HF/50MHz Receiving and Transmitting Band Pass Filters with 3 Equal Inductors –part1

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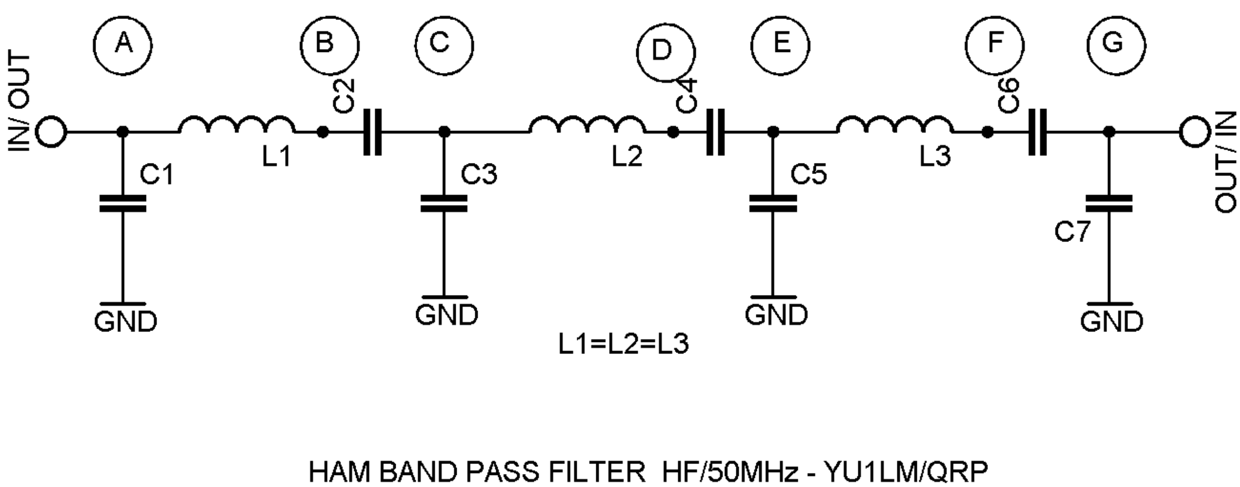
I designed and realized a lot different types filters. Starting SDR design the new moments for me was that it is necessary to have band-pass (BP) filters which can be used in receiving and transmitting paths. This series of 4-5 articles are my research how to do and solve these requirements at the best and simple way. Different filters in other parts are results of some transformation delta to star (tee) and vice versa and different schematics approach. I added some files from simulation in LT Spice [2] freeware software also to show voltage and current in all nodes to be aware capacitors component quality from break voltage and current point of view. All components are taken in analyses with real losses. The designer's target specification at the start was:

1. The filters have IL(insertion loss) lower than 0.5dB (~11% power loss with inductors Qo ~150-200)
2. All filter components values have to be standard values.
3. Coils are without taps!
4. Inductors can be changed with RF chokes than filter IL have to be smaller than 2dB.
5. Termination return loss S11, S22 are better than -20dB (VSWR=1.22).
6. Frequencies harmonically related to central frequency from lower and upper side are attenuated ~30dB or more.
7. BP filters have 50Ohms termination impedance and filters are symmetrical structure and it is not important what is input or output.
8. Calculated bandwidth -3dB 10-25% of central frequency
9. No tune design and design with low sensitivity to component tolerances

The first BP filter is realized like it is proposed at picture 1 down.

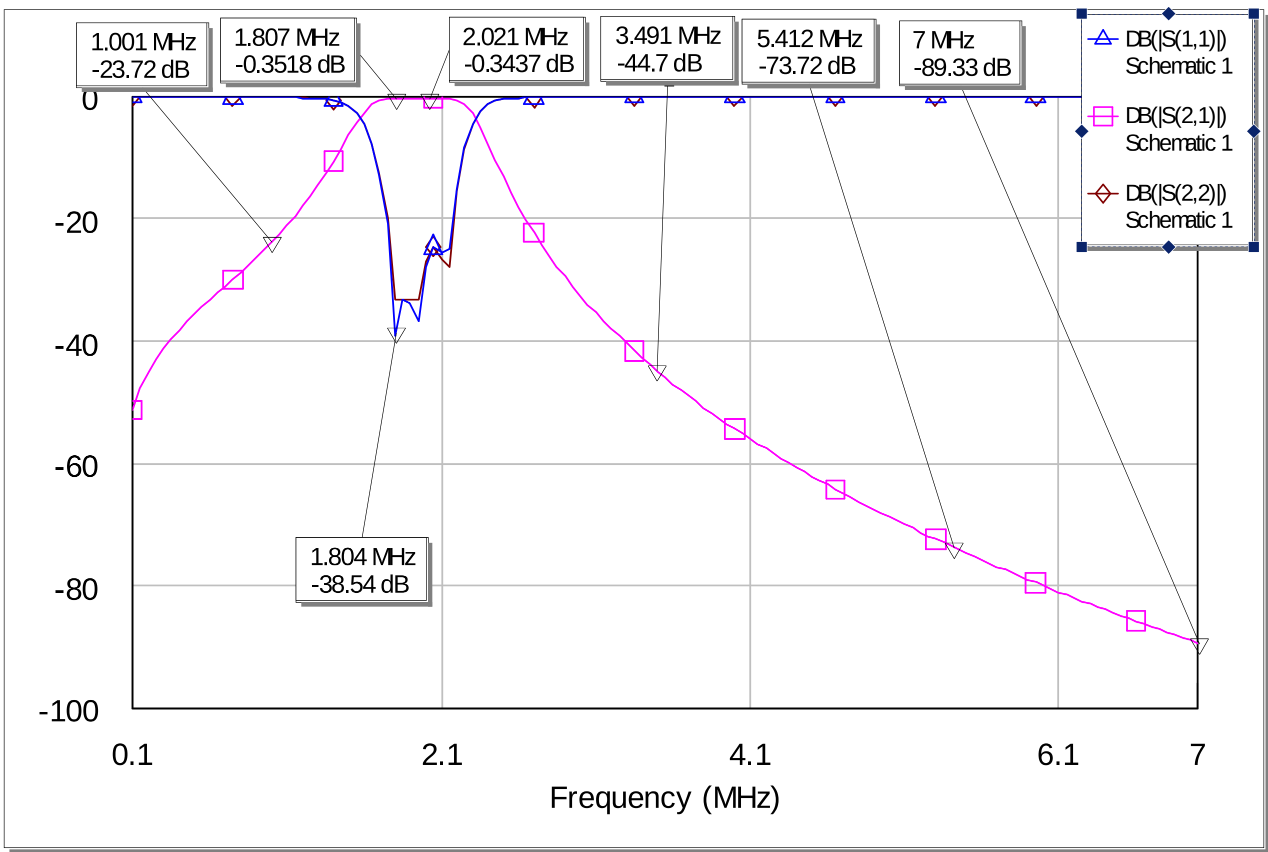


Picture1. HF/50 MHz BP (band-pass) filter version 1.

