H3. 1 $e \Rightarrow 88\%$ $\quad G = eD \quad D = \frac{4\pi}{\Omega_A}$

$$\Omega_A = \int_0^{\pi}\int_0^{\frac{2\pi}{3}} 1 \cdot \operatorname{sen}\theta \, d\theta \, d\phi = \pi\left[-\cos\theta\right]_0^{2\pi/3} =$$

$$= \pi\left[\frac{1}{2}+1\right] = \frac{3\pi}{2} \qquad D = \frac{4\pi}{\frac{3\pi}{2}} = \frac{8}{3}$$

$$G = 0{,}88 \cdot \frac{8}{3} \simeq 2{,}35 \qquad G(dB) = 10\log_{10}(2{,}35) \simeq 3{,}7\,dB$$

H3. 2 $$E_{rad}^{iso} = 2E_0 \frac{e^{-jkr}}{r}\left(\frac{\hat{\theta}+\hat{\phi}}{\sqrt{2}}\right)$$

$$E_{rad}^{lazo} = E_0 \operatorname{sen}\theta \frac{e^{-jkr}}{r}\hat{\phi}$$

Campo total $$\bar{E}_{total} = E_0 \frac{e^{-jkr}}{r}\left[\frac{2}{\sqrt{2}}\hat{\theta} + \left(\frac{2}{\sqrt{2}} + \operatorname{sen}\theta\right)\hat{\phi}\right]$$

$$r(\theta,\phi) = \frac{2 + (\sqrt{2}+\operatorname{sen}\theta)^2}{2+3+2\sqrt{2}} = \frac{2+(\sqrt{2}+\operatorname{sen}\theta)^2}{5+2\sqrt{2}}$$

H3. 3 $D_t = 25\,dB \qquad D_r = 18\,dB$

$$D_t = 10^{\frac{25}{10}} = 316{,}23 \qquad D_r = 10^{\frac{18}{10}} = 63{,}1$$

$$P_r = D_t D_r \left(\frac{\lambda}{4\pi r}\right)^2 (1-|\rho|^2)\, e_r$$

suponemos

$$|\hat{e}_t \cdot \hat{e}_r^*|^2 = 1$$

$$\Gamma = \frac{Z_A - Z_0}{Z_A + Z_0} = \frac{73-50}{73+50} = \frac{23}{123} \simeq 0,187$$

$$|\Gamma|^2 = 0,035$$

$$(1-|\Gamma|^2) \simeq 0,965 \qquad e_r = 0,76.$$

$$P_t = P_r \left(\frac{4\pi r}{\lambda}\right)^2 \frac{1}{D_t D_r} \frac{1}{e_r(1-|\Gamma|^2)} =$$

$$= 5\cdot 10^{-3} \left(\frac{4\pi \cdot 200\lambda}{\lambda}\right)^2 \frac{1}{(63,1)(316,23)} \cdot \frac{1}{0,76} \frac{1}{0,965} =$$

$$= 2,158 \text{ W}$$

$$10 \log \frac{2,158 \text{ W}}{10^{-3} \text{ W}} \simeq 33,34 \text{ dBm}.$$

$\boxed{H3.4}$ $\qquad G = G_t = G_r = 30\text{dB}$

$$G = 10^{\frac{30}{10}} = 1000 \qquad \lambda = \frac{3\cdot 10^8}{300\cdot 10^6} = 1 \text{ m}.$$

$$r = 16090 \text{ m}. \qquad P_t = 500 \text{ W}$$

a) $$P_r = P_t \, G \, G \left(\frac{\lambda}{4\pi r}\right)^2 = 500\cdot(1000)^2 \left(\frac{1}{4\pi \, 16090}\right)^2$$

$$= 12,23 \cdot 10^{-3} \text{ W} = 12,23 \text{ mW}$$

b) $$\cancel{P_d} \neq \langle S \rangle = \frac{P_t G_t}{4\pi r^2} = \frac{|E_i|^2}{2\eta_0}$$

$$|E_i| = \frac{1}{r}\sqrt{\frac{2\eta_0 P_t G_t}{4\pi}} = \frac{1}{r}\sqrt{60 P_t G_t} =$$

