SKA1-LOW CONFIGURATION COORDINATES – COMPLETE SET

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1 Purpose

This document, which will be an Applicable Document in the Level 1 Requirements Specification for SKA1 [6], is a full definition of the SKA1-low station coordinates.

2 Context

The document describes the SKA1-low configuration, optimised for a variety of priority science uses, and informed by consultation with potential users of the telescope (see Section 6). The document is based primarily on science and calibration requirements for SKA1-low, as motivated in [4]. This document is entirely descriptive and does not provide any motivation.

In October 2017 the coordinates were adjusted to permit a clearance station diameter of 40 m (see Table 1*) without overlap and with sufficient space for physical access to closely spaced stations. The locations of the core stations, the locations of the clusters within the inner spiral and locations of stations within all clusters were increased in size (pattern magnified) by a factor of 40/35 (see Section 8).*

3 References

The following documents are referenced here. In the event of conflict between the contents of the referenced documents and this document, this document shall take precedence.

[1] 'SKA1 System Baseline Design', P.E. Dewdney, W. Turner, R. Millenaar, R. McCool, J. Lazio, T. J. Cornwell, SKA Document SKA-TEL-SKO-DD-001, Mar 12, 2013.

[2] 'SKA1 Array Configurations', R. Braun and P. E. Dewdney, SKA Document SKA-OFF.AG.CNF-SKO-TN-001, May 16, 2014.

[3] 'SKA1-low Configuration Coordinates', P. E. Dewdney, SKA-TEL-SKO-0000422, Rev 1, Dec. 16, 2015.

[4] 'SKA1-Low Configuration – Constraints & Performance Analysis', P. E. Dewdney, J. Wagg, R. Braun, W. Turner, SKA-TEL-SKO-0000557, Rev A, May 31, 2016.

[5] 'NIMA TR8350.2, Department of Defence World Geodetic System 1984', 3rd Edition Amendment 1, 3 January 2000.

[6] 'SKA Phase 1 System Requirements Specification', SKA-TEL-SKO-0000008, Rev. 11.

4 Scope

The scope of this document is to build on the definition of station locations consistent with [3]. It

- Provides the locations of all the individual stations,
- Confirms the sizes of stations within defined bounds.

5 Assumptions

The following assumptions are made:

- The total number of antenna elements contained in the SKA1-low array is 131,072.
- The diameter of stations will remain within 45 m. This will be influenced by the area occupied by the antenna elements, which is not yet final, including sufficient area to randomise their positions effectively.[1]

[1] As well as this, there will have to be sufficient space around the antenna elements to access them for servicing.

6 Definitions

Antenna Element

An individual dual-polarisation antenna, included in the antenna-array that forms a field station. The antenna element includes the LNA and other integrated electronics. When there is reference to the performance of an antenna-element, the ground plane is also included.

Field Station

Array of antenna elements (256) within a circular area that has a clear physical boundary and a specific geographic location.

Station

A station encompasses a field station, each antenna element of which is connected to a digitiser and all signal processing equipment required to produce channelised, beam-formed signal streams. It does not include support infrastructure, such as buildings and power equipment.

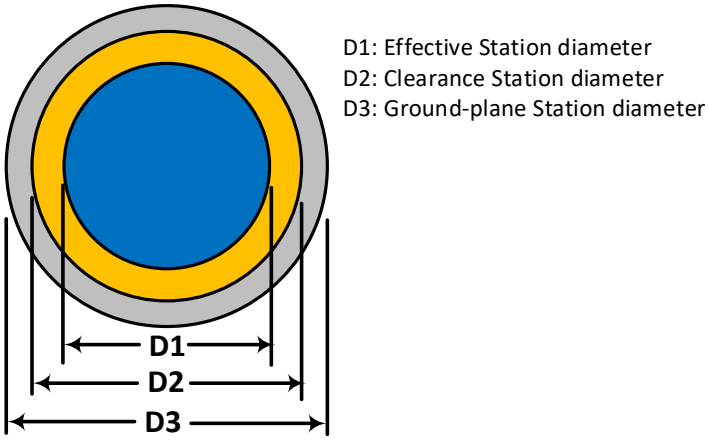

Figure 1: Definition of Field Station diameters.

