Numerical Analysis of Planar Dipole Antennas in the Vicinity of Dielectric Object Using HO-CBFM

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***Abstract* - Higher-order characteristic basis function method (HO-CBFM) is applied for the numerical analysis of planar dipole antennas in the vicinity of a dielectric object. The HO-CBFM gives the current accurately even when a block division is arbitrary. The results of numerical analysis show that the HO-CBFM can reduce the CPU time for the numerical analysis without large compromise in the accuracy of input impedance.**

***Index Terms* — Method of Moments (MoM), higher-order characteristic basis function method, volume integral equation.**

I. INTRODUCTION

Method of Moments (MoM) has been used for the numerical analysis of antennas [1]. In recent years, fast MoMs for the numerical analysis of large-scale problems have much attention. Prakash and Mittra have proposed the characteristic basis function method (CBFM) as a fast direct solver [2]. Recently, the high order CBF such as the tertiary basis function has been proposed to improve the accuracy of the CBFM and a connected patch array has been analyzed by using the CBFM with the tertiary basis function [3]. The accuracy of the current obtained by the CBFM can be enhanced using the tertiary basis function and fourth order CBF. However, the performance of the CBFM with the high order CBF has not been shown for arbitrary block division because each block corresponds to a pair of patch elements.

In this paper, the performance of a higher-order CBFM (HO-CBFM) is quantitatively evaluated for arbitrary block division. A planar dipole antenna in the vicinity of a dielectric object is analyzed using the HO-CBFM. The results of numerical analysis show that the HO-CBFM produces its input impedance accurately without large compromise in the CPU time even if block division is arbitrary.

II. NUMERICAL EXAMPLE

The HO-CBFM was applied to the numerical analysis of a planar dipole antenna in the vicinity of a dielectric object. The formulation of the HO-CBFM is shown in reference [4] and omitted here. Analysis models and their block division in the HO-CBFM are shown in Fig. 1 and Fig. 2. Antenna segments are allocated to different blocks to verify the enhancement of the accuracy of the HO-CBFM for arbitrary block division. The total number of segments N=3760 and the number of blocks $M=M_xM_yM_z=3\times5\times1=15$ in the numerical analysis model. The total number of blocks M was set to approximately satisfy $M=0.9N^{1/3}$ [5]. An extended block and

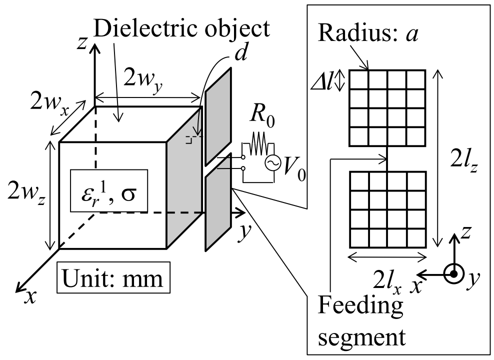

Fig. 1 A planar dipole antenna in the vicinity of a dielectric object.

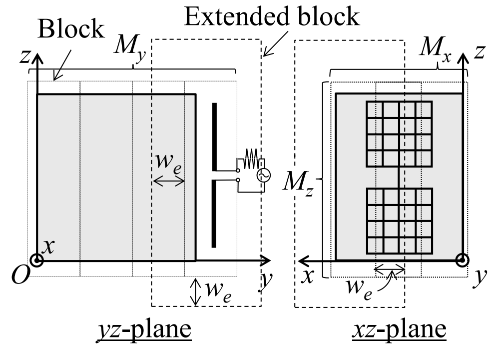

Fig.2 Block division of a planar dipole antenna in the vicinity of the dielectric object.

overlapping segments are defined by the size of the overlapping region w_e. The order of the HO-CBFM is L and the CBFM of the 2nd order (L=2) is the conventional one. Intel Core i7-3820 CPU with 64 GB memory was used for numerical simulation.

The input reactance of the planar dipole antenna obtained using the conventional second order CBFM is shown in Fig. 3. It is found that the input reactance obtained using the conventional second order of the CBFM shows poor accuracy even if the size of overlapping region w_e becomes large. In the conventional second order of the CBFM, the effect of multiple scattering between blocks is not sufficiently included in the block current because the higher-order CBFs are not used to calculate the reduced matrix. As a result, the accuracy of the conventional second order of the CBFM is poor when block division of the antenna is arbitrary.

