Virgo h-rec 4 kHz anti-aliasing

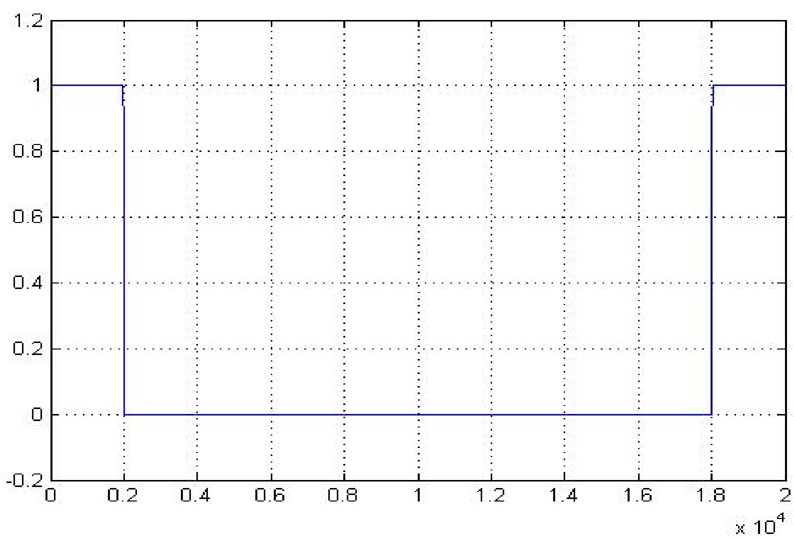
Decimation with frequency domain a-a filter

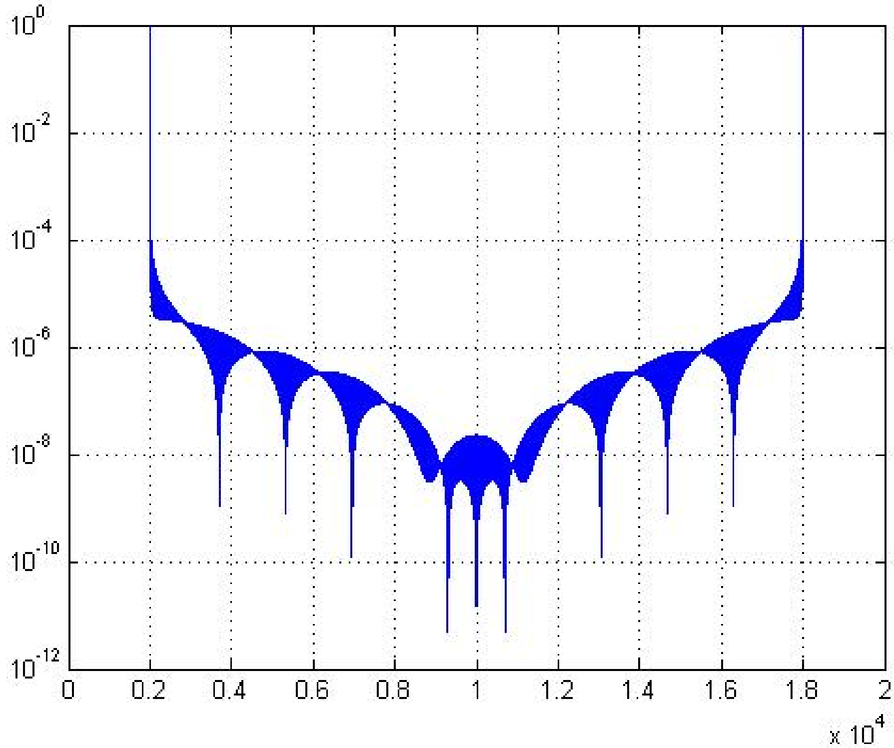
The Snag procedure, for GDs, is

- **[gdout,frfilt]=gd_decim(gdin,decim,fftlen,icreal)**
  - **gdin** sampled data input GD or double array
  - **decim** decimation ratio; also non-integer (> 1; one every decim samples)
  - **fftlen** length of the fft (divisible by 4; 0 -> 16384)
  - **icreal** =1 impose real output

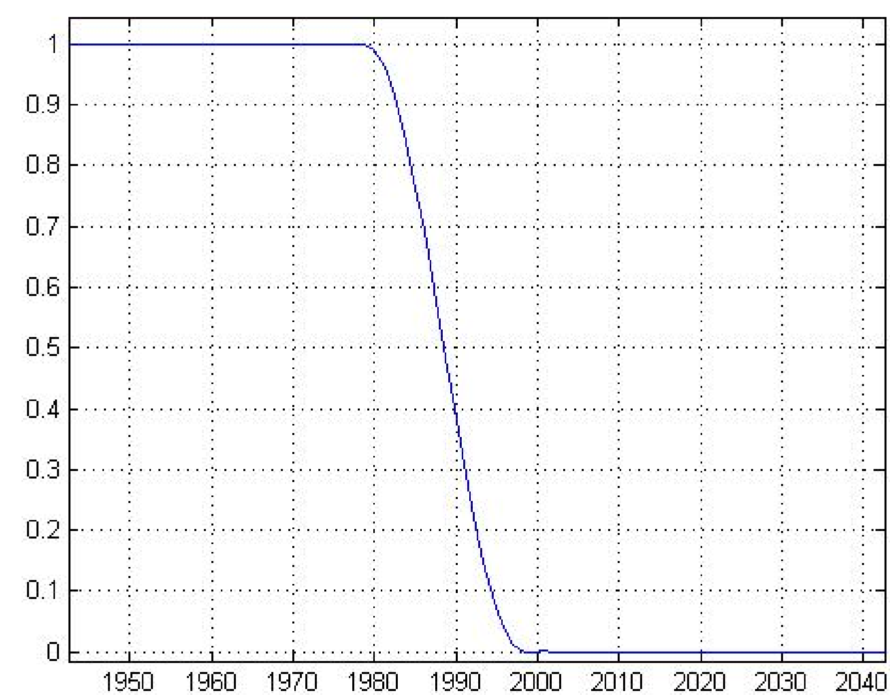
  - **gdout** output data

The frequency filter in output is given by (decim=5):

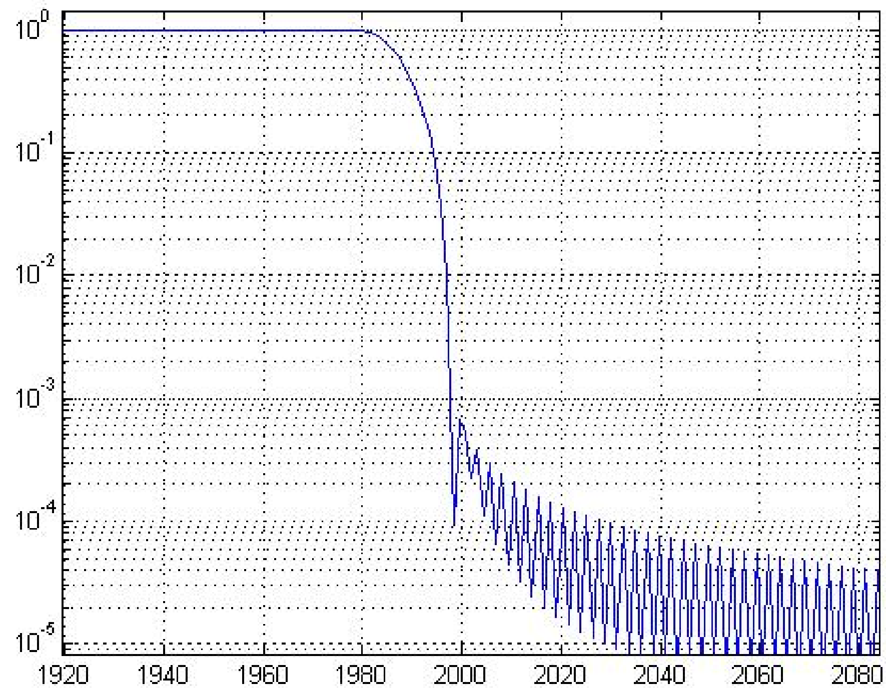




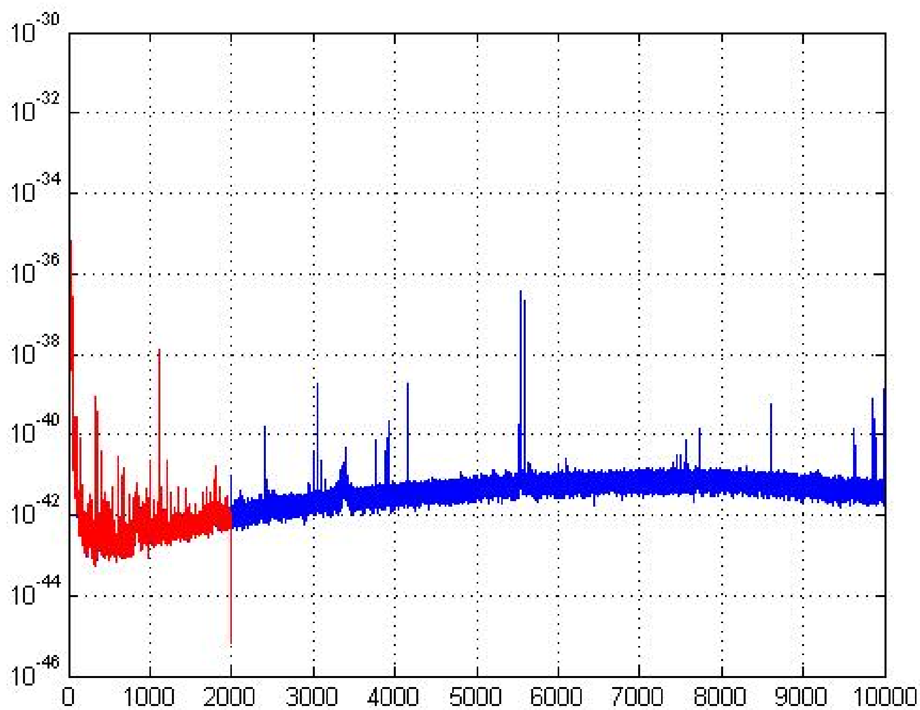
10^0
10^-2
10^-4
10^-6
10^-8
10^-10
10^-12
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
x 10^4

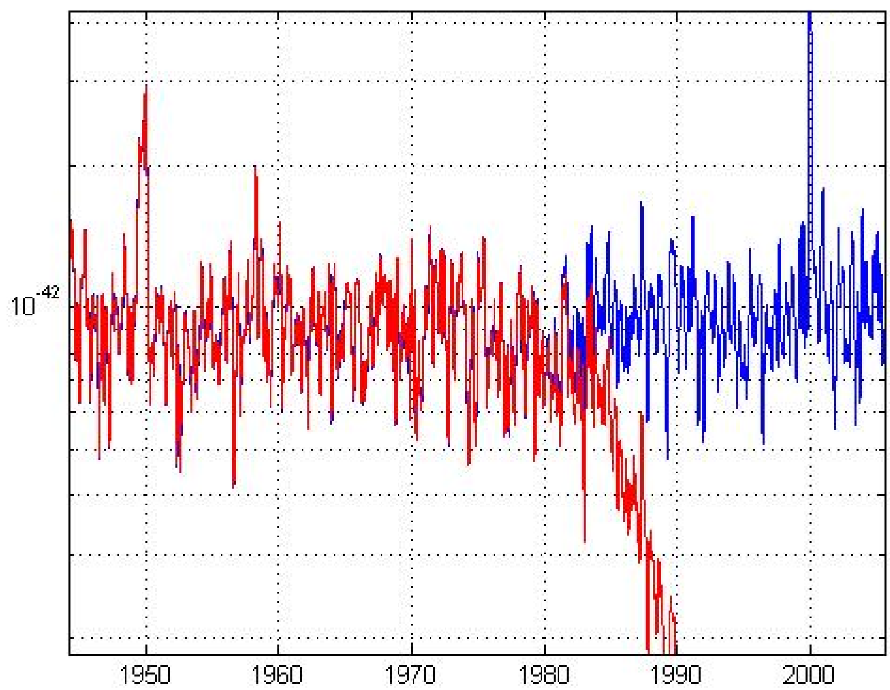


1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1950
1960
1970
1980
1990
2000
2010
2020
2030
2040

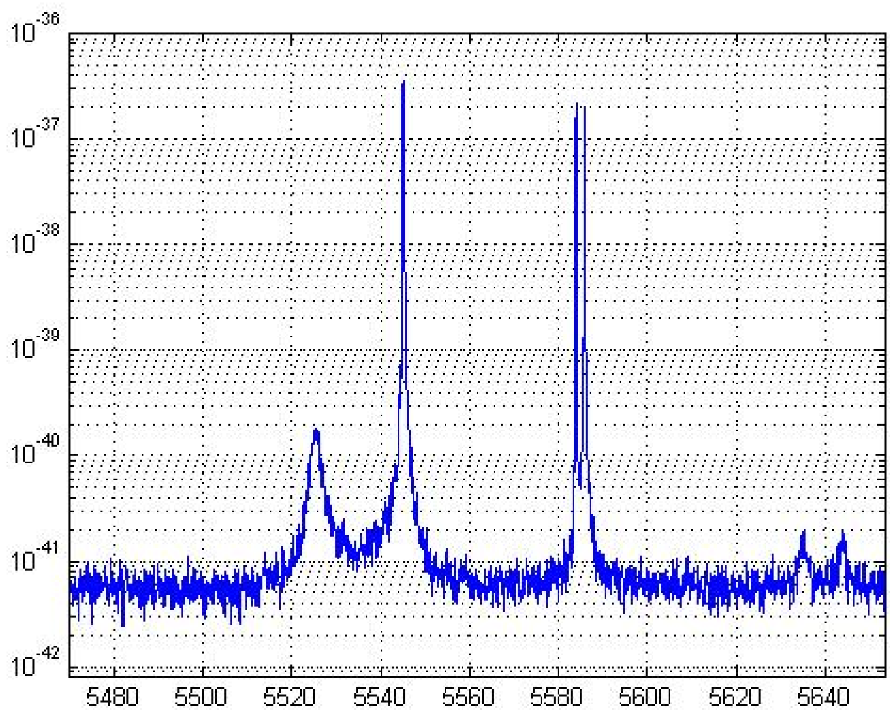


With the Virgo data:

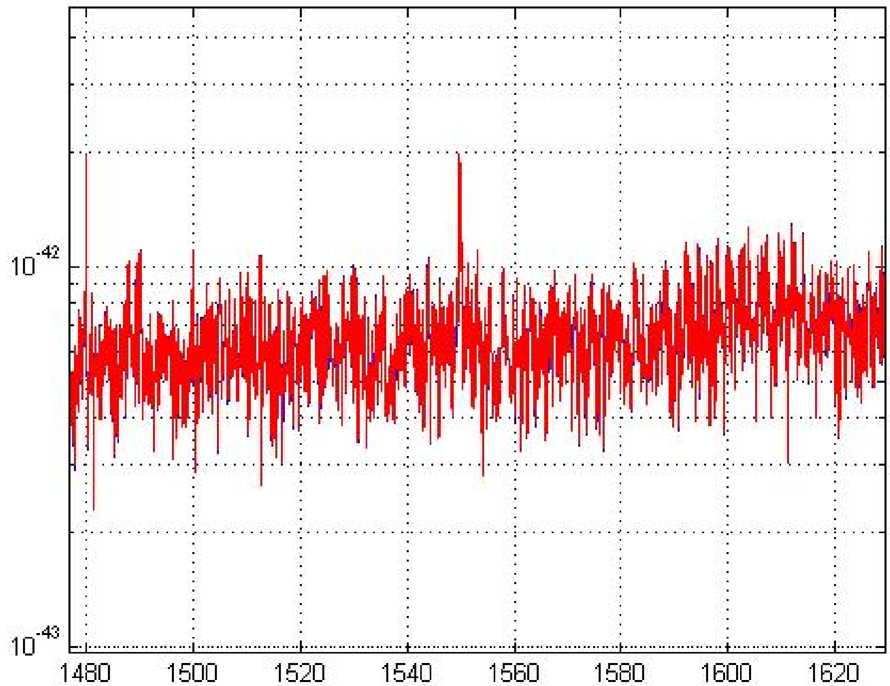



10-42
1950
1960
1970
1980
1990
2000

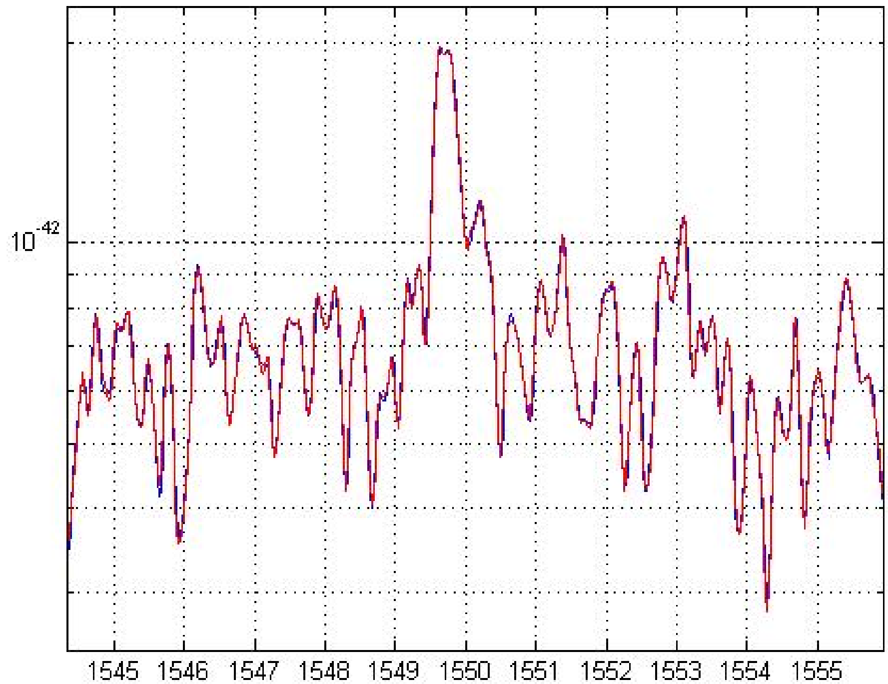
The big line:


10-36
10-37
10-38
10-39
10-40
10-41
10-42
5480
5500
5520
5540
5560
5580
5600
5620
5640

The aliased region:



The peak at 1550 is not an aliased peak, as it is seen with a zoom of the superponed spectra:


10^-42
1545
1546
1547
1548
1549
1550
1551
1552
1553
1554
1555

Butterworth low-pass

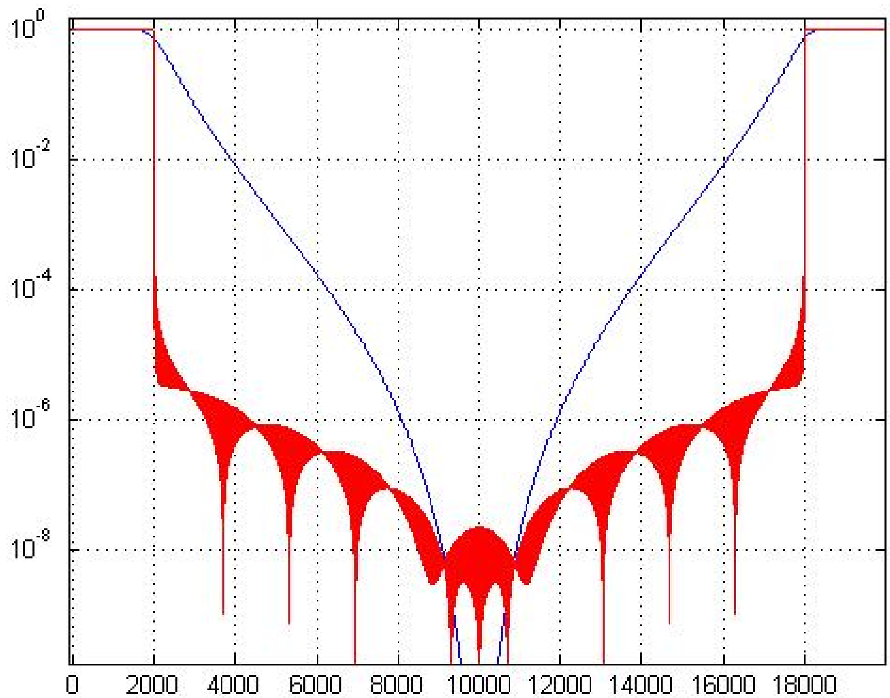
A 6-order low-pass Butterworth filter with cut at 0.2 (normalized frequency) is given by Matlab by:

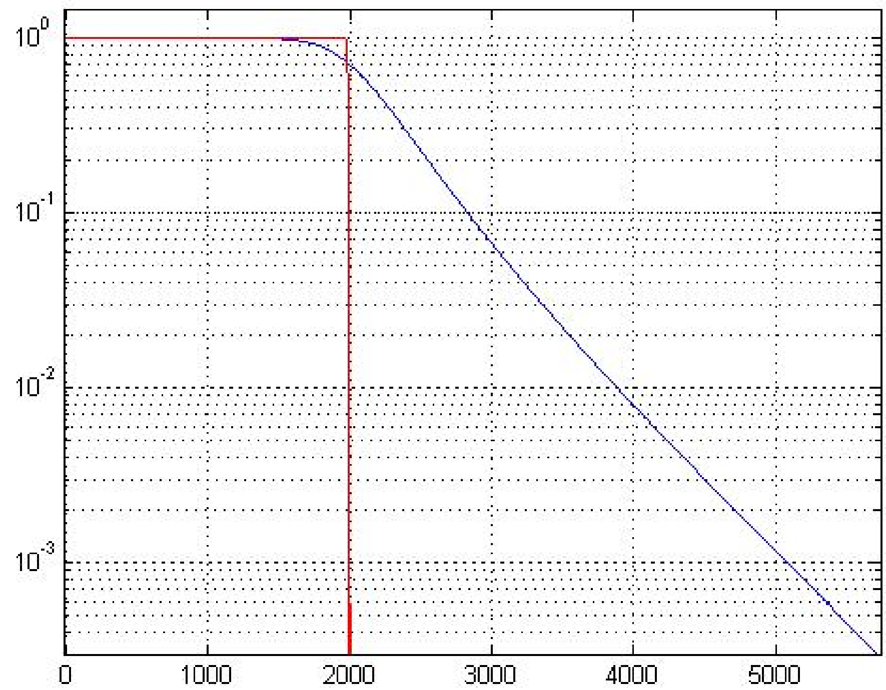
[b,a]=butter(6,0.2)

b = [0.0003 0.0020 0.0051 0.0068 0.0051 0.0020 0.0003]

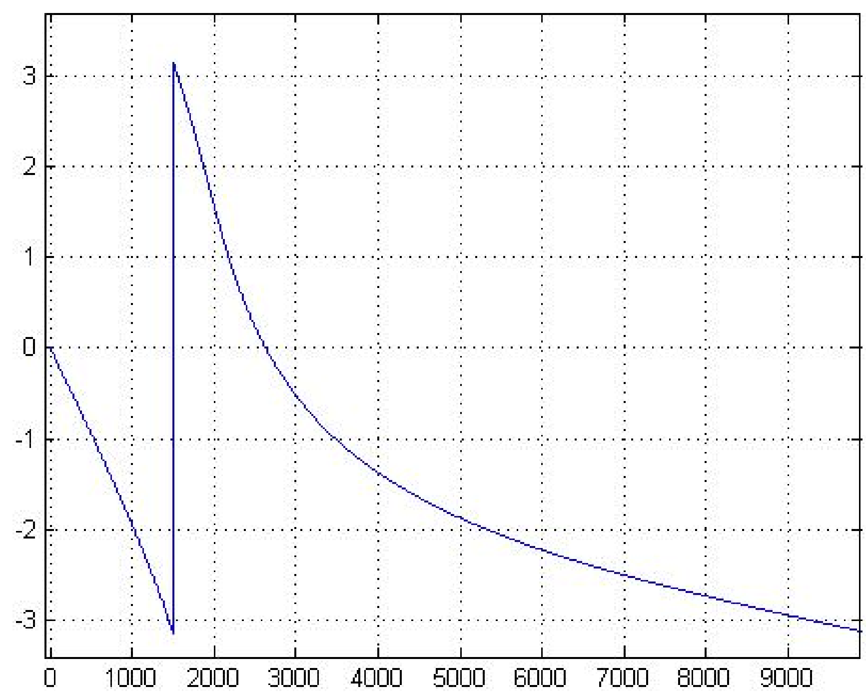
a = [1.0000 -3.5794 5.6587 -4.9654 2.5295 -0.7053 0.0838]

Here is the transfer function (together with the frequency domain a-a filter)





The frequency domain a-a filter is 0-phase, the phase of the Butterworth filter is



E-mail

Ciao Sergio,
analizzando la lista di picchi di frequenza che ci hai mandato ho trovato traccia di alcune linee che ho il sospetto siano dovute ad aliasing, queste per la precisione:

230 1584.04 197 <-----? alias of mirror ther. mode 5584Hz, wrt Fs=4000Hz
352 1584.03 111
578 1584.02 40
587 1585.89 38 <-----? alias of mirror ther. mode 5586Hz, wrt Fs=4000Hz
664 1545.06 29 <-----? alias of mirror ther. mode 5545Hz, wrt Fs=4000Hz

in effetti, il canale h_4kHz presenta questi picchi di aliasing (ti allego una figura dove confronto lo spettro h_4kHz e h_20kHz) probabilmente perche' i filtri anti aliasing usati con sono sufficientemente steep.

quindi ti chiedo: avete forse usato il canale h_4kHz per l'analisi?

Irene

Cara Irene,
grazie per la preziosissima informazione. Si, noi usiamo i dati dell'h_4kHz.
Ora faremo un'analisi dell'aliasing e, in ogni caso, dovremo partire dai dati a 20 kHz (come gia' sospettavo), facendo noi il filtro anti-aliasing in frequenza (abbiamo una lunga esperienza in questo genere di operazioni).

Ciao   Sergio

PS: Se ci sono le frequenze aliasate a 4000 Hz di distanza, pensa a quelle a specchio della banda 2000-4000 Hz !

Hi all,

There is a 6th order Butterworth low pass filter applied before decimating the data to produce the 4kHz channel. So, either there is a bug in the code or the filter parameters are not correctly set for this spectrum.
I will investigate that in the coming days.

Benoit

On Sat, 25 Mar 2006, Andrea Viceré wrote:

> It has indeed a shape about 1/f^2 at frequencies around 2.5 kHz, as

> shown in the attached mathematica notebook (last plot).
>
> In the previous plot one can see that such a filter, resulting from
> averages over 5 points, has a zero at 4 and 8 kHz (obviously), and a
> lobe in between.
>
> At frequencies around 6kHz it attenuates only by a factor about 0.25
>
>   Andrea
>
> Isidoro Ferrante wrote:
> > Irene FIORI ha scritto:
> >
> >> From a rough calculation, it seems to me that the slope of the
> >> anti-alising filter used is about 1/f^2 ... possible??
> >
> > It is absolutely reasonable: if the antialising filter is obtained
> > simply by averaging 5 samples, then the slope of the filter around
> > the new nyquist frequency could be near to 1/f^2.
> > As it was pointed out years ago, a more powerul algorithm for
> > decimation is absolutely needed in Virgo.
> > I.

Hi Irene,

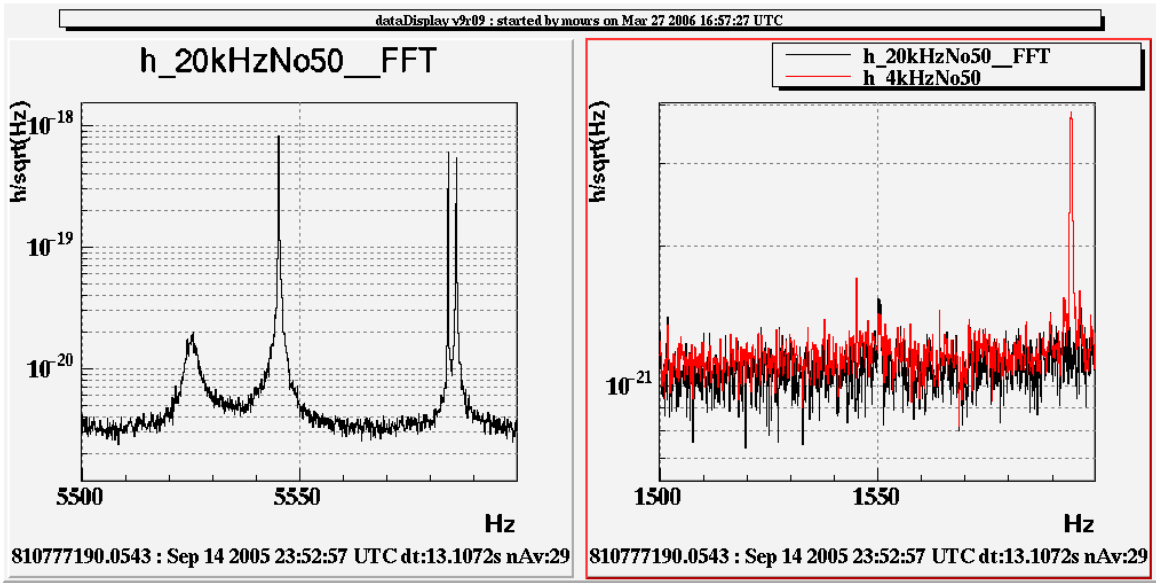
I confirm that there is a 6 order Butterworth filter before the decimation when building the h(t) 4 kHz channel.

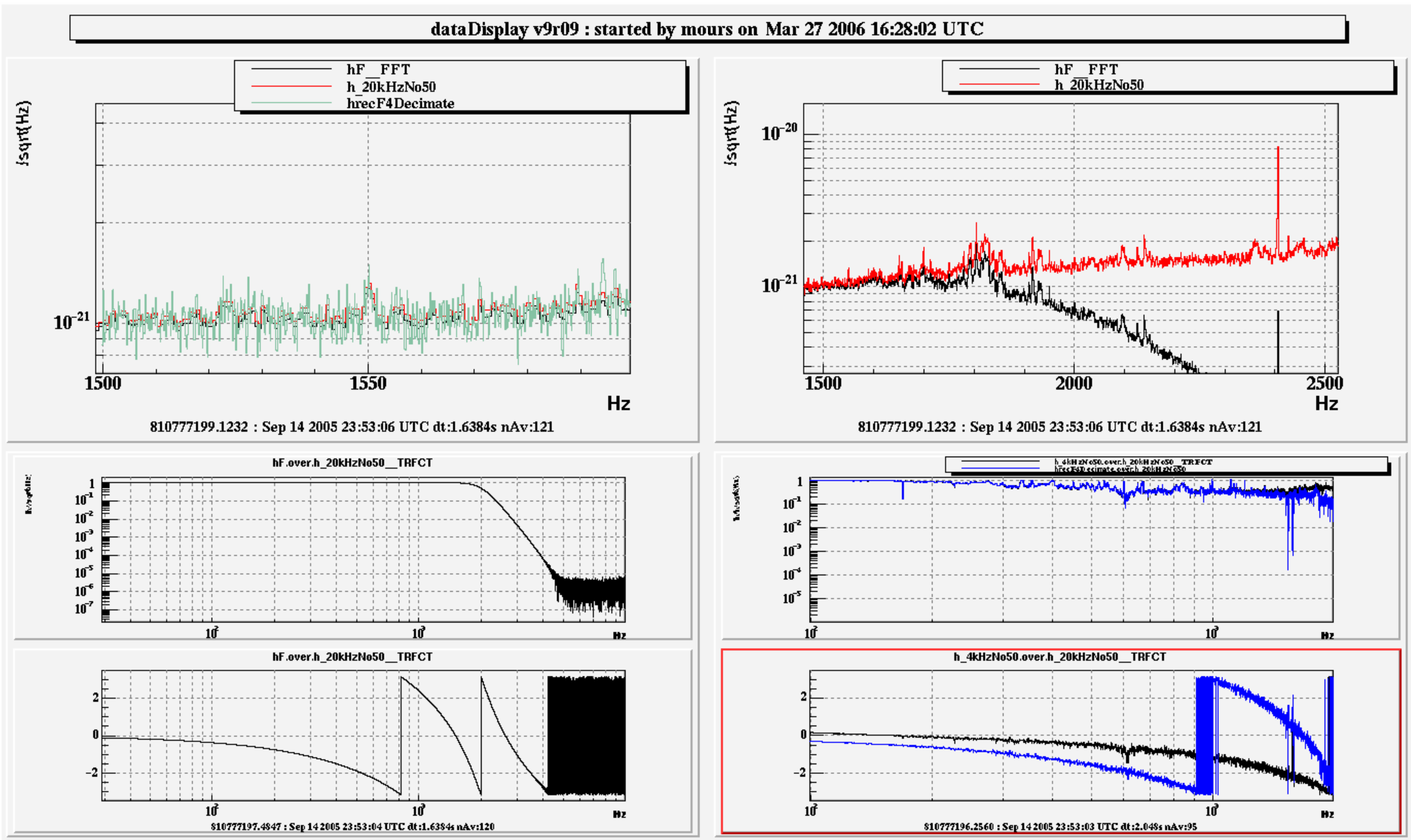
In fact, the statement you made that the filtering is 1/f^2 seems to be wrong. It seems that it is more like a 1/f^6 or 1/f^8 factor (starting at 2kHz), fully compatible with the low pass filter used. Please have a look to the attached figure 1 which shows the 1500-1600 Hz band and the 5500-5600 Hz band. You will see the huge difference in amplitude of the thermal noises lines. To see this aliasing, you need to have a good frequency resolution (long integration time) which was maybe confusing. By the way, if I cancel the low pass filtering, the effect is much more important and the nose floor on the 4kHz channel is increased by a factor 6.

