

LISTA 2

$$1) \rho(l) = \frac{0 - Z_0}{0 + Z_0} = -1 \quad Z_0 Y_{in} = \frac{1 - \rho(l)}{1 + \rho(l)} = j0,5 = \frac{1 + e^{-j4\pi l}}{1 - e^{-j4\pi l}}$$

$$\rho(l) = -e^{-j2\pi l} \quad l = \frac{2\pi n - j \ln(-\frac{3}{5} - \frac{4j}{5})}{4\pi}, n \in \mathbb{Z}$$

$$l \approx 0,0795 + j75 (6,28319(n+1) - 2,2143) \approx (0,3238 + \frac{n}{2})m, n \in \mathbb{Z}$$

$$2) V_1 = V_2^+ e^{rL} + V_2^- e^{-rL}$$

$$I_1 = \frac{1}{Z_0} [V_2^+ e^{rL} - V_2^- e^{-rL}]$$

$$\begin{bmatrix} V_2 \\ I_2 \end{bmatrix} = \begin{bmatrix} 1 & 1 \\ 1/Z_0 & -1/Z_0 \end{bmatrix} \begin{bmatrix} V_2^+ \\ V_2^- \end{bmatrix} \Leftrightarrow \begin{bmatrix} V_2^+ \\ V_2^- \end{bmatrix} = \begin{bmatrix} 1/2 & Z_0/2 \\ 1/2 & -Z_0/2 \end{bmatrix} \begin{bmatrix} V_2 \\ I_2 \end{bmatrix}$$

$$V_1 = e^{rL} (V_2/2 + Z_0 I_2/2) + e^{-rL} (V_2/2 - Z_0 I_2/2)$$

$$I_1 = e^{rL} (\frac{V_2}{2Z_0} + \frac{I_2}{2}) + e^{-rL} (\frac{I_2}{2} - \frac{V_2}{2Z_0})$$

$$\begin{bmatrix} V_1 \\ I_1 \end{bmatrix} = \frac{1}{2} \begin{bmatrix} e^{rL} + e^{-rL} & Z_0(e^{rL} - e^{-rL}) \\ \frac{1}{Z_0}(e^{rL} - e^{-rL}) & e^{rL} + e^{-rL} \end{bmatrix} \begin{bmatrix} V_2 \\ I_2 \end{bmatrix} = \begin{bmatrix} \cosh(rL) & Z_0 \sinh(rL) \\ \frac{\sinh(rL)}{Z_0} & \cosh(rL) \end{bmatrix} \begin{bmatrix} V_2 \\ I_2 \end{bmatrix}$$

$$3) a) z_e = \frac{225}{75} = 3 \quad \rho(l) = 0,5 \quad \text{COE} = 3$$

$$b) z_e = 1 \quad \rho(l) = 0 \quad \text{COE} = 1$$

$$c) z_e = 0,2 \quad \rho(l) = -0,65 \quad \text{COE} = 5$$

$$d) z_e = j0,6 \quad |\rho(l)| = 1 \quad \text{COE} = \infty$$

$$e) z_e = j3 \quad |\rho(l)| = 1 \quad \text{COE} = \infty$$

$$f) z_e = 0,6 + j1,6 \quad |\rho(l)| = 0,71 \quad \text{COE} = 6$$

$$4) z_e = 1 + j1 \quad |\rho(l)| = 0,45 \quad \text{COE} = 2,6$$

$$a) z_0 = 2 + j1 \quad Z_0 = 150 + j75 \Omega$$

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4) b) $z_0 = 0,5 + j0,5$

$Z_0 = 37,5 + j37,5 \Omega$

c) $z_0 = 0,6 + j0,65$

$Z_0 = 45 + j48,75 \Omega$

d) $z_0 = 1 + j1$

$Z_0 = 75 + j75 \Omega$

e) idem acima

f) $L = \frac{\lambda}{4}(n+1) - 0,162\lambda = 0,088\lambda + \frac{\lambda}{4}n, n \in \mathbb{Z}$

