Linear prediction of audio signals

Toon van Waterschoot and Marc Moonen
Katholieke Universiteit Leuven, ESAT-SCD, Kasteelpark Arenberg 10, B-3001 Leuven, Belgium
toon.vanwaterschoot@esat.kuleuven.be
http://homes.esat.kuleuven.be/~tvanwate/

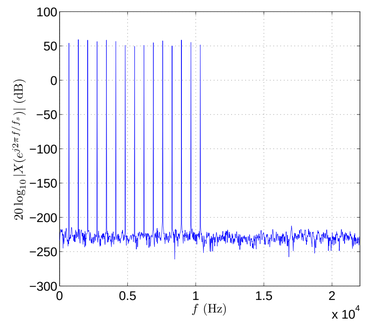
Linear prediction audio applications:
- audio compression (warped LP)
- lossless audio coding
- audio (spectral) analysis
- audio signal whitening (feedback/echo cancellation)

Tonal audio signal model, $t = 1, ..., M$:

$$x(t) = \sum_{n=1}^{N} A(n) \sin[n\omega_0 t + \phi(n)] + e(t)$$

Residual spectral flatness measure:

$$\text{SFM}_R = \frac{\exp\left\{\frac{1}{M}\sum_{f=0}^{\tilde{f}_s} \ln\left[|R(f)|^2\right]\right\}}{\frac{1}{M}\sum_{f=0}^{\tilde{f}_s} |R(f)|^2}$$

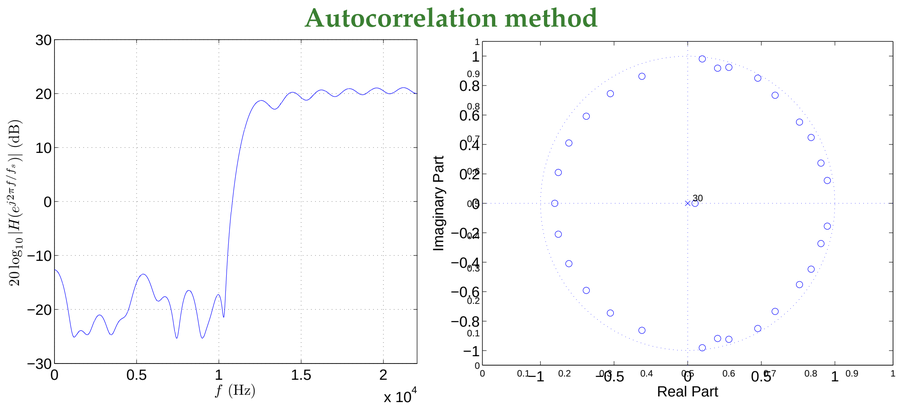


- $f_s = 44.1$ kHz
- $\omega_0 = 2\pi/64$ rad ($f_0 = 689.1$ Hz)
- $M = 2048$ samples $= 46.4$ ms
- $N = 15$
- $e(t) \equiv 0$
- $A(n) \sim \mathcal{U}(0, 1)$
- $\phi(n) \sim \mathcal{U}(0, 2\pi)$

LP method	SFM_R (dB)
LP (autocorrelation)	-6.92
LP (covariance)	-52.97
Pole-zero model	-1.19
High-order LP	-0.55
Pitch prediction	-15.37
Warped LP	-5.17
Selective LP	-1.76

Conventional linear prediction methods

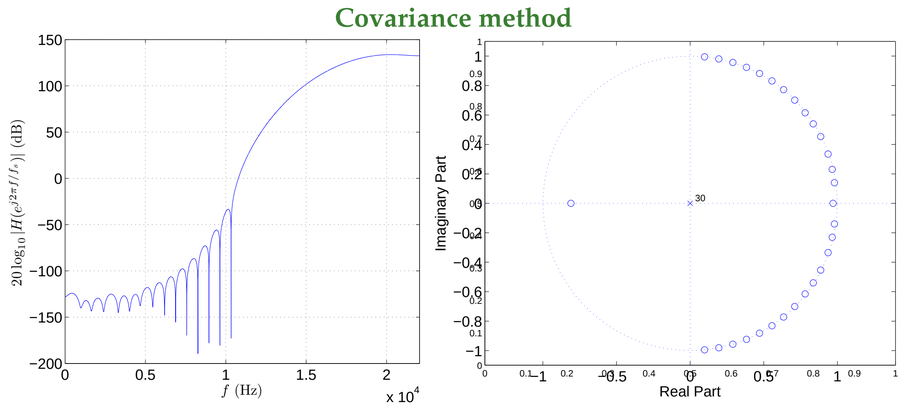
Autocorrelation method



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residual spectral flatness maximization

