Windows

Sample Size and Shape

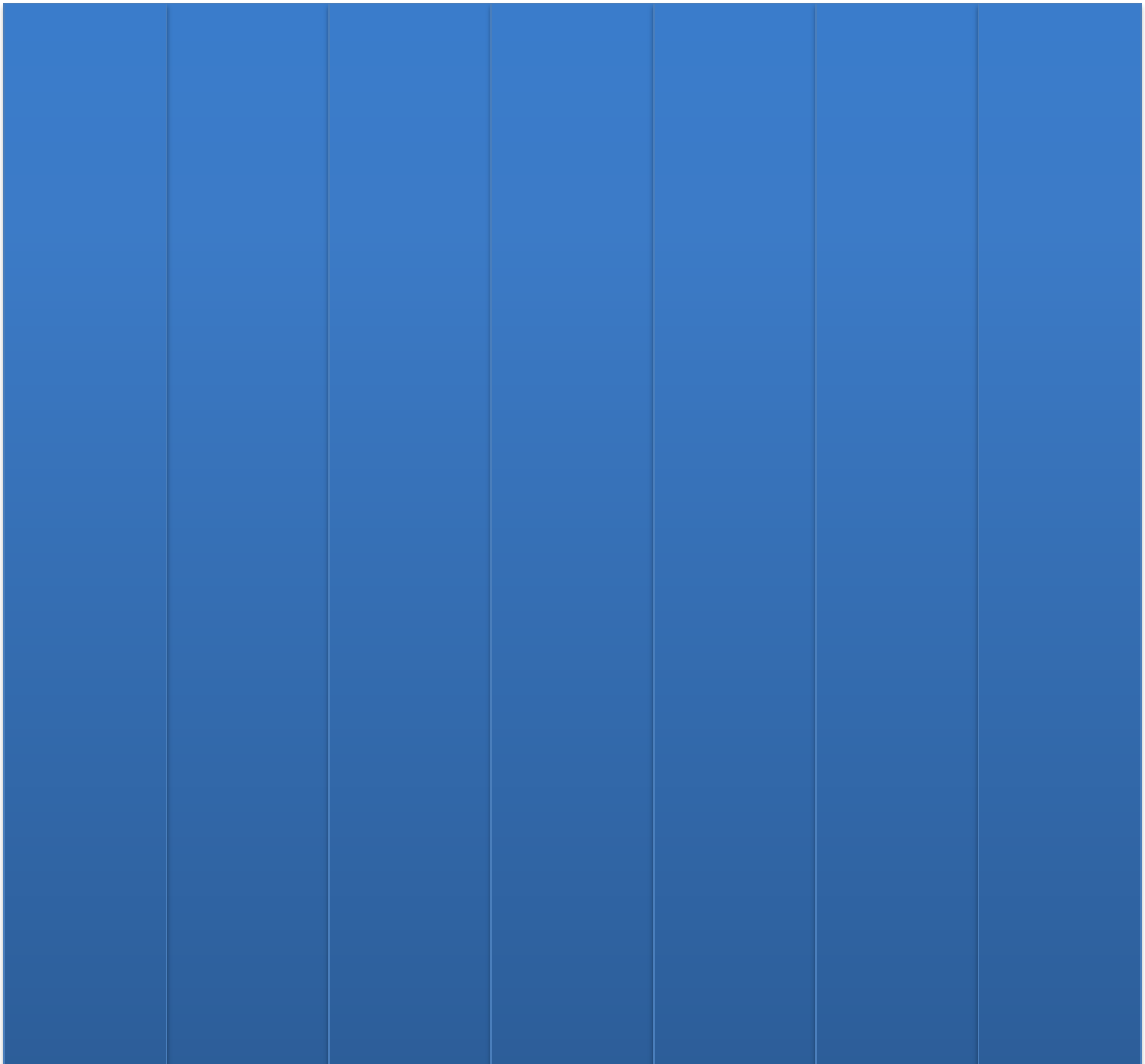
- Spectrogram
- Broadband
- Formants
- Narrowband
- Harmonics
- Tradeoffs
- Window step size
- Window shape

The Window Analogy

When we talked about sampling frequency, we failed to mention that the samples are not the same in every case.

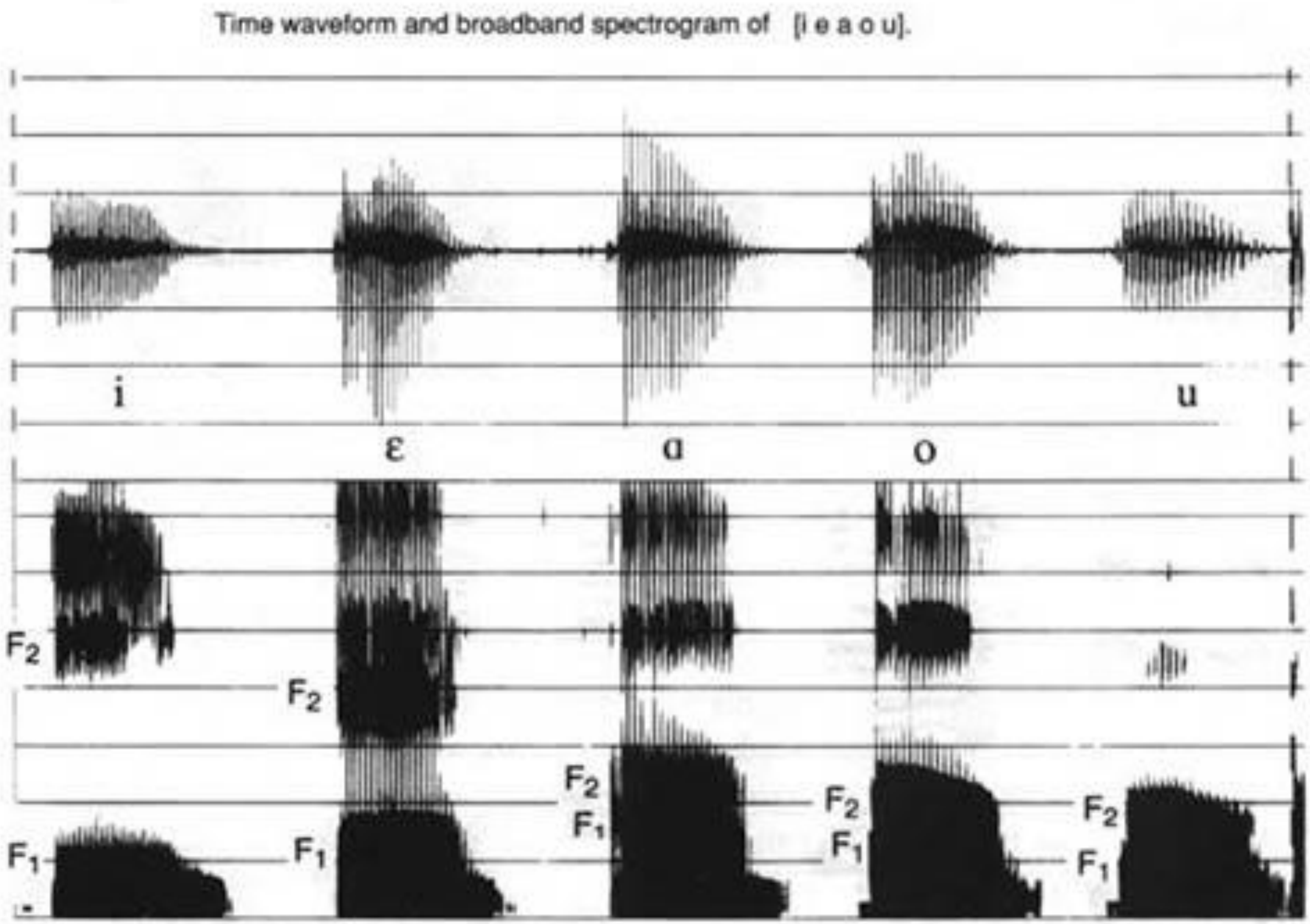
In fact, the size, shape and relative positions of each sample, affect what the output looks like.

