Inspection of stainless steel heat exchanger tube with eddy current array probe

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Introduction

- Context
- Eddy Current Array + Bobbin probe design
  - Overview
  - Operating principle
- Result on various calibration defects
- Comparison with low resolution array probe
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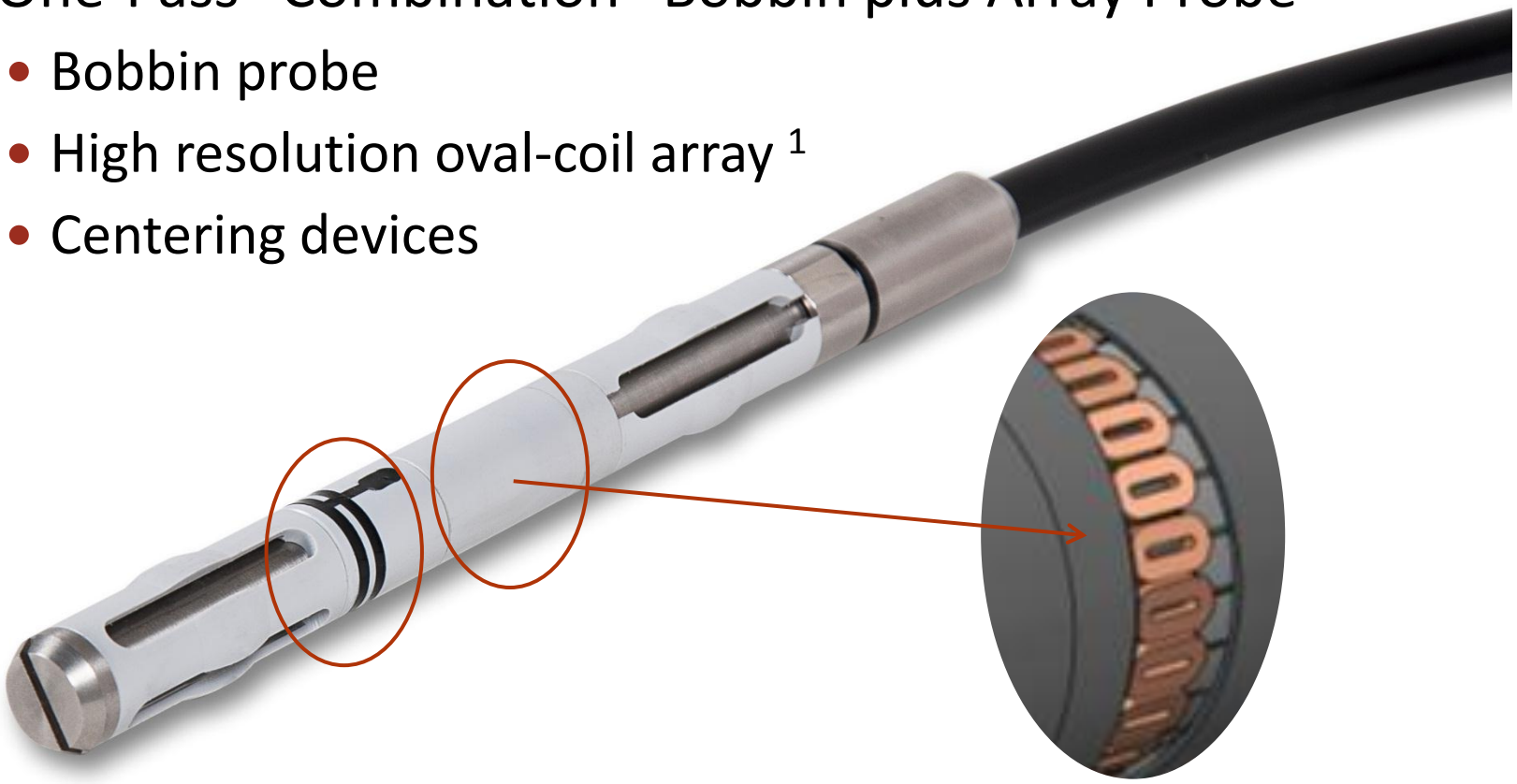
- Conclusions

Context

- Non ferrous heat exchanger and condenser tubes may be affected by several damage mechanisms:
  - Pitting
  - Erosion
  - Fretting
  - Cracking
- The bobbin probe inspection faces major limitations with respect to:
  - Detection and sizing circumferential cracking
  - Evaluate circumferential extent of volumetric flaws
- Rotating probe can be use to improve the inspection but this solution remains slow
- The Eddy Current Array + Bobbin probe technology is the solution to perform high resolution inspection at the bobbin speed in a single pass.

DefHi™ Probe[1]

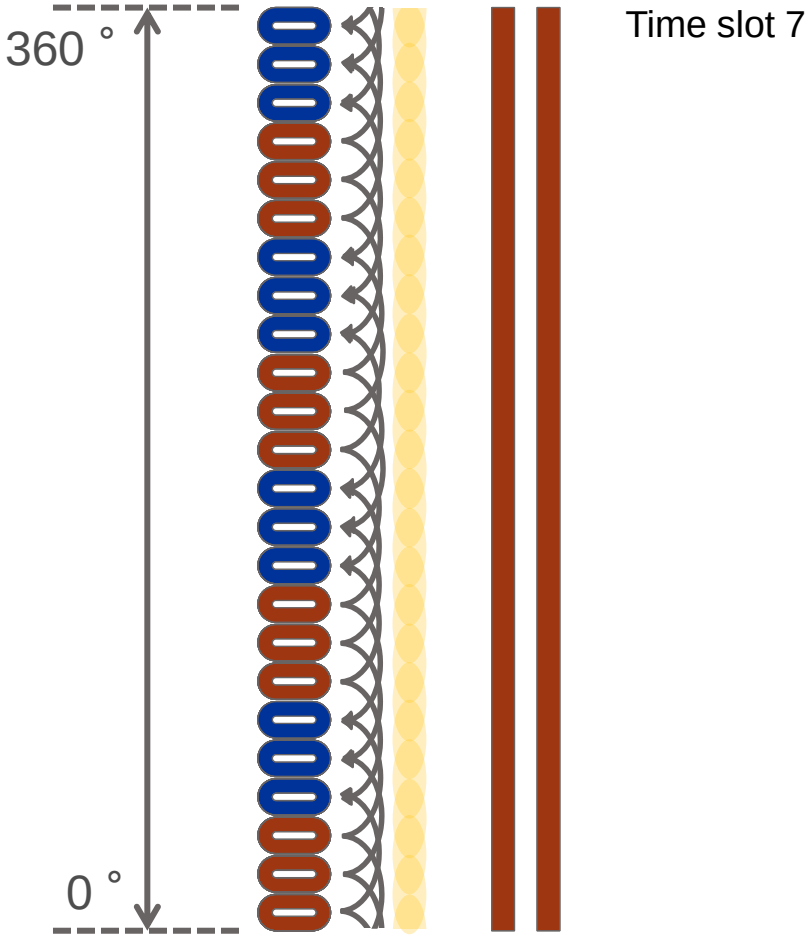
- One-Pass “Combination” Bobbin plus Array Probe
  - Bobbin probe
  - High resolution oval-coil array [1]
  - Centering devices



[1] US Patent Pending - Eddyfi NDT Inc.