Error! Reference source not found. Figure 1 illustrates three definitions of field station diameters as follows:

Effective Station diameter (D1)

The diameter of a circle that is a best-fit circle, centred at the station location, to the centres of symmetry of the antenna elements in a station. The inverse of this diameter in wavelengths will approximate the width of the unweighted station beam on the sky in units of radians.

Clearance Station diameter (D2)

The minimum diameter of a right circular cylinder, centred at the station location, that contains all the structure of the antenna elements in a station. Essentially this is the envelope of the station structure above ground level.

Ground-plane Station diameter (D3)

The diameter of a circular ground plane underlying the antenna elements and centred at the station location.

Note: Because of local ground conditions, access, or other reasons, it may not be practical for the ground plane to be entirely circular in all cases.

Station location

The position of the centre of a Field Station.

Central area

An area 1700 m in radius with a centre at the centre of the array. This is defined mainly to be consistent with previous documentation.

Inner Spiral

Cluster-numbers 1 to 4 on each arm, nominally within the Central Area. (Note that this definition is maintained only for historical reasons, as only the outer spirals were defined first).

Outer Spiral

Cluster-numbers greater than 4 on each arm, nominally outside the Central Area.

Core

An area of approximately 1000 m in diameter within which the individual stations are randomly located with no overlap.

Cluster

A group of six stations placed randomly around a cluster location, defined for stations outside the core area.

Cluster location

The average location of the stations in cluster.

Cluster diameter

The diameter of the area within which individual field stations are located.

7 Description

Reference [1] contains an initial outline of outer station positions for SKA1-low. These were further refined in [2] and again in this document. The central location in [1] underwent scrutiny in Australia, which resulted in a change in the location for the core that is flood-free and provides protection from potential radio-frequency interference (RFI) from ASKAP.

As a result of discussions with potential users in Dec, 2015, it became possible to define the locations of the outer clusters of stations. The locations of the centres of these clusters, forming an approximate 3-armed spiral, are contained in [3], and are shown in Figure 2.

After similar discussions in Feb. 2016 it became possible to define the sizes and configurations of individual stations. A summary of the result is as follows:

- Individual stations will have identical effective diameters, the values chosen (after Feb. 2016) to be between 35 and 45 m.
- 256 antenna elements will be placed randomly inside each station, which means that there will be 512 stations all together.
- The core, with a diameter of ~1 km will contain a non-overlapping, random configuration of stations.
- Stations will be clustered in groups of 6 outside the core area, randomly placed within an area 100-150 m in diameter at each location[2].
- Each arm of the spiral will contain 16 clusters, including 4 inside the central area.

[2] The final size of stations will depend on the size of the final antenna elements.

Small adjustments of the positions of some of the stations have been made, as more detailed surveys and servicing plans have been developed and carried out in 2016. Also, if stations become significantly larger because of adjustments made to the size of antenna elements, some station positions within a cluster may have to be adjusted. Any proposed changes will be documented, recorded and assessed in a subsequent engineering change proposal (ECP).

Figure 2 shows the positions of cluster locations outside the central area. Figure 3 is an enlarged view of an area 8 km wide, showing the clusters inside the central area and the stations in the core. Figure 4 is similar, for a 4-km wide area. The positions of individual stations can be seen at this scale. Figure 5 shows the positions of individual stations in the core area. Figure 6 is the same as Figure 5, except that it contains labels. Figure 7 is an expanded view of a typical cluster of stations.

The longitudes and latitudes all the central positions of the stations and the centre of the array are provided in Appendix I (Table 2), based on the WGS84 system [5].

A labelling system provides unique identifiers for the stations (see Appendix I):

- Individual stations within the core are given a number.
- Stations in clusters are given a 2-part number. The first part identifies the cluster location; the second part identifies the station within the cluster.
- Clusters labels contain a single letter designating the 'spiral arm' on which they are located, followed by a number from 1-16.
- Station numbering within a cluster location (1-6) in order of South to North (e.g. Figure 7).
- The spiral arm designation is based on the general direction of the outermost part of the spiral, namely 'N' (north), 'E' (east), 'S' (south).

Several of the figures in this document contain these labels.

8 Modifications of Oct. 2017

The effective station diameter has been defined to be 38 m (see Table 1). Also, the pattern of locations of the core stations, the clusters inside the central area and the stations within the clusters have been enlarged by a factor of 40/35. These changes have been reflected in Table 2 and the figures below.

