Beispiele Filter:

Bsp. Hochpass:
Es ist ein Butterworth Hochpass mit
$f_c = 100$ MHz, $f_H = 50$ MHz, $A_H \geq 50$ dB, $Z_o = 50\ \Omega$
zu dimensionieren. Die Anzahl Induktivitäten soll minimal sein.

$f_H := 50 \cdot 10^6$ $\quad f_c := 100 \cdot 10^6$ $\quad A_H := 50$ $\quad Z_0 := 50$

$\omega_c := 2 \cdot \pi \cdot f_c$

Hochpass - Tiefpass - Transformation:

$$n := \frac{\log\left(10^{\frac{A_H}{10}} - 1\right)}{2 \cdot \log\left(\frac{f_c}{f_H}\right)} \qquad n = 8.305$$

$$n := \mathrm{ceil}(n) \qquad \underline{\underline{n = 9}}$$

Normierte Elementwerte (Tiefpass):

$k := 0 .. n + 1$

$$g(k) := \begin{cases} 1 & \text{if } ((k=0) + (k=n+1)) \\ \left[2 \cdot \sin\left[\frac{(2 \cdot k - 1) \cdot \pi}{2 \cdot n}\right]\right] & \text{otherwise} \end{cases}$$

Pole:

$i := 1 .. n$

$$p(i) := -\sin\left[\frac{(2 \cdot i - 1) \cdot \pi}{2 \cdot n}\right] + j \cdot \cos\left[\frac{(2 \cdot i - 1) \cdot \pi}{2 \cdot n}\right]$$

Resultate Tiefpass (Butterworth):

Ordnung, Anzahl Filterelemente: $n = 9$

Normierte Elementwerte:

k	g(k)
0	1
1	0.347
2	1
3	1.532
4	1.879
5	2
6	1.879
7	1.532
8	1
9	0.347
10	1

Pole:

i	p(i)
1	-0.174+ 0.985j
2	-0.5+ 0.866j
3	-0.766+ 0.643j
4	-0.94+ 0.342j
5	-1
6	-0.94− 0.342j
7	-0.766− 0.643j
8	-0.5− 0.866j
9	-0.174− 0.985j

Tiefpass - Hochpass - Transformation:

Entnormierte Elementwerte (Hochpass):

$$R(k) := g(k) \cdot Z_0$$

$$L(k) := Z_0 \cdot \frac{1}{\omega_c \cdot g(k)}$$

$$C(k) := \frac{1}{g(k) \cdot Z_0 \cdot \omega_c}$$

Ein- und Ausgangswiderstand: $R(0) = 50$ $R(n+1) = 50$

Entnormierte Elementwerte (Hochpass):

Erstes Element = Serie

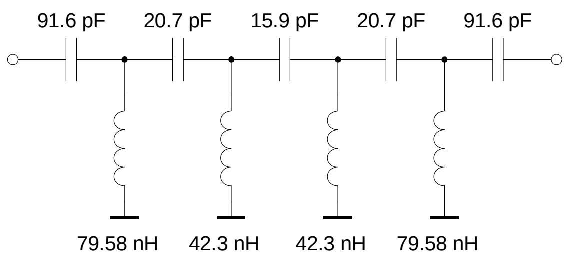
s	C(s)
1	$9.165 \cdot 10^{-11}$
3	$2.078 \cdot 10^{-11}$
5	$1.592 \cdot 10^{-11}$
7	$2.078 \cdot 10^{-11}$
9	$9.165 \cdot 10^{-11}$

p	L(p)
2	$7.958 \cdot 10^{-8}$
4	$4.234 \cdot 10^{-8}$
6	$4.234 \cdot 10^{-8}$
8	$7.958 \cdot 10^{-8}$

Erstes Element = Parallel $s := 1, 3 .. n$ $p := 2, 4 .. n$

s	L(s)
1	$2.291 \cdot 10^{-7}$
3	$5.194 \cdot 10^{-8}$
5	$3.979 \cdot 10^{-8}$
7	$5.194 \cdot 10^{-8}$
9	$2.291 \cdot 10^{-7}$

