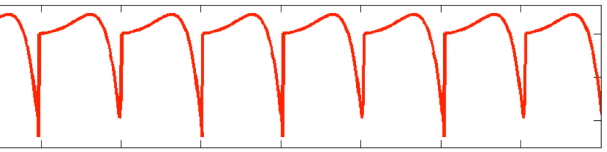
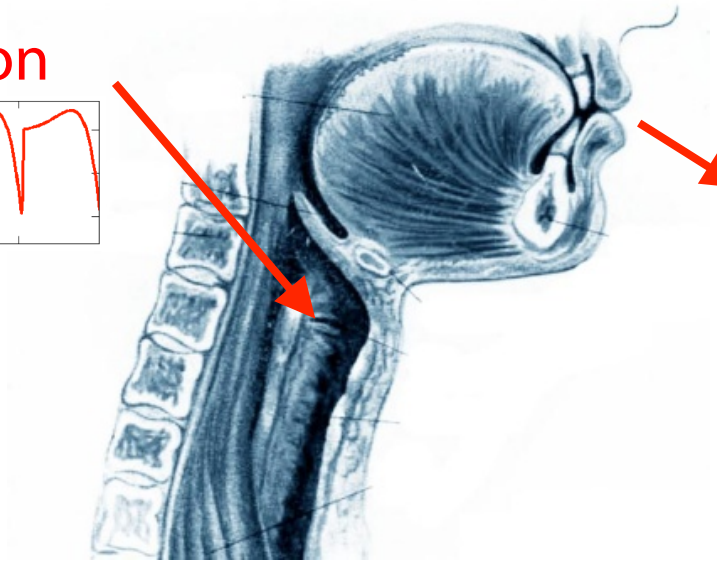
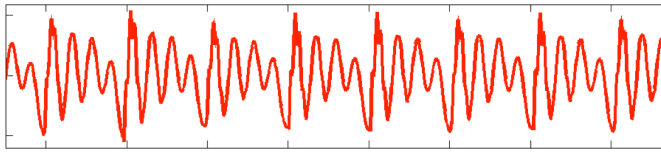
The goal of Glottal Inverse Filtering is to recover the glottal excitation and the vocal tract filter

