8.7 Design a low-pass, maximally flat lumped-element filter having a passband of 0–2 GHz, and an attenuation of at least 20 dB at 3.4 GHz. The characteristic impedance is 50 Ω. Use CAD to plot the insertion loss versus frequency.

- Also, draw labeled sketch of design. CAD- Use MathCad, Matlab, … to plot insertion loss versus frequency. **Normalize passband to 0 dB.**

➢ Calculate $|\omega/\omega_c| - 1 = |3.4/2| - 1 = 0.7$. From Figure 8.26, we see that a LP filter of order ***N* = 5** is needed to meet the 20 dB attenuation specification.

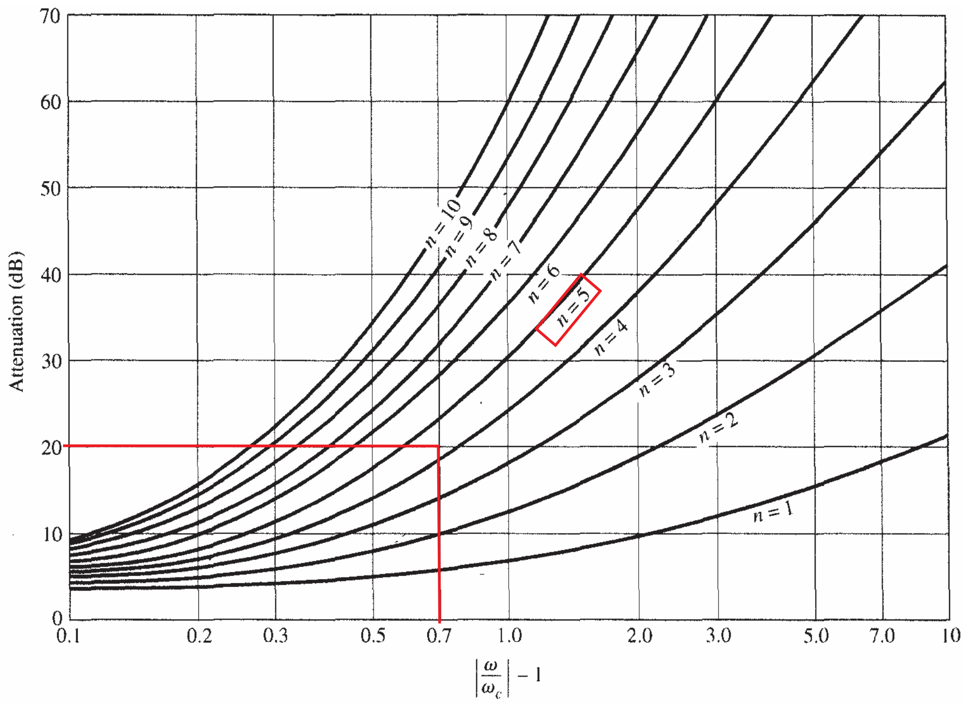


FIGURE 8.26 Attenuation versus normalized frequency for maximally flat filter prototypes.
Adapted from G. L. Matthaei, L. Young, and E. M. T. Jones, *Microwave Filters, Impedance-Matching Networks, and Coupling Structures*, Artech House, Dedham, Mass., 1980, with permission.

➢ From Table 8.3, we get the immittances: $g_1 = g_5 = 0.618$, $g_2 = g_4 = 1.618$, $g_3 = 2$, and $g_6 = 1$ (matched).

TABLE 8.3 **Element Values for Maximally Flat Low-Pass Filter Prototypes ($g_0 = 1$, $\omega_c = 1$, $N = 1$ to 10)**

N	g_1	g_2	g_3	g_4	g_5	g_6	g_7	g_8	g_9	g_{10}	g_{11}
1	2.0000	1.0000									
2	1.4142	1.4142	1.0000								
3	1.0000	2.0000	1.0000	1.0000							
4	0.7654	1.8478	1.8478	0.7654	1.0000						
5	0.6180	1.6180	2.0000	1.6180	0.6180	1.0000					
6	0.5176	1.4142	1.9318	1.9318	1.4142	0.5176	1.0000				
7	0.4450	1.2470	1.8019	2.0000	1.8019	1.2470	0.4450	1.0000			
8	0.3902	1.1111	1.6629	1.9615	1.9615	1.6629	1.1111	0.3902	1.0000		
9	0.3473	1.0000	1.5321	1.8794	2.0000	1.8794	1.5321	1.0000	0.3473	1.0000	
10	0.3129	0.9080	1.4142	1.7820	1.9754	1.9754	1.7820	1.4142	0.9080	0.3129	1.0000

Source: Reprinted from G. L. Matthaei, L. Young, and E. M. T. Jones, *Microwave Filters, Impedance-Matching Networks, and Coupling Structures*, Artech House, Dedham, Mass., 1980, with permission.

