第一章、

$\Gamma(z)=\Gamma_L e^{-j2\beta z}=\Gamma_L e^{-j2\theta}$，其中 $\Gamma_L=\dfrac{Z_L-Z_0}{Z_L+Z_0}$ $\Rightarrow$ 同时在无耗线上，$|\Gamma|$不变

$Z_{in(z)}=Z_0\dfrac{Z_L+jZ_0\tan(\beta z)}{Z_0+jZ_L\tan(\beta z)}$ $\Longrightarrow$ ①短路终端，有 $Z_{in(z)}=jZ_0\tan(\beta z)$，$Z_L=0$

②开路终端，有 $Z_{in(z)}=-jZ_0\dfrac{1}{\tan(\beta z)}$，$Z_L=-j\infty$

$$Y_{in}=Y_0\frac{Y_L+jY_0\tan(\beta z)}{Y_0+jY_L\tan(\beta z)}$$

输入功率：$P_{in}=\dfrac{1}{2}\dfrac{|U^+(z)|^2}{Z_0}-\dfrac{1}{2}\dfrac{|U^-(z)|^2}{Z_0}=\dfrac{1}{2}\dfrac{|U^+(z)|^2}{Z_0}(1-|\Gamma|^2)$

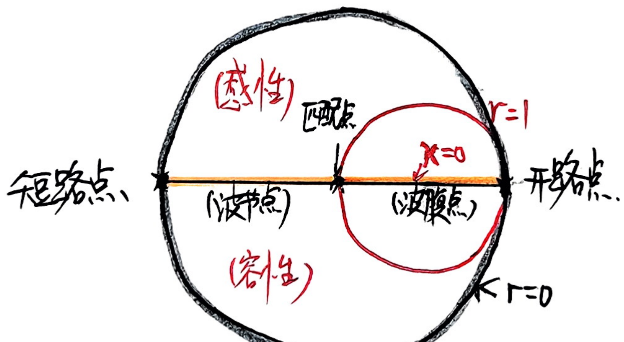
$Z_{in(z)}=Z_0\dfrac{1+\Gamma(z)}{1-\Gamma(z)}$ $\Longleftrightarrow$ $\Gamma(z)=\dfrac{Z_{in}(z)-Z_0}{Z_{in}(z)+Z_0}$

$\rho=\dfrac{1+|\Gamma|}{1-|\Gamma|}$ $\Longleftrightarrow$ $|\Gamma|=\dfrac{\rho-1}{\rho+1}$

在非阻抗匹配的无耗传输线上，只有电压波节点和波腹点上的阻抗为纯电阻！

且 $R_{max}=Z_0\rho=Z_0\dfrac{1+|\Gamma|}{1-|\Gamma|}$，$R_{min}=Z_0/\rho=Z_0\dfrac{1-|\Gamma|}{1+|\Gamma|}$

圆图：



并联支节：

方程：$\begin{cases}\tan^2(\beta l_1')=\dfrac{1}{\rho}\\ \tan(\beta l_2)=\dfrac{1}{(1-\rho)\tan(\beta l_1')}\end{cases}$

l_{min1} 为到最近的波节点的距离

①情况 $l_1'>0$，$l_2>\dfrac{\lambda}{4}$

解一 $\begin{cases}l_1'=\dfrac{\lambda}{2\pi}\arctan\left(\dfrac{1}{\sqrt{\rho}}\right)\\ l_2=\dfrac{\lambda}{4}+\dfrac{\lambda}{2\pi}\arctan\left(\dfrac{\rho-1}{\sqrt{\rho}}\right)\end{cases}$ 正

②情况 $l_1'<0$，$l_2<\dfrac{\lambda}{4}$

解二 $\begin{cases}l_1'=-\dfrac{\lambda}{2\pi}\arctan\left(\dfrac{1}{\sqrt{\rho}}\right)\\ l_2=\dfrac{\lambda}{2\pi}\arctan\left(\dfrac{\sqrt{\rho}}{\rho-1}\right)\end{cases}$ 反

