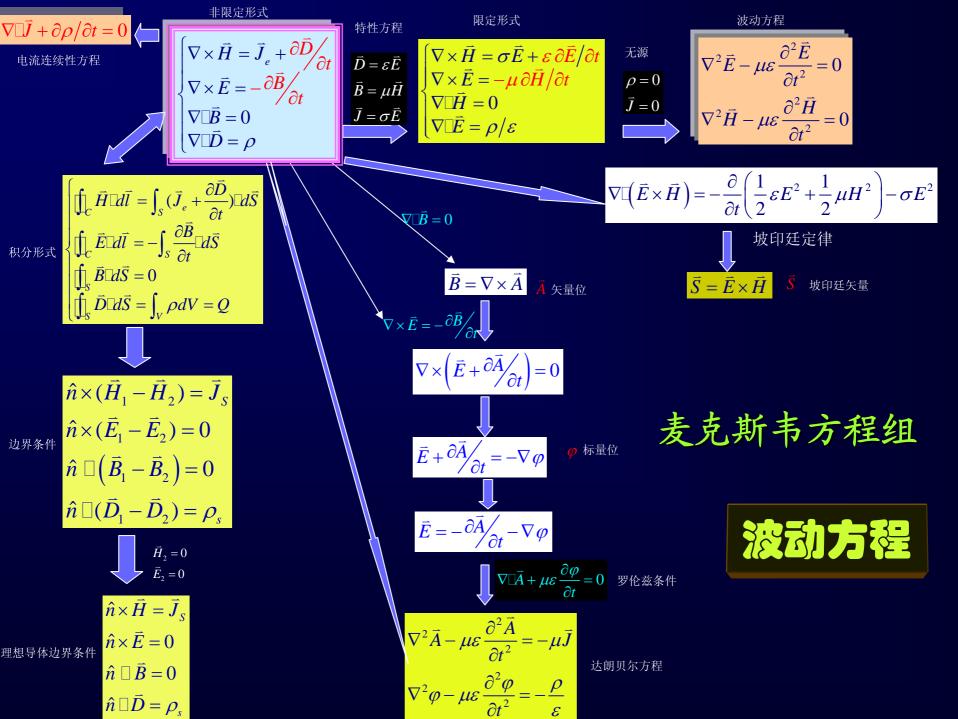
电磁波传输类型





时变电磁场



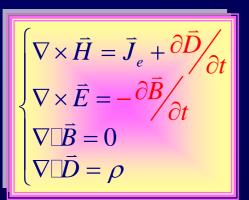
时皆电视场



麦克斯韦方程组

$$\vec{E}(\vec{r},t)$$

瞬时

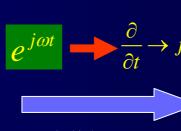




无源
$$ho = 0$$
 $\bar{J} = 0$

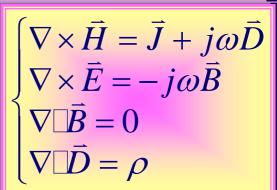
$$\nabla^{2}\vec{E} - \mu\varepsilon \frac{\partial^{2}\vec{E}}{\partial t^{2}} = 0$$

$$\nabla^{2}\vec{H} - \mu\varepsilon \frac{\partial^{2}\vec{H}}{\partial t^{2}} = 0$$





麦克斯韦方程组(时谐场)



