DESIGN CONSIDERATIONS FOR A PLANAR NEAR-FIELD SCANNER

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ABSTRACT

Planar Near-Field scanning is becoming the method of choice for the testing of many types of antennas. These antennas include planar phased arrays, space deployable satellite antennas and other antennas either too large to move during the test or otherwise sensitive to the gravity vector. The planar scanner is a major component of the measurement system and must provide an accurate and stable platform for moving the RF probe across the test antenna's aperture.

This paper describes basic design requirements for a planar near-field scanner. Based on recent development activity at Scientific-Atlanta several design considerations are presented.

Scanner parameters discussed include basic scanner concepts and geometry, scanner accuracy and stability, RF system including cabling and accuracy, load carrying requirements of the RF probe carriage, position and readout systems and drive and control systems.

A scanner will be presented which incorporates many of the design features discussed.

KEYWORDS

Scanner; Near-Field, Planar; Positioner

1. INTRODUCTION

The primary function of any planar near-field scanner is to support and move a small RF probe antenna over a very accurate X-Y plane. Secondary functions include providing an RF path from the probe through the scanner to a fixed accessible interface and facilities to reduce its own interference within the RF field. This paper discusses the design consideration for such a scanner.

While both vertically and horizontally oriented scanners may be used for Planar Near-Field scanning only the vertically oriented scanner will be presented here. However most of the data may be applied to either case.

In the design of a planar scanner several factors must be considered. They can be itemized as follows:

1. Design Geometry
2. Mechanical Accuracy and Stability
3. Electromagnetic Performance
4. Scanning Speed
5. Load Carrying Capability
6. Upgradeability

2. DESIGN GEOMETRY

Two types of planar scanner are common, the box frame and the moving tower. The moving tower design offers the most advantages (Figure 1). Although there are a number of manufacturing advantages, the primary motivation to select this type relates to system performance. The major advantages are described below:

1. The traveling tower presents fewer structural elements to shield with absorber and provides for a less cluttered aperture.

2. The structural load path is much more direct reducing the impact of changing loads.

3. Coordinated drive systems (top and bottom or left and right) are not required, increasing the reliability.

4. Alignment and calibration is greatly simplified since the adjustments need not be spread over large distances.

5. Thermal gradient effects are minimized since the bulk of the structure is at ground level, with no supporting elements located in the regions sensitive to temperature change.

3. MECHANICAL ACCURACY AND STABILITY

The absolute accuracy of the position of the probe antenna is fundamentally important in near-field measurements and this has been proven in extensive research done at the National Institute of Standards and Technology (NIST), an acknowledged world leader in near-field scanning techniques. Although many techniques for correcting errant probe position data are available, none are universally accepted. Hence every effort should be made to start with accurate probe position information.

To obtain high probe position data accuracy, a primary design goal of a planar scanner must be the accuracy and stability of the scan plane. All major elements of the design must be carefully selected to promote this goal. The performance sensitivities may be grouped into three categories: structural stability, dynamic stability and motion control.

The structural foundation of the scanner is literally the cornerstone of the scanner design. An ideal foundation for a relatively small scanner is a granite surface plate which is unambiguously supported on three adjustable mounting feet (Figure 2). Larger scanners may employ poured concrete foundations or large steel beams. In either case the surface plate must provide an extremely flat, stable reference plane. This surface plate is drilled with mounting holes for the balance of the system components to attach to. High capacity bearing rails are directly attached to the plate and provide for X-axis travel. The Y axis tower structure is an extremely rugged weldment providing a structurally stable support for the Y axis rails and carriage assembly.

The elements of this configuration have been analyzed for a Scientific-Atlanta scanner using this type of design. The scanner has a 6 by 6 foot scan plane and uses a granite block surface plate as its foundation. The configuration was analyzed using finite element methods both statically and dynamically. The analysis confirms that the design criteria is achieved by this design.

In addition to the dynamic structural analysis, provisions must be made to assure excellent dynamic performance. The scanner described above uses a drive system designed specifically to achieve this high level of performance. Smooth servo control is provided by a multi-motor controller which can be fully integrated with a system computer for automatic control. This controller has some application within the machine tool industry and is of an extremely robust design. Although normally configured for two DC servomotors, the scanner is readily field-retrofittable for two additional axes, either DC servo or stepper motors.

