Memo 8

US SKA Technology Development Project Memo Series

TDP Antenna Specification: Structural Mechanical Portion

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Rev B, April 2009

US SKA TDP

TDP Antenna Specification
Structural Mechanical Portion, Rev B
SKA US TDP for SP or PAF

Matt Fleming, 2009-April-24

SKA = Square Kilometer Array
US = United States
TDP = Technology Development Project
AWG = Antenna Working Group
SPF = Single Pixel Feed
PAF = Phase Array Feed

This document contains the current working specifications for the US TDP antenna structural mechanical design work. Although many requirements for the antenna are still undetermined, portions of the design can proceed with guidance from this document. The largest unknown is the preferred optics design. This choice is based on scientific discussions still in progress. At this point the preferred feed is also unknown. It may be one of several wide band single pixel feeds or a phased array feed or a combination of these. All of the WBSP feeds seem to favor a Gregorian secondary optics configuration probably of slightly different F/D between 0.38 and 0.65. The PAF candidates will likely favor a prime focus at F/D of 0.50, although recent thoughts have imagined the PAF using a Gregorian secondary as well. Interest in very high dynamic range and low noise has made the offset designs more attractive, because of less blockage and reduced diffraction. Having observed the lower cost and success of the 6m ATA antennas and similar units done for JPL, we are compelled to fully investigate the use of hydroformed aluminum reflector surfaces in early design & costing efforts. Fortunately hydroformed reflectors lend themselves to fairly similar designs for both symmetric and offset optics. Even the likely reflector support structure concepts can be adapted to both designs. This allows us to carry both symmetric and offset antenna designs forward in parallel. At this point we will carry 3 designs forward: a symmetric Gregorian, an offset Gregorian mounted low and an offset Gregorian mounted high.

The purpose of this design effort is to produce data for a costing model and eventually drawings and a physical prototype. We start by fixing the following usual requirements: aperture diameter, survival criteria, range of motion, desired frequency range, and so on. The initial design goal is to satisfy the environmental survival criteria while keeping in mind major performance goals such as surface accuracy and pointing performance and the like. Once that design is complete, all other listed specifications will be evaluated to determine their resultant performance. Then a series of design improvements will be employed to achieve each specification goal. The cost for these improvements will have to be evaluated against the added scientific capability.

The terms specifications, requirements, goals, and properties are often used to describe an antenna. We should consider the term specification applies to an item having either a design requirement or goal, and use the term property for what is actually measured from a finished device. The ATA started with design specifications and now has a fairly complete list of properties.

This specification document will evolve. Our list of specifications below has several sections. Section 1 has the very basic physical specifications to define the antenna. Section 2 has the more complete specifications defining antenna performance for three defined environmental categories. And section 3 is a catch all for specifications or design features we consider important and want to stay aware of.

Section 1 describes many fixed specifications, but some remain open for discussion. Item 13, secondary diameter, is set by desired low frequency and several assumptions. Secondary size will have a significant effect on weight, wind load, shroud size and so on. It is critical the science requirement for lowest frequency performance is important enough to justify extra costs. Item 14 equivalent focal length is dependent on feed opening angle characteristics and effects secondary shape. Item 15 is only relevant for offset designs. It is the ratio of distance from aperture center to the closest edge of the secondary divided by the aperture diameter. The offset will need to be adjusted to prevent blockage or diffraction while accommodating feed, shroud and support systems. The ATA actually has $Yc = 0.45$ causing some blockage, but allowing a feed mounting point and reducing the antenna height. Item 17, minimum spacing, is very important for the short baselines considered critical for certain types of observations. Item 20, azimuth range, has implications to encoder mounting, cable wrap design and cost; less is better. Other items listed here deserve careful consideration. Item 31, power consumption, and peak power drawn by all antennas working together, has major infrastructure and operation cost implications.

Section 2 describes specifications that are effected by environmental conditions. The environments are defined as follows:

Precision: night time, low wind speeds, (best conditions)
Standard: daytime, low wind speeds, (solar heating issues)
Degraded: day or night, medium to strong winds, possibly daytime in dead calm.

Items 57 thru 60 and 62 thru 65 have been added to the table to quickly illustrate the changing performance throughout the available frequency range for each environment. As higher dynamic range is entertained these entries will help illustrate performance tradeoffs and the possible need for more stringent specifications. There are issues related to pointing accuracy and baseline pathlength stability that may not be adequately defined. Perhaps some specifications should have an associated per unit of time component. Other items listed here need further discussion at another time.

Section 3 describes other specifications or design features we consider important and want to stay aware of. Feed shrouding, for spillover control and diffraction issues are very important for high dynamic range and calibration. Perhaps the manufacturing tolerance on certain axis offsets will be important for calibration and baseline stability.

Please note that we very much welcome comments, additions and clarifications to the items listed so far and look forward to suggestions from all sources.

