A Robust Strain Estimator Using Combined Radio-frequency and Envelope Cross-correlation

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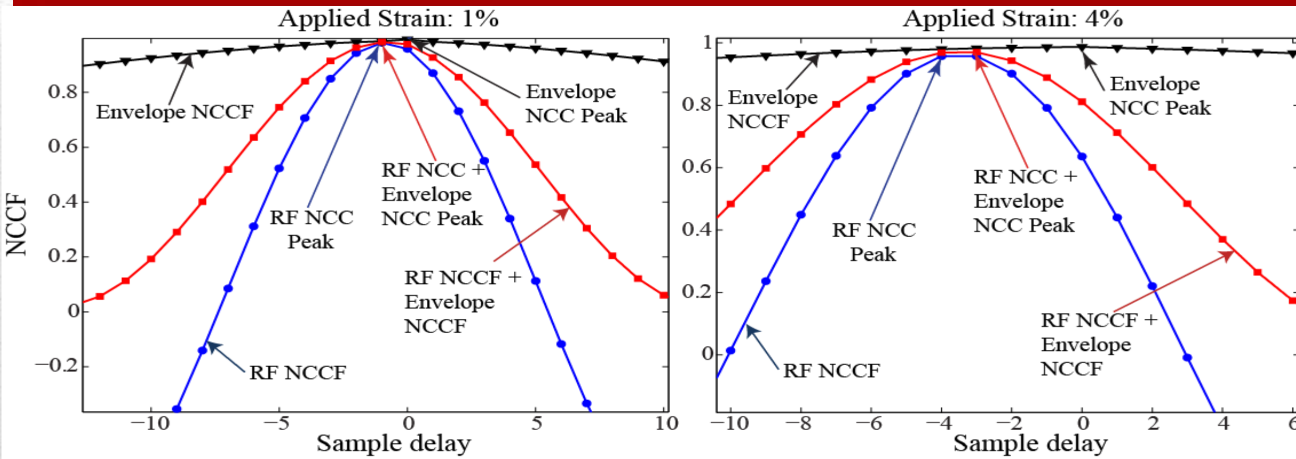
These phenomenon is illustrated as:

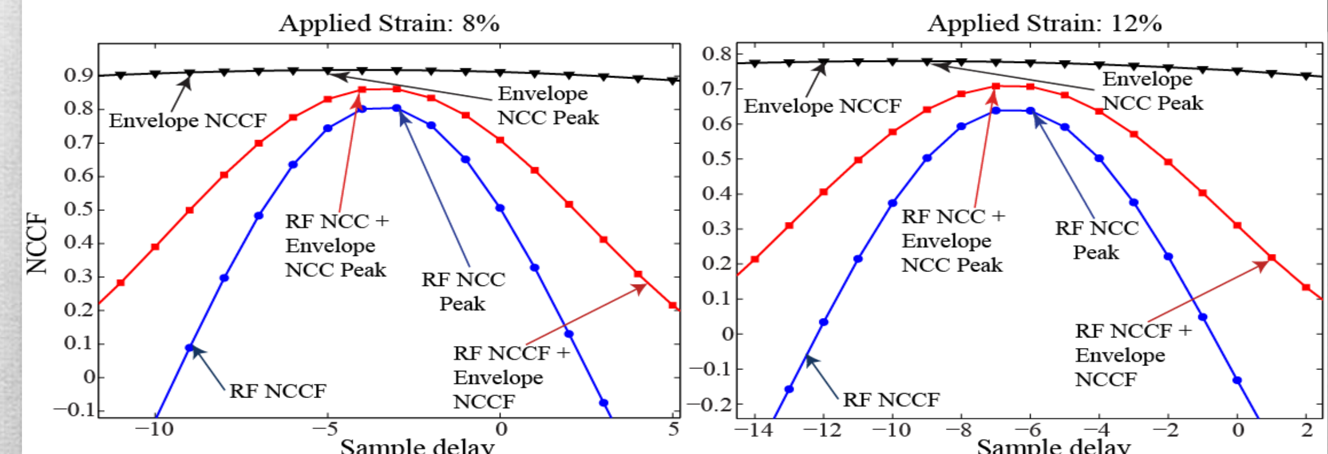


True Strain	Estimated strains from the above NCC peaks		
	RF NCCF	Envelope NCCF	RF NCCF+ Envelope NCCF
0.01	0.0113	0.0151	0.0124

