Random Excitation by Optimized Pulse Inversion in Contrast Harmonic Imaging

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Tours, France

April 26th, 2012

ACOUSTICS 2012

Outline

Introduction

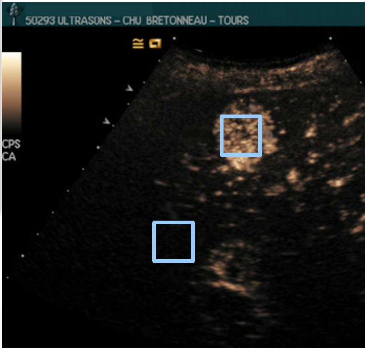
Ultrasound Contrast Imaging

Contrast Agents

- Injection of contrast agents ⇒ perfusion imaging
- Encapsulated microbubbles: mean diameter between 1 to 10 μm
- High nonlinear behavior

Contrast to Tissue Ratio

$$CTR = \frac{E_{microbubbles}}{E_{tissue}}$$



[F. Tranquart]

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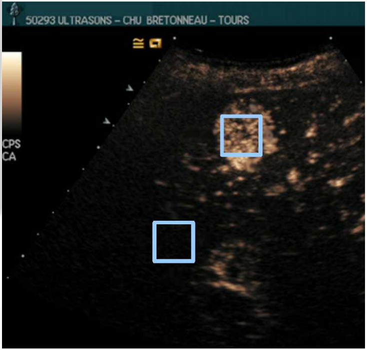

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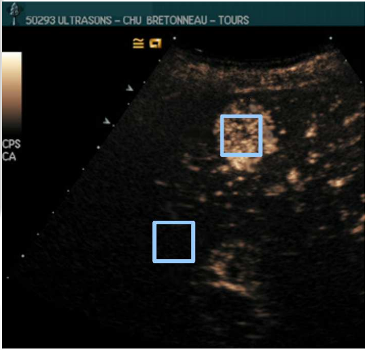

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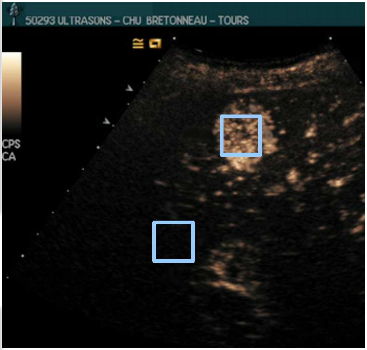

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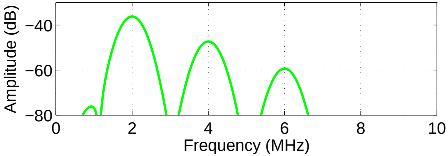

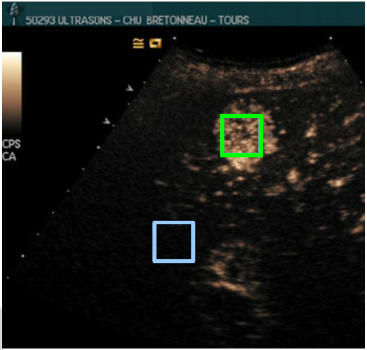

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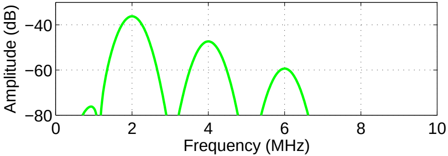

