Verification of Generalized Far-Field Mode Filtering Based Reflection Suppression Through Computational Electromagnetic Simulation

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***Abstract*—A novel cylindrical mode-based measurement and post processing technique has recently been presented that allows data that has been acquired on a non-equally spaced abscissa to be processed rigorously. This technique was initially examined and validated using extensive, empirically derived data. However, the recent development of a digital-twin representation of a far-field antenna measurement system enables further and more detailed validation to be performed with results able to be assessed against a reliable "truth" model. This paper reports the results of that study presenting new analysis that further verifies the utility and flexibility of the very general error correction measurement and post-processing technique in configurations that hitherto have not been considered.**

Keywords—Antenna, Measurement, Computational Electromagnetic Simulation, Far-Field, MARS, Multipath Suppression.

I. Introduction

The Mathematical Absorber Reflection Suppression (MARS) technique [1] is a widely deployed measurement and mode-filtering based technique that is used to identify and subsequently extract the effects of range reflections from antenna range measurements. A detailed treatment of the technique and its deployment in numerous areas of application is left to the open literature [1]. A recent advancement has, for the first time, allowed the far-field implementation of this technique to be used rigorously with irregularly spaced data, [2]. A significant portion of the early development work was predicated on verification by empirical means with more detailed, full-wave three-dimensional electromagnetic simulations only becoming available comparatively recently [3, 4]. The development of these very general digital twins has enabled measurement configurations to be examined that were not previously convenient, or perhaps possible, providing far greater freedom and control in the way in which a given, otherwise ideal, measurement can be perturbed.

A WR75 standard gain horn (SGH) was used as the antenna under test (AUT) which was modelled offset from the origin of the measurement coordinate system in a proprietary full-wave three-dimensional computational electromagnetic (CEM), integral equation, solver. An offset is a necessary attribute of any MARS type measurement and provides the means for the mode orthogonalization that underpins the success of the technique. The field was obtained at each orientation of the AUT as it was sequentially stepped around the origin for each measurement, providing one complete simulation per far-field "measured" antenna pattern data point where the position of the points was permitted to vary randomly by up to 60% of the sample spacing about the ideal location. A 500 mm × 500 mm perfectly conducting metal plate was then introduced to perturb the system thereby simulating a highly demanding scattering case. The metal plate was positioned at several different locations within the system at 1 m, 2 m, 3 m and 4 m from the axis of the measurement system to provide a series of different simulated perturbed "measurements". While a great deal of time, trouble and ingenuity has been directed towards establishing the precise effect that the location of the AUT within the test system has on the effectiveness of the post-processing, comparatively little has been done to attain a similar degree of understanding regarding the importance of the position of the scattering body. In practice, it is difficult to precisely control and adjust this sort of perturbing parametric change and so this is a topic for which the computational electromagnetic (CEM) approach is particularly appropriate. The resulting far-field simulated "measurements" were processed using the generalized far-field MARS processing [1, 2] with the results being presented in Section II below.

II. Simulation and Post Processing Results

Figure 1 below presents the simulated far-field amplitude "measurements" of the unperturbed, reference, far-field pattern of the WR75 AUT together with equivalent measurements with the reflecting plate located at the four positions described above. Figure 2 presents the equivalent phase patterns once the AUT has been mathematically translated back to the origin.

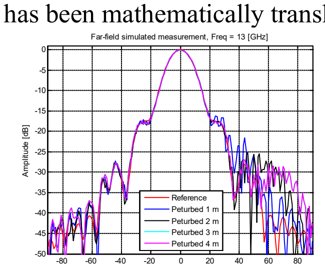

Fig. 1. Far-field amp cut showing reference and perturbed simulations with varying offsets of scatterer.

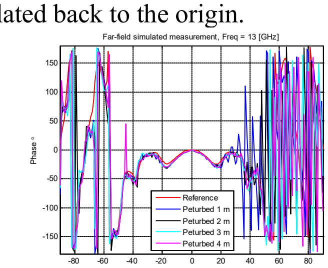

Fig. 2. Far-field phase cut showing reference and perturbed simulations with varying offset of scatterer.

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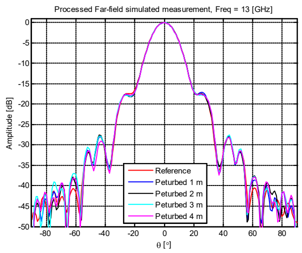

Fig. 3. Far-field processed amp cut showing reference and perturbed simulations with varying offsets of scatterer.

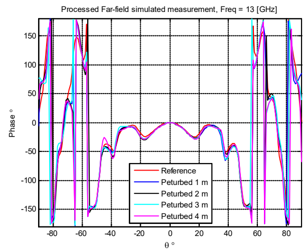

Fig. 4. Far-field processed phase cut showing reference and perturbed simulations with varying offset of scatterer.

