A TURNKEY NEAR-FIELD MEASUREMENT SYSTEM FOR PULSE MODE APPLICATIONS

David S. Fooshe[1], Kenneth Thompson[2], Matt Harvey[3]

[1]Nearfield Systems Inc.
1330 E. 223rd Street Bldg 524
Carson, CA 90745 USA
(310) 518-4277
dfooshe@nearfield.com

[2] Naval Surface Warfare Center – Crane Division
Code 803, Bldg 3168, Aegis Microwave Components Division,
Crane, IN 47522-5080 USA
(812)854-5230
Thompson_Ken@crane.navy.mil

[3] Technical Service Corporation
116 W. 6th Street Suite 200,
Bloomington, IN 47401 USA
(812)336-7576
Mharvey@TSC.com

ABSTRACT

NSI recently delivered a Turnkey Near-field Antenna Measurement System (TNAMS) to the Naval Surface Warfare Center – Crane Division (NSWC-CD) in Crane Indiana. The system supports characterization and calibration of the Navy's active array antennas. TNAMS includes a precision 12' x 9' vertical planar near-field robotic scanner with laser optical position measurement system, dual source microwave instrumentation for multiple frequency acquisition, and a wide PRF range pulse mode capability. TNAMS is part of the Active Array Measurement Test Bed (AAMTB) which supports testing of high power active arrays including synchronization with the Navy's Active Array Measurement Test Vehicle (AAMTV), now under development. The paper summarizes the hardware configuration and unique features of the pulse mode capability for high power phased array testing and the TNAMS interface to the AAMTV and AAMTB computers. In addition, range test data comparing antenna patterns with various pulse characteristics is presented.

Keywords: Antenna Measurements, Near-Field, Facilities, Pulse-Mode, Scanners, Phased Arrays, Optical.

1. SYSTEM AND FACILITY OVERVIEW

The TNAMS system was installed at the NSWC-CD facilities in November 1996 with testing completed in January 1997. TNAMS includes a high precision robotic scanner, laser optical position measurement system, microwave subsystem and high frequency (up to one Megahertz PRF) pulse mode capability; all controlled by the NSI near-field data acquisition and processing software. The robotic scanner includes X, Y, Z and Pol axes for probe positioning. The laser optical position measurement system is used to achieve a scan plane accuracy of 0.0005 inches rms. The microwave subsystem is based on the HP 85301B E80 antenna measurement system which includes the HP 8530A receiver configured for wide-band pulse mode operation. The NSI data acquisition and processing software controls all system hardware and antenna measurement functions.

The role of the AAMTB is to provide an independent Navy facility to evaluate and demonstrate active array critical components and subsystems, to develop and assess active array test, diagnosis and calibration techniques, to evaluate and demonstrate active array architectures and to conduct system performance demonstrations. Of particular interest are High Power Superposition(1) (HPS) mutual coupling calibration techniques, photonics probe diagnostics, true time delay beamsteering and wideband radiating elements.

TNAMS is the centerpiece of the AAMTB and is shown in Figure 1.

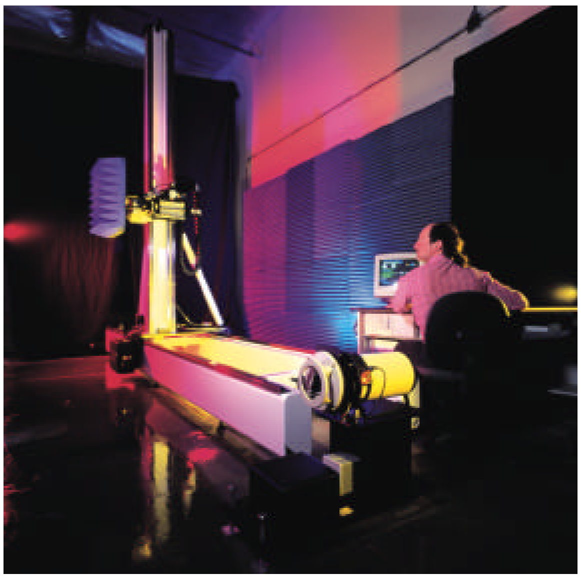

Figure 1 TNAMS 12' x 9' Near-field Scanner

The AAMTB chamber and TNAMS have been fitted with air cooled high power anechoic material to tolerate the peak power levels developed by the AAMTV transmitter. TNAMS is used in pulsed mode under the control of an Array Control Computer (ACC) to collect near-field data in both AUT receive and transmit modes. The unique feature of the AAMTB is the synchronization of two asynchronous rf pulsed systems. Some modification of the standard TNAMS software was required to allow this synchronization capability. The AAMTB configuration is shown in Figure 2.

