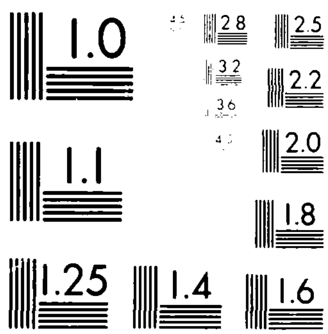
AD-A170 475 FIRST INTERIM REPORT (0001AA) ON THE WORK PERFORMED BY 1/1
NUMERICAL COMPUTAT..(U) NUMERICAL COMPUTATION CORP
STONY BROOK NY 10 FEB 86 N00014-68-C-0109

UNCLASSIFIED F/G 12/1 NL




MICROCOPY RESOLUTION TEST CHART

Contract No. N00014-86-C-0109

First Interim Report (0001AA) on the work performed by Numerical Computation Corp. during the period of December 15, 1985 - February 10, 1986.

The scattering of normal incident time-harmonic TEM electromagnetic wave by a cylindrical target with axis along z-direction is considered, e.g., $\underline{E} = E_x \underline{i}_x + E_y \underline{i}_y$ and $\underline{H} = H_z \underline{i}_z$, where $\underline{i}_a$ is the unit vector in the $\underline{a}$-direction. The whole space domain $\Omega$ is divided into three connected but non-overlapping sub-domains, the interior region $\Omega_1$ representing the target and possessing a non-orthogonal cylindrical grid system centered in itself, the intermediate region $\Omega_2$ representing the free space just outside of the target and possessing the same grid system, and the exterior region $\Omega_3$ representing the far-field free space but truncated at a large distance away from the target and possessing the standard orthogonal cylindrical grid system (Fig. 1).

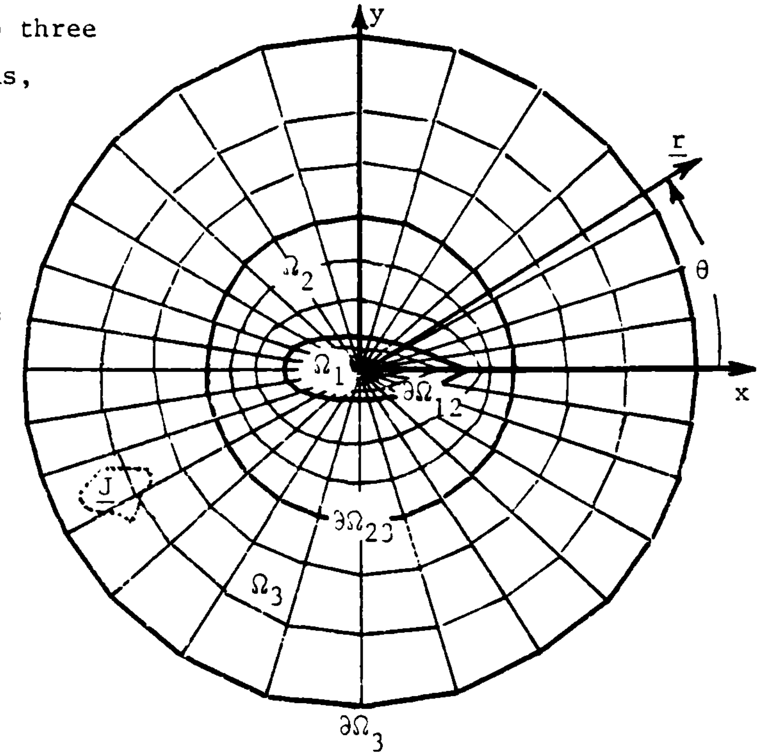



Fig. 1

To facilitate the discretization of the Maxwell's equations on the non-orthogonal grid system, the following integral forms of the Maxwell's equations are used.

$$\begin{cases} \oint \underline{E}_1 \cdot d\underline{\ell} = i\omega \oiint \underline{\underline{\mu}}\,\underline{H}_1 \cdot d\underline{s}, \\ \oint \underline{H}_1 \cdot d\underline{\ell} = \oiint (\underline{\underline{\sigma}} - i\omega\underline{\underline{\varepsilon}}) \cdot \underline{E}_1 \cdot d\underline{s}, \end{cases} \quad \underline{x} \in \Omega_1,$$

$$\begin{cases} \oint \underline{E}_2 \cdot d\underline{\ell} = i\omega \oiint \mu_o \underline{H}_2 \cdot d\underline{s}, \\ \oint \underline{H}_2 \cdot d\underline{\ell} = -i\omega\varepsilon_o \oiint \underline{E}_2 \cdot d\underline{s}, \end{cases} \quad \underline{x} \in \Omega_2,$$

