A LOW COST PORTABLE NEAR-FIELD ANTENNA MEASUREMENT SYSTEM

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ABSTRACT

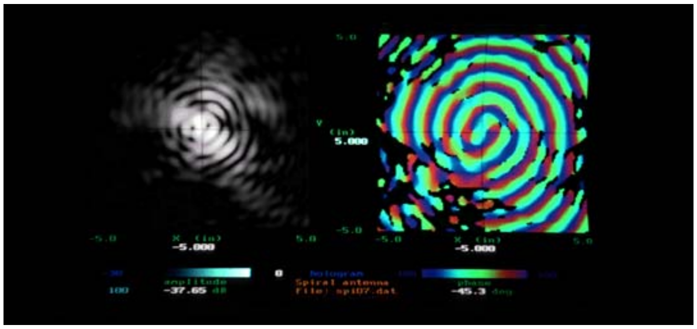
Implementing an antenna test range has traditionally been viewed as a major and costly undertaking, requiring significant long term facility planning, computer hardware interfacing, and software development. This paper describes a complete low cost, yet high accuracy portable near-field measurement system that was privately built for less than $2,000 and interfaced to a PC compatible computer.

The design and operation of this system, including the scanner, microwave hardware, and computer system will be described. This system has since been extended into a commercial product capable of providing rapid and accurate measurements of small to medium size feeds and antennas within a small office or lab space at significantly lower cost than standard antenna test techniques. The system has demonstrated an equivalent sidelobe noise level of less than -50dB, includes a probe corrected far-field transform and holographic back projections, and can output pattern cuts, contour plots, 3D plots, and grey scale images of antenna performance.

INTRODUCTION

This paper describes the development and applications of a small, portable and low cost near-field antenna measurement system. The system was originally built by one of the authors to support the writing of a book about near-field antenna measurements, and has since evolved into a commercial product. The system is ideal for a variety of applications including:

1. Testing of small antennas on the flight line, in an integration area or an office area.
2. Feed and subreflector testing.
3. Diagnostics of anechoic chamber performance.
4. Material testing (ie antenna mesh surface qualification)
5. Educational applications.
6. Cost sensitive applications.



Amplitude Phase

Figure 1 Phasefront of a small X-band weather radar antenna shown as a grey scale amplitude (left) and phase (right) image.

Antenna performance analysis by near-field methods provides many advantages over more conventional techniques. Advantages include:

1. High accuracy
2. Minimal facility requirements
3. High throughput
4. Complete antenna characterization
5. Control of zero G effects for spacecraft antennas
6. Minimal real estate requirements
7. No delay due to weather
8. Compatible with most security requirements

2. BASIC NEAR-FIELD MEASUREMENT CONCEPTS

A near-field measurement system consists of a robotically positioned probe antenna which is connected to a microwave interferometer. The probe antenna is moved over a surface near the antenna under test. The interferometer measures the phase front of the antenna under test. An example of a phase front is shown in Figure 1. A Fourier transform of the measured near-field phasefront results in the equivalent far-field pattern.

A near-field measurement system can be alternately thought of as a compact range (or collimator) with a synthetic (phased array) aperture instead of a real (parabolic dish) aperture. The synthetic aperture is formed by moving the probe antenna to positions which correspond to the element positions in a phased array. Beam forming for the phased array requires a combination of phase shifters (for beam steering) and summers. For a planar set of sample points, this is accomplished by a computer using a 2D Fourier transform to perform simultaneous beam steering to many different far-field angles.

All near-field measurement systems (planar, cylindrical or spherical) derive the equivalent far-field antenna performance through 2 basic steps:

1. Measure the phase front of the antenna under test using a probe antenna connected to a microwave interferometer. The microwave interferometer probe is robotically or electronically positioned. The probe positions correspond to the element positions in the aperture of a phased array antenna.
2. The measured phasefront energy is sorted into the actual directions of propagation using Fourier transform methods. This is also known as beam forming. The transform output is an angular spectrum (antenna pattern). The computed near-field angular spectrum is the same as the far-field angular spectrum since electromagnetic energy travels in a straight line.

