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Lab Notes

Consultants' Network of Silicon Valley

NCAC National Council of Acoustical Consultants Member

Volume 5, Issue 1 **February 2012**

Audio & Electroacoustics

- *Consulting*
- *Design / Testing*
- *Training*

Inside this issue:

Seminars and Project Work

Last October 2011, I gave a well received tutorial at the AES 131st Convention in New York entitled "Telephonometry: The Practical Acoustics of Handsets, Headsets, and Mobile Devices". Over 60 persons attended. Q&A continued literally until we had to clear the room!

Headphone and headset testing continue to be a growth area for CJS Labs. Having both the KEMAR manikin and the Brüel & Kjær Head And Torso Simulator, enables testing to virtually any standard or specification. Look for a possible headset testing tutorial at the AES Convention here in San Francisco, this coming October.

We are currently augmenting our capabilities for telecom testing, in particular VoIP phones and loudspeaking telephones, to TIA 810 / TIA 920 and IEEE 1329, respectively.

We have been busy in recent months with intellectual property evaluation projects. We also continue to do in-house training and seminars for our clients, both on general electroacoustics as well as customized topics. The most recent was in Sydney, Australia last December.

Standards News

IEEE 269 Amendments

Amendments to IEEE 269-2010 were recently re-balloted and should be released and available next month. Check the IEEE website for details: http://standards.ieee.org/findstds/standard/269-2010.html

ANSI S3.36 Revision

ANSI S3, Working Group 67, which I chair, expects to complete the revision of the ANSI S3.36 Manikin standard later this year. Stay tuned for details.

Acoustics Today

An invited presentation I gave at the recent ASA meeting last November in San Diego, will appear as a feature article in the next issue of Acoustics Today. It describes my working group's improved process for expedited standards development and revision work. Acoustics Today is published by ASA and is free to members.

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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CJS Labs is a consulting firm based in San Francisco, California. We specialize in audio and electroacoustics applications. With over 25 years of industry experience in engineering and technology management, our areas of expertise include transducers, acoustics, system design, instrumentation, measurement and analysis techniques, hearing science, speech intelligibility, telephonometry, and perceptual coding. We also offer project management, technology strategy, and training services

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

Cross Spectrum Analysis & Frequency Response Estimators

In the Frequency Domain, the **Frequency Response** is the output spectrum divided by the input spectrum.

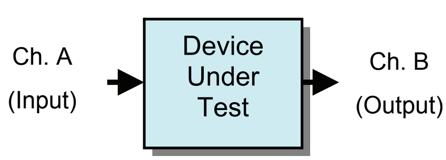
$$H(f) = \frac{Y(f)}{X(f)}$$

The result is complex, usually plotted as magnitude and phase. If the input and output spectra are in dB, the transfer function can easily be calculated by simply subtracting the input spectrum from the output spectrum (in dB). Note that for transducers, the transfer function and dB reference have dimensions corresponding to the output and input spectra, respectively, e.g., Pa/V, V/Pa, etc.

In general, 2-channel FFT Analyzers utilize **Cross Spectrum Analysis** for response measurements. The complex response is calculated and is available in both the time and frequency domains. This is by far the most flexible and general purpose type of analysis for sound, vibration, and electroacoustics. Compensation for the delay from system input to system output is applied to reduce errors. Any arbitrary signal can be used for the analysis, as simultaneous measurements of the stimulus at the system input and the response at the system output are made. The stimulus must, however, provide adequate signal at all frequencies of interest in the analysis. Not surprisingly, different stimuli are useful for different applications — but that is a subject for another Lab Notes installment!

Additional post processing can be used to apply windows in the time or frequency domains to segment the data. The response can then be recalculated in the other domain based upon appropriately limited data.

For an analysis of a system with Ch. A measuring the input and Ch. B measuring the output, the main functions and their definitions are shown.



Complex Conjugate Spectrum $A^*(f) = \mathcal{Re}\{A\} - \mathcal{Im}\{A\}$

Averaged Auto Spectrum, Ch. A $G_{AA} = \overline{A^*(f) \times A(f)}$

Cross Spectrum $G_{AB} = \overline{A^*(f) \times B(f)}$

Frequency Response Estimators

$$H_1 = \frac{G_{AB}}{G_{AA}} \qquad H_2 = \frac{G_{BB}}{G_{AB}}$$

An advantage of this approach is that the effects of noise at the input or output of the system under test can be reduced by spectral averaging and the appropriate choice of frequency response estimator. Note that Frequency Response estimator H_1 does not use the output auto spectrum, thus reducing the effects of noise at the system output. This is the most commonly used estimator and is appropriate for most electroacoustic measurements. Similarly, estimator H_2 does not use the input auto spectrum, thus reducing the effects of noise at the system input.

Another useful feature of these methods is that many additional functions describing the quality of the system and/or measurement are easily calculated, providing additional diagnostic information. Examples include coherence, non-coherent power, and cross-correlation. Future Lab Notes issues will deal with applications of these functions.

Cross spectrum methods are applicable to any linear, causal, time invariant system and find wide use in sound and vibration measurements and structural testing (modal analysis). The technique is often useful for systems incorporating transducers where either the transducers are not accessible as a separate sub-system, or only the overall system response is of interest (e.g., telephones, hearing aids). Another interesting electroacoustic application is to analyze the response of a room plus public address system using music as the test signal. Cross spectrum analysis is typically not well suited to transducer measurements, where sine-based measurements of harmonic, intermodulation, or difference frequency distortion are important. Likewise, cross spectrum analysis may also be inapplicable for systems incorporating intensive non-linear signal processing, or without a stable delay relationship between the input and output (e.g., digital hearing aids, mobile phones, etc.).

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Volume 5, Issue 2 **May 2012**

Inside this issue:

ASA/ANSI S3 Accredited Individual Expert

On 28 March 2012, I received word from the Acoustical Society of America Committee on Standards that I had been nominated and approved by vote as an Individual Accredited Expert. My responsibilities will include review and comment of all balloted standards in S3 Bioacoustics as well as technical support and responding to enquiries from the working groups during standards development.

ASACOS also informed me that my nomination as Chair of S3 had also been approved. I take over as Chair, ironically, on 18 May 2012, my 50th birthday (!).

ANSI S3.36—Manikins

Working Group S3/67 has completed our revision of ANSI S3.36 'Specification for a Manikin for Simulated *In-Situ* Airborne Acoustical Measurements'. After some editorial work from ASA, it is expected to go to ballot in June and be available for purchase later this year.

News & Recent Developments

Electroacoustic Measurements Book—New 2012 Edition

The compendium of slides and notes from the CJS Labs training seminars is scheduled to be revised and updated later this year. Stay tuned for more information.

Modern Tools for Standards Development

The invited presentation I gave at ASA meeting in November in San Diego, appeared as a one of several featured articles in the January special 'Standards' issue of Acoustics Today (published by ASA). In it, the improvements to the standards development process employed by the working groups I chair are described. A copy is available on our website:

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

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

Best regards,

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Windows 7 Audio Properties: Levels in dB

It is apparently not well known that the user can also display the Audio Properties gain slider settings in dB by right-clicking on the slider (see Fig 1.).

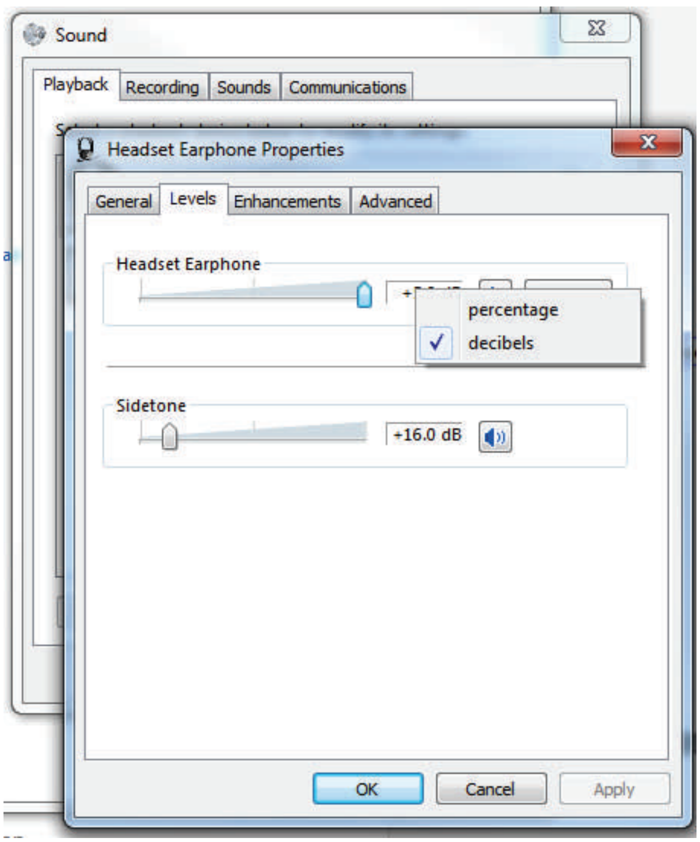

Fig. 1. Level settings in dB in MS Windows 7

In addition, you may also find the following attributes and information useful:

The minimum and maximum dB settings are defined by the audio driver by exposing it via

KSPROPERTY_AUDIO_VOLUMELEVEL

Windows 7 will use the minimum dB level, the maximum dB level, and the dB steps for the volume slider.

Windows 7 will not perform a validation of these decibel values. If an audio driver exposes something which doesn't make sense like +15 dB to +16 dB in steps of 0.01 dB, Windows 7 will map (0 .. 100) to that range. The driver also specifies the default value.

If the audio driver does not expose

KSPROPERTY_AUDIO_VOLUMELEVEL

in the signal path, Windows 7 will inject a software volume audio processing object (**APO**). The minimum will be a "severe attenuation", effectively silence. The maximum will be 0 dB for most devices, but for microphones it will be "significant amplification", ca. +30 dB.

Note that there is a bug in Windows 7, so the default for the OS is to the top of the slider. For Windows 8, the expected 'fix' will be a default of 0 dB.

The apparent reason for allowing digital gain in this case is that a number of digital microphones output a very low signal level with the MS class driver when captured with 0 dB gain.

Note that **Microphone Boost** is exposed only if the audio driver exposes it to Windows. Ideally a device should only expose **Microphone Boost** if it has analog gain.

The user can always ensure that Windows 7 does not add any attenuation/gain by making sure all microphone and/or loudspeaker sliders are set to 0 dB.

Please contact us for more information.

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Volume 5, Issue 3 September 2012

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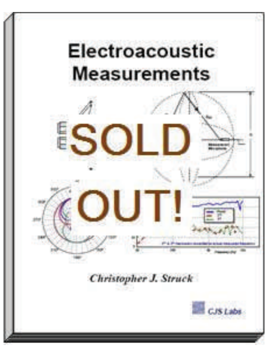
Inside this issue:

"Electroacoustic Measurements" Book: *OUT OF PRINT!*



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AES 133rd Tutorial & ASA Standards Meetings

AES 133rd Convention

The AES 131st Convention will again be held here in San Francisco at Moscone Center 26-29 October 2012. The program is available at the AES website:

http://www.aes.org/events/133/

On Saturday, 27 October 2012 at 11:00AM, I will be giving a Tutorial lecture entitled *"Getting the Sound Out of (and Into) Your Head: The Practical Acoustics of Headsets".* In this presentation, I will describe the free and diffuse field target responses, choice of ear and mouth simulators, manikins, calibration, and relevant standards and test methods. Applications to analogue, USB, and Bluetooth wireless devices will be shown. More information is available at:

http://www.aes.org/events/133/tutorials/?ID=3264

Please contact us if you plan to attend the AES 131st Convention in San Francisco and would like to set up a meeting.

ASACOS S3 Kansas City

As Chair of ANSI/ASA Subcommittee 3 on Bioacoustics, I will be in Kansas City 22-24 October at the 164th ASA Meeting to participate in standards meetings. If you will be at ASA in Kansas City and would like to set up a meeting, please let us know.

News & Recent Developments

IHCON

I attended the IHCON hearing research conference in in Lake Tahoe in August. There were many interesting sessions with lots of good research presentations and posters. It was also a great opportunity to meet and discuss projects and exchange information with the leading researchers in the hearing field. Information about the presentations is available at:

http://www.hei.org/ihcon/2012_Schedule.pdf

ANSI/ASA S3.36-2012

The revision of ANSI/ASA S3.36 'Specification for a Manikin for Simulated *In-Situ* Airborne Acoustical Measurements' completed by Working Group S3/67 went out to ballot in July. Voting was completed in August and after addressing some editorial comments, the document is expected be released and available for purchase from the ASA Standards store later this fall.

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

Best regards,

Christopher J. Struck

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Time Synchronous Averaging

As previously mentioned, an important practical measurement consideration is the reduction of uncorrelated background noise. Using **Synchonous Averaging** (a.k.a., "Complex Averaging", "Time Domain Averaging", or "Vector Averaging"), a correlated test stimulus, which is identical for every record, adds on a "Signal" basis (i.e., 2x = X+6 dB), while the uncorrelated background noise, which is the same level, but not the same signal, adds on a power basis (sqrt($2x^2$)= X+3 dB). In this case, all samples are treated as complex vectors (magnitude and phase), rather than simple power averaging. Therefore, an effective measurement S/N increase of 3 dB is gained for every doubling of the either the measurement time or the number of complex averages. Most analysis systems and time selective techniques offer this option. The stimulus may be a sinusoid or a pseudo-random noise signal (i.e., a repetitive random noise with a period equal to the analysis length).

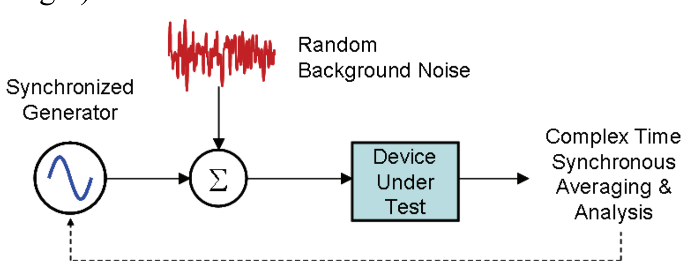

Fig. 1 Time-synchronous system analysis with additive background noise

Since the averaging is complex and correlated, increasing the number of averages (or sweep time) effectively lengthens the Time Window. Seen in the frequency domain, this is a narrowing of the main lobe of the Fourier transform of the time window, a *sin(x)/x* function. This can also be seen as a more selective filter, thus reducing noise at all other frequencies. This is the effective bandwidth of the analysis, as shown in the diagram, where *B* is the initial filter bandwidth for the analysis.

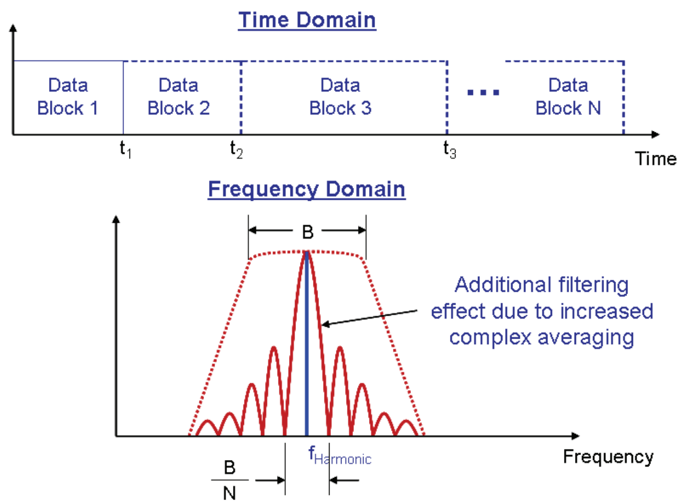

Fig. 2 Effective bandwidth vs. number of averages

Note also that since the stimulus is synchronized to the analysis record and is zero at the beginning and end of each data block, no time window is required.

For a white background noise spectrum, the approximate amount of additional noise reduction can be computed as

$$20 \log_{10} \sqrt{N}$$

where N is the number of averages.

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Volume 5, Issue 4 **December 2012**

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Inside this issue:

Headphones & Headsets at ALMA

ALMA Winter Symposium 2013

The ALMA Winter Symposium will be held 6-7 January 2013 at the Tuscany Suites in Las Vegas, NV. The theme of this year's symposium is 'Micro Speakers'. In that spirit, I will be presenting an informational talk at 9:00am on Sunday 6 January 2013 entitled, ***"An Introduction To Headphone and Headset Acoustics"***. I will present the acoustics of headphones & headsets as a typical application for micro drivers. The differences between headphones and a typical loudspeaker design will be highlighted. The Insertion Gain concept will be reviewed and appropriate free and diffuse field target responses will be detailed. I will show some typical measurement examples as well practical methods for obtaining consistent data. Applications to analogue, USB, and Bluetooth wireless devices will be shown. Finally, I will review relevant standards test methods, test fixtures, and calibration.

Information about the ALMA Winter Symposium, registration, and hotel information can be found at:

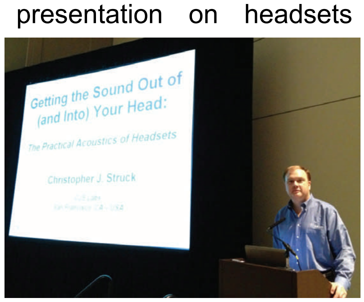
http://www.almainternational.org/

Please contact us if you plan to attend the ALMA Winter Symposium in Las Vegas in January, and would like to set up a meeting.

News & Recent Developments

AES 133rd Convention

I attended the AES 131st Convention here in San Francisco in October. I met with exhibitors, vendors, and clients and attended a number of excellent papers and posters. My own tutorial presentation on headsets was well attended and was followed by a lively Q/A session.



ASA & ASACOS - Kansas City

I also attended the Acoustical Society 164th Meeting in Kansas City in October. I was there primarily in my capacity as Chair of ANSI/ASA Subcommittee 3 on Bioacoustics, attending standards meetings. Fortunately, I also had the chance to see a few presentations and meet with some of the exhibitors. Next year, ASA will be in here in San Francisco in December 2013.

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

Happy Holidays!

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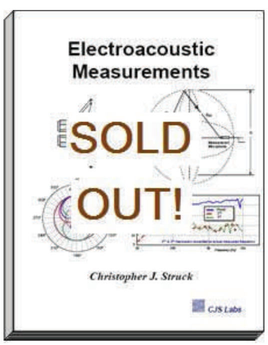

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Coherence

In a 2-channel FFT measurement, the frequency response is generally calculated using the cross spectrum (see Lab Notes, Vol. 5, Issue 1). An appropriate frequency response estimator is generally chosen to mitigate the effects of noise at either the system input or system output. The cross spectrum method also offers the advantage of easily calculating other useful descriptors. The most important of these is perhaps the **Coherence** function. Mathematically, coherence is equal to the correlation coefficient squared. More importantly, the coherence is a function between 0 and 1 that provides a measure of the linearity between the system input and system output at each frequency. The coherence is calculated as

$$\gamma^2 = \frac{|G_{AB}|^2}{G_{AA} \times G_{BB}}$$

where G_{AB} is the cross spectrum, G_{AA} is the input power spectrum, and G_{BB} is the output power spectrum.

For a perfectly linear, causal, time-invariant, and noise-free system, the coherence is unity at all frequencies. However, in practice, most systems violate one or more of these constraints. The most common reasons for $\gamma^2 < 1$ are the following:

- Non-linearities
- Time variance
- Noise at the input and/or output
- Uncompensated delay between system input and system output
- Spectral Leakage (resolution and/or time windowing errors)
- Insufficient spectral averaging

As an example, consider the following two systems:

$Y = 2X$

X	Y
1	2
2	4
3	6

$$\gamma^2 = \frac{(1\cdot 2 + 2\cdot 4 + 3\cdot 6)^2}{(1+4+9)\cdot(4+16+36)} = \frac{784}{784} = 1$$

$Y = X^2$

X	Y
1	2
2	4
3	9

$$\gamma^2 = \frac{(1\cdot 1 + 2\cdot 4 + 3\cdot 9)^2}{(1+4+9)\cdot(4+16+81)} = \frac{1296}{1414} = 0.9165 \quad < 1$$

The first example shows a perfectly linear system at one frequency, averaged for 3 input levels. The coherence in this case is exactly 1. The second example shows a non-linear system at one frequency, averaged for the same 3 input levels. In this case, the coherence is less than 1. Note that frequency response estimators calculate the response averaged over many records. If only one record (average) is acquired, the coherence will be 1, but this is not statistically significant and therefore provides no information.

The coherence function is most useful as a 'measurement of the quality of the measurement'. It can be used to de-bug the test set up and improve the measurement S/N by simply being mindful of the aforementioned issues.

Please contact us for more information.