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Lab Notes

IEEE CNSV

NCAC National Council of Acoustical Consultants Member

Volume 12, Issue 1 **March 2019**

Electroacoustics & Audio

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

Inside this issue:

Training Services

CJS Labs offers customized in-house training. Our design experience, proven processes, and measurement expertise will make your product development more efficient. Learn how to optimize both your designs and test routines. Having a thorough understanding of 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.

Loudspeaker Design Tutorial at AES 146th in Dublin, Ireland

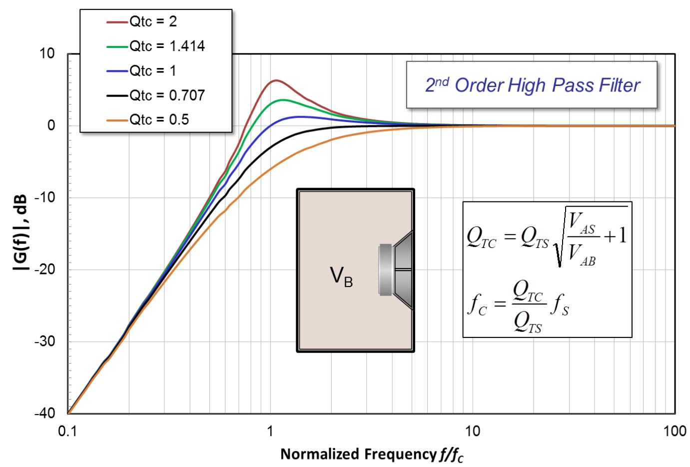
The AES 146th Convention takes place 20-23 March 2019 in Dublin, Ireland.

http://www.aes.org/events/146/

On Thursday, 21 March 2019, I will be presenting a tutorial entitled *"Almost Everything You Ever Wanted To Know About Loudspeaker Design"* :

http://www.aes.org/events/146/tutorials/?ID=6597

The session is T-17 taking place at 12:45. I hope to see you there!



News and Upcoming Events

Standards Meetings at ASA in Louisville, KY

ASACOS and the S-Committees will meet at ASA in Louisville, KY which takes place 13-17 May 2019.

https://acousticalsociety.org/asa-meetings/

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

Fundamentals of Electroacoustics—Santa Clara, CA

The 1-day *Electroacoustics* training course on held in Santa Clara, CA in February in conjunction with Listen, Inc. was a huge success, with over 40 attendees. The psychoacoustics module now features live sound demonstrations. The sessions were lively with lots of questions from the participants

ASA Standards Video

A short video I produced giving an overview of the ASA Standards Program is now posted on the ASA Standards homepage:

https://acousticalsociety.org/acousitcal-society-standards/

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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Shotgun Microphone Directivity

The interference tube or "Shotgun" microphone is a specialized, high directionality device used to pick up distant on-axis sounds and reject off-axis noise.

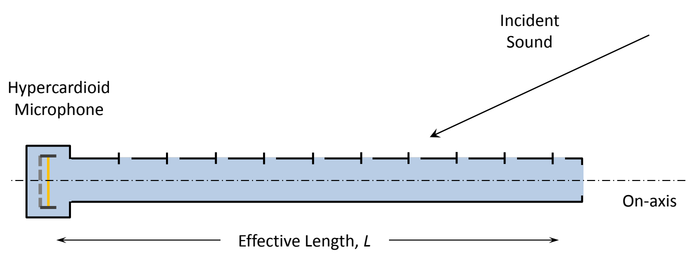

Fig. 1 Shotgun microphone.

For sound arriving on-axis, the signal will be the in-phase sum of all contributions from the various openings along the length of the tube. For off-axis sound, phase cancelation will occur due to the differences in the individual path lengths. The acoustical impedance at each opening is adjusted so that sound entering the tube does not exit at the next opening, but instead propagates along the length of the tube to the first order directional microphone element, usually a hypercardioid.

The polar response for a shotgun microphone with an effective tube length of 0.3m is shown in Fig. 2.

