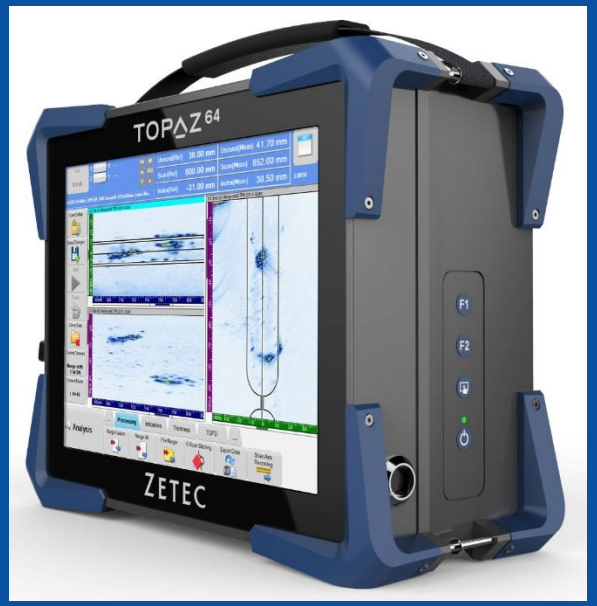
SlovCert

ZETEC
THE INSPECTION ADVANTAGE

TOPAZ 64 &
TFM FMC Technology



2019 March

Introduction

- PA UT is a mature and accepted technology in Power Generation, Oil & Gas, Aerospace, Heavy Industry, …
- The next technological step is *FMC (Full Matrix Capture)* and *TFM (Total Focusing Method)*
- Zetec's new TOPAZ64 includes FMC and TFM technology
- *Experimental validation of the improvements* in flaw detection and characterization capability is *essential for industry adoption.*

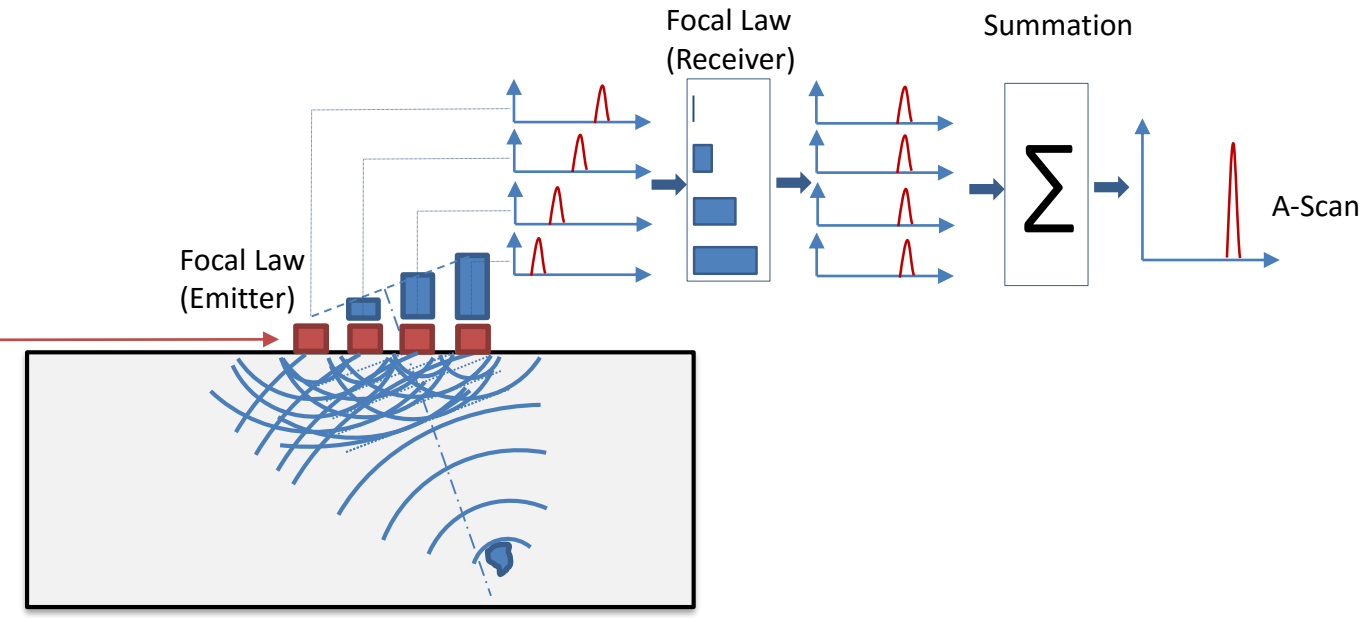
Overview

- Principles of TFM & FMC
- FMC Data & Offline Processing
- Data Quantity & Inspection Strategy
- TFM Codes
- Topaz 64
- Case studies : HIC, HTHA, thick vessel welds, dissimilar metal welds
- Conclusions

Principles of TFM & FMC

Principles of the Standard Phased Array

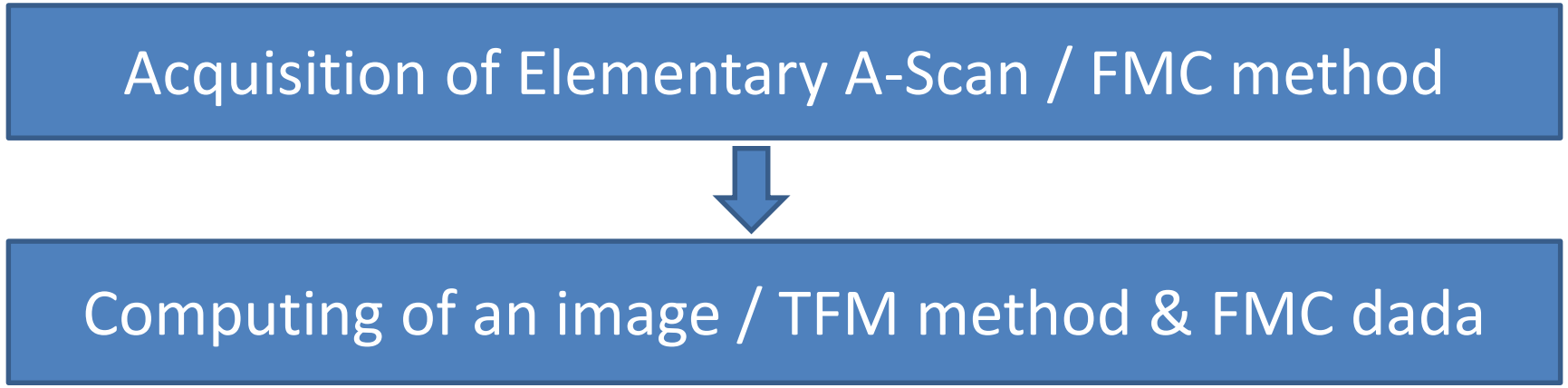
- The instrument pulses every relevant probe element, using the delay defined by the focal law.
- Energy from each probe element is summed together, creating constructive and destructive interference



- The instrument digitizes signal received back on each relevant probe element and performs a summation of signals according the focal law.
- The end ***result is a summed and digitized A-Scan***
- This Process is ***repeated for every focal law (angle, aperture) to generate a Sector Scan or Linear Scan. Raw signals are not saved***

Principles of TFM (Imaged Focused on any points)

It's a 2 steps Process

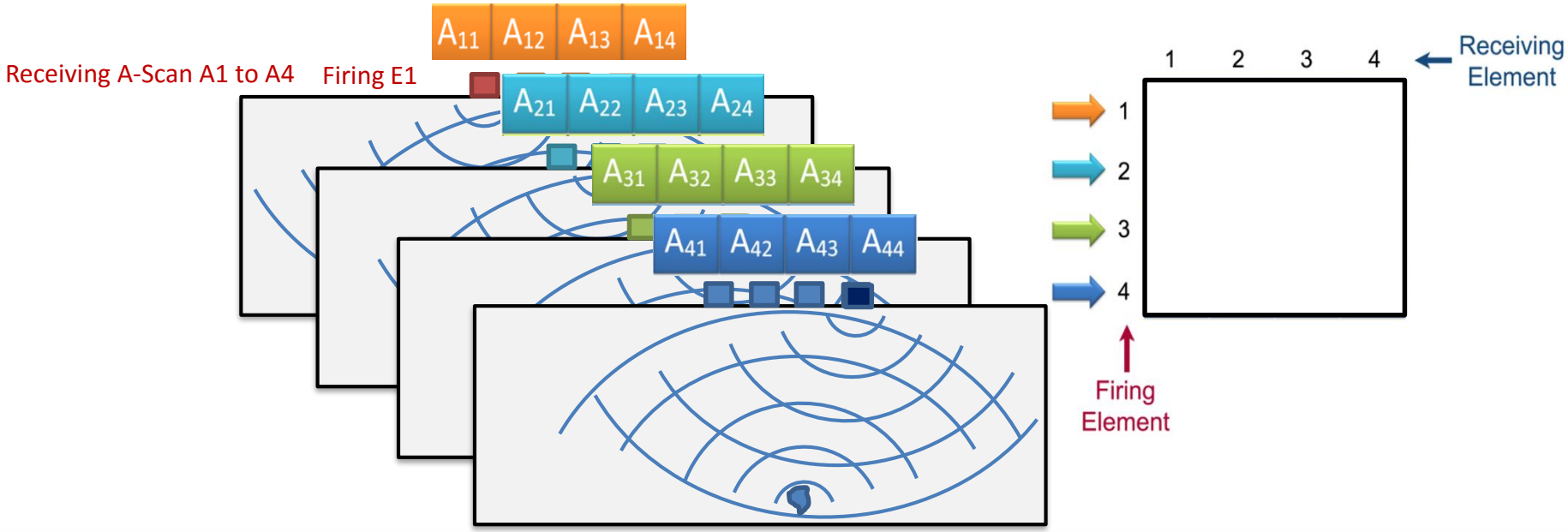


This global process can be real-time or off line

- Elementary A-Scan: A-Scan signal from receiving element,
- FMC: Full Matrix Capture, method for collecting of elementary A-Scans.
- TFM: Total Focusing Method

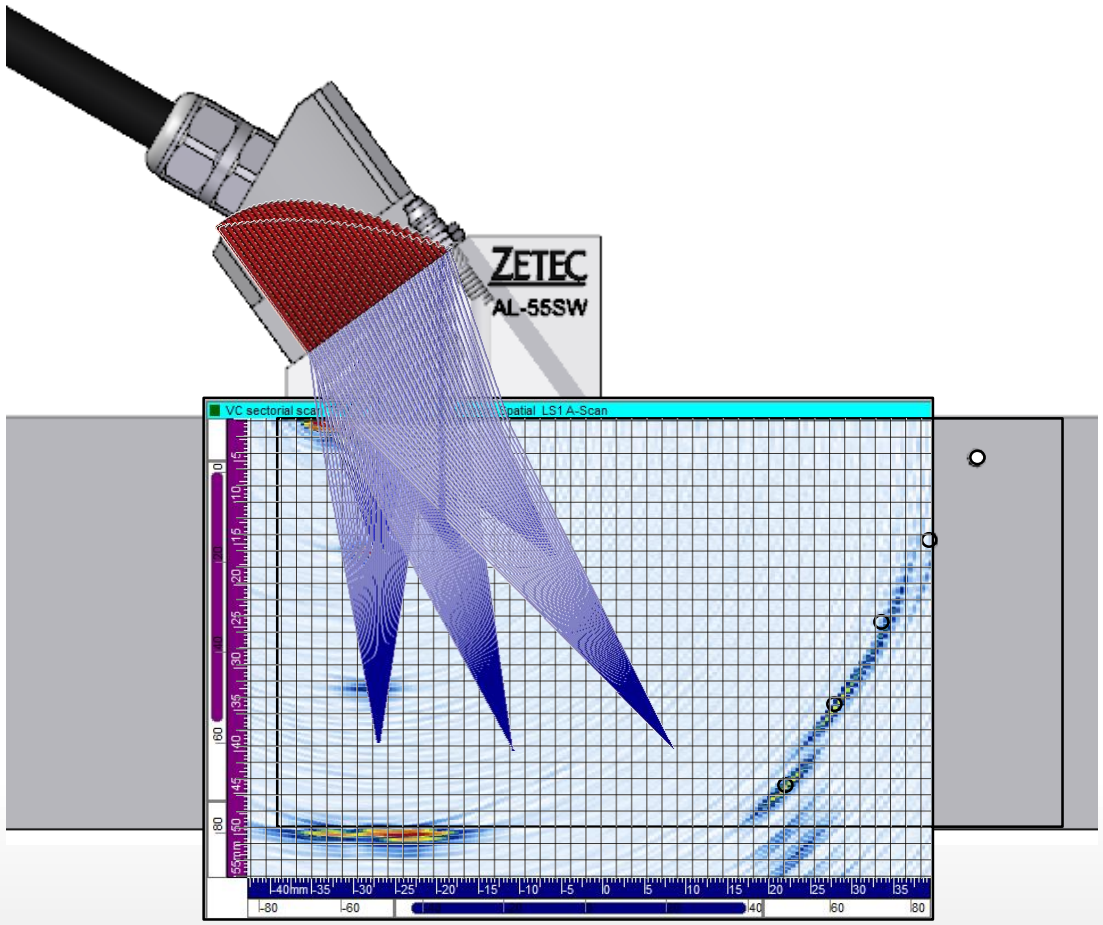
FMC (Full Matrix Capture)

Full Matrix Capture (FMC) consists of ***capturing and recording A-Scan signals from every transmitter-receiver pair*** in the array

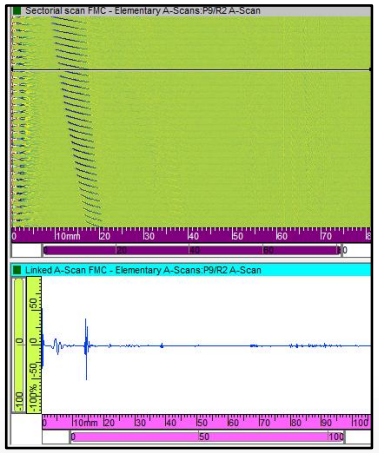


From raw A-scan it is possible to generate UT imaging for ***any given focal law / beam*** (aperture, angle, focus depth), and for ***improved algorithms (e.g. TFM)*** through ***post processing***