特别的波长段，

1、λ/4输入阻抗：$Z_{in}(\frac{\lambda}{4})=\frac{Z_0^2}{Z_L}$

2、λ/8输入阻抗：$Z_{in}(\frac{\lambda}{8})=Z_0\frac{Z_L+jZ_0}{Z_0+jZ_L}$

第二、三章：

矩形波导：

$$\lambda_g=\frac{2\pi}{\beta},\ V_p=\frac{\omega}{\beta}=\frac{2\pi f}{\beta}$$

截止波数：$K_{cmn}^2=(\frac{m\pi}{a})^2+(\frac{n\pi}{a})^2$

截止波长：$\lambda_c=\frac{2\pi}{K_{cmn}}=\frac{2}{\sqrt{(m/a)^2+(n/b)^2}}$

TE10模：

截止波数：$K_c=\frac{\pi}{a}$

截止波长：$\lambda_c=2a$

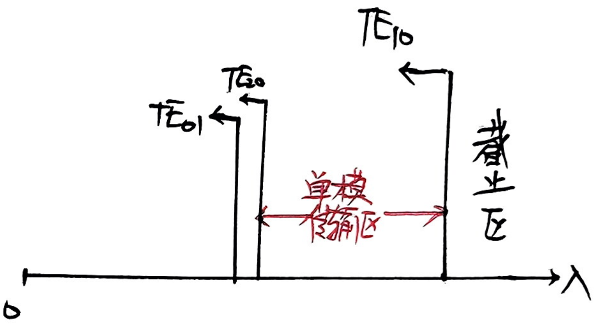
传输功率为 $P=\frac{ab\,E_{10}^2}{4\,Z_{TE10}}$

相速 $V_p=c/\sqrt{1-(\frac{\lambda}{2a})^2}>c$，群速 $V_g=c\cdot\sqrt{1-(\frac{\lambda}{2a})^2}<c$

传播模式：

当a>2b时，第一个高次模为TE20模。

当a<2b时，第一个高次模为TE01模。



同轴线：TEM

介质填充波导有导体损耗和介质损耗

$$Z_0=\sqrt{\frac{\mu}{\varepsilon}}\frac{\ln(b/a)}{2\pi}$$

若(外半径/内半径) b/a变大，则特性阻抗Z_0增加，相速度V_p不变

带状线：TEM

物理尺寸不改变V_p，λ_g

$V_p=\frac{c}{\sqrt{\varepsilon_r}}$

$Z_0=\frac{1}{V_pC}=\frac{\sqrt{\varepsilon_r}}{cC}=\frac{Z_0^a}{\sqrt{\varepsilon_r}}$

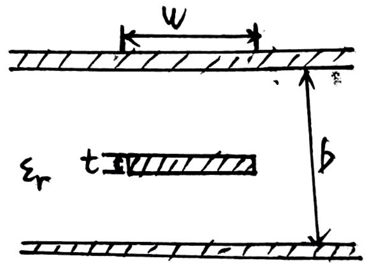
$\lambda_g=\frac{\lambda_0}{\sqrt{\varepsilon_r}}$ → 自由空间波长

而 $C\propto\frac{\varepsilon_r S}{d}\propto\frac{\varepsilon_r W}{d}$

则 W↑，则C↑，Z_0↓，V_p不变，λ_g不变

(t↓) b↑，则C↓，Z_0↑，V_p不变，λ_g不变

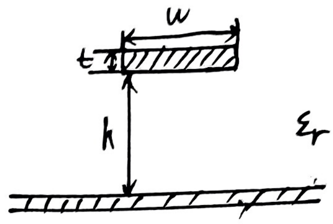
ε_r↑，则C↑，Z_0↓，V_p↓，λ_g↓



微带线: 准TEM

若忽略损耗, $\begin{cases} v_p = \dfrac{c}{\sqrt{\varepsilon_e}} \\ Z_0 = \dfrac{1}{v_p C} = \dfrac{\sqrt{\varepsilon_e}}{cC} = \dfrac{Z_0^a}{\sqrt{\varepsilon_e}} \\ \lambda_g = \dfrac{\lambda_0}{\sqrt{\varepsilon_e}} \end{cases}$ 而 $C \propto \dfrac{\varepsilon_e S}{d} \propto \dfrac{\varepsilon_e W}{d}$

▲ ε_e 变化同 C



则 $w\uparrow$, 则 $C\uparrow$, $Z_0\downarrow$, 且 $\varepsilon_e\uparrow$, $v_p\downarrow$, $\lambda_g\downarrow$

$h\uparrow$, 则 $C\downarrow$, $Z_0\uparrow$, 且 $\varepsilon_e\downarrow$, $v_p\uparrow$, $\lambda_g\uparrow$