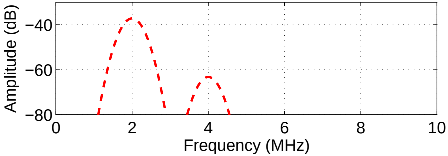

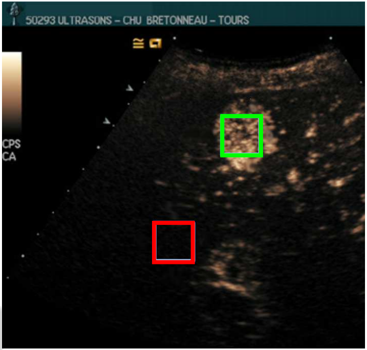

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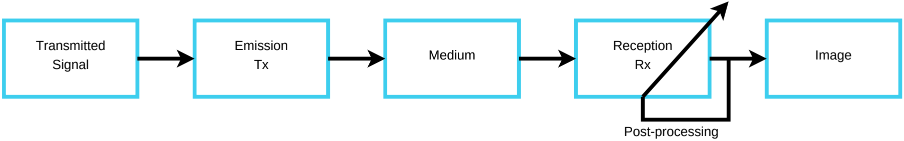
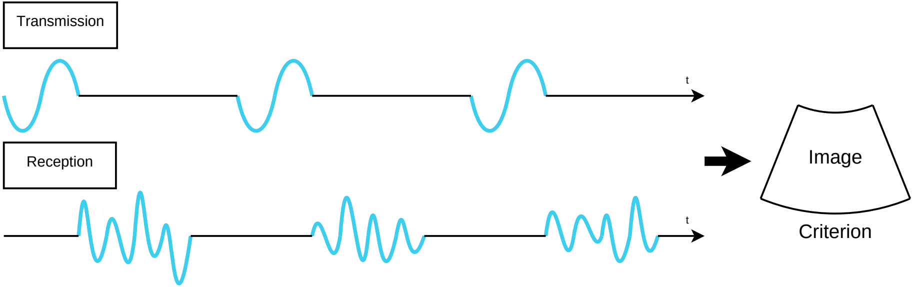
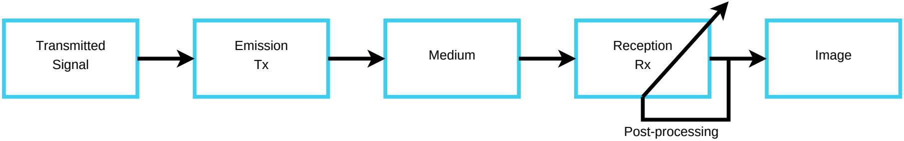
Ultrasound Contrast Harmonic Imaging



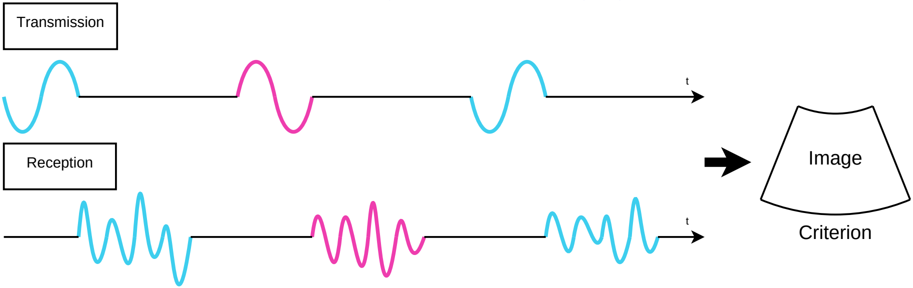
Ultrasound Harmonic Imaging using post-processing



