PROBE CORRECTION EFFECTS ON PLANAR, CYLINDRICAL AND SPHERICAL NEAR-FIELD MEASUREMENTS

Greg Hindman, David S. Fooshe

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

ABSTRACT

The accuracy of the probe antenna pattern used for probe-corrected near-field measurements is critical for maintaining high accuracy results. The probe correction is applied differently in the three standard near-field techniques – planar, cylindrical, and spherical. This paper will review the differences in sensitivity to probe correction for the three techniques and discuss practical aspects of probe correction models and measurements.

Keywords: Antenna Measurements, Near-field, Probe Correction, Polarization, Scanners, Planar, Cylindrical, Spherical

1. INTRODUCTION

Near-field antenna measurements require an accurate representation of the probe pattern used to measure the antenna under test (AUT). Since the measured near-field data includes the response of the AUT combined with the probe, the effects of the probe pattern must be removed prior to arriving at the true AUT pattern. This process of removing the probe effect is called 'probe correction' and is performed as part of the near-field to far-field transform algorithm. The degree to which the probe effects can be removed depends upon how well the probe model used in the transform matches the actual probe used during the measurement. While the probe model accuracy directly affects the accuracy of the resulting AUT pattern, the probe correction is applied differently for planar, cylindrical and spherical measurements. The goal of this paper is to examine the probe pattern sensitivity to the type of near-field scan for two different AUT types and scan geometry. An analytical derivation of the spherical near-field transform algorithm with and without probe correction is given in [1] along with measured results.

2. TEST APPROACH

To determine probe pattern sensitivity, near-field measurements were taken on two types of AUTs using planar, cylindrical and spherical scans. An X-band standard gain horn (SGH) and an X-band phased array antenna were used in the measurements. The near-field data was then processed with and without probe correction and the results compared. Additional scans were taken with greater AUT to probe separation to determine sensitivity to probe distance.

For example, the SGH was mounted on the AUT test stand and three data sets were taken. One each with planar, cylindrical and spherical scanning. An X-band open-ended-wave-guide (OEWG) probe was used in each case. For each of the three data sets a far-field transformation was performed and plotted using the OEWG model [2]. The three data sets were then processed and plotted without probe correction. The measurement process was repeated using a high gain phased array antenna for a weather radar application. The resulting plots are compared in Section 4.

The three different types of near-field scans are shown in Figures 1, 2 and 3 respectively.

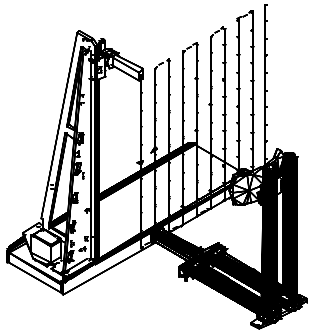


Figure 1 Planar Near-field Scan

The planar scan surface generally is preferred for high-gain spacecraft antennas because all significant plane-wave energy is usually within 10º of the bore-sight axis and alignment is quite simple. Other advantages of planar scan surfaces include simple probe correction and better zero gravity simulation because the antenna under test is stationary.

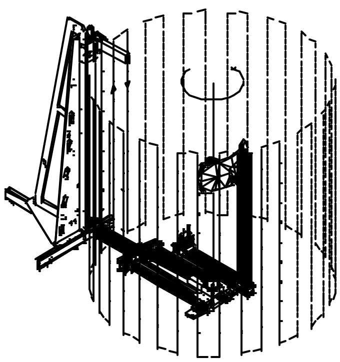


Figure 2 Cylindrical Near-field Scan

Cylindrical surfaces are often used with television broadcast antennas, cell phone base station antennas and certain spacecraft tracking telemetry and control (TT&C) omni antennas, which have a narrow pattern on one axis and a broad pattern on a second axis.

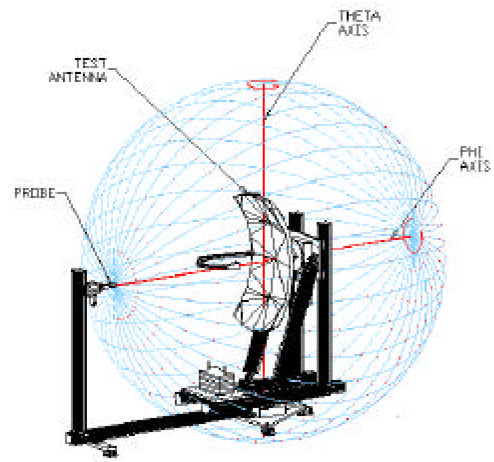


Figure 3 Spherical Near-field Scan

A spherical scan is used for low-gain antennas and antenna feed elements because the energy is captured at large angles from the AUT bore-sight [3].

