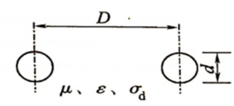
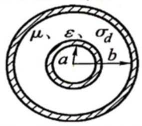
几何长度l **相波长**λ_p **电长度**$\bar{l} = l/\lambda_p$ **长线** $\bar{l}$大于或接近1

均匀长线 分布参数 R1、L1、C1、G1 为常量；**均匀无耗长线** $R_1 = 0, G_1 = 0$的均匀长线





	平行双线		同轴线
C_1/（F/m）	$\dfrac{\pi\varepsilon}{\mathrm{arcosh}\,(D/d)}$	C1+C1 并	$\dfrac{2\pi\varepsilon}{\ln\,(b/a)}$
L_1/（H/m）	$\dfrac{\mu}{\pi}\mathrm{arcosh}\left(\dfrac{D}{d}\right)$	L1+L2 串	$\dfrac{\mu}{2\pi}\ln\dfrac{b}{a}$
R_1/（Ω/m）	$\dfrac{2}{\pi d}\sqrt{\dfrac{\omega\mu}{2\sigma_c}}$	R1+R2 串	$\sqrt{\dfrac{f\mu}{4\pi\sigma_c}}\left(\dfrac{1}{a}+\dfrac{1}{b}\right)$
G_1/（S/m）	$\dfrac{\pi\sigma_d}{\mathrm{arcosh}\,(D/d)}$	G1+G2 并	$\dfrac{2\pi\sigma_d}{\ln\,(b/a)}$

导线电导率 σ_c **介质介电常数**ϵ **磁导率**μ **电导率**σ_d

相移常数 $\beta = \omega\sqrt{L_1C_1} = 2\pi/\lambda_p$ **特性阻抗** $Z_0 = \sqrt{\frac{L_1}{C_1}} = \frac{U^+(z)}{I^+(z)} = -\frac{U^-(z)}{I^-(z)}$

相速度 $v_p = \lambda_p f = 1/\sqrt{L_1 c_1} = 1/\sqrt{\epsilon\mu} = 1/\sqrt{\epsilon_0\epsilon_r\mu_0\mu_r} = c/\sqrt{\epsilon_r\mu_r}$ **缩短系数** $\sqrt{\epsilon_r\mu_r}$

输入阻抗 $Z_{in} = U(z)/I(z) = Z_0(Z_L + jZ_0 tan\beta z)/(Z_0 + jZ_L tan\beta z)$

归一化阻抗 $\bar{Z}_{in}(z) = Z_{in}/Z_0$ $\bar{Z}_L(z) = Z_L/Z_0$ $\bar{Z}_{in}(z) = (\bar{Z}_L + jtan\beta z)/(1 + j\bar{Z}_L tan\beta z)$

周期性 $Z_{in}(z = \lambda/2) = Z_L$ **倒置性** $Z_{in}(z = \lambda/4) = Z_0^2/Z_L = 1/\bar{Z}_L$

输入导纳 $Y_{in} = 1/Z_{in} = Y_0(Y_L + jY_0 tan\beta z)/(Y_0 + jY_L tan\beta z)$

反射系数 $\Gamma(z) = \frac{U^-(z)}{U^+(z)} = \frac{Z_L - Z_0}{Z_L + Z_0}e^{-j2\beta z} = |\Gamma(z)|e^{j\varphi_\Gamma(z)}$

终端反射系数 $\Gamma_L = \Gamma(0) = \frac{Z_L - Z_0}{Z_L + Z_0} = |\Gamma_L|e^{j\varphi_0}$ 有$|\Gamma(z)| = |\Gamma_L|$ 其中 $\varphi_\Gamma(z) = \varphi_0 - 2\beta z$

驻波比 $\rho = |U|_{max}/|U|_{min}$ 有 $U(z) = U^+(z)[1 + \Gamma(z)]$ $|U|_{max/min} = |U^+|(1 \pm |\Gamma|)$

