A Gaussian Beam based Numerical Approach for Analysis of EM Scattering by Large Multiple Plate Structures

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INTRODUCTION

It is of interest to study high frequency wave scattering from multiple plate structures, as for example a fully 3-D trihedral type structure. Iterative physical optics (IPO) \cite{1, 2} may be used to find the interactions between the plates, but may become cumbersome at these high frequencies. It is therefore proposed, based on some past experience dealing with other reflector antenna and RCS problems \cite{3, 4}, to investigate if the use of GBs as the field basis functions within a GB based IPO in an FMM-like concept (fast multipole method \cite{5}), would lead to a faster and more tractable analysis of such multiple wave interactions from very large plate structures.

With the above view in mind, the following simple 2-D problem of the EM plane wave scattering by a three sided plate as shown in Figure 1 is analyzed. Of particular interest is to evaluate the field doubly scattered onto plate #3; i.e. the field arriving at plate #3 via the scattering from plates #2 and #1, respectively, after plate #1 is directly illuminated by an incident plane wave. These evaluations are performed within the IPO approximation for convenience. Such an IPO approach is reasonable for well illuminated large flat plates \cite{2}.

SUMMARY OF APPROACH

First, a reference solution is obtained. This reference solution consists of a conventional numerical evaluation for the fields scattered by the plates #1 and #2 using the PO integrals. The field that arrives at plate #3 in a sequential manner from plates #2 and #1 respectively, after plate #1 is directly illuminated by the incident field, is then observed in terms of the induced current on plate #3 again to within the PO approximation. Next, the same set of computations are performed using GBs. First, the fields scattered from plate #1, as in the above reference numerical PO solution, is expanded in a set of GBs which then propagate from plate #1 to plate #2 to induce a current (within the PO approximation) on plate #2. The fields scattered from plate #2 are again expanded in a new set of GBs which then propagates from plate #2 to plate #3. The GB expansions for field scattered from plates #1 and #2, respectively, are obtained by dividing each of the plates into subsections (analogous to groups within the FMM algorithm). A cluster of GBs is launched radially outwards from the center of each subsection as shown in Figure 1. The GBs are assumed to have equiangular spacing and are otherwise identical. A typical GB launched from a subsection is shown in Figure 2. The GB expansion coefficients are found from the induced currents on the plates. This GB representation closely resembles the phase-space Gabor expansion in terms of GBs as in \cite{6}, but is different from it as discussed previously in \cite{3, 4}.

Based on past work,\cite{3, 4} the subsections are chosen to be $5\lambda$ in extent where $\lambda$ is the free space wavelength. Each cluster contains 33 GBs with the rules for choosing the GB parameters as in\cite{3, 4}. It is noted that the subsection size may be optimized to achieve a minimum computational cost for a given geometry, but this is not demonstrated here for simplicity. The GB fields are valid both in the near and far zone and it is interesting to note that for observation points which are not too close to the plate corners or to the plates from where they are launched, only a selected few of these GBs are dominant and hence only they may be retained to produce sufficiently accurate field values.

Thus, the most significant reason for selecting the GB expansion approach is based on the fact that, due to their localized nature, not all the GBs in any cluster contribute to a given observation point on...
the next plate. Indeed, this property was mentioned earlier where it was noted that only 5-8 GBs were usually remained significant. All the other GBs in the cluster fall below \( 1/e \) of their fields on axis. Consequently, such an expansion could lead to an efficient analysis. In terms of operational counts, if there are \( N \) sample points on each plate, it takes \( N^2 \) operations to compute the PO radiation from one plate to the next. With the GB approach it takes a maximum of \( 8N_sN \) operations, where \( N_s \) is the number of subsections and it is assumed that 8 GBs per subsection are used at each observation point. As mentioned earlier, the operational count may be minimized by choosing an optimum subsection size, much like the FMM approach to choosing the group size.

**NUMERICAL RESULTS**

A parallel polarized plane wave is incident on the dihedral structure of Figure 1. Numerical results are obtained for this example. In this example, the first, second and third strips have the same length \( D = 100\lambda \). The sub-sectional lengths are taken to be \( L_x = 5\lambda \) corresponding to a total of 20 sub-sections for each of the plates or strips. The incident plane wave makes an angle of \( \Psi = 130^\circ \) with the first strip. The tilt angle for the second strip is \( c_1 = 70^\circ \). The observation is made on plate #3 with an angle \( \theta_3 = 90^\circ \). Figure 3 shows the comparison between the reference solution, which is obtained by integrating the induced PO currents numerically both on the first strip and second strip, and the GB solution described previously. The agreement between the GB solution and conventional numerical PO solution is quite good. To find the scattered magnetic field from the first strip on the second strip, 52,122 GBs were used while numerical integration requires \( (100/0.25)^2 = 160,000 \) computations, assuming quarter-wavelength sampling of the PO integral. Similarly, from the second strip to third strip, 52,759 GB’s are needed while required number of operations for the reference solution is again 160,000. It is proposed as part of ongoing study to develop a near optimal strategy for the use of GBs within the IPO approach in an FMM like concept, and to do the RCS from fully 3-D and very large trihedral structures using such an approach.

**References**


Figure 1: The problem geometry consisting of a 2-D three sided bent plate or strip illuminated by a plane wave.

Figure 2: Launching of a Gaussian Beam from the center of a subsection.

Figure 3: The magnitude of the current on strip 3 using the PO approximation.