The input reactance obtained using the HO-CBFM is shown in Fig. 4. The input reactance obtained using the HO-CBFM

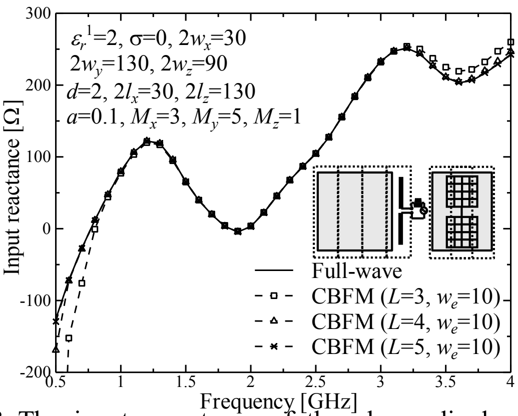

Fig. 3 The input reactance of the planar dipole antenna obtained using the conventional second order of the CBFM.

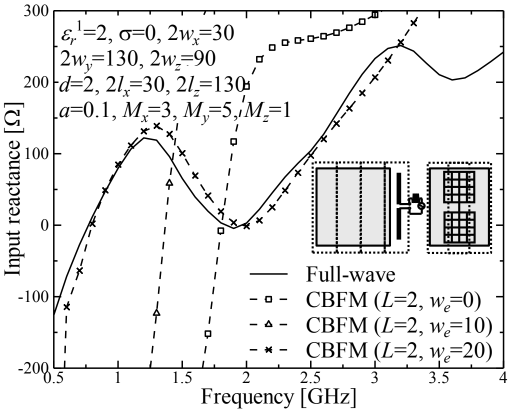

Fig. 4 The input reactance of the planar dipole antenna obtained using the HO-CBFM.

agrees well with that using the full-wave simulation. In the HO-CBFM, the effect of multiple scattering between blocks is sufficiently included in the block current because the higher- order CBFs are used to calculate the reduced matrix. As a result, the accuracy of the HO-CBFM is better than the conventional second order of the CBFM when block division of the antenna is arbitrary.

The accuracy of the HO-CBFM is evaluated using relative root mean square error (RRMSE) of the input impedance.

$$RRMSE = \sqrt{\frac{1}{M_s}\sum_{i=1}^{M_s}\frac{\left|Z_f - Z_c\right|^2}{\left|Z_f\right|^2}}, \quad (3)$$

where M_s is the number of sampling points, Z_f represents the input impedance obtained using full-wave simulation, and Z_c represents the input impedance obtained using the HO-CBFM. The RRMSE and the CPU time of the HO-CBFM are shown in Fig. 5. It is found that the RRMSE of the input impedance obtained using the HO-CBFM decreases when the order of the CBFM increases. However, the RRMSE of the input impedance obtained using the HO-CBFM with w_e=0 is still large even if the order of the HO-CBFM increases. The size of overlapping region w_e affects the quality of the CBFs and

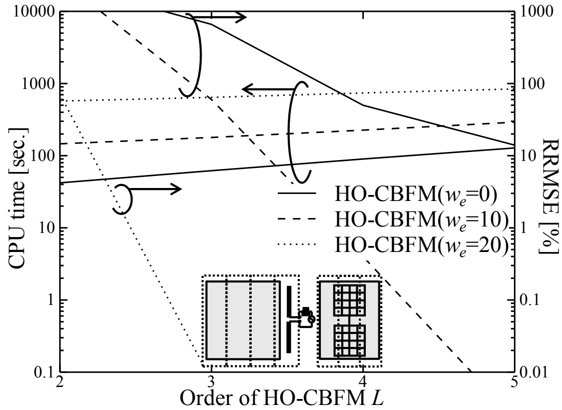

Fig. 5 The RRMSE and the CPU time of the HO-CBFM.

the reduced matrix obtained from CBFs without the overlapping region includes fictitious edge effects between the adjacent blocks. As a result, the accuracy of the HO-CBFM without the overlapping region becomes poor even if the order of the HO-CBFM increases. The CPU time of the HO-CBFM increases when the order of HO-CBFM increases. However, the CPU time of the HO-CBFM is sufficiently small in comparison with 1592 sec. of the CPU time of the full-wave simulation.

III. CONCLUSION

In this paper, the performance of the HO-CBFM was quantitatively evaluated for arbitrary block division. The HO-CBFM produces the current accurately without large compromise in the CPU time even if block division is arbitrary.

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