All axes parameters can be controlled from the system computer, though only the X and Y axes are used actively for scan and step axes during data acquisition. Precision motion control is assured by both rate feedback through a tachometer in each motor and position feedback through optical glass scales on both the X and Y axes. This system has been demonstrated to provide excellent mechanical drive and readout precision.

4. ELECTROMAGNETIC PERFORMANCE

The electromagnetic performance of the scanner is as important as the mechanical accuracy. This is often overlooked in attempts to use a commercial scanner designed without electromagnetic considerations. Commercial scanners in general have no provisions for mounting microwave absorber. Without microwave absorber covering the exposed structure of the scanner, standing waves are set up between the antenna under test and the scanner. These standing waves seriously impact the measurement accuracy just as reflections do on conventional far-field ranges. Good scanner design must include mounting surfaces for microwave absorber (Figure 3).

The second electromagnetic issue that is often ignored when a commercial scanner is used is the RF path to the probe antenna. The accuracy with which phase and amplitude data can be recorded is directly impacted by the phase and amplitude changes induced by this moving path. Scientific-Atlanta offers a proprietary cable correction option that can provide an order of magnitude improvement over the best non-corrected systems designed to date.

5. SCANNING SPEED

With modern instrumentation systems it is possible to make measurements at multiple frequencies of multiple output ports at two orthogonal polarizations in a single scan of the antenna aperture. Even so, the time to make the measurement is determined by the speed of the scanner. A scanner must be able to move the probe fast enough to take advantage of the high measurement speed of the instrumentation. This will maximize test facility throughput and reduce testing costs.

An example of the effects of scanner speed on overall measurement time is presented in Table 1. In this example the time required to scan a 6 by 6 foot scan plane is shown assuming data is taken at .5 inch increments and with .5 inch between scans. This would be the case if a $\lambda/2$ sampling criteria were used at 12 GHz. This example allows 5 seconds between scans and assumes that the system is scanner speed limited.

Table 1

Scanner Speed In/Sec	Total Test Time(Hours)
1	3.1
3	1.2
6	.7

6. LOAD CARRYING CAPABILITY

Invariably certain measurements will require the scanner to carry a significant load. This load might be the result of a low frequency probe antenna, electronics necessary to select polarization or probe antenna ports, multipliers for millimeter frequency operation, power amplifiers required to boost system sensitivity, or the electronics needed for the cable correction option. Individually these are relatively light loads, but since several may be present at once, the scanner must be designed to accommodate these types of loads. Many commercial scanners use stepper motor drives that virtually preclude the use of any but the lightest of probe antennas.

7. UPGRADEABILITY

High quality planar scanners are not inexpensive, and when one invests in a planar scanner one expects it to last and be productive for a long time. Unfortunately it is often difficult to foresee tomorrow's test problems. Hence it is important that a scanner can be upgraded for future applications. A well designed scanner is one that allows capability to be added in the field as needs dictate. Such upgrades might be the addition of a motorized Z axis and polarization axis. Laser position readouts might also be an add-on as well as RF path correction electronics (Figure 4).

8. APPLICATION OF THESE CONCEPTS

The concepts described above have been implemented in the Scientific-Atlanta Model 5906 Planar Scanner. The Model 5906 provides a six foot by six foot vertically oriented scan plane (Figure 5).

The Scientific-Atlanta Model 5906 Planar Scanner is the first standard product planar scanner to be both designed and manufactured specifically for near-field measurements. Before the introduction of the Model 5906 engineers were faced with two choices. They could either specify their requirements and have a custom designed scanner built to their specifications, or they could try to adapt a scanner designed for a different purpose to the near-field measurement problem. The first of these choices was expensive and the second often fraught with disappointment.

The Model 5906 was designed specifically with planar near-field scanning in mind. As a result it has the features that are necessary to make fast, accurate microwave antenna measurements. And because it is a standard product, it is supported by Scientific-Atlanta's worldwide service organization.

Specifications for the Model 5906 are shown in Table 2.

Table 2
Model 5906 Specifications

Travel (Useable) X Axis Y Axis Z Axis	 72 inches (1830 mm) 72 inches (1830 mm) 4 inches (102 mm)
Planarity, X-Y Plane	0.005 inch RMS (127μm RMS)
Readout Accuracy X Axis Y Axis Z Axis	 0.000028 inch RMS (7μm RMS) 0.000028 inch RMS (7μm RMS) 0.001 inch RMS (25.4 μm)
Readout Resolution X Axis Y Axis Z Axis	 0.00008 inch RMS (2μm) 0.00008 inch RMS (2μm) 0.001 inch (25.4 μm)
Positioning Resolution X Axis Y Axis Z Axis	 0.00008 inch (2μm) 0.00008 inch (2μm) 0.001 inch (25.4 μm)
Velocity X Axis Y Axis	 6 in/sec (152 mm/sec) 6 in/sec (152 mm/sec)
Drive System X Axis Y Axis Z Axis	 Servo motor/rack & pinion Servo motor/rack & pinion Micrometer knob/ball screw
Position Transducer X Axis Y Axis Z Axis	 Linear encoder on glass scale Linear encoder on glass scale Micrometer
Load Capacity Y Axis Platform Z Axis Platform	 50 pounds (22.7 kilograms) 25 pounds (11.3 kilograms)
Overall Size	120 inches long (3048 mm) 48 inches wide (1219 mm) 121.3 inches high (3081 mm)
Weight (approximate)	7000 pounds (3182 kilograms)

9. SUMMARY AND CONCLUSIONS

Planar Near-Field scanners must be designed to provide a precision plane over which the RF probe antenna is moved. The scanner must be stable to maintain this accuracy day in and day out in a production or engineering environment. In addition the scanner must provide practical means to implement an RF transmission line to interface the probe to the instrumentation system and to provide shielding from the electromagnetic field without compromising the inherent accuracy of the scanner.

The Scientific-Atlanta Model 5906 meets these requirements. The scanner provides a 6 by 6 foot scan plane and can support probe carriage loads up to 50 pounds. The 5906 is designed specifically for planar near-field testing and as such, much attention was given to the features and facilities needed to accomplish the task.

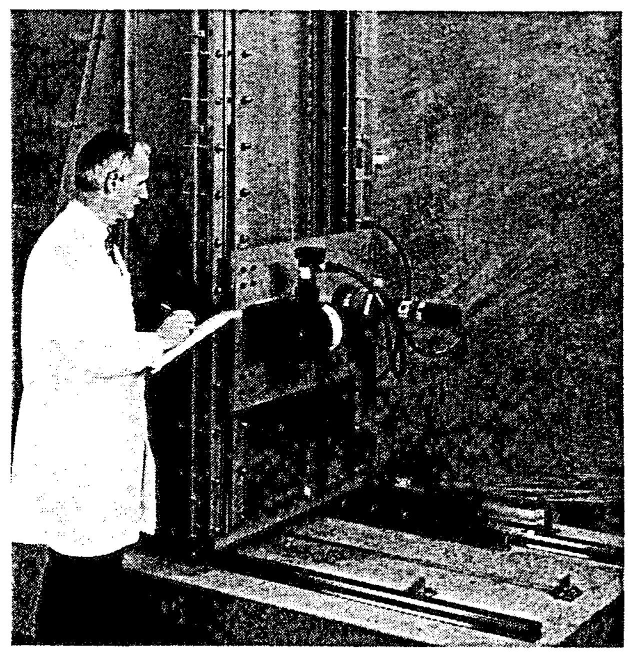

Figure 1
Moving Tower Configuration

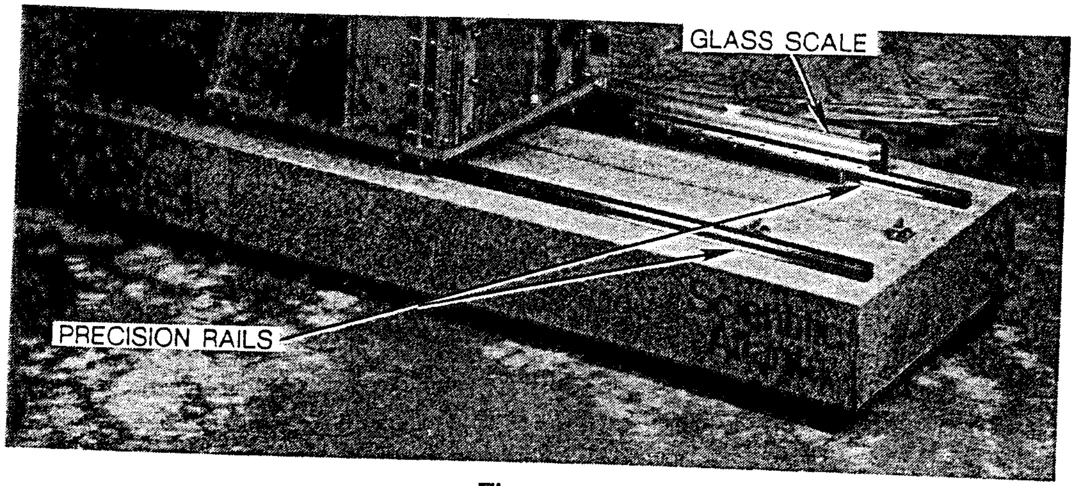

Figure 2
Granite Surface Plate Foundation with Rail System and Glass Scale Readouts