5) a) $\rho_0 = \frac{50 + j162,5 - 125}{50 + j162,5 + 125} = 0,2329 + j0,7123 = 0,7494 \angle 71,9^\circ$

b) $\text{COE} = \frac{1 + |\rho|}{1 - |\rho|} = 6,98$

6) $\lambda = \frac{u}{f} = 2\text{m}$ $L = 0,17\lambda$ $\Gamma_0 = 0,25$

$\Gamma_0 = 0,9 + j1,45$

$R_0 = 45 + j72,5$

$G_0 = 1/R_0 = 6,3685 - j10,048\text{mS}$

7) $\frac{\lambda}{2} = 8\text{cm}$ $L_{\text{min}} = 0,09375\lambda$

$z_{\text{min}} = \frac{1}{\text{COE}} = 0,5$

$z_0 = 0,65 - j0,45$

$Z_0 = 32,5 - j22,5 \Omega$

8) a) $\frac{\lambda}{4} = 30\text{cm}$ $\lambda = 120\text{cm}$ $f = \frac{u}{\lambda} = \frac{3 \cdot 10^8}{1,2} = 250\text{MHz}$

b) $\text{COE} = \frac{V_{\text{max}}}{V_{\text{min}}} = 3$ $|\rho| = \frac{\text{COE} - 1}{\text{COE} + 1} = 1/2$

c) $Z_{\text{max}} = \frac{V_{\text{max}}^2}{P_{\text{en}}} = 150 \Omega$ $Z_{\text{min}} = \frac{100^2}{600} = 16,67 \Omega$

d) $Z_0 = \frac{Z_{\text{max}}}{\text{COE}} = Z_{\text{min}} \text{COE} = 50 \Omega$

e) Maior defasagem \rightarrow máximas fase em $Z(z)$

$\angle \rho = \pm 90^\circ \rightarrow \angle z_0 \frac{1 + j|\rho|}{1 - j|\rho|} = \pm 53,13^\circ$

($\angle(\cdot) \equiv$ argumento de (\cdot))

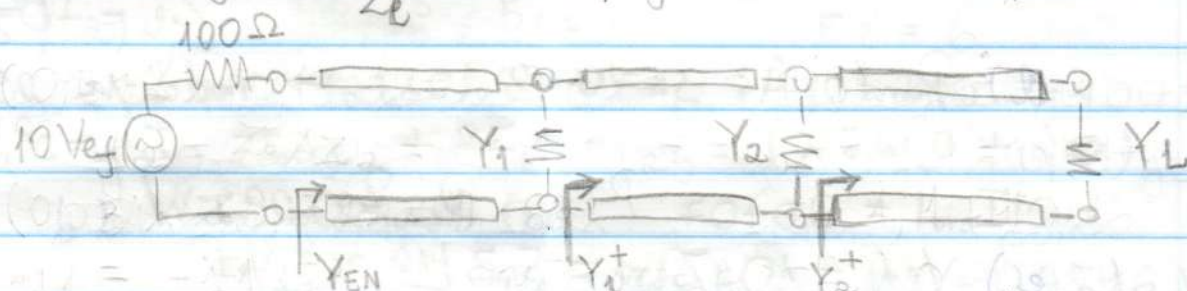
9) a) $|p| = 1/6$ $P_{\text{en}} = P_i(1 - |p|^2) = 486,11 \text{ mW}$

b) $Z_{\text{max}} = Z_0 \cos \epsilon = 70 \Omega$ $Z_{\text{min}} = Z_0 / \cos \epsilon = 35,7 \Omega$

c) $V_{\text{max}} = \sqrt{P_{\text{en}} Z_{\text{max}}} = 5,833 \text{ V}_{\text{ef}}$ $V_{\text{min}} = 4,167 \text{ V}_{\text{ef}}$

$Z_0 = \frac{V_{\text{max}}}{I_{\text{max}}} = \frac{V_{\text{min}}}{I_{\text{min}}} \rightarrow I_{\text{max}} = 116,67 \text{ mA}_{\text{ef}}$ $I_{\text{min}} = 83,33 \text{ mA}_{\text{ef}}$

10) a) $y_L = \frac{Z_0}{Z_L} = 0,46 - j0,7$ $(0,392 \lambda)$



$y_1 = Z_0/Z_1 = -j1,15$ $y_2 = Z_0/Z_2 = 0,2$

$y_2^+ = (y_L + 0,132 \lambda = 0,524 \lambda) = 0,32 + j0,14$

$y_2 + y_2^+ = 0,52 + j0,14$ $(0,03 \lambda)$

$y_1^+ = (0,162 \lambda) = 1,09 + j0,76$

$y_1 + y_1^+ = 1,5 - j0,39$ $(0,344 \lambda)$

$y_{\text{en}} = (0,476 \lambda) = 0,7 - j0,07$

$Z_{\text{en}} = Z_0/y_{\text{en}} = 141,44 + j14,14 \Omega$

b) $|I_{\text{en}}| = \frac{10}{\sqrt{241,44^2 + 14,14^2}} = 41,35 \text{ mA}_{\text{ef}}$

