SKA Mask Specifications

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1 Introduction

During the meeting on WP3 in May 2009, see [2], it was agreed that:

1. per action item 3.1.1.3 the SPDO was to deliver a mask specification report, detailing geographical constraints. Example information: slopes, hills, roads, outcrops, precursor, other installations and existing infrastructure. This should include a specification for the GIS data source, which should preferably be common for both continents and have high enough resolution to allow accurate determination of buffer zones and derived parameters, such as slope.

2. per action item 3.1.2.3 the SPDO was to deliver, together with the site proponents, a report on the RFI mask constraints, specifically the aspect of EMI buffer zone requirements. The classification of the types of radio interference to be shared under EMI is the aggregate of unintentional transmissions coming from population and industry centres, traffic and generally unlicensed devices. At the meeting it was agreed that conservative estimates of required buffer zones are to be assumed, based on best estimates of likely transmission levels and best-practice propagation models. If it is considered that, for a particular location, geographic shielding will result in a smaller mask buffer size, this then will be demonstrated through best-practice industry standard propagation modelling, and possibly tested through some field measurements if required for verification. Radio interference originating from intentional transmissions by licensed sources, such as CB radio and mobile telephones, do not classify as EMI for the purpose of this document. Other methods of evaluation apply, as well as regulatory measures to prevent these sources from being used near telescope locations.

This document captures the views that have led to geographic and EMI mask considerations in the community, and distils specifications from these based on the earlier agreement in [2] that conservative estimates should be used, consistent with SKA specifications for radio-quiet protection from SKA Memo 73.

It is understood that not all sites may be able to satisfy all constraints in placement of every array-station. Array-stations may be placed in “non-compliant” locations and this will be clearly indicated and taken into consideration during assessment of configurations.

This document is structured to:
- summarise the general EMI considerations in chapter 2;
- give the **definitions** of the mask categories in chapter 3;
- list the **standards** and **methods** that apply per category in chapter 4;
- give the **specifications** for the corresponding buffer zones in chapter 5;
- list **data sources** for the various categories in chapter 6.

The chapters on definitions, standards and methods, specifications and data sources discuss the various categories in the same order.

2 EMI considerations

Contributions in thinking about the EMI masks have been forthcoming from both site proponents, South Africa and Australia. These contributions are summarised in [10]. Since the creation date of that document, three additional documents have been issued:

1. Reference [12], “Geographical Mask Considerations”, which is a collection of arguments of geographical, EMI and configurations design nature, by RSA. The document is based on an early version of [11].

2. Reference [14], “Calculation of buffer zones for intermediate stations of the SKA as a function of frequency”, which is a continuation of [5]. Based on the principles for analysis of required separation distances for EMI as given in [5], it expands the analysis for a frequency range of 70 to 1000 MHz.

3. Reference [15], ”Mining mask determination”, which is a summary of mask considerations that apply to mines.

4. Reference [16], “Buffer zones for arc welding equipment”, which provides an update on the determination of buffer zones that apply to arc welding equipment.

The principles for assessing EMI constraints used in the current document are based on arguments in all reference documents and email exchanges.

It is noted that for the EMI analysis intentional radio transmissions are not considered but should be addressed separately.

2.1 EMI mask principles

Assessment of required separation distances in the intermediate region follows the general reasoning of using an agreed maximum tolerable level of EMI in that region, estimating the level of EMI emanating from a range of sources, and finally to find required propagation attenuation for those sources and hence separation distances. These aspects are introduced in the following sections and in the chapters on mask standards and methods, chapter 4, these are expanded where needed.

2.1.1 Maximum EMI level in intermediate region

The ultimate goal is that at SKA sites the interference is below the agreed threshold of the Recommendation ITU-R RA769-2 levels, plus 15 dB. This is the level that was defined in [3] for the intermediate zone in the Radio Quiet Zone, i.e. 150 km from the SKA core (for naming definitions, see [4]). This level, at 100 MHz, is -245 dBW/Hz.

2.1.2 Levels of EMI sources

Masks have to be defined for a range of features that are associated with EMI. For this purpose the expected levels are to be estimated, using appropriate assumptions and applying agreed international standards. In practice that means for example using estimates of traffic densities, mixes of appliances and tools, estimates of practical generated EMI levels, international standards on maximum allowed EMI levels.

2.1.3 Propagation and separation levels

Recommendation ITU-R P1546-3 is used for estimating the required propagation loss as a function of distance and type of terrain between the interference source and the radio telescope in order to keep the level at the telescope below the maximum, while using Recommendation RA1513 to specify that the interference level can be exceeded for a maximum of 5% of time per day. For a given level of RFI a minimum separation distance can thus be calculated for a range of applicable scenarios.

The principle used in the determination of separation distances, see [14], is to apply the propagation attenuation for the frequency range of 70 MHz up to 1 GHz, of which the lower bound is the lowest frequency specified for the SKA. The most demanding combination of EMI levels and propagation attenuation for the separation distance is certain to be found within that range. The height of the receiving antenna is a parameter to be considered for establishing the propagation loss according to the rules of P1546-3. For the receiving antenna a height corresponding to dishes is used (15 m) for the lowest frequency that these are currently assumed to be operating, for which 300 MHz is taken. For frequencies lower than 300 MHz it is assumed that low antennas (1 m) are used. This cross-over frequency is a conservative figure, but reflects current (early 2010) design parameters.

