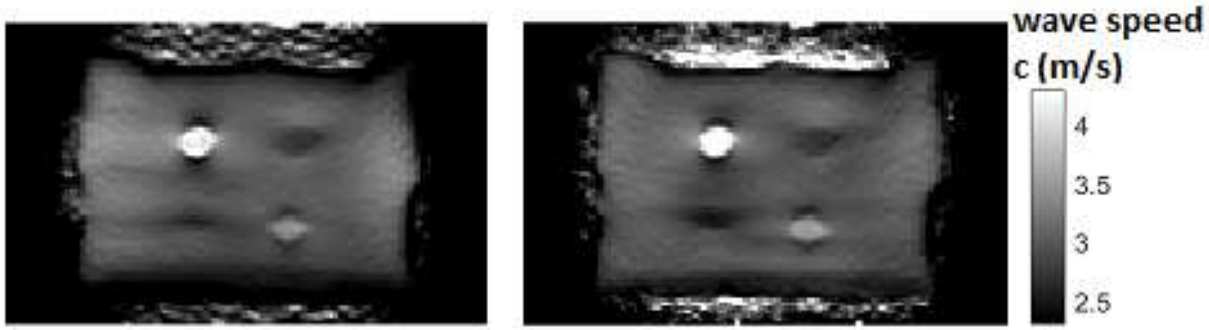

Amplitude-weighted OSS-weighted

OSS-Weighted Averaging in Multifrequency Inversion for MR Elastography

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Multi-frequency MR Elastography (MMRE) [1, 2]

- Influence of amplitude nulls on elastograms are reduced
- Regions of low elastic strain in one frequency are compensated by high elastic strain in another frequency

[1] Papazoglou S, Hirsch S, Braun J, Sack I. Multifrequency inversion in magnetic resonance elastography. Phys Med Biol 2012;57:2329–2346 McCurry M et al., Elastojournal, 41(3): 724-33, 2015.
[2] Tzschatzsch H , Guo J, Dittmann F, Hirsch S, Barnhill E, Johrens K, Braun J, Sack I. Tomoelastography by multifrequency wave number recovery from time-harmonic propagating shear waves. Med Image Anal2016;30:1–10

k-MDEV [2]

- Smoothing
- Unwrapping
- Fourier transformation over time
- Directional filtering
- Reconstruction of wave numbers
- Summation of amplitude-weighted wave numbers

[2] Tzschatzsch H , Guo J, Dittmann F, Hirsch S, Barnhill E, Johrens K, Braun J, Sack I. Tomoelastography by multifrequency wave number recovery from time-harmonic propagating shear waves. Med Image Anal2016;30:1–10

Hypothesis

- Combining the elastograms at different frequencies by strain-weighted averaging such as octahedral shear strain (OSS) [3] weighted averaging instead of amplitude-weighted averaging could be more advantageous

- Direct dependence of shear modulus on strain

[3] McGarry MDJ, Van Houten EEW, Perrinez PR, Pattison AJ, WeaverJB, Paulsen KD. An octahedral shear strain-based measure of SNR for3D MR elastography. Phys Med Biol 2011;56:N153–N164

Octahedral Shear Strain (OSS)

$$OSS = \frac{2}{3}\sqrt{(\epsilon_{xx} - \epsilon_{yy})^2 + (\epsilon_{yy} - \epsilon_{zz})^2 + (\epsilon_{xx} - \epsilon_{zz})^2 + 6({\epsilon_{xy}}^2 + {\epsilon_{yz}}^2 + {\epsilon_{xz}}^2)}$$

