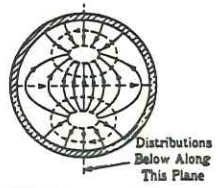
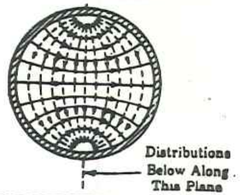
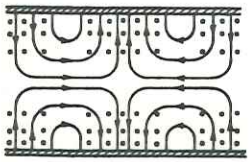
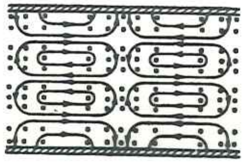
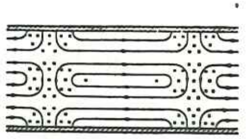
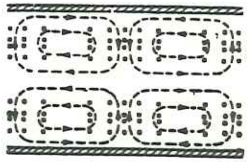
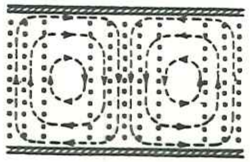
Fíjense en la dirección de las líneas de E.
BAJA ATENUACIÓN

Similar al TE$_{10}$ en guías rectangulares

Table 8.9
Summary of Wave Types for Circular Guides[a]

Wave Type	TM_{01}	TM_{02}	TM_{11}	TE_{01}	TE_{11}
Field distributions in cross-sectional plane, at plane of maximum transverse fields					
Field distributions along guide					
Field components present	E_z, E_r, H_ϕ	E_z, E_r, H_ϕ	$E_z, E_r, E_\phi, H_r, H_\phi$	H_z, H_r, E_ϕ	$H_z, H_r, H_\phi, E_r, E_\phi$
p_{nl} or p'_{nl}	2.405	5.52	3.83	3.83	1.84
$(k_c)_{nl}$	$\frac{2.405}{a}$	$\frac{5.52}{a}$	$\frac{3.83}{a}$	$\frac{3.83}{a}$	$\frac{1.84}{a}$
$(\lambda_c)_{nl}$	$2.61a$	$1.14a$	$1.64a$	$1.64a$	$3.41a$
$(f_c)_{nl}$	$\frac{0.383}{a\sqrt{\mu\varepsilon}}$	$\frac{0.877}{a\sqrt{\mu\varepsilon}}$	$\frac{0.609}{a\sqrt{\mu\varepsilon}}$	$\frac{0.609}{a\sqrt{\mu\varepsilon}}$	$\frac{0.293}{a\sqrt{\mu\varepsilon}}$
Attenuation due to imperfect conductors	$\frac{R_S}{a\eta}\frac{1}{\sqrt{1-(f_c/f)^2}}$	$\frac{R_S}{a\eta}\frac{1}{\sqrt{1-(f_c/f)^2}}$	$\frac{R_S}{a\eta}\frac{1}{\sqrt{1-(f_c/f)^2}}$	$\frac{R_S}{a\eta}\frac{(f_c/f)^2}{\sqrt{1-(f_c/f)^2}}$	$\frac{R_S}{a\eta}\frac{1}{\sqrt{1-(f_c/f)^2}}\left[\left(\frac{f_c}{f}\right)^2+0.420\right]$

[a] Electric field lines are shown solid and magnetic field lines are dashed.

