UR Signals and Systems

Perceptual Long-Term Harmonic plus Noise Modeling for Speech Data Compression

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Outline

- ❑ Long-Term Harmonic plus Noise Model (LT-HNM)
- ❑ Perceptual LT-HNM for Data reduction
- ❑ Experimental Results for Data Compression

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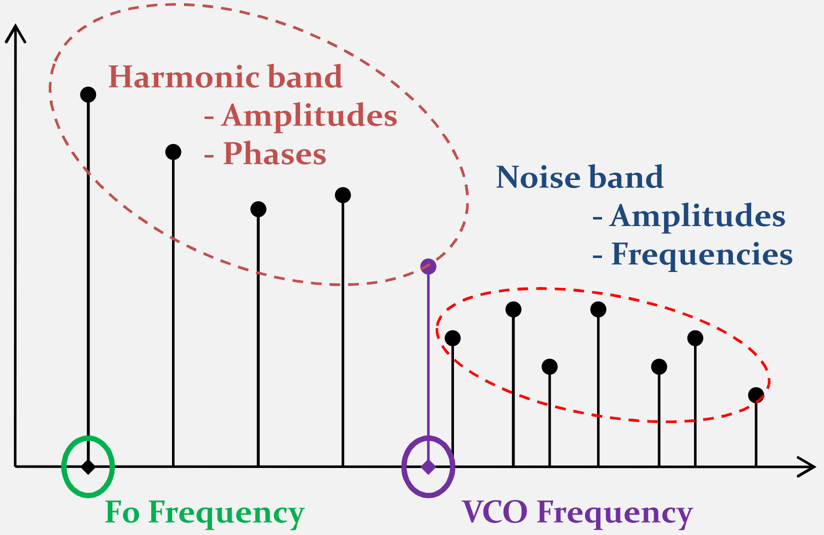
Long-Term Harmonic plus Noise Model (LT-HNM)

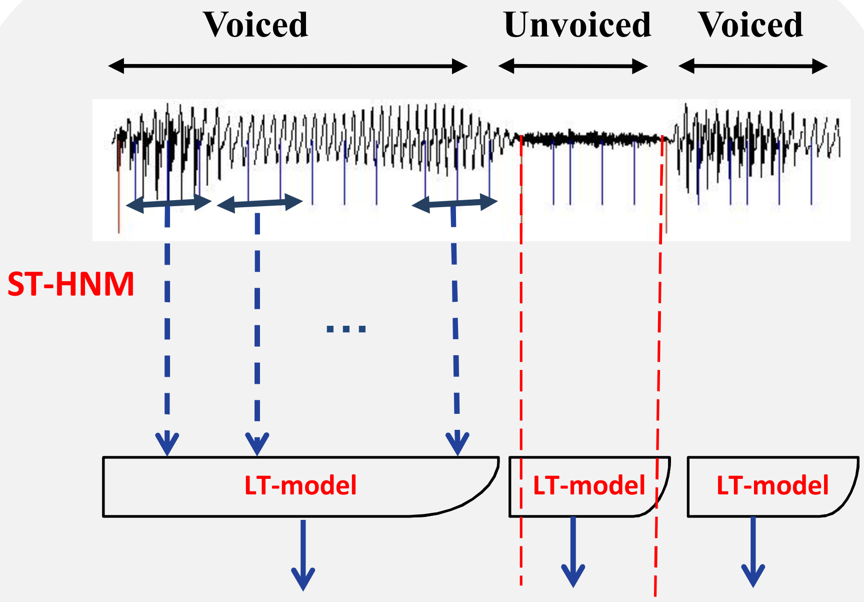
ST-model: Harmonic plus Noise Model (HNM)



❑Harmonic plus Noise Models:

- harmonic band: multiples of the fundamental frequency (F0)
- noise band: peak picking frequencies

❑The two bands are separated by a voicing cut-off frequency (VCO)



❑Speech signal is segmented into voiced ($F_0 \neq 0$) and unvoiced ($F_0 = 0$) LT-sections

❑ A Long-Term model is applied to the ST-HNM parameters (F_0, VCO frequencies and spectral amplitudes) for each LT-section.

