Filtri
a
microonde

Esempio 1 (1/3)

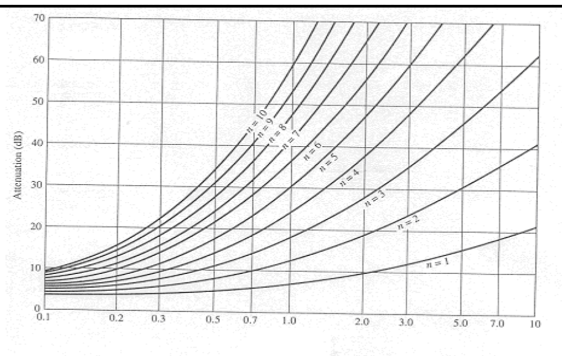
Si progetti un **filtro passa basso massimamente piatto** con:

- f_C = 2 GHz A_{cdb} = 3 dB
- $A|_{f\,=\,3\,GHz} \geq 15$ dB

➢ Tipo di filtro: Butterworth

➢ A_{CdB} = 3 dB   (K = 1)
($\omega' = 3 / 2 = 1.5 \Rightarrow \omega' - 1 = 0.5 \rightarrow A_{dB} > 15$ dB) N = 5

➢ g_0 = 1.0000
g_1 = 0.6180
g_2 = 1.6180
g_3 = 2.0000
g_4 = 1.6180
g_5 = 0.6180
g_6 = 1.0000



ω' - 1

Butterworth
3 dB

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	1.000			
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

Esempio 1 (2/3)

- Scegliamo circuito che inizia con C parallelo

$$R'_0 = g_0\ R_0 = 1.0000 \times 50 = 50\ \Omega$$

$$C''_1 = \frac{g_1}{R_0\ 2\pi\ f_C} = \frac{0.6180}{50 \times 2\ \pi \times 2 \cdot 10^9} = 0.984\ \text{pF}$$

$$L''_2 = \frac{R_0\ g_2}{2\pi\ f_C} = \frac{50 \times 1.6180}{2\ \pi \times 2 \cdot 10^9} = 6.438\ \text{nH}$$

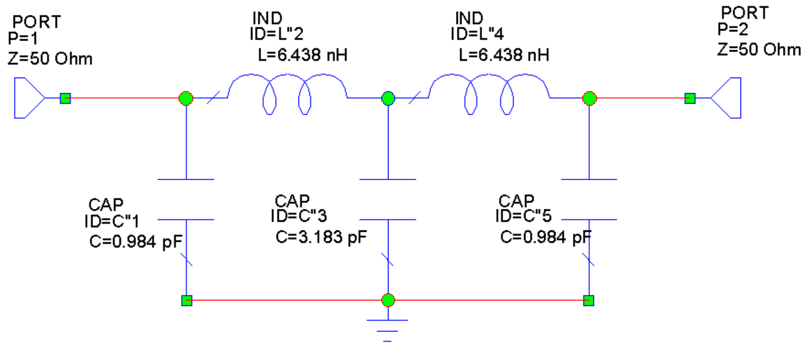
$$C''_3 = \frac{g_3}{R_0\ 2\pi\ f_C} = \frac{2.0000}{50 \times 2\ \pi \times 2 \cdot 10^9} = 3.183\ \text{pF}$$

$$L''_4 = \frac{R_0\ g_4}{2\pi\ f_C} = \frac{50 \times 1.6180}{2\ \pi \times 2 \cdot 10^9} = 6.438\ \text{nH}$$

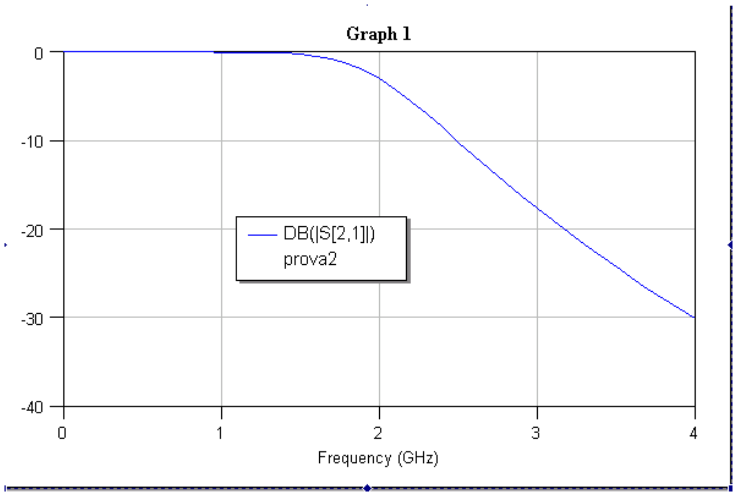
$$C''_5 = \frac{g_5}{R_0\ 2\pi\ f_C} = \frac{0.6180}{50 \times 2\ \pi \times 2 \cdot 10^9} = 0.984\ \text{pF}$$

$$R'_6 = g_6\ R_0 = 1.0000 \times 50 = 50\ \Omega$$

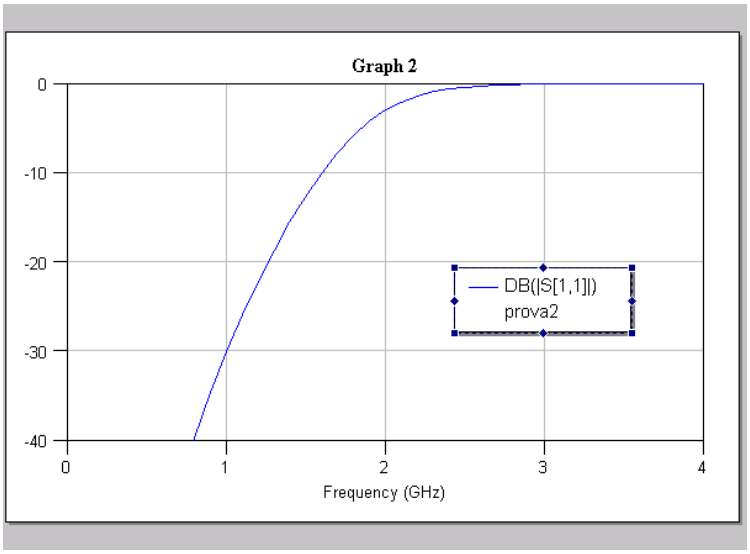
Esempio 1 (3/3)



Risultati



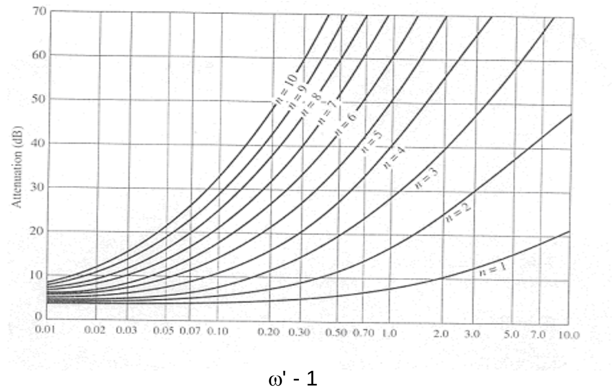
Risultati



Esempio 2 (1/3)

Confrontare la risposta del filtro precedente con quella di un filtro a **ripple costante (3.0 dB)** di **pari ordine** e con la **stessa frequenza di taglio**

- Tipo di filtro: Chebyshev
- Ripple = 3.0 dB (K = 1) N = 5
- g_0 = 1.0000
  g_1 = 3.4817
  g_2 = 0.7618
  g_3 = 4.5381
  g_4 = 0.7618
  g_5 = 3.4817
  g_6 = 1.0000



Chebyshev
3 dB

N	g_1	g_2	g_3	g_4	g_5	g_6	g_7	g_8	g_9	g_{10}	g_{11}
1	1.9953	1.0000									
2	3.1013	0.5339	5.8095								
3	3.3487	0.7117	3.3487	1.0000							
4	3.4389	0.7483	4.3471	0.5920	5.8095						
5	3.4817	0.7618	4.5381	0.7618	3.4817	1.0000					
6	3.5045	0.7685	4.6061	0.7929	4.4641	0.6033	5.8095				
7	3.5182	0.7723	4.6386	0.8039	4.6386	0.7723	3.5182	1.0000			
8	3.5277	0.7745	4.6575	0.8089	4.6990	0.8018	4.4990	0.6073	5.8095		
9	3.5340	0.7760	4.6692	0.8118	4.7272	0.8118	4.6692	0.7760	3.5340	1.0000	
10	3.5384	0.7771	4.6768	0.8136	4.7425	0.8164	4.7260	0.8051	4.5142	0.6091	5.8095

Esempio 2 (2/3)

- Scegliamo circuito che inizia con C parallelo

$$R'_0 = g_0\, R_0 = 1.0000 \times 50 = 50\ \Omega$$

$$C''_1 = \frac{g_1}{R_0\ 2\pi\ f_C} = \frac{3.4817}{50 \times 2\ \pi \times 2 \cdot 10^9} = 5.541\,\mathrm{pF}$$

$$L''_2 = \frac{R_0\ g_2}{2\pi\ f_C} = \frac{50 \times 0.7618}{2\ \pi \times 2 \cdot 10^9} = 3.031\,\mathrm{nH}$$

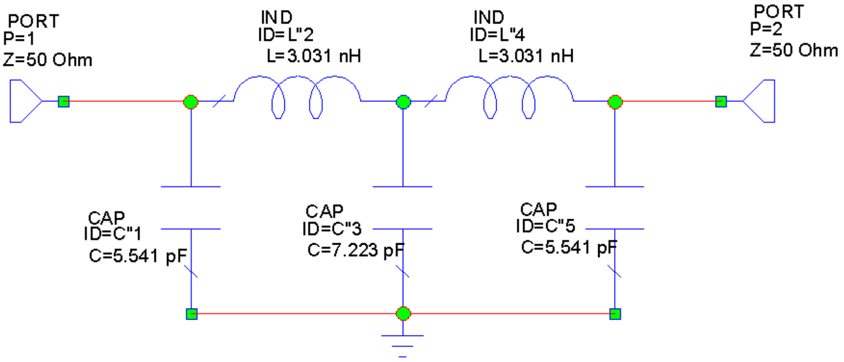
$$C''_3 = \frac{g_3}{R_0\ 2\pi\ f_C} = \frac{4.5381}{50 \times 2\ \pi \times 2 \cdot 10^9} = 7.223\ \mathrm{pF}$$

$$L''_4 = \frac{R_0\ g_4}{2\pi\ f_C} = \frac{50 \times 0.7618}{2\ \pi \times 2 \cdot 10^9} = 3.031\,\mathrm{nH}$$

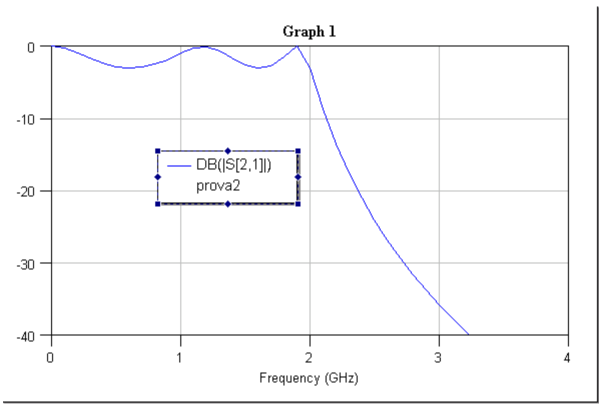
$$C''_5 = \frac{g_5}{R_0\ 2\pi\ f_C} = \frac{3.4817}{50 \times 2\ \pi \times 2 \cdot 10^9} = 5.541\,\mathrm{pF}$$

$$R'_6 = g_6\, R_0 = 1.0000 \times 50 = 50\ \Omega$$

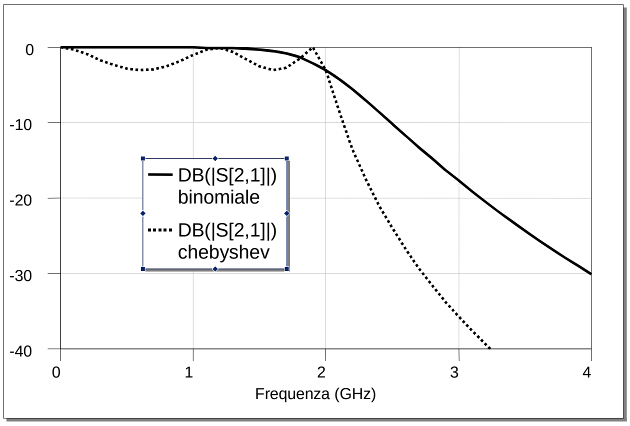
Esempio 2 (3/3)



Risultati



Confronto tra i due filtri



Esempio 3 (1/3)

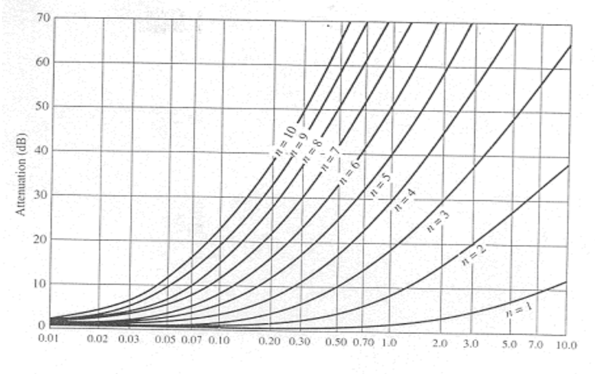
Si progetti un filtro passa banda che abbia:

- una risposta a ripple costante di 0.5 dB
- Tipo di filtro: Chebyshev
- Δ = 100 MHz f_1=950 MHz - f_2=1050 MHz
- F_0 = 0,9987 ~ 1 GHz
- A=15 dB per f=1.1 GHz -> f' = 2 -> **N=3**

➢ g_0 = 1.0000
g_1 = 1.5963
g_2 = 1.0967
g_3 = 1.5963
g_4 = 1.0000

$$\omega' = \frac{\omega_0}{\omega_2 - \omega_1}\left(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}\right) = \frac{1}{\Delta}\left(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}\right)$$

$$\text{con:} \quad \omega_0 = \sqrt{\omega_1\,\omega_2} \quad \text{(centro banda)}$$



Chebyshev
0.5 dB

ω' - 1

N	g_1	g_2	g_3	g_4	g_5	g_6	g_7	g_8	g_9	g_{10}	g_{11}
1	0.6986	1.0000									
2	1.4029	1.7071	1.9841								
3	1.5963	1.0967	1.5963	1.0000							
4	1.6703	1.1926	2.3661	0.8419	1.9841						
5	1.7058	1.2296	2.5408	1.2296	1.7058	1.0000					
6	1.7254	1.2479	2.6064	1.3137	2.4758	0.5696	1.9841				
7	1.7372	1.2583	2.6381	1.3444	2.6381	1.2583	1.7372	1.0000			
8	1.7451	1.2647	2.6564	1.3590	2.6964	1.3389	2.5093	0.8796	1.9841		
9	1.7504	1.2690	2.6678	1.3673	2.7329	1.3673	2.6678	1.2690	1.7504	1.0000	
10	1.7543	1.2721	2.6754	1.3725	2.7392	1.3806	2.7231	1.3485	2.5329	0.8842	1.9841

Esempio 3 (2/3)

- Scegliamo circuito che inizia con L serie

$$G'_0 = g_0 / R_0 = G'_4 = g_4 / R_0 = 1.0000/50\ \mathrm{S} \Rightarrow R'_0 = R'_4 = 50\ \Omega$$

$$L''_1 = \frac{R_0\, g_1}{\omega_2 - \omega_1} = \frac{R_0\, g_1}{\Delta\, \omega_0} = \frac{50 \times 1.5963}{0.1 \times 2\,\pi \times 1 \cdot 10^9} = 127.0\ \mathrm{nH}$$

$$C''_1 = \frac{\omega_2 - \omega_1}{\omega_0^2\, R_0\, g_1} = \frac{\Delta}{\omega_0\, R_0\, g_1} = \frac{0.1}{2\,\pi \times 1 \cdot 10^9 \times 50 \times 1.5963} = 0.199\ \mathrm{pF}$$

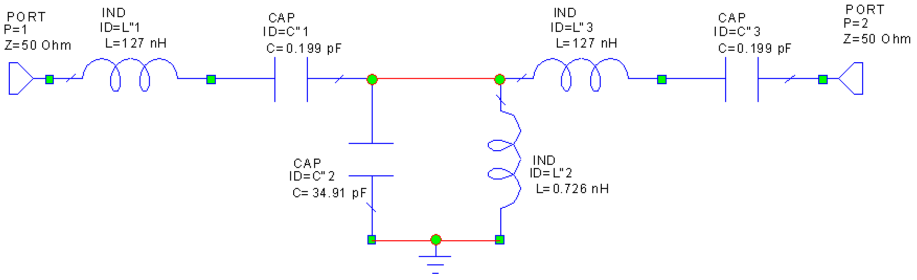
$$L''_2 = \frac{R_0 (\omega_2 - \omega_1)}{\omega_0^2\, g_2} = \frac{R_0\, \Delta}{\omega_0\, g_2} = \frac{50 \times 0.1}{2\,\pi \times 1 \cdot 10^9 \times 1.0967} = 0.726\ \mathrm{nH}$$

$$C''_2 = \frac{g_2}{R_0 (\omega_2 - \omega_1)} = \frac{g_2}{R_0\, \Delta\, \omega_0} = \frac{1.0967}{50 \times 0.1 \times 2\,\pi \times 1 \cdot 10^9} = 34.91\,\mathrm{pF}$$

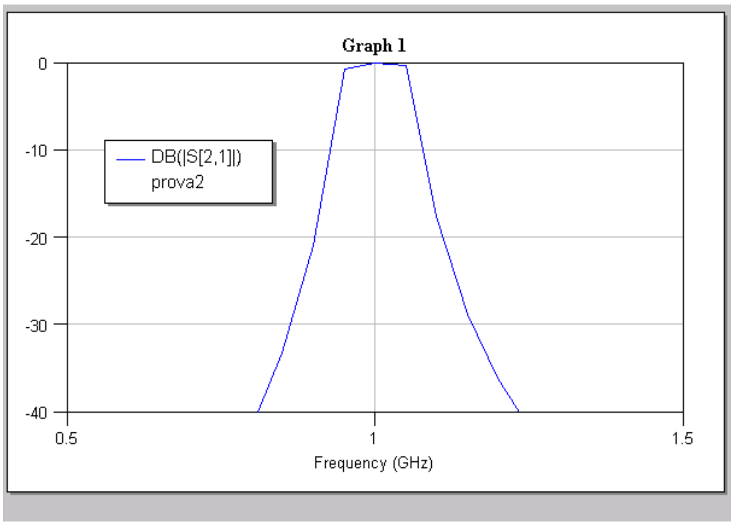
$$L''_3 = \frac{R_0\, g_3}{\omega_2 - \omega_1} = \frac{R_0\, g_3}{\Delta\, \omega_0} = \frac{50 \times 1.5963}{0.1 \times 2\,\pi \times 1 \cdot 10^9} = 127.0\ \mathrm{nH}$$

$$C''_3 = \frac{\omega_2 - \omega_1}{\omega_0^2\, R_0\, g_3} = \frac{\Delta}{\omega_0\, R_0\, g_3} = \frac{0.1}{2\,\pi \times 1 \cdot 10^9 \times 50 \times 1.5963} = 0.199\ \mathrm{pF}$$

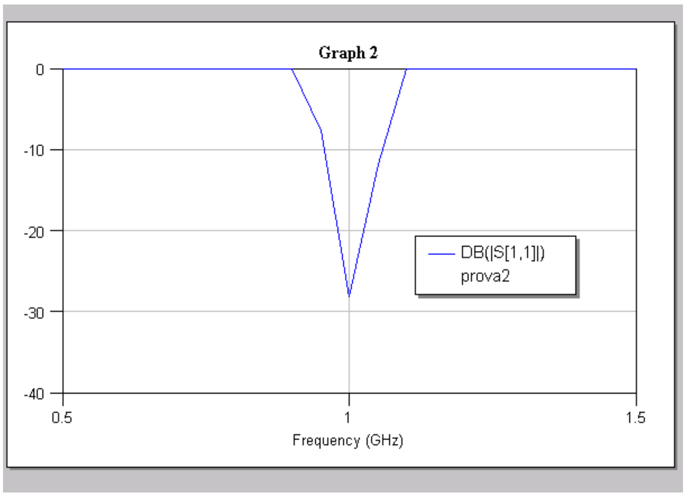
Esempio 3 (3/3)



Risultati



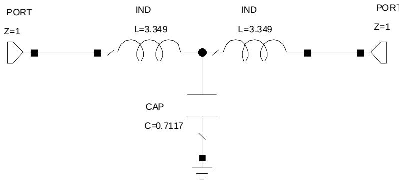
Risultati



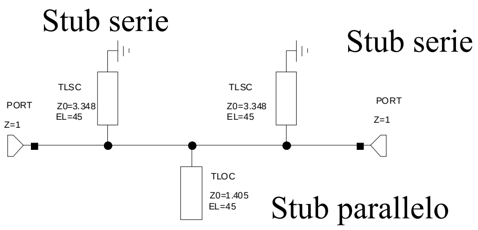
filtri su microstriscia specifiche di progetto

- filtro passa basso
- frequenza di taglio 4 GHz
- Chebyshev 3 dB
- N=3

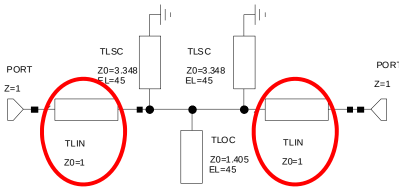
PBPR



Trasformazioni
di Richard



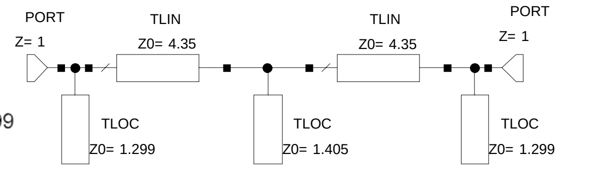
Aggiungo due
tratti di linea

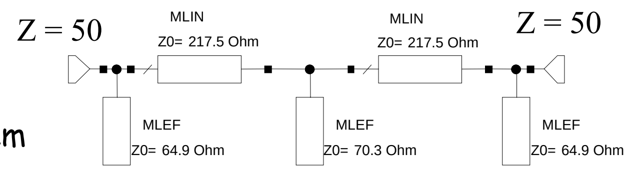


Circuito

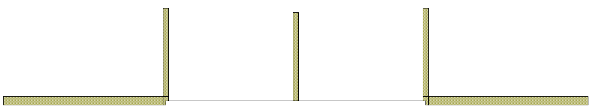
Identità di Kuroda

$$n^2 = 1 + \frac{Z_2}{Z_1} = 1 + \frac{1}{3.3487} = 1.299$$

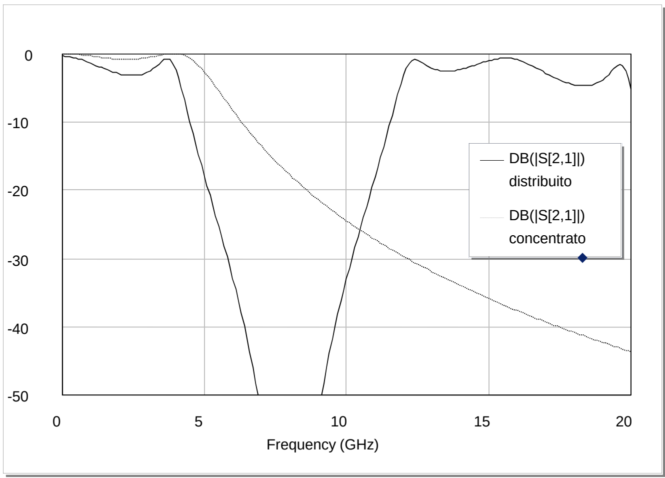




R04003 da 254µm



Risultati



Filtro a Step

Si supponga di voler progettare un filtro a step passa basso cha abbia una risposta massimamente piatta ed una frequenza di taglio di 5.5 GHz e che abbia più di 10dB di attenuazione a 7 GHz. Si supponga inoltre che la più alta impedenza di linea praticamente disponibile (Z_H) sia 75 Ω, e la più bassa (Z_L) 15 Ω.

A 7 GHz si ha:

$$\frac{\omega}{\omega_C} - 1 = \frac{7.0}{5.5} - 1 = 0.273$$

quindi la Fig. 6.10 ci dice che N = 5 fornisce l'attenuazione necessaria a 7 GHz.

Dalla Tabella di Fig. 6.11 si ricavano i valori degli elementi del prototipo:

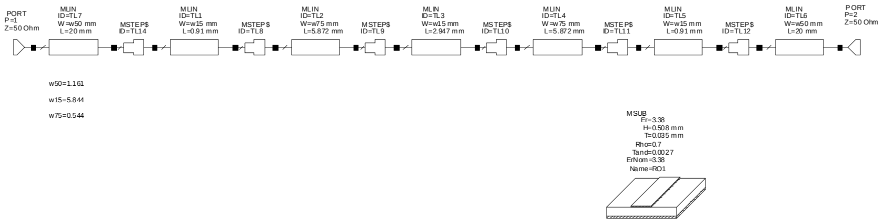
$g_1 = 0.618$, $g_2 = 1.618$, $g_3 = 2$, $g_4 = 1.618$, $g_5 = 0.618$

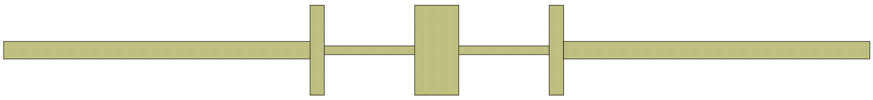
Successivamente, si usano le (6.73) e (6.74) per trovare le lunghezze elettriche delle sezioni delle linee di trasmissione ad alta e bassa impedenza per sostituire le induttanze in serie e le capacità in parallelo; si ha:

$$\beta l_1 = \frac{g_1 R_0}{Z_H} = 10.62° \qquad \beta l_2 = \frac{g_2 Z_L}{R_0} = 61.80° \qquad \beta l_3 = \frac{g_3 R_0}{Z_H} = 34.38°$$

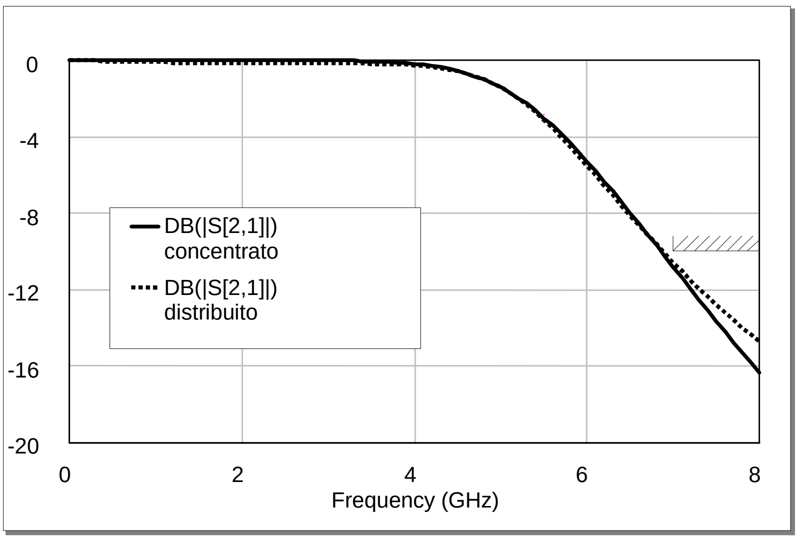
$$\beta l_4 = \frac{g_4 Z_L}{R_0} = 61.80° \qquad \beta l_5 = \frac{g_5 R_0}{Z_H} = 10.62°$$

Filtro a Step





Risultati



Filtri passa banda