$\frac{16.5}{25}$

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Question 1 (6 pts)

3.5

A 3-port network is completely characterized at some frequency $\underset{=}{\omega}$ by the scattering matrix:

$$S = \begin{bmatrix} 0 & 0.2 & 0.5 \\ 0.5 & 0 & 0.2 \\ 0.5 & 0.5 & 0 \end{bmatrix}$$

If a matched load is attached to port 2, while a short circuit has been placed at port 3, then;

a) Find the reflection coefficient at port 1
b) Find the transmission coefficient from port 1 to port 2

a) $[V^-] = [S][V^+]$

$V_1^- = \cancelto{0}{V_1^+ S_{11}} + V_2^+ S_{12} + V_3^+ S_{13}$

$V_2^- = V_1^+ S_{21} + \cancelto{0}{V_2^+ S_{22}} + V_3^+ S_{23}$

$V_3^- = V_1^+ S_{31} + V_2^+ S_{32} + \cancelto{0}{V_3^+ S_{33}}$

Need to find $\frac{V_1^-}{V_1^+}$?!

other info:

$V_3 = 0 = V_3^+ + V_3^-$

$\boxed{V_3^+ = -V_3^-}$

Mated load @ port ②:

means that

$S_{21} = 0.5 = \frac{V_2^-}{V_1^+}$ α

$\boxed{V_2^- = 0.5 V_1^+}$ α

$\cancel{\frac{V_1^-}{V_1^+} = \frac{V_2^+}{V_1^+} S_{12} + \frac{V_3^+}{V_1^+} S_{13}}$

the equations are:

$V_1^- = V_2^+ S_{12} + V_3^+ S_{13}$

$V_2^- = V_1^+ S_{21} - V_3^- S_{23} = 2V_2^- S_{21} - V_3^- S_{23}$

$V_3^- = V_1^+ S_{31} + V_2^+ S_{32} = 2V_2^- S_{31} + V_2^+ S_{32}$

$\boxed{\frac{V_1^-}{V_1^+} = \frac{V_2^+}{V_1^+} S_{12} + \frac{V_3^-}{V_1^+} S_{13}}$ --①

$\boxed{\frac{V_2^+}{V_1^+} S_{32} + \frac{2V_2^-}{V_1^+} S_{31} = \frac{V_3^-}{V_1^+}}$ --②

=

$(-1 + 2S_{21}) V_2^- = V_3^- S_{23}$

$\frac{V_3^-}{V_2^-} = \frac{S_{23}}{2S_{21} - 1} = \frac{2V_3^-}{V_1^+}$ --③

sub. ③ into ②:

Now ② becomes

$\frac{0.5 S_{23}}{2S_{21} - 1} = \frac{V_2^+}{V_1^+} S_{32} + \underbrace{\frac{2V_2^-}{V_1^+}}_{=1} S_{31}$

so $\frac{V_2^+}{V_1^+} S_{32} = \frac{0.5 S_{23}}{2S_{21} - 1} - S_{31} \Rightarrow \boxed{V_2^+/V_1^+ = \frac{0.5\, S_{23}/S_{32}}{2S_{21} - 1} - \frac{S_{31}}{S_{32}}}$ --④

Continue behind the last page:

Question 2 (5 pts)

4.5

A microwave antenna feed network operating at 5 GHz requires a 50 Ω printed transmission line that is 16 λ long. A copper microstrip, with d = 0.16 cm, $\varepsilon_r = 2.20$, $\sigma = 5.8*10^7$ S/m and tan δ = 0.001 is used. Calculate the total loss in using this transmission line.

