A Spatially Weighted Regularization Method for Attenuation Coefficient Estimation

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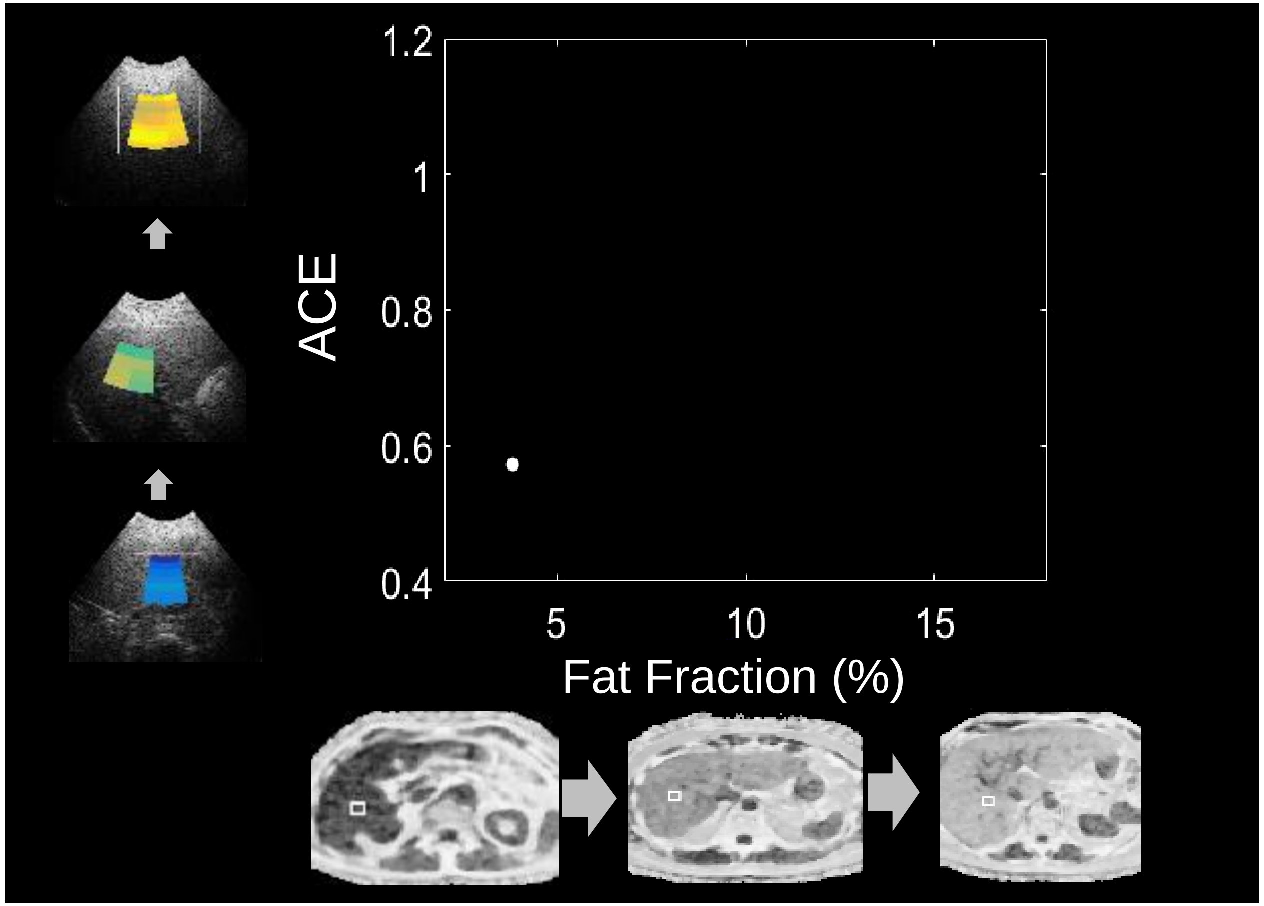
Attenuation Coefficient Estimate (ACE)

