CEM2:

1) ONDAS GUIADAS:

$\nabla\phi = \frac{1}{h_1}\frac{\partial\phi}{\partial u_1}\hat{u}_1 + \frac{1}{h_2}\frac{\partial\phi}{\partial u_2}\hat{u}_2 + \frac{1}{h_3}\frac{\partial\phi}{\partial u_3}\hat{u}_3$ $\quad \nabla\times\vec{A} = \begin{vmatrix} \frac{\hat{u}_1}{h_2h_3} & \frac{\hat{u}_2}{h_1h_3} & \frac{\hat{u}_3}{h_1h_2} \\ \partial/\partial u_1 & \partial/\partial u_2 & \partial/\partial u_3 \\ h_1A_1 & h_2A_2 & h_3A_3 \end{vmatrix}$

$\nabla\times\vec{E}_i = -j\omega\mu_i\vec{H}_i$ $\quad \nabla\times\vec{H}_i = j\omega\varepsilon_i\vec{E}_i$ $\quad \varepsilon_{eq} = \varepsilon' - j\left(\varepsilon'' + \frac{\sigma}{\omega}\right)$ $\quad \gamma_{0i}^2 = -\omega^2\mu_i\varepsilon_i$

$\Delta F_{H_i}(u_1,u_2) - \gamma_{ci}^2 F_{H_i}(u_1,u_2) = 0$ Ec de Helmholtz $\quad \gamma = \sqrt{\gamma_{0i}^2 - \gamma_{ci}^2}$

CART. $\nabla\cdot\vec{A} = \frac{\partial A_x}{\partial x} + \frac{\partial A_y}{\partial y} + \frac{\partial A_z}{\partial z}$ $\quad \mu_0 = 4\pi\cdot10^{-7}$ (H/m) $\quad \varepsilon_0 = \frac{1}{36\pi\cdot10^9}$ (F/m)

TEM: $\vec{E} = -\nabla_t\phi\cdot e^{-\gamma_0 z}$ $\quad \vec{H} = \frac{\hat{z}\times\vec{E}}{\eta}$ $\quad V = -\int_{C_1}^{C_2}\vec{E}\cdot d\vec{l}$ $\quad I = \oint_{C_2}\vec{H}\cdot d\vec{l}$

$L\frac{\Delta l}{2}$ $R\frac{\Delta l}{2}$ $G\Delta l$ $C\Delta l$ Condición: $|\Delta l\cdot\gamma| \ll$

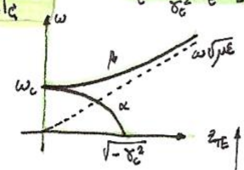
2) GUÍAS DE ONDA CONDUCTORAS:

· Modos TM: $\begin{cases} F_H = 0 \\ \Delta_t F_E - \gamma_c^2 F_E = 0 \\ F_E|_c = 0 \end{cases}$ $\quad \vec{E}_t = \frac{\gamma}{\gamma_c^2}\nabla_t E_z$ $\quad \vec{H}_t = \frac{-j\omega\varepsilon}{\gamma_c^2}\nabla_t E_z\times\hat{z} = \frac{\hat{z}\times\vec{E}_t}{Z_{TM}}$ $\quad Z_{TM} = \frac{\gamma}{j\omega\varepsilon}$ $\quad \gamma = \sqrt{-\omega^2\mu\varepsilon - \gamma_c^2}$

Modos TE $\begin{cases} F_E = 0 \\ \Delta_t F_H - \gamma_c^2 F_H = 0 \\ \left.\frac{\partial F_H}{\partial n}\right|_c = 0 \end{cases}$ $\quad \vec{E}_t = \frac{j\omega\mu}{\gamma_c^2}\nabla_t H_z\times\hat{z} = Z_{TE}\vec{H}_t\times\hat{z}$ $\quad \vec{H}_t = \frac{\gamma}{\gamma_c^2}\nabla_t H_z$ $\quad Z_{TE} = \frac{j\omega\mu}{\gamma}$ $\quad \gamma = \sqrt{-\omega^2\mu\varepsilon - \gamma_c^2}$

$\gamma_c^2 = -\omega_c^2\mu\varepsilon$, $f_c = \frac{\sqrt{-\gamma_c^2}}{2\pi\sqrt{\mu\varepsilon}}$ $\quad \begin{cases} f<f_c \Rightarrow \gamma^2>0 \Rightarrow \gamma=\alpha \text{ modo al corte} \\ f>f_c \Rightarrow \gamma^2<0 \Rightarrow \gamma=j\beta \text{ modo guiado} \end{cases}$ $\quad \gamma = \pm\gamma_0\sqrt{1-\left(\frac{f_c}{f}\right)^2}$ $\quad \beta = \omega\sqrt{\mu\varepsilon}\sqrt{1-\left(\frac{f_c}{f}\right)^2}$