$$\begin{bmatrix} \epsilon_{xx} & \epsilon_{xy} & \epsilon_{xz} \\ \epsilon_{yx} & \epsilon_{yy} & \epsilon_{yz} \\ \epsilon_{zx} & \epsilon_{zy} & \epsilon_{zz} \end{bmatrix} = \begin{bmatrix} \frac{du}{dx} & \frac{1}{2}\left(\frac{du}{dy} + \frac{dv}{dx}\right) & \frac{1}{2}\left(\frac{du}{dz} + \frac{dw}{dx}\right) \\ \frac{1}{2}\left(\frac{du}{dy} + \frac{dv}{dx}\right) & \frac{dv}{dy} & \frac{1}{2}\left(\frac{dw}{dy} + \frac{dv}{dz}\right) \\ \frac{1}{2}\left(\frac{du}{dz} + \frac{dw}{dx}\right) & \frac{1}{2}\left(\frac{dw}{dy} + \frac{dv}{dz}\right) & \frac{dw}{dz} \end{bmatrix}$$

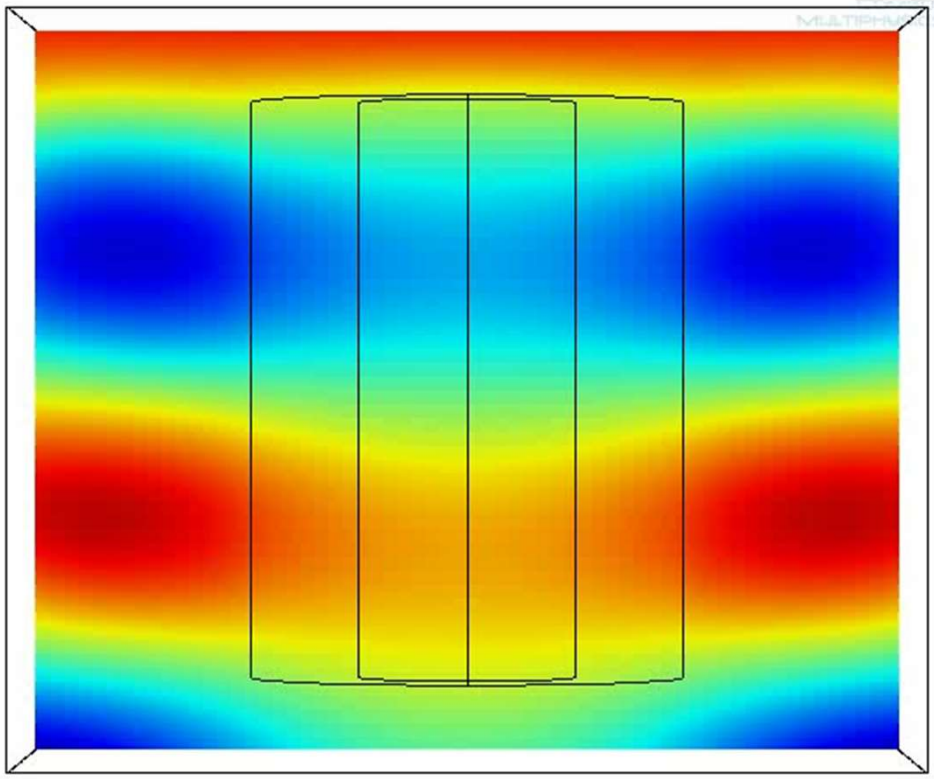
Inversion

- k-MDEV has been implemented
  - No change in the algorithm
  - Instead of $|u|^4$ weighted averaging of wave speed