The values of the station diameters D1, D2 and D3 have been defined as in Table 1.

Table 1: Values for Station Diameters [m] (see Section 6)		
D1	Effective Station diameter	38
D2	Clearance Station diameter	40
D3	Ground-plane Station diameter	42

As noted in Section 7, adjustments in the positions of the locations of stations and clusters from those provided in Table 2 to account for obstacles may be made. The guidelines for these adjustments are as follows, subject to not compromising the heritage corridors or overlapping adjacent stations:

1) For each of the 48 station clusters (E1 – 16, S1 – 16 and N1 – 16), the average coordinate (of the 6 stations in that cluster) should not be shifted by more than 2% from its nominal location. For the first ring of clusters (at radius of 700 m) this corresponds to 14 m, while for the most distant clusters (at radius 40 km) this corresponds to 800 m.

2) Both within each cluster and within the Core, each station should not be shifted by more than 4 m from its nominal location relative to (a) the average cluster coordinate for the 48 station clusters or (b) from the Core centre for the Core stations.

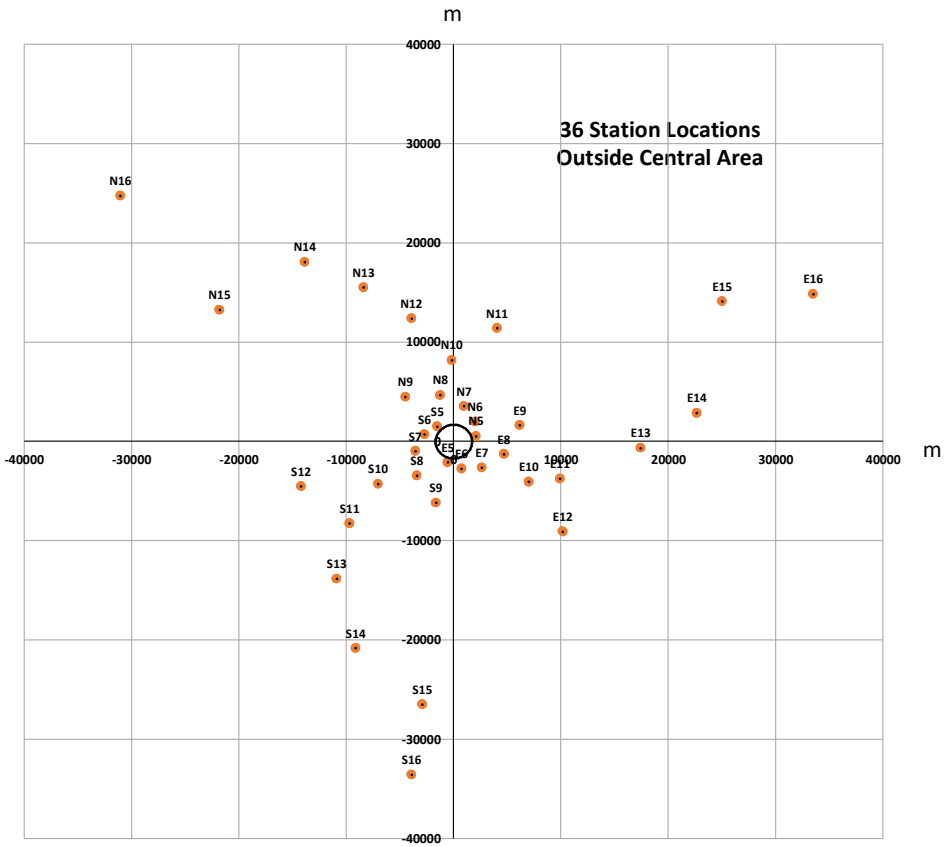

Figure 2: The configuration of the 36 cluster locations outside the central area, 12 on each spiral arm.

Notes:

i. The circle at the centre is the SKA1-low Central Area.
ii. Top is north, right is east.
iii. The scale is metres.
iv. Only the 36 outer station locations are shown.
v. The numbering system is discussed in Section 7.

