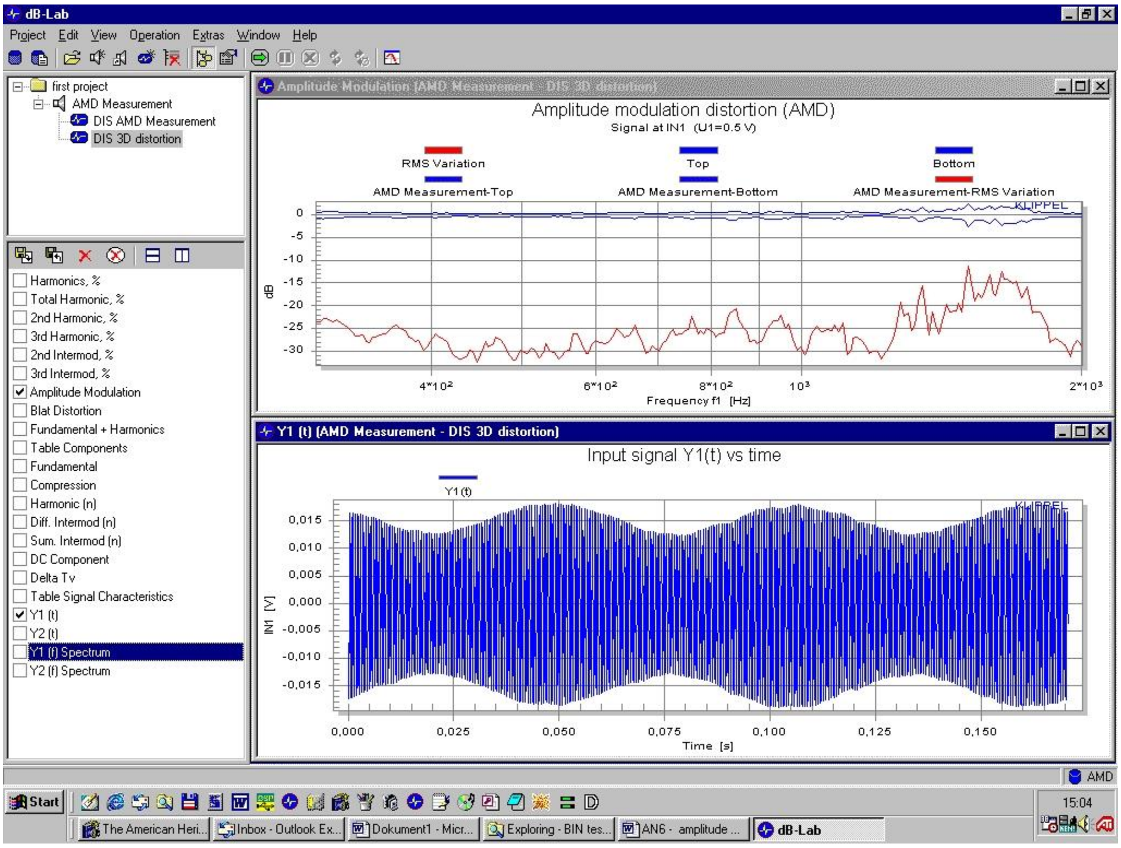
Loudspeaker FM and AM Distortion AN 10

Application Note to the KLIPPEL R&D SYSTEM

The amplitude 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 maximal variation of the envelope of the voice tone f_1 is represented by the top and bottom value referred to the averaged envelope. The amplitude modulation distortion (AMD) is the ratio between the rms value of the variation referred to the averaged value and is comparable to the modulation distortion L_{d2} and L_{d3} of the IEC standard 60268 provided that the loudspeaker generates pure amplitude modulation of second- or third-order. The measurement of amplitude modulation distortion (AMD) allows assessment of the effects of Bl(x) and Le(x) nonlinearity and radiation distortion due to pure amplitude modulation without 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. *Example:* ***voice tone**: U_1 = 0.5 V rms, f_1 swept from 4 times resonance frequency (4*f_s) to 10 kHz (minimal resolution 40 points per decade)* ***bass tone**: U_2 = 2 V rms, f_2 = 1/4th of the resonance frequency f_s*
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). If no anechoic chamber is available, the measurement should be done in the near field.
Modulation Distortion	Excited with a two-tone signal the loudspeaker produces modulation distortion caused by amplitude and phase (frequency) modulation. Both types of modulation 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 nth-order centered around the voice tone f_1. The phase of the intermodulation component depends on the type of modulation. To separate the effect of amplitude modulation from phase modulation the envelope of the high-frequency tone f_1 (voice tone) may be investigated. Amplitude modulation only varies the instantaneous amplitude (envelope) of voice tone while not distorting the phase of the voice tone. Contrary, the phase modulation does not change the envelope of the voice tone but varies only the instantaneous phase or frequency.
Second-order Modulation (FM + AM)	The IEC standard 60268 defines the second-order modulation distortion $$L_{d2} = 20\lg\left(\frac{P(f_2 - f_1) + P(f_2 + f_1)}{P(f_1)}\right)$$ in decibels. (Note: This formula states f_2 as base ton, in contrast to IEC 60268, where f_1 is used as base tone.)
Third-order Modulation (FM + AM)	The IEC standard 60268 defines the third-order modulation distortion $$L_{d3} = 20\lg\left(\frac{P(f_2 - 2f_1) + P(f_2 + 2f_1)}{P(f_1)}\right)$$ in decibels. (Note: This formula states f_2 as base ton, in contrast to IEC 60268, where f_1 is used as base tone.)
Total Modulation Distortion (FM+ AM)	Summarizing the 2nd and 3rd-order modulation distortion we get the modulation distortion $$L_{dm} = 10\lg\left(\exp_{10}(L_{d2}/10) + \exp_{10}(L_{3d}/10)\right).$$
Amplitude Modulation (AM only)	The distortion of the pure amplitude modulation can be assessed separately by measuring the variation of the envelope of the high-frequency tone f_1 (voice tone). The envelope E[k] of the voice tone f_1 is derived from the time discrete sound pressure signal p[k] by considering the fundamental of f_1 and the summed-tone and difference-tone intermodulation f_1+(n-1)f_2 and f_1-(n-1)f_2, respectively, with 1< n < N. Calculating the averaged envelope

