MISCELLANEOUS CORRECTIONS TO THE BASELINE DESIGN

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Author ....R.McCool, T. Cornwell
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Name	Designation	Affiliation	Date	Signature
Submitted by:				
Roshene McCool	Domain Specialist Signal transport and Networks	SKAO	2013-10-16	
Accepted by:				
Approved by:				
Peter Dewdney	SKA Architect	SKAO	2013-10-17	Peter E. Dewdney Digitally signed by Peter E. Dewdney DN: cn=Peter E. Dewdney, o=SKA Organisation, ou=Architecture Group, email=p.dewdney@skatelescope.org, c=GB Date: 2013.11.04 15:25:36 Z

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Name	SKA Organisation
Registered Address	Jodrell Bank Observatory Lower Withington Macclesfield Cheshire SK11 9DL Registered in England & Wales Company Number: 07881918
Fax.	
Website	www.skatelescope.org

TABLE OF CONTENTS

1 INTRODUCTION 5
2 SYNCHRONISATION 5
3 TIMING 5
4 LFAA STATIONS FROM 911X289 TO 1024X256 6
5 LIMIT SUB-ARRAYS TO 16 6
6 TWO-ZONE BASELINE DEPENDENT AVERAGING 6
7 SPLIT/RENAME OF NIP 7
8 SKA1-LOW MAXIMUM BASELINE 7

LIST OF FIGURES

LIST OF TABLES

LIST OF ABREVIATIONS

1PPS	1 Pulse per second
BIPM	Bureau International des Poids et Mesures
GPS	Global Positioning System
IAT	International Atomic Time
RFI	Radio Frequency Interference
SKA	Square Kilomter Array
SKA1	Square Kilometre Array Phase 1
SKA1_LOW	SKA1 Low frequency array
SKA1_MID	SKA1 Mid frequency array
SKA1_SURVEY	SKA1 Survey Array
SKA2	Square Kilometre array Phase 2
UTC	Coordinated Universal Time
VLBI	Very Long Baseline Interferometry.

1 Introduction

The following sections are miscellaneous addenda and error corrections to the Baseline Design document [1].

2 References

[1] SKA1 System Baseline Design SKA-TEL-SKO-DD-001 Rev 1.

3 Synchronisation (replaces Section 11 of [1])

It is the function of the synchronisation sub-system within the SKA to provide the frequency reference signals required, over the required bandwidths and link distances. The coherence of signals from SKA1 telescopes is fundamental to their operation. Loss of coherence will result in a reduction in signal to noise. Coherence can be maintained through the use of accurate independent clocks or by a frequency reference distribution from a central reference clock. At every antenna or station, the synchronisation system will provide a standard reference sine wave from which clocks for digitisation and/or local oscillator signals can be derived (if needed), and a pulse-per-second (1-pps) signal (or similar), derived from the reference sine wave. The 1-pps signal is delivered with sufficient accuracy that digitised samples can be unambiguously aligned at the correlator.

Based upon SKA1 sensitivity and dynamic range requirements, the coherence losses should be limited to:

- 2% maximum coherence loss, equivalent to 0.2 radians, within an integration period.
- 2% maximum coherence loss, equivalent to 0.2 radians, within a solution interval for in-beam calibration.
- Maximum of 1 radian phase drift between calibration intervals for out of beam calibration sources.
- Maximum of 0.05 radians RMS about a linear slope calibration, between calibration intervals, for out of beam calibration sources.

Whilst SKA1-low, SKA1-survey and SKA1-mid may have different synchronisation requirements, derived from their top frequency of operation, a common approach to design may lead to a single site-wide, or even SKA1-wide synchronisation system design.

The status of the synchronisation as a single point of failure means that the provision of redundant clock sources and equipment may be required.

The existence of a distributed coherent signal to SKA1 telescope sub-systems could generate correlated RFI within the images generated by the array. The impact on all the telescopes on the site will have to be assessed to ensure that such interference, if present, is not harmful. If so, appropriate shielding measures or offset frequency/phase switch techniques will be needed.

