Technion Israel Institute of Technology

High Speed Digital Systems Lab
Electrical Engineering Department

HS DSL

NATIONAL INSTRUMENTS

Sub-Nyquist Radar Sensing

Front-End and Algorithm

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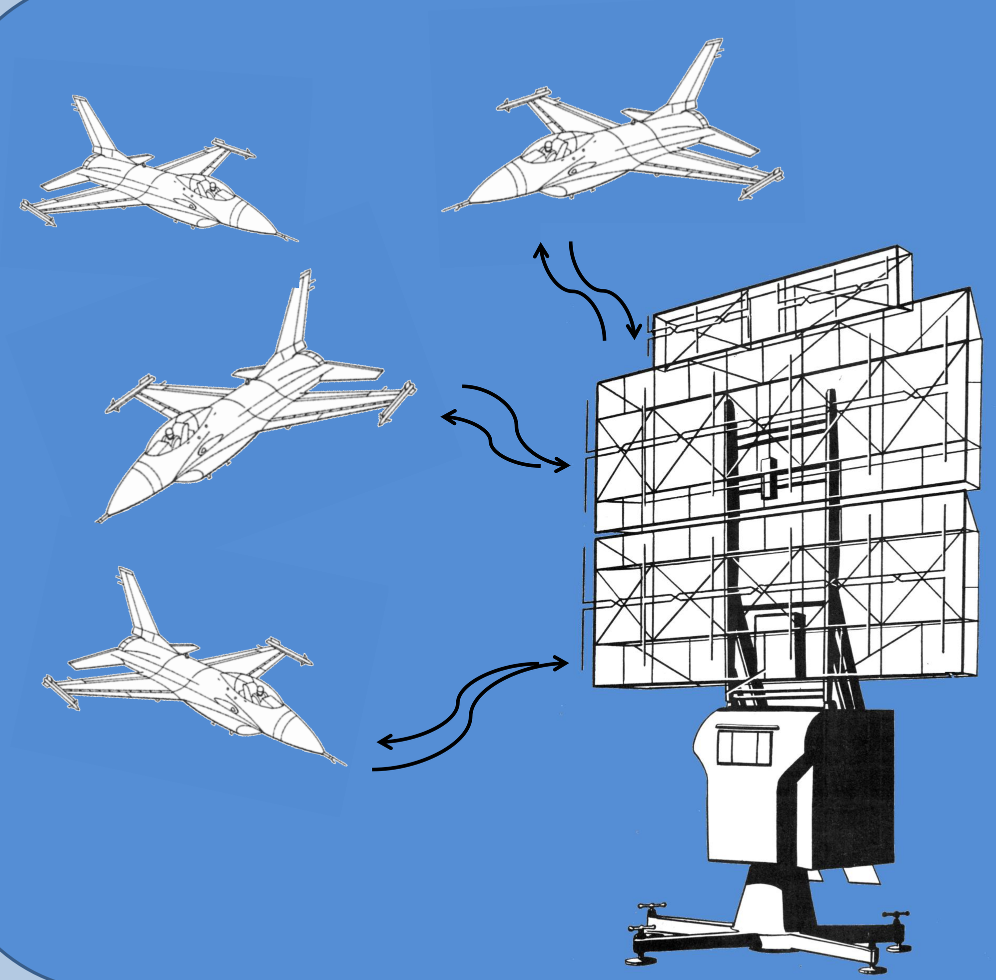
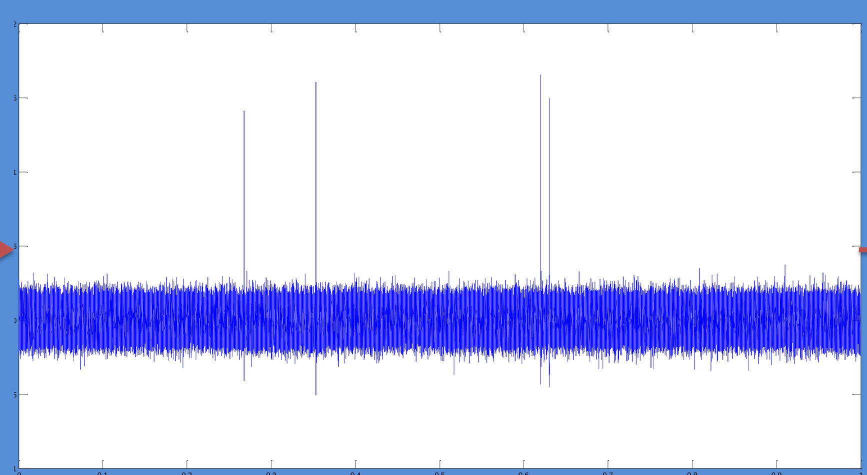
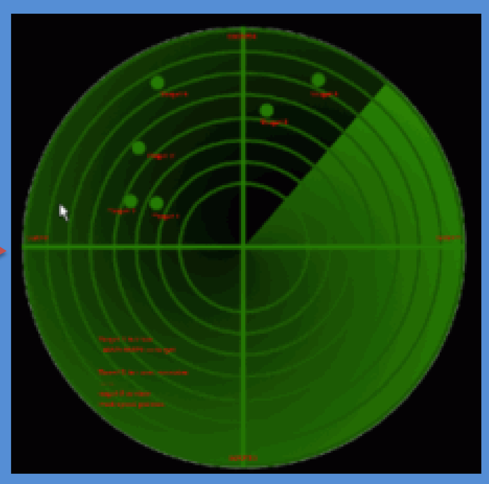
The Radar Problem





