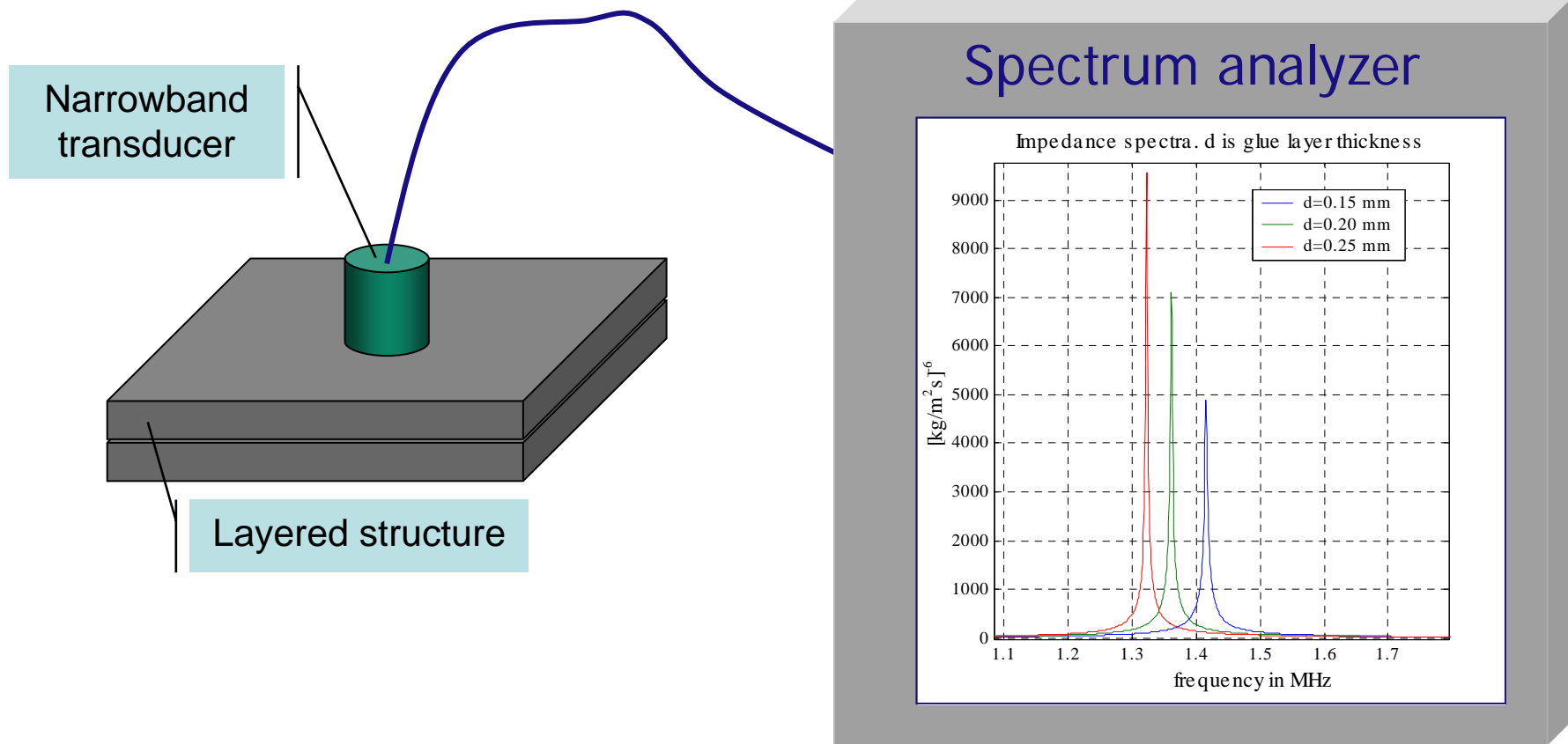


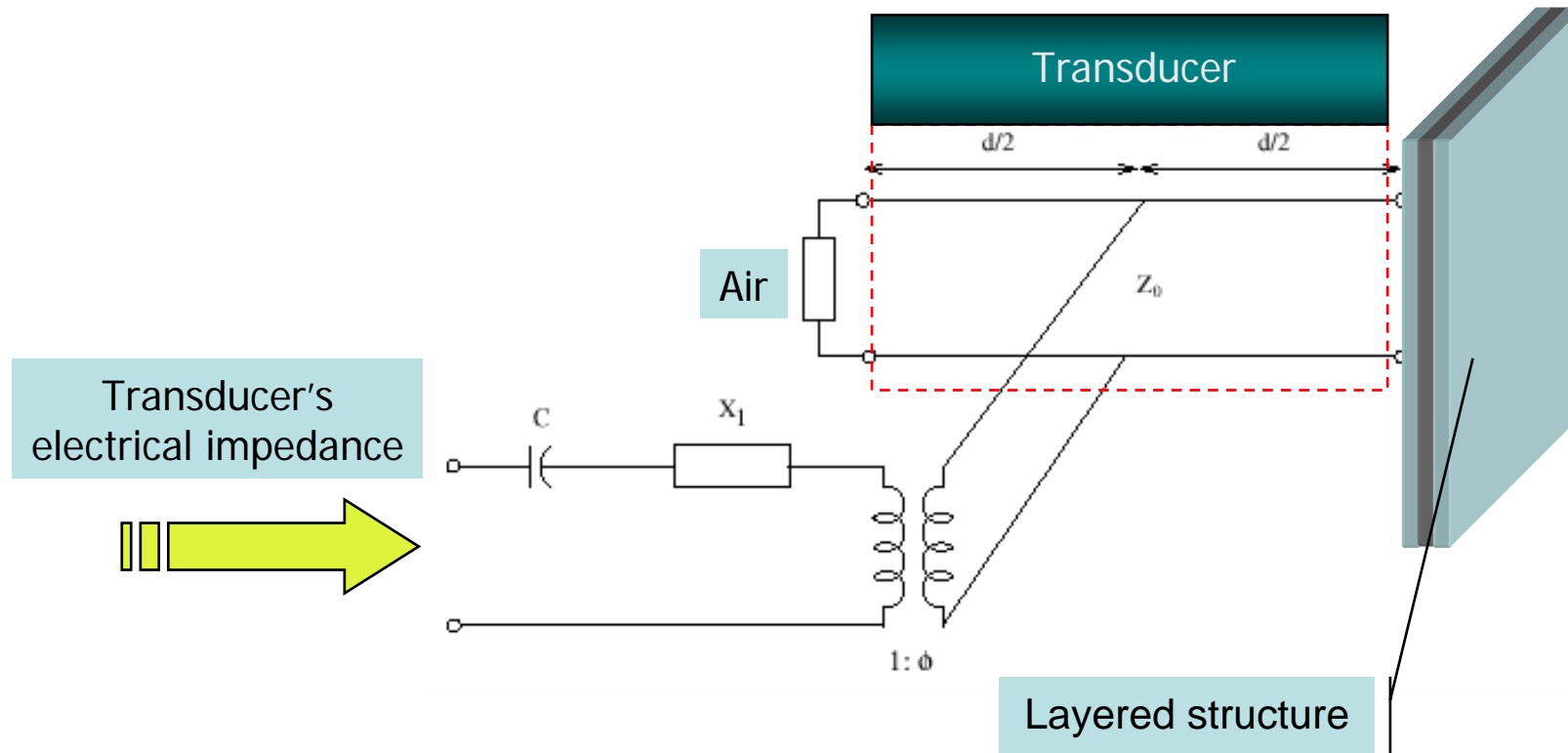
Narrow Band Ultrasonic Spectroscopy

N-BUS

Narrowband Resonance Spectroscopy



Principle of narrowband spectroscopy





Narrowband spectroscopy of composite structures

Why narrowband not broadband spectroscopy ?

- Local test preferred (high local sensitivity possible)
- Result easy to handle (no training data required)
- Simulation tool available
- Tradition in aircraft industry



Simulation toolbox

Simulation of imp/adm variations due to changes in material parameters

Single frequency plot at 400000 Hz

Legend:

- Admittance/Density of layer 5 from 870 to 1160
- Admittance/Speed of layer 5 from 1800 to 2400

Buttons: Plot, External Display, Length & angle

Parameter

- Density
- Thickness
- Speed
- z

Admittance
 Impedance

Z1: 500

Speed sweep Nominal: 2400

Start value	Step	Stop value
1800	100	2400

Frequency sweep Res. frequency: 183.44 kHz

Single frequency	Step	Stop value
360e3	500	4.39005e+007

Change transducer ...

