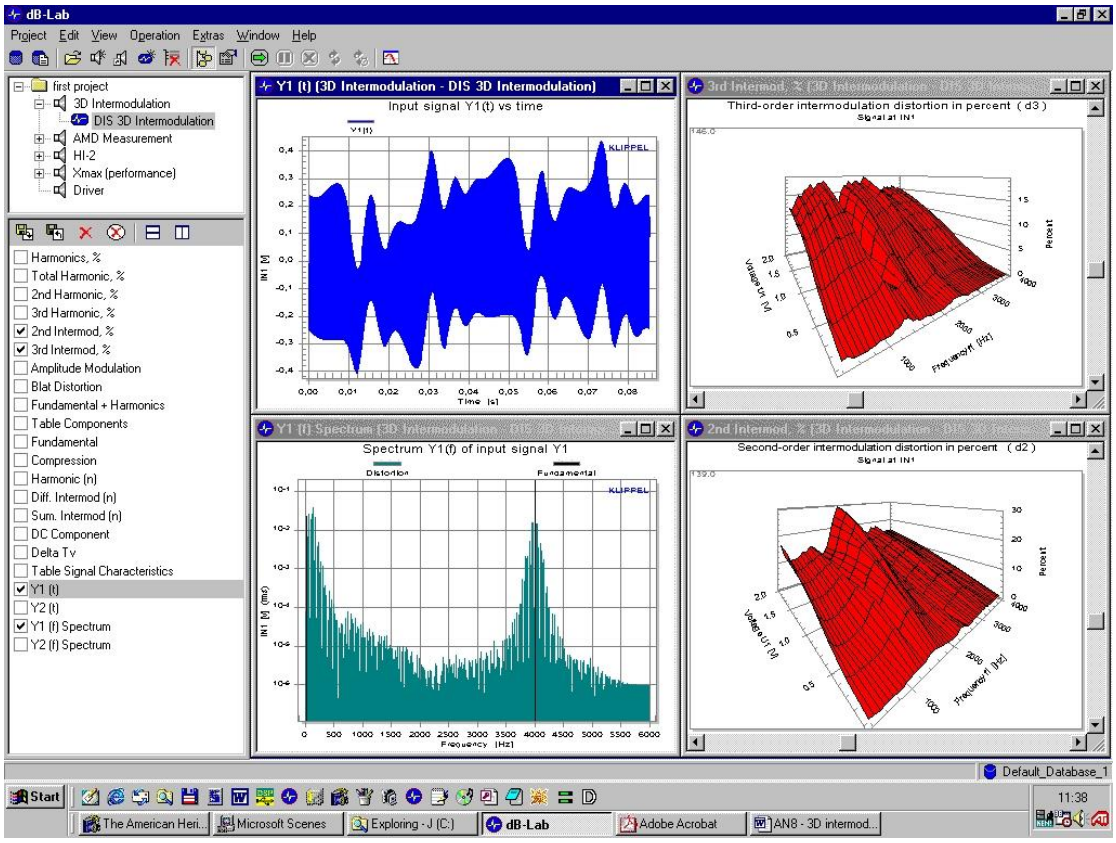
3D Intermodulation Distortion Measurement AN8

Application Note of the KLIPPEL R&D (Document Revision 1.1)

FEATURES

The modulation of a high frequency tone f_1 (voice tone) and a low frequency tone f_2 (bass tone) is measured by using the 3D Distortion Measurement module (DIS) of the KLIPPEL R&D SYSTEM. The amplitude of the summed and difference-tone components centered around the voice tone f_1 shows the effect of all types of modulation (amplitude, phase and frequency modulation) and are expressed as 2^{nd} and 3^{rd} order modulation distortion according to IEC 60268. A series of measurements is performed to reveal the dependency of the distortion on frequency and the amplitude of the excitation stimulus. Intermodulation distortion is a critical symptom of motor nonlinearities represented by a nonlinear Bl(x), L_e(x) and nonlinearities in the acoustical radiation (Doppler effect).