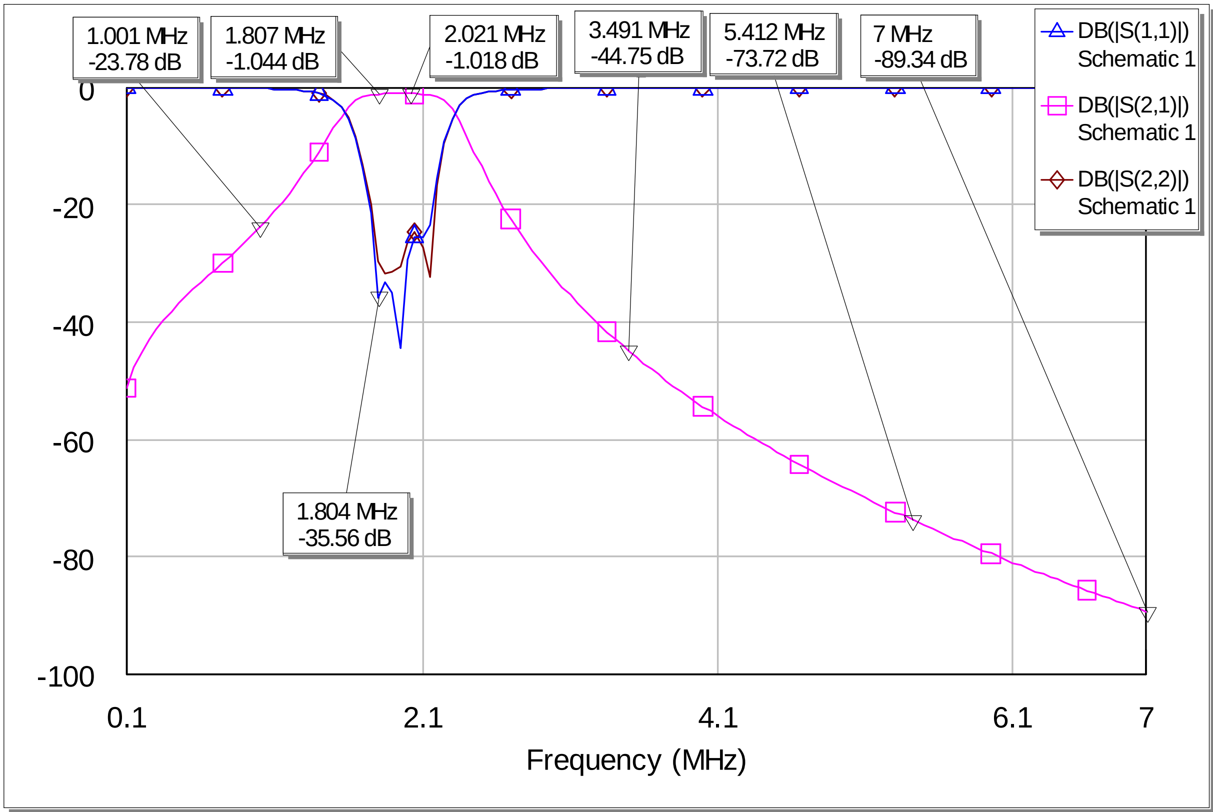
The component values for L and C are in table 1 and frequency response at other pictures down.

BAND	L[uH]	C1[pF]	C2[pF]	C3[pF]	C4[pF]	C5[pF]	C6[pF]	C7[pF]
1.8MHz	**12**	**560**	**820**	**2200**	**1000**	**2200**	**820**	**680**
3.5MHz	**6.8**	**33**	**330**	**1000**	**470**	**1000**	**330**	**33**
7MHz	**3.3**	**0**	**180**	**560**	**270**	**560**	**180**	**0**
10MHz	**2.2**	**27**	**150**	**390**	**220**	**390**	**150**	**27**
14MHz	**1.5**	**10**	**100**	**270**	**150**	**270**	**100**	**10**
14-18MHz	**1.2**	**39**	**120**	**270**	**270**	**270**	**120**	**39**
21-24MHz	**0.82**	**68**	**100**	**220**	**120**	**220**	**100**	**68**
24-28MHz	**0.68**	**22**	**68**	**150**	**100**	**150**	**68**	**22**
50MHz	**0.47**	**47**	**33**	**120**	**33**	**120**	**33**	**47**

