PES UNIVERSITY

UE22EC351B

WAVEGUIDES, CAVATIES AND RADIATION FROM POINT SOURCE

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Problems based on Unit 2

Problem 1:

A waveguide that is rectangular has its dimensions in the ratio a:b=2:1 is supporting TE11 mode, and it has cut-off frequency of 9 GHz. (a) Determine the dimensions of the waveguide.

Solution:

TE_{mn} mode m=1, n=1

Unless otherwise specified, free space is present inside the waveguide.

Width is greater than the height (a $>$ b)

$$f_{cmn} = \frac{k_c}{2\pi\sqrt{\mu\epsilon}} = \frac{1}{2\sqrt{\mu\epsilon}}\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}$$

$$f_{cmn} = \frac{C}{2\sqrt{\mu_r\epsilon_r}}\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}$$

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In free space $\mu_r = 1, \epsilon_r = 1$

$$9x10^9 = \frac{3x10^8}{2\sqrt{1x1}}\sqrt{\left(\frac{1}{a}\right)^2 + \left(\frac{1}{b}\right)^2}$$

$$\frac{a}{b} = \frac{2}{1}$$

a=2b

$$60^2 = \left(\frac{1}{2b}\right)^2 + \left(\frac{1}{b}\right)^2$$

$$3600 = \left(\frac{1}{2b}\right)^2 + \left(\frac{1}{b}\right)^2$$

b = 0.018m and a = 2b = 2(0.018)

a = 0.037m

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Problem 2:

If the operating frequency of the wave is 18GHz and cut-off frequency of 9GH, determine

(i) wave number or phase constant β.

(ii) Phase velocity Vg

(iii) wave impedance of the wave Zg.

Solution: (i) wave number or phase constant β.

$$\beta = \omega\sqrt{\mu\epsilon}\sqrt{1-\left(\frac{f_c}{f}\right)^2}$$

$$\beta = {}^{\omega}/_{C}\sqrt{1-\left(\frac{f_c}{f}\right)^2}$$

$\omega = 2\pi f = 36\,\pi\,10^9$

$\sqrt{\mu\epsilon} = \sqrt{\mu_o\epsilon_o} = \frac{1}{c} = 1/3\text{x}10^8$

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$$\beta = {36\,\pi\,10^9}/{3x10^8}\sqrt{1-\left(\frac{9}{18}\right)^2}$$

β =326.483 rad/m

(ii) Phase velocity Vg

$$V_g = {c}/{\sqrt{\mu_r \epsilon_r}\sqrt{1-\left(\frac{fc}{f}\right)^2}} = {\omega}/{\beta}$$

$$V_g = {3x10^8}/{\sqrt{1x1}\sqrt{1-\left(\frac{9}{18}\right)^2}}$$

V_g = 3.464 x 10^8m/s

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(iii) wave impedance of the wave Zg.

$$Z_g = \eta_o \Big/ \sqrt{1-\left(\frac{fc}{f}\right)^2} = \omega\mu / \beta$$

$$Z_g = 120\pi \Big/ \sqrt{1-\left(\frac{9}{18}\right)^2}$$

$$Z_g = 435.31\ \Omega$$

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Problem 3:

An air-filled rectangular waveguide of inside dimensions 7x3.5cm operates in dominant mode(TE10).

(i) Find the cut-off frequency.

(ii) Determine the phase velocity of the wave in the guide at a frequency of 3.5 GHz.

(iii) Determine the guided wavelength at the same frequency.

Solution: (i) the cut-off frequency $m = 1, n = 0$

$$f_{cmn} = \frac{k_c}{2\pi\sqrt{\mu\epsilon}} = \frac{1}{2\sqrt{\mu\epsilon}}\sqrt{\left(\frac{m}{a}\right)^2}$$

$$f_{c10} = \frac{1}{2a\sqrt{\mu\epsilon}}$$

where in air filled medium $\sqrt{\mu\epsilon} = \sqrt{\mu_o\epsilon_o} = \frac{1}{c} = 1/3\text{x}10^8$

$$f_{c10} = \frac{c}{2\sqrt{\mu_0\epsilon_o}},$$

$$f_{c10} = \frac{3x10^8}{2x7x10^{-2}\sqrt{1x1}}$$

$$f_{c10} = 2.14 \text{ GHz}$$

(ii) the phase velocity of the wave in the guide at a frequency of 3.5 GHz

$$V_g = {}^{C}\Big/_{\sqrt{\mu_r \epsilon_r}\sqrt{1-\left(\frac{f_c}{f}\right)^2}}$$

$$V_g = {}^{3x10^8}\Big/_{\sqrt{1x1}\sqrt{1-\left(\frac{2.14}{3.5}\right)^2}}$$

$$V_g = 3.78\ x10^8 \text{m/s}$$

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(iii) the guided wavelength at the same frequency

$$\lambda_g = \lambda \Big/ \sqrt{\mu_r \epsilon_r}\sqrt{1-\left(\frac{fc}{f}\right)^2}$$ where $\lambda = c/f = 3x10^8/3.54 = 0.085$

$$\lambda_g = \lambda \Big/ \sqrt{1-\left(\frac{2.14}{3.5}\right)^2}$$

$$\lambda_g = \frac{0.085}{0.79}$$

$$\lambda_g = 0.108$$

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Problem 4:

A rectangular waveguide resonator is operating at 9 GHz in dominant mode. If the resonator dimensions are in the ratio of a:b:d=2:1:4, determine the dimensions of the resonator, if it is filled with dielectric having ϵ_r = 4.

Solution: Dominant mode TE_{101}, m=1, n=0, p=1

a=2b and d=4b , $f_r = 9GHz$

$\mu_r \epsilon_r = 1x4 = 4$

$$f_r = \frac{C}{2\sqrt{\mu_r \epsilon_r}} \sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2 + \left(\frac{p}{d}\right)^2}$$

$$9x10^9 = \frac{3x10^8}{2\sqrt{4}} \sqrt{\left(\frac{1}{2b}\right)^2 + \left(\frac{0}{b}\right)^2 + \left(\frac{1}{4b}\right)^2}$$

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$$3x10x4 = \sqrt{\left(\frac{1}{2b}\right)^2 + \left(\frac{1}{4b}\right)^2}$$

b = 4.658mm

a = 9.317mm

d = 18.63mm

THANK YOU

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