Glottal excitation





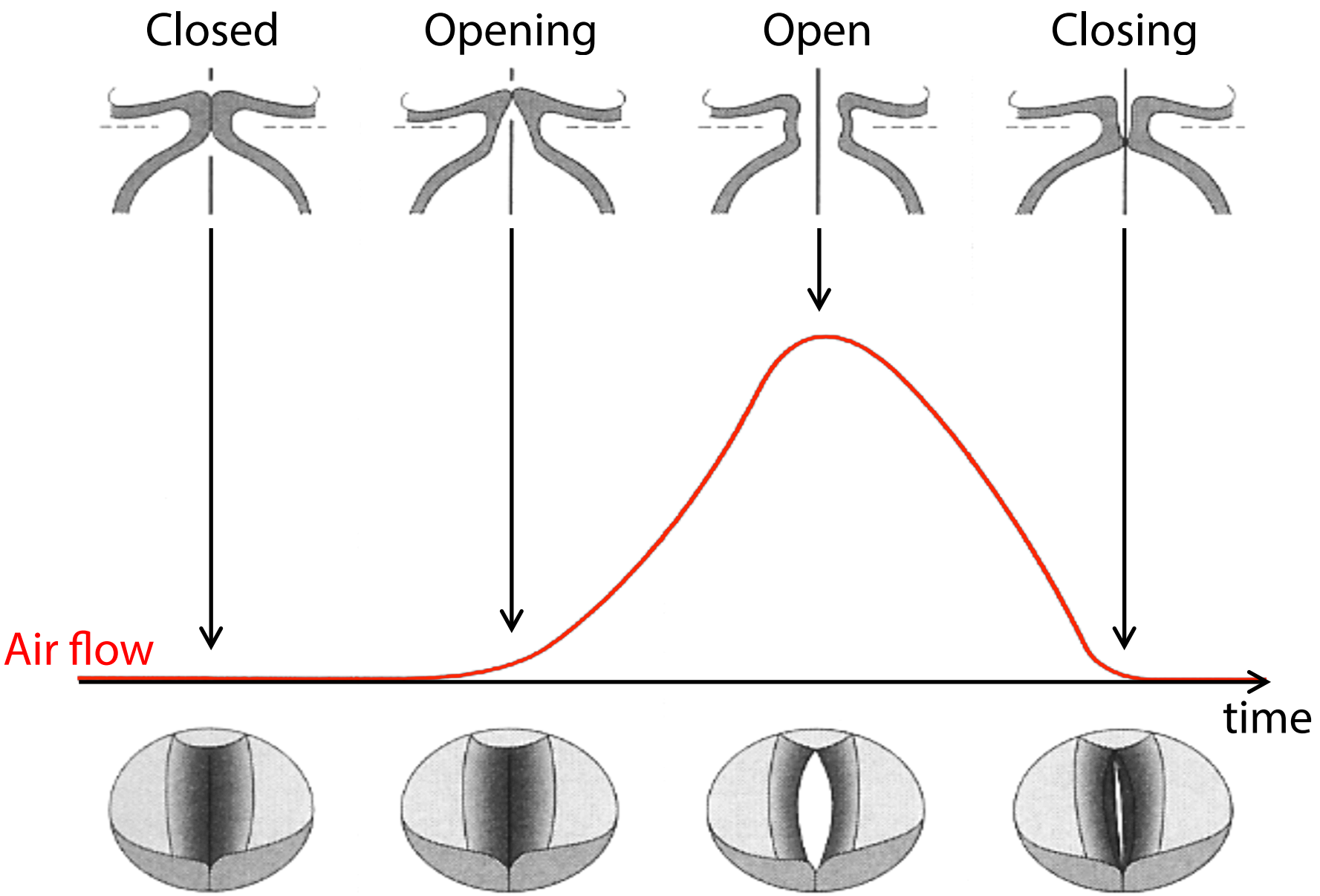
Speech signal



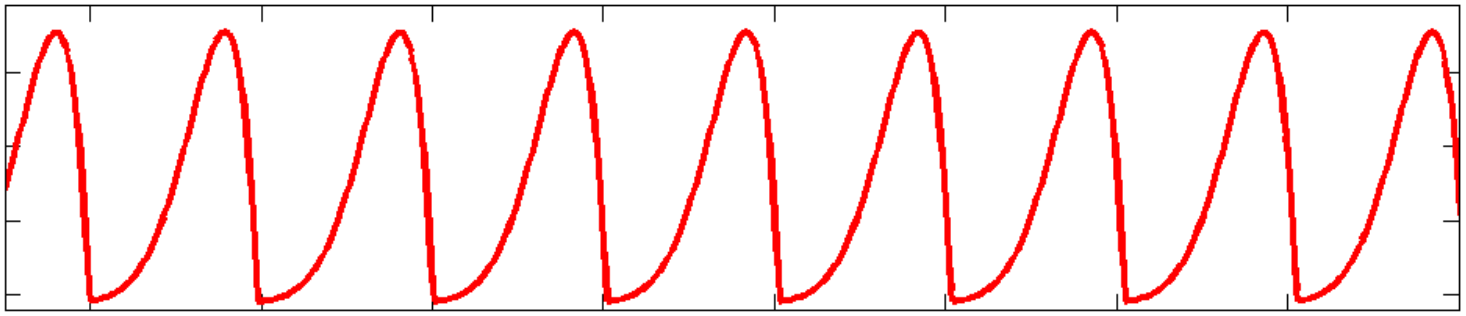
Direct problem: If we know the glottal excitation signal and the shape of the vocal tract, what does the microphone record?

Inverse problem: Given a speech signal recorded by a microphone, find the glottal excitation and the vocal tract.