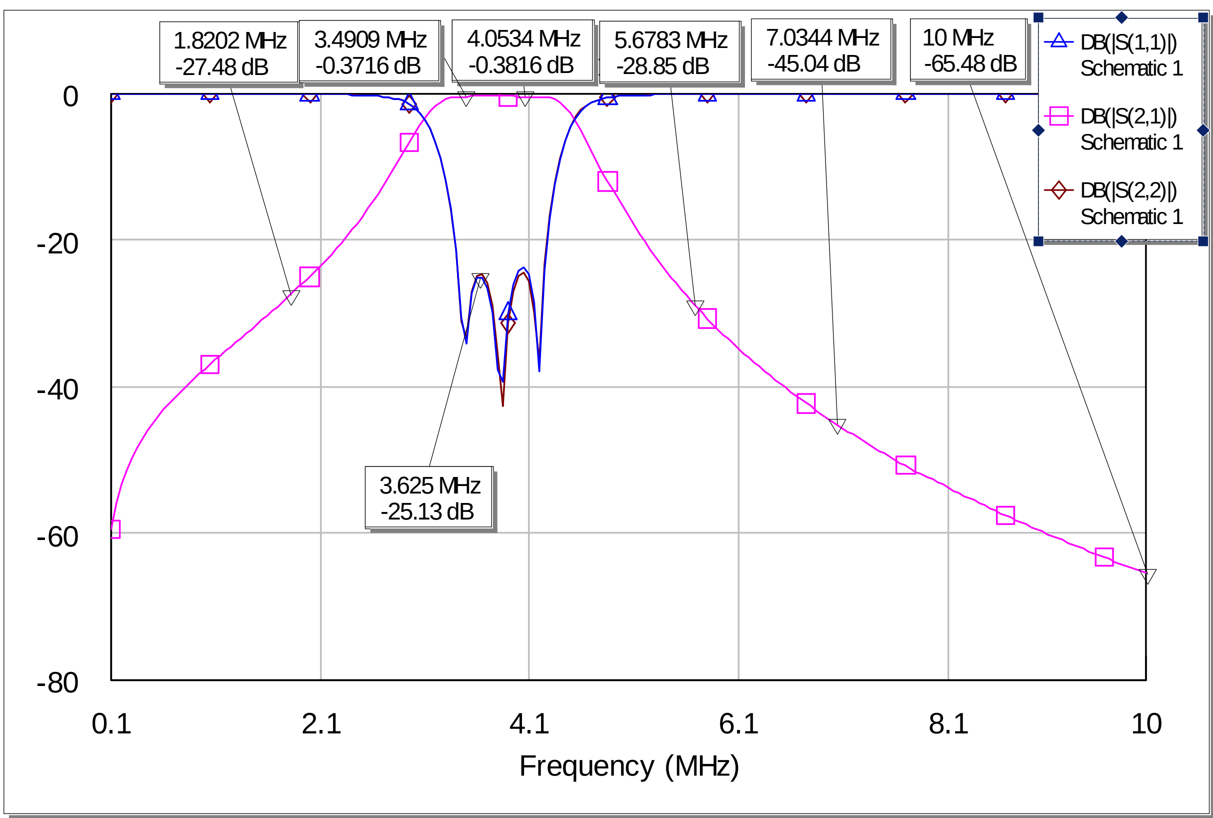
Table1. Element values for BP filters



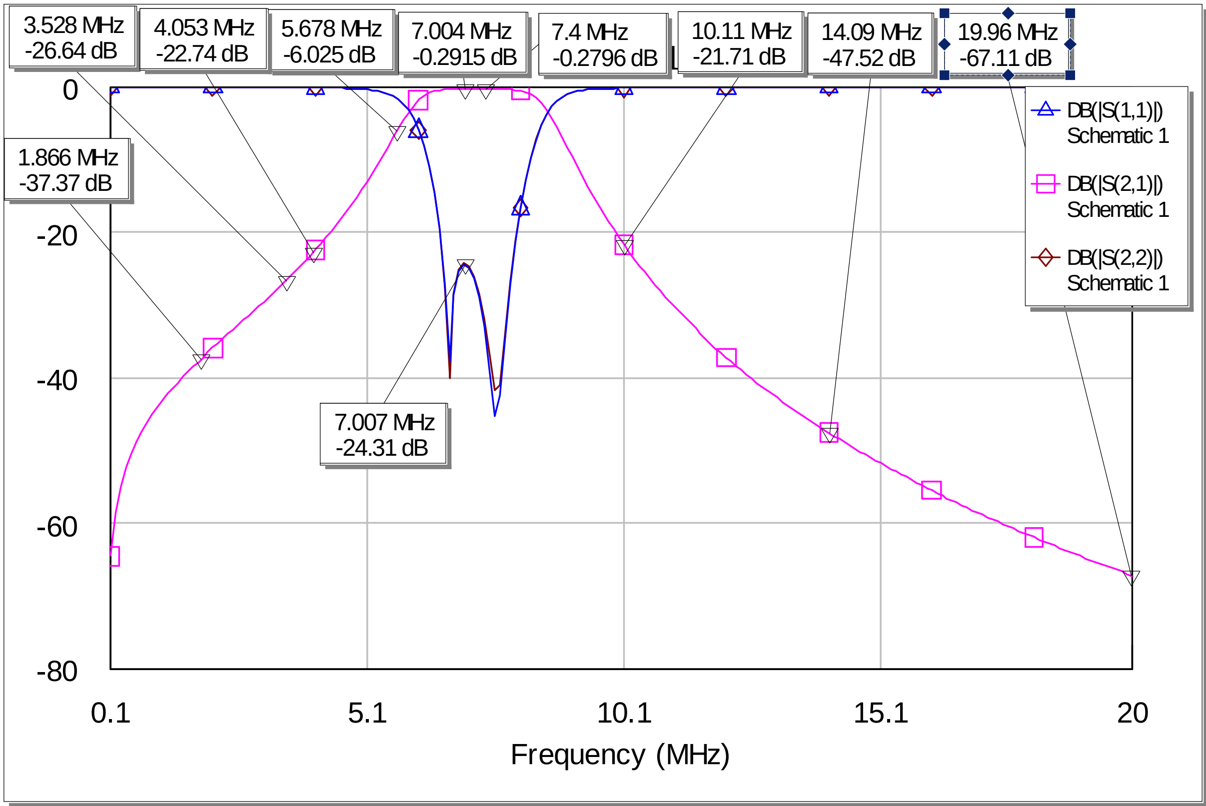
BP Filter for 1.8MHz



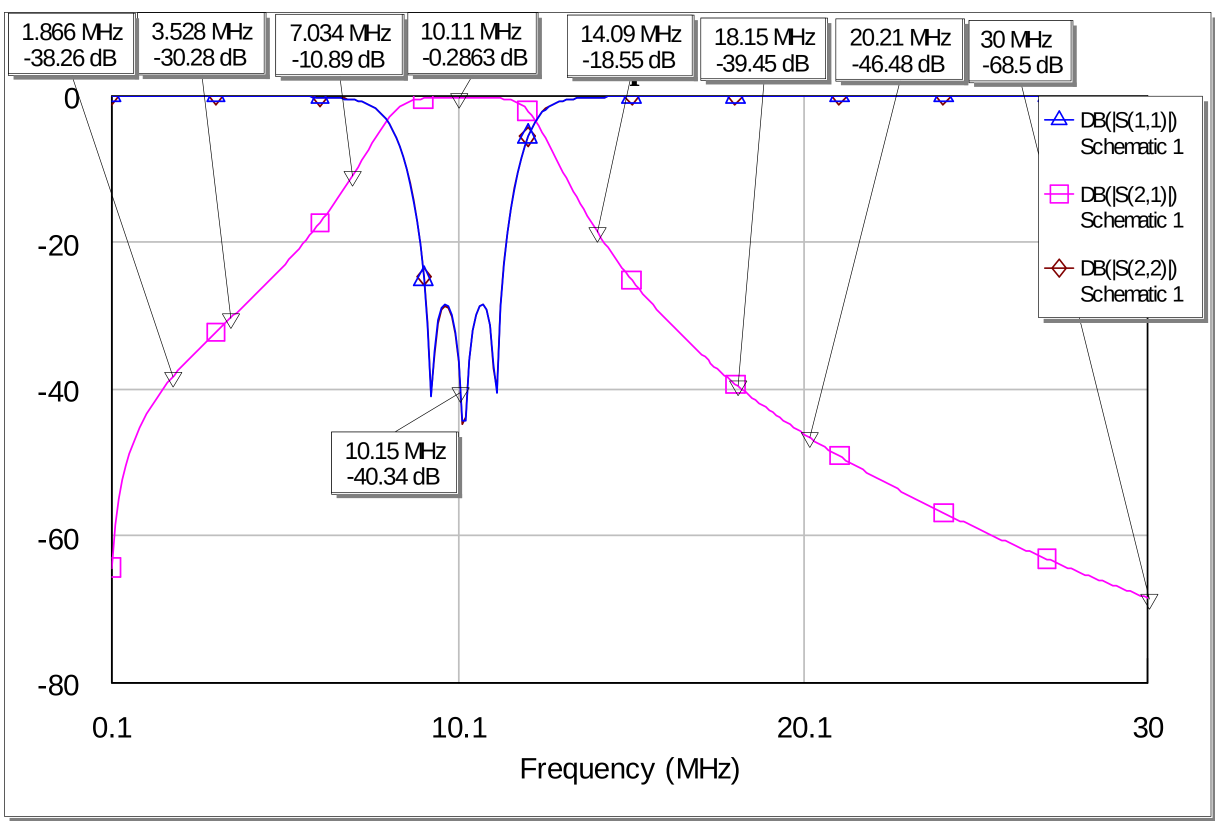
BP Filter for 1.8MHz high Q inductors were changed with choke Qo~60. BP IL is increasing for 0.7dB (use only in receiving part)



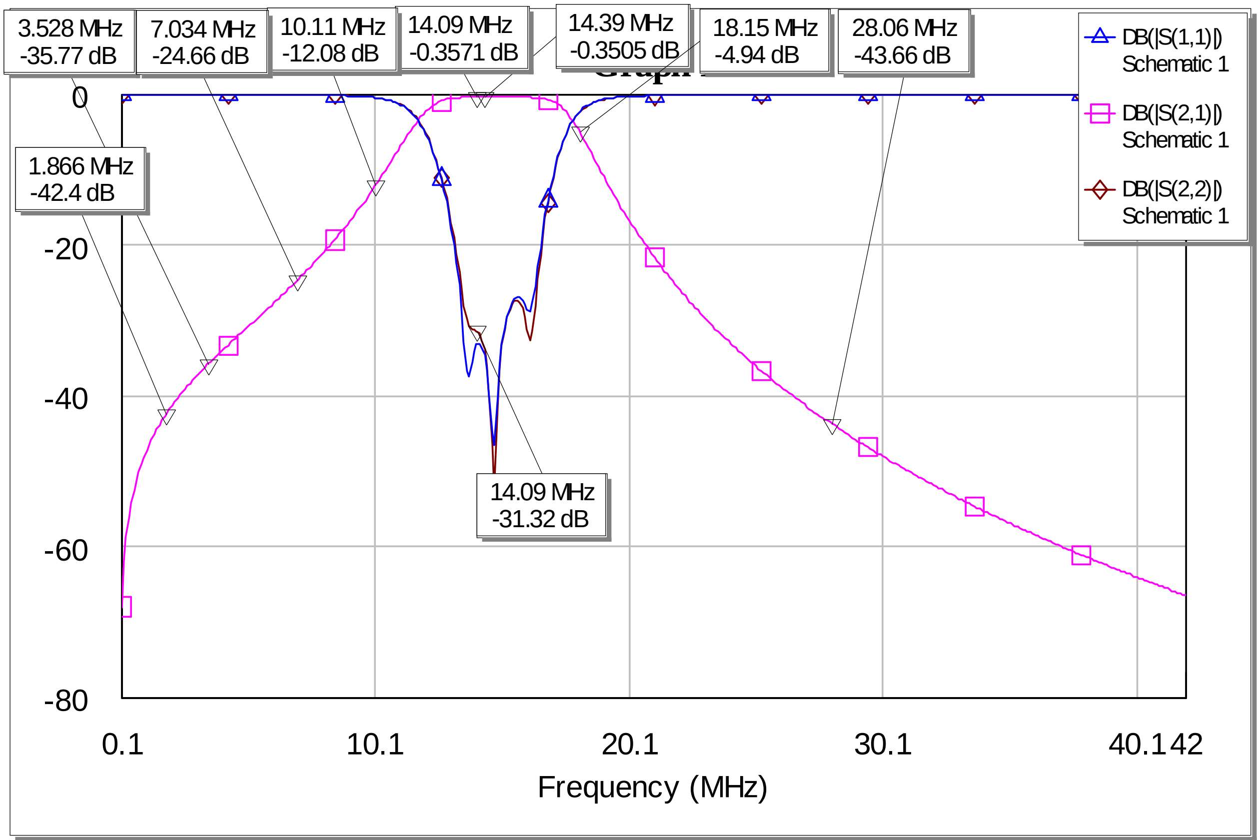
BP Filter for 3.5MHz



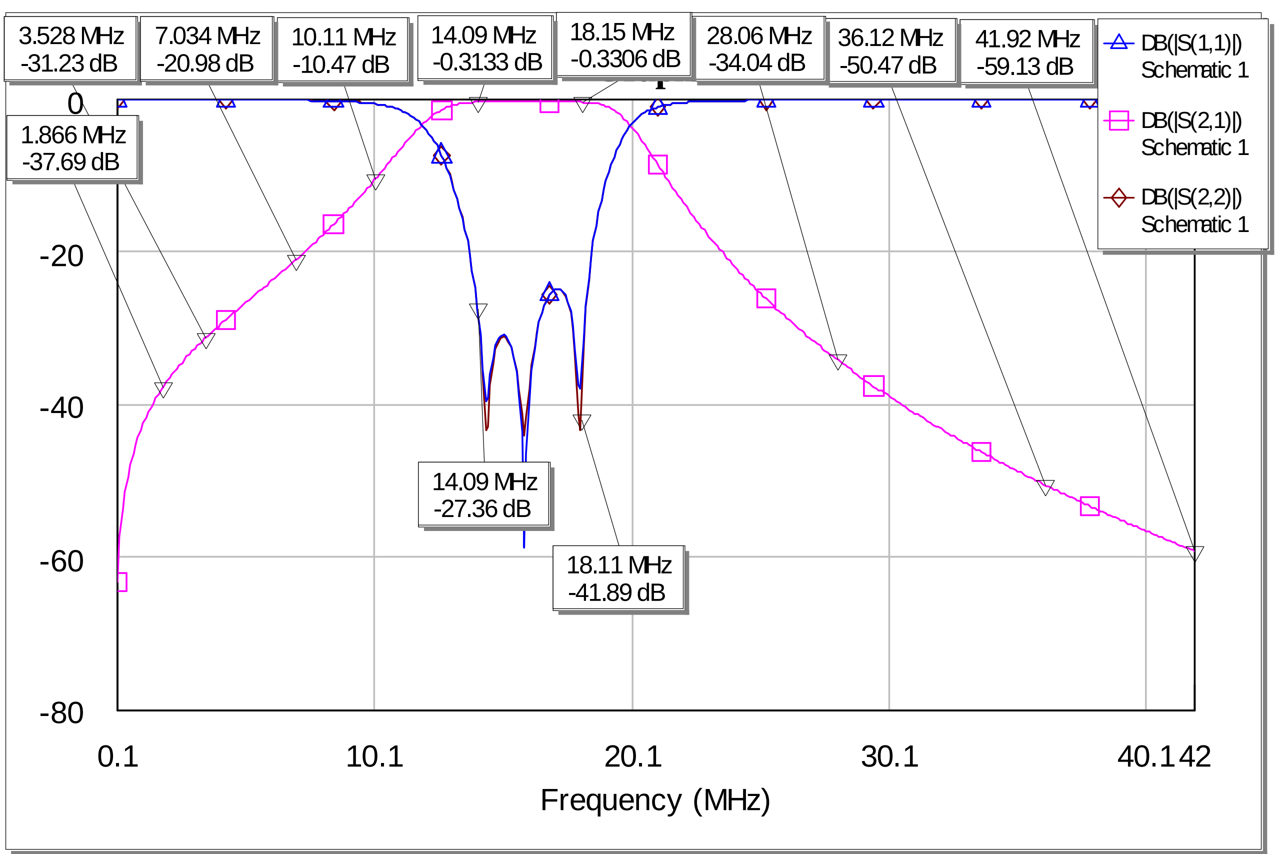
BP Filter for 7MHz



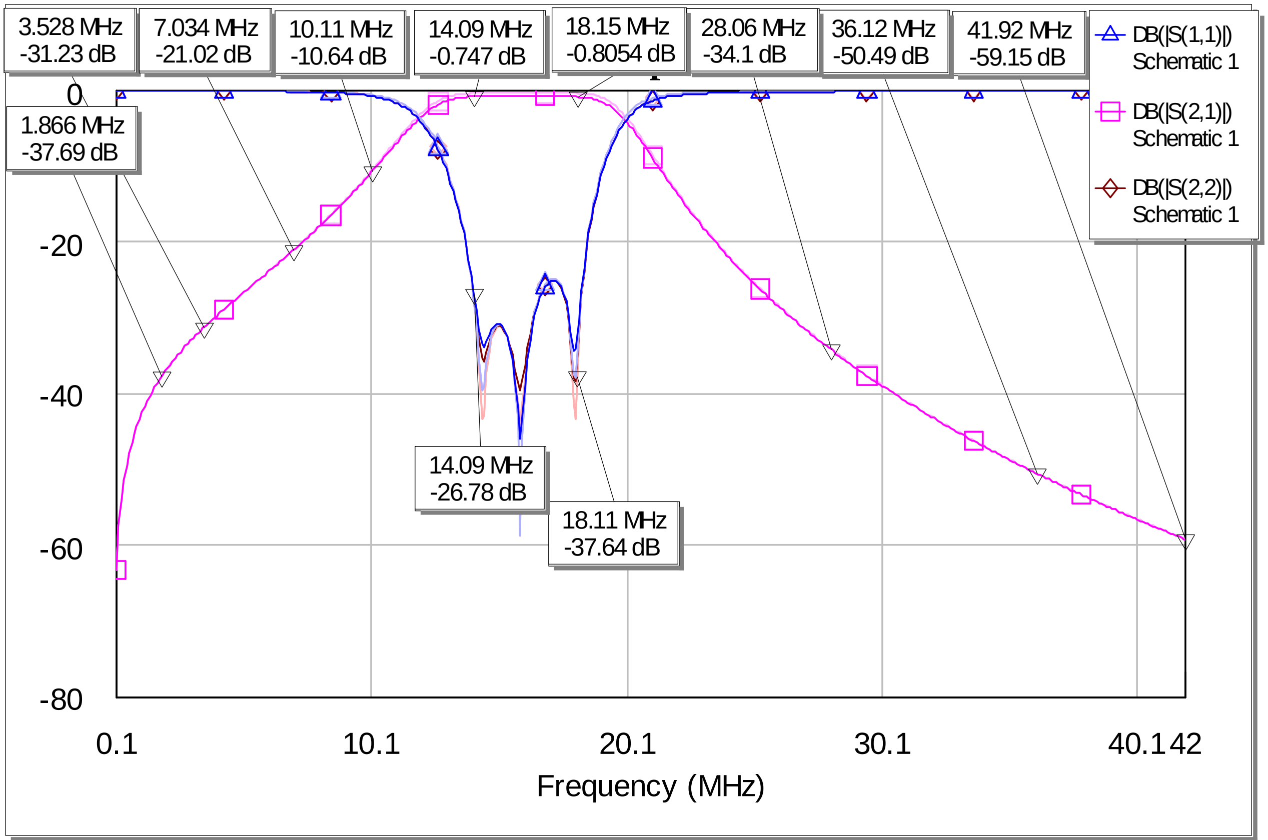
BP Filter for 10MHz



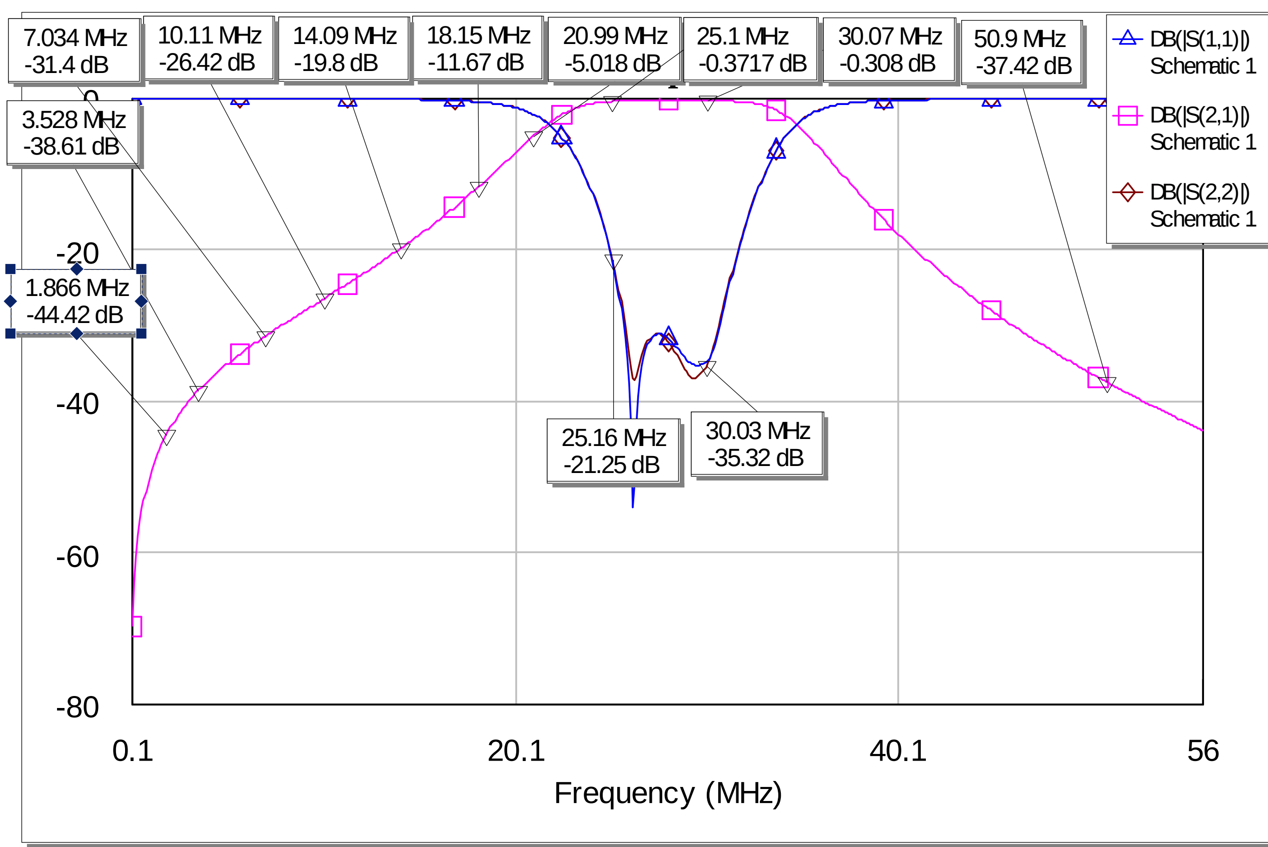
BP Filter for 14MHz



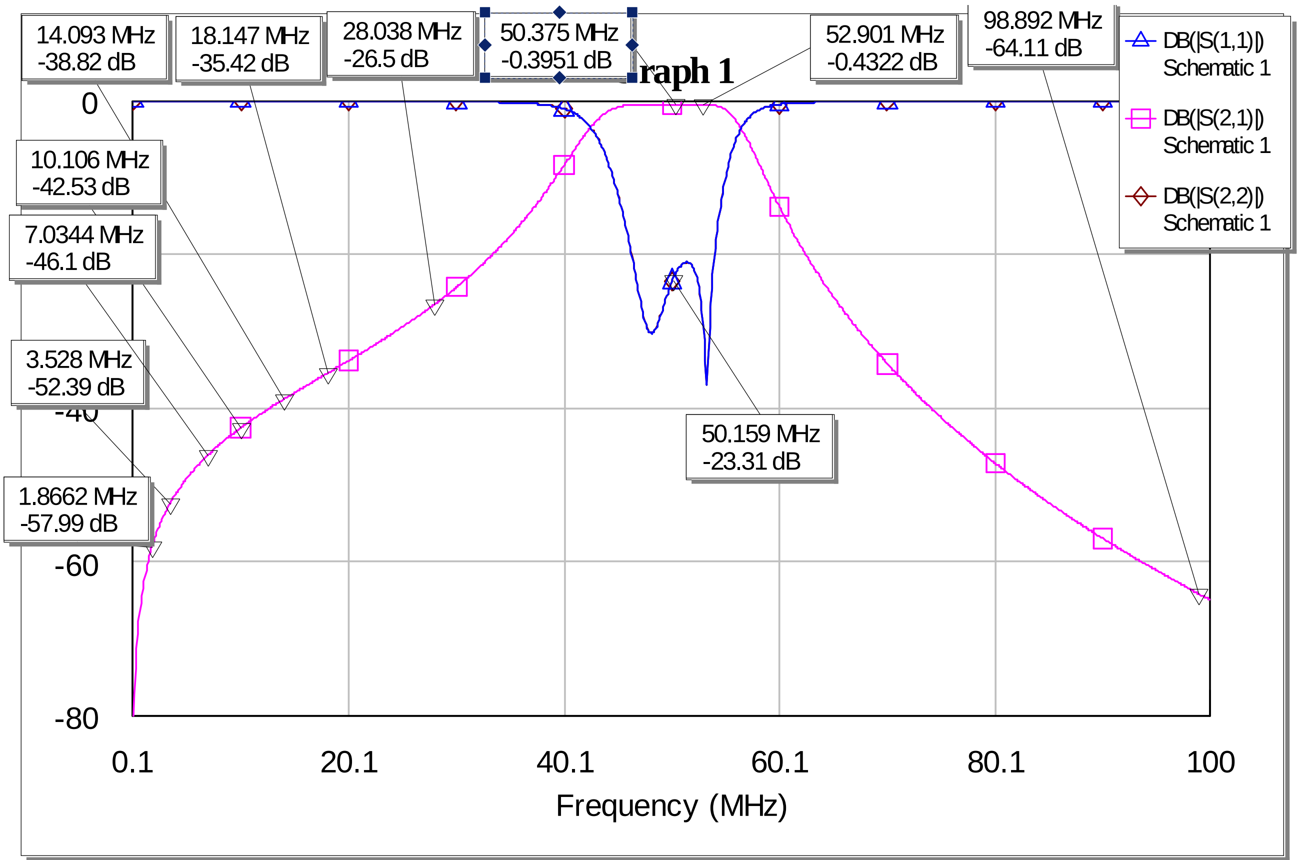
BP Filter for 14-18MHz



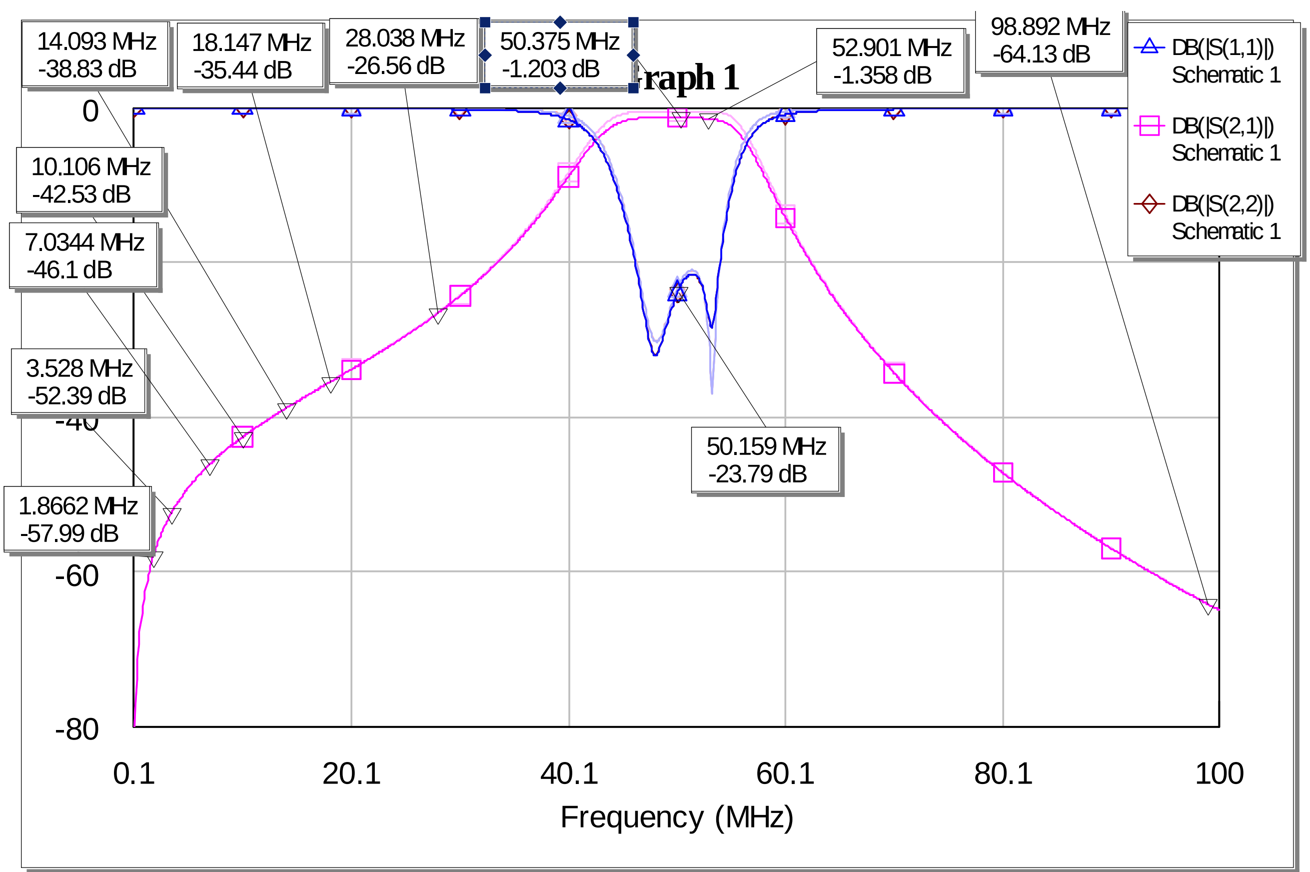
BP filter for 14-18MHz high Q inductor were changed with choke Qo~60. BP IL is increasing for 0.5dB (use only in receiving part)



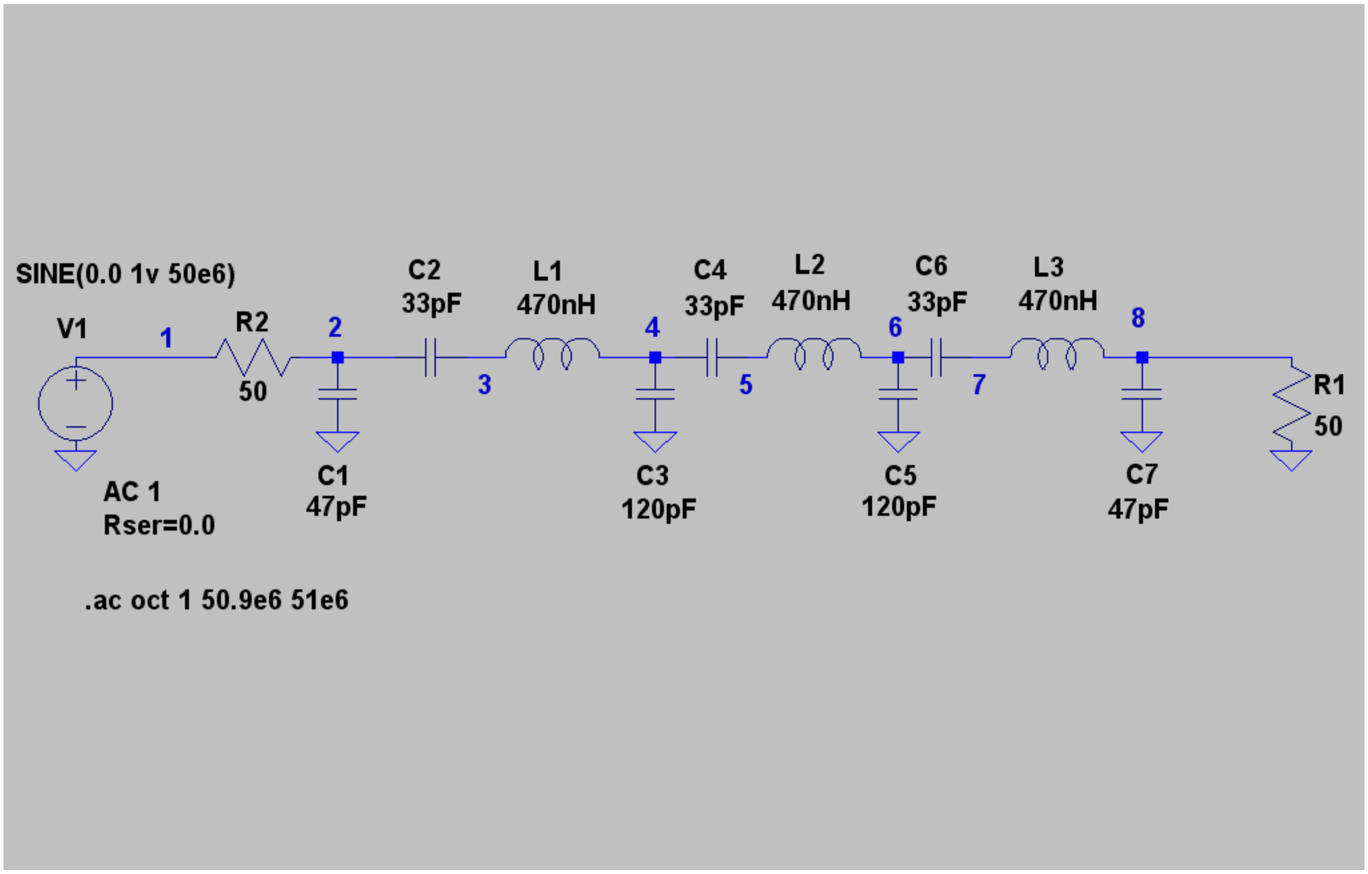
BP Filer for 24-30MHz



BP Filter for 50-52MHz



BP Filter for 50MHz high Q inductors were changed with chokes Qo~60. BP IL is increasing for 0.8dB (use only in receiving part)



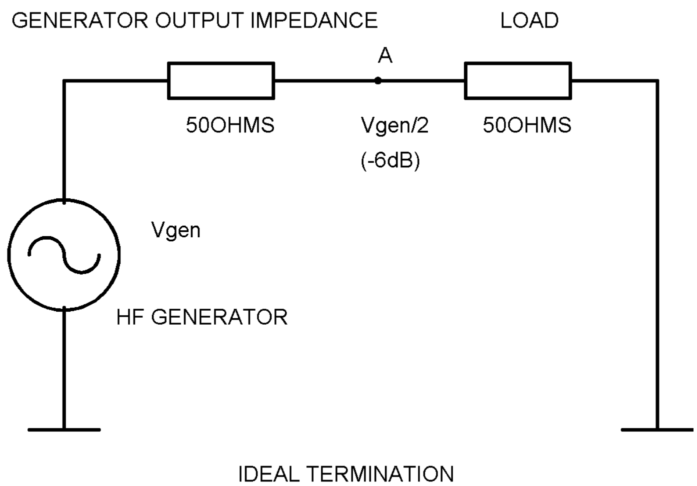
TX=100W VSWR=1.0 voltage magnitude in [V] and current in [A] peak

```
frequency:     5.1e+007       Hz
V(n002):       mag:    108.952 phase: -0.0132292°        voltage
V(n003):       mag:     315.23 phase:    33.0984°        voltage
V(n004):       mag:    103.461 phase:   -80.5319°        voltage
V(n005):       mag:    381.266 phase:   -52.1328°        voltage
V(n006):       mag:    112.705 phase:     171.92°        voltage
V(n007):       mag:    325.498 phase:   -157.324°        voltage
V(n008):       mag:     99.593 phase:    89.8427°        voltage
V(n001):       mag:        200 phase:          0°        voltage
I(C7):         mag:    1.49995 phase:  -0.157315°        device_current
I(C6):         mag:    2.49346 phase:    126.824°        device_current
I(C5):         mag:    4.33384 phase:    81.9198°        device_current
I(C4):         mag:    3.11313 phase:   -132.511°        device_current
I(C3):         mag:    3.97841 phase:   -170.532°        device_current
I(C2):         mag:     2.4506 phase:     137.98°        device_current
I(C1):         mag:     1.6409 phase:    89.9868°        device_current
I(L3):         mag:    2.49346 phase:    126.824°        device_current
I(L2):         mag:    3.11313 phase:   -132.511°        device_current
I(L1):         mag:     2.4506 phase:   -42.0199°        device_current
I(R2):         mag:    1.82096 phase:   -179.984°        device_current
I(R1):         mag:    1.99186 phase:    89.8427°        device_current
I(V1):         mag:    1.82096 phase:   -179.984°        device_current
```

TX=5W VSWR=1.0 voltage magnitude in [V] and current in [A] peak

```
frequency:     5.1e+007       Hz
V(n002):       mag:    24.5142 phase: -0.0132292°        voltage
V(n003):       mag:    70.9267 phase:    33.0984°        voltage
V(n004):       mag:    23.2788 phase:   -80.5319°        voltage
V(n005):       mag:    85.7849 phase:   -52.1328°        voltage
V(n006):       mag:    25.3585 phase:     171.92°        voltage
V(n007):       mag:     73.237 phase:   -157.324°        voltage
V(n008):       mag:    22.4084 phase:    89.8427°        voltage
V(n001):       mag:         45 phase: -2.20872e-018°     voltage
I(C7):         mag:   0.337489 phase:  -0.157315°        device_current
I(C6):         mag:   0.561029 phase:    126.824°        device_current
I(C5):         mag:   0.975114 phase:    81.9198°        device_current
I(C4):         mag:   0.700455 phase:   -132.511°        device_current
I(C3):         mag:   0.895143 phase:   -170.532°        device_current
I(C2):         mag:   0.551384 phase:     137.98°        device_current
I(C1):         mag:   0.369203 phase:    89.9868°        device_current
I(L3):         mag:   0.561029 phase:    126.824°        device_current
I(L2):         mag:   0.700455 phase:   -132.511°        device_current
I(L1):         mag:   0.551384 phase:   -42.0199°        device_current
I(R2):         mag:   0.409716 phase:   -179.984°        device_current
I(R1):         mag:   0.448168 phase:    89.8427°        device_current
I(V1):         mag:   0.409716 phase:   -179.984°        device_current
I(V1):         mag:   0.291354 phase:   -179.984°        device_current
```

Pictures are taken from LTspice CAD simulation of BP filter for 50MHz. Little explanation of picture ideal voltage generator have output impedance zero at HF systems output impedance is 50Ohms and load is also 50 Ohms in ideal case that mean that we are losing half voltage (-6dB) in transfer from ideal generator to ideal load VSWR=1.0 .



Notice at diagram that it is difference between input port 2 and critical nodes 3 (6 and7) near 3 times but most critical is C4 nodes 4 and 5 voltage is 4 time input voltage. In case normal HF/VHF RIG with power amplifier Pout=100W=50dBm Veff=70.1V and peak value is Vpeak =100V. Built in capacitors have to be with breaking voltage of min 500V. In the case QRP power amplifier Pout =5W =37dBm Veff=15.83V or Vpeak= 22.5V . Built in capacitors for QRP output power have to be with minimum breaking voltage of 100V and this is quite different compared with classic LP low pass in power amplifiers!!!!! For classic solution with LP and for QRP output power it is enough build in capacitors with breaking voltage of 50V!!! All this observations and calculations are OK if we have acceptable VSWR to VSWR=2. With VSWR over 3 capacitors must be with higher breaking voltage specification for 100W 1000V and for QRP powers 200V!

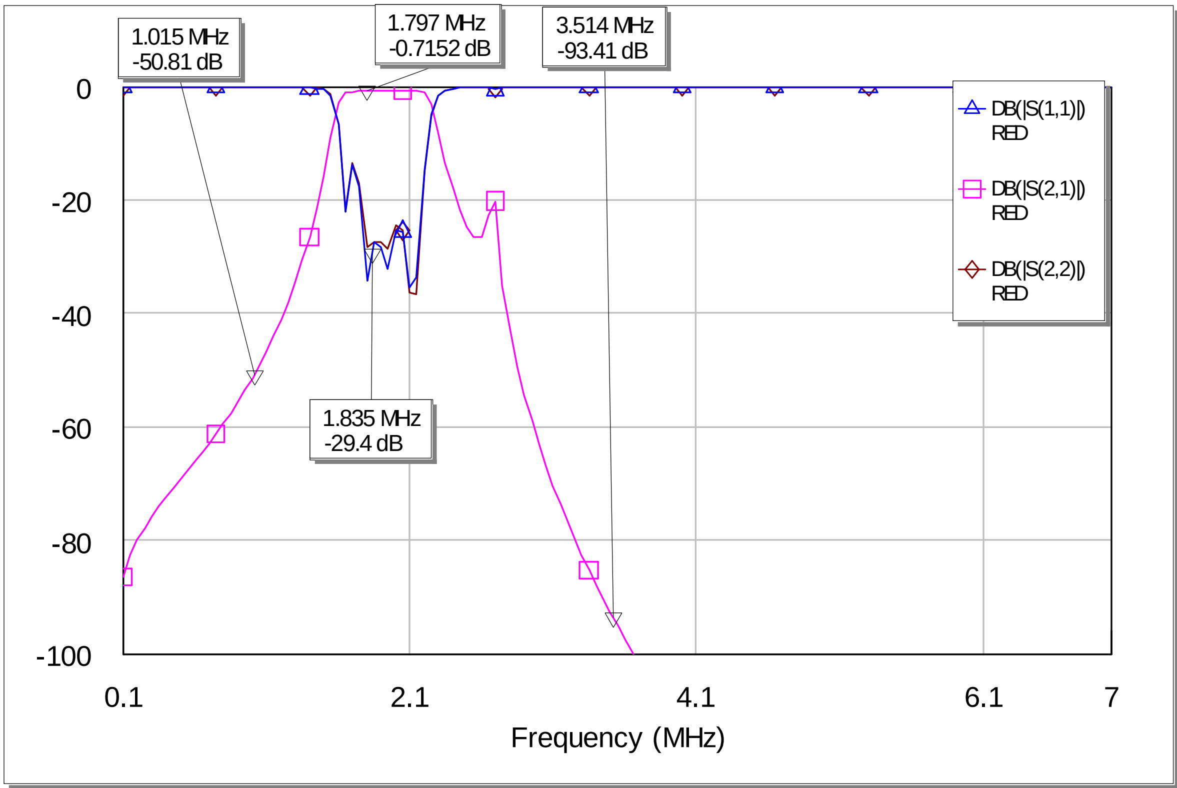
WARNING!

All built in components have to be adequate quality very high Q. This mean that capacitors have adequate breaking voltages, high current and that ring cores are from adequate RF materials (Amidon T106-, T130-**)for used frequency and square surface for used output power to avoid filter destruction or equipment damages. About selection component for high power RF BP filters please read article [4,5] from well known filter designer expert Ed W3NQN.**

I am using very good freeware software from Wilfried DL5SWB for ring and air coils turns calculation [3]. Fine inductance adjustment for better SWR is possible with squeezing or unfolding wire turns on ring before fixing with small quantity of glue or silicon.

My proposal for BP realization is usage better SMD porcelain capacitors from ATC [7]. These capacitors have extremely good performances for HF /VHF /UHF bands in high power filters/amplifiers. Only small disadvantage is price but all other things are better than with high performances classic capacitors. Also this capacitors enable calculation predictable realization at higher frequencies (21MHz and up) which isn't common case with capacitors with leads.

If we are cascading two equal filters for example filters for band 1,8MHz we can expect next frequency response from that new filter picture down. Additional hump in the amplitude frequency response is normal and it is expected from this type of filter. These types of filter are generally not ideal for the cascading without parasitic pass bands.



Two equal BP for 1.8MHz cascaded

I wish you successful BP realization and I apologize for some possible mistakes. I made great effort to share my projects with all who are interesting for. Anyway, send me your comments positive or negative, results or photos of your realization are welcome.

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References:

1. ***www.yu1lm.qrpradio.com***
2. ***http://www.linear.com/designtools/software/***
3. ***www.dl5swb.de***
4. ***Ed Wetherhold W3NQN – Clean Your Signal with Band-Pass Filter –part1), QST May 1998(pages 44-48) ,***
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