# Aurorafilter User Guide

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Aurorafilter is an experimental computer program that possibly can assist a human to recognize auroral CW signals. The human ear-brain system is very well designed. A human can concentrate on a weak CW signal in a large noisy bandwidth. Thus, a narrow CW filter does not help as much as the SNR is reduced by the filter. But, in the case of an auroral signal there is no tone to concentrate on. That may be a reason for a significant gain of a filter matched to the specific situation.

### The Aurora Signal

An aurora signal is heavily spread and additionally it is shifted in frequency. Figure 1 shows the spectra of SK4MPI on 144.412 Mhz taken by the author at QTF 30 and at QTF 330 in two subsequent minutes without changing anything at the receiver. The frequency shift may be considerably greater if the scatter area is at QTF>60 at both stations (or QTF<300). Both stations see the same shift.

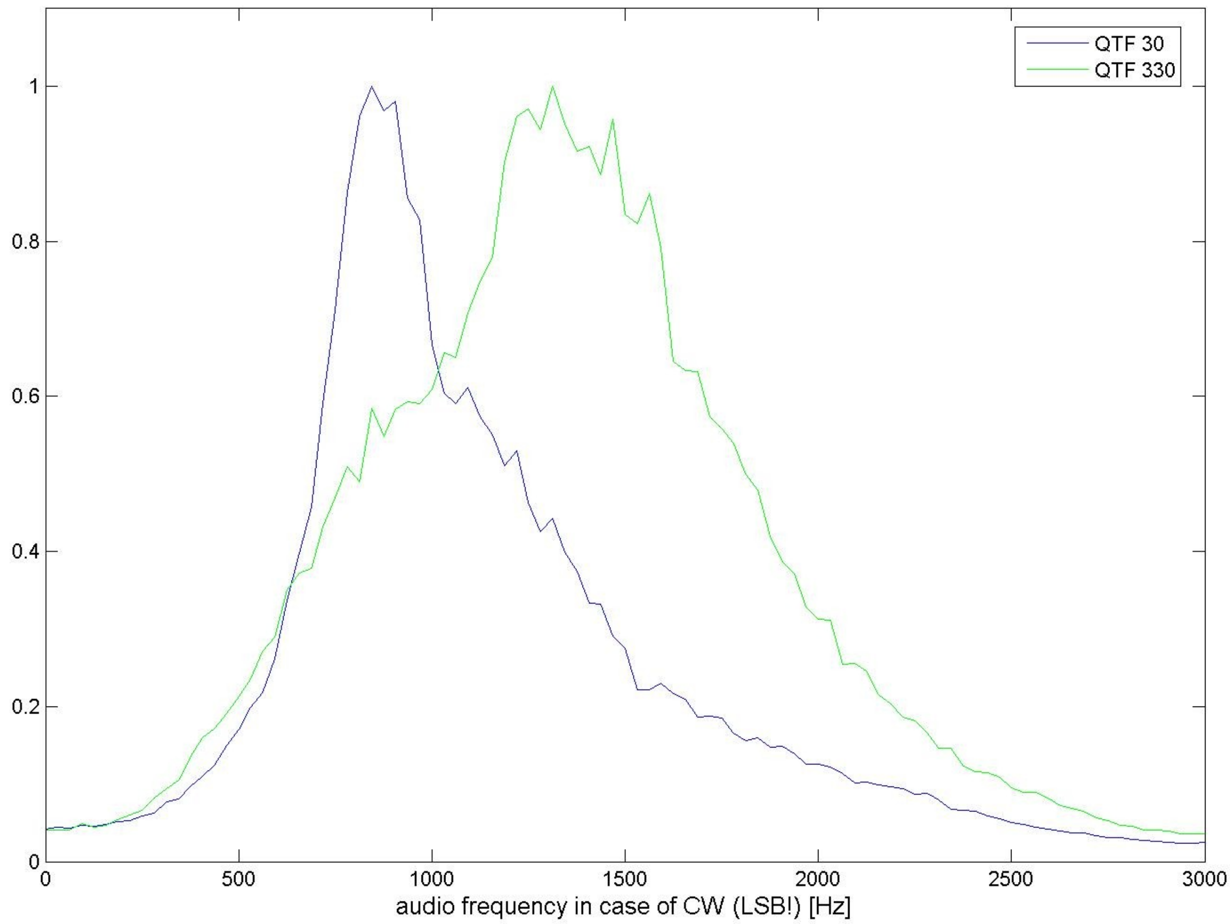



**Figure 1.** Spectra of SK4MPI taken by the author with antenna at QTF 30° and QTF 330° without changing anything at the receiver.

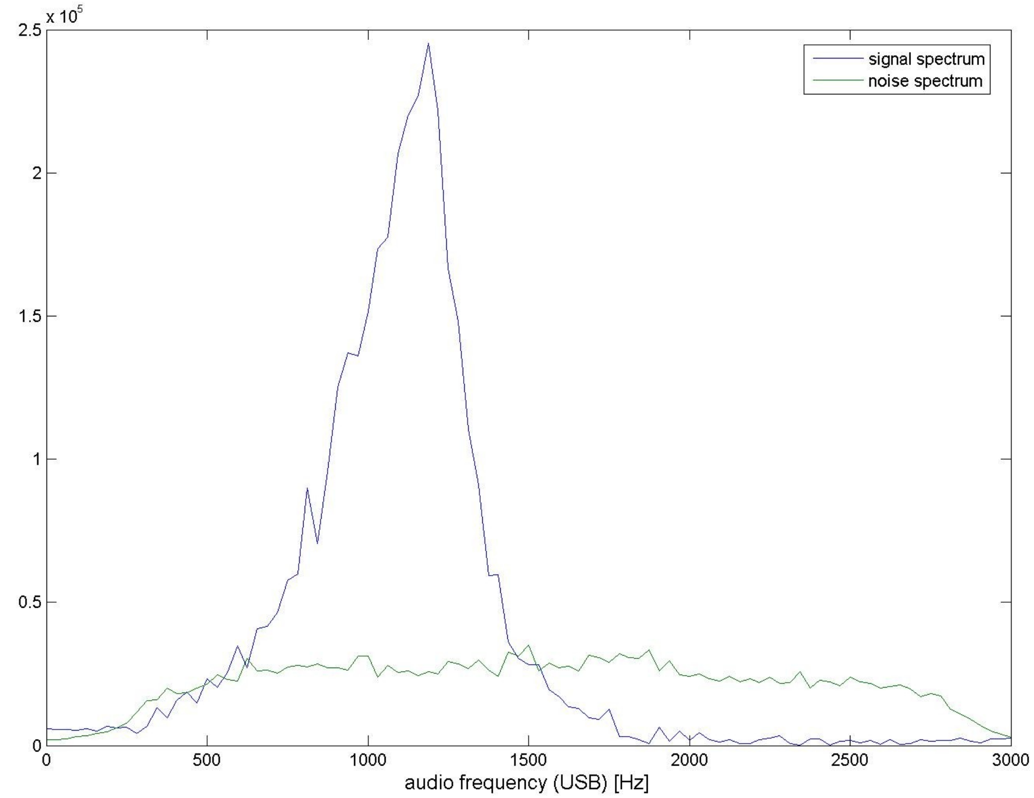



**Figure 2.** A typical aurora spectrum. The spectrum of the noise is taken from the gaps between the CW-keyed signal. The noise spectum is subtracted from the original spectrum of the keyed signal.