Advanced Focusing Techniques - TFM

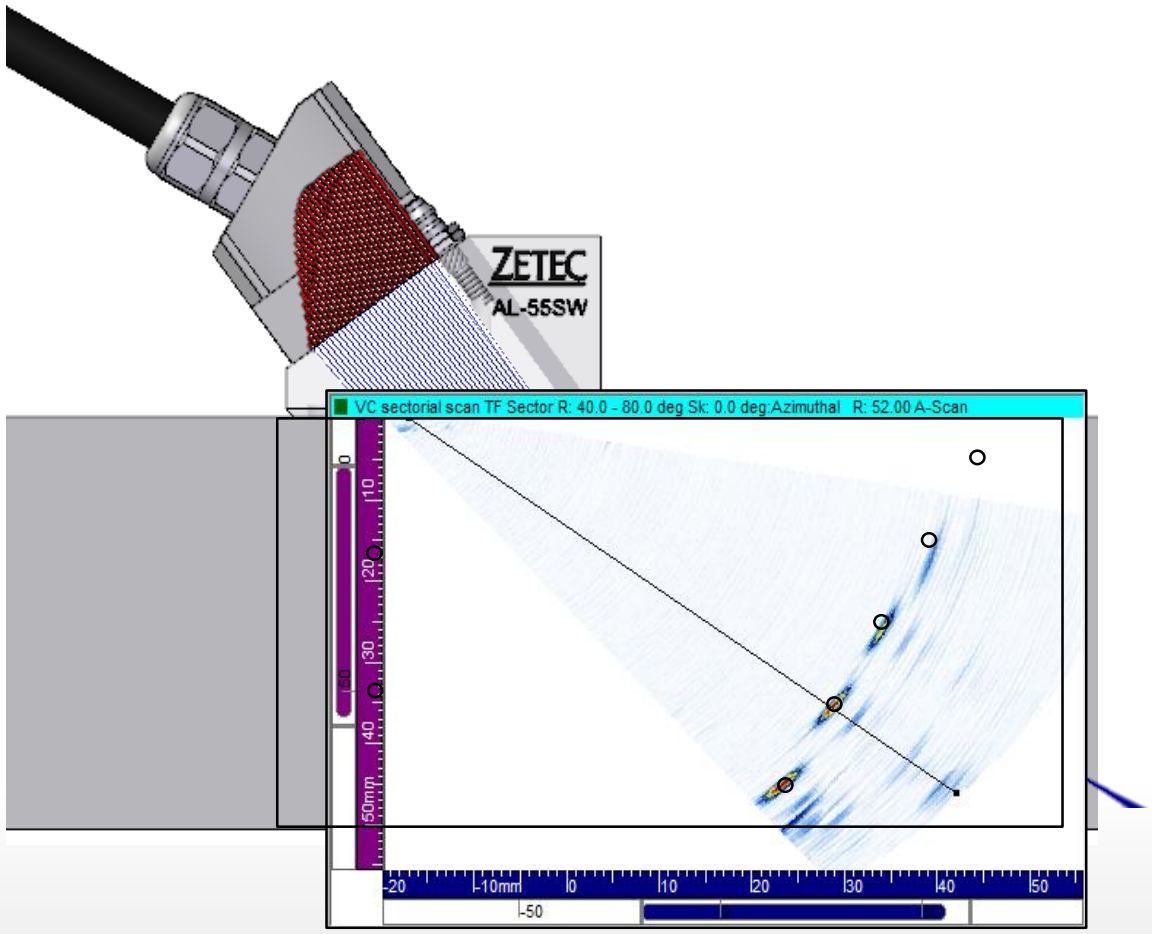


TFM – Frame LW

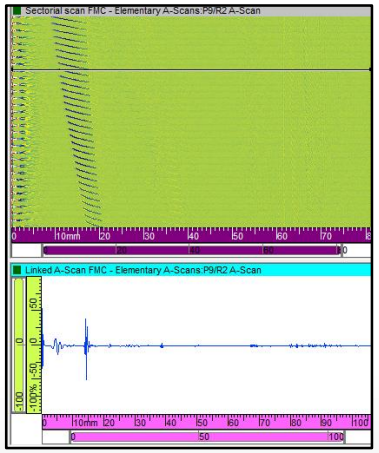


FMC Raw Data

Advanced Focusing Techniques - STF



Sectorial Totally Focused

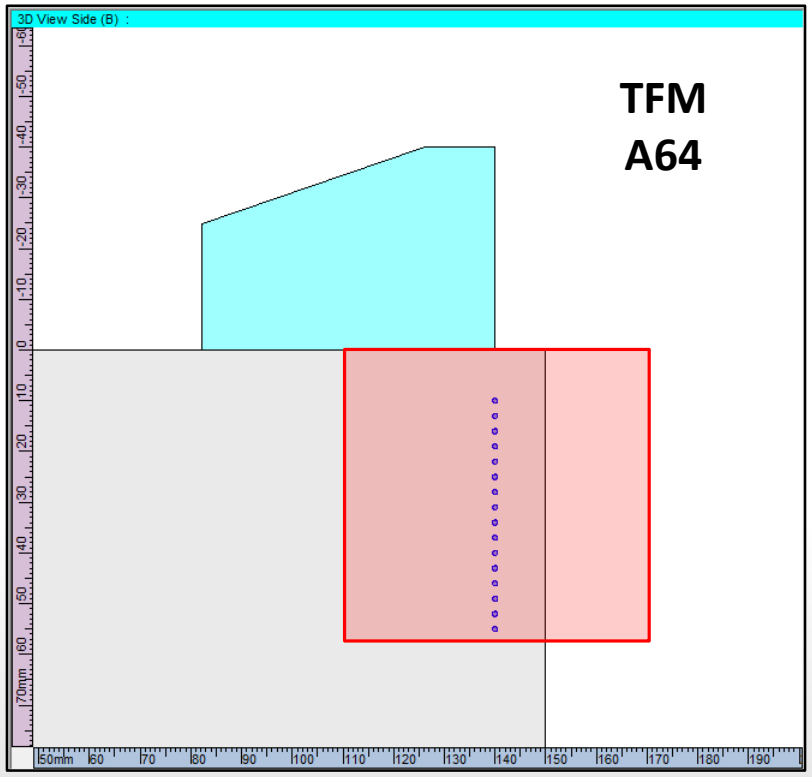


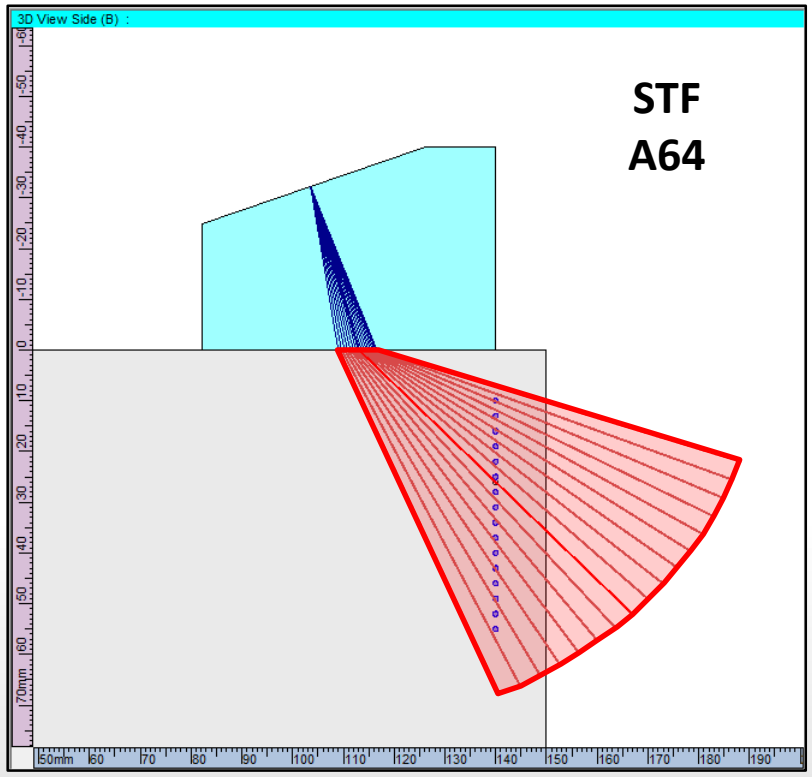
FMC Raw Data

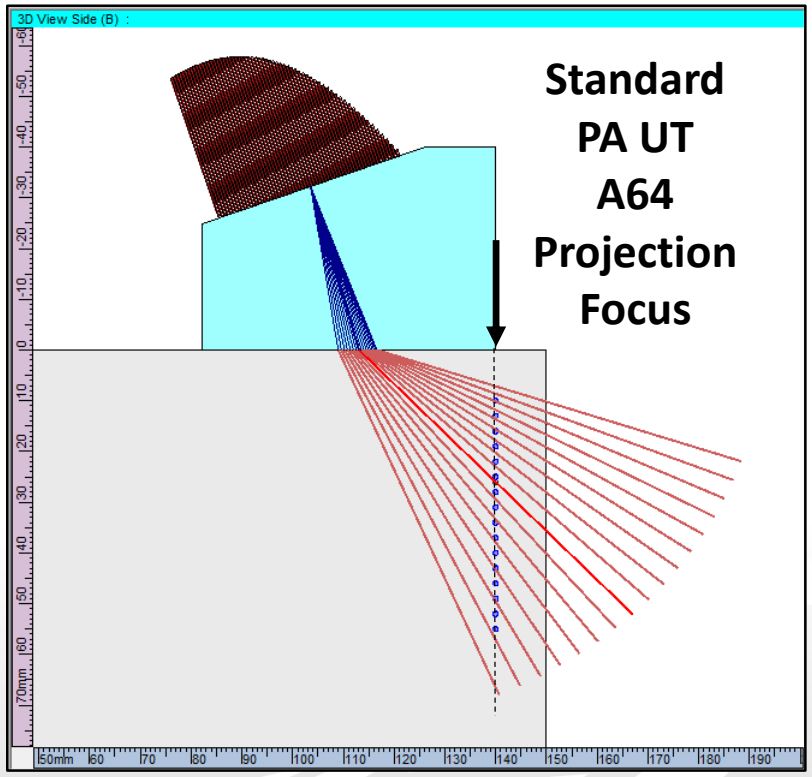
Benefits of Advanced Focusing Techniques

5 MHz linear array, 64 elements, LW wedge on Ø 1 mm SDH

Comparison of *focusing capability, TFM, STF versus standard PA UT*







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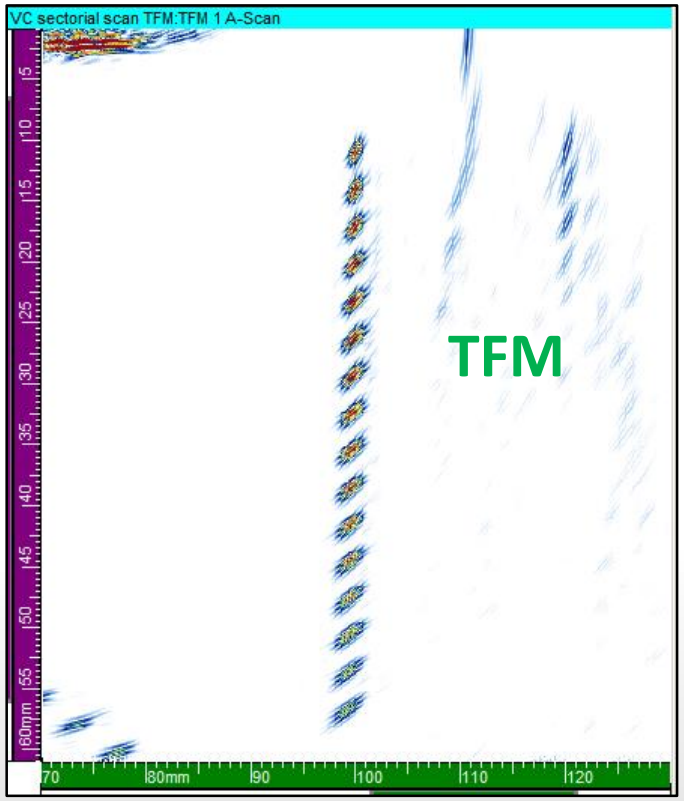

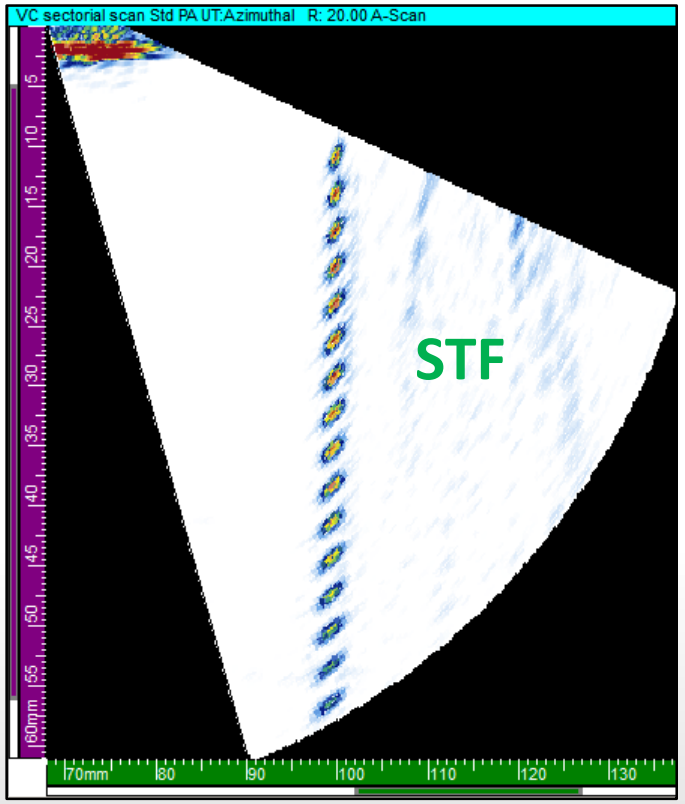

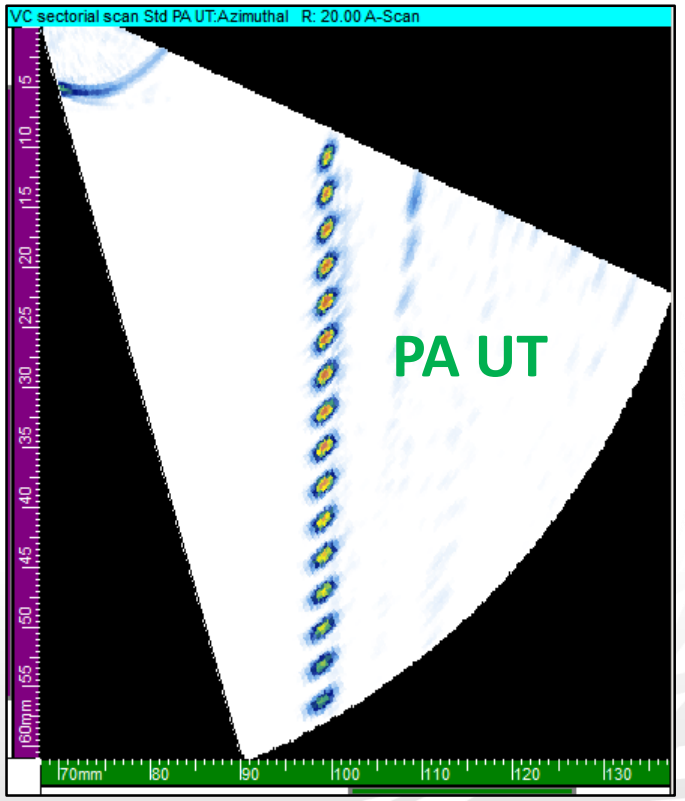

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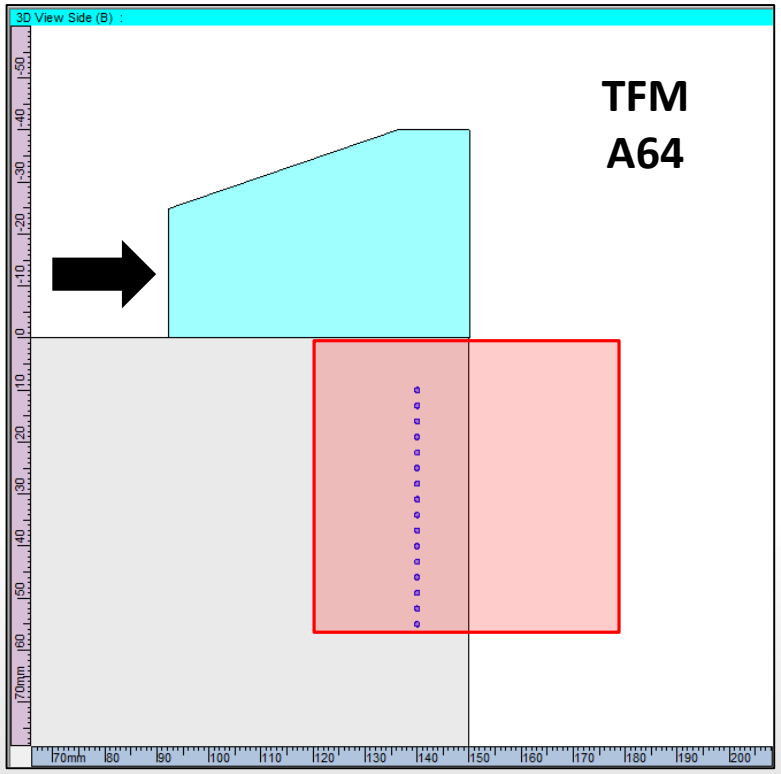