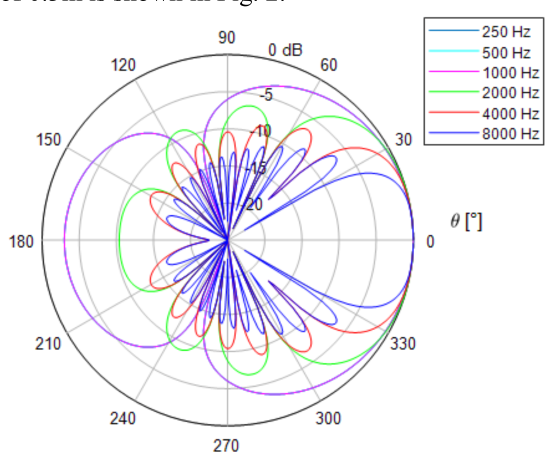

Fig. 2 Polar response of 0.3m shotgun microphone.

The system is effectively a summing array. The net sum of the contributions along the length of the shotgun tube as a function of wavelength and angle of incidence yields the polar response of the shotgun microphone for a given effective length, L

$$\rho(\theta)=\frac{\sin\left[\frac{\pi}{\lambda}(L-L\cos\theta)\right]}{\frac{\pi}{\lambda}(L-L\cos\theta)}$$

The tube acts to increase the directivity of the first order microphone element above the frequency f_0 = c/2L. Below this frequency, the device is essentially only the first order directional microphone.

The Directivity Index and Distance Factor for the 0.3m shotgun microphone are shown in Fig. 3.

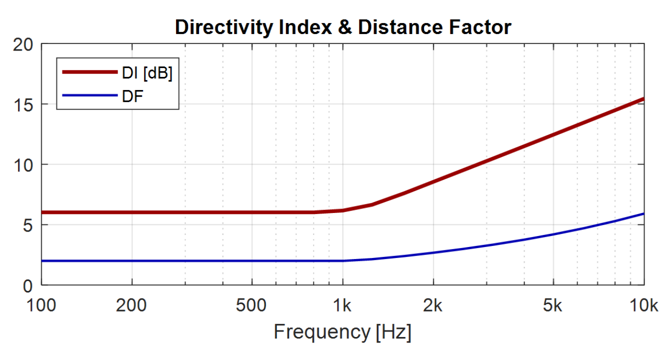

Fig. 3 DI and DF of 0.3m shotgun microphone.

The shotgun microphone is typically used in broadcast journalism, live sporting events, film, video, and surveillance applications.

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AES International Conference on Headphone Technology San Francisco, CA — 27-29 August 2019

I am co-chair of the AES International Conference on Headphone Technology, which will be held 27-29 August 2019 here in San Francisco at Golden Gate Club in the historic Presidio. I will also be giving a paper entitled, "*Objective Measurements of Headphone Acoustic Noise Cancellation Performance*".

Registration is now open:

http://www.aes.org/conferences/2019/headphones/

News and Upcoming Events

AES 146th Loudspeaker Design Tutorial—Dublin

My tutorial at the AES 146th in Dublin, "Almost Everything You Ever Wanted To Know About Loudspeaker Design" was a great success, with over 60 attendees and lots of requests for the PDF lecture notes.

New Tutorial: Microphone Electroacoustics

I will be debuting a new tutorial on Microphone Electroacoustics at the AES 147th in New York in October. It covers design, principles of operation, configurations, interfacing, performance metrics, and applications. Stay tuned for details.

ASA Standards Video

The URL to the ASA Standards promo video in the last issue was incorrect. Here is the correct URL:

https://acousticalsociety.org/acoustical-society-standards/

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

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First Order Directional Microphones

A first order directional microphone is sometimes called a 'gradient' microphone, as its response is proportional to pressure gradient, rather than pressure. Any desired first order polar pattern of the cardioid family can be formed by a normalized weighted combination of omni and bidirectional (cosine) elements. For sources in the far field, the general equation for a first order directional microphone is given by

$$\rho(\theta) = \alpha + \beta cos(\theta)$$

where

ρ	is the output
α	is the omnidirectional component
β	is the cosine (bidirectional) component
k	is the wave number ($2\pi/\lambda$)
r	is the distance to the source
θ	is the angle

$$0 \geq \beta \geq 1 \qquad \text{and} \qquad \alpha = 1 - \beta$$

The primary single-figure directional metric is the Directivity, or Q. Directivity can be measured or calculated from the polar equation as

$$Q = \frac{1}{1 - 2\beta + \frac{4\beta^2}{3}}$$

This is the power ratio of the free field on-axis response to the diffuse field (random incidence) response. Functionally, this is the S/N for an on-axis source compared to diffuse reverberant noise. This is more commonly given as the Directivity Index, which is simply

$$DI = 10\log_{10} Q$$

The Hypercardioid pattern has the highest DI and will therefore provide approximately 6 dB of S/N improvement over an omnidirectional microphone of the same sensitivity under the same conditions. The Supercardioid is slightly lower, at 5.7 dB, while the Cardioid and Bidirectional microphones are 4.8 dB.

