

# Optimization of the Contrast Tissue Ratio in Ultrasound Contrast Imaging by an Adaptive Transmit Frequency

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*Imagery and Brain*

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  - Results and Discussion in Harmonic Imaging
  - Results and Discussion in Pulse Inversion Imaging
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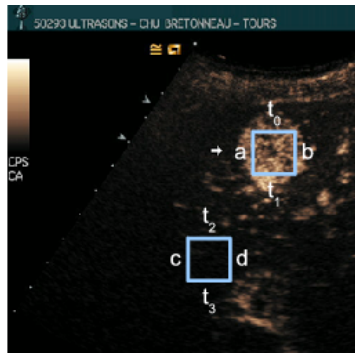
# Introduction

# Problematic

## Objectives

- Improve the echographic contrast in ultrasound contrast imaging
  - Using of ultrasound contrast agent : microbubbles
- ⇒ Optimizing the Contrast Tissue Ratio, i.e. maximizing the ratio :

$$CTR = \frac{\sum_{i=a}^b \sum_{t=t_0}^{t_1} y_i(t)^2}{\sum_{j=c}^d \sum_{t=t_2}^{t_3} y_j(t)^2}$$

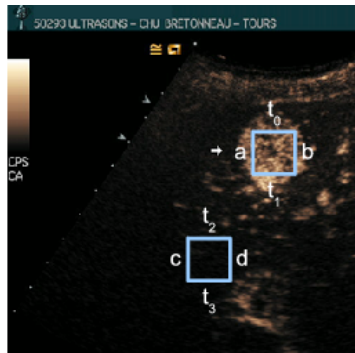


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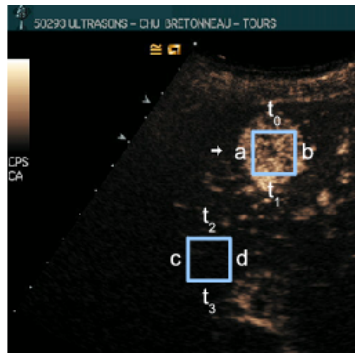


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## Standard System in Harmonic Contrast Imaging

- Nonlinear behavior of the microbubbles
- Transmit at  $f_0 \rightarrow$  Received at  $2f_0$

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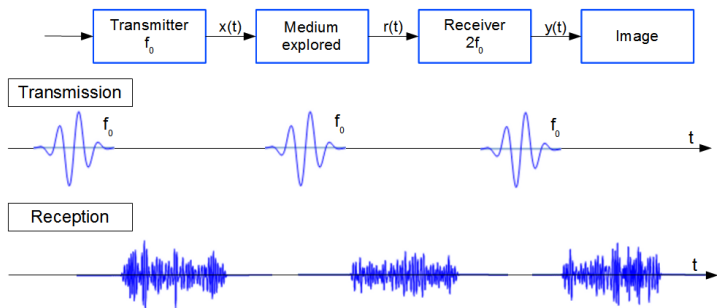
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## Needs

- Overcome theses drawbacks

⇒ Adaptive method by automatic adjustment of the transmit frequency

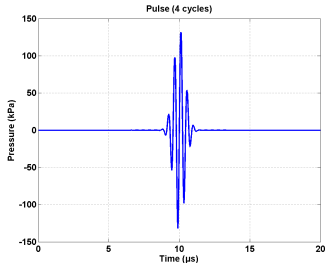
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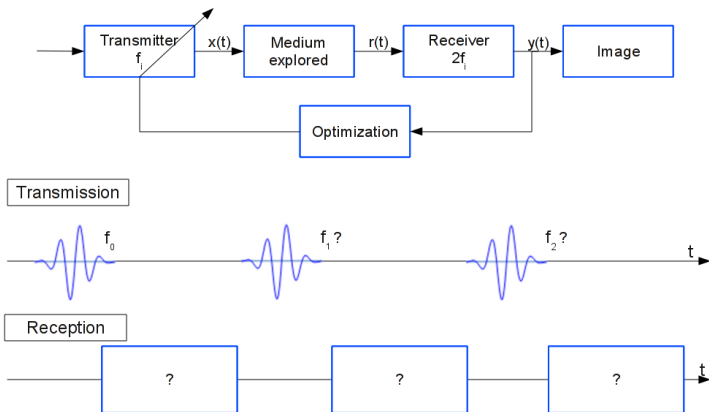


## Methods

Adaptive Harmonic Imaging

Adaptive Pulse Inversion Imaging

# Adaptive Harmonic Imaging





# Optimization Method

## Principle : Method of Gradient

Seeking the maximum by "go-up the descent"

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## Algorithm

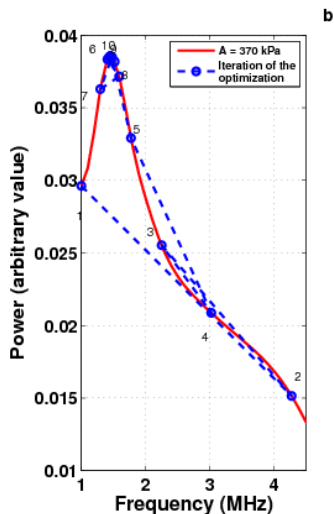
Optimal frequency modified by

$$f_{k+1} = f_k + \alpha_k \cdot \nabla E(f_k)$$

with

$$\nabla E(f_k) = \frac{E_k - E_{k-1}}{f_k - f_{k-1}}$$

•  $\alpha_k$  constant.

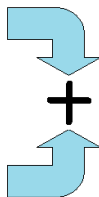


# Principle of the Pulse Inversion Imaging

Transmit signal



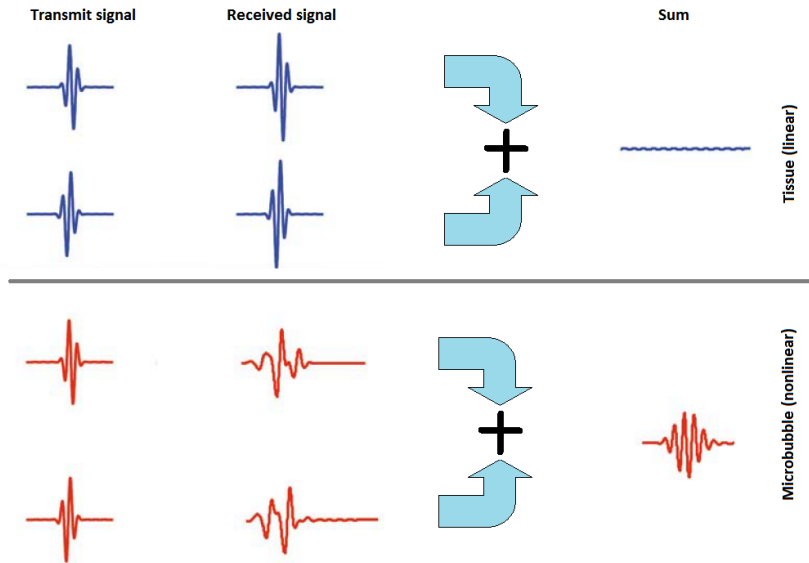
Received signal



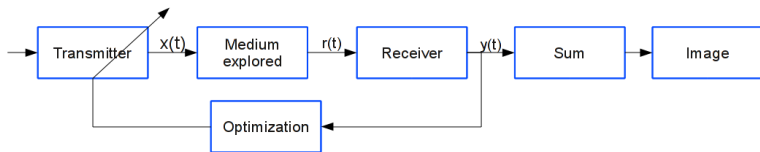
Sum



## Principle of the Pulse Inversion Imaging



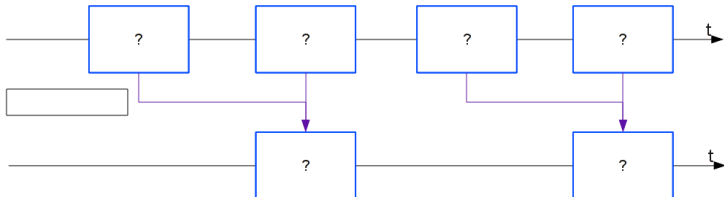
# Adaptive Pulse Inversion Imaging



Transmission



Reception



**Materials**  
Simulations  
*In vitro* experiments

# Numerical Simulations

## Microbubble Model

- Model approxing the SonoVue<sup>TM</sup> contrast agents
- Nonlinear model using BubbleSim (L. Hoff, 2000) with modified Rayleigh-Plesset equation
- Hypothesis : response of the SonoVue =  $N$  response of one microbubble

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- linear response

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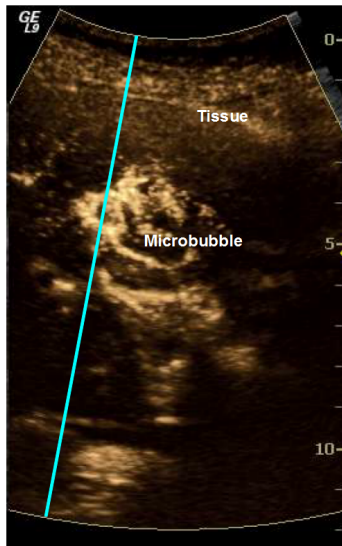
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# Experimental setup

## Materiel

- SonoVue™ (Bracco Research, Geneva, Switzerland)
- Perpendicular position of transducers
- Properties of transducers
  - single element PZT
  - Transmitter (2.25 MHz - bandwidth : 74%)
  - Receiver (3.5 MHz - bandwidth : 63%)

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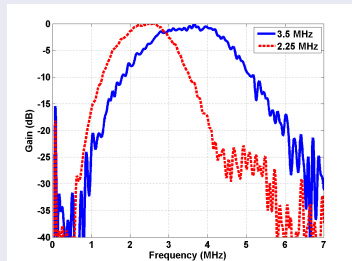
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## Transfer Function



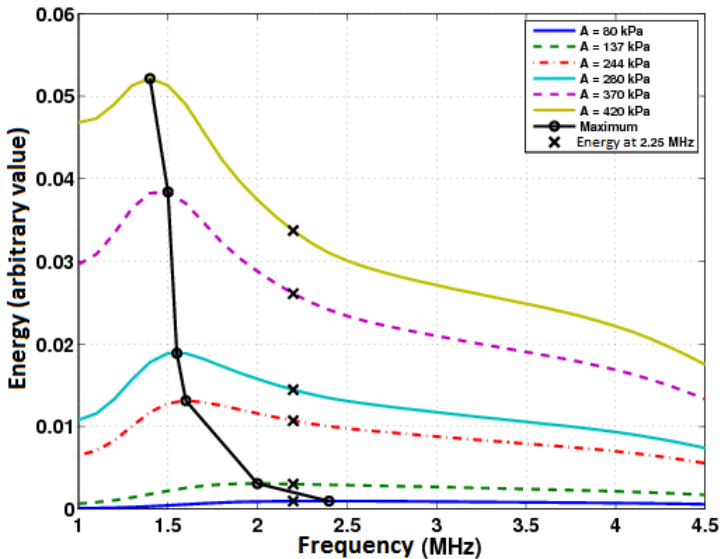
# Results and Discussion

## Harmonic Imaging

## Pulse Inversion Imaging

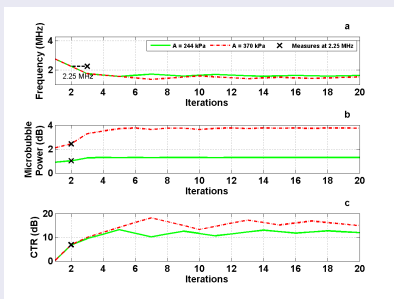
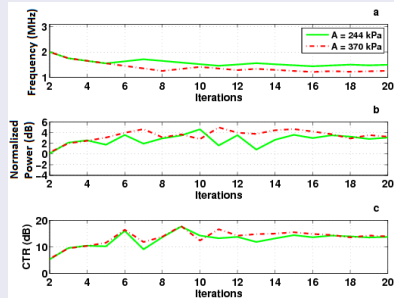


## Energy Backscattered by a Microbubble in Simulation

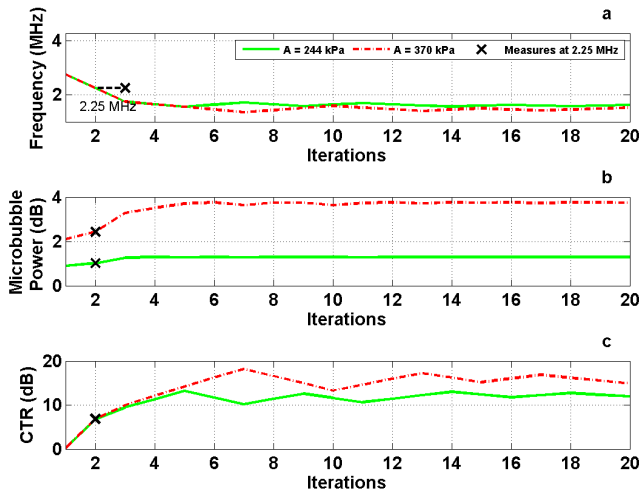


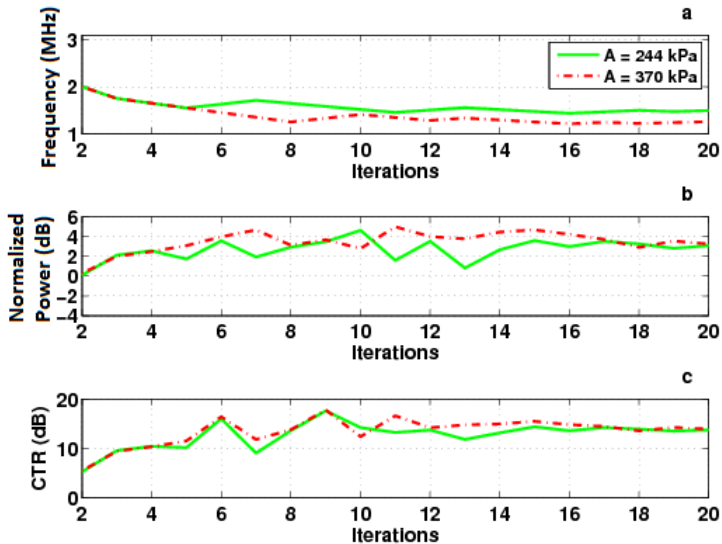
## Adaptive Harmonic Imaging

## Simulation

*In vitro* Experiment

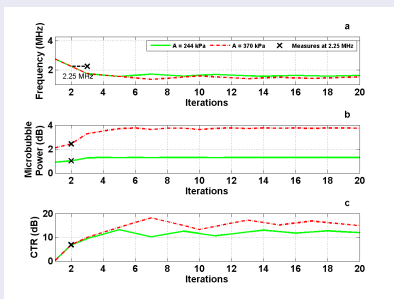
## Simulation in Adaptive Harmonic Imaging



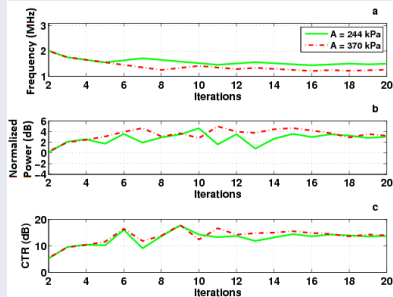
*In vitro* Experiment in Adaptive Harmonic Imaging

# Adaptive Harmonic Imaging

## Simulation



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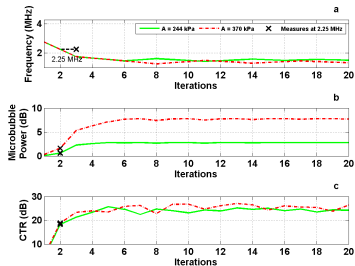
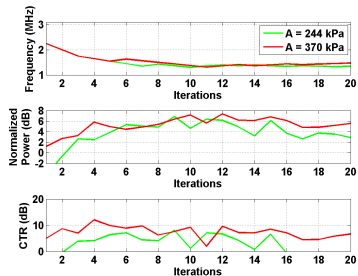


## Discussions

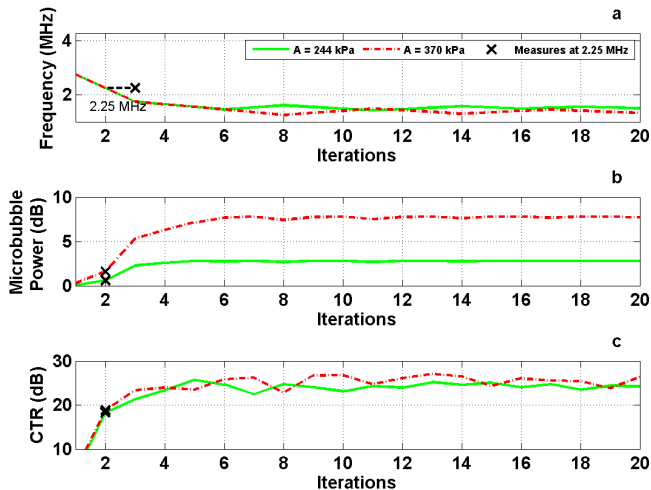
- Optimal frequency around 1.5 MHz
- CTR gain of 4 dB compared to the CTR in the central frequency

