Short Note On The Use Of Spherical Modal Filtering to Remove RF Leakage From SNF Measurements

Jeffrey A. Fordham
David Musser
MI Technologies, 1125 Satellite Blvd, Suite 100, Suwanee, Georgia, USA

***Abstract*—Near-field antenna measurement accuracy is reduced by various factors associated with the antenna test range environment and instrumentation hardware used. One such factor is associated with energy leakage in the RF hardware used in the measurement. In spherical near-field measurements, the sidelobe accuracy can be greatly impacted by RF leakage.**

In this brief note on the use of spherical modal filtering and the IsoFilter™ technique, it will be shown how the IsoFilter™ technique can be used to reduce the impact of leakage and stray signals in spherical near-field measurements.

***Index Terms*—Spherical Near-field, Antenna Diagnostics, IsoFilter™, Error Analysis.**

I. Introduction

The spherical near-field (SNF) antenna measurement process outlined by Hansen [1] involves measuring the fields radiated by an antenna under test (AUT), using the SNF transformation equation to generate a set of spherical wave coefficients ("modes"), and then computing the far-field antenna patterns from the set of modes. These modes represent the set of sources within what is known as the "minimum sphere" i.e. the smallest sphere centered at the SNF coordinate origin and encompassing the AUT [1].

It has been shown [2] that undesired sources of energy such as secondary scattering sources are associated with modes that can be truncated in the reconstruction of the far-field antenna pattern. By truncating these sources, the far-field antenna patterns can be presented as if they were measured without the scattered energy present.

Other sources of stray signals are present in antenna ranges other than secondary scattered energy. In this short note, an example is presented where the technique is used to isolate and remove RF leakage from a SNF measurement using spherical modal filtering. RF leakage is present in complex RF subsystems due to a wide variety of sources such as; improperly torqued coax connectors, insufficient shielding on signal sources, amplifiers and other active devices as well as improperly aligned waveguide connectors. RF cross-talk internal to RF instruments can exist, as well. For the purposes of this article, cross-talk is differentiated from leakage in that its amplitude and phase does not change as the AUT and probe are moved. Leakage in the RF measurement changes as the probe and AUT are moved during the measurement.

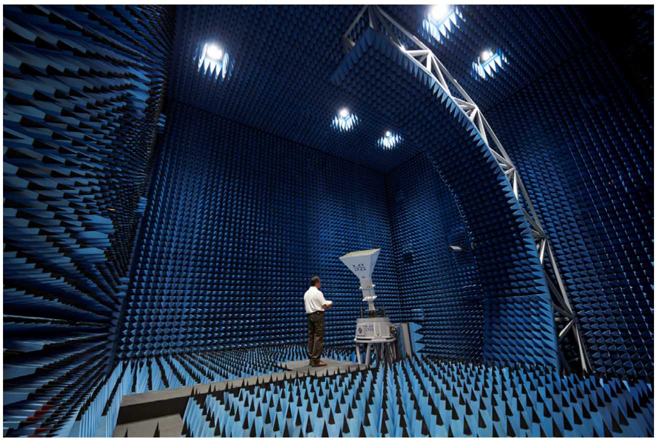

Figure 1 Arch over Azimuth Spherical Near-field Measurement System.

II. Background

Spherical modal filtering, augmented with a translation of the measurement origin has been demonstrated to reduce the level of scattered signals within a spherical near-field (SNF) measurement. This technique, known as IsoFilter™, was introduced by Hess [2] as it applied to testing of automotive antennas on outdoor ranges where significant stray signals existed. Hess later extended the technique for antennas that were located well away from the coordinate origin [3].

Hess showed some results of the ability to remove scattering from a ground plane behind a horn and later published a theoretical basis behind the technique describing how translating the origin was the key behind the reduction in the scattered energy [5].

III. Measurement Description

The spherical near-field measurement system used to perform these experiments consisted of an MI Technologies spherical near-field arch with a 5 meter radius, an azimuth axis, an absorber lined anechoic chamber and RF instrumentation.

The antenna under test (AUT) in this measurement consisted of a standard gain horn. Figure 1 shows a photograph of the chamber, the Arch, and a standard gain horn mounted on the azimuth positioner. The SGH shown in the picture is larger than the Ku-band SGH results presented in this short note.

The arch consists of a steel super structure supporting a circular track. A carriage travels along this track carrying a polarization roll axis over a slide axis that is used for fine adjustment of the radial dimension as the carriage moves along the arch. A probe consisting of an open-ended rectangular waveguide is mounted on the roll axis of the carriage assembly. The arch allows the probe to be moved along the theta axis of the SNF coordinate system with theta=0 located at the zenith position. The total travel of the probe along the arch is 135 degrees.

