S_X_MPL Signal Acquisition Modeling and Processing Lab

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Cognitive Sub-Nyquist Radar for Automotive Application

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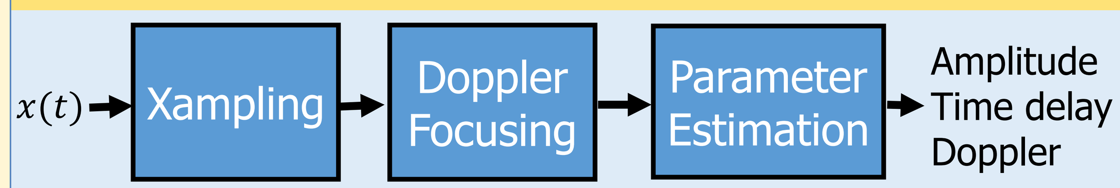
Motivation and Contributions

- High resolution radar requires high bandwidth signals
- Wideband signals need a complex analog front end receiver design which consumes high power
- Digital processing of wideband signals requires large memory and large computational power
- We present a sub-Nyquist cognitive radar prototype for automotive application where the sampling and recovery method implemented in hardware which reduces the rate by 20 fold
- This approach provides both simple recovery and robustness to noise by performing beamforming on the low rate samples
- For automotive applications, simultaneous transmission of multiple vehicles is achieved by cognitive band selection. This also aids in robust reconstruction

Sub-Nyquist Radar

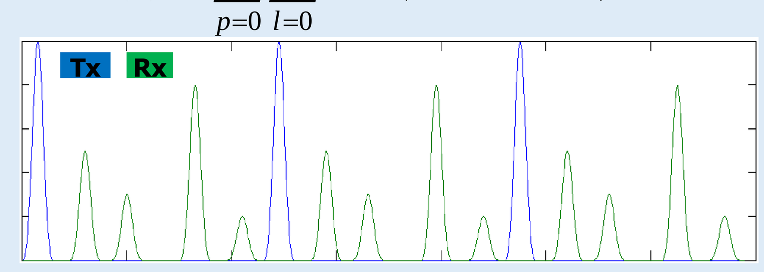


- Xampling– A process of sampling a signal at a low rate in such a way that preserves the required information.
- Doppler Focusing - A method of digitally beamforming the low rate samples which is both numerically efficient and robust to noise.
- Estimation – A modified OMP, matched to our samples, produces target locations and Doppler frequencies.

Signal Model and Recovery

- L targets, each defined by 3 degrees of freedom: amplitude α_ℓ, delay τ_ℓ, and Doppler frequency ν_ℓ.
- After transmitting P equispaced high-bandwidth pulses $h(t)$, the received signal:

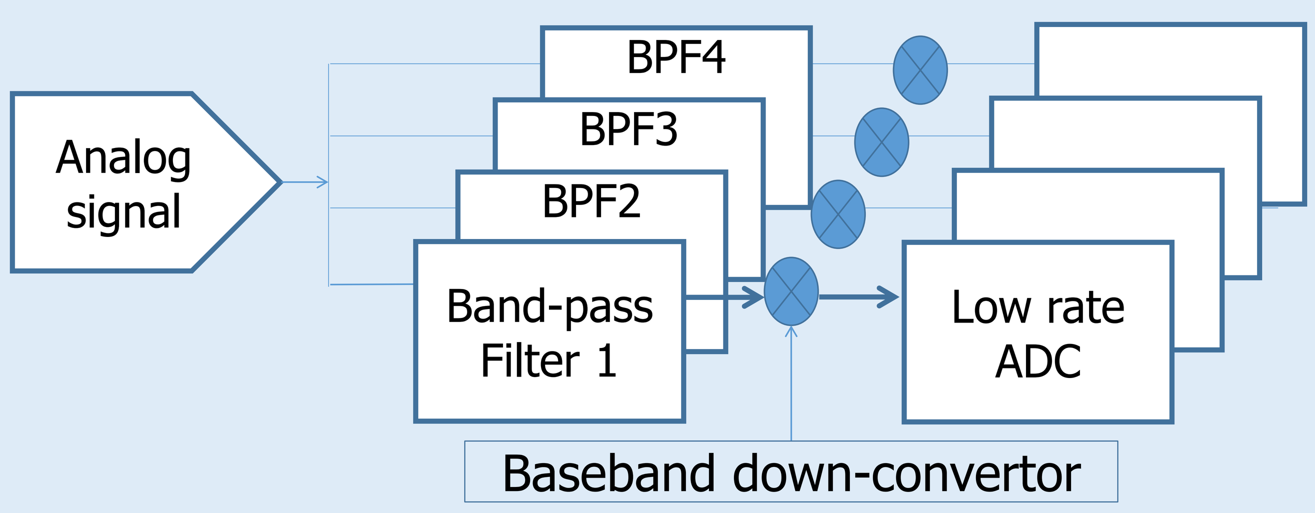
$$x(t)=\sum_{p=0}^{P-1}\sum_{l=0}^{L-1}\alpha_l h(t-\tau_l-p\tau)e^{-j\nu_l p\tau}$$

