Motivation

- Lack of precise knowledge of constitutive properties of the breast tissue
- Time Reversal (TR) harnesses multipath propagation to enhance focusing resolution
- TR Clutter Suppression
- Focused frequency time reversal (FFTR) matrices and the TR-based Multiple Signal Classification (MUSIC) algorithm

Conventional MIMO Radar for Breast Imaging

Conventional MIMO Radar Received Signals:

• Assuming all transmitted signals be the same i.e., \( F(\omega) \), in the matrix form:

\[
\mathbf{R}(\omega) = \sum_{l=1}^{L} X_l \mathbf{K}_l^T(\omega) F(\omega) + \mathbf{K}_l(\omega) F(\omega) + \mathbf{N}(\omega),
\]

where \( \mathbf{K}_l(\omega) \) is the transmit-receive response matrix of the tumor from path \( l \) for \( 1 \leq l \leq L \) and \( \mathbf{K}_l(\omega) \) is the clutter response and the coefficients \( X_{lt} = X_l \).

• Conventional Clutter Suppression: The clutter is characterized in the spatial and spectral domains as a multivariate complex Gaussian random process. Then, after whitening the clutter + noise, we have

\[
\tilde{\mathbf{R}}(\omega) = \mathbf{R}_{\text{sub}}^2 \mathbf{K}_l(\omega) F(\omega) + \mathbf{R}_{\text{sub}}^2 \mathbf{R}_c(\omega),
\]

with the whitened clutter-noise term \( \tilde{\mathbf{R}}(\omega) \sim CN(0, I_{N\times N}) \).

Simulations Using FDTD Method

The final step will be to form the pseudospectrum of FFTR-MUSIC as follows.

\[
A(\omega_0, r) = \mathbf{g}^H(\omega_0) \mathbf{F}^{\text{Sig}}(\omega_0) \mathbf{U}_{\text{Sig}}(\omega_0) \mathbf{F}^{\text{Sig}}(\omega_0) \mathbf{g}(\omega_0, r),
\]

where \( \mathbf{U}_{\text{Sig}}(\omega_0) \) is the signal subspace matrix at the focused frequency resulted from the SVD of \( \mathbf{P}_l(\omega_0) \) and \( \mathbf{g}(\omega_0, r) = [G(x_1, \omega_0), \ldots, G(x_N, \omega_0)]^T \).

Finally, the FFTR-MUSIC image is given by

\[
I(r) = (1 - A(\omega_0, r))^{-1}.
\]

MRI-based breast model: (a) Permittivity of the numerical domain comprised of transmitting and receiving antennas, water, breast skin, breast tissue, tumor, ribs and muscle between ribs. (b) The corresponding conductivity, and (c) Electromagnetic parameters and values.