

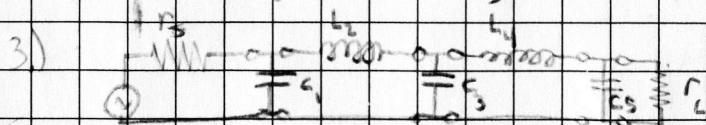
TITLE Lab C: Filters

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Low-Pass Filter (Butterworth)

$$1) N=5, f_c = 2.5 \text{ GHz}$$

$$2) g_1 = 0.6180, g_2 = 1.6180, g_3 = 2.000, g_4 = 1.6180, g_5 = 0.6180$$



$$4) \frac{-j}{wC} = -j \tan(\beta L), L = \frac{\lambda}{8} \rightarrow \frac{1}{wC_1} = Z_0 \rightarrow Z_0 = \frac{1}{0.61803} = 1.61804$$

$$Z_1 = 1.61803 = g_1$$

$$Z_2 = 0.5000$$

$$Z_3 = 1.61803$$

$$Z_4 = 1.61804$$

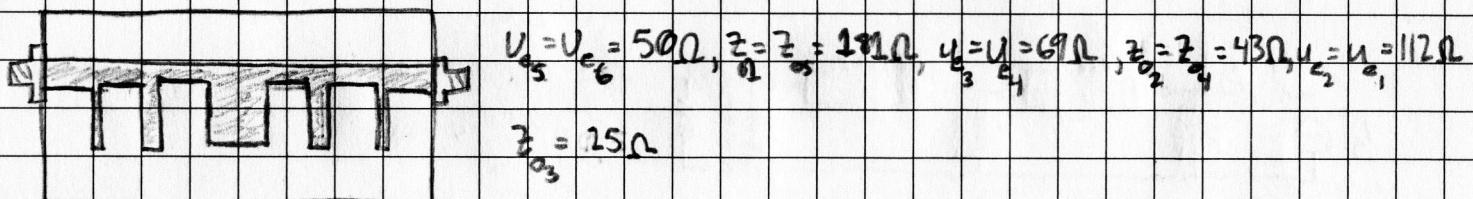
$$5) \text{Add } 6 \frac{\lambda}{8} \text{ unit elements. } N_1 = 1 + \frac{1}{1.61803} = 2.61804 = N_2 \rightarrow Z_1' = \frac{1}{2.61804} = 0.3827 \Omega, Z_2' = 0.3827 \Omega$$

$$N_3 = N_4 = 1 + \frac{1}{0.3827} = 3.61804 \rightarrow Z_3' = Z_4' = 3.613 \Omega, U_{e_1}' = \frac{1.61803}{2.61804} = 0.61803$$

$$N_5 = N_6 = 2 + \frac{1}{3.613} = 1.3897 \Omega$$

$$U_e_5 = U_e_6 = 1, U_{e_1} = U_{e_2} = 1.61803 (1.3897) = 2.23607 \Omega, U_{e_3} = U_{e_4} = \frac{1}{2.613} = 3.613 \Omega = 1.38461 \Omega$$

$$Z_1 = Z_5 = 3.61804, Z_2 = Z_4 = 2.23607 (1.38461) = 0.85416, Z_3 = 0.5000$$



$$6) 50\Omega \rightarrow w = 3.29847 \text{ mm} \quad l = \frac{\lambda}{8} = 8.0412 \text{ mm}$$

$$181\Omega \rightarrow w = 0.0859 \text{ mm} \quad E_{eff} = 3.179$$

$$69\Omega \rightarrow w = 2.7624 \text{ mm}$$

$$43\Omega \rightarrow w = 3.9643 \text{ mm}$$

$$12\Omega \rightarrow w = 0.54114 \text{ mm}$$

$$25\Omega \rightarrow w = 9.3974 \text{ mm}$$

$$(z = x\lambda) \rightarrow x = \frac{1}{2\pi} \tan^{-1} \left(\frac{Z_{0a}}{2Z_0} \right)$$

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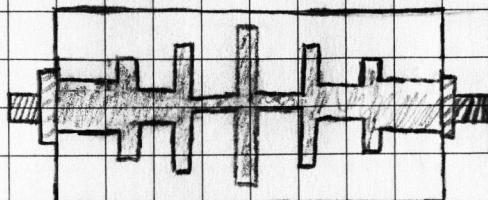
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Low-Pass Tapped-Stub Filter (Butterworth)

$$7) \frac{Z_1}{Z_2} = \frac{Z_1}{Z_3} = 181 \Omega \Rightarrow \frac{1}{2} Z_{oc}^B = \frac{89}{2} \cot(\beta L) \Rightarrow L = 0.0384\lambda = 2.783 \text{ mm}$$

$$\frac{Z_2}{Z_4} = \frac{Z_2}{Z_3} = 43 \Omega \Rightarrow L = \frac{1}{2\pi} t \tan\left(\frac{89}{86}\right) = 0.1277\lambda = 8.530 \text{ mm}$$

$$\frac{Z_3}{Z_5} = 25 \Omega \Rightarrow L = \frac{1}{2\pi} t \tan\left(\frac{89}{50}\right) = 0.1685\lambda = 10.841 \text{ mm}$$



