

Bob Shaffer

# Ultrasonic Inspection: Transducer Design for Forging Inspection

# Outline

1. Application: 45S Immersion testing of critical Forging component
2. Customer needs to reduce inspection time
3. Linear Array vs. Conventional to reduce number of mechanical indexes
4. Calibration Block and Data from Existing Inspection

# Existing Immersion Test Specifications

## 17 Transducer Specifications

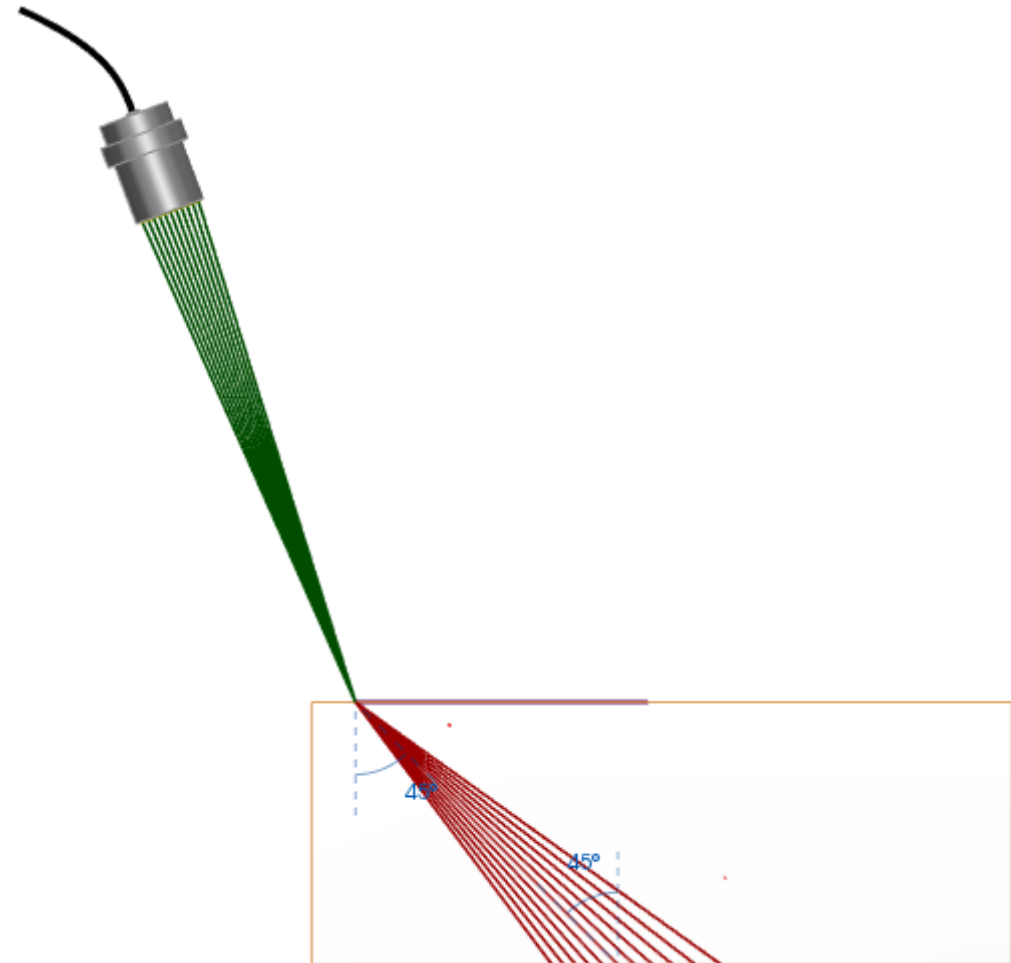
Element Size (in.)	0.75
Frequency (MHz)	5.0
Focus (in.)	6.0
BW%	60

## Immersion Test Specifications

Test angle/Mode	45S
Water Path (in.)	6.0
Index (in.)	0.04

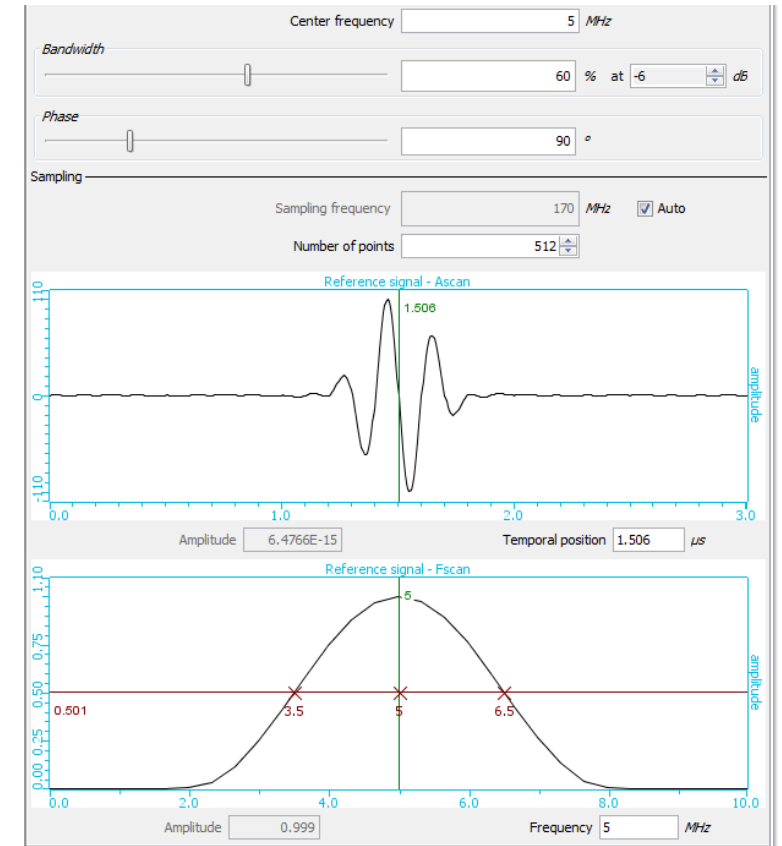
## Calibration Block Specifications

Material	Rene 95
SDH Size (in.)	0.02
SDH Depth 1 (in.)	0.25
SDH Depth 2 (in.)	2.0
Shear Velocity (in/uS)	0.117

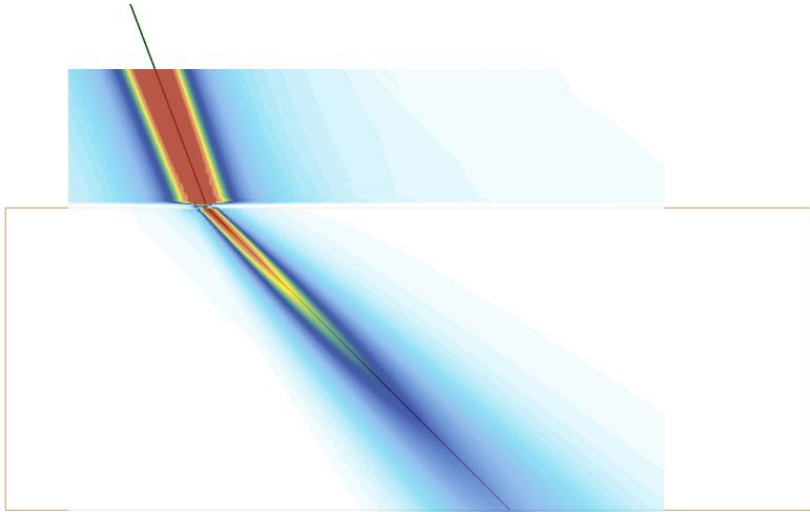


# CIVA Model of Existing Immersion Transducer

- Beam Computation performed of existing test.
  - Transducer Parameters same as I7.
  - Reference signal shown at left.
  - Calibration Block same as existing.
  - Benchmark Beam formation in Calibration Block.
    - Slice along Shear Axis
    - Slice Perpendicular to Shear Axis @ .25" depth.
    - Slice Perpendicular to Shear Axis @ 2.0" depth.
- Inspection Simulation performed for Calibration Block SDH responses.
  - .02" SDH @ .25" Depth
  - .02" SDH @ 2.0" Depth

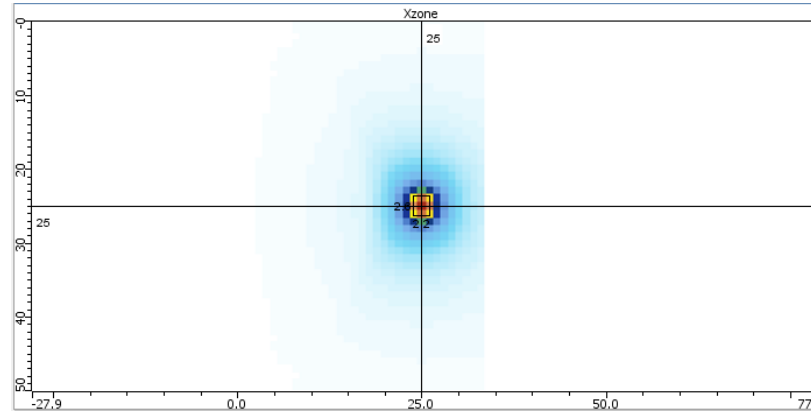


# Beam Computation Results

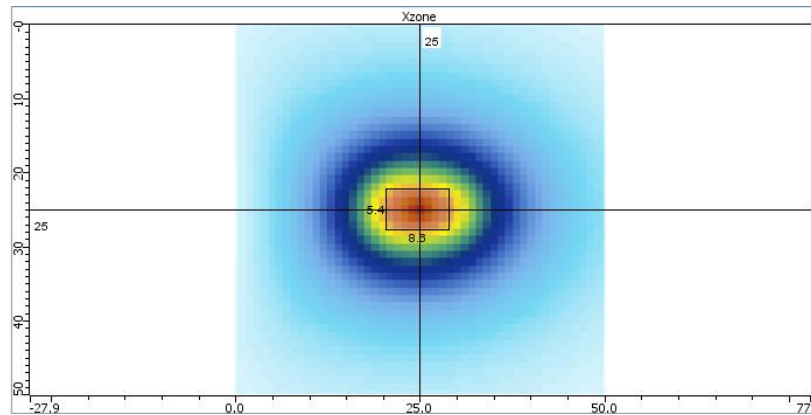


Slice along Shear Axis, +21 dB added to show Beam formation in Block

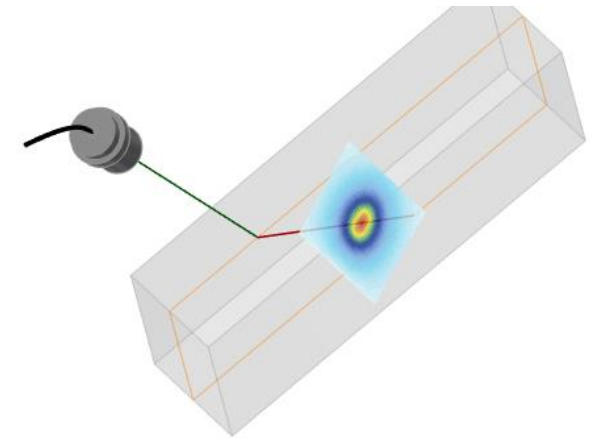
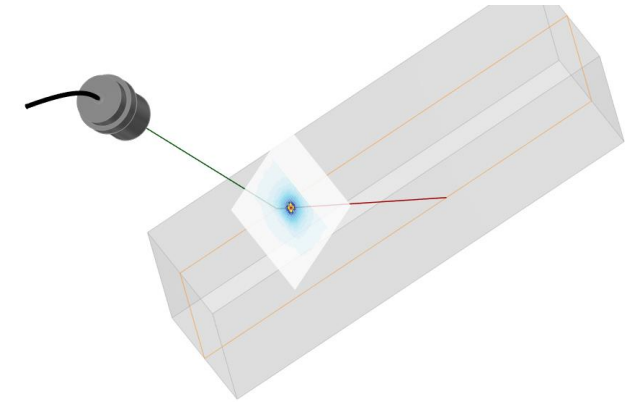
Depth (in.)	Beam Size (mm)			
	-3dB (X-Zone)	-3dB (Z-Zone)	-6dB (X-Zone)	-6dB (Z-Zone)
0.25	2.6	2.2	3.8	3.2
2.0	5.4	8.6	9.8	14.5



