Ultrasonic in-ditch Inspection Techniques

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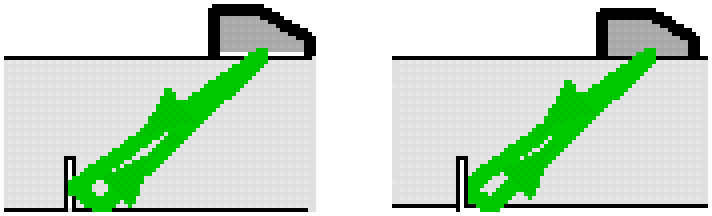
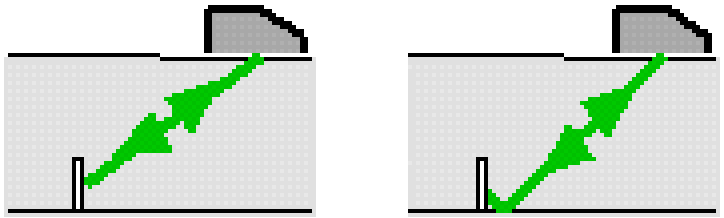
Outline

- Shear Wave
- Time of Flight Diffraction (ToFD)
- Phased Array (PA)
- Acoustic Imaging
  - Inverse Wave EXtrapolation (IWEX)
  - Full Waveform Capture (FWC)
  - Full Matrix Capture (FMC)
  - Total Focusing Method (TFM)

Shear Wave Inspection



Corner Reflection



Tip Diffraction

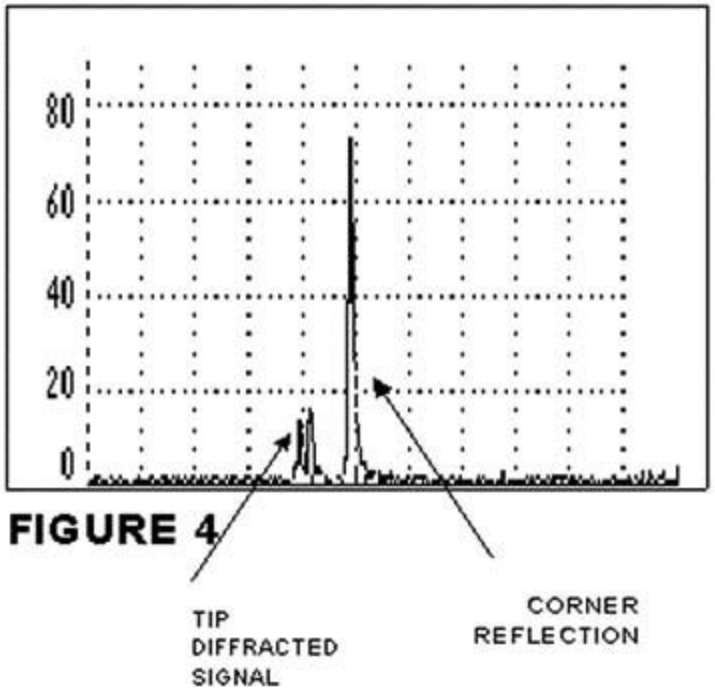
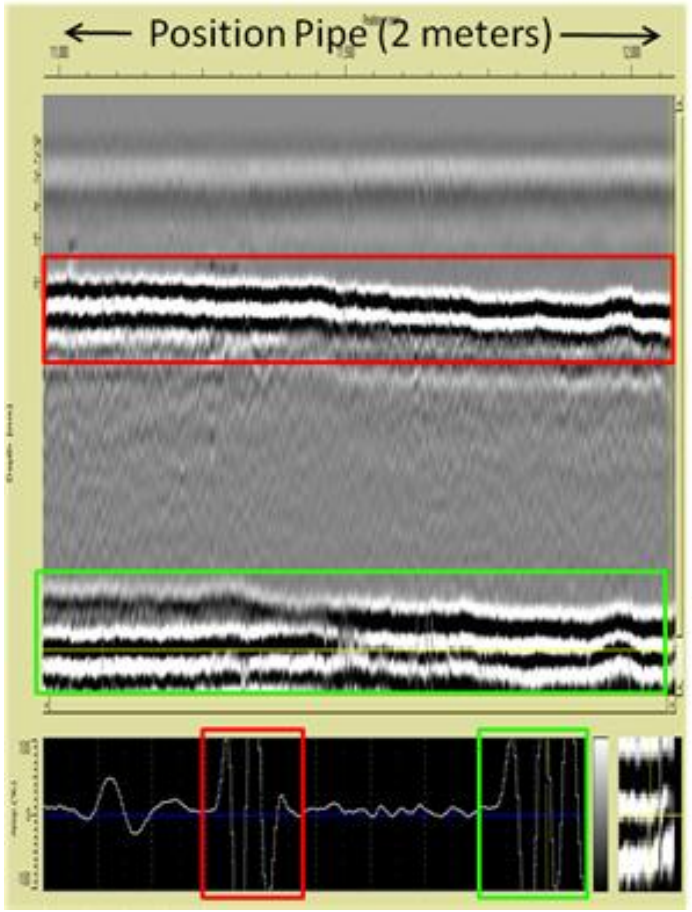
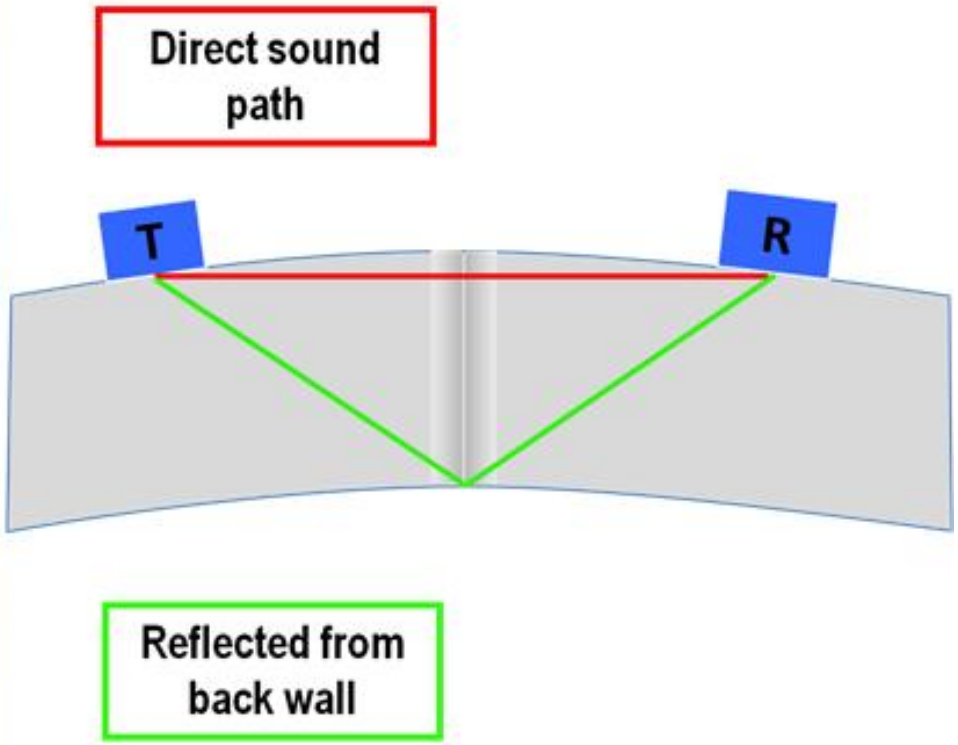