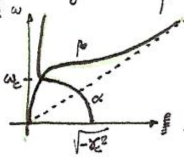
$f<f_c$: $\frac{\omega^2}{\omega_c^2} + \frac{\alpha^2}{\omega_c^2\mu\varepsilon} = 1$ $\quad f>f_c$: $\frac{\omega^2}{\omega_c^2} - \frac{\beta^2}{\omega_c^2\mu\varepsilon} = 1$

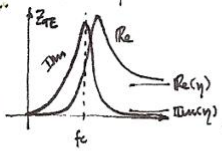


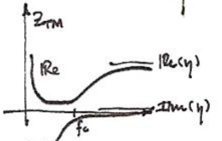
$Z_{TE} = \pm\frac{\eta}{\sqrt{1-\left(\frac{f_c}{f}\right)^2}}$ Reales $f>f_c$ Imag. $f<f_c$ $\quad Z_{TM} = \pm\eta\sqrt{1-(f_c/f)^2}$

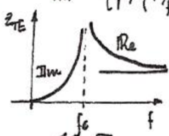
CON PÉRDIDAS: $tg\delta \ll 1$

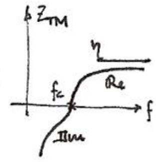
$f_c = \frac{\sqrt{-\gamma_c^2}}{2\pi\sqrt{\mu\varepsilon'}}$ $\quad \beta \approx \omega\sqrt{\mu\varepsilon'}\sqrt{1-\left(\frac{f_c}{f}\right)^2}$ $\quad \alpha \approx \beta\frac{tg\delta}{2}\frac{1}{1-\left(\frac{f_c}{f}\right)^2}$











GUÍA DE ONDA RECTANGULAR:

No TEM.

TM: $\vec{E}_{z_{mn}} = A\,\text{sen}\left(\frac{m\pi x}{a}\right)\text{sen}\left(\frac{n\pi y}{b}\right)e^{-\gamma_{mn}z}\hat{z}$ $\quad$ TM_{mn} m: variac. en x, n: variac. en y

$\gamma_{mn} = \sqrt{-\omega^2\mu\varepsilon + \left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2}$ $\quad f_{c_{mn}} = \frac{c}{2}\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}$

TE: $\vec{H}_{z_{mn}} = A\cos\left(\frac{m\pi x}{a}\right)\cos\left(\frac{n\pi y}{b}\right)e^{-\gamma_{mn}z}\hat{z}$ $\quad$ TE $\begin{cases} m=0,1,2\ldots \\ n=0,1,2\ldots \end{cases}$ $\quad -\gamma_c^2 = \left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2$

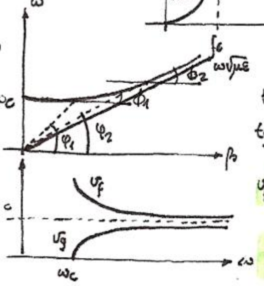
Modo fundam. TE_{10}: $-\gamma_{c_{10}}^2 = \left(\frac{\pi}{a}\right)^2$ $\quad f_{c_{10}} = \frac{c}{2a}$ $\quad \gamma = \sqrt{-\omega^2\mu\varepsilon + \left(\frac{\pi}{a}\right)^2}$

$\vec{H}_z = A\cos\left(\frac{\pi x}{a}\right)e^{-\gamma z}\hat{z}$ $\quad$ TM $\begin{cases} m=1,2\ldots \\ n=1,2\ldots \end{cases}$

$\vec{H}_t = A\frac{\gamma a}{\pi}\text{sen}\left(\frac{\pi x}{a}\right)e^{-\gamma z}\hat{x}$ $\quad \vec{E}_t = A\frac{-j\omega\mu a}{\pi}\text{sen}\left(\frac{\pi x}{a}\right)e^{-\gamma z}\hat{y}$

Cara ancha inferior: $\vec{J}_s = A\left[-\frac{\gamma a}{\pi}\text{sen}\left(\frac{\pi x}{a}\right)\hat{z} + \cos\left(\frac{\pi x}{a}\right)\hat{x}\right]e^{-\gamma z}$

Cara estrecha izquierda: $\vec{J}_s = -A\hat{y}e^{-\gamma z}$



$tg\phi = v_g$ $\quad tg\varphi = v_f$ $\quad v_f = \frac{\omega}{\beta} = \frac{c}{\sqrt{1-\left(\frac{f_c}{f}\right)^2}}$ $\quad v_g = \frac{\partial\omega}{\partial\beta} = c\sqrt{1-\left(\frac{f_c}{f}\right)^2}$

a=2b: TE_{10}, TE_{20}, TE_{01}, TM, TE_{30}

b<a<2b: TE_{10}, TE_{01}, TE_{20}, TE_{30}

a=b: TE_{10}, TE_{01}, TM_{11}

GUÍA CUADRADA:

