A LARGE COMBINATION HORIZONTAL AND VERTICAL NEAR FIELD MEASUREMENT FACILITY FOR SATELLITE ANTENNA CHARACTERIZATION

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ABSTRACT

A large horizontal near field measurement facility has been validated and commissioned at Lockheed Martin's Sunnyvale, CA facility. The new measurement facility will be used for characterizing antennas for a variety of satellites over a frequency range of 1 – 26.5 GHz. A horizontal near field scanner with a 14m x 7.8m (46' x 26') effective scan area has been designed to allow for 9.8m (32') of vertical clearance permitting zenith oriented satellites to be easily positioned within the range and tested in an efficient manner. The facility will soon support the measurement of antennas that are in a vertical orientation. This is accomplished with a novel add-on that allows vertical planar near field scanning on the same range. The vertical scanner has an effective coverage area of 13.6m (45') horizontal x 9m (30') vertical. The system is being used to test commercial communications satellites.

Keywords: Near-field, Satellite Testing,

1. INTRODUCTION

Lockheed Martin Corp. recently inaugurated the world's largest commercial satellite production facility in Sunnyvale, CA. This new 158,000-square-foot facility has been designed to produce 16 satellites per year in an assembly-line manner, most of them for telecommunications customers. A key element in this new facility is the near-field antenna test range. This 14m x 7.8m (46' x 26') combination horizontal and vertical range, supplied by Nearfield Systems, Inc., (NSI) is the largest static article near-field scanner in the world. The range allows for rapid setup and testing of a variety of spacecraft with zenith oriented antennas. A novel vertical tower allows near field testing of vertically oriented satellite antennas without the need to reorient the spacecraft. This vertical add-on will be installed during 3Q97.

The first antennas to be tested are on a large communications satellite used for high-powered direct broadcast service. Lockheed Martin Corp. manufactures the antennas at its facility in East Windsor, NJ. then integrates and tests the spacecraft at its Sunnyvale, CA facility.

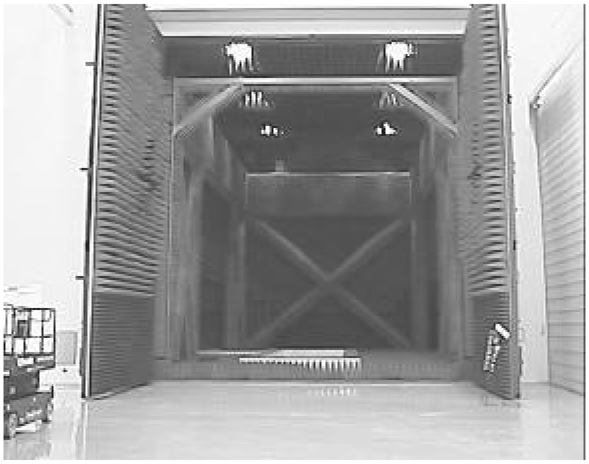

Figure 1. Lockheed Martin 14m x 7.8m (46'x 26') NF Range

Satellite antenna test verification can be done using a variety of methods including near-field, far-field, compact range, or analysis with measured feed data. Large aperture sizes demand large and expensive compact range systems. When considering alternative test methods, Lockheed Martin chose the planar near-field method based on the following advantages:

- Minimal real-estate requirements
- Lower cost than compact range
- No motion of test antenna or satellite
- More symmetrical gravity effects on antennas
- Co-located with spacecraft assembly area
- High accuracy and high test throughput
- Complete characterization of antenna

Lockheed Martin selected Nearfield Systems Inc. (NSI) to implement a large precision planar near-field system for tests on their satellite antennas. NSI's scanner design includes a high accuracy optical system for tracking and correcting the probe position errors yielding a overall scanner planarity of < 0.05 mm (0.002") RMS over the entire scan area.

The RF subsystem includes a high speed Hewlett Packard HP8530A microwave receiver used in the dual-source external mixer configuration.

