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The Open University of Sri Lanka
Department of Electrical and Computer Engineering
ECX6243/ECX6333 – Microwave Engineering and Applications
Final Examination 2015/2016

Time: 9.30-12.30hrs. Date: 2016- 12 - 02

Answer any FIVE questions.

1.

(a) (i) Write the relationship between $\nabla \times \underline{H}$, $\underline{J}$ and $\underline{D}$.

(ii) Using the answer to (i) derive an expression for the charge density (ρ) induced in a metallic medium when an electromagnetic wave propagating.
[For any given vector $\underline{A}$, $\nabla.(\nabla \times \underline{A}) = 0$]

(b) When an electromagnetic wave is propagating in a metal there will be induced electric charges.
Show that the induced charge density (ρ) in copper disappears extremely fast.

Conductivity of copper = $6 \times 10^{7}\, S/m$
Permittivity of copper at the given frequency $\cong 8.85 \times 10^{-12}\, F/m$

[Assume that the charge density disappears when it becomes 5 % of its original value. Also note that $e^{-3} = 5\ \%$]

2.

(a) (i) What is a *TEM* wave?

(ii) For a *TEM* plane wave propagating in air, draw the $\underline{E}$ vector and the $\underline{H}$ vector. Also mark the direction of propagation on the same diagram.

(iii) Speed of a TEM wave in air is c_0. The same wave travels at a speed of c_1 in a dielectric medium whose relative permittivity and relative permeability are ε_r and μ_r respectively.
Write the relationship between c_1 and c_0.

(b) In a coaxial cable a wave travels from A to B. Due to a line fault, a wave starting from A at $t = 0$ is reflected back to A at $t = 1.5\,\mu s$. Locate the position of the fault.
[The dielectric medium in the cable has $\varepsilon_r = 2.1$ and $\mu_r \cong 1$. Speed of light in free space is $3 \times 10^{8}\, m\, s^{-1}$]

3.

(a) The inner surface of a waveguide is some times plated with a thin layer of Silver or Gold. What is the reason for this?

(b) Why can't TEM mode exist in a waveguide?

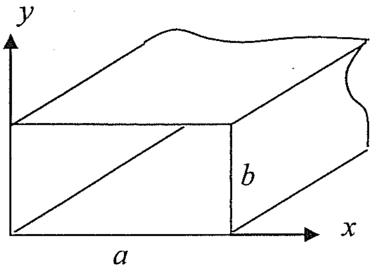
(c)

$$\vec{E}_x = -\frac{jm\beta\pi}{ak_c^2}\vec{A}\cos\left(\frac{m\pi\, x}{a}\right)\sin\left(\frac{n\pi\, y}{b}\right)e^{-j\beta z}$$

$$\vec{E}_y = -\frac{jn\beta\pi}{bk_c^2}\vec{A}\sin\left(\frac{m\pi\, x}{a}\right)\cos\left(\frac{n\pi\, y}{b}\right)e^{-j\beta z}$$

$$\vec{H}_x = \frac{jn\omega\varepsilon\pi}{bk_c^2}\vec{A}\sin\left(\frac{m\pi\, x}{a}\right)\cos\left(\frac{n\pi\, y}{b}\right)e^{-j\beta z}$$

$$\vec{H}_y = -\frac{jm\omega\varepsilon\pi}{ak_c^2}\vec{A}\cos\left(\frac{m\pi\, x}{a}\right)\sin\left(\frac{n\pi\, y}{b}\right)e^{-j\beta z}$$



Transverse Field components inside a rectangular waveguide for TM_{mn} mode are given above.

(i) Find the value of the above field components for

1. TM_{0n} mode
2. TM_{m0} mode

(ii) The cutoff frequency f_c for a waveguide operating in TM_{mn} mode (or TE_{mn} mode) is given by $f_c = \frac{1}{2\sqrt{\mu\varepsilon}}\left[\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2\right]^{\frac{1}{2}}$. Use the results of (i) to show that the dominant TM_{mn} mode is TM_{11}.

