Formulário
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Antenas e Guias de Onda

Revisões

$Z_{IN} = \frac{Z_0^2}{Z_L}$

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

$\Gamma_0 = \frac{Z_L - Z_0}{Z_L + Z_0}$

$VSWR = \frac{E_{max}}{E_{min}} = \frac{1+\rho}{1-\rho}$

Parâmetros S e T

$$\begin{bmatrix} v_1^{ref} \\ v_2^{ref} \end{bmatrix} = \begin{bmatrix} s_{11} & s_{12} \\ s_{21} & s_{22} \end{bmatrix} \begin{bmatrix} v_1^{inc} \\ v_2^{inc} \end{bmatrix}$$

$$\begin{bmatrix} v_1^{inc} \\ v_1^{ref} \end{bmatrix} = \begin{bmatrix} t_{11} & t_{12} \\ t_{21} & t_{22} \end{bmatrix} \begin{bmatrix} v_2^{ref} \\ v_2^{inc} \end{bmatrix}$$

$$\begin{bmatrix} t_{11} & t_{12} \\ t_{21} & t_{22} \end{bmatrix} = \begin{bmatrix} \frac{1}{S_{21}} & -\frac{S_{22}}{S_{21}} \\ \frac{S_{11}}{S_{21}} & S_{12} - \frac{S_{11}S_{22}}{S_{21}} \end{bmatrix}$$

$$\begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} = \begin{bmatrix} \frac{T_{21}}{T_{11}} & T_{22} - \frac{T_{21}T_{12}}{T_{11}} \\ \frac{1}{T_{11}} & -\frac{T_{12}}{T_{11}} \end{bmatrix}$$

Amplificadores

$\rho_{IN} = S_{11} + \frac{S_{12}S_{21}\rho_L}{1 - S_{22}\rho_L}$

$\rho_{OUT} = S_{22} + \frac{S_{12}S_{21}\rho_S}{1 - S_{11}\rho_S}$

$G_T = \frac{P_L}{P_{AVS}} = \frac{1-|\Gamma_s|^2}{|1-\Gamma_{IN}\Gamma_s|^2}|S_{21}|^2\frac{1-|\Gamma_L|^2}{|1-S_{22}\Gamma_L|^2}$

$G_A = \frac{P_{AVL}}{P_{AVS}} = \frac{1-|\Gamma_s|^2}{|1-S_{11}\Gamma_s|^2}|S_{21}|^2\frac{1}{1-|\Gamma_{OUT}|^2}$

$G_P = \frac{P_L}{P_{IN}} = \frac{1}{1-|\Gamma_{IN}|^2}|S_{21}|^2\frac{1-|\Gamma_L|^2}{|1-S_{22}\Gamma_L|^2}$

$G_{TU} = \frac{1-|\Gamma_s|^2}{|1-S_{11}\Gamma_s|^2}|S_{21}|^2\frac{1-|\Gamma_L|^2}{|1-S_{22}\Gamma_L|^2}$

$G_{TU,max} = \frac{1}{|1-S_{11}|^2}|S_{21}|^2\frac{1}{|1-S_{22}|^2}$

$G_T = \frac{P_L}{P_{AVS}} = \frac{P_{AVL}}{P_{AVS}}\frac{P_L}{P_{AVL}} = G_A L_L$

$G_T = \frac{P_L}{P_{AVS}} = \frac{P_{IN}}{P_{AVS}}\frac{P_L}{P_{IN}} = L_S G_P$

Estabilidade

$|\Gamma_S| < 1 \wedge |\Gamma_L| < 1 \wedge |\Gamma_{IN}| < 1 \wedge |\Gamma_{OUT}| < 1$