2.1.4 Electric fences

The CISPR 14 standard gives disturbance limits for electric fences to 30 MHz. These can be extrapolated using the 20 dB per decade roll of as for power lines, taking a voltage of 11 kV, which comes close to the voltage used in electric fences. This level can then be used to find the minimum separation distance. It is noted that unlike power lines, electric fences are designed to be intentionally ‘sparking’ at regular intervals, for which a bigger separation distance than calculated, wherever possible, would be appropriate.

The specification for a separation distance to electric fences should be used to inform planners to require that these fences will not occur within the given distance from an SKA antenna. It will most likely not be possible to include these fences into a mask because there is no data source containing all of these. In practice that means that fences will have to be removed and replaced by non-electric means within that distance to antennas.

For the purpose of this document, to provide specifications for the masks, the electric fences will not be considered any further.

3 Mask category description and definitions

The following subsections describe and give the definitions for the mask categories used in this document.

3.1 Populated and industrial areas

SKA receptors cannot be placed too closely to populated and industrial areas because of RFI/EMI and for safety reasons. The analysis in input documents [5], [10] and [14] concerning EMI arguments, leads to separation distances that are much larger than needed for other (geographical) reasons. Therefore there will be no need to generate separate geographical masks for populated and industrial areas, on the condition that the EMI masks are complete.

3.1.1 Farms

Definition: An individual, active, as opposed to abandoned, farm, farmstead, homestead or station (Australia) where people live or are active and where tools and vehicles are used.

3.1.2 Towns

The generic term ‘town’ is used to denote human settlements or population centres. Classification of grades of human settlements is taken as given in [12].

3.1.2.1 Towns grade 1

Definition: Settlements of up to 100 people.
Note that a homestead is considered to be a building or an isolated group of buildings belonging to the same farming operation, operated by a small number of people, up to perhaps 20, while a small town is a collection of dwellings with the stated maximum number of people.

3.1.2.2 Towns grade 2

Definition: Settlements of 100 to 1000 people.

3.1.2.3 Towns grade 3

Definition: Settlements of 1000 to 5000 people.

3.1.2.4 Towns grade 4

Definition: Settlements of more than 5000 people.

3.1.3 Mines

Active mines (i.e. mine sites where current mining operations are occurring) constitute areas of avoidance for SKA receptors for RFI/EMI and safety reasons. Mineral reserves where it is known that the deposits will be developed and exploited as future mining operations within the SKA lifetime must also be included as areas of avoidance with appropriate EMI buffer zones applied. Appropriate EMI buffer zones lead to separation distances that are much larger than needed for other (geographical) reasons. Therefore there will be no need to generate separate geographical masks for mines, on the condition that the EMI masks are complete.

Minerally prospective areas that are not being actively mined and there are no known plans to mine these regions, do not have EMI buffer zones applied to them. These will have to be flagged in the mask documentation, see chapter 7, along with the methods for and results of assessing the possibility for these mines becoming active within the lifetime of the SKA. These cases will be subject to independent consultancy assessment during the WP3.8 investigations for the sustainability of the quality of science.

Definition: A mining operation is one that is being actively mined or where it is known that it will be actively mined during the lifetime of the SKA.

3.1.4 Power lines

Power lines are a known source of EMI and buffer zones are required around power line infrastructure. The EMI buffer zones will be greater than the geophysical buffer zones.

It is recognised that specially designed power lines to the SKA sites may have substantially reduced emission levels due to sparking. For this, the separation distances as calculated for standard power lines may not apply. Where it can be demonstrated by in-field measurements that lower levels of emission result, then smaller buffer zones based on the lower levels of emission can be taken and put in the EMI mask. The mask documentation, see chapter 7, must then list the separation distance that was taken, and outline the field measurements that were taken and the results obtained.

It is recognised that these newly designed power lines are likely to deteriorate in noise performance over time. It is stressed that when special low emission levels are taken for mask definition, the sites must make commitments to maintain the power lines to that emission specification during the lifetime of the SKA. This point shall specifically be reported in the mask documentation, see chapter 7, and the maintenance regime must be described so that it can be costed as part of the infrastructure costing to be completed by an industry consultant.

Definition: Power lines are the commonly understood structures where overhead power cables are used to distribute electrical power.

3.1.5 Arc welders

Arc welding activities at farmsteads, in towns and industrial areas, will cause high levels of EMI for the duration of their actual use. Therefore known presence and active use of this kind of equipment will lead to appropriate buffer zones. Because of the nature of this class of equipment it will not be in reason to assume that every farm or town has operating arc welding equipment present. Industrial areas may have a likely arc welding threat, and the buffer zone should apply there.

Definition: Arc welding activities need to be considered and buffer zones applied if necessary in industrial areas.

