Formulas

$\lambda = c/f$

$c_0 = \dfrac{1}{\sqrt{\mu_0 \varepsilon_0}}$

$\eta_0 = \sqrt{\dfrac{\mu_0}{\varepsilon_0}} \simeq 120\pi\,[\Omega]$

$\vec{H} = \hat{n} \times \dfrac{\vec{E}}{\eta}$

$\varepsilon = \varepsilon_r \varepsilon_0$

$\mu = \mu_r \mu_0$

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

$\eta = \dfrac{\omega\mu}{k} = \sqrt{\dfrac{\mu}{\varepsilon}} = \eta_0 \sqrt{\dfrac{\mu_r}{\varepsilon_r}}$

(lossy) $\eta = j\omega\mu/\gamma$

$c = \dfrac{1}{\sqrt{\mu\varepsilon}} =$

$\lambda = \dfrac{2\pi}{k} = \dfrac{2\pi}{\omega\sqrt{\mu\varepsilon}} = \dfrac{2\pi v_p}{\omega} = \dfrac{v_p}{f}$

$v_{phase} = \dfrac{\Delta z}{\Delta t} = \dfrac{\omega}{k} = \dfrac{1}{\sqrt{\mu\varepsilon}} = \dfrac{c}{\sqrt{\varepsilon_r \mu_r}}$

$v_{phase\,(lossy)} = \dfrac{\omega}{\beta}$

$\gamma = j\omega\sqrt{\mu\varepsilon} = jk = j\omega\sqrt{\mu\varepsilon'(1 - \tan\delta)}$, $\sigma = 0$

$\gamma = \alpha + j\beta$

$\gamma = j\omega\sqrt{\mu\varepsilon}\sqrt{1 - \dfrac{j\sigma}{\omega\varepsilon}}$

lossless γ

$\gamma = j\beta = j\omega\sqrt{\mu\varepsilon} = jk_0\sqrt{\mu_r\varepsilon_r}$

$k = \omega\sqrt{\mu\varepsilon} = \omega\sqrt{\varepsilon_0\mu_0}\sqrt{\varepsilon_r\mu_r} = k_0 n$

$k_0 = \omega\sqrt{\varepsilon_0\mu_0}$ $\quad \boxed{\sqrt{\varepsilon_r\mu_r} = n}$ $\quad \boxed{n = \dfrac{c}{v_p}}$

$\Gamma = \dfrac{\eta - \eta_0}{\eta + \eta_0}$, $\quad T = 1 + \Gamma = \dfrac{2\eta}{\eta + \eta_0}$

$\lambda = \dfrac{2\pi}{\beta} = \dfrac{2\pi}{\omega\sqrt{\mu\varepsilon}} = \dfrac{\lambda_0}{\sqrt{\mu_r\varepsilon_r}}$

TL Theory

$$\begin{bmatrix} \cos\beta l & jZ_0 \sin\beta l \\ jY_0 \sin\beta l & \cos\beta l \end{bmatrix}$$

$\lambda = \dfrac{2\pi}{\beta}$

$v_p = \dfrac{\omega}{\beta} = \dfrac{k_0 c}{\beta}$

$\gamma = \sqrt{(R + j\omega L)(G + j\omega C)}$

$Z_0 = \sqrt{\dfrac{R + j\omega L}{G + j\omega C}}$

LL: $\boxed{\beta = \omega\sqrt{\mu\varepsilon} = \omega\sqrt{LC}}$

LL: v_p, $Z_0 = \sqrt{\dfrac{L}{C}}$, γ

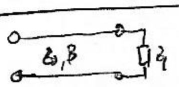
Power flow

$P = \dfrac{1}{2} V_0 I_0^*$

Power Av

$P_{av} = \dfrac{1}{2}\mathrm{Re}[V(z) I^*(z)] = \dfrac{1}{2}\dfrac{|V_0|^2}{Z_0}(1 - |\Gamma|^2)$

$\Gamma = \dfrac{Z_L - Z_0}{Z_L + Z_0}$



$V(z) = V_0^+(e^{-j\beta z} + \Gamma e^{j\beta z})$

$I(z) = \dfrac{V_0^+}{Z_0}(e^{-j\beta z} - \Gamma e^{j\beta z})$

$\lambda/4$ transformer

$Z_{in} = \dfrac{Z_0^2}{Z_L}$

Power delivered to the load

$P = \dfrac{1}{2}\mathrm{Re}\{V_{in} I_{in}^*\} = \dfrac{1}{2}|V_g|^2 \dfrac{R_{in}}{(R_{in} + R_g)^2 + (X_{in} + X_g)^2}$

$RL = -20\log(|\Gamma|)$

$SWR = \dfrac{V_{max}}{V_{min}} = \dfrac{1 + |\Gamma|}{1 - |\Gamma|}$

$Z_{in} = Z_0 \dfrac{Z_L + jZ_0 \tan\beta l}{Z_0 + jZ_L \tan\beta l}$

$Z_{in} = Z_0 \dfrac{1 + \Gamma e^{-2j\beta l}}{1 - \Gamma e^{-2j\beta l}}$

Max available power

$P = \dfrac{1}{2}|V_g|^2 \dfrac{1}{4R_g}$

Low losses T.L.

