Development of Signal Processor and Extractor Module for 3D Surveillance Radar

Mohit Gaur
Deputy Manager
Radar Dept.

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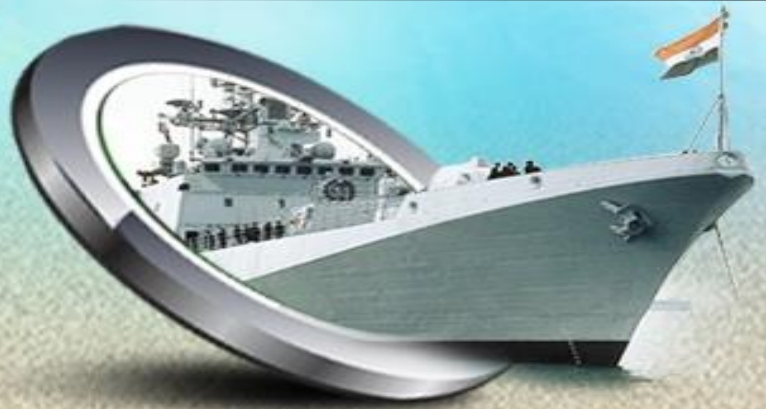
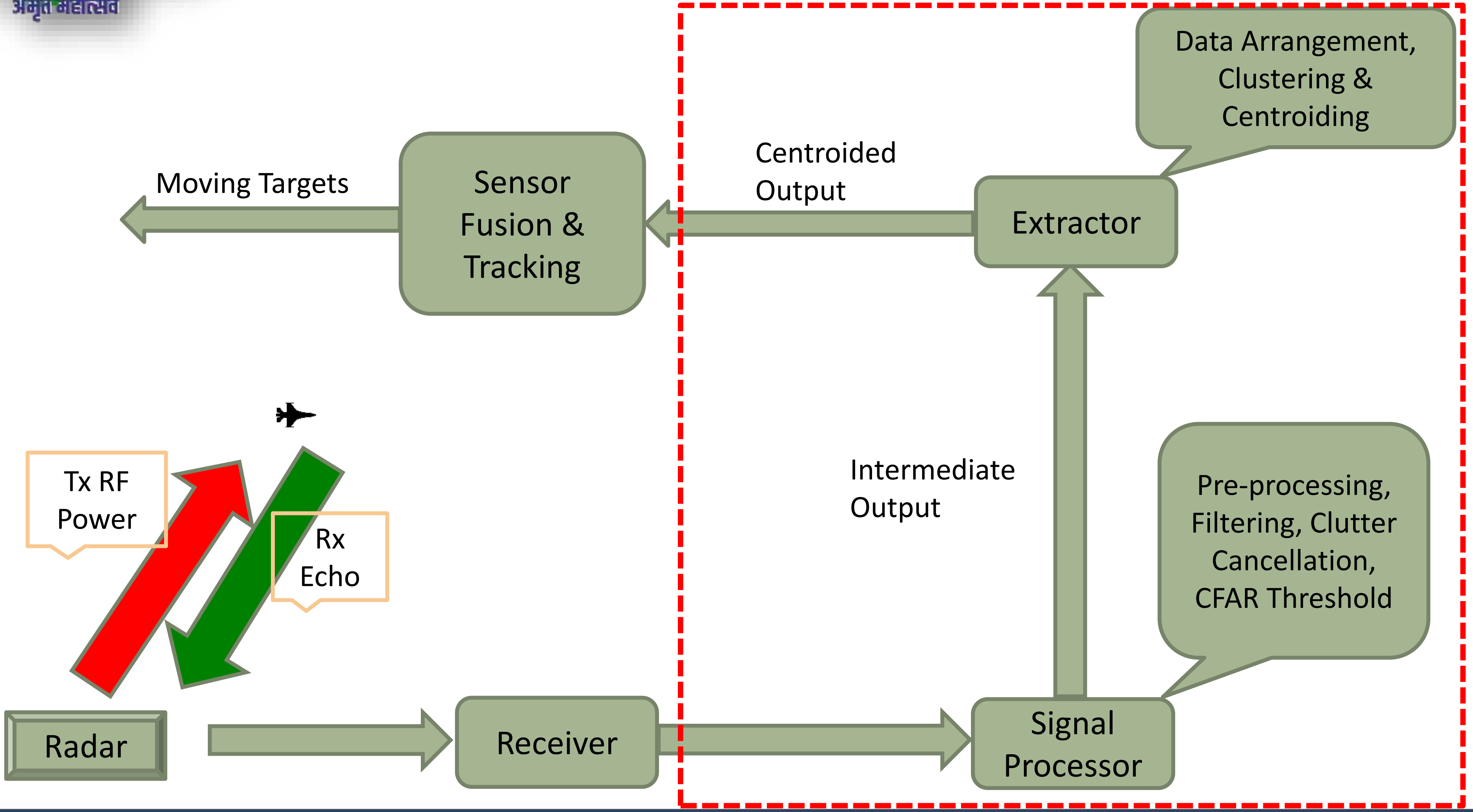


