33 BY 16 NEAR-FIELD MEASUREMENT SYSTEM

Terrance Speicher*, Sevtap Sapmaz* and Michiharu Niwata**

* Nearfield Systems Incorporated
1330 E. 223rd Street Bldg. 524
Carson, CA 90745 USA
Tel: +1–310–518 4277 Fax: +1–310–518 4279
E-mail: tspeicher@nearfield.com and ssapmaz@nearfield.com

** Toshiba Corporation Komukai Works
1, Komukai, Toshiba-cho, Saiwai-ku, Kawasaki, 210 Japan
Tel: +81–44–548 5092 Fax: +81–44–541 4286
E-mail : michiharu.niwata@toshiba.co.jp

ABSTRACT

Nearfield Systems Inc. (NSI) has delivered the world's largest vertical near-field measurement system. With a 30m by 16m scan area and a frequency range of 1GHz to 50GHz, the system consists of a robotic scanner, laser optical position correction, computer and microwave subsystems. The scanner and microwave equipment are installed in an anechoic chamber 40m in length by 24m in width by 25m in height. The robotic scanner controls the probe positioning for the 33m by 16m vertical scanner using X, Y, Z and polarization axes. The optical measurement package precisely determines the X and Y axes position, alignment errors along the X and Y axes, and Z-planarity over the XY scan plane.

Keywords: Antenna Measurements, Near-Field, Robotic Scanner, System Design, Microwave System Design.

1. INTRODUCTION

The world's largest vertical near-field measurement system is described in this paper. This range accommodates a 30m by 16m scan area at a frequency range from 1GHz to 50GHz. The system consists of a robotic scanner, optics correction, computer and microwave subsystems. The scanner and microwave equipment are installed in a shielded anechoic chamber 40m in length by 24m in width by 25m in height. The facility overview is discussed in Section 2. The robotic scanner is discussed in Section 3. The laser optics is discussed in Section 4. The computer subsystem is discussed in Section 5. The microwave subsystem is discussed in Section 6. The test results are discussed in Section 7.

2. FACILITY OVERVIEW

The robotic scanner is installed in a shielded chamber with the control room adjacent to the test floor. The system provides the capability for computer controlled multiple frequency, multiple beam, multiple polarization near-field antenna measurements.

Figure 1 is a photograph from the left wall showing the expanse of the range. The base of the scanner is below floor level in a pit that extends along the back wall. The pit can be enclosed at floor level and microwave absorber laid upon it for uninterrupted coverage from wall to wall. The tower transverses from left to right along the back wall and is covered with microwave absorber on all sides. The tower can be moved to the right corner and parked in a storage pocket when the chamber is used for other than near-field antenna tests.

Figure 2 is a photograph along the right wall showing the immensity of the chamber compared to two persons standing in front of the scanner. The tower is positioned just outside of the storage pocket that provides an entrance door into the control room. The access door shown on the right wall enters into the staging area outside the large chamber doors shown in the right foreground. Absorber walkways can be seen leading to locations around the perimeter of the chamber. Tower struts can be seen through the slot with the probe near the top. The tower profile of 305mm absorber necks down 12m above the floor at the top of the truss tower above, which the column extends.

Successful design of the mechanical aspects of the near-field scanner began with customer coordination on the facility housing the measurement system. The scanner became an integral part of the facility during installation. Proper design considerations were made for the stability of the foundation that supports the scanner, the storage of the movable tower when not in use and the environment in which antennas will be tested. Repeatable measurements over time will provide reliable characterization of antenna performance.

The foundation plays a significant role for scanners with large horizontal and vertical dimensions. Heavy scanners, constructed in segments for transportation, must be attached directly to the foundation. Anchoring the base beams through the shielding was a coordinated effort between the facility and scanner contractors. Strength was not a design driver, but seismic forces can be significant.[1] Under normal operation, members are loaded in compression at all times.

The large shielded anechoic chamber is used for applications in addition to near-field measurements. To minimize sources of reflections, the scanner base is installed in a pit below floor level and the tower moves into a pocket for storage. By installing the base beams below floor level, a pit cover entirely encloses the base of the scanner. By moving the tower into a storage pocket in the corner of the chamber and completely covering all sides with absorber, the chamber is free of any vertical obstructions. Completely covering the robotic scanner provides additional utilization of the test facility.

Temperature stability within the chamber was analyzed as changing temperatures create internal strains and corresponding deformations that potentially distort the scan plane of the probe. Minimizing gradients and bulk temperature changes reduce the distortion inherent in a device constructed of various materials. The environmental conditions inside the chamber during scans are 25±3°C nominal temperature and 50±10% relative humidity.