$\rho = \frac{1+|\Gamma|}{1-|\Gamma|}$ $|\Gamma| = \frac{\rho-1}{\rho+1} = -\frac{I^-(z)}{I^+(z)}$ **行波系数** $K = |U|_{min}/|U|_{max} = 1/\rho$

工作状态	Z_L	$\lvert\Gamma_L\rvert$	ρ	反射情况
行波状态	$Z_L = Z_0$	0	1	无反射
驻波状态	$Z_L = 0$、∞或者jX_L	1	∞	全反射
行驻波状态	Z_L为其它值	$0<\lvert\Gamma_L\rvert<1$	$1<\rho<\infty$	部分反射

Z_0与$\Gamma(z)$ $Z_{in}(z) = Z_0\frac{1+\Gamma(z)}{1-\Gamma(z)}$

Z_0与ρ $Z_{in}(z_{max}) = Z_0\rho$

Z_0与ρ $Z_{in}(z_{min}) = Z_0/\rho$

行波 $P(z) = 1/2Re[U(z)I^*(z)] = 1/2|U_L||I_L|$

电压与电流同向切值不变；Z_0值不变呈纯阻性；功率全被负载吸收，最高效

驻波 $Z_L = 0$ 终端短路 $\Gamma(z) = e^{j(\pi-2\beta z)}$ $Z_{in}(z) = jZ_0 \tan\beta z$ $P(z) = 0$

U I节点为0，腹点为行波振幅的 2 倍 电压正弦 电流余弦 $T = \lambda/2$

位　置	$0<z<\lambda/4$	$z=\lambda/4$	$\lambda/4<z<\lambda/2$	$z=\lambda/2$
$\tan\beta z$	>0	∞	<0	0
输入阻抗	呈感性	LC 并联谐振	呈容性	LC 串联谐振

驻波 $Z_L = \infty$ 终端开路 $\Gamma(z) = e^{-j2\beta z}$ $Z_{in} = -jZ_0 \cot\beta z$

驻波 $Z_L = jX_L$ 终端接纯电抗 $\Gamma(z) = e^{j(\varphi_0-2\beta z)}$ $\Gamma_L = e^{j\varphi_0}$

$X_L > 0$ 终端接感性 $jX_L = jZ_0 \tan\beta l_L$ 离负载最近的是电压腹点 电流节点

$X_L < 0$ 终端接容性 $jX_L = -jZ_0 \cot\beta l_C$ 离负载最近的是电流腹点 电压节点

行驻波 $U(z) = U_{行} + U_{驻}$ $|U|_{max} = Z_0|I|_{max}$ $|U|_{min} = |I|_{min}$

驻波状态	$Z_L = 0$	$Z_L = \infty$	$Z_L = jX_L$ 且 $X_L > 0$	$Z_L = jX_L$ 且 $X_L < 0$
对应的行驻波状态	$Z_L = R_L < Z_0$	$Z_L = R_L > Z_0$	$Z_L = R_L + jX_L$ 且 $X_L > 0$	$Z_L = R_L + jX_L$ 且 $X_L < 0$

$Z_{in}(z) = Z_0\frac{Z_L + jZ_0 \tan\beta z}{Z_0 + jZ_L \tan\beta z} = R_{in} + jX_{in}$ $\lambda/2$周期性 $\lambda/4$倒置性 容性感性互换

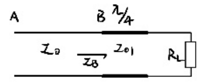
传输功率 $P(z) = \frac{1}{2}Re\big(U(z)I^*(z)\big) = \frac{|U^+|^2}{2Z_0}Re[1 - |\Gamma|^2] = |U_{max}||U_{min}|/(2Z_0)$

	条　件	位　置	振　幅
电压腹点（电流节点）	$\varphi_\Gamma = -2n\pi$	$z_{max} = \frac{\varphi_0\lambda}{4\pi} + n\frac{\lambda}{2}$	$\lvert U\rvert_{max} = \lvert U^+\rvert(1+\lvert\Gamma\rvert)$ $\lvert I\rvert_{min} = \frac{\lvert U^+\rvert}{Z_0}(1-\lvert\Gamma\rvert)$
电压节点（电流腹点）	$\varphi_\Gamma = -(2n+1)\pi$	$z_{min} = \frac{\varphi_0\lambda}{4\pi} + (2n+1)\frac{\lambda}{4}$	$\lvert U\rvert_{min} = \lvert U^+\rvert(1-\lvert\Gamma\rvert)$ $\lvert I\rvert_{max} = \frac{\lvert U^+\rvert}{Z_0}(1+\lvert\Gamma\rvert)$