Current transducer: fokker_r9_fr460.mat
 Current res. freq. 450500
 Current thickness
 New res. freq. 100000
 Chg transducer res freq

Change structure ...

Current structure: lower_wing_skin.mat

Single frequency
 Hold plot
 Normalize

Plot configuration

Speed lines 5 Speed Rows Columns
 Frequency spec. 10 Frequency spec rate 1 1

Use subplots 1

Layers

2400	1160	0.00015	-0.2
6140	2770	0.00127	-0.05
2400	1160	0.00015	-0.2
6140	2770	0.001	-0.05

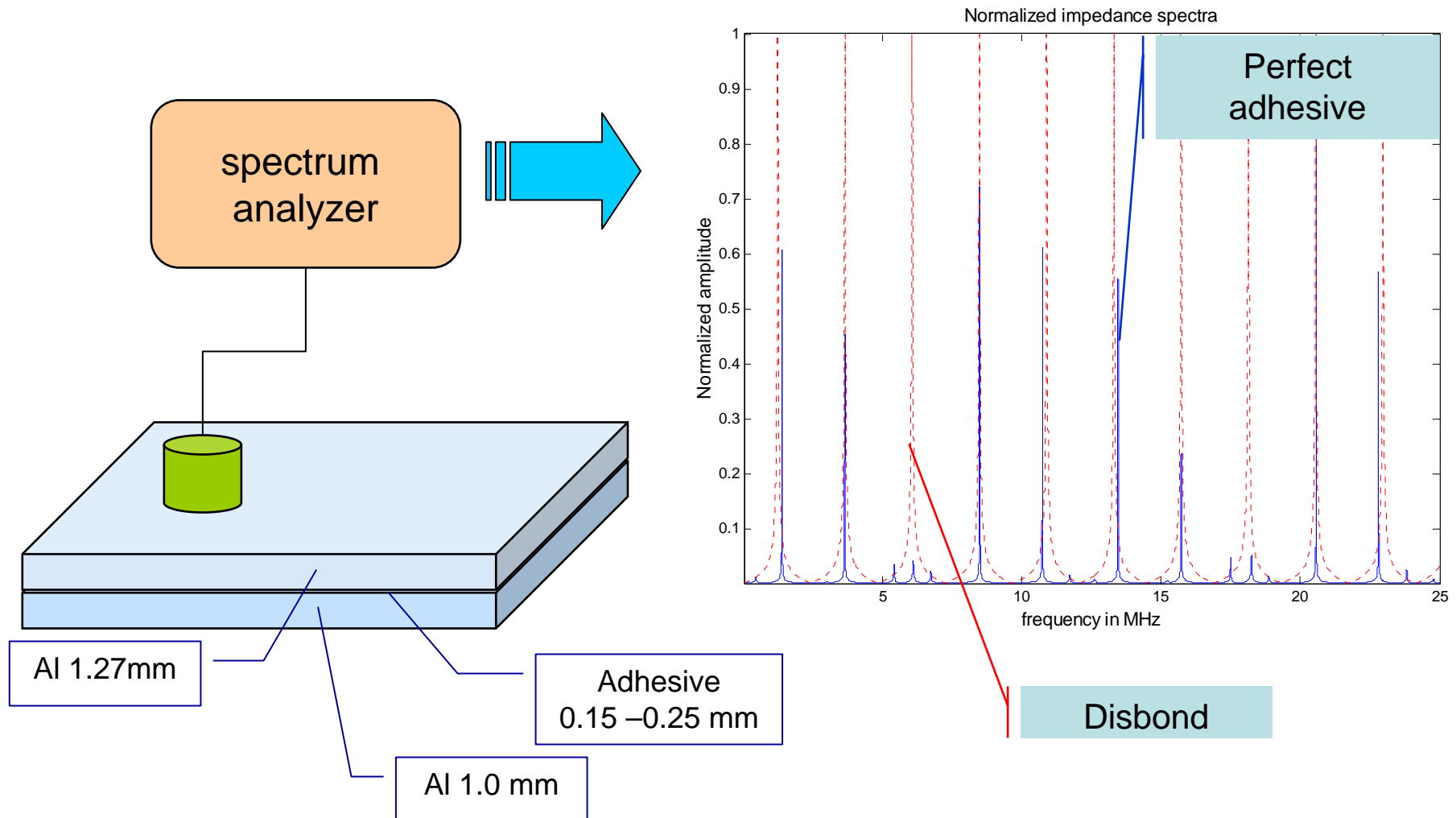
Plot res. spec. Unloaded transducer
 Recalc. res. freq. Structure only
 Exclude loaded

History

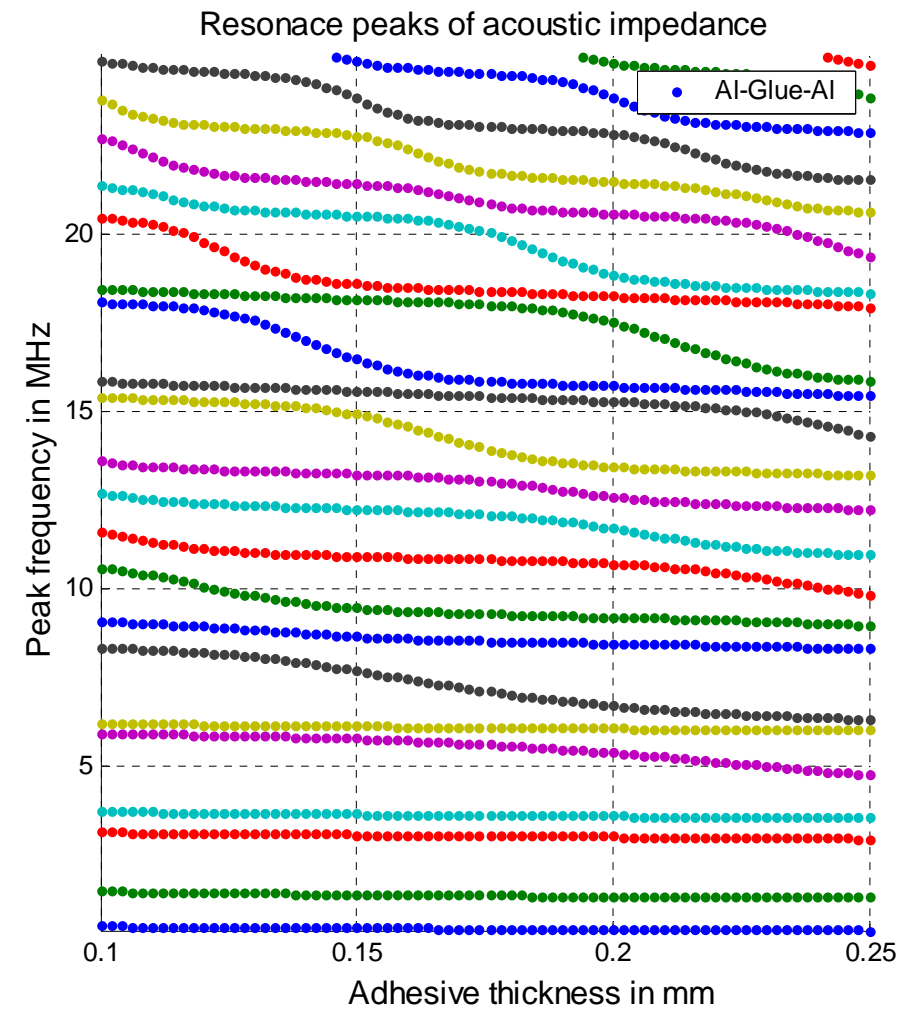
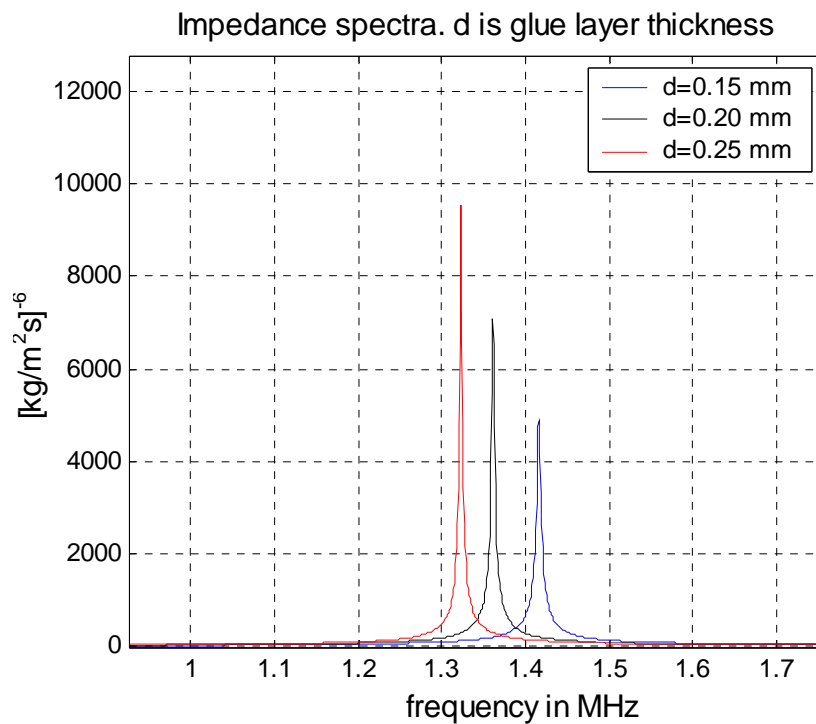
- Admittance/Speed of layer 5 from 1800 to 2400
- Admittance/Density of layer 5 from 870 to 1160
- Admittance/Speed of layer 5 from 1800 to 2400
- Admittance/Density of layer 5 from 870 to 1160
- Admittance/Speed of layer 5 from 1800 to 2400

