Cognitive Radar

Boris Frayman, Michal Aharonov,
Alex Dikopoltsev, Robert Ifraimov, Eli Shoshan and Yonina C. Eldar
Technion-Israel Institute of Technology

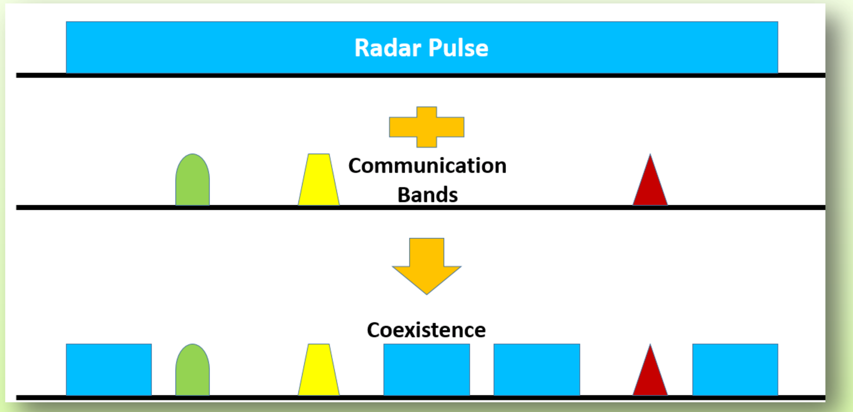
S_X_MPL
Signal Acquisition Modeling and Processing Lab

Project Goal

Demonstrating the feasibility of a "Cognitive Radar" system which uses different narrow bands instead of a wide band transmission. Thus achieving efficient spectrum utilization.

Motivation and Background

- With the advances in technology the demand for Bandwidth keeps growing.
- High resolution radar requires a wideband transmission for accurate results.
- It is essential to minimize the bandwidth used by radar systems.
- Bandwidth minimization enables slower and therefore cheaper sampling and data processing.



Signal Modeling & Doppler Focusing

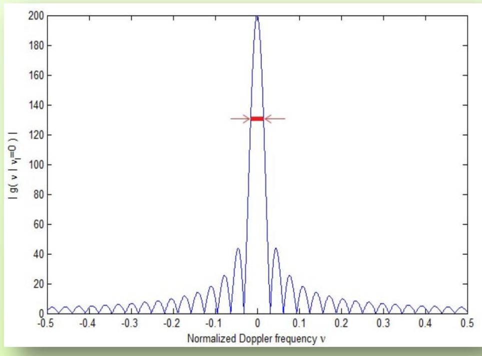
Assuming the following model for the transmitted signal: $x_t(t)=\sum_{p=0}^{P-1} h(t-p\cdot PRI)$

The received signal will be: $x_r(t)=\sum_{p=0}^{P-1}\sum_{l=0}^{L-1}\alpha_l h(t-\tau_l-p\cdot PRI)e^{-j\nu_l p\cdot PRI}$

Performing a DFT yields: $\Phi(t;\nu)=\sum_{p=0}^{P-1} x_p(t+p\cdot PRI)e^{j\nu p\cdot PRI}=\sum_{l=0}^{L-1}\alpha_l h(t-\tau_l)\sum_{p=0}^{P-1}e^{j(\nu-\nu_l)p\cdot PRI}$

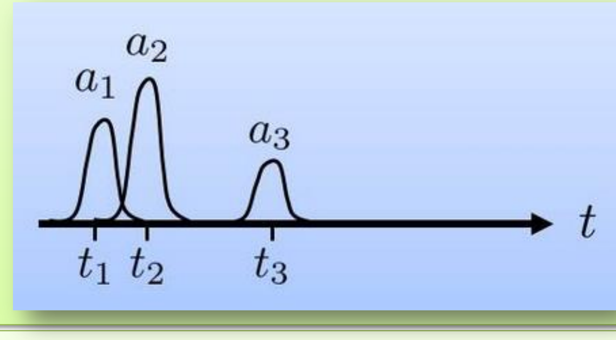
The final sum in the above expression gives the desired frequency isolation:

$$g(\nu\,|\,\nu_l)=\sum_{p=0}^{P-1}e^{j(\nu-\nu_l)p\cdot PRI}\cong\begin{cases}P; & |\nu-\nu_l|<2\pi/(P\cdot PRI)\\ 0\,; & otherwise\end{cases}$$



