POSITION CORRECTION ON LARGE NEAR-FIELD SCANNERS USING AN OPTICAL TRACKING SYSTEM

Antenna Measurement Techniques Association Conference
October 3 - October 7, 1994

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ABSTRACT

Large scanners used for near-field antenna measurements require careful attention to the design and fabrication process to maintain probe position accuracy[1]. This paper discusses the design, implementation, and results of a novel optical probe position tracking system used by NSI on a number of large near-field scanners. This system provides measurement of the probe X, Y and Z position errors, and real-time on-the-fly position correction. The use of this correction can significantly enhance measurement accuracy, and can reduce the cost of building large near-field scanners.

SYSTEM CAPABILITIES

The NSI optical subsystem provides measurements of both the probe X and Y positionS, and the X, Y and Z position errors, with a novel patent-pending design approach which minimizes hardware costs and alignment concerns. The system uses an XY beam monitor assembly (BMA) inserted into the laser beam path to derive the scanner XY straightness errors. This configuration does not require the addition of another laser head for the straightness measurements, as is typical of most other systems. For customers with existing near-field ranges using HP laser interferometer equipment, only a re-arrangement of the optical components is required to support the BMA. The independent Z-plane subsystem uses a spinning plane laser to measure the probe's out-of-plane Z motion.

OPTICAL SUBSYSTEM DESCRIPTION

The optical subsystem consists of the following key elements:

1. HP-5517C laser head
2. NSI-5906 XY optics assembly on X carriage
3. X and Y axis retroreflectors
4. Y-axis retroreflector adjuster (optional)
5. NSI-5908 Z-plane laser
6. NSI 5904 Z-plane sensor mounted at probe
7. Computer control electronics and software

The XY linear position and XY lateral errors in the scanner are derived from the single HP laser source using the unique layout of components in the NSI optics subassembly. The laser is located at the -X,-Y corner of the scanner and the beam is directed along the X axis. The optics assembly is mounted to the X-axis carriage. The X-axis retroreflector is fixed mounted to the +X side of the scanner, while the Y-axis retroreflector travels with the probe carriage assembly. Figure 1 is a block diagram of the X/Y optics equipment layout.

The Z-plane laser is also mounted at the -X,-Y corner of the scanner, and sweeps out a vertical or horizontal plane, depending on the scanner configuration. The Z-plane sensor is mounted near the probe.

NSI OPTICS ASSEMBLY

The NSI optics assembly travels with the X carriage and includes the optics and electronics for the laser interferometer distance measurements and the straightness measurements for the scanner rails. The elements which make up the optical subassembly include:

8. Precision mounting platform
9. Pentamirror to generate Y-directed beam
10. NSI-5901 X and Y axis interferometers
11. X & Y axis doppler receivers (HP-10780C)
12. NSI-5902 Beam Monitor Assembly (BMA)
13. NSI 5903 Laser to Quadrature Converter

The pentamirror beamsplitter separates the laser beam into two paths which are orthogonal within a 2.5 arcsec tolerance. Because the interferometers were required to be in motion, the deviation of the beam through the interferometer was an important design constraint. The standard HP-10702A interferometer has a 30 arc-minute deviation, and the option 001 has a 30 arc-second deviation. The long travel lengths on several of the NSI scanner configurations required a 2 arc-second beam deviation tolerance. An interferometer manufactured by NSI is used to meet this requirement.

Standard HP doppler receivers were used to derive the path length differences between the reference beams from the interferometers and the test beams to the externally mounted retroreflectors. The output of the receivers were converted to quadrature signals for X and Y and sent differentially back to the computer for processing in the DSP card.

The optics assembly is precision aligned at NSI on a granite bench, leaving only the laser and plate relative alignment to the scanner to be performed in the field. Figures 2 and 3 show the optics assembly and components.

Z-PLANE SUBSYSTEM

The Z-plane measurement system is based on the use of a spinning plane laser mounted at one corner of the scanner, and a lateral sensor mounted near the probe. The plane laser sweeps out a plane against which the probe position errors are tracked. The laser is calibrated in software to correct for coning and runout errors. The Z-sensor is a custom NSI designed package which includes the sensor, gain ranging and detection electronics. The sensing package is 6" by 3" by 1" and weighs only 0.75 lbs, making it quite easy to mount at the probe. The sensor's linear operating range is about ±0.2 inches. Figure 4 shows the sensor package.

