BELL FILTER IMPLEMENTATION

ISP & I.ISP parameters description

STORM|AUDIO

BELL FILTER

A type of filter that allows the boost or cut of a specified set of frequencies around a center frequency. Bell filters allow user adjustment of the center frequency, Q, and the amount of gain or attenuation. While so far it is common definition, things change for the definition of the Q itself and its effect.

GENERAL Q DEFINITION

Considering the figure 1 where the Center frequency and the Bandpass are shown, Q is the result of the center frequency divided by the difference of the upper -3dB frequency and the lower -3dB frequency.

$$Q = \frac{f_c}{f_{high} - f_{low}}$$

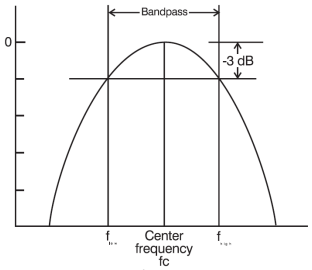

Figure 1.

CONSTANT-Q AND NON CONSTANT-Q

With the above general definition, one can observe that there is a dependency between the Q and the amount of gain/attenuation used as illustrated in the figure 2.

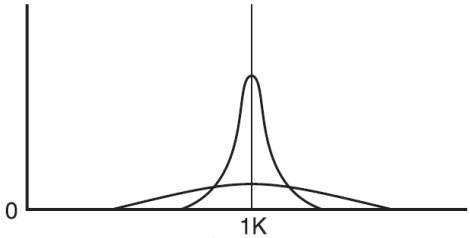

Figure 2.

We can clearly see that the filter only achieves its specified bandwidth at one boost setting. At all others, the bandwidth is wider (lower Q value). This means that for gain or attenuation amounts that are less than maximum, a far greater number of frequencies are affected. This is not convenient when using a response curve to deduct the required correction in terms of Q and gain/attenuation to apply to an equalizer.

To cope with this issue, Constant-Q has been defined.

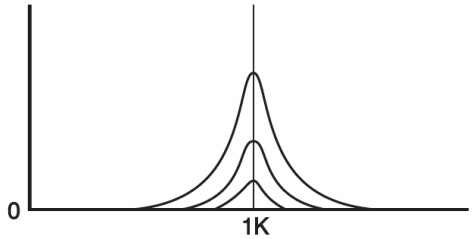

Figure 3.

Looking at figure 3 frequency response curves, you can see that even for small amounts of gain or attenuation, the filter maintains its specified bandwidth. Bandwidth will not vary with gain adjustment.

MULTIPLE BANDWIDTH DEFINITIONS

Reading the available litterature and DSP manufacturer material, one can easily get lost when dealing with the actual bandwidth definition they use.

Some will use the traditional bandpass definition with the -3dB to peak definition. Other definitions will be described here using the term Filter Gain, to mean the gain for the Bell filter at either frequency at the endpoints of the bandwidth.

Instead of considering the bandpass response, a reasonable definition is to make the (Bell) Filter Gain –3 dB from the peak. But if, for example, a filter response only ranges from 0 dB to +2 dB, it's impossible to use a –3 dB response point. The Bell filter has this dilemma for small settings. This is remedied by choosing the filter gain to be one-half of the peak (setting) dB for settings under 6 dB. At 6 dB, these two definitions agree, and this will be referred to as the 3 dB Hybrid method here.

While this helps define small gain filters, it is not that simple to use.

STORMAUDIO BANDWIDTH DEFINITION

StormAudio Constant-Q Bell filters definition sets the bandwidth such that the width at mid-height of the bell remains constant, which is a consistent definition that results in a comparatively narrower response curve for large settings. It is sometime called "dB/2" method.

For example, for a bell located at 1kHz, a gain for example of 12dB and with Q = 1, the peak will have a width of 1kHz at mid-height of the peak (ie at 6dB). See figure 4. This makes it quite easy to determine bell filter settings from the reading of a speaker curve.

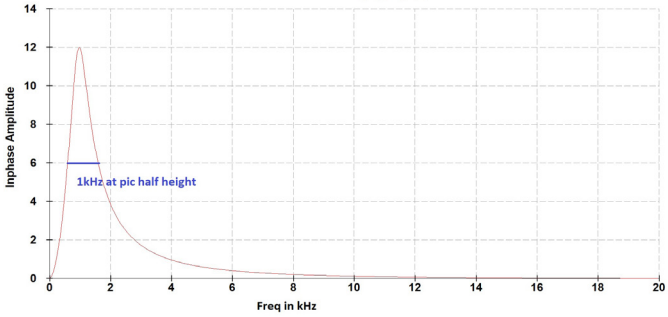

Figure 4.

This definition is commonly used in digital signal processors, but it still exhibits one issue: frequency vs sampling rate dependency. The higher in frequency the correction is done, the lesser the bandwidth follows the actual definition of bandwidth equal center frequency for Q=1.

Some compensation has to be used.

Figure 5 illustrates a bell filter of 12 dB gain, 10 kHz center frequency and Q=1. You can see the bandwitdh is quite close to 10 kHz.

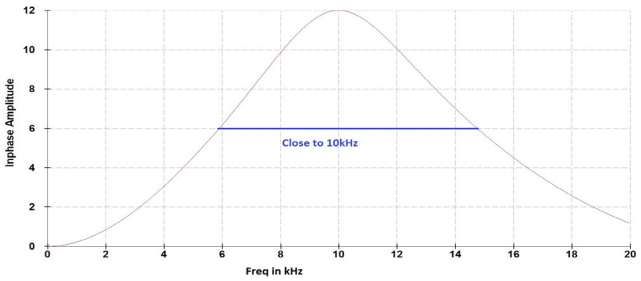

Figure 5.

Figure 6 illustrates the non-compensated version of the filter: one can clearly see the bandwidth being narrower.

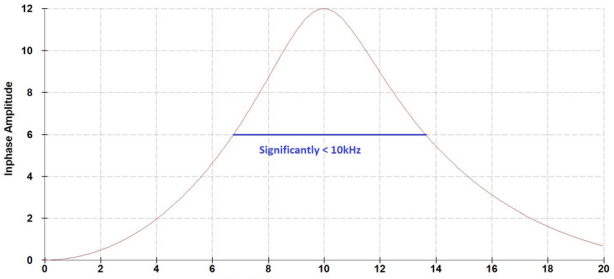

Figure 6.

A factor K has to be applied to a non compensated Q, as shown below:

$$Q_{storm} = Q.K$$

where

$$K = \frac{2.\pi.fc/fs}{\sin(2.\pi.fc/fs)}$$

Important note:

Applying this factor K will be necessary for filters defined for use with Datasat or Trinnov audio video processor and implemented on StormAudio processors.

References:

- *RaneNotes 101 & 117 combined "Constant-Q Graphic Equalizers", Dennis Bohn*
- *RaneNotes 167 "Why DSP Boxes Set the Same Way Differ", Ray Miller*
- *Technical Paper 106 , "Equalizers and Constant-Q", Richard Chinn*