Covariance method



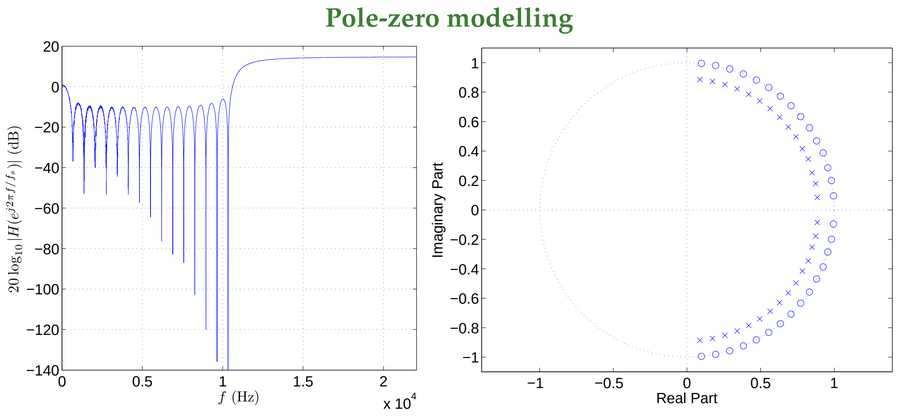
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high-resolution tonal components identification

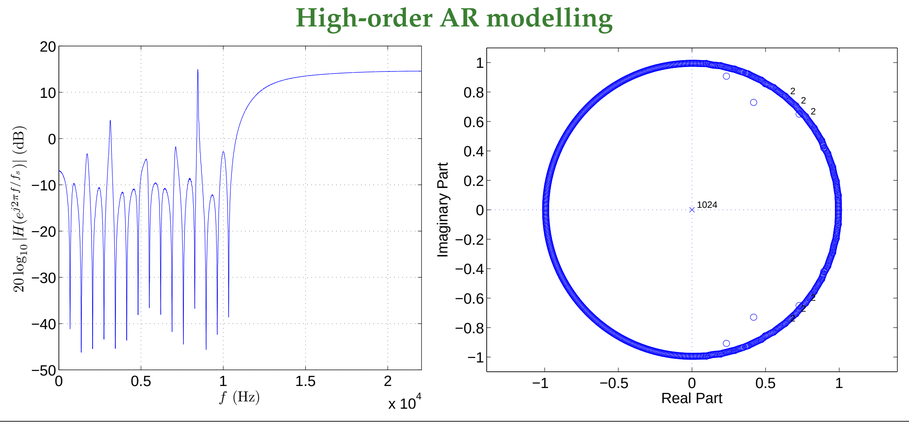
Conjectures:
1. AR($2N$) model is not suited for achieving BOTH residual spectral flatness and and high-resolution tonal components identification, UNLESS tonal components are **uniformly distributed** in Nyquist interval ($\omega_0 = \pi/(N+1)$)
2. AR($2N$) model with covariance method fails to identify tonal components when **noise** is added to tonal signal ($e(t) \neq 0$)