$P_{\text{en}} = |I_{\text{en}}|^2 R_{\text{en}} = 244,8 \text{ mW}$

11) $z_L = 1 + j3$ $\text{rodo } 0,077 \lambda \rightarrow (0,203 \lambda + 0,077 \lambda = 0,28 \lambda)$
 $(0,3 \lambda) = 2,2 - j4,2 \rightarrow 110 - j210 \Omega$

$[Z_{\text{en}} \text{ rel. a } Z_{02}] = 0,88 - j1,68$ $(0,322 \lambda)$

$\text{rodo } 0,291 \lambda \rightarrow (0,613 \lambda \equiv 0,113 \lambda)$ $z_{\text{en}} = 0,35 + j0,8$

$Z_{\text{en}} = 43,75 + j100 \Omega$

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12) a) $z_L = 1,4 - j0,4$ $\lambda = 3 \text{ m}$ $L_2 = 0,20067 \lambda$
 $z_{in_2} = 0,62$ $Z_{in_2} = 31 \Omega$ $P_{enz} = -0,2346$

b) Impedância vista pela linha 1 (75Ω) =
 $\frac{1}{1/(31 + j) + 1/360}$ $z = 0,48$ (0λ)
 $\lambda_1 = 2 \text{ m}$

→ rodando $100 \text{ cm} = 0,5 \lambda$ $Z_A = 36 \Omega$ $P_A = -0,3514$

c) $z_{in_2} = 0,62$ ($0,5 \lambda$) → ($0,2993 \lambda$) = $1,4 - j0,4$
 $Z_L = 70 - j20 \Omega$

d) Ponto A: $z_A = 0,48$ (0λ) → roda-se 25 cm
 $(0 \lambda + 0,125 \lambda)$ $z_{in} = 0,78 + j0,625$ $Z_{in} = 58,5 + j46,9 \Omega$
 $|I_{env}| = 0,0707$ $P_{env} = 0,292 \text{ W}$

e) $V_{en_1} = \frac{10}{75 + Z_{in}}$ $Z_{in} = 5,3 / 19,36^\circ$ V_{ef}

Ao final da linha 1: $V = V_{en} e^{j \frac{4\pi}{\lambda} (0,625 \lambda)} (1 - 0,3514)$
 $V = 3,438 / 109,36^\circ$ V_{ef}

f) $|V_{en_2}| = 2,66$ V_{ef} $P_{en_2} = P_L = \frac{2,66^2}{31} = 0,23 \text{ W}$

13) a) $|p(z=0)| = 1/2$ $\frac{1/2}{3/5} = \frac{5}{6} = 10^{-\frac{\alpha_{dB} L}{10}}$
 $|p(z=2,4 \lambda)| = 3/5$

$A_{dB} = \alpha_{dB} L + 10 \log \left(\frac{1 - |p(z=0)|^2}{1 - |p(z=2,4 \lambda)|^2} \right) = (0,7918 + 0,6888) \text{ dB}$

b) Primeiro mínimo: $\Delta p_{min} = 180^\circ = \pi$ (-108°)

$\angle p(z=2,4 \lambda) = \pi + 2\beta \times 0,1 \lambda = \pi + 4\pi \times 0,1 = 1,4 \pi = 252^\circ$

$p(z=2,4 \lambda) = p_{min} \times 10^{\frac{\alpha_{dB} \times 0,1 \lambda}{10}} \times e^{j 2\beta \times 0,1 \lambda} = |p(z=2,4 \lambda)| e^{j 2\beta \times 0,1 \lambda} e^{j \pi}$

$p(z=2,4 \lambda) = 0,6 / -108^\circ$

$Z(z=2,4 \lambda) = Z_0 \frac{1+p}{1-p} = (37 - j659) \Omega$

c) $p(z=0) = |p(z=0)| e^{j 0,5 \pi} e^{-j 2\beta \times 2,4 \lambda} = 0,5 / -36^\circ$
 $Z(z=0) = (170 - j133,3) \Omega$

máximo de corrente a 0°
 $+ 2\beta (0,351 - 0)$

(5)

