Midterm II with Solutions

Name ______________________________
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UNIVERSITY OF UTAH

ELECTRICAL AND COMPUTER ENGINEERING DEPARTMENT

MICROWAVE ENGINEERING I

ECE 5320/6322

MIDTERM EXAMINATION NO. II

November 7, 2014

1. (25 points)

For conjugate matching of output of a microwave amplifier, it is important to connect the load of effective impedance 20 – j20 through a reactive circuit such that the impedance between points CC' appears to be the complex conjugate of the generator output impedance $Z_g = 40 + j30$ ohms.

Using the circuit of topology given in Fig. 1,

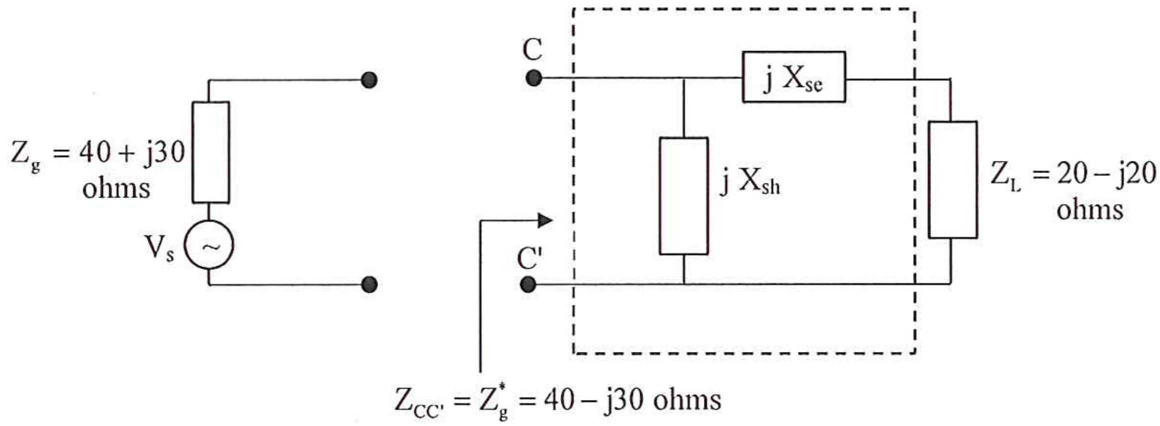



Fig. 1. An inverted L-circuit to convert the load impedance $Z_L = 20 - j20$ ohms to conjugate of the generator impedance $Z_g^* = 40 - j30$ ohms.

Pts

15 a. Without using a Smith chart, calculate the series reactance j $X_{se}$ and shunt susceptance j $X_{sh}$ which may be used. Use a **series inductance** for $X_{se}$ and a **shunt capacitance** for $X_{sh}$, if possible.

10 b. Calculate the values of inductance and capacitance elements that are needed for the above circuit given that the frequency is 3.5 GHz.

1. The suggested geometry is the same as that of Topology 2 on p.55 of Chapter 5 Notes.

This problem may be solved in terms of admittances.

$$Y_{cc'} = \frac{1}{40-j30} = \frac{1}{20-j20+jX_{se}} + \frac{1}{jX_{sh}} \qquad (1)$$

$$\frac{40+j30}{2500} = \frac{20-j(X_{se}-20)}{400+(X_{se}-20)^2} - \frac{j}{X_{sh}} \qquad (2)$$

Equating real parts on both sides of Eq. (2)

$$\frac{20}{400+(X_{se}-20)^2} = \frac{40}{2500}$$

$$\left[400+(X_{se}-20)^2\right] = \frac{2500 \times 20}{40} = 1250 \qquad (3)$$

$$(X_{se}-20) = \pm\sqrt{850} = \pm 29.15$$

$$X_{se} = \underbrace{49.15}_{\text{inductance}} ; \underbrace{-9.15}_{\text{capacitance}}$$

Noting that a series inductance $X_{se}$ is recommended

we take $X_{se} = 49.15 = \omega L_{se}$ (4)

For this selection we get (upon equating the imaginary parts on both sides of Eq. (2))

$$-\frac{j\,29.15}{1250} - \frac{j}{X_{sh}} = \frac{j\,30}{2500}$$

from Eq. (3) →

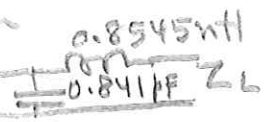
$$\frac{1}{X_{sh}} = -\frac{29.15}{1250} - \frac{15}{1250} = -\frac{44.15}{1250}$$

$$X_{sh} = -\frac{1250}{44.15} = -28.31 \rightarrow \frac{-1}{\omega C_{sh}} \qquad (5)$$

b. From Eqs. (4) and (5)

$$L_{se} = \frac{49.15}{2\pi \times 3.5 \times 10^9} = \boxed{2.235 \text{ nH}} ; \quad C_{sh} = \frac{1}{2\pi \times 3.5 \times 10^9 \times 28.31} = \boxed{1.606 \text{ pF}}$$

The conjugate matching circuit is as shown



2. (25 points)

