Due 10/05/09

EE6311 Fall 2009 Homework #3
Introduction to AWR Microwave Office or Agilent ADS
Transmission Lines

If designing in AWR:

- Read the AWR introduction "Getting Started (this version is 2004)." specifically:
- #3. AWR Design Environment Suite Section; review the Basic Operations sections
- #4 MWO: Using the Linear Simulator; read and perform the tasks outlined in the "Creating a Lumped Element Filter" project.
- Print out your final filter design example and response.

OR

If designing in Agilent ADS:

- Watch the ADS movies on the following site: http://ece-classweb.ucsd.edu/fall07/ece166/.
  ADS Tutorials
    - Watch ADS example 1: *.wmv file ~ 4 minutes, OR
    - Read ADS tutorial and/or Basics of ADS
- Using the elements from the #4 MWO: Creating a Lumped Element Filter" project, design the project in ADS
- Print out your final filter design example and response.

For the following transmission lines, design each network "on paper" first using the graphical method. You will be determining the required width of the center conductor to give you the impedance value required. Then use MWO or ADS to simulate the TML. Submit your final circuit schematic and frequency (2 – 15 GHz) response plots (on the same graph of |S21| in dB, |S11| in dB) for each design.

Use: Center frequency, f_o = 10 GHz for all designs
Port impedances = 50 Ω unless specified otherwise
substrate ε_r = 2.2 762um
substrate thickness, h = 0.381mm for microstrip, b=0.762mm for stripline, h=1mm for CPW
conductor thickness = 10 μm
conductor metal = Au (use default value for rho in AWR or ADS)

1. Determine the appropriate line widths for microstrip transmission lines with the following characteristic impedances: Use an empirical or graphical method to compute line widths and then use AWR TxLine or Agilent Linecalc to compare.

a) Z_0 = 35 Ω, place quarter-wave transformers on each side to match the line impedance to the port impedance
b) Z_0 = 50 Ω
c) Z_0 = 150 Ω, place quarter-wave transformers on each side to match the line impedance to the port impedance, for this case, plot |S11| on the Smith Chart

2. Repeat problem 1 for stripline transmission media.

Homework #3

$f = 10$ GHz

Design of transmission lines

Microstrip (a) $Z_0 = 35\,\Omega$

(b) $Z_0 = 50\,\Omega$

(c) $Z_0 = 150\,\Omega$

$\epsilon_r = 2.2$

$h = 381\,\mu m$

$35\,\Omega$ $\frac{W}{h} \approx 5 \Rightarrow W = 1.905$ mm

$50\,\Omega$ $\frac{W}{h} \approx 2.9 \Rightarrow W = 1.105$ mm

$150\,\Omega$ $\frac{W}{h} \approx 0.28 \Rightarrow W 0.107$ mm

$Z_{trans} = \sqrt{(35)(50)} = 41.83\,\Omega$ $\epsilon_{eff} = 1.8$

$Z_{trans} = \sqrt{(50)(150)} = 86.6\,\Omega$ $\epsilon_{eff} = 1.8$

μstrip

$41.83\,\Omega$; $\frac{W}{h} \approx 3.2 \Rightarrow W \approx 1.22$ mm

$86.6\,\Omega$; $\frac{W}{h} \approx 1.4 \Rightarrow W \approx 0.533$ mm

$\hookrightarrow \lambda/4 = \frac{c}{f\sqrt{\epsilon_{eff}}} = 0.559$ cm

Stripline (a) $Z_0 = 35\,\Omega$

(b) $Z_0 = 50\,\Omega$

(c) $Z_0 = 150\,\Omega$

$\epsilon_r = 2.2$

$h = 0.762$ mm

$\sqrt{\epsilon_r} Z_0 = 51.91$ $W/b \approx 1.6 \Rightarrow W = 1.22$ m

$\sqrt{\epsilon_r} Z_0 = 74.2$ $W/b \approx 0.9$; $W = 0.69$ m

$\sqrt{\epsilon_r} Z_0 = 222$ $\frac{W}{b} \approx 0.08$; $W \approx 0.061$ m

$\sqrt{\epsilon_r} Z_0 = 62.0$ $\overset{W/b}{\approx} 1.2 \Rightarrow W \approx 0.914$ m