High Rate A/D Conversion

Digital Signal Processing

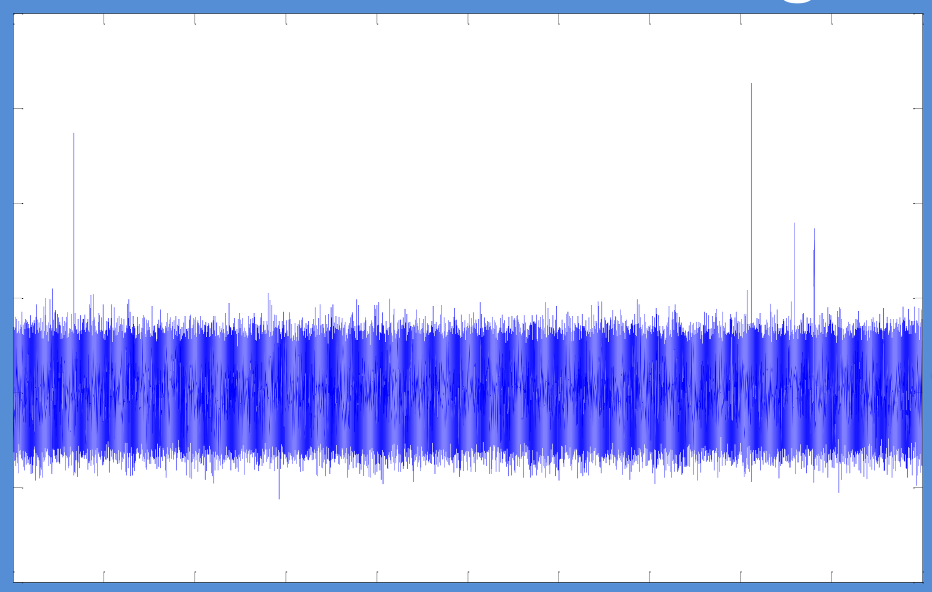


Xampling of Radar Signals

Wideband signals can be sampled at rates much lower than their Nyquist rate, given that they have a Finite Rate of Innovation [1,2,3]. Radar signals with a limited number of targets, are FRI signals with the distances and cross sections (RCS) as unknowns. Using our innovative technique, we are able to reconstruct the distances and the cross sections while reducing the sampling rate by a factor of approximately 30 compared to classical Nyquist-based approaches.