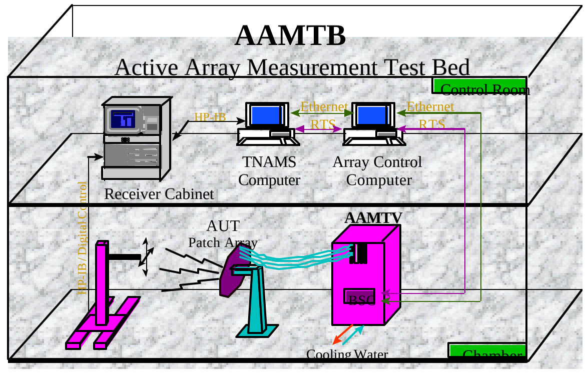

Figure 2 NSWC-CD AAMTB Configuration

The AAMTV is composed of a 64 element patch array, T/R module based transmitter and receiver, a wideband dual channel beamformer assembly, VME based digital and computer circuitry, and a T/R module temperature monitoring system. The AAMTV is shown in Figure 3.

Figure 3 AAMTV Phased Array

The AAMTV is controlled from an internal Beam Steering Computer (BSC) and synchronized to the TNAMS. Both the TNAMS and BSC computers are programmed by the ACC prior to initiating a test. The ACC first builds a state vector for the TNAMS computer and a state table for the BSC based on input from the test engineer. The ACC then downloads the necessary configuration parameters to both the TNAMS computer and the BCS. With this configuration the TNAMS is controlled directly from the ACC, bypassing the normal user interface.

2. SCANNER & OPTICS SUBSYSTEM

The TNAMS system supports X, Y, Z and Pol motion control for a series of microwave probes covering the bands from 2 to 18 GHz. The Scanner provides a 12 ft. x 9 ft scan plane, a 10 inch Z-axis stage and a 360 degree rotary polarization stage. The uncorrected scanner planarity is 0.002 inches rms. With active Z-plane correction a planarity of 0.0005 inches rms was achieved.

The NSI laser optical position measurement subsystem[2][3] includes a linear XY Laser, patented NSI-OP-5906A optics interface, Z-plane spinning laser and a Z-plane sensor. The optics interface, shown in Figure 4, uses the linear XY laser to measure X-axis and Y-axis position to within .001 inches. The optics interface also measures the following four lateral error components:

- Y-error along the X-axis
- Z-error along the X-axis
- X-error along the Y-axis
- Z-error along the Y-axis

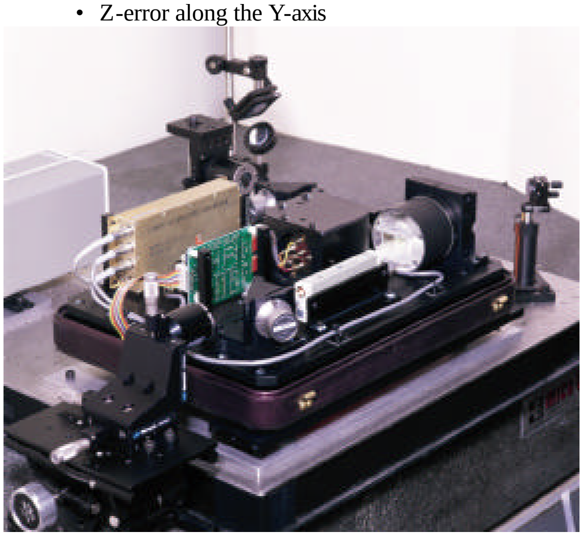

Figure 4 NSI Laser Optical Position Measurement System

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-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. Similarly, the Y-error and X-error information is also used by the position correction software to move the scanner to the corrected position.

