Antenna Concept for the ngVLA

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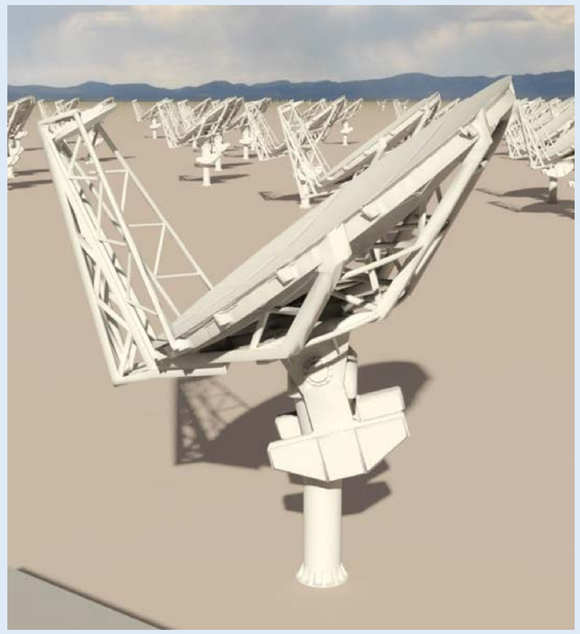

Figure 1: Sketch of an 18m, feed low, alt-az pedestal based antenna concept for the ngVLA.

Design Considerations

After analysis of science requirements and development of a detailed cost model, 18m has been chosen as the aperture size for the baseline antenna design. This aperture size offers a good balance of sensitivity and survey speed, while also meeting construction and operation cost targets. The 18m aperture is also the largest size under consideration that may still be achievable with single-piece rim-supported composite reflectors, ensuring that novel designs are still viable as the project matures towards a conceptual design down select.

For high dynamic range imaging, the optimum optical configuration is an offset geometry with an unblocked aperture. The unblocked aperture will minimize scattering, spillover, and sidelobe pickup. Both performance and maintenance requirements favor a receiver feedarm on the low side of the reflector. The selection between a dual offset Cassegrain geometry and a Gregorian configuration with low feedarm and a radiation shield is based on the preferred feed geometry. The offset Gregorian with a wide secondary angle of illumination (110 degrees, see Figure 2) leads to very compact feed designs that can be housed in common cryogenic dewars, reducing operations costs.

Technical Risks

Antennas of comparable specification have been previously built, but ngVLA's central challenge is building such antennas affordably and in volume. The most challenging specification is the referenced pointing requirement which requires a very stiff structure, more substantial foundation and more advanced drive system, increasing the cost of the antenna. The solution to this is believed to be in the application of new and novel technologies in the design and construction of the structure. This includes the evaluation of wheel and track type mount designs employing commercially available crane rail components, and the use of composite reflectors and structural members in both the feed arm and backup structure to reduce mass while increasing overall structural stiffness.

References

R. Selina, *ngVLA Antenna: Preliminary Technical Specifications Version A (2017)*
R. Selina D. Chalmers, *Statement of Work – NRC 18m ngVLA Antenna Study (2017)*
L. Baker, D Chalmers, *ngVLA Optical Design Study – Statement of Work (2017)*
M. Fleming, *ngVLA Memo #25 Exploration of Suitable Mounts for a 15m Offset Antenna (2017)*
D. Chalmers, G Lacy, M. Islam, M. Fleming, L. Baker, *ngVLA Memo #26 ngVLA Technical Study – Offset Gregorian Antenna (2017)*
M. Fleming, R. Schultz, D. Enterline, *ngVLA Memo #27 Various Suitable Mounts for an 18m Antenna (2017)*

Abstract

The Karl Jansky Very Large Array (VLA) has proven to be one of the most productive radio telescopes at centimeter wavelengths. The NRAO is now investigating the future of centimeter wavelength astronomy in the northern hemisphere, spanning the gap between thermal and non-thermal emission mechanisms, and bridging the capabilities of ALMA and SKA1.

The scientific mission, specifications and technical concept of a next generation VLA (ngVLA) are presently being developed. Preliminary goals for the ngVLA are to increase both the system sensitivity and angular resolution of the VLA and ALMA tenfold for frequencies spanning 1.2 GHz to 116 GHz. Specifications and costs for the ngVLA system, and major components such as the antennas, are in development in anticipation of the Astro2020 Decadal Survey and a facility design and construction proposal to the National Science Foundation (NSF).

The design of the antenna will be a major construction and operations cost driver for the facility. The antennas must have acceptable aperture efficiency and pointing precision for operation up to 116 GHz, with five to ten times the total collecting area of the VLA. Unblocked apertures are preferred, with wide subreflector subtended angles for compact feed and receiver packages. Improved reliability, and ease of access to the receiver and servo electronics packages, will be required to meet the operations cost requirement.

We present the high-level requirements for the antenna, the proposed antenna specifications and concept, and studies and design work under way towards a baseline design. We also discuss areas of technical risk, where technical advances may be required for affordable antenna production and assembly.