Xampling approach

Received Wideband Signal



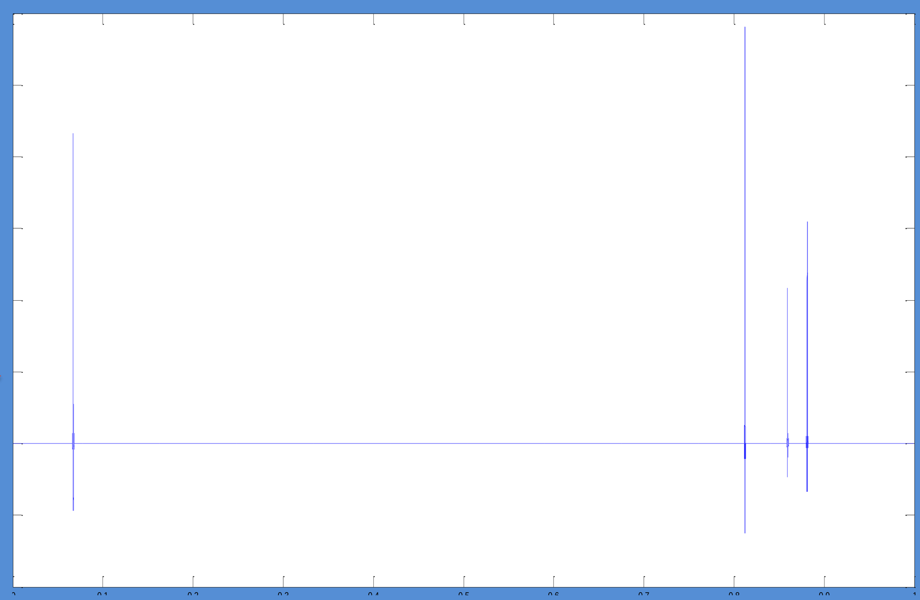
Sub-Nyquist Sampling & Processing

Analog Pre-Processing

Low Rate A/D

Digital Reconstruction Algorithm

Reconstructed Signal



Flow of Reconstruction Algorithm

Low-Rate Samples From 4 Channels $c_i[n]$

FFT Calculation $C_i[k] = DFT\{c_i[n]\}$

Extraction of desired Spectrum samples y

Signal Proxy $s = A^H r$

Maximal Projection $n_l = argmax\{s\}$

Grid Interpolation $\hat{t}_l = n_l \Delta + \delta$ $\Omega \leftarrow \Omega \cup \{\hat{t}_l\}$

Amplitudes Estimations $\hat{a} = (A_\Omega)^\dagger y$ Performed once at the last iteration

outputs $a_l, \hat{t}_l$

Subspace Projection $\hat{y} = A_\Omega (A_\Omega)^\dagger y$

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References

[1] G. Itzhak, E. Baransky, et al "A hardware prototype for Sub-Nyquist radar sensing", *submitted to SCC 2013*

[2] R. Tur, Y. C. Eldar, and Z. Friedman, "Innovation rate sampling of pulse streams with application to ultrasound imaging," Signal Processing, IEEE Trans. on, vol. 59, no. 4, pp. 1827–1842, 2011.

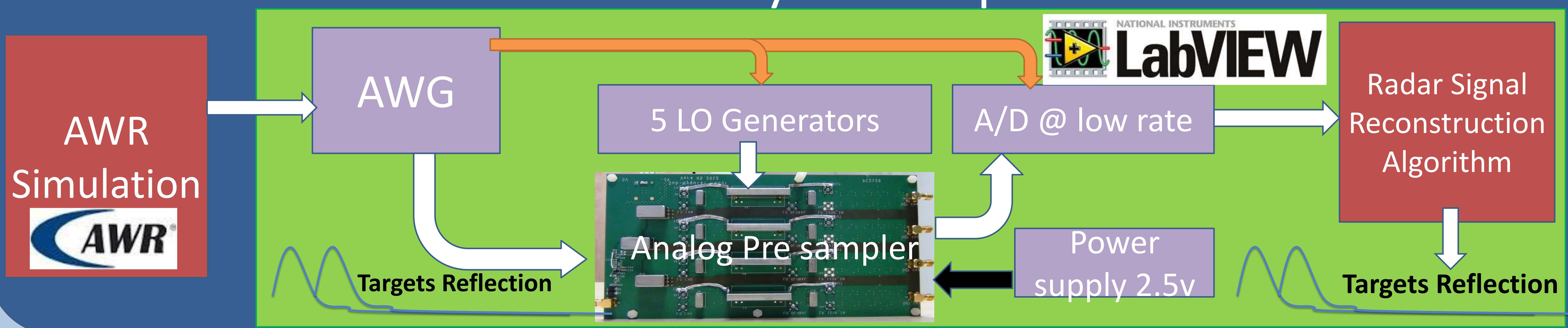
[3] K. Gedalyahu, R. Tur, and Y.C. Eldar, "Multichannel sampling of pulse streams at the rate of innovation," Signal Processing, IEEE Trans. on, vol. 59, no. 4, pp. 1491–1504, 2011.

