NETWORKING WITH UWB
ULTRA WIDE BAND GROUP AT UNIVERSITY OF ROME "LA SAPIENZA"

Ultra Wide Band Group at
University of Rome La Sapienza

A Physiologically Produced Impulsive UWB signal: Speech

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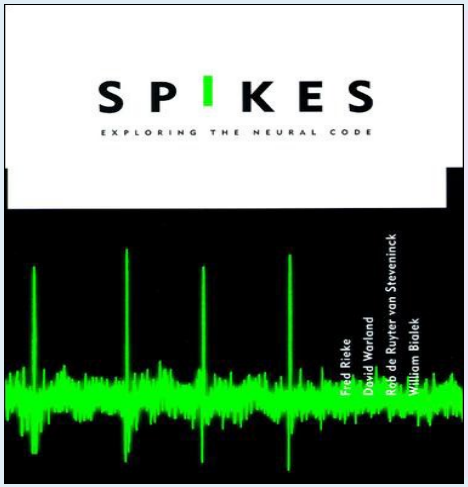
Keynote speech, ICUWB 2010, September 20-23, 2010

Observation: many physiologically produced signals are impulsive in nature

Their waveforms have Impulse Radio wave shapes

They are UWB since their centre frequency is the zero frequency

… a coincidence?

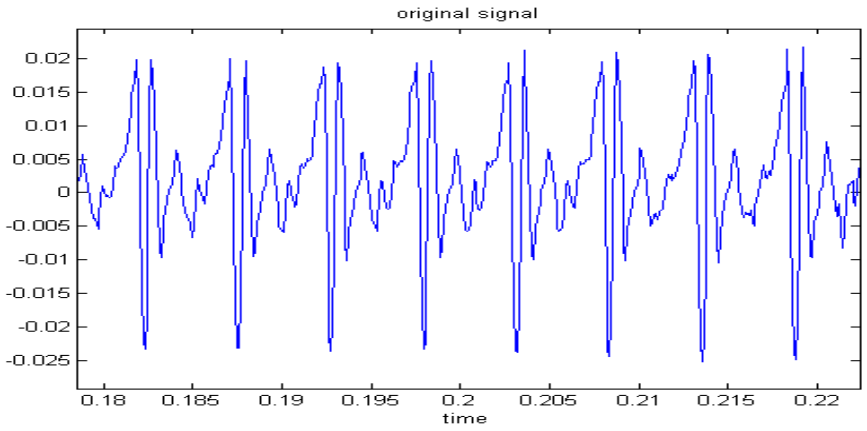


Neuronal pulses

Much of neural computation involves processing these neuronal spike trains

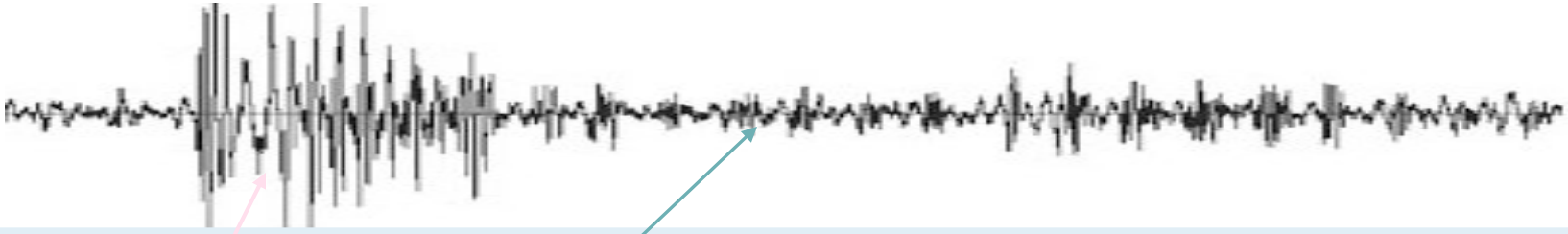
Spikes, Exploring the Neural Code (Computational Neuroscience)

QRS-complex pulses



Speech pulses

Speech waveform

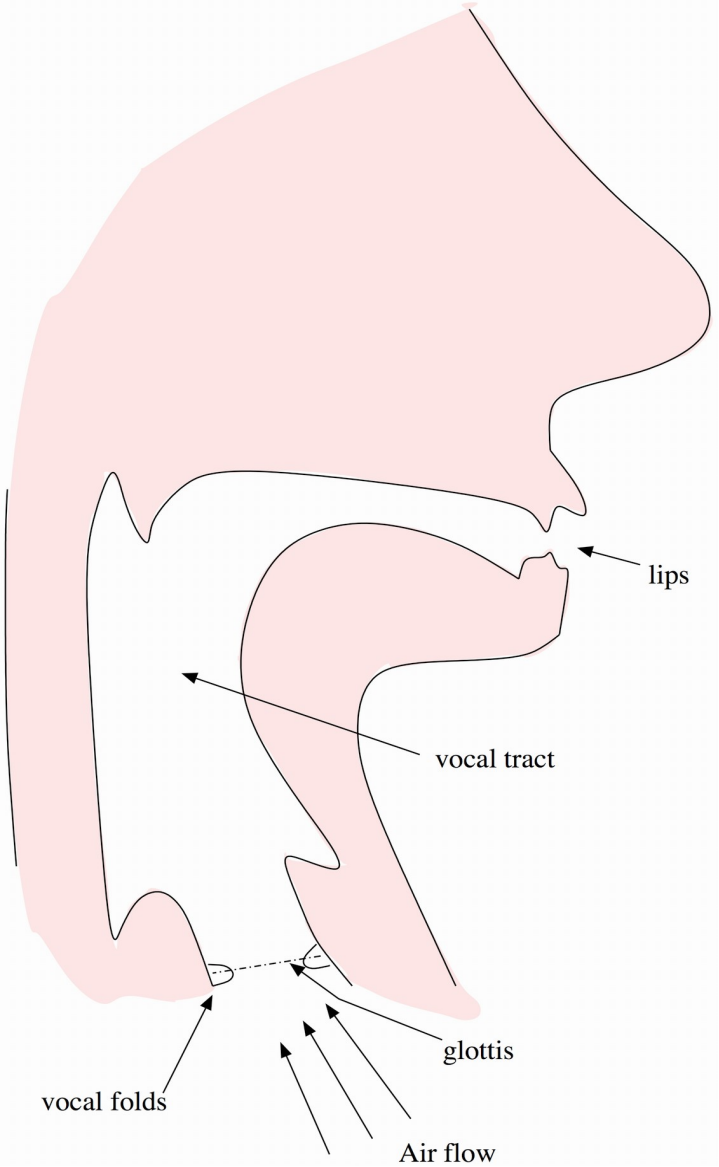


Presence of periodic vs. noise-like portions

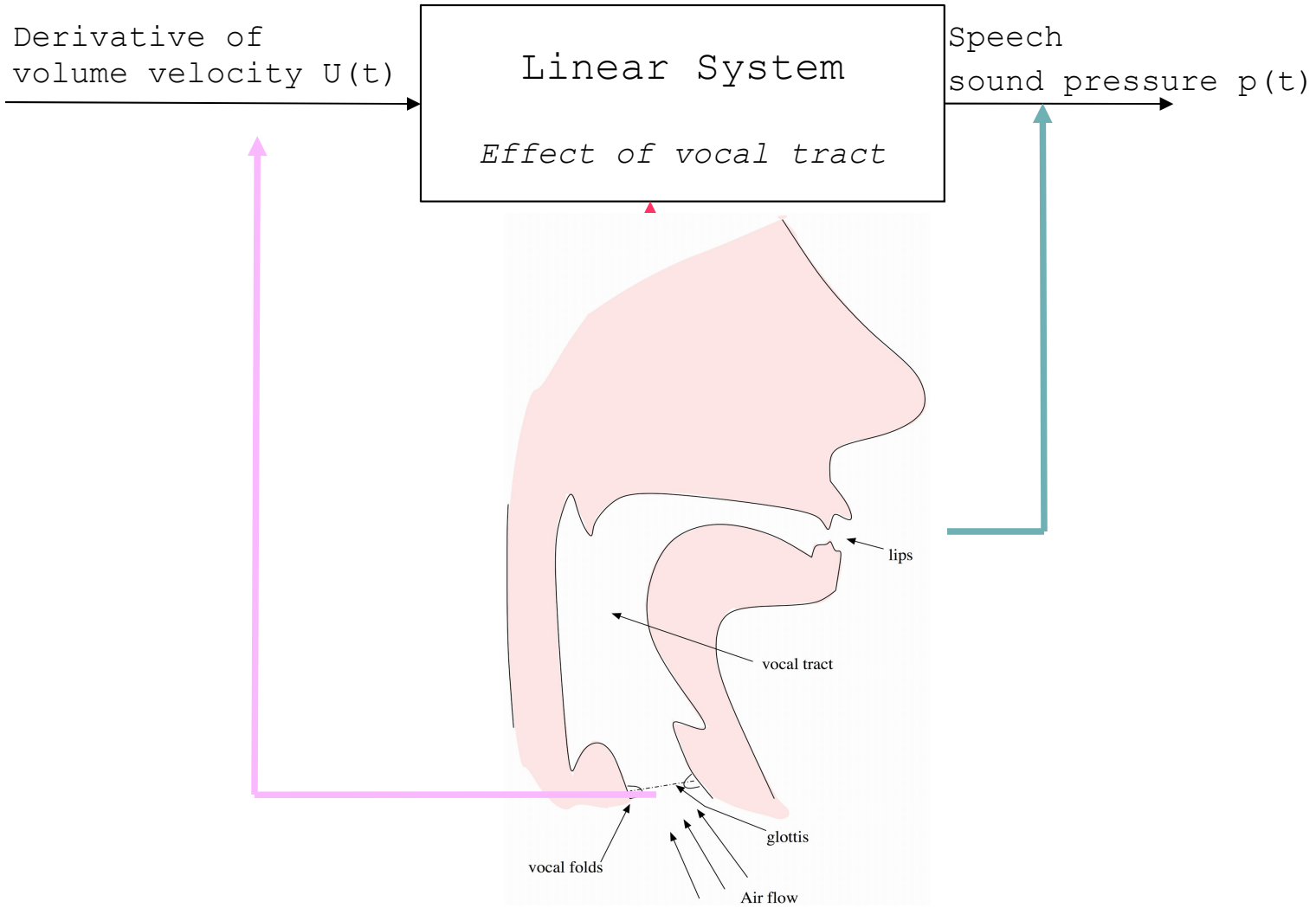
Periodic portions correspond to voiced sounds: during production, vocal folds vibrate

Noise-like portions correspond to voiceless sounds: during production vocal folds do not vibrate

