IMPROVING AND EXTENDING THE MARS TECHNIQUE TO REDUCE SCATTERING ERRORS

Greg Hindman & Allen C. Newell
Nearfield Systems Inc.
19730 Magellan Drive
Torrance, CA 90502

ABSTRACT

The Mathematical Absorber Reflection Suppression (MARS) technique is a method to reduce scattering errors in near-field and far-field antenna measurement systems. Previous tests by the authors had indicated that NSI's MARS technique was not as effective for directive antennas. A recent development of a scattering reduction technique for cylindrical near-field measurements has demonstrated that it can also work well for directive antennas. These measurements showed that the AUT should be offset from the origin by a distance at least equal to the largest dimension of the AUT rather than only 1-3 wavelengths which had been used for smaller antennas in the earlier MARS measurements. Spherical near-field measurements have recently been concluded which confirm that with the larger offsets, the MARS technique can be applied to directive antennas with excellent results.

The MARS processing has recently been modified to produce significantly improved results. This improvement is especially useful for antennas where the phase center of the horns is located inside the horn and varies with frequency like pyramidal Standard Gain Horns (SGH). Fewer modes are required for the translated pattern and the filtering is more effective at reducing the effect of scattering. The improvement is very apparent for pyramidal horns.

Keywords: NIST, 18-term, error evaluation, absorber, reflection, spherical near-field, suppression, MARS

1. Introduction

The NSI MARS processing technique has been in use by NSI and our customers since its introduction in 2005 [1]. Validation of the MARS technique has been published in the 2005 paper and additional papers [2,3,4,5]. This paper will focus on improving and extending the MARS technique.

Directive antennas, which have previously shown limited improvement with MARS processing, can now also benefit from MARS scattering reduction, as long as we can offset the AUT center by about one AUT diameter from the spherical theta/phi axis intersection. Results will be demonstrated on an X-band waveguide array antenna at 9.3 GHz.

Additional work has also been done to optimize the MARS processing to make it more effective for antennas with phase center variation with frequency. Results will be demonstrated for pyramidal horns.

2. MARS Use for Directive Antennas

Prior work had concluded that AUT offsets of a few wavelengths from spherical theta/phi intersection were adequate for good suppression with the MARS technique but that directive antennas received minimal reflection suppression with that type of offset. Recent work on extending MARS to Cylindrical near-field [6], however showed good results with directive antennas with larger offsets, and so we chose to investigate directive antennas further using the spherical nearfield geometry.

We chose to use an X-band weather radar antenna, with directivity of about 28 dBi at 9.3 GHz. The antenna was mounted in NSI's Spherical Nearfield test chamber as shown in Figure 1. The range includes a NSI-700S-75 spherical scanner, and has 36" pyramidal absorber on the walls and 24" pyramidal absorber on the scanner. The probe used was a NSI-RF-RGP20 ridged guide horn.

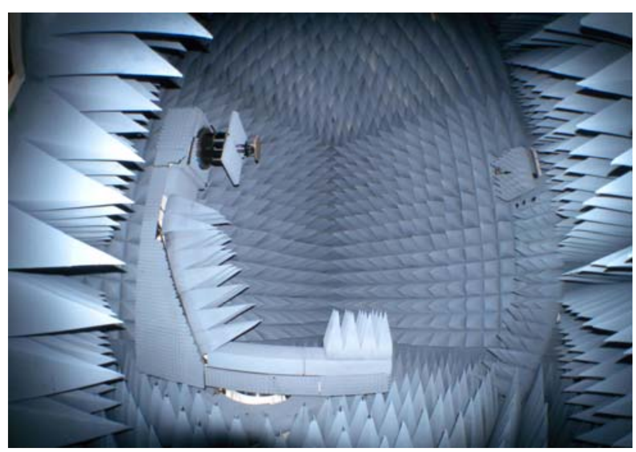

Figure 1– X-band Waveguide Array on NSI-700S-75 SNF Scanner

The far-field radiation pattern of the antenna is shown in Figure 2 and Figure 3.

