14' X 14' PORTABLE PLANAR NEAR-FIELD SCANNER SYSTEM (PPNFSS) FOR THE AEGIS ARRAY

George E. Mc Adams*, Richard Romanchuk**

*Nearfield Systems Incorporated
1330 E. 223rd St. Suite 524, Carson, CA 90745 USA
Tel: (310)-518-4277 Fax: (310)-518-4279
E-mail: gmcadams@nearfield.com

**Naval Surface Warfare Center - Port Hueneme Division (Code 4C-34)
4363 Missile Way, Port Hueneme, CA 93043
Tel: (805)-228-7365 Fax: (805)-228-7326
E-Mail: romanchukrm@phdnswc.navy.mil

Abstract

This paper presents an accurate and portable method for RF testing of AN/SPY-1 Antenna Arrays on Navy ships. With four antennas per ship, the usual methods for RF testing are time consuming and very costly. Currently, the most thorough and accurate method of testing is to remove an array and ship it to the original equipment manufacturer's near-field facility. A Portable Planar Near-Field Scanner System (PPNFSS) was developed by Nearfield Systems Inc. for the Naval Surface Warfare Center-PHD to perform RF testing without removing the array from the ship. The system consists of a portable robotic scanner, optics, microwave subsystem, environmental/anechoic enclosure and active thermal control system. The system was designed to mount to various array/ship configurations with severe envelope and environment constraints. The design is modular to allow packaging in ruggedized transit cases and a 48 ft. shipping container.

Keywords: Antenna Measurements, Measurement Systems, Near-Field, Portable Scanner, Robotic Scanner, and System Design.

1. Introduction/Background

AEGIS AN/SPY-1 antennas are state of the art phased array radar antennas operating in the S-Band frequency range. These radar antennas are used by the Navy aboard AEGIS cruisers and destroyers, as the primary air search radar antennas. Each AEGIS ship has four of these arrays. Each one of these arrays is permanently mounted in a stationary position on the ship.

During the past several years, questions concerning the condition of the phased array antennas prompted investigation into a feasible method of measuring receive and transmit parameters of the antennas. If the antenna parameters have degraded over time the combat readiness of the AEGIS Radar System will be affected. The results of this investigation led the Port Hueneme Division of the Naval Surface Warfare Center (PHD NSWC) to decide on a Portable Planar Near-Field Measurement System as the most feasible method. Removing the antennas from any ship is costly and time prohibitive. This measurement technique will allow the Navy to track the parameters of the SPY-1 antennas. Antennas identified as detrimentally effecting the mission performance would be removed and overhauled. This paper describes the system and test results performed at NSWC-PHD

2. System Description

The PPNFSS consists of a robotic scanner, optics system, computer system, RF system, noise isolation system and active thermal control system, assembly stand and storage system.

2.1 Scanner

The design requirements for the PPNFSS were very demanding. The size of the system was critical because the 12 different AEGIS array ship mounting locations had different restrictions. A weight requirement of 10,000 lb was imposed due to the ship deckhouse structural analysis. RF noise isolation design goals were for 40-50 dB of isolation from inside and outside. This had to be accomplished within the envelope provided.

The severe packaging requirements, originally 16' x 16', for a 14' x 14' scan plane area, moved the design from a horizontal type scanner[1] to a scanner with A-Frame supports[2], a stationary X-Bridge and a moving Y-Beam. See Figure 1. The Primary A-Frame and X-Bridge are rigidly attached. The Secondary A-Frame has a pivoting attachment to the X-Bridge for installation onto a ship which can be securely tightened. The movement of the Y-beam in the X-axis direction is controlled with a stepper motor having a rack and pinion drive system. The movement of the probe carriage in the Y-axis direction is controlled with a stepper motor, through a worm gear drive reducer and stainless steel timing belts. The motor has been sized to handle the weight imbalance since no counterweight system is used. The Z-stage is controlled with a stepper motor and ball screw drive.

The probe carriage is mounted to the Y-Beam. No counter weight system was used due to the packaging requirements. The probe locations can be adjusted from 12 to 33” from the array under test. This is accomplished with a 10” Z-Stage and different probe extension tubes. This approach provides test flexibility for the different AEGIS arrays.

The optics and motor control equipment are mounted to the primary A-frame between the support tubes. This provides the most stable mounting location for this hardware.

2.2 Optics System

The laser optics measurement package 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 the 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 a scan.

The laser optical position measurement subsystem includes a linear XY laser, NSI patented NSI-OP-5906A optics interface[3], Z-plane spinning laser and two Z-plane sensors.

The Z-plane spinning laser is used as a reference for the XY scan plane. The Z-plane sensors are used to measure the Z-error as the probe carriage is moved about in the XY scan plane. The Z-errors, 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.

2.3 Computer and RF System

An IBM-PC computer operates the scanner, optics and microwave subsystems, it also performs the data processing functions. The computer is capable of cross-axis correction to improve the overall scanner accuracy and planarity during the antenna measurement acquisition process. The system is equipped with a hand held remote unit to facilitate the assembly and alignment process. The software, NSI V3.5.2, 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.