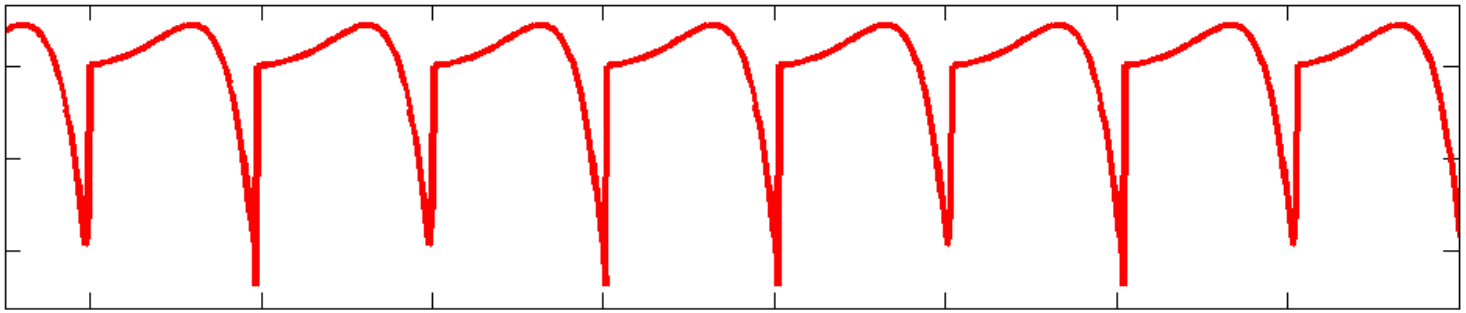
Glottal flow as function of time



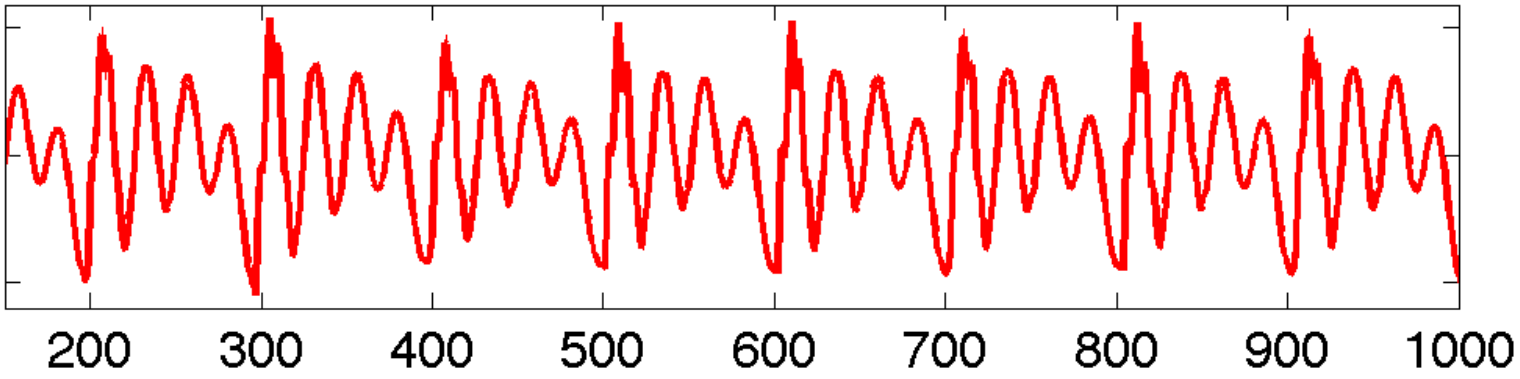
Air flow



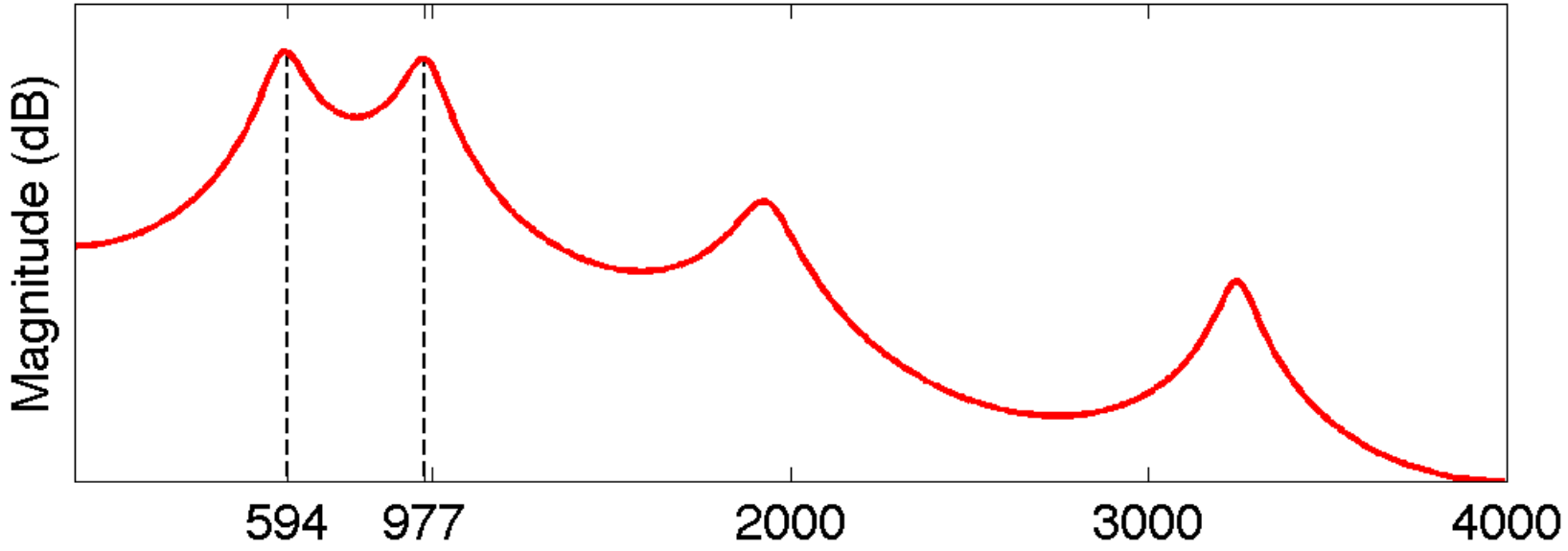
Air pressure



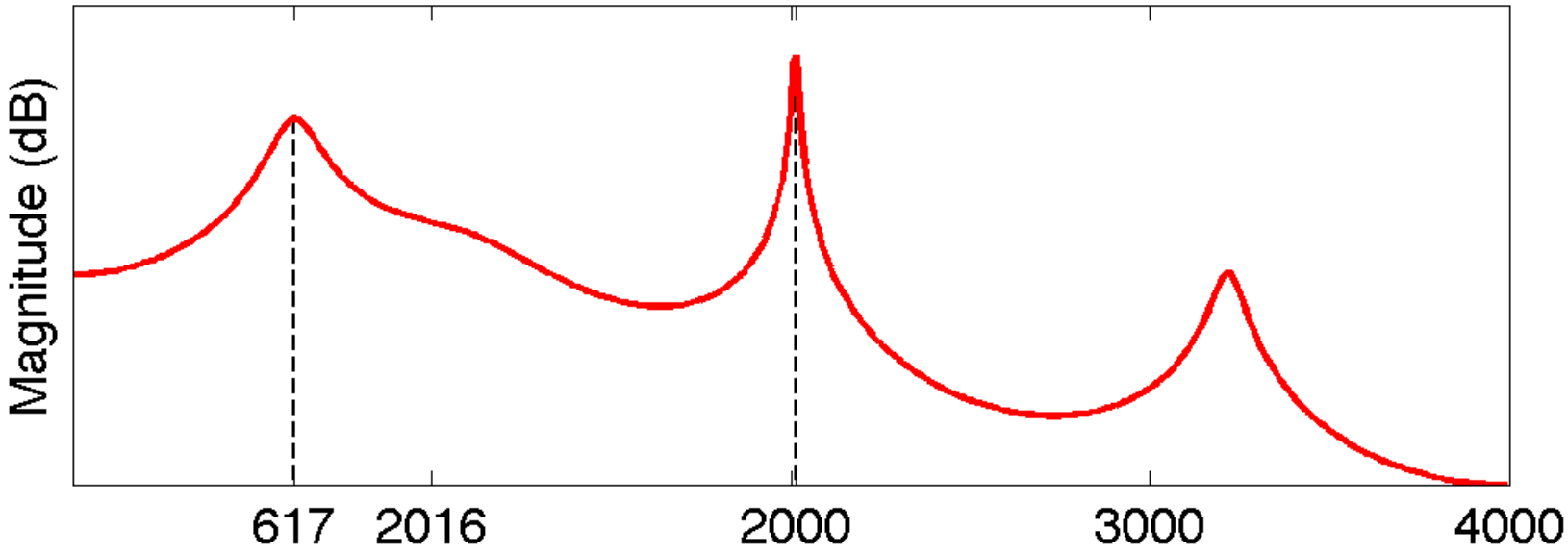
Signal recorded by microphone



The effect of the vocal tract is analogous to a frequency equalizer. Here vowel “a”



The effect of the vocal tract is analogous to a frequency equalizer. Here vowel “e”

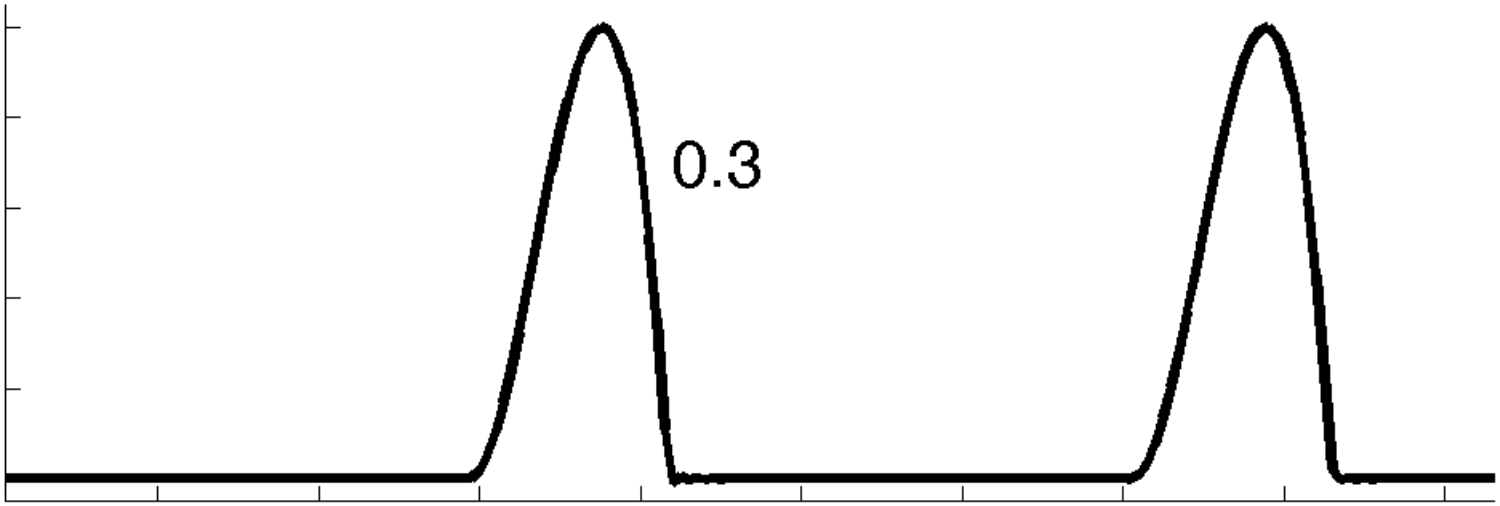


An improved GIF algorithm has important applications

1. Computational speech synthesis:
Clearer information announcements,
more efficient automatic telephone-based services, and
devices that help handicapped people express emotions.

2. Noise-robust automatic speech recognition:
Efficient and reliable man-machine interfaces.

We use the Klatt model for the glottal excitation



The Klatt model has only one parameter called K,
with values between zero and one.

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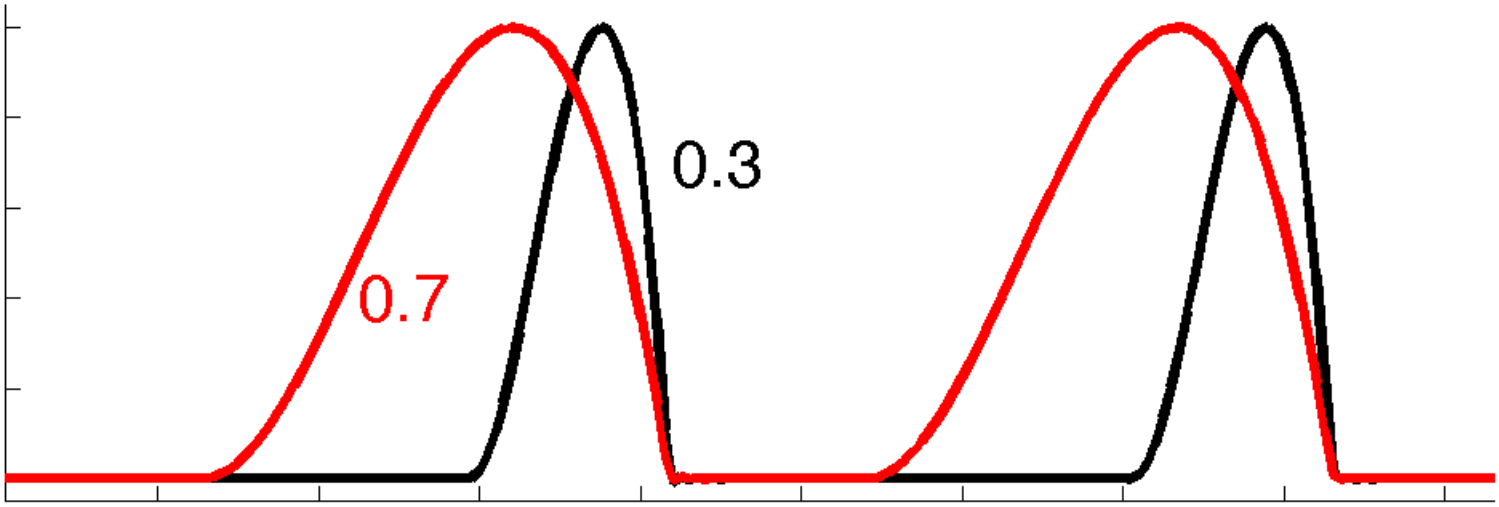