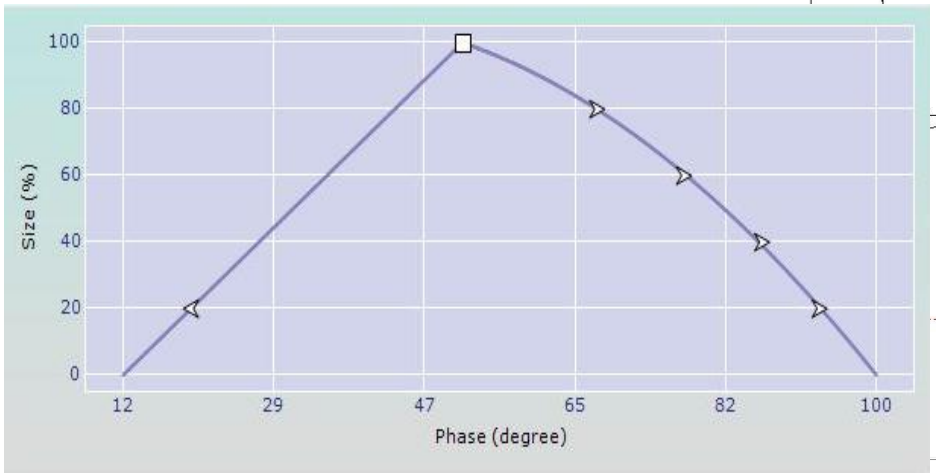
Operating mode

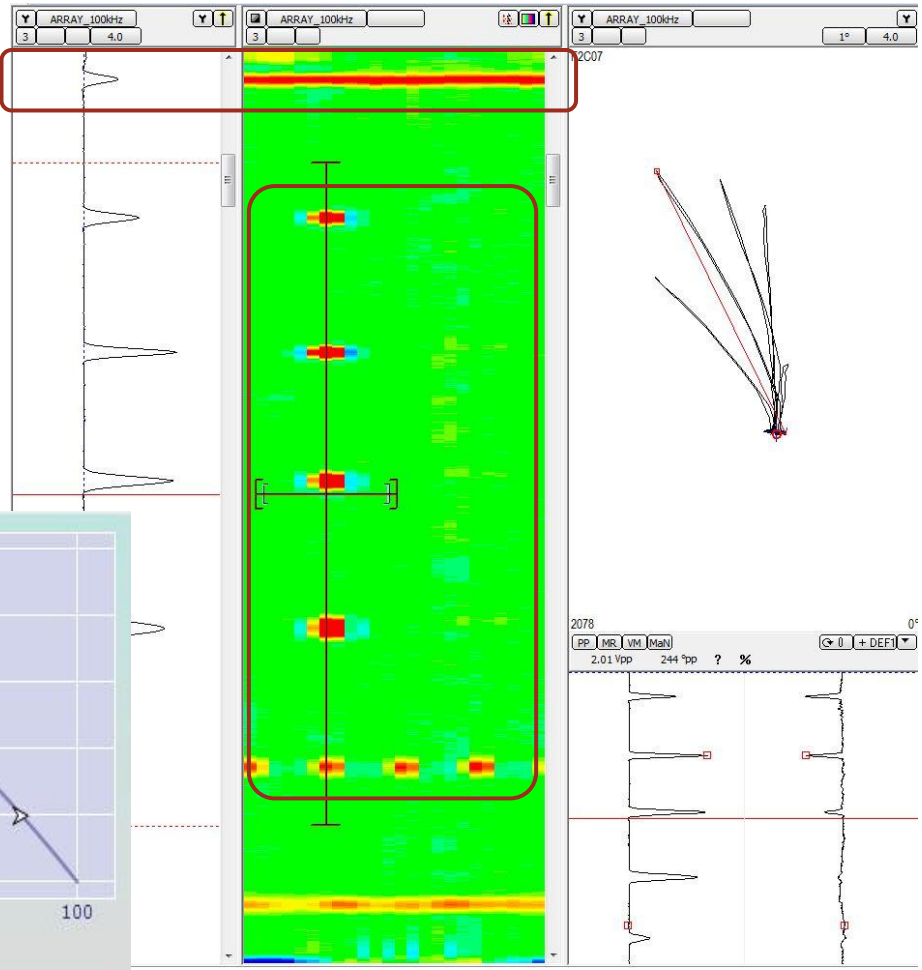
- Oval-coils array + Bobbin
  - 12 transmitter
  - 12 receivers
  - 2 bobbins
  - Excitation pattern
    - 2 poles
    - 2 skip coils
    - 6 time slots for the array
    - 1 time slot for the bobbin



Results for ASME standard

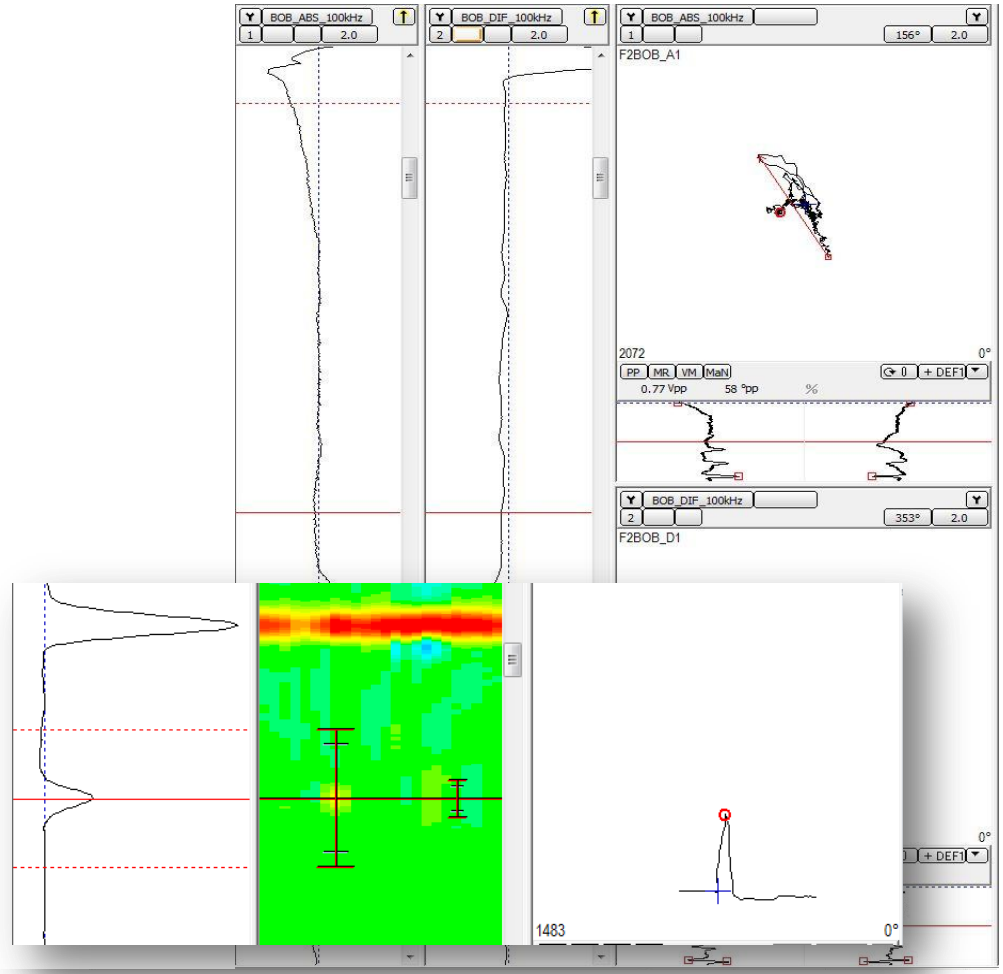
- Calibration on the ID groove
- OD Pits detected on at least 2 channels
- Sizing based on phase to depth curve.





