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

$$-\nabla \times \overline{\mathcal{E}} = \frac{\partial \overline{\mathcal{B}}}{\partial t} + \overline{\mathcal{M}}^i$$

$$\nabla \times \overline{\mathcal{H}} = \frac{\partial \overline{\mathcal{D}}}{\partial t} + \overline{\mathcal{J}}^c + \overline{\mathcal{J}}^i$$

$$\nabla \cdot \overline{\mathcal{B}} = 0$$

$$\nabla \cdot \overline{\mathcal{D}} = q$$

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

$$\oint \overline{\mathcal{E}} \cdot d\mathbf{l} = -\frac{d}{dt}\iint \overline{\mathcal{B}} \cdot d\mathbf{s}$$

$$\oint \overline{\mathcal{H}} \cdot d\mathbf{l} = \frac{d}{dt}\iint \overline{\mathcal{D}} \cdot d\mathbf{s} + \iint \overline{\mathcal{J}} \cdot d\mathbf{s}$$

$$\iint \overline{\mathcal{B}} \cdot d\mathbf{s} = 0$$

$$\iint \overline{\mathcal{D}} \cdot d\mathbf{s} = \iiint q_v d_\tau$$

1.3 Relation of field to circuit quantities

$$v \,(\text{voltage in volts}) = \int \overline{\mathcal{E}} \cdot d\mathbf{l}$$

$$i \,(\text{current in amp}) = \iint \overline{\mathcal{J}} \cdot d\mathbf{s}$$

$$q \,(\text{chanrge in coulombs}) = \iiint q_v d_\tau$$

$$\psi \,(\text{magnetic flux in weber}) = \iint \overline{\mathcal{B}} \cdot d\mathbf{s}$$

$$\psi^e \,(\text{electric flux in coulombs}) = \iint \overline{\mathcal{D}} \cdot d\mathbf{s}$$

$$u \,(\text{magnetomotive force in amp}) = \int \overline{\mathcal{H}} \cdot d\mathbf{s}$$

1.4 relations of a complex domain to time domain

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

1.5 Maxwell equations in complex form

$$-\nabla\times\mathbf{E} = j\omega\widehat{\mu}(\omega)\,\mathbf{H}+\mathbf{M}^{i}=\widehat{z}(\omega)\,\mathbf{H}+\mathbf{M}^{i}$$

$$\nabla\times\mathbf{B} = j\omega\widehat{\epsilon}(\omega)\,\mathbf{E}+\mathbf{J}^{c}=j\omega\widehat{\epsilon}(\omega)\,\mathbf{E}+\widehat{\sigma}(\omega)\,\mathbf{E}=\left(j\omega\widehat{\epsilon}(\omega)+\widehat{\sigma}(\omega)\right)\mathbf{E}=\widehat{y}(\omega)\,\mathbf{E}$$

in free space

$$\widehat{y}(\omega)=j\omega\epsilon_o$$
$$\widehat{z}(\omega)=j\omega\mu_o$$

for all frequencies and all field intensities.

for non-magnetic metals

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

in ferromagnetic metals

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

in good dielectric (nonmagnetic dielectric)

$$\widehat{y}(\omega)=j\omega\widehat{\epsilon}$$
$$\widehat{z}(\omega)=j\omega\mu_o$$

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 $\lambda = \frac{2\pi}{k}$