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Lab Notes

NCAC
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Volume 2, Issue 1 **February 2009**

Audio & Electroacoustics

- *Consulting*
- *Design*
- *Training*

Inside this issue:

Order Your Copy of "Electroacoustics Measurements"

This essential reference for making proper transducer measurements is a 300+ page, bound, fully annotated compendium of slides and information from the CJS Labs Electroacoustic Measurements training seminar. Covers all topics from the course. Literature references for each chapter are also included.

Ordering information:

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

ALMA Seminar Hits Jackpot in Vegas

Although attendance was down slightly from previous years, the full day *"Electroacoustic Measurements"* seminar at the ALMA Winter Symposium in Las Vegas, on 5 January 2009 was a great success. Acoustic, test methods, and analysis techniques were detailed. Participants were engaged, asking questions throughout. Additional information is available at the ALMA website:

http://www.almainternational.org/2009_winter_symposium.php

Standards News

The IEEE Subcommittee on Telephone Instrument Testing released IEEE 1652 *"Standard for the Application of Free Field Acoustic Reference to Telephony Measurements"* at the end of 2008. IEEE 269 *"Methods for Measuring Transmission Performance of Analog and Digital Telephone Sets, Handsets, and Headsets"* and IEEE 1329 *"Standard for Measuring Transmission Performance of Speakerphones"* have been extensively revised and are currently open for ballot. Both should be released later this year. ANSI S3.22-2003 "Specification of Hearing Aid Characteristics" was adopted by the FDA in late 2008. In September, I took over as Chair of the ANSI S3 Working Group on Couplers and Ear Simulators. We reaffirmed ANSI S3.7 *"Method for Coupler Calibration Of Earphones"* and are currently working on a revision of the ANSI S3.25 standard *"For An Occluded Ear Simulator"*.

Recent News & Upcoming Events

AES 36th

I recently co-authored a paper entitled "*Ensuring Accurate Playback and Analysis of Binaural Recordings for Automotive Sound Systems". The paper* will be presented at AES 36th International Conference: *Automotive Audio—Sound In Motion*, in Dearborn, MI, 2–4 June 2009. Info at: http://www.aes.org/events/36/

Brüel & Kjær Type 4232 Acquisition

CJS Labs has just acquired a Brüel & Kjær Type 4232 Anechoic Test Box. This device enhances our capabilities to perform measurements of miniature microphones, and hearing aids. The high isolation enables equivalent input noise measurements.

CJS Labs Joins IEEE CNSV

CJS Labs became a member of the IEEE Consultants Network in Silicon Valley. CNSV info at:

http://www.californiaconsultants.org/

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

Best regards,

Christopher J. Struck

CEO & Chief Scientist

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Back issues of Lab Notes are available on our website at:
http://cjs-labs.com/_wsn/page5.html

Setting Up Simulated Free Field Measurements

Generally, when performing a measurement of a loudspeaker or other source, only the direct sound from the transducer is desired, without influence from the room/environment or other noise sources. An anechoic chamber with sound absorbing surfaces can be used to eliminate reflections. However, not only is such a facility expensive, but the effective lower frequency is limited by the depth of the absorbing material ($\lambda/4$).

An alternative is to perform time selective measurements. Time Selectivity is based upon the constant speed of sound. The means that the Direct Sound always follows the shortest path and arrives at the measurement microphone first. Time Delay and Distance are therefore directly related: $\tau = d/c$. A Simulated Free Field is created by completing the measurement before the arrival of the first reflection. The Path Length Difference between the Direct Sound and the first Reflection is the available measurement time (Time Window).

