भारत इलेक्ट्रॉनिक्स
BHARAT ELECTRONICS

Development of Signal Processor & Extractor Module For 3D Surveillance Radar using MATLAB

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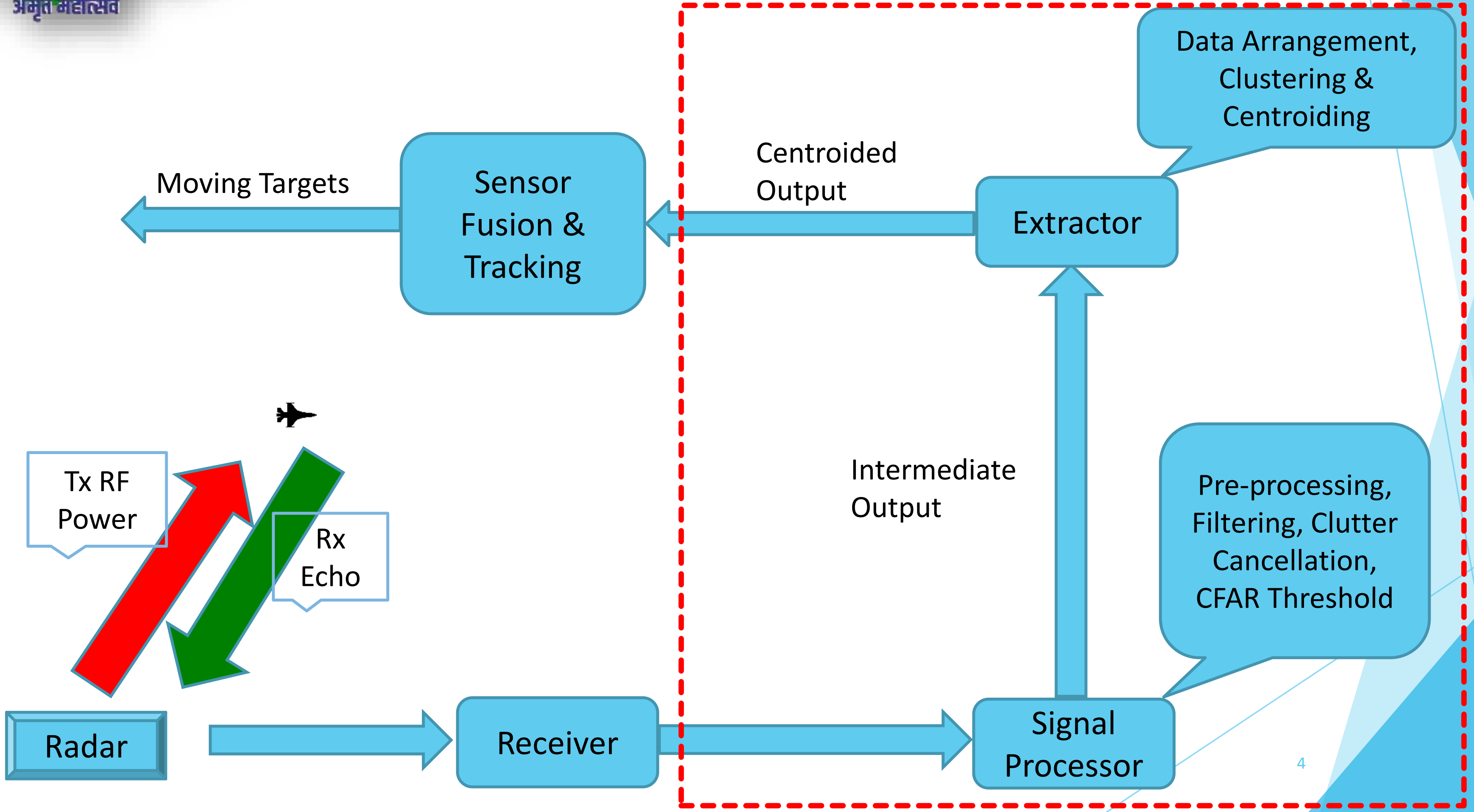
AGENDA

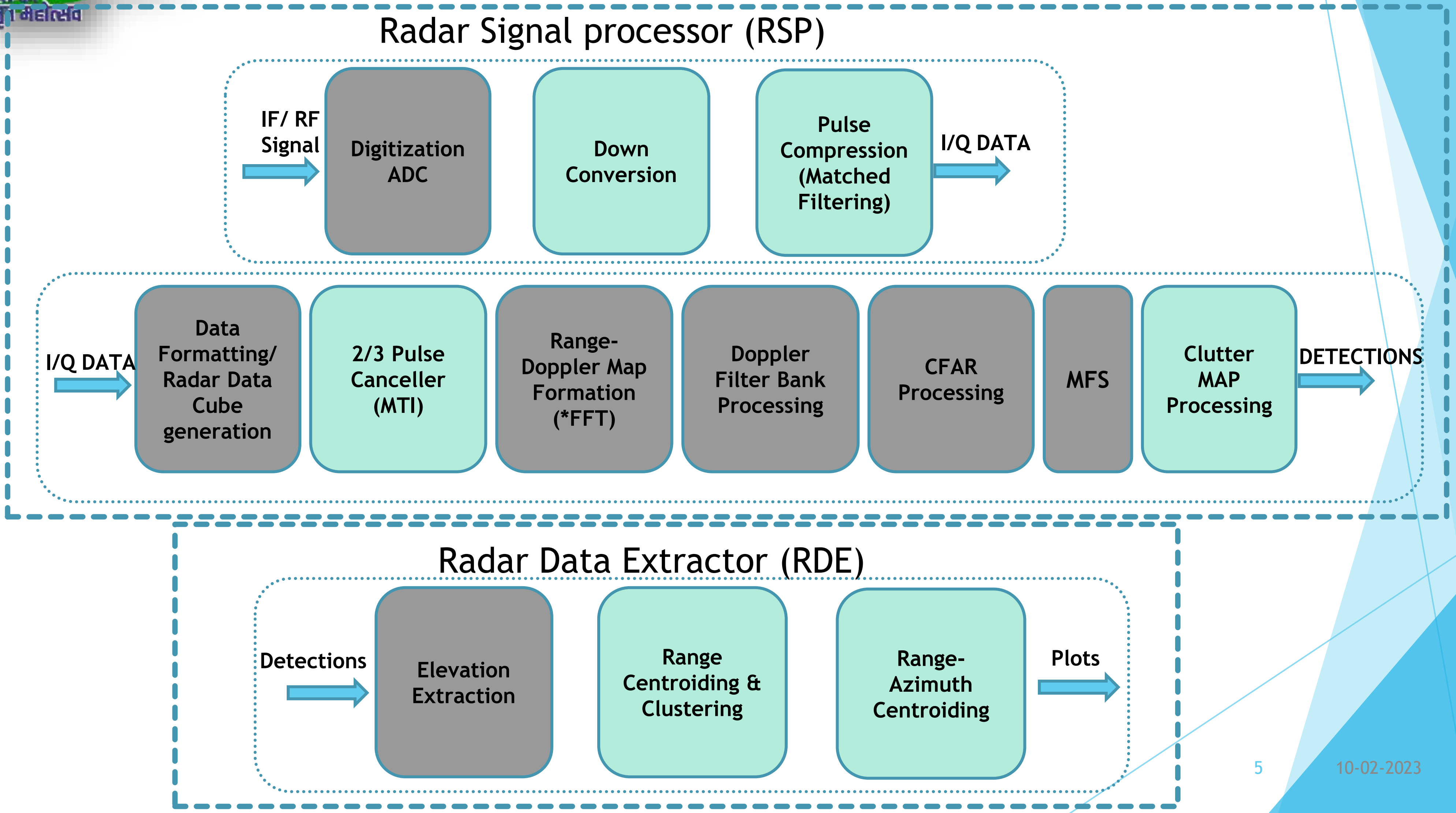
- Modelling customized signal processor modules for 3D surveillance radars
- Discussion on algorithmic complexities in conventional approach
- Ease of implementing and testing algorithms in MATLAB
- Quantifying performance during multiple developmental phases