9-3

ry of TE^z_{mn} and TM^z_{mn} mode characteristics of circular waveguide

$TE^z_{mn}\left(\begin{matrix} m = 0,1,2,\ldots, \\ n = 1,2,3,\ldots \end{matrix}\right)$	$TM^z_{mn}\left(\begin{matrix} m = 0,1,2,3,\ldots, \\ n = 1,2,3,4,\ldots \end{matrix}\right)$
$-A_{mn}\dfrac{m}{\varepsilon\rho}J_m(\beta_\rho\rho)[-C_2\sin(m\phi)+D_2\cos(m\phi)]e^{-j\beta_z z}$	$-B_{mn}\dfrac{\beta_\rho\beta_z}{\omega\mu\varepsilon}J'_m(\beta_\rho\rho)[C_2\cos(m\phi)+D_2\sin(m\phi)]e^{-j\beta_z z}$
$A_{mn}\dfrac{\beta_\rho}{\varepsilon}J'_m(\beta_\rho\rho)[C_2\cos(m\phi)+D_2\sin(m\phi)]e^{-j\beta_z z}$	$-B_{mn}\dfrac{m\beta_z}{\omega\mu\varepsilon}\dfrac{1}{\rho}J_m(\beta_\rho\rho)[-C_2\sin(m\phi)+D_2\cos(m\phi)]e^{-j\beta_z z}$
0	$-jB_{mn}\dfrac{\beta_\rho^2}{\omega\mu\varepsilon}J_m(\beta_\rho\rho)[C_2\cos(m\phi)+D_2\sin(m\phi)]e^{-j\beta_z z}$
$-A_{mn}\dfrac{\beta_\rho\beta_z}{\omega\mu\varepsilon}J'_m(\beta_\rho\rho)[C_2\cos(m\phi)+D_2\sin(m\phi)]e^{-j\beta_z z}$	$B_{mn}\dfrac{m}{\mu}\dfrac{1}{\rho}J_m(\beta_\rho\rho)[-C_2\sin(m\phi)+D_2\cos(m\phi)]e^{-j\beta_z z}$
$-A_{mn}\dfrac{m\beta_z}{\omega\mu\varepsilon}\dfrac{1}{\rho}J_m(\beta_\rho\rho)[-C_2\sin(m\phi)+D_2\cos(m\phi)]e^{-j\beta_z z}$	$-B_{mn}\dfrac{\beta_\rho}{\mu}J'_m(\beta_\rho\rho)[-C_2\cos(m\phi)+D_2\sin(m\phi)]e^{-j\beta_z z}$
$-jA_{mn}\dfrac{\beta_\rho^2}{\omega\mu\varepsilon}J_m(\beta_\rho\rho)[C_2\cos(m\phi)+D_2\sin(m\phi)]e^{-j\beta_z z}$	0
$\dfrac{\partial}{\partial(\beta_\rho\rho)}$	
$\dfrac{\chi'_{mn}}{a}$	$\dfrac{\chi_{mn}}{a}$
$\dfrac{\chi'_{mn}}{2\pi a\sqrt{\mu\varepsilon}}$	$\dfrac{\chi_{mn}}{2\pi a\sqrt{\mu\varepsilon}}$
$\dfrac{2\pi a}{\chi'_{mn}}$	$\dfrac{2\pi a}{\chi_{mn}}$

-3 (*Continued*).

	$TE^z_{mn}\left(\begin{matrix} m = 0,1,2,\ldots, \\ n = 1,2,3,\ldots \end{matrix}\right)$	$TM^z_{mn}\left(\begin{matrix} m = 0,1,2,3,\ldots, \\ n = 1,2,3,4,\ldots \end{matrix}\right)$
$_c$)	$\beta\sqrt{1-\left(\dfrac{f_c}{f}\right)^2}=\beta\sqrt{1-\left(\dfrac{\lambda}{\lambda_c}\right)^2}$	
$_c$)	$\dfrac{\lambda}{\sqrt{1-\left(\dfrac{f_c}{f}\right)^2}}=\dfrac{\lambda}{\sqrt{1-\left(\dfrac{\lambda}{\lambda_c}\right)^2}}$	
)	$\dfrac{v}{\sqrt{1-\left(\dfrac{f_c}{f}\right)^2}}=\dfrac{v}{\sqrt{1-\left(\dfrac{\lambda}{\lambda_c}\right)^2}}$	
$_c$)	$\dfrac{\eta}{\sqrt{1-\left(\dfrac{f_c}{f}\right)^2}}=\dfrac{\eta}{\sqrt{1-\left(\dfrac{\lambda}{\lambda_c}\right)^2}}$	$\eta\sqrt{1-\left(\dfrac{f_c}{f}\right)^2}=\eta\sqrt{1-\left(\dfrac{\lambda}{\lambda_c}\right)^2}$
$_c$)	$j\dfrac{\eta}{\sqrt{\left(\dfrac{f_c}{f}\right)^2-1}}=j\dfrac{\eta}{\sqrt{\left(\dfrac{\lambda}{\lambda_c}\right)^2-1}}$	$-j\eta\sqrt{\left(\dfrac{f_c}{f}\right)^2-1}=-j\eta\sqrt{\left(\dfrac{\lambda}{\lambda_c}\right)^2-1}$
	$\dfrac{R_s}{a\eta\sqrt{1-\left(\dfrac{f_c}{f}\right)^2}}\left[\left(\dfrac{f_c}{f}\right)^2+\dfrac{m^2}{(\chi'_{mn})^2-m^2}\right]$	$\dfrac{R_s}{a\eta}\dfrac{1}{\sqrt{1-\left(\dfrac{f_c}{f}\right)^2}}$