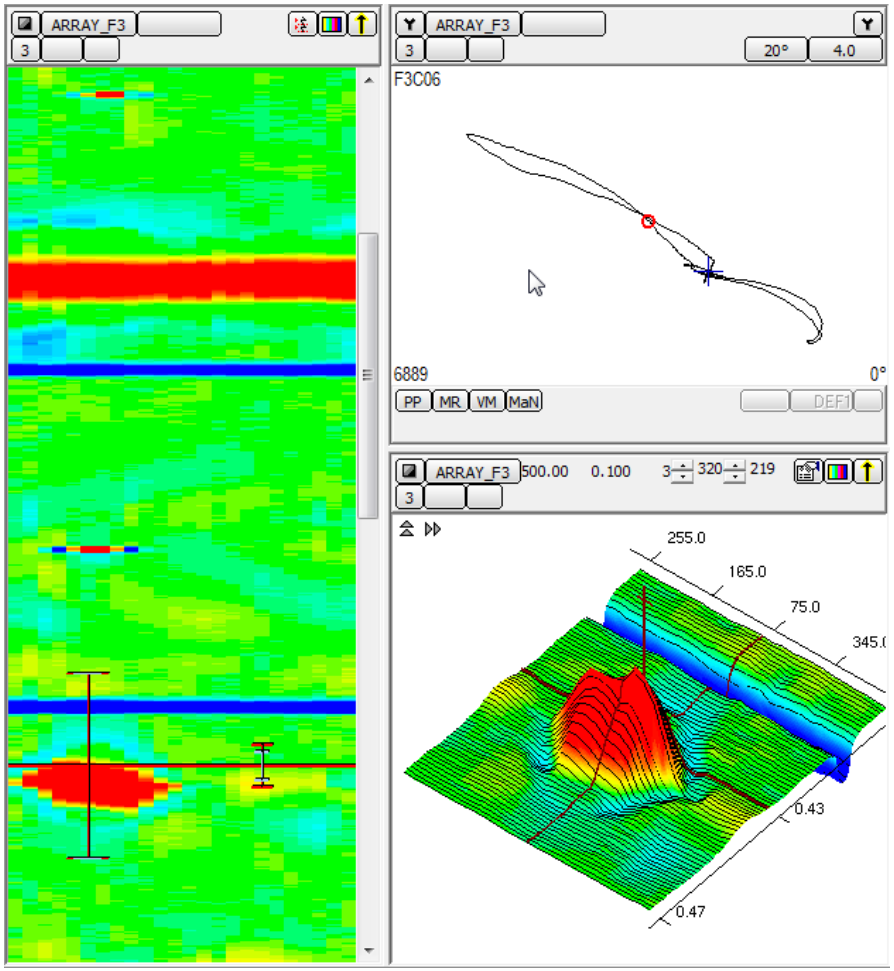
Circumferential Cracks

- Detection of external ED notch (0.005“ width)
  - 80% x 50°
  - 60% x 50°
  - 40% x 50°
  - 40% x 25°
  - 20% x 50°
- Bobbin results for the same defects



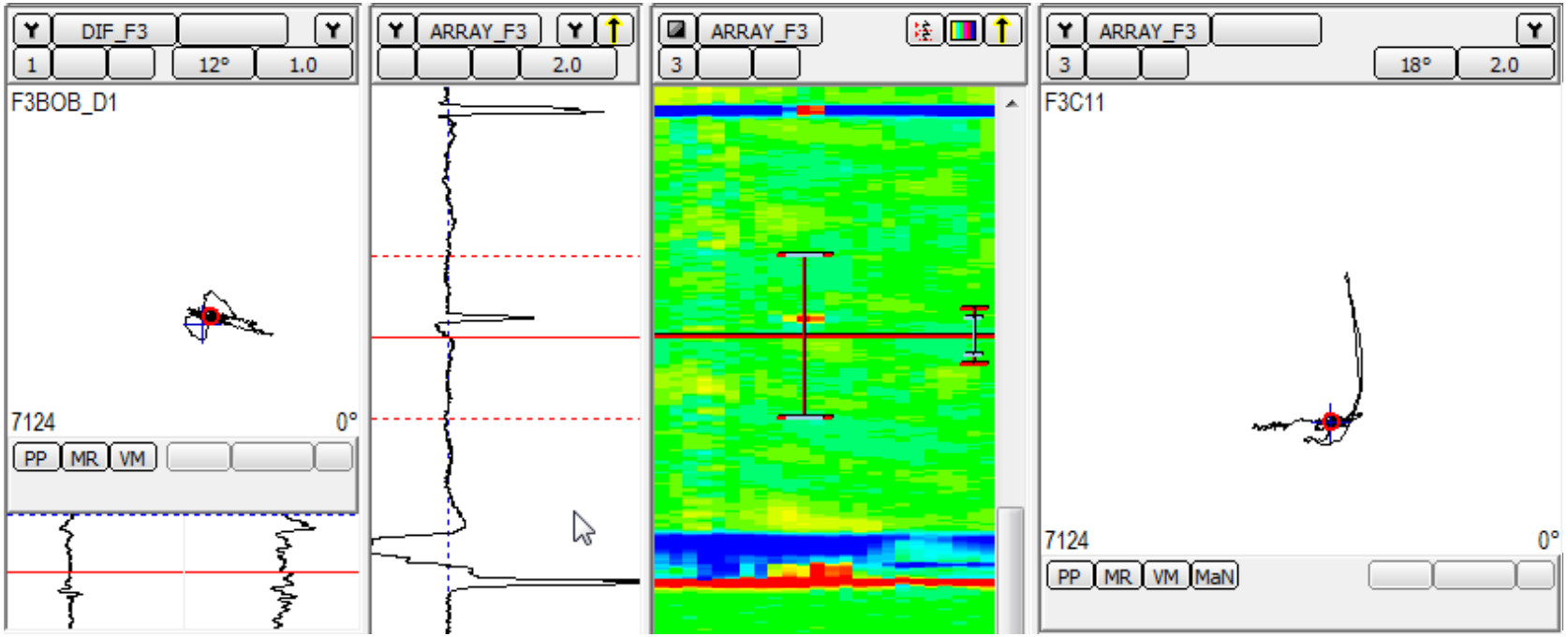
Taper Defects

- Since the probe provides an absolute signal, it is possible to see a representative profile of the defect.