Filters

$L = \frac{g_k Z_0}{2\pi f_c}$

$C = \frac{g_k}{2\pi Z_0 f_c}$

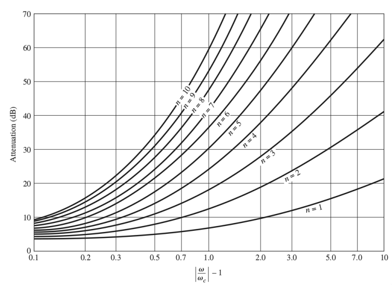
Transformada de Richards

$\omega_c = tan(\beta l)$

$Z = jg_k\omega_c \Rightarrow Z = jZ_0\tan(\beta l) \qquad \wedge Z_0 = g_k$

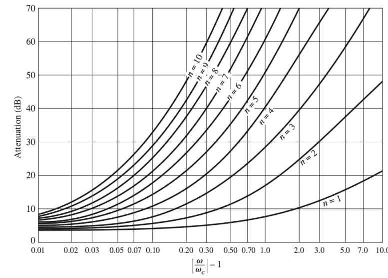
$Y = jg_k\omega_c \Rightarrow Y = \frac{j\tan(\beta l)}{Z_0} \qquad \wedge Z_0 = \frac{1}{g_k}$

Maximum Flat (3dB)



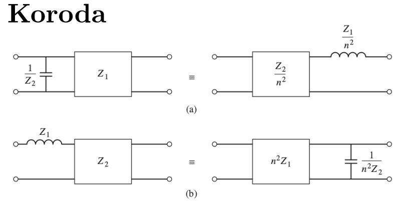
N	g_1	g_2	g_3	g_4	g_5	g_6	g_7	g_8	g_9	g_{10}	g_{11}
1	2.0000	1.0000									
2	1.4142	1.4142	1.0000								
3	1.0000	2.0000	1.0000	1.0000							
4	0.7654	1.8478	1.8478	0.7654	1.0000						
5	0.6180	1.6180	2.0000	1.6180	0.6180	1.0000					
6	0.5176	1.4142	1.9318	1.9318	1.4142	0.5176	1.0000				
7	0.4450	1.2470	1.8019	2.0000	1.8019	1.2470	0.4450	1.0000			
8	0.3902	1.1111	1.6629	1.9615	1.9615	1.6629	1.1111	0.3902	1.0000		
9	0.3473	1.0000	1.5321	1.8794	2.0000	1.8794	1.5321	1.0000	0.3473	1.0000	
10	0.3129	0.9080	1.4142	1.7820	1.9754	1.9754	1.7820	1.4142	0.9080	0.3129	1.0000

Equal Ripple (3dB)



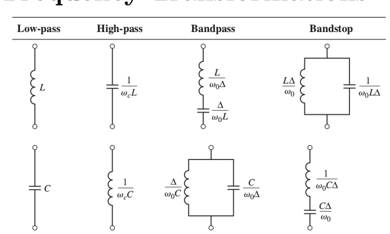
N	g_1	g_2	g_3	g_4	g_5	g_6	g_7	g_8	g_9	g_{10}	g_{11}
1	1.9953	1.0000									
2	3.1013	0.5339	5.8095								
3	3.3487	0.7117	3.3487	1.0000							
4	3.4389	0.7483	4.3471	0.5920	5.8095						
5	3.4817	0.7618	4.5381	0.7618	3.4817	1.0000					
6	3.5045	0.7685	4.6061	0.7929	4.4641	0.6033	5.8095				
7	3.5182	0.7723	4.6386	0.8039	4.6386	0.7723	3.5182	1.0000			
8	3.5277	0.7745	4.6575	0.8089	4.6990	0.8018	4.4990	0.6073	5.8095		
9	3.5340	0.7760	4.6692	0.8118	4.7272	0.8118	4.6692	0.7760	3.5340	1.0000	
10	3.5384	0.7771	4.6768	0.8136	4.7425	0.8164	4.7260	0.8051	4.5142	0.6091	5.8095

Koroda



$n^2 = 1 + \frac{Z_2}{Z_1}$

Frequency Transformations



$\Delta = \frac{\omega_2 - \omega_1}{\omega_0}$

Stepped Impedance

Bobine $\rightarrow \beta l = \frac{LZ_0}{Z_{high}}$

Condensador $\rightarrow \beta l = \frac{CZ_{low}}{Z_0}$

Guias de Onda

$E_z = 0$	$H_z = 0$	Modos TEM
$E_z = 0$	$H_z \neq 0$	Modos TE ou H
$E_z \neq 0$	$H_z = 0$	Modos TM ou E
$E_z \neq 0$	$H_z \neq 0$	Modos Híbridos