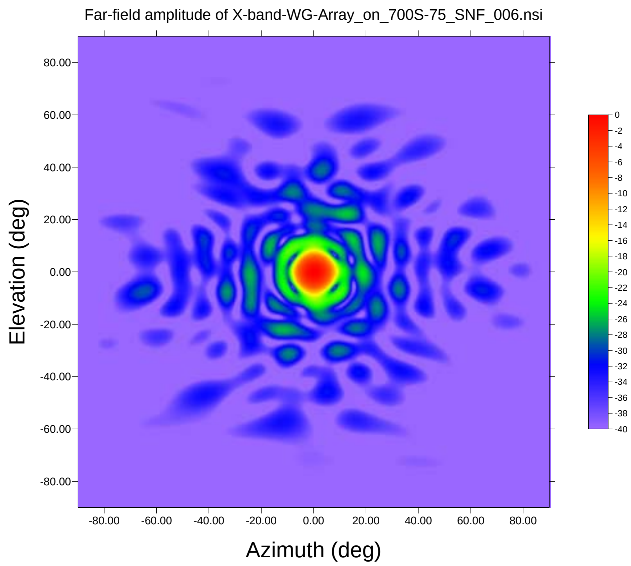

Figure 2– Far-field pattern in clean chamber

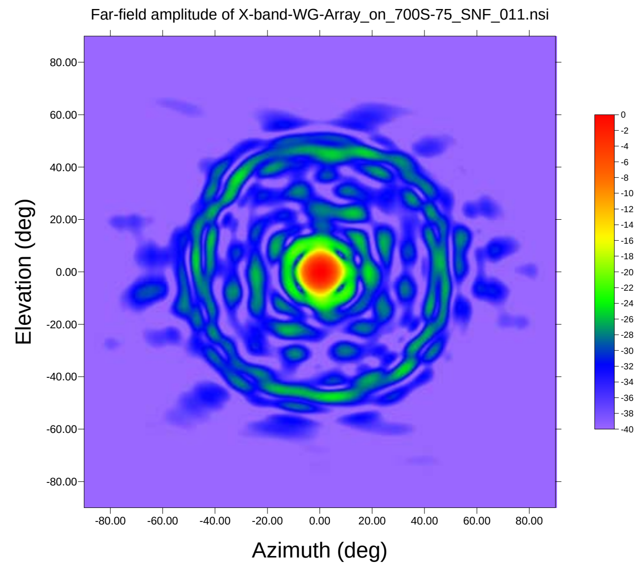

Figure 4– Far-field pattern with metal plate obstruction

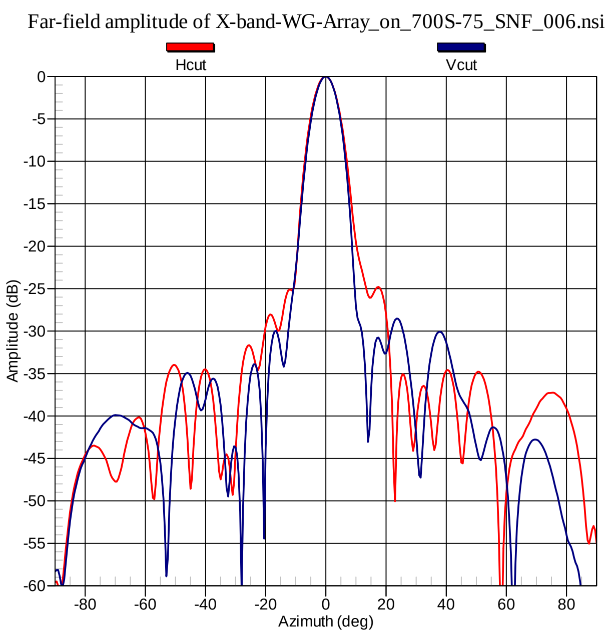

Figure 3– X-band Waveguide Array on NSI-700S-75 SNF Scanner

To demonstrate the effectiveness of the MARS technique, we introduced an obstruction in the chamber, similar to what we have done in prior studies. The obstruction is a 2’x2’ metal plate placed along one side wall of the chamber. The obstruction causes a maximum interference when the theta positioner is at around +45° and this translates into a sidelobe ring in the farfield pattern, which is elevated about 20 dB above normal as shown in Figure 4. A photo of the range with metal plate obstruction is shown in Figure 5

