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EXAM - 22 May 2014
ELT-47246 Passive RF Circuits

Examiner: Toni Björninen

Calculator: Allowed (also programmable).

Additional instructions: Use also written explanations – normally a computation alone does not convey all the relevant information. A collection of formulas is provided.

Problem 1. Concept test.

Select the all the correct statements – no further justifications needed. Correct choice: plus 1 point. Incorrect choice: minus 1 point (negative total score will be set to zero).

Q1: Basic concepts.

(a) At a high frequency, a shunt capacitor may be replaced with an open-ended transmission line stub
(b) There is no equivalent transmission line stub configuration to represent an inductor at high frequencies
(c) Quarter-wave transformer is used to transform a resistive load to a desired resistance
(d) A finite and non-zero complex impedance can always be matched to a given non-zero resistance using two purely reactive lumped components

Q2: Your task is to design a microstrip transmission line with the characteristic impedance of 50 Ω on a typical dielectric circuit board. To complete the task with engineering precision you need to know...

(a) Relative permittivity of the board material
(b) Loss tangent of the board material
(c) Thickness of the board
(d) Conductivity of the board metallization

Q3: Your task is to impedance-match an antenna to a 50 Ω source. With your current matching circuit, the input reflection coefficient is −17 dB, but this is still 3 dB from the design goal: −20 dB.

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(a) The matching is not good enough to safely feed the antenna: the signal reflected back to the source is likely to damage it.
(b) Due to imperfect matching, the power delivered to the antenna from the source is only 50% of the target.
(c) Here the 3 dB difference has little impact on the power transfer from the source to antenna.

Problem 2. Transmission lines.

Consider a loss-free 50 Ω transmission line with the lenght of $d = \lambda/8$. Suppose the line is terminated with with load impedance of 150 Ω. Determine the

(a) Input impedance
(b) Input reflection coefficient in a 50 Ω system
(c) Voltage amplitude at the center point of the line when it is fed from a 5 V source with the internal impedance of 50 Ω

Problem 3. Passive microwave components.

Name the below components and briefly explain their operation when an excitation is applied at port(s) labelled with "in". Determine which of the properties: loss-free, reciprocal and matched are associated with each component.

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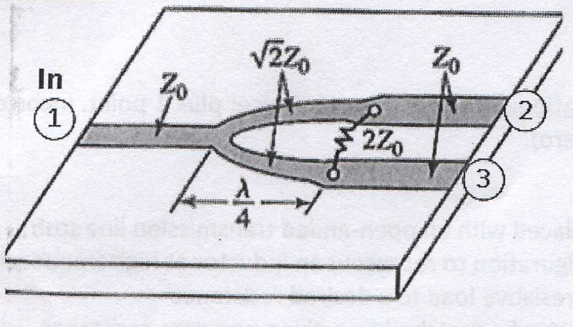
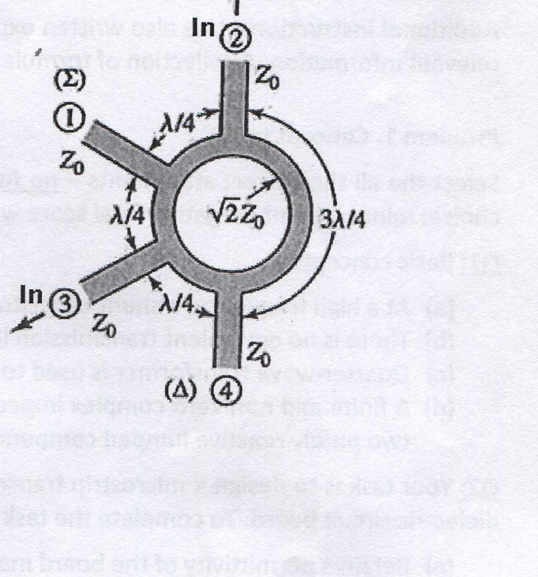
Component 1

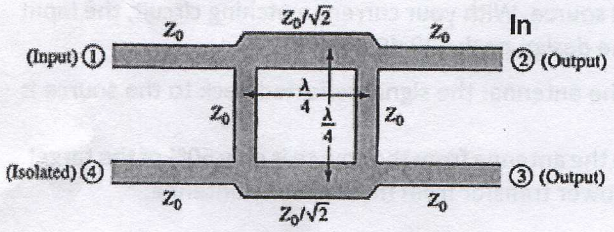


$$S = \frac{-j}{\sqrt{2}} \begin{pmatrix} 0 & 1 & 1 \\ 1 & 0 & 0 \\ 1 & 0 & 0 \end{pmatrix}$$

Component 3



Component 2



$$S = \frac{-1}{\sqrt{2}} \begin{pmatrix} 0 & j & 1 & 0 \\ j & 0 & 0 & -1 \\ 1 & 0 & 0 & j \\ 0 & -1 & j & 0 \end{pmatrix}$$

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$$Z_0 = \sqrt{\frac{R + j\omega L}{G + j\omega C}} \qquad \lambda = \frac{c_0}{f\sqrt{\varepsilon_r \mu_r}} \qquad \gamma = \alpha + j\beta \qquad \beta = \frac{2\pi}{\lambda}$$

$$V(z) = V_f e^{-\gamma z} + V_b e^{\gamma z}$$
$$I(z) = I_f e^{-\gamma z} + I_b e^{\gamma z}$$

$$Z_{in} = Z_0 \frac{Z_L + jZ_0 \tan(\beta l)}{Z_0 + jZ_L \tan(\beta l)}$$

$$\frac{V_f}{I_f} = Z_0 = -\frac{V_b}{I_b}$$

$$\Gamma_L = \frac{V_b(0)}{V_f(0)} = \frac{Z_L - Z_0}{Z_L + Z_0}$$

$$\Gamma_{in} = \frac{V_b(-d)}{V_f(-d)} = \frac{Z_{in} - Z_0}{Z_{in} + Z_0} = \Gamma_L e^{-2\gamma d}$$

$$\mathbf{S}^* \mathbf{S} = \mathbf{U}$$