# Reflection Suppression In Cylindrical Near-Field Measurements Of Electrically Small Antennas

S.F. Gregson[#1], A.C. Newell[#2], G.E. Hindman[#3]

[#]*Nearfield Systems Inc.*
*19730 Magellan Drive, Torrance, CA 90502, USA*
[1]sgregson@nearfield.com
[2]anewell@nearfield.com
[3]ghindman@nearfield.com

***Abstract*— Reflections in antenna test ranges can often constitute the largest single term within the error budget of a given facility [1]. For some time, a technique named Mathematical Absorber Reflection Suppression (MARS) has been used to reduce range multi-path effects within spherical near-field and far-field antenna measurement systems [2, 3,]. Whilst the technique presented herein is also a general purpose measurement and post-processing technique, uniquely, this technique is applicable to cylindrical near-field antenna test ranges. Here, the post-processing involves the analysis of the cylindrical mode spectrum of the measured field data which is then combined with a filtering process to suppress spurious scattered signals [4]. This paper provides an introduction to the measurement technique and a description of the novel near-field to far-field transform algorithm before presenting preliminary results of actual range measurements of a low gain antenna. These results illustrate the success of the technique which is found to yield improvements comparable to those attained with the corresponding spherical MARS technique.**

## I. Introduction

This paper describes new a technique which has been developed by NSI in order to suppress reflections in cylindrical near-field antenna measurement facilities. Here, a unique measurement and mathematical post processing technique is implemented that, as will be shown below, requires only a minimal amount of detailed information about the antenna under test (AUT), the probe, and the range geometry. The processing is applied during the near-field to far-field transformation process and utilises the well established principles of the cylindrical near-field theory. The technique is entirely generic in nature and can be applied to a variety of different antenna types, *i.e.* no specific a priori assumptions about the arrangement of current sources are made. Thus, this technique is equally applicable to aperture, and non-aperture type antennas. It is assumed however that the near-field antenna pattern function is spatially band-limited (*i.e.* current sources occupy a finite region of space) and that the multiple reflections, arising from the various scatterers within the chamber are essentially not spatially band-limited. That is, the scattering current sources occupy a finite region of space that is larger, and preferably *very* much larger, than that occupied by the AUT. In essence, a new mathematical operator is applied to the measured data that orthogonalises those cylindrical mode coefficients (and thus fields) associated with the AUT from those modes (and thus fields) associated with other spurious sources. In this way, the unwanted contributions can be effectively and rigorously filtered out. Generally, it is difficult or at best impractical to distinguish between those cylindrical modes that are due to the true antenna pattern, and those that arise from unwanted scattering if only the usual measurement and processing of the measured data are employed. Thus, successful processing requires that an alternative strategy be employed. In practice this results in the need to offset the antenna from the cylindrical rotation axis, forcing a larger amount of data to be taken during the MARS measurement process than would be the case for an equivalent measurement of an identical antenna installed within a perfect anechoic environment. Thus, the price of the successful filtering is an increase in the time required to take a near-field measurement.

## II. Overview Of Measurement Technique

Although a detailed mathematical treatment is left to the open literature [4, 5] an overview of the MARS process is presented herein. Figure 1 below contains a schematic representation of a conventional cylindrical near-field antenna measurement system. Here the AUT, or more specifically, the majority of the current sources, are situated about the origin of the range measurement co-ordinate system. This is generally taken to be the point at which the $\phi$ axis, *i.e.* the centre of rotation, intersects with the range centre line. Thus, the conceptual smallest cylinder that circumscribes the majority of the current sources which is coaxial with the sampling cylinder (which is formed from the intersection of linear and rotational axes) is minimised.

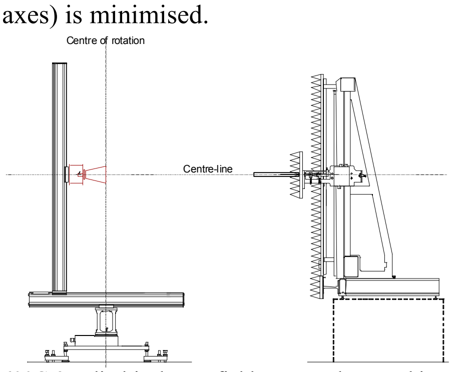


Fig. 1 NSI-600C-3 cylindrical near-field system shown taking conventional near-field measurements.