Long-Term Harmonic plus Noise Model (LT-HNM)

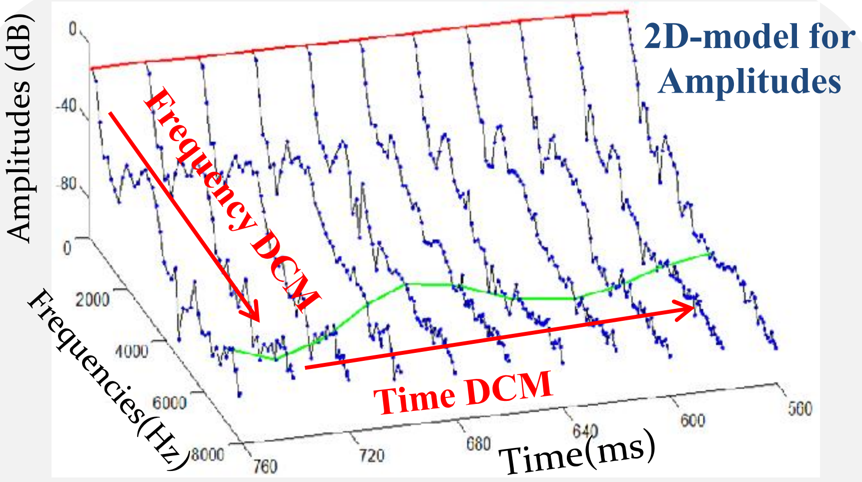
LT-model: Discret Cosine Model (DCM)

$$\hat{X}(n) = \sum_{p=0}^{P} c_p \cos\left(\frac{p\pi n}{N}\right)$$

❑ Applying a DCM to the time trajectory of the ST-HNM parameters (F0, FV and amplitudes) in a LT time section.

❑ Exploits the correlation between successive ST-parameters

❑ Optimization of the model order P



For amplitudes, we apply a DCM twice:

❑ first along the frequency axis to model the spectral amplitudes in a ST-frame (1D-DCM)

❑ second along the time axis to model the time trajectory of the 1D-DCM coefficients in a LT-section (2D-DCM).

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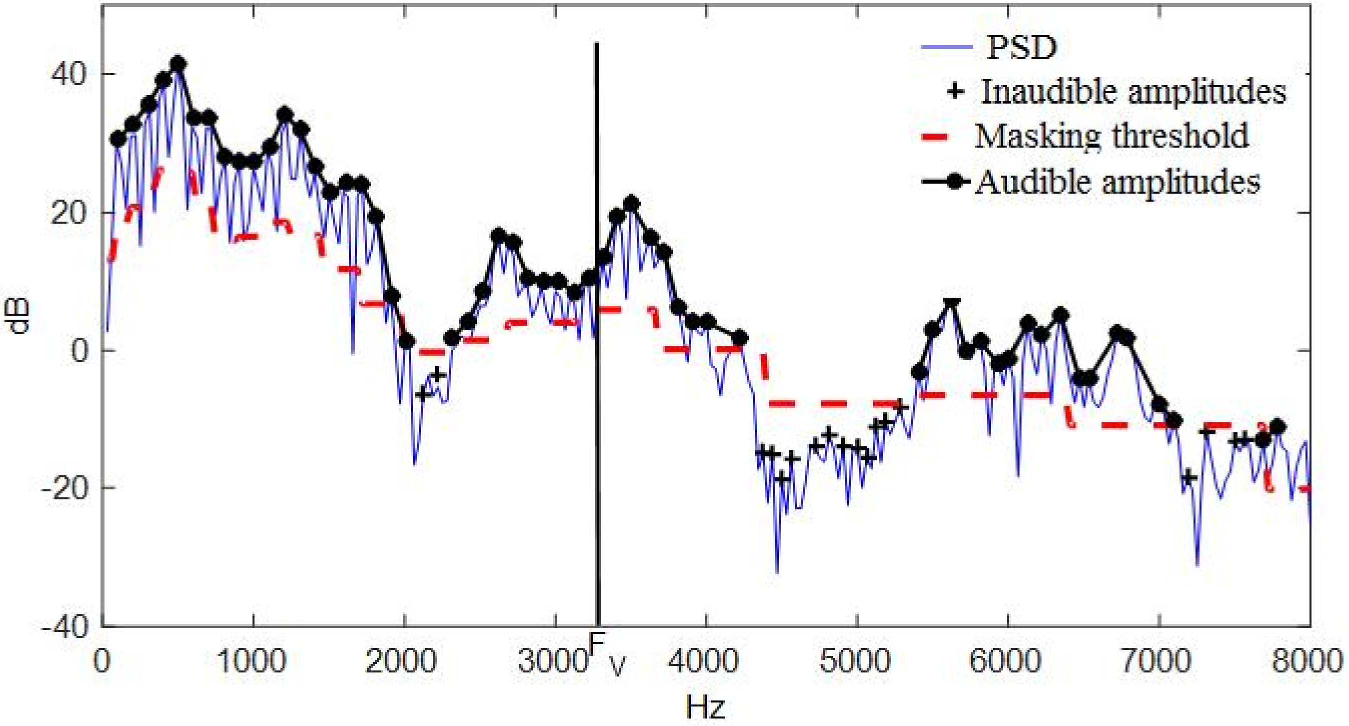
□ Long-Term Harmonic plus Noise Model (LT-HNM)

