Walk through of the process to setup a TFM inspection

Swedish Conference | Gary Luckett| 07th April 2022

Agenda

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01 Introduction

Introduction

FMC/TFM advantages & challenges

▲ Better imaging
▼ Several wave modes

Use of FMC/TFM in inspection projects worldwide

- Complementary technique
- Characterization

Factors limiting FMC/TFM application

- Knowledge
- **Codes**
- Technology

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02 FMC/TFM in codes

Codes Governing FMC/TFM

Organization	Code including FMC/TFM
ASME ✓	ASME BPVC Sec. V, Article 4. 2019
ISO ✓	ISO/DIS 23865 [IIW]: Non-destructive testing — Ultrasonic testing — General use of full matrix capture / total focusing technique (FMC/TFM)
API –	API 510 Refers to ASME Section V, Articles 4, 5 and 23
AWS –	PAUT was added to AWS D1.1 on 2020, no FMC/TFM yet

FMC/TFM in ASME Code

ASME BPVC Sec. V, Article 4. 2019

Main requirements:

- Written procedure → Qualification, Scan plan
- Cal blocks → Notch, slot, side-drilled holes (SDHs)
- Calibration → Amplitude fidelity, Performance verification
- Personnel qualification → 80 h training with detailed content
- Examination / Evaluation / Documentation

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03

Requirement – Scan Plan

Scan Plan in TFM

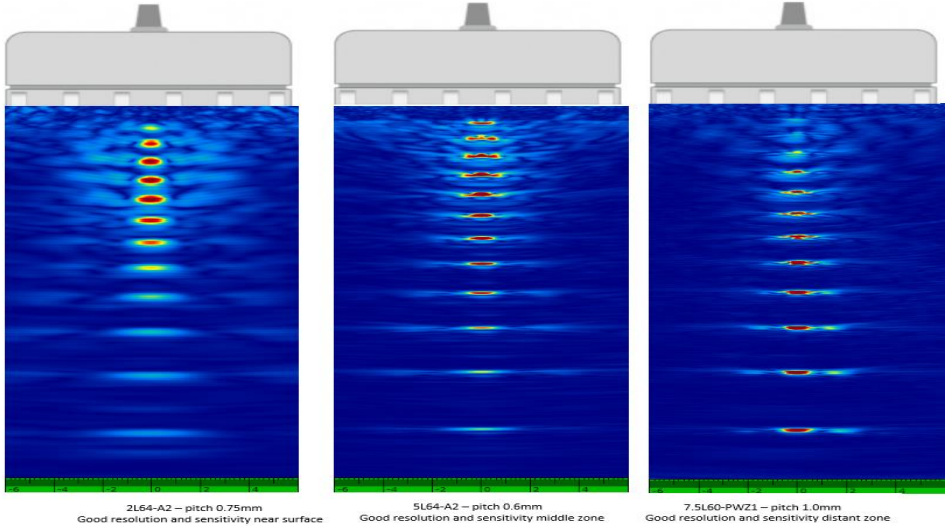
Main steps

1. Part and/or weld definition
2. Probe selection
3. Zone setting
4. Wave set selection: TT, TTT, TTTT, LL, LLL, etc.
5. Flaw definition: planar or spherical, expected angle
6. **Modeling**: Acoustic Influence Map (AIM) and Sensitivity Index evaluation

Probe Selection

Parameters to consider

- **Aperture** → *"Long enough to produce a far enough near field"* Appendix F-432
- **Number of elements** → *"Larger array is better for farther in time detection to improve resolution"* Appendix F-432



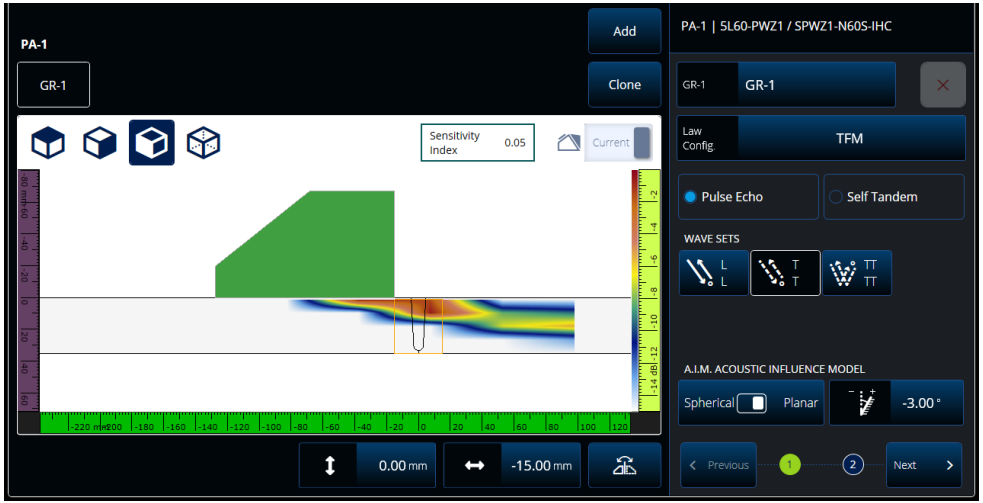
Scan Plan in TFM

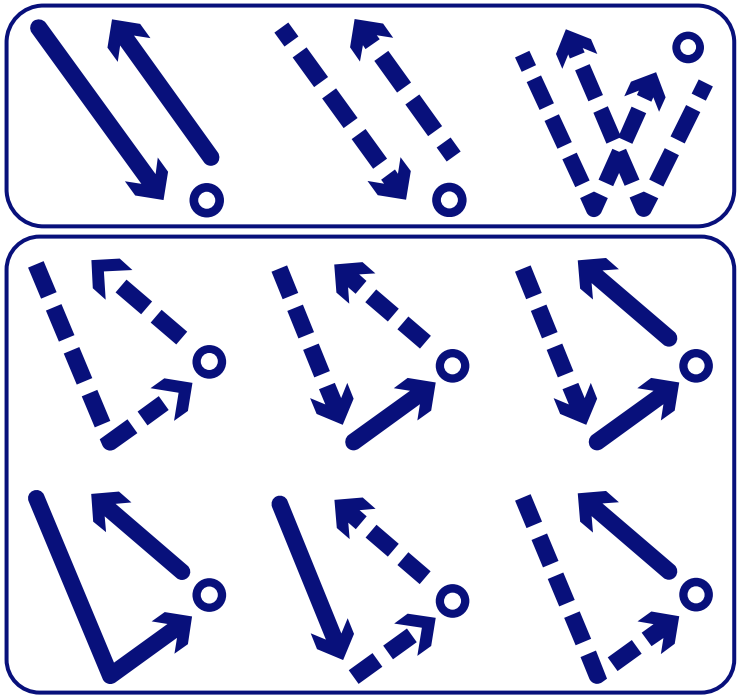
Why modeling is essential

1. Many wave sets are available (commonly 9+)
2. Proper wave sets are critical for detection and sizing
3. The type, orientation, and position of the flaw influence wave set selection
4. Part geometry will change wave set results
5. Focus is expected everywhere in the zone (need to confirm proper probes, frequencies, etc.)

