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

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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

ROHINI

3DTCR

REVATHI

3DCAR AKASH
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

Radar Signal processor (RSP)

IF/RF Signal

- Digitization ADC
- Down Conversion
- Pulse Compression (Matched Filtering)

I/Q DATA

Data Formatting /Radar Data Cube generation

- 2/3 Pulse Canceller (MTI)
- Range-Doppler Map Formation (*FFT)

Range-Doppler Map Formation

- Doppler Filter Bank Processing
- CFAR Processing

MFS

Clutter MAP Processing

DETECTIONS

Radial Data Extractor (RDE)

- Elevation Extraction
- Range Centroiding & Clustering
- Range-Azimuth Centroiding

Plots
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
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
Waveform Analysis

Digital Pulse Compression using Matched Filtering

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

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

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

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

Ref: Principles of Modern Radar (Mark A. Richards)
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
\( \alpha \) 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
CA CFAR Detector Results

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

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

Detection Map for a single beam, single dwell data
Single scan/Single Beam CA CFAR Detections

MATLAB
Phased Array System Toolbox
Radar Toolbox

Detected from Model Signal Processor (2 beams)

Reference from Radar (all beams)
Robust CFAR Detectors

Results achieved are in consonance with expected outcomes
Radar Data Extractor Functionality

Data Formatting/Radar Data Cube generation → Digital Signal Processing → Radar Data Extractor (RDE) → Tracker

Centroid-Based Clustering

Cluster

Centroid
Antenna Pattern Curve Fitting for Elevation Estimation

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

Step 2: Calculation of Elevation Angle

![ORIGINAL DATA](image1.png)

![ELEVATION ESTIMATION](image2.png)
Radar Data Extractor - Results

Step 3: Calculation of Range Centroid

Step 4: 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**

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THANK YOU