(a)

True Strain	Estimated strain from the above NCC peaks		
	RF NCCF	Envelope NCCF	RF NCCF+ Envelope NCCF
0.04	0.0439	0.0483	0.0440

(b)



True Strain	Estimated strains from the above NCC peaks		
	RF NCCF	Envelope NCCF	RF NCCF+ Envelope NCCF
0.08	0.0877	0.0815	0.0820

(c)

True Strain	Estimated strains from the above NCC peaks		
	RF NCCF	Envelope NCCF	RF NCCF+ Envelope NCCF
0.12	0.1274	0.1239	0.1239

(d)

ss-correlation
very noisy at

he envelope-
to echo de-

Basic Concept & observations

- To take advantages from both the RF and envelope signals, we define a piecewise-linear weight through which RF NCC function and envelope NCC functions are weighted summed.

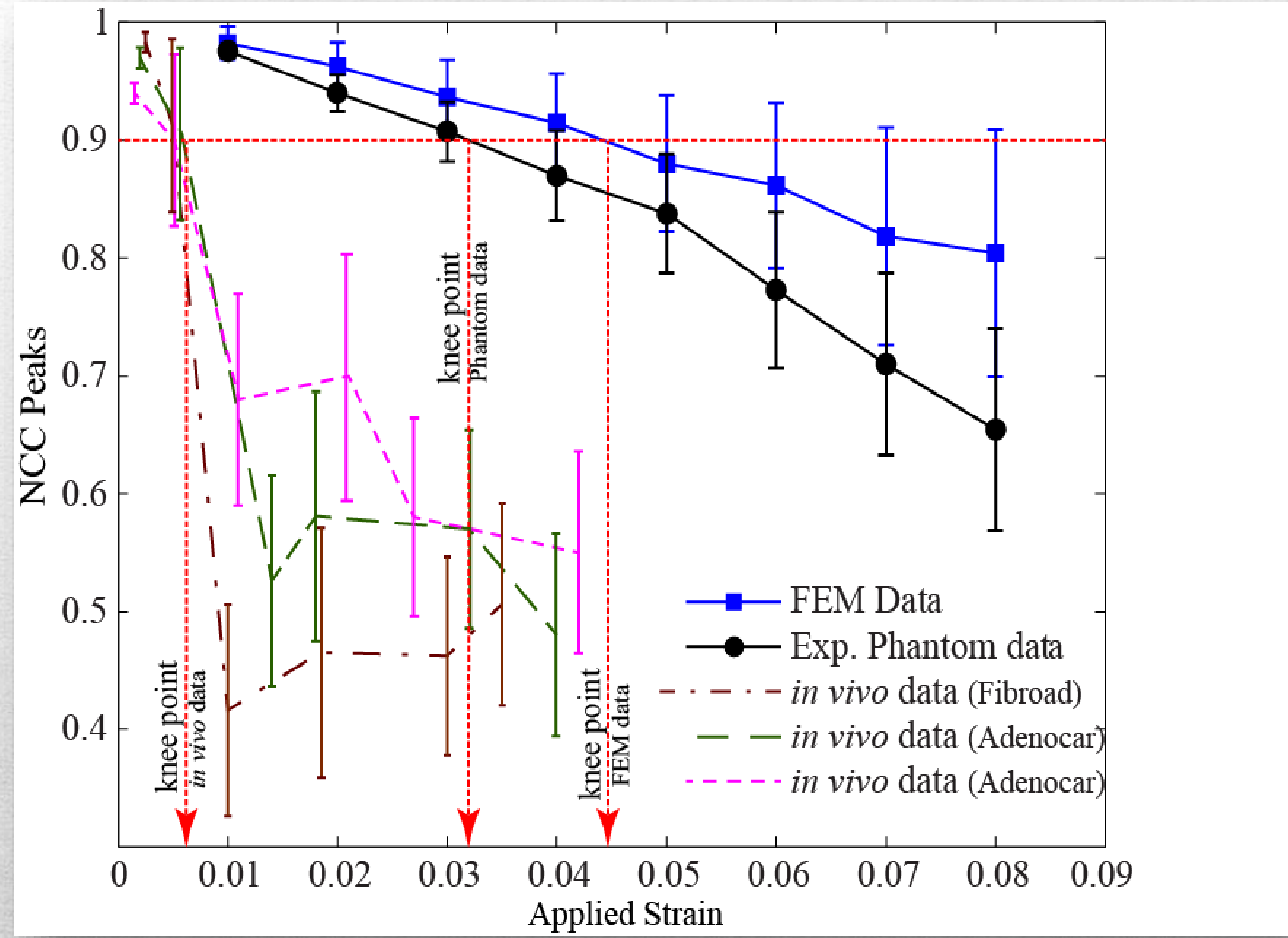
  We choose a piecewise-linear weight because:

  - At low strain RF NCC function itself works better than the summation of RF and envelope NCC functions.
  - Giving equal weights to both the RF NCC function and envelope NCC function works the best at high strain.

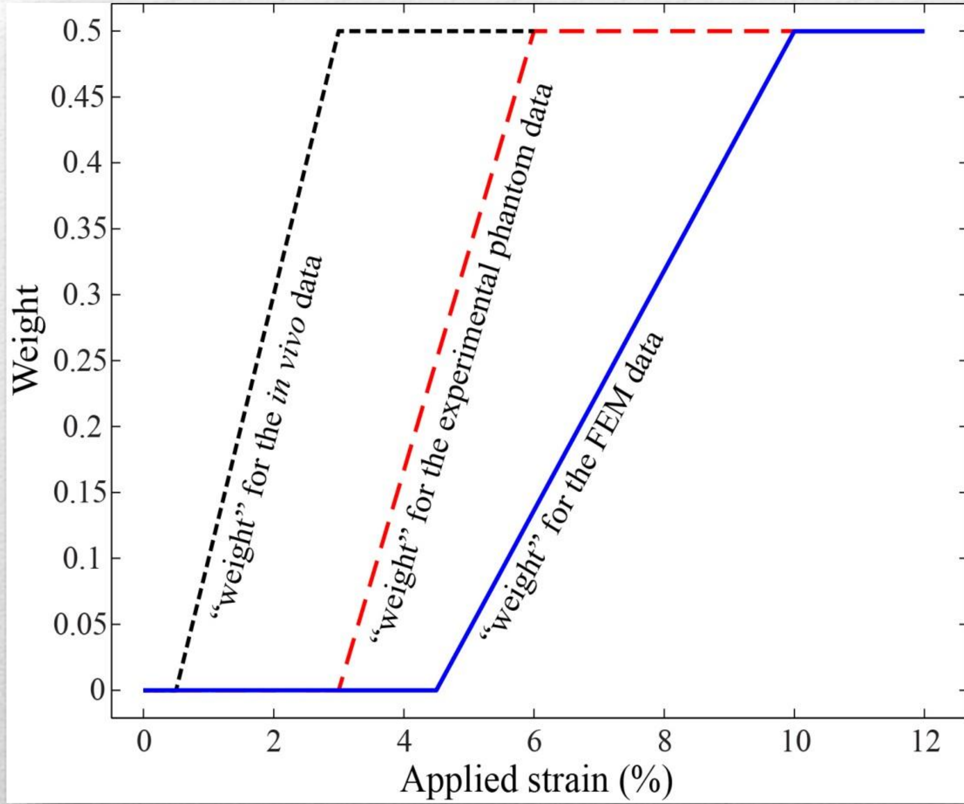
- The degree of echo decorrelation due to the increase of the applied strain may depend on the data types (e.g., computer-simulated phantom, tissue-mimicking phantom, *in*-*vivo* patient data, etc.).

- From these observations, we define some knee strain points for different data types.

Knee points
for different data



Representation of the NCC peaks vs. applied strain for the FEM phantom, experimental phantom and in vivo data. By taking NCC peak value 0.9 as threshold, some knee strain points are defined.



Piece-wise-linear weight

$$LW = \begin{cases} 0 & for \quad s_{ap} \le s_{knee} \\ \dfrac{0.5(s_{ap} - s_{knee})}{s_{\max} - s_{knee}} & for \quad s_{knee} < s_{ap} \le s_{\max} \\ 0.5 & for \quad s_{ap} > s_{\max} \end{cases}$$

Here, s_{knee} denotes the "knee strain", s_{max} denotes the maximum strain and s_{ap} denotes the approximate applied strain.