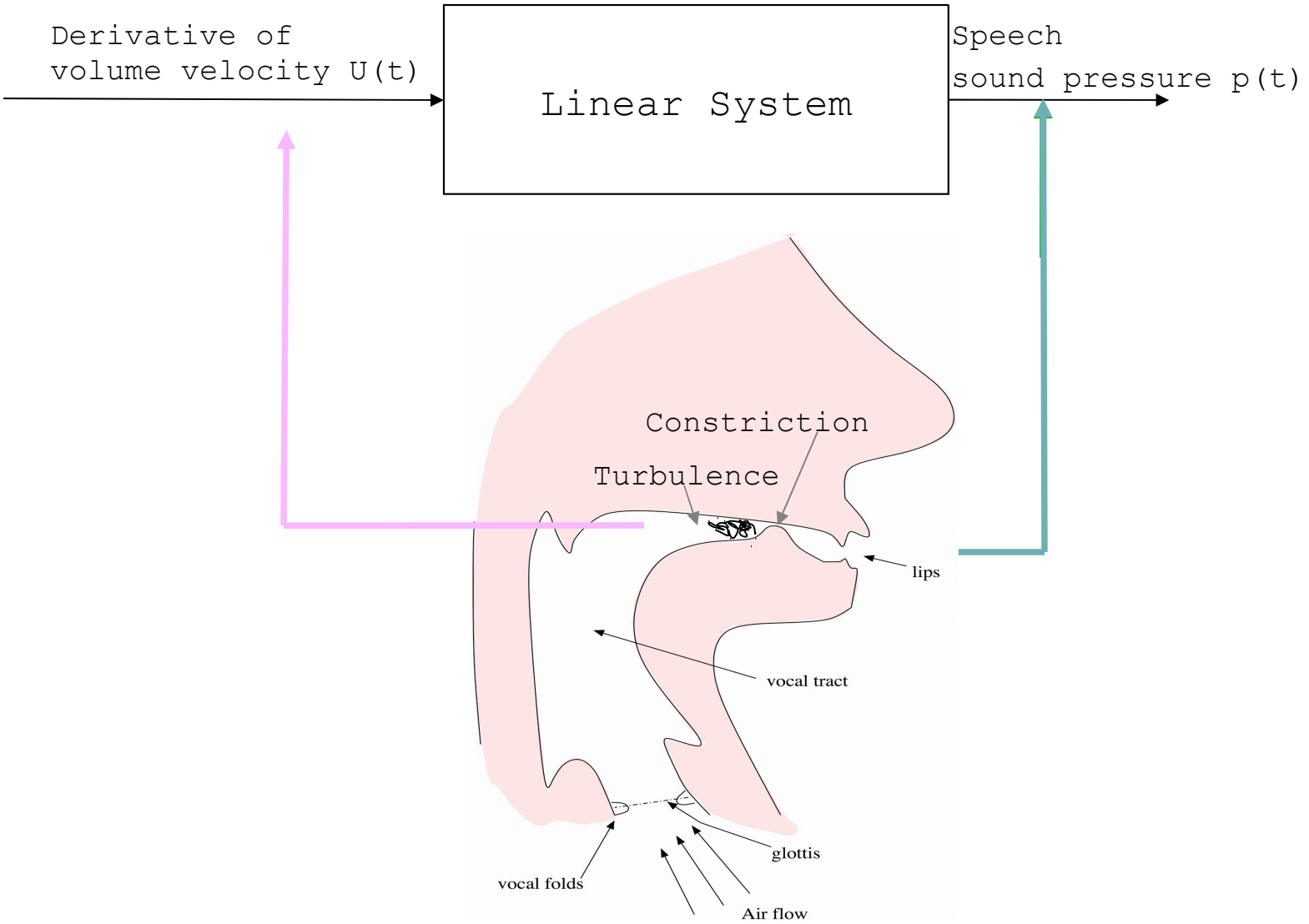
Speech production mechanism



Speech production model for voiced sounds



Speech production model for voiceless sounds



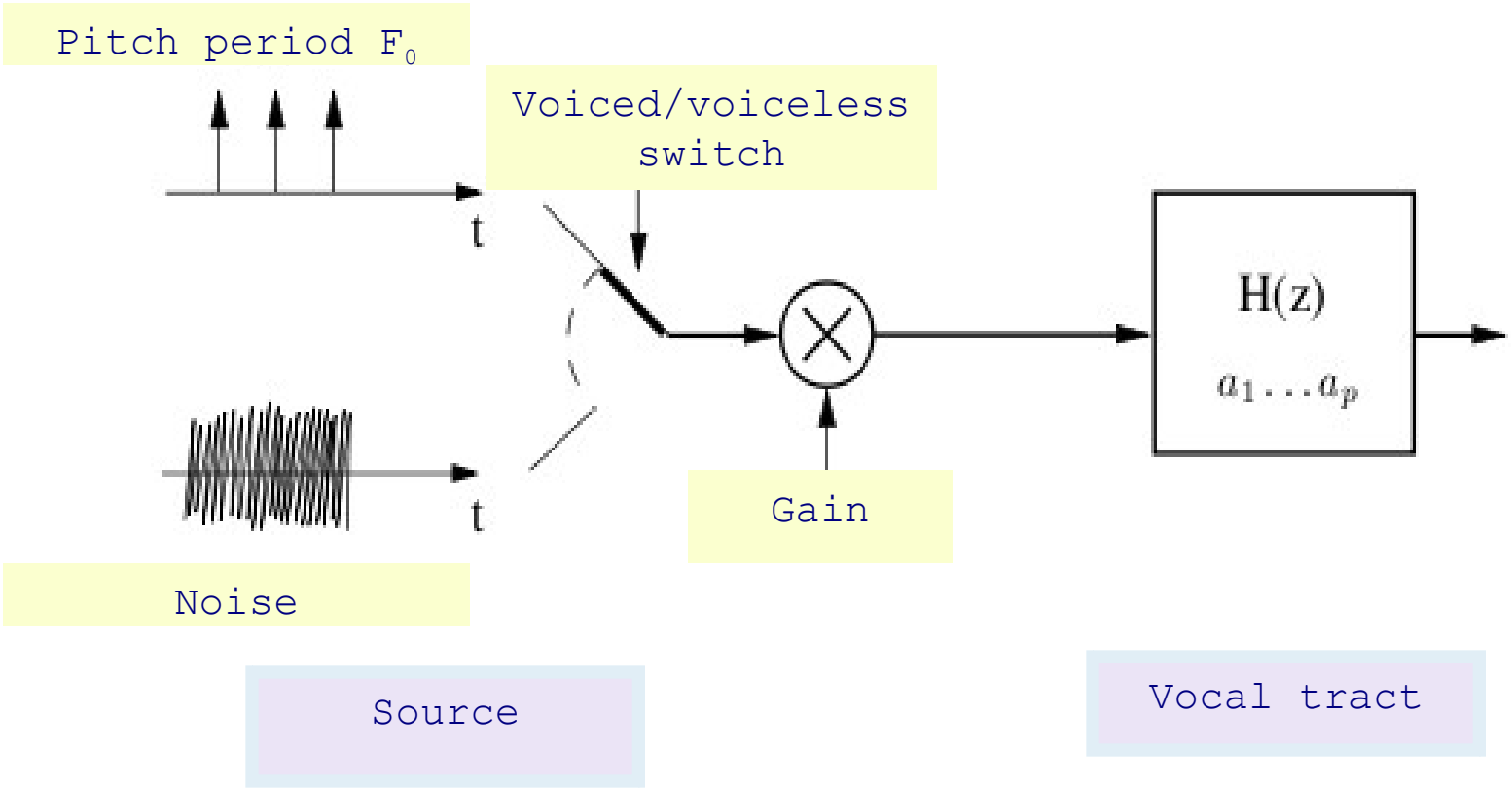
Spectrum of a voiced sound

By courtesy of Hari Arsikere UCLA Speech Processing and Auditory Perception Laboratory
UCLA, USA, Prof. Abeer Alwan Director

Spectrum of a voiceless sound

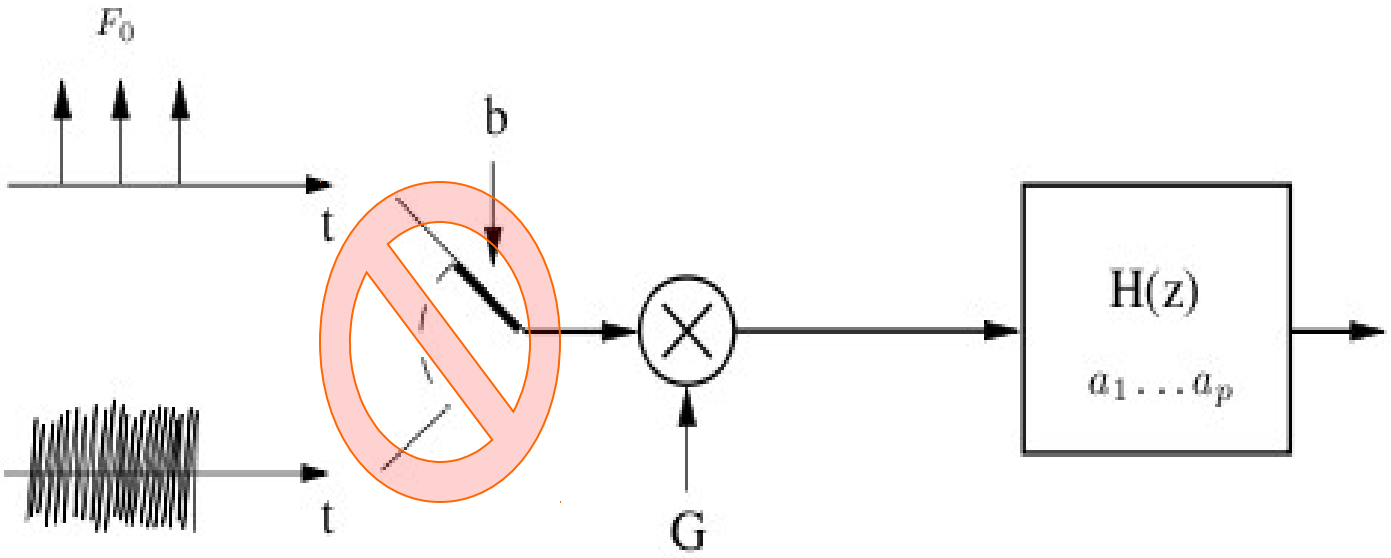
By courtesy of Hari Arsikere UCLA Speech Processing and Auditory Perception Laboratory
UCLA, USA, Prof. Abeer Alwan Director

The model in the VOice CODER VOCODER



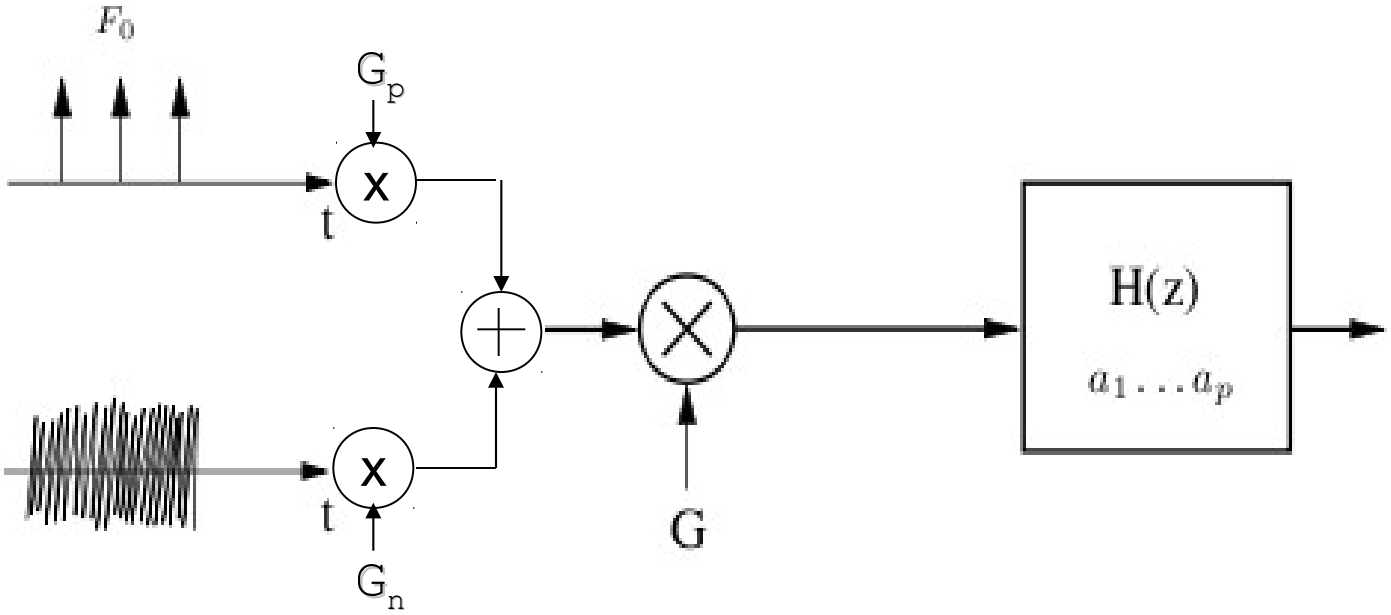
Based on analog vocoder, Homer W. Dudley, patent 1939

VOCODER strongest limitation



The model is way too simplistic in the case of sounds with a mixed voiced-voiceless nature

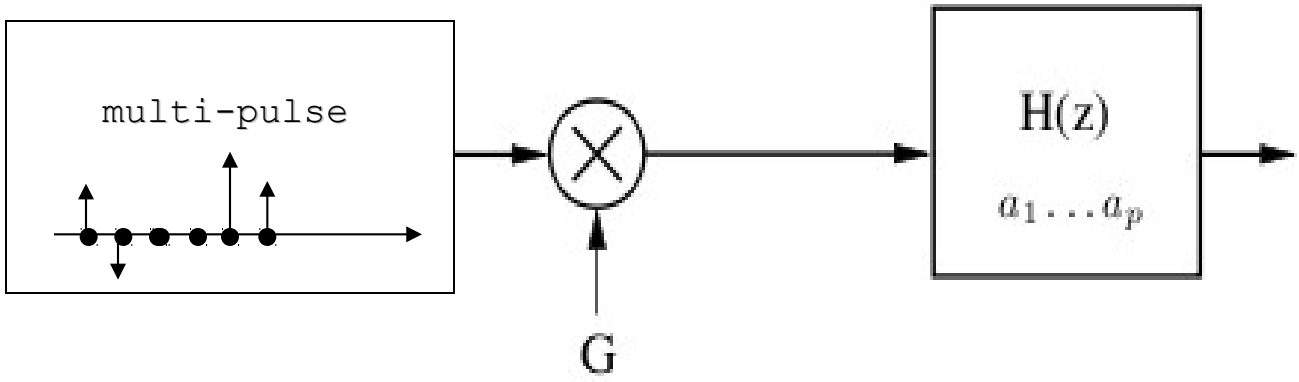
Mixed-Excited VOCODER



This model is based on linear combination of periodic and noise excitation

CELP VOCODER

Used in GSM, UMTS and many others



The best multi-pulse is selected from a set stored in a codebook

But why "best" is "best" still remains to be understood

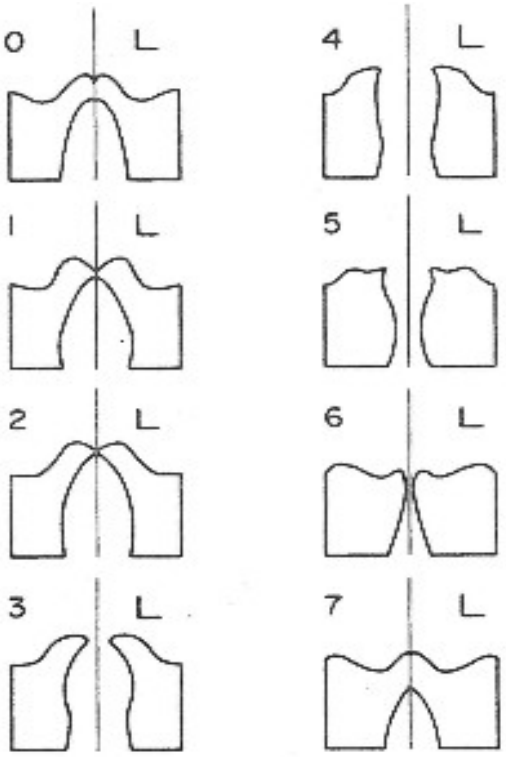
Based on multi-pulse model presented by Atal and Remde, ICASSP, 1982

Spectrum of a mixed sound

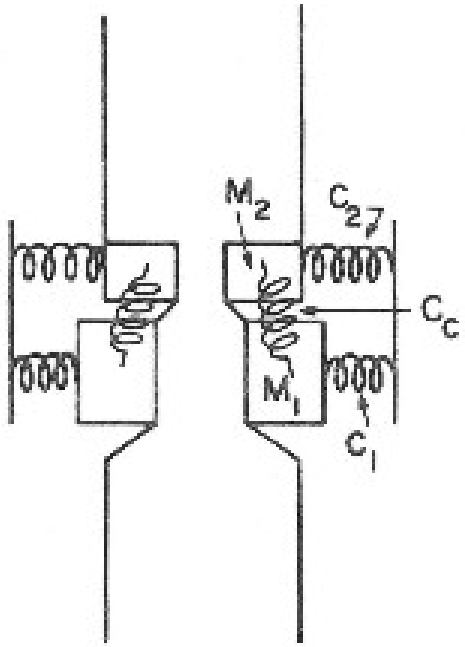
Periodicity loss at low frequencies

Tilt at high frequencies

Vocal folds



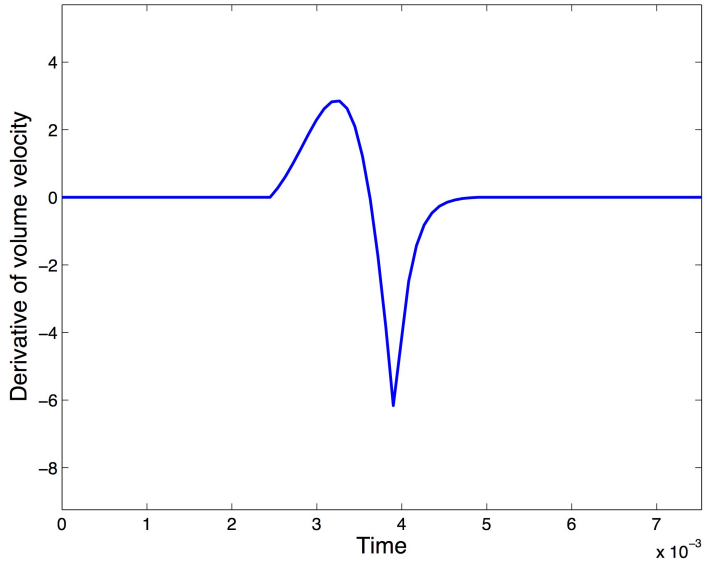
Lateral sections of vibrating vocal folds