The specifications for the range are as follows:

Parameter	***Delivered Capability***
Scan Area	14m x 7.8m (46'x 26')
Scan Plane Orientation	Horizontal
Probe Height from Floor	9.8m (32')
Z –Axis Travel Range	24 cm (9.8")
Probe Roll Travel	0-360º
Planarity (corrected)	< 0.03 mm (0.0014") RMS
X Position Accuracy	0.025 mm (0.001") RMS
Y Position Accuracy	0.025 mm (0.001") RMS
Scan Speed	0.76 m/s (30 ips) (y) 0.25 m/s (10 ips) (x)
Test Frequency Range	1-26.5 GHz
Polarization Switch	2 ports
AUT Switch	4 ports
Gain Accuracy	±0.3 dB
Cross-polarization Accuracy	±1.31 dB at –30 dB
Sidelobe Accuracy	±1.14 dB at –30 dB
Pointing Accuracy	±0.023º

TABLE 1.

2. DESIGN REQUIREMENTS

Table 1 summarizes the performance specifications of the system. Key among these was to provide high throughput for the production tests required for commercial satellite testing. The frequency coverage was from 1-26.5 GHz. Multiplexing requirements were to measure up to 64 switch and frequency configurations on-the-fly while scanning at speeds up to 0.42 m/sec. (17 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.

3. HARDWARE DESCRIPTION

SCANNER - The scanner consists of two precision X-axis rails spanned by a Y-axis bridge. The rails are supported on a rigid steel support frame, putting the system approximately 10 meters in the air to allow clearance for the antennas and the complete satellite if required. The X motion is accomplished using motor drives at both rails, synchronized by the computer software and running at speeds up to 0.25 m/s (10 ips). The Y axis drive uses a high speed rack and pinion drive system providing probe scan speeds up to 0.76 m/s (30 ips). The scanner orientation with respect to the test antenna is shown in figure 2. The system is also provided with 24 cm (9.8") of Z-axis travel for changing the probe to antenna spacing and a rotator for use with single polarization probes.

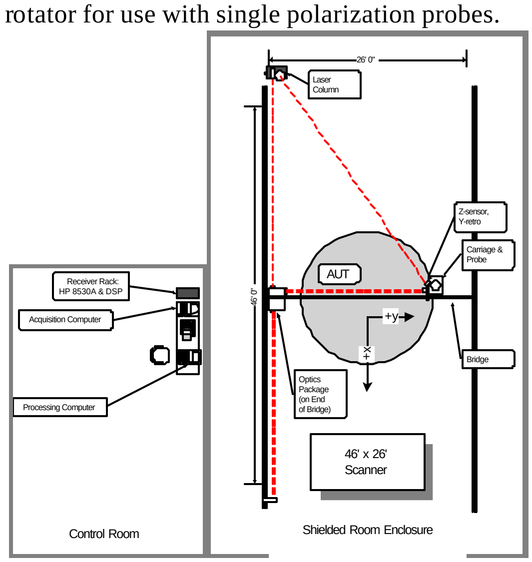

Figure 2. Lockheed NF Range Layout

OPTICAL STRUCTURE MONITOR - Because the system is located in a seismically active area in California, a basic design objective was to allow for and compensate for some movement of the structure due to ground settling and small earthquake effects. An optical structure monitoring system was designed and implemented to track probe X and Y linear positions, and probe X,Y, and Z errors. The system uses HP laser interferometers for the linear position feedback, and a custom designed NSI optical subsystem for measuring the probe position errors. The probe Z position error is derived using a spinning plane laser tracked by a sensor at the probe (see Figure 3).

