CJS Labs

Technology · Research · Strategy · Solutions

Lab Notes

NCAC National Council of Acoustical Consultants Member

Volume 9, Issue 1 **March 2016**

Electroacoustics & Audio

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

Inside this issue:

CJS Labs 10th Anniversary

2016 marks CJS Labs 10th year. A lot has happened since I first set out as an independent consultant. Here are a few highlights:

2006: C. J. Struck departs Tymphany and takes on consulting project work as CJS Labs.

2007: CJS Labs is licensed as a Sole Proprietorship in San Francisco. cjs-labs.com website launched. First electroacoustics seminars.

2008: Issue No. 1 of Lab Notes. Seminars with Klippel. KEMAR manikin acquired. NCAC membership.

2009: First ALMA Seminar. Membership in IEEE CSNV. AES Headphone tutorial. First expert witness project and trial deposition. C. J. Struck becomes a AES Journal reviewer.

2010: ASA Award for S3.25 as Chair of WG37. First public CJS Labs electroacoustics seminars. 'Electroacoustics Measurements' course notes book. AES paper on impedance data fitting.

2011: C. J. Struck becomes Chair of ANSI Standards Committee 3 - Bioacoustics. Acquisition of Brüel & Kjær Type 4128 Head And Torso Simulator. Microphone clinic at AES San Francisco. AES Telephony tutorial. First international seminar in Sydney, Australia.

2012: C. J. Struck becomes an ANSI accredited Independent Expert.

2013: ASA Award for S3.36 as Chair of WG67. AES paper on headphone response.

2014: Loudspeaker Design seminars at the Audio Design Workshop in Silicon Valley and at AES. Loudspeaker Industry Sourcebook interview. First seminars with Listen, Inc. First International training in Shanghai.

2015: C. J. Struck appointed ASA Standards Director. Member of IEC TC-29 and Head of US Delegation.

2016: CJS Labs celebrates 10th Anniversary. Membership in INCE and SMPTE. Invited speaker at FDA. ASA Award for S3.20 as Chair of WG73. Seminars in Poland. AES paper on headphone testing.

Training Services

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http://www.cjs-labs.com/training_seminars.html

Contact us to schedule a training course for your organization.

News and Recent Developments

Acoustical Society Meeting, in Salt Lake City

ASA will meet 23-27 May in Salt Lake City, UT at the Downtown City Creek Marriott Hotel.

http://acousticalsociety.org/content/spring-2016-meeting

Standards Committee meetings take place Monday and Tuesday. I am well booked in meetings, but contact me if you will be there and would like to discuss your project.

AES in Paris

The AES 140th Convention will take place 4-7 June 2016 in at the Palais des Congrès in Paris.

http://www.aes.org/events/140/

I will be attending on my way to client seminars in Poland. If you or others in your organization will be attending and would like to set up a meeting, please contact us.

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

Christopher J. Struck

CEO & Chief Scientist

CJS Labs

CJS Labs

"Sound Advice Spanning 3 Decades"

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CJS Labs is a consulting firm based in San Francisco, CA. We specialize in audio and electroacoustics applications. With 30 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, patent & IP evaluation, and training services

Back issues of Lab Notes are available on our website at:
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Boundary Effects on Sources at Low Frequencies

A sound source, such as a loudspeaker, will experience an increase in directivity with increasing frequency, as the wavelength of sound becomes small compared to the size of the baffle. As the baffle the driver is mounted on is larger than the driver, this occurs at a lower frequency than for the driver diaphragm itself. The effect on the response is a shelving transition (see Fig. 1), increasing to 6 dB above $ka = 2$. where k is the Wave Number $2\pi/\lambda$ and a is the effective radius (i.e., the radius of a flat circular piston with the same surface area). The Directivity Index effectively increases from 0 to 3 dB as the device transitions from radiating spherically (into a full space) to radiating hemi-spherically (into a half space).