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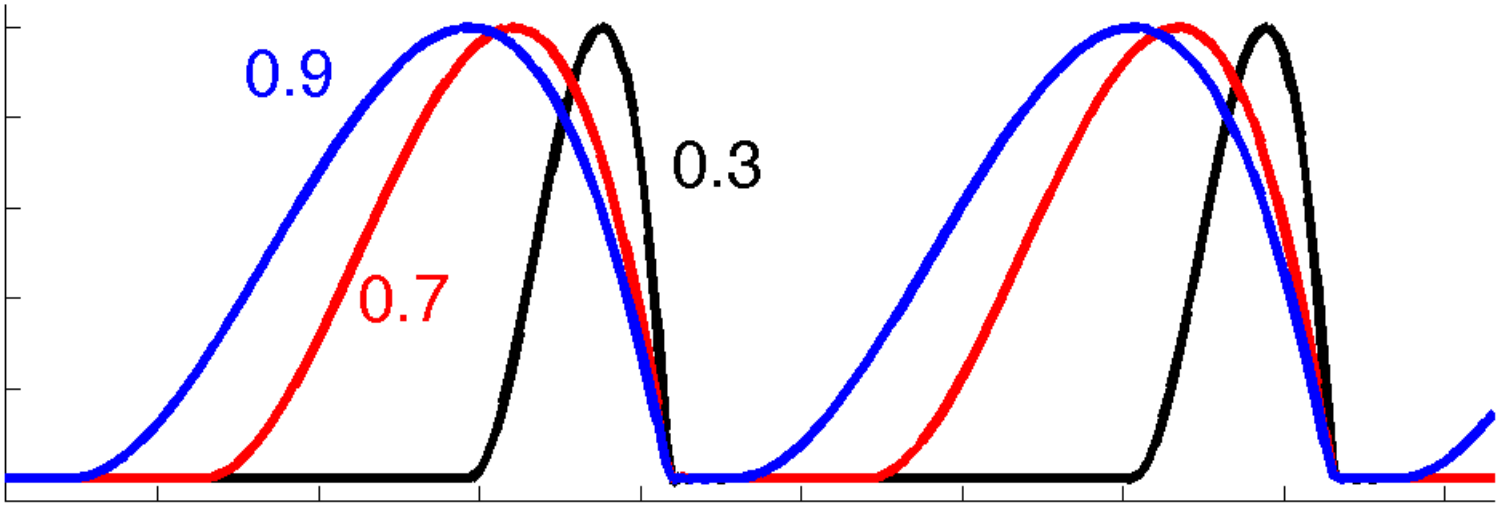
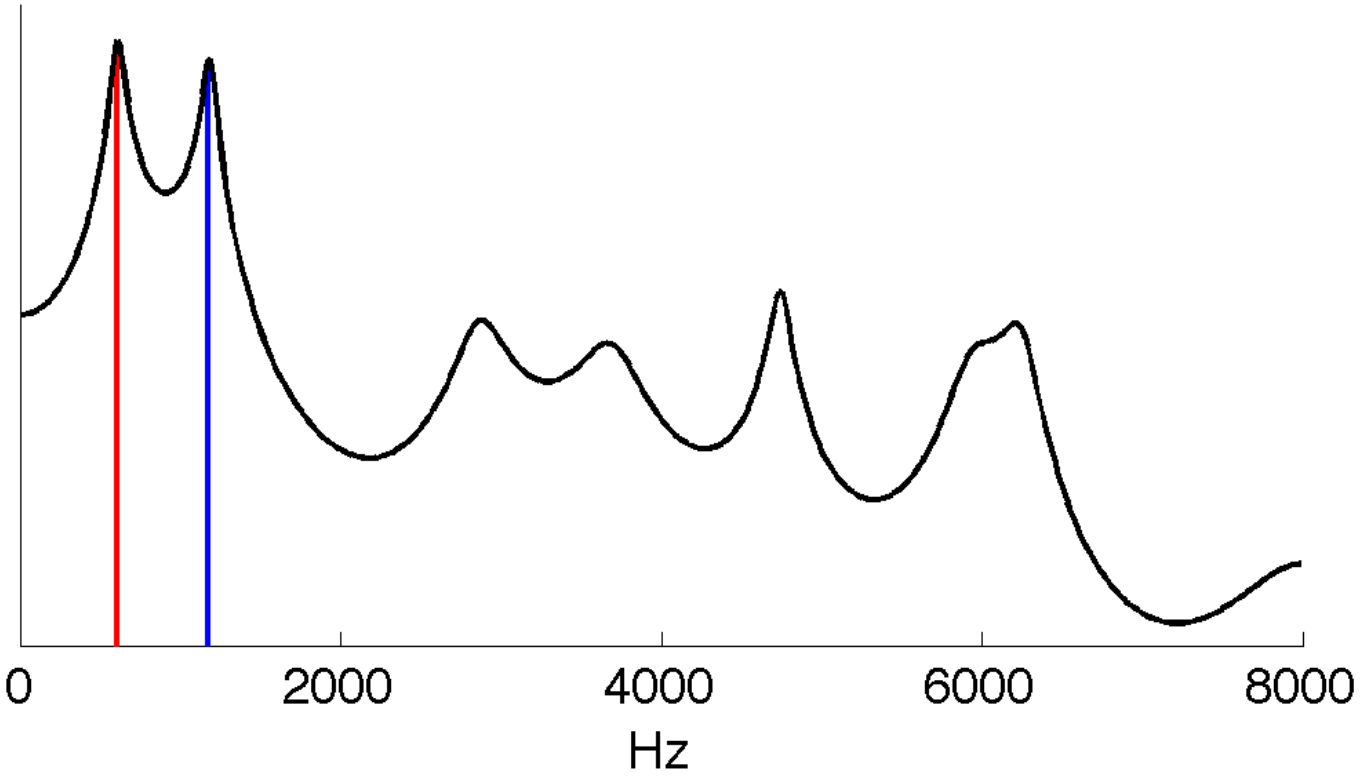
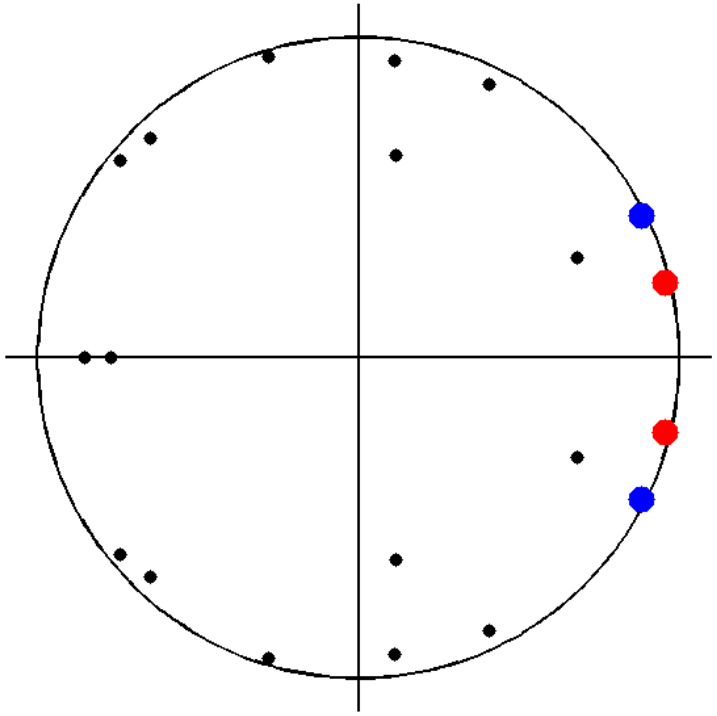


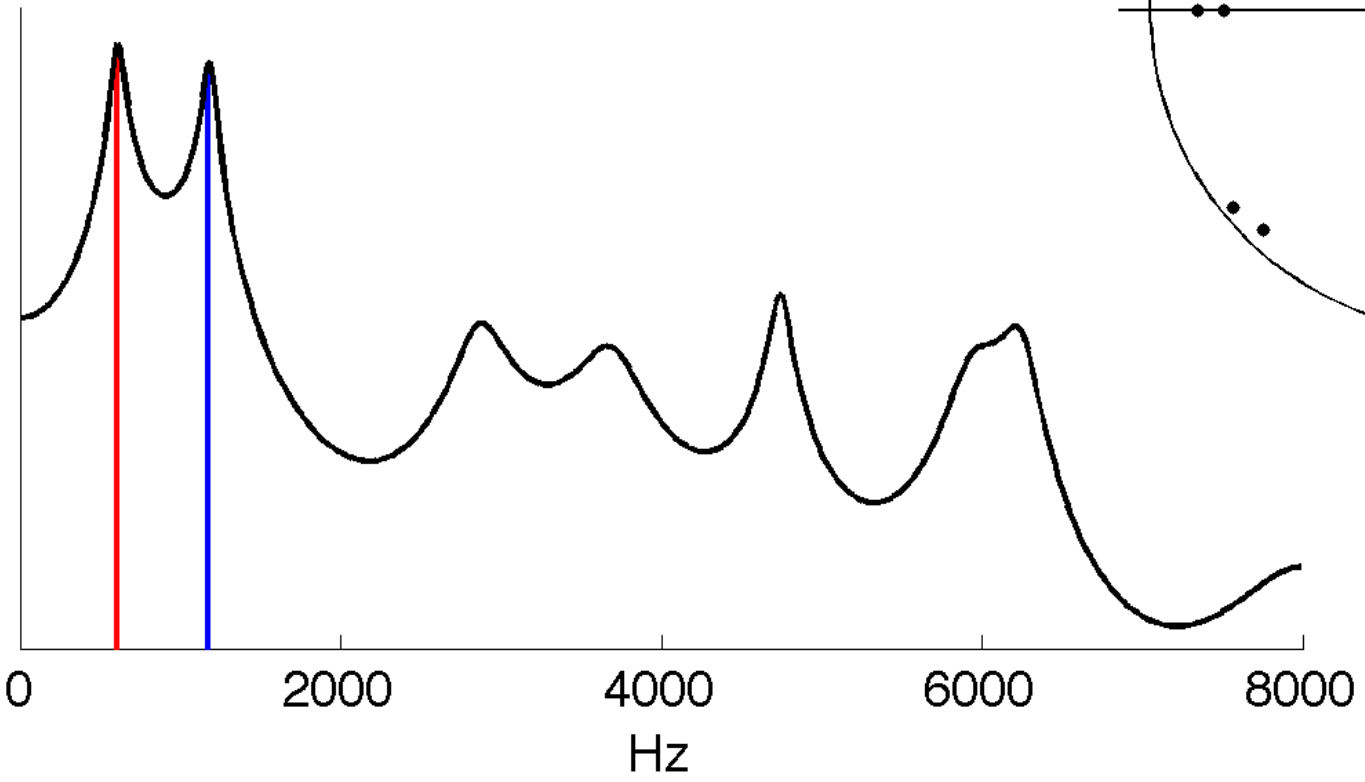
The Klatt model has only one parameter called K,
with values between zero and one.