3. NEAR-FIELD MEASUREMENT SYSTEM DESIGN

A near-field measurement system consists of 3 functional subsystems:

1. Microwave interferometer
2. Probe positioning subsystem
3. Computational subsystem

The project was started by obtaining a scanner mechanism. The scanner mechanism that we initially used was part of a microfilm camera system which was purchased from a surplus dealer. The scanner has a positioning range of 18 by 24 inches with a Z-plane accuracy of 0.005 inches, which was sufficient for the intended application. The mechanism uses a pair of DC stepper motors to provide the X and Y probe positioning. The computer can drive the scanner in both raster and plane polar scan patterns. The steppers are interfaced to a Compaq 386/20 computer by a parallel output card driving a translator box. The computer outputs a pulse for each motor step. This technique allows precise synchronization with the RF hardware and is low cost. The near-field measurement system has since been further extended by adding a rotational axis for the test antenna, allowing cylindrical scanning capability.

An RF system is required to measure the complex gain and phase through a path which includes the antenna under test and the probe antenna. The commercial version currently uses an HP 8510B, Wiltron 360 or other vector network analyzer to perform this measurement.

When the initial near-field measurement system was built, no network analyzers were available. As an alternate, a simple microwave interferometer was built from surplus components. A 12.725 GHz crystal phase locked source provided the test frequency. The receiver consisted of a line stretcher, mixer and several other components. The receiver could only measure the inphase or quadrature signal component at a given time so two measurement passes were required. The line stretcher was set for a ¼ wavelength difference between the 2 passes. The interferometer is shown with the near-field scanner in Figure 2 and a block diagram is shown in Figure 3.

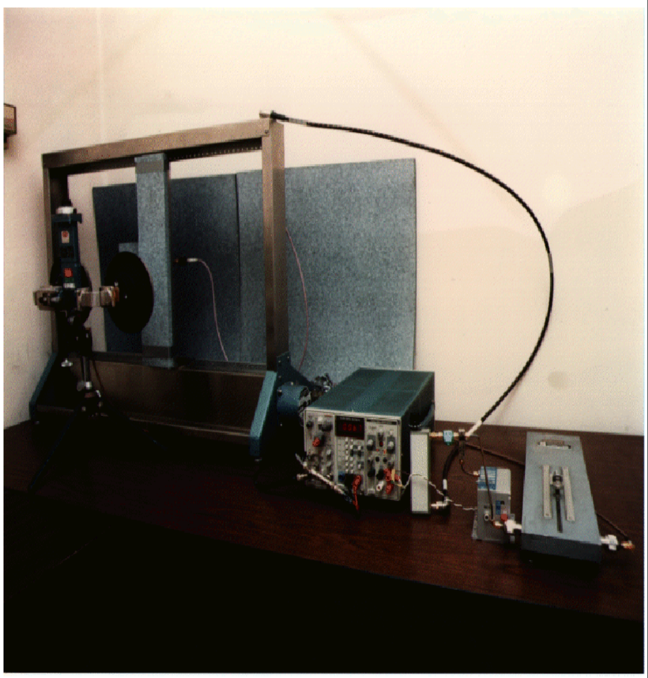


Figure 2 Near-Field Scanner withMicrowave Interferometer

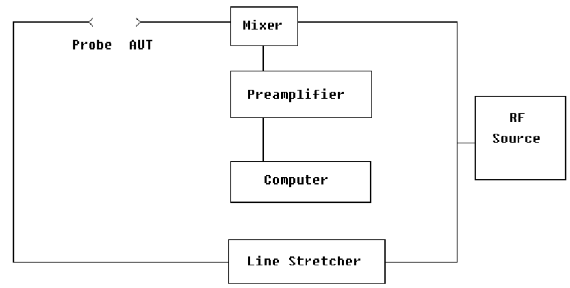


Figure 3 Microwave Interferometer Block Diagram

This design worked reasonably well for the intended application but suffered from several problems. The need for 2 measurement passes was not desirable and more importantly, this design was quite sensitive to mixer leakage and 1/f noise.

These problems were eliminated by adding a computer controlled QPSK modulator which phase modulated the transmitted signal. This effectively converted the receiver into a superheterodyne configuration which drastically reduced the 1/f noise and leakage. AM to PM and PM to AM conversion due to QPSK modulator amplitude/phase unbalance was eliminated by a combination of a software model and statistical calibration method. This system worked quite well.