However, the MARS measurement technique adopts a fundamentally opposing strategy whereby the test antenna is deliberately displaced from the centre of rotation thereby increasing the maximum radial extent (MRE), and correspondingly decreasing the sample spacing. This arrangement can be seen depicted schematically in Figure 2 below.

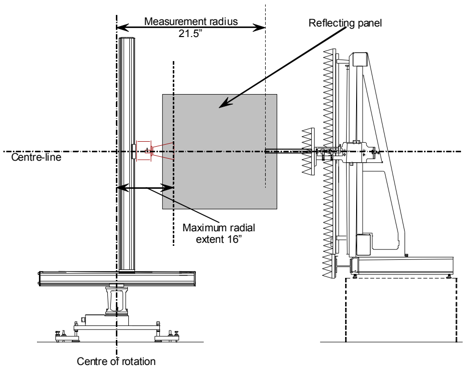


Fig. 2 NSI-600C-3 cylindrical near-field system shown taking near-field measurements intended for MARS processing.

It is well known that the radiated near electric field can be expanded in a set of orthogonal transverse electric (TE) and transverse magnetic (TM) cylindrical mode coefficients (CMC) using conventional cylindrical near-field theory and the sampling theorem [5]. Once this mode set has been determined from the measured data, the spatial filtering effects of the scanning near-field probe can be compensated for through the use of an inversion of the transmission formula and an auxiliary characterisation of the scanning probe. Again, this is implemented using standard formula [5]. Whilst it is true that the highest order CMC is dependant upon the frequency of the AUT and the MRE. Here, the MRE is dependant upon the spatial distribution of the majority current sources, *i.e.* the physical dimensions of the AUT, and the way in which these sources have been installed within the facility. Thus, as the highest order CMC needed to represent the radiated field depends upon the MRE in a fundamental way, when the AUT is mathematically translated back to the origin of the measurement co-ordinate system, the maximum order CMC needed to represent the ideally orientated AUT is reduced. Thus, any mode with a higher order than this can be filtered out of the mode spectrum using a filter function without altering the pattern that is associated purely with the AUT. Hence, any mode of higher order than this cut-off containing a significant amount of power must represent a scattered signal, rather than with the AUT. Hence filtering the mode spectra will result in a suppression of any spurious multipath effects.

## III. Preliminary Range Measurements

In order that the novel cylindrical MARS technique could be investigated, a low gain broadband dual ridge horn antenna assembly was acquired using an NSI-200V-3x3 combination planar, cylindrical, spherical near-field measurement system, This system can be seen presented in Figure 3 below where the testing was conducted in an open office type environment. Although, parts of the scanner were covered in absorber, the "chamber" itself is free from absorber and as such a great many scatterers were present in the local environment including a reflecting plate which was used to further increase scattering, this is visible to the left of the picture. A low gain AUT, *i.e.* an NSI-RF-RGP40, was selected for these tests as this is a class of antenna that typically illuminates the walls of the measurement chamber with significant amounts of power and as such measurements of this class of antennas are prone to multipath effects.

