TECHNION Israel Institute of Technology
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Electronics
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S_X_MPL Signal Acquisition Modeling and Processing Lab

Xampling-Enabled Coexistence in Spectrally Crowded Environments

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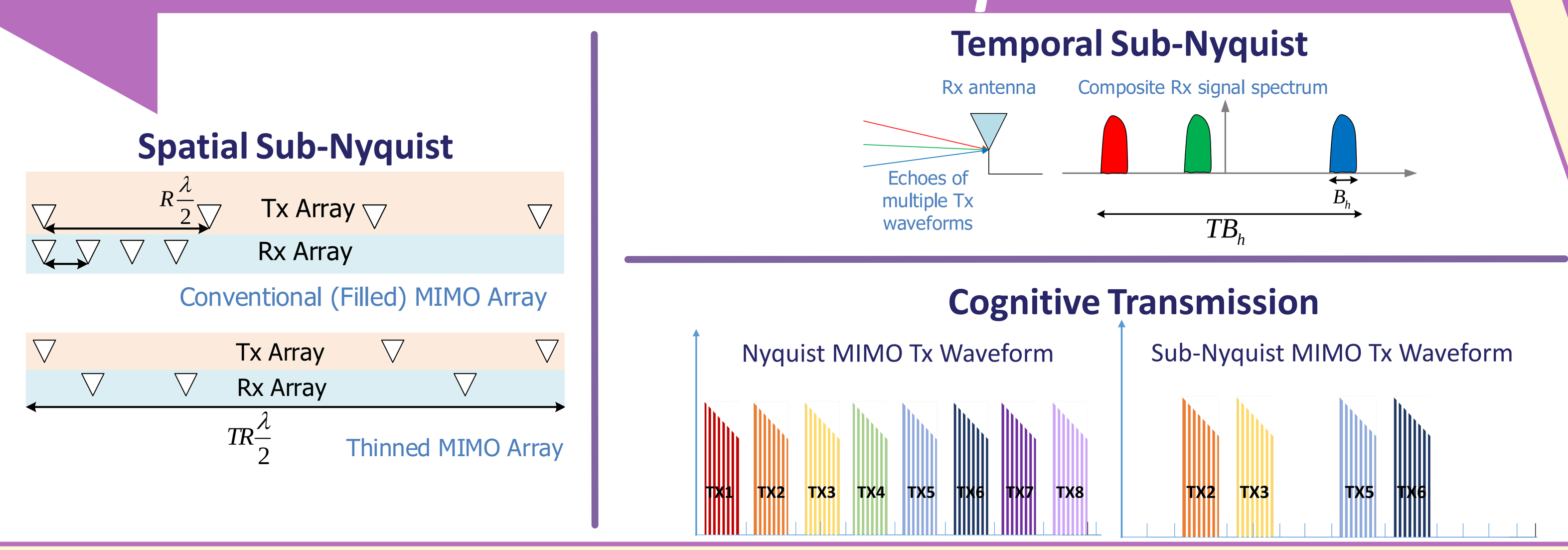
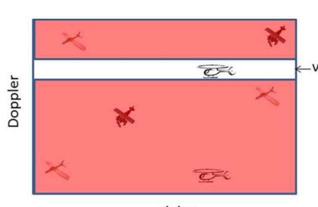
Cognitive Sub-Nyquist MIMO Radar (SUMMeR)

