

A Hybrid Numerical-Composite UTD Ray Analysis of the Radiation by Large Locally Convex Conformal Arrays on Large Platforms

Federico Puggelli ¹, Prabhakar Pathak ^{*2}, Matteo Albani ³, Panuawat Janpugdee ^{#4}

University of Siena

Dept. of Information Engineering, Via Roma 56, 53100, Siena, Italy

¹puggelli@unisi.it

³matteo.albani@dii.unisi.it

**The Ohio State University*

ElectroScience Lab., Dept. ECE, 1320 Kinnear Rd., Columbus, Ohio, USA

²pathak.2@osu.edu

Chulalongkorn University

Dept. of Electrical Engineering, Thailand

⁴p.janpugdee@gmail.com

Abstract—A new efficient hybrid numerical-composite UTD ray solution is presented to describe the radiation from an aperture formed by a large phased array antenna mounted conformally on a locally convex, but otherwise relatively arbitrary large platform. The aperture distribution is first obtained from a numerical solution for the array fields, which takes into account only the local array portion of the platform geometry, via the finite element-boundary integral (FE-BI) or the finite element method (FEM) based approaches. The electromagnetic (EM) equivalence theorem can be used to obtain the equivalent sources over the array aperture; the latter equivalent sources then radiate the array fields via a new composite uniform geometrical theory of diffraction (UTD) for arrays. This composite UTD describes the fields radiated by the entire array in terms of just a few rays arising from a point in the interior of the array aperture, and from specific points on the edges and corners of the array aperture boundary. These rays once launched from the array aperture then interact with the rest of the platform via the conventional UTD. Such an approach is far more efficient than solving the whole large complex array and its even larger platform simultaneously in some numerical fashion. Furthermore, it provides a physical insight into the array radiation mechanisms.

I. INTRODUCTION

The EM fields radiated by a large conformal antenna array on a locally convex but otherwise large complex platform is considered in this work. Such an array could be formed by simple elements placed directly and conformally on a large complex platform, as, for example, in airborne, shipborne or spaceborne applications. Also, one can have more complex arrays for such applications, which include highly inhomogeneous antenna elements embedded in layered media with a radome cover that is flush mounted, so that it forms a smooth aperture in the locally convex part of the platform, as shown in Fig. 1. An EM analysis which can predict the array radiation pattern for the configuration in Fig. 1 via a direct numerical solver will become quite challenging (in terms of CPU time

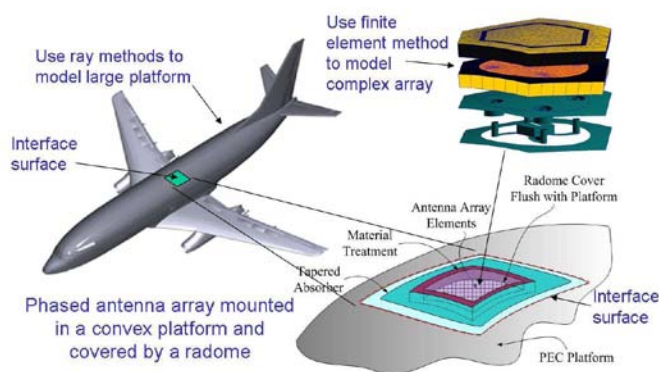


Fig. 1. Aperture formed by a complex array placed conformally on an airborne platform.

and memory) especially at X-band and higher. Hence, a hybrid approach, that combines a direct numerical solver for just the local convex array part of the platform via FE-BI or FEM, together with the UTD which accounts for the rest of the platform, is far more efficient and physically appealing. This hybrid approach which systematically combines FE-BI/FEM with UTD via the equivalence theorem is summarized below.

II. TECHNICAL APPROACH

The approach basically employs the following steps.

First, the EM fields are obtained numerically only in the local neighborhood of the large array aperture using FE-BI or FEM together with domain decomposition [1,2]. This aperture is essentially formed either by the array antenna elements on the locally convex platform, or by an array of complex elements recessed just a little below the skin line of the locally convex but otherwise relatively arbitrarily shaped remaining part of the large platform. In the latter case, one has a radome

which forms the aperture or window that is flush with the locally convex array portion of the platform as in Fig. 1. This numerical aperture field information needs to be transformed into UTD rays which are launched from it as described in the next step.

The second step therefore involves taking the aperture field and utilizing an equivalence theorem which allows one to define equivalent tangential electric and magnetic current sources directly in terms of the field values. If the platform outside the array aperture is assumed to be a perfect electric conductor (PEC), then one can in this equivalence theorem cover the aperture as well by PEC so that only the magnetic currents \overline{M}_a which are defined over the area occupied by the aperture radiate in the presence of the entirely PEC platform (since the aperture is now closed by PEC). One notes that $\overline{M}_a = \overline{E}_a \times \hat{n}$ at each point over the area where \overline{E}_a is the electric field found numerically (via FE-BI or FEM) at any point in the aperture, and \hat{n} is the unit outward normal vector to any point on this locally convex aperture surface. If $\overline{r}' = x'\hat{x} + y'\hat{y} + z'\hat{z}$ is any point in the array aperture expressed in 3-D rectangular coordinates (x', y', z') , then $\overline{M}_a(\overline{r}')$ is next converted via an appropriate mapping into an effective 2-D space (u, v) . The advantage of this transformation is that the numerical values of $\overline{M}_a(u, v)$ can be expressed in a suitable basis set via DFT in which only a few basis remain non-negligible. Equally important is that the basis set allows one to directly and systematically find the fields radiated by it in terms of rays. Hence, this second step is a crucial one to convert numerical values of \overline{M}_a into rays emanating from the aperture as will be elaborated on in the third step.

The third step in the hybrid process is that each of the dominant basis set, of which there are only a few (typically 10% of the total samples needed according to the requirements imposed by the sampling theorem), now can be shown to radiate fields which can be cast into the UTD ray format. It is seen that a composite array UTD radiation solution, which has been recently obtained provides a description for the radiated field from the "entire" array aperture in terms of just a few rays for each of the dominant basis set. These UTD ray fields for any given dominant basis arise, for a given near or far zone observer, from an aperture interior point, from aperture edges and corners, thus providing a vivid physical picture for array radiation which no other method provides [3,4].

Previously, the present authors obtained a ray solution which consisted of a non-uniform part which exhibited singularities at the array edge and corner induced shadow boundaries. This non-uniform part had to be regularized via additive terms, called the shadow boundary transition region terms, which kept the total field bounded and continuous everywhere. Such an additive regularization did not lead to a nice, compact UTD ray format. The new composite UTD form presented here, and which has been developed recently, is far more compact and efficient than the previous non-UTD solution; this new UTD solution for composite array radiation will be emphasized.

III. CONCLUSIONS

A new composite array UTD has been developed to compactly describe the radiation by a conformal array on a large platform via rays. It is hybridized with a numerical solver for modeling only the large complex convex conformal array part of the platform and then converts the resulting numerical aperture field data into UTD ray fields to describe array radiation in presence of rest of the platform. Examples of complex arrays, with vivaldi elements, on typical aircraft will be illustrated to demonstrate the accuracy and efficiency of the present hybrid approach; these examples are not shown due to space limitations.

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