3.2 Bodies of water

It is obvious that open seas, rivers and lakes are not suitable for locating SKA stations. That is also true for islands that have no good access for services (power, fibre) or for people. It is important to stay away from areas near bodies of water, floodplains that are at risk of inundation, or applicable watercourses.

The masks for bodies of water are of geographical nature only.

3.2.1 Water Body

Definition:
A water body is defined as:
1. a named perennial or seasonal body of water. ‘Named’ for the reason that the information is available in an official hydrological survey;
2. an unnamed but locally recognised body of water, either perennial or seasonal
3. a floodplain, i.e. an area that is subject to seasonal or occasional flooding (greater than or equal to once every 25 years) to a depth larger than tbd

3.2.2 Watercourse

Definition:
A watercourse is a named or unnamed natural channel which water flows along from time to time. These can be further defined in a hierarchy of mask importance:

1. Major watercourse – Perennial (named and unnamed)
2. Major watercourse – Seasonal (named and unnamed)
3. Minor watercourse – Perennial (named and unnamed)
4. Minor watercourse – Seasonal (named only)

It is anticipated that a seasonal minor watercourse (unnamed), is minor in name and nature and therefore could be diverted during standard earthworks and needs not be included in the mask analysis.

3.3 High wind areas

Excessive winds act as a significant cost driver for dish structures, foundations and bearings. Survival wind speeds of greater than 160 km/hr for telescope structures would place significant additional cost constraints on the SKA. These regions should be masked out.

Definition: Regions defined by national or international standards to be areas where wind speeds greater than 160km/hr are likely to be exceeded should be masked out. Where no national standards exist, regions known from local historical records to be areas where wind speeds greater than 160km/hr are likely to be exceeded should be masked out and SKA stations that fall within these areas should be flagged as non-compliant.

3.4 Roads

It is essential to site SKA array-stations away from roads to protect the receptors from RFI and EMI influences caused by vehicles and people. The geographical buffer zone around roads, to protect receptors from other influences associated with roads, will be much smaller than the EMI buffer zones. Therefore there will be no need to generate separate geographical masks for roads, other than service roads mentioned below, on the condition that the EMI masks are complete. The definition of what constitutes a minor or a major road therefore follows the same definition as used for EMI considerations, see [5], [10] and [14].

For permanent and temporary service roads on the site the EMI argument does not apply and a geographical buffer zone around existing and planned roads of this type must be applied. The size of the buffer zone is based on the requirement to be able to transport major telescope structures when other telescopes are already installed, as will be the case during the transition from SKA phase 1 to phase 2. The minimum distance between dishes is assumed to be 22.5 m (actually 1.5D).

3.4.1 Minor roads

Definition: A road used by the public (i.e. not a radio astronomy observatory service road) with on average 10 vehicles per day passing a point of closest approach to the site.

3.4.2 Major roads

Definition: A road used by the public with traffic that can be seen as continuous during more than 5% of the day.

3.4.3 Intermediate Roads

These will need to be assessed on a case-by-case basis depending on the traffic density, interpolating results for minor and major roads.

3.4.4 Service roads

Definition: Private roads (i.e. not used by the public) that provide access to telescope installations for SKA or precursor installations. For cases where these roads do not exist or have not been planned yet, it is the responsibility of the final layout design process to plan for this kind of new infrastructure.

3.5 Railroads

The same argument as for roads is true for railroads: the buffer zone will be determined by RFI and EMI considerations primarily. Likewise, there will be no need to generate separate geographical masks for railroads on the condition that the RFI masks are complete. The definition of what constitutes a railroad for local transport or for heavy use therefore follows the same definition as used for EMI considerations, see [5], [10] and [14].

3.5.1 Railroad, light use

Definition: A railway with on average of order four trains per day passing the point of closest approach to the site.

3.5.2 Railroad, heavy use

Definition: A railway with on average one 2 km long train per 4 km segment of rail line at a time.

3.5.3 Railroad, intermediate use

These will need to be assessed on a case-by-case basis, depending on the usage, interpolating the results for minor and major railroads.

3.6 Slopes and rugged terrain

Terrain with an average slope above 5 degrees is considered to be unsuitable for building because of cost and antenna shadowing considerations. The slope should be less than 5 degrees and be based on digital elevation model data of sufficient resolution to derive the slope.

In general, where there would be a significant cost penalty to build and operate a station due to the ruggedness of the terrain, those areas should be masked out. This includes mountains, but areas in mountainous or hilly terrain that have reasonably good access for services and people and are flat enough (i.e. slope less than 5 degrees) and have acceptable sky visibility (see 3.7) can be acceptable. The increased cost of construction in such regions will be estimated during the detailed infrastructure costing exercise to be undertaken when array configurations are determined. An example of such a location would be the top of a mesa. On the other hand, a flat valley floor may not be suitable because of mountains or hills blocking the view down to the horizon, thereby violating the sky visibility specification.

The masks for slopes and rugged terrain are of geographical nature only.

3.6.1 Digital Elevation model (DEM)

Definition: A DEM is a digital representation of ground surface topography or terrain

3.6.2 Slope

Definition: The difference in terrain elevation, identifying the tilt or incline of the land, where the maximum rate of change in elevation is determined by the relation to neighbouring land. For a surface it is the maximum rate of change in elevation over each cell and its 8 neighbouring cells, expressed in degrees of tilt.

