

# **Finite Difference Time Domain**

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D. Saravanan

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Department of Physics  
Indian Institute of Technology Madras

# Introduction

To learn and do three-dimensional electromagnetic simulation using the finite-difference time-domain (FDTD) method.

Type of material:

1. Free space
2. Complex dielectric material
3. Frequency-dependent material

Some choice that have been made:

1. The use of Normalised Units Maxwell's equations have been normalized by substituting

$$\tilde{E} = \sqrt{\frac{\epsilon_0}{\mu_0}} E$$

this is a system similar to Gaussian units.

The reason for using it here is the simplicity in the formulation. The  $E$  and  $H$  fields have the same order of magnitude. This has an advantage in formulating the PML.

2. Maxwell's Equations with the Flux Density Time-domain Maxwell's equations from which the FDTD formulation is developed

$$\frac{\partial E}{\partial t} = \frac{1}{\epsilon_0} \nabla \times H$$

$$\frac{\partial H}{\partial t} = -\frac{1}{\mu_0} \nabla \times E$$

straight forward formulation

$$\frac{\partial D}{\partial t} = \nabla \times H$$

$$D = \epsilon_0 \epsilon_r^* E$$

$$\frac{\partial H}{\partial t} = -\frac{1}{\mu_0} \nabla \times E$$

formulation using the flux density in this formulation, it is assumed that the material has a circulated magnetic permeability, that is,  $\mu_r = (1/\epsilon_r) \mu_0$

## Pulse propagating in free space in one dimension

Time-dependent Maxwell's curl equations for free space:

$$\frac{\partial E}{\partial t} = \frac{1}{\epsilon_0} \nabla \times H$$

$$\frac{\partial H}{\partial t} = -\frac{1}{\mu_0} \nabla \times E$$

simple one-dimensional case:

$$\frac{\partial E_x}{\partial t} = -\frac{1}{\epsilon_0} \frac{\partial H_y}{\partial z}$$

$$\frac{\partial H_y}{\partial t} = -\frac{1}{\mu_0} \frac{\partial E_x}{\partial z}$$