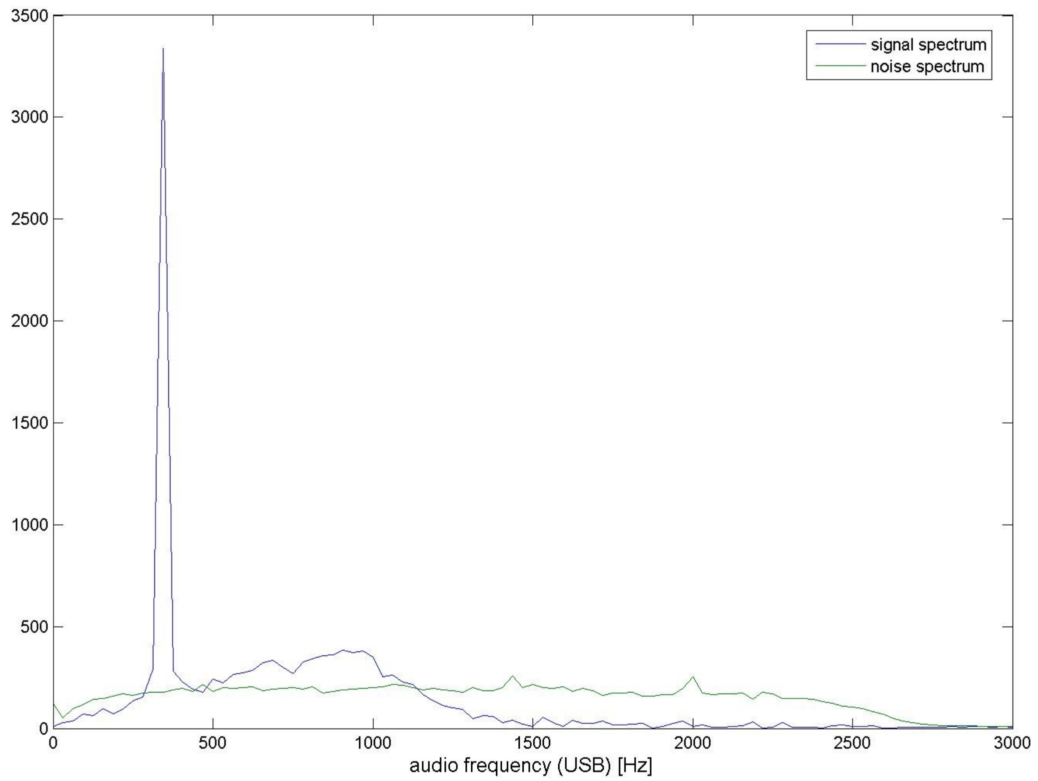



**Figure 3.** Signal of a station heard by tropo and by aurora. The unshifted tropo signal is at about 300 Hz while the weak aurora signal spreads from 0 to 1300 Hz with a triangular shape (USB).

The spectrum of a typical aurora signal has a shape similar to a triangle. Figures 2 gives an example. Sometimes, especially when an antenna with a broad horizontal radiation pattern is used and the scattering area is large, then the spectrum may be a sum of several triangles with different frequency shift. The green colored spectrum of SK4MPI in Figure 1 is an example.

## General Hints for Aurora Contacts

For a CQ call usually a frequency without QRM and birdies is selected. For aurora, this is not adequate. If you choose a clear frequency you want to have the answer to your CQ call just here. The question now is, where should I send my CQ such that a caller will use a frequency that will be shifted to my chosen clear segment? On 144 Mhz this is not a great problem since the shift is less than 1 kHz. But there is another effect that leads to an additional shift. A CW-operator usually adjusts the CW tone to about 700 Hz. The CW transmitter frequency is generated such that it would produce this tone when heard with the receiver. Unfortunately, aurora signals are tuned to a considerably higher audio frequency for optimum reception (1000...1200 Hz). The problem is illustrated by the following (typical!) example:

Doppler shift is $df = +500$ Hz
Both stations tune the aurora signal peaking at $f_t = 1200$ Hz
Both transceivers use a CW tone of $f_{CW} = 700$ Hz
Both transceivers use LSB as the CW mode

transmitter frequency at A : $f_A$
received frequency at B : $f_A + df$
transmitter frequency at B : $f_B = f_A + df + f_t - f_{CW} = f_A + 1000$ Hz
received frequency at A : $f_B + df = f_A + 1500$ Hz
Since A also tunes to 1200 Hz instead of 700 Hz, he has to adjust the RIT to +2000 Hz.

What we learn from this example is:

(1) The CQ calling operator must use the RIT.

(2) If the Doppler shift is positive (QTF 0...90) the the doppler shift and the psycho-acoustic shifts are added to about 2000 Hz. If the Doppler shift is negative both shifts can compensate.

(3) Since a CQ caller knows his QTF he can roughly predict the total shift to be expected. Thus he should call CQ on a frequency shifted by the predicted shift, but at opposite sign. The preset of the RIT therefore should roughly be as follows:

| QTF | 270 | 330 | 0 | 30 | 90 |
|---|---|---|---|---|---|
| RIT | 0 | 500 | 1000 | 1500 | 2000 |

Nevertheless, you should tune the RIT when listening after a CQ call because the Doppler shift also depends on the callers location and on his psycho-acoustic shift.

## The Modes of Aurora Filter

Aurora filter offers three modes: *linear filter* , *non-linear filter* , and *clear-tone CW* .

The *linear filter* is a simple bandpass with a selectable shape. If the filter shape matches the signal spectrum then the SNR is maximized.

Both, the *none-linear filter* and the *clear-tone CW* mode perform an incoherent amplitude demodulation of the linearly filtered signal. The amplidude is lowpass-filtered matched to the typical CW speed in auroral conditions. In the *clear-tone CW* mode this filtered amplitude multiplies a sine tone of 680 Hz. In the *non-linear filter* mode it multiplies the linearly filtered signal. In both these modes a careful adjustment of the input volume is neccessary in order to suppress the noise but not to cut weak signals. The white noise-level field on the volume bar gives a hint where the noise level should be.

All modes can be used in propagation conditions other than aurora, such as FAI, rain scatter, and TEP. The triangular filters are matched to the aurora case. In the other cases a Gaussian filter or araised-cosine filter probably is better.

## The Features of Aurora Filter

Aurorafilter is a quasi-realtime application that takes the input from the left input channel of the soundcard and puts the output of the signal processing to both, left and right output channel of the soundcard. Aurorafilter is available only for WinXP. Unfortunately, the Windows system is not designed for this type of application. There may be dropouts on the output.

Aurorafilter uses two windows, one User Interface Window with START/STOP-button and menu bar, and a window displaying the actual signal spectrum and the filter response in frequency domain (red line). The spectrum display must be used to control the tuning, since the audio output of all modes does not contain sufficient information about the tuning.

The audio processing is started and stopped by pushing the START/STOP button. Most items of the menu bar can be changed while the filter is running. The menu bar now is discussed using screen shots.