$$= \frac{1}{16090}\sqrt{60\cdot 500\cdot 1000} = 0,341 \text{ V/m}.$$

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H3.5 $P_t = 120\ W \qquad G_t = 42\ dB \qquad G_s = 31\ dB$

$$f = 6\ GHz \qquad \lambda_0 = \frac{c}{f} = \frac{3 \cdot 10^8}{6 \cdot 10^9} = \frac{1}{20} = 0{,}05\ m$$

$$R = 35900 \cdot 10^3\ m.$$

$$G_t = 10^{42/10} = 15849 \qquad G_s = 10^{31/10} = 1259$$

$$P_r = P_t \frac{G_t\ G_r\ \lambda^2}{(4\pi R)^2} = \frac{120\ (15849)\ (1259)\ (0{,}05)^2}{(4\pi)^2\ (35{,}9 \cdot 10^6)^2} =$$

$$= 2{,}94 \cdot 10^{-11}\ W$$

$$10 \log_{10} \frac{P_r\ [W]}{1 \cdot 10^{-3}\ W} = -75{,}32\ dBm$$

H3.6 $f = 10\ GHz \qquad P_t = 100\ W \qquad G_A = 36\ dB$

a) $R_1 = 40\ km = 40\,000\ m \qquad G_B = 30\ dB$

$$G_A = 10^{36/10} = 3981 \qquad G_B = 10^{30/10} = 1000$$

$$f \Rightarrow \lambda_0 = \frac{c}{f} = \frac{3 \cdot 10^8}{10 \cdot 10^9} = \frac{3}{100} = 0{,}03\ m.$$

$$P_r = \frac{100 \cdot (3981) \cdot (1000)\ (0{,}03)^2}{(4\pi \cdot 40 \cdot 10^3)^2} = 1{,}78 \cdot 10^{-5}\ W$$

$$= 17{,}8\ \mu W$$

b) En este caso.

satelite

$$\hat{e}_r = \hat{\theta} \qquad \hat{e}_s = \frac{\hat{\theta} + j\hat{\phi}}{\sqrt{2}}$$

$$|\hat{e}_r \cdot \hat{e}_s^*|^2 = \left|\frac{1}{\sqrt{2}}\right|^2 = \frac{1}{2} \qquad -3\,dB$$

apartado a)

$$P_2 = \frac{P_t G_A G_B \lambda^2}{(4\pi R_1)^2} |\hat{e}_r \cdot \hat{e}_s^*|^2 = P_{r_1} \cdot \frac{1}{2} = 8{,}9 \cdot 10^{-6}\,W$$
$$= 8{,}9\,\mu W$$

la misma

c) $$P_2 = \frac{P_t G_A G_B' \lambda^2}{(4\pi R_2)^2} |\hat{e}_r \cdot \hat{e}_s^*|^2 \qquad G_B'?$$

$$R_2 = 80 \cdot 10^3\, m.$$

$$8{,}9 \cdot 10^{-6} = \frac{100\,(3981)\, G_B' (0{,}03)^2 (1/2)}{(4\pi \cdot 80 \cdot 10^3)^2}$$

$$G_B' = \frac{8{,}9 \cdot 10^{-6} (4\pi \cdot 80 \cdot 10^3)^2}{100\,(3981)\,(0{,}03)^2 (1/2)} = 3995{,}53$$

al aumentar la distancia R_2, la antena debe tener una ganancia mayor para compensarlo.

$$10 \log_{10} 3995{,}53 = \underline{36\,dB}$$

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$\boxed{H3.7}$ $Z_0 = 50\,\Omega$ $\varepsilon_r = 2{,}2$ $f = 2\,GHz$.

a)

$$\beta = \frac{2\pi\, 2\cdot 10^9 \sqrt{2{,}2}}{3\cdot 10^8} = 62{,}13\ m^{-1}$$

$$P_0{}^t = \frac{1}{2}\frac{|V_0^+|^2}{Z_0} = 80\ W \qquad V_0^+ = \sqrt{80\cdot 50\cdot 2} = 40\sqrt{5}\ V$$

$$= 89{,}44\ V$$

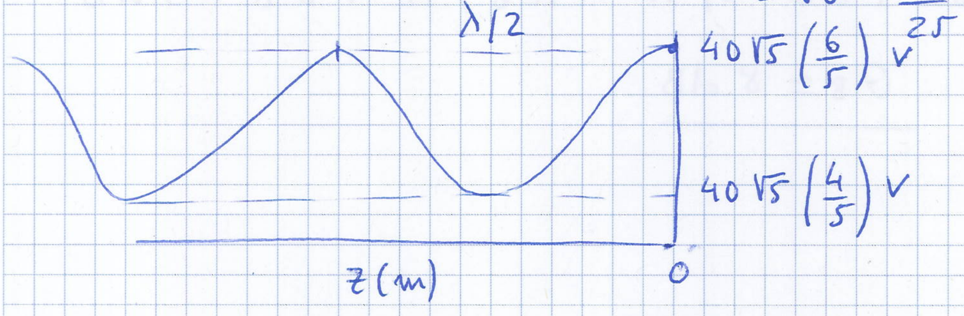
$$\tilde{V}(z) = 40\sqrt{5}\, e^{-j62{,}13 z}\ [V]$$

$$V(z,t) = \mathrm{Re}\{\tilde{V}(t)\, e^{j\omega t}\} = 40\sqrt{5}\cos(2\pi\cdot 2\cdot 10^9 t - 62{,}13 z)\ V$$

b)

$$\Gamma = \frac{75-50}{75+50} = \frac{25}{125} = \frac{1}{5} \qquad P_t = 80\left[1 - \left(\frac{1}{5}\right)^2\right] =$$

$$= 80\cdot\frac{24}{25} \simeq 76{,}8\ W$$



$$V_{max} = 120\ V = 40\sqrt{5}\,(1 + |\Gamma|) \qquad 1 + |\Gamma| = 1{,}341$$

$$|\Gamma|_{max} = 0{,}341$$

$$Z_{A\,max} = Z_0\left[\frac{1+\Gamma}{1-\Gamma}\right] = 50\,\frac{1{,}341}{0{,}659} = 50\cdot 2{,}03 \simeq 101{,}74\,\Omega$$

Papel ecológico.

c) La potencia transferida a la antena es 76,8 W y su eficiencia 90%

$$\lambda_0 = \frac{c}{f} = 0,15 \text{ m}$$

$$10 \log_{10} 76.8 = 18,85 \text{ dB}$$

$$D_A = 23 \text{ dBi}$$

$$10 \log_{10} 0,9 = -0,45 \text{ dB}$$

La pol a 45° lineal $\quad \hat{e}_A = \frac{\hat{\theta}+\hat{\phi}}{\sqrt{2}} \quad \hat{e}_B = \hat{\theta}$

$$\left| \frac{\hat{\theta}+\hat{\phi}}{\sqrt{2}} \cdot \hat{\theta} \right|^2 = \frac{1}{2} \Rightarrow -3 \text{ dB}$$

$$\left(\frac{\lambda_0}{4\pi d}\right)^2 = \left(\frac{0,15}{4\pi \cdot 25000}\right)^2 = 2,2797 \cdot 10^{-13}$$

$$10 \log_{10} 2,2797 \cdot 10^{-13} = -126,42 \text{ dB.}$$

$$10^{-8} \text{ W} \Rightarrow -80 \text{ dB}$$

$$-80 = 18,85 + 23 - 0,45 - 126,42 + G_B - 3 \text{ dB}$$

$$\underline{G_B \simeq 8 \text{ dB}}$$

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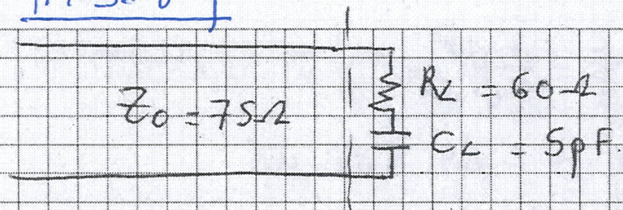
P3 $\boxed{H3.8}$



