Optimising SKA1-Mid Scale-Dependent Sensitivity

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Abstract

In this report we study the scale dependent sensitivity of the SKA1-Mid and SKA1-SUR baseline designs. We propose changes to the baseline design that enhance the sensitivity of SKA1-Mid at smaller angular scales (e.g. 0.4-1 arcsec at 650MHz) without compromising the performance at larger scales. The changes we propose are guided by the SKA1-Mid level-zero science requirements [2], which suggest that very long baselines (> 150km) are not necessary to achieve the SKA1-Mid science objectives. In particular, we show that a 254 dish layout with a maximum baseline of 120km improves the SKA1-Mid survey speed by more than 55% and is > 10 times faster than SKA-SUR as defined in the baseline design (see Table 12) on angular scales 0.4-1 arcsec (over 650-1000MHz), without compromising the performance at larger scales. We note that the 2nd generation configurations of R. Braun increase the maximum baseline of SKA1-SUR from ~ 50 km to > 70 km, in this case SKA1-Mid continues to have a higher survey speed (2.7 times faster than SKA1-SUR at the higher resolution). Such an improvement on these scales could be transformational for other sciences, such as cosmology with weak lensing. Furthermore, this layout spans significantly less space which could potentially reduce trenching and data transport costs. We also show that with a conservative addition of 12 dishes the SKA1-Mid survey speed can be improved by up 67% on the smaller angular scales.

Given the discrepancy with the figures in the L0 document we would like the project office to check both ours and their assumptions and ensure that this inconsistency is resolved as soon as possible.

1 Introduction

The SKA at mid frequencies (SKA-Mid) will be built in two phases, SKA-Mid phase one (SKA1-Mid) and phase two (SKA2-Mid) in South Africa, and SKA survey (SKA-SUR) in phase 1 in Australia. The key science goals for SKA1-Mid include the study of the history and role of neutral hydrogen in the Universe from the dark ages to the present-day, the use of pulsars as probes of fundamental physics [1] and continuum and HI surveys to pin down the cosmological model. The large emphasis on key science projects is outlined in several SKA memos, as the baseline design has emerged. It should however be noted that changes which do not compromise the key science cases are possible and such changes could be transformational for other science cases.

In this document, we attempt to gauge the scale-dependent sensitivity of the mid-frequency arrays described in the *SKA1 System Baseline Design* (BD) document [1]. The performance of this configuration is then compared to two alternative configurations and the SKA-SUR 1st and 2nd generation configuration[1].

The rest of this document is laid out as follows: in subsection 1.2 we discuss the science requirements for SKA1-Mid, then in subsection 1.3 we describe the layouts that we consider. In section 2 we describe our simulation techniques and the metrics we generated from the experiment. Finally, the results and concluding remarks are in section 3.

1.1 SKA1 Mid-frequency Baseline Design

The mid-frequency array described in the BD is a 254 dish array with about 36% of the dishes within a radius of 400m (core), 40% of the dishes are between 400m and 4km (outer-core) and the remaining 24% are in 3 three spiral arm-like structures starting from about 2km and stretching out to a radius of around 100km. Figures 1 and 2 show the BD layout and baseline distribution histogram (log_{10} space). With about 200 fifteen metre dishes (bar the 64 13.5 metre MeerKAT dishes) within a radius of 4km, this array promises high sensitivity, with noise values around 63μJy beam^{-1} hr$^{1/2}$ [1]. However, with three distinct dish-density regions, the resulting

[1] The 2nd generation SKA-SUR configuration has much longer baselines than in the baseline design (~ 50 km compared to ~ 75 km).

full sensitivity (natural weighting) point spread function (PSF) has two pedestals corresponding to the abrupt changes in dish densities from the core to the outer-core and from the outer-core to the spiral arms (see Appendix A). With such a configuration, a uv-weighting that tends towards uniform is required to obtain high resolution and uv-tapering might be also be required to get a well behaved PSF. Leading to significantly lower sensitivity due to the down-weighting of baselines[2]. It is therefore important to quantify the scale-dependent sensitivity of this configuration, i.e., what is the sensitivity at different angular scales.

1.2 SKA1-Mid science requirements

In this subsection we outline the scientific rationale for a change in the baseline design, which we believe is as cost neutral as possible given the information we received from the SKA office and which gives a direction which is different for the configuration of SKA-MID. We have based the propositions in this document upon the assessment workshop for the Cosmology working group where extensive discussion have taken place with the pulsar and transient senior scientists, along with direct communication with the Continuum Science SWG, plus several informal discussions between the Cosmology members and the HI/continuum members.

1.2.1 Highlights of requirements of each science area

Pulsar science: The pulsar search science is mainly dependent on the core of SKA-MID. One of the key factors being the instantaneous sensitivity which depends on the number of antennas in the core. Furthermore if the antennas are moved out of the core, the synthesised beam would be reduced which increases the pulsar search time. During the discussions in the SWG, it was our understanding that an increase of the core area of around 10% would be an acceptable perturbation in the overall pulsar search, although one in which computation costs increase (see Pulsar SWG for more details). We also note that the Pulsar SWG requires the full sensitivity of SKA-MID for accurate timing of the pulsars discovered in the survey.

Cosmology: In what concerns the baseline distribution in this document we have four aspects which we would like to highlight: Cosmology with continuum and HI galaxy surveys, weak gravitational lensing and intensity mapping.

- **Cosmology with HI surveys**: The key requirement for HI surveys for cosmology is to have a large survey speed coupled with baselines which do not resolve out the flux of the galaxies being observed. Given the sizes of galaxies and the fact that we would like a significant amount of the flux not to be resolved out, the baselines of most interest are baselines below around 5km. Hence an outer core is the most important aspect of a telescope for such science. However losing a small amount of sensitivity compared to the baseline design in this region of uv space is not critical and was discussed at the Cosmology science assessment workshop, and in fact we find that we do not lose any sensitivity in this regime for out preferred configuration.
- **Cosmology with weak lensing**: Here the main aspect is a high sensitivity at scales which can measure the structure and shape of the galaxies in continuum. Given the size of galaxies, this requires significant sensitivity at scales which correspond to 0.5 to 1 arcsec. The current baseline design has a natural sensitivity very close to the JVLA at the scales of interest, something that will only damage the scientific reputation of the SKA. For these reasons having a larger number of antennas in the spiral arms out to around 70-80 km is beneficial for this science and the lack of those baselines would simply make such a survey unfeasible. Such studies also have to be done with SKA-MID as SKA-SUR does not have enough antennas on the longer baselines (and does not have a long enough maximum baseline) to produce reliable maps for weak lensing. Furthermore, the number of UV tracks is much lower than SKA-MID providing a poorer sampling of the spatial frequencies of interest.
- **HI and continuum morphologies**: In the current baseline design there is a lack of sensitivity in the baselines which one would need to study morphologies of the detected continuum and HI galaxies. The baselines needed for morphological studies of galaxies are similar to the baselines needed for the weak lensing experiment, and therefore should be advantageous for galaxy evolution studies which are central to the goals of the HI and Continuum SWGs.
- **Cosmology with intensity mapping surveys**: Intensity mapping requires very short baselines and would benefit from having several clusters of antennas placed either in the core or in the outer core. This arrangement is not incompatible with the configuration proposed here and is briefly discussed below.

[2]uniform uv-weighting down-weights the uv-points corresponding to shorter baselines, and hence gives better resolution, while a uv-taper down-weights the edges of the uv-coverage (longer baselines) to decrease sidelobe levels

1.2.2 General rationale

Cost Neutral proposal: We propose here a baseline change outlined in this document. The scientific rationale is that baselines larger than $\sim 80-90$km are expensive given that the signal needs significant boosting to reach the main correlator, and the extra trenching and the key fact that none of the main science goals are directly affected by a modest reduction of the maximum baseline (the science case that we believe to have the most stringent requirement for high resolution is the 40mas at $\nu \sim 14$GHz for the Cradle of Life) . This cost saving should allow for extra antennas to be placed in the spiral arms. A cost saving along these lines may allow for extra antennas, and we provide information for an SKA1-Mid configuration with an additional 12 antennas as an example of the increase in sensitivity/survey speed.

We also note here that we have assumed an approximate cost neutrality for the SKA-Mid in isolation. If we were to consider a solution where the whole of the mid-frequency SKA1 as cost neutral (i.e. not interfering with SKA-Low baseline costing) then a significant number of additional dishes could be distributed within our proposed configurations which would substantially increase the imaging capability, the survey speed and the sheer volume of science that could be carried out with the SKA at mid-frequencies, but which could not be carried out with a separate site solution for the mid-frequency SKA. We assume such studies will be incorporated into the new science case for the SKA, but do not consider them here.

A proposal that should be encompassing of all science cases: The rationale that the array has significant UV coverage all the way up to 70-80 km baselines to cover the above science cases would suggest a smooth transition form the core to the outer core to the spiral arms. This is obtained by a slight puffing up of the core. The number of antennas in the core is preserved in our proposal. This transitions to the outer core which is slightly reduced as the main science for the outer core is the HI detection for cosmology and galaxy evolution. We propose this sacrifice as the science loss here is minimal for a loss of around 9 antennas. We further propose to reduce the spiral arms as no science directly needs the longest baselines in the baseline design, and instead move the spiral arms to within 120 km, with the extra 9 antennas which were sacrificed from the outer core plus a configuration with an extra 12 antennas.