Alternative linear prediction methods

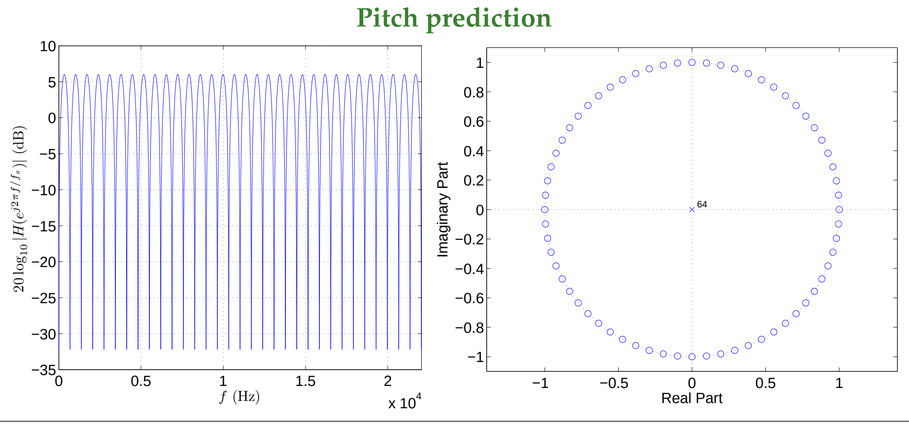
Pole-zero modelling



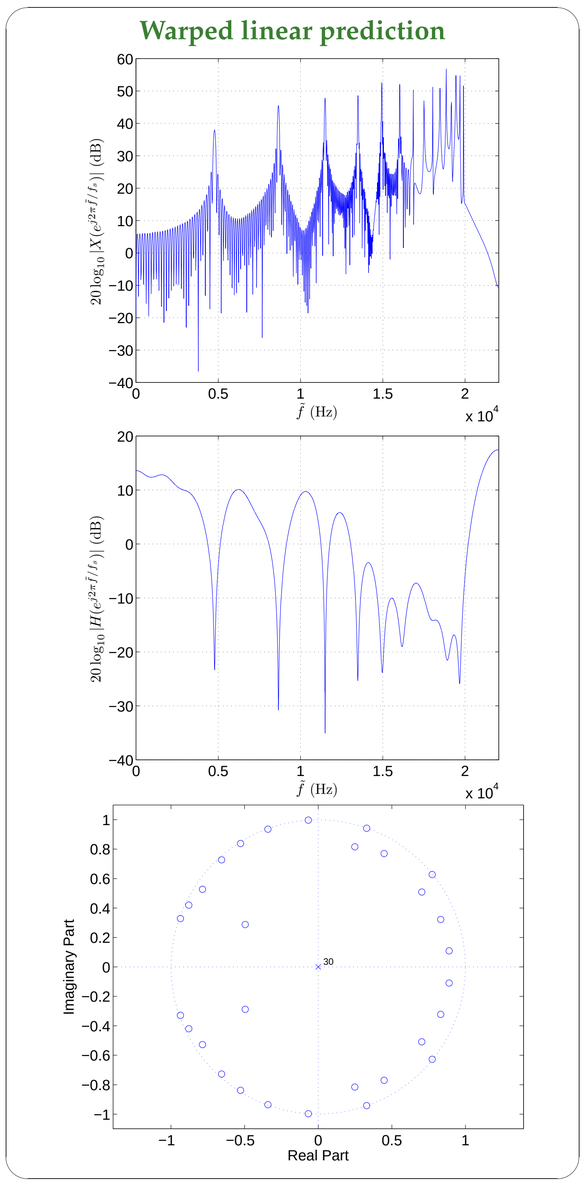
High-order AR modelling



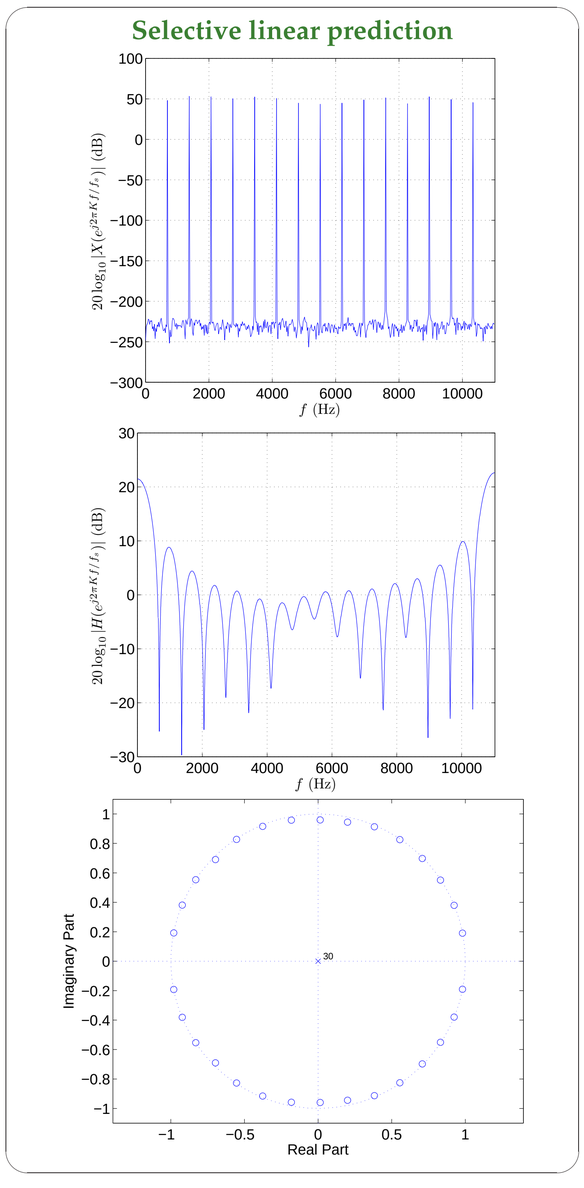
Pitch prediction



Warped linear prediction



Selective linear prediction



See also: T. van Waterschoot and M. Moonen, "Comparison of linear prediction models for audio signals," *EURASIP J. Audio, Speech, Music Process.*, submitted for publication. `ftp://ftp.esat.kuleuven.be/pub/sista/vanwaterschoot/abstracts/07-29.html`