Multivariate Change Detection on High Resolution Monovariate SAR Image Using Linear Time-Frequency Analysis

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Motivations

Change detection between two multivariate images I and J: $\begin{cases} \mathbf{I} = [\mathbf{i}_1, \mathbf{i}_2, \dots, \mathbf{i}_K] \in \mathbb{C}^{p\times K} \\ \mathbf{J} = [\mathbf{j}_1, \mathbf{j}_2, \dots, \mathbf{j}_K] \in \mathbb{C}^{p\times K} \end{cases}$

$$\forall k,\ \mathbf{i}_k \sim \mathcal{CN}(\mathbf{0}_p, \mathbf{C}_i) \text{ and } \mathbf{j}_k \sim \mathcal{CN}(\mathbf{0}_p, \mathbf{C}_j)$$

Detection Problem: $\begin{cases} H_0 : \mathbf{C}_i = \mathbf{C}_j \\ H_1 : \mathbf{C}_i \neq \mathbf{C}_j \end{cases}$

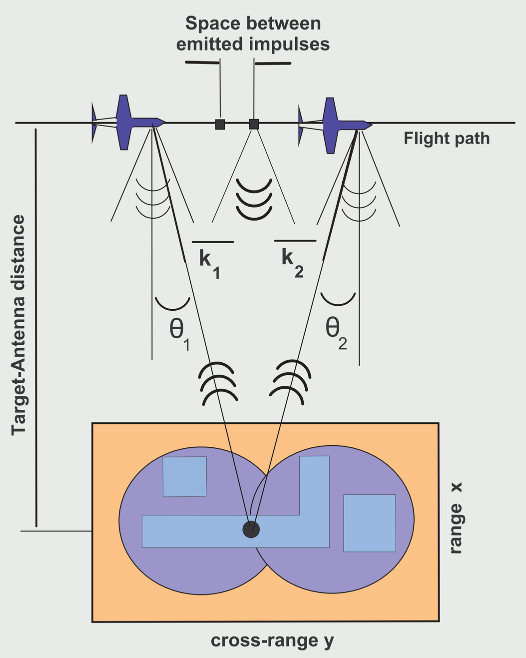
Detector: $$\hat{\Lambda}_{\mathrm{GLRT}} = \frac{\left| \frac{1}{2K} \left(\sum_{k=1}^{K} \mathbf{i}_k \mathbf{i}_k^H + \sum_{k=1}^{K} \mathbf{j}_k \mathbf{j}_k^H \right) \right|^{2K}}{\left| \frac{1}{K} \sum_{k=1}^{K} \mathbf{i}_k \mathbf{i}_k^H \right|^{K} \left| \frac{1}{K} \sum_{k=1}^{K} \mathbf{j}_k \mathbf{j}_k^H \right|^{K}}.$$

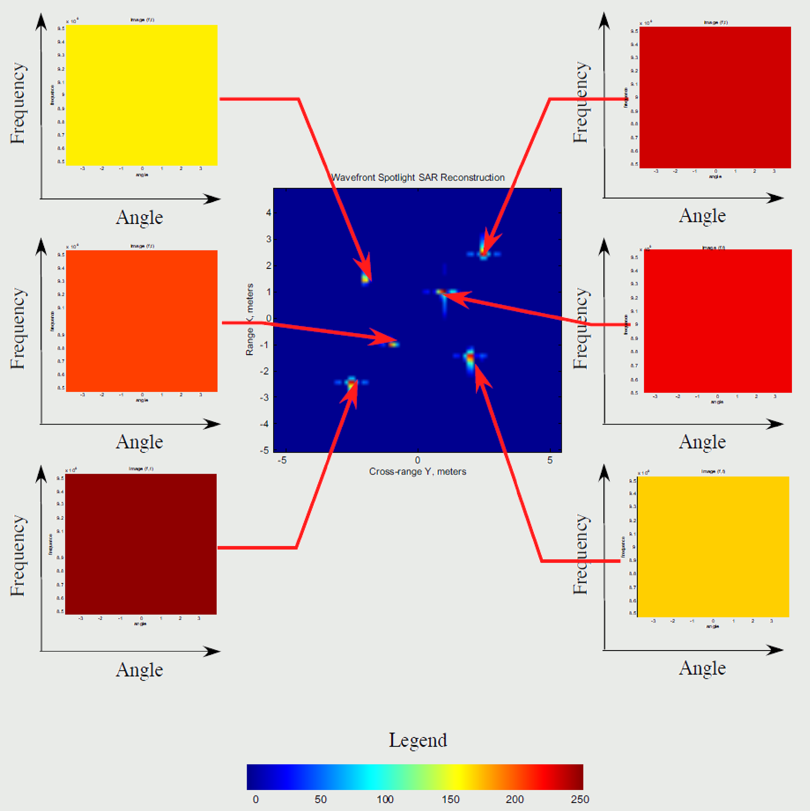
Polarimetric (p=3) diversity is generally used but not available for monovariate images.