AGENDA

- 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



Challenges & Requirements

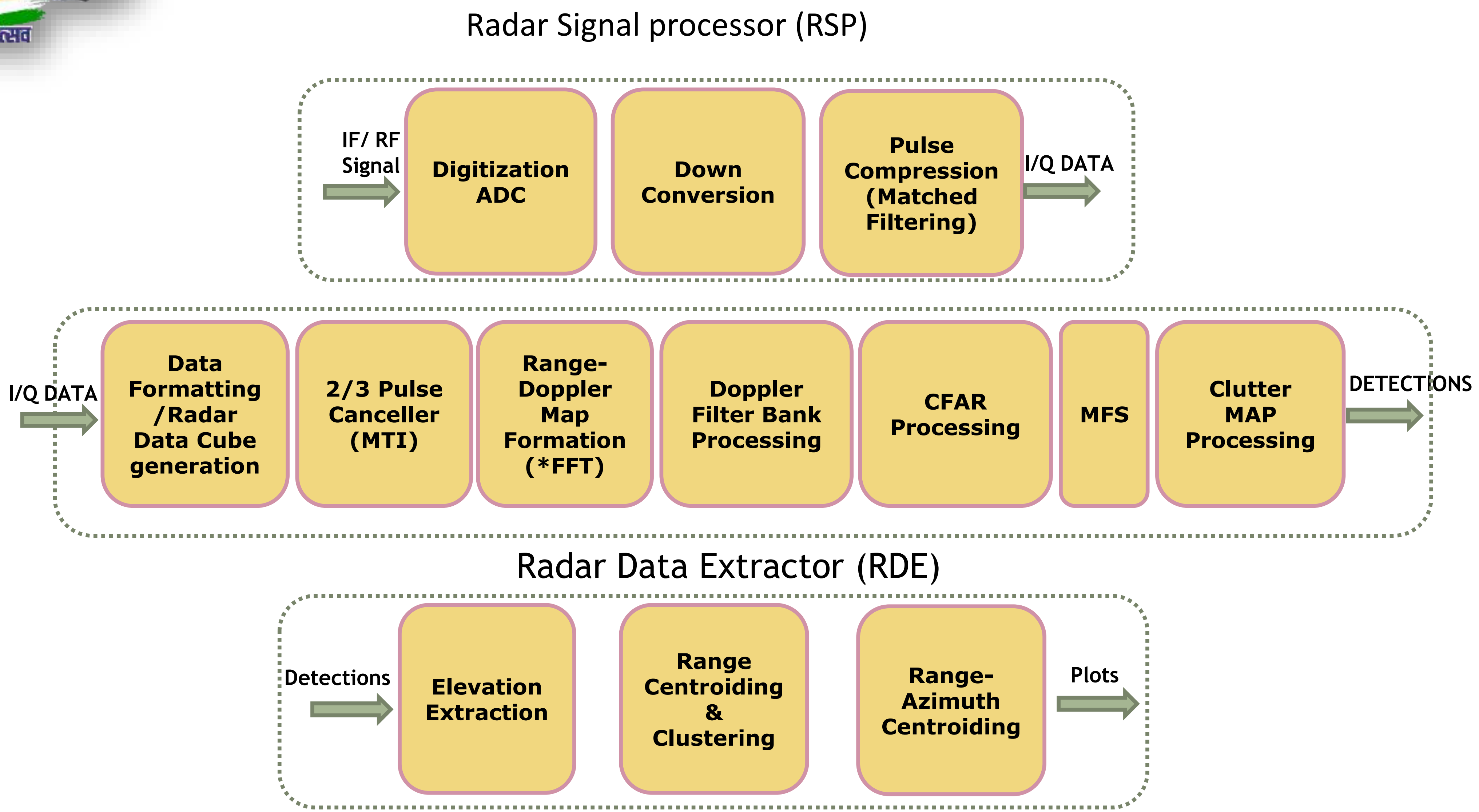
Challenges

- 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

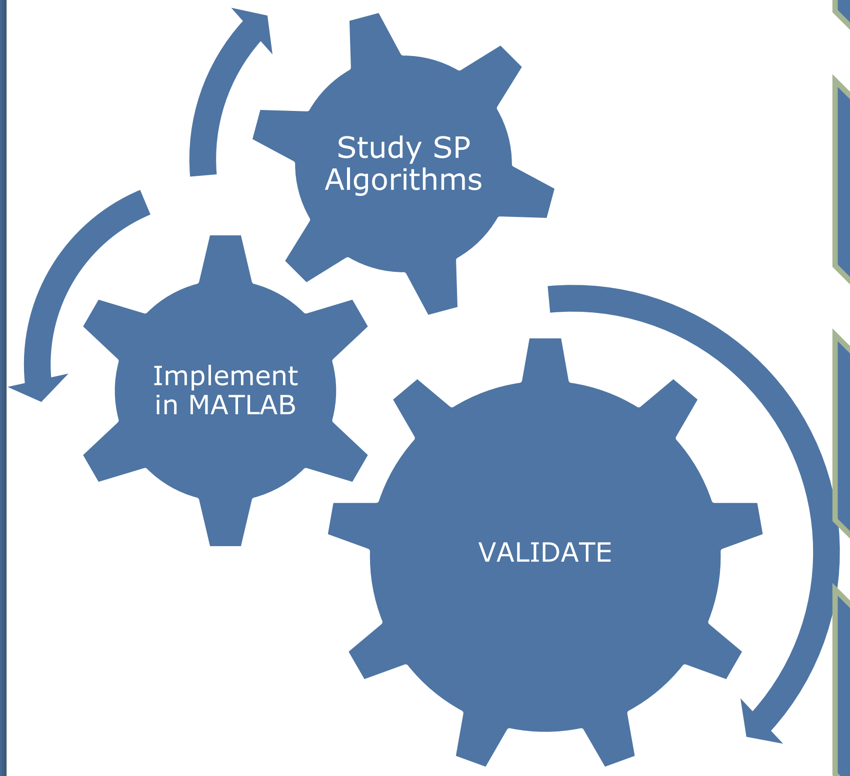
Requirements

- 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

Algorithmic workflow for RSP & RDE



APPROACH



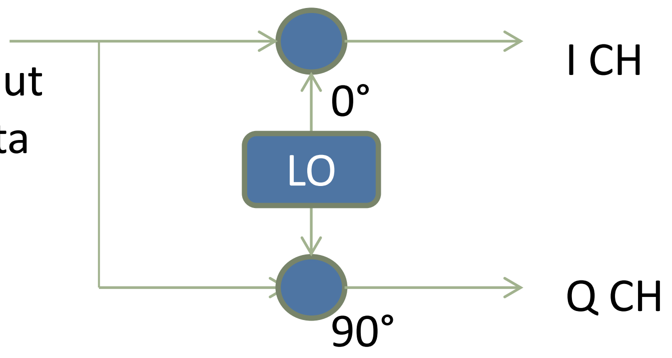
Phase-1
- Realization of main SP Algorithms in MATLAB

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

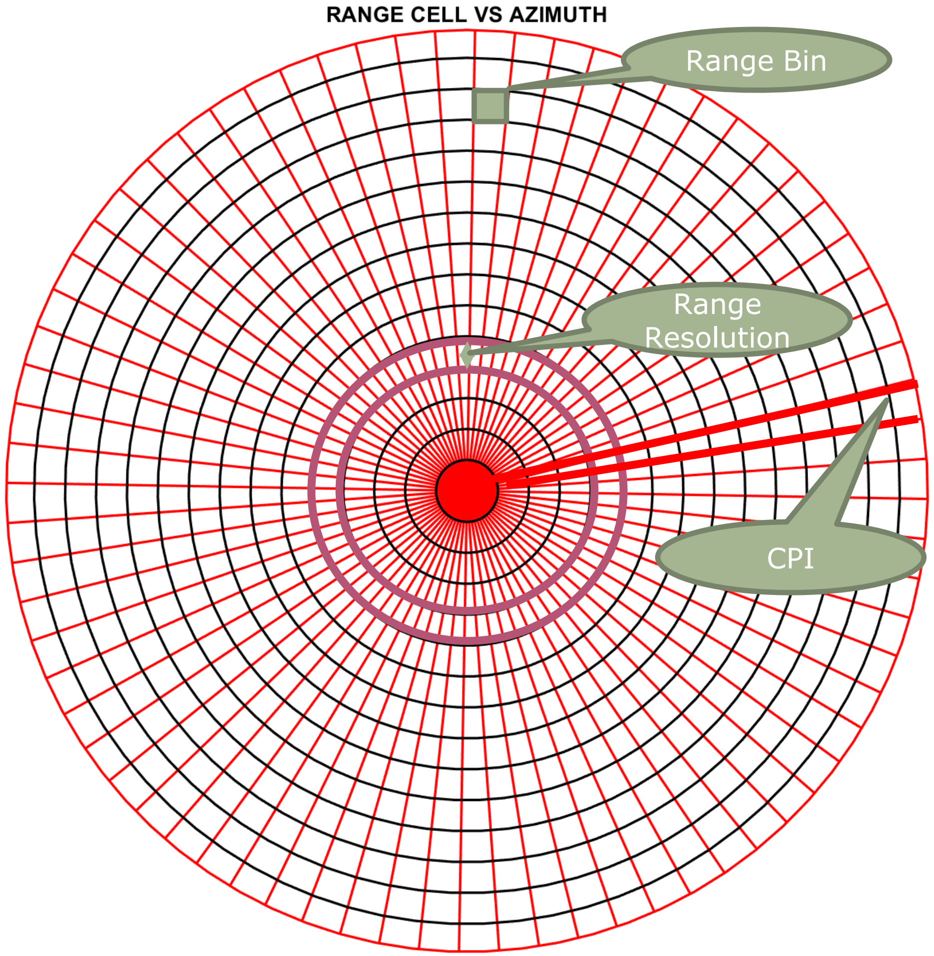
Future Scope
- Land & Sea Clutter simulation
- WTG Clutter characterization
- WTG Cutter Mitigation

IQ Data Volume Estimate



I Channel & Q Channel

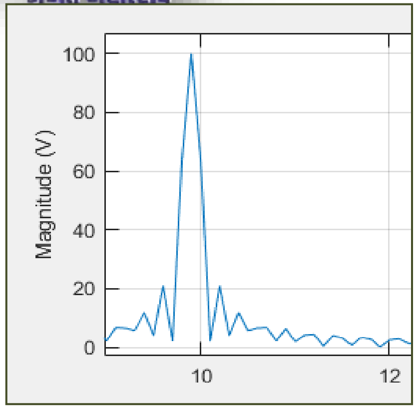
Range = 150000 m
Range cell = 30m
CPI = 400/scan
Total Number of Range cells = (150000/30) x 400 = 20,00,000
IQ data size = 4 bytes/Range cell/Pulse
Avg number of pulses per CPI = 8
Total Data of single scan & single beam = 64000000 Bytes/scan = 64 MB/scan/Beam
Number of beams = 7
Total Data of 7 beams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



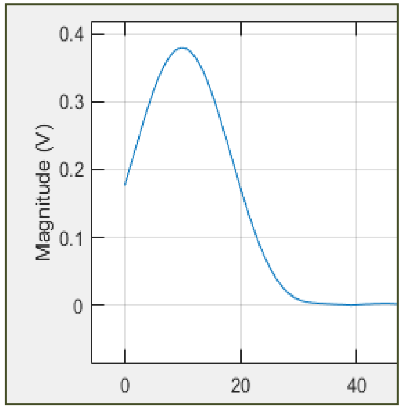
PPI Depiction

Waveform Analysis

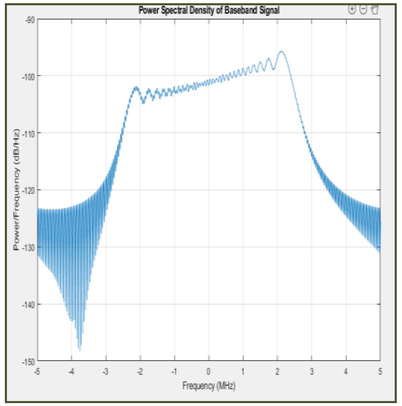
Digital Pulse Compression using Matched Filtering