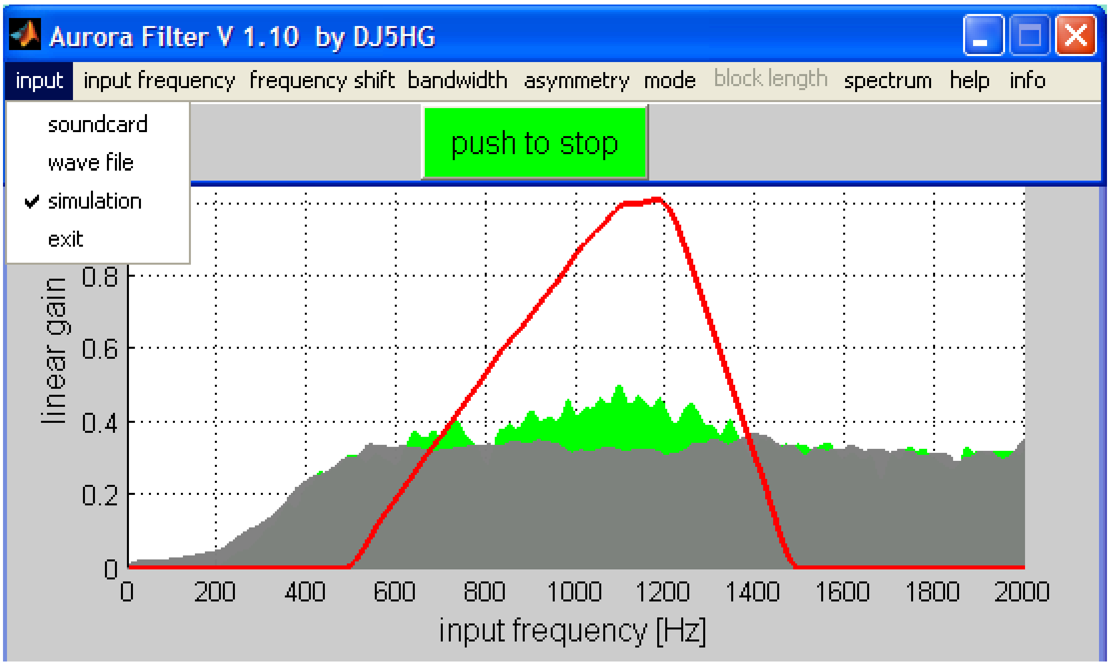



**Figure 4.** The User Interface of aurora filter V 1.10. The filter input may be the analog input of the sound card, a wave file or a simulated signal (choose this for a first try). If the simulation is selected then the wave-file **aurora.wav** is read as the filter input. The author's best choice for the parameters in the *simulation* is: input frequency: 1100 Hz;
frequency shift: -300 Hz; bandwith: 1200 Hz triangle;

asymmetry: larger wing left; mode: none linear filter

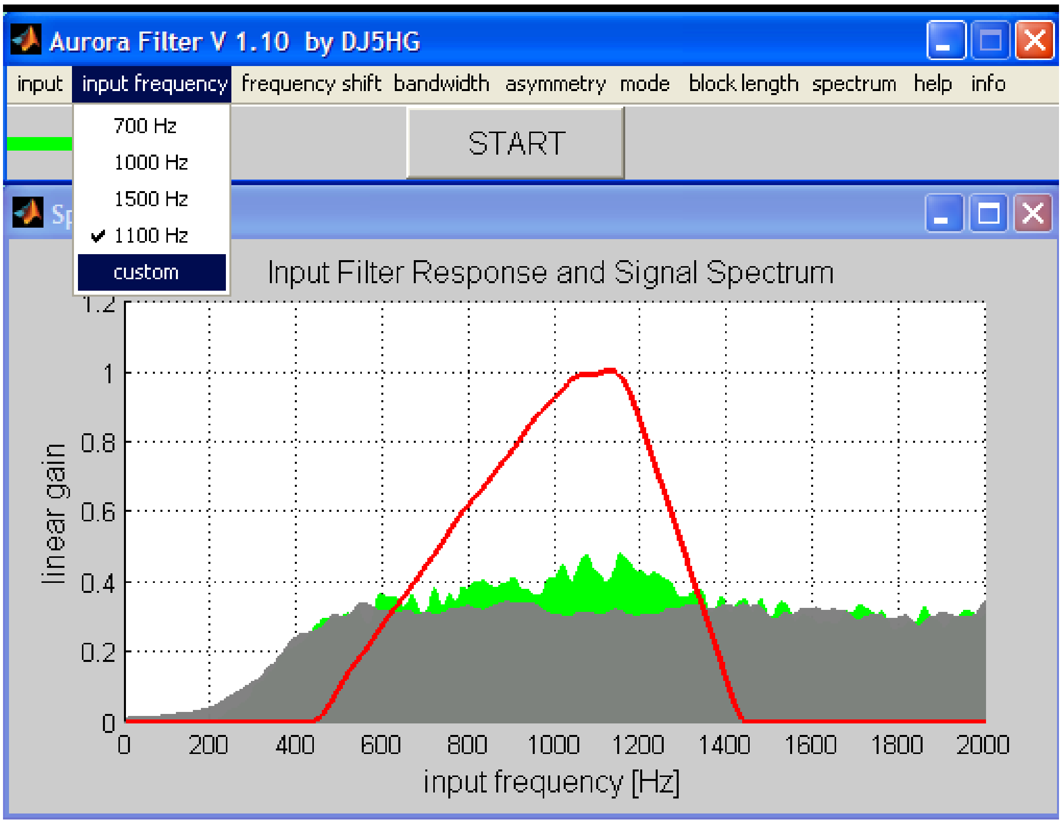



**Figure 5.** The three upper selectable input center frequencies are pre-assigned by the program. The fourth value (1100 Hz in this case) can be changed by selecting „custom". Then a small editor window waits for your input. The custom value can be changed only when the filter is stopped.

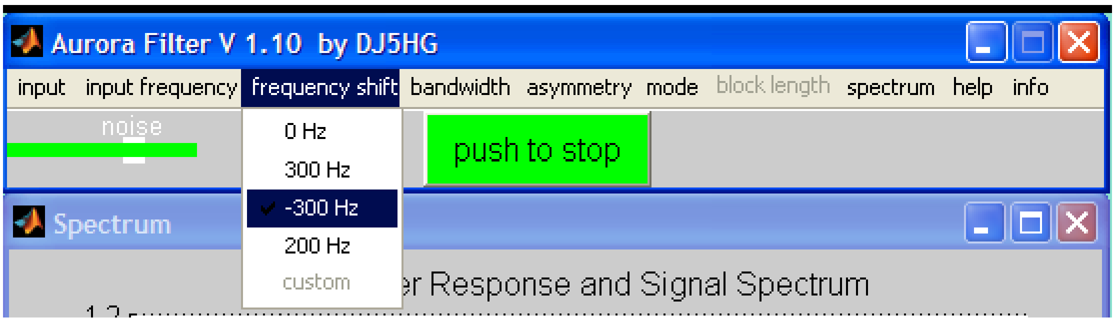



**Figure 6.** Aurora filter can shift the output spectrum by selectable values. The three upper values of the pulldown menu are preassigned in the program. A fourth value can be defined by selecting „custom". In that case a text input window will appear that waits for your input. The custom value can be changed only when the filter is stopped. All assigned values including the custom value can be interchanged while the filter is running.

