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The Open University of Sri Lanka
Faculty of Engineering Technology
Department of Electrical and Computer Engineering

Study Programme	: Bachelor of Technology Honours in Engineering
Name of the Examination	: Final Examination
Course Code and Title	: **EEX6543 / ECX6243 Microwave Engineering and Applications**
Academic Year	: 2019/20
Date	: 10th October 2020
Time	: 0930-1230 hrs.

General Instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **Eight (8)** questions in **Six (5)** pages.
3. Answer any **Five (5)** questions only. All questions carry equal marks.
4. Answer for each question should commence from a new page.
5. Relevant charts / codes are provided.
6. This is a Closed Book Test **(CBT).**
7. Answers should be in clear handwriting.
8. Do not use red color pen.

1.

(a) Write the Maxwell's equations in the differential form. [4 *Marks*]

(b) Modify the equations you wrote in 1(a) if the medium of propagation is source free.

[3 *Marks*]

(c) Using the vector identity $\nabla \times (\nabla \times \underline{A}) = \nabla(\nabla \cdot \underline{A}) - \nabla^2 \underline{A}$ derive the wave equation

$$\nabla^2 \underline{E} = -\frac{1}{c^2}\frac{\partial^2 E}{\partial t^2}$$ for the electric field of the propagating wave, where c is a constant.

Assume that the medium is source free. [8 *Marks*]

(d) If the free space permeability $\mu_0 = 4\pi \times 10^{-7}$ H/m and the free space permittivity $\varepsilon_0 = 8.854 \times 10^{-12}$ F·m⁻¹, find the value of c and hence the speed of electromagnetic wave propagation in free space. [5 *Marks*]

2.

(a) What conditions should an *E*-field satisfy at a metallic boundary? [3 *Marks*]

(b) A rectangular waveguide has breadth a and height b as shown in Fig.2.

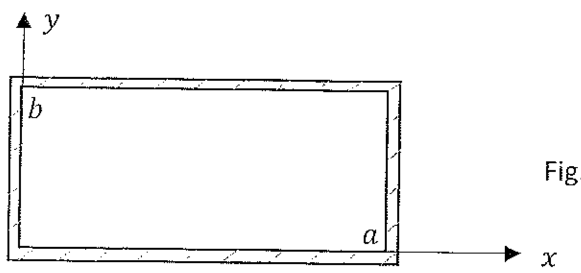

Fig.2

For TM waves electric field component along the waveguide E_z is given by $A sin(k_x x) sin(k_y y)$ where A is a constant.

By applying the boundary conditions for a *E*-field mentioned in 2 (a) show that

$k_x = \frac{m\pi}{a}$ and $k_y = \frac{n\pi}{b}$ where m and n are integers. [6 *Marks*]

(c) Cutoff wave number of a waveguide is given by $k_c = \sqrt{k_x^2 + k_y^2}$. An air-filled rectangular waveguide is operating in the TM_{11} mode at 6 GHz. The internal dimensions of the waveguide are 7.6 cm and 3.8 cm.

(i) Find the cutoff wave number. [3 *Marks*]

(ii) Find the cutoff frequency. [4 *Marks*]

(iii) Find the guide wavelength. [4 *Marks*]

3.

(a)

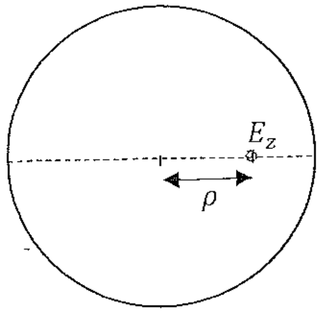

Fig. 3.

The axial electric field strength $E_z(\rho, 0, 0)$ at an axial distance ρ, of an air-filled cylindrical waveguide for TM_{nm} mode (on a horizontal diameter) is given by $B_n J_n(k_c\rho)$ where k_c is the cutoff wavenumber and $J_n(x)$ is a Bessel function of the first kind and n^{th} order.
(For a given value of n, $J_n(x) = 0$ will have number of roots $p_{n1}, p_{n2}, p_{n3}, \ldots . p_{nm}$.)
B_n is a constant. The internal radius of the waveguide is a .

(i) Prove that $k_c = \frac{p_{nm}}{a}$ [5 *Marks*]

(ii) The radius of the waveguide is 4 cm. Show that if the waveguide is excited in the TM_{11} mode using a 2 GHz oscillator, the signal will be highly attenuated and no signal propagation will take place. [5 *Marks*]

Value of n	p_{nm}		
	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	11.602

Table. 1 Roots of $J_n(x) = 0$

(b) A cylindrical resonator is constructed having a length of d of the waveguide given in 3 (a)(ii).

