

# A NOVEL DUAL BRIDGE NEAR-FIELD MEASUREMENT FACILITY

Jeff Way  
Northrop Grumman Aerospace Systems  
Redondo Beach, CA

John Demas  
Nearfield Systems Inc.  
19730 Magellan Drive  
Torrance, CA 90502

## ABSTRACT

Northrop Grumman Aerospace Systems (NGAS), working with Nearfield Systems Inc. (NSI) and others, has installed a state-of-the-art near-field antenna measurement system to test various payload antenna systems. This horizontal planar near-field system was designed to measure antennas with up to 30' diameter apertures. In addition, a second bridge was included in the design so that the range can operate either as one very large scanner or as two autonomous ranges and double the testing throughput of the range. This near-field system features a large scan plane of nearly 40 ft. x 47 ft. with two smaller scan planes of 17' x 47' each. This horizontal near-field measurement system has the capability to operate from 500 MHz to 75 GHz using NSI's high speed Panther receiver and high speed microwave synthesizers. The system is capable of performing conventional raster scans, as well as directed plane-polar scans tilted to the plane of a specific Antenna Under Test (AUT). The range was completed in December 2011. This paper will describe this near-field range's design and installation, present test data and plots from its acceptance test including results of a NIST 18-term error assessment.

**Keywords:** Near-field, Planar, Scanner, Satellite Testing, Dual Bridge.

## 1. Introduction

Outdoor far-field antenna testing is no longer a common antenna test method since alternate methods of antenna testing such as near-field and compact range methods have become preferred. They offer the advantage of security, 24 hour testing and decreased real estate foot prints. To that end the, NGAS has closed its Capistrano Test Site (CTS) which had been a major resource for outdoor testing and topic of a recent AMTA paper.<sup>[1]</sup> However, in order to preserve some of range's capability, a large horizontal near-field range has been constructed.

This horizontal near-field range took the place of a pre-existing smaller near-field that was installed 12 years ago.<sup>[2],[3]</sup> The scanner was sized to measure apertures up to 30' in diameter. A design consideration to double the throughput of the range was the addition of a second horizontal bridge. This allowed the NF Scanner to operate as one very large scanner or as two separate smaller scanners. The design of the transitioning and locking out motions was a major challenge for NSI, the scanner manufacturer. A description of that system is provided in this paper.

This paper provides a brief description of the range, the hardware and software functions thought processes involved in developing the final configuration. Also briefly described is the installation and building preparation tasks performed.

NGAS selected NSI to provide a large precision planar near-field system in its Redondo Beach facility. In addition Far West provided the extensive facility design and modifications required to accommodate the new range. Additionally they provided the fabrication of the scanner support structure designed by Stephen Woolley and Associates. High level design requirements included the following:

- Conduct concurrent testing of two separate antennas within the same facility
- Be reconfigurable to accommodate a single large aperture test up to 30' in diameter
- Support testing from 0.5 – 67 GHz in either AUT Tx or AUT Rx modes
- Support high speed data collection of multi-frequency, multi-port data
- support X-Y raster scans or plane polar (Starburst) scans at a horizontal or inclined plane orientation

## 2. Design Overview

NSI responded with a unique system design that met these requirements. A key element is the novel dual bridge approach that provides two independent horizontal near-field range scanning capability within the same facility. The range incorporates two independent Y-axis bridges, designated “north” and “south,” that ride on a common set of X-rails. Each bridge is part of an independent scanner system with its own RF, computer, laser correction and motor control system. The independent scanners can support simultaneous testing of two antennas or one of the bridges, north, can be stowed in a parking area permitting the other (south) bridge full X-axis travel. When thus configured the south range operates as one large scanner and is ideal for testing large aperture antennas. The range supports traditional planar X-Y raster scans and plane-polar (starburst) scans either in level (horizontal) or at an inclined plane.



Figure 1 - Northrop Grumman Near-Field Range Model

Both scanners provide a minimum of 7.9 m (26') of probe tip to floor clearance that allows for testing of large vertical assemblies. The high capacity probe carriage for each scanner is attached to a 1.02m (40") linear translation Z-axis stage and accommodates probes covering 500 MHz up to 75 GHz. Three different length probe extension tubes can be used alone or can be combined together in different combinations to locate the probe at the optimum distance from the test antenna aperture.