The Z-plane laser measurement system consists of the NSI-OP-5908 rotating Z-plane laser installed at the base of the scanner and a Z-plane sensor mounted on the probe antenna platform at a 45 degree angle for illumination by the rotating Z-plane laser beam. The Z-plane sensor has a measurement range of ±0.1 inch with 0.001 inch rms accuracy, and interfaces with a Digital Signal Processing (DSP) unit which receives the processed photodetector information.

The NSI software controls scanner axis motion, optical sensors, and supports real-time sensor 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. During rf data acquisition, the NSI software performs cross-axis correction of the X-axis and Z-axis errors, while scanning continuously along the Y-axis.

3. MICROWAVE SUBSYSTEM

The TNAMS microwave subsystem is based on the HP 85301B antenna measurement system for operation from 2 – 18 GHz. The system includes an HP 8530A microwave receiver with wideband pulse mode capability[4], HP 83621A microwave frequency synthesizers, HP 85310A LO/IF distribution and mixer subsystem, an HP microwave switch for RX/TX range reversal and other HP microwave components. The microwave equipment is controlled by the NSI system controller via GP-IB interface. Hardware triggers are employed for on-the-fly data collection during scanning.

4. TEST SET INTEGRATION

Communication and synchronization between the ACC, BSC and TNAMS systems are implemented via a real-time signal interface. The TNAMS microwave source generates the rf pulse under control of the TNAMS computer. The ACC is responsible for sequencing TNAMS and BSC computers through selected test sequences. Control signal interfaces between the computer elements are shown in Figure 5.

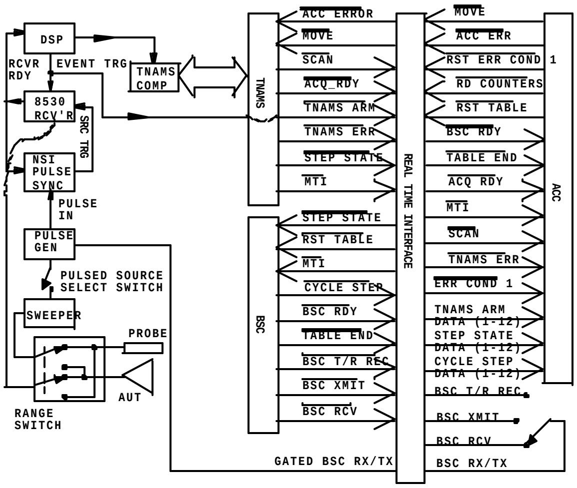

Figure 5 AAMTB Signal Control Diagram

The user interface to the ACC computer is the scenario generator, which the operator uses to generate a setup file for both the TNAMS and AAMTV. The Graphic User Interface (GUI) for the scenario generator, shown in Figure 6, allows direct operator control of measurement and beam characteristics. The beam states may be repeated for each polarization (pol) type and frequency data point.

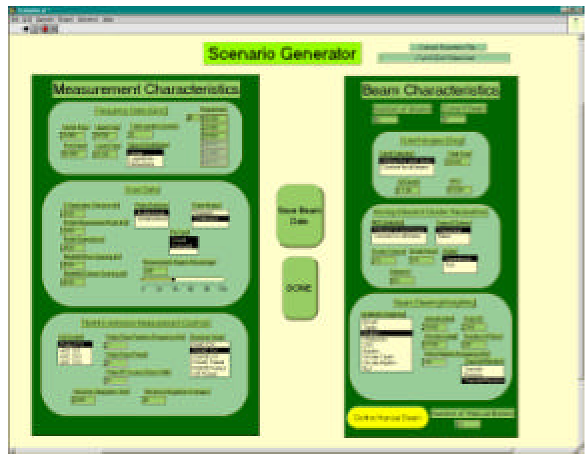

Figure 6 AAMTB Test Scenario Generator

The operator may enter the frequency range, scan data and invoke other TNAMS antenna measurement controls. The frequency data points can be entered manually by selecting a non-uniform distribution, or automatically by selecting either linear or logarithmic distributions. Parameters for the scanner and rf source are set up in the scan data and TNAMS Antenna Measurement Controls sections. These parameters describe how the data is collected and how the scanner operates.