TDP Antenna Summary Specifications

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	Name	Variable			Units	Comments	
10	Optics type		Undetermined				
11	Apeture diameter	D =	12.0		m	(12.0 m = 39.4 ft) (113.1 m²)	
12	Primary focal ratio	f / D	0.40		ratio	(ASKAP 0.5 prime FPA)	
13	Secondary diameter		2.4		m	set 4λ for min freq. (4 x 0.60 = 2.4)	
14	Equivalent focal ratio		0.65		ratio		
15	Offset ratio	yc / D	0.50		ratio		
16	Polorization preserved		yes				
17	Minimum spacing		18.0		m	operation dia + 0.5m clearance. (short baselines are very important)	
18	Frequency range		0.50	10.00	GHz	min & max	
19	Mount type		Azimuth-Elevation				
20	Azimuth range		-270	+270	deg	zero at south, +90 East.	
21	Elevation range		+12	+91	deg	zero at horizon [offset +12 +91 deg]	
22	Max ambient		-10	+55	°C	(+14°F to +131°F)	
23	Solar exposure		30	13	MJ/m²	mean daily, summer, winter.	
24	Stow wind speed		20		m/s	1%, 88 hours / year	(20 m/s = 72 Km/hr = 44.7 mph)
25	Survival wind speed		45		m/s	for 97% survival in clean wind.	(45 m/s = 162 Km/hr = 100.7 mph)
26	Feed weight SPF		40		kg	estimated ATA	(40 kg = 88 lbs)
27	Feed weight PAF		200		kg	estimated ASKAP FPA	(200 kg = 441 lbs)
28	Operation		Continuous			use 24 hours / 7 days a week.	
29	Az dirve cycle		2,400		deg/day	assumes 200 cyc, 6 deg slew, 6 deg track.	
30	El dirve cycle		1,000		deg/day	assumes 200 cyc, 4 deg slew, 1 deg track.	
31	Power range		500	1500	watts	Includes 200w for 1/10 zone node.	
32	Underground air supply		4.25		m³/min		(150 cu-ft / min = 4.25 cu-m/min)

1.0m = 39.3700 inch
1.0 m = 3.28084 feet
1.0 kg = 2.2046 lbs
1.0 m/s = 2.2369 mph
1.0 ft³/min = 0.28317 m³/min
C = 3.0x10^8 m/sec

	Performance / Environ		Precision		Standard		Degraded		Rev B Section 2 of 3	
	Name	Variable	Required		Required		Required		Unit	Comment
50	Environment		night, low wind		day, low wind		strong wind			day, dead calm, may = degraded
51	Time at this state		48%		48%		3%		%	observing time. < 1% maintenance
52	Wind speed		7		7		20		m/s	(7 m/s, 25.2 Km/hr, 15.6 mph)
53	Design Frequency	F =	10		6.0		1.4		GHz	(20 m/s, 72 Km/hr, 44.7 mph)
54	Wavelength	W =	3.00		5.00		21.43		cm	W = C / F = 30 / F (in GHz)
55	Beam size	B =	0.18		0.29		1.25		deg	B = 70 (W / D) for offset FWHM
56	Surface accuracy	S =	1/10	3.00	1/10	5.00	1/10	21.43	mm	S = ratio x W (rms)
57		10.0	10%		17%		71%			
58	as % wavelength	6.0	6%		10%		43%			10% = 1/10 is okay
59	various frequencies	1.4	1%		2%		10%			5% = 1/20 is good
60		0.5	1%		1%		4%			
61	Pointing accuracy	P =	1/10	1.05	1/10	1.75	1/10	7.50	arc-min	P = ratio x B x 60 (rms)
62		10.0	10.0%		16.7%		71.4%			10.0% = 1/10 is okay
63	as % Beam FWHM	6.0	6.0%		10.0%		42.9%			3.3% = 1/30 is okay for survey
64	various frequencies	1.4	1.4%		2.3%		10.0%			1.0% = 1/100 is best for survey
65		0.5	0.5%		0.8%		3.6%			
66	Optical path change									
67	Baseline path change									
68	Tracking rate								deg/sec	Satelites? Aircraft ?
69	Az slew rate		3.0		3.0		1.0		deg/sec	(higher than 3.0 may be possible)
70	El slew rate		1.0		1.0		1.0		deg/sec	
71	Slew Time		1.08		1.08		3.08		min.	to anywhere on sky, Az 180°, El 78°
72	Keyhole									near zenith region > tracking rate.
73	Phase shift									
74	Ae / Tsys									
75										

	TDP Antenna Features of Interest (several designs)						Rev B Section 3 of 3
	Name	Variable	symmetric	offset low	offset high	Units	Comments
101	Blockage secondary		4.0	0	0	%	possible offset bottom edge
102	Blockage feed legs		10.7	0	0	%	symmetric, tri or quad
103	Defraction effects						symmetric blockage, offset edge
104	Survival az position		not critical	difficult	difficult	deg	[offset windsock up to +/- 8.3 rev]
105	Survival el position		+90	+110	+60	deg	[offset +12 deg]
106	Maintenance stow		+12	+12	+90	deg	1% , 88 hours / antenna / year
107	Access system		-->	-->	-->		Special man basket truck.
108	Reflector surface		no walk	no walk	no walk	feet	
109	Elevation imbalance					lb-ft	
110	Electronics cooling		-->	-->	-->		Air distributed from undergroud deliver
111	Fiber path thermal		1.0	1.0	1.0	°C/hr	max tolerable rate of temp change.
112	Reflector protection						
113	Lightning protection						
114	Feed protection		radome ?	radome critical	okay		birds spiders etc.
115	Spillover control		shroud ?	large shroud	unknown		major issue for calibration