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 $B(x)$ and $L(x)$ nonlinearity and radiation distortion due to pure amplitude modulation without Doppler effect.

CONTENTS:

1. Method of Measurement
2. Checklist for dominant modulation distortion
3. Using the 3D distortion measurement (DIS)
4. Setup parameters for DIS Module
5. Example
6. More Information
# 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 \((4f_s)\) to 10 kHz (minimal resolution 40 points per decade)
- **Bass tone:** \(U_2 = 2\) V rms, \(f_2 = 1/4\) 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 \(f_2 + (n-1)f_1\) of \(n\)-th 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 \(f_2\) (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

\[
L_{sd2} = 20 \log \left( \frac{P(f_2 - f_1) + P(f_2 + f_1)}{P(f_1)} \right)
\]

in decibels. (Note: This formula states \(f_2\) as base tone, 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

\[
L_{sd3} = 20 \log \left( \frac{P(f_2 - 2f_1) + P(f_2 + 2f_1)}{P(f_1)} \right)
\]

in decibels. (Note: This formula states \(f_2\) as base tone, in contrast to IEC 60268, where \(f_1\) is used as base tone.)

### Total Modulation Distortion (FM+ AM)

Summarizing the 2\textsuperscript{nd} and 3\textsuperscript{rd}-order modulation distortion we get the modulation distortion

\[
L_{sd} = 10 \log (\exp_{10}(L_{sd2} / 10) + \exp_{10}(L_{sd3} / 10))
\]

### 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 \(f_2\) (voice tone).

The envelope \(E[k]\) of the voice tone \(f_2\) is derived from the time discrete sound pressure signal \(p[k]\) by considering the fundamental of \(f_2\) and the summed-tone and difference-tone intermodulation \(f_1 + (n-1)f_2\) and \(f_2 - (n-1)f_1\), respectively, with \(1 < n < N\).

Calculating the averaged envelope
Loudspeaker FM and AM Distortion

Checklist for dominant modulation distortion

\[ E = \frac{1}{K} \sum_{k=1}^{K} E[k] \]

versus the periodic time signal \( p[k] \) we define the rms amplitude modulation distortion

\[ d_{AMD}^2 = \frac{2}{K} \sum_{k=1}^{K} (E[k] - E)^2 \]

expressed in percent or in decibels

\[ L_{AMD} = 20 \log \left( \frac{d_{AMD}}{100} \right) \]

### Modulation distortion in speakers

The variation of force factor \( B_l(x) \) 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

<table>
<thead>
<tr>
<th>NONLINEARITY</th>
<th>( L_{2m} ) 2nd+3rd order (AM + FM)</th>
<th>( L_{d2} ) 2nd order (AM + FM)</th>
<th>( L_{d3} ) 3rd order (AM + FM)</th>
<th>( L_{AMD} ) total (AM only)</th>
</tr>
</thead>
<tbody>
<tr>
<td>asymmetry in ( B_l(x) ) (coil offset)</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>symmetrical decay of ( B_l(x) )</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>asymmetry in ( L_e(x) )</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>symmetry in ( L_e(x) )</td>
<td>O</td>
<td></td>
<td>O</td>
<td></td>
</tr>
<tr>
<td>radiation distortion</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Doppler Distortion</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

X dominant source O negligible source
3 Using the 3D distortion measurement (DIS)

Requirements

- The following hardware and software is required for assessing $X_{\text{max}}$
  - 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 ($f_1$).
   - Switch off Voltage Sweep.
   - Set $U_{\text{end}}$ 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 $L_{AM}$ 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 $L_{AM}$ 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

<table>
<thead>
<tr>
<th>Related Application Notes</th>
<th>AN 8_3D Intermodulation Distortion Measurement, KLIPPEL R&amp;D System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Related Specification</td>
<td>S4_DIS</td>
</tr>
<tr>
<td>Software</td>
<td>User Manual for KLIPPEL R&amp;D SYSTEM.</td>
</tr>
</tbody>
</table>

Find explanations for symbols at:

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

Last updated: 08.01.16