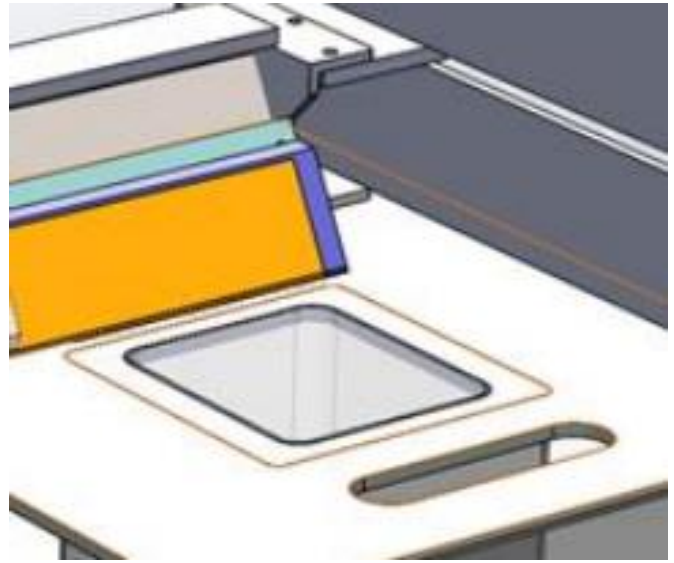
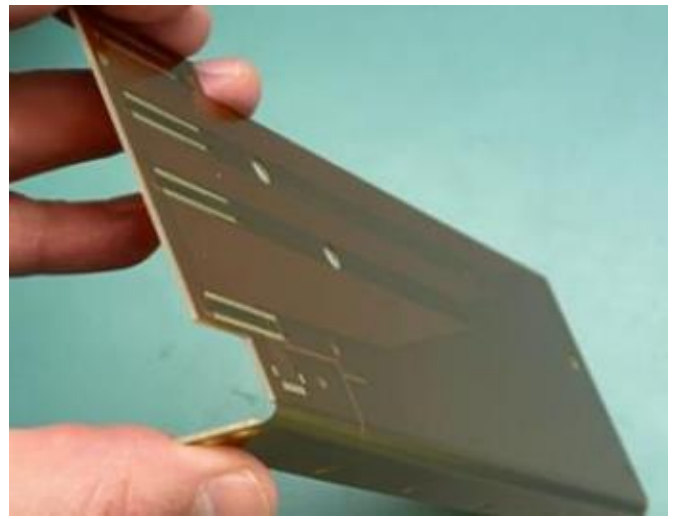
In-situ Sensing and Post-production Inspection for Additive Metal Parts Using Eddy Current Arrays





Dr. Neil Goldfine and Dr. Andrew Washabaugh
Neil.goldfineoverseas@jenteksensors.com | Andrew.Washabaugh@jenteksensors.com

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www.jenteksensors.com

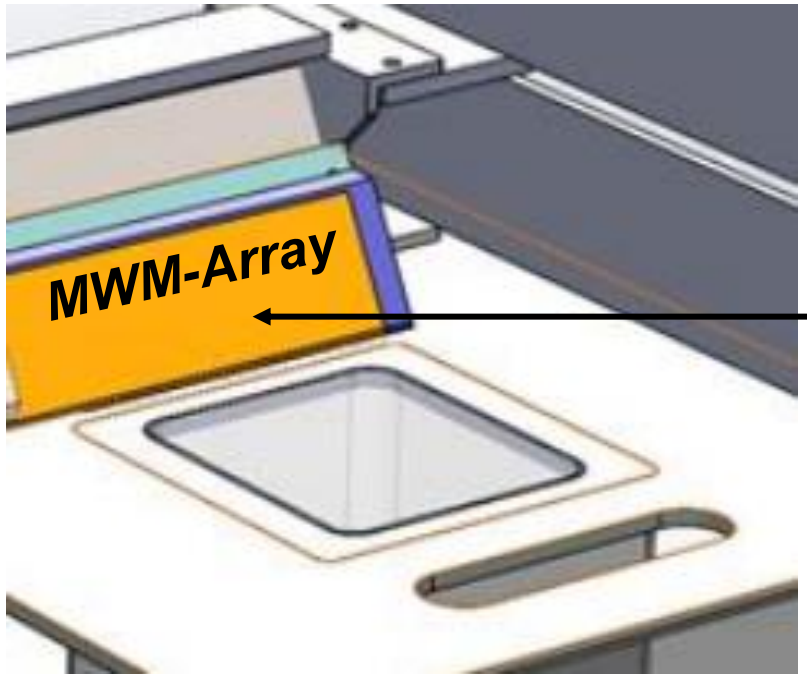
Agenda

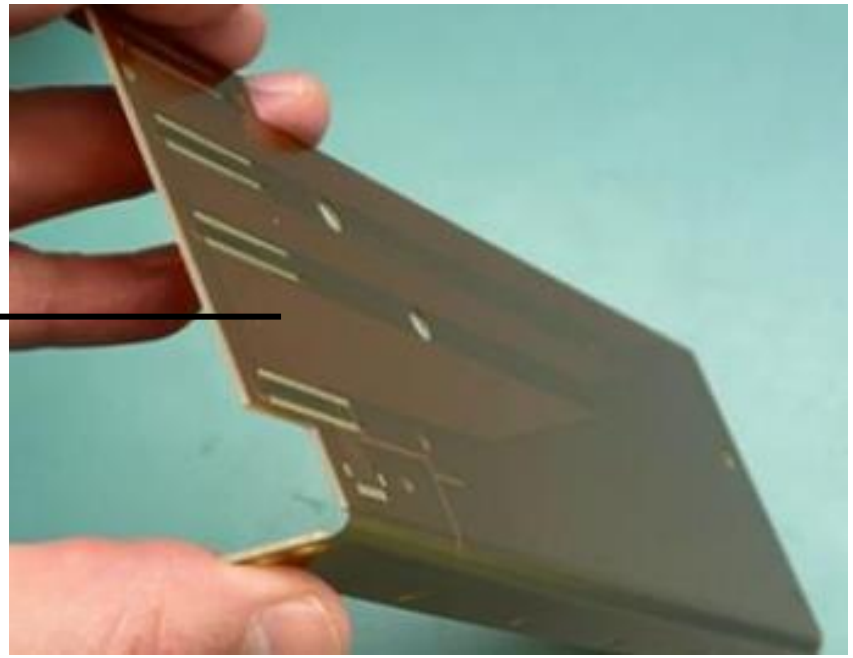
- JENTEK in-situ sensing technology for AM
  - Eddy current arrays for LPBF
  - Simulated results
  - Z-directed filtering
  - Measurement grid approaches
- JENTEK post-process NDT for AM
  - Machined surface inspection (holes and surfaces)
  - Metallurgical assessment
  - Volumetric crack detection for thin walls (surface and subsurface)

JENTEK has completed two integrated demonstrations on SLM 125 machines with a 79-channel MWM-Array for full width layer-by-layer in-situ sensing.

JENTEK has completed an integrated demonstration on an EB-DED machine.

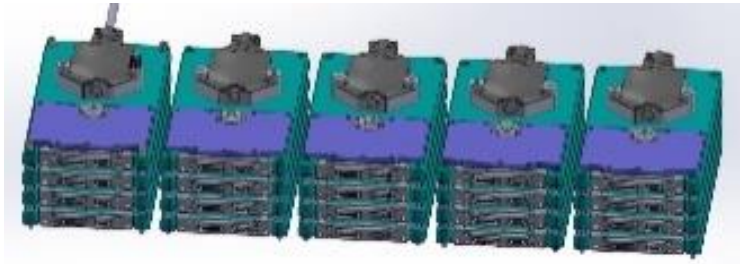
JENTEK Approach for Laser Powder Bed Fusion (LPBF)





