The Nonstandard FDTD Method and Its Applications

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1. Introduction

The FDTD method was developed over 40 years ago, and evolved by many researchers. The FDTD method has been recognized as a powerful tool because of its versatility. The drawback of the method is that there are phase velocity errors when the spatial division by cells is insufficient. To overcome this difficulty, many approaches have been proposed, for example, higher-order methods such as FDTD (2,4), the method of modifying the speed of light, etc. Recently, Cole proposed the nonstandard FDTD (NS-FDTD) method [1,2]. Various extensions of the method have been carried out, and other similar methods have been developed by many researchers [3-9]. In this paper we review our research on the NS-FDTD method.

2. NS-FDTD Method

The NS-FDTD method is composed of two major procedures as shown in Fig. 1: a) making the numerical phase velocity isotropic. The numerical phase velocity c_{ni} has isotropic characteristics for any frequency compared to the numerical phase velocity c_n of FDTD because the method utilizes the values at 36 nodes in calculating the value at a single node, and b) increasing numerical phase velocity. The numerical phase velocity c_{nNS} of the NS-FDTD method is increased to the physical phase velocity c_0 by the nonstandard finite-difference (NS-FD) approach using correction functions of the form $s_\alpha(\Delta) = 2\sin(\alpha\Delta/2)/\alpha$. However, the NS-FD method is effective only at a single frequency; this makes the NS-FDTD method valid only at single frequency. Furthermore, only cubic cells were considered, and only the behavior of the electric field was described in [2]. The FDTD method can be recovered from the NS-FDTD method by setting the parameters which are associated with the FD Laplacians for isotropy and correction functions to zero.

3. Our NS-FDTD Research

We have extended the nonstandard FDTD method and applied the method to various problems [10]. Fig. 2 shows the diagram of our research on NS-FDTD method.

The NS-FDTD method is basically limited to a monochromatic frequency. Therefore, the method can be applied to the single frequency case. We have developed new methods, which allow a wideband analysis with NS-FDTD. In the new methods, a correction function is not used, but only the isotropic characteristic of the method is used.

In the new method, we can handle a pulse wave input directly. The effect of the correction function is transformed into time domain equation. So, the wideband simulation is possible although the method is limited to the lossless case.

There are two ways, a) formulation in the space domain, b) formulation in the time domain.

4. Applications

The method has been applied to various problems such as large-scale cavity and photonics, and effectiveness was shown. In the presentation, some results are demonstrated. First, we demonstrate the result for large-scale cavity analysis. Fig.3 shows a three-dimensional cavity model coated with a thin RAM. In the analysis, the concept of complex surface impedance boundary condition (CSIBC) was used to model thin RAM. Fig.4 shows comparison of monostatic RCS. The effectiveness of the method is shown. Next, we demonstrate the application of newly proposed wideband NS-FDTD (WNS-FDTD) method. Fig.5 shows the simulation results of a Gaussian pulse propagation. In the figure, it is shown that a pulse wave propagates without distortion. The figure shows the effectiveness of the WNS-FDTD method.

5. Conclusions

In this paper, we have briefly introduced our research on the NS-FDTD method. Now, we are investigating the development of wideband NS-FDTD method to treat pulse waves using the formulation in the time domain by using the similar way to treat the dispersive materials in the usual FDTD method.

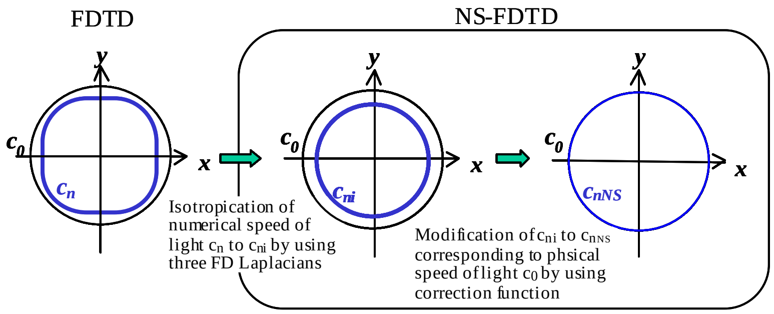


Figure 1: Schematic view of the NS-FDTD method.

