Rapid Hand-held Scanning for Corrosion Imaging

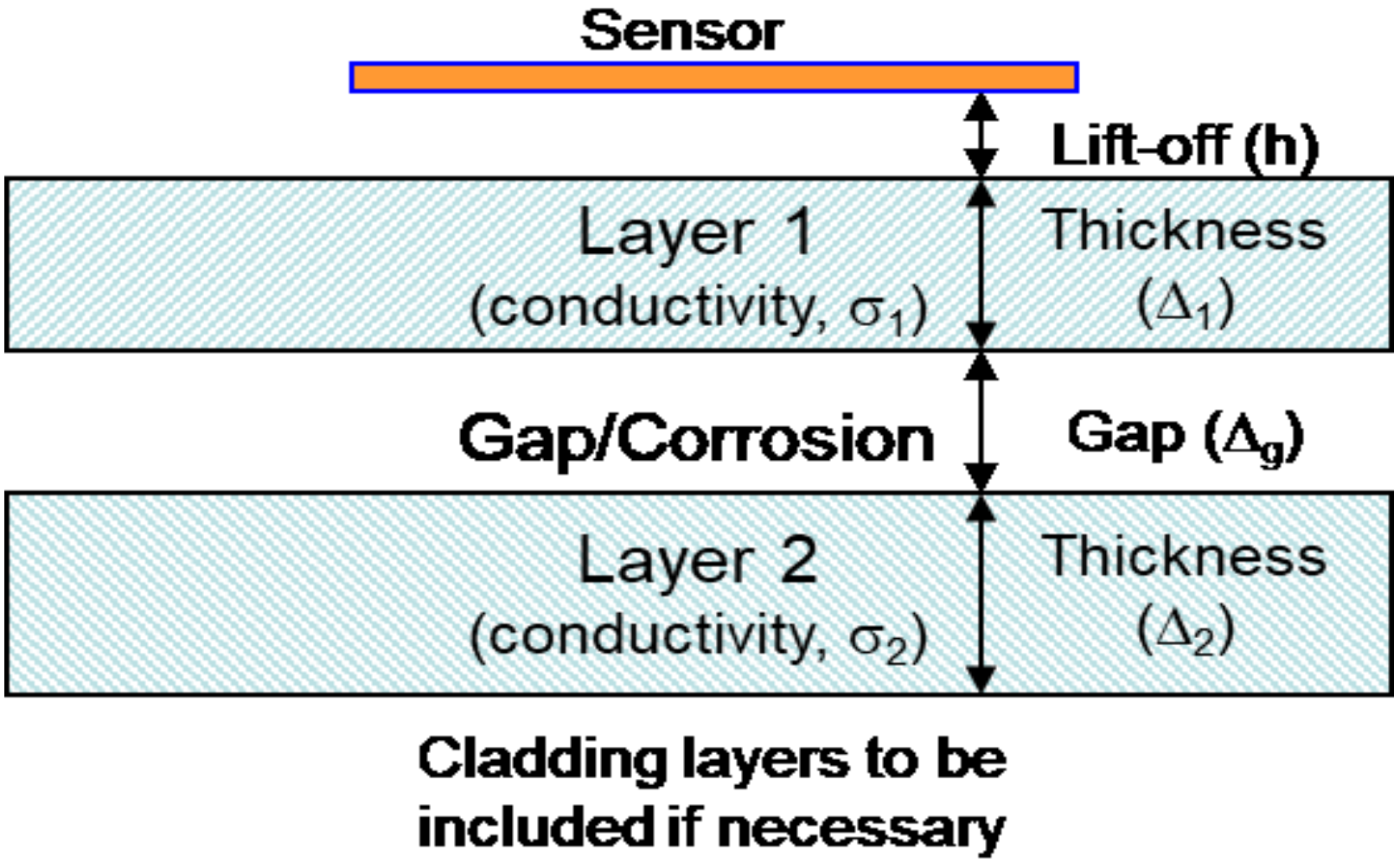
AA&S 2019

Andrew Washabaugh, Stuart Chaplan, Mark Windoloski,
Karen Diaz, Jared Nelms, Zachary Thomas, Neil Goldfine

JENTEK Sensors, Inc., 121 Bartlett Street, MA 01752

jET® + **jAI™**

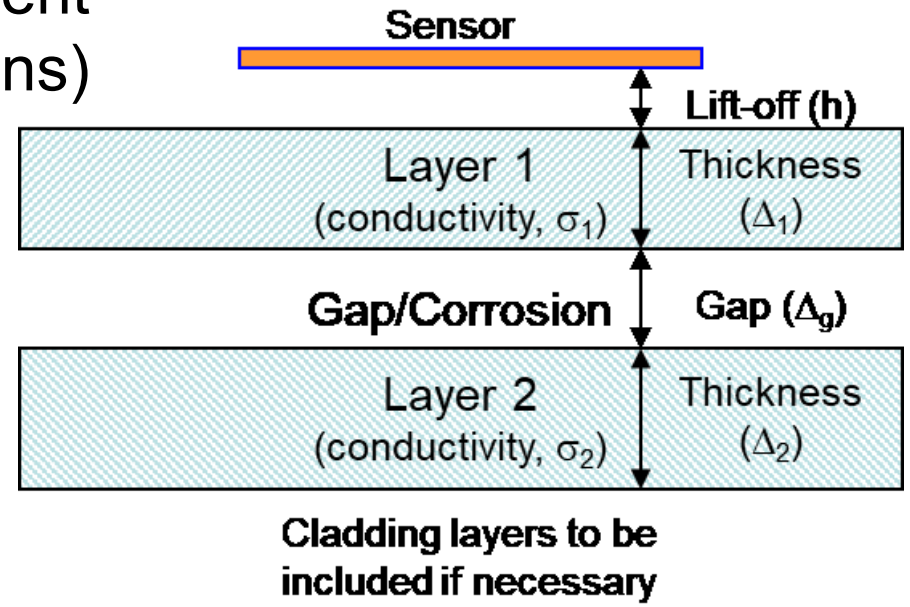
Aircraft Joint Problem Description



Aircraft Joint Problem Description

Prior Work

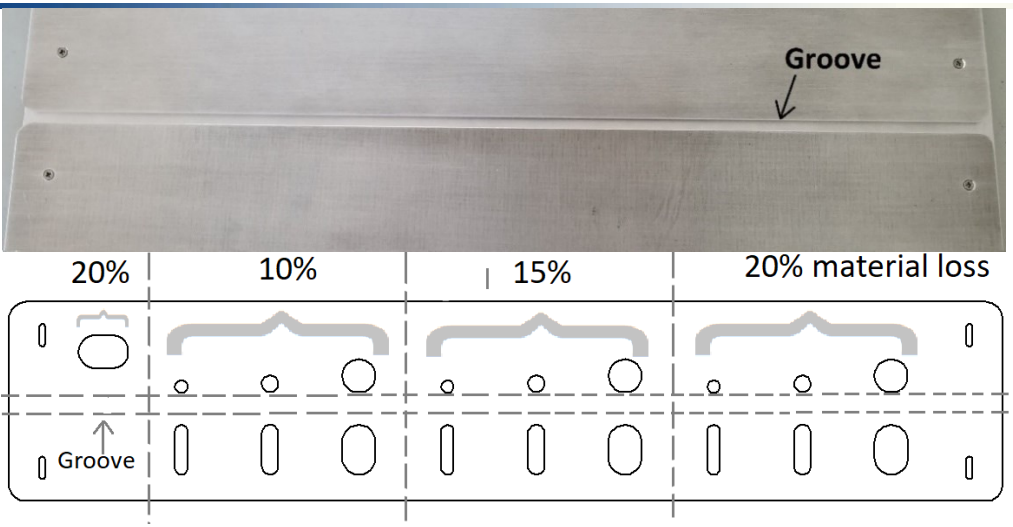
- 2003 Demonstrated independent measurement of (0.040 in. skins)
  - 1st layer thickness
  - 2nd layer thickness
  - Gap
  - Liftoff (paint thickness)
- Limitations in 2003 Work
  - Slow
  - High cost of systems
  - Limited portability of systems

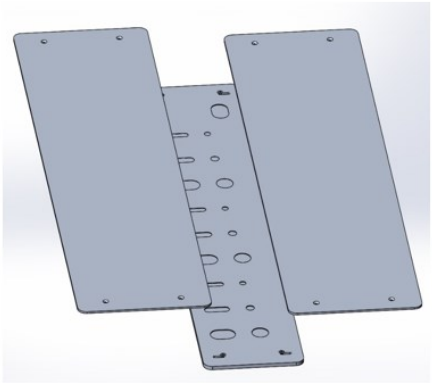


Goal of ongoing work (thicker layers)

- Scan speed 1 inch per second
- jET for improved portability (<1 pound plus tablet computer)
- GS8200 for wider scans (<15 pounds plus tablet computer)
- Easily adaptable to new and thicker applications (jAI)

Simple Joint Sample with Material Loss Areas



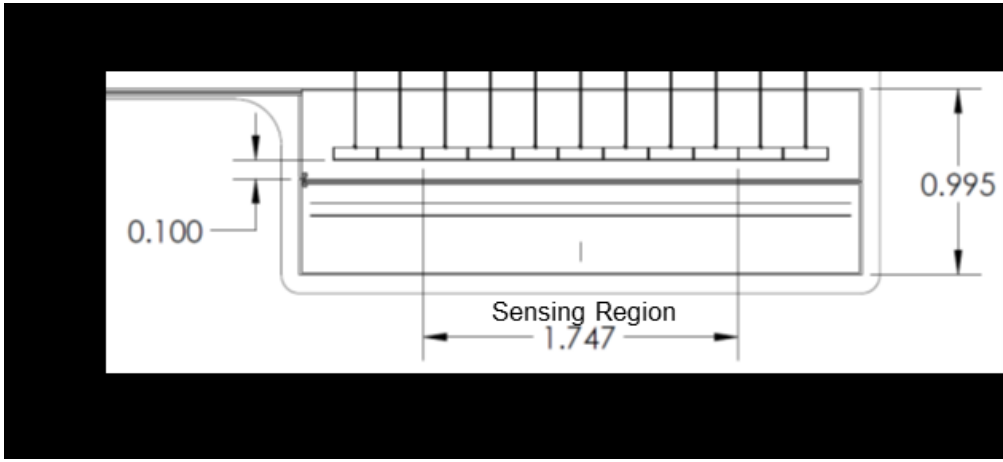


- Two upper layers (skin) over top of a single lower layer (spar)
- The upper layers form a “groove” over the lower layer that can be adjusted to different widths.
- The lower layer contains simulated corrosion defects of varying shape and percent material loss depths.

jET with MWM-Array Technology

jET

MWM-Array



- jET
  - 3 frequencies simultaneously
  - 7 channels simultaneously
  - Up to 1000 measurements/sec per channel
- MWM-Array
  - Designed for model based inverse methods
  - Drive sense gap determines depth of penetration

