

Applications and Justification of Coherent Modulation Filtering

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ELECTRICAL ENGINEERING

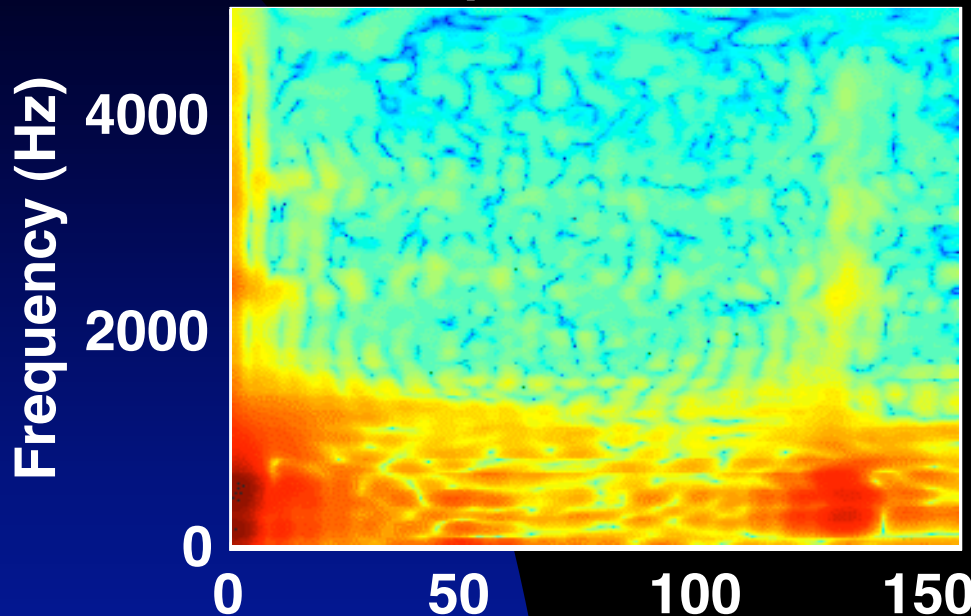
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“Clear” Speech Modulation Spectra



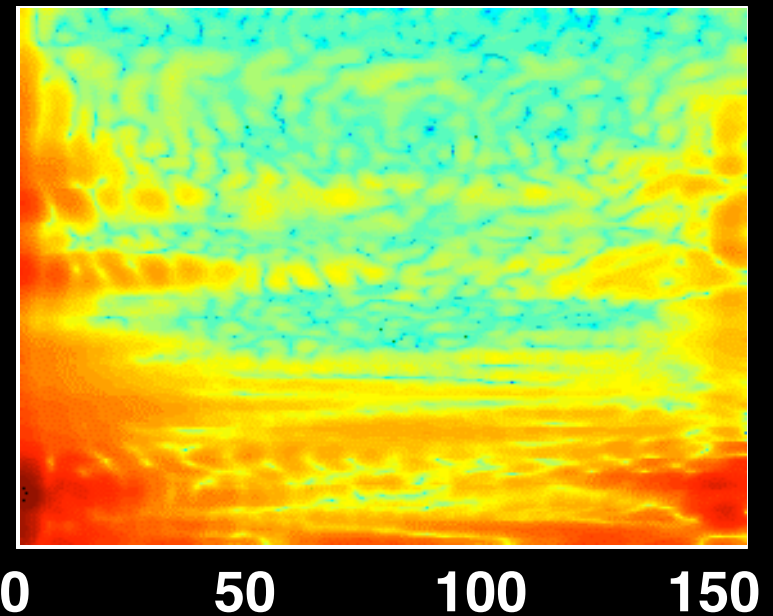
Normal Speech: “foils”



Modulation frequency (Hz)



Clear Speech: “foils”



Modulation frequency (Hz)

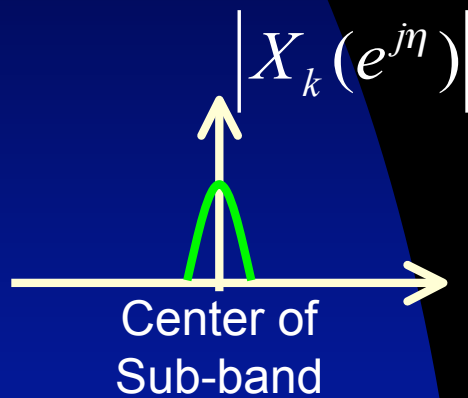
Key new engineering challenge: How to automatically change normal speech to clear speech?