Scan Plan in TFM

AIM tool





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04 Calibration

Requirements for Calibrating TFM

Main steps

1. Search unit performance (element check)
2. Velocity
3. Wedge Verification
4. Amplitude Fidelity → **Unique to TFM**
5. Resolution verification
6. Path verification
7. Sizing verification (length and height)
8. Sensitivity
9. Encoder Calibration

Performance verification

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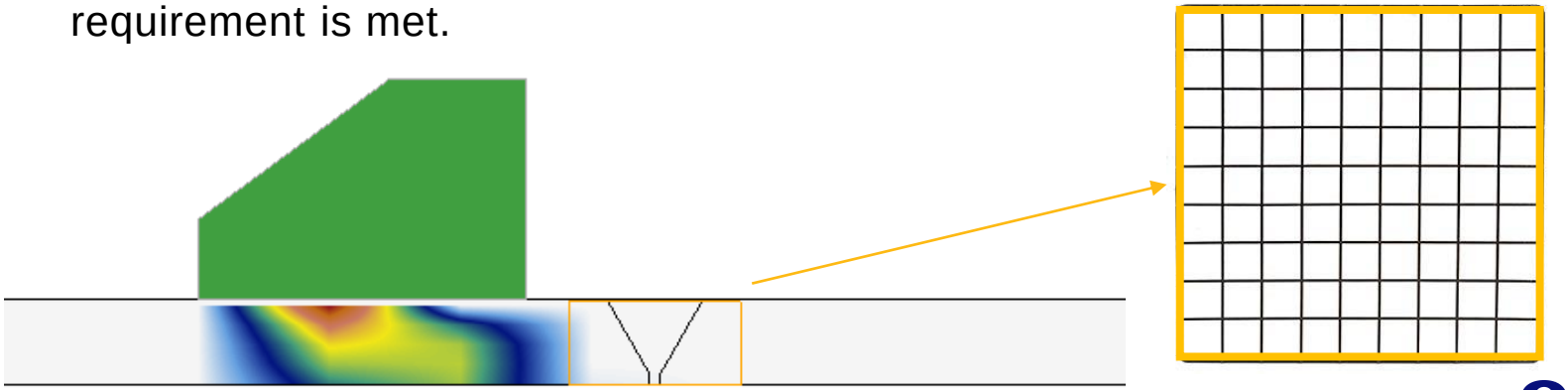
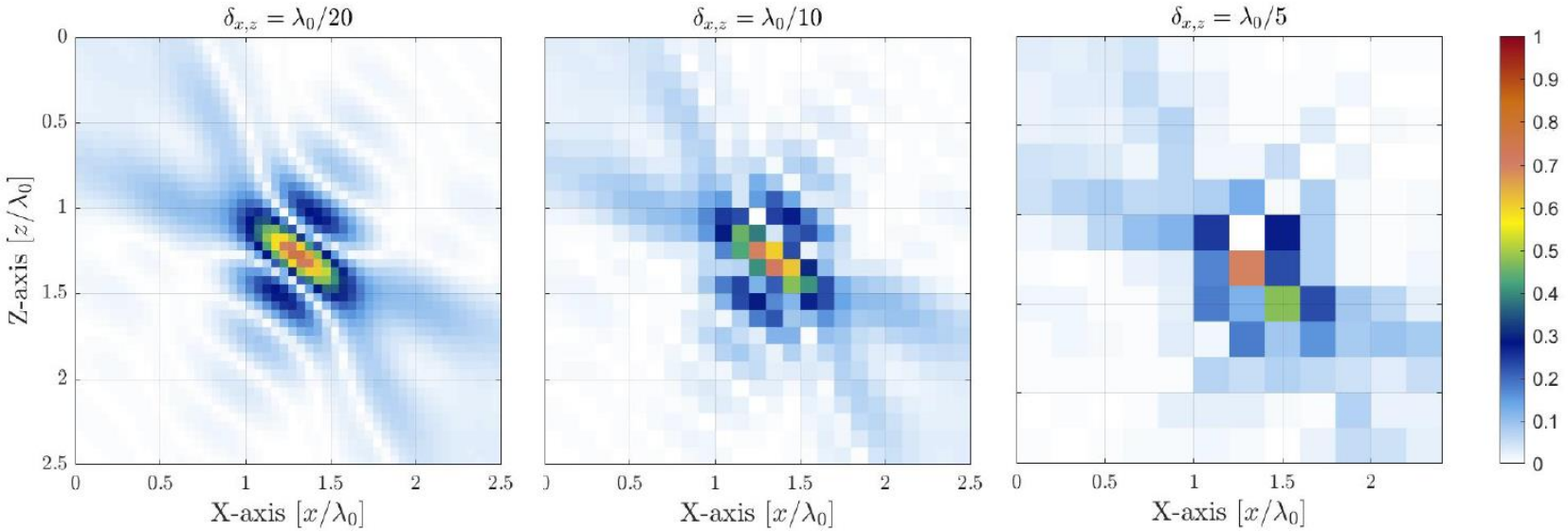
Amplitude Fidelity

- **Definition:** Amplitude fidelity (AF) is the measurement (in dB) of the maximum amplitude variation of an indication *caused by the TFM grid resolution*
- **Parameters:** Probe frequency and bandwidth, material velocity, grid resolution, applied envelope, etc.
- When the amplitude fidelity is above 2 dB, the user can either increase the resolution, reduce the zone size, or increase the probe frequency until the requirement is met.



