NDTS
NDT SOLUTIONS

Eddy Current Inspection
Conventional to Array

2017 A4A NDT Forum

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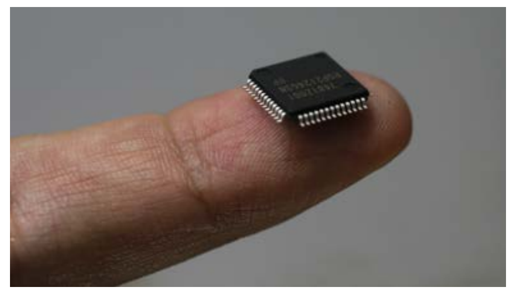
NO NEED TO WORRY
WE STILL HAVE ENOUGH
DUCT TAPE

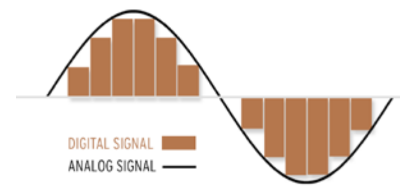
- Eddy current testing (ECT) as a technique for testing finds its roots in electromagnetism. Eddy currents were first observed by François Arago in 1824, but French physicist Léon Foucault is credited with discovering them in 1855.
  - Basic form — the single-element ECT probe — a coil of conductive wire is excited with an alternating electrical current. This wire coil produces an alternating magnetic field around itself. The magnetic field oscillates at the same frequency as the current running through the coil. When the coil approaches a conductive material, currents opposed to the ones in the coil are induced in the material — eddy currents.
- Eddy Current Arrays (ECA) have been evaluated since the late 70's and 80's as they were limited due to the computer capabilities.

Why is Eddy Current Inspection being utilized more at the fabrication, assembly, OEM and MRO levels?

Besides, being environmentally friendly/green, cost-effective, typically as sensitive as most inspection modalities.

It's the computer power,





The physics of Eddy Current has not change, system integration and improved software make it possible!

Single Channel Instrument

Multi Channel Instrument

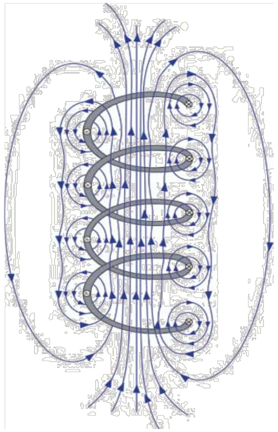
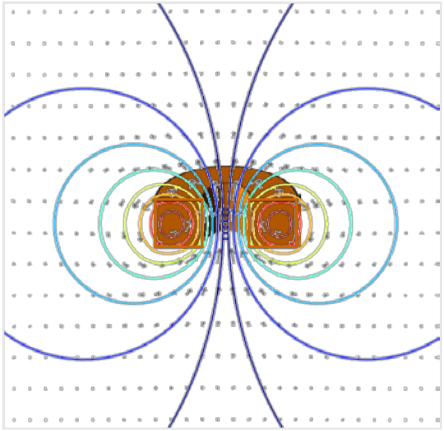
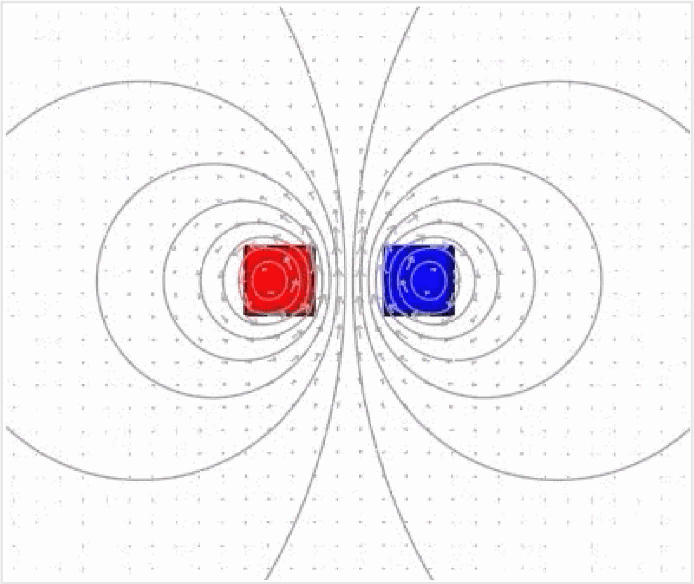
ECT on surfaces

- When it comes to surface applications, the performance of any given inspection technique depends greatly on the specific conditions — mostly the types of materials and defects, but also surface conditions, etc.
- Effective on coatings/paint: yes
- Computerized record keeping: partial
- 3D/Advanced imaging: none
- User dependence: high
- Speed: low
- Post-inspection analysis: none
- Requires chemicals/consumables: no

Eddy current array

- Eddy current array (ECA) and conventional ECT share the same basic working principles. ECA technology provides the ability to electronically drive an array of coils (multiple coils) arranged in specific pattern called a topology that generates a sensitivity profile suited to the target defects. Data acquisition is achieved by multiplexing the coils in a special pattern to avoid mutual inductance between the individual coils.
- Faster inspections
- Wider coverage
- Less operator dependence — array probes yield more consistent results compared to manual raster scans
- Better detection capabilities
- Easier analysis because of simpler scan patterns
- Improved positioning and sizing because of encoded data
- Array probes can easily be designed to be flexible or shaped to specifications, making hard-to-reach areas easier to inspect

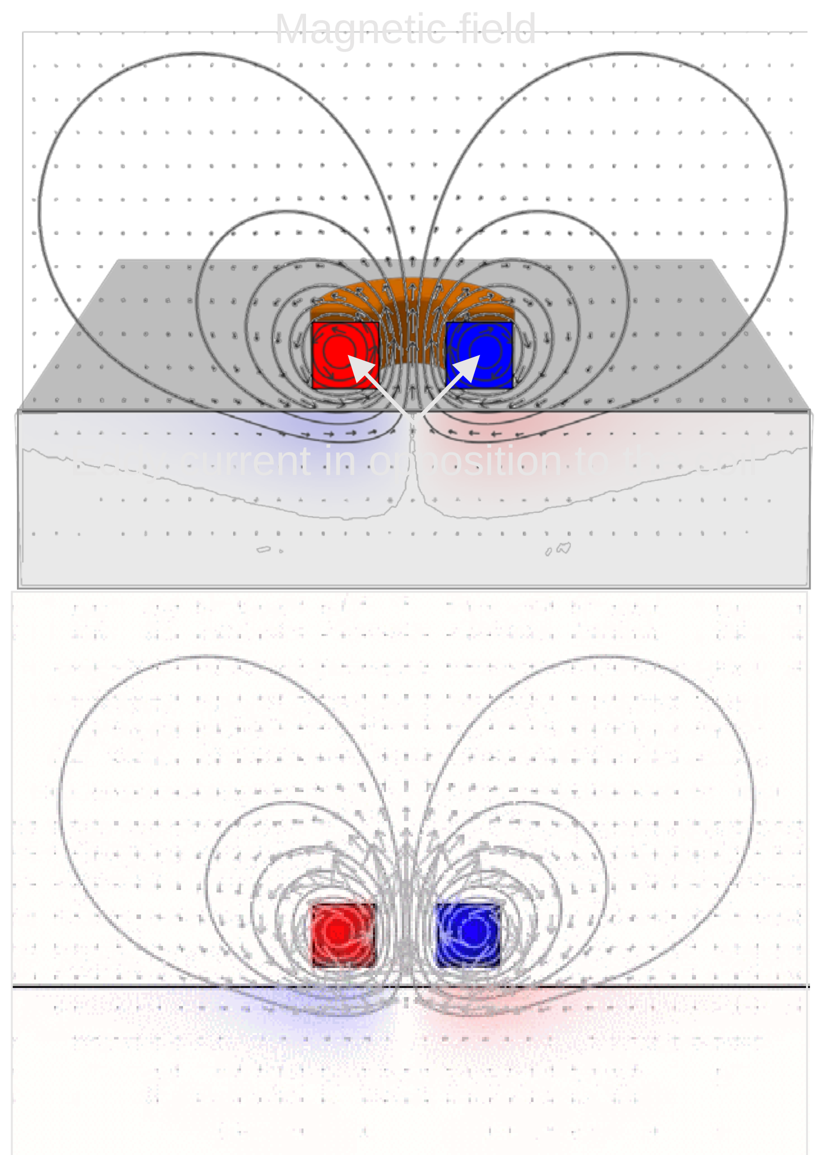
Back to Basics-Physics,

- When the wire is shaped into a coil, the interaction of each turn produces a global magnetic field around the coil.
- This magnetic field oscillates at the same frequency as the current injected into the coil.

Back to Basics-Physics,

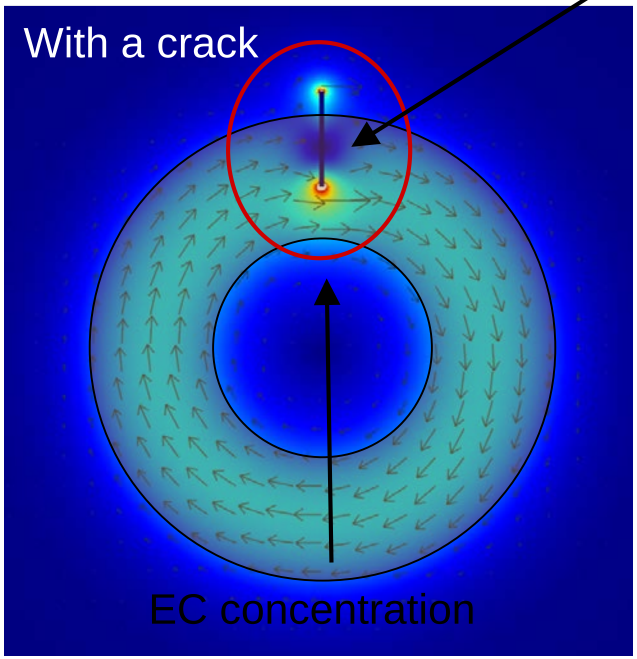
- When this coil is placed over a conductive part, opposed alternating currents are generated; these are the eddy currents.
- The eddy currents oscillate at the same frequency as the current injected in the coil but with a small delay; this is the phase lag.



How Eddy Currents works?

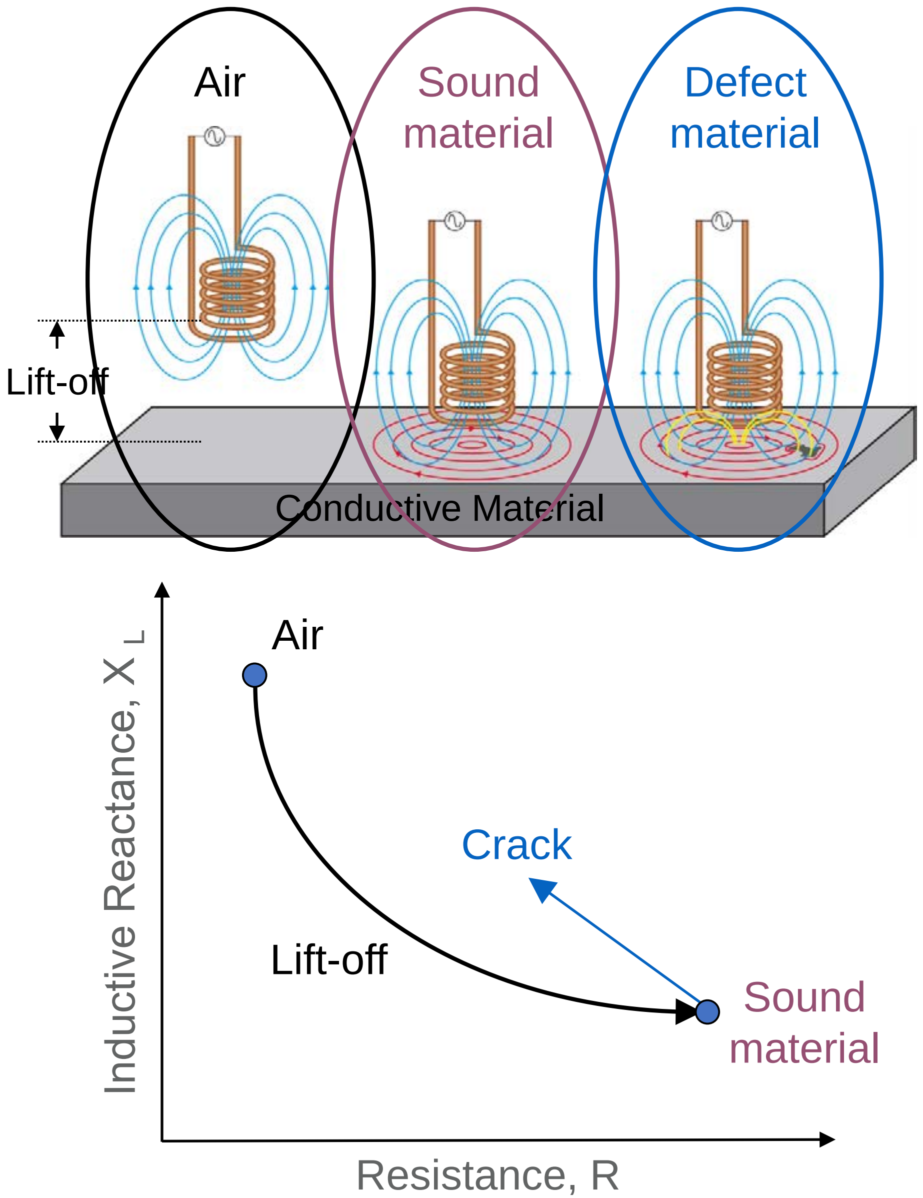
- Back to basics:
  - If a defect in the part disturbs the path of the eddy currents, it creates a local magnetic field that changes the balanced condition of the system.
  - Such changes can be detected by monitoring variations of the coil impedance.

