Non-linear Digital Processor for dedicated loudspeaker systems

A. Bellini, G. Cibelli, E. Ugozolotti, A. Farina, C. Morandi

D.I.I. - University of Parma
ITALY

ASK Industries
ITALY

1998 ICCE
Los Angeles, CA
Outline

- Loudspeaker physical conformation;
- Loudspeaker non-linear modeling;
- Digital audio Processor for distortion compensation;
- DSP implementation;
- Measured distortion results;
Basic loudspeaker conformation

- Electric- mechano-acoustic transducers:
  - \( p(t) = k e(t) \)

- Non-linear behavior:
  - The magnetic induction \( B \) is not constant with displacement
  - non ideal suspension stiffness
  - \( R = R(T) \)
Loudspeaker modeling

Audio electric signal

\[ i(t) \rightarrow R_e \]

\[ F(t) \rightarrow C_m, M_m \]

\[ p(t) \rightarrow Z_a \]

BL:1

1:S_d
**Loudspeaker modeling**

Audio signal

- Non-linear loudspeaker I/O relation is linearized around fixed displacements $x_n$
- $\psi_{x_n}$ accounts only for non-linear behavior

\[
\varphi_{\hat{x}_n}(s) = \frac{p(s)}{e(s)}
\]

\[
\psi_{\hat{x}_n}(s) = \frac{\varphi_{\hat{x}_n}(s)}{\varphi_0(s)}
\]
Loudspeaker non-linear modeling

\[ e(t) \xrightarrow{\text{H}(n)} \psi(n) \xrightarrow{\varphi_{\text{SPL}}(n)} p(t) \]

\[ \varphi_0(s) = \frac{p(s)}{e(s)} \overset{\rightarrow}{\varphi_{\text{SPL}}(n)} \]

is similar to SPL measurements
Audio processor

- The more critical part is the synthesis of the H(n) filter
DSP implementation

Audio signal $e(t)$

(Non-linear model) $^{-1}$

Audio processor

Power Audio amplifier

$p(t)$
DSP implementation

- Audio processor implemented with a 320C54x DSK;
- 40 MIPS, 10Kword Dual Access RAM;
- Sampling frequency 23148 Hz;
- Converter resolution 14 bit.
Multirate Audio processor

\[ e(t) \rightarrow \text{HPF} \rightarrow \phi_{SPL}^{-1}(n) \rightarrow \text{Delay} \rightarrow \text{Interpolator} \rightarrow \text{LPF} \]

Non-linear processing:

- \[ \phi_{SPL}^{-1}(n) \]
- \[ \psi^{-1}(n) \]
- \[ H(n) \]
Audio processor measurements

- Audio processor
- Power Audio amplifier
- Electric signal
- Acoustic pressure
- Audio analyzer B&K 2012
- Anechoic room
SPL Results

Amplitude input 4 V

- **normal**
- **digital pre-processed**

**Distortion [mV]**

- 400
- 350
- 300
- 250
- 200
- 150
- 100
- 50

**f [Hz]**

- 20
- 60
- 100
- 140
- 180
SPL Results

Amplitude input 5 V

Distortion [mV]

f [Hz]

normal
digital pre-processed
Conclusion

- Definition of a non-linear model for low frequency loudspeaker systems;
- Design of a parametric audio processor for the compensation of non-linear distortion of loudspeaker;
- Implementation of the audio processor with a low cost commercial DSP;
- Measured reduction of Distortion with the insertion of the audio processor;