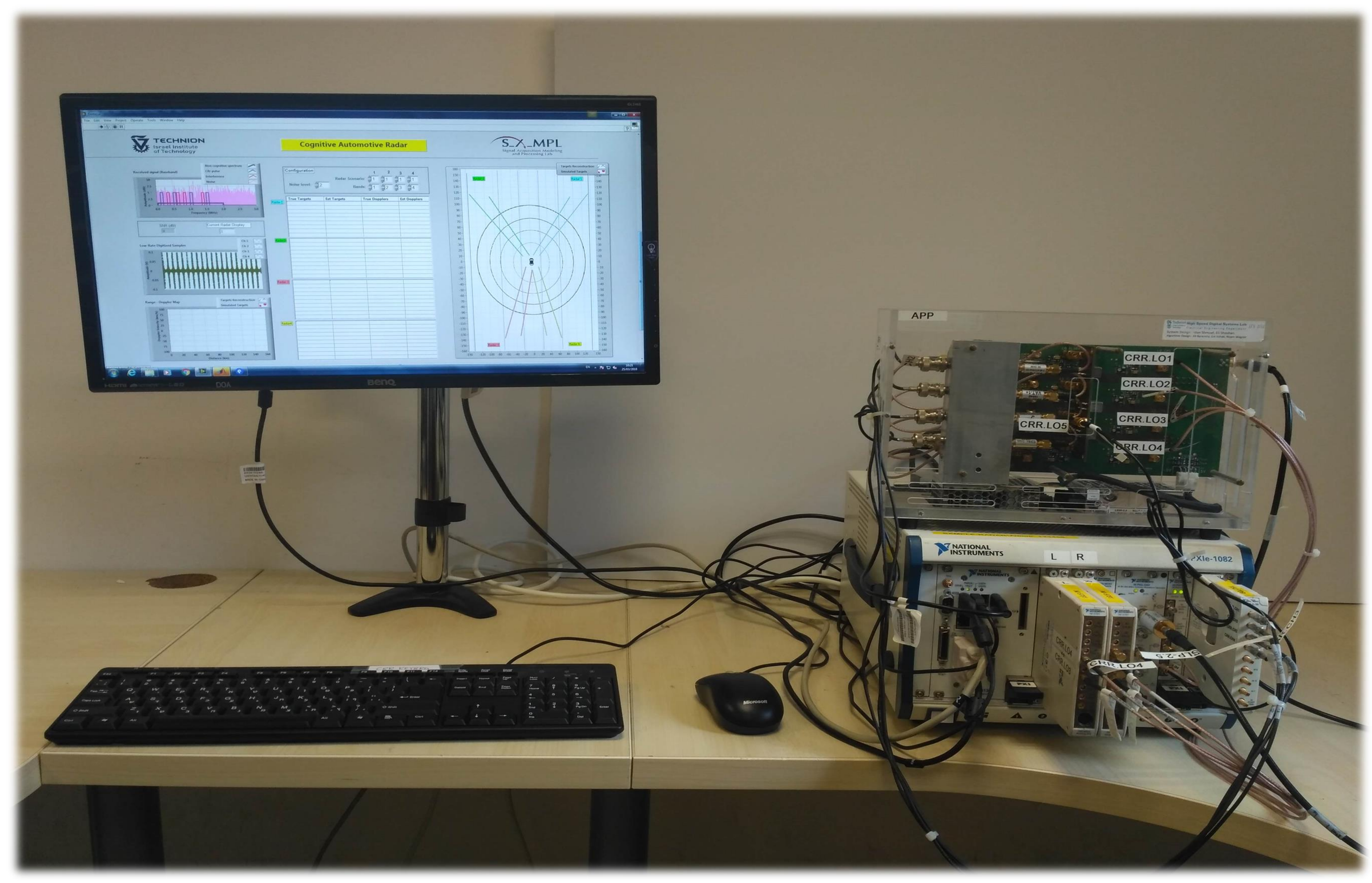


- This is an FRI model as $x(t)$ is completely defined by $3L$ parameters
- The signal's Fourier coefficients contain the required parameters.