<u>Top view:</u>
Eddy current path and density



How Eddy Currents work:

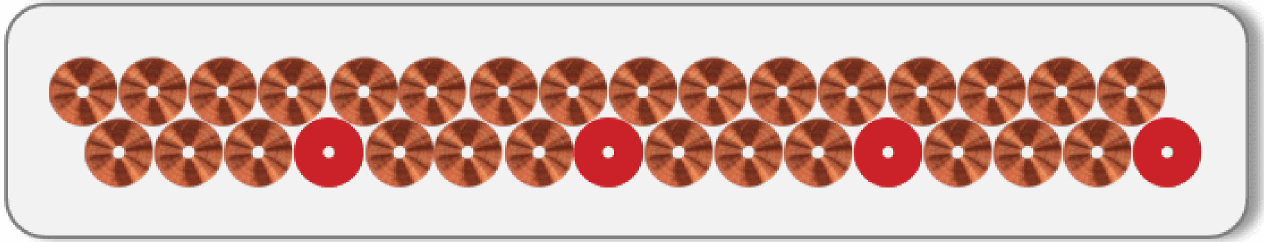
- Representation in impedance plane:
  - A coil in the air has an impedance, which results from a resistance and a reactance.
  - If the coil moves closer to a conductive material, the impedance of the coil changes (because of the eddy currents) and follows the *Lift-off* path.
  - When the coil is over the surface of the material, the impedance stabilizes to its sound value.
  - If the coil passes over a defect in the material, the impedance of the coil changes and follows the *Crack* path.



Conventional Eddy Current Probe

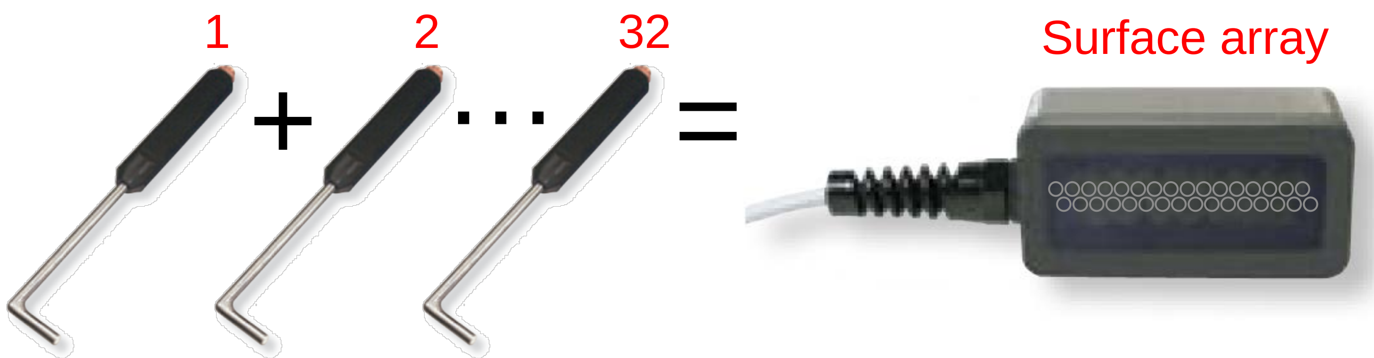
What is ECA?

- ECA is ECT
  - Same depth of penetration
  - Same probe configuration available (Absolute, reflection, etc..)
- Multiple ECT coils in one probe
- C-Scan images; allow to show detailed information, post processing of all channels at the same time

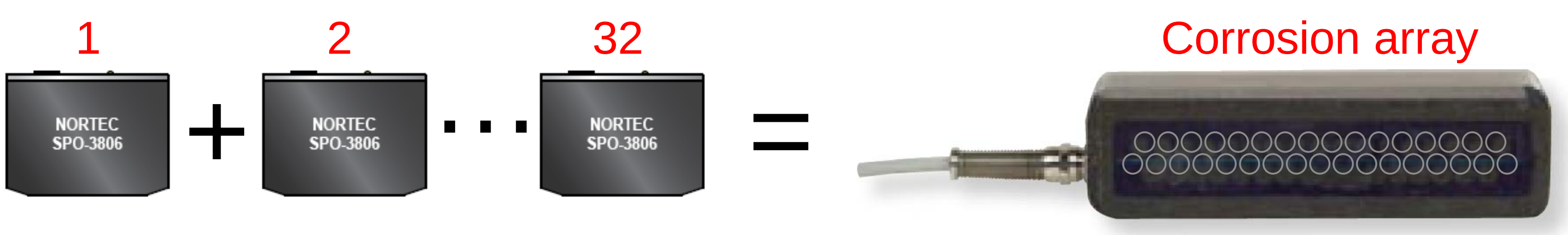


Elements in ECA Probe

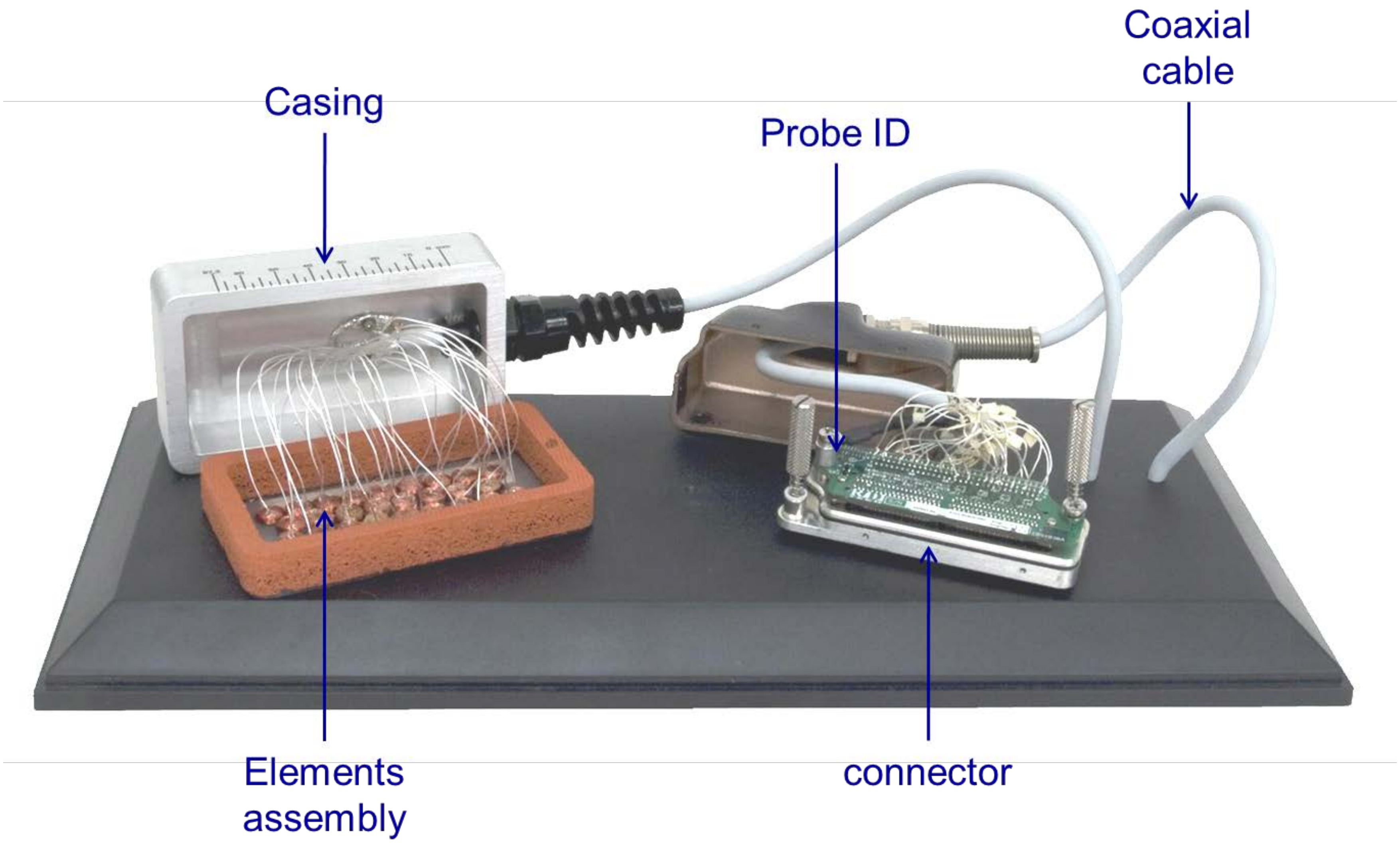
- Elements are the individual EC probes used to make the array probe.
- Any type of EC probe can be used as an element. For example:
  - Pencil probe:



  - Sliding probe:

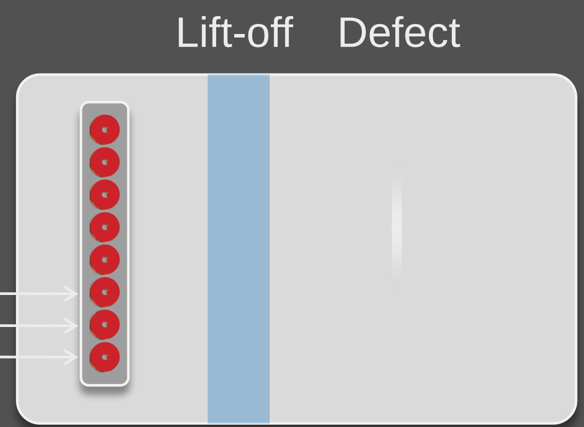


Elements in ECA Probe

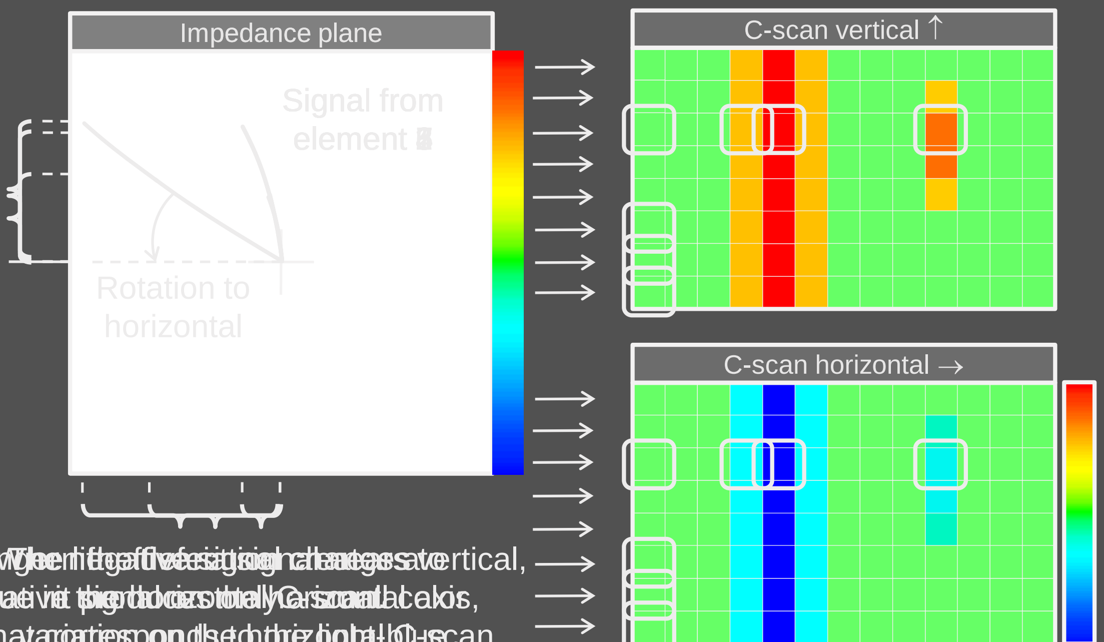


Representation in C-scan

Before calibration



- To calibrate, the signal from each element is rotated in order to bring the lift-off signal on the horizontal axis of the impedance plane