Recent Insights

- Proven in: Atlas, Li, and Thompson, “Homomorphic Modulation Spectra,” *Proc. ICASSP 2004*:
 - ◆ For most natural sounds and speech, the modulation envelope is complex and not necessarily real and positive, as was assumed for previous studies.
 - ◆ Coherent *carrier* detection is instead needed to retain this complex envelope.
- More recently, to be submitted to *J. Acoust. Soc. Am.*:
 - ◆ Coherent and bandlimited carrier detection is required for distortion-free modulation filtering.

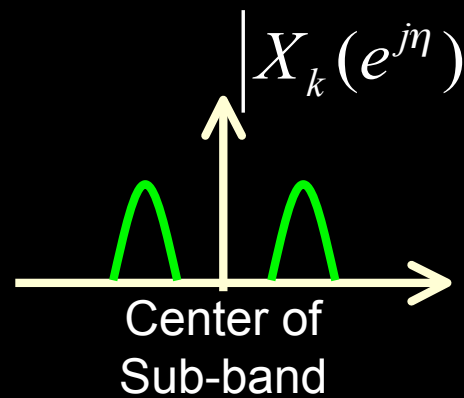
For Example: Symmetry Properties of Harmonic(s) in Frequency Subbands

Real and Non-Negative Modulator



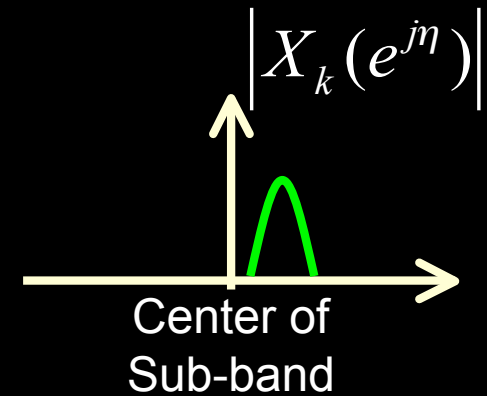
- Symmetric
- Positive-Definite

Real and Partially Negative Modulator



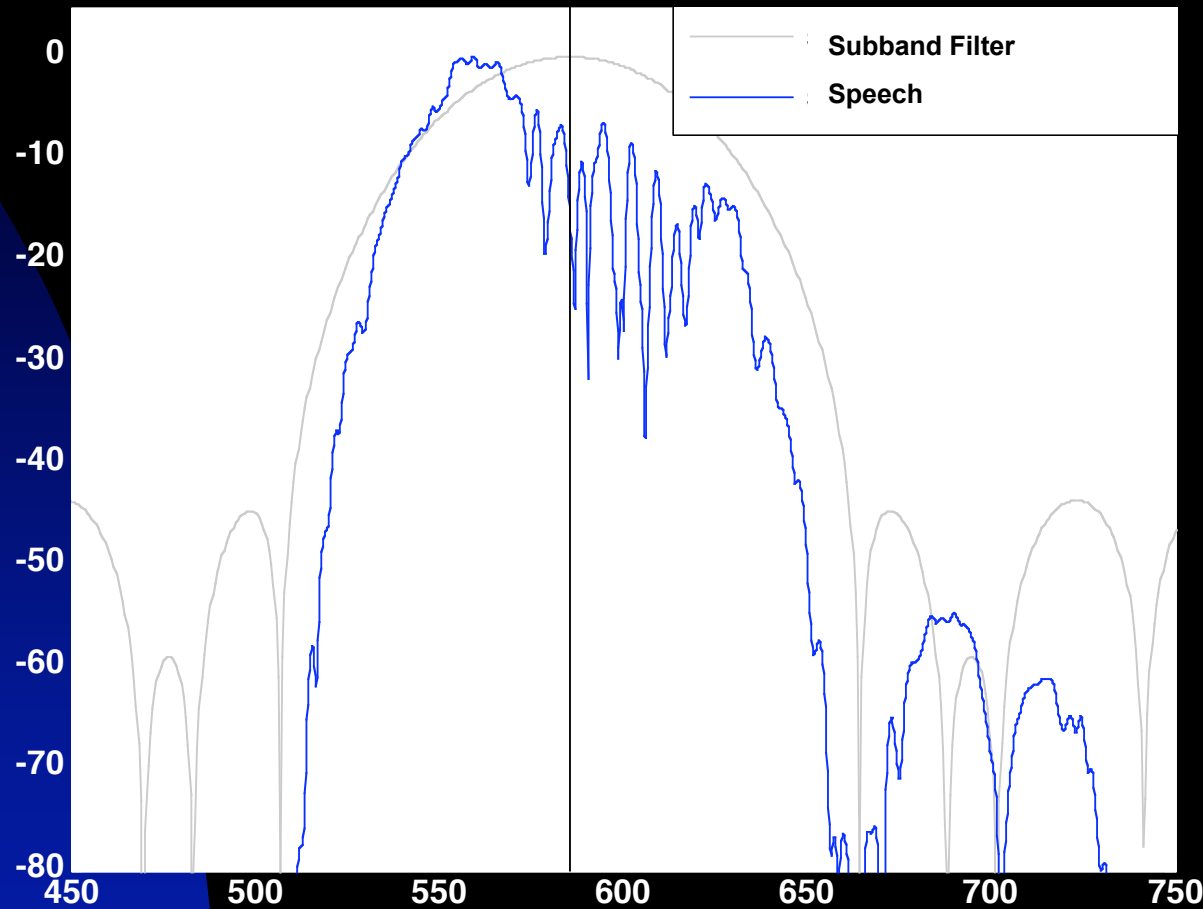
- Symmetric
- Not Positive-Definite

Complex Modulator



- Not-Symmetric
- Not Positive-Definite

An Example Sub-band for Voiced Speech



Modulator can't be non-negative and real in time

