Measuring Accurate Low Cross Polarization Using Broad Band, Dual Polarized Probes

Patrick Pelland, Allen Newell
Nearfield Systems Inc.
19730 Magellan Drive,
Torrance, CA, 90502-1104, USA

***Abstract*— There are a number of near-field measurement scenarios where the use of broad band probes is desirable. These probes allow one to make the most efficient use of chamber occupancy time by covering a wide bandwidth using a single probe in place of a collection of narrow band probes. Dual-polarized probes allow one to further reduce test time by a factor of two by eliminating the need to rotate the probe by 90 degrees to perform two-polarization antenna measurements. However, the reduction in test times yielded using these probes can also lead to a decrease in performance if the probe is not properly calibrated. This paper will describe a procedure to calibrate both the pattern and polarization properties of broad band, dual-polarized probes for use in near-field antenna measurements. Results of the calibration procedure for two of these probes will be presented here. Once calibrated, these antennas were used to measure the performance of standard gain horns (SGH) and compared to baseline measurements acquired using a good polarization standard open-ended waveguide (OEWG). Examples of these results from 300 MHz to 12 GHz will be presented.**

***Index Terms*—broad band, near-field, dual polarized probes, cross-polarization, calibration, pattern correction.**

I. INTRODUCTION

All variations of near-field antenna measurements require the use of a probe antenna with known radiation characteristics to accurately compute the radiation pattern of a particular antenna under test (AUT). Once the AUT's radiation pattern has been computed, a variety of other far-field parameters can then be extracted (directivity, beamwidth, beam pointing, etc.). One parameter that is often required is the far-field radiation pattern's cross component amplitude level in a specific direction or region in space. However, to accurately measure an AUT's cross-polarization amplitude one must have accurate knowledge of the probe's radiation pattern. For this reason, it is common industry practice to make use of simple probes with radiation patterns that can be easily modeled using reference to industry standard antenna design literature. One such example of these antennas is the open-ended waveguide (OEWG) probe used extensively in near-field antenna measurements. These OEWG probes can be used without calibration for most applications, have low on-axis cross-polarization levels (more than 50 dB below the main component), are relatively inexpensive and easy to manufacture. However, they are narrow band devices and contain only a single RF feed point, meaning the probe must be rotated 90 degrees to acquire dual-polarized AUT performance data. A collection of OEWG probes is shown in Figure 1.

There are a number of near-field measurement situations where the use of a broad band probe is desirable. This allows one to make the most efficient use of range occupancy time by using a single broad band probe in place of several OEWG probes. Unfortunately, most broad band probes do not have low cross polarization patterns over their full operating frequency ranges. In [1], the authors described a probe calibration procedure that could improve the performance of a broad band, log periodic probe with an axial ratio on the order of only 15 to 20 dB. Once calibrated, its effective axial ratio was as high as 40 to 50 dB. A broad band probe calibrated using this method could then be used in near-field antenna measurements to produce high accuracy AUT polarization results.

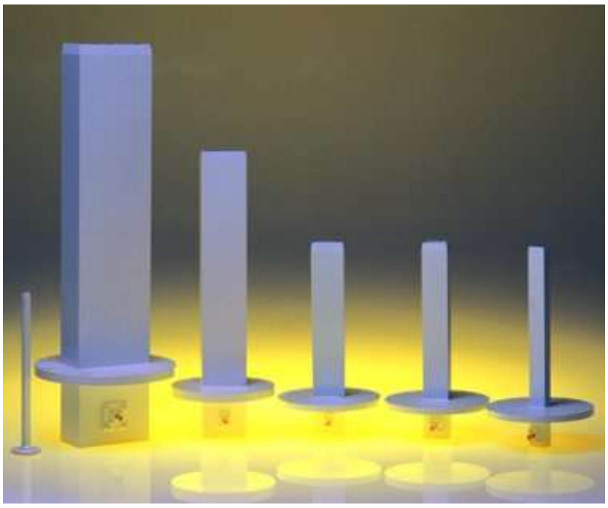

Figure 1. Collection of Open-Ended Waveguide (OEWG) Probes

This paper will present a continuation of the research presented in [1] by extending the calibration process to dual-polarized probes. These are often desirable to further reduce test time by a factor of two by switching electronically between the two ports rather than rotating the near-field probe by 90 degrees. However, the probe pattern calibration procedure must be extended to include polarization correction to account for differences in the polarization properties of the two ports of the dual-polarized probe. This paper will describe this polarization correction procedure. Examples of two broad band, dual-polarized probes calibrated using this method will be presented here along with the results of the pattern and polarization calibration procedures. Once calibrated, these dual-polarized, broad band probes will be used to measure the performance of standard gain horns (SGH) with known performance to verify the effectiveness of the calibration procedure.

