MEASURING LOW CROSS POLARIZATION USING A BROAD BAND, LOG PERIODIC PROBE

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ABSTRACT

There are a number of near-field measurement situations where it is desirable to use a broad band probe to avoid the need to change the probe a number of times during a measurement. But most of the broad band probes do not have low cross polarization patterns over their full operating frequency range and this can cause large uncertainties in the AUT results. Calibration of the probe and the use of probe pattern data to perform probe correction can in principle reduce the uncertainties. This paper reports on a series of measurements that have been performed to demonstrate and quantify the cross polarization levels and associated uncertainties that can be measured with typical log periodic (LP) probes. Two different log periodic antennas were calibrated on a spherical near-field range using open ended waveguides (OEWG) as probes. Since the OEWG has an on-axis cross polarization that is typically at least 50 dB below the main component, and efforts were made to reduce measurement errors, the LP calibration should be very accurate. After the calibration, a series of standard gain horns (SGH) that covered the operating band of the LP probe were then installed on the spherical near-field range in the AUT position and measurements were made using both the LP probes and the OEWG in the probe position. The cross polarization results from measurements using the OEWG probes where then used as the standard to evaluate the results using the LP probes. Principal plane patterns, axial ratio and tilt angles across the full frequency range were compared to establish estimates of uncertainties. Examples of these results over frequency ranges from 300 MHz to 12 GHz will be presented.

Keywords: near-field, measurements, spherical, planar, near-field probe calibration, polarization.

1.0 Introduction

Rectangular open-ended waveguide OEWG probes are used frequently for planar, cylindrical, and spherical near-field measurements. They have very good polarization properties on-axis and along the two principal planes where the cross-polarization level is typically -50 dB compared to the main polarization. Their limited bandwidth may require the use of multiple probes when measuring broad-band antennas. It is therefore desirable to use a broad-band probe for these types of measurements were a single probe can be used to cover the operating frequency of the antenna under test AUT.

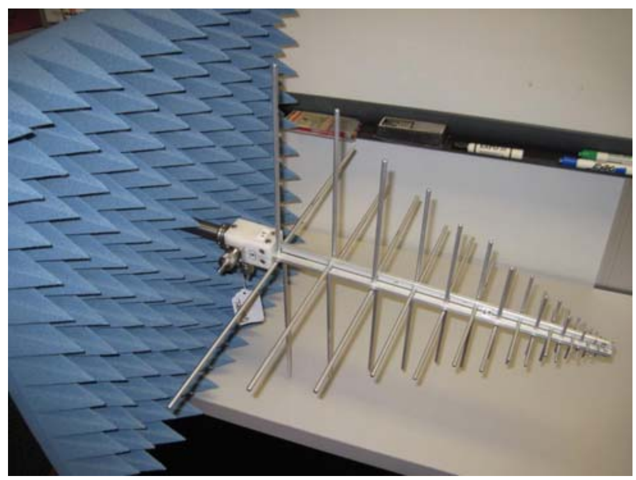

Figure 1-One of the log-periodic antennas used in the tests.

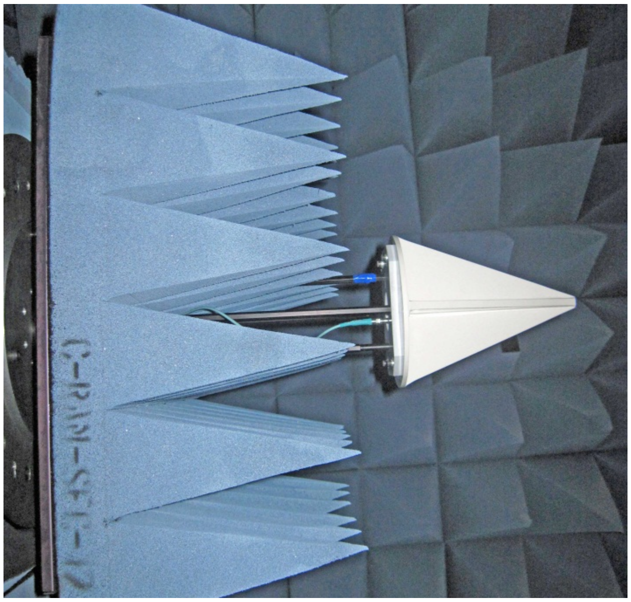

Figure 2-The second log-periodic antenna mounted in the NSI spherical near-field range.