FIGURE 4

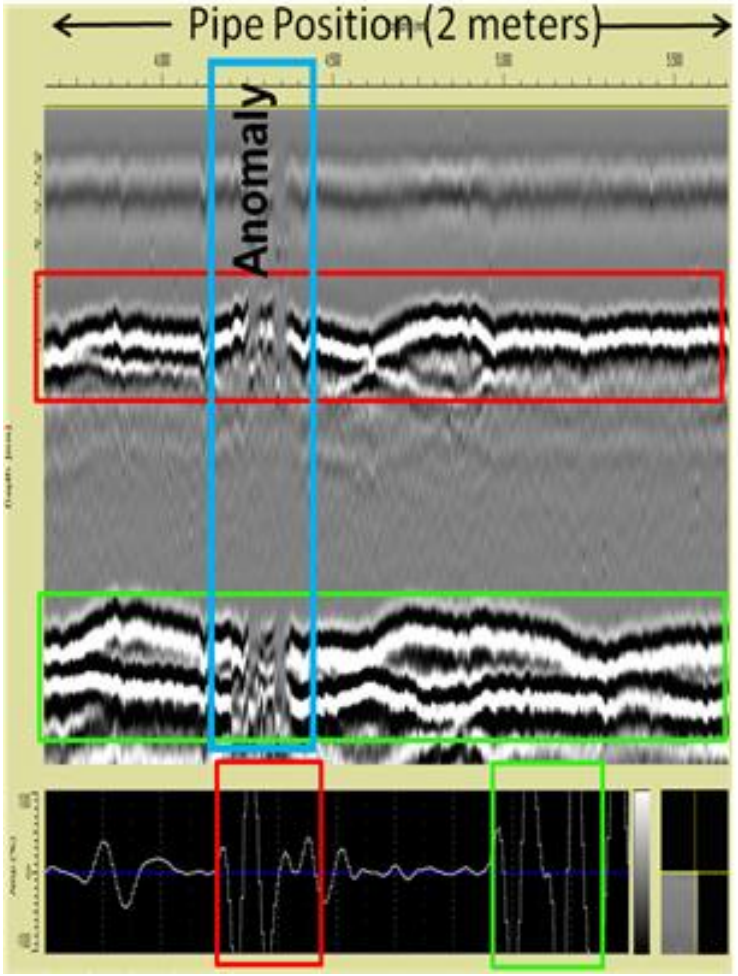
Time of Flight Diffraction (ToFD)

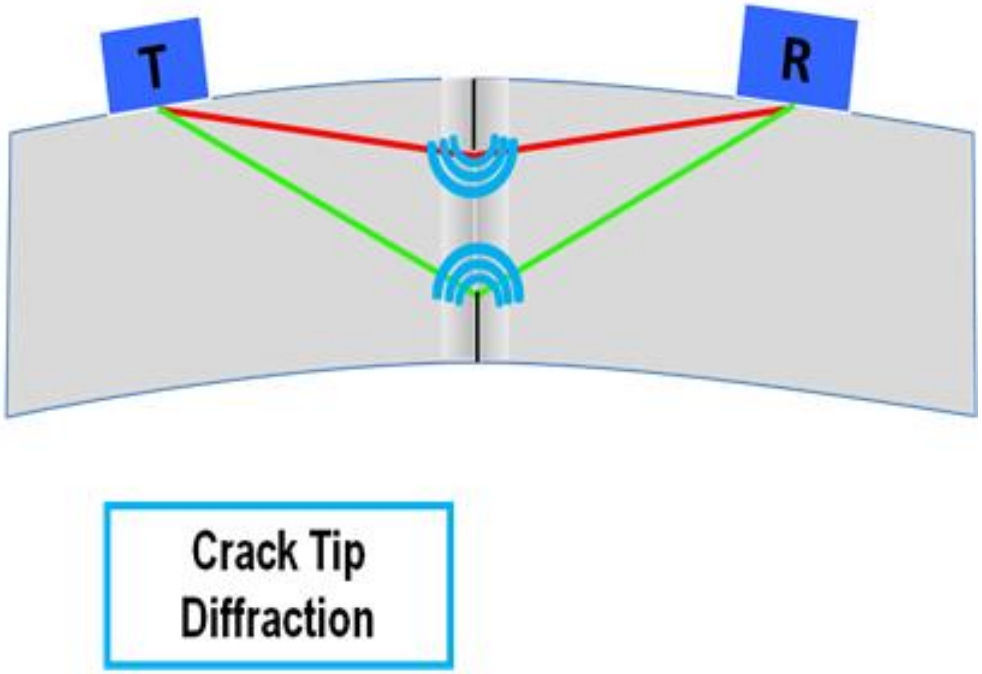




- ToFD works by comparing arrival times from direct arrivals and reflections off the back wall to diffracted signals.