$\varepsilon_r\uparrow$, 则 $C\uparrow$, $Z_0\downarrow$, 且 $\varepsilon_e\uparrow$, $v_p\downarrow$, $\lambda_g\downarrow$

物理尺寸改变 v_p, λ_g

附. $\varepsilon_e = 1+q(\varepsilon_r-1)$, 其中 $q \approx \frac{1}{2}\left[1+\left(1+\frac{12h}{w}\right)^{-\frac{1}{2}}\right]$

第四章:

阻抗矩阵 $\begin{cases} U_1 = Z_{11}I_1 + Z_{12}I_2 \\ U_2 = Z_{21}I_1 + Z_{22}I_2 \end{cases}$ — $\begin{cases} 互易: Z_{12}=Z_{21} \\ 对称: Z_{11}=Z_{22} \end{cases}$ $\xrightarrow{归一化}$ $[z] = \begin{bmatrix} \dfrac{Z_{11}}{Z_{e1}} & \dfrac{Z_{12}}{\sqrt{Z_{e1}Z_{e2}}} \\ \dfrac{Z_{21}}{\sqrt{Z_{e1}Z_{e2}}} & \dfrac{Z_{22}}{Z_{e2}} \end{bmatrix}$

导纳矩阵 …

转移矩阵 $\begin{cases} U_1 = AU_2 - BI_2 \\ I_1 = CU_2 - DI_2 \end{cases}$ — $\begin{cases} 互易: ad-bc=1=AD-BC \\ 对称: a=d \end{cases}$ $\xrightarrow{归一化}$ $[a] = \begin{bmatrix} A\sqrt{\dfrac{Z_{e2}}{Z_{e1}}} & \dfrac{B}{\sqrt{Z_{e1}Z_{e2}}} \\ C\sqrt{Z_{e1}Z_{e2}} & D\sqrt{\dfrac{Z_{e1}}{Z_{e2}}} \end{bmatrix}$

在始端 $\begin{cases} Z_{in} = \dfrac{AZ_L - B}{CZ_L - D} \\ \Gamma_{in} = \dfrac{Z_{in}-Z_{e1}}{Z_{in}+Z_{e1}} \end{cases}$

散射矩阵 $\begin{cases} b_1 = S_{11}a_1 + S_{12}a_2 \\ b_2 = S_{21}a_1 + S_{22}a_2 \end{cases}$ — $\begin{cases} 互易: S_{12}=S_{21} \\ 对称: S_{11}=S_{22} \end{cases}$ 无耗 $\Rightarrow \begin{cases} |S_{21}| = \sqrt{1-|S_{11}|^2} \\ \phi_{21} = \phi_{11} \pm \dfrac{\pi}{2} \end{cases}$ 或 $\begin{matrix} |S_{11}|^2+|S_{21}|^2=1 \\ S_{11}^*S_{21}+S_{21}^*S_{11}=0 \end{matrix}$

[S]和[a]的转换:

推导: 令 $u_1 = a_1+b_1$, $u_2 = a_2+b_2$, $i_1 = a_1-b_1$, $i_2 = a_2-b_2$

有 $\begin{cases} a_1+b_1 = a(a_2+b_2) - b(a_2-b_2), & ① \\ a_1-b_1 = c(a_2+b_2) - d(a_2-b_2), & ② \end{cases}$

①+②, $2a_1 = (a+c-b-d)a_2 + (a+b+c+d)b_2$

即: $b_2 = \dfrac{2}{a+b+c+d}a_1 + \dfrac{b+d-a-c}{a+b+c+d}a_2$

①-②, $2b_1 = (a+d-b-c)a_2 + (a+b-c-d)b_2$

则 $2b_1 = \dfrac{2(a+b-c-d)}{a+b+c+d}a_1 + \left[(a+d-b-c) + \dfrac{(b+d-a-c)(a+b-c-d)}{a+b+c+d}\right]a_2$

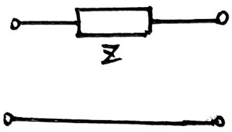
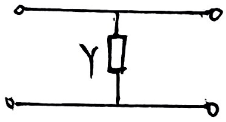
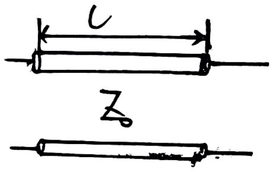
$b_1 = \dfrac{a+b-c-d}{a+b+c+d}a_1 + \dfrac{2(ad-bc)}{a+b+c+d}a_2$