Preliminary Technical Specifications

Parameter	Summary of Requirement	Reference Reqs.
Frequency Range	1.2-116 GHz	ANT0101, ANT0102, ANT0103
Diameter	18m	ANT0202
Number of Antennas	214	ANT0401
Surface Accuracy	**Precision Operating Conditions** 160 µm RMS (λ/16 @ 116 GHz), primary and subreflector combined. **Normal Operating Conditions** 300 µm RMS, primary and subreflector combined.	ANT0501, ANT0502
Pointing Accuracy	**Precision Operating Conditions:** Absolute pointing: 18 arc sec RMS Referenced pointing: 3 arc sec RMS (4 deg angle, 15 min time) **Normal Operating Conditions:** Absolute pointing: 35 arc sec RMS Referenced pointing: 5 arc sec RMS (4 deg angle, 15 min time)	ANT0611, ANT0612, ANT0621, ANT0622
Tracking Range	Azimuth: ± 270 deg Elevation: 12 deg to 88 deg	ANT0801, ANT0802
Movement Rate	Slew: Azimuth 90 deg/min, Elevation 45 deg/min. Tracking: Azimuth 7.5 deg/min, Elevation 3.5 deg/min.	ANT0901, ANT0902, ANT0906
Antenna Geometry	Offset Gregorian, satisfying Mizuguch-Dragone polarization condition, with focal point on bottom.	ANT0201, ANT0206, ANT0211
Environmental conditions	**Survival Conditions at Stow Position:** Wind ≤ 50 m/s, temperature ≥ -40 C, 2.5 cm radial ice, 25 cm snow in dish. 2.0 cm diameter hailstones **Precision Operating Conditions:** Night time only, wind ≤ 7 m/s, temperature ≥ -15 C, no precipitation. **Normal Operating Conditions:** Day and night, wind ≤ 10 m/s, temperature ≥ -15 C, no precipitation.	ANT1411 through ANT1446

Optical Concept

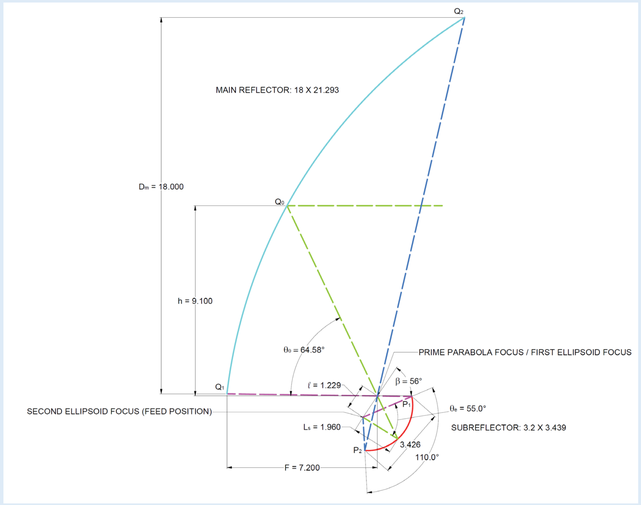

Figure 2: Preliminary optical concept of the ngVLA 18m aperture antenna. Minimal clearance is provided between the subreflector and main aperture to increase stiffness of the feed arm, and the wide subtended angle of the subreflector reduces the feed size.

Design Studies

The ngVLA project is presently in the requirements definition and conceptual development stage. Proceeding to a more detailed design and eventual construction requires endorsement from the National Academies of Sciences Astro2020 Decadal Survey and the NSF Division of Astronomical Sciences Directorate. The overall merit of this project will be judged, in part, based on technical readiness and cost realism. Since the antennas are expected to represent of order 50% of the project construction costs, several studies are underway.

General Dynamics: A contract is under negotiation with General Dynamics Corp, Richardson TX, for a costed reference design which meets the identified project specifications. The intent of this work is to explore cost effective concepts that meet the project requirements and to provide a reference design with known technical risk and cost. This reference design is required to contain enough detail to produce a reliable cost estimate and performance estimate. Where the latter should demonstrate that the specifications are met, it is not expected to contain enough detail to allow construction of prototype or production units. NRAO's expectation is that the technical requirements will not push technical boundaries. Rather, the key challenge of this work is to deliver a design that can be manufactured in volume and delivered affordably. A second challenge is reducing the maintenance burden and total lifecycle cost.

NRC-18 Meter Study: A similar study is being undertaken by the National Research Council of Canada. The work by NRC is intended to be complementary to the reference design. Since the reference design is low technical risk, it may inherently avoid emerging technologies and techniques that present possible added-value to the project but are not deemed sufficiently technically mature for mass production and robust cost estimation. NRCs work is intended to be higher-risk and higher-reward, ensuring that novel and viable concepts continue development through to the conceptual design down-select.

NRC-Optics Study: The Astronomy Technology Program at NRC-HAA Penticton has recently committed to conduct a study of the optics for the offset Gregorian 18m parabolic antenna to meet the requirements of the NRAO ngVLA project. The objectives of this study are; to define the optical prescription for the ngVLA reference designs and to provide EM performance analysis of the reference design optics. The optical design will employ shaped reflectors to optimize forward gain and reduce spillover temperature with single pixel feeds. This optical design will be used by both General Dynamics and NRC Canada for their respective design studies.

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