MWM-Array Technology - Depth of Penetration

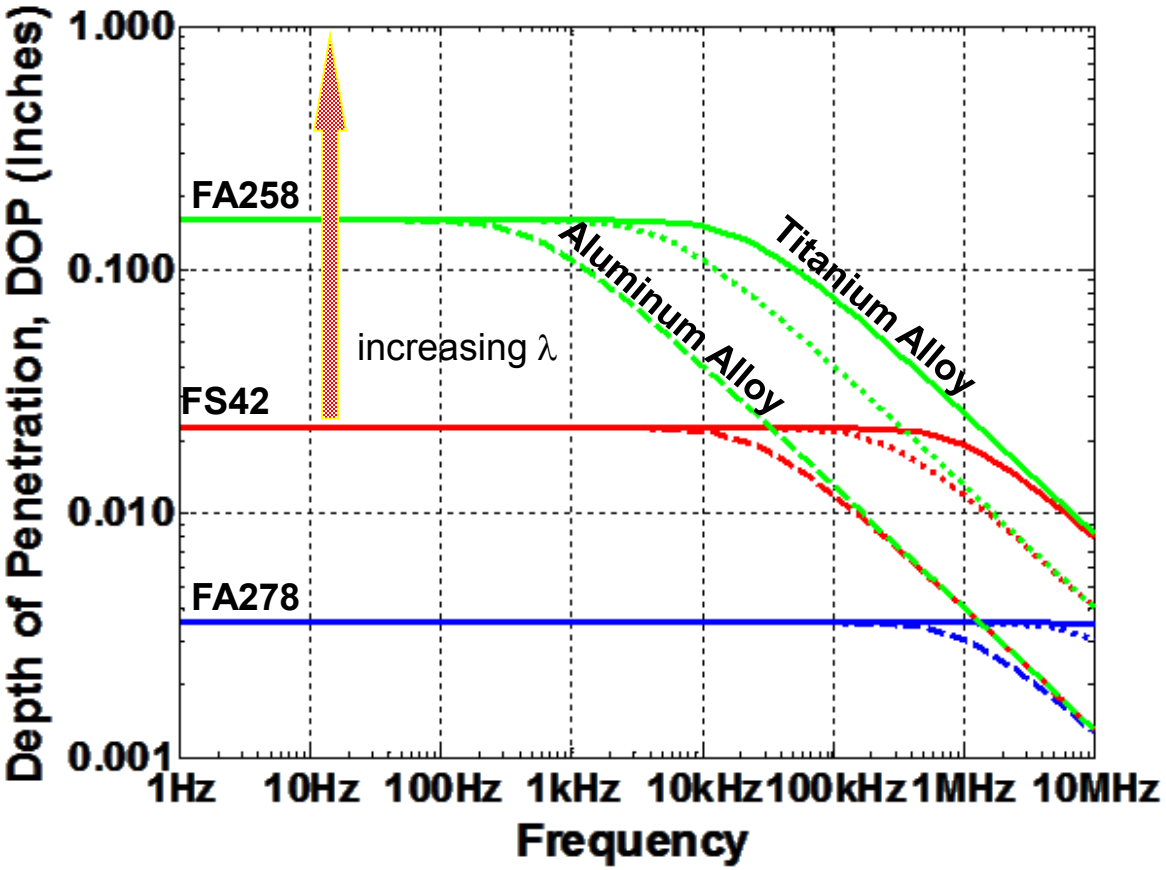
Field Variation with Depth ≈ $e^{-\Gamma_n z}$

$$\Gamma_n = \sqrt{(2\pi n/\lambda)^2 + j2/\delta^2}$$

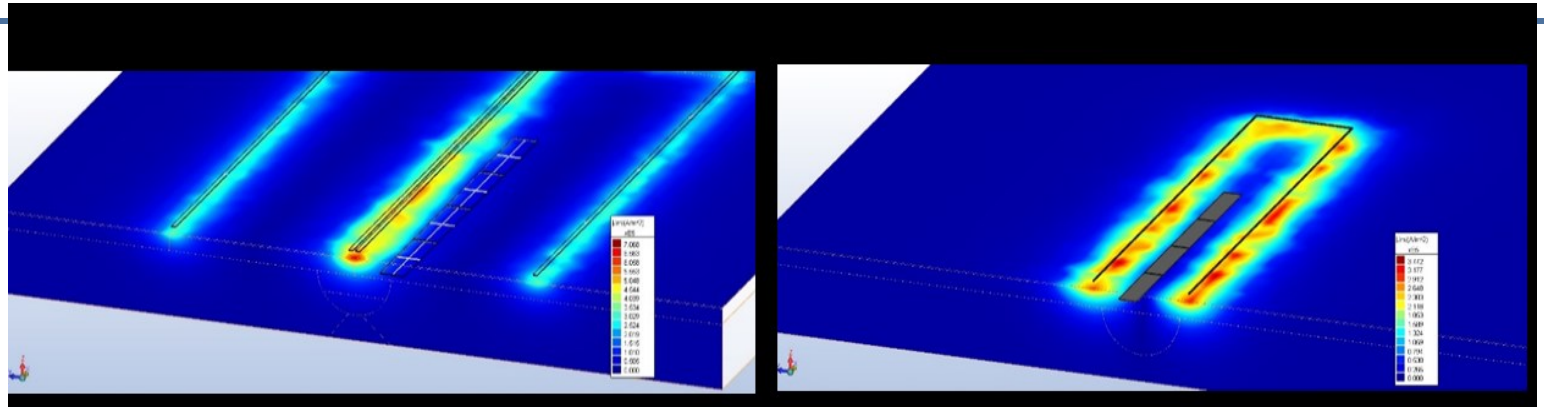
Spatial Fourier Mode Depth of Penetration = $1/\mathrm{Re}(G_n)$

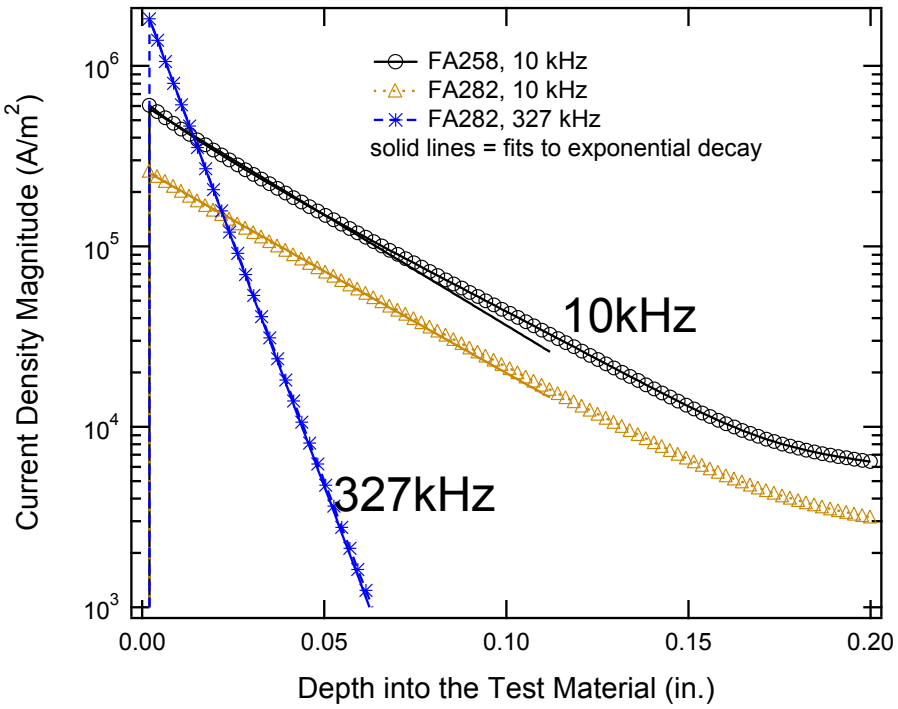
Low frequency asymptote = $\lambda/2\pi$

Skin depth: $\delta = \sqrt{\frac{1}{\pi f \mu \sigma}}$



MWM-Array Induced Eddy Currents

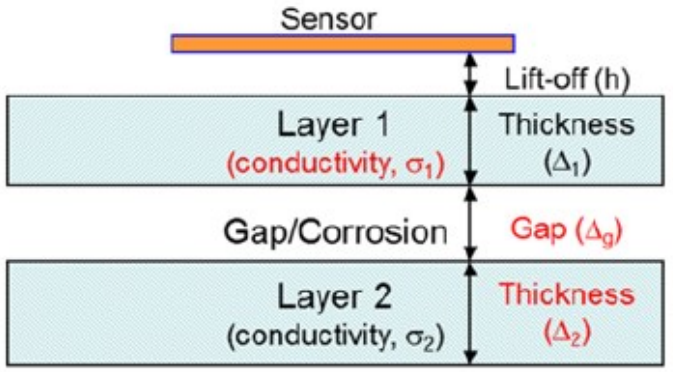




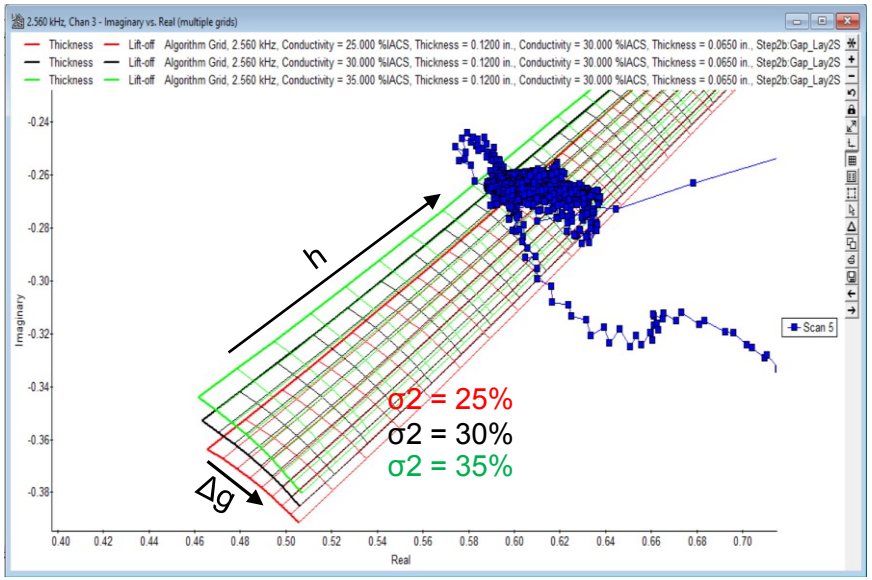
- Upper images show the baseline material responses.
- Left plot shows the current density magnitude under the drive windings of the MWM-Arrays.

Model Based Multivariate Inverse Methods (MIMs)

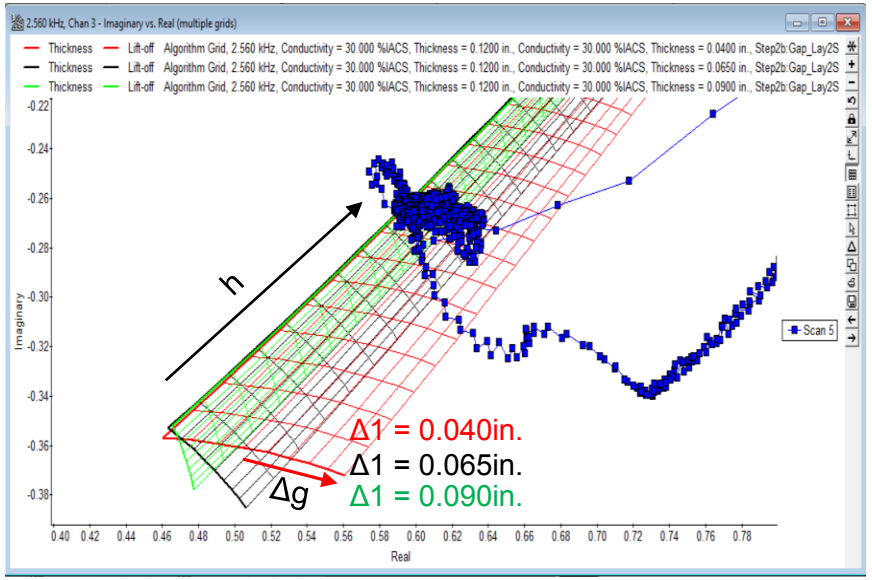
- Lattice is collection of 2-D grids (sensor response surfaces)
- Single frequency can estimate up to two unknowns
- Two frequencies can estimate up to four unknowns, etc.



