Behaviour of Orthogonal Wave Functions and Their Application to the Correction of Antenna Measurements

S F Gregson *, A C Newell †, G E Hindman ‡

**NSI, USA sgregson@nearfield.com, †NSI, USA anewell@nearfield.com, ‡NSI, USA ghindman@nearfield.com*

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Abstract

Mathematical Absorber Reflection Suppression (MARS) is a well-established, widely used measurement and post-processing mode orthogonalization and filtering technique [1, 2] that has been extensively used to locate and then supress measurement errors arising from scattered fields when antenna testing is performed in echoic environments. Furthermore, it has been shown that this form of processing has reduced those uncertainties associated with bias leakage error, second order truncation effects, and mutual coupling (*i.e.* multiple reflections between the test antenna and the probe) leading to a worthwhile reduction in the overall range uncertainty budget. The success of MARS, and other mode orthogonalization and filtering strategies [3], is dependent upon the behaviour of the orthogonal vector wave functions (that are used to expand the electromagnetic fields) under an isometric translation of co-ordinate systems. This translation of origins is applied as part of the digital post-processing with the resulting mode orthogonalization being observed irrespective of whether plane, cylindrical, or spherical elemental vector mode bases are used. Within this paper and presentation, simulated and measured data will be used to demonstrate the power and flexibility of this technique when correcting measured data highlighting the specific behaviour of the various commonly used vector wave functions.

1 Introduction

In many applications, an antenna measurement can be compromised by range reflections, *i.e.* scattering, and often this is often found to represent one of the largest components within the overall facility level uncertainty budget [4]. When taking indoor antenna measurements spurious indirect, *i.e.* scattered fields, are largely managed by lining the interior surfaces of the test chamber and covering much of the measurement equipment with electromagnetic (EM) absorbing material. This EM absorbent material is typically manufactured from open-cell Carbon impregnated urethane foam which is cut into, pyramidal, wedge, or other geometrical shapes. As the depth of the pyramids or wedges is proportional to the free space wavelength of the illuminating EM radiation, this material can become sizeable as the test frequency decreases. Thus, most absorber is optimised so that its performance is tailored for use across a predetermined frequency range with some degradation in reflectivity performance outside of that band being suffered. Furthermore, this material cannot be perfectly impedance matched for all angles of incidence and polarisations with the some scattering being unavoidable. Whilst considerable effort can be devoted to optimising the placement of this material within the test environment, it cannot be installed everywhere with linear bearings, lights, fire detection & suppression equipment, CCTV equipment, *etc.* generally be left exposed.

Although many scattering suppression methods have been deployed with commonly encountered examples including: time-gating (both hardware and software), background subtraction, parametric repeat measurement, spatial filtering, and waveform correlation; it is only recently that generalised, frequency domain, mode filtering & orthogonalization based techniques have become available for use with *all* geometries of near- and far-field antenna pattern testing. The MARS technique has been successfully deployed to minimise range reflections within spherical [1, 2], cylindrical [5], plane-rectilinear [6], plane-polar [7] near-field measurement systems; as well with far-field [8], single parabolic reflector [9], and dual cylindrical reflector compact antenna test ranges (CATR) [10]. In addition to empirical verification 11], the effectiveness of the MARS technique has been attested to extensively through the use of computational electromagnetic simulation (CEM) [10, 12, 13], and across a wide frequency range spanning from UHF to mm-wave frequencies. In every case, the modal expansion and translation of origins facilitated the de-aggregation of antenna and spurious fields with this mode orthoganlization and filtering underpinning the success of the technique. Thus, significant benefits were brought, irrespective of whether examining linear or circularly polarised antennas possessing high or low directive gains with meaningful results being obtained from simulations and measurements alike, even where limited or no absorber was used. Thus, as will be highlighted within the accompanying presentation, it is clear that the underlying MARS principle is not a "peculiarity" of any single mathematical treatment, modal basis, or sampling scheme but is a far more general characteristic that allows the behaviour of orthogonal wave functions to be applied to the correction of antenna measurements.

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