The construction of a facility to house the large range addressed the support and attachment of the robotic scanner within the shielded foundation, the covering of structural elements with microwave absorber and the temperature and humidity control of a massive amount of air. These considerations allow for maximum utilization of the range for microwave antenna testing.

3. ROBOTIC SCANNER

The robotic scanner provides probe positioning control of 33m horizontal X-axis (3m is the storage pocket) by 16m vertical Y-axis by 250mm lateral Z-axis by 360 degree polarization-axis. Design principles include using symmetry and kinematic attachments. Support for the scanner's horizontal axis beams are on machine levelers spaced intermittently to the vertical axis tower bearing distance. The moving tower weight is balanced on its three linear bearings to produce comparable deformations. The tower attaches at three locations to linear bearings for adjustment in two lateral directions. The column is three segments connected with field joints attached to the top of the tower and to the bottom of the tower. These elements assure repeatable operation of the scanner.

Figure 3 is a photograph of the scanner during assembly at the NSI's factory in California. The base consists of two parallel rails of structural I-beam segments connected with strut cross members. The tower carriage is shown to the left with the bottom segment of the tower in place. The upper tower segment is shown to the right ready to be lifted into place. The carriage provides a platform for the rack of RF equipment to move with the tower.

Figure 4 is a photograph of the scanner during installation in Toshiba's chamber in Japan. The control room is shown through the open door at the far end of the room. The base is shown in the pit before the pit cover supports were added. The column is seen in front of the tower before the absorber was added. The probe is near the bottom of travel.

Several features assisted the installation and operation of the scanner. Since the scanner is permanently attached to the foundation, sufficient support and adjustment at this interface was paramount. Machine levelers were used to provide continuity through the shielding from the scanner to the foundation and allow for flatness tolerances between the bottom of the beams and the pit floor. During operation of the scanner, the tower moves over the horizontal rails causing varying forces into the foundation. Attention to mass balance leads to similar deflections between front and rear rail so the tower does not nod at the antenna during scans. By keeping attachments statically determinant, elastic deflections result in rigid body motion instead of deformations. Building precision into the system at the design stage makes alignments in the field easier.[2]

The vertical tower is a moving mass during an antenna measurement. The tower is supported at three locations, two on the front rail and one on the rear rail. The machine levelers for the rear beam are staggered with respect to the front beam. The center of mass is located to load each linear bearing equally. The tower is aligned about its two vertical planes by making vertical adjustments at its three support points. The rear point is adjusted to move the top of the tower closer to or away from the antenna under test until the probe travel is vertical in the YZ-plane. The front points are adjusted differentially to move the top of the tower laterally with respect to the AUT until the probe travel is vertical in the XY-plane.

The goal in the construction and installation of the planar scanner was to provide a stable platform to repeatedly move an RF probe in an XY-plane. Therefore, the rails on the base beams form an XZ-plane for the tower to move upon, and the rails on the tower form a YZ-plane for the probe carriage to move upon. Small imperfections can be mapped and corrected with the control software.

4. LASER OPTICS

An optical measurement package of laser optics provides precise determination of X and Y axes position, alignment errors along the X and Y axes, and Z-planarity over the XY scan plane. To accomplish this, two independent laser systems are provided. The XY laser determines scanner position and alignment errors while the spinning Z-plane laser determines the planarity errors. These measured errors are used to correct the probe position during scans. With laser feedback, the positioning error is 0.025mm for the X-axis and 0.049mm for the Y-axis. Using the NSI structure monitor capability, planarity of the scan plane is correctable to within 0.057mm rms.

The NSI laser optical position measurement subsystem includes a linear XY laser, patented NSI-OP-5906A optics interface[3], Z-plane spinning laser and a Z-plane sensor. The optics interface uses the linear XY laser to measure X-axis and Y-axis position to within 0.049mm. The optics interface also measures four lateral error components: Y-error and Z-error along the X-axis and X-error and Z-error along the Y-axis to within 0.066mm rms.

A spinning Z-plane laser is used as a reference for the XY scan plane. The NSI Z-plane sensor is used to measure the Z-error as the probe platform is moved about the XY scan area. The Z-error, measured at regular intervals, are stored in an error map and used by the position correction software to move the probe, in real-time, to create a highly accurate scan plane. Similarly, the position correction software to move the scanner to a corrected position also uses the Y-error and X-error information.