$f_0 = 5\,GHz$

$Z_0 = 50\,\Omega$

$\ell = 16\lambda$

$$A = \frac{Z_0}{60}\sqrt{\frac{\epsilon_r+1}{2}} + \frac{\epsilon_r-1}{\epsilon_r+1}\left(0.23+\frac{0.11}{\epsilon_r}\right) \Rightarrow \boxed{A = 1.16}$$

$$B = \frac{377\pi}{2Z_0\sqrt{\epsilon_r}} \Rightarrow \boxed{B = 7.99}$$

Assume $\frac{W}{d} < 2$:

$$\frac{W}{d} = \frac{8e^A}{e^{2A}-2} = 3.12 \text{ it is NOT } < 2$$

so we are sure that $\frac{W}{d} > 2$:

$$\frac{W}{d} = \frac{2}{\pi}\left[B-1-\ln(2B-1)+\frac{\epsilon_r-1}{2\epsilon_r}\left\{\ln(B-1)+0.39-\frac{0.61}{\epsilon_r}\right\}\right]$$

$$\boxed{\frac{W}{d} = 3.08}$$

$$\epsilon_e = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2} \times \frac{1}{\sqrt{1+12d/W}} = 1.87 \Rightarrow \boxed{\epsilon_e = 1.87}$$

$$\alpha_d = \frac{K_0\epsilon_r(\epsilon_e-1)\tan\delta}{2\sqrt{\epsilon_e}(\epsilon_r-1)} \quad ; \quad K_0 = \frac{\omega}{c} = \frac{2\pi\times5\times10^9}{3\times10^8} = 104.72$$

$$\boxed{\alpha_d = 0.061} \text{ Np/m}$$

$$\alpha_c = \frac{R_s}{Z_0 W} \quad , \quad R_s = \sqrt{\frac{\omega\mu_0}{2\sigma}} = 0.0184\,\Omega \quad , \quad W = \frac{W}{d}\cdot d$$

$$= (3.08)(0.16)$$

$$= 0.4928$$

so $\boxed{\alpha_c = 7.47\times10^{-4}}$ Np/cm $= 7.47\times10^{-2}$ Np/m

$$\alpha = \alpha_c + \alpha_d = \overset{0.1357}{\cancel{0.06175}} \text{ Np/m}$$

$$= \overset{}{\cancel{0.5363}} \text{ dB}$$

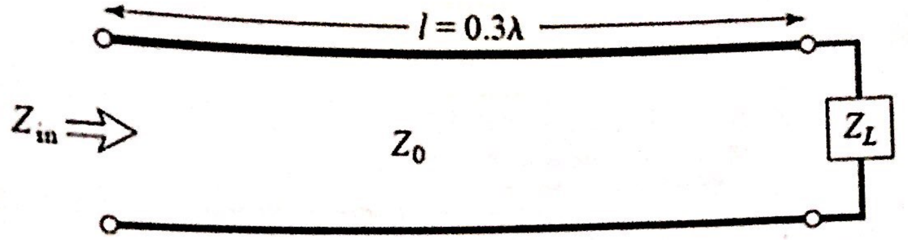
$$1.1787$$

1114 935

Question 3 (6 pts)

9.5

A lossless transmission line of electrical length $\ell = 0.3\lambda$ has a characteristics impedance of 100Ω is terminated with a complex load has a reflection coefficient at the load of $\Gamma = 0.803e^{-j94.76^o}$ as shown in the accompanying figure.



A. Find the load impedance Z_L, the reflection coefficient at the input of the line, and the input impedance to the line.

B. Design a lossless L-section matching circuit to match the load to the transmission line at 3 GHz. (Draw the equivalent circuit and determine the value of these elements).

$Z_o = 100\ \Omega$

$\ell = 0.3\lambda$

$\rho = 0.803 \angle -95^\circ$ ✓

$7\overset{6}{8}m \rightarrow 1$

$? \rightarrow 0.803$

$\Rightarrow \underline{6.1cm}$ → for ρ_L.

