Optimum Block Division in CBFM for Fast MoM

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1. Introduction

Method of Moments (MoM) is one of the powerful method for numerical analysis of antennas or scatterers [1]. Recently, many fast MoM for large scale problems has been proposed and various large scattering problems have been analyzed [2], [3]. In general, there is trade-off between the accuracy of solution and CPU time in the fast MoM. Nevertheless, in practice, the pattern of the large scattering problems can be obtained accurately using the fast MoM because the scattering pattern is obtained by integration of current over an analysis model. On the other hand, it is difficult to obtain current or input impedance of an antenna in large radiation problems accurately by using the fast MoM because the current is evaluated by the weighted residual and it is not necessarily accurate at each point. Because the accuracy of the solution and CPU time of the fast MoM depend on some parameters, parameter optimization is indispensable to keep a balance between those of the fast MoM.

As a one of the fast MoM, CBFM (Characteristic Basis Function Method), which is a fast solver based on purely algebraic algorithm, has been proposed and applied to analysis of conducting problem [4]. In the CBFM, the original problem is decomposed into some blocks, where the block consists of some segments, and the size of the original problem is compressed into smaller one. The CBFM is one of the effective solvers but the most application of the CBFM has been limited to analysis of conducting problem without dielectric object. In this paper, the CBFM is applied to analysis of an antenna in the vicinity of a dielectric object. From the view point of the accuracy of the solution and CPU time, the optimum block division for the CBFM is demonstrated numerically.

2. Optimum block division in CBFM

In the CBFM, CPU time depends on the number of blocks M. As shown in the reference [5], the number of blocks M in the CBFM has alreeady been optimized from the view point of CPU time. The optimum number of blocks M_o is as follows.

$$M_o \approx 0.9N^{1/3}. \tag{1}$$

The mimimum CPU time of the CBFM is $O(N^{7/3})$ when $M = M_o$.

On the other hand, the accuracy of the CBFM depends on the block division. As an example for the block division, dipole antenna in the vicinity of dielectric object is shown in Fig. 1. Different three block divisions for the dipole antenna in the vicinity of the dielectric object are also shown in Fig. 2. In Fig. 2, segments of the dielectric object are only allocated to different blocks in block division (a) and (b) while all segments of the dipole antenna are allocated in the same block. The block for the antenna segments includes segments of the dielectric object in the vicinity of the dipole antenna in block division (a). On the other hand, the block for the antenna segments includes no segments of the dielectric object in block division (b). In block division (c), the antenna segments are allocated to different blocks.

The size of the overlapping region w_e shown in Fig. 2 is also important parameter. Since the size of the extended block is determined by w_e, the accuracy as well as CPU time of the CBFM depend on w_e. Please refer to [4], for details of the principle of the CBFM and physical meaning of the extended block.

3. Numerical Analysis

Optimum block division in the CBFM is numerically demonstrated in this section. As a simulation model, dipole antenna and infinitesimal slot antenna in the vicinity of a dielectric object are chosen, respectively. As is the case with the dipole antenna shown in Fig. 1, the infinitesimal slot antenna is also parallel to the dielectric object. Feeding segment of the infinitesimal slot antenna is parallel to the x-axis while feeding segment of the dipole antenna is parallel to the z-axis. Richmond's MoM is used and the antenna is divided into wire segments [1] and number of blocks $M = M_y M_z$. As shown in reference [6], a monopole segment is introduced to include the effect of a dielectric object accurately. In this paper, the work station with Intel Core i5 2.8 GHz CPU and 8 GB RAM is used for numerical simulation.

Figs. 3 and 4 show the input impedance of the antennas obtained by the CBFM with the block division (a). It is found that the the input impedance can be obtained accurately by the CBFM with the block division (a). In addition, the effect of the dielectric object to the input impedance is clearly appeared without overlapping region (i.e. $w_e = 0$). As shown in Fig. 2, segments of the dielectric object in the vicinity of the antenna are originally allocated in the block for the antenna in the block division (a). Therefore, the input impedance including shortning effect is obtained without overlapping region in the CBFM with the block division (a).

On the other hand, in the CBFM with the block division (b), the input impedance including shortning effect can be obtained when the overlapping region exists. As shown in Fig. 2, segments of the dielectric object in the vicinity of the antenna are originally allocated outside the block for the antenna in the block division (b). Therefore, in the CBFM with the block division (b), the input impedance including shortning effect is obtained only when the overlapping region exists, namely, the extended block includes segments of the dielectric object in the vicinity of the antenna.

