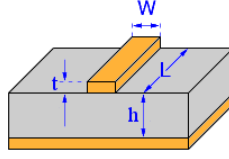


# Microstrip formulas

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1. Effective dielectric constant

$$\epsilon_{r,eff} = \begin{cases} \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2} \left[ \frac{1}{\sqrt{1+12\frac{h}{W}}} + 0.04 \left(1.0 - \frac{W}{h}\right)^2 \right] & W/h \leq 1.0 \\ \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2\sqrt{1+12\frac{h}{W}}} & W/h \geq 1.0 \end{cases}$$

2. Characteristic impedance

$$Z_0 = \begin{cases} \frac{60}{\sqrt{\epsilon_{r,eff}}} \ln \left( \frac{8h}{W} + \frac{W}{4h} \right) & \frac{W}{h} \leq 1 \\ \frac{120\pi}{\sqrt{\epsilon_{r,eff}} [W/h + 1.393 + 0.667 \ln(W/h + 1.444)]} & \frac{W}{h} \geq 1 \end{cases}$$

3. Design W to obtain a given characteristic impedance  $Z_0$

$$\frac{W}{h} = \begin{cases} \frac{8e^A}{e^{2A}-2} & \frac{W}{h} < 2 \\ \frac{2}{\pi} \left[ B - 1 - \ln(2B - 1) + \frac{\epsilon_r-1}{2\epsilon_r} \left( \ln(B - 1) + 0.39 - \frac{0.61}{\epsilon_r} \right) \right] & \frac{W}{h} > 2 \end{cases}$$

where

$$A = \frac{Z_0}{60} \sqrt{\frac{\epsilon_r+1}{2}} + \frac{\epsilon_r-1}{\epsilon_r+1} \left( 0.23 + \frac{0.11}{\epsilon_r} \right)$$

$$B = \frac{377\pi}{2Z_0\sqrt{\epsilon_r}}$$

4. Excess length (fringing capacitance for an open-ended microstrip)

$$\frac{\Delta L}{h} = 0.412 \frac{\epsilon_{r,eff}+0.3}{\epsilon_{r,eff}-0.258} \cdot \frac{W/h+0.264}{W/h+0.8}$$

5. Width correction due to finite metallization thickness

$$\frac{\Delta W}{t} = \frac{1.0}{\pi} \ln \left[ \frac{4e}{\sqrt{\left(\frac{t}{h}\right)^2 + \left(\frac{1/\pi}{W/t+1.1}\right)^2}} \right]$$

6. Conduction loss constant

$$\alpha_c(\text{Np/m}) = \begin{cases} \frac{R_s}{2\pi} \frac{\left(\frac{8.0h}{W} - \frac{W}{4h}\right) \left(1.0 + \frac{h}{W} \left(1 + \frac{\partial W}{\partial t}\right)\right)}{hZ_0 e^{\frac{Z_0}{60}}} & W/h \leq 1.0 \\ \frac{Z_0 R_s}{14400\pi^2 h} \left[ 1.0 + \left(\frac{h}{W}\right)^2 \left(0.44 + 6.0 \left(1.0 - \frac{h}{W}\right)^5\right) \right] \left(1.0 + \frac{W}{h} + \frac{\partial W}{\partial t}\right) & W/h \geq 1.0 \end{cases}$$

where

$$\frac{\partial W}{\partial t} = \begin{cases} \frac{1.0}{\pi} \ln \frac{4.0\pi W}{t} & \frac{W}{h} \leq \frac{1}{2\pi} \\ \frac{1.0}{\pi} \ln \frac{2.0h}{t} & \frac{W}{h} \geq \frac{1}{2\pi} \end{cases}$$

7. dielectric loss constant

$$\alpha_d(\text{Np/m}) = \pi \frac{q \tan \delta}{\lambda_0 / \sqrt{\epsilon_{r,eff}}}$$

where  $q$  is the “filling factor”:

$$q = \frac{\epsilon_{r,eff}-1}{\epsilon_r-1}$$

## References

- [1] B. C. Wadell, *Transmission Line Design Handbook*. Artech House, 1991.
- [2] D. M. Pozar, *Microwave Engineering*. John Wiley & sons, 1998.