SUMMeR Concepts

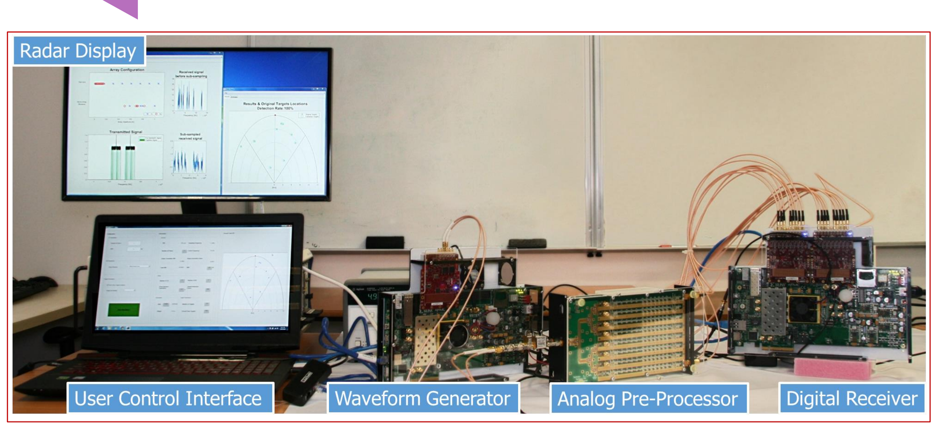


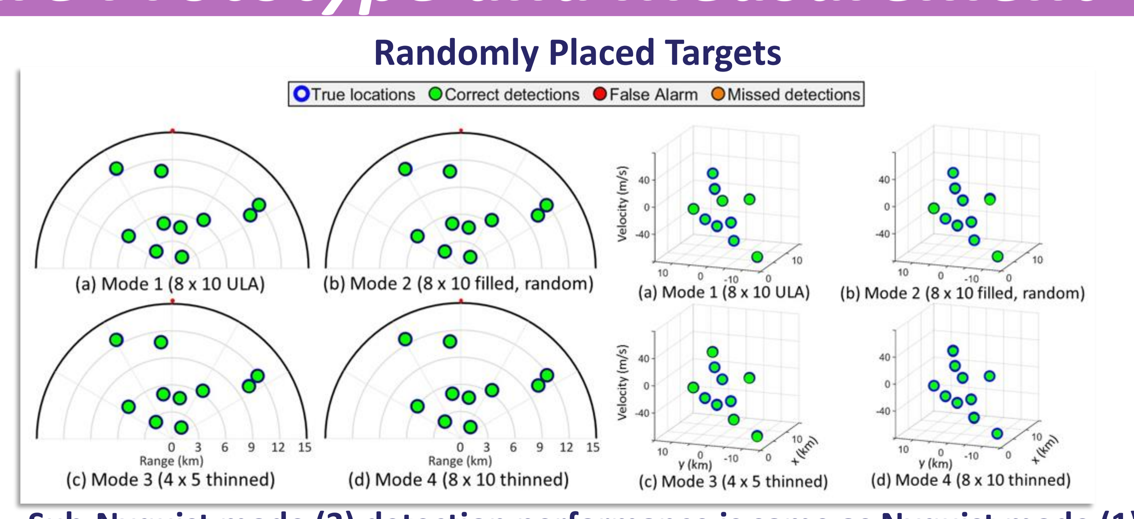
Spatio-Temporal Xampling and Doppler Processing

- Received signal for P pulses at the qth antenna after demodulation:
- Fourier coefficients of the mth transmitter channel at the qth receiver:
- Xampling retrieves the Fourier coefficients from low rate samples
- Doppler focusing for a specific frequency ν
- Goal: Recover delay, azimuth, Doppler and reflectivity from $\phi_{m,q}[k]$
- Fourier coefficients for the mth transmission in matrix form
- Use OMP for simultaneous sparse 3D recovery with focusing