CAR Series of Radars

Radar System Block Diagram



Algorithmic workflow for RSP & RDE



Challenges & Requirements

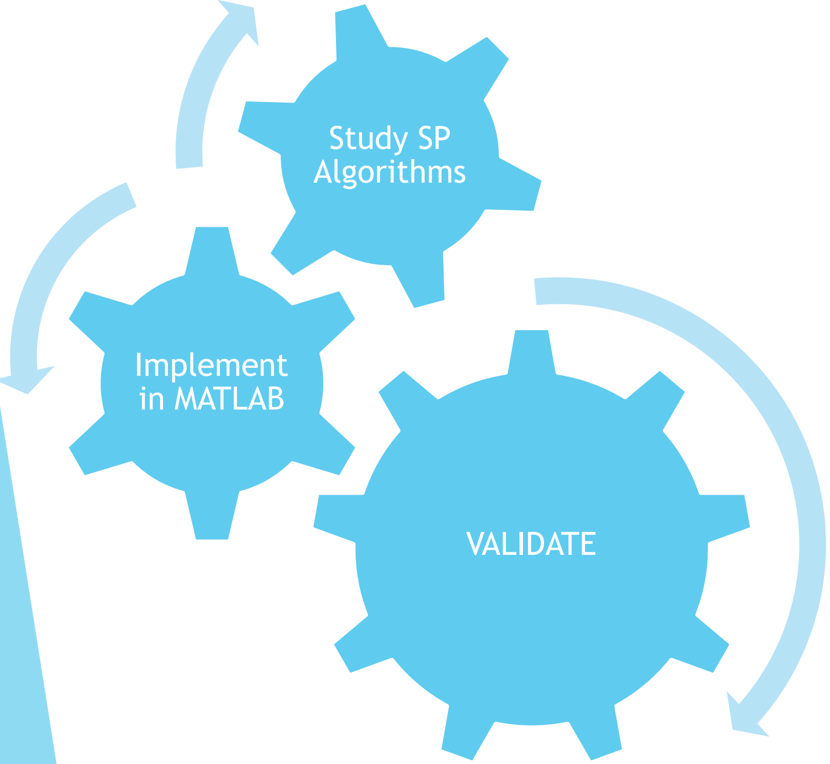
Challenges

- Present RSP code written in legacy languages deployed in obsolete hardware
- Limitations in recording of I/Q level data
- Performance evaluation under non-homogenous clutter environment
- WTG Clutter mitigation for a Low PRF Radar

Requirements

- Development of Radar Signal Processor (RSP) for 3D surveillance radar
- Validate on field recorded data I/Q Data
- Realize Radar Data Extractor in MATLAB
- Test bed for performance evaluation of different algorithms available for Proof of Concept

APPROACH



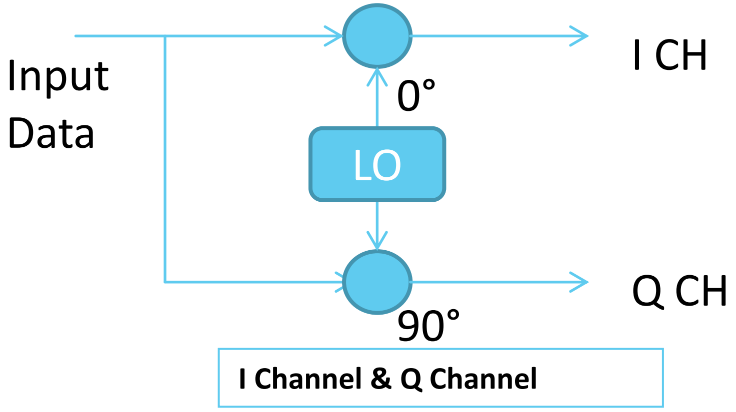
Phase-1
- Realization of main SP Algorithms in MATLAB

Phase-2
- Validation on Actual Radar site recorded data

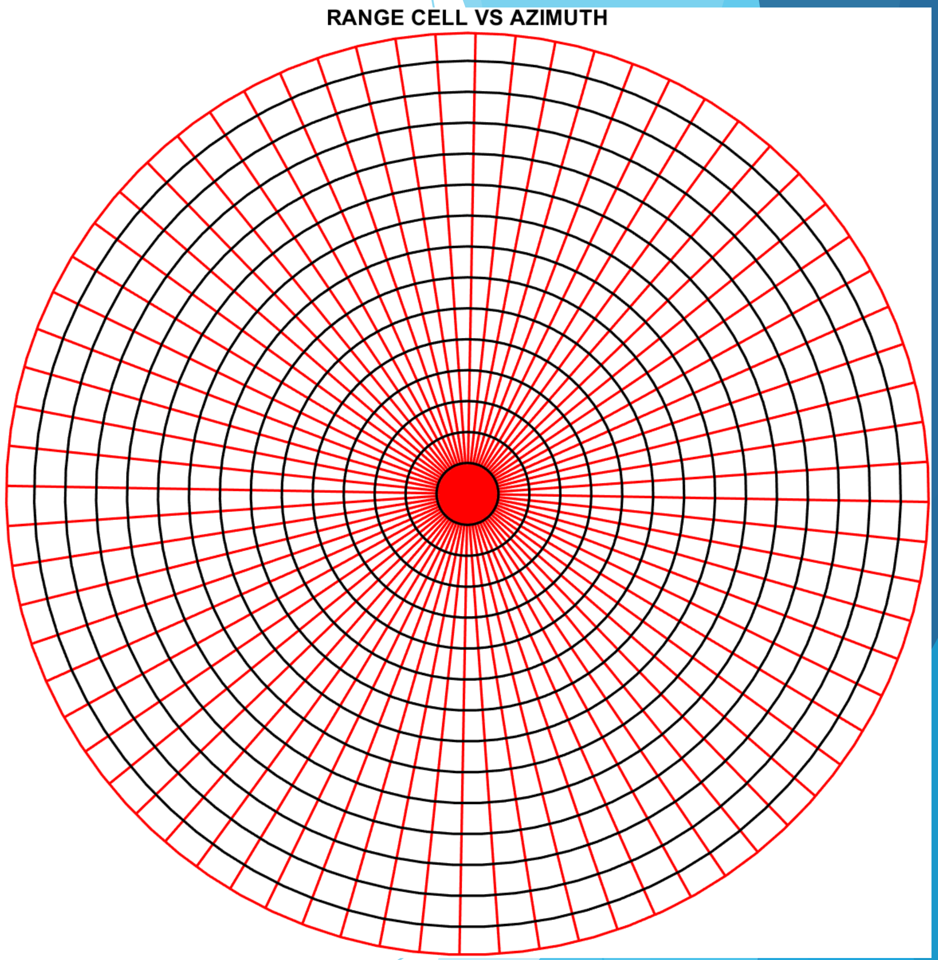
Phase-3
- Implementation & Performance analysis with Robust CFAR algorithms
- Realization of Radar Data Extractor in MATLAB

Future Scope
- Land & Sea Clutter simulation
- WTG Clutter characterization
- WTG Cutter Mitigation

IQ Data Volume Estimate

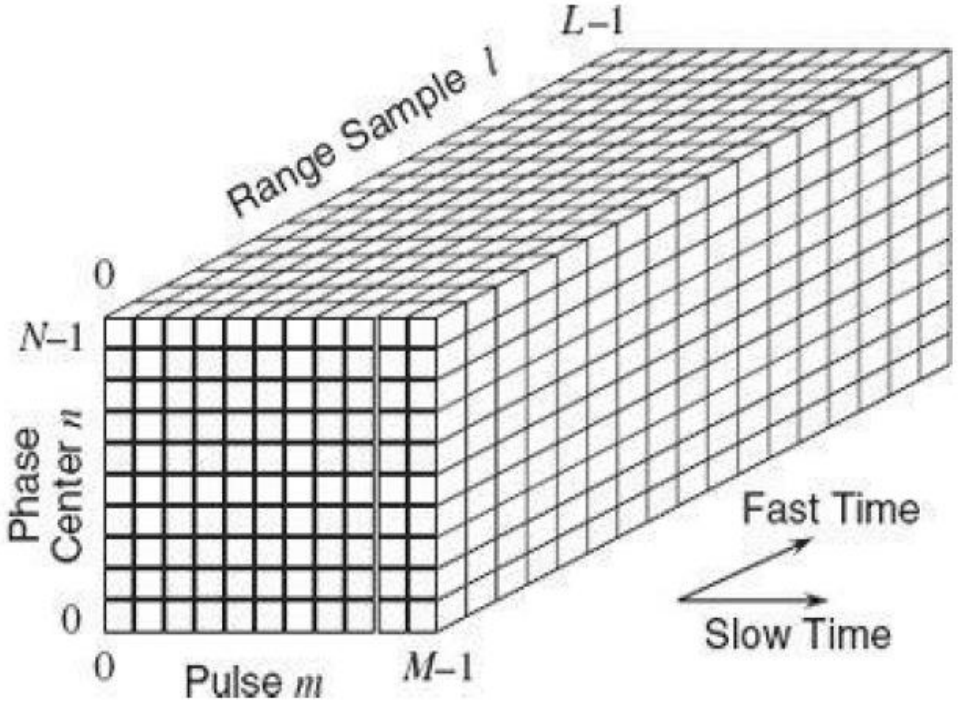


- Range = 150000 m
- Range cell = 30m
- CPI = 400/scan
- Total Number of Range cells = (150000/30) x 400 = 20,00,000
- IQ data size = 4 bytes/Range cell/Pulse
- Avg number of pulses per CPI = 8
- Total Data of single scan & single beam = 64000000 Bytes/scan = 64 MB/scan/Beam
- Number of beams = 7
- Total Data of 7 beams for a single scan = 448 MB/Scan
- Size of 1 minute recording file = 6.72 GB