For low-frequency measurements this often requires the use of a log periodic (LP) antenna like the test antennas used in this study shown in Figures 1 and 2 as the probe. These probes have main component patterns that are adequate for most applications. However the cross component properties of these, and other broad-band probes, can limit their ability to measure low level cross polarization of the test antennas. A sample cross polarization characterization for a dual port LP antenna is

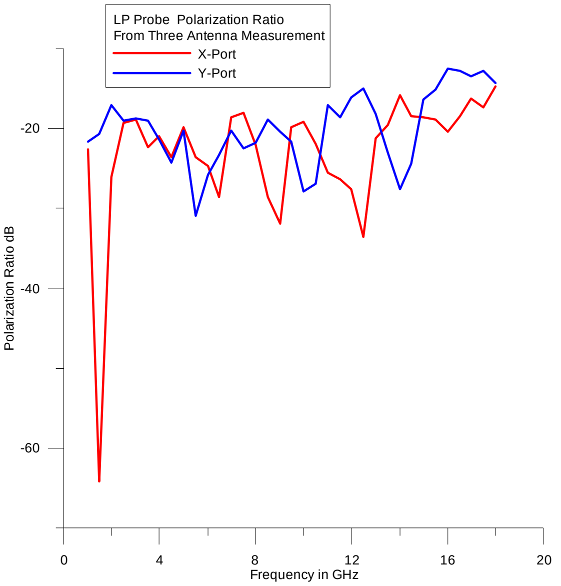

Figure 3 Polarization ratios for the two ports of an LP probe.

shown in figure 3. The average cross-polarization ratio for this antenna is approximately -20 dB, but it varies with frequency by as much as 40 dB and this property could cause large uncertainties in the measured cross-polarization of the test antennas.

To overcome these limitations and still use the broad-band properties, the probe can be calibrated and probe correction pattern files produced at small frequency increments across the band. In principle, if these probe correction files are used in the processing of measured near-field data, the accuracy of the cross-authorization results should be greatly improved. Demonstrating that this is true is the object of this paper.

2.0 Measurements

The following measurements and tests were performed to demonstrate how much improvement could be achieved with accurate calibration techniques.

Two broadband probes were used in these tests as shown in figures 1 and 2. One of the probes is shown mounted as the antenna under test in the NSI spherical near-field range and the open-ended waveguide probe mounted in the probe position in figure 4.

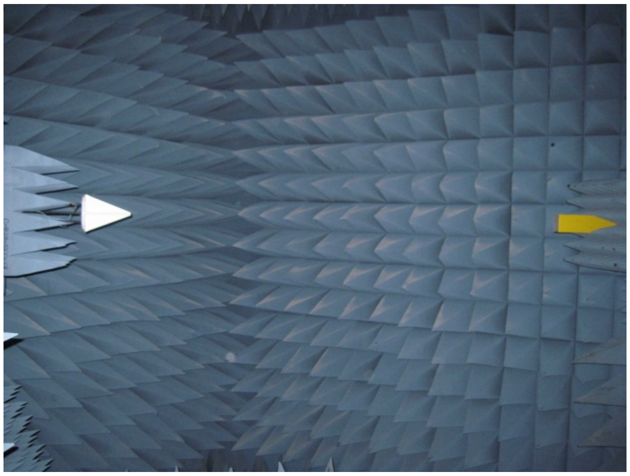

Figure 4-The LP antenna and open ended waveguide probe on the spherical near-field range.

Three basic configurations were used during this testing as summarized in Table 1. The first was used to calibrate the LP antennas using the OEWG probes. The second was used to measure reference data on the SGH's with OEWG probes. And the third was to verify that good cross pol measurements of the SGH's can be done with the calibrated LP's.

Table 1 Summary of test configurations.

Test Config:	1	2	3
AUT:	LP	SGH	SGH
Probe:	OEWG's	OEWG's	LP's
Reason:	LP calibration	Reference	Confirm calibrated LP probe performance

In the first configuration, spherical near-field measurements were performed using the AUT and probe combination shown in figure 4 over the operating bandwidth of the OEWG. The waveguide probe was then replaced with a similar probe that would cover the frequencies in the adjacent waveguide band. This process was repeated until near-field data had been obtained over the complete operating bandwidth of the LP probe. A sample of the far-field main and cross polarized far-field patterns are shown in Figures 5 and 6.

