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# Ultrasonic inspection of aerospace composite structures using narrowband ultrasonic spectroscopy

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- ✓ Motivation
- ✓ Simulations
- ✓ Results
- ✓ Conclusions

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Aerospace Testing Expo 2006 Europe , April 4-6 2006





# Motivation

Further development of existing methods to cope with new materials, such as, GLARE or CFRP

- Improved sensitivity
- Improved defect characterization

**Solution:**  
Sensing transducer's electrical impedance



# Ultrasonic Spectroscopy

- Theory
- Simulations
- Experimental results



# Ultrasonic Spectroscopy

- In most applications ultrasonic signals are analyzed in time domain
- Ultrasonic spectroscopy is based on frequency analysis of ultrasonic signals



# Broadband Spectroscopy

- Tapping a wine glass
  - Sound glass - full harmonic tone
  - Cracked glass - dull tone
- URS can be used for
  - material characterization
  - detecting defects





# Ultrasonic Spectroscopy

## ● Broadband spectroscopy

- A couple of broadband transducers that sense object's resonance spectrum in pitch-catch mode
- Weak acoustic coupling

## ● Narrowband spectroscopy

- A narrowband resonance transducer integrated with the test object
- Strong acoustic coupling

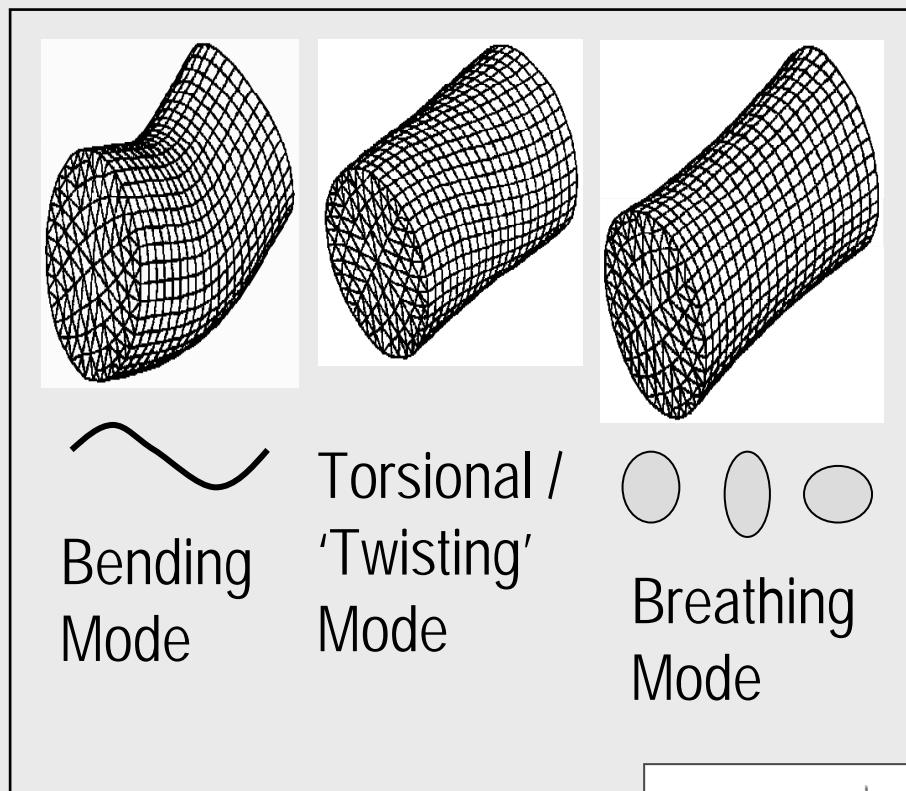


# Broadband Spectroscopy

Resonance frequencies depend upon

- density
- elastic constants
- object geometry
- presence of flaws

## Resonance modes





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# Broadband Spectroscopy

Commercial instruments



Quasar QRI 2000

Aerospace Testing Expo 2006 Europe , April 4-6 2006





# Narrowband Spectroscopy

## Commercial instruments



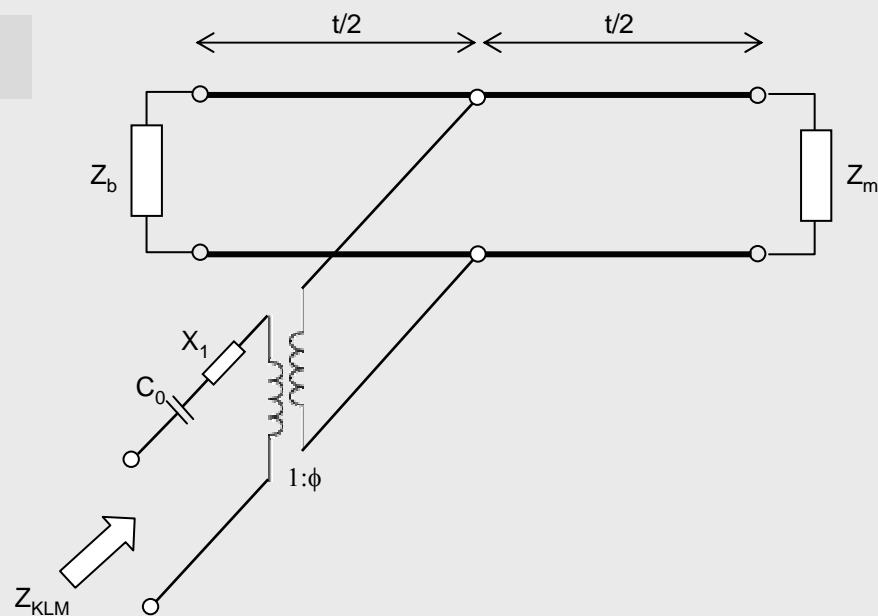
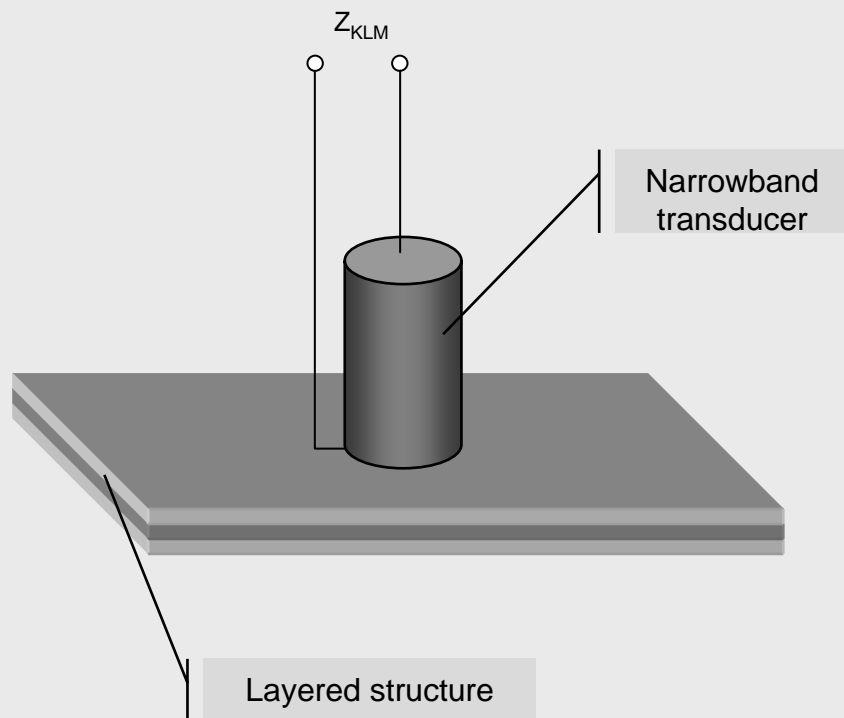
Fokker Bond Tester