□ Perceptual LT-HNM for Data reduction

□ Experimental Results for Data Compression

Auditory Masking



❑ A masking threshold is computed for each ST-frame

❑ The spectrum amplitudes (harmonic + noise) are compared to the masking threshold

→ **Only amplitudes above the mask are selected as audible**

ST-HNM Data Reduction

p-ST-HNM

Only audible amplitudes are considered in the ST-HNM, inaudible ones are discarded from the model

→ The data size of the model parameters is considerably reduced: up to 50% in a ST-frame

→ Reduction of the data-rate with the equivalent perceptual quality

⇩

p-LT-HNM

The LT-modeling is applied to the parameters of the p-ST-HNM

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Double data-compression: auditory masking + LT-modeling

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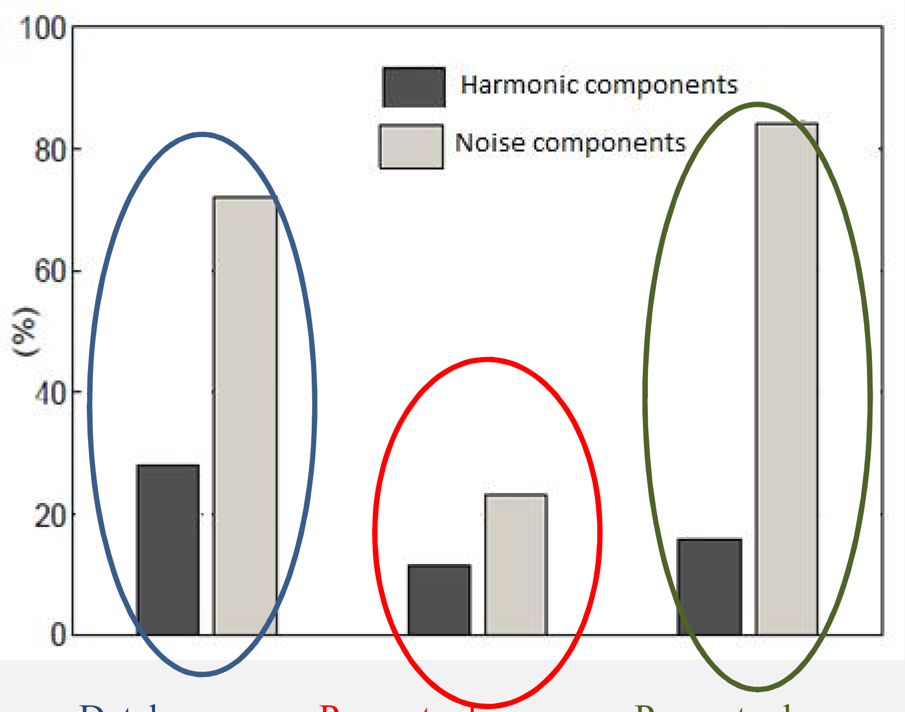
Overall Data Reduction

Database

- 600 TIMIT speech samples at 16kHz
- Total duration ~ 17mn
- ST-HNM analysis with 30ms ST-frames and a hop-size of 20ms (81539 ST-frames)
- The masking threshold is attenuated with -5dB