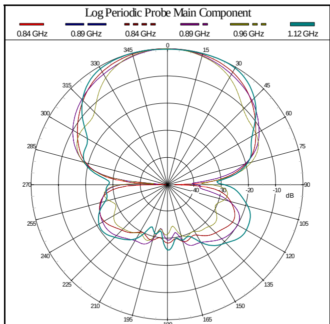

Figure 5-Main component patterns in WR975 band.

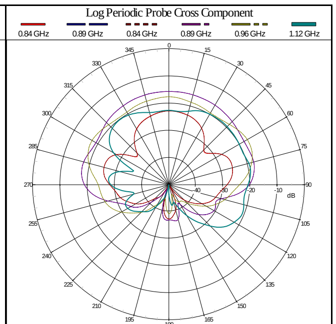

Figure 6-Cross component pattern in WR975 band.

The measurements were then processed to produce far-field patterns for the main and cross component of the LP probe at each measurement frequency. These patterns were then used to produce probe correction files that could be used with the NSI software to perform the probe correction when the LP antenna was used in the probe position to acquire near-field data. This process of near-field measurements and production of probe pattern files was carried out for both of the LP probes shown in Figures 1 and 2. The axial ratio of one port of the LP probe shown in Figure 1 that will be used in the following example is shown in Figure 7. It is noisier than Figure 3 because it was derived from a single near-field measurement assuming that the OEWG probe did not have any cross polarized response. Figure 3 was derived from an on-axis three antenna measurement that averaged some of the room scattering and noise effects and accounted for the true polarization properties of the two other antennas. Figure 7 shows that the LP probe used in the following examples has an axial ratio of between 20 and 40 dB. The spikes in the curve above 50 dB are due to measurement errors and do not indicate actual axial ratios this large for the LP antenna.

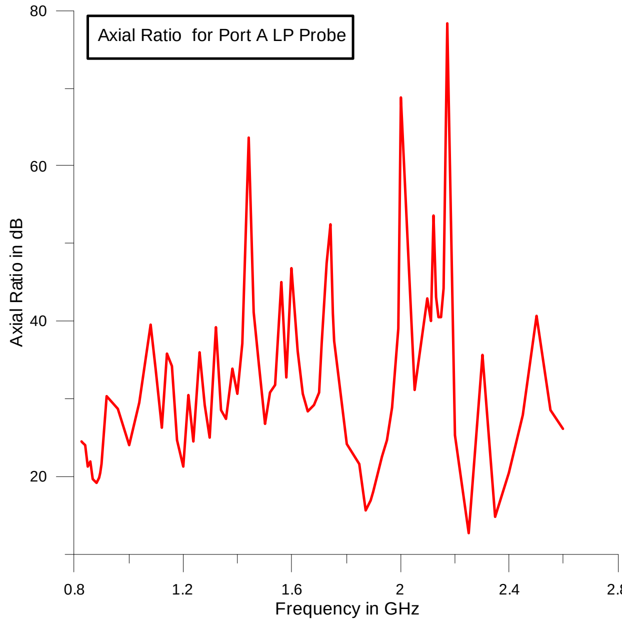

Figure 7-Axial ratio for one port of the LP probe obtained from near-field measurements.

After completing the probe pattern measurements, the LP probe was then removed from the AUT position on the spherical range and replaced with a standard gain horn (SGH) in the same band as the currently mounted OEWG probe. Spherical near-field measurements were performed over the operating bandwidth of the horn and probe and processed to produce probe-corrected far-field patterns for the SGH. Since the OEWG has a very low cross polarization level along the two principal planes, the corresponding far-field patterns of the SGH should be reliable at levels of -50 dB or higher. One of the LP probes was then installed in place of the OEWG probe and the near-field measurements repeated. The far-field patterns produced from these measurements could then be compared with the OEWG results and used to estimate the uncertainty of the cross polarized results. One example of a pattern comparison is shown in Figure 8.

