This assignment has three sections A, B C and D. Maximum Marks of this assignment is 10

Book : Handbook of Microwave Integrated circuits , By R.K Hoffmann
Chapter-3
Chapter-6.
Use: MATLAB
And software Txline or online calculator

Section-A : Microstrip Line Based on Chapter-3

Write a program to plot characteristic impedance using MATLAB and compare results as shown in Fig.1 and in table below.

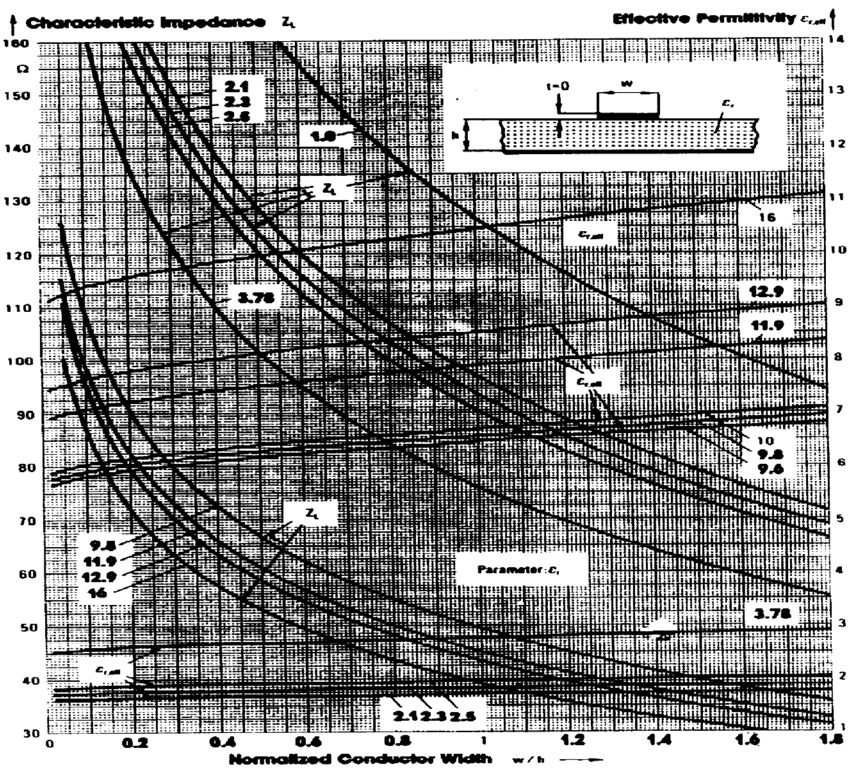


Fig. 3.4 Circuit parameters Z_L and $\epsilon_{r,eff}$ of microstrip on various technologically important substrates: PTFE (ϵ_r = 2.1), polyolefin (ϵ_r = 2.3), glass-reinforced PTFE (ϵ_r = 2.5), fused quartz (ϵ_r = 3.78), alumina ceramic (ϵ_r = 9.6, 9.8, or 10), semi-insulating Si (ϵ_r = 11.9), semi-insulating GaAs (ϵ_r = 12.9), and nonmagnetic ferrite (ϵ_r = 16), with t = 0 for $w/h \leq 1.8$ by the method of lines.

Fig.1 Plot characteristic impedance and Effective permittivity with W/h ratio

Program 1: To show the variation of characteristics impedance and effective relative permittivity with respect to width to height ratio using Hammerstad and O. Jensen formula.

Characteristic Impedance: $Z_{LO} = Z_L(\epsilon r = 1) = \frac{\eta_o}{\frac{w}{h}+1.98+\left(\frac{w}{h}\right)^{0.172}}$

Effective Permittivity

$$\varepsilon reff = \frac{\varepsilon r + 1}{2} + \frac{\varepsilon r - 1}{2}\left(1 + \frac{10h}{w}\right)^{-a.b}$$

$$a = 1 + \frac{1}{49} ln\left(\frac{\left(\frac{w}{h}\right)^4 + \left(\frac{w}{52h}\right)^2}{\left(\frac{w}{h}\right)^4 + 0.432}\right)$$

$$b = 0.564\left[\frac{(\varepsilon r - 0.9)}{\epsilon r + 3}\right]^{0.053}$$

$$Z_L\left(\frac{w}{h}, \varepsilon r\right) = \frac{Z_{LO}}{\sqrt{\epsilon r, eff}}$$

w/h	Hoffaman Book Results			MATLAB Code Results			Online calculator		
	Er=2.1	Er=3.78	Er=9.8	Er=2.1	Er=3.78	Er=9.8	Er=2.1	Er=3.78	Er=9.8
0.02									
0.05									
0.1									