Figure 3 Spinning plane Z laser with XY laser below plate

RF EQUIPMENT - The RF subsystem is based on a Hewlett Packard 8530A receiver. The HP8530A was selected because of its high performance and excellent reliability. The multiple frequency switching requirements and cable lengths dictated selection of the dual-source, external mixer system configuration for the HP8530A. The HP85320A&B mixer option was chosen which allows wide band operation of the system from 1-26.5 GHz without the need to change cables. The RF system is configured to allow transmit from either the probe or the AUT with a minimal amount of recabling. Figure 5 (located at the end of the paper) is a block diagram of the RF equipment implemented on the range.

Eleven Open Ended Wave Guide (OEWG) probes were supplied along with three dual CP and three dual linear versions to enable testing over the entire band. Because the test antennas were large and the far-field coverage requirements were quite narrow, high gain probes were desirable. Nine standard gain horns were also provided.

VERTICAL ADD-ON - A vertical tower add-on that provides vertical scan capability in the same facility will be installed 3Q97. The add-on (shown in Figure 4) allows for testing spacecraft with vertically oriented antennas. The add-on utilizes the existing computer, RF and existing resources that were installed as part of the horizontal range. The vertical tower is supported by a base rail and is attached to the X rail at the top of the horizontal scanner. The base rail supports the entire weight of the vertical scanner and, together with the X-rail and Y-bridge of the horizontal scanner, defines the nominal vertical scan plane.

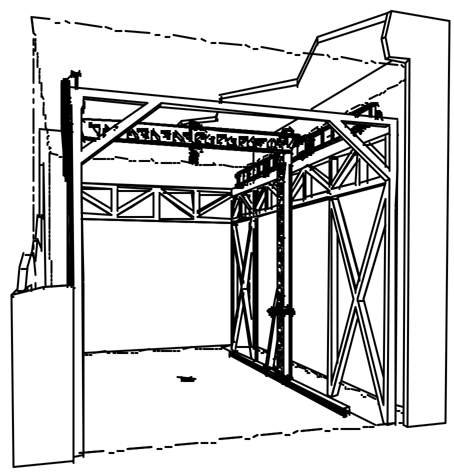

Figure 4. Vertical Add-On Scanner

Y-axis motion for the vertical scan is provided by a probe carriage running along a pair of linear guides similar to that used as the base rail. A carriage-mounted stepper motor drives a pinion against a stationary rack on the providing vertical motion. A carriage counterweight system located on the inside of the tower allows for the use of smaller drive components and acts as a fail-safe; preventing the carriage from dropping in the event of a drive system failure.

4. 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 corrections during data processing, or to actually correct the probe position real-time while scanning. For instance, small movements of the X and Z axes while scanning the Y axis can be used to keep the probe moving in a straight line.

The synchronization module required the PC to take direct control of the HP8360 sources. Both units are fed with a frequency list at the beginning of each forward or reverse scan. The sources can then be triggered from the PC while scanning with a TTL trigger line. Since the frequency of one source is offset from the other by 20 MHz, the HP8530A receiver remains phase locked and in its fast data mode during the entire measurement sequence. The PC simply triggers the receiver at the appropriate times and reads the data from its buffer. The frequency lists are scanned in reverse order on the reverse pass to insure the near-field points at a given frequency are spatially aligned with the forward pass.

The NSI software also has a built-in expert system and an automated test sequencer. The expert system aids the operator in designing the near-field test and insuring the test parameters selected will yield acceptable results. The automated test sequencer allows complex test scenarios to be set up by an experienced range technician, and run by novice operators with a minimum of keystrokes.

5. SUMMARY

A state-of-the-art near-field test range has been implemented at Lockheed Martin's Commercial Satellite Production Facility in Sunnyvale, CA. This system is enabling Lockheed Martin Corp. to measure, analyze and characterize the main mission antennas on the commercial satellites in record time. At the time of this writing, the first satellite was undergoing testing to verify antenna performance.