Two-mass model of vocal folds

From Stevens, *Acoustic Phonetics*, The MIT Press, 2000

The LF model of the glottal source



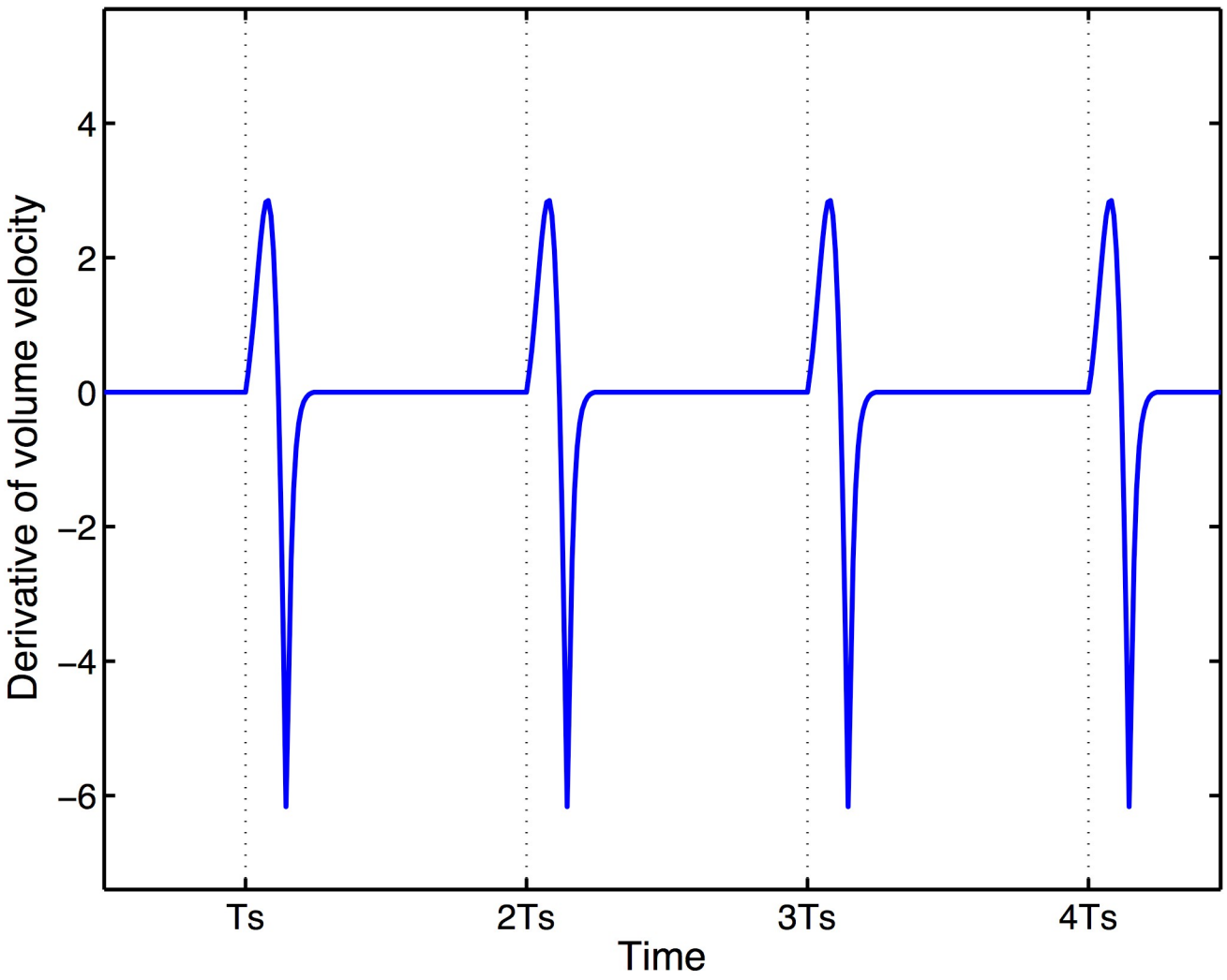
Derivative of the glottal airflow

Looks like the transmitter antenna output: first derivative of a bell-shape pulse

Introduced by G.Fant et al. in 1985, refined by G. Fant, "The LF-model revisited.Transformations andfrequency domain analysis", in "STL-QPSR Journal", vol. 36, 119-156, 1995