Two independent RF and computer control systems allow fully independent scanner operation. The DSS compliant Panther based RF system on each range supports multi frequency, multi beam measurements of up to 2 million points per second in either AUT transmit or AUT receive mode.



Figure 2 - Mounting of Probe Using Extension Tubes

Both systems include a high accuracy XYZ laser optics system for tracking and correcting the probe position errors yielding a overall scanner planarity of < 0.025 mm (0.001") RMS over the entire scan area.

The specifications for the range are as follows:

Table 1 - Scanner Specifications

Parameter	Delivered Capability
Scan Area (approx.)	12.2 m x 14.3 m or 2x 5.1 m x 14.3 m (40' x 47' or 2x 17' x 47')
Scan Plane Orientation	Horizontal, Tilted Plane
Tilt Range	0° - 30°
Correction	XYZ Laser Optics, MTI Thermal Correction
Probe Height from Floor	7.9 m (26')
Z -Axis Travel Range	1.02 m (40")
Probe Roll Travel	0° - 360°
Planarity (corrected)	< 0.025 mm (0.001") RMS
X Position Accuracy	0.025 mm (0.001") RMS
Y Position Accuracy	0.025 mm (0.001") RMS
Scan Speed	0.51 m/s (20 ips) (y) 0.25 m/s (10 ips) (x)
Test Frequency Range	0.5-75 GHz
Polarization Switch	2 ports
AUT Switch	4 ports

## 3. Design Requirements

Table 1 summarizes the key performance specifications of the system. The overall goal was to provide high throughput for the production tests required for a wide range of satellite antennas as well

as other more general antenna testing. The delivered frequency coverage was from 0.5-75 GHz. Multiplexing requirements were to measure up to 64 switch and frequency configurations on-the-fly while scanning at speeds up to 0.51 m/s (20 inches per second). The data is typically taken for 8 frequencies, 4 antenna beam ports, and 2 polarizations during a given data acquisition scan. The gain accuracy and cross polarization requirements dictated the need for low cross polarization probes and probe pattern calibration.

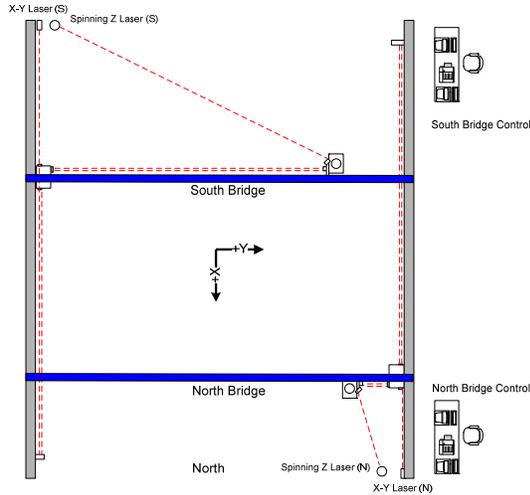


Figure 3 - NG NF Range Layout

#### 4. Hardware Description

**SCANNER** – The requirement to have dual independent bridges riding on a common set of X beams over such a large span and maintain accuracies required for mmWave measurements up to 75 GHz posed significant engineering challenges. Significant static, thermal and dynamic analysis was performed for both the steel support structure as well as the scanner itself. The scanner consists of two precision X-axis rails that are 16.8 m (55') long with a height of 0.9 m (36"). The beams are spaced 16.5 m (54') apart. The X beams are spanned by two Y-axis bridges. Each bridge weighs 4400 kg (9700 lbs) and has a rectangular cross section. Internal webbing provides rigidity. The scanner is supported on a rigid steel support frame, putting the system approximately 10.7 m (35') in the air to allow clearance for large antennas and the complete satellite payload if required. The support structure was designed and analyzed to minimize mechanical vibration and coupling between the two Y bridges during scanner motion. The X motion is accomplished using stepper motor drives at both ends of the bridges, synchronized by the computer software and running at speeds up to 0.25 m/s (10 ips).



