Finite Difference Time Domain (FDTD) Technique

What is FDTD?

Finite-Difference Time-Domain (FDTD) is a popular electromagnetic modeling techniques. It is easy to understand, easy to implement in software, and since it is a time-domain technique it can cover a wide frequency range with a single simulation run.

The FDTD method belongs in the general class of differential time domain numerical modeling methods. Maxwell's (differential form) equations are simply modified to central-difference equations, discritized, and implemented in software. The equations are solved in a leap-frog manner; that is, the electric field is solved at a given instant in time, then the magnetic field are solved at the next instant in time, and the process is repeated over and over again.

How does FDTD work?

When Maxwell's differential form equations are examined, it can be seen that the time derivative of the E field is dependent on the Curl of the H field. This can be simplified to state that the change in the E field (the time derivative) is dependent on the change in the H field across space (the Curl). This results in the basic FDTD equation that the new value of the E field is dependent on the old value of the E field (hence the difference in time) and the difference in the old value of the H field on either side of the E field point in space. Naturally this is a simplified description, which has omitted constants, etc. But the overall effect is as described.

The H field is found in the same manner. The new value of the H field is dependent on the old value of the H field (hence the difference in time), and also dependent on the difference in the E field on either side of the H field point.

This description holds true for 1-d, 2-d, and 3-d FDTD techniques. When multiple dimensions are considered, the difference in space must be considered in all appropriate dimensions.

Using FDTD

In order to use FDTD a computational domain must be established. The computational domain is simply the ?space? where the simulation will be performed. The E and H fields will be determined at every point within the computational domain. The material of each cell within the computational domain must be specified. Typically, the material will be either free-space (air), metal (perfect electrical conductors (PEC)), or dielectrics, any material can be used, as long as the permeability, permittivity, and conductivity can be specified.

Once the computational domain and the grid material is established, a source is specified. The source can be an impinging plane wave, a current on a wire, or an electric field between metal plates (basically a voltage between the two plates), depending on the type of situation to be modeled.

Since the E and H fields are determined directly, the output of the simulation is usually the E or H field at a point or a series of point within the computational domain.

What are the strengths of the FDTD Technique?

Every modeling technique has some strengths and some weaknesses. Some types of models were a given technique will excel and some types of models were the same technique will have difficulty (if it is even possible to use) performing rapidly and accurately.

FDTD is a very versatile modeling technique. It is a very intuitive technique, so users can easily understand how to use it, and know what to expect from a given model.

FDTD is a time domain technique, and when a time-domain pulse (such as a Gaussian pulse) is used as the source pulse, then a wide frequency range is solved with only one simulation. This is extremely useful in applications where resonant frequencies are not known exactly, or anytime that a broadband result is desired.

Since FDTD is a time-domain technique which finds the E/H fields everywhere in the computational domain, it lends itself to providing animation displays (movies) of the E/H field movement throughout the model. This type of display is extremely useful to understanding exactly what is going on in the model, and to help insure that the model is working correctly.

FDTD allows the user to specify the material at all points within the computational domain. All materials are possible and dielectrics, magnetic materials, etc. can be simply modeled without the need to resort to ?work arounds? or ?tricks? to model these materials.

FDTD allows the effects of apertures to be determined directly. Shielding effects can be found, and the fields both inside and outside a structure can be found directly.

FDTD provides the E and H fields directly. Since most EMI/EMC modeling applications are interested in the E/H fields, it is best that no conversions must be made after the simulation has run to get these values.

Since the computational domain must end at some point (or we would be modeling the entire universe!!), a boundary must be established. FDTD has a number of very good absorbing boundary conditions to chose from (and some that are not quite so good). The absorbing boundary condition (ABC) simulates the effect of free space beyond the boundary forever.

What are the weaknesses of the FDTD Technique?

Since FDTD requires that the entire computational domain be gridded, and these grids must be small compared to the smallest wavelength and smaller than the smallest feature in the model, very large computational domains can be developed, which result in very long solution times. Models with long, thin features, (like wires) are difficult to model in FDTD because of the excessively large computational domain required.

FDTD finds the E/H fields directly everywhere in the computational domain. If the field values at some distance (like 10 meters away) are desired, it is likely that this distance will force the computational domain to be excessively large. Far field extensions are available for FDTD, but require some amount of post processing.