$\lambda = \frac{1}{8} = 0,125\,m.$

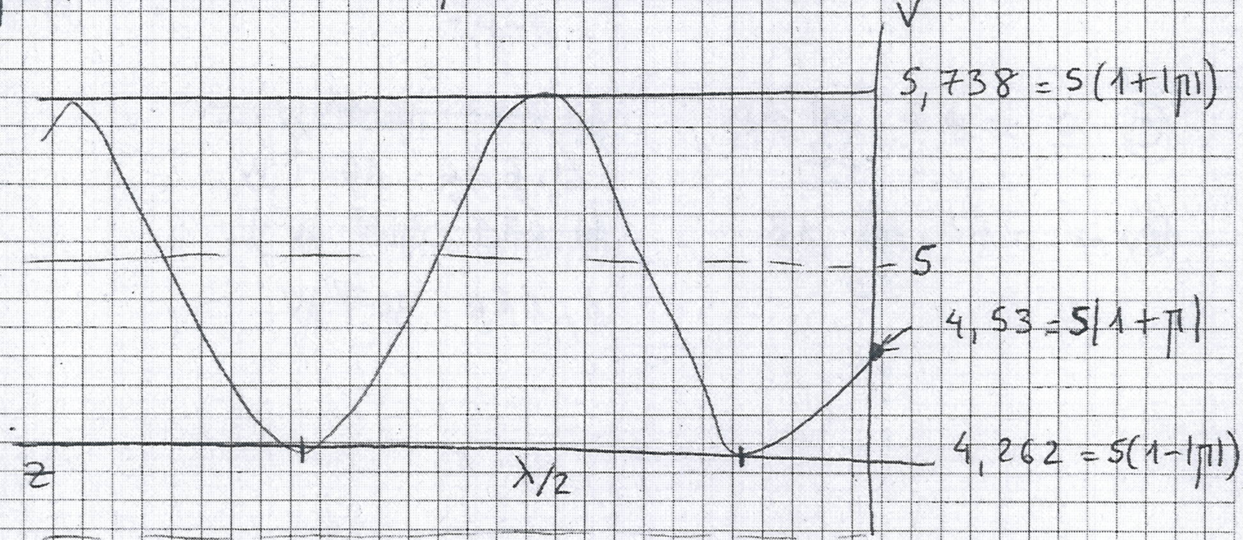
$f_0 = 2,4\,GHz \qquad V_0 = 5V \Rightarrow \lambda = \frac{2\pi}{\beta} = \frac{c}{f} = \cancel{\frac{2,4\cdot10^9}{3\cdot10^8}}\ \frac{3\cdot10^8}{2,4\cdot10^9} =$

a) $Z_A = R_L + \frac{1}{j\omega C_L} = R_L - \frac{j}{\omega C_L} = 60 - \frac{j}{2\pi\cdot2,4\cdot10^9\cdot5\cdot10^{-12}}$

$= 60 - 13,263j\ \Omega$

$\Gamma(0) = \frac{Z_A - Z_0}{Z_A - Z_0} = -0,1005 - 0,108j$

$|\Gamma(0)| = 0,1476 \qquad \phi_\Gamma = -2,3196 \Rightarrow -132,91°$



b) $G_A = (1 - |\Gamma(0)|^2)\, e_{dc} \cdot D_A = 0,9782 \cdot 0,9\, D_A$

$P_{entrada} = \frac{1}{2}\frac{|V_0^+|^2}{Z_0} = \frac{1}{2}\frac{5^2}{75} = \frac{1}{6}\,W \simeq 0,1666\,W$

$P_{radiada} = \overbrace{P_{in}(1 - |\Gamma(0)|^2)}^{0,163} \cdot e_{dc} = 0,1467\,W$

$G_A = -0,0957 - 0,4576 + 7 \simeq 6,447 \simeq \underline{6,4\,dB}$

Papel ecológico.