$\beta \simeq \omega\sqrt{LC}$

$\alpha = \frac{1}{2}\left(\frac{R}{Z_0} + G Z_0\right)$

Terminated lossy line

$Z_{in} = Z_0 \frac{Z_L + Z_0 \tanh \gamma l}{Z_0 + Z_L \tanh \gamma l}$

cutoff wavenumber $k_c^2 = k^2 - \beta^2$

$k = \omega\sqrt{\mu\varepsilon} = \frac{2\pi}{\lambda}$

Rect. waveguide

$f_{c_{mn}} = \frac{k_c}{2\pi\sqrt{\mu\varepsilon}} = \frac{1}{2\pi\sqrt{\mu\varepsilon}} \sqrt{\left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2}$

Circular waveguide

TE → TE_{11} $f_{c_{nm}} = \frac{p'_{nm}}{2\pi a\sqrt{\mu\varepsilon}}$ — No TE_{10}, si TE_{01}

TM → TM_{01} $\beta_{nm} = \frac{p_{nm}}{2\pi a\sqrt{\mu\varepsilon}}$ — No TM_{10}, $TM_{01} > TE_{11}$

Slab

TM → $f_c = \frac{nc}{2d\sqrt{\varepsilon_r - 1}}$

TM_0 always

TE → $f_c = \frac{(2n-1)c}{4d\sqrt{\varepsilon_r - 1}}$

NO TE_0

Stripline

TEM → $v_p = \frac{c}{\sqrt{\varepsilon_r}}$

$\beta = k_0\sqrt{\varepsilon_r}$

Microstrip

$v_p = \frac{c}{\varepsilon_e}$

$\beta = k_0\sqrt{\varepsilon_e}$

Quarter wave transf

$Z_1 = \sqrt{Z_0 Z_L}$ *

First modes propagate

TE_{10}, TE_{20}, TE_{01}, TE_{11} & TM_{11}

concept of impedance

$\eta = \sqrt{\frac{\mu}{\varepsilon}}$, $Z_w = \frac{E_t}{H_t}$, $Z_0 = \sqrt{\frac{L}{C}}$

Modal Anal.

$Z = \frac{k_0 \eta_0}{\beta}$

TE_{n0} $\beta = \sqrt{k_0^2 - \frac{n\pi}{a}}$

op
se cambia
el width

$Z_{air} = \frac{k_0 \eta_0}{\beta_{air}}$

$Z_{ox} = \frac{k_0\sqrt{\varepsilon_r} \frac{\eta_0}{\sqrt{\varepsilon_r}}}{\beta_{ox}}$

Resonators

$\omega_0 = \frac{1}{\sqrt{LC}}$

series : $Q_0 = \frac{1}{R}\sqrt{\frac{L}{C}}$ $Q_E = \frac{\omega_0 L}{R_L}$

parallel: $Q_0 = R\sqrt{\frac{C}{L}}$ $Q_E = \frac{R_L}{\omega_0 L}$

$\frac{1}{Q_L} = \frac{1}{Q_0} + \frac{1}{Q_e}$

Resonant cavity

$k_{mnl} = \sqrt{\left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2 + \left(\frac{l\pi}{d}\right)^2}$

$f_{mnl} = \frac{c}{2\pi\sqrt{\mu_r\varepsilon_r}} k_{mnl}$

Series : $\frac{\omega_0 L}{R} = \frac{1}{\omega_0 RC}$

parallel: $\omega_0 RC = \frac{R}{\omega_0 L}$

$Z_L = j\omega L$

$Z_C = \frac{1}{j\omega C}$

Filters

$b_c = \omega C_0 Z_0$

$b_L = -\frac{Z_0}{\omega L_0}$

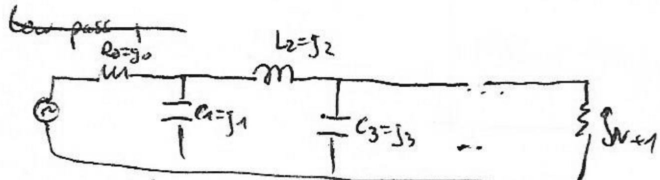
block impe

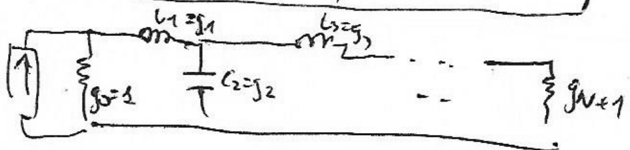
$Z_B = \frac{\pm B Z_0}{\sqrt{A^2 - 1}}$

Insertion loss method

$IL = 10 \log P_{LR}$

~~Low pass~~





Scaling $L' = R_0 L$

$C' = \frac{C}{R_0}$

$R_L' = R_0 R_L$

$C_k' = \frac{C_k}{\omega_c R_0}$

$L_k' = \frac{L_k R_0}{\omega_c}$

$\omega = \frac{1}{\sqrt{LC}}$