Idea: Use **Spectro-Angular** Diversity in High-Resolution SAR Images.

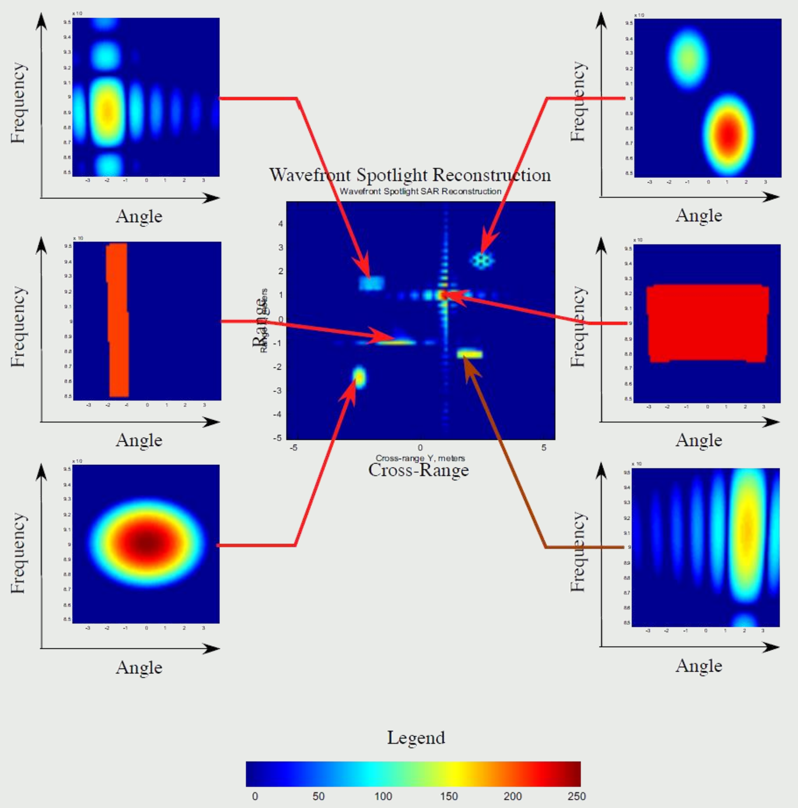
Spectro-Angular Diversity

In High-resolution Images, SAR pixels may be **dispersive** and **anisotropic**.





Isotropic and white scatterers



anisotropic and colored scatterers

Construction Of Diversity

Traditional SAR reconstruction:

$$I(\mathbf{r}) = \int_{\mathcal{D}} H(\mathbf{k}) \exp\left(2\, i\, \pi\, \mathbf{k}^T \mathbf{r}\right) d\mathbf{k}$$

With: $\mathbf{r}$, pixel position
$\mathbf{k} = [k\cos(\theta), k\sin(\theta)]^T$, wave vector
H, backscattering coefficient
$\mathcal{D}$, frequency and angular support of H

Use of short time Fourier Transform:

$$W_{l,m}(\mathbf{r}) = \int_0^{2\pi} \mathrm{d}\theta \int_0^{+\infty} k\ H(k,\theta)\ \phi_{l,m}(k,\theta)\ e^{+j2\pi\mathbf{k}^T\mathbf{r}}\ \mathrm{d}k$$

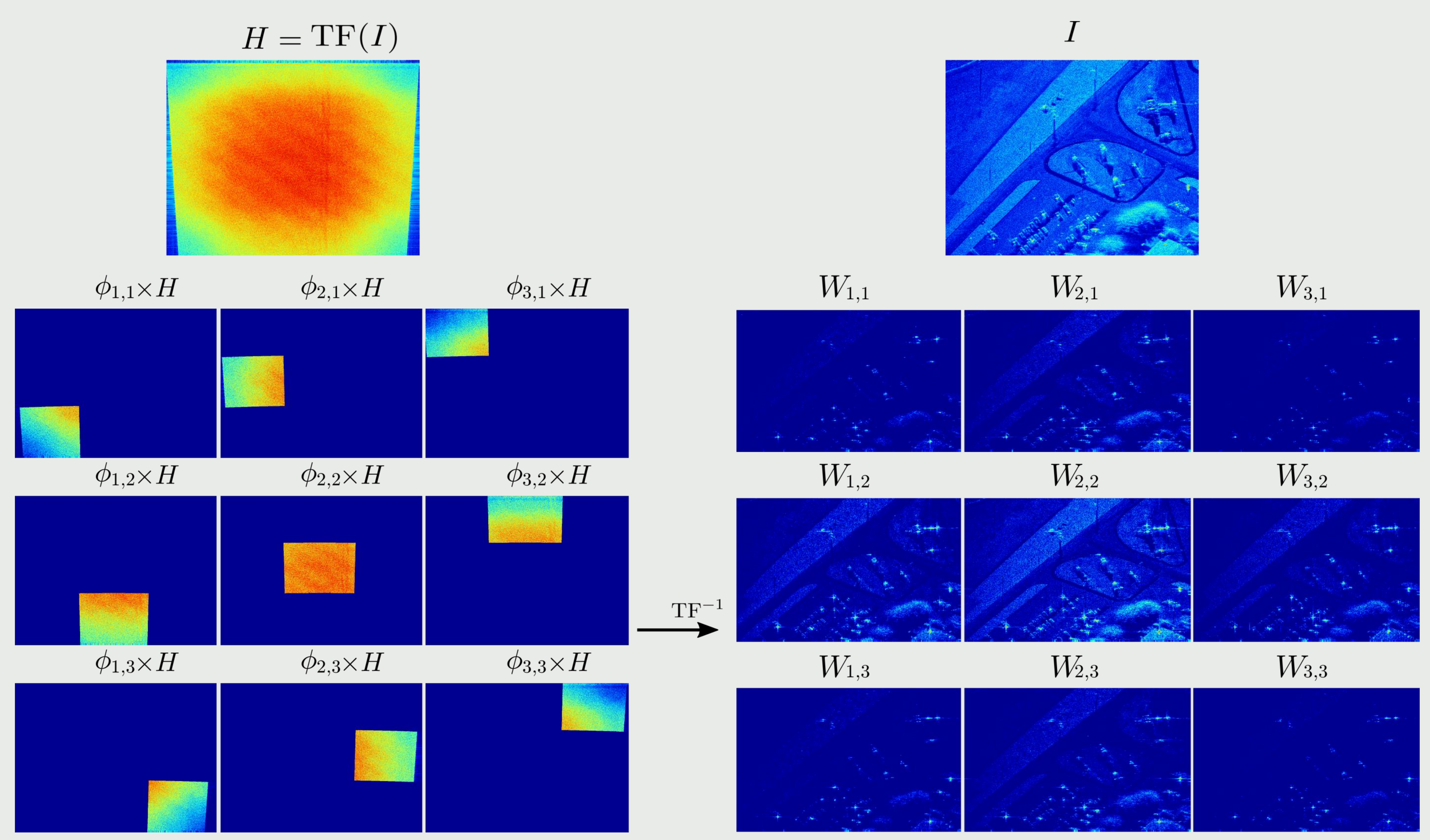
With: $\phi_{l,m}(k,\theta) = \begin{cases} 1 \text{ if } (k,\theta) \in \Delta_{l,m} \\ 0 \text{ otherwhise} \end{cases}$

