Development of Processing Cost in two Indicative SKA roll-out scenarios

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Abstract

We present the potential performance and the year of potential operation of existing and planned radio telescopes for comparison with a first 10 % stage of SKA.

It will be shown that this SKA-A could be optimized for surveying within an instrumental budget of € 120 M by spending 50% on digital receivers, beamformers, correlator and imaging computer. When the digital design is frozen in 2013 the system could be fully operational in 2016 and then outperform existing systems by at least a factor 4 in the assumed 0.7-1.4 GHz frequency range.

We investigate how the installment cost evolves in stages B and C when the digital design is frozen in 2016 and 2019 respectively and compare a system based on 15 m dishes and Phased Array Feeds with a system using 22 m and 44 m Aperture Array stations.

Comparing SKA stage A performance

Country	Telecop	Area	Dishes	Size	Max BL	Beams	FoV	Ready
		10^4 m^2	#	m	km	#	deg^2	Year
China	Fast	7	1	300	0.3	<130	< 0.04	>2013
India	GMRT	5	30	45	25	< 36	< 5	>2013
EU	EVN	2	<16	<100	10,000	1	<0.002	1993
US	E-VLA	1.3	27	25	36	1	0.26	2010
SA	Meerkat	0.9	80	12	60	1	1.13	>2013
AU	ASKAP	0.4	36	12	6	18	33	>2012
NL	WSRT-A	0.6	12	25	1.5	21	10	>2011
SKA-A	PAF	4	225	15	100	21	22	>2016
SKA-A	AA	4	105	22	100	100	28-112	>2016

Digital Systems Scaling over time

Moore's law predicts every 3 years an increase of processing power by a factor 4 at constant cost.

Digital SKA systems such as beam-formers, cross-correlators and imaging processors are however performance limited by internal and external I/O rates.

We expect 10 GbE for stage A and 40 GbE and 100 GbE I/O channels for stages B and C respectively, however the system cost per Gb/s will only decrease marginally.

We applied these observations to scale the actual design of the APERTIF system that will be frozen in 2010 and rolled out in 2011 and 2012

The sizes of two cascaded processing systems are simply related by the number of operation performed on the same data stream.

Staged development and roll-out

Industry uses a continuous development to stay state-of-the-art and so needs SKA to get maximum performance over time.

This is especially true for digital electronics that dominate the cost of a survey instrument such as the SKA.

For a fast-track SKA materialization a continuous roll-out with three succeeding correlator systems is foreseen supporting 225 dishes of 15 m providing 40,000 m^2 in 2016, 735 dishes in 2019 and and 2250 dishes in 2022.

Relative processing cost for PAF and AA

Stage	Ap	Avg. BL	Station	Size	FoV	Beams	Ap	Receiv	Beam Form	Correl ator	Image
	10^4 m^2	km		m	deg^2	average	**M€**	**M€**	**M€**	**M€**	**M€**
PAF-A	4	3	225	15	22	21	60	18	14	25	2.5
PAF-B	9	30	510	15	22	21	135	35	26	66*	66*
PAF-C	27	200	1550	15	22	21	405	93	62	177*	**<708***
Total	40		2250				600	146	102	268	169
AA-A	4	3	105	22	28-112	100	60	11	15	31	2
AA-B	9	30	237	22	28-112	100	135	20	28	84*	57*
AA-C	27	200	177	44	28-112	400	405	60	71	218*	**<436**
Total	**40**		**519**				**600**	**91**	**114**	**333**	**159**

* Complete new system with 10 times performance replaces previous system.

< Needed to image full FoV at high resolution but actually 100 M€ that limits in stage C high resolution imaging to 3 beams with PAF and to 25 beams with AA

Conclusions

- Post correlation processing is before 2023 not affordable for a full size SKA of dishes with Phased Array Feeds (PAF) using high Resolution for all of its possible beams.
- The dominant cost for gridding in an imaging system scales proportional with the correlator output sample rate.
- For line imaging is the correlator output sample rate proportional with the ratio of the average baseline length over station diameter.
- The larger size of Aperture Array stations reduces the number of baselines and allows a larger FoV to be processed by a given size of correlator system.
- Aperture array (AA) stations have a 4 times larger FoV at the low end of an octave frequency range, increasing the survey speed where it is needed most.
- The presented analysis shows however that in stages A and B the cost of station beamformers, correlator and image processor is comparable for PAF and AA scenario and both have comparable FOV at the highest frequency of 1.4 GHz.
- The actual size of the final corelator system for the SKA should be matched to the actually available post-correlation processing capacity.
- Further system design study is needed to provide an adequate station distribution supported by a correlation and an imaging system that maximizes scientific output over the full roll-out period of the SKA.