

*EXCITATION FREQUENCY OPTIMISATION TO ENHANCE
HARMONICS BACKSCATTERED BY A NONLINEAR MEDIUM*

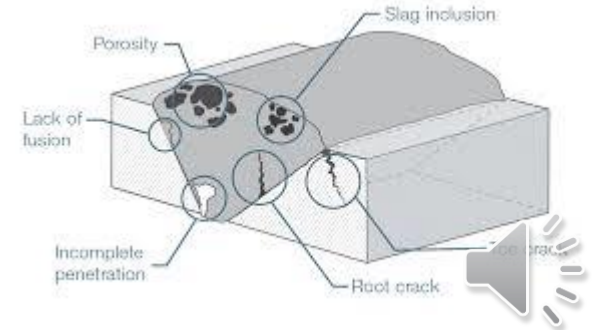
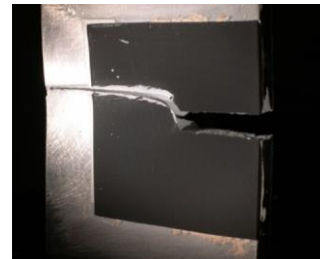
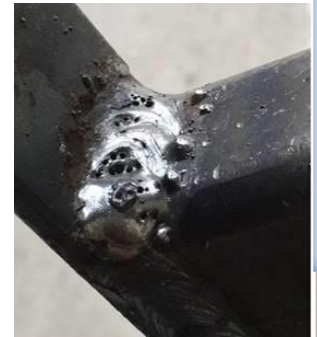
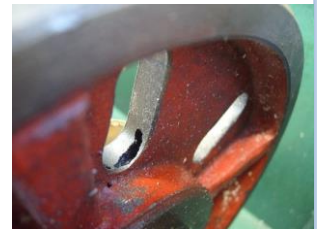
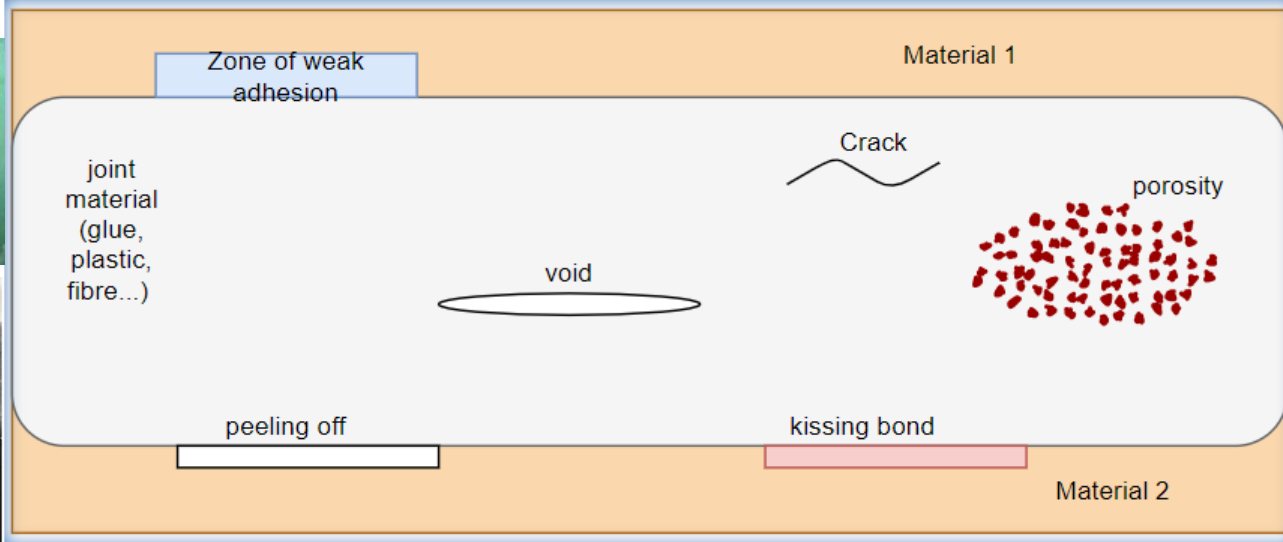
Volodymyr Gatsa ^{1,2} Sébastien Ménigot ^{1,2} Vincent Tournat ²