This arrangement is very beneficial for HI and continuum morphological studies, furthermore it produces a survey speed which allows weak lensing experiments to be possible with SKA-1. We believe that it does not strongly affect HI and pulsar science as a whole and allows for better imaging capabilities with SKA-MID.This would be greatly beneficial for the project compared to the baseline design. Furthermore we suggest that several clusters of around 6 antennas, depending on the exact masking of roads/environments, be placed in the core/outer core as to increase the sensitivity for intensity mapping. We do not investigate this here as we believe it will only cause a minor perturbation in the survey speed and sensitivities that we discuss.

1.2.3 Specific layout implementation:

The general scientific requirements for SKA1[2] (level zero science requirements document; SRD) published by the SKA project office (SPO) in March 2014 suggest that (at least for SKA1-Mid), an array with a maximum baseline of around 100km is required. Therefore, we seek a layout with the shortest possible maximum baseline that does at least as well as the "second generation" baseline design in the resolution range 0.4-1 arcsec over 650, 800 and 1000MHz while not significantly compromising the performance at the larger angular scales. Moreover, as stated previously, having a layout which performs just as well as (or better) than the baseline layout but which covers significantly less space translates to a reduction in trenching and data transport costs, which presents an opportunity to re-invest the funds somewhere else, therefore we consider the conservative addition of 12 dishes. However, we note that improvements on the scales of interest are still possible without these 12 additional dishes. In the next section we present two alternative layouts, these layouts have maximum baselines of 120km. The scale dependent sensitivity of these layouts is compared to the SKA1-Mid and SKA-SUR baseline layouts in section 2.

1.3 Background on Layouts

The following SKA1-Mid layouts are under consideration here:

REF2A100B173 The SKA-Mid "Second-generation" layout (254 dishes) produced by Robert Braun (September 2013)[3]. This layout has a maximum baseline of 173km. In this report we also refer to this layout as REF2.

Wi-j**A**k**B**l This is the REF2 layout with the core "puffed up" by 10%, with i dishes moved from the outer core to the spiral arms and j extra dishes added to the spiral arms. The spacing in the arms is then optimised to get more sensitivity on the longer ($>$ 50km) baselines (See baseline distribution histograms in Figure 2). Each spiral arm stretches out to k kilometres and the maximum baseline length is l kilometres.

[3]We assume this to be the baseline layout.

SKASUR-A28B43 The SKA survey layout (96 dishes) released by the SPO (March 2013) and is the configuration from the Baseline Design. This layout has a maximum baseline of 50km. In this report we also refer to this layout as SKASUR.

RB-A40B75 This is a SKA survey layout (96 dishes) produced by Robert Braun (September 2013). This layout has maximum baseline of 75km. We assume that this would increase the cost of SKA1-SUR compared to the Baseline Design.

The details of the layouts are tabulated in Table 1, and Figure 1 shows the layouts and Figure 2 shows the baseline distribution histogram for the different layouts. Figure 5 shows the uv-coverage for the different layouts at 1.1GHz for declinations -50,-30,-10 degrees and for 8hr tracks. At this point no optimisation has been done on the antenna distributions and we emphasise that further improvements can be and should be made.

Table 1: Breakdown of the SKA1-Mid layouts under consideration.

REF2A100B173 [254 dishes]	SKA dishes	Legacy dishes	Both	%
Core	70	30	100	39.4
Outer-core	60	34	94	37.0
Spiral-arms	60	0	60	23.6
W9-0A72B120 [254 dishes]				
Core	70	30	100	39.4
Outer-core	51	34	85	33.5
Spiral-arms	69	0	69	27.1
W9-12A60B120 [266 dishes]				
Core	70	30	100	37.6
Outer-core	51	34	85	32.0
Spiral-arms	81	0	81	30.4

Table 2: Breakdown of the SKA survey layouts under consideration.

SKASUR-A28B53 [96 dishes]	SKA dishes	Legacy dishes	Both	%
Core	18	36	54	56.25
Spiral-arms	42	0	42	43.75
RB-A40B75 [96 dishes]				
Core	24	36	60	62.5
Spiral-arms	36	0	36	37.5

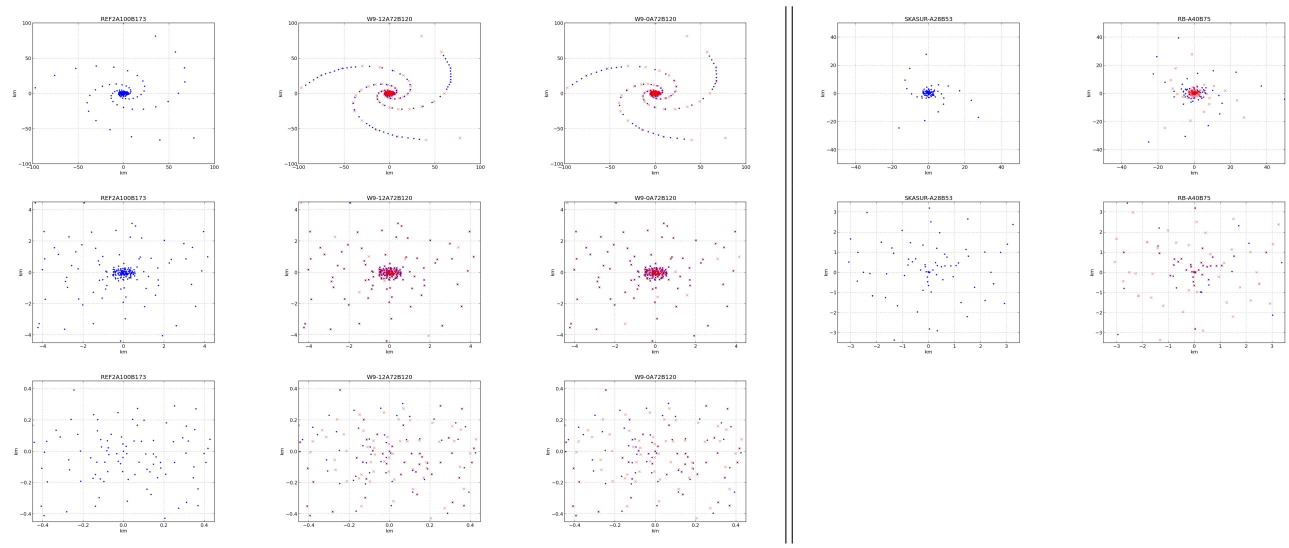

Figure 1: Antenna layouts, REF2 plotted as a reference (red crosses) for SKA1-Mid layouts, and SKASUR plotted as reference for the RB-A40B75 layout. The vertical lines separate SKA1-Mid and SKA survey layouts.

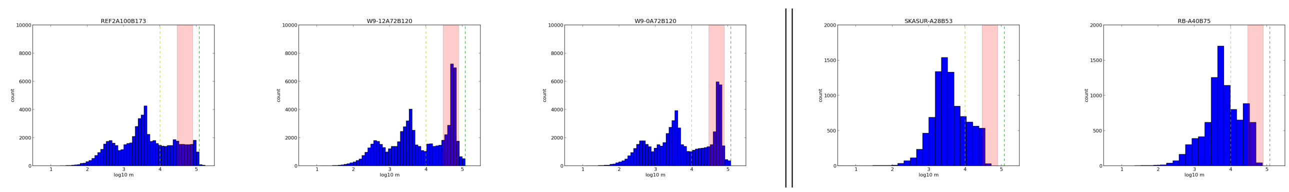

Figure 2: Baseline distribution with the uv-distance in log_{10} km . Yellow and green dashed lines mark 10 and 120 kilometres respectively, and the pink strip represents baselines from 30-80km.

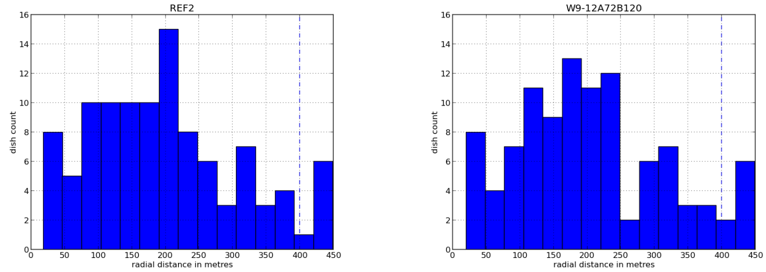

Figure 3: Dish density histograms of the core of the SKA1-Mid layouts under consideration. The dashed line marks 400m. The core of the W-9-j layouts is the same, therefore we only need to plot one of these.

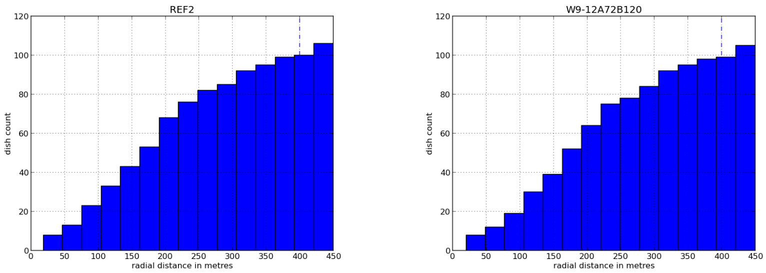

Figure 4: Cumulative dish density histograms of the core of the SKA1-Mid layouts under consideration. The dashed line marks 400m. The core of the W-9-j layouts is the same, therefore we only need to plot one of these.

