CJS Labs

Technology · Research · Strategy · Solutions

Lab Notes

NCAC
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Member

Audio & Electroacoustics
- *Consulting*
- *Design / Testing*
- *Training*

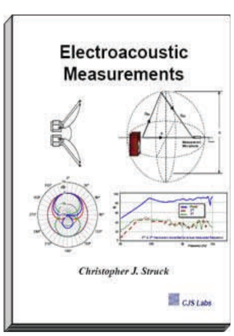
Volume 3, Issue 1 **February 2010**

Inside this issue:

"Electroacoustic Measurements" Book

THE essential reference for making proper electroacoustical transducer measurements. A 300+ page, bound, fully annotated compendium of slides and notes from the CJS Labs training seminars. Literature references for each chapter are also included. Ordering information:

http://www.cjs-labs.com/sitebuildercontent/sitebuilderfiles/OrderingCourseNotes.pdf



Project Work for 2010

A visit to the Smithsonian in Washington DC last fall inspired me to investigate the operating principles of the phonograph cartridge, essentially a dual orthogonal velocity probe. Vinyl is apparently still quite big in the audiophile and collector circles! The photo is of the 1899 Edison cylinder player.

Many industries are still feeling the effects of the economic decline in 2009. CJS Labs was no exception, with a noticeable decline in new projects. Fortunately we have weathered the storm and are currently busy with several interesting projects, involving both hardware and software development. A list of recent project work is available on our website at:

http://www.cjs-labs.com/sitebuildercontent/sitebuilderfiles/CJSLabsRecentProjectsList.pdf

Meanwhile, we still offer seminars and training as well as the "Electroacoustic Measurements" seminar notes, available from our website (see sidebar for more information).

Please contact us and let us know how we can be of service to you and your organization.

Recent News & Upcoming Events

Standards News

Several IEEE telecom standards, including 269 and 1329, are currently out for ballot and should be available later this year. Stay tuned for updates.

AES News

In 2009, I became a reviewer for the AES Journal. Although a volunteer assignment, I found the process very interesting and was pleased to help improve the quality of the technical articles in the JAES. The AES 129th Convention will be here in San Francisco this fall. More info will be available at the AES website later this spring.

American Academy of Audiology: Audiology NOW!® 2010

AudiologyNOW!® 2010, the annual conference for the American Academy of Audiology, will be held in San Diego, 14-17 April 2010. More info at:

http://www.audiologynow.org/

We plan to attend. Please contact us if you would like to set up a meeting.

Best regards,

Christopher J. Struck

CEO & Chief Scientist

CJS Labs

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"Sound Advice since 1986"

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Back issues of Lab Notes are available on our website at:
http://www.cjs-labs.com/id5.html

Noise-Canceling Headphones & Headsets: Measurement of Passive and Active Noise Isolation

Measurement of Noise Isolation is performed as an Insertion Loss (substitution) test. First, the background noise level in the test space is checked. This should be at least 10 dB below any subsequently measured level in each band. Next, the spectrum and level are verified. Although a perfectly flat spectrum is not required, sufficient stimulus is required in all bands, across the entire bandwidth of interest. Again, 1/3 octave bands are preferred, but the measurement can be performed with an FFT and then processed (power summed) to obtain the equivalent 1/3 octave spectrum. Using FFT, two passes may be required to obtain sufficient resolution at low frequencies. A typical test level is 90 dB SPL, so use hearing protection if you are in the same room! Ideally, a reverb chamber would be used, but good results can be obtained as long as the spectrum is uniform. The manikin is placed into the sound field, with the centre of the head at the reference point where the acoustic test spectrum was verified. The open ear response is then measured.