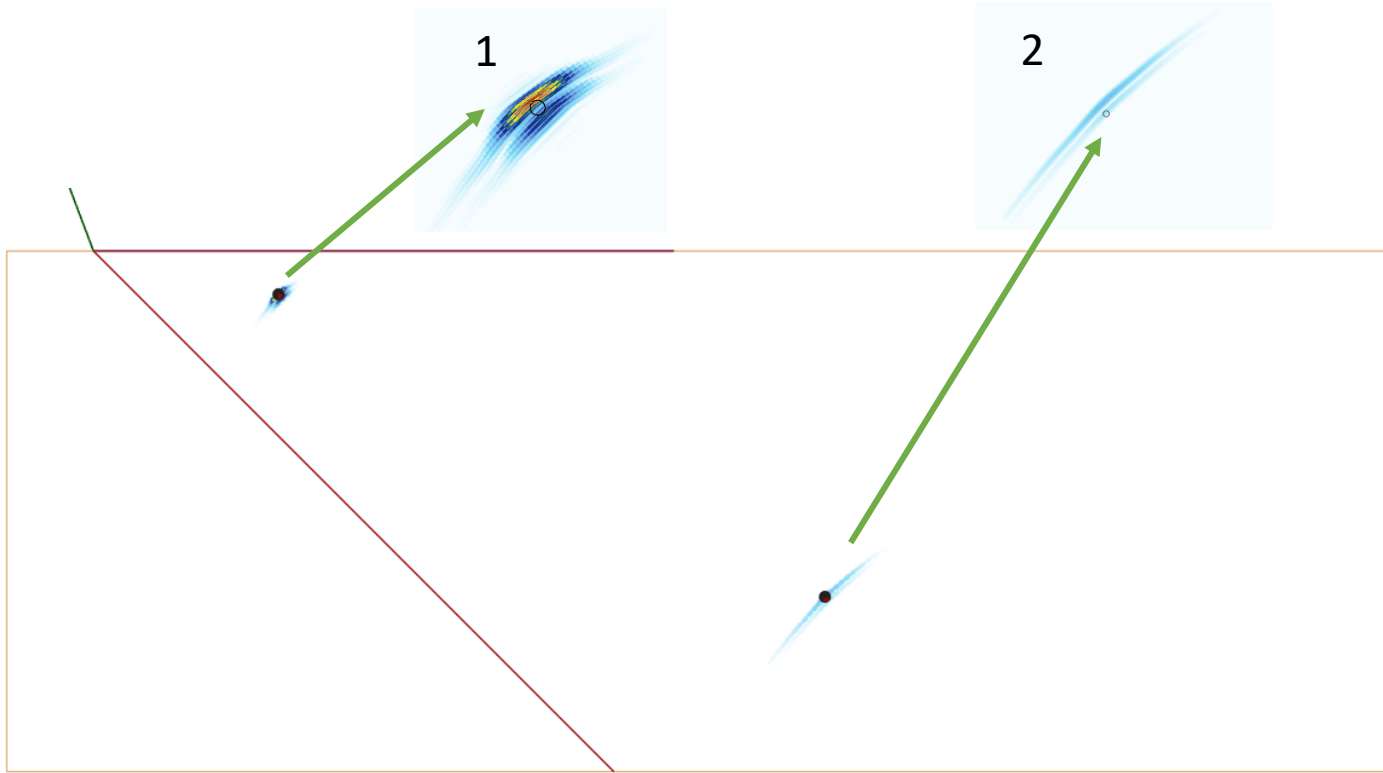
Slice @ .25" Depth



Slice @ 2.0" Depth



# Inspection Simulation Results

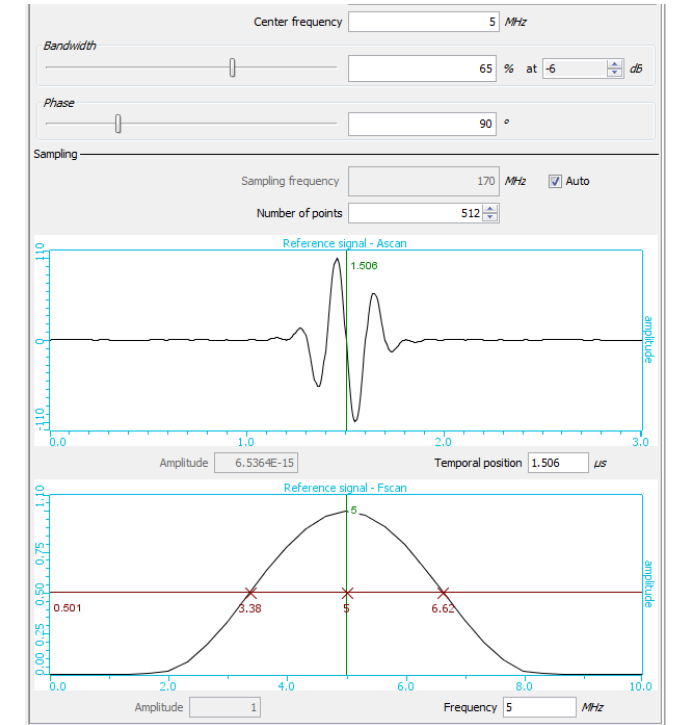


- Relative Amplitude of the 2.0" SDH to the .25" SDH is -18.3dB
- Customer supplied 63.2dB for .25" SDH & 79.2dB for 2.00" SDH. Difference is -16dB.

Cursors Measures View Options Palette/Gain Gates Selection Measures on Selection Indications table Display Rays										
Id	Gate	Valid	Visibility	Locked indication	Name	Comment	Type	Amplitude max signal(dB)	Depth (Amp Max Ascan) (in)	
1	[Configuration] Gate 1 (Σ) (L11)	<input checked="" type="checkbox"/>					Flaw	0	0.25	
2	[Configuration] Gate 1 (Σ) (L11)	<input checked="" type="checkbox"/>					Flaw	-18.3	1.99	

# CIVA Modeling of a Phased Array to duplicate Beam Formation and SDH response of the I7 Transducer

- Using the Beam Computation and Inspection Simulation results above for the I7, define and model a Phased Array that produces similar results.
  - Model an Immersion test same as existing.
  - Start with a Phased Array that has Total Aperture approximately the same size as I7.
  - Same Frequency as I7.
  - Secondary Axis (Elevation) Focus = 6.0".
  - Focus Primary Axis at 6.0" (Surface).

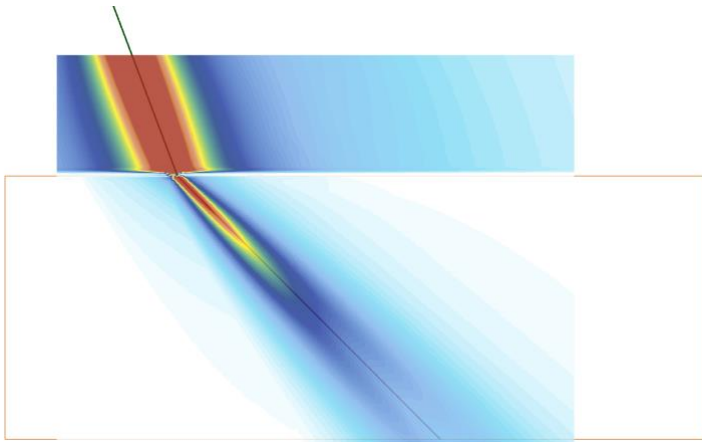


Phased Array Specifications	
Primary Axis Aperture size (mm)	20
Secondary Axis Aperture Size (mm)	20
# Elements	20
Pitch (mm)	1.0
Frequency (MHz)	5.0
Bw%	65

Calibration Block Specifications	
Material	Rene 95
SDH Size (in.)	0.02
SDH Depth 1 (in.)	0.25
SDH Depth 2 (in.)	2.0
Shear Velocity (in/uS)	0.117

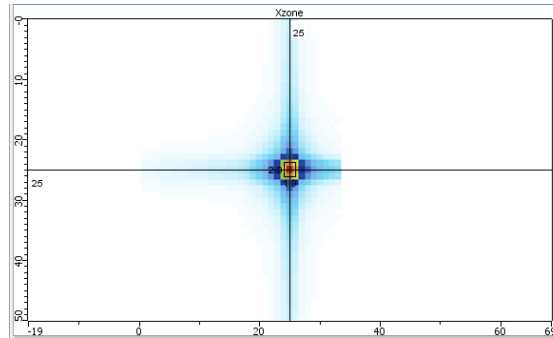
Immersion Test Specifications	
Test angle/Mode	45S
Water Path (in.)	6.0
Index (in.)	0.04

# Beam Computation Results

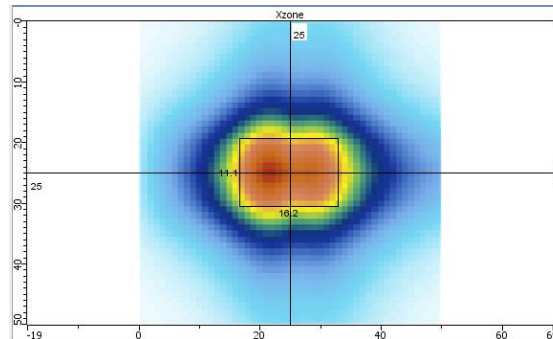


Slice along Shear Axis, Sensitivity referenced to I7 Beam Computation, +21 dB added to show Beam formation in Block

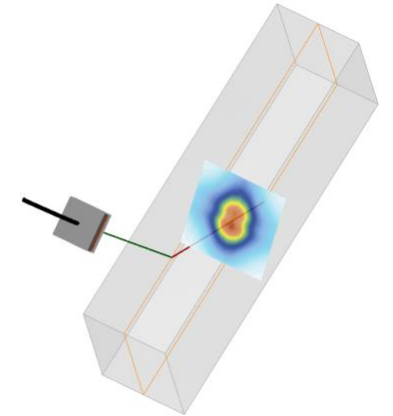
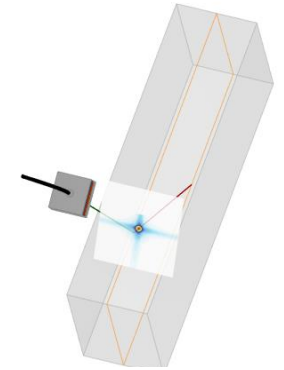
Depth (in.)	Beam Size (mm)			
	-3dB (X-Zone)	-3dB (Z-Zone)	-6dB (X-Zone)	-6dB (Z-Zone)
0.25	2.3	1.9	3.3	3
2.0	11.1	16.2	16.1	22



Slice @ .25" Depth

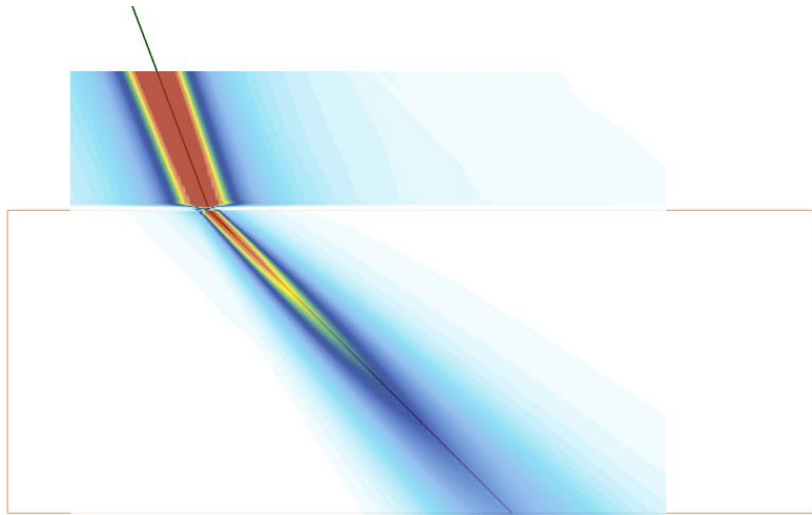


Slice @ 2.0" Depth

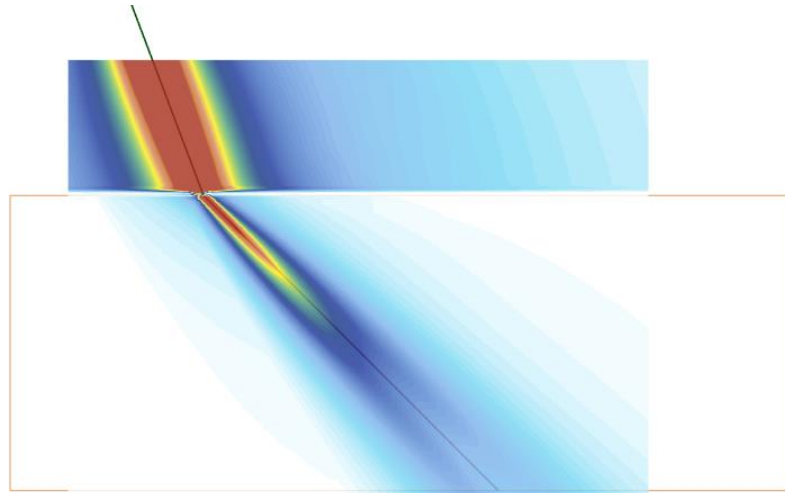




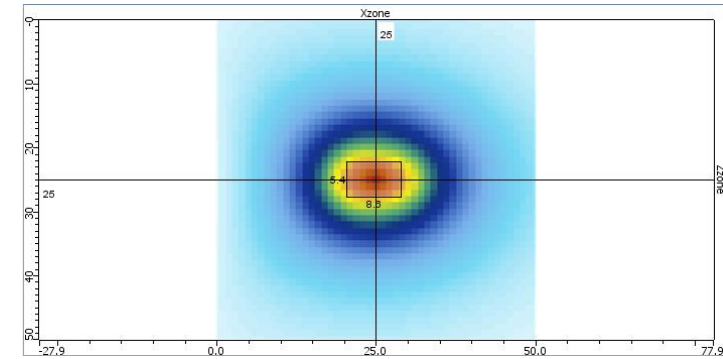
# Comparison to I7 Results



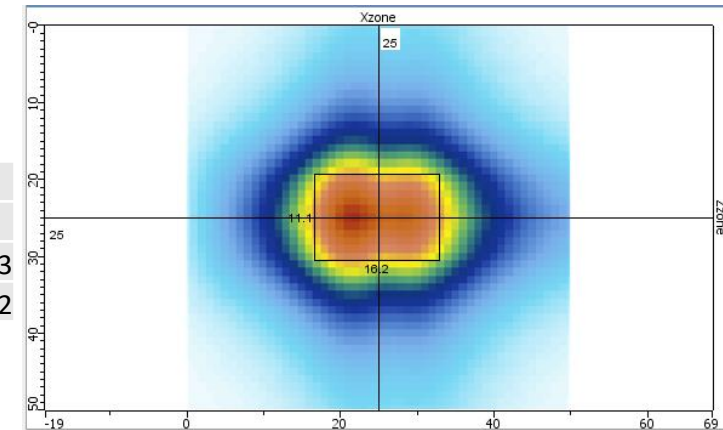
I7



Phased Array



I7  
Slice @ 2.0" Depth

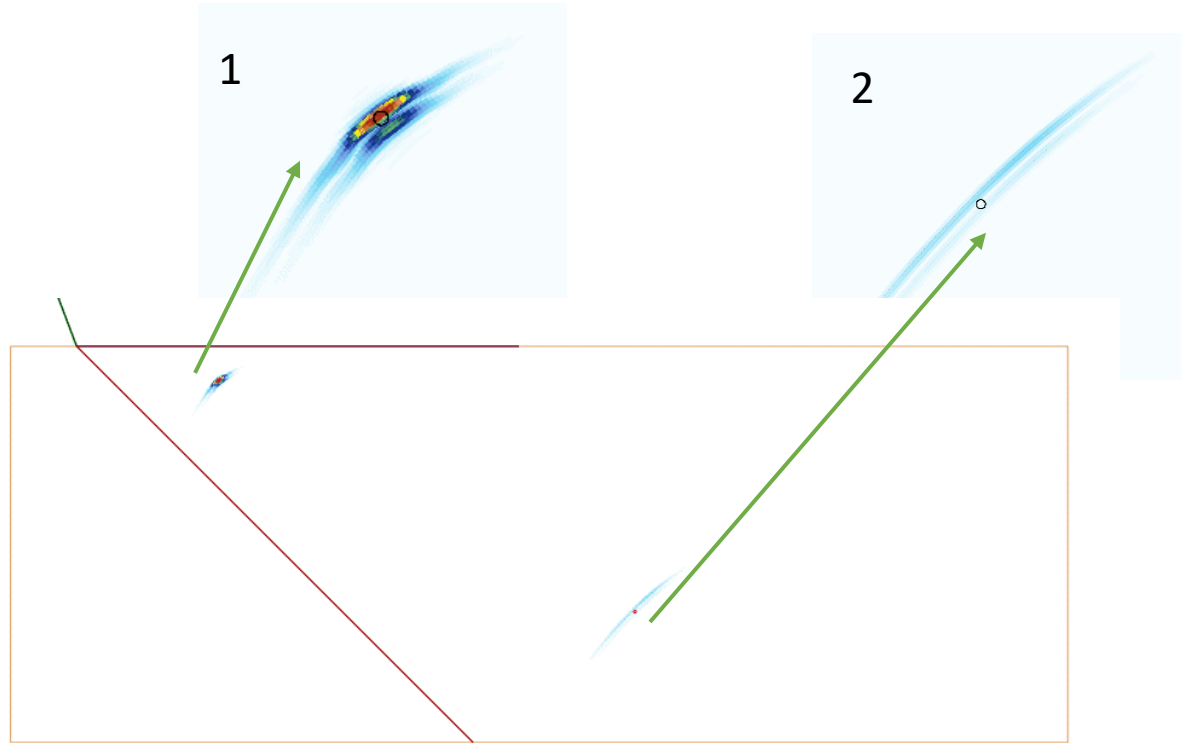


Phased Array  
Slice @ 2.0" Depth

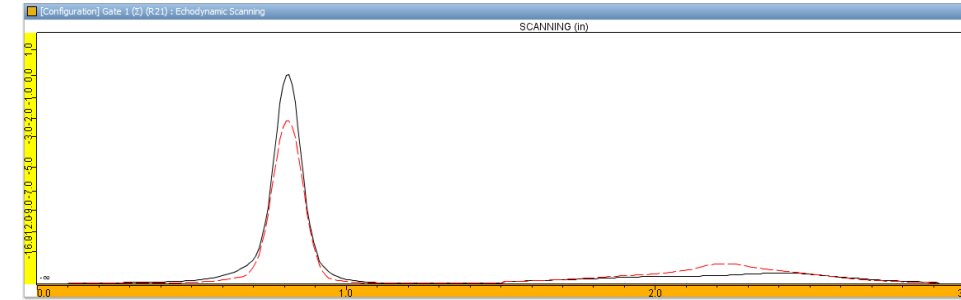
Depth (in.)	Beam Size (mm)			
	-3dB (X-Zone)	-3dB (Z-Zone)	-6dB (X-Zone)	-6dB (Z-Zone)
0.25	2.6	2.2	3.8	3.2
2.0	5.4	8.6	9.8	14.5

Depth (in.)	Beam Size (mm)			
	-3dB (X-Zone)	-3dB (Z-Zone)	-6dB (X-Zone)	-6dB (Z-Zone)
0.25	2.3	1.9	3.3	3
2.0	11.1	16.2	16.1	22

# Inspection Simulation Results



Superimposition of I7 and Phased Array Scanning Envelopes. Dashed Red is I7.



Sensitivity set relative to the I7 Inspection Simulation. .25" Deep SDH is +2.2 dB compared to I7 and 2.0" SDH is -5.7dB. Relative Amplitude of the 2.0" SDH to the .25" SDH is -26.2dB

Id	Gate	Valid	Visibility	Locked indication	Name	Comment	Type	Amplitude max signal(dB)	Depth (Amp Max Ascan) (in)
1	[Configuration] Gate 1 (Σ) (R21)	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>			Flaw	2.2	0.25
2	[Configuration] Gate 1 (Σ) (R21)	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>			Flaw	-24	1.92

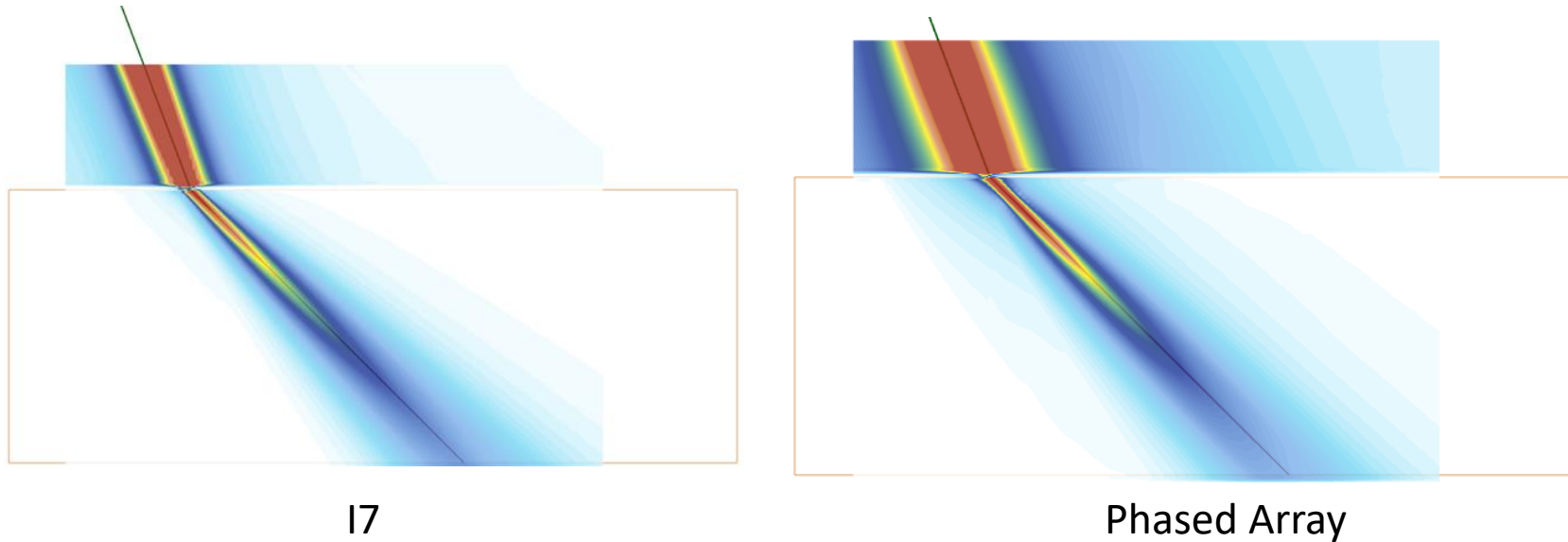
# Initial Conclusions

- The Beam Formation in the Block is not as uniform with the Phased Array as the I7 Probe.
- Although the Phased Array is more sensitive at .25" Depth by +2dB, it is less sensitive at 2.0" depth by -5.7dB.
- The relative amplitude of the (2) SDH's is 18.3dB with the I7 and 26.2 dB with the Phased Array.

## Next Steps

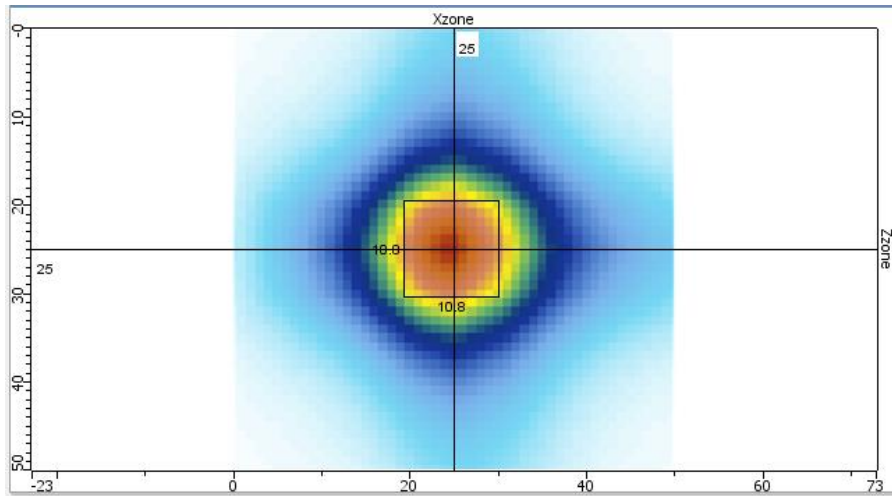
- Using the I7 results as a sensitivity reference for Beam Computation and Inspection simulation
  - Vary the Secondary axis (Elevation) focus and the Primary Axis focus to achieve a Beam uniformity closer to the I7
  - Compare SDH responses with same variants

# Beam Computation Results with 7.0" Secondary Axis Focus

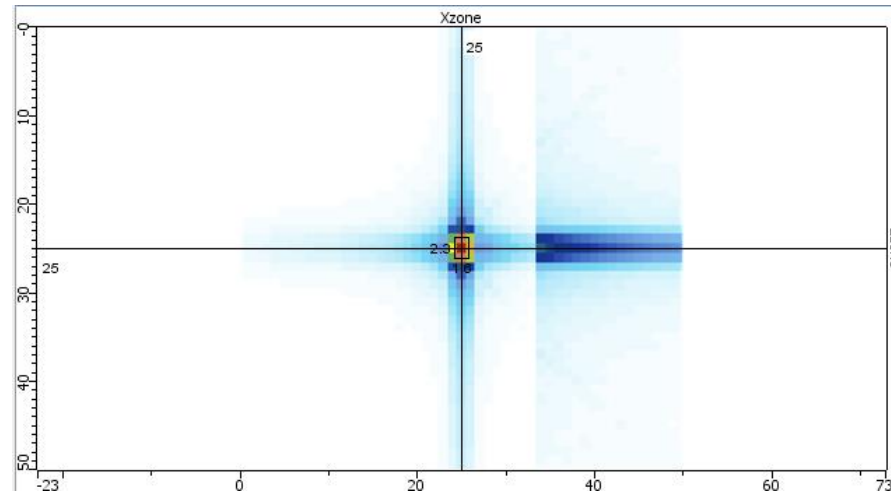


- Increasing the Focus from 6.0" to 7" in the Secondary Axis Produces a more uniform Beam.

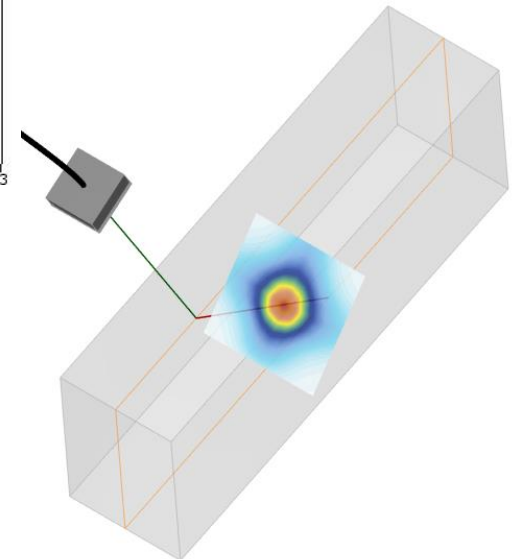
# Beam Computation Results with 7.0" Secondary Axis Focus



Slice @ 2.0" Depth



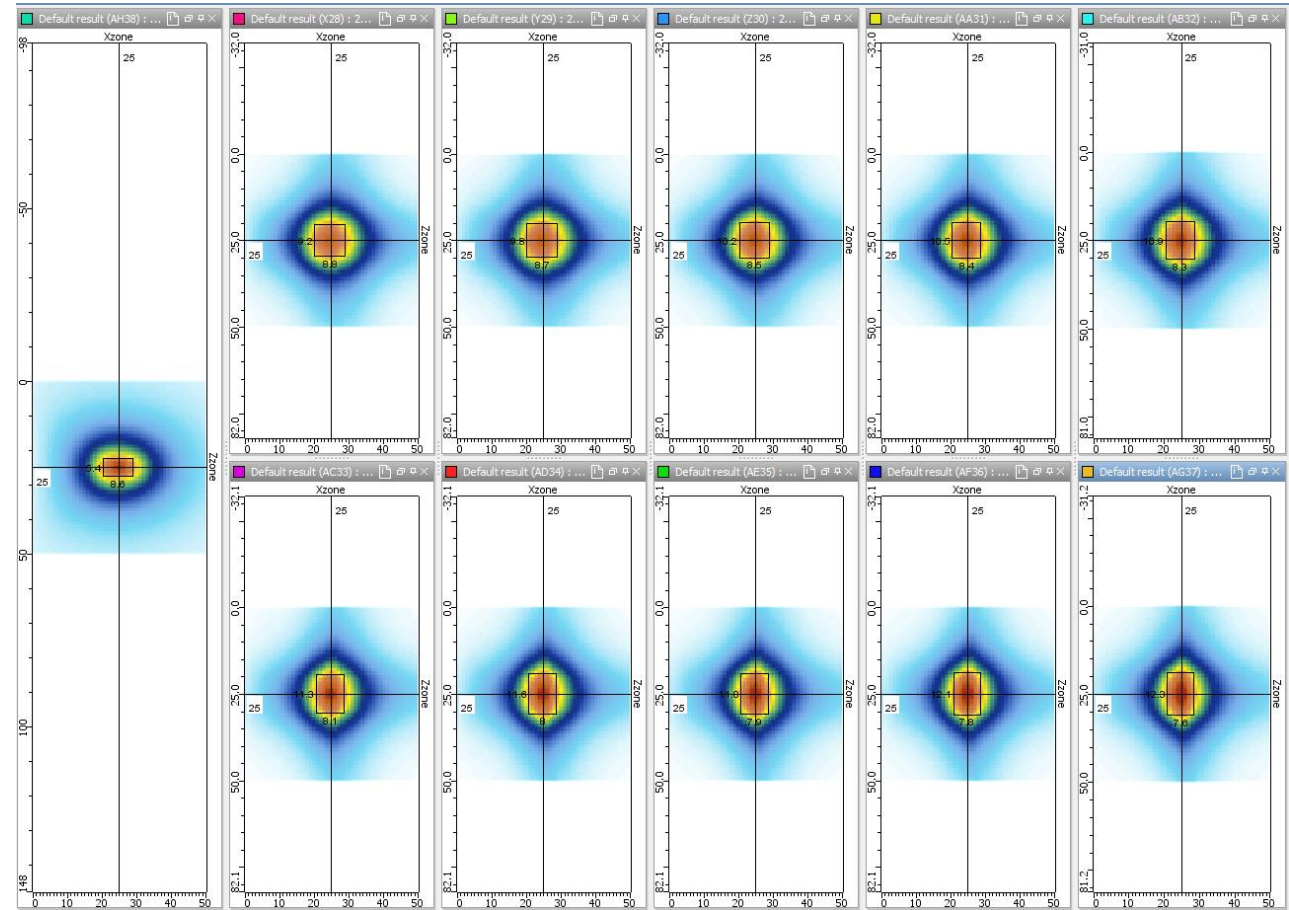
Slice @ .25" Depth



Depth (in.)	Beam Size (mm)			
	-3dB (X-Zone)	-3dB (Z-Zone)	-6dB (X-Zone)	-6dB (Z-Zone)
0.25	2.3	1.6	3.3	2.6
2.0	10.8	10.8	15.8	16.3

- Parametric Study Varying Elevation Focus of the Array from 7.0" to 8.0"
- -3dB Spot size at 2.0" Depth Perpendicular to Beam
- Z-Zone match at 7.22" FCS

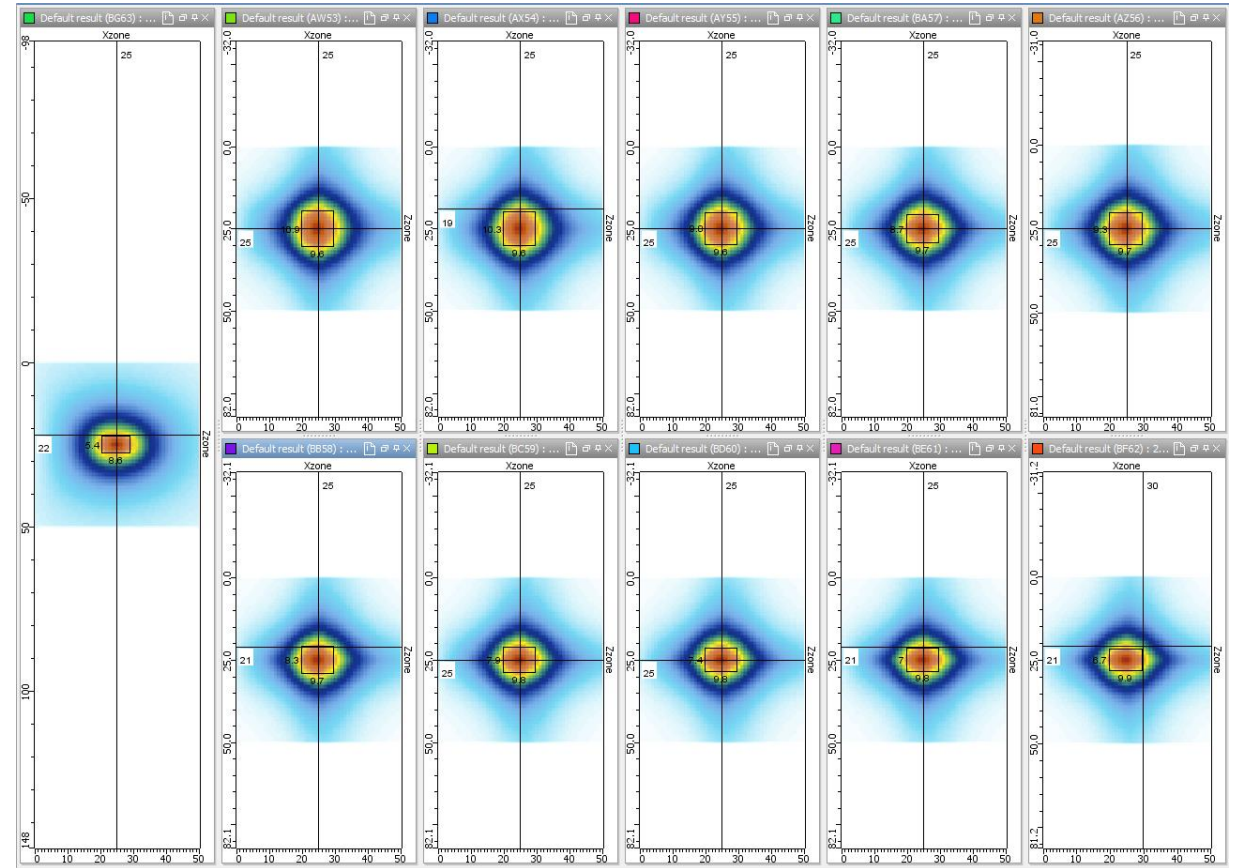
Focus (in.)	-3dB Beam Size (mm)	
	-3dB (X-Zone)	-3dB (Z-Zone)
17	5.4	8.6
7.00	9.2	8.8
7.11	9.8	8.7
<b>7.22</b>	<b>10.2</b>	<b>8.5</b>
7.33	10.5	8.4
7.44	10.9	8.3
7.56	11.3	8.1
7.67	11.6	8
7.78	11.8	7.9
7.89	12.1	7.8
8.00	12.3	7.6