¹ ESEO GROUP, Angers, France

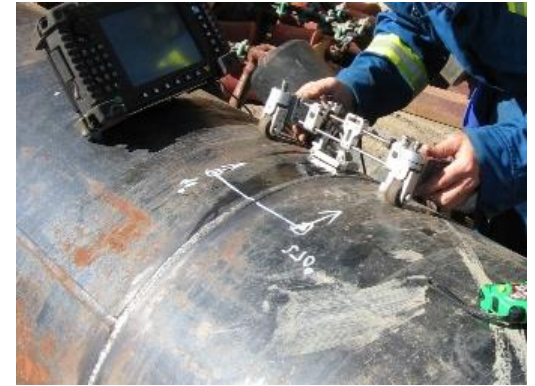
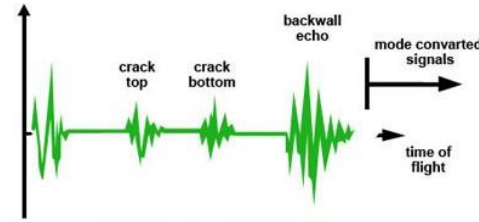
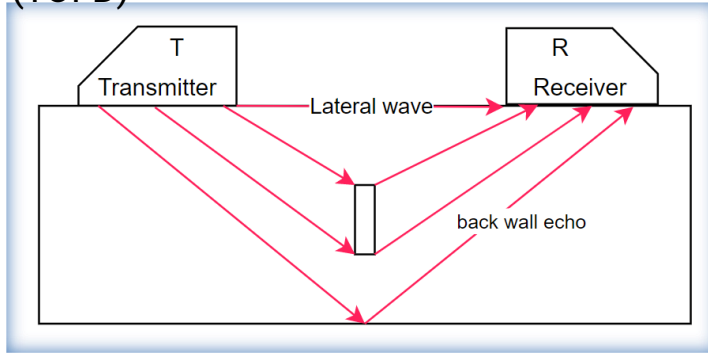
LAUM, UMR-CNRS 6613, Le Mans Université, Le Mans, France



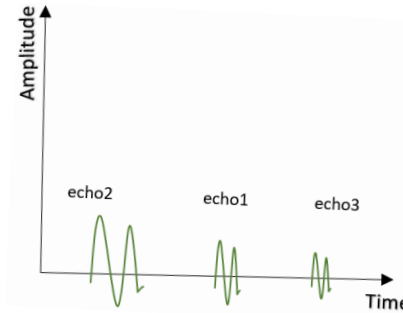
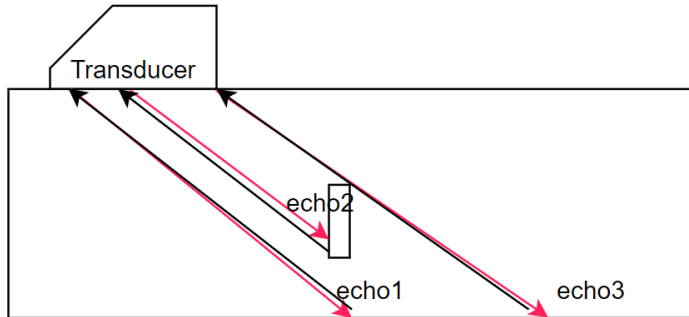
Types of defects (example of bonding)



Time of Flight Diffraction experiment (TOFD)



Echo experiment (A-scan)



Interest of the nonlinearity

Source of nonlinearity

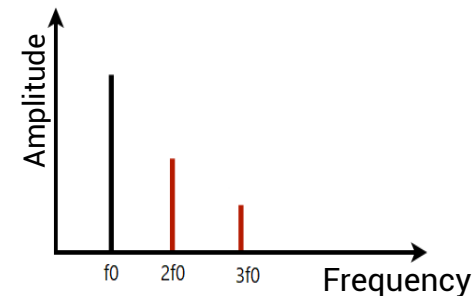
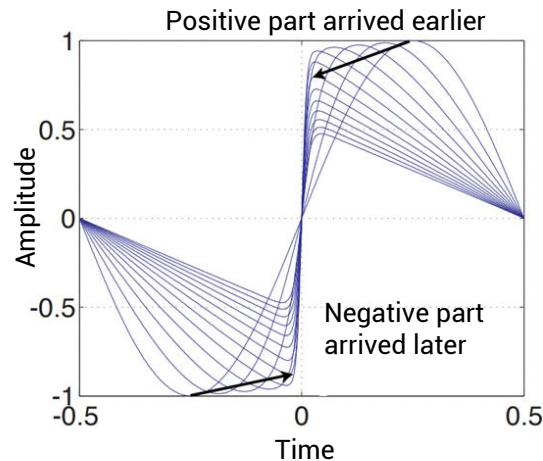
- Microcracks
- Delamination
- Weak adhesion bonds
- Porosity
- Propagation

Nonlinear phenomenas

- Harmonics generation
- Intermodulation of frequencies components
- Amplitude depended shift to resonance frequencies
- Nonlinear contribution to measured parameters (attenuation, velocity ...)