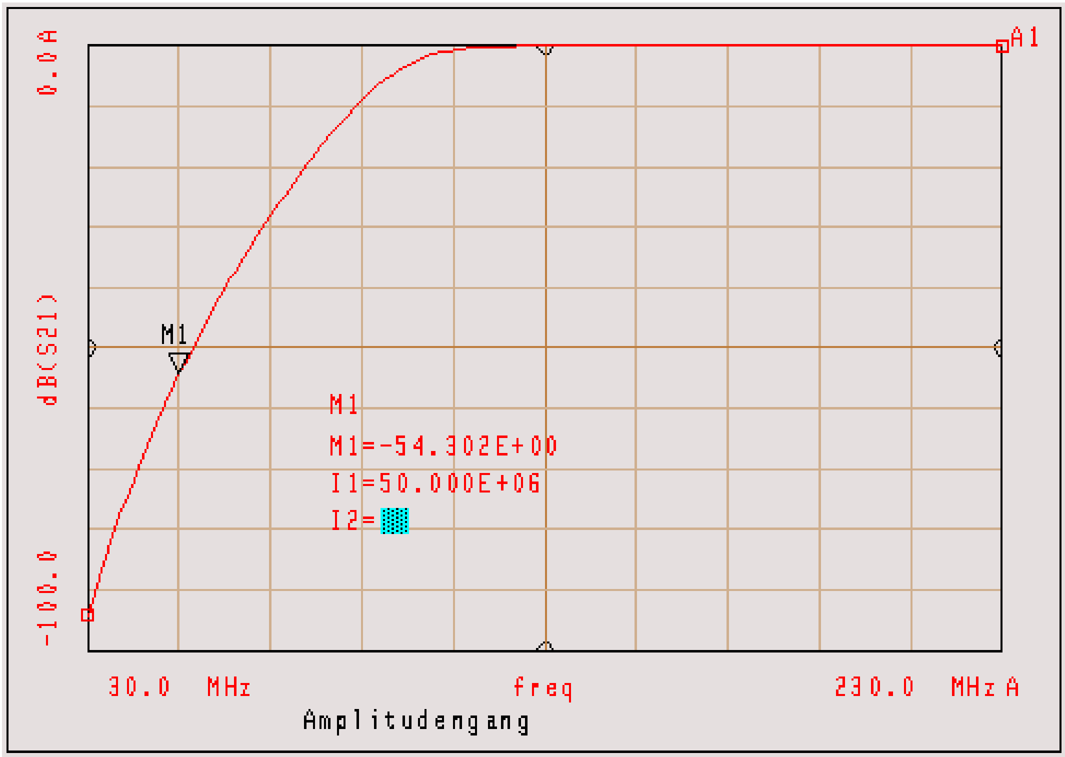
p	C(p)
2	$3.183 \cdot 10^{-11}$
4	$1.694 \cdot 10^{-11}$
6	$1.694 \cdot 10^{-11}$
8	$3.183 \cdot 10^{-11}$

