P5.1

$\frac{B_1}{A_1} = R_{12} e^{i2k_{1x}d}$, $\frac{A_1}{B_1} = R_{10}$.

$\therefore R_{10} R_{12} e^{i2k_{1x}d} = 1 = e^{i2m\pi}$

$\vec{H_2} = \hat{y} A_1 (1+R_{12}) e^{ik_{1x}d} e^{ik_{2x}(x-d)} e^{ik_z z}$

$\vec{H_1} = \hat{y} A_1 \{ e^{ik_{1x}x} + \frac{1}{R_{10}} e^{-ik_{1x}x} \} e^{ik_z z}$

$\vec{H_0} = \hat{y} A_1 (1+\frac{1}{R_{10}}) e^{-ik_{0x}x} e^{ik_z z}$

$\because k_{0x} = ik_{0xI}$, $k_{0x} = ik_{0xI}$, $R_{10} = e^{i2\varphi_{10}}$, $R_{12} = e^{i2\varphi_{12}}$

$\therefore 2\varphi_{10} + 2\varphi_{12} + 2k_{1x}d = 2m\pi$, $k_z^2 + k_{1x}^2 = k_1^2$, $k_z^2 - k_{xI}^2 = k^2$

$\therefore m\pi - \varphi_{10} - \varphi_{12} = k_{1x} d = \sqrt{k_1^2 - k^2}\, d = k_1 \sqrt{1 - \frac{\mu_0 \varepsilon_2}{\mu_0 \varepsilon_1}}\, d$

$$\therefore k_1 = \frac{m\pi + \arctan \frac{\varepsilon_1 \sqrt{\varepsilon_2 - \varepsilon_0}}{\varepsilon_0 \sqrt{\varepsilon_1 - \varepsilon_2}}}{d\sqrt{1 - \frac{\varepsilon_2}{\varepsilon_1}}}$$

P9.1

$\vec{E}=\hat{y}(Ae^{ik_x x}+Be^{-ik_x x})e^{ik_z z}$

$x=0$: $A+B=0$

$x=d$: $Ae^{ik_x d}+Be^{-ik_x d}=0$

$\therefore 2i\sin(k_x d)=0$

$\therefore$ 导波条件: $k_x d=m\pi$, $m=1,2,\cdots$

$\therefore$ 当 $m=1$ 时,

$k_{cm}=\frac{\pi}{d}$

$\therefore f_{cm}=c\cdot k_{cm}/2\pi=1875\ Hz$

P9.2

(1) 当 $\frac{\omega}{c}>\frac{m\pi}{d}$ 时, 波才能传导

$\therefore m<\frac{\omega d}{c\pi}=3.464$

对于TE, $m=1,2,3$　　对于TM, $m=0,1,2,3$

(2) $k_x d=2\pi$, $k_x=\frac{2\pi}{d}$

假设, $\vec{H}=\hat{y}H_0\cos\frac{2\pi}{d}x\,e^{ik_z z}$

$\vec{E}=\frac{H_0}{\omega\varepsilon_0}[\hat{x}k_z\cos\frac{2\pi}{d}x-\hat{z}i\frac{2\pi}{d}\sin\frac{2\pi}{d}x]e^{ik_z z}$

(3) $v_p=\frac{\omega}{k_z}=3.674\times10^8\ m/s$,

$v_g=\frac{d\omega}{dk_z}$, $k_z^2+k_x^2=k^2=\omega^2\mu_0\varepsilon_0$

$\therefore v_g=\frac{k_z}{\omega\mu_0\varepsilon_0}=2.45\times10^8\ m/s$

(4) 当发生全反射时,

$n_2\sin\theta=n_1$　　$\therefore\sin\theta=\sqrt{\frac{\varepsilon_1}{\varepsilon_0}}=\sqrt{3}$, 不成立

$\therefore$ 不可能发生全反射.

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(5)

$\theta_B = \arctan\sqrt{\frac{\varepsilon_1}{\varepsilon_0}} = \frac{\pi}{3}$

$\because \omega = 30\,GHz \quad \therefore \lambda = \frac{2\pi \cdot c}{\omega} = 0.01 \cdot 2\pi\ m$

$\therefore \frac{k_x}{\sin\theta_B} = \lambda$

$\therefore \frac{m\pi}{d} = \lambda \sin\theta_B \quad \therefore m = 3$

P9.3

$\cancel{k_x d = m\pi}$ $2k_x d + 4\varphi_{10} = 2m\pi$

$k_z^2 + k_x^2 = \omega^2 \mu\varepsilon = k^2$

$k_z^2 - k_{xI}^2 = \omega^2 \mu_0 \varepsilon_0 = k_0^2$

当cutoff时，$k_z = k$，$k_{xI} = 0$，$\varphi_{10} = 0$

$\therefore m\pi = k_x d = \sqrt{k^2 - k_0^2}\, d = k\sqrt{1 - \frac{\mu_0\varepsilon_0}{\mu\varepsilon}}\, d$