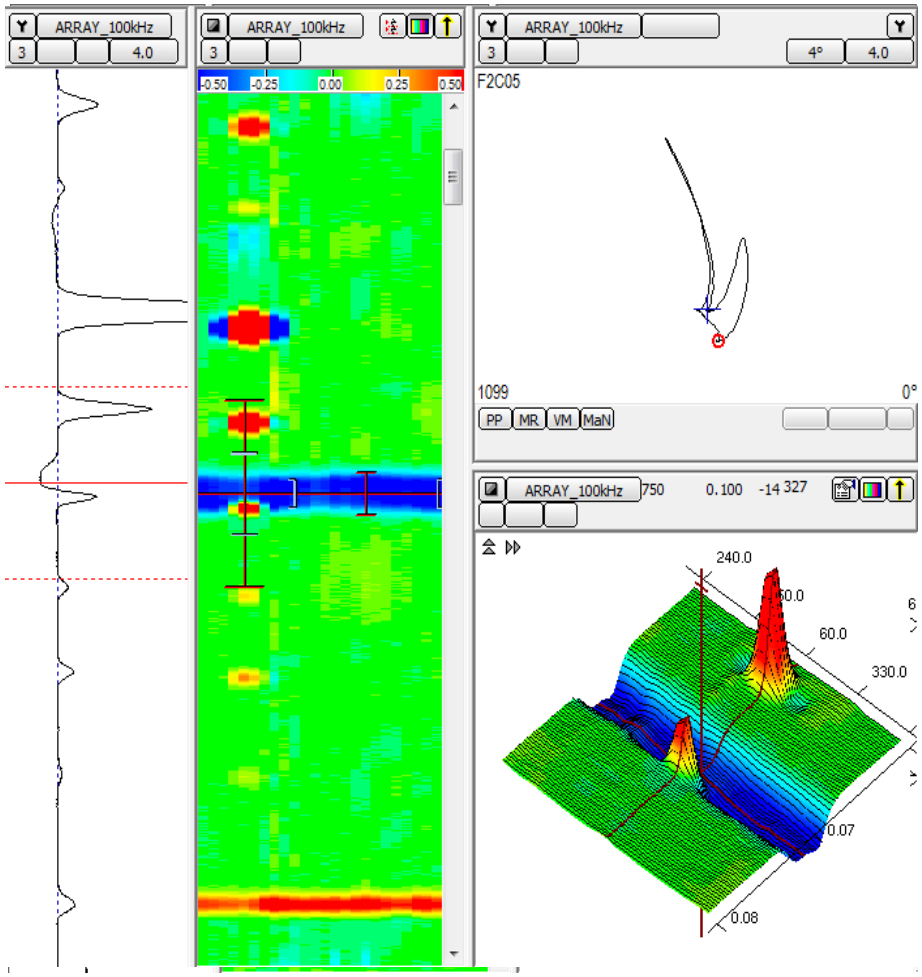
Shallow Small Defects

- The high resolution of the probe allows a better detection of small isolated pit
  - 20% ID round bottom hole, 0.125” diameter
  - 20% OD flat bottom hole, 0.125” diameter



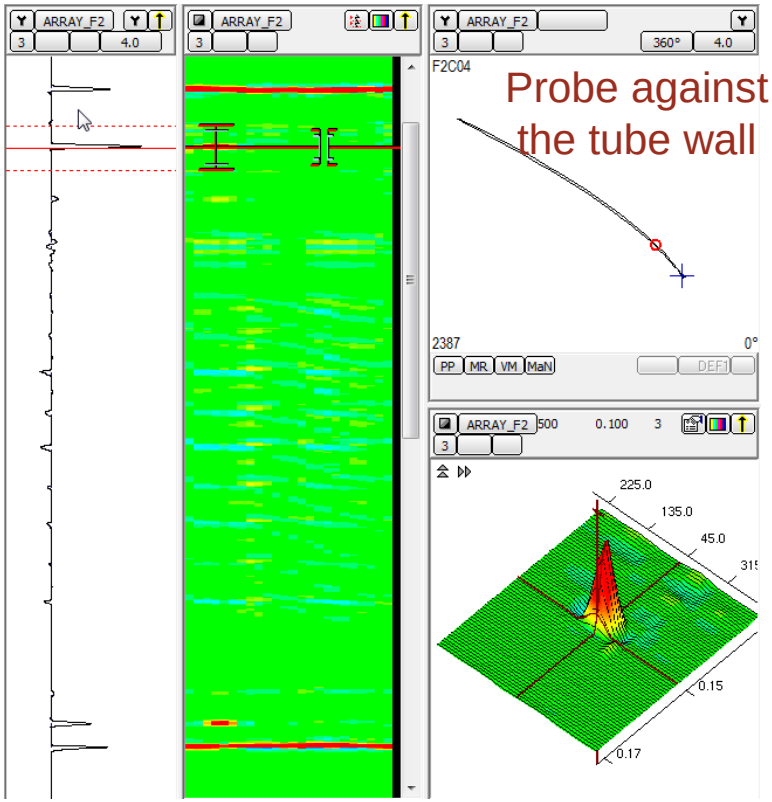
Defects at Support Plate

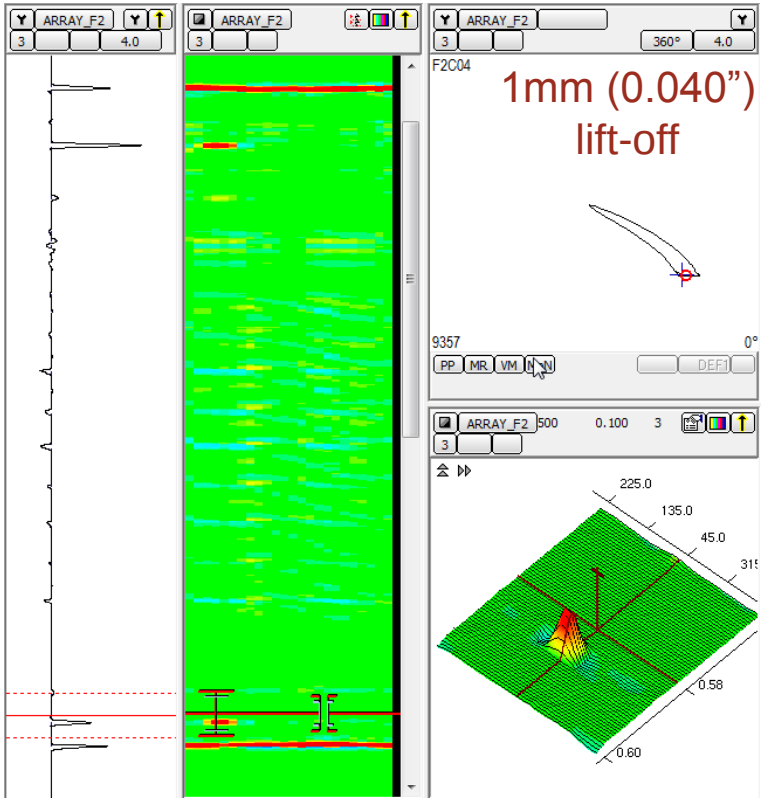
- Wear scars
  - 60%, extent: 270°
  - 20%, extent: 270°
- OD pits
  - 80%, diam.: 0.375”
  - 30%, diam.: 0.312”
- Circumferential crack
  - 60%, extent: 50°



Sensitivity vs Lift-Off

- Defect phase angle is constant even with high lift-off variation providing reliable depth sizing.

