Study notes, ECE 3343 EM, Northeastern Univ. Boston

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Abstract

these are course notes for EM 1, course taken at northeastern univeristy in the winter of 1993

Contents

1 Maxwell equations

1.1 Maxwell time domain equations

$$
\begin{aligned}
-\nabla \times \overline{\mathcal{E}} &= \frac{\partial \overline{\mathcal{B}}}{\partial t} + \overline{\mathcal{M}}^{i} \\
\nabla \times \overline{\mathcal{H}} &= \frac{\partial \overline{\mathcal{D}}}{\partial t} + \overline{\mathcal{J}}^{c} + \overline{\mathcal{J}}^{i} \\
\nabla \cdot \overline{\mathcal{B}} &= 0 \\
\nabla \cdot \overline{\mathcal{D}} &= q
\end{aligned}
$$

1.1.1 equation of continuity

$$
\nabla \cdot \overline{\mathcal{J}} = -\frac{\partial q_v}{\partial t}
$$

1.2 Maxwell integral form of time domain equations

$$
\begin{aligned}
\oint \overline{\mathcal{E}} \cdot d\mathbf{l} &= -\frac{d}{dt} \iint \overline{\mathcal{B}} \cdot d\mathbf{s} \\
\oint \overline{\mathcal{H}} \cdot d\mathbf{l} &= \frac{d}{dt} \iint \overline{\mathcal{D}} \cdot d\mathbf{s} + \iint \overline{\mathcal{J}} \cdot d\mathbf{s} \\
\iint \overline{\mathcal{B}} \cdot d\mathbf{s} &= 0 \\
\iint \overline{\mathcal{D}} \cdot d\mathbf{s} &= \iiint q_v d_\tau
\end{aligned}
$$

1.3 Relation of field to circuit quantities

$$
\begin{aligned}
v\,(\text{voltage in volts}) &= \int \overline{\mathcal{E}} \cdot d\mathbf{l} \\
i\,(\text{current in amp}) &= \iint \overline{\mathcal{J}} \cdot d\mathbf{s} \\
q\,(\text{chanrge in coulombs}) &= \iiint q_v d_\tau \\
\psi\,(\text{magnetic flux in weber}) &= \iint \overline{\mathcal{B}} \cdot d\mathbf{s} \\
\psi^e\,(\text{electric flux in coulombs}) &= \iint \overline{\mathcal{D}} \cdot d\mathbf{s} \\
u\,(\text{magnetomotive force in amp}) &= \int \overline{\mathcal{H}} \cdot d\mathbf{s}
\end{aligned}
$$

1.4 relations of a complex domain to time domain

$$
\overline{\mathcal{A}} = \sqrt{2} Re \left(\mathbf{A} e^{j\omega t} \right)
$$

1.5 Maxwell equations in complex form

$$
\begin{aligned}
-\nabla \times \mathbf{E} &= j\omega \widehat{\mu}(\omega) \mathbf{H} + \mathbf{M}^i = \widehat{z}(\omega) \mathbf{H} + \mathbf{M}^i \\
\nabla \times \mathbf{B} &= j\omega \widehat{\epsilon}(\omega) \mathbf{E} + \mathbf{J}^c = j\omega \widehat{\epsilon}(\omega) \mathbf{E} + \widehat{\sigma}(\omega) \mathbf{E} = (j\omega \widehat{\epsilon}(\omega) + \widehat{\sigma}(\omega)) \mathbf{E} = \widehat{y}(\omega) \mathbf{E}
\end{aligned}
$$

in free space

$$
\begin{aligned}
\widehat{y}(\omega) &= j\omega \epsilon_o \\
\widehat{z}(\omega) &= j\omega \mu_o
\end{aligned}
$$

for all frequencies and all field intensities.

for non-magnetic metals

$$
\begin{aligned}
\widehat{y}(\omega) &= \sigma + j\omega \epsilon_o \\
\widehat{z}(\omega) &= j\omega \mu_o
\end{aligned}
$$

in ferromagnetic metals

$$
\begin{aligned}
\widehat{y}(\omega) &= \sigma + j\omega \widehat{\epsilon} \\
\widehat{z}(\omega) &= j\omega \widehat{\mu}
\end{aligned}
$$

in good dielectric (nonmagnetic dielectric)

$$
\begin{aligned}
\widehat{y}(\omega) &= j\omega \widehat{\epsilon} \\
\widehat{z}(\omega) &= j\omega \mu_o
\end{aligned}
$$

where

$$\widehat{\epsilon}(\omega) = \epsilon^{'} - j\epsilon^{''} = |\widehat{\epsilon}|\, e^{-j\delta}$$

where $\epsilon^{'}$ called a-c capacitivity, $\epsilon^{''}$ called dielectric loss factor, δ called dielectric loss angle.

and

$$\widehat{\mu}(\omega) = \mu^{'} - j\mu^{''} = |\widehat{\mu}|\, e^{-j\delta_m}$$

where $\mu^{'}$ called a-c inductitvity, $\mu^{''}$ called magnetic loss factor, δ_m called magnetic loss angle.

2 some relations

$$k = k^{'} - jk^{''}$$

where K is the wave number

$$k = \sqrt{-\widehat{zy}}$$

and

$$\eta = \mathcal{R} + j\mathcal{X}$$

where η is the intrinisc impedence. for air

$$k = \omega\sqrt{\mu\epsilon}$$
$$\eta = \sqrt{\frac{\mu}{\epsilon}}$$

speed of light

$$c = \frac{1}{\sqrt{\epsilon_o\mu_o}} = 3 \times 10^8 m/s$$

wave impedence, is the ratio of components of **E** to components of **H**

interinsic wave length $\lambda = \frac{2\pi}{k}$