Rectangular con a=b

Modos fundam: TE_{10}, TE_{01} $\quad \begin{cases} \vec{E}_t|_{TE_{10}} = E_M\,\text{sen}\left(\frac{\pi x}{a}\right)e^{-\gamma_{10}z}\hat{y} \\ \vec{E}_t|_{TE_{01}} = E_M\,\text{sen}\left(\frac{\pi y}{a}\right)e^{-\gamma_{01}z}\hat{x} \end{cases}$ $\quad \gamma_{10} = \gamma_{01}$

Comb. lineales: $\vec{E}_t|_{TE_{10}+jTE_{01}} = E_M\left[\text{sen}\left(\frac{\pi x}{a}\right)\hat{y} + j\,\text{sen}\left(\frac{\pi y}{a}\right)\hat{x}\right]e^{-\gamma z}$

POLARIZ. CIRCULAR EN LAS DIAGONALES

GUÍA CIRCULAR:

No TEM

TM: $\vec{E}_{z_{nm}} = AJ_n\left(\frac{p_{nm}}{a}r\right)\cos(n\varphi)e^{-\gamma_{nm}z}\hat{z}$

$\gamma_{nm} = \sqrt{-\omega^2\mu\varepsilon + \left(\frac{p_{nm}}{a}\right)^2}$ $\quad f_{c_{nm}} = \frac{p_{nm}c}{2\pi a}$

$p'_{11} = 1.841$

$p_{01} = 2{,}405$

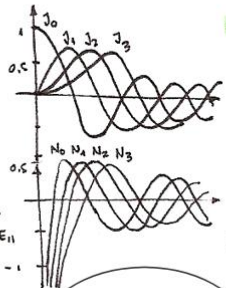
$p'_{01} = 3.832$

TE: $\vec{H}_{z_{nm}} =$ $\quad f_{c_{nm}} = \frac{p'_{nm}c}{2\pi a}$

$\gamma_{nm} = \sqrt{-\omega^2\mu\varepsilon + \left(\frac{p'_{nm}}{a}\right)^2}$

TM_{nm} n: orden Bessel, var. angular; m: orden del cero, var. radial

TE_{11} (1), TM_{01} (1.31), TE_{21} (1.66), TM_{11} TE_{01} (2.08), TE_{31} (2.28) — $f_c / f_c|_{TE_{11}}$ — MONOMODO



Modo fund. TE_{11}: $-\gamma_c^2 = \left(\frac{p'_{11}}{a}\right)^2$ $\quad f_c = \frac{p'_{11}c}{2\pi a}$ $\quad \gamma = \sqrt{-\omega^2\mu\varepsilon + \left(\frac{p'_{11}}{a}\right)^2}$

$\vec{H}_z = AJ_1\left(\frac{p'_{11}}{a}r\right)\cos\varphi\, e^{-\gamma z}\hat{z}$

$\vec{H}_t = A\frac{\gamma a}{p'_{11}}\left[-J'_1\left(\frac{p'_{11}}{a}r\right)\cos\varphi\,\hat{r} + \frac{a}{p'_{11}r}J_1\left(\frac{p'_{11}}{a}r\right)\text{sen}\,\varphi\cdot\hat{\varphi}\right]e^{-\gamma z}$

$\vec{E}_t = A\frac{j\omega\mu a}{p'_{11}}\left[J'_1\left(\frac{p'_{11}}{a}r\right)\cos\varphi\cdot\hat{\varphi} + \frac{a}{p'_{11}r}J_1\left(\frac{p'_{11}}{a}r\right)\text{sen}\,\varphi\,\hat{r}\right]e^{-\gamma z}$

$\begin{cases} \hat{n} = -\hat{r} \\ r = a \end{cases}$ $\vec{J}_s = AJ_1(p'_{11})\left[\cos\varphi\cdot\hat{\varphi} - \frac{\gamma a}{(p'_{11})^2}\text{sen}\,\varphi\,\hat{z}\right]e^{-\gamma z}$

Modo TE_{01}: $-\gamma_c^2 = \left(\frac{p'_{01}}{a}\right)^2$ $\quad f_c = \frac{p'_{01}c}{2\pi a}$ $\quad \gamma = \sqrt{-\omega^2\mu\varepsilon + \left(\frac{p'_{01}}{a}\right)^2}$

$\vec{H}_z = AJ_0\left(\frac{p'_{01}}{a}r\right)e^{-\gamma z}\hat{z}$

$\vec{H}_t = -A\frac{\gamma a}{p'_{01}}J'_0\left(\frac{p'_{01}}{a}r\right)\hat{r}e^{-\gamma z}$ $\quad \vec{E}_t = A\frac{j\omega\mu a}{p'_{01}}J'_0\left(\frac{p'_{01}}{a}r\right)\hat{\varphi}e^{-\gamma z}$

