100,	CENT-3
-0.00781622866556821,	-0.00224126749579257,	0,	100,	CENT-4
0.00288919554241276,	-0.00889202948140571,	0,	100,	CENT-5
0.00934963310047343,	-1.14496200499337e-17,	0,	100,	CENT-6
0.00288919554241278,	0.0088920294814057,	0,	100,	CENT-7
-0.00756401209264948,	0.0054955764348406,	0,	100,	CENT-8
-0.00756401209264949,	-0.00549557643484058,	0,	100,	CENT-9
0.00661874272531934,	-0.00847160428633477,	0,	100,	CENT-10
0.010102278460395,	0.0036769286337533,	0,	100,	CENT-11
-0.00037519123771547,	0.0107440711867414,	0,	100,	CENT-12
-0.0103341593902122,	0.00296327250213067,	0,	100,	CENT-13
-0.00601167055778671,	-0.00891266803629055,	0,	100,	CENT-14
0.0104831778438453,	-0.00655061648014342,	0,	100,	CENT-15
0.00946948667934615,	0.00794584269296427,	0,	100,	CENT-16
-0.00463071327360493,	0.011461417380083,	0,	100,	CENT-17
-0.012331424776639,	-0.000862297214629407,	0,	100,	CENT-18
-0.00299052647294755,	-0.0119943463782744,	0,	100,	CENT-19
0.0139032333721227,	-0.00295522345005189,	0,	100,	CENT-20
0.00710692004114442,	0.0123095463756352,	0,	100,	CENT-21
-0.00951091539436956,	0.0105629414962875,	0,	100,	CENT-22
-0.0129849888871181,	-0.0057812894618478,	0,	100,	CENT-23
0.00148575086822054,	-0.0141359749600231,	0,	100,	CENT-24
0.0161846437534262,	0.00227460331102306,	0,	100,	CENT-25
0.0028380537100366,	0.0160954019788586,	0,	100,	CENT-26
-0.0144306302226282,	0.0076729020672013,	0,	100,	CENT-27
-0.011756673692605,	-0.0113532875857553,	0,	100,	CENT-28
0.00716460645177037,	-0.0146896197713277,	0,	100,	CENT-29
0.0165929746637896,	0.00882264093500052,	0,	100,	CENT-30
-0.00326331926513029,	0.018507202566277,	0,	100,	CENT-31
-0.0186098166974192,	0.00261543912451038,	0,	100,	CENT-32
-0.00823818032243708,	-0.0168907722152089,	0,	100,	CENT-33
0.0135183416211969,	-0.0130545104105789,	0,	100,	CENT-34
0.0144590306334673,	0.0160583797829093,	0,	100,	CENT-35
-0.0108043412090372,	0.0187136671400135,	0,	100,	CENT-36
-0.0211364801539822,	-0.00449269743622899,	0,	100,	CENT-37
-0.00225872239200265,	-0.0214903070250911,	0,	100,	CENT-38
0.0197405131215547,	-0.00878904246160279,	0,	100,	CENT-39
-0.0269353407917602,	-0.0168310678399118,	0,	100,	OUT-0
0.00768382026146014,	-0.030818116736983,	0,	100,	OUT-1
0.0316842016598303,	-0.00221557509702168,	0,	100,	OUT-2
0.0118980950496918,	0.0294488158333298,	0,	100,	OUT-3
-0.024330776179222,	0.0204159438405867,	0,	100,	OUT-4
-0.0332919369978106,	-0.0493573113725475,	0,	100,	OUT-5
0.0366538316776,	-0.0469147514587033,	0,	100,	OUT-6
0.0559452398498807,	0.0203623979613354,	0,	100,	OUT-7
-0.00207776595252319,	0.05949941067796,	0,	100,	OUT-8
-0.0572293685771476,	0.016410254191957,	0,	100,	OUT-9
-0.0193786507266387,	-0.109901652672741,	0,	100,	OUT-10
0.0985343873232972,	-0.0523916226554985,	0,	100,	OUT-11
0.0802762593992225,	0.0775218099174162,	0,	100,	OUT-12
-0.0489209833120337,	0.100302765366871,	0,	100,	OUT-13
-0.110511012683924,	-0.0155312999560722,	0,	100,	OUT-14
0.0506064329978128,	-0.202970441139741,	0,	100,	OUT-15

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0.208674572676093,     -0.0145919150260911,   0,    100,  OUT-16
0.0783620537230496,    0.193952087680123,     0,    100,  OUT-17
-0.160244634699478,    0.134460791737005,     0,    100,  OUT-18
-0.177398424695295,    -0.110850523251594,    0,    100,  OUT-19
0.241408533817723,     -0.30898492320968,     0,    100,  OUT-20
0.368462283357979,     0.134108134312172,     0,    100,  OUT-21
