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Lab Notes

Electroacoustics & Audio

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

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Volume 8, Issue 1 **March 2015**

Inside this issue:

Training Seminars

CJS Labs also offers customized in-house training. Our design experience, proven processes, and measurement expertise will make your development more efficient. Learn how to optimize both your designs and test routines. Having a thorough understanding of the fundamentals, correct terminology, and proper techniques will also enable you to make more informed decisions and communicate more effectively with your customers and vendors as well as within your own organization. Understand why certain failure modes are problematic, even if they are not obvious or audible. Sample course outlines and details are available on our website: http://www.cjs-labs.com/training_seminars.html

Contact us to schedule a training course for your organization.

ALMA and CES 2015 in Las Vegas

I presented a seminar entitled "***An Overview of Loudspeaker System Design***" at Winter ALMA on 4 January 2015 at the Tuscany Suites & Casino in Las Vegas, NV. This seminar covered a wide outline of topics including closed and ported enclosures, Thiele-Small parameters, crossovers, equivalent circuits, diffraction effects, time alignment, basic nonlinearities, modal behaviour, and cone break up. In addition, I showed a complete ported system design step-by-step. I was also a panel member for the Inter-Organizational Standards Forum. If you were unable to attend and are interested in these topics, the materials are available. Please contact us.

After ALMA, I remained in Las Vegas to attend the opening day of CES. Everything from mass market consumer products to electric cars to boutique audio devices were on display from more than 3600 exhibitors. Over 170000 persons attended.

CES2015Wrap

News and Recent Developments

Winter NAMM 2015

January was a very busy month indeed. In addition to ALMA and CES, I also attended the Winter National Association of Music Merchants show in Anaheim, CA for the first time. Although I was only there a day, the 4 exhibit halls I visited were jam packed with every type of musical instrument and processor effect imaginable. Particularly interesting were the number of in-ear monitors featured there. I was able to speak with a number of the designers directly.

IEC TC 29 - Electroacoustics

The US National Committee recently appointed me as a representative to IEC Technical Committee 29 - Electroacoustics. In this capacity, I will serve on three working groups: WG 5 - Measurement Microphones; WG 13 - Hearing Aids; and WG 21 - Couplers & Ear Simulators.

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

Christopher J. Struck
CEO & Chief Scientist
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Exponential Averaging Time

One of the most common signal descriptors is the Root-Mean-Square (RMS) Level. For a time signal, it is calculated as shown in Eq. 1.

$$L_p = \sqrt{\frac{1}{T}\int_0^T p^2(t)\,dt}$$

The typical ‘live’ display of a sound level meter uses **Exponential Averaging**, where the output of the detector decays at a rate determined by the **time constant**, τ, i.e., the most recent samples are maximally weighted and older samples have progressively less influence on the average. With **Linear Averaging**, the measurement is performed for the entire averaging time T_A, , and all samples are equally weighted throughout the average. This yields an **integrated** result, showing the equivalent constant level (or L_{EQ}) for the entire period of the average. Note that the peak response of the exponential time weighting is equal to twice that of the linear time weighting and $T_A = 2\tau$ so that the area under the Linear and Exponential curves is the same and the result is always correctly scaled for stationary signals (see Fig. 1).

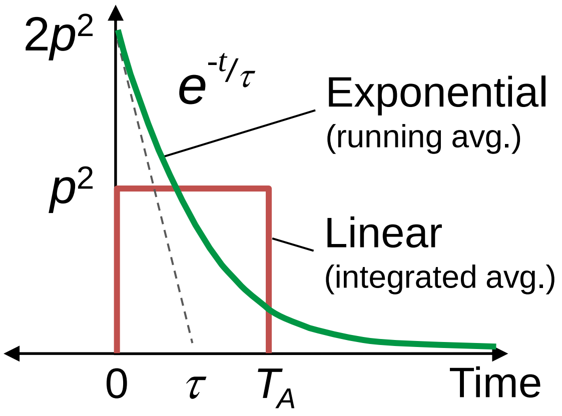

Fig. 1. Exponential and Linear averaging times.