Representation in C-scan

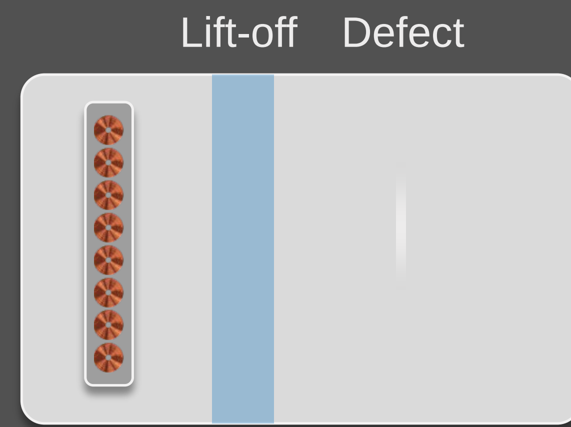
After calibration

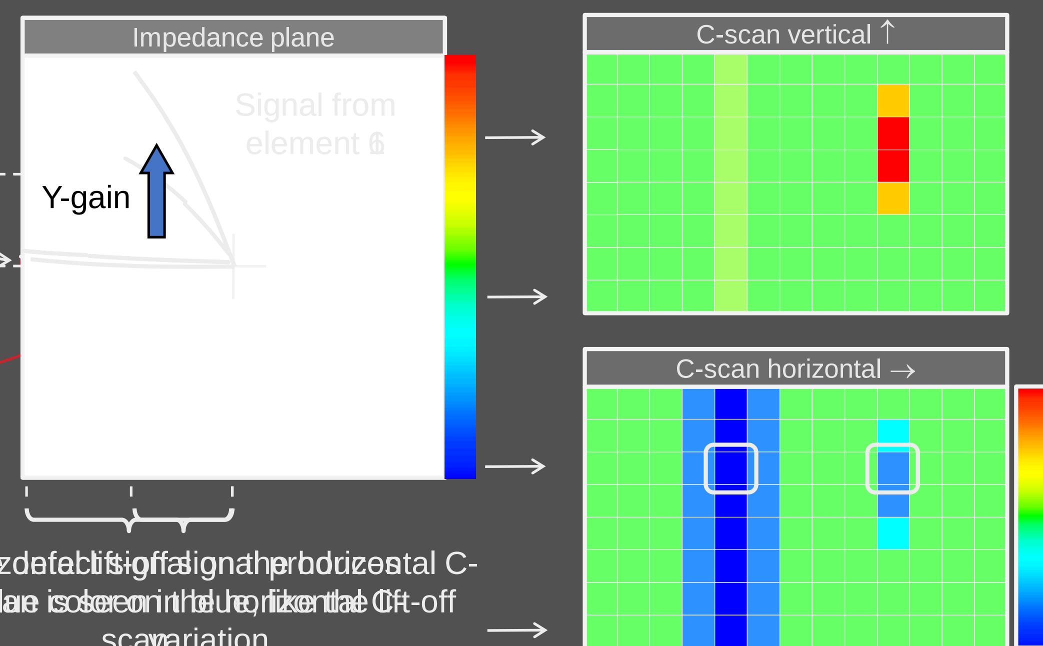
- The elements show a horizontal lift-off signal in the impedance plane.
- Defects have a strong vertical component
- Additional gain may be used on the Y-axis to increase the defect signal and improve the color contrast in the vertical C-scan.

Large lift-off variation may have a small positive vertical component, that creates a yellow color in the vertical Cscan.

The defect is easily detected on the vertical C-scan while the small lift-off variations are not seen.

However, a small lift-off variation remains horizontal and are not seen in the vertical Cscan, which is very useful for defect detection.





The horizontal lift-off signal produces a clear signal in the horizontal C-scan.

The defect is also seen in blue, like the lift-off variation.

ECA Advantages

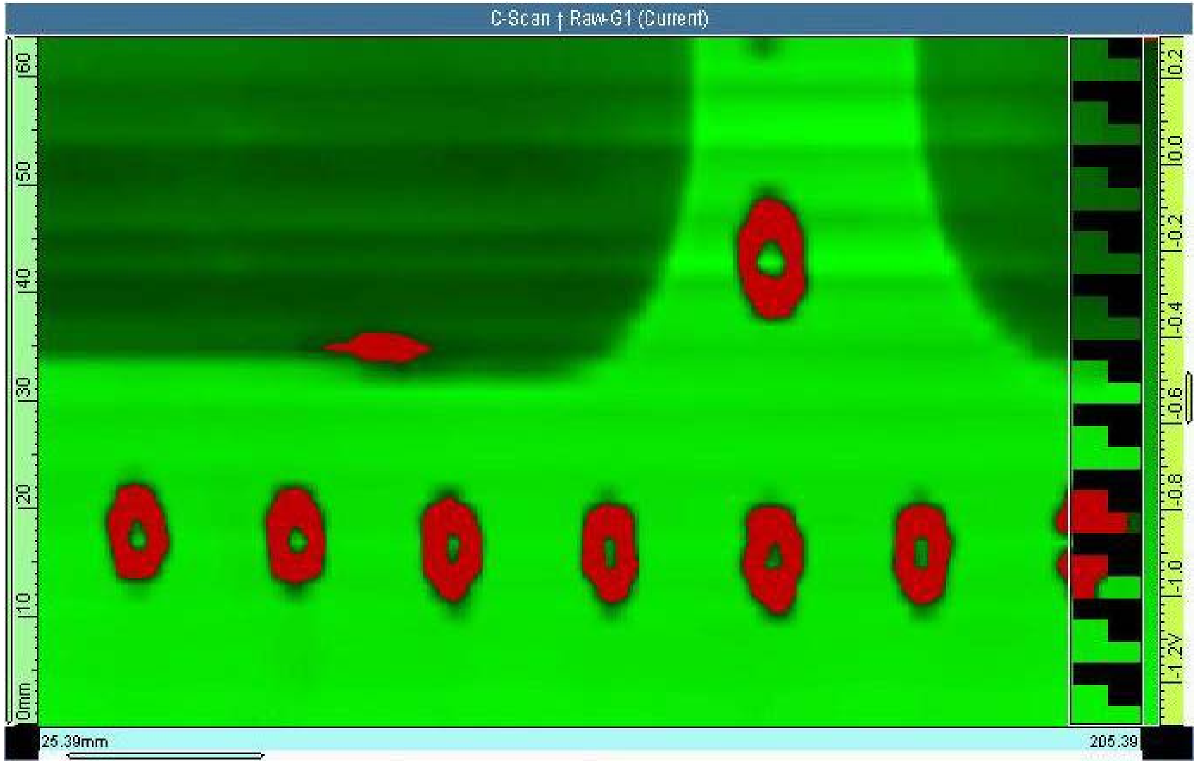
✓Time saving

✓Large probe coverage

✓Detailed Image (C-Scan)

✓Better POD

✓Picture worth a thousand words.

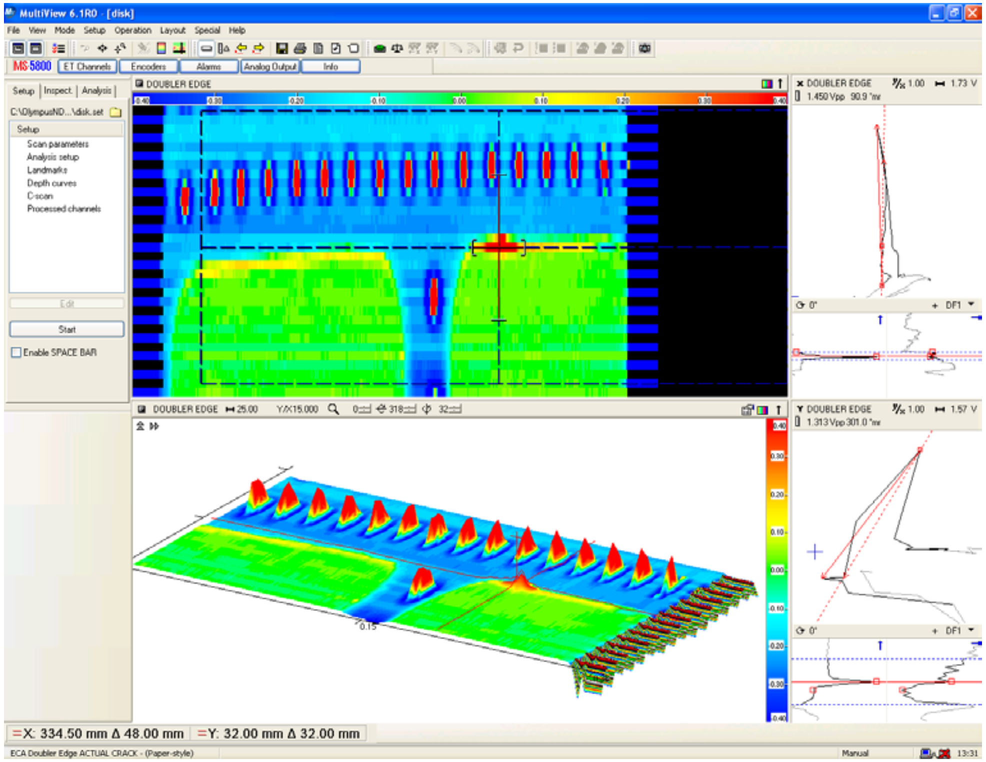


ECA with External Multiplexer

ECA Instrument

MS5800 + MultiView :

- ✓ PC-base instrument
- ✓ Data, Setup and Report Recording capability
- ✓ Up to 64 channel using external multiplexer(128 channels when using two multiplexers)
- ✓ 2D and 3D C-Scan display
- ✓ Frequency range: 20 Hz to 6 MHz
- ✓ Encoded capability



ECA Probes

- Standard probe
- Custom Probe

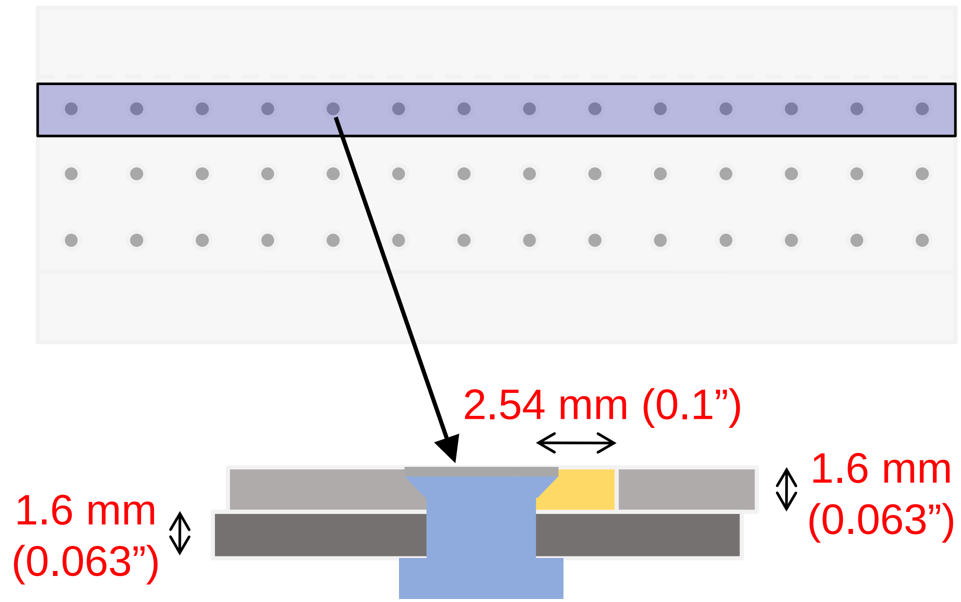
ECA in Aerospace

Maintenance procedures already qualified with ECA

Company	Aircraft model	Technology	Procedure description	Procedure #
Airbus	A330	ECA	Corrosion on the inner face	53-21-36 part 6
Boeing	737	ECA	Crack at the upper row of fastener of the lap splice	53-30-40 part 6
Boeing	737	ECA	Crack at the doubler edge	53-30-25 part 6
Boeing	737	ECA	Crack at the lap joint (Scribe mark)	53-00-16 part 6
Boeing	757	ECA	Crack at the upper row of fastener of the lap splice	53-30-12 part 6
Boeing	747	ECA	Crack at the lap joint (Scribe mark)	53-30-30 part 6
Bombardier	Q400	ECA	Surface crack at the fastener hole	51-00-11-250-801
Boeing	787	Bondtesting C-scan	Disbond	51-00-17 part 4

Skin lap splices on B737, B757, Q400

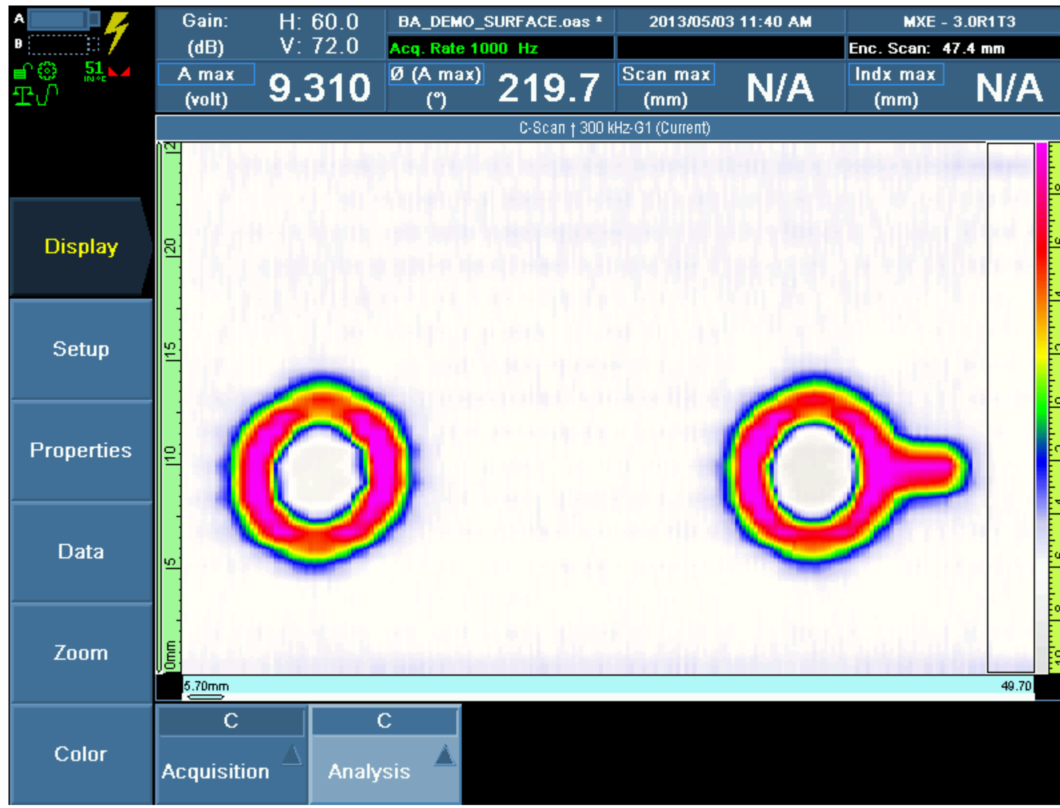
- Inspection of the upper row of fasteners of the skin lap splices to detect near surface cracks.
- The procedure is included in the Boeing 737, 757 and Bombardier Q400 nondestructive test manual.
  - It uses the high resolution surface array probe SBBR-026-300-032.