A) $SWR = \dfrac{1+|\rho|}{1-|\rho|} = 9.15$

from the smith chart:

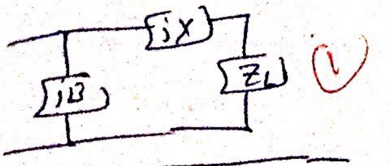
$(Z_L)_N = 0.225 - j0.875$

so $Z_L = (Z_L)_N \times 100 = \boxed{22.5 - j\,87.5}\ \Omega$ ✓ ①

@ input: $Z_{in} = 0.7 + j2 \Rightarrow Z_{in} = 70 + j200\ \Omega$ ①

$\rho_{in} = \underline{0.803\, e^{+j\,49^\circ}}$ ①

B) $Z_L = 0.225 - j0.875$ (outside $1+jx$ circle).



①

$X = \pm\sqrt{R_L(Z_0-R_L)-X_L}$

$B = \pm \dfrac{\sqrt{(Z_0-R_L)/R_L}}{Z_0}$

$X = \pm 42.8$ & $B = \pm 0.019$ ✓

take $X = 42.8$, $B = 0.019$.

$X = \omega L \Rightarrow L = \dfrac{42.8}{2\pi f} = \underline{2.27nH}$.

$B = 0.019 = \omega C \Rightarrow C = \dfrac{0.019}{\omega} = \underline{1.01\,pF}$. ✓ ①

take $X = -42.8$ & $B = -0.019$

$X = \dfrac{1}{\omega C} \Rightarrow C = \underline{1.24\,pF}$ & $B = \dfrac{1}{\omega L} \Rightarrow L = \underline{2.79nH}$

0.5

3

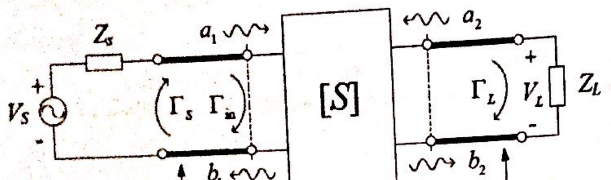
3

$$V_L = V_0^+ (\underbrace{e^{-j\beta z}}_{=1} + \rho_L \underbrace{e^{j\beta z}}_{=1})$$
$$= V_0^+ (1+\rho_L)$$
$$= b_2 (1+\rho_L)$$ just find $V_s \rightarrow b_2$

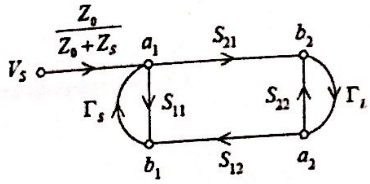
Question 4 (6 pts)

a) [3 pts.] Determine Γ_{in}

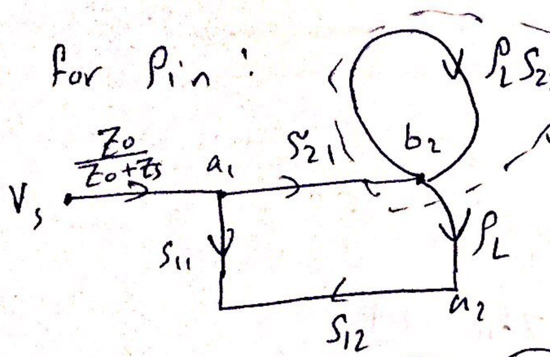
b) [3 pts.] Determine V_L using only signal flow graph if the load is located at z = 0.



TLs are infinitesimally short, with characteristic impedance Z_0.

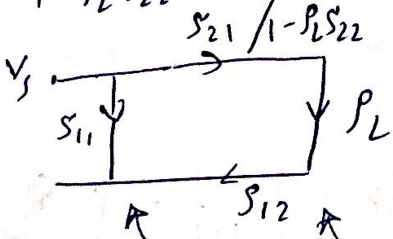


a) for ρ_{in} :



self loop Rule.

$$\frac{1}{1-\rho_L S_{22}}$$



parallel Rule.

so $$\rho'_{in} = S_{11} + \frac{S_{12} S_{21} \rho_L}{1-\rho_L S_{22}}$$ 3

(series Rule).