The family of classical first order polar patterns and corresponding directivity index are shown in Fig. 1.

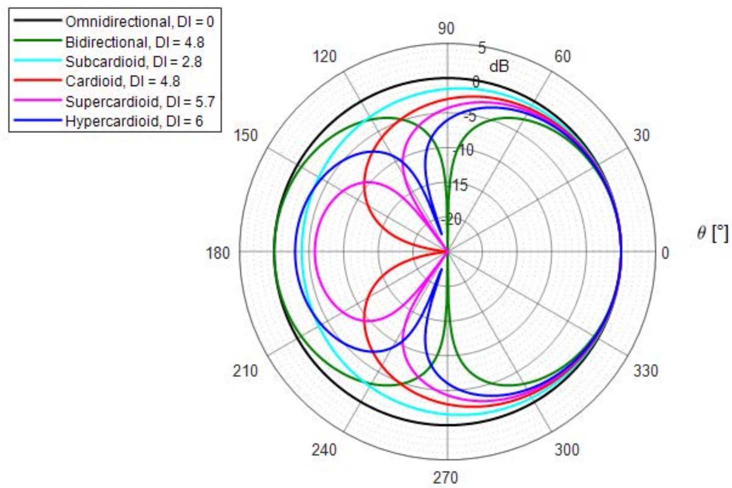

Fig. 1 First order polar patterns and Directivity Index.

Note that although the polar pattern is typically shown as 2-dimensional in a single plane, it is actually 3-dimensional — symmetric about its primary axis. The 3-D cardioid pattern is shown in Fig. 2.

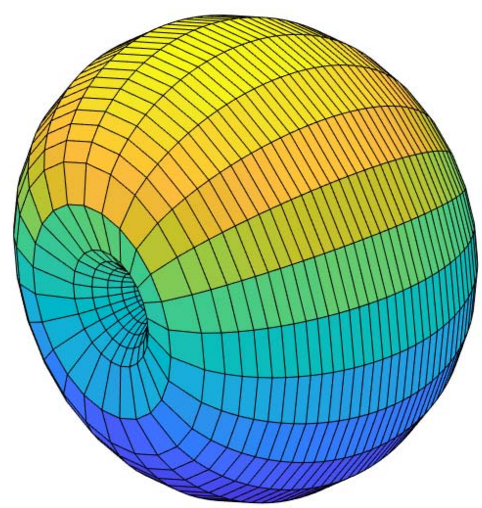

Fig. 2 3-D cardioid polar pattern.

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Volume 12, Issue 3 **September 2019**

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Inside this issue:

AES International Conference on Headphone Technology

The AES International Conference on Headphone Technology, which I co-chaired, took place here in San Francisco in the Presidio at the Golden Gate Club 27-29 August 2019 and was a great success. Over 240 persons attended. Sessions on the topic of headphones included papers, posters, workshops, demo and exhibits. I also presented a paper entitled, "*Objective Measurements of Headphone Acoustic Noise Cancellation Performance*".

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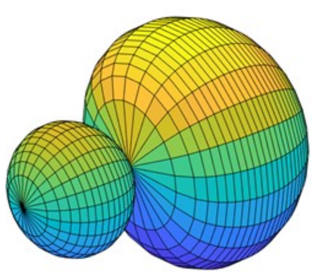

ASA 178th Meeting San Diego, CA

The 178th Meeting of the Acoustical Society of America (ASA) will be held Monday through Friday, 2-6 December 2019 at The Hotel del Coronado in San Diego, CA. The ASA Committee on Standards, which I chair, will meet Tuesday morning, 3 December. More information available at:

https://acousticalsociety.org/asa-meetings/

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Summed Line Arrays

Monopole sources or receivers summed together will form an array. The elements could be microphones, hydrophones, or sound sources. Fig. 1 shows a simple microphone array.