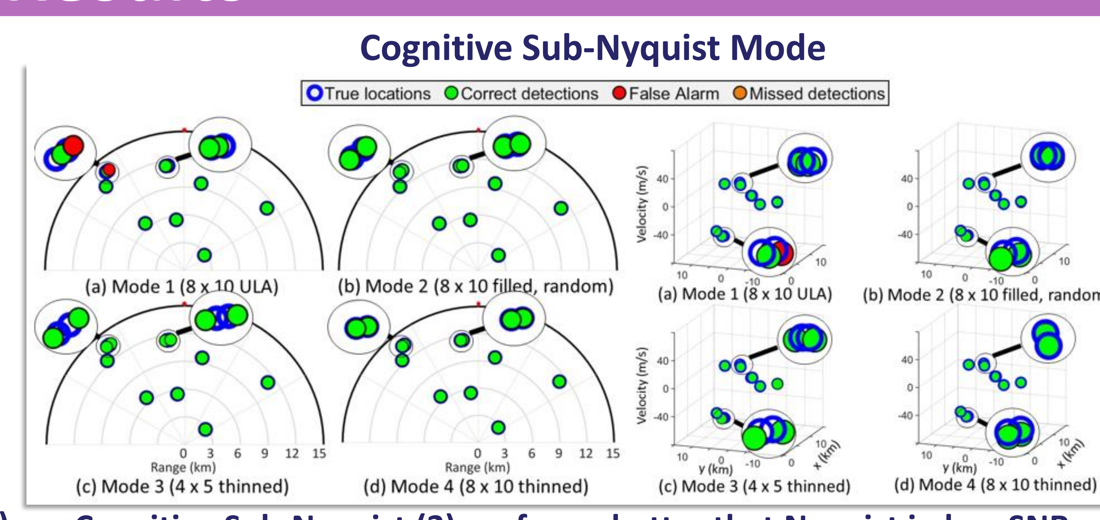


Hardware Prototype and Measurement Results





Sub-Nyquist mode (3) detection performance is same as Nyquist mode (1)

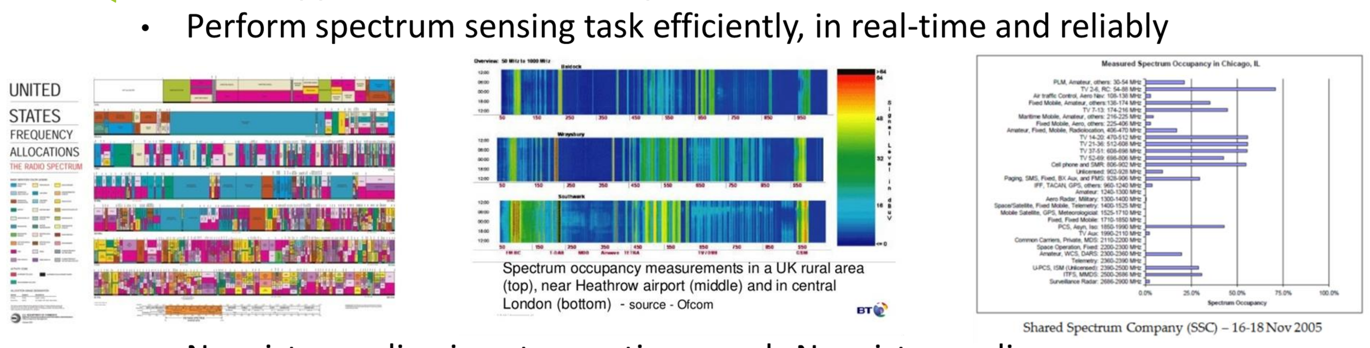


Cognitive Sub-Nyquist (3) performs better that Nyquist in low SNR

CompreSsed CArrier and Direction-of-arrival Estimation (CaSCADE)

Cognitive Radio (CRo)

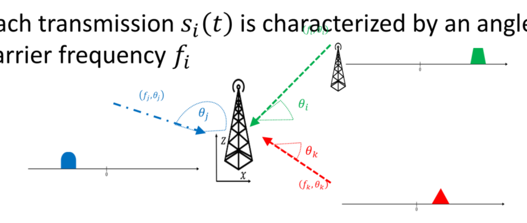
- Address the conflict between spectrum saturation and underutilization
- Grant opportunistic access to spectrum "holes" to unlicensed users
- Perform spectrum sensing task efficiently, in real-time and reliably



- Nyquist sampling is not an option ⇒ sub-Nyquist sampling
- Joint DOA estimation and spectrum sensing increase CR efficiency

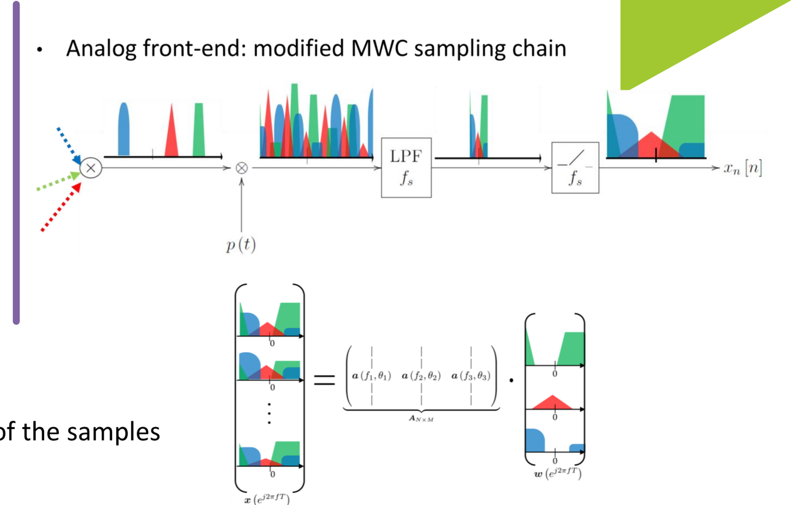
Signal Model and Sampling Scheme

- Multiband model: M signals with max. bandwidth B and max. frequency $\frac{f_{Nyq}}{2}$
- Each transmission $s_i(t)$ is characterized by an angle of arrival (AOA) θ_i and carrier frequency f_i



Goal: perfect blind reconstruction of θ_i, f_i and $s_i(t)$

- Analog front-end: modified MWC sampling chain



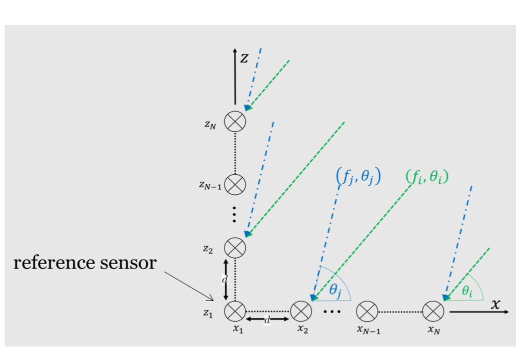
- Relation between known discrete time Fourier transforms (DTFTs) of the samples from the ULA in x axis and unknown signal Fourier transform:

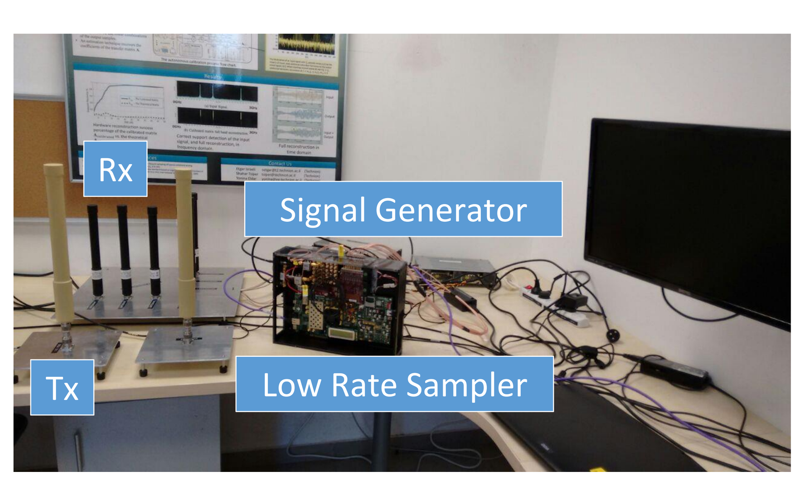
Algorithm, Hardware Prototype and Results

- L-shape ULA with N sensors in x axis and $N+1$ sensors in z axis:
- Phase accumulation in x axis: $\Delta\phi_{X_n}(f_i,\theta_i) = \frac{2\pi d}{c} \cdot n \cdot f_i \cos(\theta_i)$
- Phase accumulation in z axis: $\Delta\phi_{Z_n}(f_i,\theta_i) = \frac{2\pi d}{c} \cdot n \cdot f_i \sin(\theta_i)$
- Received signal at n^{th} sensor in x axis: $U_n(f) = \sum_{i=1}^{M} S_i(f-f_i)e^{j\Delta\phi_{X_n}(f_i,\theta_i)}$
- To overcome the pairing problem:

Compute cross correlation matrices between ULAs

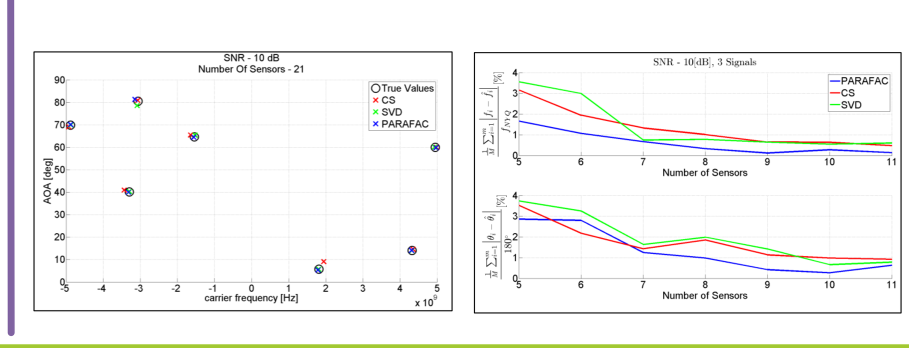
- Perform joint SVD on the cross-correlations
- Compute θ_i and f_i from the paired eigenvalues