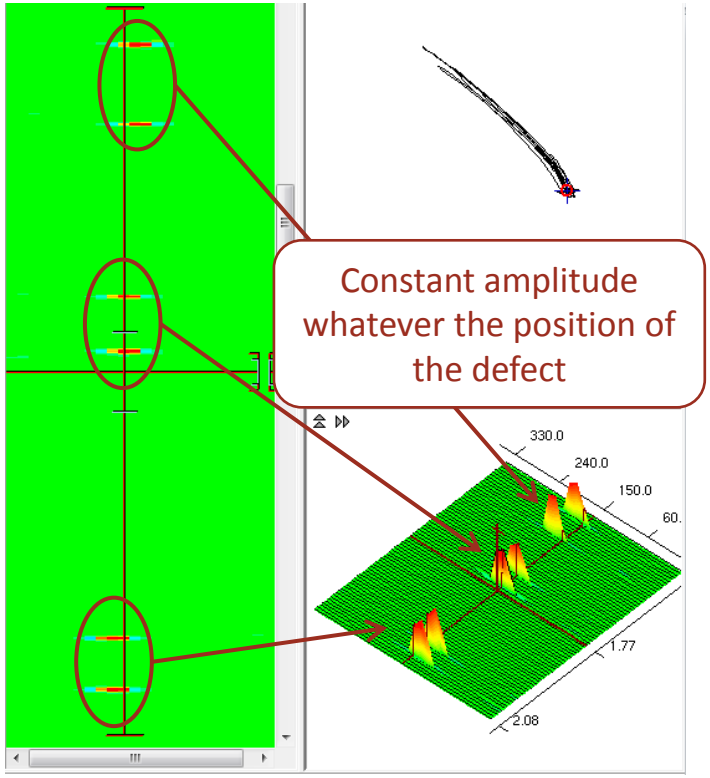




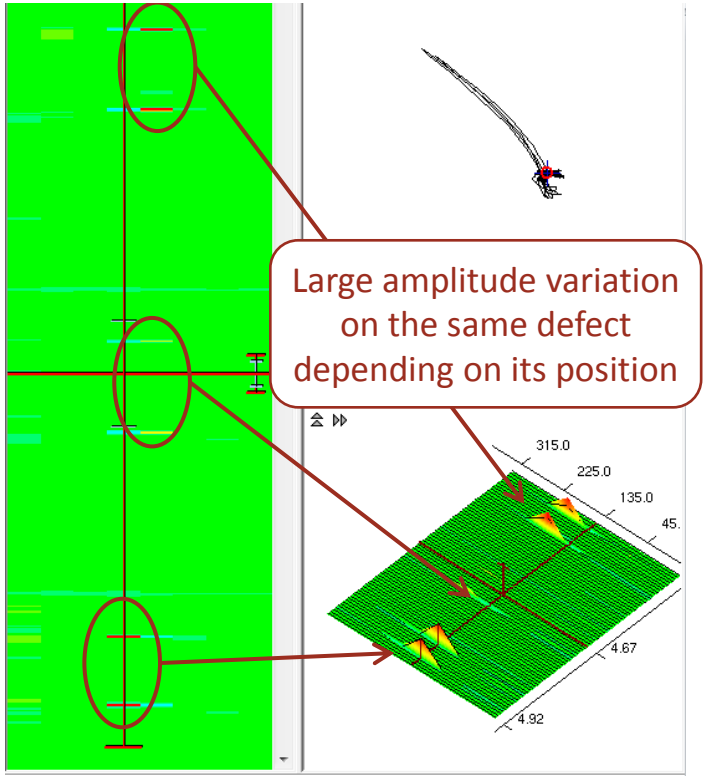
High Resolution Value

- Reliable and repeatable detection

  ASME hole scanned 3 times with 15° rotation



DefHi probe with 24 channels

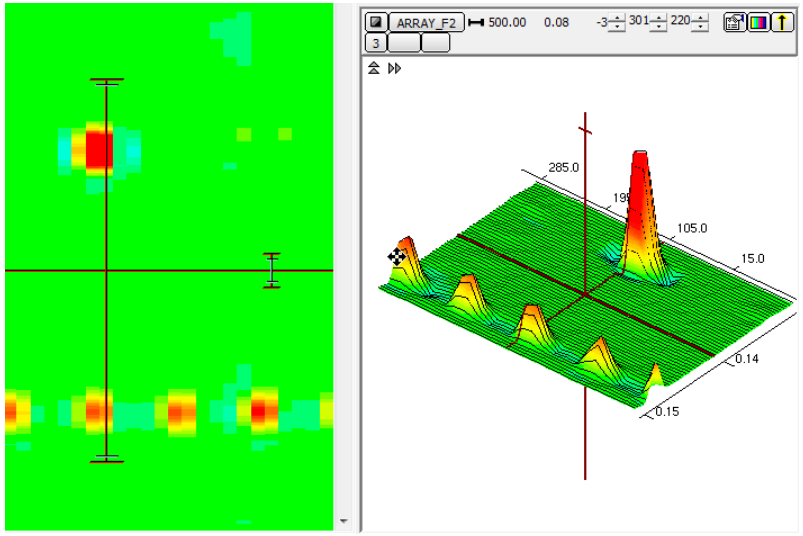


8 channels array

High Resolution Value

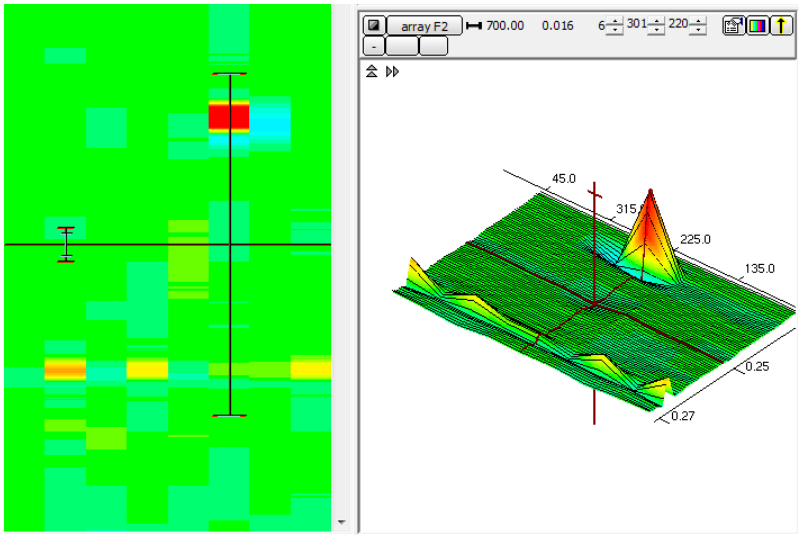
- Improved defect representation in C-scan
  ASME 40% FBH and 4 x 20% FBH