SOFTWARE FEATURES

The data acquisition software includes the following functions:

14. Sensor signal processing
15. Deformation table and adaptive filter
16. Scanner error correction on-the-fly
17. Real time sensor displays
18. Automatic data recording for calibration
19. Servo tracking of Y-axis retroreflector in X and Z directions

The deformation table is used because the optical sensor measurements are subject to atmospheric noise, and require averaging over time to enhance the signal to noise ratio. The table size is selectable and is dependant on the straightness of the scanner. Low frequency warpage due to manufacturing tolerances or rail bowing can be handled quite well with small grid sizes -- a 7 x 7 size is typical.

The real-time sensor displays, and ability to plot the sensor data versus X or Y motion are invaluable tools for scanner rail alignment, as well as aiding the system optical alignment process. During RF data acquisition, the NSI software will scan the Y-axis, while performing cross-axis corrections of the probe position by stepping the X-axis and Z-axis stepper motors, according to the interpolated values derived from the deformation table.

In one large near-field design using a 19m by 8m near-field scanner, the scanner errors caused sufficient misalignment in the return laser beam from the probe Y-axis retroreflector that it exceeded the capture range of the HP laser receivers. This problem was solved by adding a small dual-axis stepper control system to the Y-axis retroreflector and dynamically adjusting its position while scanning in X and Y, to keep the return beam from the retro-reflector lined up on the receiver aperture.

SYSTEM PERFORMANCE

Figure 5 shows a series of measurements of the probe retroreflector Z motion, as Z vs. Y cuts for 20 different X positions spaced 1 meter apart on this 19 meter scanner. The error was caused by a combination of scanner tower tilt and scanner-induced twist in the laser optics plate. These errors were significantly beyond the ability of the standard laser receiver to operate. With use of the real-time software tracking and the small retro adjuster, the Y-axis retroreflector was tracked to eliminate the errors and keep the laser system aligned. Figure 6 shows the results with the NSI optics system enabled.Other error components, such as the scanner orthogonality and X rail leveling errors are handled in a similar manner. The residual error of the system after the optical correction is on the order of 2 mils (0.05 mm) rms.

CONCLUSION

This paper has described a unique system for measuring and correcting for scanner and probe positioning errors in large scanners. NSI has implemented 4 of these systems on large near-field scanners. Significant improvements in scanner accuracy can be achieved through optical means. Real-time correction of scanner errors are accomplished through software control, allowing the nearfield probe to travel in an essentially perfect plane. The combination of probe position correction and NSI's Motion Tracking Interferometer[2] (MTI) which corrects for AUT motion and RF cable phase change during a scan due to thermal variations can greatly enhance the accuracy of large near-field test facilities.

REFERENCES

1. Implementation of a 22' x 22' Planar Near-field Measurement System for Satellite Antenna Measurements, by Greg Hindman, Greg Masters, Antenna Measurement Techniques Association (AMTA) symposium, October 1993.

2. A 550 Ghz Near-field Antenna Measurement System for the NASA Submillimeter Wave Astronomy Satellite by Dan Slater, Antenna Measurement Techniques Association (AMTA) symposium, October 1994.