Figure 4 - NGAS Dual Bridge Near Field Scanner

The Y axis probe carriage drive uses a precision stepper motor coupled to a rack and pinion drive system and provides probe scan speeds up to 0.51 m/s (20 ips). The scanner orientation with respect to the test antenna is shown in Figure 3. The system has 1.02 m (40") of Z-axis travel for changing the probe to antenna spacing and a rotator for use with single polarization probes.

**X-Y RASTER OR PLANE POLAR SCANS**-The measurement system supports both conventional planar X-Y raster scans, as shown in Figure 5, or plane polar (starburst) scans as depicted in Figure 6. Properly used, starburst scan can result in significantly reduced measurement times overall antenna gain is desired but sidelobe accuracy is less important.

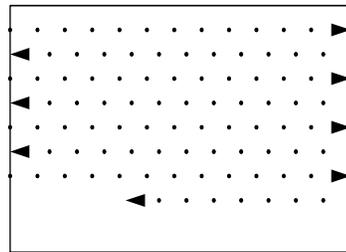


Figure 5 - Conventional Bi-directional X-Y Raster Scan

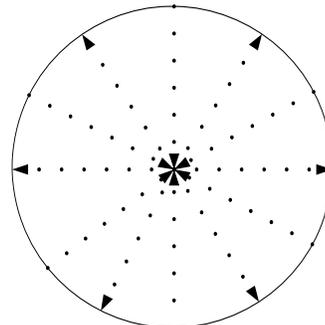


Figure 6 - Plane Polar or Starburst Scan

#### INCLINED SCAN PLANE OPERATION-

NGAS may test antennas that are attached to a spacecraft structure. The mounting of these antennas orients the aperture at an inclined plane. To optimally scan an antenna, the scan plane should be normal to the direction of propagation. The south range has a unique capability to perform planar X-Y and plane polar scan on an inclined plane while tilting the probe inclination of the scan plane up to 30 degrees and oriented at any azimuth angle.

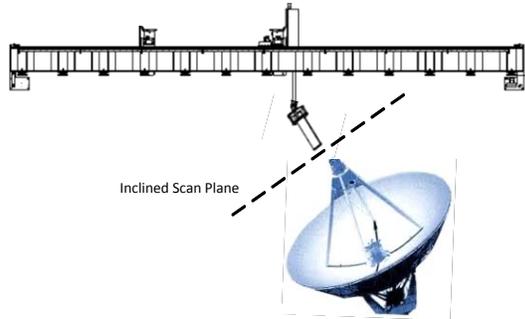


Figure 7 - Inclined Scan Plane

The NSI2000 measurement software is used to set the orientation and tilt angle of the probe and then executes a coordinated XYZ motion to move the probe in either an X-Y raster or polar inclined plane to match the AUT aperture orientation.

#### OPTICAL STRUCTURE MONITOR –

Each scanner has an independent XYZ optical structure monitoring system designed to track probe X and Y linear positions, and probe X, Y and Z errors. The system uses NSI patented laser interferometers for the linear position feedback and a separate spinning laser for measuring the probe Z axis position errors. The NSI2000 software reads the Z position sensor as the scanner is moved through its full range of XY travel and creates a Z error map. The values in this error map are used during subsequent scans drive the Z axis compensating for the errors resulting in the probe moving in a corrected plane. Laser tracker measurements show that both the north and south scanners have a corrected planarity of <math><0.050\text{ mm (0.002'') RMS}</math>.

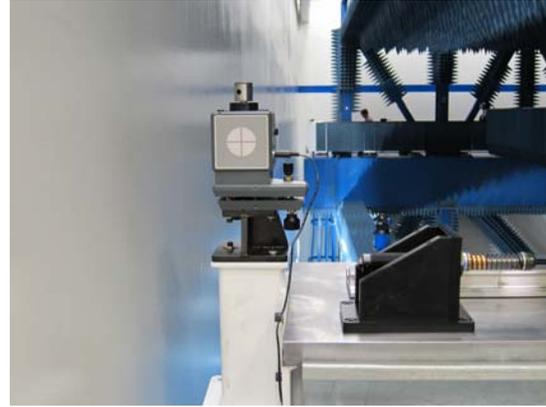


Figure 8 - Spinning plane Z laser

#### RF EQUIPMENT –

The RF subsystem is based on NSI Panther 9100 RF subsystem that was selected because of its high speed performance and excellent reliability. The system operates in the 0.5 to 50 GHz range in coax using two separate mixers and in waveguide to cover the band and from 50–75 GHz. Vertical equipment cabinets containing the receiver, sources, down converters and motor control electronics are located on the personnel catwalks at the scanner cable track entry points. Communications between the equipment racks and the control computers, located at the floor level, is through a high speed LAN and serial link.

