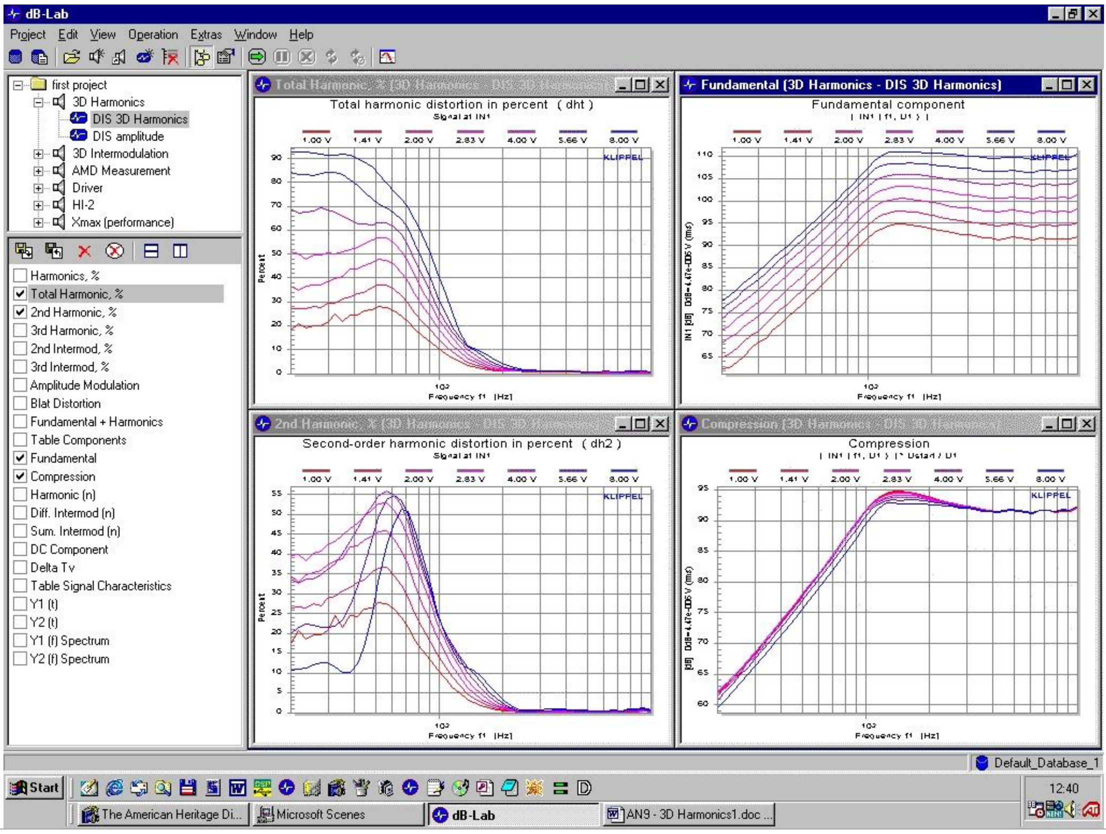
3D Harmonic Distortion Measurement AN9

Application Note to the KLIPPEL R&D (Document Revision 1.0)

FEATURES

The harmonic distortion component of an excitation tone varied in frequency and voltage is measured with the DIS module (3D distortion measurement) of the KLIPPEL R&D SYSTEM. The 3D measurement reveals the complicated relationship between the excitation amplitude (voltage) and the amplitude of the harmonic distortion components which depends on the heating of the voice coil and other nonlinear effects. The connection between common speaker nonlinearities (motor, suspension, etc.) and the harmonic distortion components is discussed.



CONTENTS:

1 Method of Measurement

Excitation signal	A sinusoidal signal with variable frequency and amplitude is applied to the terminals of the loudspeaker. <u>Voltage Sweep:</u> A series of n_U subsequent measurement with different excitation voltages is performed. The n_U voltages are spaced linearly or logarithmically between the starting voltage U_{start} and final voltage U_{end}. <u>Frequency Sweep:</u> A series of n_f subsequent measurement with different excitation frequencies is performed. The n_f frequencies are spaced linearly or logarithmically between the starting frequency f_{start} and final frequency f_{end}. *For example:* $U_{start} = 0.1\ V_{rms}$, $U_{end} = 2\ V_{rms}$ *(8 points linearly spaced)* $f_{start} = 20\ Hz$, $f_{end} = 1\ kHz$ *(50 points linearly spaced)*
Loudspeaker setup	Free-field or half-space free-field conditions are recommended for the measurement. The microphone should be placed in 1 meter distance from the speaker (on axis).
Total harmonic distortion	The IEC standard 60268 defines the total harmonic distortion $$d_{ht} = \frac{\sqrt{P(2f)^2 + P(3f)^2 + ... + P(Nf)^2}}{\sqrt{P(f)^2 + P(2f)^2 + P(3f)^2 + ... + P(Nf)^2}} * 100\%$$ in percent and $$L_{ht} = 20 \lg\left(\frac{d_{ht}}{100}\right) \text{dB}$$ in decibels,
2^{nd} order harmonic distortion	The second-order harmonic distortion is defined as $$d_{h2} = \frac{P(2f)}{\sqrt{P(f)^2 + P(2f)^2 + P(3f)^2 + ... + P(Nf)^2}} * 100\%$$ in percent and $$L_{h2} = 20 \lg\left(\frac{d_{h2}}{100}\right) \text{dB}$$ in decibels.
3^{rd} order harmonic distortion	The third-order harmonic distortion is defined as $$d_{h3} = \frac{P(3f)}{\sqrt{P(f)^2 + P(2f)^2 + P(3f)^2 + ... + P(Nf)^2}} * 100\%$$ in percent and $$L_{h3} = 20 \lg\left(\frac{d_{h3}}{100}\right) \text{dB}$$ in decibels.

2 Using the DIS Module

Requirements	The following hardware and software is required • Distortion Analyzer + PC • DIS software module + dB-Lab • Microphone
Setup  	**Connect the microphone to the input** IN1 **at the rear side of the Distortion Analyzer. Set the speaker in the approved environment and connect the terminals with output** Speaker 1**. Switch the power amplifier between the connectors** OUT1 **and** Amplifier**.**
Preparation	Create a new object. Add a new DIS operation based on the template **DIS 3D Harmonics AN 9**.
Measurement	1. Start the measurement *DIS 3D Harmonics AN 9* 2. Open the windows *2nd Harmonics, % and 3rd Harmonics, %* 3. Open the window *Harmonic (n)* and select order n on property page *Display* 4. Print the results or create a report

3 Relationship between speaker nonlinearities and harmonic distortion

Nonlinearity	Distortion Measure	Critical Frequency Range	Relatinship Between Input voltage and amplitude of Distortion		
			$X << X_{max}$	$x < X_{max}$	$x \approx X_{max}$
Offset of coil in equal-length configuration	$d_{h2}(f)$	$f < f_s$	quadratic	less than quadratic	less than quadratic
		$f \approx 2f_s$	quadratic	more than quadratic	more than quadratic
Symmetric Bl(x) in equal-length configuration	$d_{h3}(f)$	$f < f_s$	cubic	cubic	less than cubic
Symmetric Bl(x) due long coil overhang	$d_{h3}(f)$	$f < f_s$	negligible distortion	more than cubic	less than cubic
Asymmetric pot spider	$d_{h2}(f)$	$f \approx f_s$	quadratic	less than quadratic	less than quadratic
Symmetric spider	$d_{h3}(f)$	$f \approx f_s$	cubic	less than cubic	less than cubic
Asymmetric surround limiting	$d_{h2}(f)$	$f \approx f_s$	negligible distortion	more than quadratic	less than quadratic
Symmetric surround limiting	$d_{h3}(f)$	$f \approx f_s$	negligible distortion	more than cubic	less than cubic
Inductance asymmetry	$d_{h2}(f)$	$f \approx 2f_s$	quadratic	quadratic	quadratic

4 Setup parameters for the DIS module

<table>
<tr><td>Template</td><td>Create a new Object, using the operation template DIS 3D Harmonics AN 9 in dB-Lab. If this database is not available you may adjust the default DIS setup as described below. You may also modify the setup parameters according to your needs.</td></tr>
<tr><td>Default setting for harmonic measurement</td><td>

Open the property page Stimulus.
Select Harmonics in the drop down box Mode.
Select Sweep in group Voltage U_1.
Set U_{start} to 1 V_{rms}, U_{end} to 8 V_{rms}, Points to 4 and Spaced to lin. Make sure the signal level is appropriate for loudspeaker.
Select Sweep in group Frequency f1 and specify a sweep with 50 points spaced logarithmically between 20 Hz and 1000 kHz.
Select Additional excitation before measurement and set it to 0.01 s.
Set maximal order of distortion analysis to N = 16.
Open property page Protection.
Select Monitoring: Voice coil temperature and amplifier gain.
Select Abort measurement if: increase of voice coil temperature (Speaker 1) exceeds and set the temperature to 100 K.
Open property page Input. Select IN 1 (Mic). Select Off in group Y2 (Channel 2).
Open property page Display. Select Signal at IN1 in drop down box State signal.