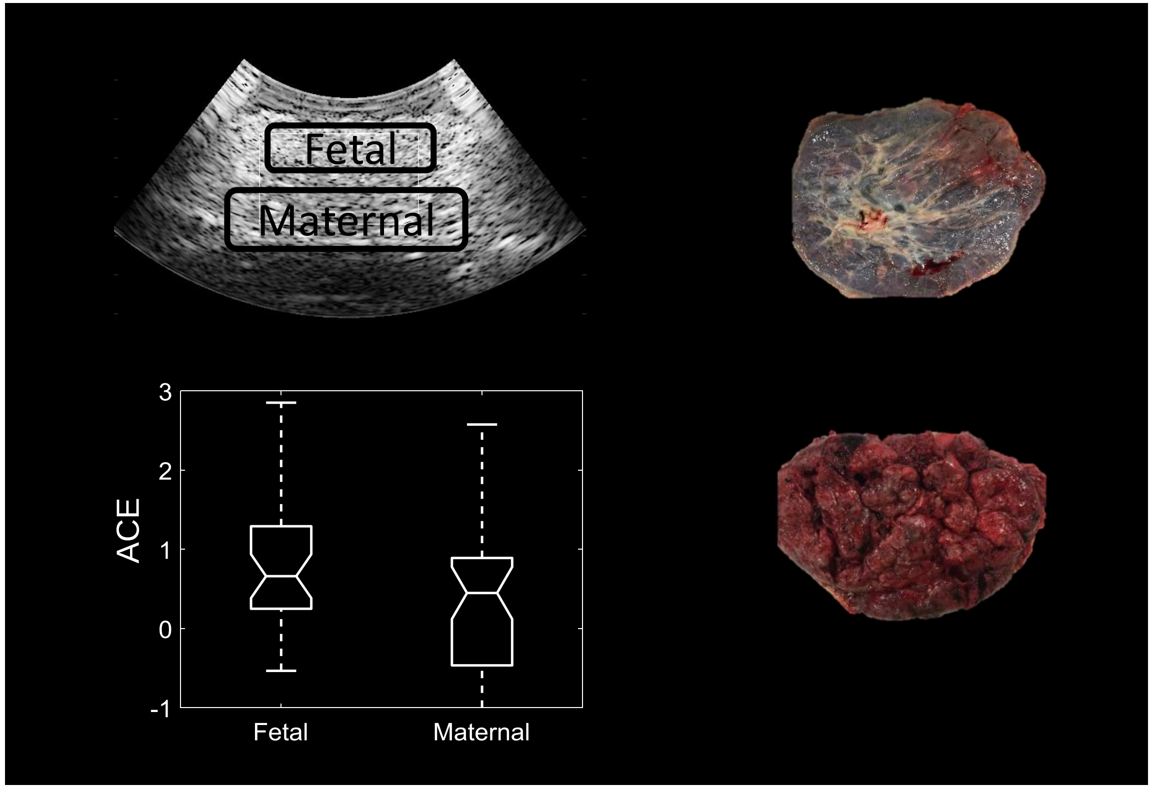
- A promising clinical tool to detect and monitor fatty liver



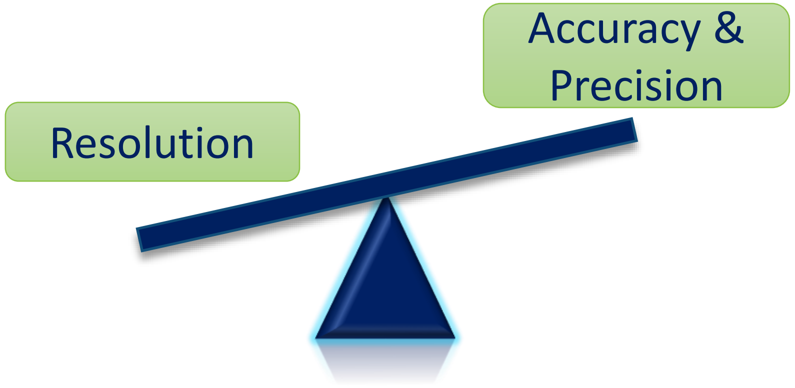
Attenuation Coefficient Estimate (ACE)

- A promising clinical tool to detect and monitor fatty liver

- Potential for placental tissue characterization;



Trade-off: Resolution and Measurement Quality



TV Regularization: A Solution to Extend the Trade-off

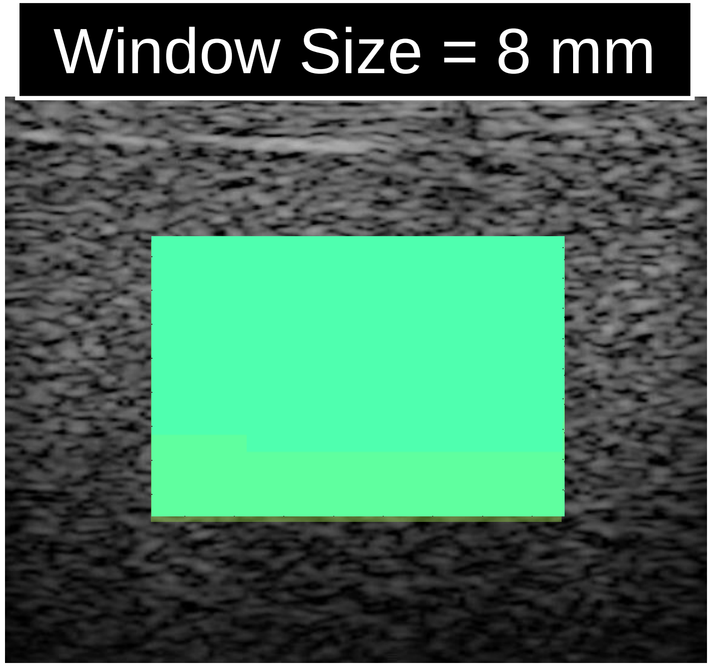
$$\hat{x} = \arg\min_{x}\{||y - Ax||_2^2 + \lambda . TV(\alpha) + \lambda . TV\ (\beta)\}$$