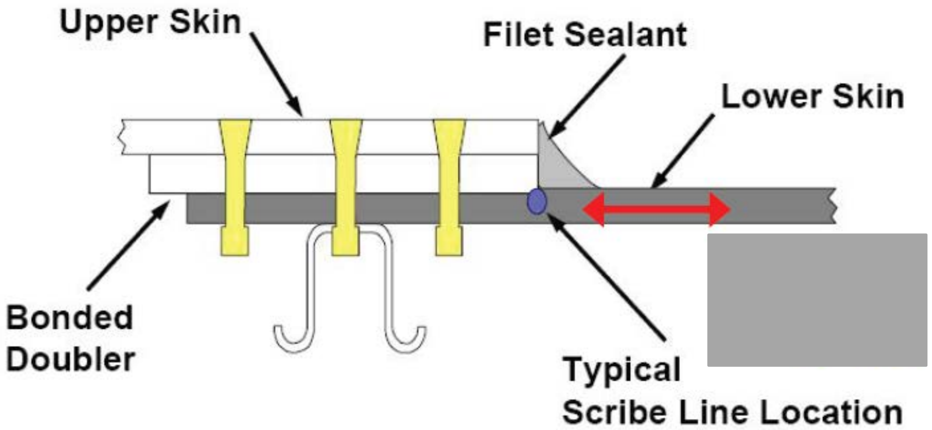
SBBR026-ENC: probe kit which include encoder

Skin lap splices on B737, B757, Q400

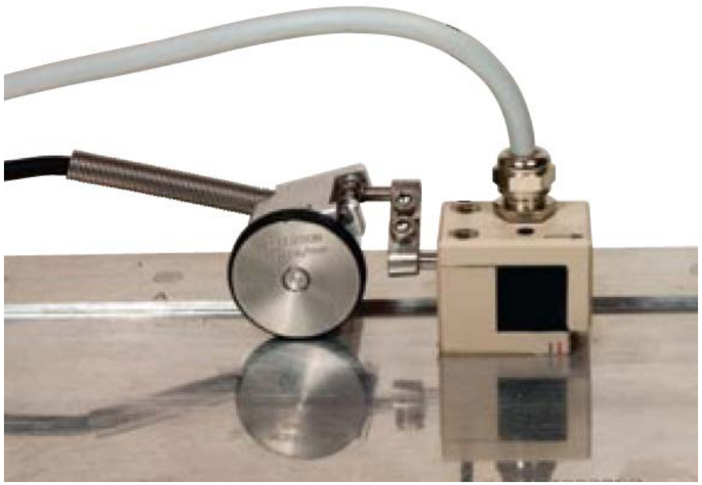
- Benefits:
  - Probe positioning not critical compared to EC sliding probe or pencil probe.
  - Fast
  - Reliable
  - Easy to analyze with the C-scan image.



Scribe mark on Boeing 737 & 747 aircraft

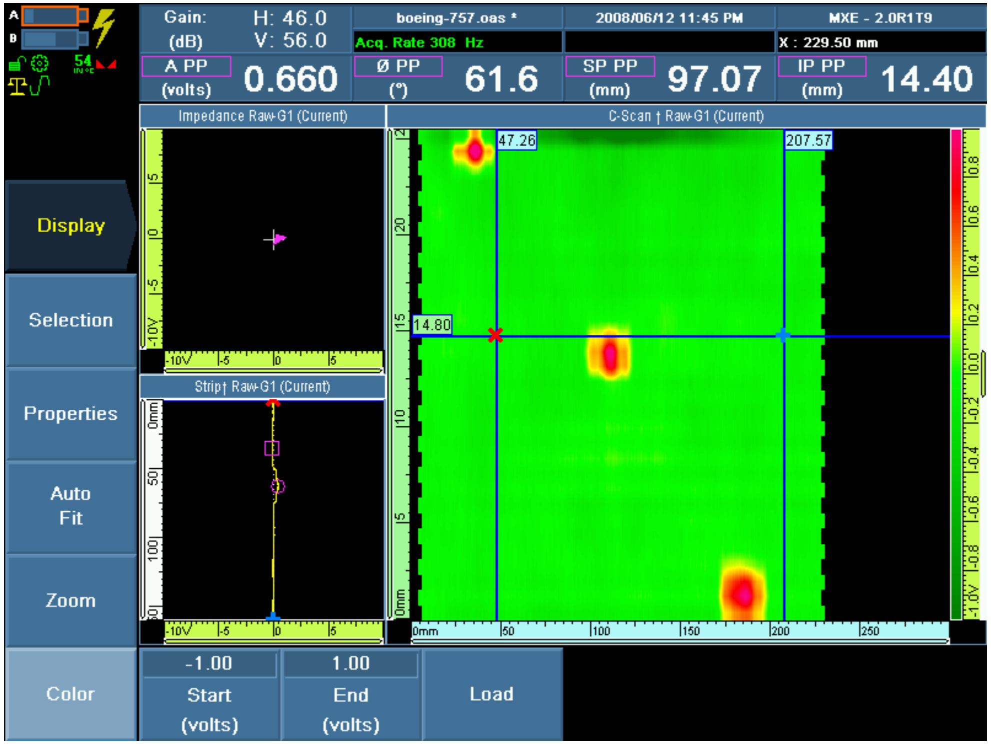


- Inspection of the lower skin for detection of scribe marks.
- These marks appear as surface crack located between 1.5 mm (0.06”) to 25.4 mm (1.0”) from the edge of the upper skin.
- The procedure uses the high resolution surface array probe SBBR-026-300-032.



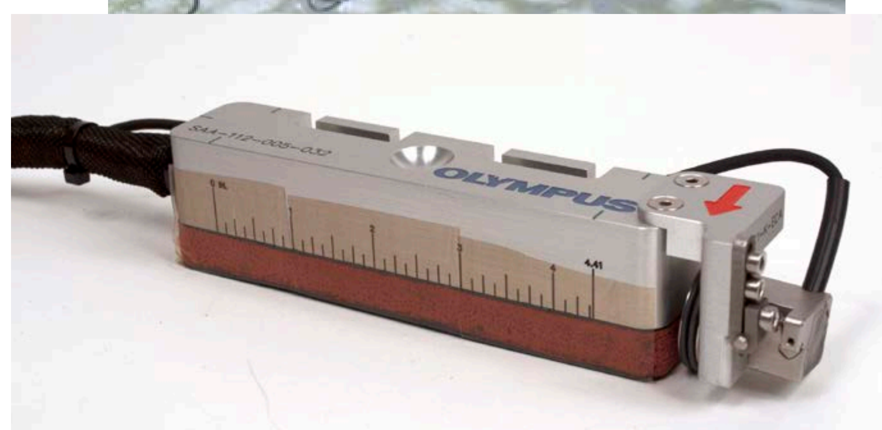
Scribe mark on Boeing 737 & 747 aircraft

- Benefits:
  - One pass inspection.
  - Scribe mark detected from 1.5 mm (0.06”) to 25.4 mm (1.0”) to the edge.
  - Reliable inspection (100% coverage).
  - Easy to analyze with the C-scan image.



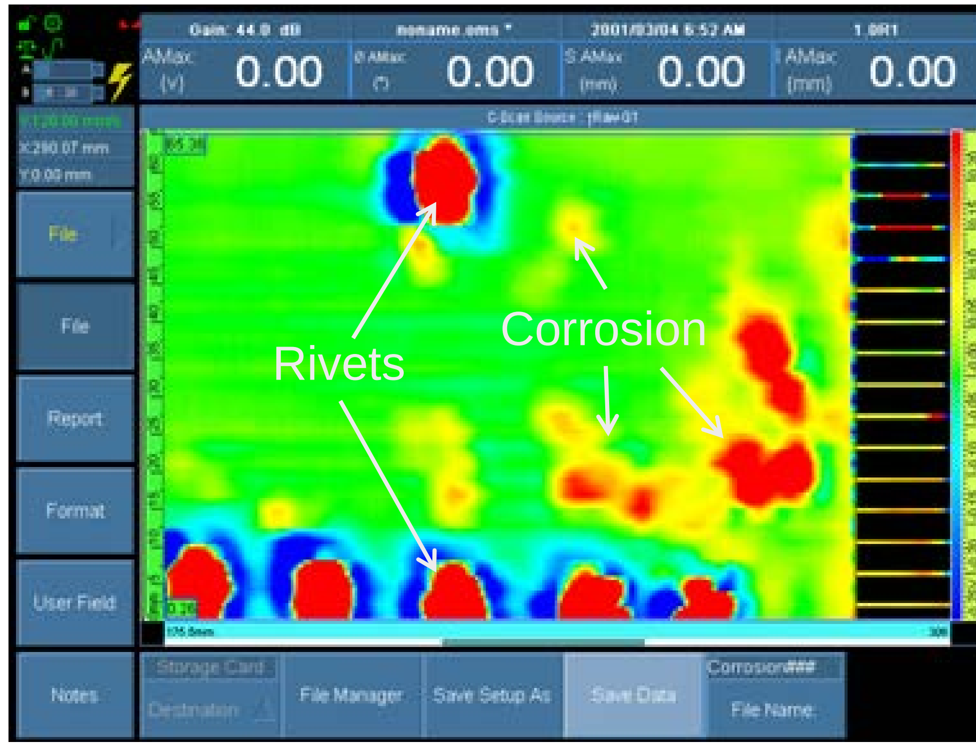
Corrosion on Airbus A330/340

- Corrosion between the first layer and an internal acoustic panel.
- The procedure uses the SAA-112-005-032 probe which has a low frequency and a large footprint.
- Raster scanning can be done to cover larger area by using the GLIDER manual scanner.



