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# Reduced Time-on-Target and Cognitive Radar


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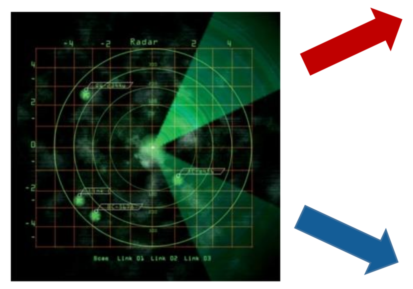
## Contributions

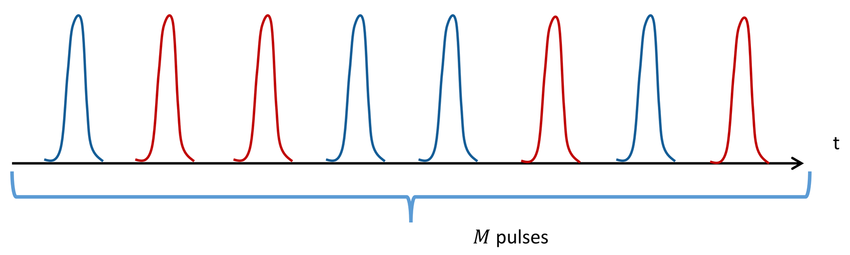
Two extensions of pulse Doppler sub-Nyquist radar:

- Reduced time-on-target: Xampling in time and frequency
- Cognitive radar: dynamic transmission and reception

## Reduced Time-on-Target

- Fast time sub-Nyquist: break the link between bandwidth and range resolution
- Slow time sub-Nyquist: break the link between time-on-target and Doppler resolution
- Uniform pulse Doppler radar: send $M$ pulses to one direction with PRI=τ
  - Recover one delay-Doppler map in CPI=$M$τ
- Non-uniform pulse Doppler radar: send $P = M/k$ pulses in $k$ directions
  - Recover $k$ delay-Doppler maps in CPI=$M$τ






Non-uniform Doppler pulses reduce the time-on-target without harming the range/Doppler resolution

## Non Uniform Pulse Doppler Radar – 2D Xampling

- Received signal:

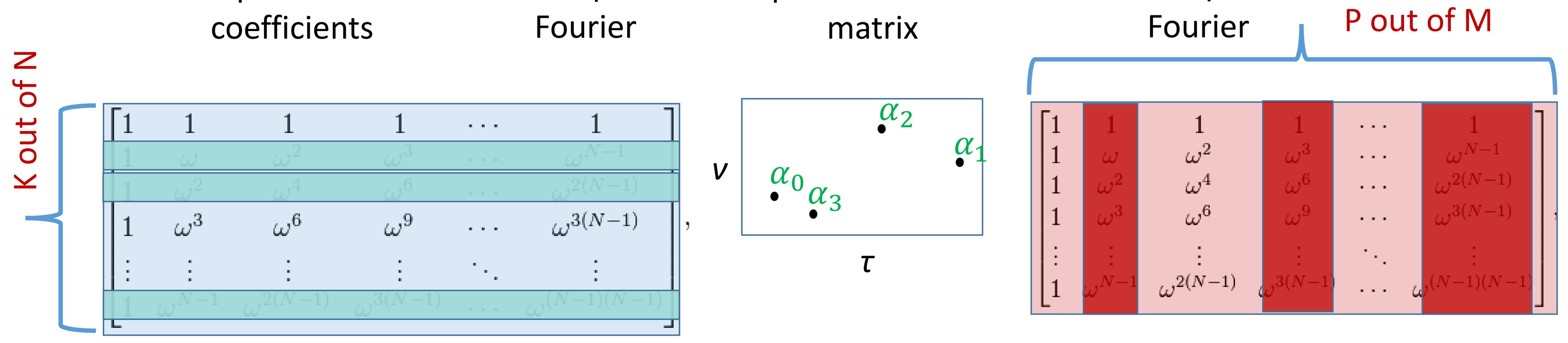
$$x(t) = \sum_{p=0}^{P-1} \sum_{l=0}^{L-1} \alpha_l h(t - \tau_l - m_p \tau) e^{-j\omega_l m_p \tau}$$