Acquiring Fourier Coefficients

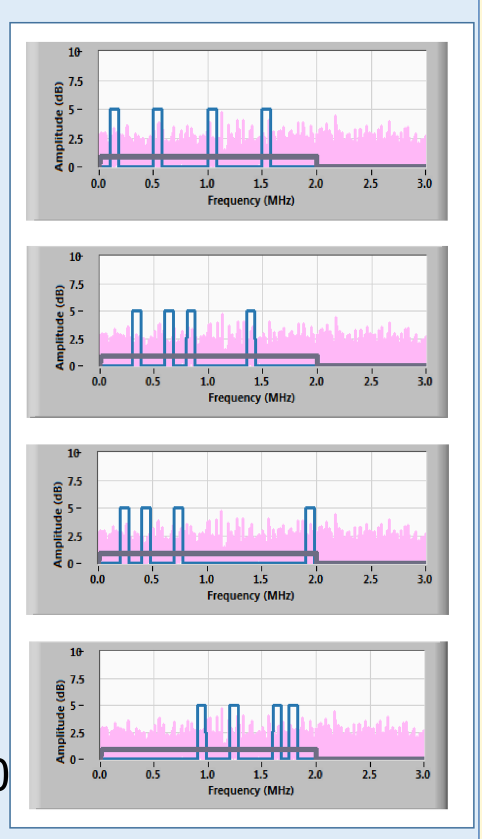
- Multichannel analog processing and low rate sampling scheme are used to extract spectral information for specific frequency bands.
- Calculating Fourier coefficients is performed digitally after sampling



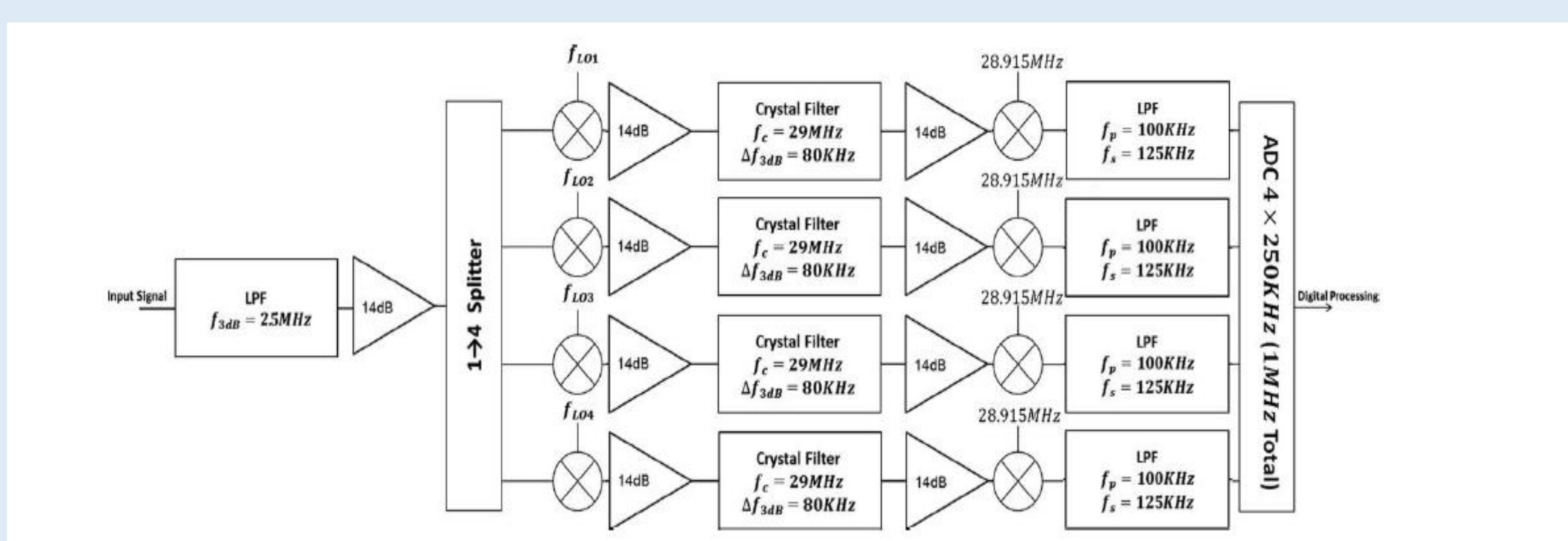


Radar Bands

- Four radars transmits sequentially in four different directions.
- Available bandwidth is 2 MHz; Divided into 16 sub-bands of 80 KHz bandwidth.
- Each radar transmits in four random sub-bands to avoid interference.
- Each of the sub-bands are sampled individually at 250 KHz.