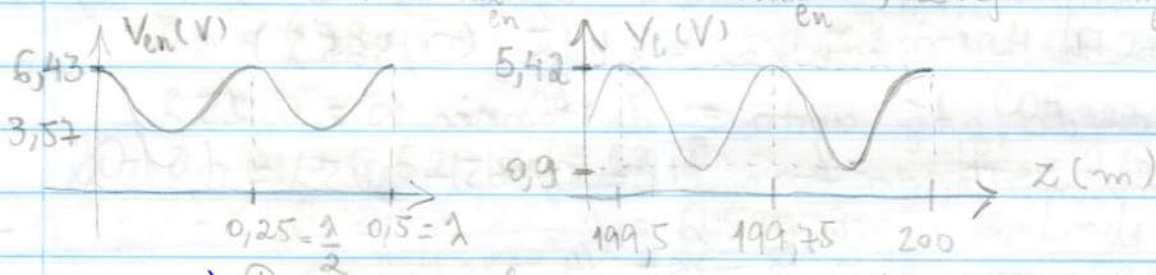
14) a) $|p_e| = 1/3$ $\angle p_e = \frac{4}{\lambda} \cdot 180^\circ \cdot 0,351 = 252^\circ \equiv -108^\circ$
 $Z_e = Z_0 \frac{1+p_e}{1-p_e} = (33,8 - j24,1) \Omega$
b) $p_o = p_e \cdot 10^{\frac{-0,1 \cdot 9,51}{10}} \cdot e^{-j \frac{4\pi}{\lambda} \cdot 9,51} = 0,268 / -108^\circ$
 $Z_L = (37,51 - j20,59) \Omega$
c) $A_{dB} = 0,1 \cdot 9,51 + 10 \log \left(\frac{1 - |p_o|^2}{1 - |p_e|^2} \right) = 0,95 + 0,188 = 1,138 \text{ dB}$

15) a) $p_e = \frac{300 - 50}{300 + 50} = 5/7 \angle 0^\circ$ $\cos \epsilon = 6$
 $p_{en} = p_e \cdot 10^{\frac{-0,02 \cdot 200}{10}} \cdot e^{-j \frac{4\pi}{\lambda} \cdot 200}$ $L = 200 \text{ m} = 400 \lambda$ ($\lambda = 50 \text{ cm}$)
 $p_{en} = 0,28436$ $\cos \epsilon_{en} = 1,79471$
b) $Z_{en} = 89,74 \Omega$
 $I_{en} = \frac{10}{139,73} = 0,0716 \text{ A}$ $P_{en} = 0,4596 \text{ W}$

c) $A_{dB} = 0,02 \cdot 200 + 10 \log \left(\frac{1 - 0,284^2}{1 - (5/7)^2} \right) = 6,735 \text{ dB}$

$P_e = P_{en} \cdot 10^{\frac{-A_{dB}}{10}} = 0,0975 \text{ W}$

d) GERADOR: $Z_{max} = Z_0 \cos \epsilon = 90 \Omega$ \rightarrow pto de V_{max} em $z=0$ e $z=200$
 $V_{max_L} = \sqrt{P_e \cdot Z_{max}} = 6,43 \text{ V}_{ef}$ $V_{min} = \frac{V_{max}}{\cos \epsilon} = 3,57 \text{ V}_{ef}$
CARGA: $Z_{max} = 300 \Omega$ $V_{max_{en}} = 5,42 \text{ V}_{ef}$ $V_{min_{en}} = 0,9 \text{ V}_{ef}$



e) Para uma frequência diferente, ocorrerá defasagem nos valores de entradas (menor λ , maior fase).

A atenuação permanece igual. $\lambda' = 0,4995 \text{ m}$

$p_{en} = 0,284 / 0 - 4 \cdot 180^\circ \cdot \frac{200}{0,4995} = 0,284 / +72^\circ$

$Z_{en} = (50,8 + j29,8) \Omega$ $|I_{en}| = 0,09514 \text{ A}$ $P_{en} = 0,4598 \text{ W}$
 $P_e = 0,0975 \text{ W}$

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16) a) $p_L = 5/7 \angle 0^\circ$ $\text{COE}_L = 6$ $\lambda = \frac{v}{f} = 25 \text{ cm}$