Database statistics

Perceptual compression rate

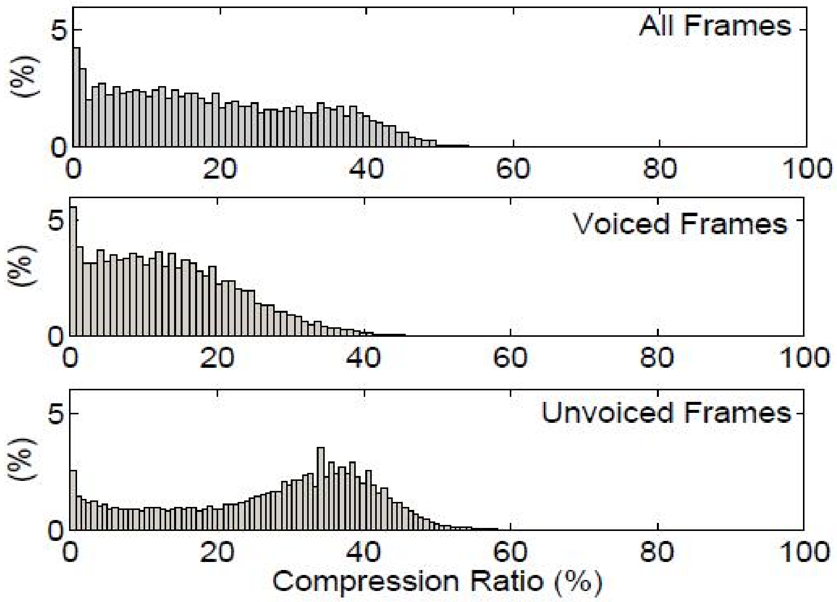
Perceptual compression statistics

❑ 72% of database frequencies are noise frequencies, while 27.8% are harmonics

❑ Total frequency components compression ≈ 20%: noise band compression ≈ 23.3%, harmonic band compression ≈ 11.3%

❑ 84.1% of achieved compression is due to the noise band, while the harmonic frequencies contribute only by 15.% to the total compression

Data Reduction in V/UV ST-frames

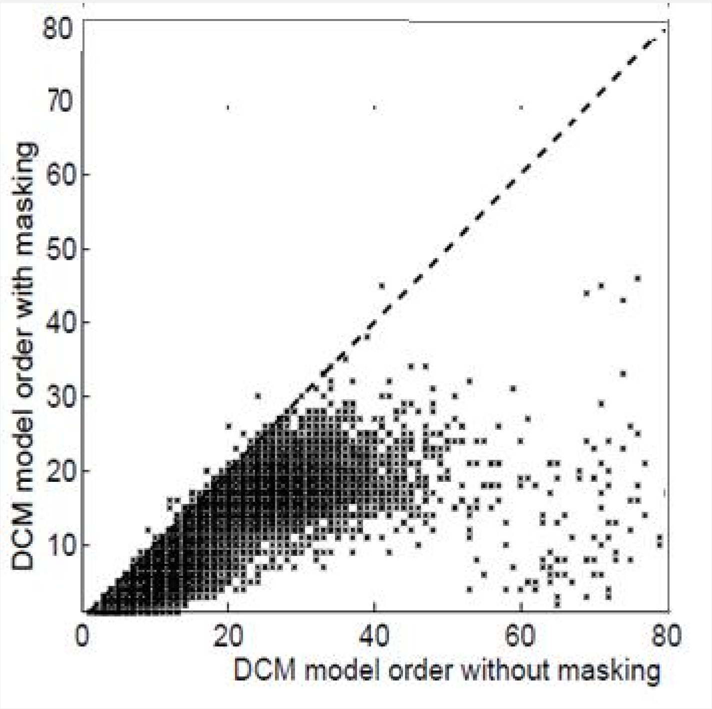


❑ Data compression rate is up to 50% in a ST-frame

❑ Compression rate is higher for unvoiced ST-frame (entirely composed of noise frequencies)

❑ Higher contribution of noise band to the total compression

Reduction of the LT-HNM coefficients rate



The 1D-DCM order is considerably reduced when applying the auditory masking

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The data size to be LT-modeled is reduced