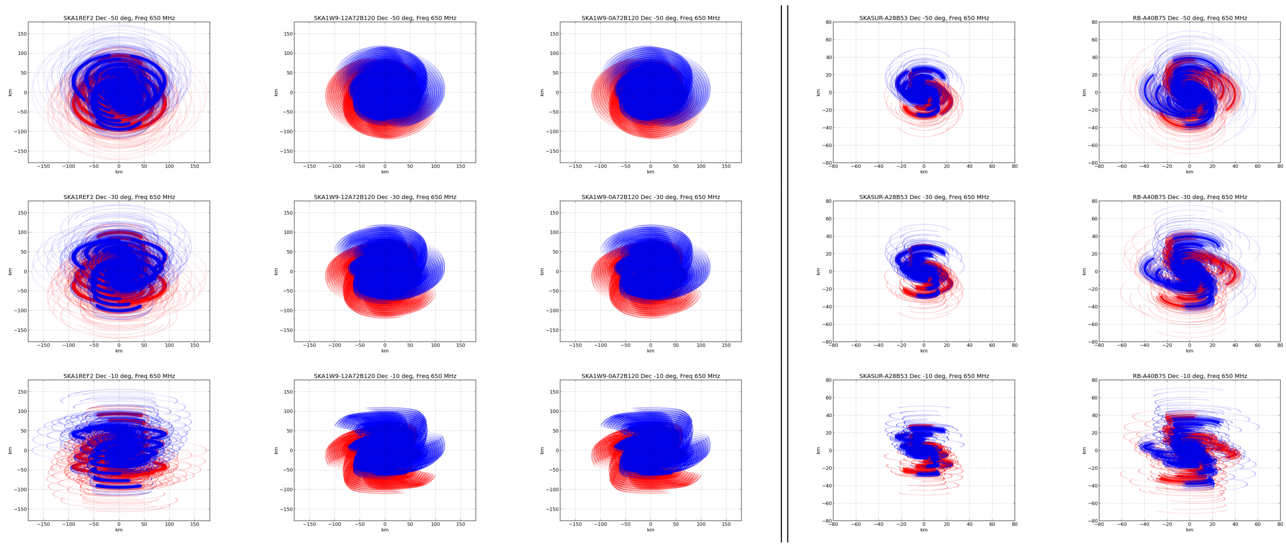

Figure 5: UV-Coverage for 8-hr tracks at 650MHz (50MHz bandwidth) at declinations -50,-30,-10 for the different layouts. Blue indicates uv-points, red indicates conjugate uv-points. The vertical lines separate SKA1-Mid and SKA survey layouts.

2 The Experiment

Our aim is to investigate the scale-dependent sensitivity of the layouts described in the previous section. We use the `makems` tool to make simulated measurement sets (MS) of 8hr tracks with a 60s integration time for declinations -50, -30 and -10 degrees, at frequencies of 650, 800 and 1000MHz, with a single 50MHz channel. The expected rms noise per real and imaginary part for each visibility is calculated as

$$\sigma_{\mathrm{vis}} = \frac{\mathrm{SEFD}}{\sqrt{2\Delta t \Delta \nu}}. \tag{1}$$

We use the baseline design's SEFD values for the SKA and legacy dishes. The noise for visibilities corresponding to baselines between SKA and legacy dishes is calculated using $\mathrm{SEFD}_{\mathrm{MIX}} = \sqrt{\mathrm{SEFD}_{\mathrm{SKA}} \times \mathrm{SEFD}_{\mathrm{LEGACY}}}$. The MS is then filled with random Gaussian noise using the computed value of the noise for a given integration and bandwidth. We then use the (CASA-derived) `lwimager` tool to make naturally weighted maps of the PSF as well as dirty maps of the noise. The following metrics were generated:
Note: These metrics are generated at different angular scales, this is done by applying an inner-taper[4] to taper out baselines that do not fall within a given resolution range, i.e., we only consider uv-points that correspond to a given resolution.

- PSF full width at half maximum (FWHM) size (mean of the FWHM dimensions). This was measured by making high-resolution images of the PSF (0.05 arcsec resolution), and fitting a Gaussian to the PSF. (Table 3). A catalog of PSF cross-sections (full uv-coverage) is provided in Appendix A.
- PSF symmetry (PSF size parameters are obtained as explained above). As a measure of PSF symmetry, we define $\mathrm{PSF}_{sym} = 1 - \mathrm{FWHM}_{min}/\mathrm{FWHM}_{maj}$, then $\mathrm{PSF}_{sym} = 0$ is perfect symmetry, and the symmetry degenerates as $\mathrm{PSF}_{sym} \rightarrow 1$ (Table 4).
- Rms pixel noise at different angular scales for 50kHz, 50MHz and 166MHz wide bands (Tables 5 - 7).
- SNR for a 10μJy source at 1000MHz with a spectral index of -0.7 after 8hrs for a 166MHz band (Table 8).
- Average SNR over frequencies 650, 800 and 1000MHz (166MHz band) after 8 hours, for a 10μJy source at 1000MHz with a spectral index of -0.7. $\overline{\mathrm{SNR10}} = \sqrt{\frac{1}{3}(\mathrm{SNR10}^2_{650} + \mathrm{SNR10}^2_{800} + \mathrm{SNR10}^2_{1000})}$ (Table 9).
- Hours required to reach a mean SNR of 10 (Table 10).
- Survey Speed. These values are calculated using the FOV values in the SRD (band 1 for SKA1-Mid and band 2 PAF FOV for SKASUR) and the values in Table 8. Note that unlike the SKASUR FOV, the SKA1-Mid FOV changes across the band ($\mathrm{FOV}_{\mathrm{Mid}} \sim \nu^{-2}$). $\mathrm{SS}_{\mathrm{Freq}} = \mathrm{FOV}_{\mathrm{Freq}} \times \mathrm{SNR}^2$.
- Average survey speed. $\overline{\mathrm{SS}} = \sqrt{\frac{1}{3}(\mathrm{SS}^2_{650} + \mathrm{SS}^2_{800} + \mathrm{SS}^2_{1000})}$ (Table 12).

In appendix B the above mentioned metrics are presented for a 2.5GHz band at 8, 12 and 13.8GHz, at a declination of -30 degrees.

Table 3: FWHM PSF sizes (in arcsec) for the different layouts at different angular scales. These values are generated at 650, 800 and 1000MHz for angular scales {0.4-1, 0.4-2, 1-2, 2-3, 3-4, 600-3600} arcsec and are labelled *resbin* {1, 2, 3, 4, 5, 6} respectively. This is done for natural weighting at declinations -10, -30 and -50 degrees. For each column the intensity of the colour increases with the value.

(a) DEC=-10, natural weighting

	650MHz						800MHz						1000MHz					
resbin	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
REF2	0.7	0.9	1.3	2.3	3.4	803.1	0.6	0.8	1.3	2.4	3.3	792.3	0.6	0.8	1.3	2.3	3.3	777.1
W9-12A72B120	0.8	1.0	1.2	2.3	3.3	804.3	0.7	0.8	1.3	2.3	3.3	800.6	0.6	0.7	1.3	2.3	3.3	788.1
W9-0A72B120	0.8	1.0	1.2	2.3	3.3	802.2	0.7	0.8	1.3	2.4	3.3	796.6	0.6	0.7	1.3	2.3	3.3	787.5
SKASUR	1.2	1.9	1.9	2.5	3.4	1029	1.0	1.7	1.6	2.3	3.4	943.3	1.0	1.4	1.4	2.4	3.4	914.7
RB-A40B75	0.9	1.5	1.5	2.4	3.3	1072	0.9	1.3	1.4	2.4	3.4	984.2	0.8	1.2	1.3	2.3	3.4	948.6

(b) DEC=-30, natural weighting

	650MHz						800MHz						1000MHz					
resbin	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
REF2	0.6	0.9	1.3	2.3	3.4	797.3	0.6	0.8	1.3	2.4	3.3	790.6	0.6	0.8	1.3	2.4	3.3	770
W9-12A72B120	0.8	0.9	1.2	2.4	3.4	800.3	0.7	0.8	1.3	2.3	3.3	799.6	0.6	0.7	1.3	2.4	3.3	779.7
W9-0A72B120	0.8	0.9	1.2	2.4	3.3	798.1	0.7	0.8	1.3	2.3	3.3	795.5	0.6	0.7	1.3	2.3	3.4	778.6
SKASUR	1.3	2.0	1.9	2.5	3.4	1097	1.0	1.7	1.6	2.3	3.4	973.7	1.0	1.4	1.4	2.4	3.3	903.9
RB-A40B75	1.0	1.5	1.5	2.4	3.3	1167	1.0	1.3	1.4	2.4	3.4	1019	0.8	1.2	1.3	2.4	3.4	933.8

(c) DEC=-50, natural weighting

	650MHz						800MHz						1000MHz					
resbin	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
REF2	0.7	0.9	1.3	2.3	3.3	799.8	0.6	0.8	1.3	2.4	3.3	789.6	0.6	0.8	1.3	2.4	3.3	776.9
W9-12A72B120	0.8	1.0	1.2	2.4	3.3	801.5	0.7	0.8	1.3	2.3	3.3	795.8	0.6	0.7	1.3	2.3	3.3	784.2
W9-0A72B120	0.8	0.9	1.2	2.3	3.4	799.6	0.7	0.8	1.3	2.4	3.3	791	0.6	0.7	1.3	2.3	3.4	780.1
SKASUR	1.4	2.0	1.9	2.4	3.4	1031	1.1	1.7	1.6	2.4	3.3	962.8	1.0	1.5	1.4	2.4	3.4	936.8
RB-A40B75	0.9	1.5	1.5	2.4	3.4	1051	0.9	1.3	1.4	2.4	3.4	975.9	0.8	1.2	1.3	2.4	3.4	948.3

[4]The weights for the taper are generated using a Butterworth function.