Staveley BondMaster™ 1000



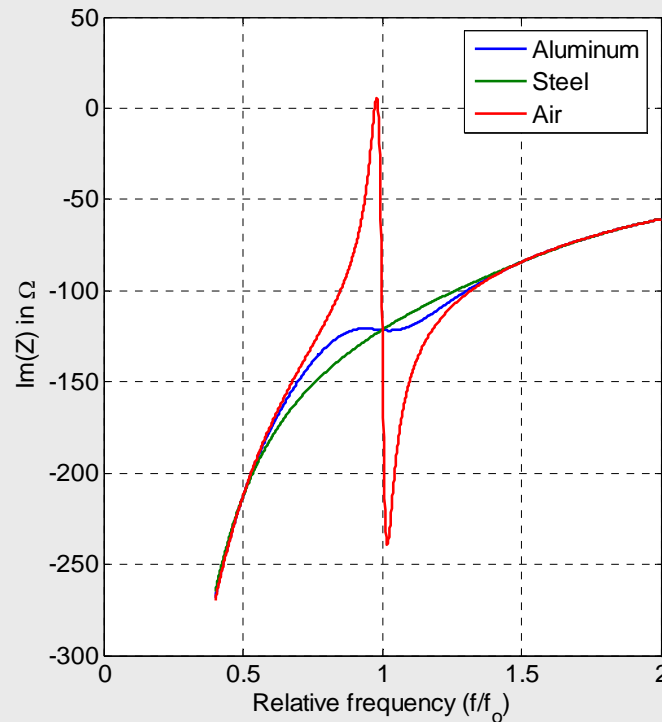
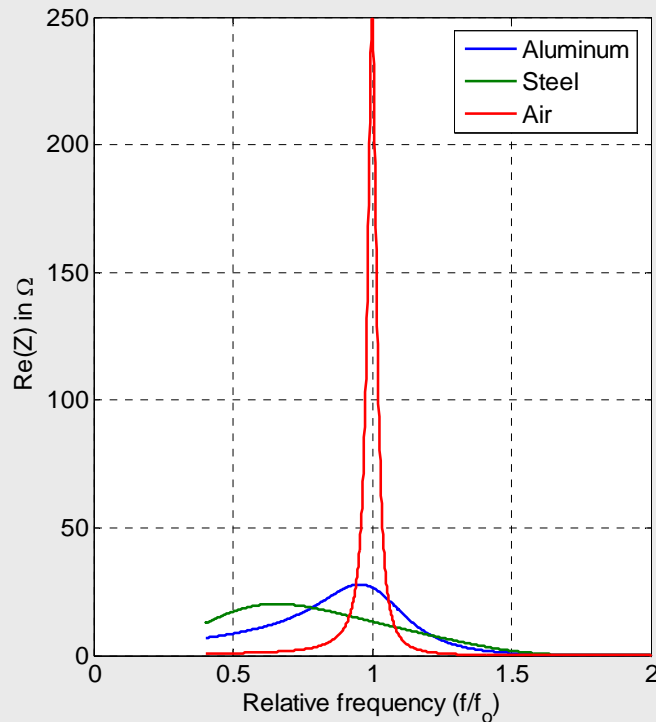
# Principle of narrowband spectroscopy (NBS)



# Variations of transducer's impedance



$Z_{KLM}$  as a function of frequency for different materials (near resonance)

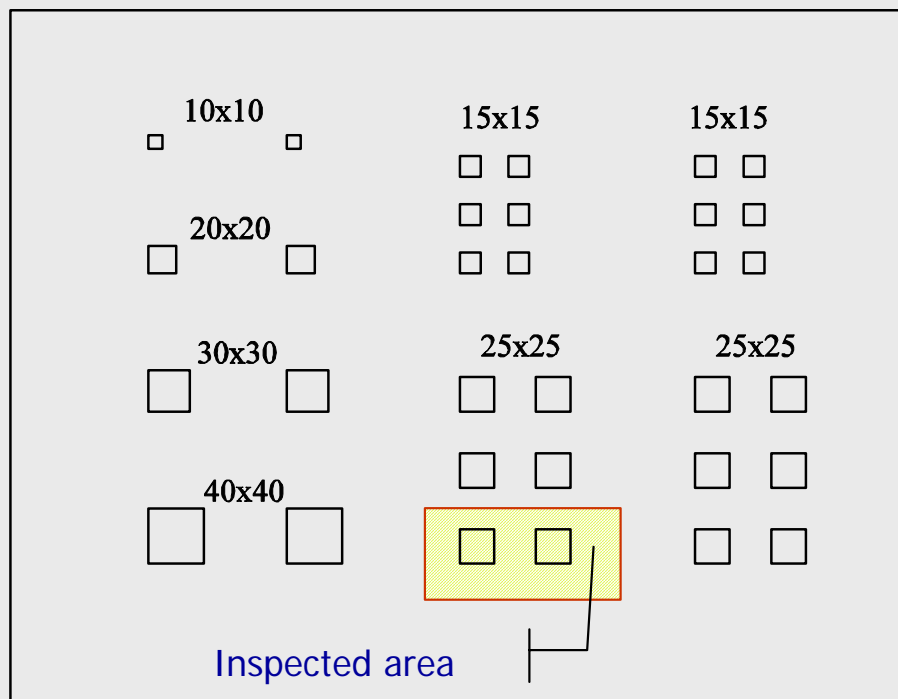
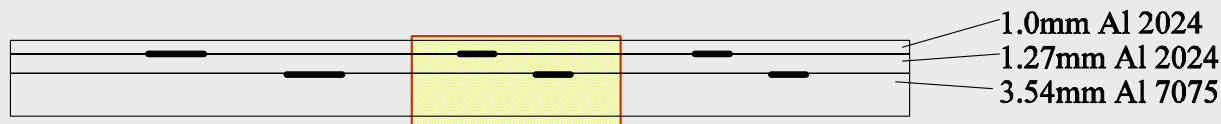