c) $\hat{e}_A = \dfrac{\hat{u}_H + 5j\,\hat{u}_V}{\sqrt{1^2+5^2}} \qquad \hat{e}_B = \begin{cases} \hat{u}_H \\ \hat{u}_V \end{cases}$

$$\frac{\lambda_0^2}{(4\pi d)^2} = (3{,}3157)^2 \simeq 1{,}0994 \cdot 10^{-7} \qquad D_d = 1.5 \quad D_d \simeq 1{,}76\,\text{dB}$$

$$f = 2{,}4\,\text{GHz} \qquad \lambda_0 = \frac{c}{f} = \frac{3 \cdot 10^8}{2{,}4 \cdot 10^9} = \frac{1}{8}\,\text{m} = 0{,}125\,\text{m}$$

$$L_{esp\text{-}lib} = 10 \log_{10} \left(\frac{\lambda_0}{4\pi d}\right)^2 \simeq -69{,}588\,\text{dB}$$

$$|\hat{e}_A \cdot \hat{e}_B^*|^2 \longrightarrow \begin{cases} \hat{e}_B = \hat{u}_H \Longrightarrow \left|\dfrac{1}{\sqrt{26}}\right|^2 = \dfrac{1}{26} \Rightarrow -14{,}15\,\text{dB} \\[2ex] \hat{e}_B = \hat{u}_V \Longrightarrow \left|\dfrac{5}{\sqrt{26}}\right|^2 = \dfrac{25}{26} \Rightarrow -0{,}17\,\text{dB} \end{cases}$$

$$P_R = -7{,}78 - 0{,}0957 - 0{,}4576 + 7 - 69{,}588 \;\begin{cases} -14{,}15 \simeq \cancel{-88{,}07\,\text{dB}} & A \\ -0{,}17 \simeq \cancel{-71{,}09\,\text{dB}} & B \end{cases}$$

$$-70{,}9213 + \underbrace{1{,}76}_{\text{dipolo}}$$

A $\simeq -83{,}\cancel{84}$ 32 dB $\quad$ ~~$(4{,}395 \cdot 10^{-19}\,\text{W})$~~ $\quad 4{,}656 \cdot 10^{-9}\,\text{W}$

B $\simeq -69{,}\cancel{59}$ 33 dB $\quad$ ~~$(1{,}099 \cdot 10^{-7}\,\text{W})$~~ $\quad 1{,}166 \cdot 10^{-7}\,\text{W}$

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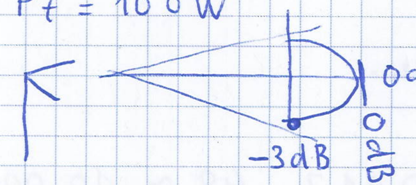
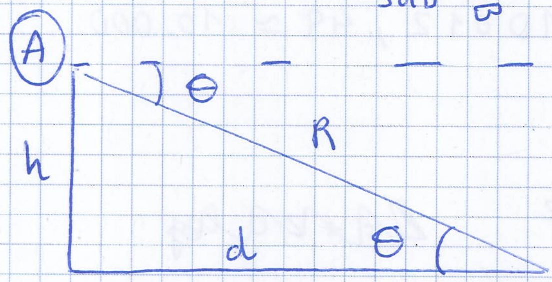
H3.9 $f = 2.6\,GHz$ $\lambda_0 = \frac{3}{20} = 0,15\,m$

a) $P_t = 100\,W$



ancha de haz a −3 dB en $\Theta \Rightarrow \Theta_{-3dB} = 5,7°$



Θ es el ángulo con el que la antena transmisora (A) ve la la receptora

$$\Theta = \arctg \frac{0,5}{10} = 2,86 \simeq \frac{\Theta_{-3dB}}{2}$$

Con ese ángulo la antena en esa dirección radia justo 3 dB menos $\Rightarrow -3\,dB$

$$G_A \left(\begin{array}{c}\text{en la dirección del} \\ \text{enlace}\end{array}\right) = 12\,dBi - 3\,dB = 9\,dBi \quad (7,94)$$