The RF system consists of an HP 83624B synthesized sweeper, an HP 8530A microwave receiver, and an HP 8511A frequency converter. The RF equipment test range is 2-18 GHz

2.4 RF Noise Isolation

A RF noise isolation system with a design goal of 50 dB isolation from external noise and 40 dB from internal reflections was specified. This was accomplished with an enclosure design consisting of composite panels with flat and pyramidal absorber attached. The pyramidal absorber is on the "roof" of the enclosure directly in front of the array. All of the walls are covered with the flat absorber. There is a cable feed through location in the +X wall. At this location the cables from the ship board control room are connected. Access panels are incorporated into the design for minor optical adjustments when the system is mounted to a ship.

2.5 Thermal Control

Most antenna measurement scanners are located in a controlled room inside of a building.[1] The PPNFSS requirement for mounting to a ship presented thermal design considerations. The thermal control system consists of an Environmental Control Unit (ECU), insulated duct work, see Figure 2, and design features incorporated into the scanner support structure. The thermal control system supplies controlled air directly to the enclosure volume and through the scanner support structure, to minimize thermal changes in the structure. The scanner enclosure consists of composite panels with flat or pyramidal absorber mounted on the inside surfaces. This design provides an insulated thermal environment and a RF shielding capability. Four air supply ducts are in the +Y wall on the enclosure and the scanner structure is fed through the trunion at the secondary A-Frame to X-Bridge interface. The flow is split, inside the X-bridge, to allow air into the secondary A-Frame and the X-Bridge. The flow through the X-Bridge is then channeled into the Primary A-Frame. There are two flow control methods. A damper is used to split the airflow between the enclosure supply duct and the scanner supply duct, and two flow outlets on each A-Frame that can be set before installation onto a ship.

2.6 Assembly stand

The PPNFSS has an assembly stand to allow assembly and alignments to be performed away from the ship. Figure 1 shows the scanner on the assembly stand during the initial factory assembly. The scanner will be transported from the assembly area to the pier next to the ship on the assembly stand. The stand has simulated mounting locations for the scanner support feet.

2.7 Storage System

The PPNFSS can be stored in a 48' shipping container. The container has two sections, one for the assembly stand and scanner hardware, and the other for the enclosure, computer and RF system equipment. A removable roof over the assembly stand and scanner section allows for crane access to the hardware. See Figure 3. The components are located in the shipping container in reverse order. The first piece required for assembly is on the top shelf. The shelf levels are removable for access to the hardware below. The second section of the container has a floor roller system to facilitate the removal of the enclosure panels. It also contains a shelving system to store all of the enclosure flat and pyramidal absorber and other miscellaneous components. See Figure 4. The computer, RF equipment, optics equipment and probe carriage are protected with ruggedized transit cases, which are stored in the second section of the container.

3. Assembly

The PPNFSS is designed to be assembled and reassembled at different locations. The components in the storage container are removed with a crane as needed for the assembly process. The assembly stand is assembled first, the scanner structural components are next. The electronic and optical equipment are installed next. The scanner is initially aligned before the enclosure is installed. After the initial alignment, the enclosure is assembled around the scanner. The alignment is verified and adjustments made as required.

The system is now ready for transport from the assembly area to pierside beside a ship. The entire assembly stand and scanner system are picked up with a crane and set down on a flat bed truck for transport. The scanner will be lifted from the assembly stand on the flat bed truck up to the AEGIS array location on the chosen ship deckhouse. Prior to this, the mounting interfaces must be located and welded to the ship deckhouse structure. There are two installation guide posts to facilitate installation onto the ship.

A mock-up of the PPNFSS was built and test runs were made at the San Diego shipyard. Figure 5 is an array on a CG class ship. Figures 6 and 7 represent the lifting of the mock-up to an array on a DDG class ship.

4. Test Results

The PPNFSS was tested at NSWC-PHD for mechanical and RF functional verification. The mechanical tests included scanner alignment, position and planarity. Mechanical system performance is tabulated in Table 1. The corrected Z-planarity is shown in Figure 8.

The RF functional and validation tests were performed with a NIST calibrated X-band slotted array. Various RF tests were performed. Continuous and stop motion scans, multiple reflection tests, RF leakage, RF system stability, thermal stability, and measurement noise level tests were performed.

The RF system stability test recorded four scans and verified that the variation of maximum directivity resulting from each scan did not exceed 0.05 dB. A RF stability test was performed and the peak-to-peak variations, due to thermal changes, were 0.052 dB and 2.082° for amplitude and phase respectively. See Figures 9 and 10.

5. Conclusion

The delivered scanner has been tested in a controlled environment and has demonstrated good performance. Future tests include a landbased test using an array mounted to a building. This will demonstrate the mounting method and RF test of an actual AEGIS SPY1 array. This is currently scheduled for the end of August 1999. The final test is to move the PPNFSS to a ship yard and install the unit onto a ship.