Instead need modulator (AM) times carrier (FM or pitch harmonic)!

Some Recent Demonstrations and Results

✎ Coherent Modulation Filter-Based Enhancement in noise from Schimmel, Atlas ICASSP 2007:

◆ Before Processing



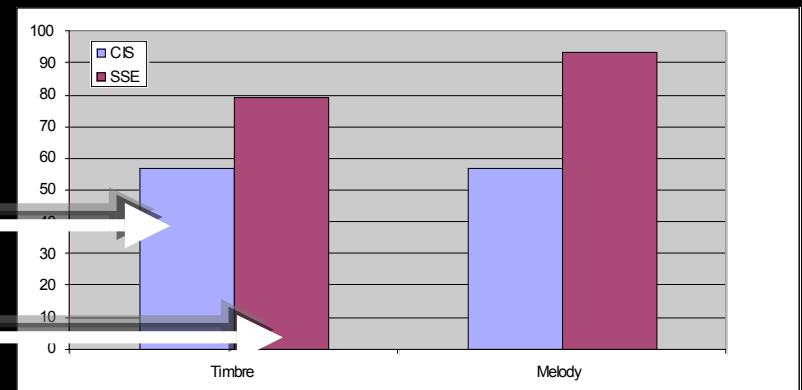
◆ After Processing, 2-12 dB SRT improvement



✎ Cochlear implant simulations, from Nie, King, Atlas, et al, Conf. on Impl. Aud. Pros. 2007:

Task was timbre and melody recognition.

Blue was standard incoherent envelope and **magenta** was *fixed* coherent envelope.



Timbre Accuracy Melody Accuracy

Conclusions

- The modulation spectra is a useful tool for speech analysis at the crucial 50-500 msec time rate.
- Modifying modulation spectra of natural speech requires careful analysis for the reduction of unintended side-effects.
- Coherent demodulation (even with fixed carriers) offers a useful and distortion-free alternative over previous incoherent magnitude and Hilbert envelop approaches.