On the Extraction of the Snore Acoustic Signal by Indedependent Component Analysis

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Introduction

- Importance of Snore for Physicians
- State of the Art
- BSS: an Appropriate Tool ?
- Feasibility of ICA applied to snore
- ICA Assumptions
- Test on Recorded Signals
- Conclusion and Future Work

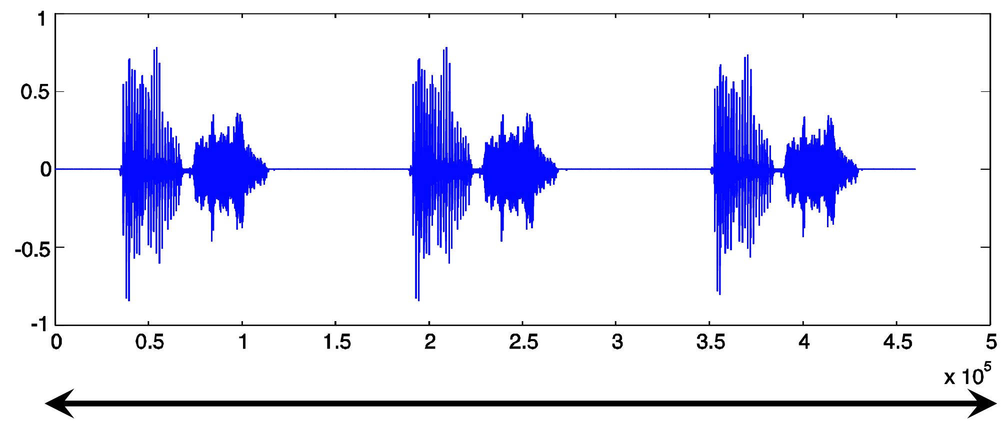
Outline

- The Snore
- Measurement : State-of-the-Art
- BSS can be achieved by ICA
- ICA Assumptions Test
- Real-World Tests
- Discussion
- Conclusion

The Snore

Specificities

- Vibrations of tissues
- Male patients
- During Sleep
- Most Power < 5kHz



10 Sec

Consequences

- Acoustic Nuisances
- ↗ Tiredness
- ↗ Probability of Cardiovascular & Cerebral Accidents

Measurement to Evaluate Risks !!!

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Measurement: State of the Art

Problem remains…

Microphones

- Ambiant: Noise ~~(filtering)~~
- Thorax: LF Filter (Distorsions)
- Under-the-nose: unconfortable

Piezoelectrics

- Under the mattress: OK for detection but KO for spectral analysis

BSS ? Non-Invasive , avoid « extrenal » perturbations
But : Assumptions ? Indeterminations ?

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BSS can be achieved by ICA

$$\mathbf{X} = \mathbf{A} \cdot \mathbf{S}$$

Recorded By **n** Sensors

Mixing System

m « sources »:

Snore Acoustic Signal,
Ambiant Noise

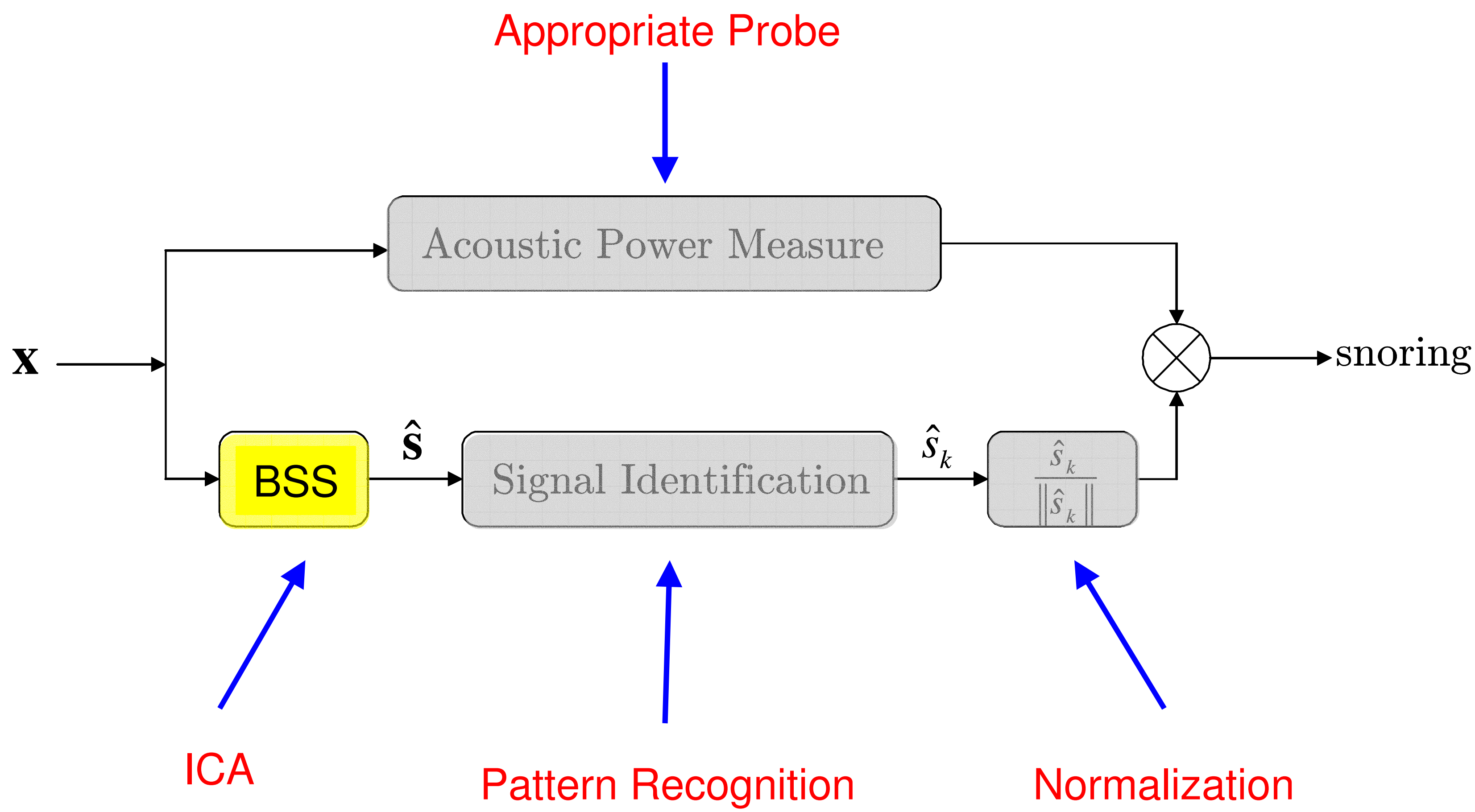
Aim: Find **B** such that $\mathbf{Y}=\mathbf{B.X}=\mathbf{B.A.S}=\mathbf{P.D.S}$

Permutations

Diagonal

ICA → Update rules for **B** If « Si » Independent

Measurement Process if BSS



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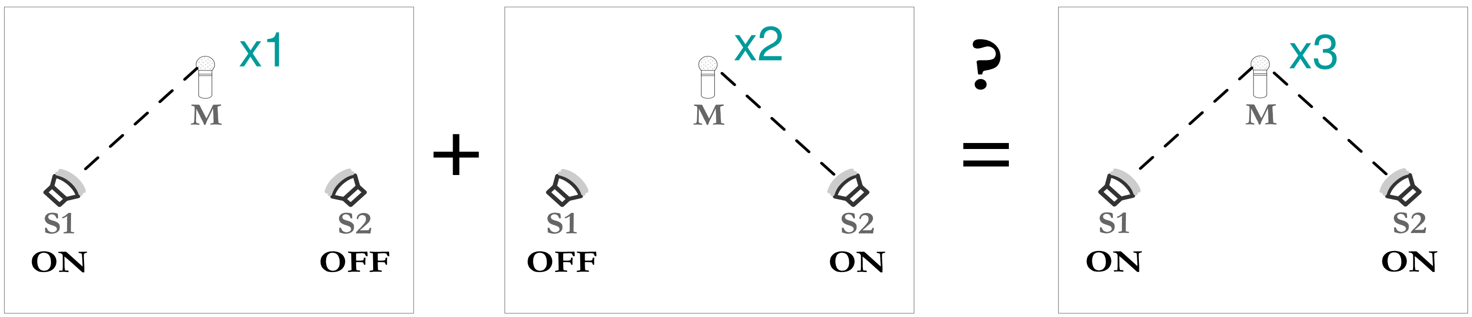
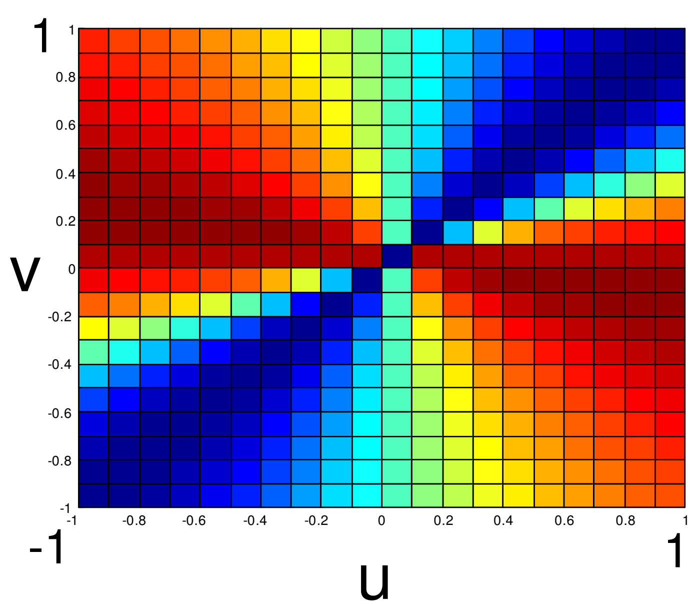
ICA: Main Assumptions (1/2)

Linearity of the mixtures in the air





R=Cov(X3 ; uX1+vX2)

Det(R) = Min for (u=v) !

OK

ICA: Main Assumptions (2/2)

Instantaneity of the mixtures

- To avoid multi-propagation paths (convolutive mixtures) : echo-free room
- Finite Sound Velocity

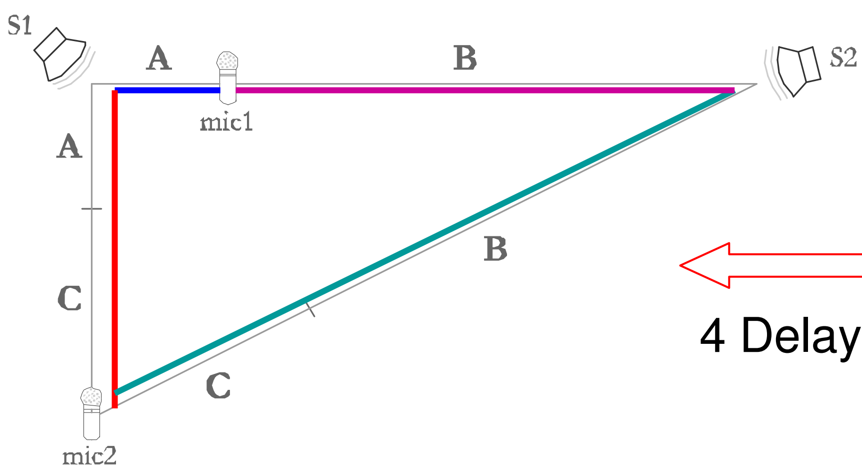
⇓

Location of Sources/Sensors important to avoid propagation delays!

Particular Geometrical Configuration

ICA: # Delays Reduction

Limit the delays to a single number



4 Delays !

$$\overbrace{}^{s'_1(t)} \quad \overbrace{}^{s'_2(t)}$$

$$\begin{aligned} x_1(t) &= a_{11}s_1(t-\tau_a) + a_{12}s_2(t-\tau_b) \\ x_2(t) &= a_{21}s_1(t-\tau_{a+c}) + a_{22}s_2(t-\tau_{b+c}) \end{aligned}$$

$$\tau_{i+j} = \tau_i + \tau_j$$

- Change of variables
- Additivity of delays

$$\begin{aligned} x_1(t) &= a_{11}s'_1(t) + a_{12}s'_2(t) \\ x_2(t) &= a_{21}s'_1(t-\tau_c) + a_{22}s'_2(t-\tau_c) \end{aligned}$$

Unique Delay !

ICA: Delay Compensation

Idea : Records will be Synchro
When Cov [X1(t) ; X2(t+T)] Max

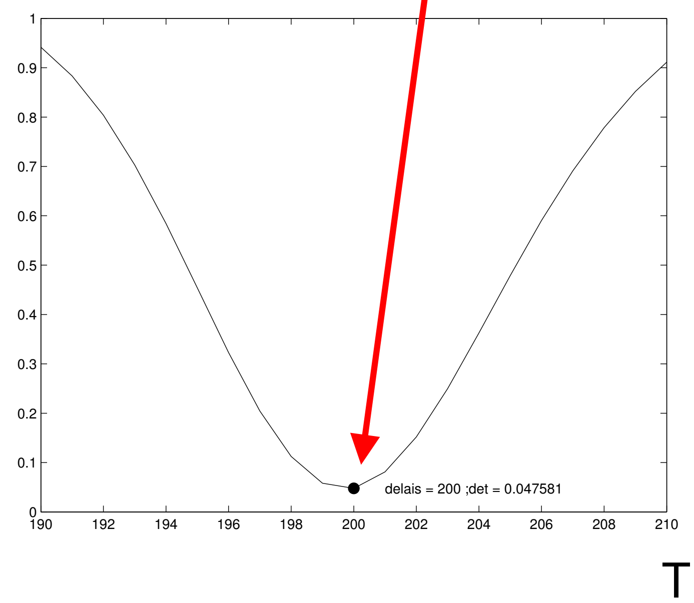
$$x_1(t) = a_{11}s'_1(t) + a_{12}s'_2(t)$$
$$x_2(t) = a_{21}s'_1(t-\tau_c) + a_{22}s'_2(t-\tau_c)$$

i.e. Cov [X1(t) ; X2(t+T)] Max for T= τc

⇕

$$min_T \; DET(Cov(x_1(t), x_2(t+T)))$$

T = τc



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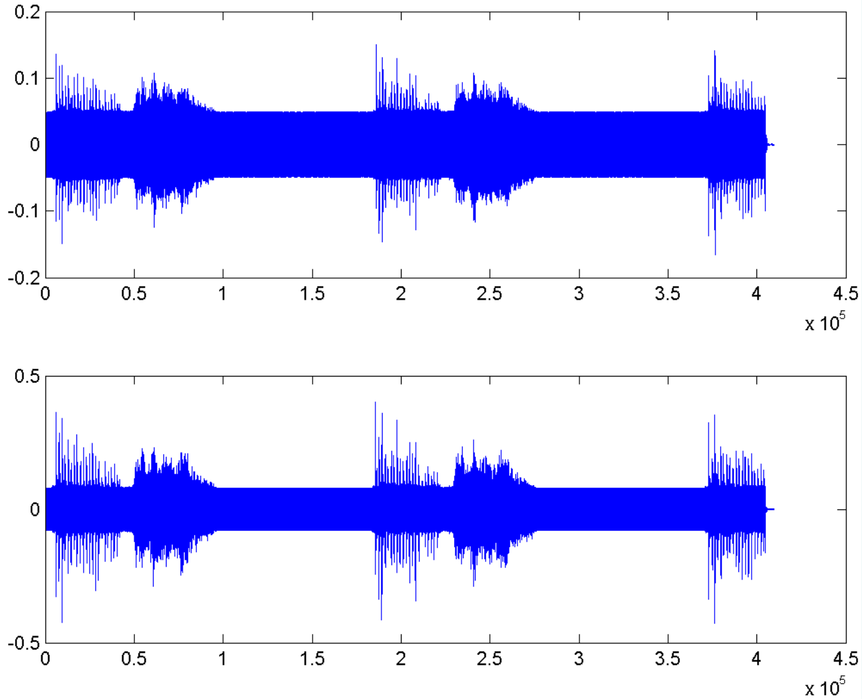
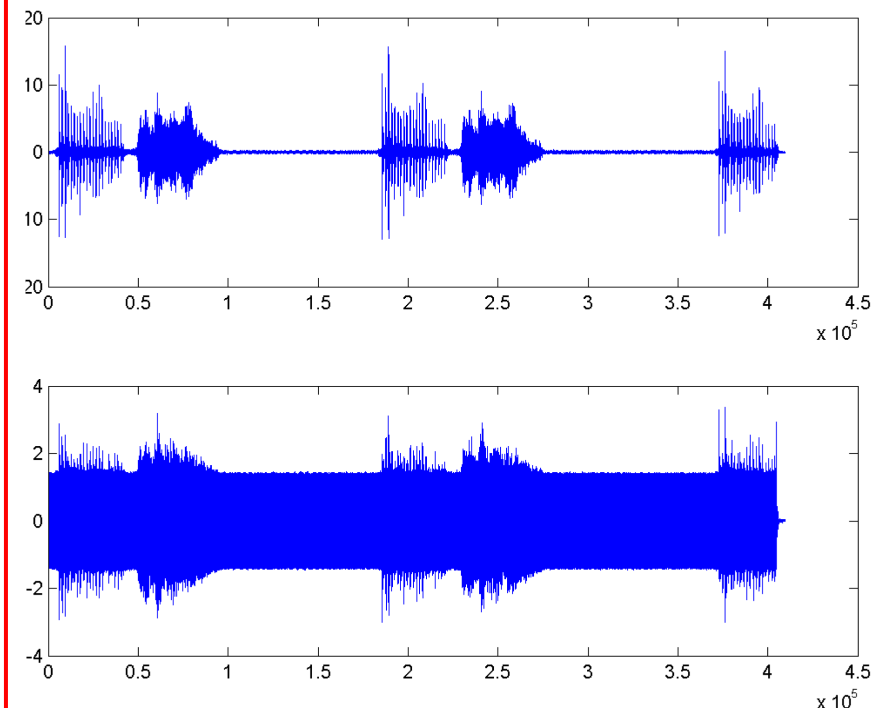
Snore and Sine Mixture : OK

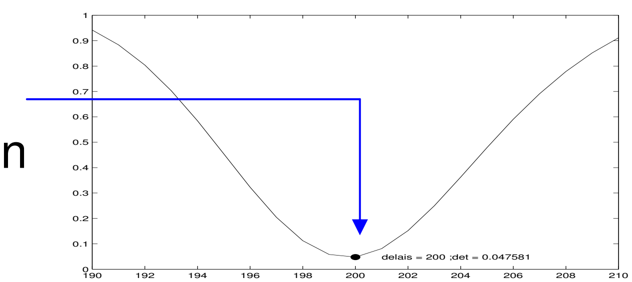
Recorded Mixtures



Estimated Sources



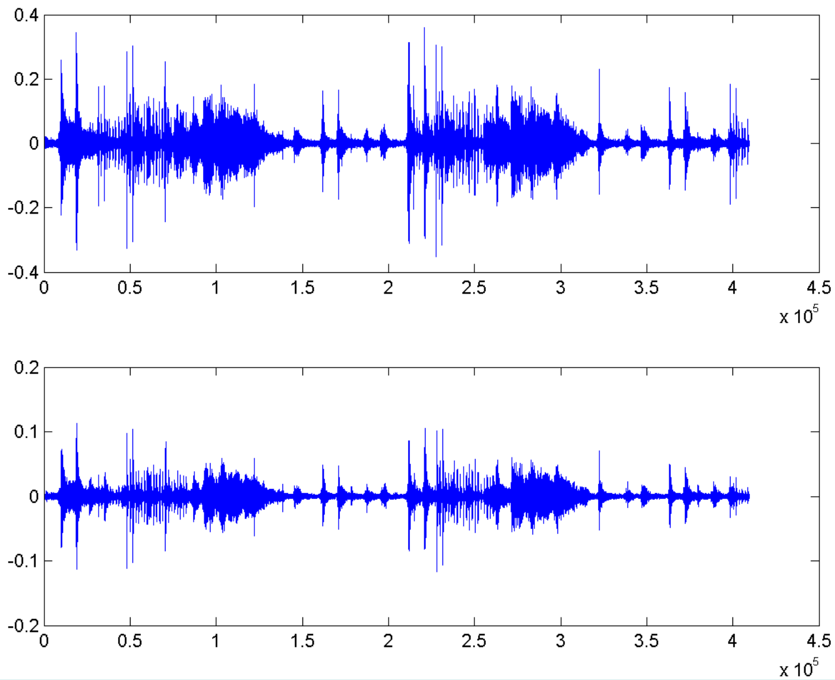
Delay-compensation



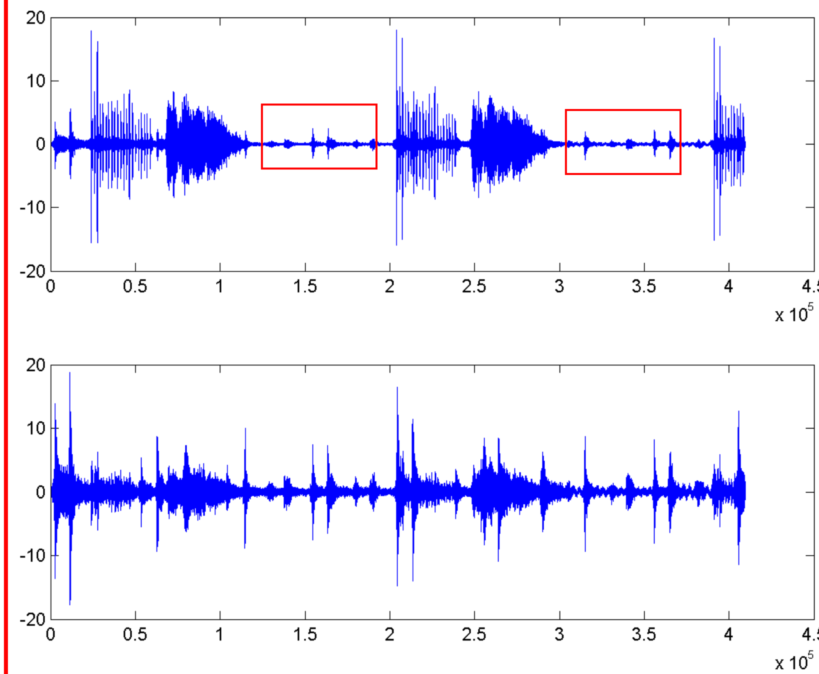
Snore very-well extracted !

Snore and Wide-Band ?