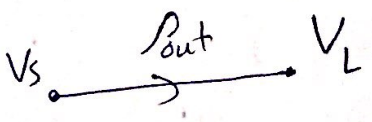
where $$\rho_L = \frac{Z_L - Z_0}{Z_L + Z_0}$$

$\Rightarrow$ ρ_{in} is the series of $\frac{Z_0}{Z_0+Z_s}$ & ρ'_{in}

$$\boxed{\rho_{in} = \left(\frac{Z_0}{Z_0+Z_s}\right)\left(S_{11} + \frac{S_{12} S_{21} \rho_L}{1-\rho_L S_{22}}\right)}$$ #. ✓

b) The same for ρ_{out} it could be found that:

$$\rho_{out} = \left(\frac{Z_0}{Z_0+Z_s}\right)\left(S_{22} + \frac{S_{12} S_{21} \rho_L}{1-\rho_L S_{11}}\right)$$ ✓



so V_L is given by:

$$V_L = \rho_{out} V_S .$$

✓

Question 5 (2 pts) 0.5

a) What is a Quasi TEM and why the microstrip line has this type of modes.

it is a type close to the exact TEM mode
ase in μstrip, since there is TE or TM mode
could be for the corrisponding μstrip, then like
this type Quasi TEM could use between them.
✗

b) Why the waveguide has a low bandwidth at microwave frequencies.

since it has a larger size.
✗

Continue Q_1:

sub. ④ & ③ into ①:

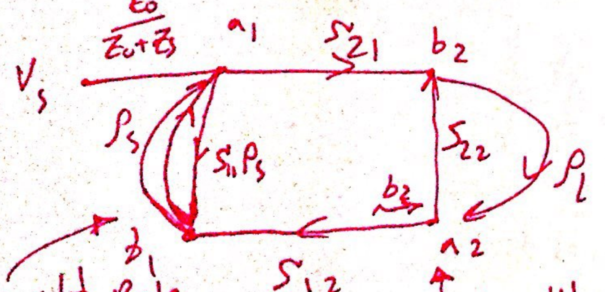
$$\frac{V_1^-}{V_1^+} = \left(\frac{0.5 S_{23}/S_{32}}{2S_{21}-1} - \frac{S_{31}}{S_{32}}\right) S_{12} - \frac{0.5 S_{23}}{2S_{21}-1} S_{13}$$

substituting the values:

⇒ reflection @ port 1 = ✓

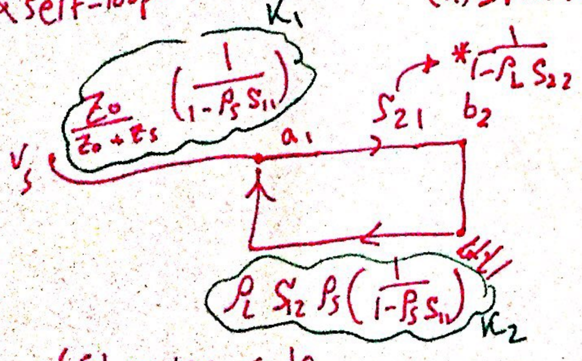
ρ_{21}

b) . Trans. coef. port $(1 \longrightarrow 2) = \dfrac{V_2^-}{V_1^+} = \underline{\underline{0.5}}$



(1) split Rule
(2) & self-loop.

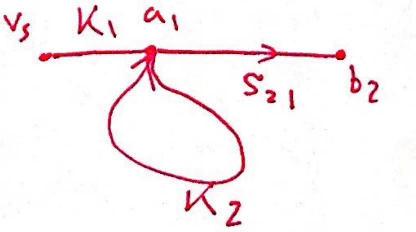
(3) split.
(4) split rule.

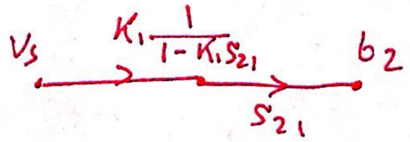


(5) series rule.
(6) split rule for $\underline{a_1}$.

⇒

⇒





$$b_2 = K_1 \frac{1}{1-K_2 S_{21}} \times S_{21}$$

$$V_L = b_2(1+\rho_L)$$

The Smith Chart

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