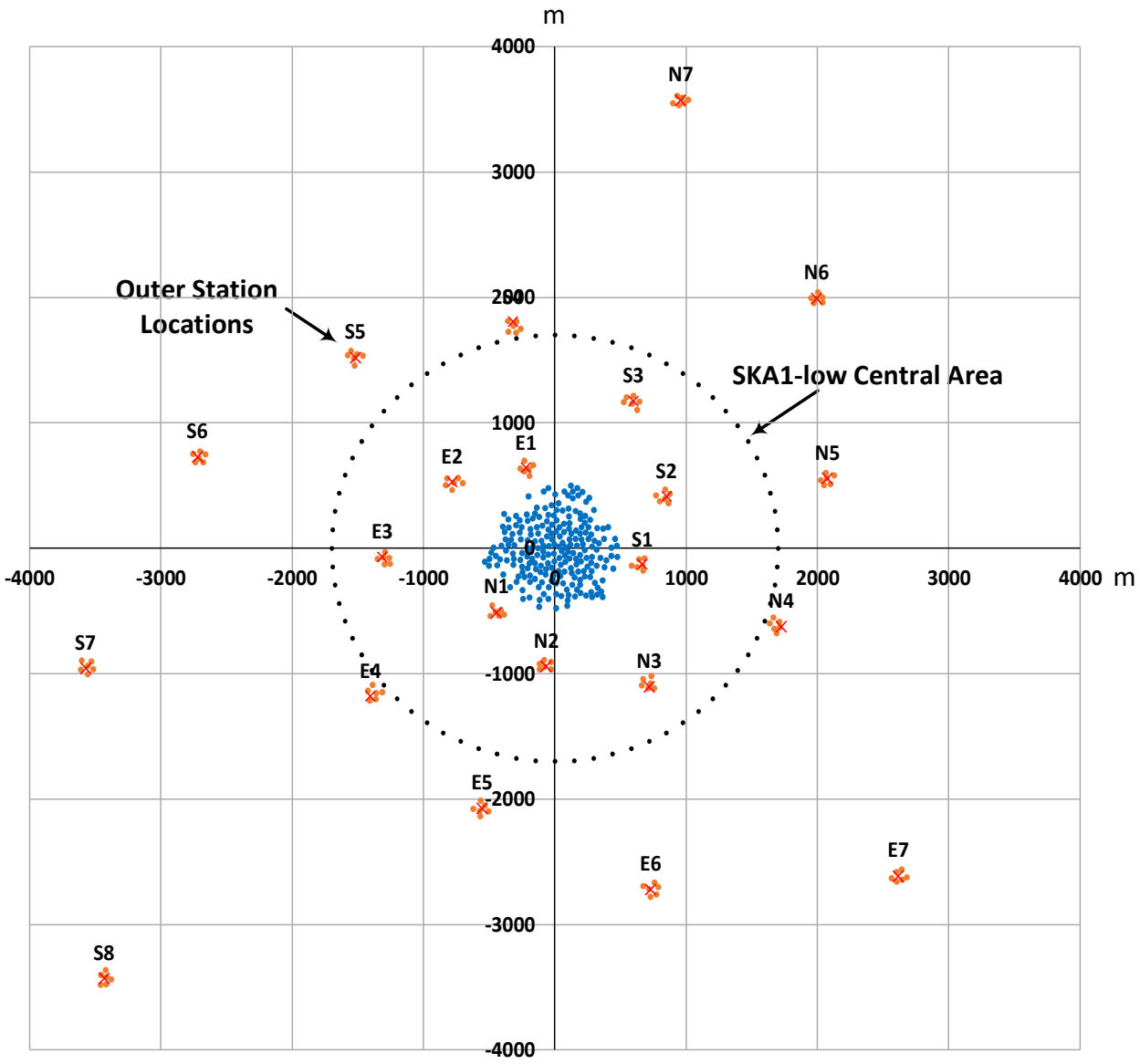

Figure 3: The SKA1-low configuration at a 4-km scale. The central area is bounded by the dotted circle. The red crosses are the positions of the cluster locations. As a result of adjustments in Oct. 2017, the fourth cluster in each spiral now lies slightly outside the central area.

Notes:

i. Top is north, right is east.
ii. The scale is metres.
iii. The blue dots are stations in the core.
iv. The black dots are clusters of stations within the central area.
v. The orange dots are clusters of outer stations.
vi. The small red crosses are the locations of clusters defined in [3].
vii. The numbering system is discussed in Section 7.