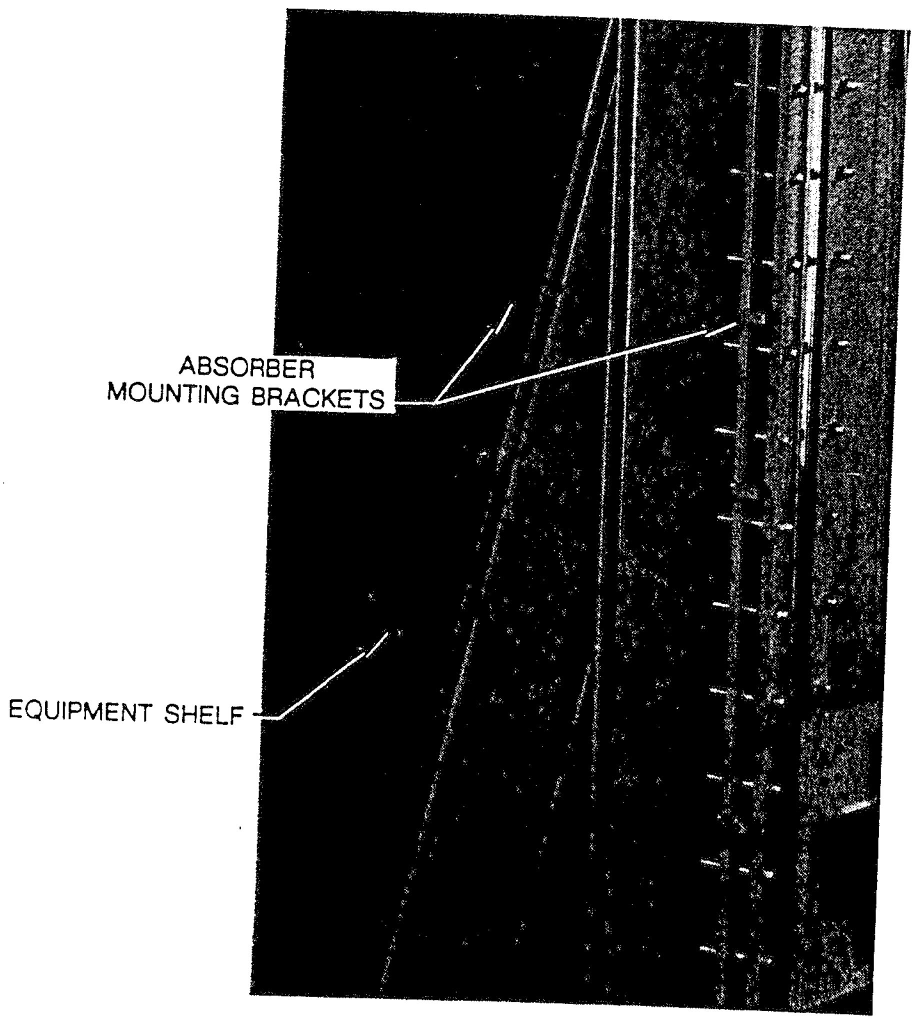

Figure 3
Absorber Mounting Brackets and Equipment Shelf Detail

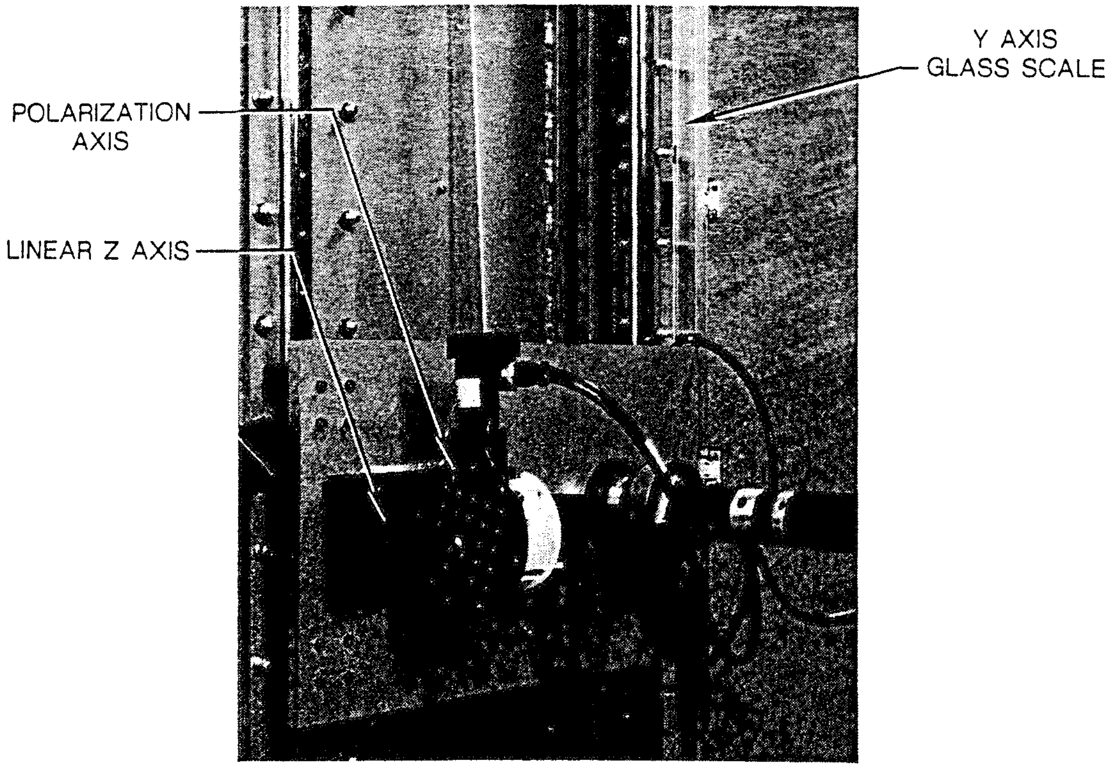

Figure 4
Vertical Axis Drive Train with Z and Polarization Axes

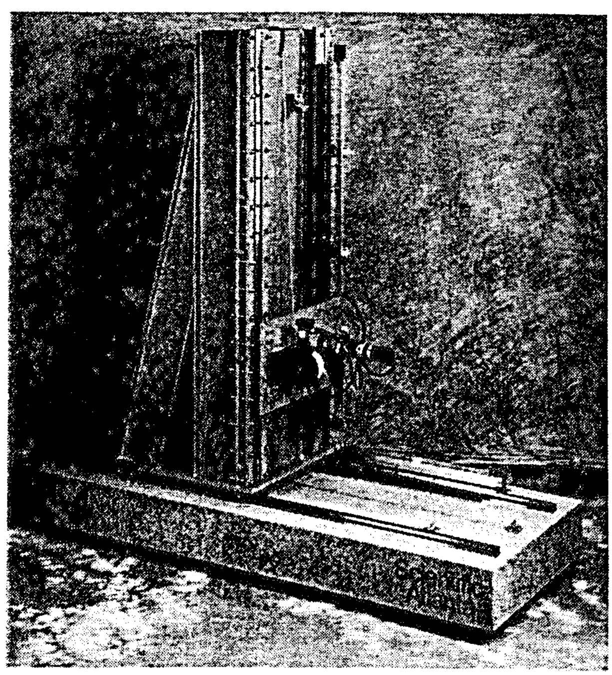

Figure 5
Model 5906 Planar Scanner