Imagine viewing the world through different kinds of windows



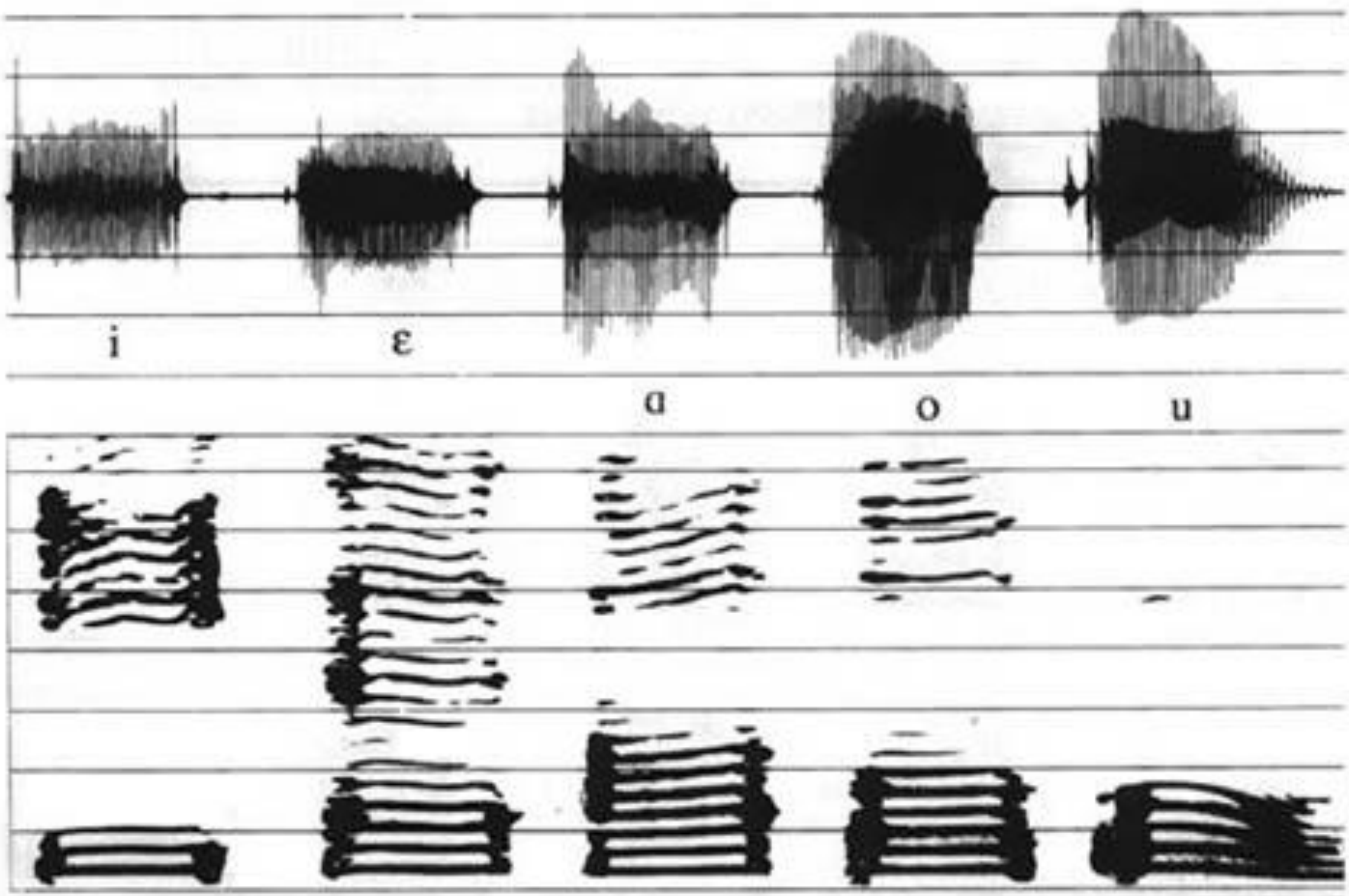
There are two main kinds of spectrographic voice analysis:

Broadband (bandwidth of 300-500 Hz)



Narrowband (bandwidth of 45-50 Hz).

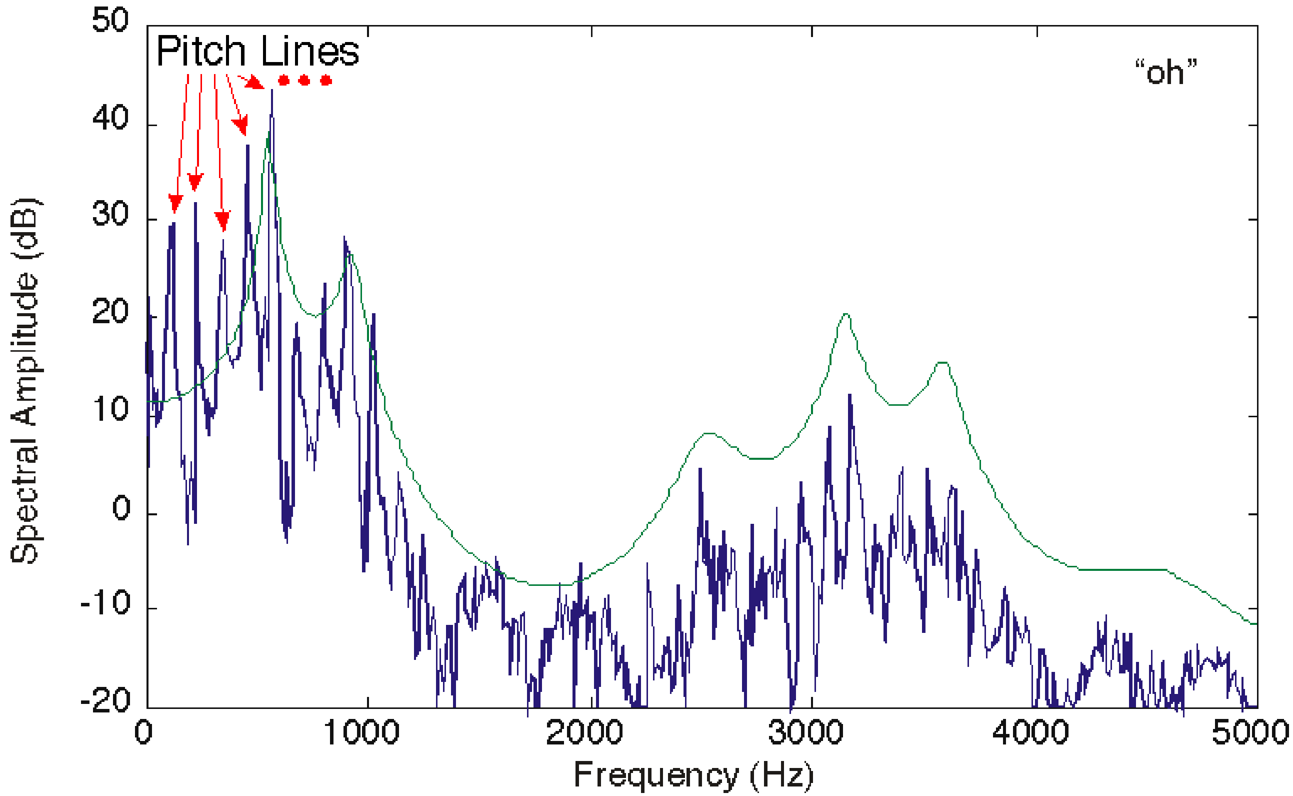
Time waveform and narrowband spectrogram of [i e a o u].



