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# Adaptive Ultrasound Technology for the Inspection of Variable Geometry Composite Material


**Presenter** | Etienne Grondin
**Olympus NDT Canada, Quebec**

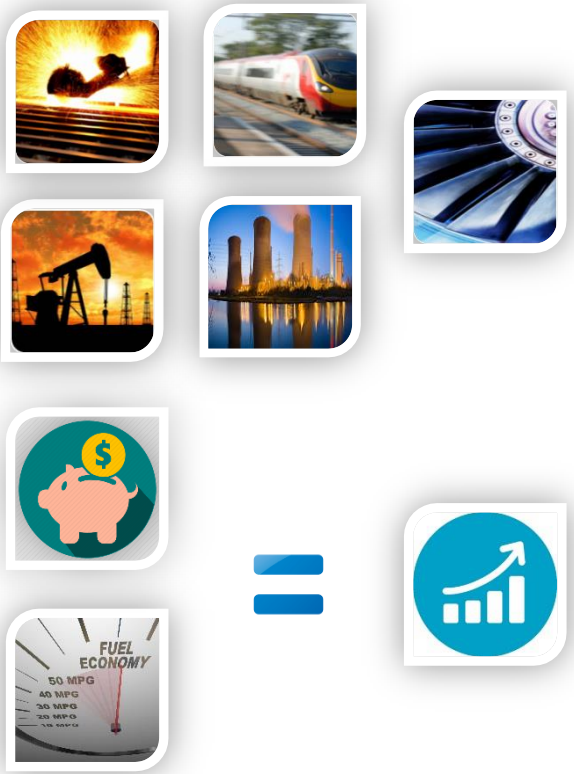
# Agenda

1. **Introduction and evolution of NDE in the aviation industry**
2. **Complex geometry inspection challenges**
3. **Goals**
4. **Solution : Adaptive focusing**
   - Design introduction & overview
   - Results
5. **Conclusion & next steps**

# Introduction

- UT technology & instruments have been used in a wide variaty of industries for NDE over the last 20 years

- Introduction of carbon laminates composite, in conjuction with recent low oil prices helped airline companies to save $$$ explaining above normal growth

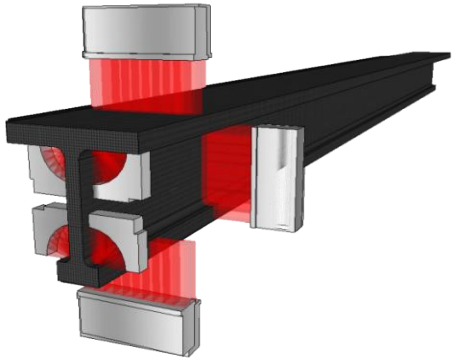


# Introduction

- Consequently, aviation components manufacturers are facing new challenges :
  - Rise in production rate
  - Increasingly complex geometry
  - Lack of skilled operators
  - More demanding inspection requirements

# Introduction

- Evolution of PA instruments help address these challenges



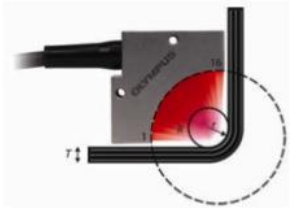
- Scalable PA instruments provide the following benefits
  - Faster inspection
  - Improved coverage for better repeatability
  - Improved radius inspection

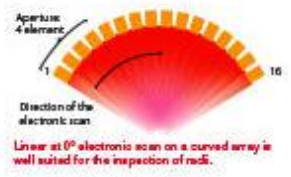
**PRF**
*Up to **20 kHz***

High pulsing frequency

**Data Throughput**
*Up to **30 MB/s***

High data transfer rate

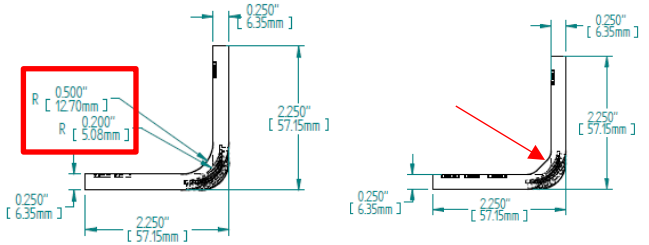




# Introduction

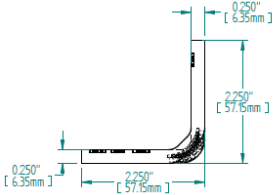
- Some **challenges remain** when full volumetric inspection of **varing geometry** (varying, flatten radius, tilted parts) is required.

- Today these parts are either inspected manually or via complex mechanical devices, that are error-prone, hard to configure and costly




# Challenges

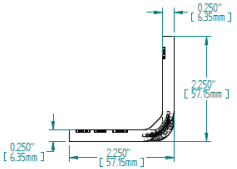
- Inspection of carbon laminates parts with the following characteristics :
  - Variable radius
  - Variable opening angle



Variable Radius


Variable Opening

- Inspection of non-constant (weighted) radius generated by the manufacturing process



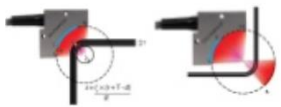
Weighted

- Inspection of rounded flat surfaces generated by the manufacturing process

- Part vs probe alignment (curved and flat arrays)

# Goals

- **<u>Improve & simplify</u> the inspection of complex geometry components**
  - Variable & weighted radius
  - Variable opening and twisted parts
- **<u>Flexible</u> solution to allow inspection from :**
  - Inside & outside radius
  - Flat surface

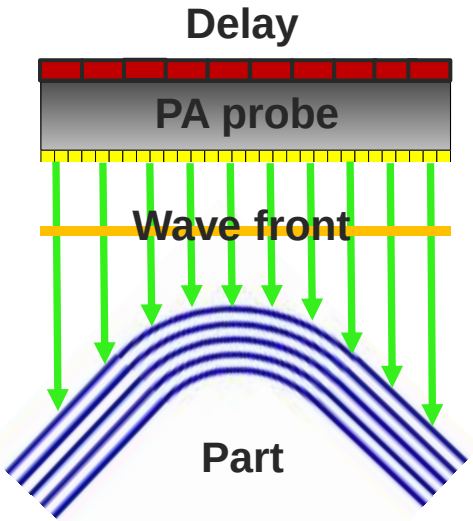


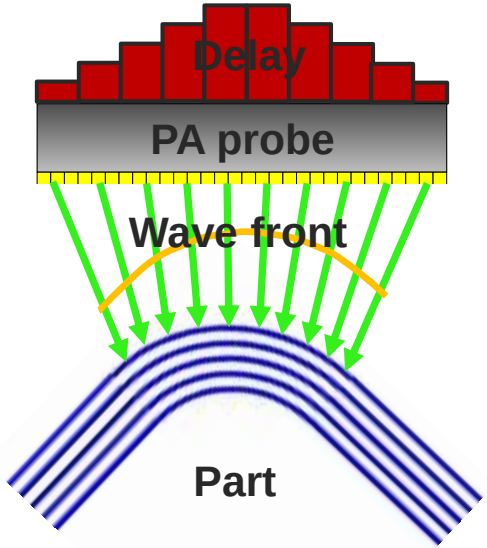
Outside Inside

- **<u>Performant</u> solution**
  - Inspection speed has to be similar to what is achieve today with standard phased array
- **<u>Reliable & robust</u> solution**