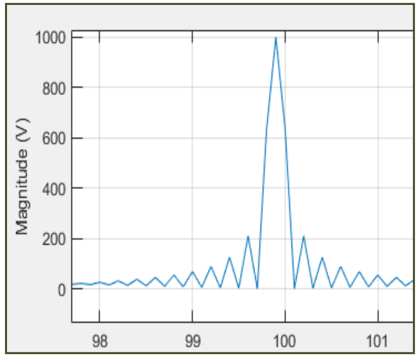
10 uS PW/Without Window



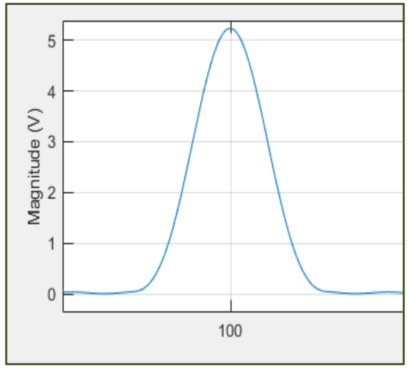
10 uS PW/Hamming Window



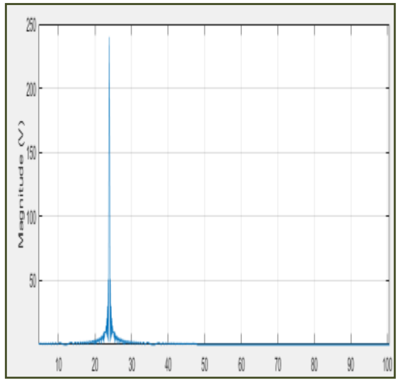
LFM @ LPRF



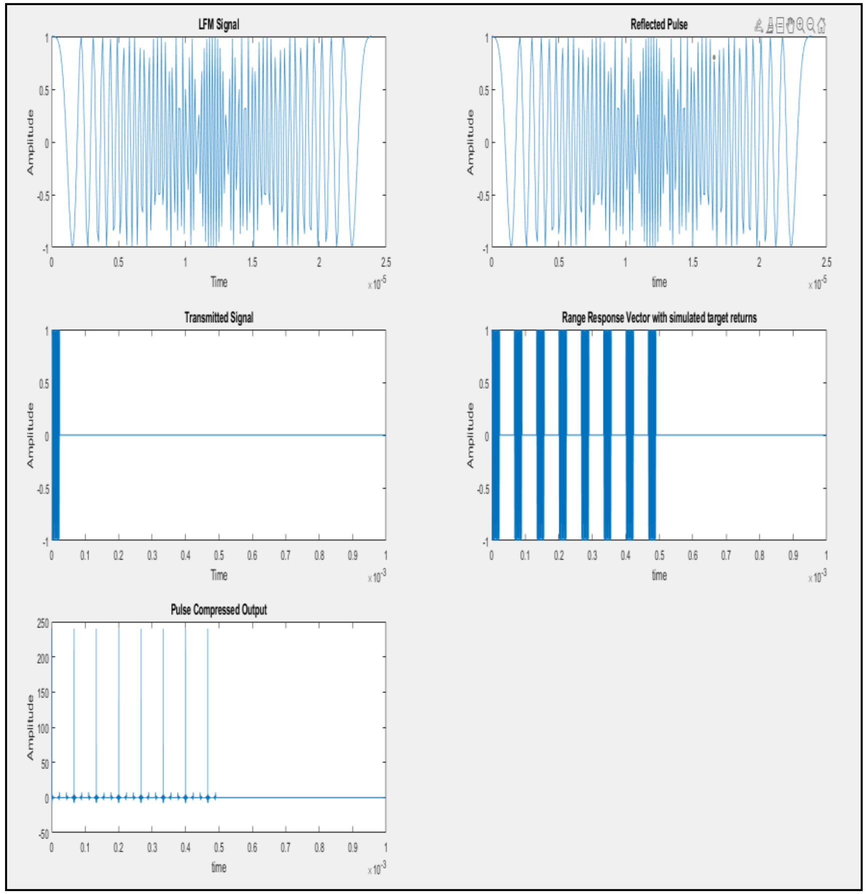
100 uS PW/Without Window



100 uS PW/Hamming Window



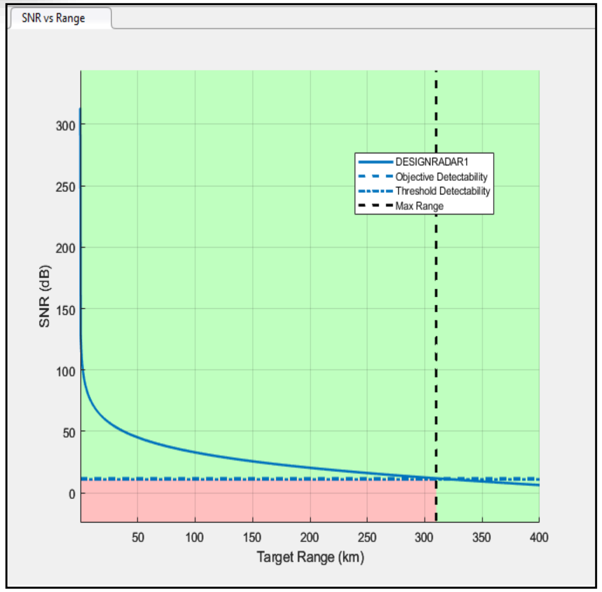
Matched Filter Response @ LPRF

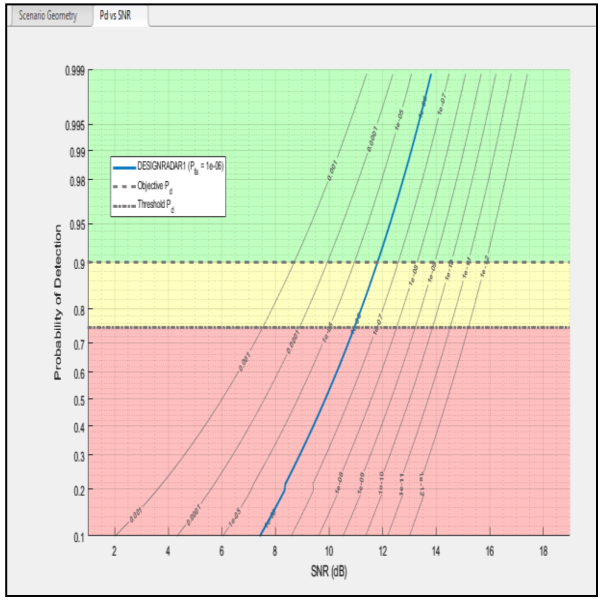


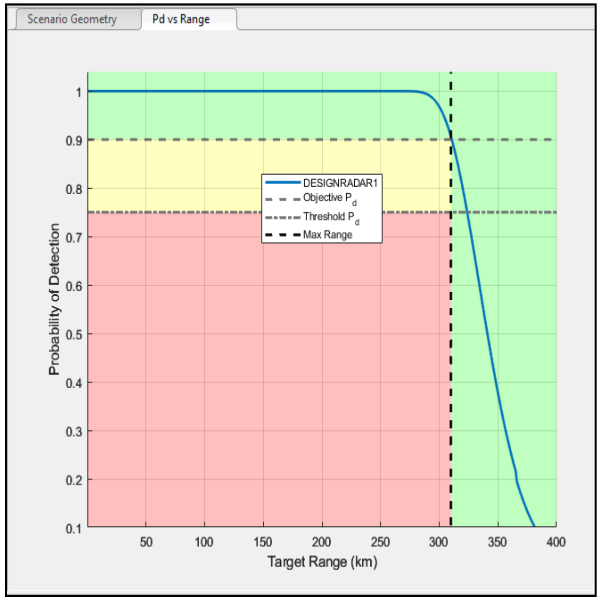
Pulse Compressed Signal App

Analyze the effect of various waveform parameters in Digital Pulse Compression

Radar Designer Calculations

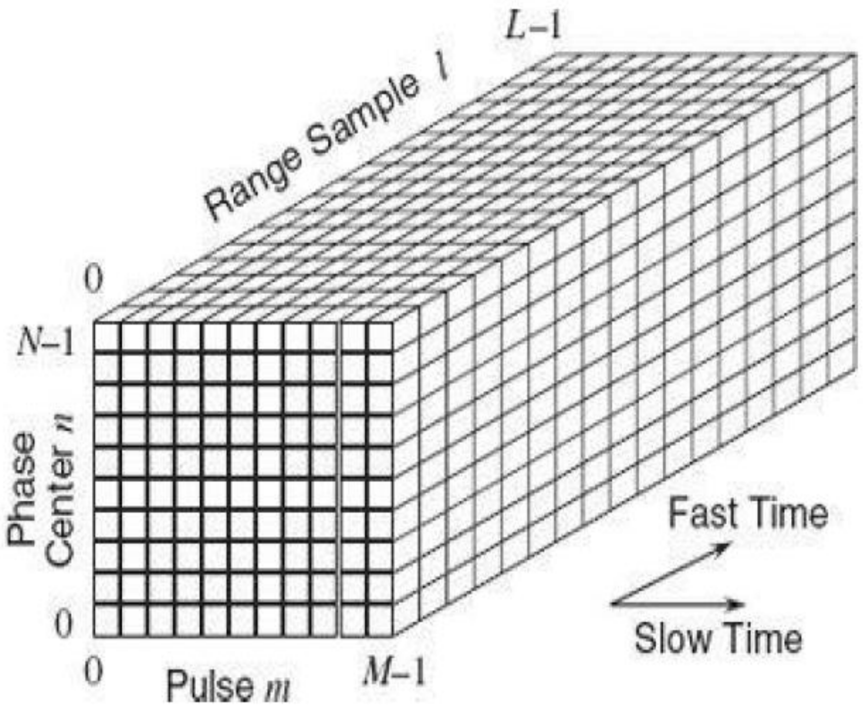




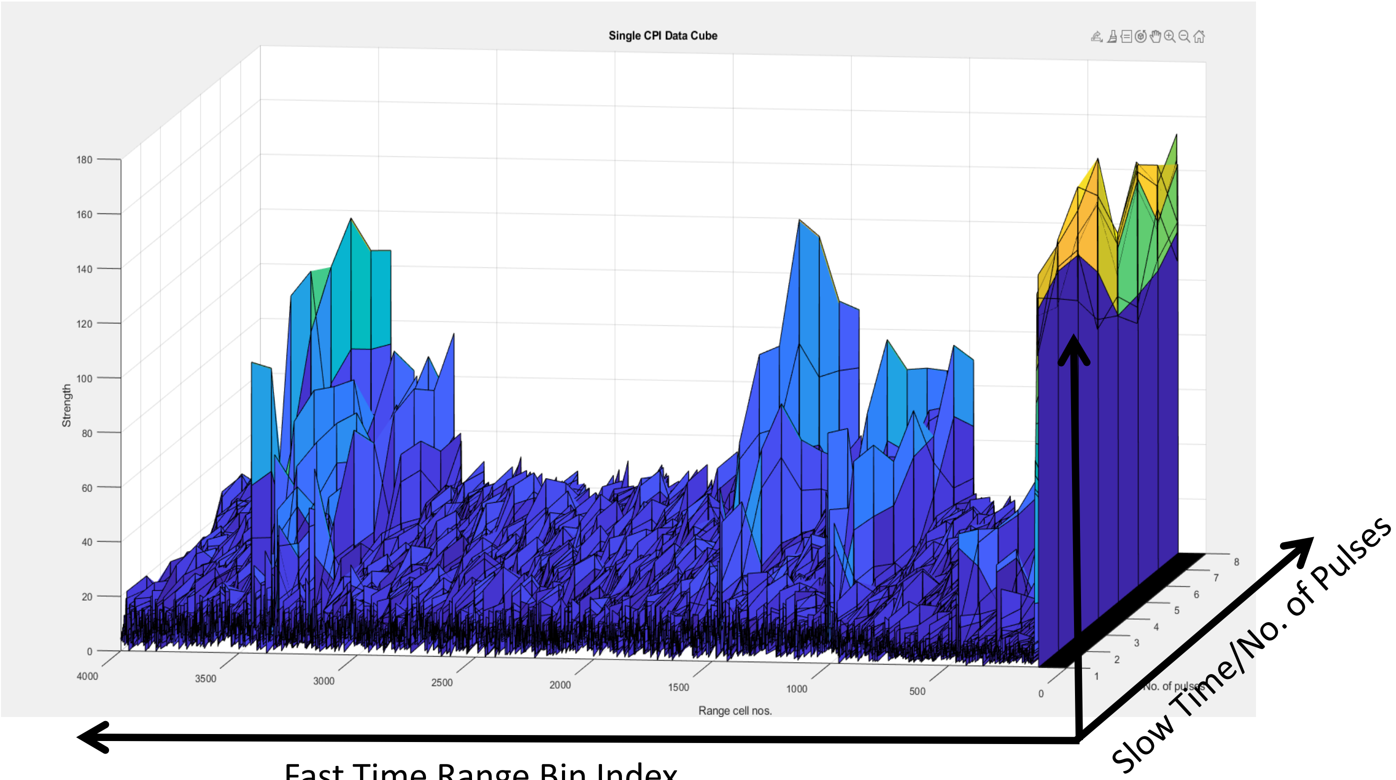


- Radar Designer App of MATLAB Radar Toolbox has been used to study the effect on critical Parameters like Tx Power, Tx Waveform Pulse width meeting Design specifications
- Strong Visualization for easy understanding

