Ultrasound contrast agents modeling using an extended Volterra model

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Summary

Introduction
- Ultrasound imaging
- Ultrasound contrast imaging
- Limitations and solutions
- Sub and ultra harmonic imaging

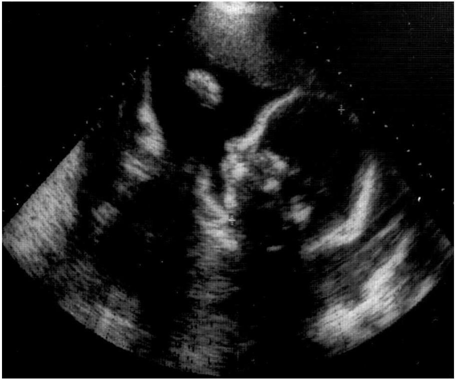
Volterra model

Extended Volterra model

Simulation results

Conclusion and perspectives

Ultrasound imaging

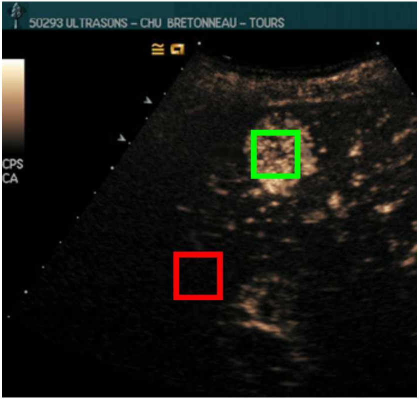


Emission and reception at the same frequency

Ultrasound contrast imaging

Ultrasound Conrast Agents (UCA)

- Gaz microbubbles: mean diameter 1 to 10μm
- Injection in the venous circualtion
- Nonlinear behavior: generation of harmonics



Harmonic imaging

- Harmonic imaging: emission at the frequency f and reception at the first harmonic $2f$
- Contrast enhancement

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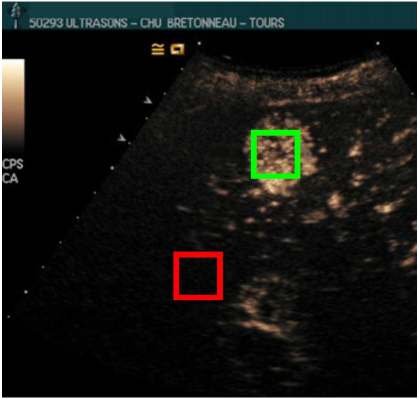

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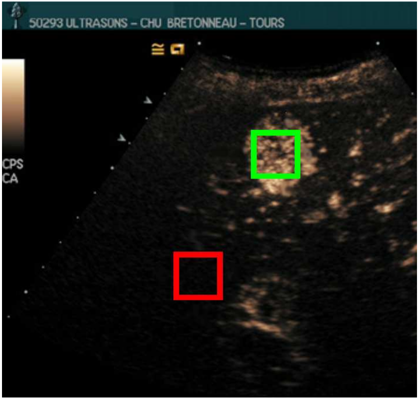

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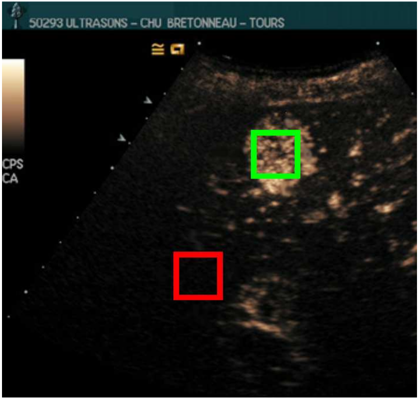

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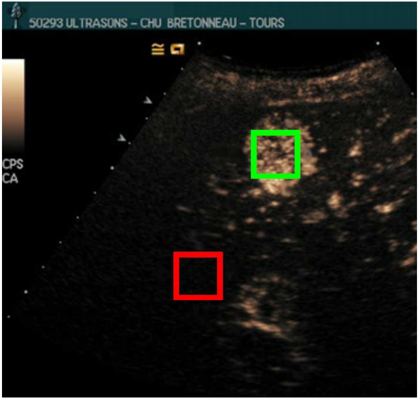

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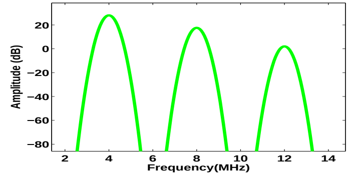