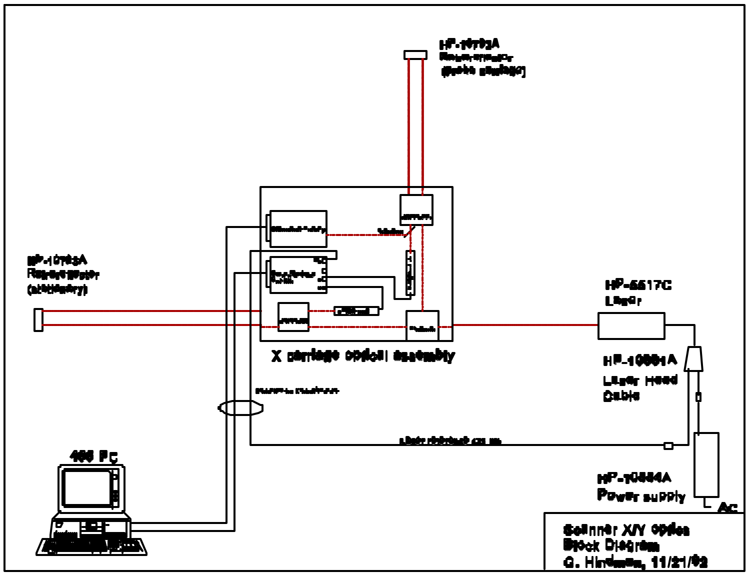

Figure 1 -Scanner X/Y Optics Block Diagram

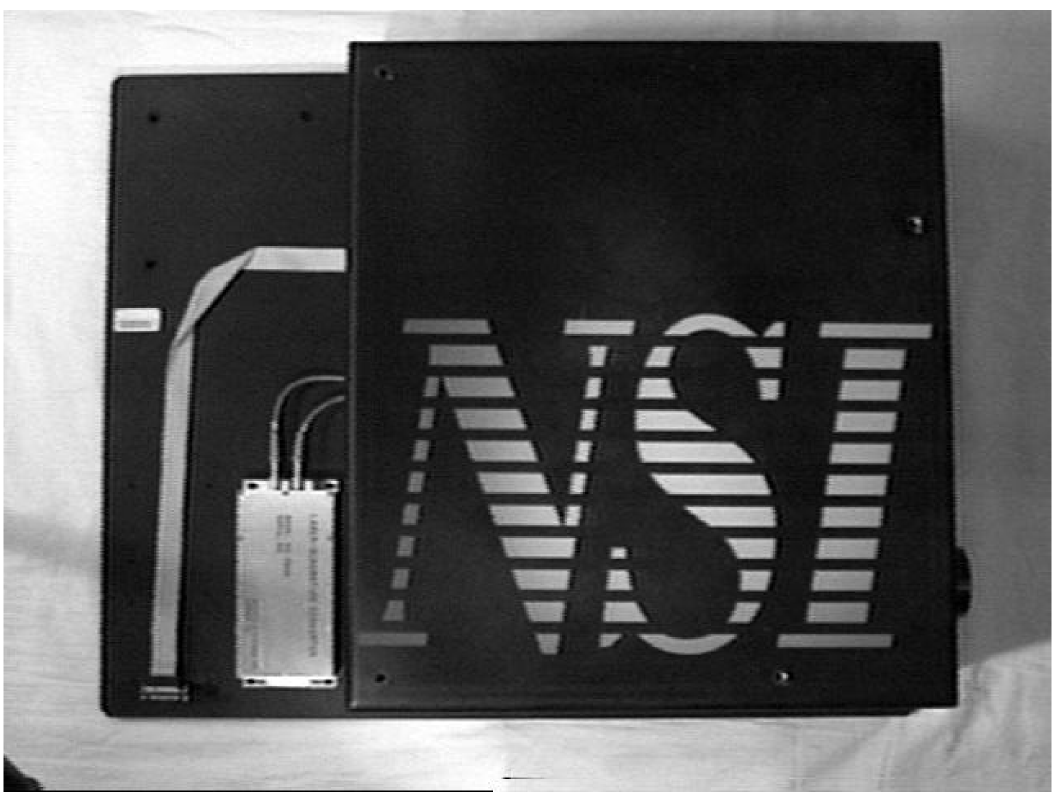

Figure 2-NSI Optical Subassembly Plate

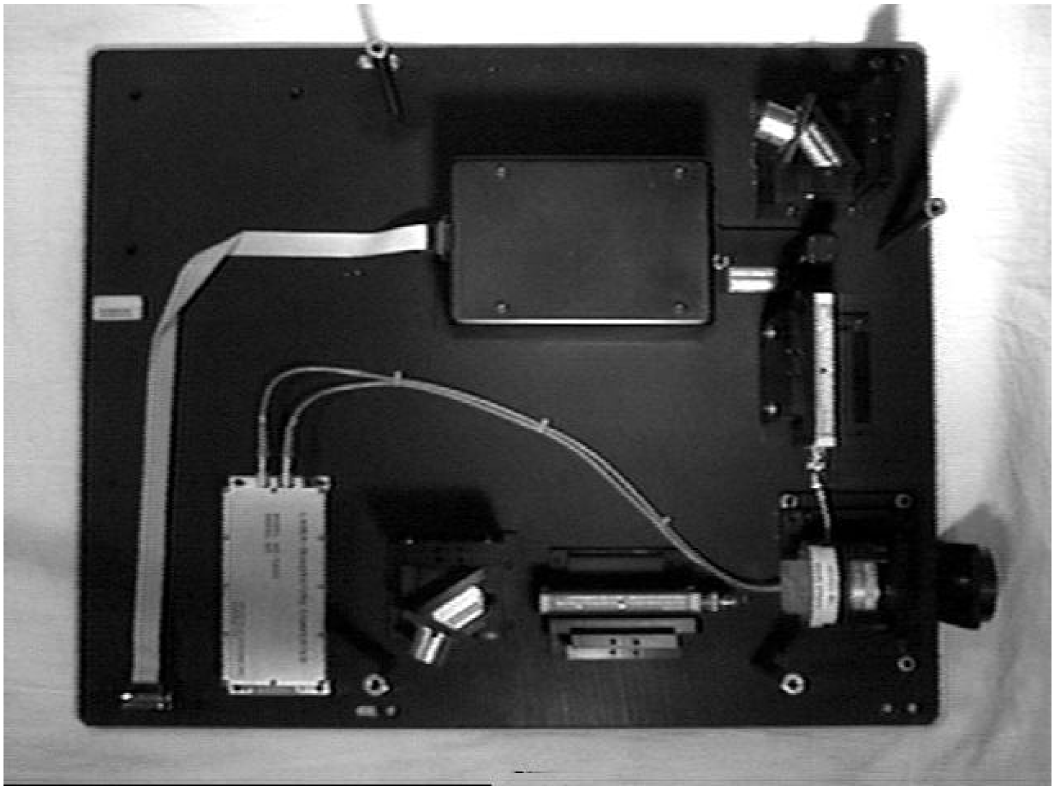

Figure 3 -NSI Optical Subassembly Components

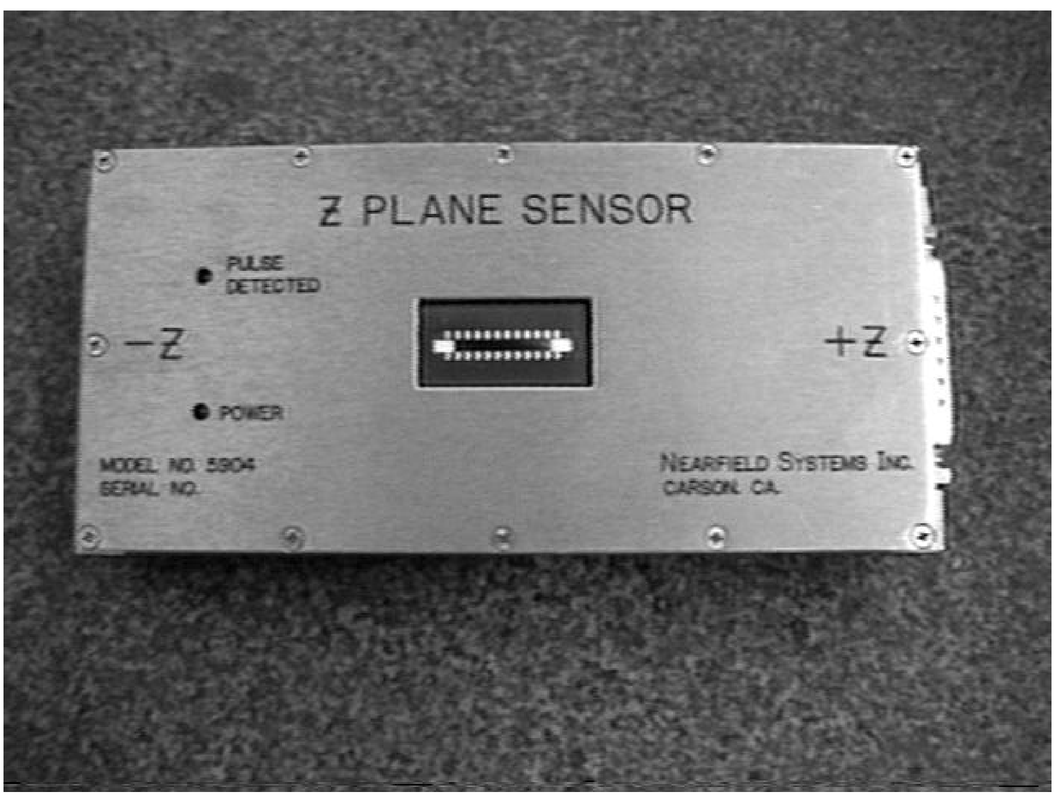