$\vec{J}_s = AJ_0(p'_{01})\hat{\varphi}e^{-\gamma z}$

GUÍA COAXIAL:

SÍ TEM: modo fundamental

TM: $J_n(\sqrt{-\gamma_c^2}a)N_n(\sqrt{-\gamma_c^2}b) - J_n(\sqrt{-\gamma_c^2}b)N_n(\sqrt{-\gamma_c^2}a) = 0$

$\gamma_{nm} = \sqrt{-\omega^2\mu\varepsilon - \gamma_{c_{nm}}^2}$

TE: $J'_n(\sqrt{-\gamma_c^2}a)N'_n(\sqrt{-\gamma_c^2}b) - J'_n(\sqrt{-\gamma_c^2}b)N'_n(\sqrt{-\gamma_c^2}a) = 0$

TE_{11}: 1er superior

$\sqrt{-\gamma_{c_{11}}^2} \approx \frac{2}{a+b}$ $\quad f_{c_{11}}\Big|_{1^{er}sup} \approx \frac{c}{\pi(a+b)} = \frac{c}{\pi(1+b/a)}\cdot\frac{1}{a}$

POTENCIA TRANSMITIDA:

$W_T(z) = \frac{1}{2}\text{Re}\left[\int_S(\vec{E}_t\times\vec{H}_t^*)\,d\vec{s}\right] = \frac{1}{2}\text{Re}\left[\int_S Z_{modo}\vec{H}_t\cdot\vec{H}_t^*ds\right]$

$= \frac{1}{2}\text{Re}(Z_{modo})\int_S\vec{H}_t\cdot\vec{H}_t^*ds$

$= \frac{1}{2}\text{Re}\left(\frac{1}{Z_{modo}^*}\right)\int_S\vec{E}_t\cdot\vec{E}_t^*ds$

$f<f_c \Rightarrow W_T = 0$ CORTE

$f>f_c \Rightarrow W_T \neq 0$ TRANSM.

TE: $W_T(z) = \frac{\gamma\gamma^*}{2(-\gamma_c^2)}\text{Re}(Z_{TE})\int_S\vec{H}_z\cdot\vec{H}_z^*ds$

TM: $W_T(z) = \frac{\gamma\gamma^*}{2(-\gamma_c^2)}\text{Re}\left(\frac{1}{Z_{TM}^*}\right)\int_S E_z\cdot E_z^*ds$

TE_{10}: $W_T = E_M^2\frac{ab}{4\eta}\sqrt{1-\left(\frac{f_c}{f}\right)^2}$

TE_{11}: $W_T = E_M^2\frac{\pi a^2}{4\eta}\left[\underbrace{4J_1^2(p'_{11})\left(1-\frac{1}{(p'_{11})^2}\right)}_{\approx 0.955}\right]\sqrt{1-\left(\frac{f_c}{f}\right)^2}$

TEM: $W_T = E_M^2\frac{\pi(a^2-b^2)}{4\eta}\left[\frac{4\ln(a/b)}{(a/b)^2-1}\right]$

POTENCIA DISIPADA:

$\alpha = \frac{W_{pd}(z)}{2W_T(z)}$

ORTOGONALIDAD:

$W_{cruce} = \frac{1}{2}\text{Re}\left[\int_S\langle\vec{E}_{t1}\times\vec{H}_{t2}^*\rangle d\vec{s}\right] = 0$

2 modos TE: $(\gamma_{c1}^2 - \gamma_{c2}^2)W_{cruce} = 0$ Para cles prop. dif. modos ortogon.

2 modos dist. son ortog. no degenerados ⇒ ortogon. Para mismo tipo, calcular W_{cruce}

$[ABCD] = \begin{bmatrix} [U]Ch(\gamma_0 l) & [Z_0]Sh(\gamma_0 l) \\ [Z_0]^{-1}Sh(\gamma_0 l) & [U]Ch(\gamma_0 l) \end{bmatrix}$ $\quad [Z] = \begin{bmatrix} [Z_0]\frac{1}{Th(\gamma_0 l)} & [Z_0]\frac{1}{Sh(\gamma_0 l)} \\ [Z_0]\frac{1}{Sh(\gamma_0 l)} & [Z_0]\frac{1}{Th(\gamma_0 l)} \end{bmatrix}$

LINEA TRANSMISIÓN MULTICONDUCTORA:

$\Delta_t\Phi^j(u_1,u_2) = 0$

$\Phi^j(u_1,u_2)|_{pantalla} = 0$

$\Phi^j(u_1,u_2)|_{c_i} = \Phi_i^j$

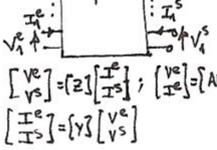
$\phi_i^j \begin{cases} 0 & i\neq j \\ 1 & i=j \end{cases}$

$\vec{E}^j(\vec{r}) = -\nabla_t\Phi^j(u_1,u_2)e^{-\gamma_0 z}$ $\quad \vec{H}^j(\vec{r}) = \frac{\hat{z}\times\vec{E}^j(\vec{r})}{\eta}$

$V_i(z) = \sum_{j=1}^N a^j\phi_i^j e^{-\gamma_0 z} = a^i\phi_i^i e^{-\gamma_0 z} = V_{0i}e^{-\gamma_0 z}$

$I_i(z) = c\sum_{j=1}^N c_{ij}V_j(z)$

$c_{ij} = \frac{q_i^j}{\phi_i^j}$ $\quad [C] = \begin{bmatrix} c_{11} & \cdots & c_{1N} \\ \vdots & & \vdots \\ c_{1N} & & c_{NN} \end{bmatrix}$ $\quad [V(z)] = \begin{bmatrix} V_1(z) \\ \vdots \\ V_N(z) \end{bmatrix}$ $\quad [I(z)] = \begin{bmatrix} I_1(z) \\ \vdots \\ I_N(z) \end{bmatrix}$ $\quad [V(z)] = \underbrace{\left[\frac{1}{c}[C]^{-1}\right]}_{[Z_0]}[I(z)]$



$[Y] = \begin{bmatrix} [Z_0]^{-1}\frac{1}{Th(\gamma_0 l)} & [Z_0]^{-1}\frac{1}{Sh(\gamma_0 l)} \\ [Z_0]^{-1}\frac{1}{Sh(\gamma_0 l)} & [Z_0]^{-1}\frac{1}{Th(\gamma_0 l)} \end{bmatrix}$

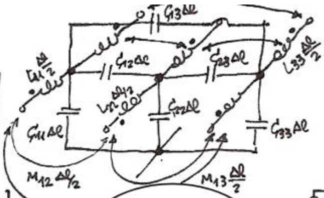
$\begin{bmatrix} V^e \\ V^s \end{bmatrix} = [Z]\begin{bmatrix} I^e \\ I^s \end{bmatrix}$; $\begin{bmatrix} V^e \\ I^e \end{bmatrix} = [ABCD]\begin{bmatrix} V^s \\ I^s \end{bmatrix}$

$\begin{bmatrix} I^e \\ I^s \end{bmatrix} = [Y]\begin{bmatrix} V^e \\ V^s \end{bmatrix}$

CIRCUITO EQUIVALENTE:

$|\gamma_0 \Delta l| \ll 1$

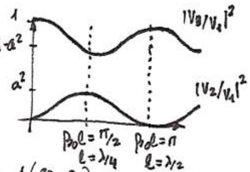
$$[ABCD] = \begin{bmatrix} [U]\left(1+\frac{(\gamma_0\Delta l)^2}{2}\right) & [Z_0]\gamma_0\Delta l \\ [Z_0]^{-1}\gamma_0\Delta l & [U]\left(1+\frac{(\gamma_0\Delta l)^2}{2}\right) \end{bmatrix}$$



$M_{13}\frac{\Delta l}{2}$

$L_{ii} = \frac{[c]^{-1}_{ii}}{c^2}$ $M_{ij} = \frac{[c]^{-1}_{ij}}{c^2}$

$C_{ii} = \sum_k c_{ik}$ $C_{ij}\Big|_{i\neq j} = -c_{ij}$



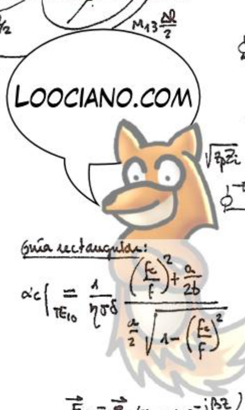
Ejemplo N=2:

$$[Z] = \begin{bmatrix} Z_1 & Z_2 & Z_3 & Z_4 \\ Z_2 & Z_1 & Z_4 & Z_3 \\ Z_3 & Z_4 & Z_1 & Z_2 \\ Z_4 & Z_3 & Z_2 & Z_1 \end{bmatrix}$$

C_i: $Z_i = \frac{\sqrt{\mu\varepsilon}}{C_i}$ C_p: $Z_p = \frac{\sqrt{\mu\varepsilon}}{C_p}$

$Z_1 = \frac{Z_p+Z_i}{2j\,tg(\beta_0 l)}$ $Z_2 = \frac{Z_p-Z_i}{2j\,tg(\beta_0 l)}$

$Z_3 = \frac{Z_p+Z_i}{2j\,sen(\beta_0 l)}$ $Z_4 = \frac{Z_p-Z_i}{2j\,sen(\beta_0 l)}$



ADAPTACIÓN:

$$Z_{e1} = Z_0 \cdot \frac{1-\left[\frac{Z_pZ_i}{2Z_0^2}+\frac{1}{4}\left(\frac{Z_p}{Z_i}+\frac{Z_i}{Z_p}\right)\right]tg^2(\beta_0 l)+j\left[\frac{Z_p+Z_i}{4Z_0}\left(\frac{Z_0^2}{Z_pZ_i}+3\right)\right]tg(\beta_0 l)}{1-\left[\frac{Z_0^2}{2Z_pZ_i}+\frac{1}{4}\left(\frac{Z_p}{Z_i}+\frac{Z_i}{Z_p}\right)\right]tg^2(\beta_0 l)+j\left[\frac{Z_p+Z_i}{4Z_0}\left(\frac{3Z_0^2}{Z_pZ_i}+1\right)\right]tg(\beta_0 l)}$$

$Z_0 = \sqrt{Z_pZ_i}$

TRANSMISIÓN:

$$\frac{V_3}{V_1} = \frac{\sqrt{1-a^2}}{\sqrt{1-a^2}\cdot\cos(\beta_0 l)+j\,sen(\beta_0 l)}$$ $a = \frac{Z_p-Z_i}{Z_p+Z_i}$

$V_4/V_1 = 0$

$$V_2/V_1 = \frac{ja\,sen(\beta_0 l)}{\sqrt{1-a^2}\cdot\cos(\beta_0 l)+j\,sen(\beta_0 l)}$$

③ GUÍAS DE ONDA CONDUCTORES REALES:

$\alpha = \frac{W_p}{2W_T} = \frac{W_{pd}+W_{pc}}{2W_T} = \alpha_d+\alpha_c$ $W_{pc} = \frac{1}{2\sigma\delta}\int_c \vec{H}\cdot\vec{H}^*dl$

$\delta = \frac{1}{\sqrt{\pi\mu f\sigma}}$

Guía rectangular:

$$\alpha_c\Big|_{TE_{10}} = \frac{1}{\eta\sigma\delta}\frac{\left(\frac{f_c}{f}\right)^2+\frac{a}{2b}}{\frac{a}{2}\sqrt{1-\left(\frac{f_c}{f}\right)^2}}$$

Guía circular:

$$\alpha_c\Big|_{TE_{11}} = \frac{1}{\eta\sigma\delta}\frac{\left(\frac{f_c}{f}\right)^2+\frac{1}{(p'_{11})^2-1}}{a\sqrt{1-\left(f_c/f\right)^2}}$$ $\frac{1}{(p'_{11})^2-1} \approx 0{,}42$

Guía circular:

$$\alpha_c\Big|_{TE_{01}} = \frac{1}{\eta\sigma\delta}\frac{\left(f_c/f\right)^2}{a\sqrt{1-\left(f_c/f\right)^2}}$$

④ GUÍA DE ONDA CERRADAS MULTIDIELÉCTRICAS:

No hay TEM

$\hat{n}_{12}\times(\vec{E}_2-\vec{E}_1)\Big|_{salto} = 0$

$\hat{n}_{12}\times(\vec{H}_2-\vec{H}_1)\Big|_{salto} = 0$

Cuando $\omega\to 0$: $\gamma \doteq j\omega$, $E_z \approx 0$, $H_z \approx 0$ } Casi TEM

$\vec{E}_{ti} = \vec{e}_{ti}(u_1,u_2)e^{-j\beta z}$ { $\nabla_t\times\vec{e}_{ti} = 0$, $\nabla_t\cdot\vec{e}_{ti} = 0$

$\vec{H}_{ti} = \vec{h}_{ti}(u_1,u_2)e^{-j\beta z}$ { $\nabla_t\times\vec{h}_{ti} = 0$, $\nabla_t\cdot\vec{h}_{ti} = 0$

A alta frecuencia, modos híbridos

$I_H = \frac{\mu_0}{L}\cdot\psi_0$ $\beta V_E = \omega L I_H$ $\omega C V_E = \beta I_H$

$\beta = \omega\sqrt{LC} = \omega\sqrt{\mu_0\varepsilon_0\frac{C}{C_0}}$ $V_E/I_H = \sqrt{\frac{L}{C}}$

$Z_0 = \sqrt{\frac{\mu_0\varepsilon_0}{C_0\cdot C}} = \frac{\varepsilon_0}{C_0}\cdot\frac{\eta_0}{\sqrt{C/C_0}}$

$\eta_0 = \sqrt{\frac{\mu_0}{\varepsilon_0}} = 120\pi\ (\Omega)$

$L = \frac{\mu_0\varepsilon_0}{C_0}$

$\varepsilon_{eff} = \varepsilon_0\frac{C}{C_0} = \varepsilon_0\varepsilon_{reff}$ $\gamma = j\beta = j\omega\sqrt{\mu_0\varepsilon_{eff}}$ $P = \frac{1}{2}VI^*$ $Z_{VP} = \frac{|V|^2}{2P}$ $Z_{IP} = \frac{2P}{|I|^2}$

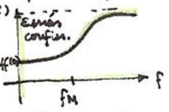
$\eta_{eff} = \frac{\eta_0}{\sqrt{\varepsilon_{reff}}}$ $Z_0 = k_g\,\eta_{eff}$ $Z_0 = k_g\frac{\eta_0}{\sqrt{\varepsilon_{reff}(0)}} = \frac{Z_0\ vacío}{\sqrt{\varepsilon_{reff}(0)}}$

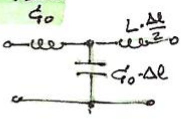
$$Z_0(f) = \frac{Z_0\ vacío}{\sqrt{\varepsilon_{reff}(f)}} = \frac{Z_0\ vacío}{\sqrt{\varepsilon_r-\frac{\varepsilon_r-\varepsilon_{eff}(0)}{1-(f/f_r)^2}}}$$

$Z_0 = \frac{\varepsilon_0}{C_0}\sqrt{\frac{\mu_0}{\varepsilon_{eff}(0)}} = \frac{\varepsilon_0}{C_0}\cdot\eta_{eff}(0)$

$\beta = \omega\sqrt{\mu_0\varepsilon_{eff}(0)}$

COAXIAL: $C_0 = \frac{2\pi\varepsilon_0}{\ln(b/a)}$ $Z_0 = \frac{\eta}{2\pi}\ln(b/a)$





⑤ GUÍAS DIELÉCTRICAS: FIBRA ÓPTICA:

·Fibra salto índice.

$R \leq R_0$:

$E_{z1} = A_1 J_m(\alpha r)e^{jm\varphi}e^{-j\beta z}$

$H_{z1} = B_1 J_m(\alpha r)e^{jm\varphi}e^{-j\beta z}$

$E_{\varphi 1} = \frac{1}{\alpha^2}\left(\frac{m\beta}{r}A_1J_m(\alpha r)+j\omega\mu\alpha B_1J'_m(\alpha r)\right)e^{jm\varphi}e^{-j\beta z}$

$H_{\varphi 1} = \frac{1}{\alpha^2}\left(\frac{m\beta}{r}B_1J_m(\alpha r)-j\omega\varepsilon_1\alpha A_1J'_m(\alpha r)\right)e^{jm\varphi}e^{-j\beta z}$

$E_{r1} = \frac{1}{\alpha^2}\left(\frac{\omega\mu m}{r}B_1J_m(\alpha r)-j\beta\alpha A_1J'_m(\alpha r)\right)e^{jm\varphi}\cdot e^{-j\beta z}$

$H_{r1} = \frac{1}{\alpha^2}\left(\frac{-\omega\varepsilon_1 m}{r}A_1J_m(\alpha r)-j\beta\alpha B_1J'_m(\alpha r)\right)e^{jm\varphi}e^{-j\beta z}$

$r \geq R_0$:

$E_{z2} = A_2K_m(ar)e^{jm\varphi}e^{-j\beta z}$

$H_{z2} = B_2K_m(ar)e^{jm\varphi}\cdot e^{-j\beta z}$

$E_{\varphi 2} = \frac{1}{a^2}\left(\frac{-m\beta}{r}A_2K_m(ar)-j\omega\mu a B_2K'_m(ar)\right)e^{jm\varphi}\cdot e^{-j\beta z}$

$H_{\varphi 2} = \frac{1}{a^2}\left(\frac{-m\beta}{r}B_2K_m(ar)+j\omega\varepsilon_2 a A_2K'_m(ar)\right)e^{jm\varphi}\cdot e^{-j\beta z}$

$E_{r2} = \frac{1}{a^2}\left(\frac{-\omega\mu m}{r}B_2K_m(ar)+j\beta a A_2K'_m(ar)\right)e^{jm\varphi}e^{-j\beta z}$

$H_{r2} = \frac{1}{a^2}\left(\frac{\omega\varepsilon_2 m}{r}A_2K_m(ar)+j\beta a B_2K'_m(ar)\right)e^{jm\varphi}e^{-j\beta z}$

Mayor excitabilidad: mayor AN

$AN = \sqrt{n_1^2-n_2^2}$

$V^2 = \beta_0^2R_0^2(n_1^2-n_2^2)$ $\theta_A = arcsen(AN)$

$V = \beta_0R_0\sqrt{n_1^2-n_2^2} = \beta_0R_0\cdot AN = \omega\sqrt{\mu_0\varepsilon_0}\cdot R_0AN = \frac{2\pi}{C_0}R_0AN\cdot f$

Ec. característica:

$$\left[\frac{J'_m(u)}{uJ_m(u)}+\frac{K'_m(w)}{wK_m(w)}\right]\left[\frac{n_1^2J'_m(u)}{uJ_m(u)}+\frac{n_2^2K'_m(w)}{wK_m(w)}\right]-\left(\frac{m\beta}{\beta_0}\right)^2\cdot\left(\frac{V}{u\cdot w}\right)^4 = 0$$

Para m=0:

$\frac{n_1^2J'_0(u)}{uJ_0(u)}+\frac{n_2^2K'_0(w)}{wK_0(w)} = 0$ Ec. TM

$\frac{J'_0(u)}{uJ_0(u)}+\frac{K'_0(w)}{wK_0(w)} = 0$ Ec. TE

Frecuencias de corte:

Modos TE_{0n}

Ec. caract$\Big|_{\omega\to 0} \Rightarrow V_c \doteq p'_{0n}$ $V_c\Big|_{TE_{0n}} = \frac{2\pi}{C_0}R_0AN\,f_c\Big|_{TE_{0n}} \Rightarrow f_c\Big|_{TE_{0n}} = \frac{p'_{0n}\cdot C_0}{2\pi R_0\cdot AN}$

Modos HE:

$f_c\Big|_{HE_{11}} = 0$ $f_c\Big|_{HE_{1n}} = \frac{p_{1,n-1}\cdot C_0}{2\pi R_0AN}$

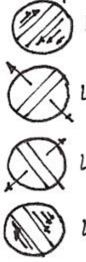
Modos TM_{0n}

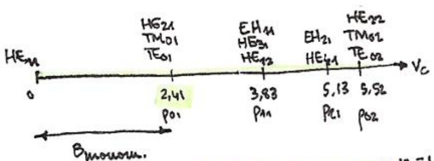
Ec. caract$\Big|_{\omega\to 0} \Rightarrow V_c = p_{0n} \Rightarrow f_c\Big|_{TM_{0n}} = \frac{p_{0n}\cdot C_0}{2\pi R_0\cdot AN}$

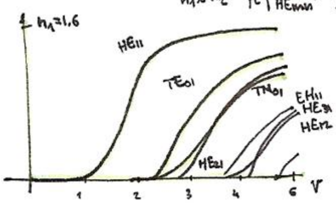
$p_{01} = 2{,}4$

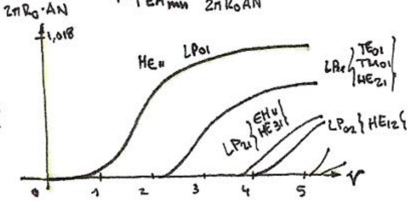
$m>1$, $n_1 \approx n_2$ $f_c\Big|_{HE_{mn}} = \frac{p_{m-2,n}\cdot C_0}{2\pi R_0\cdot AN}$ $f_c\Big|_{EH_{mn}} = \frac{p_{mn}C_0}{2\pi R_0AN}$

Para el modo superior LP_{11}:









Pequeño salto índice: $\Delta n = n_1-n_2 = [0.001-0.02]$

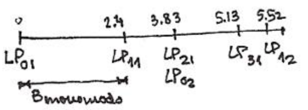
$$W_T = \frac{1}{2}Re\int_{S_t}\vec{E}_t\times\vec{H}_t^*\,d\vec{s} = \underbrace{\frac{1}{2}Re\int_{r=0}^{R_0}\int_{\varphi=0}^{2\pi}\vec{E}_t\times\vec{H}_t^*\,d\vec{s}}_{W_T\ núcleo}+\underbrace{\frac{1}{2}Re\int_{r=R_0}^{\infty}\int_{\varphi=0}^{2\pi}\vec{E}_t\times\vec{H}_t^*\,d\vec{s}}_{W_T\ cubierta}$$

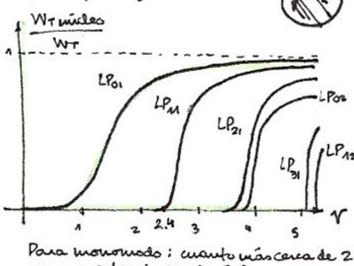
$W_{rad} = \lim_{r\to\infty}\frac{1}{2}Re\int_{S_{ext}}\vec{E}\times\vec{H}\,d\vec{s}$

Pequeño salto, LP_{mn}:

$$\frac{W_T\ núcleo}{W_T} = \frac{w^2}{V^2}\left(1-\frac{J_m^2(u)}{J_{m-1}(u)J_{m+1}(u)}\right)$$

$$LP_{mn}\begin{cases} EH_{m-1,n} & \begin{cases} Si\ m-1=0 \ \{ TE_{0n}, TM_{0n} \\ Si\ m-1=-1 \ \{ NADA \end{cases} \\ HE_{m+1,n} \end{cases}$$





Para monomodo: cuanto más cerca de 2.4, mayor potencia por el núcleo.