System Solutions for Emerging Automotive Radar Applications

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TI training – summary

System Solutions for Emerging Automotive Radar Applications

The presentation focuses on a few Non-ADAS applications and puts forth TI's standard offering initiatives in this context. These applications include obstacle detection for door/ trunk opening, occupancy sensing, gesture detection and driver vital-sign monitoring. These non-ADAS applications deploy the traditional strengths of radar to accurately locate obstacles in different contexts (such as free space sensing) as well as unique strengths of radar that are not often discussed in Automotive ADAS applications. For example, occupancy sensing and gesture recognition exploit radar's sensitivity to small movements, whereas driver vital-sign monitoring exploit a radar's capability to accurately estimate the frequency of vibrating objects

What you'll learn:

- Understand challenges of single-board and single-chip radar
- Learn how to overcome these challenges with TI products
- Learn about non-ADAS application and TI's standard offering initiatives

Training level: Intermediate

Course Details:

Audience: All

Specific TI Designs & Parts Discussed:

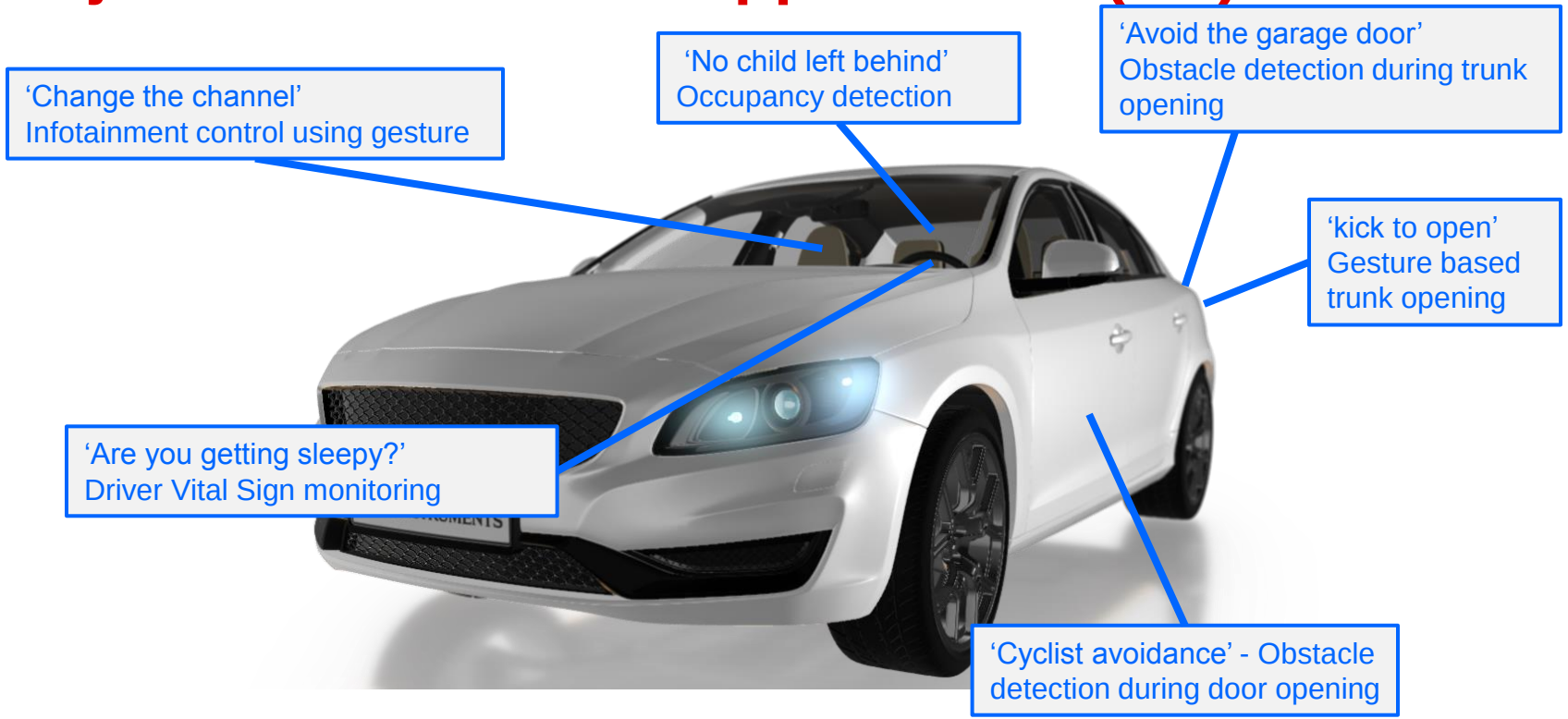
- AWR1443, AWR1642, LP87524, LP8770.
- TIDA-01570

Adjacent Automotive Applications

Agenda

- Adjacent automotive applications using radar
  - Obstacle detection.
  - Driver vital sign monitoring.
  - Occupancy detection.
  - Gesture recognition.