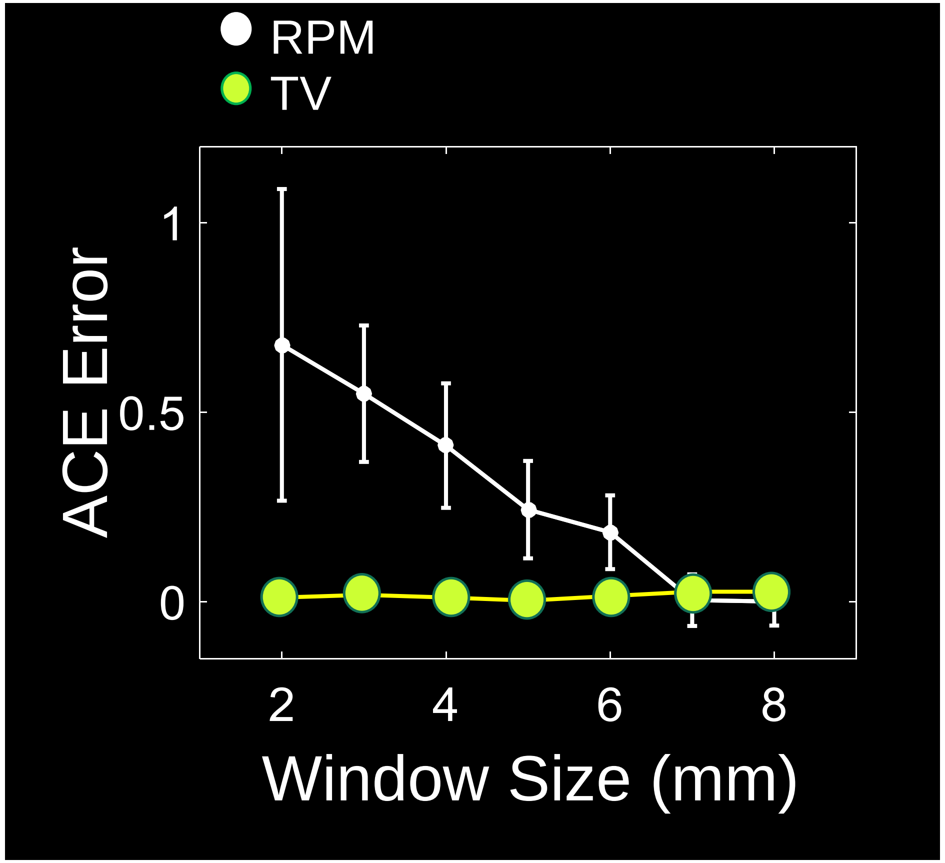
$$x = [\alpha\ \beta]$$

α = Attenuation Coefficient Estimate (ACE)

β = Backscatter Coefficient (BSC)

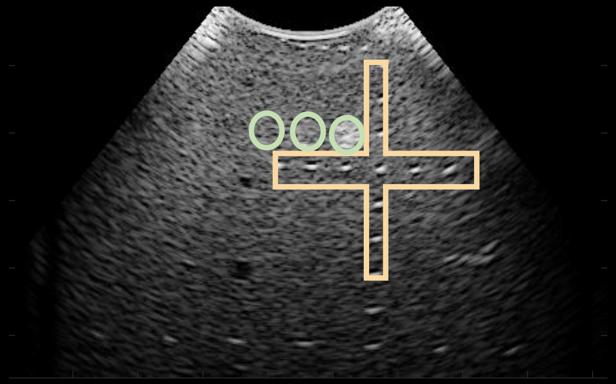
TV Regularization: A Solution to Extend the Trade-off





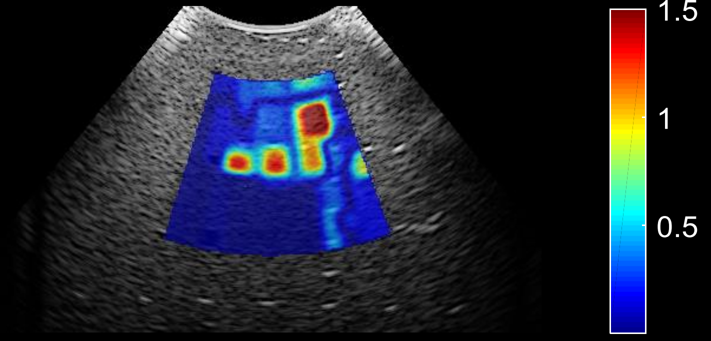
Inhomogeneity

CIRS 040 Phantom
(ACE = 0.7 dB/cm/MHz)