This means that the *effective* Averaging Time, T_A, is always equal to 2 times the **Time Weighting** or time constant, τ. With Exponential Averaging, the output level of the detector decays at a rate determined by the time constant (τ = RC), which corresponds to a 1-pole low pass filter or integrator with cutoff frequency $f_C = 1/(2\pi\tau)$. This integration or filtering operates on the squared magnitude signal. Time Weightings according to IEC 60651 and IEC 61672/ANSI S1.4 are shown in Fig. 2. The Fast and Slow time weightings have equal attack and release times. Impulse time weighting has a 1.5 second hold/release time in order to enable the user to read the value from the meter. For Exponential Time Weighting, the indicated level of an abruptly stopped signal decays exponentially toward zero. The time constant, τ, therefore represents the time for the step response to reach ca. 36.8% of its final value.

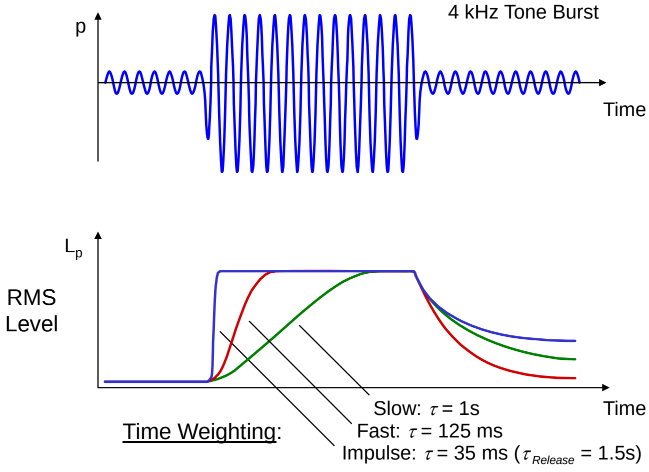

Fig. 2. ANSI/IEC Exponential Time Constants.

Please contact us for more information.

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Volume 8, Issue 2 **June 2015**

Inside this issue:

New Role: ASA Standards Director

I am pleased to announce that my appointment as Standards Director of the Acoustical Society of America was approved by the ASA Executive Council at the ASA 169th Meeting in Pittsburgh in May. In this role — which is in addition to the activities here at CJS Labs — I direct the activities of the four S-Committees: ASC S-1 Acoustics, ASC S-2 Shock & Vibration, ASC S-3 Bioacoustics (including Subcommittee 1 on Animal Bioacoustics), and ASC S-12 Noise. These committees consist of over 80 Working Groups and approximately 500 volunteers who contribute to the development and maintenance of standards in these fields. In addition the Standards Director manages the Technical Advisory Groups (TAGs) liaison and US vote in IEC and ISO for international standards in these fields. ASA also maintains two ISO Secretariats. This also means that I am now an Associate Editor of the Journal of the Acoustical Society of America (JASA) for Acoustical Standards News and an *ex-officio* member of the ASA Executive Council. I am also still Chair of ASC S3 Bioacoustics as well as Working Group Chair for S3WG37: Couplers, Ear Simulators, and Earphones; S3WG67: Manikins; and S3WG73: Bioacoustic Terminology.

Acoustical Society of America

News and Recent Developments

Inter-Noise

I'll be presenting a paper at entitled "**An Overview of the ANSI/ASA Standards Program**" at Inter-Noise 2015, which takes place here in San Francisco 9-12 August. If you are planning on attending and would like to set up a meeting, please contact us.

Fundamentals of Electroacoustics Seminars

I will be teaching the 1-day Electroacoustics seminar, again in conjunction with Listen, twice this fall :

Boston: 22 September 2015

San Jose: 5 October 2015

Locations and registration details should be available soon. Call 617-556-4104 or visit https://www.listeninc.com/news-events/training/ for more information.

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

Christopher J. Struck
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Averaging Time & Confidence Limits

If a random Gaussian amplitude distributed signal (e.g., pink or white noise) is measured and RMS averaged over an infinitely long time, the result will converge to the true RMS value. For a finite averaging time, however, there will be some uncertainty about the true mean value. This can be described in terms of statistical probability: There is a probability *P(L)* of 68% that the measured signal level will be within the limits of $\pm\sigma$ (one Standard Deviation); a probability *P(L)* of 95% of being within $\pm 2\sigma$; a probability *P(L)* of 99.7% of being within $\pm 3\sigma$.