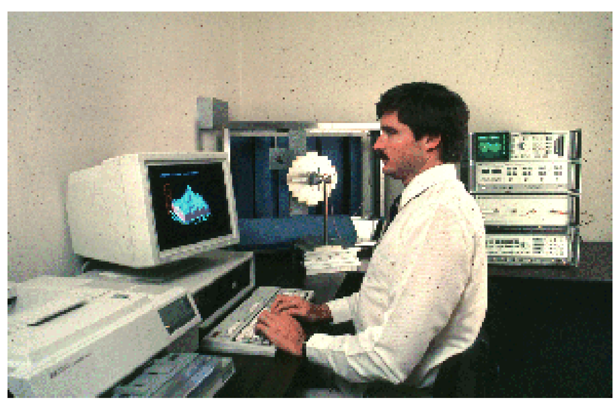


Figure 4 Near-Field Measurement System

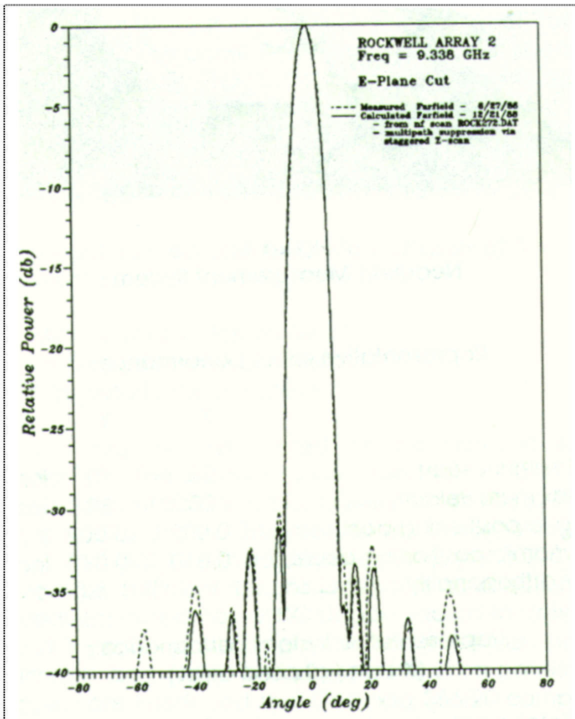


***Figure** 5 Far-Field/Near-field Comparison for X-band Weather Radar Antenna*

The data acquisition and processing was implemented on a Compaq 386/20 (IBM PC compatible) computer. The scanner was controlled by outputing pulses from a parallel port directly to the step motor translator. The receiver used a single board ADC to provide a computer interface. The near-field to far-field and holographic transforms were accomplished by a factored DFT. This algorithm provided the advantage of being moderately fast, simple and outputing directly in angle space. The algorithm also supports both raster and plane polar scan patterns. The software for the near-field measurement system can be broken down into 2 major groups:

Data acquisition:

1. Determine desired measurement position
2. Move probe to desired position
3. Measure the complex gain through the AUT/probe path.
4. Save the measurements to disk storage
5. Go to step 1 until all points have been measured.

Data transformation:

1. Transform the near-field measurements to the far-field.
2. Plot results

The experimental near-field measurement system worked quite well and caught the attention of various people. We decided to convert the prototype system into a commercial product. Needless to say, substantial work was required. We added support for industry standard network analyzers such as the HP8510B and Wiltron 360 and further improved the drive system to support high speed scanning at speeds approaching 30 inches per second. A 1 foot diameter X-band antenna could now be completely characterized in a few minutes. The software was greatly enhanced to provide new capabilities, faster operation, greater user friendliness, and complete documentation. A new multipath suppression technique was developed to allow a -50dB sidelobe noise floor in an office environment[(1)].

Representative Robot Performance:

	X	**Y**	**MEASUREMENT**
Maximum Scan	**24**	**18**	**inches**
Maximum Velocity	**30**	**30**	**ips**
Static Positioning Accuracy	**0.002**	**0.002**	**inch**
Dynamic Positioning Accuracy	**0.010**	**0.010**	**inch**
XY Orthogonality		**5.0**	**arcsec**

Representative System Performance:

(X-Band Phased Array)

Sidelobe Noise Level	**-50.**	**dB**
Gain Measurement Uncertainty	**0.3**	**dB**

Boresight Accuracy	**0.05**	**deg**
Measurement Time	**2.**	**minutes**
Processing Time	**2.**	**minutes**

APPLICATIONS

A small and portable near-field measurement system can perform many useful operations in addition to basic near-field antenna measurements. A list of applications include:

1. The near-field measurement system can measure the equivalent far-field antenna performance using near-field measurement techniques. Results of near-field antenna measurements can include:

    - Far-field pattern
    - X&Y cuts
    - Directivity measurements
    - Axial ratio
    - Beam width
    - Beam pointing
    - Phase center position
    - Defocussing
    - Autotrack bias, scale factor lin.
    - Reflector surface distortion
    - Feed position errors
    - Microwave holographic measurements

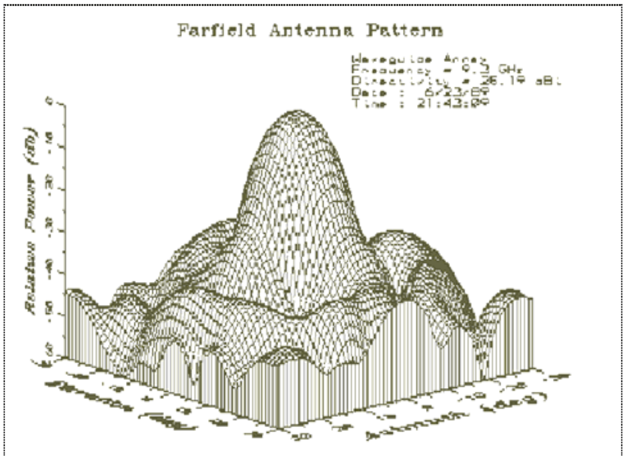


Figure 6 Waveguide Array Farfield Pattern

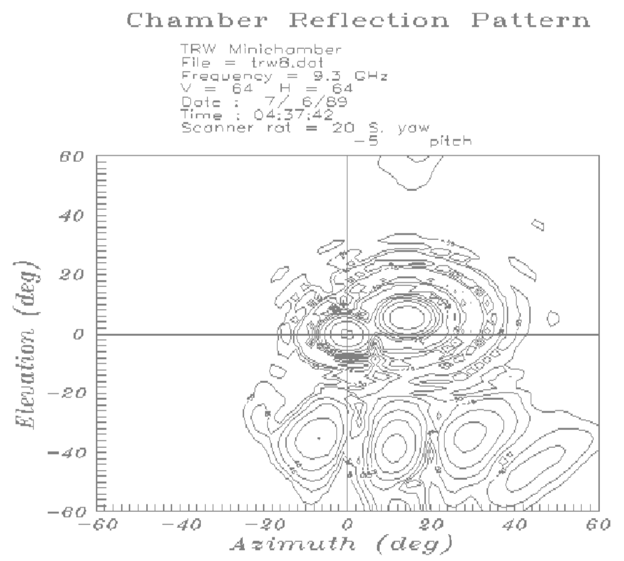


Figure 8 Contour Plot of Scattering In Anechoic Chamber

2. Holographic methods can be used to provide focused microwave images of antenna and radome defects. Figure 7 is a holographic back-projection on a small X-band phased array antenna, showing the position of an intentionally blocked slot.

3. Because it is portable, it can be easily setup and used to perform diagnostic tests of anechoic chambers. As such, it can be used to image and locate multipath interference within compact ranges and anechoic chambers.

4. The portable near-field measurement system can be used to image leakage emissions at specific frequencies from electronic systems. This concept treats the leakages from the electronic system as a series of antenna elements. Specific emission areas can be detailed by a holographic back projection to the equipment surface.

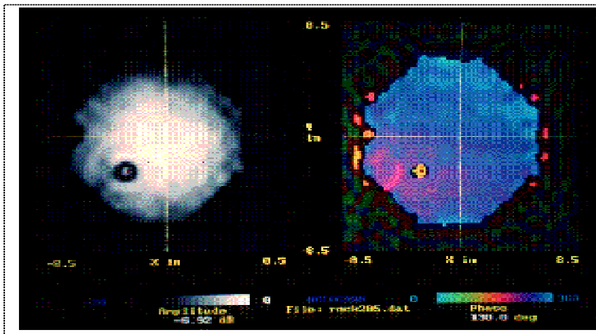
5. Material properties such as the leakage of mesh reflector materials are readily handled by near-field measurements. Holographic techniques can be used to image specific regions of degradation.
6. The system requires a capability to precisely determine the position of the microwave probe antenna. As such, the system can also determine the precise position of other payloads. For example a touch probe could be used to rapidly make dimensional measurements in the field.

5. CONCLUSION

New uses for near-field measurement systems occur when the system is made small, portable and low cost. These new uses include measuring antenna performance on the flight line, in an office environment or for educational environments. Because of the portability, imaging anechoic chamber multipath, leakage and other chamber error sources is also possible.

REFERENCES

1. G. Hindman and D. Slater, “Error Suppression Techniques for Near-Field Antenna Measurements”, 1989 Antenna Measurement Techniques Association Symposium, Monterey, CA Oct. 9-13, 1989.



Amplitude **Phase**

Figure 74 Holographic Back Projection