Mixed-Phase Speech Modeling and Formant Estimation Using Differential Phase Spectrums

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Z-Plane and Discrete Fourier Transform

**Z TRANSFORM**

\[ H(z) = \sum_{k=0}^{\infty} h(k)z^{-k} \]

**DISCRETE FOURIER TRANSFORM**

\[ z = e^{j\theta} \]

\[ H(e^{j\theta}) = \sum_{k=0}^{\infty} h(k)e^{-j\theta k} = H(z)|_{z=e^{j\theta}} \]

\[ H(w) = F\{h(t)\} = a(w) + jb(w) \]

**AMPLITUDE**

\[ |H(w)| = \sqrt{a^2 + b^2} \]

**PHASE**

\[ \vartheta(w) = \arctan\left(\frac{b(w)}{a(w)}\right) \]

**GROUP DELAY**

\[ D(w) = -\frac{d(\vartheta(w))}{dw} \]
Mixed-Phase Speech Model

For source-filter separation, causal and anti-causal parts of the mixed-phase signal needs to be separated.

Causality cannot be observed on amplitude spectrum, so we can look for solutions in phase spectrum.
Analysis of Speech Signal Group Delay Function

Problem!
Group Delay Functions are most often very noisy

Possible reason:
Zeros close to unit circle
(roots of the z-transform polynomial)

Proposal:
Calculate differential phase on other circles (than unite circle)
Diff-Phase Spectrum Plots for a real speech example
Diff-Phase Spectrum and Amplitude Spectrum Plots for a real speech example
Proposition: Differential Phase Spectrums calculated on circles other than unit circle on z-plane.
Analysis of Differential Phase Spectrums
Detecting causal and anti-causal resonances

R = 1.2
R = 1.05
R = 0.99
R = 0.85
Analysis of Synthetic Speech Signal
Example Plots For Real Speech Signals

Inverted!
Difficulties in analysis of differential phase plots

Zeros

They also exist far from unit circle and may dominate differential phase plots

Which value of R to be used

There is no single best R value which provides clear pictures of formants.

Windowing effects

The effect of windowing needs to be studied

Hard to imagine the convolution process in z-plane