3.6.3 Rugged terrain

Definition: Terrain with a slope exceeding the slope specification or terrain where there is high variance of elevation surrounding it. For a surface it is where there is a high variance from one cell with the neighbouring cells, expressed as standard deviation (TBD).

3.7 Horizon limit

The horizon limit is the minimum elevation required to be observable from all antennas. This minimum elevation shall be 15°. In individual cases where a small nearby obstruction can be levelled off at limited cost, such an obstruction would not disqualify the location, but the obstruction should be noted in the mask documentation, see chapter 7, and the cost involved will be estimated during the detailed infrastructure costing exercise to be undertaken when array configurations are determined.

See 3.9 and [9] for considerations of horizon limits with respect to different types of SKA receptor technologies, dishes and aperture arrays, near site infrastructure.

It is noted that in the most dense parts of the core for the dishes, that the minimum distance for a portion of the dishes is such that in fact the specification for the horizon limit cannot be met because of mutual obstruction of the sky. This “shadowing” effect is recognised as a consequence of the requirement to place some of the dishes very close together. It is up to the configurations design task force (CTF) to minimise these occurrences while meeting the scientific requirements as much as possible.

The masks for horizon limit are of geographical nature only.

Definition:
The horizon limit is defined as that minimum elevation (15 degrees) for which no obstructions, manmade or natural, should obstruct the view of the receptors in all azimuth directions, as measured from the base level of the antenna structure in the direction of the primary beam.

3.8 Environmental and cultural exclusion areas

These areas include, for example, protected parks and cultural heritage areas. If for some of these areas no GIS data source can be mined for this kind of information, the areas should be excluded and that information put into the mask by digitising the relevant areas. The following should be identified and masked as a minimum requirement:

- Reserves (National Parks, Nature Reserves, Conservation parks etc)
- Environmental Sensitivity (Public Drinking water source areas, Environmentally Sensitive areas, Threatened Ecological Communities)
- Heritage sites (Aboriginal heritage sites)
- Geoheritage (possible heritage sensitivity)
- Other private or inaccessible land

Any other areas to be excluded for a particular location should also be identified to ensure that a complete list of excluded areas is created.

Definition:
Environmental and cultural exclusion areas are defined as those areas where it would not be acceptable to site array-stations due to environmental, social, logistical or legal reasons.

3.9 Site infrastructure

At the inner region of the array it will be inevitable that some areas will not be available for placing receptors, because of the presence of precursor telescopes and other existing (and remaining) and planned infrastructure, both buildings and constructions, but also infrastructure in the ground.

For defining the no-go areas associated with buildings, constructions and other infrastructure it is required to use a buffer zone, which takes the horizon limit argument, see chapter 3.7, of minimum elevation of 15° into account for the SKA dishes. Likewise for the precursor telescopes the SKA dishes should not obstruct the view of the telescopes.

The term ‘dishes’ was used explicitly here, because for the aperture array elements a more restrictive maximum height for infrastructure should be counted with. As described in [9], no site structures should be seen from ground level up to a minimum elevation angle of 5°. It is therefore advisable to keep the cores of the aperture arrays away from buildings and to keep those buildings low.

The masks for slopes and rugged terrain are of geographical nature only. Implicit in this statement is that isolation from RFI/EMI sources in the site's inner region must be achieved.

Definition:
Existing infrastructure comprises of precursor telescopes and other existing (and remaining) and planned infrastructure, both buildings and constructions, and infrastructure in the ground.

4 Mask standards and methods

For each of the mask categories the standards that apply and comments on the methodology are listed.

4.1 Populated and industrial areas

4.1.1 Farms

When access roads to a farmstead are such that the roads fall in the category defined for minor roads, then the same buffer zones as for the minor roads should apply. If on the other hand the traffic density is less, then the zone can be smaller. This must then be noted in the mask documentation, see chapter 7.

For the analysis a mix of appliances, tools, equipment and on-site vehicles is assumed to be present and active, both indoors and outside. CISPR standard 14-1:2003 is used for finding the emission limits for the appliances and tools and CISPR standard 12:2006 for the vehicles. This then leads to a minimum separation distance.

The mix is taken to include:
7 ordinary household appliances
2 tools <700 W
1 tool 700-1000W
1 tool >1000W
1 vehicle, emitting at 20 dB less than the standard.
This is the ‘reduced mix’ mentioned in [14], which takes into account that not all equipment present at a farm will be switched on at the same time.

It is noted that special machining and welding equipment may produce very high levels of RFI. If farms are present where this work takes place for >5% of the time, then buffer zones applicable to this equipment must be used.

4.1.2 Towns

Roads will lead to towns and they must be accounted for in the same manner as minor and major roads. Towns can be seen as a collection of farmstead-like environments, with an aggregate of household and business appliances and machines. Bigger towns may include industrial areas where very radio noisy activities, such as welding, takes place.

4.1.2.1 Towns grade 1 (<100)

Assuming 5 people per dwelling, there are 20 dwellings per 100 people town. Further assuming that on average a third of the devices are in use, this gives 7 equivalent dwellings, which each is assumed to equal the emission of a farm, see 4.1.1. No additional clutter is assumed. This then leads to a minimum separation distance.

4.1.2.2 Towns grade 2 (100-1000)

Assumptions are:
200 dwellings
one third of these are active
5 dB clutter
These parameters then lead to a minimum separation distance.

4.1.2.3 Towns grade 3 (1000-5000)

Assumptions are:
1000 dwellings plus 50 business premises
one third of these are active
10 dB clutter

These parameters then lead to a minimum separation distance.

4.1.2.4 Towns grade 4 (>5000)

Assumptions are:
2000 dwellings plus 100 business premises
one third of these active
10 dB clutter
These parameters then lead to a minimum separation distance.

4.1.3 Mines

Appropriate buffer zones are required around active mines and future mining areas within the 180km radius zone.

The size of the buffer zone depends on the scale and type of mining operation present. The following procedure should be followed:

Appropriately complete databases should be used to determine the scale of present and future mining activity at any identified location. The following buffer zones are appropriate:

Activity	**Infrastructure present**	**EMI Buffer zone distance**	**Comment**
Small scale end-of life gold mining	Caravans, crushers, satellite phone use, metal detectors?	14 km	As for farmstead
Larger scale underground gold mining mine entrance and operations	Trucks, mine shaft, sometimes processing plant	14 km	As for farmstead
Mine camp operations	Accommodation huts, RF comms, vehicles	21 km	As for grade 1 town
Iron ore extraction	Vehicles, diggers	21 km	As for collection of several vehicles – grade 1 town operations
Crushing plant	Crushing plant, diesel generator	14 km	As for farmstead
Mining truck haul road within mine site	Mining trucks, several per day	14 km	As for minor road with 3 m vehicle height
Prospective mine area	Obtain assessment from geological survey team as indicated below	case-by-case determination based on likely mining operation	Defined based on information received (see below).
Rail line for mines	Rail line	14.5 km	As for single rail line carrying 8 trains per day (3 m vehicle height)
Large-scale surface mining operation	Accommodation, comms, mine processing factory	>= 21km depending on scale of activity and equipment used.	

The following process should be followed before confirming an array-station site, even if the array-station site is in an apparently acceptable area:

1. The site should be identified by latitude and longitude.

2. Any nearby mining licenses should be identified on approved databases, and the type of license should be identified.

3. A geological survey team should be consulted for an assessment of the mineral prospectivity of the area, and the likelihood and scale of any mining development in the future.

4. The appropriateness of buffer zones already established should be checked and adjusted if necessary.

World-standard geological survey and mapping services should be made available to respond to queries during the process described above.

Note that the buffer zones defined above do not take into consideration the existing Mineral Resource Management Area controls implemented by the Government of Western Australia, which require mining operations to be consistent with the radio-quietness requirements of the radio astronomy activities. They thus represent a particularly conservative approach within 80km radius of the core site.

4.1.4 Power lines

Emission powers have been derived for high voltage power lines, for 60 MHz and 20dB per decade roll off in [14], with an Australian standard as basis for limits on interference – AS/NZS 2344:1997. It is noted that above a voltage of 66 kV coronal discharge dominates, while spark gap noise is seen below that voltage as well. Both effects diminish at approximately 20 dB per decade as frequency increases from the reference frequency of 60 MHz in the standard. The derived levels of EMI for a range of line voltages are then used to find the minimum separation distances for these cases.

Concerning dedicated power lines, especially designed for the SKA, see the proviso in chapter 3.1.4.

4.1.5 Arc welders

An analysis of the required buffer zones around arc welders has been given in [16]. CISPR 11:2004 has been used for the limits for class A EDM and arc welding in several frequency domains. The results of those calculations is a buffer zone of 21 km.

4.2 Bodies of water

The importance of waterways in the environment requires a standardised approach to enable management of riparian and foreshore land surrounding bodies of water. Floodplains or areas subject to inundation also need to be avoided.

4.2.1 Water Body

Appropriate buffer zones are required around a water body. This buffer distance needs to be set to 50m, no development is allowed in this zone.

4.2.2 Watercourse

Appropriate buffer zones are required along a watercourse. A watercourse is generally displayed as a centreline. To allow for the actual width of the watercourse and a water body buffer of 50m, all major water course buffer distances need to be set to 100m either side of the centreline or 50m from the edge of bank, if defined (for both perennial and seasonal, named and unnamed watercourses). All minor watercourse buffer distances need to be set to 60m either side of the centreline or 50m from the edge of bank, if defined (for perennial watercourses, named and unnamed, and seasonal named watercourses only).

4.2.3 Floodplain

For floodplains actual 25 year historic data shall result in an exclusion area based on inundation mapping using up to date datasets or other adequate data. The source of information should be described. If adequate data do not exist this should be flagged as a risk in the appropriate documentation.

4.3 High wind areas

The areas where high wind (>160km/hr) is likely to occur, according to the definition given in chapter 3.3, must be taken into account as exclusion zones and SKA stations that fall within these areas should be flagged as non-compliant.

