

Microwaves

Series 6

Problem 1

Determine the dimensions of a quarter wave transformer made in microstrip line technology, which will allow matching a 12.5Ω line to a line having a characteristic impedance of 50Ω . The frequency of the signal is 3.8 GHz, and we use a dielectric substrate having a thickness of 0.6 mm and a relative permittivity $\epsilon_r=9.5$.

First, we compute the characteristic impedance of the transformer, using:

$$Z_{tran} = \sqrt{Z_1 Z_2} = 25 \Omega$$

The problem is then to construct a section of microstrip line having a characteristic impedance of 25Ω on a substrate of thickness 0.6 mm and of relative permittivity $\epsilon_r=9.5$ we find from equation 4.92.

$$\frac{w}{h} = 3.188$$

We then obtain the effective permittivity $\epsilon_e = 7.2$ from equation 4.89. At 3.8 GHz, the free space wavelength is 78.9 mm. The guided wavelength is thus:

$$\lambda_g = \frac{\lambda_o}{\sqrt{\epsilon_e}} = 29.41 \text{ mm}$$

Thus, the length of the quarter wave transformer is of 7.35 mm

Problem 2

A microstrip line has a characteristic impedance of 50Ω and a width of 1.8 mm. The permittivity of the substrate is 3. What is the frequency corresponding to the limit of apparition of radiation? Do we need to correct for dispersion at this frequency?

In this problem, we want to find the thickness of the substrate. We get:

$$B = \frac{\pi \cdot 376.6}{2\sqrt{3} \cdot 50} = 6.8326$$

$$\frac{w}{h} = \frac{3-1}{3\pi} \left\{ \ln(6.8326 - 1) + 0.39 - \frac{0.61}{3} \right\} + \frac{2}{\pi} \{6.8326 - 1 - \ln(2 \cdot 6.8326 - 1)\}$$

$$= 2.5106$$

We get

$$h = \frac{1.6}{2.5106} = 0.72 \text{ mm}$$

The frequency above which radiation is non negligible is given by:

$$f_m = \frac{2.14 \cdot \sqrt[4]{3}}{0.72} = 3.91 \text{ GHz}$$

The frequency above which we need to take dispersion into account is given by

$$f_d = \frac{Z_c}{2\mu_0 h} = 27.63 \text{ GHz}$$

We see that the dispersion becomes important at frequency much higher than the frequency at which radiation starts. It is thus not necessary to take dispersion into account at this frequency.

Problem 3

In a waveguide (either circular or rectangular, it does not matter) where a given single mode is excited, a 5 GHz signal has a wavelength $\lambda_g = 8 \text{ cm}$. We fill this waveguide with a lossless liquid, and see that the wavelength is now of 6.8 cm. What is the relative dielectric permittivity of the liquid ?

Solution

We compute first the longitudinal propagation coefficient β for this waveguide filled with air:

$$\beta = \frac{2\pi}{\lambda_g} = \frac{2\pi}{0.08} = 78.54$$

From this, we obtain the relevant eigenvalue for the propagating mode from

$$\beta = \sqrt{k^2 - k_c^2} ; k_c^2 = k^2 - \beta^2 = \frac{\omega^2}{c^2} - \beta^2 = 10966.23 - 6168.53 = 4797.7$$

We compute now the longitudinal propagation for the filled waveguide :

$$\beta = \frac{2\pi}{\lambda_g} = \frac{2\pi}{0.068} = 92.24$$

From which we obtain the relative permittivity :

$$\beta = \sqrt{k^2 - k_c^2} \quad ; \quad k_c^2 = k^2 - \beta^2 = \frac{\omega^2 \varepsilon}{c^2} - \beta^2$$

$$\varepsilon = \frac{c^2}{\omega^2} (k_c^2 + \beta^2) = 0.000091(4797.7 + 8508.2) = 1.21$$