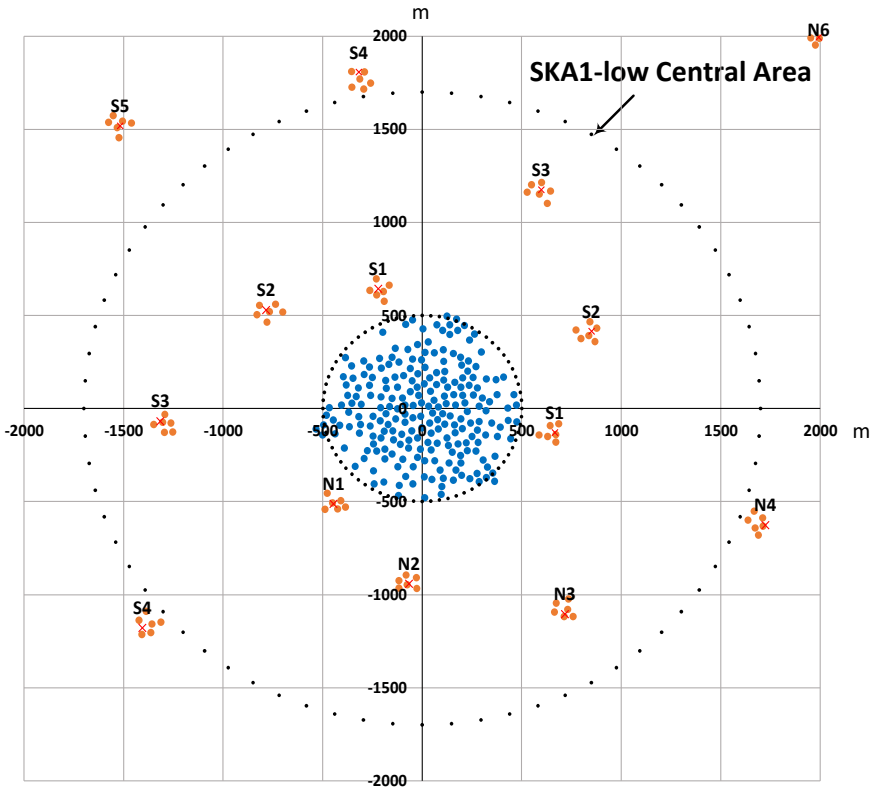

Figure 4: The SKA1-low configuration at a 2-km scale. The central area is shown inside the large dotted circle. The core area is inside the small dotted circle. The red crosses are the positions of the cluster locations.

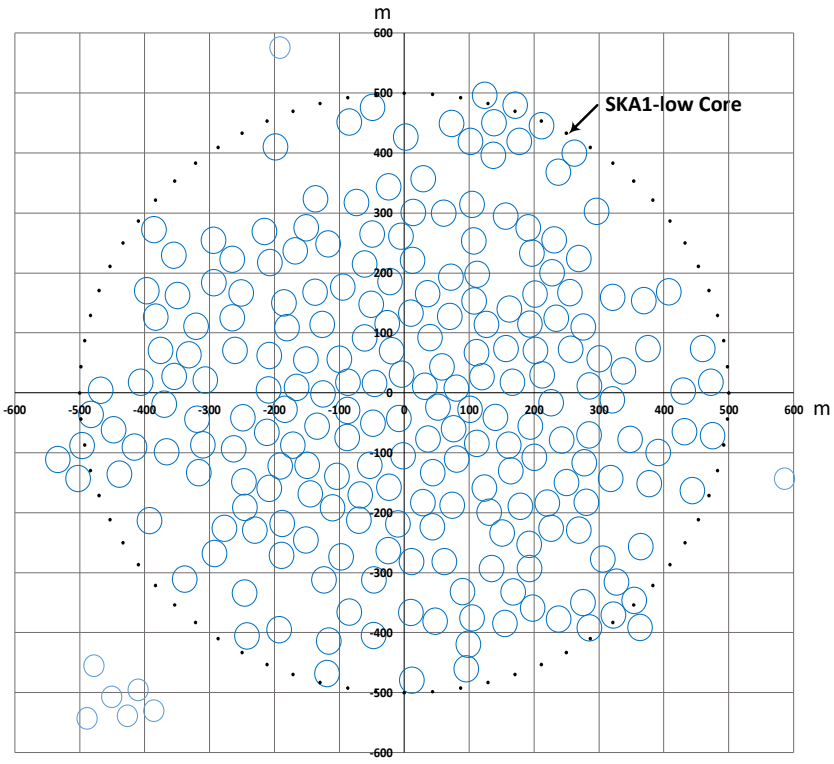

Figure 5: The core area showing the locations of individual stations. One cluster of stations is shown in at the lower left. Circles only approximately to scale.