REFERENCES

1. Near-field Antenna Measurements, by Dan Slater, Artech House, Norwood, MA, 1991.
2. Implementation of a 22' x 22' Planar Near-Field System for Satellite Antenna Measurements by G. Hindman and G.F. Masters, Antenna Measurement Techniques Association (AMTA) symposium, October 1993.
3. An Automated Test Sequencer for High Volume Near-Field Measurements, by Greg Hindman, Dan Slater, Antenna Measurement Techniques Association (AMTA) symposium, October 1993.
4. Position Correction on Large Near-Field Scanners Using an Optical Tracking System by G. Hindman, Antenna Measurement Techniques Association (AMTA) symposium, October 1994.

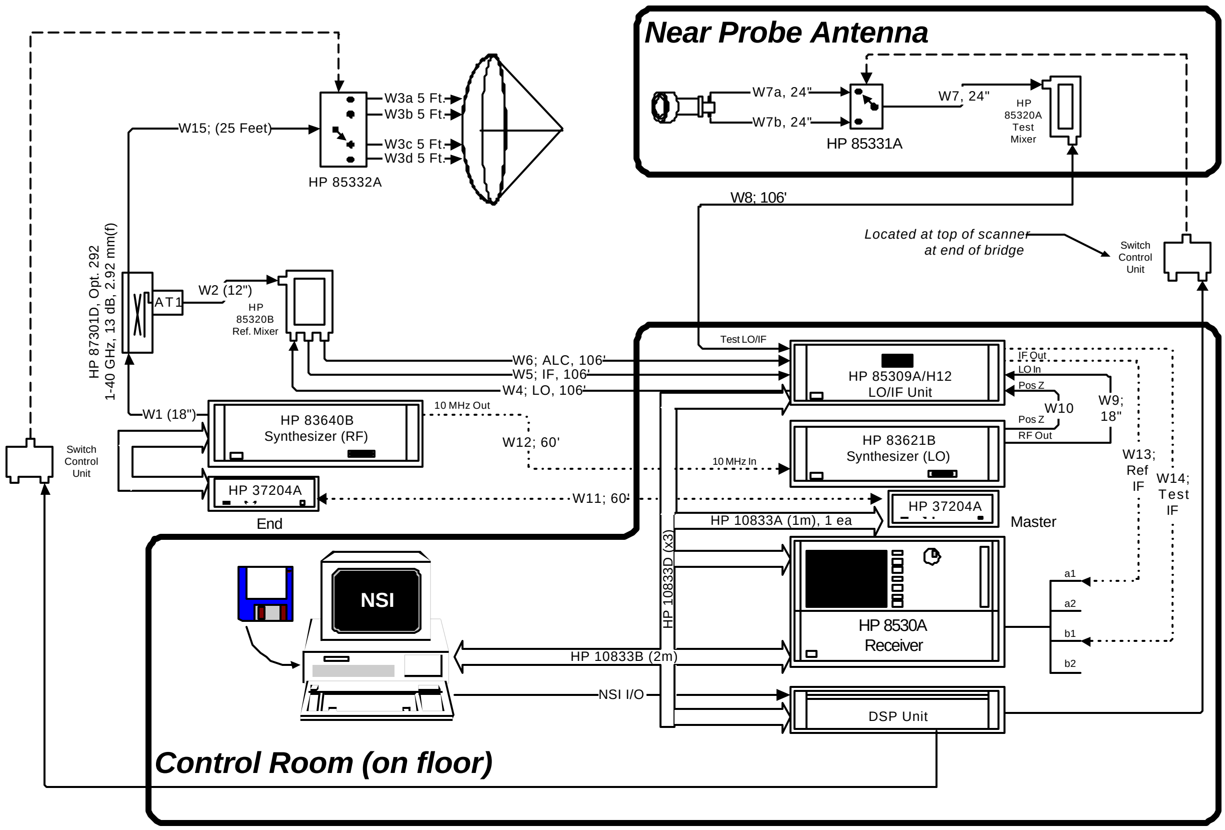

Figure 5. Lockheed RF System Block Diagram – Transmit from AUT