Buttons: View, Delete, Clear

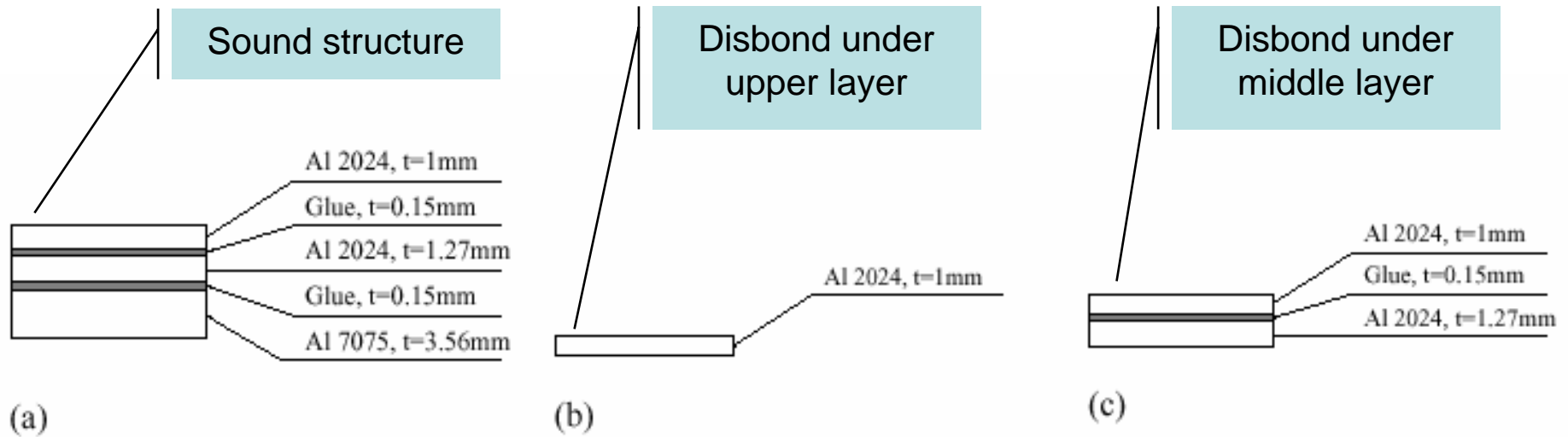
Example: two-layered Al structure



Influence of adhesive layer thickness

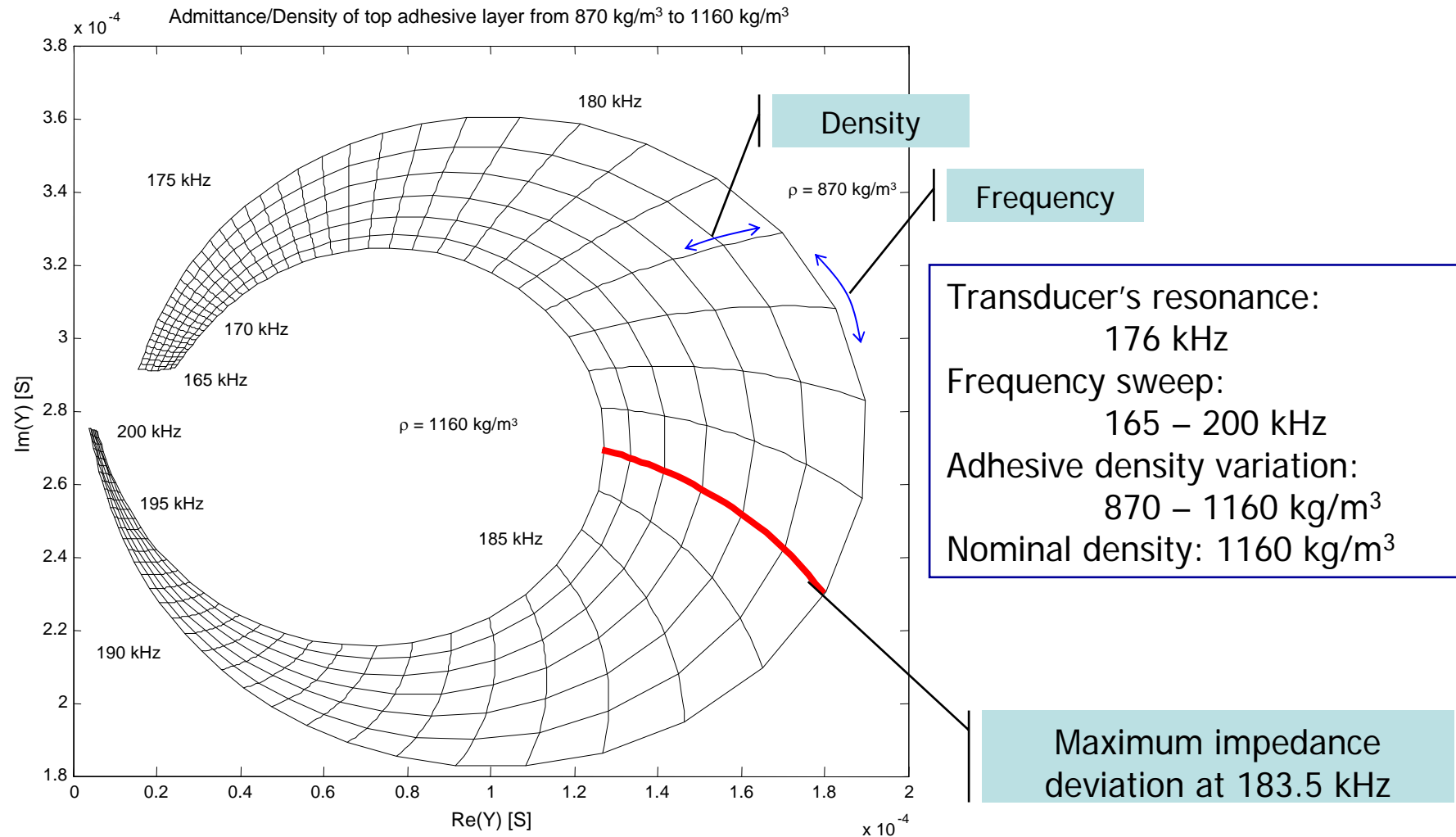


Impedance: three-layered Al structure



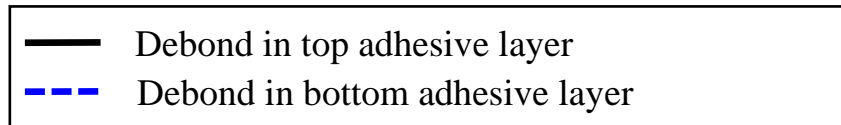


Electrical impedance on three-layered Al structure

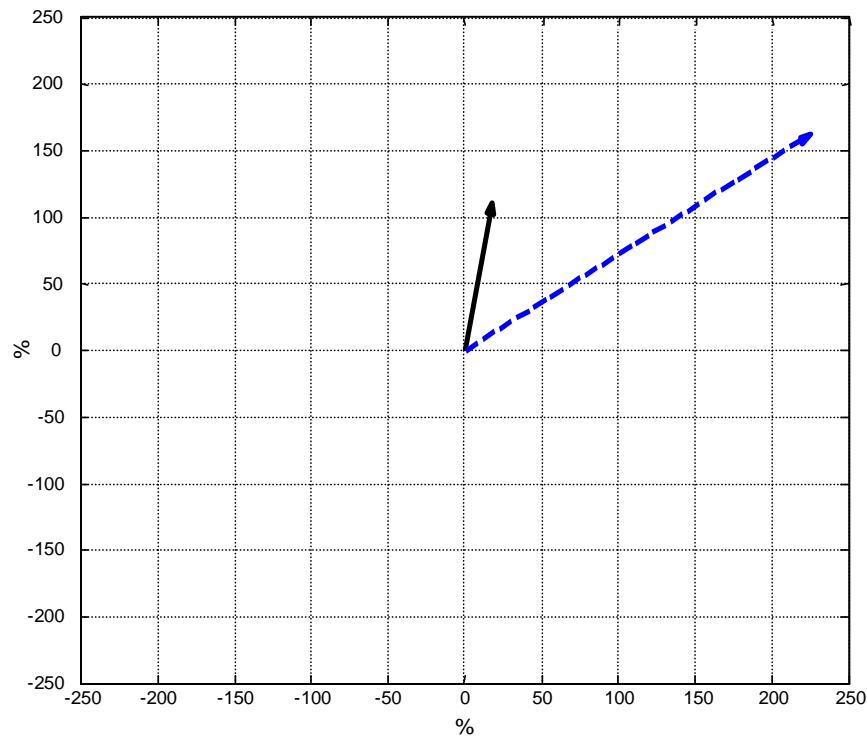




Selection of frequency

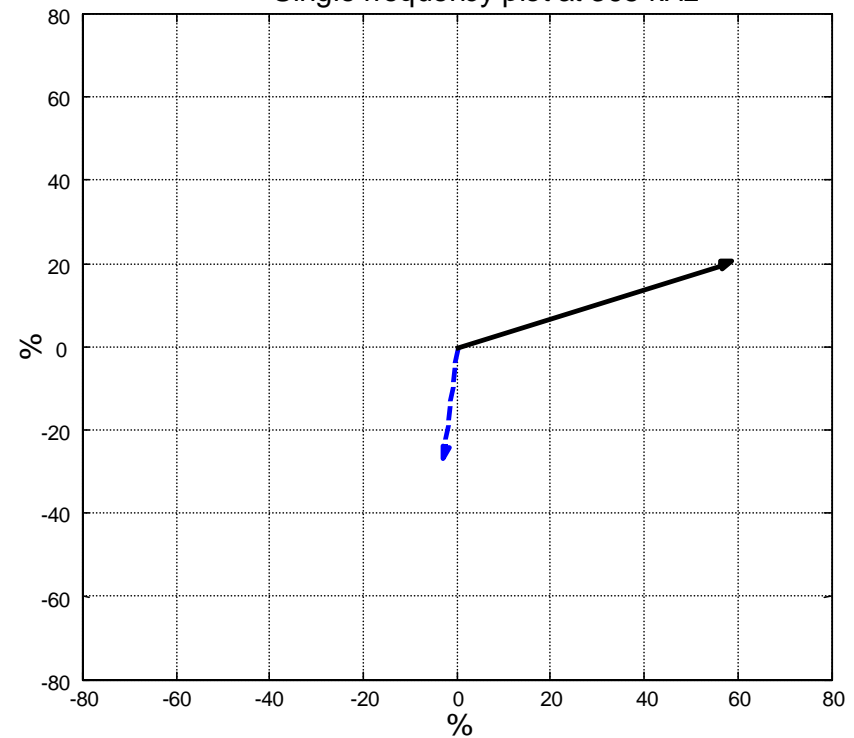


Single frequency plot at 176 kHz



Transducer's resonance at 176 kHz

Single frequency plot at 395 kHz