Radar Data Cube



Single Beam dwell Data in MATLAB



Results

Frequency Domain Transformation

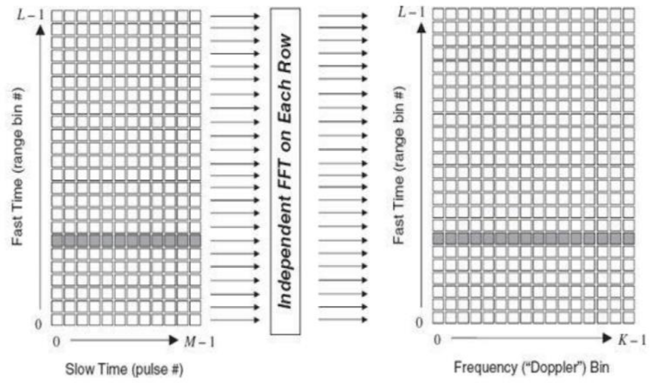


FIGURE 5.15 Conversion of the fast-time/slow-time data matrix to a range-Doppler matrix.

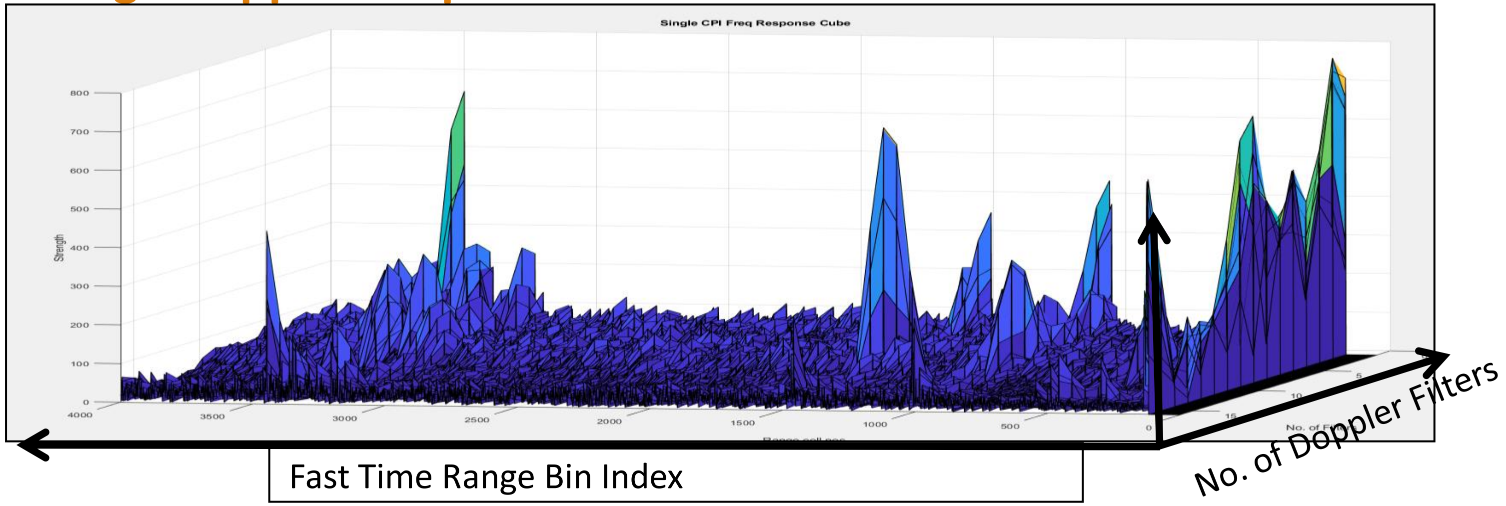
Ref: Principles of Modern Radar (Mark A. Richards)

Range Doppler Map generated using ***Range Doppler Response*** function under ***Phased Array System 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 heterogeneous interference.
- ➢Estimates statistics of interference from Radar measurements & adjusts the threshold.

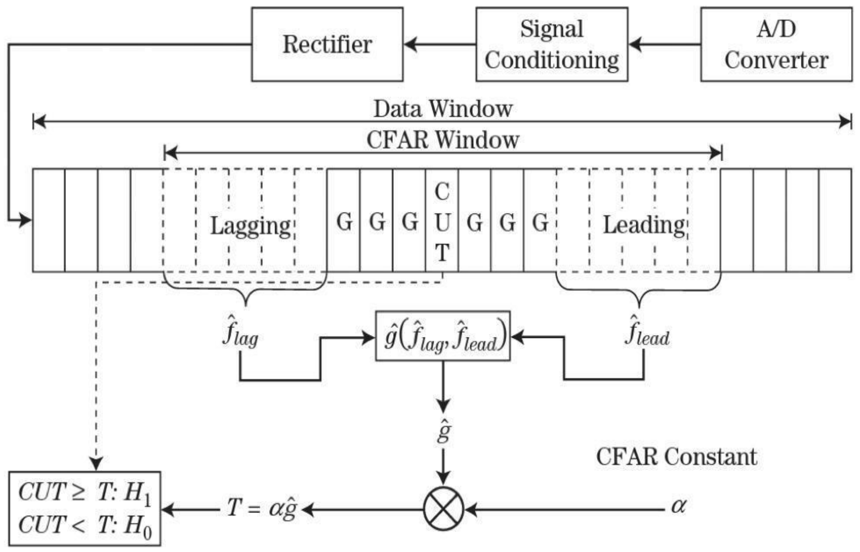
$$T = \alpha \hat{g}$$

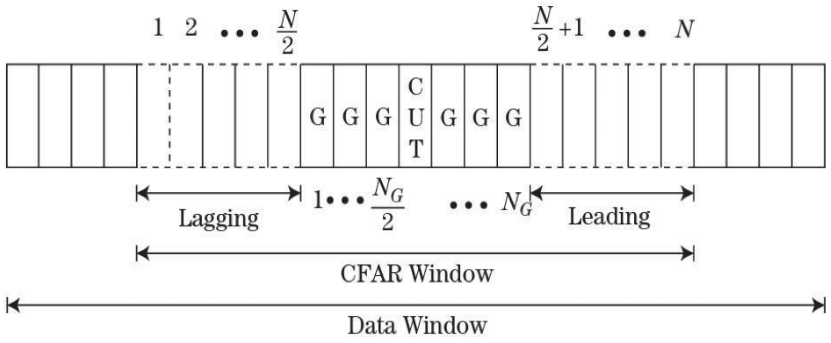
$\hat{g}$ Interference statistic

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

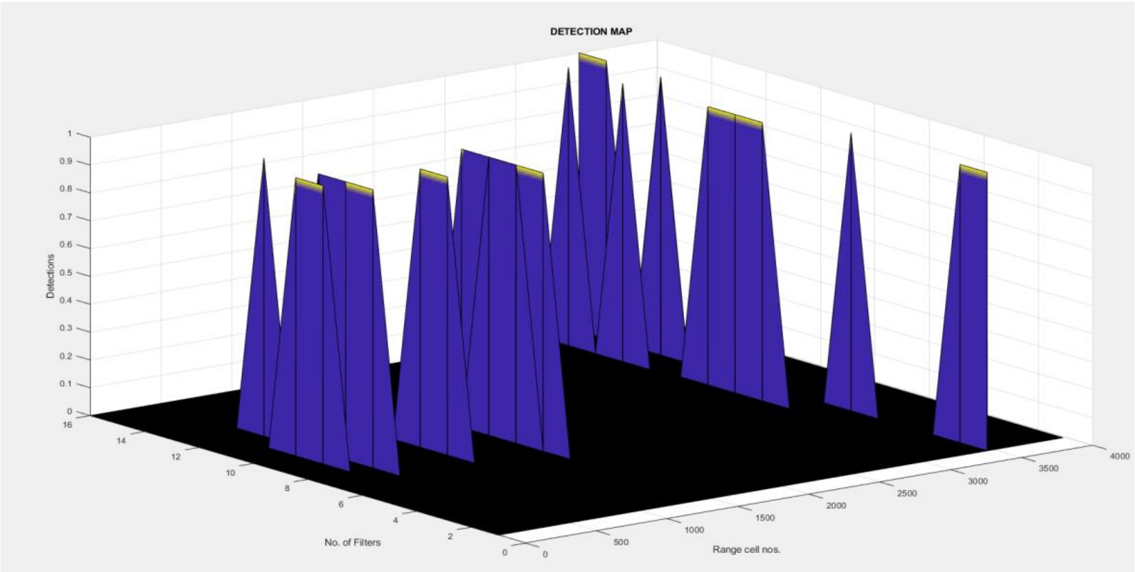
(SOCA-CFAR, TM-CFAR, OS-CFAR:) To suppress mutual Target Masking





CA CFAR Detector Results

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



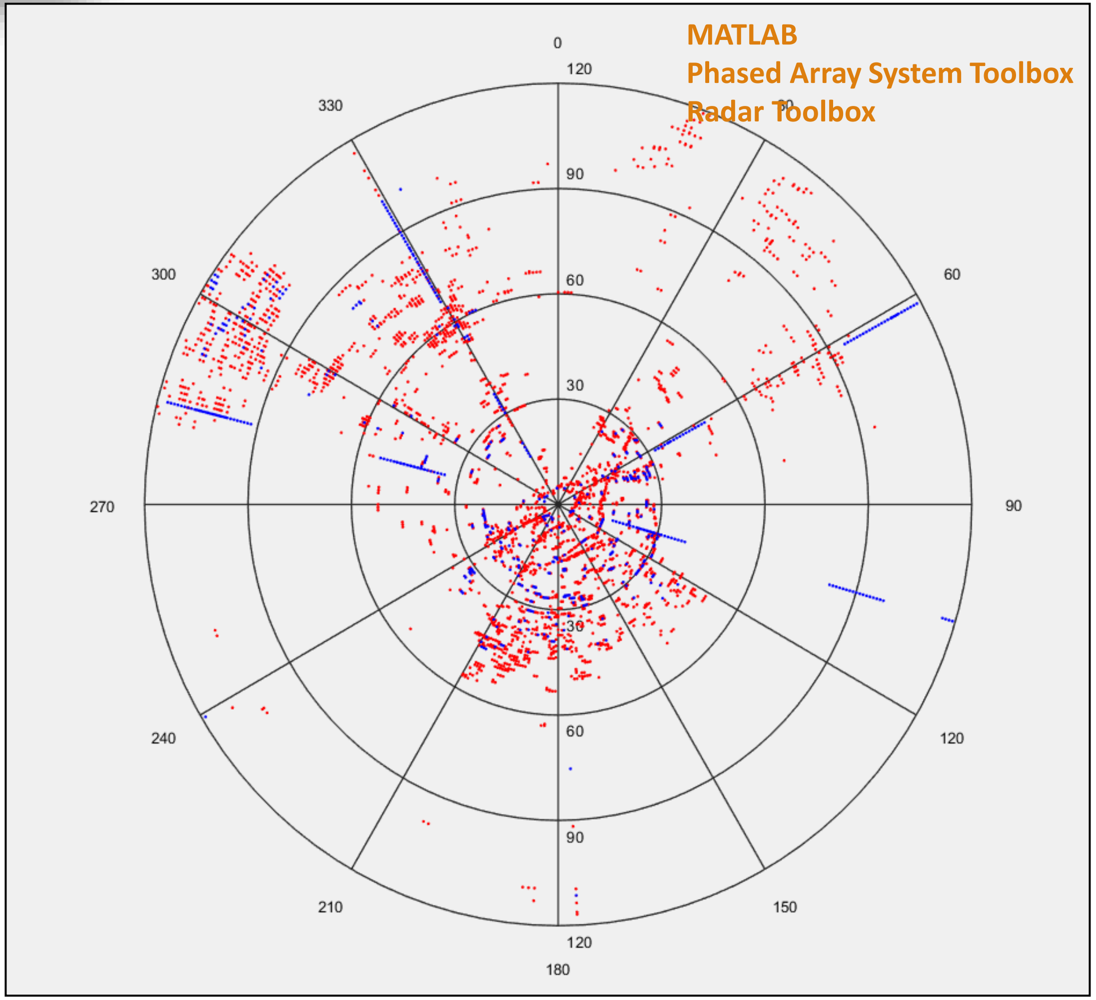
Detection Map for a single beam, single dwell data