- For the filter architecture of Fig 8.25a, we get the necessary scaled shunt capacitances and series inductances using the immittances and equations (8.64d) (8.67a), and (8.67b):

$$g_1 = g_5 = 0.618 \;\Rightarrow\; C_1' = C_5' = \frac{C_k}{R_0\,\omega_c} = \frac{g_1}{R_0\,\omega_c} = \frac{0.618}{50(2\pi)2\times10^9} \;\Rightarrow\; \underline{C_1' = C_5' = 0.9836\text{ pF}}$$

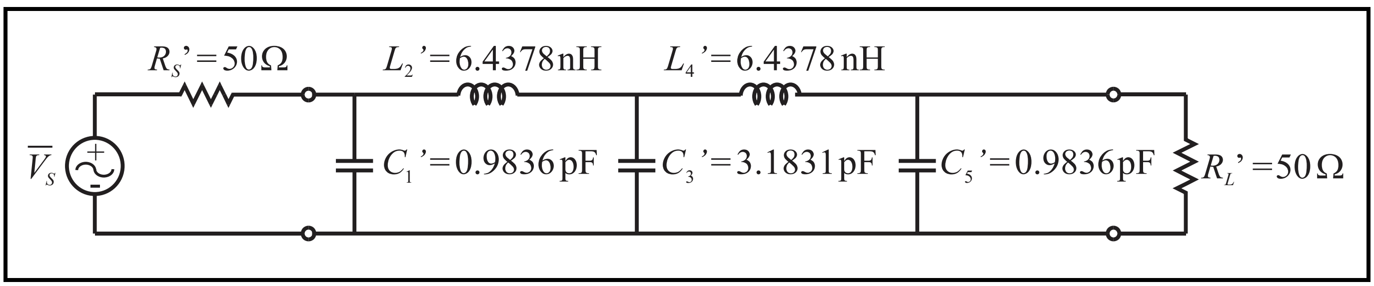
$$g_2 = g_4 = 1.618 \;\Rightarrow\; L_2' = L_4' = \frac{R_0\,L_k}{\omega_c} = \frac{R_0\,g_2}{\omega_c} = \frac{50(1.618)}{(2\pi)2\times10^9} \;\Rightarrow\; \underline{L_2' = L_4' = 6.4378\text{ nH}}$$

$$g_3 = 2 \;\Rightarrow\; C_3' = \frac{C_3}{R_0\,\omega_c} = \frac{g_3}{R_0\,\omega_c} = \frac{2}{50(2\pi)2\times10^9} \;\Rightarrow\; \underline{C_3' = 3.1831\text{ pF}},$$

and, per (8.64d), $g_6 = 1 \;\Rightarrow\; R_L' = R_0\,R_L = R_0\,g_6 = 50(1) \;\Rightarrow\; \underline{R_L' = 50\ \Omega}$.

- Further, the source resistance per (8.64c) is: $R_S' = R_0 \;\Rightarrow\; \underline{R_S' = 50\ \Omega}$.

- The resulting LP filter circuit is:



- MathCad was used to calculate the filter response as shown on the following page.

- Note that the insertion loss is less than -20 dB at 3.4 GHz (blue diamond).

Define constants

VS := 1 V   RS := 50 Ω   RL := 50 Ω $fc := 2\cdot10^9$ Hz

$C1 := 0.9836\cdot10^{-12}$ F   C5 := C1 $L2 := 6.4378\cdot10^{-9}$ H   L4 := L2

$C3 := 3.1831\cdot10^{-12}$ F

Parallel impedance of RL & C5 $Z1(f) := \left(\frac{1}{RL} + j\cdot2\cdot\pi\cdot f\,C5\right)^{-1}$

Series impedance of L4 & Z1 $Z2(f) := j\cdot2\cdot\pi\cdot f\cdot L4 + Z1(f)$

Parallel impedance of Z2 & C3 $Z3(f) := \left(\frac{1}{Z2(f)} + j\cdot2\cdot\pi\cdot f\,C3\right)^{-1}$

Series impedance of L2 & Z3 $$Z4(f) := j \cdot 2 \cdot \pi \cdot f \cdot L2 + Z3(f)$$

Input impedance of LP filter w/ load $$Zin(f) := \left(\frac{1}{Z4(f)} + j \cdot 2 \cdot \pi \cdot f \cdot C1 \right)^{-1}$$

Voltage division to get Vld $$Vld(f) := VS \cdot \frac{Zin(f)}{RS + Zin(f)} \cdot \frac{Z3(f)}{Z4(f)} \cdot \frac{Z1(f)}{Z2(f)}$$

$n := 0..4000$ $f_n := n \cdot 10^6$ $VL_n := Vld(f_n)$ $VLdeg_n := \arg(VL_n) \cdot \frac{180}{\pi}$

$VLdB_n := 20 \cdot \log(|VL_n|)$ $IL_n := VLdB_n - 10 \cdot \log(0.25)$