Orthogonalization

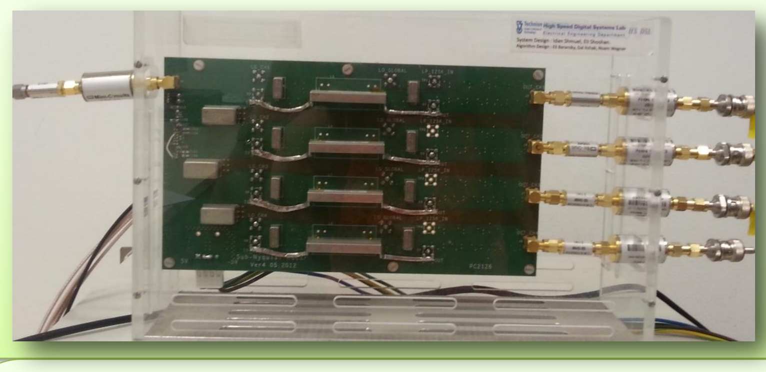
By implementing an OMP algorithm we aim to achieve orthogonalization between the target pulses, which minimizes the damage to the remaining data after a target is analyzed and it's pulse is subtracted.



Block Diagram of the Entire System

Transmission of a 4 narrow bands signal → The signal returns from the targets with changes in amplitude and phase, and a time shift → Analog preprocessing board → Sampling with total rate of 1 MSps → Digital processing witch includes a CS algorithm → Outputs of the system: Velocities and target positions

Pre-Processing Board



Split the signal into 4 channels → Apply crystal BPFs to keep only the desired band in each channel → Transfer the filtered bands to base band (almost) → Sampling of the four channels Sampling freq.: 4X250KHz → Transfer the samples data to the DSP

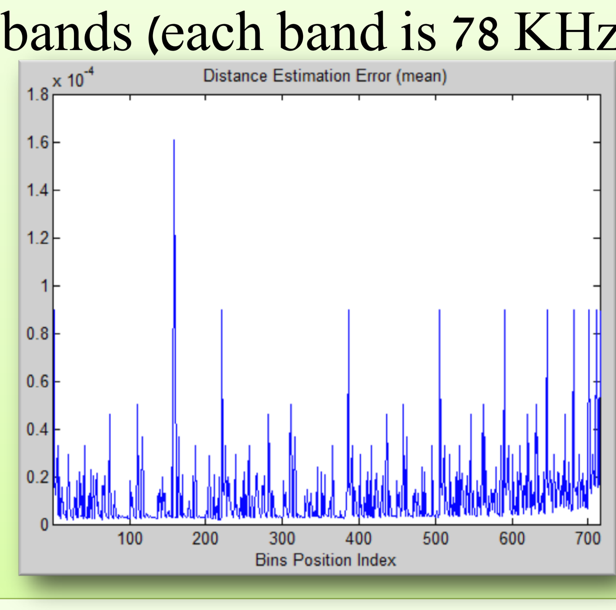
Digital Signal Processing

Received data calibration → Doppler focusing and DFT → Find the target with maximum amplitude for each Doppler frequency, using the OMP algorithm → Pick the target with the largest amplitude and improve it's Doppler resolution using LS → Perform the OMP algorithm with the revised frequency and get updated parameters (while performing Orthogonalization) → Check the target amp. Vs noise thresholds: relative amp., RMS → Build the target pulse according to the parameters found and subtract from the data → Advance to the next target

Simulation Results

First remove the redundant frequency bands from the wideband transmitted signal (10MHz), leaving only the necessary four bands (each band is 78 KHz wide), and verify that switching to four narrow bands doesn't impede system performance.

In the next phase we evaluate the Mean Distance estimation error for different band positions (noting that the velocity estimation error isn't influenced by the band positions). The evaluation is performed by going over all the possible band positions between zero and 10MHz with a resolution of 1MHz.



Conclusions:

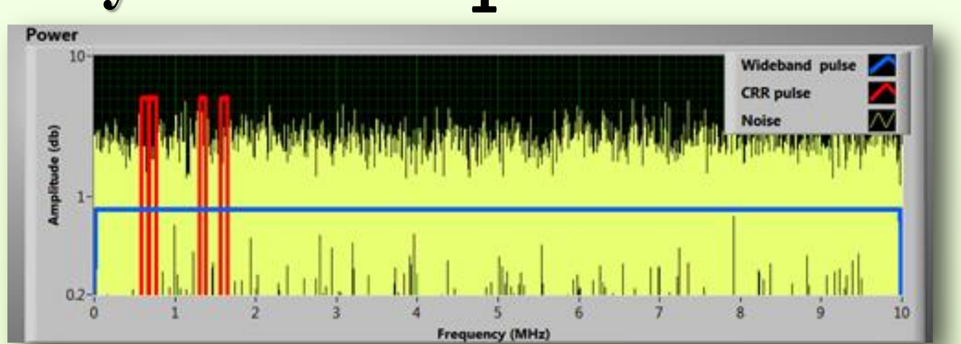
- The cyclical behavior implies that only the relative positions of the bands matter, and not their absolute positions.
- High estimation precision is achieved by adequate spacing between bands.