# Adaptive Focusing Solution Introduction

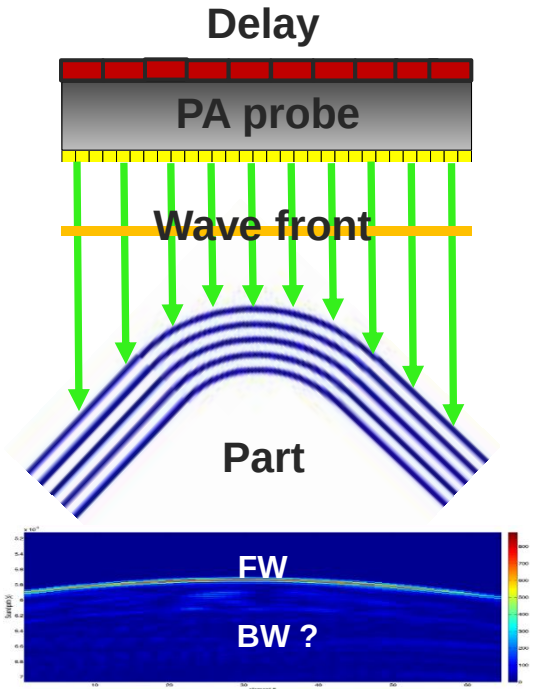
- What is the most desirable configuration ?

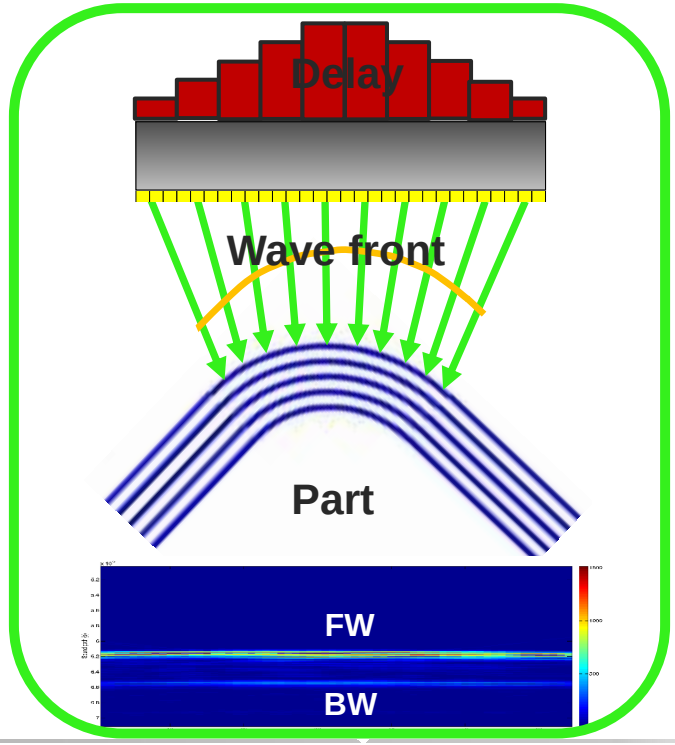


# Adaptive Focusing Solution Introduction

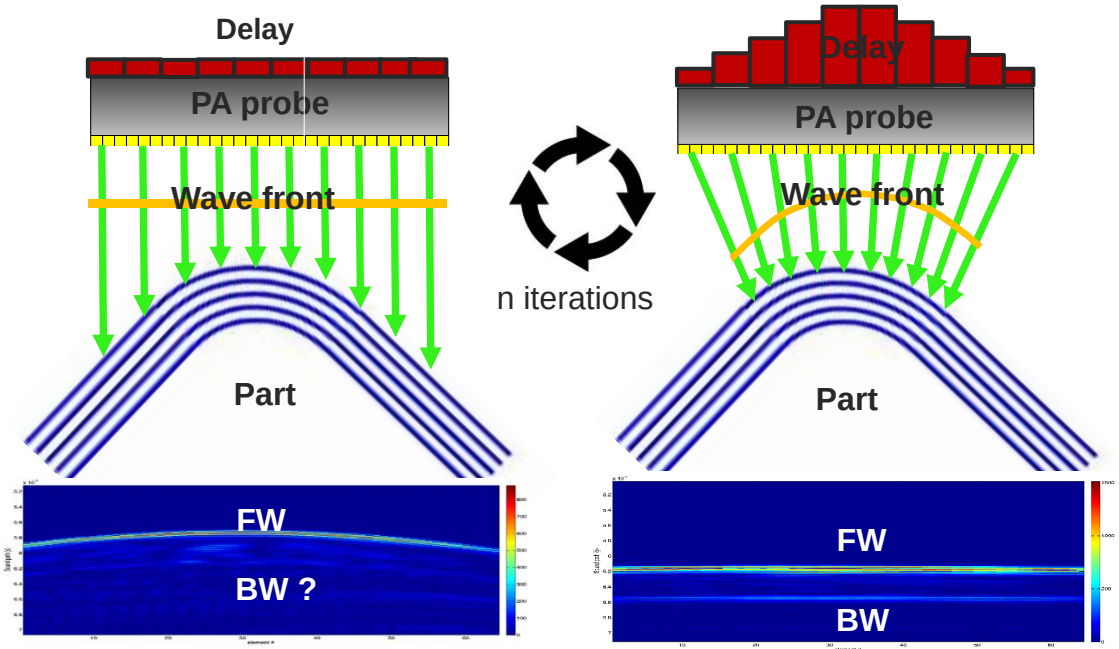
- What is the most desirable configuration ?