The Z-plane laser measurement system consists of the NSI-OP-5908 rotating laser installed at the base of the scanner and a sensor mounted on the probe antenna platform at a 45 degree angle for illumination by the rotating laser beam. The Z-plane sensor has a measurement range of $\pm$6mm with 0.025mm rms accuracy, and interfaces with a Digital Signal Processing unit, which receives the processed photodetector information.

5. COMPUTER SUBSYSTEM

The computer subsystem includes two locally networked computers for acquisition and processing. The data acquisition controller operates the scanner, optics and microwave subsystems while the data processing computer performs the computations with the measured data.

The data acquisition controller is capable of cross-axis correction to improve overall scanner accuracy and planarity during the antenna measurement acquisition process. The system is equipped with a hand held remote unit to control the scanner from the inside of the chamber.

The NSI software controls scanner axes motion, optical sensors, and supports real-time displays of sensor data versus X or Y motion. The real-time sensor displays may also be plotted versus time for stability and sensitivity testing.

6. MICROWAVE SUBSYSTEM

The microwave subsystem provides continuous wave and pulsed antenna measurements from 1GHz to 50GHz. A 4-port PIN switch provides fast switching between 4 AUT ports for multiple beam measurements during scans. A 2-port PIN switch provides fast polarization switching for primary and cross polarization measurements while scanning. The HP 8530A microwave receiver provides highly accurate, automated amplitude and phase measurements of the antenna response. The NSI software controls the dual source configuration to perform multiple frequency switching during scanning.

The microwave subsystem forms a two-arm microwave interferometer with one arm containing the AUT and the probe antenna. The other arm is the reference arm directly coupled between the RF source and receiver. The microwave interferometer measures the amplitude and the phase through the AUT relative to the fixed reference. Key elements of the subsystem are the RF and LO sources, LO/IF distribution unit with remote mixers, and the HP 8530A microwave receiver. The remote mixers allow improved performance by reducing the length of high frequency cables. Lower frequency, and therefore lower loss, LO and IF cables are used for the long runs to the mixers, while the RF path is limited to that necessary to provide the RF signals from the mixers to the AUT and probe.

The RF and LO sources provide continuous wave and pulsed signals from 1GHz to 18GHz. A source multiplier extends the frequency range from 18GHz to 50GHz using K-band (18GHz to 26.5GHz), Ka-band (26.5GHz to 40GHz) and Q-band (40GHz to 50GHz) multipliers. Harmonic multiplier factors are used in the software to set the LO and RF source to the correct frequency depending upon the band of operation. Hardware reconfiguration is required to change between bands, or to reverse the range from AUT transmit to AUT receive mode.

Computer controlled frequency switching allows multiple frequency measurements during each scan. Computer controlled switching of the AUT beam selection 4-port PIN switch allows measurement of up to four AUT ports during scanning. In addition, computer-controlled switching of the probe antenna polarization (using a dual Pol probe) allows the measurement of principal and cross polarization characteristics during each scan.

The HP 8530A microwave receiver provides highly accurate, automated near-field amplitude and phase measurements of the antenna response. NSI software controls the RF configuration and performs multiplexed data acquisition during scans.

7. TEST RESULTS

The Toshiba site tests consisted of the scanner mechanical performance and functional tests, including accuracy, resolution and alignment. Mechanical system performance is tabulated in Table 1.

System RF functional and performance testing was done using an S-band standard gain horn. The SGH was mounted in front of the scanner and centered about the scan area. Table 2 tabulates the NIST 18-term error budget for the gain uncertainty and for the –20dB sidelobe uncertainty. [4] The total error in gain is 0.33dB rms dominated by the probe gain measurement and the total error in -20dB sidelobe is 1.02dB rms dominated by mutual coupling between the probe and AUT.

8. CONCLUSION

For Toshiba's application, NSI used the principles of precision machine design and system to construct the world's largest vertical near-field antenna measurement system.

REFERENCES

[1] D. Slater, *Near-field Antenna Measurements*. Norwood, MA: Artech House, 1991.
[2] J. Demas and T. Speicher, "Innovative Mechanical Designs for Scanners." *Antenna Measurements Techniques Association Symposium*. Boston, MA: 1997.
[3] G. Hindman, "Position Correction on Large Near-field Scanners using an Optical Tracking System." *Antenna Measurements Techniques Association Conference*. Long Beach, CA: 1994.
[4] A. C. Newell, "Error Analysis Techniques for Planar Near-field Measurements," *IEEE Transactions on Antennas and Propagation* Vol.36, No.6 (June 1988).