ToFD Diffracted Signals

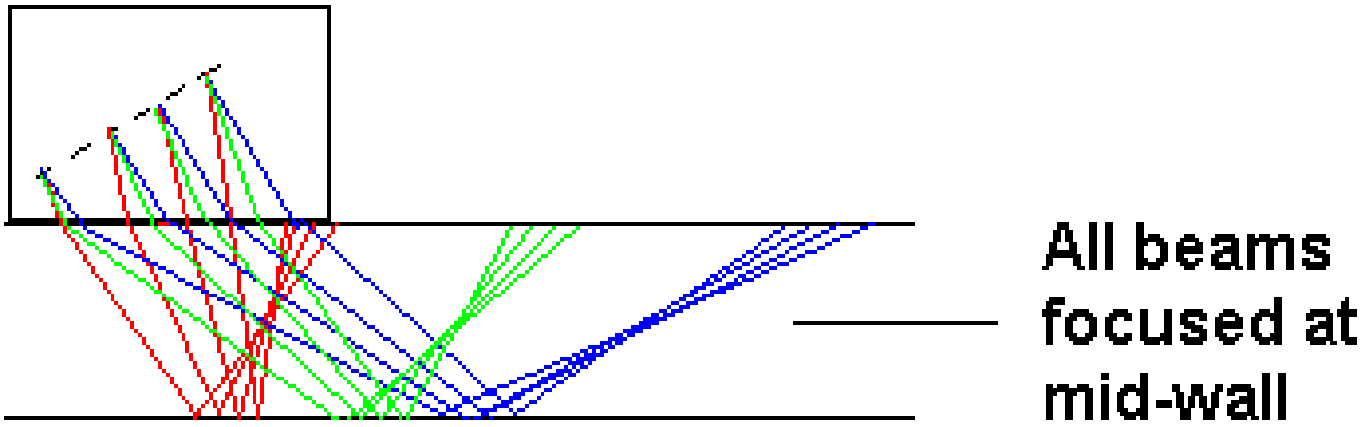




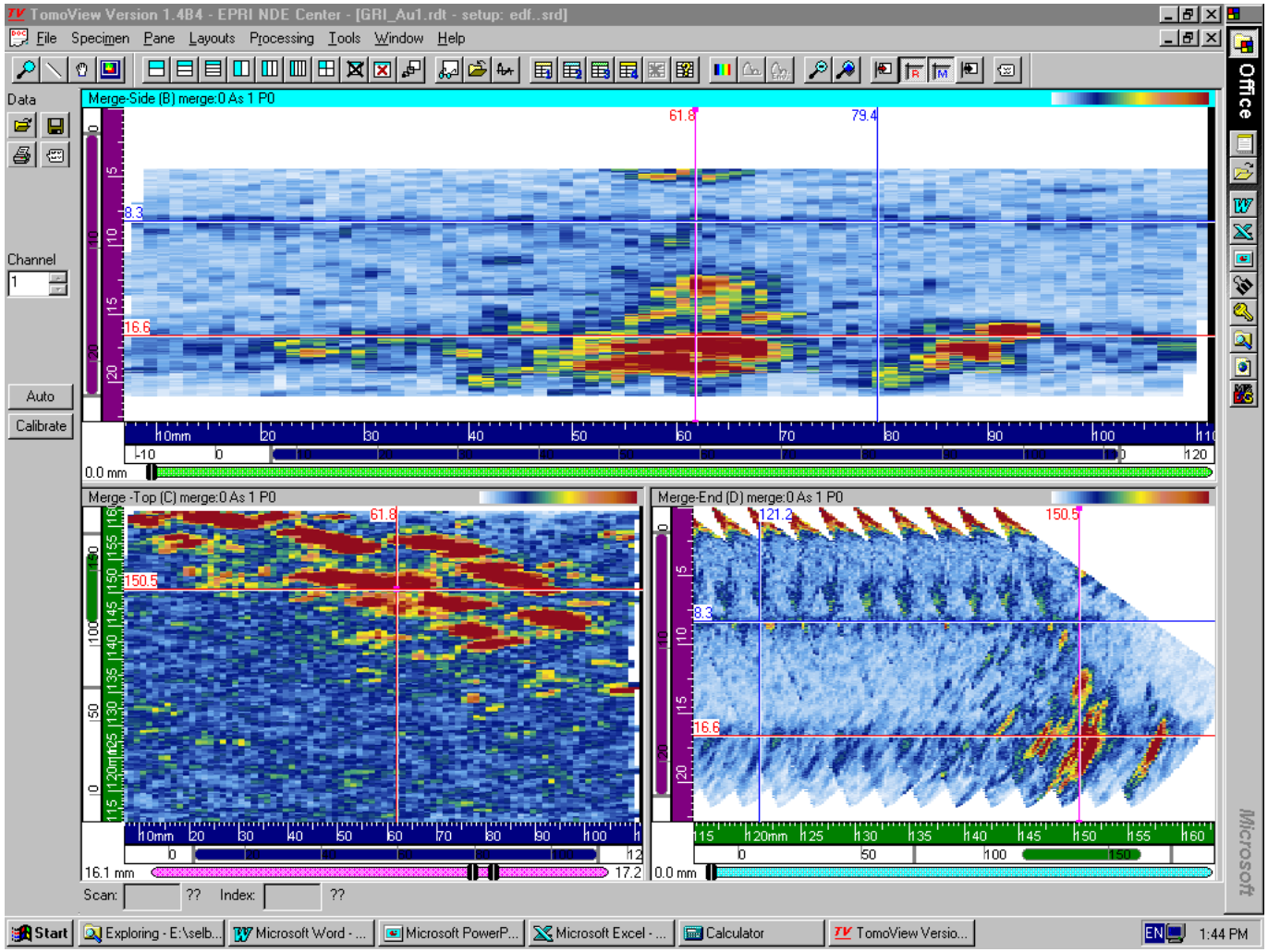
- Diffracted signals arrive after the direct arrivals but before the reflected signal off the back wall

Phased Array Transducers

- Sub-elements can be fired at precise times to focus the beam
- Focused at mid-wall for maximum tip resolution (only 3 of many foci shown for clarity)