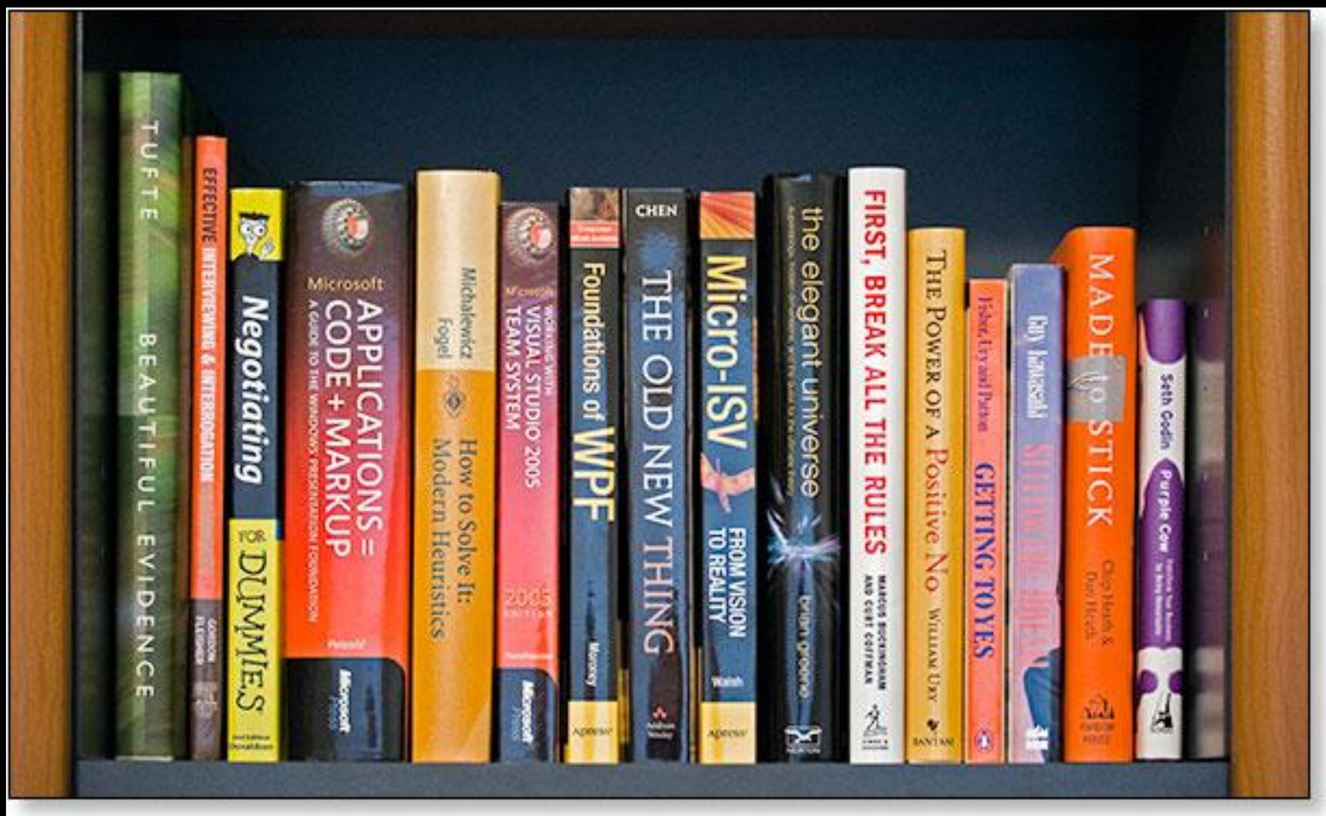
To calculate the spectrogram,

digital speech data is broken into chunks in the time domain.

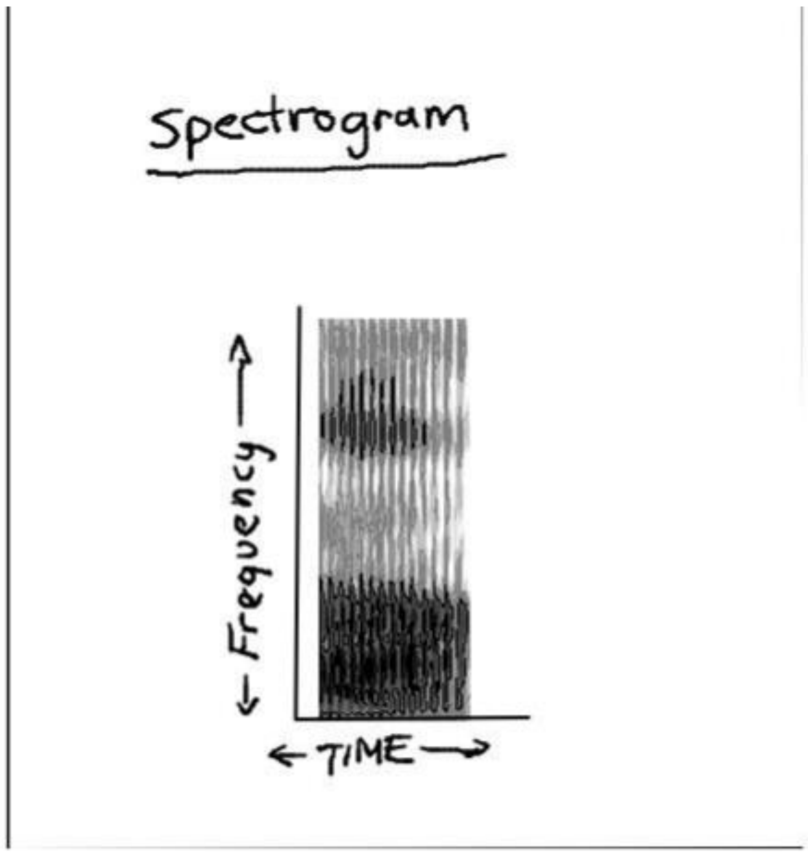
Each chunk is converted into a power spectrum.



