The Next-Generation Very Large Array Antenna Design Study

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ngvla
Next Generation Very Large Array

Table 1: ngVLA Antenna Key Requirements

Parameter	Value
Antenna Diameter	6m & 18m
Number of Antennas	244 x 18m, 19 x 6m
Antenna Optics	Offset Gregorian, Feed Low, Shaped
Frequency Range	1.2 GHz – 50.5 GHz, 70 GHz – 116 GHz
Surface Accuracy (Precision Operating Conditions)	160 µm RMS
Pointing Accuracy (Precision Operating Conditions)	Absolute pointing: 18 arc sec RMS Referenced pointing: 3 arc sec RMS

Abstract

The next-generation Very Large Array (ngVLA) is an astronomical observatory planned to operate at centimeter wavelengths (25 to 0.26 centimeters, corresponding to a frequency range extending from 1.2 GHz to 116 GHz). The observatory will be a synthesis radio telescope constituted of approximately 244 reflector antennas each of 18 meters diameter and 19 antennas of 6m diameter, operating in a phased or interferometric mode.

The NRC has conducted a design study for 6m and 18m Offset Gregorian, Feed-low, Azimuth/Elevation antennas for the ngVLA. The goal is to pursue a **novel** approach to antenna design, that may offer greater value than traditional manufacturing techniques.

We provide an overview of the current status of the NRC 18m antenna design study. The concepts for major antenna elements such as the primary reflector, mount, and drive system are presented. We also describe the major development activities that are presently underway to advance the design.

Antenna Design Study

The NRC has conducted design studies for 6m and 18m Offset Gregorian, Feed-low, Azimuth/Elevation antennas for the ngVLA. NRAO's expectation is that the technical requirements will not push technical boundaries but that the key challenge will be to deliver a design that can be manufactured in volume, delivered affordably, have low maintenance and total lifecycle costs. The designs generated as part of these studies are not expected to be the final design. The specifications for the final antenna design may change based on lessons learned in this design exercise or other parallel activities. The goal is to pursue a **novel** approach to antenna design, that may offer greater value than traditional manufacturing techniques.

The design work has concentrated on the 18m, Figure 1, as it presents the higher risk/challenge. Lessons learned on the 18m will be applied to the 6m as appropriate.

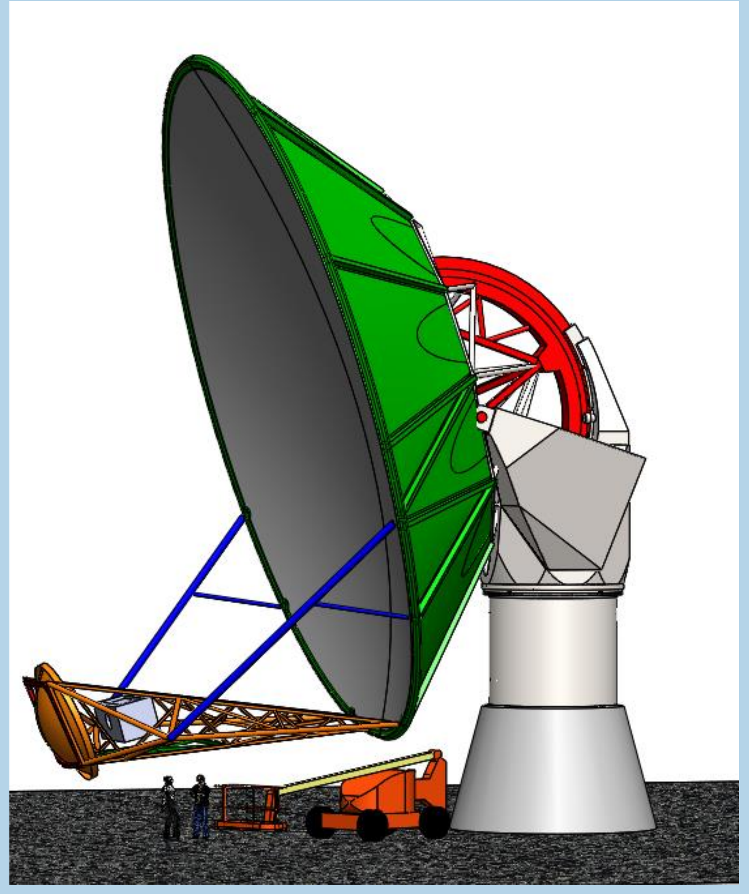

Figure 1: NRC 18m Antenna Concept.