0.4									
1.0									
2.0									
5.0									
10.0									

Program 2:

To show the variation of characteristics impedance and effective relative permittivity with respect to width to height ratio using schneider's formula.

for $0 < w/h \leq 1$

$$Z_{Lo} = Z_L = 60ln\left(\frac{8h}{w} + \frac{w}{4h}\right)$$

for $w/h \geq 1$

$$Z_{LO} = Z_L(\varepsilon r = 1) = \frac{120\pi}{\frac{w}{h} + 2.42 + \left(\frac{0.44h}{w}\right) + \left[1 - \frac{h}{w}\right]^6}$$

Effective Permittivity for $1 \leq \varepsilon r < \infty$ and $0 < w/h < \infty$

$$\varepsilon reff = \frac{\epsilon r + 1}{2} + \frac{\varepsilon r - 1}{2}F$$

$$F = \left(1 + \frac{10h}{w}\right)^{-0.5}$$

$$Z_L\left(\frac{w}{h}, \varepsilon r\right) = \frac{Z_{LO}}{\sqrt{\epsilon r, eff}}$$

w/h	Hoffaman Book Results			MATLAB Code Results			Online calculator		
	Er=2.1	Er=3.78	Er=9.8	Er=2.1	Er=3.78	Er=9.8	Er=2.1	Er=3.78	Er=9.8
0.02									
0.05									
0.1									
0.4									
1.0									
2.0									
5.0									
10.0									

Program 3:

To show the variation of characteristics impedance and effective relative permittivity with respect to width to height ratio using wheeler's formula.

for w/h<1

$$Z_L = \frac{60}{\sqrt{\epsilon eff}} ln\left(\frac{8h}{w} + \frac{w}{4h}\right)$$

$$\varepsilon eff = \frac{\varepsilon r + 1}{2} + \frac{\varepsilon r - 1}{2}\left[\frac{1}{\sqrt{1 + \frac{12h}{w}}} + 0.04\left(1 - \frac{w}{h}\right)^2\right]$$

for w/h>1

$$Z_L = \frac{120\pi}{\sqrt{\varepsilon eff}}\left(\frac{1}{\frac{w}{h} + 1.393 + 0.677\left(ln\left(\frac{w}{h}\right) + 1.444\right)}\right)$$

$$\varepsilon eff = \frac{\varepsilon r + 1}{2} + \frac{\varepsilon r - 1}{2}\left[\frac{1}{\sqrt{1 + \frac{12h}{w}}}\right]$$

w/h	Hoffaman Book Results			MATLAB Code Results			Online calculator		
	Er=2.1	Er=3.78	Er=9.8	Er=2.1	Er=3.78	Er=9.8	Er=2.1	Er=3.78	Er=9.8
0.02									
0.05									
0.1									
0.4									
1.0									
2.0									
5.0									
10.0									

SECTION-B

Write a program in MATLAB and plot the dispersion curve as in Hoffman book (or Eeff Vs Frequency)

Program 1:

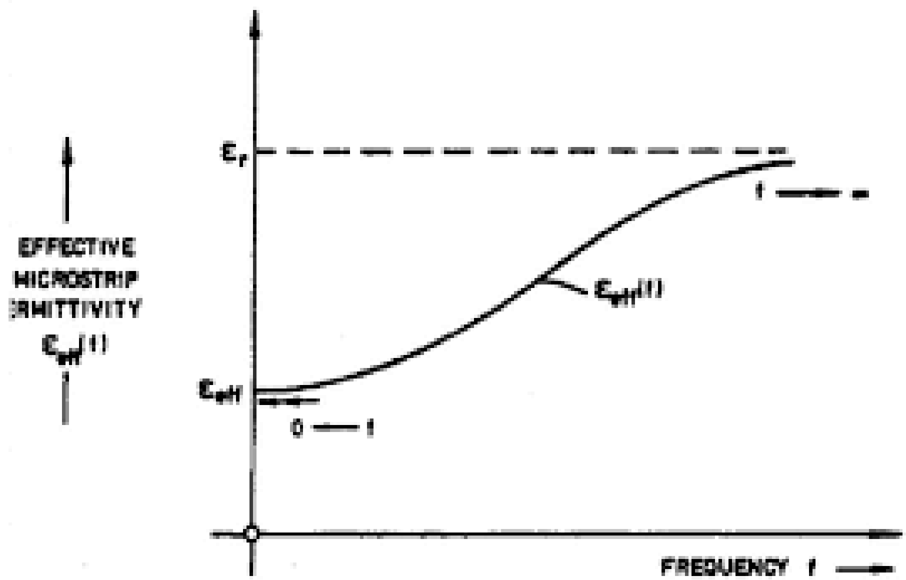
W.E Getsinger Dispersion Model of Microstrip (Eeff Vs Freq.)