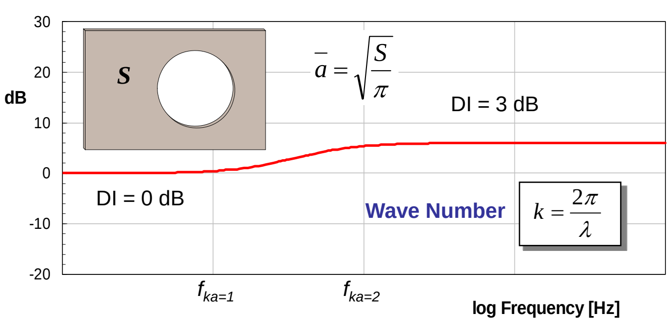

Fig. 1. 4π - 2π baffle loading vs. baffle size.

So what happens to the free field response of a loudspeaker when it is placed near one or more boundaries?

At very low frequencies, if a sound source is very close to a solid plane boundary (e.g., speaker near a wall), sound radiation will be over a hemisphere (half space) instead of free field (full space), as sound energy is reflected from the boundary. This halving of the radiation impedance doubles the apparent level, an increase of 6 dB (see Fig. 2). The addition of another perpendicular boundary (e.g., speaker near two walls), again halves the radiation impedance, again doubling the apparent level (+ 12 dB compared to free field). The addition of a third mutually perpendicular boundary (e.g., speaker on the floor and near two walls), halves the radiation impedance and doubles the apparent level yet again (+ 18 dB compared to free field).

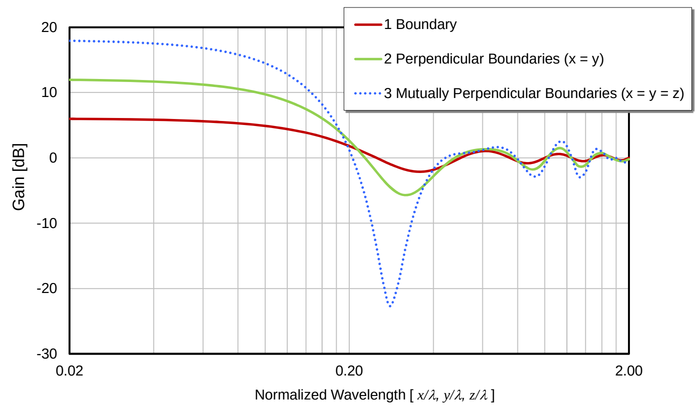

Fig. 2. Influence of boundaries on response, where x = y = z = Distance to Wall or Floor Boundary

Note that the sound pressure level goes up by 6 dB for each additional boundary. Alternatively, this can be viewed as a progressive increase in the directivity of the source, as the source radiates into a progressively smaller solid angle. There is also a response dip near $\lambda/4$, which can be mitigated by careful placement and crossover design.

Please contact us for more information.

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10 Years Anniversary

IEEE CNSV

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Volume 9, Issue 2 **June 2016**

Inside this issue:

Invited Presentation at the US FDA

I was invited by the US Food and Drug Administration to make a presentation at their public forum on "Streamlining Good Manufacturing Practices (GMPs) for Hearing Aids" which took place 21 April 2016 at the FDA facility in Silver Spring, MD. Over 40 persons spoke or made presentations responding to the PCAST report regarding potential rule- making for Personal Sound Amplification Devices (PSAPs). Information about the event, as well as downloads of the presentations and webcast are available at:

http://www.fda.gov/MedicalDevices/NewsEvents/WorkshopsConferences/ucm480336.htm

Electroacoustics Seminar in Santa Clara, CA

I will be teaching the 1-day Fundamentals of Electroacoustics seminar in Santa Clara, on Monday, 10 October 2016, held in conjunction with Listen, Inc. Details and registration are available at:

https://www.listeninc.com/news-events/training/

News and Recent Developments

IHCON 2016

I'll be attending IHCON at Granlibakken, Lake Tahoe, CA, 10-14 August 2016

http://IHCON.usc.edu

InterNoise 2016 in Hamburg

I'm presenting a paper entitled "*Opportunities for international liaison: Acoustical standards in the new millennium*" at InterNoise in Hamburg, which takes place 21-24 August 2016

http://www.internoise2016.org/

Headphones at AES in Aalborg

I will present a paper entitled "*Refinements in Headphone Testing*" at the AES Headphone conference in Aalborg 24-26 August 2016

http://www.aes.org/conferences/2016/headphones/

Please let us know if you will be attending any of these events and would like to set up a meeting.

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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Measurement Uncertainty

Although calibration of the measurement system minimizes the effects of bias errors, random errors will still remain. The maximum permitted measurement uncertainty due to these random errors must be considered in the application of any performance specifications in the form of tolerance limits. Measurement tolerances apply to the performance of a device as measured with perfectly accurate measurement equipment. To ensure that performance is within a specified tolerance when using real and imperfect measurement equipment, the acceptance interval must be include both the tolerance and the maximum permitted uncertainty, U_{MAX}. To ensure that performance is within a specified tolerance, e.g., for outgoing inspection QC/QA, tolerances are reduced by U_{MAX}. To confirm that performance is outside of the specified tolerance, e.g., for incoming inspection, tolerances are increased by U_{MAX}.

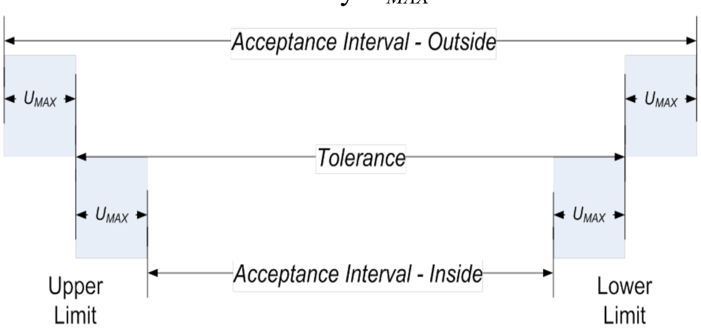

Fig. 1 Tolerances, acceptance intervals, and U_{MAX}.

The maximum permitted measurement uncertainty is found by determining the standard uncertainty for each source of measurement error. These errors may be computed or estimated, found from manufacturer's calibration data, or determined empirically from a statistically significant number of similar measurements. Standard uncertainties dB are then converted to linear percentages, which are then squared and summed. The square root of this sum is the total standard uncertainty. The total standard uncertainty times 2 yields the expanded uncertainty with a coverage factor of $k = 2$ (equivalent to 2σ or a probability of approximately 95%). This value is the maximum permitted uncertainty, U_{MAX}, which is usually expressed in dB. An example of an uncertainty budget for a loudspeaker test is shown in Fig. 2.

Component	Standard Uncertainty [in dB]	U^2 [in %²]
Generator Accuracy To enable harmonic distortion measurements to 0.1%, the generator distortion must be < 0.05%. This is equivalent to a standard uncertainty of 0.043 dB.	0.043	0.25000
Microphone The uncertainty of a working standard microphone as per the standards and quoted on its calibration certificate is 0.1 dB with a coverage factor of k=2. This is equivalent to a standard uncertainty of 0.1/2 = 0.05 dB.	0.05	0.33328
Microphone Preamplifier The manufacturer quotes the preamp to be within ± 0.02 dB with a 95% probability or 2σ. This is equivalent to a standard uncertainty of 0.02/2 = 0.01 dB.	0.01	0.01327
Analysis System / RMS Detector Typical measurement system detector accuracy is 0.1 dB with a coverage factor of k=2. This is equivalent to a standard uncertainty of 0.1/2 = 0.05 dB.	0.05	0.33328
Positioning The error in positioning the microphone should be limited to ±0.5cm. Relative to 1m, this is equivalent to a standard uncertainty of 0.04 dB.	0.04	0.25000
Total Standard Uncertainty	$\sqrt{\sum U^2}$	1.08620
U_{MAX} (k = 2)		2.17 % 0.19 dB

Fig. 2 Example loudspeaker test uncertainty budget.

