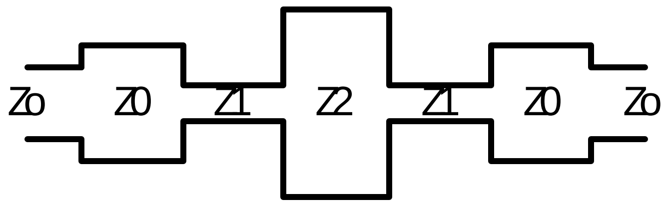
Microwave Stepped Impedance Filter Design Sheet
Type-2



Chris Haji-Michael
www.sunshadow.co.uk/chris.htm

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 Zo 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 wepage 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:

$nH := 10^{-9} \cdot henry$

$L_{ar\_db} := 0.5$ Passband ripple in dB

$N := 17$ Order of the filter, this needs to be between 3 and 18.

$f_c := 1 \cdot GHz$ Cutoff frequency.

$Z_o := 50 \cdot \mathbf{O}$

$EL := 20deg$ Electrical Length of each section

LPF Frequency Response, for Chebychev Polynomials

This section plots the frequency response for the Chebychev LPF

$Y_o := \frac{1}{Z_o}$ $\mathbf{e} := 10^{\frac{L_{ar\_db}}{10}} - 1$ $\mathbf{a} := \sin(EL)$

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

$\mathbf{a} = 0.342$

$\mathbf{e} = 0.12202$

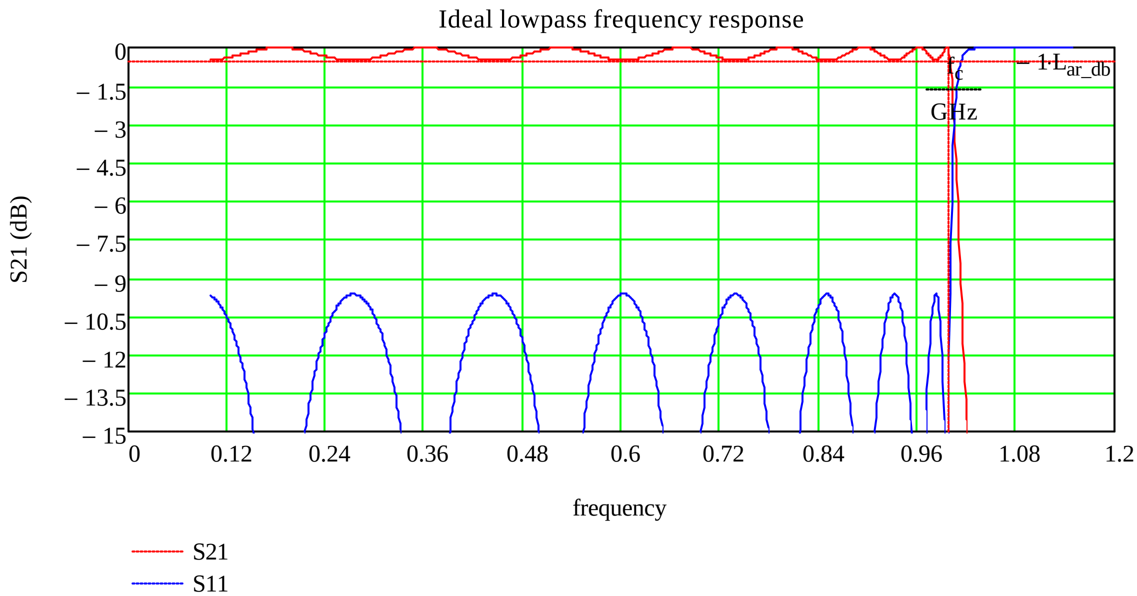
$$Max\_Atten := 10\cdot\log\left[\frac{1}{1+\mathbf{e}^2\cdot\left(\cosh\left(N\cdot \operatorname{acosh}\left(\frac{1}{\mathbf{a}}\right)\right)\right)^2}\right]$$

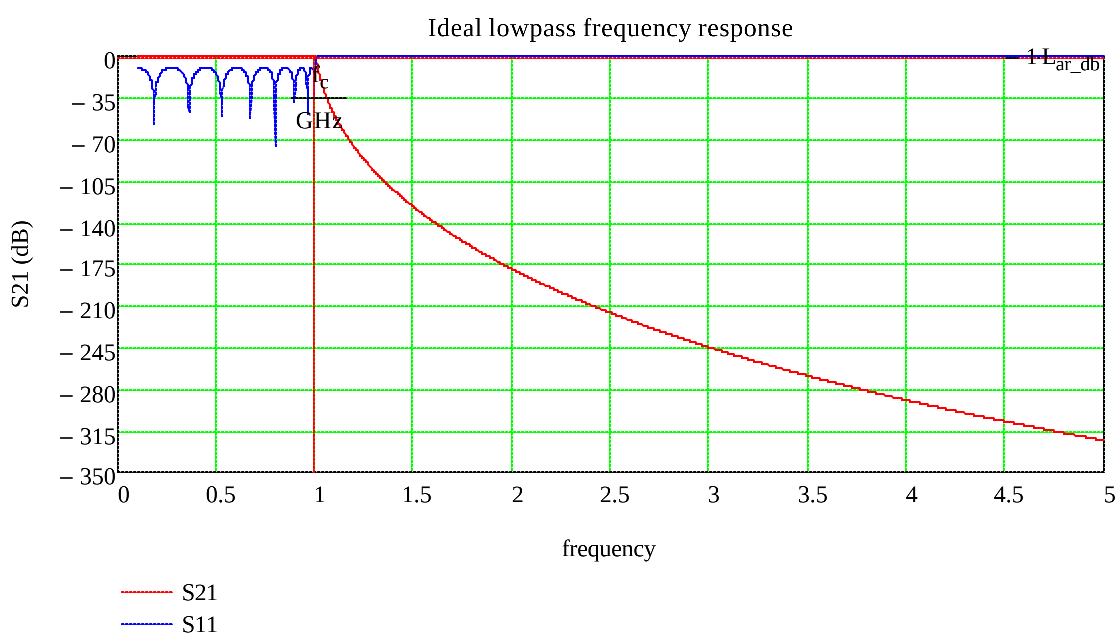
$Max\_Atten = -231.96$ dB

$$f_{lp\_hp\_sweep\_wide} := \frac{f_c}{10}, \frac{f_c}{10}+\frac{f_c}{500} .. f_c\cdot 5$$

$$f_{lp\_hp\_sweep\_narrow} := \frac{f_c}{10}, \frac{f_c}{10}+\frac{f_c}{1000} .. f_c\cdot 1.15$$

$$S11_A(f,f_1) := 10\cdot\log\left[1-10^{\left(\frac{-L_A(f,f_1)}{10}\right)}\right]$$





Calculate the Chebychev (g) Polynomials

$$? := \sinh\left(\frac{1}{N}\cdot \operatorname{asinh}\left(\frac{1}{\mathbf{e}}\right)\right)$$

$? = 0.165$

$$A_1 := \frac{1}{?} \qquad A_2 := \frac{?}{?^2 + \left(\sin\left(\frac{\mathbf{p}}{N}\right)\right)^2} \qquad A_3 := \frac{\left[?^2 + \left(\sin\left(\frac{\mathbf{p}}{N}\right)\right)^2\right]}{\left[?^2 + \left(\sin\left(\frac{2\mathbf{p}}{N}\right)\right)^2\right]\cdot ?}$$

$$A_4 := \frac{\left[?^2 + \left(\sin\left(\frac{2\mathbf{p}}{N}\right)\right)^2\right]\cdot ?}{\left[?^2 + \left(\sin\left(\frac{3\,\mathbf{p}}{N}\right)\right)^2\right]\cdot\left[?^2 + \left(\sin\left(\frac{\mathbf{p}}{N}\right)\right)^2\right]}$$

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

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

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

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

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

$$n := 1, 2 .. N$$

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

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

$$g_n := AA_n \left[\frac{2 \cdot \sin\left[(2 \cdot n - 1) \cdot \dfrac{\mathbf{p}}{2 \cdot N}\right]}{\mathbf{a}} - \frac{\mathbf{a}}{4} \left[\frac{?^2 + \left(\sin\left(\dfrac{n\,\mathbf{p}}{N}\right)\right)^2}{\sin\left[\dfrac{(2 \cdot n + 1) \cdot \mathbf{p}}{2N}\right]} + \frac{?^2 + \left[\sin\left[\dfrac{(n-1)\mathbf{p}}{N}\right]\right]^2}{\sin\left[\dfrac{(2 \cdot n - 3) \cdot \mathbf{p}}{2N}\right]} \right] \right]$$

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

n = odd

n = even

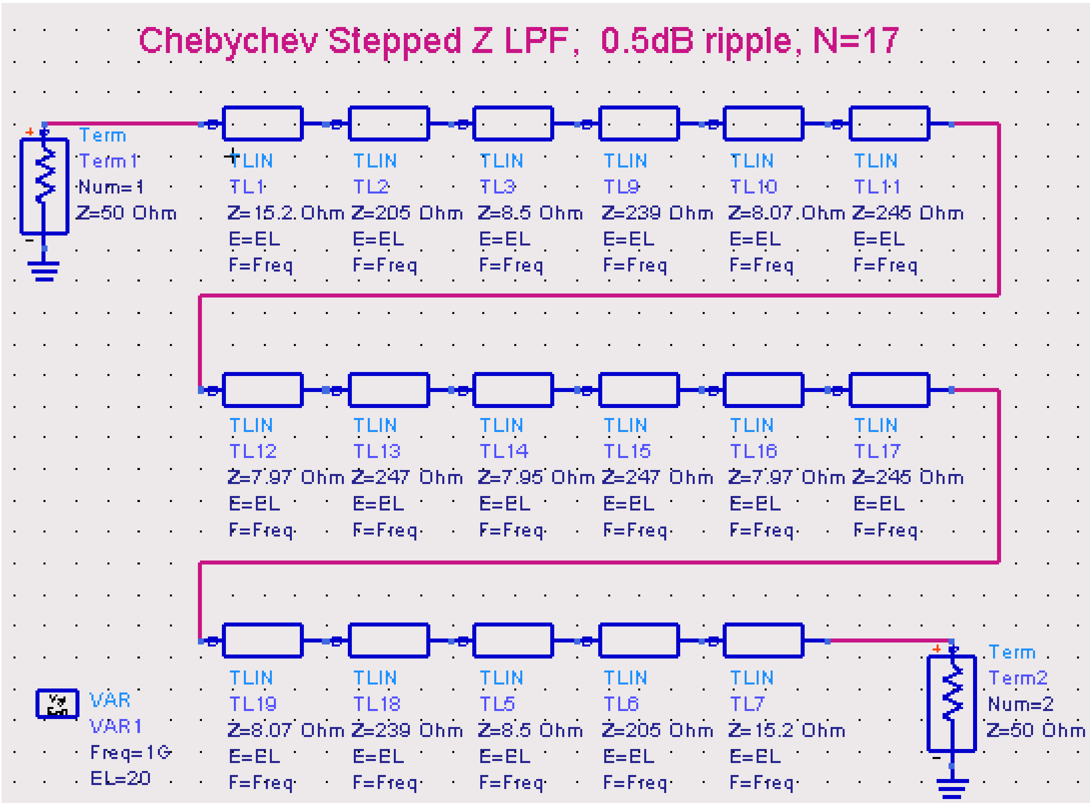
$AA_n =$	$g_n =$	$Z_n =$ (· ohm)
6.043	3.298	15.159
2.706	4.095	204.771
2.341	5.884	8.498
1.403	4.784	239.216
1.481	6.2	8.065
1.017	4.899	244.941
1.187	6.275	7.968
0.884	4.93	246.481
1.11	6.292	7.946
0.884	4.93	246.481
1.187	6.275	7.968
1.017	4.899	244.941
1.481	6.2	8.065
1.403	4.784	239.216
2.341	5.884	8.498
2.706	4.095	204.771
6.043	3.298	15.159

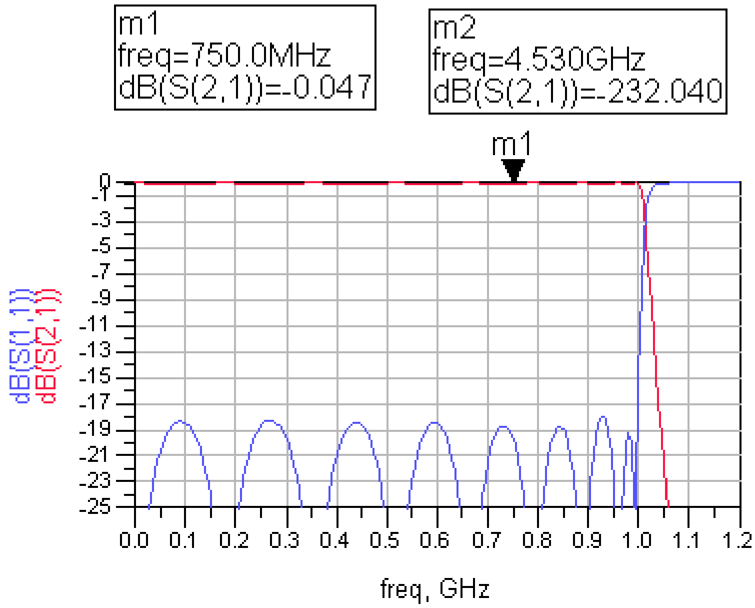
Simulation Results

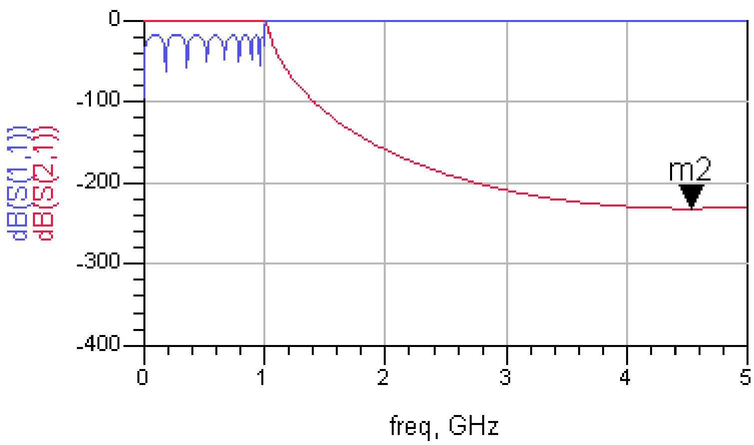
To test these values I have run a simulation on ADS for N=17, L=0.5dB, 20-degree EL, Zo=50R. You can see the results are in good agreement. Both the ripple and return loss (S11) are better than expected; although these match better for N=18, I have no idea why this is.
Quite a good filter.

If the extremes of Zo 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
m1
dB(S(1,1))
dB(S(2,1))
freq, GHz


m2
dB(S(1,1))
dB(S(2,1))
freq, GHz