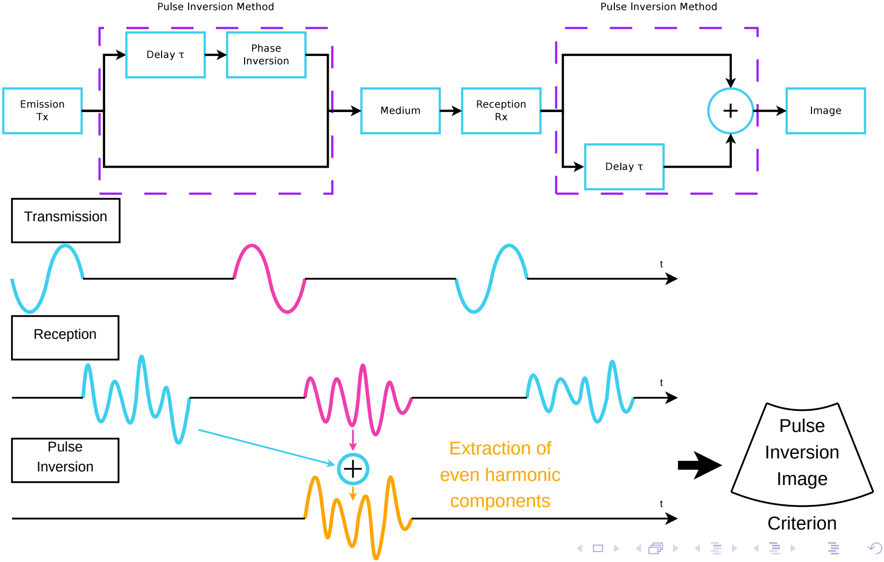
Ultrasound Contrast Harmonic Imaging



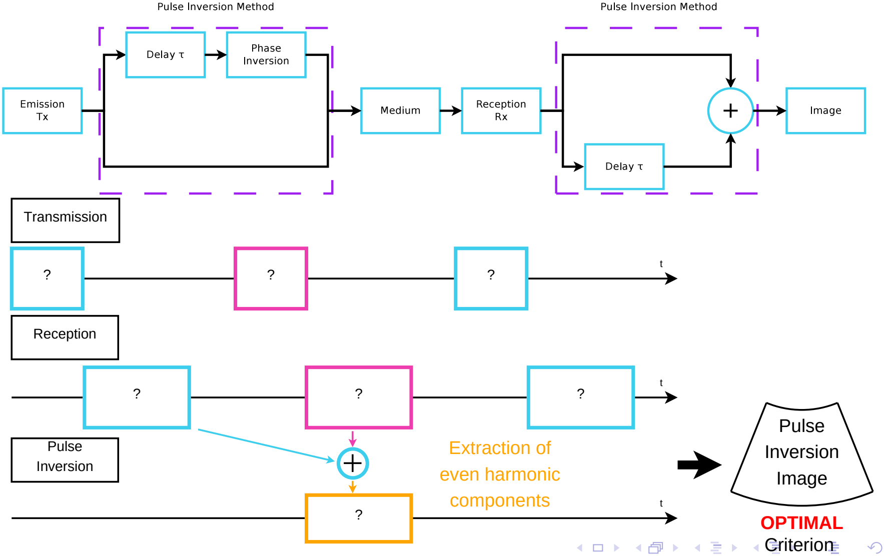
Encoding Harmonic Imaging



Pulse Inversion Imaging

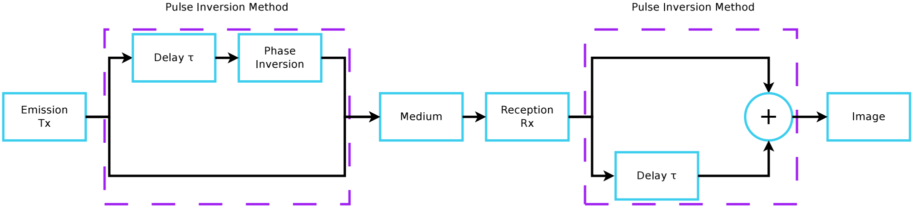


What is the best command to optimize the criterion?