Table 4: PSF symmetry (see section 2) for the different layouts at different angular scales. These values are generated at 650, 800 and 1000MHz for angular scales {0.4-1, 0.4-2, 1-2, 2-3, 3-4, 600-3600} arcsec and are labelled *resbin* {1, 2, 3, 4, 5, 6} respectively. This is done for natural weighting at declinations -10, -30 and -50 degrees. For each column the intensity of the colour increases with the value.

(a) DEC=-10, natural weighting

	650MHz						800MHz						1000MHz					
resbin	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
REF2	0.05	0.05	0.02	0.04	0.07	0.00	0.06	0.06	0.06	0.02	0.06	0.03	0.06	0.05	0.02	0.05	0.01	0.02
W9-12A72B120	0.05	0.05	0.03	0.05	0.06	0.02	0.06	0.05	0.05	0.01	0.06	0.02	0.05	0.05	0.03	0.06	0.03	0.01
W9-0A72B120	0.05	0.05	0.03	0.07	0.04	0.03	0.06	0.05	0.05	0.01	0.06	0.03	0.05	0.05	0.03	0.04	0.04	0.02
SKASUR	0.6	0.4	0.4	0.3	0.06	0.3	0.5	0.4	0.4	0.1	0.2	0.2	0.4	0.3	0.4	0.1	0.2	0.2
RB-A40B75	0.3	0.3	0.3	0.2	0.1	0.3	0.3	0.2	0.2	0.2	0.02	0.3	0.3	0.2	0.2	0.06	0.1	0.2

(b) DEC=-30, natural weighting

	650MHz						800MHz						1000MHz					
resbin	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
REF2	0.1	0.1	0.07	0.08	0.06	0.02	0.09	0.09	0.08	0.06	0.08	0.03	0.07	0.07	0.07	0.07	0.05	0.04
W9-12A72B120	0.2	0.1	0.01	0.05	0.06	0.02	0.1	0.1	0.00	0.07	0.06	0.02	0.1	0.1	0.06	0.05	0.02	0.02
W9-0A72B120	0.2	0.1	0.00	0.04	0.08	0.03	0.1	0.1	0.02	0.07	0.07	0.03	0.1	0.1	0.07	0.08	0.02	0.00
SKASUR	0.6	0.5	0.5	0.2	0.1	0.4	0.5	0.4	0.4	0.06	0.2	0.3	0.5	0.4	0.4	0.1	0.1	0.2
RB-A40B75	0.4	0.3	0.3	0.2	0.02	0.4	0.4	0.3	0.2	0.2	0.08	0.3	0.3	0.3	0.2	0.01	0.09	0.2

(c) DEC=-50, natural weighting

	650MHz						800MHz						1000MHz					
resbin	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
REF2	0.1	0.1	0.04	0.06	0.02	0.02	0.1	0.1	0.07	0.07	0.08	0.03	0.05	0.06	0.07	0.05	0.04	0.02
W9-12A72B120	0.1	0.1	0.01	0.05	0.02	0.01	0.1	0.09	0.00	0.05	0.06	0.05	0.09	0.09	0.06	0.03	0.02	0.01
W9-0A72B120	0.1	0.1	0.01	0.04	0.05	0.03	0.1	0.09	0.01	0.03	0.09	0.06	0.09	0.09	0.05	0.05	0.05	0.01
SKASUR	0.7	0.4	0.4	0.1	0.06	0.2	0.5	0.3	0.3	0.09	0.05	0.2	0.4	0.3	0.3	0.06	0.2	0.2
RB-A40B75	0.3	0.3	0.3	0.2	0.08	0.3	0.2	0.3	0.3	0.02	0.05	0.2	0.2	0.2	0.2	0.1	0.04	0.2

Table 5: Noise (in μJy) for a 50kHz band after an 8hr synthesis with a 60s integration for the different layouts at different angular scales. These values are generated at 650, 800 and 1000 MHz, at angular scales {0.4-1, 0.4-2, 1-2, 2-3, 3-4, 600-3600} arcsec and are labelled *resbin* {1, 2, 3, 4, 5, 6} respectively. This is done for natural weighting at declinations -10, -30 and -50 degrees. For each column the intensity of the colour increases with the value.

(a) DEC=-10, natural weighting

	650MHz						800MHz						1000MHz					
resbin	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
REF2	110	78.0	110	150	180	390	99.0	75.0	110	150	180	490	99.0	75.0	120	150	180	650
W9-12A72B120	81.0	60.0	83.0	140	180	430	70.0	57.0	98.0	150	190	530	64.0	55.0	110	150	200	700
W9-0A72B120	87.0	63.0	89.0	160	190	440	75.0	62.0	110	160	210	540	68.0	59.0	120	170	240	690
SKASUR	5200	450	570	530	620	2800	2900	390	460	500	620	3100	780	240	260	360	400	3500
RB-A40B75	1500	330	380	450	540	2500	680	300	350	440	550	2700	320	190	240	310	330	3000

(b) DEC=-30, natural weighting

	650MHz						800MHz						1000MHz					
resbin	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
REF2	110	77.0	120	150	180	420	99.0	75.0	120	160	180	530	98.0	74.0	120	160	180	680
W9-12A72B120	78.0	58.0	85.0	140	180	460	69.0	57.0	100	150	190	570	64.0	55.0	110	150	210	720
W9-0A72B120	82.0	63.0	94.0	170	200	460	74.0	62.0	120	160	200	580	69.0	60.0	120	170	230	740
SKASUR	5700	510	580	560	600	2900	2800	410	460	500	590	3200	660	240	270	340	380	3600
RB-A40B75	1400	330	370	450	570	2600	630	290	340	460	560	2900	320	190	240	310	320	3000

(c) DEC=-50, natural weighting

	650MHz						800MHz						1000MHz					
resbin	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
REF2	110	77.0	120	150	180	410	99.0	73.0	110	160	190	530	98.0	74.0	120	160	190	690
W9-12A72B120	79.0	58.0	85.0	150	180	450	69.0	57.0	100	150	190	560	66.0	56.0	110	150	210	710
W9-0A72B120	82.0	62.0	91.0	170	200	450	73.0	62.0	120	170	200	560	69.0	60.0	120	170	240	730
SKASUR	7500	510	630	540	570	3000	3400	420	510	480	550	3300	870	240	280	320	380	3700
RB-A40B75	1700	330	380	470	540	2700	710	300	350	470	530	3000	330	190	230	300	300	3200

Table 6: Noise (in μJy) for a 50MHz band after an 8hr synthesis with a 60s integration for the different layouts at different angular scales. These values are generated at 650, 800 and 1000 MHz, at angular scales {0.4-1, 0.4-2, 1-2, 2-3, 3-4, 600-3600} arcsec and are labelled *resbin* {1, 2, 3, 4, 5, 6} respectively. This is done for natural weighting at declinations -10, -30 and -50 degrees. For each column the intensity of the colour increases with the value.

(a) DEC=-10, natural weighting

	650MHz						800MHz						1000MHz					
resbin	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
REF2	3.5	2.5	3.6	4.8	5.7	12.0	3.1	2.4	3.6	4.9	5.7	15.0	3.1	2.4	3.7	4.9	5.8	20.0
W9-12A72B120	2.6	1.9	2.6	4.5	5.6	14.0	2.2	1.8	3.1	4.6	5.9	17.0	2.0	1.7	3.4	4.6	6.3	22.0
W9-0A72B120	2.8	2.0	2.8	5.2	6.1	14.0	2.4	2.0	3.5	5.1	6.5	17.0	2.2	1.9	3.9	5.2	7.5	22.0
SKASUR	160	14.0	18.0	17.0	20.0	89.0	93.0	12.0	14.0	16.0	20.0	98.0	25.0	7.5	8.3	11.0	13.0	110
RB-A40B75	49.0	11.0	12.0	14.0	17.0	80.0	22.0	9.5	11.0	14.0	17.0	86.0	10.0	5.9	7.5	9.8	10.0	96.0

(b) DEC=-30, natural weighting

	650MHz						800MHz						1000MHz					
resbin	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
REF2	3.4	2.4	3.6	4.7	5.8	13.0	3.1	2.4	3.6	5.0	5.8	17.0	3.1	2.4	3.8	5.0	5.8	22.0
W9-12A72B120	2.5	1.8	2.7	4.6	5.7	14.0	2.2	1.8	3.3	4.6	5.9	18.0	2.0	1.7	3.4	4.8	6.7	23.0
W9-0A72B120	2.6	2.0	3.0	5.4	6.2	15.0	2.3	2.0	3.7	5.2	6.5	18.0	2.2	1.9	3.9	5.3	7.3	23.0
SKASUR	180	16.0	18.0	18.0	19.0	93.0	90.0	13.0	15.0	16.0	19.0	100	21.0	7.7	8.6	11.0	12.0	110
RB-A40B75	45.0	11.0	12.0	14.0	18.0	84.0	20.0	9.2	11.0	15.0	18.0	90.0	10.0	5.9	7.5	9.9	10.0	96.0