Using LW, the robust NCC function is calculated as

$$\rho_\alpha(k) = LW \times \rho_\alpha^{env}(k) + (1 - LW) \times \rho_\alpha^{rf}(k)$$

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Time-lag calculation

- We use non-stretched ($\alpha = \alpha_{max}$) and globally-stretched (α_{ap}) post-compression rf echo windows to find the NCC peak to image the lesion precisely. Here, α is the stretching factor related with the strain as,

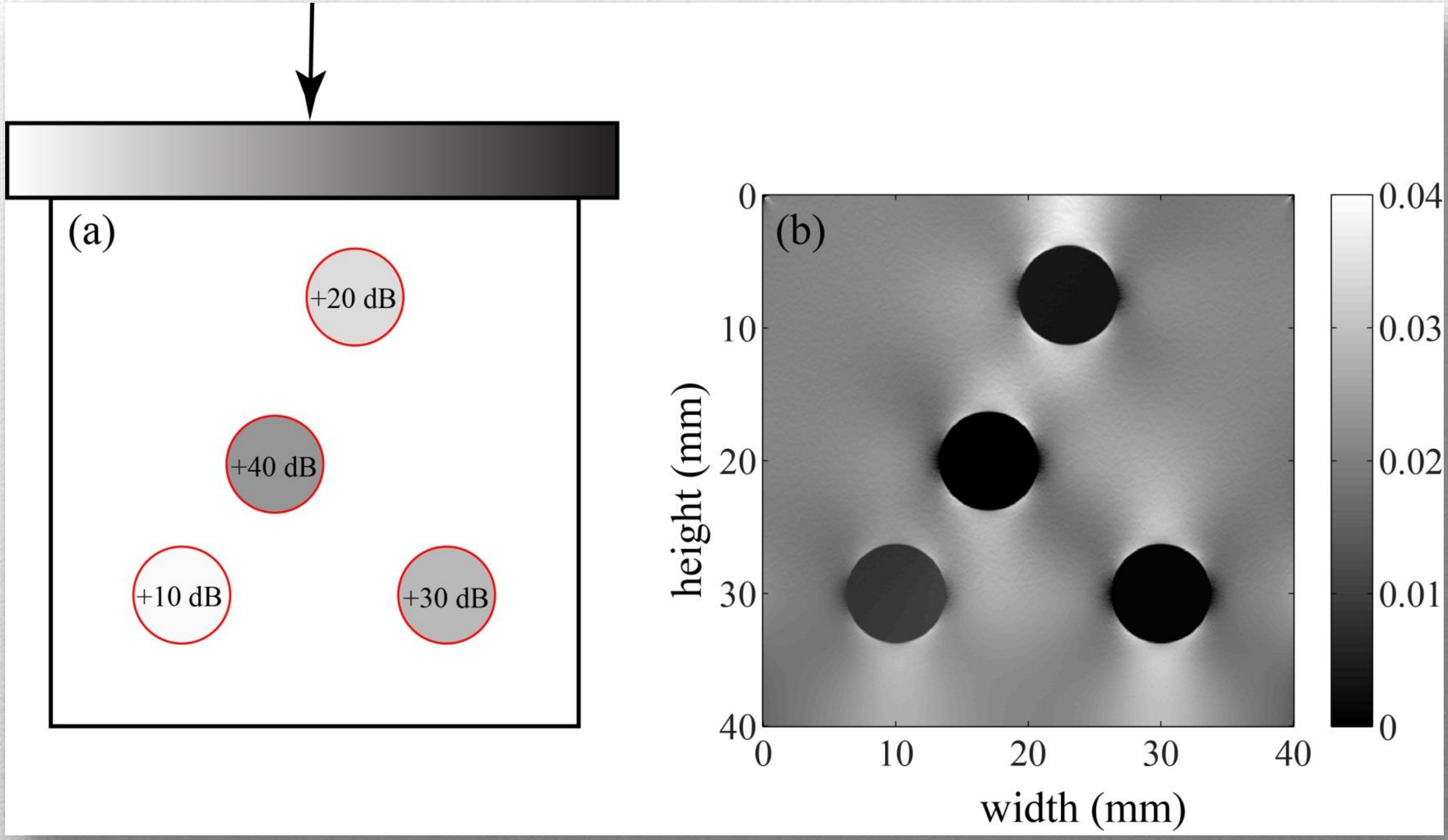
$$s = 1 - \alpha$$

- Therefore, from the NCC functions, the discrete time-lag is calculated as,

$$k_{\alpha}^{(i_s, j_s)} = \arg\max_{k} \{\rho_{\alpha}(k)\}, \quad \text{for } \alpha = \alpha_{max} \text{ and } \alpha_{ap}$$

Subsequently, from these time-lags, displacement is estimated and using least-square-error-based strain estimation technique, strain is calculated.