Random Excitation

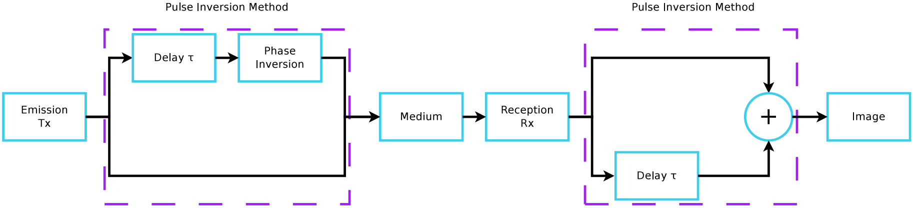
Principle of Random Excitation



Principle of Implementation

1. Find the input signal $x(t)$ of the pulse inversion imaging system
2. Optimize the CTR
3. Random search by Monte-Carlo method

Principle of Random Excitation



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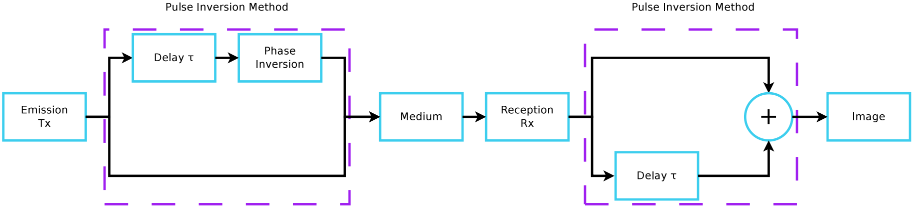

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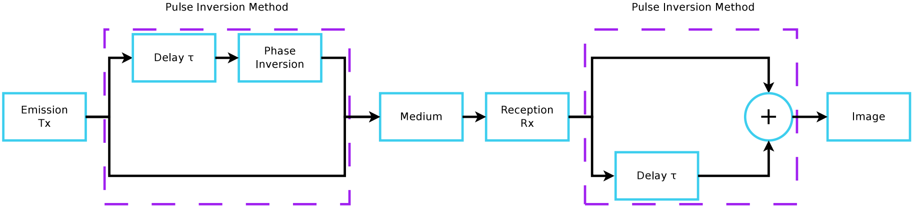

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Simulation Model

Simulation Properties

- Transducer centred at $f_c = 3$ MHz
- Microbubble
  - Free simulation software Bubblesim [Hoff, 2001]
  - Modified Rayleigh-Plesset Equation
  - Diameter: 2.5 μm
  - Shell thickness: 1 nm
  - Resonance Frequency: 3.1 MHz
- Tissue : Rayleigh diffusion

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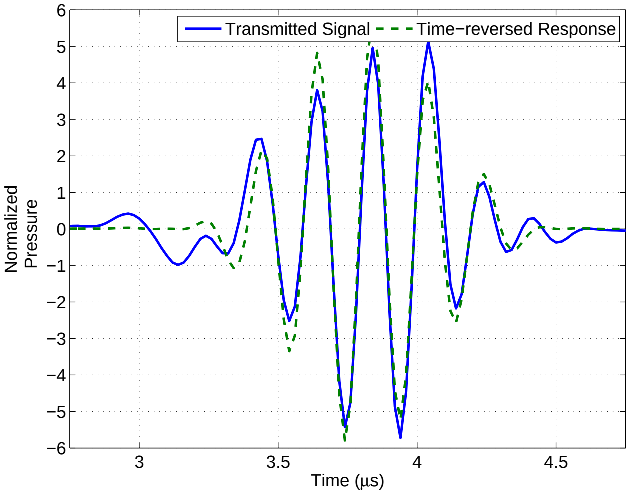
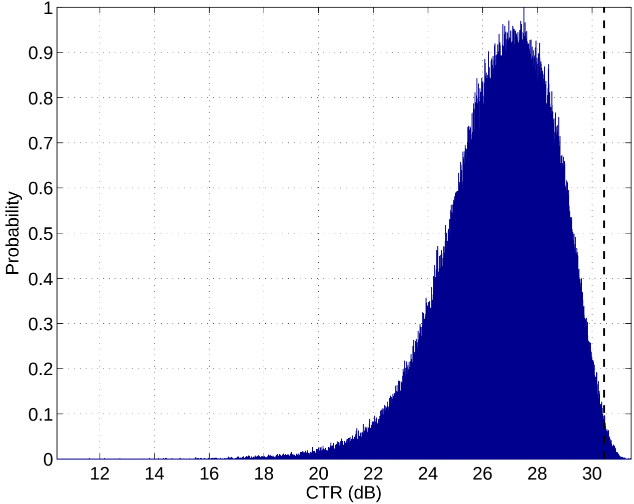
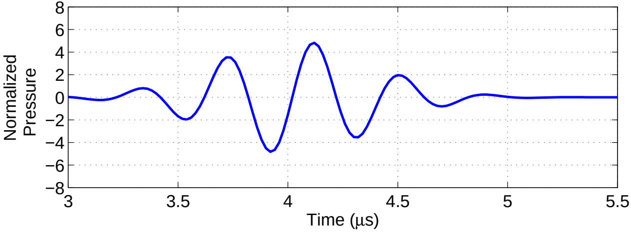
Results for linear system: Optimization of microbubble power