It is possible to increase the low pass filtering by for instance adding a second low pass filter (again 6th order). With this, all the aliasing seems to be gone (see upper left plot of the attached figure 2). However, there is a larger distortion for the phase of the 4 kHz channel (blue curve of the lower right plot) to be compared to the already non negligible effect (black curve on the bottom right plot). This may be the dominant effect for the inspiral search... to be checked!

Best,

Benoit


dataDisplay v9r09 : started by mours on Mar 27 2006 16:57:27 UTC
h_20kHzNo50__FFT
h/sqrt(Hz)
10^{-18}
10^{-19}
10^{-20}
5500
5550
Hz
810777190.0543 : Sep 14 2005 23:52:57 UTC dt:13.1072s nAv:29
h_20kHzNo50__FFT
h_4kHzNo50
h/sqrt(Hz)
10^{-21}
1500
1550
Hz
810777190.0543 : Sep 14 2005 23:52:57 UTC dt:13.1072s nAv:29


dataDisplay v9r09 : started by mours on Mar 27 2006 16:28:02 UTC
hF__FFT
h_20kHzNo50
hrecF4Decimate
/sqrt(Hz)
10^{-21}
1500
1550
Hz
810777199.1232 : Sep 14 2005 23:53:06 UTC dt:1.6384s nAv:121
hF__FFT
h_20kHzNo50
/sqrt(Hz)
10^{-20}
10^{-21}
1500
2000
2500
Hz
810777199.1232 : Sep 14 2005 23:53:06 UTC dt:1.6384s nAv:121
hF.over.h_20kHzNo50__TRFCT
hF.over.h_20kHzNo50__TRFCT
810777197.4847 : Sep 14 2005 23:53:04 UTC dt:1.6384s nAv:120
h_4kHzNo50.over.h_20kHzNo50__TRFCT
810777196.2560 : Sep 14 2005 23:53:03 UTC dt:2.048s nAv:95

Hi Benoit,

thanks for the clarification. If I understand well, the problem is due to large thermal lines that survive even to a 1/f^8 filter resulting from the 1/f^6 butterworth + 1/f^2 average.

About what do to for the future, instead of further increasing the order of the low pass filter, which should be sufficient for broadband noise, I would propose that the 4kHz stream is produced after having placed notch filters in correspondence of the dangerous thermal lines above 4kHz.

It is probably not necessary for these notches to be adaptive, since they could be broad, as long as they guarantee an attenuation of the order of 100 (TBC !!).

To be sure that such a strategy is sufficient, I would like to understand well the background issue: looking to the figure

http://wwwcascina.virgo.infn.it/DataAnalysis/Noise/doc/C7/Lines/aliasing6.gif

made by Irene, I see red lines, but also an higher red background; should I interpret it as an effect of a smaller averaging, and therefore a larger variance? Or is it leakage from those lines?

Thanks

Andrea