We model the effect of the vocal tract by a linear filter, much like a frequency equalizer

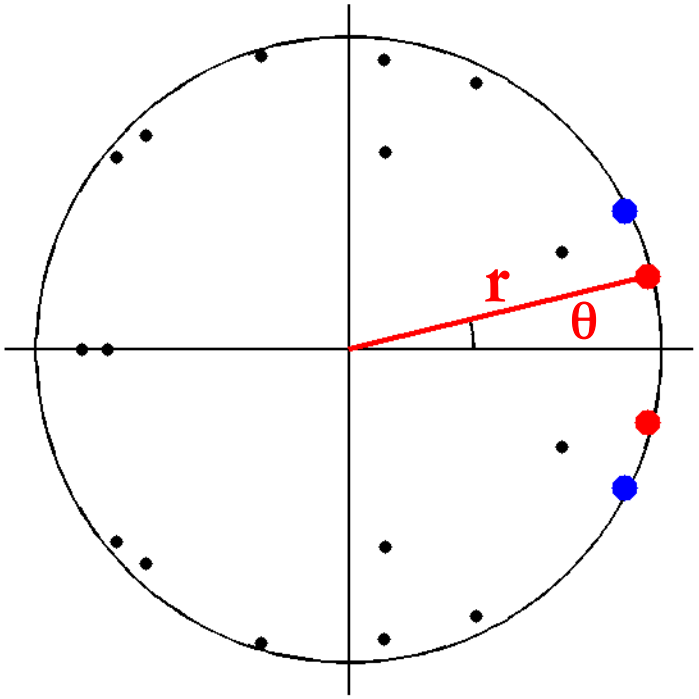


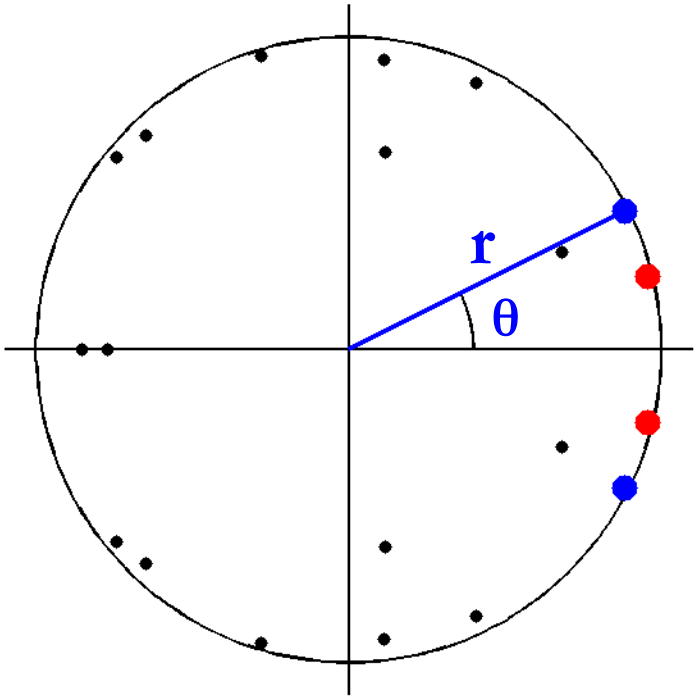
Technically, the frequency response is described by an all-pole filter





Looking at two first formants leads to four parameters for the vocal tract

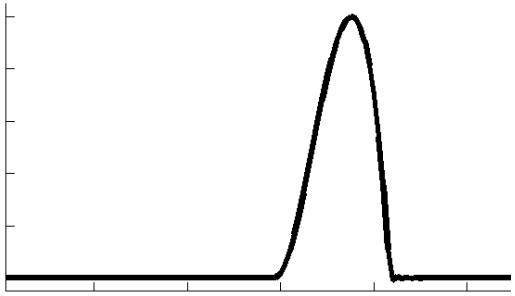




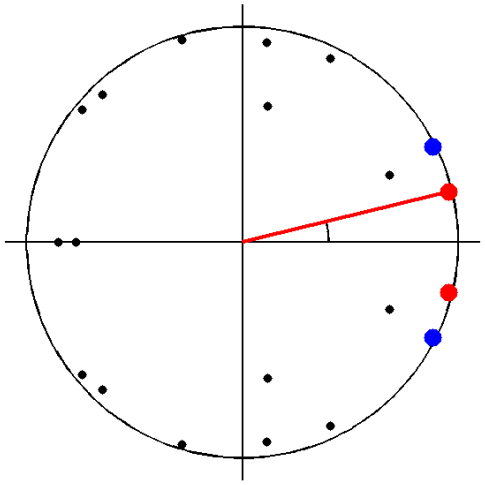
Angle and length of the pole corresponding to the first formant