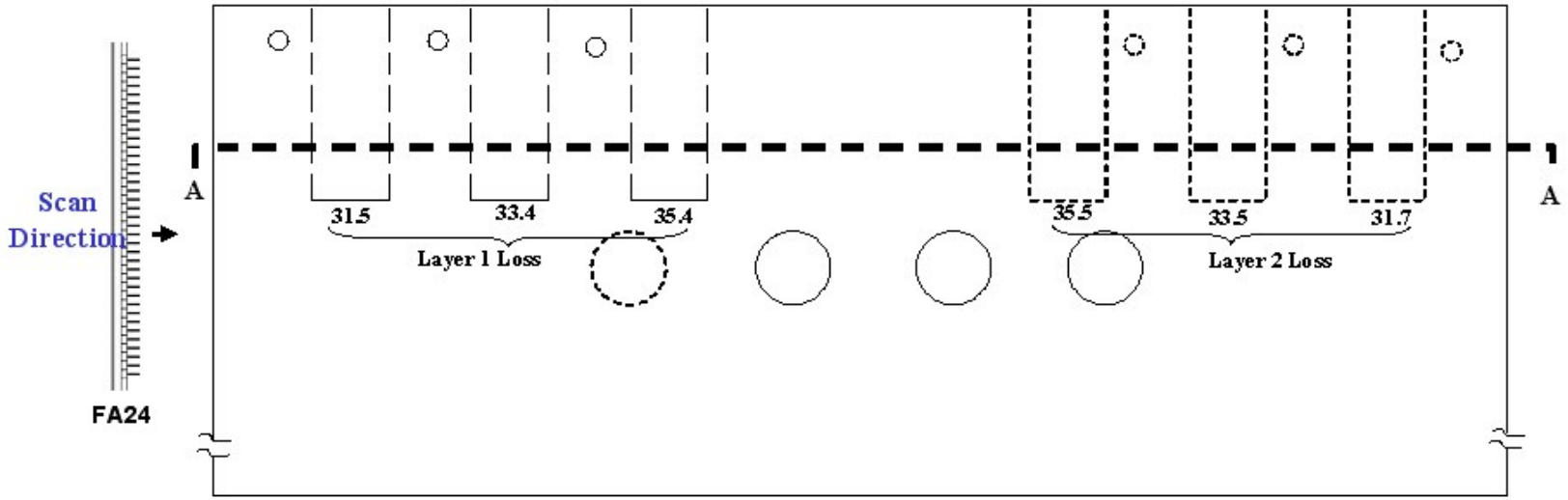
2.56 kHz Δ_g –h Lattice
(Layer 2 Conductivity varied)



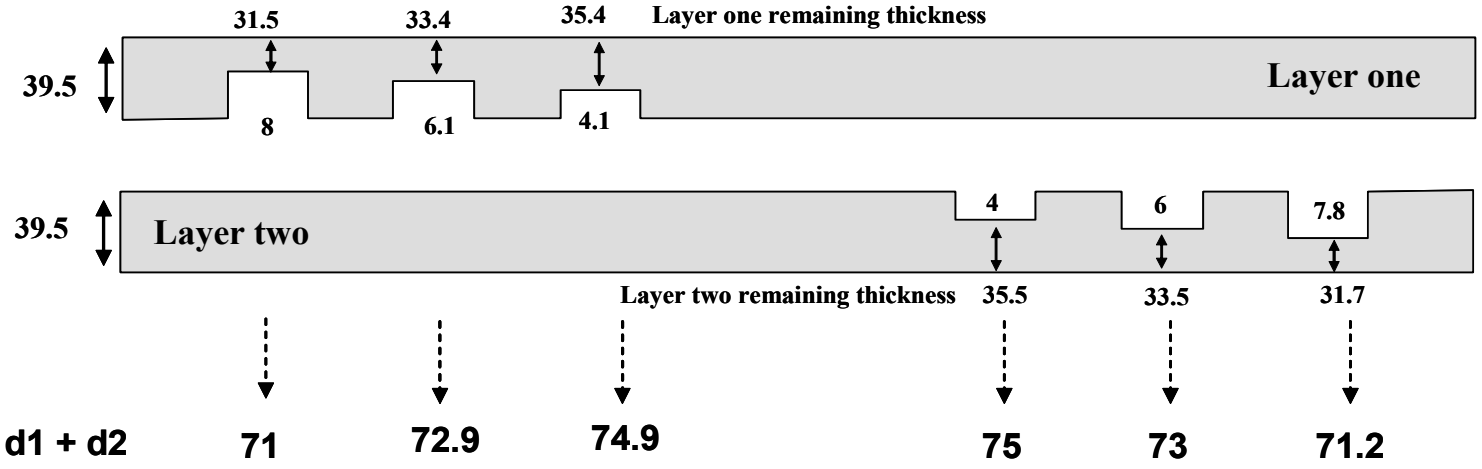
2.56 kHz Δ_g–h Lattice
(Layer 1 Thickness varied)



2003 Results on Air Force Material Loss Standard (1)

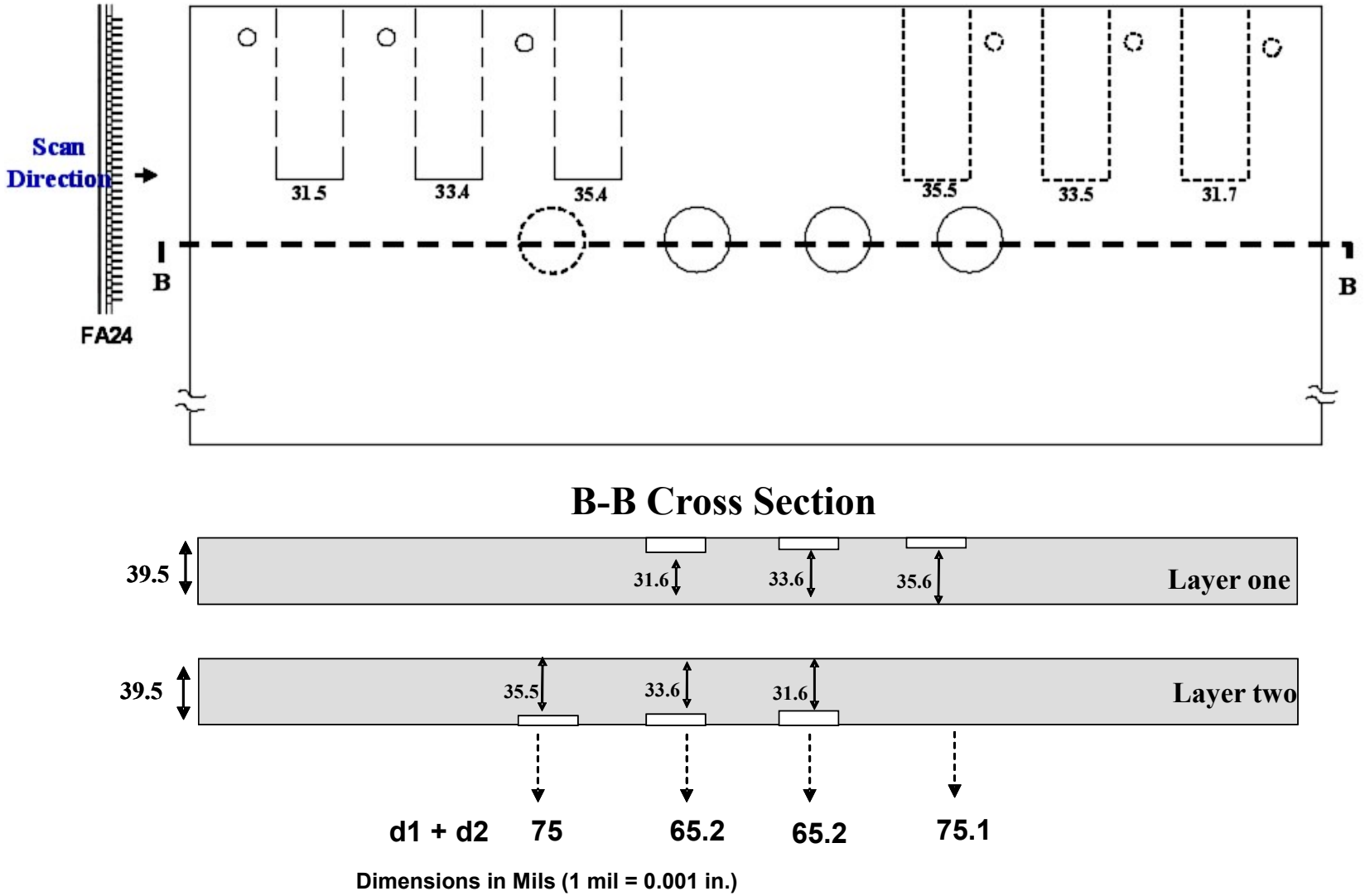


A-A Cross Section



Dimensions in Mils (1 mil = 0.001 in.)

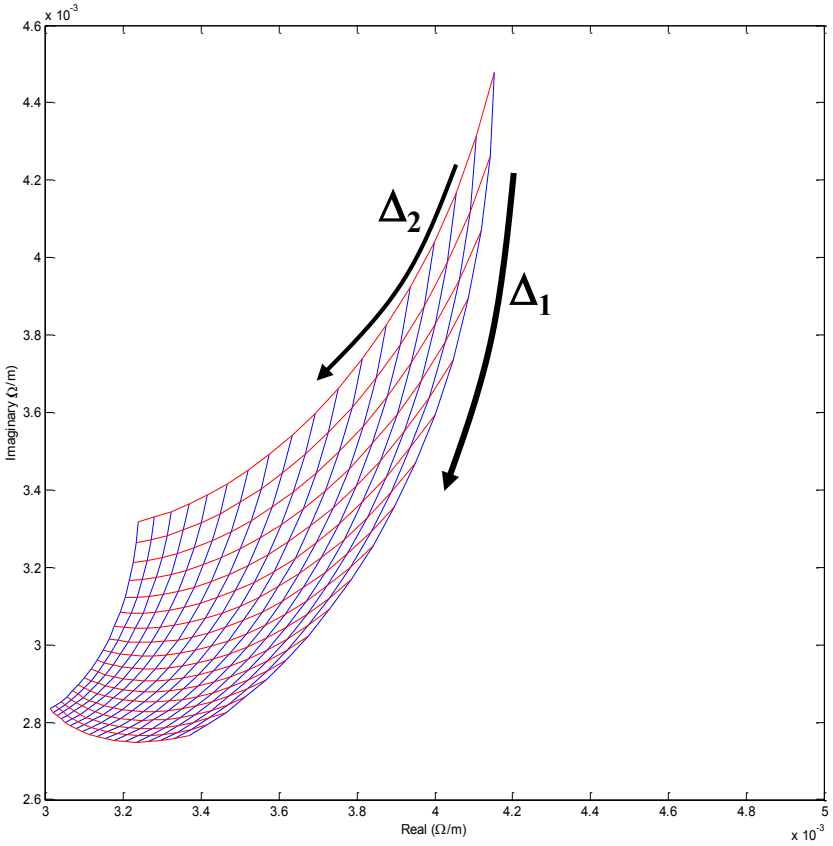
2003 Results on Air Force Material Loss Standard (2)



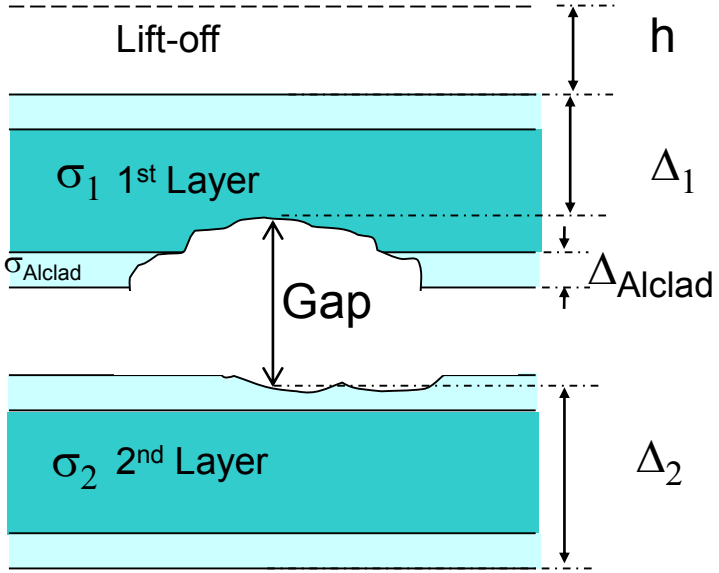
Model Based Multivariate Inverse Methods (MIMs)

1st Layer Loss vs. 2nd Layer Loss

Example Measurement Grid at 10 kHz for a Gap of 0.011 in.