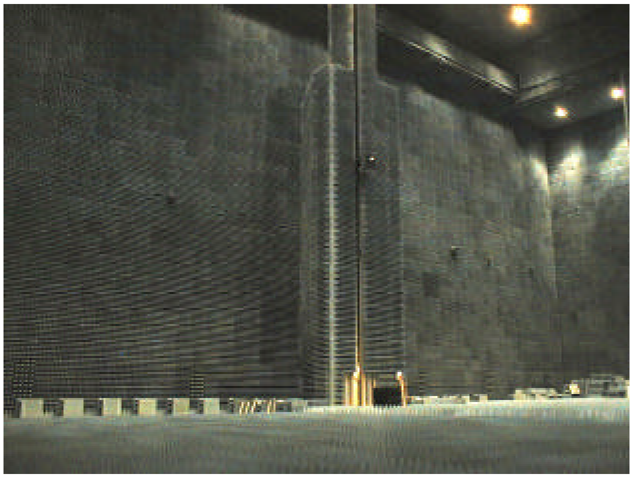
Figure 1 Toshiba Range


Figure 2 Near-field Scanner

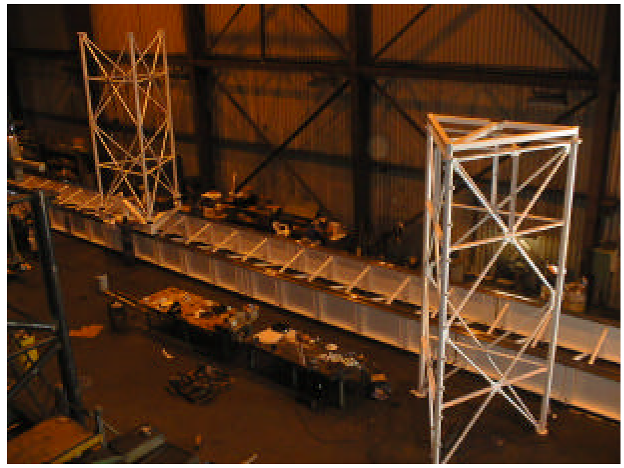
Figure 3 Scanner Assembly

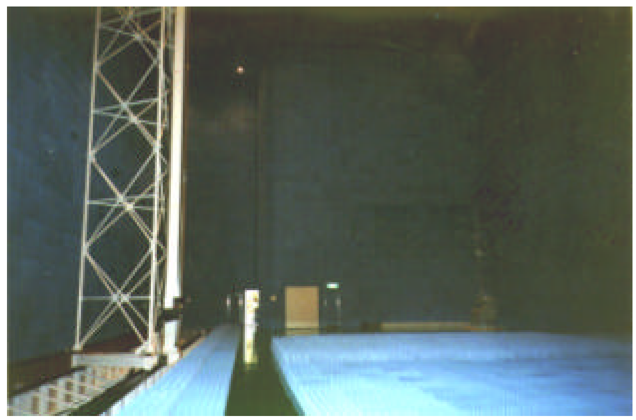
Figure 4 Scanner Installation

Table 1 System Performance

Parameter	X-axis	Y-axis	Z-axis	Pol-axis
Travel	33m	16m	250mm	360deg
Speed	250mm/s	250mm/s	20mm/s	45deg/s
Accuracy	0.013mm	0.001mm	0.011mm	0.01deg
Resolution	0.040mm	0.040mm	0.017mm	0.03deg
Planarity (rms) Uncorrected	______	_____	0.580mm rms	________
Planarity (rms) corrected	______	_____	0.057mm rms	________

Table 2 NIST Error Budget

#	Item	Gain Uncer-tainty (dB rms)	-20dB Sidelobe Uncer-tainty (dB rms)
1	Probe Relative Pattern	0.00	0.15
2	Probe Polarization Ratio	0.00	0.00
3	Probe Gain Measurement	0.25	0.00
4	Probe Alignment Error	0.01	0.25
5	Normalization Constant	0.01	0.00
6	Impedance Mismatch Error	0.15	0.00
7	AUT Alignment Error	0.00	0.00
8	Data Point Spacing (Aliasing)	0.00	0.03
9	Measurement Area Truncation	0.06	0.27
10	Probe XY Position Errors	0.00	0.00
11	Probe Z Position Error	0.00	0.00
12	Mutual Coupling (Probe/AUT)	0.09	0.83
13	Receiver Amplitude Linearity	0.01	0.01
14	Systematic Phase Error	0.12	0.12
15	Receiver Dynamic Range	0.00	0.00
16	Room Scattering	0.03	0.48
17	Leakage And Crosstalk	0.02	0.00
18	Random Amplitude/Phase Error	0.00	0.01
	Total (dB, Rss)	0.33	1.02