    → Square of OSS weighted averaging of square of wave speed

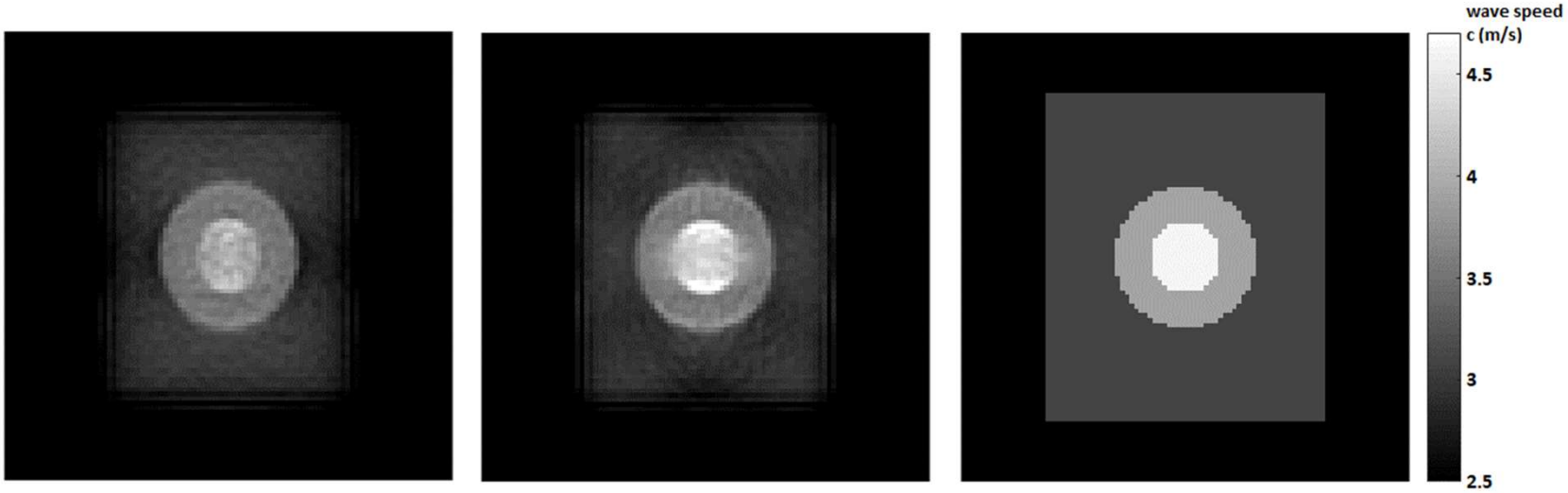
Simulation Data

- Fr



	Stiffness Damping (s)
Backgroun	2.5×10^{-4}
Disc inclusi	2.5×10^{-4}
Inner inclus	2.5×10^{-4}