TE

TABLE 9-1
Zeroes χ'_{mn} of derivative $J'_m(\chi'_{mn}) = 0$ ($n = 1, 2, 3, \ldots$) of the Bessel function $J_m(x)$

	$m = 0$	$m = 1$	$m = 2$	$m = 3$	$m = 4$	$m = 5$	$m = 6$	$m = 7$	$m = 8$	$m = 9$	$m = 10$	$m = 11$
$n = 1$	3.8318	1.8412	3.0542	4.2012	5.3175	6.4155	7.5013	8.5777	9.6474	10.7114	11.7708	12.826
$n = 2$	7.0156	5.3315	6.7062	8.0153	9.2824	10.5199	11.7349	12.9324	14.1155	15.2867	16.4479	17.600
$n = 3$	10.1735	8.5363	9.9695	11.3459	12.6819	13.9872	15.2682	16.5294	17.7740	19.0046	20.2230	21.430
$n = 4$	13.3237	11.7060	13.1704	14.5859	15.9641	17.3129	18.6375	19.9419	21.2291	22.5014	23.7607	25.008
$n = 5$	16.4706	14.8636	16.3475	17.7888	19.1960	20.5755	21.9317	23.2681	24.5872	25.8913	27.1820	28.460

TM

TABLE 9-2
Zeroes χ_{mn} of $J_m(\chi_{mn}) = 0$ ($n = 1, 2, 3, \ldots$) of Bessel function $J_m(x)$

	$m = 0$	$m = 1$	$m = 2$	$m = 3$	$m = 4$	$m = 5$	$m = 6$	$m = 7$	$m = 8$	$m = 9$	$m = 10$	$m = 11$
$n = 1$	2.4049	3.8318	5.1357	6.3802	7.5884	8.7715	9.9361	11.0864	12.2251	13.3543	14.4755	15.5898
$n = 2$	5.5201	7.0156	8.4173	9.7610	11.0647	12.3386	13.5893	14.8213	16.0378	17.2412	18.4335	19.6160
$n = 3$	8.6537	10.1735	11.6199	13.0152	14.3726	15.7002	17.0038	18.2876	19.5545	20.8071	22.0470	23.2759
$n = 4$	11.7915	13.3237	14.7960	16.2235	17.6160	18.9801	20.3208	21.6415	22.9452	24.2339	25.5095	26.7733
$n = 5$	14.9309	16.4706	17.9598	19.4094	20.8269	22.2178	23.5861	24.9349	26.2668	27.5838	28.8874	30.1791

REPRESENTACION GRAFICA DE LAS FUNCIONES DE BESSEL

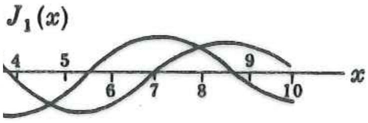


Fig. 24-1

funciones de Neumann

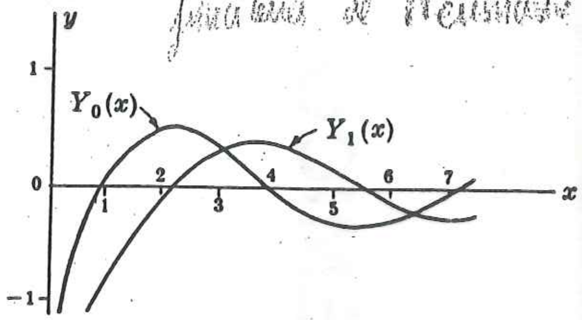


Fig. 24-2

Bessel modificada.