Sub-Nyquist Radar Sensing

Hardware and Supporting System

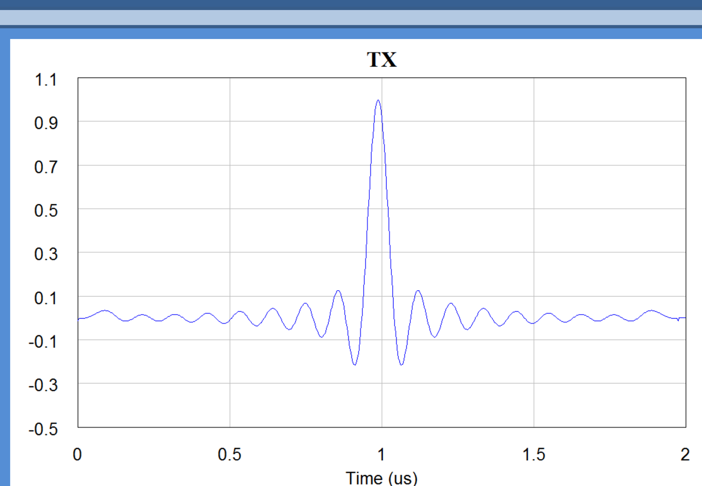
Idan Shmuel, Eli Shoshan, Rolf Hilgendorf and Prof. Yonina Eldar (Technion)
Eran Castiel and Ahsan Aziz (National Instruments)