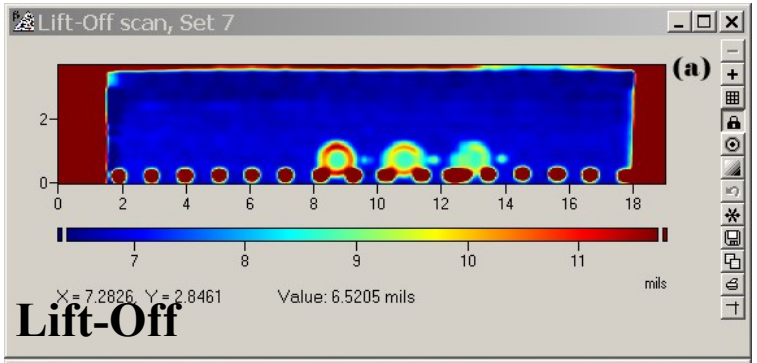


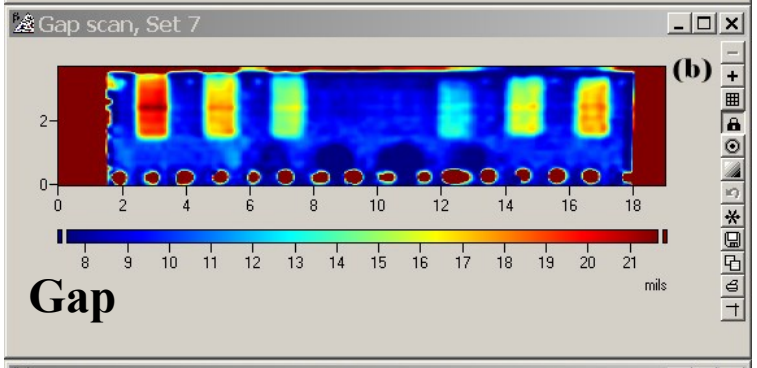
gap of 11 mils

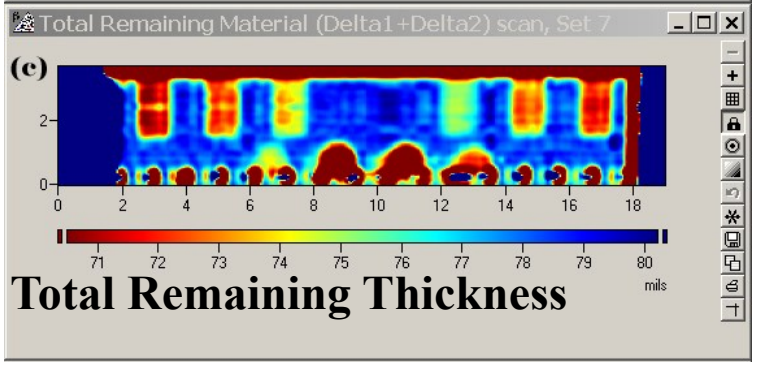


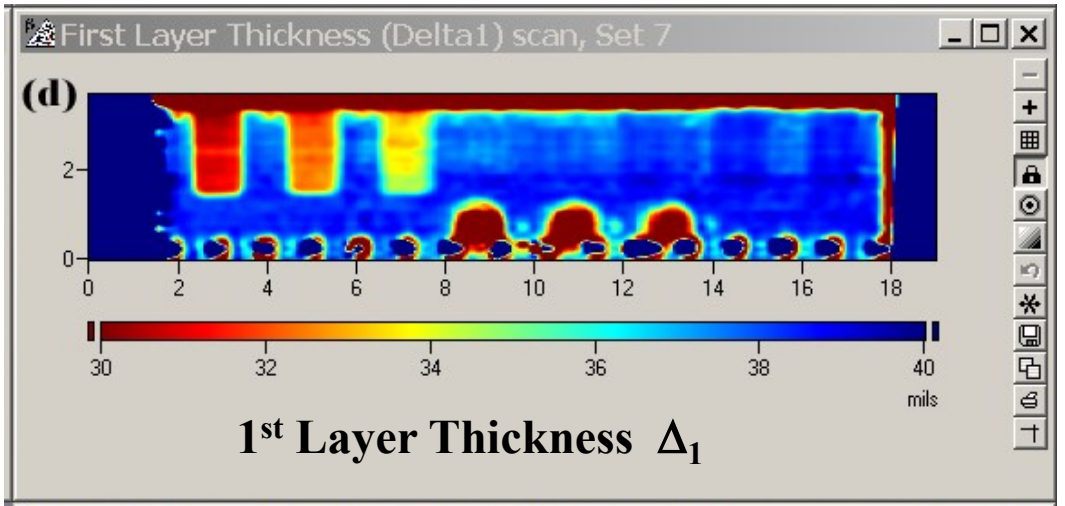
2003: Results for 4-Unknown Results h, Δ_1, Δ_2, Gap

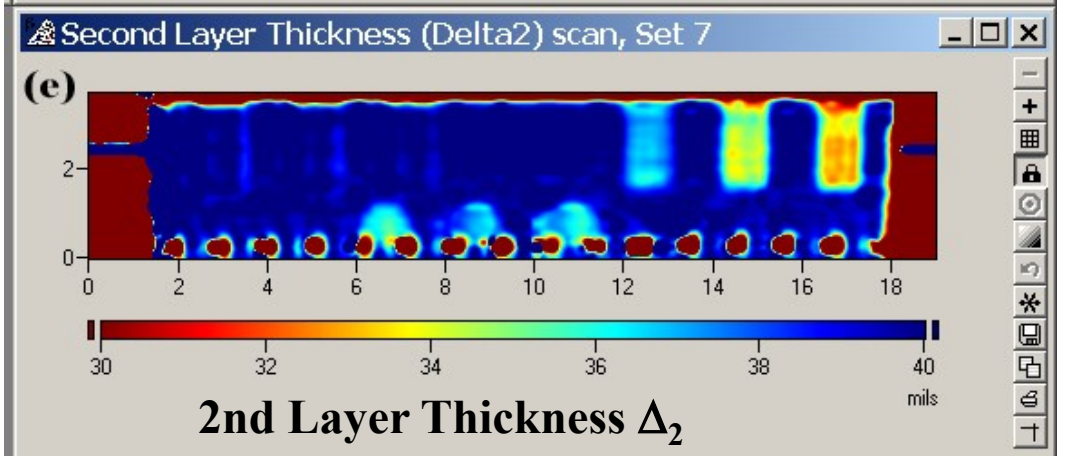
Independent 1st and 2nd layer loss imaging independent of gap





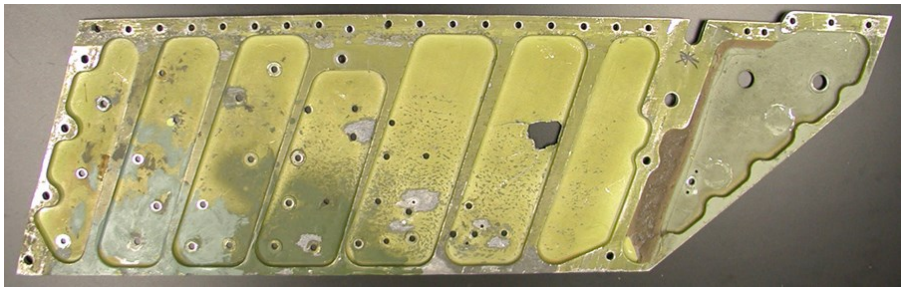




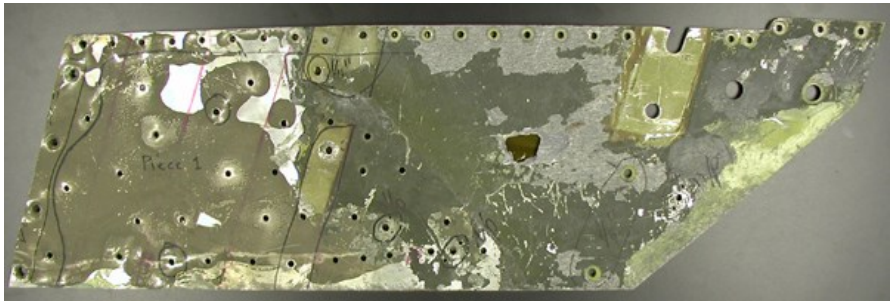


2003: Internal Geometric Feature and Hidden Damage Imaging: C-130 Flight Deck Chine Plate