Results for nonlinear pulse inversion imaging system



Results for nonlinear pulse inversion imaging system



$$f_{opt} = 2.5 \text{ MHz}$$

$$CTR = 30.4 \text{ dB}$$

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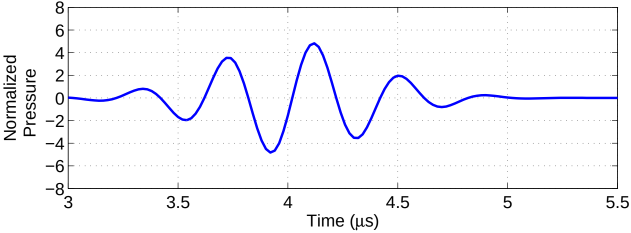

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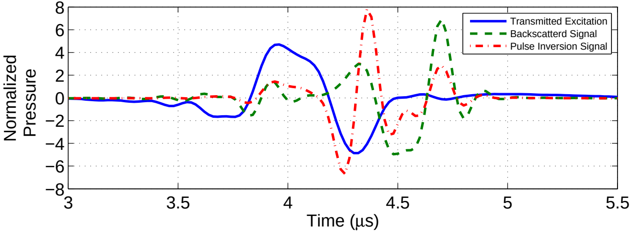
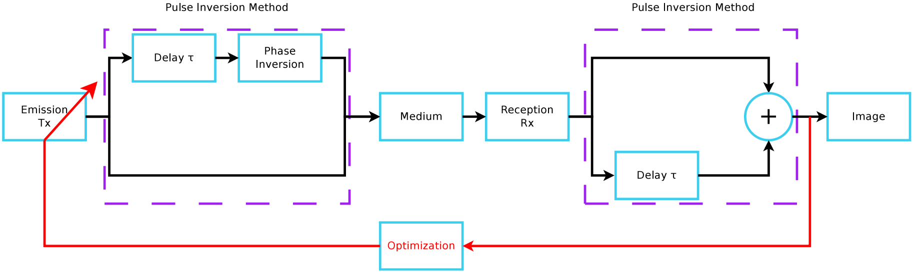


$CTR = 31.4$ dB

1 million of tests

Parametric Optimization

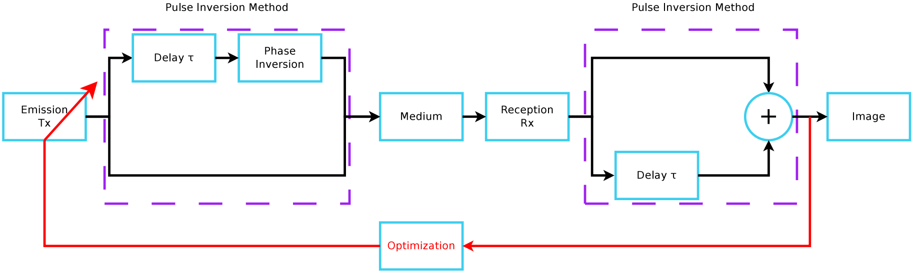
Implementation of the Parametric Optimization