Propagation nonlinearity exemple

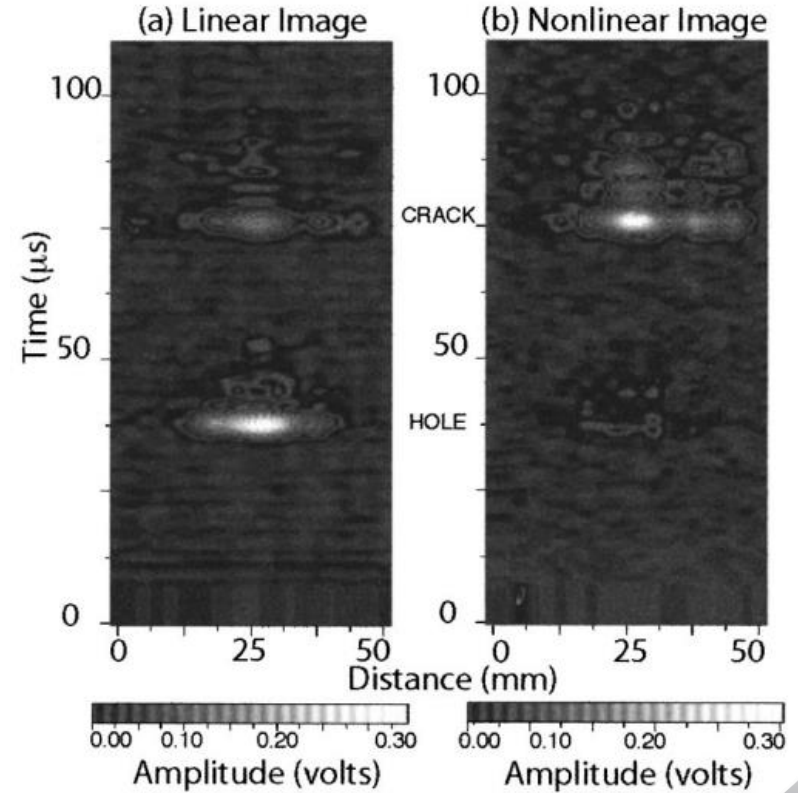
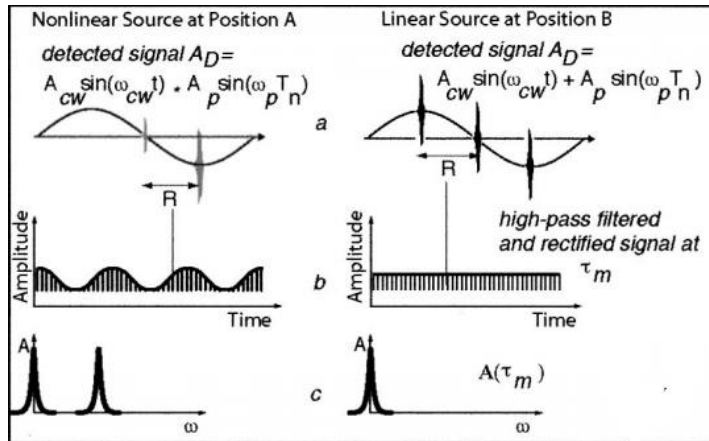
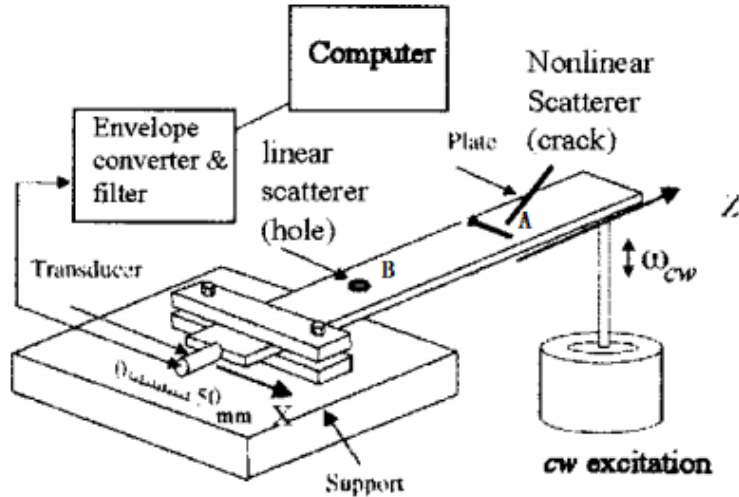
1. the magnitude of the waves is high enough
2. wave propagation is no longer linear



