Accurate Planar Near-Field Results Without Full Anechoic Chamber

Greg Hindman, Stuart Gregson, Allen Newell
Nearfield Systems Inc.
Torrance, CA, USA
ghindman@nearfield.com

***Abstract* - Planar near-field antenna measurements have largely been performed within fully absorber lined anechoic chambers. However, when measuring medium to high gain antennas, one can often obtain excellent results when testing within only a partially absorber lined chamber [1], or in some cases even when using absorber placed principally behind the acquisition plane.**

As absorber can be bulky and costly, its usage often becomes a significant factor when planning a new facility. This situation becomes more difficult when the designated test environment is not exclusively devoted to antenna pattern testing with non-ideal absorber coverage being, in some cases, mandated, c.f. EMC testing. Planar test systems lend themselves to deployment within multipurpose installations as they are routinely constructed so as to be portable [2] thereby allowing partial or perhaps complete removal of the test system between measurement campaigns. Many of NSI's large planar near-field system installations are implemented with only a partially lined chamber [3]

This paper will present measured data taken using a number of different planar antenna test systems with and without anechoic chambers to summarize what is achievable and to provide design guidelines for testing within non-ideal anechoic environments. NSI's Planar Mathematical Absorber Reflection Suppression (MARS) technique [4, 5, 6] will be utilized to show additional improvements in performance that can be achieved through the use of modern sophisticated post processing.

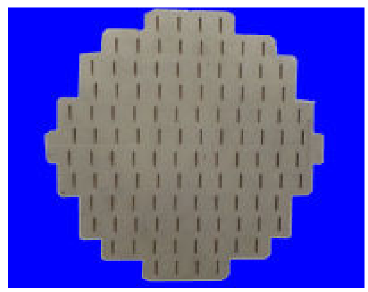
Keywords: Absorber, Chamber, Planar Near-Field, Reflection Suppression, Scattering, MARS.

I. Introduction

The goal of the paper is to show real measured results obtained from several planar near-field measurement systems employing different chamber / absorber treatments. Three different systems will be used to demonstrate that when medium to high gain antennas are tested on planar near-field systems, a full anechoic environment is often not required. To demonstrate this, an antenna with known radiation pattern will be measured on all three systems with various absorber configurations, including the case where no absorber is used at all.

II. ANTENNA USED FOR COMPARISON TESTS

The antenna under test was a Litton 12 inch Slotted WaveGuide Array (SWGA) operating at 9.375 GHz. NSI often uses antennas of these types for our on-site range accuracy assessments, and for conducting range assessments using the NIST 18 term range assessment procedure. This light-weight, mechanically rigid, antenna has a peak directivity of approximately 28 dBi, making it an ideal candidate for measurement on a PNF system. It also has sufficiently low sidelobes to allow for accuracy assessments to be performed on them. Figure 1 shows an image of the Litton 12" SWGA along with some performance specifications.



Antenna	12" SWGA
Frequency	9.375 GHz
3 dB Beamwidth	~ 8 deg
Directivity	~ 28 dBi
E-plane sidelobes	~ -25 dB
H-plane sidelobes	~ -30 dB

Figure 1 - AUT Used for Comparisons

III. SUMMARY OF SYSTEMS USED FOR TESTING

Three different planar near-field systems were used to test the SWGA. First, NSI's in-house 300V-12x12 scanner, shown in Figure 2, was selected as the baseline system for the comparison. Numerous range assessments have been completed using this system so there is an abundance of documentation regarding typical achievable uncertainties. Detailed RF, mechanical and alignment calibration logs are also available. In addition, this chamber has 36" back wall pyramidal absorber, which should provide maximum attenuation of stray signals, which is of primary interest for this paper. This system resides within an anechoic chamber, which is an industry standard for high accuracy near-field systems. Note that even though the scanner has a large 12'x12' scan plane, our testing was performed only over a 5'x5' scan area to allow direct comparison with subsequent testing which was performed on a portable 5'x5' scanner. The effect of truncation to a 5'x5' plane for this antenna testing over the ±60 degree angular coverage window used for this evaluation was negligible.