	$$\overline{E} = \frac{1}{K}\sum_{k=1}^{K} E[k]$$ versus the periodic time signal p[k] we define the rms amplitude modulation distortion $$d_{AMD} = \frac{\sqrt{\frac{2}{K}\sum_{k=1}^{K}\left(E[k]-\overline{E}\right)^2}}{\overline{E}} *100\%$$ expressed in percent or in decibels $$L_{AMD} = 20\lg\left(\frac{d_{AMD}}{100}\right).$$
Modulation distortion in speakers	The variation of force factor Bl(x) versus displacement x causes significant amplitude modulation. The variation of the radiation conditions cause both amplitude and frequency modulation distortion. The Doppler effect causes mainly phase modulation because the time delay varies with the changed distance between moving diaphragm and the fixed listening point. The AMD distortion d_{AMD} and L_{AMD} are closely related to the modulation distortion defined in the IEC standard 60268 paragraph 24.4. The second order modulation distortion d_2 in percent and L_{d2} in decibel correspond to the AMD distortion d_{AMD} and L_{AMD}, respectively, if the loudspeaker has a second-order homogenous nonlinearity causing pure amplitude modulation. The third order modulation distortion d_3 in percent and L_{d3} in decibel are equal to the AMD distortion d_{AMD} and L_{AMD}, respectively, if the loudspeaker has a third-order homogenous nonlinearity causing pure amplitude modulation. The Doppler effect as a dominant source of phase modulation, which contributes to the second-order modulation d_2 measured by IEC 60268 but produces no d_{AMD}.

2 Checklist for dominant modulation distortion

NONLINEARITY	L_{dm} 2nd+3rd order (AM + FM)	L_{d2} 2nd order (AM + FM)	L_{d3} 3rd order (AM + FM)	L_{AMD} total (AM only)
asymmetry in Bl(x) (coil offset)	X	X		X
symmetrical decay of Bl(x)	X		X	X
asymmetry in Le(x)	X	X		X
symmetry in Le(x)	O		O	O
radiation distortion	X	X		X
Doppler Distortion	X	X		
X dominant source	O negligible source			

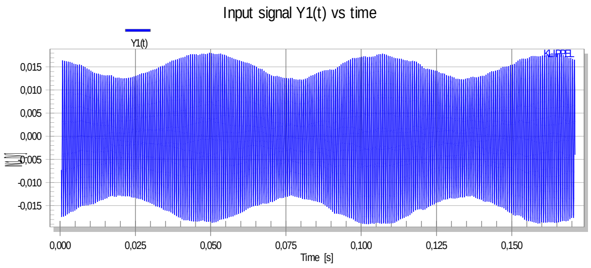
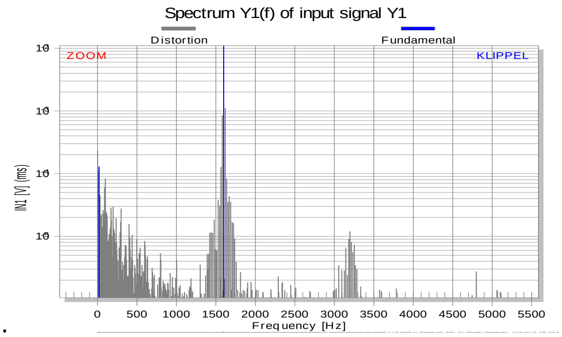
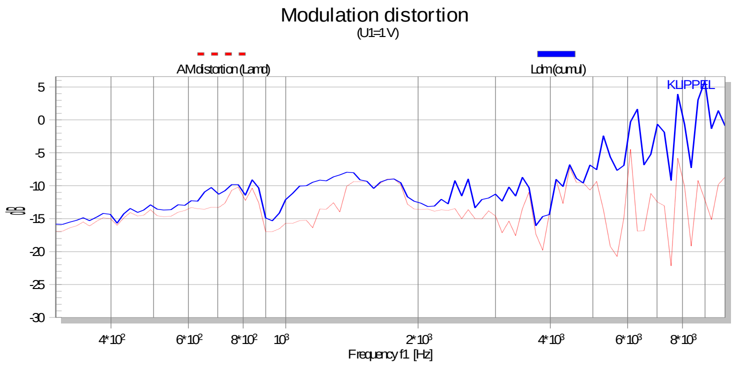
3 Using the 3D distortion measurement (DIS)

