

# Foundation® Digital Advantage – Parametric Filters

According to Floyd Toole,\* “Given the right signal and listening circumstances, it is possible to hear resonances that would be very difficult to detect by any technical measurements.” So even small errors in an audio system that are not smoothed out accurately, may be audible.

In Foundation™ Digital every effort was made to ensure that natural sounding audio was maintained. This is why each Foundation™ Digital hybrid comes equipped with Parametric Filters. Parametric Filters prove to be an invaluable tool when it comes to removing frequency response anomalies or resonances such as Insertion Gain Errors due to their flexibility and accuracy.

Graphic Equalizers, on the other hand, often lack the needed resolution to provide accuracy in many situations and are usually not as flexible as their parametric counterparts.

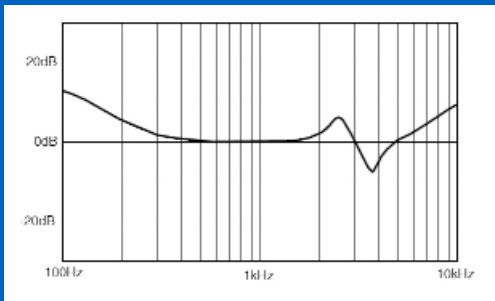
To visually show the advantage of Parametric Filters over Graphic Equalizers a quick experiment was conducted and the results are shown below.

Consider Plot 1 to be the inverse of an Insertion Gain Error curve. Insertion Gain Errors are undesired modifications to the open ear response due to putting a hearing aid into a person’s ear. It would be desirable to remove these errors to get back to as flat a response as possible.\*\*

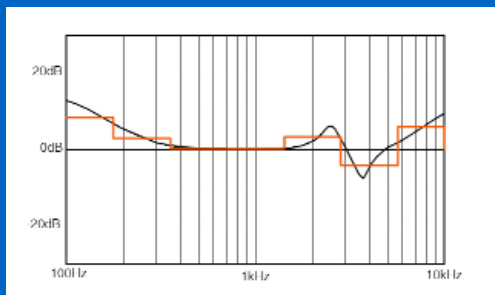
The objective of the experiment was to see how closely we could match Plot 1 using different types of equalizing filters. Applying these different filters in a hearing aid will hopefully flatten out the Insertion Gain Errors. The closer the match with Plot 1, the better the removal of the Insertion Gain Errors. See Plot 1 – Insertion Gain Error Inverse

We first start our experiment with a Graphic Equalizer with 1 octave spacing, as shown in Plot 2. It is visually evident that there is considerable mismatch between the Insertion Gain Error Inverse curve from Plot 1 and the “matched” curve using the Graphic Equalizer with 1 octave spacing. There are significant differences at all frequencies except perhaps between 400Hz and 1.5kHz. Clearly, this filter does not have enough resolution to closely match the Insertion Gain Error Inverse curve and so this equalizer curve cannot remove the Insertion Gain Errors very well. See Plot 2 – Graphic Equalizer with 1 Octave Spacing.

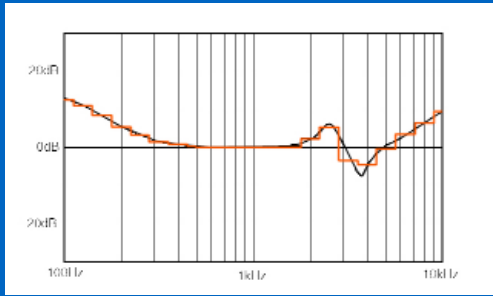
Next we tried a Graphic Equalizer with 1/3 Octave Spacing, which brought us considerably closer to the target filter response. However, an exact match could still not be achieved especially between 1.5kHz and 5kHz. These



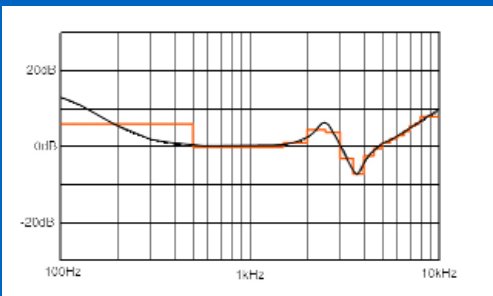
**Plot 1 – Insertion Gain Error Inverse**



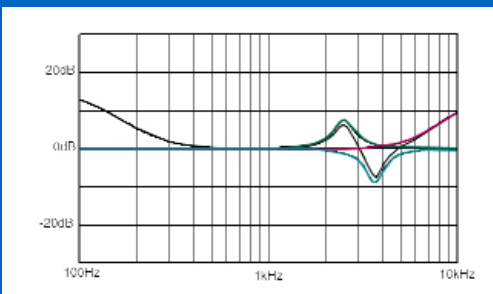
**Plot 2 – Graphic Equalizer with 1 Octave Spacing.**



**Plot 3 – Graphic Equalizer with 1/3 octave spacing.**



**Plot 4 - FFT-type Graphic Equalizer with 500Hz spacing.**



**Plot 5 – Four Parametric Filters utilized to match the error signal.**

improvements came with the price of the need to adjust all of the bands separately. This can be very time consuming if it needs to be done manually and can even be somewhat time consuming for an automatic fit routine. See Plot 3 – Graphic Equalizer with 1/3 octave spacing.

Since the mid to high frequencies showed the largest differences with the 1/3 octave filters, we next tried using a FFT-type Graphic Equalizer with 500Hz spacing. The FFT-type Graphic Equalizer has much better resolution at the high frequencies but, as can be seen in Plot 4, it has very poor resolution in the low frequencies and consequently does not match the inverse Insertion Gain Error curve very well at all below 500Hz. Also, even with the greater resolution at higher frequencies it was still not possible to exactly match the transitions between 2kHz and 3kHz. See Plot 4 - FFT-type Graphic Equalizer with 500Hz spacing.

Finally, we tried the Parametric Filters available in Foundation™ Digital. Plot 5 shows the four Parametric Filters that were used to match the inverse Insertion Gain Errors curve. We first used a low frequency shelf filter to boost the low frequencies, then an EQ filter centred at 2.5kHz to match the missing pinna resonance, then an EQ filter centred at 3.6kHz to match the undesired receiver resonance and finally a high frequency shelf filter to boost the high frequencies.

The sum of these curves is shown in black; it so closely matches the inverse Insertion Gain Error curve that you may not be able to see them both. The error signal was accurately matched through the combination of these four Parametric Filters thus allowing the complete removal of the Insertion Gain Errors. See Plot 5 – Four Parametric Filters utilized to match the error signal.

From this simple experiment we have been able to show that the inverse Insertion Gain Error curve was much more accurately matched using the Parametric Filters available on Foundation™ Digital than with any of the Graphic Equalizers.

\* Toole et al, “The Modification of Timbre by Resonances: Perception and Measurement”, *Journal of the Audio Engineering Society*, Vol. 36, No. 3, March 1988.

\*\* United States Patent Killion et al, Patent No: US 6,466,678 B1  
 United States Patent Killion et al, Patent No: US 6,047,075  
 United States Patent Killion et al, Patent No: US 5,812,679