The speed of the particles contributes to the speed of the wave

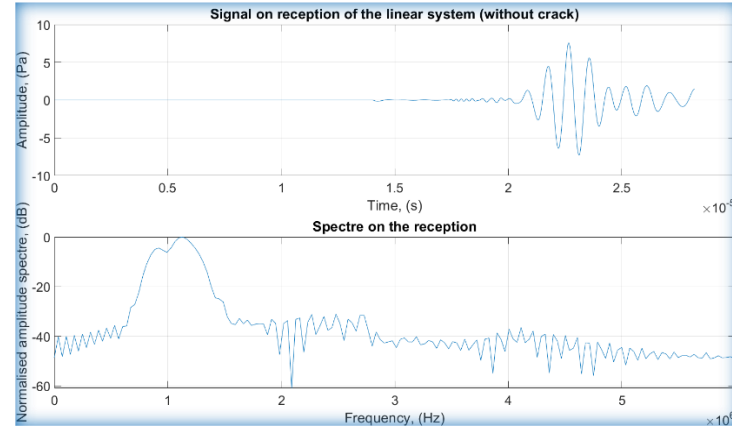
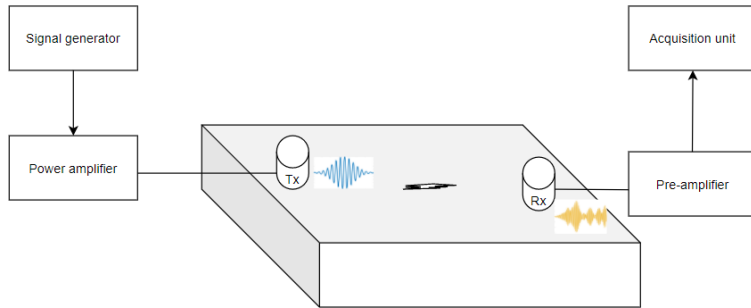


Different types of cracks: Vibro-acoustic modulation experiment

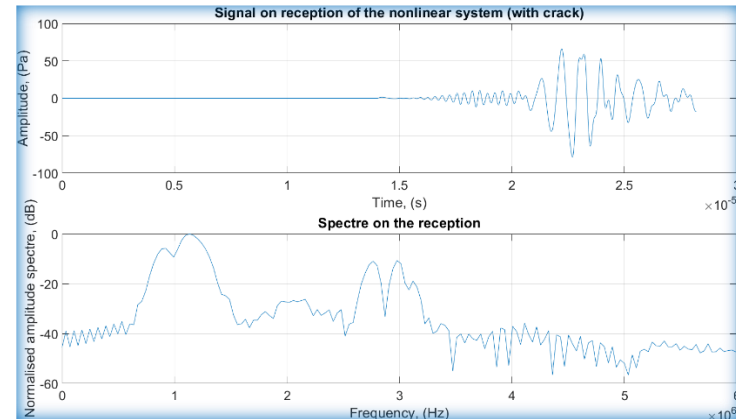
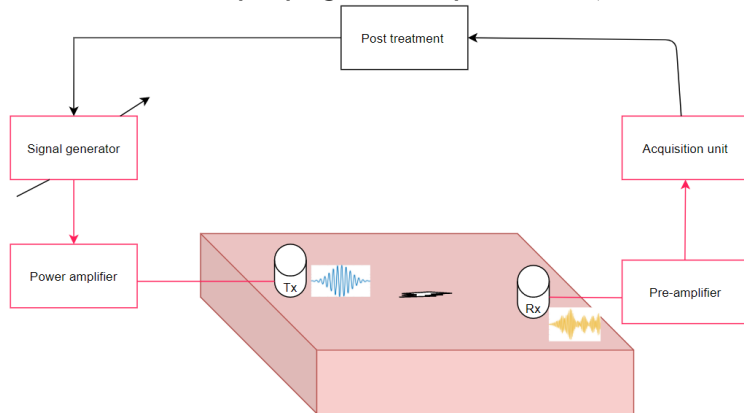


Nonlinear Nondestructive evaluation

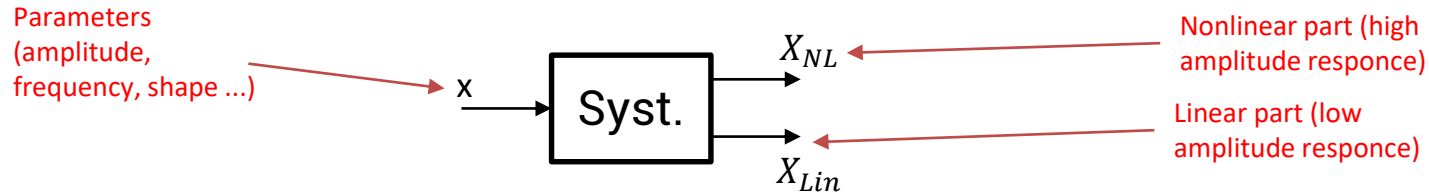
Nonlinear wave propagation experiment



Nonlinear wave propagation experiment (closed loop)



Initial signal parameters and cost function



Idea :

adjustment using the function of cost.

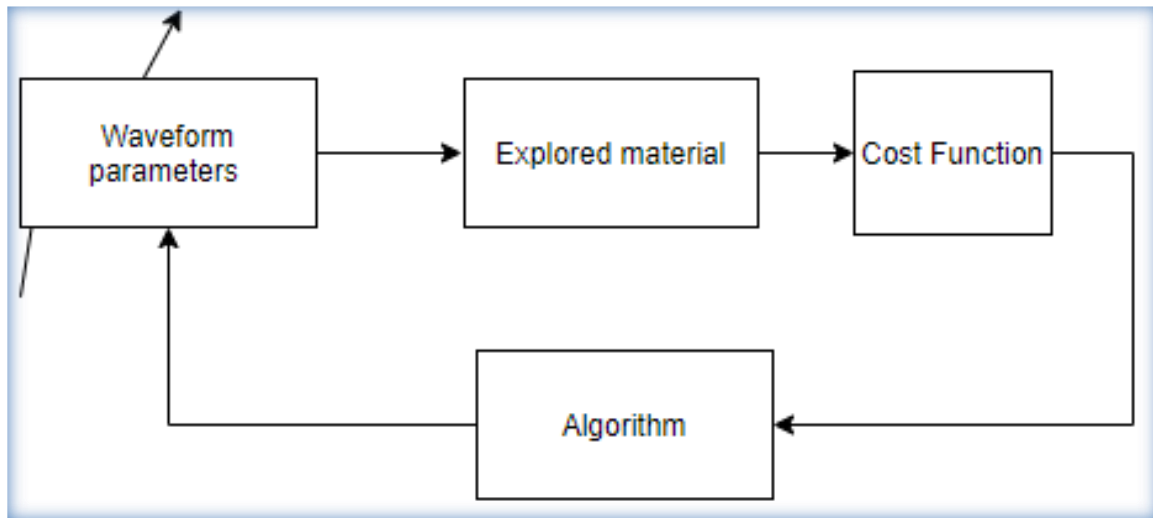
$$\left. \begin{aligned} \max(G) &= \min(E_{NL}) \rightarrow +\infty \\ \min(J) &= \max(E_{Lin}) \rightarrow 0 \end{aligned} \right\}$$

$$\max(CF) = \max\left(\frac{E_{NL}}{E_{Lin}}\right)$$

CF - Nonlinear Linear Ratio



Algorithm → Optimize the detection of the nonlinear answer from the damage



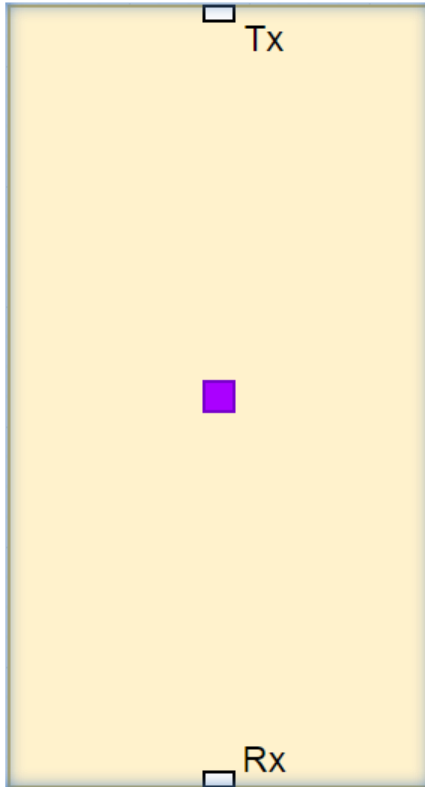
Parameters for x - is a random frequency f_0

Cost-function - investigate response of the system by specific features

Algorithm - use information of input and output of the system and suggest the following initial parameter to input



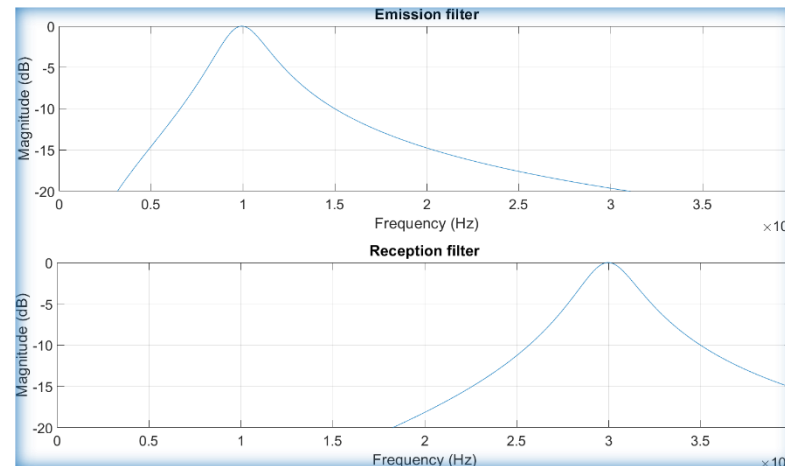
Simulated sample (2D aluminum alloy plate)