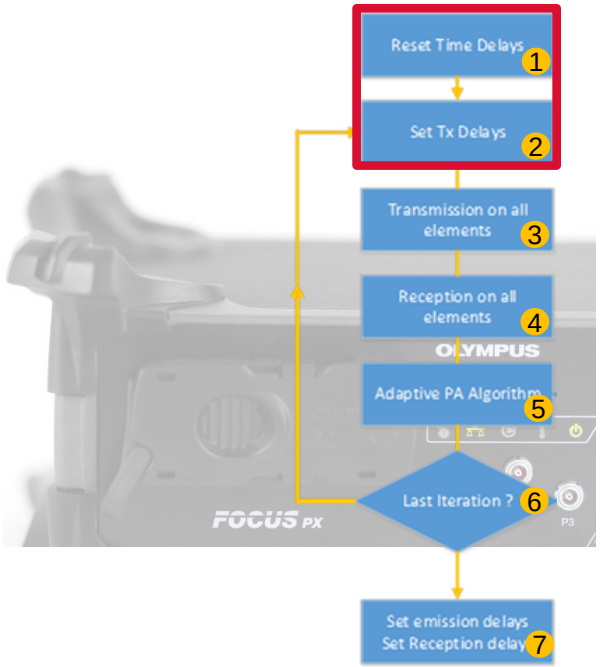



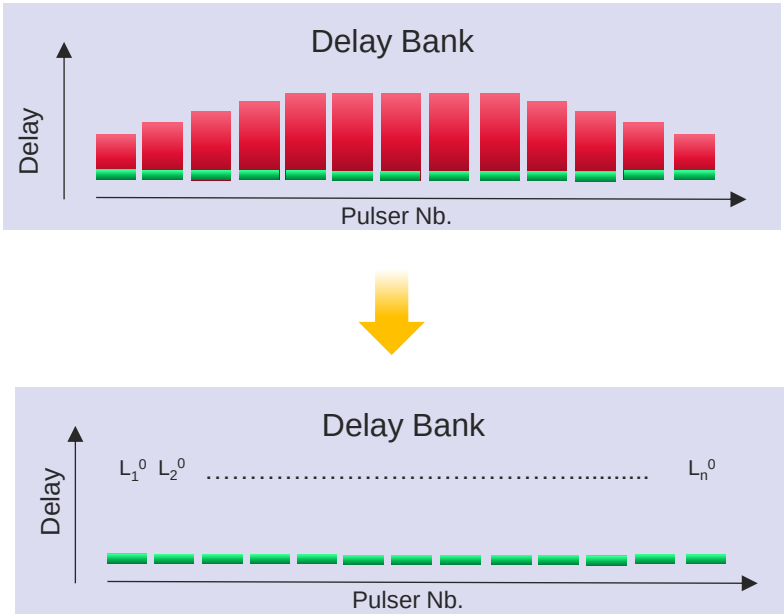
# Adaptive Focusing Solution Introduction

- Adaptive Focusing is an iterative process that allows the transmission of a wave-front parallel to the part

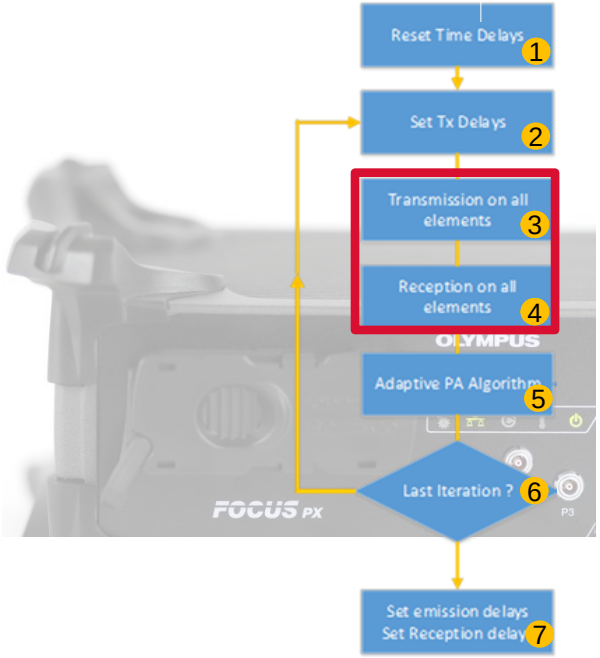


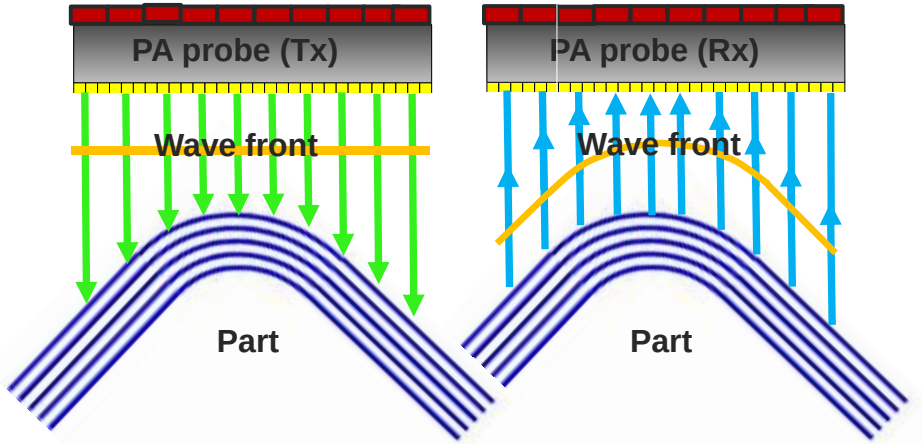
# Adaptive Focusing Solution Design

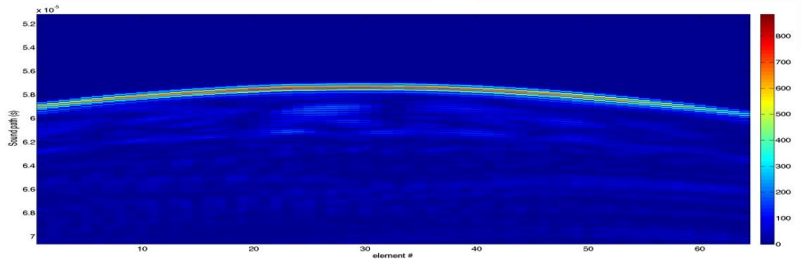


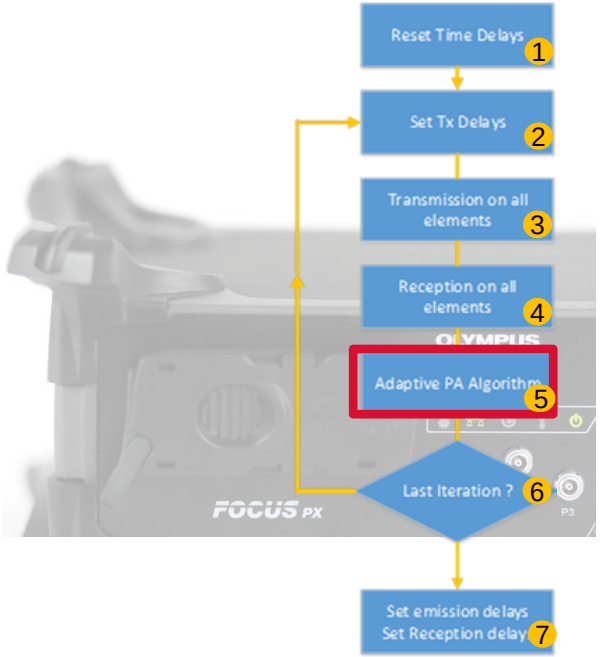
# Adaptive Focusing Solution Design



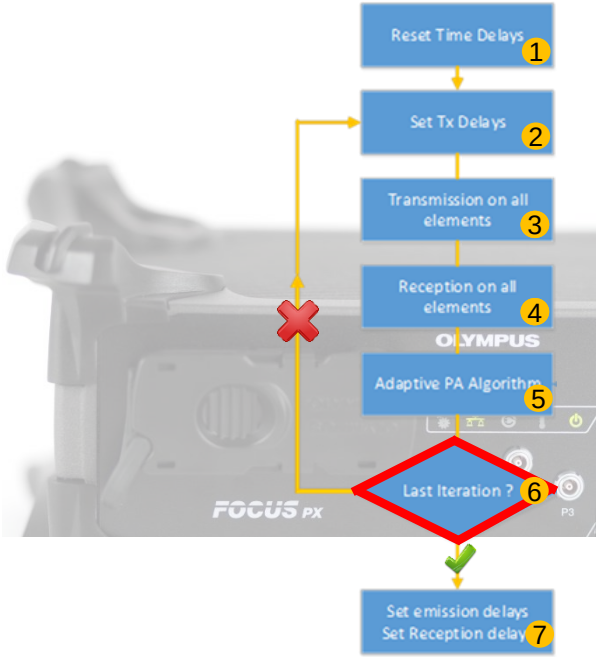



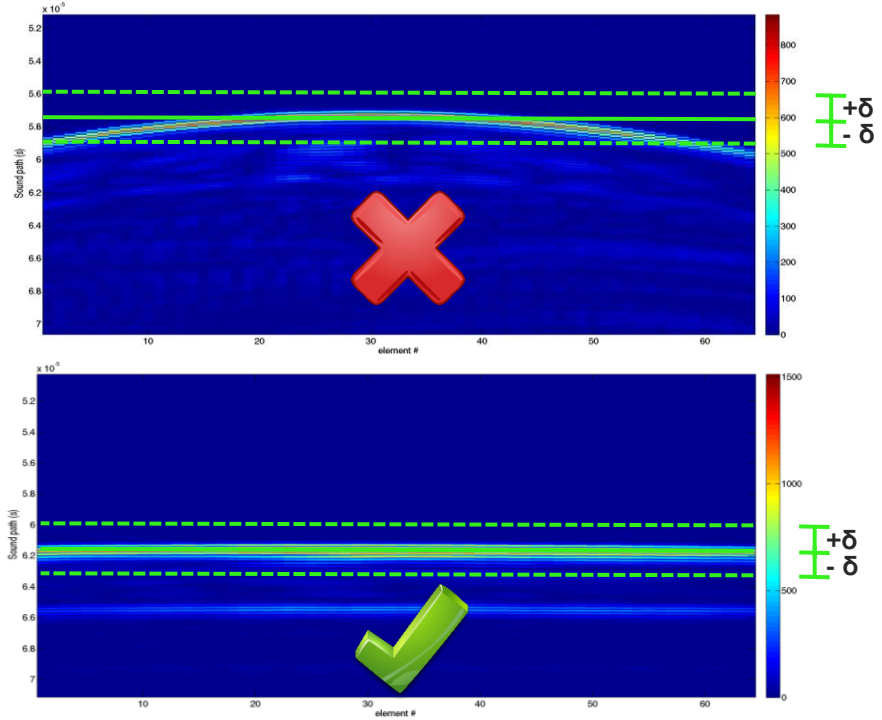



# Adaptive Focusing Solution Design



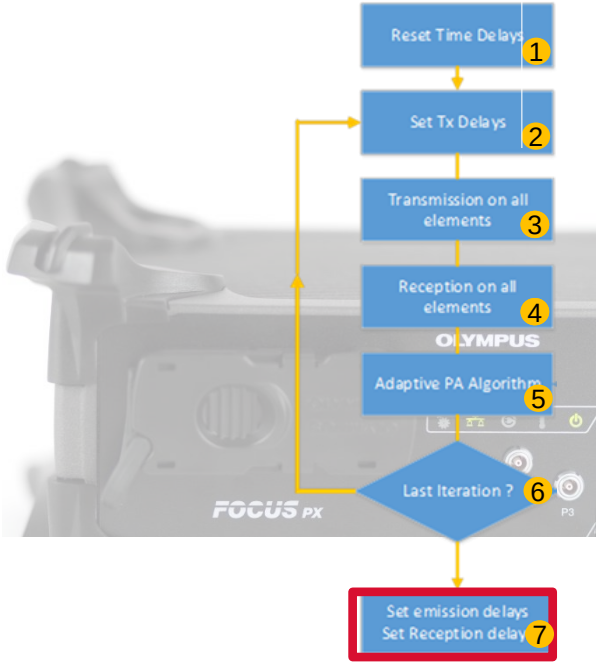

# Adaptive Focusing Solution Design

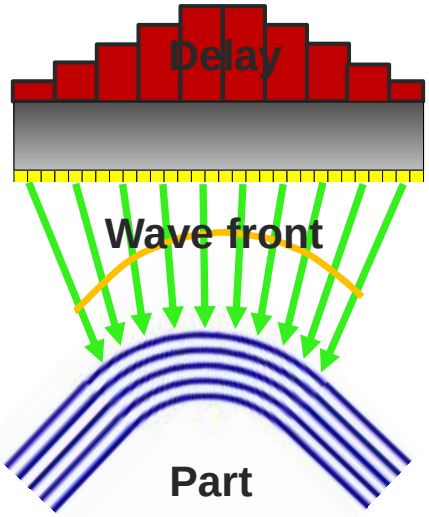


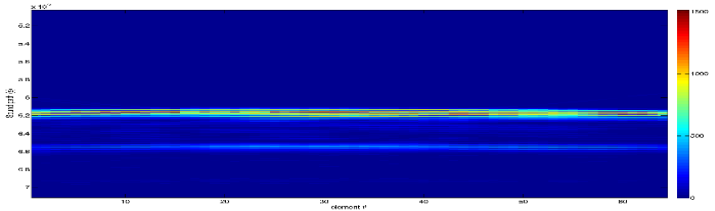




Is the frontwall corrected within a predefined tolerance (δ ) ?

# Adaptive Focusing Solution Design

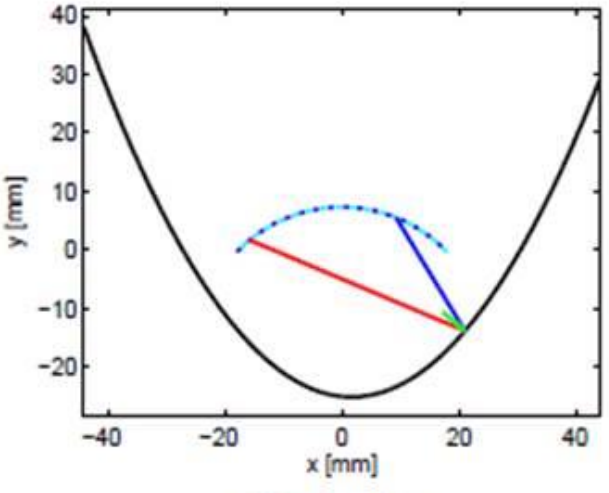


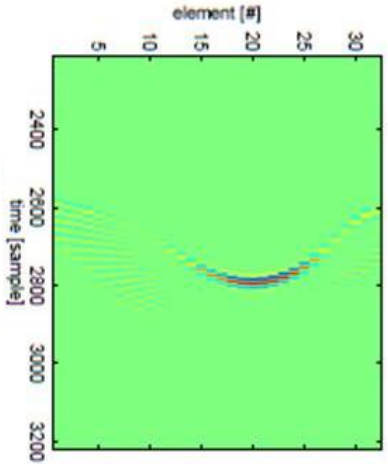



# Adaptive Focusing Solution Results

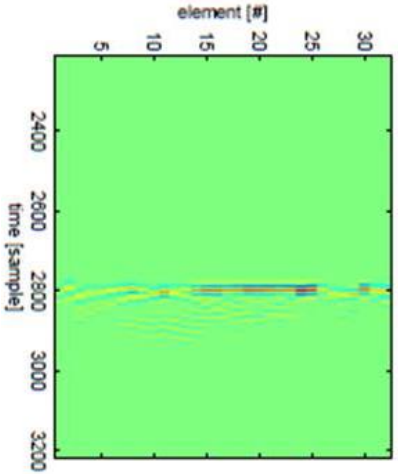
- **Simulation**




Configuration




First iteration

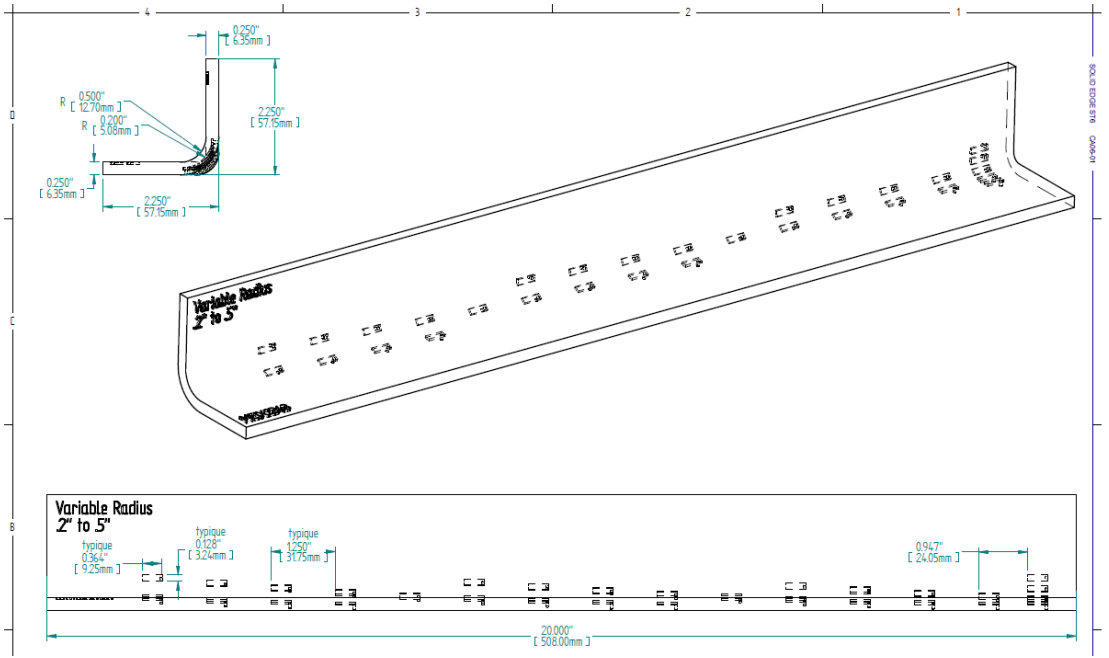



Last iteration

# Adaptive Focusing Solution Results

- **Case 1 : Varying radius**
- **Part & Scan Parameters**
  - **Geometry**: L shape
  - **Radius** : 5mm to 10mm
  - **Scan** : External face
  - **Probe** : 5CC25-32R4

  - **Wedge** : SR4-IE90



# Adaptive Focusing Solution Results

- **Case 1 : Varying radius**
- **Results**
  - *Detection*
    - 28\30 with AF
    - 20\30 without AF
  - *Defect Size*
    - 77 $mm^2$ with AF
    - 66 $mm^2$ without AF
  - *SNR*
    - *23 dB with AF*
    - *9 dB without AF*

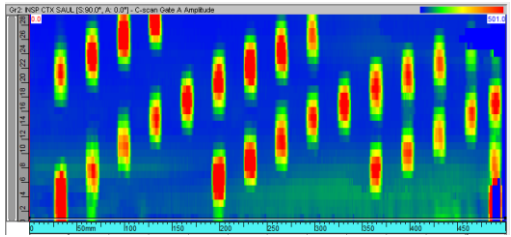


**Figure 1** : Amplitude C-Scan **with AF**

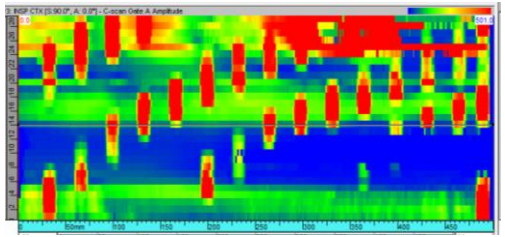


**Figure 3** : Amplitude C-Scan **without AF**

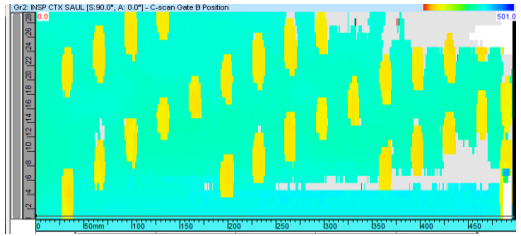


**Figure 2** : Position C-Scan **with AF**

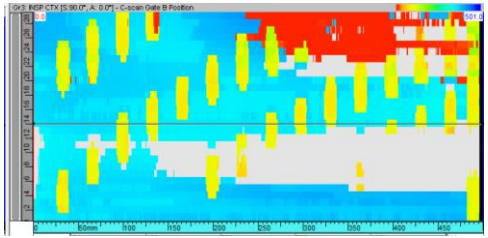
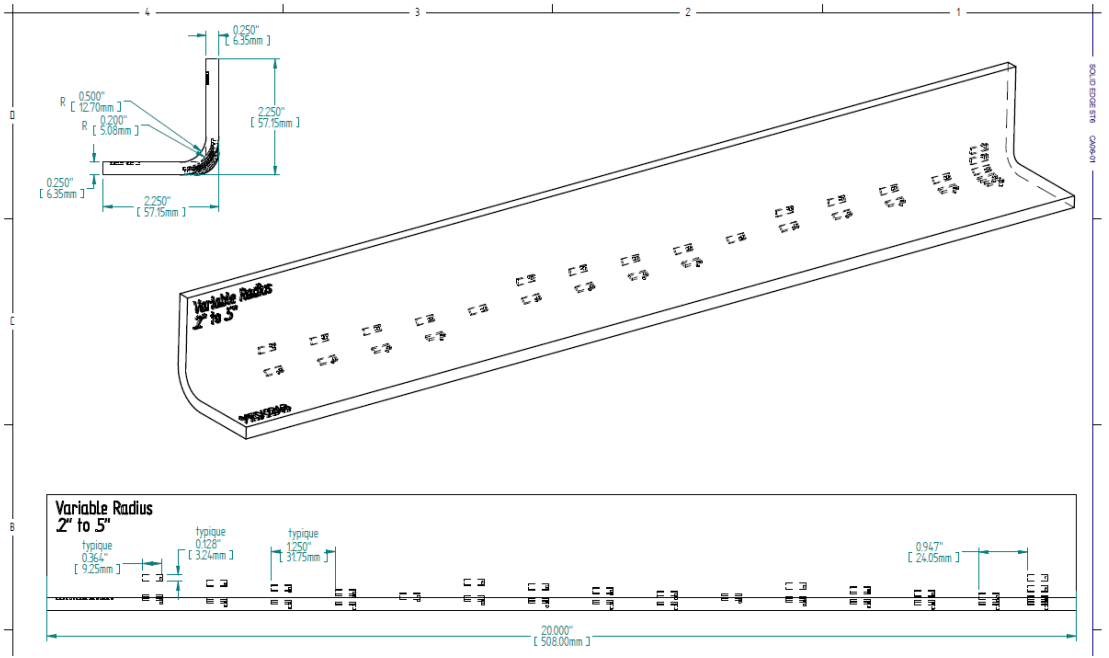


**Figure 4** : Position C-Scan **without AF**

# Adaptive Focusing Solution Results

- **Case 2 : Varying radius**
- **Part & Scan Parameters**
  - **Geometry**: L shape
  - **Radius** : 5mm to 10mm
  - **Scan** : Internal face
  - **Probe** : 5CC25-32R4

  - **Wedge** : SR4-IE90



# Adaptive Focusing Solution Results

- **Case 2 : Varying radius**
- **Results**
  - *Detection*
    - 26\30 with AF
    - 18\30 without AF
  - *Defect Size (area in mm)*
    - 91 $mm^2$ with AF
    - 84 $mm^2$ without AF
  - *SNR*
    - *22 dB with AF*
    - *22 dB without AF*

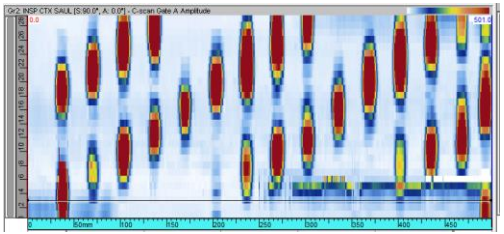


**Figure 1** : Amplitude C-Scan **with AF**

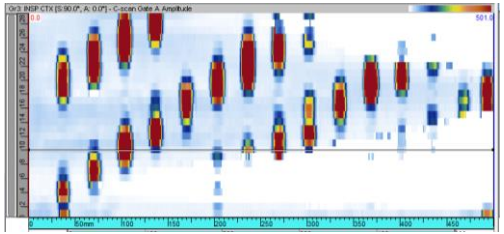


**Figure 3** : Amplitude C-Scan **without AF**

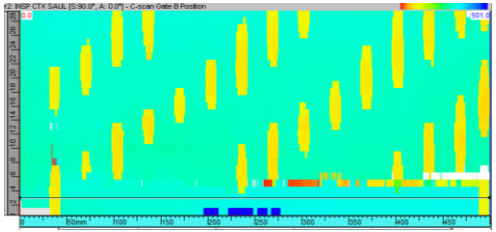


**Figure 2** : Position C-Scan **with AF**

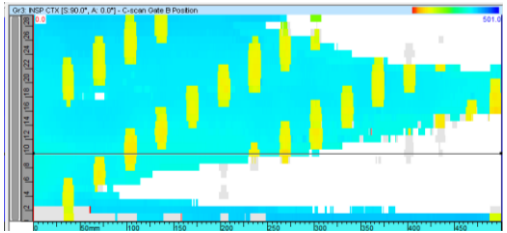


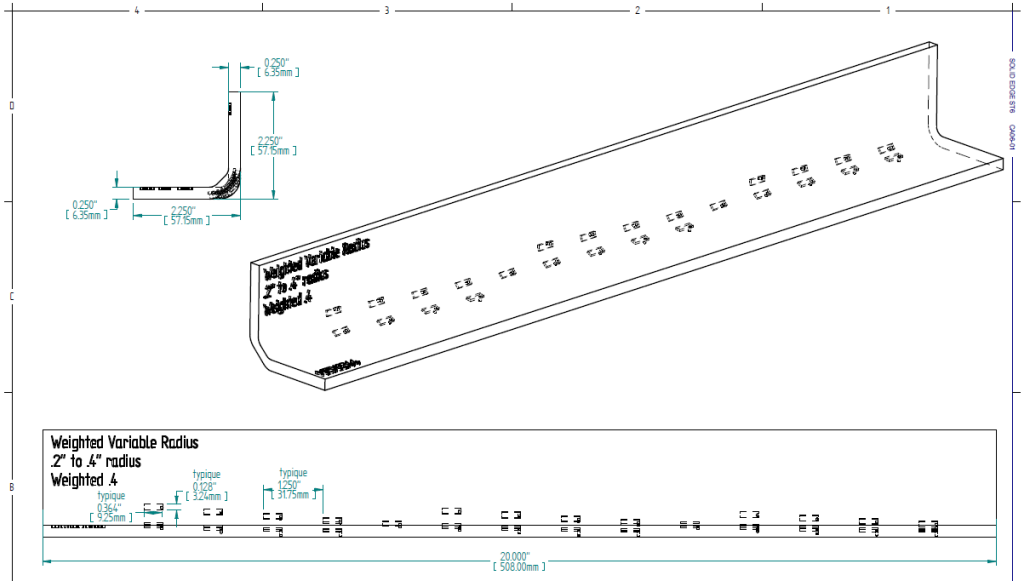
**Figure 4** : Position C-Scan **without AF**

# Adaptive Focusing Solution Results

- **Case 3 : Varying & weighted radius**

- **Part & Scan Parameters**
  - **Geometry**: L shape
  - **Radius** : 5mm to 10mm
  - **Weighted** : 10mm
  - **Scan** : Internal face
  - **Probe** : 5CC25-32R4

  - **Wedge** : SR4-IE90



# Adaptive Focusing Solution Results

- **Case 3 : Varying & weighted radius**
- **Results**
  - *Detection*
    - 26\30 with AF
    - 13\30 without AF
  - *Defect Size (area in mm)*
    - 90 $mm^2$ with AF
    - 88 $mm^2$ without AF
  - *SNR*
    - *12 dB with AF*
    - *0 dB without AF*

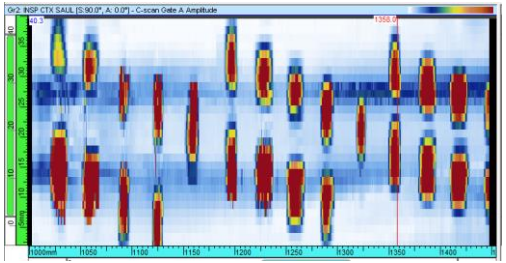


**Figure 1** : Amplitude C-Scan **with AF**

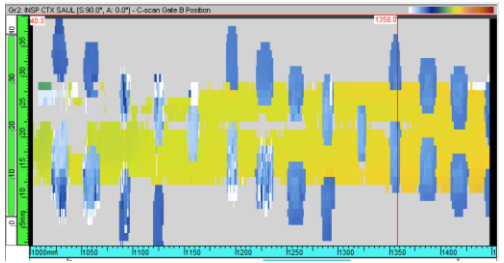


**Figure 2** : Position C-Scan **with AF**

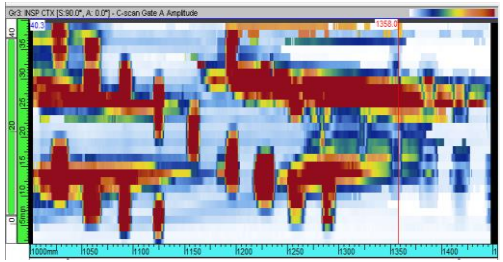


**Figure 3** : Amplitude C-Scan **without AF**

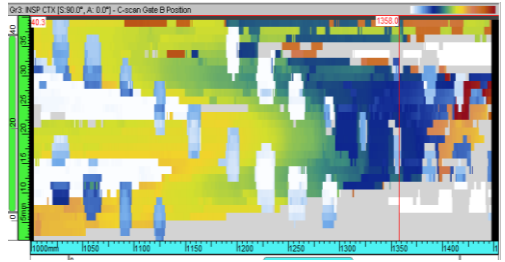


**Figure 4** : Position C-Scan **without AF**

# Adaptive Focusing Solution Results

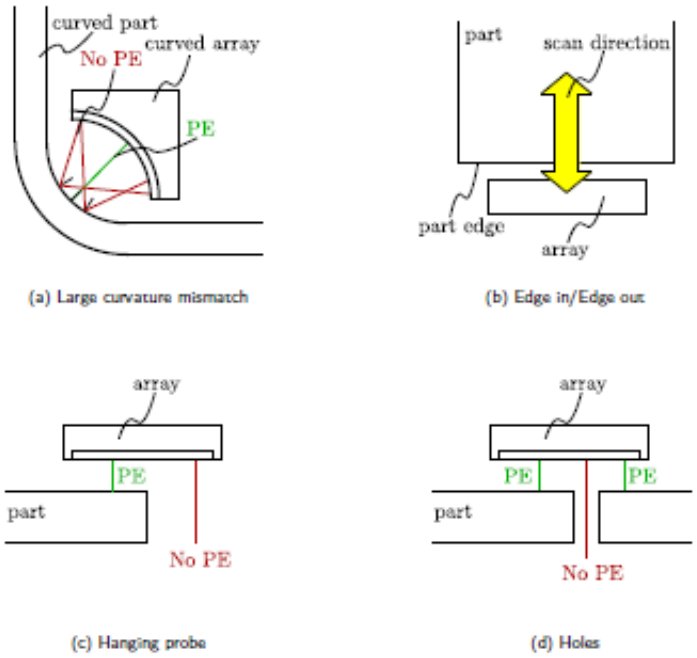
- **Productivity**

| Parameters | |
|---|---|
| Nb. Of Elements | 32 |
| Aperture Size | 4 |
| Aperture Steps | 1 |
| Water path | 25 mm |
| Material Thickness | 8.5 mm |
| Material Velocity | 2700 m\s |
| Nb. Of iterations | 5 |

| PRF with AF | PRF without AF |
|---|---|
| 300 Hz | 517 Hz |

# Adaptive Focusing Solution Results

- **Reliability and ruggedness**




(a) Large curvature mismatch

(b) Edge in/Edge out

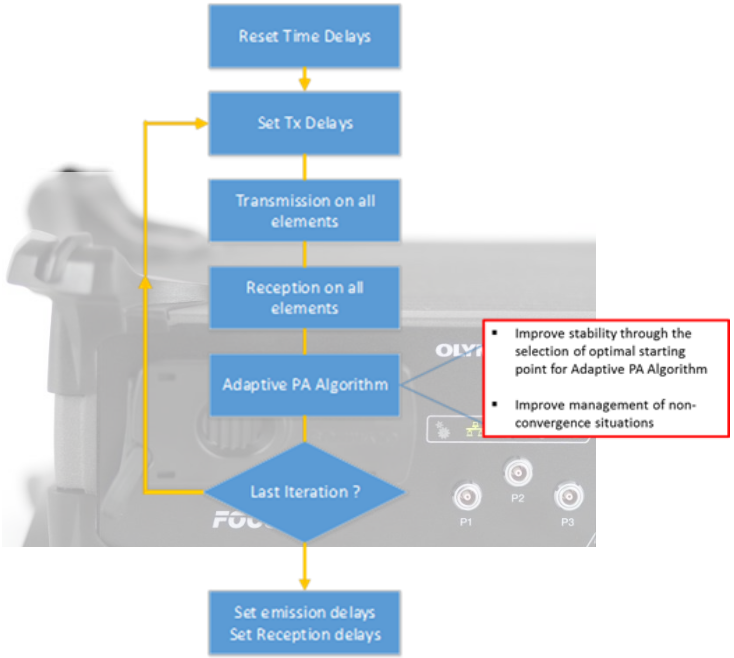
(c) Hanging probe

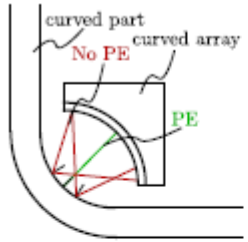
(d) Holes

# Conclusion

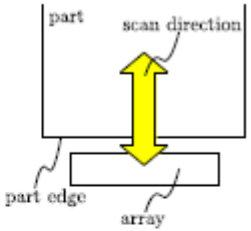
- **Improve & simplify the inspection of complex geometry components** ✓
  - Variable & weighted radius
  - Variable opening and twisted parts
- **Flexible solution allowing inspection from** ✓
  - Inside & outside radius
  - Flat surface
- **Performant solution** ✓
  - Inspection speed has to be similar to what is acheive today with standard phased array
- **Reliable & robust solution** ✗

# Conclusion & Next Steps

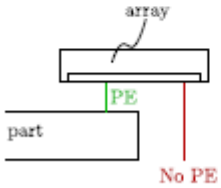


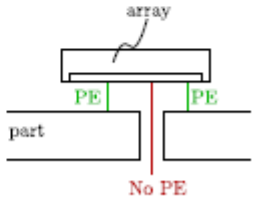

(a) Large curvature mismatch




(b) Edge in/Edge out

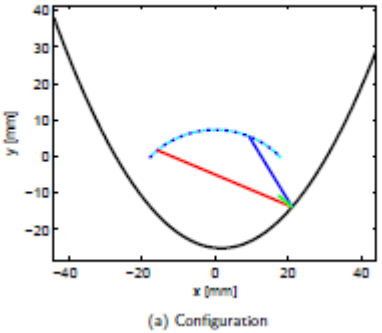



(c) Hanging probe




(d) Holes

# Conclusion & Next Steps



(a) Configuration

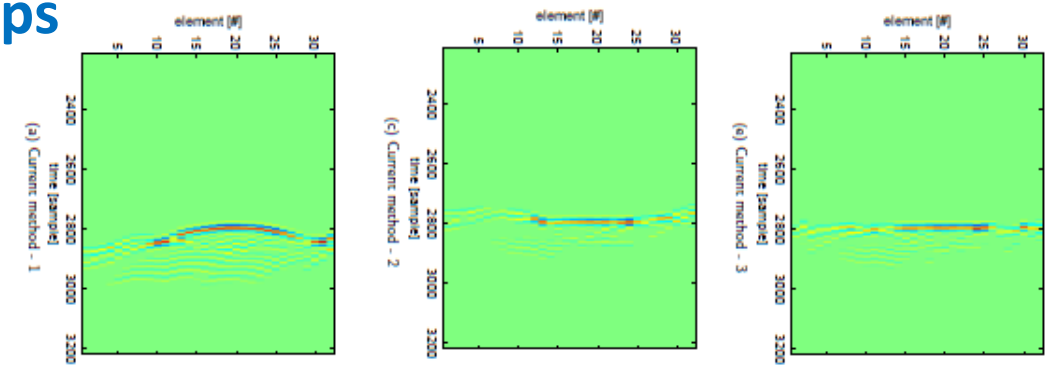



**Figure 1** : With first generation AF

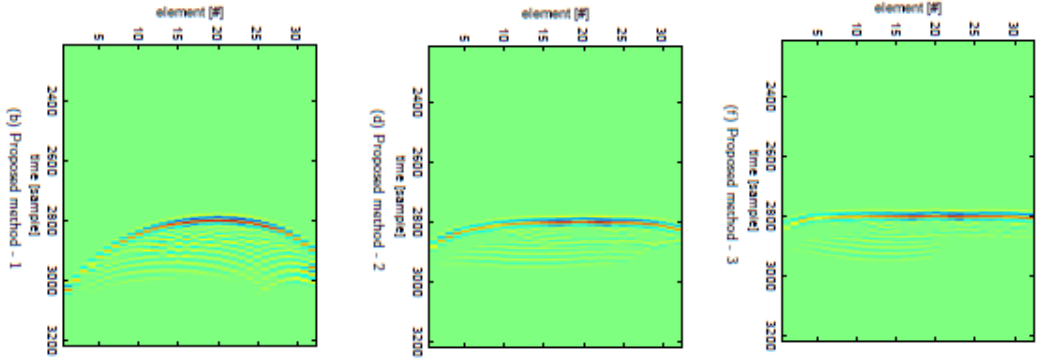



**Figure 2** : With second generation AF

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# Thank you

For more info please contact
Etienne.grondin@olympus-ossa.com


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