Next, the NSI-200V-5x5 shown in Figure 3 and Figure 6 was used. This system is used primarily for research and development tasks at NSI, but operates to the same mechanical and RF tolerances as the reference system. The first difference between this scanner and the reference is the reduction in total scan area available. This system has 5 ft of travel in both X and Y axes, while the first system can acquire data over a 12x12 ft surface. The second major difference between the two systems is the lack of anechoic chamber for this scanner. Figure 2 shows that this chamber is typically installed within in an open-laboratory environment lacking any absorber treatment. For the purposes of this paper, 12” pyramidal absorber was added behind the scan plane only.

The last system used for these evaluations was another NSI-200V-5x5 planar near-field scanner. This system is not a permanent fixture at NSI as it is eventually destined to be delivered to a customer. Prior to delivery to customers, all of these systems must be validated mechanically and electrically to confirm conformance with performance specifications. During this evaluation, the SWGA was mounted as AUT to serve both as RF validation and to provide additional data for the purposes of this paper. In this case, the system was evaluated with no absorber (Figure 7), 4” flat absorber (Figure 5) and Figure 12” pyramidal absorber (Figure 4). TABLE I below shows a summary of the test systems and configurations used here.

In all of these test systems, the range was configured with both a probe Z translation stage, and an AUT Z translation stage. The probe stage is typically used to take two data sets at ¼ wavelength apart to suppress on-axis multipath between AUT and probe. We also use the AUT Z axis translation stage to allow changes between the AUT and the scanner tower and back wall absorber for range reflection evaluation. The majority of the testing was performed with dual probe-Z and dual AUT-Z measurements for the processing shown here, although single Z results are also summarized in TABLE II. The nominal AUT to probe separation used was 6 wavelengths so as to minimize truncation, multiple reflections. etc.

TABLE I. SYSTEMS USED FOR TESTING

Test	Scanner	Location	Back Wall Absorber	Figure
1	300V-12x12	Chamber	36” pyramidal	2
2	200V-5x5 #1	Lab	12” Pyramidal	3
3	200V-5x5 #2	Lab	12” Pyramidal	4
4	200V-5x5 #2	Lab	4” Flat	5
5	200V-5x5 #1	Lab	None	6
6	200V-5x5 #2	Lab	None	7

IV. PATTERN MEASUREMENT RESULTS

The results of the testing in the 6 configurations are shown in Figure 8 thru 13 in the form of 2D false color checkerboard images, and Figure 14 thru 19 in the form of Azimuth (E-plane) pattern cuts and comparisons. Elevation (H-plane) results were similar and omitted for the sake of brevity.

As can be seen in the 2D images, the test result from the full anechoic chamber (Figure 8), is virtually identical to the results from the two tests on the systems with only pyramidal absorber installed behind the scanner plane (figures 9 and 10). The result in Figure 11 with the 4” flat absorber back wall behind the scanner is very similar but some sidelobe ripple is noticeable at the right hand side of the pattern. Figure 12 and Figure 13 from the testing with no absorber behind the scanner show noticeable corruption in the antenna pattern sidelobes all over.

In Figure 14, we show the baseline E-plane pattern used from the 300V-12x12 system in the full anechoic chamber. In Figure 15 thru Figure 19 we show the results from the other systems with various types of absorber treatment and also include a subtraction from the baseline pattern and show a residual Error to Signal (E/S) ratio [7], which is used as a measure of similarity.

In Figure 15, for instance, we see that the pattern subtraction E/S level shows about -42 dB peak error and about -54 dB RMS error level, which is excellent for a system with only back wall absorber. In Figure 16 the other 5’x5’ scanner with only a 12” pyramidal backwall absorber, we see about a -40 dB peak error level and a -52 dB RMS error level. The RMS error levels on the other 3 comparisons, with 4” absorber backwall, and both systems with no absorber, have poorer RMS error levels of -49 dB, -45 dB and -43 dB respectively. See TABLE II below, summarizing the RMS E/S ratios for the various configurations vs. the baseline data in the full anechoic chamber. Note that in that table we also show the results if only a single Z plane measurement were acquired and the results are also quite acceptable for many test applications.