(c) DEC=-50, natural weighting

	650MHz						800MHz						1000MHz					
resbin	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
REF2	3.4	2.4	3.7	4.8	5.8	13.0	3.1	2.3	3.6	4.9	5.9	17.0	3.1	2.3	3.7	5.0	5.9	22.0
W9-12A72B120	2.5	1.8	2.7	4.6	5.6	14.0	2.2	1.8	3.2	4.6	5.9	18.0	2.1	1.8	3.5	4.9	6.6	23.0
W9-0A72B120	2.6	1.9	2.9	5.2	6.2	14.0	2.3	1.9	3.7	5.3	6.4	18.0	2.2	1.9	3.9	5.4	7.5	23.0
SKASUR	240	16.0	20.0	17.0	18.0	94.0	110	13.0	16.0	15.0	18.0	100	28.0	7.6	8.8	10.0	12.0	120
RB-A40B75	53.0	11.0	12.0	15.0	17.0	84.0	22.0	9.6	11.0	15.0	17.0	94.0	10.0	6.0	7.4	9.6	9.4	100

Table 7: Noise (in μJy) for a 166MHz band after an 8hr synthesis with a 60s integration for the different layouts at different angular scales. These values are generated at 650, 800 and 1000 MHz, at angular scales {0.4-1, 0.4-2, 1-2, 2-3, 3-4, 600-3600} arcsec and are labelled *resbin* {1, 2, 3, 4, 5, 6} respectively. This is done for natural weighting at declinations -10, -30 and -50 degrees. For each column the intensity of the colour increases with the value.

(a) DEC=-10, natural weighting

	650MHz						800MHz						1000MHz					
resbin	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
REF2	1.9	1.4	2.0	2.6	3.1	6.8	1.7	1.3	2.0	2.7	3.1	8.5	1.7	1.3	2.1	2.7	3.2	11.0
W9-12A72B120	1.4	1.0	1.4	2.5	3.1	7.5	1.2	1.0	1.7	2.5	3.2	9.3	1.1	0.9	1.9	2.6	3.5	12.0
W9-0A72B120	1.5	1.1	1.5	2.8	3.4	7.6	1.3	1.1	1.9	2.8	3.6	9.5	1.2	1.0	2.1	2.9	4.1	12.0
SKASUR	90.0	7.8	9.8	9.2	11.0	49.0	51.0	6.8	7.9	8.7	11.0	54.0	13.0	4.1	4.6	6.2	6.9	60.0
RB-A40B75	27.0	5.8	6.6	7.8	9.3	44.0	12.0	5.2	6.1	7.6	9.5	47.0	5.6	3.3	4.1	5.4	5.7	52.0

(b) DEC=-30, natural weighting

	650MHz						800MHz						1000MHz					
resbin	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
REF2	1.9	1.3	2.0	2.6	3.2	7.2	1.7	1.3	2.0	2.7	3.2	9.1	1.7	1.3	2.1	2.7	3.2	12.0
W9-12A72B120	1.3	1.0	1.5	2.5	3.1	7.9	1.2	1.0	1.8	2.5	3.2	9.9	1.1	0.9	1.9	2.7	3.7	13.0
W9-0A72B120	1.4	1.1	1.6	2.9	3.4	8.0	1.3	1.1	2.1	2.9	3.5	10.0	1.2	1.0	2.1	2.9	4.0	13.0
SKASUR	100	8.8	10.0	9.7	10.0	51.0	49.0	7.1	8.1	8.7	10.0	55.0	11.0	4.2	4.7	5.8	6.5	62.0
RB-A40B75	25.0	5.8	6.5	7.7	9.8	46.0	11.0	5.1	6.0	8.0	9.7	50.0	5.5	3.2	4.1	5.5	5.5	52.0

(c) DEC=-50, natural weighting

	650MHz						800MHz						1000MHz					
resbin	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
REF2	1.9	1.3	2.0	2.6	3.2	7.1	1.7	1.3	2.0	2.7	3.2	9.1	1.7	1.3	2.0	2.7	3.3	12.0
W9-12A72B120	1.4	1.0	1.5	2.5	3.1	7.8	1.2	1.0	1.8	2.5	3.2	9.7	1.1	1.0	1.9	2.7	3.6	12.0
W9-0A72B120	1.4	1.1	1.6	2.9	3.4	7.9	1.3	1.1	2.0	2.9	3.5	9.7	1.2	1.0	2.1	2.9	4.1	13.0
SKASUR	130	8.8	11.0	9.3	9.9	51.0	59.0	7.3	8.8	8.3	9.6	57.0	15.0	4.2	4.8	5.6	6.6	65.0
RB-A40B75	29.0	5.8	6.6	8.1	9.4	46.0	12.0	5.3	6.0	8.2	9.1	52.0	5.7	3.3	4.1	5.3	5.2	55.0

Table 8: SNR after 8 hours relative to a 10μJy source at 1000Hz (166 MHz band) with a spectral index of -0.7 for the different layouts. These values are generated at 650, 800 and 1000 MHz, at angular scales {0.4-1, 0.4-2, 1-2, 2-3, 3-4, 600-3600} arcsec and are labelled *resbin* {1, 2, 3, 4, 5, 6} respectively. This is done for natural weighting at declinations -10, -30 and -50 degrees. For each column the intensity of the colour increases with the value.

(a) DEC=-10, natural weighting

	650MHz						800MHz						1000MHz					
resbin	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
REF2	7.0	10.0	6.8	5.1	4.3	2.0	6.8	9.0	5.9	4.3	3.7	1.4	5.8	7.7	4.9	3.7	3.1	0.9
W9-12A72B120	9.6	13.1	9.4	5.5	4.4	1.8	9.6	11.8	6.8	4.6	3.6	1.3	8.9	10.5	5.4	3.9	2.9	0.8
W9-0A72B120	8.9	12.3	8.8	4.8	4.0	1.8	9.0	10.8	6.1	4.2	3.3	1.2	8.5	9.8	4.7	3.5	2.4	0.8
SKASUR	0.1	1.7	1.4	1.5	1.2	0.3	0.2	1.7	1.5	1.3	1.1	0.2	0.7	2.4	2.2	1.6	1.4	0.2
RB-A40B75	0.5	2.3	2.0	1.7	1.4	0.3	1.0	2.2	1.9	1.5	1.2	0.2	1.8	3.1	2.4	1.9	1.8	0.2

(b) DEC=-30, natural weighting

	650MHz						800MHz						1000MHz					
resbin	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
REF2	7.2	10.1	6.8	5.3	4.2	1.9	6.8	9.0	5.8	4.3	3.7	1.3	5.8	7.8	4.8	3.6	3.1	0.8
W9-12A72B120	10.0	13.3	9.2	5.4	4.3	1.7	9.8	11.8	6.5	4.6	3.6	1.2	9.0	10.6	5.3	3.8	2.7	0.8
W9-0A72B120	9.4	12.4	8.3	4.6	4.0	1.7	9.1	10.8	5.7	4.1	3.3	1.2	8.3	9.6	4.7	3.4	2.5	0.8
SKASUR	0.1	1.5	1.3	1.4	1.3	0.3	0.2	1.6	1.4	1.3	1.1	0.2	0.9	2.4	2.1	1.7	1.5	0.2
RB-A40B75	0.6	2.3	2.1	1.8	1.4	0.3	1.1	2.3	1.9	1.5	1.2	0.2	1.8	3.1	2.4	1.8	1.8	0.2

(c) DEC=-50, natural weighting

	650MHz						800MHz						1000MHz					
resbin	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
REF2	7.2	10.2	6.7	5.1	4.2	1.9	6.8	9.2	5.9	4.3	3.6	1.3	5.9	7.8	4.9	3.7	3.1	0.8
W9-12A72B120	9.8	13.3	9.2	5.3	4.4	1.7	9.8	11.8	6.6	4.6	3.6	1.2	8.8	10.3	5.2	3.8	2.8	0.8
W9-0A72B120	9.5	12.7	8.6	4.7	4.0	1.7	9.2	10.9	5.8	4.0	3.3	1.2	8.3	9.6	4.7	3.4	2.4	0.8
SKASUR	0.1	1.5	1.2	1.4	1.4	0.3	0.2	1.6	1.3	1.4	1.2	0.2	0.7	2.4	2.1	1.8	1.5	0.1
RB-A40B75	0.5	2.3	2.1	1.7	1.4	0.3	0.9	2.2	1.9	1.4	1.3	0.2	1.8	3.1	2.5	1.9	1.9	0.2

Table 9: SNR after 8 hours relative to a 10μJy source at 1000Hz (166 MHz band) with a spectral index of -0.7 averaged over 650,800 and 1000MHz, for the different layouts at different angular scales. These values are generated for angular scales {0.4-1, 0.4-2, 1-2, 2-3, 3-4, 600-3600} arcsec and are labelled *resbin* {1, 2, 3, 4, 5, 6} respectively. This is done for natural weighting at declinations -10, -30 and -50 degrees. For each column the intensity of the colour increases with the value.

