Scattering Reduction In Spherical Near-Field Measurements

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

Allen_newell@qwest.net

Introduction

Reflections in antenna test ranges can often be the largest source of measurement errors. This paper will show the results of a new technique developed by NSI to reduce scattering from the walls or other objects in the measurement chamber. The technique, named Mathematical Absorber Reflection Suppression (MARS), is a post-processing technique that involves analysis of the measured data and a filtering process to suppress the undesirable scattered signals. The technique is a general technique that can be applied to any spherical near-field test range. It has also been applied to extend the useful frequency range of microwave absorber in an anechoic chamber. The paper will show typical improvements in pattern performance and directivity measurements, and will show validation of the MARS technique by comparing results between a high quality anechoic chamber and a range with limited or no absorber.
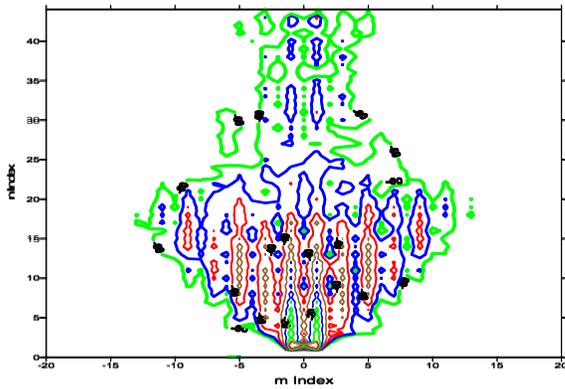
Spherical Near-Field Basics

Figure 1 **Typical spherical mode amplitudes for the S-band SGH antenna.**

Far-field results of Spherical near-field measurements are calculated by using a Spherical mode expansion technique developed by The Technical University of Denmark and NIST [1]. The basic idea is that near-field measurements in a Theta-Phi coordinate system can be uniquely described with a set of spherical mode coefficients. The spherical mode coefficients are determine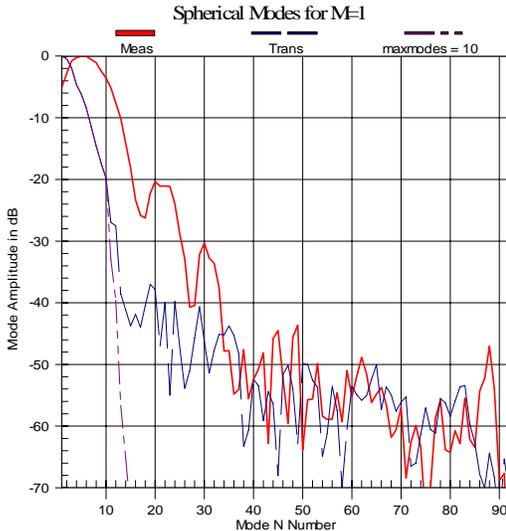d from the measured data in a very efficient manner. These coefficients are then corrected for the effects of the probe to determine the AUT mode coefficients. The same efficient processing is then used to produce far-field patterns, gain and polarization in a Theta-Phi coordinate system.

The spherical mode coefficients are generated by the regular processing of the measured data. These coefficients are complex numbers that are functions of the polarization index s, the phi index m and the theta index n. A plot of the

amplitudes of the spherical modes for s = 1 for a typical measurement on an S-band Standard Gain Horn (SGH) is shown in Figure 1.

A more concise graphical display is obtained by selecting the m index for the maximum amplitude and plotting the mode amplitude vs. the mode n number. The solid curve in Figure 2 shows a mode plot for sample data for s = 1, m = 1. As an inherent part of the far-field transform, the spherical algorithm uses a mode filtering technique. The mode cutoff is based on the fact that modes above a certain n-index number are exponentially attenuated and not detected by the probe. The mode cutoff is determined by the physical dimensions of the AUT and its position within the measurement sphere through the Maximum Radial Extent (MRE), the radius of the minimum sphere that will completely enclose the AUT. Mode filtering is also a key part of the MARS processing.

MARS Measurements and Analysis

Figure 2

The purpose of the MARS approach is to reduce the influence of scattering on far-field pattern results. A combination of measurement geometry and a mathematical post processing technique are used that require a minimum amount of information about the AUT, probe, and range geometry. The processing is applied during regular near-field to far-field transformation and is general enough to apply to different types of spherical measurement geometries and to different antenna types. It has been shown that the mathematical post processing will be more successful if the AUT phase center is offset by at least two wavelengths from the origin of the measurement sphere during the measurement. This offset causes the phase of the scattered signals to vary more rapidly over the measurement sphere and to produce the higher order modes shown in Figure 2. The offset position of the AUT requires a smaller angular spacing in the near-field data than for a centered position. In most cases, the MARS data spacing is one half of the centered spacing. The data for Figure 2 was taken with an offset of 3.6 wavelengths and a 2.5 degree spacing as compared to 6 degrees for no offset. The smaller spacing results in calculation of the higher order modes which are due to both the offset position of the AUT and the scattering within the chamber. To improve the discrimination between AUT and scattered modes, the far-field pattern derived from all the modes is mathematically translated to the origin by applying a phase shift to the far-field. The spherical transform is then applied to this translated data resulting in the

narrower mode plot shown in Figure 2 by the dashed line. Since the spherical coefficients derived from this second transformation are for a far-field of the AUT


**Figure 3 WR284 SGH on NSI ARCH range with no absorber.**

with its phase center at the origin, the physical size of the antenna can be used to determine the mode cutoff. In this case, the cutoff was for n = 10 and by removing all higher order modes, the effect of scattering is reduced.