Figure 2. NSI-RF-RGP-20 Broad-Band Dual-Ridged Horn (DRH)

II. COMPARISON OF VARIOUS PROBE TYPES

As previously discussed, three of the most significant advantages of using OEWG probes are their broadly distributed co-polarized radiation patterns, low on-axis cross-polarization amplitude levels and the ease of characterizing their radiation properties using theoretical models. These three factors allow one to make high accuracy near-field measurements using a low cost probe. Furthermore, the broad patterns exhibited by these OEWG probes reduce the importance of high accuracy probe alignment in many cases. Unfortunately, these OEWG probes have relatively narrow bandwidths compared to some publicly available alternatives. These probes are also fed using a single coaxial RF port meaning two complete scans are required to fully characterize the cross-pol performance of the AUT. For a spherical near-field (SNF) measurement system two complete scans are required even if cross-polarization information is not of interest.

To reduce the number of probes required to cover a particular bandwidth one may consider using a broadband dual-ridged horn (DRH) probe like the one depicted in Figure 1 which operates from 1.7 – 20 GHz. By comparison, a set of roughly seven OEWG probes would be required to cover the same bandwidth. These types of probes are also significantly smaller and lighter than the OEWG alternative for the lowest operating frequency (1.7 GHZ in this example). It is important to note that these probes have radiation properties that vary less predictably with frequency than the OEWG probes do. Because of this, these probes must be characterized and calibrated before they can be used in near-field antenna measurements. If the performance of the probe is not accurately known, the probe correction process cannot be used to isolate the response of the AUT from the measured data which is a combination of the probe and AUT performance.

Figure 3. 300 MHz – 3 GHz Dual-Polarized Broad Band Log Periodic Probe Calibrated using this Procedure.

While the type of probe depicted in Figure 2 can significantly reduce the number of setup changes in a near-field antenna range, it is only fed using a single coaxial connection, meaning two complete data sets must be acquired in order to obtain AUT cross-pol data. In [1], the authors make of use of the log periodic probes shown in Figures 3 and 4. Both of these probes are refered to as Dual-log periodic (DLP) probes, meaning that they are fed with two orthogonally-polarized ports. However, the authors of [1] made use of a single port on the probe with the second port terminated, denoted LP in this paper. In this configuration, the drawback of requiring two complete antenna measurements is not eliminated. This should be considered a single-polarized probe, albeit with orthogonal dipole elements which reduce its performance over traditional single-polarized log periodic probes. This paper will extend the research presented in [1] to allow one to make use of both DLP ports as a way to reduce measurement time by a factor of two.

Table I summarizes the probes discussed in this section. While it is be no means an exhaustive list of probe types available for use in near-field measurements, it is useful for comparison purposes.

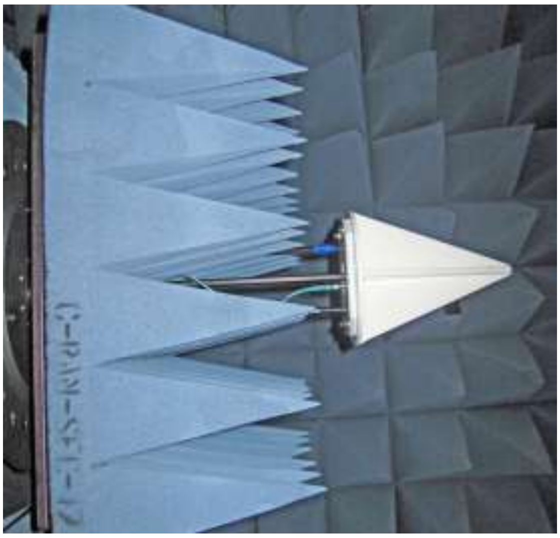

Figure 4. 1.0 – 26.5 GHz Dual-Polarized Broad Band Log Periodic Probe Housed in Protective Radome

TABLE I. COMPARISON OF VARIOUS NEAR-FIELD PROBE OPTIONS DISCUSSED IN THIS PAPER

Type	OEWG	DRH	LP	DLP
Cost	Low	High	High	High
Bandwidth	Narrow	Broad	Broad	Broad
Measurement Time	2x	2x	2x	1x
Calibration Required	None	Pattern	Pattern	Pattern & Polarization

III. CHARACTERIZATION OF DLP PROBES

Before using a probe like the ones discussed here in a near-field antenna measurement environment, an accurate understanding of the probe's radiation characteristics is required. The first step is to mount the probe candidate as AUT in an SNF antenna range like the large scanner shown in Figure 5. An SNF range allows one to measure the performance over a full sphere which should provide the most accurate measure of the probe candidate's performance due to its inherently lower truncation level. See [1, Table 2] for a collection of error assessment results obtained after performing a series of tests on the DLP antenna. Once the error assessment was complete, probe pattern correction files were generated to be used during the probe correction process. Figure 6 shows this probe's main component E-plane pattern for six frequencies in the WR975 band.

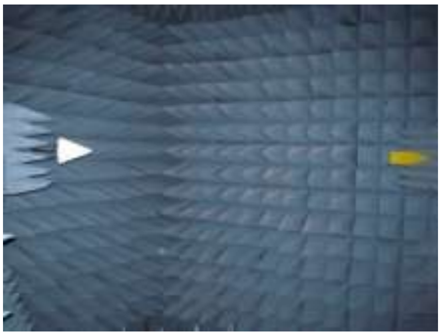

Figure 5. NSI-RF-DLP-04 Dual-Log Periodic Probe Mounted as AUT in NSI's In-House SNF Antenna Test Facility

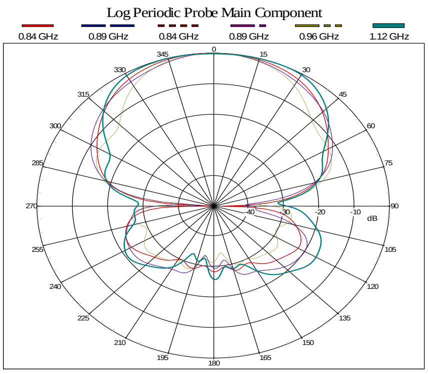

Figure 6. Log Periodic Main Component Amplitude Patterns in WR975 Band Measured During Probe Calibration Procedure

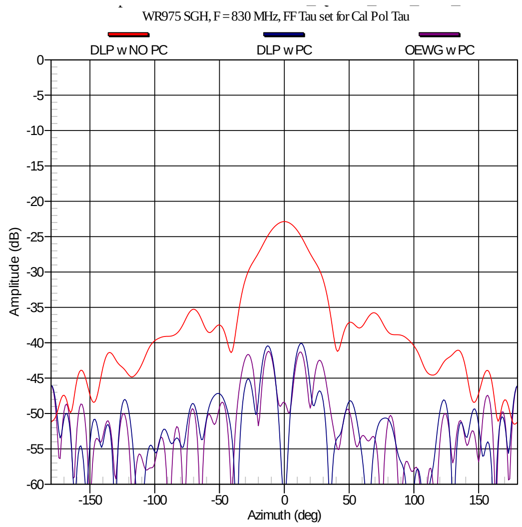

Figure 7. WR975 Standard Gain Horn E-Plane Cross-Polarization using the OEWG and DLP Probes with and without Probe Correction

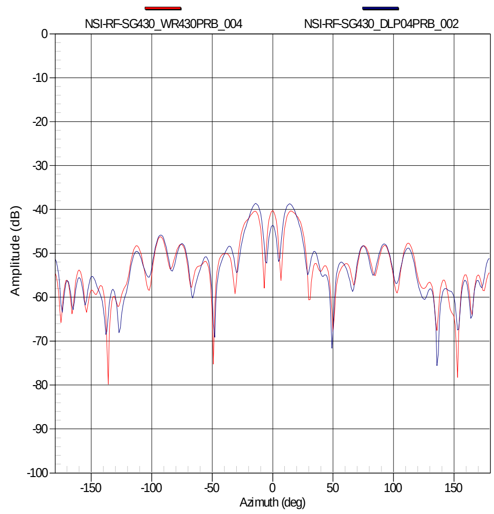

Figure 8. E-Plane Cross-Polarization Amplitude for the WR430 Standard Gain Horn Measured using the OEWG and LP Probes

IV. VALIDATION OF THE PROBE CORRECTION PROCESS

Once the calibration procedure for the DLP probe was completed, a series of validation tests were peformed in three OEWG bands on the same SNF test system used for the calibration procedure: WR975, WR650 and WR430. Figure 7 shows the E-plane cross-polarization amplitude for the WR975 standard gain antenna for three measurement scenarios at 830 MHz. First, the purple curve shows the SGH cross-pol measured using the WR975 OEWG probe with appropriate probe correction applied to the far-field data. It is important to note that this OEWG probe has not been calibrated and the theoretical model used for probe correction does not include cross-pol information. Next, the red curve was generated when the SGH was measured using the LP without any probe correction applied. This curve illustrates the importance of accurate probe pattern data for the probe correction process when the probe's cross-pol level are not sufficiently low to be negligible. Finally, the blue curve shows the far-field cross-pol levels of the SGH measured using the LP probe with proper probe correction applied. This case shows good agreement with the measurements performed using the OEWG probe down to -55 dB. Figure 8 shows a similar comparison performed on a WR430 SGH where the red curve was generated using the OEWG probe and the blue curve corresponds to the LP probe with probe correction applied.

