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***Abstract*—A new hybrid method, the DG-FDTD/IPO, has recently been proposed to analyze surrounded antennas mounted on large platforms. In this paper the capabilities of this method to go through such large and complex problems are shown. More precisely, a deep analysis of the far-field radiated for a canonical antenna-on-platform scenario is proposed.**

***Index Terms*—radiation analysis, antenna on structure, DG-FDTD, IPO, hybrid methods**

I. Introduction

It is well known that the radiation characteristics of antennas can be strongly altered when they have to operate in a complex environment. In the specific context of antennas mounted on large platforms, such as satellites, planes or vehicles, the radiation characteristics are influenced by both complex elements close to the antenna and by the platform itself. For these reasons, antennas mounted on complex structures must be analyzed in their complete environment of integration [1].

To do so, many methods are available that have been developed over the years. These methods can be separated into two groups, rigorous methods [2], [3], [4] and hybrid methods [5], [6]. A hybrid method allowing modular analysis has been proposed recently [7]. This method, called DG-FDTD/PO, consists of a hybridization of the Dual-grid FDTD (DG-FDTD) [8] with Physical Optics (PO). The antenna and its complex vicinity are first analyzed in two successive FDTD steps. Then a PO simulation of the platform is performed.

In this paper, we present the deep analysis of a canonical structure by the DG-FDTD/IPO. The Iterative Physical Optics (IPO) [9] is used instead of the traditional PO in order account for multiple reflections. This paper aims at demonstrating that this new modular method provides an efficient tool to separate the contributions of the different elements participating in the EM radiation.

This detailed analysis is presented in section II using three sub-cases of increasing complexity. Finally, conclusions are drawn in the last section.

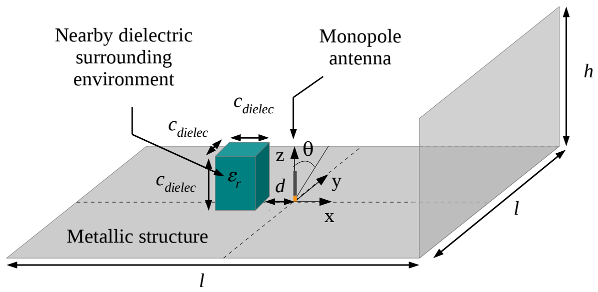


Fig. 1. Antenna mounted on a metallic structure. l = 3.9 m = 13 λ_{1GHz}, h = 1.15 m = 3.83 λ_{1GHz}, d = 0.15 m = 0.5 λ_{1GHz}, C_{dielec} = 0.18 m = 0.6 λ_{1GHz}, ϵ_r = 10

II. Deep analysis with the DG-FDTD/IPO

In order to show the possibilities offered by this new hybrid method the scenario presented in Fig. 1 is considered. Note that the analyzed structure is identical to the one used to validate the DG-FDTD/PO in [7]. The complete scenario is first analyzed with the DG-FDTD/IPO method in II-A. Then, it is decomposed into three sub-cases (Fig. 2) in order to identify the influence of the different involved elements and thus to illustrate the capabilities of the method. The analysis of the three sub-cases with the DG-FDTD/IPO are presented in II-B, II-C and II-D. All the results shown in this paper corresponds to simulations performed at 1 GHz (operating frequency of the monopole).

A. Complete structure

The DG-FDTD/IPO simulation of the complete scenario (Fig. 1) is performed using two simulations steps as presented in Fig. 3 (see [7] for more details). The antenna and its complex vicinity are first simulated rigorously and efficiently using the DG-FDTD method. Then, an asymptotic simulation of the metallic structure hosting the antenna is performed with the IPO method. A parametrical study on the IPO iteration number N, not presented here because of space limitation, has shown that a single iteration ($N = 1$) is sufficient for the