From Figs. 7 and 8, it is found that the input impedance of the antennas obtained by the CBFM with the block division (c) is inaccurate. Especially, the input impedance of the dipole antenna shows huge discrepancy compared with that of the full-wave. In the CBFM with the block division (c), discontinuity occurs on the current path related to the input impedance when the block division is across the feeding segment. That is because large error occurs in the input impedance of the dipole antenna, namely, the block division is across the feeding segment along z-axis. On the other hand, the feeding segment of the infinitesimal slot antenna is along x-axis and error of the input impedance is small compared with that of the dipole antenna since the block division is not across the feeding segment. It is numerically confirmed that CPU time of the CBFM is $O(N^{7/3})$ when $M \approx M_o$ but omitted due to limitations of space.

4. Conclusion

In this paper, three block divisions in the CBFM were discussed for fast and accurate numerical analysis of the antenna in the vicinity of the dielectric object. From the results of the numerical simulation, it was found that the input impedance of the antenna can be obtained accurately when all of the antenna segments are allocated in the same block. It was shown that effect of the dielectric object to the input impedance of the antenna occurs when segments of the dielectric object in the vicinity of the antenna are allocated in the block for the antenna.

References

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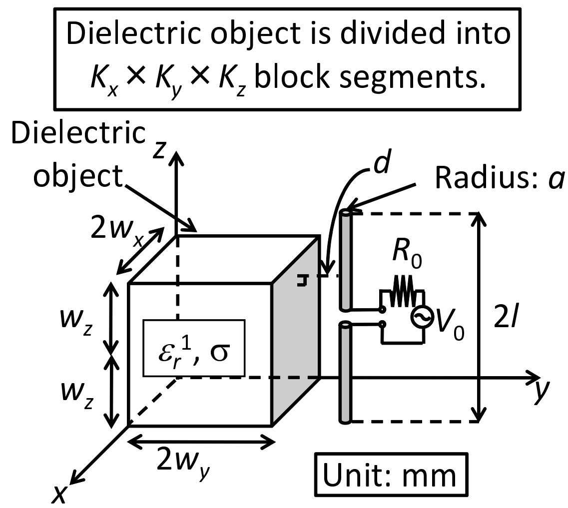
5. Figures and Tables



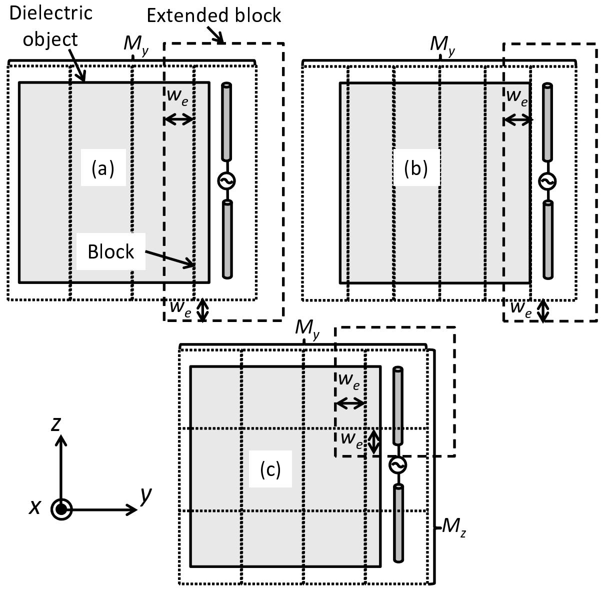
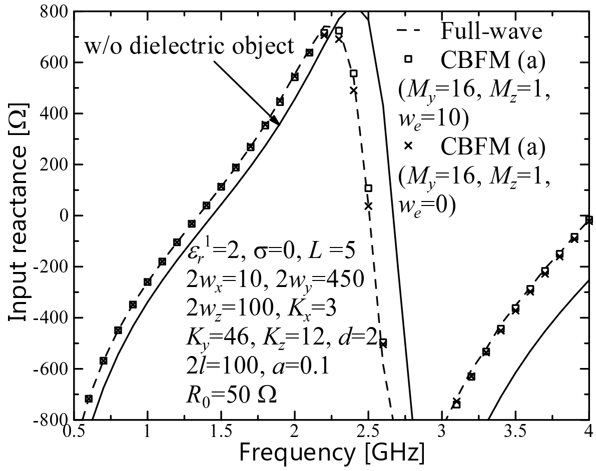


Figure 1: Dipole antenna in the vicinity of dielectric object.

Figure 2: Three block divisions.



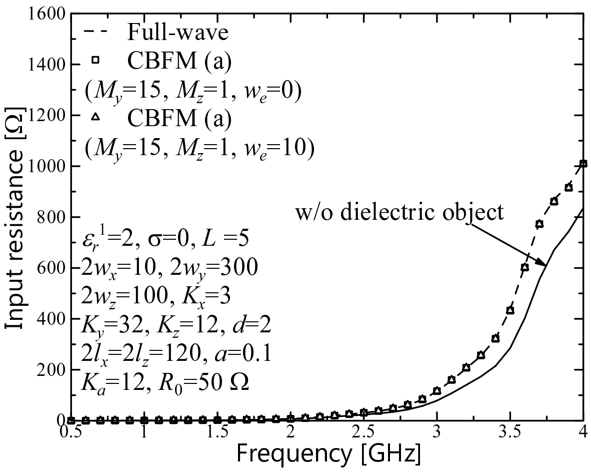


Figure 3: Input reactance: Dipole antenna, (a).