V. Probe Polarization Calibration Procedure

In order to extend the probe calibration process to yield accurate AUT cross-pol levels for the case where the DLP is used as probe, the probe's polarization properties must be known. Using a combination of polarization and pattern correction, the on-axis cross-pol results of Figures 9 and 10 were obtained. In Figure 9, a WR650 SGH was measured with the DLP probe shown in Figure 3. When the probe is used in single polarization configuration (LP), the resulting SGH far-field on-axis cross-pol levels in red are obtained. As shown in the previous section, this data agrees well with the OEWG standard. Next, a second measurement is performed where the probe is used in the DLP configuration to reduce total test time. When standard pattern correction is applied, the cross-pol levels shown in the blue curve results. These decrease in apparent AUT axial ratio values can be attributed directly to the lack of polarization correction for the second of the DLP's ports. Finally, the golden curve shows the results when both pattern and polarization correction are applied, showing good agreement to the LP case.

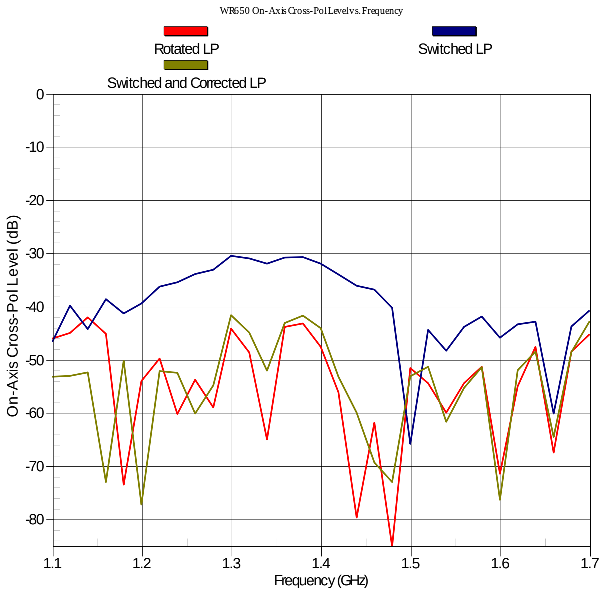

Figure 9. NSI-RF-SG650 On-Axis Cross-Pol Amplitude vs. Frequency using the Various Probe Configurations

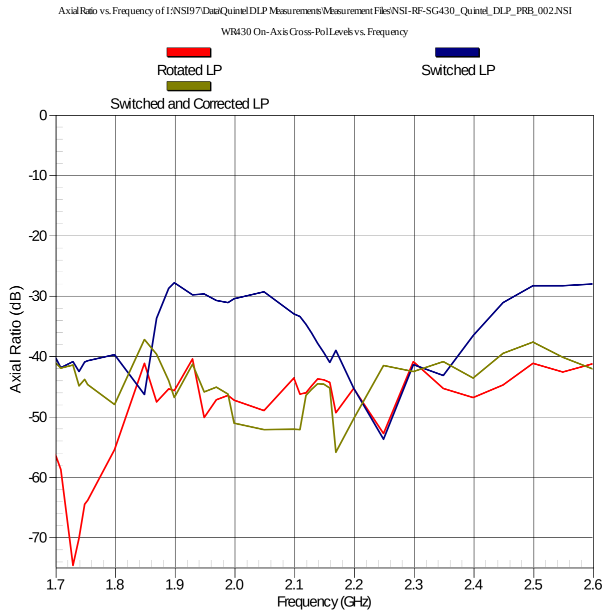

Figure 10. NSI-RF-SG430 On-Axis Cross-Pol Amplitude vs. Frequency using the Various Probe Configurations

VI. Concluding Remarks

It has been shown here that broad band probes with relatively low axial ratios can be calibrated for better performance to be used as near-field probes. The calibration procedure should be performed using a good polarization standard like an OEWG and an error assessment should be completed to ensure the pattern characterization yields an accurate representation of the broad band probe. If the calibration process is extended to include both pattern and polarization correction a dual-polarized probe like the DLP shown here can be used to reduce total test time by a factor of two and maintain the same level of accuracy.

References

[1] A. Newell and P. Pelland, "Measuring Low Cross Polarization Using a Broad Band, Log Periodic Probe", Proc. Antenna Measurement Techniques Association (AMTA) Annual Symp., 2012.