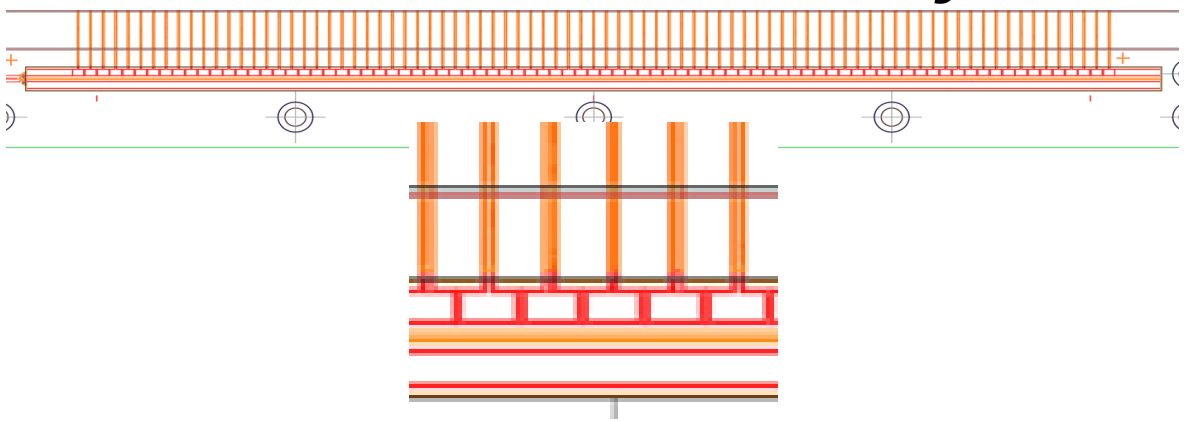
GS9000 fully parallel instrument

79-channel

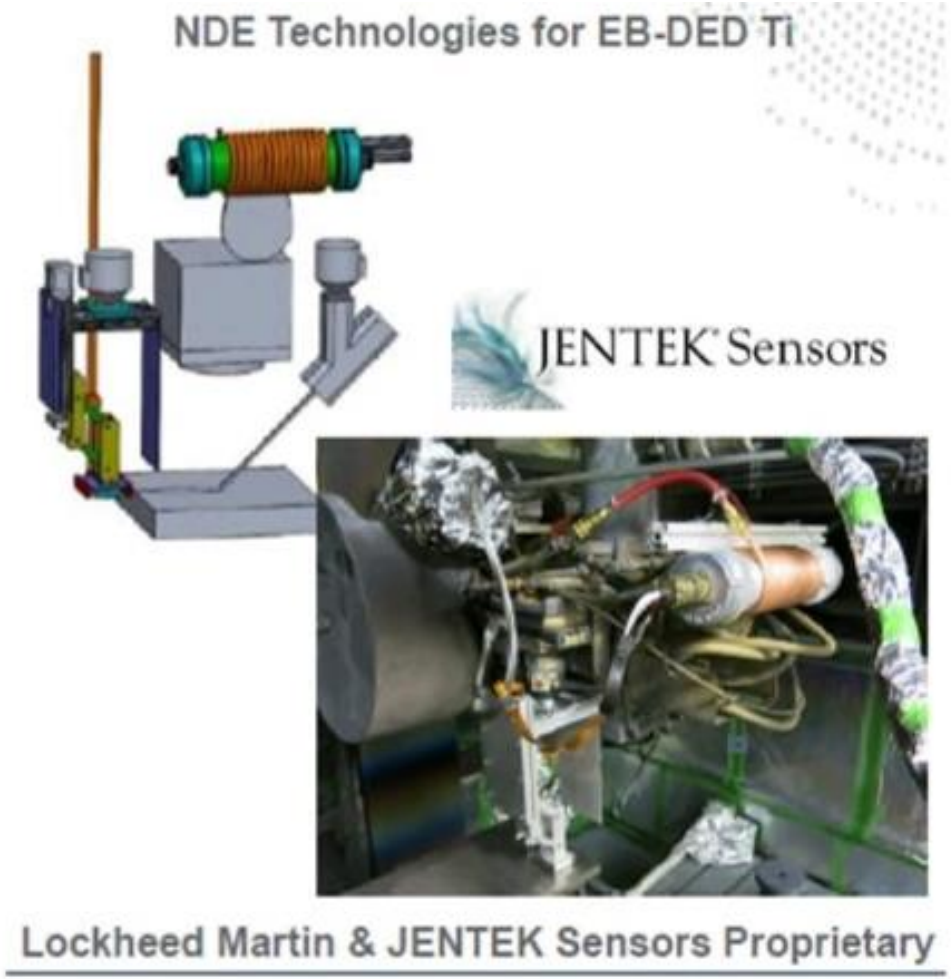


395-channel

79-channel MWM-Array



JENTEK Project for Electron Beam Direct Energy Deposition (EB-DED)



Slide from public Lockheed Martin presentation

(left images)

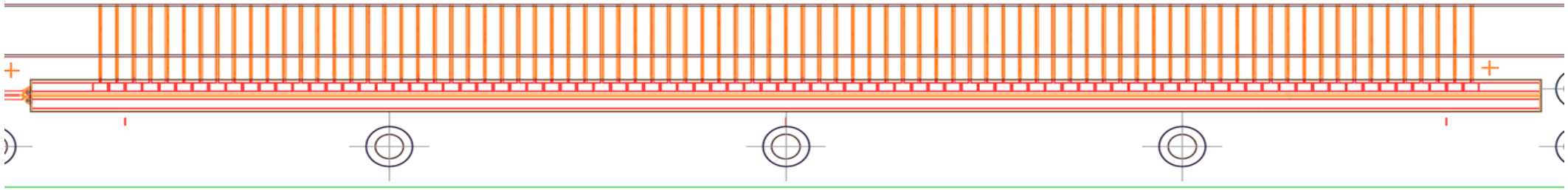
LOCKHEED MARTIN 39

MWM-Array LPBF Sensing Element Width Study

FA332 (for comparison)

1.65 mm sense element spacing

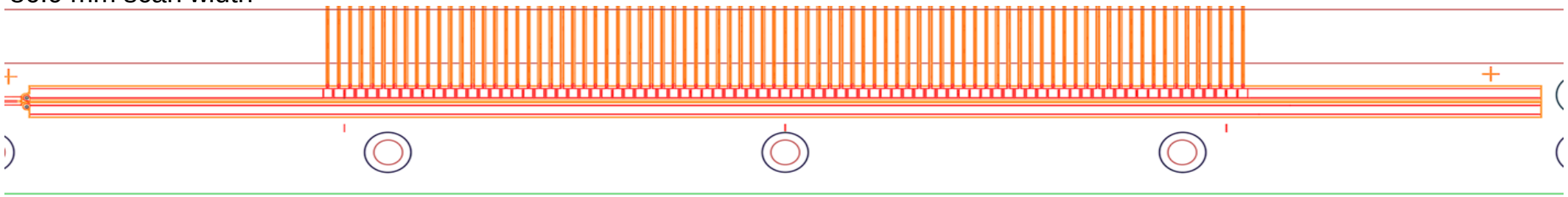
130.0 mm scan width



FA364

1.10 mm sense element spacing

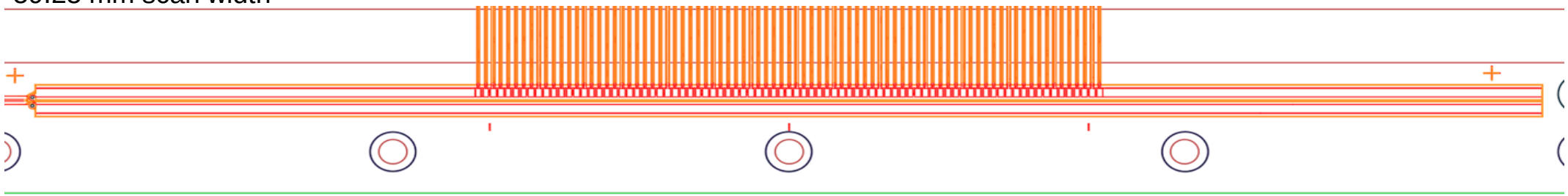
86.9 mm scan width



FA366

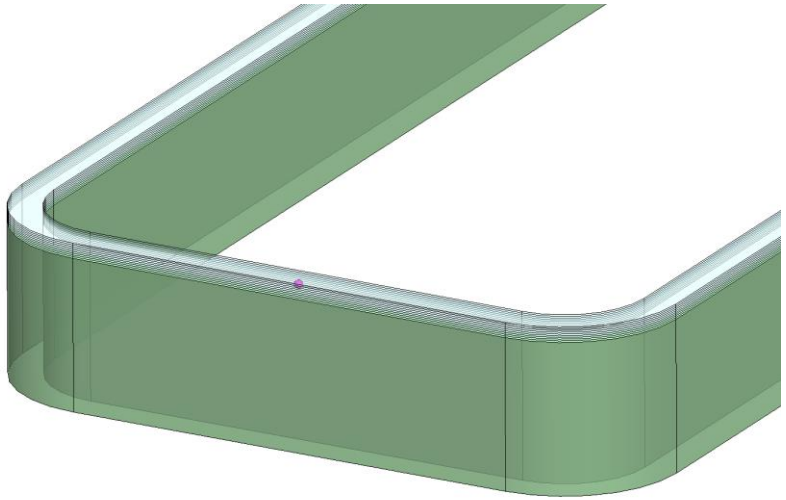
0.75 mm sense element spacing

59.25 mm scan width

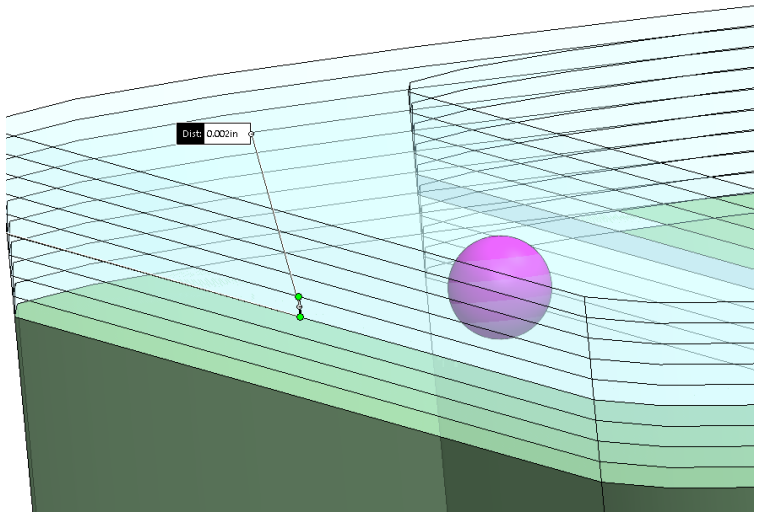


z-Directed Filtering

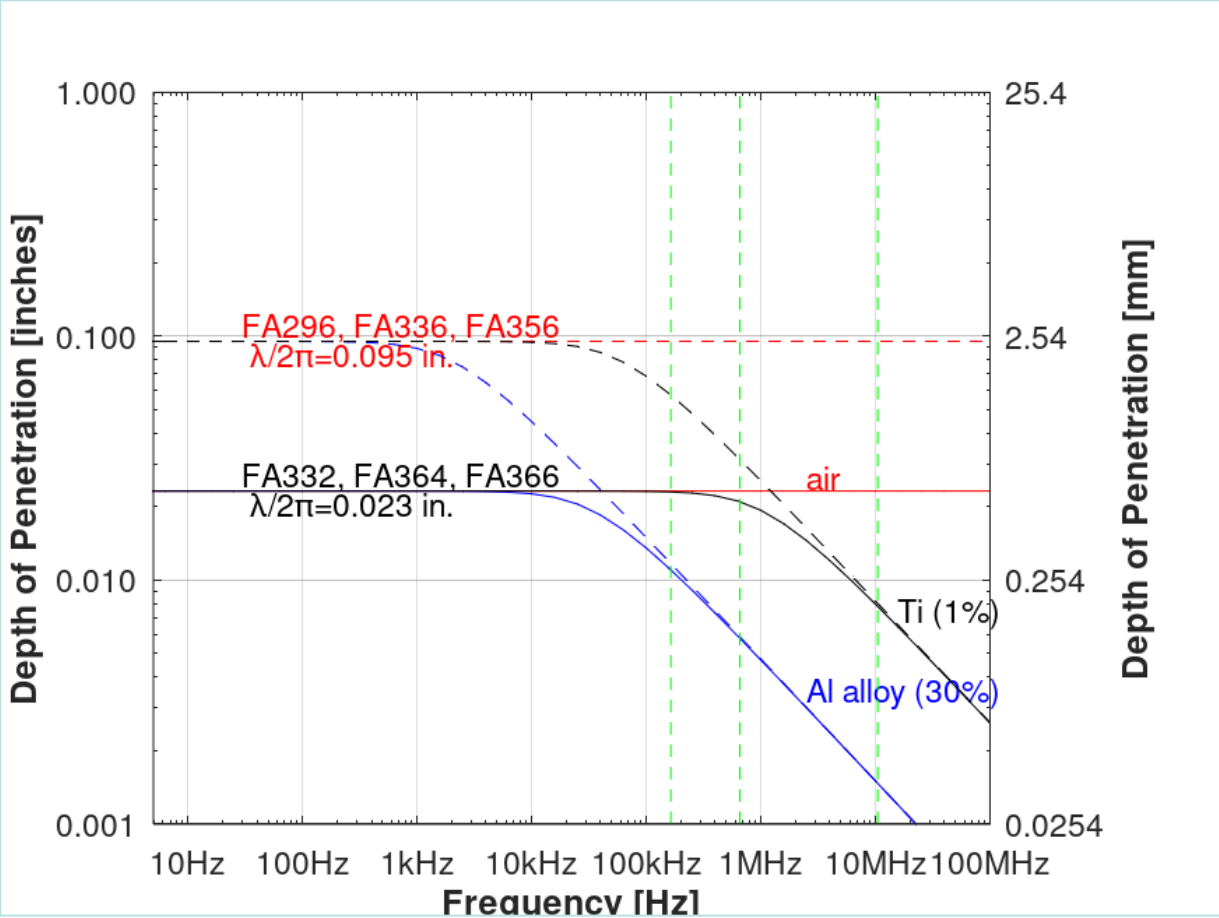
Thin wall (1 mm) vertical wall example



MWM-Array scans every 50 microns (0.002 in.) - multiple scans have the opportunity to sense the same 250 micron defect

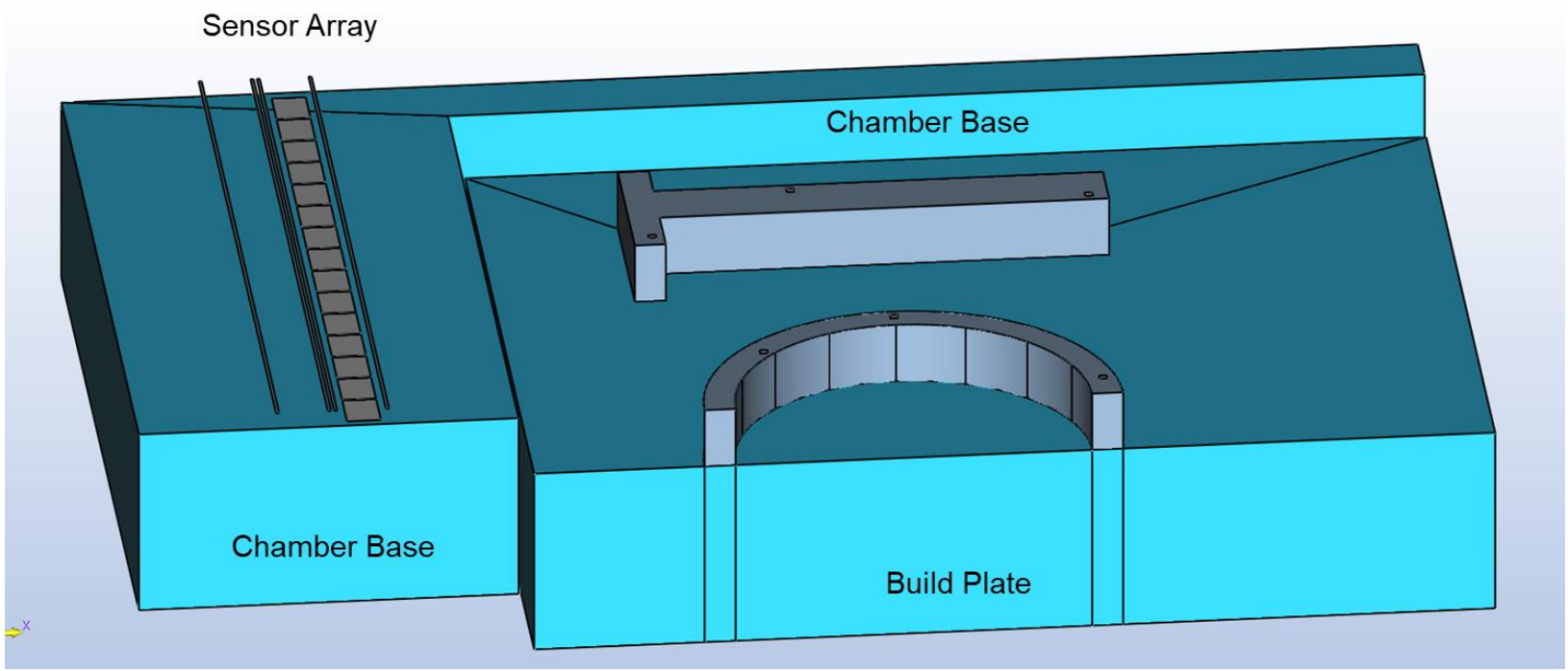


3-D Volumetric MWM-Array Imaging at Three Frequencies

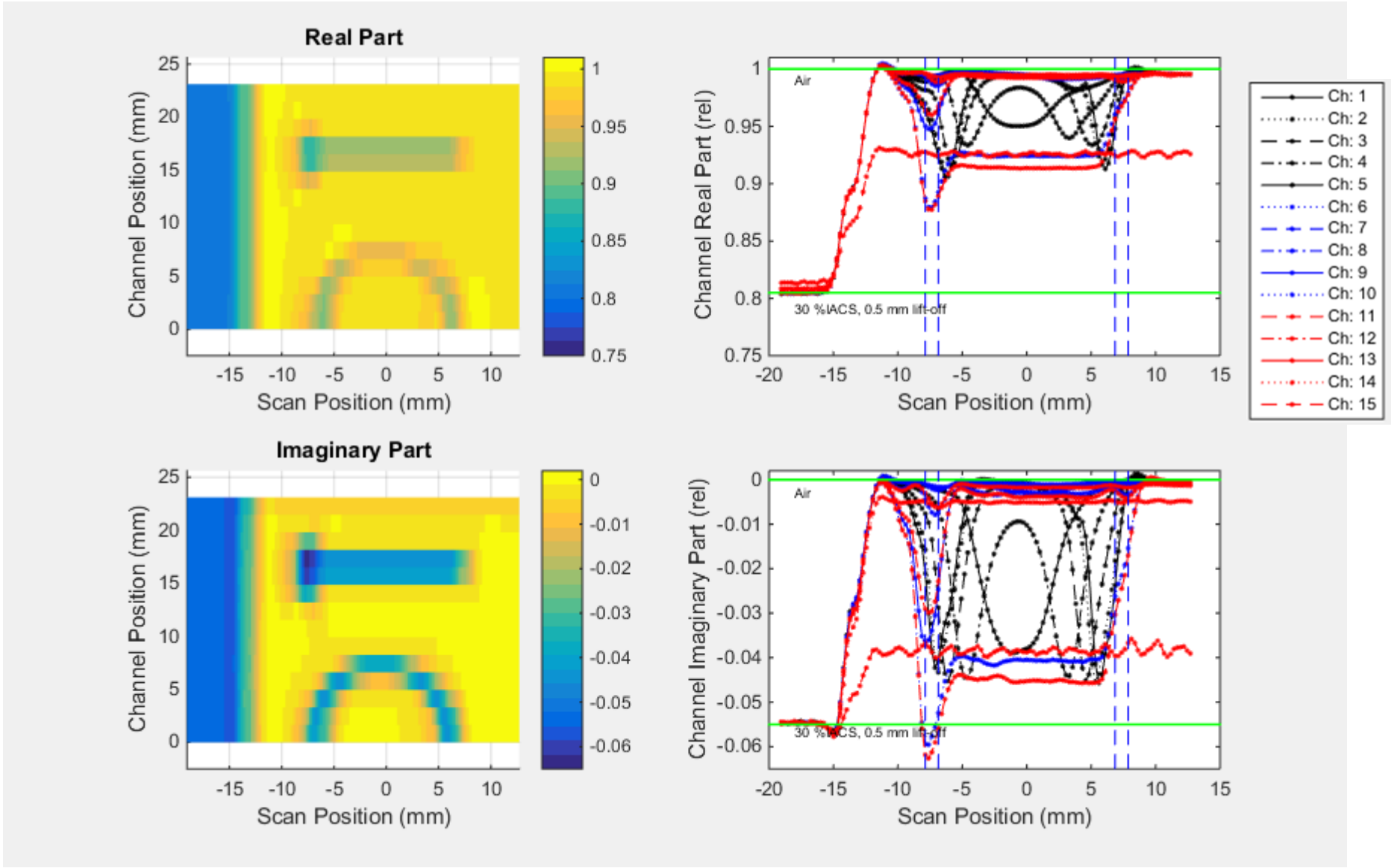


- Detect surface and sub-surface defects
- Sense three to five printed layers below the current process layer
- Full powder bed width imaging
- 0.75 to 2mm sensing element size
- Fully parallel data taken simultaneously at all channels at three frequencies