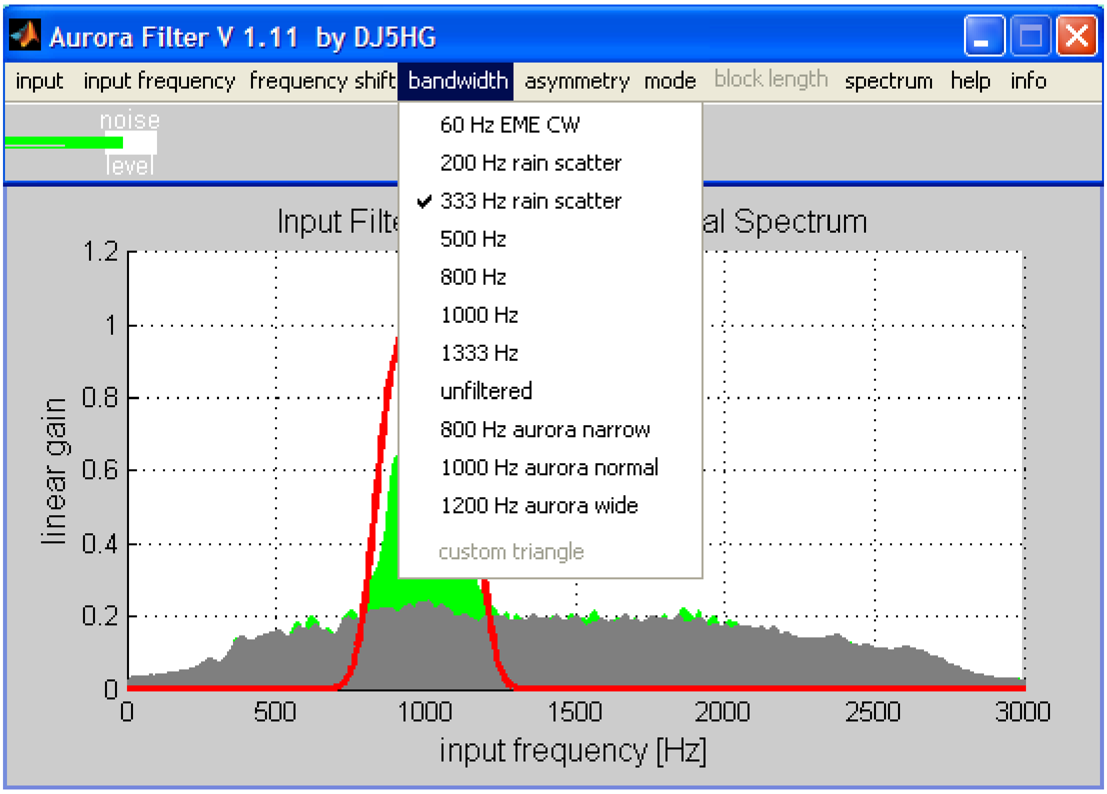



**Figure 7.** The aurora bandwidths of the bandwidth pulldown menu are 50 dB-bandwidths of triangle-shaped filters. They are preassigned by the program. A fourth triangle-shaped filter can be chosen according to your own demands by selecting „custom“. The rain scatter filters are Gaussian-shaped. The other filters are raised-cosine band pass filters (r = 0.5). The bandwidth for raised-cosine and Gaussian shape are at -6 dB. All filters can be interchanged while the filter is running. In the „unfiltered“ case there is still a Hilbert filter running (which is a high pass).

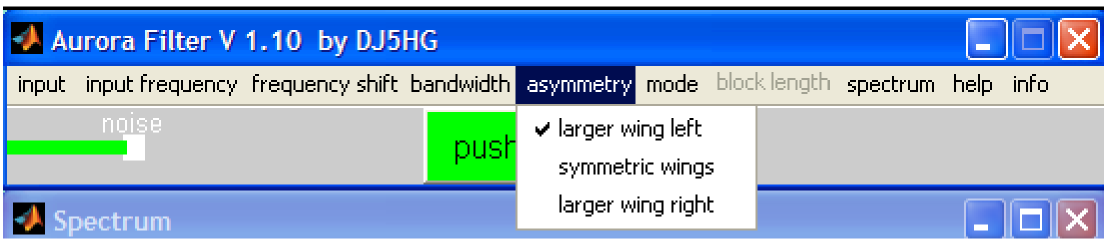



**Figure 8.** The aurora filters including the custom filter are designed in three modes of symmetry. Here the mode „larger wing left“ is selected. At very narrow bandwidth the difference vanishes.

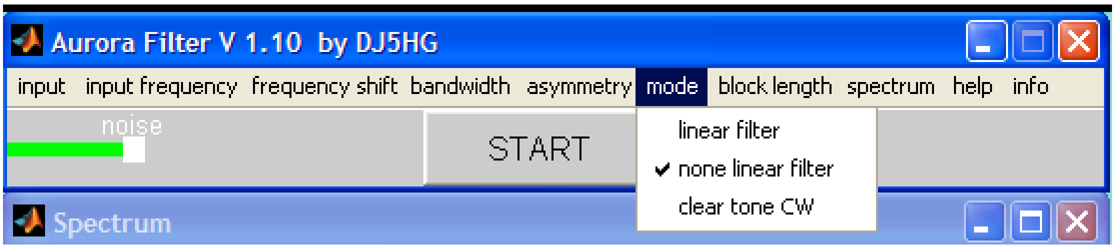



**Figure 9.** Pulldown menu to select the mode. The *linear filter* filters the input signal according to the frequency response shown in the spectrum window. The *none-linear filter* additionally performs a decompression of the amplitude. This mode seems to be surprisingly well suited for aurora signals. In the *clear tone CW* mode any information of the spectrum is lost. Tuning must be done using the spectrum display. These three exclusive modes can be interchanged at running filter.


**Figure 10.** The blocklength is the number of samples acquired in a buffer of the sound system before transported into the filter program. Since this buffer causes a substantial delay between the audio input and the corresponding audio output you should use the smallest possible value. The Matlab Data Aquisition Toolbox does not allow smaller blocks than 800 samples. The latency caused by the buffer is the greatest handicap of the filter. The Windows system was not designed for realtime applications. It cannot guarantee the neccessary quality of service. Only a large buffer helps to minimize dropouts on the output. So, please be aware of the fact that you do not use an adequate system for this application. Unfortunately, the Matlab Data Aquisition Toolbox is available only for Windows. As a consequence of the delay between input and output you should not listen to your own CW side tone through aurorafilter.

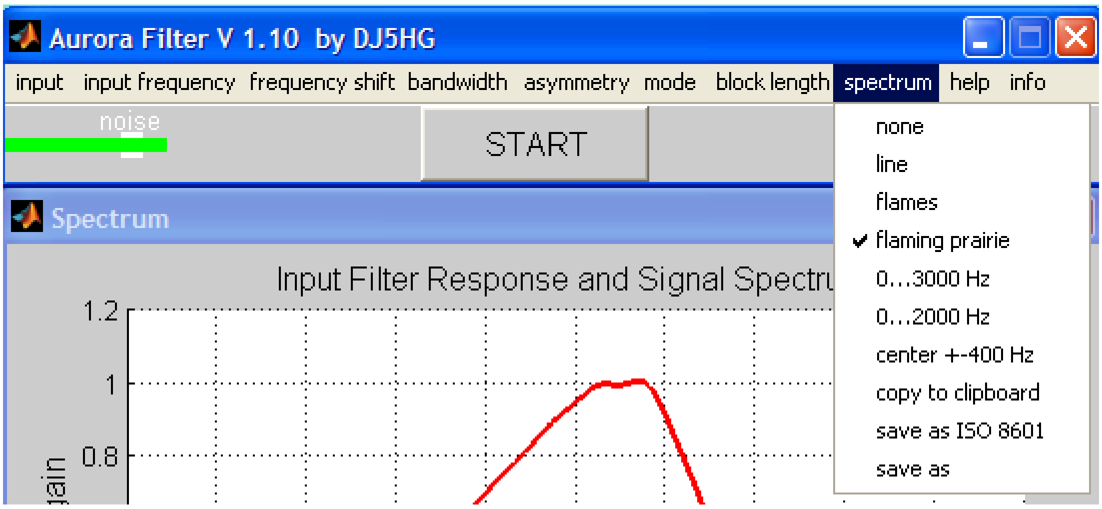



**Figure 11.** The spectrum can be displayed in several modes. The modes *line* and *flames* are usual signal spectra. The *flaming prairie* mode assumes a keyed CW signal and tries to separate keyed parts from not keyed parts to get both, the noise spectrum (displayed in grey) and the spectrum of signal plus noise (displayed in green). This mode is very sensitive. The spectrum pulldown menu also offers three modes for the limits of the spectrum axis. Also, you can copy the spectrum display to the clipboard or save the figure to disk. The program will remember your last custom values and your settings at the time of the last program exit when you load the program again.