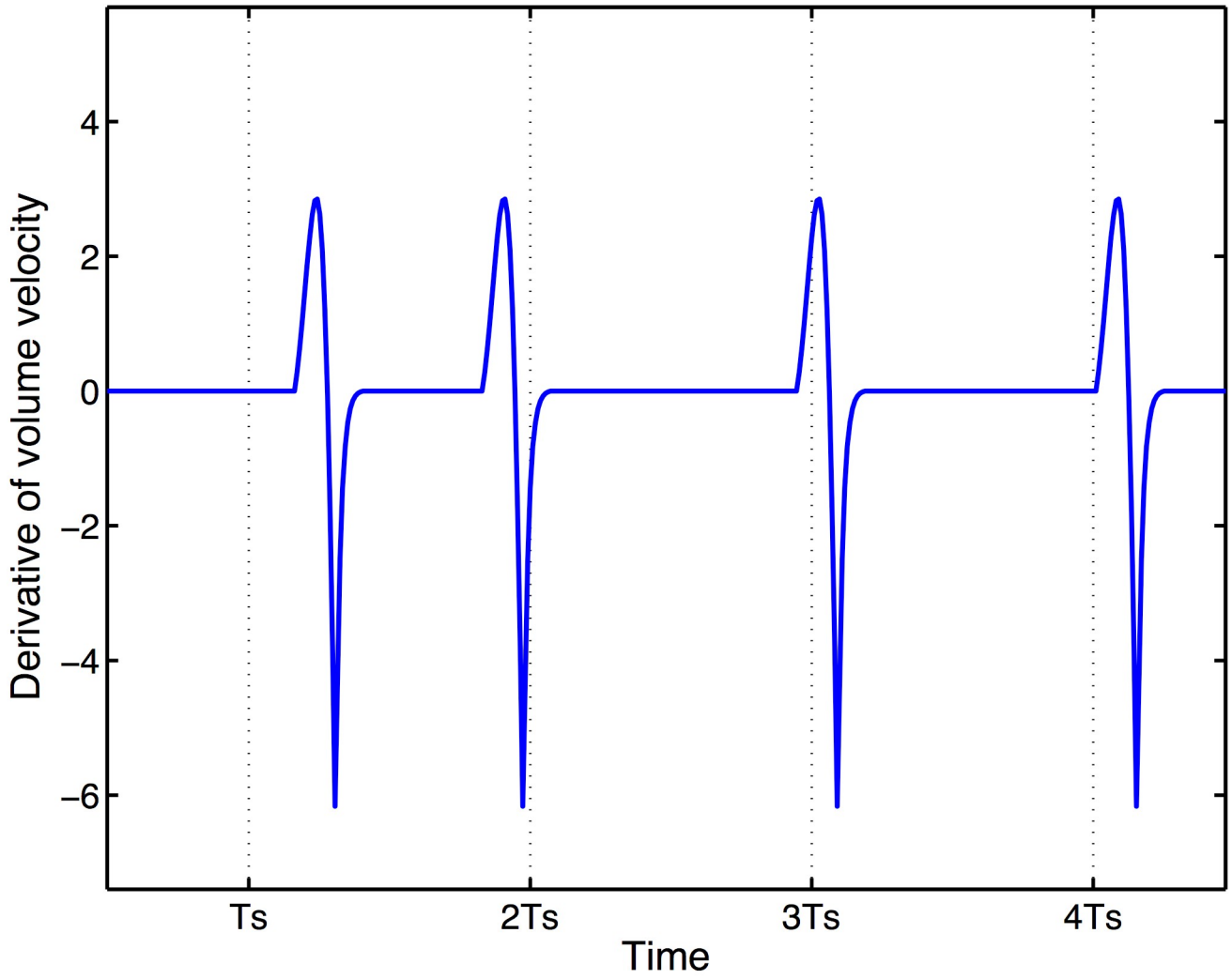
Excitation signal at the glottis

idealistic

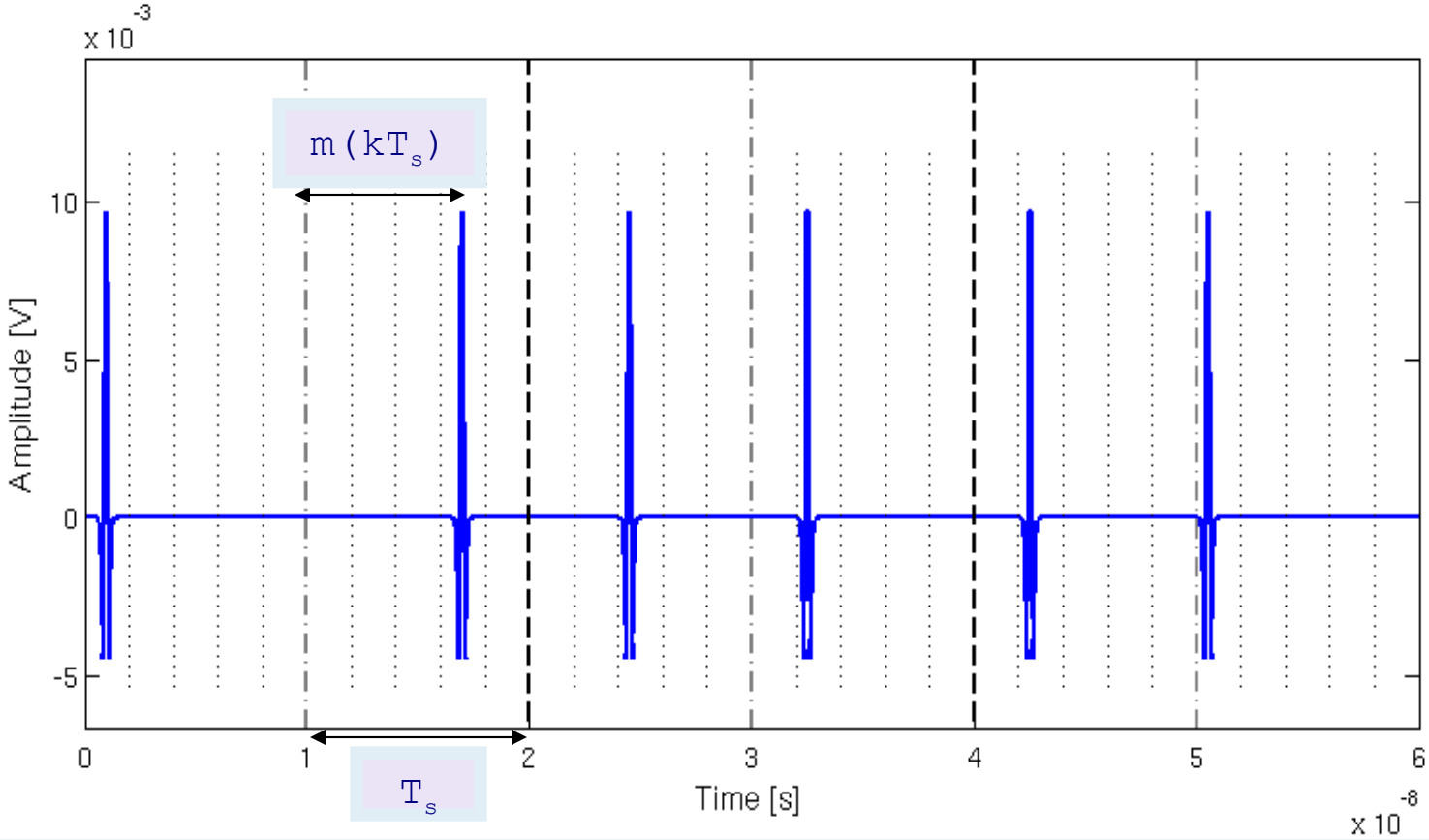


Excitation signal at the glottis

realistic



Impulse Radio UWB
Pulse Position Modulation



Samples $m(kT_s)$ of an analog wave $m(t)$ determine pulse position

From M.-G. Di Benedetto and G. Giancola, Understanding Ultra Wide Band Radio Fundamentals, Prentice Hall, 2004

Impulse Radio UWB
Pulse Position Modulation

$$P_{x_{PPM}}(f) = \frac{|\Pi(\phi)|^2}{T_\sigma}\left[1 - |\Omega(\phi)|^2 + \frac{|\Omega(\phi)|^2}{T_\sigma}\sum_{\nu=-\infty}^{+\infty}\delta(\phi - \frac{\nu}{T_\sigma})\right]$$

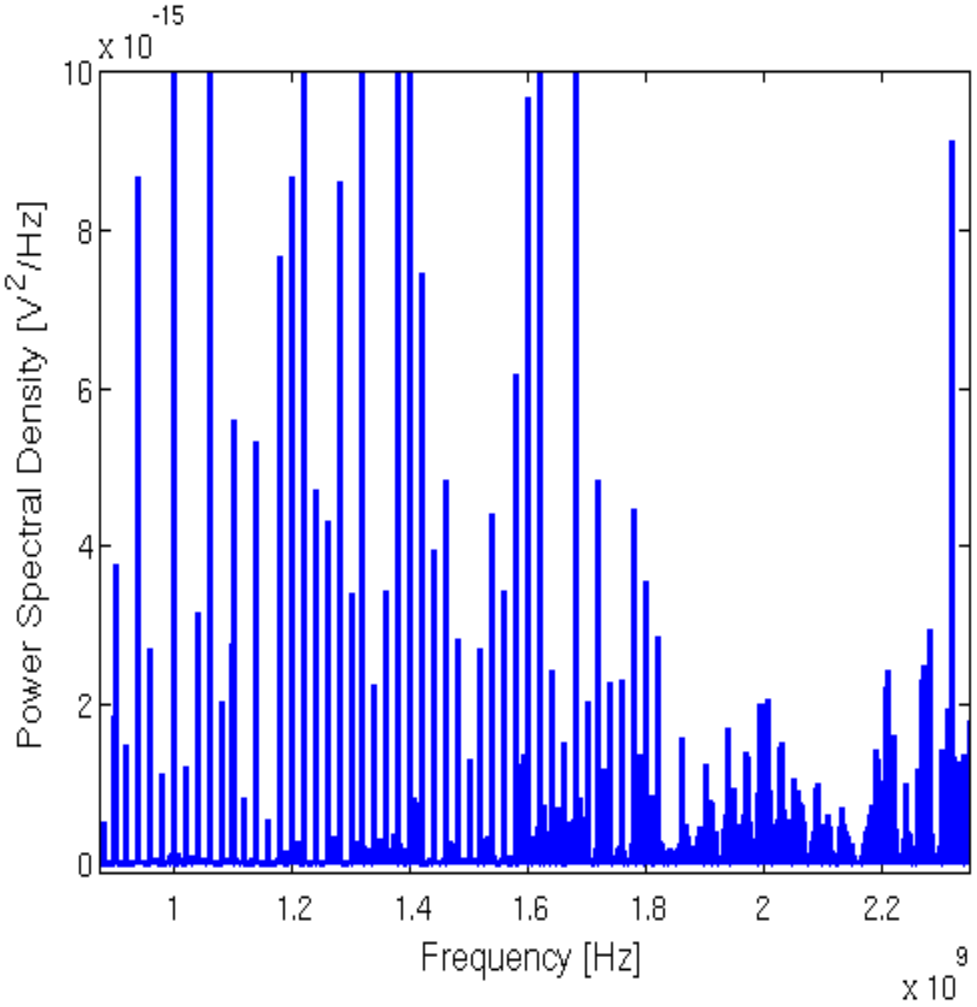
where $W(f)$ is the Fourier transform of the probability density w and coincides with the characteristic function of w computed in $-2\pi f$

$$W(f) = \int_{-\infty}^{+\infty} \omega(\sigma)\varepsilon^{-j2\pi\phi\sigma}\delta\phi = \left\langle \varepsilon^{-j2\pi\phi\sigma} \right\rangle = X(-2\pi\phi)$$

w(s) is the probability density function of samples $m(kT_s)$ of a stationary continuous process $m(t)$