4.4 Roads

4.4.1 Minor roads

EMI considerations dominate for the masks.
Local traffic applies, where the interference is assumed to come from a single vehicle on the road. It is further assumed that the local road has on average 10 vehicles per day passing the point of closest approach to the site travelling at a certain speed. The speed and the number of vehicles determine the separation distance at which the maximum interference level is exceeded for 5% or less of time per day. The analysis is based on the limits for radio emissions from complete vehicles given in CISPR standard 12:2006.

4.4.2 Major roads

EMI considerations dominate for the masks.
For this type of road it is assumed that traffic is continuous, at least for more than 5% of the day. The road has four lanes with a total density of 80 vehicles per km of road (one vehicle per lane per 50 m). An analysis of the aggregate emissions arriving at the receiver then leads to a minimum separation distance to the major road. The analysis for major roads relaxes the applied CISPR emission levels, for a large number vehicles, by 20 dB, on the basis of unpublished measurements in Australia, see also [6].

4.4.3 Service roads

For permanent service roads on the site the EMI argument does not apply and a buffer zone around existing and planned roads of this type must be applied. The size of the buffer zone is based on the requirement to be able to transport major telescope structures when other telescopes are already installed, as may be the case during the transition from SKA phase 1 to phase 2. The minimum distance between dishes is assumed to be 22.5 m (actually 1.5D).

4.5 Railroads

4.5.1 Railroad, local transport

Analogous to the analysis for minor roads, in this case of order 4 trains per day. The maximum level of emissions from a train is taken from EN 50121-2:2006, reduced by 15 dB for actual emissions.

4.5.2 Railroad, heavy use

A similar approach as for major roads is used, with the assumption of continuous traffic of 2 km long trains and one train per 4 km segment. Again the analysis assumes a 15 dB reduction with respect to EN 50121-2:2006, for the actual emissions.

4.6 Slopes and rugged terrain

4.6.1 Digital Elevation Model (DEM)

A minimum DEM shall be used for all raster analysis (slope, rugged terrain and horizon limit).

This DEM shall be derived from 20m contours or from 1 second (30m x 30m) Shuttle Radar Topography Mission (SRTM) data, as a minimum. The sampling distance of the DEM shall be 30m x 30m minimum and shall extend 20km beyond the study area (180km from the proposed Core), to allow for horizon limit analysis.

4.6.2 Slope

The definition in chapter 3.6.1 indicates that the slope information must be derived from terrain elevation sources with sufficient resolution to arrive at accurate slopes. In [12] a method is described:
1. for each cell there are 8 neighbouring cells;
2. calculate the slope to each of the neighbour cells, which (in radians) is the difference in elevation per cell-pair, divided by the distance between cells (equal to the grid resolution for the four orthogonal cells and equal to √2 times that resolution for the four diagonal cells);
3. take the maximum of those 8 slopes.

The base terrain model must use a maximum cell size no larger than 30m x 30m to derive and mask the areas of slope greater than 5 degrees.

4.6.3 Rugged terrain

The method would be based on the minimum DEM, see chapter 4.6.1, and then a standard deviation of "Std Dev = 6" shall be applied using an overlapping neighbourhood statistics function (standard deviation) with a neighbourhood of 3 x 3 cells

The exclusion zones shall be automatically extracted or digitized. The mask documentation, see chapter 7, shall reflect the methods used.

The base terrain model must use a maximum cell size no larger than 30m x 30m to derive and mask the areas

4.7 Horizon limit

The method to arrive at horizon limit data can follow a procedure to:
1. evaluate terrain elevations in all directions from the cell under investigation up to a distance adequate to check for any visibility blockage. The method used must be outlined so it can be verified.
2. to calculate the horizon limits in these directions and for these distances;
3. to take the maximum of the horizon limits in all directions and distances.

The method will use a "Visibility" tool that systematically analyses the centroid of each cell within the study area using the minimum DEM and searches that DEM for any cells visible above 15 degrees from that cell. If other cells are visible, the cell containing the centroid being analysed will be masked out. The method will then analyse every subsequent cell within the study area.

The base terrain model must use a maximum cell size no larger than 30m x 30m to derive and mask the areas

4.8 Environmental and cultural exclusion areas

Appropriate data sources must be identified and used to derive the exclusion zones. If for some of these areas no GIS data source can be mined for this kind of information, the areas should be excluded and that information put into the mask by digitising the relevant areas.

4.9 Site infrastructure

Current, permanent infrastructure and future plans for infrastructure in the inner region of the site, as indicated in chapter 3.9, must be digitized and included as exclusion zones in the masks.

The horizon limit shall be applied for the dishes to ensure unobstructed view of the sky, as measured from ground level.

The elevation limit of 5° applies for aperture array elements.

For existing infrastructure in the ground – buried fibre and power, ducts, manholes, etc – a buffer zone of 2 m is to be applied.

5 Mask specifications

Based on the **descriptions and definitions** of the categories for the masks, in chapter 3, the appropriate **standards and methods**, in chapter 4, Table 1 provides the **specifications** for the buffer or exclusion zones, where the determining factor may be geophysical, EMI related or a combination of both.