## Adaptive Pulse Inversion Imaging

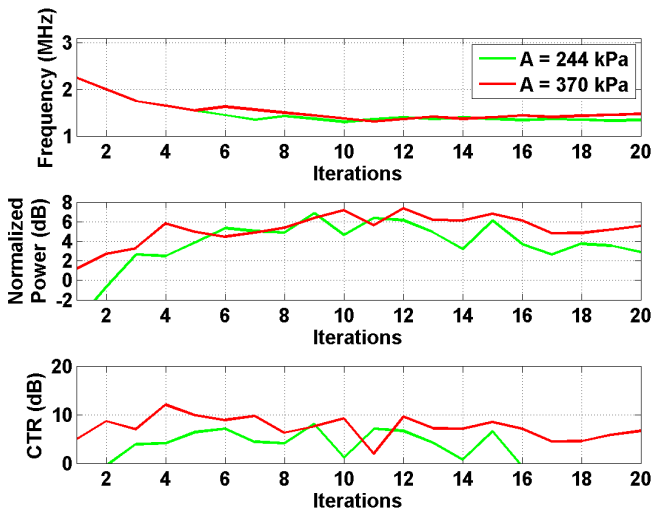
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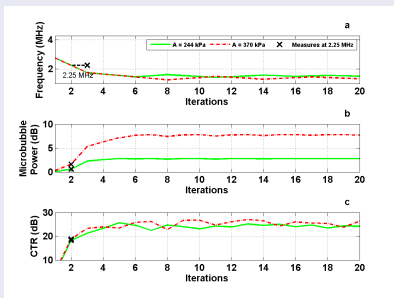
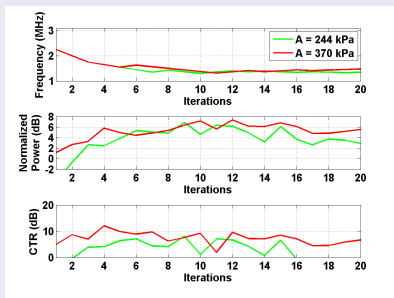
# *In vitro* Experiment in Adaptive Pulse Inversion Imaging





## Adaptive Pulse Inversion Imaging

## Simulation

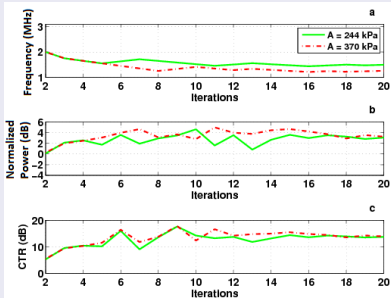
*In vitro* Experiment

## Comparison

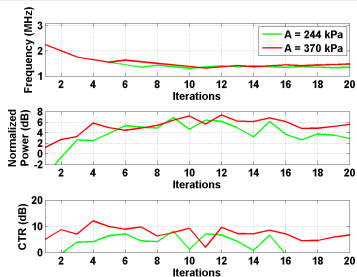
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# Comparison between Adaptive Harmonic Imaging and Adaptive Pulse Inversion Imaging

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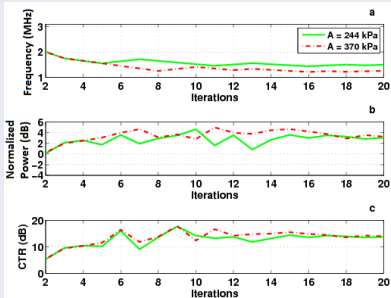


## Pulse Inversion Imaging

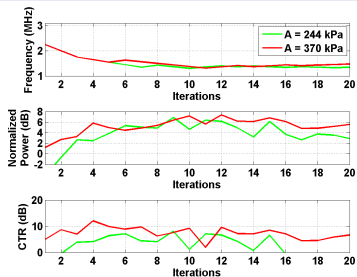


# Comparison between Adaptive Harmonic Imaging and Adaptive Pulse Inversion Imaging

## Harmonic Imaging



## Pulse Inversion Imaging



## Problem

Instrumentation time is too long

# Conclusion

# Conclusion & Perspective

Conclusion :

- Gain of around 4 dB with our adaptive system
- ⇒ Optimization of the CTR in harmonic imaging and pulse inversion imaging

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## Perspectives :

- Optimization with other imaging method like Contrast Pulse Sequence (modulation with amplitude and phase)
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# Thank you for your attention

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