

# Generalized Probe-Position Compensation Methods for Near-Field Antenna Measurements<sup>1</sup>

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**Abstract**— The National Institute of Standards and Technology (NIST) has developed computationally efficient near-to far-field transformation algorithms that allow for probe location and polarization compensation when measurements are not made on canonical grids. A major application of such methods is at higher frequencies, where it is difficult or impractical to locate a probe to required tolerances for the standard transforms. Our algorithms require knowledge of the actual position of the probe at the measurement points. This information can be furnished by state-of-the-art optical tracking devices. Probe position information is routinely obtained by the NIST CROMMA (Configurable Robotic MilliMeter-wave Antenna facility). Even at lower frequencies, probe-location compensation techniques allow in principle, the use of less precise and therefore less expensive scanning hardware. Our approach also provides the flexibility to process data intentionally collected on nonstandard grids (plane-polar, spiral, etc.) or with mixed geometries (such as a cylinder with a hemispherical or planar end cap). We present actual probe position compensation results at 183 GHz. **Keywords:** near-field scanning; probe position compensation; spherical near-field scanning.

## I. INTRODUCTION

Standard fast near- to far-field transforms require that complex (real and imaginary) data measured on a regular grid. Typically, probe-location accuracies of 0.01–0.02 wavelengths are needed to achieve acceptable sidelobe uncertainties [1]. Probe position compensation methods have been developed that do not require measurement points located on a regular grid but the actual probe positions still must be known to the stated accuracies [2, 3]. Implementation of these techniques for spherical near-field (SNF) measurements has been impractical until very recently. The new NIST CROMMA (Configurable Robotic MilliMeter-wave Antenna facility), however, can accurately track six degrees of freedom (three of location such as  $r$ ,  $\theta$ ,  $\varphi$  and three of orientation such as roll, tilt and yaw) [4, 5, 6]. Therefore, CROMMA is able to record deviations from ideal probe location and polarization. Prior NIST work does not include correction for nonideal polarization. Here we present more general results for probe location and polarization compensation.

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For spherical near-field measurements the position parameters are  $r$ ,  $\theta$ ,  $\varphi$  (the usual spherical angles) and  $\chi$  (the polarization angle of the probe). The original work [3] assumed no polarization deviations and that both polarizations were measured at the same point. Our new software allows for polarization discrepancies and does not require that both polarizations are measured at the same point.

We present some actual measurement results at 183 GHz from the NIST CROMMA Facility.

## II. MEASUREMENTS

Spherical near-field measurements were performed on a WR-5 standard gain horn with nominal gain of 24 dB. A standard near-field-to-far-field transform was used to calculate the far field pattern from the measured near-field data. These results were compared to both measured and theoretical patterns in Francis et al [7]. Location compensation was not employed in [7], even though the information was available. This is because the polarization compensation had not been implemented. Since then we have been able to implement the compensation for non-ideal polarization. Preliminary results are shown in Figure 1, which compares the pattern in the azimuth plane with and without position correction.

The information obtained by our laser tracker includes six degrees of freedom information including both location and orientation information [5]. Location information was evaluated and presented in [7]. However from this information, we are also able to evaluate the orientation of the probe during the measurements. A histogram of the pointing errors is presented in Figure 2 for the  $\theta$  component and in Figure 3 for the  $\varphi$  component. Note that the spread in the pointing error for the  $\theta$  component is significantly greater than that for the  $\varphi$  component. However, even though the spread in the pointing error is less for the  $\varphi$  component, its average error is larger. That is, the offset in the  $\varphi$  component is larger. The difference is due to the probe being rotated 90° between the two components resulting in a different mass distribution.

## III. CONCLUSIONS AND FUTURE WORK

We have successfully used the six degrees of freedom information obtained by the CROMMA to perform position correction for measurements of a WR-5 standard gain horn. The major effect is due to errors in the polarization axis  $\chi$ .

Since the CROMMA facility provides information on six degrees of freedom, the possibility exists for including compensation for orientation errors (tilt and yaw) as well as the correction for errors in  $r$ ,  $\theta$ ,  $\phi$ , and  $\chi$ . We intend to explore this possibility in future work.

The alignment of CROMMA is excellent at this frequency, so position compensation effects are small. More rigorous tests of position compensation ability are being planned. The possibility of compensating for known variations in probe pointing will be considered.