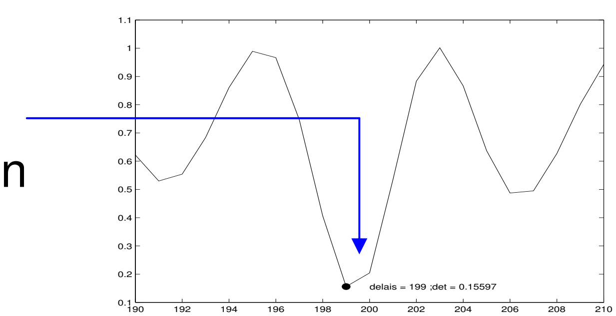
Recorded Mixtures



Estimated Sources



Delay-compensation



Snore **Not** well extracted !

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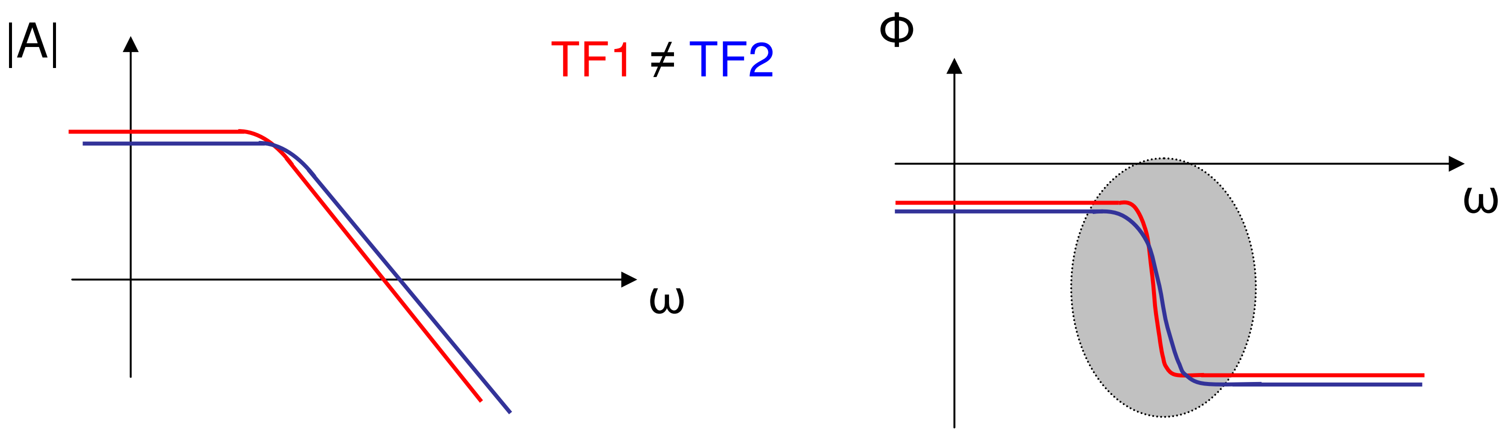
Delay: 2 components

$$D = D1 + D2$$

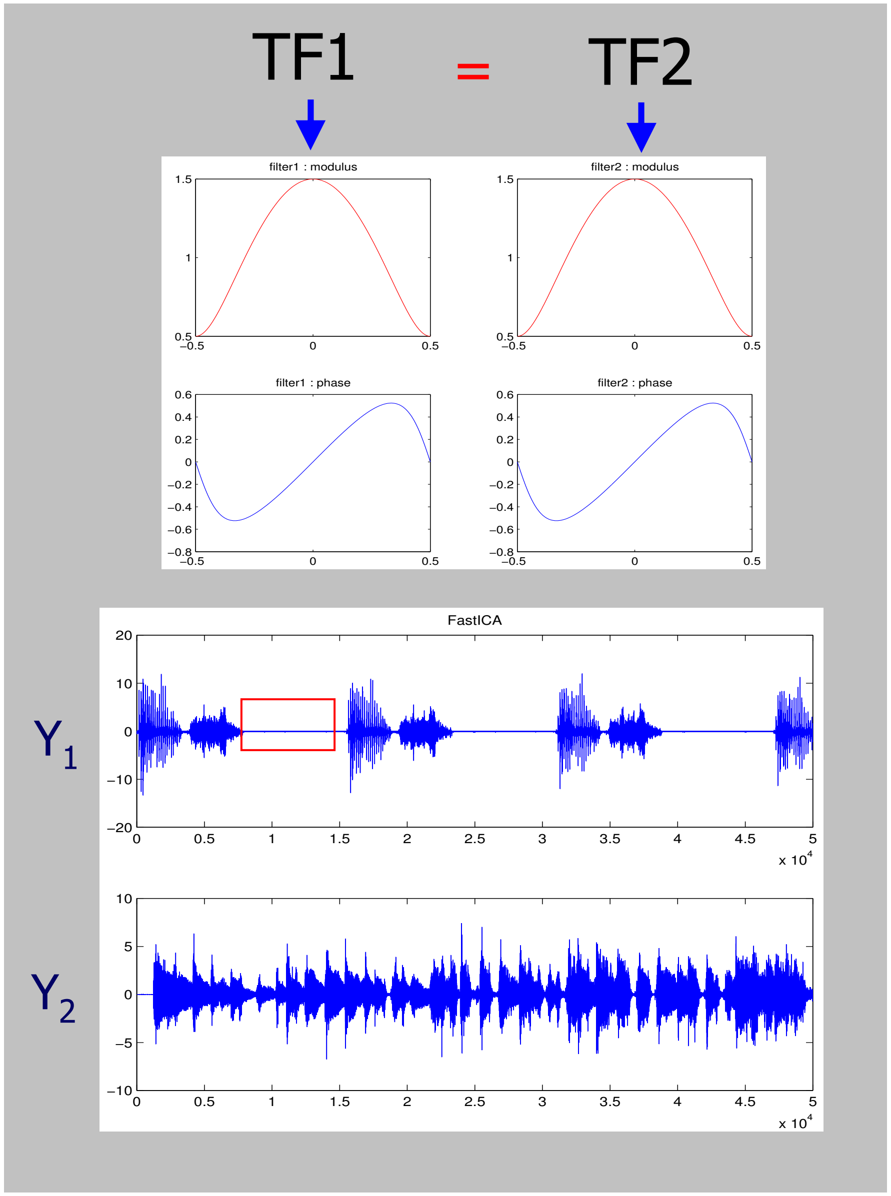
F(ΔX) : due to finite speed of sound
(OK if Particular Configuration)

