Radar Cross Section of Aircraft with Engine Inlets

FEKO's rigourous and asymptotic solvers are used to solve a multi-scale problem.

Introduction

At radar frequencies, 1 GHz and above, asymptotic methods are usually preferred to calculate the radar cross section (RCS) of targets like aircraft, since the main parts of the target are more than an order of magnitude larger than the wavelength. Suitable asymptotic methods include ray-launching geometrical optics and physical optics. However, for an engine inlet with fan blades, a rigorous method is required, e.g. the multi-level fast multipole method (MLFMM). The challenge then becomes how to combine rigorous and asymptotic methods to compute the RCS of an aircraft with engine inlet, such as the one shown in Figure 1. This white paper describes a two-step method that obtains accurate results in limited time.

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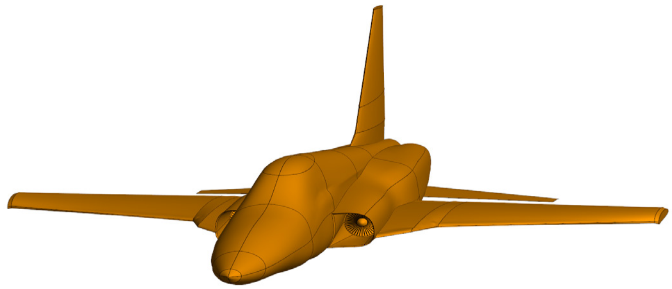

Figure 1: Aircraft model with engine inlet and fan

Strategy

In a case where not enough computer resources are available to handle the entire problem with a rigorous method, a two-step method can be applied. One cannot simply add solutions of two partial scattering problems, one rigorous and one asymptotic. This is due to the fact that the incident field at the engine inlet's aperture is no longer a plane wave, since it has already interacted with the aircraft (Figure 2). Therefore, the proper first step is to solve the scattering problem shown in Figure 3 with a rigorous method. The total fields at the apertures of both inlets, which consist of fields traveling into and fields traveling out of the engine inlets, are sampled and stored. The rigorous method of choice is the multi-level fast multipole method (MLFMM).

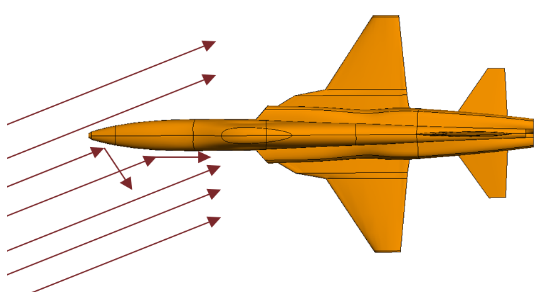

Figure 2: The illumination of the engine inlet is not a plane wave

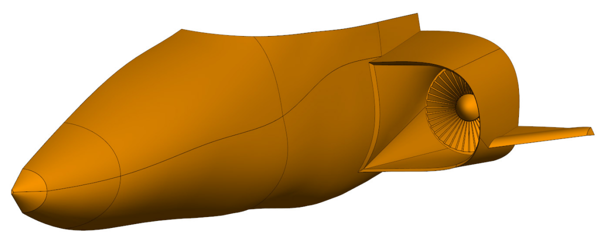

Figure 3: Step 1 - Determine the total field in the engine inlet's aperture with a rigorous method wave

In the second step, the sampled fields from step 2 are added to the incident plane wave, as shown in Figure 4, and the entire aircraft is solved with an asymptotic method. For this step, one can choose between physical optics and ray-launching geometrical optics. In this second step the former is preferred when the fields experience only one interaction before traveling to infinity, while the latter is necessary when the rays experience multiple interactions between parts of the aircraft.

In this case, physical optics is appropriate. For efficiency, a combination of physical optics and large-element physical optics (LE-PO) was used. Physical optics was used close to the aperture, where the magnitude of the combined incident fields show considerable spatial variation, while LE-PO was used on surfaces farther from the aperture, where combined incident fields are locally closer to plane waves.

