UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 8 Examination in Engineering: November 2016

Module Number: EE8209 **Module Name: Microwave Communication**

[Three Hours]

[Answer **all questions,** each question carries **10 marks]**

All the notations have their usual meanings.

Q1 a) Derive an expression for the attenuation of TM_{nm} mode in a circular waveguide with finite conductivity.

[2Marks]

b) A circular copper waveguide has a radius 0.4 cm. It is filled with a dielectric material with $\xi_r = 1.5$ and $\tan\delta = 0.002$.

i) Determine the first four propagation modes and their cut-off frequencies

[2Marks]

ii) Calculate the total attenuation for the dominant mode.

[2Marks]

c) i) Derive a transcendental equation for the cutoff frequency of the TM modes of a coaxial waveguide.

[2Marks]

ii) Using tables, obtain an approximate value of $k_c a$ for TM_{01} mode when $(b/a) = 2$

[2Marks]

Q2 a) The maximum power capacity of a coaxial line is limited by voltage breakdown and is given by

$$P_{\max} = \frac{\pi a^2 E_d^2}{\eta_0} \ln \frac{b}{a}$$

where E_d is the field strength at breakdown.

i) Determine the value of $\frac{b}{a}$ that maximizes the maximum power capacity

ii) Show that the corresponding characteristics impedance is $30\,\Omega$

[5 Marks]

b) A radio transmitter is connected to an antenna having an impedance $(80 + j\,40)\,\Omega$ with a $50\ \Omega$ coaxial cable. If the $50\ \Omega$ transmitter delivers 30 W when connected to a $50\ \Omega$ load, how much power is delivered to the antenna?

[5 Marks]

Q3. a) Briefly explain the following parameters of a transmission line.

i) Intrinsic impedance

ii) Wave impedance

iii) Characteristics impedance

[3 Marks]

b) A transmission line has the following per unit length parameters; $L = 0.5\ \mu\text{H/m}$, $C = 200\ \text{pF/m}$, $R = 4.0\ \Omega\text{/m}$, and $G = 0.02\ \text{S/m}$.

i) Calculate the propagation constant and characteristics impedance of the transmission line at 800MHz.

[3 Marks]

ii) If the line is 30 cm long, what is the attenuation in dB?

[2 Marks]

iii) Recalculate these quantities in the absence of loss.

[2 Marks]

Q4 a) Consider a rectangular waveguide with $a = 2.286\,\text{cm}$ and $b = 1.016\,\text{cm}$ cm, air filled for $z < 0$ and Rexolite filled ($r = 2.54$) for $z > 0$, as shown in Figure Q4 a). If the operating frequency is 10 GHz, use an equivalent transmission line model to compute the reflection coefficient of a TE_{10} wave incident on the interface from $z < 0$.

Hint: $k_0 = 209.4\,\text{m}^{-1}$

$$\beta_a = \sqrt{k_0^2 - \left(\frac{\pi}{a}\right)^2}$$

$$\beta_d = \sqrt{\epsilon_r k_0^2 - \left(\frac{\pi}{a}\right)^2}$$

[5 Marks]

b) Determine the scattering parameters of the 3 dB attenuator circuit shown in Figure Q4 b). Assume that the Characteristics impedance of the wave guide is 50 Ω .

[5 Marks]

Q5 A two-port network consist of the following scattering matrix.

$$[S] = \begin{bmatrix} 0.15\angle 0^\circ & 0.85\angle -45^\circ \\ 0.85\angle 45^\circ & 0.2\angle 0^\circ \end{bmatrix}$$

a) Determine whether the network is reciprocal and lossless.

[5 Marks]

b) If port 2 is terminated with a matched load, what is the return loss seen at port 1?

[3 Marks]

c) If port 2 is terminated with a short circuit, what is the return loss seen at port 1?