Results: Finite Element Modeling (1)



Results: Finite Element Modeling (2)

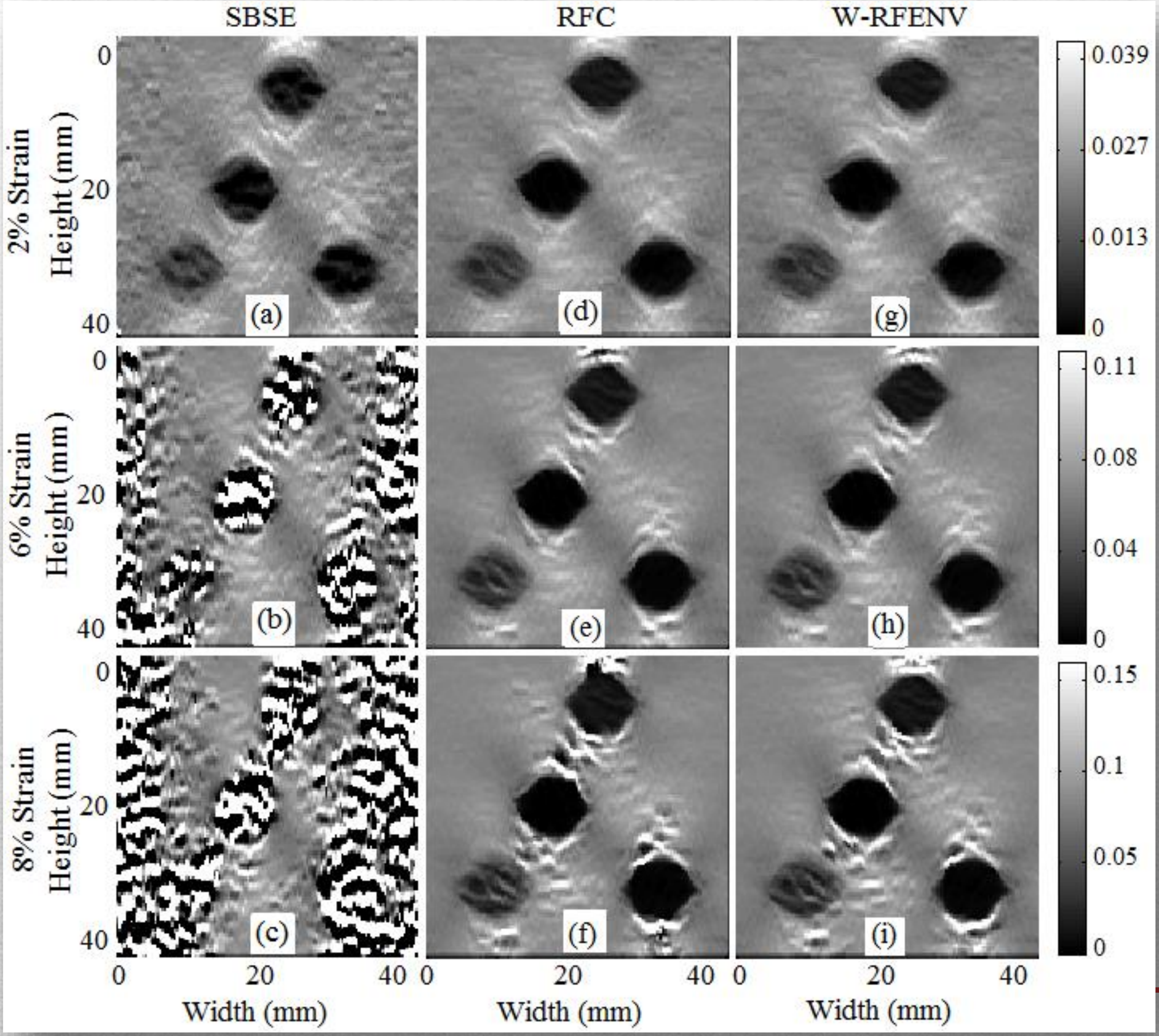


Fig: Strain images of the FEM simulation phantom generated by different methods. Results (a-c) are produced by the Novel spline based strain estimation (SBSE), (d-f) are produced by the proposed method by using only RF NCCF (RFC) and (g-i) are produced by the proposed method by using weighted sum of RF and Envelope NCCF (W-RFENV)