### 5. Parking Control and Interlock Unit

Having two independent bridges that share the same X axis rails posed a unique safety problem demanding a special solution. The bridges can either be configured to run concurrently, each sharing approximately 50% of the X axis travel range, or the north bridge can be moved into a parking area at the far end of the X axis travel to permit the south Bridge to have maximum travel range. Since each scanner system is independently controlled and transitioning from one mode to the other requires a complex interlock system to ensure that the bridges do not interfere with each other. NSI provided a safety interlock system that provides independent control of the north scanner system. The Parking Control Unit (PCU) utilizes a Programmable Logic Array that monitors various removable limit stops associated with each scanner system. To transition from one mode to the other requires an operator to climb personnel access ladders to the scanner level and take control of the scanner system using a remote Operator Panel.



Figure 9 - Parking Control Unit (PCU) Operator Panel

The control panel was located at the scanner level to ensure the operator has optimal visual overview of the scanners as the range is transitioned. The panel provides the operator with status indicators of the scanner limits, the current mode of the scanners and the ability to independently move the north bridge into and out of the parking area once a stringent set of conditions are met. During parking and unparking activities, the measurement controllers are locked-out to prevent inadvertent scanner motion.

## 6. Software Description

The software uses NSI's PC-based menu-driven software package. Additional modules were provided for the optical structure monitoring system and the time synchronization requirements for the multiple frequency measurements.

The optical module reads the various sensors and derives the probe X, Y, and Z position errors. These errors are then used to provide either correction during data processing or to correct the probe position real-time while scanning.

Critical timing is managed by the Panther 9100 beam controller that is part of the Panther 9100 receiver. Both the RF and LO sources are fed with a frequency list at the beginning of the acquisition. The sources are then be triggered from the PC while scanning with a TTL trigger line. The frequency lists are scanned in reverse order on the reverse pass to insure the near-field points at a given frequency/beam position are spatially aligned with the forward pass.

## 7. NIST 18 Term and ATP Results

The NGAS near field scanner system was commissioned on 15 December 2011. Independent mechanical measurements indicated that the accuracy and planarity met or exceeded the original requirements of the job. Plots for room scattering are shown for 60 GHz, 20 GHz and 0.5 GHz.