Amplitude Fidelity

Resolution effect



AF= 0.3 dB

AF= 1.2 dB

AF= 5.2 dB

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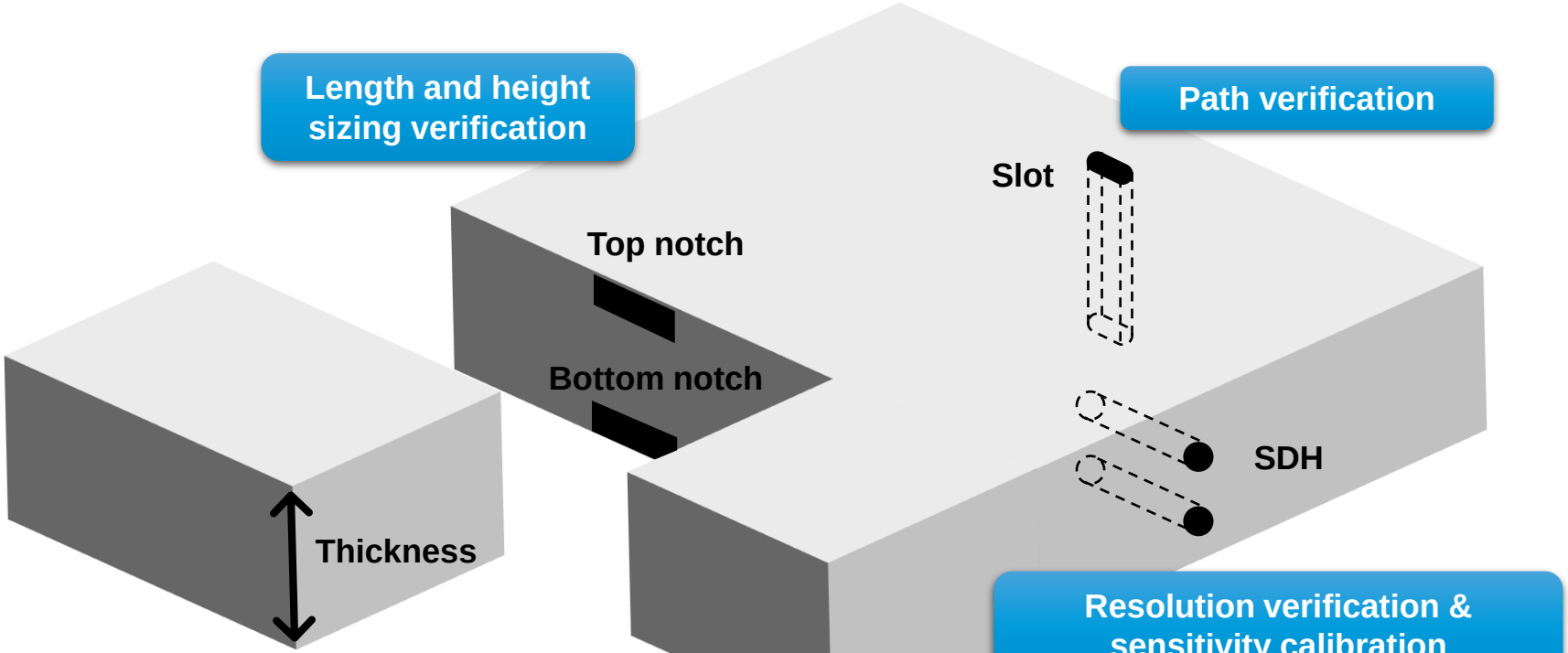
05 Performance Demonstration

Calibration Block



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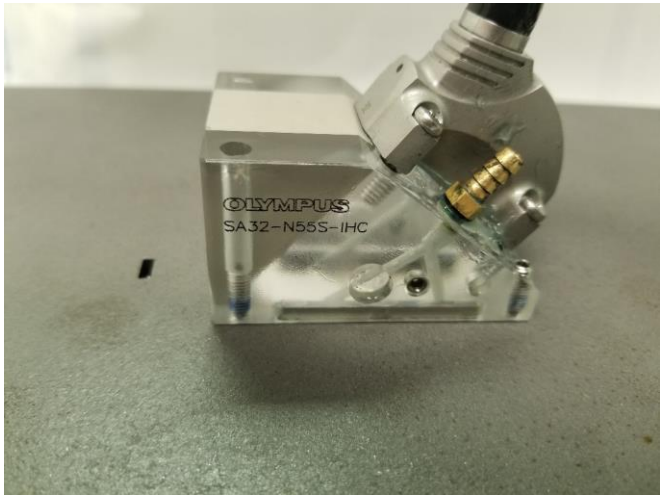
Performance Verification

Path verification



- Using P/E modes cannot detect the full extent of the slot; therefore, self tandem modes are necessary.

→ Multigroup in OmniScan X3 unit

Courtesy of K. Shane Walton

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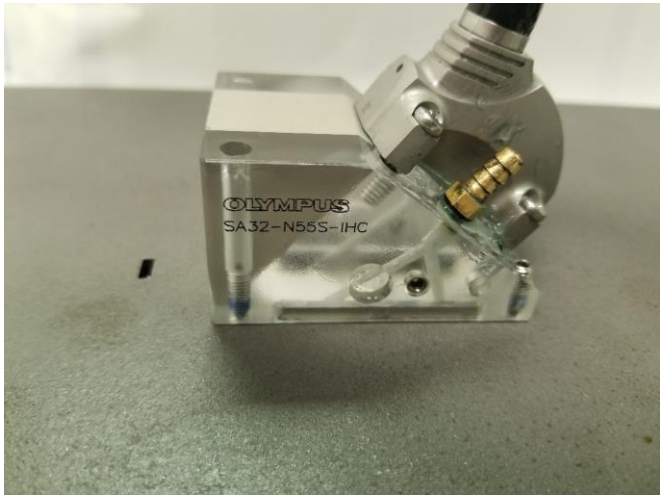
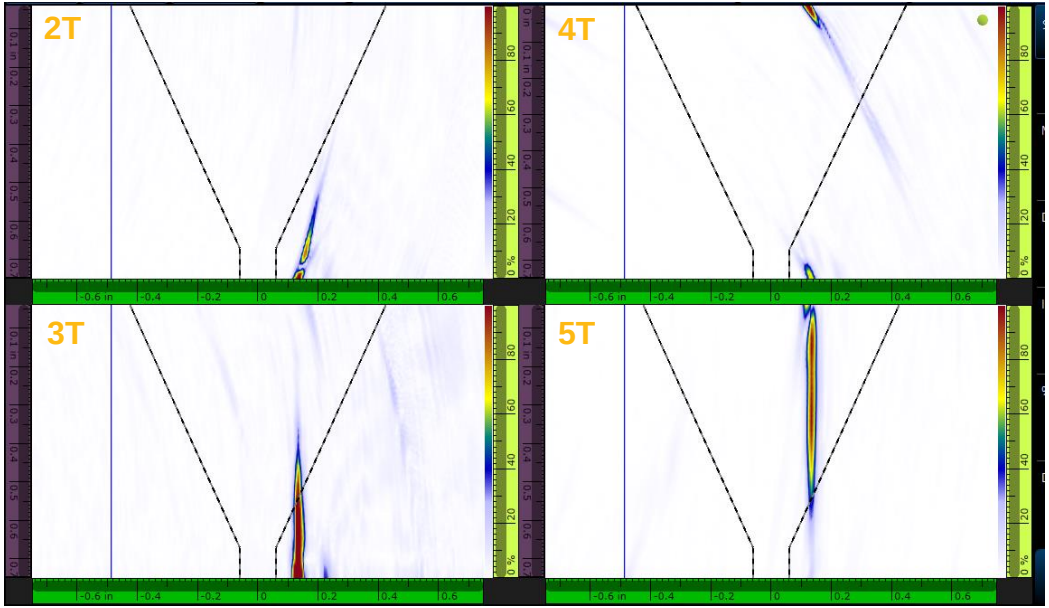
Performance Verification

Path verification





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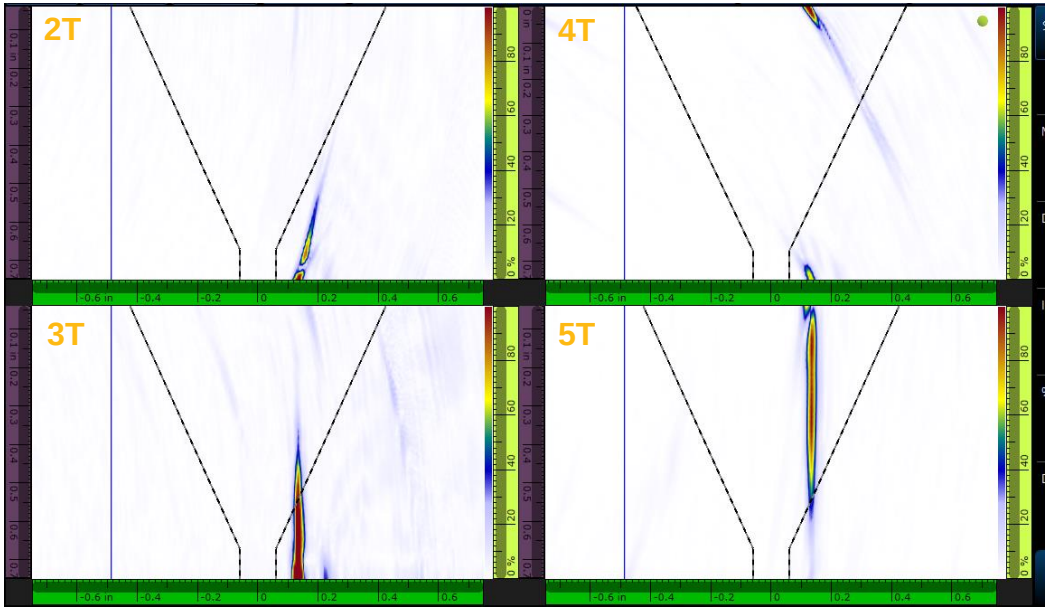
Performance Verification

Path verification

> "The imaging paths used during calibration shall be the same as those for the examination."

XI-471.1.1 Image Paths



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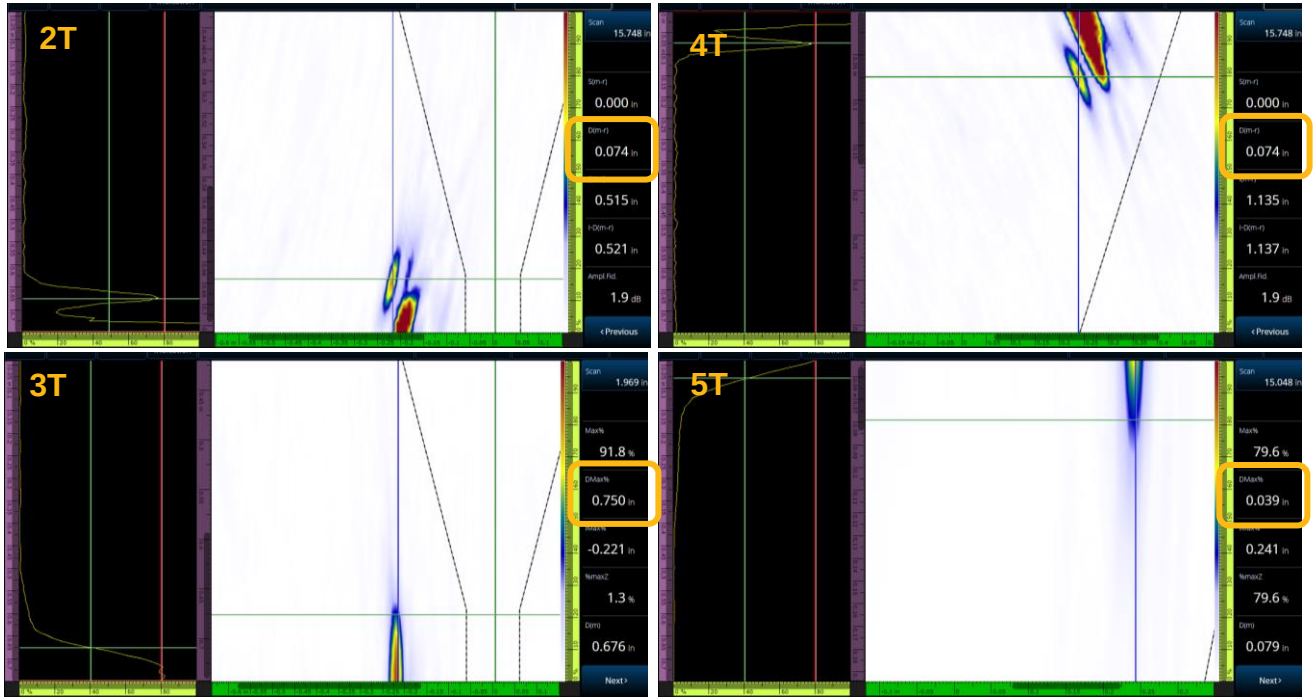
Performance Verification

Height sizing verification



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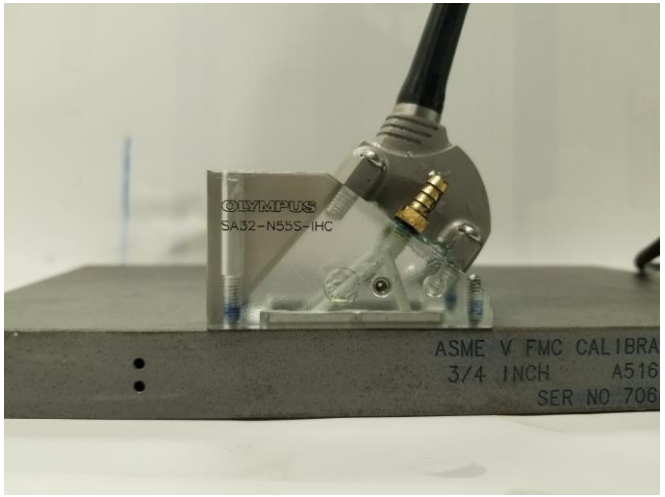
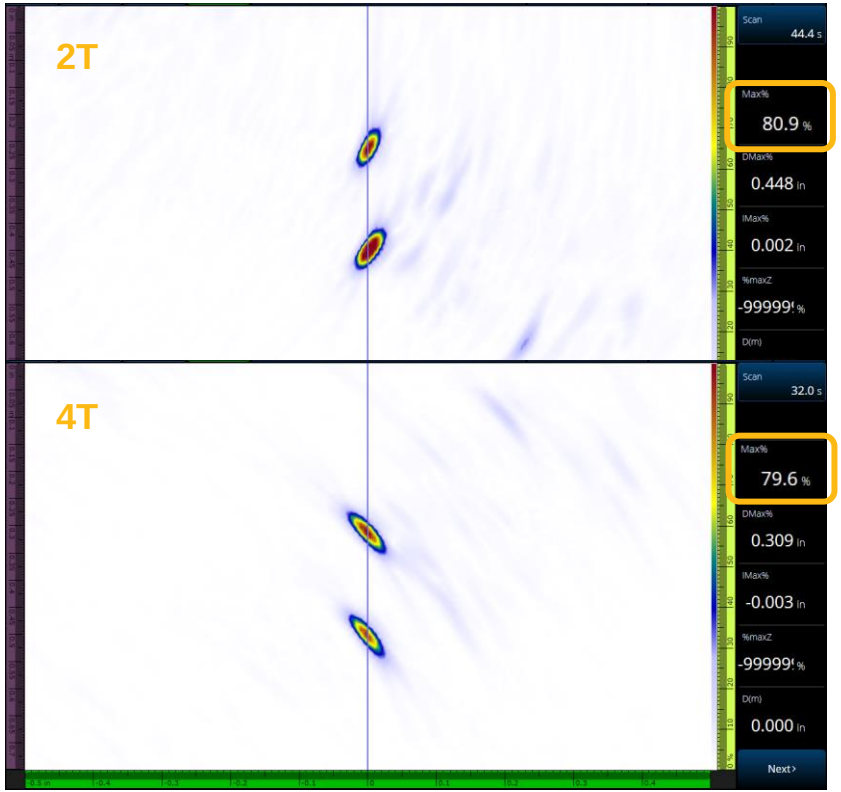
Performance Verification

Sensitivity





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Requirement – Personnel

Personnel Certification for PAUT & TFM

Certification	Required training and examination
PCN/CSWIP	The minimum required duration of training which includes both theoretical and practical elements is: Level 1: 80 hours; Level 2: 40 hours (Direct Level 2: 104 hours for CSWIP and 120 hours for PCN) The minimum duration for experience prior to or following success in the qualification examination is: Level 1: 3 months for CSWIP and 1 month for PCN Level 2: 3 months (Direct Level 2: 6 months for CSWIP and 4 months for PCN)
API QUPA	Examinations are open to any applicant with a current or previous certification in ASNT UT Level II, Level III, or equivalent. Candidates need to successfully complete a performance demonstration examination for their specific program.
ASNT TC 1-A	Level II: 80 hours of training + 160 hours' experience

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Limitations of TFM

Limitations of TFM

Limitations

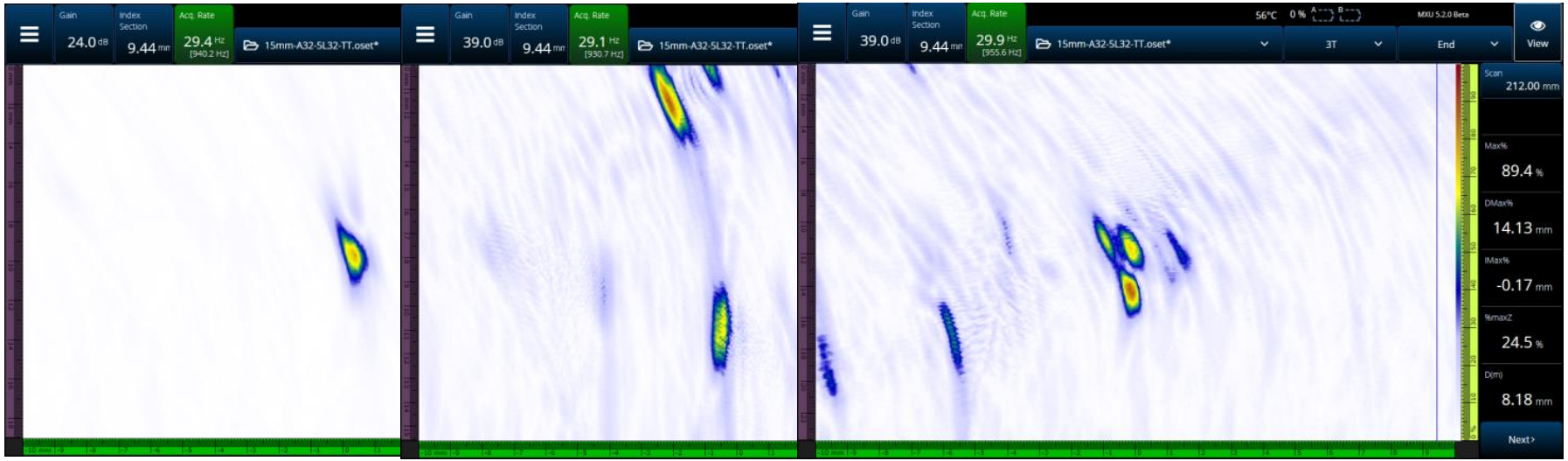
1. Works within the near field (Probe selection is key)
2. Lack of Trained inspectors
3. Lack of acceptance of the codes
4. Limitations with complex geometry
5. Limitations related to scan speed and data file size
6. Sensitive to variations in thickness → Tandem Techniques
7. Sensitive to variations in velocity → Tandem Techniques

Limitation

Thickness Variation

Demonstration

3T



19 mm	15.6 mm (−25%)	23.75 mm (+25%)

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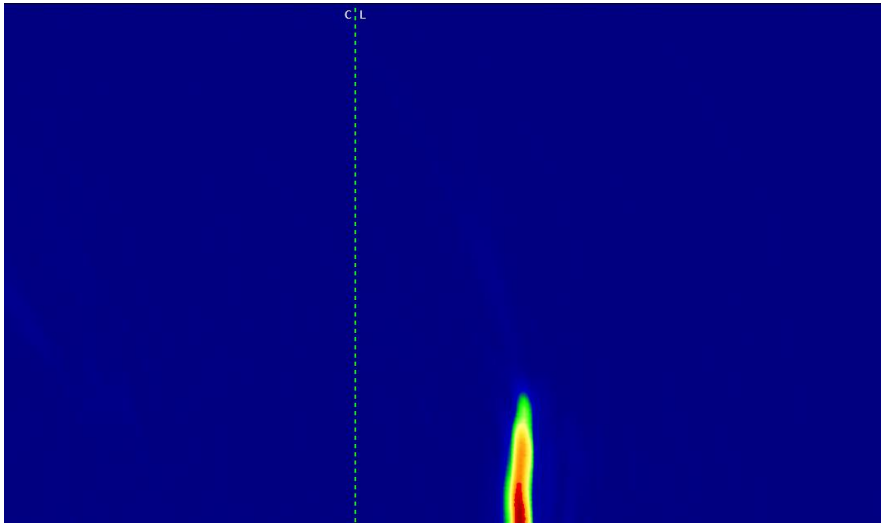
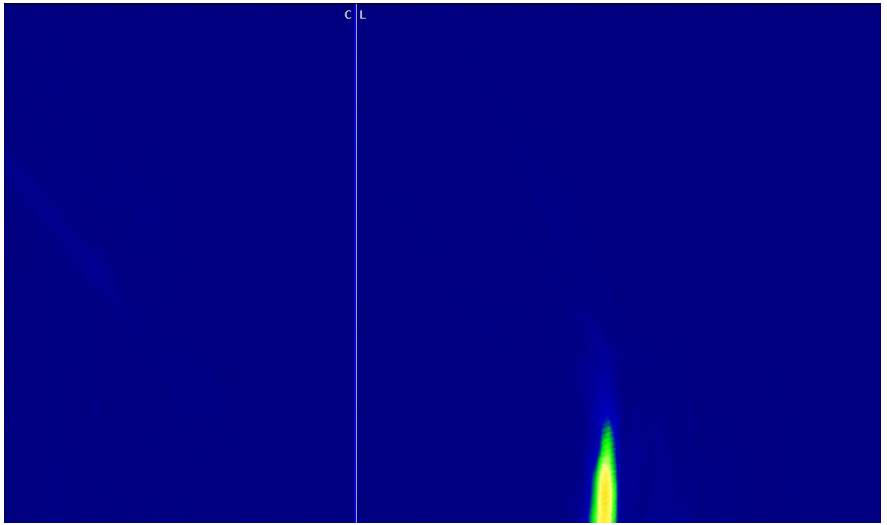
Limitation

Velocity Variation

Demonstration

3T





Velocity	Difference of 80mm/s (-17.9dB)

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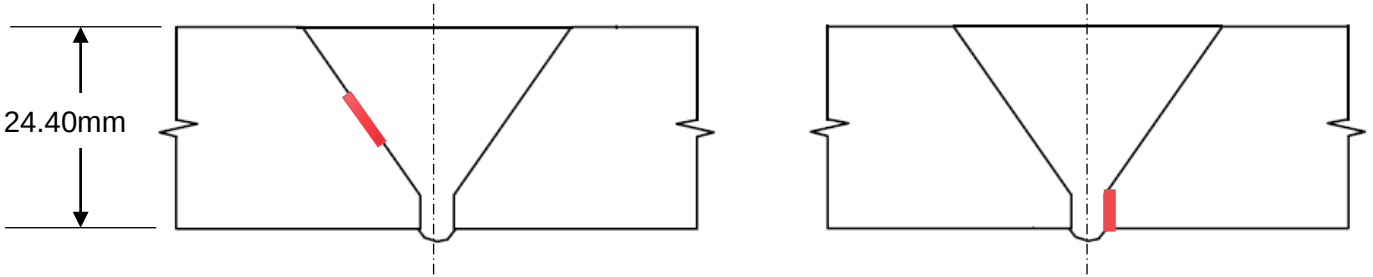
Example Weld

Demonstration

Description

- Part: 24.4mm Carbon Steel
- Weld Prep: V bevel
- 2 flaws
- OmniScan™ X3 flaw detector
- Probe: 5L64-A32
- Wedge: SA32-N55S-IHC



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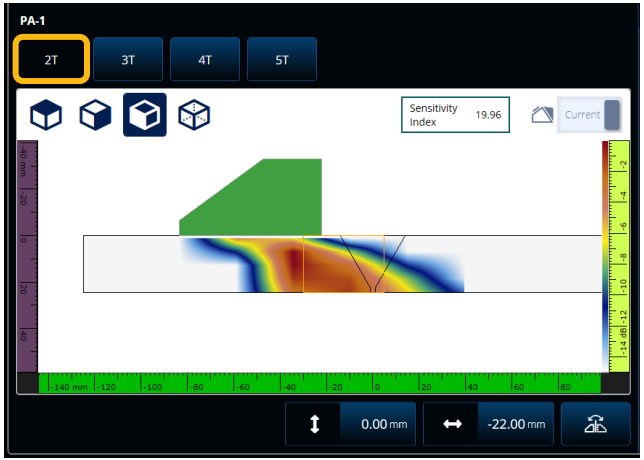
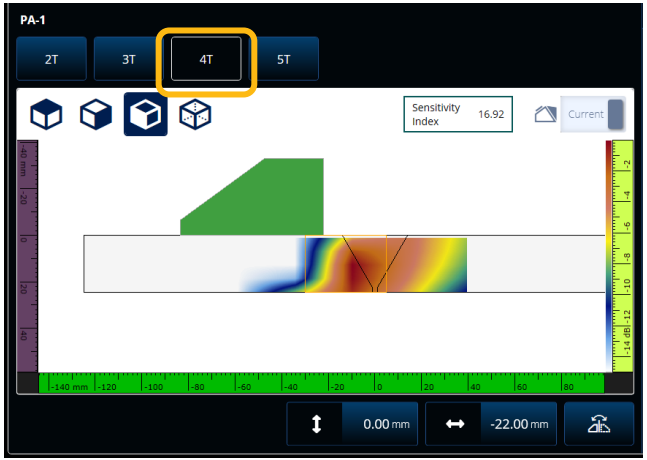
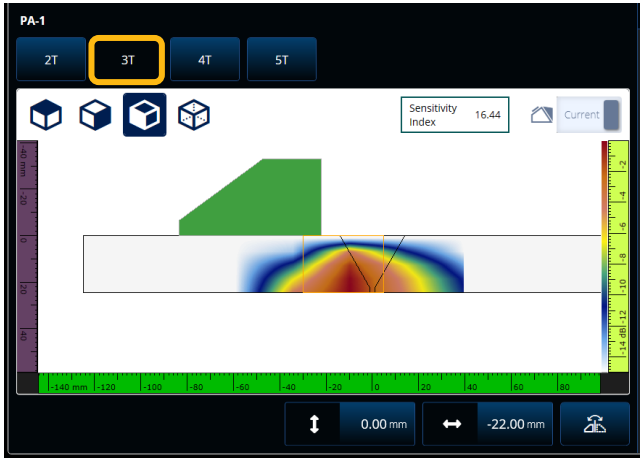
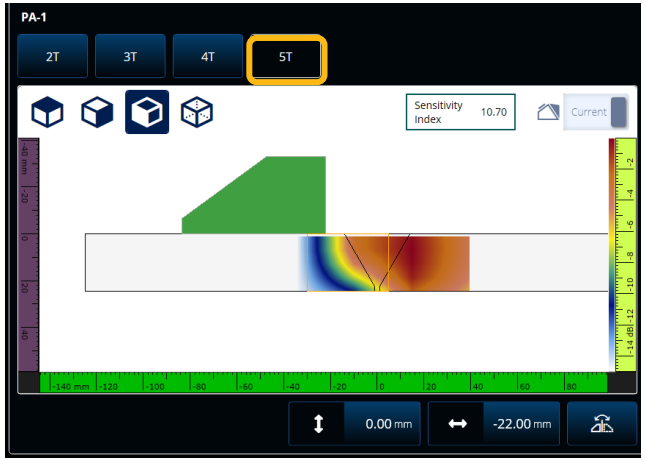
Demonstration - AIM Scan Plan