Results: Finite Element Modeling (3)

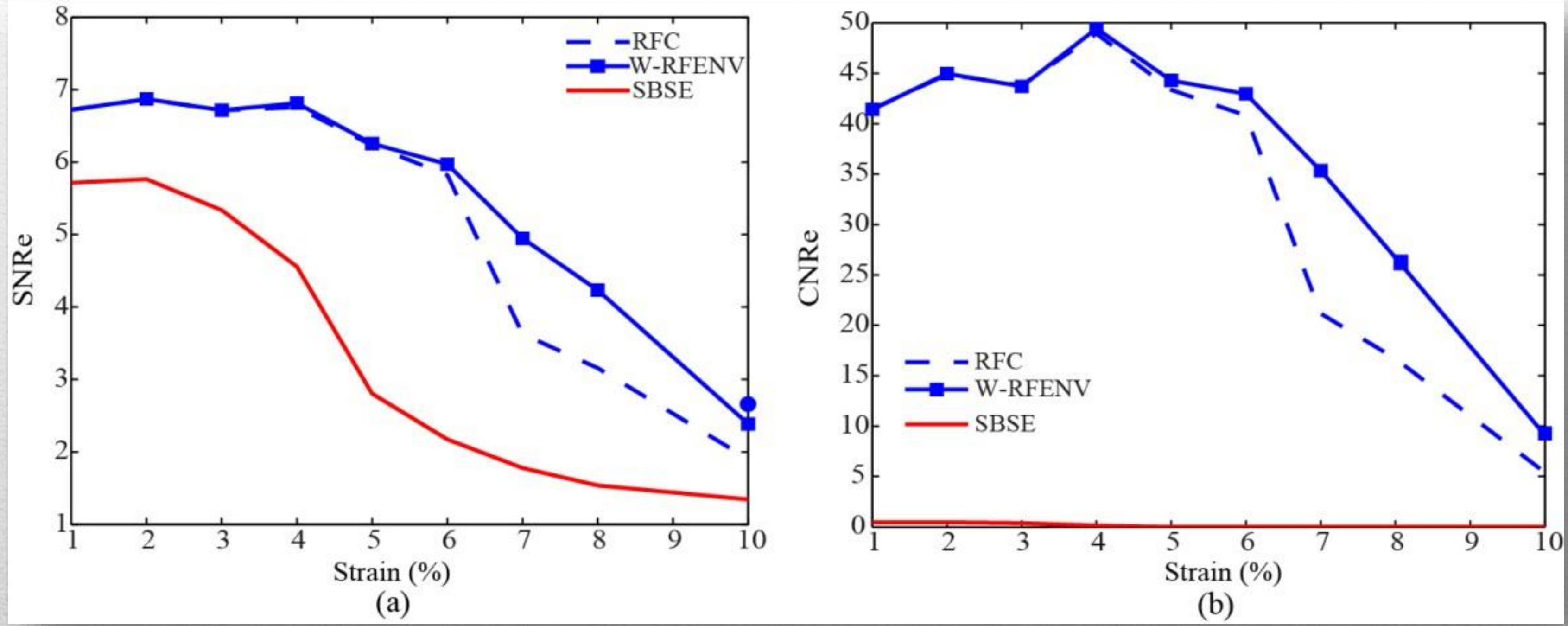


Fig: Performance comparisons of different methods using numerical indices. (a) SNRe vs. applied strain (b) CNRe vs. applied strain.