Figures 3 and 4 present equivalent far-field patterns with MARS processing. Inspection of Figures 3 and 4 clearly show the effectiveness of the MARS processing. So that a quantitative measure of the degree of agreement could be determined, the root mean square (RMS) difference levels between the reference and perturbed patterns were compute first without, and then with, generalized FF-MARS processing. The improvement in the RMS difference level was <0,1> 9.49 dB, <0,2> 9.99 dB, <0,3> 7.63 dB and <0,4> 5.76 dB, where 0 denotes the reference pattern and 1, 2, 3, and 4 denote respectively the 1 m, 2 m, 3 m and 4 m cases described above. In each example, a very worthwhile improvement has been obtained. The reduced degree of improvement seen in Cases 3 and 4 results from the less pronounced impact that the perturbing scatterer has on the simulated "measurement" which is merely a consequence of its increased remoteness in proximity from the AUT.

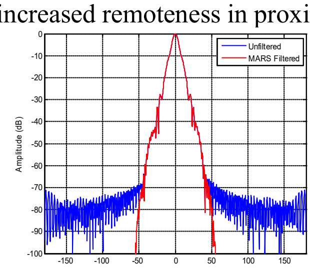

Fig. 5. Reference equivalent cylindrical mode spectra for unperturbed simulated measurement.

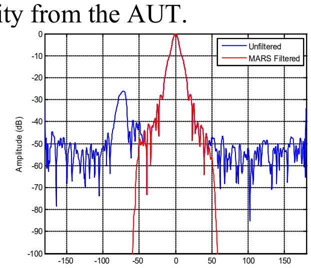

Fig. 6. Equivalent cylindrical mode spectra for simulated measurement with 1 m offset scatterer.

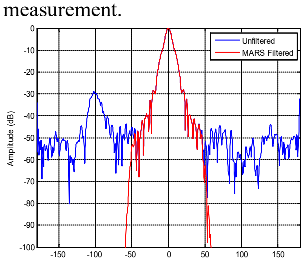

Fig. 7. Equivalent cylindrical mode spectra for simulated measurement with 2 m offset scatterer.

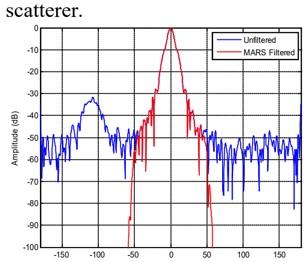

Fig. 8. Equivalent cylindrical mode spectra for simulated measurement with 3 m offset scatterer.

By way of an alternative way in which to view this system, Figure 5 presents a plot of the amplitude of the equivalent cylindrical mode coefficients (CMC) [1, 2, 3] for the simulated "measurement" of the unperturbed WR75 AUT. The blue trace represents the amplitude of the CMCs with the red trace denoting the filtered modes associated with the AUT as determined from an application of the standard cylindrical sampling theorem [1]. By way of a comparison, Figures 6, 7 and 8 present equivalent mode plots for the 1 m, 2 m and 3 m offset perturbed cases respectively. The mode spectra shown here exhibit the same features as have been established previously using largely empirically means [1, 2]. That is to say, those modes associated with the AUT are situated around the lowest order mode (*i.e.* at $n = 0$) with those modes associated with the scatterer being shifted towards higher orders. Crucially, and for the first time, it is evident from inspection of these plots that the center of the spectrum of the scattering modes only weakly depends upon the magnitude of the separation between the scatterer and the AUT. This is evident from inspection of Figures 6, 7 and 8 where the center of the perturbing mode spectra is at, *circa*, n =-75, -100 and -110 respectively for the three cases presented. Although not shown as a consequence of space, this was also observed with the 4 m case. Thus, the larger the displacement of the scatterer, the greater the mode bandwidth of those modes and correspondingly, the greater the reduction in the power contained within those individual vector modes. In each case however, those modes remained remote from the AUT modes thereby permitting their effective extraction from the measurement by means of mode filtering. Larger separations than those considered here can reasonably be expected to yield spectra containing successively higher order modes with those mode spectra having broader bandwidths with individual mode coefficient containing far less power.

III. Summary and Conclusion

A full-wave three-dimensional CEM model which serves as a digital-twin of a spherical far-field antenna measurement has been constructed and validated [3, 4]. A series of two-dimensional far-field pattern datasets were obtained through numerical simulation with the AUT offset from the rotation center and a metal plate introduced as a scatterer at several different positions. As presented above, we have demonstrated that generalized FF-MARS processing [2] can be used to suppress these effects with results that almost entirely remove the scattering artefacts, even for cases where the scatterer is in close proximity to the AUT, and the measurement is acquired on a non-equally spaced abscissa. As this paper presents recent findings of an on-going program of research, the future plans include a further examination of the choice of mode filter function, placement of the AUT together with a demonstration of FF-MARS with electromagnetic scattering measurements and ISAR imaging.

References

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