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1 Method of Measurement

Excitation Signal	Two sources of sinusoidal signals (voice tone + bass tone) with an amplitude ratio U_1:U_2=1:4 and with a frequency range of f_1: f_2 > 8 : 1 shall be connected to the terminals of the loudspeaker and varied versus frequency and amplitude. Amplitude Sweep: A series of measurements is performed while varying the amplitude in n_U points spaced linearly or logarithmically between starting amplitude U_{start} and end amplitude U_{end}. Frequency Sweep: A series of measurements is performed while varying the frequency in n_f points spaced linearly or logarithmically between starting frequency f_{start} and end frequency f_{end}. *For example:* voice tone f_1: *U_{start} = 0.1 V rms , U_{end}= 2 V rms (8 points linear spaced)* *f_{start}= 300 Hz (> 8*f_s), f_{end}= 4 kHz (50 points linearly spaced)* bass tone: *$U_2 = 4*U_1$, f_2 = 20 Hz*
Loudspeaker Setup	The loudspeaker shall be brought under free-field or half-space free-field condition. The measurement is taken 1 meter from the speaker (on axis).
Modulation Distortion	Exciting with a two-tone signal the loudspeaker produces modulation distortion caused by amplitude and phase (frequency) modulation. Both modulations will produce difference intermodulation components at frequencies $f_1 - (n-1)f_2$ and summed-tone intermodulation distortion $f_1+(n-1)f_2$ of n^{th}-order centered around the voice tone f_1. The IEC standard 60268 defines the second-order modulation distortion $d_2 = \frac{P(f_1 - f_2) + P(f_1 + f_2)}{P(f_1)} * 100\%$ and the third-order modulation distortion $d_3 = \frac{P(f_1 - 2f_2) + P(f_1 + 2f_2)}{P(f_1)} * 100\%$ in percent. (Note: These formulas state f_2 as base tone, in contrast to IEC 60268, where f_1 is used as base tone.)

2 Using 3D Distortion Measurement (DIS)

Requirements	The following hardware and software is required: • Distortion Analyzer + PC • Software module 3D Distortion Measurement (DIS) + 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 SPEAKER 1. Connect the power amplifier between OUT1 and connector AMPLIFIER.
Preparation	1) Create a new object 2) Add a new DIS operation, based on the "DIS 3D Intermodulation AN8" template.
Measurement	1) Start the measurement "DIS 3D Intermodulation AN8" 2) Open the windows 2nd Intermod, % and 3rd Intermod, % 3) Open property page DISPLAY and select 2D or 3D as graph plot style 4) Print the results or create a report

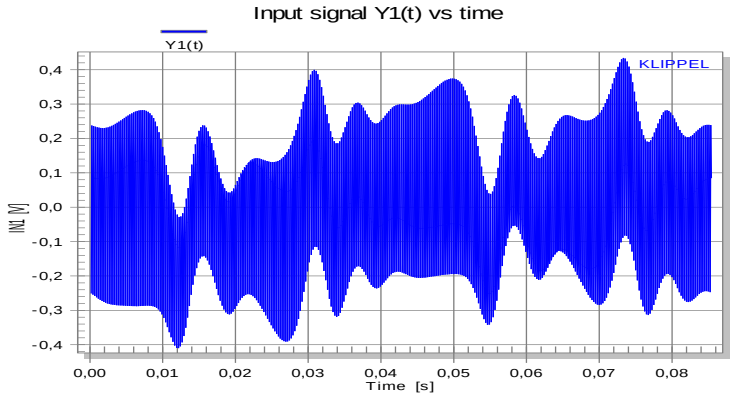
3 Relationship between speaker nonlinearity and intermodulation distortion