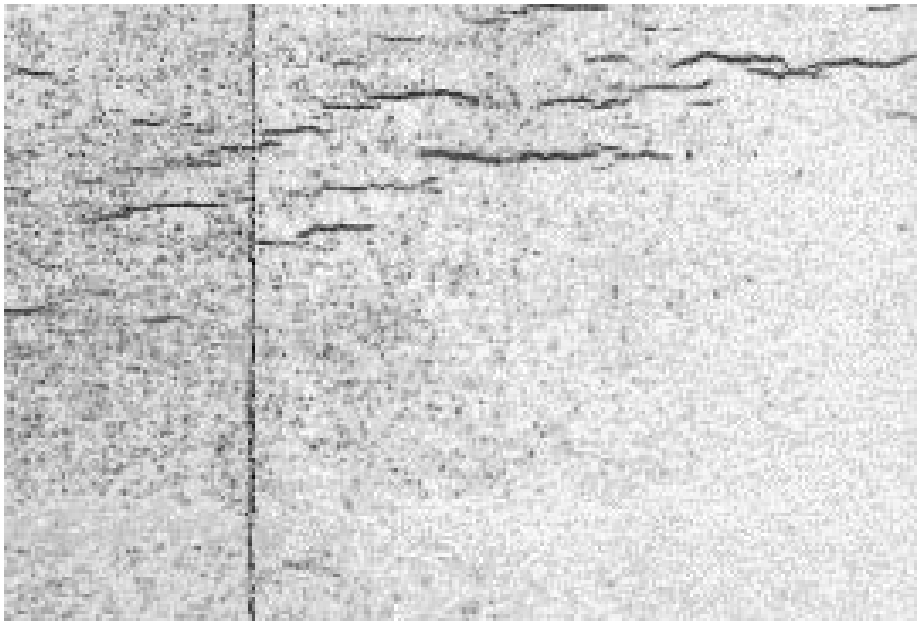


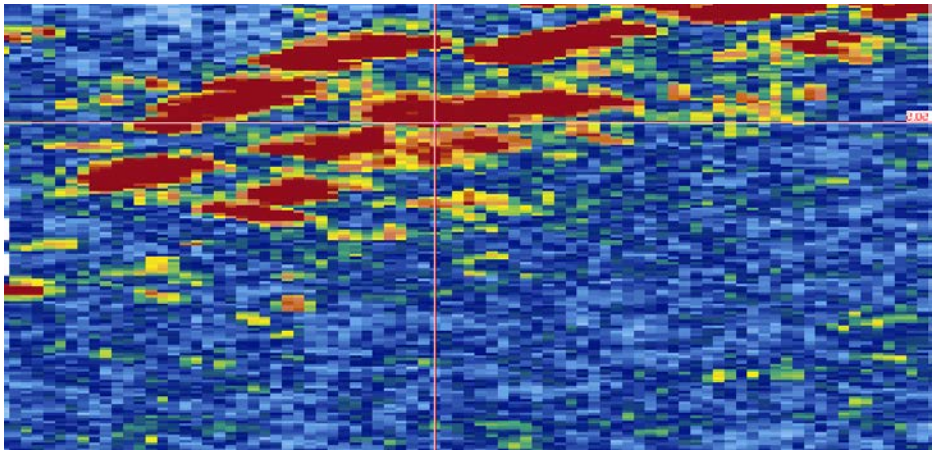
Phase Array Imaging



Sample result:
Specimen
1093 30B2,
near location 1

Plan View Comparison

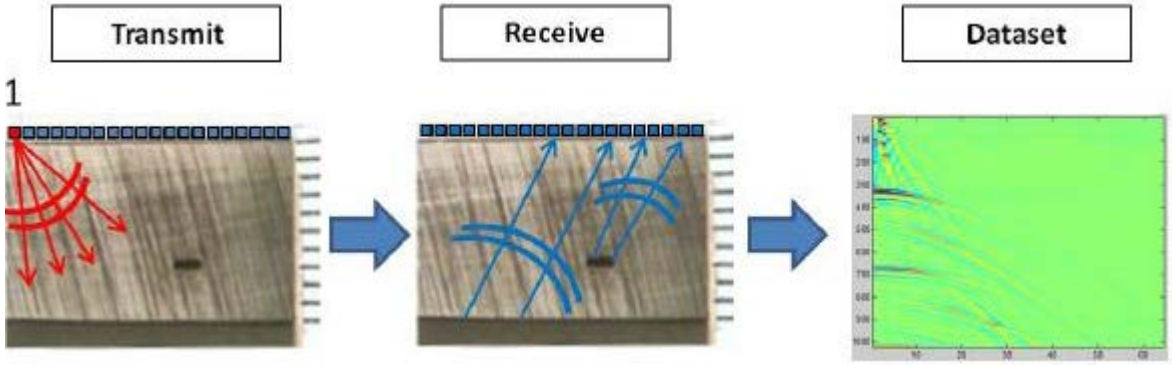




- The plan view of the outside surface from phased array can be compared to actual to a magnetic particle photo of the surface

Full Waveform Capture Imaging

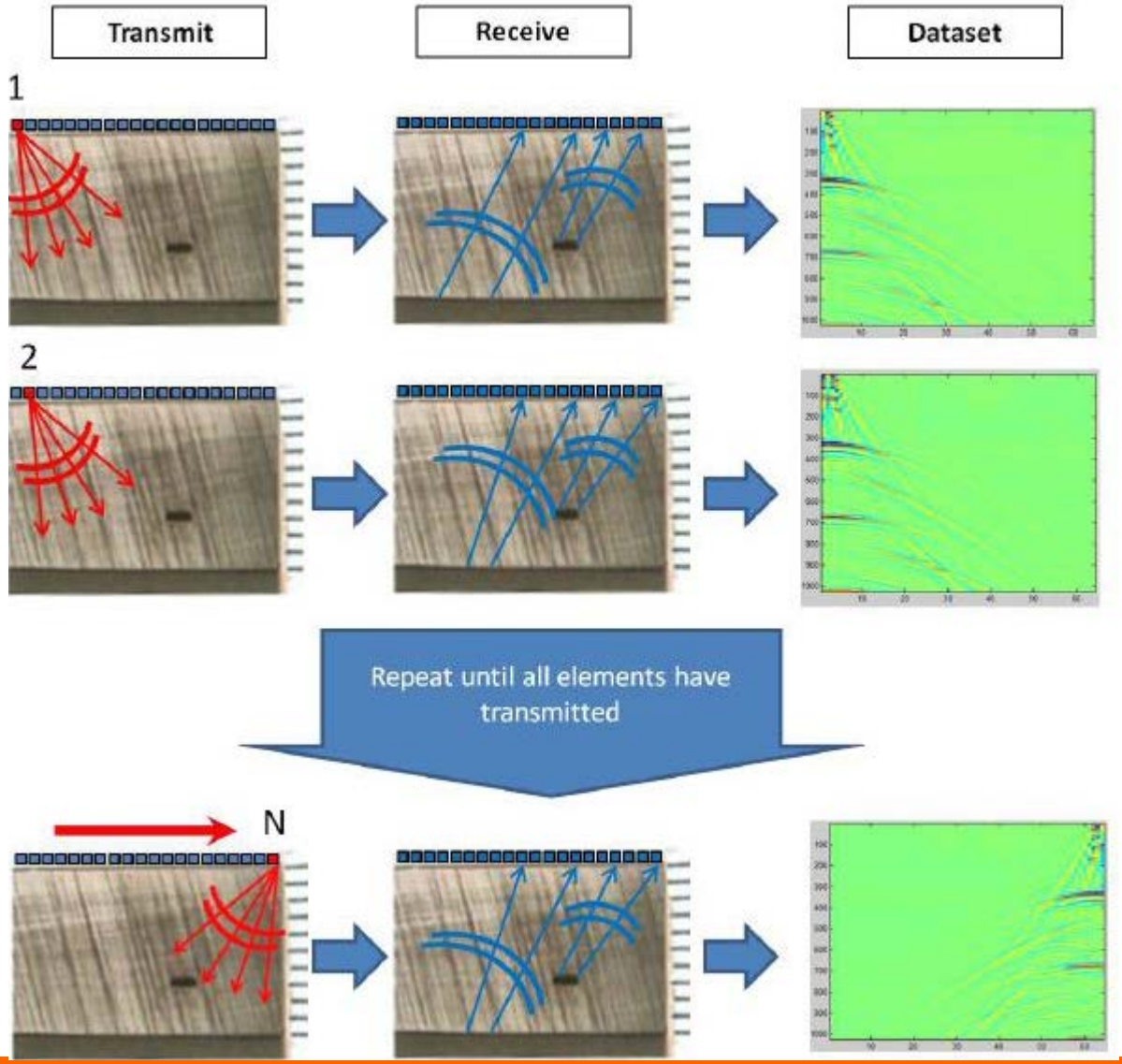
A transducer element is fired and the reflection waveform is recorded for all the other transducer elements