# Ultrasonic Spectroscopy

- Theory
- Simulations
- Experimental results

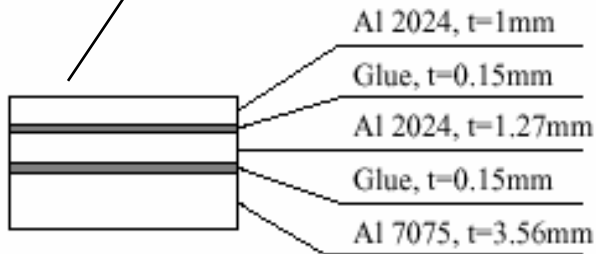
# Example 1: Layered aircraft structure



# Example 1: Layered aircraft structure



Sound structure



(a)

Disbond under upper layer



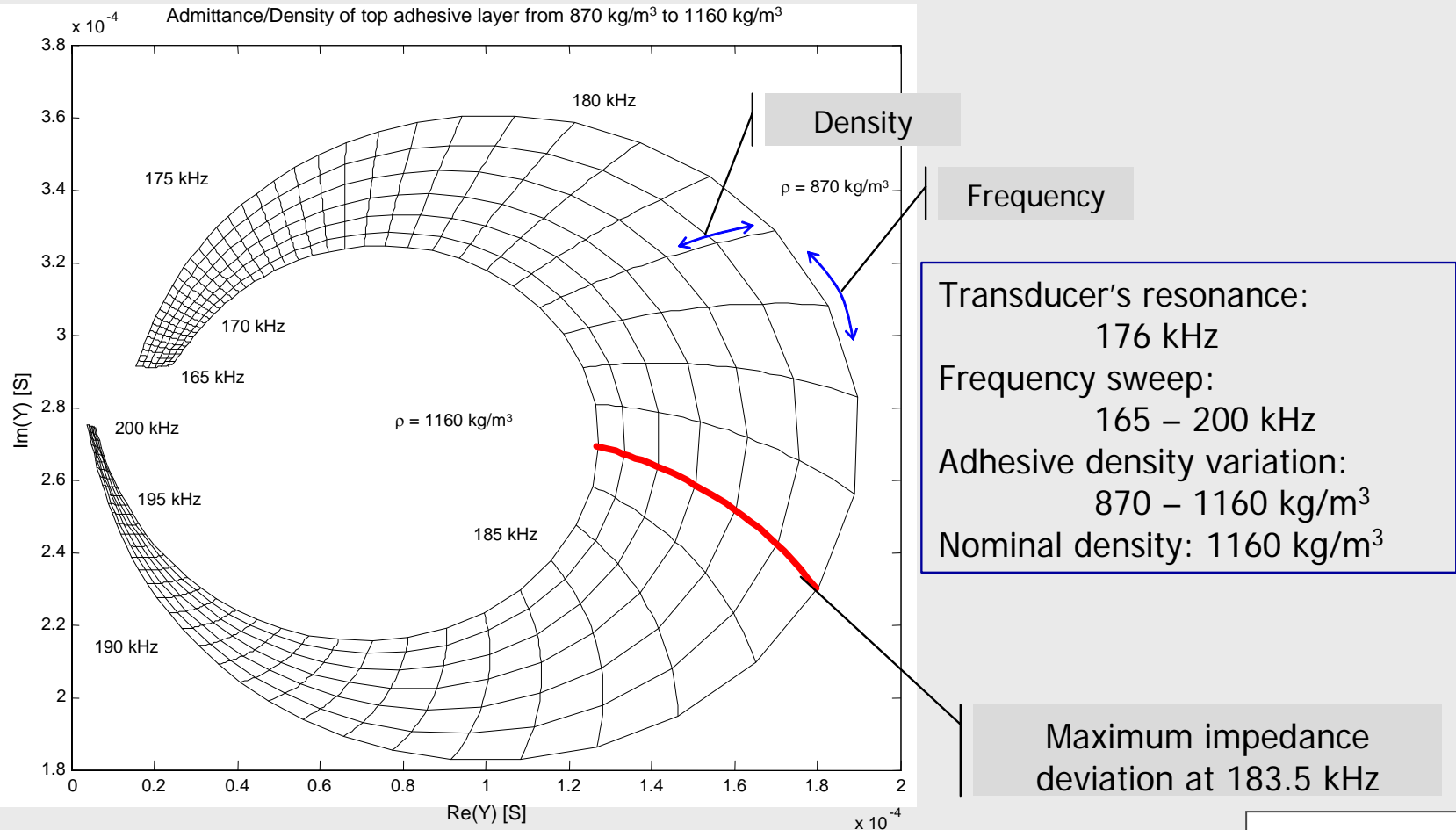
(b)