The MARS measurement and processing has been validated for a variety of antennas at frequencies from 500 MHz to 50 GHz by comparing results from a high quality chamber with MARS processed data taken with either limited or no absorber. One example is shown in Figures 3-5. The WR284 Standard Gain Horn (SGH) was measured on the arch scanner without any absorber as shown in

Figure 3. The resulting far-field patterns showed a scattering level only 17 dB below the peak as seen in Figure 4. When the MARS processing was applied, the difference between the quality chamber results and the MARS processed data was at the -35 dB level. Typical improvements of 10 to 20 dB have been seen in other comparisons.
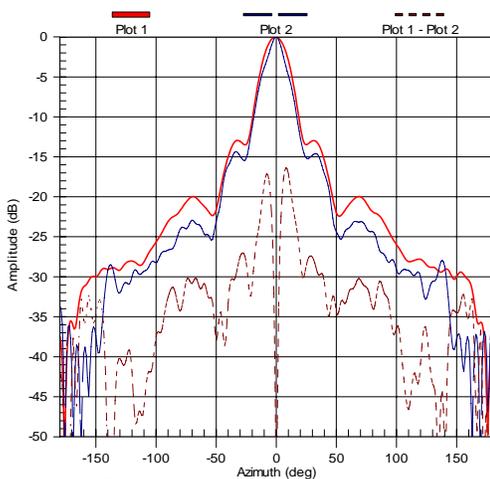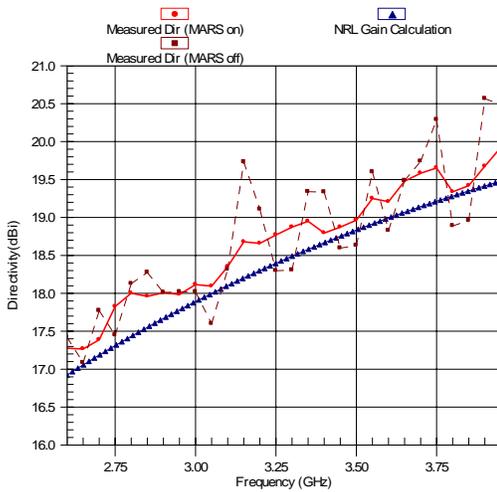

Figure 4 SGH comparison without MARS.
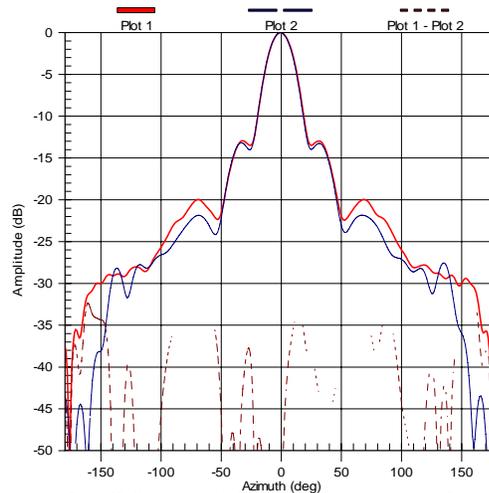
Figure 5 SGH comparison with MARS

To check the performance over a broader frequency range, multi-frequency data was obtained on the SGH and the directivity compared with the NRL directivity calculations with and without the MARS processing. Figure 6 shows this result.

The maximum difference from the NRL curve with MARS off is about 1.7 dB, whereas when the MARS processing is applied, the large discrepancies disappear and the maximum difference drops to only about 0.5 dB.

Figure 6 Directivity versus frequency of WR-284 SGH on ARCH range with no absorber or chamber compared to NRL directivity, with and without MARS.

It is not practical or necessary to perform the comparisons described above to assure reliability in each MARS application. The MARS processing can be used with confidence since all the steps in the measurement and analysis are consistent with the well established spherical near-to-far-field theory and measurement techniques, and all comparisons have been very positive. The offset of the AUT and the resulting smaller data point spacing are valid if the spacing satisfies the sampling criteria. The translation of the far-field pattern to the origin with the phase shift is rigorous. The selection of the mode cutoff for the translated pattern is based on the physical dimensions of the AUT and its translated location. The recommended mode cutoff is calculated from the AUT dimensions but can be modified by the user if the spherical mode plots such as Figure 2 suggest a different cutoff. The results of the MARS processing will always reduce, but not eliminate, the effective of scattering. The final result with MARS can be degraded if the sampling of the near-field data is too large or the final filter is too small, but this is also true for regular spherical processing. Both of these parameters are controlled by the user and must be correctly selected.

Fast and automated techniques have been developed to estimate the scattering reduction achieved in a MARS measurement and processing. Some of these will be described in the talk.[2]

References:

[1] Hansen, J. E., Editor (1988) "Spherical Near-Field Antenna Measurements", London: Peter Peregrinus.
[2] Hindman, G, Newell, A.C., " Spherical Near-Field Self-Comparison Measurements", AMTA 26th Annual Meeting & Symposium, Atlanta, GA, Oct. 2004.