 $\bar{E}(\bar{r})$ 复数

$$e^{j\omega t}$$
 $\rightarrow -\omega^2$

$$k = \omega \sqrt{\mu \varepsilon}$$

波数

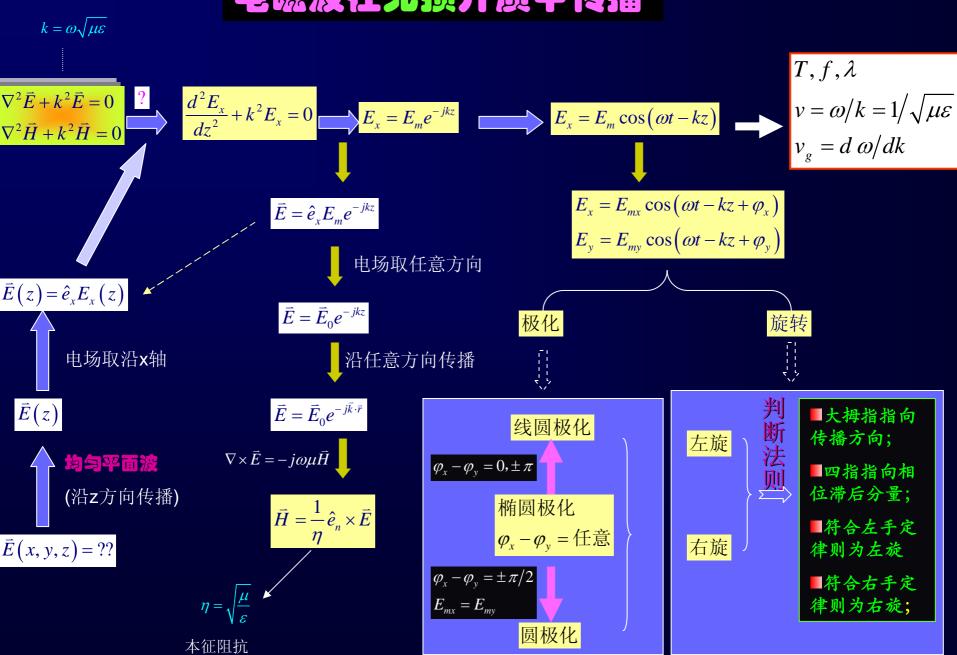


$$\nabla^2 \vec{E} + k^2 \vec{E} = 0$$
$$\nabla^2 \vec{H} + k^2 \vec{H} = 0$$

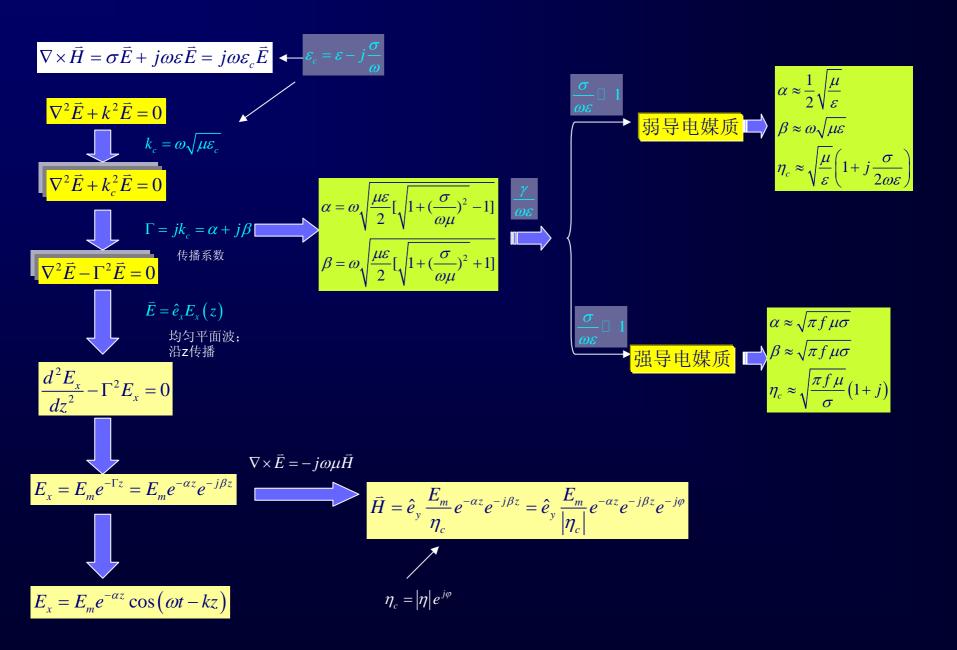
亥姆霍兹方程

波动方程

电磁波在无损介质中传播



电磁波在有损介质中传播



电磁波垂直入射一理想导体

入射波

$$E_x^+ = E_m^+ e^{-j\beta z}$$

$$H_y^+ = \frac{E_m^+}{\eta} e^{-j\beta z}$$

反射波

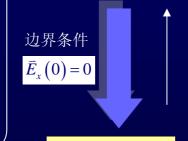
$$E_x^- = E_m^- e^{j\beta z}$$

$$H_{y}^{-} = \frac{E_{m}^{-}}{\eta} e^{j\beta z}$$

合波

$$E_{x} = E_{x}^{+} + E_{x}^{-}$$

$$= E_{m}^{+} e^{-j\beta z} + E_{m}^{-} e^{j\beta z}$$



$$E_m^+ = -E_m^-$$

$$E_x = -2jE_m^+ \sin(\beta z) \Longrightarrow E_x = 2E_m^+ \sin(\beta z)\sin(\omega t)$$

$$H_y^- = -\frac{E_x^-}{\eta}$$

$$H_{y} = H_{y}^{+} + H_{y}^{-} = \frac{2E_{m}^{+}}{\eta} \cos \beta z$$

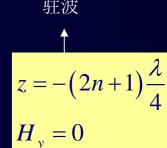


$$H_{y} = \frac{2E_{m}^{+}}{\eta} \cos(\beta z) \cos(\omega t)$$