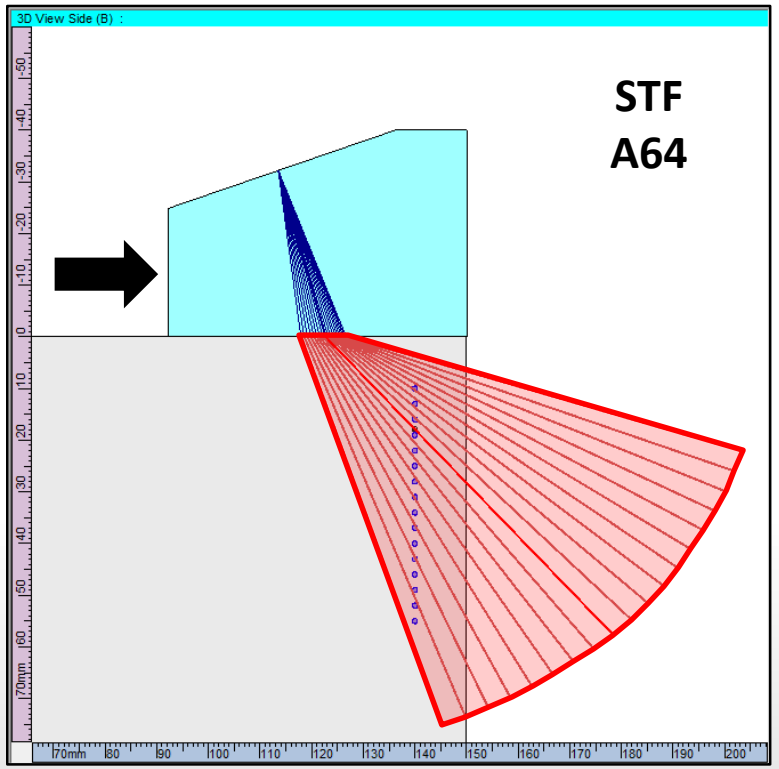

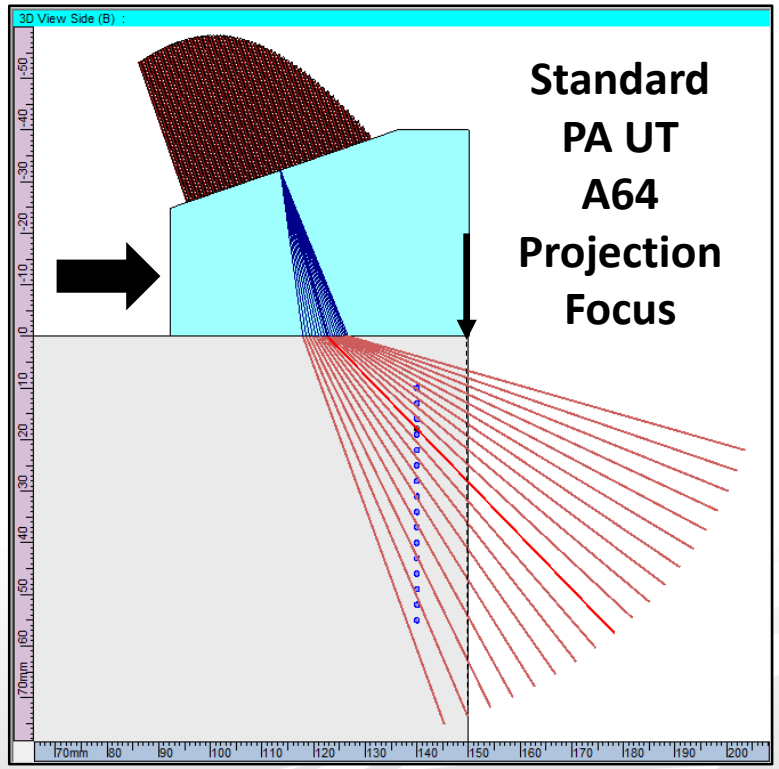

Benefits of Advanced Focusing Techniques

5 MHz linear array, 64 elements, LW wedge on Ø 1 mm SDH

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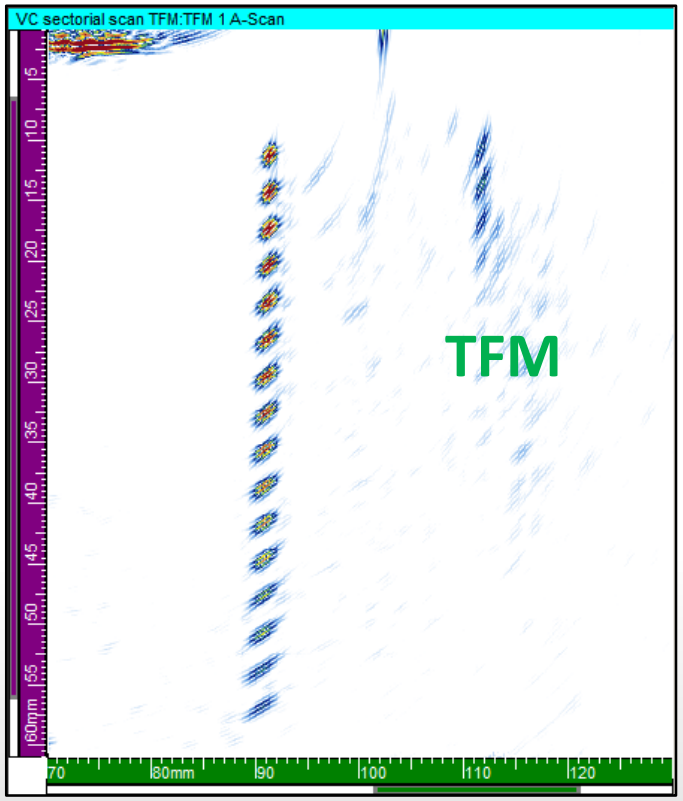
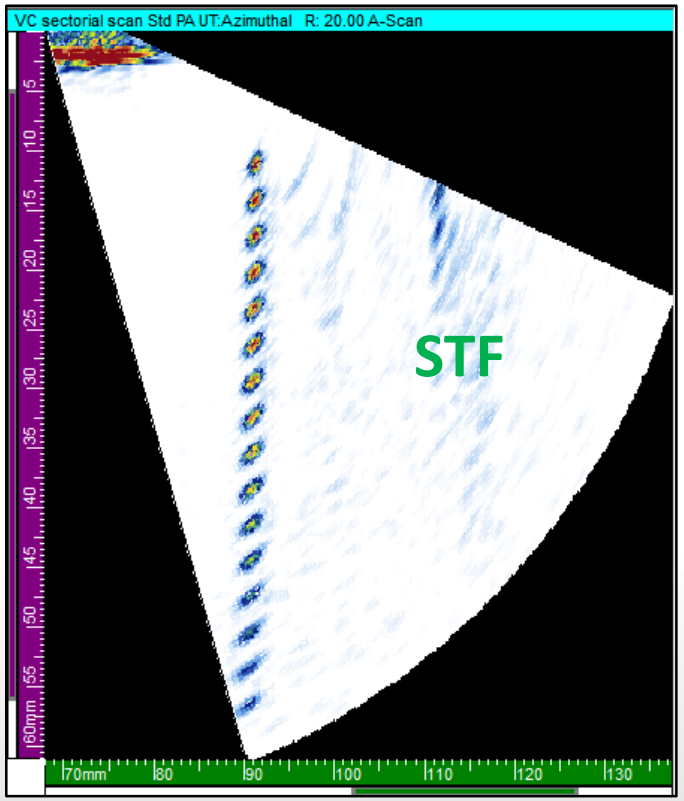
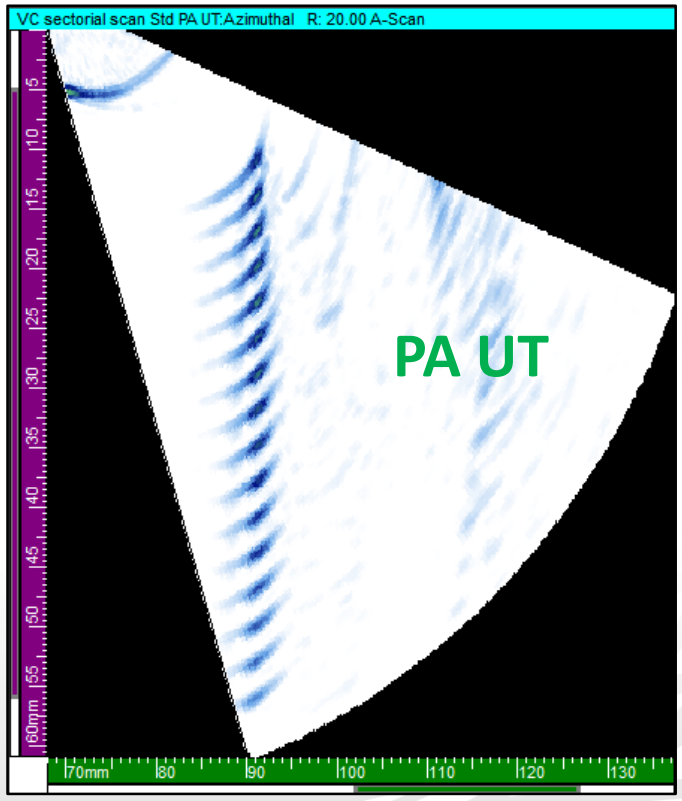


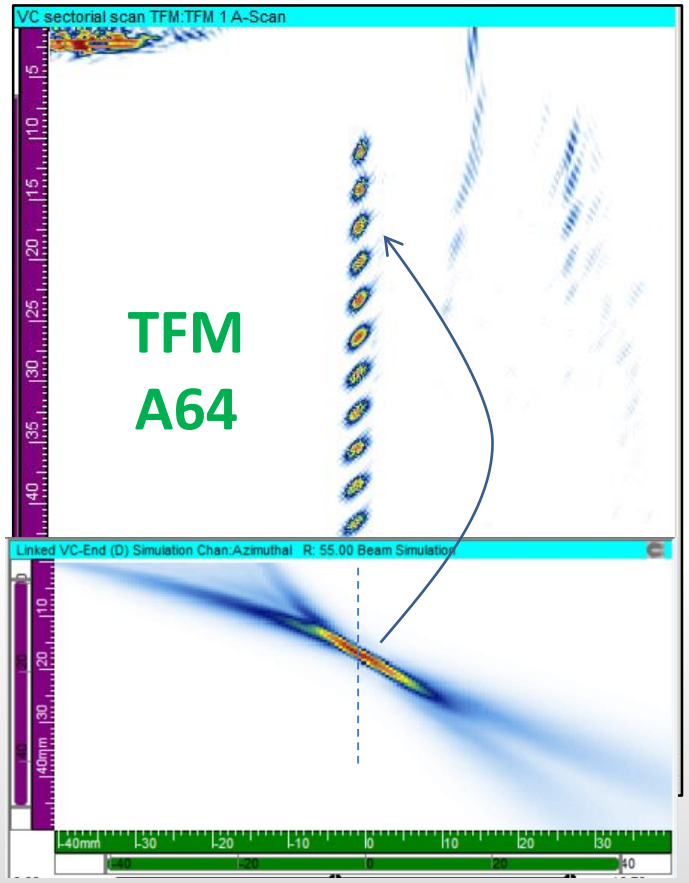


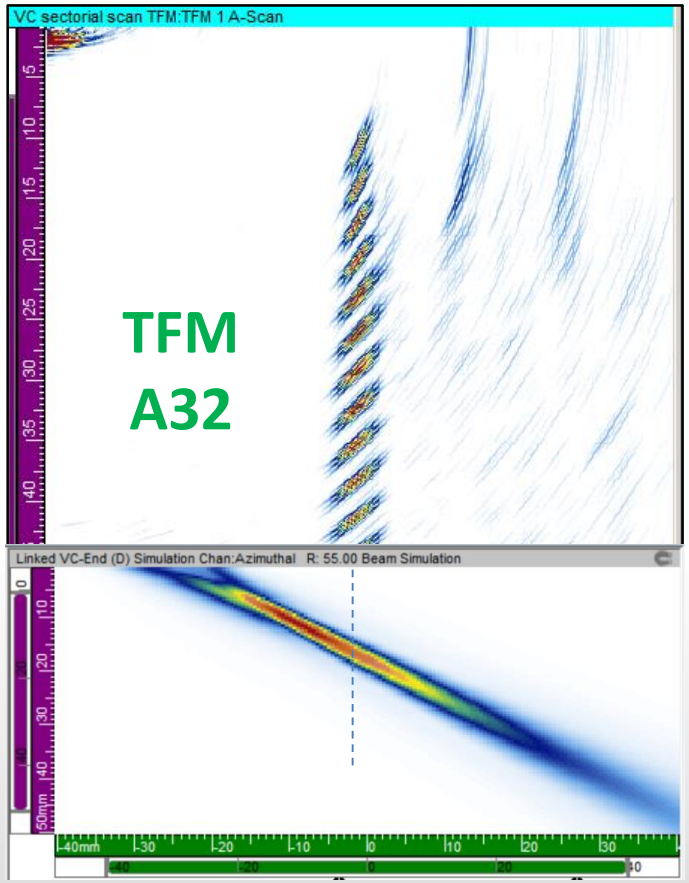


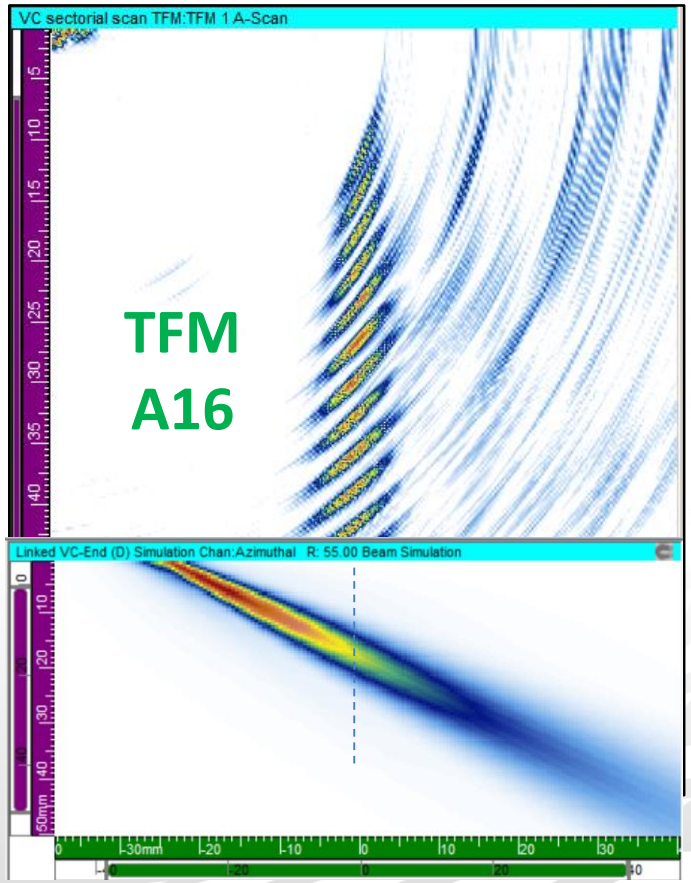
Benefits of Advanced Focusing Techniques