Cutoff angles and active array element parameters are specified to create a High Power Superposition (HPS) scan. The beam steering and weighting section defines the beam. The operator selects the amplitude weighting and specifies antenna transmit, receive, or transmit and receive modes of operation. The manual beam definition section allows for mutual coupling or other unusual setups for the antenna.

The Manual Beam Configurer display, shown in Figure 7, is part of the interface between the operator and the active array. The operator is able to input pulse characteristics and module data, and to save the data. The state setup section allows the operator to specify the number of array test states. The pulse characteristics section allows the operator to enter the information needed by the AAMTV. The AAMTV contains two separate beamformers which can be used simultaneously for transmit (TX), receive (RX) or both. The array data section displays the 64 elements and the mode of each element. The setup data can be saved to a file at any time.

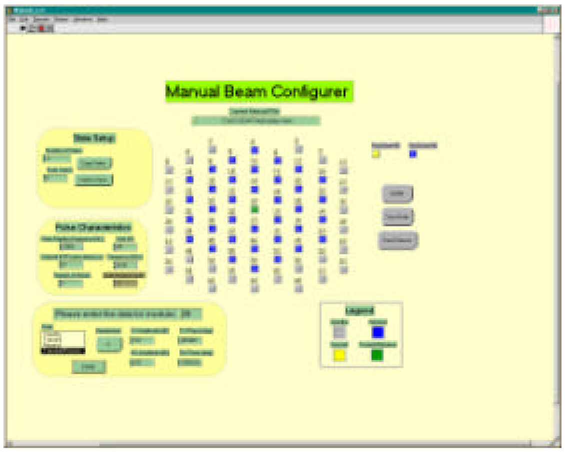

Figure 7 Manual Beam Configurer Display

The data collected in the manual beam configurer is sent to a state vector generator, which creates a file that TNAMS uses to define the parameters for executing a scan. Other parameters collected in the manual beam configurer are sent to a state table generator, which creates a file the BCS uses to control the state of the active array.

5. HIGH POWER PULSED ACTIVE ARRAY TESTING

A potential safety problem in dealing with high power active arrays in the near-field is the high peak and/or average power radiated. This problem can be reduced if only a small number of elements are radiating at any one time, as opposed to the entire array of elements. This approach is appropriate as electromagnetic fields behave linearly, thus superposition may be applied. For example, if a point in the field around two or more radiating elements is measured in amplitude and phase, the same result is obtained by radiating each element separately, measuring the field at the same point in space for each element and then performing a complex sum of the individual measurements. Applying this approach to a large number of elements is a direct extension of superposition and is referred to as HPS. (It should be noted that although electromagnetic fields behave linearly, the element pattern and electrical characteristics do change slightly when the element is radiating in the presence of other close-by radiating elements. This is a potential source of error of the HPS technique and will be evaluated during our testing.)

Using superposition at each spatial sampling point, each element (or group of elements) in the array can be radiated individually. The response measured at each point from an element (or group of elements) can then be summed to calculate the total field at that sample point. The concept of activating only single elements, or groups of elements, at each sample point is referred to as the Moving Cluster Elements (MEC) technique. The MEC technique causes a significant increase in total scan time because at each required spatial sampling point, the antenna is cycled through its appropriate states, i.e. the required elements, or groups of elements, must be individually turned on and off. The scan time can be reduced by enlarging the element clusters, however, the total radiated power is increased.

A potential source of error with the HPS approach involves an approximation used to reduce measurement time. This approximation assumes that there are only a certain number of elements in the array that significantly contribute to the field at each measurement point. This is similar to a "field of view" concept where the probe can only "see" elements within some solid angle surrounding the probe. Depending upon the desired error, the number of elements the probe can "see" at each location in the near-field measurement grid can be reduced. Assuming only a small number of elements are activated at each measurement point, the total scan time is, thereby, reduced.

