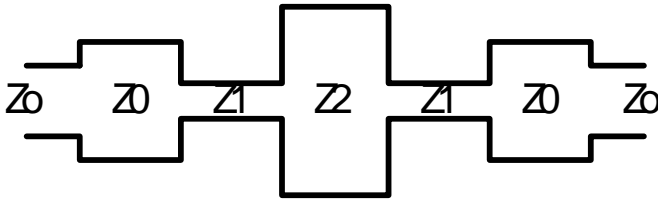


Microwave Stepped Impedance Filter Design Sheet Type-2

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This sheet is used to design microwave stepped impedance filters where each section is of the same length. The maths for this are from "Theory & Design of Microwave Filters", Ian Hunter, IEE Press.

There are three steps to this filter design:

Step 1, Get the filter g-values. This sheet calculated these values according to the Chebychev polynomial. Other sources of g cannot be used here as the g-values are modified by the length of the transmission line.

Step 2, Calculate Z_0 and wavelength depending on the type of filter.
 This MathCAD sheet stops at this point.

Step 3, Calculate length and width. One method is to use Linecalc which is part of ADS. For microstrip designs I have written a MathCAD sheet which is available from my webpage that works well for thin tracks, less well for thicker tracks. Also you can try transcalc.sourceforge.net for a Linecalc equivalent.

Yellow is user input, Green is output

Main user input area:

$$\mu\text{m} := 10^{-6} \cdot \text{m} \quad \text{nH} := 10^{-9} \cdot \text{henry}$$

$L_{\text{ar_db}} := 0.5$	Passband ripple in dB
$N := 17$	Order of the filter, this needs to be between 3 and 18.
$f_c := 1 \cdot \text{GHz}$	Cutoff frequency.
$Z_0 := 50 \cdot \Omega$	
$EL := 20\text{deg}$	Electrical Length of each section

LPF Frequency Response, for Chebychev Polynomials

This section plots the frequency response for the Chebychev LPF

$$Y_o := \frac{1}{Z_o} \quad \varepsilon := 10^{\frac{L_{\text{ar_db}}}{10}} - 1 \quad \alpha := \sin(EL)$$

$$L_A(f, f_c) := \begin{cases} 10 \cdot \log \left[1 + \varepsilon \cdot \left(\cos \left(N \cdot \arccos \left(\frac{f}{f_c} \right) \right) \right)^2 \right] & \text{if } f \leq f_c \\ 10 \cdot \log \left[1 + \varepsilon \cdot \left(\cosh \left(N \cdot \operatorname{acosh} \left(\frac{f}{f_c} \right) \right) \right)^2 \right] & \text{if } f > f_c \end{cases}$$

$$\alpha = 0.342$$

$$\varepsilon = 0.12202$$

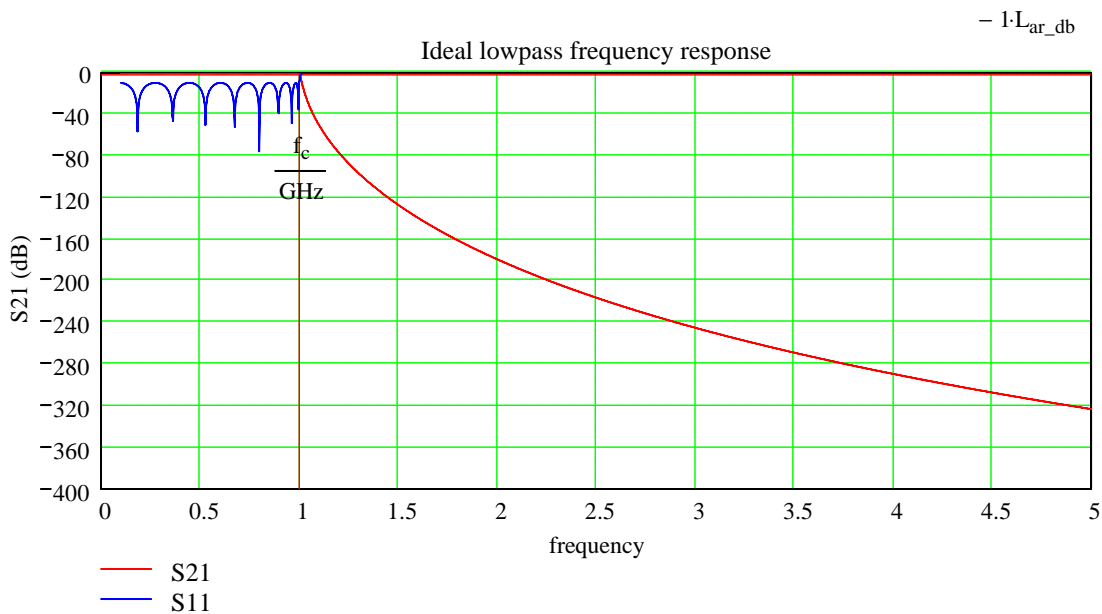
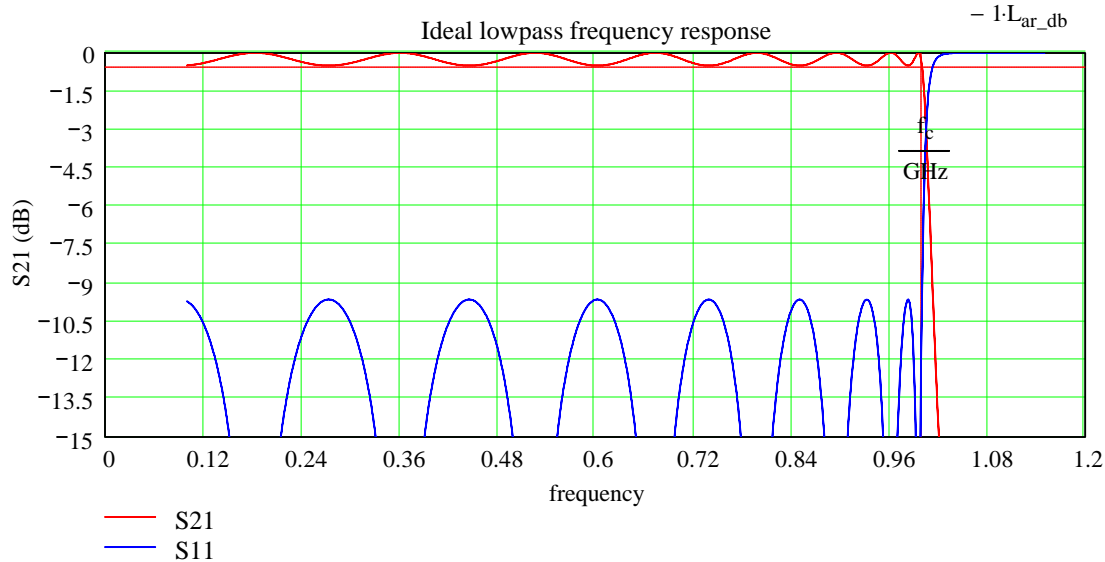
$$\text{Max_Atten} := 10 \cdot \log \left[\frac{1}{1 + \varepsilon^2 \cdot \left(\cosh \left(N \cdot \operatorname{acosh} \left(\frac{1}{\alpha} \right) \right) \right)^2} \right]$$

$$\text{Max_Atten} = -231.96 \quad \text{dB}$$

$$f_{\text{lp_hp_sweep_wide}} := \frac{f_c}{10}, \frac{f_c}{10} + \frac{f_c}{500} \dots f_c \cdot 5$$

$$S_{11A}(f, f_1) := 10 \cdot \log \left[1 - 10^{\left(\frac{-L_A(f, f_1)}{10} \right)} \right]$$

$$f_{\text{lp_hp_sweep_narrow}} := \frac{f_c}{10}, \frac{f_c}{10} + \frac{f_c}{1000} \dots f_c \cdot 1.15$$



Calculate the Chebychev (g) Polynomials

$$\eta := \sinh\left(\frac{1}{N} \cdot \operatorname{asinh}\left(\frac{1}{\varepsilon}\right)\right)$$

$$\eta = 0.165$$

$$A_1 := \frac{1}{\eta} \quad A_2 := \frac{\eta}{\eta^2 + \left(\sin\left(\frac{\pi}{N}\right)\right)^2} \quad A_3 := \frac{\left[\eta^2 + \left(\sin\left(\frac{\pi}{N}\right)\right)^2\right]}{\left[\eta^2 + \left(\sin\left(\frac{2\pi}{N}\right)\right)^2\right] \cdot \eta}$$

$$A_4 := \frac{\left[\eta^2 + \left(\sin\left(\frac{2\pi}{N}\right)\right)^2\right] \cdot \eta}{\left[\eta^2 + \left(\sin\left(\frac{3\pi}{N}\right)\right)^2\right] \cdot \left[\eta^2 + \left(\sin\left(\frac{\pi}{N}\right)\right)^2\right]}$$

$$A_5 := \frac{\left[\eta^2 + \left(\sin\left(\frac{3\pi}{N}\right)\right)^2\right] \cdot \left[\eta^2 + \left(\sin\left(\frac{\pi}{N}\right)\right)^2\right]}{\left[\eta^2 + \left(\sin\left(\frac{4\pi}{N}\right)\right)^2\right] \cdot \left[\eta^2 + \left(\sin\left(\frac{2\pi}{N}\right)\right)^2\right] \cdot \eta}$$

$$A_6 := \frac{\left[\eta^2 + \left(\sin\left(\frac{4\pi}{N}\right)\right)^2\right] \cdot \left[\eta^2 + \left(\sin\left(\frac{2\pi}{N}\right)\right)^2\right] \cdot \eta}{\left[\eta^2 + \left(\sin\left(\frac{5\pi}{N}\right)\right)^2\right] \cdot \left[\eta^2 + \left(\sin\left(\frac{3\pi}{N}\right)\right)^2\right] \cdot \left[\eta^2 + \left(\sin\left(\frac{\pi}{N}\right)\right)^2\right]}$$

$$A_7 := \frac{\left[\eta^2 + \left(\sin\left(\frac{5\pi}{N}\right)\right)^2\right] \cdot \left[\eta^2 + \left(\sin\left(\frac{3\pi}{N}\right)\right)^2\right] \cdot \left[\eta^2 + \left(\sin\left(\frac{\pi}{N}\right)\right)^2\right]}{\left[\eta^2 + \left(\sin\left(\frac{6\pi}{N}\right)\right)^2\right] \cdot \left[\eta^2 + \left(\sin\left(\frac{4\pi}{N}\right)\right)^2\right] \cdot \left[\eta^2 + \left(\sin\left(\frac{2\pi}{N}\right)\right)^2\right] \cdot \eta}$$

$$A_8 := \frac{\left[\eta^2 + \left(\sin\left(\frac{6\pi}{N}\right)\right)^2\right] \cdot \left[\eta^2 + \left(\sin\left(\frac{4\pi}{N}\right)\right)^2\right] \cdot \left[\eta^2 + \left(\sin\left(\frac{2\pi}{N}\right)\right)^2\right] \cdot \eta}{\left[\eta^2 + \left(\sin\left(\frac{7\pi}{N}\right)\right)^2\right] \cdot \left[\eta^2 + \left(\sin\left(\frac{5\pi}{N}\right)\right)^2\right] \cdot \left[\eta^2 + \left(\sin\left(\frac{3\pi}{N}\right)\right)^2\right] \cdot \left[\eta^2 + \left(\sin\left(\frac{\pi}{N}\right)\right)^2\right]}$$

$$A_9 := \frac{\left[\eta^2 + \left(\sin\left(\frac{7\pi}{N}\right)\right)^2\right] \cdot \left[\eta^2 + \left(\sin\left(\frac{5\pi}{N}\right)\right)^2\right] \cdot \left[\eta^2 + \left(\sin\left(\frac{3\pi}{N}\right)\right)^2\right] \cdot \left[\eta^2 + \left(\sin\left(\frac{\pi}{N}\right)\right)^2\right]}{\left[\eta^2 + \left(\sin\left(\frac{8\pi}{N}\right)\right)^2\right] \cdot \left[\eta^2 + \left(\sin\left(\frac{6\pi}{N}\right)\right)^2\right] \cdot \left[\eta^2 + \left(\sin\left(\frac{4\pi}{N}\right)\right)^2\right] \cdot \left[\eta^2 + \left(\sin\left(\frac{2\pi}{N}\right)\right)^2\right] \cdot \eta}$$

$n := 1, 2 \dots N$

$$A_n := \begin{cases} 0 & \text{if } n > 9 \\ A_n & \text{otherwise} \end{cases}$$

$$AA_n := \begin{cases} A_n & \text{if } n < \frac{N}{2} + 0.75 \\ A_{N-n+1} & \text{if } n > \frac{N}{2} + 0.75 \end{cases}$$

$$g_n := AA_n \left[\frac{2 \cdot \sin \left[\frac{(2 \cdot n - 1) \cdot \pi}{2 \cdot N} \right]}{\alpha} - \frac{\alpha}{4} \left[\frac{\eta^2 + \left(\sin \left(\frac{n\pi}{N} \right) \right)^2}{\sin \left[\frac{(2 \cdot n + 1) \cdot \pi}{2N} \right]} + \frac{\eta^2 + \left[\sin \left[\frac{(n-1)\pi}{N} \right] \right]^2}{\sin \left[\frac{(2 \cdot n - 3) \cdot \pi}{2N} \right]} \right] \right]$$

$$Z_n := \begin{cases} \frac{Z_o}{g_n} & \text{if } \left(n - 2 \cdot \text{trunc} \left(\frac{n}{2} \right) \right) > 0.5 & n = \text{odd} \\ Z_o \cdot g_n & \text{if } \left(n - 2 \cdot \text{trunc} \left(\frac{n}{2} \right) \right) < 0.5 & n = \text{even} \end{cases}$$

$AA_n =$

6.043
2.706
2.341
1.403
1.481
1.017
1.187
0.884
1.11
0.884
1.187
1.017
1.481
1.403
2.341
2.706
6.043

$g_n =$

3.298
4.095
5.884
4.784
6.2
4.899
6.275
4.93
6.292
4.93
6.275
4.899
6.2
4.784
5.884
4.095
3.298

$Z_n =$

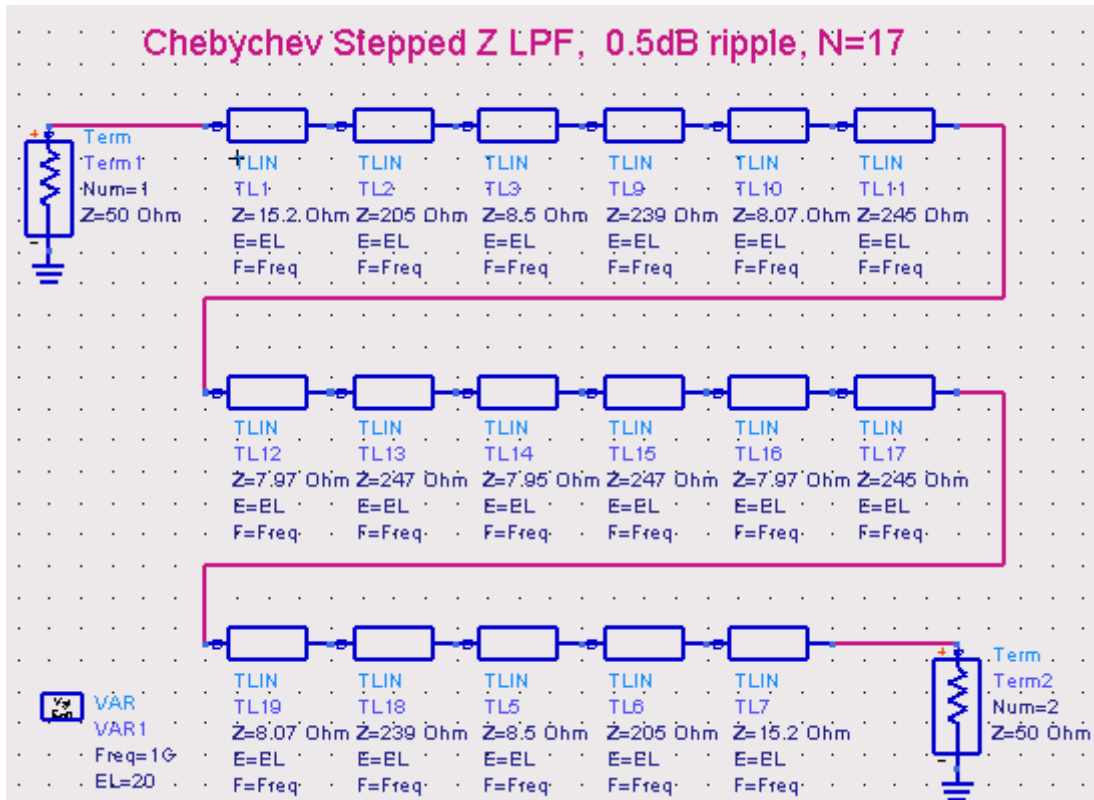
15.159	ohm
204.771	
8.498	
239.216	
8.065	
244.941	
7.968	
246.481	
7.946	
246.481	
7.968	
244.941	
8.065	
239.216	
8.498	
204.771	
15.159	

Simulation Results

To test these values I have run a simulation on ADS for $N=17$, $L=0.5\text{dB}$, 20-degree EL, $Z_0=50\Omega$. You can see the results are in good agreement. Both the ripple and return loss (S11) are better than expected; although these match better for $N=18$, I have no idea why this is. Quite a good filter though.

If the extremes of Z_0 are too much for your process then you can increase the effective length (EL).

You can see the downside of these filters that the frequency response repeats and the out of band attenuation is not a good we would like although at 232dB agrees perfectly.



m1
freq=750.0MHz
dB(S(2,1))=-0.047

m2
freq=4.530GHz
dB(S(2,1))=-232.040