Adjacent Automotive Applications (1/2)



Adjacent Automotive Applications (2/2)

- Why Radar:
  - Fine Range and velocity resolution
  - Robust under weather
  - Aesthetics: can be placed behind a façade
  - Multi-use : E.g. parking sensor doubles as a ‘kick-to-open’ sensor
  - High Sensitivity to small movement.

- The AWR1642 76-81 GHz integrated radar sensor is ideally suited for these applications:
- Chirp with 4GHz bandwidth
- 2 TX – 4 RX
- C6748 DSP @600MHz
- ARM R4F @200MHz
- 1.5MB on-chip

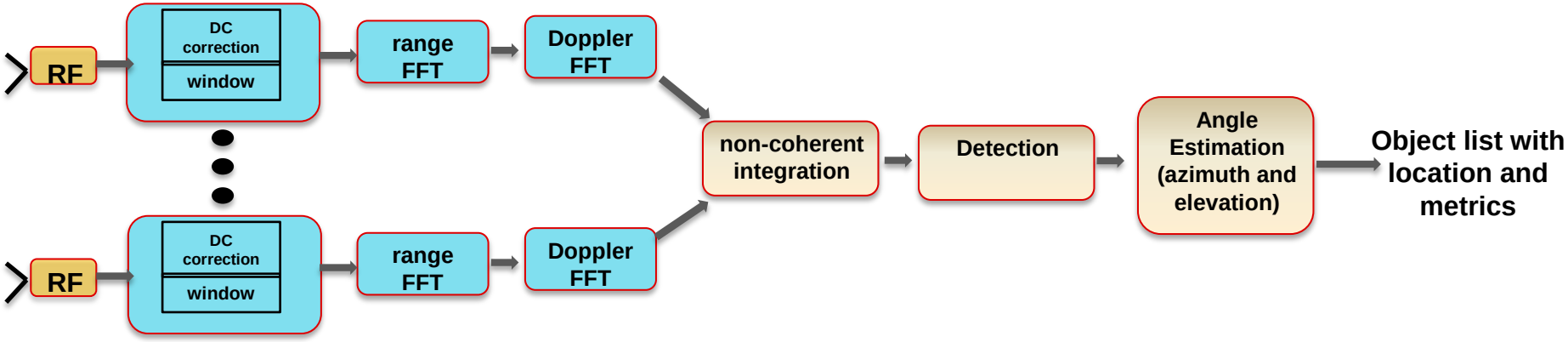
- Application note
http://www.ti.com/lit/wp/spry315/spry315.pdf

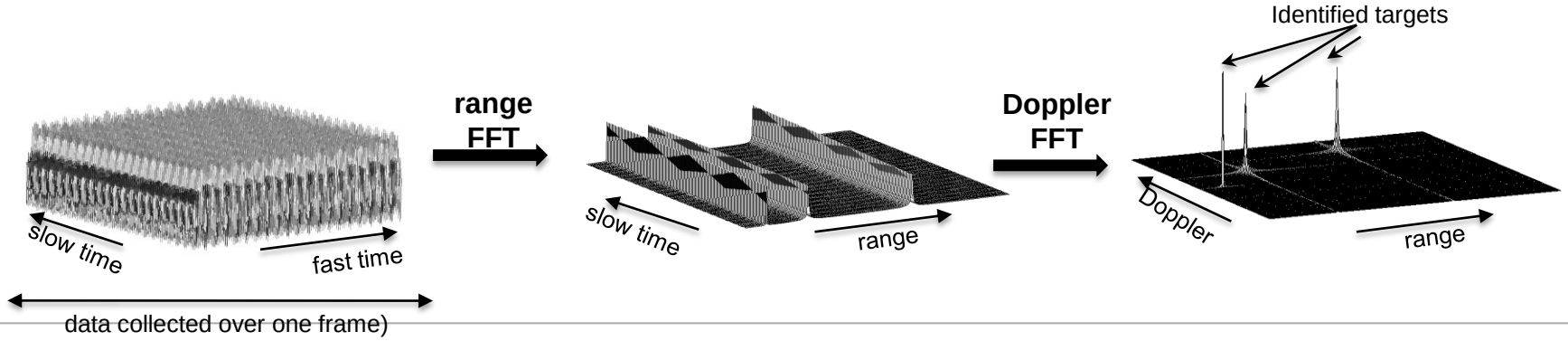
Obstacle Detection Sensor

Obstacle Detection Sensor (1/4) – Applications

- **Car Door Opening**
  - Detect obstacles around car door and lock movement to avoid damage
- **Trunk Opening**
  - Detect obstacles around trunk to avoid damage while opening
- **Parking assistance**
  - Detect objects like plastic, metal cones, curb, tree, mesh, other cars, motorcycle, pedestrian while parking a car
- **Detect potholes/Speed bumps**
  - For smoother driving by tuning the suspension based on the road ahead.

