EE2025 Engineering Electromagnetics: July-Nov 2019

Tutorial 5: Parallel plane and rectangular waveguides

1. A parallel plane waveguide is filled with a material with dielectric constant 9. The height of the waveguide is 50 cm. At 1 GHz how many modes can be propagated inside the waveguide and what are their cut-off frequencies ?

2. (a)Derive the expressions for the transverse field components in terms of the longitudinal field components E_z and H_z, in Cartesian and cylindrical coordinate systems.
(b)Using the general formulation, find modes in parallel plate waveguide

3. For a 5 cm $\times$ 3 cm rectangular waveguide, the maximum peak electric field of the dominant mode at 5 GHz is 10 V/m. Find the maximum peak magnetic field inside the waveguide. Also find the total power carried by the waveguide.

4. For the fundamental mode inside a rectangular waveguide the logitudinal magnetic field is given as

$$H_z = 20\cos(10y)e^{-j\beta z}A/m$$

Find the cut-off frequency of the mode. Also, find the frequency at which the group velocity is 1/3 of the phase velocity.

5. A rectangular waveguide has conducting fins running along its length as shown in Figure 1. Find the lowest frequency which will propagate on the waveguides.

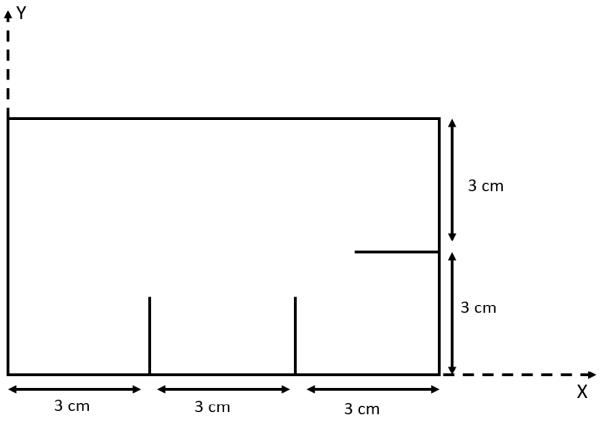

Figure 1

6. Inside an air-filled waveguide, the total magnetic field is given as

$$\mathbf{H} = 10\cos(\pi x)\sin\left(\frac{\pi y}{2}\right)e^{-j\beta z}\hat{y}A/m$$

Find the vector electric field, the phase constant β and the cut off frequency of the wave. The frequency of the wave is 2 GHz.

7. Standard air-filled waveguides have been designed for the radar bands. One type, designed WG-16, is suitable for X-band applications. Its dimensions are, $a = 2.29$ cm and $b = 1.02$ cm. If it is desired that a WG=16 waveguide operate only in the dominant TE_{10} mode and that the operating frequency be at least 25 % above the cutoff frequency of the TE_{10} mode but no higher than 95 % of the next higher cutoff frequency, what is the allowable operating frequency range ?

8. A standard air-filled S-band rectangular waveguide has dimensions $a = 7.21$ cm and $b = 3.40$ cm. What mode types can be used to transmit electromagnetic waves having the following wavelengths?
(**a**) $\lambda = 10$ cm
(**b**)$\lambda = 5$ cm

9. Parallel plate waveguide made of two perfectly conducting infinite planes spaced 3 cm apart operates at 10 GHz. Which of the modes (TEM/TE/TM) would be preferable for carrying the largest time average power through this waveguide, without causing dielectric breakdown. Justify by explicitly calculating the largest time average power that can be propagated through these modes.
(Given dielectric breakdown of air occurs at $3 \times 10^6 V/m$).

10. An air-filled $a \times b$ ($b < a < 2b$) rectangular waveguide to be constructed to operate at 3 GHz in the dominant mode. We desire the operating frequency to be at least 20 % higher than the cut off frequency of the dominant mode and also atleast 20 % below the cut off frequency of the next higher order mode.
(**a**) Give a typical design for the dimensions a and b
(**b**)Calculate for your design β, u_p, λ_g at the operating frequency
(**c**)Define intrinsic impedance for TE mode. Calculate intrinsic impedance at the operating frequency

11. A resonant cavity of 6 cm $\times$ 3 cm $\times$ 4 cm is excited in the lowest mode. The peak electric field inside the cavity is 100 V/m. Find the resonant frequency of the cavity and the total energy stored inside the cavity.