

Optimal Control by Transmit Frequency in Tissue Harmonic Imaging

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Tours, France



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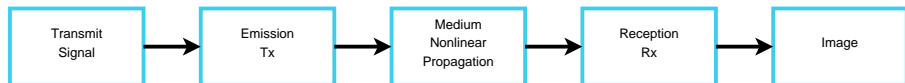


Outline

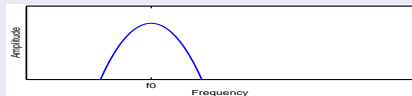
- 1 Introduction
 - Ultrasound Imaging System
 - Ultrasound Second Harmonic Imaging
 - Problematic
- 2 Implementation of the Closed Loop System
 - Cost Function
 - Algorithm
- 3 Materials
- 4 Results
 - Simulation
 - Experiment
- 5 Conclusions & Prospects

Introduction

Ultrasound Imaging System

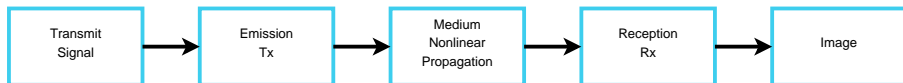


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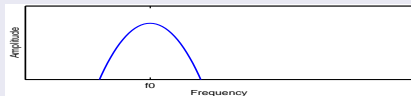


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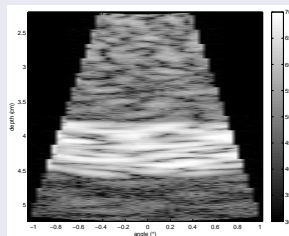
Ultrasound Imaging System



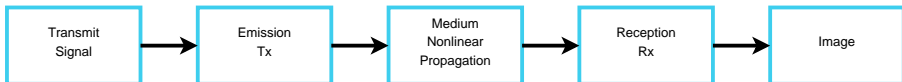
Transmission



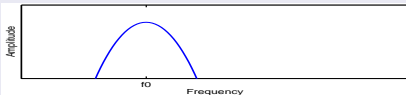
Reception



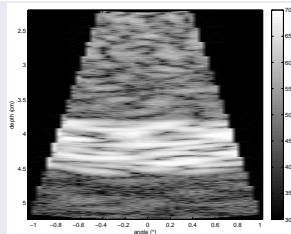
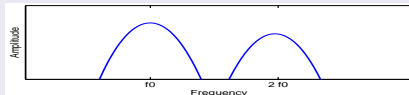
Ultrasound Imaging System



Transmission

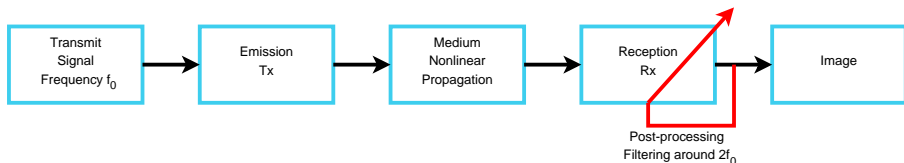


Reception

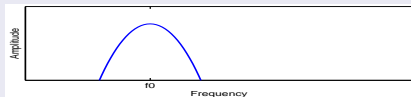


Ultrasound Second Harmonic Imaging

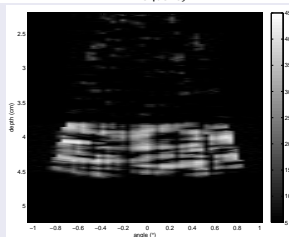
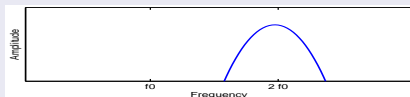
Ultrasound Second Harmonic Imaging



Transmission

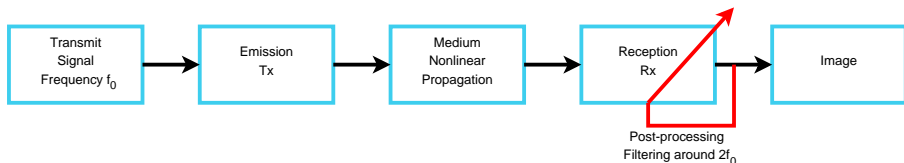


Harmonic Reception

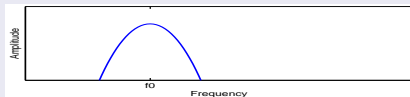


Ultrasound Second Harmonic Imaging

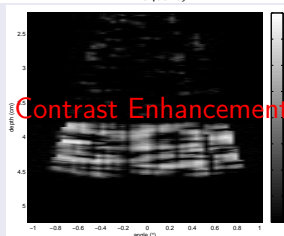
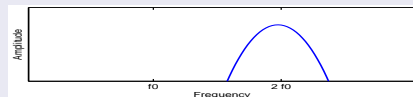
Ultrasound Second Harmonic Imaging