Several coils see the defects providing uniform response



DefHi probe with 24 channels

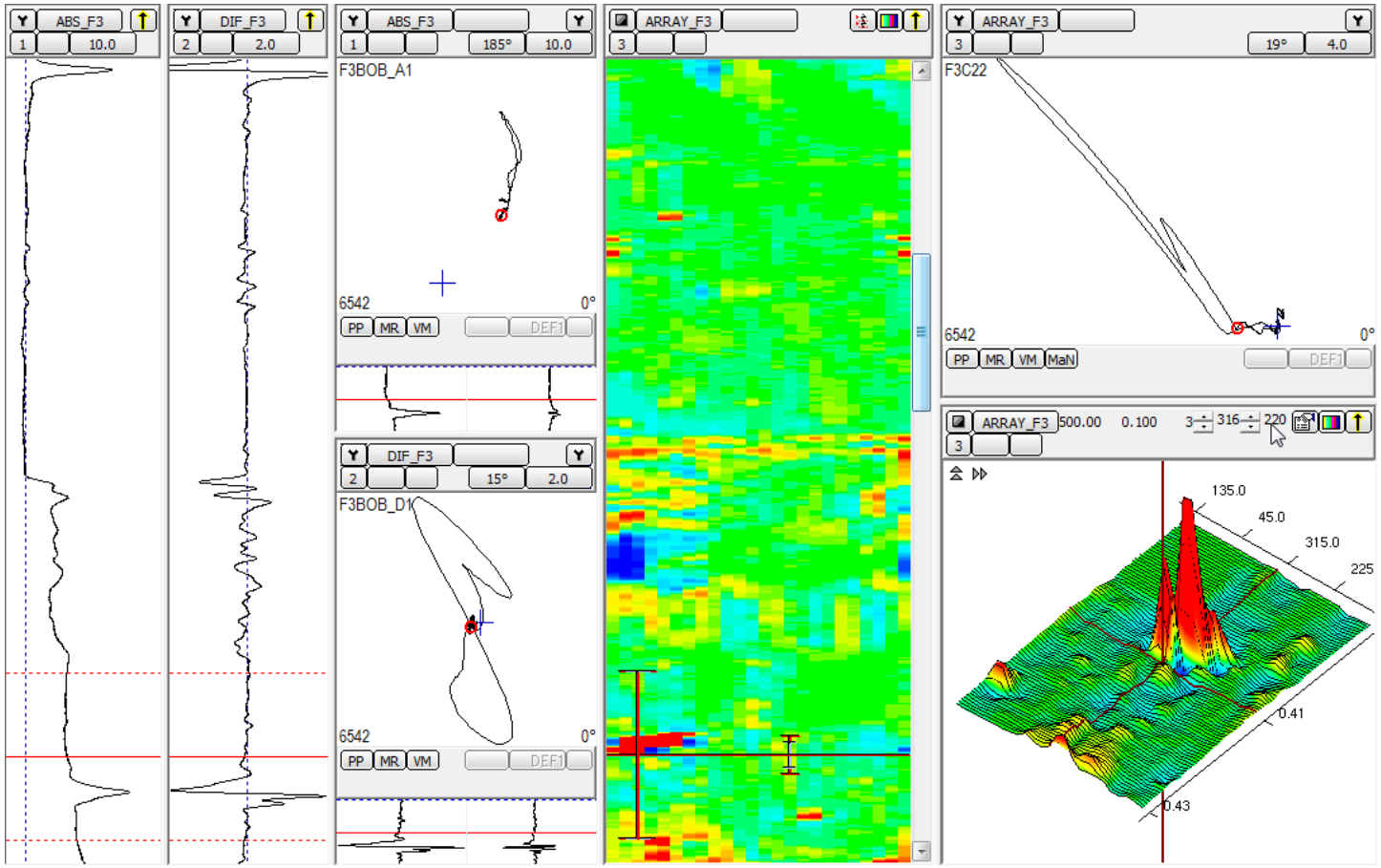
Only one coil can see the defects resulting in non uniform signature.



