Fast Measurement of Harmonic Distortion

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Introduction

Loudspeakers driven at high levels generate non-linear signal components in the output signal. These artefacts are (in most cases) unwanted but inherent in the non-linear nature of electro-dynamic loudspeakers. Dominant causes are the motor and suspension nonlinearities [1].

Assessing the quality of loudspeakers regarding distortion requires a variety of measurements such as harmonic, intermodulation or multi-tone distortion tests. While these tests shall be done completely in the design phase, they are not applicable during the production process mainly due to time constraints. It has been proven that most defects can be detected using harmonic distortion tests.

For the standard compliant specification of the product a steady state measurement under well defined conditions (driver in a baffle, anechoic measurement) is required to ensure comparability. Contrary during the production process absolute results are not required, the most important aspect is the reproducibility of tests against a “golden unit”, which is defined to have characteristic properties of the production batch [2].

Harmonic Distortion Measurement

Appling a harmonic distortion test two basic quality aspects of loudspeakers can be assessed:

- Regular distortion are caused by the nonlinear properties of the speaker design. They are usually dominating the 2nd to 5th harmonics as well as the Total Harmonic Distortion (THD).
- Irregular distortion such as rub and buzz, wire beats, glue problems are usually broadband effects with much smaller amplitude than regular distortion. Therefore the lower order regular distortion masking these effects. (See Fig. 1).

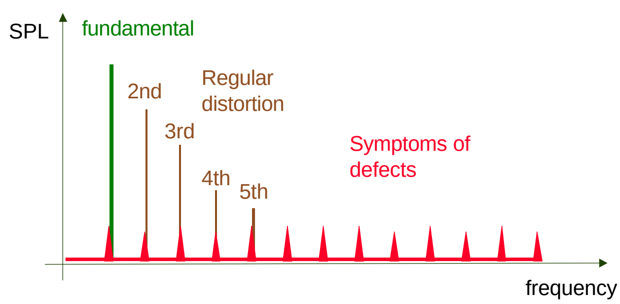

Figure 1: Response spectrum of harmonic measurement

The stimulus for harmonics tests is a sinusoidal tone exciting only one frequency. As excitation signals stepped sine signals or continuous sine sweeps may be used.

	Step Sine	Sine Sweep
Isolation from Fundamental	FFT or Fixed Filter	Tracking Filter or Impulse Response Technique [3]
Continuous Excitation	No	Yes
Steady State	Yes	No
Duration	Long	Short

Table 1: Properties of excitation signals

A stepped sine signal has an optimal energy distribution since at each step the same number of periods will be used. Therefore at low frequencies, where the displacement and the probability of rub and buzz defects is high, most of the test time is used. However, the main draw back is the non-continuous excitation which may result in a missed defect. While regular distortion do not show very small band effects, the nature of irregular distortion can be extremely small in bandwidth and energy (Table 1).

Most testing equipments are using sine sweeps. A linear sweep distributes most of its energy (which is equal with the “Aufenthaltsdauer” per octave) at high frequencies (spends constant time per absolute bandwidth) and is not useful for distortion testing (Fig. 2). State of the art is a logarithmic sweep (spends constant time per relative bandwidth). The log sweep also travels much faster through the low frequency range then the stepped sine signal. To combine the positive properties of the step sine and the continuous sweep a log sweep with variable speed profile was developed. This provides a piece wise approximation of the stepped sine signal mapping (Fig. 2).

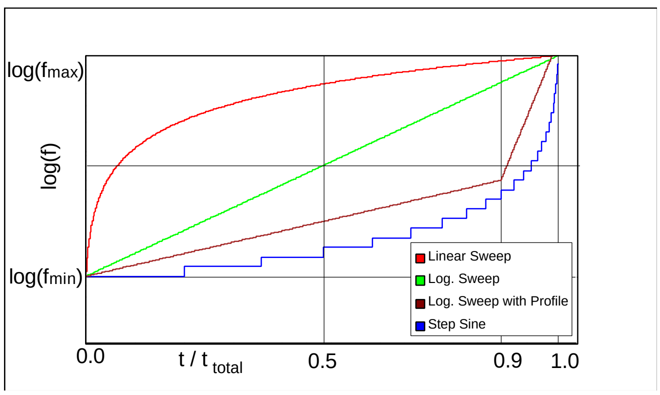

Figure 2: Frequency Time mapping of excitation signals

Duration of Testing

For the calculation of the stepped sine test duration it was assumed to use 5 periods at each step with a resolution of 1/10 octave. This provides nearly steady state and a minimum of resolution to avoid the missing of defects.

In Fig. 2 the duration of the presented excitation modes are listed. The sweep durations are calculated under the condition that the first period was completed at the specified starting frequency (20 or 50Hz). The actual frequency of the sweep start may be therefore considerably lower.