Demo System Top Level

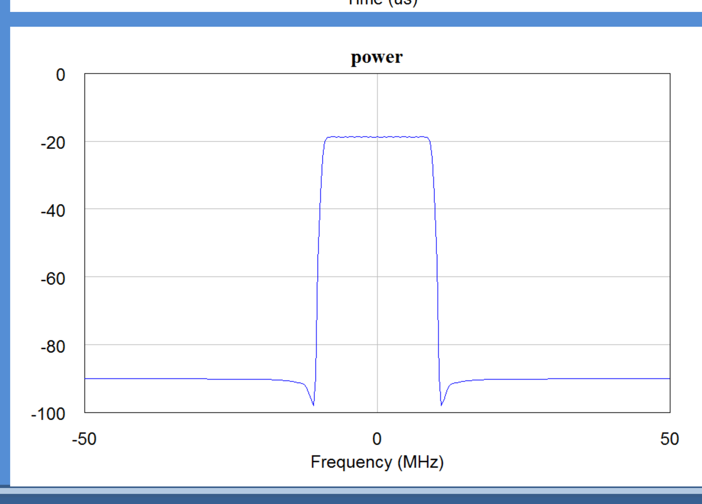


AWR RF Medium simulation

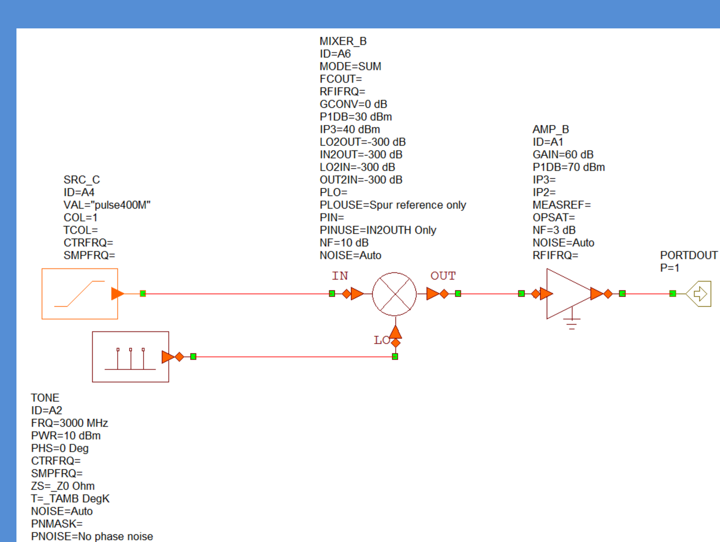
Pulse in time domain



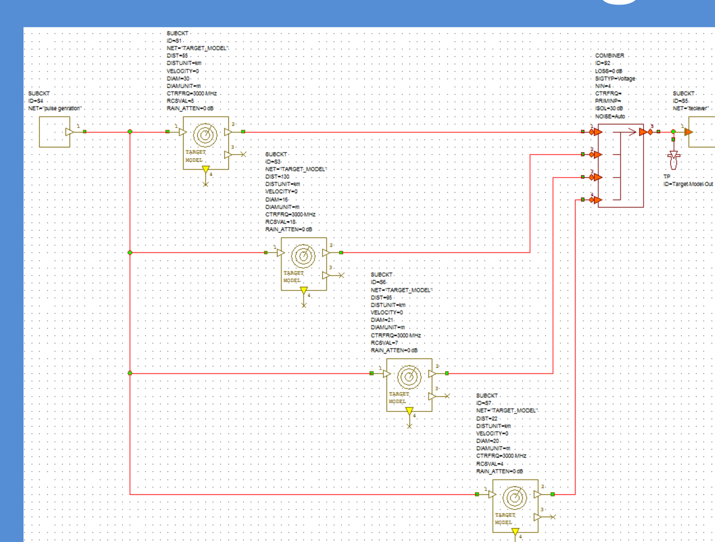
Pulse in frequency domain



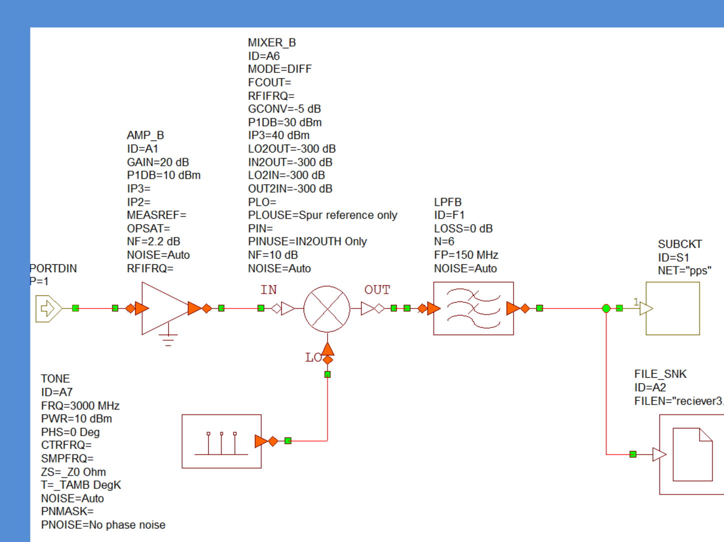