(a) DEC=-10, natural weighting

resbin	1	2	3	4	5	6
REF2	6.6	8.9	5.9	4.4	3.8	1.5
W9-12A72B120	9.4	11.9	7.4	4.7	3.7	1.4
W9-0A72B120	8.8	11.0	6.8	4.2	3.3	1.3
SKASUR	0.5	2.0	1.7	1.5	1.3	0.2
RB-A40B75	1.2	2.6	2.1	1.7	1.5	0.2

(b) DEC=-30, natural weighting

resbin	1	2	3	4	5	6
REF2	6.6	9.0	5.9	4.5	3.7	1.4
W9-12A72B120	9.6	11.9	7.2	4.7	3.6	1.3
W9-0A72B120	9.0	11.0	6.4	4.1	3.3	1.3
SKASUR	0.5	1.9	1.7	1.5	1.3	0.2
RB-A40B75	1.3	2.6	2.2	1.7	1.5	0.2

(c) DEC=-50, natural weighting

resbin	1	2	3	4	5	6
REF2	6.7	9.1	5.9	4.4	3.7	1.4
W9-12A72B120	9.5	11.9	7.2	4.6	3.7	1.3
W9-0A72B120	9.0	11.1	6.6	4.1	3.3	1.3
SKASUR	0.4	1.9	1.6	1.6	1.4	0.2
RB-A40B75	1.2	2.6	2.2	1.7	1.6	0.2

Table 10: The hours required to reach a mean SNR of 10 (average over 650,800 and 1000MHz), relative to a 10μJy source at 1000MHz with a spectral index of -0.7 for the different layouts at different angular scales. These values are generated for angular scales {0.4-1, 0.4-2, 1-2, 2-3, 3-4, 600-3600} arcsec and are labelled *resbin* {1, 2, 3, 4, 5, 6} respectively. This is done for natural weighting at declinations -10, -30 and -50 degrees. For each column the intensity of the colour increases with the value.

(a) DEC=-10, natural weighting

resbin	1	2	3	4	5	6
REF2	18.4	10.0	22.9	40.5	56.2	360.7
W9-12A72B120	9.1	5.7	14.6	35.7	58.7	436.6
W9-0A72B120	10.3	6.6	17.5	46.1	73.5	442.6
SKASUR	3829	204.6	269.8	365.1	498.9	1.588e+04
RB-A40B75	540	120.8	174.3	271.5	356.2	1.244e+04

(b) DEC=-30, natural weighting

resbin	1	2	3	4	5	6
REF2	18.1	9.9	23.3	40.5	58.6	409.2
W9-12A72B120	8.7	5.6	15.4	36.9	61.3	484.2
W9-0A72B120	9.9	6.6	19.4	48.3	72.9	495
SKASUR	2841	224.9	285.1	359.6	448	1.698e+04
RB-A40B75	504.1	118.2	170.5	279.8	358.6	1.347e+04

(c) DEC=-50, natural weighting

resbin	1	2	3	4	5	6
REF2	18.1	9.7	23.1	41.1	59.4	404.5
W9-12A72B120	8.9	5.7	15.4	37.6	59.7	470.1
W9-0A72B120	9.8	6.5	18.6	48.5	72.7	478.9
SKASUR	4929	226.4	317.2	328.9	422.6	1.772e+04
RB-A40B75	573.8	121.9	171.1	285.1	322.1	1.411e+04

Table 11: Relative (w.r.t RB-A40B75 at 800MHz) survey speeds for the different layouts, calculated using the FOV (using PAF FOV for SKASUR) values given in the SRD [2] and the values in table 8. These values are generated at 650, 800 and 1000MHz for angular scales {0.4-1, 0.4-2, 1-2, 2-3, 3-4, 600-3600} arcsec and are labelled *resbin* {1, 2, 3, 4, 5, 6} respectively at declinations -10, -30 and -50 degrees. For each column the intensity of the colour increases with the value.

(a) DEC=-10, natural weighting

	650MHz						800MHz						1000MHz					
resbin	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
REF2	4.5	1.8	1.1	1.0	1.1	5.8	2.8	1.0	0.6	0.5	0.6	1.8	1.3	0.5	0.2	0.2	0.3	0.5
W9-12A72B120	8.3	3.1	2.1	1.1	1.2	4.7	5.6	1.6	0.7	0.5	0.5	1.5	3.1	0.8	0.3	0.3	0.2	0.4
W9-0A72B120	7.2	2.7	1.8	0.9	1.0	4.7	4.8	1.4	0.6	0.4	0.4	1.5	2.7	0.7	0.2	0.2	0.2	0.4
SKASUR	0.02	0.6	0.5	0.9	1.0	1.3	0.05	0.6	0.6	0.8	0.8	0.8	0.6	1.2	1.3	1.1	1.4	0.5
RB-A40B75	0.3	1.1	1.1	1.3	1.4	1.5	1.0	1.0	1.0	1.0	1.0	1.0	3.2	1.9	1.6	1.4	2.1	0.6

(b) DEC=-30, natural weighting

	650MHz						800MHz						1000MHz					
resbin	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
REF2	4.0	1.7	1.1	1.2	1.1	5.7	2.4	0.9	0.5	0.5	0.5	1.8	1.1	0.4	0.2	0.2	0.3	0.5
W9-12A72B120	7.6	3.1	2.0	1.2	1.2	4.7	4.8	1.6	0.7	0.6	0.5	1.5	2.6	0.8	0.3	0.2	0.2	0.4
W9-0A72B120	7.1	2.6	1.6	0.9	1.0	4.7	4.2	1.4	0.5	0.5	0.5	1.5	2.2	0.7	0.2	0.2	0.2	0.4
SKASUR	0.02	0.5	0.5	0.9	1.2	1.3	0.05	0.5	0.6	0.8	0.9	0.8	0.7	1.1	1.2	1.4	1.6	0.5
RB-A40B75	0.3	1.0	1.1	1.4	1.3	1.6	1.0	1.0	1.0	1.0	1.0	1.0	2.9	1.8	1.6	1.5	2.3	0.7

(c) DEC=-50, natural weighting

	650MHz						800MHz						1000MHz					
resbin	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
REF2	5.2	1.9	1.1	1.2	1.0	6.4	3.1	1.0	0.6	0.5	0.5	2.0	1.5	0.5	0.2	0.2	0.2	0.5
W9-12A72B120	10.0	3.3	2.1	1.3	1.1	5.3	6.2	1.7	0.7	0.6	0.5	1.7	3.3	0.8	0.3	0.3	0.2	0.5
W9-0A72B120	9.4	3.0	1.8	1.0	0.9	5.2	5.7	1.5	0.5	0.5	0.4	1.7	3.0	0.7	0.2	0.2	0.1	0.5
SKASUR	0.01	0.5	0.4	1.0	1.1	1.3	0.04	0.5	0.5	1.0	0.9	0.8	0.5	1.1	1.1	1.6	1.4	0.5
RB-A40B75	0.2	1.1	1.1	1.4	1.2	1.6	1.0	1.0	1.0	1.0	1.0	1.0	3.4	1.9	1.6	1.7	2.2	0.7

Table 12: Relative (w.r.t RB-A40B75) average survey speeds for the different layouts, calculated using the FOV (PAF FOV for SKASUR) values given in the SRD [2] and the values in table 8. These values are generated for angular scales {0.4-1, 0.4-2, 1-2, 2-3, 3-4, 600-3600} arcsec and are labelled *resbin* {1, 2, 3, 4, 5, 6} respectively. This is done for natural weighting at declinations -10, -30 and -50 degrees. For each column the intensity of the colour increases with the value.

(a) DEC=-10, natural weighting

resbin	1	2	3	4	5	6
REF2	1.6	0.9	0.6	0.5	0.5	3.2
W9-12A72B120	3.1	1.6	1.1	0.6	0.5	2.7
W9-0A72B120	2.7	1.3	0.9	0.4	0.4	2.7
SKASUR	0.2	0.6	0.7	0.7	0.7	0.8
RB-A40B75	1.0	1.0	1.0	1.0	1.0	1.0

(b) DEC=-30, natural weighting

resbin	1	2	3	4	5	6
REF2	1.6	0.8	0.6	0.6	0.4	3.2
W9-12A72B120	3.2	1.5	1.0	0.6	0.4	2.6
W9-0A72B120	2.7	1.2	0.8	0.4	0.4	2.5
SKASUR	0.2	0.5	0.6	0.8	0.8	0.8
RB-A40B75	1.0	1.0	1.0	1.0	1.0	1.0

(c) DEC=-50, natural weighting

resbin	1	2	3	4	5	6
REF2	1.8	0.9	0.6	0.5	0.4	3.2
W9-12A72B120	3.3	1.6	1.0	0.6	0.4	2.7
W9-0A72B120	3.0	1.4	0.8	0.4	0.4	2.6
SKASUR	0.1	0.6	0.6	0.9	0.7	0.8
RB-A40B75	1.0	1.0	1.0	1.0	1.0	1.0

3 Conclusions

The metrics we have used suggest that the science goals (at least those listed in the SRD in addition to cosmology with weak lensing and HI surveys) can be met by a layout which covers significantly less space compared to the baseline layout. The SKA1-W9-0A72B120 layout performs significantly better at smaller angular scales, up to a 42% improvement in terms of the noise properties and a 70% improvement in survey speed, without compromising the larger scales. Moreover, the SKA1-Mid performance can be further enhanced by adding a handful of dishes in the spiral arms as can be seen with the SKA1W9-12A72B120 layout.