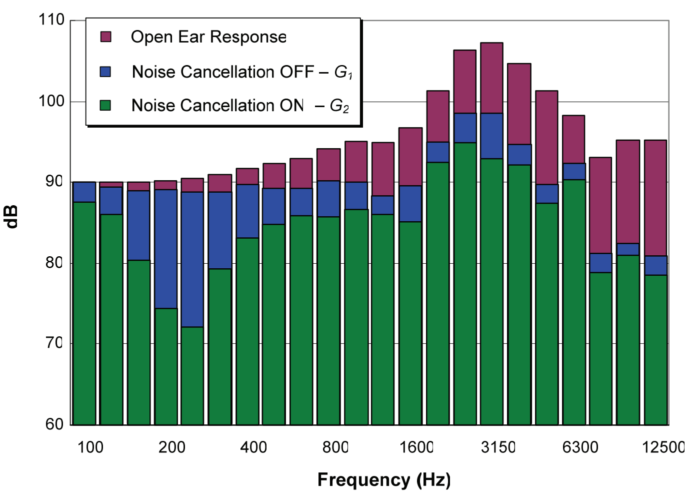

Fig. 1 — Noise spectra: Manikin open ear, Passive earphone $G_1(f)$, Earphone with Active Noise Cancellation $G_2(f)$.

Next, the headphones or headset under test are placed on the manikin and the test is repeated. This gives the test spectrum $G_1(f)$. If the headphones incorporate active noise cancellation, this should then be switched on and the test repeated to obtain the second spectrum $G_2(f)$.

The actual noise isolation can then be computed from the acquired data as follows:

$$L_{Passive}(f) = G_1(f) - G_{Open\ Ear}(f)\ \ [in\ dB] \qquad (Eq.\ 1)$$

$$L_{Active + Passive}(f) = G_2(f) - G_{Open\ Ear}(f)\ \ [in\ dB] \qquad (Eq.\ 2)$$

$$L_{Active}(f) = L_{Active + Passive}(f) - L_{Passive}(f)\ [in\ dB] \qquad (Eq.\ 3)$$

If the data was obtained via narrow band FFT, the spectra should be power summed into 1/3 octaves. This reduces narrowband calculation errors, improves the data visualization, and also correlates well to loudness and hearing, as the width of a critical band is approximately 1/3 octave above 400 Hz. The passive attenuation (plotted as gain) is $G_1(f)$ minus the open ear response (in dB). The total attenuation (passive and active) is $G_2(f)$ minus the open ear response (in dB). Since the passive attenuation cannot be switched off (!), the contribution of the active noise cancellation must be "backed out" of the overall level by subtracting the calculated passive attenuation from the total attenuation (in dB), as shown.

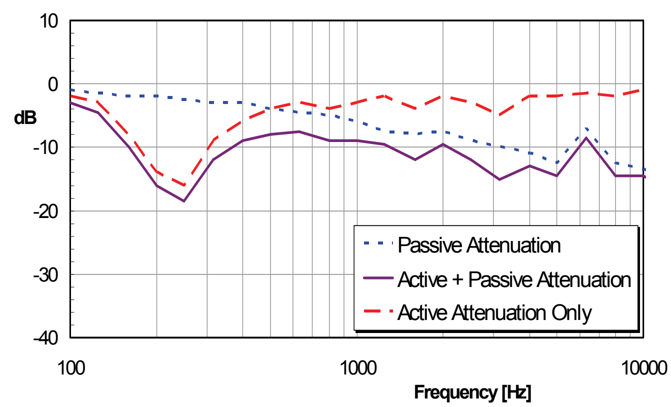

Fig. 2 Passive and active noise isolation.

Typically, the active cancellation is more effective at low frequencies, where the wavelength of sound is long, while the passive attenuation is greater at high frequencies where occlusion and absorption are more effective.

Contact us for more information.

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Volume 3, Issue 2 **May 2010**

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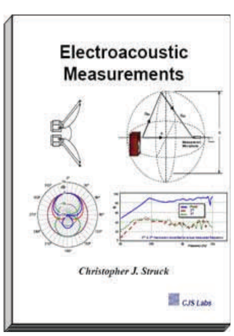

Acoustical Society of America Award

In April, Christopher Struck was presented with the Certificate Of Appreciation from the Acoustical Society of America "for contributions as Working Group Chair for ANSI/ASA S3.25-2009 American National Standard for an Occluded Ear Simulator". The standard was published in October 2009 and is available for purchase at the ASA website.

New Website Launched

In March, CJS Labs unveiled our new website: http://www.cjs-labs.com/

In addition to a friendlier layout and new graphics, new content has been posted, including downloadable test signals and technical papers. Back issues of the Lab Notes can also be found there. The downloadable content now requires a password. Contact us, and we'll provide that to you.