Setting of Iterative Optimization

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

Implementation of the Parametric Optimization



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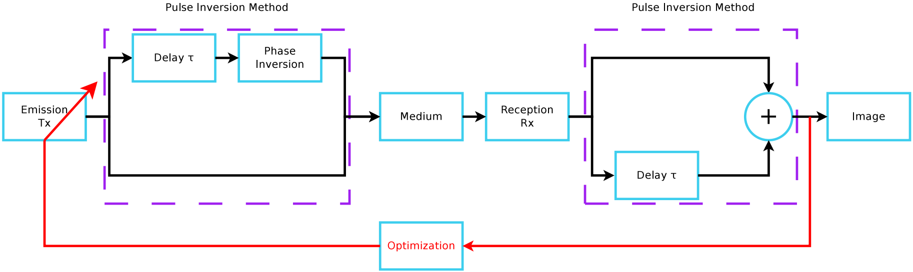

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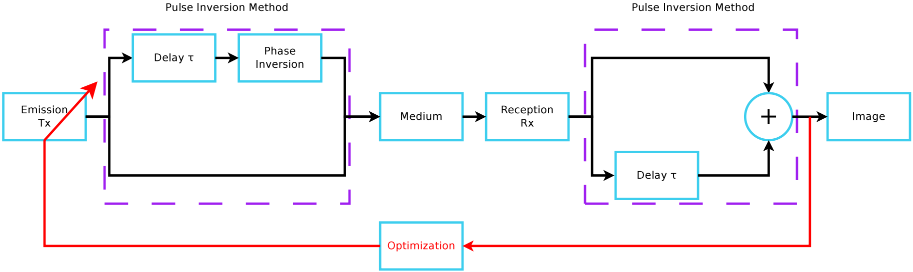

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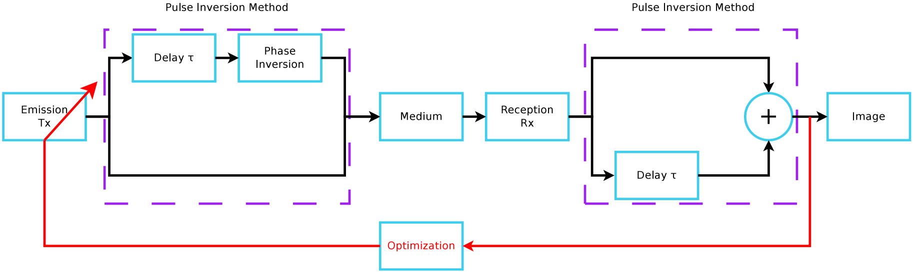

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Optimization Setting

1. Maximization of the *CTR*
2. Input signal described by autoregressive model

$$\hat{x}(t) = \sum_{i=0}^{M-1} h_1(i) x(t-i)$$

3. Nelder-Mead's Algorithm based on simplex

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$$\hat{x}(t) = \sum_{i=0}^{M-1} h_1(i)x(t-i) + \sum_{i=0}^{M-1}\sum_{j=i}^{M} h_2(i,j)x(t-i)x(t-j) + \cdots$$

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Order $K = 3$ and memory $M = 3 \Rightarrow$ 19 parameters

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Results with Parametric Optimization

	Pulse	Random	Random with Parametric Optimization
CTR	30.4 dB	31.4 dB	

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Comparison

	Random	Random with Parametric Optimization
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Comparison

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		Random	Random with Parametric Optimization
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N_{test}	15	2165	258

Conclusion & Prospects

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- Know the optimal shape of the optimal command
- Random process without *a priori* knowledge of the medium
- Suboptimal excitation by combination between random process and parametric optimization
- Decrease test number
- Prospects:
  - Analysis the optimal excitation
  - Find the optimal command by metaheuristic

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Thank you for your attention

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ACOUSTICS 2012

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