Buffer and Exclusion Zone Specification			
Class	**Type**	**Separation distance (km), or exclusion zone**	**Notes**
Populated and industrial areas			
Farm/homesteads	EMI	13.5	
towns, grade 1	EMI	21	
towns, grade 2	EMI	27	
towns, grade 3	EMI	31	
towns, grade 4	EMI	37.5	
small-scale or underground gold mining	EMI	14	
larger scale underground gold mining - mine entrance and operations	EMI	14	
mine camp operations	EMI	21	
iron ore extraction	EMI	21	
crushing plant	EMI	14	
mining haul road	EMI	14	
rail line for mines	EMI	14.5	
large-scale mining operations	EMI	>=21	
Arc welders	EMI	21	
power lines, <11 kV	EMI	1	6 m
66 kV	EMI	4	20 m
132 kV	EMI	4.5	20 m
220 kV	EMI	7	36 m
330 kV	EMI	7.5	36 m
750 kV	EMI	8	36 m
Water body – named and unnamed	Geo	A buffer zone of 50 m around water bodies	
Major watercourse (perennial/seasonal – named and unnamed)	Geo	A buffer zone of 100 m either side of the centreline or 50m from the edge of bank, if defined	
Minor watercourse (perennial) – named and unnamed / Minor watercourse (seasonal) - named	Geo	A buffer zone of 60 m either side of the centreline or 50m from the edge of bank, if defined	
Floodplain/area subject to inundation	Geo	A buffer zone of 50 m around areas to be excluded	
cyclonic weather	Geo	Terrain with occurrence of cyclonic	

		activity within the intermediate region, based on 25 year historic data shall be excluded.	
minor roads	EMI	10.5	
major roads	EMI	33.5	
service roads	Geo	A buffer zone of 15 m on either side of the service road is to be applied.	
rail, local	EMI	10.5	
rail, heavy use	EMI	30.5	
slopes	Geo	Terrain with a slope exceeding 5° shall be excluded.	
rugged terrain	Geo	Terrain with large slope variation in the sense of the definition shall be excluded.	
horizon limit	Geo	Terrain with a horizon limit exceeding 15° shall be excluded. For sites where aperture arrays will be present the horizon limit will be 5°.	
environmental and cultural exclusion	Geo	Environmental and cultural zones shall be excluded.	
site infrastructure	Geo	The horizon limit shall be applied for the dishes to ensure unobstructed view of the sky, as measured from ground level. The elevation limit of 5° applies for aperture array elements. For infrastructure in the ground – buried fibre and power, ducts, manholes, etc – a buffer zone of 2 m is to be applied.	

Table 1, specified separation distances and exclusion zones

6 Mask data sources

The GIS data sources are listed here per category.

It is recommended that common data sources are used wherever possible. Sites may propose to use sources that are specific for their region of the world. The quality of the data sources shall be sufficient for the purpose of use. The scale of the data needs to be able to recognise and have mapped the smallest features required in the EMI and geographic mask, eg. grade 1 towns, homesteads etc. Assessment of this by consultants will be invited.
The data sources that have been used will be fully accounted for in the mask documentation.

6.1 Populated and industrial areas

6.1.1 Towns

Australia: (Landgate, Western Australia)

South Africa: Population data is sourced from Statistics South Africa, updated with a community survey dataset (2007). The 2009/2010 population estimate will be quality checked with a dwelling inventory derived off Spot 2.5m resolution satellite imagery.

6.1.2 Farms

Australia: (Landgate, Western Australia), enhanced by additional government department information

South Africa: ?

6.1.3 Mines

Australia: (Department of Mines and Petroleum, Western Australia)

South Africa: ?

6.1.4 Power lines

Australia: (Western Power, Western Australia)

South Africa: (including wind turbines) Data is sourced from Eskom, the national electrical distribution company, for high-voltage and medium-voltage networks. This was last updated in September 2009. The location of wind turbines, planned and existing, will be sourced from Eskom and the Department of Public Entreprise.

6.1.5 Industrial areas

Australia: Not applicable to Australia. All industrial areas are defined within the 'Towns' definition, (Landgate, Western Australia)

South Africa: Data is sourced from the National Land Cover Dataset for South Africa.

6.1.6 Airports and other transport hubs

Australia: (Landgate, Western Australia)

South Africa: Data is sourced from the Department of Land Affairs, Chief Directorate Surveys and Mapping. The custodian of this dataset is the South African Civil Aviation Authority.

6.2 Bodies of water

Australia: (Geodata Topo 250K Series 3 - Geoscience Australia)

South Africa: Data is sourced from the Department of Water, Forestry and Fisheries, on a 1:50,000 scale.

6.2.1 Floodplains

Australia: Defined areas are mapped as 'area subject to inundation' sourced from Geodata Topo 250K Series 3 - Geoscience Australia), enhanced by local knowledge at the core

South Africa: This data will be sourced from the 1:50,000 topographic series, further enhanced by the use of Council for Geoscience inundation mapping. In addition, the South African SKA Project Office has sourced 2.5m resolution colour Spot 5 satellite imagery annually since 2006.