The Demo System

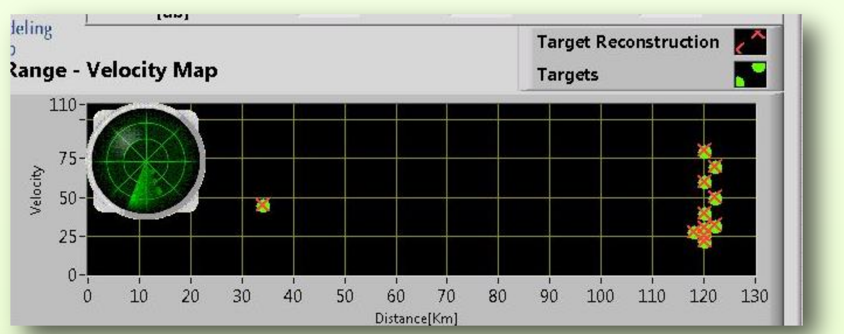
The system GUI includes the following components:

1. Our four bands (red), wide band with equal energy (blue) and noise (yellow)
2. The recovered targets on a Delay-Doppler map
3. Average Range accuracy
4. The Bands we use (red) and other communication bands (white)
5. Received signal in antenna
6. Samples of the four channels

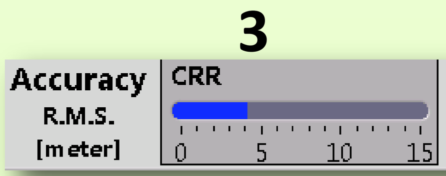
1



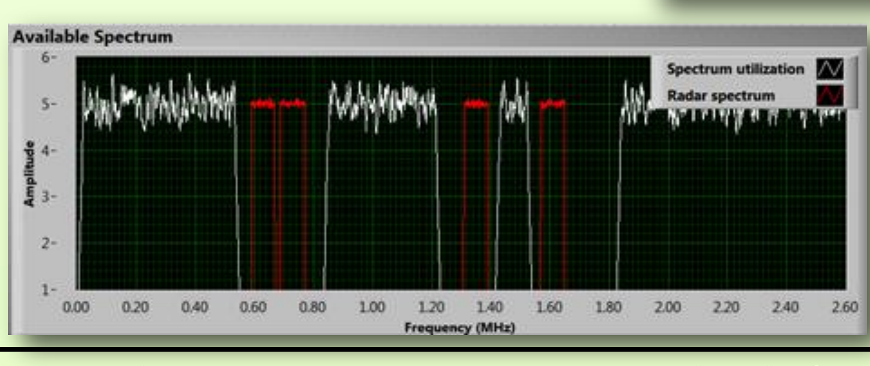
2



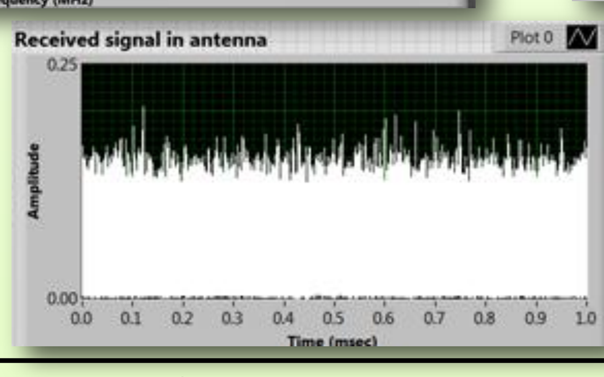
3