Equation involved

$$\varepsilon reff(f) = \varepsilon r - \frac{\varepsilon r, eff, stat}{1 + G1\left(\frac{f}{f_p}\right)^2}$$

$$f_p = \frac{c_o Z_{L,stat}}{2h\eta_o}$$

$$G1 = 0.6 + 0.009 Z_{L,stat}$$



Program 2:

M.V Schneider Model of Dispersion in Microstrip (Eeff Vs Freq.)

Equation involved

$$\varepsilon eff(f) = \varepsilon r, eff, stat\left[1 + \left(\frac{f}{f_{p4}}\right)^2 \frac{1 - \sqrt{\frac{\varepsilon r, eff, stat}{\varepsilon r}}}{1 + \left(\frac{f}{f_p}\right)^2 \sqrt{\frac{\varepsilon r, eff, stat}{\varepsilon r}}}\right]$$

$$f_{p4} = \frac{c_o}{4h\sqrt{\varepsilon r - 1}}$$

Program 3:

Hammerstad-Jenson Model of Dispersion in Microstrip line (Eeff Vs Freq.)

Equation involved

$$\varepsilon reff(f) = \varepsilon r - \frac{\varepsilon r, eff, stat}{1 + G1\left(\frac{f}{f_p}\right)^2}$$

$$f_p = \frac{c_o Z_{L,stat}}{2h\eta_o}$$

$$G1 = \frac{\pi^2(\varepsilon r - 1)}{12\varepsilon r, eff, stat}\sqrt{\frac{2\pi Z_{L,stat}}{\eta_o}}$$

SECTION-C

Write a program to compute the conductor and dielectric loss as mentioned in Hoffman book.

Chapter-6

For conductor loss use equation-6.1

6.1.2 Attenuation Equations According to the Incremental Inductance Rule

From the general rule of inductive increments, Section 2.4.3, relations (2.64) to (2.67), and the special microstrip equation (2.69), we can generate an equation for α_ρ, assuming that the equations for the characteristic impedance Z_{L1} and the effective permittivity $\epsilon_{r,\text{eff}}$ are known for finite conductor thickness $t > 0$. This also assumes the skin effect condition $t > 3\delta$ (δ = skin depth, from (2.53)) to be fulfilled. Wheeler's equations (3.4) to (3.11) for Z_L (w/h, $t = 0$, ϵ_r), $\epsilon_{r,\text{eff}}$ (w/h, $t = 0$, ϵ_r), and the corrections (3.48), (3.50), (3.51), for $t > 0$, were used by Pucel, Massé, and Hartwig [2.105, 3.68] to derive equations for α_ρ, following which

$$\alpha_\rho = \{R_F/(Z_L h)\} \cdot A_\rho \tag{6.1}$$

The geometry factor A_ρ (w/h, t/h) for $0 < w/h < 1/(2\pi)$ is (in dB)

$$A_\rho = \frac{8.68}{2\pi}\left\{1 - \left(\frac{w_{\text{eq},0}}{4h}\right)^2\right\} \cdot \left[1 + \frac{h}{w_{\text{eq},0}} + \frac{h}{\pi w_{\text{eq},0}}\left\{\frac{t}{w} + \ln\left(\frac{4\pi w}{t}\right)\right\}\right] \tag{6.2}$$

for $0.16 \leqslant w/h \leqslant 2$:

$$A_\rho = \frac{8.68}{2\pi}\left\{1 - \left(\frac{w_{\text{eq},0}}{4h}\right)^2\right\} \cdot \left[1 + \frac{h}{w_{\text{eq},0}} + \frac{h}{\pi \cdot w_{\text{eq},0}}\left\{\ln\left(\frac{2h}{t}\right) - \frac{t}{h}\right\}\right] \tag{6.3}$$

and for $2 < w/h < \infty$:

$$A_\rho = \frac{8.68 \cdot \left[\dfrac{w_{\text{eq},0}}{h} + \dfrac{w_{\text{eq},0}/(\pi h)}{\{w_{\text{eq},0}/(2h)\} + 0.94}\right]}{\left[\dfrac{w_{\text{eq},0}}{h} + \dfrac{2}{\pi} \cdot \ln\left\{5.44\pi \cdot \left(\dfrac{w_{\text{eq},0}}{2h} + 0.94\right)\right\}\right]^2} \cdot \left[1 + \frac{h}{w_{\text{eq},0}} + \frac{h}{\pi w_{\text{eq},0}} \cdot \left\{\ln\left(\frac{2h}{t}\right) - \frac{t}{h}\right\}\right] \tag{6.4}$$

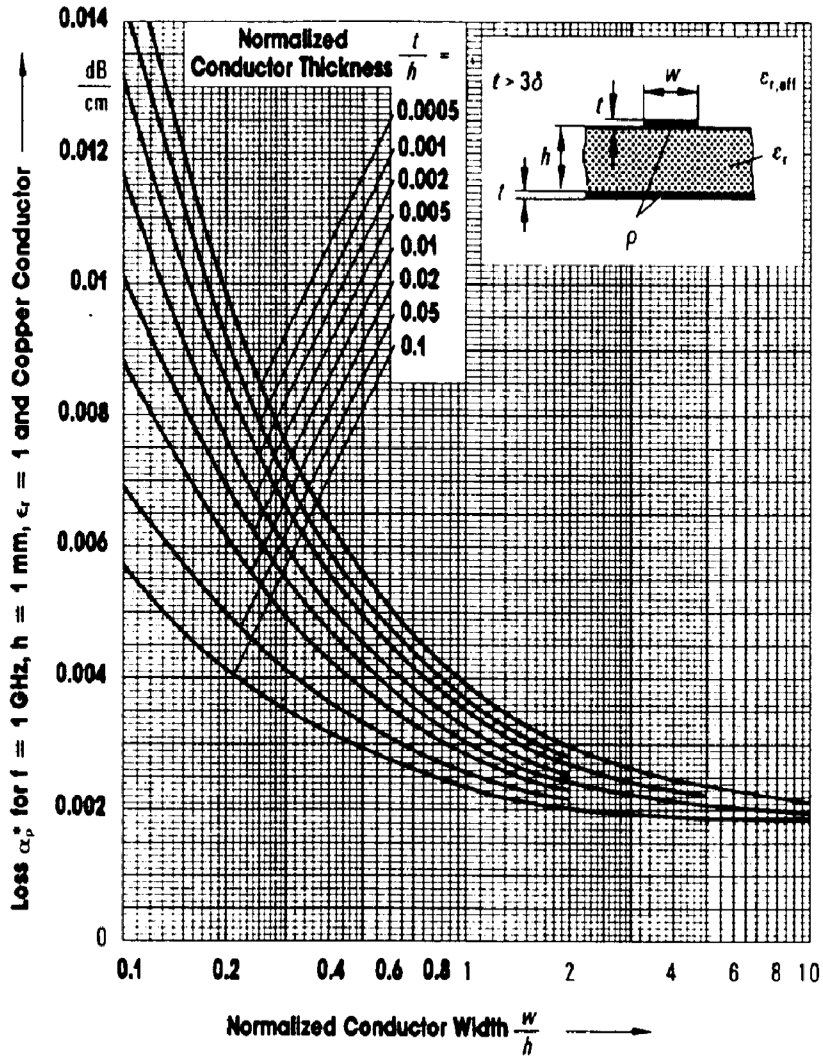


Fig. 6.1 Normalized conductor loss α_ρ for microstrip with $f = 1$ GHz, $\epsilon_r = 1$, $h = 1$ mm, and $\rho = 1.72 \times 10^{-6}$ Ωcm (copper).
Note: For any value of f in GHz, h in mm, $\epsilon_{r,\mathrm{eff}}$ $(w/h, \epsilon_r)$, and ρ in Ωcm, the conductor loss in dB/cm is

For dielectric loss use equation-6.11

$$\alpha_\epsilon = \alpha_\epsilon^* \cdot f \cdot \tan\delta_\epsilon \cdot 1000$$