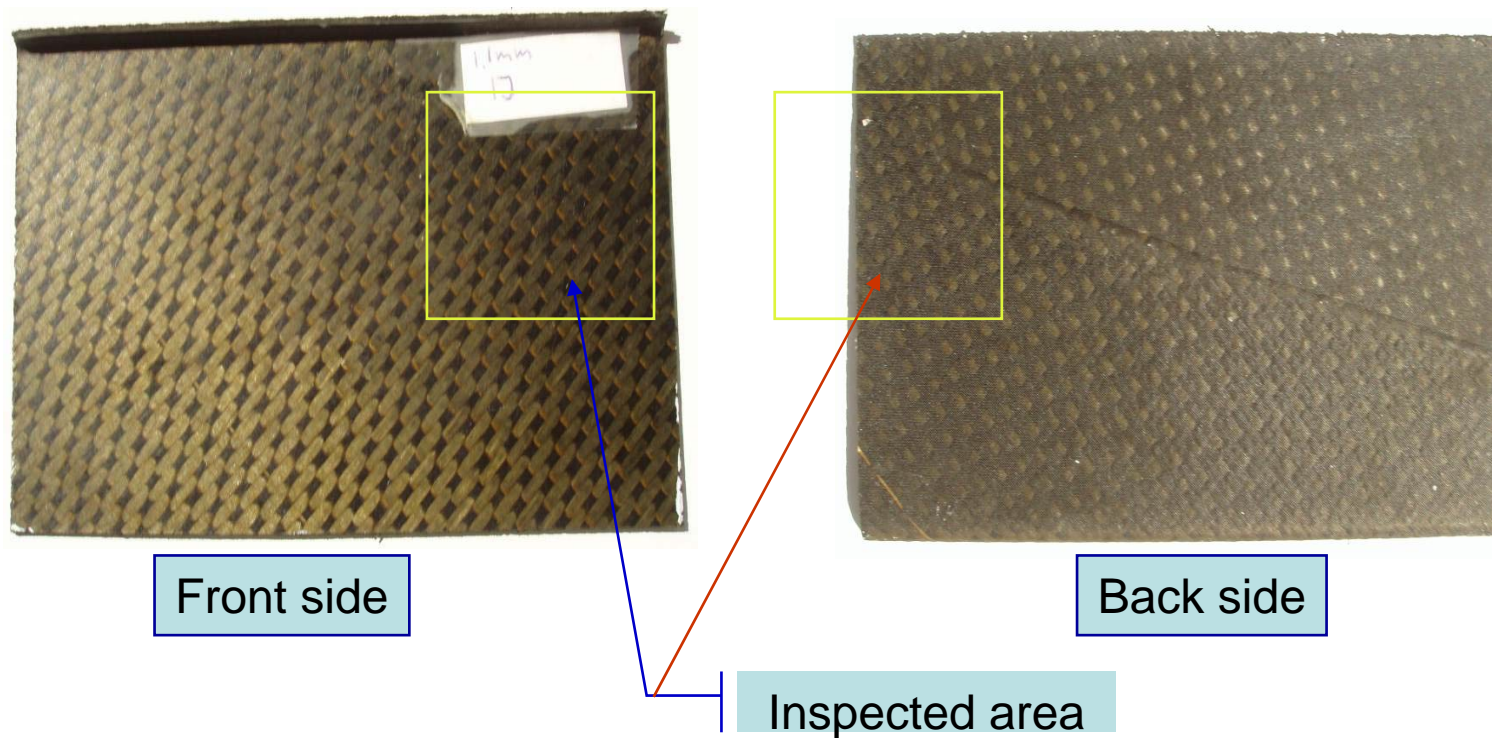


Transducer's resonance at 439 kHz

APEX RESEARCH TECHNOLOGIES

CFRP specimen with 1J impact

CFRP specimen with impact and local variation in thickness



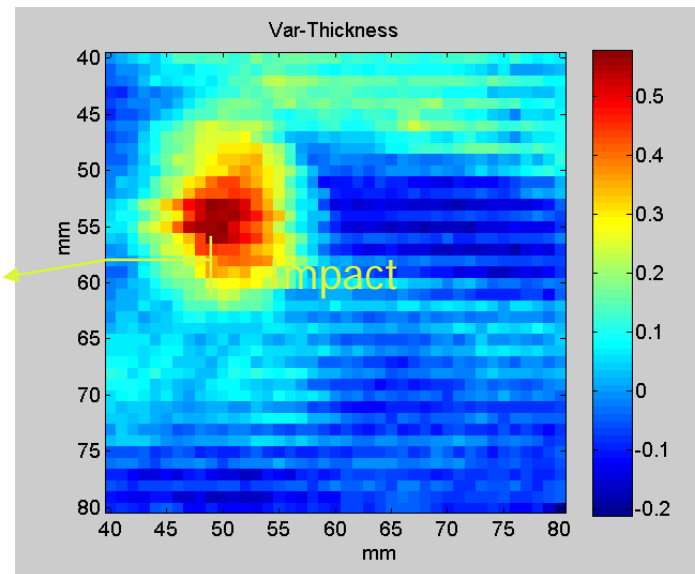


APEX RESEARCH TECHNOLOGIES

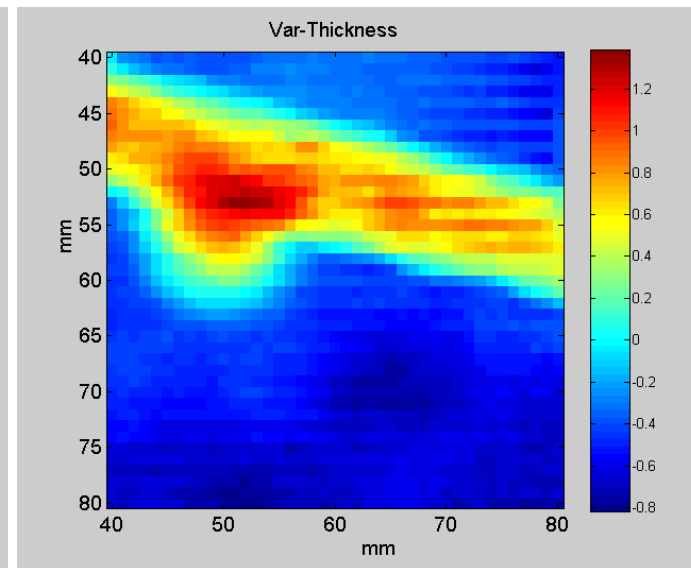
CFRP specimen with 1J impact

Inspection of CFRP specimen with impact and local variation in thickness

Transducer's frequency 1 MHz



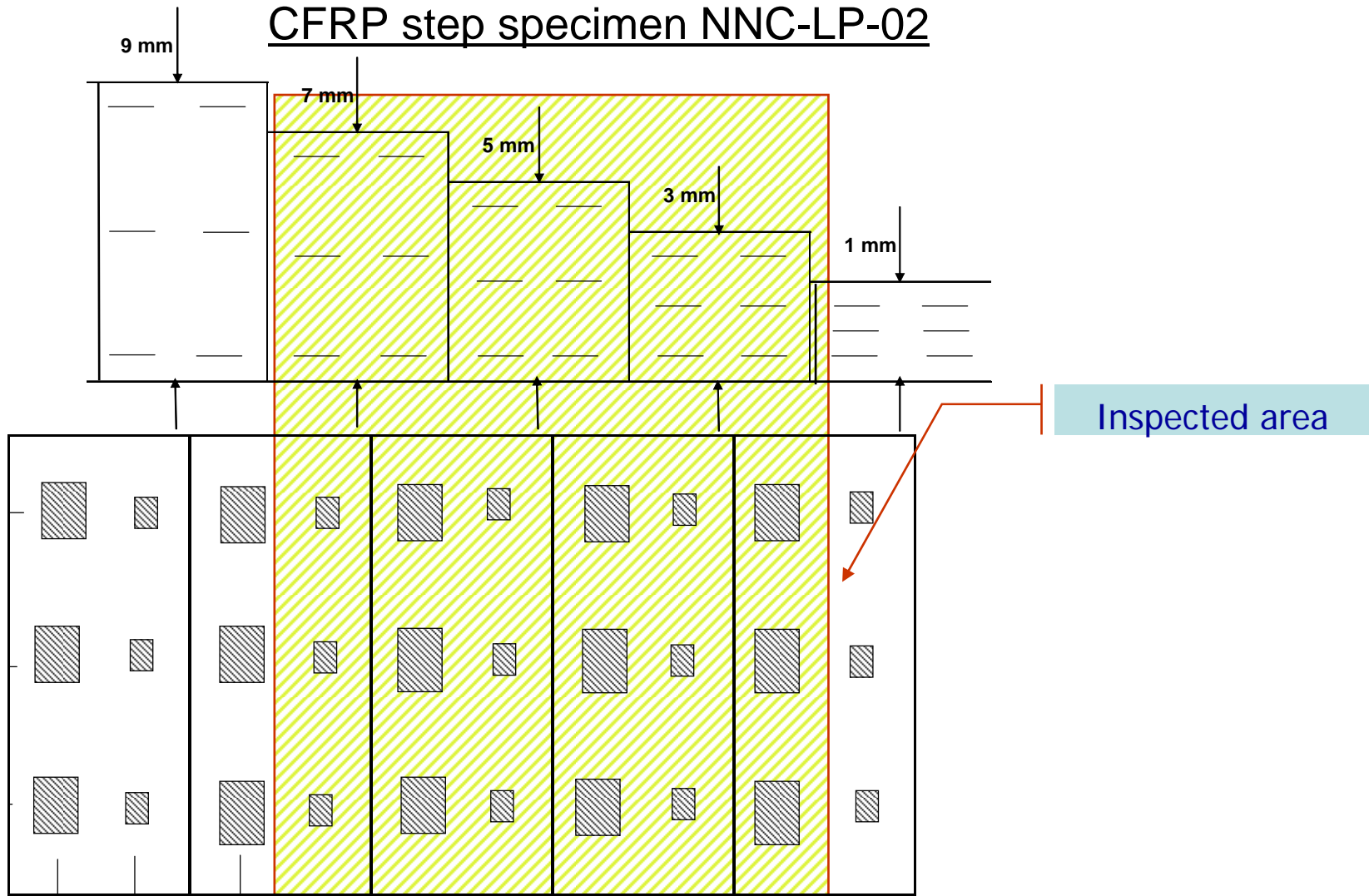
Transducer's frequency 2 MHz





APEX RESEARCH TECHNOLOGIES

CFRP step specimen NNC-LP-02