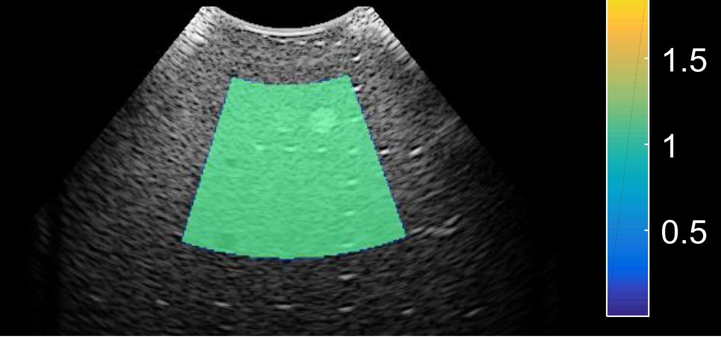


- Scatterers with different size
- Scatterers with different density

ACE Error Map

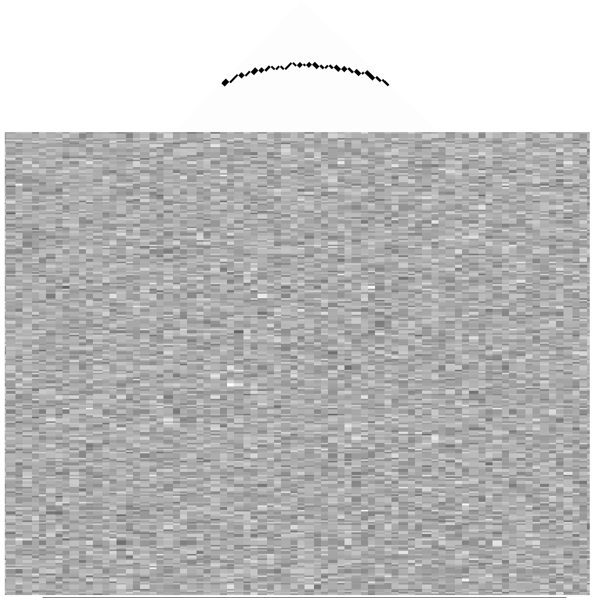


BSC Map

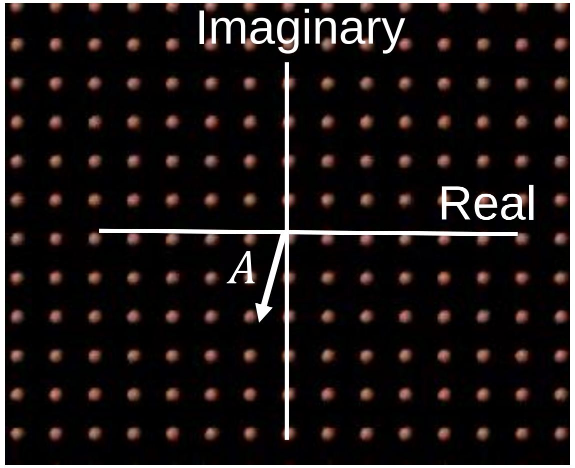


TV regularization
- introduces large ACE error;
- fails to capture BSC variation at the target locations.

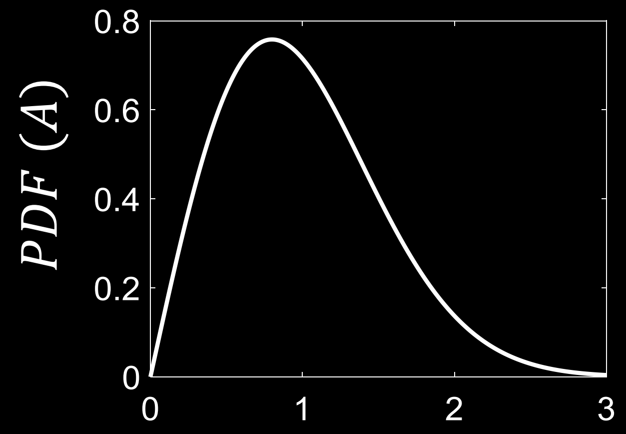
In Search for an Inhomogeneity Indicator



Homogeneous Medium



Received US Signal Amplitude (from a large number of uniformly distributed scatteres)

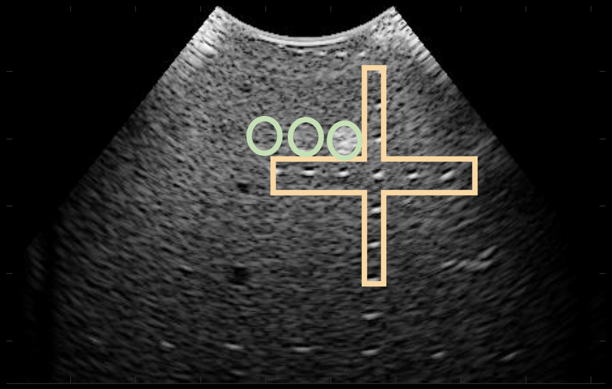


Envelope SNR, SNR_{opt}

$$= \frac{|\bar{A}|}{\text{var}(|A|)} = \sqrt{\pi(4-\pi)} = 1.9$$

In Search for an Inhomogeneity Indicator

CIRS 040 Phantom
(ACE = 0.7 dB/cm/MHz)