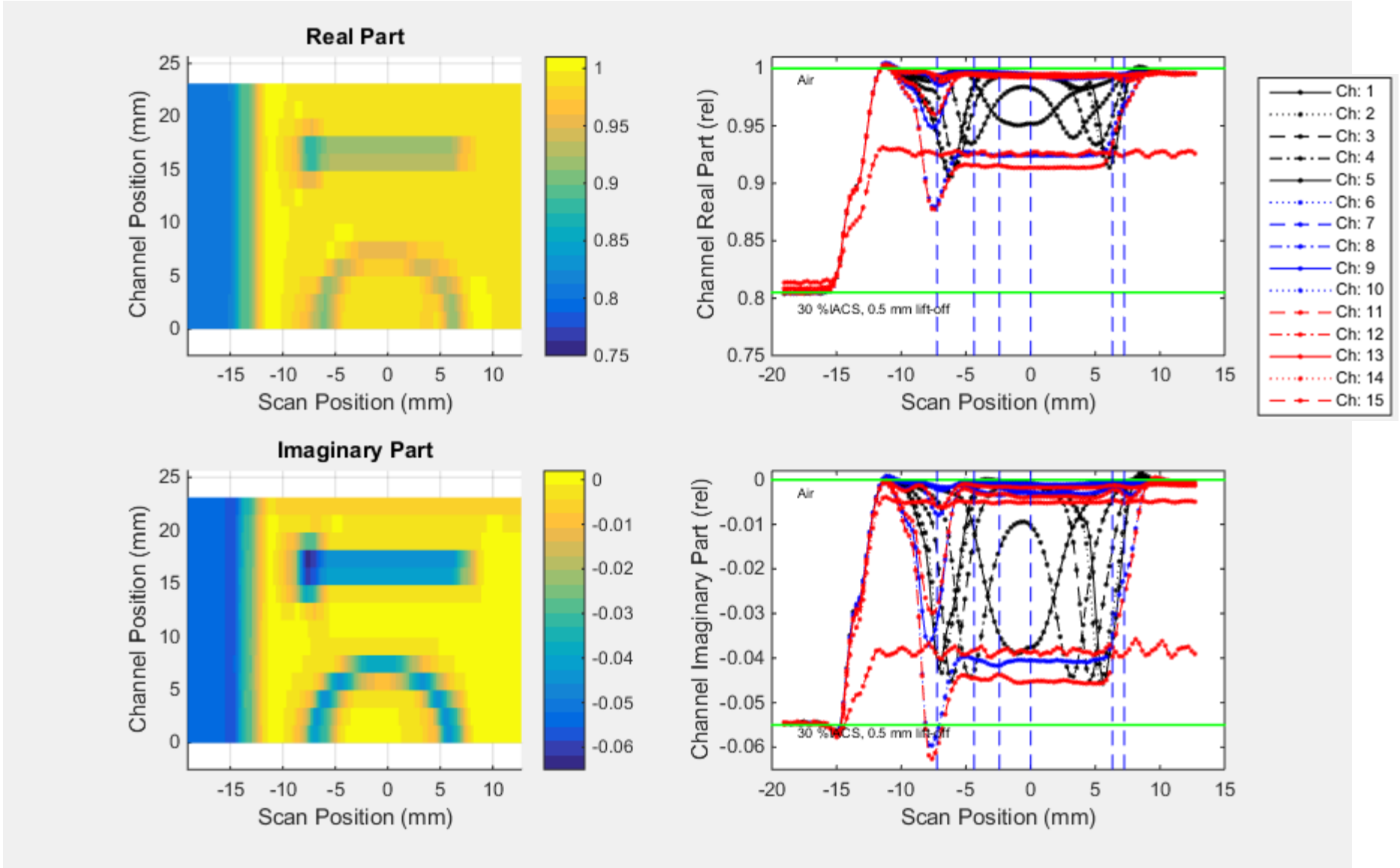
Simulated response geometry



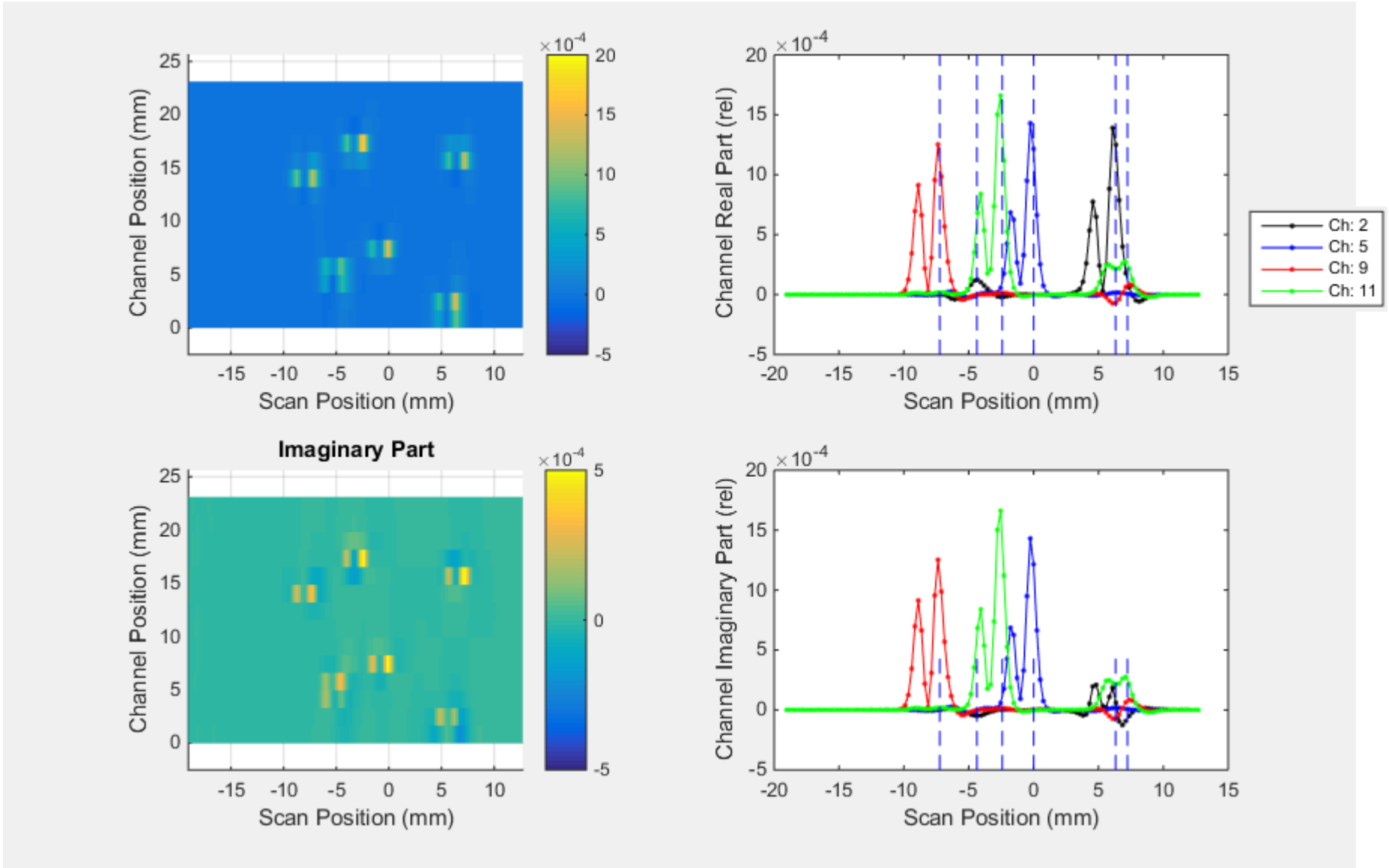
Simulated response – No Flaws



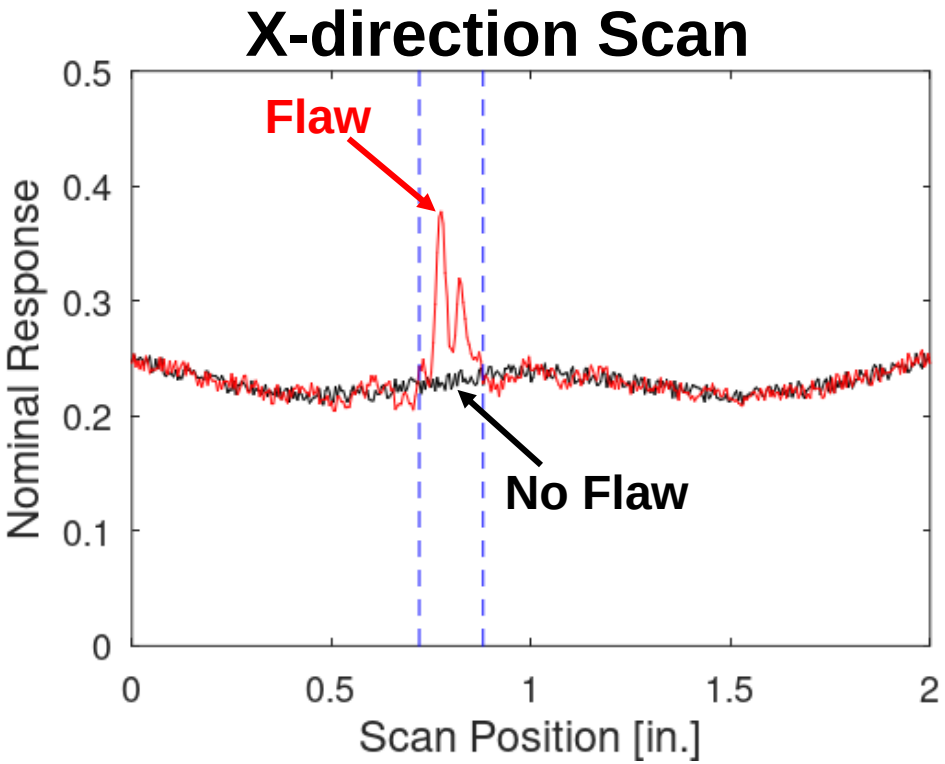
Simulated response – Multiple 0.010 in. Flaws