-0.0136846081214113,   0.391869790154137,     0,    100,  OUT-22
-0.376919478603557,    0.108079013549635,     0,    100,  OUT-23
-0.219266730460068,    -0.325072014786412,    0,    100,  OUT-24
0.648978634662979,     -0.345056510853085,    0,    100,  OUT-25
0.528732258310002,     0.510570045015457,     0,    100,  OUT-26
-0.322219210307012,    0.660614527078256,     0,    100,  OUT-27
-0.72785263527402,     -0.102290156957336,    0,    100,  OUT-28
-0.127639048345019,    -0.723837904583177,    0,    100,  OUT-29
1.3744743419983,       -0.0961033005401496,   0,    100,  REM-0
0.516229516152395,     1.27748386991625,      0,    100,  REM-1
-1.05556260315064,     0.885601555597299,     0,    100,  REM-2
-1.16852882789487,     -0.730087716466084,    0,    100,  REM-3
0.33338759996287,      -1.33689441220136,     0,    100,  REM-4
2.42770680575767,      0.883278661577965,     0,    100,  REM-5
-0.0902171774699261,   2.5817321584955,       0,    100,  REM-6
-2.48336178067584,     0.711832969911033,     0,    100,  REM-7
-1.44523995726277,     -2.14143146932642,     0,    100,  REM-8
1.59111199369102,      -2.03541207414717,     0,    100,  REM-9
3.49024618625907,      3.36453476899044,      0,    100,  REM-10
-2.128637528275,       4.35494385303548,      0,    100,  REM-11
-4.79948832438962,     -0.673704478204421,    0,    100,  REM-12
-0.843526013707927,    -4.77263178163862,     0,    100,  REM-13
4.28139376633963,      -2.27314610540949,     0,    100,  REM-14
3.43833643732577,      8.44341802646415,      0,    100,  REM-15
-7.00450635187936,     5.84251439788713,      0,    100,  REM-16
-7.74565600589814,     -4.8139345675157,      0,    100,  REM-17
2.22204112116356,      -8.8390899569087,      0,    100,  REM-18
9.09013075206413,      -0.632954869555381,    0,    100,  REM-19
-0.621566273798893,    17.2574491546163,      0,    100,  REM-20
-16.637004164102,      4.69330222928319,      0,    100,  REM-21
-9.86117970502325,     -14.24666979127,       0,    100,  REM-22
10.8344585641487,      -13.5278681109306,     0,    100,  REM-23
16.2836852578837,      5.82713783211864,      0,    100,  REM-24
-16.3603091706194,     30.0074264453148,      0,    100,  MAX-0
-33.5504070214281,     -4.4414038534658,      0,    100,  MAX-1
-6.63294832781891,     -33.2280286706305,     0,    100,  MAX-2
30.5950746693439,      -15.142827975001,      0,    100,  MAX-3
25.7210152122008,      22.7385013719281,      0,    100,  MAX-4
```

SNLD 3 arm asymmetric array (Figure 2)

```
# This is a comment
# SNLD defined core + central area
# Longitude, Latitude, Elevation, Diameter, Name
-0.00179666916119919,  0.00179666916031584,   0,    140,  CORE-0
0.00179666916119919,   0.00179666916031584,   0,    140,  CORE-1
-0.00179666916119919,  -0.00179666916031584,  0,    140,  CORE-2
0.00179666916119919,   -0.00179666916031584,  0,    140,  CORE-3
0.00433754304756353,   0.00433754303513396,   0,    140,  CORE-4
-0.00433754304756353,  0.00433754303513396,   0,    140,  CORE-5
```

0.00433754304756353,	-0.00433754303513396,	0,	140,	CORE-6
-0.00433754304756353,	-0.00433754303513396,	0,	140,	CORE-7
0.00490859178131008,	0,	0,	140,	CORE-8
-0.00490859178131008,	0,	0,	140,	CORE-9
0,	0.00490859178131008,	0,	140,	CORE-10
0,	-0.00490859178131008,	0,	140,	CORE-11
0.00288919554241276,	-0.00889202948140571,	0,	140,	CENT-0
0.00934963310047343,	-1.14496200499337e-17,	0,	140,	CENT-1