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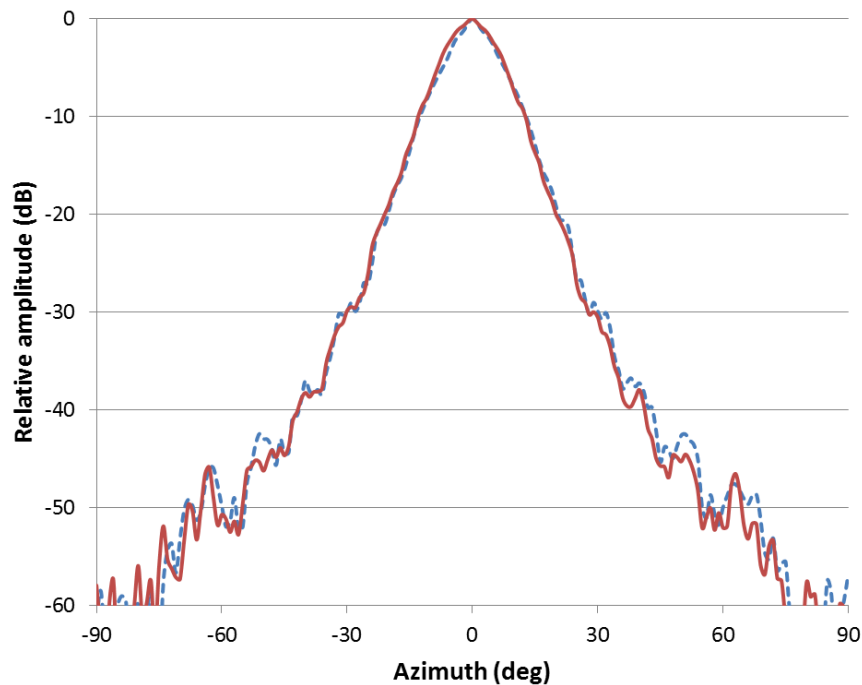


Figure 1. Azimuth pattern of a WR-5 standard gain horn with position correction (red, solid) and without position correction (blue, dashed).

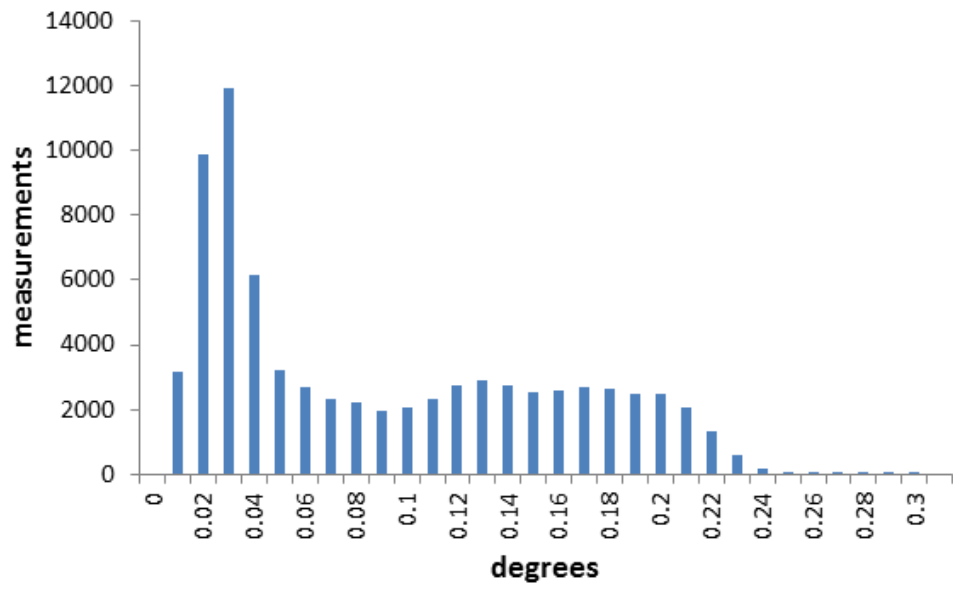


Figure 2. Histogram of the pointing error for the  $\theta$  component.

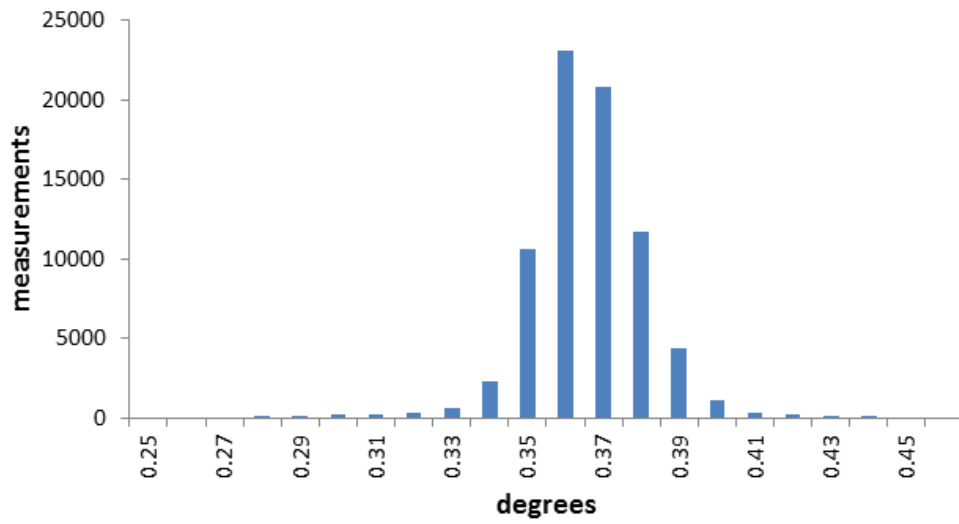


Figure 3. Histogram of the pointing error for the  $\varphi$  component.