[2 Marks]

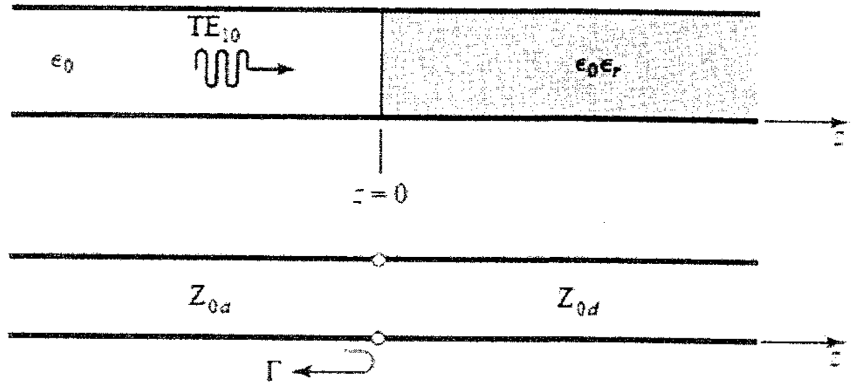

Figure Q4 a): Geometry of a partially filled waveguide

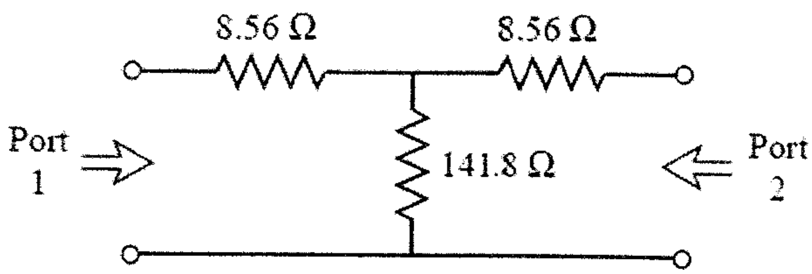

Figure Q4 b): A matched 3 dB attenuator with a 50 Ω characteristic impedance

Table 1: Summary of results for circular waveguide

Quantity	TE_{nm} Mode	TM_{nm} Mode
k	$\omega\sqrt{\mu\epsilon}$	$\omega\sqrt{\mu\epsilon}$
k_c	$\frac{p'_{nm}}{a}$	$\frac{p_{nm}}{a}$
β	$\sqrt{k^2-k_c^2}$	$\sqrt{k^2-k_c^2}$
λ_c	$\frac{2\pi}{k_c}$	$\frac{2\pi}{k_c}$
λ_g	$\frac{2\pi}{\beta}$	$\frac{2\pi}{\beta}$
v_p	$\frac{\omega}{\beta}$	$\frac{\omega}{\beta}$
α_d	$\frac{k^2\tan\delta}{2\beta}$	$\frac{k^2\tan\delta}{2\beta}$
E_z	0	$(A\sin n\phi+B\cos n\phi)J_n(k_c\rho)e^{-j\beta z}$
H_z	$(A\sin n\phi+B\cos n\phi)J_n(k_c\rho)e^{-j\beta z}$	0
E_ρ	$\frac{-j\omega\mu n}{k_c^2\rho}(A\cos n\phi-B\sin n\phi)J_n(k_c\rho)e^{-j\beta z}$	$\frac{-j\beta}{k_c}(A\sin n\phi+B\cos n\phi)J'_n(k_c\rho)e^{-j\beta z}$
E_ϕ	$\frac{j\omega\mu}{k_c}(A\sin n\phi+B\cos n\phi)J'_n(k_c\rho)e^{-j\beta z}$	$\frac{-j\beta n}{k_c^2\rho}(A\cos n\phi-B\sin n\phi)J_n(k_c\rho)e^{-j\beta z}$
H_ρ	$\frac{-j\beta}{k_c}(A\sin n\phi+B\cos n\phi)J'_n(k_c\rho)e^{-j\beta z}$	$\frac{j\omega\epsilon n}{k_c^2\rho}(A\cos n\phi-B\sin n\phi)J_n(k_c\rho)e^{-j\beta z}$
H_ϕ	$\frac{-j\beta n}{k_c^2\rho}(A\cos n\phi-B\sin n\phi)J_n(k_c\rho)e^{-j\beta z}$	$\frac{-j\omega\epsilon}{k_c}(A\sin n\phi+B\cos n\phi)J'_n(k_c\rho)e^{-j\beta z}$
Z	$Z_{TE}=\frac{k\eta}{\beta}$	$Z_{TM}=\frac{\beta\eta}{k}$

Table 2: value of P_{nm} for TM modes of circular waveguide

n	p_{n1}	p_{n2}	p_{n3}
0	2.405	5.520	8.654
1	3.832	7.016	10.174
2	5.135	8.417	11.620

Table 3: Valiue of p'_{nm} for TE modes of circular waveguide

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0	2.405	5.520	8.654
1	3.832	7.016	10.174
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