0.00288919554241278,	0.0088920294814057,	0,	140,	CENT-2
-0.00756401209264948,	0.0054955764348406,	0,	140,	CENT-3
-0.00756401209264949,	-0.00549557643484058,	0,	140,	CENT-4
0.0104831778438453,	-0.00655061648014342,	0,	140,	CENT-5
0.00946948667934615,	0.00794584269296427,	0,	140,	CENT-6
-0.00463071327360493,	0.011461417380083,	0,	140,	CENT-7
-0.012331424776639,	-0.000862297214629407,	0,	140,	CENT-8
-0.00299052647294755,	-0.0119943463782744,	0,	140,	CENT-9
0.0161846437534262,	0.00227460331102306,	0,	140,	CENT-10
0.0028380537100366,	0.0160954019788586,	0,	140,	CENT-11
-0.0144306302226282,	0.007672902067201 3,	0,	140,	CENT-12
-0.011756673692605,	-0.0113532875857553,	0,	140,	CENT-13
0.00716460645177037,	-0.0146896197713277,	0,	140,	CENT-14
0.0144590306334673,	0.0160583797829093,	0,	140,	CENT-15
-0.0108043412090372,	0.0187136671400135,	0,	140,	CENT-16
-0.0211364801539822,	-0.00449269743622899,	0,	140,	CENT-17
-0.00225872239200265,	-0.0214903070250911,	0,	140,	CENT-18
0.0197405131215547,	-0.00878904246160279,	0,	140,	CENT-19
-0.0243973888551506,	-0.0118994010898904,	0,	140,	OUT-0
-0.0110406967653533,	-0.0247978092426784,	0,	140,	OUT-1
0.00748206126729663,	-0.0260930466552317,	0,	140,	OUT-2
-0.0332919369978106,	-0.0493573113725475,	0,	140,	OUT-3
0.00622317516896131,	-0.0592095354265565,	0,	140,	OUT-4
0.0428263903198121,	-0.0413569533637765,	0,	140,	OUT-5
-0.00910871174057363,	-0.130260421656538,	0,	140,	OUT-6
0.0767522064077239,	-0.105640197953516,	0,	140,	OUT-7
0.126699778066988,	-0.0315897736796698,	0,	140,	OUT-8
0.125548664154515,	-0.257410970544195,	0,	140,	OUT-9
0.261636284802718,	-0.116487413776239,	0,	140,	OUT-10
0.275301846626132,	0.0789411805025181,	0,	140,	OUT-11
0.520772265533428,	-0.35125609132412,	0,	140,	OUT-12
0.624716147810949,	0.0656589832557517,	0,	140,	OUT-13
0.43636355347024,	0.451853951351957,	0,	140,	OUT-14
1.3744743419983,	-0.0961033005401496,	0,	140,	REM-0
1.11476161691132,	0.80981669571487,	0,	140,	REM-1
0.333387599962872,	1.33689441220136,	0,	140,	REM-2
2.71760793143448,	1.32473291093719,	0,	140,	REM-3
1.2305492021888,	2.76150598287241,	0,	140,	REM-4
-0.833988126470445,	2.90586547451415,	0,	140,	REM-5
3.72576611478724,	5.50280137454594,	0,	140,	REM-6
-0.697396553496416,	6.60569693093697,	0,	140,	REM-7
-4.78837350479764,	4.60873206871092,	0,	140,	REM-8
1.04813659160272,	14.65971396853,	0,	140,	REM-9
-8.76385019783159,	11.843793696951,	0,	140,	REM-10
-14.2778777002257,	3.51871468365375,	0,	140,	REM-11
-16.3603091706194,	30.0074264453148,	0,	140,	MAX-0
-31.4571591189544,	13.0804395682714,	0,	140,	MAX-1
-32.7704706117689,	-8.82237538378424,	0,	140,	MAX-2

SNLD 3 arm symmetric array (Figure 5)

```
# This is a comment
# SNLD defined core + central area
# Longitude, Latitude, Elevation, Diameter, Name
-0.00179666916119919,   0.00179666916031584,    0,     140,   CORE-0
0.00179666916119919,    0.00179666916031584,    0,     140,   CORE-1
-0.00179666916119919,   -0.00179666916031584,   0,     140,   CORE-2
0.00179666916119919,    -0.00179666916031584,   0,     140,   CORE-3
0.00433754304756353,    0.00433754303513396,    0,     140,   CORE-4
-0.00433754304756353,   0.00433754303513396,    0,     140,   CORE-5
0.00433754304756353,    -0.00433754303513396,   0,     140,   CORE-6
-0.00433754304756353,   -0.00433754303513396,   0,     140,   CORE-7
0.00490859178131008,    0,                      0,     140,   CORE-8
-0.00490859178131008,   0,                      0,     140,   CORE-9
