Microwave Coupled Filter Design Sheet

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This sheet is used to design microwave Coupled filters. The real author of this sheet is **Lance Lasceri** of **tools.rfdude.com,** I have modified and annotated his original sheet to make it easier to understand, well at least for my application. The maths for this can be found at www.acusd.edu/~ekim/e194rfs01/iec19aek.pdf. The filter topology is also different to the one Lance uses. I have also added some simulation results at the end.

There are three steps to this filter design:

Step 1, Get the filter g-values, this sheet calculated the g values according to the Chebychev polynomial, but these can be obtained in a variety of ways from books or from a program freely available from my web page. You will be pleased to know that these g-values agree with my program!!

Step 2, Calculate Zoo/Zoe 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:

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

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

$N := 5$ order of the filter (this sheet is only valid for odd values of N)

$f_{low} := 10 \cdot GHz$

$f_{high} := 15 \cdot GHz$

bandpass cutoff frequencies, these are the equiripple band edge frequencies, not necessarily the 3 dB cutoff frequencies.

$Z_o := 50 \cdot \Omega$

BPF Frequency Response, for Chebychev Polynomials

This section plots the frequency response for the Chebychev polynomial values calculated later. The frequency response is for the coupled BPF.

$Y_o := \frac{1}{Z_o}$ $\quad f_{gm} := \sqrt{f_{low} \cdot f_{high}}$ $\quad bw := \frac{f_{high} - f_{low}}{f_{gm}}$ $\quad bwpercent := bw \cdot 100$

$$\varepsilon := 10^{\frac{L_{ar\_db}}{10}} - 1$$

bwpercent = 40.825 $f_{gm} = 12.247\,\text{GHz}$ $\varepsilon = 0.122$

$$L_A(f, f_1) := \begin{cases} 10 \cdot \log\left[1 + \varepsilon \cdot \left[\cos\left(\left(N \cdot \text{acos}\left(\frac{f}{f_1}\right)\right)\right)\right]^2\right] & \text{if } f \le f_1 \\ 10 \cdot \log\left[\left[1 + \varepsilon \cdot \left[\cosh\left(\left(N \cdot \text{acosh}\left(\frac{f}{f_1}\right)\right)\right)\right]^2\right]\right] & \text{if } f > f_1 \end{cases}$$