$L = 40,1 \text{ m} = 160,4 \lambda$ $p_{en} = p_L \cdot 10^{-\frac{\alpha_L L}{10}} e^{-j \frac{4\pi}{\lambda} \cdot 160,4 \lambda}$

$p_{en} = 0,2837 \angle +72^\circ$ $\text{COE}_{en} = 1,792$

b) $Z_{en} = 50 \frac{1+p_{en}}{1-p_{en}} = (50,8 + j29,8) \Omega$

c) $A_{dB} = 0,1 \cdot 40,1 + 10 \log \left(\frac{1-0,2837^2}{1-(5/7)^2} \right) = 6,745 \text{ dB}$

$P_L = 20 \cdot 10^{-\frac{A_{dB}}{10}} = 4,2314 \text{ W}$

d) Para uma linha com perdas, uma maior distância carga-gerador causa maior atenuação no módulo da coef. de reflexão. Quando o mesmo tende p/ 0, a impedância $Z(z=0) = Z_0 \frac{1+p(z)}{1-p(z)}$ vale $\approx Z_0 \times 1$

e) A atenuação é em base no quanto de potência cai na carga em relação a de entrada.

17) $y_L = Z_0/Z_L = 1,25 + j1,25$ (0,182 λ)

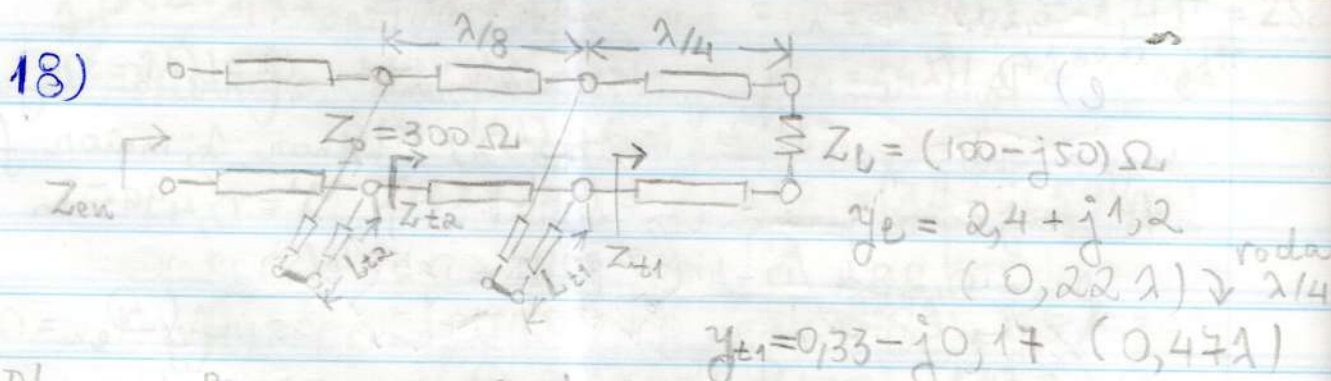
rodando até admitância unitária \rightarrow (0,167 λ) = 1 + j1,15

• distância do toco $d_1 = 0,167 - 0,182 \lambda + 0,5 \lambda = 0,485 \lambda$

toco de admitância -j1,15 (0,365 λ)

girando até curto \equiv admitância $\infty \equiv 0,25 \lambda$

• comprimento do toco $L_1 = 0,365 \lambda - 0,25 \lambda = 0,115 \lambda$



Na circunferência de admit. unitária deslocada: 0,33 + j0,25

• $y_{\text{toco}} = +j0,42 = 0,064 \lambda$ $L_{L1} = 0,064 + \frac{1}{4} = 0,314 \lambda$

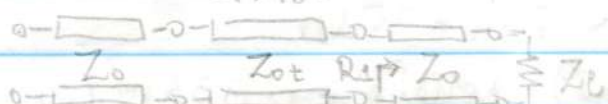
rodando $\lambda/8$

$$0,33 + j0,25 (0,045\lambda) \rightarrow 1 + j1,25 (0,17\lambda)$$

$$y_{Toco2} = -j1,25 = 0,35 + j\lambda \quad L_{t2} = 0,35 + \lambda - \frac{1}{4} = 0,124\lambda$$

$$19) p_L = 0,6 / 62,0^\circ \quad \lambda = \frac{3 \cdot 10^8}{300 \cdot 10^6} = 1 \text{ m}$$

$$L_{t1} = \frac{62^\circ}{4 \times 180^\circ} \lambda = 0,086\lambda \quad R_1 = 300 \Omega$$



$$Z_{ot} = \sqrt{R_1 Z_0} = 150 \Omega$$

$$L_1 = 8,6 \text{ cm}$$

$$L_t = \lambda/4 = 25 \text{ cm}$$

linha casada, COE = 1

$$\bullet \text{ Para } f = 272,5 \text{ MHz} \quad \lambda = 1,101 \text{ m}$$

$$\text{Saída do transformador: } p_1 = p_L e^{-j0,312\pi} = 0,6 / 5,76^\circ$$

$$Z_1 = (289,1 + j54,4) \Omega \quad p_{t1} = 0,338 / 14,3^\circ$$

$$\text{Entrada do trafo: } p_{t2} = p_{t1} \cdot e^{-j0,908\pi} = 0,338 / -149,19^\circ$$

$$Z_2 = (78,4 - j30,6) \Omega \quad p_{en} = 0,197 / -72,38^\circ$$

$$COE_{272,5} = 1,49$$

$$\bullet \text{ Para } f = 327,5 \text{ MHz} \quad \lambda = 0,916 \text{ m}$$

$$\text{Saída do trafo: } p_1 = 0,6 / 62^\circ - \frac{4 \cdot 180^\circ \cdot 0,086}{0,916} = 0,6 / -5,596^\circ$$

$$Z_1 = (289,65 - j53) \Omega \quad p_{t1} = 0,337 / -13,9^\circ$$

$$\text{Entrada: } p_{t2} = 0,337 / -13,9^\circ - \frac{4 \cdot 180^\circ \cdot 0,25}{0,916} = 0,337 / -210,4^\circ$$

$$Z_2 = (78,45 + j30,2) \Omega \quad p_{en} = 0,194 / 72,35^\circ$$

$$COE_{327,5} = 1,48$$

$$20) a) p_L = 0,62017 / 7,125^\circ \quad \lambda = \frac{2 \cdot 10^8}{300 \cdot 10^6} = 2/3 \text{ m}$$

$$d_1 = \frac{7,125^\circ}{4 \times 180^\circ} \lambda = 6,597 \text{ mm} \quad z_1 = L - d_1 = 49,9934 \text{ m}$$

$$R_1 = Z_0 \frac{1+p}{1-p} = 319,92 \Omega$$

$$b) L_t = \lambda/4 = 1/6 = 16,667 \text{ cm}$$

$$Z_0' = \sqrt{R_1 Z_0} = 154,9 \Omega$$

$$c) y_L = 0,235 - j0,059 \text{ rodando até } 1 + j1,6 (0,178\lambda)$$

$$(0,5\lambda - 0,49\lambda + 0,178\lambda) = 0,188\lambda \quad d_2 = 0,1253 \text{ cm}$$

$$Z_2 = L - d_2 = 49,87467 \text{ m}$$

$$Y_{d2} = \frac{1}{Z_0} (1 + j1,6) = (13,33 + j21,33) \text{ mS}$$

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d) Admitância de entrada do cabo = $-j21,33 \text{ mS}$

Normalizada = $-j1,0667 (0,37\lambda)$

→ rodando até $0,25\lambda + (Y_{\text{final}} \rightarrow \infty) = 0,37\lambda - 0,25\lambda =$
 $\ell_t = 0,12\lambda$

e) $\lambda_t = \frac{3 \cdot 10^8}{300 \cdot 10^6} = 1 \text{ m}$ $\ell_t = 12 \text{ cm}$

f) Carga casada → $Z_{\text{en}} = 75 \Omega$

$$P_{\text{en}} = P_{\text{max}} = \frac{E_g^2}{4 \cdot R_g} = \frac{10^2}{4 \cdot 75} = 0,333 \text{ W}$$

$$g) |I_e| = \sqrt{\frac{1/3}{300}} = 33,333 \text{ mA}_{\text{ef}}$$

21) a) $y_L = 0,8 - j0,4 (0,395\lambda) \rightarrow (145\lambda) 1 + j0,5$
 $0,5\lambda - 0,395\lambda + 0,145\lambda = 0,25\lambda$ $d = 75 \text{ cm}$

b) Impedância da componente = $+j600 \Omega$

$$j\omega L = j2\pi f L = j600 \quad L = \frac{600}{200\pi \cdot 10^6} = 954,93 \text{ nH}$$

c) $z_t = j2 (0,176\lambda) \rightarrow (0\lambda) j0 \text{ (curto)}$
 $\ell_t = 52,8 \text{ cm}$

$$d) V_{\text{en}} = \frac{10 \times 300}{600} = 5 \text{ V}_{\text{ef}} \quad p_{\text{en}} = p_L e^{-2j\beta L}$$

$$V_L = V_{\text{en}}^+ \cdot (1 + p_L) \cdot e^{-2j\beta L} = V_{\text{en}} \frac{(1 + p_L)}{(1 + p_{\text{en}})} e^{-j\frac{4\pi}{\lambda} L}$$