Results: Breast *in vivo*

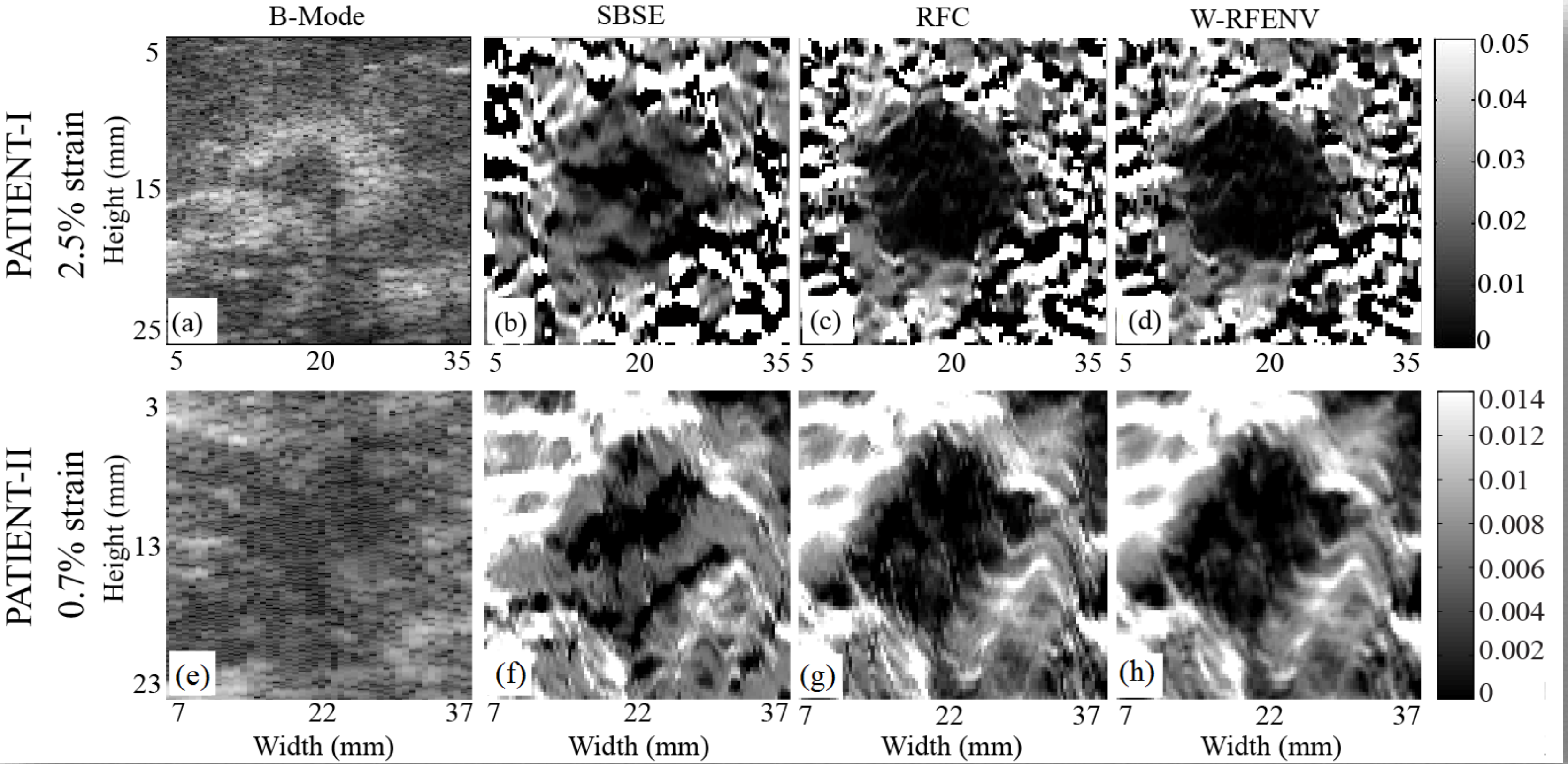


Fig: Strain images of the in vivo breast data generated by different methods. Fig. (a, c) are B-mode images. Results (b, f) are produced by the SBSE and (c, g) are produced by the proposed method by using only RF NCCF (RFC), and (d, h) are produced by the proposed method by using weighted sum of RF and Envelope NCCF (W-RFENV).

Patient	Age(years)/ Mass Specification
I	38/ Adenocarcinoma
II	63/ Adenocarcinoma

SUMMARY

- Proposed strain estimator
  - *In vivo* cases produce improved strain images compared to other strain estimators
  - High SNR strain image preserving lesion edge at high strain.

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Thank You!!!

Faculty Disclosure: <u>No</u> relationships or affiliations exist with any commercial entities for *this* presentation

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