6.3 Roads

Australia: The roads dataset has been compiled by Landgate by merging the roads layers from 1:25000, 1:50000 and 1:100000 digital datasets. (Landgate, Western Australia), the inner 180km is primarily 100,000 scale (+/-25m accuracy)

South Africa: Data is sourced from 1:50,000 topographic series with 2009 updates from the Northern Cape Department of Transport. This dataset also includes measured vehicular traffic volumes.

6.4 Railroads

Australia: Department of Mines and Petroleum, Western Australia

South Africa: Data is sourced from 1:50,000 topographic series with 2009 updates from the Northern Cape Department of Transport.

6.5 Slopes and rugged terrain

Australia: 20m resolution Digital Elevation Model (DEM) derived from 20m contours, (Landgate, Western Australia) enhanced by a 35km x 35km ALOS 5m DEM (with 2m contours) at the core

South Africa: 20m resolution Digital Elevation Model is derived from 20m contours sourced from 1:50,000 topographic series. These contours are originally digitised from 1:10,000 orthophotography.

6.5.1 Slope

Australia: (derived from DEM data)

South Africa: (derived data))

6.5.2 Rugged terrain

Australia: (derived from DEM data)

South Africa: (derived data)

6.6 Horizon limit

Australia: (derived from DEM data)

South Africa: ?

6.7 Environmental and cultural exclusion areas

6.7.1 Reserves

Australia: Department of Environment and Conservation)

South Africa: This data is sourced from the Department of Environmental Affairs.

6.7.1.1 National Parks

6.7.1.2 Nature Reserves

6.7.1.3 Conservation parks

6.7.2 Environmental Sensitivity

6.7.2.1 *Public Drinking water source areas*

Australia: Department of Water, Western Australia

South Africa: ?

6.7.2.2 *Environmentally Sensitive areas*

Australia: Department of Environment and Conservation

South Africa: ?

6.7.2.3 *Threatened Ecological Communities*

Australia: Department of Environment and Conservation

South Africa: ?

6.7.3 Heritage sites

Australia: (Aboriginal heritage sites) (Department of Indigenous Affairs)
South Africa: ?

6.7.4 Geoheritage

Australia: (possible heritage sensitivity) (Department of Mines and Petroleum, Western Australia)

South Africa: ?

6.7.5 Other private or inaccessible land

6.8 Site infrastructure

6.9 Geophysical information

Australia: Not a mask constraint but if required - Landsystems, geology and soils maps are available via Department of Agriculture and Food, WA, and Department of Mines and Petroleum, Western Australia

South Africa: A detailed survey has been undertaken by the South African Council for Geoscience. Further to this, a detailed soil map of South Africa, soil type maps and terrain type maps are available through the Agricultural Research Council: Institute for Soil, Climate and Water.

7 EMI mask documentation

A document shall be prepared that gives a complete overview of the information that has gone into the masks, either by automated GIS database extraction or by digitisation. GIS data sources shall be specified. That document shall also state that no exceptions to the rules were applied and where the masks lack required exclusion data.

The documentation shall include circumstances that have been mentioned in previous chapters.

The document will become part of the documentation attached to the final configuration design.

8 References

[1] SKA Memo 100, Preliminary Specifications for the Square Kilometre Array, 200712

[2] Notes, Meeting on WP3, Configurations Design and RFI monitoring, V1.0, 2009-06-11

[3] SKA Memo 73, Spectrum Protection Criteria for the Square Kilometre Array, November 2005

[4] Nomenclature for site characterisation regions, Michelle Storey, 2009-05-27

[5] Principles for placement of SKA sites in the intermediate zone (within 150 km of core), Carol Wilson, Ron Beresford, May 2009

[6] Response to Adrian Tiplady's comments of 17 July, Michelle Storey, Carol Wilson, 27 July 2009

[7] EMI from sources within Populated Area, Adrian Tiplady, 15 August 2009

[8] Vehicle EMI and Implications for Buffer Zones, Adrian Tiplady, September 2009

[9] Geographical considerations for the layout of the SKA core areas, SPDO, Version 1.0, 20090904

[10] SKA Mask EMI Considerations and Specification, Rob Millenaar, Version 1.1, 5 October 2009

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[12] Geographical Mask Considerations, Adrian Tiplady, 11 October 2009

[13] Comments on "Geographical Mask Considerations", Carol Wilson and Michelle Storey, 20 October 2009

[14] Calculation of buffer zones for intermediate stations of the SKA as a function of frequency (70 MHz to 1 GHz), Carol Wilson, 20 October 2009

[15] Mining mask determination V1, Michelle Storey, 9 November 2009

[16] Buffer zones for arc welding equipment, Carol Wilson, 27 November 2009

[17] Use of Arc Welding in the Mining Industry, C. van der Merwe, 30 November 2009

[18] Comments on the Current SKA Mask Criteria South Africa, 30 November 2009

[19] South African Response to Aurecon SKA Mask Analysis, A. Tiplady, A. Fortescue, 11 December 2009