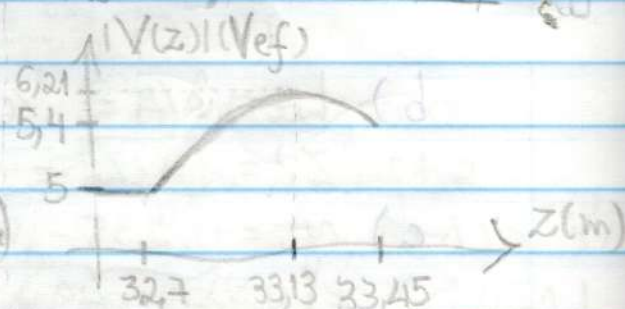
linha casada = $p(z=32,7) = 0$ e $V(z=32,7) = V_{\text{en}}$

$$p_L = 0,2425 / 75,964^\circ$$

$$V_L = 5,4232 / -167,5^\circ \text{ V}_{\text{ef}}$$

$$e) p_{\text{max}} = |p_L| / 0^\circ$$

$$d_{\text{max}} = \frac{75,964^\circ}{4 \times 180^\circ} \lambda = 0,3165 \text{ m}$$



$$\text{Pto de máximo} = 32,7 + (0,75 - d_{\text{max}}) = 33,13 \text{ m}$$

$$V(33,13) = V_{\text{en}} \frac{(1 + |p_L|)}{(1 + p_{\text{en}})} e^{-j\frac{4\pi}{\lambda} L} = 6,2125 / 180^\circ \text{ V}_{\text{ef}}$$

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$$22) a) A_{dB} = 0,01 \cdot 150 + 10 \log \left(\frac{1 - |p_{en}|^2}{1 - |p_{en}|^2} \right) \quad p_L = (0,4152 / -41,6^\circ)$$

$$|p_{en}| = 0,294$$

$$A_{dB} = 1,929 \text{ dB}$$

$$b) \eta = \frac{P_{carga}}{P_{disponível}} \cdot 100\% = \frac{P_{en} \cdot A}{P_d} \cdot 100\% = (1 - |p_{en}|^2) \cdot 10^{\frac{-A_{dB}}{10}} \cdot 100\%$$

$$\eta = 58,59\%$$

$$c) y_L = 0,46 + j0,31 \quad (0,058 \lambda) \rightarrow (0,16 \lambda) \quad 1 + j0,95$$

$$d_L = 0,102 \lambda = 2,04 \text{ cm}$$

$$y_L = -j0,95 \quad (Z_{0L} = Z_0) \quad (0,380 \lambda) \rightarrow (0,25 \lambda) j\infty$$

$$L_L = 0,130 \lambda = (\lambda_L = \lambda) \quad 2,60 \text{ cm}$$

$$d) A_{dB} = \alpha_{dB}(L - d_L) = 1,5 \text{ dB}$$

$$P_{carga} = P(z = 49,9796) = P_d (1 - |p_{en}|^2) \cdot A \quad \eta = (1 - |p_{en}|^2) 10^{\frac{-A_{dB}}{10}} \cdot 100\%$$

$$\eta = 70,8\%$$

$$e) p_{en} = 0,294 / -41,6^\circ \quad d_T = \frac{41,6^\circ}{4 \times 180^\circ} \lambda = 0,058 \lambda = 1,16 \text{ cm}$$

$$L_T = \lambda/4 = 5 \text{ cm}$$

$$Z(d_T) = 945 \Omega$$

$$Z_{0T} = 68 \Omega$$

$$f) A_{dB} = 0,01 \cdot 150,0 + 10 \log \left(\frac{1 - |p(d_T)|^2}{1 - |p_L|^2} \right) = 1,93 \text{ dB}$$

$$\eta = \frac{P_d (1 - |p_{en}|^2) 10^{\frac{-A_{dB}}{10}} \cdot 100\%}{P_d} = 64,12\%$$

