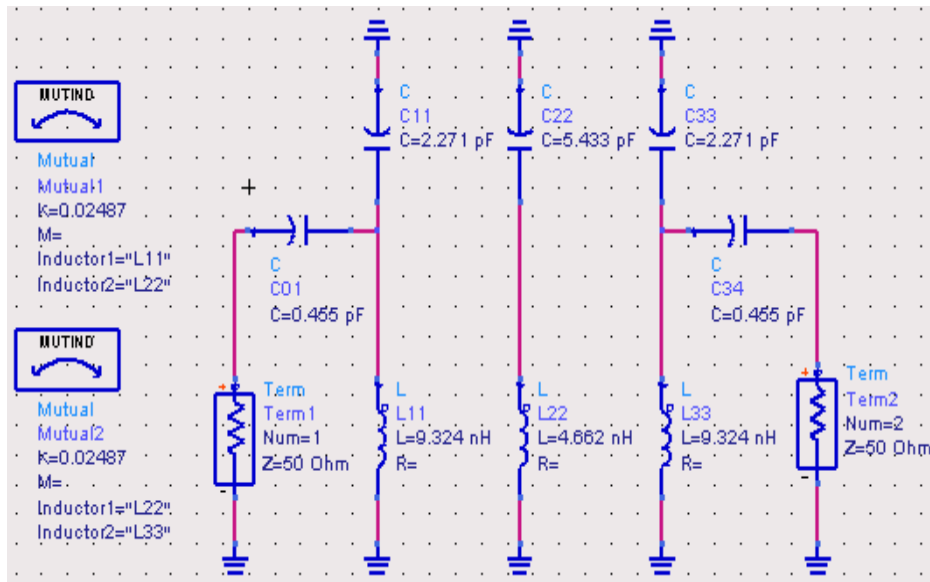


Magnetically Coupled Chebychev BPF

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



This sheet is used to design a **microwave magnetically coupled BPF**. The maths for this filter is derived from equations in "Theory & Design of Microwave Filters", Ian Hunter, IEE Press.

The Chebychev plotting part of this sheet was written by Lance Lascari, <http://tools.rfdude.com>

Main user input area:

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

$L_{\text{ar_db}} := 10$ Passband return loss in dB

$N := 3$ Order of the filter, this needs to be above 2

$f_{\text{gm}} := 1 \cdot \text{GHz}$ $\text{bandwidth} := 20 \cdot \text{MHz}$ $Z_0 := 50 \cdot \Omega$

Start Calculating...

$$f_{\text{low}} := f_{\text{gm}} - \frac{\text{bandwidth}}{2} \quad f_{\text{high}} := f_{\text{gm}} + \frac{\text{bandwidth}}{2} \quad \text{bw} := \frac{f_{\text{high}} - f_{\text{low}}}{f_{\text{gm}}}$$

$$f_{\text{bp}}(f) := \frac{1}{\text{bw}} \cdot \left(\frac{f}{f_{\text{gm}}} - \frac{f_{\text{gm}}}{f} \right) \cdot f_{\text{gm}} \quad \text{bwpercent} := \text{bw} \cdot 100 \quad \alpha := \frac{f_{\text{gm}}}{\text{bandwidth}}$$

bwpercent = 2

$\alpha = 50$

LPF Frequency Response, for Chebychev Polynomials

This section plots the frequency response for the Chebychev BPF

$$Y_o := \frac{1}{Z_o} \quad \varepsilon := \left(10^{\frac{2 \cdot L_{\text{ar_db}}}{10}} - 1 \right)^{-0.5}$$

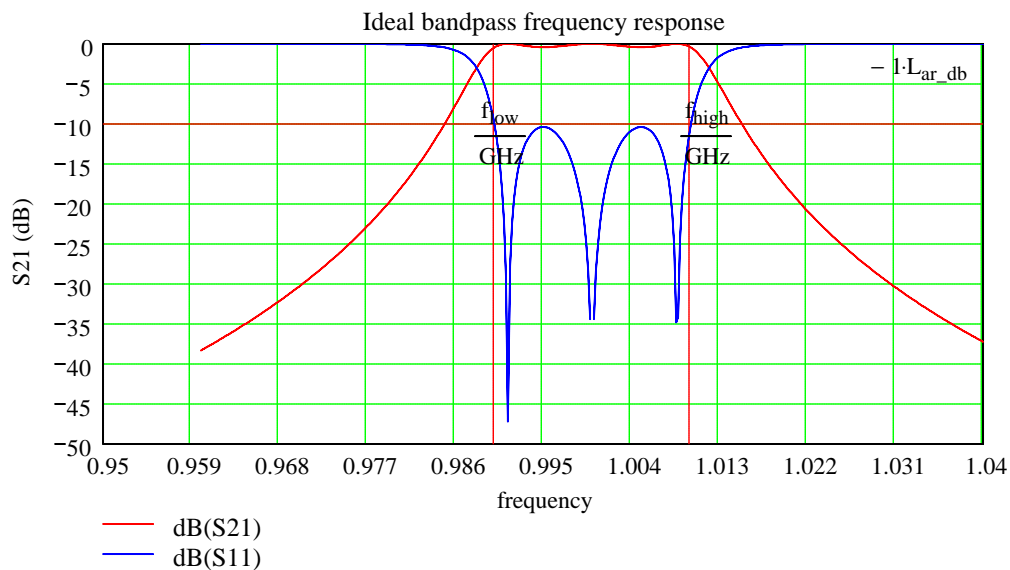
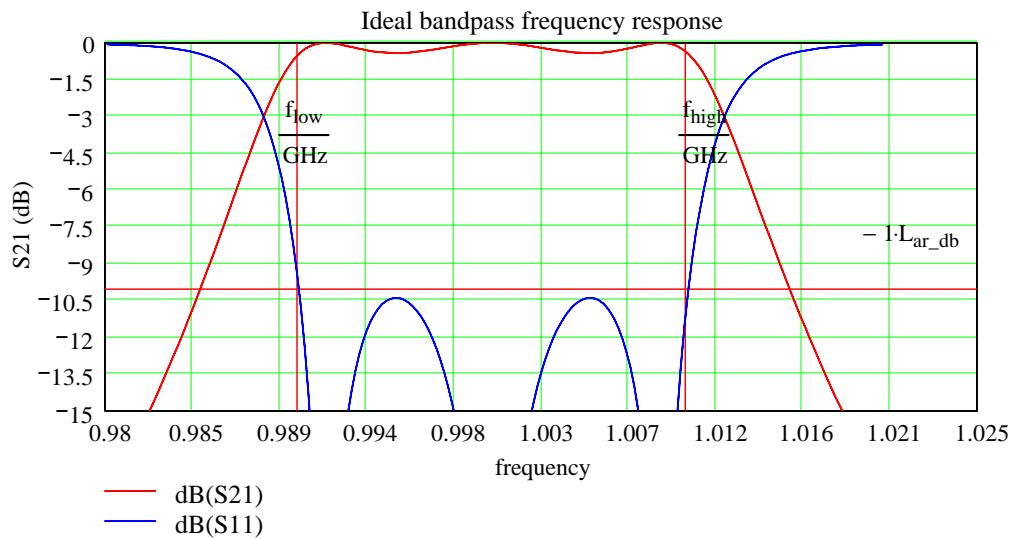
$\varepsilon = 0.1005$

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

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

$$f_{\text{bp_narrow}} := 0.99 \cdot f_{\text{low}}, \frac{f_{\text{high}} - f_{\text{low}}}{100} + 0.99 \cdot f_{\text{low}} .. 1.01 \cdot f_{\text{high}}$$

$$f_{\text{bp_wide}} := (f_{\text{gm}} - 2 \cdot f_{\text{gm}} \cdot \text{bw}), (f_{\text{gm}} - 2 \cdot f_{\text{gm}} \cdot \text{bw}) + \frac{f_{\text{gm}} \cdot \text{bw}}{100} .. f_{\text{gm}} + (2 \cdot f_{\text{gm}} \cdot \text{bw})$$



Calculate the circuit values.....

$$\eta := \sinh\left(\frac{1}{N} \cdot \operatorname{asinh}\left(\frac{1}{\varepsilon}\right)\right) \quad n := 1, 2..N \quad K_{nn, nn+1} := \frac{\left[\eta^2 + \left(\sin\left(\frac{nn \cdot \pi}{N}\right)\right)^2\right]^{0.5}}{\eta}$$

$$mn := 1, 2..N - 1$$

$$C_n := \frac{2}{\eta} \sin\left[\frac{(2 \cdot n - 1) \cdot \pi}{2 \cdot N}\right]$$

$$\operatorname{Cap}_{0,1} := \frac{1}{\left[2 \cdot \pi \cdot f_{gm} \cdot (\alpha - 1)^{0.5} \cdot Z_o\right]}$$

$$\operatorname{Cap}_{N,N+1} := \frac{1}{\left[2 \cdot \pi \cdot f_{gm} \cdot (\alpha - 1)^{0.5} \cdot Z_o\right]}$$

$$\operatorname{Cap}_{0,1} = 0.455 \text{ pF}$$

$$\operatorname{Cap}_{N,N+1} = 0.455 \text{ pF}$$

$$\operatorname{Ind}_{n,n} := \frac{Z_o}{C_n \cdot 2 \cdot \pi \cdot f_{gm}}$$

$$\operatorname{Cap}_{n,n} := \frac{C_n}{2 \cdot \pi \cdot f_{gm} \cdot Z_o}$$

$$\operatorname{Cap}_{1,1} := \frac{C_1}{2 \cdot \pi \cdot f_{gm} \cdot Z_o} - \frac{(\alpha - 1)^{0.5}}{2 \cdot \pi \cdot f_{gm} \cdot Z_o \cdot \alpha}$$

$$\operatorname{Cap}_{N,N} := \operatorname{Cap}_{1,1}$$

Cap _{n,n} =	
2.271	pF
5.433	
2.271	

Ind _{n,n} =	
9.324	nH
4.662	
9.324	

K _{nn, nn+1} =	
α	=
0.02487	
0.02487	

Simulation Results

To test these values I have run a simulation on ADS for $N=3$, Return Loss 10dB, $BW=20\text{MHz}$, $Z_0=50\Omega$.
You can see the results are in good agreement. Both the ripple and return loss (S11) agree.

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.