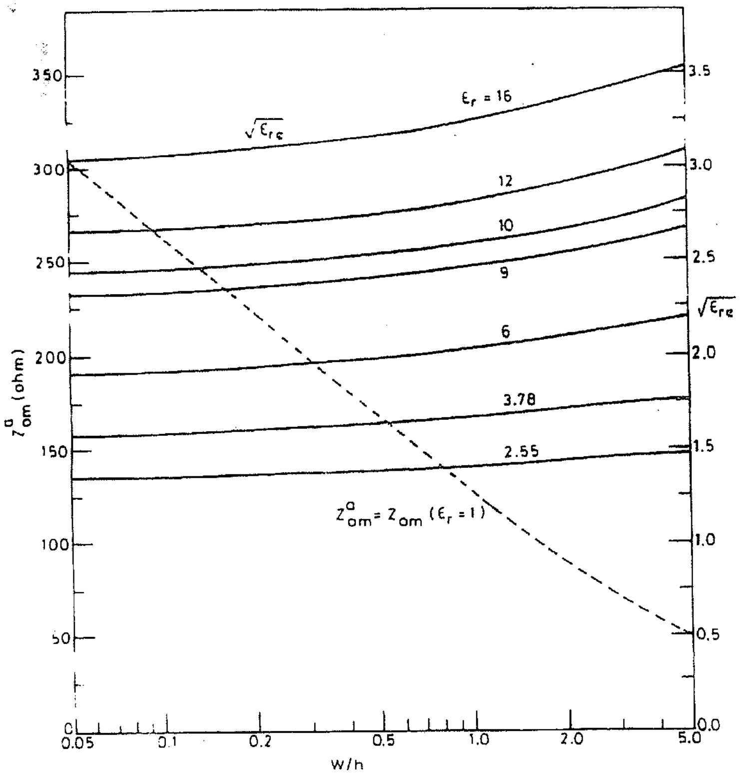
$\sqrt{\epsilon_r} Z_0 = 128$ $\approx W/b \approx 0.3 \Rightarrow W = 0.229$ m

---

$\lambda = \frac{c}{f\sqrt{\epsilon_r}} = \frac{3 \times 10^{10}\ \text{cm/s}}{10 \times 10^9 \sqrt{2.2}} = 2.02$ cm

$\lambda/4 = 0.5056$ cm

as Figure 2.8. Here ε_{re} is the same as ε_{eff} above.



Wheeler's formulas

[illegible] Impedance and Effective Dielectric Constant using Whe

In this figure the value of $\sqrt{\varepsilon_{re}}$ is plotted as a function of W/h for various values of the substrate dielectric constant ε_r. The variation of characteristic impedance for air microstrip (Z^a_{om} or $\varepsilon_r = 1$) is also shown by the dotted curve. The impedance for any value of ε_r can be obtained by dividing Z^a_{om} by the corresponding value of $\sqrt{\varepsilon_{re}}$. It may be seen from Figure 2.8 that the impedance value decreases when the strip width to substrate height ratio (W/h) is increased, since an increase in W (or decrease in h) increases the line capacitance.

Since the guided wavelength in the microstrip λ_g is related to ε_{re} by the expression

$$\lambda_g = \frac{\lambda_o}{\sqrt{\varepsilon_{re}}} \tag{2.30}$$

and ε_r values. The parameter range of w/h and ε_r is chosen such that it spans the domain of typically encountered, practical values.