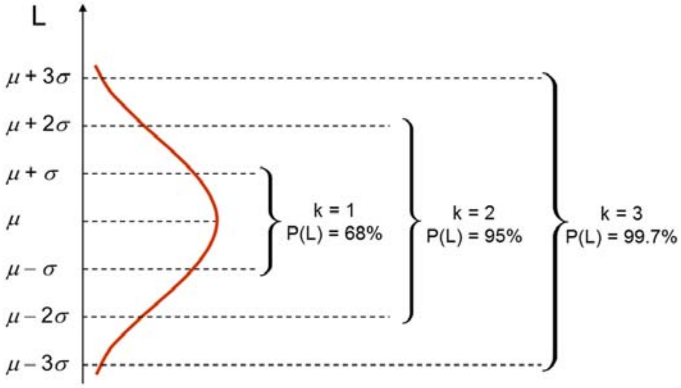

Fig. 1. Normal Gaussian distributed random variable.

This concept is familiar from QC production testing and process control, where 6σ generally gives a good indication of $[L_{MAX} - L_{MIN}]$ for normal well-behaved processes. *k* is the Coverage Factor, i.e., the Expanded Uncertainty or the number of Standard Deviations in the probability distribution. For a measurement of random noise, the standard deviation can be calculated as

$$\sigma = \frac{1}{2\sqrt{BT_A}}$$

where *B* is the filter bandwidth and T_A is the effective measurement time (integrating time or record duration, whichever is shorter). In acoustical measurements (e.g., 1/N octave bands or FFT), the Confidence Limits are a function of the number of statistical Degrees of Freedom, 2*BT*. The Confidence Interval, L_σ , can be calculated for a given bandwidth, averaging time, and coverage factor as

$$L_\sigma = \frac{4.34k^2}{\sqrt{BT_A}}$$

in dB. It is interesting to note that $10\log_{10}(e) = 4.34$!

Alternatively, the averaging time could be determined in order to obtain a given confidence interval for a given bandwidth and coverage factor as

$$T_{A_{P(L)}} = \frac{\left(4.34k^2\right)^2}{L_\sigma^2 B}$$

in seconds. For a normal Gaussian distributed random variable, the averaging time for 95% confidence is $4T_{A(68\%)}$ and the averaging time for 99.7% confidence is $9T_{A(68\%)}$.

The assumption in these simplified statistics is that $2BT > 100$. For $2BT < 100$, the *T factor* is used in place of *k*. The *T Distribution* is a probability density function for samples drawn from a population, as opposed to the Normal Distribution, which uses the entire population. More examples can be found in ISO/IEC 98-1: Guide to Uncertainty in Measurement (GUM).

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Volume 8, Issue 3 **September 2015**

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AES 139^{th} in New York

The AES 139^{th} Convention will take place 29 October - 1 November 2015 at the Jacob Javitts Center in New York City. More info at:

http://www.aes.org/events/139/

Thursday, 29 October, at 9:00am, I will be giving a tutorial entitled "*Almost Everything You Ever Wanted to Know About Loudspeaker Design*"

http://www.aes.org/events/139/productdevelopment/?ID=4603

Steve Temme of Listen, Inc. and I will also be giving a paper on Thursday 29 October 2015, at 2:30PM entitled: "*Headphone Response: Target Equalization Trade-offs and Limitations*"

http://www.aes.org/events/139/papers/?ID=4542

If you will be at the AES 139^{th} in New York and would like to set up a meeting, please do not hesitate to contact us.

ASA - Jacksonville, FL

The Acoustical Society of America 2015 Fall Meeting will take place 2-6 November in Jacksonville, FL. Information about the ASA Meeting is available at:

http://acousticalsociety.org/

I will be at ASA in Jacksonville for the Executive Council and Standards meetings.

Please contact us if you will be at ASA in Jacksonville and would like to set up a meeting.

