

# University Defence Research Collaboration (UDRC) Signal Processing in a Networked Battlespace (Related Project)

E\_WP6: RF Interference Mitigation for UWB SAR using Image Sparsity  
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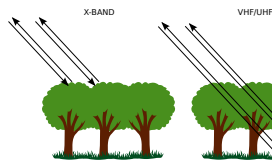
**Abstract:** Ultra-wide band (UWB) synthetic aperture radar (SAR) systems, that use the VHF/UHF bands, find civilian and military applications primarily due to the foliage penetration property of large wavelength RF waves. A major problem for VHF/UHF SAR systems are radio, television and communications systems.

The presence of other systems can produce to two types of radio frequency interference (RFI). One occurs when the SAR system interferes with other users. The second occurs when other users interfere with the SAR system. The first type of RFI is strictly regulated and therefore certain specified bands must be avoided. The second type of interference occurs within the bands where transmission is allowed. Strong interference from other users within these bands, particularly from narrowband (AM and FM) transmitters, can deteriorate the dynamic range of the resulting SAR image.

In this work we propose a new SAR image formation algorithm which simultaneously produces a SAR image and also suppresses RFI, without introducing large range side lobes. The proposed method achieves this by leveraging the approximate sparsity of SAR images.

## Why use the VHF/UHF spectrum

- Foliage Penetration (FoPEN) Radar
- Ground Penetration Radar (GPR)
- Scattering is dependent on wavelength.

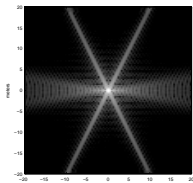


## Issues with the VHF/UHF spectrum

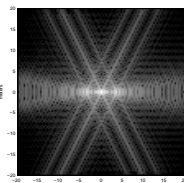
- Interference between SAR systems and radio, television and communications systems.
- Radio frequency interference (RFI)
- Interference Types:
  1. SAR systems can interfere with other spectrum users.
  2. Other users in the spectrum can interfere with SAR system.

## RFI suppression

- Strong interference from AM/FM transmitters.
- RFI pre-processing suppression methods: estimate-and-subtract or linear filter.
- Estimate-and-subtract: estimate the frequencies and phases of the RFI and then abstract.  
*Can be computationally expensive and approximation dependent.*
- Linear filter: minimise RFI using linear filter, e.g. LMS filter and Wiener filter.  
*Can produce large side lobes.*



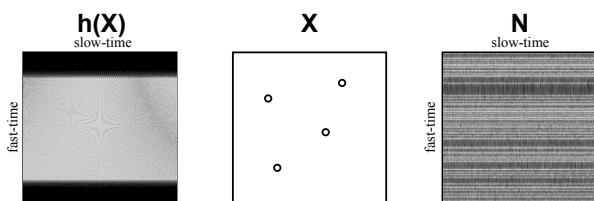
Example PSF



Filtered PSF

## Acquisition Model:

$$Y = h(X) + N$$



## RFI-aware Sparse Image Formation

$$\hat{X} = \underset{X}{\text{minimise}} \|X\|_1$$

$$\text{subject to } \|Y - h(X)\|_{Q_N^{-1}} \leq \epsilon,$$

where,  $\|A\|_Q = \text{vec}(A)^H Q \text{vec}(A)$

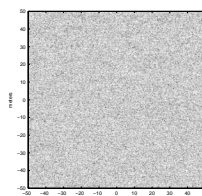
$Q_x = E[x x^H]$  is the covariance matrix of the RFI which can be estimated using *dead time* measurements.

## VHF/UHF SAR Simulation Parameters

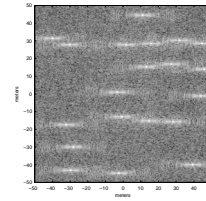
parameter	value
carrier frequency ( $\omega_0$ )	$2\pi \times 308 \times 10^6$ rad/s
chirp bandwidth ( $2\alpha T$ )	$2\pi \times 324 \times 10^6$ rad/s
IF bandwidth	$2\pi \times 60 \times 10^6$ rad/s
scene radius ( $L$ )	75 m
altitude	7000 m
stand-off distance	7000 m
aperture length	7000 m
number of aperture samples	300
number of targets	20
number of interferes	80
signal to noise ratio (SNR)	-10 dB
signal to interference ratio (SIR)	-80 dB

## Numerical Experiment Results

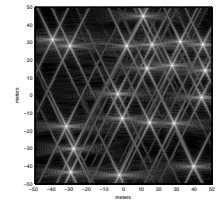
### Reconstructed Images:



Filtered back-projection

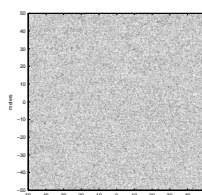


Wiener filtered followed by filtered back-projection

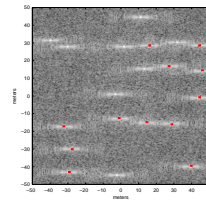


RFI-aware sparse image formation

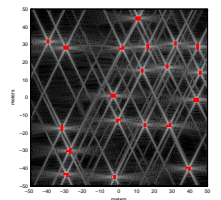
### CFAR Results:



Filtered back-projection



Wiener filtered followed by filtered back-projection



RFI-aware sparse image formation

## Conclusion:

- RFI-aware sparse image formation has provably near optimal performance for ideally sparse SAR images.
- It produces images of better quality than linear filter based RFI suppression strategies.
- The algorithm is also sufficiently versatile such that it could be modified to also address the issue of range sidelobes due to transmitter notching.

## Future Work:

- Integrate into the algorithm knowledge of the transmitter's spectrum notching.
- Investigate the trade offs between image quality and computational complexity.
- Demonstrate on real VHF-UHF system where the RFI is not ideally stationary.