- Fourier coefficients:

$$c_p[k] = \frac{1}{\tau} H\left(\frac{2\pi k}{\tau}\right) \sum_{l=0}^{L-1} \alpha_l e^{-j\omega_l m_p \tau} e^{-j2\pi \tau_l / \tau}$$

- 2D Xampling:

$$C = H F_N A (F_M)^T$$

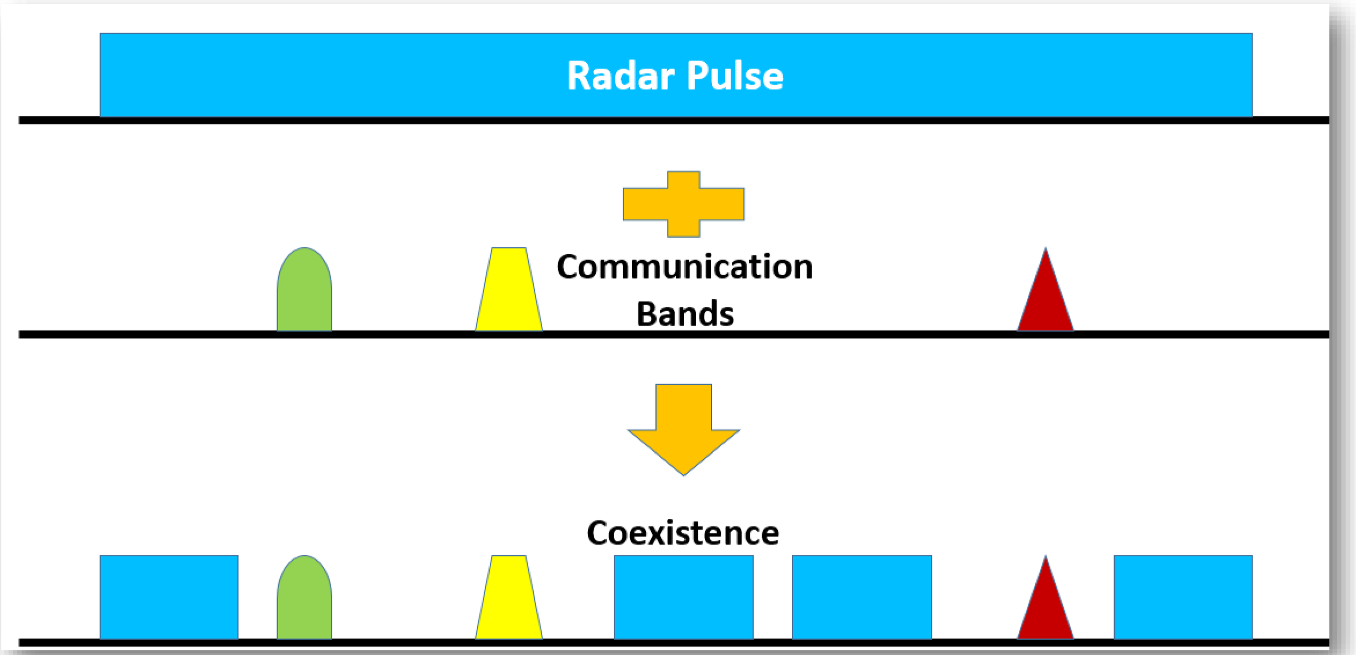



The minimal number of samples required for perfect recovery of $\mathbf{A}$ with $L$ targets in a noiseless environment is $4L^2$, with $K \geq 2L$ and $P \geq 2L$.