CFAR Detector under Phased Array Toolbox

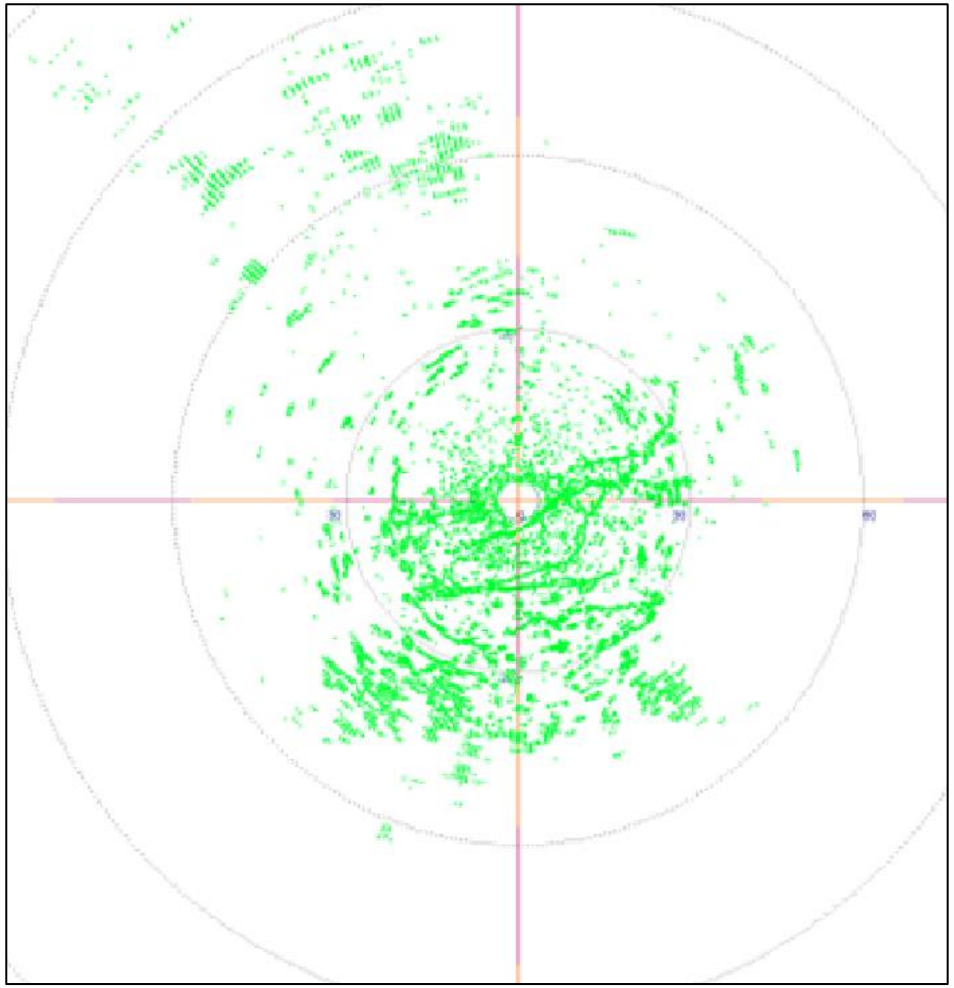
```
% CFAR Detector object creation
TYPE = 'CA';
NUM_OF_GUARD_CELLS = 2;
NUM_OF_TRAINING_CELLS = 16;
PFA = 1e-6;
NUM_OF_RANGE_CELLS = 4000;
CA_CFAR_Detector = phased.CFARDetector('Method',TYPE,...
                                        'NumGuardCells',NUM_OF_GUARD_CELLS,...
                        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

CFAR Threshold dynamically adjusts itself to ensure desired Probability of False Alarm

Single scan/Single Beam CA CFAR Detections



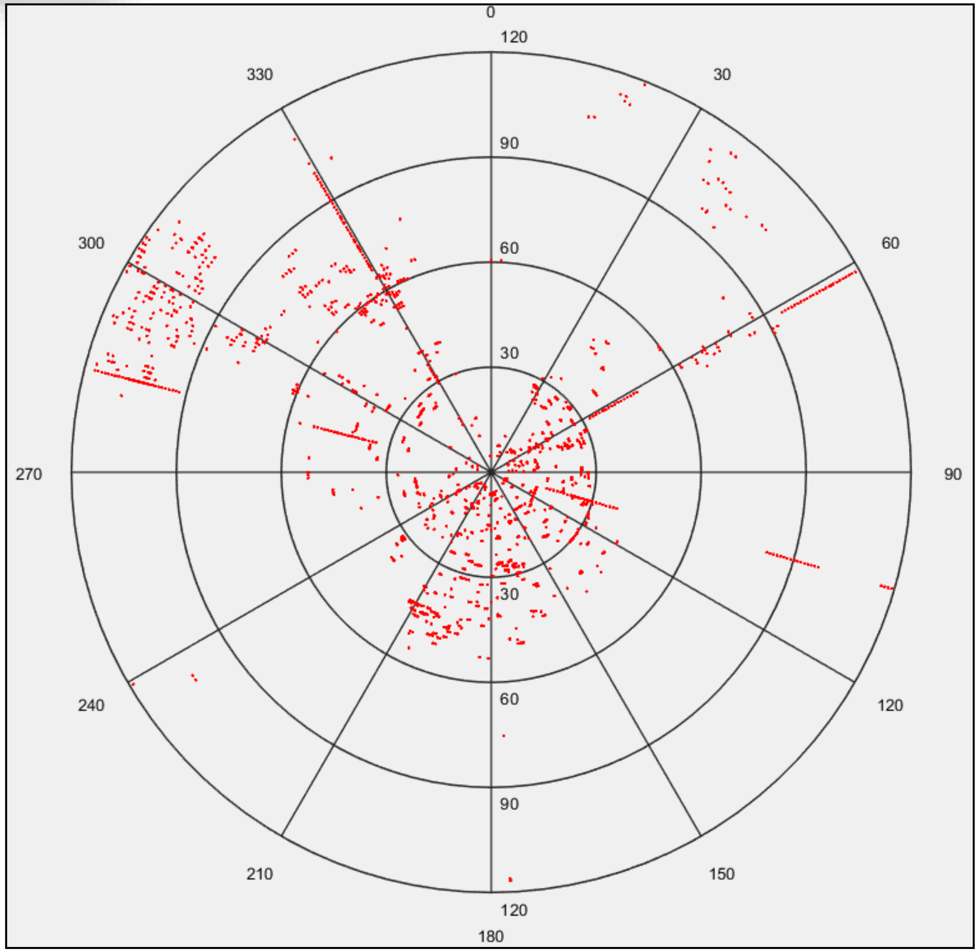
Detections from Model Signal Processor (2 beams)



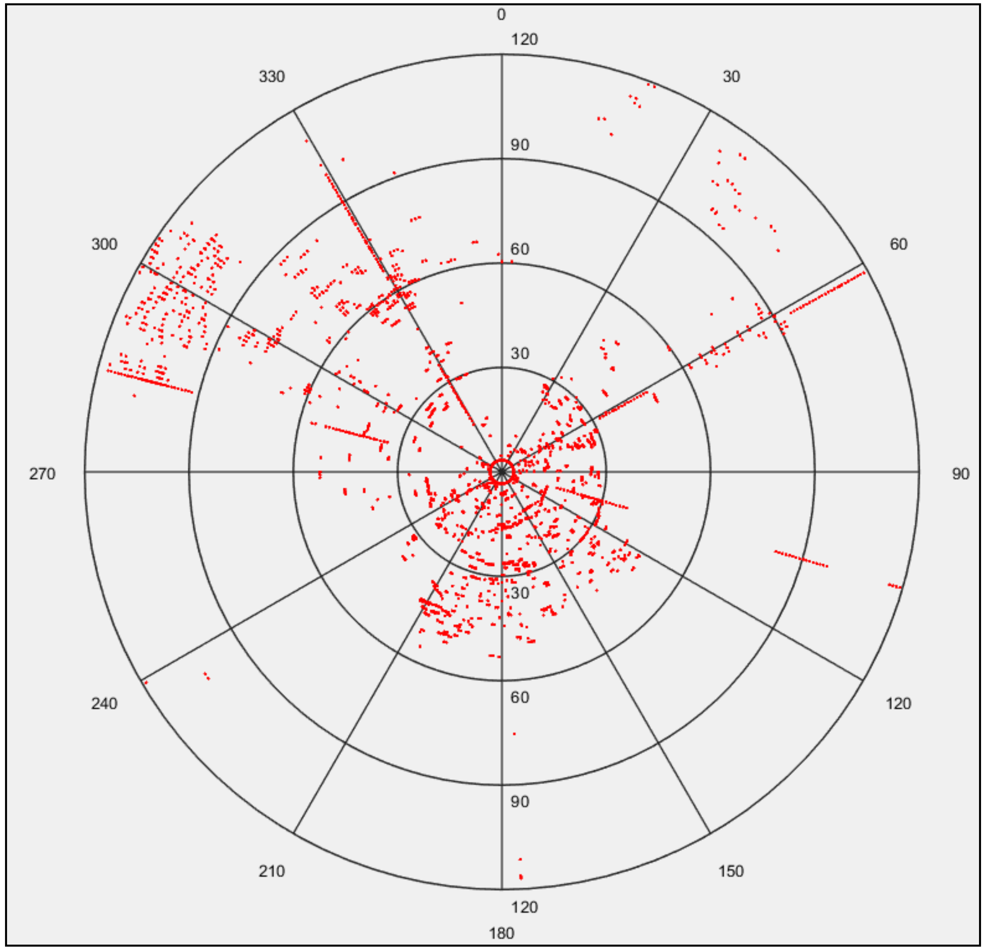
Reference from Radar (all beams)

Robust CFAR Detectors

GO CA CFAR

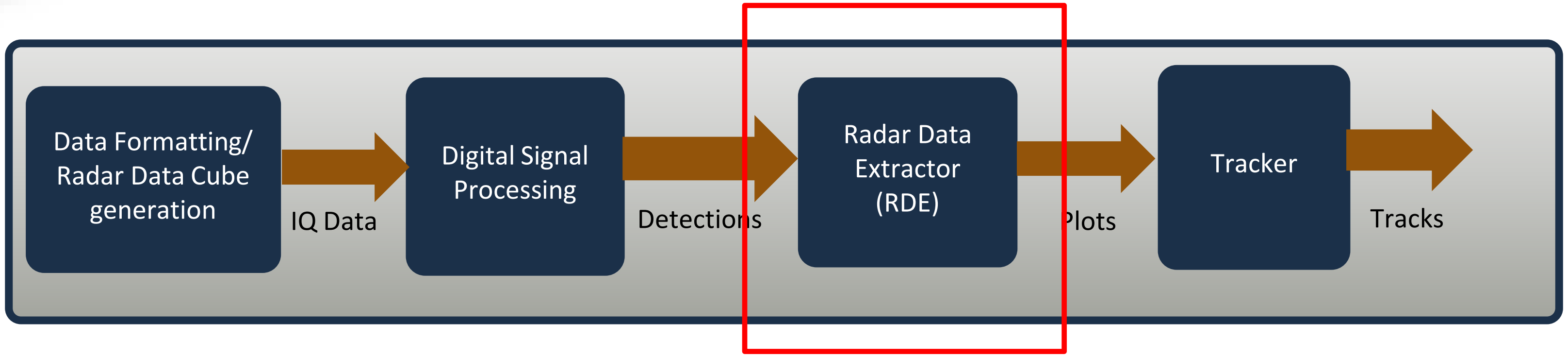


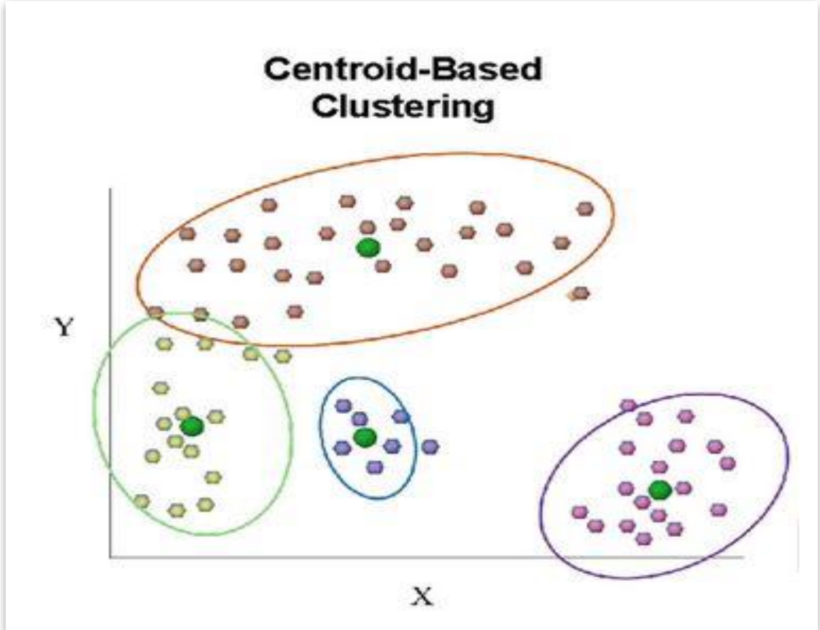
SO CA CFAR

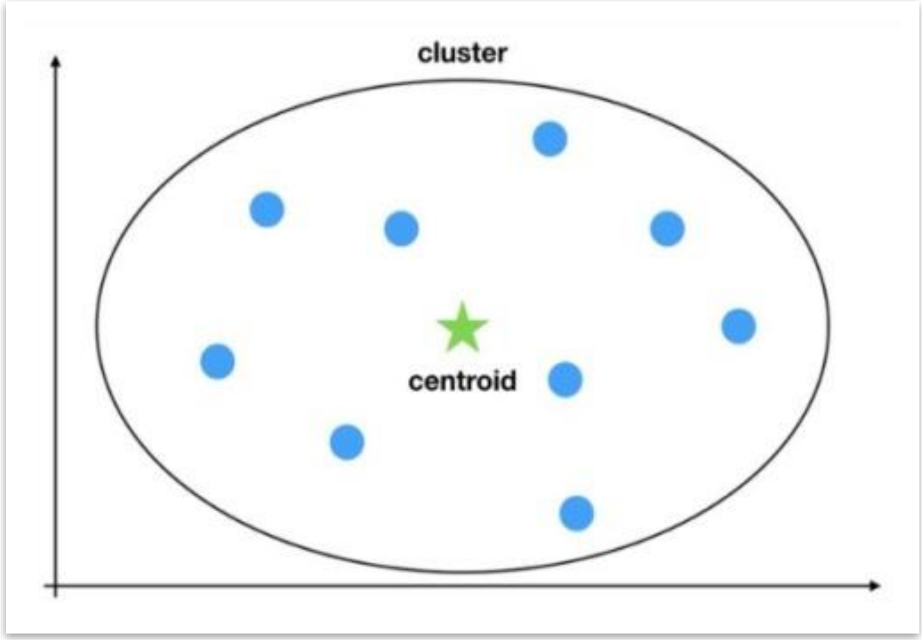


Results achieved are in consonance with expected outcomes