Primary Reflector Structure

The NRC ngVLA antenna design is based on the Single-piece Rim-supported Composite (SRC) reflector technology developed at NRC over the past decade. The SRC concept has been successfully implemented in the DVA1 antenna, designed to work up to 10GHz, and in the DVA2 reflector, designed to work up to 50GHz. Both of these antennas used a tubular steel frame Back-Up Structure (BUS).

In scaling the concept to 18m, it was found that it was not possible to meet the surface accuracy requirements for 116GHz operating frequency with the discrete attachment points between the BUS and reflector surface. A composite outer BUS (oBUS) was developed to provide quasi-continuous support for the reflector surface, Figure 2, enabling much higher surface accuracy under loading to be achieved.

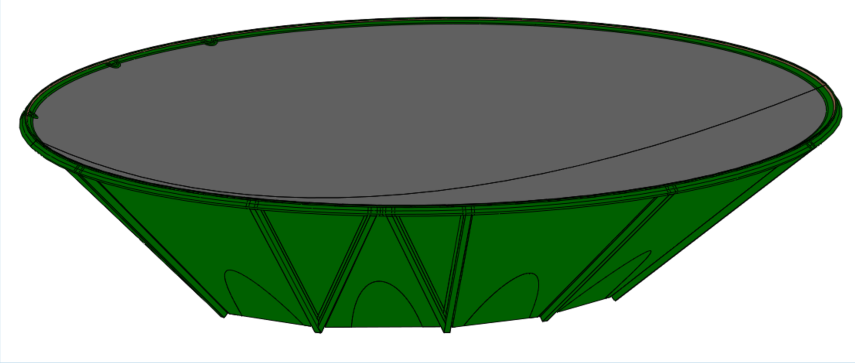

Figure 2: ngVLA Primary Reflector Surface and oBUS

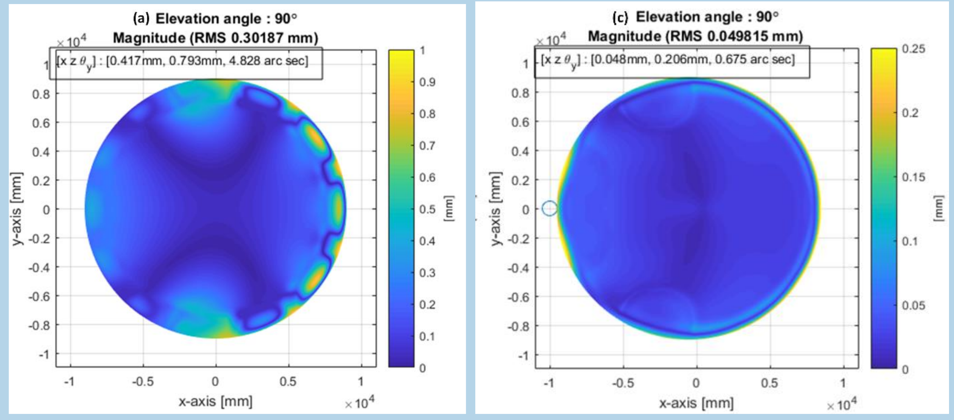

Figure 3: FEA Results Gravity at 90 deg El Angle (note difference in colour scales)

The Finite Element Analysis (FEA) results for gravitational deformations at 90 degrees elevation angle are shown in Figure 3 with tubular (left) and cone (right) back-up structures. The effect of the discrete support points can be seen clearly in the left hand image (Note difference in colour scales).

Primary Surface Adjustment

The initial surface accuracy is largely dependent on the accuracy of the mold but in order to achieve and maintain the required surface accuracy NRC has developed a surface adjustment concept that incorporates ~200 adjusters around the perimeter of primary reflector surface. Figure 4 shows a cross-section of the adjuster concept. Figure 5, a slice of an axially-symmetric reflector model, illustrates the improvement that can be made with the adjusters.