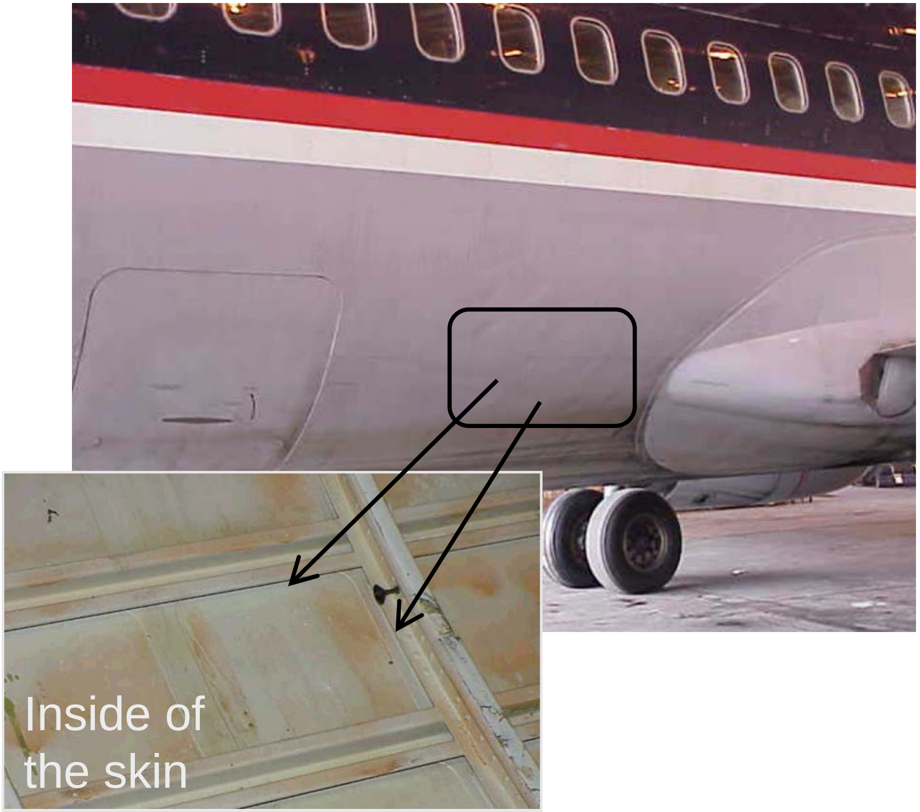
Corrosion on Airbus A330/340

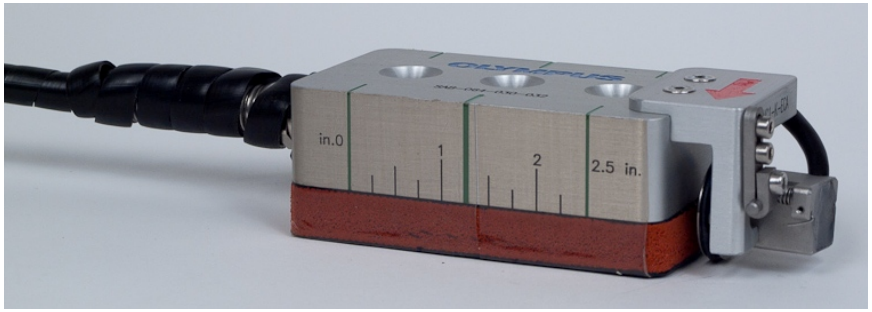
- Benefits:
  - Simple manual inspection.
  - C-Scan allows easier detection of small corrosion in large area.
  - Better reliability.
  - Better reproducibility.
  - Time saving:
    - Area : 12 m^2 (1550 ft^2)
    - Normal time: 9 hours
    - With ECA: 1 hour



Cracks at the doubler edge on Boeing 737

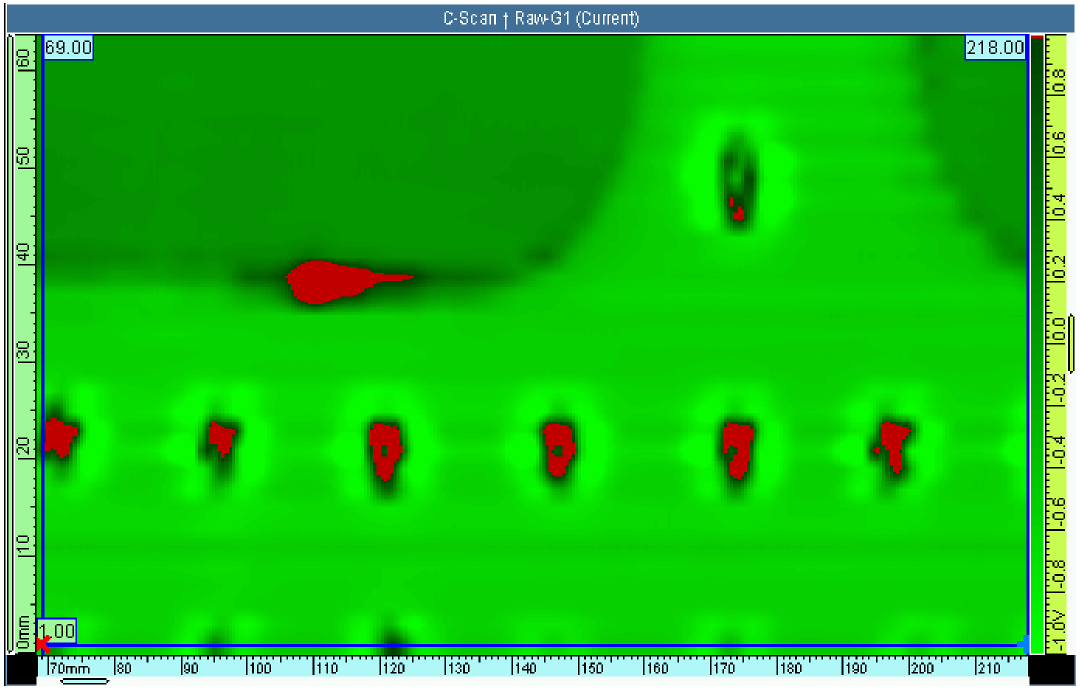
- The inspection is done from the outside and cracks as small as 6 mm (0.240”) long by 0.25 mm (0.010”) deep located at the edge of the doubler can be detected.
- The procedure is now included in the Boeing 737 nondestructive test manual.
- It is an optional inspection procedure to Part 6, 53-30-25.
  - It uses the SAB-064-030-032 and an encoder.





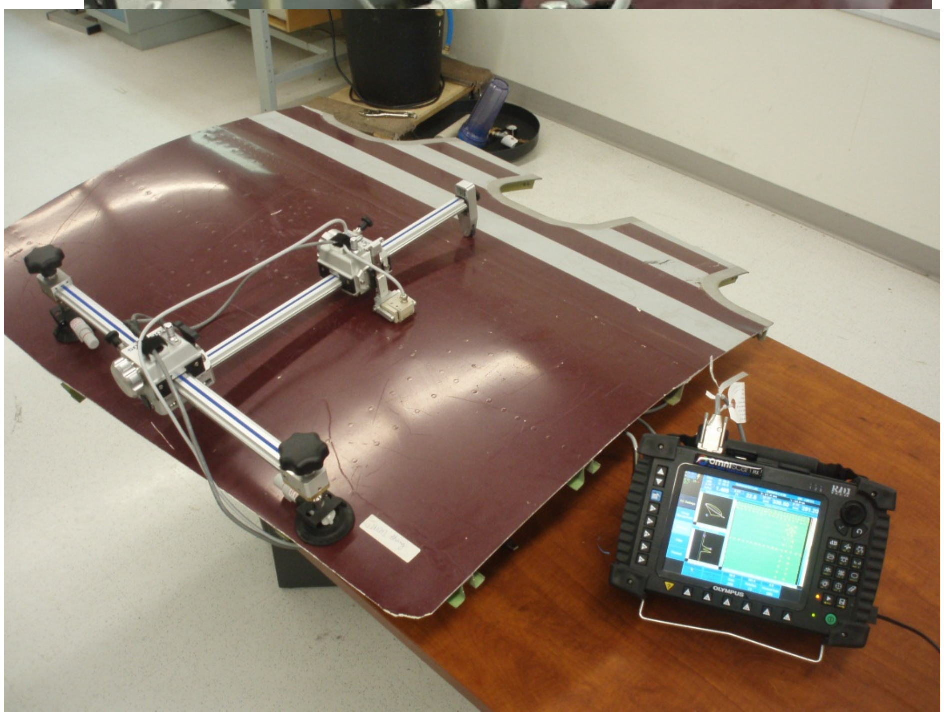
Cracks at the doubler edge on Boeing 737

- Benefits:
  - Simple manual inspection.
  - Probe positioning is not as important as for typical EC spot probe inspection.
  - C-Scan allows easy location of the doubler edge for fast and simple detection of the initiating cracks.
  - Better reproducibility.
  - Time saving: up to ten times faster (typically 10 hours/person for 737 inspections).



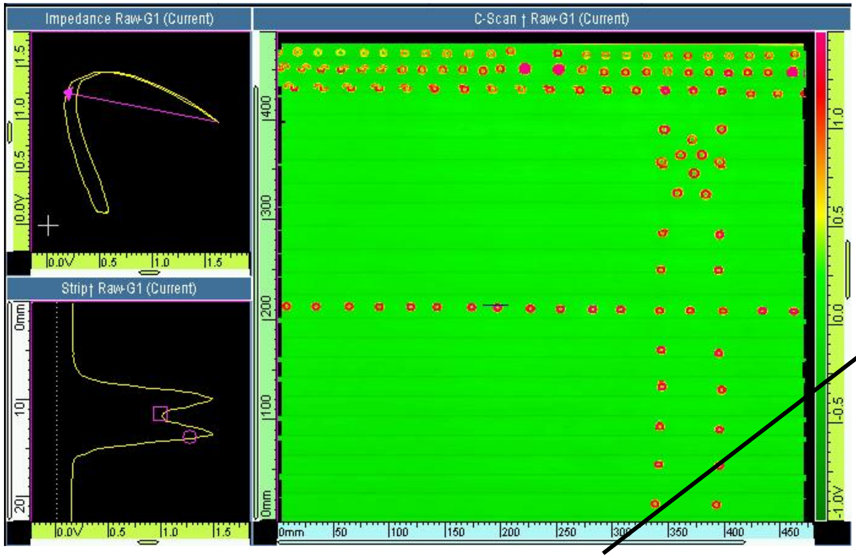
Raster Scan

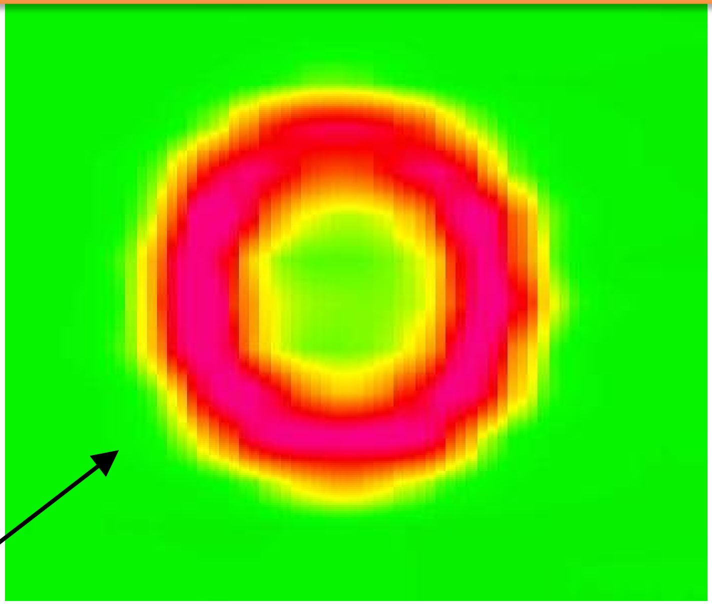
- Available with OmniScan ECA



Raster Scan

- Fuselage scan :
  - 500mm x 500mm (19,7'' x 19,7'')
  - Scan resolution: 0,2mm (0,008'')

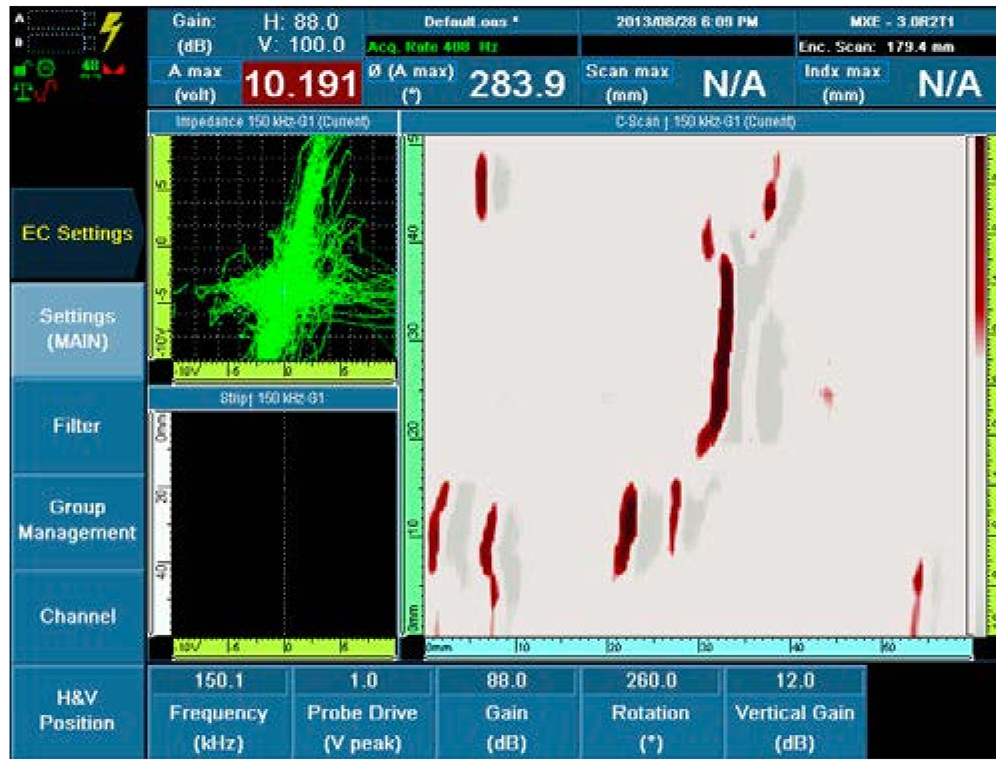




Replacement of Traditional NDT methods

ECA can be a good replacement of traditional NDT method such as Liquid Penetrant and Magnetic Particle, for surface defect detection. ECA can also be use without removing paint or thin coating on over the surface.