LT360EX Turntable

CJS has augmented our test capabilities with the acquisition of a LinearX LT360EX programmable turntable. This key instrument enables polar response measurements of loudspeakers, microphones, and simulated In-Situ testing of hearing instruments and mobile devices using a test manikin.

Recent News & Upcoming Events

Fall Seminar

We will be offering our 1-day seminar *"Fundamentals of Electroacoustic Measurements"*, on 8 November 2010 (immediately after AES), at the Grand Hyatt, San Francisco, CA For more information, click on the link below:

http://www.cjs-labs.com/sitebuildercontent/sitebuilderfiles/EASeminar-8Nov2010.pdf

Fee: $399-

Email cjs@cjs-labs.com or phone (415) 923-9535 to reserve your place. The course fee includes beverages, lunch, and a printed set of the course notes. We look forward to seeing you in November in San Francisco.

Audiology NOW!® 2010

I attended the AudiologyNOW!® 2010, conference in San Diego in April. I also attended the ANSI S3WG48 Working Group meeting on Hearing Aids. Discussions included IEC harmonization and telephone compatibility.

Please contact us and let us know how we can be of service to you and your organization.

Best regards,

Christopher J. Struck

CEO & Chief Scientist

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Interpolation for Acoustical Data

Many measurement applications require data at the ISO R3 Preferred Frequencies. Other applications require data be reformatted from a linear (e.g., FFT) to a logarithmic format or vice-versa. In some cases, a frequency response measurement is performed at a high resolution, while single-value post-process calculations are carried out only on a subset of the measured data. If it is not possible to perform the test at the required frequencies or if one does not wish to re-measure the data at the new format, some form of data interpolation is required to convert the measurement data to the required format. For reasonably accurate results, some prerequisite conditions should be met:

- The spectrum or response should be relatively smooth
- The spectrum or response should be adequately sampled in frequency, i.e., the Q of any peaks or dips should be well captured
- The upper and lower frequencies of interest should be included in the span, i.e., no extrapolation beyond the end-points
- The basic shape of the curve should be preserved in the new format

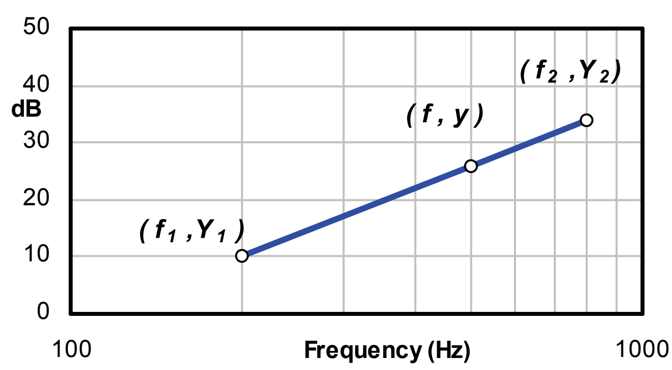

Fig. 1 dB vs. log frequency data— semi-log x axes.

Of the many possible data interpolators (e.g., linear, cubic spline, etc.) the most appropriate for acoustical data is semi-log interpolation, as the vast majority of acoustical data is dB vs. log frequency. Assuming the data is in decibels on a log frequency scale, the conversion can be performed as straight-line interpolation on a semi-log axes.

So, the problem reduces to:

Given (f_1, Y_1), (f_2, Y_2), and f, what is y ?

Solution: The point-point form of the Equation of a Line, in semi-log coordinates:

$$\frac{y - Y_1}{\log f - \log f_1} = \frac{Y_2 - Y_1}{\log f_2 - \log f_1}$$

$$y = Y_1 + \frac{\log f - \log f_1}{\log f_2 - \log f_1} \cdot (Y_2 - Y_1)$$

Solving for y yields the second equation, which can easily be used in your favourite programming language, such as Matlab.

Rearranging the terms to solve for an unknown frequency results in

$$f = 10^{\left\{ \frac{(\log_{10} f_2 - \log_{10} f_1) \cdot (y - Y_1)}{(Y_2 - Y_1)} + \log_{10} f_1 \right\}}$$

In these equations, the ordinate data is assumed to be in dB, and y is the unknown data point between the known Y_1 and Y_2 points, at f_1 and f_2, respectively. In general, f is the new (known) frequency at which the new data point is required.

Three different MatLab m-files have been created to perform this calculation: A function with simple input arguments and the most common frequency formats built-in and user selectable — including the ISO R Series of Preferred Frequencies — that can be called from another m-file; A GUI-interface that uses the aforementioned function on any text file (e.g., *.csv, *.txt, etc.) or Excel file; and a general purpose semi-log interpolation function, with similar input arguments to the standard interpolators found in Matlab.

Contact us for more information.

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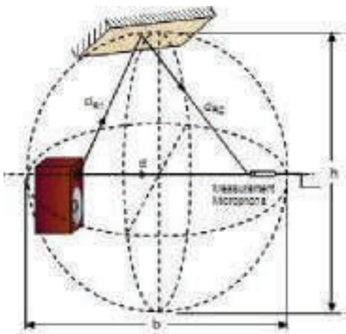
Volume 3, Issue 3 **August 2010**

Inside this issue:

Space Still Available for SF Electroacoustics Seminar



Limited space is still available for *"Fundamentals of Electroacoustic Measurements"* , a 1-day seminar to covering all aspects of electroacoustic measurements. The course will be held on 8 November 2010, immediately after the AES 129th Convention, at the Grand Hyatt in San Francisco. For more information, click on the link below:

http://www.cjs-labs.com/sitebuildercontent/sitebuilderfiles/EASeminar-8Nov2010.pdf

Fee: $399-

The class is quickly filling up and space is limited. So Email cjs@cjs-labs.com or phone (415) 923-9535 today to reserve your place. Your space is not guaranteed until payment is received. The course fee includes beverages, lunch, and a printed set of the course notes. We look forward to seeing you in San Francisco.

Recent News & Upcoming Events

ANSI S3WG67

I have taken over as Chair of the ANSI S3 Working Group 67 on Test Manikins. We will be working on a revision of ANSI S3.36. Stay tuned for more information.

IHCON

I'll be at IHCON in August.
http://www.hei.org/ihcon/

AES 129th Convention

The AES 129th Convention will be held in San Francisco 4-7 November 2010 at Moscone Center.
http://www.aes.org/events/129/

I'll be giving a tutorial: *"Headphones, Headsets & Earphones: Electroacoustic Design & Verification".*

During the AES 129th, I will also be presenting a paper entitled *"ZFIT: A MATLAB Tool for Thiele-Small Parameter Fitting and Optimization".* We will send out detailed information about the time and location of these events as soon as it is available.

Let us know if you will be attending and would like to set up a meeting. We hope to see you there.

Please contact us and let us know how we can be of service to you and your organization.

Best regards,

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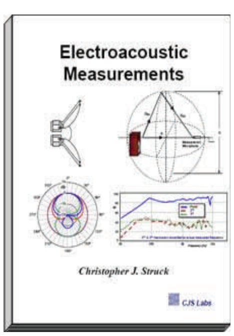

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Selecting the Appropriate FFT Window

When performing FFT analysis, spectral 'leakage' (energy spillage into adjacent FFT bins) can occur due to the truncation of any signal longer than the finite time record. By a careful application of the appropriate Time Window prior to the FFT, these effects can mitigated. It is important to understand the effects of the chosen window in both the time and frequency domains for a proper signal analysis. The signal being analyzed is effectively multiplied by the Time Window. Therefore, the complex frequency spectrum of the signal is convolved with the Fourier Transform of the Time Window. Many technical references on digital signal processing are available for details on this subject. So, instead here we focus on choosing the appropriate time window for a given application.

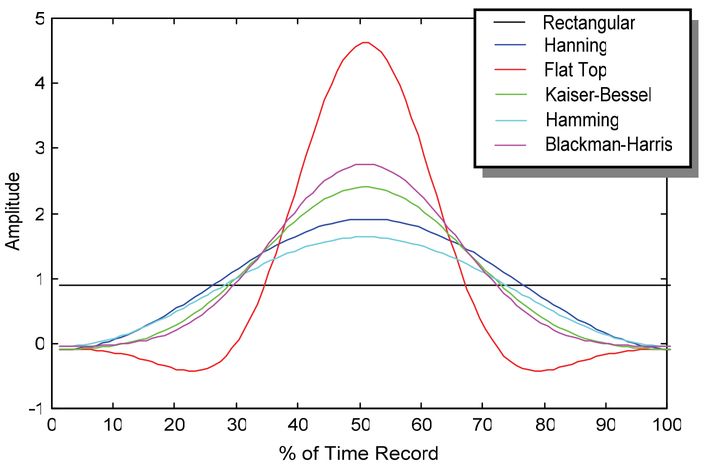

Fig 1. Various Windows in the Time Domain.

For transient signals contained within the time record, the rectangular (or 'boxcar') is appropriate. For continuous signals longer than the record length, the Hanning (or Hann) window is most commonly used. The Flat Top window should be used when calibrating with a pistonphone or other external calibrator or generator. Other special purpose windows and their applications are shown in Fig. 3. Note that Δf is the frequency resolution. The Equivalent Noise Bandwidth (ENB) is the width of an ideal filter that gives the same level with a white noise source. The reciprocal of the ENB tells the minimum amount of overlap required for 'gapless' real-time analysis.

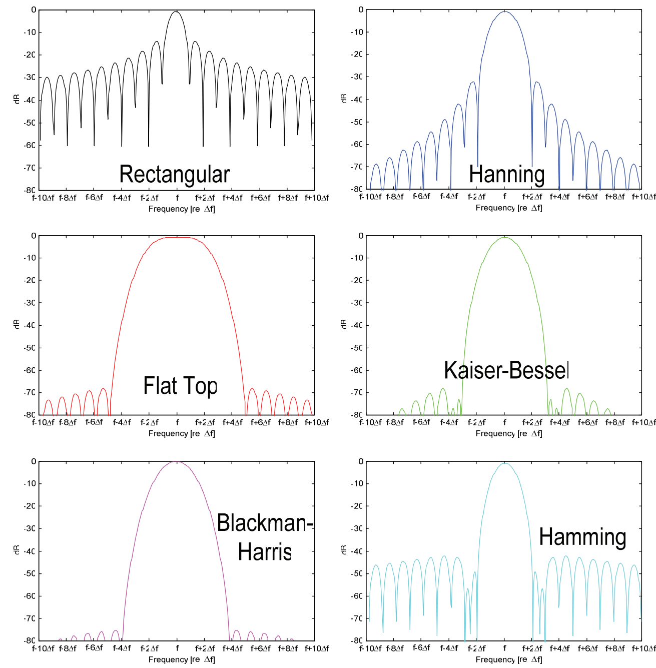

Fig. 2. Windows in the Frequency Domain.
This is the filter 'shape' of a single FFT bin.

Time Window	Equivalent Noise Bandwidth	Application
Rectangular	Δf	Synchronized sine or pseudo-random noise, Impulses / self-windowing signals within the time record
Hanning	1.5 Δf	General purpose – Random continuous signals
Flat Top	3.77 Δf	Calibration – Amplitude of non-synchronous sinusoids
Blackman-Harris	2 Δf	Multi-Sine & Harmonics
Kaiser-Bessel Hamming	1.8 Δf 1.36 Δf	Two-tone frequency separation

Fig. 3. Summary of different FFT Time Windows and their applications.

Other 'user-defined' windows are also possible. Contact us for more information.

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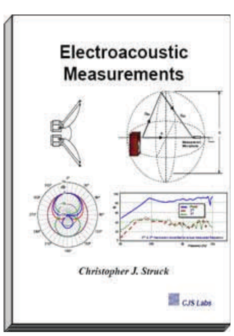
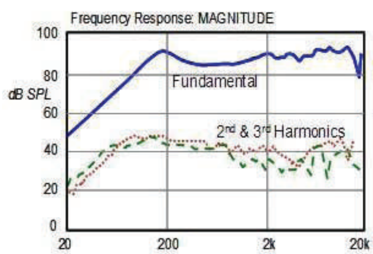


Last Chance to Enroll in SF Electroacoustics Seminar



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Friday 5 November 2010 at 9:00am, I will be chairing the P7 Papers Session: Loudspeaker Design and Amplifiers.

On Friday 5 November 2010 at 6:00pm, I will also be presenting a paper entitled *ZFIT: A MATLAB Tool for Thiele-Small Parameter Fitting and Optimization*.

As a Lab Notes reader, you can obtain a free Exhibits Only badge to the AES 129th here.

Let us know if you will be attending and would like to set up a meeting. We hope to see you there.

IEEE 269-2010

The latest revision of the IEEE 269 telephone testing standard was published on 10 August 2010 and is available from IEEE:
http://standards.ieee.org/downloads/269/269-2010/

Please contact us and let us know how we can be of service to you and your organization.

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Minimum Phase Response Derived from the Magnitude of the Frequency Response

There are many applications in audio and acoustics where a filter to meet a target frequency response is desired. In certain cases, only the magnitude is known and the complex response, including the phase must be synthesized. In general, there is not a unique solution, but rather a family of responses with the same magnitude and different phases, typically with increasing group delay. Sometimes, any one of these responses can be used. But in general, it is the minimum phase response that is desired, particularly for low-latency applications.

It can be shown that the response can be separated into a minimum phase portion cascaded with (i.e., multiplied by, in the frequency domain) a pure delay all-pass portion (see Eq. 1).

$$H(f) = A(f)_{\min} \cdot A(f)_{All\ Pass} \cdot e^{j(\phi(f)_{\min} + \phi(f)_{All\ Pass})}$$

$$= A(f)_{\min} \cdot e^{j(\phi(f)_{\min} + \phi(f)_{All\ Pass})}$$

Equation 1

The All-Pass function has poles and zeroes that are negative conjugates of one-another, so the magnitude is unity.

Using the natural logarithm (base *e*), the terms of Eq. 1 can be re-arranged to show that for a minimum Phase system, the phase is not independent of the magnitude, but can be derived using the Hilbert Transform (Eq. 2).

$$\phi(f)_{\min} = H^{-1}\left[\ln\left|A(f)_{\min}\right|\right]$$

Equation 2

The Matlab Signal Processing Toolbox includes a `hilbert` function, however this function computes the so-called analytic signal rather than simply taking the Hilbert Transform.

In Matlab, `Y = HILBERT(X)` computes the so-called discrete-time analytic signal

$$Y = \mathrm{Re}\{X\} + j \cdot \widetilde{X}$$

where $\widetilde{X}$ is the Hilbert transform of the vector Re $\{X\}$.

As a note, the actual Hilbert Transform of a signal is computed in Matlab using `Y = IMAG(HILBERT(X))`.

In block processing DSP applications using FIR filtering (e.g., FFT), both the phase and magnitude are required in order to use the IFFT to obtain the real-valued impulse response for further time-domain processing.

Another application is the processing of a measured loudspeaker response. The response of a single driver can be compared to the equivalent filter having the same magnitude response. This does not work for multiple driver systems incorporating crossovers, however, which in general are not minimum phase.

A special Matlab function has been created for these applications. `PHI = HILBERTPHASE(X)` returns the minimum phase [in degrees] of the frequency response of a system, corresponding to the input magnitude X [in dB].

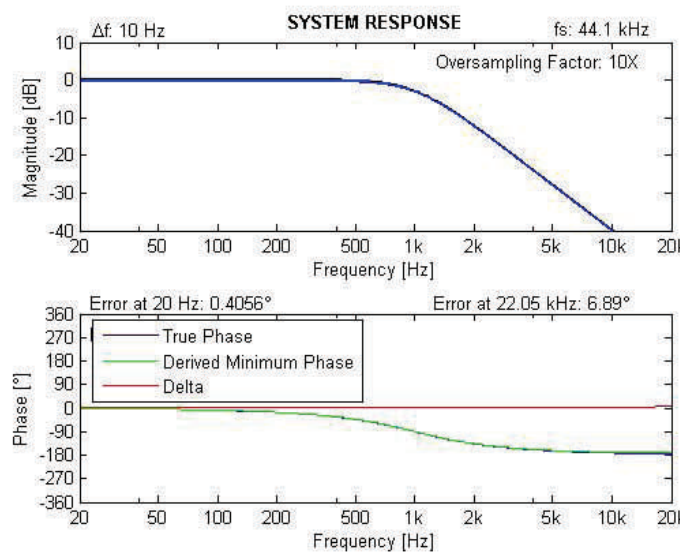

Fig 1. Magnitude and Hilbert-derived Phase response.

The magnitude of a 2^{nd} order low pass filter is shown in Fig. 1. The phase, Hilbert-derived phase, and difference (error) are also shown. Oversampling improves the high frequency error while increasing the frequency resolution improves the low frequency error. Contact us for more information.