$$\vec{J}_s = n \times \vec{H} \Big|_{z=0} = \hat{e}_x \, 2E_m^+ / \eta$$

$$z = -n\frac{\lambda}{2}$$

$$E_x = 0$$



电磁波垂直入射一导电媒质

入射波

$$\vec{E}_{1}^{+} = \hat{e}_{x} E_{m1}^{+} e^{-\Gamma_{1} z}$$

$$\vec{H}_{1}^{+} = -\hat{e}_{y} \frac{E_{m1}^{+}}{\eta} e^{-\Gamma_{1} z}$$

反射波

$$E_{1}^{-} = E_{m1}^{-} e^{\Gamma_{1} z}$$
 $H_{1}^{-} = -\frac{E_{m1}^{-}}{\eta} e^{\Gamma_{1} z}$

合波

(媒质1)

$$egin{align} ec{E}_1 &= ec{E}_1^+ + ec{E}_1^- \ ec{H}_1 &= ec{H}_1^+ + ec{H}_1^- \ \end{align}$$

透射波

(媒质2波)

边界条件:

场量切向连续

$$E_{1t}(0) = E_{2t}(0)$$
$$H_{1t}(0) = H_{2t}(0)$$



媒质2 $H_{2}^{+} = -\hat{e}_{y} \frac{E_{m2}^{+}}{\eta} e^{-\Gamma_{2}z}$

媒质1



$$E(x,t) = \hat{e}_x E_m e^{-\alpha z} \cos(\omega t - kz)$$



$$\delta = 1/\alpha$$

$$\Gamma = \frac{E_{m1}}{E_{m1}^{+}} = \frac{\eta_2 - \eta_1}{\eta_2 + \eta_1}$$

$$\tau = \frac{E_{m2}^+}{E_{m1}^+} = \frac{2\eta_2}{\eta_2 + \eta_1}$$



$$E_{m1}^{+} + E_{m1}^{-} = E_{m2}^{+}$$
 $\frac{E_{m1}^{+}}{\eta_{1}} - \frac{E_{m1}^{-}}{\eta_{1}} = \frac{E_{m2}^{+}}{\eta_{2}}$