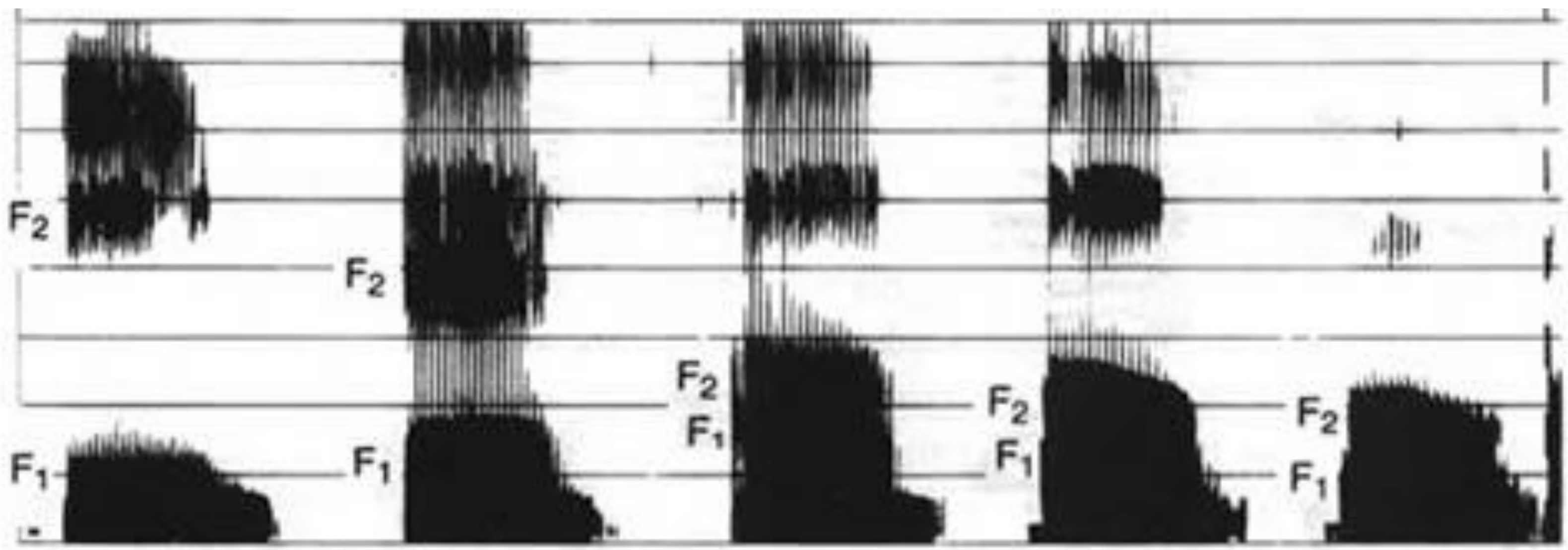
The power spectra are lined up next to each other, like books on a shelf.



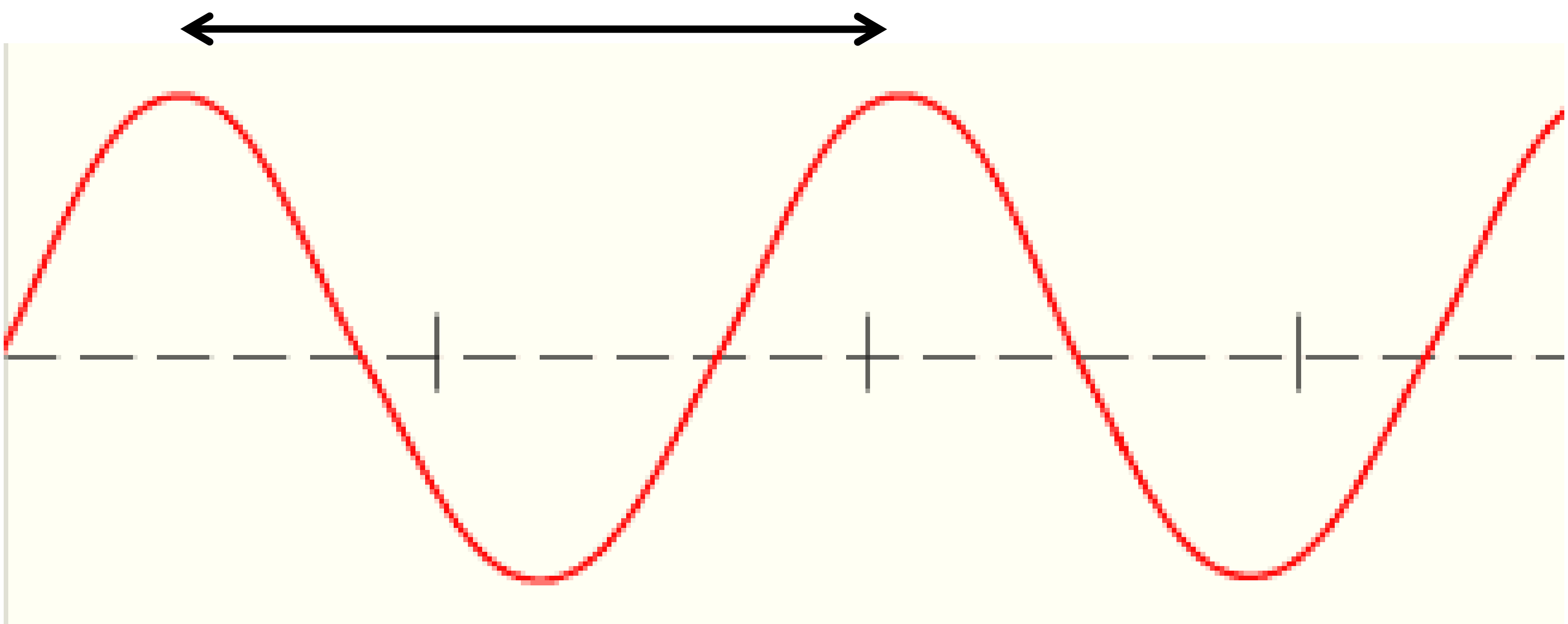
So that each spectrum corresponds to a vertical region in the spectrogram



- In a broadband spectrogram,
- the analysis window is so short (~5 ms),



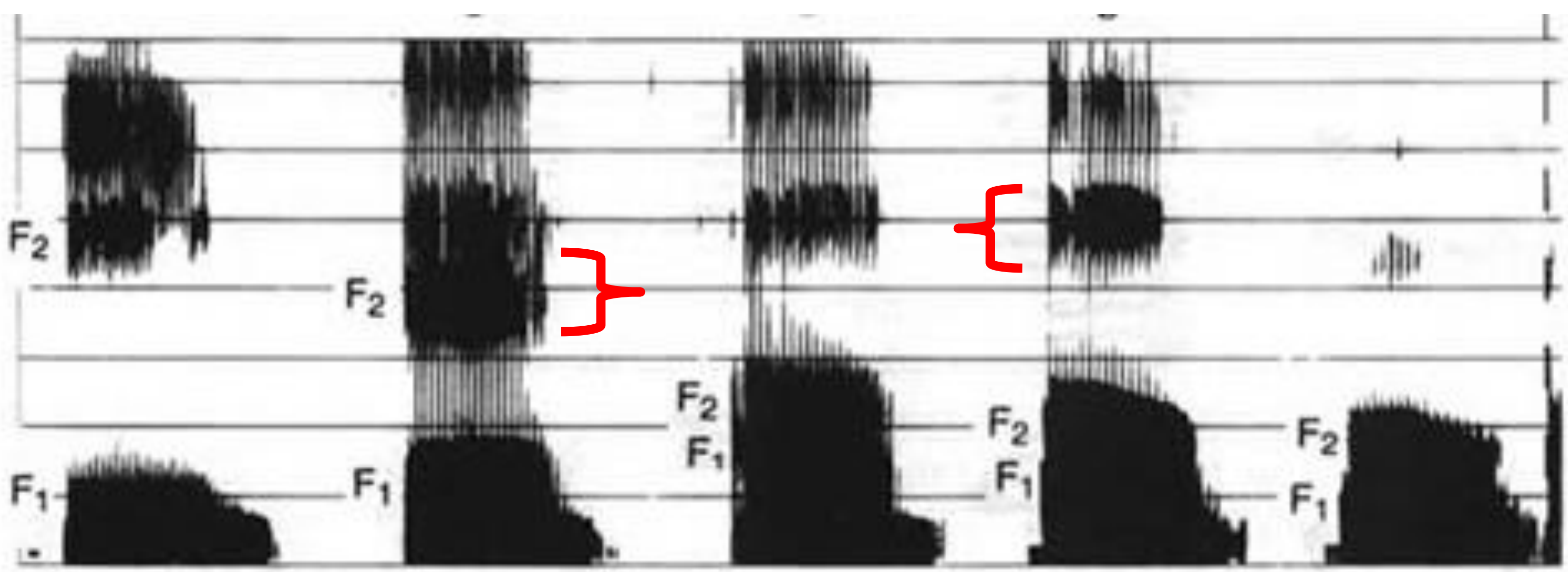
that each window contains only one wave period of the fundamental frequency.