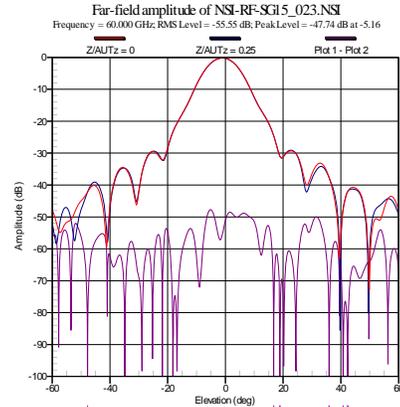


Figure 90 - 60 GHz Room Scattering C-pol Vcut

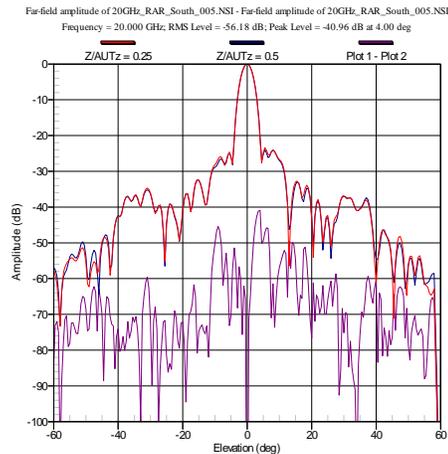


Figure 101 - 20 GHz Room Scattering C-pol Vcut

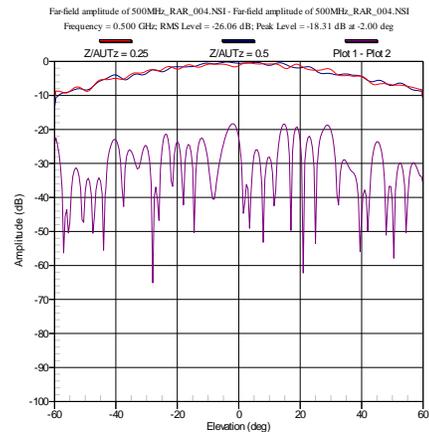


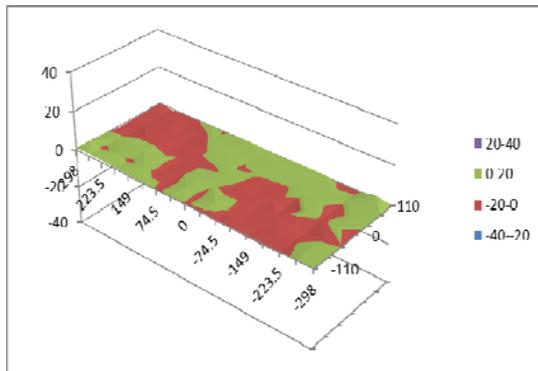
Figure 112- 0.5 GHz Room Scattering C-pol Vcut

As part of the commissioning process, full NIST 18 term error assessments were conducted for each range at L-band, X-band and Ku band. The results of independent laser tracker measurements showed that the planarity of the north and south scanners were <0.025 mm (0.001") RMS.

**Table 2 - Laser Tracker Planarity Data - North**

Y position	X position							
position	-110	-73.333	-36.667	0	36.667	73.333	110	
298	1.16	0.7	0.25	-0.91	-0.37	-0.43	-0.28	
260.75	1.33	-0.23	0.61	-1.25	-0.6	-0.36	-0.72	
223.5	1.09	0.33	0.78	-0.28	-0.44	-0.2	-0.16	
186.25	0.66	-0.2	0.84	-0.22	-0.28	-0.73	0.01	
149	0.52	0.36	0.5	-0.55	-0.61	-0.27	0.27	
111.75	0.48	-0.27	-0.43	-0.19	-0.15	0.1	-0.06	
74.5	-0.15	-0.31	-0.07	-0.12	0.12	0.16	0.3	
37.25	0.21	0.56	0.3	-0.06	0.18	0.13	0.57	
0	-0.12	-0.18	0.06	0.11	-0.05	0.09	0.33	
-37.25	-0.26	0.79	-0.27	-0.03	0.01	0.26	0.2	
-74.5	-0.69	-0.05	-0.21	-0.26	-0.02	0.22	0.46	
-111.75	-0.63	-0.38	-0.64	-0.2	-0.06	0.28	0.43	
-149	-0.96	-0.42	-0.28	-0.94	0.31	0.15	0.29	
-186.25	-0.8	-0.06	-0.51	0.33	0.37	0.21	-0.24	
-223.5	-0.63	-0.19	-1.15	-0.11	-0.56	0.28	-0.18	
-260.75	0.43	0.77	-0.28	0.16	0.3	0.54	1.59	
-298	0.1	0.54	-0.02	-0.48	0.27	0.61	-0.25	

p-p: 2.833 mil  
rms: 0.492 mil



**Figure 12 - Planarity North System - Laser Tracker**

## 8. Facility Modifications

The existing seismic isolation pad was enlarged to accommodate the larger scanner footprint. The floor was excavated and re-bar was inserted into the existing slab and bonded into place. An additional bank of lamps was added to improve lighting and the existing HVAC system was left intact. It has provided better than  $\pm 2^{\circ}\text{F}$  temperature stability. New pop-down sprinkler heads were employed in the fire suppression system with 30" pyramidal absorber on the ceiling.

## 9. Acknowledgements

The authors would like to acknowledge the contributions of the following team members that played critical roles in the project: NGAS – Scott Delaney, Pat Vaughn and Mark DeSmidt; Steven Woolley & Associates – Dan Woolley; NSI – Hulean Tyler and Scott Caslow; Far West – Chris Clausen.

## 10. Summary

A state-of-the-art near-field test range has been implemented at Northrop Grumman Aerospace Systems in Redondo Beach, CA. This system is well suited to measure, analyze and characterize various antennas with minimal time and a high facility throughput.

## 11. References

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