5 MHz linear array, 64 elements, LW wedge on Ø 1 mm SDH

Influence of active aperture on *TFM focusing capability*





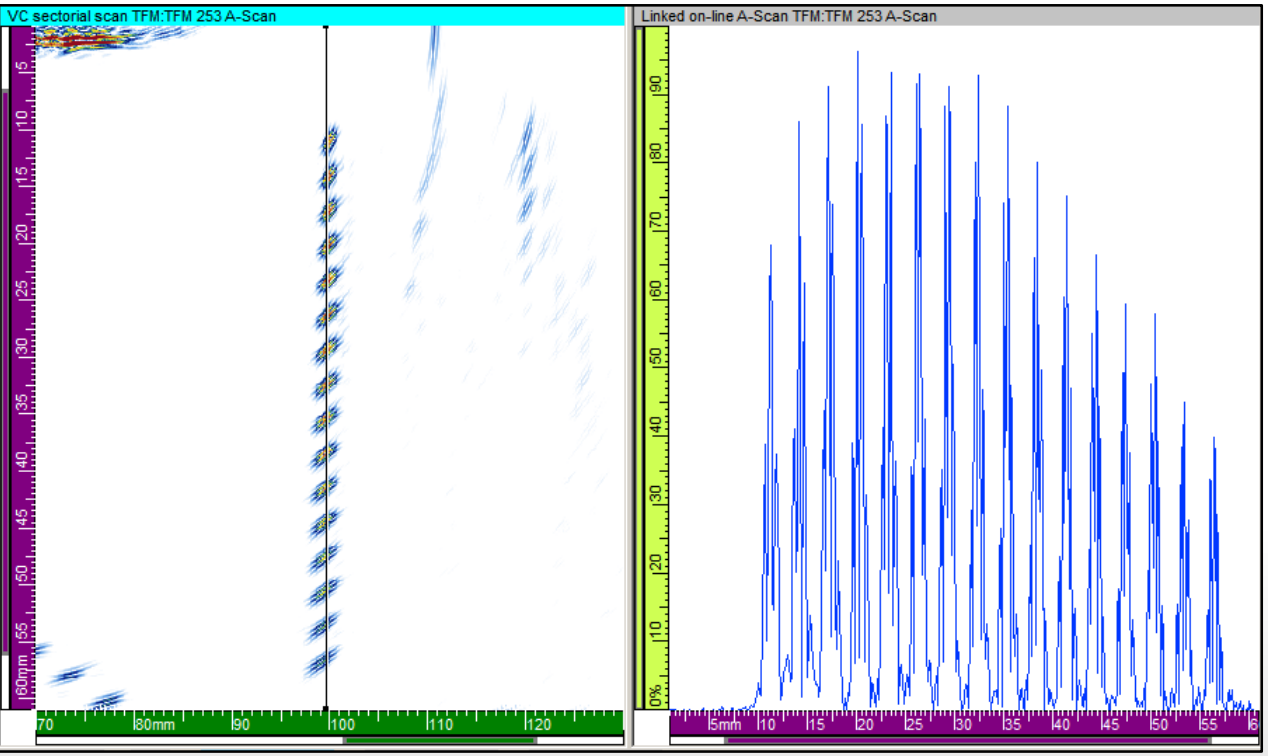


Amplitude Fidelity – Impact on the Detection

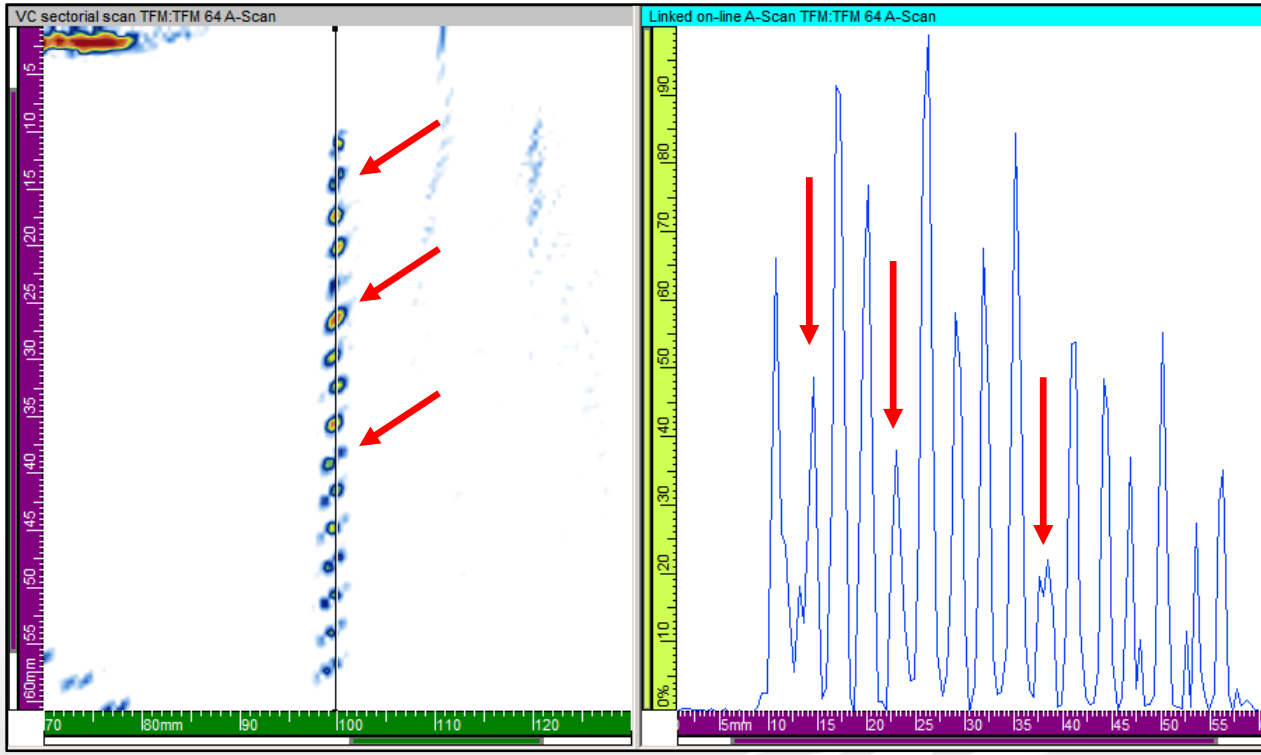
5 MHz linear array, 64 elements, LW wedge on Ø 1 mm SDH

Influence of the TFM frame resolution on detection (amplitude fidelity)

10 pixels per wave length



2.5 pixels per wave length (lost up to 10dB)



TFM Image Size version Resolution (Medium R -2dB)

Frequency	5MHz, LW, Carbon Steel		
Pixels	256x	512x	1024x
Application	HTHA, Corrosion, LW inspection Carbon Steel		
Frame	60mm	120mm	240mm

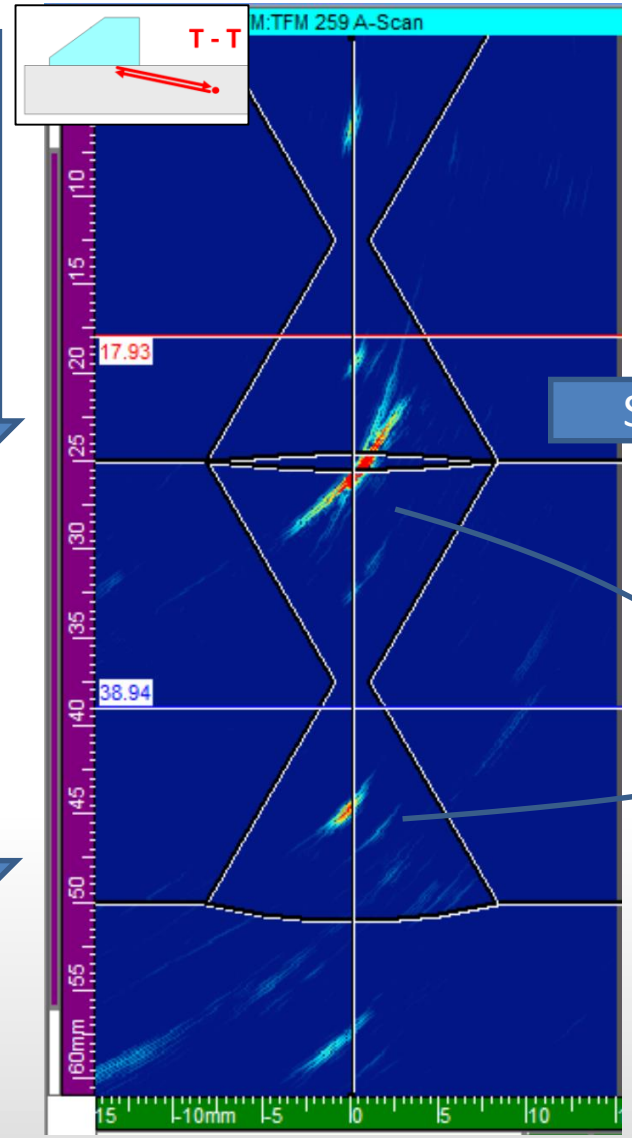
For High Resolution (10 pixels/p, 0.5dB), thickness must be /2

Frequency	5MHz, SW, Carbon Steel		
Pixels	256x	512x	1024x
Application	Weld Inspection, Carbon Steel, SW40 to 70		
Frame	33mm	66mm	132mm

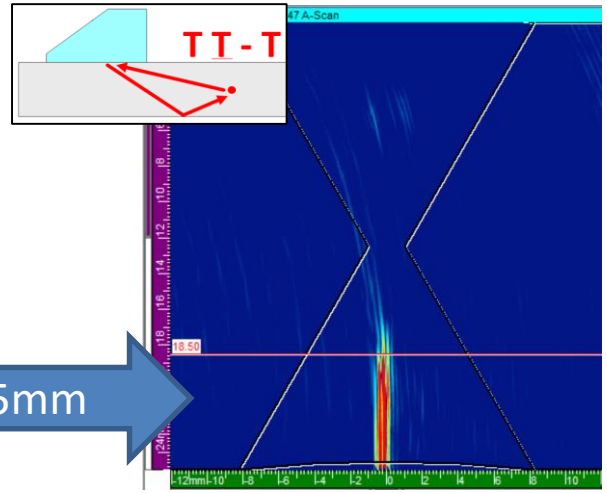
Inspection Modes

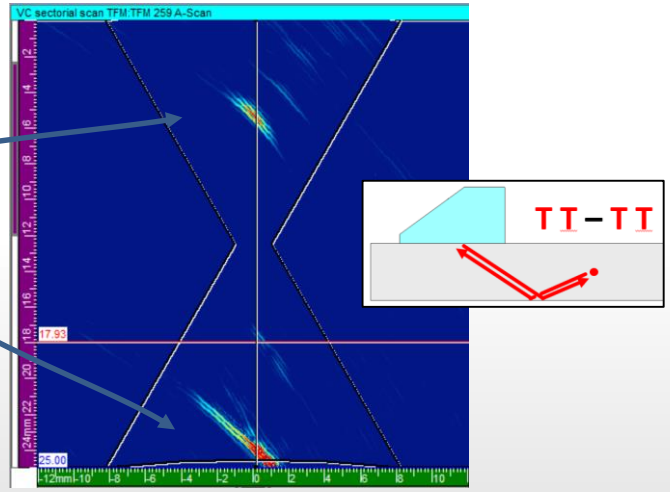
1st Leg

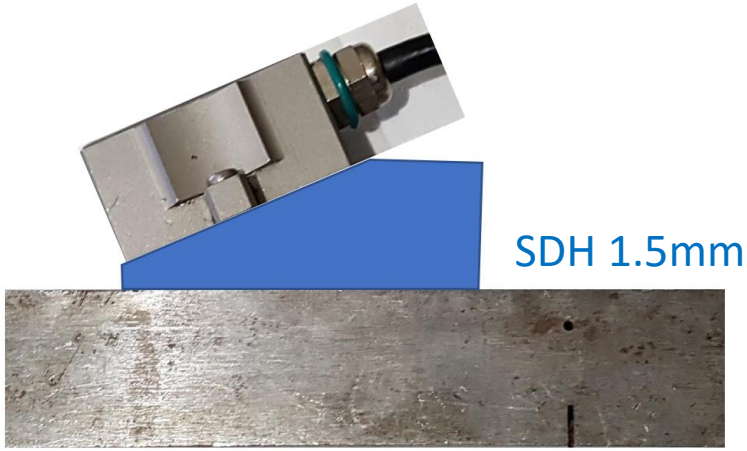
2nd Leg



Slot 6.35mm







SDH 1.5mm

Slots 6.35mm

Data Quantity & Offline Processing

TFM – Data Quantity

Pipe 12”, dual side, res. 1mm

Frame Size

- 256^2 pixels → 65K points → 128KB
- 512^2 pixels → 262K points → 0.5MB
- 1024^2 pixels → 1M points → 2MB

- 122MB
- 498MB
- 3.7GB

HMC (half FMC)

- 32.5MB

- 60.8GB

Linear Scanning, 64E aperture 10 Elements, A-Scan 1024 points

- 110KB

- 105MB

Sectorial Scanning, 40 to 70 res 1 deg, A-Scan 1024 points

- 62KB

- 59MB

FMC Data & Offline processing

UV3 allows the FMC data processing, in the objective to

- Generate new TFM data (channel) with
  - Higher image resolution
  - Alternative mode
  - New specimen shape,
  - New material velocity
- Generate “standard” PA channels, for evaluating
  - Inspection Method, (Impact of detection/sizing according to PA parameters)
  - Impact of dead elements

TFM – Codes

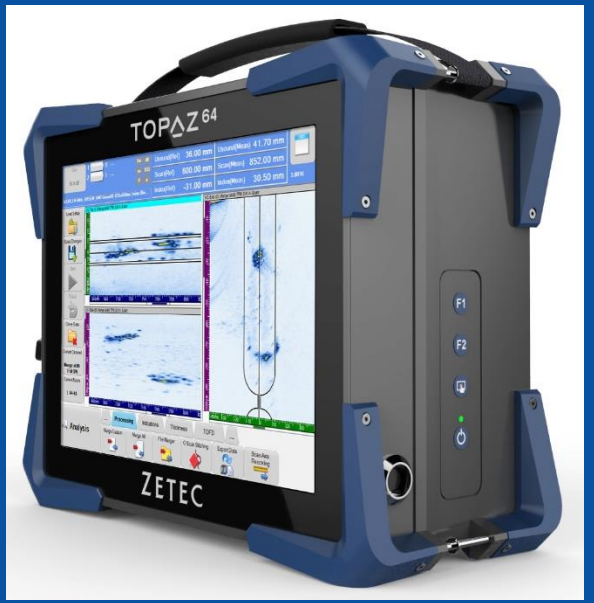
Codes

- Currently, this new methodology is **not supported** by Codes
- It is not permitted to use this technique for “Code compliant” inspections
- 2 working groups on FMC/TFM was founded
  - Zetec, other manufacturers, users and authorities are participating
  - Draft in progress
  - Issues to resolve

  ASME Section V
  - Schedule is to have a mandatory appendix for publication by December 2019

  IW, ISO codes
  - Schedule is to have a code for September 2020
  - The content, rules, should be as the ASME code, but under the ISO form.