$$\begin{cases} \oint \underline{E}_3 \cdot d\underline{\ell} = i\omega\mu_o \oiint \underline{H}_3 \cdot d\underline{s}, \\ \oint \underline{H}_3 \cdot d\underline{\ell} = \oiint (\underline{J} - i\omega\varepsilon_o \underline{E}_3) \cdot d\underline{s}, \end{cases} \quad \underline{x} \in \Omega_3,$$

with boundary conditions at $\partial\Omega_{12}$,

$$\underline{n} \times \underline{E}_2 = \underline{n} \times \underline{E}_1, \qquad \underline{n} \times \underline{H}_2 = \underline{n} \times \underline{H}_1,$$

$$\varepsilon_o \underline{E}_2 \cdot \underline{n} = \underline{\underline{\varepsilon}} \underline{E}_1 \cdot \underline{n}, \qquad \mu_o \underline{H}_2 \cdot \underline{n} = \underline{\underline{\mu}} \underline{H}_1 \cdot \underline{n}, \tag{2}$$

and the asymptotic terminating condition at $\partial\Omega_3$,

$$\underline{n} \times \underline{E}_3 = (\mu_o/\varepsilon_o)^{\frac{1}{2}}(\underline{n} \times \underline{H}_3), \tag{3}$$

where $\underline{n}$ is the unit normal vector at the interfaces and

$$\underline{\underline{\varepsilon}} = \begin{bmatrix} \varepsilon_x & 0 & 0 \\ 0 & \varepsilon_y & 0 \\ 0 & 0 & \varepsilon_z \end{bmatrix}, \qquad \underline{\underline{\mu}} = \begin{bmatrix} \mu_x & 0 & 0 \\ 0 & \mu_y & 0 \\ 0 & 0 & \mu_z \end{bmatrix}.$$

Eq. (1) is discretized by using the rectangle rule on the line integral around the edges of all incremental quadrilateral defined by the grid system. Let each grid point of the non-orthogonal polar grid system be denoted by $(r_{ij}, \theta_j) \equiv (i,j)$, where "i" and "j" denote the i-th closed cylindrical grid line and the j-th radial grid line respectively; let the center of the quadrilateral defined by $(i,j)$, $(i+1,j)$, $(i,j+1)$ and $(i+1,j+1)$ be denoted by $(i+\frac{1}{2},j+\frac{1}{2})$; let $\Delta\ell_{\alpha,\beta}$ be the incremental distance between the points $\alpha$ and $\beta$, and $\Delta A_\gamma$ be the area of the incremental quadrilateral centered at $\gamma$. Moreover, let $i = 1,2,3,\ldots,I$, and $j = 1,2,3,\ldots,J$.