阻抗匹配 $Z_L = Z_0$ **击穿电压** $|U|_{br}$ **功率容量** $P_{br} = |U|_{br}^2/(2Z_0\rho)$

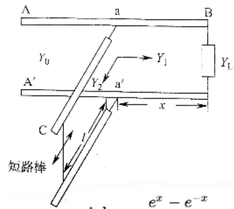
共轭匹配 $Z_g = Z_{in}^*$ $Z_g = R_g + jX_g$ $Z_{in} = R_{in} + jX_{in}$ $P_{max} = E_g^2/8R_g$ g 指信号源

负载匹配 行波 $Z_L = Z_0$ **信号源匹配** $Z_g = Z_0$



λ/4 阻抗变换器 窄带 $Z_B = Z_{01}^2/R_L$ $Z_{01} = \sqrt{Z_0 R_L}$

$|\Gamma_B| = |\bar{R}_L - 1|/\sqrt{(\bar{R}_L + 1)^2 + 4q\bar{R}_L tan^2(\frac{\pi f}{2f_0})}$



并联单枝节匹配器 窄带 $Y_1 = Y_0 + jB$

$Y_2 = -jB$ $Y_{aa'} = Y_1 + Y_2 = Y_0$

并联双支节 窄带 间距有 $\lambda/8$ $3\lambda/8$ 两种

$\sinh x = \dfrac{e^x - e^{-x}}{2}$

适用同轴线 ；一个频点匹配 存在匹配禁区

$\cosh x = \dfrac{e^x + e^{-x}}{2}$

有耗传输线 $Z_0 = \sqrt{\frac{R_1 + j\omega L_1}{G_1 + j\omega C_1}} = R + jX_0$

传播常数 $\gamma = \sqrt{(R_1 + j\omega L_1)(G_1 + j\omega C_1)} = \alpha + j\beta$ **衰减常数** α **相移常数** β

令$j\beta \to \gamma$ 有$Z_{in}(z) = Z_0(Z_L + Z_0 tanh\,\gamma z)/(Z_0 + Z_L tanh\gamma z)$ $|U(z+l)| = |U(z)|e^{\alpha l}$

衰减量 相距l的两点间单向波振幅相对变化的对数值 $A = ln|U(z+l)/U(z)| = \alpha l$ (NP)

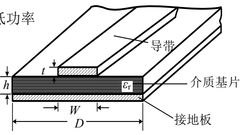
$\alpha = a/l$ (dB/m或NP/m) $1NP = 8.686dB$ $A = 10lg|U(z+l)/U(z)|$ (dB)

传输线损耗 Q **导体损耗** $Q_c = \omega L_1/R_1$ **介质损耗** $Q_d = \omega C_1/G_1 = 1/tan\delta$

介质损耗正切 $tan\delta$ 有$1/Q = 1/Q_c + 1/Q_d$ **有耗传输线效率** $\eta = P_L/P_{in}$

均匀有耗传输线效率 $\eta = 1/[cosh(2\alpha l) + 1/2(\rho + 1/\rho)sinh(2\alpha l)]$

微带线 小 轻 频带宽 高可靠；损耗大 P_{br}低；中低功率



准 TEM 模

$$Z_0^0 = \sqrt{\frac{R_1^0 + j\omega L_1^0}{G_1^0 + j\omega C_1^0}} = \sqrt{\frac{L_1^0}{C_1^0}} = \frac{1}{cC_1^0}$$

有效电介质常数

$$Z_0^\varepsilon = \sqrt{\frac{L_1}{C_1^\varepsilon}} = \sqrt{\frac{L_1^0}{\varepsilon_r C_1^0}} = \frac{Z_0^0}{\sqrt{\varepsilon_r}}$$