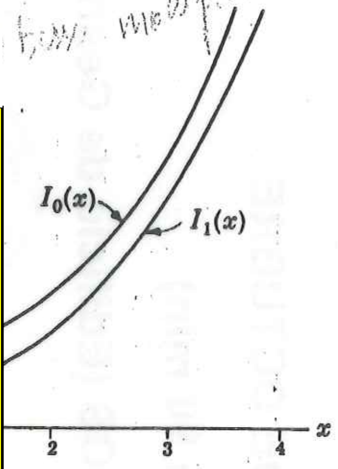


Fig. 24-3

funciones de Bessel tipo

(2ª solución de E.B.M.
ν no entero)

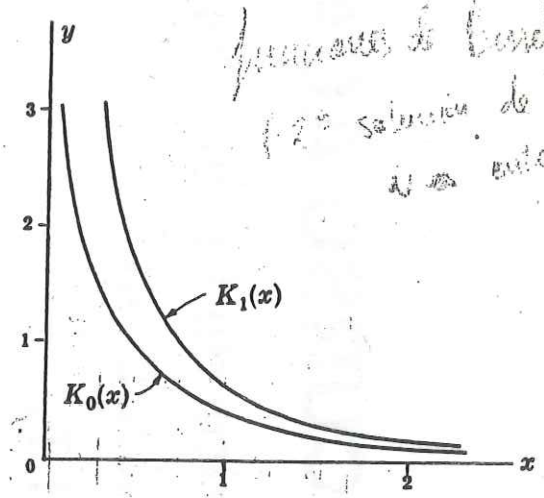