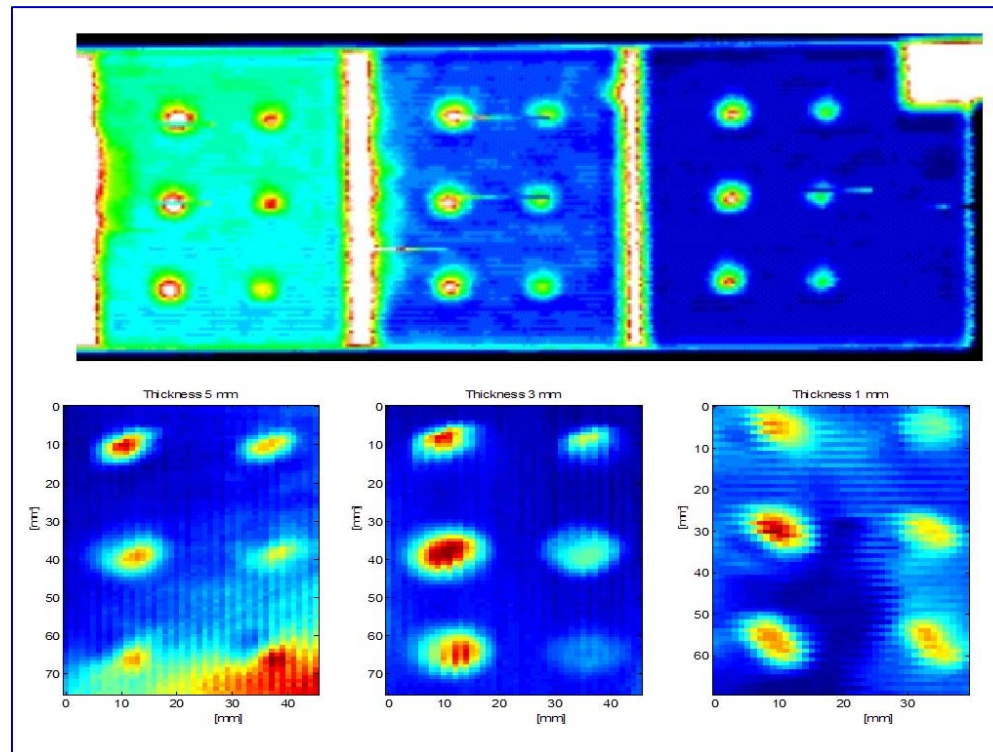




APEX RESEARCH TECHNOLOGIES

CFRP step specimen NNC-LP-02

Inspection of CFRP step specimen NNC-LP-02 with artificial defects

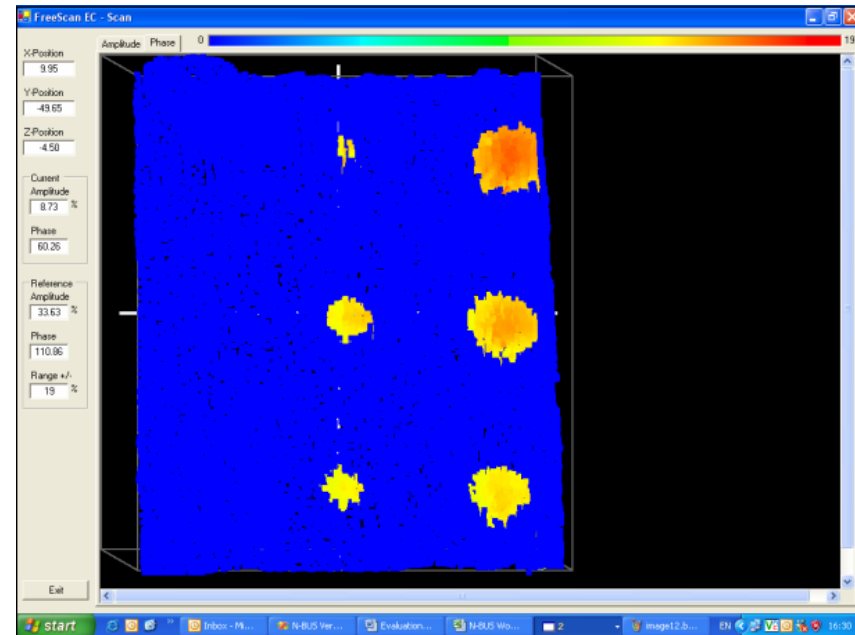
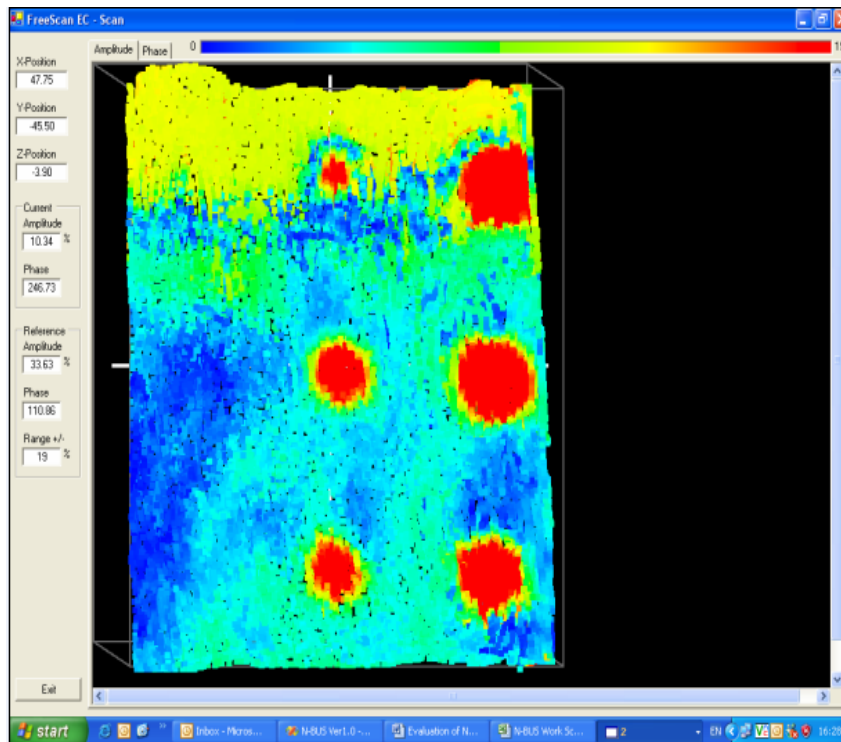


UT C-scan, transmission

Spectroscopy C-scan,
one side inspection



FreeScan N-BUS (CFRP)





Case Study

Detection of defects in new Low Density Carbon – Carbon composite material

Conclusion : N-BUS with FreeScan is ideal solution for in-service inspection of C-C parts because in-situ defect detection can be carried out