Note that we also processed the data with NSI’s Planar MARS (P-MARS) technique to suppress residual errors (mostly arising from range multipath) and we show that results in TABLE II as well, and one can see the additional improvement up to 12 dB for one of the test cases with no absorber wall! See Figure 20 below.

TABLE II. RESULTS OF PATTERN TESTS

				RMS E/S ratio vs REF		
Test	**Scanner**	**Loc**	**Back Wall Abs**	**1Z**	**4Z**	**MARS**
1	300V-12x12	Cha	36” Pyr		REF	
2	200V-5x5 #1	Lab	12” Pyr	-53	-54	-61
3	200V-5x5 #2	Lab	12” Pyr	-50	-52	-55
4	200V-5x5 #2	Lab	4” Flat	-47	-49	-52
5	200V-5x5 #1	Lab	None	-42	-45	-51
6	200V-5x5 #2	Lab	None	-41	-43	-55

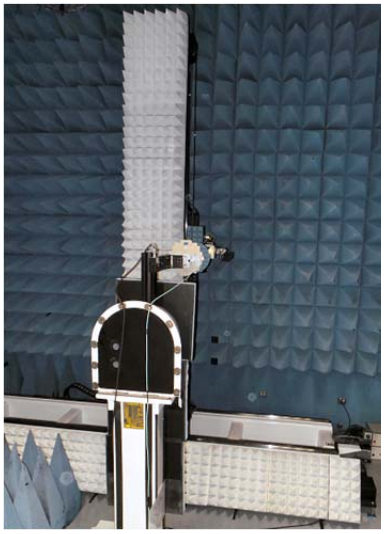


Figure 2 - 300V-12x12 PNF in NSI Chamber with 36” Back Wall Absorber

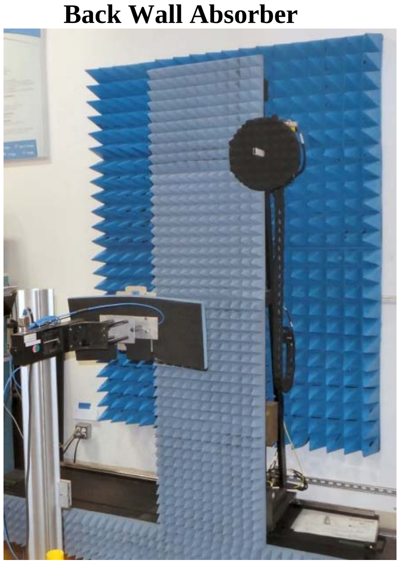


Figure 3 - 200V-5x5 PNF Scanner in NSI Lab with Small Section of 12" Back Wall Absorber

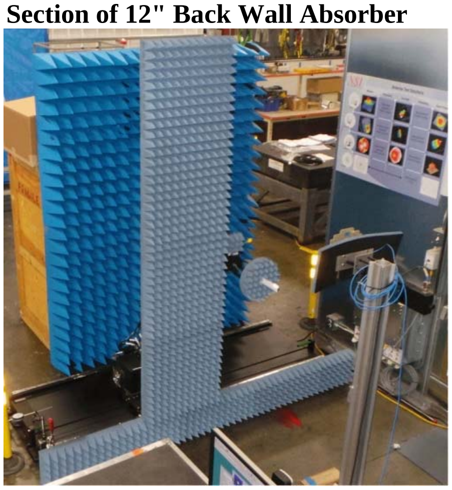


Figure 4 - 200V-5x5 PNF Scanner in NSI Lab with wall of 12" Pyramidal Absorber Behind Scanner