Disbond under middle layer



(c)

# Example 1: Layered aircraft structure



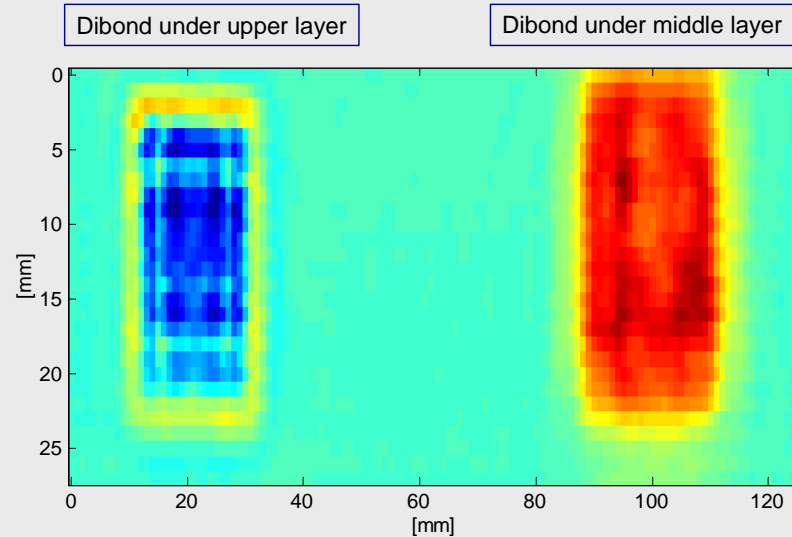
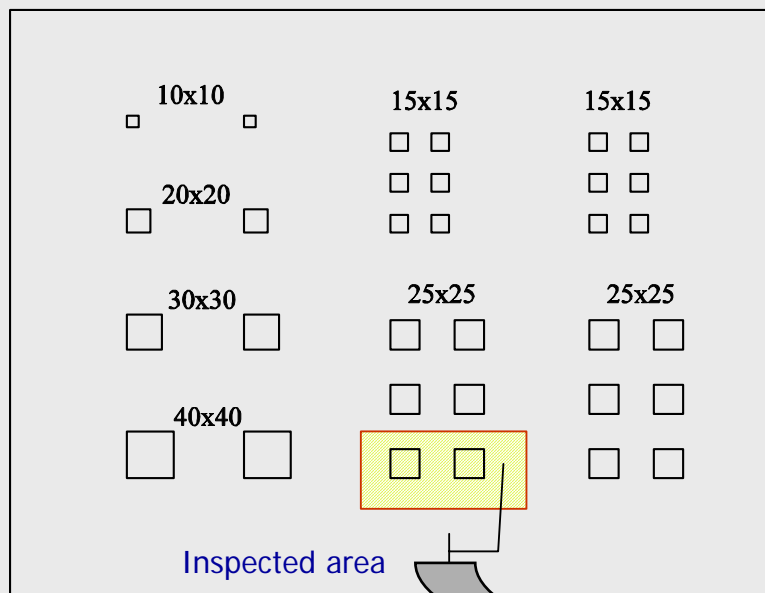
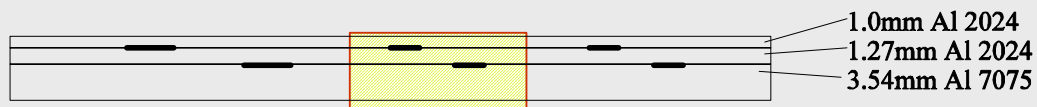