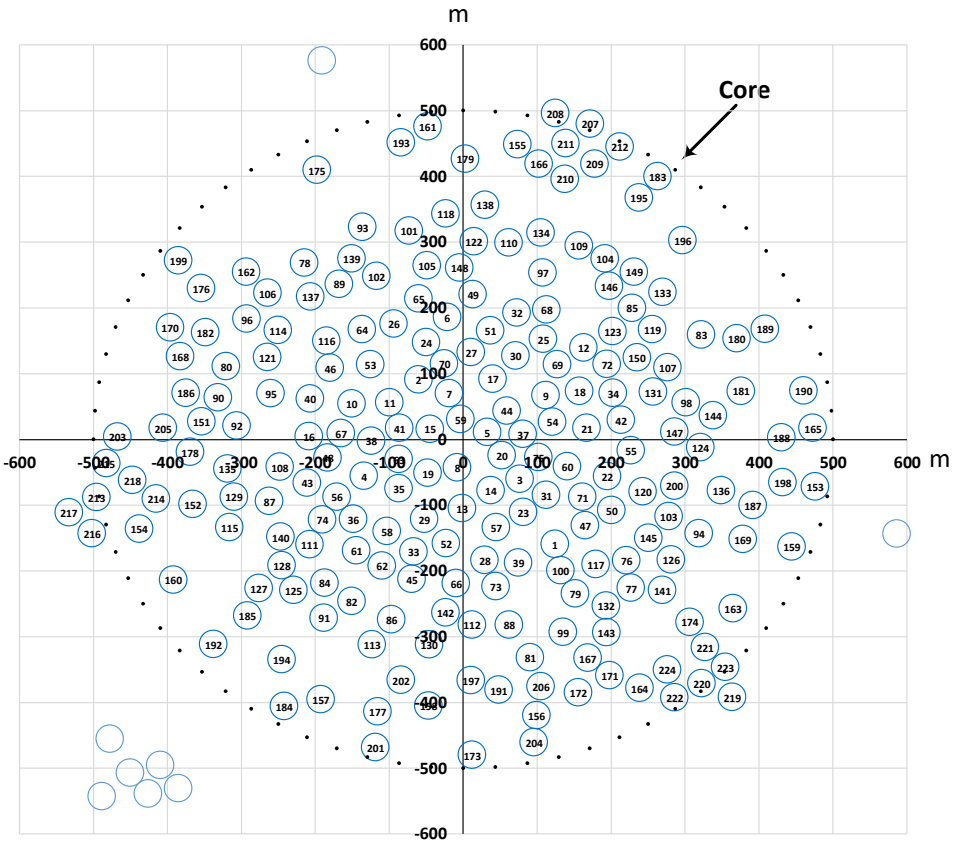

Figure 6: The same as Figure 5 with each station showing a label for each station. Circles only approximately to scale.

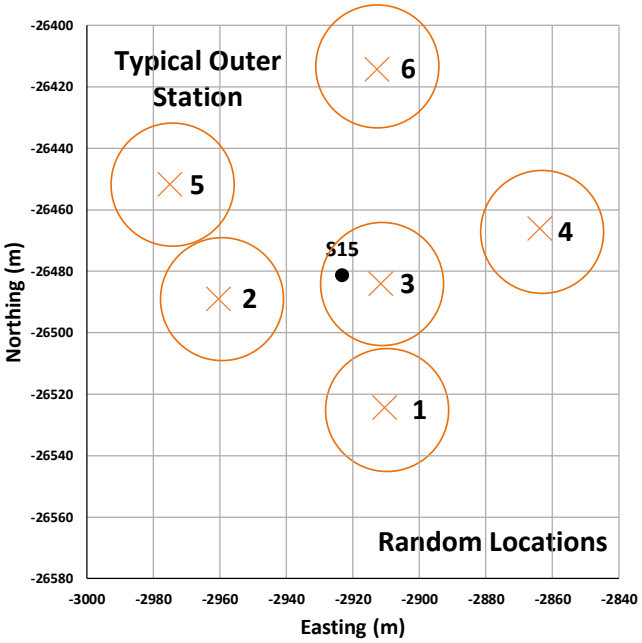

Figure 7: An example of the configuration of an individual cluster, S15 in Figure 2. Each circle is an individual station. The 6 stations in each cluster are randomly located within the cluster and are labelled from south to north. The black dot is the cluster location. Circles only approximately to scale.