This causes the harmonics of the fundamental to lack precision.

That is, frequency components within a 300-500 Hz bandwidth are not easily distinguished.

These blurred harmonics are called **formants**



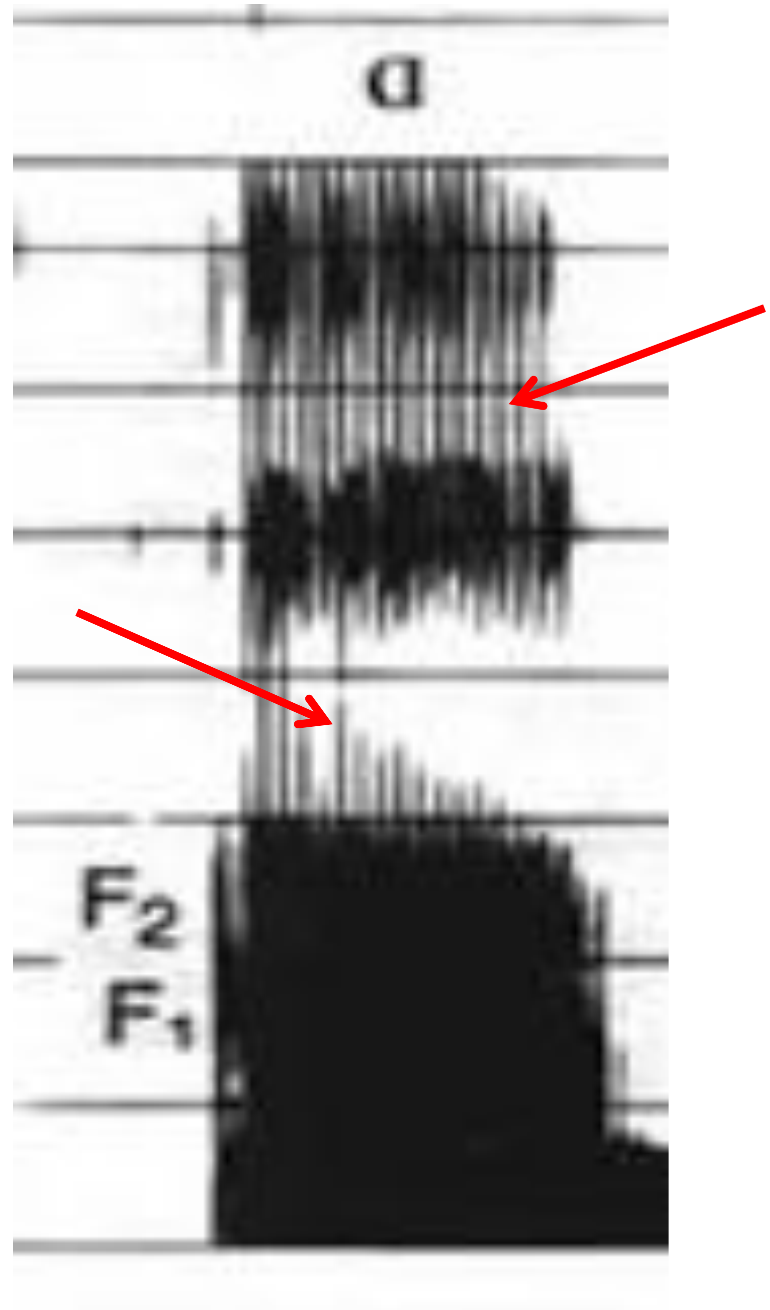
The wide bandwidth allows for excellent time resolution.

…remember Nyquist's theorum?

we are sampling fast enough (twice F0), to completely resolve F0.

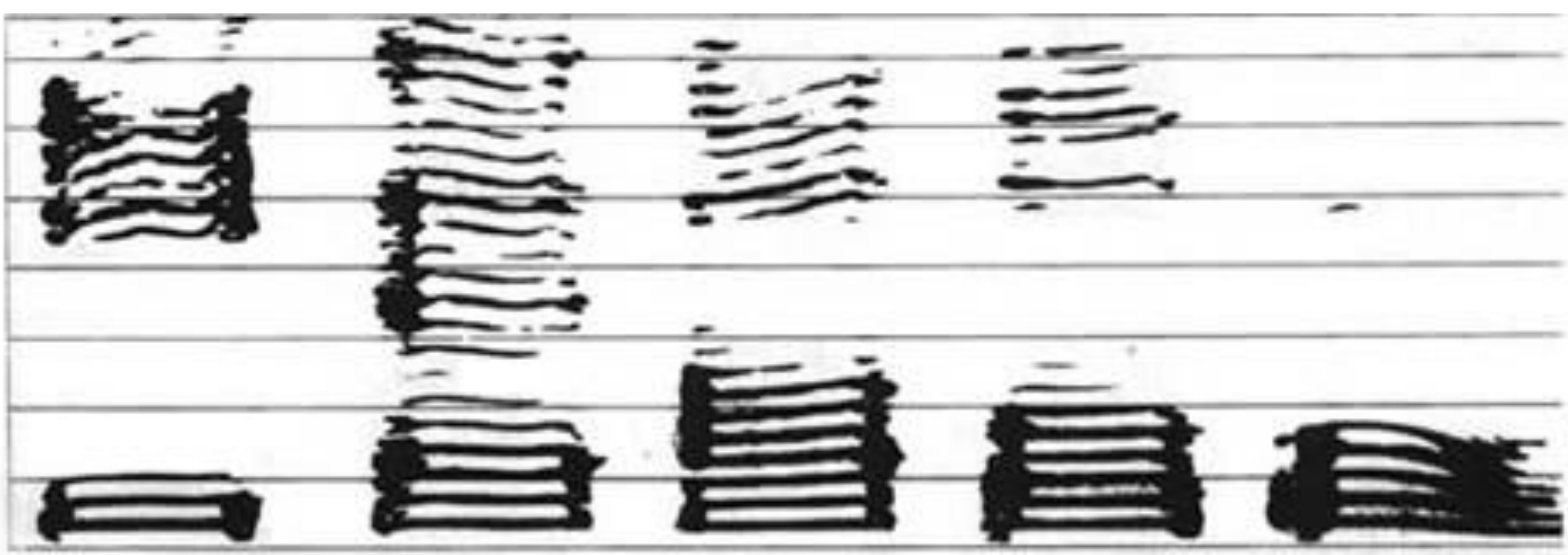
That's why you can see the energy peaks from each individual vibration of the vocal folds.

And you can determine F0 by counting the number of individual vertical lines per unit time.