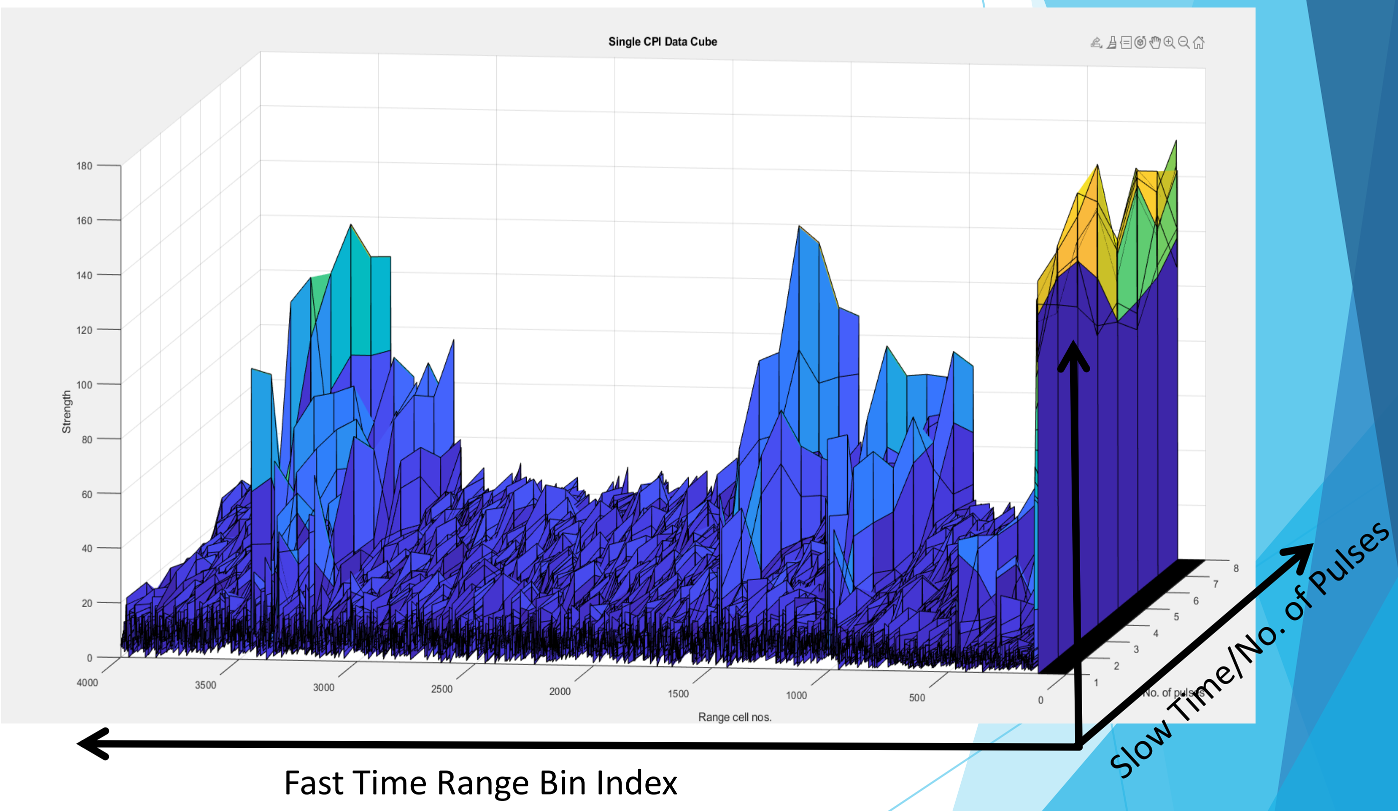


PPI Depiction

Radar Data Cube



Single Beam dwell Data in MATLAB



Results

Frequency Domain Transformation

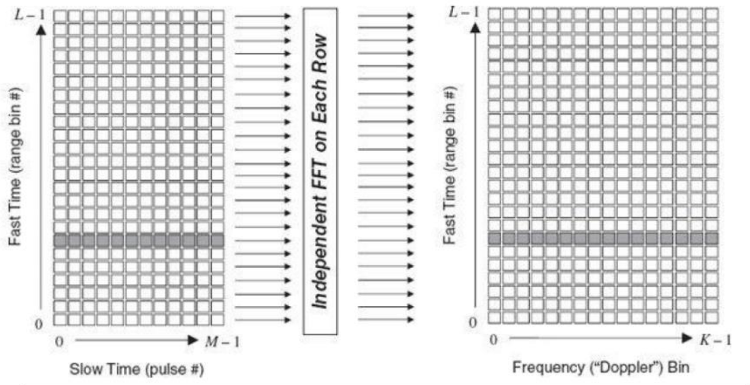


FIGURE 5.15 Conversion of the fast-time/slow-time data matrix to a range-Doppler matrix.

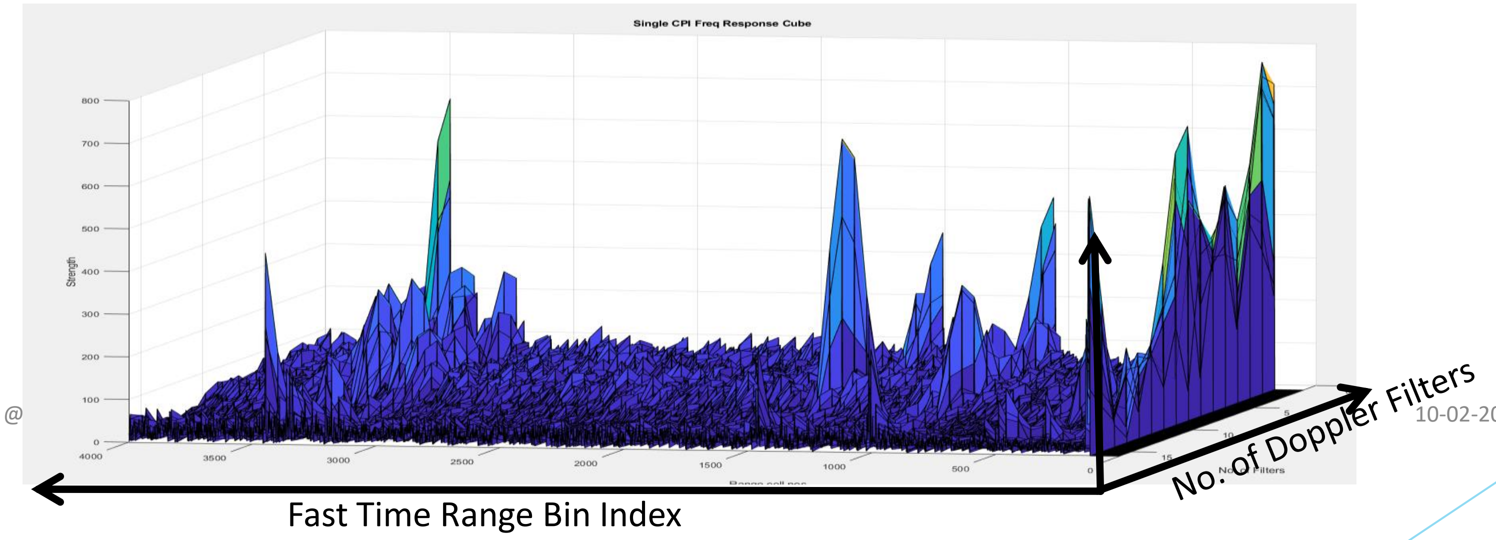
Ref: Principles of Modern Radar (Mark A. Richards)

Range Doppler Map generated using ***Range Doppler Response*** function under ***Phased Array Toolbox***

```
FFT_Length = 16;
Range_Doppler_Res_Cal = phased.RangeDopplerResponse('RangeMethod','FFT',...
                                                    'DopplerFFTLengthSource','Property',...
                                                    'DopplerFFTLength',FFT_Length,...
                                                    'DopplerWindow','None')

[Range_Doplr_Resp,Range_Vector,Doppler_Vector] = Range_Doppler_Res_Cal(raw_cpi_data);
```

Range Doppler Map Results



CFAR Detector

- Maintain desired Pfa in presence of heterogenous interference.
- Estimates statistics of interference from Radar measurements & adjusts the threshold.

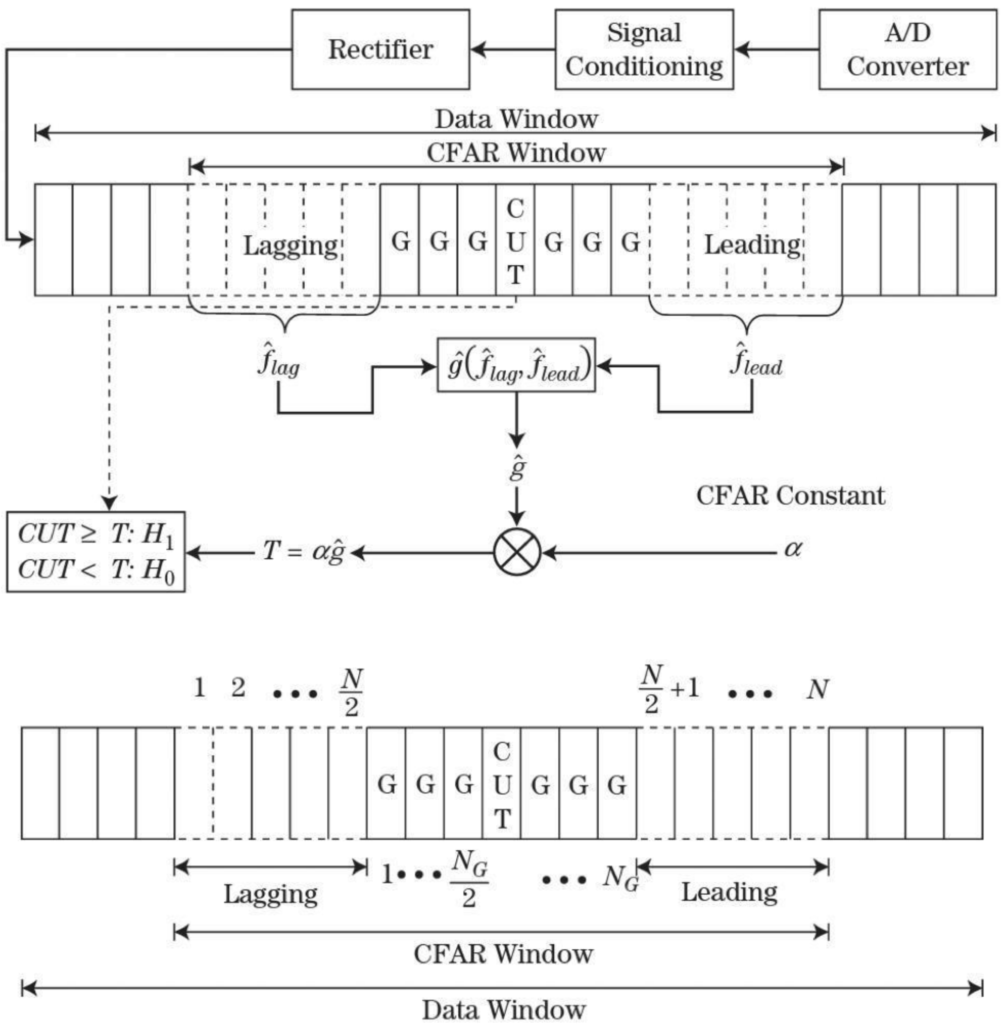
$$T = \alpha \hat{g}$$

$\hat{g}$ Interference statistic

α CFAR Constant (depends on Pfa)

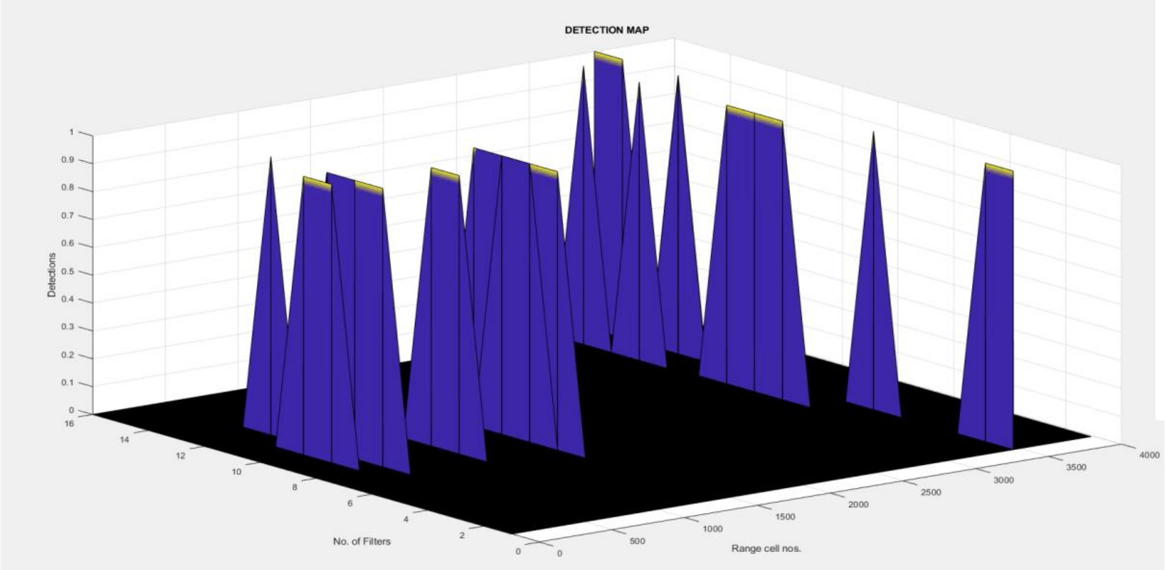
- Basic CFAR Architecture
- Types of CFAR :
  - CA-CFAR (Best for homogenous env)
  - GOCA-CFAR (Min clutter edge false alarms)
  - SOCA-CFAR
  - TM-CFAR
  - OS-CFAR

To suppress mutual Target Masking (SOCA-CFAR, TM-CFAR, OS-CFAR)



CA CFAR Detector Results

- Assuming stationary Clutter response Zero velocity filter
- All remaining Doppler filters are processed by CFAR detector




```
% CFAR Detector object creation
TYPE = 'CA';
NUM_OF_GUARD_CELLS = 2;
NUM_OF_TRAINING_CELLS = 16;
PFA = 1e-6;
NUM_OF_RANGE_CELLS = 4000;
CA_CFAR_Detector = phased.CFARDetector('Method',TYPE,...
                                       'NumGuardCells',NUM_OF_GUARD_CELLS,...
                                       'NumTrainingCells',NUM_OF_TRAINING_CELLS,...
                                       'ThresholdFactor','Auto',...
                                       'ProbabilityFalseAlarm',PFA,...
                                       'OutputFormat','CUT result')
```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Single scan/Single Beam CA CFAR Detections

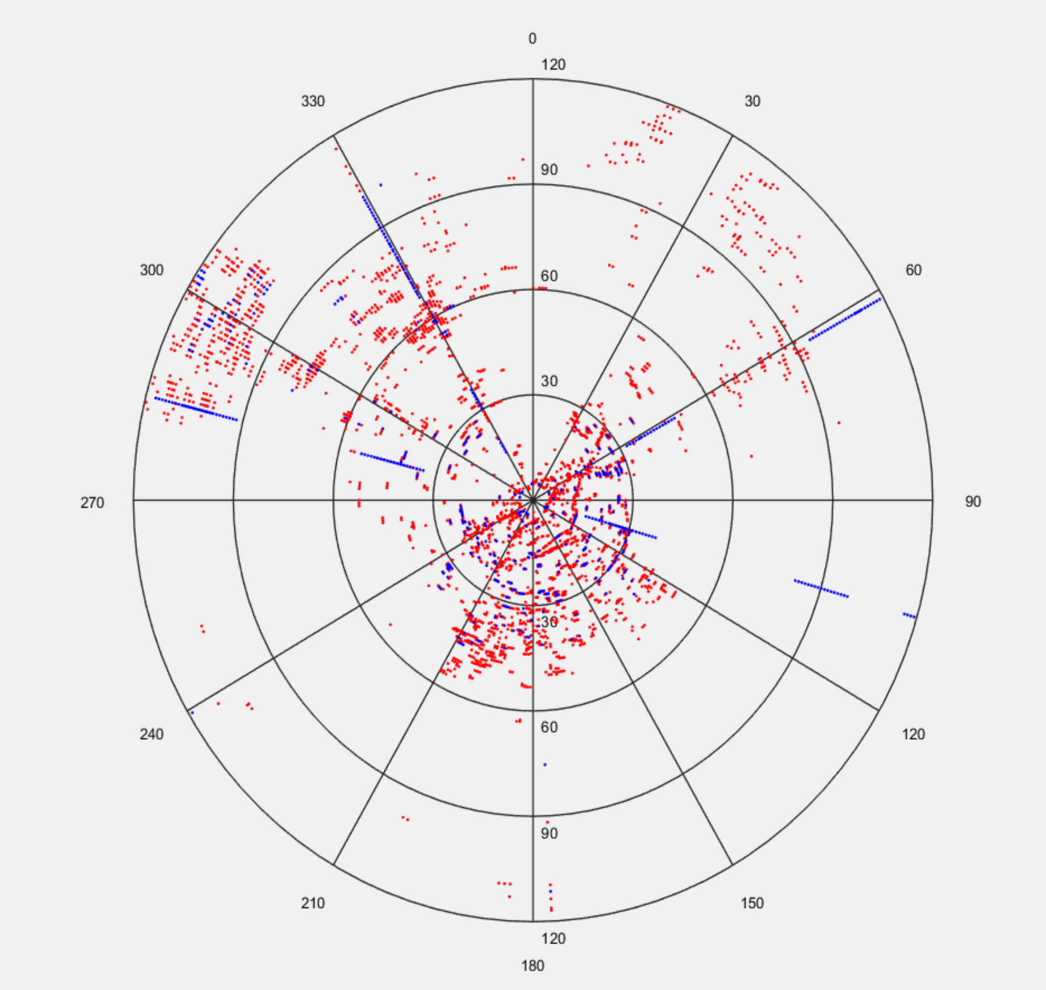

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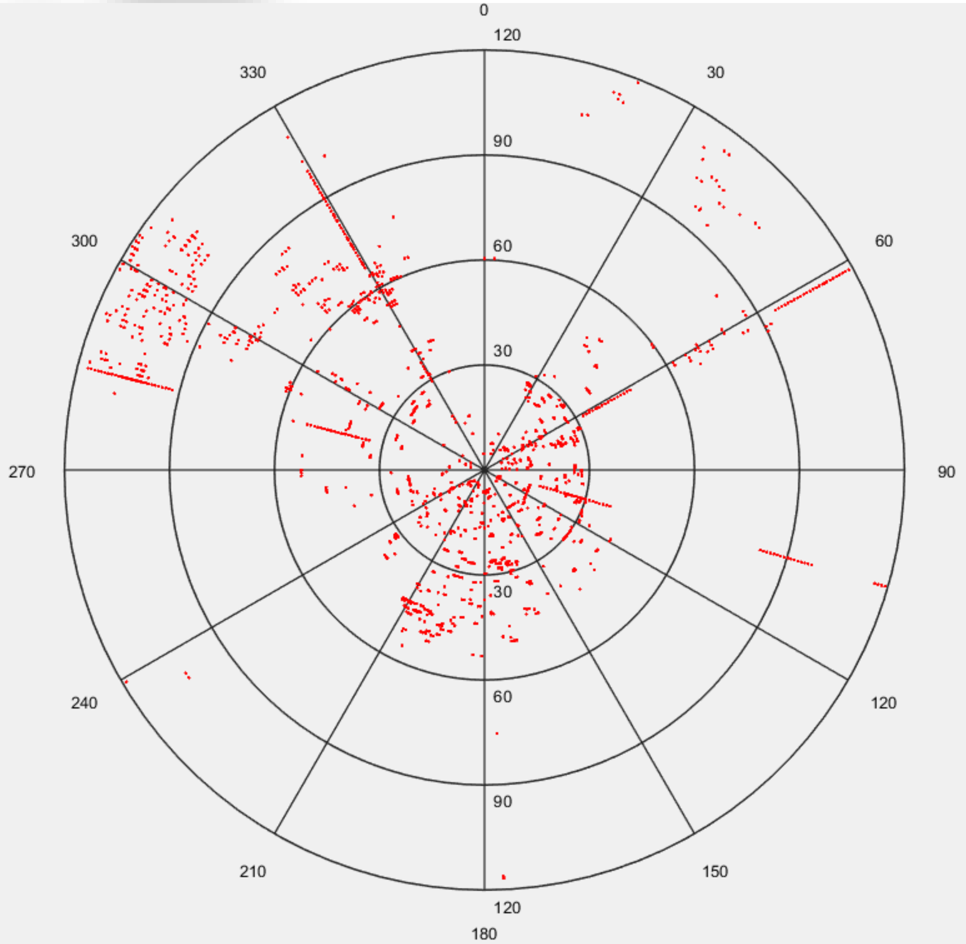
Figure: The figure is plotted in Radar PPI using MATLAB. It depicts the detections of lowest beam.

- Validation using site recorded IQ data.
- Usage of built in functions in toolboxes
- Performance comparison done with legacy code
- Results strikingly similar to what's available in actual Radar
- Validation over 24 scans of high Volume IQ Data.

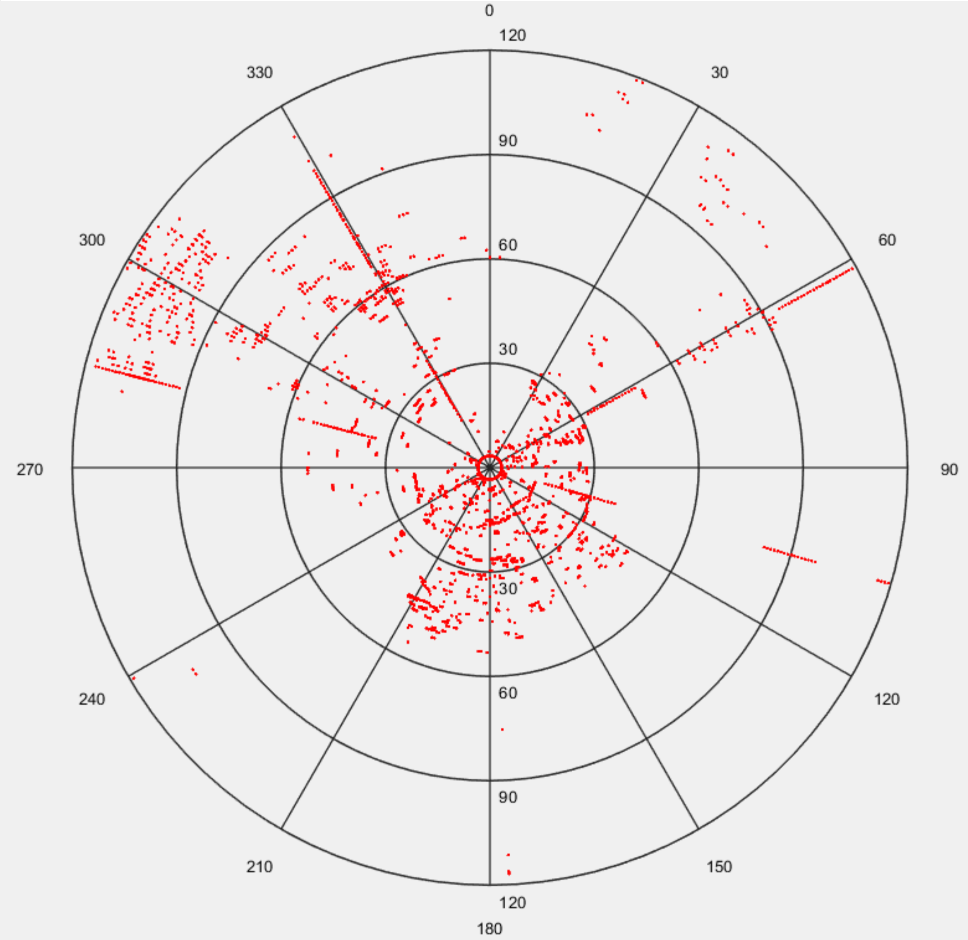
MATLAB
Phased Array Toolbox
Radar Toolbox