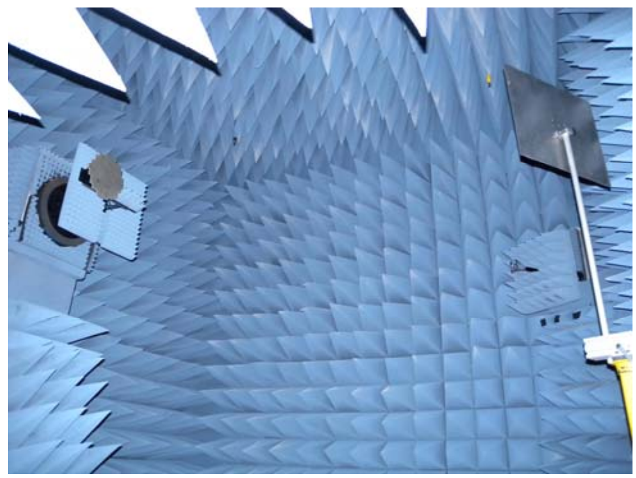

Figure 5 – 2’x2’ Metal Plate Obstruction in Chamber

For this case, we had the AUT translated -13.2” in Z (about 110% of the AUT diameter) from the theta/phi intersection axis, and we used a minimum sphere radius of 16”, which is about double that which would be required if the AUT was centered in the coordinate system. This requires a correspondingly higher number of samples, and of course, increases the test time. In the MARS processing of the directive antenna data, one file is selected as the “Truth Model” (TM) and its far-field is compared to the far-field from another file denoted as the “Scattering File” (SF) where scattering from the metal plate has been induced to estimate the improvement due to MARS. In all cases where the antenna is displaced in X, Y and/or Z, the TM is a file with no artificial scattering in the chamber. Figure 6 shows an example of the significant improvement (about 17 dB) obtained using MARS to suppress the reflection from the obstruction SF as compared to the TM.

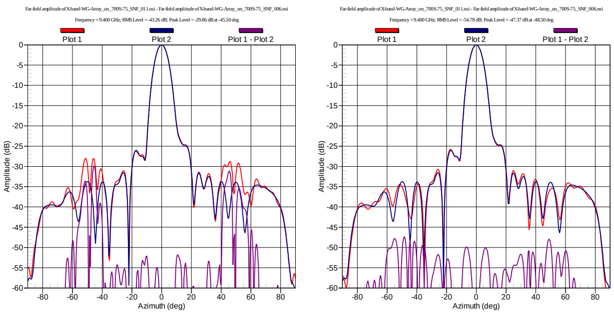

Figure 6 – Sidelobe error (left) and MARS improvement (right) comparing TM to SF with 2'x2' Metal Plate Obstruction in Chamber with AUT offset to Z = -13.2"

We decided to study several other AUT locations to evaluate MARS effectiveness as well. We built a bracket to shift the AUT laterally by about its diameter (12"), as shown in Figure 7.

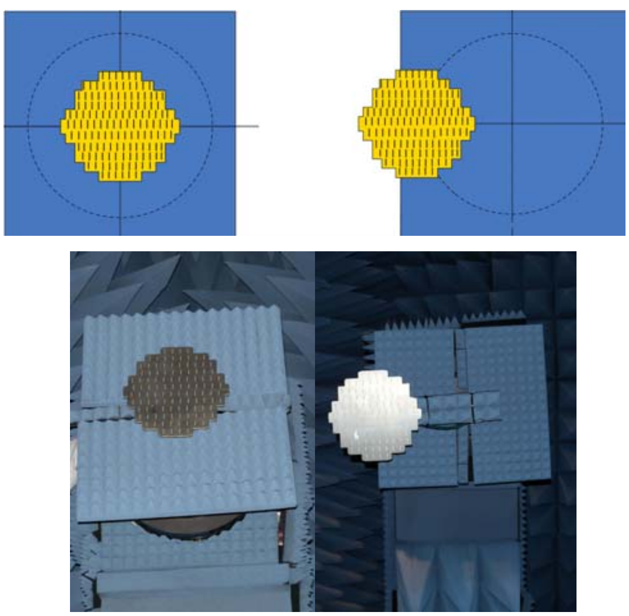

Figure 7 – X-band Waveguide Array Antenna at centered and lateral offset positions

Results with the lateral offset showed about 10 dB reduction in scattering as shown in Figure 8.

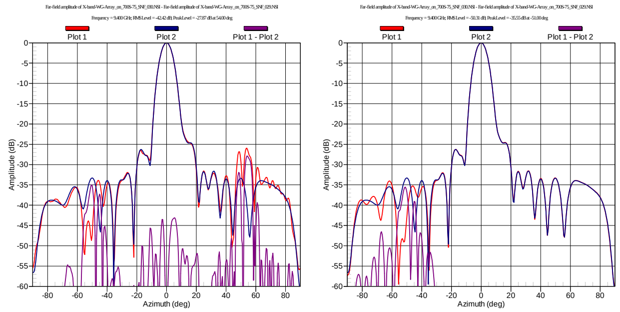

Figure 8 – Sidelobe error (left) and MARS improvement (right) comparing TM to SF with 2'x2' Metal Plate Obstruction in Chamber with AUT offset to X = -12", Z = -9.7"

With this same offset technique, we also tested with the AUT offset in the +Y direction the same amount. A summary of the 5 test cases and MARS results is shown in Figure 9**.** The MARS improvement is significant in all cases when the AUT center is offset by greater than 1 diameter from the theta/phi axis intersection point.