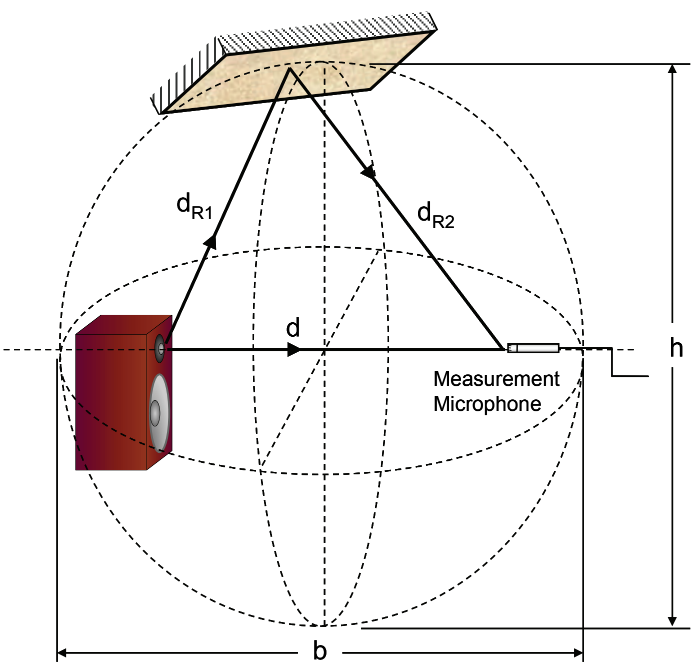

Fig. 1 The Simulated Free Field test set up forms a virtual ellipsoid with the microphone and source at the focal points.

The Time Window, T, is determined by the path length difference between the direct sound and the first reflection.

$$T = \frac{(d_{R1} + d_{R2}) - d}{c} \qquad \text{Eq. 1}$$

So, in any room, an ellipsoid can be defined within which a time selective simulated free field measurement can be made. The governing distance in most ordinary rooms is floor to ceiling height. The loudspeaker and microphone sit at the focal points of the ellipsoid, usually centered at half the ceiling height. The reciprocal of the time window, T, gives the lower frequency limit and frequency resolution, Δf. Given the path length difference, the lowest frequency that can be measured is governed by the room size, similar to an anechoic chamber, but without any special (or expensive) treatment. For a given low frequency limit, the size (L × W × H) of the untreated room for either an anechoic chamber or time selective measurements is more or less identical given the depth of absorbing material that must be fitted to the walls floor and ceiling.

In order to assist you in setting up simulated free field measurements, an Excel spreadsheet has been created and is available on our website: http://www.cjs-labs.com/sitebuildercontent/sitebuilderfiles/SimulatedFFMeas.xls

	A	B	C	D	E	F
1	Simulated Free Field Measurement Worksheet					
2						
3	*Mic & Source Height for Desired Low Frequency Limit*					
4	**Metric**				**English**	
5	Desired Low Frequency Limit:	100.0				Hz
6	Distance Between Mic and Source:	1.00	m		3.00	ft
7	Speed of Sound:	344.8	m/s		1131.2	ft/s
8	*Required Height of Mic & Source:*	2.68	m		8.53	ft
9	*Time Window Width:*	10.00				ms
10						
11						
12	*Low Frequency Limit for Given Mic & Source Height*					
13	**Metric**				**English**	
14	Mic & Source Height:	1.00	m		3.00	ft
15	Distance Between Mic and Source:	1.00	m		3.00	ft
16	Speed of Sound:	344.8	m/s		1131.2	ft/s
17	*Low Frequency Limit:*	278.9	Hz		305.1	Hz
18	*Time Window Width:*	3.58	ms		3.28	ms

It will calculate the mic and source height required for a desired low frequency limit or the low frequency limit for the mic and source height in your set up, in English or metric units. Try it and find out what your set up is capable of!

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Volume 2, Issue 2 **May 2009**

Inside this issue:

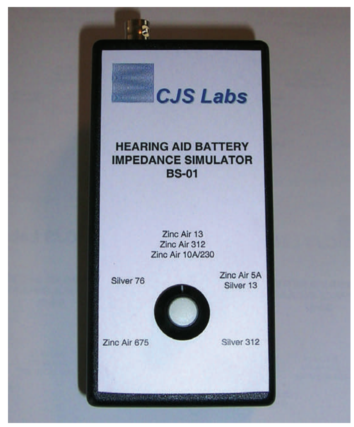
SoundCheck Test Solutions

SoundCheck Sequences for Hearing Aid Tests

CJS Labs recently completed a collaboration with Listen, Inc. of Boston, MA (www.listeninc.com) to create a suite of test sequences for performing hearing tests according to ANSI S3.22-2003 and IEC 60118-7.

Hearing Aid Battery Impedance Simulator

The measurement of hearing aid battery current drain requires accurate simulation of the battery impedance. The CJS Labs BS-01 provides the correct impedance for Zinc Air 13, 312, 675, 10A/230, and 5A and Silver 76, 13, and 312 battery types.



Matlab SoundCheck Control and Data Transfer

CJS Labs offers Matlab programming assistance for electroacoustic testing applications, including SoundCheck control and data transfer. One-on-one consulting is available to help you get your customized application up and running. A utility m-file that performs data transfer and illustrates the seven SC "commands" is also available.

