Semester S1

Foundations of electromagnetic wave propagation

EXAMINATION

PART S. VERDEYME

Consider the waveguide presented figure 1. The material embedded in this support is characterized by its relative permeability μ_r =1 and its relative permittivity ε_r = 1. It is bounded by perfect magnetic walls (PMW), placed in x=0, x=a=22.86 mm, and by perfect electric walls (PEW), placed at y=0 and y=b=10.16 mm. We will work in the frequency domain.

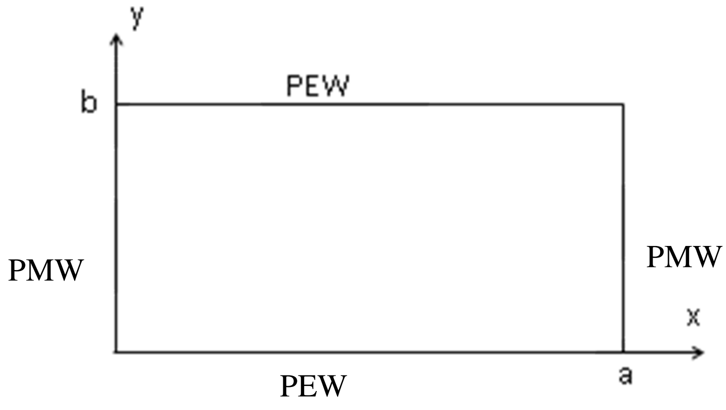

Figure 1

1) TEM Mode

a) Can you consider that the propagation along this support (figure 1) is quite similar to the propagation along a microstrip line ? Explain why.

b) We give for this TEM mode :

$$\overrightarrow{H(x,y)} = \frac{V}{bZ_0}\overrightarrow{e_x} \qquad \overrightarrow{E(x,y)} = -\frac{V}{b}\overrightarrow{e_y}$$

where : Z_0 is the plane wave impedance

V is the voltage on the conductor placed in the plane y=b (the other conductor is grounded)

Compute the expression of :

- the waveguide metallic losses per unit length on the TEM mode, for conductors characterized by their surface resistance R_s
- the power transmitted through the line
- the attenuation coefficient of the waveguide.

2) TE Mode

This waveguide is now excited on TE modes. On a PMW, the H_z component cancels (in the planes defined by x=0 and x=a), and you know the condition for the magnetic field on the PEW.

a. From the propagation equation, considering the waveguide lossless,:

- compute the expressions of the first TE mode cutoff frequency and the H_z component of this mode.

- From the following expressions, compute all the E and H field components of the first TE mode.

$$\left(\gamma^2+k_o^2\right)\overrightarrow{E_t}(\xi,\eta)=-\gamma\overrightarrow{\nabla_t}E_z(\xi,\eta)+j\omega\mu\vec{u}\wedge\overrightarrow{\nabla_t}H_z(\xi,\eta)$$

$$\left(\gamma^2+k_o^2\right)\overrightarrow{H_t}(\xi,\eta)=-\gamma\overrightarrow{\nabla_t}H_z(\xi,\eta)-j\omega\varepsilon\vec{u}\wedge\overrightarrow{\nabla_t}E_z(\xi,\eta)$$

With $\vec{u}$ the unitary vector in the z direction.

b. The metallic enclosure placed in the plane y=0 and y=b is now again a real conductor, characterized by its conductivity σ.

- Compute the waveguide metallic losses on the first TE mode
- Compute the power transmitted through the waveguide
- Compute the attenuation coefficient of the waveguide.

3) **Compare now the attenuation per unit length of this support on the TE and TEM modes**:

- At the cutoff frequency of the TE mode
- For $\beta >> K_c$

Conclude