→ 0 (linha cascada)

$$23) a) Z_{L2} = \frac{50}{50\sqrt{2}} = \sqrt{2}/2 \rightarrow \text{girando } \lambda/4 \rightarrow Z_{en2} = \sqrt{2} \quad Z_{en2} = 50\sqrt{2} \Omega$$

$$b) \rho_{L1} = \frac{25\sqrt{2} - 50}{25\sqrt{2} + 50} = -0,1716 \quad \rho_{en1} = +0,1716$$

$$c) Z_{en} = 70,71 \Omega \quad I_{en} = 58,58 \text{ mA}_{ef} \quad P_{en} = 0,243 \text{ W}$$

$$P_{L3} = P_{L2} = 0,121 \text{ W}$$

$$d) Z_{th2} = 50 // 50\sqrt{2} = 29,29 \Omega \quad E_{th2} = 4,14 \text{ V}_{ef} = 5,86 \text{ V}$$

$$e) P_{L2} = 0,414 \text{ W}$$

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24) a) $Y_L = 0,5 (0\lambda) \rightarrow (0,25\lambda) 2 = Z_2 \quad Z_2 = 600 \Omega$

$\frac{Z_2}{Z_0} = 0 (0,25\lambda) \rightarrow (0,15\lambda) 0,35 + j1,32 \quad Z_1 = (26,4 + j98,7) \Omega$

b) $V_1 = 3,61 / 30,81^\circ \text{ Vef} \quad V_2 = 4,44 / 72^\circ \text{ Vef}$

$V_L = V_2^+ (1 + \rho_L) e^{-2\beta L_2} = V_2 \frac{(1 + \rho_L)}{(1 + \rho_{Z_2})} e^{-\frac{4\pi}{\lambda} L_2} = 2,22 / -108^\circ \text{ Vef}$

c) $Y_2 = 1/8 (0\lambda) \rightarrow (0,196\lambda) 1 + j2,5 \quad d_t = 0,196\lambda$

$Y_t = -j2,5 (0,311\lambda) \rightarrow (0,25\lambda) \infty \quad L_t = 0,061\lambda$

d) $\omega_m \rightarrow Z_1 = 75 \Omega \quad V_1 = E_g/2 = 2,5 \text{ Vef}$

$P_{en} = 83,33 \text{ mW}$

e) $A_{dB} = \alpha_{dB} \cdot L + 10 \log \left(\frac{1 - |\rho(31,704\lambda)|^2}{1 - |\rho(31,9\lambda)|^2} \right)$

$\rho(31,704\lambda) = \frac{7}{9} e^{-\frac{4\pi}{\lambda} d_t} 10^{-\frac{\alpha_{dB} d_t}{10}} = 0,7743 / -141,12^\circ$

$A_{dB} = (3,19 + 0,059) \text{ dB} = 3,249 \text{ dB}$

$P_L = P_{en} 10^{-A_{dB}/10} = 39,44 \text{ mW}$

25) a) $\rho_{Z_2} = -\frac{157}{443} \quad \rho_L = \rho_{Z_2} e^{\frac{4\pi}{\lambda} L_2} = 0,3544 / 150,48^\circ$

$Z_L = (150,55 + j60,13) \Omega$

b) $P_{Z_2} = P_L = 0,175 \text{ W}$

$V_L = 5,5244 / 43,7^\circ \text{ Vef}$

c) $P_{to \text{ de m\u00edn}}: 4P_{\text{m\u00edn}} = 0$

$d_{\text{m\u00edn}} = 0,209\lambda$

$Z_{\text{m\u00e1x}} = 629,368 \Omega \quad |I_{\text{m\u00edn}}| = 16,67 \text{ mAef}$

d) $\rho_{L1} = 93/193 = 0,482$

e) $\rho_{Z1} = 0,184 / 144^\circ$

$Z_1 = (36,28 + j8,12) \Omega$

f) $A_{dB} = (4,18 + 1) \text{ dB}$

$P_{Z1} = P_{Z2} 10^{-A_{dB}/10} = 0,577 \text{ W}$

g) $L_t = 0,25\lambda \quad Z_{0,t} = 84,56 \Omega$

$A_{dB} = (4,18 + 0,14) \text{ dB}$