References

[1] D. Slater, "*Nearfield 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

Table 1 Mechanical Performance

Description	Requirement	Performance
Scan Area	14' x 14'	14' x 13.5'
System Size	16' x 16'	18.9' x 16.7'
X and Y Axis Level	+/- 0.1 mm	X = 0.0016 mm Y= 0.0024 mm
Axis Orthogonality	+/- 0.1 mm	0.000 mm
Uncorrected Position Error	+/-0.010"	X = 0.005" Y = 0.005"
Laser Position Repeatability	+/-0.002"	X = 0.00025" Y = 0.0018"
Z Position Repeatability	+/-0.002"	Z = 0.0005"
Planarity (uncorrected)	0.080" p-p	0.029" p-p
Planarity (corrected)	0.0060" rms	0.0016" rms

Figure 1 System Factory Assembly

Figure 2 Enclosure, ECU and Ducts

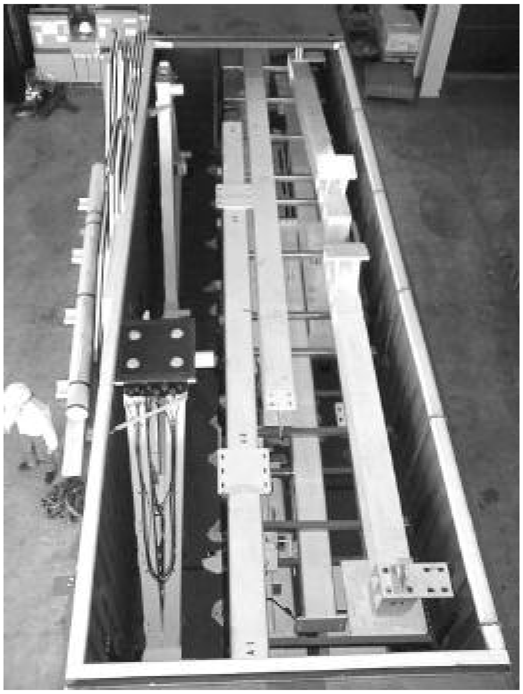

Figure 3 Shipping Container - Open End

Figure 4 Shipping Container - Closed End

Figure 5 AEGIS Array - CG Class

Figure 6 Mock Up Test on DDG Class Ship - Forward Array

Figure 7 Mock Up Test on DDG Class Ship - Aft Array

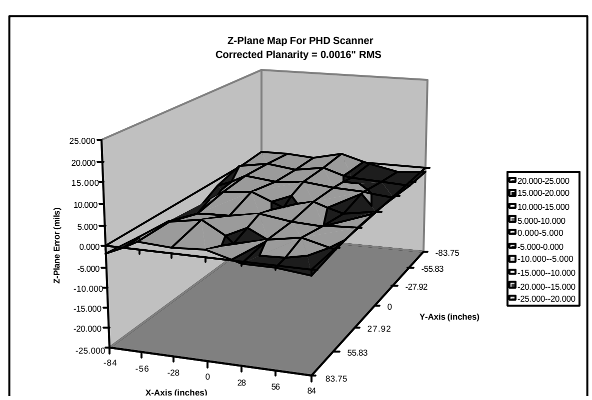

Figure 8 Z-Planarity (corrected)

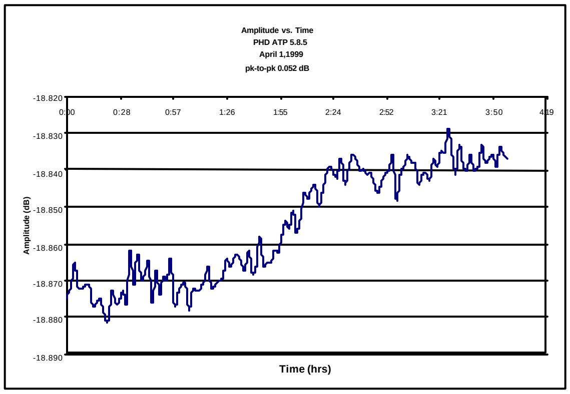

Figure 9 RF Thermal Stabilty - Amplitude

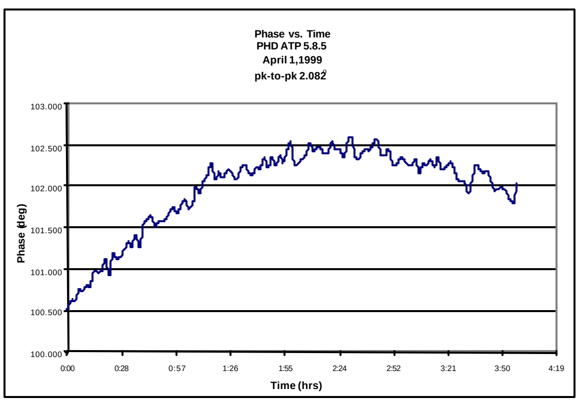

Figure 10 RF Thermal Stabilty - Phase