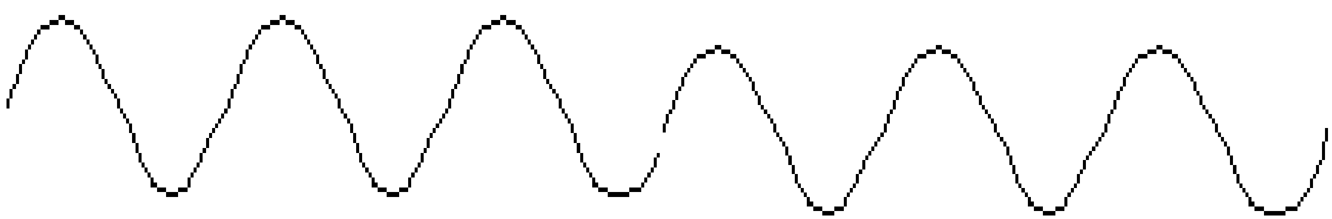


Narrowband

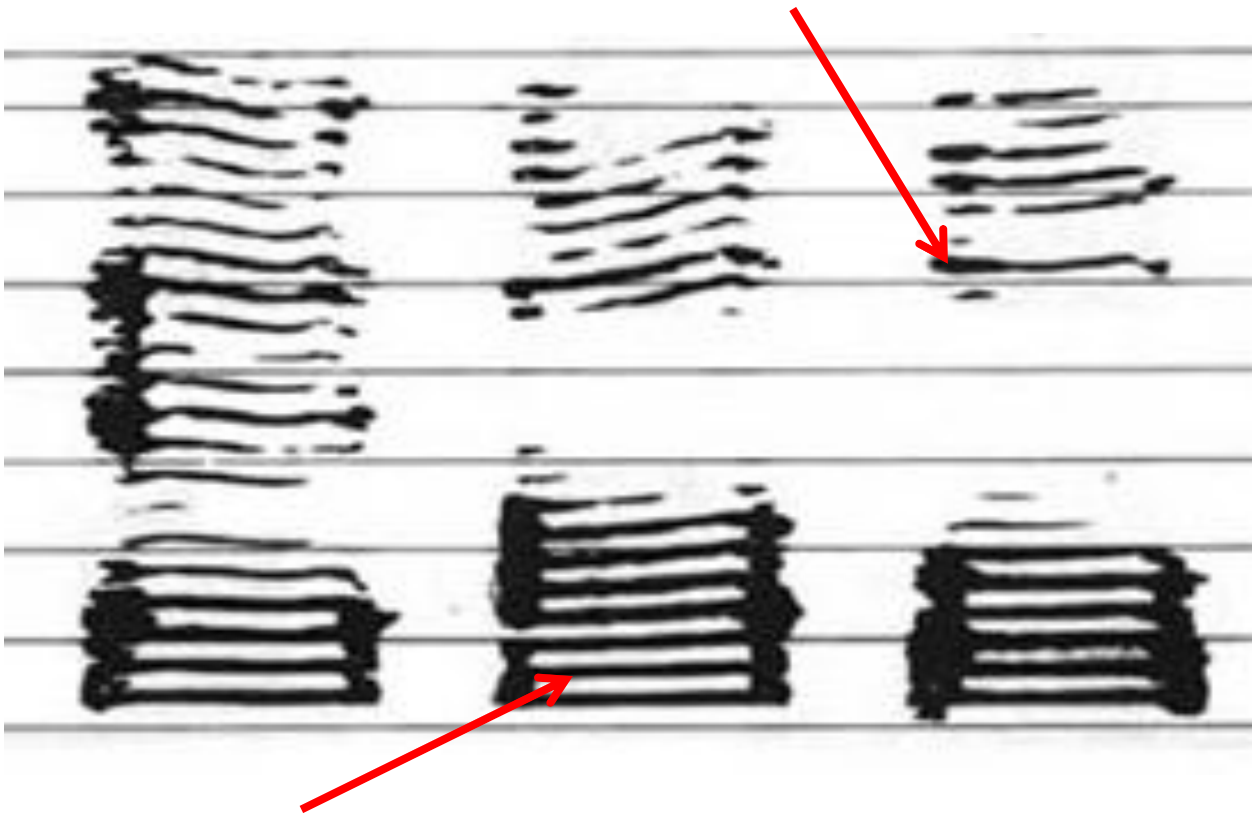
- If we increase the timespan of the window to ~30 ms,



then the analysis window includes more periods of the wave,



and the spectrogram can tell us the location of the harmonics with greater precision....



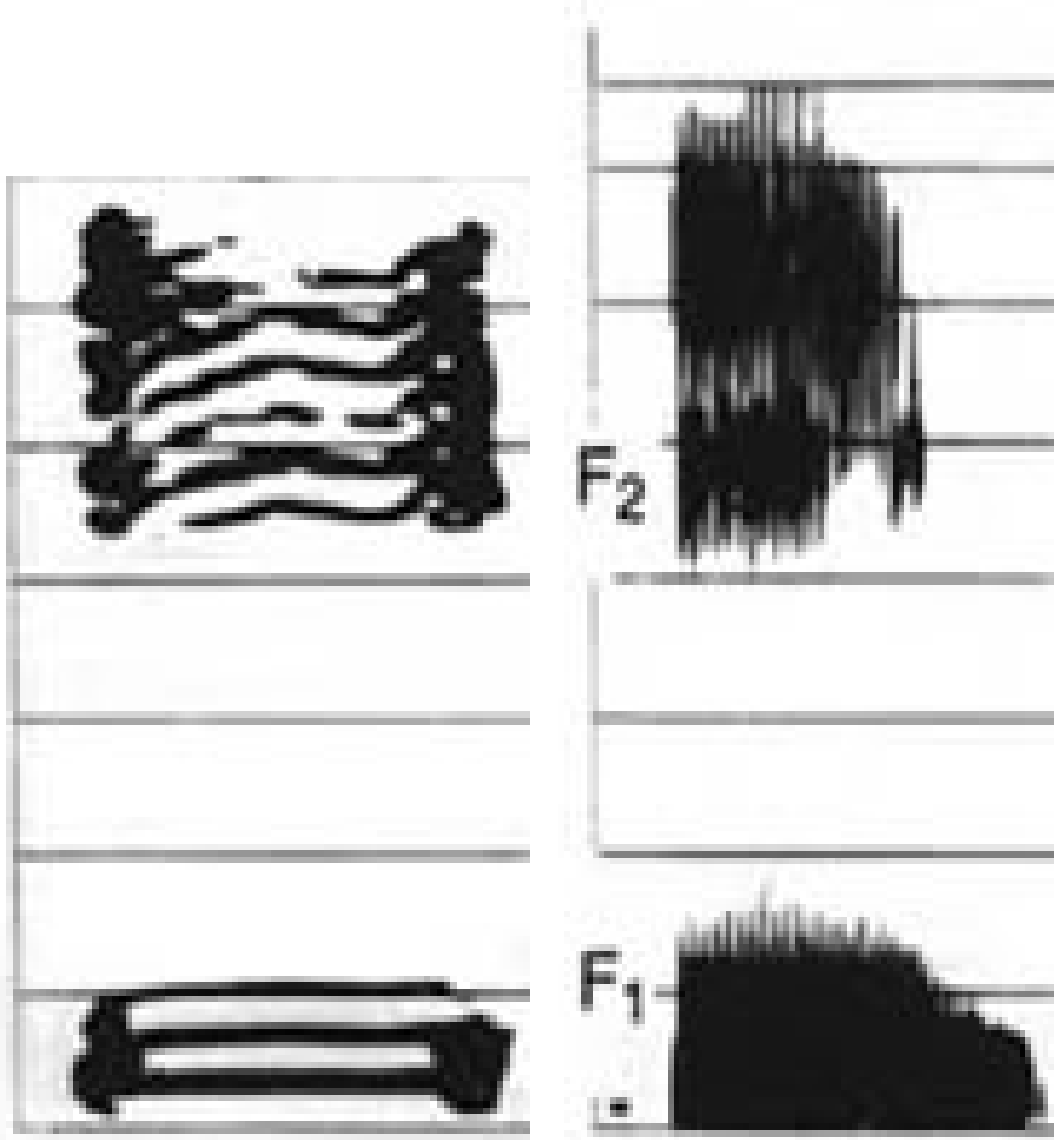
Put another way,

the window smoothes the signal in the time domain, averaging out fast changes;

but its time resolution is not good enough to isolate each individual cycle of vibration,

and the formant structure of the sound is not rendered as clearly as with a broadband analysis.