Robust CFAR Detectors

GO CA CFAR

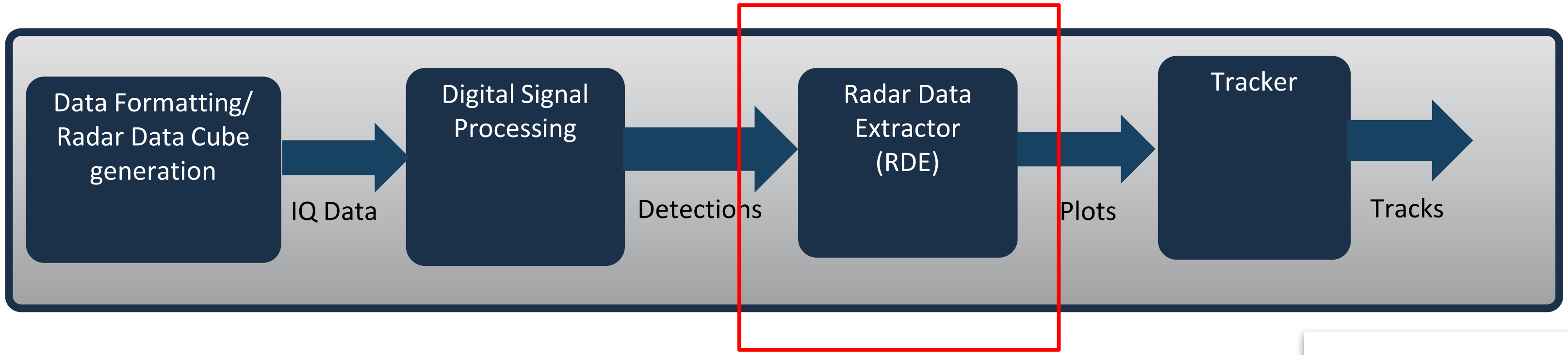


SO CA CFAR

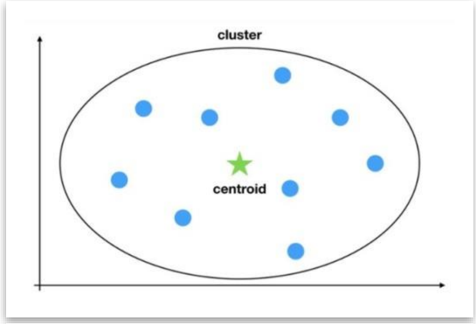


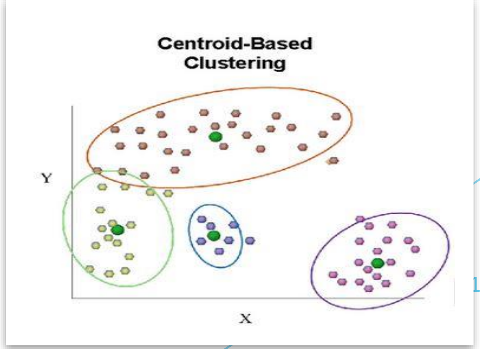
Results achieved are in consonance with expected outcomes

Radar Data Extractor Functionality



- Input: Detections i.e. o/p of RSP
- Hits generated across the beam width
- Declare a plot position on all validated targets
- Correlate all threshold crossings
- Grouping detections from the same target





Realization of Radar Data Extractor

Milestone 1 (Building Input Interface)

Provision of receiving Signal processor data into MATLAB

Milestone 2 (Development)

Modular implementation of existing extractor module in MATLAB

Milestone 3 (Testing & Validation)

