REVIEW OF ELECTROMAGNETIC COMPUTATIONAL ANALYSIS METHODS USED FOR METAMATERIAL BASED ANTENNA

Sandeep Sharma[1], Dr.M.R.Tripathy[2]

[1]*Department of Electronics and Communication,*

Bhagwan Parshuram Institute of Technology, (GGSIPU) Delhi (India)

[2]*Department of Electronics and Communication*

Amity School of Engg. and Technology, Noida, U.P (India)

ABSTRACT

This paper provides a review of most commonly used numerical methods for computational electromagnetic which have been used for analysis of metamaterial based antenna. It gives mainly the strengths and weakness of given methods.

IndexTerms: Computational Electromagnetic, Metamaterials, Numerical Methods

I. INTRODUCTION

With the increasing the demand of enhancing the performance of small antennas using metamaterials, search has been pursued actively for different ways to increase directivity, reduce side lobes and back lobe levels, improve the bandwidth. Metamaterials belongs to the group of artificial media which became one of the most important topics of classical electromagnetic theory in last two decades. The permittivity, permeability and conductivity of a material characterize its ability to interact with an electromagnetic field. In nature magnitude of these three quantities are restricted to mostly positive values. Metamaterials are the artificially produced composite media exhibiting electromagnetic responses that natural material does not provide.

II. REVIEW OF COMPUTIONAL METHODS

In the following section the mostly used computational electromagnetic numerical methods are presented, their strengths and weaknesses are also stated.

2.1 AEM (Asymptotic-Expansion Methods)

AEM are high frequency methods. They are only accurate when the dimensions of the objects being analyzing are large compared to the wavelength of the field. Physical Optics (PO) approximation is efficient method for analyzing large scatters. It is a current-based method in which the physical optics approximation is used to obtain the current density induced on a surface. Geometrical Optics (GO) or Geometrical Optics with Aperture Integration (GO/AI) is a ray-based method. In GO analysis geometrical optics techniques (ray tracing) are used to set up equivalent currents on an aperture plane which is normal to the axis of the reflector.

Strength

a) works well for large, smooth surfaces with low curvature

b) Ignore the edge diffractions

c) Integration over the aperture plane can be performed with ease

Weakness: integration of the reflector may be complicated

2.2 BEM (Boundary-Element Methods)

The first step in a BEM is to represent the problem geometry as a distribution of equivalent surface currents in a homogeneous medium (usually free space). The fields exterior to an object consist of fields incident on the object, fields reflected from the object and fields emanating from the object. Since the forms are only valid for current distributions in a uniform homogeneous medium, all objects in the problem space must be removed and replaced with (initially unknown) surface currents conforming to their boundaries.

Strength

a) good for modeling unbounded problems

b) Good for modeling metal plates and thin wires

c) good for modeling structure with lumped circuit elements

Weakness: homogeneous/complex structure may be complicated

2.3 . FDTD (Finite Difference Time Domain Method)

FDTD method is a direct solution of Maxwell's time dependent curl equations. It uses simple central-difference approximations to evaluate the space and time derivatives. Because the basic elements are cubes, curved surfaces on a scatterer must be staircase.

Strength

a) ability to obtain wideband results using a transient excitation in one simulation

b) Great flexibility, good at modeling inhomogeneous or complex materials

c) quick implementation on massively parallel computers

Weakness

a) staircased approximation may lead to significant errors

b) Uniform cells must be small enough to model necessary detail, but still fill the entire volume

c) Dispersion errors for too large time steps

d) Difficult to model thin wires

2.4 FEM (Finite Element Method)

FEM techniques always solve a differential equation. The domain problem must be finite and bounded, FEM code divide it into small elements. To form a linear system of equations, the governing differential equation and associated boundary conditions are converted to an integro-differential form using either a variational method

Strength

a) good at modeling inhomogeneous or complex materials

b) Good at modeling problems that combine small detailed geometries with larger objects

c) Good at modeling structures in the resonant cavities or waveguides

Weakness

a) absorbing boundary required for modeling unbounded (radiation) problems

b) Difficult to model thin wires accurately

2.5 FVTD (Finite Volume Time Domain Method)

FVTD is based on Maxwell's curl equations in their conservative form [3]

$$\iiint_{v} B dv = \iint n \times E da \quad (1)$$

Where ∂v represents the boundary enclosing V. The FVTD method solves the above form of Maxwell's equations numerically by integration over small elementary volumes.