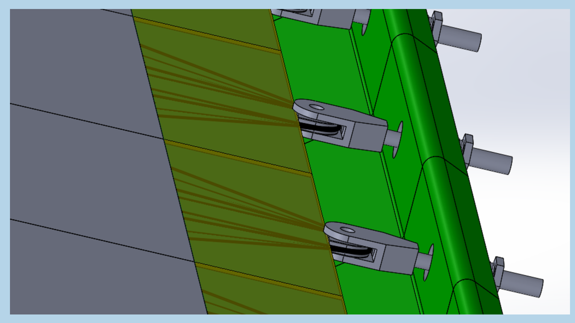

Figure 4: Surface Adjustment Concept

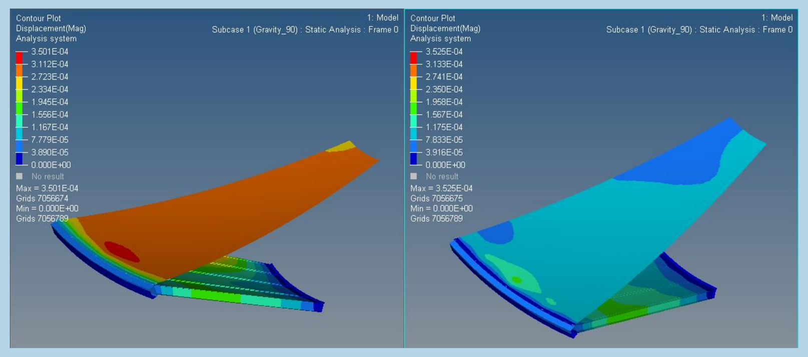

Figure 5: Surface Adjustment Modeling; Left before adjustment, right after adjustment (units are in meters).

Mount

In an earlier design study NRC had explored the 'wheel and track' concept for a 15m ngVLA capable antenna, however the cone oBUS developed for the 18m lends itself well to a pedestal/yoke style of mount, Figure 6. The oBUS is mated to a fabricated steel inner Back-Up Structure (iBUS) at 11 discrete points. The elevation axis and elevation drive arc are both incorporated into the iBUS.

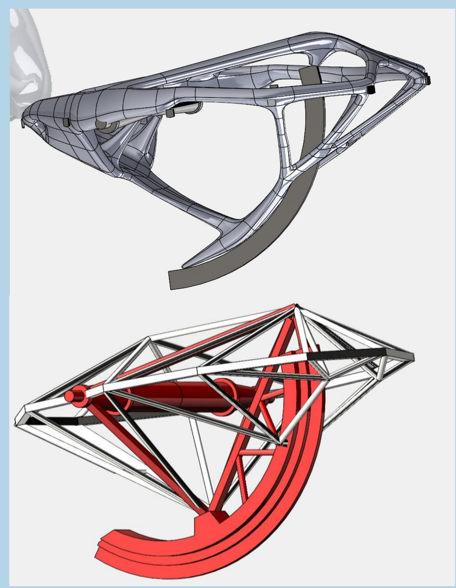

Figure 7: iBUS optimization result (top) and rationalized structure (bottom)

