Fast Computation of Radar Cross Section for Multiple Incident Angles by using Characteristic Basis

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Conventional approaches to solving scattering problems by using the Method of Moments (MoM) involves the geometry discretization with a size ranging from λ/10 to λ/20. Thus, as the object becomes large in terms of the wavelength, the size of the associated MoM matrix grows very rapidly, and this, in turn, places an inordinately heavy burden on the CPU in terms of memory and time. One of the promising techniques that utilizes higher level basis functions to reduce the size of the MoM matrix is the recently introduced Characteristic Basis Function Method (CBFM) [V.V.S.Prakash and R.Mittra, "Characteristic basis Function Method: A new technique for fast solution of integral equations", Microwave Opt. Tech. Lett., Jan. 2003]. The CBFs are specially constructed to fit the object geometry by incorporating the physics of the problem into the basis functions, and the domain spanned by these functions can be many wavelengths. However, these CBF's depend on the excitation vector, and hence, must be regenerated anew for each change of the incident angle. This poses a problem when the response of the structure needs to be computed for a large number of incident angles. The present study is focused to alleviate the aforementioned problem by employing a set of basis functions that are invariant to the angel of incidence, and are derivable from the original CBF's. Also, we present a systematic way of improving the accuracy of the solution by using these new invariant basis.

In order to derive a set of basis that are invariant of the angle of incidence, we first analyze the geometry for a small number of incident angles, say K, for which we construct the CBF's. For a given block 'i', the set of vectors $\{J_j^{(i)}\}_k$ with k = 1,2, .., K define a reduced order subspace Ξ_i of the original Hilbert space. These basis vectors define a subspace Ξ containing the CBF's, but one has to decide how many of them are necessary. In order to define an orthonormal basis of Ξ_i, vectors $\{J_j^{(i)}\}_k$ are arranged column wise in a matrix Y, which is subjected to the singular-value decomposition (SVD). Since the singular values typically range over several orders of magnitude, not all of them are needed to achieve a desired accuracy level. Let 'L' be the number of significant singular values that need to be retained. We make use of the L left singular vectors to construct basis for each of the blocks. The original matrix is then reduced to a size of ML x ML. It is possible that the number of significant singular values L be greater than M, in which case the size of the reduced matrix is slightly greater than that obtained with the original CBFM. However, this is offset by the fact that the same set of basis functions can now be used over the entire range of incident angles, and, hence, a numerically efficient solution to the scattering problem can be obtained by using these in place of the conventional CBF's.

The numerical accuracy and the computational advantages of the proposed technique are illustrated by studying the problem of plane wave scattering from PEC objects, while varying the incident angle over a wide range. Our numerical experiments reveal that the results obtained from the proposed approach are even closer to those of the rigorous MoM simulation, than when the original CBFM is used, including the grazing angle cases, which are difficult to simulate accurately.