3. TEST SETUP

The NSI 200V-3x3 SCP near-field scanner with spherical, cylindrical and planar capability was used for the measurements. Azimuth and phi rotators are added to the standard planar scanner to arrive at the SCP configuration. The scanner spherical and cylindrical alignment was performed using recently developed techniques for spherical rotator alignment [4]. Sensitivity to spherical alignment error was also considered during the alignment process [5].

The AUT is mounted on the phi stage, which is then mounted on the azimuth rotator and placed in front of the planar near-field scanner. Software control of the six axes allows ease of switching between planar, cylindrical or spherical setups. The test setup is shown in Figure 4.

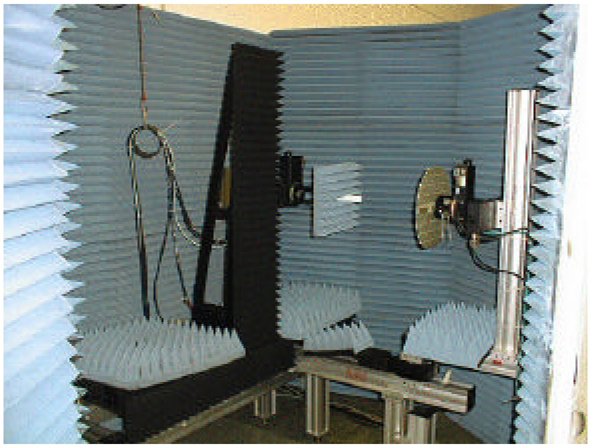


Figure 4 SCP Test Setup

For planar near-field ranges and the linear axis of a cylindrical near-field range, the correct scan length is based on the physical geometry as shown below.

Scan length = $D + P + 2Z\tan\theta$

Where

D = antenna diameter

P = probe diameter

Z = AUT to probe distance

θ = Maximum processing angle from bore-sight

The angular span of a spherical near-field range and the azimuth span of a cylindrical near-field range are based on the physical geometry as shown below.

Scan angle = $\min\{2[\theta + \arctan(D/2Z)], 360^\circ\}$

The scan pattern should not be significantly larger than these two rules indicate. Excessive over scanning consumes time and disk storage and can result in poor quality data due to noise.

Although the OEWG model was used in processing the data, the cosine model or measured probe patterns are equally valid depending upon the probe used and the accuracy desired. The difference between the actual probe pattern and the model should always be considered in the near-field range error budget.

4. MEASURED DATA

The measured data is presented below in Figures 5 through 18 and described in the text above each figure. Figures 5 and 6 show the comparison between the probe corrected results from each type of near-field scan, using a small X-band Standard Gain Horn (SGH), tested at 12 GHz. As expected, the azimuth cut shows excellent agreement between cylindrical and spherical results, with the planar result agreeing well until beyond about 50 degrees from bore-sight due to truncation effects in the near-field scanning technique in the X direction. The elevation cut comparison also shows good results between the three techniques until about 50 degrees, where both the cylindrical and planar techniques lose accuracy due to truncation in the Y direction. In Figures 7-12, results for the SGH antenna are shown for each technique with and without probe correction. Probe correction is shown abbreviated as 'PC = On' or 'PC = Off'. Figures 13-18 show the equivalent results for the X-band phased array antenna at 9.338 GHz. The slight 'bumpiness' in the SGH planar patterns is due to minor truncation effects in the test setup.