(iii) Find the cutoff wave length for TM_{11} mode if the waveguide is filled with air. For the waveguide $a = 2b = 4.4\ cm$

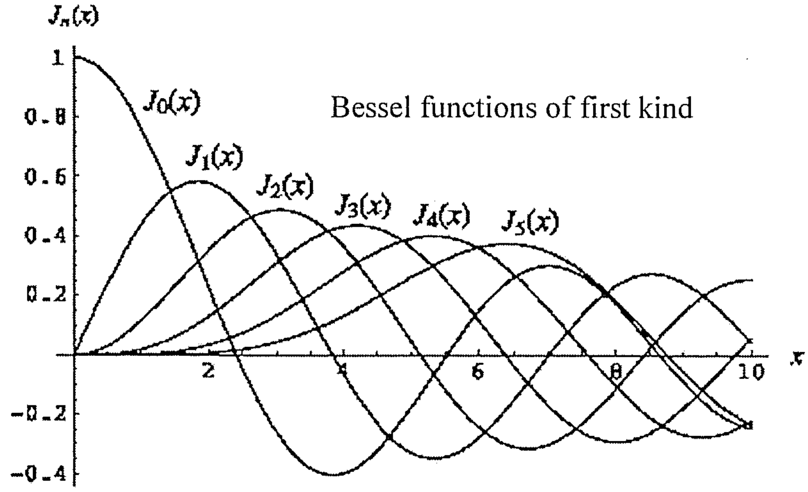
4.

(a) The radial magnetic component H_ρ in a rectangular waveguide whose internal radius is *a*, is given by $H_\rho = A\,J_n(\rho\ k_c)\ \sin n\varphi$, where A is a mode- and the frequency dependent constant. $J_n(x)$ is a Bessel function of first kind and of order n. Show that $J_n(a\ k_c) = 0$.

(b) The propagation constant β_{nm} for a wave propagating in a cylindrical waveguide for TM_{nm} mode is given by $\beta_{nm} = \sqrt{\omega^2\mu\varepsilon - \left(\frac{\rho_{nm}}{a}\right)^2}$

(i) Derive an expression for the cutoff frequency.

(ii)



Some Bessel functions of first kind are given in the above diagram.
Find the lowest cutoff frequency of a circular waveguide operating in TM_{3m} mode.
The internal radius of the waveguide is 1.4 cm. The waveguide is filled with air.

5.

(a) A wave enters into the auxiliary arm (arm 3) of an E-plane Tee.
Draw the E-field patterns in arms 1, 2 and 3 for TE_{10} mode.

(b) For the E-plane Tee given in (a), let the change of the phase of the signal when coupled from port 3 to port 1 is α, and the change of the phase is β when the signal is coupled from port 3 to port 2.
Is $\alpha = \beta$? Justify your answer.

(c) Write the scattering matrix $[s]$ for an E-plane Tee. Minimize the number of variables in $[s]$. Describe the principles you applied for minimization process.

(d) If the above Tee junction is lossless, explain how you would evaluate $[s]$. [Actual calculations are not expected.]

6.

(a) To measure the VSWR of a line, the forward wave and the reflected wave should be separated first. Then they should be independently connected to the two input terminals of a ratio meter.
With the help of a diagram explain how this done using two directional couplers.

(b) When designing a r.f communication network for a larger area, that area is subdivided into number of smaller areas (cells). What is the main advantage of process?

(c) Briefly explain the following with reference to a cellular communication network:

(i) frequency reuse ratio.
(ii) co-channel interference.

(iii) sectoring

7.

(a) A cellular operator is planning a cellular network in a certain area. The total bandwidth allocated for the operator is 69 *MHz*. Duplex channels are used for voice and control purposes. The bandwidth of a duplex channel is 50 *kHz*. 1 *MHz* is reserved for control channels. If the frequency reuse ratio is 7

(i) find the total number of channels available per cell.
(ii) find the number of voice channels available per cell.

(b) Explain why the $\frac{S}{N}$ ratio in a cellular system cannot be improved by increasing the transmitter power.

(c) How does the $\frac{S}{N}$ ratio depend on the frequency reuse ratio?

8.

(a) Using a diagram briefly explain the principle of operation of a double cavity Klystron amplifier.

(b) Draw a block diagram of the down link of a satellite communication system. Also discuss the various stages of processing the received signal undergoes.

(c) (i) What is understood by the aperture of an antenna?

(ii) Total power transmitted by an antenna at a point P is P_t. Find the power density at a point Q if $PQ = d$. The transmitting gain of the antenna in the direction of PQ is G_t.

(iii) An object at Q with capture area A totally reflects the signal incident on it. Reflected signal is recaptured by the antenna at P. If the receiving gain of the antenna in the direction of PQ is G_R write an expression for the power captured by the antenna.