/i/



NARROWBAND **BROADBAND**

So, in general: longer time windows-> smoother energy, but you lose temporal detail, and vice versa.

The point is, there is a tradeoff:

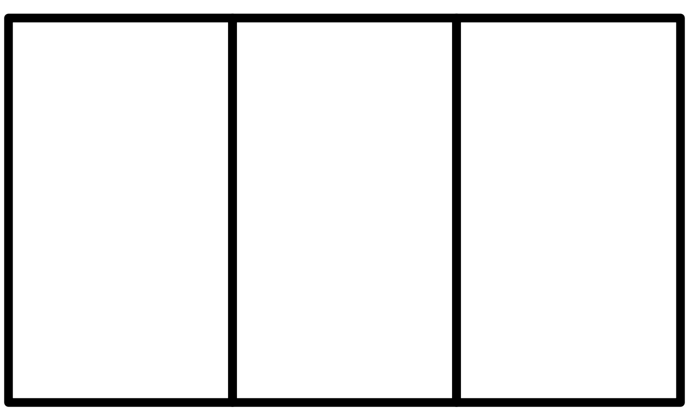
When we increase resolution in one respect, we decrease it in another.

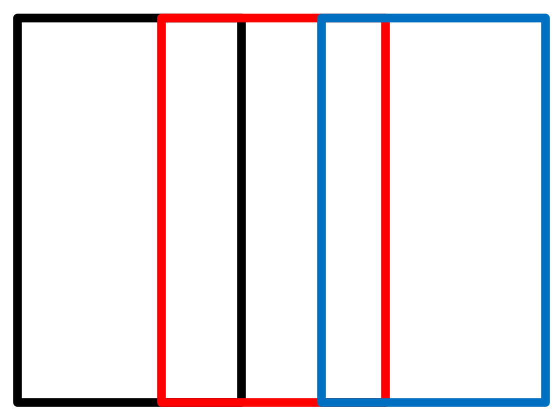
Although there will always be tradeoffs in signal processing, we can take steps to get the best signal possible.

How can you maximize temporal resolution and smooth energy signal at the same time?

One way is to control window overlap.

A good compromise between temporal and frequency resolution results from **overlapping the windows**

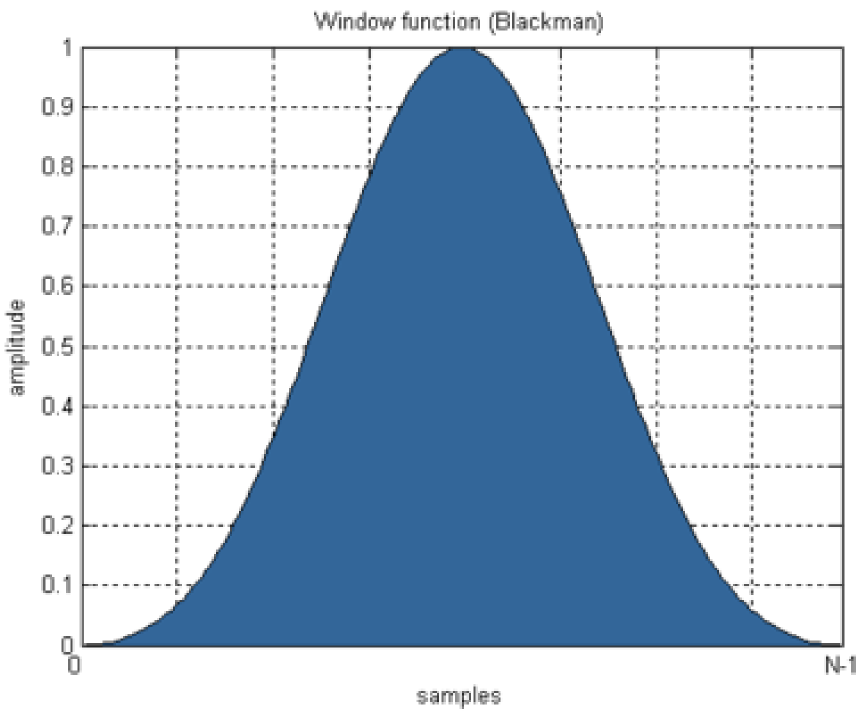


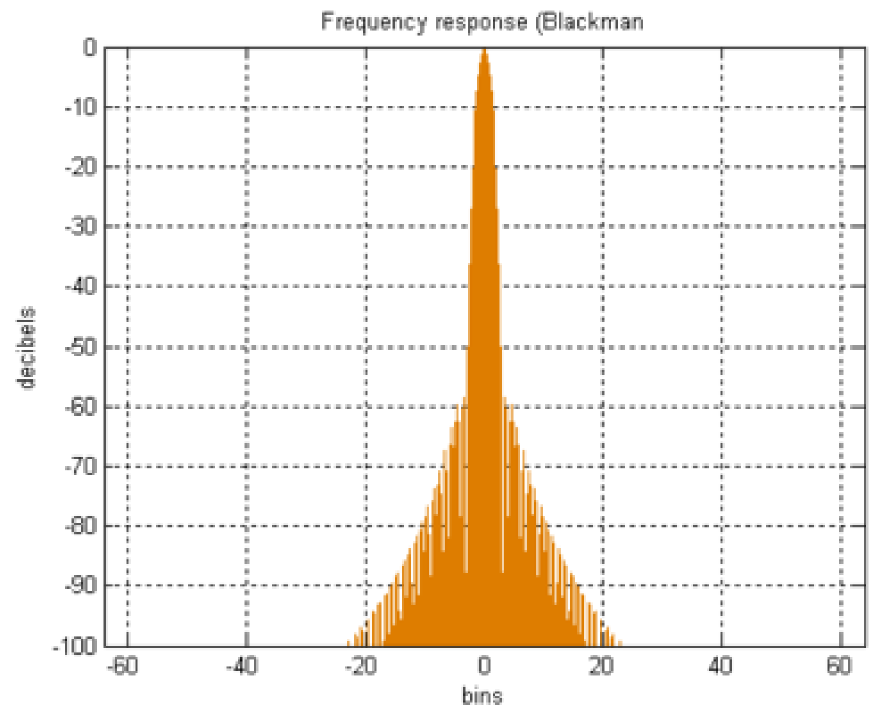


The degree of overlap is called
Window Step Size.