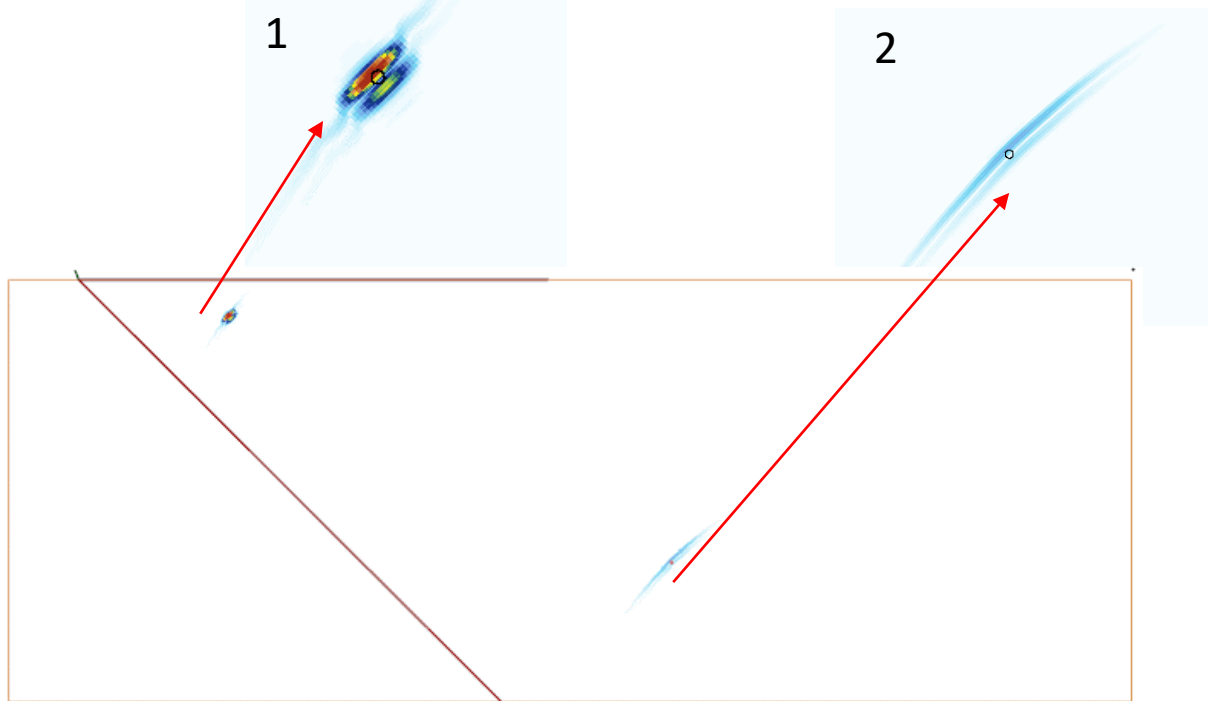


- Parametric Study Varying Array active focus from 0mm to 6.35mm Depth
- -3dB Spot size at 2.0" Depth Perpendicular to Beam
- Z-Zone match at 7.22" FCS

Focus (mm)	-3dB Beam Size (mm)	
	-3dB (X-Zone)	-3dB (Z-Zone)
17	5.4	8.6
0.00	9.6	10.9
0.71	9.6	10.3
1.41	9.8	9.6
2.12	9.7	8.7
2.82	9.7	8.3
3.53	9.7	8.3
4.23	9.8	7.9
4.94	9.8	7.4
5.64	9.8	7
6.35	9.9	6.7

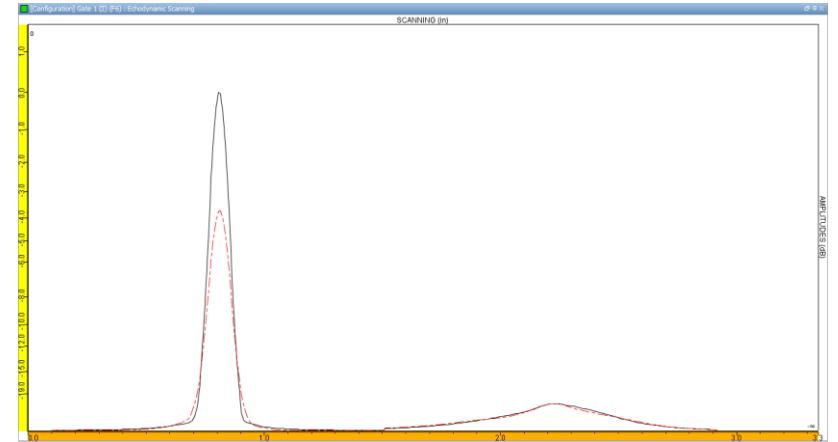


# Revised Array Results



Id	Gate	Valid	Visibility	Locked indication	Name	Comment	Type	Amplitude max signal(dB)	Depth (Amp Max Ascan) (in)
1	[Configuration] Gate 1 (Σ) (D3)	<input checked="" type="checkbox"/>					Flaw	3.7	0.26
2	[Configuration] Gate 1 (Σ) (D3)	<input checked="" type="checkbox"/>					Flaw	-18.2	1.98

Superimposition of I7 and Phased Array Scanning Envelopes. Dashed Red is I7.



Sensitivity set relative to the I7 Inspection Simulation. .25" Deep SDH is +3.7 dB compared to I7 and 2.0" SDH is Equal.



# Summary

- Correlating Existing Inspection and Calibration procedure to CIVA model increases confidence in modeling data.
- Provides a target for Probe optimization in CIVA.
- Modeling allows all probe parameters to be evaluated