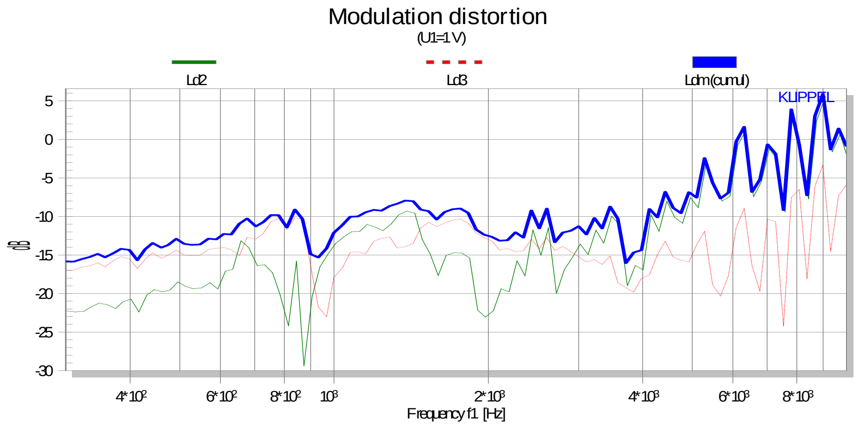
Requirements	The following hardware and software is required for assessing X_{max} • Distortion Analyzer + PC • Software module 3D Distortion Measurement (DIS) + dB-Lab • Microphone
Setup 	**Connect the microphone to the input IN1 at the rear side of the Distortion Analyzer. Set the speaker in the approved environment and connect the terminals with SPEAKER 1. Switch the power amplifier between OUT1 and connector AMPLIFIER.**
Preparation	• Create a new object DRIVER • Assign a new DIS operation, based on the **DIS FM + AM Distortion AN10** template.
Measurement	• Start the measurement DIS FM + AM Distortion template. • Open the window **Modulation** • Print the results or create a report

4 Setup parameters for DIS Module

Template	Create a new Object, using the operation template **DIS FM + AM Distortion AN10** 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 for AMD Measurement	1. Open the property page *Stimulus:* Select mode *Intermodulations (f1)*. Switch off Voltage Sweep. Set U_{end} to 1 V rms. Set U_2/U_1 to 12 dB. Switch on the Frequency Sweep with 100 points spaced logarithmically between 300 Hz and 10 kHz. Set frequency of the bass tone to f_2 = 12 Hz. Disable additional excitation time. 2. On property page *Protection,* disable temperature measurement and any protection. 3. Open property page *Input*. For *Channel 1*, select (*Mic) IN1.* Switch off the second channel (Y2). 4. Open property page *Display*. Select *Signal at IN1* as State signal.

5 Example

Two-tone Signal	After running the measurement, open the window *Waveform Y1* to see the sound pressure versus measurement time.  This variation of the envelope shows a pure amplitude modulation of the voice tone f_1 according to frequency f_2 = 6 Hz.
Spectrum	Open the window Spectrum *Y1* to see the spectrum of the reproduced two-tone signal:  . The bass tone at f_2=6 Hz causes harmonic distortion at lower frequencies and intermodulation centered around the voice tone at f_1 = 1600 Hz. The distortion above 3 kHz are harmonics of the voice tone f_1,
Contribution from Amplitude Modulation	The figure below shows the result window *Modulation* after performing and selecting the L_{AMD} and L_{dm} distortion subsets.  The solid curve shows the distortion L_{dm} caused by amplitude and frequency modulation. The dashed curve shows the distortion L_{AMD} caused by amplitude modulation only. Clearly, the AM modulation is dominant at low frequencies while the frequency modulation mainly caused by the Doppler effect is about 15 dB higher at high frequencies.
Contribution from 2nd and 3rd order	The figure below shows the result window *Modulation* after performing and selecting the L_{dm}, L_{d2} and L_{d3} distortion subsets.



Again, the solid curve shows the distortion L_{dm} caused by amplitude and frequency modulation. The green thin line shows the 2nd order modulation distortion L_{d2} according to IEC 60268, which becomes dominant at higher frequencies due to the Doppler effect. The red dashed line shows the 3rd order modulation distortion L_{d3} according IEC 60268, which is dominant at low frequencies which is typical for Bl(x) distortion due to limited voice coil height.

6 More Information

Related Application Notes	AN 8_3D Intermodulation Distortion Measurement, KLIPPEL R&D System
Related Specification	S4_DIS
Software	User Manual for KLIPPEL R&D SYSTEM.

Find explanations for symbols at:

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

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