The Next-Generation Very Large Array Antenna Design Study

Dean Chalmers, Gordon Lacy, Mohammad Islam, Richard Hellyer
National Research Council of Canada,
Matt Fleming
Minex Engineering,

Ron Osterried, Matthew Wessel
SED Systems,
Mike Matusky, Giovanni Bonomi
Phase USA

ngVLA Antenna Design Study

The NRC is conducting a design study for 6 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 design generated as part of this SOW is 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.

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

Table 1: ngVLA Antenna Key Requirements

Parameter	Value
Antenna Diameter	6m & 18m
Number of Antennas	214 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

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.

Figure 1: DVA1 Antenna

The SRC concept has been successfully implemented in the DVA1 antenna, Figure 1, 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 a continuous support for the reflector surface, Figure 2, enabling much higher surface accuracy under gravitational loading to be achieved.

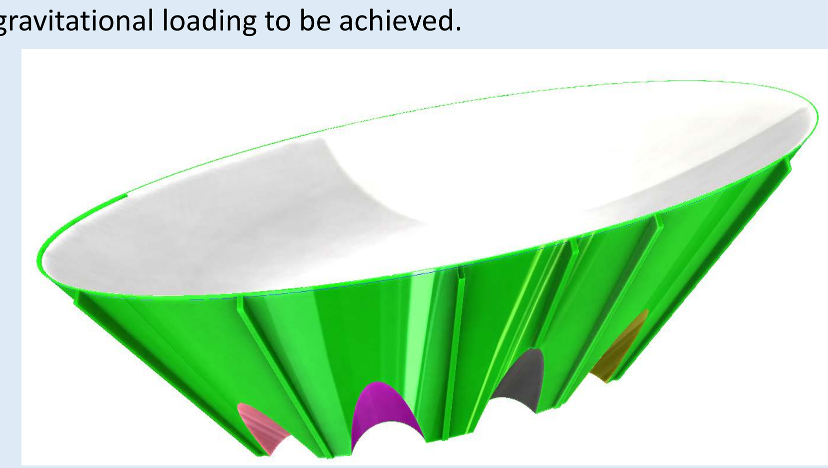

Figure 2: ngVLA Primary Reflector Surface and oBUS

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).

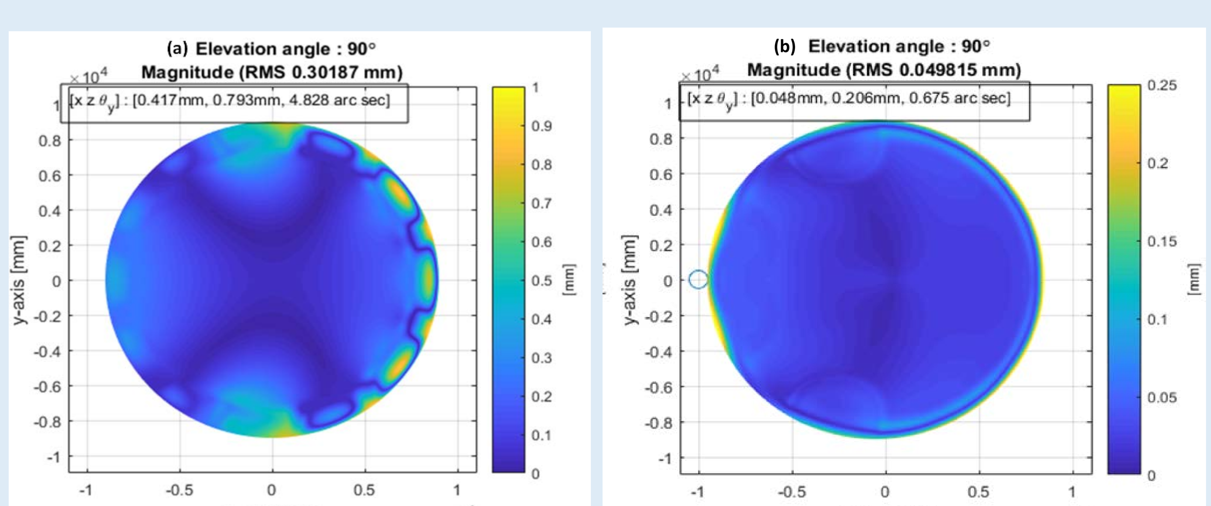

Figure 3: FEA Results Gravity at 90 deg El Angle (note difference in colour scales)

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 214 reflector antennas each of 18 meters diameter and 19 antennas of 6m diameter, operating in a phased or interferometric mode.