La antena B tiene una apertura efectiva de λ^2

$$A_e = \lambda^2 \qquad \left[\; A_e(\Theta,\phi) = \frac{\lambda^2}{4\pi} G(\Theta,\phi) \right.$$

$$G_B = \frac{4\pi}{\lambda^2} \cdot A_e = \frac{4\pi}{\lambda^2} \cdot \lambda^2 = 4\pi \Rightarrow G_B = 11\,dB \quad (12,58)$$

Desacoplo en (A)

$$\Gamma = \frac{Z_A - Z_0}{Z_A + Z_0} = \frac{75-50}{75+50} = 0,2$$

$$(1 - |\Gamma_A|^2) = 1 - 0,04 = 0,96$$

$$100\,(1 - |\Gamma|^2) = 96\,W$$

Papel ecológico.

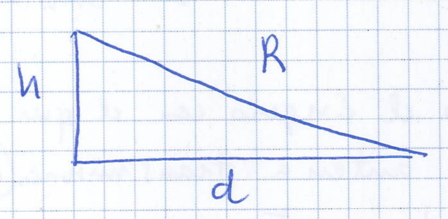
Pérdidas por polarización

$\hat{e}_A = \hat{\theta}$ lineal vertical

$\hat{e}_B = \dfrac{\hat{\theta} + j\hat{\phi}}{\sqrt{2}}$ circular a izq.

$$|\hat{e}_A \cdot \hat{e}_B^*|^2 = \left|\frac{1}{\sqrt{2}}\right|^2 = \frac{1}{2} \Rightarrow -3\,dB$$

Pérdidas de espacio libre.



$R \simeq 10012,49 \simeq 10.000$

$$\left(\frac{\lambda_0}{4\pi R}\right)^2 = 1,42 \cdot 10^{-12}$$ ~~L = L + 20 log~~

$$10 \log_{10} 1,42 \cdot 10^{-12} = -118,46 \simeq -118,5\,dB$$

El balance se obtiene como:

$$P_r = P_t + G_A + G_B - L_{desacoplo\ A} - L_{esp.\ libre} - L_{pol}$$

$$= 20\,dB + 9\,dB + 11\,dB - 0,17\,dB - 118,5\,dB - 3\,dB =$$

$$= -81,67\,dB$$

o en unidades naturales

$$P_r = P_t\, G_t\, G_r\, (1 - |\rho_t|^2) \left(\frac{\lambda}{4\pi R}\right)^2 |\hat{e}_A \cdot \hat{e}_B^*|^2$$

sin desadaptación

$$= 100\,(7'94)\,(12'58)\,(1,42 \cdot 10^{-12})\,(0,96)\left(\frac{1}{2}\right) \cong 6,8\,10^{-9}\,W$$

$$10 \log_{10} 6,8\,10^{-9} \simeq \cancel{-182,21\,dB}\ -81,67\,dB$$

~~pequeños~~ errores por decimales

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6) Recibimos la misma potencia $6,8 \cdot 10^{-9}$ W pero la P_t' es ahora 40 W, tenemos que calcular G_B' nueva para estimar su superficie equivalente.

$$G_B' = \frac{P_r}{P_t' \; G_A (1-|\Gamma|^2) \cdot \left(\frac{\lambda}{4\pi R}\right)^2 \cdot |\hat{e}_A \cdot \hat{e}_B^*|^2}$$

$$= \frac{6,8 \cdot 10^{-9}}{40\,(7,94)\,(0,96)\,(1,42 \cdot 10^{-12})\,(0,5)} = 31,41$$

Antes $\quad A_e = \lambda^2 \qquad G_B = \frac{4\pi}{\lambda^2} A_e = 4\pi$

ahora $\quad G_B' = 31,41$

$$A_e' = \lambda^2 A = \frac{G_B' \cdot \lambda^2}{4\pi}$$

$$A = \frac{G_B' \lambda^2}{4\pi \lambda^2} = \frac{31,41}{4\pi} = 2,5$$

$\Rightarrow$ Luego se necesita ahora una antena con superficie o apertura equivalente de aproximadamente $\underline{2,5\,\lambda^2}$

la potencia es menor la superficie debe aumentar.

Papel ecológico.