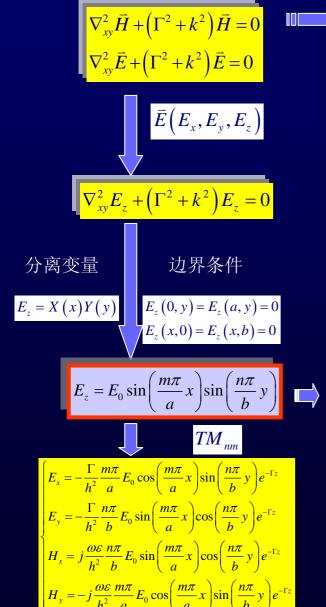


$$\Gamma + 1 = \tau$$

$$\begin{array}{c} \nabla \times \vec{H} = \vec{J} + j\omega\vec{D} \quad \nabla \cup \vec{B} = 0 \\ \nabla \times \vec{E} = -j\omega\vec{B} \quad \nabla \cup \vec{D} = \rho \end{array}$$

矩形波导

 $h^2 = \Gamma^2 + k^2$



$$E_{x} = j \frac{\omega \mu}{h^{2}} \frac{n\pi}{b} H_{0} \cos\left(\frac{n\pi}{a}x\right) \sin\left(\frac{n\pi}{b}y\right) e^{-\Gamma z}$$

$$E_{y} = -j \frac{\omega \mu}{h^{2}} \frac{m\pi}{a} H_{0} \sin\left(\frac{m\pi}{a}x\right) \cos\left(\frac{n\pi}{b}y\right) e^{-\Gamma z}$$

$$H_{x} = \frac{\Gamma}{h^{2}} \frac{m\pi}{a} H_{0} \sin\left(\frac{m\pi}{a}x\right) \cos\left(\frac{n\pi}{b}y\right) e^{-\Gamma z}$$

$$H_{y} = \frac{\Gamma}{h^{2}} \frac{n\pi}{a} H_{0} \cos\left(\frac{m\pi}{a}x\right) \sin\left(\frac{n\pi}{b}y\right) e^{-\Gamma z}$$

$$H_{y} = \frac{\Gamma}{h^{2}} \frac{n\pi}{b} H_{0} \cos\left(\frac{m\pi}{a}x\right) \sin\left(\frac{n\pi}{b}y\right) e^{-\Gamma z}$$

$$E_{y} = -j \frac{\omega \mu}{a} \frac{m\pi}{a} H_{0} \sin\left(\frac{m\pi}{a}x\right) \cos\left(\frac{n\pi}{b}y\right) e^{-\Gamma z}$$

$$H_{y} = \frac{\Gamma}{h^{2}} \frac{n\pi}{b} H_{0} \cos\left(\frac{m\pi}{a}x\right) \sin\left(\frac{n\pi}{b}y\right) e^{-\Gamma z}$$

$$H_{y} = \frac{\Gamma}{h^{2}} \frac{n\pi}{b} H_{0} \sin\left(\frac{m\pi}{a}x\right) \sin\left(\frac{n\pi}{b}y\right) e^{-\Gamma z}$$

$$E_{y} = -j \frac{\omega \mu}{a} \frac{m\pi}{a} H_{0} \sin\left(\frac{n\pi}{b}y\right) e^{-\Gamma z}$$

$$H_{y} = \frac{\Gamma}{h^{2}} \frac{n\pi}{b} H_{0} \cos\left(\frac{m\pi}{a}x\right) \sin\left(\frac{n\pi}{b}y\right) e^{-\Gamma z}$$

$$H_{y} = \frac{\Gamma}{h^{2}} \frac{n\pi}{b} H_{0} \sin\left(\frac{m\pi}{a}x\right) \sin\left(\frac{n\pi}{b}y\right) e^{-\Gamma z}$$

$$H_{y} = \frac{\Gamma}{h^{2}} \frac{n\pi}{b} H_{0} \sin\left(\frac{m\pi}{a}x\right) \sin\left(\frac{n\pi}{b}y\right) e^{-\Gamma z}$$