0,                      0.00490859178131008,    0,     140,   CORE-10
0,                      -0.00490859178131008,   0,     140,   CORE-11
0.00288919554241276,    -0.00889202948140571,   0,     140,   CENT-0
0.00934963310047343,    -1.14496200499337e-17,  0,     140,   CENT-1
0.00288919554241278,    0.0088920294814057,     0,     140,   CENT-2
-0.00756401209264948,   0.0054955764348406,     0,     140,   CENT-3
-0.00756401209264949,   -0.00549557643484058,   0,     140,   CENT-4
0.0104831778438453,     -0.00655061648014342,   0,     140,   CENT-5
0.00946948667934615,    0.00794584269296427,    0,     140,   CENT-6
-0.00463071327360493,   0.011461417380083,      0,     140,   CENT-7
-0.012331424776639,     -0.000862297214629407,  0,     140,   CENT-8
-0.00299052647294755,   -0.0119943463782744,    0,     140,   CENT-9
0.0161846437534262,     0.00227460331102306,    0,     140,   CENT-10
0.0028380537100366,     0.0160954019788586,     0,     140,   CENT-11
-0.0144306302226282,    0.0076729020672013,     0,     140,   CENT-12
-0.011756673692605,     -0.0113532875857553,    0,     140,   CENT-13
0.00716460645177037,    -0.0146896197713277,    0,     140,   CENT-14
0.0144590306334673,     0.0160583797829093,     0,     140,   CENT-15
-0.0108043412090372,    0.0187136671400135,     0,     140,   CENT-16
-0.0211364801539822,    -0.00449269743622899,   0,     140,   CENT-17
-0.00225872239200265,   -0.0214903070250911,    0,     140,   CENT-18
0.0197405131215547,     -0.00878904246160279,   0,     140,   CENT-19
-0.0243973888551506,    -0.0118994010898904,    0,     140,   OUT-0
0.0225038787237516,     -0.0151790571157773,    0,     140,   OUT-1
0.00189351044808082,    0.0270784589506031,     0,     140,   OUT-2
-0.0332919369978106,    -0.0493573113725475,    0,     140,   OUT-3
0.0593906524016956,     -0.00415299823071633,   0,     140,   OUT-4
-0.0260987311231115,    0.0535103112738759,     0,     140,   OUT-5
-0.00910871174057363,   -0.130260421656538,     0,     140,   OUT-6
0.117363221808462,      0.0572418089007908,     0,     140,   OUT-7
-0.108254545320338,     0.0730185298309619,     0,     140,   OUT-8
0.125548664154515,      -0.257410970544195,     0,     140,   OUT-9
0.160151625112954,      0.237432880133506,      0,     140,   OUT-10
-0.285698539406724,     0.0199779044393685,     0,     140,   OUT-11
0.520772265533428,      -0.35125609132412,      0,     140,   OUT-12
0.0438197632918725,     0.626626764095882,      0,     140,   OUT-13
-0.564588104262503,     -0.275361441171668,     0,     140,   OUT-14
1.3744743419983,        -0.0961033005401496,    0,     140,   REM-0
-0.604094714189966,     1.23836189897342,       0,     140,   REM-1
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-0.770574499271805,	-1.14223789007484,	0,	140,	REM-2
2.71760793143448,	1.32473291093719,	0,	140,	REM-3
-2.50697154313962,	1.68994391789743,	0,	140,	REM-4
-0.211074135660614,	-3.01570601099686,	0,	140,	REM-5
3.72576611478724,	5.50280137454594,	0,	140,	REM-6
-6.62621026537878,	0.462307553144085,	0,	140,	REM-7
2.92234719089457,	-5.96743087594079,	0,	140,	REM-8
1.04813659160272,	14.65971396853,	0,	140,	REM-9
-13.2643146480527,	-6.38523880012148,	0,	140,	REM-10
12.2672722843834,	-8.15577265148061,	0,	140,	REM-11
-16.3603091706194,	30.0074264453148,	0,	140,	MAX-0
-20.5296166724602,	-27.4708930145061,	0,	140,	MAX-1
33.7444041651143,	-2.22445467676296,	0,	140,	MAX-2