News and Recent Developments

Fundamentals of Electroacoustics Seminars

I will be teaching the 1-day Electroacoustics seminar, again in conjunction with Listen, Inc. twice this fall:

Boston: 22 September 2015

San Jose: 5 October 2015

Registration and location details are available at

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ASA Standards Director Press Release

A copy of the press release announcing my appointment is available at:

http://acousticalsociety.org/sites/default/files/Christopher_Struck.pdf

InterNoise 2015 Paper

The paper I presented at InterNoise here in San Francisco in August is available on our website:
http://www.cjs-labs.com/sitebuildercontent/sitebuilderfiles/ANSI-ASA_Standards-IN2015.pdf

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Center Frequencies & Band Limits of Fractional Octave Filters

Real-time filter analysis is usually performed in constant percentage bandwidths, typically denoted in fractional octaves. However, as per ANSI S1.11 / IEC 61260, the center frequencies are actually calculated as fractional *decades*. The true center frequency of any fractional octave band is calculated as

$$f_C = 10^{\frac{3N}{10B}} \qquad [1]$$

for ***odd*** *B*, *i.e.*, for ***odd*** fractional octaves, *OR*

$$f_C = 10^{\frac{3(N+0.5)}{10B}} \qquad [2]$$

for ***even*** *B*, *i.e.*, for ***even*** fractional octaves

where:

f_C is the fractional octave band center frequency

B is the fractional octave band denominator,

e.g., 3 for 1/3 octave, 12 for 1/12 octave, etc.

N is the positive integer Band Number

These equations yield the *true* center frequencies for each band. However, by convention, the ISO R10 preferred frequencies are used to *label* 1/3 octave bands.

Note that for *even* fractional octave bands (e.g., 1/6 octave, 1/12 octave, etc.), the center frequencies are shifted one-half band. This ensures that when combined, adjacent bands will exactly comprise the equivalent wider bandwidth (see Fig. 1).

The -3 dB upper and lower passband limit frequencies for a fractional octave filter are calculated as

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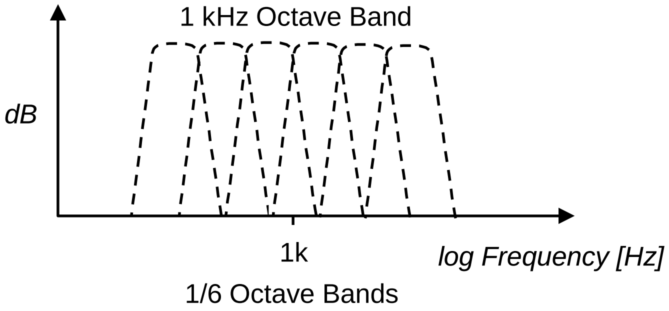

Fig. 1 Six 1/6 octave bands comprise one octave.

$$f_3 = 10^{\frac{3N}{10B} \pm \frac{3}{20B}} \qquad [3]$$

for ***odd*** *B*, *i.e.*, for ***odd*** fractional octaves, ***OR***

$$f_3 = 10^{\frac{3(N+0.5)}{10B} \pm \frac{3}{20B}} \qquad [4]$$

for ***even*** *B*, *i.e.*, for ***even*** fractional octaves

This is best illustrated by example:

Example 1: For 1/3 octaves, *B* = 3 and the fractional octave band is ***odd***. The center frequency for band number 20 is found using Equation 1: f_c = 100 Hz. The upper and lower passband limits are found using Equation 3: The lower limit is 89.13 Hz, and the upper limit is 112.20 Hz.

Example 2: For 1/12 octaves, *B* = 12 and the fractional octave band is ***even***. The center frequency for band number 80 is found using Equation 2:
f_c = 102.92 Hz. The upper and lower passband limits are found using Equation 4: The lower limit is 100 Hz, and the upper limit is 105.93 Hz.

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Volume 8, Issue 4 **December 2015**

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IEC TC 29 - Electroacoustics Meetings, Paris

I was scheduled to attend the IEC Technical Committee 29 - Electroacoustics international standards meetings in Paris in November as Head of the US Delegation, however, I was forced to cancel my trip at the last minute due to the terrorist acts that took place on Friday, 13 November 2015, the day before I was scheduled to depart. The attempted bombing took place at the Stade de France, directly across from AFNOR, where the IEC meetings were held.