结论:

$$\begin{cases} a = (1+S_{11})(1-S_{22})+S_{12}S_{21} \cdot \dfrac{1}{S_{21}} \\ b = (1+S_{11})(1+S_{22})-S_{12}S_{21} \cdot \dfrac{1}{S_{21}} \\ c = (1-S_{11})(1-S_{22})-S_{12}S_{21} \cdot \dfrac{1}{S_{21}} \\ d = (1-S_{11})(1+S_{22})+S_{12}S_{21} \cdot \dfrac{1}{S_{21}} \end{cases} \qquad \begin{cases} S_{11} = a+b-c-d \cdot \dfrac{1}{a+b+c+d} \\ S_{12} = 2(ad-bc) \cdot \dfrac{1}{a+b+c+d} \\ S_{21} = 2 \cdot \dfrac{1}{a+b+c+d} \\ S_{22} = b+d-a-c \cdot \dfrac{1}{a+b+c+d} \end{cases}$$

且有 $\Gamma_{in} = \dfrac{b_1}{a_1} = S_{11} + \dfrac{S_{12}S_{21}\Gamma_L}{1-S_{22}\Gamma_L}$

常见双端口网络:

常见双端口网络	[A]矩阵	[Z]矩阵	[Y]矩阵	[S]矩阵
① 	$\begin{bmatrix} 1 & Z \\ 0 & 1 \end{bmatrix}$	无	$\begin{bmatrix} \frac{1}{Z} & -\frac{1}{Z} \\ -\frac{1}{Z} & \frac{1}{Z} \end{bmatrix}$	—
② 	$\begin{bmatrix} 1 & 0 \\ Y & 1 \end{bmatrix}$	$\begin{bmatrix} \frac{1}{Y} & \frac{1}{Y} \\ \frac{1}{Y} & \frac{1}{Y} \end{bmatrix}$	无	—
③  $\theta = \frac{2\pi l}{\lambda_g}$	$\begin{bmatrix} \cos\theta & jZ_0\sin\theta \\ jY_0\sin\theta & \cos\theta \end{bmatrix}$ $\Downarrow$ 假设 $Z_{01}=Z_{02}=Z_0$ $\begin{bmatrix} \cos\theta & j\sin\theta \\ j\sin\theta & \cos\theta \end{bmatrix}$	—	—	$\begin{bmatrix} 0 & e^{-j\theta} \\ e^{-j\theta} & 0 \end{bmatrix}$

第五章：

衰减元件 $[S_\alpha]=\begin{bmatrix}0 & e^{-\alpha l}\\ e^{-\alpha l} & 0\end{bmatrix}$

相移元件 $[S_\theta]=\begin{bmatrix}0 & e^{-j\theta}\\ e^{-j\theta} & 0\end{bmatrix}$

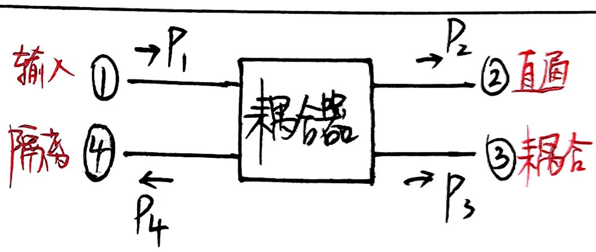
理想隔离器：无相移 — $[S_I]=\begin{bmatrix}0 & 0\\ 1 & 0\end{bmatrix}$　有相移 — $[S_I]=\begin{bmatrix}0 & 0\\ e^{-j\theta} & 0\end{bmatrix}$

环行器：$[S]=\begin{bmatrix}0 & 0 & e^{j\theta}\\ e^{j\theta} & 0 & 0\\ 0 & e^{j\theta} & 0\end{bmatrix}$

谐振器：谐振频率，品质因数，等效电导

$$Q\approx\frac{2}{\delta}\cdot\frac{V}{S}$$

定向耦合器



耦合度 $C=10\lg\frac{P_1}{P_3}=20\lg\frac{1}{|S_{13}|}$

隔离度 $I=10\lg\frac{P_1}{P_4}=20\lg\frac{1}{|S_{14}|}$

定向度 $D=I-C$

输入驻波比：$\rho=\frac{1+|S_{11}|}{1-|S_{11}|}$