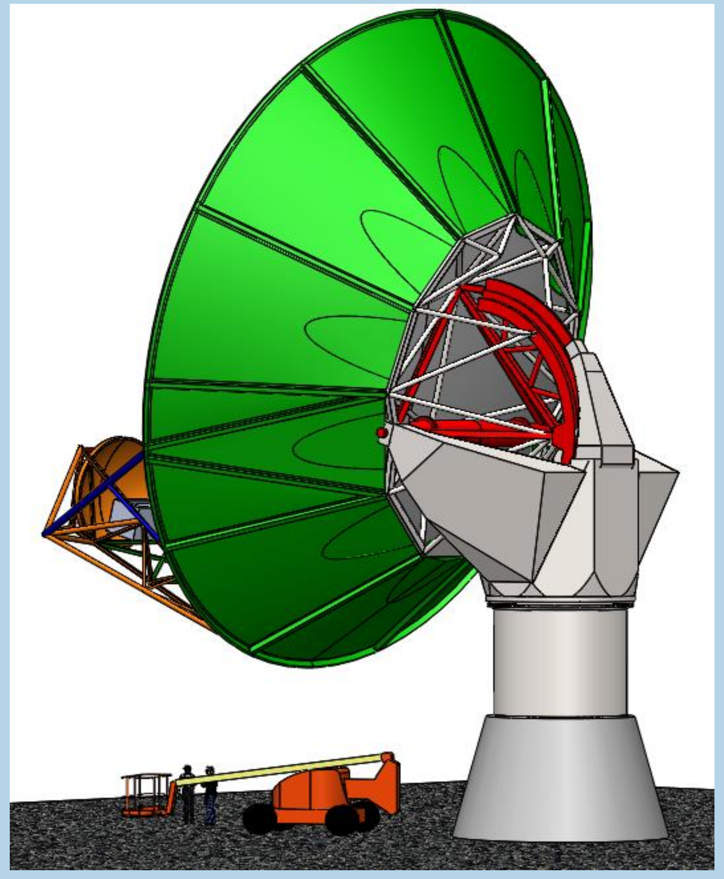

Figure 6: NRC 18m Pedestal Mount Concept

The iBUS structure will be fabricated steel. The iBUS structure was designed using topology optimization software, Figure 7 top, and then the result rationalized to a manufacturable structure Figure 7 bottom.

In order to accommodate low elevation angles with the feed-low configuration while minimizing the offset of the elevation axis the elevation drive sector was moved to above the elevation axis and a pocket created in the yoke center for clearance when at high elevation angles, Figure 8. The elevation drive motors (direct or gear) can be mounted on a superstructure at the back of the yoke.