The NRC is conducting a design study for 6 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.

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 a compliant connection between the oBUS and primary reflector surface and adjusters tangential to the surface around the perimeter. Figure 4 shows a cross-section of the connection and Figure 5 illustrates the improvement that can be made using the adjusters (units are meters).

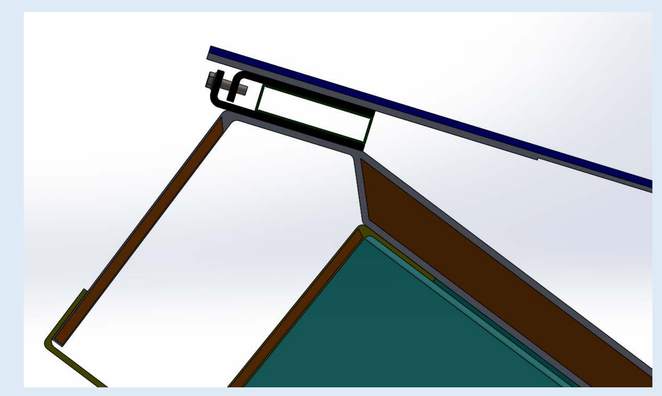

Figure 4: Surface Adjustment Concept

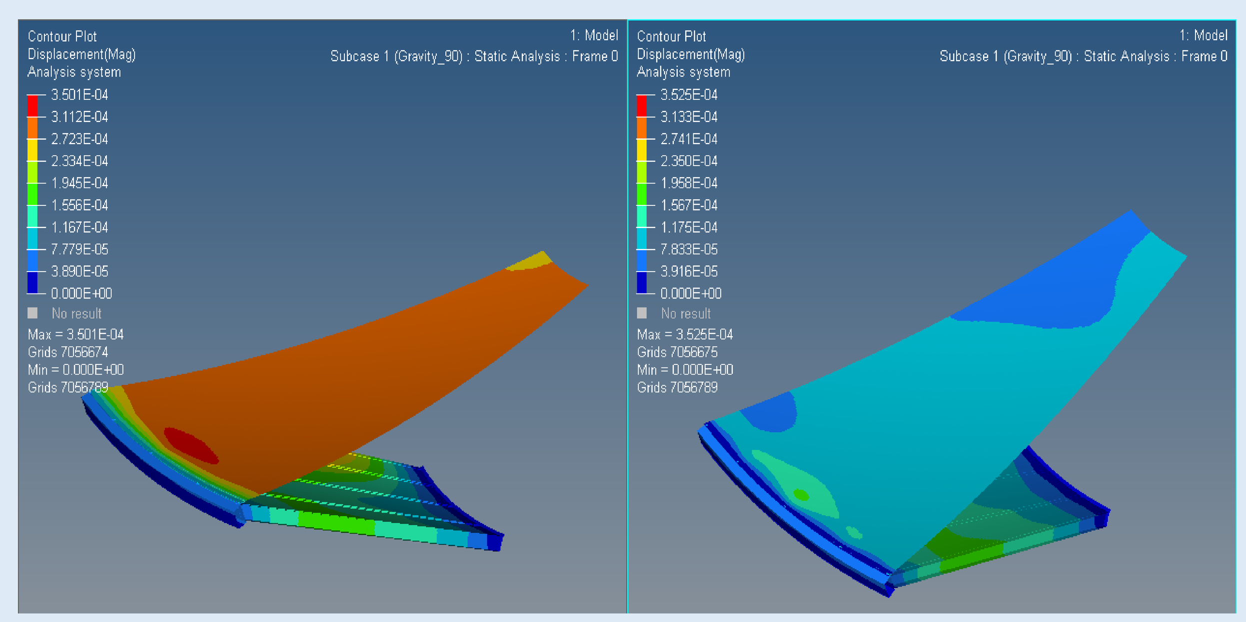

Figure 5: Surface Adjustment Modeling; Left before adjustment, right after adjustment

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, Figure 6.

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. Working with Phase USA the NRC team is investigating the application of direct drive on the ngVLA 18m antenna. 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. The current pedestal and iBUS design are compatible with both drive types so development of the design can carry-on in parallel to the drive study.