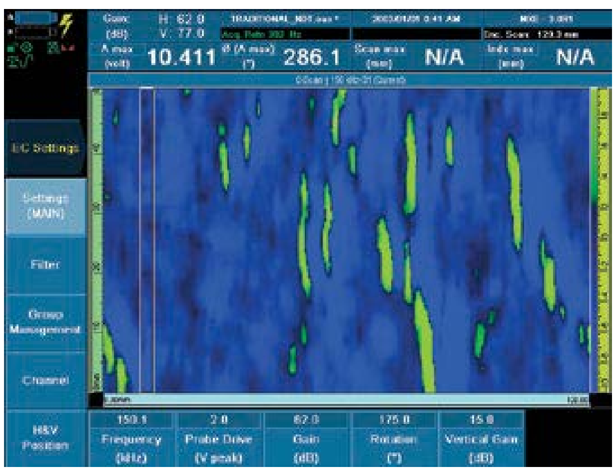
Picture of penetrant indications



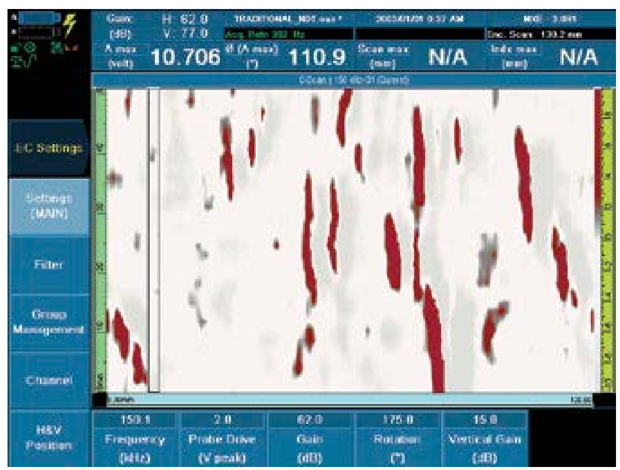
Eddy current array indications with red dye color palette

A Variety of Familiar Color-Palette Choices, Offering More Possibilities

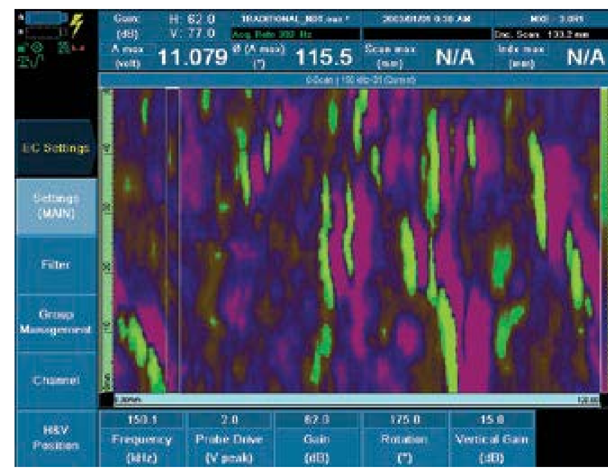
The ECA software features a range of color-palette representations that replicate the look of traditional NDT methods and facilitate the intuitive display of ECA signals such as Penetrant indications.



Penetrant Testing (fluorescent)



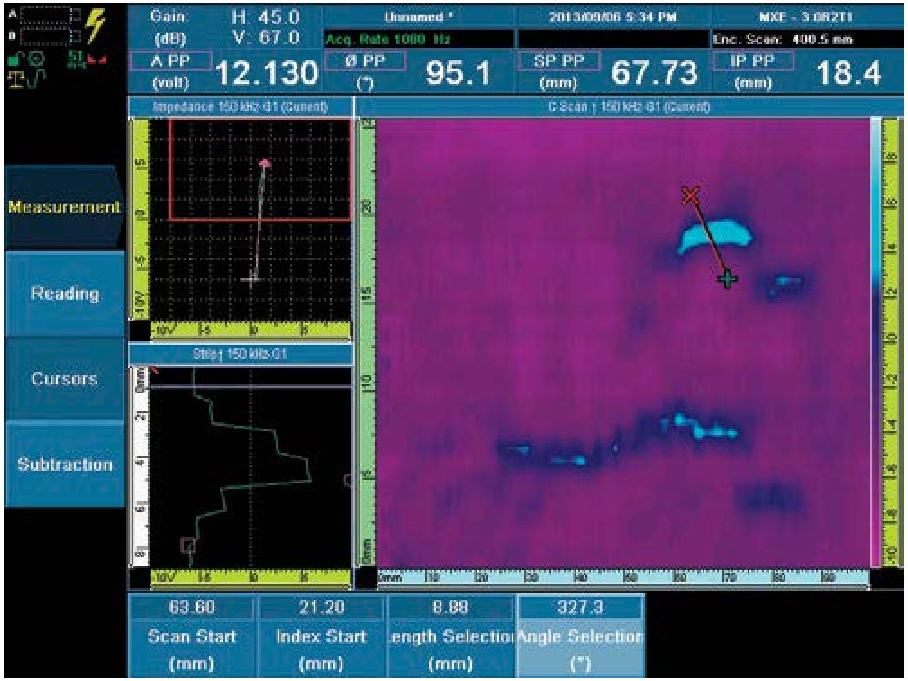
Magnetic Particle (red powder)



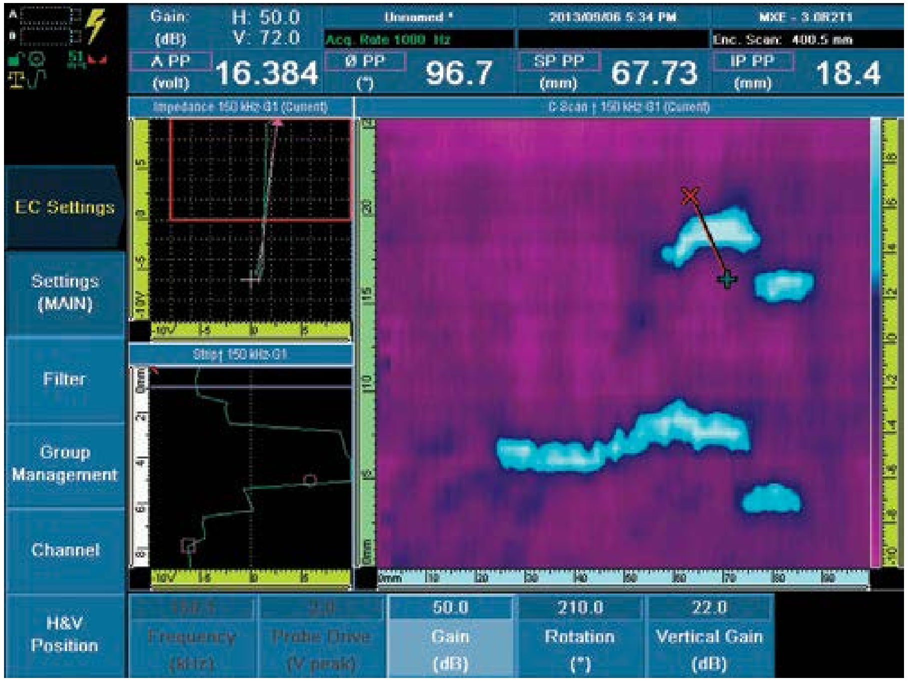
Magnetic Particle (fluorescent)

Post Processing Inspections after Completion

Even after an in-field inspection has been completed, ECA continues to provide value due to integrated data-storage, analysis, and reporting functionalities. With the ECA you can review individual indications and apply corrections as needed. The ECA software features newly redesigned, intuitive data cursors that can be operated directly from the instrument (on-site) or with a mouse connected by USB (office use).



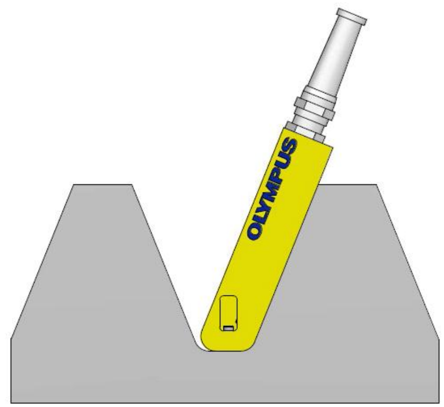
New MXE 3.0 selection cursors are very intuitive and allow to quickly select any indication.

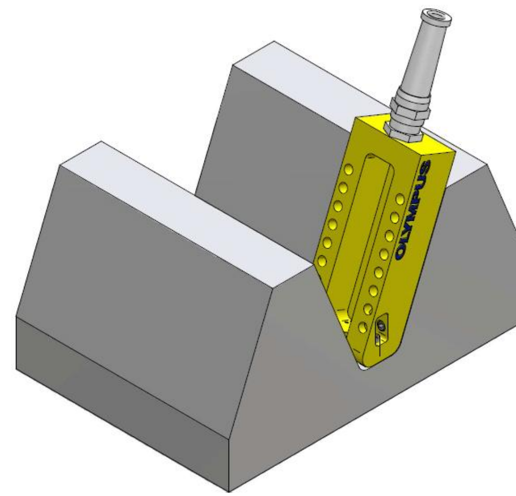


Corrections can be easily done on recorded data. Above example shows gain (contrast) adjustment.

Gear teeth inspection

ECA can be use for Gear-Tooth Surface Inspection for the Mining Industry. ECA offer a very good alternative to the traditional MPI inspection for this type of maintenance.