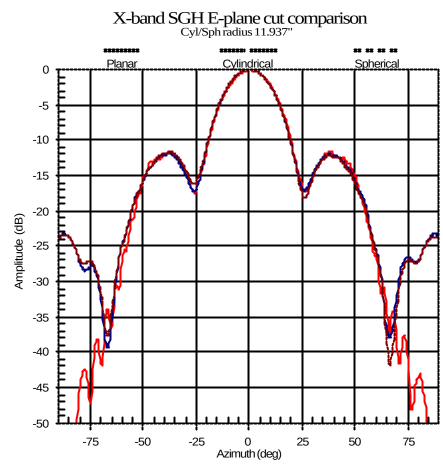
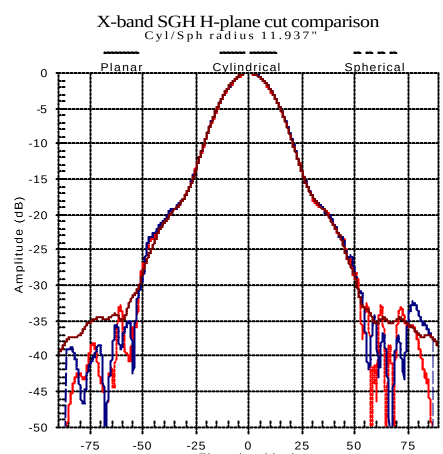


Figure 5



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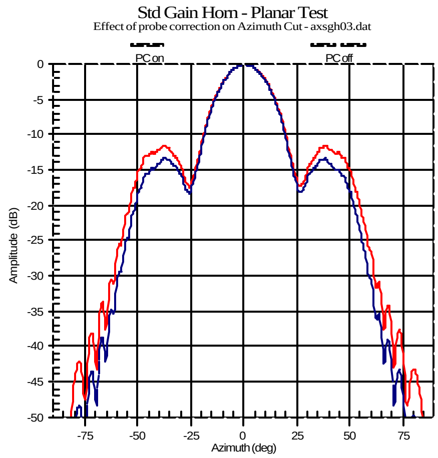


Figure 7

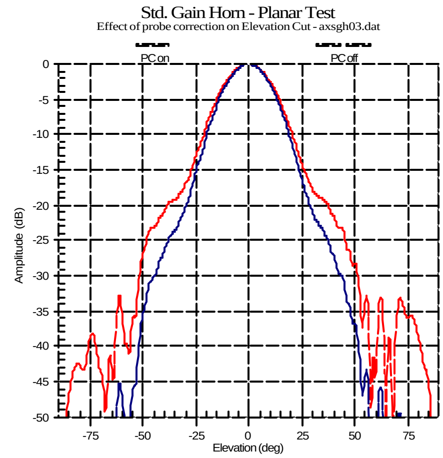
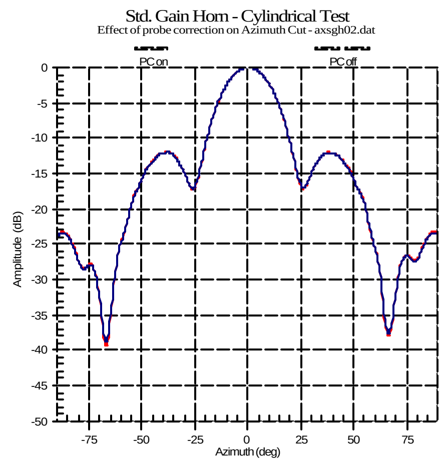


Figure 8



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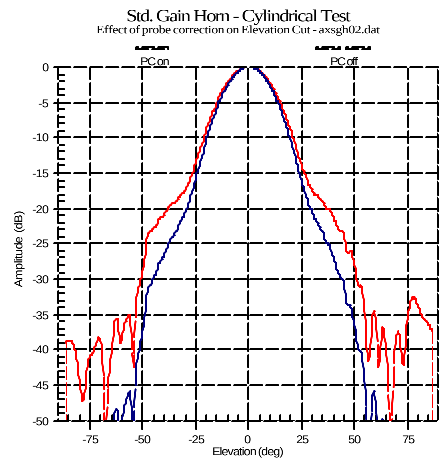

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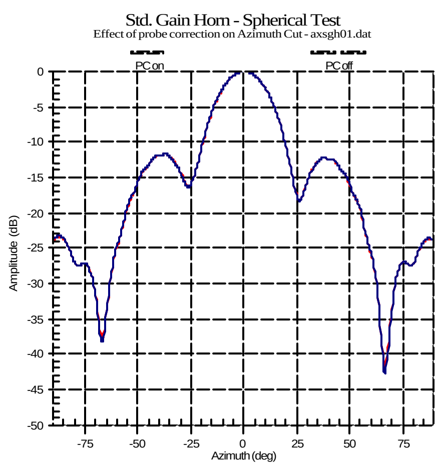