## Cognitive Radar – Motivation

Radar system with adaptive transmission and reception capabilities

- Instead of wideband signal transmission, we transmit only chosen bands
- These bands can be spread along the frequency axis in many different combinations




- Coexistence: bands are narrower than Nyquist wideband
- Dynamism: change frequency bands for maneuvering and evasion

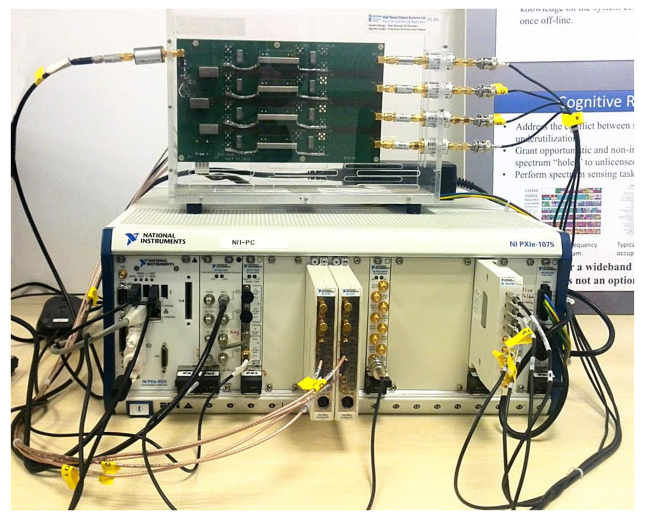
## Cognitive Radar – Implementation

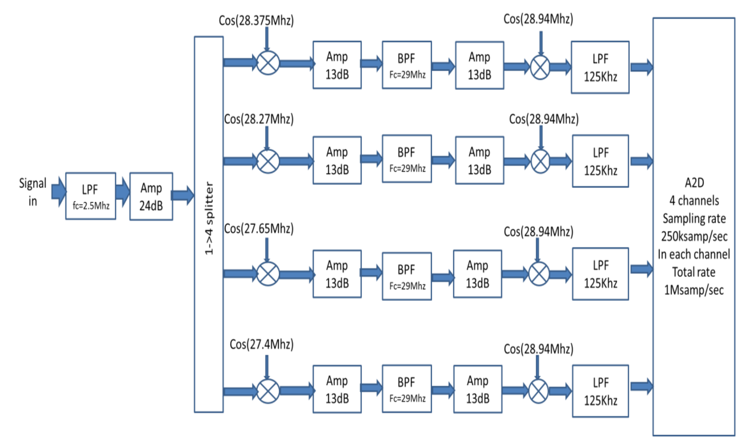
- Transmitter:
  - Only in the available bands
  - Dynamic changes in frequency bands location
- Receiver:
  - Sampling only transmitted bands
  - Xampling techniques to accurately detect targets despite low total bandwidth
  - Recovery process: identical
- Advantages:
  - Reduced transmitted bandwidth: 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

## Hardware Prototype

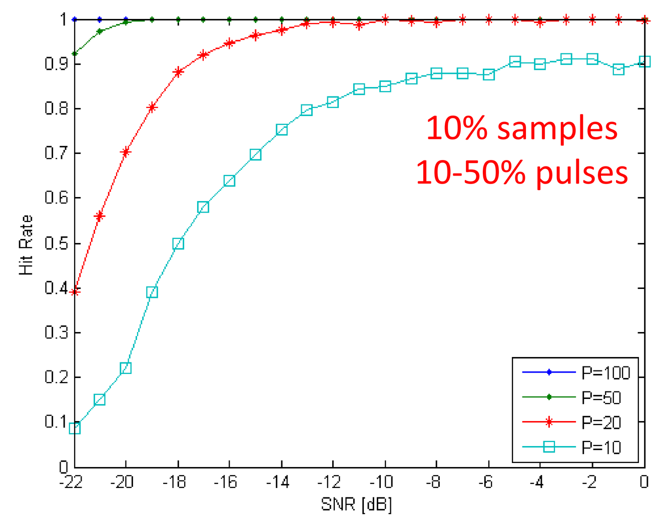
- Sub-Nyquist pulse Doppler radar system