Analog Pre-Processor (APP)

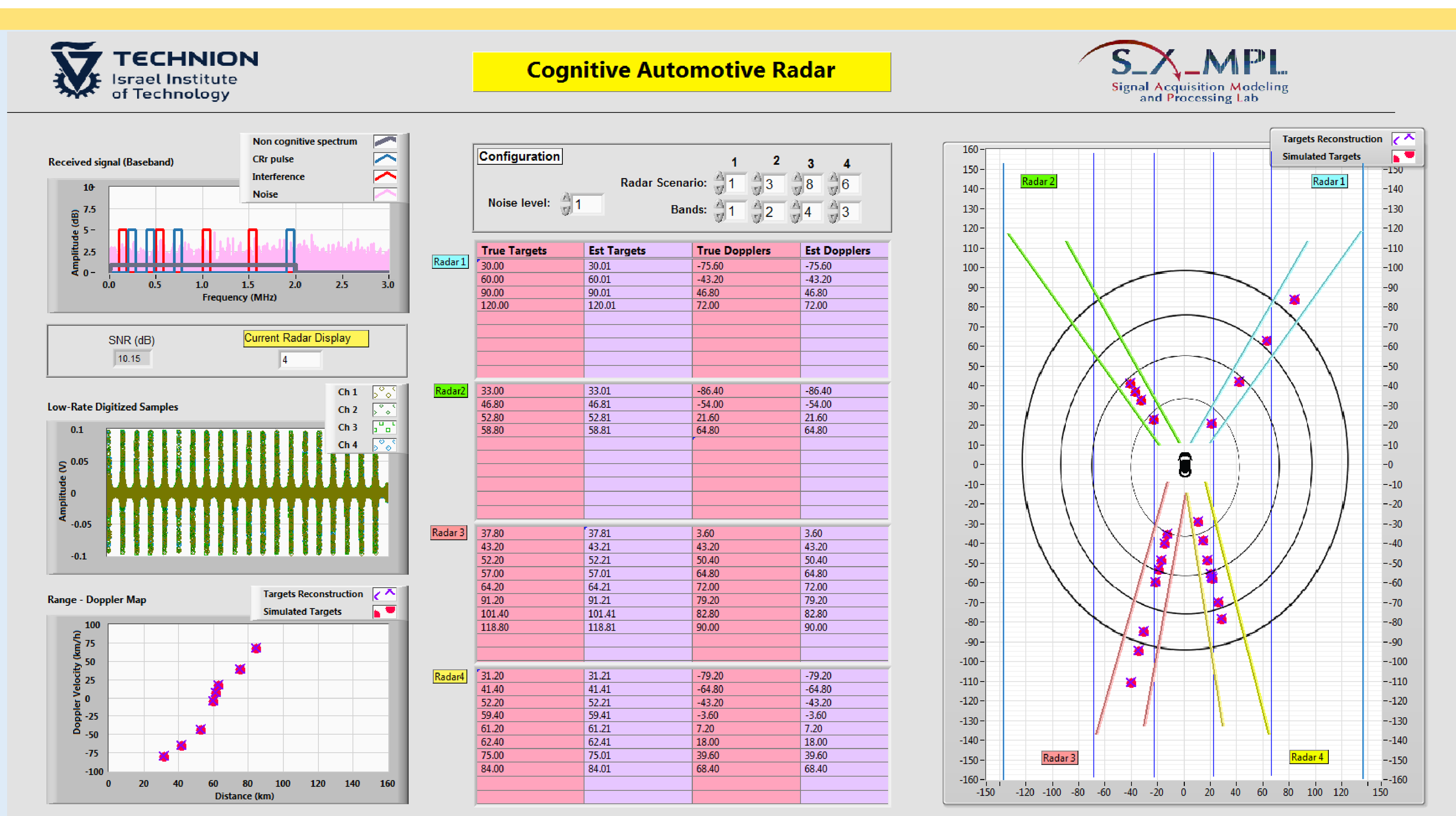


Block diagram of 4-channel crystal receiver. Four up-modulating LOs have frequency values: f_{LO1} = 28.375 MHz, f_{LO2} = 28.275 MHz, f_{LO3} = 27.65 MHz, f_{LO4} = 27.391 MHz.

Crystal Bandpass Filter Characteristics

Parameter	Value
Center Frequency	29 MHz
–3dB Bandwidth	80 KHz
Maximal Pass-band Ripple	1 dB
Stopband Frequencies	28.94 MHz, 29.06 MHz
Minimal Stopband Attenuation	60 dB

User Interface



Results