TOPAZ 64



TOPAZ 64

ZETEC
THE INSPECTION ADVANTAGE

- 64/128PR configuration for *two-side inspection of thick welds, with 64 active elements* + 2 separate conventional PE/TOFD channels at 200 V
- Magnesium casing, *No air intake,*
- *12” Hi-Res multi-touch* display, 1024 x 768 pixels
- Windows 7 64 bits Ultimate
- SSD 512 GB
- *Fast Ethernet, USB3, HDMI*

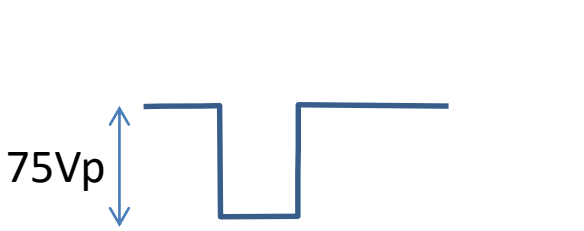
TOPAZ 64

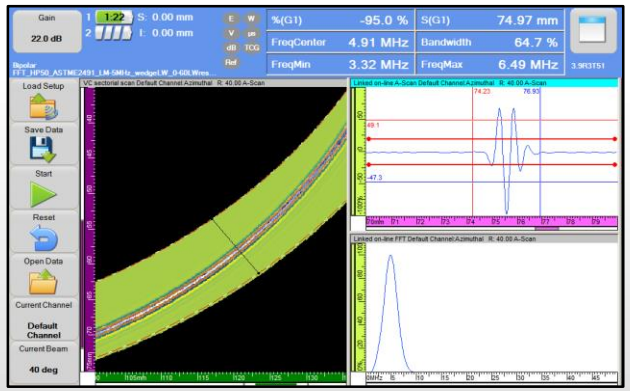
ZETEC
THE INSPECTION ADVANTAGE

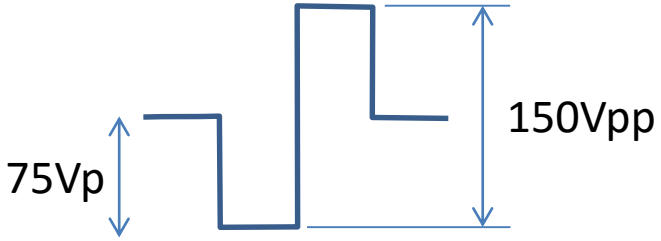
- *"Live" TFM,* with frames *65k (256^2),*
- Option *Live" TFM High Resolution,* with frames up to *1 MB pixels (1024^2),*
- Multi-groups, with TFM multi-modes
- *Recording of TFM data groups*,
- Option for recording *FMC data on the fly*
- *3 Encoders*
- Driven by *UltraVision Touch*

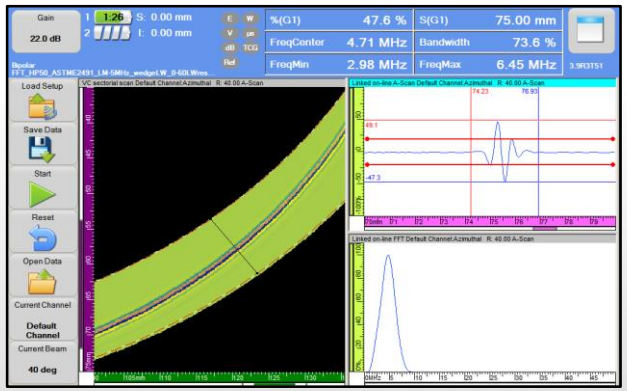
EMITTER

- Unipolar 75Vp or Bipolar 150Vpp, *+40% acoustic energy*
- *“Duty Cycle Control”*
  - *Emission pulse stable, at the correct voltage (EN codes Code Compliance) in all cases (Pulse Width, Recurrence, Scanning speed, temperature)*



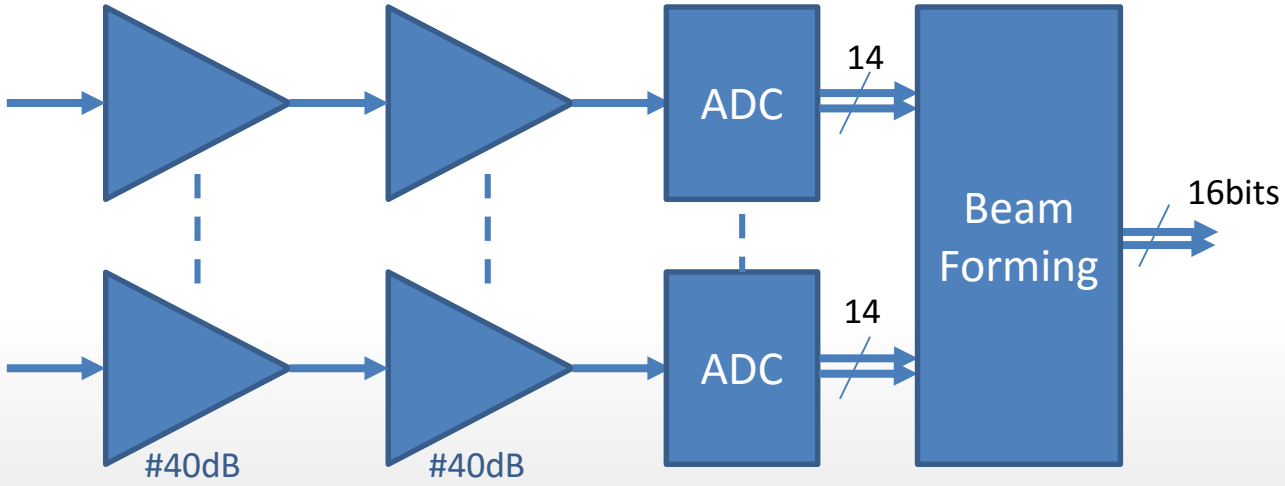






AMPLIFIER

- 2 Stages amplifier (per channel)
- 75 dB (Analog Gain)
- 14 bits ADC, 16 bits after beam forming (aperture 4E)



Bipolar EMITTER

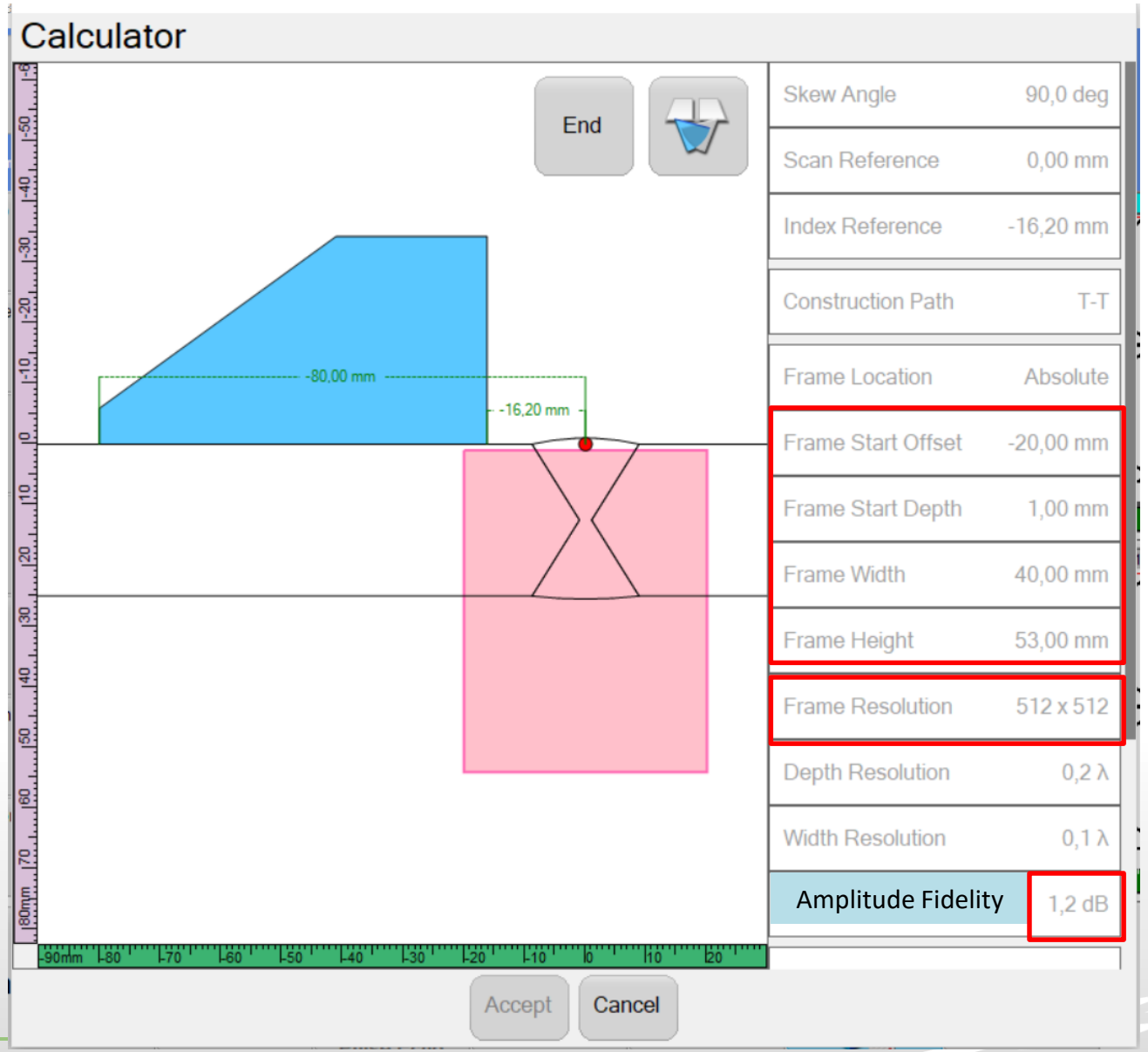
+

2 stages AMPLIFIER
(versus 1 stage)

=

SNR Improvement from 12 to 18 dB

TOPAZ64 - TFM Calculator



Frame size in mm

Frame size in pixels

Indicator of the Image Quality

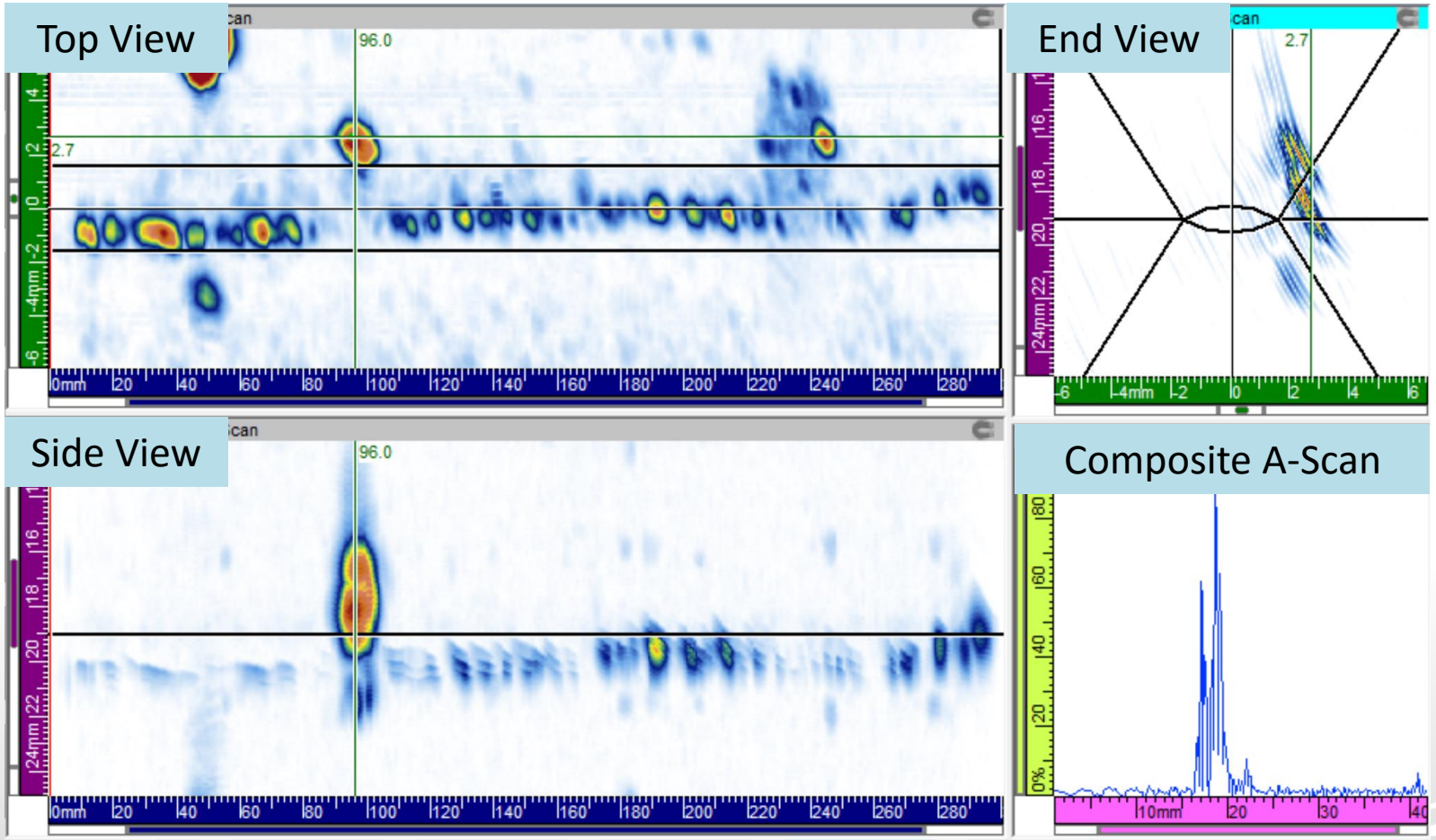
< 0.5dB : High Resolution

≤ 2dB : Code Compliance (2019)

> : Poor quality

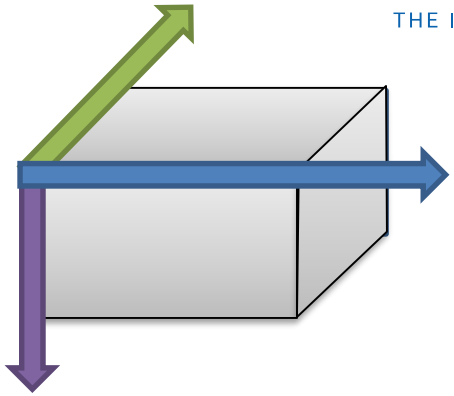
TOPAZ64 - Tools

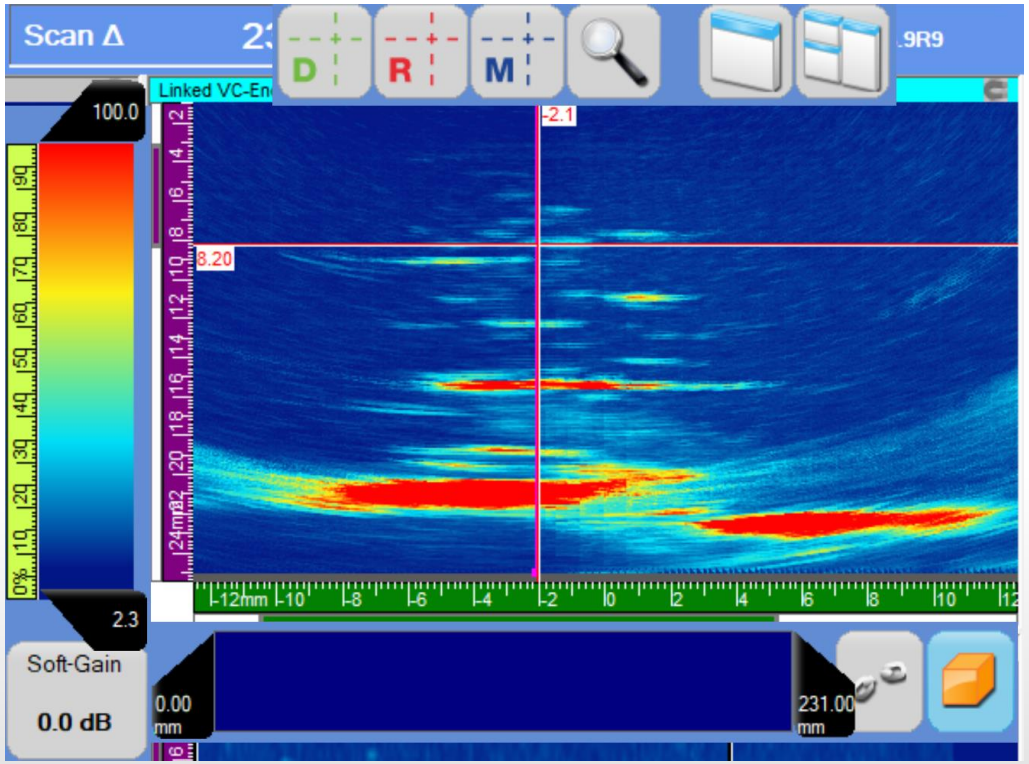
- *All UT tools available for PA also available for TFM*