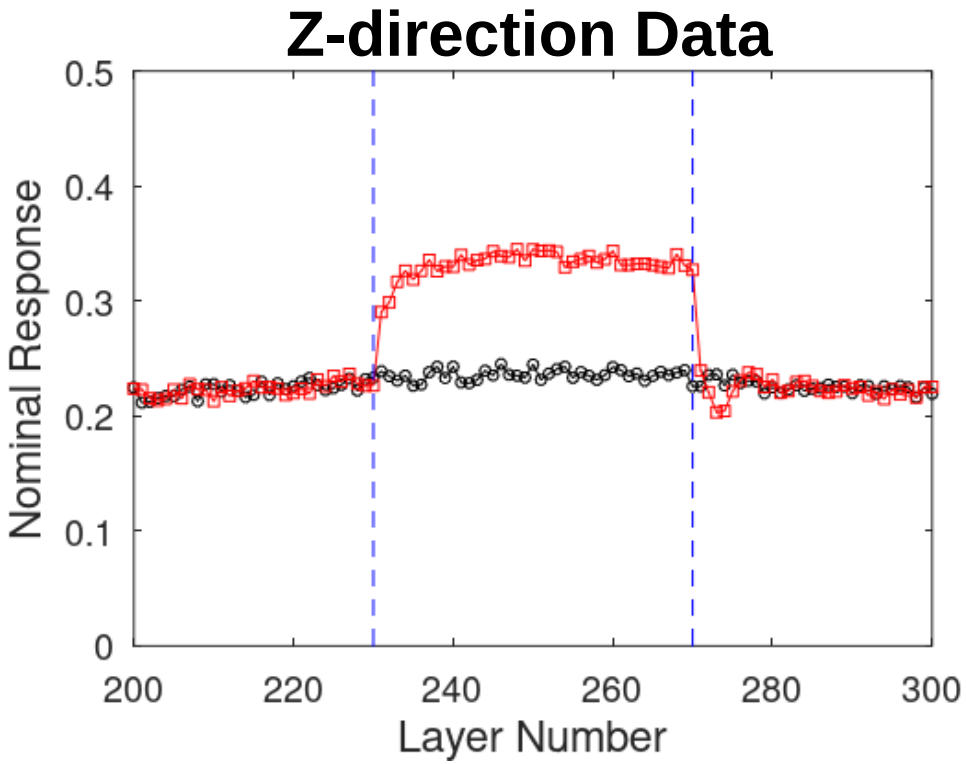


Simulated Response, Baseline Subtracted



Simulated z-Directed Filtering for 2mm tall cylindrical flaw





Typical dual-rectangle drive flaw response.

Sensitivity to the last three to six layers.

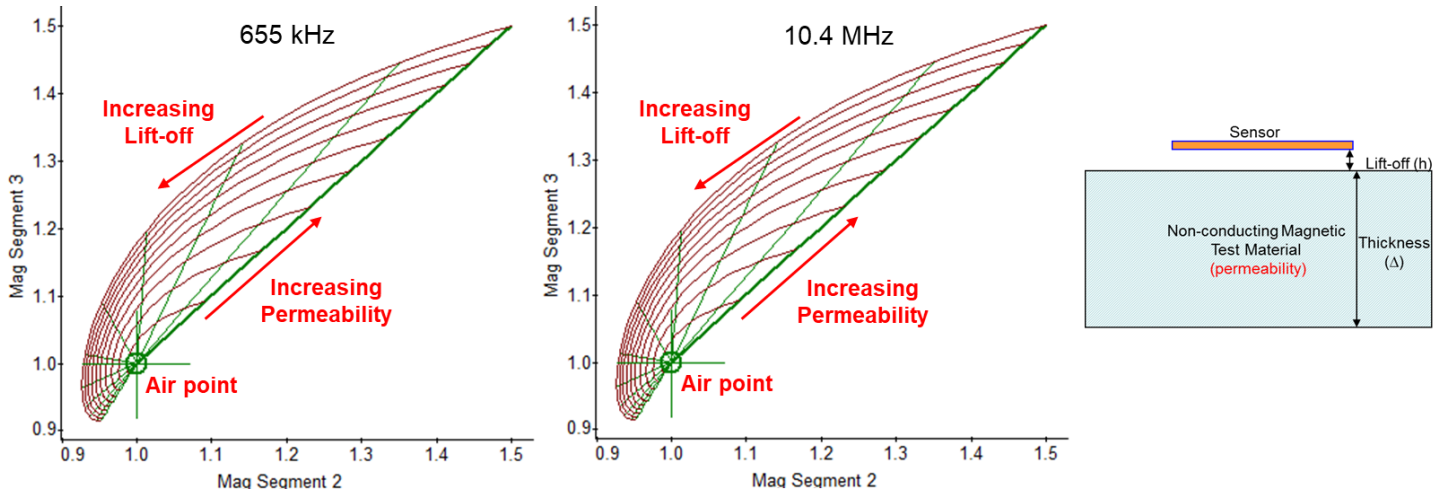
Ferrous (magnetic) Material Representation (Permeability & Lift-off)

JENTEK uses:

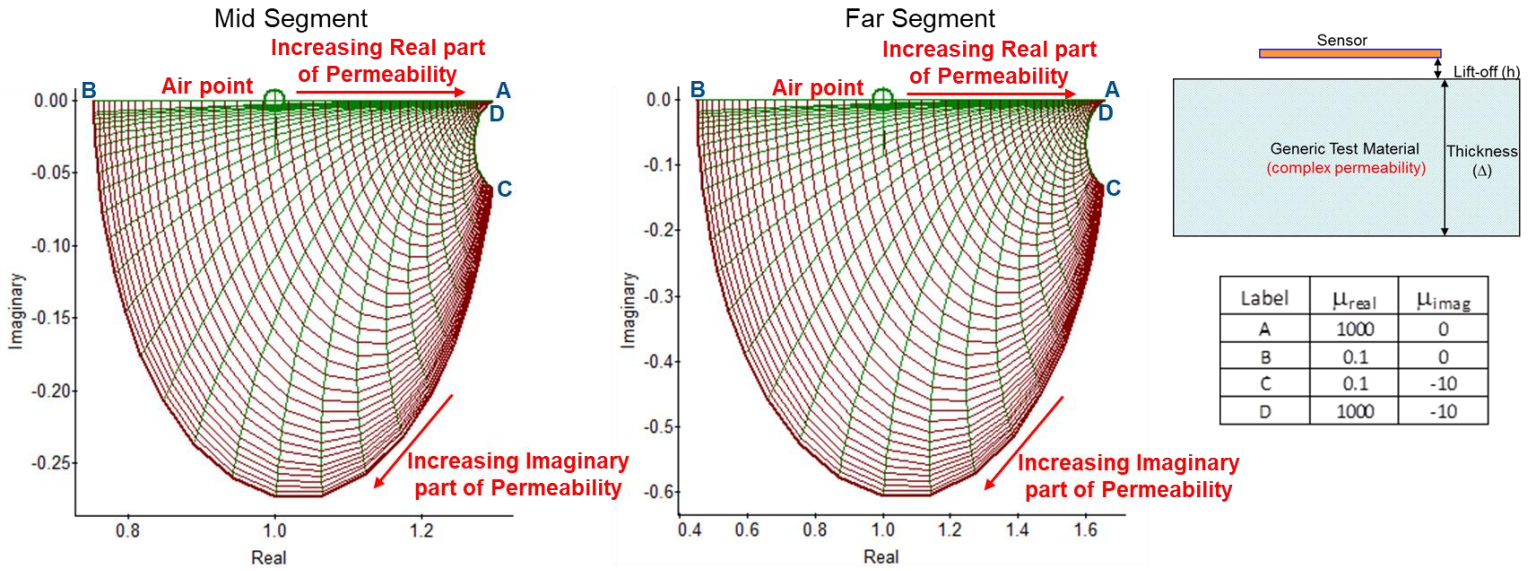
1. Pre-computed databases (grids) to provide rapid solutions for physics-based models.

2. Intelligent filtering/AI to enhance defect responses and correct for geometric variations.

Segmented sensor grids for estimation of permeability and lift-off



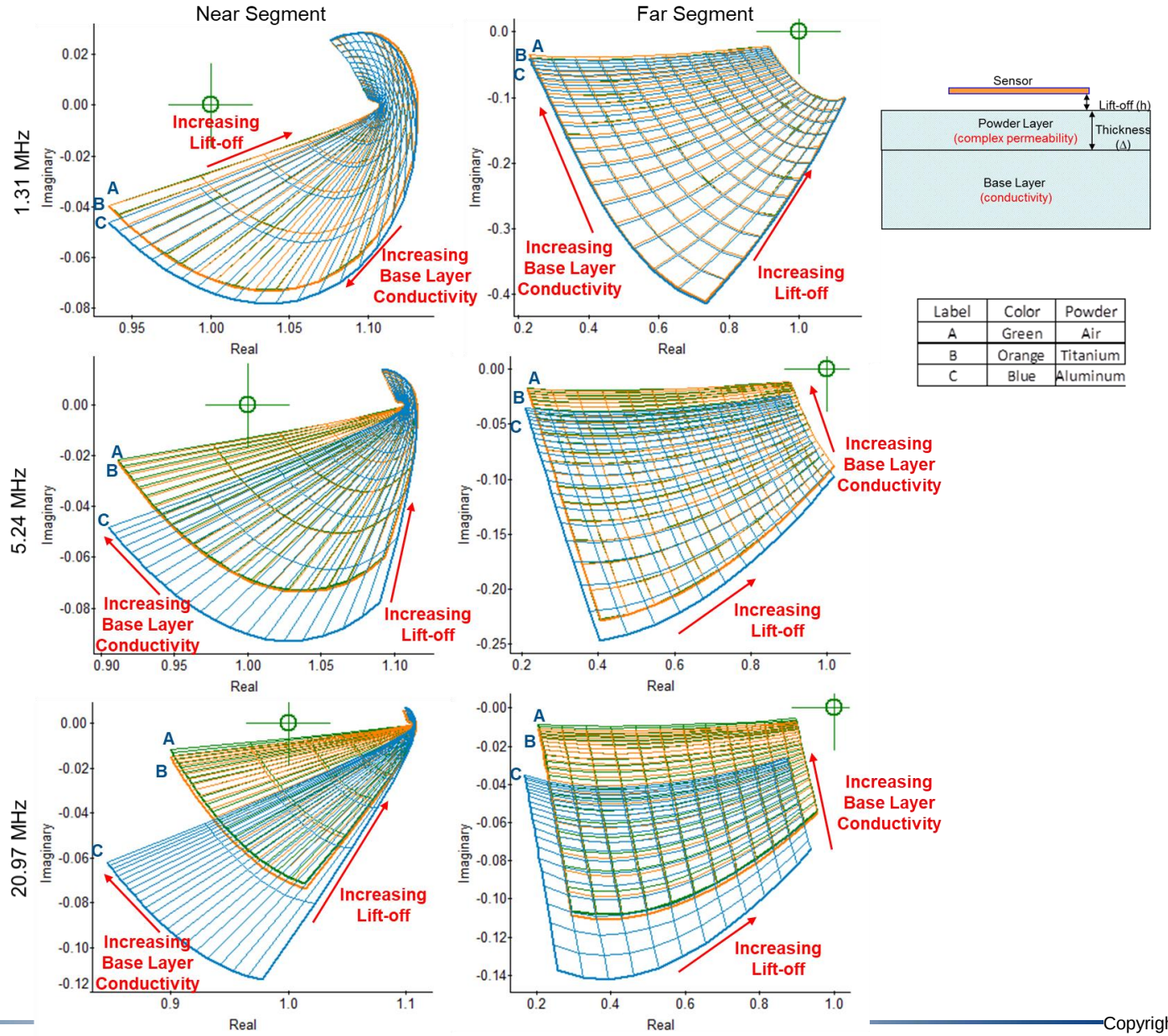
Complex mu – halfspace, 0.020 in. lift-off, FA294