Figure 4: Input resistance: Infinitesimal slot antenna, (a).

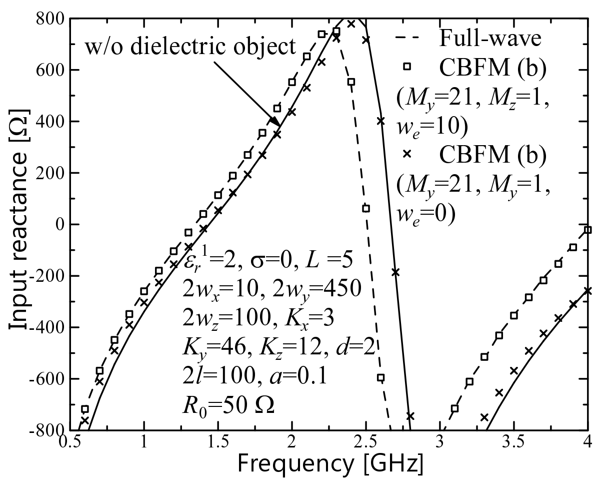


Figure 5: Input reactance: Dipole antenna, (b).

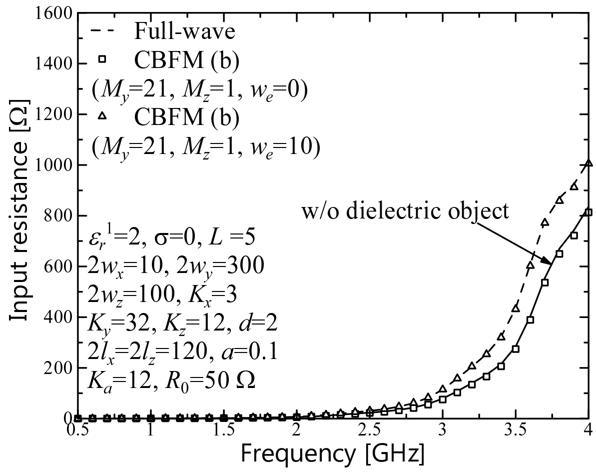


Figure 6: Input resistance: Infinitesimal slot antenna, (b).

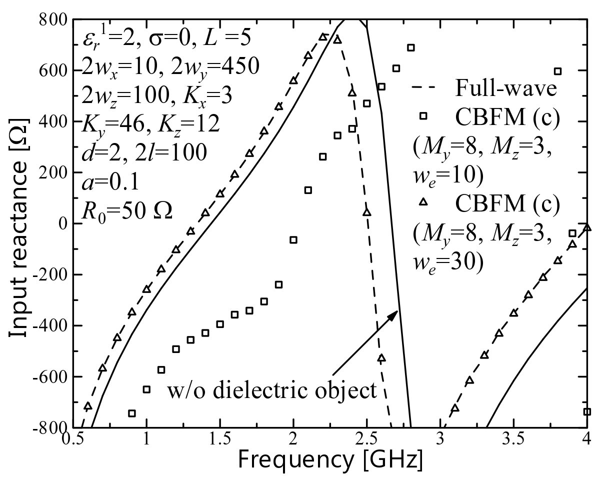


Figure 7: Input reactance: Dipole antenna, (c).

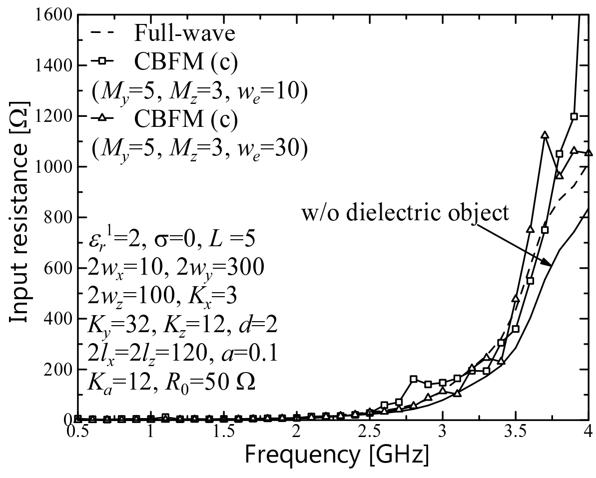


Figure 8: Input resistance: Infinitesimal slot antenna, (c).