Defect Detection in thin C-C composites



Objectives

- To determine the capabilities of N-BUS instrument with FreeScan system for detection of defects in Unknown Carbon – Carbon Composite Samples
- To compare N-BUS results with Ultrasonic immersion C-Scan in through transmission mode
- To compare N-BUS results with Ultrasonic immersion C-Scan in pitch catch mode



Details of Samples

- Defects in 1.35 mm Thick Plate Sample

Thickness of the Sample: 1.35 mm

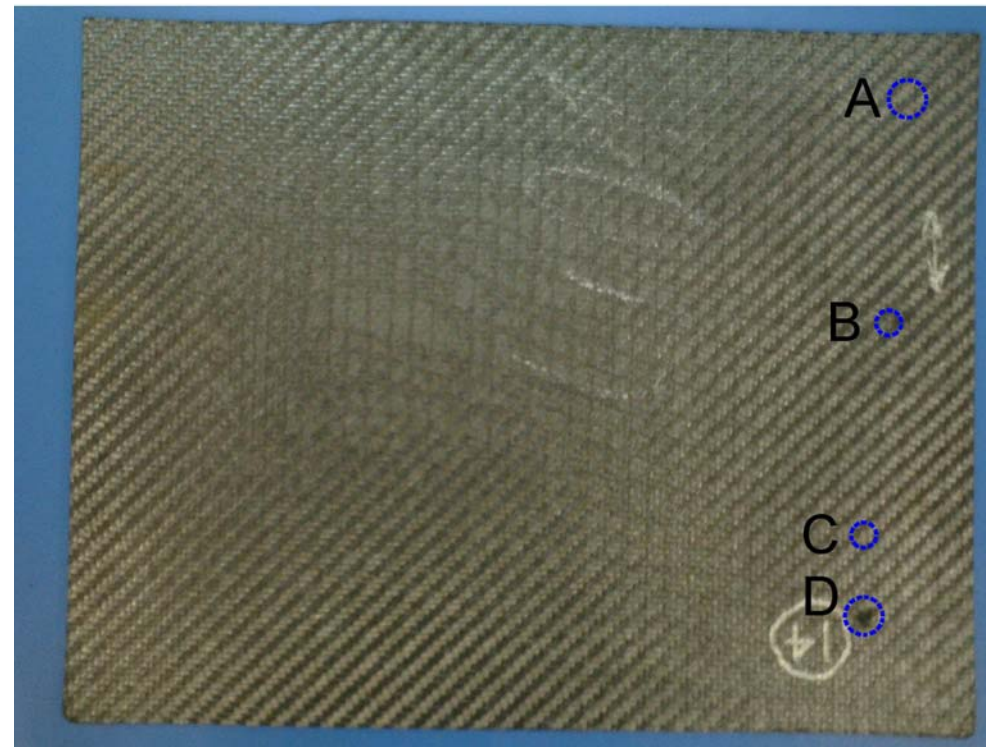
Defects' details:

A. deep: 0.25 mm, diameter: 1 mm

B. deep: 0.23 mm, diameter: 4 mm

C. deep: 0.18 mm, diameter: 1 mm

D. deep: 0.38 mm, diameter: 7 mm



Details of Samples

- Defects in 2.79 mm Thick Plate Sample

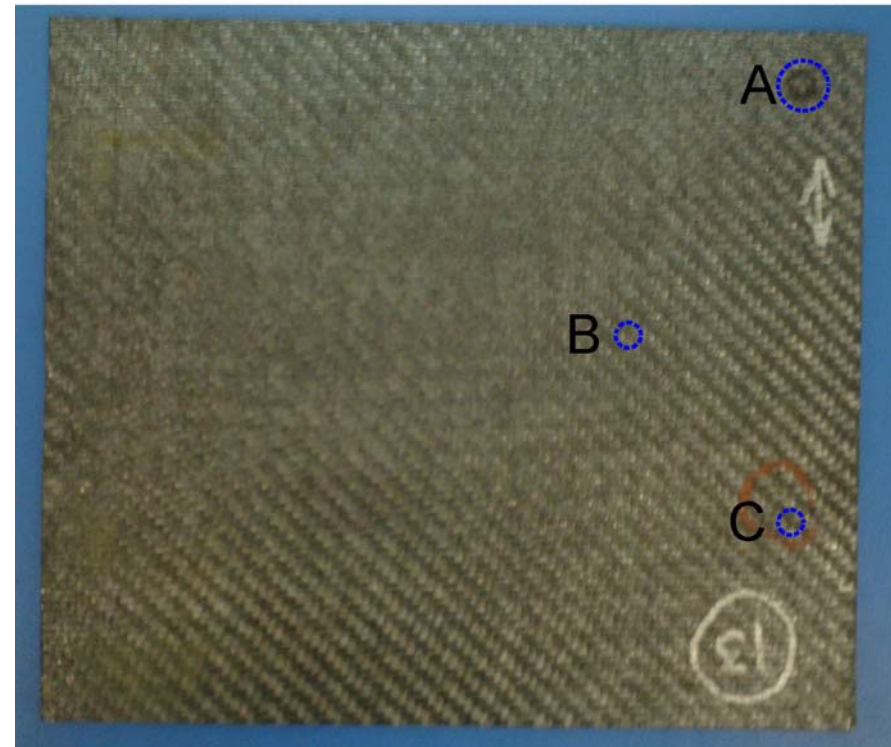
Thickness of the Sample: 2.79 mm

Defects' details:

A. deep: 0.18 mm, diameter: 6 mm

B. deep: 0.29 mm, diameter: 2.6 mm

C. deep: 0.05 mm, diameter: 4 mm



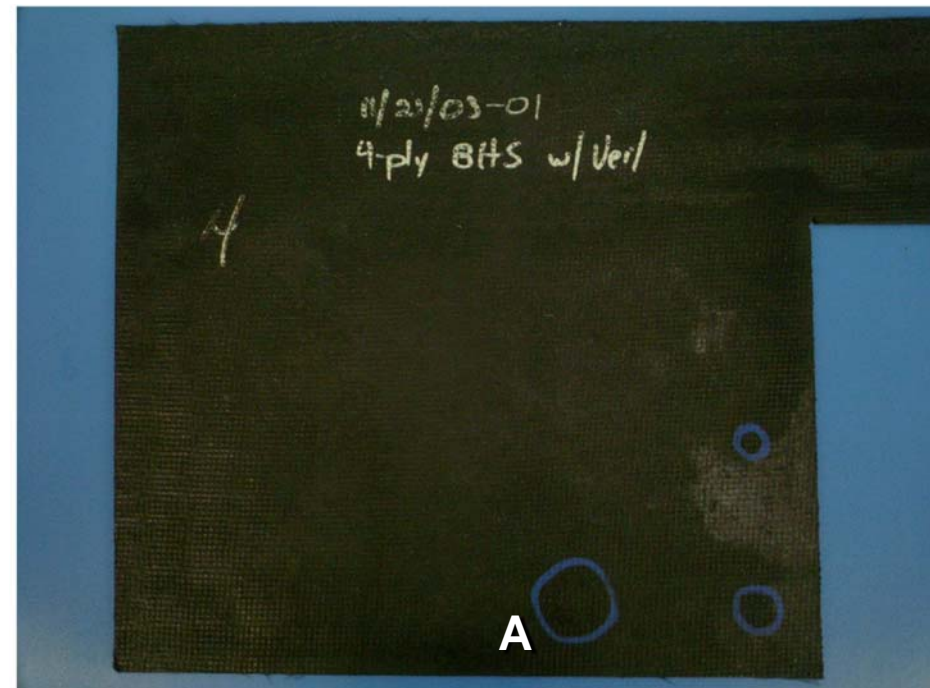


Details of Defect

- Defects in 1.90 mm Thick Cut Sample

Thickness of the Sample: 1.90 mm

A. Deep: 0.25 mm, diameter: 20 mm





Details of Scanning

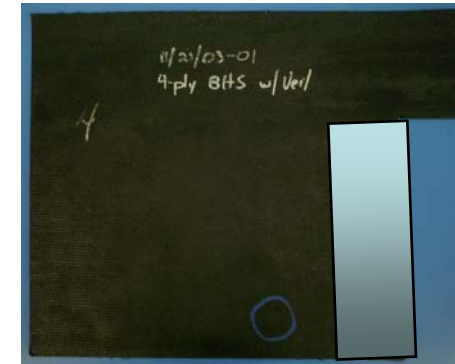
- All the samples were scanned by
 - Ultrasonic Immersion scanning in through transmission mode using 5 MHz probe
 - Ultrasonic Immersion scanning using pitch catch mode using 5 MHz probe
 - N-BUS scanning using 1 MHz probe



1 mm thick plate



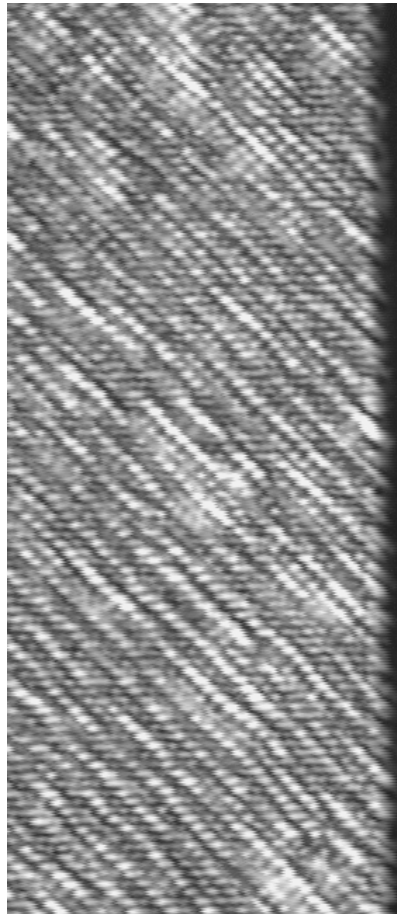
3 mm thick plate



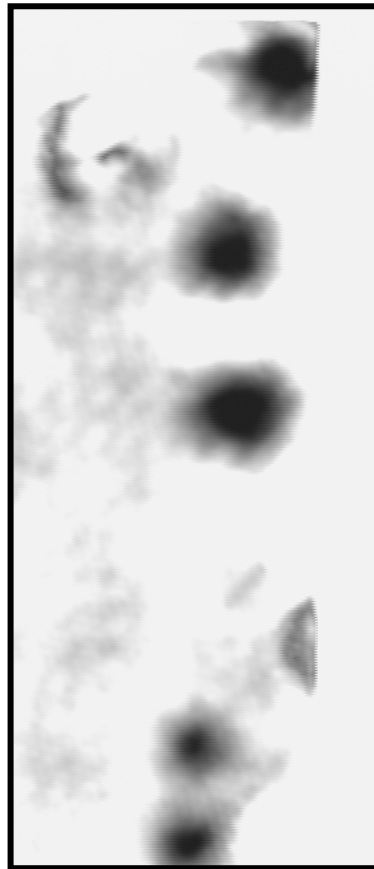
2 mm thick cut plate

- Due to restrictions in current C-Scan setup, the samples were scanned for 70 mm width at the right side as marked in the pictures above
- Scanning for N-BUS was also done over the same area for comparison purposes