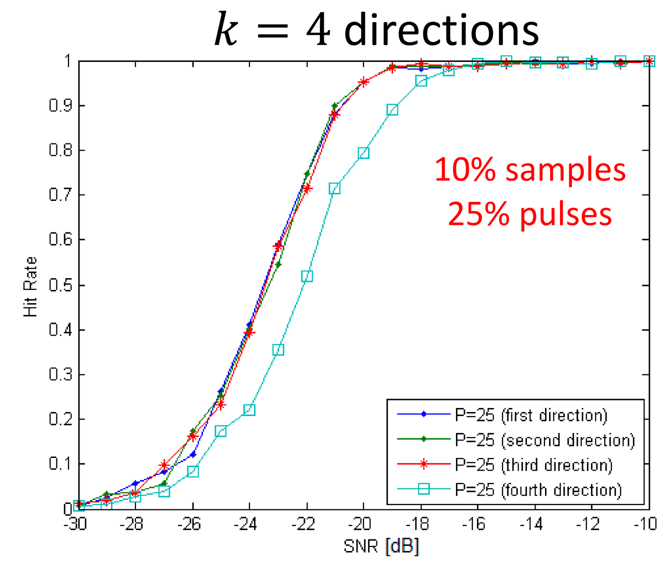




## Simulations results

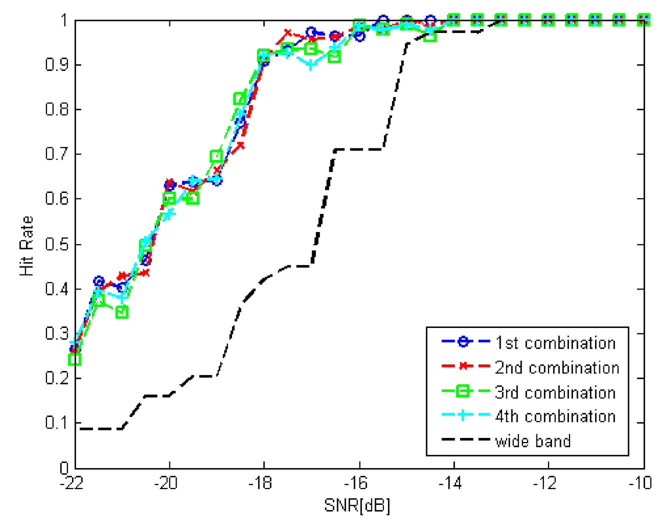
- Reduced time-on-target




| Nyquist rate | Sampling rate | Num. of targets L | PRI τ | Num. of pulses M | CPI Mτ |
|---|---|---|---|---|---|
| 200 MHz | 20 MHz | 5 | 10 μsec | 100 | 1 msec |

- Cognitive radar




| | |
|---|---|
| Nyquist rate | 10 MHz |
| Sampling rate | 320 KHz |
| Num. of targets L | 3-6 |
| PRI τ | 1 msec |
| Num. of pulses M | 100 |
| CPI Mτ | 0.1 sec |

## References


- [1] S. Haykin, "Cognitive radar - A way of the future," IEEE Signal Processing Magazine, vol. 23, pp. 30–40, Jan. 2006.
- [2] E. Baransky, G. Itzhak, I. Shmuel, N. Wagner, E. Shoshan, and Y. C. Eldar, "A sub-Nyquist radar prototype: Hardware and applications," IEEE Trans. Aerosp. and Elect. Syst., vol. 50, pp. 809–822, Apr. 2014
- [3] O. Bar-Ilan and Y. C. Eldar, "Sub-Nyquist radar," Int. ITG Conf. Syst., Comm., Coding, Jan. 2013