Label	μ_{real}	μ_{imag}
A	1000	0
B	0.1	0
C	0.1	-10
D	1000	-10

Measurement Grid Methods (Nonferrous)

Sensitivity to most recent process layer and prior three to six layers.



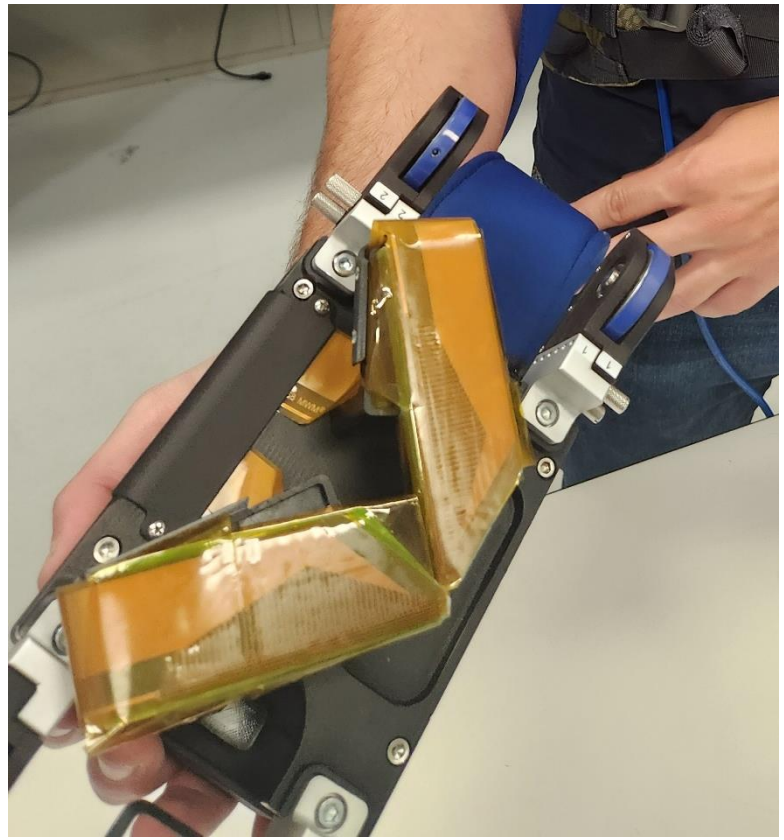
JENTEK post-process NDT for AM

- Machined surface inspection (holes and surfaces)
- Metallurgical assessment
- Volumetric crack detection for thin walls (surface and subsurface)

Post-process NDT for Relatively Rough Surfaces

Backpack Portable NDT Scanning System (GS9000 Version)

± 45 degree scanner for crack detection and weld inspection



JENTEK NDT Systems

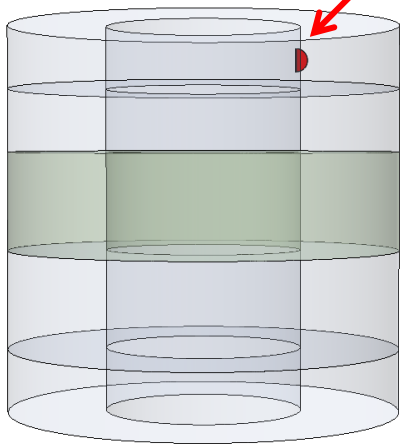
jET

jETi

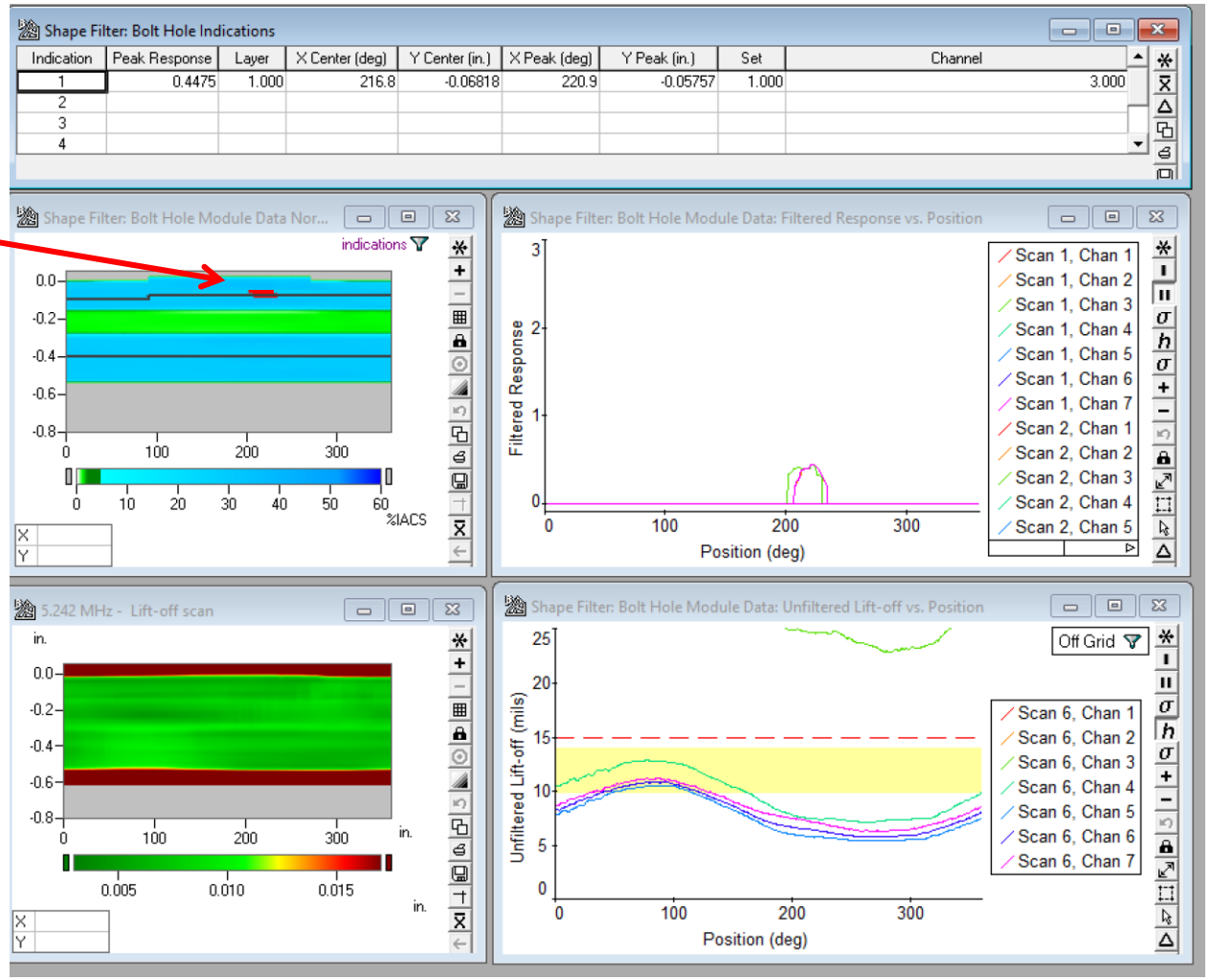
GS9000 Backpack Portable

Bolt Hole NDT with jETi (30 x 15 mil; mid-wall flaw)

0.030 in. x 0.015 in.



