

# CJS Labs

Technology · Research · Strategy · Solutions

# Lab Notes



Consultants' Network  
of Silicon Valley



National Council of  
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Member

## Audio & Electroacoustics

- Consulting
- Design / Testing
- Training

Volume 5, Issue 1

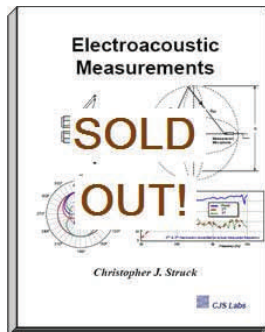
February 2012

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**“Electroacoustic Measurements” Book: OUT OF PRINT!**



*THE essential reference for making proper electroacoustical transducer measurements. A bound, fully annotated compendium of slides and notes from the CJS Labs training seminars. Literature references for each chapter are also included. A new and expanded revision is planned for late 2012. Contact us to reserve your copy!*

## Seminars and Project Work

Last October 2011, I gave a well received tutorial at the AES 131<sup>st</sup> 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 loud-speaking 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 stan-

dard 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

**CJS Labs**





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[http://www.cjs-labs.com/  
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## Cross Spectrum Analysis & Frequency Response Estimators

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

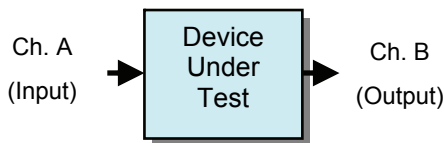
$$H(f) = \frac{Y(f)}{X(f)}$$

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  $A^*(f) = \text{Re}\{A\} - \text{Im}\{A\}$

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, telephony, and perceptual coding. We also offer project management, technology strategy, and training services

*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*

$$H_1 = \frac{G_{AB}}{G_{AA}}$$

$$H_2 = \frac{G_{BB}}{G_{AB}}$$

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.).

Please contact us for more information.