Case #	AUT Center Location X (in)	Y (in)	Z (in)	radius to AUT center (in)	radius to AUT center (lambda)	radius to AUT center (AUT diameters)	MARS improvement (dB)
1	0	0	-13.2	13.2	16.8	1.1	17
2	0	0	-6.2	6.2	7.9	0.5	3
3	-12	0	-5.6	13.2	16.8	1.1	9
4	-12	0	-9.7	15.4	19.6	1.3	10
5	0	12	-9.7	15.4	19.6	1.3	24

Figure 9 – MARS improvement for 5 test cases

These results confirm the value of MARS for spherical near-field for directive antennas, when appropriate AUT offset is used.

3. MARS Technique Overview

The purpose of the MARS approach is to reduce the influence of scattering on far-field pattern results. We use a mathematical post processing technique that requires a minimum amount of information about the AUT, probe and antenna range geometry. The processing is applied during regular near-field to far-field transformation. MARS uses the standard NIST Spherical Near-field to Far-Field Transformation Algorithm. As an inherent part of the far-field transform, the NIST algorithm uses a mode filtering technique. The mode cutoff is based on the fact that modes above a certain index number are exponentially attenuated and not detected by the probe. The mode cutoff is determined by the physical dimensions of the AUT. A typical mode plot on the Waveguide Array Antenna at 9.2 GHz is shown in Figure 10. In this figure, we have overlaid the measured mode plot, the shifted mode plot based on analytically translating the AUT phase center to the origin, and the filtering plot, showing where we have truncated the higher order modes.

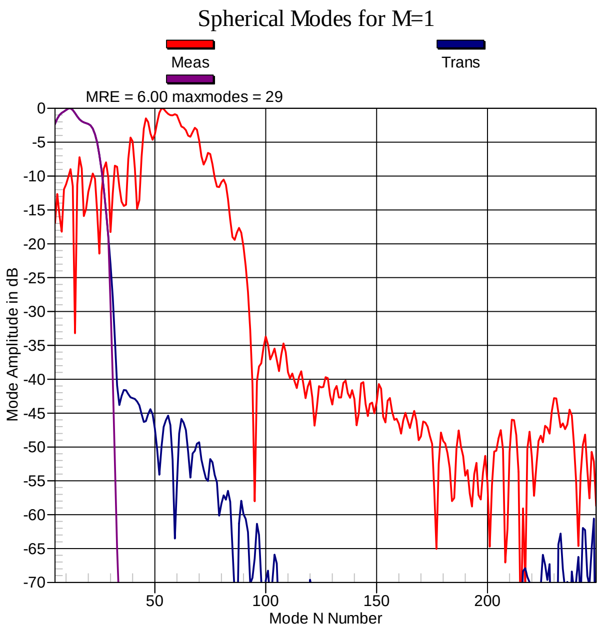

Figure 10 – Spherical Modes and MARS Filtering Example

The selection of which modes to filter out is made automatically by the MARS processing algorithm based on user inputs identifying the physical size MRE (Maximum Radial Extent) sphere which can contain the antenna. The user can also override the default filtering for evaluation during processing. In this case, the minimum sphere which contains the translated antenna aperture causes the MARS processing to filter out all higher order modes above N=29 as these can not be part of the antenna's true far-field radiation pattern.

4. MARS Technique Improvement on Antennas with Phase Center Displaced from the Aperture

In prior work, we have often used the AUT phase center as the translated origin for the MARS processing as shown in Figure 11.

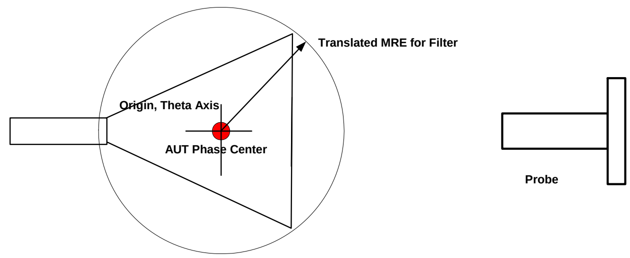

Figure 11 Schematic for the phase center of a pyramidal horn translated to the origin of the spherical coordinate system.