$$H_{y} = \frac{\Gamma}{h^{2}} \frac{n\pi}{b} H_{0} \sin\left(\frac{m\pi}{a}x\right) \sin\left(\frac{n\pi}{b}y\right) e^{-\Gamma z}$$

$$H_{y} = \frac{\Gamma}{h^{2}} \frac{n\pi}{b} H_{0} \sin\left(\frac{m\pi}{a}x\right) \sin\left(\frac{n\pi}{b}y\right) e^{-\Gamma z}$$

$$H_{y} = \frac{\Gamma}{h^{2}} \frac{n\pi}{b} H_{0} \sin\left(\frac{m\pi}{a}x\right) \sin\left(\frac{n\pi}{b}y\right) e^{-\Gamma z}$$

$$H_{y} = \frac{\Gamma}{h^{2}} \frac{n\pi}{b} H_{0} \sin\left(\frac{m\pi}{a}x\right) \sin\left(\frac{n\pi}{b}y\right) e^{-\Gamma z}$$

$$H_{y} = \frac{\Gamma}{h^{2}} \frac{n\pi}{b} H_{0} \sin\left(\frac{m\pi}{a}x\right) \sin\left(\frac{n\pi}{b}y\right) e^{-\Gamma z}$$

$$H_{y} = \frac{\Gamma}{h^{2}} \frac{n\pi}{b} H_{0} \sin\left(\frac{m\pi}{a}x\right) \sin\left(\frac{n\pi}{b}y\right) e^{-\Gamma z}$$

$$H_{y} = \frac{\Gamma}{h^{2}} \frac{n\pi}{b} H_{0} \sin\left(\frac{m\pi}{a}x\right) \sin\left(\frac{n\pi}{b}y\right) e^{-\Gamma z}$$

$$H_{y} = \frac{\Gamma}{h^{2}} \frac{n\pi}{b} H_{0} \sin\left(\frac{m\pi}{a}x\right) \sin\left(\frac{n\pi}{b}y\right) e^{-\Gamma z}$$

$$H_{y} = \frac{\Gamma}{h^{2}} \frac{n\pi}{b} H_{0} \sin\left(\frac{m\pi}{a}x\right) \sin\left(\frac{n\pi}{b}y\right) e^{-\Gamma z}$$

$$H_{y} = \frac{\Gamma}{h^{2}} \frac{n\pi}{b} H_{0} \sin\left(\frac{m\pi}{a}x\right) \sin\left(\frac{n\pi}{b}y\right) e^{-\Gamma z}$$

$$H_{y} = \frac{\Gamma}{h^{2}} \frac{n\pi}{b} H_{0} \sin\left(\frac{m\pi}{a}x\right) \sin\left(\frac{n\pi}{b}y\right) e^{-\Gamma z}$$

$$H_{y} = \frac{\Gamma}{h^{2}} \frac{n\pi}{b} H_{0} \sin\left(\frac{m\pi}{a}x\right) \sin\left(\frac{n\pi}{b}y\right) e^{-\Gamma z}$$

$$H_{y} = \frac{\Gamma}{h^{2}} \frac{n\pi}{b} H_{0} \sin\left(\frac{m\pi}{a}x\right) \sin\left(\frac{n\pi}{b}y\right) e^{-\Gamma z}$$

$$H_{y} = \frac{\Gamma}{h^{2}} \frac{n\pi}{b} H_{0} \sin\left(\frac{n\pi}{b}x\right) e^{-\Gamma z}$$

$$H_{y} = \frac{\Gamma}{h^{2}} \frac{n\pi}{b} H_{0} \sin\left(\frac{n\pi}{b}x\right) e^{-\Gamma z}$$

$$H_{y} = \frac{\Gamma}{h^{2}} \frac{n\pi}$$