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# Ultrasonic Spectroscopy

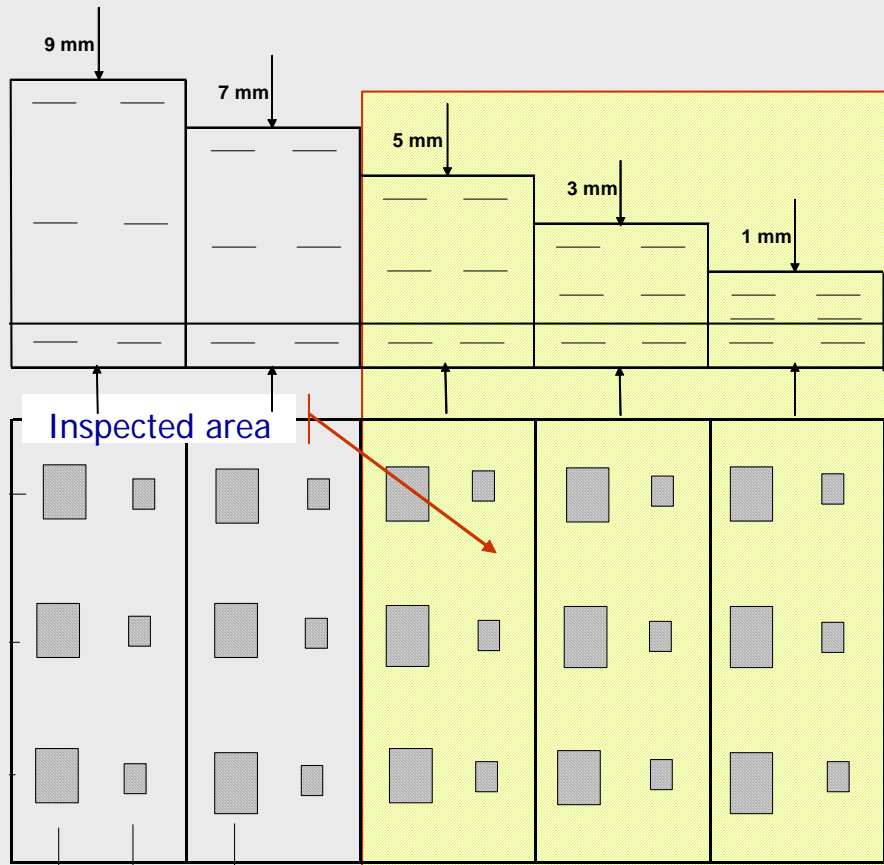
- Theory
- Simulations
- **Experimental results**