Reconstructed wave speed maps



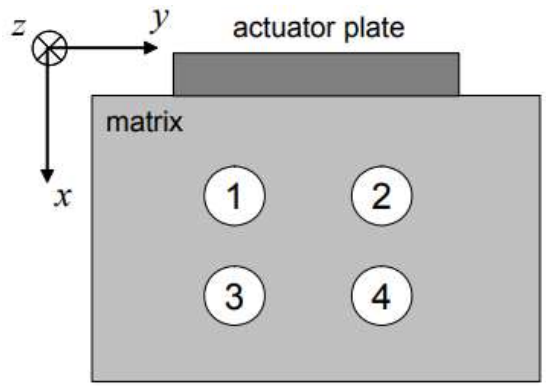
Amplitude-weighted

OSS-weighted

Ground truth

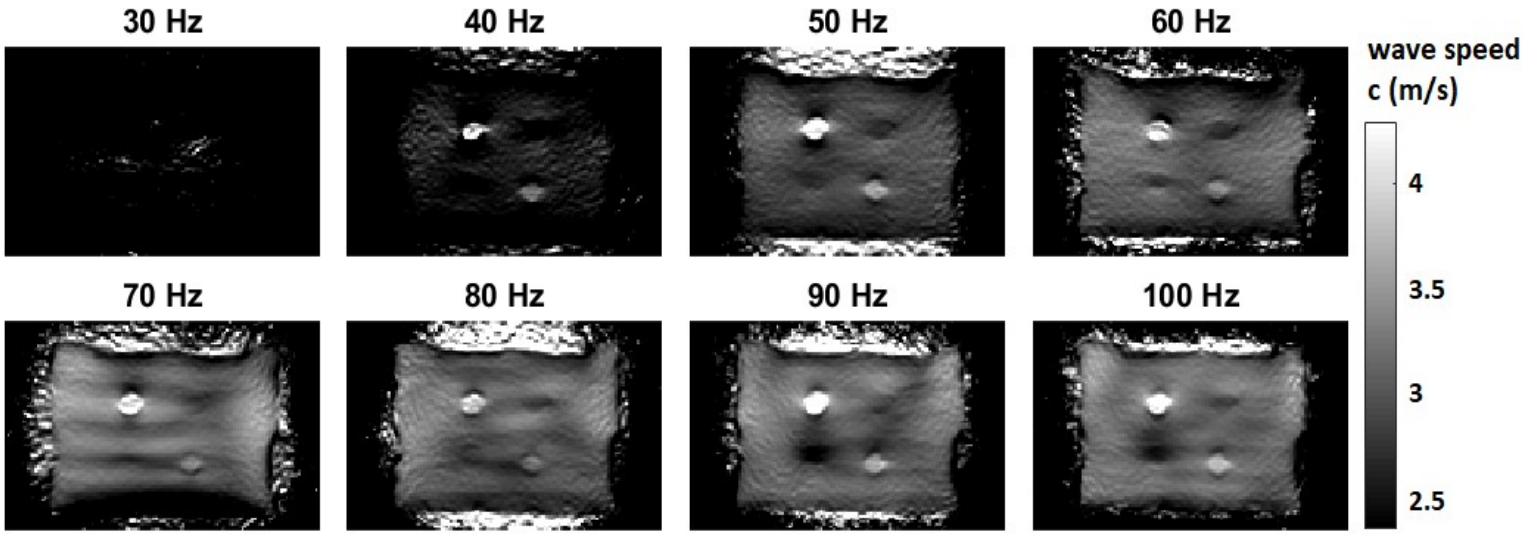
Data

- MRE phantom data provided by Charité - Universitätsmedizin Berlin, Germany on the ISMRM MRE study group webpage, also reported in [1, 2].

