Motivation

• *Field rejects are $$$*

• *Reproduce + analyse the problem before repair*
Audio System Evaluation over the product life cycle

Definition

Target Application Condition

Performance

Target

Product Specification

Standard Measurement Condition

Development
(components, system)

Physical Evaluation

Production

EOL Testing

Service

Field Monitoring

Target Application Condition

Audio System Evaluation with Music Signals

After Sales / Field Measurements

Objectives
- evaluation of the performance as seen by the end user
- long term testing under real condition
- Prevention of a total failure
- Service for customer complaint

Challenges
- audio signal used
- influence of other sound sources
- use of compromised test elements
- measurement shall be realized at low cost

Acoustical measurements
using (available) microphones reveal
- Frequency Response, SPL
- Overall transfer function
- Coherence
- Residual Distortion

Electrical measurements:
based on voltage and current monitoring (control technology) reveal
- Voice coil and magnet temperature
- Peak displacement and offset in coil rest position
- Change of suspension stiffness indicating fatigue
- anticipation of a motor or suspension defect
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

Reproduced Sound Quality
Generation of Signal Distortion in an Audio System

Desired Small Signal Performance

Large Signal Performance (motor, suspension)

Undesired Defects
- Rubbing coil, Buzzing parts
- Wire beat
- Loose particles, air leak noise
- Parasitic vibration of other components
Properties of Music Stimulus

- Dense stimulus / Most complex
- Non persistent excitation
- Non stationary excitation (Unknown time structure)
- Defects occur quasi randomly

→ How to separate defect from accepted response?

State of the art

Linear System Identification:
- Correlation Technique
- Requires Stationary Signals

\[ H(f,n) = \frac{\hat{S}_{x,y}(f,n)}{\hat{S}_{x,x}(f,n)} \]

Incoherence:
- Power metric
- Good for Noise problems
- Moderate for regular non-linearities
- Poor for time varying TRF
- Poor for impulsive distortion

\[ \gamma(f,n) = \frac{\hat{S}_{x,y}(f,n)}{\sqrt{\hat{S}_{x,x}(f,n)\hat{S}_{y,y}(f,n)}} \times 100\% \]

\[ IC_{dB}(f,n) = 10 \log \left( 1 - \frac{\gamma(f,n)}{100\%} \right) \text{ dB} \]
State of the art

Correlation Technique

Incoherence:
- Requires long (statistical!) time for accurate estimation (see paper) for low energy symptoms.
  \[ e_c(f) = \frac{\Delta \mathcal{C}(f)}{\mathcal{C}(f)} \leq \frac{100\%}{\sqrt{K}} \]
  \[ T_{\text{res}} \geq \frac{K}{2} \]
- \( T \) is defined by required resolution (Wofer 1 Hz / Midrange 5 Hz)
- \( K \) (number of processed blocks) = f(error)
- Example: \( df = 1\text{Hz} \), total time \( -5\text{s} \)
  \( \rightarrow \) error: 30\%, Incoherence too low by 1.5dB
- Assumption: stationary excitation
- When using non-stationary signals: Symptoms may be not stable!
- No Auralization of separated distortion (power measure!)

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State of the art

Correlation Technique / Measurement Results

Distortion from regular nonlinearities mask symptoms from rattling
\( \rightarrow \) Incoherence measurement is not sensitive for impulsive distortion
Acoustical In-Situ Measurement

Linear Distortion

Properties:
- Adaptive identification
- Fast initial learning
- Copes with non-stationary input
- Follows changes of linear system → Improved separation
- Typical ANC method

Compression of SPL Output

Short term response measured within 1 s (without voice coil heating)

Long term response measured after applying the sinusoidal stimulus for 1 min
Influence of Ambient Conditions

Properties of the mechanical suspension depend on humidity, temperature
→ voice coil displacement cannot be predicted by time-invariant parameters
→ adaptive learning process required

Acoustical In-Situ Measurement
Residual Distortion

Properties:
• Model identifies linear system only → Separation of residual from linear distortion
• Exploit Residual:
  • Non-linear Distortion
  • Defect Distortion
  • Noise
Assessing Regular Nonlinear and Irregular Distortion

Impact on sound quality:
- Parasitic resonances are excited by sufficient (kinetic) energy
- Defect occurs rarely
- Depends on
  - Level (not highest!)
  - Phase relationship
- Distortion require high state (e.g. Bl(x))

Audio system defect: *Parasitic Vibration problem*

Most defects behave as a **nonlinear oscillator**
- active above a critical amplitude
- new mode of vibration
- powered and synchronized by stimulus
Residuum of the Linear Modeling
(defect in car)

Time Frequency Analysis of the Residuum
Standard EOL test of defect

Using log sweep

Acoustic In-Situ Measurements
Auralization

Adaptive Identification provides:
- Separated linear response
- Purified from time variant linear distortion
- Residual Distortion to be scaled up and down

Benefit:
- Objective Criteria
- Rate importance
- Is this defect acceptable?
- Action required?
Finding most critical section

Challenge:
- Find highest distortion in a long recording
- Non-Stationary excitation

Solution:
- Check Crest factor of Residual:
  High Peak and Low Mean distortion indicate impulsive distortion (defect symptom)

Summary

- Simple Setup
  - Wave file / Web based solutions
- Comprehensive System Evaluation
  - Linear Response + Residual distortion
- Using any stimulus
  - Customer specific audio material
- Fast Identification of defects
  - Automatic selection of critical section
  - Time Domain Analysis
  - Auralization