Detailed information regarding measurement uncertainty can be found in ISO/IEC Guide 98-3 Uncertainty of measurement – Part 3: Guide to the expression of Uncertainty in Measurement (GUM).

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Volume 9, Issue 3 **September 2016**

Inside this issue:

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http://www.cjs-labs.com/training_seminars.html

Contact us to schedule a training course for your organization.

AES Headphone Technology Conference in Aalborg

Over 100 persons attended the AES conference on Headphone Technology in Aalborg, Denmark 24-26 August 2016. Keynotes, papers, posters, and demo sessions were lively with great interaction between all participants. Dinners at the Aalborg concert hall and Robbers Camp were a hit with attendees. My paper, entitled "*Refinements in Headphone Testing*" was well received with a good Q&A session afterwards.

http://www.aes.org/conferences/2016/headphones/

InterNoise 2016 Hamburg

I presented a paper entitled "*Opportunities for international liaison: Acoustical standards in the new millennium*" at InterNoise in Hamburg, which took place 21-24 August 2016. The conference was bustling with over 1200 persons attending and over 900 papers and posters.

http://www.internoise2016.org/

IHCON Lake Tahoe

I also attended the IHCON hearing research conference at Granlibakken, Lake Tahoe, CA, 10-14 August 2016. Topics were wide ranging, including neurological implications and strategies for tracking and improving cognition.

http://IHCON.usc.edu

News and Recent Developments

ASA Standards Award

I received an award at the ASA meeting in Salt Lake City for chairing S3 Working Group 73, which revised the S3.20 Bioacoustical Terminology Standard.

ASA Standards Manager Neil Stremmel presenting the award for the S3.20 standard.

AES Los Angeles

The AES 141st Convention takes place in LA 29 Sep.—2 Oct. 2016. I'm giving a tutorial on Headphone Testing, Session PD1 on THU 29 Sep. at 2:15pm

http://www.aes.org/events/141/productdevelopment/?ID=5158

Electroacoustics Seminar in Santa Clara, CA

There are still spaces available for the 1-day Fundamentals of Electroacoustics seminar in Santa Clara, CA on Monday, 10 October 2016, held in conjunction with Listen, Inc. Details and registration at:

https://www.listeninc.com/news-events/training/

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

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Sound Radiation:
Ideal Point Source in a Free Field

A **free field** describes idealized sound propagation with no reflections. A so-called *point source* will radiate spherically into a free field in all directions if there are no reflections. Under these conditions the sound intensity reduces by one fourth for every doubling of distance, *r*, as the pressure, *p*, is distributed over four times the surface area, *S* (see Fig. 1). The

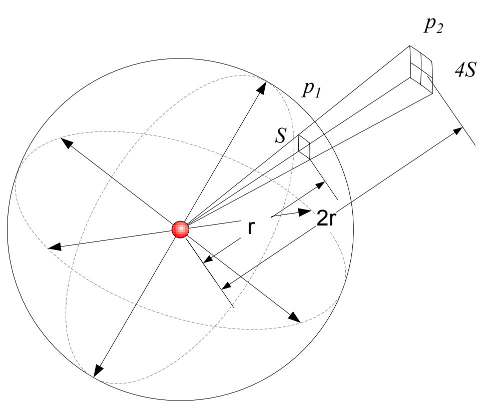

Fig. 1 Ideal Point Source radiating into a Free Field.

sound pressure level therefore decreases by 6 dB for every doubling of distance. This effect of spherical spreading is known as the "Inverse Square Law". A small loudspeaker will typically behave as a point source at distances several times greater than its largest dimension.