P-wave speed [m/s]	6398
S-wave speed [m/s]	3030
Density [kg/m ³]	3122
Young modulus [Pa/m ²]	$70 \cdot 10^9$
Poisson ratio	0.33
Density [kg/m ³]	2966

Sample dimensions	[100 ; 50] mm
Crack dimensions	[8 ; 8] mm

Tx	Band-pass filter [fc = 1MHz]
Rx	Band-pass filter [fc = 3MHz]

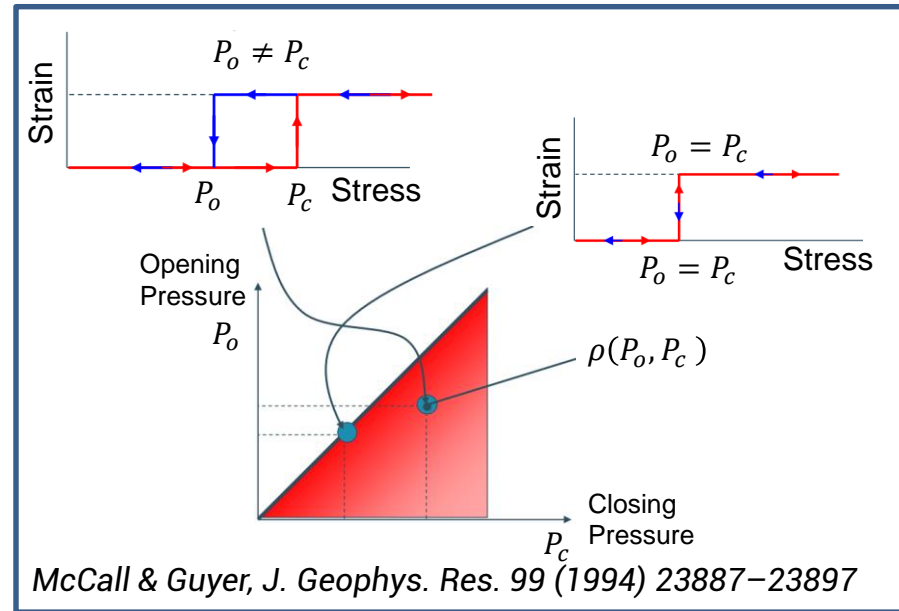


Simulateur

Pseudospectral / staggered A-B method, with linear propagation of longitudinal and shear waves.

Crack hysteresis behavior described by hysteretic elementary units (HEU)