Compared methods:

- PARAFAC: iterative algorithm (based on alternating least squares)
- Compressed sensing (CS): exploiting the spectrum sparsity
- Joint SVD ESPRIT (SVD): analytic solution (as presented)

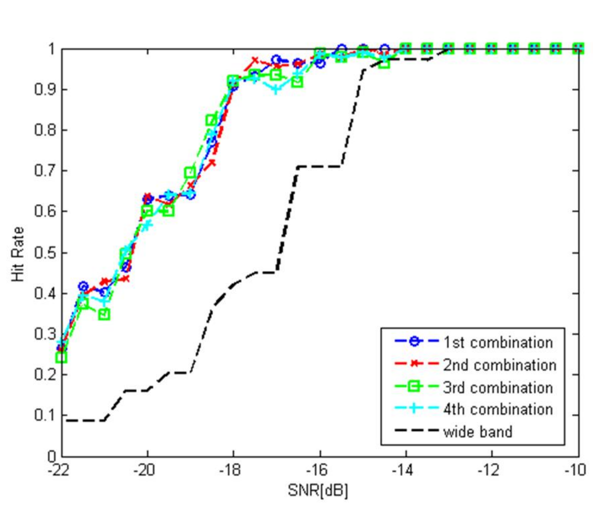


Spectral Coexistence via Xampling (SpeCX)

Cognitive Radar (CRr)

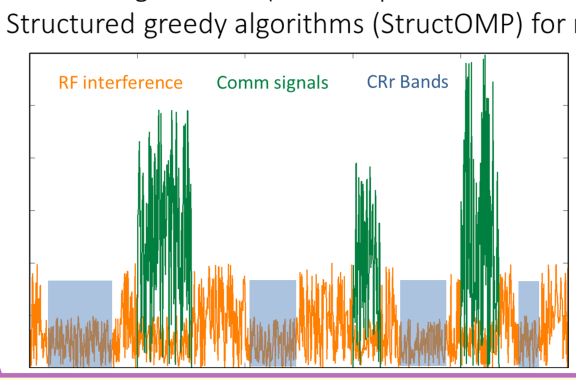
- Transmitter:
  - Only in the available bands
  - Dynamic changes in frequency bands location
- Receiver:
  - Sampling only transmitted bands
  - Xampling techniques to accurately detect targets despite low total bandwidth
  - Recovery process: identical
- Advantages:
  - Reduced transmitted bandwidth: coexistence with communication signals
  - Inherent high SNR system: all the power that was spread along the wideband is now concentrated in the narrow bands
  - Preservation of resolution: Xampling recovery techniques

By transmitting only the bands to sample, we achieve better performance without trade-off

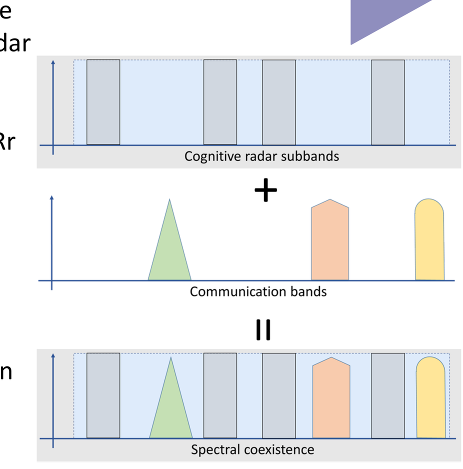


Spectral Coexistence

- Radio Environment Map (REM) is assumed to be known
- Goal: Select bands with minimal interference
- Finding a block sparse vector
- Known length blocks (receiver passband is known *a priori*)
- Structured greedy algorithms (StructOMP) for recovery



- Comm systems can share the unused cognitive radar transmit spectrum
- Recovery for CRo and CRr signals is via Xampling
- Spectral coexistence without loss of range resolution in CRr
- CS-based blind sensing in CRo



Hardware Prototype and Measurement Results