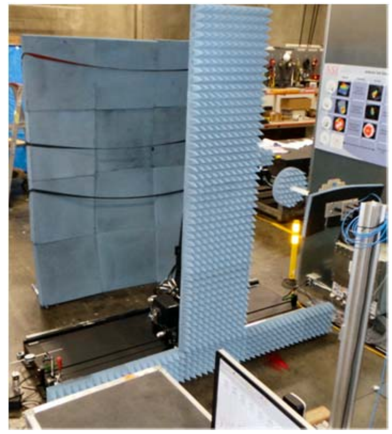


Figure 5 - 200V-5x5 PNF Scanner in NSI Lab with 5" Tower Absorber and wall of 4" Flat Absorber Behind Scanner

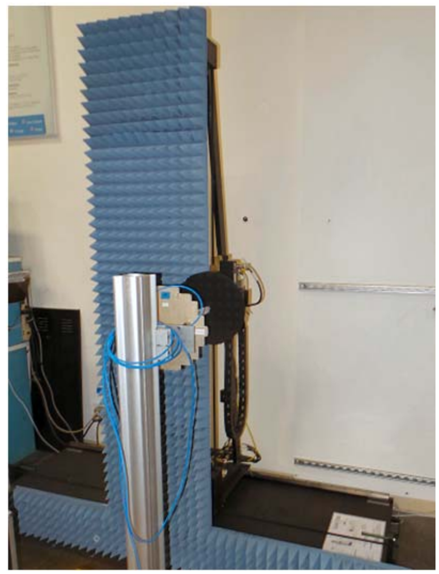


Figure 6 - 200V-5x5 Scanner with No Back Wall Absorber

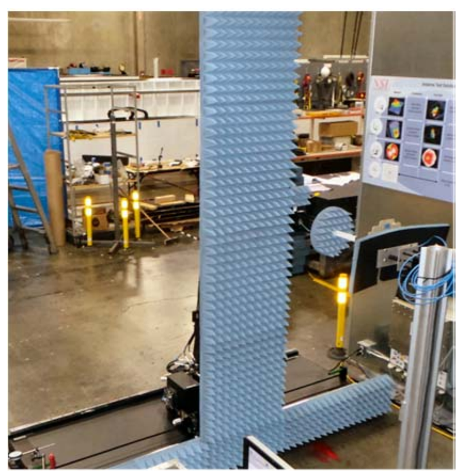


Figure 7 - 200V-5x5 PNF Scanner in NSI Lab with No Back Wall Absorber

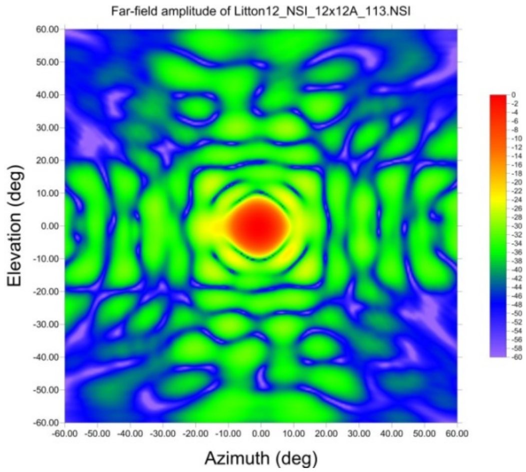


Figure 8 - Main Component Amplitude for 300V-12x12 with 36” Absorber

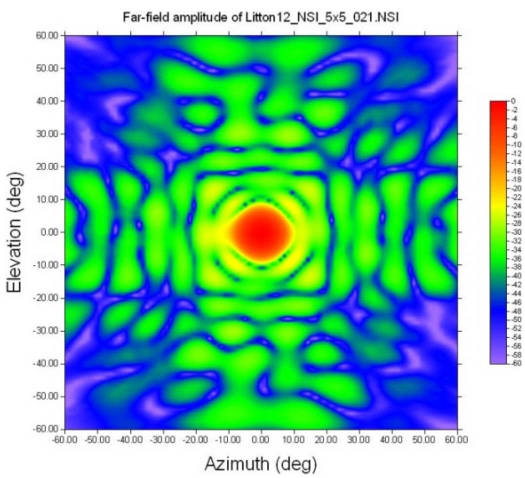


Figure 9- Main Component Amplitude for 200V-5x5 #1 with 12” Absorber

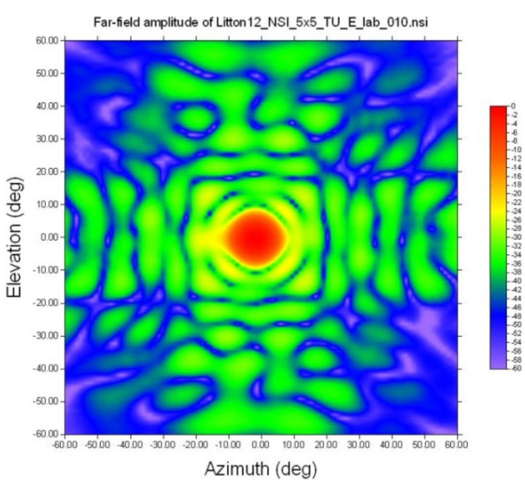


Figure 10 - Main Component Amplitude for 200V-5x5 #2 with 12” Absorber

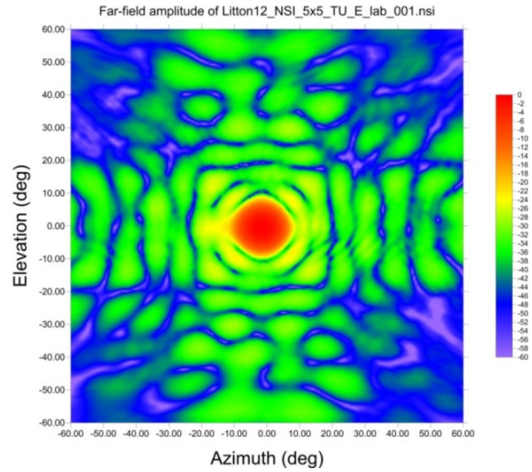