Crack hysteretic behavior, PM space model

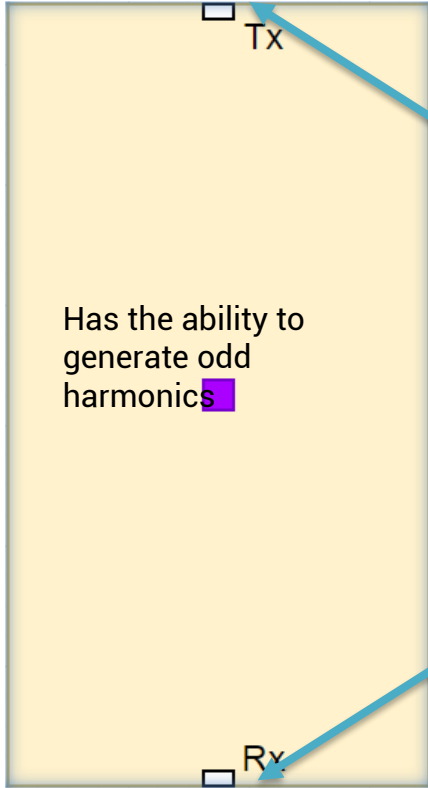


T. Goursolle et al. / *International Journal of Non-Linear Mechanics* 43 (2008) 170–177



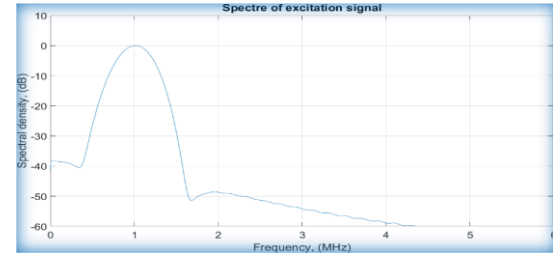
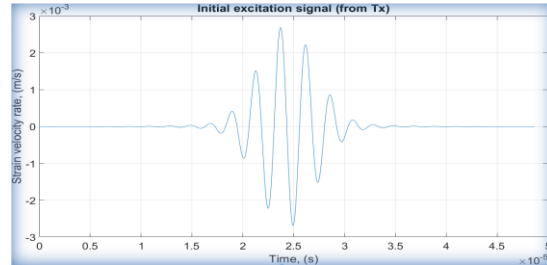
Initial excitation signal

$$x_{ext}(t) = A \cdot \exp\left(-\frac{(t - t_0)^2}{(t_0)^2}\right) \cdot \sin(t \cdot 2\pi \cdot f_{ext})$$

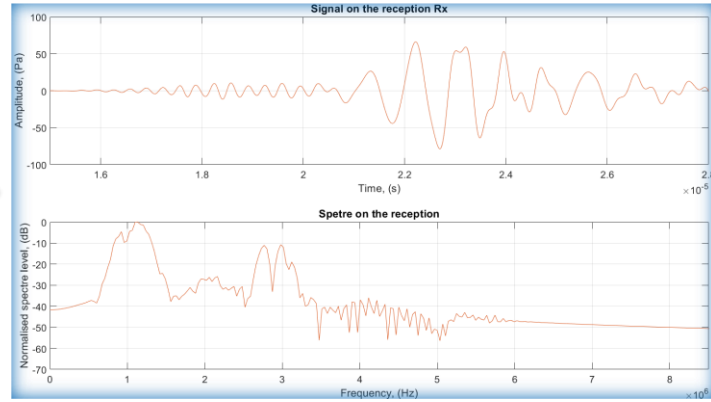


Has the ability to generate odd harmonics

Post treatment on the output



Output signal

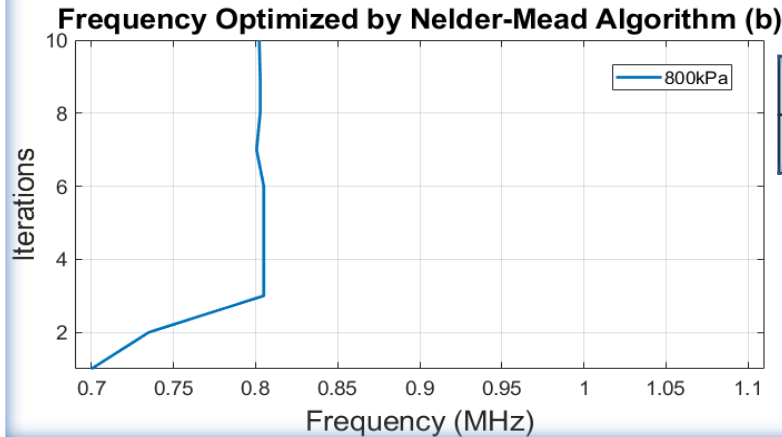
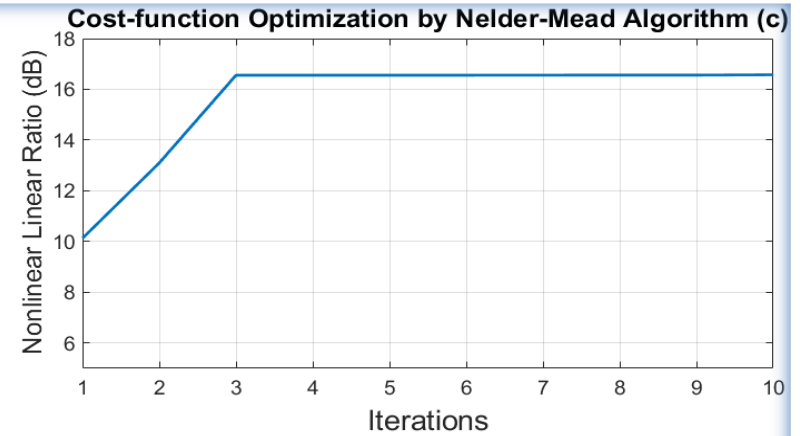
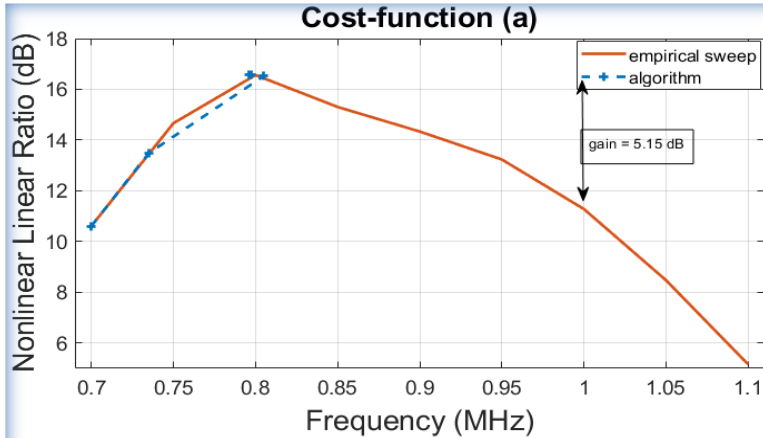