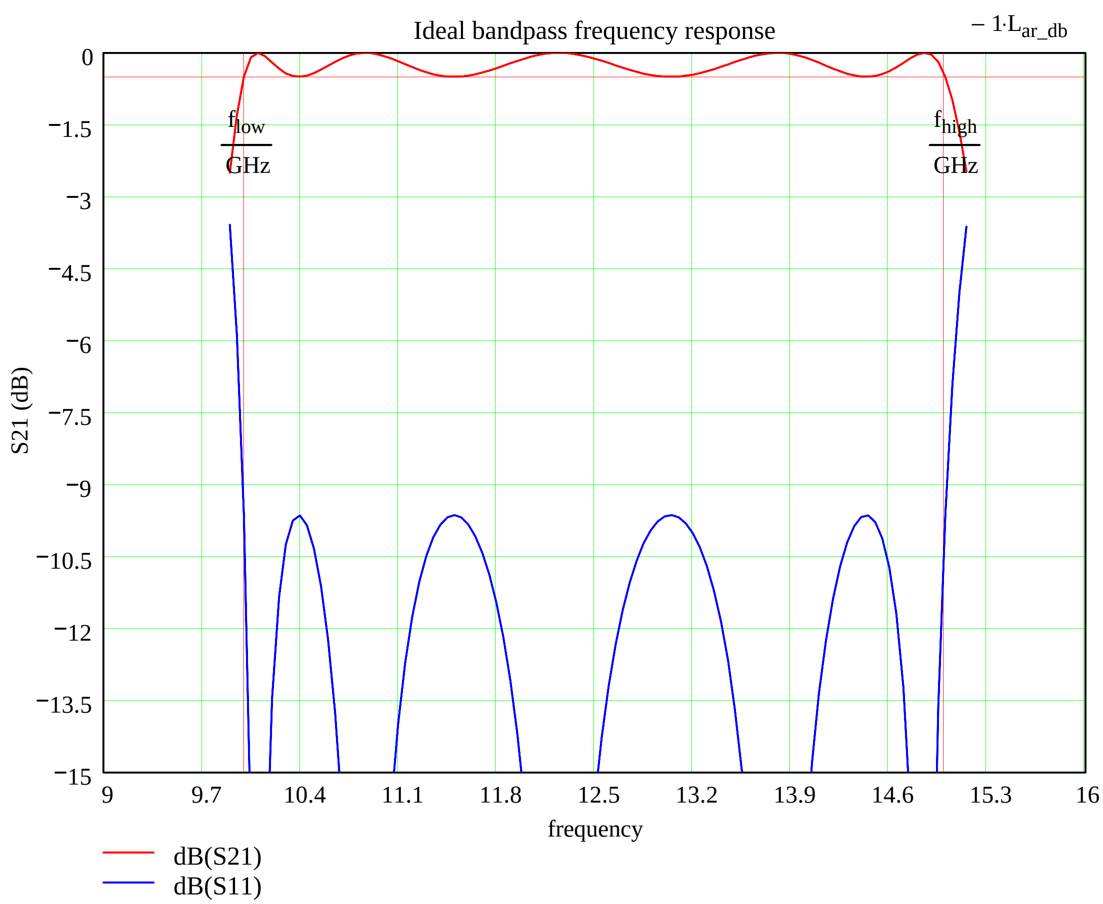
f1 = fc for lowpass, f_gm for bandpass

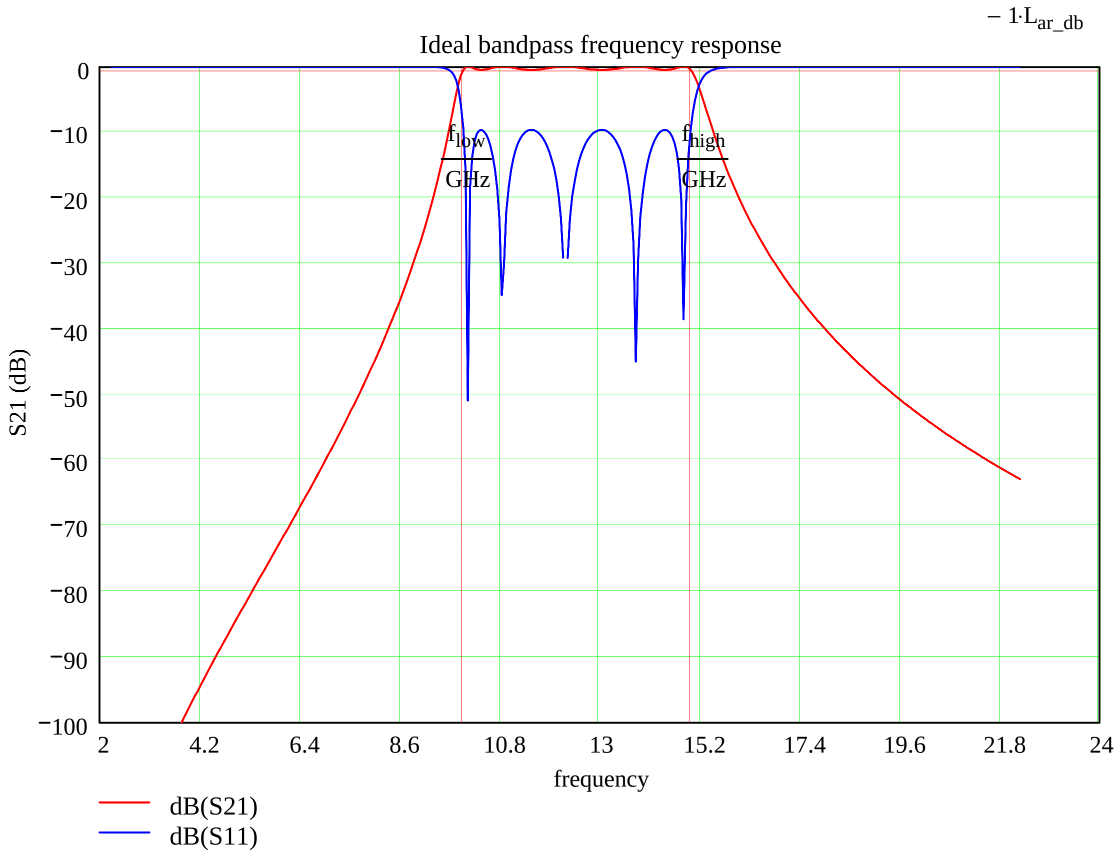
$$S11_A(f, f_1) := 10 \cdot \log\left[1 - 10^{\left(\frac{-L_A(f, f_1)}{10}\right)}\right]$$