However for antennas like pyramidal horns when the phase center is not close to the aperture, this required more spherical modes due to the MRE for the offset position. The MARS processing has been modified to instead use a fixed offset location based on center of the AUT aperture as illustrated in Figure 12. With this improvement, fewer modes are required for the translated pattern and the filtering is more effective at reducing the effect of scattering on the final patterns.

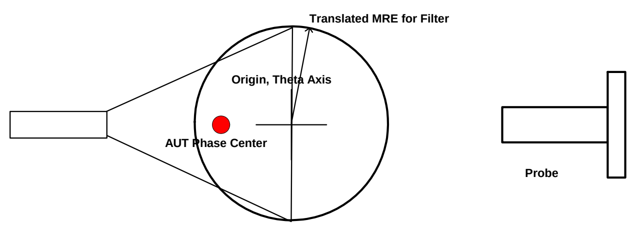

Figure 12 Schematic for the aperture of a pyramidal horn translated to the origin of the coordinate system**.**

The scattering reduction can be improved by as much as 10 dB by translating the aperture rather than the phase center as illustrated in Figures 13 and 14.

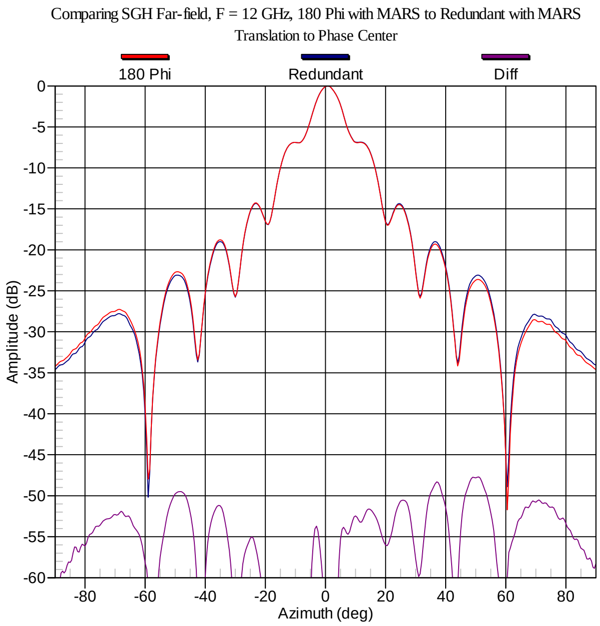

Figure 13 Comparing far-field patterns from MARS processed 180 phi subset with full redundant data to estimate scattering improvement. Using phase center translation.

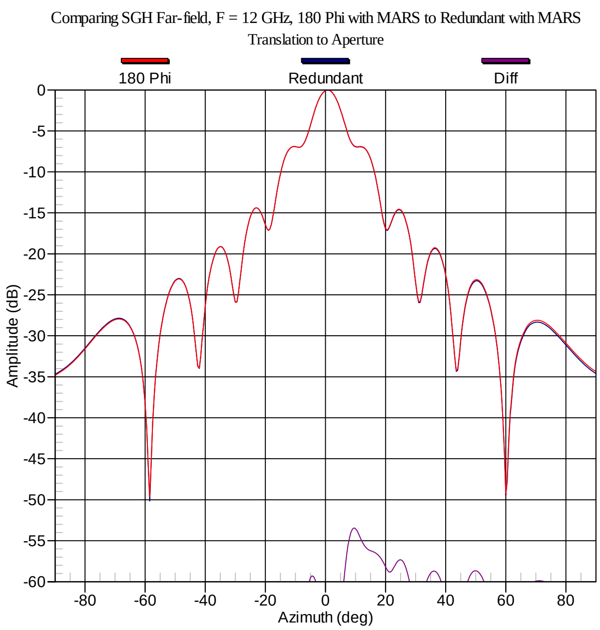

Figure 14 Comparing far-field patterns from MARS processed 180 phi subset with full redundant data to estimate scattering improvement. Using aperture translation.

5. Summary

This paper summarizes additional results and improvements in the MARS technique. MARS has now been shown to be extremely effective in processing of directive antennas, in addition to the prior reported results with lower and medium directivity antennas. Improvements of more than 10 dB in scattering reduction have been demonstrated. We have also improved the processing algorithm to achieve better results for lower gain antennas where the phase center varies significantly with frequency. These enhancements to the technique and the recent NSI extension of the MARS technique to cylindrical near-field measurements give the antenna test engineer extremely useful tools in the continuing battle to achieve higher measurement accuracies.

6. REFERENCES

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