Appendix I

Table 2 below contains the WGS84[3] referenced set of locations for the SKA1-low stations, as illustrated in the above figures and described in the main text above.

Table 2: WGS84 Positions of SKA1-low Stations			
Station ID	Label	Longitude	Latitude
0[4]	*Array Centre*[4]	*116.7644482*[4]	*-26.82472208*[4]
1	C1	116.7656958	-26.82616213
2	C2	116.7638445	-26.82390208
3	C3	116.7652199	-26.82526649
4	C4	116.7631025	-26.82522621
5	C5	116.7647773	-26.8246256
6	C6	116.7642328	-26.82304955
7	C7	116.7642588	-26.82409112
8	C8	116.7643702	-26.82511158
9	C9	116.7655743	-26.82412009
10	C10	116.7629315	-26.82423299
11	C11	116.7634496	-26.82421895
12	C12	116.7660855	-26.82346334
13	C13	116.764434	-26.82567181
14	C14	116.7648241	-26.82542327
15	C15	116.7639977	-26.82458089
16	C16	116.76235	-26.82468264
17	C17	116.7648535	-26.82389246
18	C18	116.7660333	-26.82406202
19	C19	116.7639692	-26.82518608
20	C20	116.7649743	-26.82494359
21	C21	116.7661302	-26.82456892
22	C22	116.7664076	-26.82523076
23	C23	116.7652657	-26.82572228
24	C24	116.7639449	-26.82339374
25	C25	116.7655391	-26.82334585
26	C26	116.7635051	-26.82313511
27	C27	116.7645575	-26.82352795
28	C28	116.7647429	-26.82638203
29	C29	116.7639194	-26.8258175
30	C30	116.7651615	-26.82357469
31	C31	116.7655796	-26.82548882
32	C32	116.7651775	-26.8229872
33	C33	116.7637741	-26.82626327

[3] WGS84 is an Earth-centred, Earth-fixed terrestrial reference system and geodetic datum [5].

[4] This coordinate refers only to the centre of the array. No stations are placed at the array centre.

34	C34	116.7664875	-26.82408735
35	C35	116.7635733	-26.82539741
36	C36	116.7629533	-26.82581548
37	C37	116.7652622	-26.82465247
38	C38	116.763197	-26.82474328
39	C39	116.7651991	-26.82641603
40	C40	116.762365	-26.82416395
41	C41	116.7635821	-26.82456678
42	C42	116.7665961	-26.82445806
43	C43	116.7623278	-26.82532
44	C44	116.7650416	-26.82433315
45	C45	116.7637493	-26.82664258
46	C46	116.7626395	-26.82374404
47	C47	116.7661077	-26.8259025
48	C48	116.7626086	-26.82497718
49	C49	116.7645825	-26.82273373
50	C50	116.7664695	-26.82569579
51	C51	116.7648189	-26.8232324
52	C52	116.7642184	-26.82614823
53	C53	116.7631868	-26.82369673
54	C54	116.7656619	-26.82448298
55	C55	116.7667313	-26.82487753
56	C56	116.762731	-26.82551227
57	C57	116.7648979	-26.82592941
58	C58	116.7634101	-26.82598422
59	C59	116.7644141	-26.82444769
60	C60	116.7658658	-26.82509463
61	C61	116.7629985	-26.82624788
62	C62	116.7633453	-26.8264584
63	C63	116.7635748	-26.8249937
64	C64	116.7630735	-26.82321344
65	C65	116.763844	-26.82278994
66	C66	116.7643541	-26.82669943
67	C67	116.7627885	-26.8246428
68	C68	116.7655856	-26.8229407
69	C69	116.76573	-26.82369721
70	C70	116.7641935	-26.82368476
71	C71	116.7660719	-26.82551408
72	C72	116.7664051	-26.82368991
73	C73	116.7648915	-26.82674108
74	C74	116.7625325	-26.82582826
75	C75	116.7654735	-26.82497225
76	C76	116.7666724	-26.8263833
77	C77	116.7667323	-26.82676355