ϵ_0	$8.854187817 \times 10^{-12} F \cdot m^{-1}$
μ_0	$4\pi \times 10^{-7} H \cdot m^{-1}$

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

$\eta = 120\pi \rightarrow$ Impedância Característica do ar

Retangulares

O modo TM não se propaga se $n = 0$ ou $m = 0$
$\lambda_0 \rightarrow$ Comprimento de onda em meio livre
$\lambda_{0c} \rightarrow$ Comprimento de onda de corte no meio
$k = \omega\sqrt{\mu\epsilon} = \frac{2\pi}{\lambda}$

$f_{c_{mn}} = \frac{v}{2}\sqrt{\left(\frac{n}{y_1}\right)^2 + \left(\frac{m}{z_1}\right)^2}$

$\lambda_{c_{mn}} = \frac{2}{\sqrt{\left(\frac{n}{y_1}\right)^2 + \left(\frac{m}{z_1}\right)^2}}$

$\beta = \sqrt{k^2 - k_c^2} = \sqrt{k^2 - \left(\frac{n}{y_1}\right)^2 - \left(\frac{m}{z_1}\right)^2}$

$k_c^2 = \left(\frac{n}{y_1}\right)^2 - \left(\frac{m}{z_1}\right)^2$

$\gamma = \alpha_d + j\beta = \sqrt{k_c^2 - k^2}$

$\gamma = \sqrt{\left(\frac{n}{y_1}\right)^2 - \left(\frac{m}{z_1}\right)^2 - \omega^2\mu\epsilon} = \sqrt{k_c^2 - \beta_0^2}$

$v_p = \frac{\omega}{\beta} = \frac{v_0}{\sqrt{1 - \left(\frac{n\lambda_0}{2y_1}\right)^2 - \left(\frac{m\lambda_0}{2z_1}\right)^2}} = \frac{v_0}{\sqrt{1 - \left(\frac{\lambda_0}{\lambda_{0c}}\right)^2}}$

$Z_{TE} = \frac{k\eta}{\beta}$ e se $f > f_c$, $Z_{TE} = \frac{Z_d}{\sqrt{1 - \left(\frac{\lambda_0}{\lambda_{0c}}\right)^2}}$

$v = \frac{c}{\sqrt{\epsilon_r}}$

$\lambda = \frac{\lambda_0}{\sqrt{\epsilon_r}}$

Cilíndrico

$n \rightarrow$ ordem da função de Bessel
$k \rightarrow$ raiz da ordem n da função de Bessel
$k' \rightarrow$ raiz da ordem n da derivada da função de Bessel
$a \rightarrow$ raio do guia de onda
$p_{nm} \rightarrow$ raiz de ordem m da função de Bessel de ordem n
$p'_{nm} \rightarrow$ raiz de ordem m da derivada da função de Bessel de ordem n
Os modos TE e TM obrigam a $m \neq 0$

Modo TE_{nm}

$k_{c_{nm}} = \frac{p'_{nm}}{a}$

$\beta_{nm} = \sqrt{k^2 - k^c} = \sqrt{k^2 - \left(\frac{p'_{nm}}{r}\right)^2}$

$f_{c_{nm}} = \frac{k_c}{2\pi\sqrt{\mu\epsilon}} = \frac{p'_{nm}}{2\pi a\sqrt{\mu\epsilon}}$

$f_c = \frac{v}{2\pi}\frac{k'nm}{a}$
$\lambda_c = \frac{2\pi a}{k'nm}$
$Z_{TE} = \frac{\eta k}{\beta}$

k	J_0'(x)	J_1'(x)	J_2'(x)	J_3'(x)	J_4'(x)	J_5'(x)
1	3.8317	1.8412	3.0542	4.2012	5.3175	6.4156
2	7.0156	5.3314	6.7061	8.0152	9.2824	10.5199
3	10.1735	8.5363	9.9695	11.3459	12.6819	13.9872
4	13.3237	11.7060	13.1704	14.5858	15.9641	17.3128
5	16.4706	14.8636	16.3475	17.7887	19.1960	20.5755

Modo TM

$k_{cm} = \frac{p_{nm}}{a}$

$\beta_{nm} = \sqrt{k^2 - k^c} = \sqrt{k^2 - \left(\frac{p'_{nm}}{r}\right)^2}$

$f_{c_{nm}} = \frac{k_c}{2\pi\sqrt{\mu\epsilon}} = \frac{p_{nm}}{2\pi a\sqrt{\mu\epsilon}}$
$f_c = \frac{v}{2\pi}\frac{knm}{a}$
$\lambda_c = \frac{2\pi a}{knm}$
$Z_{TM} = \frac{\eta\beta}{k}$

k	J_0(x)	J_1(x)	J_2(x)	J_3(x)	J_4(x)	J_5(x)
1	2.4048	3.8317	5.1356	6.3802	7.5883	8.7715
2	5.5201	7.0156	8.4172	9.7610	11.0647	12.3386
3	8.6537	10.1735	11.6198	13.0152	14.3725	15.7002
4	11.7915	13.3237	14.7960	16.2235	17.6160	18.9801
5	14.9309	16.4706	17.9598	19.4094	20.8269	22.2178

Perdas

Dielétrico $\rightarrow \alpha_d = \omega\epsilon\tan(\delta)$
$\alpha_{d_{mn}} = \frac{\omega\tan(\delta)}{2c\sqrt{1-\left(\frac{f_{c_{mn}}}{f}\right)^2}} = \frac{\omega\sqrt{\mu\epsilon}\tan(\delta)}{2\beta} = \frac{k^2\tan(\delta)}{2\beta}$
Não há propagação ($f < f_c$):
$\alpha = \frac{2\pi}{\lambda}\sqrt{\left(\frac{\lambda}{\lambda_c}\right)^2 - 1}$

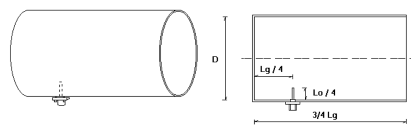
Há propagação ($f > f_c$):
$\alpha_d = \frac{\pi\tan(\delta)}{\lambda\sqrt{1-\frac{\lambda}{\lambda_c}}}$

$\alpha_c = \frac{Re[Z_c]}{Z_d y_1}\frac{1+2\frac{y_1}{x_1}\left(\frac{\lambda}{\lambda_c}\right)^2}{\sqrt{1-\left(\frac{\lambda}{\lambda_c}\right)^2}}$

$P_{max} = \frac{E^2 y_1 z_1}{4Z_{TE}}$
$R_S = \frac{1}{\sigma\delta} = \sqrt{\frac{\omega\mu}{2\sigma}} \rightarrow$ Efeito de Skin

Propagação ($f > f_c$)

$\gamma = \pm\sqrt{\left(\frac{p'_{nm}}{a}\right)^2 - \omega^2\mu\epsilon}$
$f_c = \frac{1}{2\pi\sqrt{\mu\epsilon}}\frac{p'_{nm}}{a}$
$\lambda_{0c} = \frac{2\pi a}{p'_{nm}}$
$\beta = \sqrt{\omega^2\mu\epsilon - \left(\frac{p'_{nm}}{a}\right)^2}$
$\lambda_g = \frac{\lambda_0}{\sqrt{1-\left({}^{\lambda_0}/{}_{\lambda_{0c}}\right)^2}}$
$v_p = \frac{\omega}{\beta} = \frac{v_0}{\sqrt{1-\left({}^{\lambda_0}/{}_{\lambda_{0c}}\right)^2}}, \qquad v_0 = {}^1/{}_{\sqrt{\mu\epsilon}}$



Fibras

$\sin(\theta_2) = \left(\frac{\mu_1}{\mu_2}\right)\sin(\theta_2)$
$\theta_1 = \theta_c \Rightarrow \theta_2 = 90°$
$\sin(\theta_c) = \frac{n_2}{n_1}$
$\sin[\theta_{i_{max}}] = \frac{\sqrt{n_1^2 - n_2^2}}{n_0}$
Fractional Difference $\rightarrow \Delta = \frac{n_1 - n_2}{n_1}$
Guide light effective $\Rightarrow \Delta << 1$
$NA = n_1\sqrt{2\Delta}$
θ close to $\theta_{critical} \Rightarrow$ Higher order modes
θ larger than $\theta_{critical} \Rightarrow$ Lower order modes
$v = \frac{2\pi d}{\lambda}\sqrt{\mu_1^2 - \mu_2^2} = \frac{2\pi d}{\lambda}NA$
$M = \frac{V^2}{2}$
Velocidade de Fase $\rightarrow v_f = \frac{\omega}{k} = \frac{c}{n}$
Velocidade de Grupo $\rightarrow v_g = \frac{d\omega}{dk} = \frac{c}{m}$
$m = n - \lambda_0\frac{dn}{d\lambda_0}$

Antenas

Diretividade $\rightarrow D(\theta,\Phi) = \frac{U(\theta,\Phi)}{U_0}$
Na direção de máximo $\rightarrow D(\theta,\Phi) = 4\pi\frac{U_{max}}{P_{rad}}$
$G(\theta,\Phi) = \frac{U(\theta,\Phi)}{U_0} = 4\pi\frac{U_{max}}{P_{in}}$
Densidade de uma antena isotrópica sem perdas:
$U_0 = \frac{P_{rad}}{4\pi} = \frac{P_{in}}{4\pi}$
$U(\theta,\Phi) = R^2 S_{rad} = R^2\frac{1}{2}\frac{|E_\theta|^2}{\eta}$
$G(\theta,\Phi) = e_t D(\theta,\Phi)$
$\rho = \frac{P_{rad}}{P_{IN}}$

Potência

$P_{in} = P_{rad} + P_D$
$P_D = P_{ref} + P_c + P_d$
$P_{ref} \rightarrow$ Potência refletida por desaptação
$P_c \rightarrow$ Potência dissipada nas paredes condutoras da antena
$P_d \rightarrow$ Potência dissipada no dielétrico

Eficiência

eficiência $\rightarrow e_t = \frac{P_{rad}}{P_{in}} = e_r e_c e_d$
Eficiência de Radiação $\rightarrow e_{cd} = e_c e_d$
$S_{rad} = \frac{1}{2}(E \times H^*)$
$e_r = \frac{P_{tran}}{P_{in}} = (1 - |\rho|^2)$

Impedância

$Z_A = R_A + jX_A \Rightarrow R_A = R_r + R_p$
Efeito de Skin $\rightarrow \delta = \sqrt{\frac{2}{\omega\mu\sigma}}$

Effective Area

$A_e = \frac{P_T}{S_i} =$
$S_{isotropica} = \frac{P_{rad1}}{4\pi r^2}$
$S_1 = D_1\frac{P_{rad1}}{4\pi r^2}$
$S_i \rightarrow$ Densidade de Potência
$A_e = \frac{\lambda^2}{4\pi}G$

Transmissão

$P_{rad} = e_{t1}P_{in}$
$G_1 = e_{t1}D_1$
$P_T = A_{e2}S_1 = A_{e2}G_1\frac{P_{in}}{4\pi r^2}$
$|E_\theta| = \frac{\eta I\Delta Z}{2\pi R\lambda}\sin(\theta)$

Fórmula de Friis

$P_T = A_{e2}\frac{P_{in}}{4\pi r^2}G_1 = P_{in}\left(\frac{\lambda}{4\pi r}\right)^2 G_t G_r$
$\left(\frac{\lambda}{4\pi r}\right)^2 \rightarrow$ Perdas em espaço livre

Radar

$P_{ref} = S_i\sigma$
$P = A_e S_A = P_t\sigma G^2\frac{1}{4\pi}\left(\frac{\lambda}{4\pi r^2}\right)^2$

Antenas Filiformes

$H_\Phi = j\frac{\beta I\Delta z}{4\pi r}e^{-j\beta r}\sin(\theta)$
$E_\theta = j\eta\frac{\beta I\Delta z}{4\pi r}e^{-j\beta r}\sin(\theta)$

Dipolo

$P = P_{rad} + jQ = \eta\frac{\pi}{3}\left(\frac{I\Delta z}{\lambda}\right)^2\left[1 - j\frac{1}{(\beta r)^3}\right]$
$\eta = \sqrt{\frac{\mu}{\epsilon}}$
Em campo distante ($f >> \lambda$), Q é desprezável face a P_{rad}
Resistência de Radiação $\rightarrow R_r = \eta\frac{2\pi}{3}\left(\frac{\Delta z}{\lambda}\right)^2$
$U(\theta,\Phi) = r^2 S = r^2\frac{1}{2}\left(\frac{|E|^2}{\eta}\right)$
$U(\theta) = r^2 S_{rad} = \frac{\eta}{2}\left(\frac{\beta I\Delta z}{4\pi}\right)^2\sin^2(\theta)$
$D(\theta,\Phi) = 4\pi\frac{U(\theta,\Phi)}{P_{rad}}$
$A_e = \frac{\lambda^2}{4\pi}D$
Num dipolo curto, U_{max}, P_{rad} e R_r passa para ${}^1/{}_4$.
$U(\theta) = R^2 S_{rad}(\theta,\Phi,R)$
$S_{rad} = \frac{\eta|I_0|^2}{8\pi^2 R^2}\left[\frac{\cos\left(\frac{pi}{2}cos(\theta)\right)}{\sin(\theta)}\right]^2$
$U_n(\theta,\Phi) = \left(\frac{\cos\left(\frac{pi}{2}cos(\theta)\right)}{\sin(\theta)}\right)^2$

Monopolo

$E_2^{mono} = E_2^{di} \Rightarrow S_\theta^{mono} = S_\theta^{di} \Rightarrow U_\theta^{mono} = U_\theta^{di}, se\theta \leq \frac{\pi}{2}$
$P_{rad}^{mono} = \frac{1}{2}P_{rad}^{di}$
$D^{mono} = 2D^{di}$
$|E_g| = \frac{\eta I_0}{2\pi R}$

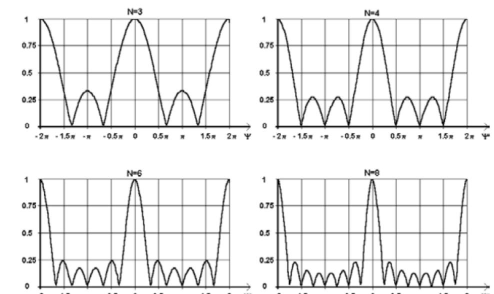
Antenas Microstrip

$W = \frac{1}{2f_r\cdot\sqrt{\epsilon_0\mu_0}}\sqrt{\frac{2}{\epsilon_r+1}}$
$\epsilon_{reff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2\cdot\sqrt{1+\frac{12d}{W}}}$
$\Delta L =$
$0.412d\cdot(\epsilon_{reff}+0.3)\frac{\frac{W}{d}+0.264}{(\epsilon_{reff}-0.258)(\frac{W}{d}+0.8)}$
$L = \frac{1}{2f_r\sqrt{\epsilon_{reff}}\cdot\sqrt{\epsilon_0\mu_0}} - 2\Delta L$
$Z_a = 90\frac{\epsilon_r^2}{\epsilon_r-1}\left(\frac{L}{W}\right)^2$

Agregados de Antenas

$\phi = \beta d\cos(\theta) + \alpha$
$E_{\theta T} =$
$j\eta\frac{I_0 e^{-j\beta R}}{2\pi R}\left[\frac{\cos\left(\frac{pi}{2}cos(\theta)\right)}{\sin(\theta)}\right]\left[2cos\left(\frac{\beta d\cos(\theta)+\alpha}{2}\right)\right]$

$FA = \frac{\sin(N\frac{\phi}{2})}{\sin(\frac{\phi}{2})}$



Pedro Martins (martinspedro@ua.pt)