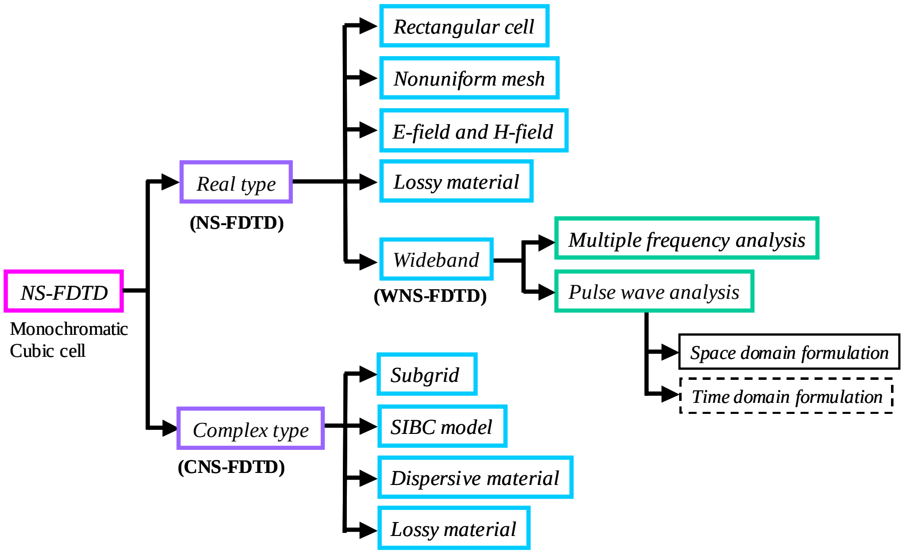


Figure 2: Diagram of our research on the NS-FDTD method.

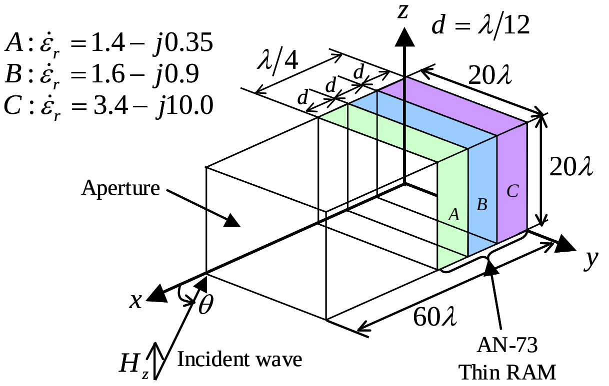


Figure 3: Three-dimensional cavity model coated with a thin RAM, AN-73. The cavity wall is a perfect electric conductor with infinitesimal thickness.

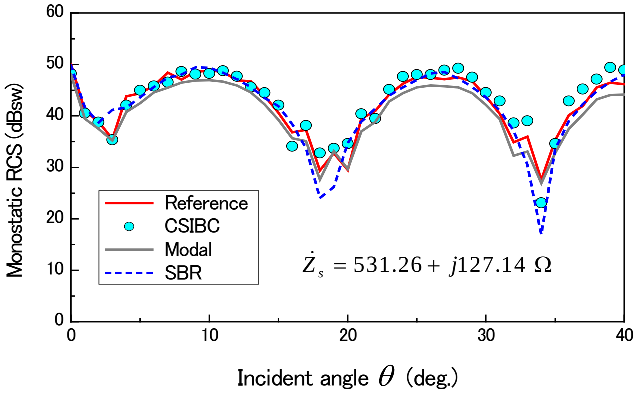
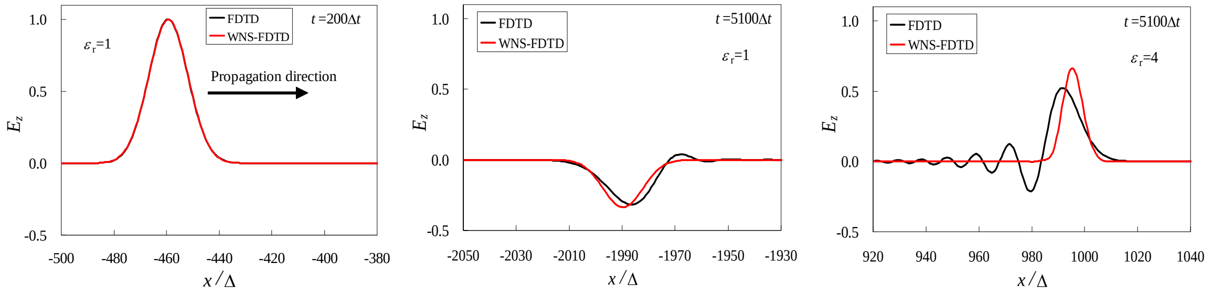


Figure 4: Comparison of monostatic RCS of the cavity with thin RAM shown in Fig.3 derived by various methods. $\Delta_{\text{CSIBC}} = \lambda/10$ for the CSIBC. The reference curve is the converged result by the standard FDTD method with $\Delta_{\text{FDTD}} = \lambda/60$.



(a) incident wave (b) reflected wave (c) transmitted wave

Figure 5: Simulation of a Gaussian pulse striking a dielectric material with $\varepsilon_r = 4$. Source at $x/\Delta = -500$, dielectric boundary at $x = 0$, $\Delta = 0.05$ m, $c_0\Delta t/\Delta = 0.5$.

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