From RF Ckt Design 2nd Ed
by Ludwig & Bogdanov

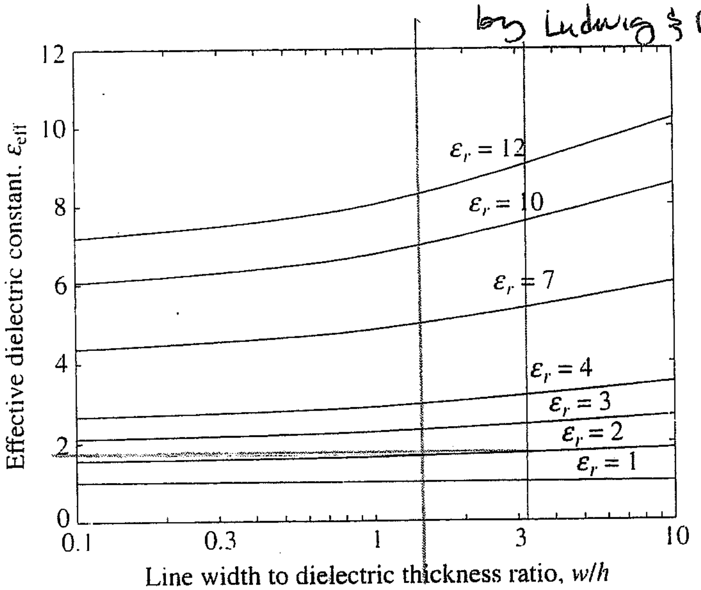
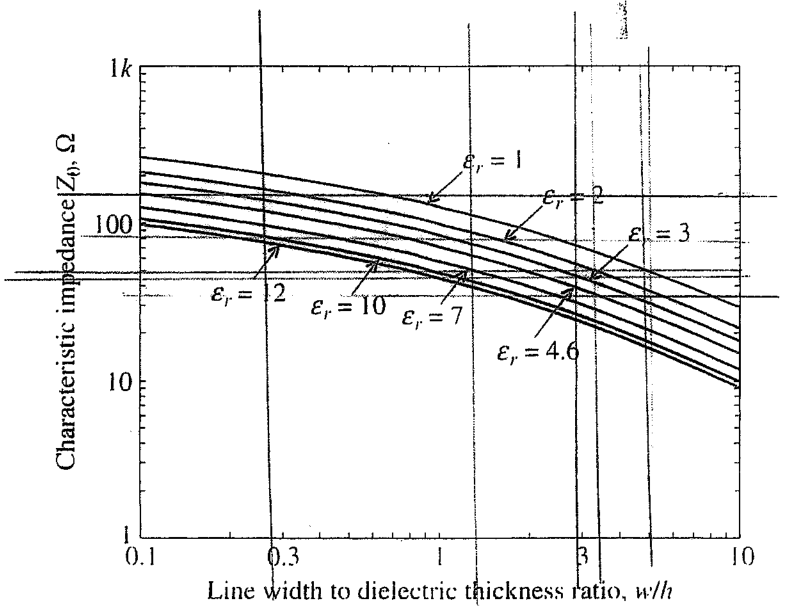


Figure 2-21 Effective dielectric constant of the microstrip line as a function of w/h for different dielectric constants.



igure 2-20 Microstrip characteristic impedance as a function of

If the strip width is wide enough so that the fringe fields do not interact, i.e.; w/b greater than or equal to 0.35, then another relation is applicable

$$Z_0 \sqrt{\epsilon} = \frac{94.15}{\left(\frac{w/b}{1 - t/b} + \frac{C'_f}{0.0885\,\epsilon_R}\right)} \tag{2-4}$$

where,

$$C'_f = \frac{0.0885\,\epsilon}{\pi}\left[\frac{2}{1 - t/b}\log_e\left(\frac{1}{(1 - t/b)} + 1\right) - \left(\frac{1}{1 - t/b} - 1\right)\log_e\left(\frac{1}{(1 - t/b)^2} - 1\right)\right] \text{Pf/cm} \tag{2-5}$$