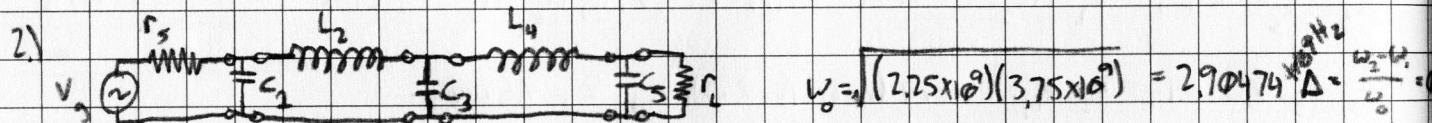
$$U_{e_1} = U_{e_2} \Rightarrow L = 8.892 \text{ mm}$$

$$U_{e_3} = U_{e_4} \Rightarrow L = 8.433 \text{ mm}$$

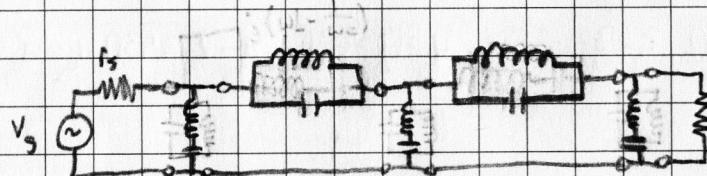
$$U_{e_5} = U_{e_6} \Rightarrow L = 8.440 \text{ mm}$$

Band-Stop Filter (Equal-Ripple)

$$1) \gamma_1 = 1.7058, \gamma_2 = 1.7296, \gamma_3 = 2.5407, \gamma_4 = 1.7296, \gamma_5 = 1.7058, \gamma_6 = 1$$



$$V_o = \sqrt{(2.25 \times 10^9)(3.75 \times 10^9)} = 290474 \text{ V} \quad \Delta = \frac{\omega_2 - \omega_1}{\omega_2}$$



$$\frac{Z_1}{n} = \frac{1.445}{\pi \Delta \omega_1}$$

$$Z_1 = 1.445 \Omega \rightarrow 1.48 \text{ mm}$$

$$\lambda/4 = 14.45 \text{ mm}$$

$$Z_2 = 2.005 \rightarrow 104 \Omega \rightarrow 0.67 \text{ mm}$$

$$Z_3 = 0.970 \rightarrow 50 \Omega \rightarrow 3.12 \text{ mm}$$

$$Z_4 = 2.005 \rightarrow 104 \Omega \rightarrow 0.67 \text{ mm}$$

$$Z_5 = 1.445 \rightarrow 75 \Omega \rightarrow 1.48 \text{ mm}$$

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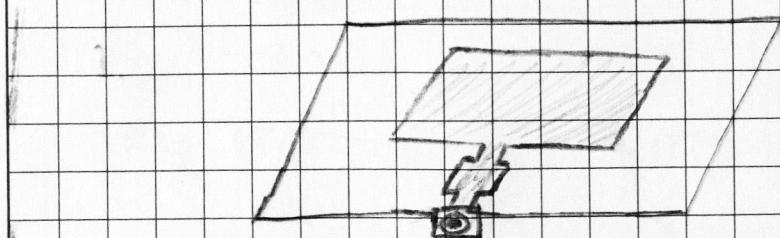
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$$f = 3 \text{ GHz}$$

$$\epsilon_r = 4.1$$

$$h = 62 \text{ mil}$$

$$Z_0 = 50 \Omega$$

$$1) W = \frac{c}{2f} \sqrt{\frac{2}{\epsilon_r + 1}} = 0.03131 \text{ m}$$

$$E_{eff} = \frac{\epsilon_r + 1}{2} \frac{\epsilon_r - 1}{2} \left[1 + \frac{h}{W} \right]^{-1/2} = 3.774$$

$$* \Delta L = 0.412h \frac{(\epsilon_{eff} + 0.3)(\frac{W}{h} + 0.264)}{(\epsilon_{eff} - 0.258)(\frac{W}{h} + 0.8)} = 0.000732 \text{ m}$$

$$L = \frac{c}{2fE_{eff}} - 2\Delta L = 0.024273 \text{ m}$$

3 GHz Patch Antenna with Quarter Wave Matching Network

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The Complete Smith Chart

$$\frac{\lambda}{4} = 13.6627$$

Black Magic Design

$$85 - j35 = 1.7 - j0.7$$

$$Z_L = \sqrt{24/(50)} = 34.641 \Omega$$

$$w = 5.4016 \text{ mm}$$

$$d = 12.29 \text{ mm}$$

$$L = 15.958 \text{ mm}$$

