ngVLA Antenna memo #11: SBA Antenna Pointing Specification for the Conceptual Design

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v1: June 24, 2021: 1st version
v2: July 30, 2021: separately define goal (based on $M = 0.6$, as v1) from a somewhat relaxed requirement based on $M = 2$.

The pointing specification for the Short Baseline Array (SBA) 6m antennas has been through several revisions in the past two years, depending upon the assumptions made in the analysis. The purpose of this memo is to define the pointing specification being adopted for the ngVLA Conceptual Design (CoD) so that it is fully consistent with the Rev.D antenna configuration being used for the CoD. I also recommend a revision to the value of one parameter in the derivation.

The antenna pointing requirements are based on the analysis presented in the ngVLA Calibration Requirements Document [1]. Expressing this requirement relative to the 18-m pointing specification, we have:

$$\sigma_{2,6m} = \left(\frac{N_{sba}}{N_{core}}\right)^{0.5} \frac{D_{18m}}{D_{6m}} \left(\frac{M_{sba}}{M_{core}}\right)^{0.25} \sigma_{2,18m} \tag{1}$$

Here D is the diameter of the antenna in question; M represent the number of independent antenna pointing samples in an observation with the given array (more on this below); N indicates the number of antennas in the given array; and σ_2 is the 2-dimensional RMS of the fully referenced residual antenna pointing offset (as defined in the calibration document).

Rev.C of the Calibration Requirements document assumes $N_{sba} = 19$, $N_{core} = 94$, $M_{core} = 1$ (corresponding to a snapshot calibration observation), and $M_{sba} = 10$ (corresponding to no clearly justified use case or criterion). I recommend we adopt a *goal* value of $M_{sba}/M_{core} = 0.6$ based on the appropriate integration time ratios of the SBA to the core[2]. With this approach, integrating data from the ngVLA core and the SBA should never result in an unacceptable degradation of dynamic range due to antenna pointing. The second change that is needed is to use the current value $N_{core} = 114$, corresponding to the 4.8 km diameter Rev.D core. The result is a **6m referenced pointing goal (relative to the 18m referenced pointing)**:

$$\boxed{\sigma_{2,6m} = 1.07 \times \sigma_{2,18m}}$$

Design work by NRC has, however, demonstrated that achieving this goal is likely to be challenging and could unacceptably increase the cost of the SBA antennas. Furthermore the EOP suggests that, considered as dedicated capability supporting the science program of the Rev.C ngVLA, the SBA is under-utilized by more than a factor of two. Therefore it would

[1] 020.22.00.00.00 − 0001 -REQ-C-Array_Calibration_Reqs by C. Hales, v.C dated 2020-11-30

[2] The stated value of 0.6 is for the "Rev.D" antenna configuration which is being adopted for the ngVLA CoDR. Previous values of this ratio were 1.03 (used in the initial version of the EOP), and ~ 2 (pre-rev.C configurations). Note that current versions of ngVLA memos 67 and 89 both use a value of 2.2 which is not fully consistent with the Rev.C or Rev.D designs.

be possible for high dynamic range projects with an SBA component to dedicate more 6m observing time as needed (essentially, to beat down systematic errors and achieve the dynamic range required). The EOP was constructed under the assumption $M = 1.03$ relevant to the Rev.C (denser & more compact) core, and while the full taperability analysis underlying the Rev.C EOP is yet to be done for the Rev.D core, it is very likely that the SBA will be somewhat less utilized by Rev.D (because $M = 0.6$) — making more 6m telescope time available. Finally, the calculation above is conservative in utilizing all 114 antennas in the expanded core. The optimum answer depends upon the detailed science use cases involved, but will in general imply a smaller number of effectively contributing antennas to the overlap region in uv space. For all of these reasons, I regard it as acceptable to define a relaxed **6m referenced pointing requirement** of

$$\boxed{\sigma_{2,6m} = 1.46 \times \sigma_{2,18m}}$$

which is the value obtained with $M = 2$, $N_{sba} = 19$, and $N_{18m} = 114$.

For the sake of clarity note that the initial version of the formalism underlying Eq. 1, as presented in early versions of the Calibration Requirements document, contained an error. The simulations described in ngVLA memo 60 aided in identifying and correcting this discrepancy. The correct formalism then incorporated in Rev.A.03 (2020-05) and subsequent versions of the Calibration and system requirements documents.