Figure 11 - Main Component Amplitude for 200V-5x5 #2 with 4” Flat Absorber

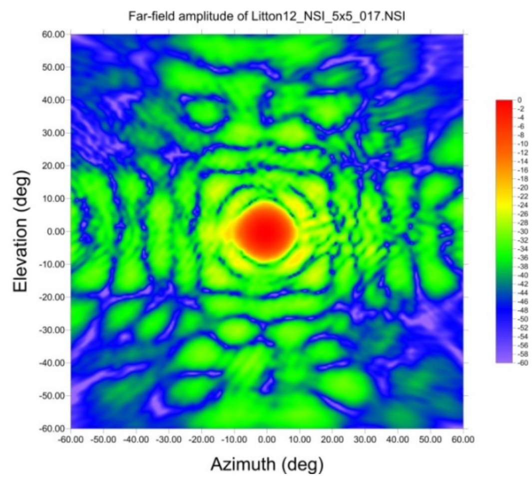


Figure 12- Main Component Amplitude for 200V-5x5 #1 with no Absorber

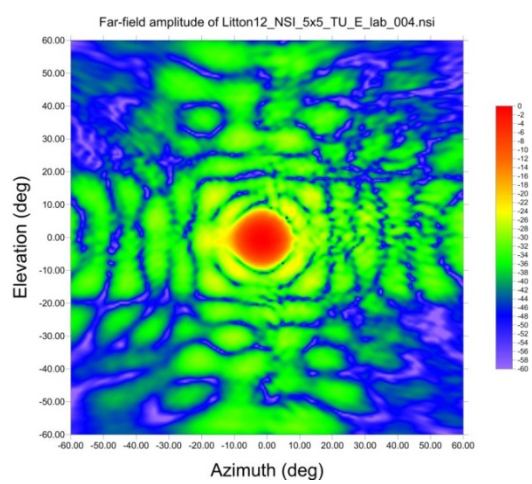


Figure 13- Main Component Amplitude for 200V-5x5 #2 with no Absorber

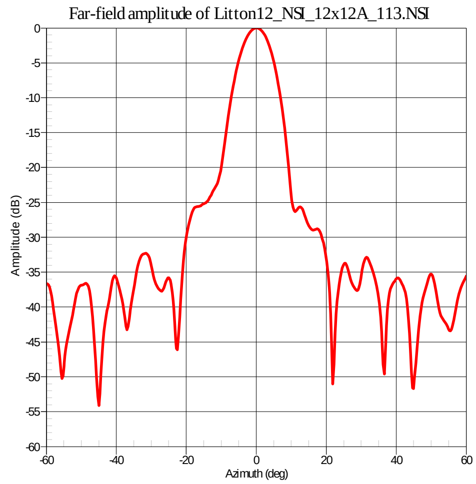


Figure 14 - Baseline E-Plane Cut of SWGA on NSI-300V-12x12

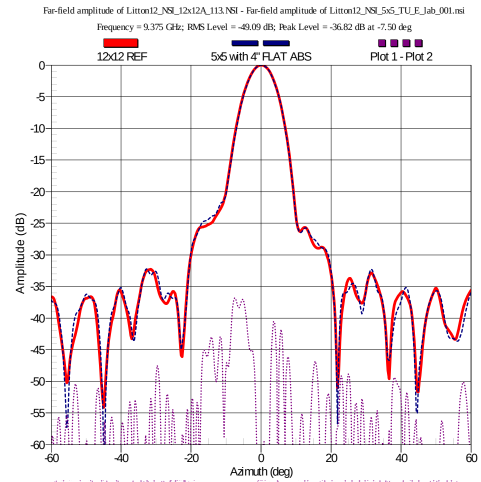


Figure 17 - 200V-5x5 #2 with 4" Flat Absorber Compared to Baseline

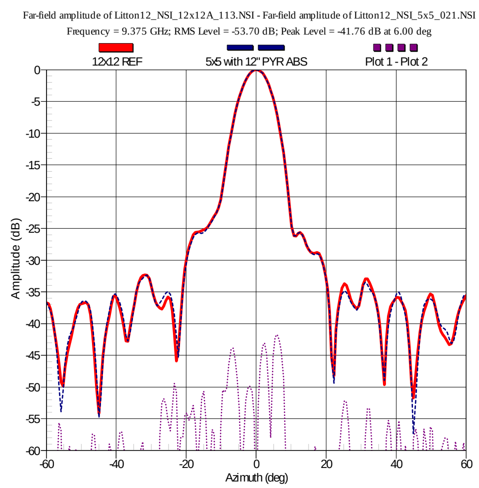


Figure 15 - 200V-5x5 #1 with 12" Absorber Compared to Baseline

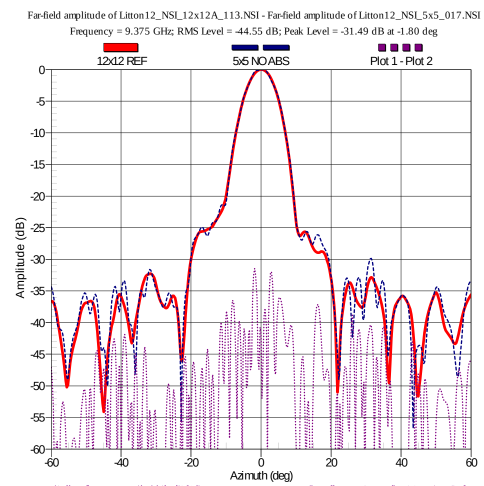


Figure 18 - 200V-5x5 #1 with no Absorber Compared to Baseline