Figure 4 - NSI Z - Plane Sensor

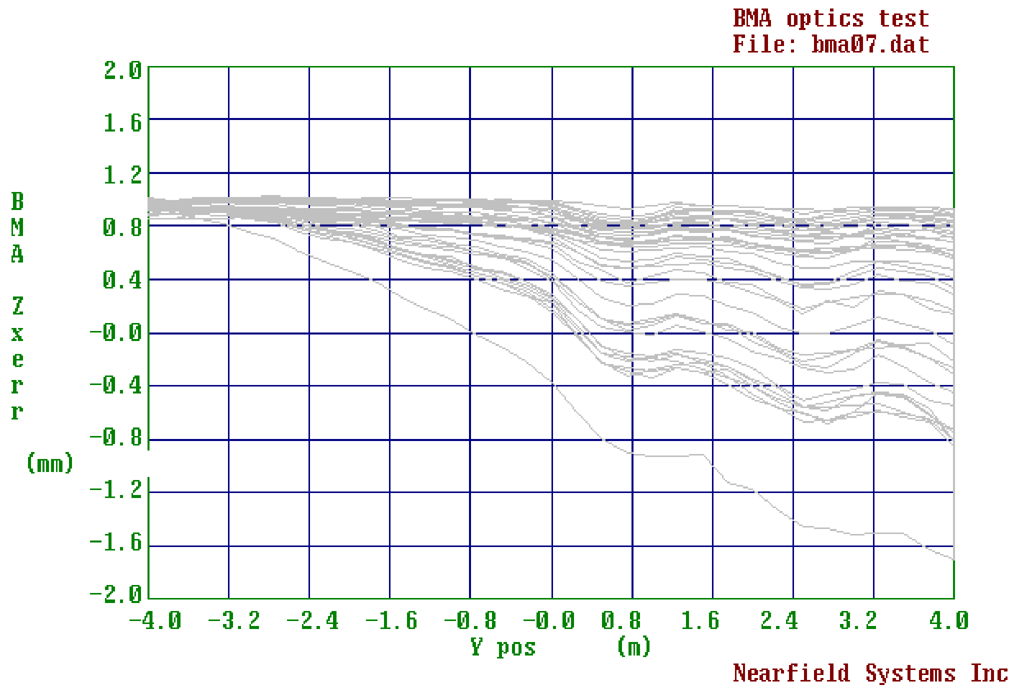

Figure 6-Scanner Z error before correction. This shows the large error detected by the optical system which are a combination of scanner error, and scanner-induced twist in the optics assembly. The magnitude exceeds the alignment tolerance of the laser receiver.

