Analysis of Specific Energy Loss by Fast Inverse Laplace Transform

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Abstract

In this manuscript, the novel computational technique of specific energy loss is proposed for pulse incidence. The specific energy until the observation time can be directly computed by our proposed method.

1. Introduction

Analysis of the specific energy absorbed into the biology medium is important for pulse incidence. Conventionally, the energy is computed by electromagnetic fields which are updated by time-domain solvers, such as the finite-difference time-domain (FDTD) method [1, 2]. To evaluate the specific energy, the sequential computation is widely used as shown in Figure 1.

It has been proposed to use the fast inverse Laplace transform (FILT) as a solver for transient electromagnetic problems [3-8]. However, the computation of specific energy until the observation time by using FILT has not been studied. It is needed the time response of electric field or evaluation of convolution integral in the complex frequency domain.

The novel computational technique based on FILT is proposed for evaluation of specific energy loss when pulse is impinged. The advantage of FILT is the solution at the specific observation time can be computed. The objective medium is assumed to be a non-dispersive lossy medium. The computational results show that the specific energy loss is obtained at the desired observation.

2. Formulation

Specific energy loss SA_{Lt} for the lossy media until observation time t is given by following equation [1]:

$$SA_{Lt}(t) = \frac{\sigma}{\rho} \int_0^t \boldsymbol{e}(t') \cdot \boldsymbol{e}(t') dt' \qquad (1)$$

Here, ρ is the mass density of medium, σ is conductivity, and $\boldsymbol{e}(t)$ is electric field in time domain.

Considering the Laplace transform to (1), specific energy loss in the complex frequency domain SA_{Ls} is written by [9, 10]

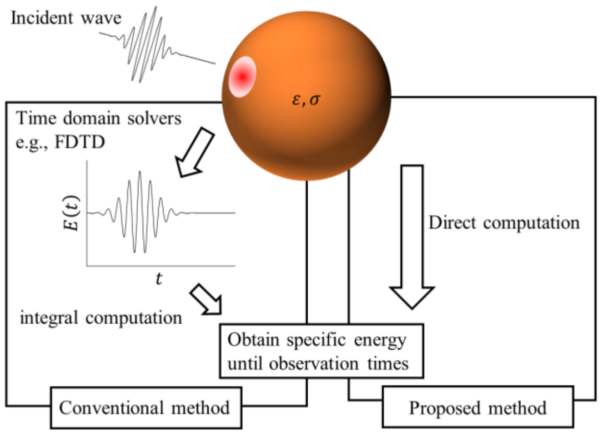

Figure 1. Computation method for specific energy absorption until a specific observation time. In the proposed method, it is directly computed without time response of fields.

$$SA_{Ls}(s) = \frac{\sigma}{\rho s} \frac{1}{2\pi i} \int_{c-i\infty}^{c+i\infty} \boldsymbol{E}(\tau) \cdot \boldsymbol{E}(s-\tau) d\tau \qquad (2)$$

Here, s is the complex frequency, $\boldsymbol{E}$ is the electric field in the complex frequency domain. The field can be transformed into the time domain by FILT.

FILT is the one of numerical inverse Laplace transformed method. The time domain function $f(t)$ can be obtained by that in the complex frequency domain $F(s)$.

$$f(t) \approx \frac{e^{\alpha}}{t} \sum_{n=1}^{K} (-1)^n \mathrm{Im}[F(s_n)] \qquad (3)$$

Here, K is the truncation number, α is the approximation parameter, s_n is the sampling point in the complex frequency domain and given by

$$s_n = \frac{\alpha + i(n-0.5)\pi}{t} \qquad (4)$$

3. Computational Results

To demonstrate the evaluation of specific energy loss computed by our proposed method, the electromagnetic scattering problems for lossy dielectric cylinder are solved. The computational model is shown in Figure 2. The relative permittivity ε_r = 52.729 and conductivity σ = 1.7388 with a frequency of 2.45 GHz [11]. The cylinder with the radius of 3 cm is modeled by staircase approximation. The space step size is 0.03/50 m. The absorbing boundary condition is assumed to be CPML (convolutional perfectly matched layer). The incident wave is linear polarized wave whose electric field has only y-component. For the incident waveform, the modulated gaussian pulse with the center frequency 2.45 GHz is assumed as shown in Figure 3. The electromagnetic fields in the complex frequency domain are obtained by the finite-difference complex-frequency-domain method [12, 13].

Figure 4 shows the specific electric loss until the observation time at the center of the cylinder. Compared with the FDTD results, our results are in good agreement. The electromagnetic field at the previous observation time is not required in the computation of (2) and (3). Therefore, our method can compute the electric energy until specific observation time. Sampling points can be arbitrary selectable.

4. Conclusions

The novel computational method for specific energy loss in the time domain is proposed. In our method, The electromagnetic field at the previous observation time is not required. Observation time can be arbitrary selectable

5. Acknowledgements

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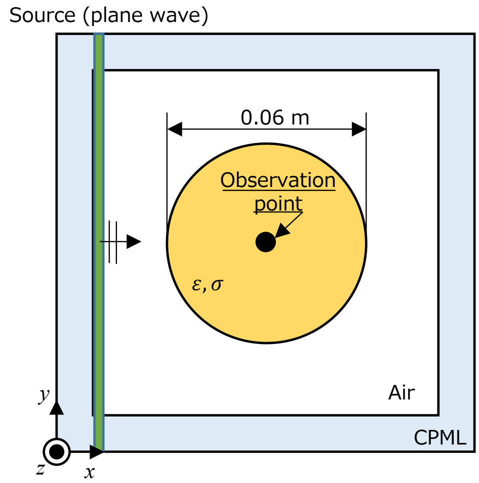

FIGURE 2. Computational model for demonstration of our method. The scatterer consists of lossy dielectric with the permittivity $\varepsilon = \varepsilon_r \varepsilon_0$ and conductivity σ.

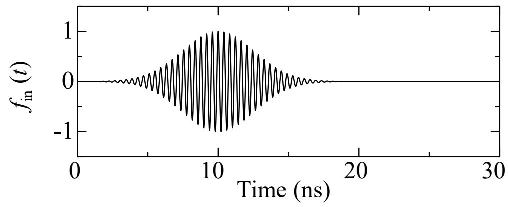

FIGURE 3. Incident waveform in time domain. The modulated gaussian pulse with center frequency f_c = 2.45 GHz is assumed.

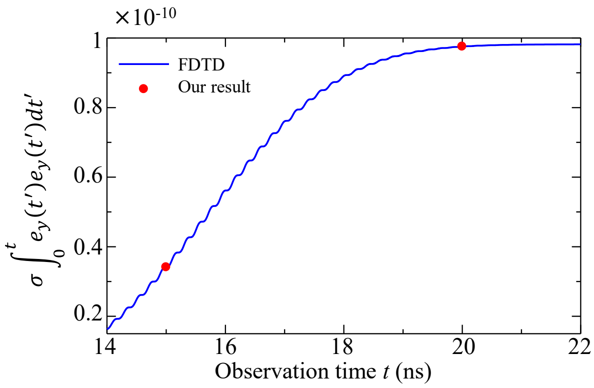

FIGURE 4. Time domain response of electric energy at observation point. The electric energy until observation can

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