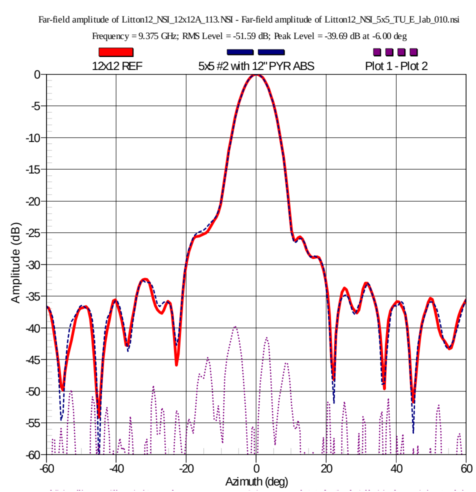


Figure 16 - 200V-5x5 #2 with 12" Absorber Compared to Baseline

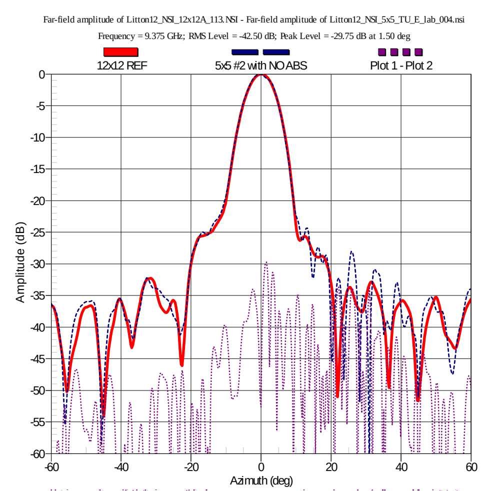


Figure 19 - 200V-5x5 #2 with no Absorber Compared to Baseline

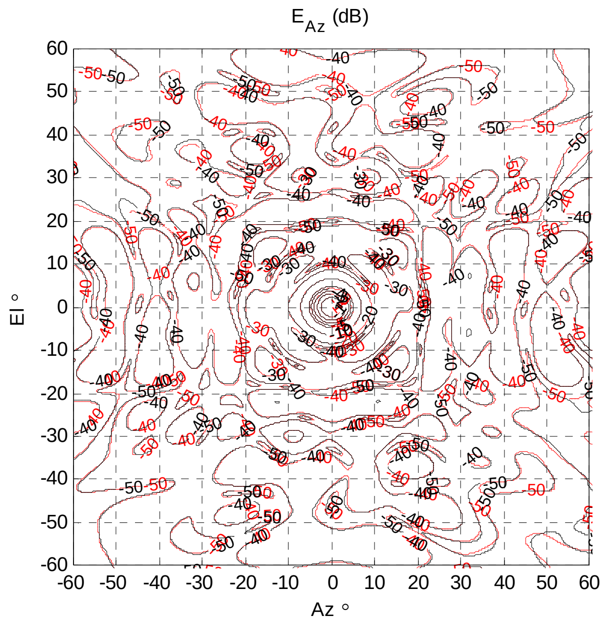


Figure 20 – Result of MARS processed comparison between reference pattern from full chamber, vs. test in lab with no back wall absorber behind 5’x5’ scanner

V. SUMMARY

These results have shown that for PNF measurements on medium to high gain antennas, excellent results can be achieved without a full anechoic chamber. One can often just construct a wall of pyramidal absorber behind the scanner to suppress reflections off the back wall. This can allow more economical measurements to be made without the investment in an expensive anechoic chamber. For cylindrical or spherical near-field systems (CNF or SNF), a full anechoic chamber is often recommended, however in many cases it may be adequate to just cover only the 4 side walls, particularly in the Phi/Theta geometry where the antenna’s main beam is only pointed azimuthally and does not illuminate the ceiling and floor regions. Additionally, NSI’s mathematical absorber reflection suppression technique can be employed to further improve the quality of the results obtained as these are now available for use with planar, cylindrical and spherical near-field systems, as well as with far-field and CATRs.

References

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