$\varepsilon_e = 1 + q(\varepsilon_r - 1)$ $Z_0 = Z_0^0/\sqrt{\epsilon_e}$

$q = 1$ 介质填充

$$q = \frac{1}{2}[1 + (1 + 10\frac{h}{W})^{-1/2}]$$

$q = 0$ 空气填充

$\oint_l H\cdot dl = \int_s J\cdot ds + \int_s \frac{\partial D}{\partial t}\cdot ds$

$\oint_l E\cdot dl = -\int_s \frac{\partial B}{\partial t}\cdot ds$ $\nabla\times\boldsymbol{H} = \boldsymbol{J} + \frac{\partial D}{\partial t}$

$\oint_s B\cdot ds = 0$ $\nabla\times\boldsymbol{E} = -\frac{\partial B}{\partial t}$

$\oint_s D\cdot ds = \int_v \rho\cdot dv$ $\nabla\cdot\boldsymbol{B} = 0$

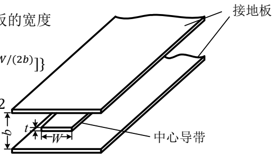
$\nabla\cdot\boldsymbol{D} = \rho$

$Z_0^0 = 60ln(8h/W + W/(4h))$ $W/h < 1$

$Z_0^0 = \frac{120\pi}{W/h + 1.393 + 0.667\ln(W/h + 1.4444)}$ $W/h \geq 1$ $v_p = \frac{c}{\sqrt{\varepsilon_e}}$ $\lambda_p = \frac{\lambda_0}{\sqrt{\varepsilon_e}}$

临界频率 $f_c = \frac{0.95}{(\varepsilon_r - 1)^{1/4}}\sqrt{\frac{Z_0}{h}}$ $\lambda_{min} > 2W\sqrt{\varepsilon_r}$ $\lambda_{min} > 2h\sqrt{\varepsilon_r}$ $\lambda_{min} > 4h\sqrt{\varepsilon_r - 1}$

λ_{min} 微带线最短工作频率 λ_0 中心工作频率 W_g 接地板的宽度



带状线 对称微带线$Z_0 = \sqrt{\mu/\epsilon}\,\pi(1 - t/b)/\{8arcosh[e^{\pi W/(2b)}]\}$

$\lambda_{min} > 2W\sqrt{\varepsilon_r}$ $\lambda_{min} > 2b\sqrt{\varepsilon_r}$ $W_g = (3\sim6)W$ $b \ll \lambda_0/2$

边界条件 切向分量不连续

$\boldsymbol{n}\cdot(\boldsymbol{B_2} - \boldsymbol{B_1}) = 0$ $B_{2n} = B_{1n}$ $\boldsymbol{n}\cdot(\boldsymbol{D_2} - \boldsymbol{D_1}) = \boldsymbol{\rho_s}$ $D_{2n} - D_{1n} = \rho_s$

$\boldsymbol{n}\times(\boldsymbol{H_2} - \boldsymbol{H_1}) = \boldsymbol{J_s}$ $H_{2t} - H_{1t} = J_s$ $\boldsymbol{n}\times(\boldsymbol{E_2} - \boldsymbol{E_1}) = 0$ $E_{2t} = E_{1t}$

本构关系 $\boldsymbol{P}$为极化强度C/m^2 **$\boldsymbol{M}$为介质的磁化强度A/m**

一般形式 $\boldsymbol{D} = \epsilon_0\boldsymbol{E} + \boldsymbol{P}$, $\boldsymbol{B} = \mu_0(\boldsymbol{H} + \boldsymbol{M})$, $\boldsymbol{J} = \sigma\boldsymbol{E}$ 各项同性线性煤质 $\boldsymbol{D} = \epsilon\boldsymbol{E} = \epsilon_0\epsilon_r\boldsymbol{E}$, $\boldsymbol{B} = \mu\boldsymbol{H} = \mu_0\mu_r\boldsymbol{H}$, $\boldsymbol{J} = \sigma\boldsymbol{J}$