Angle and length of the pole corresponding to the first formant

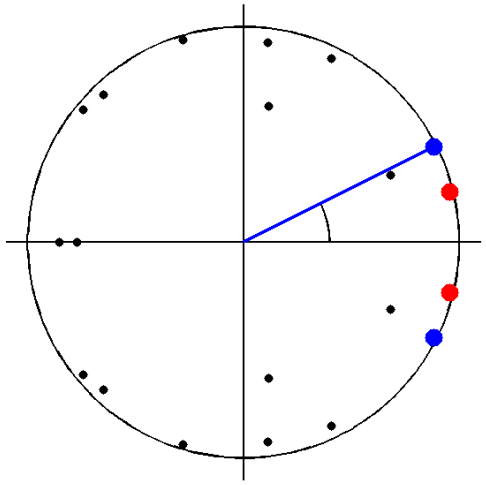
In this model, glottal inverse filtering means finding these five numbers:



K



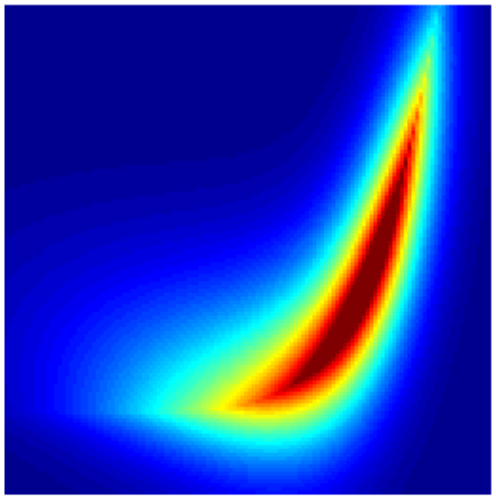
θ,r

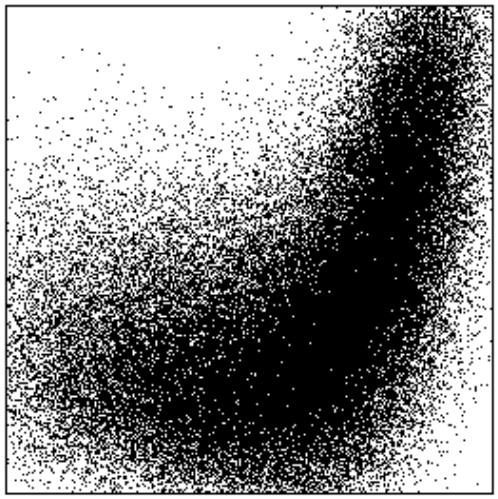


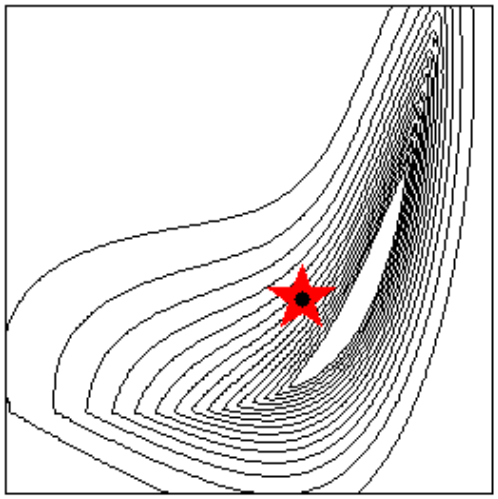
θ,r

But where does Monte Carlo come in the picture?

Markov chain Monte Carlo enables integration in high-dimensional probability space







The Markov chain Monte Carlo method produces a long sequence of excitations and vocal tracts

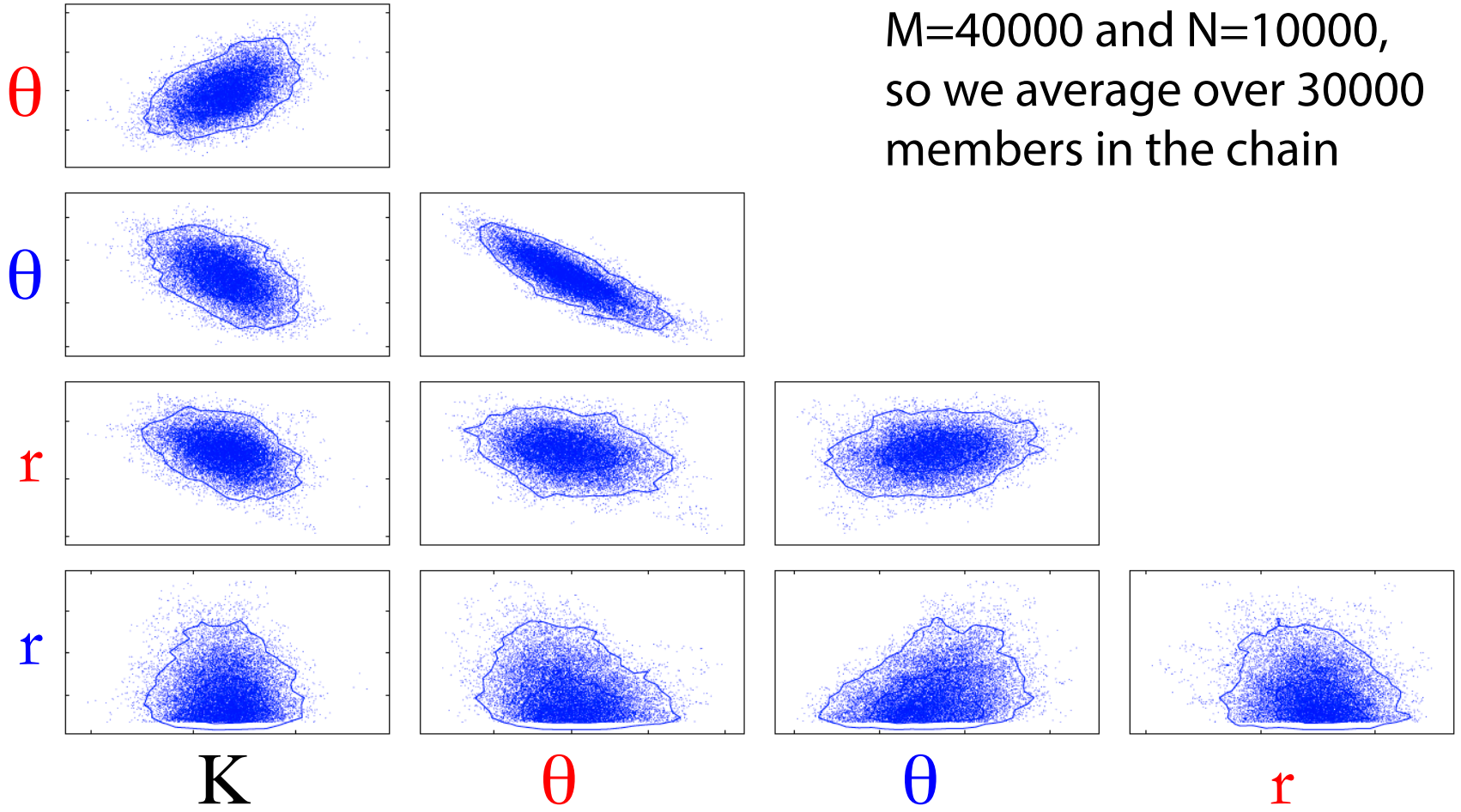
$$\underbrace{\begin{bmatrix} K_1 \\ \theta_1 \\ r_1 \\ \theta_1 \\ r_1 \end{bmatrix}, \begin{bmatrix} K_2 \\ \theta_2 \\ r_2 \\ \theta_2 \\ r_2 \end{bmatrix}, \ldots, \begin{bmatrix} K_N \\ \theta_N \\ r_N \\ \theta_N \\ r_N \end{bmatrix}}_{\text{discard}}, \underbrace{\begin{bmatrix} K_{N+1} \\ \theta_{N+1} \\ r_{N+1} \\ \theta_{N+1} \\ r_{N+1} \end{bmatrix}, \begin{bmatrix} K_{N+2} \\ \theta_{N+2} \\ r_{N+2} \\ \theta_{N+2} \\ r_{N+2} \end{bmatrix}, \ldots, \begin{bmatrix} K_M \\ \theta_M \\ r_M \\ \theta_M \\ r_M \end{bmatrix}}_{\text{average}}$$