6. TEST RESULTS

The NSWC-CD TNAMS site tests consisted of scanner mechanical and functional tests, system rf functional tests and rf performance tests. Scanner mechanical and functional tests included tests of scanner axes accuracy, resolution and alignment. A few of the key scanner parameters are shown below in Table 1.

Table 1 Scanner Performance

Parameter	X-Axis	Y-Axis	Z-Axis	Pol-Axis
Travel	12 ft	9 ft	10 in	360º
Speed	10 ips	10 ips	1.0 ips	45º/sec
Accuracy	0.001 in, rms	0.001 in, rms	0.001 in, rms	0.05º
Resolution	0.001 ips	0.001 ips	0.0005 ips	0.01º
Planarity (RMS)	-	-	0.002 in, rms	-
Planarity (RMS) Corr.	-	-	0.0005 in, rms	-

System rf functional and performance testing was done using a 28" diameter X-band slotted array radar antenna. The AUT was mounted in front of the scanner and centered about the scan area. In addition to the comprehensive suite of tests[5] performed on the system during the verification phase, a number of comparison scans were performed with very good results. For example, in Figure 8, a CW antenna pattern is shown overlaid with a pulse mode pattern. In this case, the AUT was pulsed with a 10 KHz PRF and a pulse width of 1.0 usec. Far-field amplitude differences between the patterns are approximately 0.3 dB @ peak, and approximately 1.0 dB @ -35 dB, which is within range accuracy.

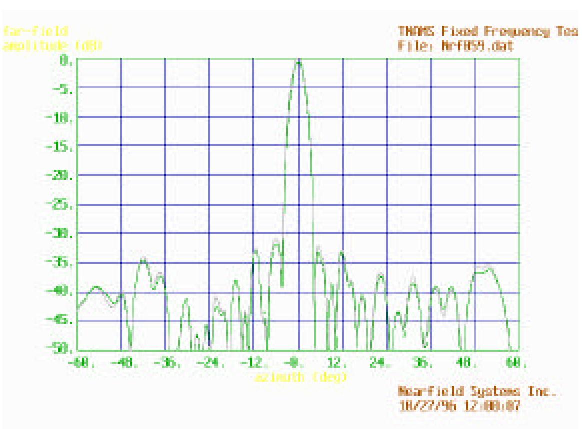

Figure 8   Antenna Pattern Overlay (CW & Pulse)

7. CONCLUSION

For the NSWC-CD TNAMS application, NSI has delivered a state-of-the-art near-field measurement system based on precision machine engineering and proven optical correction technology. NSI has also integrated the microwave subsystem, with pulse mode capability, with the software operating environment, including custom modifications, to allow the TNAMS system to be controlled by other computers. This paper has described the role of the TNAMS system in the AAMTB including specific application for evaluation of the AAMTV. A series of high level test objectives have been defined for the initial test series for the AAMTB. These include the following;

a. Investigate, develop and demonstrate thermal compensation techniques for active arrays. This includes characterization of the AAMTV and T/R module temperature sensitivity, along with AAMTV temperature compensation techniques.

b. Safely and accurately characterize active array high power TX pattern performance, including the investigation of mutual coupling errors and thermal effects, and the comparison of HPS with other techniques.

c. Develop and demonstrate in-situ TX and RX diagnosis and calibration of active arrays interleaved with normal operations.

d. Develop and demonstrate in-situ TX and RX photonics probe diagnosis of active arrays interleaved with normal operations.

e. Investigate feasibility and support development of shared aperture and multi-function rf aperture concepts and assess self EMI immunity.

f. Investigate and demonstrate cost effective wide bandwidth and wide scan angle architectures for active arrays, coincident with the development of wideband pattern measurement techniques and the benchmarking of photonics and microwave True-Time Delay (TTD) performance.

These objectives, and those yet to be defined, provide the basis for future research and evaluation of present and emerging technology for potential insertion into the Navy's active array sensors. These, and future experiments, will enhance the knowledge base in active array development and testing, for the benefit of both industry and government.

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