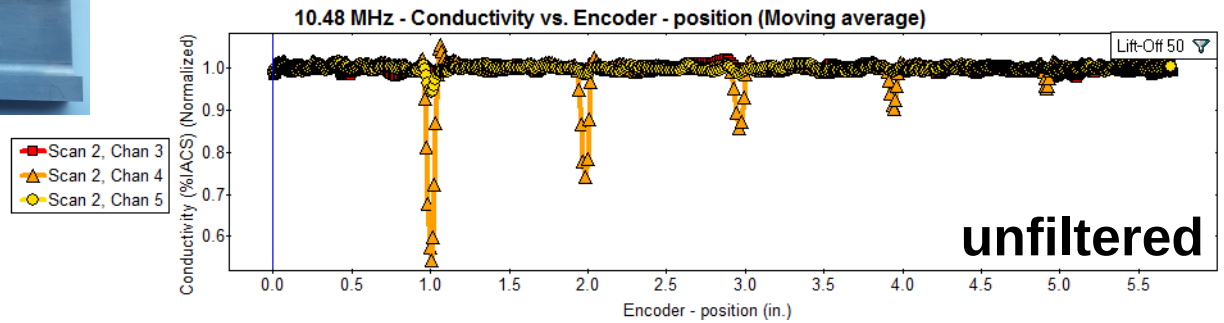
Aluminum
Aluminum
Titanium
Aluminum
Aluminum

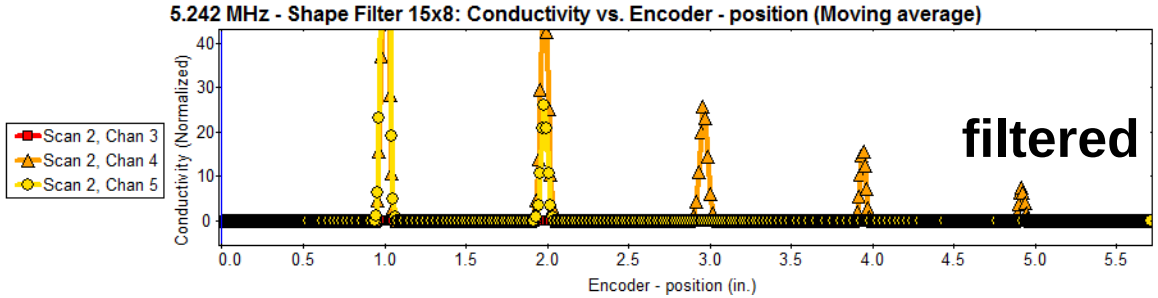


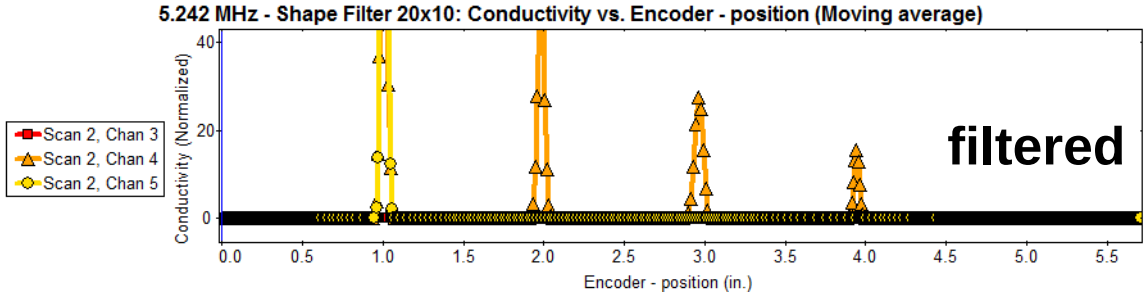
Surface Cracks in Fillets (unfiltered and filtered response)

EDM Notch Sizes:

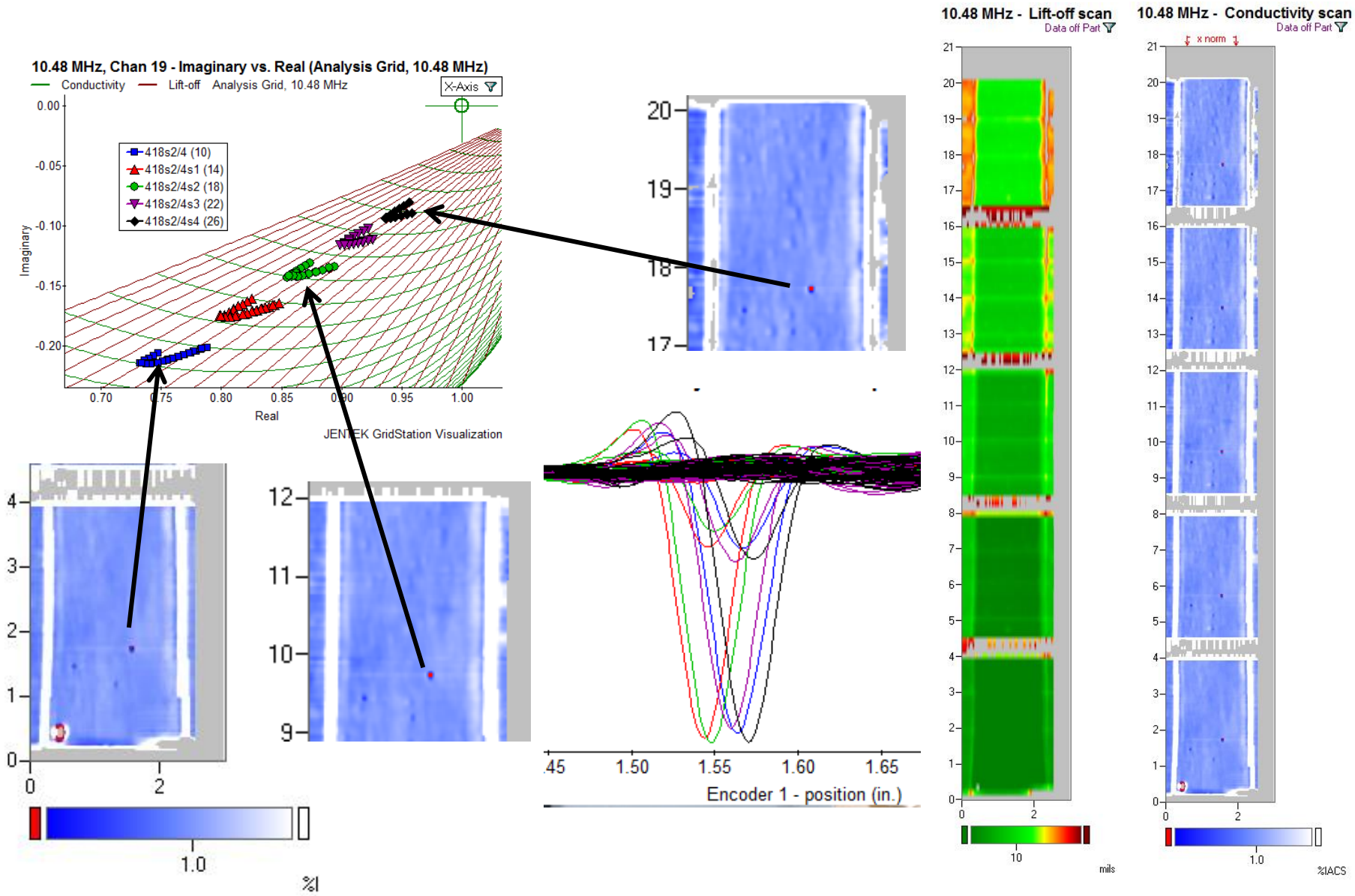
length	0.06	0.04	0.03	0.02	0.015	
depth	x0.03	x0.02	x0.015	x0.01	x0.0075	in.