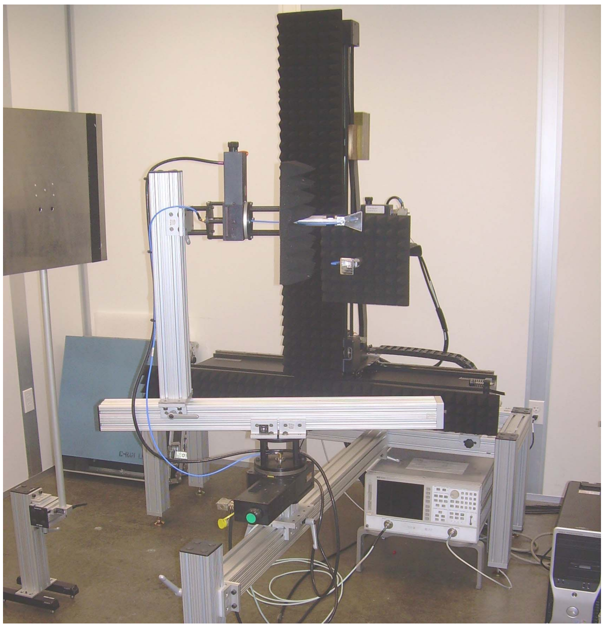

Fig. 3 NSI-200V-3x3 PCS system shown taking near-field measurements in a non-anechoic, office type, environment with a reflective plate shown to the left being used to increase range multipath effects.

When taking a standard cylindrical near-field measurement, certain parameters are required to be specified. These are the frequency, 5.0 GHz, the radius of the measurement cylinder, 21.5", the MRE, 16", the required far-field azimuth and elevation spans, 360° and ~20° respectively. In addition to this information, for the purposes of cylindrical MARS testing, the displacement between the origin of the range measurement co-ordinate system and the AUT, 9.12", and the conceptual minimised MRE, 3", are also required. The conceptual minimised MRE is the MRE when the AUT aperture is at the origin as shown in Figure 1. This arrangement can be seen presented schematically in Figure 2 above.

## IV. Preliminary Results

The NSI-200V-3x3 PCS system shown above was used to take cylindrical near-field data. This near-field data was then used to compute the CMCs. CMCs are complex numbers that are variables of the polarization index, the $\phi$ index $n$ and the Fourier variable $\gamma$. Figure 4 below contains a false colour, *i.e.* checkerboard, plot of the amplitudes of the CMCs modes for $s$ = 1, *i.e.* $B^1$, for this measurement which were generated using the standard cylindrical processing of the measured cylindrical near electric field data. Here, the maximum calculated mode depends upon the sample spacing of the near-field data and the frequency.

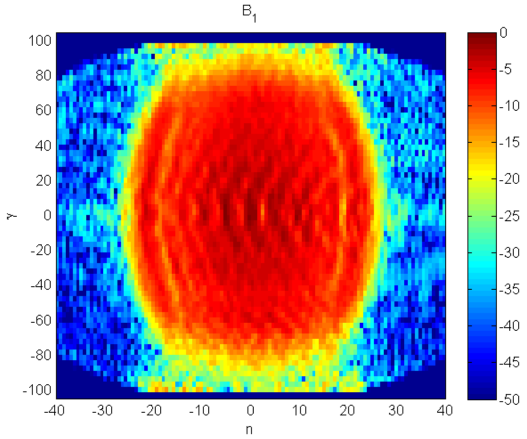


Fig. 4 Cylindrical mode coefficients obtained from standard FFT based cylindrical near-field processing.

The comparative absence of power in modes with higher order than ≈|25| that is evident in this plot is an artefact of the fact that the antenna occupies only a finite region of space and thus has only a finite effective MRE. In essence then, this is merely an artefact of the data being over-sampled in the near-field. The offset in the near-field measurement causes the phase of the scattered signals to vary rapidly over the measurement cylinder and to produce the mode pattern shown. Clearly, the CMCs obtained from the near-field measured data shown in Figure 4 above must contain contributions from both the AUT and the scatterer. After using the MARS processing [4] to mathematically translate the AUT so that its current sources are centred about, *i.e.* coincident and synonymous with, the origin of the cylindrical measurement co-ordinate system, only a lower order of CMC is required to describe the antenna radiation pattern alone. From inspection of Figure 5 below, this can be seen as corresponds to the CMCs that contain significant amounts of power being more narrowly distributed about the $n = 0$ mode index (*i.e.* in the centre of the plot) than was previously the case.