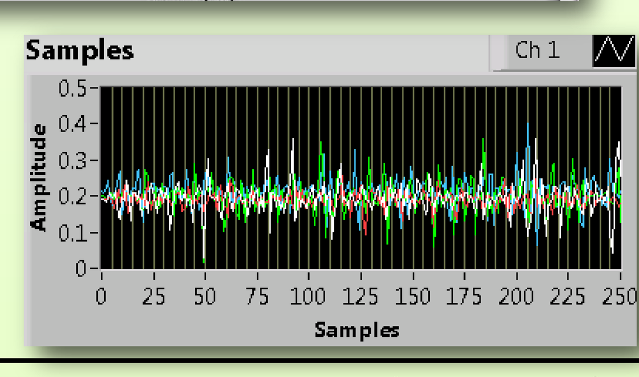
4



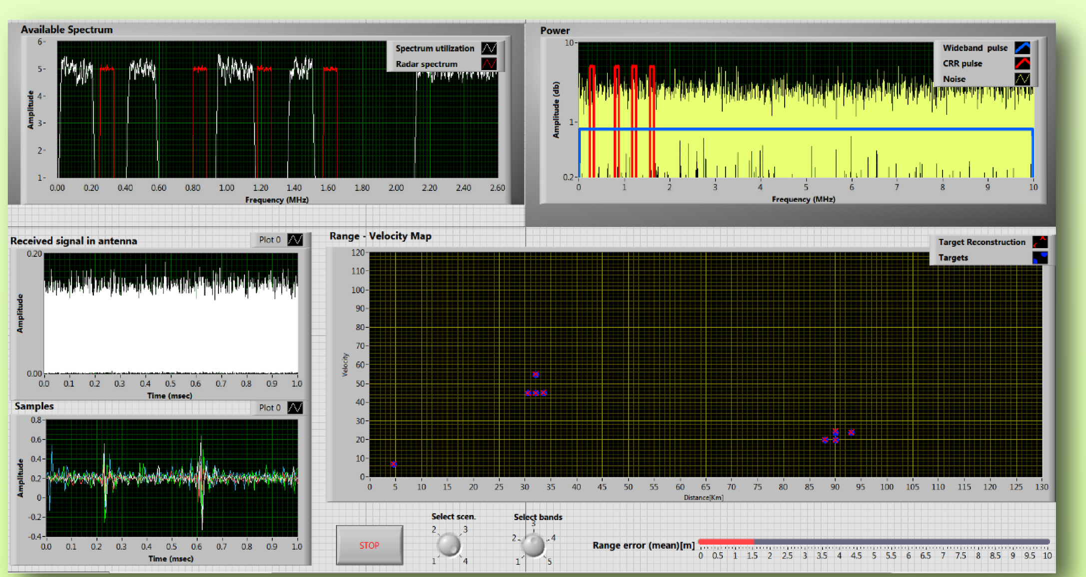
5



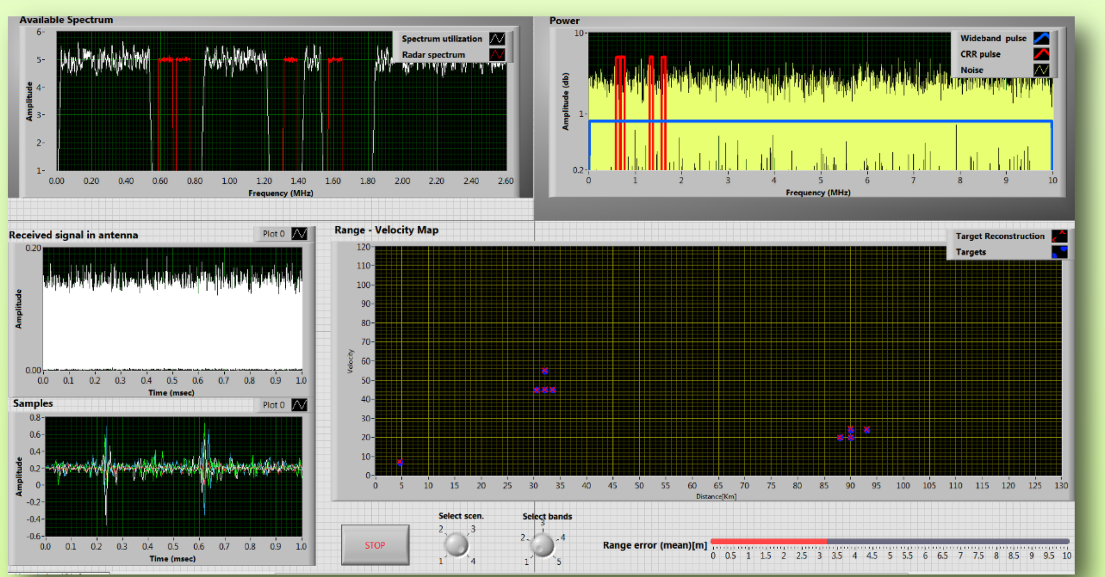
6



A scenario with two clusters of targets, high noise levels and good spacing between the frequency bands. Note the low mean range error of 1.5m.



The same scenario as to the left, except here the frequency bands are more clustered. hence the accuracy is lower.



This scenario contains ten targets, positioned at equal or close to equal distances. Despite that and the noise the system accurately identifies all the targets.