8 channels array

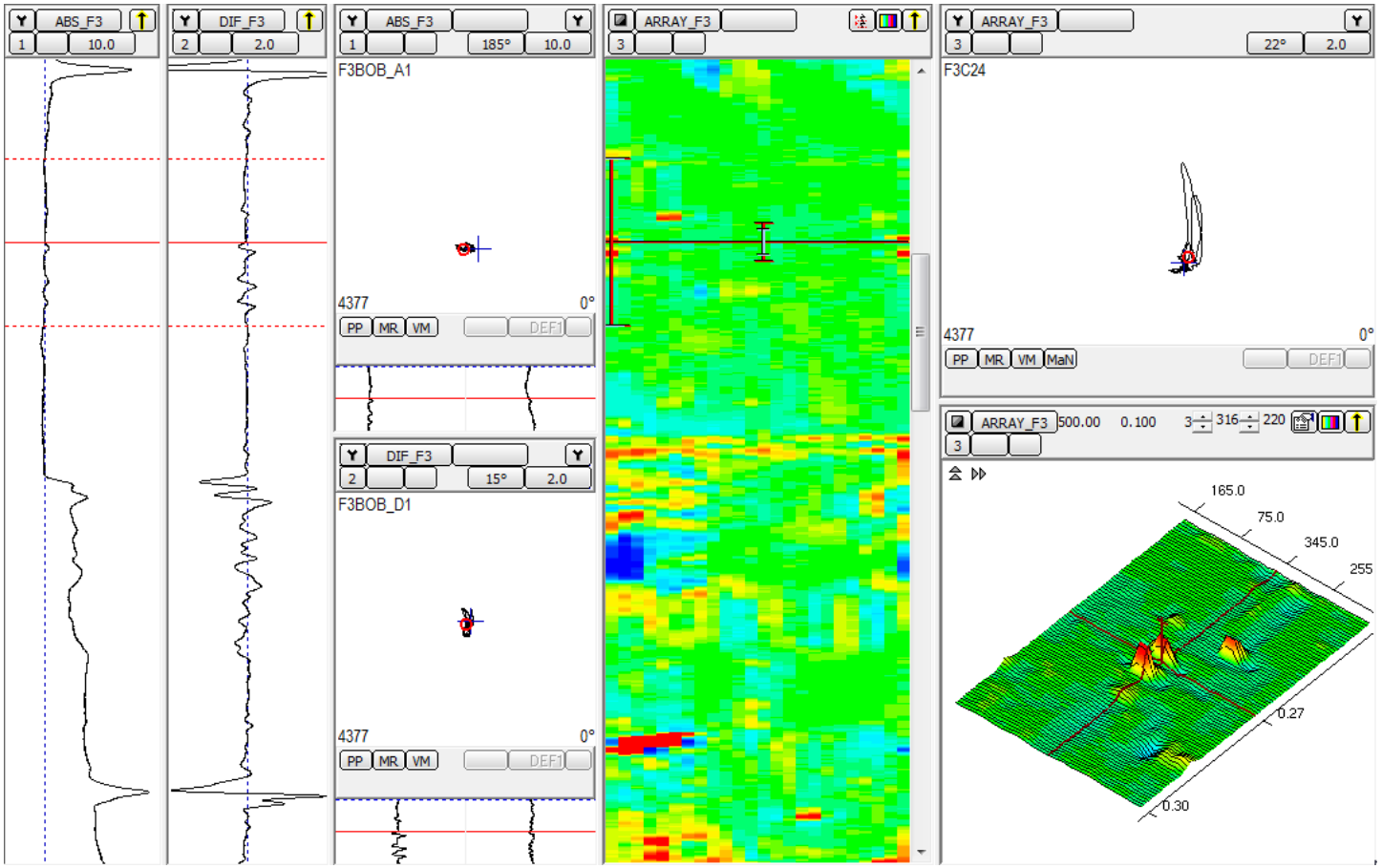
Data from real tube

- Deep OD defect, large volume



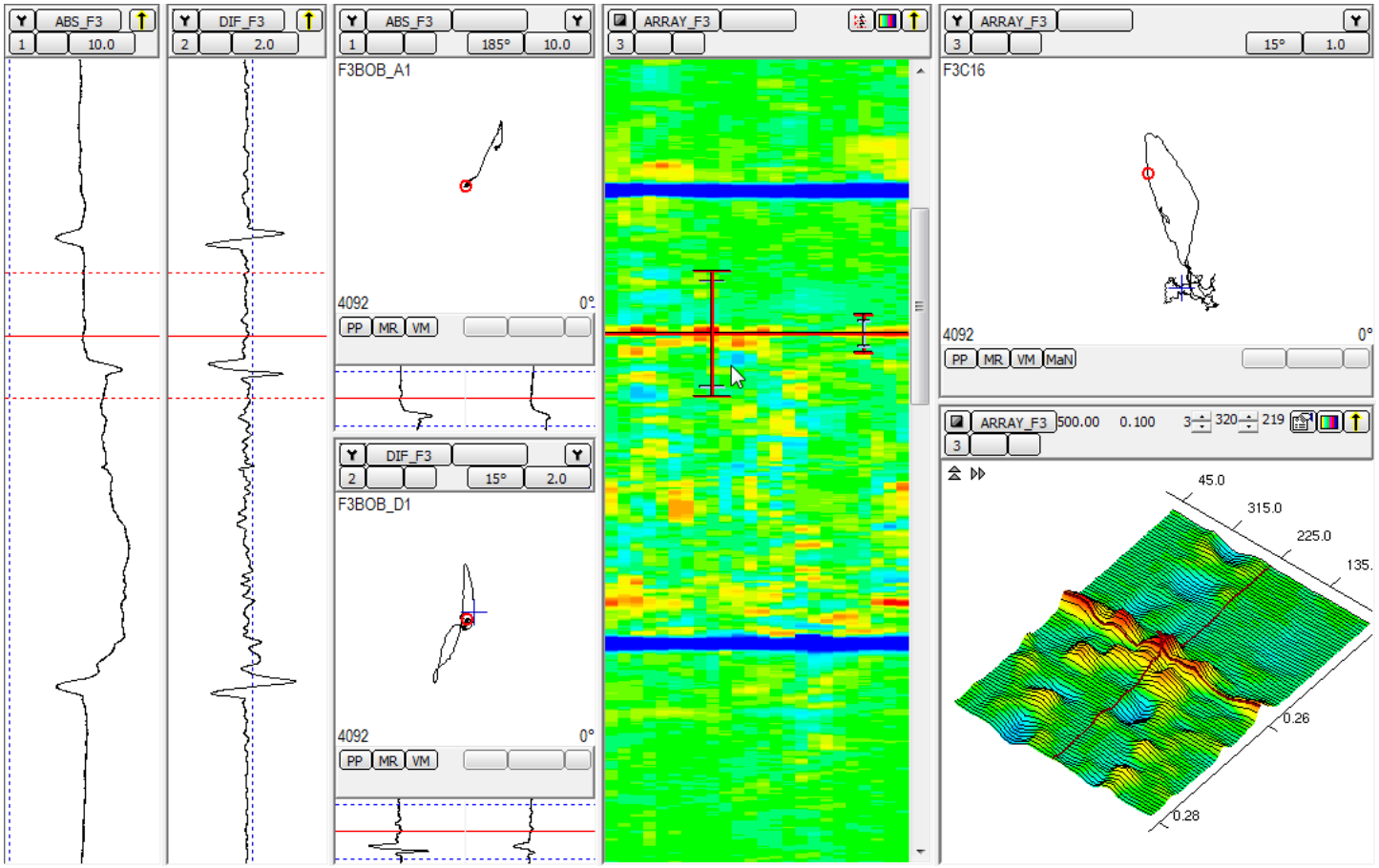
Data from real tube

- Shallow isolated OD pits



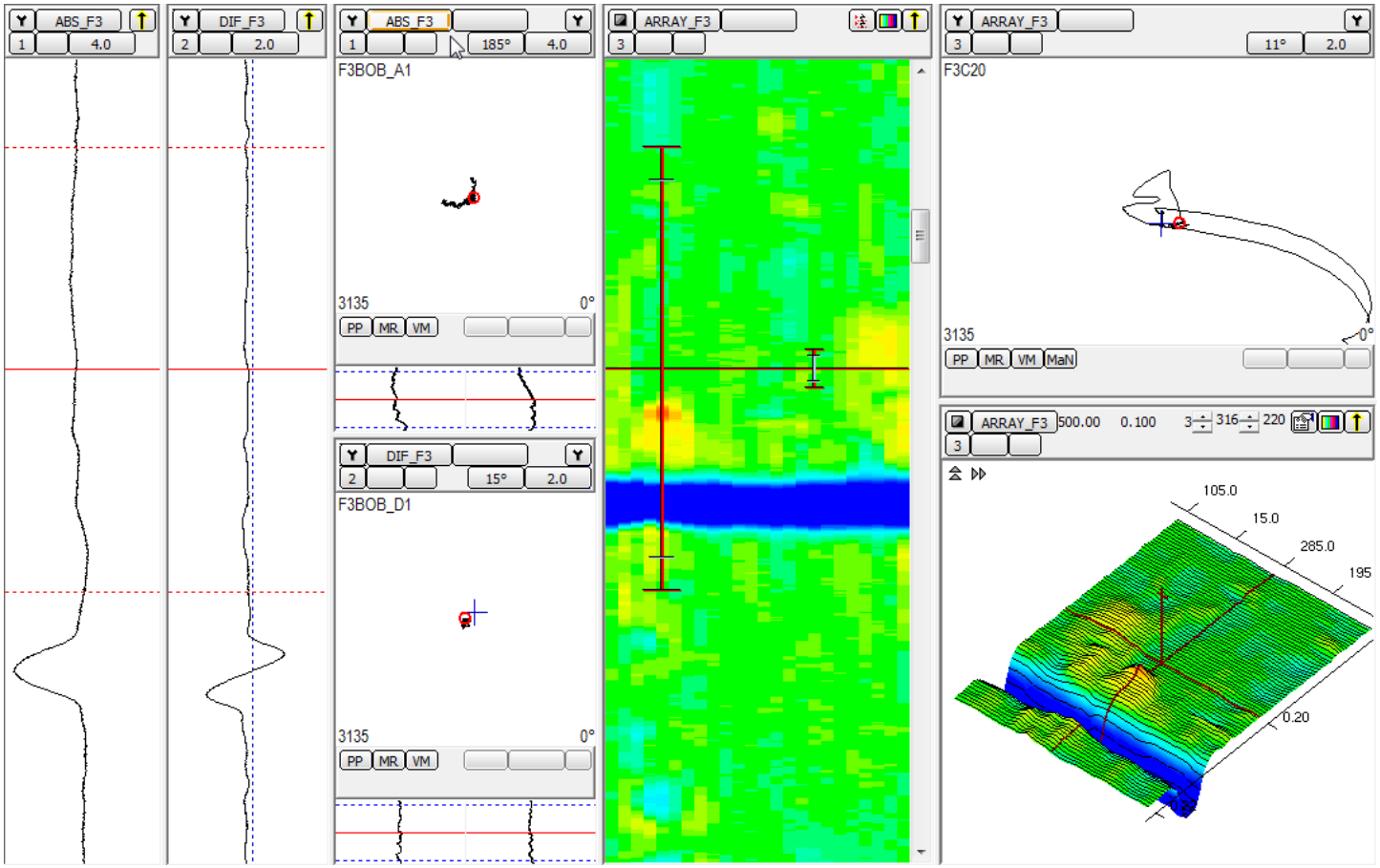
Data from real tube

- OD general corrosion



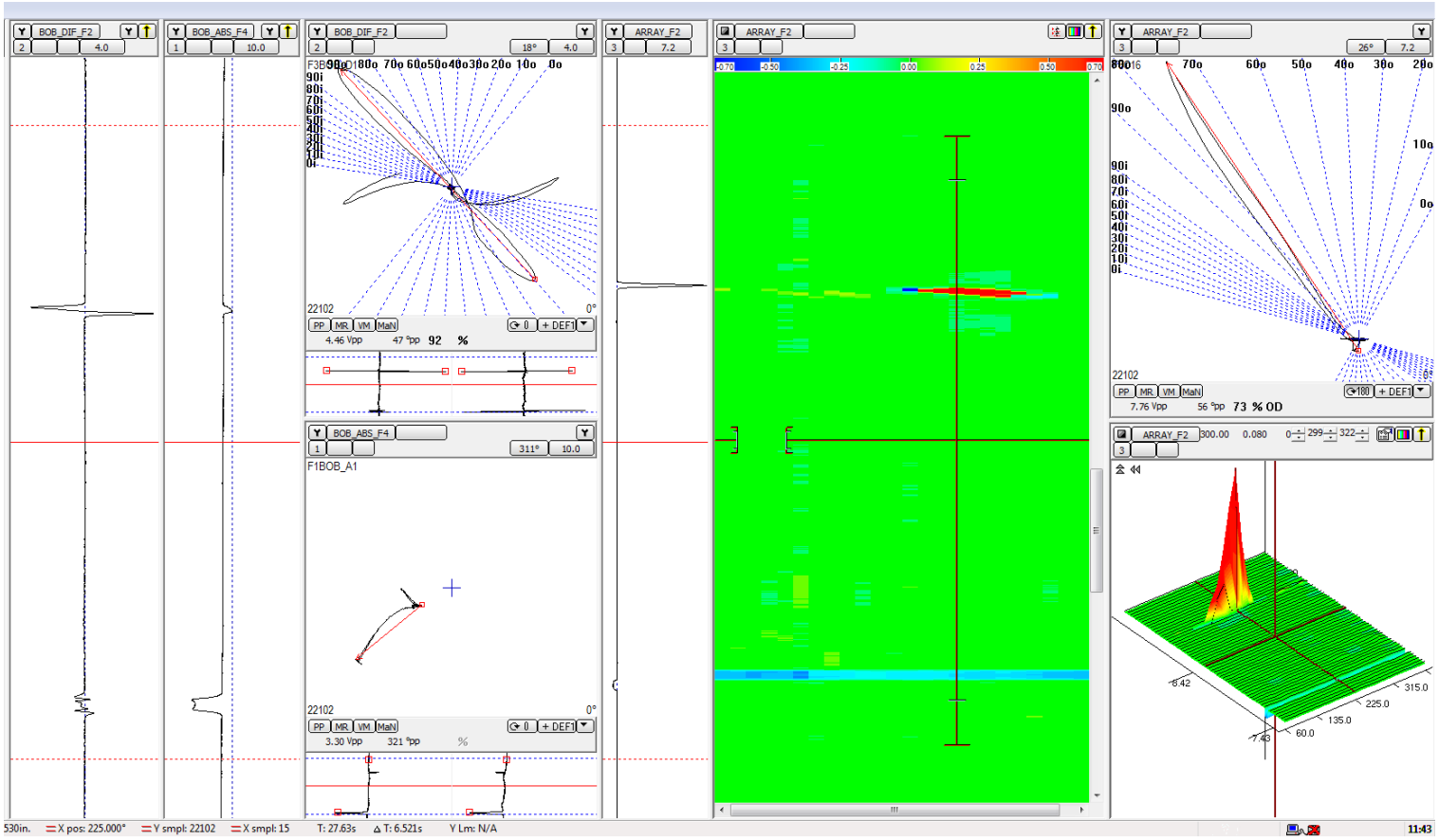
Data from real tube

- OD Pit close to the TSP not detected with the bobbin



Data from real tube

- OD Isolated Pit / Corrosion – Field Tube



Conclusions

The DefHi eddy current array probe provides several benefits for non-ferrous tubing inspection:

- One-pass inspection providing bobbin and array probe signal
- High definition which provide reliable and repeatable detection of small defects whatever the position around the circumference
- High sensitivity to pitting and circumferential cracking (ID and OD circ. crack detected down to 20% depth and 25° extension)
- More reliable characterization of flaws with C-scan imaging
- Improved detection of circumferential cracking under tube sheets