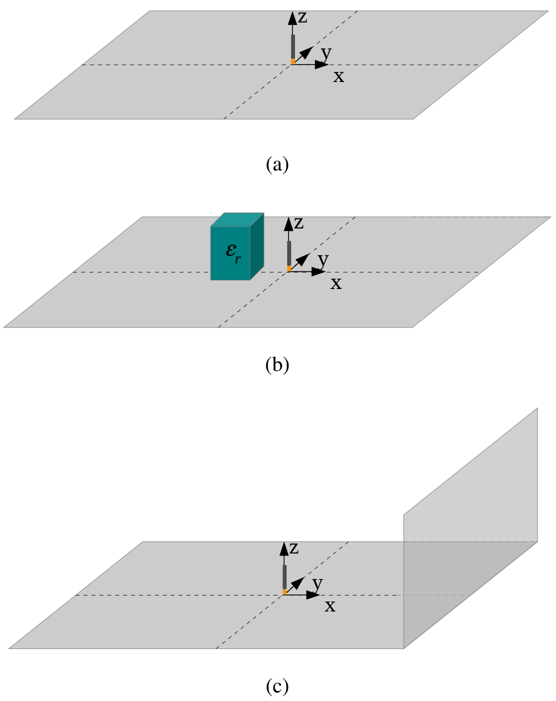


Fig. 2. (a) sub-case 1 : monopole on the square metallic plate; (b) sub-case 2 : monopole and dielectric block on the square metallic plate; (c) sub-case 3 : monopole mounted on the metallic dihedral structure.

convergence of far-field. The classical PO simulation would be consisting of an IPO simulation without iteration ($N = 0$). Fig. 4 and Fig. 5 show the far-field radiation results in the (x0z) and (y0z) planes respectively.

As described in [7] and shown in Fig. 3, DG-FDTD/IPO approach considers successively larger and larger subdomains. This hybridization scheme is very modular and thus allows identifying the contribution of the different elements participating in the radiation. To do so, we now analyze three sub-cases, each of which highlighting a specific effect in the overall radiation.

B. Subcase 1 : antenna on a square ground plane

As presented in Fig. 6a, the simulation of this scenario is decomposed into two steps. First, the fine FDTD simulation of the isolated monopole is carried out. Note that this simulation has already been performed as the first step of the DG-FDTD simulation of the complete scenario. It provides equivalent currents on an equivalent surface enclosing the monopole. Then, these currents serve as the excitation for the IPO simulation of the square ground plane. No iterative computation of these currents is necessary here given the planar shape of the structure which means IPO simply reduces to classical PO ($N = 0$). The computation time for the two steps are reported in Table I.

Fig. 5a (comparison of sub-case 1 and complete structure) clearly shows that the oscillations for the E_θ far-field in the (y0z) plane are mainly due to the metallic square plate. Note that no result is given for E_ϕ (Fig. 5b) since the symmetry of

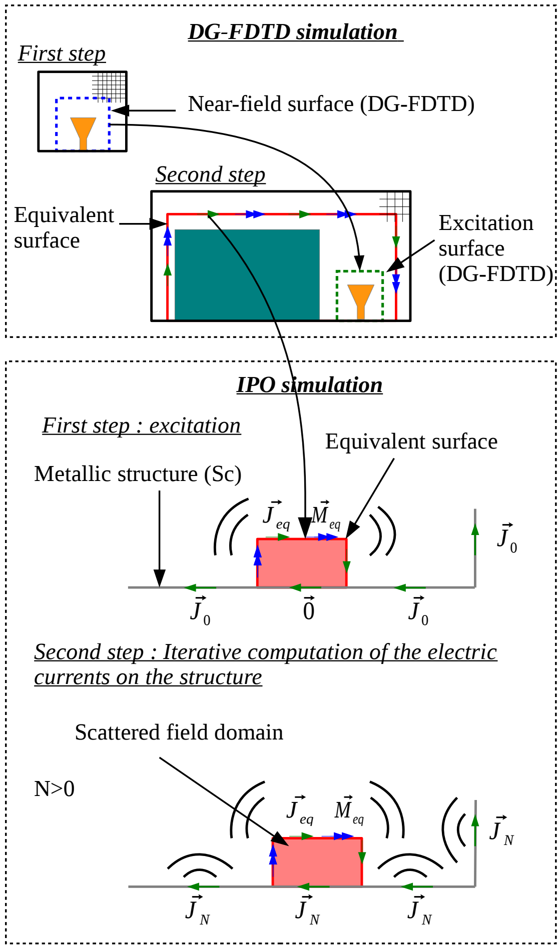


Fig. 3. DG-FDTD/IPO decomposition of the complete scenario.