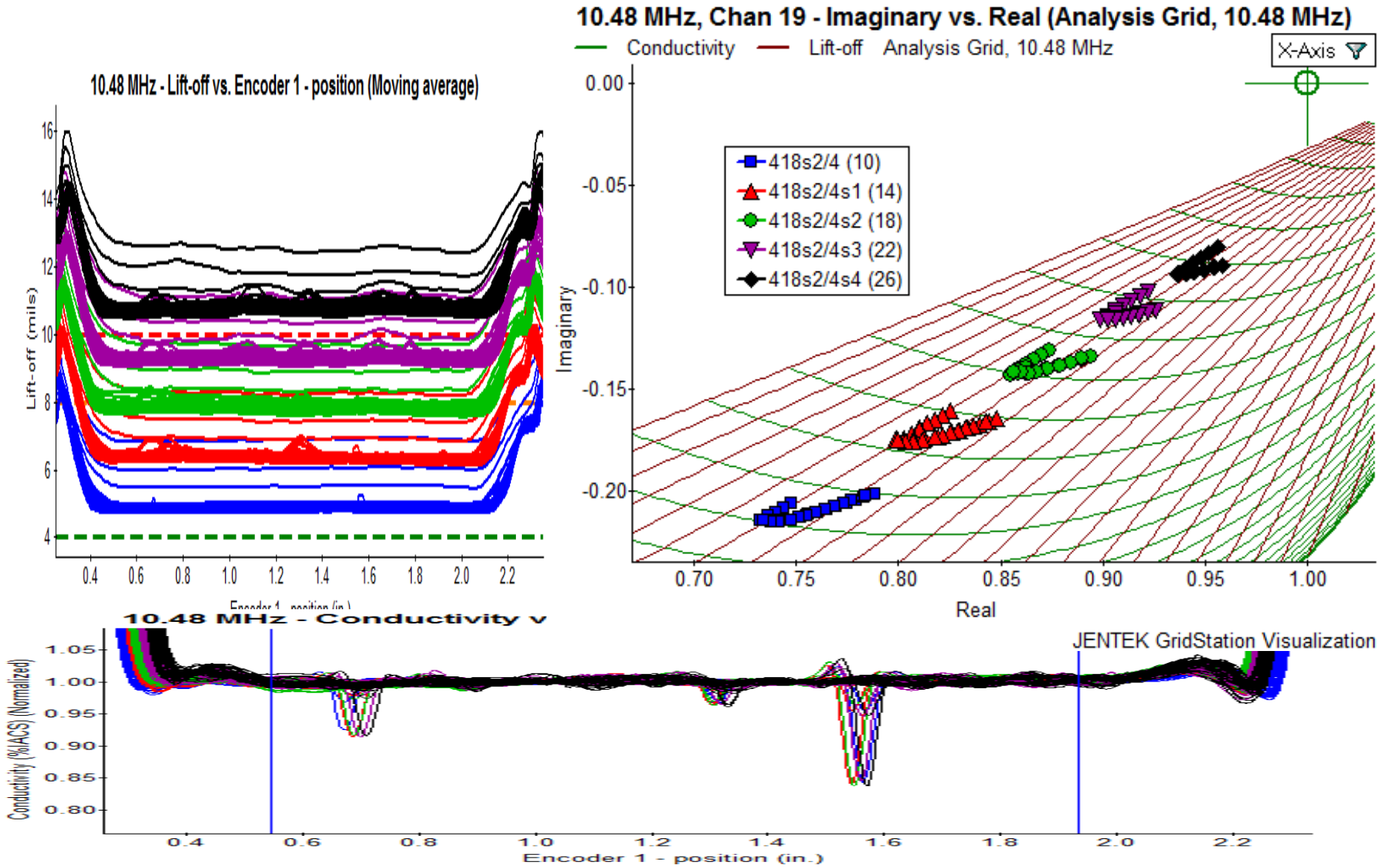




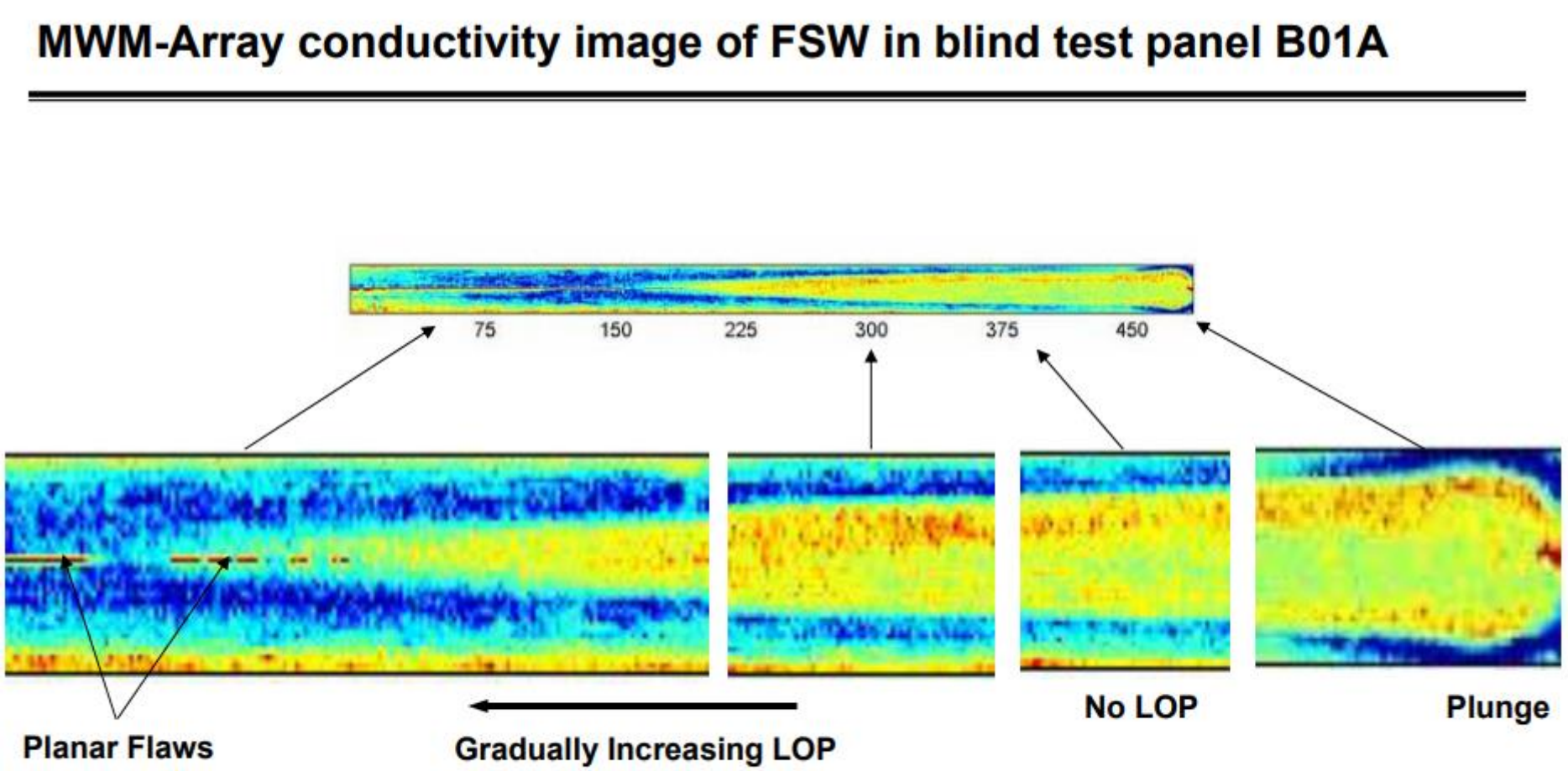
Surface Cracks: Automatic Rescaling of Conductivity Response for Variable Liftoff



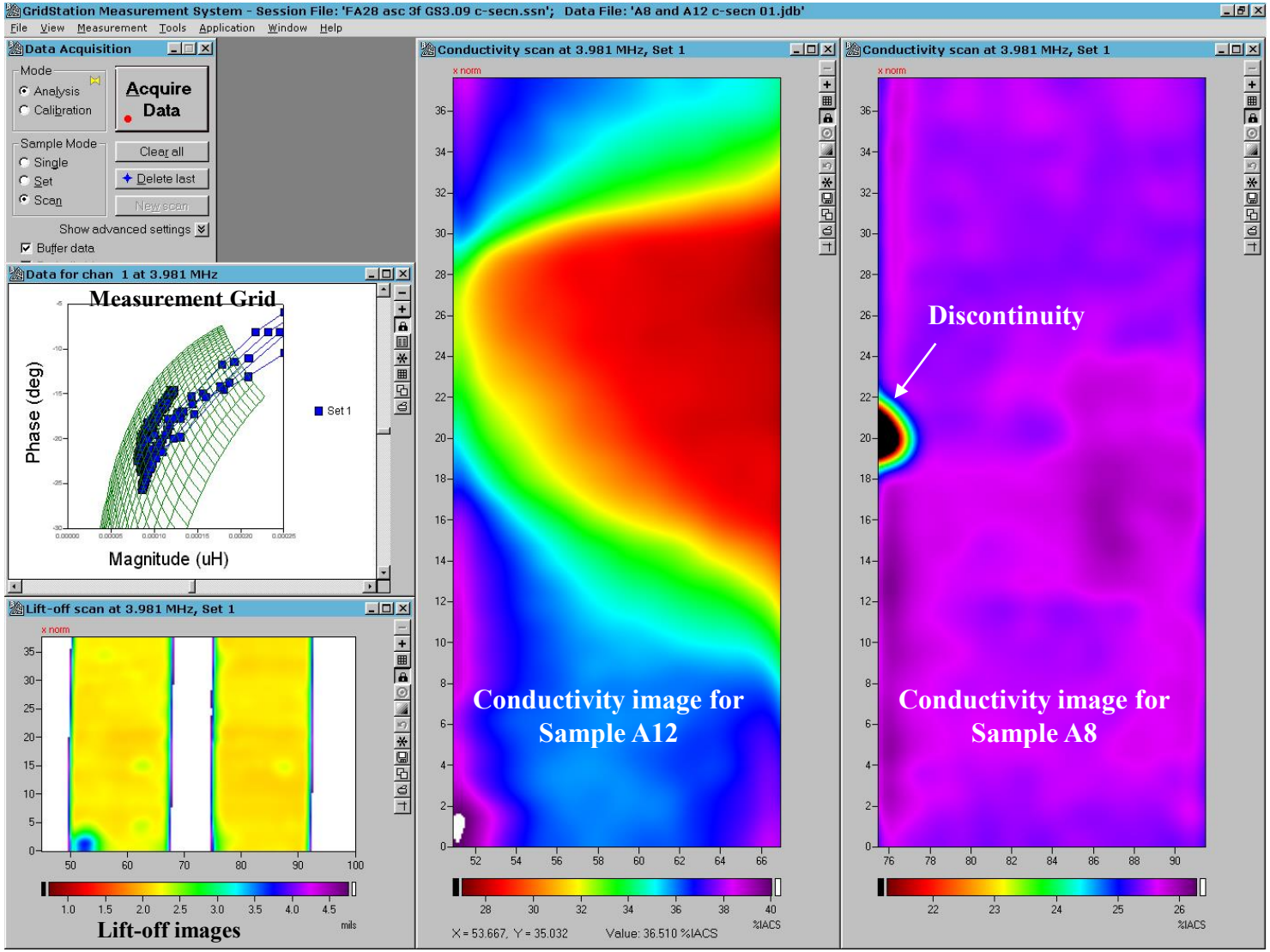
Surface Cracks: Rescaling of Conductivity Response



Friction Stir Weld Surface Image: Lack of Fusion, Weld Width DXZ Imaging



Friction Stir Weld Cross Section Image: Metallurgical Imaging



JENTEK Sensors, a history of delivering NDT solutions

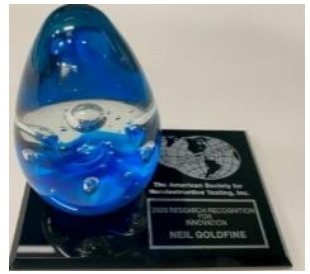
Outstanding Paper Award,
ASNT Materials Evaluation Magazine,
July 2003, Aerospace Health Monitoring

2004 Outstanding Phase III Transition Award, awarded by the Navy Transition Assistance Program

2006 National Tibbetts Award for outstanding contributions to the SBIR Program

2007 FAA/Air Transport Association 2007 “Better Way” Award for Engine Component Inspection Technology

2020
ASNT Innovation Award



Awards

Success Stories

- **2001-present; fighter aircraft engine blade inspection**
- 2002-present; C-130 propeller inspection
- **2005-present; fighter aircraft disk slot inspection**
- **2007-2011; space shuttle leading edge Inspection**
- **2009; fighter aircraft blade dovetail inspection**
- 2011-present; Rolls Royce AE engine inspection
- 2013-present; SCC crack detection for pipelines
- 2015-present; A380 pump hole inspection
- 2016-present; engine blade fir tree inspection
- **2018-present; additive manufactured part inspection**
- 2019-present; conductivity mapping for AL plate
- **2020-present; friction stir weld inspection**

Sticky solutions that produce a revenue stream over decades

New transitions with >10x revenue growth opportunities

- **Spacecraft weld inspection**
- **Additive manufacturing in-situ sensing**
- **Army asset quality and sustainment**
- NDT for aircraft
- Off-shore NDT
- NDT for automotive in-process

Targeted solutions, continual revenue

https://jenteksensors.com/resourcecenter.php

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