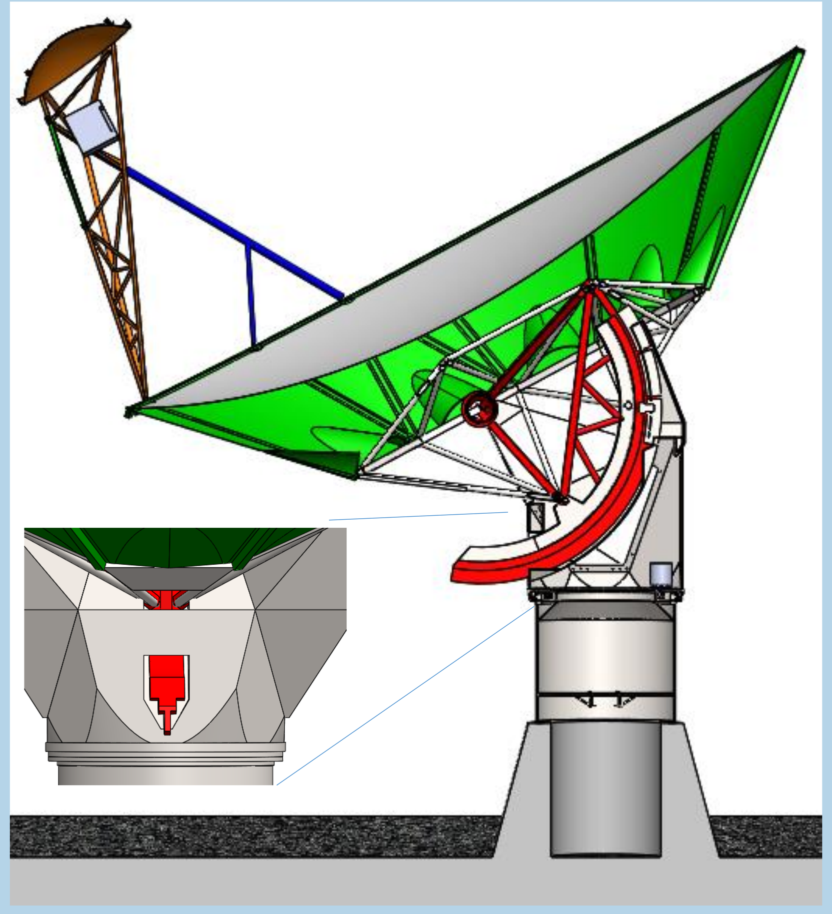

Figure 8: Pedestal Mount Cross Section

Axis Drives

The size and pointing requirements of the ngVLA require powerful, stiff axis drive systems. Direct drive systems such as those in use on the ALMA European and Japanese antennas have proven to provide exceptional performance. A trade study is underway to compare direct drives to more conventional gear train drives. The study will consider performance, capital cost and operating costs. For the current design study the NRC team, working with Phase USA, has incorporated direct drives on the ngVLA 18m antenna. The current pedestal and iBUS design are compatible with both drive types so development of the design has carried-on in parallel to the drive study.

Secondary Reflector and Feed Support Structure

The secondary reflector will also be single-piece composite. The support structure for it and the feed package will be a combination of composite tubes and molded trusses.

Multi-piece Reflector for Off-plains Antennas

The SRC concept requires that the fully assembled primary reflector be transported to the antenna station. This is feasible for ~175 of the antennas located on the Plains of St. Agustin, for the remaining antennas NRC is developing a method of segmenting the single piece surface for transport and reassembly at the antenna station.

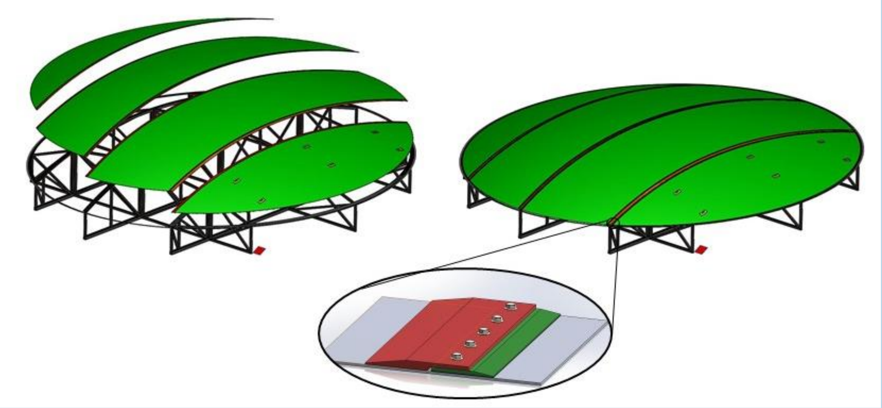

Figure 9: Multi-piece surface.

While still on the mould after manufacture a series of attachment flanges are bonded on to the single piece surface. It is then moved to a cutting jig where it is cut into 4 pieces, Figure 9. The cut surface sections can then be transported to the antenna station, Figure 10, where an assembly jig (similar to that in Figure 9) will be used to reconstruct the complete surface and attach the oBUS.

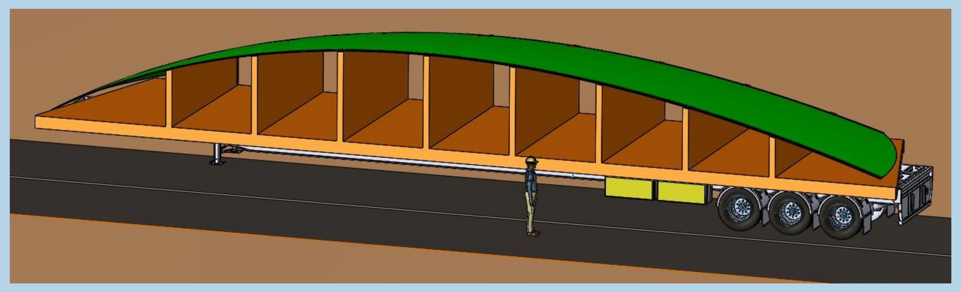

Figure 10: Surface section transport.

Future Work

Development is ongoing at NRC in several areas;

- Design and analysis of the multi-piece concept.
- Drive technology trade study.
- Materials testing and characterization.
- Manufacturing process characterization.
- Control system development.
- Prototype planning.

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