The odd and even mode impedances of a coupled coplanar microstripline are given as follows:

$$Z_{0o} = 35.0\Omega \quad ; \quad Z_{0e} = 45.7\Omega$$

For this line, calculate the following:

| Pts | |
|---|---|
| 5 | a. the characteristic impedance $Z_0$ |
| 5 | b. the coupling factor C |
| 7 | c. the maximum coupling in dB at the midband frequency $f_o$ given that the length $\ell$ of the coupled section is $\lambda_g/4$ at $f_o = 3.5$ GHz |
| 8 | d. the coupling in dB at a lower frequency of 3 GHz. |

2. a. From Eq. 7.77 of the Text

$$Z_0 = \sqrt{Z_{0e} Z_{00}} = 40\ \Omega$$

b. From Eq. 7.81

Coupling factor $C = \dfrac{Z_{0e} - Z_{00}}{Z_{0e} + Z_{00}} = \dfrac{10.7}{80.7} = 0.1326$

c. From Eq. 7.82

$$\frac{V_3}{V_0} = \frac{jC\tan\theta}{\sqrt{1-C^2} + j\tan\theta} \simeq jC\sin\theta\, e^{-j\theta} \quad (1)$$

For midband frequency $f_0$ of 3.5 GHz; $\theta = 90^\circ \leftarrow \frac{2\pi l}{\lambda_g}$

$\left|\frac{V_3}{V_0}\right| = C$; in dB $-20\log C = \boxed{17.55\ dB}$

or $-17.55$ dB

d. Eq. (1) can also be written in terms of frequency

$$\left|\frac{V_3}{V_0}\right| = C\sin\theta = C\sin\left(\frac{\pi}{2}\frac{f}{f_0}\right) = 0.1326\sin\left(90^\circ\,\frac{3}{3.5}\right)$$

$$= 0.1326\sin 77.14^\circ = 0.1293$$

in dB $\boxed{-17.77\ dB}$

Note that the coupling at 3 GHz is only 0.22 dB lower than the center frequency of 3.5 GHz.

3. (25 points)

Pts

8 a. Write the A, B, C, D parameters of the following half-section filter shown in Fig. 1.

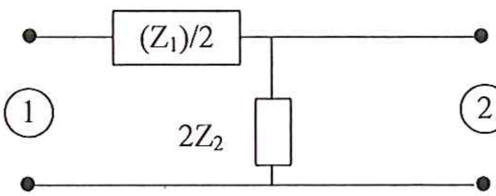



Fig. 1.

8 b. Write the input and output impedances $Z_{i1}$ and $Z_{i2}$ for this half-section filter.

5 c. Are these the same as $Z_{iT}$ and $Z_{i\pi}$ of the full-section T- and $\pi$-section filters?

4 d. Sketch the full-section T- and $\pi$-section filters corresponding to Fig. 1.

3. a. From Table 4.1 (last row) of the Text we can write (noting that $Z_2 = 0$ and $Z_3 = 2Z_2$)

$$A = 1 + \frac{Z_1}{4Z_2} \qquad B = \frac{Z_1}{2}$$

$$C = \frac{1}{2Z_2} \qquad D = 1$$

b. From Eqs. 8.27 a and 8.27 b of the Text

$$Z_{i1} = \sqrt{\frac{AB}{CD}} = \sqrt{\left(1+\frac{Z_1}{4Z_2}\right)\frac{Z_1}{2}\,2Z_2} = \sqrt{Z_1 Z_2\left(1+\frac{Z_1}{4Z_2}\right)}$$

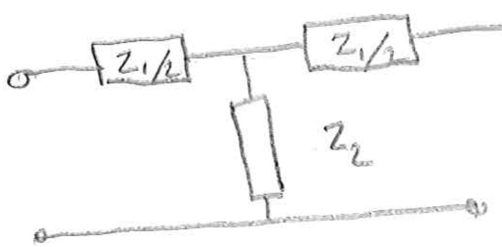
c.1 This is the same as $Z_{iT}$ of the full T-section filter given in Table 8.1 of the Text.

From Eq. 8.27 b of the Text

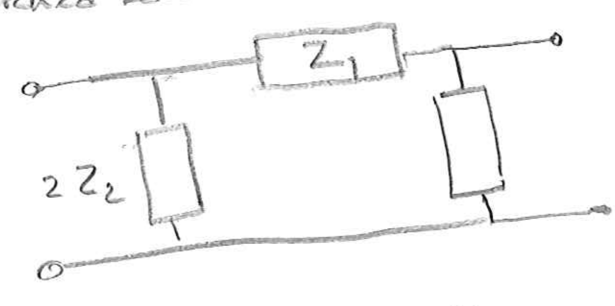
$$Z_{i2} = \sqrt{\frac{BD}{AC}} = \sqrt{\frac{Z_1/2}{\left(1+\frac{Z_1}{4Z_2}\right)\frac{1}{2Z_2}}} = \sqrt{\frac{Z_1 Z_2}{1+\frac{Z_1}{4Z_2}}}$$

c.2 This is the same as $Z_{i\pi}$ of the full Π-section filter given in Table 8.1 of the Text.

d. The full T- and Π-section filters are sketched below




Full T-Section Filter




Full Π-Section Filter

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Score:

| | | |
|---|---|---|
| Problem 1 | ________ | of a possible 25 points |
| Problem 2 | ________ | of a possible 25 points |
| Problem 3 | ________ | of a possible 25 points |
| Total | ________ | of a possible 75 points |