Strength

a) well suited for implementation with unstructured meshes

b) Good potential for the simulation of a variety of complex electromagnetic problems

c) Especially well suited for microwave device simulations

2.6 MoM (Method of Moment)

MoM is also called the Method of Weighted Residuals. It is a technique for solving linear equations of the form

$$L(\emptyset)=f \quad (2)$$

where L(Ø) is a linear operator, f is a known excitation or forcing function, and Ø is an unknown quantity. This linear system of equations has the form

$$[Z][A]=[B] \quad (3)$$

Where the elements of [Z] are known quantities that can be calculated from the linear operator and the chosen basis and weighting functions. The elements of [B] are determined by applying the weighting functions to the known forcing function. The unknown elements of [A] can be found by solving the matrix equation.

Strength

a) Can be used to solve a wide range of equations involving linear operations including integral and differential equations

b) Widely used to solve equations derived from Maxwell's equations

2.7 TDM (Time Domain Method of Moment)

Like the method of moments in the frequency domain, the MoM-TD method discretizes the scatterers or targets into segments or patches. The time axis is then divided into equal increments or time steps. The temporal basis functions are generally versions of the main function shifted by a certain number of time steps. It leads to a set of matrix equations that can be written as

[V]= [Z][I]

The vector [V] contains the known incident field quantities and the terms of the Z-matrix are functions of the geometry. The unknown coefficients of the induced current are the terms of the [I] vector or a weighted-residual (moment) method

Strength

a) Especially well suited for dealing with fast transient electromagnetic fields incident

b) Especially well suited for dealing with from structures in free space.

Weakness

a) not very effective when applied to arbitrary configurations with complex geometries or with inhomogeneous dielectrics

b) Not well-suited for analyzing the interior of conductive enclosures or thin plates with wire attachments on both sides

2.8 HLM (Transmission Line Matrix Method)

TLM method was introduced by Johns [1] in this method instead of interleaving E-field and H-field grids a single grid established and the nodes of this grid are interconnected by virtual transmission lines. Excitations at the source nodes propagate to adjacent nodes through these transmission lines at each time step

Strength

a) analysis is performed in the time domain and the entire region of the analysis is gridded

b) Complex, nonlinear materials are readily modeled

c) Impulse responses and the time-domain behavior of systems are determined explicitly

Weakness

require more computer memory per node than FDTD

III. CONCLUSION

Each method has advantages and disadvantages. In real world it is difficult to find a method for all problems' aspects, thus hybrid like FEM/BEM, MOM/PO, or FEM/PO is used.

REFERENCES

[1] P. B. Johns, R. L. Beurle, "Numerical solution of 2-D scattering problems using a transmission line matrix" Proc.Inst.Elec.Eng.,vol. 118, no. 9, , 1971, pp. 1203-1208

[2] J. F. Kauffman, W. F. Croswell, L. J. Jowers, "Analysis of the radiation patterns of reflector antennas," IEEE Trans. Antennas Propagat., vol. 24, no. l, 1976, pp. 53-65.

[3] P. Bonnet, X.Ferrierers, B.Michielsen, P. koltz "Time domain Electromagnetics, Academic Press" 1997. Ch.9.pp.307-367.

[4] K. S.Yee. "Numerical solution of initial boundary value problems involving Maxwell equation in isotropic media" IEEE Trans. Antennas Propagat.,1966 vol. 14, no. 4, pp. 302-307.

[5] KOCK.W.P,"Metal lens antenna" Proc.Inst.Elec.Eng.,vol. 118, no. 9, , 1946, vol-34 pp. 828-836

[6] Rot man, W. "Plazma simulation by artificial dielectric and parallel plate media" IRE Trans. Antennas Propagat., vol. 10, pp. 82-95.

[7] BZrillion, L. "Wave propagation in periodic structures, McGraw Hill,1946

[8] IYER. A... Eleftheriads.E.V "Negative refractive index metamaterials supporting 2-D wave." IEEE-MTT Int. Symp scattle WA WA2002Trans.vol.2, pp.412-415