Transmission

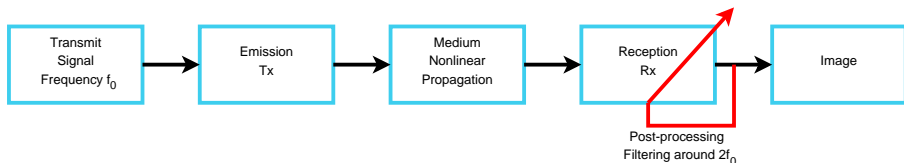


Harmonic Reception

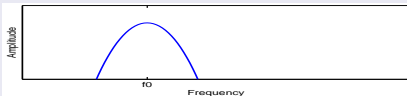


Ultrasound Second Harmonic Imaging

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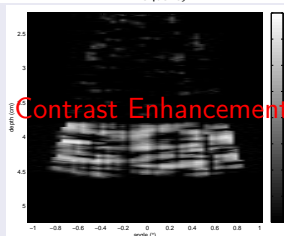
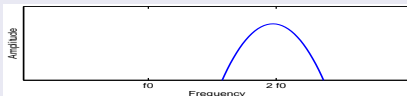
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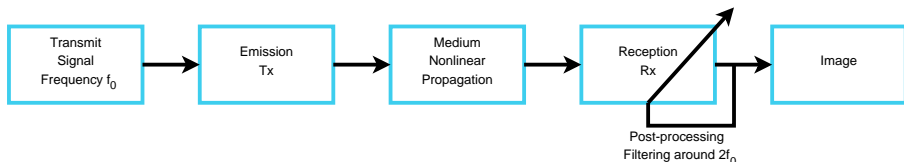
How to optimize the contrast ?

Transmit frequency f_0 ?

Harmonic Reception



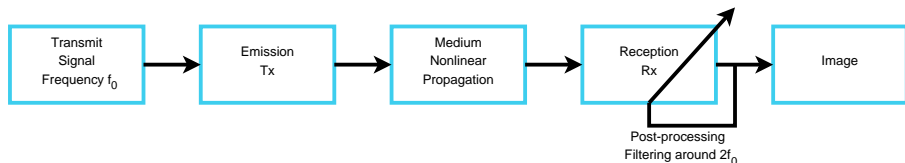
What is the best frequency ?



How to choose the transmit frequency f_0 ?

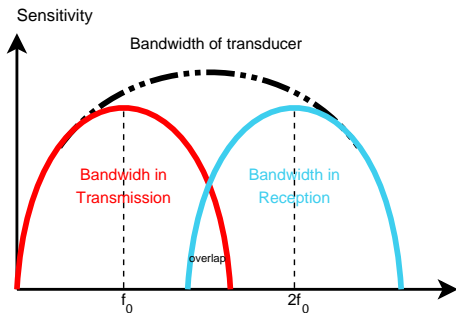
- Advice : $2/3f_c$ with $f_c =$ central frequency of the transducer
- Is it optimal ?

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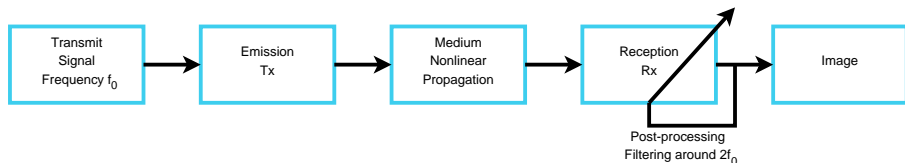


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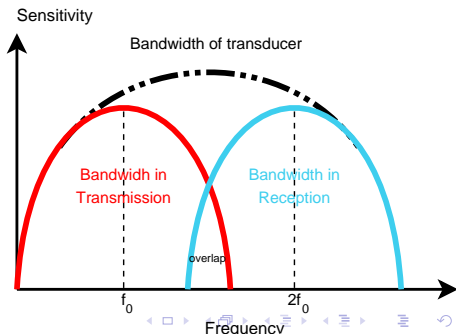


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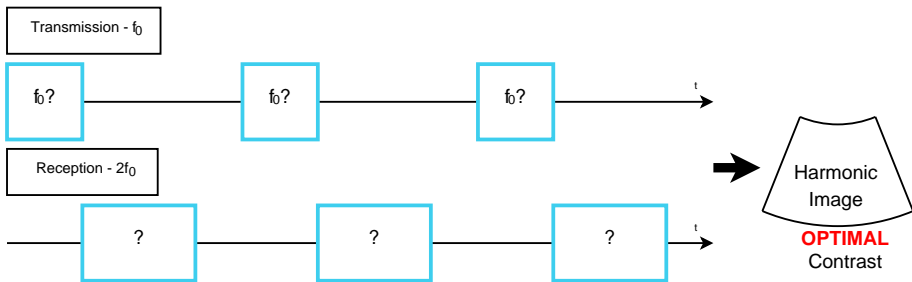
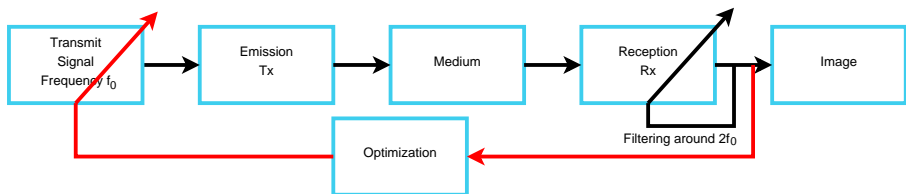


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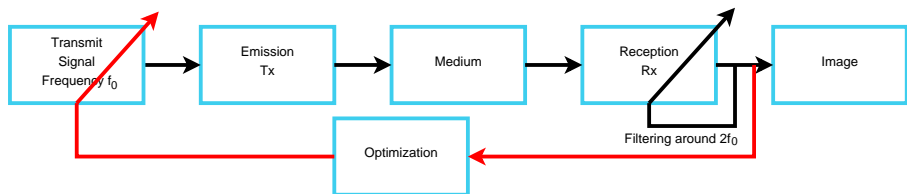


Optimal Transmit Frequency for Ultrasound Imaging System



Implementation of the Closed Loop System

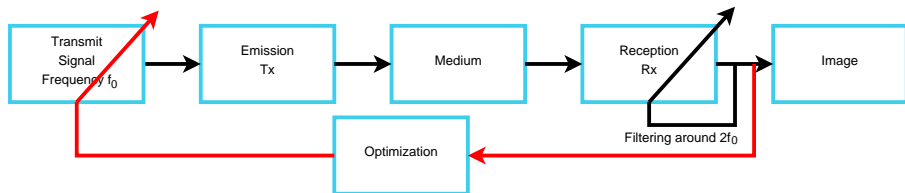
Implementation of the Closed Loop System



Setting of Iterative Optimization

- 1 Choice of the Cost Function $J(\theta)$
- 2 Choice of the parameters θ
- 3 Choice of the optimization algorithm

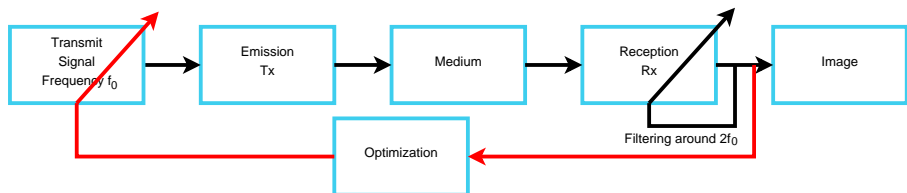
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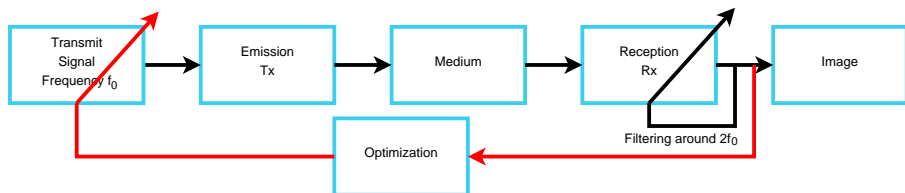
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Implementation of the Closed Loop System



Setting of Iterative Optimization

- 1 Choice of the Cost Function $J(\theta)$
- 2 Choice of the parameters $\theta \rightarrow$ **Transmit frequency f_0**
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Find the Cost Function for the Goal

Goal

Maximize the mean contrast in the whole image

① Choice of the Cost Function

- Maximize nonlinear behavior
- Minimize linear behavior
- Cost Function "*Contrast Harmonic to Fundamental Ratio*" :

$$CHFR(f_0) = \frac{\text{Second Harmonic Power}}{\text{Fundamental Power}}$$

- Constraint : constant transmitted power

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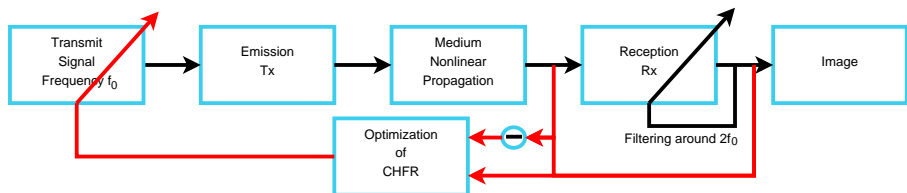
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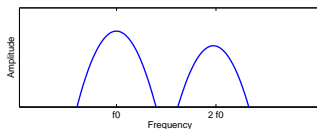
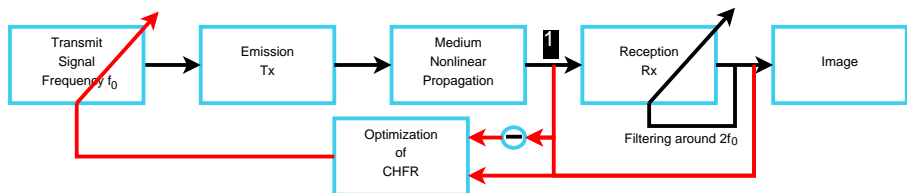
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Algorithm

Algorithm

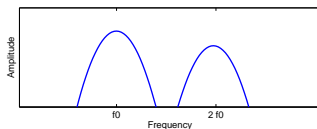
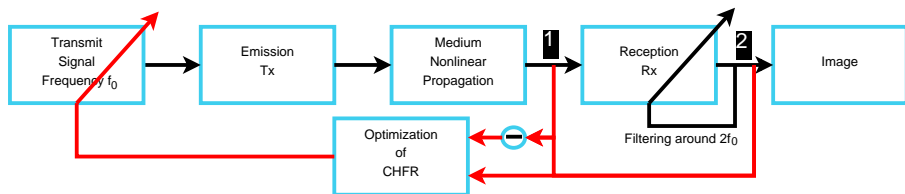


Algorithm

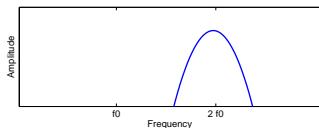


1

Algorithm



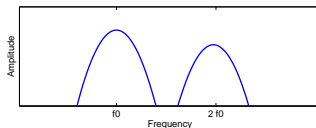
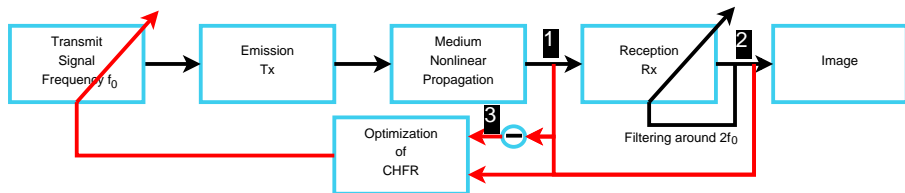
①



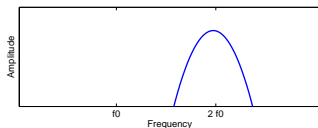
②

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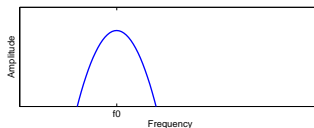
Algorithm



①

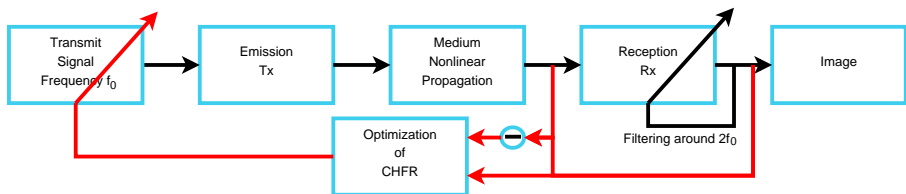


②



③

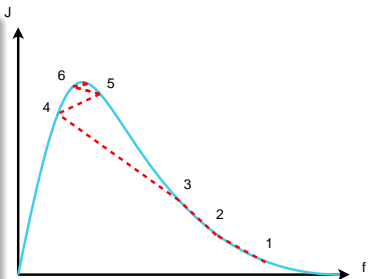
Algorithm



③ Algorithm and Principle

- **Method of Gradient**
- Seek the maximum by “going up the descent”

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

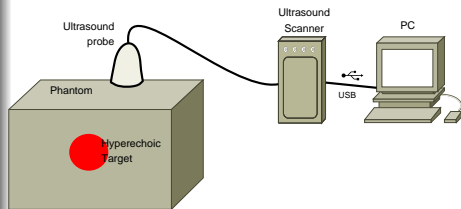


Materials

Simulation and Experimental Setup

Experiment

- “Open” Ultrasound Scanner
(MultiX WM, M2M, Les Ulis, France)
- Probe centred at $f_c = 4$ MHz
(Vermon SA, Tours, France)
- Phantom with hyperechoic target
(CIRS, Norfolk, VA, USA)



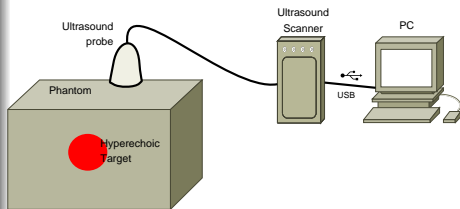
Simulation

- Transducer centred at $f_c = 3.5$ MHz
- Nonlinear propagation: pseudo-spectral method [Anderson, 2000]
- Tissue with a blood vessel

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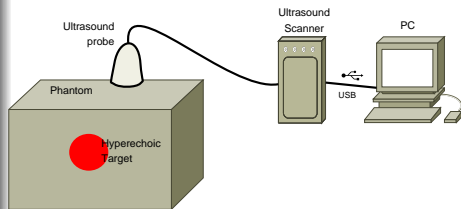
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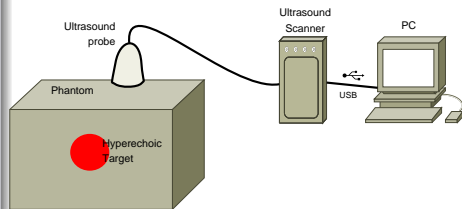
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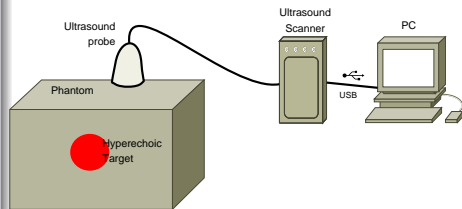
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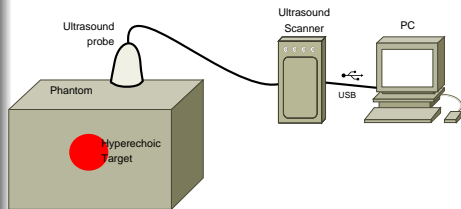
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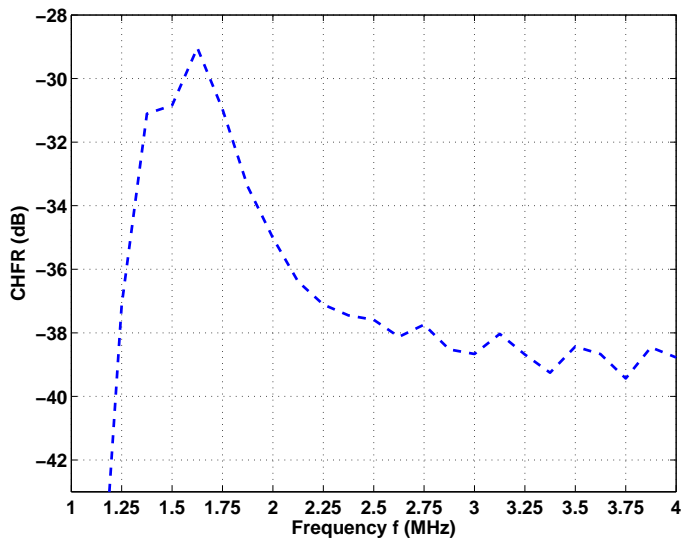


