Mesh-Free Modeling of Two-Dimensional Infinite Periodic Structure Using Green's Function for Method of Moments

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***Abstract*—This paper demonstrates a mesh-free modeling method of two-dimensional infinite periodic structure for method of moments (MoM). The mesh-free modeling method deals with the two-dimensional infinite periodic structure as a surface whose reflection coefficient is numerically known. In the same manner as a layered media Green's function (LMGF), electromagnetic response of the two-dimensional infinite periodic structure is formulated by plane wave expansion. Numerical simulation is performed and radiation performance of an array antenna over the two-dimensional infinite periodic dipole array is demonstrated.**

***Keywords*—Method of Moments, Periodic Structure, Green's Function**

I. Introduction

Modeling of a large-scale scatterer during numerical simulation is a classic but challenging problem for MoM [1]. One intuitive approach for modeling the large-scale scatterer is to follow MoM and divide it into mesh of equivalent current [2]–[4]. This approach directly deals with the large-scale scatterer as an unknown current but the number of unknowns (i.e. number of mesh) increases as the size of the scatterer increases. As a result, this approach suffers from large computational cost and acceleration techniques such as supercomputers or fast MoM are necessary [5]–[9].

One of the elegant approaches to model an infinite dielectric slab and ground plane is to model them using reflection/transmission coefficients [10]. This approach is computationally efficient because the infinite dielectric slab and ground plane are modeled in a mesh-free manner. For example, it is well-known that MoM with the LMGF follows this manner and antennas over the layered media is efficiently analyzed because antenna itself is only divided into mesh of equivalent current whereas the layered media is not [11]–[14]. However, applicability of this approach is limited to ideal scatterers whose reflection/transmission coefficients are analytically expressed.

On the other hand, our group has proposed a mesh-free modeling method of two-dimensional infinite periodic structures [15]–[17]. The proposed method deals with electromagnetic response of the two-dimensional infinite periodic structures using their reflection coefficients. The proposed method is based on semi-analytical formulation, i.e. analytically expressed Green's function combined with numerically obtained reflection coefficients. Therefore, the proposed method is applicable to numerical analysis of antennas over the two-dimensional infinite periodic structures composed of arbitrary shaped scatterers once it is combined with MoM.

In this paper, the mesh-free modeling method of two-dimensional infinite periodic structures is introduced to MoM. Performance of the MoM is demonstrated via numerical analysis of an array antenna over the two-dimensional infinite periodic array.

II. Concept

Concept of the mesh-free modeling method is shown in Fig. 1. Firstly, the reflection coefficients of the two-dimensional infinite periodic structures are obtained using Floquet's theorem. Mutual impedance between source and observation points is analytically formulated in the same manner as the LMGF except for reflection coefficients that are substituted numerically. Finally, a matrix equation is numerically obtained by MoM and is solved. Size of the matrix equation (i.e. number of unknowns) obtained by MoM with the mesh-free modeling method is small because source and observation points (i.e. antennas) are only divided into mesh of equivalent current here.

III. Numerical Simulation

Fig. 2 shows directivity of the dipole array over two-dimensional infinite frequency selective surface (FSS). It is found that the directivity of MoM with the proposed mesh-free modeling method agrees well with directivities of conventional MoM (Full-wave) except for fluctuation. The fluctuation stems from finite size of the FSS and the directivities of conventional MoM seem to approach that of

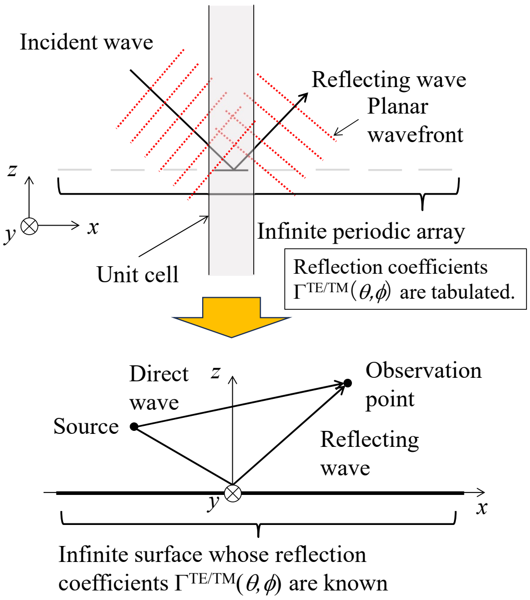

Fig. 1. Concept of the mesh-free modeling method .

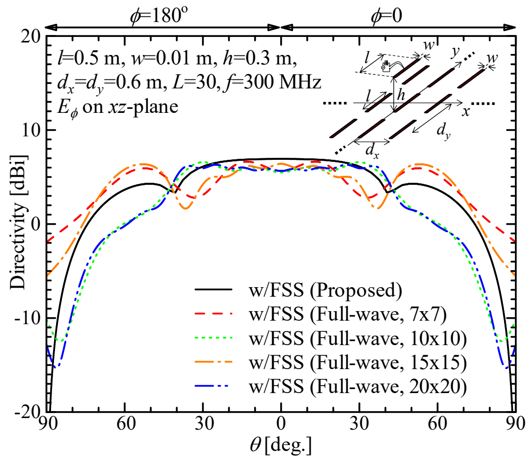

Fig. 2. Directivity of a dipole antenna over two-dimensional infinite FSS composed of dipole elements (L is number of quadrature for spherical integral for calculation of self/mutual impedance.).

MoM with the proposed mesh-free modeling method as the size of finite FSS becomes large. The number of unknowns 6015 for conventional MoM (Full-wave, 20×20) whereas it is only 15 for the MoM with the proposed meth-free method. Resultant CPU time was approximately 7200 sec. for conventional MoM and was less than one second for the MoM with the proposed mesh-free method. Therefore, it can be concluded that the MoM with the proposed mesh-free method is computationally efficient for numerical analysis of antennas over large periodic structures.

IV. Conclusion

This paper presented the mesh-free modeling method for the two-dimensional infinite periodic structures and applied it to MoM. Results of numerical simulation demonstrated that the proposed MoM works well and is computationally efficient in comparison with conventional MoM.

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