Bringing in the dishes from the longer baselines translates to a greater sensitivity on the relevant (to the science goals of SKA1-Mid) smaller scales, as can be seen in Tables 5-10. Even more encouraging is the fact that this doesn't compromise the size or the symmetry of the PSF as seen in Tables 3 and 4, as well as in Appendix A. In comparison to the SKA-SUR baseline design configurations we find that all SKA-Mid configurations significantly out perform SKA-SUR in terms of sensitivity and survey speed. Even with the 2nd generation SKA-SUR configuration with longer baselines, our proposed SKA1-Mid configuration still outperforms SKA-SUR in terms of survey speed by a factor of ~ 2.7. **We proffer the SKA1W9-0A72B120 configuration as a solution which allows for weak lensing, HI and continuum source morphology characterisation for galaxy evolution studies, as well as the other science cases detailed in the SRD. Although we note that such a configuration also needs to be analysed by other SWGs, in particular the HI SWG.**

In light of this, we request that the project office analyses the numbers used for the various figures in the various documentation purporting to the relative sensitivities and survey speeds for SKA1-Mid and SKA-SUR.

References

[1] http://www.skatelescope.org/wp-content/uploads/2013/05/SKA-TEL-SKO-DD-001-1_BaselineDesign1.pdf

[2] https://www.skatelescope.org/wp-content/uploads/2014/03/SKA-TEL_SCI-SKO-SRQ-001-1_Level_0_Requirements-1.pdf

A PSF cross-sections

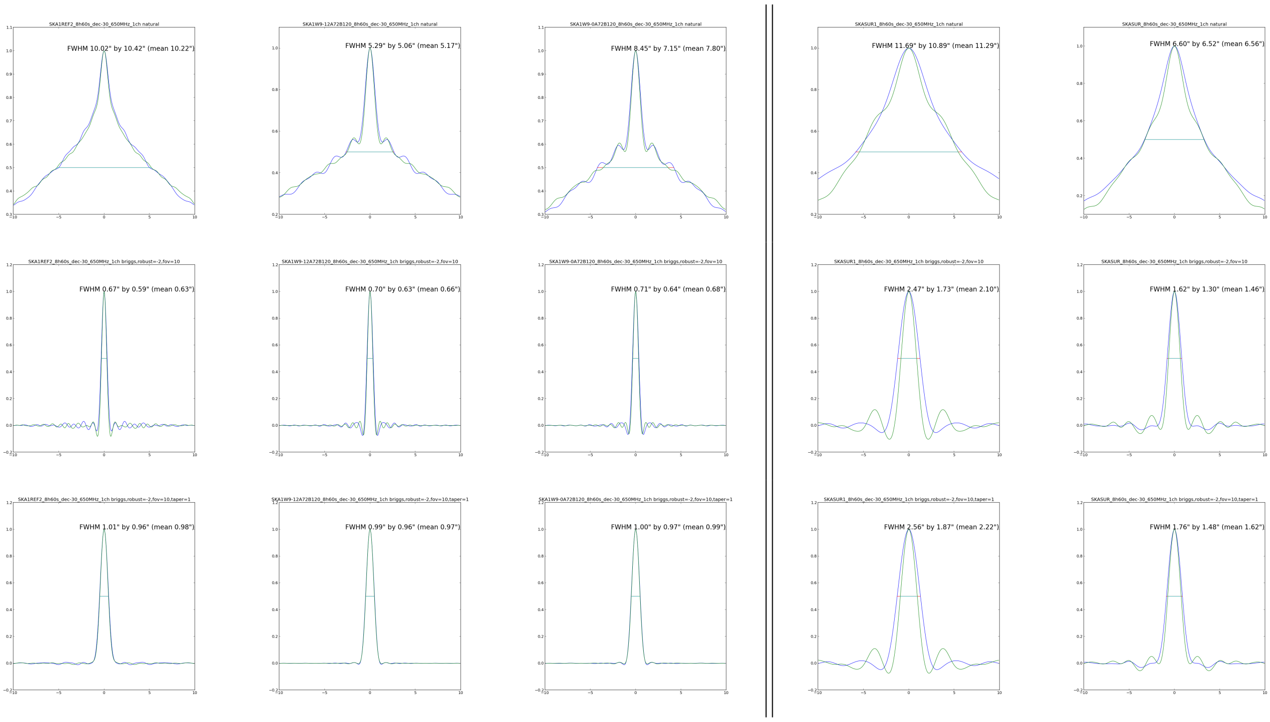

Figure 6: PSF cross-sections at Dec=-30 deg, Freq=650MHz for the different layouts. Row 1 and 2 are for natural and robust-2 weighting respectively, and row 3 is for robust-2 weighting with a 1 arcsec Gaussian taper. The blue and green curves are cross-sections along l and m respectively, and the horizontal line marks the FWHM. FWHM parameters are included in the plot.

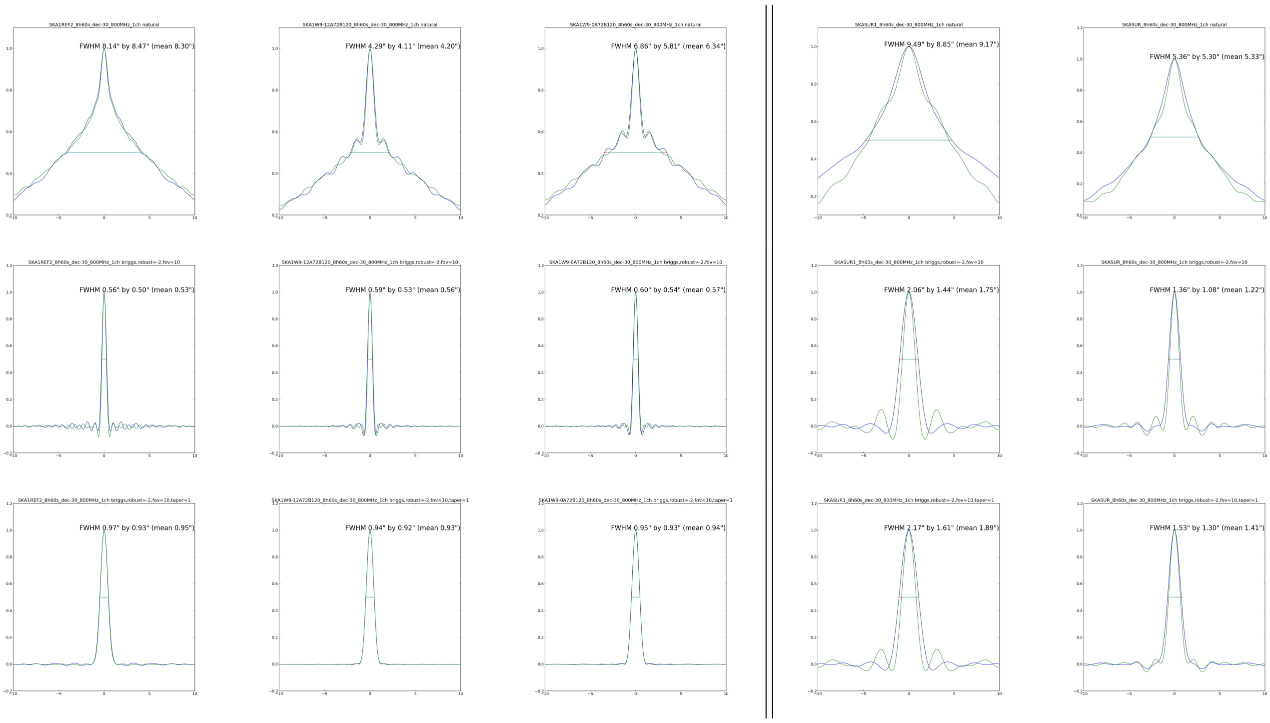

Figure 7: PSF cross-sections at Dec=-30 deg, Freq=800MHz. Row 1 and 2 are for natural and robust-2 weighting respectively, and row 3 is for robust-2 weighting with a 1 arcsec Gaussian taper. The blue and green curves are cross-sections along l and m respectively, and the horizontal line marks the FWHM. FWHM parameters are included in the plot.