Efficiency was further enhanced because FEKO automatically combines the large number of field samples in the aperture from step 1 into a smaller number of equivalent sources for step 2 without loss of accuracy. During step 2, the interior of the engine inlet is temporarily perfectly absorbing to avoid counting its contribution twice. The fields of the incident plane wave and the fields emanating from the apertures together interact with the aircraft, as shown in Figure 4, to produce the desired result: the scattered field of the entire aircraft with engine inlets and fan blades.

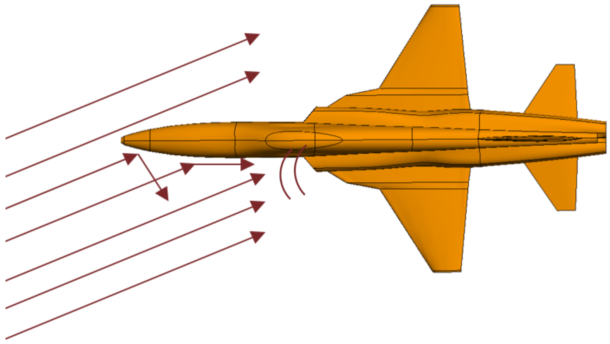

Figure 4: Step 2: Using an asymptotic method, solve the new scattering problem in which the field from step 1 has been added to the incident plane wave, and both are scattered by the aircraft

Results

Figure 5 compares results of this two-step strategy with rigorous results, produced with MLFMM. This was done at 3 GHz (a not-very-high radar frequency), at which rigorous results could still be easily obtained. At this frequency, the aircraft is 150 wavelengths long. Note that the agreement is good.

At phi=0 degrees, the incident wave hits “nose on”, and both inlets receive equal illumination. As phi increases, one of the two inlets moves into the shadow of the aircraft nose. Fields are always sampled at both inlets apertures and this kind of transition is not a problem. The main cause of discrepancies between the two-step method and MLFMM is the fact that the surface currents computed by physical optics are an approximation. The approximation becomes better as the frequency increases.

The two-step method saves an impressive amount of memory. The method used 4.7 GB in the first step, when the partial model shown in Figure 3 was analyzed with MLFMM, and only a few hundred MB in the second step, when hybrid PO / LEPO was employed. The rigorous analysis of the entire aircraft with MLFMM, on the other hand, required 96 GB, which is twenty times as much.

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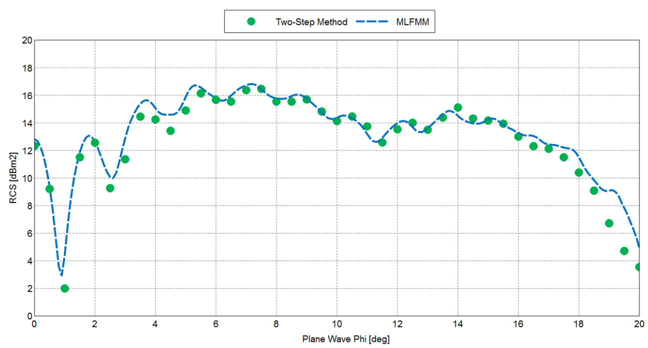

Figure 5: Comparison at 3 GHz between results obtained with the two-step method and results obtained by applying a rigorous method, MLFMM, everywhere

Conclusion

The multi-scale problem of scattering by an aircraft with an engine inlet with fan blades is challenging for most tools. FEKO, however, with its wide range of rigorous and asymptotic solvers, as well as hybridized techniques, enables users to solve this class of problem on machines with a modest amount of memory. Especially at the higher RADAR frequencies, enough memory for a rigorous simulation won’t always be available. In this case, with a technique like the two-step method, engineers can still solve their multi-scale RCS problems with good accuracy.