# Example 1: Layered aircraft structure





# Example 2: CFRP step specimen

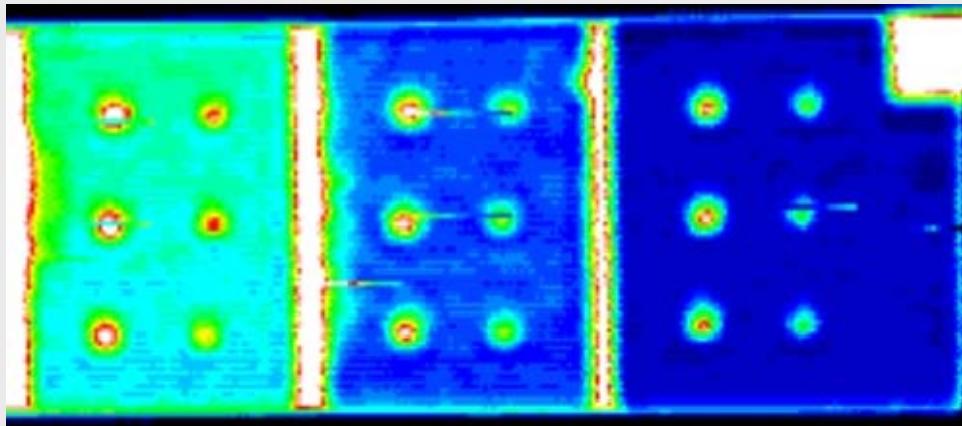


Specimen structure

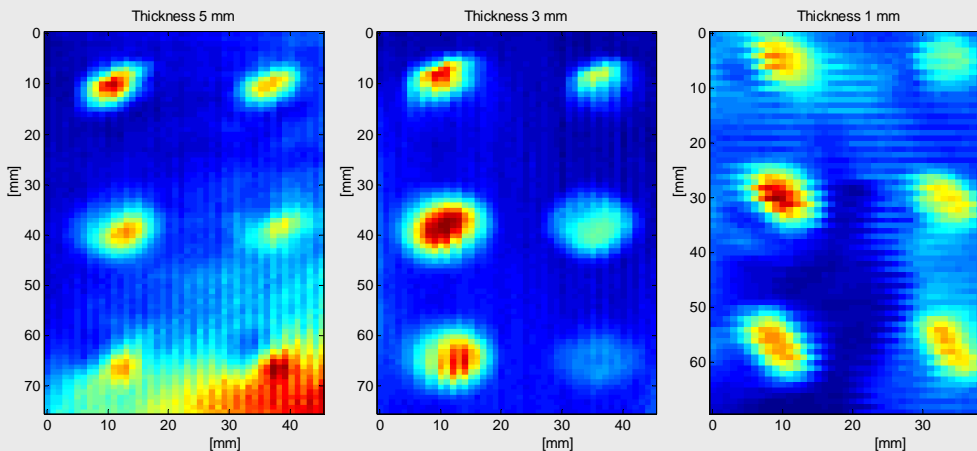




# Example 2: CFRP step specimen



C-scan in transmission

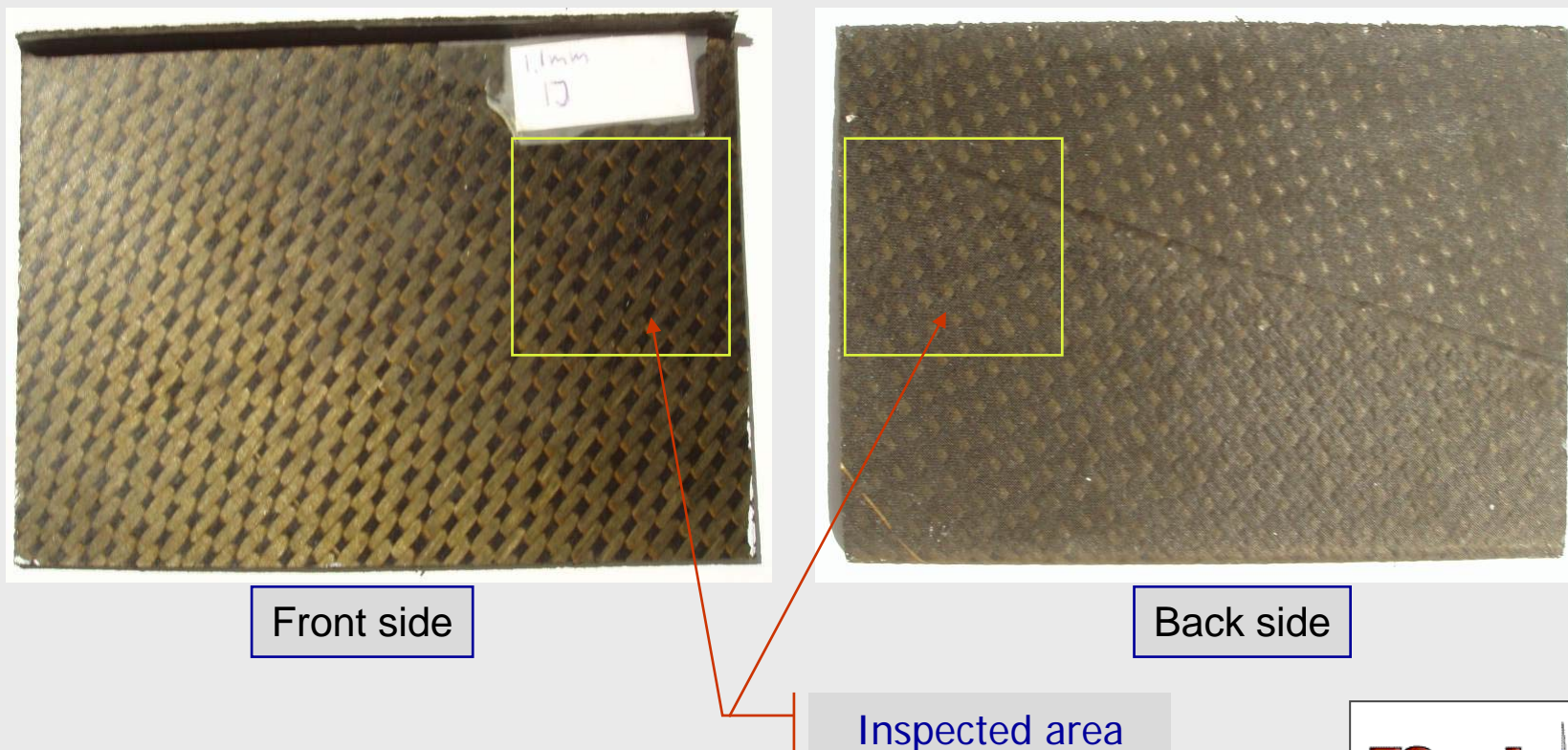


NBS inspection from one side



# Example 3: CFRP specimen with 1J impact

CFRP specimen with impact and local variation in thickness

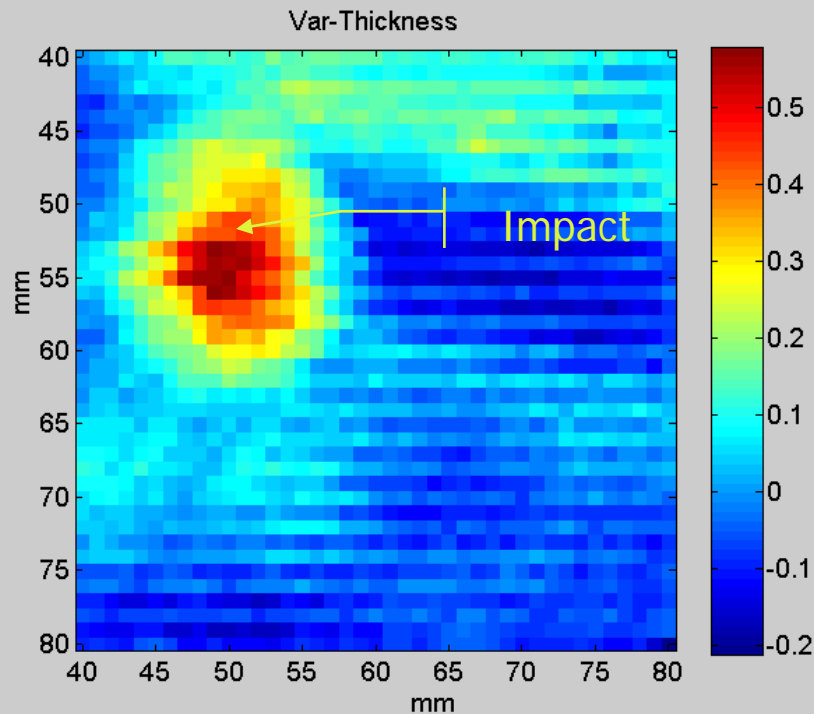


