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### Optimal Control by Transmit Frequency in Tissue Harmonic Imaging

#### Sébastien Ménigot and Jean-Marc Girault



Université François Rabelais de Tours Inserm U930 - *Imaging and Brain* Team 5 - *Imaging and Ultrasound* Tours, France

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- Ultrasound Second Harmonic Imaging
- Problematic

### (2) Implementation of the Closed Loop System

- Cost Function
- Algorithm

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- Simulation
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### Ultrasound Imaging System





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### Ultrasound Imaging System





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Ultrasound Imaging System				

### Ultrasound Imaging System











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### What is the best frequency ?



# How to choose the transmit frequency $f_0$ ?

- Advice : 2/3*f<sub>c</sub>* with *f<sub>c</sub>* = central frequency of the transducer
- Is it optimal ?

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#### Setting of Iterative Optimization

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

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- Choice of the Cost Function  $J(\theta)$
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Choice of the optimization algorithm

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#### Setting of Iterative Optimization

- Choice of the Cost Function  $J(\theta)$
- **2** Choice of the parameters  $\theta \rightarrow \text{Transmit frequency } f_0$
- Ochoice of the optimization algorithm

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Find the Cost	Function f	or 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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#### 3 Algorithm and Principle

- Method of Gradient
- Seek the maximum by "going up the descent"

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



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### Materials

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#### 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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### Simulation: Empirical Optimization



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### Simulation: Empirical Optimization



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### Simulation: Automatic Optimization



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#### Simulation: Synthetic Harmonic Images



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#### Simulation: Synthetic Harmonic Images



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### Experiment: Harmonic Images



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### **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

sebastien.menigot@univ-tours.fr jean-marc.girault@univ-tours.fr







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