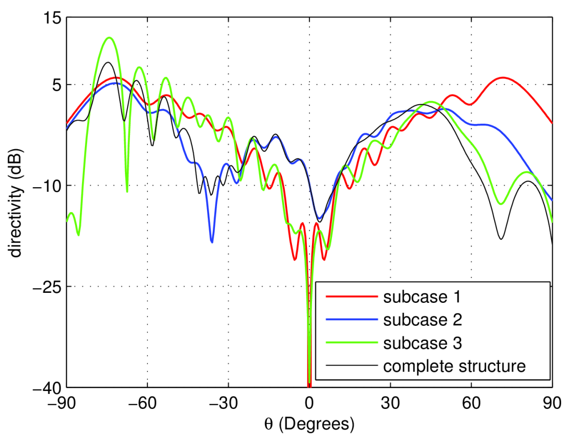
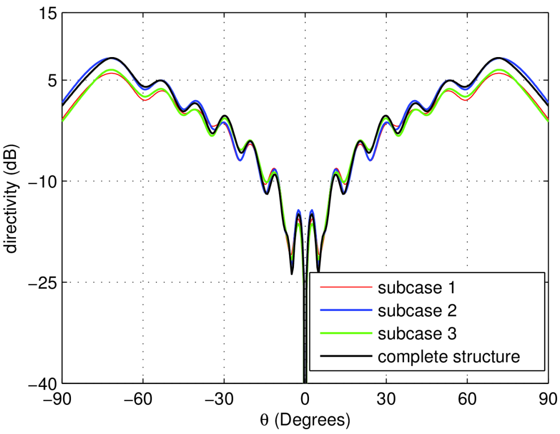


Fig. 4. Far-field results (E_θ) in the (x0z) plane at 1 GHz.

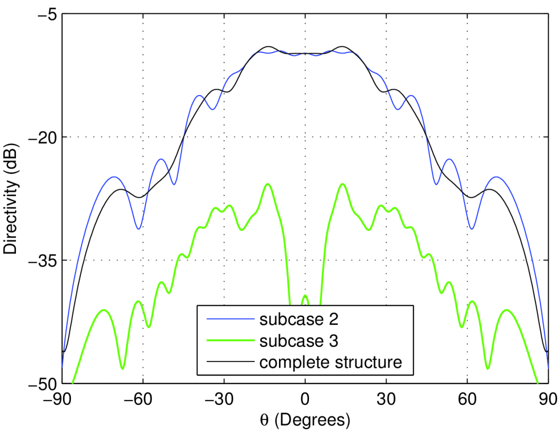
sub-case 1 leads to zero cross-polar.

C. Subcase 2 : antenna and dielectrick block on a square ground plane

Sub-case 2 is set-up to analyze the influence of the dielectric block. As described in Fig. 6a, the simulation of this scenario



(a)



(b)

Fig. 5. Far-field results (E_θ and E_ϕ respectively 5a and 5b) in the (y0z) plane at 1 GHz.

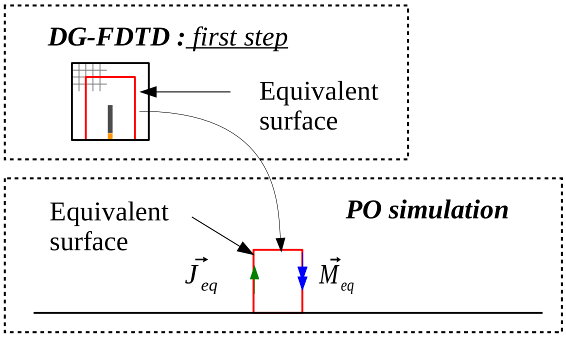
is based on two simulations. The first one, corresponding to the DG-FDTD simulation of the antenna in presence of the dielectric bloc, has already been performed during the DG-FDTD/IPO simulation of the complete structure. Hence, the equivalent currents representing the monopole and its complex vicinity can be reused to excite the asymptotic simulation of the square ground plane. As for sub-case 1, the asymptotic simulation of the metallic square plate is performed with a traditional PO method. Table I indicates the computation time for the two simulations steps.