The **help menu** offers three windows showing *hints for usage*, *principles of operation*, and *controlling by the keybord*.

**Controlling Aurorafilter by the Key Board**

Some parameters can be changed by use of the keyboard as an alternative to the menu. The spectrum window must be in focus:

| | | |
|---|---|---|
| START/STOP: | | space key |
| Filter Shape | raised-cosine: | Q or q |
| | triangular: | T or t |
| | Gaussian: | G or g |
| | symmetric | S or s |
| | larger wing left: | L or l |
| | larger wing right: | R or r |
| | S, L, and R only work in the group of aurora filters | |
| Bandwidth: | next smaller bandwidth: | Cursor left |
| | next larger bandwidth: | Cursor right |
| | This works within the group „EME until unfiltered and within the group of aurora filters. It is recommended to find stations with larger bandwidth. Then the bandwidth can be adapted by the Cursor keys. | |
| Mode | linear: | 1 |
| | non linear: | 2 |
| | clear tone CW : | 3 |
| Spectrum | none: | N or n |
| | line: | I or i |
| | flames: | F or f |
| | flaming prairie: | P or p |
| Save | copy to clipboard: | C or c |
| | save as ISO 8601: | B or b |
| | save as: | A or a |
| Help on | parameters: | h |
| | keyboard control | H |

The **info** shows the authors email address and the license conditions:

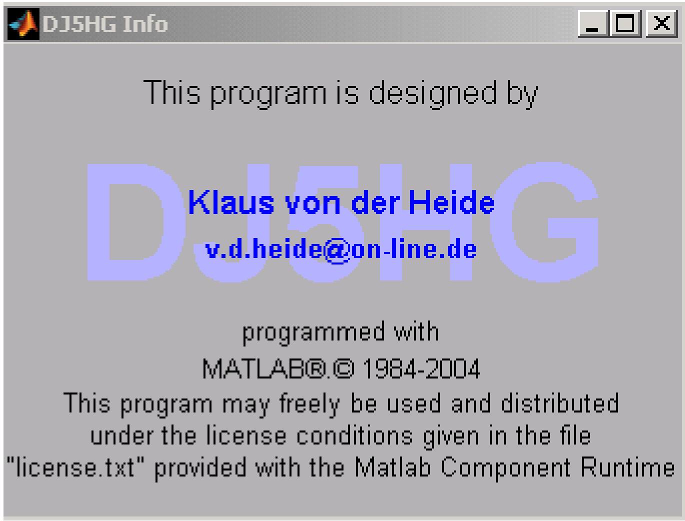



**Fig. 12.** The information display.

## Some Aurora Examples taken on 2005-08-31

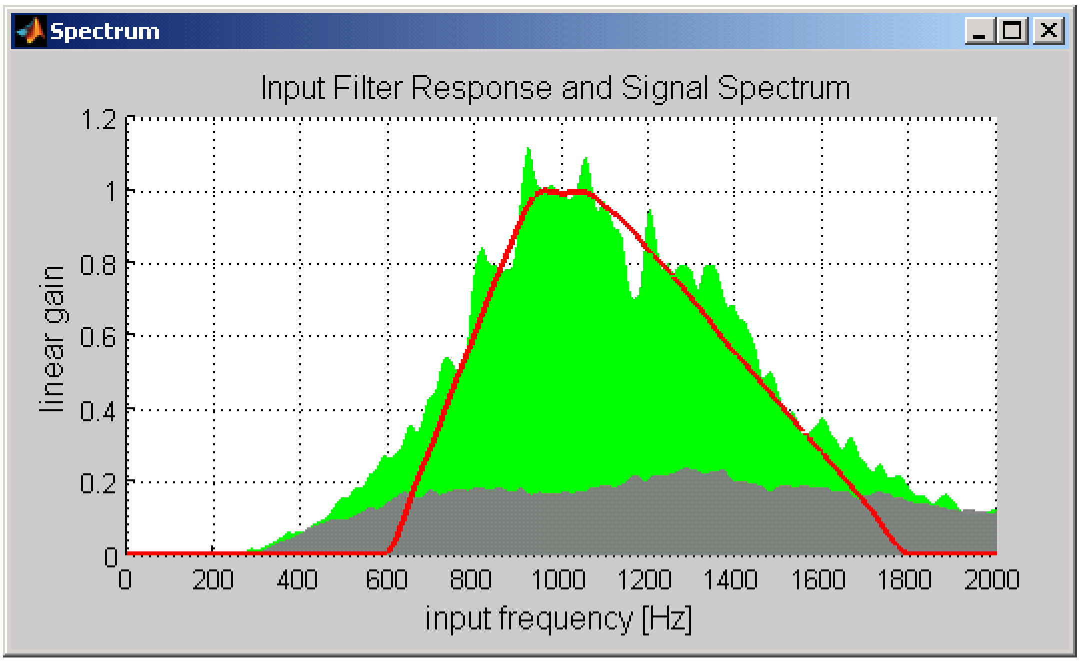



**Fig. 13.** G7RAU 55a at DJ5HG (CW = LSB)

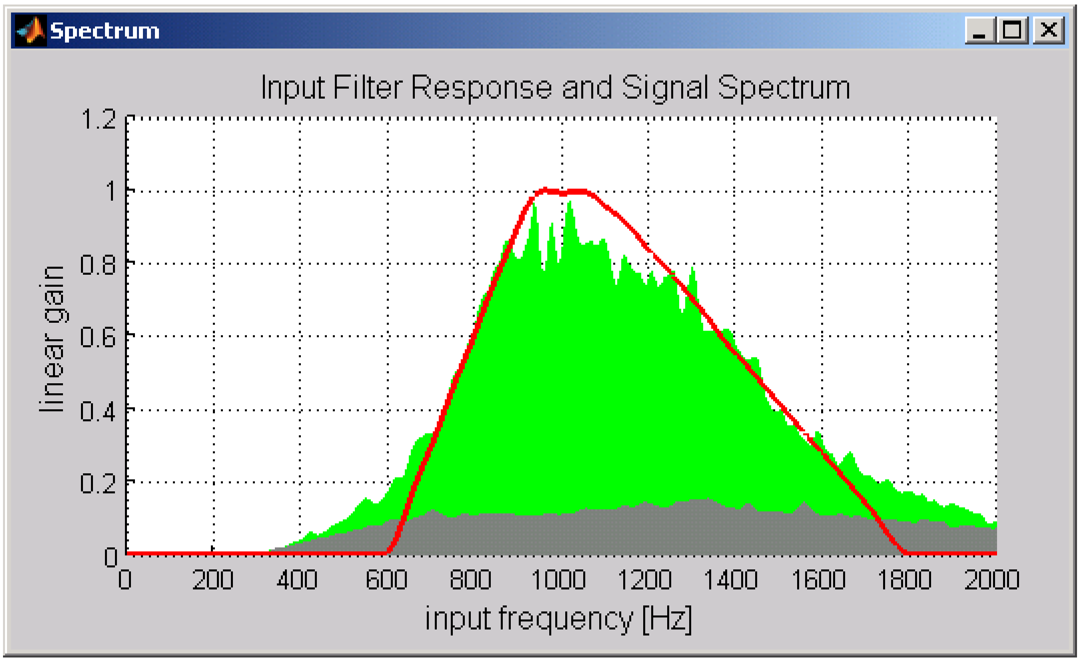



**Fig.14.** LA8WF 56a at DJ5HG (CW = LSB)

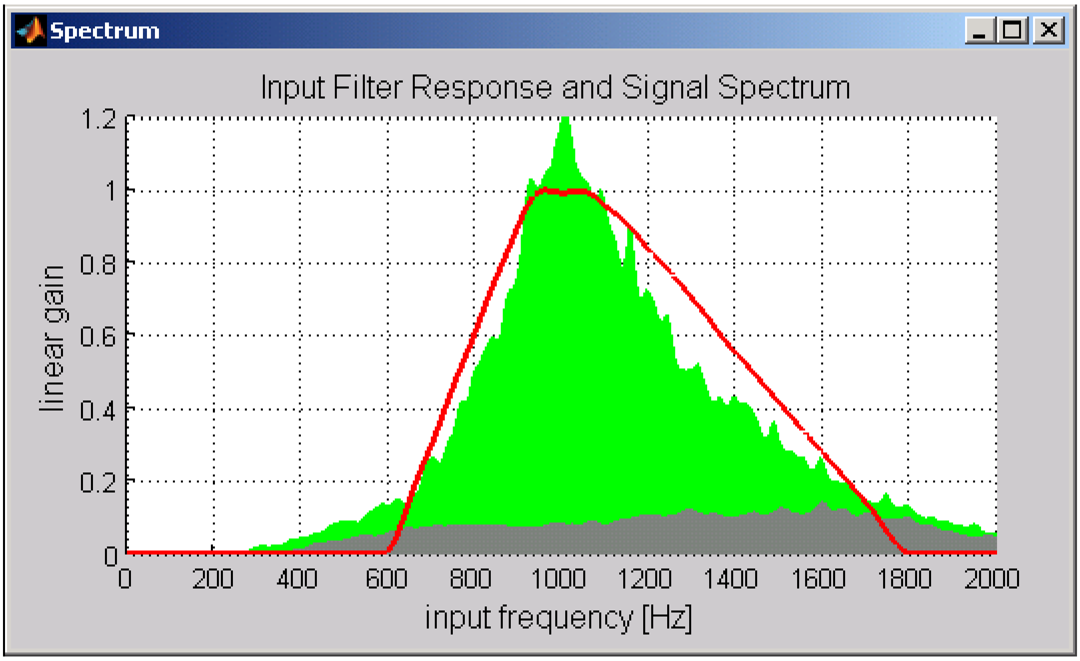



**Fig 15.** SM5EFP 57a at DJ5HG (CW = LSB)

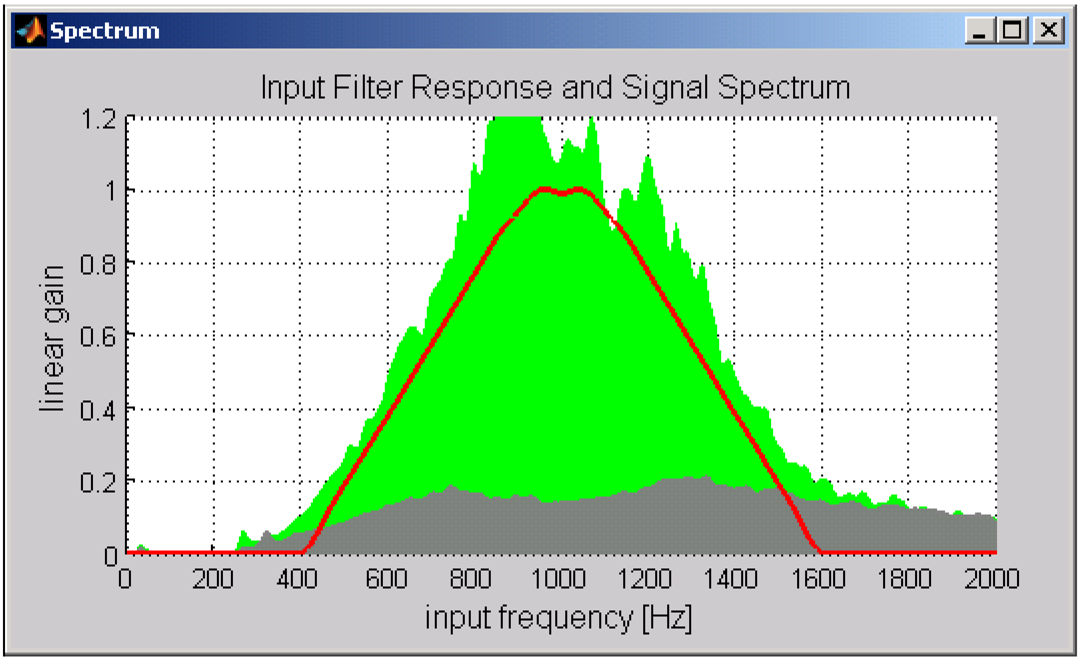



**Fig. 16.** RX1AS 58a at DJ5HG (CW = LSB)

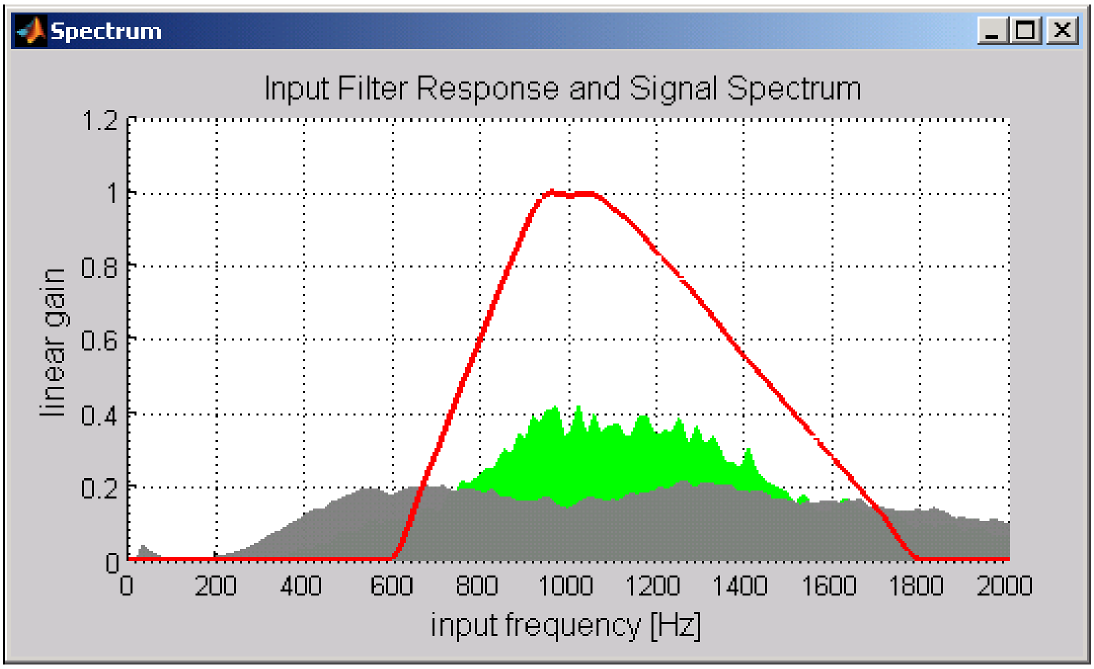



**Fig. 17.** UA2FL 52a at DJ5HG (CW = LSB)

### Some other signals

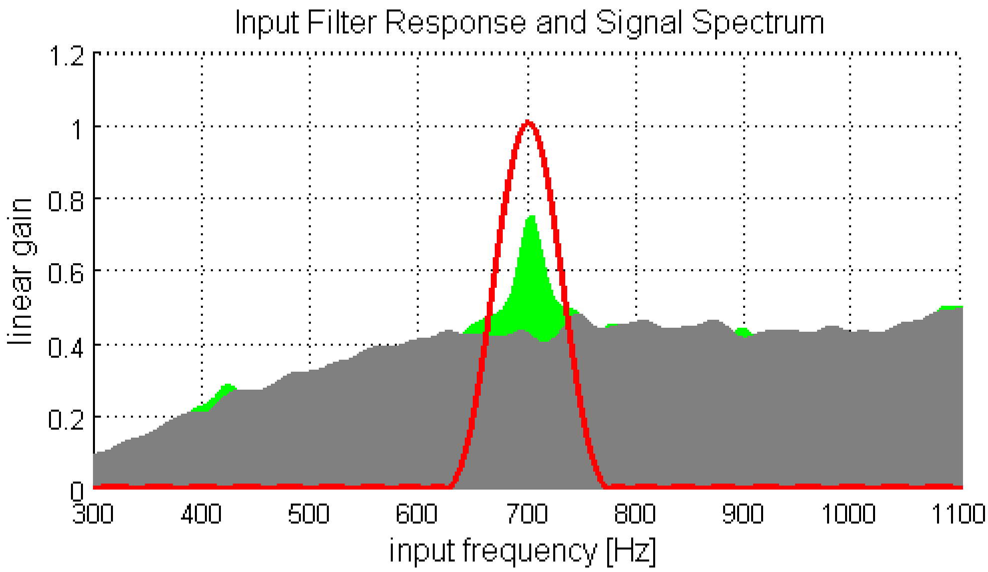



**Fig. 18**. A beacon 219 within the 60 Hz filter. The spectrum can identify unreadably weak CW signals.

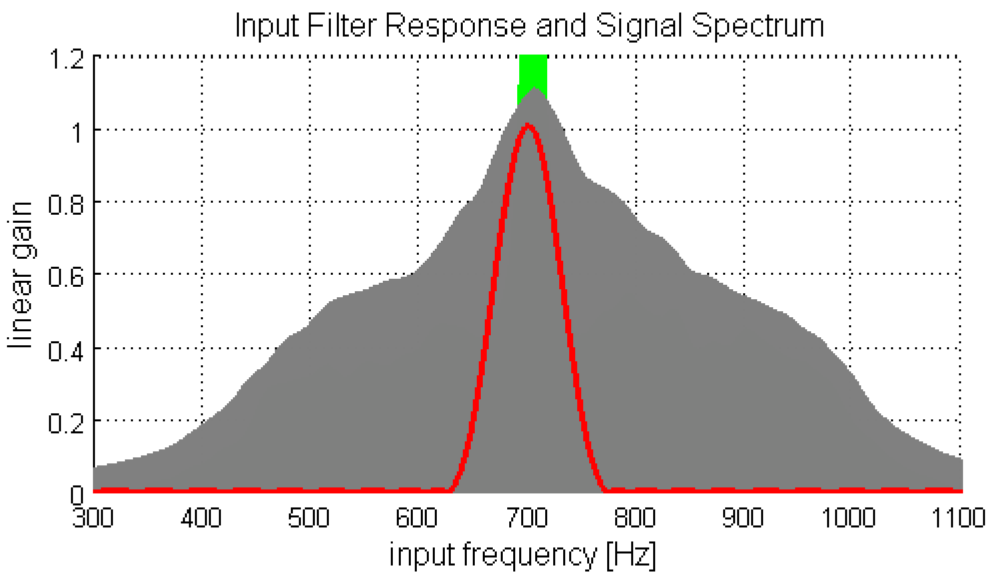
