ECUACIONES DE MAXWELL

TABLA 7.1		TABLA 7.2		
$\nabla \cdot \mathbf{D} = \rho_v$	$\oint_s \mathbf{D} \cdot d\mathbf{s} = Q$	$E_{1t} = E_{2t}$ $\mathbf{a}_{n2} \times (\mathbf{H}_1 - \mathbf{H}_2) = \mathbf{J}_s$ $(\mathbf{D}_2 - \mathbf{D}_1) \cdot \mathbf{a}_{n,1} = \rho_s$ $B_{1n} = B_{2n}$	$E_{1t} = E_{2t}$ $H_{1t} = H_{2t}$ $D_{1n} = D_{2n}$ $B_{1n} = B_{2n}$	$E_{1t} = E_{2t} = 0$ $\mathbf{a}_{n2} \times \mathbf{H}_1 = \mathbf{J}_s,\ H_{2t} = 0$ $\mathbf{a}_{n2} \cdot \mathbf{D}_1 = \rho_s,\ D_{2n} = 0$ $B_{1n} = B_{2n} = 0$
$\nabla \cdot \mathbf{B} = 0$	$\oint_s \mathbf{B} \cdot d\mathbf{s} = 0$			
$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$	$\oint_c \mathbf{E} \cdot d\boldsymbol{\ell} = -\frac{d}{dt}\int_s \mathbf{B} \cdot d\mathbf{s}$	$\nabla \times \mathbf{H} = \mathbf{J}_v + \frac{\partial \mathbf{D}}{\partial t}$	$\nabla^2 V - \varepsilon\mu \frac{\partial^2 V}{\partial t^2} = -\rho_v/\epsilon$	$\nabla^2 \mathbf{A} - \varepsilon\mu \frac{\partial^2 \mathbf{A}}{\partial t^2} = -\mu \mathbf{J}_v$
$\nabla \times \mathbf{H} = \mathbf{J}_v + \frac{\partial \mathbf{D}}{\partial t}$	$\oint_c \mathbf{H} \cdot d\boldsymbol{\ell} = I + \int_s \frac{\partial \mathbf{D}}{\partial t} \cdot d\mathbf{s}$	$\oint_c \mathbf{H} \cdot d\boldsymbol{\ell} = I + \int_s \frac{\partial \mathbf{D}}{\partial t} \cdot d\mathbf{s}$	$V(t, \mathbf{r}) = \frac{1}{4\pi\varepsilon}\int_v \frac{\rho_v(t', \mathbf{r}')}{\lvert\mathbf{r} - \mathbf{r}'\rvert}\, dv'$	$\mathbf{A}(t, \mathbf{r}) = \frac{\mu}{4\pi}\int_v \frac{\mathbf{J}_v(t', \mathbf{r}')\, dv'}{\lvert\mathbf{r} - \mathbf{r}'\rvert}$

$\mathbf{E} = -\nabla V - \frac{\partial \mathbf{A}}{\partial t}$ $\qquad$ $\mathbf{B} = \nabla \times \mathbf{A}$

ONDAS PLANAS (E x H = dir. propag)

$\nabla^2 \mathbf{H} - \varepsilon\mu \frac{\partial^2 \mathbf{H}}{\partial t^2} = 0$	$\nabla^2 \tilde{\mathbf{E}} + \varepsilon\mu\omega^2 \tilde{\mathbf{E}} = 0$	$\oint_s \mathbf{E} \times \mathbf{H} \cdot d\mathbf{s} = -\frac{d}{dt}\int_v \left\{\frac{\varepsilon}{2}(\mathbf{E} \cdot \mathbf{E}) + \frac{\mu}{2}(\mathbf{H} \cdot \mathbf{H})\right\} dv - \int_v \mathbf{E} \cdot \mathbf{J}_v\, dv$		
$\nabla^2 \mathbf{E} - \varepsilon\mu \frac{\partial^2 \mathbf{E}}{\partial t^2} = 0$	$\nabla^2 \tilde{\mathbf{H}} + \varepsilon\mu\omega^2 \tilde{\mathbf{H}} = 0$	$\oint_s \overline{\mathcal{P}} \cdot d\mathbf{s} = \frac{j\omega}{2}\int_v \left[\varepsilon^* \lvert\tilde{\mathbf{E}}(\mathbf{r})\rvert^2 - \mu \lvert\tilde{\mathbf{H}}(\mathbf{r})\rvert^2\right] dv - \frac{1}{2}\int_v \tilde{\mathbf{E}}(\mathbf{r}) \cdot \tilde{\mathbf{J}}_v^*(\mathbf{r})\, dv$		δ = 1/α γ = α + jβ = jκ
$k = \omega\sqrt{\varepsilon\mu}$	$\eta = \frac{E_0}{H_0} = \sqrt{\frac{\mu}{\varepsilon}}$	$1 + \Gamma = \tau$	$\sqrt{\varepsilon_1\mu_1}\sin\theta_i = \sqrt{\varepsilon_2\mu_2}\sin\theta_t$	$E_i + E_r = E_t$
$T = \frac{2\pi}{\omega}$	$\overline{P_v^{abs}} = \frac{1}{2}(\sigma + \omega\varepsilon'')\lvert\tilde{\mathbf{E}}\rvert^2$	$\Gamma = \frac{\eta_2 - \eta_1}{\eta_2 + \eta_1}$	$\Gamma = \frac{\eta_2\sec\theta_t - \eta_1\sec\theta_i}{\eta_2\sec\theta_t + \eta_1\sec\theta_i}$	$\Gamma = \frac{E_r}{E_i}$
$\lambda = \frac{2\pi}{k}$ = 2π/β	$\overline{\mathcal{P}} = \frac{1}{2}\Re\left[\tilde{\mathbf{E}} \times \tilde{\mathbf{H}}^*\right]$	$\overline{P_s^{abs}} = \frac{1}{2}\lvert J_s\rvert^2 R_s$	$\theta_c = \sin^{-1}\sqrt{\frac{\varepsilon_2}{\varepsilon_1}}$ TE e2>e1	$\tau = \frac{E_t}{E_i}$
$u_p = \frac{1}{\sqrt{\varepsilon\mu}}$	$\lvert\overline{\mathcal{P}}\rvert = \frac{E_0^2}{2\eta}$	$R_s = \sqrt{\frac{\pi f\mu}{\sigma}} = \sqrt{\frac{\omega\mu}{2\sigma}}$	$\Gamma = \frac{\eta_2\cos\theta_t - \eta_1\cos\theta_i}{\eta_2\cos\theta_t + \eta_1\cos\theta_i}$ TM	$\theta_B = \tan^{-1}\sqrt{\varepsilon_2/\varepsilon_1}$ brewster TM
$c = \frac{1}{\sqrt{\varepsilon_0\mu_0}}$	$\overline{\mathcal{P}} = \mathbf{a}_z \frac{\lvert E_i\rvert^2}{2\eta_1}(1 - \lvert\Gamma\rvert^2)$ O.E.	$\theta_r = \theta_i$	$S = \frac{\lvert E_1(z)\rvert_{max}}{\lvert E_1(z)\rvert_{min}} = \frac{1 + \lvert\Gamma\rvert}{1 - \lvert\Gamma\rvert}$	

TABLA 8.3		dieléctrico GRAL.	dieléctrico e''<e'	buen conductor	
β	$\Re[\kappa]$	$\omega\sqrt{\frac{(\varepsilon' + \lvert\varepsilon\rvert)\mu}{2}}$	$\omega\sqrt{\varepsilon'\mu}\left[1 + \frac{1}{8}\left(\frac{\varepsilon''}{\varepsilon'}\right)^2\right]$	$\sqrt{\pi f\mu\sigma}$	$\kappa = \omega\sqrt{\varepsilon\mu}\sqrt{1 - j\sigma/\omega\varepsilon}$
α	$-\Im[\kappa]$	$\omega\varepsilon''\sqrt{\frac{\mu}{2(\varepsilon' + \lvert\varepsilon\rvert)}}$	$\frac{\omega\varepsilon''}{2}\sqrt{\frac{\mu}{\varepsilon'}}$	$\sqrt{\pi f\mu\sigma}$	$\kappa = \beta - j\alpha$
η	$\frac{\omega\mu}{\kappa}$	$\sqrt{\frac{\mu}{(\varepsilon' - j\varepsilon'')}}$	$\sqrt{\frac{\mu}{\varepsilon'}}\left[1 + \frac{j\varepsilon''}{2\varepsilon'}\right]$	$\sqrt{\frac{\pi f\mu}{\sigma}}(1 + j)$	$\lvert\varepsilon\rvert = \sqrt{(\varepsilon')^2 + (\varepsilon'')^2}$ $\varepsilon' = \varepsilon_r\varepsilon_0$
v_p	$\frac{\omega}{\beta}$	$\sqrt{\frac{2}{(\varepsilon' + \lvert\varepsilon\rvert)\mu}}$	$\frac{1}{\sqrt{\varepsilon'\mu}}\left[1 - \frac{1}{8}\left(\frac{\varepsilon''}{\varepsilon'}\right)^2\right]$	$\sqrt{\frac{2\omega}{\mu\sigma}}$	$\tan\delta = \frac{\sigma}{\omega\epsilon}$ = ε'' / ε'

TABLA 8.4.2 - POL		TABLA 8.4.1 - POL
$\mathbf{a}_R = \frac{1}{\sqrt{2}}(\mathbf{a}_x - j\mathbf{a}_y)$	$\tilde{\mathbf{E}}_R = \mathbf{a}_R E_0 e^{-jkz} \Longleftrightarrow \frac{E_0}{\sqrt{2}}\left[\mathbf{a}_x\cos(\omega t - kz) + \mathbf{a}_y\sin(\omega t - kz)\right]$	$\tilde{\mathbf{E}}_x(z) = \mathbf{a}_x E_{0,x} e^{-jkz} \Longleftrightarrow \mathbf{E}_x(t, z) = \mathbf{a}_x \lvert E_{0,x}\rvert \cos(\omega t - kz + \phi_x)$
$\mathbf{a}_L = \frac{1}{\sqrt{2}}(\mathbf{a}_x + j\mathbf{a}_y)$	$\tilde{\mathbf{E}}_L = \mathbf{a}_L E_0 e^{-jkz} \Longleftrightarrow \frac{E_0}{\sqrt{2}}\left[\mathbf{a}_x\cos(\omega t - kz) - \mathbf{a}_y\sin(\omega t - kz)\right]$	$\tilde{\mathbf{E}}_y(z) = \mathbf{a}_y E_{0,y} e^{-jkz} \Longleftrightarrow \mathbf{E}_y(t, z) = \mathbf{a}_y \lvert E_{0,y}\rvert \cos(\omega t - kz + \phi_y)$
		$\tilde{\mathbf{E}} = (\mathbf{a}_x\cos\theta + \mathbf{a}_y\sin\theta)E_0 e^{-jkz}$

TABLA 8.5				η0 = 377 = 120 pi
$f = f_0 \frac{v_p}{v_p \mp v_{emisor}}$	$f = f_0\left(\frac{v_p \pm v_{receptor}}{v_p \mp v_{emisor}}\right)$	$f = f_0\left(1 \pm \frac{v_{emisor}}{v_p}\right)$	$f = f_0\left(1 + \frac{v_{emisor}\cos\theta}{v_p}\right)$	
$E(z) = E_0 e^{-\gamma z}\hat{x}$	$H(z) = \frac{E_0}{\eta}e^{-\gamma z}\hat{y}$	$\phi_\eta = \arctan\left(\frac{Im(\eta)}{Re(\eta)}\right)$.	$\phi_\eta = \frac{1}{2}\arctan(\tan\delta)$	
$E(z, t) = E_0 e^{-\alpha z}\cos(\omega t - \beta z + \phi_0)\hat{x}$		$H(z, t) = \frac{E_0}{\lvert\eta\rvert}e^{-\alpha z}\cos(\omega t - \beta z + \phi_0 - \phi_\eta)\hat{y}$		

LÍNEAS DE TRANSMISIÓN

TABLA 9.1					GRAL.	$Z_{in}=Z_0\frac{Z_L+Z_0\tanh(\gamma\ell)}{Z_0+Z_L\tanh(\gamma\ell)}$	$I_{in}=\frac{V_g}{Z_g+Z_{in}}$
	Co-axial	Twin-lead	Planos paralelos		$\beta=\omega\sqrt{L'C'}$	$Z_{in}=R_0\frac{Z_L+jR_0\tan(\beta\ell)}{R_0+jZ_L\tan(\beta\ell)}$	$V_{in}=\frac{V_gZ_{in}}{Z_g+Z_{in}}$
C'	$\frac{2\pi\varepsilon'}{\ln(b/a)}$	$\frac{\pi\varepsilon'}{\cosh^{-1}(d/2a)}$	$\frac{\varepsilon' w}{d}$	F/m	$Z_0=\sqrt{\frac{L'}{C'}}$	$V_0^+=V_g\left(\frac{Z_{in}}{Z_g+Z_{in}}\right)\left(\frac{e^{-\gamma l}}{1+\Gamma_L e^{-2\gamma l}}\right)$	$V_0^-=\Gamma_L V_0^+.$
L'	$\frac{\mu}{2\pi}\ln\left(\frac{b}{a}\right)$	$\frac{\mu}{\pi}\cosh^{-1}\left(\frac{d}{2a}\right)$	$\frac{\mu d}{w}$	H/m	$u_p=\frac{1}{\sqrt{L'C'}}$	$\tilde V(z)=V_0^+e^{-\gamma z}+V_0^-e^{+\gamma z}$	$\Gamma_L=\lvert\Gamma_L\rvert e^{j\theta_\Gamma}$
R'	$\frac{R_s}{2\pi}\left(\frac{1}{a}+\frac{1}{b}\right)$	$2\left(\frac{R_s}{2\pi a}\right)$	$\frac{2R_s}{w}$	Ω/m	$Z_0=\sqrt{\frac{R'+j\omega L'}{G'+j\omega C'}}$	$\tilde I(z)=I_0^+e^{-\gamma z}+I_0^-e^{+\gamma z}$	$\theta_\Gamma=-2\beta z_{max}-2m\pi$ m = 0 >> max
G'	$\frac{2\pi(\sigma_d+\omega\varepsilon'')}{\ln(b/a)}$	$\frac{\pi(\sigma_d+\omega\varepsilon'')}{\cosh^{-1}(d/2a)}$	$(\sigma_d+\omega\varepsilon'')\frac{w}{d}$	S/m	$\Gamma_L=\frac{Z_L-Z_0}{Z_L+Z_0}$	$\gamma=\sqrt{[R'+j\omega L'][G'+j\omega C']}$ (sirven expr. de O.P.)	$\theta_\Gamma=-2\beta z_{min}\pm\pi$ $-\lambda/2<z_{min}\le 0$

TR - 1/4 onda	TR – STUB			$P_{avg}=\frac{1}{2}Re[V_{in}I_{in}^*]=\frac{1}{2}\lvert I_{in}\rvert^2Re(Z_{in}).$	
$Z_{02}=\sqrt{Z_0Z_L}$	$Y_{in}=Z_{in}^{-1}=Y_0\frac{Z_0+jZ_L\tan(\beta l_L)}{Z_L+jZ_0\tan(\beta l_L)}+Y_{St}$		$V_{max}=\lvert V_0^+\rvert(1+\lvert\Gamma_L\rvert)$	$V_{min}=\lvert V_0^+\rvert-\lvert V_0^-\rvert=\lvert V_0^+\rvert(1-\lvert\Gamma_L\rvert)$	$Z_L = 0$ $Z_{in} = Z_0 \tanh \gamma l$
$Z_{in}=Z_{02}^2/Z_L$	$Y_{St}=Z_{St}^{-1}=-jY_0\cot(\beta l_{St})$	$Y_{St}=Z_{St}^{-1}=jY_0\tan(\beta l_{St})$	$I_{max}=\frac{\lvert V_0^+\rvert}{Z_0}(1+\lvert\Gamma_L\rvert)$	$I_{min}=\frac{\lvert V_0^+\rvert}{Z_0}(1-\lvert\Gamma_L\rvert)$	$Z_L = 0$ $Z_{in} = j Z_0 \tan \beta l$
$Z_{in}=Z_0.$	$\Re(Y_{in})=\Re(Y_0)=\Re\left(Y_0\frac{Z_0+jZ_L\tan(\beta l_L)}{Z_L+jZ_0\tan(\beta l_L)}\right)$		$Z_L=\infty$ $Z_{in}=\frac{-jZ_0}{\tan\beta l}$	si $l \ll 1/\beta$ $Z_{in}\approx jZ_0\beta l=j\sqrt{\frac{L'}{C'}}\omega\sqrt{L'C'}=j\omega L'l$	$Z_L = 0$ si $\beta l = m\pi$ $Z_{in} = 0$
	$\Im(Y_{in})=0=\Im\left(Y_0\frac{Z_0+jZ_L\tan(\beta l_L)}{Z_L+jZ_0\tan(\beta l_L)}+Y_{St}\right)$		$Z_L=\infty$ si $\beta l = m\pi$ $Z_{in}=\infty$ si $\beta l = (m + 1/2)\pi$ $Z_{in} = 0$		$Z_L = 0$ si $\beta l = (m + 1/2)\pi$) $Z_{in} = \infty$

GUÍAS DE ONDA

TABLA 10.3	
TM	TE
$Z_{TM}=\eta\sqrt{1-\left(\frac{\omega_c}{\omega}\right)^2}$	$Z_{TE}=\frac{\eta}{\sqrt{1-(\omega_c/\omega)^2}}$
$\beta=\omega\sqrt{\varepsilon\mu}\sqrt{1-\left(\frac{\omega_c}{\omega}\right)^2}$, for $\omega>\omega_c$	
$\alpha=k_c\sqrt{1-\left(\frac{\omega}{\omega_c}\right)^2}$, for $\omega<\omega_c$	
$u_p=\frac{1}{\sqrt{\varepsilon\mu}}\frac{1}{\sqrt{1-(\omega_c/\omega)^2}}$	
$u_g=\frac{1}{\sqrt{\varepsilon\mu}}\sqrt{1-\left(\frac{\omega_c}{\omega}\right)^2}$	

TM - G.O. R.

$\tilde E_z(x,y)=A\sin(k_xx)\sin(k_yy)$	$\tilde H_z(x,y)=0$
$\tilde E_x(x,y)=\frac{-j\beta k_x}{k_c^2}A\cos(k_xx)\sin(k_yy)$	$\tilde H_x(x,y)=-\tilde E_y(x,y)/Z_{TM}$
$\tilde E_y(x,y)=\frac{-j\beta k_y}{k_c^2}A\sin(k_xx)\cos(k_yy)$	$\tilde H_y(x,y)=\tilde E_x(x,y)/Z_{TM}$

where $k_x=\frac{m\pi}{a}$ $\quad k_y=\frac{n\pi}{b}$ $\quad m,n=1,2,3,\dots$

$$k_c=\sqrt{k_x^2+k_y^2}\qquad \omega_c=\frac{k_c}{\sqrt{\varepsilon\mu}}=\frac{1}{\sqrt{\varepsilon\mu}}\sqrt{\left(\frac{m\pi}{a}\right)^2+\left(\frac{n\pi}{b}\right)^2}$$

$$P=\frac{1}{8}\frac{\beta\omega\varepsilon}{k_c^2}A^2ab=\frac{1}{8}\left(\frac{\omega}{\omega_c}\right)^2\sqrt{1-\left(\frac{\omega_c}{\omega}\right)^2}\,\frac{A^2ab}{\eta}$$

$$\alpha_d=\frac{\eta(\sigma_d+\omega\varepsilon'')}{2\sqrt{1-(\omega_c/\omega)^2}}\qquad \alpha_c=\frac{2R_s}{\eta\sqrt{1-(\omega_c/\omega)^2}}\left[\frac{m^2b^2/a+n^2a^2/b}{m^2b^2+n^2a^2}\right]$$

TE - G.O. R.

$\tilde E_z(x,y)=0$	$\tilde H_z(x,y)=B\cos(k_xx)\cos(k_yy)$
$\tilde E_x(x,y)=\frac{j\omega\mu}{k_c^2}k_yB\cos(k_xx)\sin(k_yy)$	$\tilde H_x(x,y)=-\tilde E_y(x,y)/Z_{TE}$
$\tilde E_y(x,y)=\frac{-j\omega\mu}{k_c^2}k_xB\sin(k_xx)\cos(k_yy)$	$\tilde H_y(x,y)=\tilde E_x(x,y)/Z_{TE}$

where $k_x=\frac{m\pi}{a}$ $\quad k_y=\frac{n\pi}{b}$ $\quad m,n=0,1,2,3,\dots$

but m and n cannot both be zero.

$$k_c=\sqrt{k_x^2+k_y^2}\qquad \omega_c=\frac{k_c}{\sqrt{\varepsilon\mu}}=\frac{1}{\sqrt{\varepsilon\mu}}\sqrt{\left(\frac{m\pi}{a}\right)^2+\left(\frac{n\pi}{b}\right)^2}$$

$$P=\begin{cases}\frac{1}{8}\frac{\omega\mu\beta}{k_c^2}B^2ab=\frac{1}{8}\left(\frac{\omega}{\omega_c}\right)^2\sqrt{1-\left(\frac{\omega_c}{\omega}\right)^2}\,\eta B^2ab, & \text{for } m,n\neq 0\\ \frac{1}{4}\frac{\omega\mu\beta}{k_x^2}B^2ab=\frac{1}{4}\left(\frac{\omega}{\omega_c}\right)^2\sqrt{1-\left(\frac{\omega_c}{\omega}\right)^2}\,\eta B^2ab, & \text{for } n=0\end{cases}$$

$$\alpha_d=\frac{\eta(\sigma_d+\omega\varepsilon'')}{2\sqrt{1-(\omega_c/\omega)^2}}$$

$$\alpha_c=\begin{cases}\frac{2R_s}{\eta\sqrt{1-(\omega_c/\omega)^2}}\left\{\frac{(m^2b^2/a+n^2a^2/b)(\omega_c/\omega)^2+(m^2b+n^2a)}{m^2b^2+n^2a^2}\right\}, & \text{for } m,n\neq 0\\ \frac{2R_s}{\eta\sqrt{1-(\omega_c/\omega)^2}}\left[\left(\frac{\omega_c}{\omega}\right)^2\frac{1}{a}+\frac{1}{2b}\right], & \text{for } n=0\end{cases}$$

RADIACIÓN

$$U(\theta,\phi) = R^2\mathcal{P}_{av}\ [W/sr].$$

$$\mathcal{P}_{av} = \tfrac{1}{2}Re[E\times H^*] = \tfrac{|E_\theta|^2}{2\eta_0}\ [W/m^2].$$

$$P_r = \oint U d\Omega = \int_0^{2\pi}\int_0^{\pi} U(\theta,\phi)\sin\theta d\theta d\phi \text{ [W]}$$

$$G_D(\theta,\phi) = \tfrac{4\pi U(\theta,\phi)}{P_r}.$$

$$\frac{P_L}{P_t} = \frac{A_{e1}A_{e2}}{r^2\lambda^2}$$

$$D = G_{D,max} = \tfrac{4\pi U_{max}}{P_r}$$

$$\tfrac{P_L}{P_t} = \tfrac{G_{D1}G_{D2}\lambda^2}{(4\pi r)^2}$$

$$D(dB) = 10\log_{10}(D)$$

$$\zeta_r = \tfrac{G_p}{D} = \tfrac{P_r}{P_i}.$$

$$R_r = \frac{2P_r}{I_m^2}\ [\Omega]$$

	Elemental dipole		Half-wave dipole	
$\tilde{H}_\phi$	$\frac{j\tilde{I}_0\Delta\ell\beta}{4\pi R}e^{-j\beta R}\sin\theta$	(11.11)		
$\tilde{E}_\theta$	$\frac{j\tilde{I}_0\Delta\ell\beta}{4\pi R}\eta_0 e^{-j\beta R}\sin\theta$	(11.12)	$\frac{j\eta_0 I_0}{2\pi R}e^{-j\beta R}F(\theta)$	(11.25)
$\overline{\mathcal{P}}$	$\mathbf{a}_R\frac{1}{2}\left(\frac{I_0\Delta\ell\beta}{4\pi R}\right)^2\eta_0\sin^2\theta$	(11.13)	$\frac{\eta_0}{2}\left(\frac{I_0}{2\pi R}\right)^2\frac{\cos^2\left(\frac{\pi}{2}\cos\theta\right)}{\sin^2\theta}\mathbf{a}_R$	(11.29)
P_r	$\frac{(I_0\Delta\ell\beta)^2}{12\pi}\eta_0$	(11.14)	$(36.5\ \Omega)I_0^2$	(11.31)
R_r	$\frac{2\pi}{3}\eta_0\left(\frac{\Delta\ell}{\lambda}\right)^2$	(11.17)	$73\ \Omega$	(11.33)
$D(\theta,\phi)$	$\frac{3}{2}\sin^2\theta$	(11.20)	$1.64\frac{\cos^2\left(\frac{\pi}{2}\cos\theta\right)}{\sin^2\theta}$	(11.35)
$U(\theta,\phi)$	$\frac{1}{2}\left(\frac{I\Delta\ell\beta}{4\pi}\right)^2\eta_0\sin^2\theta$	(11.21)	$\frac{\eta_0 I_0^2}{8\pi^2}\frac{\cos^2\left(\frac{\pi}{2}\cos\theta\right)}{\sin^2\theta}$	(11.34)

$$\tilde{H}_\phi = -\frac{\tilde{I}_0\Delta\ell\beta^2}{4\pi}\left[\frac{1}{j\beta R}+\frac{1}{(j\beta R)^2}\right]e^{-j\beta R}\sin\theta$$

$$\tilde{E}_R = -\frac{2\tilde{I}_0\Delta\ell}{4\pi}\eta_0\beta^2\left[\frac{1}{(j\beta R)^2}+\frac{1}{(j\beta R)^3}\right]e^{-j\beta R}\cos\theta$$

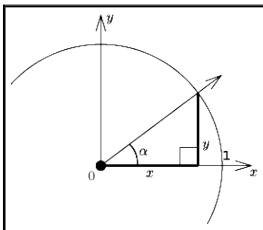
$$\tilde{E}_\theta = -\frac{\tilde{I}_0\Delta\ell}{4\pi}\eta_0\beta^2\left[\frac{1}{j\beta R}+\frac{1}{(j\beta R)^2}+\frac{1}{(j\beta R)^3}\right]e^{-j\beta R}\sin\theta$$

$$A_e(\theta,\phi) = \tfrac{P_L}{\mathcal{P}_{av}} = \tfrac{\lambda^2}{4\pi}G_D(\theta,\phi)\ [m^2].$$

PREFIJOS S.I.

PREFIJOS DEL SISTEMA INTERNACIONAL DE UNIDADES																
Prefijo	exa	peta	tera	giga	mega	kilo	hecto	deca	deci	centi	mili	micro	nano	pico	femto	atto
Símbolo	E	P	T	G	M	k	h	da	d	c	m	m	n	p	f	a
Factor	1e +18	1e +15	1e +12	1e +9	1e +6	1000	100	10	0,1	0,01	0,001	1e-6	1e-9	1e -12	1e -15	1e -18

RELACIONES TRIGONOMÉTRICAS



$$\sin(\alpha) = y \qquad \cos(\alpha) = x$$
$$\tan(\alpha) = \tfrac{y}{x} \qquad \cot(\alpha) = \tfrac{x}{y}$$
$$\sec(\alpha) = \tfrac{1}{x} \qquad \csc(\alpha) = \tfrac{1}{y}$$

$$\tan(\alpha) = \frac{\sin(x)}{\cos(x)} \qquad \cot(\alpha) = \frac{\cos(x)}{\sin(x)}$$
$$\sec(\alpha) = \frac{1}{\cos(x)} \qquad \csc(\alpha) = \frac{1}{\sin(x)}$$

α	0	$\frac{\pi}{6}$	$\frac{\pi}{4}$	$\frac{\pi}{3}$	$\frac{\pi}{2}$
$\sin(\alpha)$	0	$\frac{1}{2}$	$\frac{\sqrt{2}}{2}$	$\frac{\sqrt{3}}{2}$	1
$\cos(\alpha)$	1	$\frac{\sqrt{3}}{2}$	$\frac{\sqrt{2}}{2}$	$\frac{1}{2}$	0

$$\sin(x\pm y) = \sin(x)\cos(y)\pm\cos(x)\sin(y)$$
$$\cos(x\pm y) = \cos(x)\cos(y)\mp\sin(x)\sin(y)$$
$$\sin(2x) = 2\sin(x)\cos(x)$$
$$\cos(2x) = \cos^2(x)-\sin^2(x)$$
$$\sin^2(x) = \tfrac{1}{2}\big(1-\cos(2x)\big)$$
$$\cos^2(x) = \tfrac{1}{2}\big(1+\cos(2x)\big)$$
$$\cos^2(x)+\sin^2(x) = 1$$

$$\sinh(x\pm y) = \sinh(x)\cosh(y)\pm\cosh(x)\sinh(y)$$
$$\cosh(x\pm y) = \cosh(x)\cosh(y)\pm\sinh(x)\sinh(y)$$
$$\sinh(2x) = 2\sinh(x)\cosh(y)$$
$$\cosh(2x) = \cosh^2(x)+\sinh^2(x)$$
$$\sinh^2(x) = \tfrac{1}{2}(\cosh(2x)-1)$$
$$\cosh^2(x) = \tfrac{1}{2}(\cosh(2x)+1)$$
$$\cosh^2(x)-\sinh^2(x) = 1$$

$$\sin(x) = \frac{e^{ix}-e^{-ix}}{2i} \qquad \cos(x) = \frac{e^{ix}+e^{-ix}}{2}$$
$$\sinh(x) = \frac{e^{x}-e^{-x}}{2} \qquad \cosh(x) = \frac{e^{x}+e^{-x}}{2}$$
$$\tanh(x) = \frac{\sinh(x)}{\cosh(x)} \qquad \coth(x) = \frac{\cosh(x)}{\sinh(x)}$$

$$e^{\pm j\omega t} = \cos(\omega t)\pm j\sin(\omega t).$$

$$\sin(x)\sin(y) = \tfrac{1}{2}\big(\cos(x-y)-\cos(x+y)\big)$$
$$\cos(x)\cos(y) = \tfrac{1}{2}\big(\cos(x-y)+\cos(x+y)\big)$$
$$\sin(x)\cos(y) = \tfrac{1}{2}\big(\sin(x-y)+\sin(x+y)\big)$$
$$\sin(x)+\sin(y) = 2\sin\left(\tfrac{x+y}{2}\right)\cos\left(\tfrac{x-y}{2}\right)$$
$$\cos(x)+\cos(y) = 2\cos\left(\tfrac{x+y}{2}\right)\cos\left(\tfrac{x-y}{2}\right)$$
$$\cos(x)-\cos(y) = -2\sin\left(\tfrac{x+y}{2}\right)\sin\left(\tfrac{x-y}{2}\right)$$

OPERADORES MATEMÁTICOS

$$d\boldsymbol{\ell} = \mathbf{a}_x\,dx+\mathbf{a}_y\,dy+\mathbf{a}_z\,dz$$

$$\nabla\psi = \mathbf{a}_x\frac{\partial\psi}{\partial x}+\mathbf{a}_y\frac{\partial\psi}{\partial y}+\mathbf{a}_z\frac{\partial\psi}{\partial z}$$

$$\nabla\cdot\mathbf{A} = \frac{\partial A_x}{\partial x}+\frac{\partial A_y}{\partial y}+\frac{\partial A_z}{\partial z}$$

$$\nabla\times\mathbf{A} = \begin{vmatrix}\mathbf{a}_x & \mathbf{a}_y & \mathbf{a}_z\\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z}\\ A_x & A_y & A_z\end{vmatrix} = \mathbf{a}_x\left(\frac{\partial A_z}{\partial y}-\frac{\partial A_y}{\partial z}\right)$$
$$+\mathbf{a}_y\left(\frac{\partial A_x}{\partial z}-\frac{\partial A_z}{\partial x}\right)+\mathbf{a}_z\left(\frac{\partial A_y}{\partial x}-\frac{\partial A_x}{\partial y}\right)$$

$$\nabla^2\Phi = \frac{\partial^2\Phi}{\partial x^2}+\frac{\partial^2\Phi}{\partial y^2}+\frac{\partial^2\Phi}{\partial z^2}$$

$$\nabla^2\mathbf{E} = \mathbf{a}_x\nabla^2E_x+\mathbf{a}_y\nabla^2E_y+\mathbf{a}_z\nabla^2E_z$$

$$10\log\left(\frac{<P_0>}{<P_s>}\right)$$

$$20\log\left(\frac{|A_0|}{|A_s|}\right)$$

1 Np = 8.686 dB