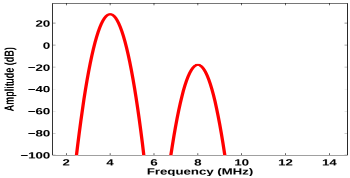

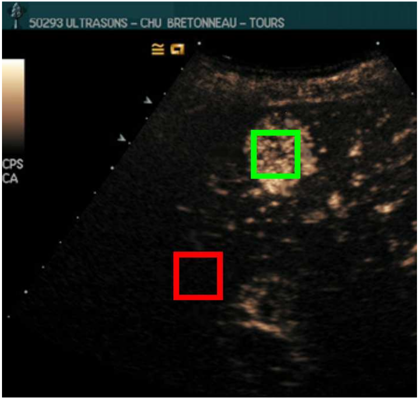

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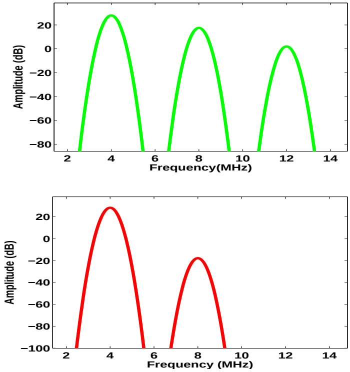

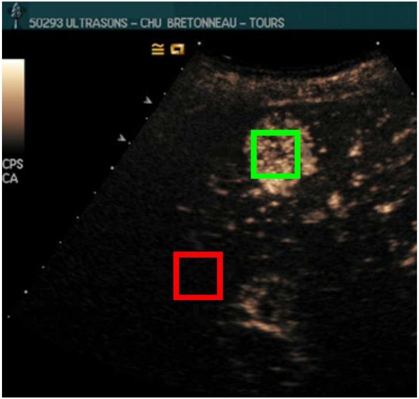

The optimal postprocessing is the Volterra/NARMA filtering include just after slide 9 and 10

Limitations and solutions

However, whatever the used postprocessing technique, there are some limitations:

Limitations

- Non linearity of tissue $\Rightarrow$ Contrast reduction

Solutions in postprocessing point of view

- Super harmonic imaging
- Sub and ultra harmonic imaging

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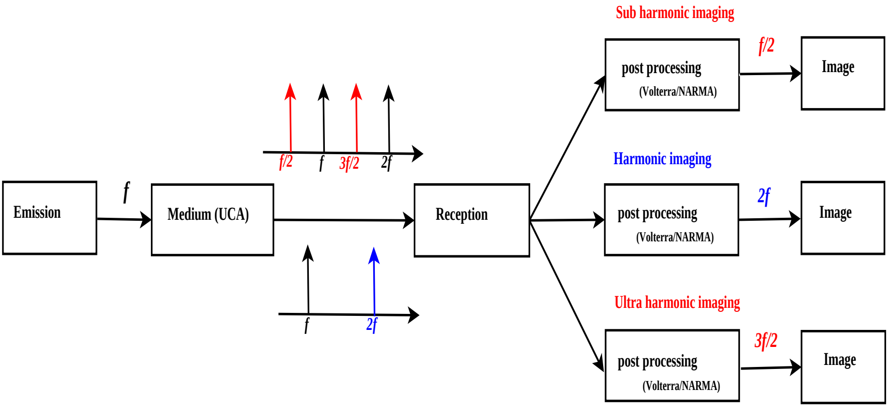
Sub and ultra harmonic imaging



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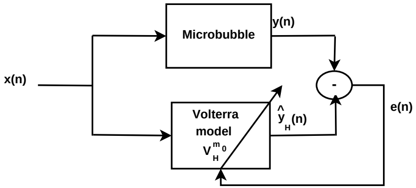
Volterra model

- Nonlinear polynomial filter
- Efficient to model nonlinear systems

$$\hat{y}(n) = h_0 + \sum_{i_1=1}^{m} h_1(i_1)x(n-i_1)$$

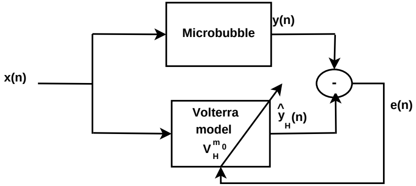


m: memory of the model

Volterra model

- Nonlinear polynomial filter
- Efficient to model nonlinear systems

$$\hat{y}(n) = h_0 + \sum_{i_1=1}^{m} h_1(i_1)x(n-i_1)$$
$$+ \sum_{i_1=1}^{m}\sum_{i_2=1}^{m} h_2(i_1,i_2)x(n-i_1)x(n-i_2)$$
$$+ \sum_{i_1=1}^{m}\sum_{i_2=1}^{m}\sum_{i_3=1}^{m} h_3(i_1,i_2,i_3)x(n-i_1)x(n-i_2)x(n-i_3).$$



