SyneRBI

Deep Learned Beamforming for Coherent Multi-Transducer Ultrasound Systems

Yi Li (yi.8.li@kcl.ac.uk), Paul Dryburgh, Josephine Pearce, Andrew Reader, Jo Hajnal, Laura Peralta Pereira

Department of Surgical & Interventional Engineering
School of Biomedical Engineering and Imaging Sciences
King's College London

QUIIN lab

Website:

WeChat:

9th Mar 2026

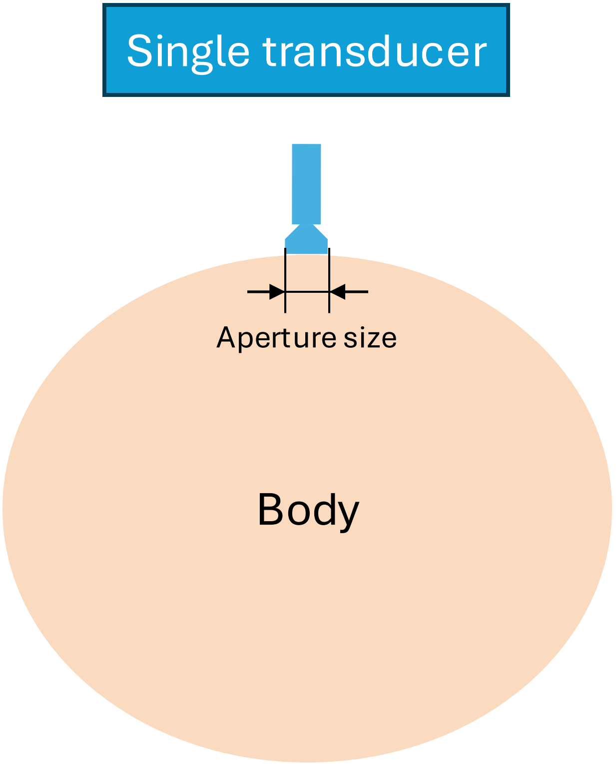
1. Introduction – CoMTUS

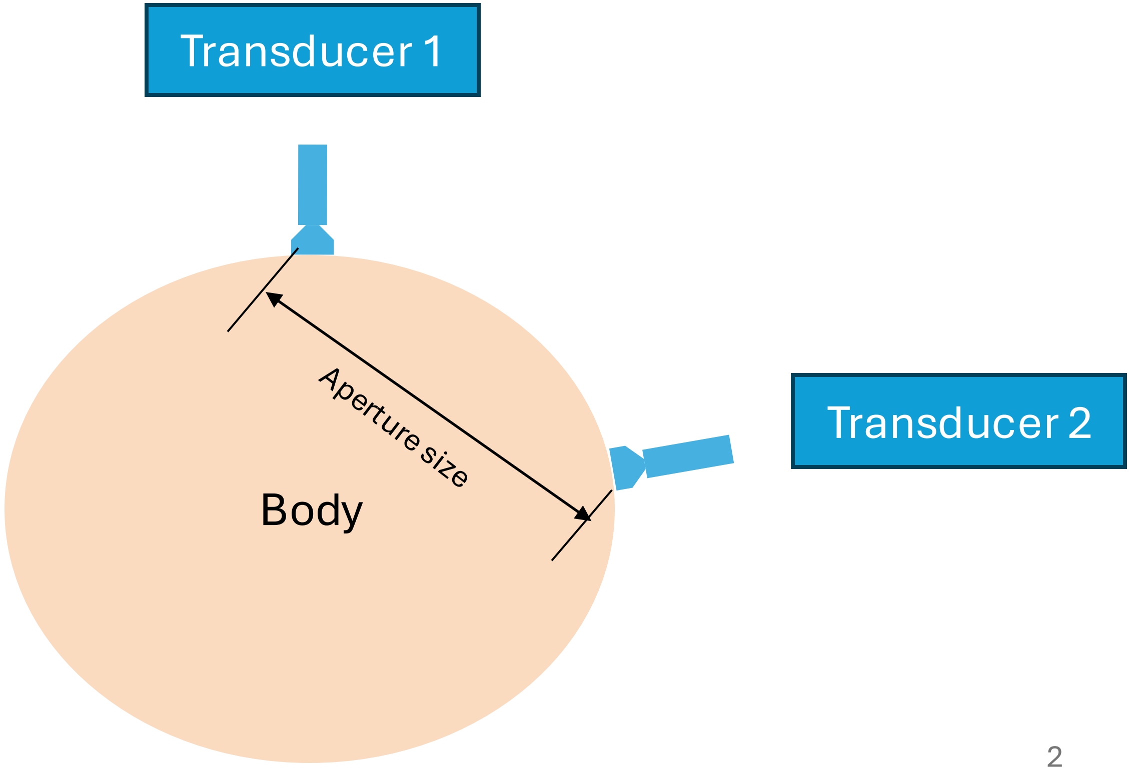
Conventional Ultrasound:

- Imaging performance are limited by handling transducer aperture size
- Geometry with huge aperture can not adjust the patient's body