transmitter



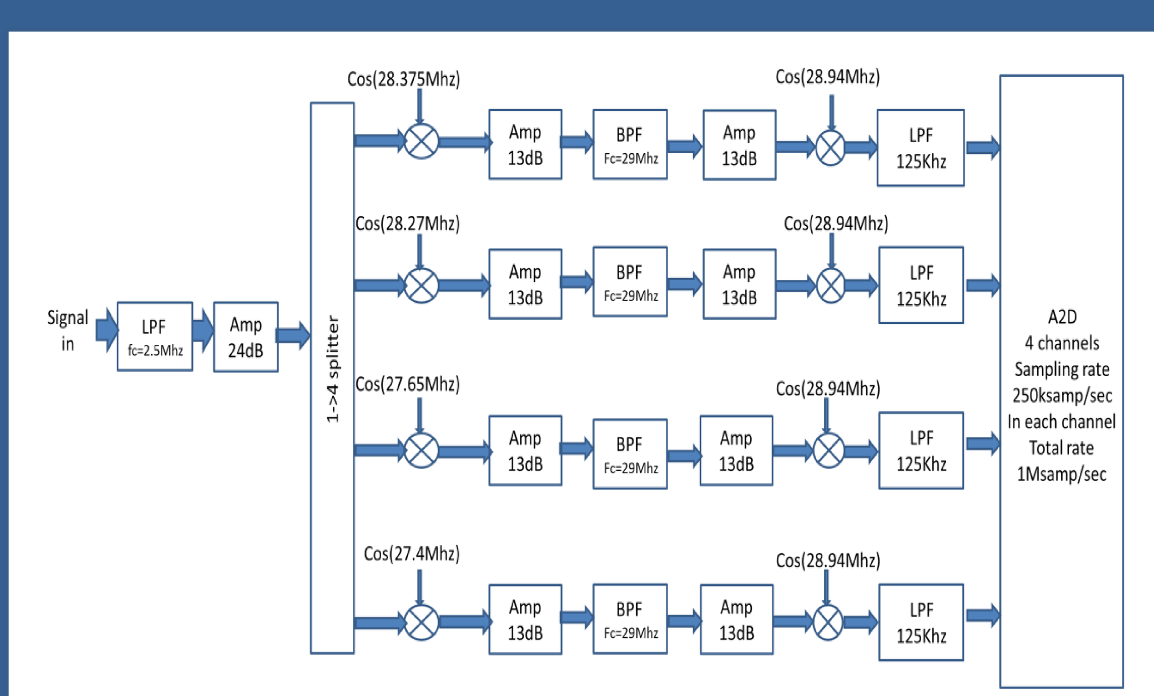
medium and targets

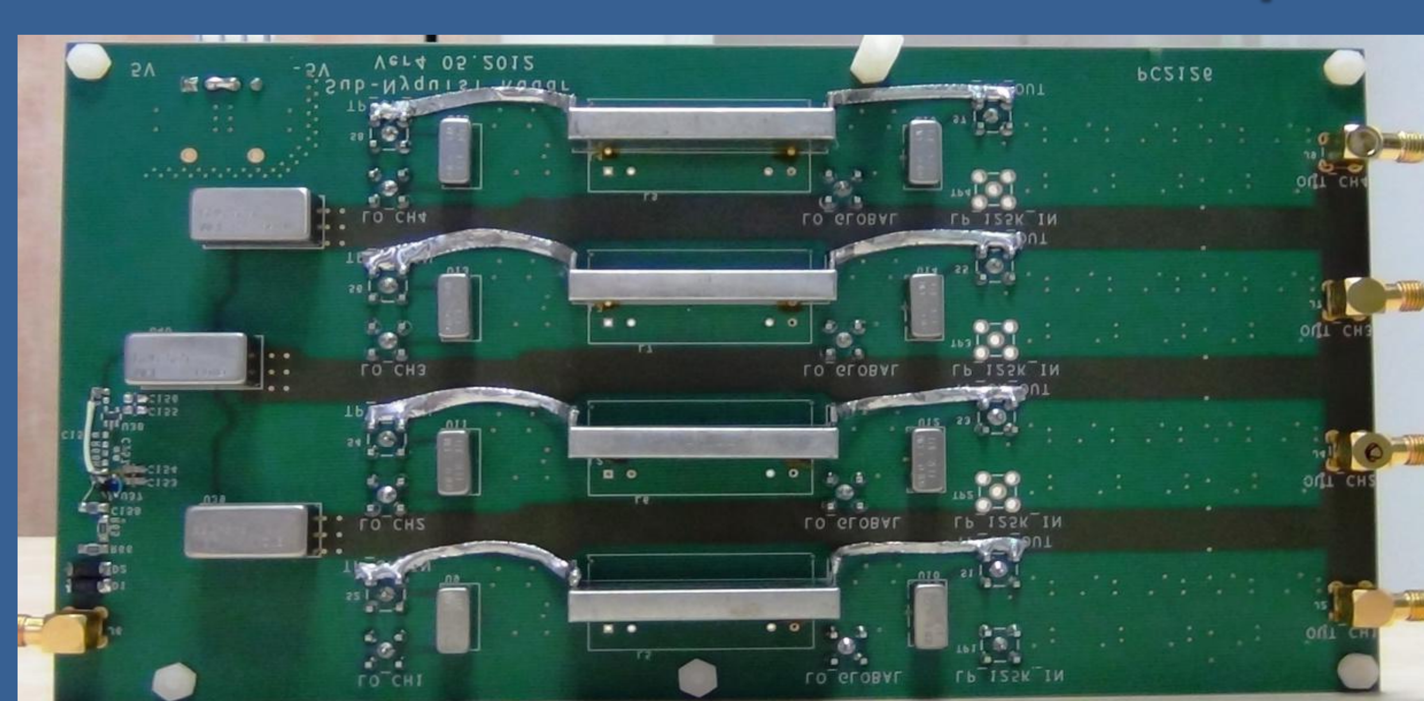


receiver front end



PPS- Pulse Pre Sampler

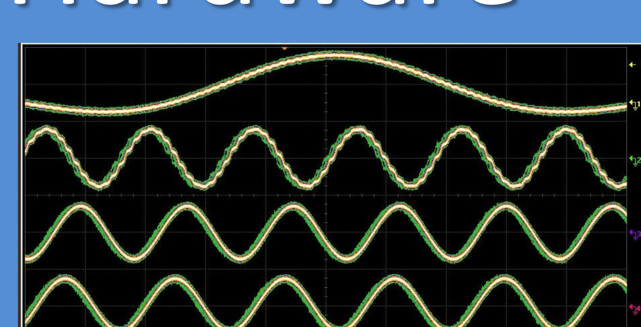




- Input signal BW< 150MHz
- Crystal filter BW 70KHz
- Modular and flexible design
- Dynamic range 65dB

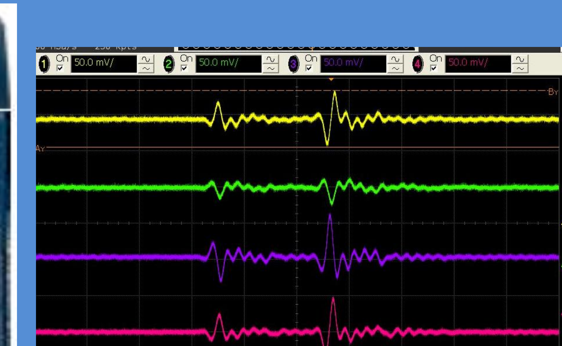
Supporting Hardware – NI System

3 NI Flex Rio 7965R FPGA and NI 5781 Baseband transceiver create 5 local oscillators waveforms with constant starting phase