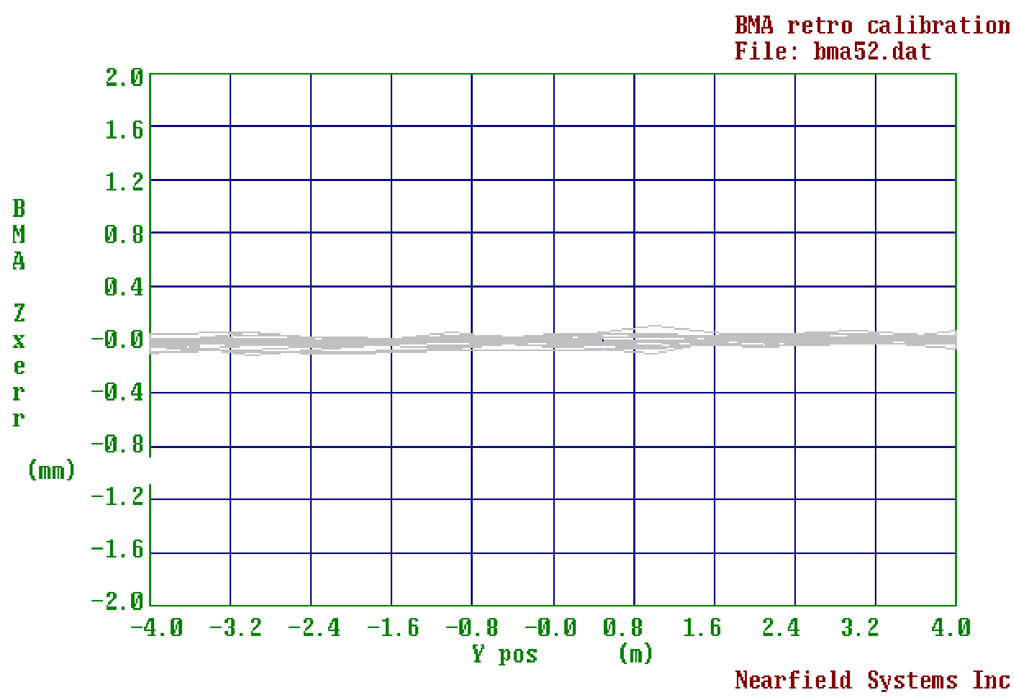

Figure 5-Residual error after correction. The BMA sensor readings have been used to correct the retroreflector position for each X,Y probe position, keeping the return beam from the retroreflector well aligned.