EDITORIAL

Data Filtering – Art or Science?

***Patrick L. Walter**, Contributing Editor*

If we define a filter as any frequency-selective device, it is apparent that all instrumentation systems behave in one way or another as data filters. This is because, as a minimum, all systems have some upper frequency limit above which their signal amplitude becomes attenuated. By convention, this limit is usually defined by the frequency at which 3 dB of attenuation occurs. If an instrumentation system has only a high-frequency limitation, we define it as a low-pass system. Many instrumentation systems also have some low-frequency limit (e.g., AC coupled systems) below which their signal amplitude becomes attenuated. Examples include all systems that perform signal-conditioning for piezoelectric transducers. If a system has both a low- and a high-frequency limitation, we define it as a band-pass system. By analogy, we can also envision band-reject systems, i.e., those systems where an intermediate range of frequencies is rejected. High-pass systems can similarly be envisioned, although in practice no real system rejects only low frequencies and subsequently passes higher frequencies extending to infinity.

During testing, it is typical to ask the test engineer: "What's the frequency response of your instrumentation system?" A typical answer for a low-pass system might be: "It has a –3 dB frequency of 20 kHz." Synonyms that can be used for the term "–3 dB frequency" are: corner frequency, cutoff frequency, or half-power frequency. At this point, the requester has been told very little about how the system attenuates high frequencies and absolutely nothing about its phase response. For a simple, RC, low-pass system, the –3 dB frequency (in radians/second) is the reciprocal of the time constant (RC product), and its frequency response (amplitude and phase) becomes uniquely defined. For any other low-pass system, the –3 dB point only indicates where the system frequency response is attenuated to 70.7% of its amplitude at 0 Hz. It has no other physical significance.

Often we'll further customize the frequency response of our instrumentation system with commercial filters. These can also be low-pass, band-pass, band-reject or high-pass in character. However, to be more descriptive, we utilize acronyms like Bessel, Butterworth, Chebychev, elliptical, etc., which are all different filter types with unique amplitude and phase responses. We further characterize these filters by their high- and low-frequency attenuation, also referred to as "roll-off characteristics." This roll-off is typically described by terms such as 2-pole, 4-pole, 6-pole, etc. If additional clarification is requested, it might be pointed out that each filter pole produces an ultimate attenuation of 20 dB/decade, which is equivalent to 6 dB/octave. Each pole also corresponds to an ultimate slope of –1 on a log-log frequency plot.

Is it any wonder that the analyst depending on the test data becomes confused? We have not even approached terminology (such as "one-third octave") that further describes filters such as those used in acoustic studies. *Most analysts are comfortable under the delusion that a filter can be envisioned as a square or "box car" function in frequency, and he/she typically does not understand or even want to acknowledge that the filter has any phase characteristics.* However, if there is any difference between the recorded data and the pretest predictions of the analyst, the analyst is likely to take the data, utter a chant for protection to the "data gods," and further process the data by digitally filtering it. His/her hope is that, by some quirk of good fortune, the now twice-filtered results will somehow agree with the predictions. Of course, with little understanding of the instrumentation system, there is little chance of agreement, and the instrumentation system and its resultant data are often unwarrantedly looked at with suspicion.

However, digital filters have their own nuances. Without elaborating on them in great detail – they can be designed to produce no phase distortion, they can be designed to replicate actual hardware filters, they can produce an output before "time zero," and they are unique in many more ways!! *Is it any wonder that data filtering is a confusing business?*

Of course, this editorial cannot begin to provide all the knowledge required to correct this situation. It does emphasize that all data are conditioned through filtered systems, and it serves as a point of departure for further personal study.

Some folks might advocate that current technology enables over-sampling with sigma-delta converters, which can be protected by crude, anti-alias filters. These data can then be post-filtered with sophisticated digital filters. However, this advocacy ignores many hardware realities. Cable bundles can severely influence test system response and test cost. For example, aircraft testing may require many miles of cables weighing thousands of pounds. Therefore, there is increasing pressure in much testing to transmit data serially, which requires closely spaced anti-alias filters. *Hardware filtering will always be a system design consideration.*

Thus, even though modern data filters have been around since the invention of the operational amplifier in the mid-1950s, the analyst and test engineer still need to learn to speak a common language if they ever want to succeed in making a comparison between data acquired from the instrumentation system and expectations established by the pretest analysis. A suggested first step to achieve this commonality would be for the test engineer to assure that a comprehensive description of his/her instrumentation system is provided on the magnetic media, or included in the report, transmitting the data to the analyst. This would both enhance communications and assure more meaningful comparisons between test series, which often are timewise separated by days, weeks, months or years. SV

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