Two-Dimensional Far-Field Mathematical Absorber Reflection Suppression

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***Abstract*—During recent years, far-field mathematical absorber reflection suppression (FF-MARS) has become a widely adopted and accepted technique for suppressing spurious range reflections within far-field and compact antenna test ranges (CATR) [1, 2, 3, 4]. Far-field measurements are particularly prone to the effects of range-reflections [5] which, when combined with the increase in signal to noise ratio that MARS often provides, makes this form of post-processing particularly beneficial to these applications [6]. FF-MARS processing is rigorous with its theoretical basis being resolutely founded within standard cylindrical near-field theory [6, 7]. FF-MARS offers the unique, and particularly pertinent for far-field applications, attributes of being able to process one-dimensional, singularly polarised, mono-chromatic, frequency-domain, far-field data without approximation or loss of generality. Hitherto, for cases where two-dimensional far-field data needed processing, recourse to standard spherical-MARS (S-MARS) was unavoidable [8, 9]. However, there are occasions when complex spherical mode based post-processing is unavailable, undesirable, or even inappropriate (such as when only a small portion of the far-field sphere is acquired, or when only a single polarisation component is available) and under these circumstances the ability to process two-dimensional data with this new FF-MARS technique can become highly desirable. For the first time, this paper shows how the existing one-dimensional FF-MARS technique can be extended to enable two-dimensional data to be processed with the success of the measurement and post-processing technique being illustrated with results obtained from actual range measurements.**

Keywords*— Far-field Antenna measurements; CATR, multipath suppression; cylindrical mode expansion; MARS

I. INTRODUCTION

The existing FF-MARS technique [1, 2, 3] is in essence a special application of the more general cylindrical MARS (C-MARS) scattering reduction measurement and post-processing technique with, in its existing form, FF-MARS being amenable only for processing one-dimensional pattern data that has been acquired along a contour of great circle cut. While this is very valuable for many applications, it is also useful to be able to process data that has been taken across a two-dimensional portion of the far-field sphere, *i.e.* over a solid angle. Figure 1 contains a schematic representation of a conventional azimuth over elevation rotator where A and E denote the azimuth and elevation spherical angles respectively [10]. Conversely, Figure 2 shows the corresponding azimuth and elevation spherical unit vectors which are denoted by red and blue arrows respectively. In each of these figures, the spheres shown are attached to, and rotate with, the test antenna [10].

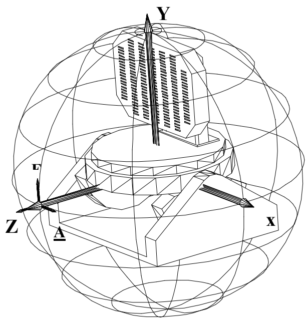

Fig. 1. Schematic of azimuth over elevation spherical positioner that can be used for taking far-field antenna pattern data.

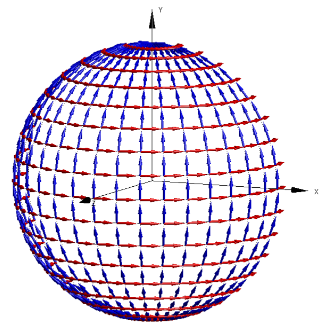

Fig. 2. Azimuth over elevation tabulating and polarisation co-ordinate systems shown.

This is a very commonly encountered form of pedestal that provides a convenient installation configuration for far-field or CATR type measurements. Additionally, and as a direct consequence of the physical implementation as shown, the AUT is necessarily offset from the intersection of the azimuth and elevation rotation axes thereby increasing the maximum radial extent (MRE) of the antenna measurement [9], and moving the AUT through a larger portion of the quiet zone during the course of a measurement than would be the case had a ϕ/θ "model tower" design be used. This is an important observation since displacing an AUT away from the origin of the measurement co-ordinate system is a necessary requirement for successful MARS processing, thereby, making this classic pedestal design particularly appropriate for this correction method [9]. From inspection of Figure 1 and 2, it can be seen that the poles of the attendant spherical co-ordinate system align with the y-axis requiring that that the elevation cuts correspond to great circle cuts with, conversely, the azimuth cuts representing conical cuts. Thus, without additional modification, FF-MARS processing can be applied sequentially to each elevation cut in turn thereby enabling two-dimensional pattern data to be corrected using the existing algorithm, *c.f.* [1]. It is not possible to apply standard FF-MARS processing to the conical, *i.e.* azimuth, cuts without modification of the processing. Azimuth cuts can be processed if an elevation over azimuth measurement co-ordinate system had been utilised [10].

II. Summary of Preliminary Results

Figures 3 and 4 contain far-field measured amplitude and phase which have been presented in the form of false colour checkerboard plots. Here, an *x*-band pyramidal standard gain horn (SGH) was acquired using an indoor far-field range incorporating an azimuth over elevation positioner (as illustrated in Figure 1). Some scattering was evident in the elevation axis, *i.e.* the pattern distortion that can be seen on amplitude and phase plots for large positive elevation angles which was a result of the chamber absorber layout. As described above, FF-MARS processing has been applied in the elevation (vertical) axis with the resulting amplitude and phase patterns being presented in Figure 5 and 6. From inspection of these figures, it is clear that there is a significant improvement in the degree of symmetry exhibited in both amplitude and phase patterns, with the absence of high angular frequency constructive and destructive interference that had blighted the unprocessed patterns providing further corroboration of the success of the process.

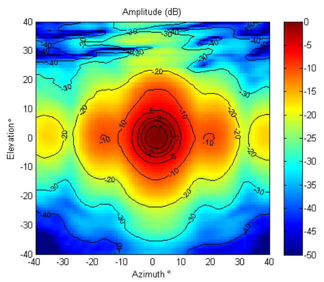

Fig. 3. Amplitude pattern prior to FF-MARS processing.

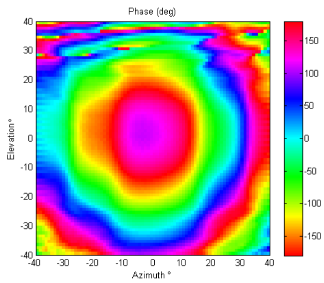

Fig. 4. Phase pattern prior to FF-MARS processing.

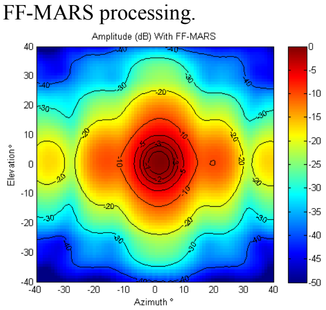

Fig. 5. Amplitude pattern with FF-MARS processing, note the improvement in symmetry.

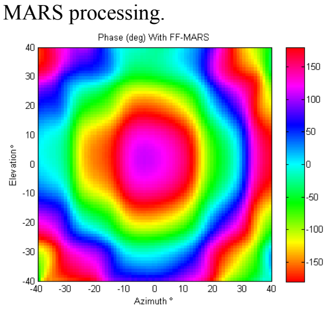

Fig. 6. Phase pattern with FF-MARS processing.

Displacing the AUT from the centre of rotation will necessarily increase the MRE and this will correspondingly decrease the angular data point spacing. However, for the purposes of MARS processing, this increasingly finely spaced abscissa is only mandated in the elevation cut with the azimuth sample spacing being entirely unaffected. Thus, as measurements are generally taken on-the-fly the additional data needed will not greatly impact upon measurement times unless highly multiplexed measurements comprising a very large number of frequencies, beam states, *etc.* are taken and providing the receiver is sufficiently fast that the beam set smear does not exceed the sample point spacing. Displacing the AUT in this way also has an implication for the Rayleigh far-field criteria, and therefore on the minimum separation needed between the AUT and the RSA as this too can be expressed in terms of the MRE [1]. However, as this constraint is encountered as a result of the pedestal design, this requirement remains irrespective of whether MARS processing is employed. As was previously the case with FF-MARS, the azimuth and elevation field components are uncoupled from one another thereby allowing FF-MARS processing to be applied to only a *single* far electric field component. Thus, dual polarised acquisitions are not mandated unless cross-polar, axial ratio, tilt angle, or polarisation sense information is required. As is usually the case for far-field measurements, probe pattern correction can be effectively ignored since in the far-field the maximum radial extent only subtends a very small angular span as seen from the RSA with the illumination remaining effectively constant over the MRE sphere.

Finally, it is important to recognize that FF-MARS as is implemented here, predominantly suppresses range reflections in only one (*i.e.* elevation) direction whereas conventional S-MARS suppresses reflection in each axis and as such S-MARS offers greater immunity from scattering artefacts. Although, this is achieved at the cost of requiring an acquisition of a minimally truncated, appropriately sampled, complete two-dimensional antenna pattern, *i.e.* $\underline{E}(\theta,\phi)$.

III. Conclusions

For the first time, this paper presents the results of a preliminary study that demonstrates that the highly effective, and hitherto one-dimensional, FF-MARS technique can be successfully extended to correct two-dimensional, *i.e.* E(Az, El), far-field antenna pattern data thereby extracting spurious scattered fields allowing high quality pattern measurements to be obtained in areas of applications where hitherto range reflections had compromised the measurements.

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