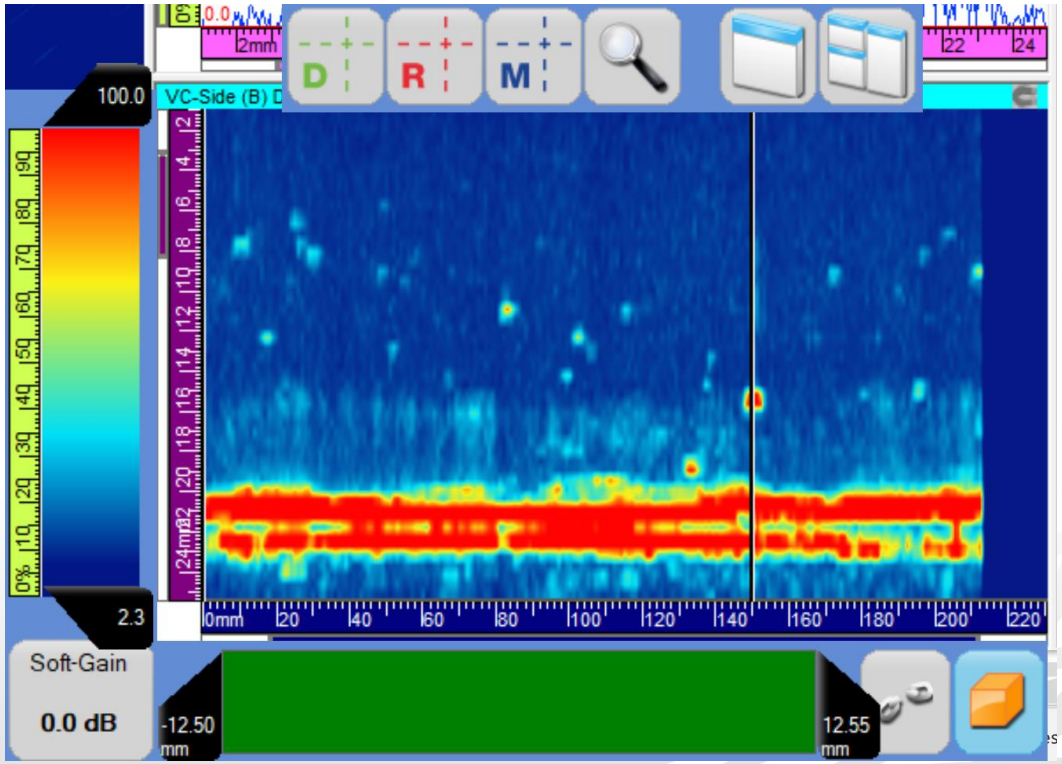


TOPAZ64 - Tools

- Projection views with slicing cursors for quick analysis, Direct global view



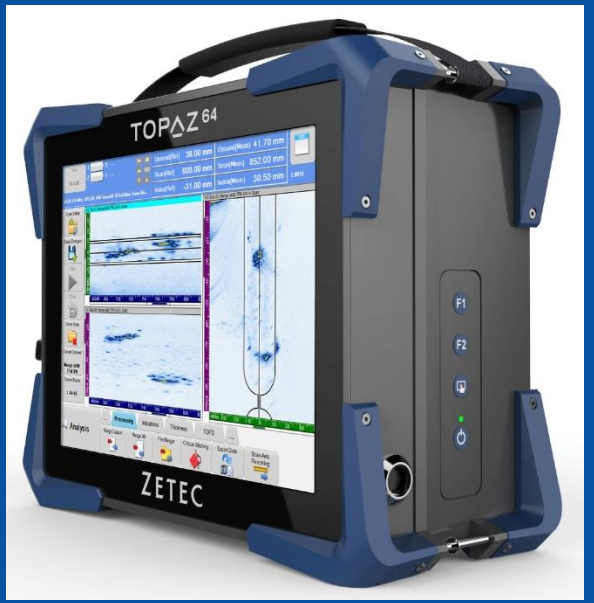




TOPAZ 64 - Configurations

Instrument model	Channel Configuration		FMC/TFM Resolution		Raw data saving	Multiple PA probes
	64/64	64/128	0.25M	1M		
ZPA-IUT-TOPAZ-64/64P	√					√
ZPA-IUT-TOPAZ-64/64P-TFM	√		√			√
ZPA-IUT-TOPAZ-64/128PR		√				√
ZPA-IUT-TOPAZ-64/128PR-TFM		√	√			√
ZPA-IUT-TOPAZ-64/128PR-TFM HR		√	√	√		√
ZPA-IUT-TOPAZ-64/128PR-TFM HR-D		√	√	√	√	√

Case Study

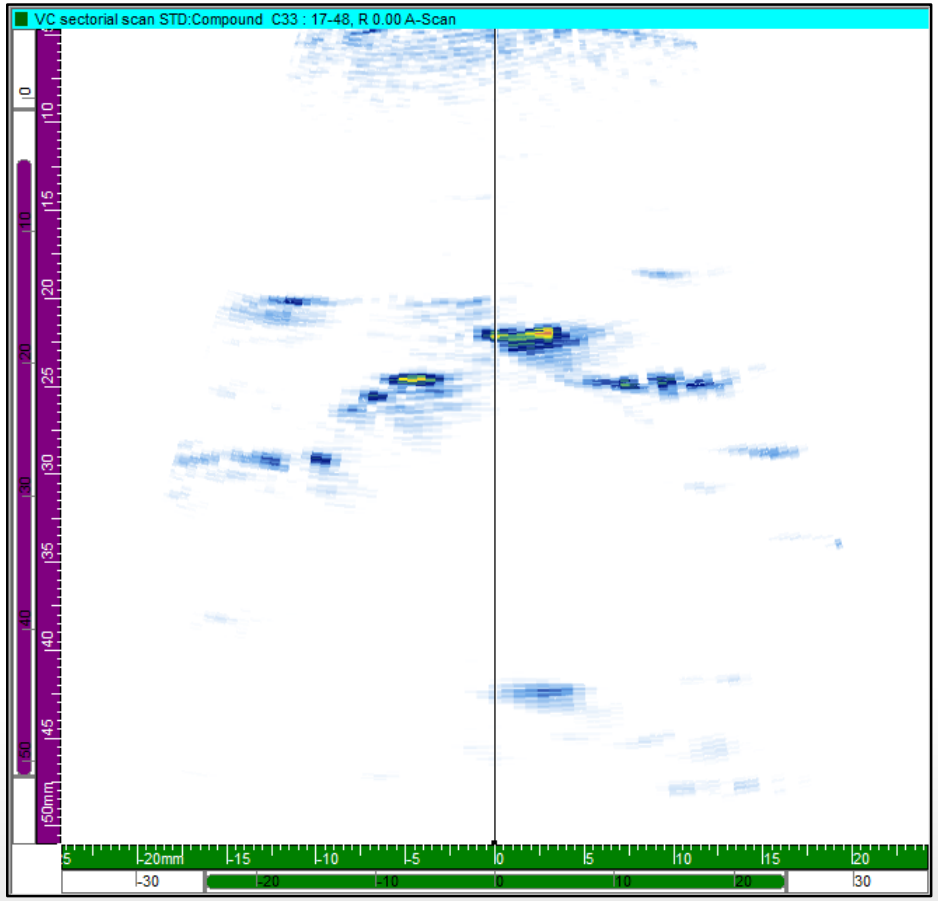


Case Study – HIC

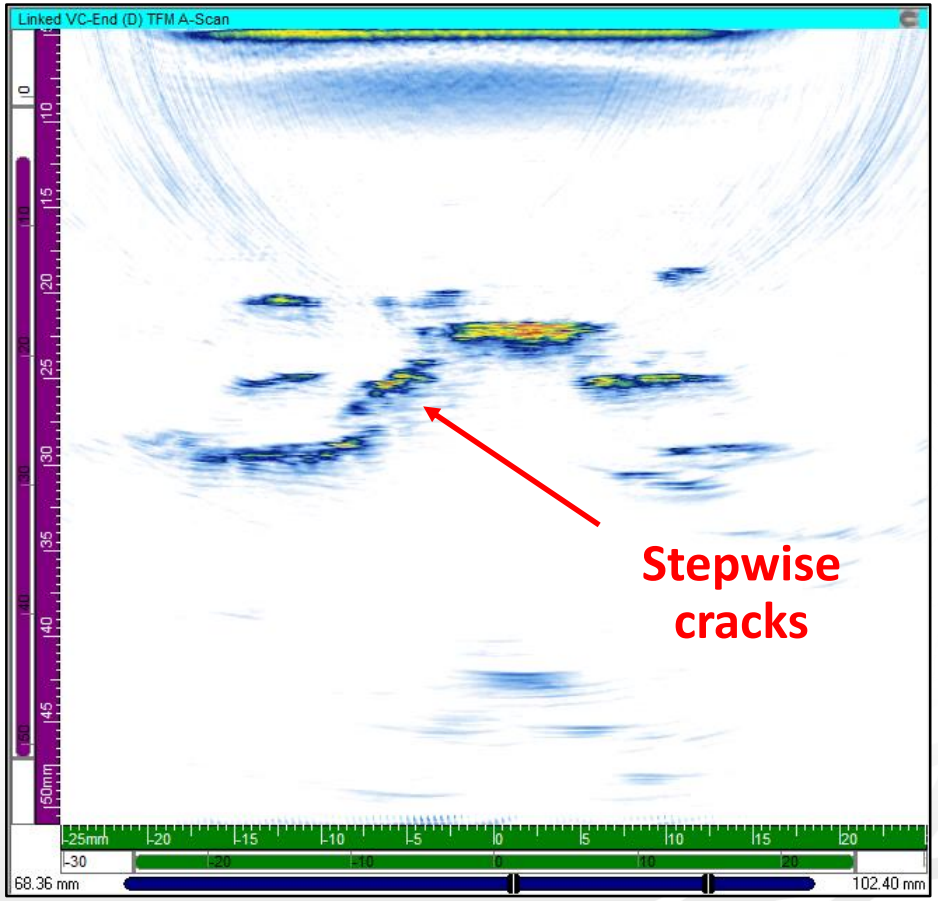
- Hydrogen Induced Cracking (HIC), is a common type of damage occurring in wet H2S refinery process environments, even at relatively low temperatures.
- Specimen T = 1.5”, with extensive HIC damage around mid-wall : hydrogen blisters connected by stepwise internal cracks
- 10 MHz linear array probe, 64 elements, in direct contact

Case Study – Hydrogen Induced Cracking

PA UT Compound Scan



TFM Frame 512 x 512



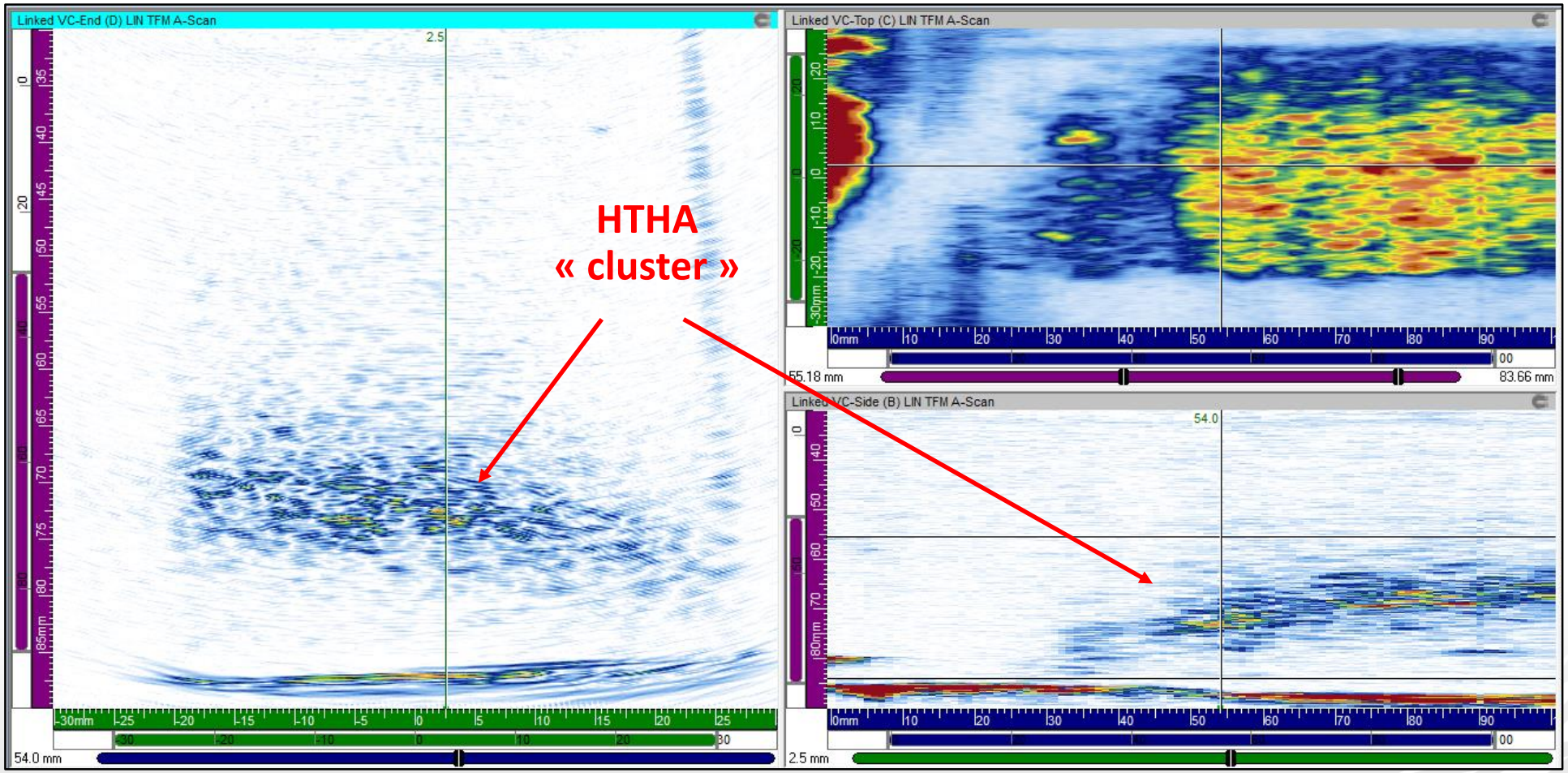
(Courtesy of Lavender International)

Case Study – HTHA

- High Temperature Hydrogen Attack, or HTHA, occurs in steels operating at high temperatures (above 400°F) in hydrogen environments, in refinery, petrochemical and chemical facilities
- Early stages of HTHA are difficult to detect, because of the small size of the voids, typically < 0.1 mm (0.004”)
- Specimen contains HTHA damage around 3” deep
- 10 MHz linear array probe, 64 elements, in direct contact

Case Study – HTHA

TFM Frame 512 x 512

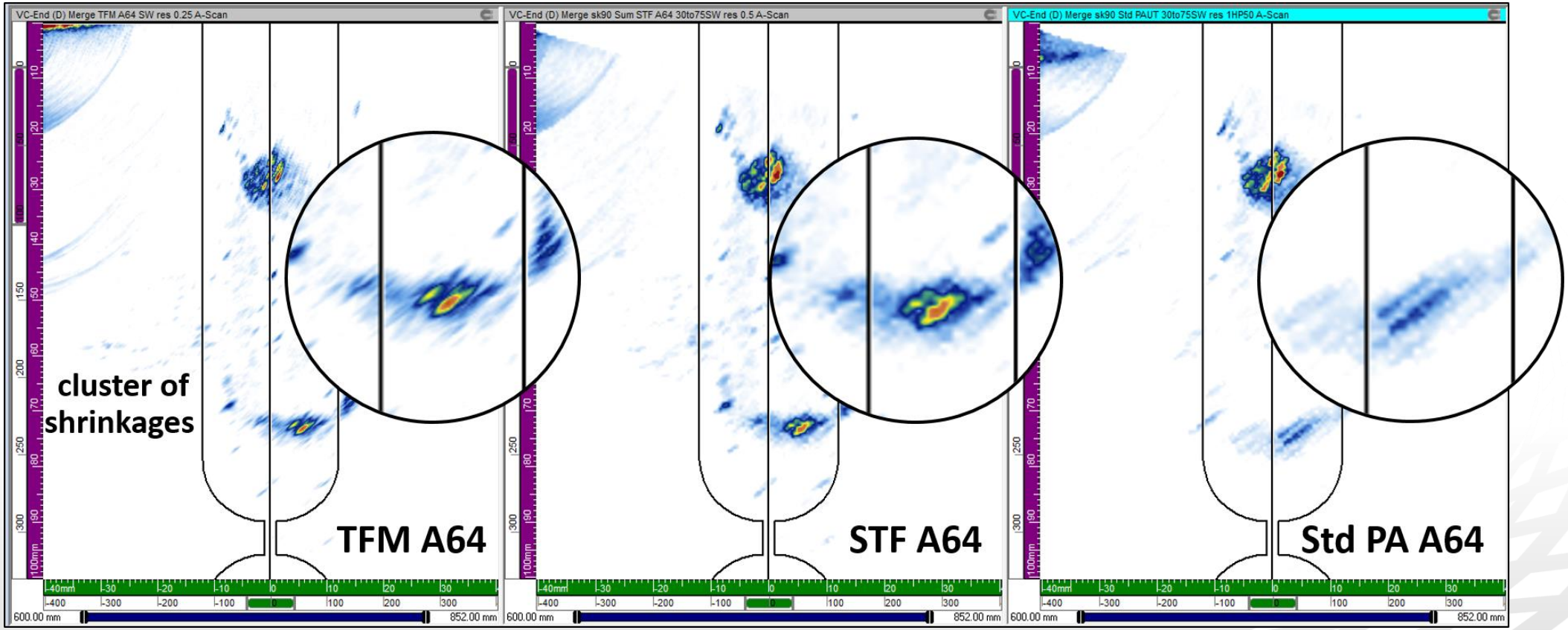


(Courtesy of Lavender International)

Case Study – Thick CS Vessel Weld

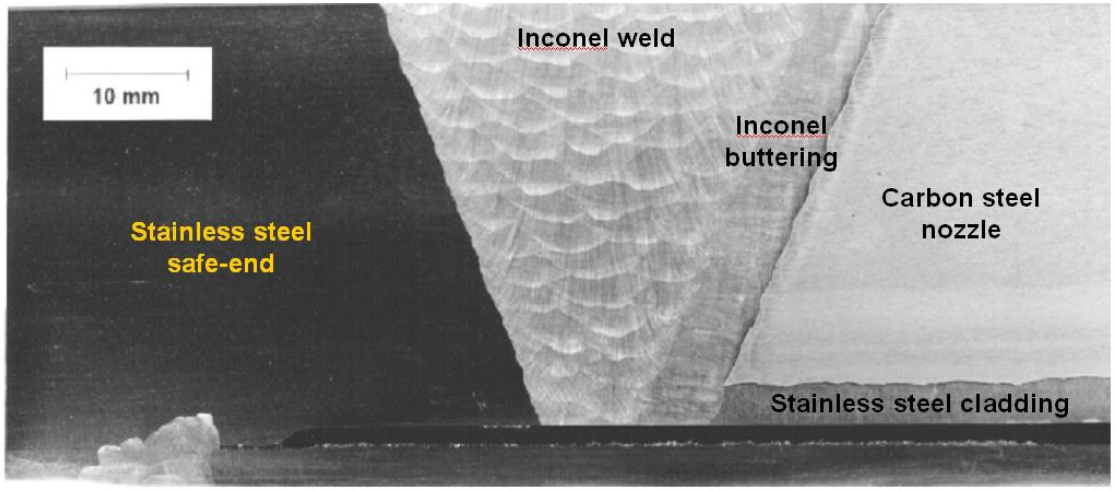
5 MHz, 64 elements, SW wedge on thick vessel weld with real flaws

Superior imaging and flaw characterization using TFM and STF



Case Study – Dissimilar Metal Weld

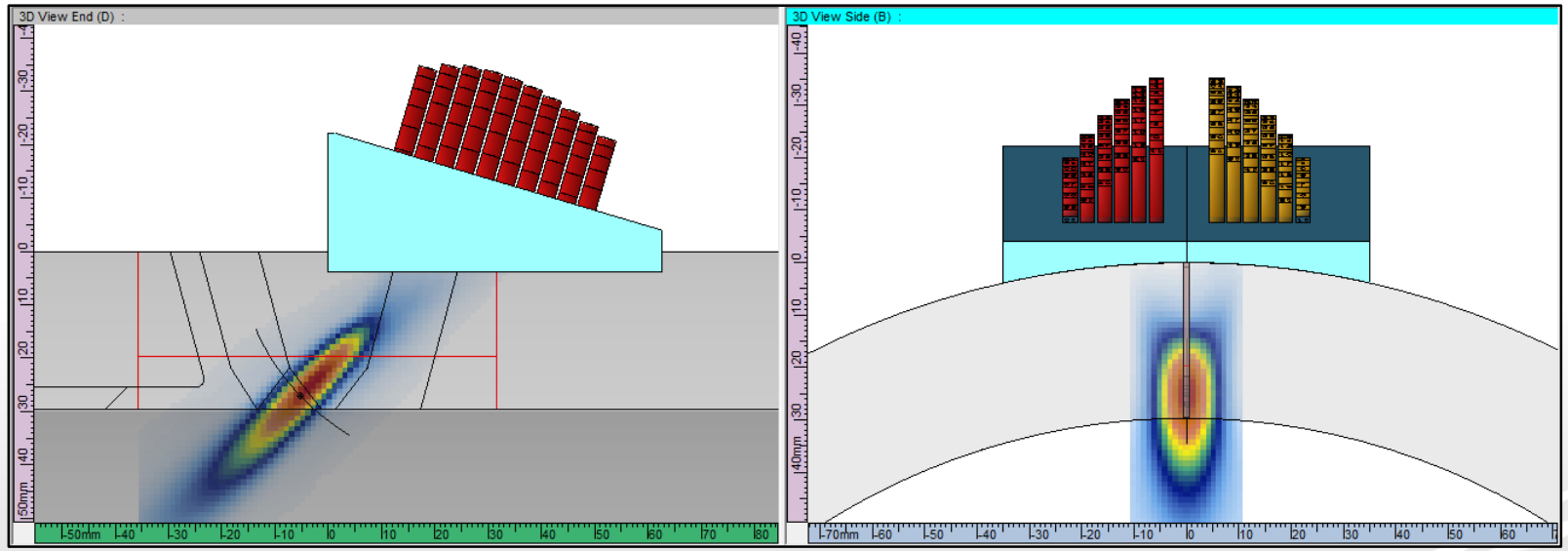
- Dissimilar metal welds typically join two or more different materials, and mostly involve Inconel Alloys
- Often used to connect cladded carbon steel vessels to stainless steel piping



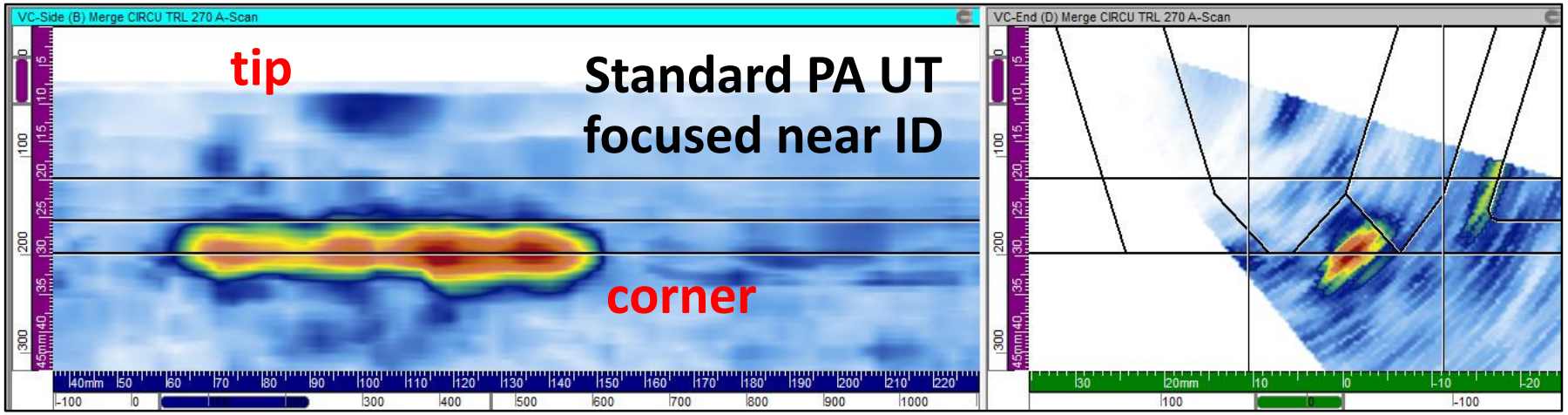
- Very challenging configurations for UT examination : propagation issues in austenitic structures, presence of multiple acoustic interfaces and sometimes very complex geometry (nozzles, tapers)
- In the late 1990's, primary water stress corrosion cracking (PWSCC) was encountered in nuclear plants all over the world, and led to development, qualification and on-site deployment of advanced PA UT inspection procedures

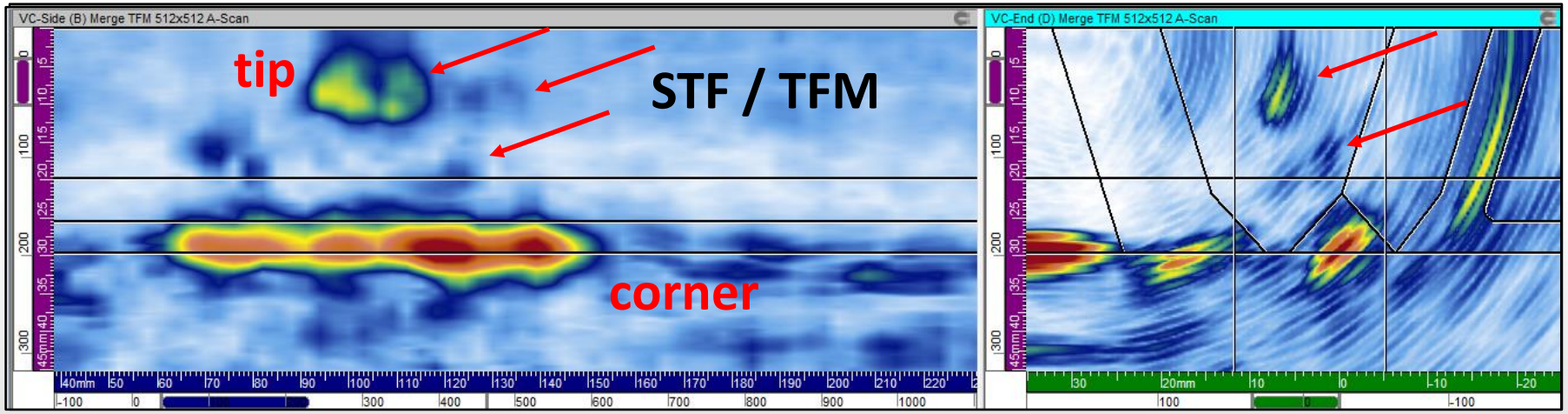
Case Study – Dissimilar Metal Weld

- Inspection technique : 1.5 MHz DMA probe, 2 x (10x6), TRL mode
- T/R configuration offers better sensitivity and SNR, and avoids “ghost echoes” caused by internal wedge reflections
- DM weld specimen, T = 1.2”, containing large ID crack

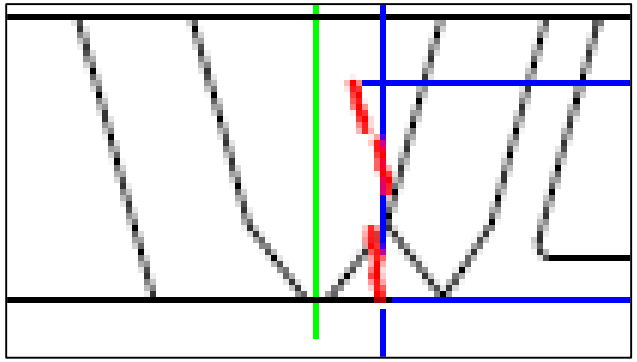


Case Study – Dissimilar Metal Weld





intended
crack morphology



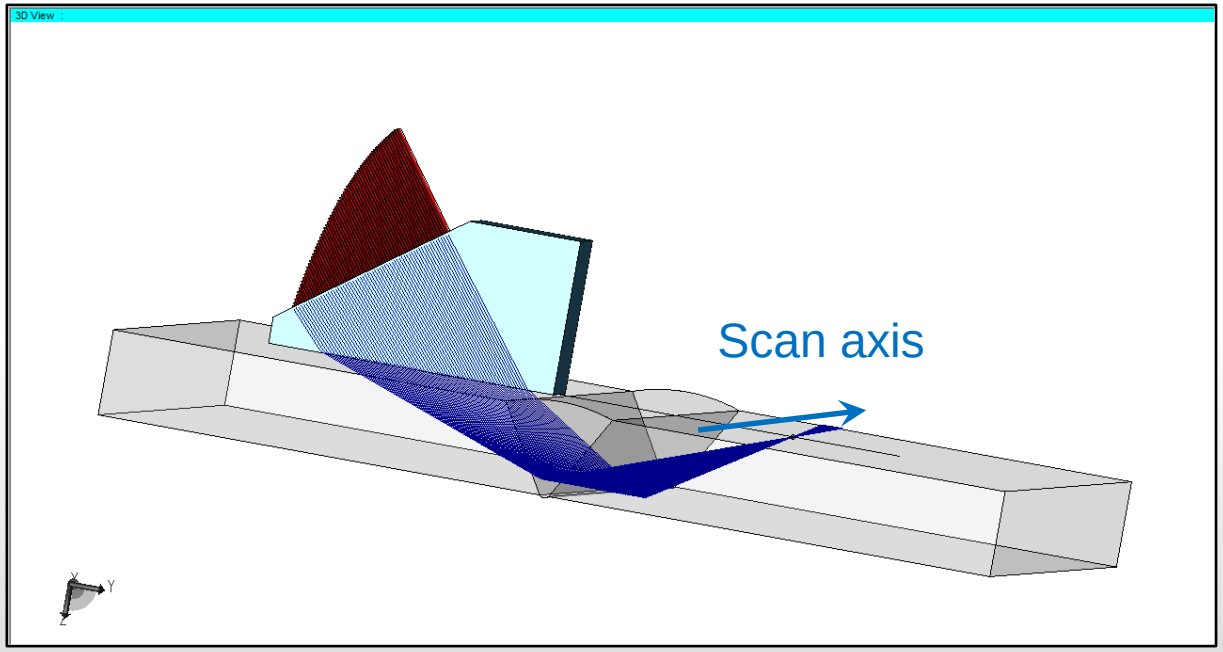
(Courtesy of EPRI and Nucleom)