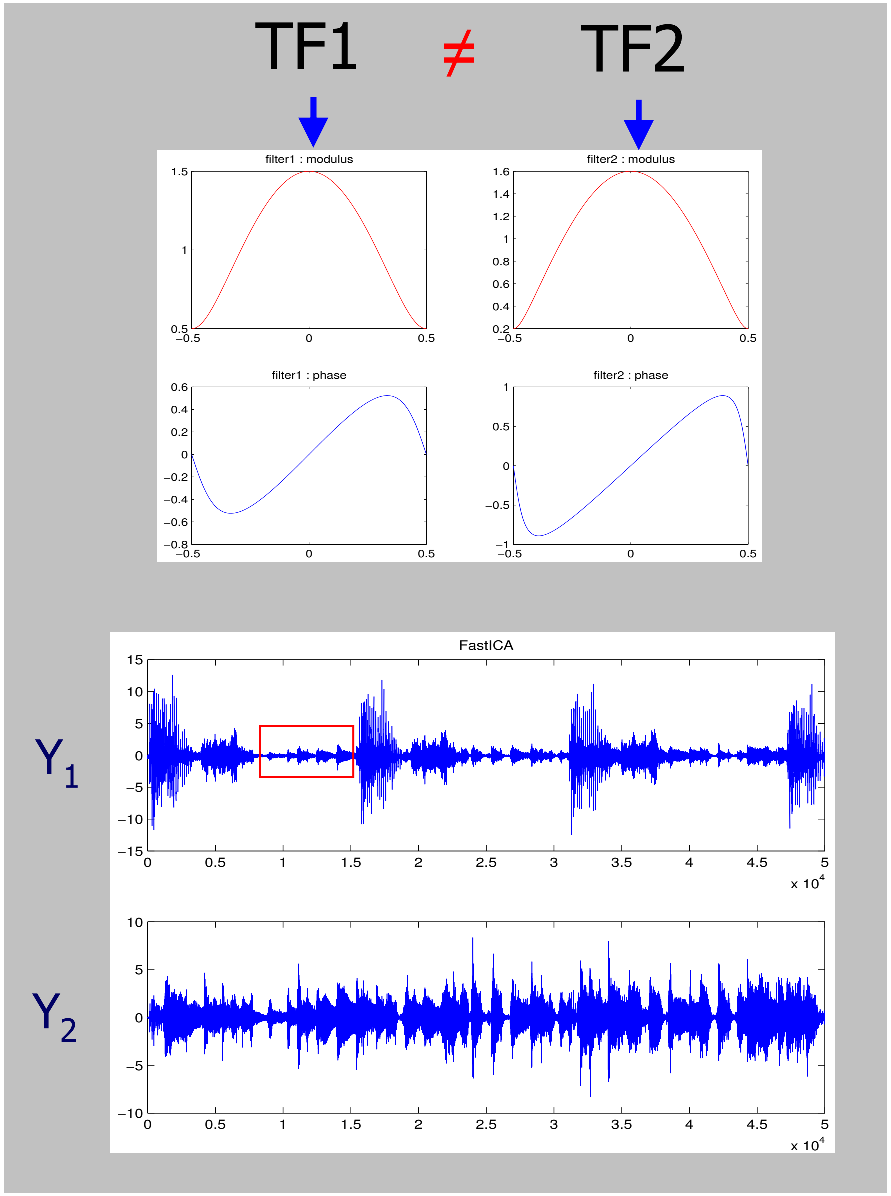
F(ω) : difference between Transfert Functions of Sensors



D2 very Thorny for ICA !

Delay: 2 Difference between TF





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Conclusion

Why BSS ?		But in Practice
▪ Flexible Location of Srces/Sensors	↔	▪ Delays (D) Compensation : Specific Configuration Required
▪ Easy way to separate sources	↔	▪ 1 Delay for Each Freq. If mixture with Large Band : Trans. Func of Hardware
▪ Few requirements on instrumentation	↔	▪ High-Quality Instrumentation Required to perform separation
▪ Well-known algorithms …	↔	▪ In Echo-Free room: other wise MIMO Deconvolution with D(Freq) !
▪ Efficient in Biomedical Applications	↔	▪ Quality of Extraction … Satisfactory but many constraints !

Not as flexible as hoped, but result not so bad … Many challenges for { Instrumentation / ICA }