As written the requirements apply to the relative synchronisation between SKA antennas, stations and digitising stages. VLBI imposes an absolute requirement on the central frequency references of the telescopes.

4 Timing (replaces Section 11.1 of [1])

The absolute timing of the data streams of the SKA1 telescopes is not strictly required for imaging observations, once the fixed delays or clock offsets from the synchronisation system have been determined for each antenna or digitisation stage. However, pulsar timing observations, astrometry and VLBI observations will require a high-precision reference to IAT.

The principle driver for timing requirements in SKA1 is the pulsar timing observations. The use of UTC (BIPM) timestamps allows the referencing of pulsar observations to a standard reference timescale. This is important for carrying out a decade long timing campaign of the pulsar sky for gravitational wave detection experiments. Pulsar measurements will be made using a central frequency reference, whose offsets with respect to UTC are monitored, with sufficient cadence and accuracy such that the SKA1 timescale can be connected to UTC with an accuracy of 10 ns, equivalent to an Allan deviation of 3 x 10-16 on a timescale of 10 years. The solution period for calculation of these offsets will be 1 day. In order to avoid large offsets, the central frequency reference will be steered to UTC to within at least 1 microsecond, with a frequency drift of less than 10 ns/day.

The use of UTC time tags and 1 PPS interrupts will be fundamental for absolute pointing of antennas and array beams (beamformers of all types) and required for other electronic sub-systems of SKA1, such as the Telescope Manager. Interfaces and requirements for these services have yet to be defined in detail. Time labels as well as counters tied to the central frequency reference may also be required. However, these requirements will be less demanding than the timing requirements derived for the pulsar observations and could be delivered using NTP or similar techniques.

5 LFAA Stations from 911x289 to 1024x256

The optimization of station size performed in the Baseline Design led to the result that there should by 911 stations of 289 antennas each. These numbers are not finely tuned, however, and so other combinations close by would also be acceptable. Since digital systems prefer powers or two, a more amenable combination would be 1024 stations of 256 antennas. For this reason, the baseline is so changed.

6 Limit sub-arrays to 16

The Baseline Design says that: “The number of sub-arrays can be as large as the number of antennas.” There is currently no science case requiring that number of sub-arrays, which could be up 1024 in the case of LFAA. Implementing such a requirement is possible but likely to lead to complexity and resource problems in Telescope Manager. Hence, we have revised this to a more modest requirement that up to 16 sub-arrays can be created.

7 Two-zone baseline dependent averaging

Two-zone baseline-dependent averaging is introduced in Tables 2, 4, 6, and 17. This allows the correlator to average short baseline and long baselines with different averaging times, for example 1.4s and 0.3s for SKA1-Survey, thus reducing the overall data rate. However, an analysis of the impact on scientific performance was not given. There are at least two areas of concern: the impact on the standard antenna-based (or closure-based) calibration scheme, and the limitations on transient detection via imaging. Consequently, two-zone baseline-dependent averaging is deprecated. For integration times, only the full baseline values in Tables 2, 4, 6, and 17 should be used.

An impact analysis of baseline-dependent averaging will be performed, and if appropriate a Change Request will be submitted.

8 Split/rename of NIP

“Non-Imaging Processor” conveys little about what the machine actually does. It also couples together two separate activities – search and timing. Finally, processing of pulsar data in the SDP domain is undifferentiated from the visibility processing. For these reasons, we have defined the following nomenclature.

Table 1 New naming convention for pulsar processing in CSP and SDP.

Activity	CSP	SDP
Searching	Pulsar Search Engine	Pulsar Search Processor
Timing	Pulsar Timing Engine	Pulsar Timing Processor

The Engines perform the high-compute-load activities in a power efficient GPU-based architecture, and the Processors perform the low-compute-load analysis in a more flexible software-based domain.

9 SKA1-low Maximum Baseline

The maximum baseline as stated in Table 1 should read 70 km instead of 50 km.