Residual Echo PSD Estimation Based on an Optimal Smoothed System Misalignment for Acoustic Echo Cancellation

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**Motivation**

- Post-Filtering is a common enhancement technique for the conventional acoustic echo canceller (AEC), especially, when it is diverged or too short.
- A reliable estimate of the (residual) echo power spectral density (PSD) is essential for designing the Post-Filter.
- For short DFT-lengths resulting in low latency a partitioned calculation is necessary, which leads to biased estimates. This bias has to be corrected.

**System model**

Partitioned frequency domain system model of an acoustic echo canceller in front of a Post-Filter:

$$X(m,l) = \begin{bmatrix} X(m,l) & \cdots & X(m,l - L_{\text{AEC}} + 1) \end{bmatrix}^T$$

$$H(m,l) = \begin{bmatrix} H_1(m,l) & \cdots & H_{L_{\text{AEC}}}(m,l) \end{bmatrix}^T$$

$$C(m,l) = \begin{bmatrix} C_1(m,l) & \cdots & C_{L_{\text{DFT}}-1}(m,l) \end{bmatrix}^T$$

$$D(m,l) = H(m,l) - C(m,l)$$

**Optimal Smoothing of the System Misalignment**

A first order recursive smoothing of the system misalignment can be exploited especially with nonstationary signals:

$$\Delta_0(m,l) = \alpha \Delta_0(m,l - 1) + (1 - \alpha) \frac{\Phi_{XX}(m,l)}{\Phi_{X}\Phi_{X}}$$

An optimal smoothing factor for the mean of a stochastic system is obtained by minimizing

$$\min_\alpha \frac{1}{\sum_{m} \mathbb{E}[|\Delta_0(m,l)|^2]}$$

**Practical Realization and Simulation Results**

- The factor $|\Delta_0(m,l)|^2$ can be interpreted as a permitted adaptation speed and set constant.
- Typical values for $0.08 < \alpha < 0.12$ and thus we choose $\alpha = 0.1$.
- As a simplification the dependence on the system misalignment can be neglected.

### Design of the Post-Filter

- Spectral subtraction: $P(m,l) = \frac{\Phi_{EE}(m,l) - \Phi_{EE}(m,l)}{\Phi_{EE}(m,l)}$

### Partitioned Calculation of the System Misalignment (I)

Assuming temporarily low correlated loudspeaker signals in the DFT-domain,

$$\mathbb{E}[X(m,l - i)X(m,l - k)] = 0, \quad \forall i \neq k,$

the partitions of the system misalignment can be calculated independently:

$$D_1(m,l) = \frac{\Phi_{XX}(m,l)}{\Phi_{X}\Phi_{X}}$$

$$\Phi_{XX}(m,l) = \mathbb{E}[X(m,l - i)X(m,l)]$$

### Partitioned Calculation of the System Misalignment (II)

With $\Xi(m,l) = \sum_{i=0}^{L_{\text{DFT}}} D_i(m,l) \cdot X(m,l - i)$ the first partition can be rewritten exemplarily:

$$\Phi_{XX}(m,l) = \frac{\mathbb{E}[X^2(m,l) \cdot \sum_{i=0}^{L_{\text{DFT}}} D_i(m,l) \cdot X(m,l - i)]}{\mathbb{E}[X^2(m,l) \cdot X(m,l)]]}$$

**Conclusions**

- A frequency dependent first order recursive smoothing factor was presented which is robust and straightforward to implement.
- Drastic enhancement of the system identification by Wiener-Hopf Equation.
- Reliable redundancy for AEC.