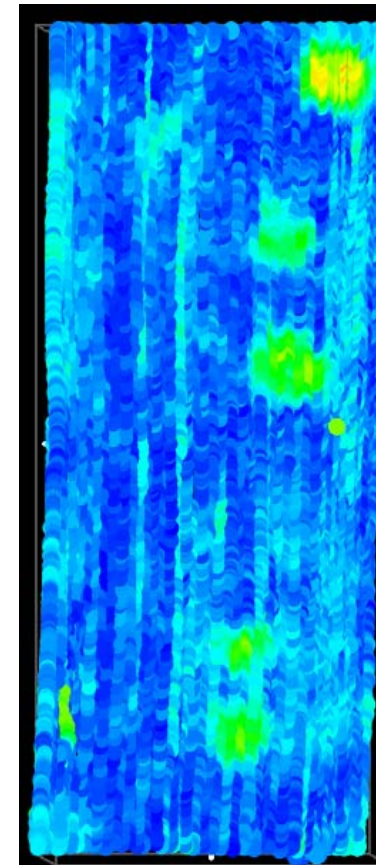
1.35 mm thick sample



**C Scan Image
Pitch – catch
at 0.25 mm pitch**

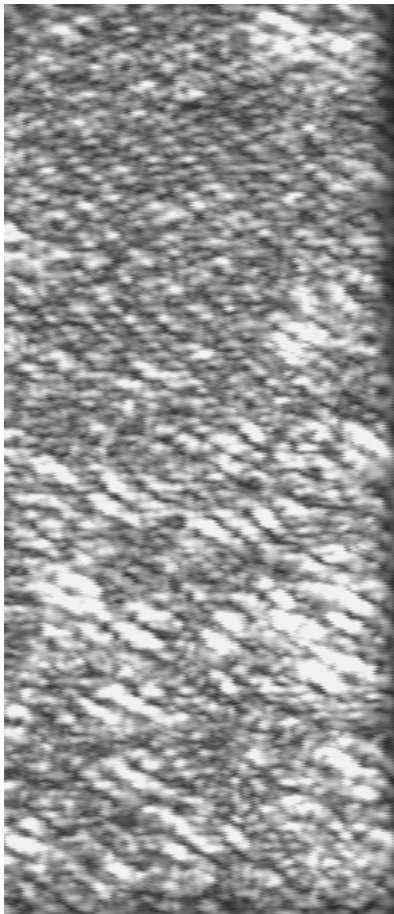


**C Scan Image
Through
Transmission
at 0.25 mm pitch**

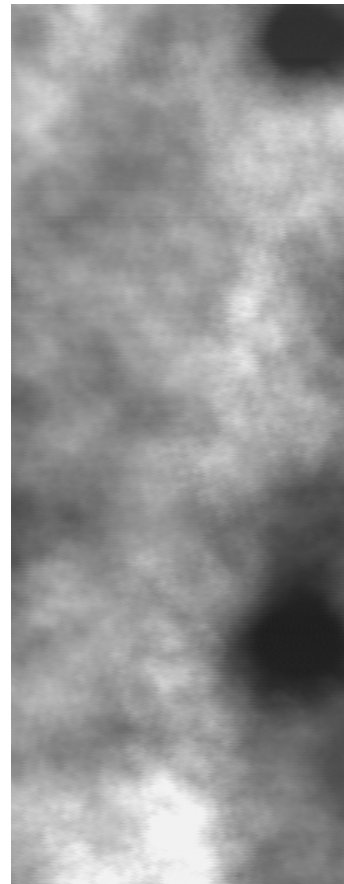


**N-BUS Scan
Image at 2 mm
pitch**

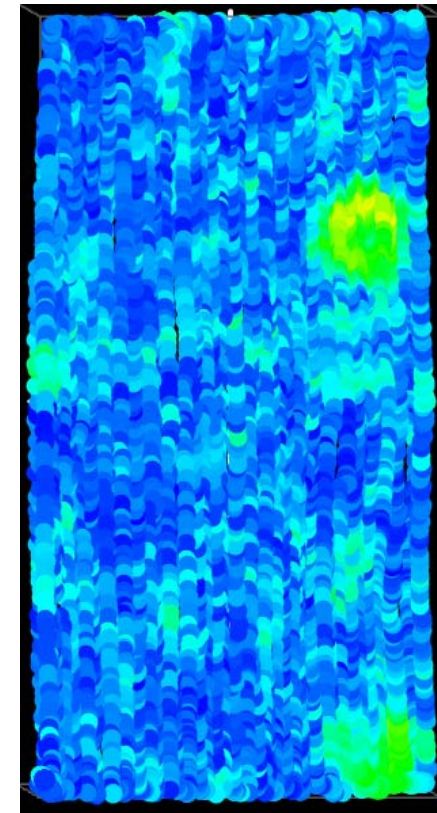
2.79 mm Thick Sample



**C Scan Image
Pitch – catch
at 0.25 mm pitch**



**C Scan Image
Through
Transmission
at 0.25 mm pitch**



**N-BUS Scan
Image at 2 mm
pitch**

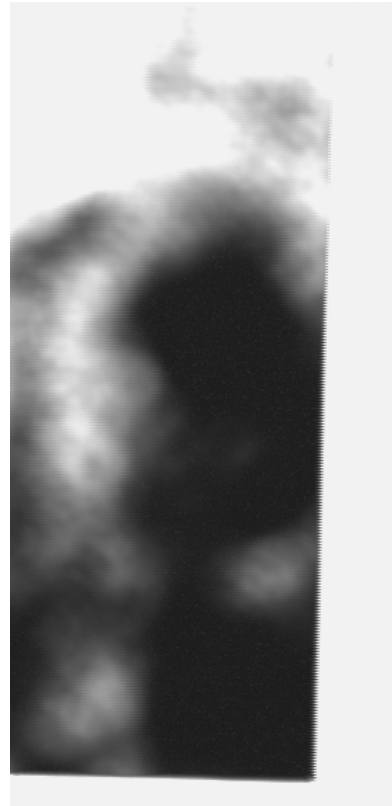
(defects on the
opposite side)



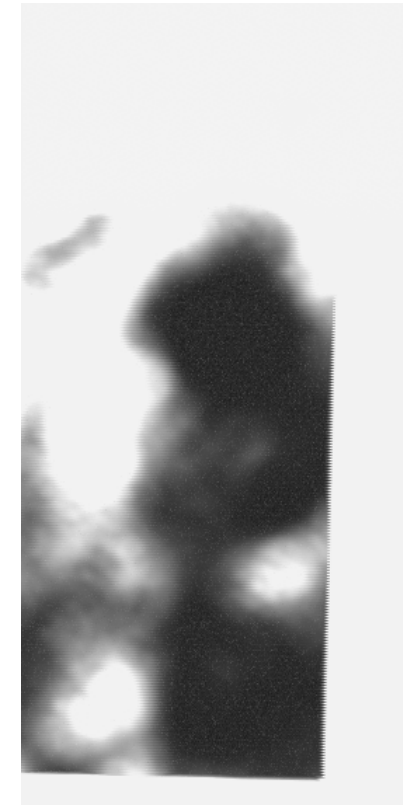
1.9 mm Thick Cut Sample



**C Scan Image
Through
Transmission at 0.25
mm pitch, 18 dB Gain**



**C Scan Image
Through
Transmission at 0.25
mm pitch, 30 dB Gain**

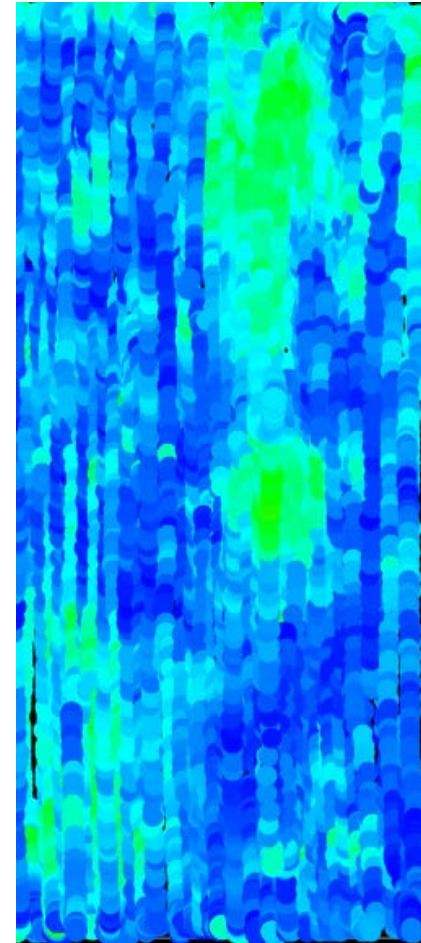


**C Scan Image
Through
Transmission at 0.25
mm pitch, 36 dB Gain**

1.90 mm Thick Cut Sample



**C Scan Image Pitch – catch
at 0.25 mm pitch**



**N-BUS Scan Image at 2
mm pitch (scanned from
opposite side)**



Conclusions

- All the defects are picked up by Ultrasonic Immersion Through Transmission Technique
- Ultrasonic Immersion Pulse Echo Technique does not pick up most of the defects
- N-BUS technique along with FreeScan detects all the defects
- NBUS is the most suitable technique for deployment in following applications:
 - **In-service inspection of large components that cannot be taken into immersion tank**
 - **Inspection of components where access from both sides is not available.**