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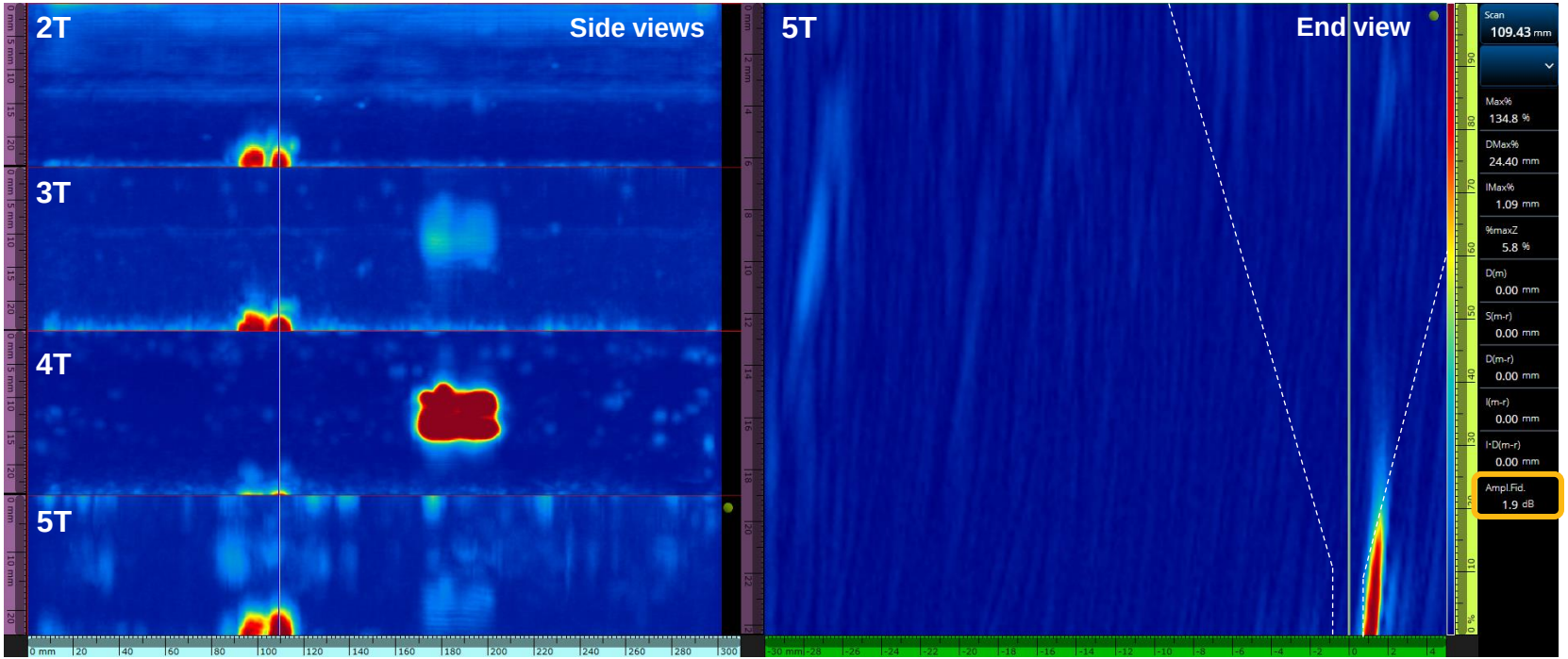
Demonstration

Results



AF
1.9 dB

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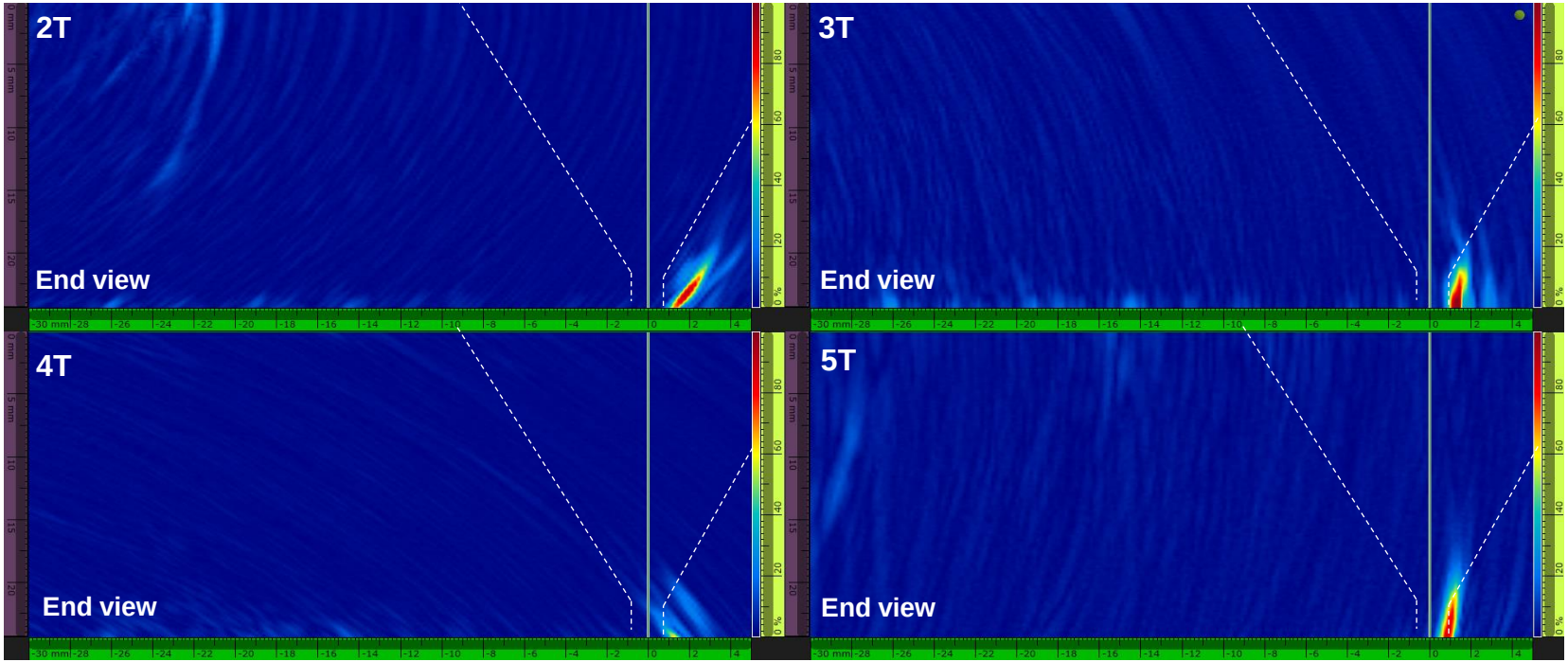
Demonstration

