UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 8 Examination in Engineering: July 2022

Module Number: EE8211 **Module Name: Microwave Communication**

[Three Hours]

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

- All the notations have their usual meanings.
- Assume permittivity of free space is $\frac{10^{-9}}{36\pi}\ F/m$

Q1 a) Derive equations for the transverse field components in terms of longitudinal fields, in cylindrical coordinates. [3 Marks]

b) A 10 GHz signal is to be transmitted inside a hollow circular conducting pipe. Determine the inside diameter of the pipe such that its lowest cutoff frequency is 20% below this signal frequency. [3 Marks]

c) If the circular waveguide is to operate in 15 GHz, what waveguide modes can be propagated circular waveguide for radius of a = 0.011 m?

[2 Marks]

d) Without deriving new equation roughly sketch the electric and magnetic field lines in typical transverse plane of a circular waveguide for TM_{11} and TE_{01} based on Figure Q1. [2 Marks]

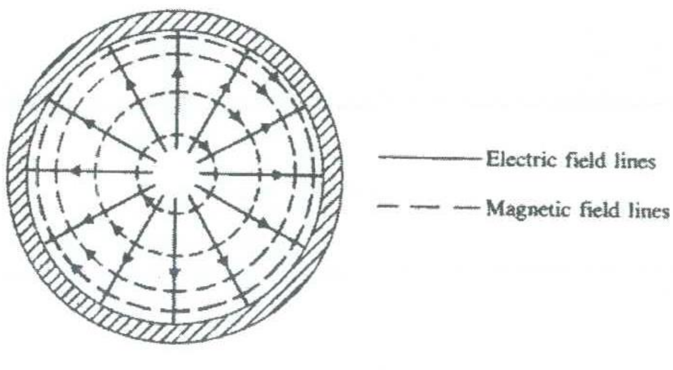

Figure Q1: Field lines for TM_{01} mode in a transvers plane of circular waveguide.

Q2. a) Consider a series RLC circuit with a current I. Calculate the power loss, the stored electric and magnetic energies and write an equation for the input impedance. [3 Marks]

b) Show that the input impedance Z of a parallel RLC circuit satisfies the condition $Z(-\omega) = Z^*(\omega)$. [3 Marks]

c) A two-port network is driven at both ports such that the port voltages and currents have the following values ($Z_0 = 50\,\Omega$). Determine the input impedance seen at each port, and find the incident and reflected voltages at each port.

$$V_1 = 10\angle 90^\circ, \quad I_1 = 0.2\angle 90^\circ,$$
$$V_2 = 8\angle 0^\circ, \quad I_2 = 0.16\angle -90^\circ.$$

[4 Marks]

Q3 a) Show that the admittance matrix of a lossless N-port network has purely imaginary elements. [3 Marks]

b) Does a nonreciprocal lossless network always have a purely imaginary impedance matrix? Briefly explain your answer. [3 Marks]

c) Derive the [Z] and [Y] matrices for the two-port networks shown in the Figure Q3(a) and Q3(b). [4 Marks]

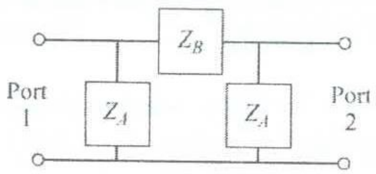

Figure Q3(a)

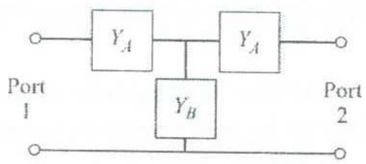

Figure Q3(b)

Q4 a) The T-model of a transmission line shown is in Figure Q4(a). Derive the telegrapher equations based on Figure Q4(a). R, L, G and C are representing series resistance per unit length, series inductance per unit length, shunt conductance per unit length and Shunt capacitance per unit length respectively. [4 Marks]

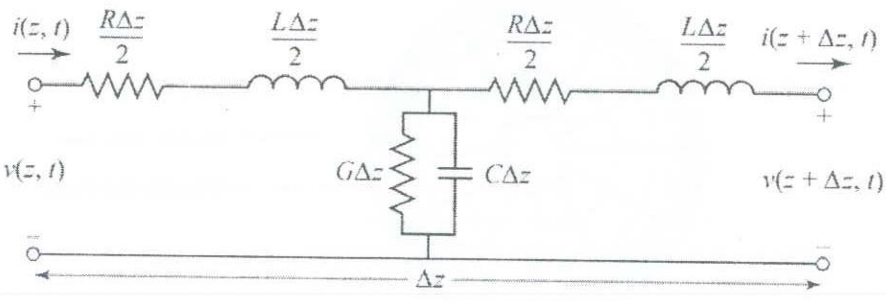

Figure Q4(a)

b) A series RLC resonator with an external load is shown in Figure Q4(b). Find the resonant frequency, the unloaded Quality factor, and the loaded Quality factor.

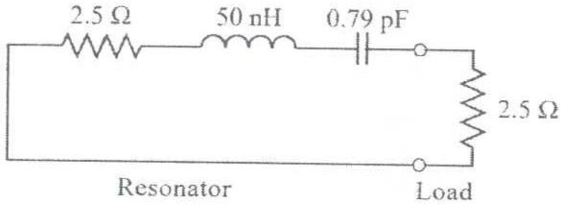

Figure Q4(b)

[3 Marks]

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

[3 Marks]

Q5 a) What do you mean by smart antenna?

[1 Mark]

b) Compare the operation of switch beam antenna system and adaptive antenna system.

[2 Marks]

c) The electric far-field component of a Hertzian dipole antenna with usual notation is given by $\bar{E}_{far} = \frac{j\eta_0\beta_0 I.\delta l.\sin\theta}{4\pi r} e^{-j\beta_0 r}\,\bar{a}_\theta$ where $\eta_0, I, \delta l$ and β_0 are the intrinsic impedance in free space, the amplitude of current, the length of Hertzian dipole and the propagation constant, respectively.

i) Show that the radiation power density vector in the radial direction is, $\hat{S}_{av} = \frac{\beta_0^2\eta_0|I^2|(\delta l)^2\sin^2\theta}{32\pi^2 r^2}\bar{a}_r$, where $\bar{a}_r$ is the unit vector in the radial direction.

[3 Marks]

ii) Using the expression derived in part (i) and applying $\eta_0 = 120\pi$, show that the total radiated power from a Hertzian dipole antenna can be given with usual notation as $P_{rad}(t) = \frac{2\pi\eta_0}{3}(\frac{\delta l}{\lambda_0})^2\frac{|I^2|}{2}$ W.

[3 Marks]

iii) Hence, calculate the radiation resistance R_{rad} of Hertzian dipole antenna.

[1 Mark]

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.

n	p'_{n1}	p'_{n2}	p'_{n3}
0	3.832	7.016	10.174
1	1.841	5.331	8.536
2	3.054	6.706	9.970