In spite of this, the meetings took place as scheduled, with 4 of 6 US delegates in attendance. Although I did not participate in the face-to-face discussions, I followed the Day Reports of the 3 working groups I am a member of: WG5 - Microphones, WG13 - Hearing Aids, and WG21 - Ear Simulators. Based upon this, and Emails with the Conveners and US delegates, I was able to prepare the required summary report for ANSI on behalf of the US Delegation.

A few highlights:

- The revision of IEC 601094-3 (reciprocity calibration of microphones) is now completed and should be published in early 2016.

- The draft of TR 62866 (0.4cc coupler) is nearly complete.

- The revision IEC 60645 (audiometers) is nearly ready for final ballot.

- Work continues on the revision of IEC 60318-7 (manikin for hearing aid measurements).

News and Recent Developments

Fundamentals of Electroacoustics Seminars

The 1-day Electroacoustics seminars we did this fall in conjunction with Listen, Inc. were a great success. Over 30 people attended the two seminars in Boston and Santa Clara. New material and psychoacoustics demos were well received and lively Q&A sessions ensued after each topic module. We look forward to doing this again next year. Stay tuned for more information.

Sound & Vibration Article

The paper I presented at InterNoise 2015 here in San Francisco last August, “The ASA Standards Program”, will be reprinted in the December issue of Sound & Vibration magazine:

http://www.sandv.com/home.htm

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Happy Holidays!

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Field Calibration of Measurement Microphones

A pressure microphone is essentially ‘uncompensated’, i.e., the voltage out is linearly proportional to the pressure in – The input being the pressure impinging upon the diaphragm. Therefore, the pressure microphone has an essentially flat response in a pressure sound field. However, in a free sound field, at higher frequencies, when the wavelength of sound is on the order of magnitude of the size of the microphone, there will be a pressure build up at the front of the microphone due to its disturbance of the sound field, causing an increase in output. The cylindrical shape of a standardized measurement microphone makes this disturbance very deterministic and well-defined.

A free field microphone is essentially the same, except that its disturbance to the sound field is compensated for. For standardized measurement microphones, this is usually accomplished by holes perforated in the back plate. These small holes are acoustically a combination mass-damper (or inductor -resistor) element in the equivalent circuit model, providing frequency-dependent damping, and tuned precisely to the so-called ‘Free Field Correction Curves’, at least over an octave or two where the free field correction is significant. This correction could of course also be accomplished with an electronic filter or as a post-process correction. However, once this correction is applied, it is now a ‘free field microphone’, i.e., it yields a flat response in a free sound field.

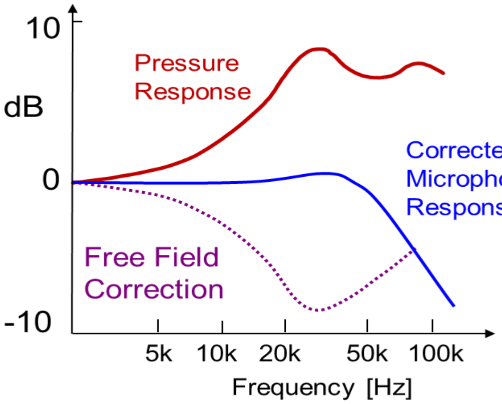

Fig 1. 0° Free Field Correction for a ½ inch mic.

Taking this compensated microphone and placing it into a calibrator (94 dB SPL at 1 kHz) is effectively placing a free field microphone into a pressure field, causing a ‘reverse error’. For a ½ inch free field microphone, this is the difference between the 0° free field response and the pressure response, or the value of the Free Field Correction curve at 1 kHz:

$$93.85 - 94.00 = -0.15 \text{ dB}$$

This is a – 0.15 dB difference in calibration level when using the sound level calibrator at 1 kHz with a free field microphone. This is why one calibrates a ½ inch free field microphone in a calibrator at 1 kHz at 93.85 dB rather than at 94.0 dB for a pressure microphone. For a 1 inch free field microphone, calibration at 1 kHz is performed at 93.70 dB. For microphones ¼ inch diameter and smaller, the difference is negligible.

Likewise, when using a pistonphone at 250 Hz, the difference between a pressure mic and a free field mic is 0 dB for all sizes of microphone. Therefore, no correction is required for this effect when using a pistonphone.

Please contact us for more information.