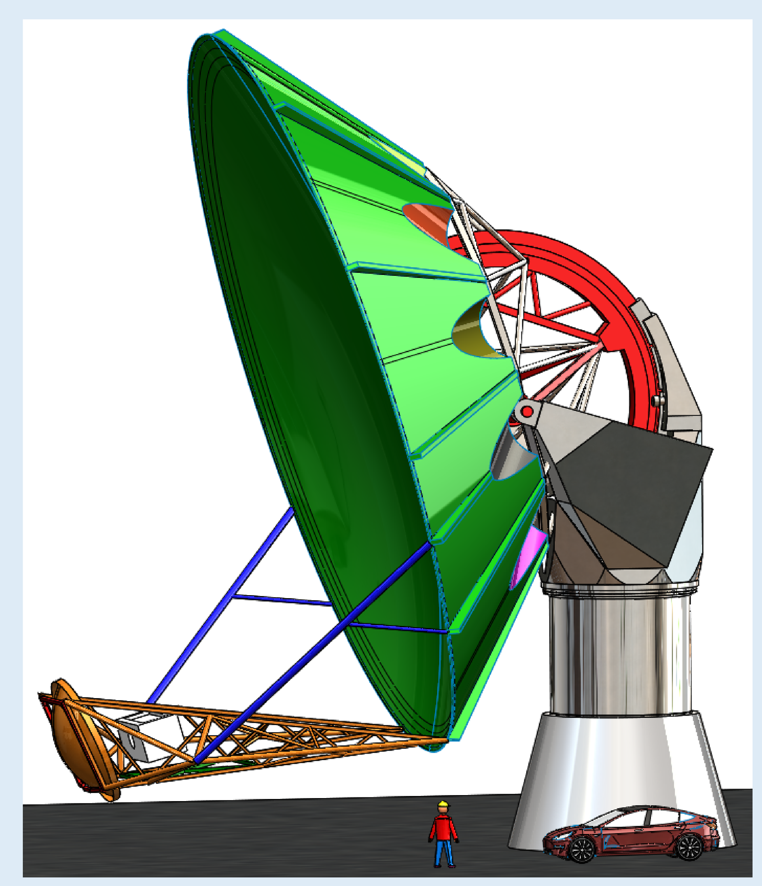

Figure 6: NRC 18m Antenna Concept.

Mount

In an earlier design study NRC had explored the wheel and track concept for a 15m ngVLA capable antenna, Figure 7. The wheel and track mount has some attractive features and was a good match for the tube frame BUS on the 15m where the elevation axis could attach to the BUS at the rim of the reflector.

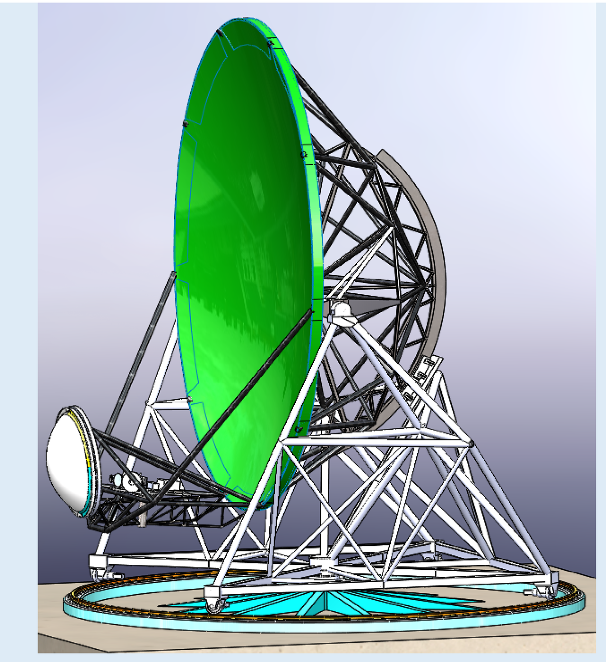

Figure 7: NRC 15m Wheel and Track Concept.

