Phase Coherence Imaging (PCI) Best Practices

Getting Started with the PCI Technique

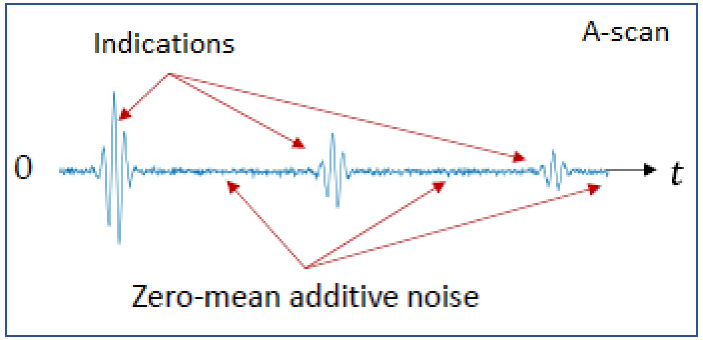
Agenda

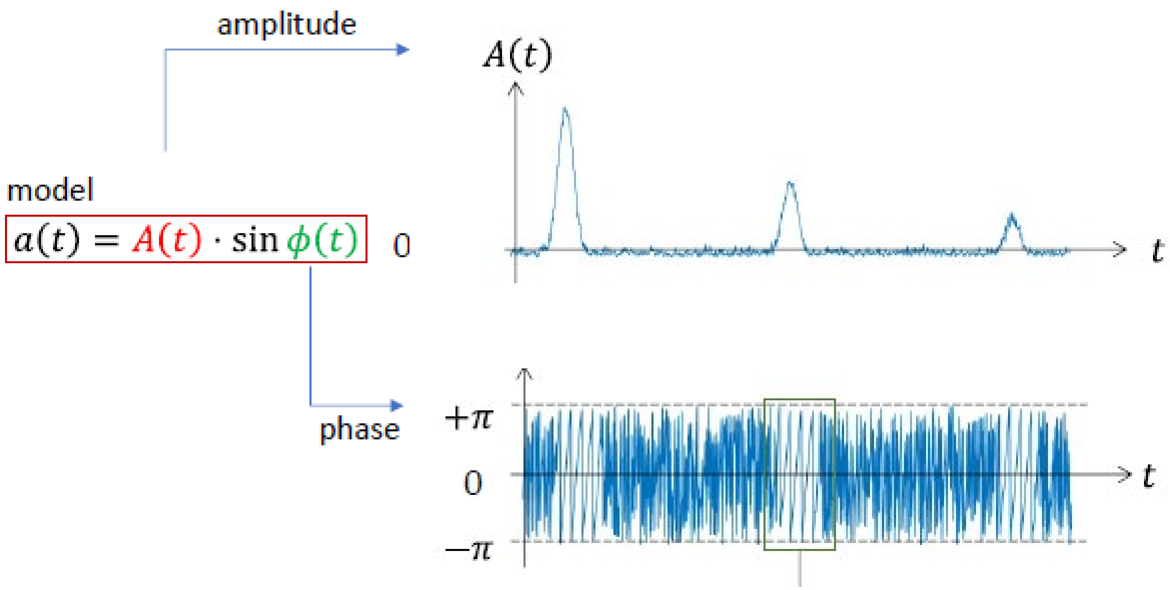
01

What is Phase Coherence Imaging (PCI)

What Is PCI?

- Phase coherence imaging (PCI) is a new technology using A-scan phase information.
- An amplitude-free variation of TFM, PCI uses FMC data that is collected for the chosen wave set(s).
- The signal is treated so that only the phase information is conserved and the amplitude is discarded.
- A TFM image is then created from the level of phase coherence between A-scans rather than the sum of the signal amplitudes.
- Phase coherence is compared through the analysis of the frequency distribution of the A-scan.

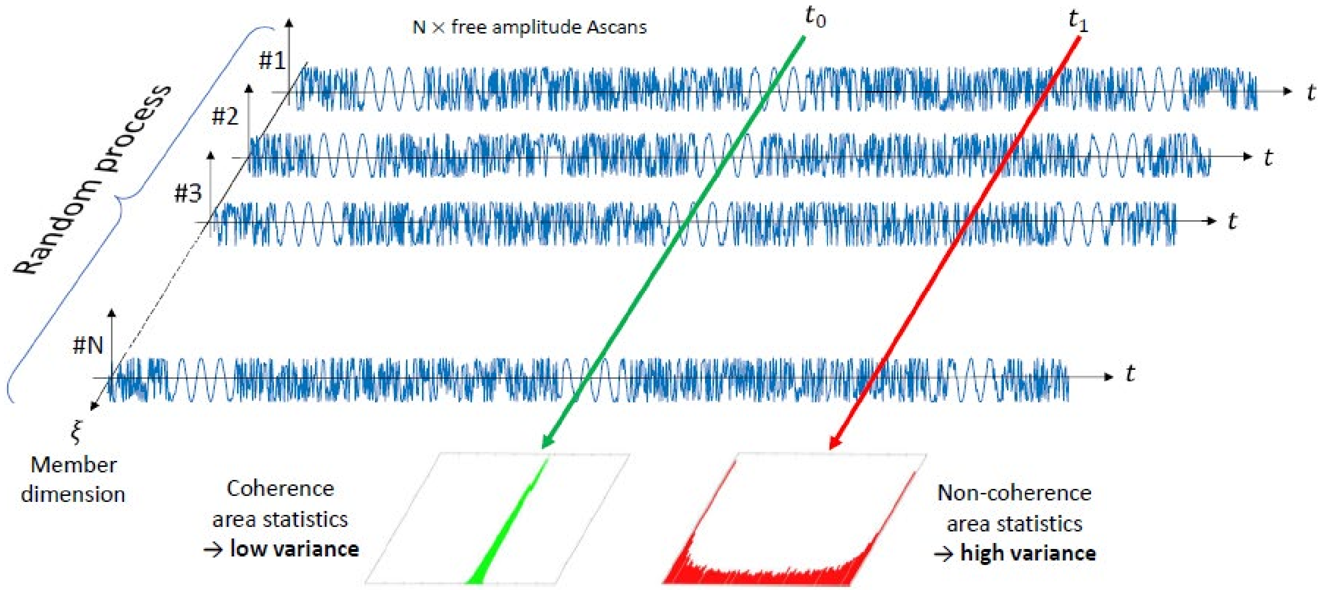




What Is PCI?

- Signal noise = low coherence (high-frequency variance noise)

- Indication = high coherence (low-frequency variance)

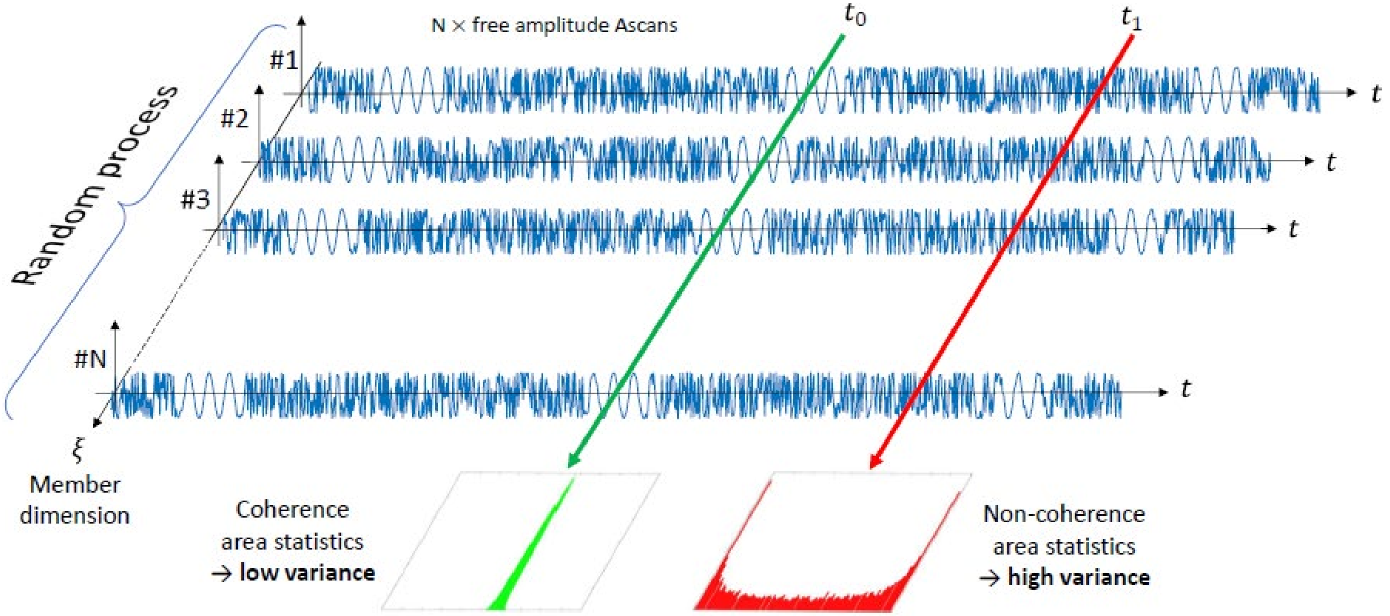


- This means that phase coherence imaging is less affected by attenuation since the frequency information is independent of amplitude.

- The PCI technique also offers improved performance in noisy materials. In many cases, the image quality is improved with high signal noise from the greater frequency distribution variance.

- The diffraction of small defects and crack tips emits a highly coherent signal compared to large reflectors, resulting in a better SNR versus amplitude-based techniques.

What Is PCI?



High coherence between A-scans

Low coherence between A-scans

- The TFM image is generated by comparing the coherence of the elementary A-scans for each point in the matrix.
- The maximum coherence value is 100%, which corresponds to all the elementary A-scans having the same frequency distribution for that point in the matrix.
- For more information about how TFM images are generated, click here.

02

Advantages

Advantages

- **Impossible to saturate the signal**—there is no gain adjustment since this technique is amplitude free.
- **No need to preadjust the gain to a reference reflector**—properly selecting wave sets using the AIM tool is sufficient.
- **More consistent scanning between inspections** because there are fewer parameters to adjust for the acquisition and during analysis.
- **Fewer groups are required for the same part coverage** since small reflectors have highly coherent responses.
- **Tip diffractions are obvious and can be used for accurate flaw sizing** since they have a stronger signal relative to reflections.
- **Better imaging close to large reflectors** such as the back wall.
- **Sizing is easier** with few manipulations.

03

Probe and Group Selection

Probe and Group Selection

In general, the same probes used with conventional TFM or PA are effective for PCI.

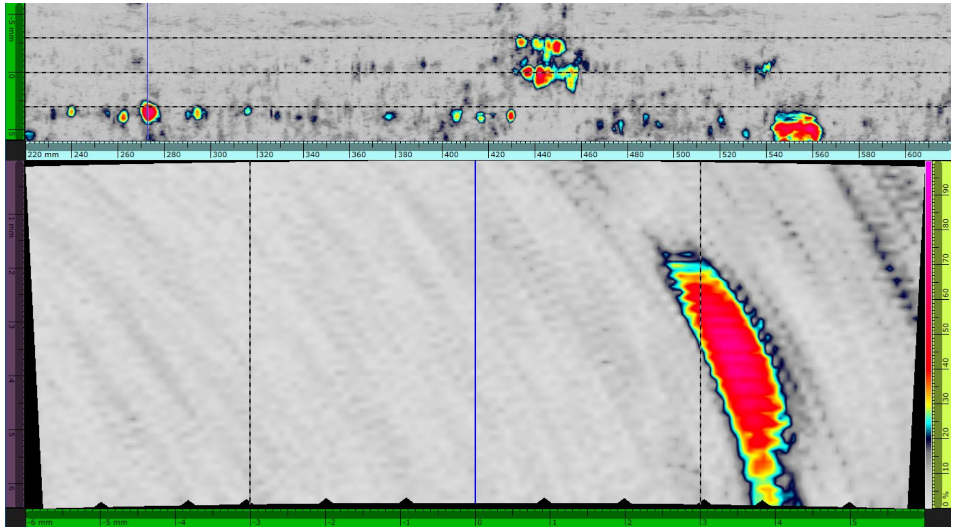
TIPS:

- Selecting a higher frequency probe with more elements often yields better results.
- Doubling the probe frequency is a good starting point.

The Acoustic Influence Map (AIM) tool is still useful for group selection since the sound distribution in the zone must be adequate for the technique to be effective.

NOTE:

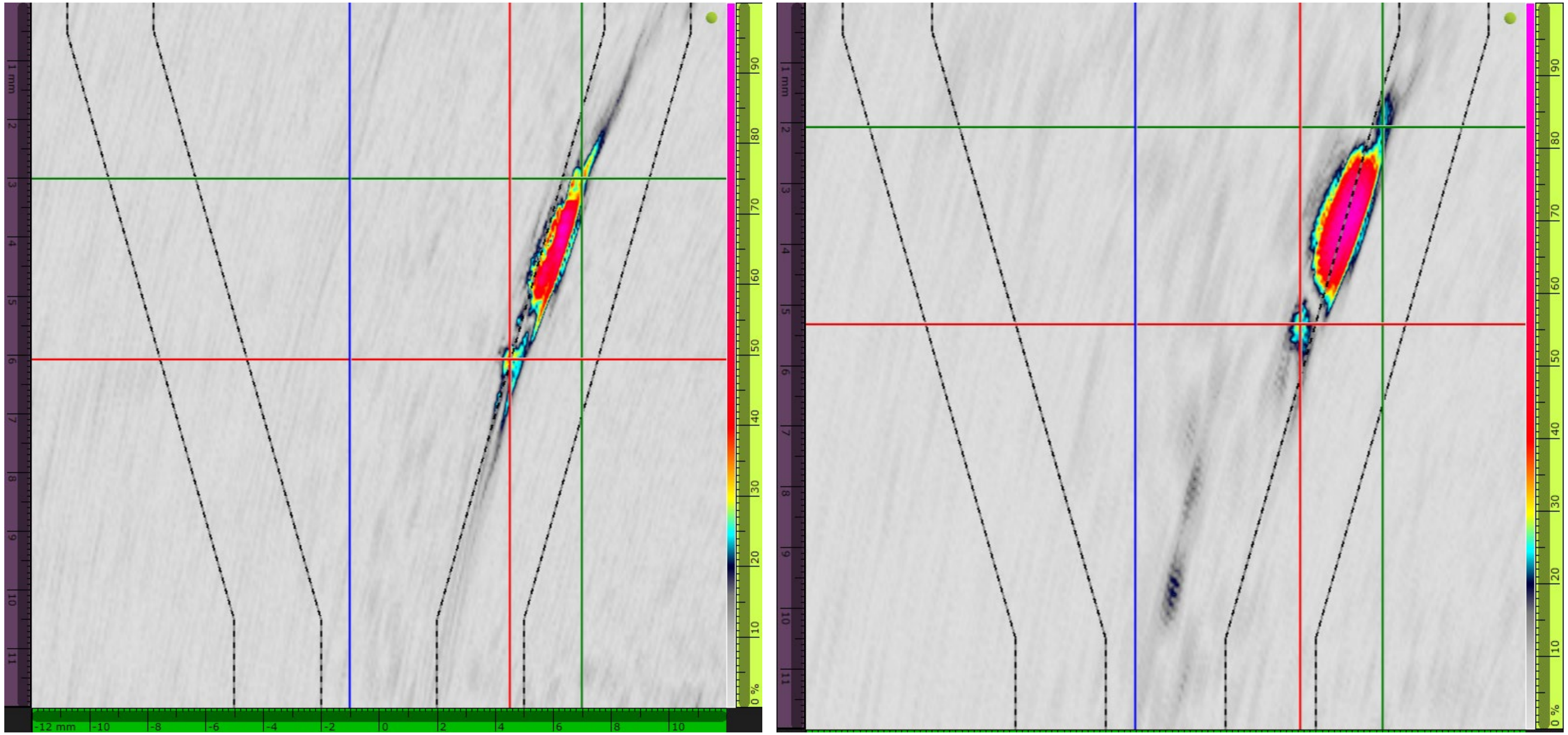
- The amplitude distribution has significantly lower impact on the final image than conventional TFM.
- Fewer groups (wave sets) are usually required to visualize all the defects with PCI than TFM.
- The TT and TT-TT wave sets have shown to be particularly effective with PCI.



Probe Selection and Setup for PCI

Characteristic	Recommendation	Reason
Frequency	Use a higher frequency probe	Higher sensitivty for smaller defects and better imaging
Number of elements	Use the maximum number of elements possible	More elements = more signal for the statistical analysis
Sparse	For the best image quality, use the full matrix setting, but sparse can be used to increase the scan speed	Full matrix = more data for the statistical analysis
Voltage	Set the voltage to 160 Vpp	The technique is improved with more noise
Element pitch	Select a probe with a larger pitch	Higher contrast between noise and defects

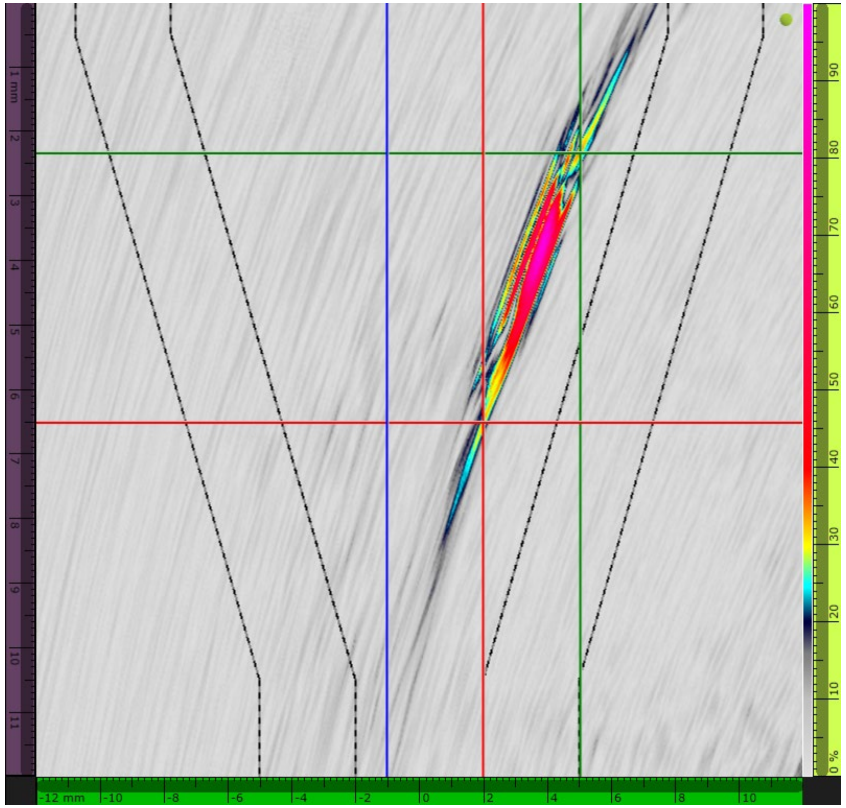
Effects of a Higher Probe Frequency

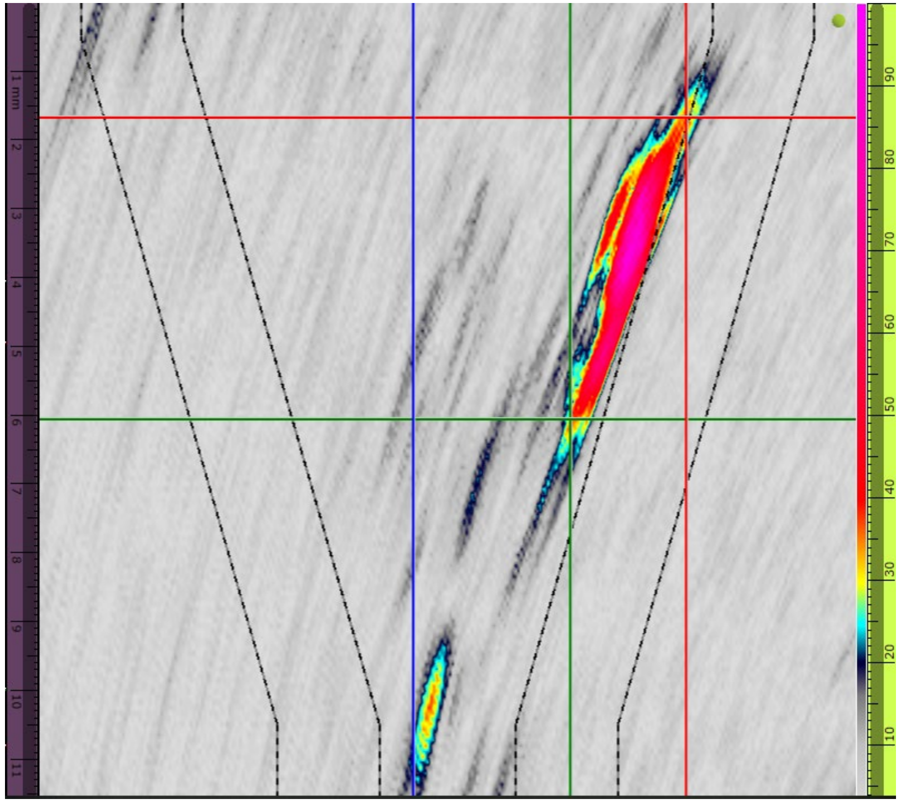


A32 probe: 10L64 versus 5L64

- Improved visualization of defect details
- Reduced background noise
- Tip diffractions become more visible with higher peak coherence

Effects of a Higher Number of Elements

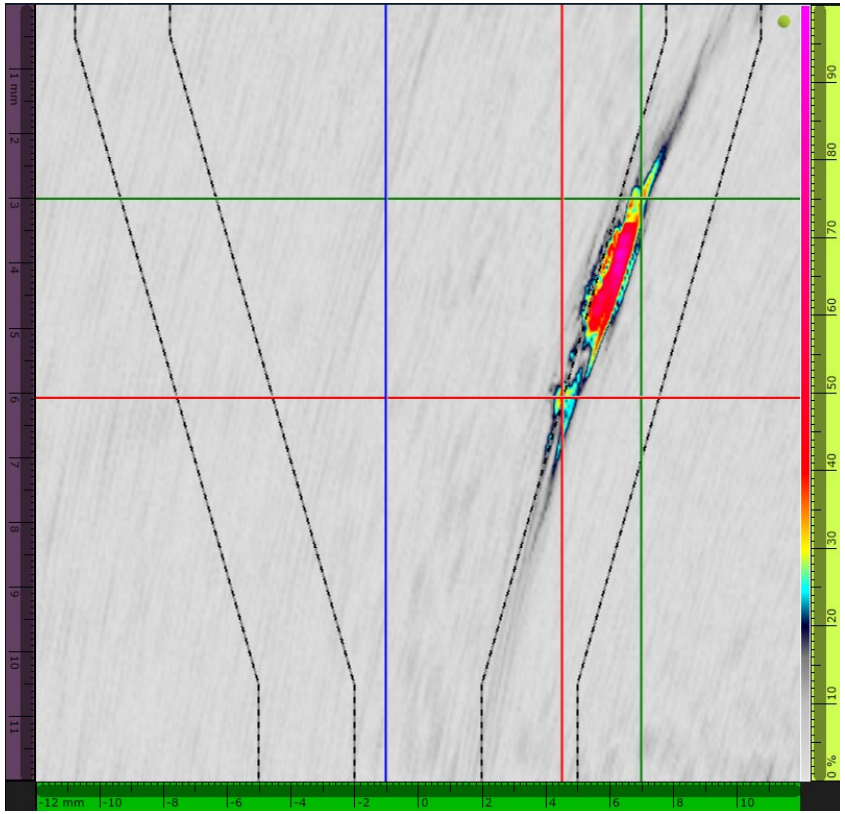


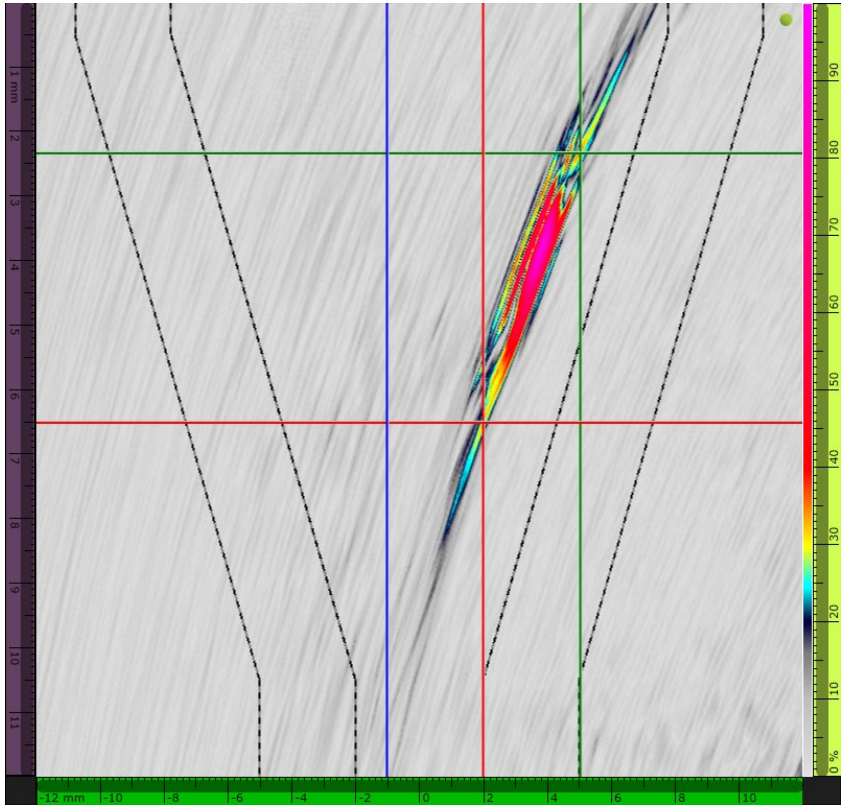


A31 probe: 10L64 versus 5L32

- Lower noise level
- Better definition of defects
- Easier sizing because the tip diffractions are easier to identify

Effects of a Higher Element Pitch

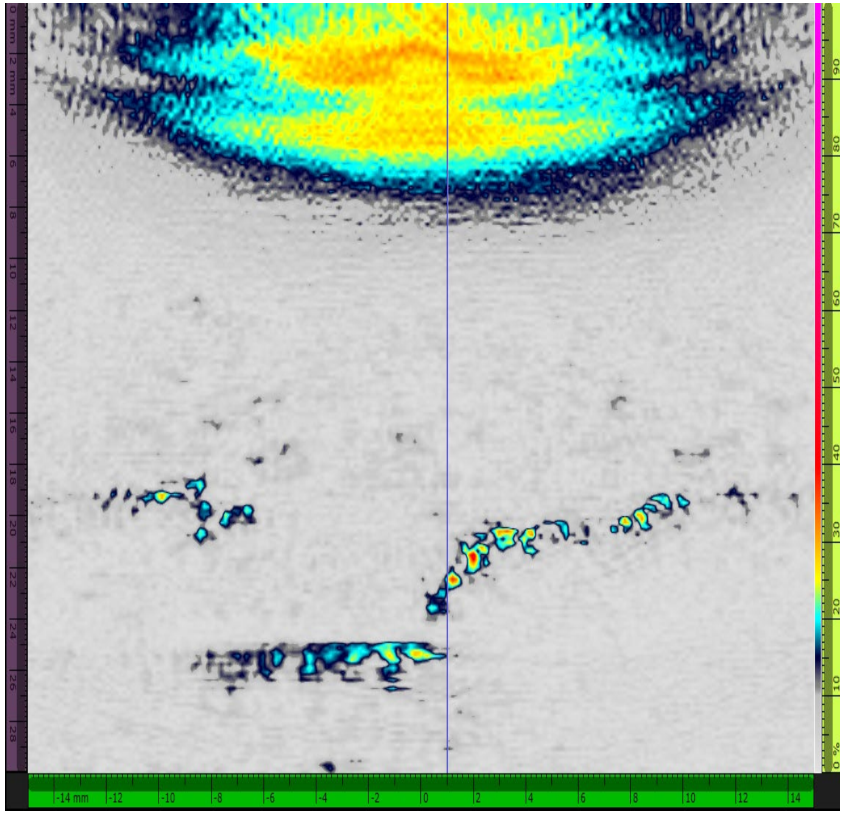


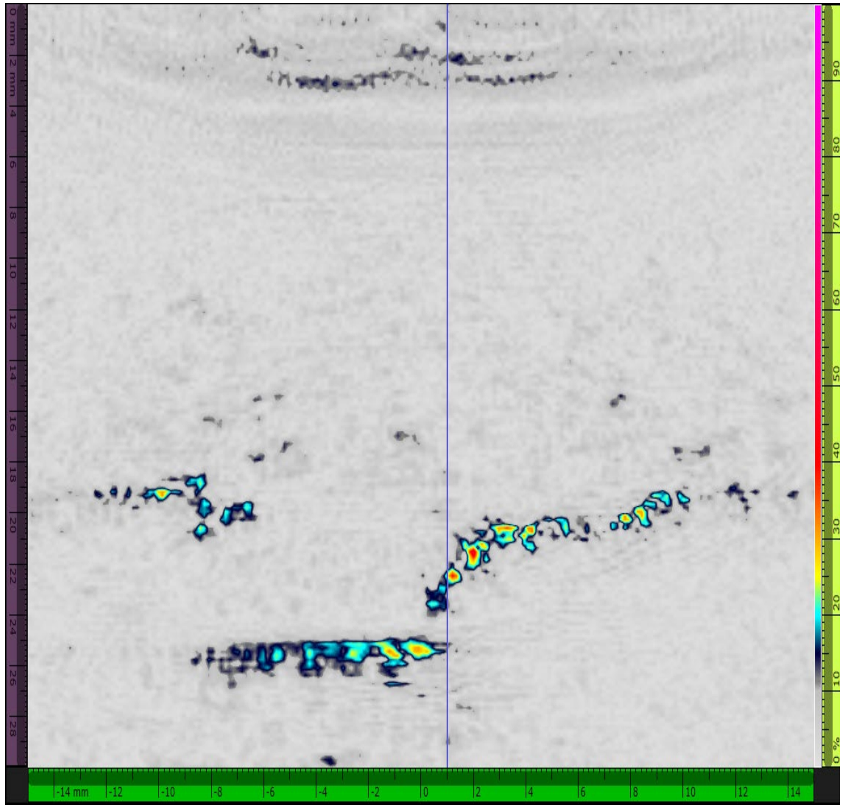


10L64-A32 versus 10L64-A31

- Lower noise
- Improved sizing due to better focusing
- Improved visualization of defects

Effects of a Higher Voltage Setting

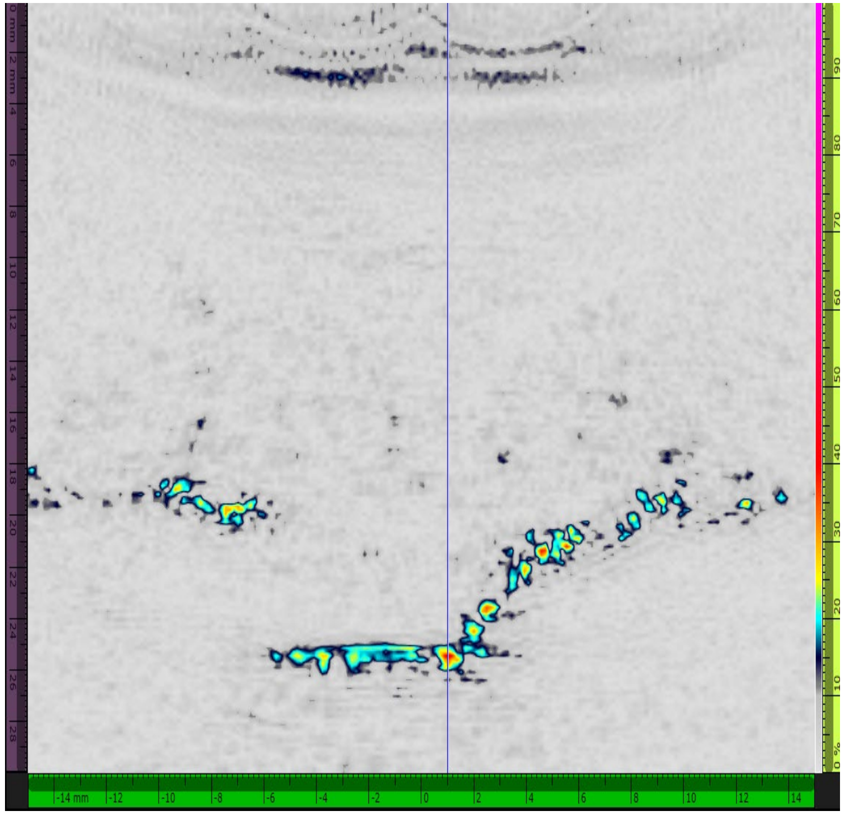


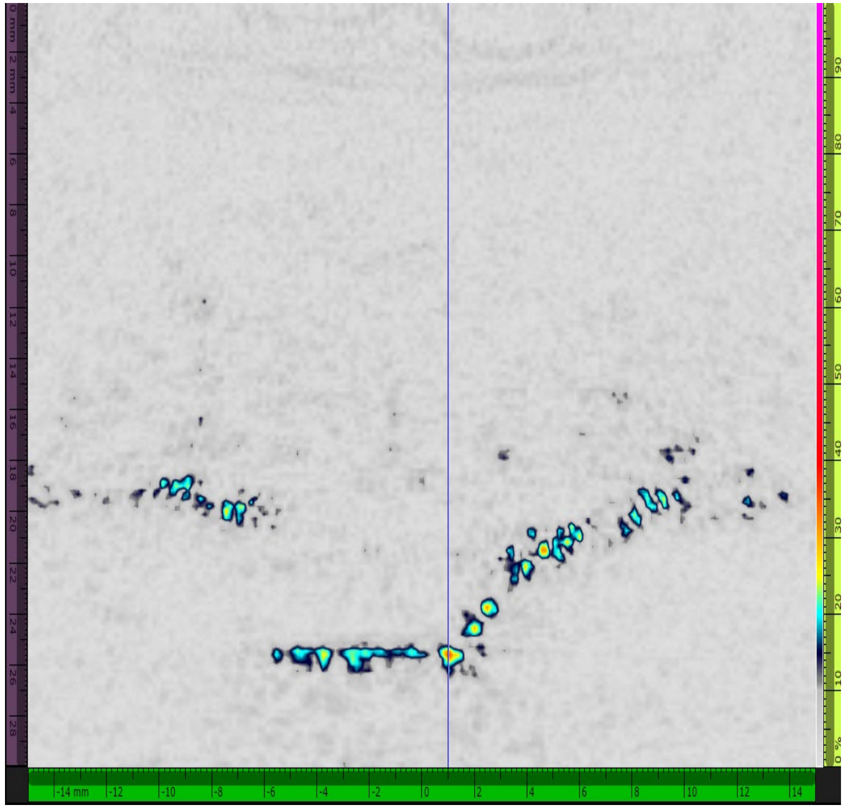


- Lower noise particularly near the probe-part interface
- Better resolution of defects

10L64-A32 10 Vpp versus 160 Vpp

Effects of Filters

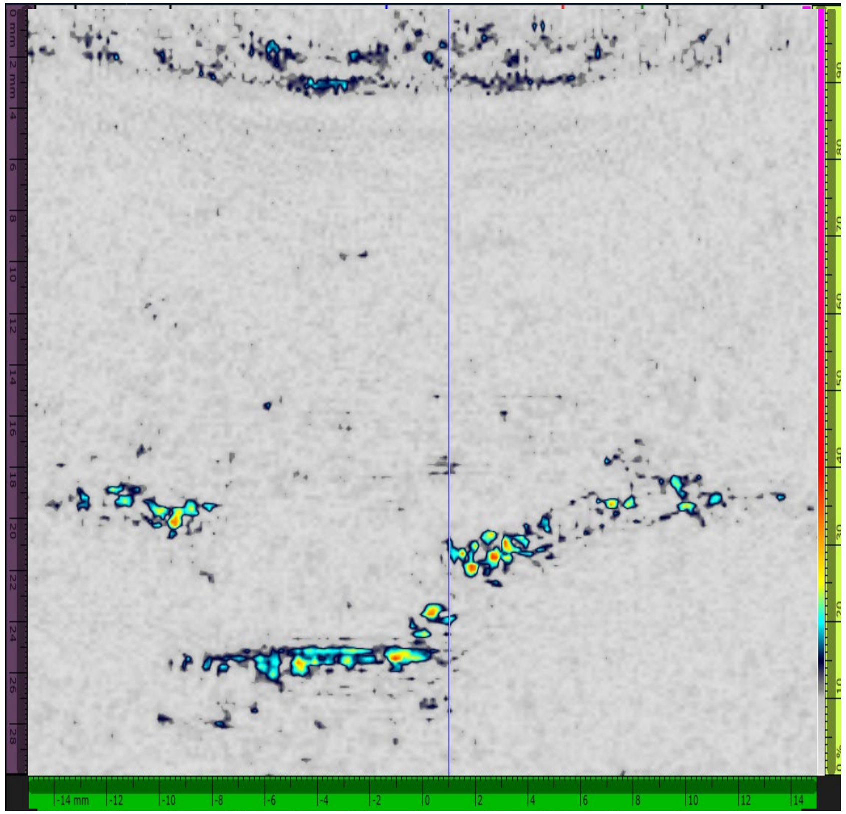


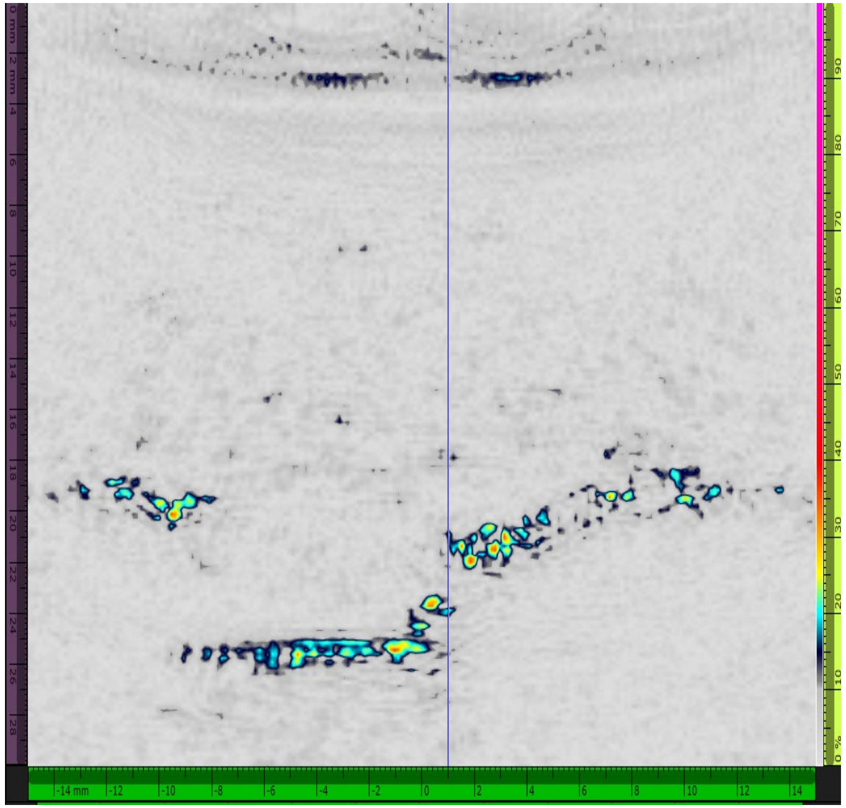


- Lower noise near the probe-part interface
- Some low-frequency coherent grain noise is removed
- Crack tip diffractions are better defined

10L64-A32: no filter versus an 8 MHz high-pass filter

Effects of the Sparse Setting





- More noise with the sparse applied
- Better scan speed with the sparse applied
- Like TFM, there is a balance between the image quality and the scan speed

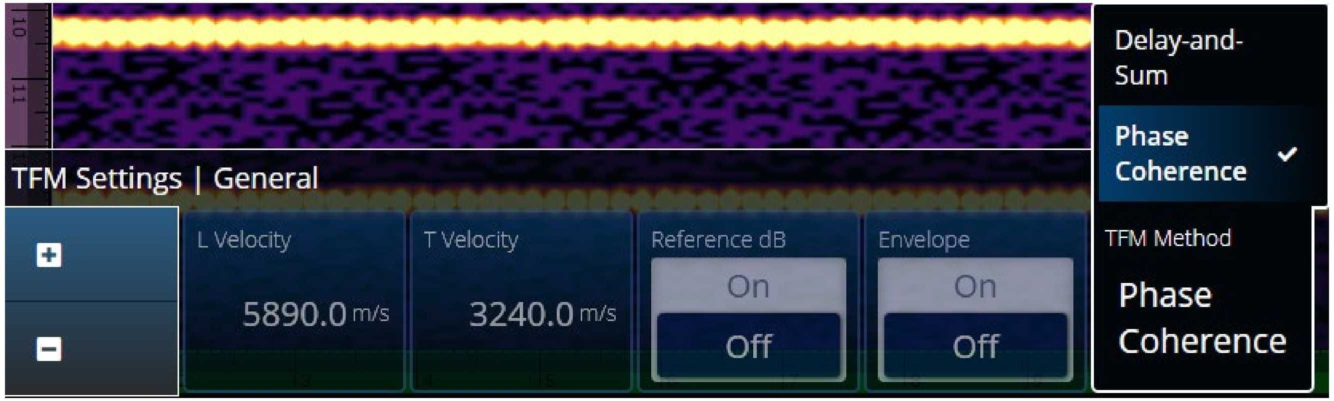
10L64-A32: ¼ sparse setting versus the full matrix

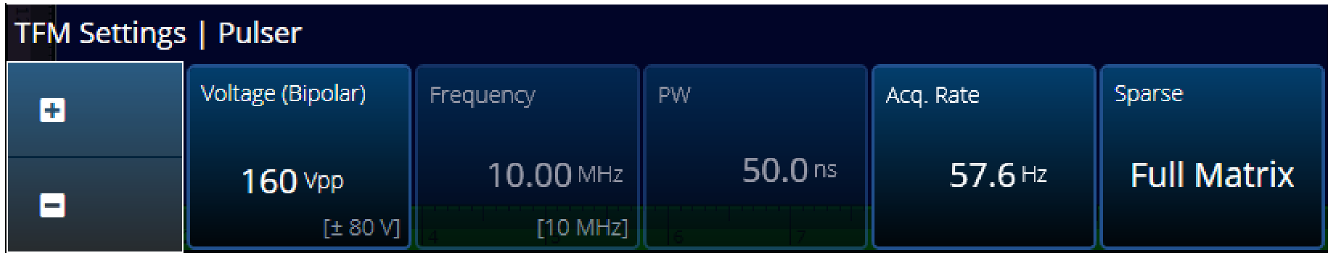
04

PCI Settings Selection

PCI Settings Selection

- On your OmniScan™ X3 64 flaw detector, start a standard TFM setup creation using the AIM tool for the sound distribution of wave sets.
- In the **TFM Settings – General**, turn off the envelope, and under the TFM method, select **Phase Coherence**.
  - The PCI parameter applies to all groups.
- Achieve the best results with the **Sparse** set to **Full Matrix** (except in cases where scan speed is a priority) and the **Voltage** set to **160 Vpp**.
- If the signal is excessively noisy, the voltage can be changed to the **10 Vpp**, but this is rarely necessary. A high-pass filter just below the probe frequency can also improve the signal-to-noise ratio (SNR).
- Adjust the image using the palette zoom (to change the bounds of the color palette) rather than the gain.





05

Use Case Examples

Use Case Examples

Smaller Defects Such as HTHA

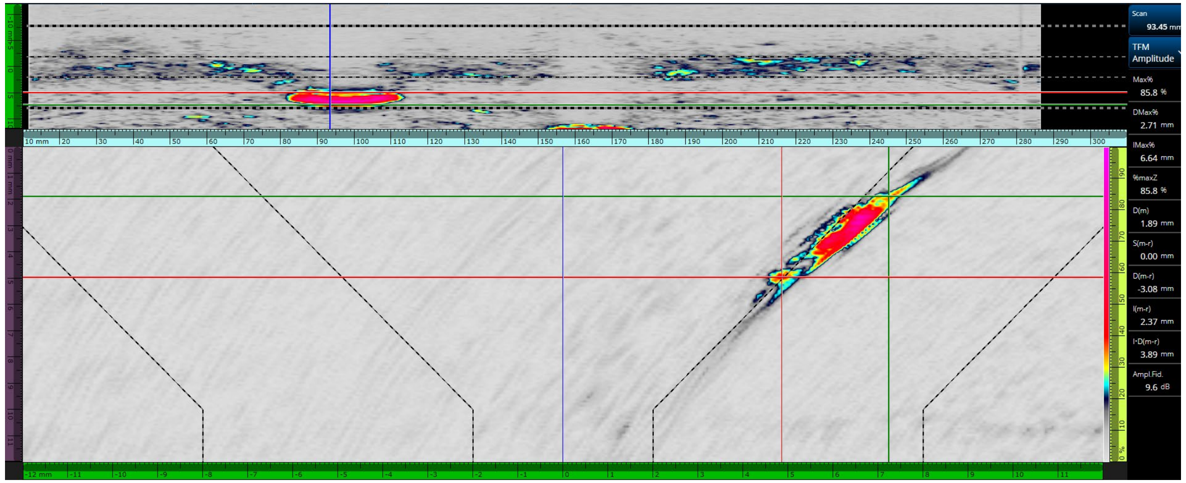
- PCI has shown to provide better results than TFM and PA in a lot of common challenging cases as well as classically difficult defects, especially on real (not machined) defects. When testing PCI, try it on real weld samples (particularly with stainless), high-temperature hydrogen attack (HTHA), stress corrosion cracking (SCC), or other samples with small natural defects.

Small Reflectors near Large Reflectors

- In general, PCI is particularly effective with small reflectors (small cracks, HTHA, porosity, etc.). This effect is amplified when these defects are near flat reflectors such as the back wall since these flat reflectors are less apparent with PCI.

Noisy Coarse-Grained or Highly Attenuative Materials

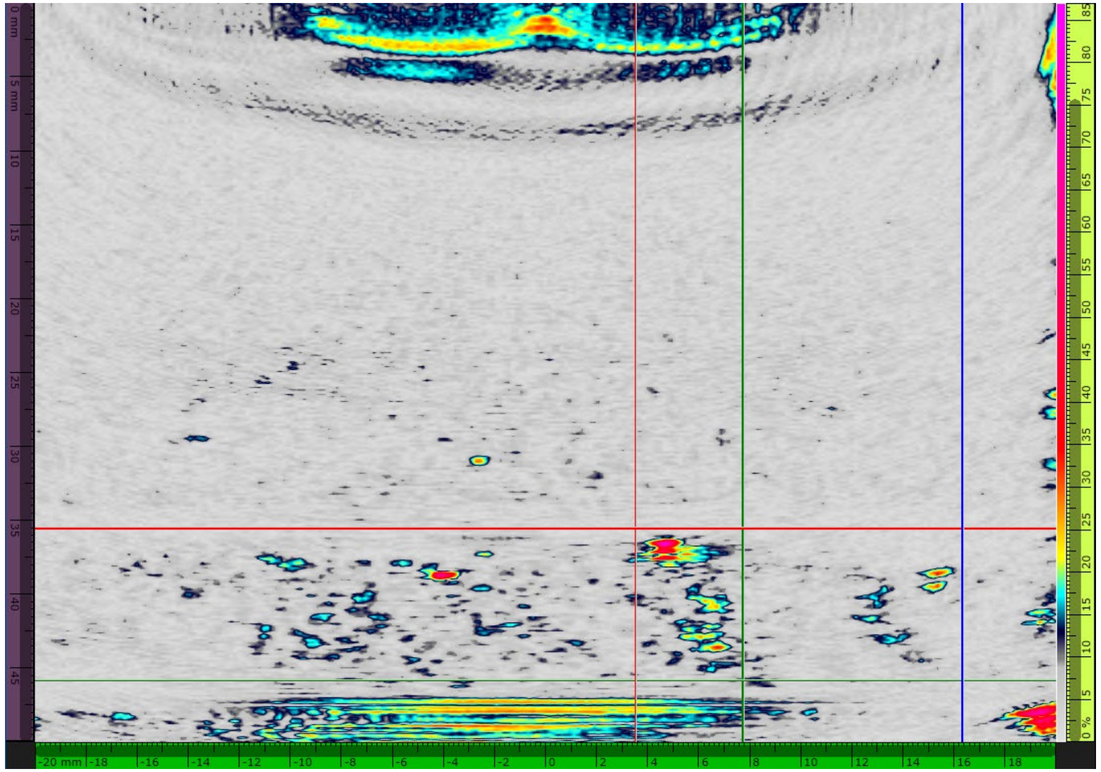
- PCI requires noise in order to be effective, so it will perform better than conventional methods for noisy materials, materials with high attenuation, or with setups that would saturate a conventional TFM configuration.

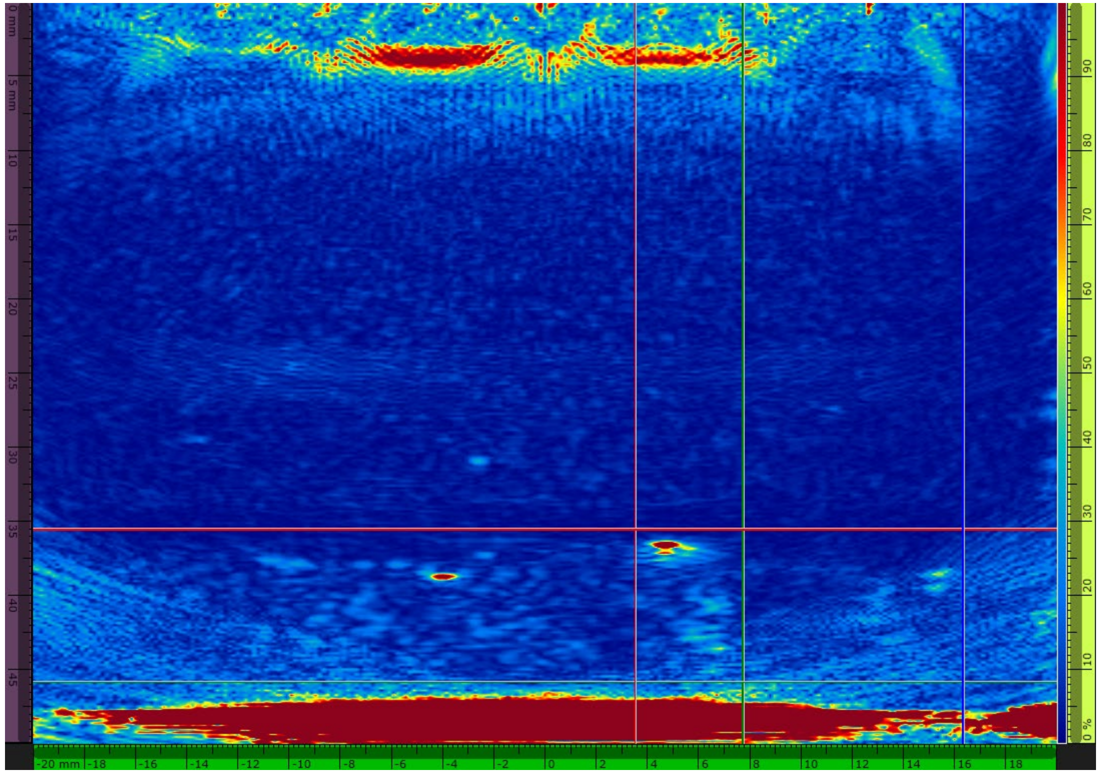


Use Case Examples

Defect	Difference from Regular TFM	Reason
Small defects (HTHA and others) close to specular reflectors	The back wall and large specular reflectors are less visible and small cracks stand out with greater contrast.	The tips of cracks diffract generating a stronger phase coherence compared with large specular reflectors.
Attenuative materials	The defects are more uniform throughout the zone and are still be visible at depth.	The phase is not affected by the amplitude of the signal, so even if the signal amplitude is weak the coherence data is still valid.
Noisy materials	The PCI signal generated from noisy elementary A-scans is cleaner and the defect better imaged.	PCI data is improved by noisy materials because there is greater variation in the phase variance between the background noise and signal from defects.
Improved sizing	The signal is not changed since it is independent of the amplitude, so there is less user error when sizing.	The phase information is not changed during analysis and small defects will diffract and are displayed as hot spots (see section “Tip Diffraction Sizing”).

HTHA

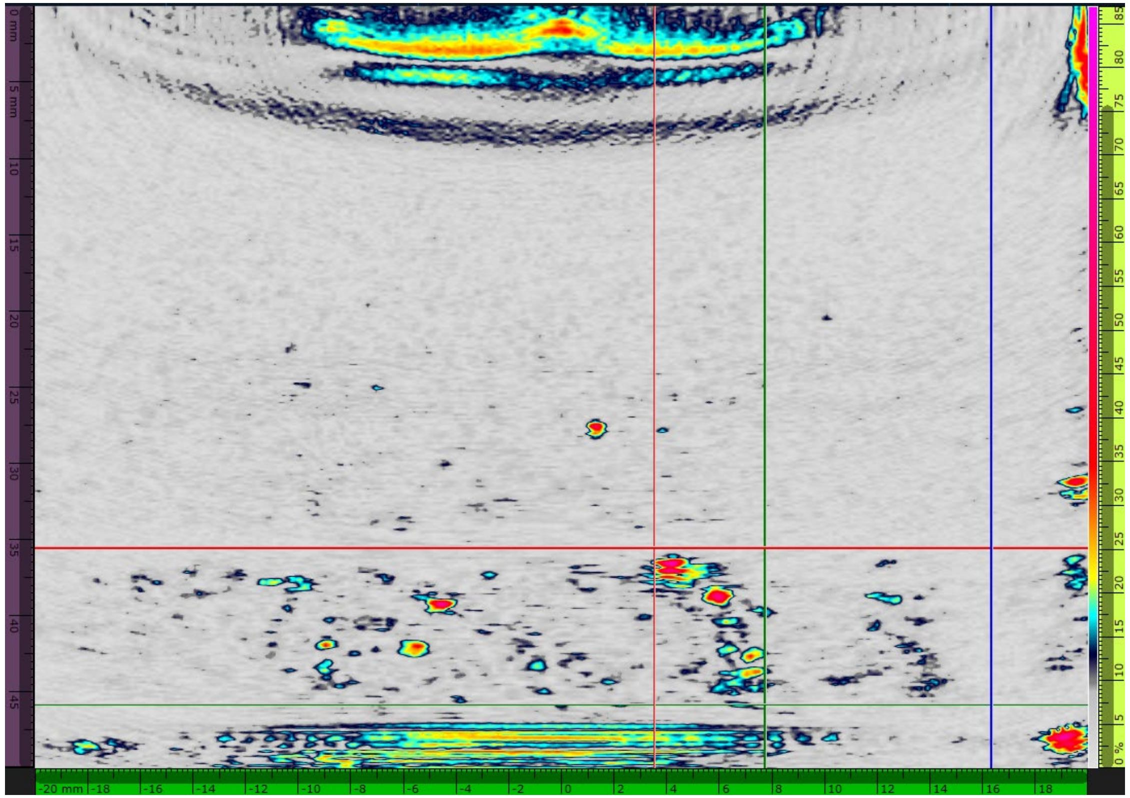


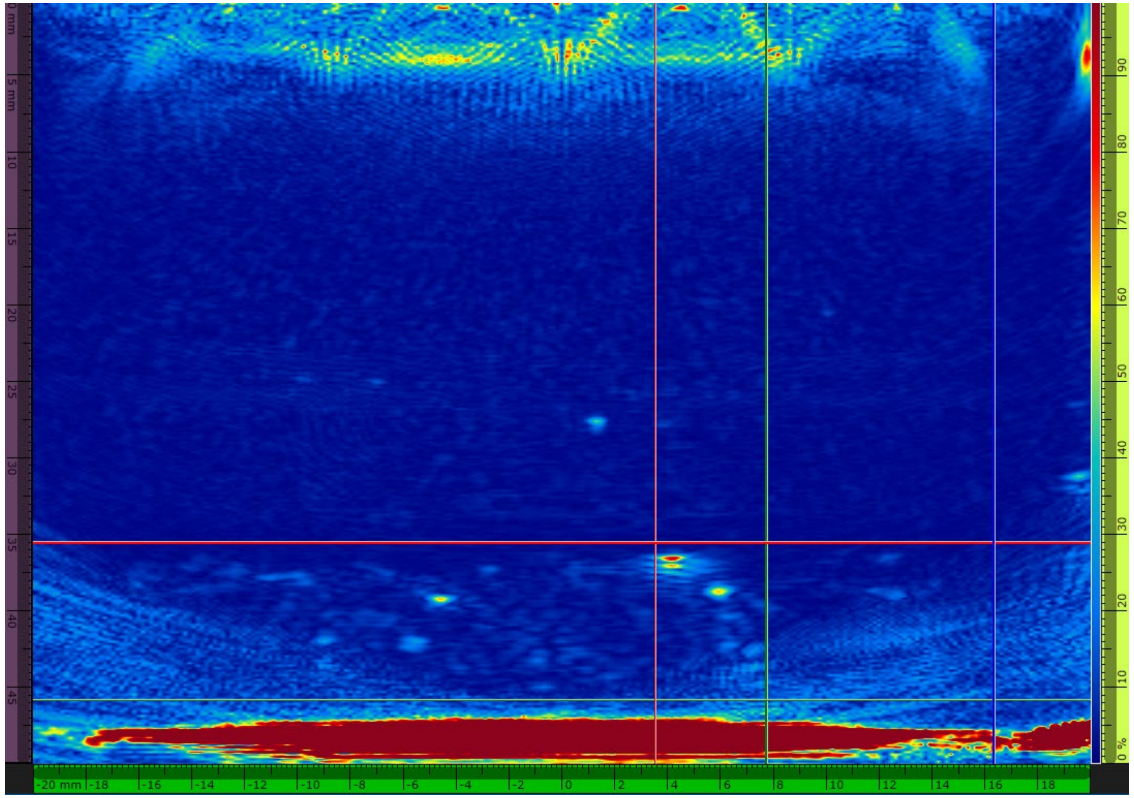


HTHA: LL wave set in PCI versus LL in TFM – 10L64-A32 probe in contact

The HTHA defects are more apparent because of the high phase coherence of crack tip diffraction.

HTHA

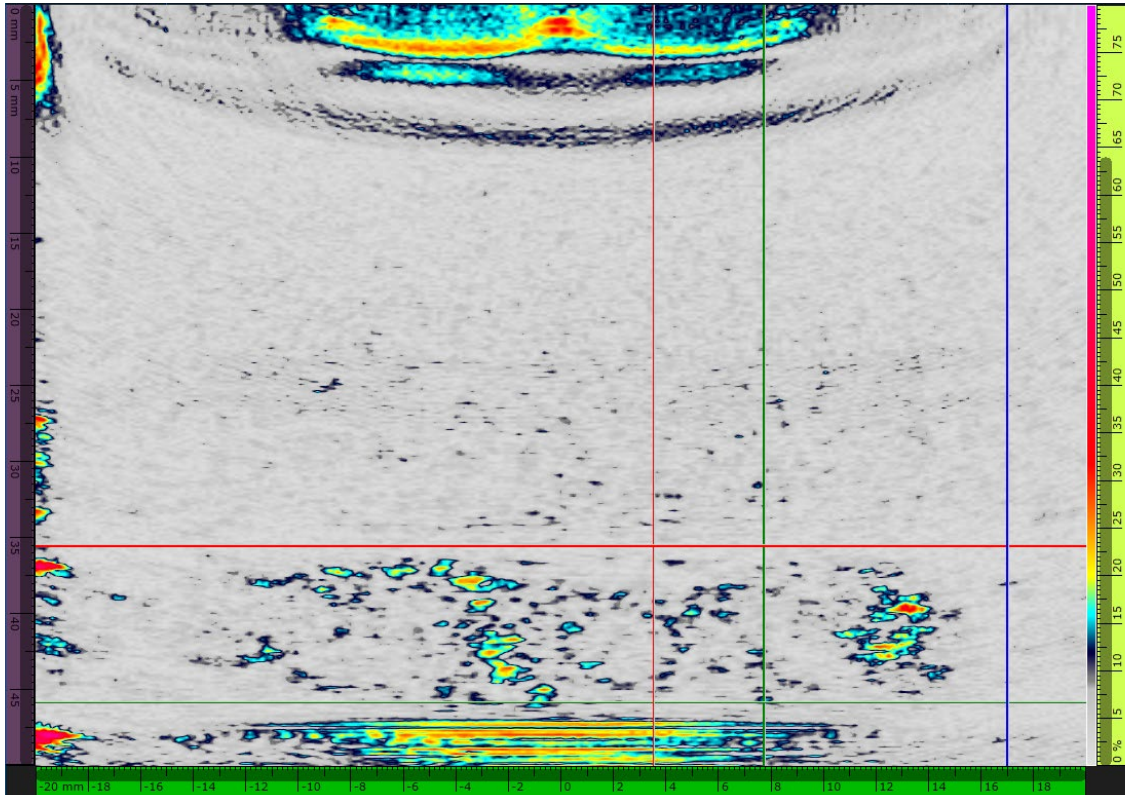


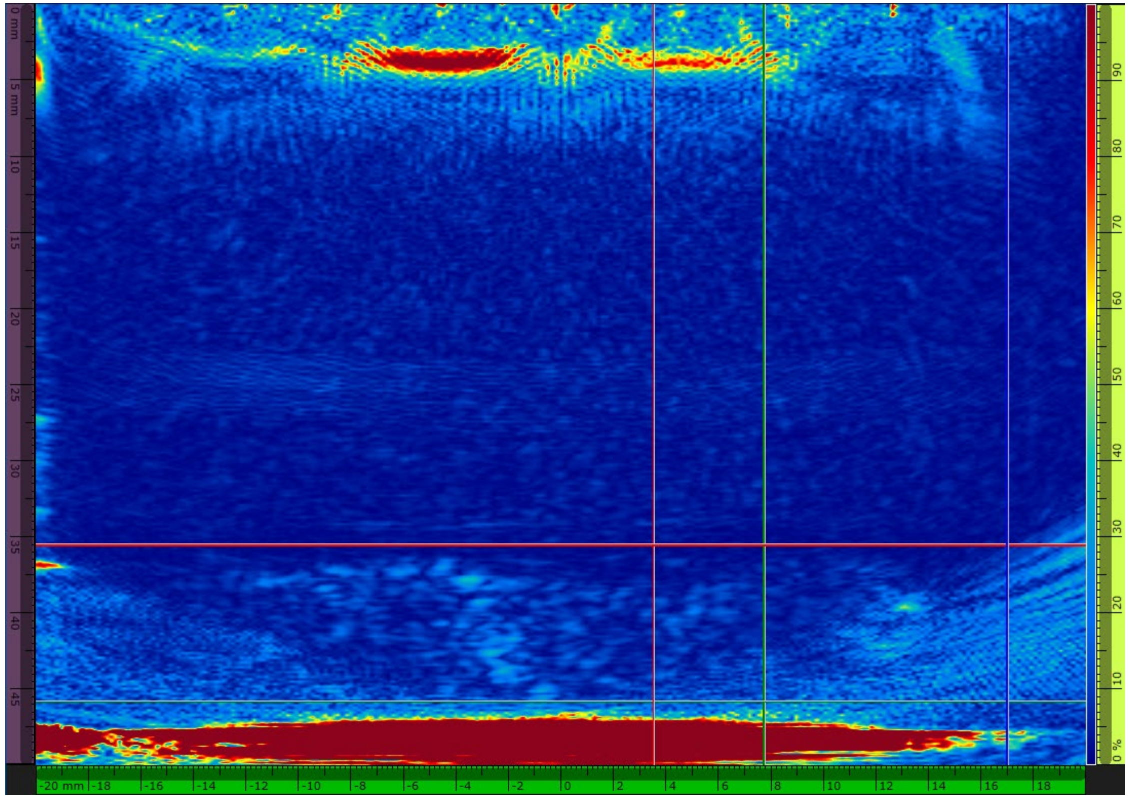


HTHA: LL in PCI versus LL in TFM – 10L64-A32 probe in contact

With conventional TFM, if the gain is increased so the signal amplitude of the HTHA defects meets the reference, the defects are hidden by the back wall, which is not the case with the PCI as amplitude is not a factor.

HTHA

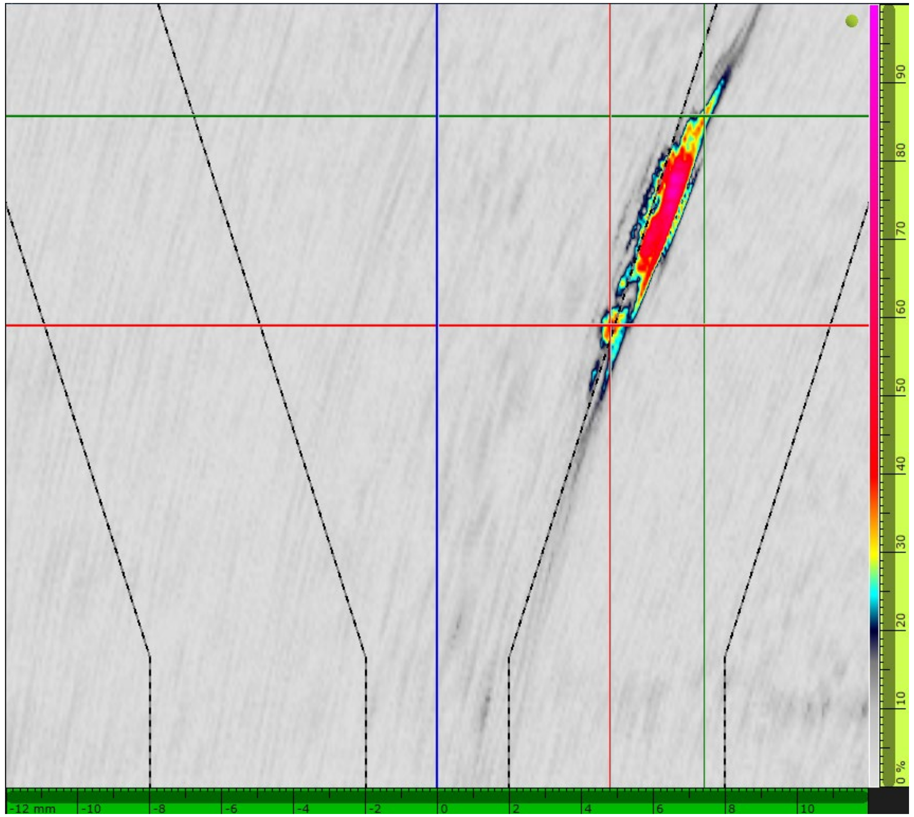
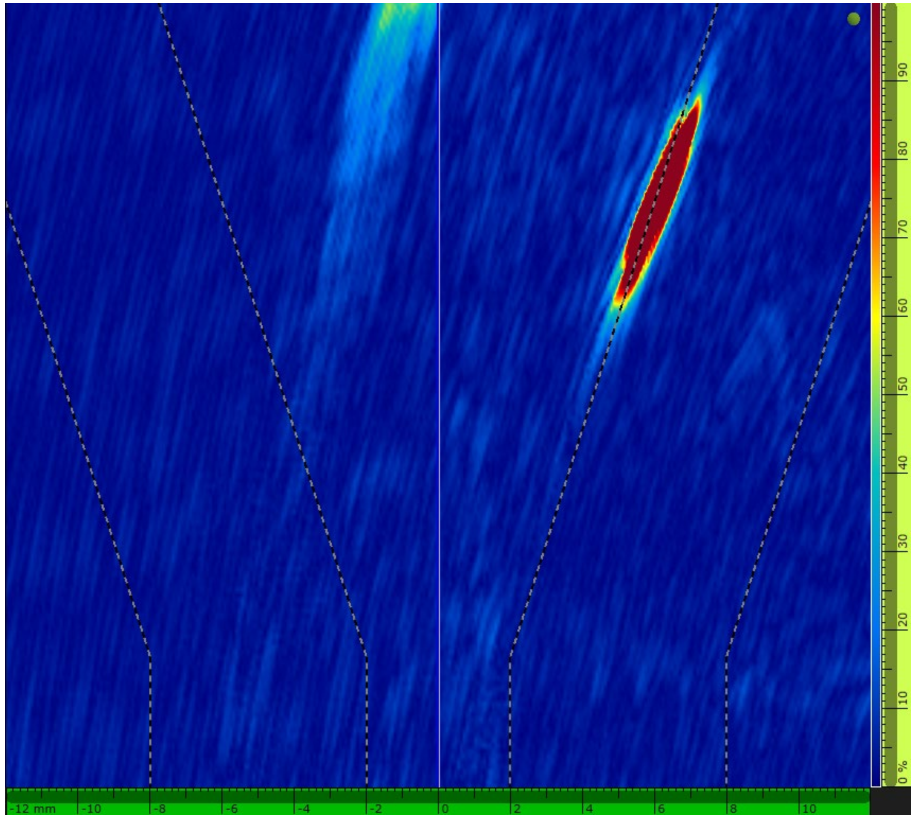




HTHA: LL in PCI versus LL in TFM – 10L64-A32 probe in contact

With PCI, the HTHA defects are clearer and with a much lower SNR near the back wall versus conventional TFM.

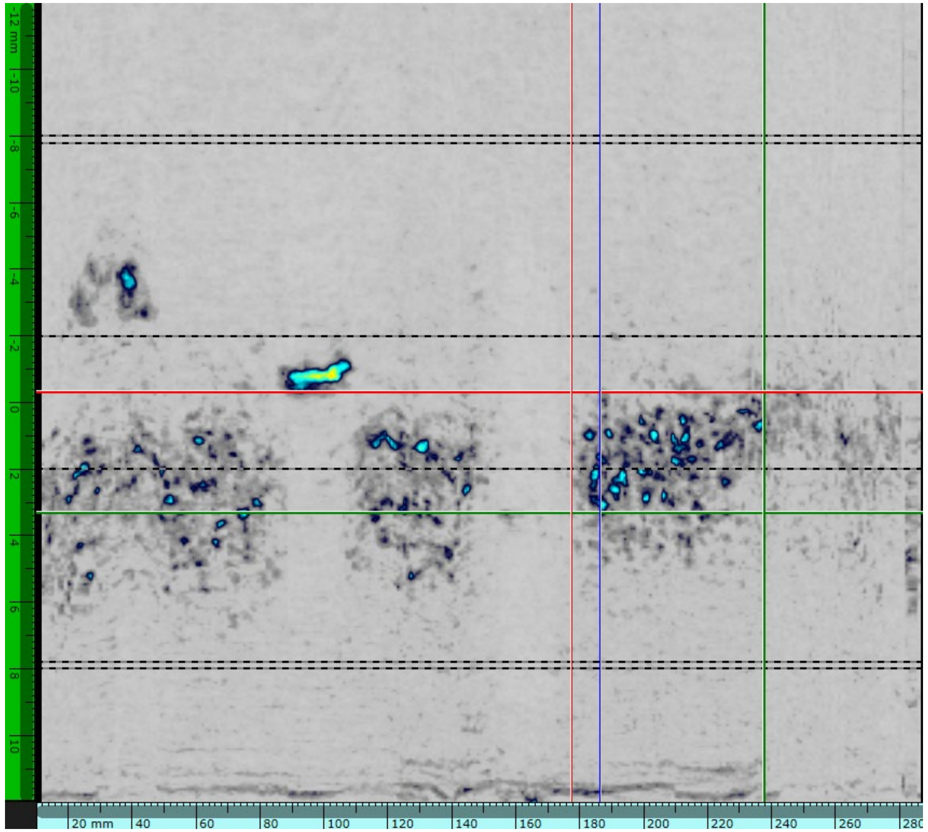
Weld in a 12 mm Stainless Steel Plate

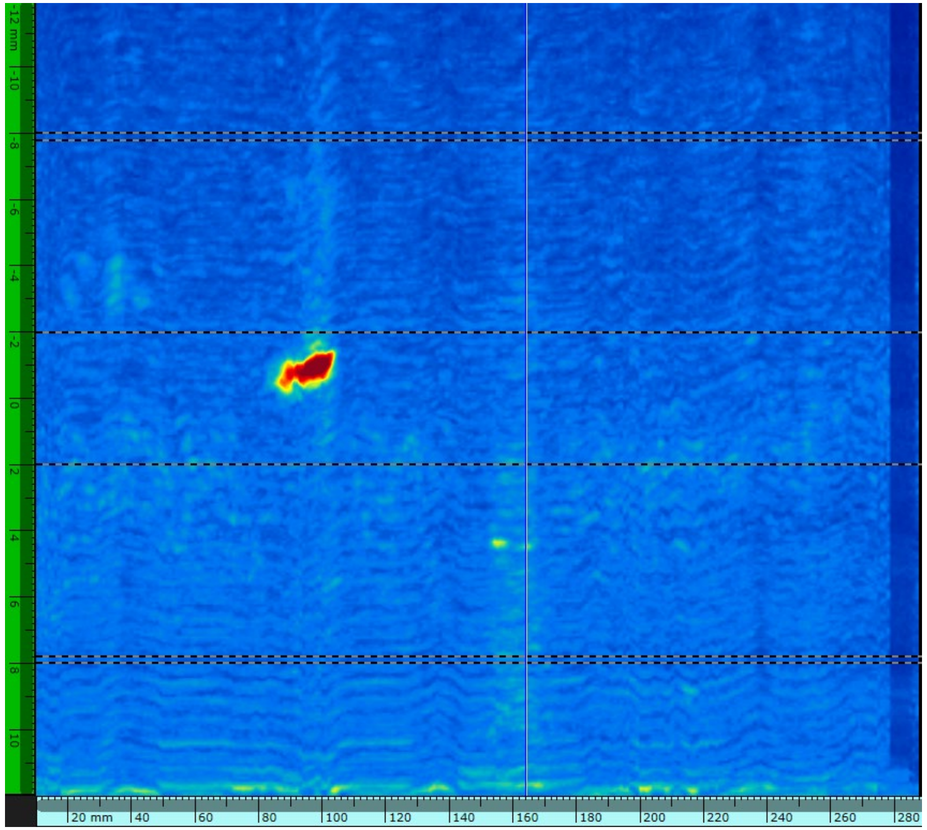



- The actual size and shape of the defect is much easier to distinguish with PCI.
- Accurate sizing can be done using the two hot spots at the extremities, which are the tip diffractions, rather than using the −6 dB method (discussed in further detail later).

Lack of fusion (LOF): TT-TT in PCI versus TT-TT in TFM – 10L64-A32 probe

Weld in a 12 mm Stainless Steel Plate

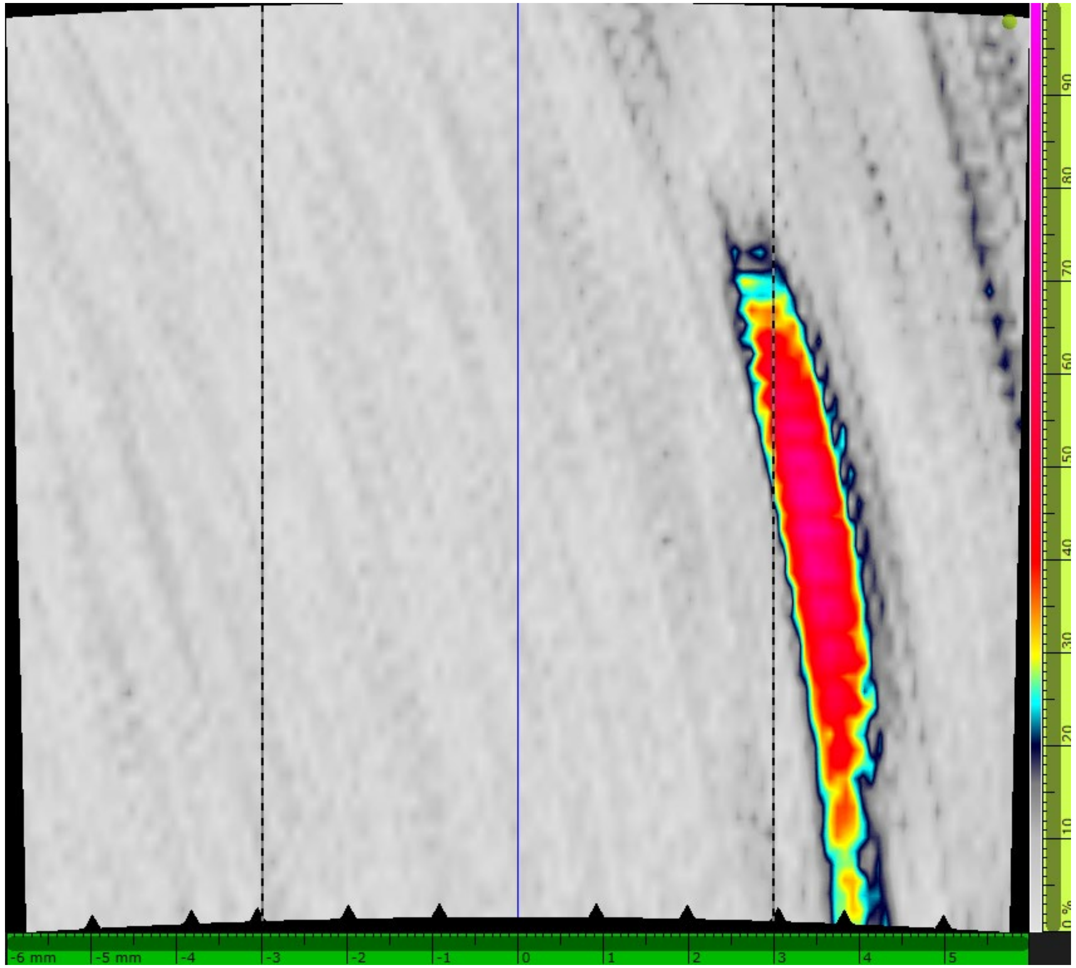


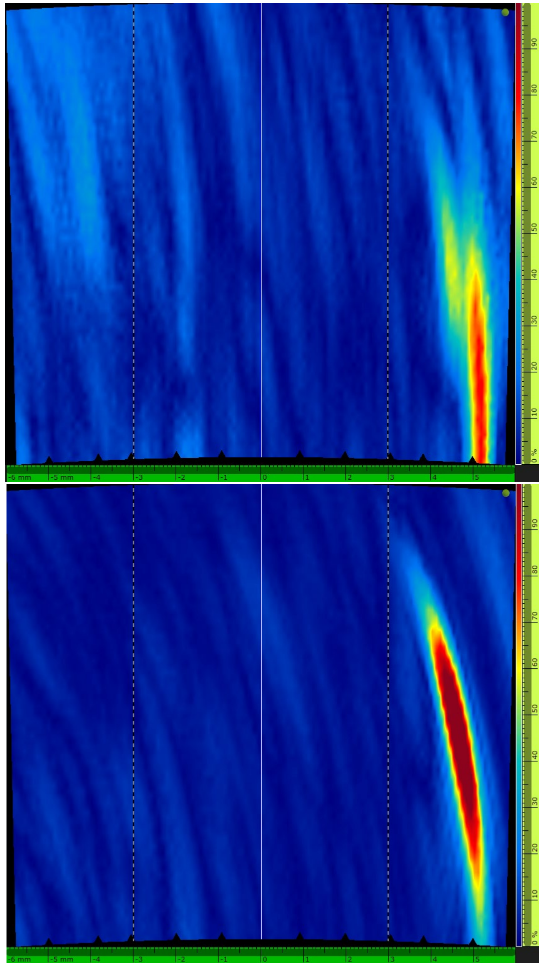


Porosity: TT in PCI and TT in TFM – 10L64-A32 probe

- Extensive porosity is revealed with the PCI but was unseen with conventional TFM.
- PCI offers similar results with other small natural defects.

Steel Pipe Electric Resistance Welding (ERW)

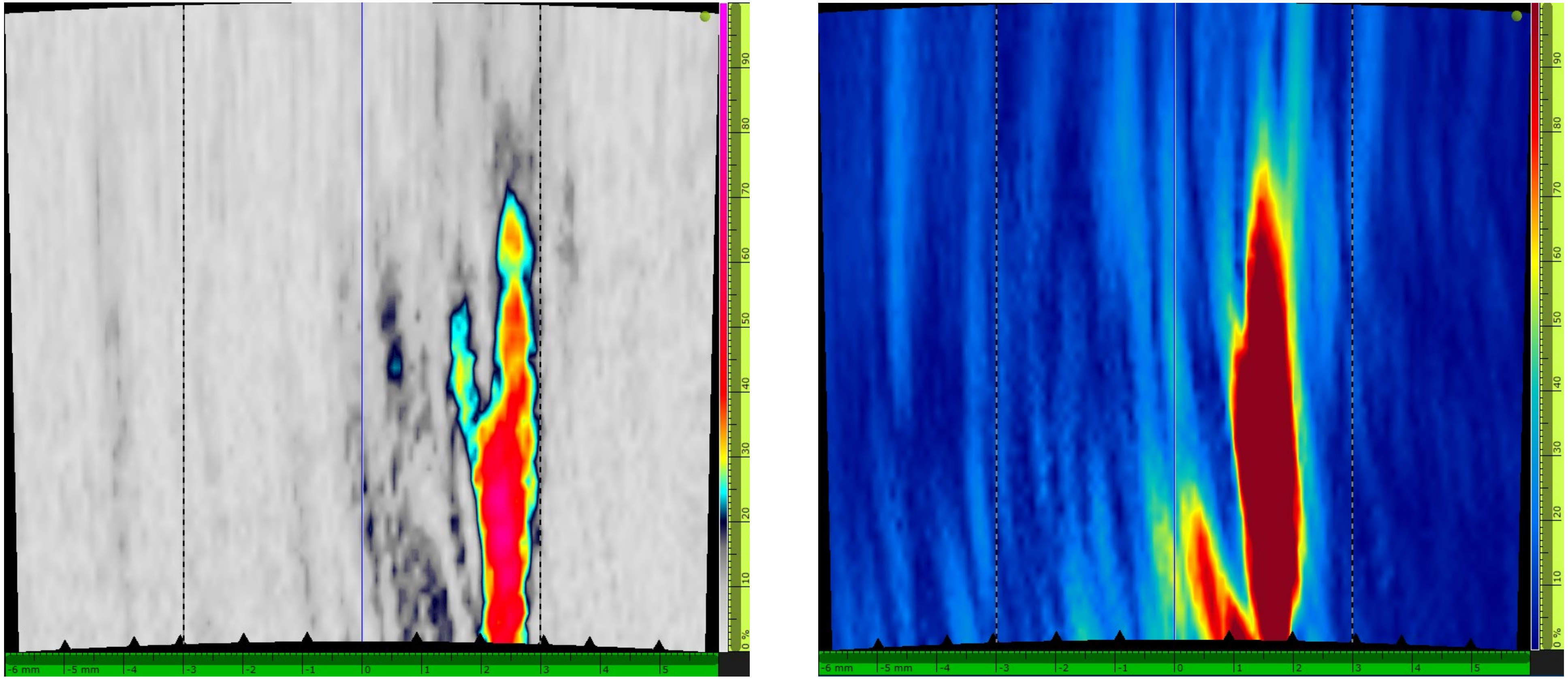




- The entire hook crack can be seen with only the TT-TT group in PCI but with conventional TFM two groups (TTT and TT-TT) are needed to see the whole crack.
- The crack can be sized using the tip diffraction.

Hook crack: TT-TT in PCI versus TTT and TT-TT in TFM – 5L32-A31 probe

Steel Pipe Electric Resistance Welding (ERW)



Branch crack: TT in PCI versus TT in TFM – 5L32-A31 probe

- PCI shows significantly more detail on the size and shape of the crack as well as the tip diffractions for easier sizing.

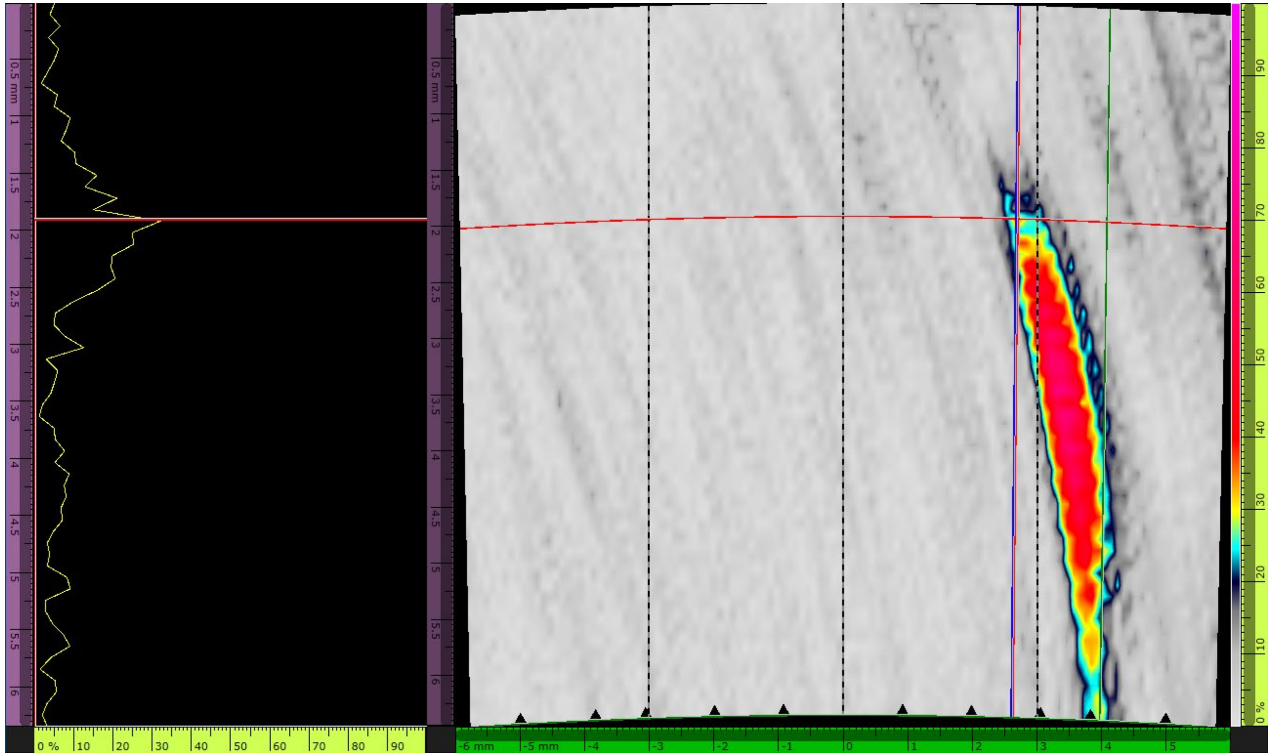
06

Tip Diffraction Sizing

Tip Diffraction Sizing

- One of the advantages of the PCI technology is that sharp tips from cracks and other defects will diffract. While these signals are rarely distinguishable in conventional TFM or PA, with PCI these diffractions signals are highly coherent and easily visible.

- Like the time-of-flight diffraction (TOFD) method, these tip diffractions can be used for accurate sizing, but with a 2D image of the defect. This means the defect can be sized in both directions.

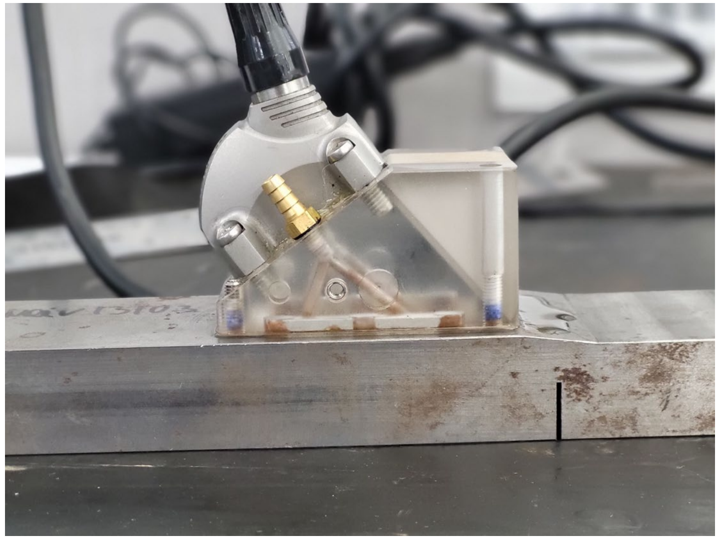


- The reference cursor is placed on the peak of the highest point of the crack in order to find its height.

- Because the tips of the crack diffract, the peak of the signal can be used for sizing rather than the −6 dB method.

Tip Diffraction Sizing – Calibration Notch

- To qualify a PCI setup, a notch sample can be used to validate the sizing.
- Like with TFM, the corner trap and notch tip show up as hot spots, which can be used as sizing markers for the notch height.



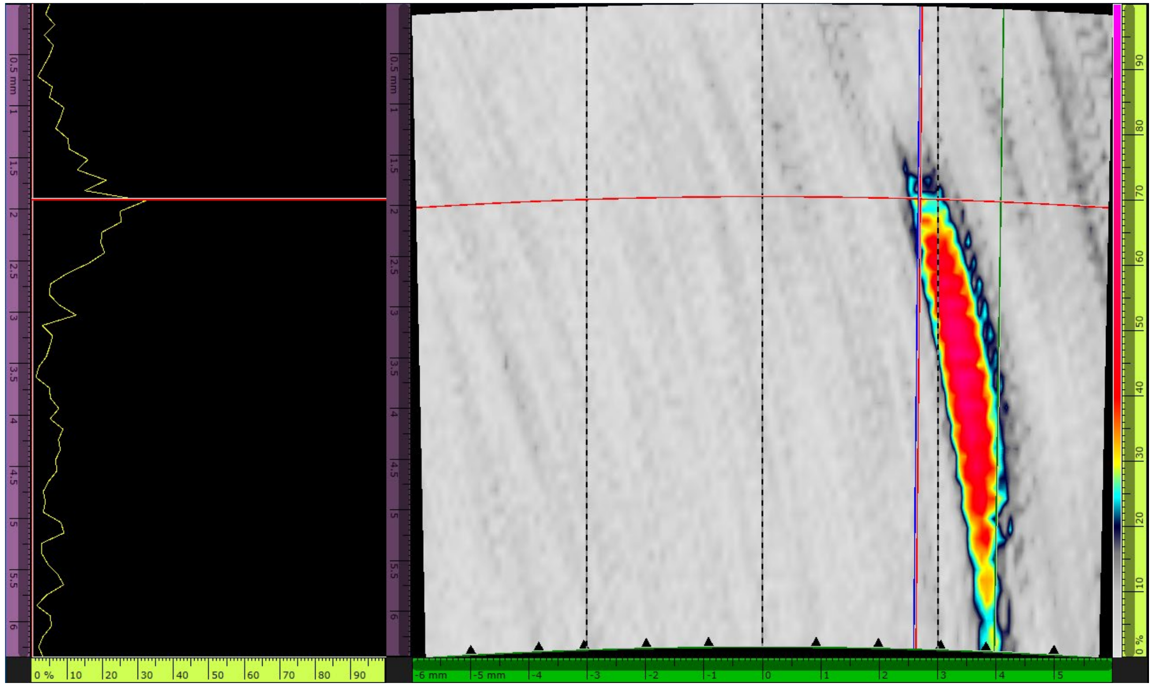
Tip Diffraction Sizing – Hook Crack Example

- Placing the cursors on the last max of the crack and the base of the crack enables the readings to be used directly for sizing.
- These 3 readings will be the height, width, and total length of the crack.
- These peaks remain constant regardless of the palette zoom.

D(m-r)
4.45 mm

I(m-r)
1.39 mm

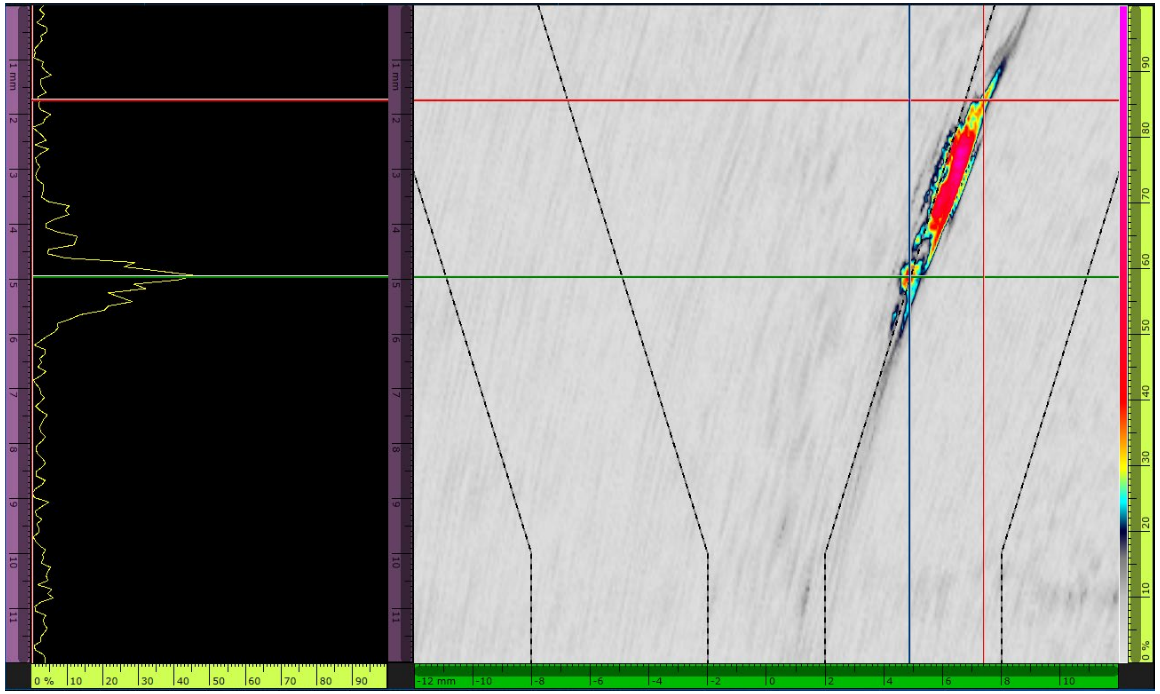
I·D(m-r)
4.65 mm



Tip Diffraction Sizing – LOF

- Like crack tips, the ends of a lack of fusion (LOF) will diffract and have ''hot spots'' at the ends.
- The cursors can be placed on each of the peaks of these hot spots, and you can use the readings for sizing.
- Since the sizing uses the peaks of these hot spots, their positions are unaffected by adjustments to the palette zoom.

D(m-r)	3.22 mm
I(m-r)	-2.54 mm
I·D(m-r)	4.10 mm



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SEEING IS SOLVING