Fig. 24-4

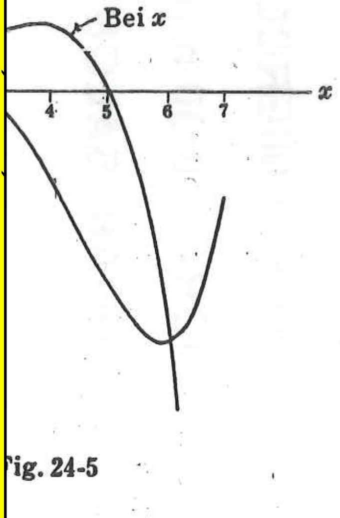


Fig. 24-5

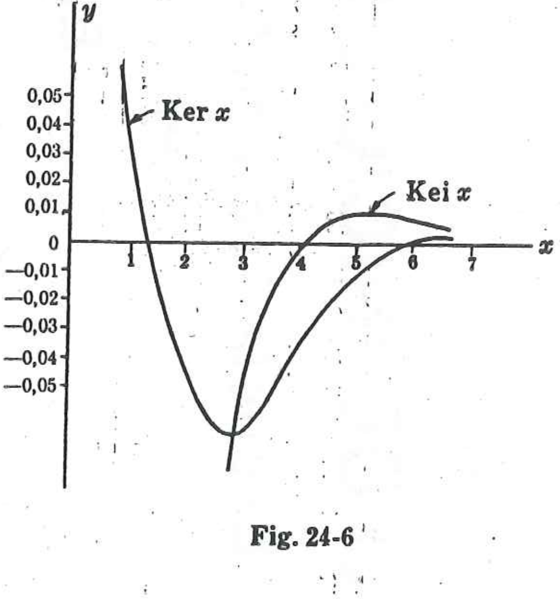
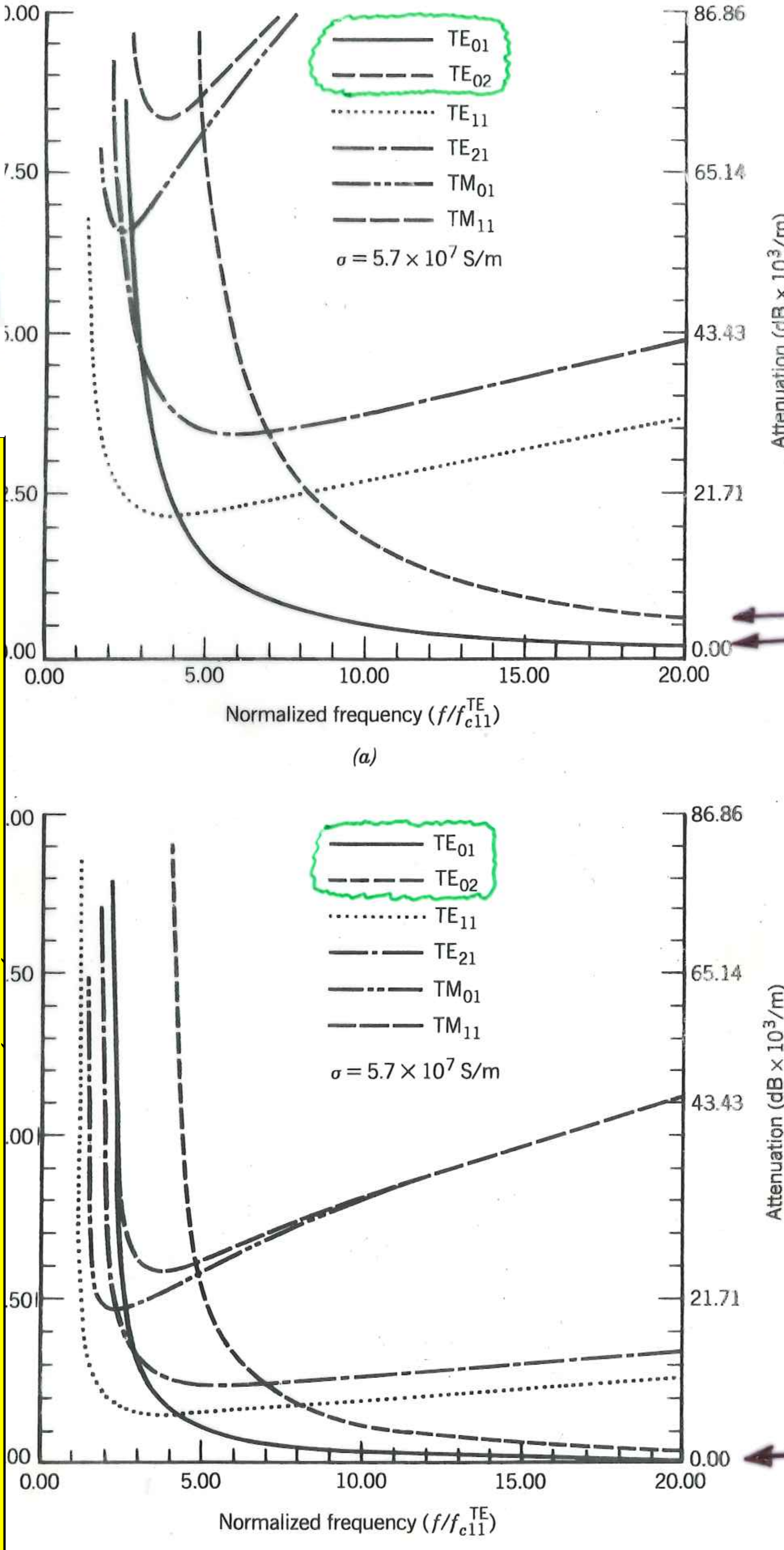