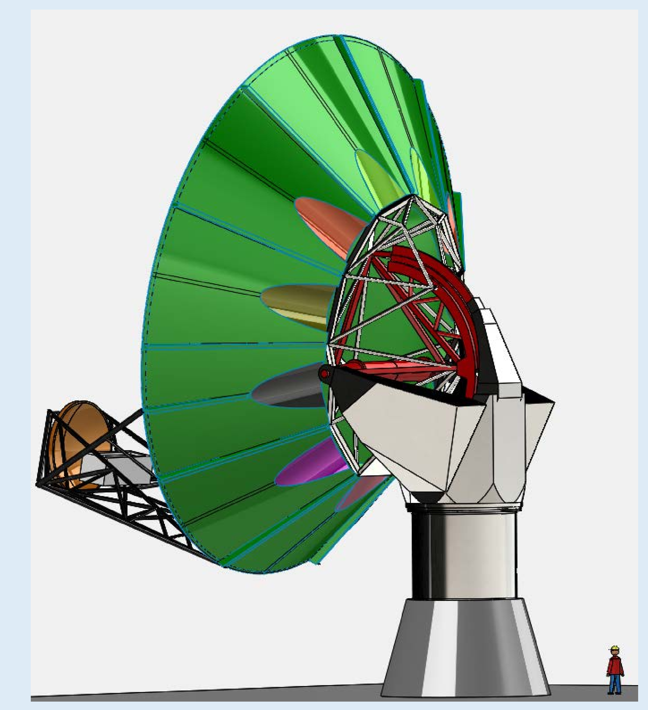

Figure 8: NRC 18m Pedestal Mount Concept

The cone oBUS developed for the 18m however lends itself to a pedestal/yoke style of mount, Figure 8. 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. Scallops between the oBUS to iBUS connection points provide compliance to reduce stress due to the mismatch of coefficients of thermal expansion of the oBUS and iBUS.

The iBUS structure will be fabricated steel. The iBUS structure was designed using topology optimization software, Figure 9 top, and then the result rationalized to a manufacturable structure Figure 9 bottom.

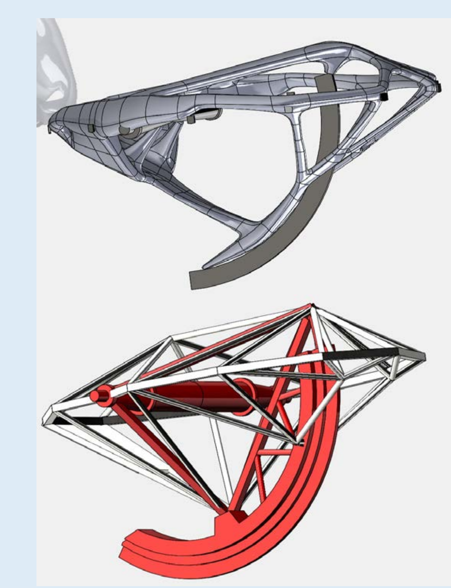

Figure 9: iBUS optimization result (top) and rationalized structure (bottom)

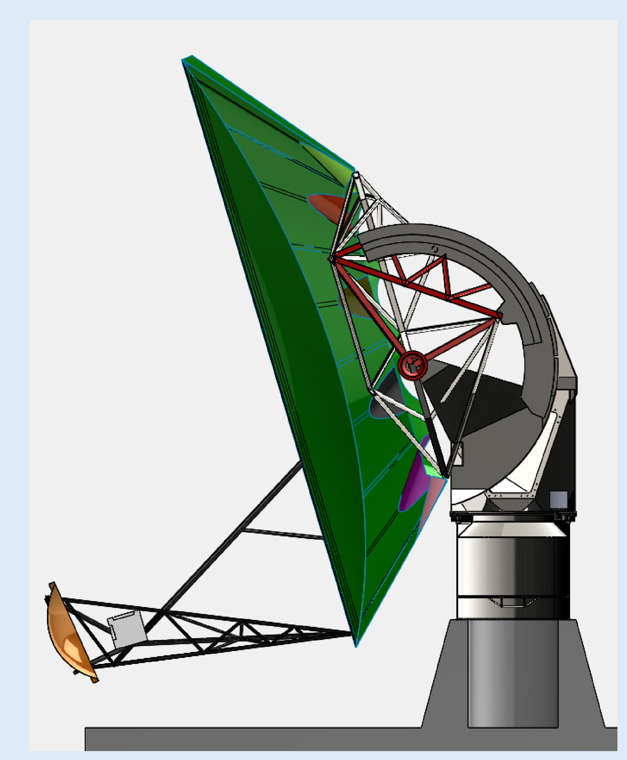

Figure 10: Pedestal Mount Cross Section

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 10. The elevation drive motors (direct or gear) can be mounted on a super structure at the back of the yoke.

Future Work

A Concept Design Review was held in May 2018 in which the design was reviewed by a panel of external experts. The design team is now working towards a Preliminary Design Review in the fall of 2018.

In addition to the drive trade study work will concentrate on detailing and analysis of the design in order to show conformance to the performance requirements at PDR.

As the design matures the cost estimate will be refined and maintenance and manufacturing plans developed.

National Research Council Canada | Conseil national de recherches Canada

Canada

ngvla

NRAO

NSF

Associated Universities, Inc.

The National Radio Astronomy Observatory is a facility of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc.