

Filters for Wideband Active Antennas to Reject Strong Input Signals from Broadcasting Stations in LW, MW and FM Bands

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The AAA1 amplifier has a very good dynamic range - it is higher than the most RF preamplifiers used in the best transceivers. But it is wideband and there are no filters at the input. Placing the antenna in a very strong field can saturate the amplifier. This might happen if there is a very strong transmitter near the antenna – e.g. 100 KW BC MW transmitter 2 – 3 km away. The only way to reduce the interference is to use a reject filter at the input for the TX frequency. This filter must be placed between the antenna and AAA-1 input.

1. Filters for active loop antenna

Before making the input filter try to do the following steps:

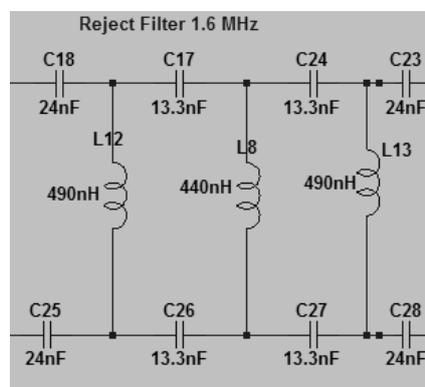
- Turn the loop to minimal signal level. The signal can be attenuated at least 20 dB.
- Use smaller loop size (but you will reduce sensitivity).
- Measure with oscilloscope the output voltage at the Control board output with 50 ohms load. The AAA-1 will work properly if the output voltage is lower than 4 V pp. Above this voltage the amplifier will begin to saturate and there will be strong nonlinear effects.

If all these steps do not eliminate the problem then the reject filter is the solution. *The next filters are not tested in hardware but are modeled in LT spice.*

1.1 High-pass Filter to reject MW band frequencies for AAA-1 amplifier

This filter is useful when there are several strong MW stations below certain frequency.

Design parameters: Chebishev 7-th order, 1.6 MHz cutoff freq.; 0.1 dB ripple; 7 ohms characteristic impedance; balanced. RFSIM99 is used to calculate the filter values.



From loop ->

-> to amplifier input +A, -A or +B, -B

Fig.1 High-pass MW filter

L & C can be made from standard values elements. X7R type capacitors and standard chokes can be used. The Q-factor of the chokes is not very important. ($Q > 10$). There must

be no inductive coupling between the loop and the filter coils so it might be better to use toroidal cores. I can not guess for the moment what is the inductive coupling between an open magnetic core inductor and the loop if the filter is placed in the amplifier box. May be it is negligible.

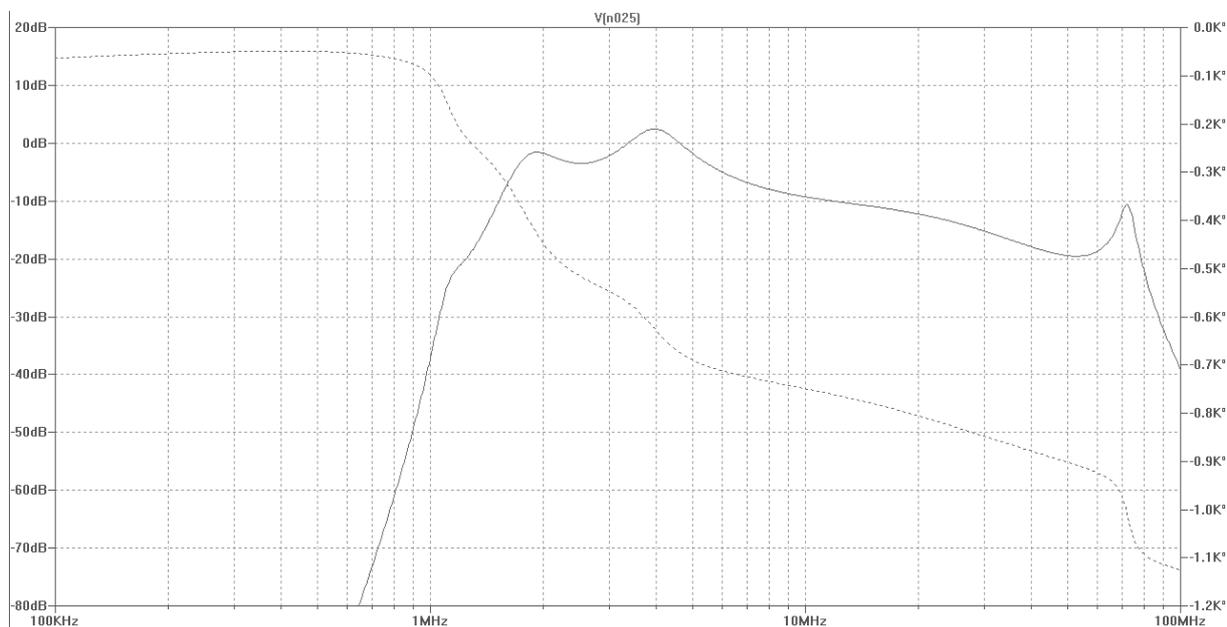


Fig.2 Frequency response (E field) from the Spice model of the AAA-1 amplifier with loop antenna with 1.1 μH inductance. The gain is: 1 $\mu\text{V}/\text{m}$ input field will give 0 dB. -35 dB attenuation @ 1MHz compared to 1.8MHz. Gain at 1.8 and 3.5 MHz is -2dB. Above 10 MHz the gain drops down significantly. Still has sufficient gain up to 7MHz.

This filter probably will degrade the noise figure of the amplifier at some frequencies. There is a strong ripple of the frequency response due to strong reactive component of the source impedance. It can not be predicted since it depends from the loop antenna parameters – mainly its inductance. The noise floor might be increased with 4 to 6 dB at frequencies between 1.8 and 5 MHz (ripple). Much better solution is to use reject filters.

1.2 Reject Filter for LW and MW band frequencies for AAA-1 amplifier

A better solution is to use a simple reject filter tuned to BC transmitter frequency at the amplifier input.

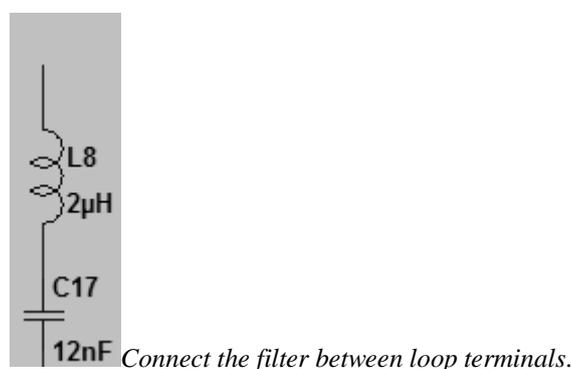


Fig.3 Reject filter

COG (NP0) type capacitor must be used. Also polyester capacitors have a good Q-factor and can work at MW frequencies. X7R capacitors have low Q-factor and the resultant Q of the filter will be between 8 and 15. This will reduce the attenuation to 20 dB which might be insufficient for some cases. L must have also high Q-factor. ($Q > 100$). Hi Q iron powder or ferrite toroidal cores can be used. Commercial chokes can be used also with value between 1 uH to 4.7 uH but there must be no inductive coupling between the loop and L. Use high current chokes (> 2 A) since their Q is higher. Check their Q-factor in data sheets – 30 and above will be acceptable. The calculation equation is the resonance frequency of serial LC circuit.

$$F = 1/(L*C)^{1/2}$$

The filter reject frequency practically is not influenced by the loop inductance.

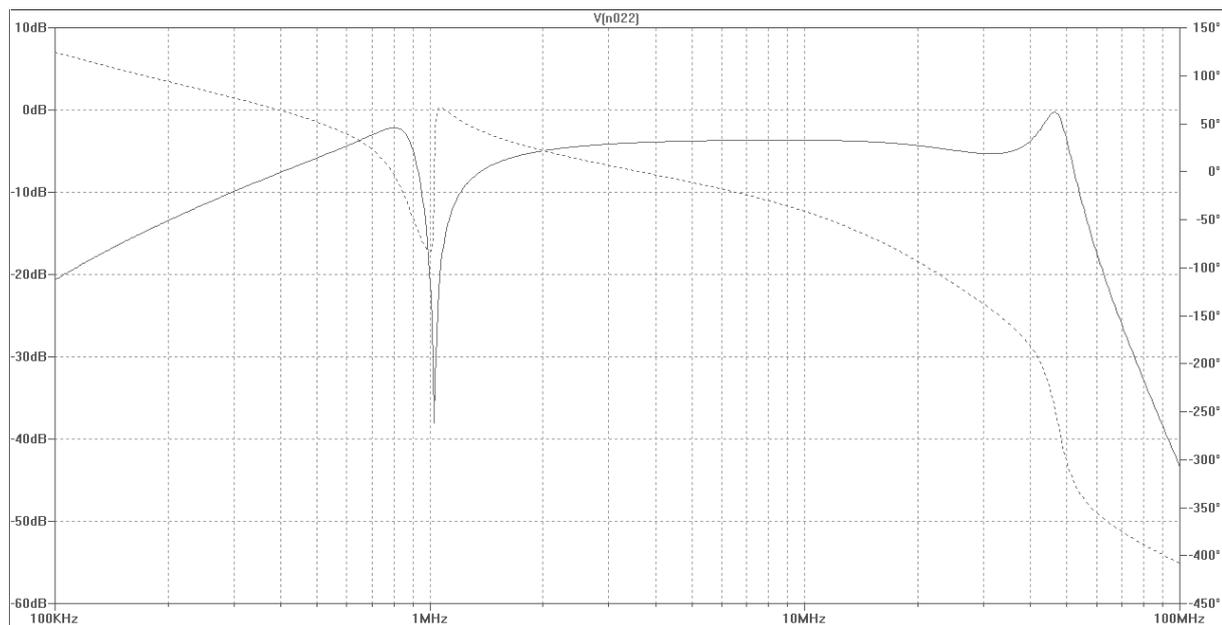
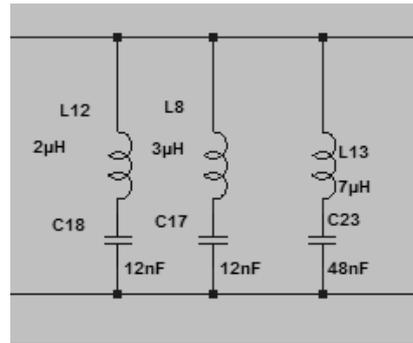


Fig.4 Frequency response (E field) from the spice model of the AAA-1 amplifier with loop antenna with 1.1 uH inductance. -29 dB attenuation @ 1MHz compared to 1.8MHz. At 1.8 MHz the gain is -1.5 dB compared to 3.5 MHz. The frequency response is flat above 3MHz and gain is -4 dB (-1.5 dB compared to the loop without input filter). The design Q-factor of L is 120. With higher Q-factor filter 40 to 50 dB attenuations might be expected.

The filter component values must be adjusted since the usual tolerances of L and C elements are within 10 % range. Additional parallel capacitors with smaller values can be added to trim the resonant frequency. This reject filter will not influence the noise figure of the amplifier at other frequencies. If the BC transmitter frequency is close to 1.8 MHz band (e.g. 1.5 MHz) a higher Q filter must be used.

1.3 Multiple reject filters

Multiple reject filters can be implemented for different frequencies if there are several nearby BC transmitters (Fig.5). But first of all try to make a reject filter only for the most powerful transmitter. Very often this will cure the problem. If this is not sufficient then insert a second filter for the next station.



Connect the filter between loop terminals

Fig.5

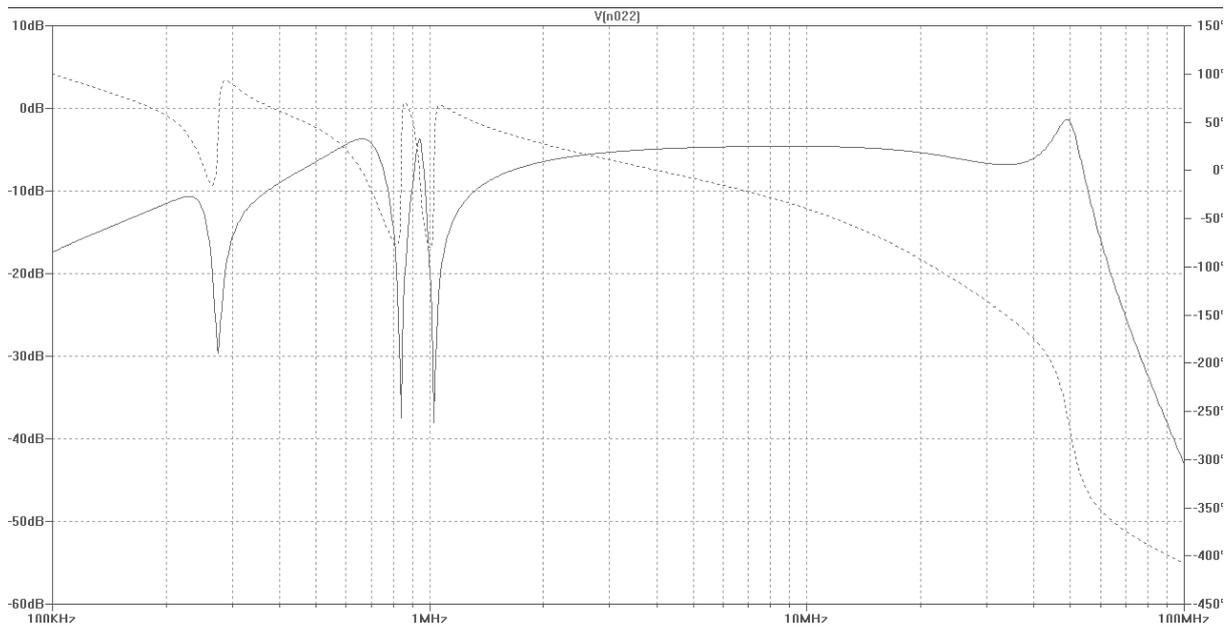


Fig. 6 Example of frequency response with 3 reject filters. 275 KHz, 841 KHz and 1026 KHz. The flat zone is -4.6 dB and maximal attenuation is -34 dB.

An example for 3 frequencies is given. This reject filter will not influence the noise figure of the amplifier at other frequencies.

Loop Antenna reject filter for 3 frequencies

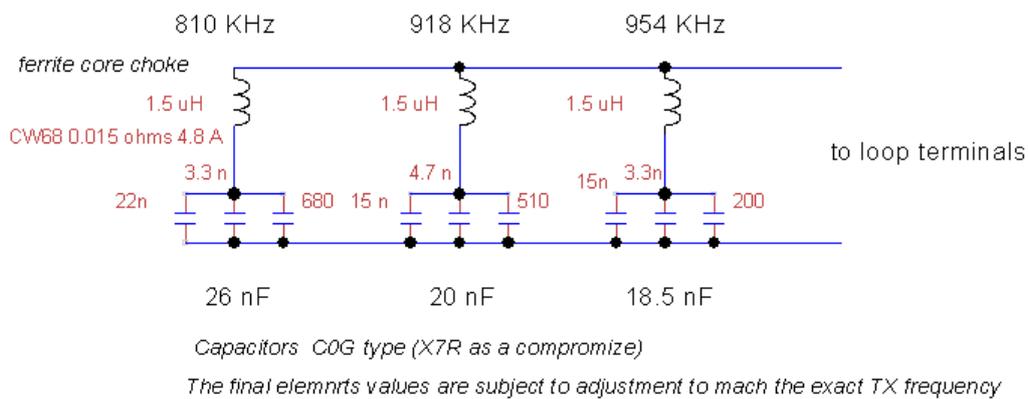


Fig.7 Practical example of another triple filter with standard elements values.

1.4 Filter for FM band frequencies

AAA-1 has internal LP filter above 50 Mhz. But in some cases, where a powerful transmitter is extremely close, an additional filtering might be needed.

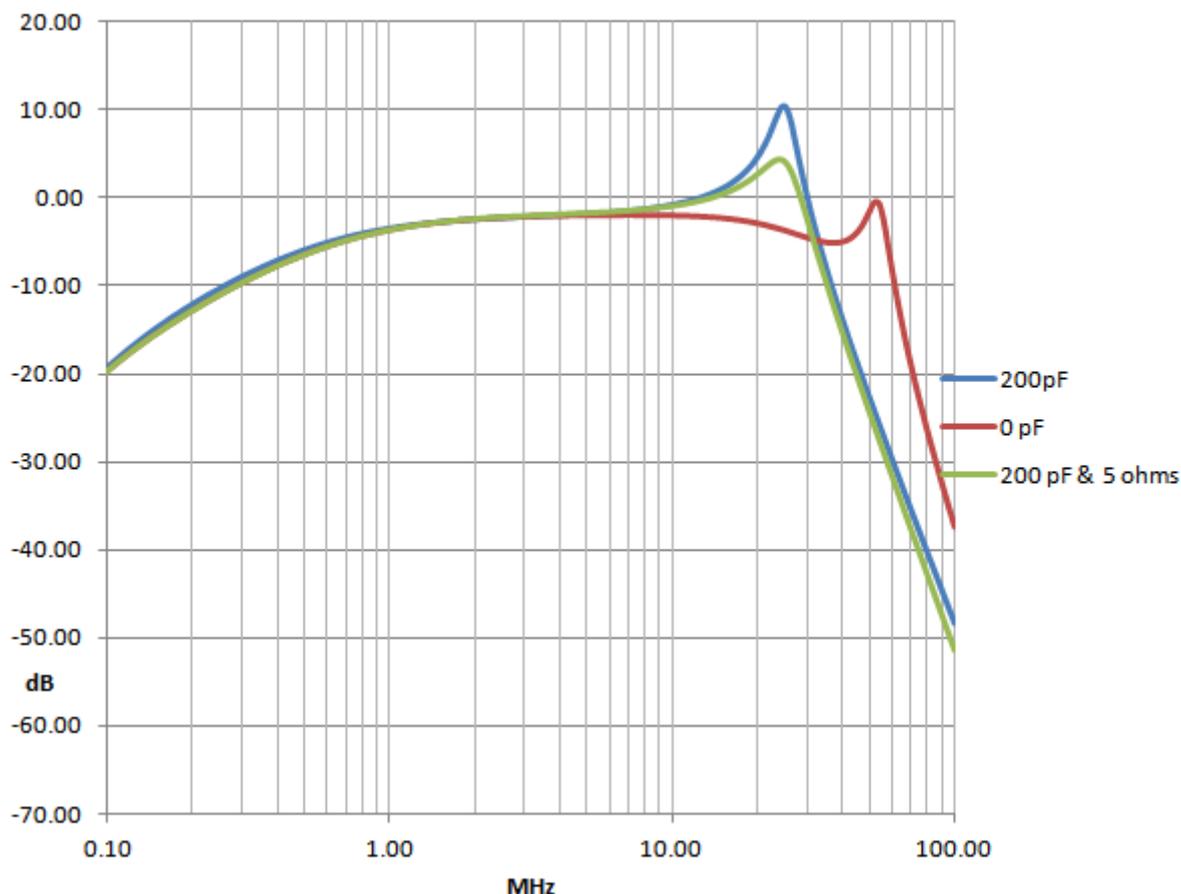


Fig. 8 Frequency responses of AAA-1C with added parallel capacitor to loop terminals.

The simplest way to increase the attenuation in FM band is to connect a parallel capacitor to the loop terminals. The frequency response of AAA-1C is shown on Fig.8 . There is an internal low pass filter and adding 200 pF reduces its cutoff frequency. There is some mismatch which gives a rise with 10 dB the gain at 25 MHz region. A 5 ohms resistor might be connected serially to the capacitor to flatten the gain. The 50 MHz band gain is reduced almost with 20 dB but we have almost 15 dB added attenuation for the FM band frequencies which in many cases might be sufficient. The capacitor must be connected immediately to the loop terminal block (+A, -A or +B -B points) at the amplifier board to avoid long leads.

1.4 Reject Filter for FM band frequencies

A serial reject LC filter can be connected immediately between the terminals +A, -A or +B,-B as shown on Fig.3. This filter must be connected at the terminals at the amplifier board to avoid long leads. The results from the simulation model is shown on Fig. 9

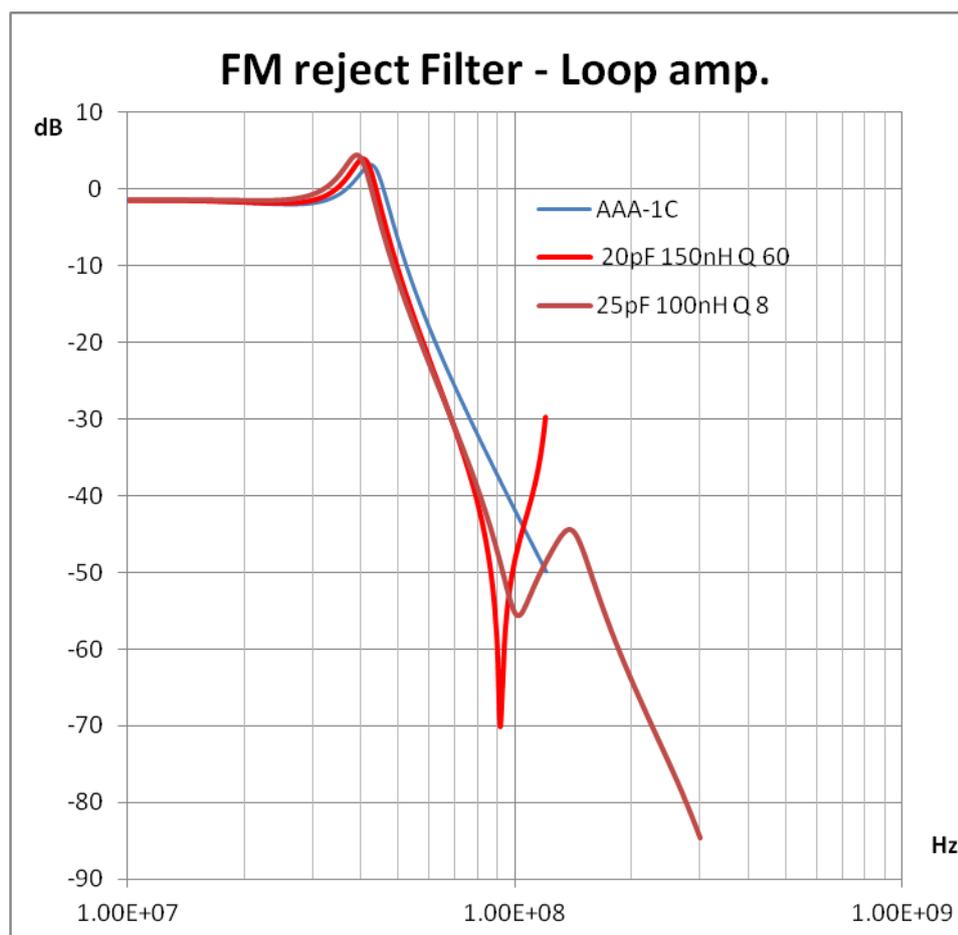


Fig.9 Input serial LC reject filter for FM band. The frequency response of the amplifier without filter is shown with blue line. High $Q = 60$ red line, Low $Q = 8$ is brown line. The resonance frequency with 20 pF and 0.15 uH is at 92 MHz. There is always a second parallel resonance at higher frequency as shown with low Q filter.

The price we pay is reduced gain at 50 MHz band with several dB. The lower frequency response of the amplifier is not changed.

A small trimmer capacitor can be used to tune the filter at exact frequency and it is not necessary to change the inductance value. If we have several powerful FM stations we can lower the Q to 20 by shunting the inductance with 1 Kohm resistor. Then the filter can be tuned at the band center at 98 MHz. In this case the attenuation in the total bandwidth will be at least 10 dB better compared to the case without filter but the rejection at the resonance point will be not so high - somewhere around -55 dB. A cheap commercial chokes between 100 and 200 nH can be used for L. Their Q -factor at 100 MHz is usually between 35 and 70.

2. Filters for active dipole amplifier

Unfortunately this simple approach can not be used quite successively for high input impedance dipole amplifier. Serial reject filter for LW and MW frequencies strongly changes the amplifier frequency response (**Fig. 10**). There is always a parallel resonance above the reject frequency which rises the gain significantly. Above the parallel resonance frequency the gain is flat. With proper selection of L/C ratio the parallel resonance can be shifted to desired frequency without changing the serial resonance frequency. By reducing the Q factor the gain peak can be lowered and a compromise solution can be found (**Fig. 12**).

At FM band the reject filter can be used with capacitor with minimal practical value but even then the overall gain of the amplifier is affected. The results from the simulation model is shown on **Fig. 12**. 6 pF case might be acceptable since the amplifier gain reduction is only 2.5 dB. The filter must be connected immediately between the terminals V1 and V2 at the amplifier board to avoid long leads.

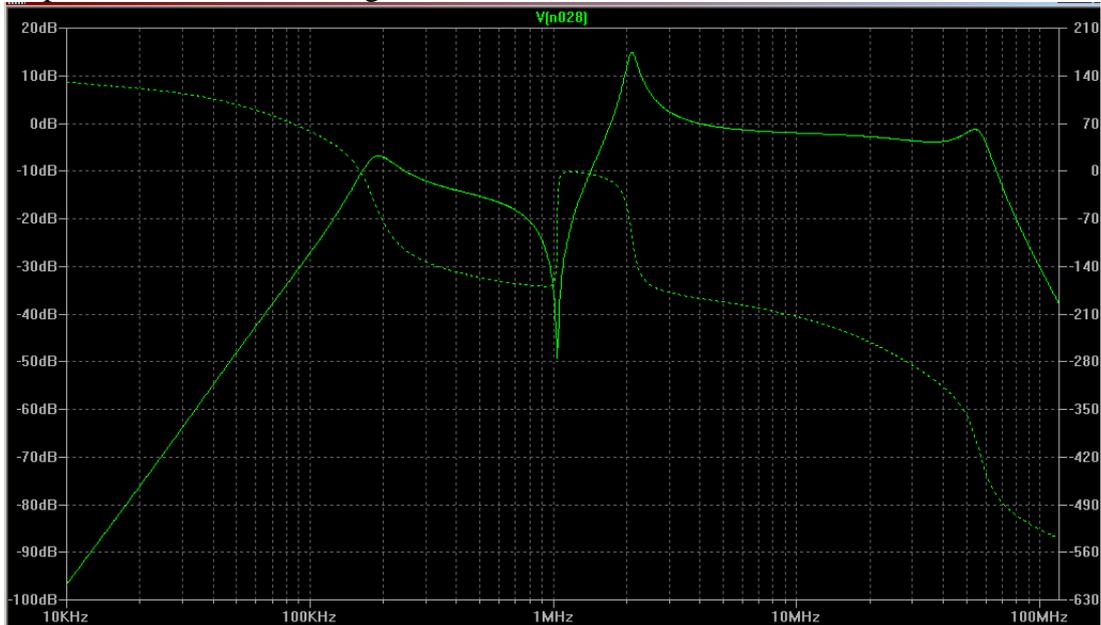


Fig.10 Frequency response (E field) from the spice model of the AAA-1 amplifier in dipole mode. A serial reject filter at 1MHz, 470 μ H, 50 pF, $Q=80$ is connected between input terminals V1,V2. By changing the L/C ratio of the resonance circuit the parasitic parallel resonance peak can be shifted to proper place. In this case the gain at 1.8 and 3.5 MHz is within 0 dB region. The attenuation between 0.5 and 1.3 MHz is at least 15 dB and can be successively used to reduce the BC level for frequencies adjacent to resonance point.

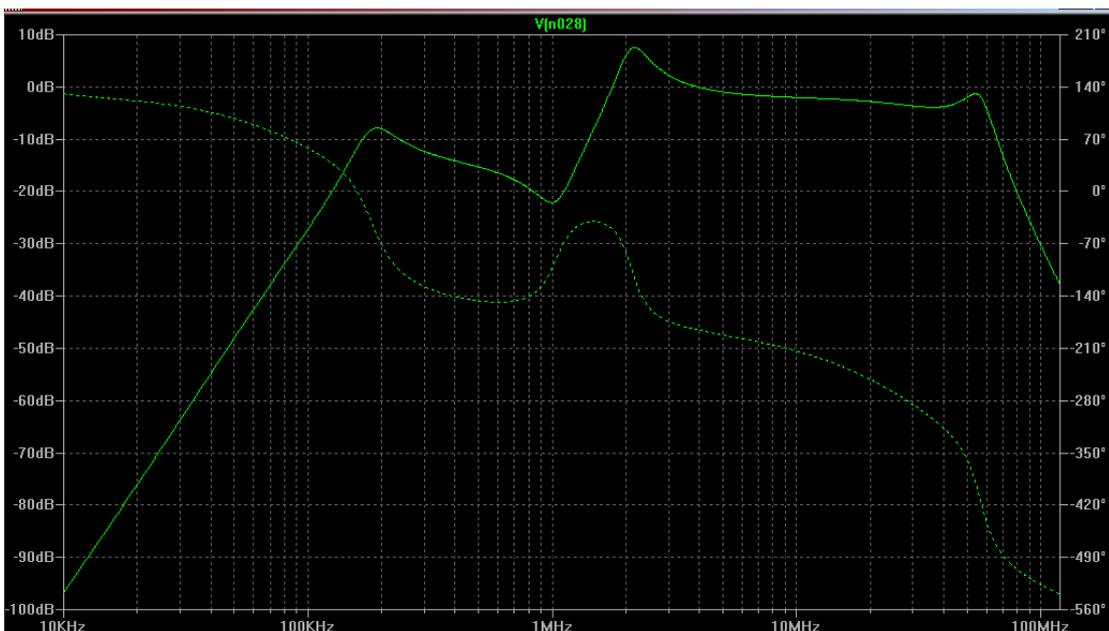


Fig. 11 The same filter with $Q=3$ by serially connecting 1 Kohm resistor. The gain peak is reduced and the attenuation between 0.5 and 1.3 MHz is almost preserved.

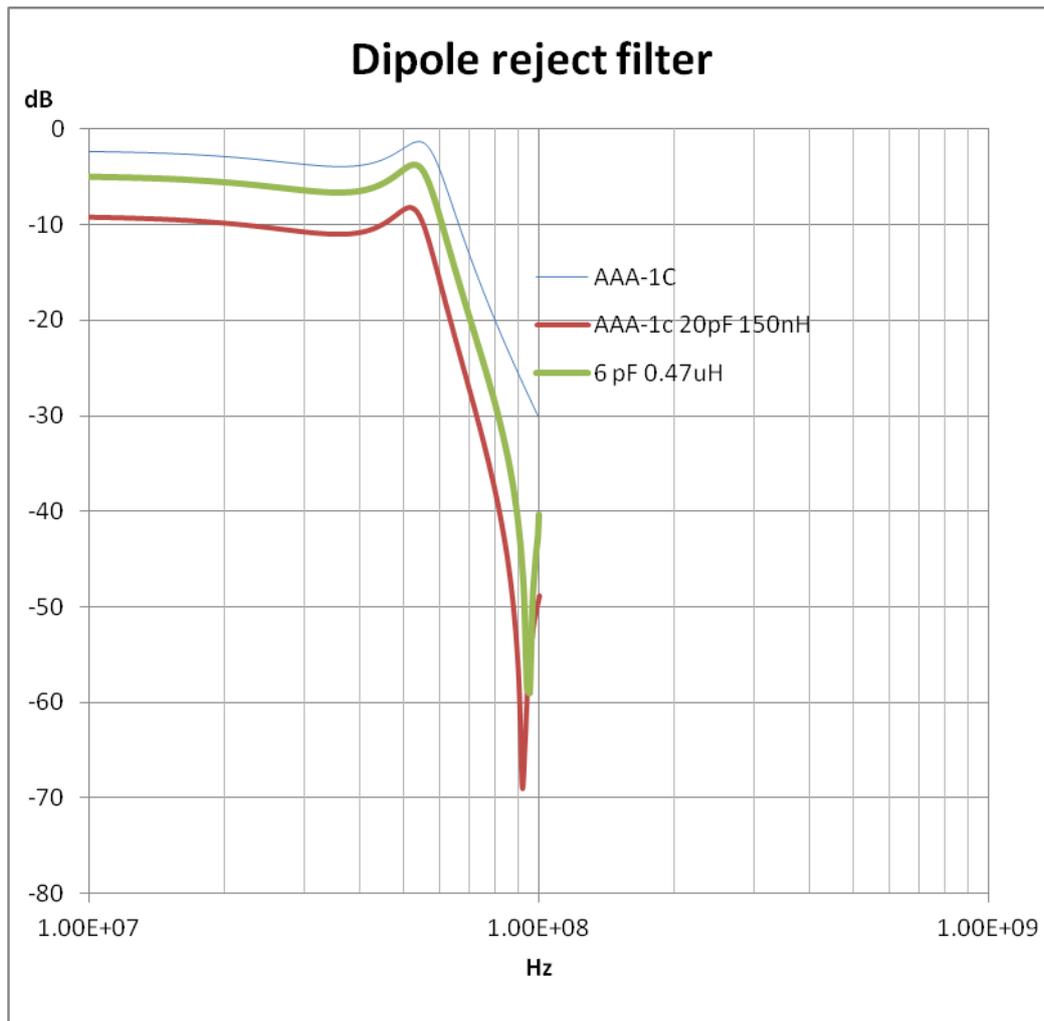


Fig.11 Input serial LC reject filter for FM band for high impedance amplifier. Two cases with different characteristic LC impedances are shown. The frequency response of the amplifier without filter is shown with blue line. The Q -factor is 60.