Cost function calculation

$$FC = \frac{E_{3h}}{E_{1h}}$$



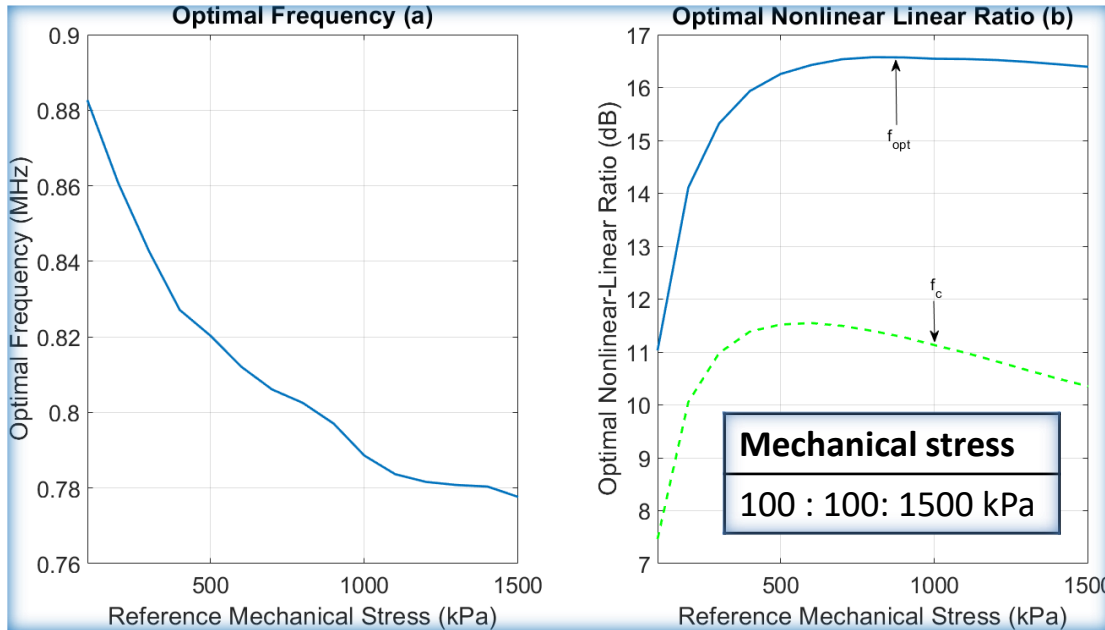
Exemple of optimisation for 800 kPa



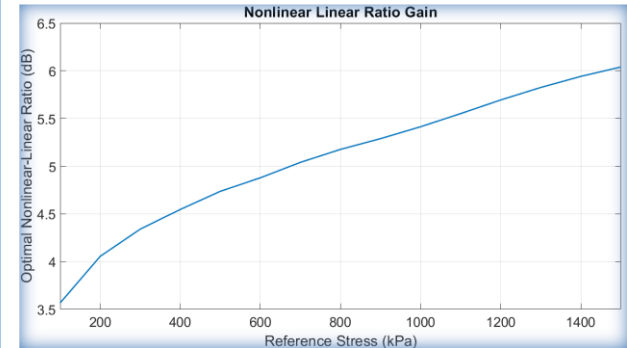
Frequency empirical sweep	Mechanical stress
700:25:1100 kHz	800 kPa (1 kPa = 1000 N/m ²)



The optimal nonlinear ratio and optimal frequency for different stresses



The gain of nonlinear linear ratio between optimal frequencies and central frequency of the transducer



1. Implementation of a propagation simulation of ultrasonic waves in a metallic medium
2. Using an iterative algorithm to adjust the system
3. Optimization of the excitation parameter (frequency) for various mechanical stresses

Perspectives :

1. The optimal command for the experiments takes into account the imperfections of the transducer and the properties of the explored medium.
2. The application of optimal methods to a nonlinear nondestructive evaluation of solids can increase the response of the defect in the studied sample.



THANK YOU!