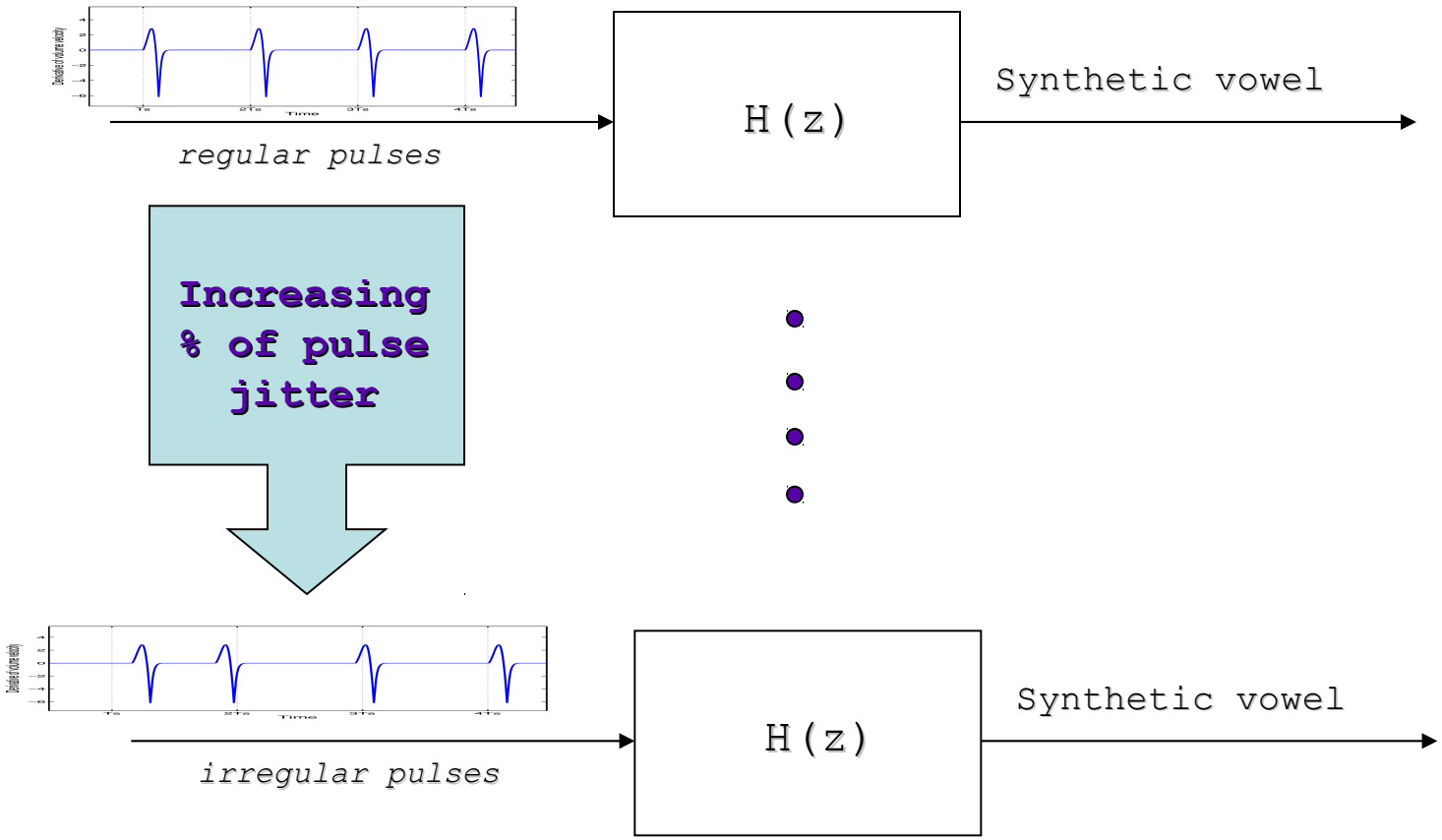
From M.-G. Di Benedetto and G. Giancola, Understanding Ultra Wide Band Radio Fundamentals, Prentice Hall, 2004

Impulse Radio UWB
Pulse Position Modulation



Experimental evidence

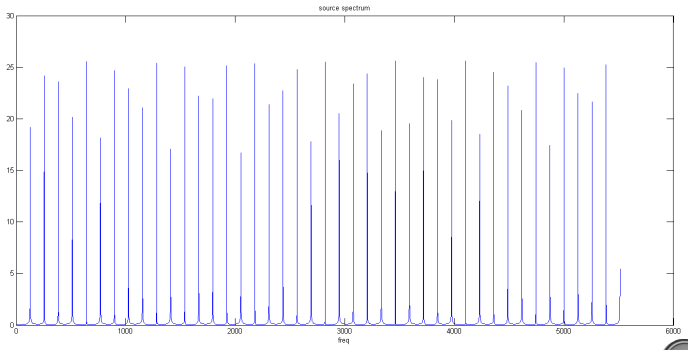
Synthesis of a vowel produced by one male and one female speaker