$\tan\delta_\epsilon \cdot f \cdot f\,(w/h,\,\epsilon_r)$. For $\epsilon_r > 9$, $\alpha_\epsilon \approx 0.91 \tan\delta_\epsilon \cdot f\sqrt{\epsilon_{r,\mathrm{eff}}}$ (α_ϵ in dB/cm and f = GHz) because $q_{\tan\delta,\epsilon} \approx 1$. With $\epsilon_{r,\mathrm{eff}}$ derived from (3.22), the dielectric loss from (2.72) for $0 < w/h < \infty$, $1 \leq \epsilon_r\ \infty$ and $\tan\delta_\epsilon < 0.1$ is

$$\alpha_\epsilon = 0.91 \cdot \tan\delta_\epsilon \cdot f\sqrt{\frac{\epsilon_r(1+F)}{2} \cdot \left\{1 + \frac{1-F}{\epsilon_r(1+F)}\right\}^{-1}} \qquad (6.11)$$

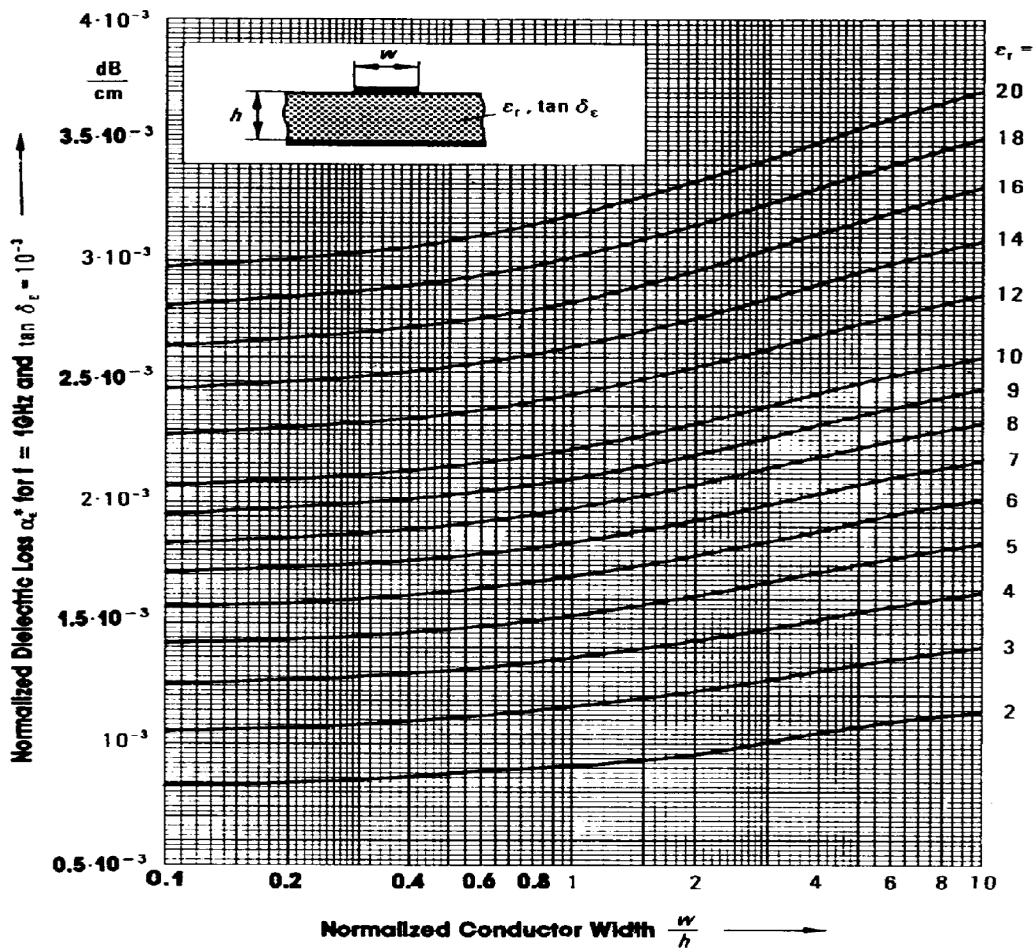


Fig. 6.4 Normalized dielectric loss α_ϵ^* for microstrip with $f = 1$ GHz, $\tan\delta_\epsilon = 0.001$.

Section-D

1. Explain with diagram the Strip line and also draw its Electric field and magnetic field distribution.

2. Explain with diagram the Microstrip line and also draw its Electric field and magnetic field distribution.
3. Explain with diagram the Coplanar waveguide line (CPW) and also draw its Electric field and magnetic field distribution.
4. Explain with diagram the Slot line and also draw its Electric field and magnetic field distribution.