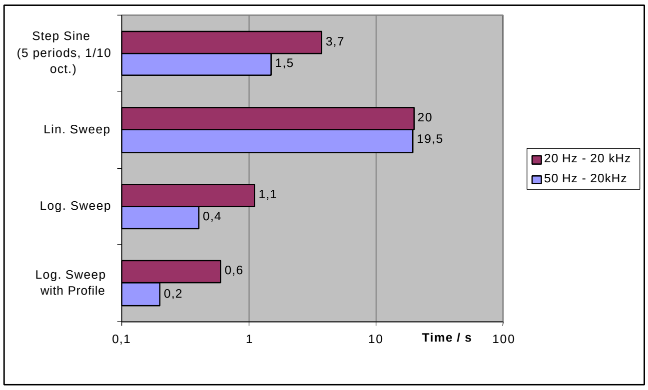

Figure 2: Duration of harmonic tests for two bandwidths

While the linear sweep is not useful, a simple log sweep is already three times faster than the step sine. Using the new sweep with speed profile, the testing time for regular harmonics can be reduced to a fraction of a second (0.2s / 0.6s).

Measurement Results

In Fig. 3 the summed harmonics (THD) are plotted for various test durations. It can be shown that the higher frequency behaviour (f>100Hz) is almost constant. At 0.2s duration the range below 100Hz deviates from the other tests by about 2dB. The cause for that drop has not been fully investigated yet. However, as mentioned before for QC testing at the production line the absolute value of distortion is not important. Tests have shown that the results are highly reproducible, even for the 0.2s sweep.

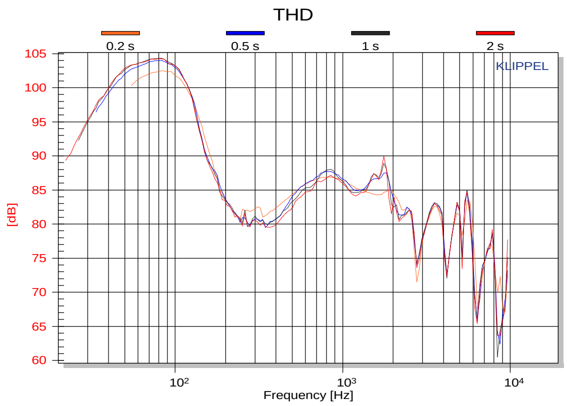

Figure 3: Harmonics vs. Duration

For irregular distortion the testing time first of all depends on the ability to excite very narrow band oscillation with a high Q-factor. No common rule can be derived for a minimum test duration but from especially critical cases it is known, that considerable higher times may be required.

In Fig. 4 a comparison of the detection of a parasitic resonance of 1/10 octave in a headphone driver is shown. When testing with a log sweep with speed profile at least 1s duration is required to excite the defect. The resonance is fully established using a 2s sweep time and additional measurement time will not improve the peak. For detecting these disturbances as a defect limits are applied that are about 6 dB above the noise floor (shown in right graph). Step sine signal can easily miss this small defect and shouldn't be used for irregular distortion testing..

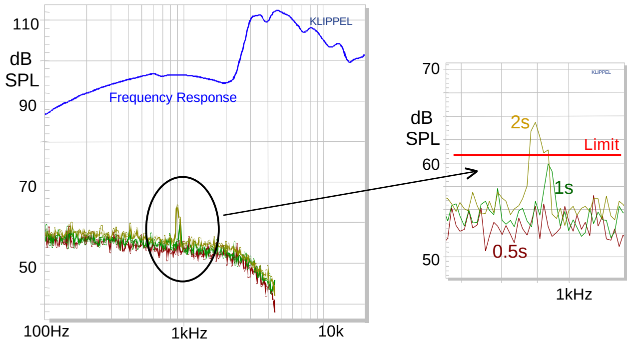

Figure 4: Rub & Buzz detection vs. Duration

Conclusions

For production testing it is possible to perform fundamental and regular harmonic distortion testing in 0.2s over the full audio bandwidth (50Hz - 20 kHz). Although not in steady state, the results are highly reproducibly and show only minor deviation from a standard compliant test scheme of much longer measurement time.

The fast harmonic test provides:

- Continuous excitation of all frequencies
- Variable sweep speed to focus the energy at critical frequencies
- Low computational load for calculation
- Minimal duration optimized for production line testing

For irregular distortion the measurement time should be prolonged until all critical defects can be detected reliably.

References

[1] W. Klippel, Tutorial: Loudspeaker Nonlinearities - Causes, Parameters, Symptoms *J. Audio Eng. Society* **54**, No. 10 pp. 907-939 (2006 Oct.).

[2] W. Klippel, S. Irrgang, U.Seidel, "Loudspeaker Testing at the Production Line" presented at the 120 Convention of the Audio Engineering Society, 2006 May 20-23, Paris

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