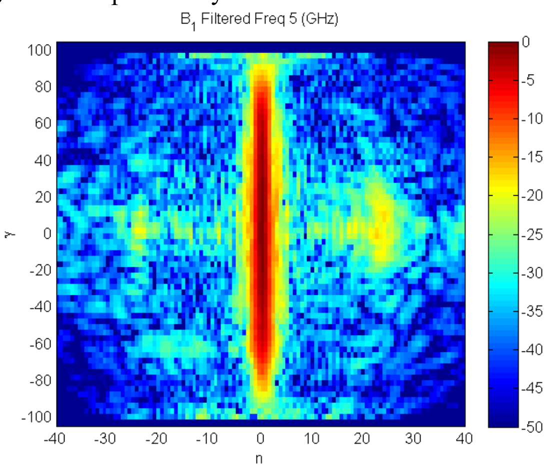


Fig. 5 Cylindrical mode coefficients shown after mathematically displacing AUT to the centre of measurement co-ordinate system. Modes containing significant power at around $n = 25$ are principally associated with the scatterer.

Crucially, although the AUT has been translated back to the origin of the measurement co-ordinate system, and as such can be represented with only a comparatively small number of CMCs, this is not the case for the scatterers which are spatially extended. Thus, as these are located elsewhere in space, they need to be represented with higher order CMCs [4]. In effect, the contributions in the domain of the CMCs from the AUT and the scatterers are separated, *i.e.* displaced so that they no-longer interfere with one another. This effect is clearly illustrated in Figure 5 above where those modes associated with scatterers can be seen outside the $|n| = 8$ mode range. Consequently, any mode that is of higher order than that required to reconstruct the field of the AUT can be filtered out using a filter function as these can not be part of the antenna's far-field radiation pattern. The filtered mode spectra can be seen illustrated in Figure 6 below. Whilst, the filtering is normally based on the size of the antenna, in principle this may be increased for analysis purposes up to a limit determined by the near-field data point spacing.

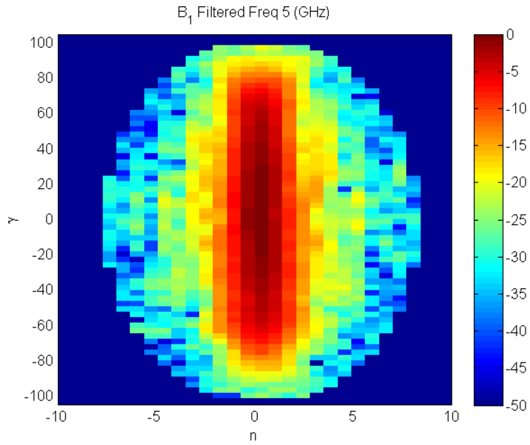


Fig. 6 Cylindrical mode coefficients after filtering out modes outside the conceptual minimum MRE. Clearly, those modes associated with the scatterer have been filtered out of the mode spectrum.

Once the probe corrected, MARS filtered, CMCs have been obtained, these can be used to obtain the electromagnetic six-vector of the AUT in the near- or far-fields. Most usually, the standard highly efficient FFT based mode summation transform is employed to recover the asymptotic far-field antenna pattern function. Figure 7 and Figure 8 contains a pseudo-colour plot of the far-field $E_{\phi}$ polarised principle field component with and without MARS filtering respectively.

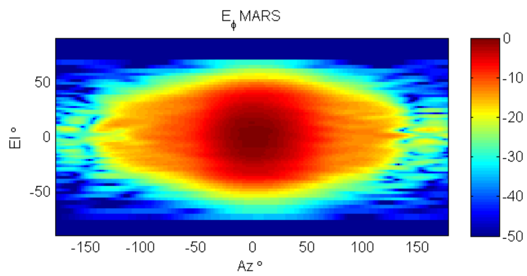


Fig. 7 Far-field pseudo-colour pattern with MARS processing applied.

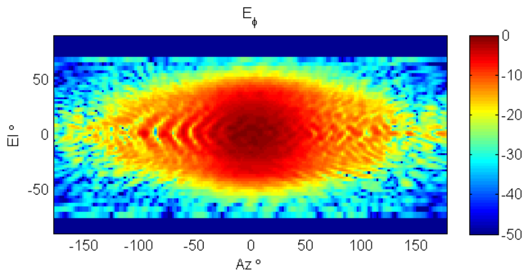


Fig. 8 Far-field pseudo-colour pattern without MARS processing.