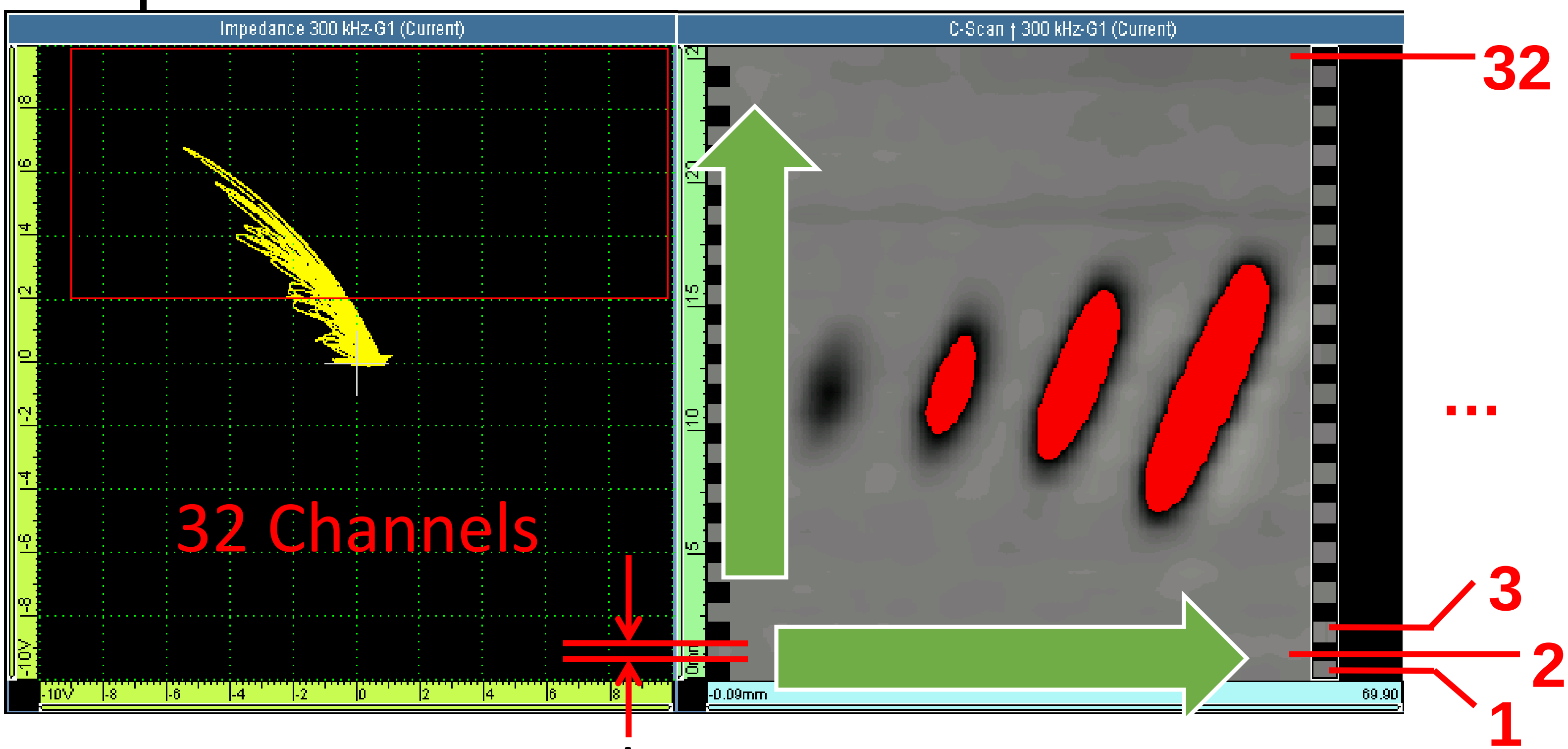




ECA Representation-Gating for acceptance criteria

Impedance Plane

C-scan



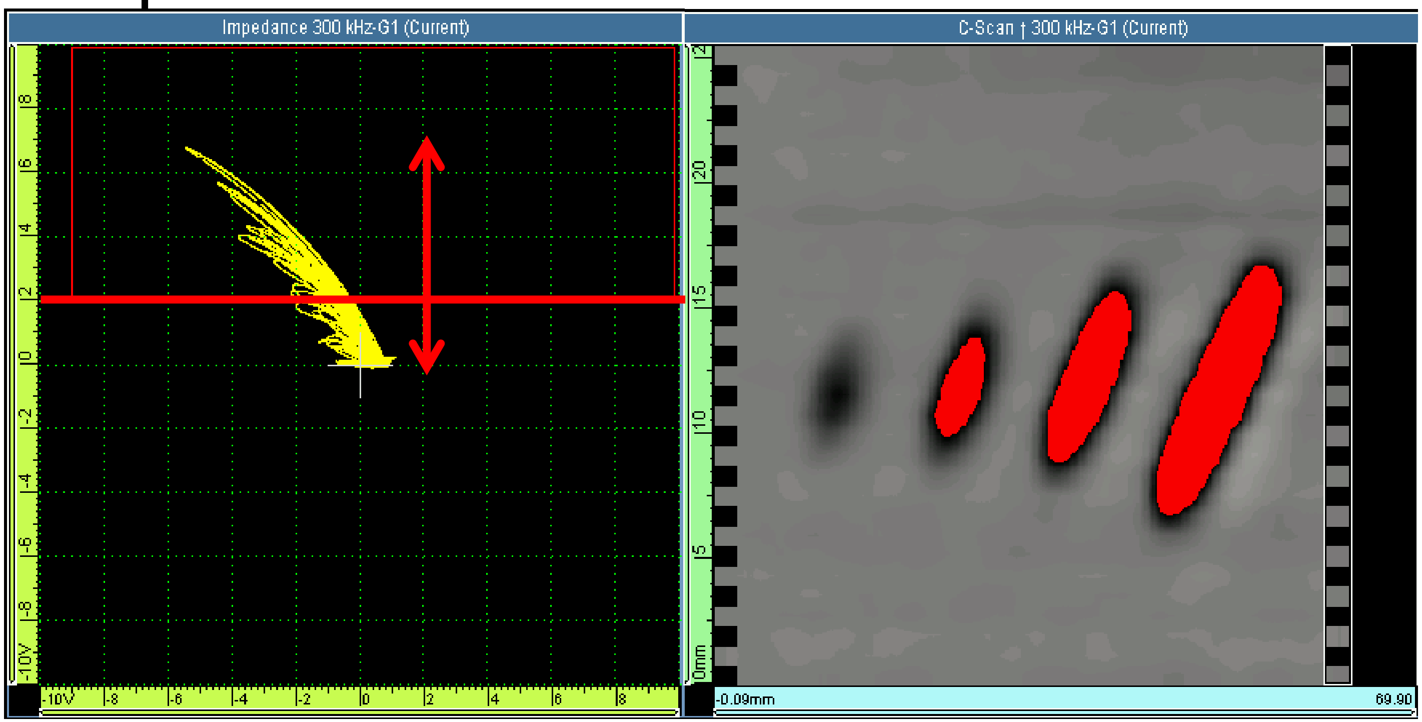
Probe Resolution

Time or Distance

ECA Representation-Gating for acceptance criteria

Impedance Plane

C-scan

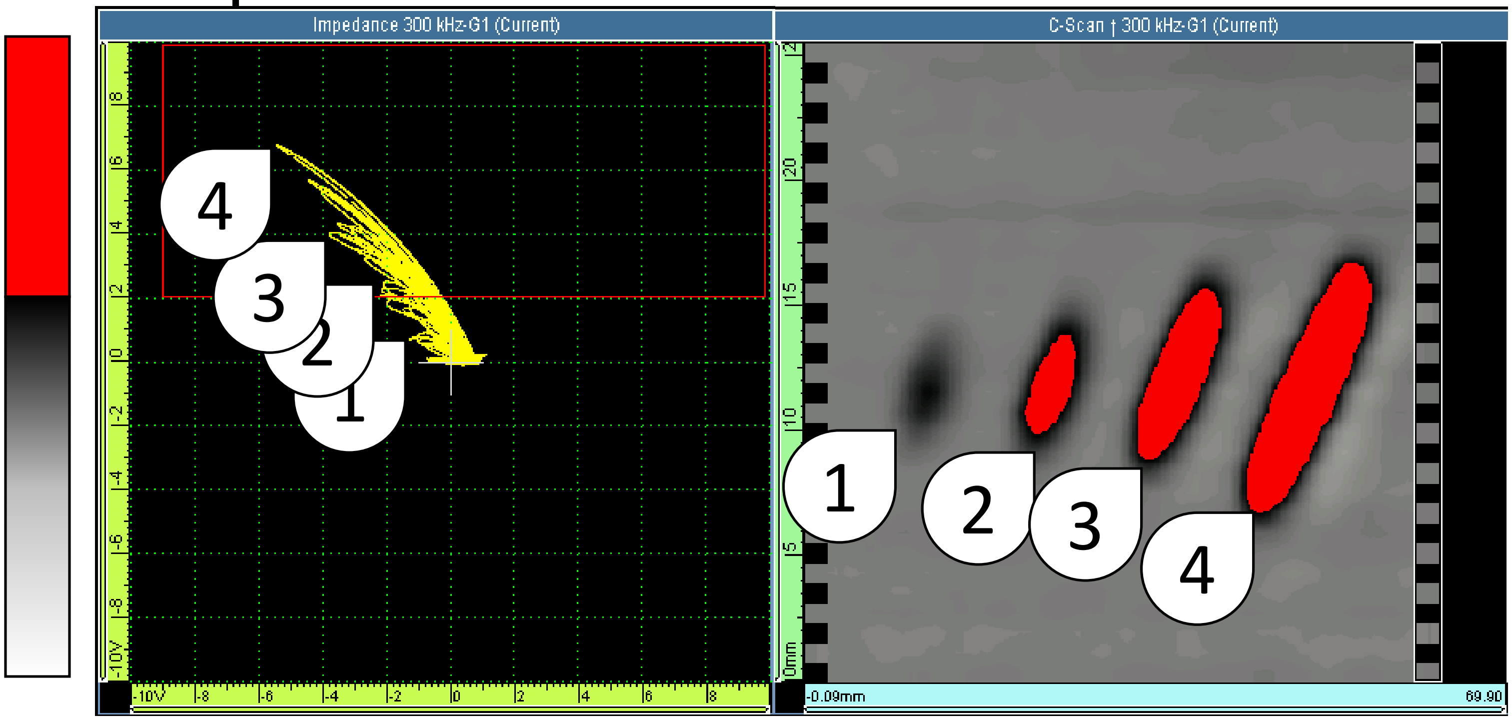


Vertical Amplitude + Color Palette

ECA Representation-Gating for acceptance criteria

Impedance Plane

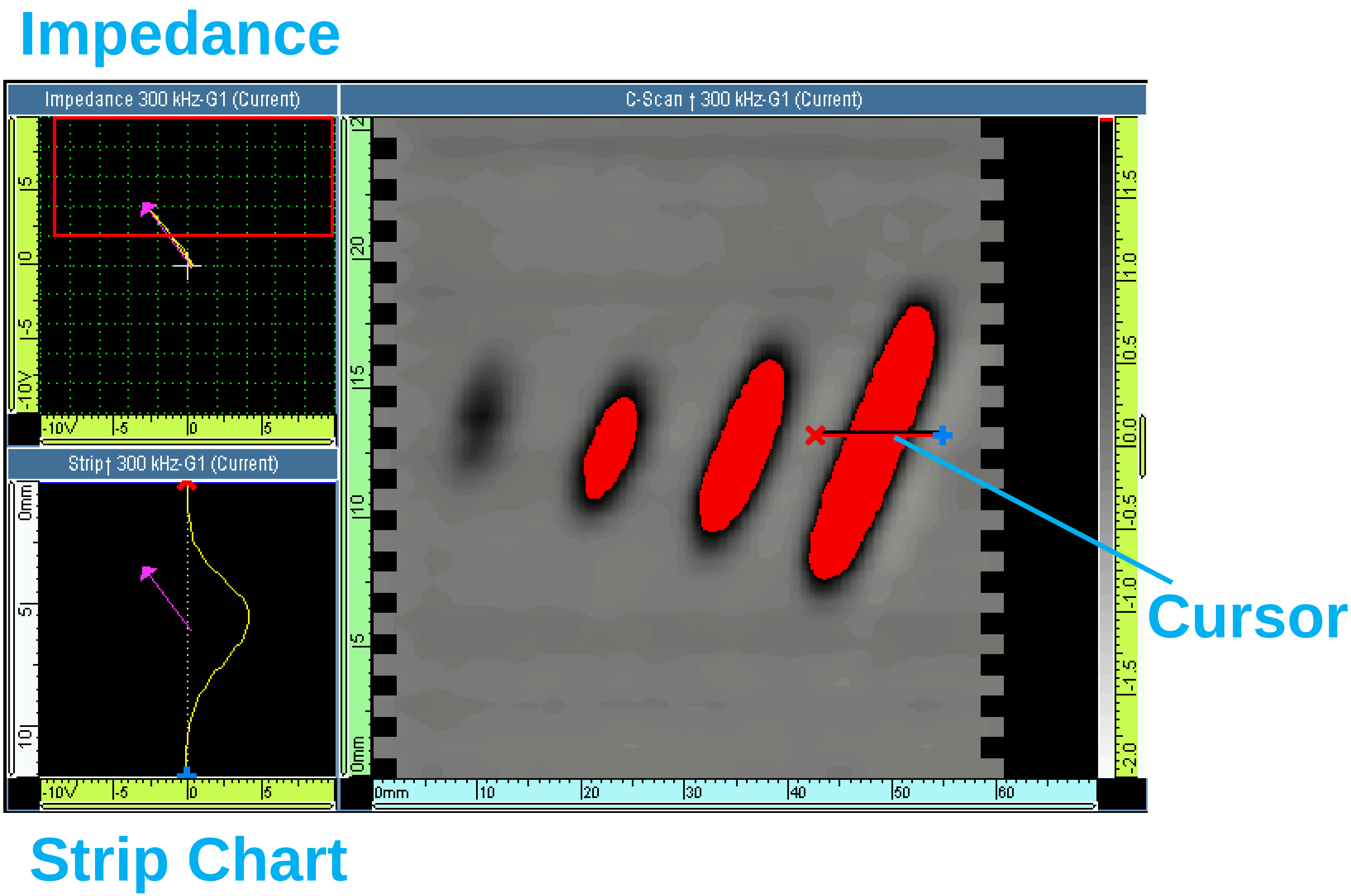
C-scan



NoGO

GO

ECA Analysis



Comparison of Methods

Eddy Current Arrays

- Simple to use (similar to ECT)
- Minimal surface preparation needed
- No de-magnetization or post cleaning required
- Not affected by weather conditions
- "Green" method

PT, MP

- VERY simple to use
- Very clean and dry surface; needs paint or coating stripping
- Exterior test requires more preparation
- Environmental concerns (paint or coating removal and re-application, waste disposal) Etching Concerns

Comparison (cont'd)