# Example 3: CFRP specimen with 1J impact

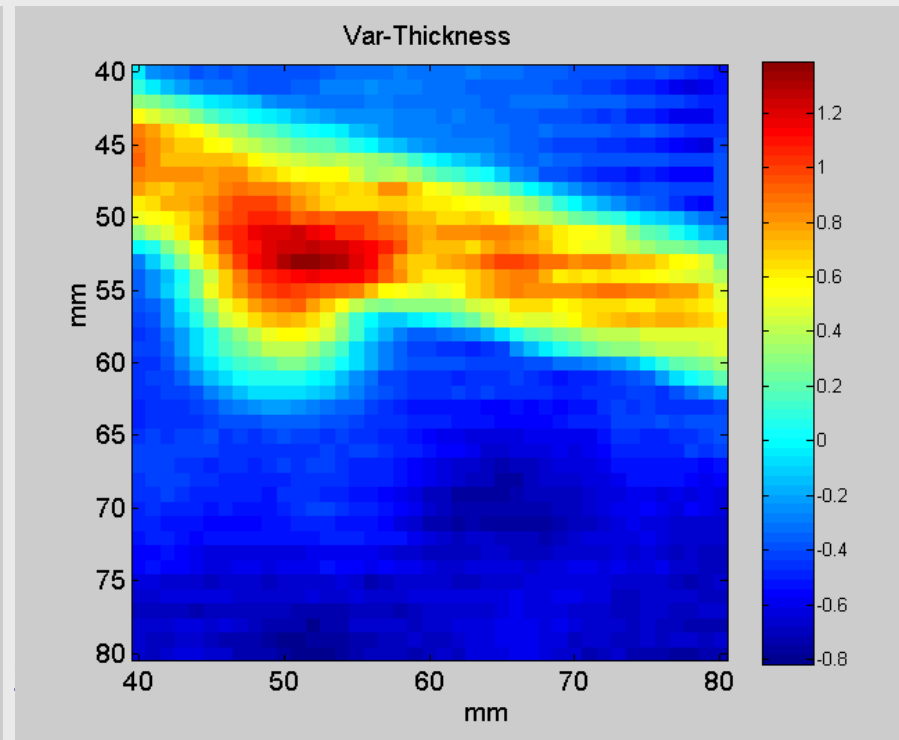


Inspection of CFRP specimen with impact and local variation in thickness

Transducer's frequency 1 MHz



Transducer's frequency 2 MHz





# Conclusions

- NBS based on transducer electrical impedance is an efficient tool for inspecting multilayered structures
- NBS was successfully applied to disbond detection in aerospace Al layered structures
- NBS was successfully applied to defect detection in CFRP
- Other applications are under investigation