$\therefore k = k_{cm} = \frac{m\pi}{d\sqrt{1 - \frac{\mu_0\varepsilon_0}{\mu\varepsilon}}}$

$k_z = k_0 = k\sqrt{\frac{\mu_0\varepsilon_0}{\mu\varepsilon}}$

$\therefore m$ 可以为 0, 1, 2

对应截止频率为 0, 12GHz, 24GHz

P10.1

(1) $k_x=\frac{m\pi}{a}$, $k_y=\frac{n\pi}{b}$, $k_x^2+k_y^2+k_z^2=\frac{\omega^2}{c^2}$.

$\therefore \frac{\pi}{a}<k_x<\frac{2\pi}{a}$, $0<k_y<\frac{\pi}{b}$

a ~~ω~~

$\therefore \frac{c\pi}{2\pi a}<f<\frac{c\pi}{2\pi b}$

$\therefore 22.9MHz<f<35.8MHz$

(2)

从第(1)问知，AM的频率小于能通过的频率，所以AM不能在该波导中传播.

(3)

FM可以在该波导中传播，比当$m=3$时。$f=68.7MHz$高，故能以至少TE_{32}的模式传播.

P10.2.

由于电流沿x正方向，则在z方向产生的是TM波.

在$z>0$时，$\vec{H}_1=\hat{y}\sum_{m=1}^{\infty}H_m\cos(\frac{m\pi}{d}x)e^{ik_zz}$

$\vec{E}_1=\hat{x}\sum_{m=1}^{\infty}\frac{k_zH_m}{\omega\varepsilon}\cos(\frac{m\pi}{d}x)e^{ik_zz}$

在$z<0$时，$\vec{H}_2=\hat{y}\sum_{m=1}^{\infty}-H_m\cos(\frac{m\pi}{d}x)e^{-ik_zz}$

$\vec{E}_2=\hat{x}\sum_{m=1}^{\infty}-\frac{k_zH_m}{\omega\varepsilon}\cos(\frac{m\pi}{d}x)e^{-ik_zz}$

在$z=0$处，利用边界条件 $\hat{n}\times(H_2|_{z=0}-H_1|_{z=0})=\vec{J}_s$

$\therefore \sum_{m=1}^{\infty}-2H_m\cos(\frac{m\pi}{d}x)=J_s\cos\frac{3\pi x}{d}$

$\therefore H_m=-\frac{J_s}{2}$, $m=3$

$\therefore \vec{H}_1=-\hat{y}\frac{J_s}{2}\cos(\frac{3\pi}{d}x)e^{ik_zz}$, $\vec{H}_2=\hat{y}\frac{J_s}{2}\cos(\frac{3\pi}{d}x)e^{ik_zz}$

$\therefore$ 该模式下的幅度为$\pm\frac{J_s}{2}$

10.3

(1) 在基波模式下，波以TE_{m0}或TE_{0n}的模式传播.

$$k_x a = m\pi,\quad k_y b = n\pi,\quad \frac{\omega^2}{c^2} = k_x^2 + k_z^2 + k_y^2$$

当$n=0$时，$k_x = \frac{m\pi}{a}$，$\frac{\omega^2}{c^2} = \left(\frac{m\pi}{a}\right)^2 + k_z^2$

取$m=1$，$k_z = 69.46\ \text{rad/m}$

$$V_g = \frac{d\omega}{dk_z} = \frac{k_z}{\omega\mu_0\varepsilon_0} = 1.66\times10^8\ \text{m/s}$$

$$\therefore t = \frac{L}{V_g} = 1.8\times10^{-6}\ \text{s}$$

当$m>1$或$n>0$时，$k_z^2<0$，无法传播

∴只有TE_{10}可以传播

(2)

$$\frac{\omega^2}{c^2} = \left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2 + k_z^2$$

TE_{10} 对应 cutoff：5GHz

TE_{20} 〃 ：10GHz

TE_{01} 〃 ：10GHz

∴此3种模式可以传播

TE_{10}：$t = \frac{L}{V_g} = \frac{L\omega\mu_0\varepsilon_0}{k_z} = 1.14\times10^{-6}\ \text{s}$

~~TE_{20}~~ TE_{20}：$t = \frac{L}{V_g} = 3.28\times10^{-6}\ \text{s}$

TE_{01}：$t = \frac{L}{V_g} = 3.28\times10^{-6}\ \text{s}$

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