Contact us for more information.

Recent News & Upcoming Events

ASA 157th

We will be at the Acoustical Society of America 157th Meeting in Portland, OR 18-22 May 2009. The ANSI S2WG37 (Ear Simulators), which I Chair, will meet on Monday 18 May at 8:30 in the Council Room. Let us know if you wish to arrange a meeting at ASA. Info at: http://asa.aip.org/portland/information.html

AES 36th Automotive Audio

Our paper entitled "*Ensuring Accurate Playback and Analysis of Binaural Recordings for Automotive Sound Systems*" will be presented at AES 36th International Conference: *Automotive Audio — Sound In Motion*, in Dearborn, MI, 2–4 June 2009. Info at: http://www.aes.org/events/36/

T-S Equations Updated

The summary sheet showing the famous Thiele-Small Parameter equations has been updated to show these formulæ in a more programming friendly format. The document can be downloaded at: http://www.cjs-labs.com/sitebuildercontent/sitebuilderfiles/Thiele-SmallEquations.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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http://cjs-labs.com/_wsn/page5.html

Calibrating Hearing Aid Telecoil Measurements

The background theory for this topic is rather complex, so in this issue we will show the specific procedure for 3 particular systems. To see diagrams of each system and a detailed technical description of the theory, see the full application note at:

http://cjs-labs.com/db4/00368/cjs-labs.com/_download/TelecoilCalibration.pdf

The general test system configuration is shown in Fig. 1.

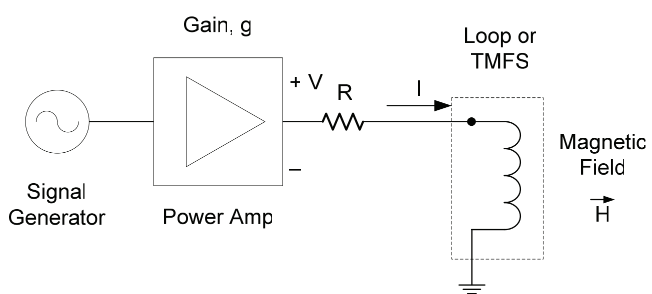

Fig. 1 Test system for hearing aid telecoil measurements.

After the microphone and sound source (power amp and loudspeaker in the anechoic test chamber) are calibrated for acoustic measurements, the second channel of the power amp is generally used for the telecoil measurement. This feeds either a test loop or a Telephone Magnetic Field Simulator (TMFS), which generates the required magnetic field as input to the hearing aid telecoil. The first step is to measure the gain g [in V/V] of the power amp. This number (in V/V or in dB) is used by the measurement system to refer the level of the stimulus signal directly to the input terminals of the device under test, i.e., the gain of the power amp will not be a part of the measurement and the test level is known at the *output* of the power amp.

For this application, we would like to specify the test level as a magnetic field strength [in units of A/m]. This requires a conversion (or transduction) of the stimulus voltage into a magnetic field strength to be performed by the test loop or TMFS. We need to know the voltage to magnetic field sensitivity k [in A/m/V] of the particular magnetic field transducer connected to the output of the power amp. This is analogous to calibrating a loudspeaker or microphone connected to our test system, so the process is very similar.

We can see by a quick inspection of the magnetic field units that what is actually required is a current, not a voltage. Fortunately, Ohm's Law, in the form of $I = V/R$, provides us with an easy voltage-to-current conversion. This means that a series resistor between the power amp output and the loop or TMFS is required as shown. After the power amp is calibrated, the total sensitivity of the channel for telecoil measurements is

$$\text{Sensitivity} = g \cdot k$$

OR $$S\,[\text{dB}] = G\,[\text{dB}] + K\,[\text{dB}]$$

Case 1:

<u>ANSI S3.22 Telephone Magnetic Field Simulator</u>

Let us consider the specific case of the Frye Telewand (part no. 043-1052-00 www.frye.com). This unit incorporates an internal 100Ω resistor. The sensitivity of this device is 0.2257 A/m/V (-12.93 dB A/m/V). Perform tests at 31.6 mA/m.

Case 2:

<u>B&K 4232 or Interacoustics TB-25 Teleloop</u>

A 1/4 W, 100 Ω series resistor is required. The sensitivity of the loop in this system is 0.04 A/m/V (-27.87 dB A/m/V).

