8.9 Design a four-section bandpass lumped-element filter having a maximally flat group delay response. The bandwidth should be 5% with a center frequency of 2 GHz. The impedance is 50 Ω. Use CAD to plot the insertion loss versus frequency.

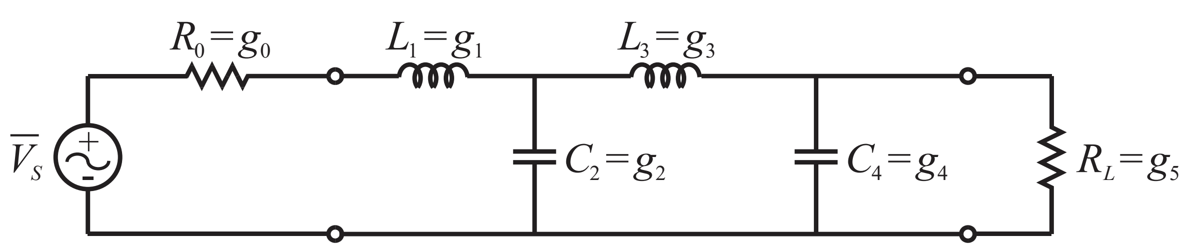
- Also, draw labeled sketch of design. CAD part is not required.

➢ Using N = 4 & Table 8.5, the immittances are: <u>**$g_0 = 1$**</u>, <u>**$g_1 = 1.0598$**</u>, <u>**$g_2 = 0.5116$**</u>, <u>**$g_3 = 0.3181$**</u>, <u>**$g_4 = 0.1104$**</u>, and <u>**$g_5 = 1.0000$**</u> (matched) for the Fig 8.25b low-pass prototype.

TABLE 8.5 Element Values for Maximally Flat Time Delay 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	1.5774	0.4226	1.0000								
3	1.2550	0.5528	0.1922	1.0000							
4	1.0598	0.5116	0.3181	0.1104	1.0000						
5	0.9303	0.4577	0.3312	0.2090	0.0718	1.0000					
6	0.8377	0.4116	0.3158	0.2364	0.1480	0.0505	1.0000				
7	0.7677	0.3744	0.2944	0.2378	0.1778	0.1104	0.0375	1.0000			
8	0.7125	0.3446	0.2735	0.2297	0.1867	0.1387	0.0855	0.0289	1.0000		
9	0.6678	0.3203	0.2547	0.2184	0.1859	0.1506	0.1111	0.0682	0.0230	1.0000	
10	0.6305	0.3002	0.2384	0.2066	0.1808	0.1539	0.1240	0.0911	0.0557	0.0187	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.



➢ Per Table 8.6 and using (8.64a) & (8.64b) for impedance scaling, each series inductor in the prototype becomes a series L & C:

$L_1 = g_1 = 1.0598$ becomes:
$$L_1' = \frac{g_1 R_0}{\omega_0 \Delta} = \frac{1.0598(50)}{(2\pi)2\times10^9(0.05)} \Rightarrow \underline{L_1' = 84.336 \text{ nH}}$$

and
$$C_1' = \frac{\Delta}{\omega_0 g_1 R_0} = \frac{0.05}{(2\pi)2\times10^9(1.0598)50} \Rightarrow \underline{C_1' = 0.07509 \text{ pF}}$$

$L_3 = g_3 = 0.3181$ becomes:
$$L_3' = \frac{g_3 R_0}{\omega_0 \Delta} = \frac{0.3181(50)}{(2\pi)2\times10^9(0.05)} \Rightarrow \underline{L_3' = 25.314 \text{ nH}}$$

and
$$C_3' = \frac{\Delta}{\omega_0 g_3 R_0} = \frac{0.05}{(2\pi)2\times10^9(0.3181)50} \Rightarrow \underline{C_3' = 0.2502 \text{ pF}}$$

- Per Table 8.6 and using (8.64a) & (8.64b) for impedance scaling, each shunt capacitor in the prototype becomes a shunt L & C:

$C_2 = g_2 = 0.5116$ becomes: $$L_2' = \frac{\Delta R_0}{\omega_0 g_2} = \frac{0.05(50)}{(2\pi)2\times10^9(0.5116)} \Rightarrow \underline{L_2' = 0.3889 \text{ nH}}$$

$$\text{and } C_2' = \frac{g_2}{\omega_0 \Delta R_0} = \frac{0.5116}{(2\pi)2\times10^9(0.05)50} \Rightarrow \underline{C_2' = 16.2847 \text{ pF}}$$

$C_4 = g_4 = 0.1104$ becomes: $$L_4' = \frac{\Delta R_0}{\omega_0 g_4} = \frac{0.05(50)}{(2\pi)2\times10^9(0.1104)} \Rightarrow \underline{L_4' = 1.8020 \text{ nH}}$$

$$\text{and } C_4' = \frac{g_4}{\omega_0 \Delta R_0} = \frac{0.1104}{(2\pi)2\times10^9(0.05)50} \Rightarrow \underline{C_4' = 3.5141 \text{ pF}}$$

- Per (8.64c), the source resistance $R_S = g_0$ becomes: $R_S' = R_0\, g_0 = (50)1 \Rightarrow \underline{R_S' = 50\ \Omega}$.

- Per (8.64d), the load resistance $R_L = g_5$ becomes: $R_L' = R_0\, g_5 = 50(1) \Rightarrow \underline{R_L' = 50\ \Omega}$.

The resulting 4 section **bandpass** filter circuit is: