FILTRE DE MICROUNDE

Proiectarea filtrelor prin metoda pierderilor de inserție

$$P_{LR} = \frac{Puterea\ disponibila\ de\ la\ sursa}{Puterea\ livrata\ sarcinii} = \frac{P_{inc}}{P_L} = \frac{1}{1 - \left|\Gamma(\omega)\right|^2}$$

$$IL = 10 \log P_{LR}$$

$$\left|\Gamma(\omega)\right|^2 = \frac{M\left(\omega^2\right)}{M\left(\omega^2\right) + N\left(\omega^2\right)}$$

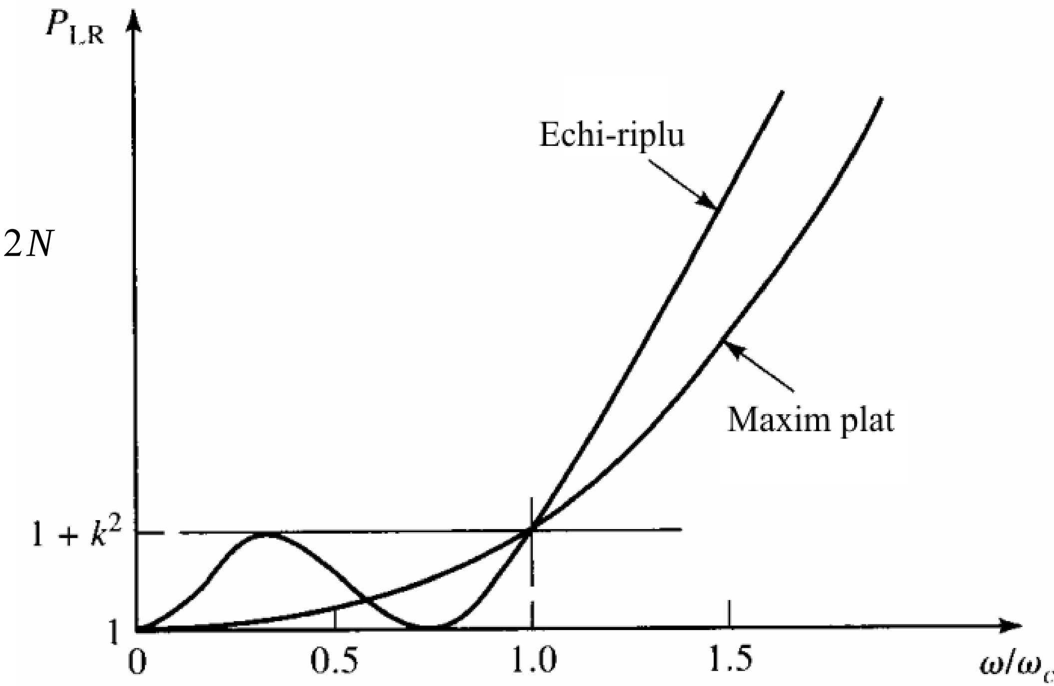
$$P_{LR} = 1 + \frac{M\left(\omega^2\right)}{N\left(\omega^2\right)}$$

Tipuri de raspunsuri

Maxim Plat

$$P_{LR} = 1 + k^2 \left(\frac{\omega}{\omega_c} \right)^{2N}$$

$$P_{LR} \approx k^2 (\omega/\omega_c)^{2N}$$

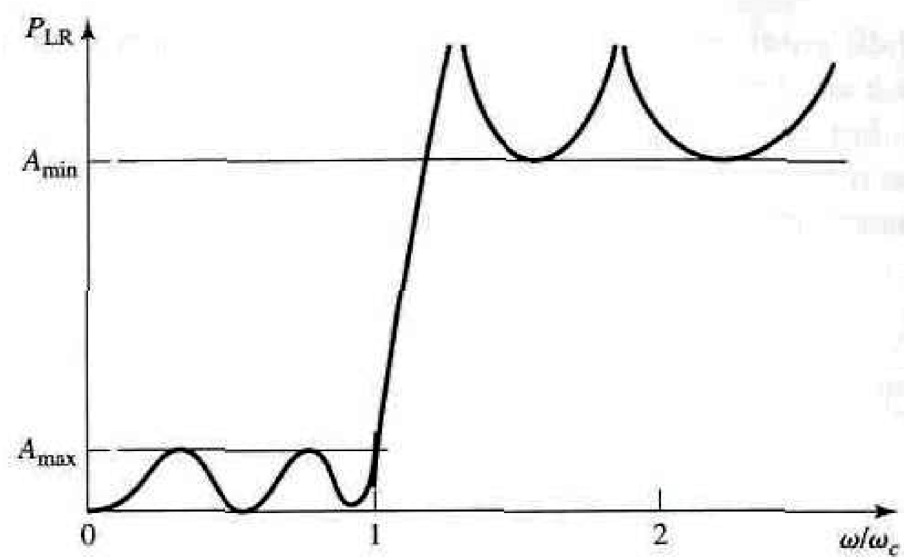


Echi-Riplu

$$P_{LR} = 1 + k^2 T_N^2 \left(\frac{\omega}{\omega_c} \right)$$

$$P_{LR} \approx \frac{k^2}{4} \left(\frac{2\omega}{\omega_c} \right)^{2N}$$

Tipuri de raspunsuri



Eliptic

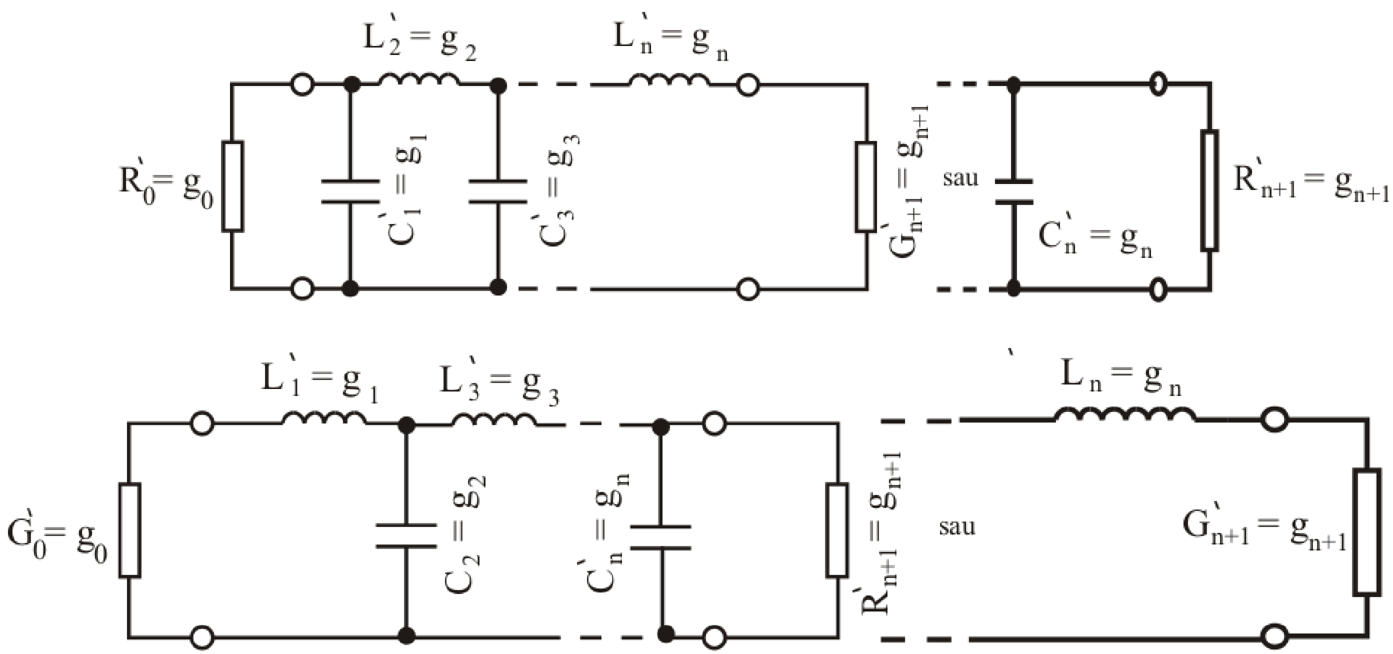
Filtru cu raspuns liniar in faza

$$\phi(\omega) = A\omega\left[1 + p\left(\frac{\omega}{\omega_c}\right)^{2N}\right]$$

$$\tau_d = \frac{d\phi}{d\omega} = A\left[1 + p(2N+1)\left(\frac{\omega}{\omega_c}\right)^{2N}\right]$$

intirzierea de grup

Filtre prototip

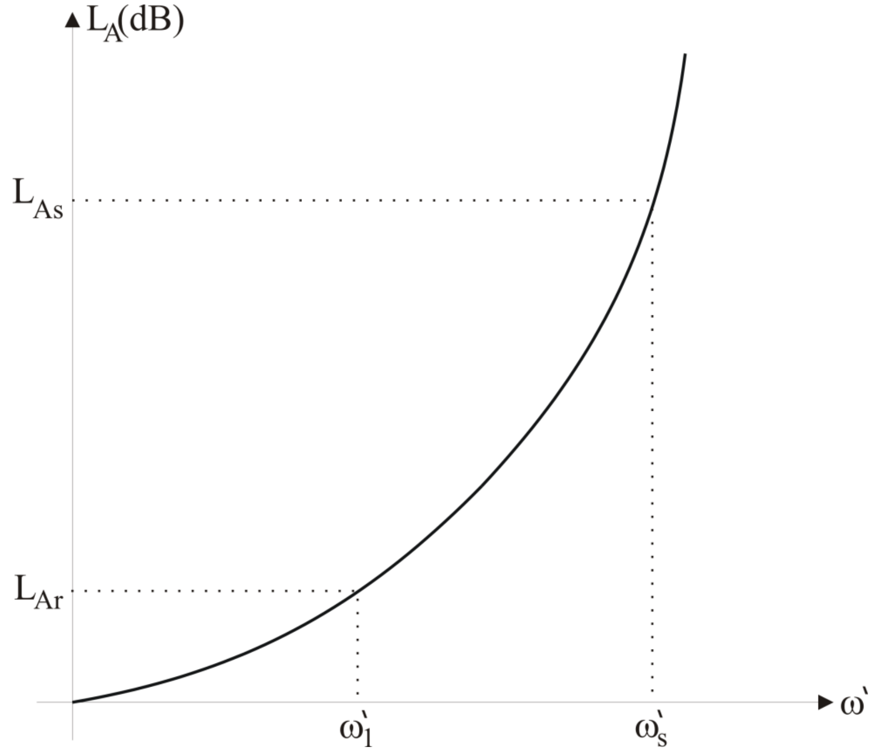


$$g_0 = \begin{cases} rezistenta\ generatorului\ R'_0\ daca\ g_1 = C'_1 \\ conductanta\ generatorului\ G'_0\ daca\ g_1 = L'_1 \end{cases}$$

$$g_{n+1} = \begin{cases} rezistenta\ de\ sarcina\ R'_{n+1}\ daca\ g_n = C'_n \\ conductanta\ de\ sarcina\ G'_{n+1}\ daca\ g_n = L'_n \end{cases}$$

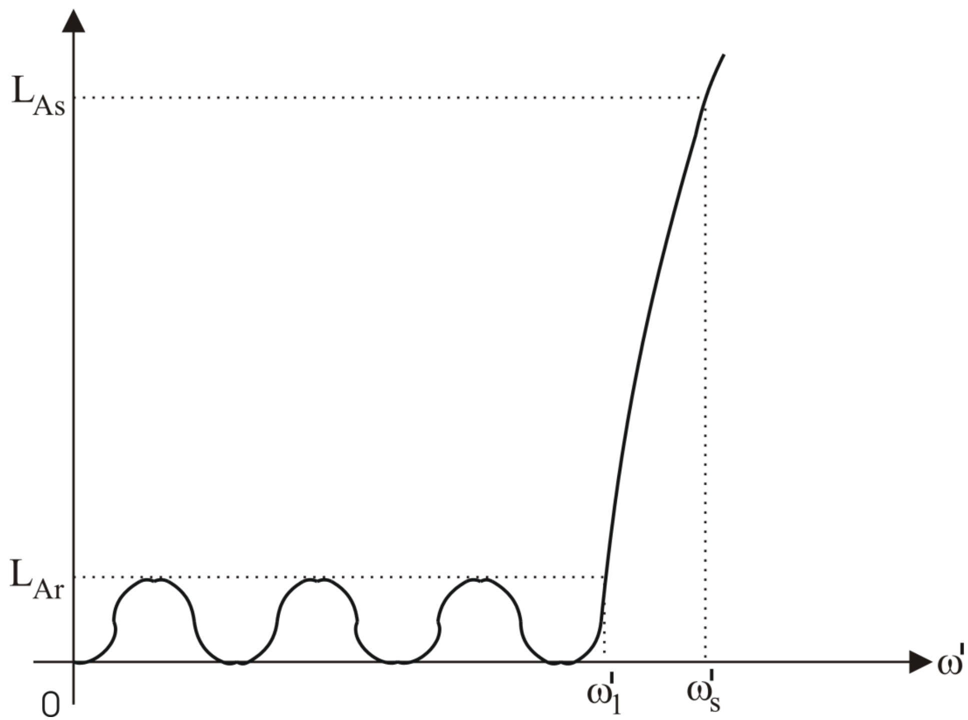
$$g_k\Big|_{k=\overline{1,n}} = \begin{cases} inductanta\ unei\ bobine \\ capacitatea\ unui\ condensator\ \ paralel \end{cases}$$

Calculul ordinului filtrului maxim plat



$$n \geq \frac{\log_{10}\left\{\left[10^{\frac{L_{As}}{10}} - 1\right] \Big/ \left[10^{\frac{L_{Ar}}{10}} - 1\right]\right\}}{2\log_{10}\left[\omega'_s / \omega'_1\right]}$$

Calculul ordinului filtrului echi-riplu



$$n \geq \frac{ch^{-1}\left(\sqrt{\left\{\left[\left(10^{0,1L_{As}}\right)-1\right]/\left[\left(10^{0,1L_{Ar}}\right)-1\right]\right\}}\right)}{ch^{-1}\left(\omega'_s / \omega'_1\right)}$$

Filtre prototip de tip maxim-plat cu terminații rezistive

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

$$g_0 = 1$$

$$g_k = 2\sin\left[\frac{(2k-1)\pi}{2n}\right], k = 1,2,3,\ldots, n$$

$$g_{n+1} = 1$$

Filtre prototip de tip echi-riplu cu terminații rezistive

$$g_1 = \frac{2a_1}{\gamma}$$

$$g_k = \frac{4a_{k-1}a_k}{b_{k-1}g_{k-1}}, k = 2,3,\ldots,n$$

$$g_{n+1} = \begin{cases} 1 \quad pentru \ n = impar \\ \coth^2\left(\frac{\beta}{4}\right) \quad pentru \ n = par \end{cases}$$

$$a_k = \sin\left[\frac{(2k-1)\pi}{2n}\right], k = 1,2,\ldots,n$$

$$b_k = \gamma^2 + \sin^2\left(\frac{k\pi}{n}\right), k = 1,2,\ldots,n$$

$$\beta = \ln\left(\coth\frac{L_{Ar}}{17,37}\right)$$

$$\gamma = \sinh\left(\frac{\beta}{2n}\right)$$

Filtre prototip de tip echi-riplu cu terminații rezistive

0.5 dB Ripple

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	0.7071	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	0.8696	1.9841				
7	1.7372	1.2583	2.6381	1.3444	2.6381	1.2583	1.7372	1.000			
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	2.7239	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	2.5239	0.8842	1.9841

Scalarea in impedanta si frecventa
FTJ

Scalarea in impedanta

$$L' = R_0 L$$

$$C' = \frac{C}{R_0}$$

$$R_s' = R_0$$

$$R_L' = R_0 R_L$$

Scalarea in frecventa

$$\omega \leftarrow \frac{\omega}{\omega_c}$$

Valorile noi

$$L_k' = \frac{R_0 L_k}{\omega_c}$$

$$C_k' = \frac{C_k}{R_0 \omega_c}$$

Scalarea in impedanta si frecventa FTS

Scalarea in impedanta

$$L' = R_0 L$$

$$C' = \frac{C}{R_0}$$

$$R'_s = R_0$$

$$R'_L = R_0 R_L$$

Scalarea in frecventa

$$\omega \leftarrow -\frac{\omega_c}{\omega}$$

Valorile noi

$$C'_k = \frac{1}{R_0 \omega_c L_k}$$

$$L'_k = \frac{R_0}{\omega_c C_k}$$

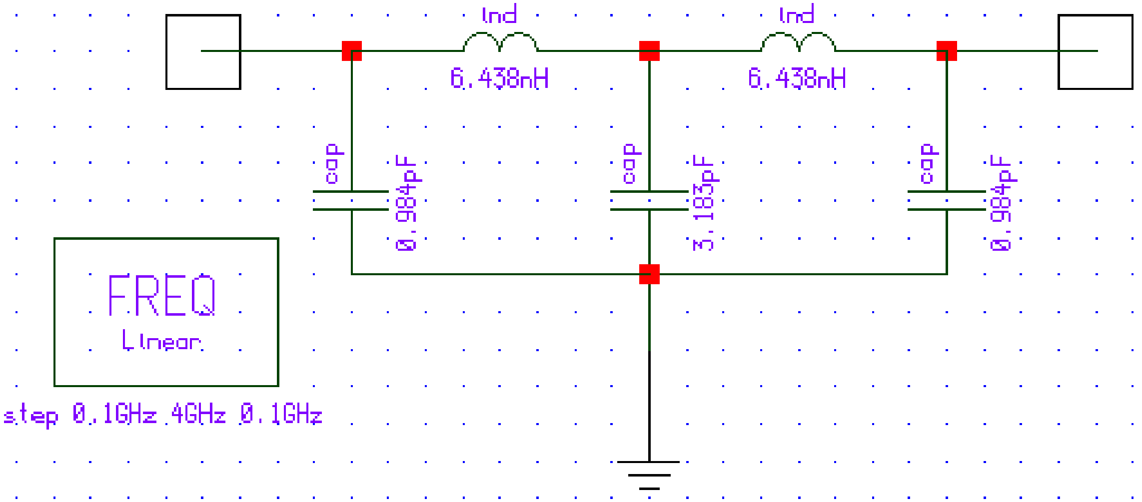
Exemplu

Să se proiecteze un filtru trece-jos de tip maxim plat cu o frecvență de tăiere de 2 GHz, care să lucreze pe 50 Ω, şi să aibă pierderi de inserție de cel puțin 15 dB la 3 GHz. Calculați răspunsul în amplitudine şi în fază între 0 şi 4 GHz. şi comparați-l cu filtrul echi-riplu, cu riplu de 3 db şi de acelaşi ordin.

Solutie

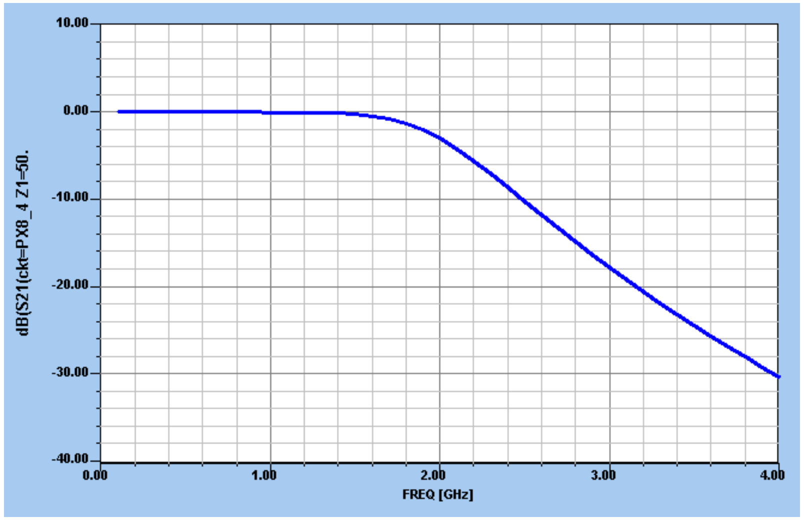
$$N \geq \frac{\log\left(10^{15/10} - 1\right)}{2\log(3/2)} = 4.22$$

g1 = 0.618
g2 = 1.618
g3 = 2.000
g4 = 1.618
g5 = 0.618

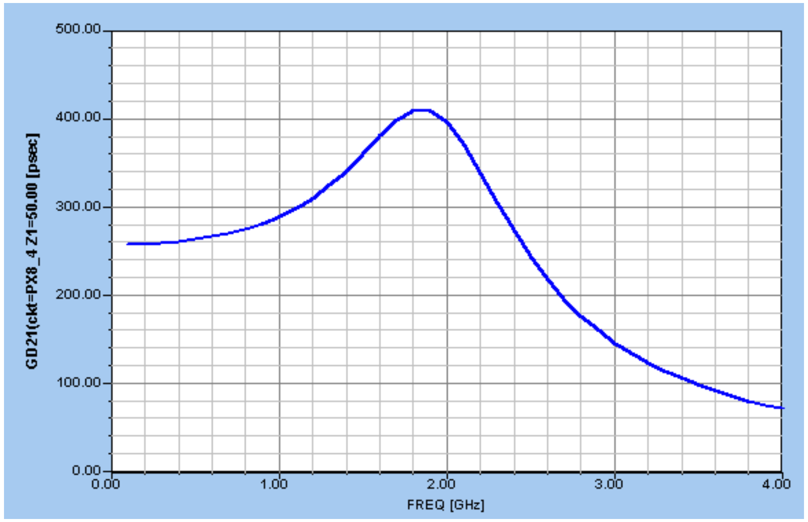


C1' = 0.984 pF,
L2' = 6.438 nH,
C3' = 3.183 pF,
L4' = 6.438 nH,
C5' = 0.984 pF.

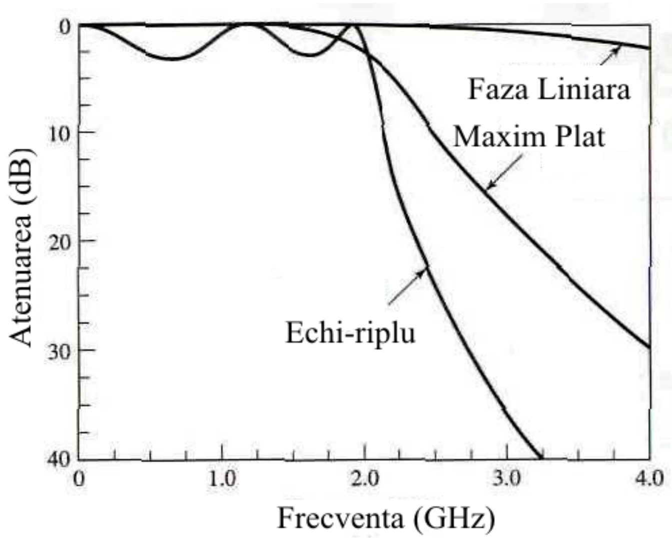
Simularea - 1



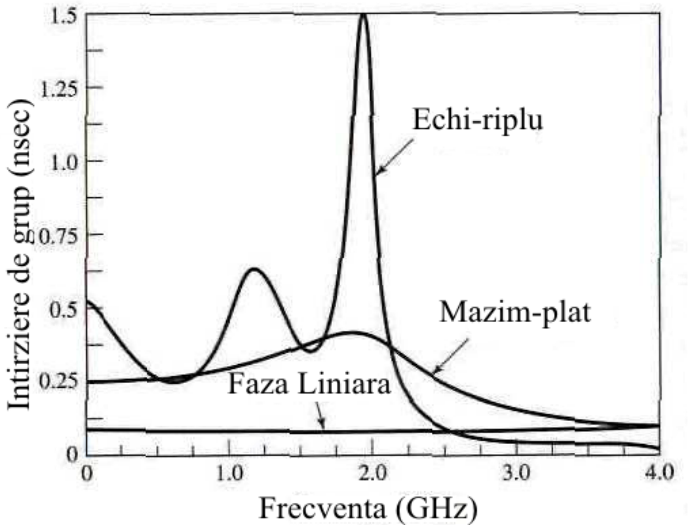
10.00
0.00
-10.00
-20.00
-30.00
-40.00
dB(S21(ckt=PX8_4 Z1=50.
0.00
1.00
2.00
3.00
4.00
FREQ [GHz]



500.00
400.00
300.00
200.00
100.00
0.00
GD21(ckt=PX8_4 Z1=50.00 [psec]
0.00
1.00
2.00
3.00
4.00
FREQ [GHz]



0
10
20
30
40
Atenuarea (dB)
Faza Liniara
Maxim Plat
Echi-riplu
0
1.0
2.0
3.0
4.0
Frecventa (GHz)



1.5
1.25
1.0
0.75
0.5
0.25
0
Intirziere de grup (nsec)
Echi-riplu
Mazim-plat
Faza Liniara
0
1.0
2.0
3.0
4.0
Frecventa (GHz)

Scalarea in impedanta si frecventa
FTJ - FTB

Scalarea in impedanta

$$L' = R_0 L$$

$$C' = \frac{C}{R_0}$$

$$R_s' = R_0$$

$$R_L' = R_0 R_L$$

Scalarea in frecventa

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

$$\Delta = \frac{\omega_2 - \omega_1}{\omega_0}$$

$$\omega_0 = \sqrt{\omega_1 \omega_2}$$

Valorile noi

Ramura serie

(in serie)

$$L_k' = \frac{L_k}{\Delta \omega_0}$$

$$C_k' = \frac{\Delta}{\omega_0 L_k}$$

Ramura paralel

(in paralel)

$$L_k' = \frac{\Delta}{C_k \omega_0}$$

$$C_k' = \frac{C_k}{\omega_0 \Delta}$$

Scalarea in impedanta si frecventa
FTJ - FOB

Scalarea in impedanta

$$L' = R_0 L$$

$$C' = \frac{C}{R_0}$$

$$R'_s = R_0$$

$$R'_L = R_0 R_L$$

Scalarea in frecventa

$$\omega \leftarrow \frac{1}{\Delta}\left(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}\right)^{-1}$$

$$\Delta = \frac{\omega_2 - \omega_1}{\omega_0}$$

$$\omega_0 = \sqrt{\omega_1 \omega_2}$$

Valorile noi

Ramura serie

(in paralel)

$$L'_k = \frac{\Delta L_k}{\omega_0}$$

$$C'_k = \frac{1}{\omega_0 \Delta L_k}$$

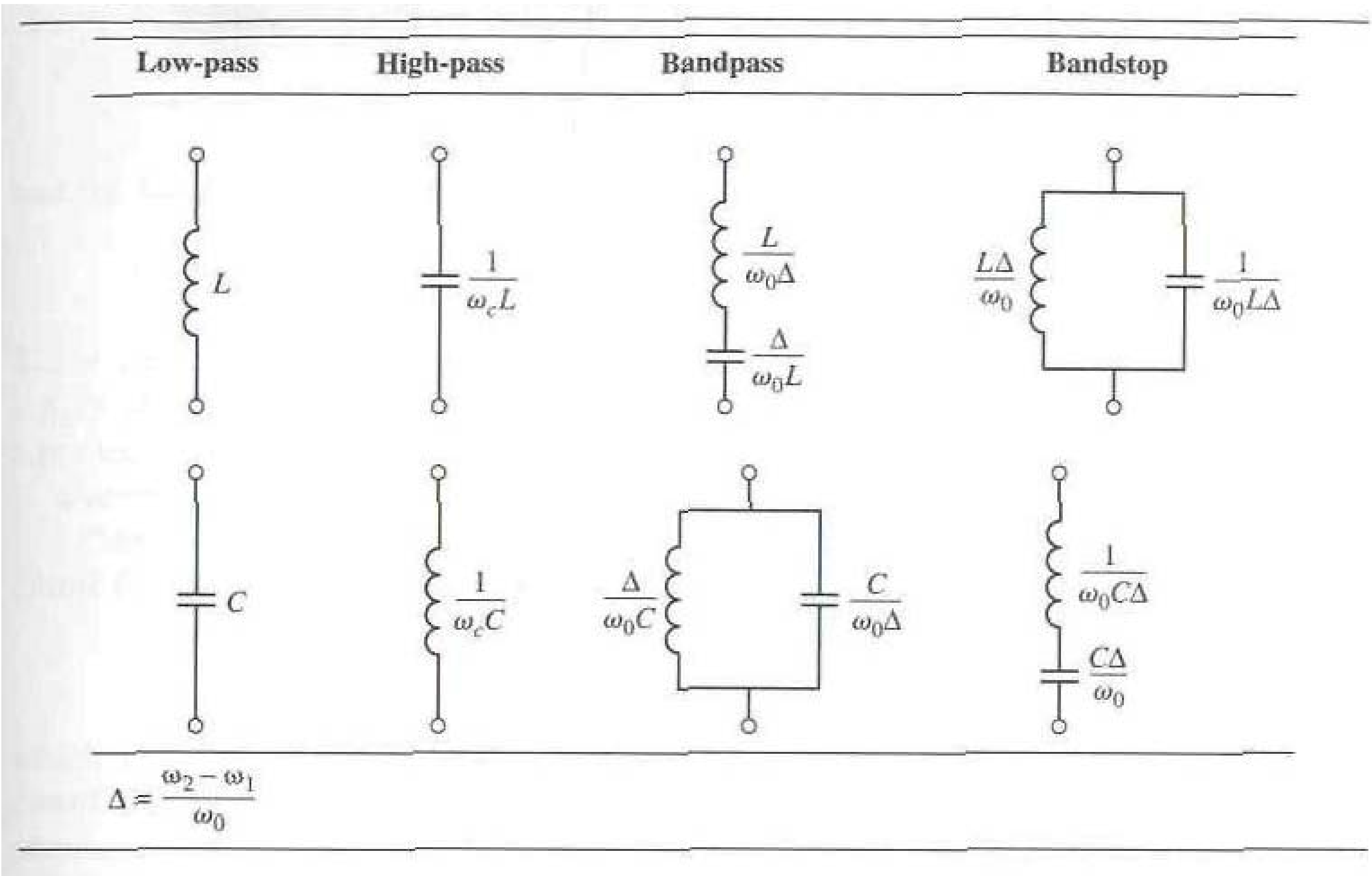
Ramura paralel

(in serie)

$$L'_k = \frac{1}{\omega_0 \Delta C_k}$$

$$C'_k = \frac{\Delta C_k}{\omega_0}$$

Transformari ale filtrului prototip

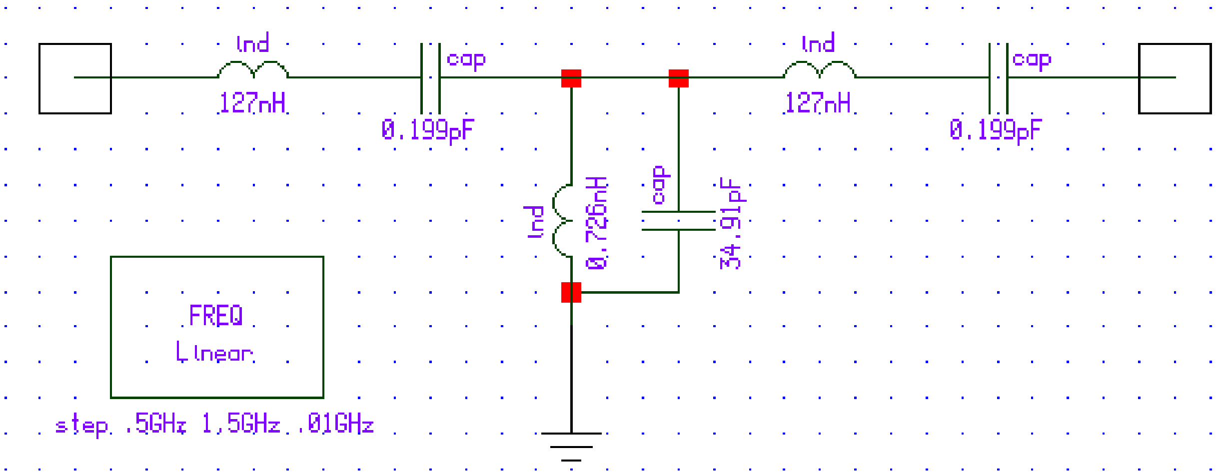


Exemplu

Să se proiecteze un filtru trece-bandă de ordinul 3, avînd riplurile în bandă de 0.5 dB. Frecvența centrala a filtrului sa fie de 1 GHz. Banda să fie de 10%, şi impedanța de 50 Ω.

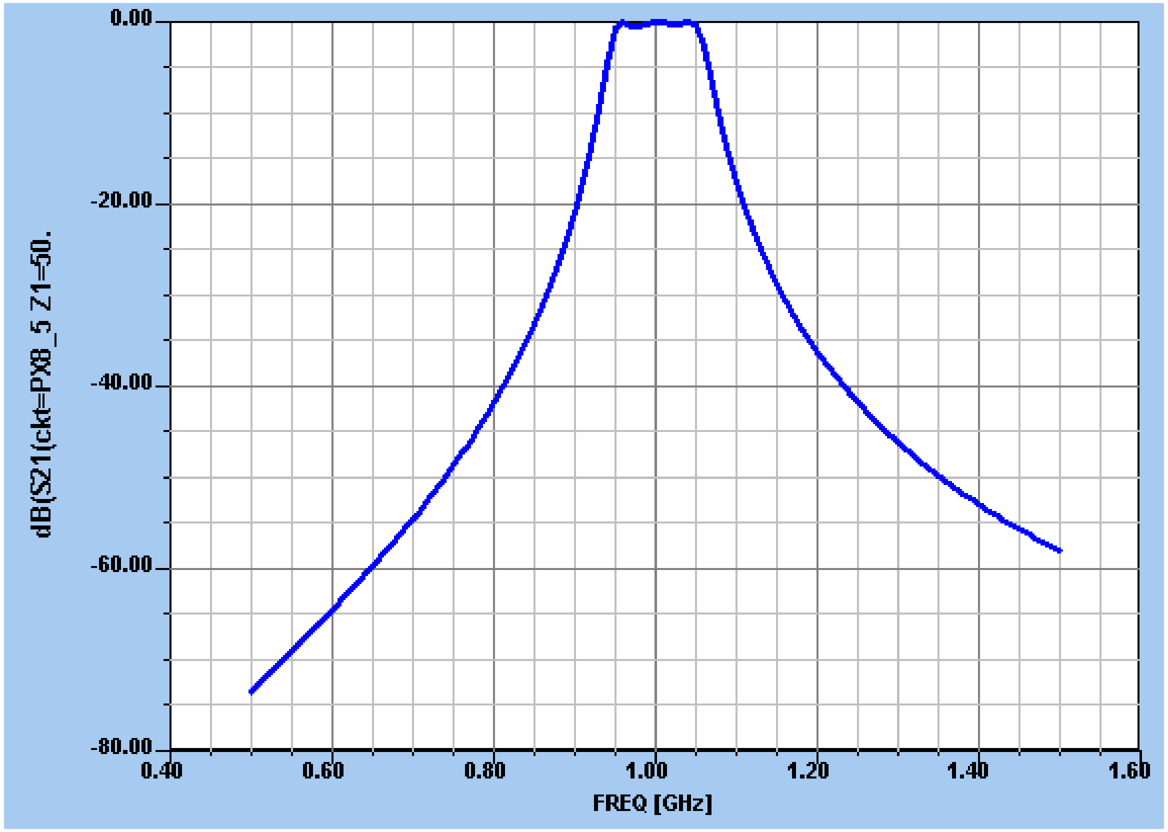
Solutie

g1 = 1.5963 = L1,
g2 **=** 1.0967 = C2,
g3 = 1.5963 = L3,
g4=1.000 =RL



L'1 = 127.0 nH,
C'l = 0.199 pF,
L'2 = 0.726 nH,
C'2 = 34.91 pF,
L'3 = 127.0 nH,
C'3 = 0.199 pF.

Simulare


0.00
-20.00
-40.00
-60.00
-80.00
0.40
0.60
0.80
1.00
1.20
1.40
1.60
FREQ [GHz]
dB(S21(ckt=PX8_5 Z1=50.