When the distance to the source is small compared to the wavelength of sound, one is said to be in the **near field** of the source. This can occur close to source at low frequencies, where the wavelength (and radius) of a spherical wave is so large that the sampled section of the wave is essentially a plane. The **far field** occurs in practice when the distance from the observer to the source is large compared to the size of the source. Therefore, the far field and the near field are determined by the relative size of the source compared to the frequency of the sound radiated, independent of the environment.

The **reverberant field** occurs in a room when sound arrives from all directions with equal magnitude and probability, as the distance to the boundaries becomes less than the distance to the source, and reflected sound dominates. In the **direct field**, sound arriving directly from the source is dominant (see Fig. 2). Therefore, the reverberant and direct fields

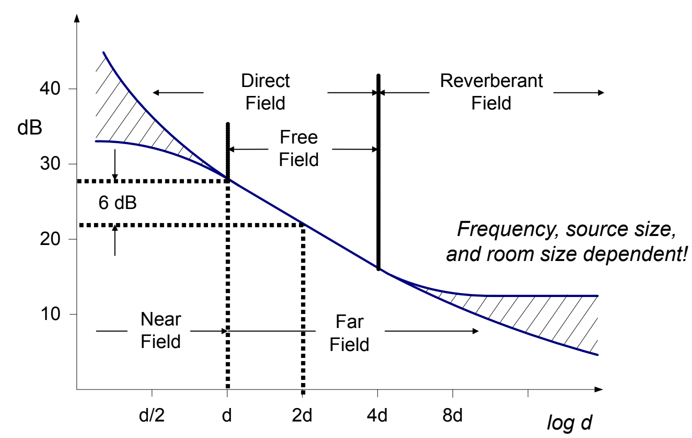

Fig. 2 Sound field for an ideal point source as a function of relative distance. Note the log distance abscissa.

are primarily functions of the room or environment. The free field is always in the far field and is a function of both the source and room. Note that a free field may not exist for a large source in a small room.

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Volume 9, Issue 4 December 2016

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Wireless Bluetooth Measurement Interface

Earlier this year, CJS Labs acquired the Portland Tool & Die Model BTC 4148 Bluetooth® Audio Measurement Interface for testing Bluetooth® enabled wireless devices such as headphones, headsets, and loudspeakers. It is controlled via USB and can be used over USB or S/PDIF audio interfaces. It is sold through Listen, Inc., which incorporates a GUI for it in their SoundCheck software. All Bluetooth® profiles and parameters are accessible via the front panel or the SoundCheck GUI. This unit significantly enhances our test arsenal for wireless devices.

Voice Coil Article

An expanded version of the article in Lab Notes Vol. 9, Issue 1, "Boundary Effects on Sources at Low Frequencies" was reprinted in the Vol. 29, No. 9 (2016 July) issue of Voice Coil. The full reprint is available on the CJS Labs website.

News and Recent Developments

ASA/JAS in Honolulu

The joint meeting of ASA and the Japan Acoustical Society took place 28 Nov—2 Dec 2016 at the Hilton Hawaiian Village in Honolulu. I attended papers and standards meetings and played in the Wednesday night Jam Session. Aloha!

Headphones at AES in Los Angeles

I gave a well received tutorial on Headphone Measurements at the AES 141st Convention in LA on the 29th of September, highlighting measurements from the new ANSI/ASA S3.7 standard. Slides from this tutorial are posted on the CJS Labs website.

Electroacoustics Seminar

24 persons attended my 1-day "Fundamentals of Electroacoustics" seminar in Santa Clara, CA on Monday, 10 October 2016. The seminar was held in conjunction with Listen, Inc. as part of their SoundCheck software training program. A lot of information was packed into the all-day session, with good Q&A on many of the topics covered.