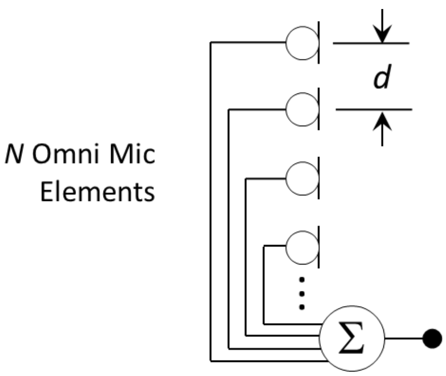

Fig. 1 Vertical microphone summing array.

The array will exhibit directional behaviour and lobing at higher frequencies where the distance separating the array elements is equal to or greater than $\lambda/2$. The response as a function of angle can be calculated as

$$R(\theta) = \left| \frac{\sin\left(\frac{N\pi d}{\lambda}\sin(\theta)\right)}{N\sin\left(\frac{\pi d}{\lambda}\sin(\theta)\right)} \right|$$

where

R	is the output
θ	is the angle [in rad]
N	is the number of elements
d	is the spacing between the elements [in m]
λ	is the wavelength [in m]
and	$\lambda = c/f$

The distance separating the elements is assumed to be equally spaced and amplitude weighted with no additional delay. Note that argument for the sine of the angle is in radians. The line formed by the microphones sits along the y-axis (90° - 270°) as a vertical broadside array.

Polar patterns for a 4-element vertical summing array with the elements spaced 20 cm apart were modeled in Matlab and are shown in the following figure.

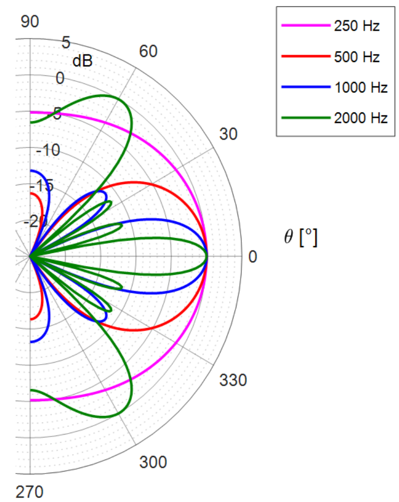

Fig. 2 Polar patterns for a 4-element array, d = 20cm.

The Directivity increases to approximately the frequency where $d/\lambda = 1$, limiting the useful range of the simple summed array as shown in Fig. 3.

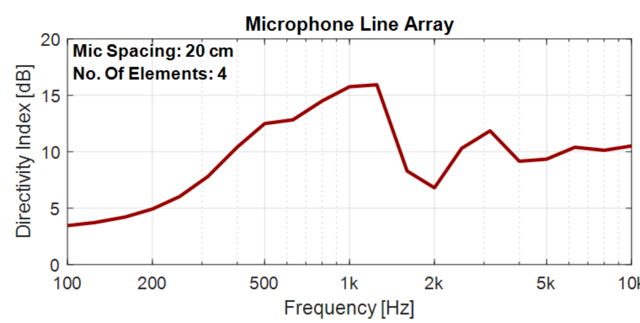

Fig. 3 Directivity Index of the 4-element array.

Control of the lobing and directivity involves changes to the spacing, amplitude scaling of the elements, and delay to summing node for each element. Numerous functions for these can be found in the literature.

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Volume 12, Issue 4 **December 2019**

Inside this issue:

ASA 178th Meeting—San Diego, CA

The 178th Meeting of the Acoustical Society of America was held 2-6 December 2019 at the historic Hotel del Coronado in San Diego, CA. The ASA Committee on Standards met on Tuesday morning, 3 December. The meeting also featured numerous sessions and technical presentations. ASA will meet again 11-15 May 2020 in Chicago, IL. More information at:

https://acousticalsociety.org/asa-meetings/

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News and Upcoming Events

ANSI/ASA S1.42-2019

ANSI Working Group S1-24, which I chair, has completed its revision of S1.42 "Design Response of Weighting Networks for Acoustical Measurement". The draft has balloted and passed and is awaiting final ANSI approval. This new revision also includes a set of Matlab m-file scripts for designing analogue and digital A-, B-, C-, D-, E, G- , and U-weighting filters. It should appear in the ASA Standards store in early 2020.