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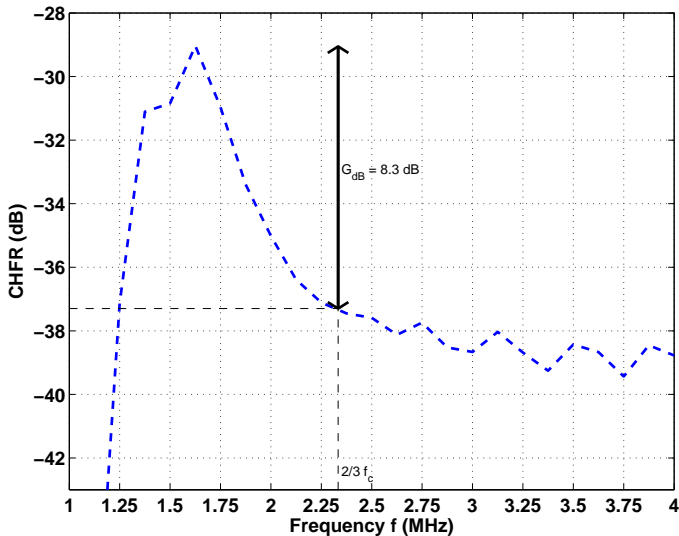
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Results

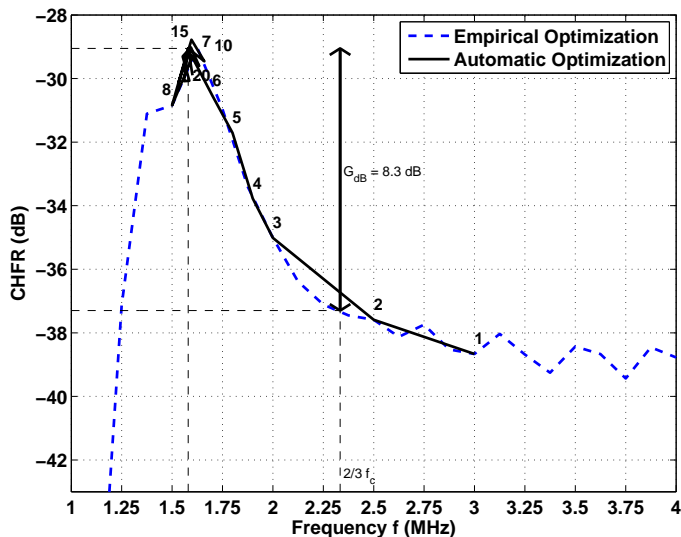
Simulation: Empirical Optimization



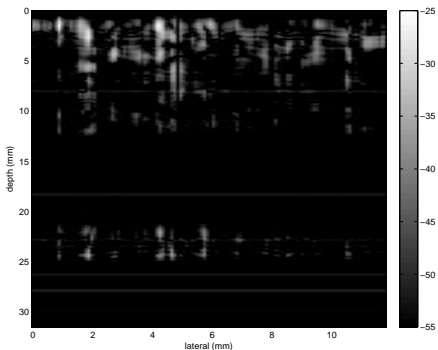
Simulation: Empirical Optimization



Simulation: Automatic Optimization



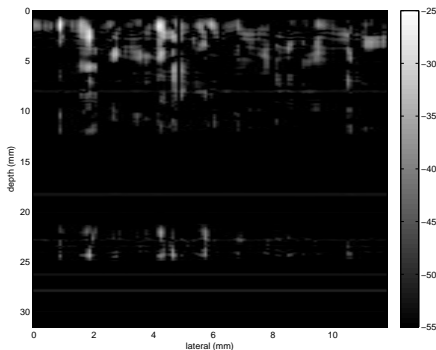
Simulation: Synthetic Harmonic Images



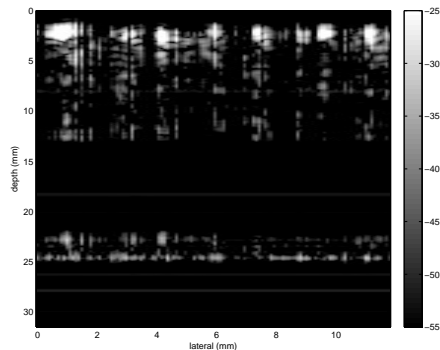
$$f_0 = 2/3f_c = 2,3 \text{ MHz}$$

Simulation

Simulation: Synthetic Harmonic Images

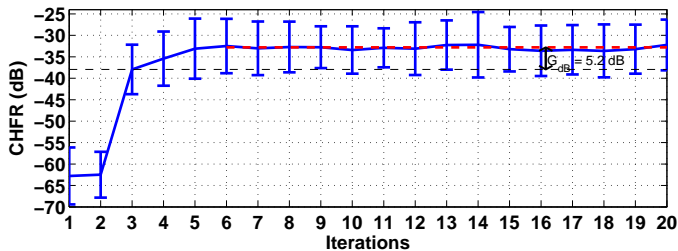
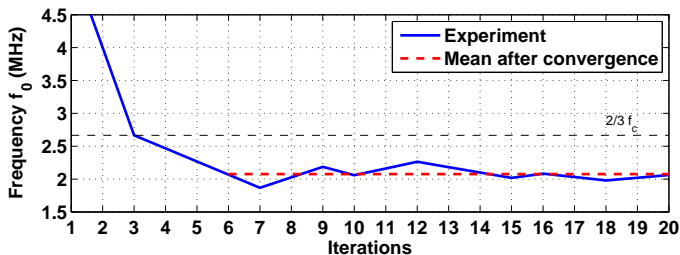


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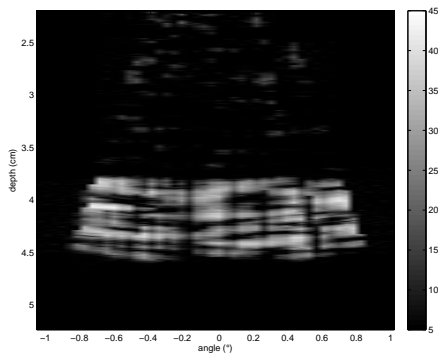


$$f_0 = f_{0,opt} = 1,6 \text{ MHz}$$

Experiment: Automatic Optimization



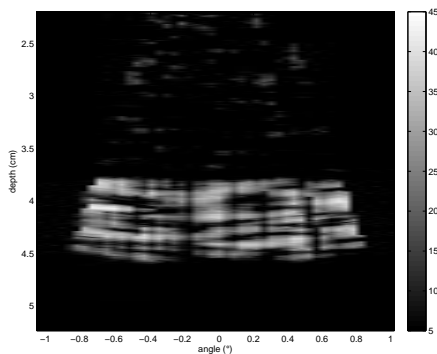
Experiment: Harmonic Images



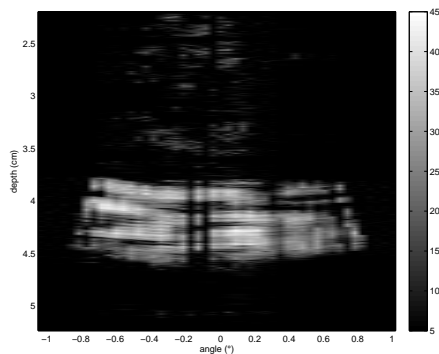
$$f_0 = 2/3f_c = 2,3 \text{ MHz}$$

Experiment

Experiment: Harmonic Images



$$f_0 = 2/3 f_c = 2,3 \text{ MHz}$$



$$f_0 = f_{0,opt} = 1,6 \text{ MHz}$$

Conclusion & Prospects

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- Automatic optimization of the contrast (*CHFR*)
- Adapt itself to optimize the contrast
- Setting without knowlegde of medium or transducer
- Gain of around 5 dB with our closed-loop system
- Prospects: application to another harmonic imaging methods

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Thank you for your attention

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Institut national
de la santé et de la recherche médicale