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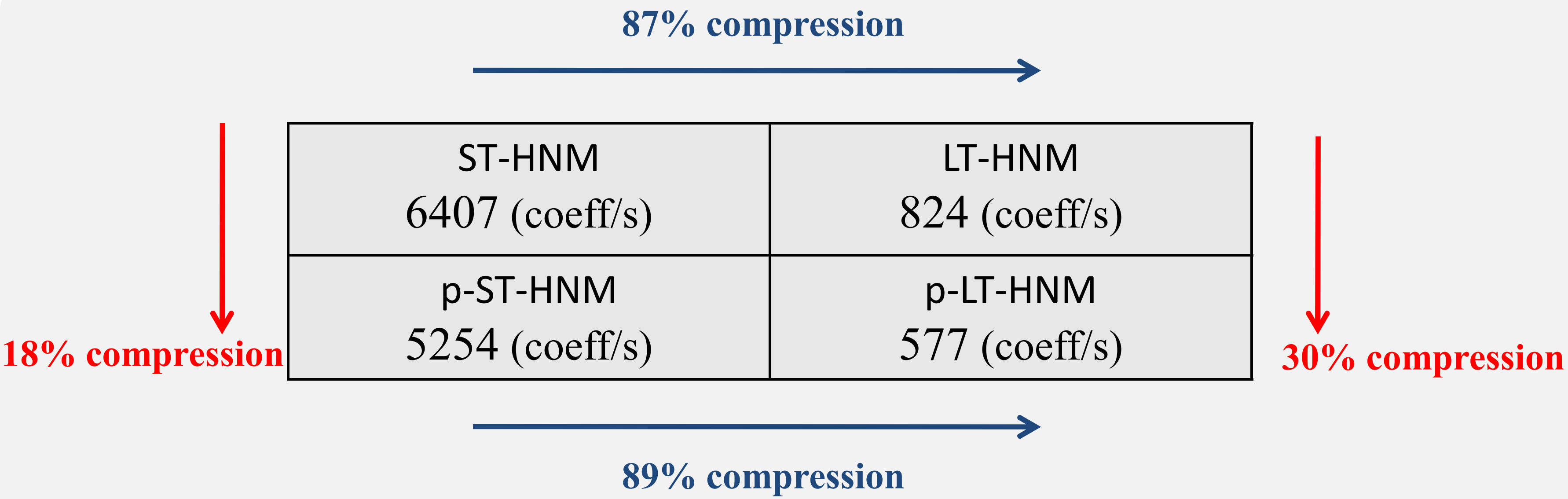
Reduction of the LT-HNM data size

Parameters-Rate Gain



87% compression

ST-HNM 6407 (coeff/s)	LT-HNM 824 (coeff/s)
p-ST-HNM 5254 (coeff/s)	p-LT-HNM 577 (coeff/s)

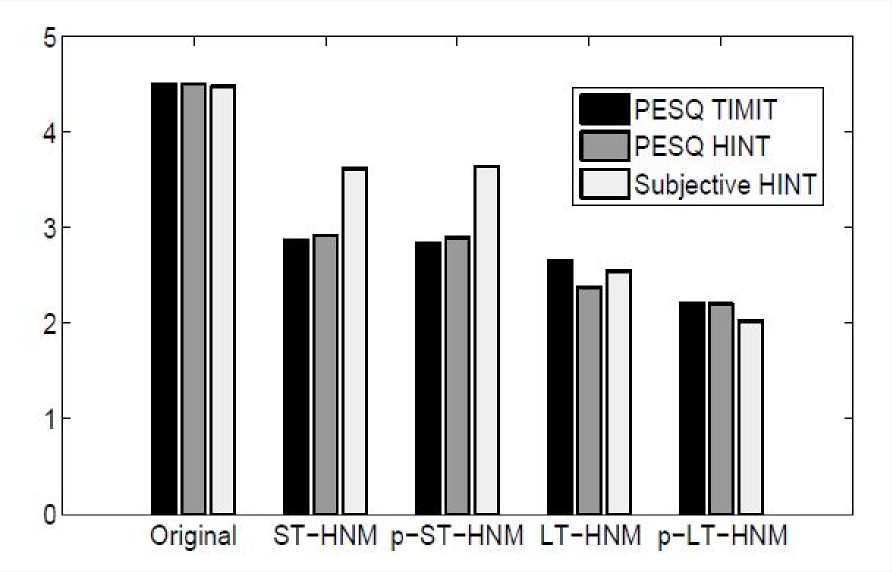
18% compression

30% compression

89% compression

Data rate gain of 18% for p-ST-HNM and 30% for p-LT-HNM

Listening Quality (PESQ and MOS Scores)



❑ Mean PESQ scores: 40 speech samples from TIMIT (English) and 20 samples from HINT (French)

❑ MOS Subjective listening test applied to HINT samples (12 French speakers participants)

→ No auditory distortion when applying the p-ST-HNM (PESQ and MOS)

→ No significant auditory distortion when applying the p-LT-HNM (PESQ and MOS)

Conclusion and Perspectives

Conclusion:

Two stages of compression:

❑ Perceptual based compression: 18% (ST-HNM → p-ST-HNM)
❑ Perceptual LT modeling: 89% (p-ST-HNM → p-LT-HNM)

→ **Total compression: 90% (ST-HNM → p-LT-HNM)**

Perceptual Quality

❑The perceptual HNM and generic HNM provide equivalent quality scores

Perspectives:

❑ A two stage vector quantization is currently being applied to the perceptual LT-HNM parameters and will to design a low bit-rate speech codec.

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