Inaccessible Side

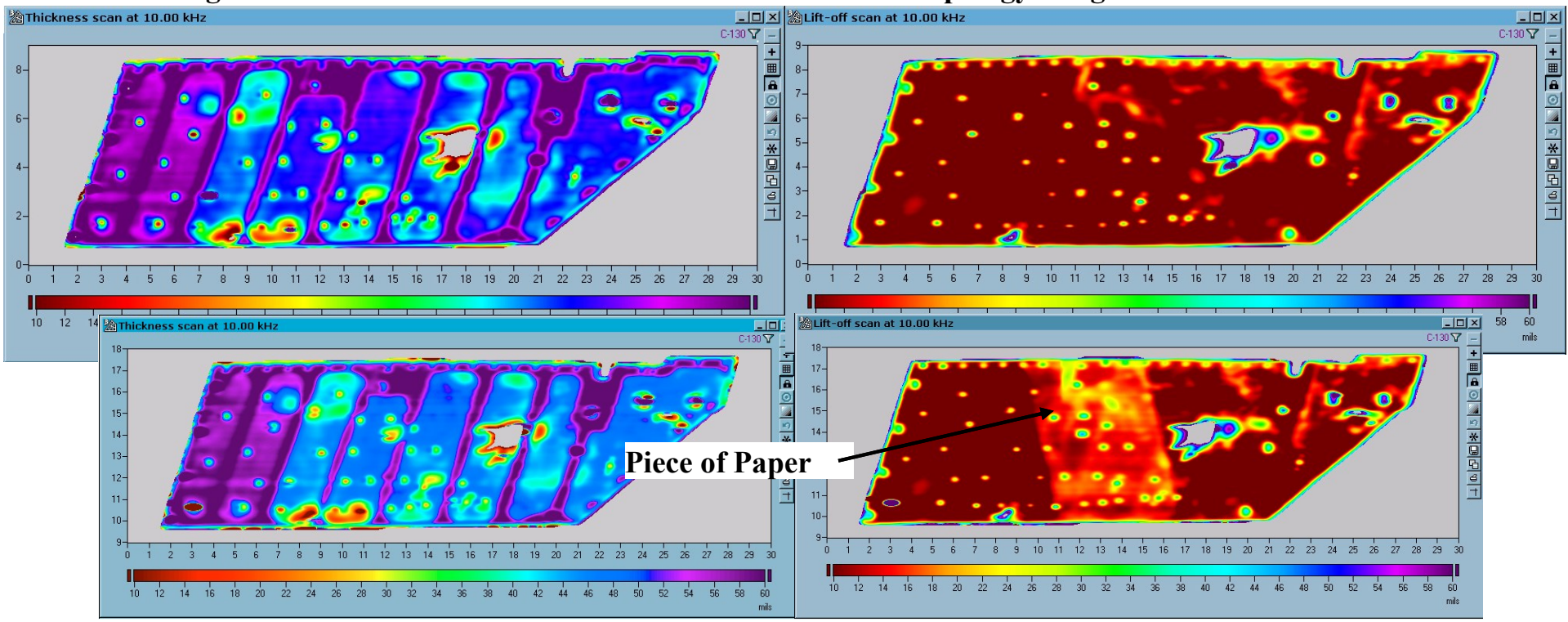


Accessible Side

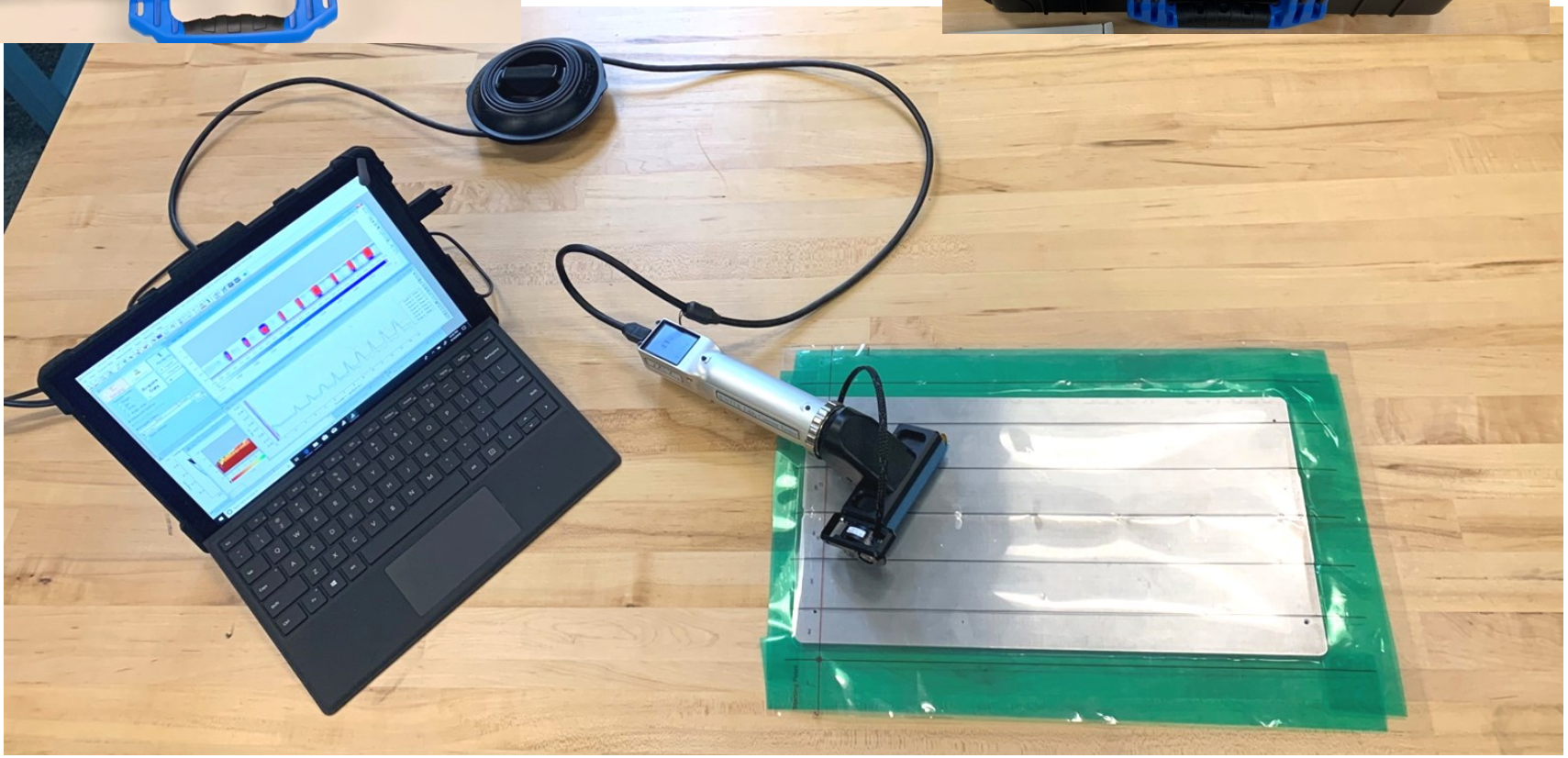


Thickness Image from Accessible Side

Surface Topology Image



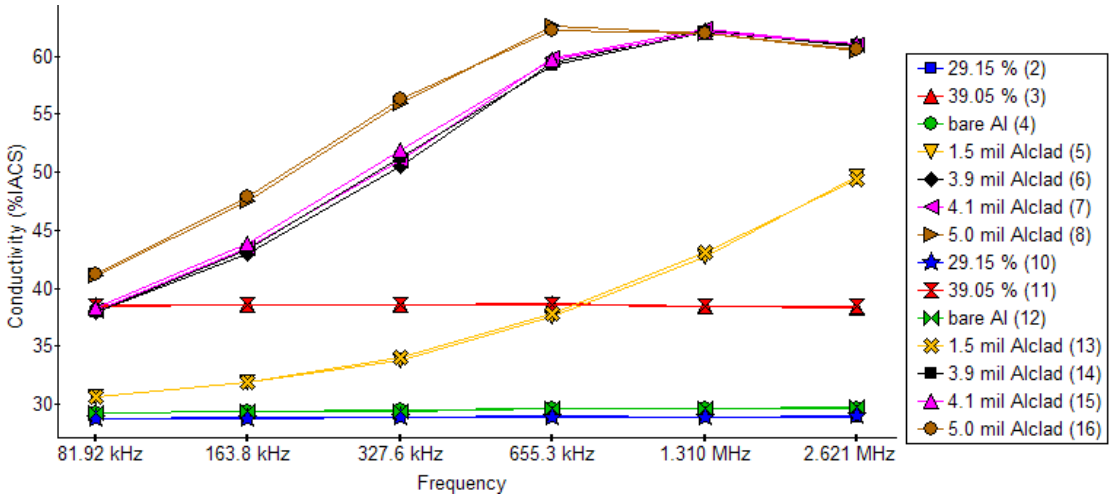
New jET Hand Held 7-Channel System

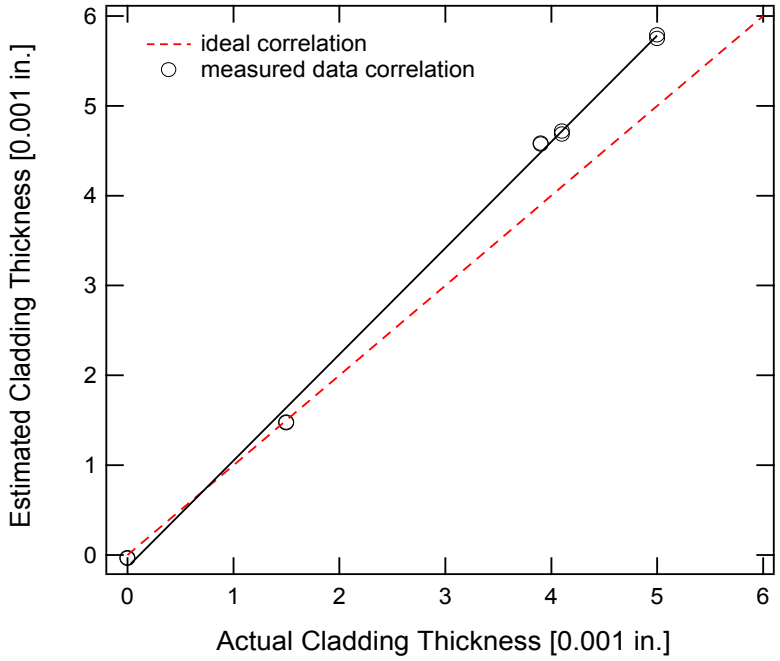


Cladding Thickness Assessment

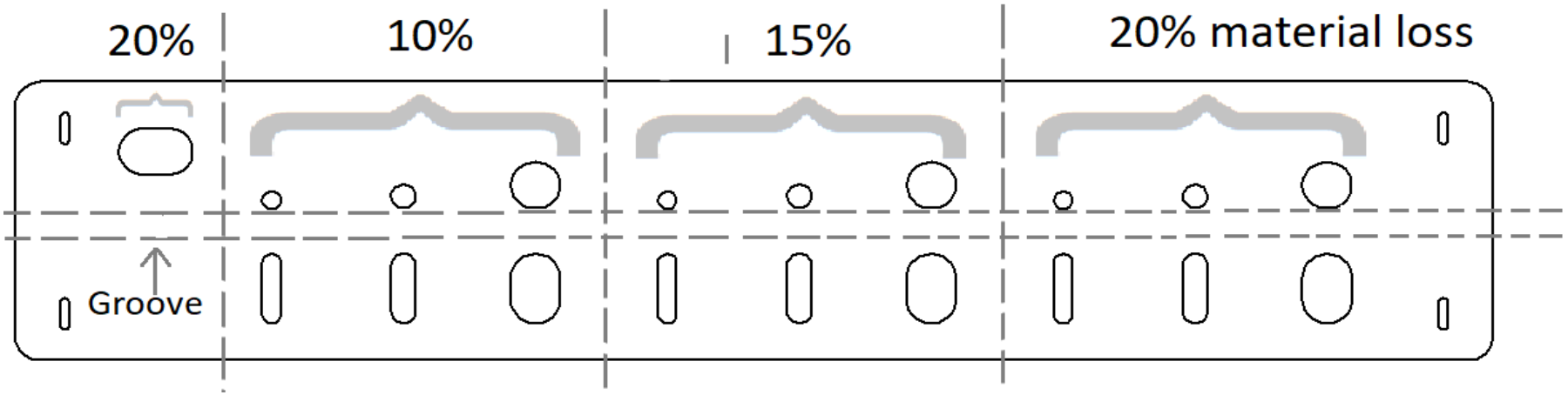
- Top: Effective conductivity values for FS42 measurements on several clad test coupons and several uncoated aluminum alloy samples.
- Bottom: Comparison of estimated and actual cladding