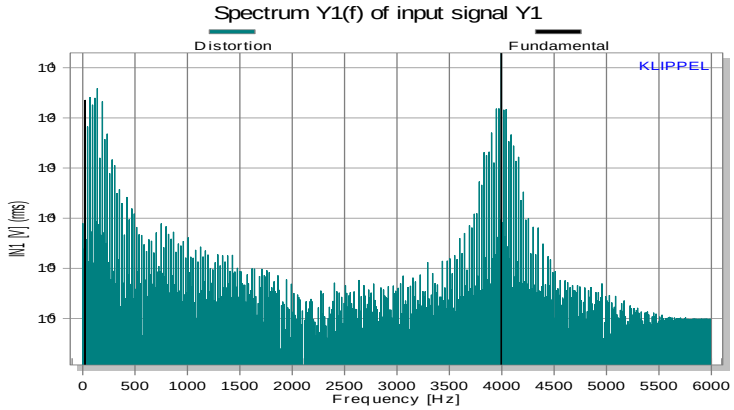
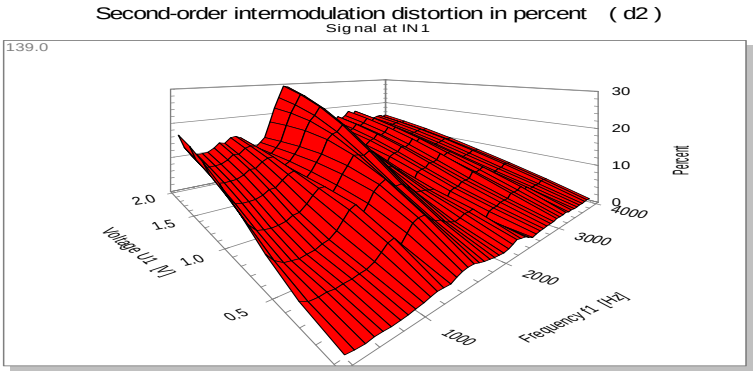
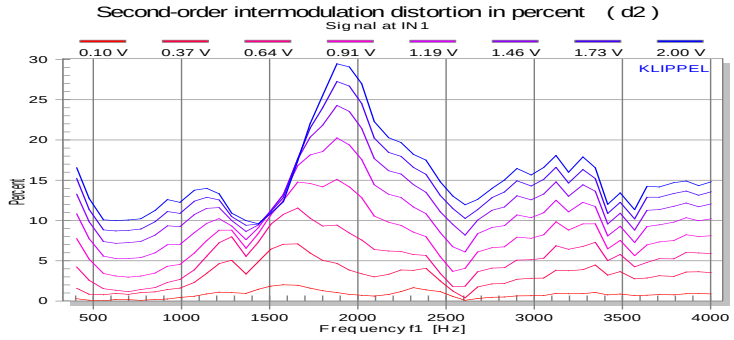
Nonlinearity	Distortion Measure	Critical Frequency Range	Input/ Output Amplitude RATIO		
			$X << X_{max}$	$x < X_{max}$	$x \approx X_{max}$
offset of coil in equal-length configuration	$d_2(f_1)$	$f_2<f_s$	regular	compression	compression
		$f_2 \approx f_s$	regular	regular	regular
		$f_2>f_s$	regular	expansion	expansion
symmetrical Bl(x) in equal-length configuration	$d_3(f_1)$		regular	regular	compression
symmetrical Bl(x) due long coil overhang	$d_3(f_1)$		negligible distortion	expansion	compression
inductance asymmetry	$d_2(f_1)$		regular	regular	regular

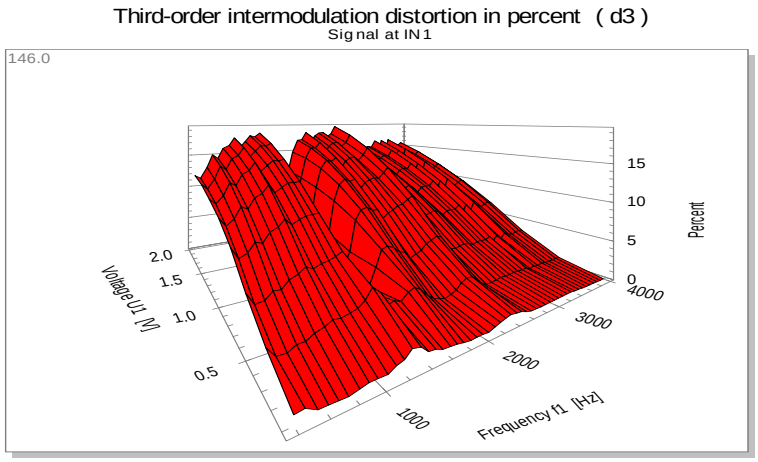
4 Setup Parameters for the DIS Module

Template	Create a new Object, using the operation template **DIS 3D Intermodulation AN8** in dB-Lab. If this database is not available, you may generate measurements based on the general DIS module. You may also modify the setup parameters according to your needs.
Default Setting	1. Open the property page **Stimulus**. Select mode **Intermodulations (f1)**. Switch on **Voltage Sweep**. Set **U_{start}** to 0.1 V rms and **U_{end}** to 2 V rms. Set **U_2/U_1** to 12 dB. Switch on the **Frequency Sweep** with 50 points spaced logarithmically between 400 Hz and 4 kHz. Set frequency of the bass tone to f_2 = 20 Hz. Set additional excitation time to 0.01 s. 2. Open property page ***Protection.*** Disable **Monitoring** and any protection. 3. Open property page **Input**. Select **IN 1 (Mic)** in group **Y1**. Switch off the second channel (group **Y2**). 4. Open property page **Display.** Select **Signal at IN1** as **State signal**.

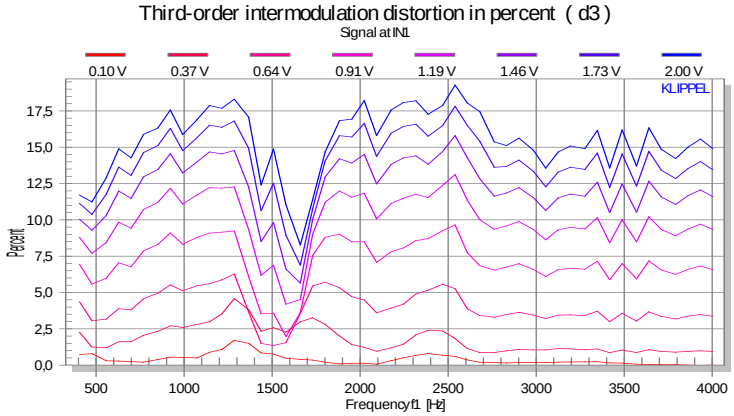
5 Example

Two-tone Signal	Open the window **Waveform *Y1*** to see the sound pressure versus measurement time.  The variation of the envelope shows effects of amplitude modulation of the voice tone f_1 according to frequency f_2 = 20 Hz.

Spectrum	Open the window **Spectrum *Y1*** to see the spectrum of the reproduced two ton-tone signal:  The bass tone at f_2=20 Hz causes harmonic distortion at lower frequencies and intermodulation centered around the voice tone at f_1 = 4000 Hz.
2nd order intermodulation distortion	The figure below shows the result window *2nd Intermod, %* in the 3D graphic mode measurement.  In the property page *Display*, select the *2D plot versus f_1* as *Plot Style* to represent the 2nd order intermodulation versus frequency for each amplitude U_1. 
3rd order intermodulation distortion	The figure below shows the result window *3rd Intermod, %* in the 3D Graph Plot Style.



In the property page *Display*, select the *2D plot versus f_1* as *Plot Style* to represent the 3rd order intermodulation versus frequency for each amplitude U_1.



6 More Information

Related Application Notes	"Multi-tone Distortion Measurement", Application Note AN 16 "3D Harmonic Distortion Measurement", Application Note AN 9 "Measurement of Amplitude Modulation Distortion", Application Note AN 10
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 KLIPPEL R&D SYSTEM.

Find explanations for symbols at:

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

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