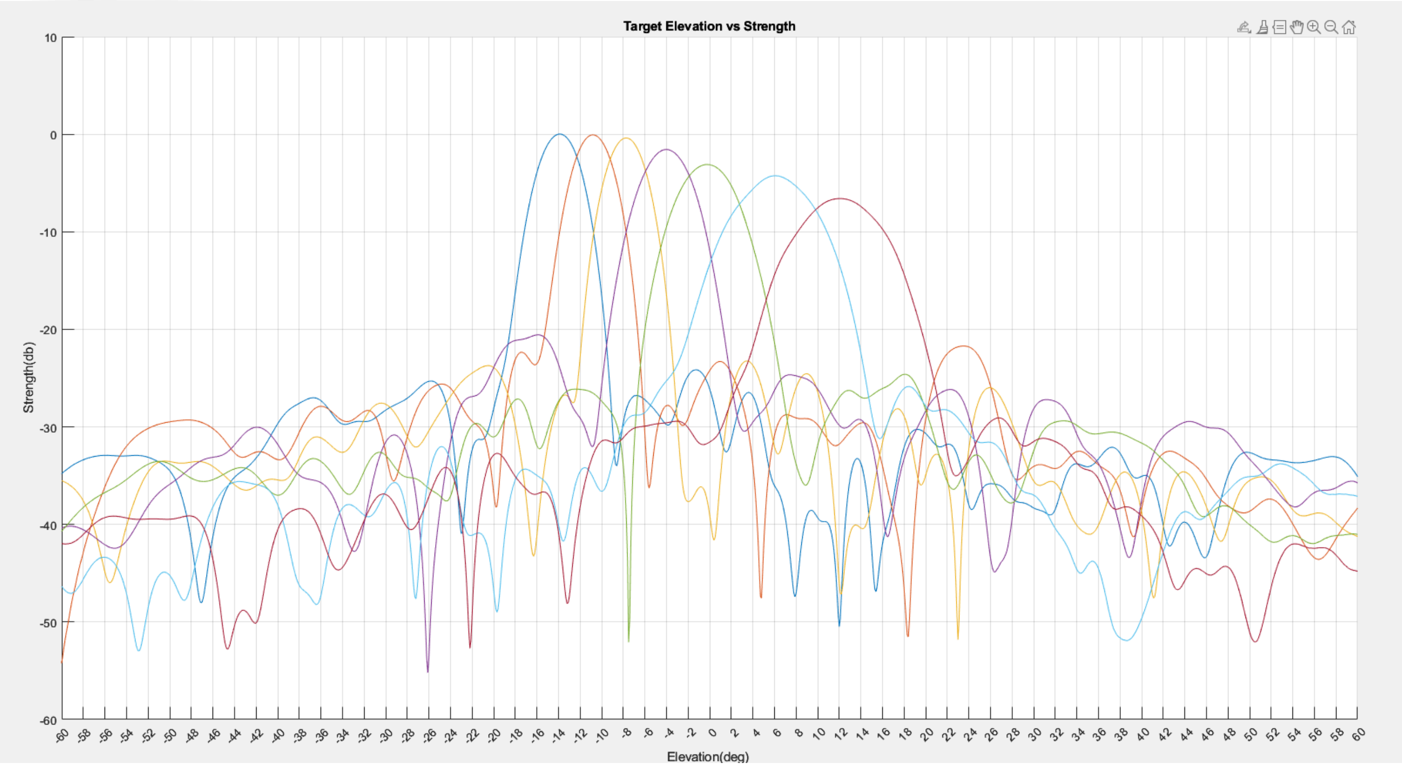
Radar Data Extractor Functionality



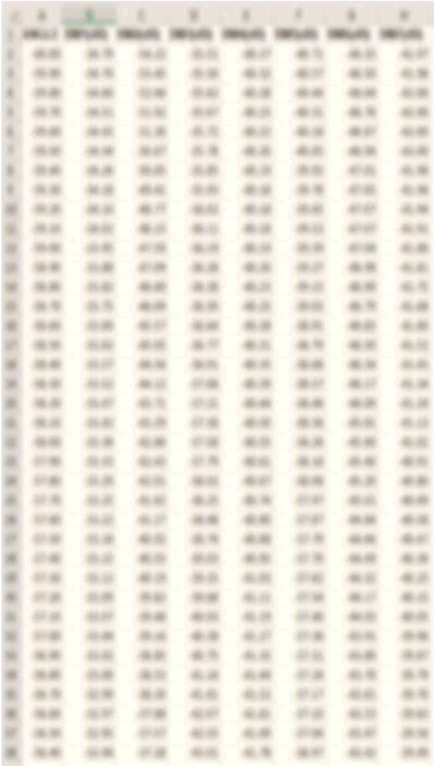




Antenna Pattern Curve Fitting for Elevation Estimation



Curve Fit Plot

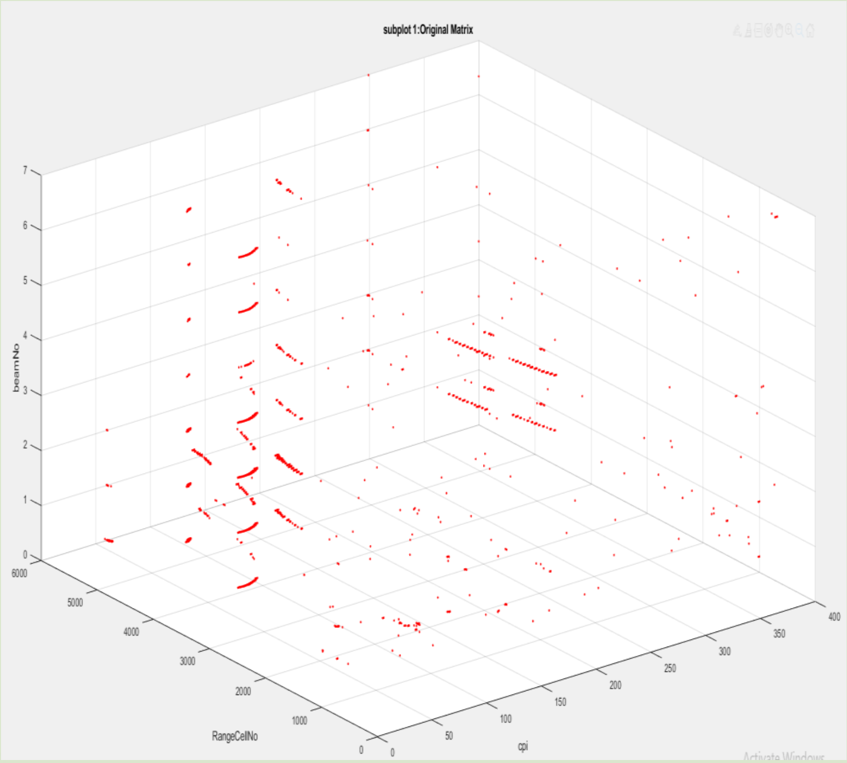


NFTR Data

Polynomial coefficients representing antenna beam pattern are used for Elevation Estimation using monopulse technique

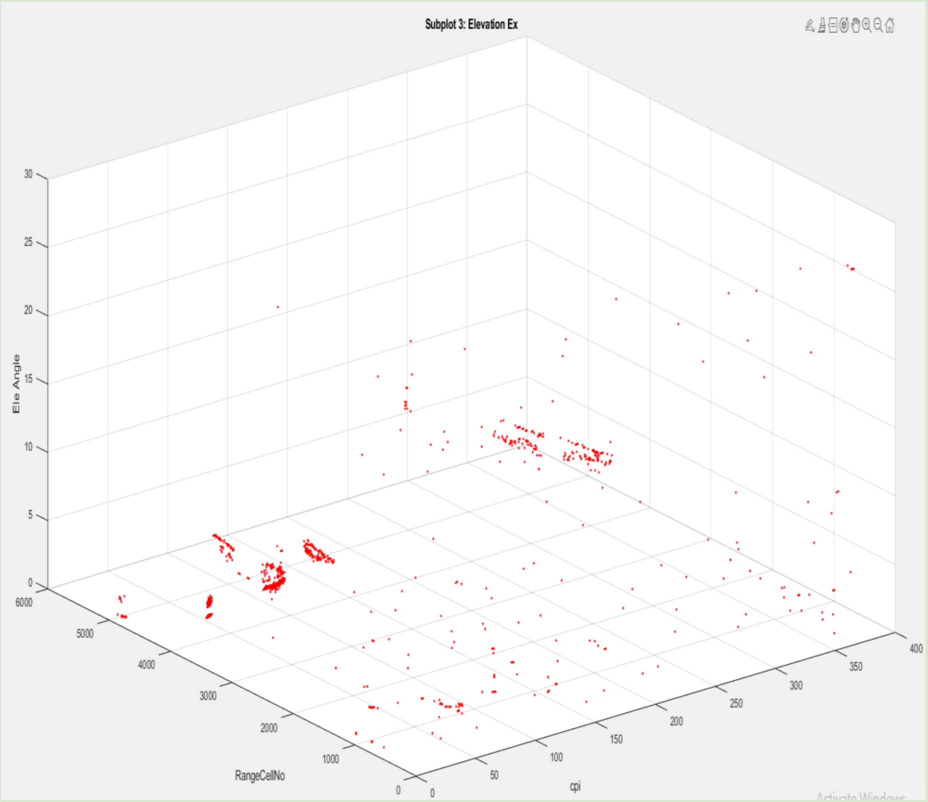
Radar Data Extractor - Results

Step 1 : Detection Data Input from SP



ORIGINAL DATA

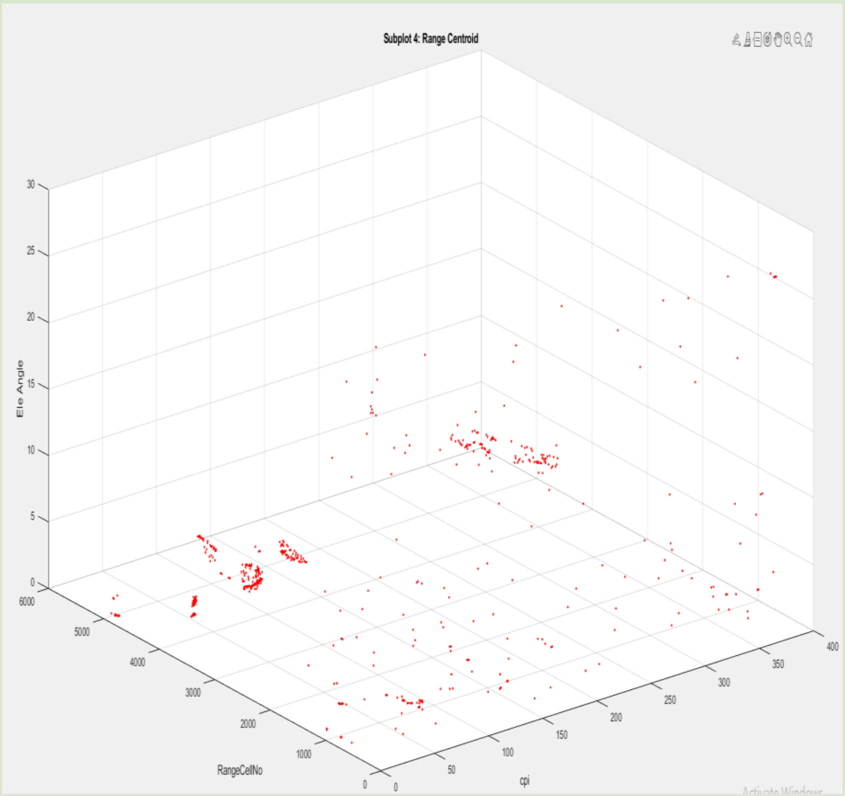
Step 2 : Calculation of Elevation Angle



ELEVATION ESTIMATION

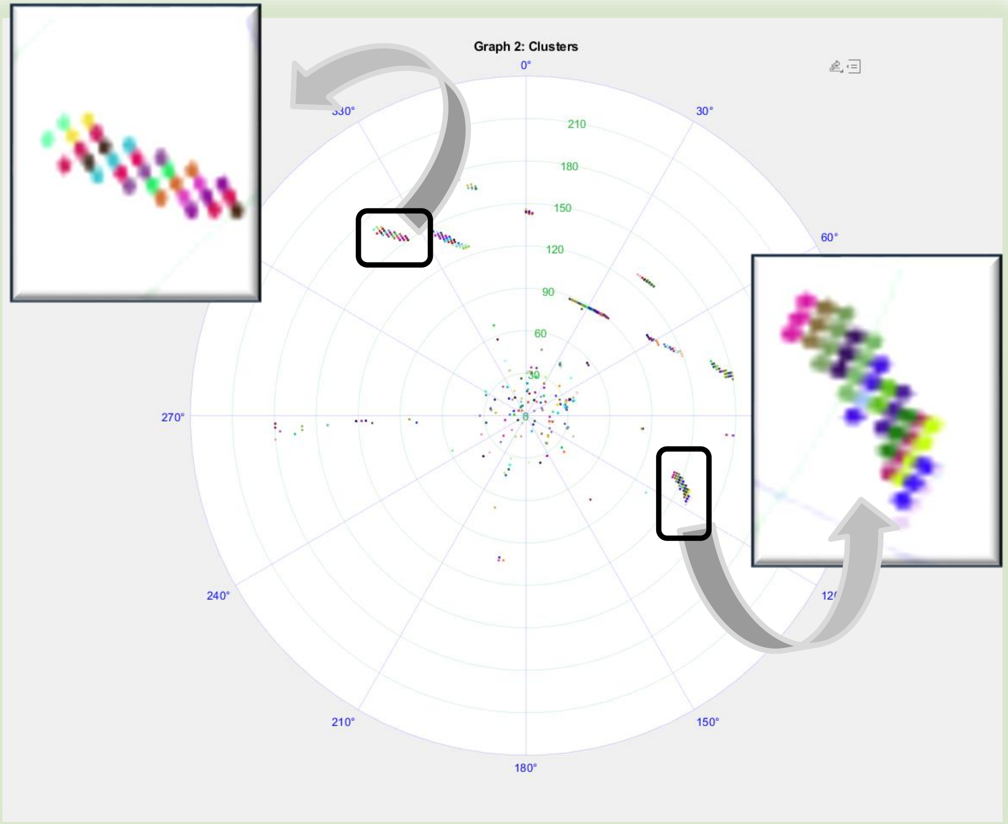
Radar Data Extractor - Results

Step 3 : Calculation of Range Centroid



RANGE CENTROIDED OUTPUT

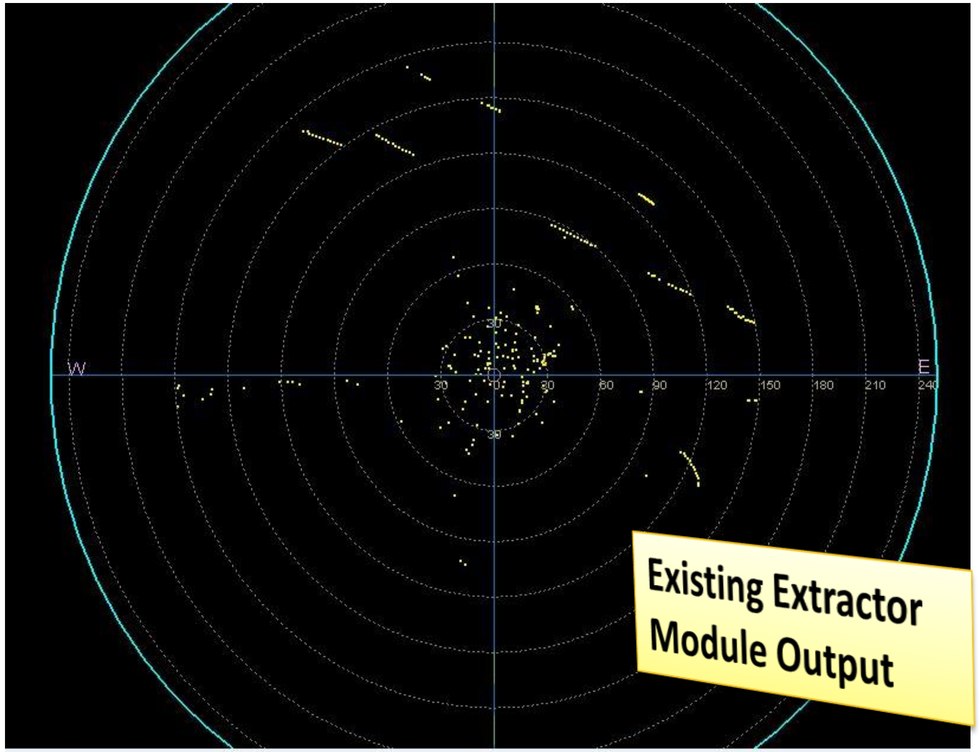
Step 4 : Clustered Output

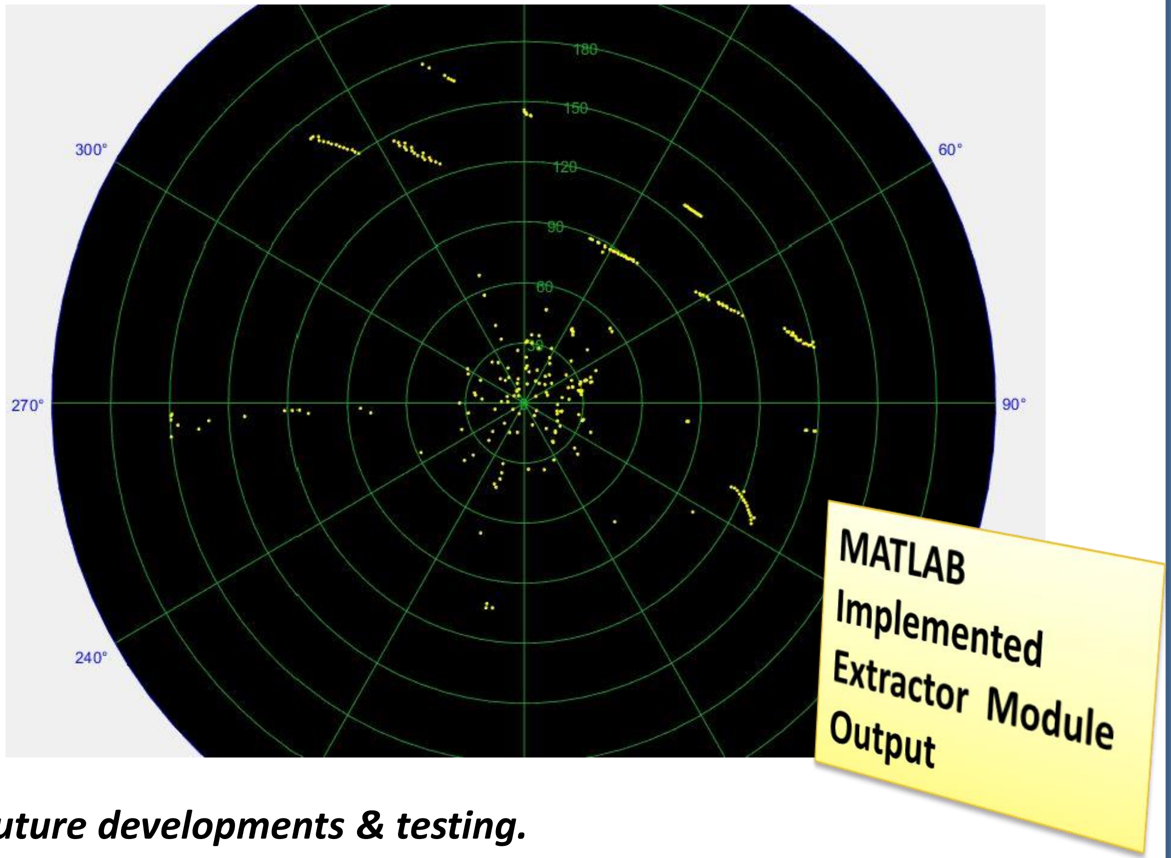


CLUSTERED OUTPUT

Validation of Data Extractor Performance

Performance of Data Extractor realized in MATLAB resembles the performance of actual Radar Data Extractor with an accuracy of more than 95%.





This will serve as test bench for future developments & testing.

Summary

- Usage of Phased Array System Toolbox, Radar Toolbox for design & simulation was found to be time saving as compared to conventional approach
- Ease of testing and performance analysis using strong Visualization tools
- Ease of Design with improved fidelity and significant reduction in development cycle time
- ***Accuracy of more than 95% achieved in Modelling of Signal Processor & Data extractor***

Acknowledgements

- Sincere thanks to **MathWorks Inc** for providing this Platform & specially to **Mr. Sumit Garg** for his excellent technical support.
- Sincere thanks to **Mr. Dheeraj Talwar (AGM) & Mr. Ram Pravesh (DGM)** from BEL for great support & motivation.
- Special Thanks to **Ms. Pratishtha** for her support in the modelling Data Extractor Module

THANK YOU