Case 3:

<u>B&K 4222 with modification WH0880</u>

The "mesh" in the test plane is modified to act as a single turn loop. A 1/4 W, 61.9 Ω series resistor is required. Interestingly, with this value of resistor, the sensitivity of this system is also 0.04 A/m/V (-27.87 dB A/m/V).

Although this may appear complex, the end result produced is simple: The test system can be set up and calibrated to produce a very well-defined magnetic field knowing only the geometry and the current (set by the series resistor). Once calibrated, the stimulus can be exactly specified as a magnetic field strength in calibrated engineering units at the test point.

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Volume 2, Issue 3 **August 2009**

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An essential reference for making proper transducer measurements. This 300+ page, bound, volume is a fully annotated compendium of slides and information from the CJS Labs Electroacoustic Measurements training seminar and covers all topics from the course. Literature references for each chapter are also included.

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

Space Still Available for NY Loudspeaker Performance Seminar

Limited space is still available for the *Loudspeaker Performance: Measurement, Analysis & Diagnostics"*, a 2-day joint seminar in conjunction with Klippel at the Novotel in New York, 13-14 October 2009 (immediately after AES). For more information, click on the link below:

http://cjs-labs.com/db4/00368/cjs-labs.com/_download/2-DaySeminarOverview2009.pdf

Fee: $895-

The class is quickly filling up and space is limited to 25 persons. So Email cjs@cjs-labs.com or phone (415) 923-9535 today to reserve your place. Your space is not guaranteed until payment is received. The course fee includes beverages, lunches, and a printed set of the course notes. We look forward to seeing you in New York.

Hearing Aid Battery Impedance Simulator

The measurement of hearing aid battery current drain requires accurate simulation of the battery impedance. The CJS Labs BS-01 provides the correct impedance for Zinc Air 13, 312, 675, 10A/230, and 5A and Silver 76, 13, and 312 battery types. A detailed product data sheet is available at:

http://www.cjs-labs.com/sitebuildercontent/sitebuilderfiles/BS-01DataSheet.pdf

Contact us for more information.

Recent News & Upcoming Events

ASA 157th — Portland

ANSI S2WG37 on Ear Simulators met in May at ASA in Portland. The revision of ANSI S3.25 is now complete and in preparation for ballot.

Loudspeaker Models

We recently completed a MatLab program for performing a LMS fit on loudspeaker impedance data. The fit is to the complex data (magnitude and phase). Seven different models are available, data can imported to and from Excel or a delimited text file. Contact us for more information.

AES Tutorial: Headphone Measurements

We will be presenting a tutorial session on headphone and earphone measurements at the AES 127th Convention in New York. More information at:

http://www.aes.org/events/127/tutorials/session.cfm?ID=2114

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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Objective Loudness Calculation

In addition to level (in dB) vs. frequency, many applications require the determination of loudness (in Sones or Phons). Given a 1/3 octave spectrum, the loudness of a stationary signal can be calculated according to ISO 532b (DIN 45631), also known as the Zwicker method.

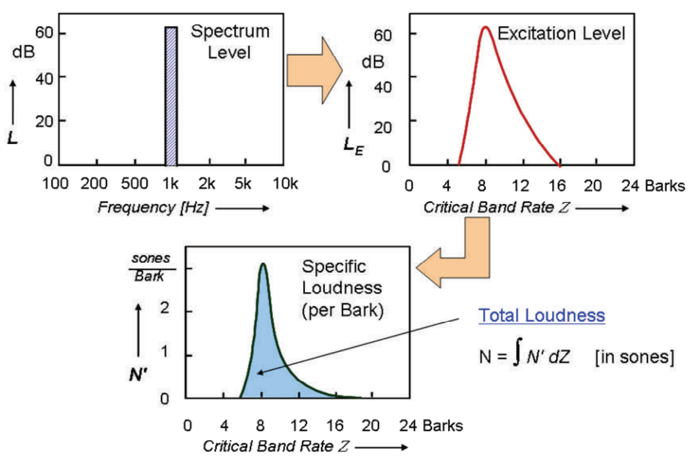

Fig. 1 The Zwicker Loudness Model

In the Zwicker loudness model, a narrow band or bands of noise result in a spectrum level, as shown in Fig. 1. This spectrum level causes the perceived Excitation Level in the ear, depicted as a masking pattern versus Critical Band Rate (in Bark). This, in turn, produces the Specific Loudness or masking pattern, N', in Sones/Bark. The Specific Loudness relates loudness to excitation within each critical band or Bark. The Total Loudness, in Sones, is the integral (area under the curve) of the Specific Loudness in all critical bands and considers masking in adjacent critical bands. Note that at low frequencies (below 400 Hz) the bands are combined differently, as the critical bandwidth is nearly constant. Above 400 Hz, the critical bandwidth is close to 1/3 octave.