In Figure 8, as expected, the reflections introduced by the close proximity reflecting plate are severe with a large amplitude spurious ripple being clearly evident on the unfiltered results, particularly in the range -110° < *Az* < -40°. Furthermore, this high frequency angular ripple is clearly absent from the MARS processed result shown in Figure 7, which is very encouraging. Here, it must be remembered that these cylindrical measurements are grossly truncated in elevation which is a consequence of selecting a comparatively large measurement radius with a cylindrical system that has only a limited linear axis span. By way of a comparison, Figure 9 and Figure 10 below contain equivalent plots for the case where the reflecting plate had been removed from the vicinity of the measurement system. Thus whilst other room scatters remain invariant between successive measurements, those effects associated purely with the plate will be absent from these measurements.

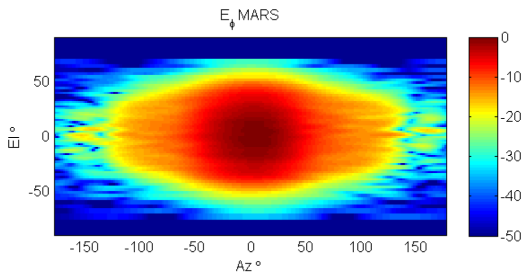


Fig. 9 Far-field pseudo-colour pattern with MARS processing applied.

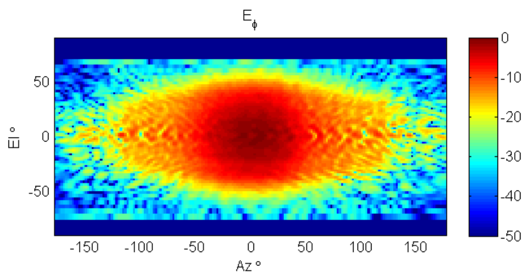


Fig. 10 Far-field pseudo-colour pattern without MARS processing.

The effect of the MARS filtering is broadly similar to that which was observed before, *i.e.* high frequency ripple is absent from the processed results. However, from inspection of Figure 7 and Figure 9, it is quite evident that the MARS processed results demonstrate very encouraging agreement. Indeed, the agreement between the filtered patterns is significantly better than the degree of agreement obtained between the respective unfiltered patterns. Previously, [4] it was found that irrespective of where the scattered modes are, the effect of the MARS process is to moves those modes that are associated with scattering object to larger magnitude mode indices, *i.e.* their distributions move away from $n$ = 0 index and that the magnitude of this displacement is dependant upon how far the AUT is displaced from the origin of the range measurement co-ordinate system. Thus, the improvement provided by the MARS processing is fundamentally dependant upon the size of the AUT offset with larger offsets capable of yielding the greatest improvements.

## V. CONCLUSIONS

Cylindrical MARS processing can be used with a very high degree of confidence since all the steps in the measurement and analysis are consistent with the well established principles of the standard cylindrical near-field theory and measurement technique, and all comparisons to date have proved overwhelmingly 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 cut-off for the translated pattern is based on the physical dimensions of the AUT and its translated location. The results of the cylindrical MARS processing will reduce, but not entirely eliminate, the effect of the scattering. The final result with cylindrical MARS can be degraded if the sampling of the near-field data is too coarse, or the mode filter is too tight, but this is also true for regular cylindrical processing. Importantly, both of these parameters are controlled by the user and must be correctly specified.

In addition to the existing spherical MARS technique, NSI has developed and validated a novel technique to suppress reflections in cylindrical near-field ranges. The technique is quite general and can be used to achieve acceptable results with use of minimal absorber or even with no anechoic chamber. It can also improve the reflection levels in a traditional anechoic chamber allowing improved accuracy as well as offering the ability to use existing chambers down to lower frequencies than the absorber might otherwise indicate.

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