IEC TC-29—Warsaw

IEC TC-29 will meet in Warsaw 23-27 March 2020 in Warsaw, Poland. Delegates and accredited experts from around the world will attend. I will head the US Delegation and participate in 4 working group meetings: WG5 on Microphones; WG13 on Hearing Aids; WG21 on Ear simulators; and WG on Modular Instrumentation. I am also Convenor of MT25, however, the revision of IEC 60263 was completed in October is awaiting translated and final CDV ballot, which is expected this spring. I will also be giving a guest lecture at Gdańsk Polyteknik the following week.

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

Happy Holidays!

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Improved Zobel Network

Passive crossover filter networks for multi-way loudspeakers generally require a resistive termination for optimum performance. The driver itself presents, at best, a semi-inductive load. Recall the inductive rise with frequency of the loudspeaker electrical impedance. The L2/R2 impedance model depicted in Fig. 1 represents the electrical impedance as seen by the amplifier output:

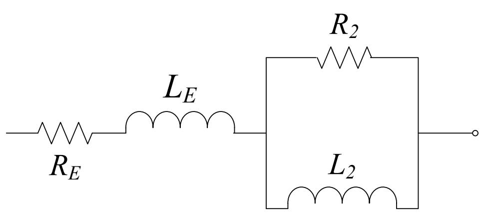

Fig. 1 L2/R2 loudspeaker electrical impedance model.

The typical Zobel network used to make the driver impedance appear closer to an ideal resistive load is a simple series resistor and capacitor shunted across the driver terminals.

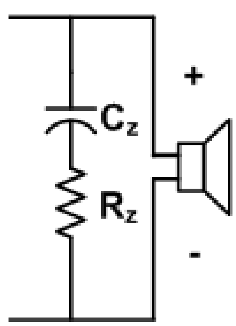

Fig. 2 Typical Zobel impedance compensation network.

The component values are calculated as

$$R_Z \approx 1.25\, R_E\ , \quad C_Z = \frac{L_E}{R_Z^2}\ , \text{ with} \quad P_R = \frac{V_{MAX}^2}{R_Z}$$

The resistor value is approximate and may need to be adjusted for more extreme voice coil impedances. The resistor should be power rated as shown to handle the current to the loudspeaker.

The flatness of the compensated impedance magnitude is typically limited when using this simplified compensation network. An improved compensation network can be realized by using the analogous circuit 'dual' of the L2/R2 model, assuming the values for the driver impedance model are known. Recall that a circuit 'dual' replaces series impedances with shunt impedances and vice versa. Capacitors become inductors and inductors become capacitors. Resistors remain resistors. Applying these principles to the network of Fig. 1 results in the following network:

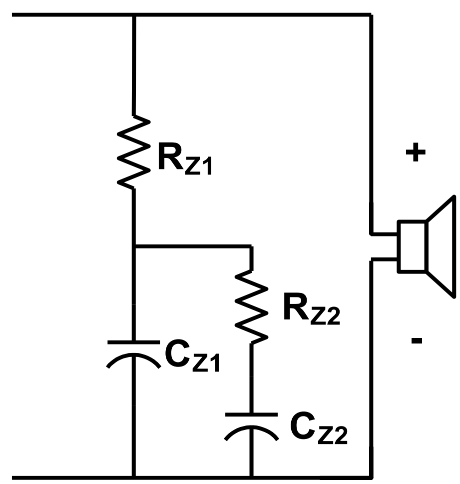

Fig. 3 Improved Zobel compensation network realized as the circuit 'dual' of the L2/R2 impedance model.

The component values for this network are calculated as

$$R_{Z1} = R_E\ , \quad R_{Z2} = R_2\ , \quad C_{Z1} = \frac{L_E}{R_E^2}\ , \text{ and} \quad C_{Z2} = \frac{L_2}{R_2^2}$$

This represents a dramatic improvement to the basic 2-component Zobel network, and compensates for the non-ideal semi-inductive behaviour of the loudspeaker driver across the entire frequency band. The component values are easily found if the L2/R2 impedance model values are known. The cost, however, is increased size, complexity, and component count.

Please contact us for more information.