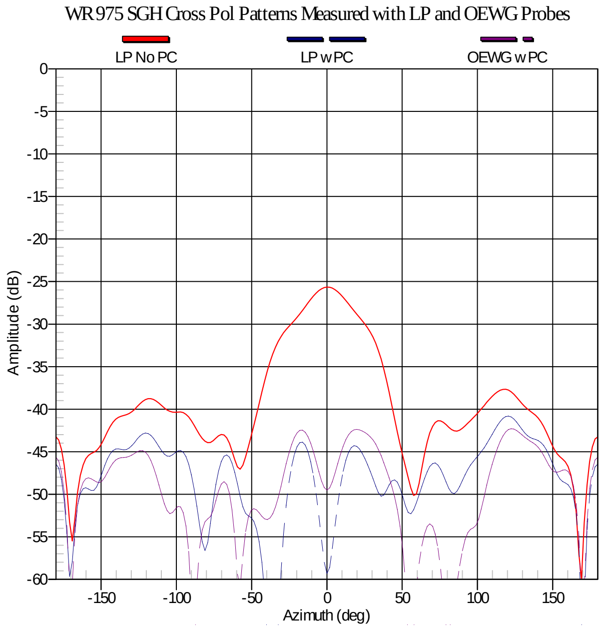

Figure 8-Comparing the cross polarized pattern of the SGH at F = 0.698 GHz using the OEWG and LP probes illustrating the great improvement in cross polarization results with the calibrated LP probe.

In Figure 8 the cross-polarized pattern measured with the LP probe and then processed using the no-probe correction option identified by the solid red curve assumes that the LP probe is perfectly polarized. This result is obtained without using the actual probe pattern data for the LP probe. The on-axis amplitude of approximately -25 dB is actually the cross-polarization level of the LP probe. Using the OEWG results as the probe, the true cross-polarization level for the horn is approximately -50 dB. This illustrates the large errors that can result from using an LP probe without probe pattern data. However when the LP probe pattern data is used as shown by the 2nd curve in figure 8, the agreement between the LP probe and the OEWG probe results are much better. Figure 8 is typical of the comparisons that were performed at other frequencies and in the other waveguide bands. A more concise representation of the comparisons is obtained by calculating the on-axis axial ratio as a function of frequency for the three cases illustrated in figure 8. Since the on-axis axial ratio is typically at or near the lowest level of cross polarization pattern, it can be used to represent the level over the full pattern.

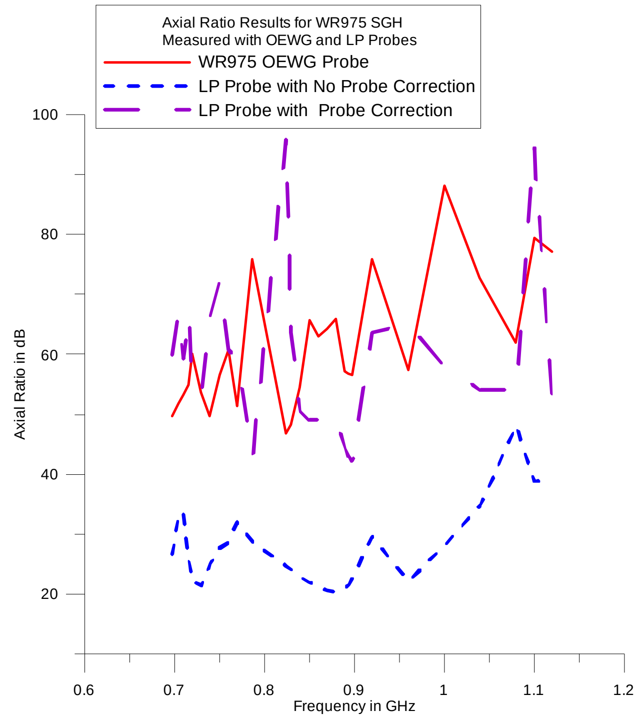

Figure 9-Axial ratio results for WR975 SGH measured with an LP and OEWG probe showing that the calibrated LP probe is almost equivalent to the OEWG .

In figure 9 and the following similar figures, the results from the OEWG measurements are considered to be the standard or reference results that are to be compared to the results using the LP probe. For high axial ratio results of 50 dB or greater, the peaks in the curves above 60 dB probably do not represent the actual properties of the antenna being measured, but are due to small errors in the measurement due to scattering, random noise, and other effects. At these points, the probe correction is calculating the difference between two nearly equal quantities and small errors in the near-field data or the probe pattern data produce results for the cross polarization amplitudes that are close to zero. The comparison between the two curves should then focus on the general level of the curve and not the fine structure.

Figure 10 is a similar comparison between the OEWG and LP probe in the WR430 band. Similar comparison curves were produced for other waveguide bands and for the other LP antenna and these will be presented at the conference.