78	C78	116.7622903	-26.82229899
79	C79	116.765972	-26.826839
80	C80	116.7612261	-26.82372357
81	C81	116.7653602	-26.82771787
82	C82	116.7629318	-26.82694292
83	C83	116.7676874	-26.8232883
84	C84	116.7625644	-26.8266925
85	C85	116.7667464	-26.82291965
86	C86	116.7634749	-26.82719424
87	C87	116.7618119	-26.82557159
88	C88	116.7650766	-26.82726871
89	C89	116.7627641	-26.82259065
90	C90	116.7611171	-26.82415185
91	C91	116.7625561	-26.82717254
92	C92	116.7613688	-26.82453504
93	C93	116.7630782	-26.82180883
94	C94	116.7676562	-26.82601497
95	C95	116.7618342	-26.82409022
96	C96	116.7615063	-26.8230708
97	C97	116.7655318	-26.82243768
98	C98	116.7674814	-26.82421677
99	C99	116.7658067	-26.82737004
100	C100	116.7657743	-26.82652234
101	C101	116.7637154	-26.82186055
102	C102	116.7632722	-26.82248305
103	C103	116.7672443	-26.82577806
104	C104	116.7663785	-26.8222438
105	C105	116.7639572	-26.82233732
106	C106	116.7617887	-26.82271557
107	C107	116.7672322	-26.82373648
108	C108	116.7619552	-26.82510197
109	C109	116.766025	-26.8220672
110	C110	116.7650688	-26.8220239
111	C111	116.7623618	-26.82616532
112	C112	116.7645691	-26.82726582
113	C113	116.7632117	-26.82754169
114	C114	116.7619306	-26.82322368
115	C115	116.7612722	-26.82592916
116	C116	116.7625917	-26.82337129
117	C117	116.7662542	-26.82643736
118	C118	116.7642128	-26.82162727
119	C119	116.7670238	-26.82321699
120	C120	116.7668953	-26.82544013
121	C121	116.7617877	-26.82359654

122	C122	116.7645958	-26.82200787
123	C123	116.7664847	-26.82324162
124	C124	116.7676787	-26.82483275
125	C125	116.7621427	-26.82679528
126	C126	116.7672799	-26.82637699
127	C127	116.7616701	-26.82676572
128	C128	116.7619853	-26.82645224
129	C129	116.7613318	-26.82551082
130	C130	116.7639869	-26.82754237
131	C131	116.7670361	-26.8240719
132	C132	116.7663923	-26.8270072
133	C133	116.7671616	-26.82270324
134	C134	116.765508	-26.82189009
135	C135	116.7612425	-26.82512591
136	C136	116.7679584	-26.82542389
137	C137	116.7623744	-26.82276627
138	C138	116.7647477	-26.82150613
139	C139	116.7629329	-26.82224217
140	C140	116.7619678	-26.82606404
141	C141	116.7671585	-26.82679451
142	C142	116.7642101	-26.82709931
143	C143	116.7663979	-26.82737196
144	C144	116.7678476	-26.8243953
145	C145	116.7669699	-26.82607547
146	C146	116.766436	-26.82262021
147	C147	116.7673229	-26.82462112
148	C148	116.7644016	-26.82236807
149	C149	116.7667764	-26.82242358
150	C150	116.7668133	-26.82360229
151	C151	116.7608894	-26.82448039
152	C152	116.7607716	-26.82561331
153	C153	116.7692364	-26.82537137
154	C154	116.7600421	-26.82595094
155	C155	116.7651875	-26.82067366
156	C156	116.7654471	-26.82851033
157	C157	116.7625149	-26.82829217
158	C158	116.7639783	-26.82837847
159	C159	116.7689187	-26.82619805
160	C160	116.7605068	-26.82665012
161	C161	116.7639655	-26.82042956
162	C162	116.761501	-26.82242644
163	C163	116.7681193	-26.8270427
164	C164	116.7668498	-26.82813455
165	C165	116.7692076	-26.82456854

166	C166	116.7654809	-26.82094253
167	C167	116.7661431	-26.82772179
168	C168	116.7606019	-26.82358528
169	C169	116.7682525	-26.8260924
170	C170	116.7604633	-26.82318797
171	C171	116.7664429	-26.82796436
172	C172	116.7660165	-26.82819704
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174	C174	116.7675314	-26.8272293
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