MWM

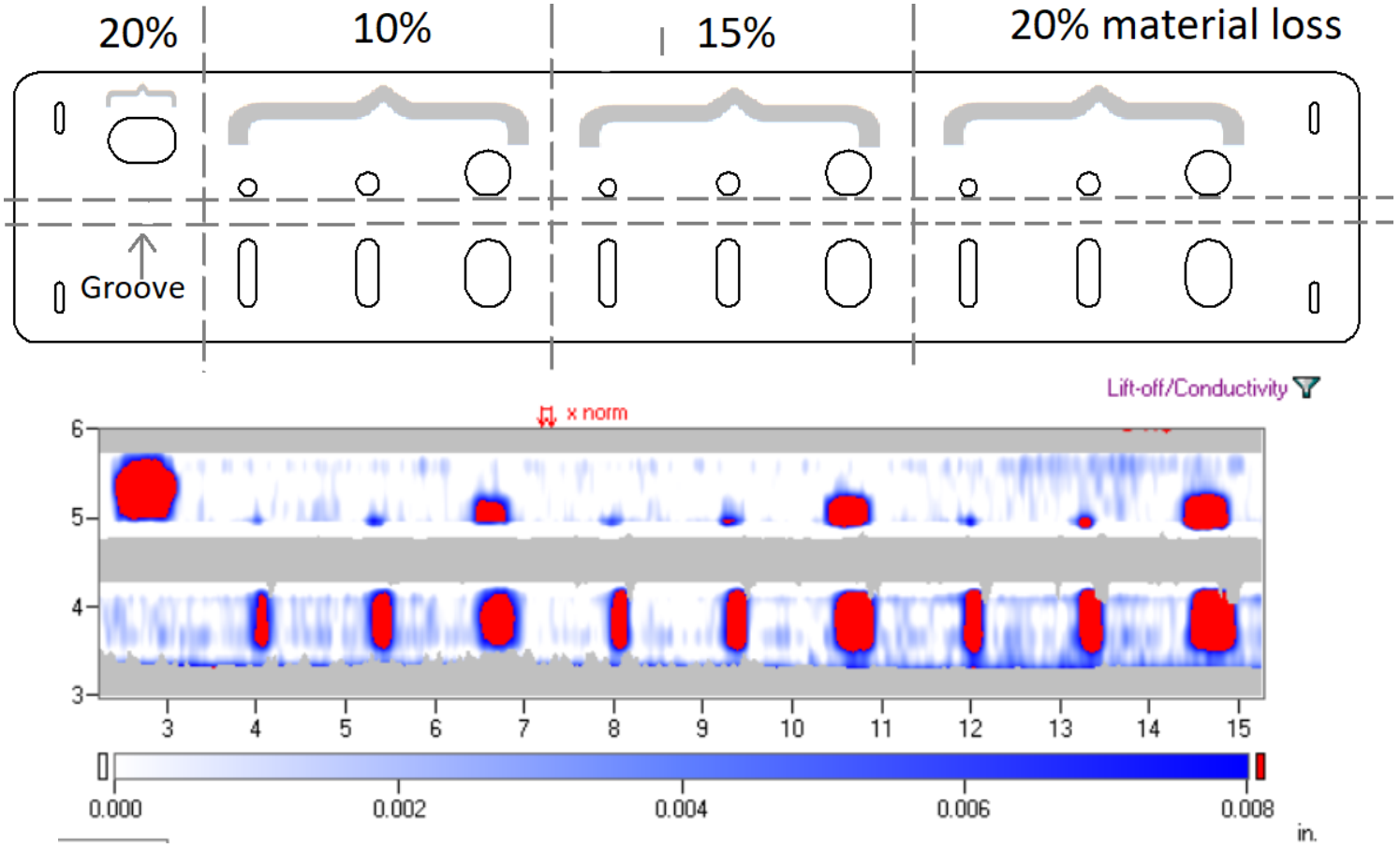




15 inch Corrosion Loss Sample

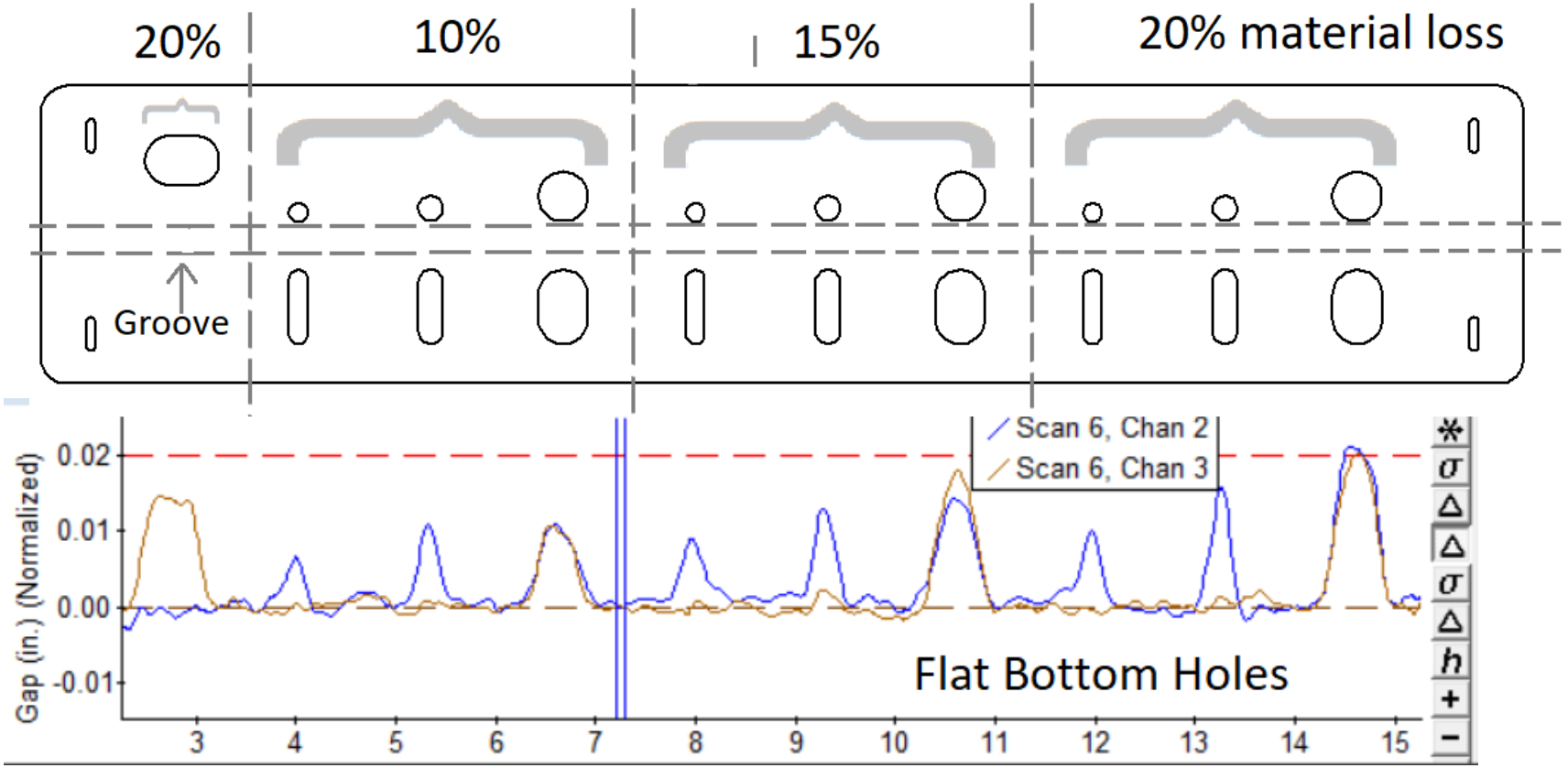


FA258: 15 inch Corrosion Loss Sample (1)



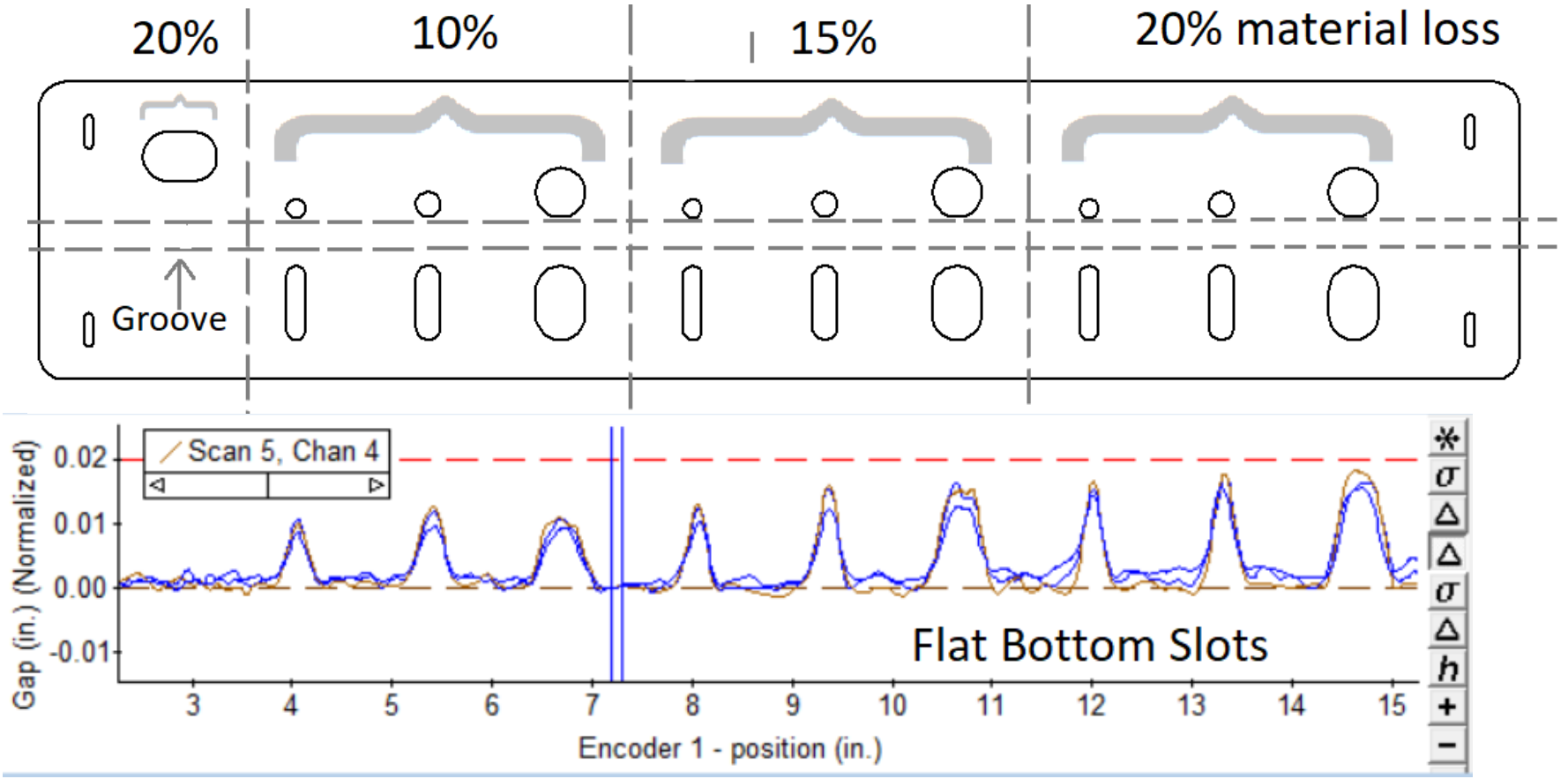
- Filtered and normalized C-scan of Gap data across the corrosion defect locations.

FA258: 15 inch Corrosion Loss Sample Holes (2)



- Normalized B-scan of Gap data across the flat bottom hole defect locations.

FA258: 15 inch Corrosion Loss Sample Slots (3)



- Normalized B-scan of Gap data across the flat bottom slot defect locations.