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

Seasons Greetings!

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A, B, & C Weighting and Their Relationship to the Equal Loudness Contours

The overall level of an acoustical measurement is often given as a **weighted** value. Before calculating the level, the signal is processed by filtering in the same way the sensitivity of hearing for the average human varies with frequency. This processing simulates the **equal loudness contours** (see Fig. 1).

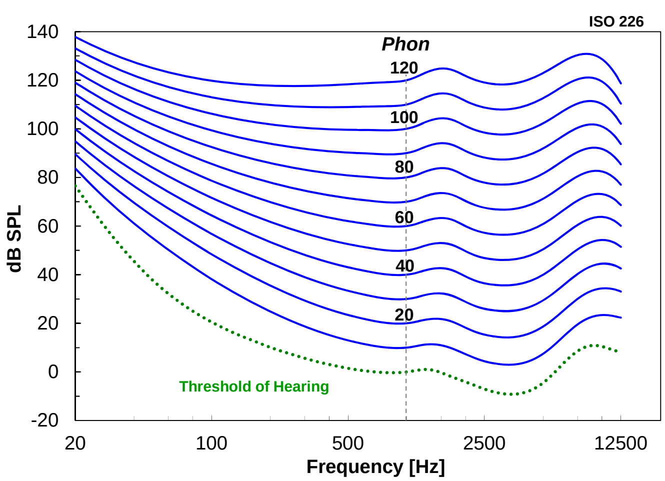

Fig. 1 Equal Loudness Contours.

Detailed in ISO 226, the equal loudness contours show that the response of human hearing varies both with frequency and with level. Each **Phon curve** indicates the level required at a given frequency to be perceived as the same loudness as a 1 kHz tone.

For example, a tone at 100 Hz must be nearly 27 dB higher in level than a 1 kHz tone at a level of 60 dB to be perceived as having the same subjective loudness.

Although an increase of 6 dB is a doubling of the sound pressure level, an increase of approximately 10 dB is generally judged to be subjectively twice as loud. Note that the smallest audible level difference for most persons is about 3 dB.

Weighting networks may be implemented as hardware or software, analogue or digital, or applied as post-processing. The design of the **A-weighting** network is based upon a smoothed version of the inverse of the 40 Phon curve, and was therefore originally intended to be used only for measurements at low levels. However, it is now commonly used for measurements at all levels. Likewise, the **B-weighting** and **C-weighting** curves approximately follow the inverse of the 70 Phon and 100 Phon equal loudness curves, respectively (see Fig. 2).

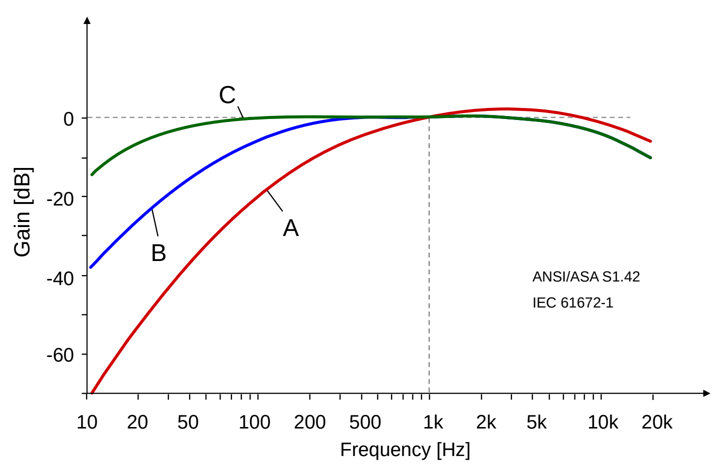

Fig. 2 Standard acoustical weighting networks.

All of the standardized weighting curves are 0 dB at 1 kHz. This ensures that having a weighting network engaged will not cause an error when calibrating your test instrumentation using a 1 kHz tone.

Please contact us for more information.