The AUT is mounted above an azimuth rotator mounted on a steel riser. The height of the steel riser was chosen to place the planned range of antennas to be tested near the center of rotation of the arch. The azimuth rotator allows the antennas to be rotated about the Phi axis of the SNF coordinate system.

The instrumentation for this antenna range consisted of an Agilent PNA Receiver, RF cables, amplifiers, couplers, mixers and rotary joint. The configuration of the RF subsystem and requirements for broad band operation allowed for the potential to have multiple leakage sources from cables and components.

The RF instruments were interfaced via Ethernet to an MI-3000 Data Acquisition and Analysis Workstation and MI-788 Networked Acquisition Controller for command, control and data collection.

For the measurement campaign, there were two different mounting configurations of the standard gain horn (SGH). In one configuration the SGH was mounted such that the main beam was aligned along the polar axis (theta=0 degrees). In another configuration the SGH was mounted in an equatorial configuration (theta=90 degrees). The goals of the campaign were to verify of the alignment of the range through an intra-range comparison which would expose different types of alignment errors as well as verify that chamber performance was within acceptable parameters.

IV. DATA PROCESSING

Figure 2 shows the amplitude of one component (E-theta) of a near-field measurement corrupted by a significant leakage source. The E-phi component is similar. Note in Figure 3 the band of energy between 80 and 120 degrees.

The Ku-Band SGH has aperture dimensions of 16 x 13 cm. For both the polar and equatorial mounts the center of the aperture was 66 cm away from the SNF coordinate origin. A record increment of 0.625 degrees was selected for the measurement, resulting in a minimum sphere of 221 cm at the measurement frequency of 12.4 GHz. In applying IsoFilter™, the region of energy sources of interest was assumed to be slightly larger than the SGH and its mount; an IsoFilter™ minimum sphere of 45.7 cm was selected for analysis. The translated coordinate origin was set to be at the center of the SGH aperture. Figure 2 shows, schematically, how the coordinate origin is translated and a new minimum sphere is assigned.

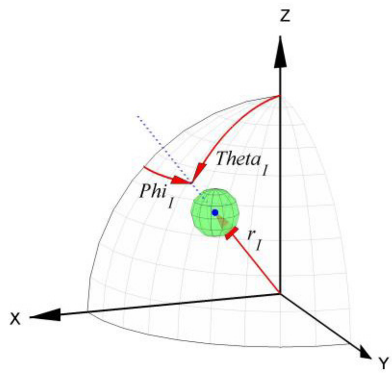

Figure 2: Diagram showing how the IsoFilter™ sphere is selected.

V. RESULTS

Figure 4 shows far-field antenna pattern overlays of the H-plane of the SGH. Results from both polar and equatorial mounting orientations are presented. The source of the RF leakage was located in the area of the steel riser below the azimuth axis. The RF leakage was detected by the measurement system in both orientations of the probe, but in the polar orientation, the RF leakage was mostly present in the back lobe of the SGH and therefore did not affect the forward hemispherical sidelobe energy significantly. Small ripples are seen in the sidelobe structure that is a result of the leakage.

For the equatorial mounted SGH, the leakage energy was present in the main beam of the SGH and for the H-plane measurement, across the full pattern. For the equatorial mounted SGH, significant stray signal ripples are present in the pattern. In this orientation, the stray signal due to RF leakage is approximately -42 dB below the peak of the main beam. This level of stray signal is greater than much of the expected sidelobe levels.

As shown in Figure 4 after the application of IsoFilter™ the significant impact of the RF leakage is removed, resulting in a stray signal level from all remaining error sources on the order of approximately -55 dB. Examination of the paper published by Hess and McBride [4] will provide more insight into the selectivity of the IsoFilter™ process.

VI. CONCLUSIONS

Based on this measurement campaign and other similar measurements, some leakage sources can effectively be removed from the results of spherical near-field antenna measurements. The best choice, of course, in any measurement system is to eliminate the sources of the leakage and cross-talk through good RF practices to a level that does not impact the measurement.

Spherical modal filtering augmented with a change of the measurement coordinate origin via the IsoFilter™ process can be used to help identify the source of the leakage. In complex measurement systems where leakage and cross-talk cannot be eliminated by changes to the hardware, IsoFilter™ can be used to minimize the effects on the results.

VII. References

[1] J. E. Hansen, Editor, Spherical Near-Field Antenna Measurements, Peter Peregrinus, Ltd., London, U.K., 1988.

[2] D. W. Hess, "The IsoFilter™ technique: isolating an individual radiator from spherical near-field data measured in a contaminated environment," Post-Deadline Paper, AMTA 2006, Austin TX.

[3] D. W. Hess, "The IsoFilter™ technique: extension to transverse offsets," Post-Deadline Paper, AMTA 2006, Austin TX.