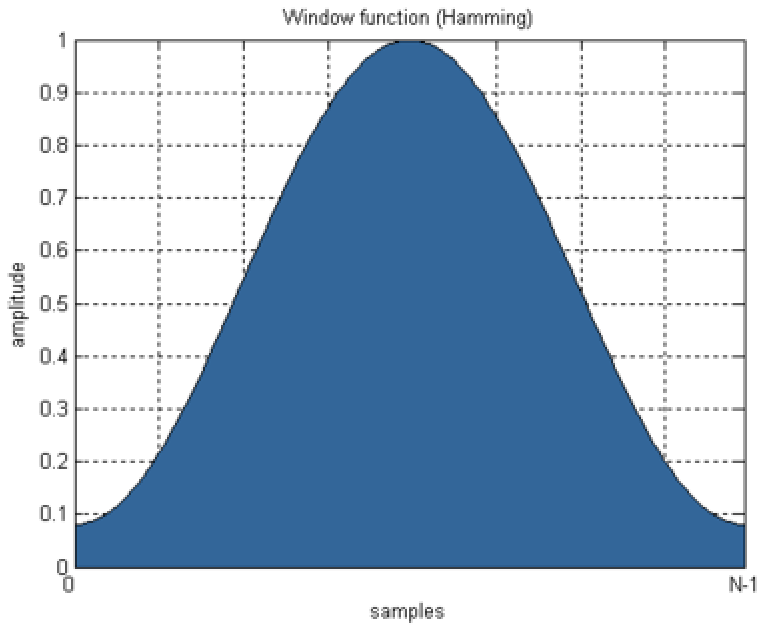
- We can also control window shape.
- That is, we take the chunk of time and multiply it by some window (filter) shape to get the final spectrum.

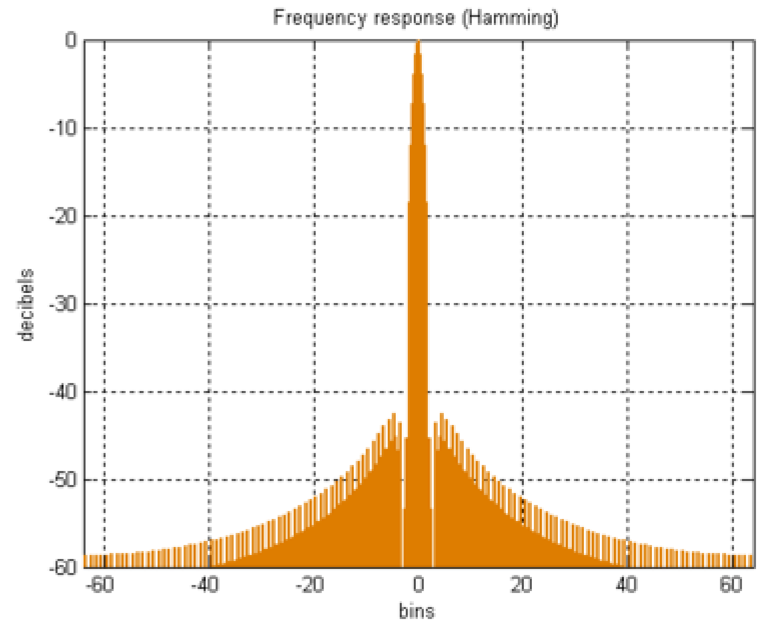
For example, **Blackman** filters are relatively leptokurtotic (narrow) and have better frequency resolution.





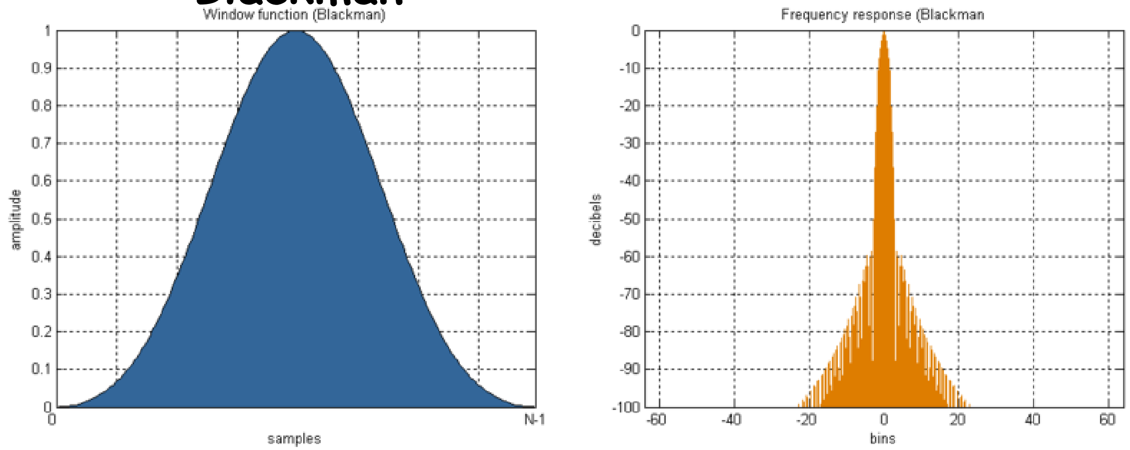
While, **Hamming** filters are wider and more center weighted and hence have better temporal resolution.



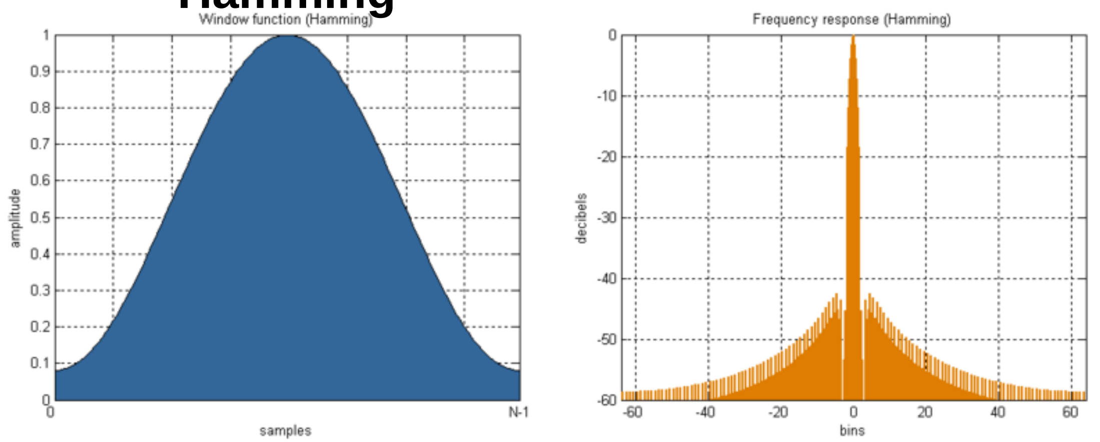


These are just 2 examples of how filter shape can influence what we see.

Blackman



Hamming



Summary

You can't have everything. There is a trade off.

When you enhance a signal in one domain (e.g. frequency), you lose resolution in some other domain (e.g. time).

Window shape and overlap can enhance signal resolution.

Analogies

The scanner has similar time-frequency **tradeoffs**.

If you collect more frequency information at one time (wide bandwidth) you decrease the time it takes to acquire an image, but SNR drops.

The issue is: acquisition speed vs image quality

And, there are tricks for creating or choosing scanner sequences: you can overlap the slices, or leave gaps between slices. You can filter out information.

But it is all about the size, shape and relative positions of the chunks you use to chop up a continuous signal.

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