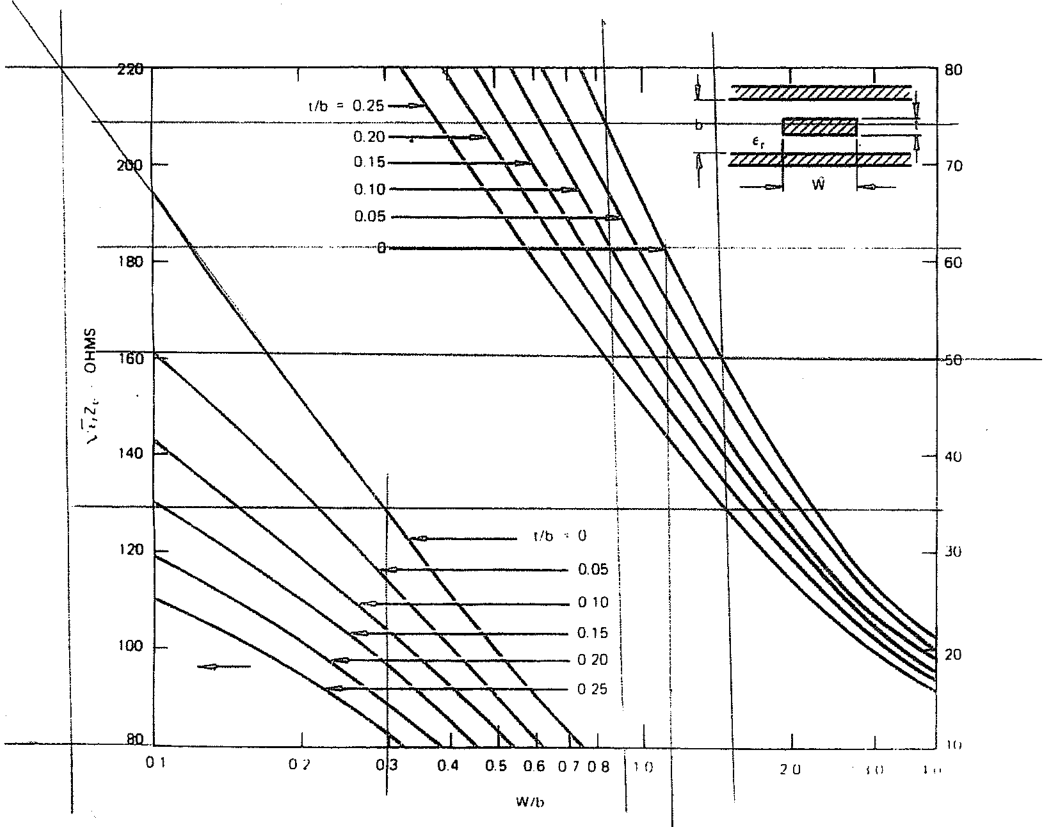


FIG. 2-3 General Curves for Characteristic Impedance of Dielectrically Loaded Stripline

-Stripline Ckt Design by Harlan Howe Jr. 1985

---

and

$$Z_{ocp} = \frac{1}{C\,v_{cp}} = \frac{30\pi}{\sqrt{\frac{\epsilon_r + 1}{2}}}\,\frac{K'(k)}{K(k)}\ \text{(ohm)} \tag{7.6}$$

where c is the velocity of electromagnetic waves in free space. Values of characteristic impedance Z_{ocp} computed from Equation (7.6) are shown in Figure 7.4. Measured values of Z_{ocp} for ϵ_r = 9.6, 16 and 130

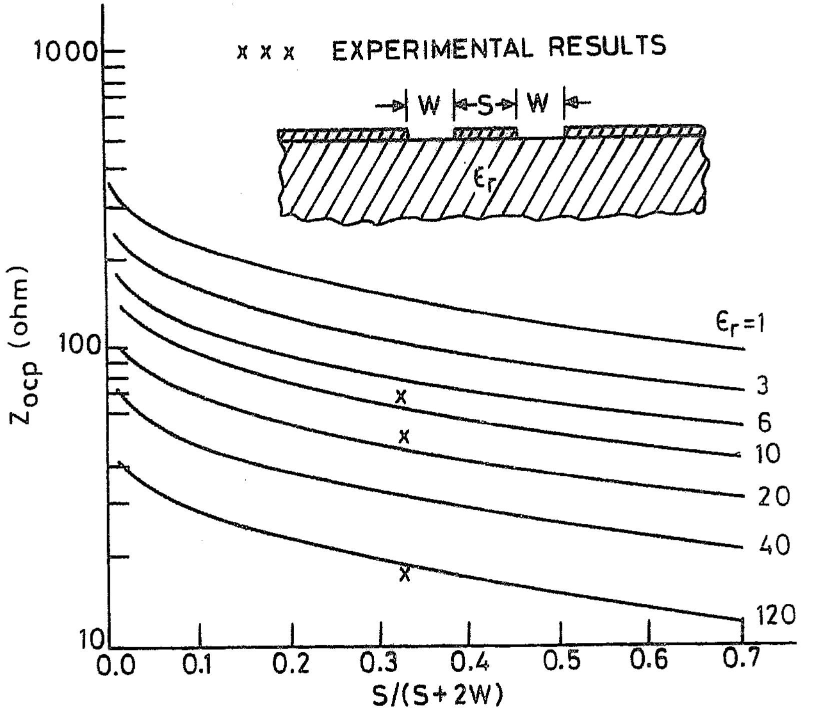


Figure 7.4 Characteristic Impedance of Coplanar Waveguides (from [1])

are also shown in this figure. Wen [1] points out that Z_{ocp} increases by less than 10 percent, for large values of ϵ_r, when the thickness of the substrate is reduced from infinite to W, the width of the slots (that is, when $W/h \to 1$).

Microstrip Lines & Slotlines KC Gupta