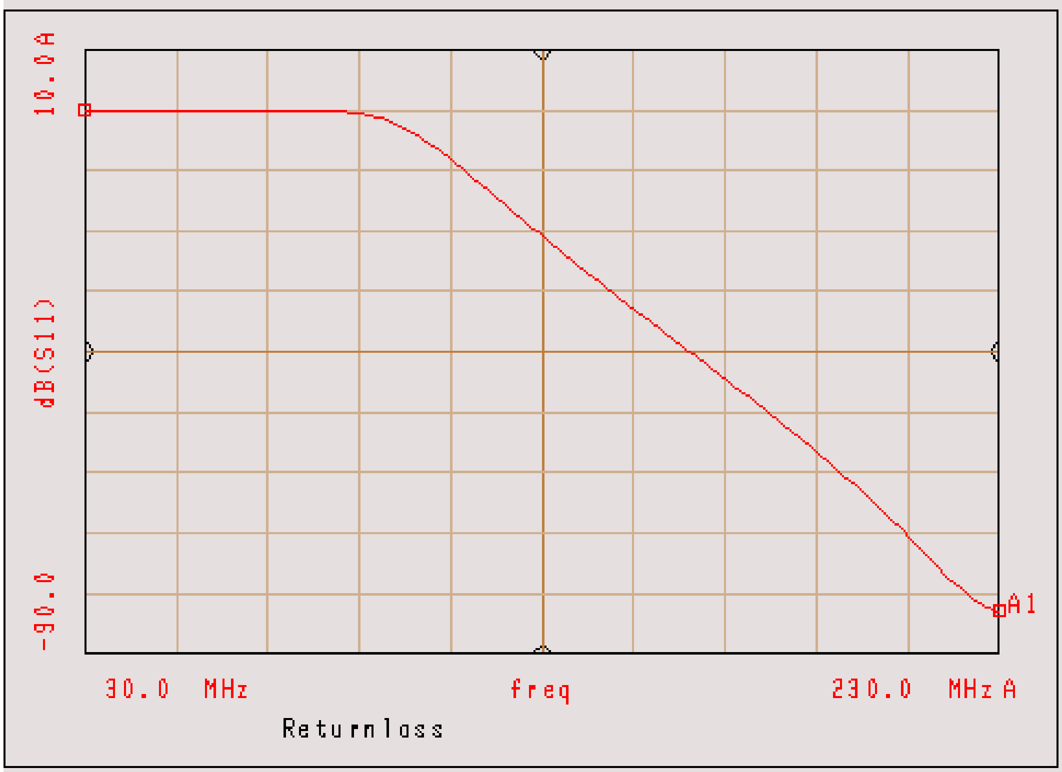


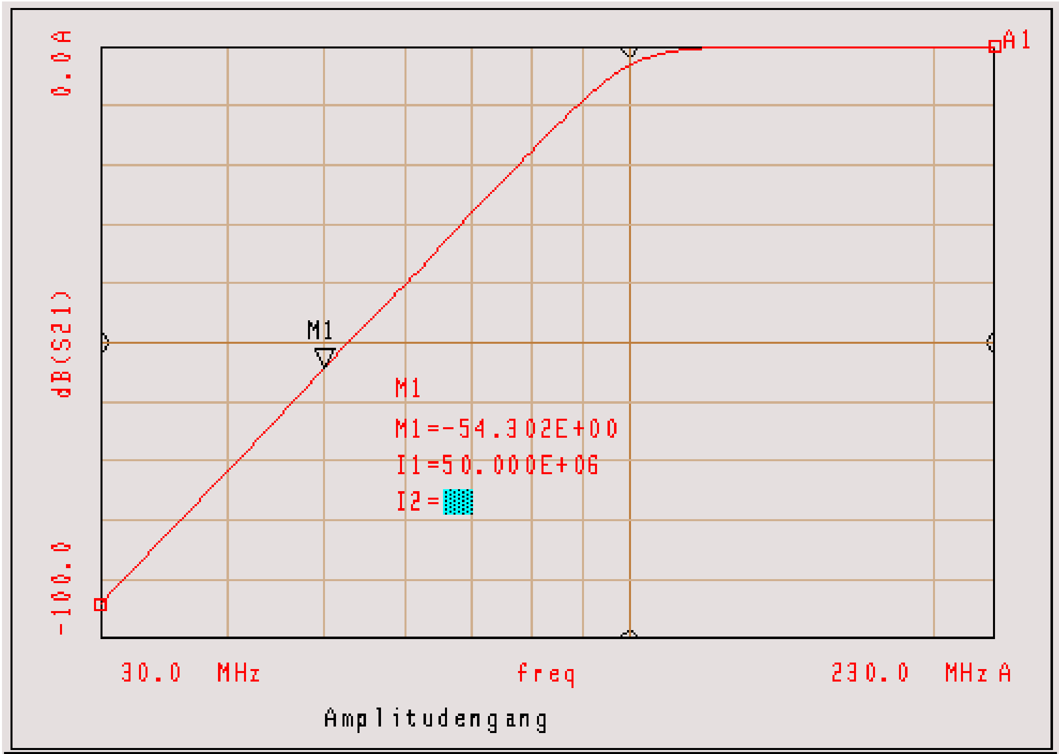
Bei 50 MHz:

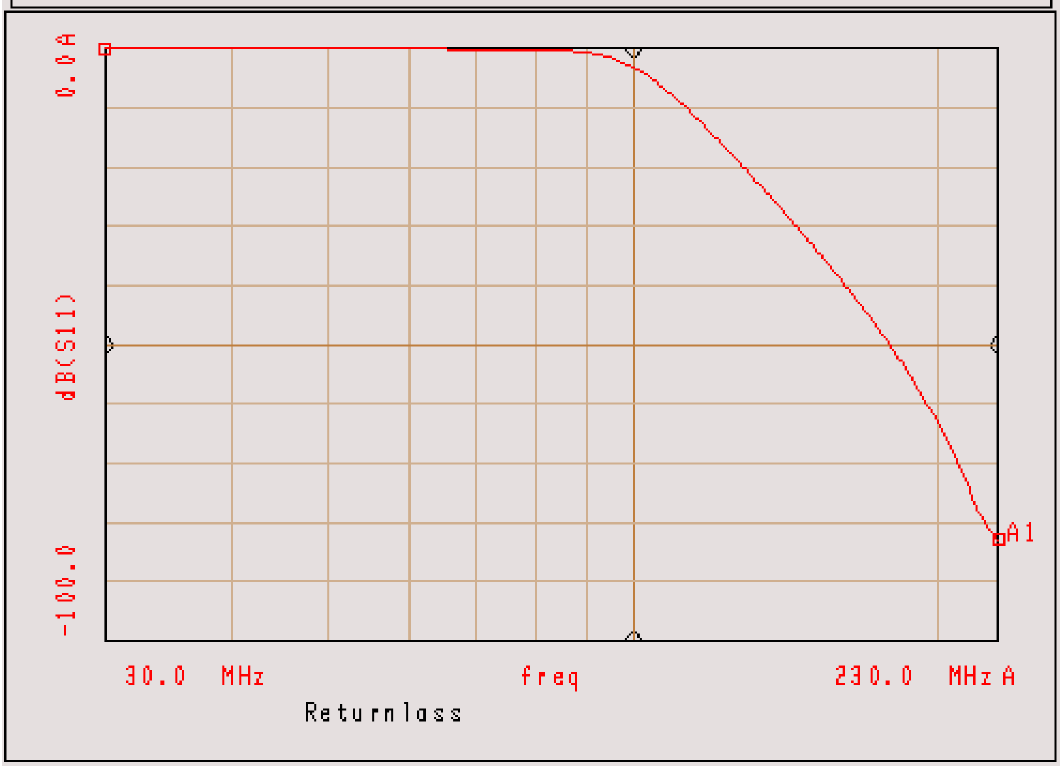
$$A := 10 \cdot \log\left[1 + \left(\frac{100 \cdot 10^6}{50 \cdot 10^6}\right)^{2 \cdot n}\right]$$

$A = 54.185$ dB


A1
0.0A
dB(S21)
-100.0
M1
M1
M1=-54.302E+00
I1=50.000E+06
I2=
30.0 MHz
freq
230.0 MHz A
Amplitudengang


10.0A
dB(S11)
-90.0
A1
30.0 MHz
freq
230.0 MHz A
Returnloss


0.0 A
dB(S21)
-100.0
M1
M1
M1=-54.302E+00
I1=50.000E+06
I2=
A1
30.0 MHz
freq
230.0 MHz A
Amplitudengang


0.0 A
dB(S11)
-100.0
A1
30.0 MHz
freq
230.0 MHz A
Returnloss

Bsp Bandsperre:

Es ist eine Chebishev Bandsperre mit
$f_1 = 110$ MHz, $f_2 = 130$ MHz,
$f_a = 115$ MHz, $f_b = 125$ MHz,
$A_H \geq 20$ dB, $A_r = 0.05$ dB
$Z_o = 50\ \Omega$
zu dimensionieren. 1. Element = parallel.
Wie gross ist A_H bei f_a, f_b?

Chebishev-Bandsperre:

$f_1 := 110 \cdot 10^6$ $\quad f_2 := 130 \cdot 10^6$ $\quad A_H := 20$ $\quad A_r := 0.05$

$f_a := 115 \cdot 10^6$ $\quad f_b := 125 \cdot 10^6$ $\quad Z_0 := 50$

Bandsperre - Tiefpasstransformation:

$$f_0 := \sqrt{f_1 \cdot f_2} \qquad f_0 = 1.196 \cdot 10^8$$

$$w := \frac{f_2 - f_1}{f_0} \qquad w = 0.167$$

$$P := \frac{w}{\left| \frac{f_a}{f_0} - \frac{f_0}{f_a} \right|} \qquad P = 2.14$$

$$\varepsilon := \sqrt{10^{\frac{A_r}{10}} - 1} \qquad \varepsilon = 0.108$$

$$n := \frac{\operatorname{arcosh}\left[\sqrt{\frac{10^{\frac{A_H}{10}} - 1}{\varepsilon^2}}\right]}{\operatorname{arcosh}(P)} \qquad n = 3.745$$

$n := \operatorname{ceil}(n)$ $\quad n = 4$

Da Ein- und Ausgang $= Z_0$: n = ungerade = 5

$n := 5$

Normierte Elementwerte (Tiefpass):

$k := 0..\ n+1$

$$m := \ln\left(\coth\left(\frac{A_r}{40\cdot\log(e)}\right)\right) \qquad a(k) := \sin\left[\frac{(2\cdot k-1)\cdot\pi}{2\cdot n}\right]$$

$$q := \sinh\left(\frac{m}{2\cdot n}\right) \qquad b(k) := q^2 + \sin\left(\frac{k\cdot\pi}{n}\right)^2 \qquad v := \begin{cases} 1 & \text{if } \mathrm{mod}(n,2)=1 \\ \coth\left(\frac{m}{4}\right)^2 & \text{otherwise} \end{cases}$$

$$g(k) := \begin{cases} 1 & \text{if } (k=0) \\ \frac{2\cdot a(1)}{q} & \text{if } (k=1) \\ v & \text{if } k=n+1 \\ \frac{4\cdot a(k-1)\cdot a(k)}{b(k-1)\cdot g(k-1)} & \text{otherwise} \end{cases}$$

Pole: $i := 1..\ n$

$$p(i) := -\sin\left[\frac{(2\cdot i-1)\cdot\pi}{2\cdot n}\right]\cdot\sinh\left(\frac{1}{n}\cdot\mathrm{arsinh}\left(\frac{1}{\varepsilon}\right)\right) + j\ \cdot\cos\left[\frac{(2\cdot i-1)\cdot\pi}{2\cdot n}\right]\cdot\cosh\left(\frac{1}{n}\cdot\mathrm{arsinh}\left(\frac{1}{\varepsilon}\right)\right)$$

$$R(k) := g(k)\cdot Z_0$$

Resultate (Chebishev):

Ordnung, Anzahl Filterelemente: $n = 5$

Ein- und Ausgangswiderstand: $R(0) = 50 \qquad R(n+1) = 50$

Normierte Elementwerte:

k =	g(k) =
0	1
1	0.998
2	1.375
3	1.828
4	1.375
5	0.998
6	1

Pole:

i =	p(i) =
1	-0.191+1.119j
2	-0.501+0.691j
3	-0.619
4	-0.501-0.691j
5	-0.191-1.119j

Tiefpass - Bandsperre - Transformation:

Entnormierte Elementwerte (Bandsperre): Erstes Element = parallel

$$C_{1p} := \frac{w \cdot g(1)}{2 \cdot \pi \cdot f_0 \cdot Z_0} \qquad C_{1p} = 4.445 \cdot 10^{-12}$$

$$L_{1p} := \frac{Z_0}{2 \cdot \pi \cdot f_0 \cdot g(1) \cdot w} \qquad L_{1p} = 3.985 \cdot 10^{-7}$$

$$C_{2s} := \frac{1}{2 \cdot \pi \cdot f_0 \cdot g(2) \cdot Z_0 \cdot w} \qquad C_{2s} = 1.158 \cdot 10^{-10}$$

$$L_{2s} := \frac{g(2) \cdot Z_0 \cdot w}{2 \cdot \pi \cdot f_0} \qquad L_{2s} = 1.53 \cdot 10^{-8}$$

$$C_{3p} := \frac{g(3) \cdot w}{2 \cdot \pi \cdot f_0 \cdot Z_0} \qquad C_{3p} = 8.139 \cdot 10^{-12}$$

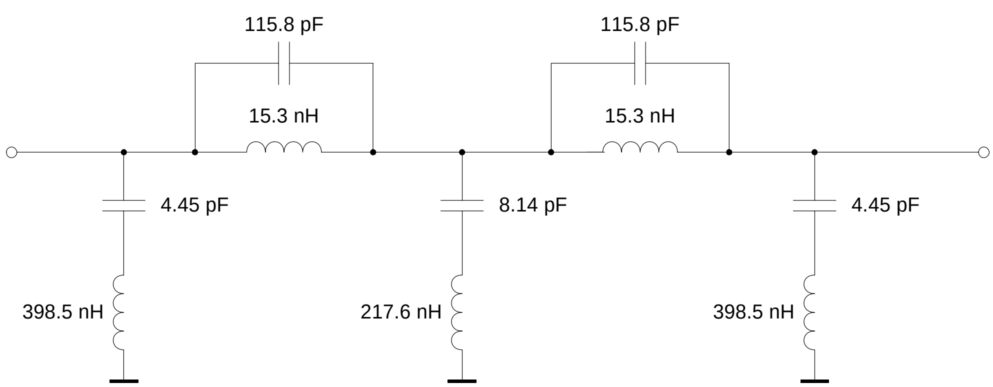
$$L_{3p} := \frac{Z_0}{2 \cdot \pi \cdot f_0 \cdot g(3) \cdot w} \qquad L_{3p} = 2.176 \cdot 10^{-7}$$

$$C_{4s} := \frac{1}{2 \cdot \pi \cdot f_0 \cdot g(4) \cdot Z_0 \cdot w} \qquad C_{4s} = 1.158 \cdot 10^{-10}$$

$$L_{4s} := \frac{g(4) \cdot Z_0 \cdot w}{2 \cdot \pi \cdot f_0} \qquad L_{4s} = 1.53 \cdot 10^{-8}$$

$$C_{5p} := \frac{g(5) \cdot w}{2 \cdot \pi \cdot f_0 \cdot Z_0} \qquad C_{5p} = 4.445 \cdot 10^{-12}$$

$$L_{5p} := \frac{Z_0}{2 \cdot \pi \cdot f_0 \cdot g(5) \cdot w} \qquad L_{5p} = 3.985 \cdot 10^{-7}$$

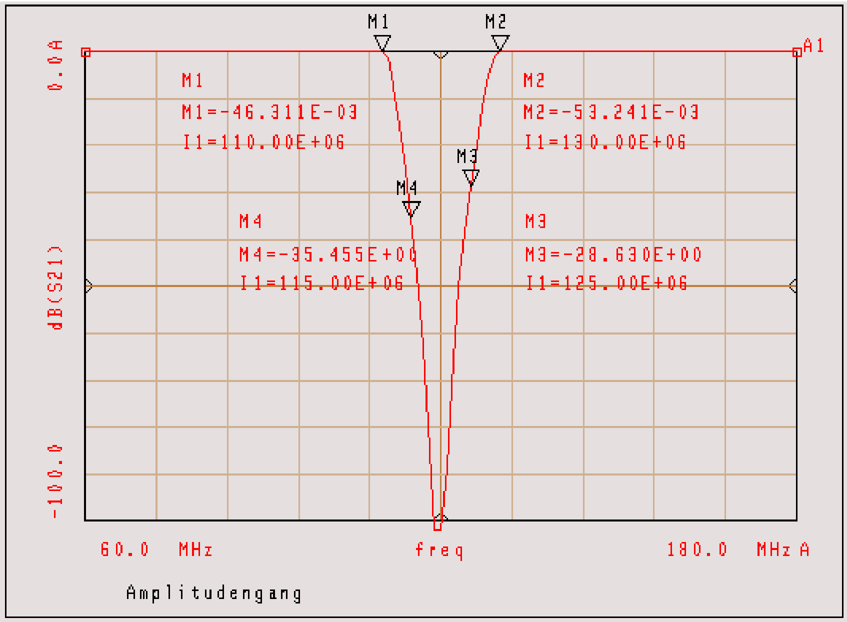


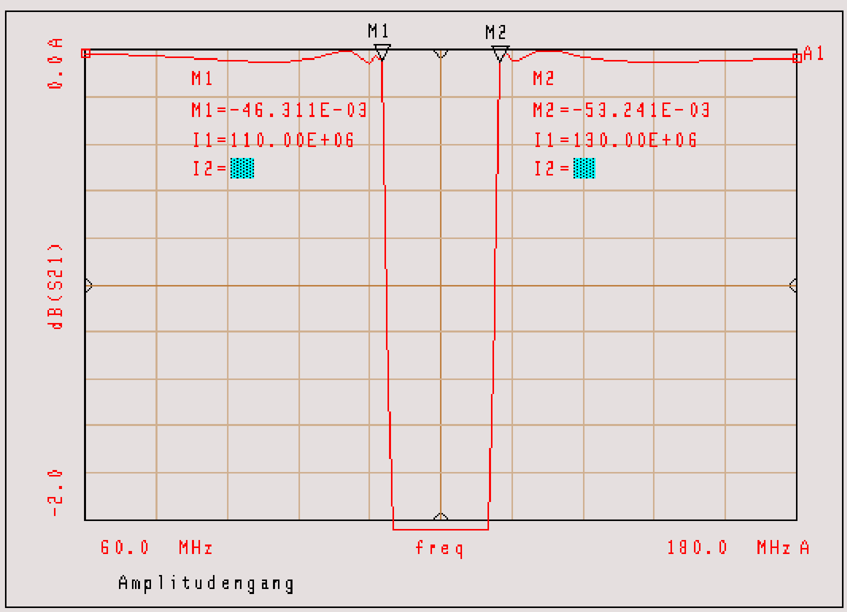
bei f_a:

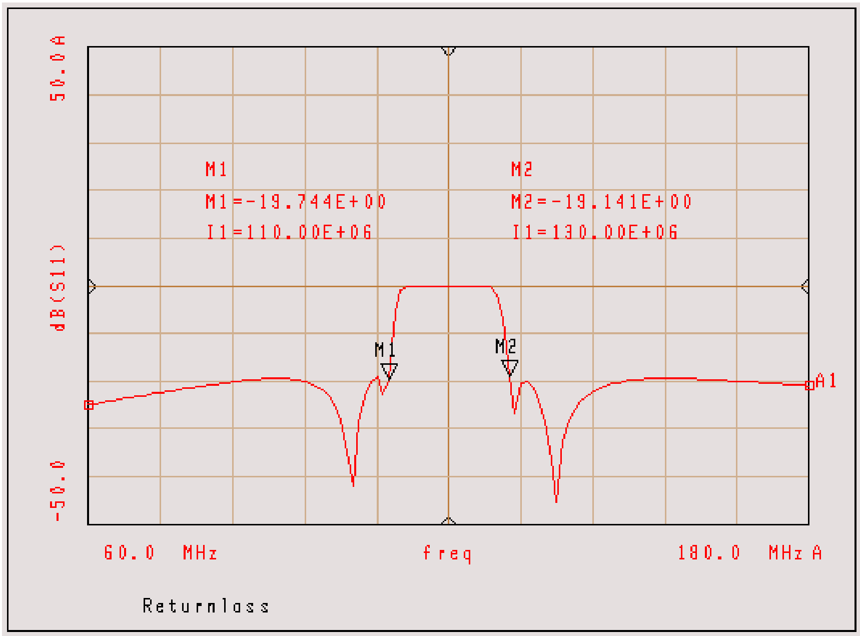
$$A_H := 10 \cdot \log\left[1 + \varepsilon^2 \cdot \left[\cosh\left[n \cdot \operatorname{arcosh}\left[\frac{w}{\left|\frac{f_a}{f_0} - \frac{f_0}{f_a}\right|}\right]\right]\right]^2\right] \qquad A_H = 35.159$$

bei f_b:

$$A_H := 10 \cdot \log\left[1 + \varepsilon^2 \cdot \left[\cosh\left[n \cdot \operatorname{arcosh}\left[\frac{w}{\left|\frac{f_b}{f_0} - \frac{f_0}{f_b}\right|}\right]\right]\right]^2\right] \qquad A_H = 28.865$$







50.0 A
dB(S11)
-50.0
M1
M1=-19.744E+00
I1=110.00E+06
M2
M2=-19.141E+00
I1=130.00E+06
M1
M2
A1
60.0 MHz
freq
180.0 MHz A
Returnloss