In Fig. 4, the results of subcase 2 show that the dielectric block strongly influences the far-field radiation pattern of the complete structure for directions defined by $-45° < \theta < +45°$. Indeed, the results are in very good agreement in this angular section of the diagram.

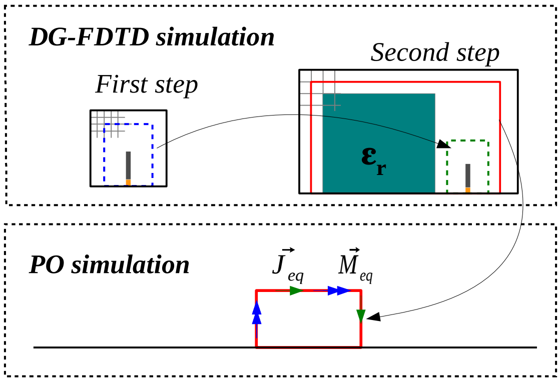
D. Subcase 3 : antenna mounted on the metallic dihedral structure

The analysis of the third sub-case aims at characterizing the influence of the vertical metallic plate on the radiation pattern. The decomposition scheme used to simulate this scenario is very close to the one presented for sub-case 1 (Fig. 6). The first step is rigorously the same. Regarding the asymptotic simulation, the square metallic plate is replaced by the dihedral structure hosting the antenna. Because of the dihedral shape of the metallic structure the IPO method is preferred (with $N = 1$). Finally, only a fast asymptotic simulation (Table I) is required to analyze sub-case 3.

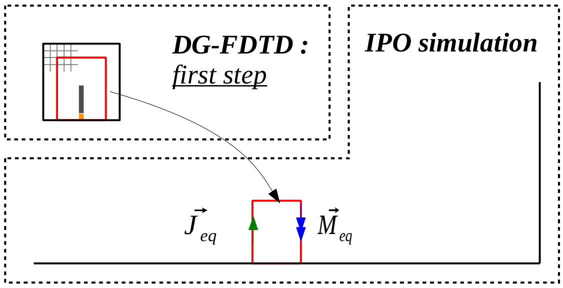
For directions defined by $\theta < -45°$ or $\theta > +45°$ in the (x0z) plane, Fig. 4 shows that the results associated to sub-case 3 and the complete structure are in good agreement. This means that the vertical plane strongly affects the radiation pattern of the complete structure for the grazing angles. More precisely, for negative value of θ angle, the vertical metallic



(a)



(b)



(c)

Fig. 6. Decomposition schemes used to simulate the sub-cases : (a) sub-case 1; (b) sub-case 2; (c) sub-case 3.

TABLE I
COMPUTATION TIME ASSOCIATED TO THE DIFFERENT STRUCTURES

Simulated structures	**Method**	**Computation time**
isolated monopole	FDTD	**2 min 30s**
monopole + dielectric block	DG-FDTD	**13 min**
square metallic plate	PO	**50s**
dihedral metallic structure	IPO	**1 min 15s**
complete structure	DG-FDTD/IPO	**14 min 15s**

plate generates oscillations due to recombination of the direct and the scattered field. Then, for positive value, the results indicate that the metallic plate is responsible for the strong attenuation observed on the radiation patten.

In the (y0z) plane, Fig. 5b shows that the cross-polar (E_ϕ component) are very close for sub-case 2 and the complete structure. This figure also indicates that cross-polar results associated to sub-case 3 and complete structure are very different. Moreover, as mentioned during the analysis of sub-case 1, the cross-polar in this plane cannot originate from the square ground plane. So, the cross-polar in the radiation diagram of the complete structure can be attributed to the presence of the dielectric block.

III. Conclusion

In this paper, we have shown the possibilities offered by a recently proposed method, the DG-FDTD/IPO, to carry out the deep analysis of surrounded antennas mounted on large metallic structures. The modularity of the method has been taken up to separate and identify the contribution of different elements in a canonical antenna-on-platform problem. In particular, we have shown that the different steps used to perform the DG-FDTD/IPO simulation of the complete structure can be reused directly or combined with fast asymptotic simulation to analyze the influence of the different elements of the structure.

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