X. Deleye, L. Hörchens, and K. Chougrani, *Comparison of Ultrasonic Imaging with other Advanced Ultrasonic Inspection Techniques,* **2012, WCNDT Durban**

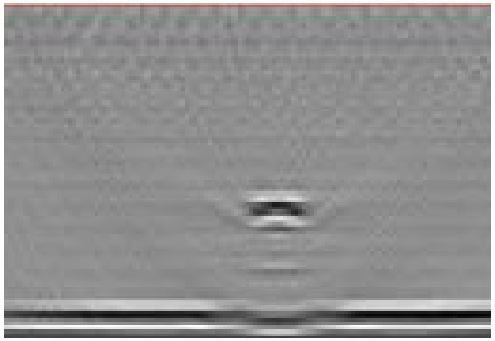
IWEX Imaging Technique

Each of the other transducer elements are subsequently fired and the reflection waveform is recorded for all the other transducer elements

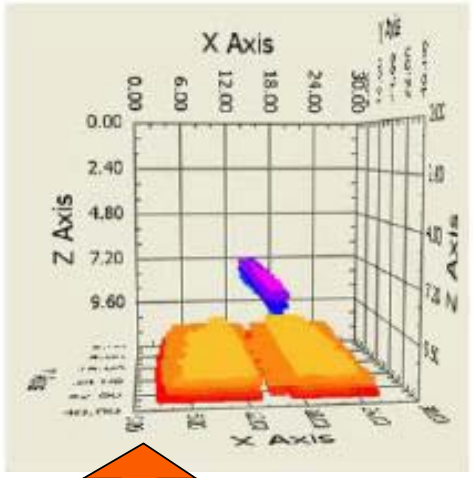


Macro

2D scan



3D scan

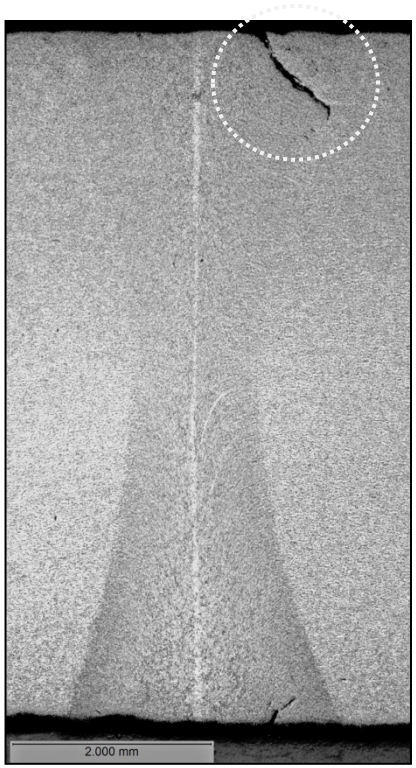


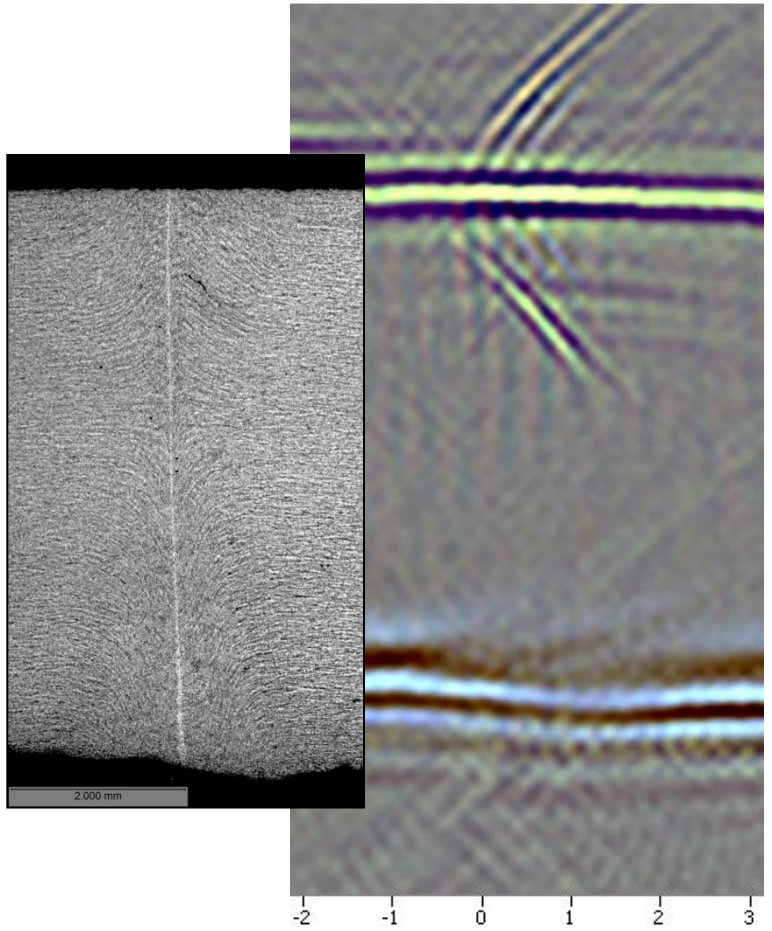
IWEX data

IWEX algorithm
(Rayleigh Integral)