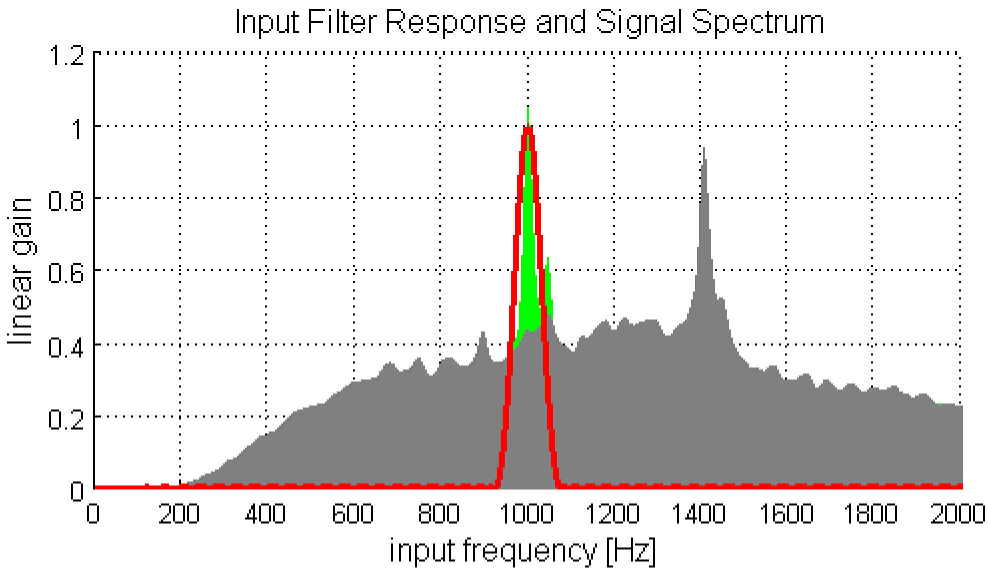



**Fig. 19.** The beacon SK4MPI transmits a long segment of an unkeyed carrier. The program then cannot separate signal and noise. Such „black hills“ often are birdies. If there is no signal then there is a „black valley“ plus a small green hill. In contrast to fig. 18 here a 500 Hz CW filter was used in the transceiver. That causes the restriction of the noise within about 450 Hz and 1000 Hz.

**Fig. 20.** This figure shows an FSK beacon. The decision what is signal and what is noise is made only from what is passing through the filter. Therefore everything in the none-keyed time segments including the second alternatively keyed carrier is adopted as noise.