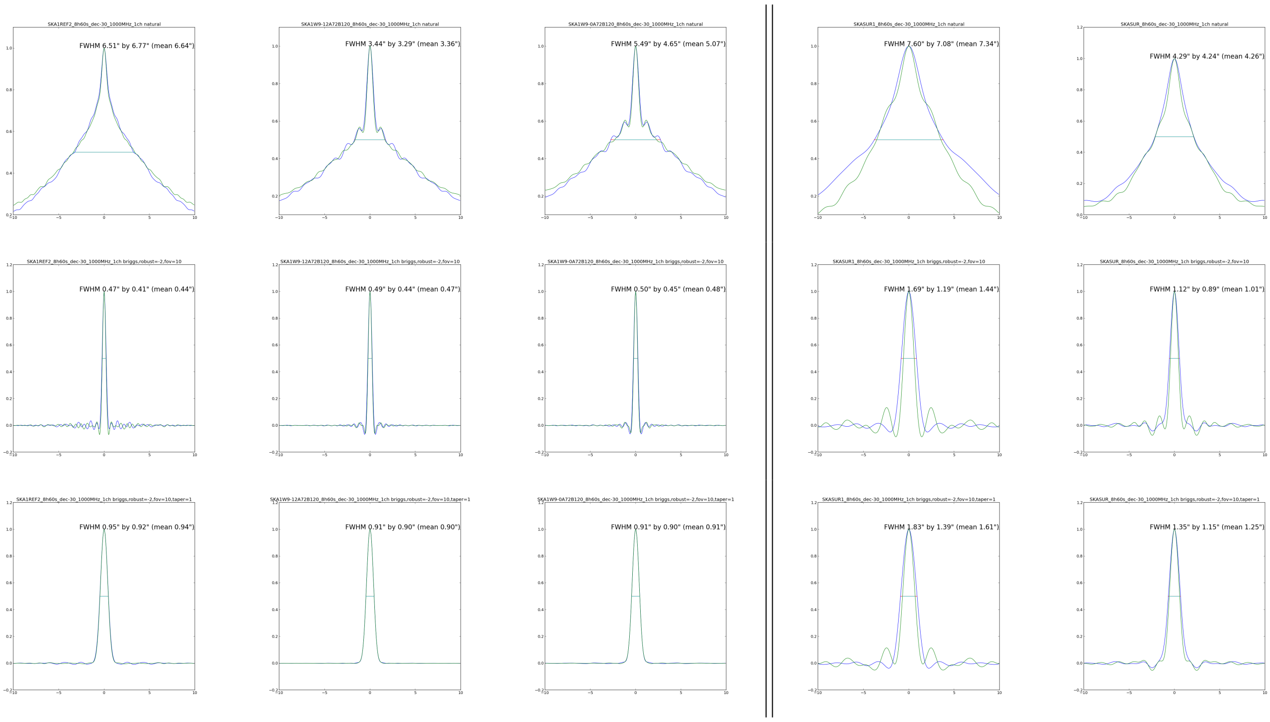

Figure 8: PSF cross-sections at Dec=-30 deg, Freq=1000MHz. Row 1 and 2 are for natural and robust-2 weighting respectively, and row 3 is for robust-2 weighting with a 1 arcsec Gaussian taper. The blue and green curves are cross-sections along l and m respectively, and the horizontal line marks the FWHM. FWHM parameters are included in the plot.

B Band 5 Scale-Dependent Sensitivity

The Tables below were generated using the BD's SEFD value of 528Jy for band 5. We make simulated measurement sets of 8hr tracks at a declination of -30 degrees at frequencies 8, 12 and 13.8GHz with a single 2.5GHz band and 60s integration time. MeerKAT do not have receivers at these frequencies, therefore the MeerKAT dishes were not considered for these simulations.

Table 13: FWHM PSF sizes (in arcsec) for the different layouts at different angular scales. These values are generated at 8, 12 and 13.8GHz, for angular scales {0.04-0.05, 0.05-0.1, 0.1-1, 1-12} arcsec and are labelled *resbin* {1, 2, 3, 4} respectively. This is done for natural weighting at a declination of -30 degrees. For each column, the intensity of the color increases with the value.

(a) DEC=-30, natural weighting

	8GHz				12GHz				13.8GHz			
resbin	1	2	3	4	1	2	3	4	1	2	3	4
REF2	0.04	0.07	0.28	1.86	0.04	0.07	0.30	1.91	0.04	0.07	0.30	2.08
W9-12A72B120	0.04	0.07	0.24	1.76	0.04	0.06	0.27	1.81	0.04	0.06	0.28	1.86
W9-0A72B120	0.04	0.07	0.25	1.77	0.04	0.06	0.31	1.80	0.04	0.06	0.32	1.85

Table 14: PSF symmetry (see section 2) for the different layouts at different angular scales. These values are generated at 8, 12 and 13.8GHz, for angular scales {0.04-0.05, 0.05-0.1, 0.1-1, 1-12} arcsec and are labelled *resbin* {1, 2, 3, 4} respectively. This is done for natural weighting at a declination of -30 degrees. For each column, the intensity of the color increases with the value.

(a) DEC=-30, natural weighting

	8GHz				12GHz				13.8GHz			
resbin	1	2	3	4	1	2	3	4	1	2	3	4
REF2	0.11	0.07	0.10	0.06	0.01	0.09	0.09	0.01	0.09	0.08	0.09	0.04
W9-12A72B120	0.13	0.12	0.03	0.13	0.16	0.05	0.06	0.08	0.11	0.02	0.06	0.03
W9-0A72B120	0.12	0.12	0.03	0.13	0.17	0.05	0.05	0.08	0.11	0.03	0.04	0.06

Table 15: Noise (in μJy) for a 2.5GHz band after an 8hr synthesis with a 60s integration for the different layouts at different angular scales. These values are generated at 8, 12 and 13.8 GHz, at angular scales {0.04-0.05, 0.05-0.1, 0.1-1, 1-12} arcsec and are labelled *resbin* {1, 2, 3, 4} respectively. This is done for natural weighting at a declination of -30 degrees. For each column, the intensity of the color increases with the value.

(a) DEC=-30, natural weighting

	8GHz				12GHz				13.8GHz			
resbin	1	2	3	4	1	2	3	4	1	2	3	4
REF2	0.90	0.49	0.25	0.29	0.91	0.48	0.25	0.32	0.85	0.48	0.24	0.35
W9-12A72B120	1.30	0.30	0.24	0.31	0.50	0.32	0.25	0.36	0.45	0.39	0.25	0.40
W9-0A72B120	1.50	0.32	0.26	0.31	0.54	0.35	0.27	0.36	0.48	0.43	0.27	0.40

Table 16: SNR after 8 hours relative to a 10μJy source at 13.8GHz (2.5GHz band) with a spectral index of -0.7 for the different layouts. These values are generated at 8, 12 and 13.8 GHz, at angular scales {0.04-0.05, 0.05-0.1, 0.1-1, 1-12} arcsec and are labelled *resbin* {1, 2, 3, 4} respectively. This is done for natural weighting at a declination of -30 degrees. For each column, the intensity of the color increases with the value.

(a) DEC=-30, natural weighting

	8GHz				12GHz				13.8GHz			
resbin	1	2	3	4	1	2	3	4	1	2	3	4
REF2	16.23	29.90	59.18	51.09	12.69	24.03	46.72	36.02	11.75	20.64	40.86	28.90
W9-12A72B120	11.16	48.78	61.58	47.14	23.23	35.44	46.87	31.82	22.06	25.84	40.14	25.13
W9-0A72B120	9.99	45.20	55.39	47.63	21.40	32.62	42.74	32.07	20.87	23.06	37.16	25.29

Table 17: SNR after 8 hours relative to a 10μJy source at 13.8GHz (2.5GHz band) with a spectral index of -0.7 averaged over 8, 12 and 13.8GHz, for the different layouts at different angular scales. These values are generated for angular scales {0.04-0.05, 0.05-0.1, 0.1-1, 1-12} arcsec and are labelled *resbin* {1, 2, 3, 4} respectively. This is done for natural weighting at a declination of -30 degrees. For each column, the intensity of the color increases with the value.

(a) DEC=-30, natural weighting

resbin	1	2	3	4
SKA1REF2	23.72	43.56	85.76	68.87
SKA1W9-12A72B120	33.92	65.60	87.18	62.18
SKA1W9-0A72B120	31.52	60.32	79.22	62.74

Table 18: The hours required to reach a mean SNR of 10 (average over 8, 12 and 13.8GHz), relative to a 10μJy source at 13.8GHz with a spectral index of -0.7 for the different layouts at different angular scales. These values are generated for angular scales {0.04-0.05, 0.05-0.1, 0.1-1, 1-12} arcsec and are labelled *resbin* {1, 2, 3, 4} respectively. This is done for natural weighting at a declination of -30 and degrees. For each column, the intensity of the color increases with the value.

(a) DEC=-30, natural weighting

resbin	1	2	3	4
SKA1REF2	1.42	0.42	0.11	0.17
SKA1W9-12A72B120	0.70	0.19	0.11	0.21
SKA1W9-0A72B120	0.81	0.22	0.13	0.20

Table 19: Relative (w.r.t REF2) survey speeds for the different layouts, calculated using the FOV (using PAF FOV for SKASUR) values given in the SRD [2] and the values in table 16. These values are generated at 8, 12 and 13.8GHz for angular scales {0.04-0.05, 0.05-0.1, 0.1-1, 1-12} arcsec and are labelled *resbin* {1, 2, 3, 4} respectively at declinations -10, -30 and -50 degrees. For each column, the intensity of the color increases with the value.

(a) DEC=-30, natural weighting

	8GHz				12GHz				13.8GHz			
resbin	1	2	3	4	1	2	3	4	1	2	3	4
REF2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
W9-12A72B120	0.48	2.68	1.08	0.86	3.30	2.19	1.00	0.77	3.60	1.50	0.97	0.77
W9-0A72B120	0.38	2.27	0.87	0.89	2.84	1.87	0.83	0.79	3.20	1.19	0.82	0.77

Table 20: Relative (w.r.t REF2) average survey speeds for the different layouts, calculated using the FOV (PAF FOV for SKASUR) values given in the SRD [2] and the values in table 16. These values are generated for angular scales {0.04-0.05, 0.05-0.1, 0.1-1, 1-12} arcsec and are labelled *resbin* {1, 2, 3, 4} respectively. This is done for natural weighting at a declination of -30 degrees. For each column, the intensity of the color increases with the value.

(a) DEC=-30, natural weighting

resbin	1	2	3	4
SKA1REF2	1.00	1.00	1.00	1.00
SKA1W9-12A72B120	1.24	2.54	1.09	0.82
SKA1W9-0A72B120	1.06	2.20	0.87	0.82