Following conditions apply to the resonator:

$\sin(\beta d) = 0$ (satisfies the boundary conditions) ———————— (1)

$\gamma = j\beta = \sqrt{k_c^2 - 4\pi^2 {f_r}^2 \mu\epsilon}$, where γ is the propagation constant. ——(2)

(i) Show that the resonant frequency of the resonator is given by [5 *Marks*]

$$f_r = \frac{1}{2\pi\sqrt{\mu\epsilon}} \sqrt{\left({k_c}^2 + \left({l\pi}/{d}\right)^2\right)}$$

(ii) Find the resonant frequency for the TM_{011} mode. [5 *Marks*]

4.

(a) A rectangular waveguide is excited using a coaxial cable as shown below:

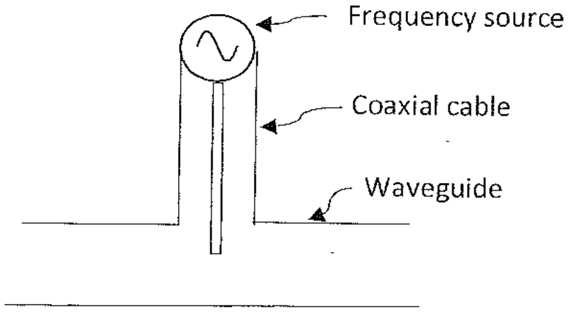

Fig. 4

(i) Sketch the E-field inside the coaxial cable and the waveguide. [5 *Marks*]

(ii) What kind of mode is excited in the waveguide? [4 *Marks*]

(b) (i) What are the 3 major losses found in waveguides? [6 *Marks*]

(ii) Briefly explain methods to minimize the losses mentioned in (4)(b)(i).

[5 *Marks*]

5.

(a) (i) Draw an $E - plane$ tee and a $H - plane$ tee. [3 *Marks*]

(ii) Indicate the directions of the E-field and the H- field at the port 1 of each of the tee's mentioned in 5(a)(i). [3 *Marks*]

(b) A Signal is fed to the side arm (port 3) of an $E - plane$ tee.

(i) Mark the direction of the E-field at the port 2 and port 3.

(ii) Write the scattering matrix [$S\ Matrix$] for $E - plane$ tee using minimum

number of parameters. Assume that the medium inside the tee to be isotropic.

[4 *Marks*]

(iii) In the $[S]$ matrix given in (c) (ii) some of the elements of the matrix are duplicated and some have negative values. Give reasons for this. [4 *Marks*]

(iv) Evaluate the $[S]$ matrix given in (c) (ii) if the ports 1 and 2 are matched. [6 *Marks*]

6.

(a) For a lossless, perfectly matched, nonreciprocal three-port junction,

(i) write the $[S]$ matrix for the junction. [2 *Marks*]

(ii) write a matrix equation that will reflect the unitary conditions of the junction. [3 *Marks*]

(iii) Assuming that $S_{21} \neq 0$, evaluate all the matrix elements. [6 *Marks*]

(iv) Show that the junction is a circulator. [3 *Marks*]

(b) (i) Describe the principle of operation of a directional coupler. [3 *Marks*]

(ii) The insertion loss of a directional coupler is 0 dB. What can you say about the power coupled to the auxiliary arm? Also find the coupling factor. [3 *Marks*]

7.

(a) Define following terms related to a cellular communication system:

(i) Cell cluster. [2 *Marks*]

(ii) Frequency reuse. [2 *Marks*]

(iii) Sectoring. [2 *Marks*]

(b) In a cellular system certain cell is allocated 22 channels. What are the factors that will decide the number of users that can be assigned to the cell? [4 *Marks*]

(c) A cellular system has 1680 cells. Each cell consists of 20 channels. The frequency reuse factor of the system is $1/_4$. On average each user of the system generates 2 calls per hour. The average call duration is 4 minutes. If the grade of service of the system is 2 % find

(i) the number of clusters. [3 *Marks*]

(ii) the total number of users in the system. [7 *Marks*]

8.