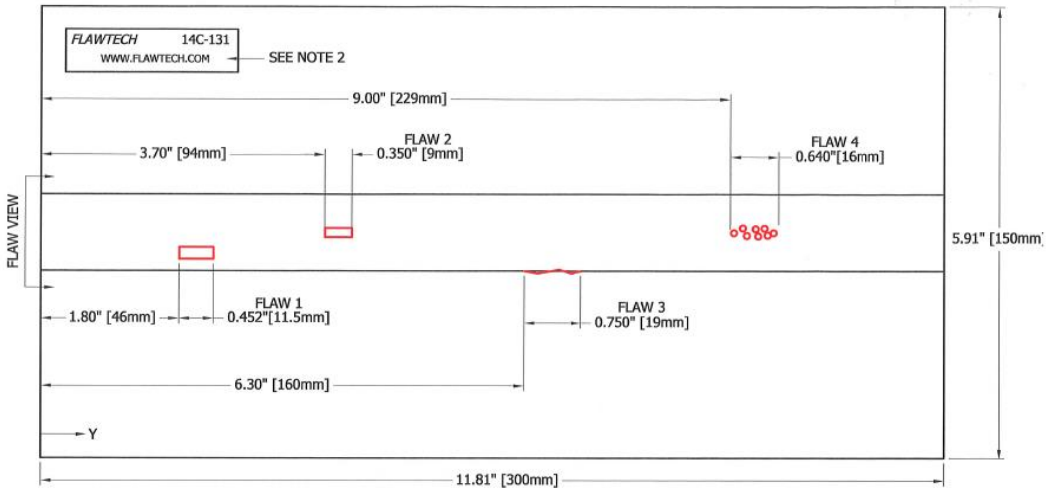
Case Studies Weld Inspection CS (Basic)

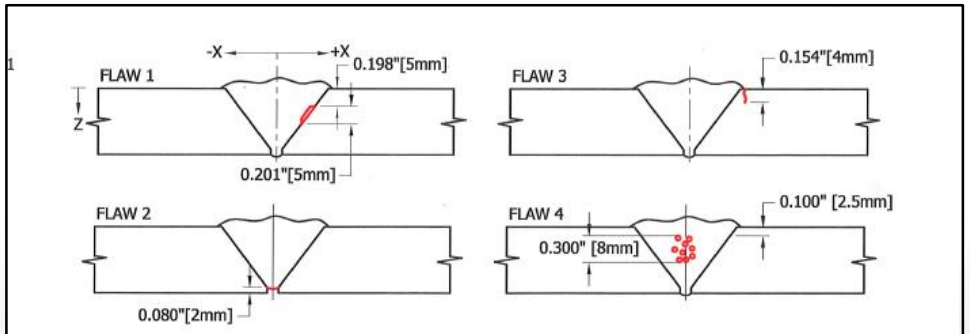
Carbon Steel Plate Weld

Carbon steel plate weld (T = 0.75”), with realistic welding defects

Linear array LM 5 MHz (64 elements) on 55SW wedge

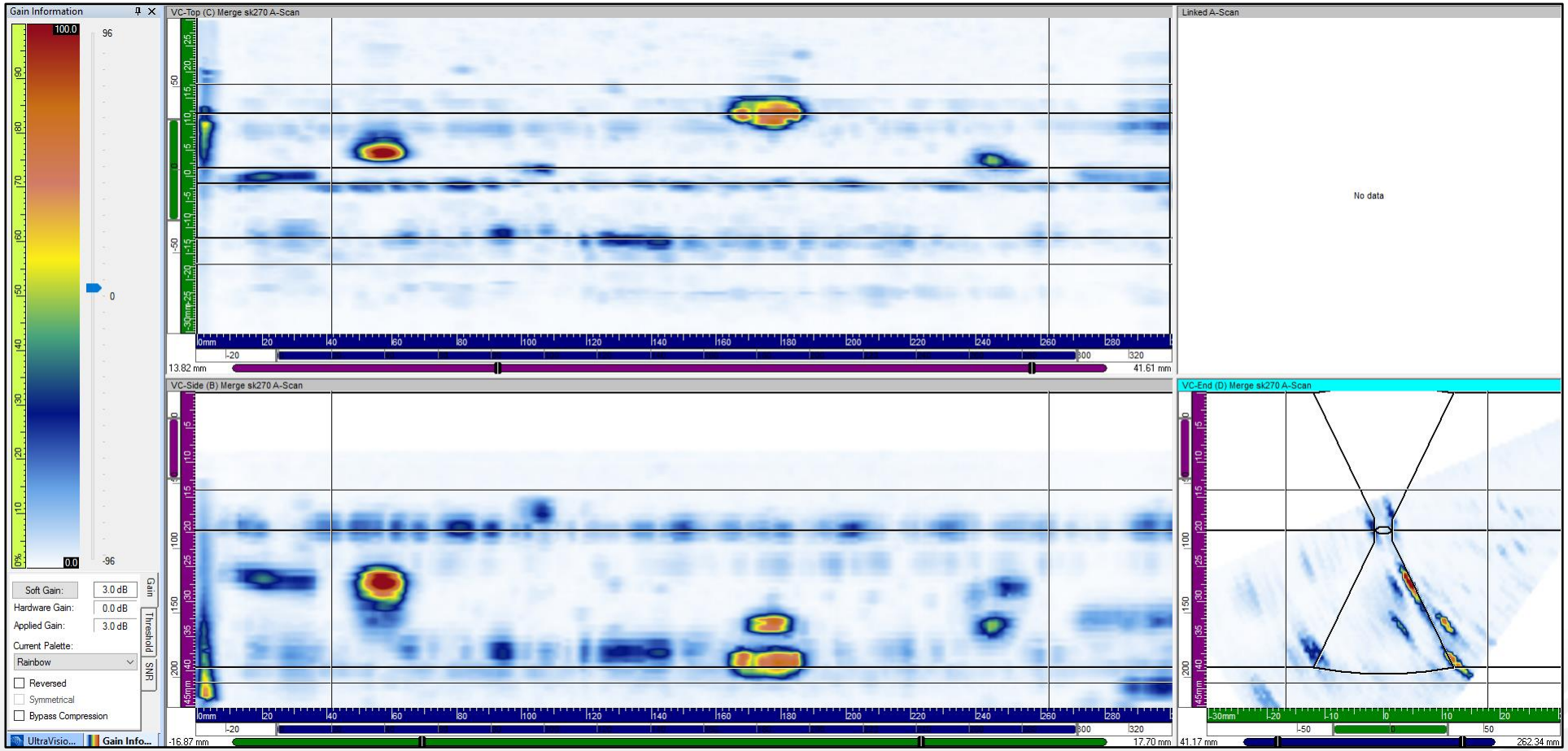






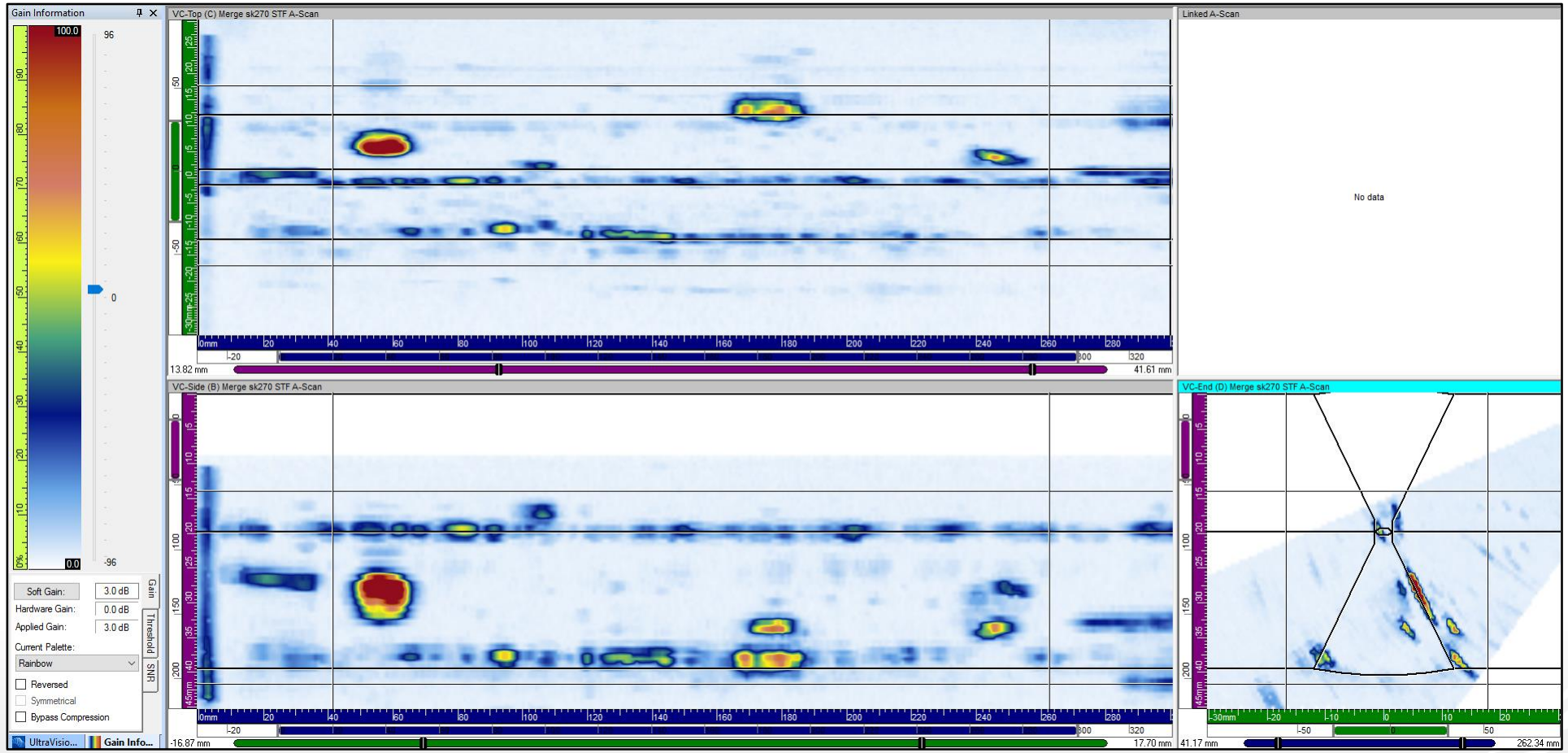
FLAW	FLAW TYPE	FLAW LENGTH	FLAW HEIGHT	X	Y	Z
1	LACK OF FUSION	0.452"[11.5mm]	0.201"[5mm]	+0.200"[5mm]	1.80"[46mm]	0.198"[5mm]
2	INCOMPLETE PEN.	0.350"[9mm]	0.080"[2mm]	C/L	3.70"[94mm]	0.670"[17mm]
3	TOE CRACK	0.750"[19mm]	0.154"[4mm]	+0.470"[12mm]	6.30"[160mm]	0.000"[0mm]
4	CLUSTER POROSITY	0.640"[16mm]	0.300"[8mm]	C/L	9.00"[229mm]	0.100"[2.5mm]

Merged Data, Standard PA



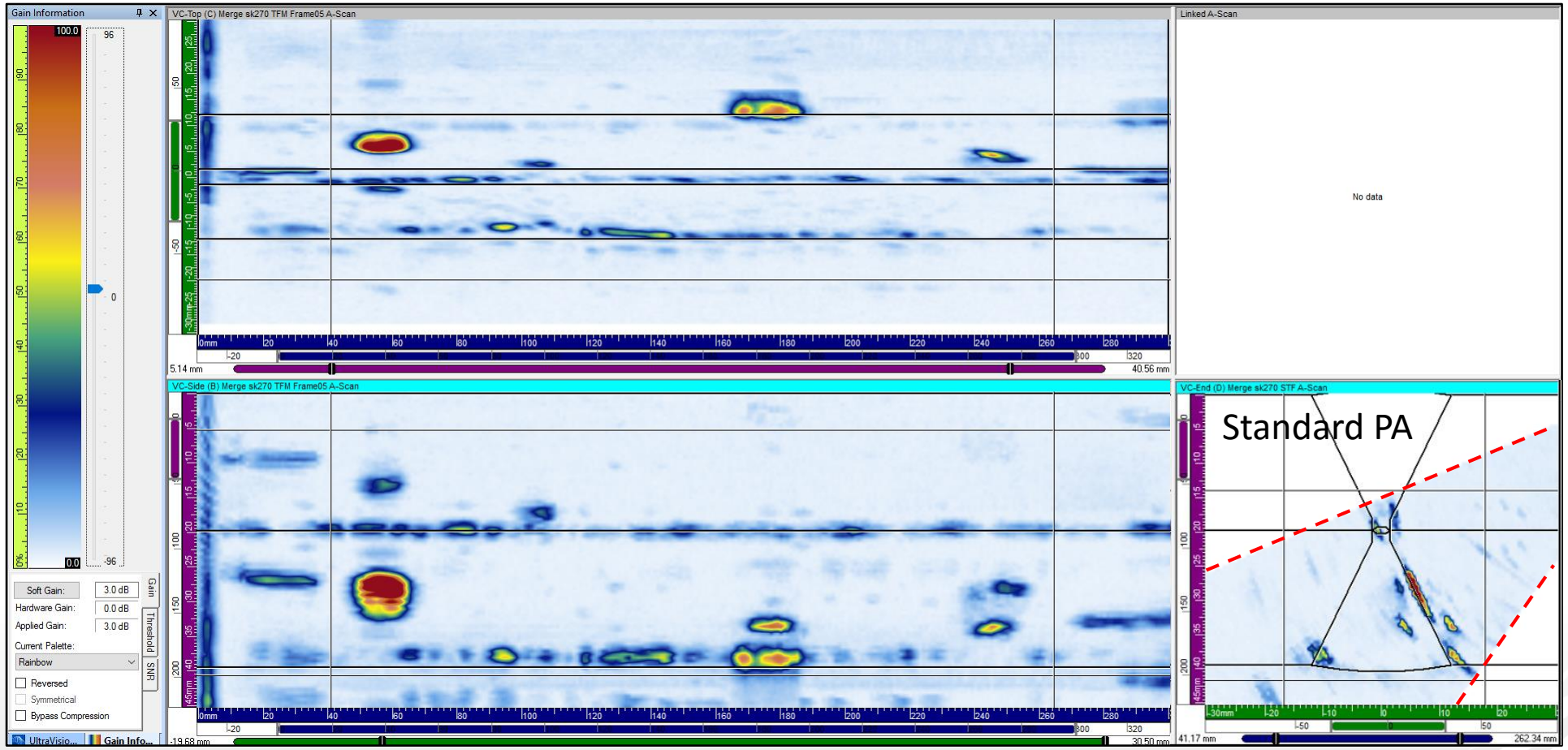
Merged data, from Standard PA Sector 40 to 70 SW, focusing at HP 50 mm, skew 270:
LOF, Incomplete Penetration, Toe Crack and Porosity visible on End View

Merged Data, STF



Merged data, from Reconstructed STF 40 to 70 SW, skew 270 :
LOF, Incomplete Penetration, Toe Crack and Porosity visible on End View

Merged data, TFM



Merged data, from reconstructed TFM frames SW, skew 270 :
LOF, Incomplete Penetration, Toe Crack and Porosity visible on End View

Conclusion

Conclusions

- Advanced focusing techniques are a *promising additional tool in the phased array UT toolkit*, to improve resolution of flaw images, and inspection coverage
- *Active aperture* and *frame resolution* are key parameters for the TFM technique, and must be carefully selected to exploit full potential of the technique
- *Careful probe selection* (wave mode, frequency) & probe position remains a requirement for succes
- In the framework of regulated inspections, *code-compliant PA UT and TOFD* techniques *can be complemented with TFM* for flaw characterization
- TOPAZ 64 offers industrially proven *PA UT and TOFD*, and *high-resolution live TFM*, in a single portable phased array unit.

TOPAZ Product Family

TOPAZ 16

Portable Value
Ideal for common inspections

TOPAZ 32

Portable Performance
Ideal for challenging inspections

TOPAZ 64

Portable Intelligence
For the most challenging inspections

a TOPAZ for every application !