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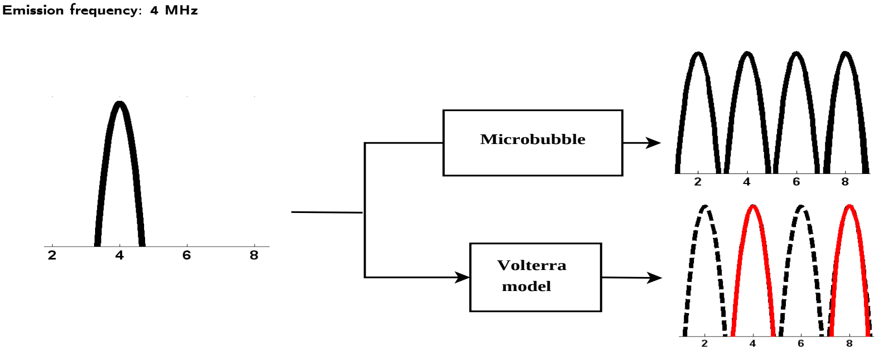

- Efficient to extract harmonics
- Problematic: Unable to extract sub and ultra harmonics

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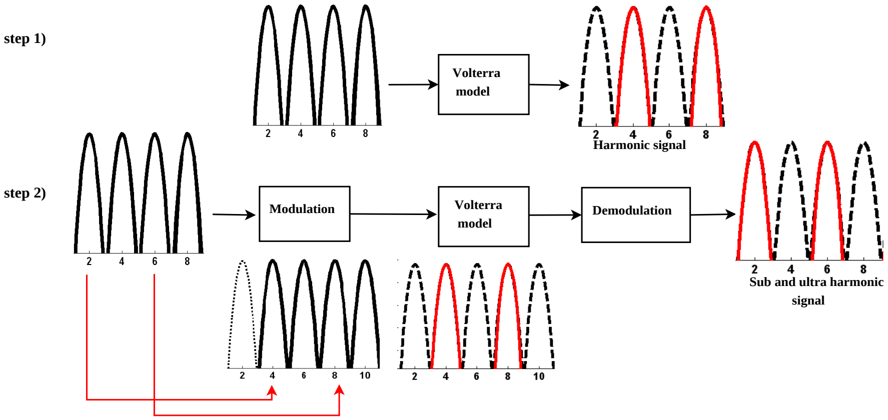
As Volterra model does not work, we propose to extend its formulation to sub and ultra harmonics



- Sub and ultraharmonic modeling and extraction

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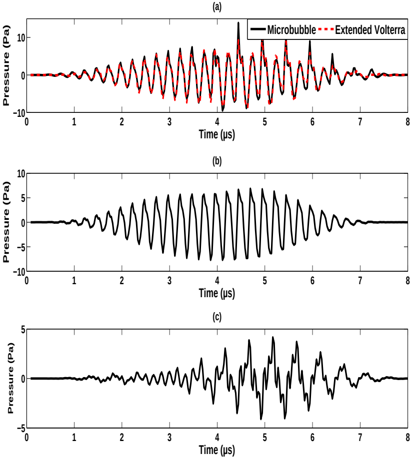

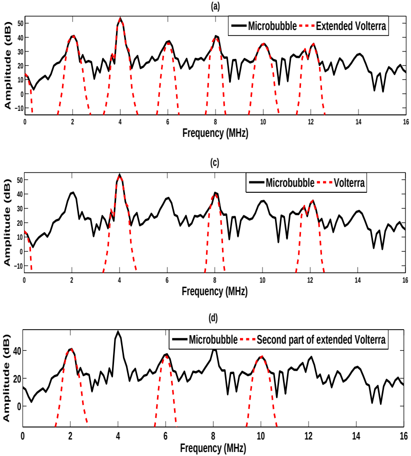

Simulation results

Relative mean square error ***RMSE*** between the microbubble backscattered signal and the modeled signals

Model	Standard Volterra	Extended Volterra
RMSE (dB)	-7.8	-11.5

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Extended Volterra model is able to:

- Model microbubble signal in presence of sub and ultraharmonics
- Extract and separate sub and ultraharmonic signal
- Make possible to realize sub and ultra harmonic imaging

Perspectives

- Separate sub harmonic components apart of ultra harmonic components

Conclusion and perspectives

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Thank you for your attention

Any questions?