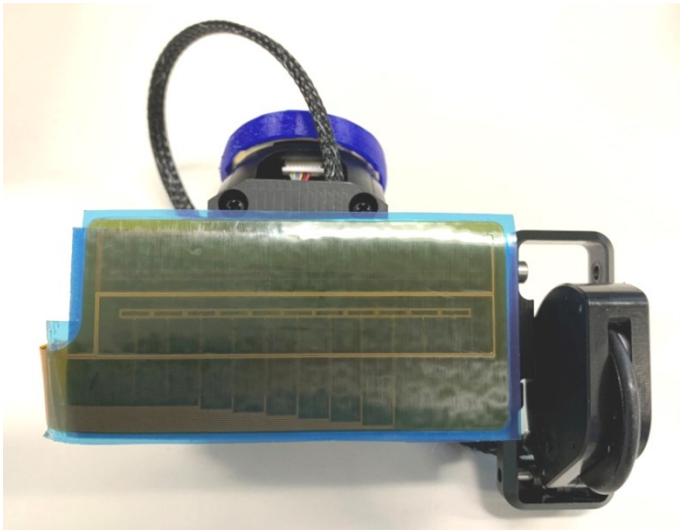
New MWM-Array Sensor FA296

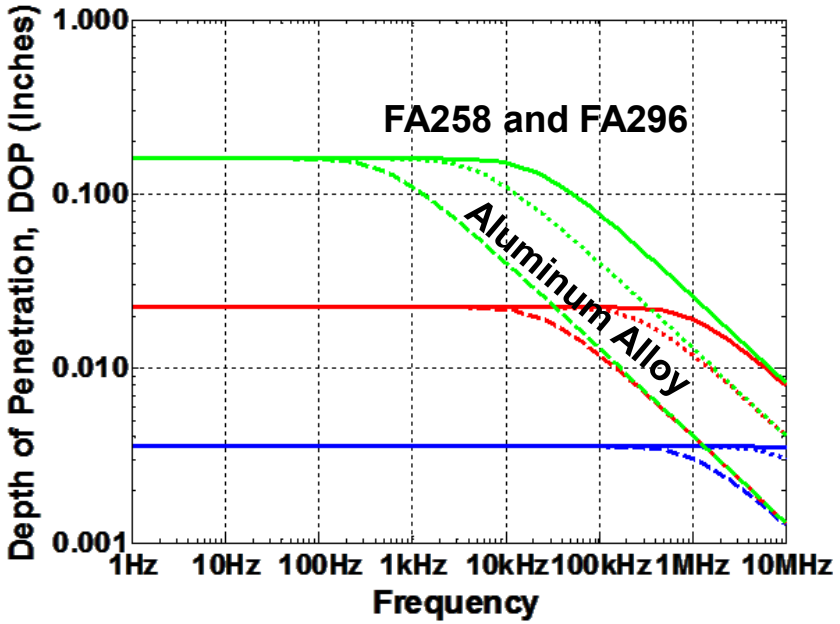
First Prototype Sensor Capability

- FA258
- Detection of corrosion up to 0.060 in. 1st layer

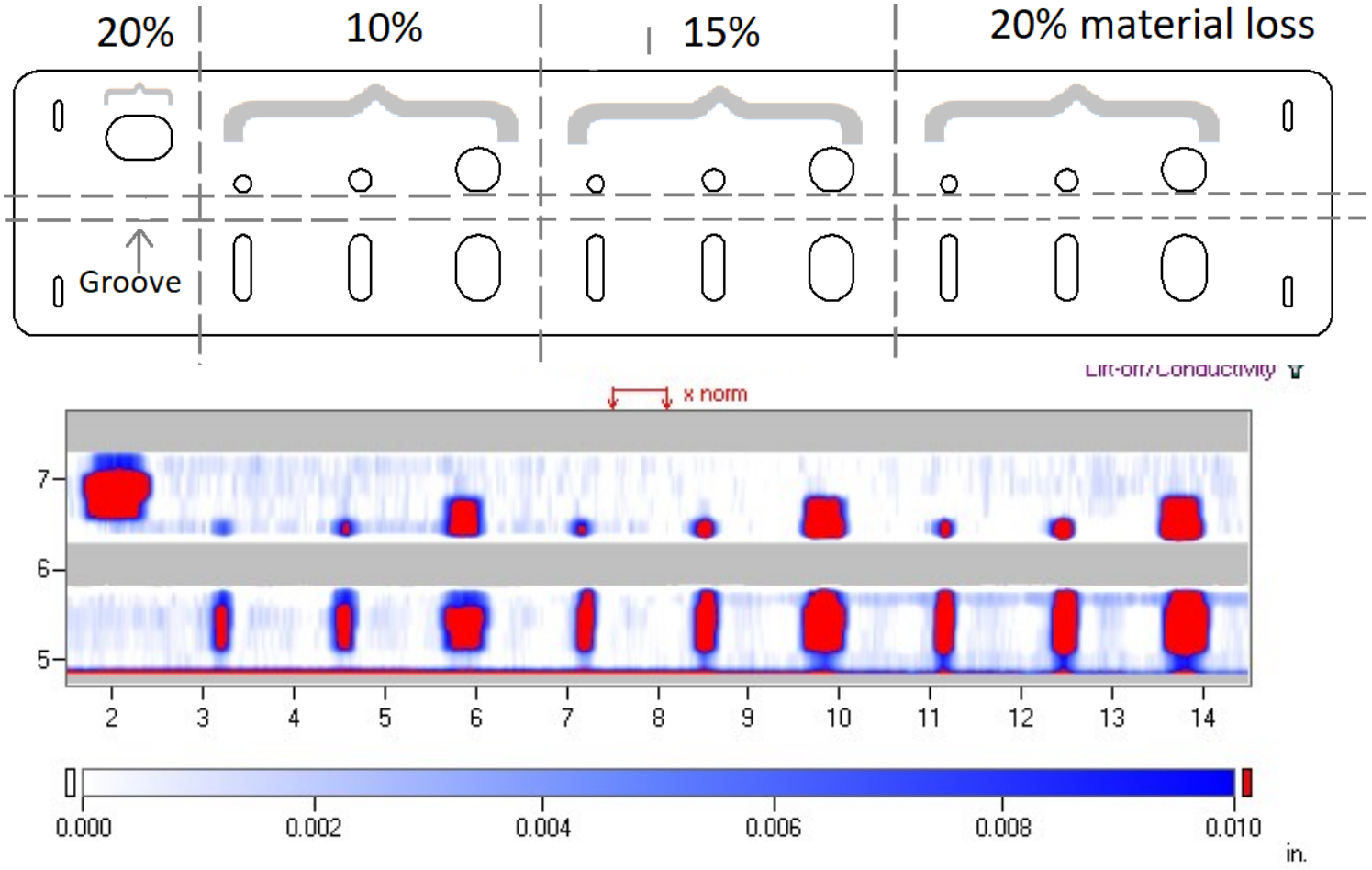
New MWM-Array Sensor

- FA296
- Operates at lower power
- Lower frequency operation
  - 2nd layer thickness measurement feasibility for thicker layers



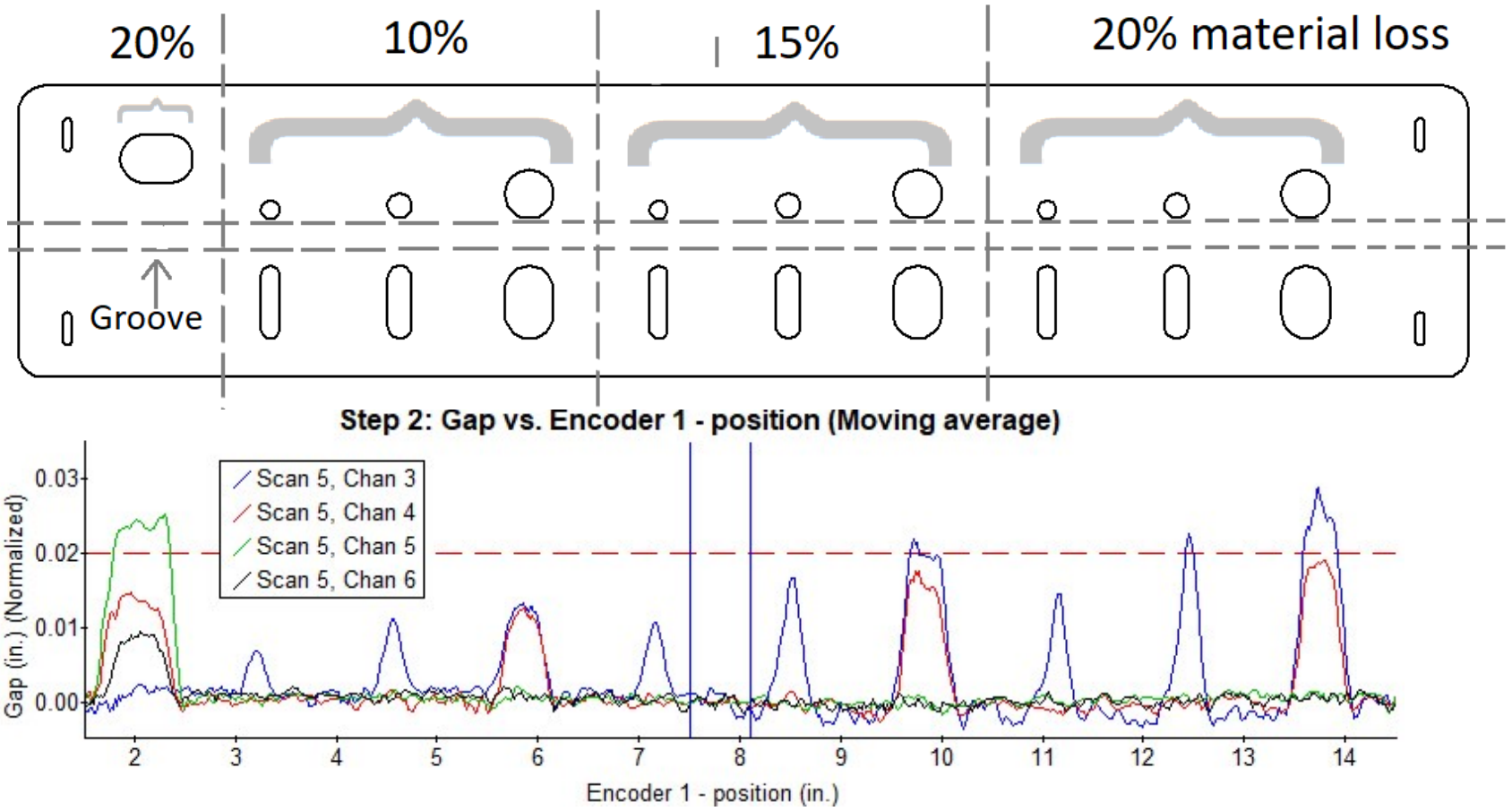


FA296: 15 inch Corrosion Loss Sample (1)



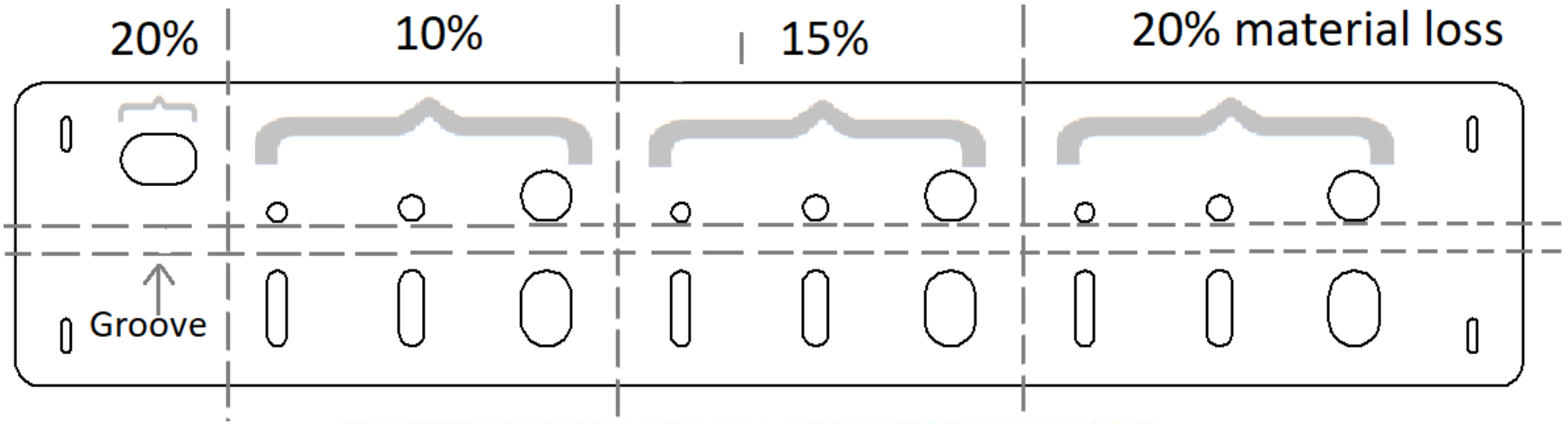
- Filtered and normalized C-scan of Gap data across the corrosion defect locations.