(a) With the help of a diagram describe the working principle of a two-cavity klystron amplifier. [5 *Marks*]

(b) What is the function of the helix in a travelling wave tube amplifier (TWT)? [3 *Marks*]

(c) Briefly explain the meaning of *Electrical tilt* as applied to an antenna. [4 *Marks*]

(d) (i) Draw the down link of a satellite communication system indicating various subsystems.

[5 *Marks*]

(ii) Why is it necessary to use a low noise amplifier (LNA) for the satellite down link?

[3 *Marks*]

Erlang B

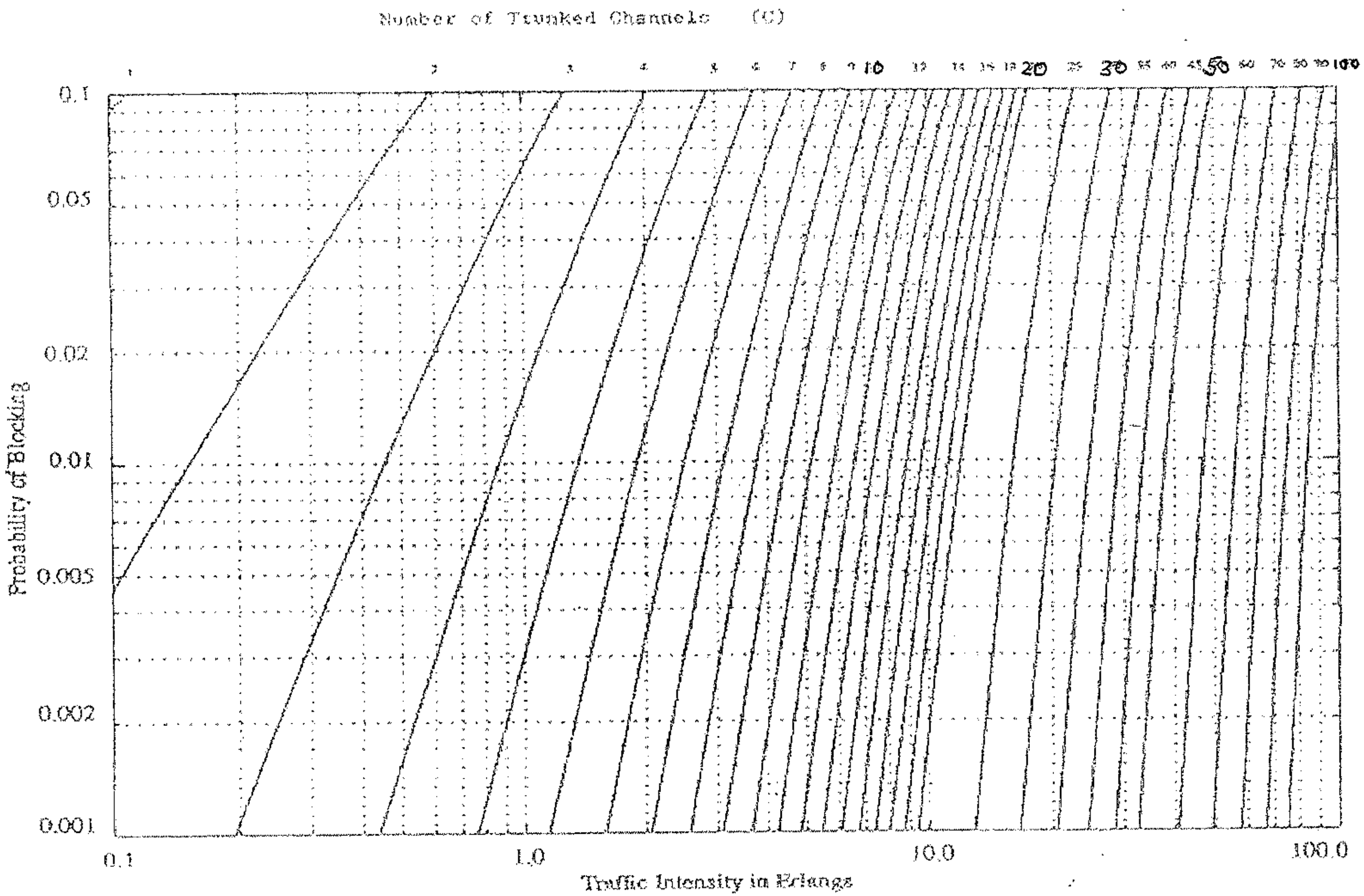

Figure 7 The Erlang B chart showing the probability of blocking as functions of the number of channels and traffic intensity in Erlangs.