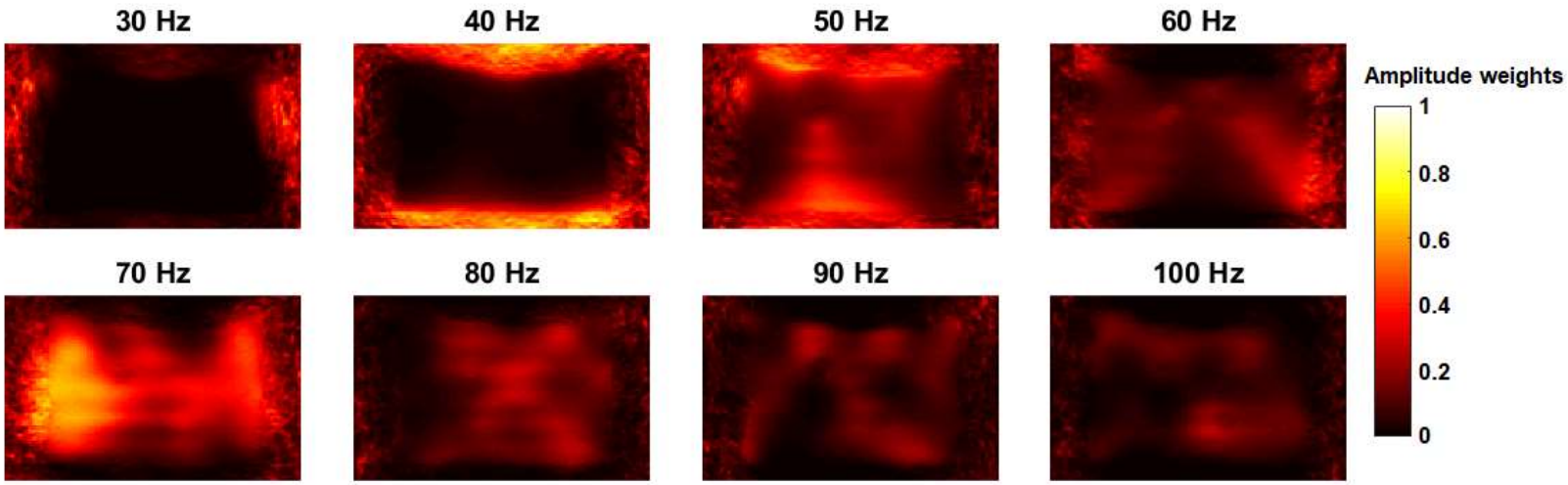


[1] Papazoglou S, Hirsch S, Braun J, Sack I. Multifrequency inversion in magnetic resonance elastography. Phys Med Biol 2012;57:2329–2346 McCurry M et al., Elastojournal, 41(3): 724-33, 2015.
[2] Tzschatzsch H , Guo J, Dittmann F, Hirsch S, Barnhill E, Johrens K, Braun J, Sack I. Tomoelastography by multifrequency wave number recovery from time-harmonic propagating shear waves. Med Image Anal2016;30:1–10

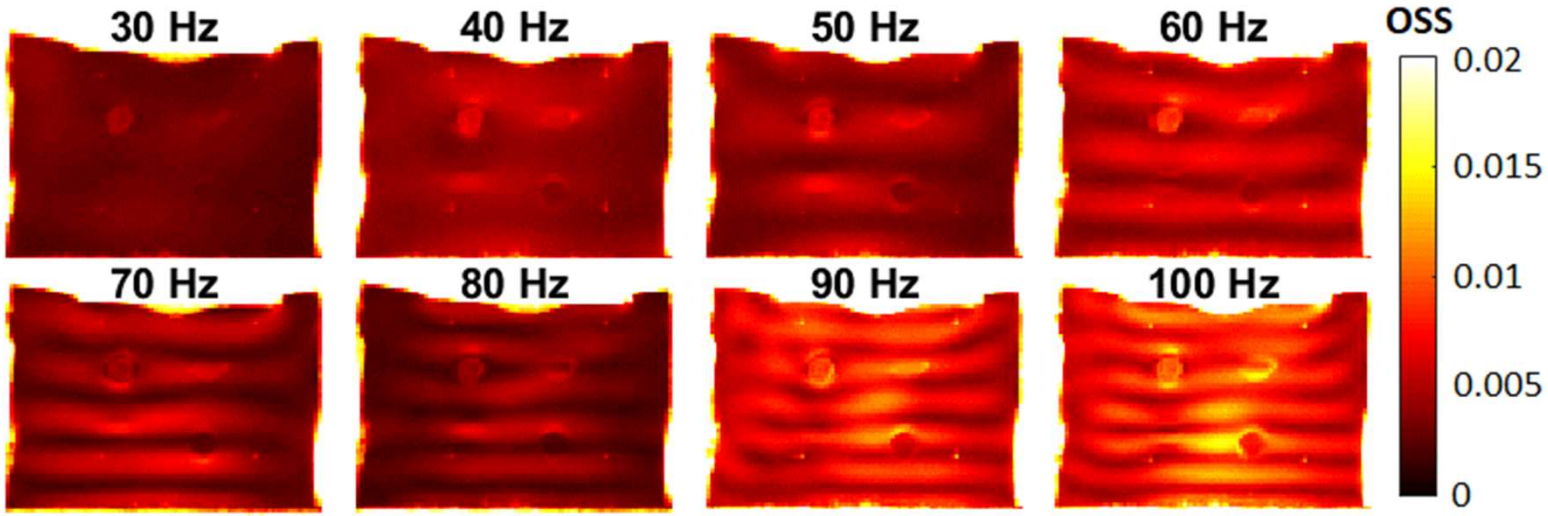
Inversion results at different frequencies



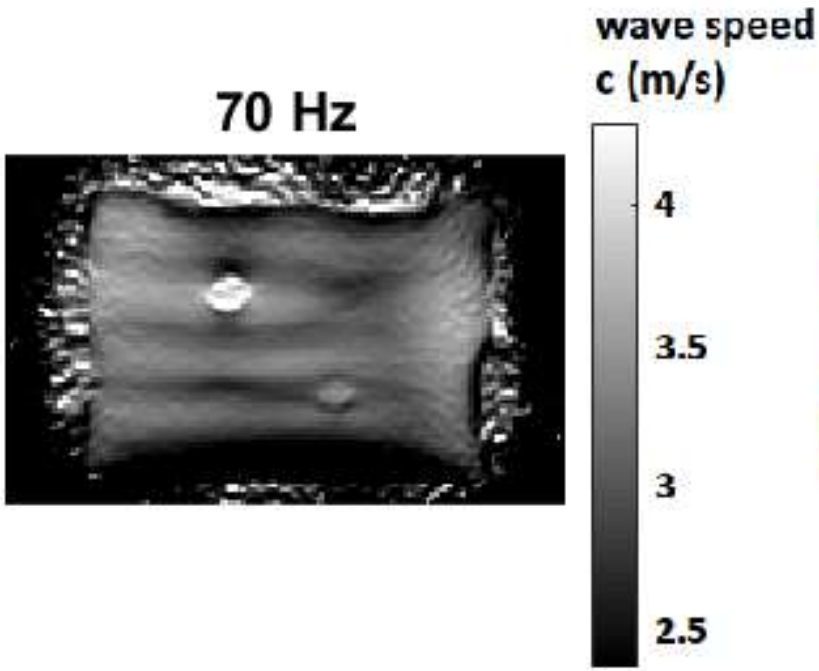
Amplitude-weight maps at different frequencies

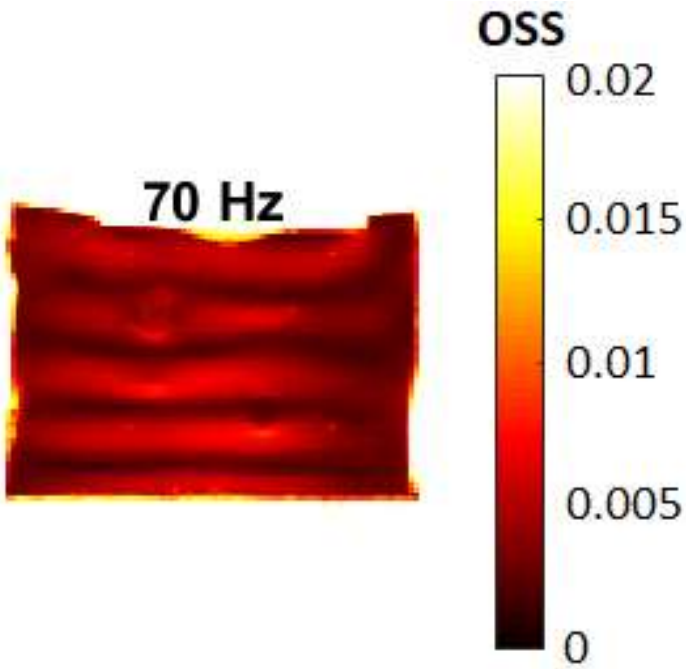


OSS maps at different frequencies

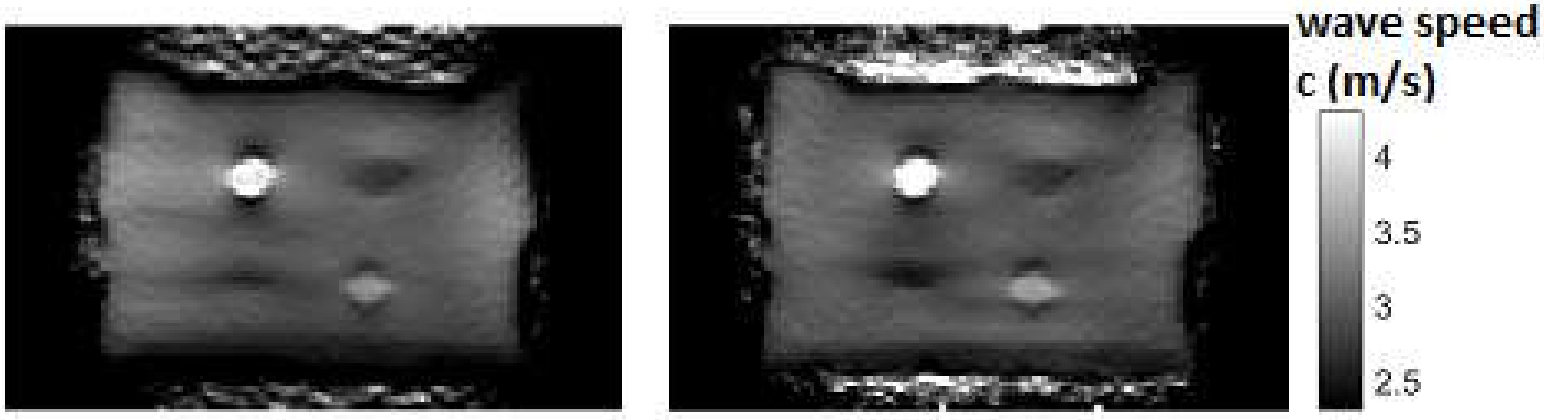


Wave artifacts





Amplitude-weighted vs. OSS-weighted averaging in MMRE



Amplitude-weighted

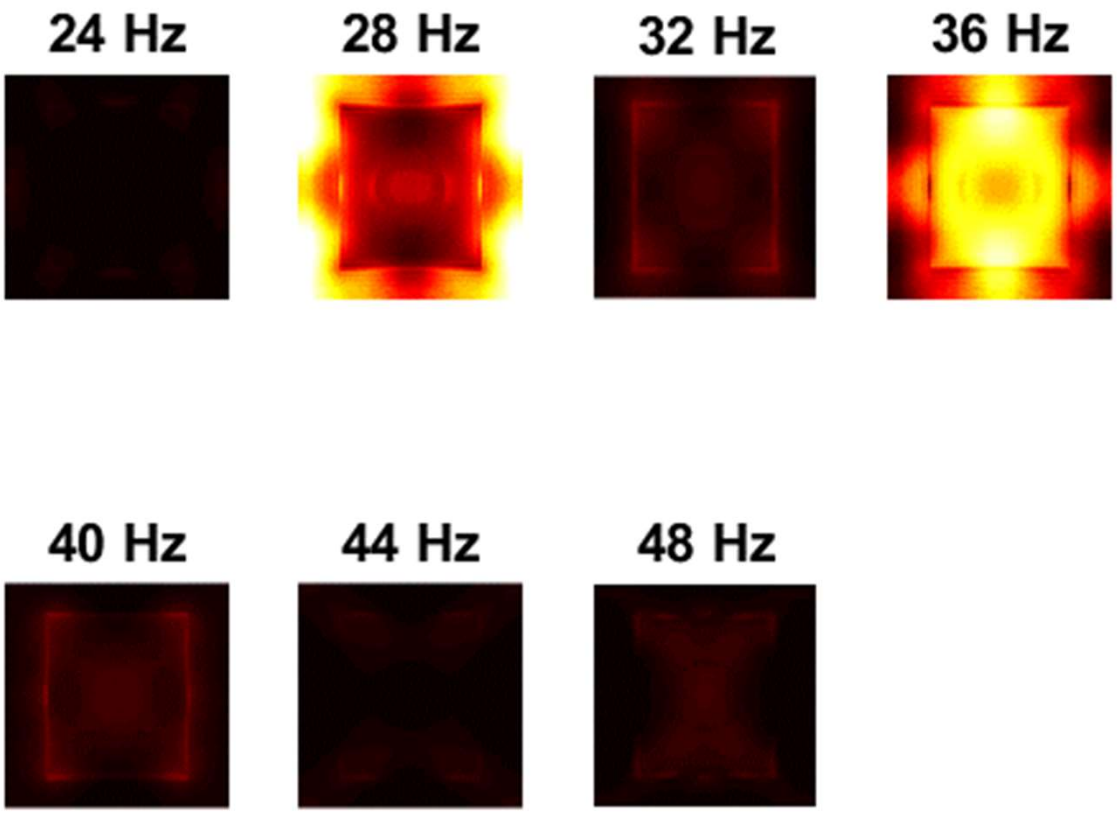
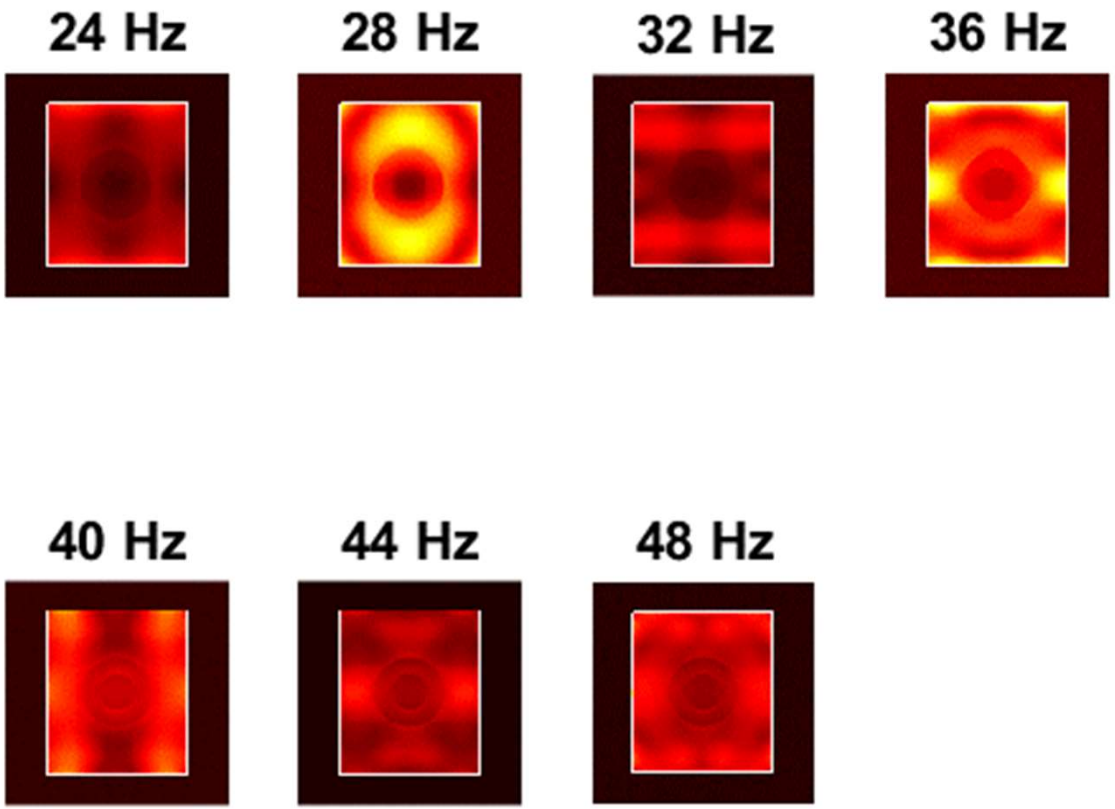
OSS-weighted

Discussion and Conclusion

- The lower left inclusion is more visible.
- Wave artifacts on the background are successfully suppressed in OSS-weighted averaging inversion result.
- OSS-weighted averaging gives better results on the boundaries.
- Using OSS-weighted averaging could be more advantageous over amplitude-weighted averaging.

Thank you for listening!

Amplitude weights for simulation



OSS weights for simulation