3D reconstruction
from multiple 2D images

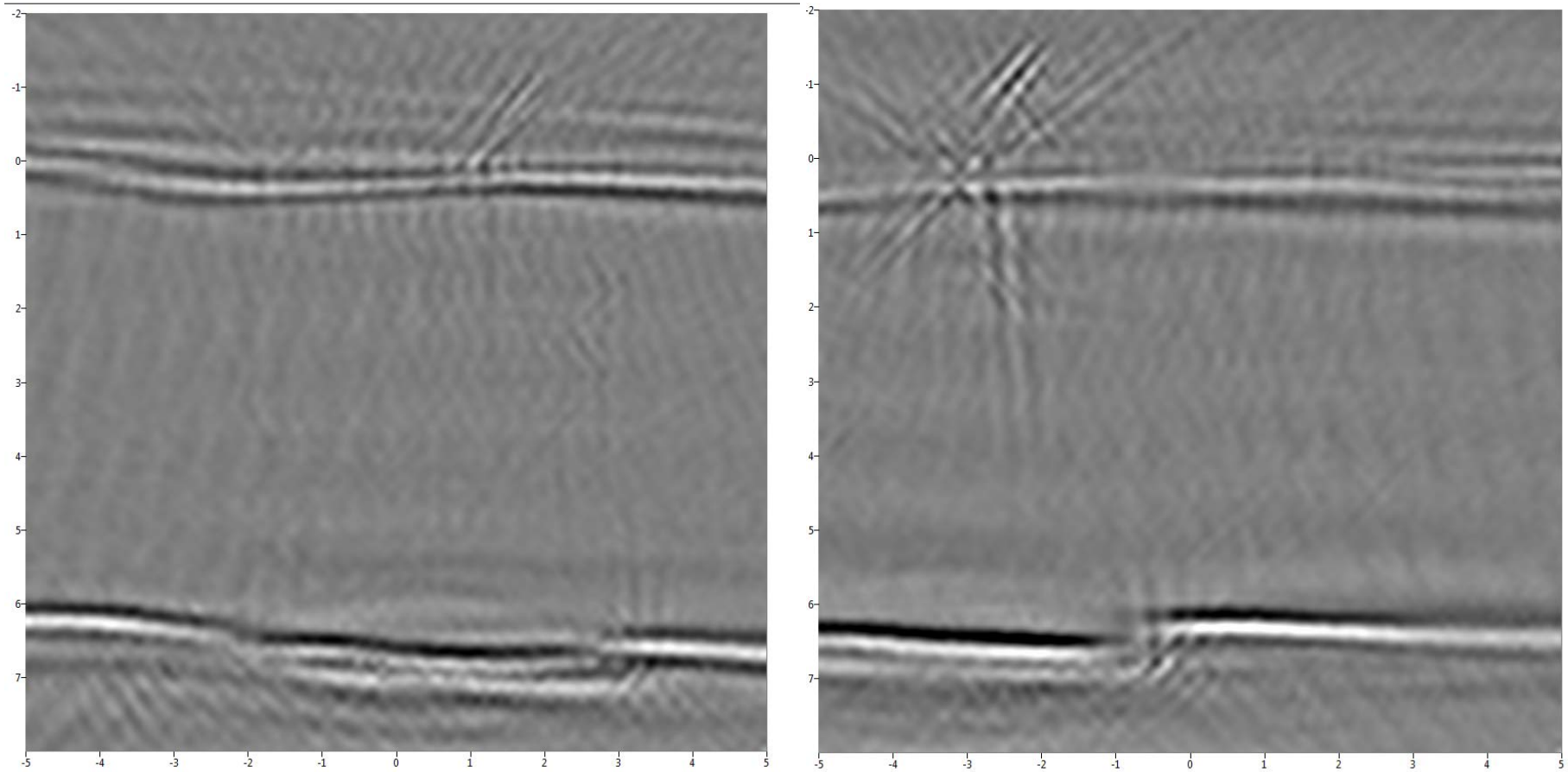
Comparison of Laminations and Hook Cracks with IWEX images





- Munendra S Tomar, NOVELL INSPECTION TECHNIQUE HELPS MANAGE LOW FREQUENCY ERW/EFW SEAM INTEGRITY, Rio Pipeline Conference, Sept 2013, Paper IBP1546_13

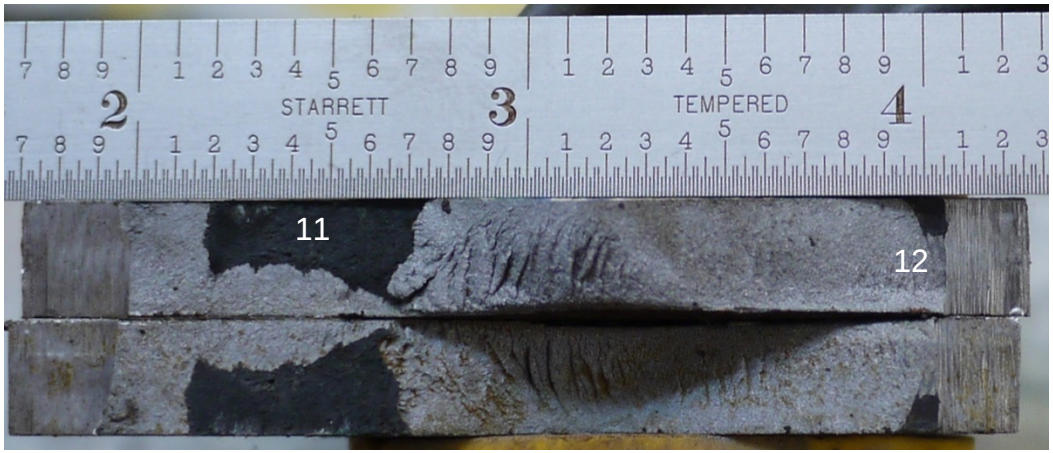
PHMSA Contract: DTPH56-13-T-000008



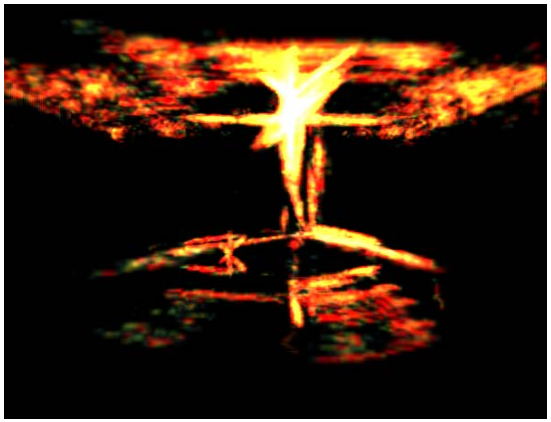
IWEX cross-sections for 16-in x 0.250-in (6.2 mm) pipe with no defect (left) and lack of fusion and poor I.D. trim (right)

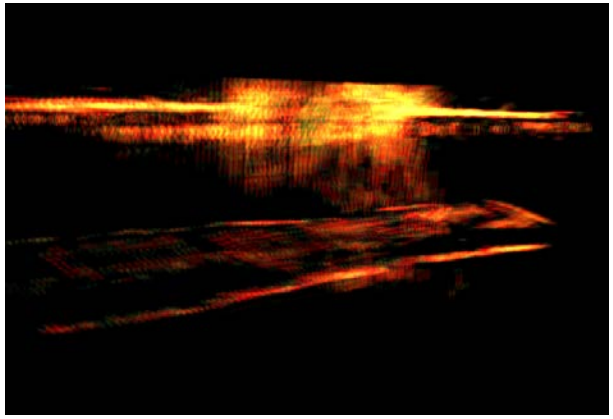
Defect # 11

Metallographic break

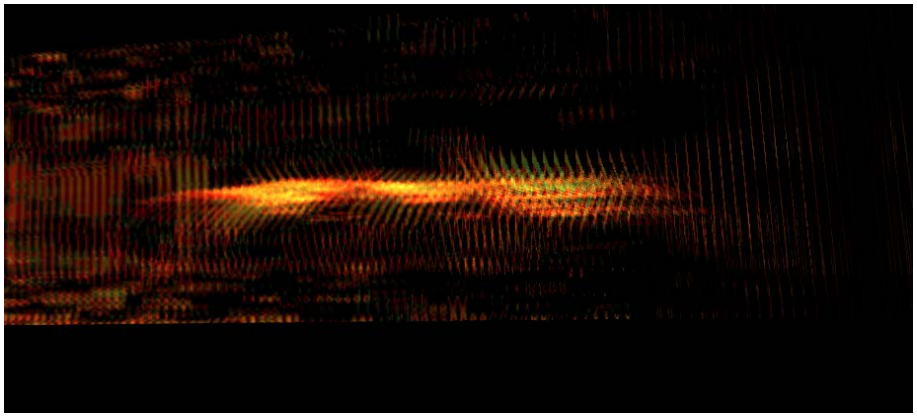


IWEX 3D end view



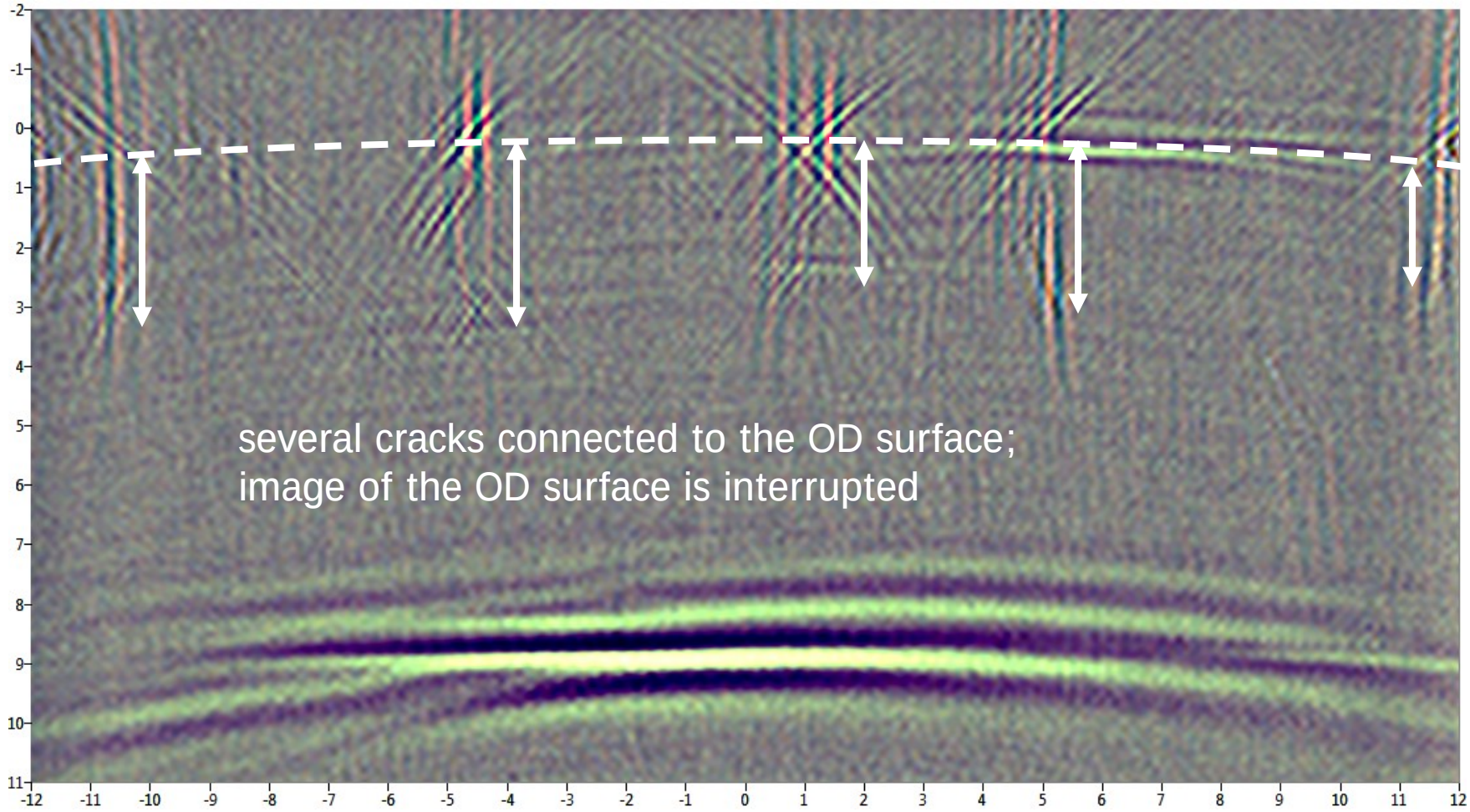


IWEX 3D side view



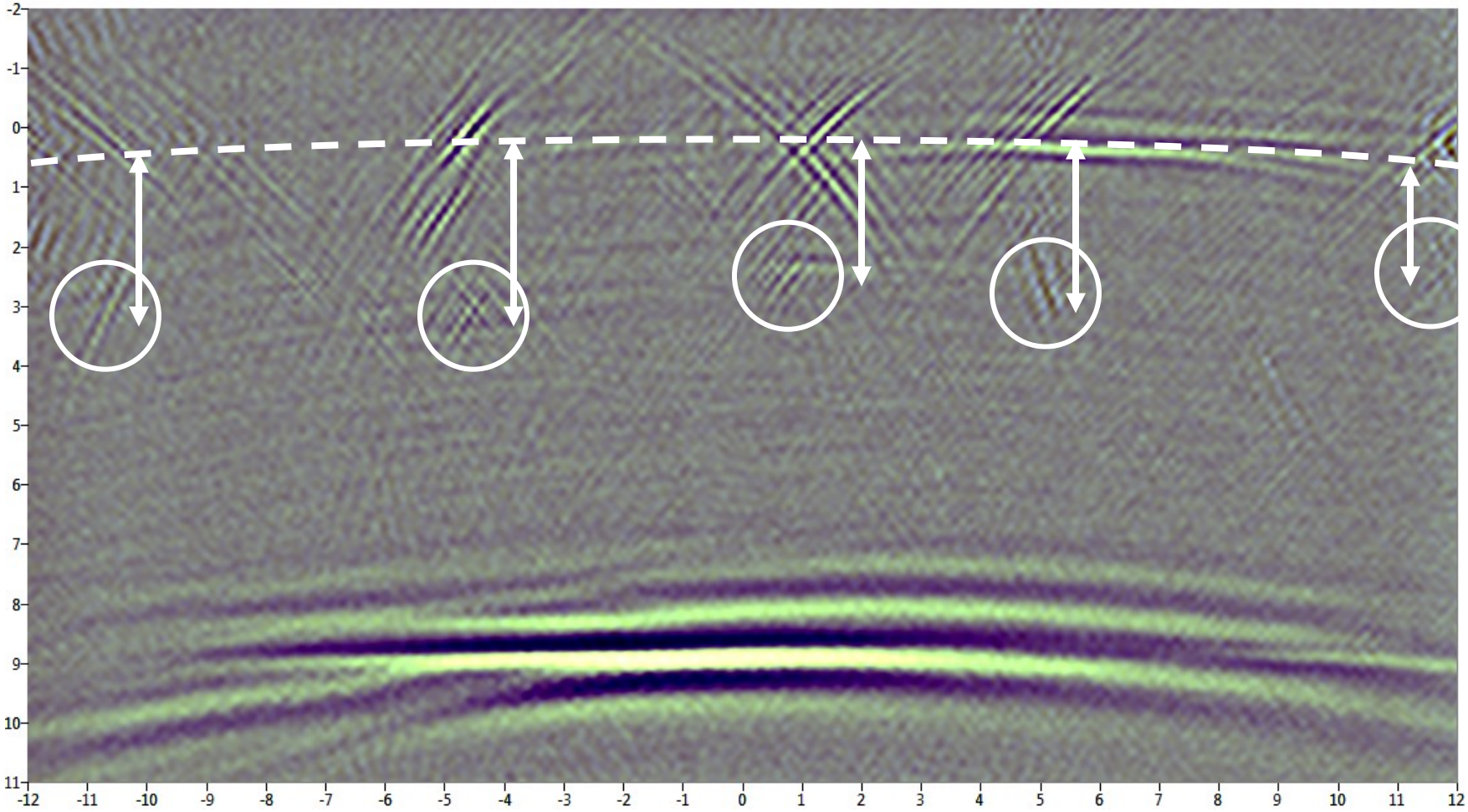
IWEX 3D top view

Several Cracks in an SCC Colony



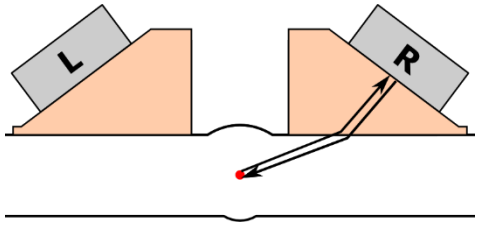
(all dimensions in millimeters)

IWEX sizing by tip diffractions

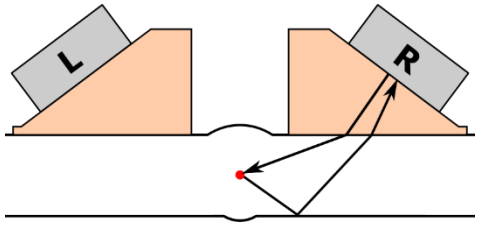


L. Hörchens, C. Wassink, and H. Haines, Ultrasound Imaging of Stress Corrosion Cracking, QNDE Conference, Boise, Idaho, July 2014

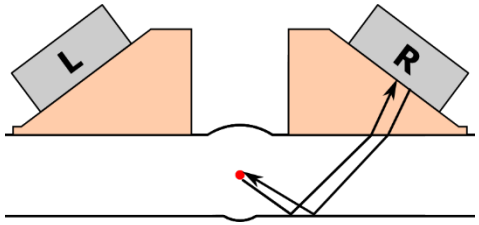
Through-wall crack



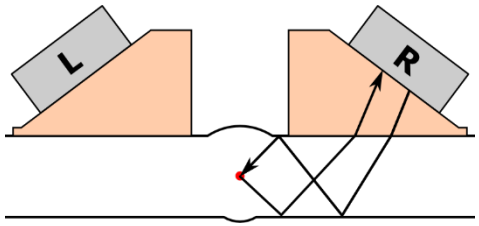
direct



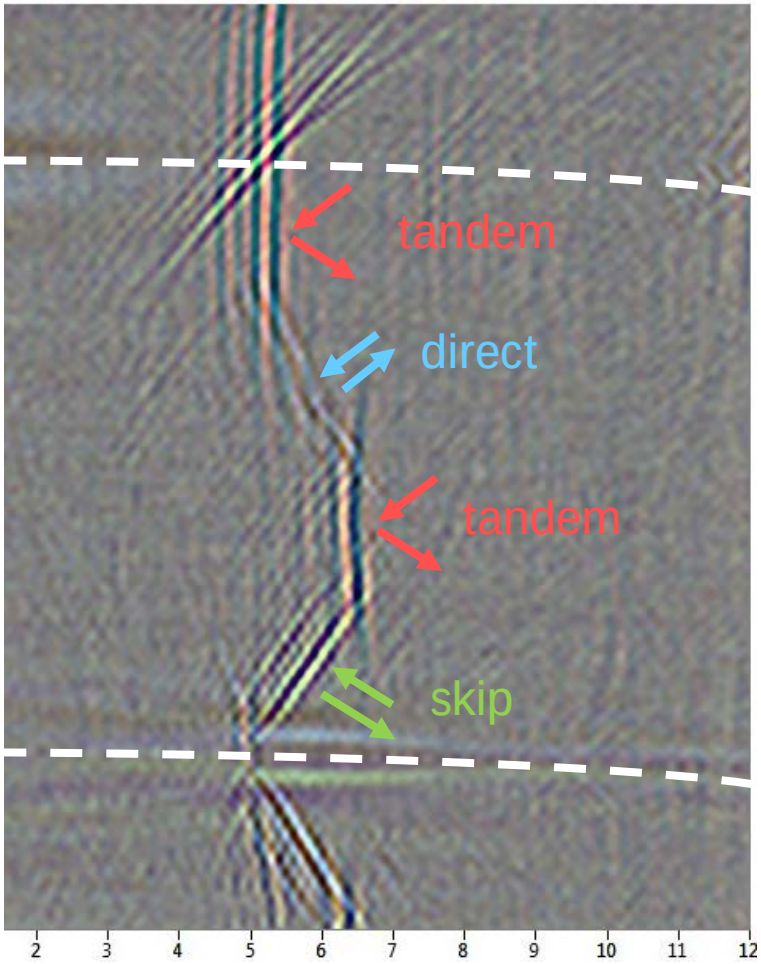
tandem



skip



tandem
(extra skip)



Ultrasonic Imaging is Improving
(No Scanning in-the-ditch yet)

- 1982 – Seismic surveys took months to process
  - Cheaper & faster to replace pipe than try UT imaging
- 2007 – Niels Pörzgen publishes PhD thesis
  - A single inversion takes 4-5 minutes
    - 100 minutes per inch
    - Equivalent to ~30 days per 40 ft joint
- 2014 – IWEX inversion speeds increase by order of magnitude from 2013
  - 20-30 inversions per second
    - Scan 1-inch per second
    - Equivalent ~10 minutes per joint

Conclusion: Ultrasonic in-ditch NDT is Evolving

- Shear Wave can look for corner reflections and tip diffractions
- ToFD uses single transducers to size cracks using tip diffractions
- Phased Array (PA) uses steered multi-element transducers to provide rudimentary images of tip diffractions and corner reflections
- Acoustic Imaging (IWEX) shows promise for:
  - Better discrimination of benign anomalies from defects
    - Benign anomalies – inclusions, poor trim, shallow LOF
    - Defects such as fatigue cracks, thru-wall LOF
  - Better imaging and sizing of multiple cracks in an SCC colony