ΔSNR_e Map

- Scatterers with different size
- Scatterers with different density

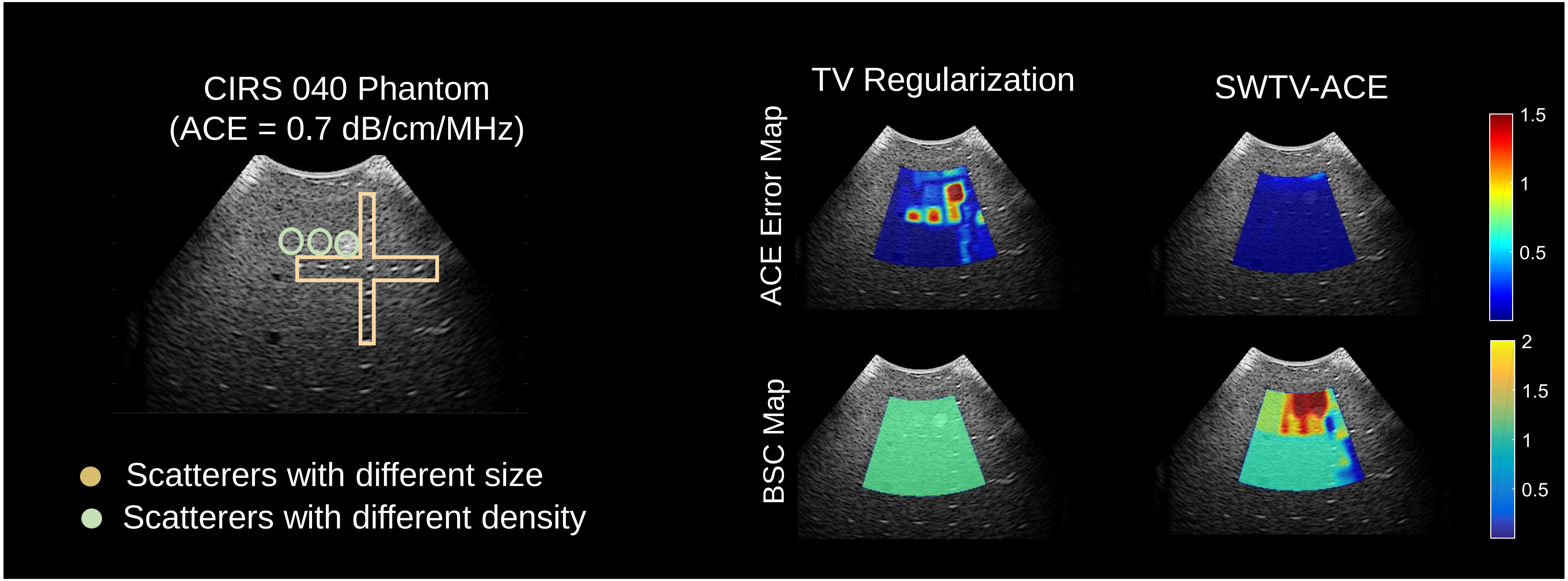
SWTV-ACE

$$\hat{x} = \arg\min_{x}\{||y - Ax||_2^2 + \lambda_1 TV(\alpha) + \lambda_2 SWTV(\beta)\}$$

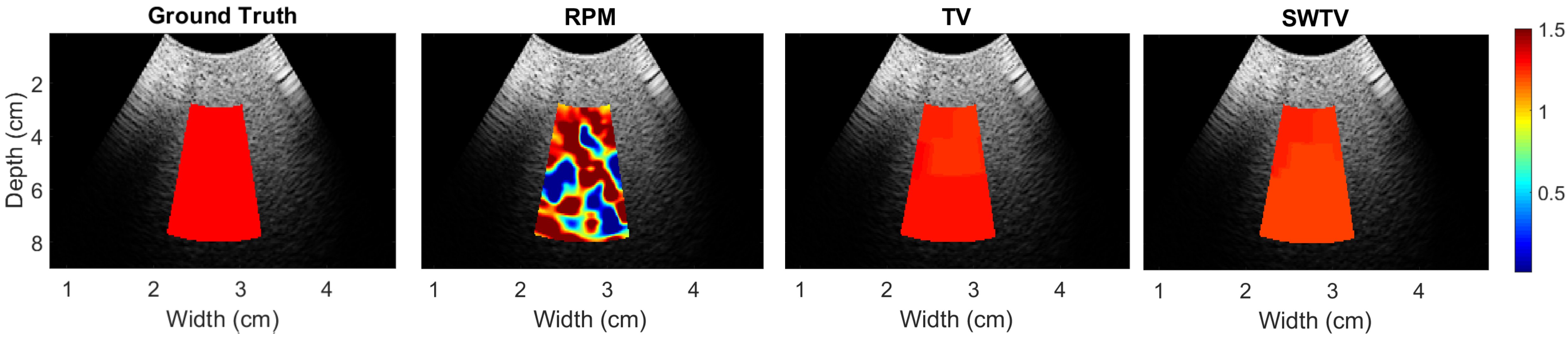
$$SWTV(\beta) = \sum_{i,j} W_{\beta}^{i,j}\left(|\beta_{i+1,j} - \beta_{i,j}| + |\beta_{i,j+1} - \beta_{i,j}|\right)$$

$$W_{\beta}(\Delta SNR_e) = \frac{a}{1 + \exp(b(\Delta SNR_e - \Delta SNR_e^{min}))}$$

SWTV-ACE


CIRS 040 Phantom
(ACE = 0.7 dB/cm/MHz)
Scatterers with different size
Scatterers with different density
TV Regularization
SWTV-ACE
ACE Error Map
BSC Map
1.5
1
0.5
2
1.5
1
0.5

Phantom 1: Uniform ACE and Uniform BSC



Phantom 1	Ground Truth (dB/cm/MHz)	Mean Absolute Error (%)			Standard Deviation (%)		
		RPM	TV	SWTV	RPM	TV	SWTV
	1.3	47.6	2.6	5.9	58.7	1.6	1.2

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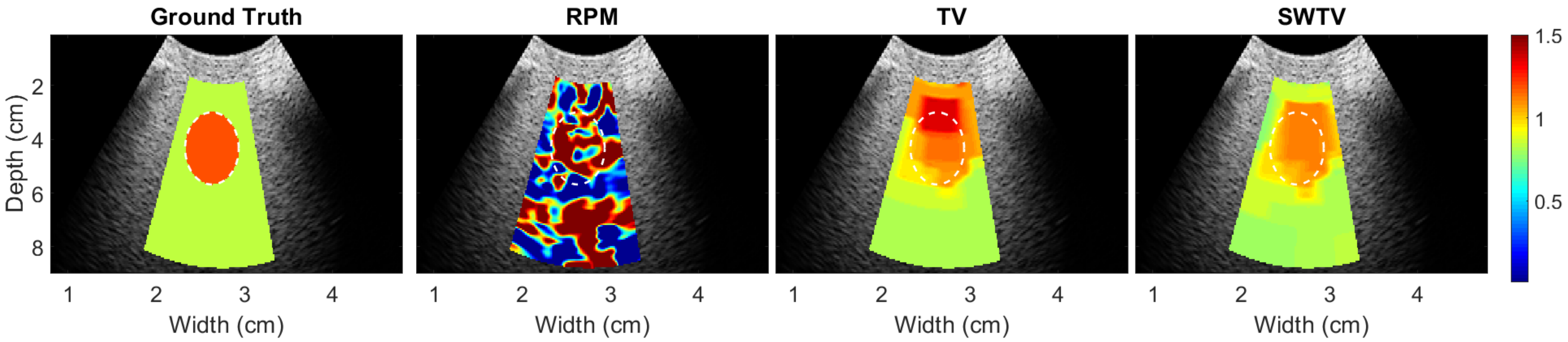
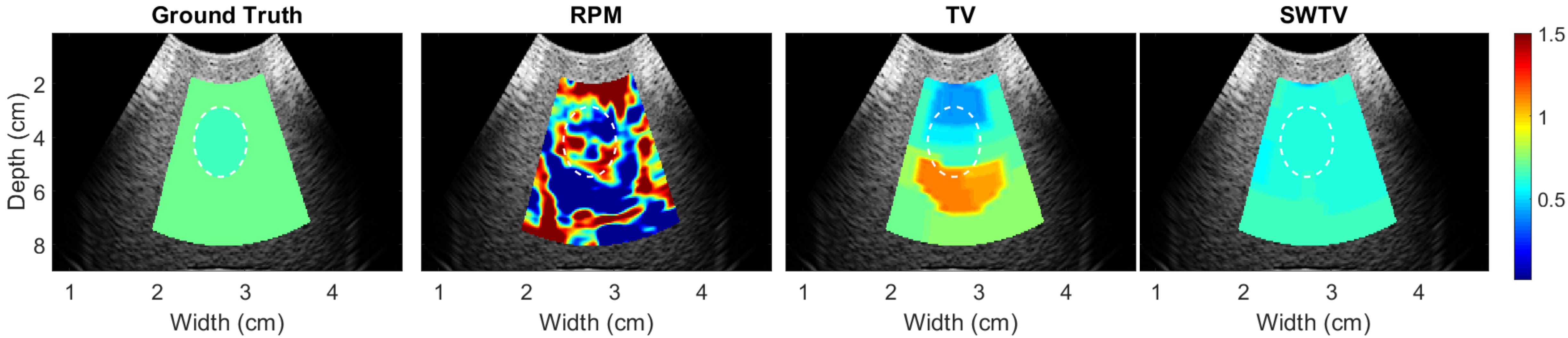
Phantom 2: Variable ACE and Uniform BSC



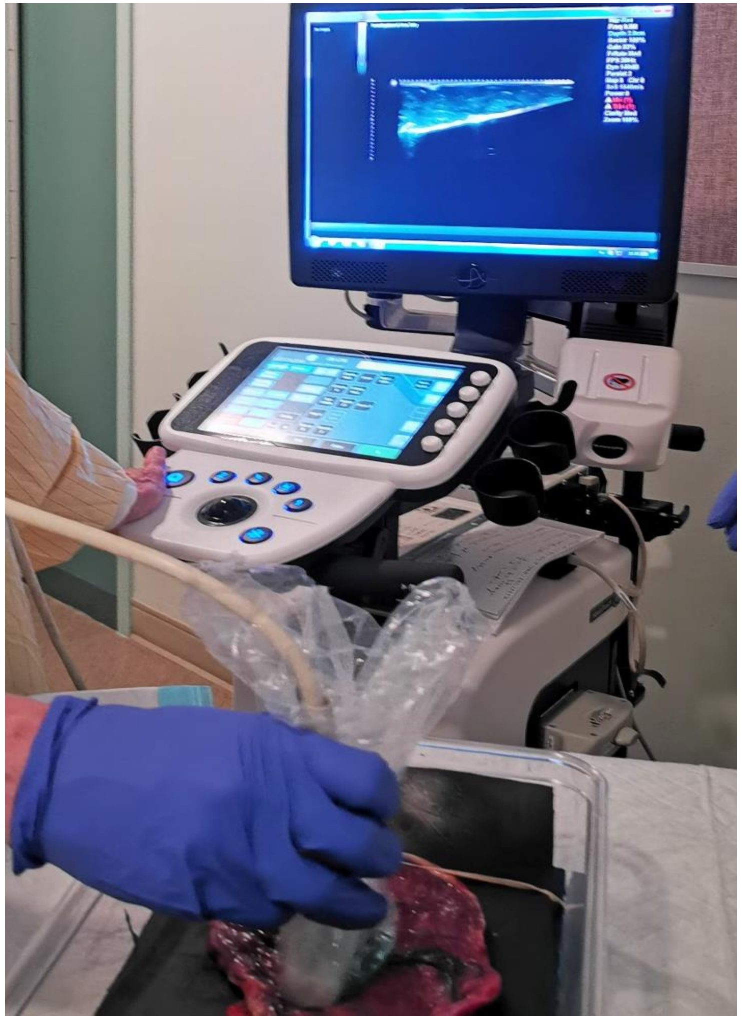
Phantom 2	Ground Truth (dB/cm/MHz)	Mean Absolute Error (%)			Standard Deviation (%)		
		RPM	TV	SWTV	RPM	TV	SWTV
Background	0.84	106.4	10.5	7.2	134.9	16.1	10.5
Inclusion	1.18	55.1	8.7	8.9	75.1	9.5	4.0

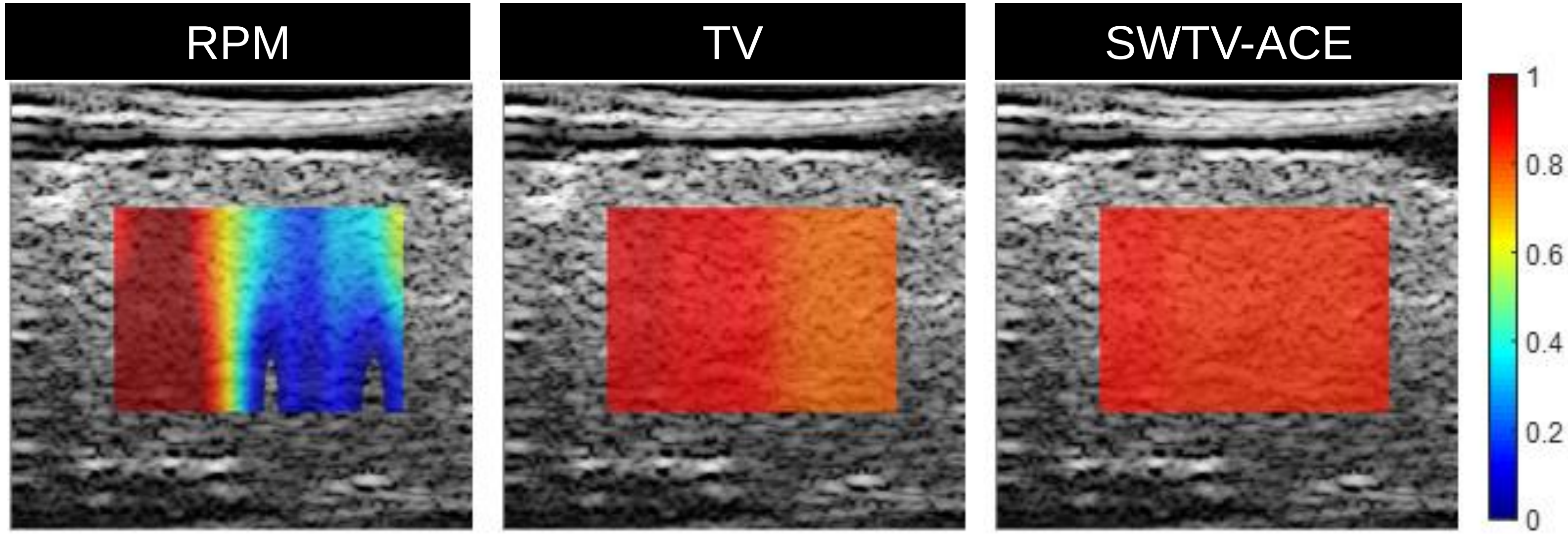
Phantom 3: Similar ACE and Variable BSC



Phantom 3	Ground Truth (dB/cm/MHz)	Mean Absolute Error (%)			Standard Deviation (%)		
		RPM	TV	SWTV	RPM	TV	SWTV
Background	0.72	103.5	19.2	15.6	132.0	26.1	12.1
Inclusion	0.65	74.9	21.0	10.2	88.0	28.3	5.0

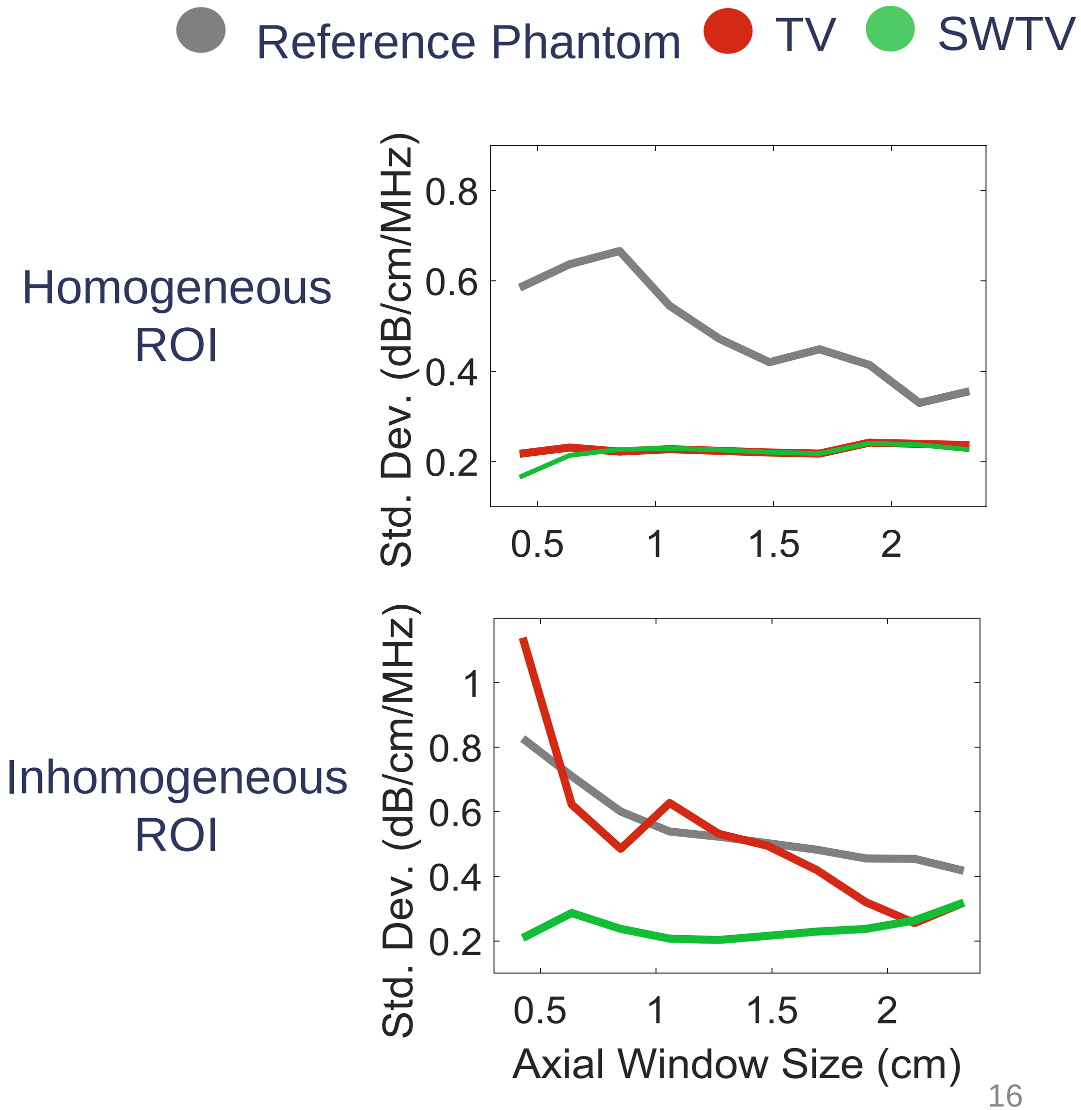
Results: Placenta *ex-vivo*





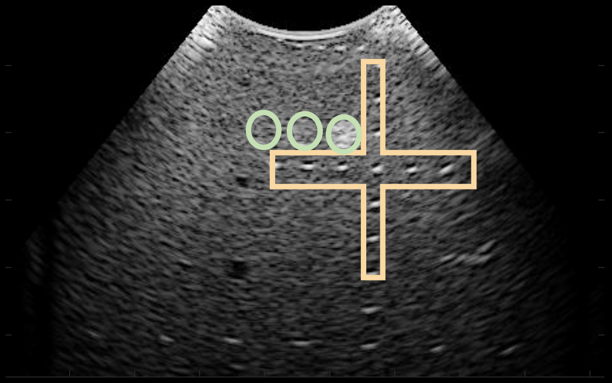
Conclusion

- SWTV-ACE improves the quality of ACE computation by reducing the estimation variance irrespective of window size and inhomogeneity.
- Improved resolution will provide local variation information within the liver. Improved precision would be required to qualify as a reliable diagnostic tool.
- The precise ACE estimation of thin and heterogeneous tissues shows promise for placental tissue characterization.



Appendix: Inhomogeneity

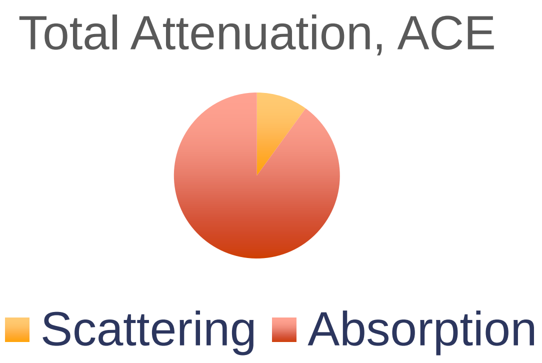
CIRS 040 Phantom
(ACE = 0.7 dB/cm/MHz)



- Scatterers with different size
- Scatterers with different density

Simplified System Equation:

$$\boldsymbol{S} = \boldsymbol{ACE} + \boldsymbol{BSC}$$



S = Power Spectrum term;

ACE = ACE term;

BSC = BSC term;

Both RPM and TV regularization introduce large ACE error and fail to account for BSC variation at the target locations.