A MatLab program has been created to perform this calculation. The m-file is a function that can be called to calculate the loudness from an 1/3 octave input spectrum. A second m-file calls this script, and can also measure the 1/3 octave spectrum from a calibrated *.wav file (see Fig. 2). The level in dBFS for 94 dBSPL can be keyed in or a calibration *.wav file containing a 1 kHz, 94 dB SPL signal can be recalled.

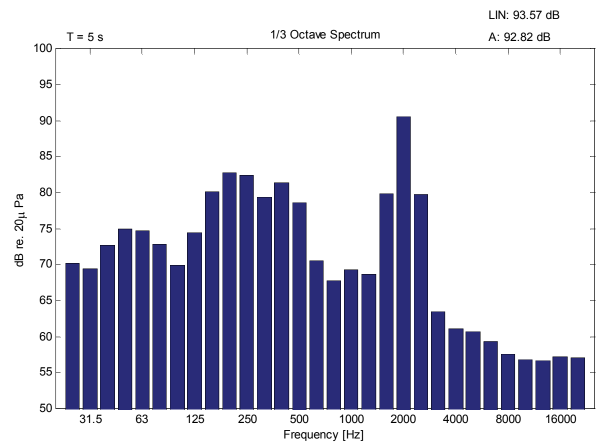

Fig. 2 Measured 1/3 octave input spectrum

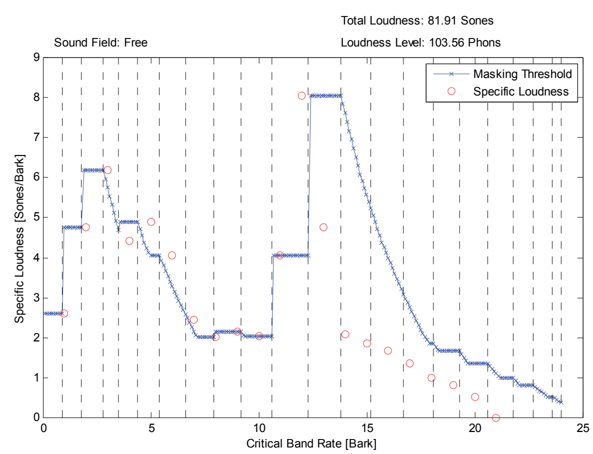

Fig. 3 Loudness, Loudness Level and masking threshold

The type of sound field (Free or Diffuse) must be specified by the user. The final display is shown in Fig. 3.

Contact us for more information.

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NYC Loudspeaker Performance Seminar Goes Deep

Attendees at the recent *Loudspeaker Performance: Measurement, Analysis & Diagnostics"* seminar were treated to in-depth presentations of linear and nonlinear system analysis and numerous practical demonstrations. The 2-day joint seminar in conjunction with Klippel GmbH, was held at the Novotel in New York, 13-14 October 2009. The spectacular view of Times Square from the meeting room and the fabulous catering not withstanding, perhaps the best feature of the event was the discussion among the attendees and instructors about practical transducer design issues, modeling methods, and test techniques.

In addition to Christopher J. Struck and Wolfgang Klippel, this year's seminar featured guest lecturer Don Keele, who spoke about low frequency performance at high levels.

Comments from the attendees were overwhelmingly positive. Due to the popularity of the class over the past 2 years, we are considering offering it again in October 2010, after the AES 129th Convention in San Francisco. Stay tuned for more information in early 2010.

Recent News & Upcoming Events

ANSI S3.25-2009 Released

A revision of the ANSI S3.25 "Occluded Ear Simulator" standard has been released. The revision work was done by the ANSI S3WG37 Working Group, which I chair. The major change is that both the Zwislocki and the IEC 711 Ear Simulators are now compliant with ANSI S3.25. A number of editorial improvements have also been incorporated. The standard is available for purchase through ASA at: http://asastore.aip.org/shop.do?pID=568

Headphone Measurements at AES 127th in NY

My tutorial session on headphone and earphone measurements at the AES 127th Convention in New York in October was a great success. Over 60 persons attended. A PDF of the PPT slides can be found at:

http://www.cjs-labs.com/sitebuildercontent/sitebuilderfiles/HeadphoneMeasurements.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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Loudspeaker Impedance Data Fitting

It has become standard industry practice to fit measured loudspeaker impedance data, usually magnitude and phase, to a model in order to determine the Thiele-Small parameters. The motional impedance is always the standard C_{MS}, M_{MS}, R_{MS} 2nd order single-degree-of freedom system. The differences are typically only in the electrical (blocked) impedance. One of the models in Fig. 1 is typically used for the electrical impedance.