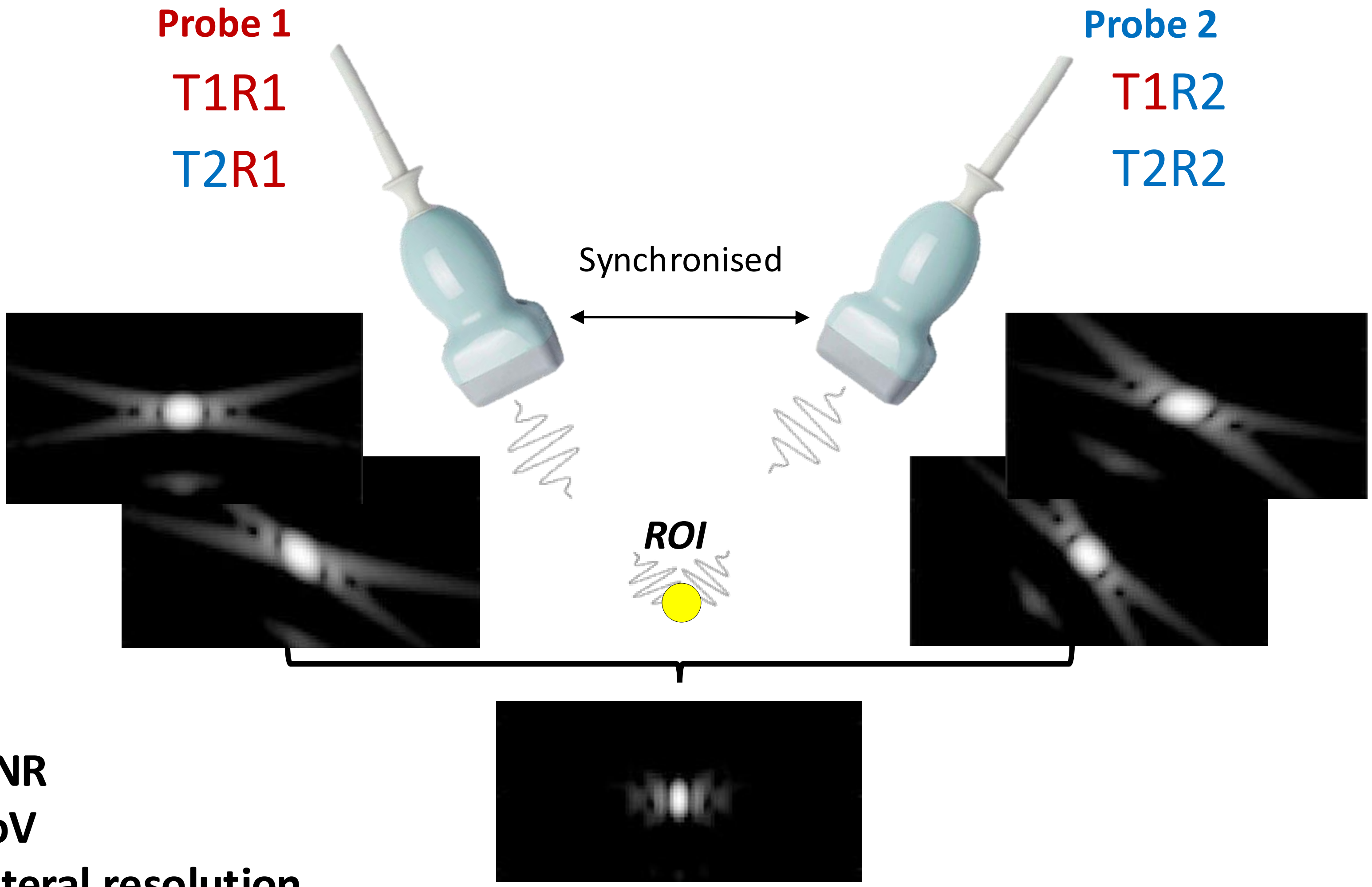
CoMTUS Advantages:

- Expanded aperture leads to **improved imaging performance**
- Multiple transducers lead to **flexible geometry**





2. Methods – Ultrasound sequence



- ✓ **Increased SNR**
- ✓ **Extended FoV**
- ✓ **Improved lateral resolution**

Peralta et al., 2025

1. Introduction – Beamforming

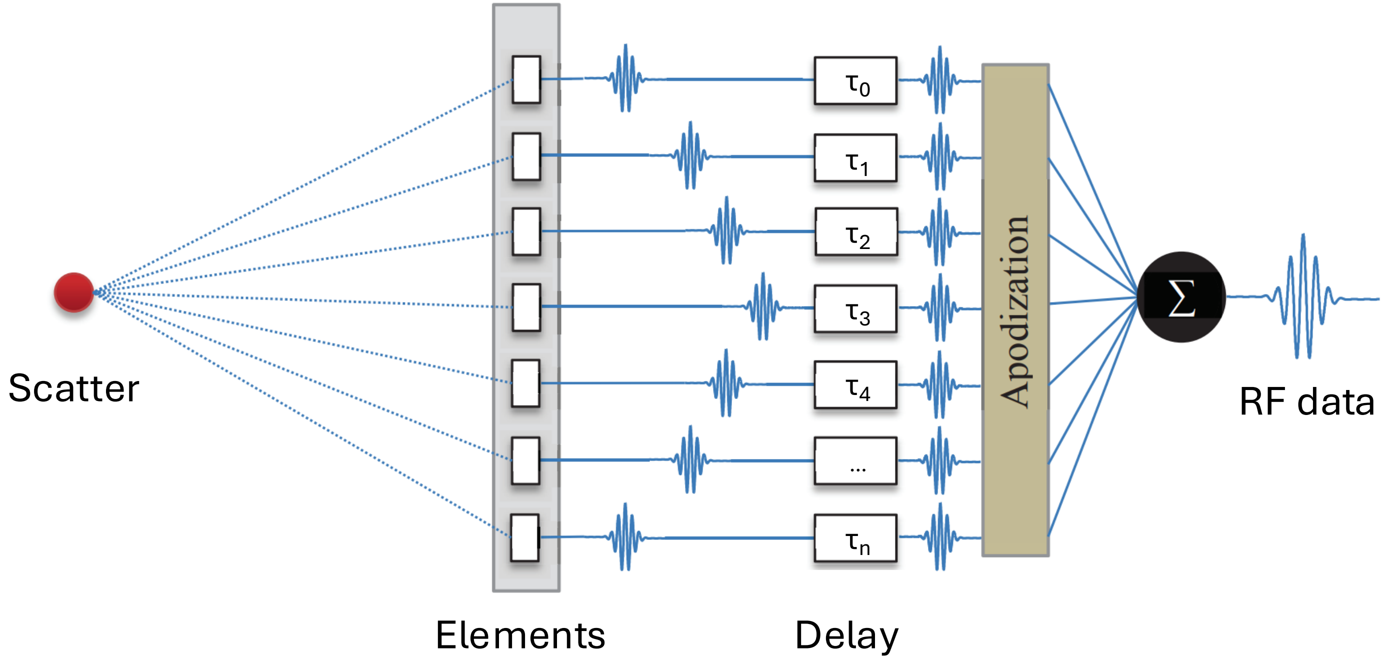
Beamforming is **vital** for ultrasound system.

What is beamforming?

How the ultrasound system prepares the wave, and how it processes the acquired signal.

What does the beamforming do?

By adjusting the phase and amplitude of signals, it can focus, steer and apodize the sound waves.



Beamforming in reception

Toulemonde, 2014

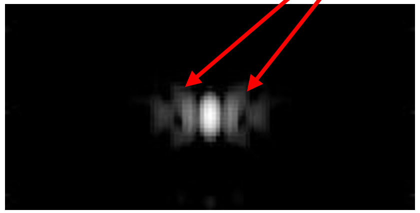
Delay and sum (DAS) is a widely used **conventional and fundamental beamformer**, serving as the **benchmark** in this study.