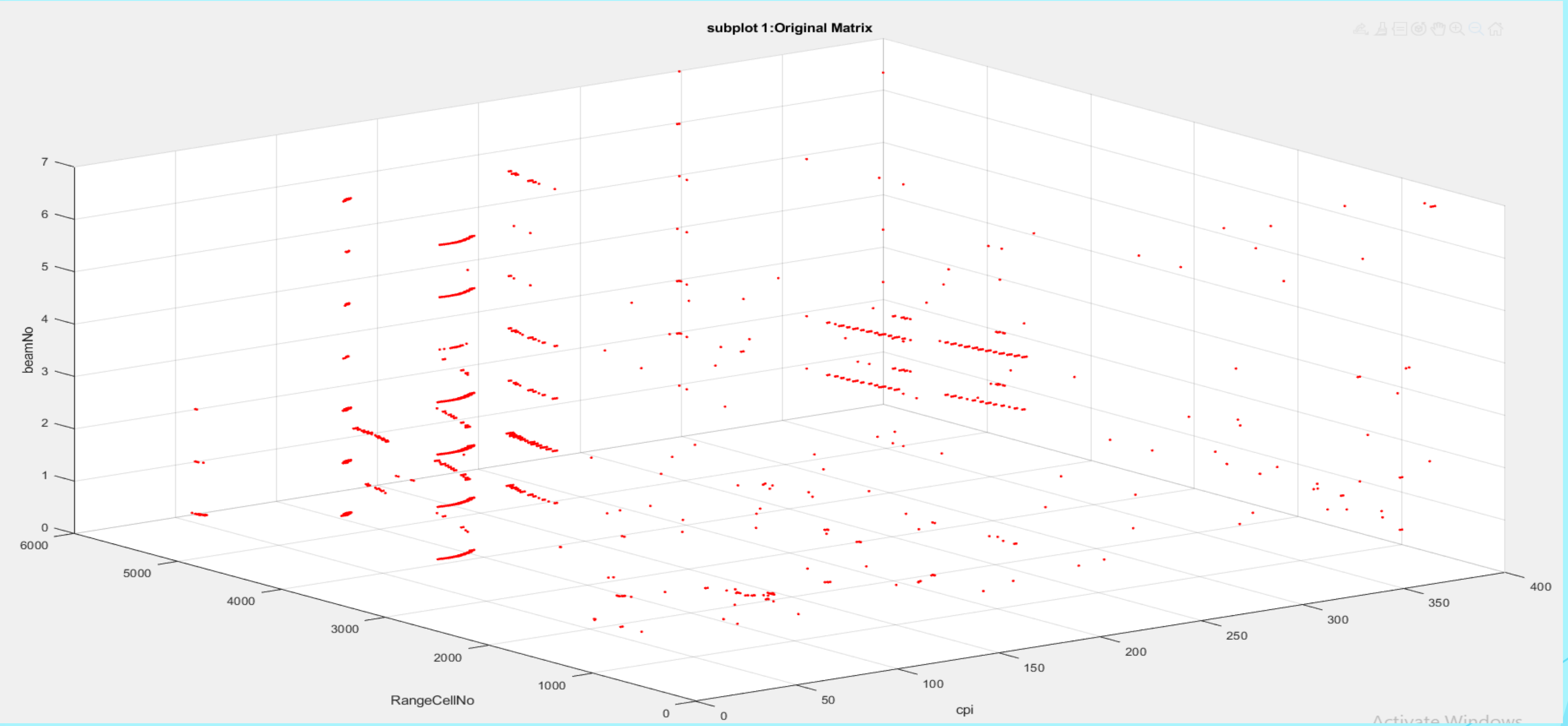
Unit Level testing with synthetic data

Integrated Testing with field recorded data

Performance Evaluation

Radar Data Extractor - Results

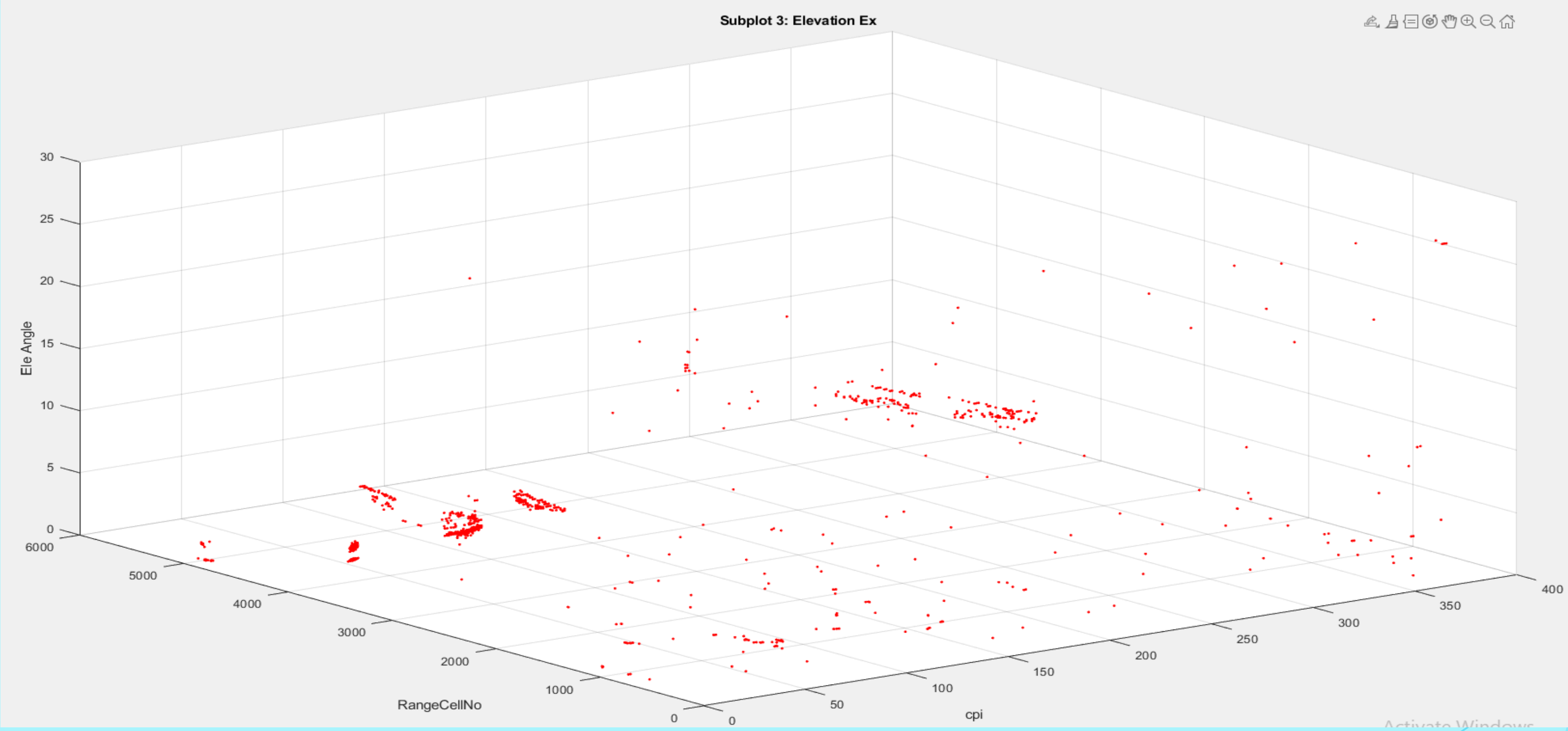
Step 1 : Detection Data Input from SP



ORIGINAL DATA

Radar Data Extractor - Results

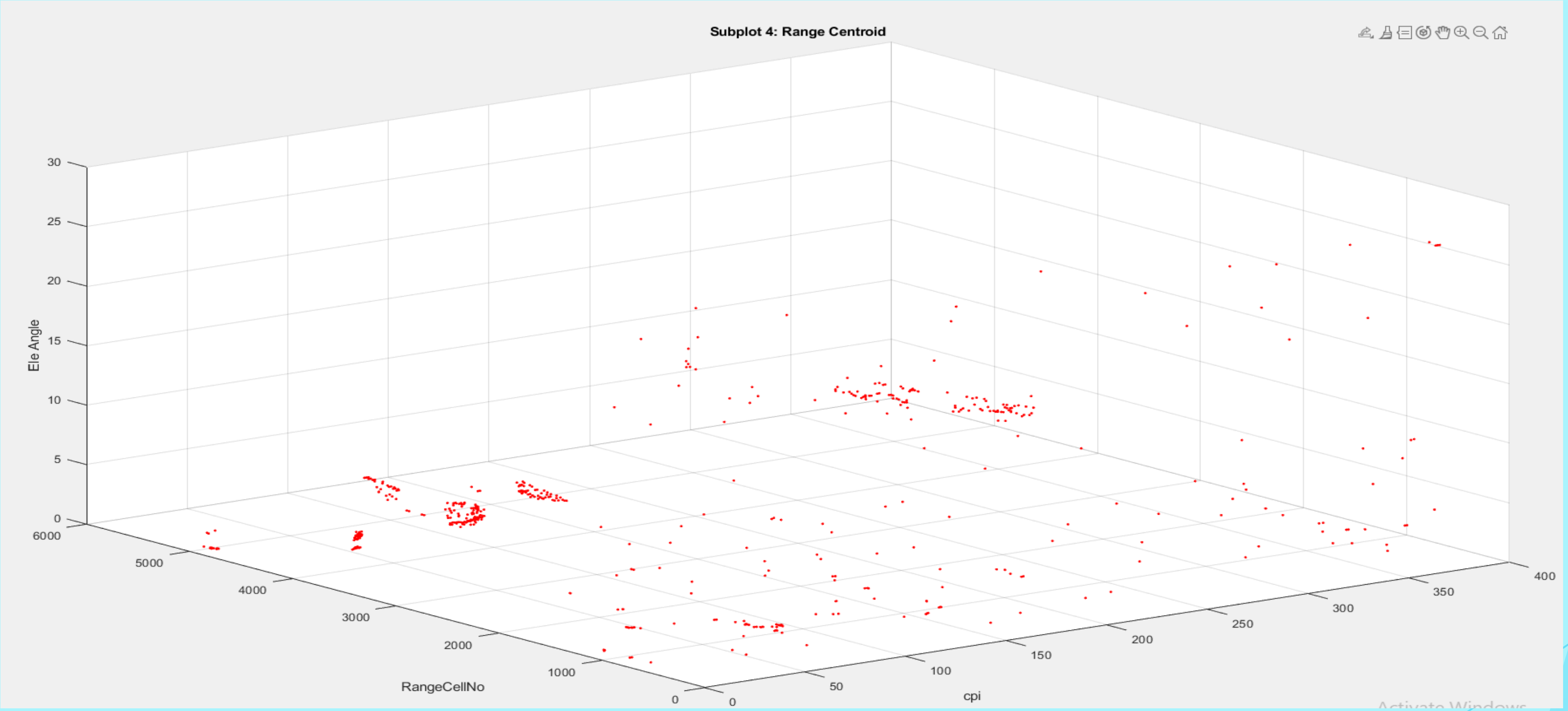
Step 2 : Calculation of Elevation Angle



ELEVATION ESTIMATION

Radar Data Extractor - Results

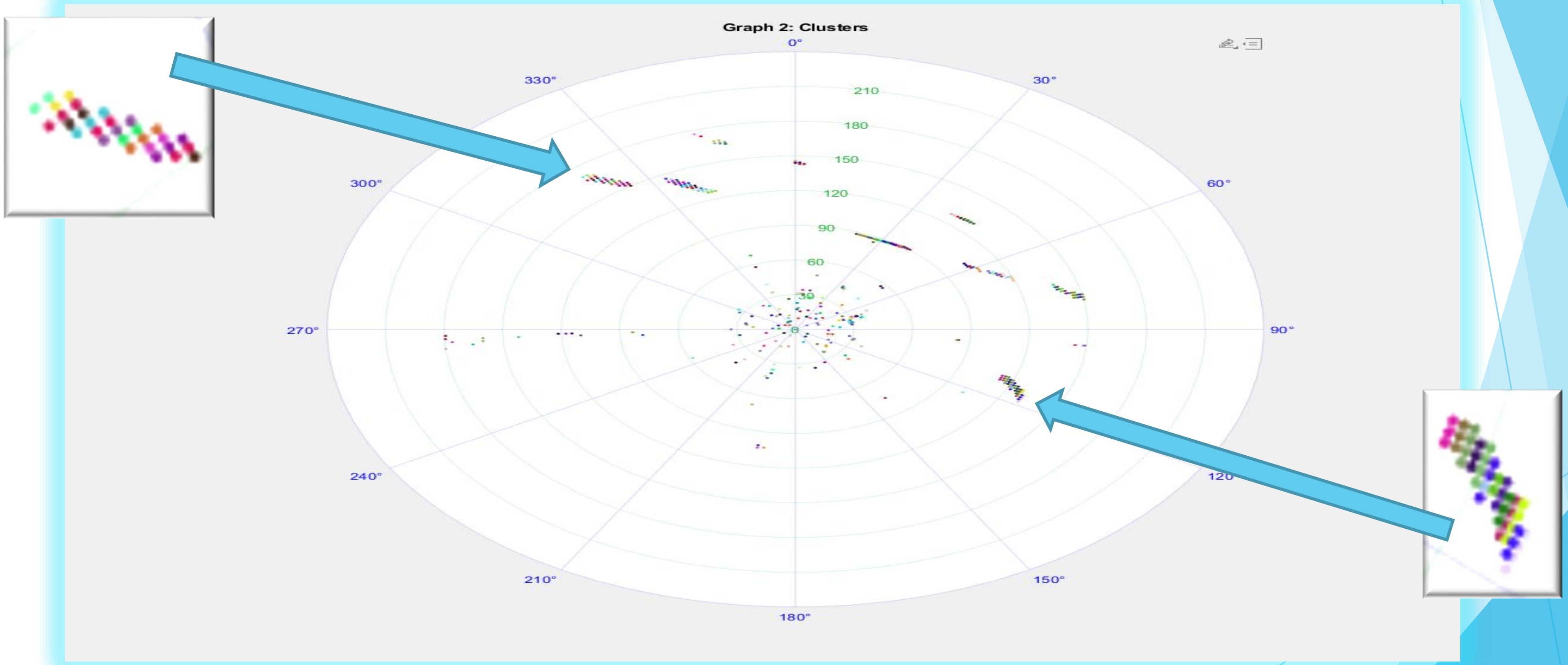
Step 3 : Calculation of Range Centroid



RANGE CENTROIDED OUTPUT

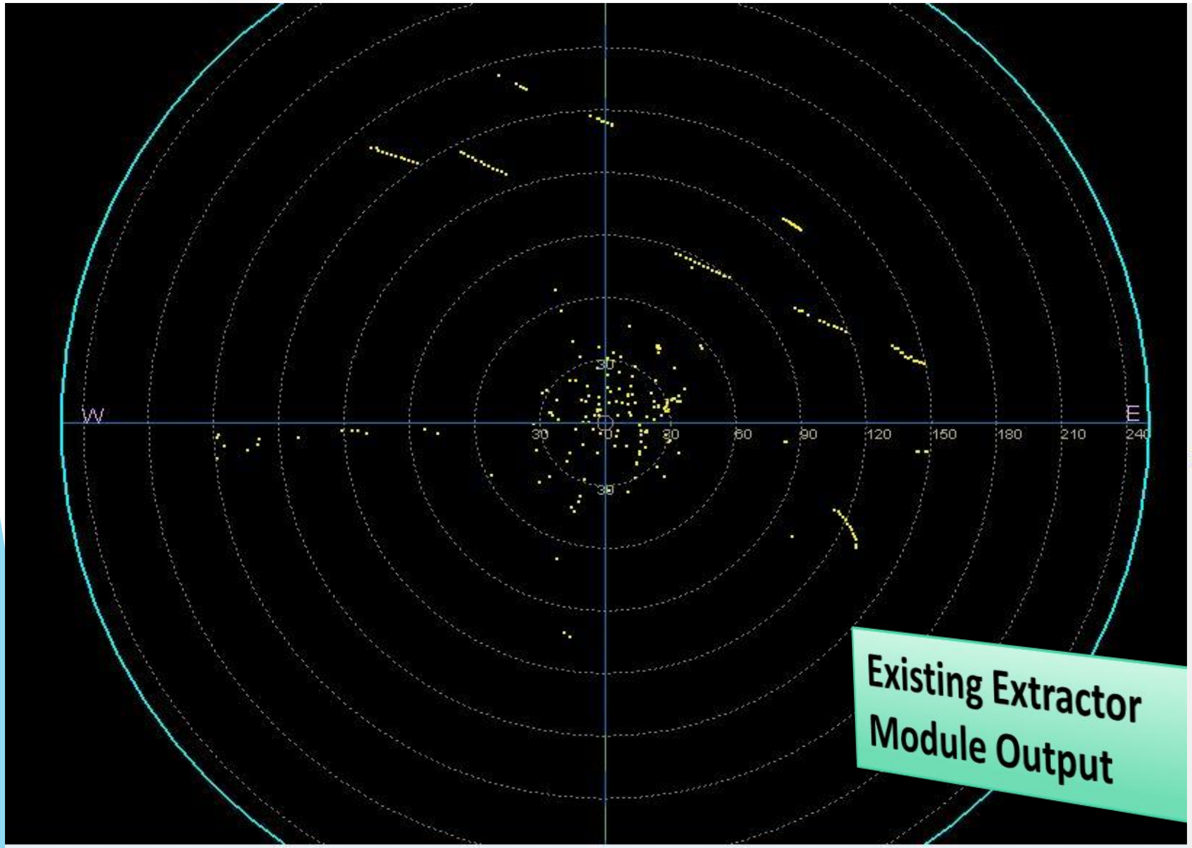
Radar Data Extractor - Results

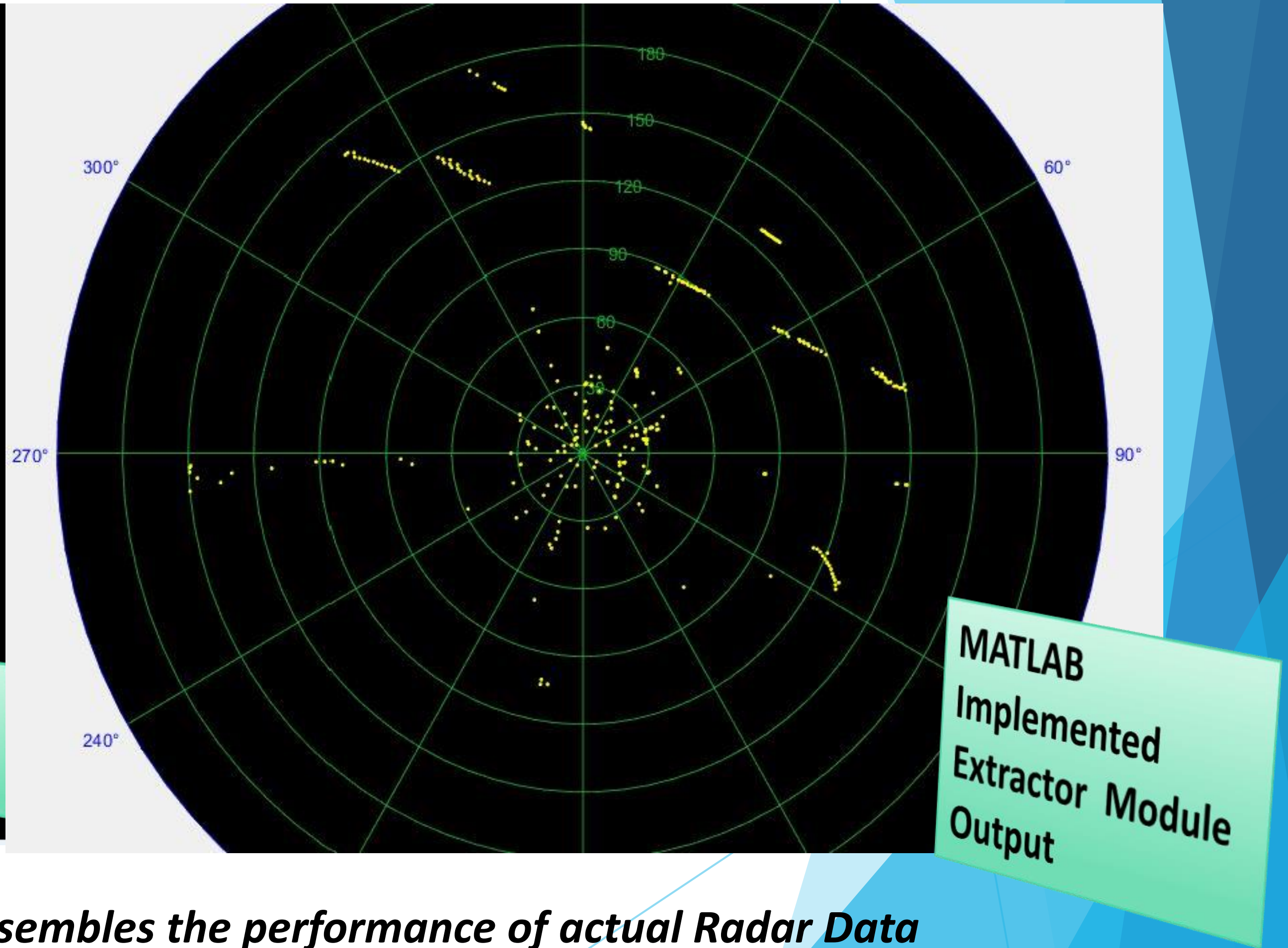
Step 4 : Clustered Output



CLUSTERED OUTPUT

Validation of Data Extractor Performance





Performance of Data Extractor realized in MATLAB resembles the performance of actual Radar Data Extractor. This will serve as test bench for future developments & testing.

Summary

- Usage of Phased Array Toolbox, Radar Toolbox for design & simulation
- GOCA_CFAR performance is better than CA_CFAR & SOCA_CFAR at clutter edges.
- Clutter simulations/synthetic data for validation
- Testing and performance analysis using strong Visualization tools
- Ease of Design with improved fidelity & reduced cycle time

Future Scope

- Land , Sea & WTG clutter modelling & simulation
- Waveform analysis & design for effective WTG clutter mitigation
- Evaluation of sensor fusion & tracking toolbox to minimize the RDE efforts
- Deployment of RSP chain on Kintex 7 FPGA family

Acknowledgement

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THANK YOU