Impact and Audibility of Distortion in Automotive Audio Applications

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Audio System Evaluation over the product life cycle

*Standard Measurement Condition*
- Product Specification
- Development (components, system)
- Physical Evaluation

*Production*
- EOL Testing

*Target Application Condition*
- Definition
- Target Performance
- Physical + Perceptual Assessment
- Service
- Field Monitoring

*Target Application Condition*
- EOL Testing
- Production
Desired and Undesired Components?

Generation of Signal Distortion in an Audio System

Desired Small Signal Performance

Undesired time variance (heating, ageing)

Desired Large Signal Performance (motor, suspension)

Undesired Defects

• Rubbing coils, buzzing parts
• Wire beat, coil bottoming
• Loose particles, air leak noise
• Parasitic vibration of other components

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What is a critical defect?

- Related to customer complaints
- Observable in in-situ condition
  - Impulsive distortion (panel buzzing, loose particles, loose electrical connection)
  - Significant air noise caused by a leakage of the enclosure (Subwoofer)
  - Excessive nonlinear distortion caused by motor instability and severe asymmetries
Evaluation in Final Application

Standard Measurements
- using R&D equipment (artificial head, analyzer, ...)
- limited to type approval test
- artificial test signal can be used
- operated by engineer

In-situ Measurements
- applicable to all units
- ordinary audio signals used as stimulus
- external
- Using existing hardware
- operated by end-user

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Listening Tests

**STIMULI**
(critical, typical program material)

Prototype, competitive products

Listening conditions

- How to make listening test more effective? (meaningful, valid, reliable data in a shorter time!!)
- How to cope with the influence of the listening conditions (stimuli, room, location)?
- How to understand relationship between physics, audibility of distortion and preference of the product?

**Psychometric methods**
(double blind testing)

Audibility, Preference

→ **Auralization Techniques**
Reduce complexity of the testing
Focus on critical questions, hypothesis
Systematic test using virtual loudspeaker modifications
Auralization of Signal Distortion

**OBJECTIVE:**
Virtual enhancement or attenuation of the distortion components
Audibility and Preference
Distortion generated Motor and Suspension

10 = “high”
100%
75%
50%
5 = “medium”
0 = “low”

rate of correct responses

audibility threshold
inaudible
just audible
audible
undesired
rated sound quality

target performance

Scaling of Signal Distortion $S_{DIS}$

0 dB
-6 dB
-12 dB
6 dB
12 dB

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Audibility and Preference

Impulsive distortion generated by rub&buzz and other loudspeaker defects

Rate of correct responses

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Audibility threshold
Psychometric function of audibility

Audible
Inaudible
Just audible
Target performance
Undesired
Rated sound quality

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Combining Physical and Perceptual Evaluation of the Audio Product Measured in Target Application

- **Objective Evaluation**
  - Engineering
  - Objective
  - Physical Data
    - Distortion, Maximal Output
    - Displacement, Temperature
  - Evaluation of Design Choices
  - Clues for Improvements

- **Subjective Evaluation**
  - Marketing Management
  - Subjective
  - Audibility of distortion Preference
  - Defining target specification
  - Tuning to the market

- **Perceptual Modeling**
  - Performance/cost ratio

- **Listening Test + Auralization**

- **S_DIS**

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