Results



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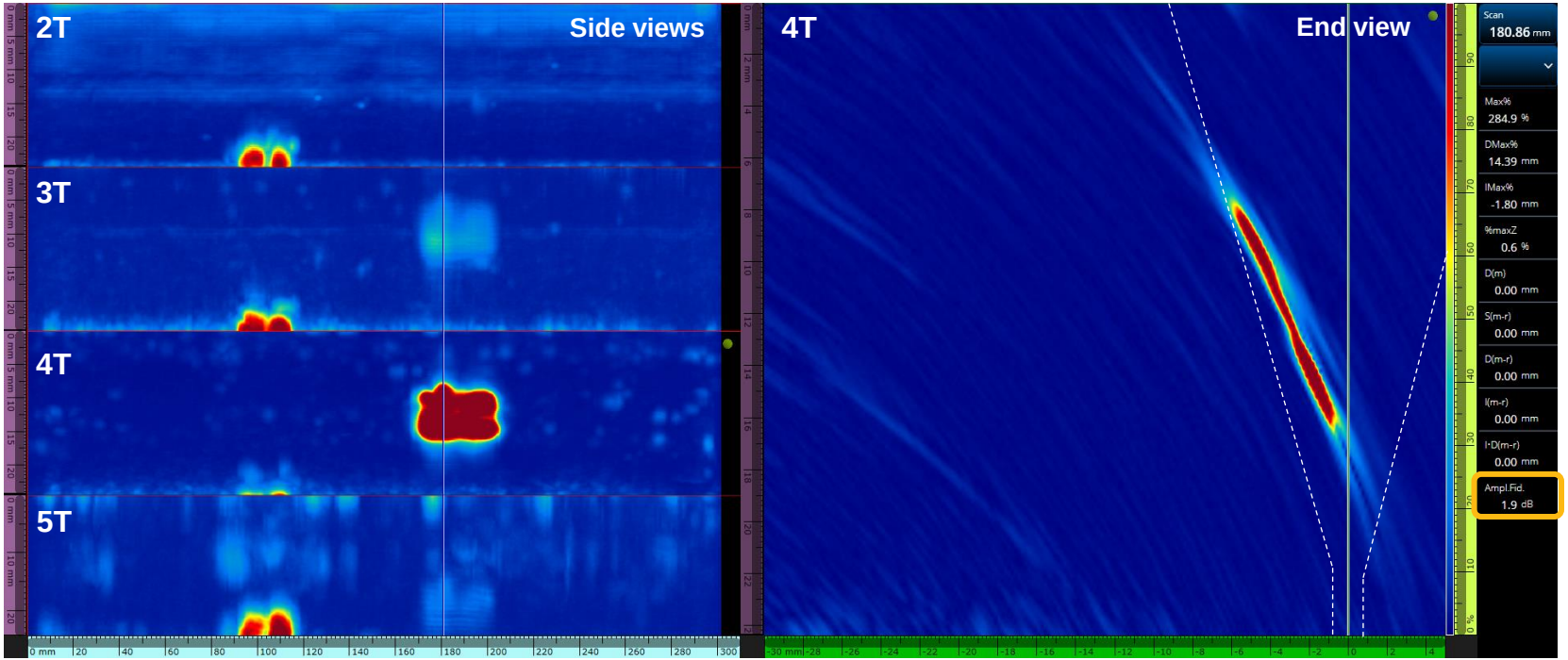
Demonstration

Results



AF
1.9 dB

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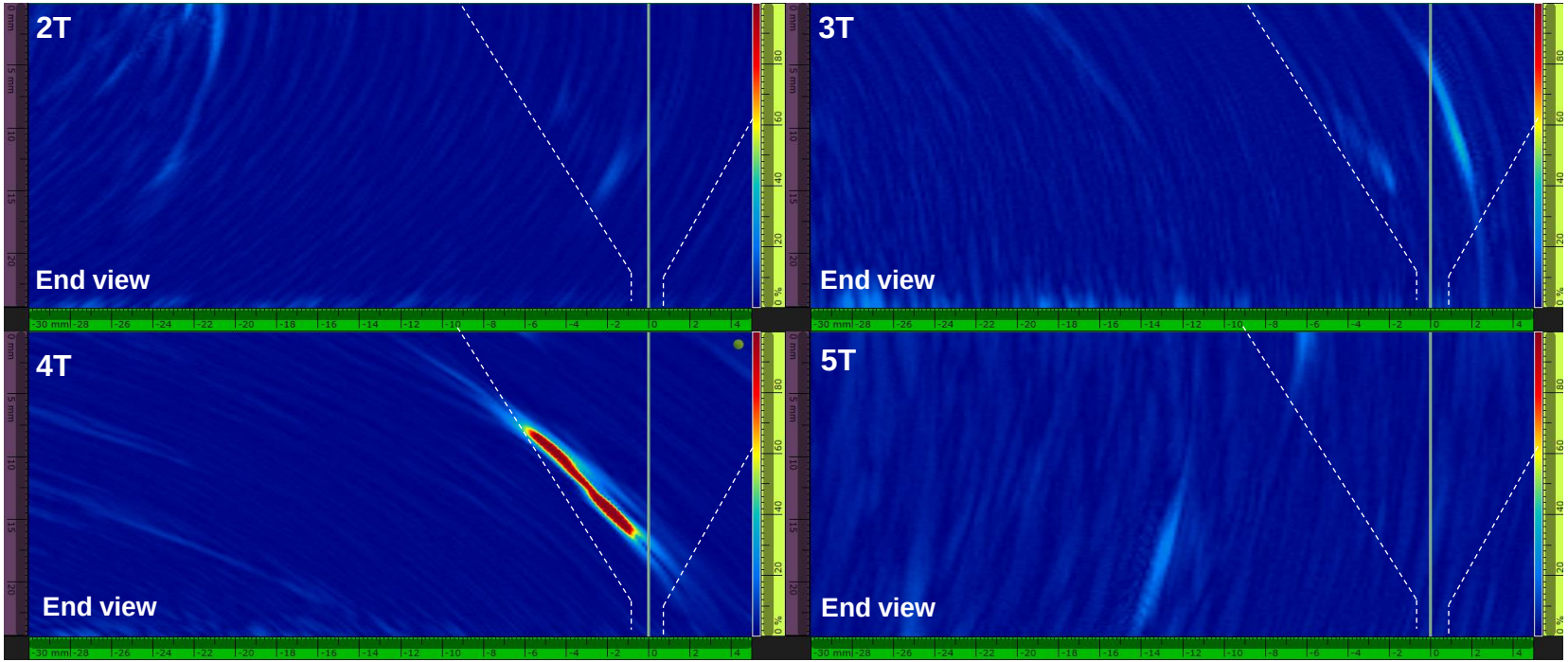
Demonstration

Results



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09 Summary

Summary

- FMC/TFM is governed by the same laws of physics as PAUT; however, the technique requires additional training since it involves new concepts and parameters.
- In comparison with requirements for PAUT inspection, amplitude fidelity is a new essential parameter to consider according to the code.
- A successful inspection is based on the selection of the proper probe and the right wave modes.
- AIM, multigroup, and the TFM envelope are essential tools for scan plan building, calibration, and sizing.
- Important to remember Phased Array and ToFD are excellent techniques for inspection of welds

Questions