$$f_{bp}(f) := \frac{1}{bw} \cdot \left(\frac{f}{f_{gm}} - \frac{f_{gm}}{f}\right) \cdot f_{gm}$$

$$f\_bp\_narrow := 0.99 \cdot f_{low}, \frac{f_{high} - f_{low}}{100} + 0.99 \cdot f_{low} .. 1.01 \cdot f_{high}$$

$$f\_bp\_wide := (f_{gm} - 2 \cdot f_{gm} \cdot bw), (f_{gm} - 2 \cdot f_{gm} \cdot bw) + \frac{f_{gm} \cdot bw}{100} .. f_{gm} + (2 \cdot f_{gm} \cdot bw)$$





Calculate the Chebychev (g) Polynomials

$k := 1..N$ $\quad \beta := \ln\left(\coth\left(\frac{L_{ar\_db}}{17.37}\right)\right)$ $\quad \gamma := \sinh\left(\frac{\beta}{2 \cdot N}\right)$ $\quad a_k := \sin\left[\frac{(2 \cdot k - 1) \cdot \pi}{2 \cdot N}\right]$

$b_k := \gamma^2 + \left(\sin\left(\frac{k \cdot \pi}{N}\right)\right)^2$

$g_k := 0$

$g_0 := 1$

$g_{N+1} := 1$

g(0) and g(N+1) represent the input/output coupling for odd order filters, these are 1 representing the generator (and equal) load resistance

$$g_k := \begin{cases} \frac{2 \cdot a_1}{\gamma} & \text{if } k = 1 \\ \frac{4 \cdot a_{k-1} \cdot a_k}{b_{k-1} \cdot g_{k-1}} & \text{otherwise} \end{cases}$$

$$g = \begin{pmatrix} 1 \\ 1.706 \\ 1.23 \\ 2.541 \\ 1.23 \\ 1.706 \\ 1 \end{pmatrix}$$

The next step is to calculate Zoo Zoe.

This next section converts the g-values to J-values and in turn to Zoo and Zoe. If you wish to use your own g-values, i.e not from the Chebychev polynomial then this is ok and you need to put them here as follows.

$n := 0, 1 .. N$

$g_{100} := 2$

$$JJ(i) := \begin{cases} \sqrt{\dfrac{\pi \cdot bw}{2 \cdot g_0 \cdot g_1}} & \text{if } i = 0 \\ \dfrac{\pi \cdot bw}{2 \cdot \sqrt{g_i \cdot g_{i+1}}} & \text{if } (1 \le i < N) \\ \sqrt{\dfrac{\pi \cdot bw}{2 \cdot g_N \cdot g_{N+1}}} & \text{if } i = N \end{cases}$$

$Jval_n := JJ(n)$

$$Jval = \begin{pmatrix} 0.613 \\ 0.443 \\ 0.363 \\ 0.363 \\ 0.443 \\ 0.613 \end{pmatrix} kg\, m^2\, s^{-3}\, A^{-2}\, mho$$

$$Zoe(n) := \frac{1}{Y_o} \cdot \left[1 + Jval_n + \left(Jval_n\right)^2\right]$$

$$Zoo(n) := \frac{1}{Y_o}\left[\left[1 - Jval_n + \left(Jval_n\right)^2\right]\right]$$

Zoe(n) = (Ω)

99.453
81.942
74.721
74.721
81.942
99.453

Zoo(n) = (Ω)

38.14
37.664
38.441
38.441
37.664
38.14

$$coupling\_db(Z_{0e}, Z_{0o}) := 20 \cdot \log\left(\frac{Z_{0e} - Z_{0o}}{Z_{0e} + Z_{0o}}\right)$$

Now calculate the coupling between sections of the filter. The first and last represent the input and output couplings. If the filter is a tapped filter, the input and output coupling is not achieved using a coupler, and these values are ignored (these are the first and last in the list, and generally represent the smallest coupling value in the filter, which is why it is often desirable to avoid such coupler designs).

coupling_db(Zoe(n), Zoo(n)) =

-7.021
-8.631
-9.881
-9.881
-8.631
-7.021

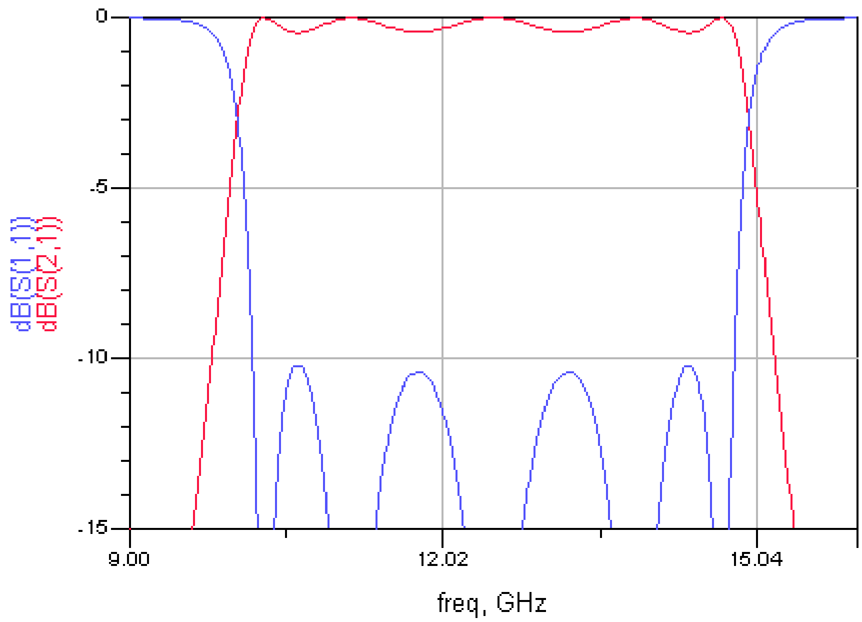
$\varepsilon_r := 4.5$ $\quad \lambda_0 := \dfrac{3 \cdot 10^8 \cdot \frac{m}{s}}{f_{gm}}$ $\quad \lambda_{guide} := \dfrac{\lambda_0}{\sqrt{\varepsilon_r}}$

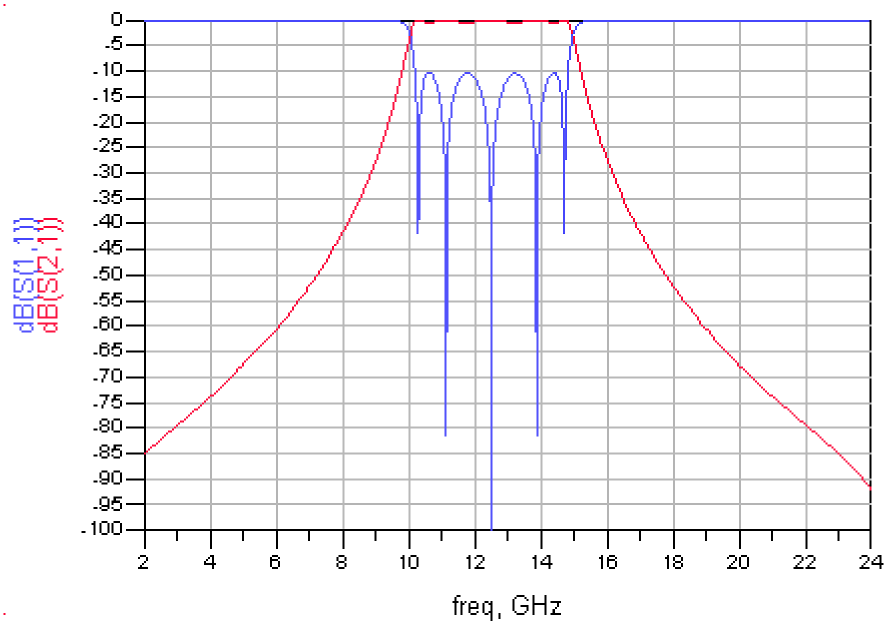
$$\frac{\lambda_{guide}}{4} = 2.887\, mm$$

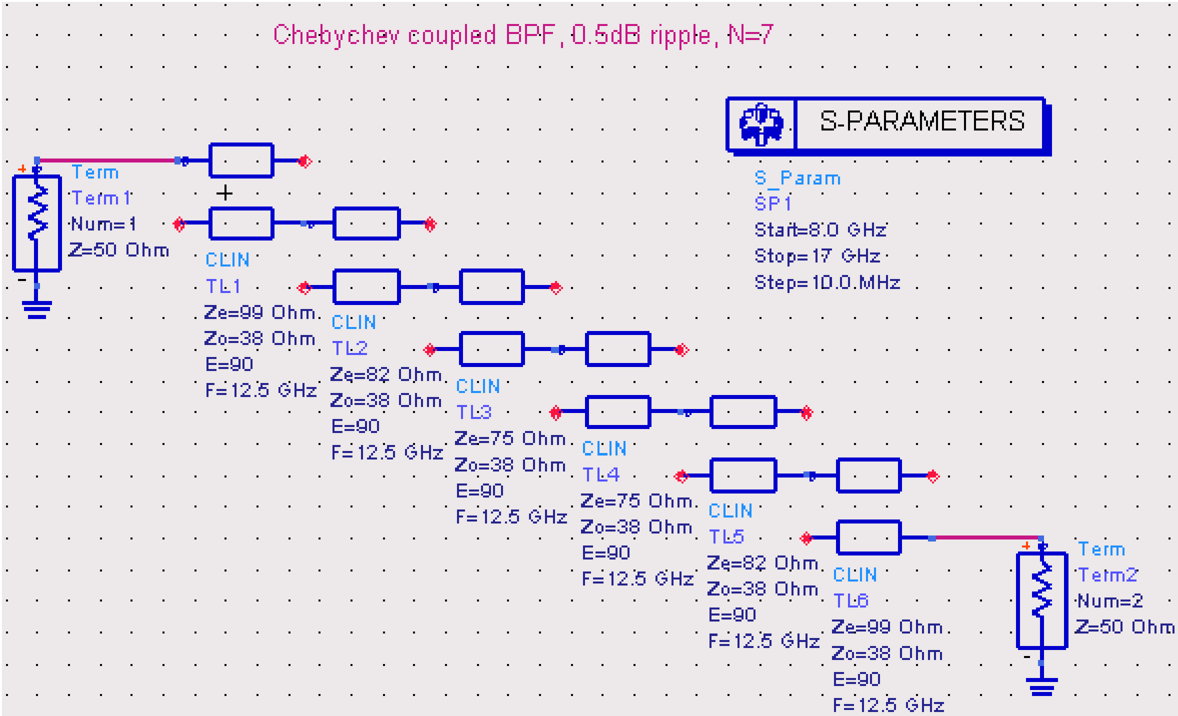
length of each quarter wave coupled section

Simulation Results

To test these values, I have run a simulation on ADS and as you can see the results are in pretty good agreement.







Chebychev coupled BPF, 0.5dB ripple, N=7
S-PARAMETERS
S_Param
SP1
Start=8.0 GHz
Stop=17 GHz
Step=10.0 MHz
Term
Term1
Num=1
Z=50 Ohm
CLIN
TL1
Ze=99 Ohm
Zo=38 Ohm
E=90
F=12.5 GHz
CLIN
TL2
Ze=82 Ohm
Zo=38 Ohm
E=90
F=12.5 GHz
CLIN
TL3
Ze=75 Ohm
Zo=38 Ohm
E=90
F=12.5 GHz
CLIN
TL4
Ze=75 Ohm
Zo=38 Ohm
E=90
F=12.5 GHz
CLIN
TL5
Ze=82 Ohm
Zo=38 Ohm
E=90
F=12.5 GHz
CLIN
TL6
Ze=99 Ohm
Zo=38 Ohm
E=90
F=12.5 GHz
Term
Term2
Num=2
Z=50 Ohm