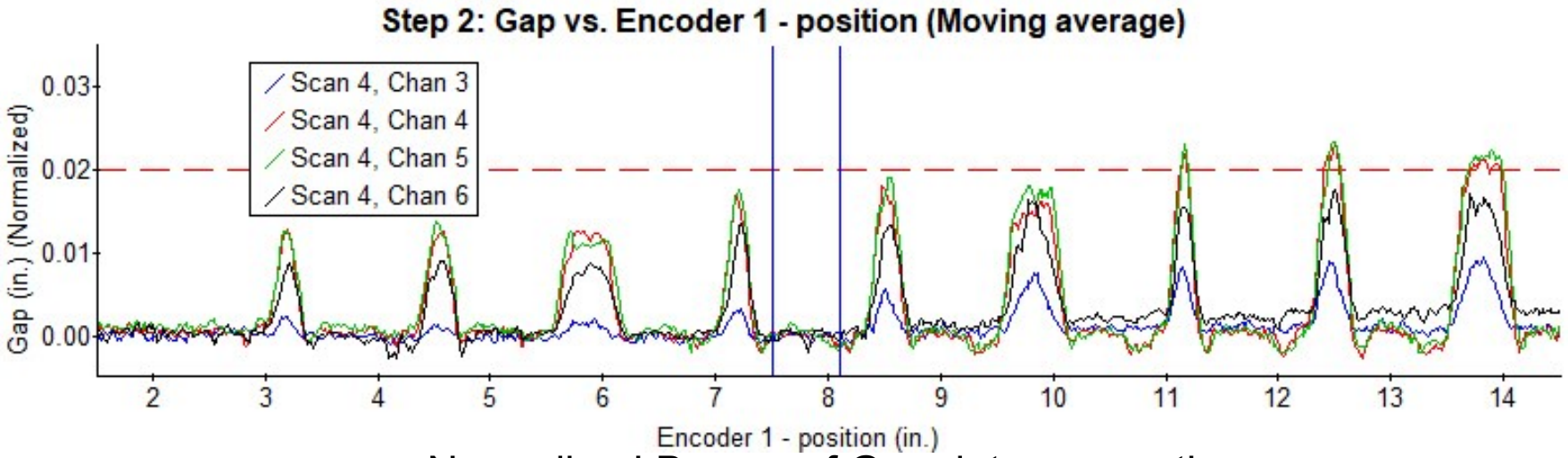
FA296: 15 inch Corrosion Loss Sample Holes (2)



- Normalized B-scan of Gap data across the flat bottom hole defect locations.

FA296: 15 inch Corrosion Loss Sample Slots (3)

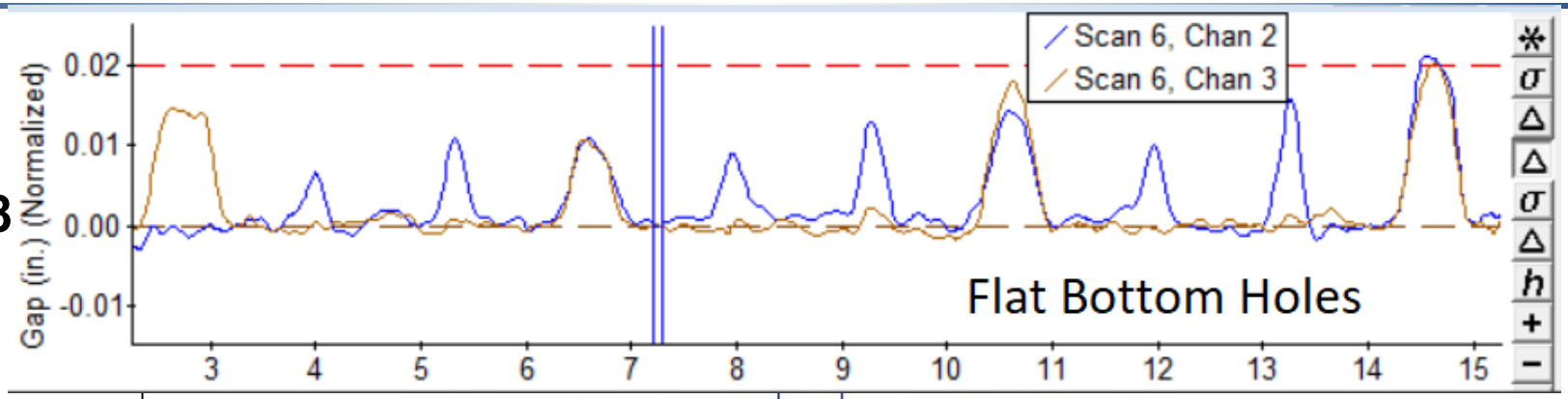




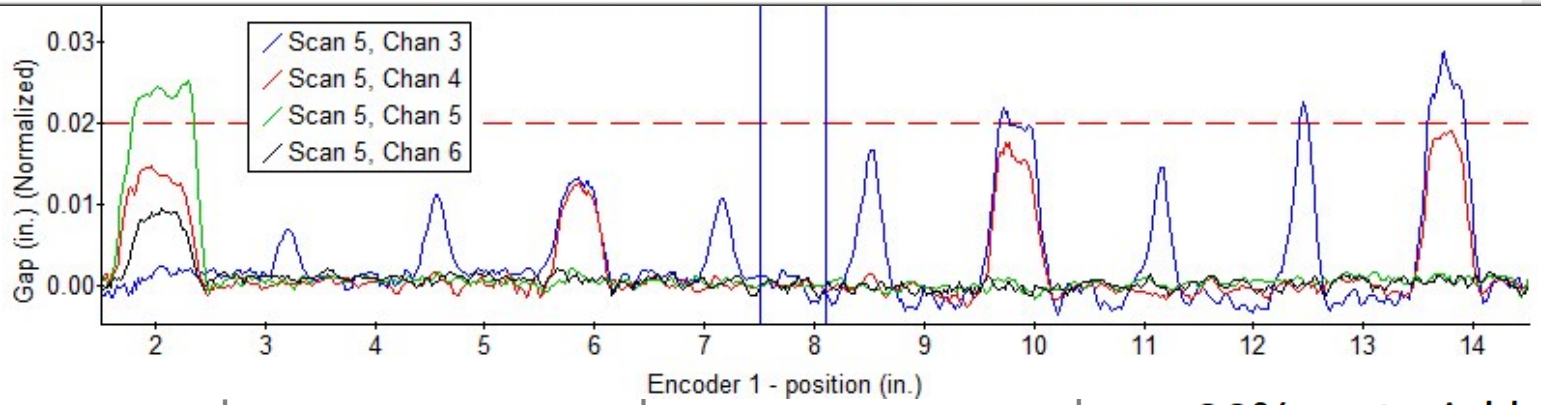
- Normalized B-scan of Gap data across the flat bottom slot defect locations.

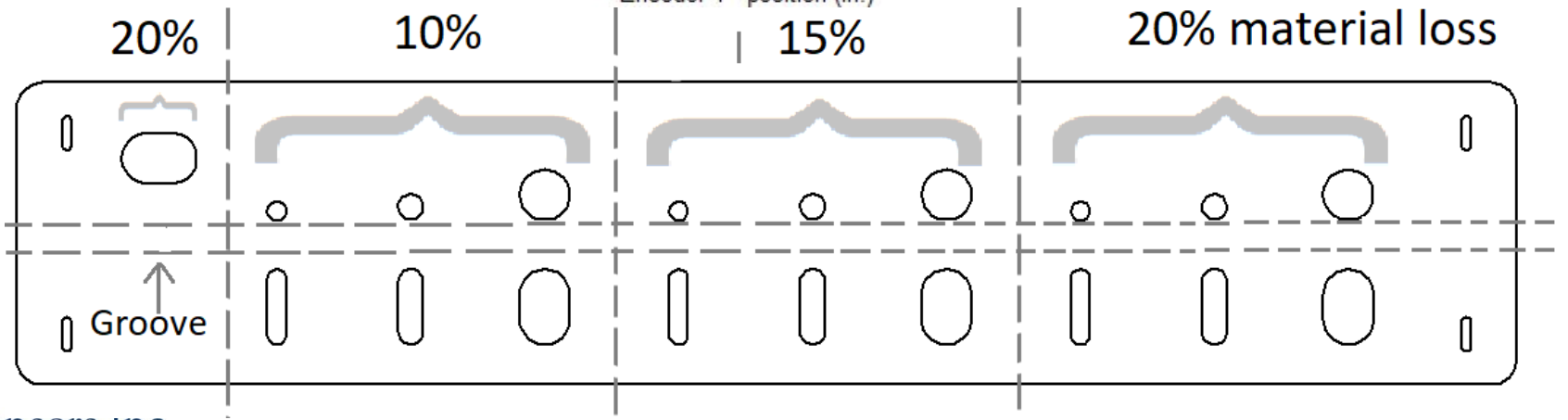
Holes: FA258 at high power vs FA296 at low power

FA258

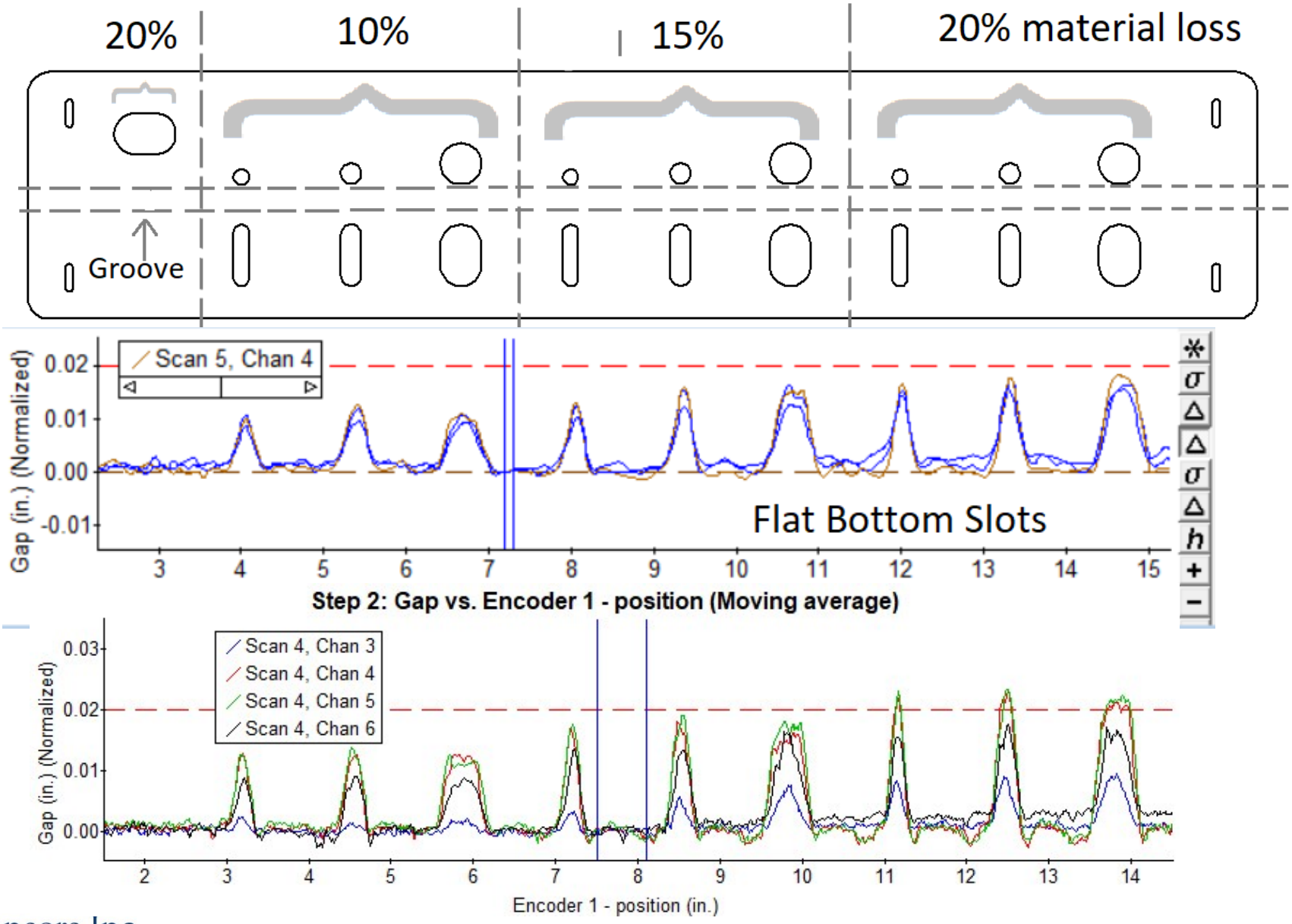


FA296





Slots: FA258 at high power vs FA296 at low power



Summary

jET + *jAI*

Demonstrated Capability

- 2003 Demonstrated independent 1st and 2nd layer corrosion loss detection capability but system was slow and costly
- 2019 Demonstrated increased speed and improved ease-of-use and portability.

Ongoing

- Improving portability of method for varied applications using augmented intelligence methods (jAI)
- Improving signal to noise to address second layer exfoliation detection, as well as improved wall loss sensitivity for thicker skins