$$\mathcal{D} = [k_{min}, k_{max}] \cup [\theta_{min}, \theta_{max}]$$
$$\kappa = k_{max} - k_{min}, \Theta = \theta_{max} - \theta_{min}$$
$$\Delta_{l,m} = \left[k_{\min} + \frac{(l-1)\kappa}{N_k}, k_{\min} + \frac{l\kappa}{N_k}\right] \cup \left[\theta_{\min} + \frac{(m-1)\Theta}{N_\theta}, \theta_{\min} + \frac{m\Theta}{N_\theta}\right]$$

For each pixel, we obtain a vector:

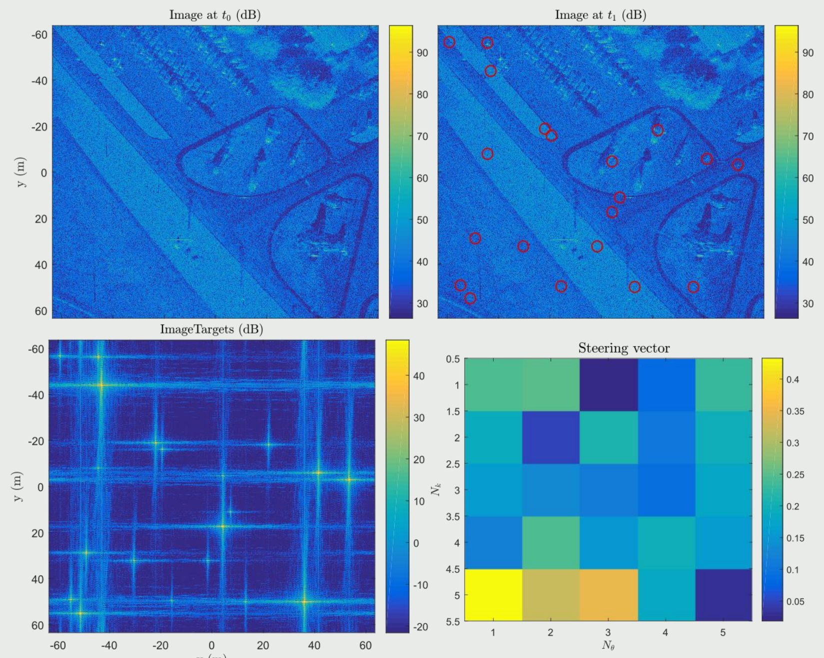
$$\mathbf{i} = [W_{1,1}(x,y), W_{1,2}(x,y), \dots, W_{N_k,N_\theta}(x,y)]^T$$

Example with 3 Sub-Bands and 3 Sub-Looks:

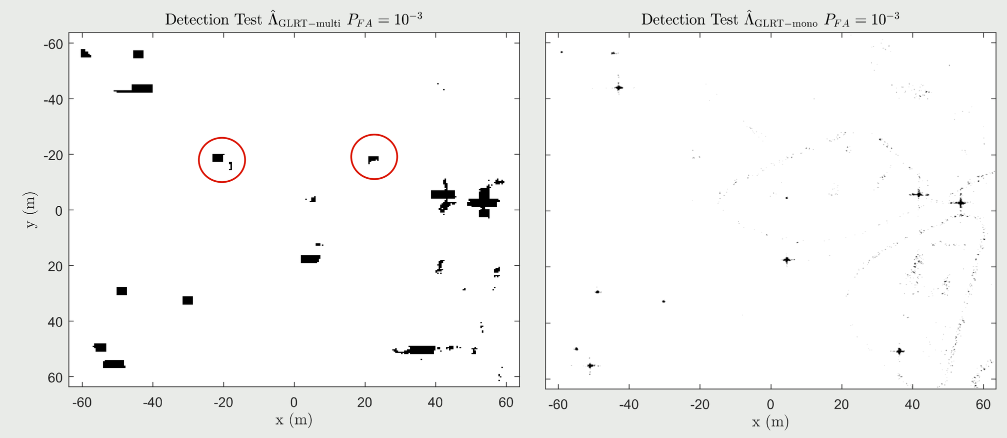


Simulations and Results

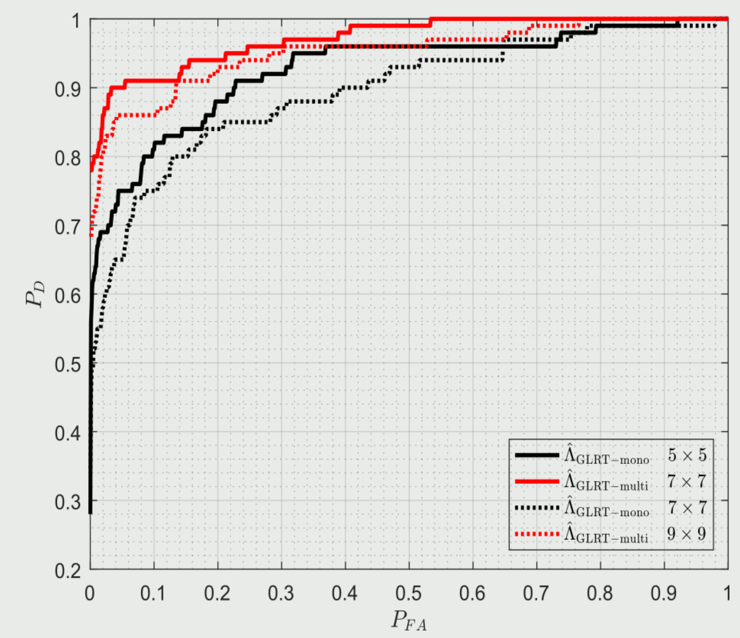
Dataset: SANDIA National Labs High Resolution SAR Image with artificially embedded targets.



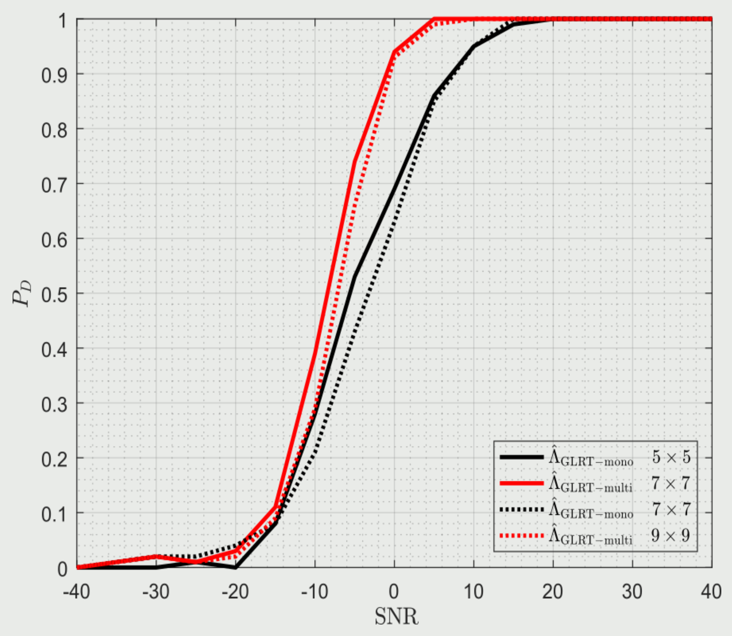
Test of detection at Pfa=10^{-3} with spectro-angular diversity (p=25, left) and without (p=1, right):



Performances estimation with Monte-Carlo Trials:



ROC curve at SNR = -5dB



Pd SNR curve at Pfa=10^{-3}

Conclusion

A new methodology for Change Detection using Spectro-Angular Diversity has been proposed. The performances were evaluated and prove to be better when using this diversity rather than working on the amplitude alone.