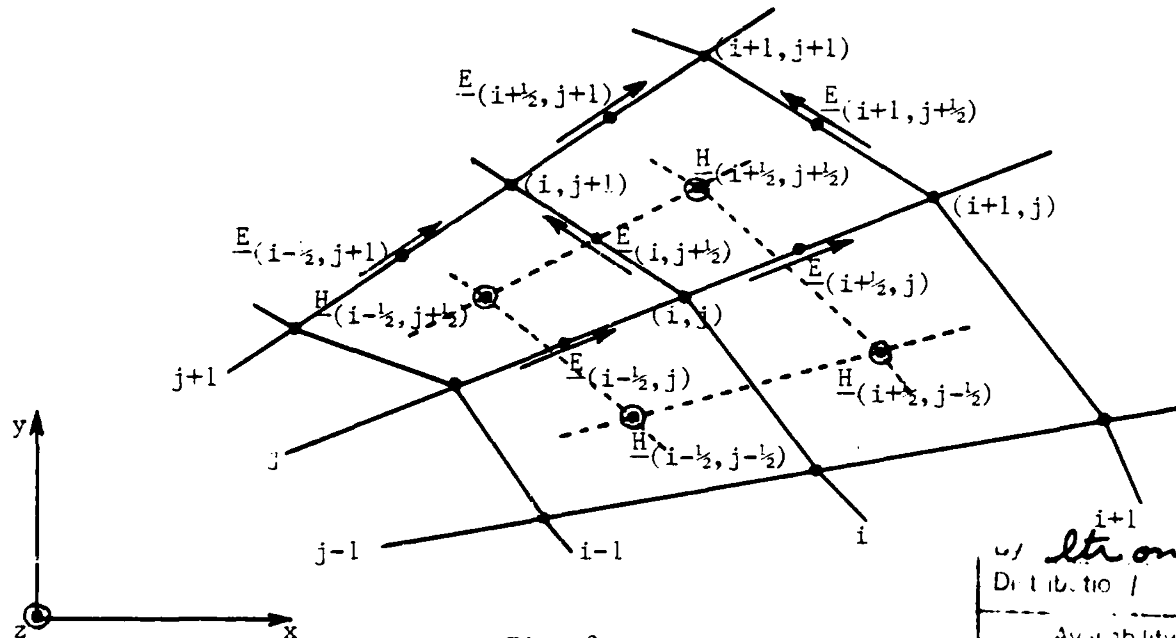



Fig. 2

In the neighborhood of $(i,j)$ of $\Omega_i$, the typical discretized (1) is

$$E_{i+\frac{1}{2},j}(r_{i+1,j}-r_{i,j}) - E_{i+\frac{1}{2},j+1}(r_{i+1,j+1}-r_{i,j+1})$$

$$+ E_{i+1,j+\frac{1}{2}}\Delta\ell_{i+1,j+\frac{1}{2}} - E_{i,j+\frac{1}{2}}\Delta\ell_{i,j+\frac{1}{2}} = i\omega\mu_{z,i+\frac{1}{2},j+\frac{1}{2}} H_{i+\frac{1}{2},j+\frac{1}{2}}\Delta A_{i+\frac{1}{2},j+\frac{1}{2}},$$

$$(H_{i-\frac{1}{2},j+\frac{1}{2}} - H_{i+\frac{1}{2},j+\frac{1}{2}})\frac{(r_{i,j+1}+r_{i,j})4\sin\frac{1}{2}(\theta_{j+1}-\theta_j)}{r_{i+1,j+1}+r_{i+1,j}-r_{i-1,j+1}-r_{i-1,j}}$$

$$= J_{i,j+\frac{1}{2}}\{\Delta\ell_{i,j+\frac{1}{2}}E_{i,j+\frac{1}{2}} - \tfrac{1}{4}(E_{i-\frac{1}{2},j}+E_{i+\frac{1}{2},j}+E_{i-\frac{1}{2},j+1}+E_{i+\frac{1}{2},j+1})(r_{i,j+1}-r_{i,j})\cos\tfrac{1}{2}(\theta_{j+1}-\theta_j)\}$$

$$- i\omega\{\Delta\ell_{i,j+\frac{1}{2}}E_{i,j+\frac{1}{2}}(\varepsilon_{x,i,j+\frac{1}{2}}\sin^2\theta_{j+\frac{1}{2}} + \varepsilon_{y,i,j+\frac{1}{2}}\cos^2\theta_{j+\frac{1}{2}})$$

$$- \tfrac{1}{4}(E_{i-\frac{1}{2},j}+E_{i+\frac{1}{2},j}+E_{i-\frac{1}{2},j+1}+E_{i+\frac{1}{2},j+1})$$

$$\cdot(\varepsilon_{x,i,j+\frac{1}{2}}(r_{i,j+1}\sin\theta_{j+1}-r_{i,j}\sin\theta_j)\sin\theta_{j+\frac{1}{2}}$$

$$+ \varepsilon_{y,i,j+\frac{1}{2}}(r_{i,j+1}\cos\theta_{j+1}-r_{i,j}\cos\theta_j)\cos\theta_{j+\frac{1}{2}})\} .$$

In this way, the most natural finite difference discretization of the Maxwell's equations on a staggered grid system (Fig. 2) is obtained.

If the differences of the material properties spread linearly across a grid zone instead of across the interface, then there is no need to impose the boundary conditions (2) at the material interface, because the boundary condition for the tangential component of $\underline{E}$ is satisfied automatically and the other three boundary conditions are also satisfied automatically but approximately. In this way, there is no cumbersome instruction and treatment at the interface to slow down the calculation on the computer. The discretization of the terminating condition (3) is

$$E_{I,j+\frac{1}{2}} = (\mu_o/\varepsilon_o)^{\frac{1}{2}} H_{I-\frac{1}{2},j+\frac{1}{2}},$$
$$j = 1,2,3,\ldots,J.$$

At this moment, we have completely discretizated (1)-(3) according to the above description. We are trying to organize these complex algebraic equations for the purpose of programming.

END

DTIC

8-86