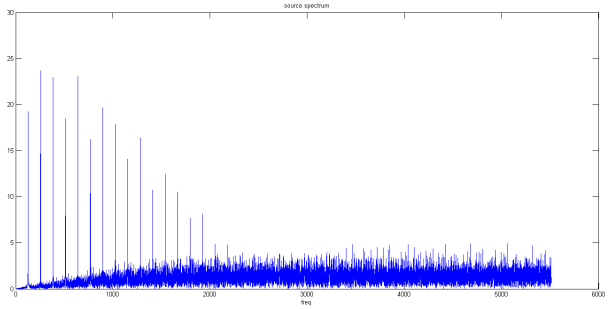
Experimental results

Synthesis of vowel [e] male speaker

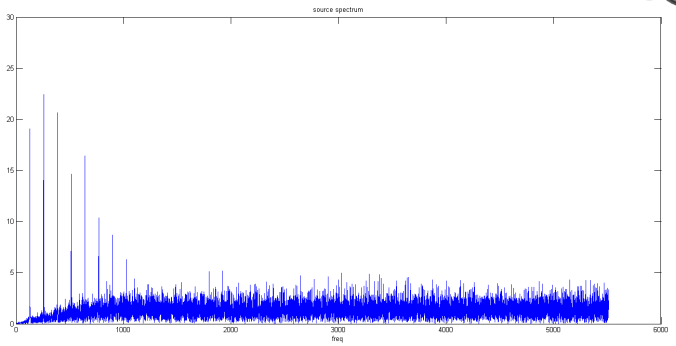
Synthetic vowel no jitter



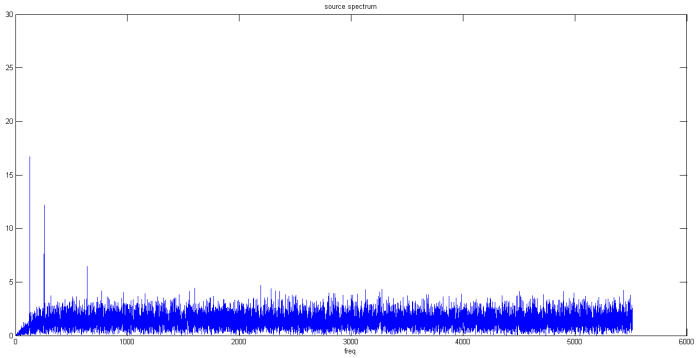
Synthetic vowel 5% jitter



Synthetic vowel 10% jitter



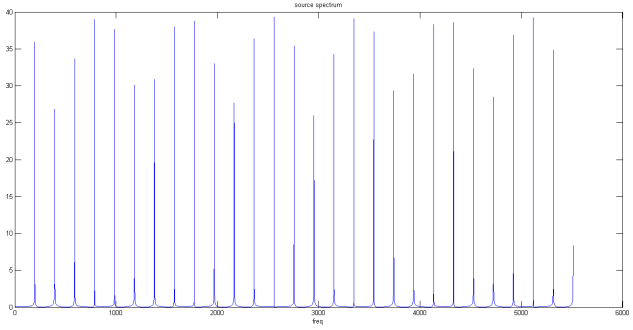
Synthetic vowel 30% jitter



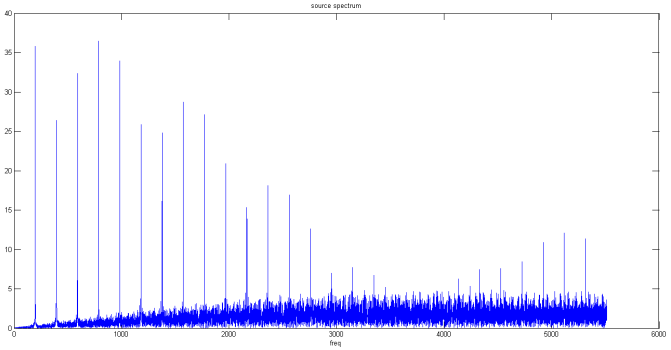
Experimental results

Synthesis of vowel [a] female speaker

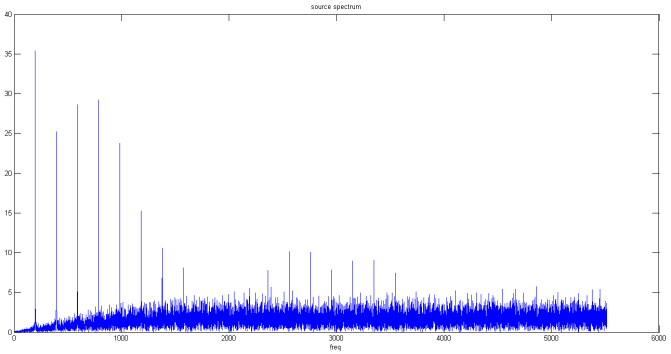
Synthetic vowel no jitter



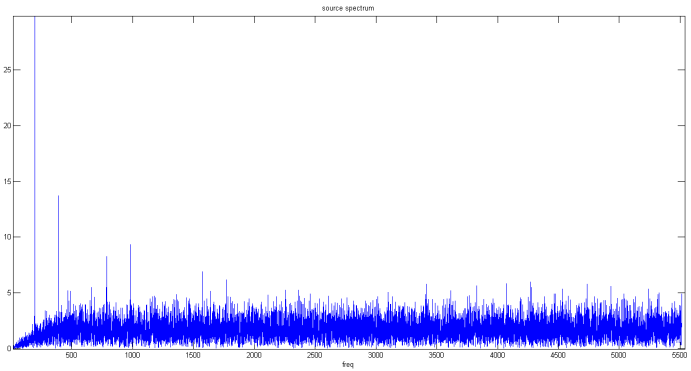
Synthetic vowel 5% jitter



Synthetic vowel 10% jitter



Synthetic vowel 30% jitter



Conclusion

- Example of how UWB theory can help us understanding the structure of impulsive physiologically produced signals
- Interesting insights can be derived from what we know about properties of non-linear modulation in UWB

- Modeling production mechanisms in order to understand basic properties of physiologically produced signals

Challenging workframe

COST Action IC0902

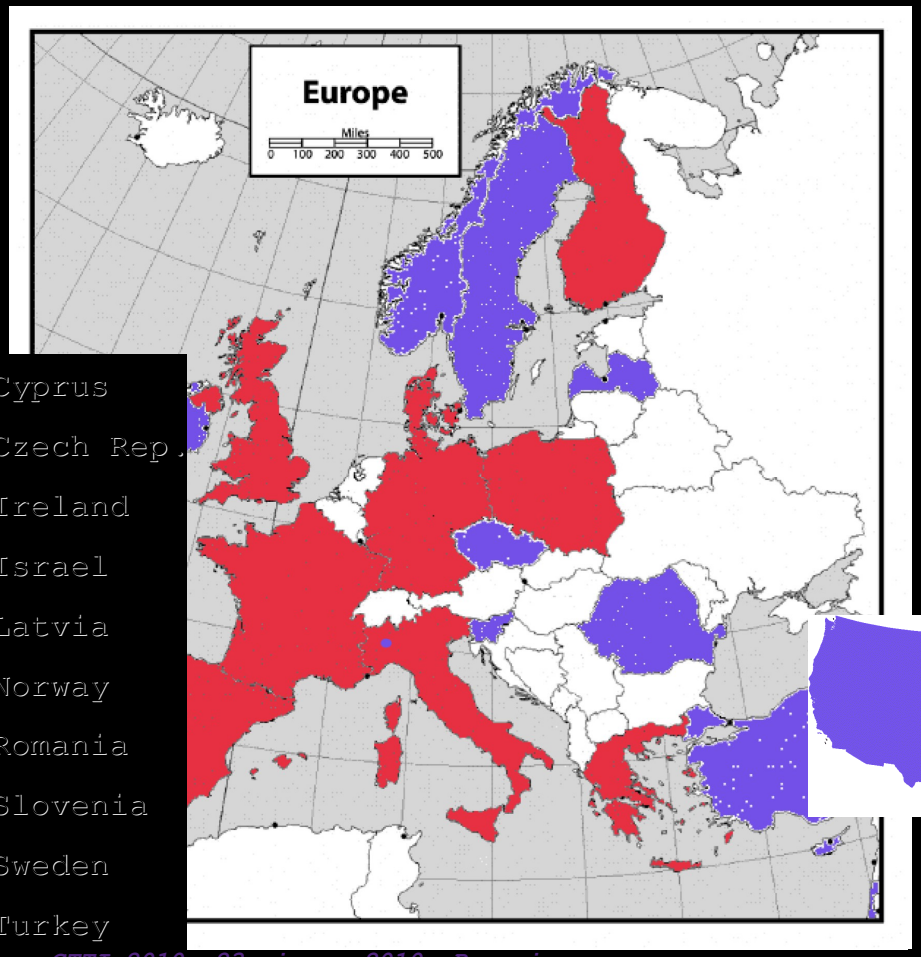
Cognitive Radio and Networking for Cooperative Coexistence of Heterogeneous Wireless Networks

Chair: Maria-Gabriella Di Benedetto

http://newyork.ing.uniroma1.it/IC0902

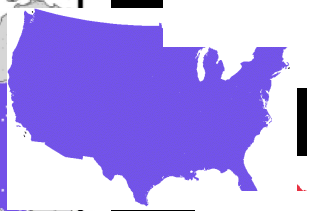
Economic dimension

Estimated economic dimension: 44 Million
for the total duration of the Action



Participation of over 30 countries

- Cyprus
- Czech Rep.
- Ireland
- Israel
- Latvia
- Norway
- Romania
- Slovenia
- Sweden
- Turkey



Challenging workframe

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EU FP7 Network of Excellence ACROPOLIS

Advanced coexistence teChnologies ofr Radio OPtimisatiOn in Licensed and unlicensed Spectrum

October 1, 2010

Keynote speech, ICUWB 2010, September 20-23, 2010