1. Introduction – Objectives

- Flexible geometry
- Discontinuous aperture
- Large data volumes

Main challenges of CoMTUS beamforming

Side-lobe artefacts

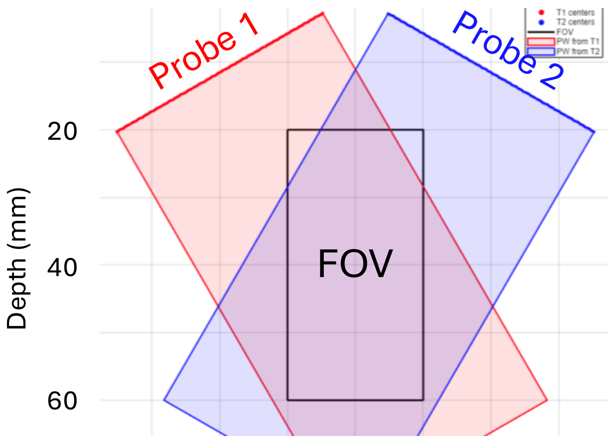


n transmissions will have n^2 datasets for 2-probe CoMTUS.

Hence, a **DNN beamformer** is needed for CoMTUS to mitigate above **challenges** and exploit its aperture **advantages**.

2. Methods – Pipeline

Geometry of CoMTUS



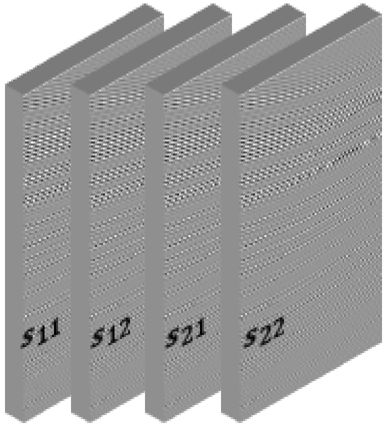
Phantom
z=[18,62]mm
x=[-11,11]mm
y=[-0.5,0.5]mm

Field II

Raw RF data
(T s*Nele)

6e19
Delay

Delayed RF data



Single-probe: 144 channels
CoMTUS: 4*144=576 channels

Sum

DAS beamformed data (z*x)

Envelope detection

DAS B-mode image in linear scale (z*x)

Log compress

DAS B-mode image in dB scale (z*x)

Post-recon DNN
Expanded U-Net
(~214M parameters)

DNN B-mode image in linear scale (z*x)

Log compress

DNN B-mode image in dB scale (z*x)

Expanded U-Net

(~215M parameters)

DNN B-mode image in linear scale (z*x)

Log compress

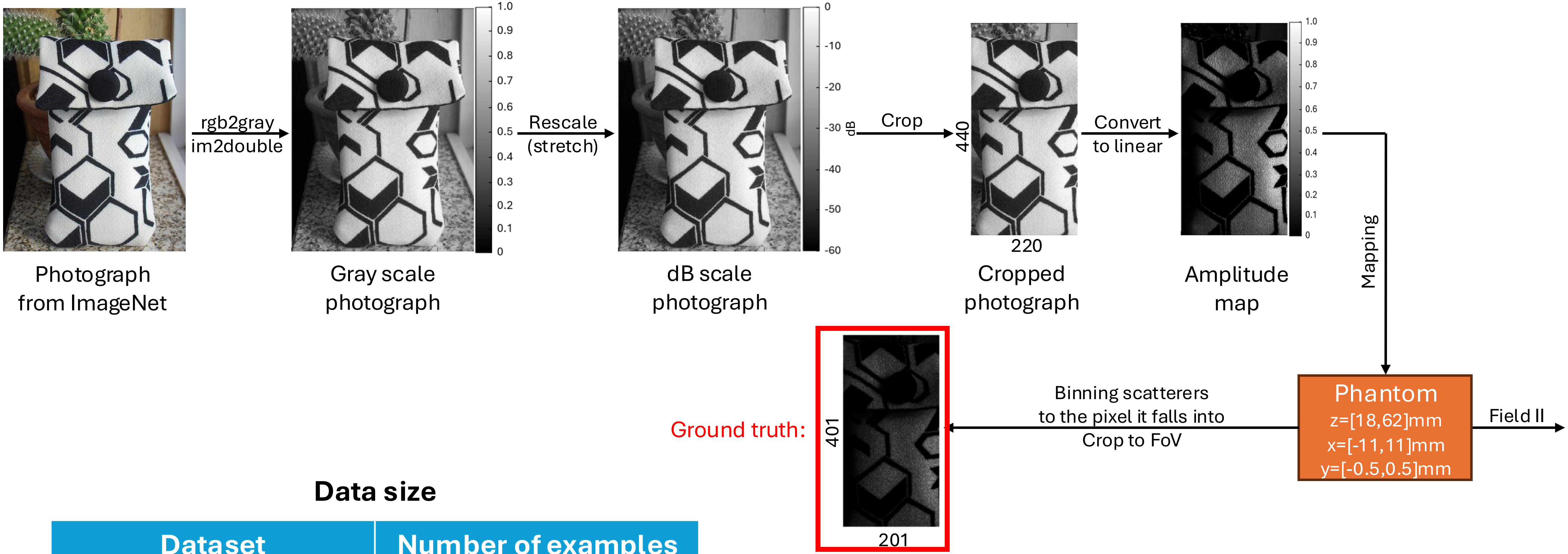
DNN B-mode image in dB scale (z*x)

Hyperparameters

Optimizer	Adamax
Learning rate	1e-4
Batch size	5
Early stopping patience	200

F0 = 3 MHz. Probes: LA332. 1 plane wave at 0° DNN, 7 plane waves from -13~13° for CPWC.

2. Methods – Phantom



Data size

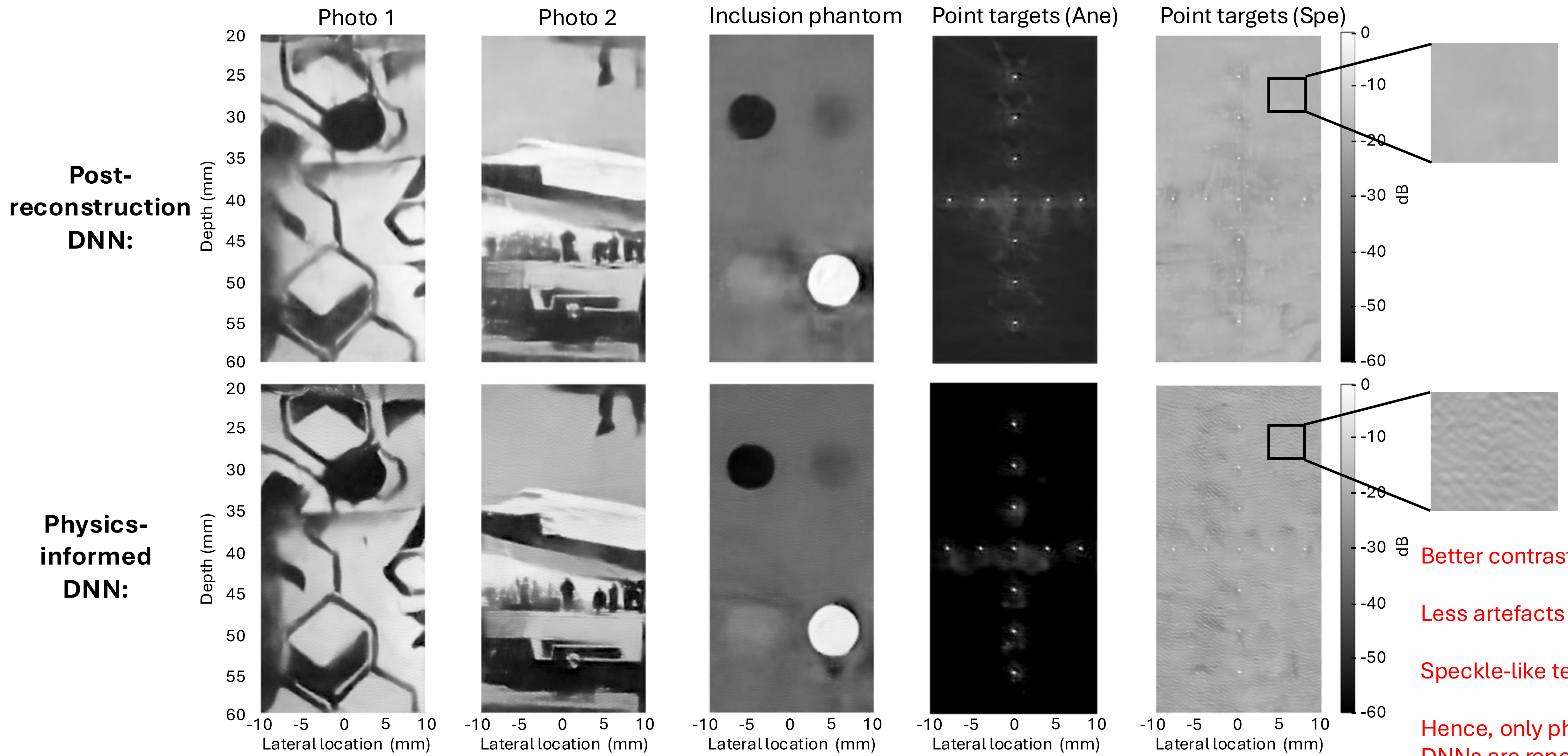
Dataset	Number of examples
Training	5800
Validation	200
Test	50

2. Methods – Configurations

Configurations

Notation	Transmissions	Acquisition	Beamformer
Ground truth (GT)	/	The map of binned scatterers.	/
Single DAS	**15** plane waves from −13° to +13°	Probe 1 transmits and receives	DAS
CoMTUS DAS	Each **7** PWs from −13° to +13° **14** total	2 probes transmit sequentially, record by both.	
Single DNN	**1** PW at 0°	Probe 1 transmits and receives	DNN
CoMTUS DNN	Each **1** PW at 0° **2** total	2 probes transmit sequentially, record by both.	

3. Results – Phy-info DNN vs Post-recon DNN



Better contrast

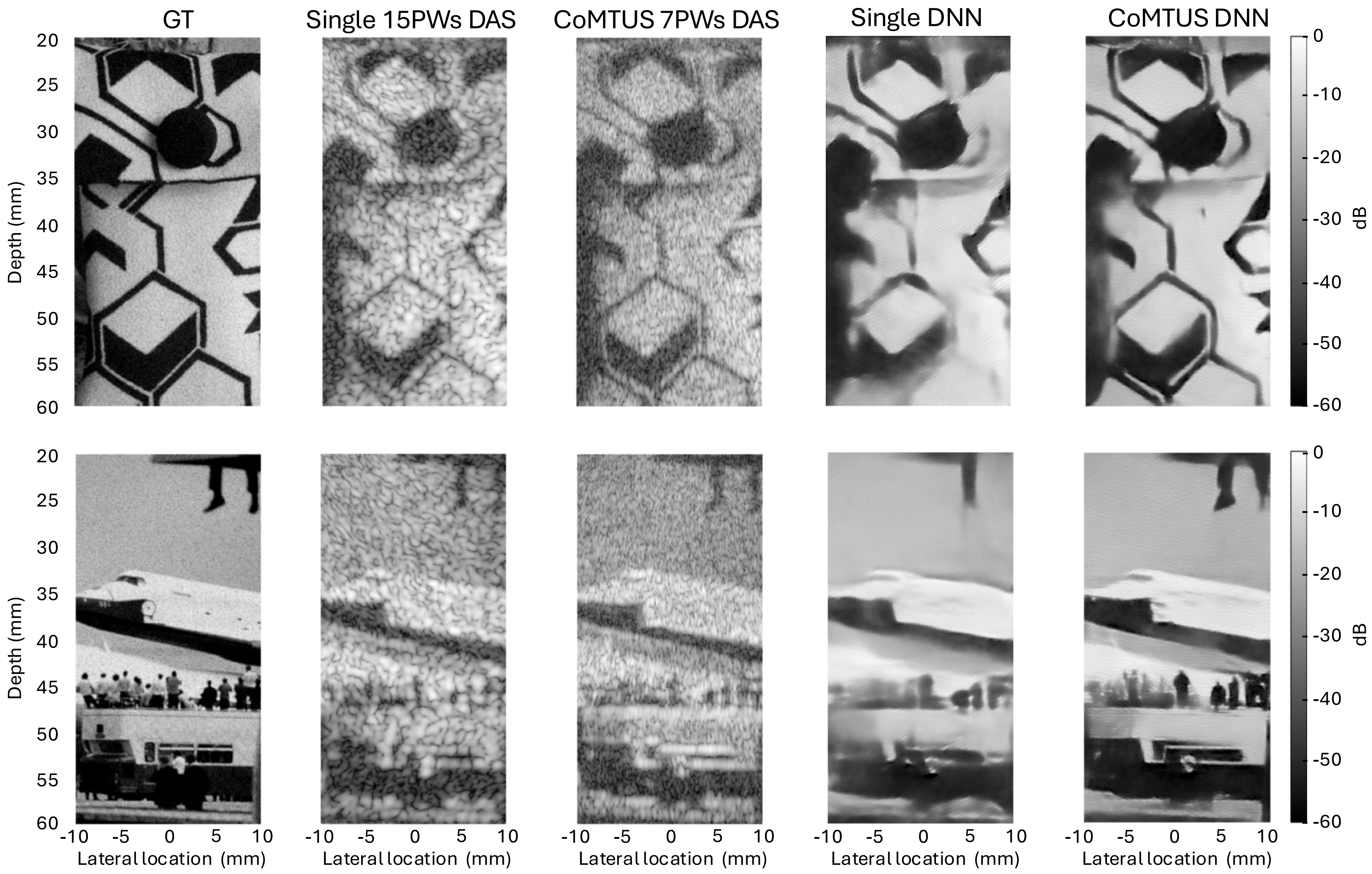
Less artefacts

Speckle-like texture

Hence, only phy-DNNs are reported.

Physics-informed DNN vs Post-reconstruction DNN for CoMTUS

3. Results – Training domain photos



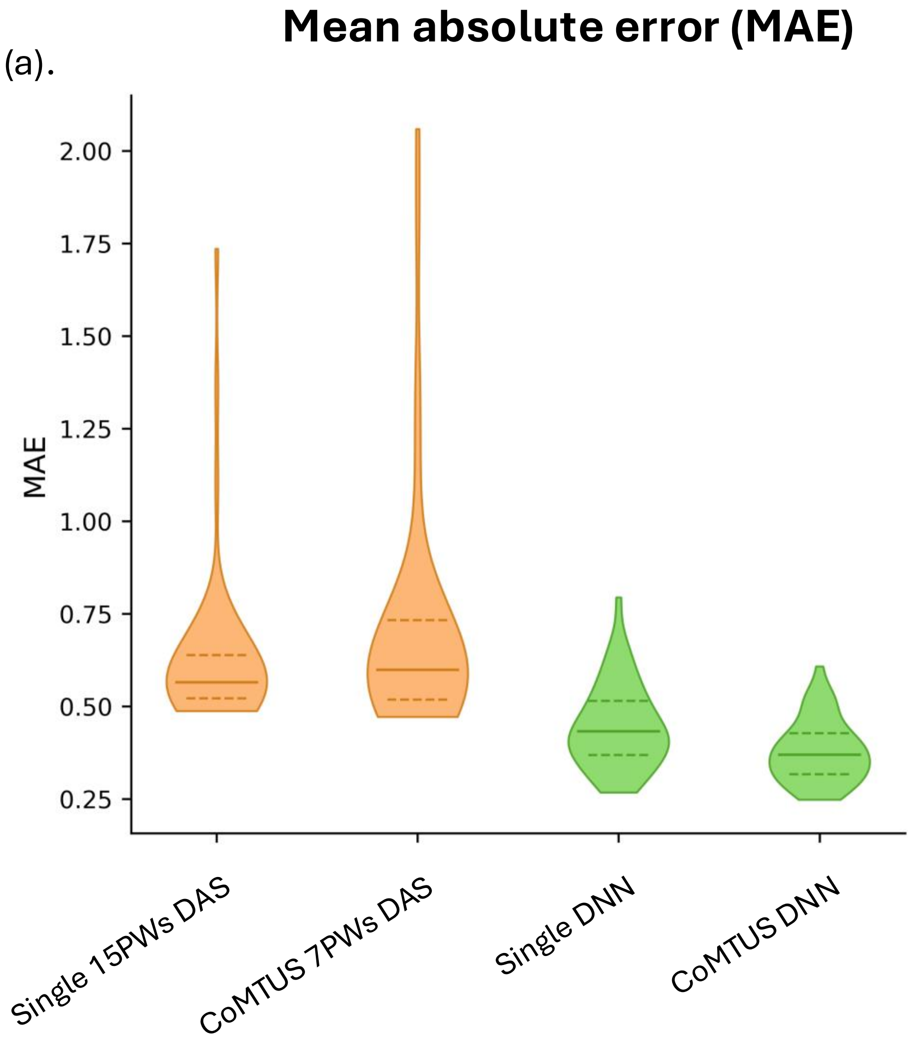
Two unseen test examples within the training domain.

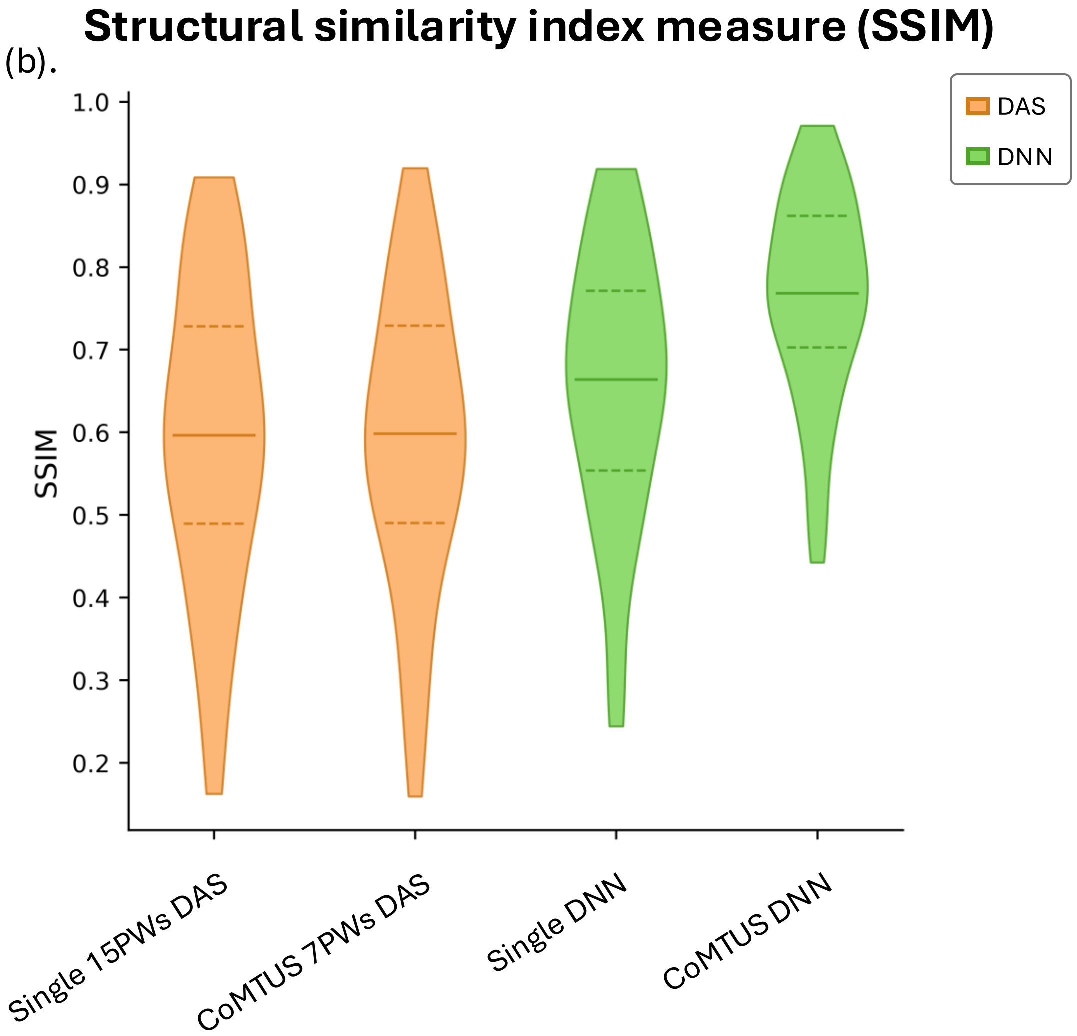
Sharper edge

Less distortion

Better contrast

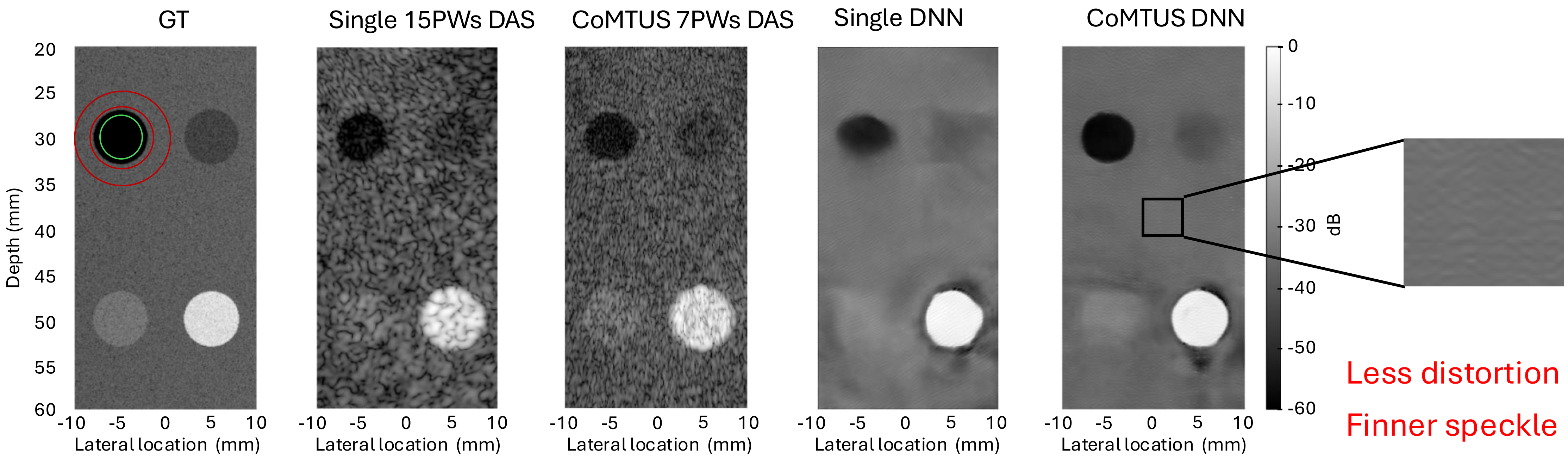
3. Results – Training domain photos





The comparison between beamformers on training-domain 50-example test dataset.

3. Results – Cross-domain inclusions



The inclusion phantom from cross-domain test dataset.

Less distortion

Finner speckle

Scaling artefacts

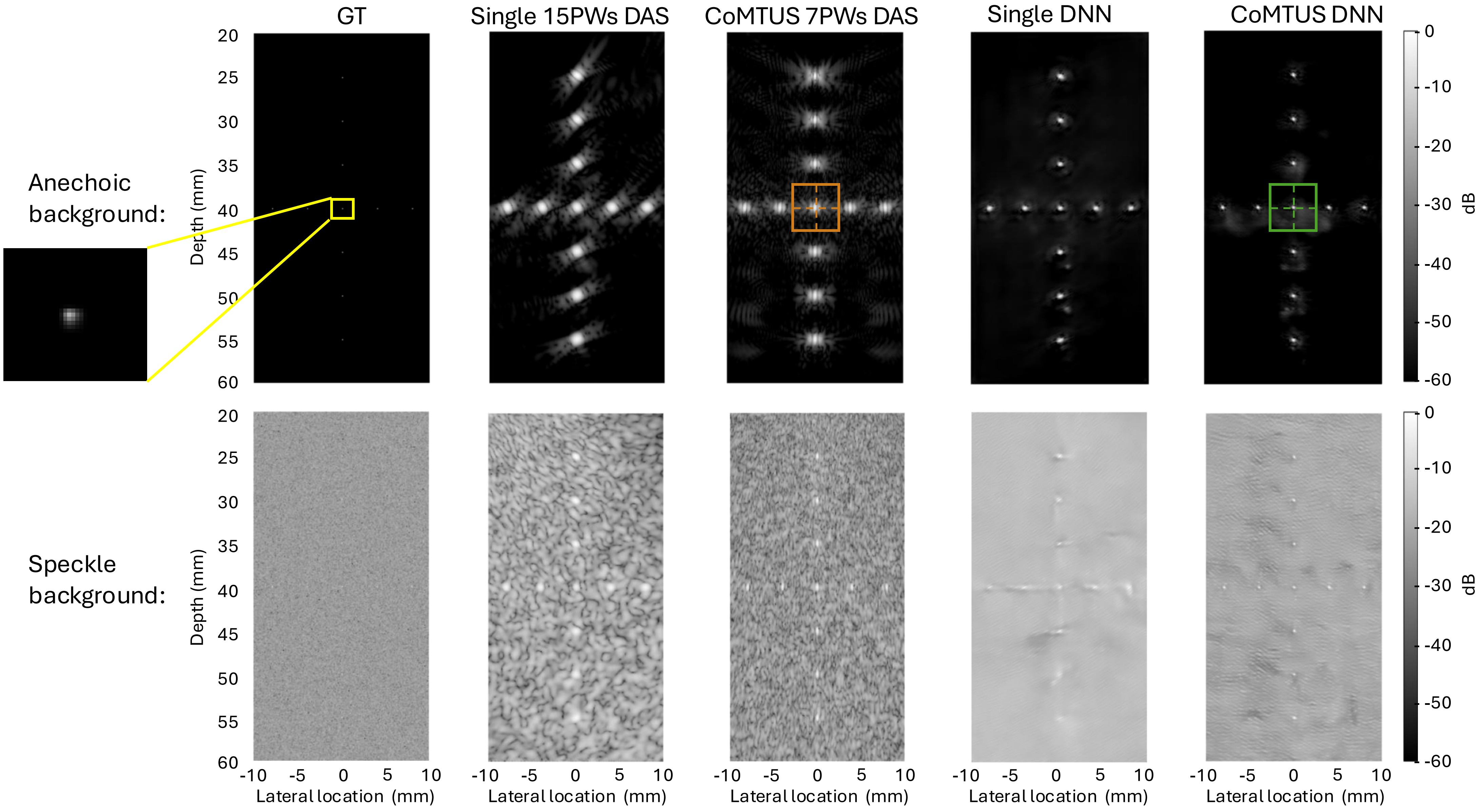
Overall best

The CR and gCNR comparison between beamformers for the inclusions.

	Single 15PWs DAS		CoMTUS 7PWs DAS		Single DNN		CoMTUS DNN	
Metrics	CR (dB)	gCNR	CR (dB)	gCNR	CR (dB)	gCNR	CR (dB)	gCNR
Anechoic	<u>-16.81</u>	0.900	-13.52	0.826	-15.99	<u>0.992</u>	**-21.65**	**1.000**
-6 dB	**-6.04**	0.458	<u>-5.37</u>	0.427	-4.80	<u>0.925</u>	-4.88	**0.963**
+6 dB	<u>5.91</u>	0.484	5.20	0.409	4.48	<u>0.836</u>	**5.95**	**0.960**
Hyperechoic	27.41	<u>0.955</u>	25.37	0.944	**33.66**	**1.000**	<u>33.44</u>	**1.000**

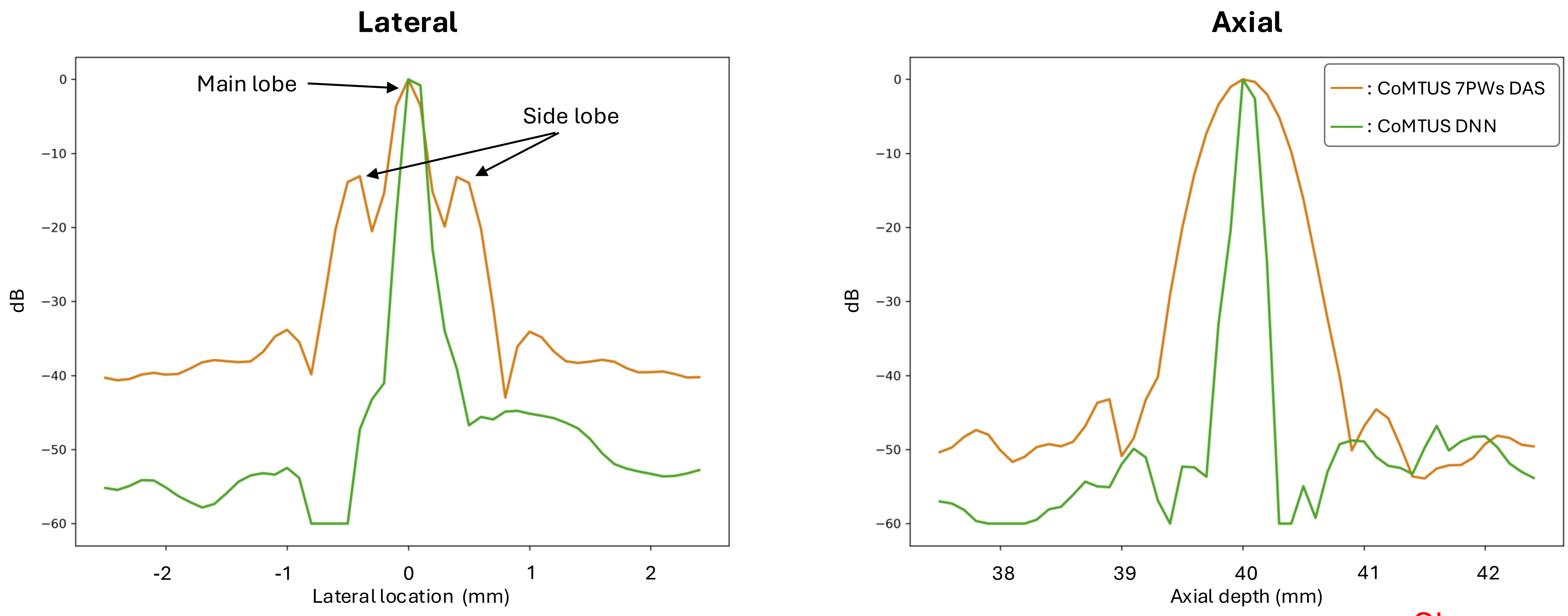
Best
<u>Second best</u>

3. Results – Cross-domain point targets



The point-target phantom from cross-domain test dataset.

3. Results – Profile of point targets



The DAS vs DNN profile of central point target under anechoic background.

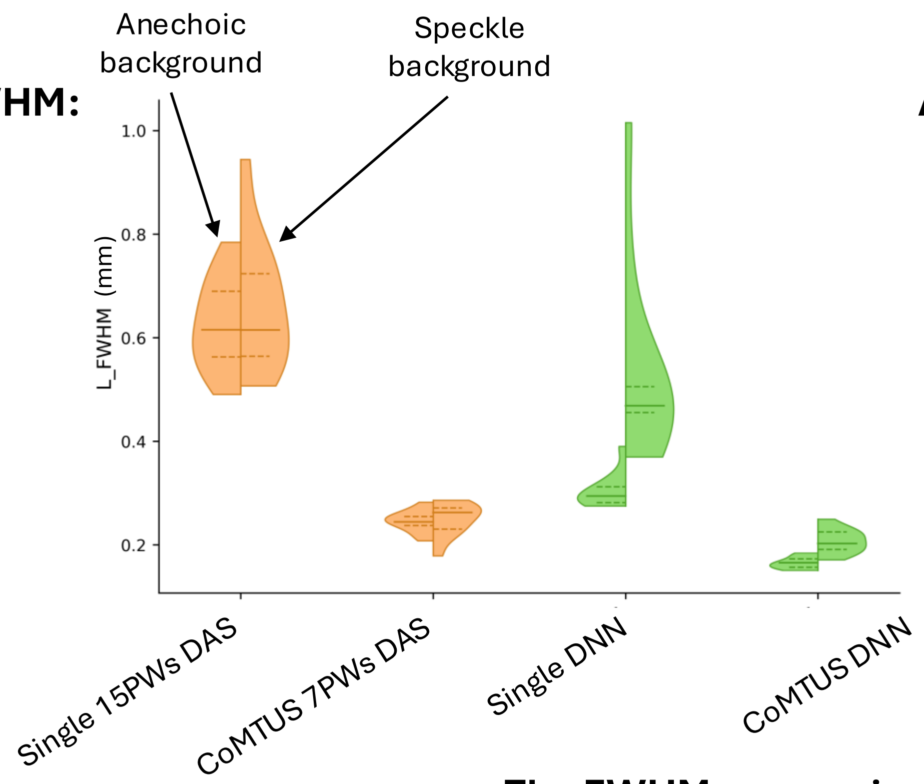
Sharper main lobe

Suppressed side lobe

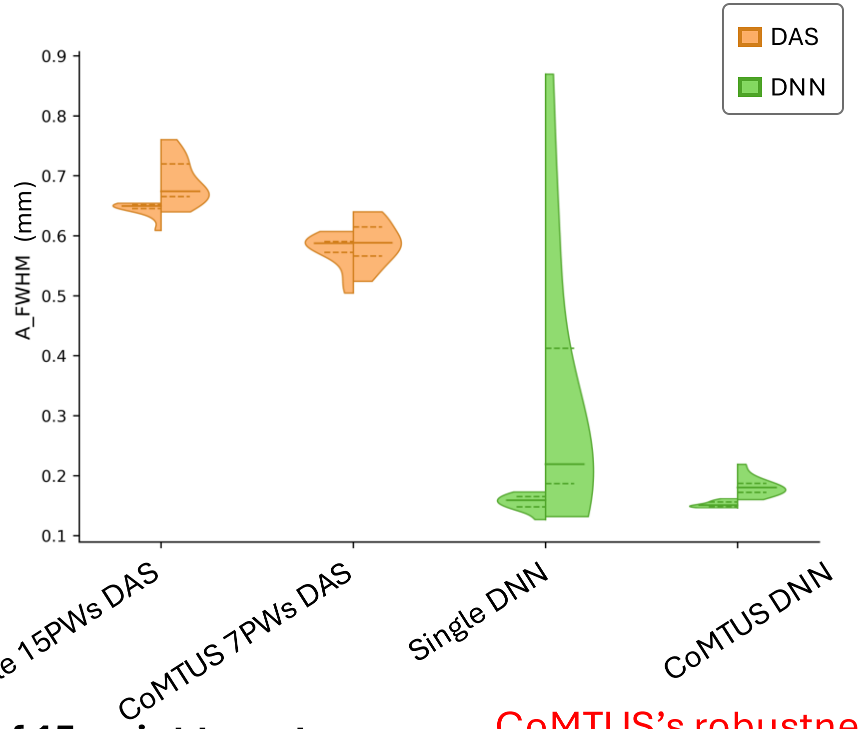
Clearer background

3. Results – Cross-domain point targets

Lateral FWHM:



Axial FWHM:



The FWHM comparison on FWHM of 15 point targets.

CoMTUS's robustness on speckle

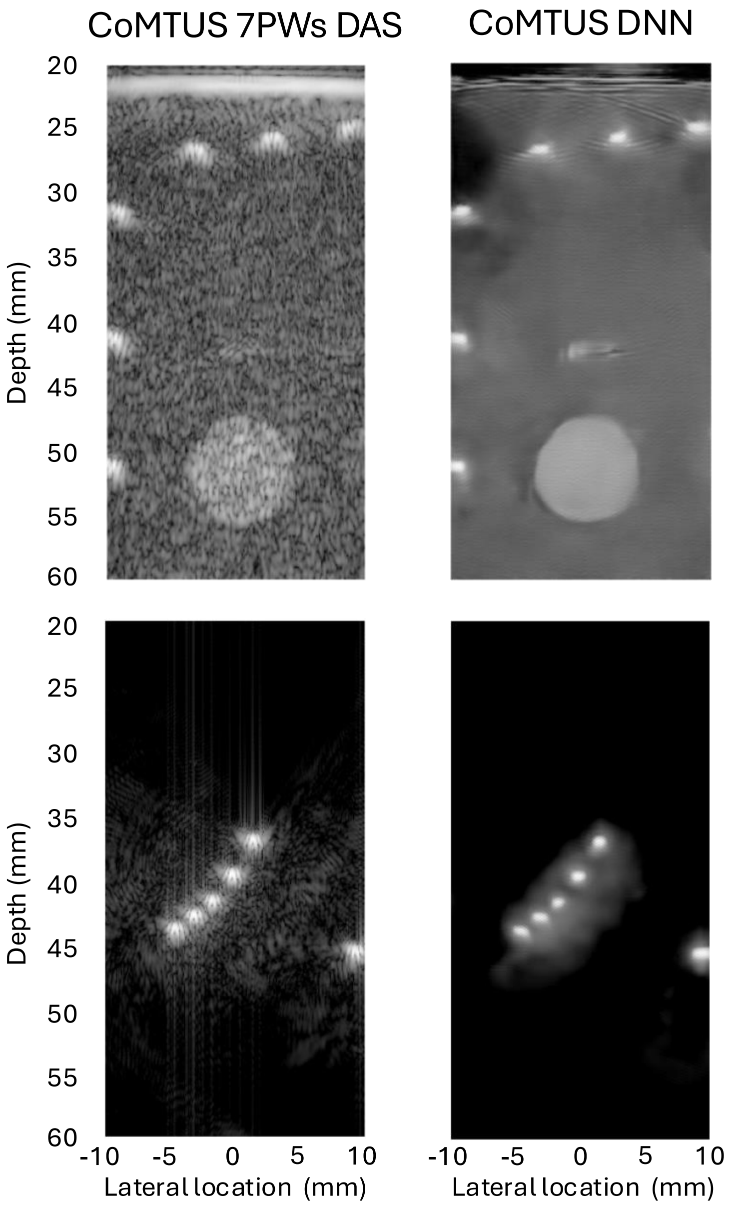
Best convergence and mean

The Lateral FWHM and Axial FWHM comparison on point-target phantoms.

	Single 15PWs DAS		CoMTUS 7PWs DAS		Single DNN		CoMTUS DNN	
Background	Anechoic	Speckle	Anechoic	Speckle	Anechoic	Speckle	Anechoic	Speckle
Lateral FWHM (mm)	0.625	0.661	0.246	0.249	0.304	0.531	**0.165**	**0.207**
Axial FWHM (mm)	0.645	0.690	0.575	0.588	0.156	0.331	**0.152**	**0.182**

Best
Second best

3. Results – In-vitro test



May not be delayed perfectly

Reduced artefacts

Suppressed side lobes

4. Conclusions

1. **Physics-informed DNN** outperforms **Post-reconstruction DNN** visually. The difference of DNNs' structure is tiny (only 0.61% on number of parameters).

2. **CoMTUS's larger aperture** improves **sensitivity/resolution/FOV** and **robustness on speckle background**, but **discontinuous aperture** introduces challenges to **conventional beamforming**.

3. **DNN beamforming** outperforms **DAS** even with 1 or 2 PWs (vs 15 or 14 PWs), which reduces the **acquisition time** and **energy**.

4. **CoMTUS + DNN** performs **best** overall, indicating that **DNN** can **mitigate CoMTUS-specific challenges** and **exploit its aperture advantages**.

QUIIN lab

Website:

WeChat:

9th Mar 2026

Thank you!

Yi Li (yi.8.li@kcl.ac.uk), Paul Dryburgh, Josephine Pearce, Andrew Reader, Jo Hajnal, Laura Peralta Pereira

Department of Surgical & Interventional Engineering
School of Biomedical Engineering and Imaging Sciences
King's College London

KING'S College LONDON