[4] D.W.Hess & S.McBride, Application of IsoFilter™ Selectivity to Antenna Diagnostics, Paper # C36P1-2, EuCAP 2010, 4th European Conference on Antennas and Propagation, 12-16 April 2010.

[5] D. W. Hess, "A theoretical description of the IsoFilter™ rejection curve," AMTA Symposium Digest, pp. 161-166, Atlanta, GA, 2010.

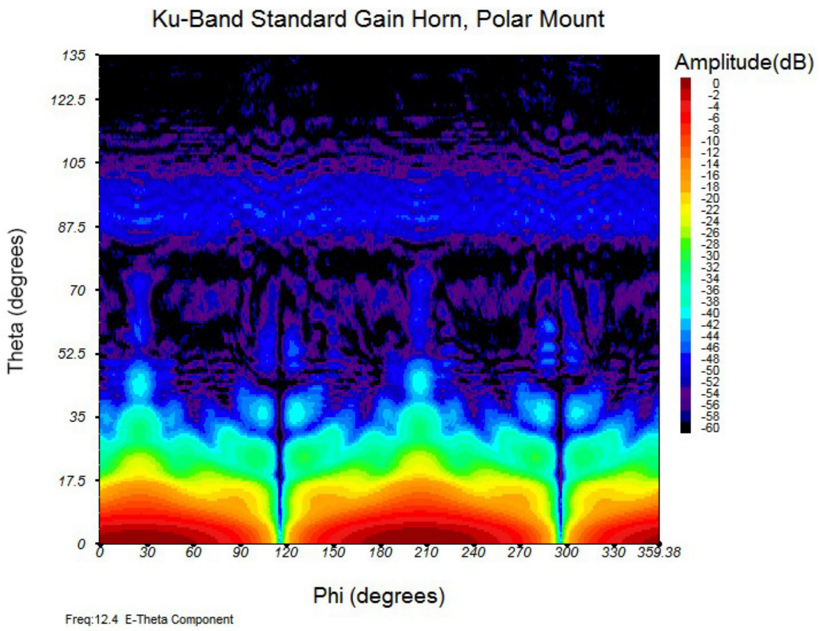

Figure 3: Contour plot of the E-Theta component of the measured near-field. Note the band of RF leakage between 80 and 120 degrees.

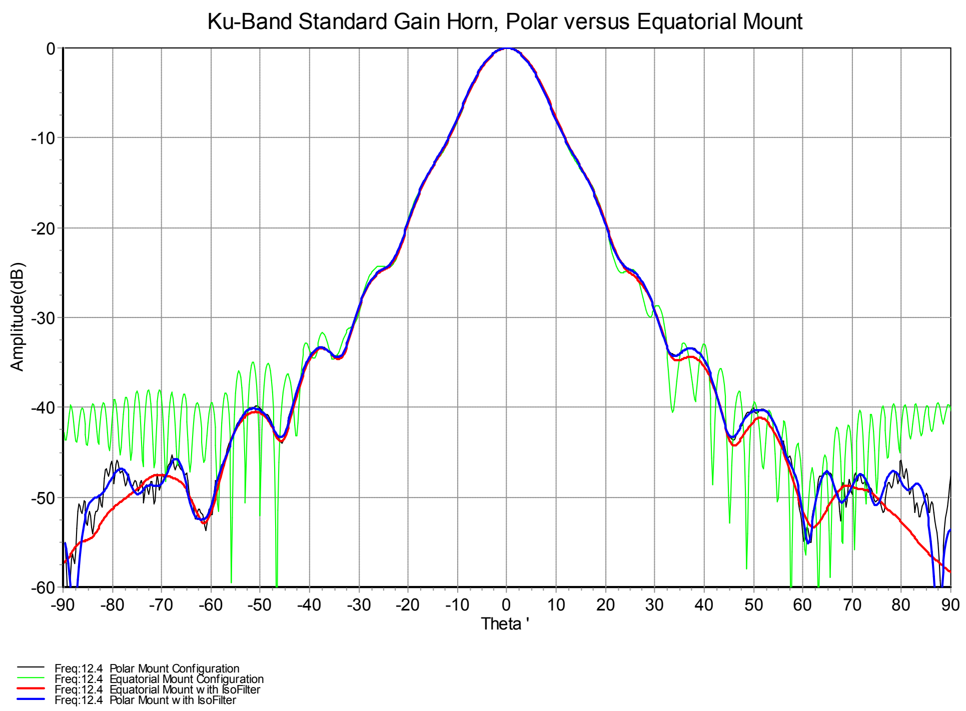

Figure 4: Comparison Plot of Far-Field H-Plane pattern of the SGH.