The choosing of the members in the above chain is done in a controllably random way. As a result, the chain explores all combinations of glottal excitation and vocal tract filter that

(1) Produce closely the measured signal, and

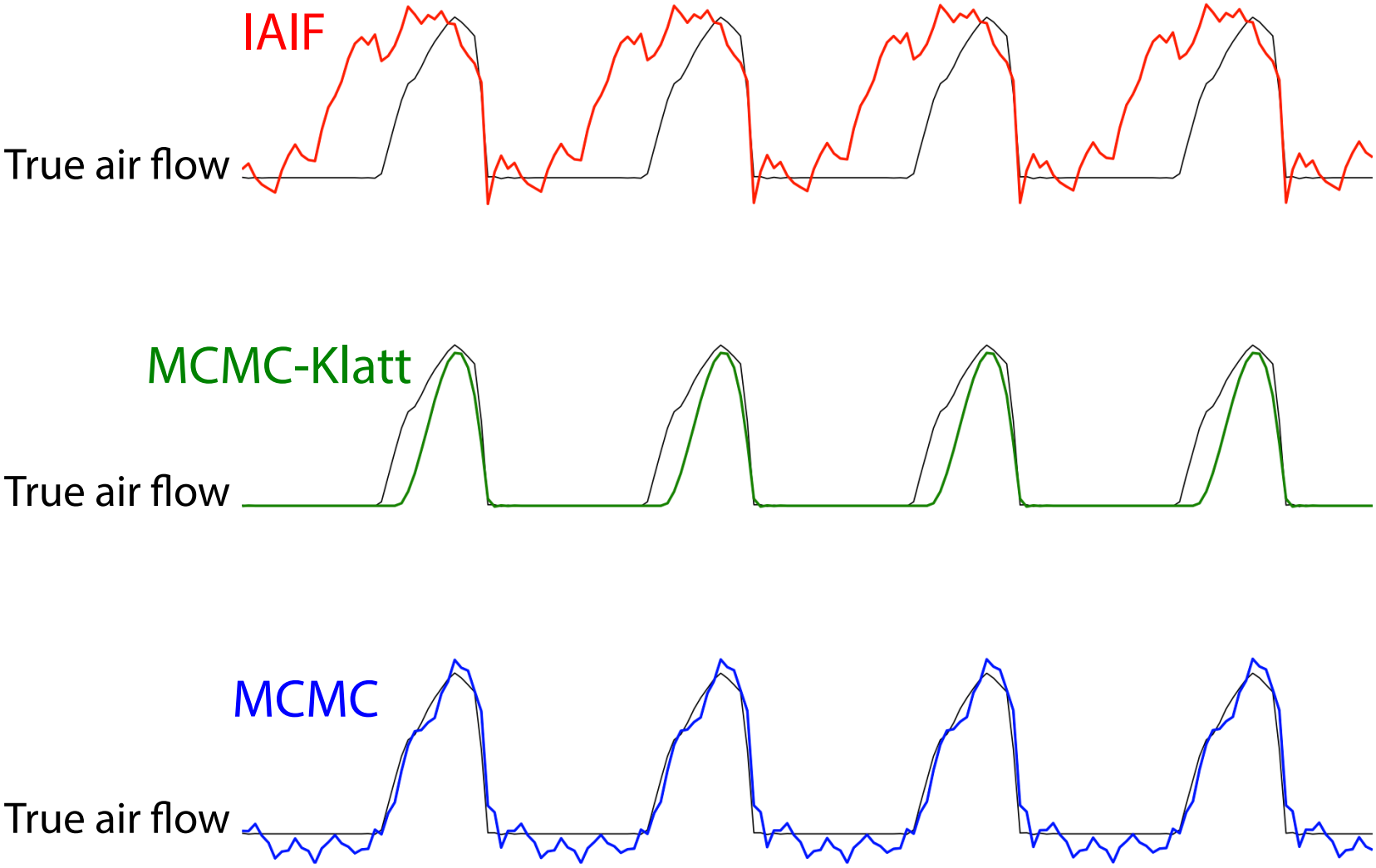
(2) Satisfy our a priori information (for example, if we know the vowel, we have a rough idea where the main formants are located)

This is an illustration of all the cross-correlations of parameters in the whole MCMC chain



M=40000 and N=10000,
so we average over 30000
members in the chain

As a result, we can improve on the classical IAIF glottal inverse filtering method



Auvinen, Raitio, Airaksinen, S, Story & Alku, in press

Improved glottal inverse filtering can increase the quality of synthetic speech

Let us compare examples of synthetic speech.

Baseline

HMM modeling
Raitio, Suni, Yamagishi, Pulakka, Nurminen, Vainio, Alku (2010)