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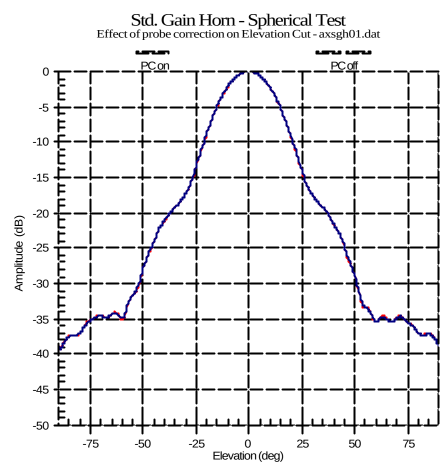

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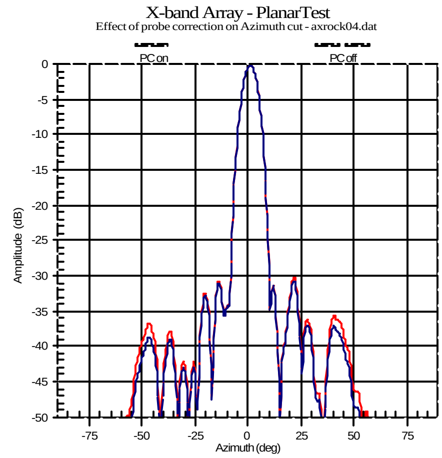

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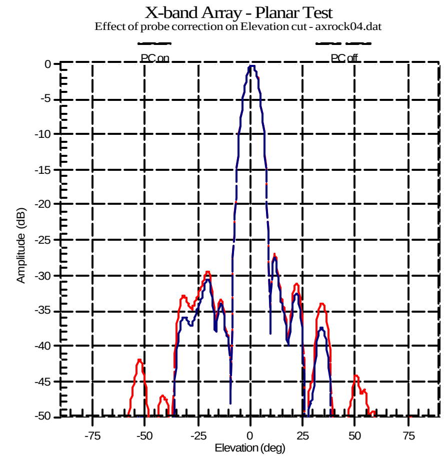

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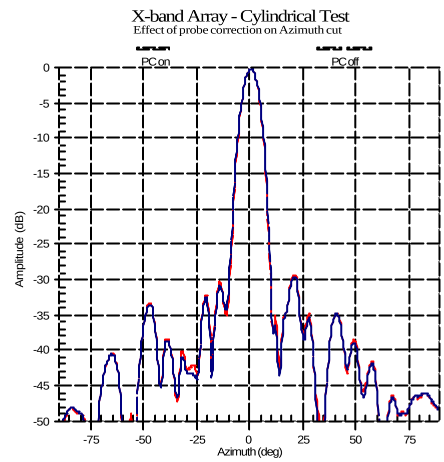

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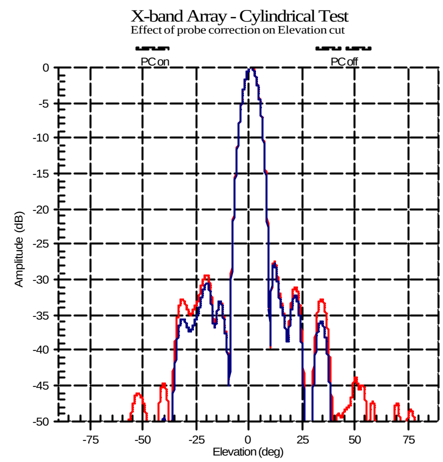

Figure 16

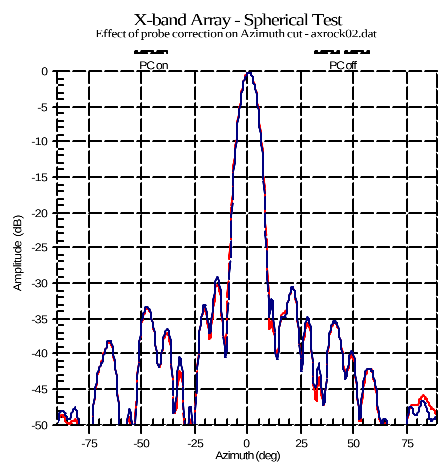

Figure 17

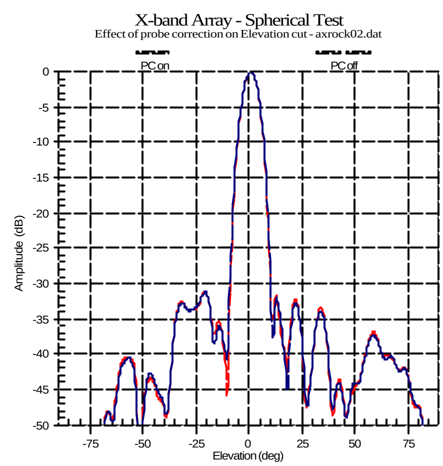

Figure 18

5. CONCLUSION

The following general conclusions are made relating to principal polarization pattern measurements:

a. Probe correction, and therefore probe accuracy is more important for planar ranges.

b. Probe correction for cylindrical ranges is important because of the linear scan axis.

c. When testing higher gain antennas like the weather radar antenna shown here, the main beam shape and close in side-lobes are only slightly affected by the planar and cylindrical Y-axis probe correction. Therefore, the probe correction accuracy is less important for these types of antennas (as long as the beam is not steered off axis).

d. Spherical probe correction may not be required depending upon AUT to probe separation and the size of the antenna. As shown in Figure 19, the greater the probe to AUT separation, the smaller the subtended angle (β) reducing the effects of the probe pattern and, therefore, the need for probe correction.

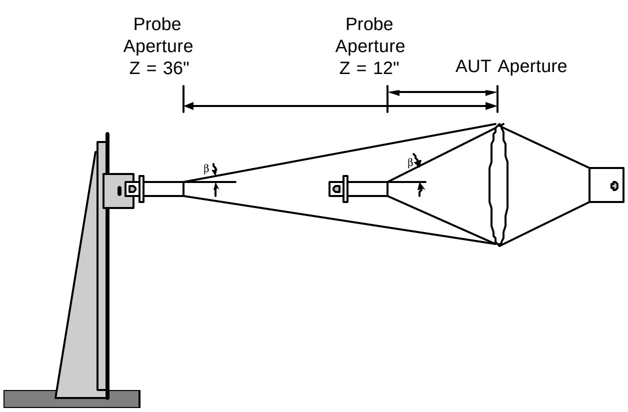

Figure 19 Probe Effects for Spherical Near-field

Based on the above observations, one might conclude that if the near-field technique were carefully chosen for a given antenna, probe correction might be eliminated entirely. While this may be true for primary polarization pattern measurements, the cross-polarization story is quite different.

Although cross-pol measurements were not included in this paper, NIST studies have shown that probe polarization correction for spherical near-field may be significant even at the larger AUT to probe separation [6]. Probe correction may be thought of as having two components, a pattern correction and a polarization correction. The pattern correction effect will be similar to the effect on principal polarization results at similar angles and pattern levels, while the polarization effects can be less predictable, and sometimes warrant use of measured probe correction data instead of the OEWG model. While the spherical plots clearly show there is little pattern correction observed for the principle polarization, the cross-pol patterns may be more sensitive to the polarization correction. At the larger separation and the low levels typical of cross-pol measurements, multiple reflections are also a dominant error source and should be considered in the measurement error budget.

Future study possibilities include comparison of the three scan types on cross-pol measurements with and without probe correction in a controlled environment with measurement of room reflections.

REFERENCES

1. Hansen, J.E., Editor (1988) Spherical Near-field Antenna Measurements, Sections 4 & 5, London: Peregrines.

2. A. Yaghjian, Approximate Formulas for the Far-Fields and Gain of open-ended Rectangular Waveguide, May 1983, NBSIR 83-1689, National Institute of Standards.

3. D. Slater, Near-field Antenna Measurements, Artech House, Norwood, MA, 1991.

4. Allen C. Newell, Greg Hindman, Alignment of Spherical Near-Field Rotators Using Electrical Measurements, Nearfield Systems Incorporated, Antenna Measurement Techniques Association (AMTA) symposium, November 1997.

5. Allen C. Newell, Greg Hindman, Quantifying the Effect of Position Errors In Spherical Near-field Measurements, Nearfield Systems Incorporated, Antenna Measurement Techniques Association (AMTA) symposium, October 1998.

6. Ronald C. Whitman, Carl F. Stubenrach, Spherical Near-field Scanning: Experimental and Theoretical Studies, National Institute of Standards and Technology, RF-TR-91-56 Final Technical Report, April 1991.