**Rain scatter**

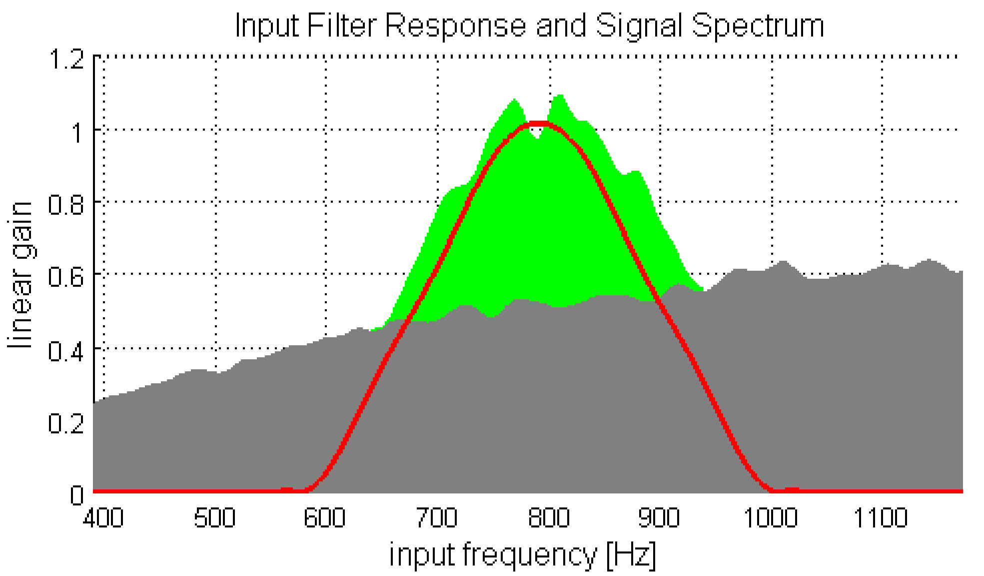



**Fig. 19.** Rainscatter signal from HB9G recorded by DJ5BV on 10369 MHz

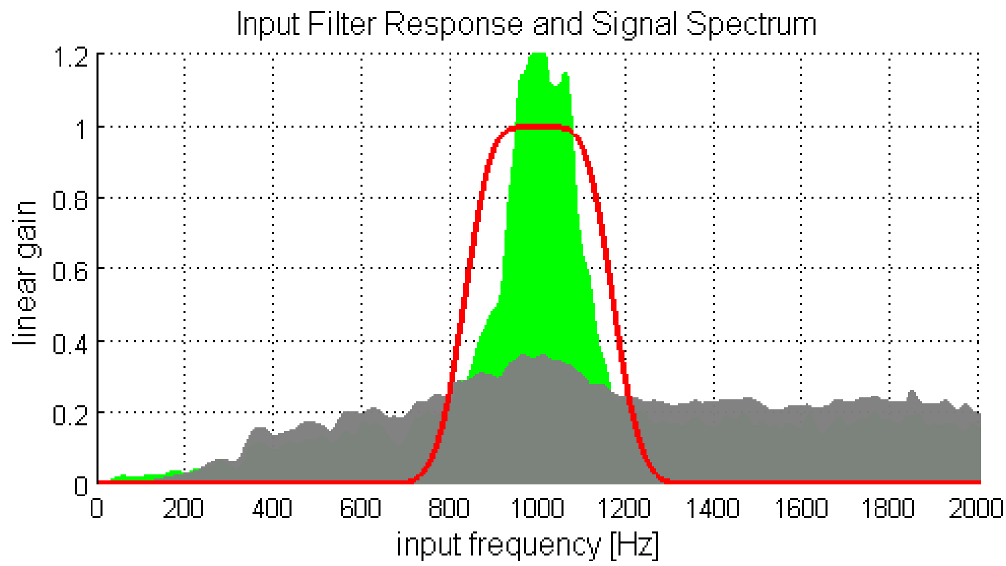



**Fig. 20.** Rainscatter signal from G3LQR recorded by DF6NA on 3 cm.

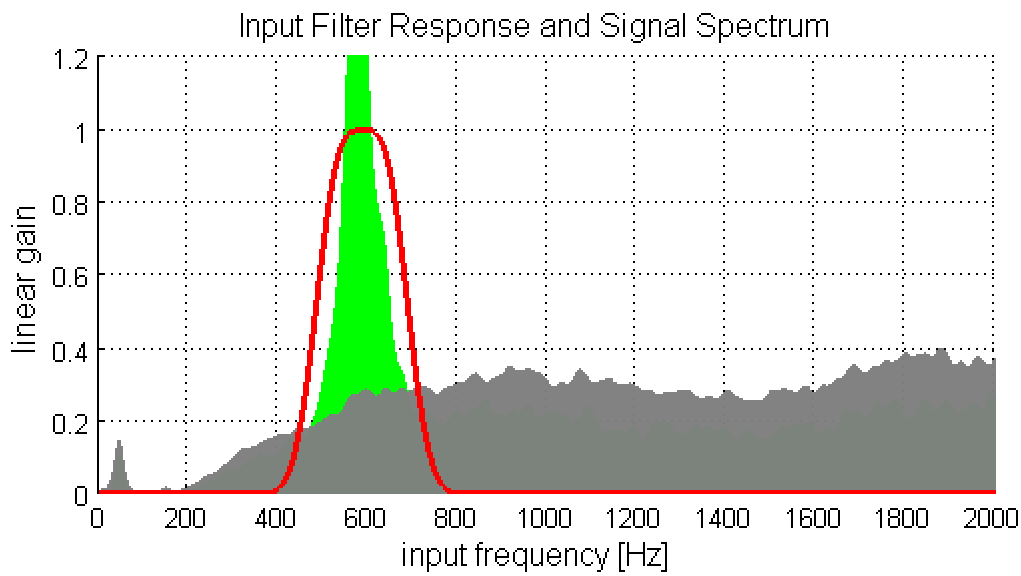



**Fig. 21.** FAI signal from FD1FHI recorded by I3LGP.

## Necessary hardware

If aurorafilter is used in a CW-QSO, then the earphones should be switched between the filter output and the transceiver CW-sidetone, and the filter input should be switched off in the transmission period.  This can be done by a relay controlled by the PTT as shown in fig. 20.

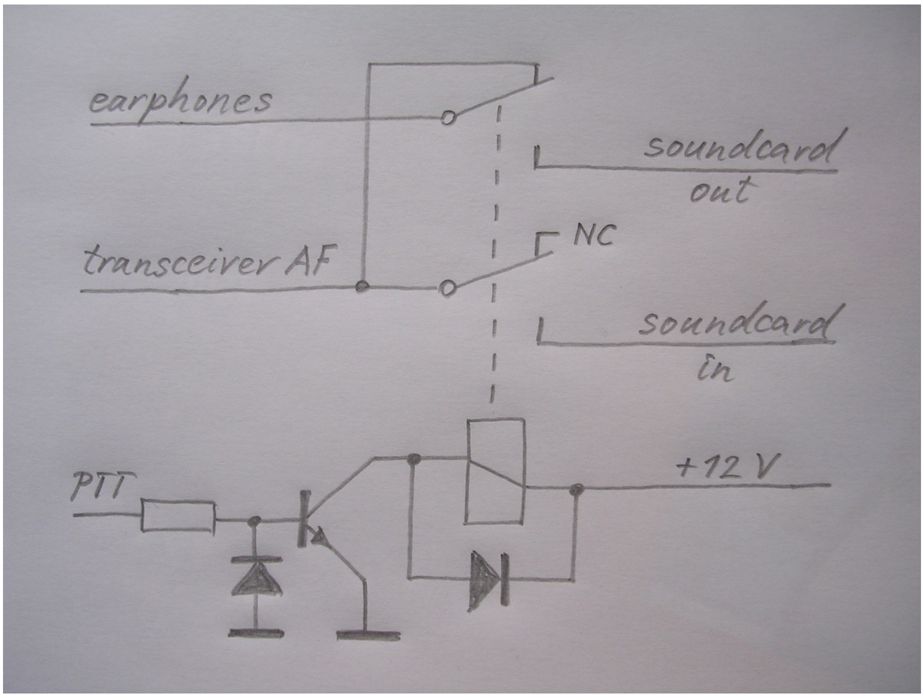



**Fig. 20**  Hardware between transceiver and soundcard.  PTT is pushed here to switch the relay off.

## History of aurorafilter

V 1.4   was the first version in the internet.
V 1.5   only was distributed by mail.  It introduced the spectrum display modes.
V 1.6   fixed some minor bugs.
V 1.7   introduced hot keys to control the filter.
V 1.8   does not reset the noise when started again in one session and does not change the noise level when the input is interrupted (i.e. by hardware of fig. 20).
V 1.9   fixed some bugs.
V 1.10  added the menu item *input* and put error messages on the clip board.
V 1.11  the rectangular filters were replaced by better sounding raised-cosine filters ( r = 0.5 ), and some bugs fixed.