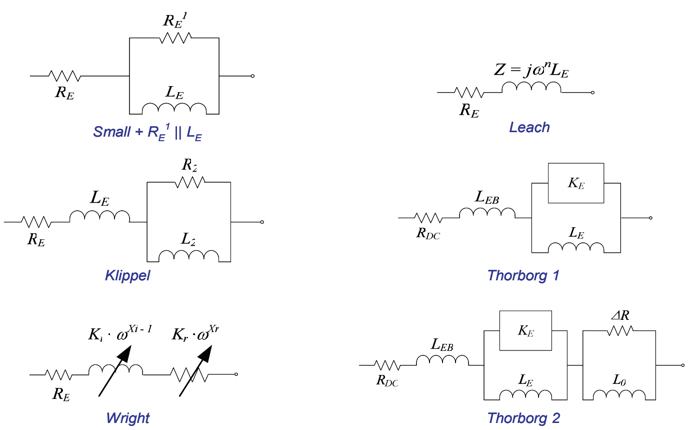

Fig. 1 Loudspeaker Electrical Impedance Models

Although a loudspeaker driver can be quite non-linear, particularly in the large-signal domain, the data fit is a linear Least Mean Squares fit to the complex data for small signals. A MatLab program has been created to perform this data fit. The measured impedance data can be in an Excel or a delimited ASCII file. Added volume, added mass, known SPL sensitivity or known initial parameter methods are all supported. Eight different user selectable electrical impedance models — three incorporating a semi-inductance — are available. An example fit is shown in Fig. 2. The curve fit results (frequency, magnitude, phase, and T-S parameters) are saved in an Excel worksheet with the name of the model used. Therefore, multiple fits of the same data using different models may be appended to the original data file as new worksheets. Afterwards, there is an option to try a new model, load new data, or exit. This m-file requires the Optimization Toolbox V4.2 (R2009a), or later.

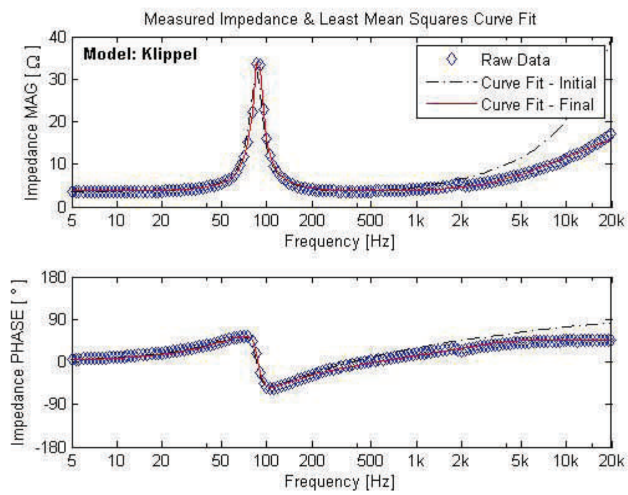

Fig. 2 Measured data and LMS fit to the selected model.

Thiele-Small Parameters

4 inch Polypropelene Driver

Model: Klippel

Re	3.71 Ω	Diameter	10.2998 cm
Zmax	36.34 Ω	Sd	83.3 cm²
fs	87.22 Hz	Vas	2.28 liters
Zmin	3.75 Ω at 550.25 Hz	Qms	7.527
		Qes	0.857
Cms	0.2345 mm/N	Qts	0.769
Mms	14.2 grams	η0	0.17 %
Rms	1.034 N·s/m	2π Sensitivity	87.7 dBSPL at 1m re: 1W into 8Ω
Bl	5.81 T·m		
Le	0.05767 mH		
R2	9.552 Ω		
L2	0.141 mH		

Mean Square Error: 0.0024   Iterations: 37

Fig. 3 Thiele-Small Parameters from data fitting.

The final display of the resulting parameters is shown in Fig. 3.

Contact us for more information.