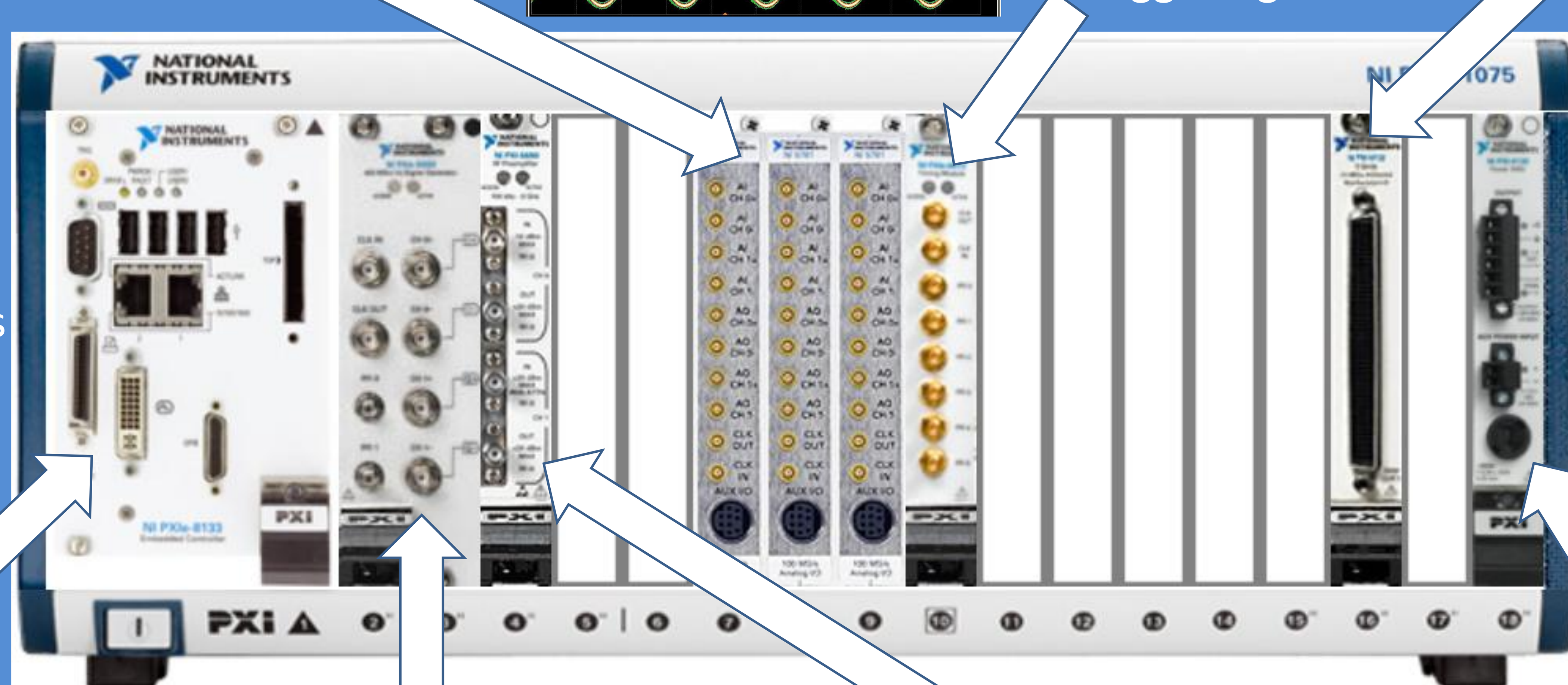
NI 6672 timing and synchronization module distribute clock and trigger signals

NI 6123 4 channels simultaneous A/D @ 250Ksamp/sec per channel

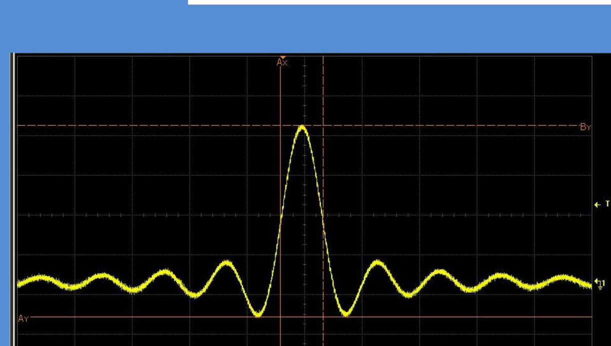


System Challenges:

- Start all devices at the same time with skew less then 1nsec
- Good synchronization- Low clock jitter and small clock drifts between devices
- Connectivity- AWR RF simulation environment to LabView



NI 8133 I7 controller Run AWR , LabView and MATLAB script



NI 5451 Arbitrary Waveform Generator transmits pulse waveform

NI 5690 RF amplifier

NI 4130 Power supply to PPS