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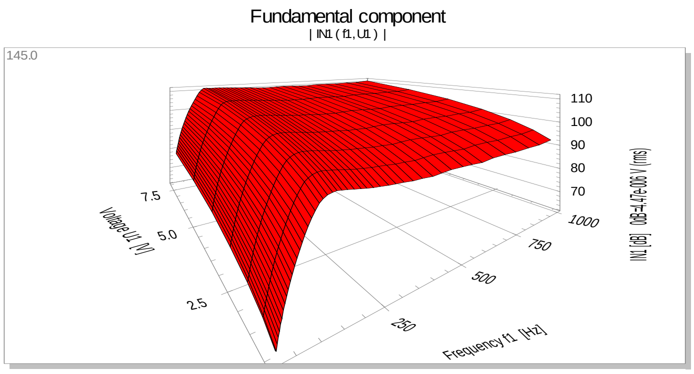
5 Example

<table>
<tr><td>Fundamental</td><td>The result window Fundamental shows the fundamental of the sound pressure versus frequency f_1 and voltage U_1 if 3D plot is selected in property page Display.



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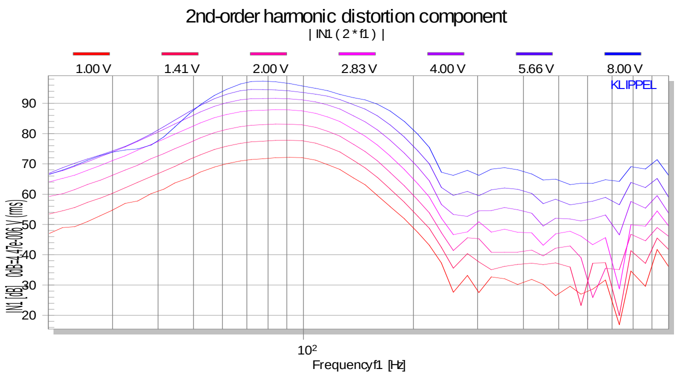
<tr><td>2nd order harmonic component</td><td>The result window Harmonic (n) shows the 2nd order harmonic component of the sound pressure in decibels versus frequency f_1 for voltages U_1 increased between U_{start} and U_{end} if 2D plot versus f1 is selected in property page Display. Change order n in property page Display.



At low and medium voltages the 2nd order distortion component raises by 6 dB revealing a quadratic relationship. The increase stagnates at the last voltage step.</td></tr>
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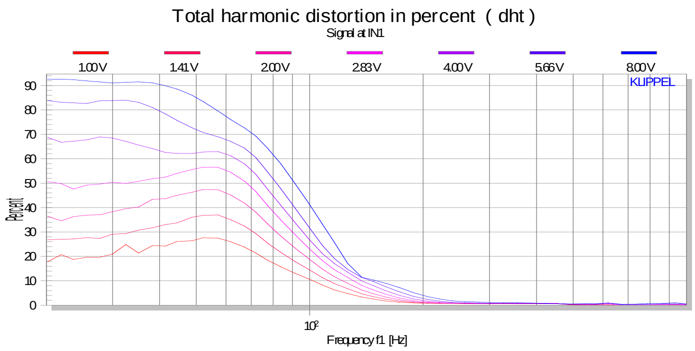
<td>Total harmonic distortion</td>
<td>The result window Total Harmonic, % shows the total harmonic distortion d_{ht} in percent according to IEC 60268 versus frequency f_1 for voltages U_1 increased between U_{start} and U_{end} if 2D plot versus f1 is selected in property page Display.



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6 More Information

Related application notes	*3D Intermodulation Distortion Measurement*, Application Note 8 *Multi-tone Distortion Measurement*, Application Note 16
Related Specification	“DIS”, S4
Papers	W. Klippel, “Loudspeaker Nonlinearities – Causes, Parameters, Symptoms” preprint #6584 presented at the 119th Convention of the Audio Engineering Society, 2006 October 6-8, San Francisco, USA Updated version on http://www.klippel.de/know-how/literature/papers.html
Software	User Manual of the *Klippel R&D System*.

Find explanations for symbols at:

http://www.klippel.de/know-how/literature.html

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