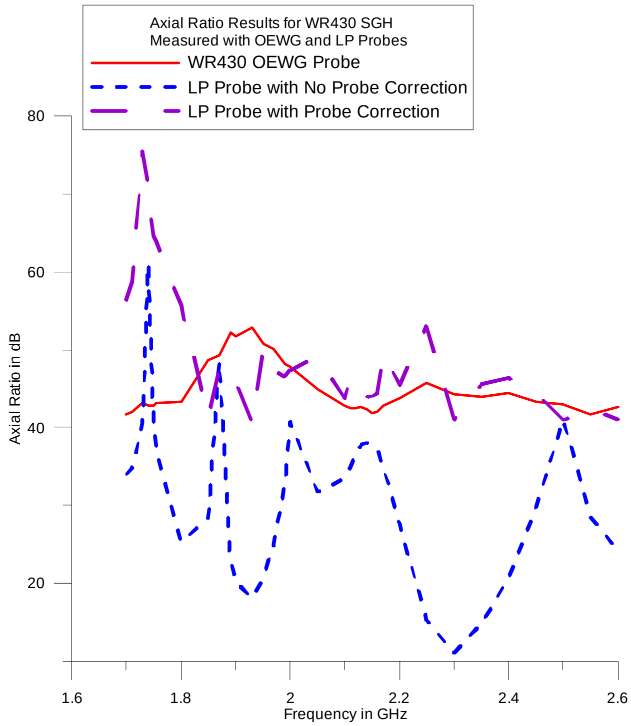

Figure 10-Axial ratio results for WR430 SGH measured with an LP and OEWG probe showing that the calibrated LP probe is almost equivalent to the OEWG .

3.0 Estimating Uncertainties

During the measurements, tests were performed to estimate the uncertainty [1] [2]. in the calibration of the LP probe and the pattern and polarization measurements on the standard gain horns. The terms that have the primary effect on the polarization measurements are listed in Table 2.

Table 2-Estimated Uncertainties in Polarization Measurements Relative to Main Component Peak.

Source of Uncertainty	RMS Uncertainty
Probe Cross Polarization	-50 dB
Near-Field Sampling Density	-52.6 dB
Receiver Dynamic Range	-56.7 dB
Room Scattering	-52.0 dB
RF Leakage	-68.6 dB
Repeatability	-71.5 dB
RSS Total	-47.3 dB

Using specific examples these estimates can be checked against the comparison curves in Figures 10 and 11. For the cases where the axial ratio of the LP was 20 dB the corresponding polarization ratio is -20 dB. From the RSS total in Table 1, the error signal level is 27.3 dB below this resulting in an uncertainty of 0.36 dB in the calibrated polarization of the LP antenna. From Equation (4) in the analysis of cross polarization uncertainties[3], the Polarization Calibration Term is -27.3 dB and the effective calibrated polarization of the LP is -47.3 dB. When the calibrated probe pattern files are used with the SGH near-field data measured with the LP probe, it is as if a -47.3 dB AR probe was being used. When measuring an axial ratio of the SGH of -40 dB the uncertainty in the measured result is ±3 dB. When the OEWG is used to measure the same AR level of the SGH, its assumed -50 dB axial ratio produces an uncertainty of ±2.4 dB. The difference between the results using the OEWG and the calibrated LP probe should therefore be on the order of 3-5 dB for a 40 dB axial ratio. For a 60 dB axial ratio of the SGH a similar analysis predicts a ±14.5 dB uncertainty using the LP probe and ±12.4 dB using the OEWG. And the difference between the axial ratio results at this level should be between approximately 10 and 20 dB. These estimates are consistent with curves in Figures 9 and 10 and we can conclude that the calibrated LP probe has an equivalent axial ratio approximately 3 dB less than OEWG that was used in its calibration.

4.0 Conclusions

A broad band probe with an axial ratio on the order of only 15 to 20 dB can be calibrated using a good polarization standard like an open ended waveguide and its effective calibrated axial ratio can be approximately 3 dB less than the standard. The broad band probes can then be used in near-field measurements and produce high accuracy polarization results.

5.0 **References**

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[2] Boldissar, F. and Haile, A Near Field Measurement Errors Due To Neglecting Probe Cross-Polarization AMTA Symposium Digest, pp 3-7., St. Louis, MO, 2007.

[3] Newell, A. C., Cross polarization uncertainty in near-field probe correction, AMTA Symposium Digest, 2008.