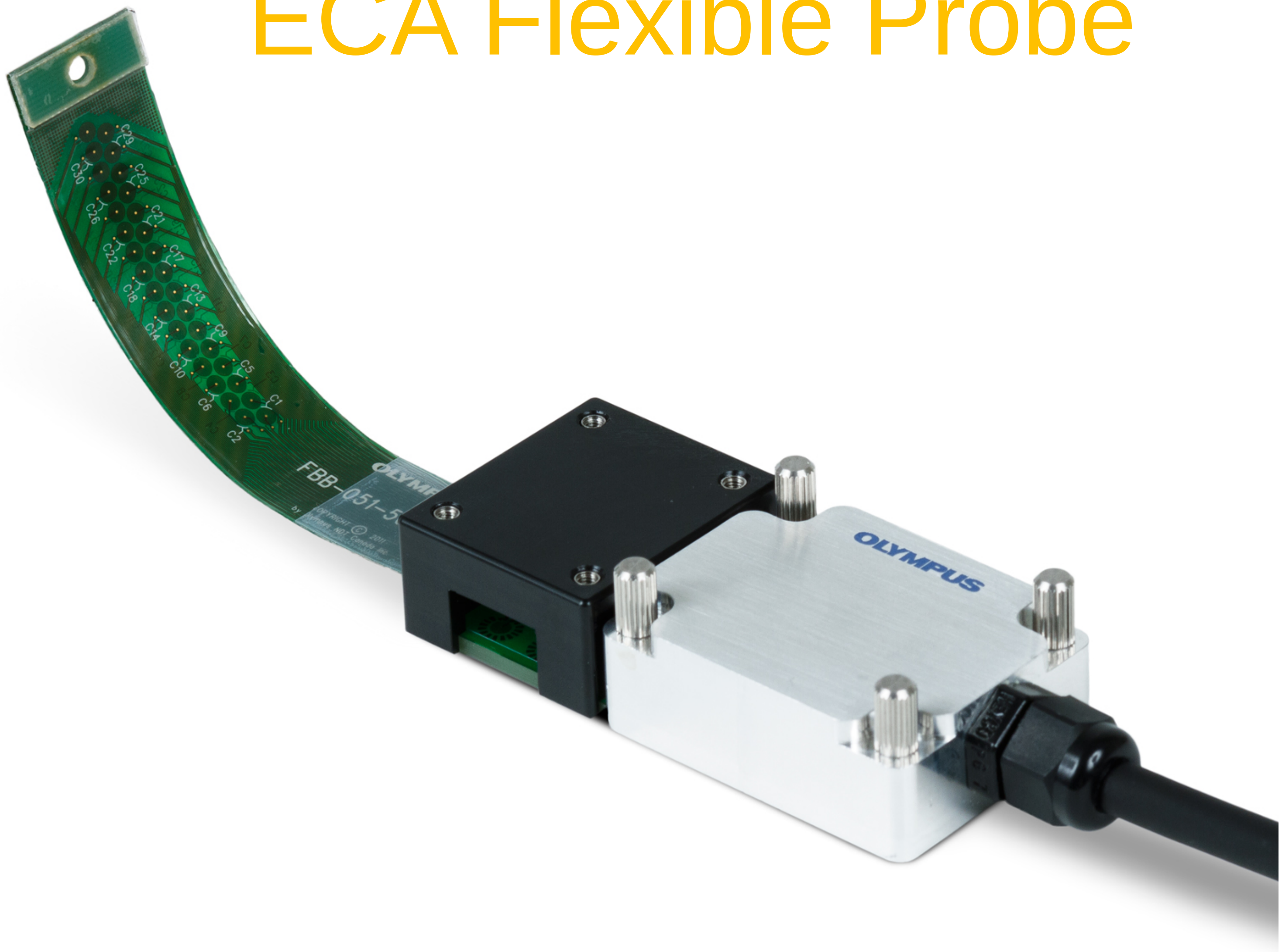
Eddy Current Arrays

- Reject Criteria (relevant or non-relevant indications)
- Excellent PoD on large surfaces & dirty cracks
- Instant results and Rapid coverage of large areas (high productivity)
- Encoded Scan capability
- Imagery and Archiving
- Post-Process Analysis

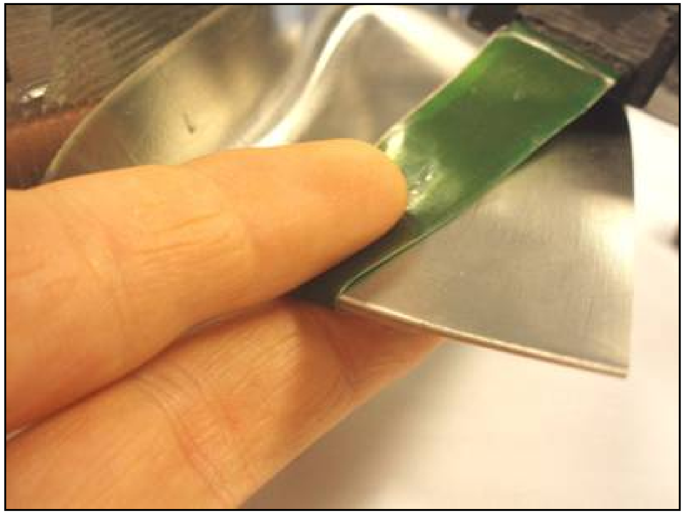
PT, MP

- Indications only; no reject criteria
- PoD highly dependant on surface preparation & crack cleanliness
- Pre and post cleaning (de-mag) time, dwell time

ECA Flexible Probe

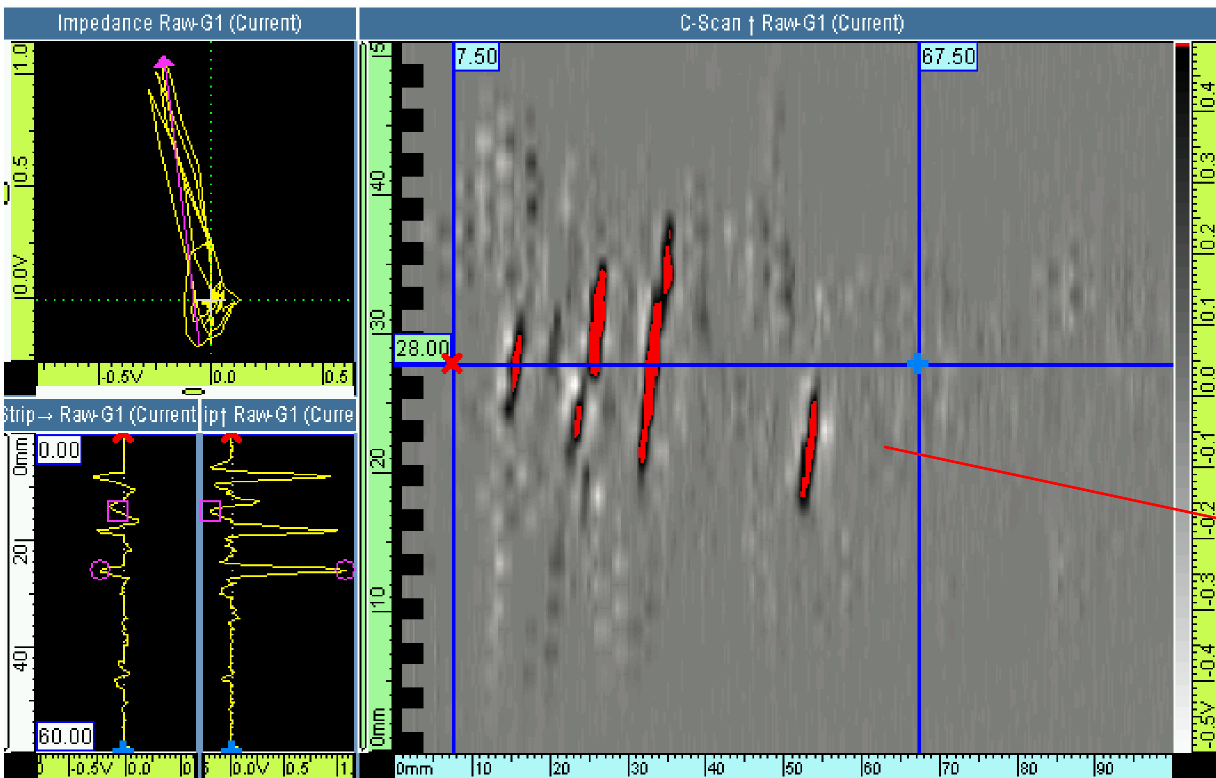


Fan Blade inspection



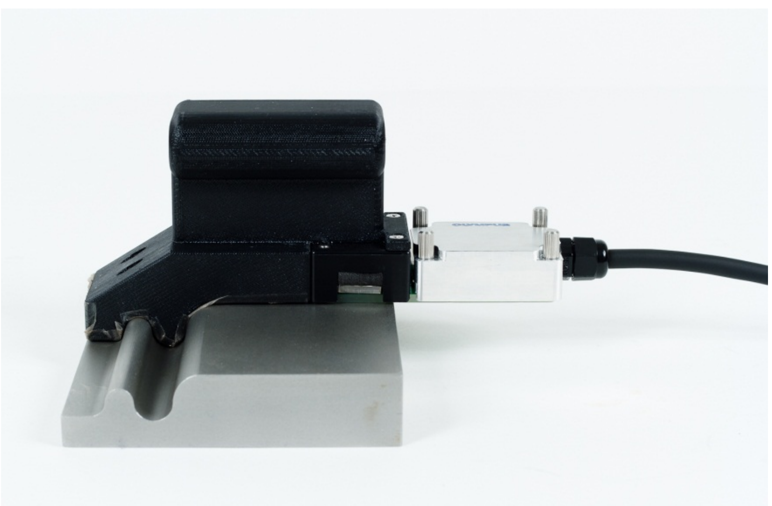
Fan Blade inspection

The ECA flexible probe is a very good solution for surface fan blade inspection. The complexity of the blade geometry does not allow to use standard rigid or semi rigid probe.



Custom Application need custom probe holder

- Customer wants to inspect a specific shape
- Using customer sample or mechanical drawing we can manufacture probe holder



Conclusion:

Eddy current array (ECA) share the same basic working principles. ECA technology provides the ability to electronically drive an array of multiple coils arranged in specific pattern called a topology that generates a sensitivity profile suited to the target defects.

Data acquisition is achieved by multiplexing the coils in a special pattern to avoid mutual inductance between the individual coils.

This will improve the inspection!

- ✓ Faster inspections
- ✓ Wider (more area) coverage
- ✓ Less operator dependence — array probes yield more consistent results compared to manual raster scans
- ✓ Improved detection capabilities
- ✓ Easier analysis because of simpler scan patterns
- ✓ Improved positioning and sizing because of encoded data
- ✓ Array probes can easily be designed to be flexible or shaped to specifications, making hard-to-reach areas easier to inspect

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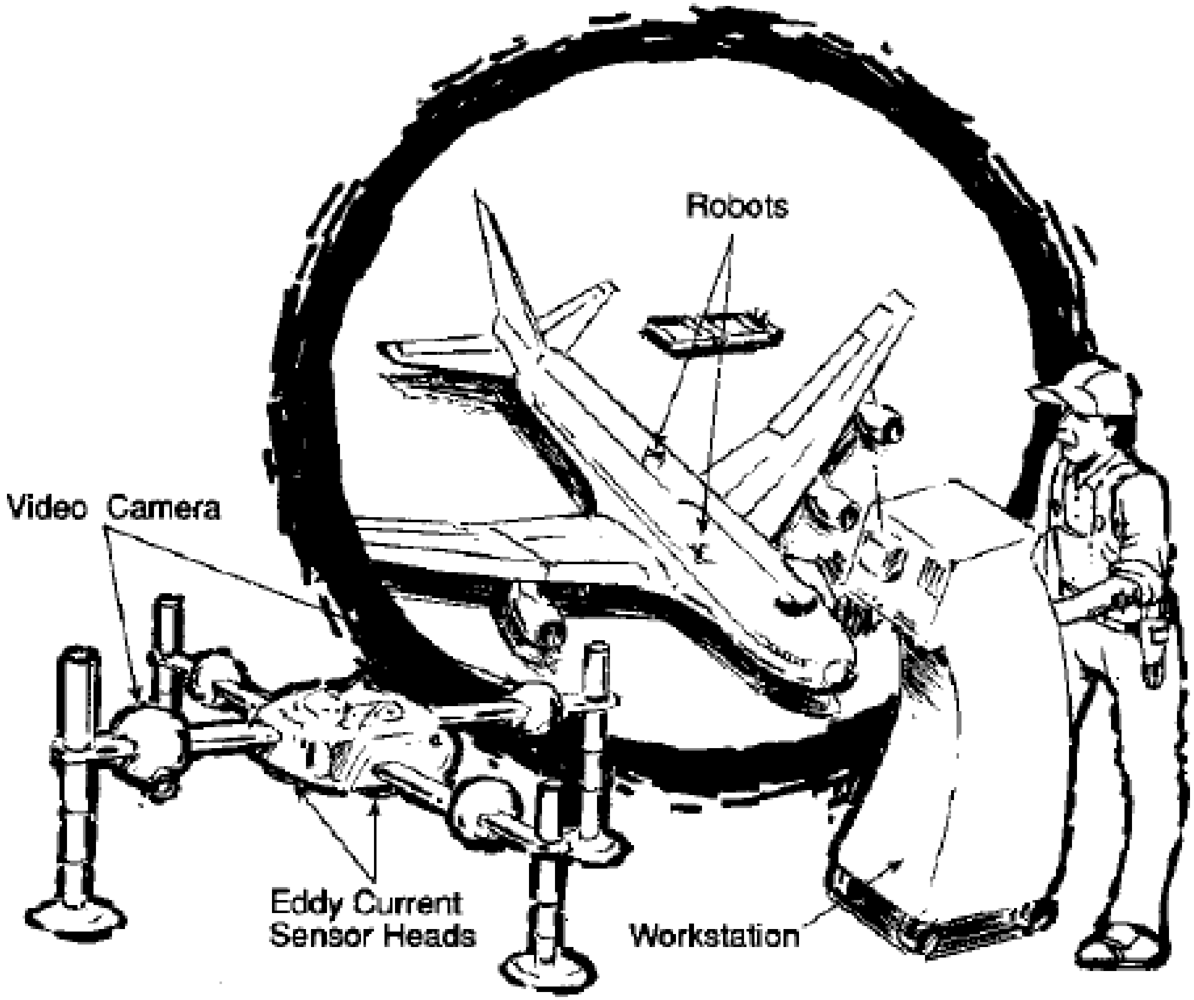
Aircraft Skin Inspection Robot



Thank you!