INDIAN INSTITUTE OF TECHNOLOGY, KHARAGPUR

Department of Electronics and Electrical Communication Engineering

End Autumn Semester Examination 2010

RF & Microwave Engineering (EC 31005)

Full Marks : 80

Time : 3 Hrs

Answer all questions. The expressions for the electromagnetic fields for particular choices of the electric and magnetic vector potentials are given below the question paper. The marks for each question is indicated to the right.

1. The expression for the magnetic field component H_x of a TM mode in a rectangular waveguide of transverse dimensions $a = 1.5\ cm$ by $b = 0.8\,cm$ and filled with a material of permittivity $\varepsilon = 4\varepsilon_0$ and permeability $\mu = \mu_0$ is given by :

$$H_x = 2\sin\left(\frac{\pi x}{a}\right)\cos\left(\frac{3\pi y}{b}\right)\sin\left(\pi \times 10^{11} t - \beta z\right)\text{ A/m}$$

For the above structure, determine

(a) The particular TM mode involved
(b) The cutoff frequency
(c) The phase constant β

(2+3+3)

2. Derive the expression of power flow in the TE_{mn} mode in a rectangular waveguide. An air-filled rectangular waveguide of dimensions $a = 4\,cm$ by $b = 2\,cm$ transports energy in the dominant mode at a rate of 2 mW. If the frequency of operation is 10 GHz, determine the peak value of the electric field in the guide.

(10+5)

3. Derive the expression for the quality factor of a rectangular resonator of dimensions a x b x c enclosed by conducting walls with a surface resistance of R and operating in the TE_{011} mode.

(20)

4. The electric field in a homogeneous nonmagnetic medium is given by $\bar{E} = 4\sin\left(2\pi \times 10^7 t - 0.8x\right)\hat{u}_z$ V/m. Find :

(a) The relative permittivity ε_r and characteristic impedance η of the medium
(b) The time average power carried by the wave
(c) The power crossing 100 cm^2 of surface in the plane $2x + y = 5$

(5+3+8)

5. Consider two two-port networks A and B with individual scattering matrices $[S^A]$ and $[S^B]$ respectively. Show that the overall S_{21} parameter of the cascade of these two networks is given by

$$S_{21} = \left(S_{21}^{A} S_{21}^{B}\right) / \left(1 - S_{22}^{A} S_{11}^{B}\right)$$

(12)

6. Write short notes on :

(a) Low profile broadband antennas
(b) Factors affecting antenna efficiency
(c) Antenna input impedance

(3+3+3)

<u>Expressions for the electromagnetic fields for particular choices of the electric and magnetic vector potentials :</u>

For $\boldsymbol{F} = \psi \boldsymbol{u_z}$,

$$E_x = -\frac{\delta\psi}{\delta y}$$
$$E_y = \frac{\delta\psi}{\delta x}$$
$$E_z = 0$$
$$H_x = \frac{1}{j\omega\mu}\frac{\delta^2\psi}{\delta x\delta z}$$
$$H_y = \frac{1}{j\omega\mu}\frac{\delta^2\psi}{\delta y\delta z}$$
$$H_z = \frac{1}{j\omega\mu}\left(\frac{\delta^2}{\delta z^2} + k^2\right)\psi$$

For $\boldsymbol{A} = \psi \boldsymbol{u_z}$,

$$E_x = \frac{1}{j\omega\epsilon}\frac{\delta^2\psi}{\delta x\delta z}$$
$$E_y = \frac{1}{j\omega\epsilon}\frac{\delta^2\psi}{\delta y\delta z}$$
$$E_z = \frac{1}{j\omega\epsilon}\left(\frac{\delta^2}{\delta z^2} + k^2\right)\psi$$
$$H_x = \frac{\delta\psi}{\delta y}$$
$$H_y = -\frac{\delta\psi}{\delta x}$$
$$H_z = 0$$