Fig. 24-6

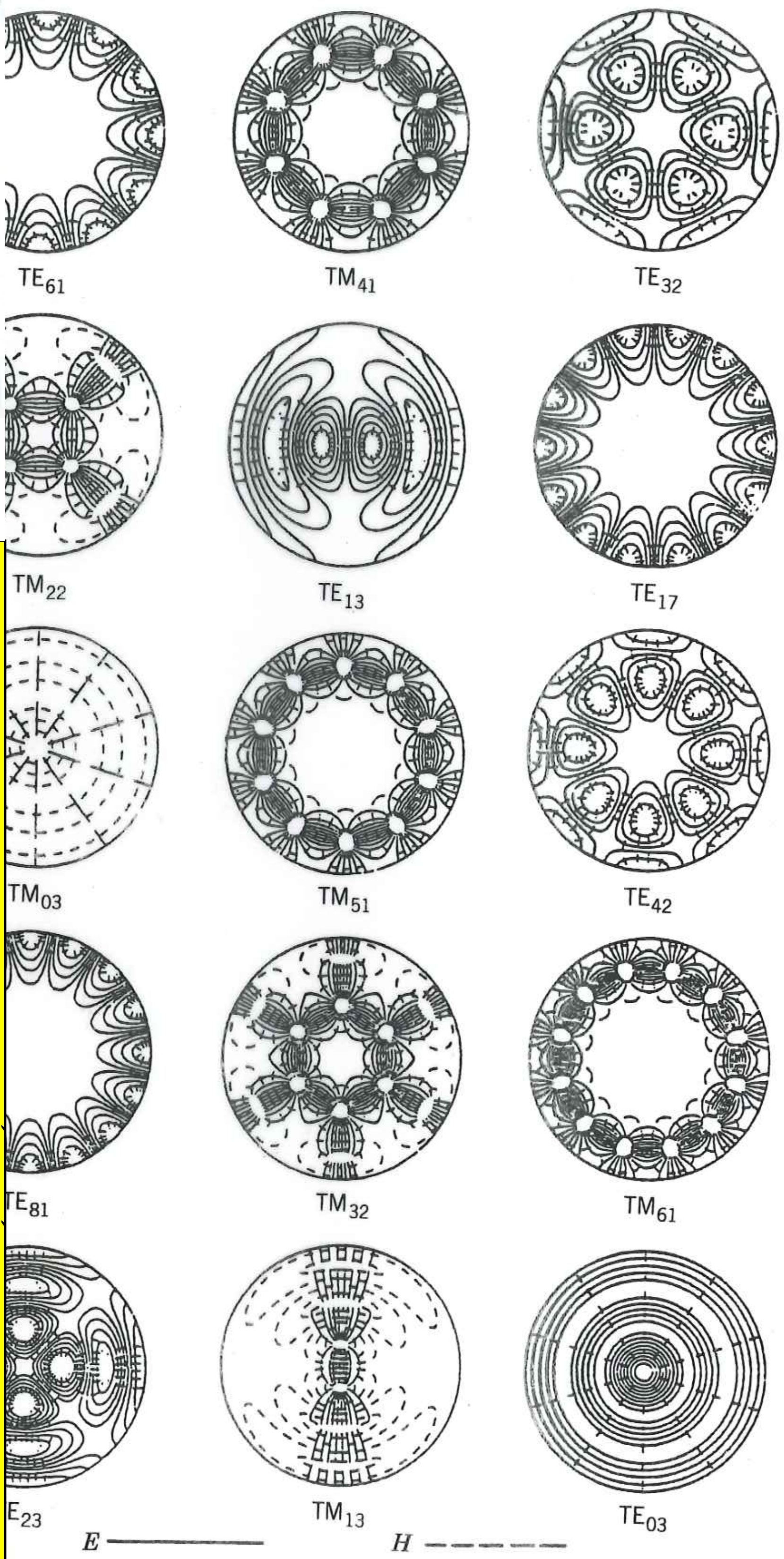


(a)

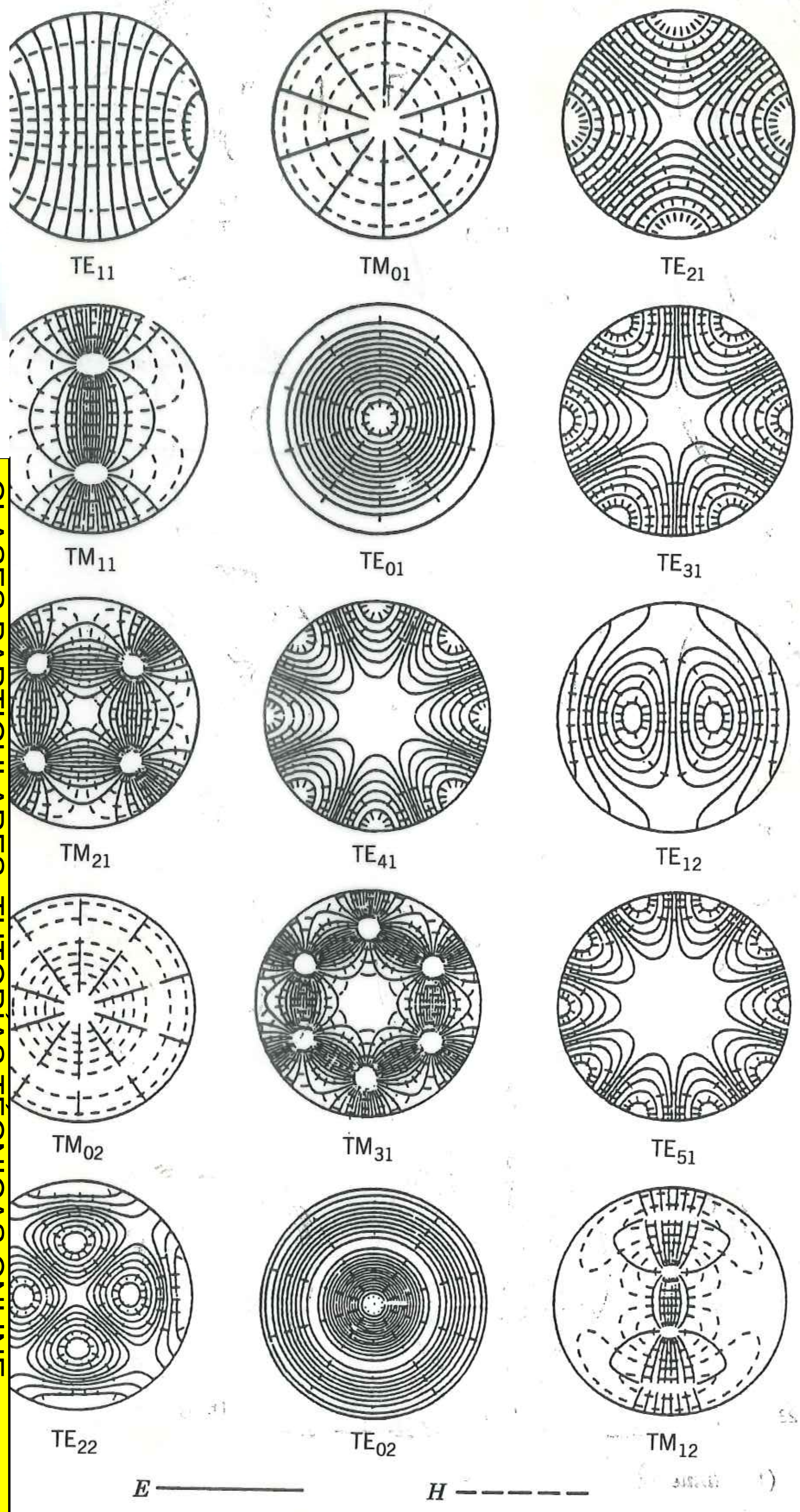
Observar esta tendencia a cero

(b)

RE 9-4 Attenuation for TE^z_{mn} and TM^z_{mn} modes in a circular waveguide. (a) $a = 1.5$ cm. (b) $a = 3$ cm.


TE61
TM41
TE32
TM22
TE13
TE17
TM03
TM51
TE42
TE81
TM32
TM61
E23
TM13
TE03
E
H

-2 (*Continued*).



URE 9-2 Field configurations of first 30 TE^z and/or TM^z modes in a circular waveguide. (*Source:* C. S. Lee, S. W. Lee, and S. L. Chuang, "Plot of modal field distribution in rectangular and circular waveguides," *IEEE Trans. Microwave Theory Tech.*, © 1966, IEEE.)

5)

1.19 bis2.

rcular de radio $a = 3$ rellena de poliestireno $\varepsilon_r = 2.56$
frecuencia de 3 GHz. Para el modo dominante

uencia de corte
itud de onda de la guía
stante de fase β (rad/cm)
pedancia
ho de banda de operación de un único modo.
sumir solo modos TE)

a)

minante es el TE_{11} y su frecuencia de corte es

$$= \frac{1.8412}{2\pi a\sqrt{\mu\varepsilon}} = \frac{1.8412\,(30\times10^{9})}{2\pi(3)\cdot\sqrt{2.56}} = 1.8315 \text{ GHz}$$

b)

$$= \frac{\lambda \xrightarrow{\text{long onda en el dieléctrico}}}{\sqrt{1-\left(\frac{f_c}{f}\right)^2}} = \frac{9.375}{0.4017} = \boxed{23.34 \text{ cm}}$$

$$\lambda = \frac{\lambda_0}{\sqrt{\varepsilon_r}} = \frac{30\times10^{9}}{2\times10^{9}\sqrt{2.56}} = \boxed{9.375 \text{ cm}}$$

comparar

c)

$$\sqrt{1-\left(\frac{f_c}{f}\right)^2} = \frac{2\pi}{\lambda}\sqrt{1-\left(\frac{f_c}{f}\right)^2} = \frac{2\pi}{9.375}(0.4017) = 0.2692 \text{ rad/cm}$$

$\varepsilon = \varepsilon_r \varepsilon_0$

$\varepsilon_r \varepsilon_0$

$$\frac{\eta}{\sqrt{1-\left(\frac{f_c}{f}\right)^2}} = \frac{120\pi/\sqrt{2.56}}{0.4017} = 586.56 \text{ ohms}$$

siguiente modo TE es el TE_{21} la anchura de

odo único TE_{11} es

$$W = \frac{3.0542}{1.8412} = 1.6588$$

Pag. 483)

A19 bis bis

n una guía de ondas circular rellena con un dieléctrico sin
s de $\varepsilon = 4$. La guía debe de operar en un único modo
te a lo largo de un ancho de banda de 1 GHz.

ntrar su radio

minar las frecuencias del ancho de banda.

odo dominante es el TE_{11} cuya frecuencia de corte es:

$$f_{c_{TE_{11}}} = \frac{X'_{11}}{2\pi a\sqrt{\mu\varepsilon}} = \frac{1{,}8412 \cdot (30\times10^{9})}{2\pi a\sqrt{4}}$$

guiente modo es el TM_{01} cuya frecuencia de corte es:

$$f_{c_{TM_{01}}} = \frac{X_{01}}{2\pi a\sqrt{\mu\varepsilon}} = \frac{2.4049(30\cdot10^{9})}{2\pi a\sqrt{4}}$$

la diferencia entre ambas frecuencias ha de ser de 1 GHz, se
mplir:

$$\frac{(2.4049 - 1.8412)\,30\cdot10^{9}}{2\pi a\sqrt{4}} = 1\times10^{9} \Rightarrow a = 1{,}3457 \text{ cm.}$$

frecuencias del ancho de banda serán:

$$f_{c_{TE_{11}}} = \frac{1.8412\times(30\times10^{9})}{2\pi\cancel{a}\sqrt{4}\times1{,}3457} = 3.2664 \text{ GHz}$$

$$f_{c_{TM_{01}}} = \frac{2{,}4049\times(30\times10^{9})}{2\pi\sqrt{4}\times1.3457} = 4.2664 \text{ GHz}$$

A19 bis.

Guías de ondas Circulares (radio: a)

	TE$_{m,n}$	**TM**$_{m,n}$
	Ceros de las Funciones Derivadas de Bessel.	Ceros de las funciones de Bessel
β	$\dfrac{X'_{m,n}}{a}$	$\dfrac{X_{m,n}}{a}$
f	$\dfrac{X'_{m,n}}{2\pi a\sqrt{\mu\varepsilon}}$	$\dfrac{X_{m,n}}{2\pi a\sqrt{\mu\varepsilon}}$
λ	$\dfrac{2\pi a}{X'_{m,n}}$	$\dfrac{2\pi a}{X_{m,n}}$
β constan	$\beta\sqrt{1-\left(\frac{f_c}{f}\right)^2}$	$\rightarrow$ igual
λ_g long. de	$\dfrac{\lambda}{\sqrt{1-\left(\frac{f_c}{f}\right)^2}}$	$\rightarrow$ igual
U_p	$\dfrac{u}{\sqrt{1-\left(\frac{f_c}{f}\right)^2}}$	$\rightarrow$ igual.
Z Imped	$\dfrac{\eta}{\sqrt{1-\left(\frac{f_c}{f}\right)^2}}$	$\eta\sqrt{1-\left(\frac{f_c}{f}\right)^2}$