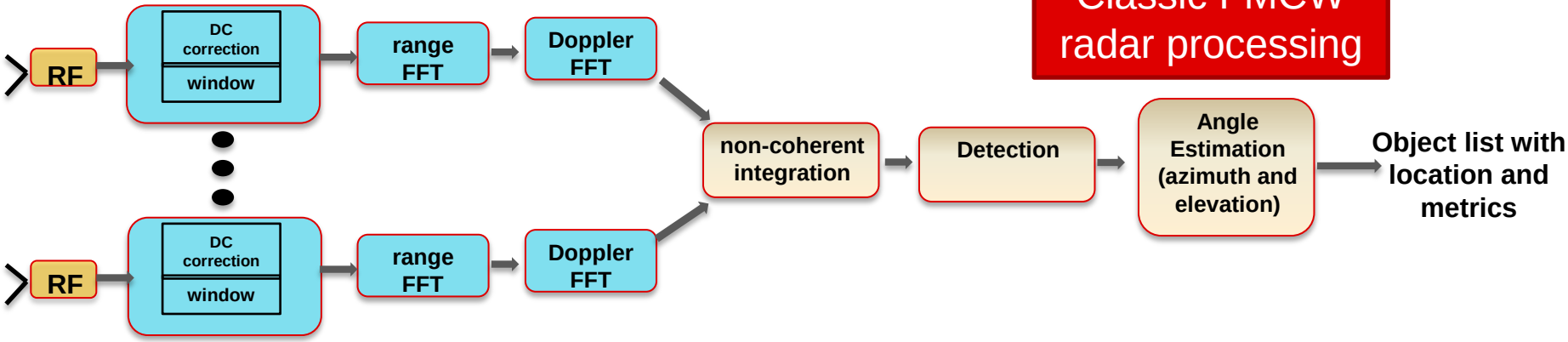
Obstacle Detection Sensor (2/4) - Processing Chain

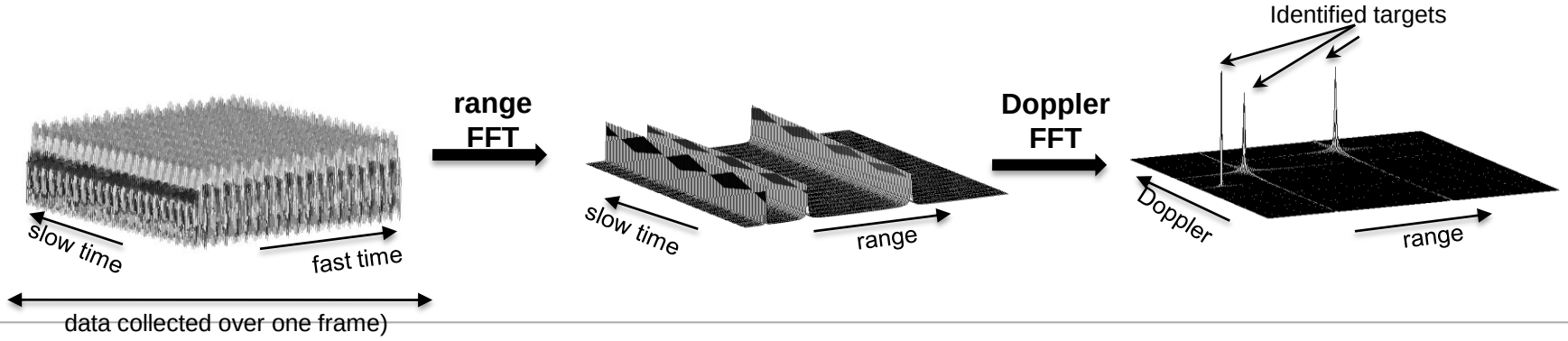




Obstacle Detection Sensor (2/4) - Processing Chain

Classic FMCW radar processing





Obstacle Detection Sensor (3/4) –Hardware Platform

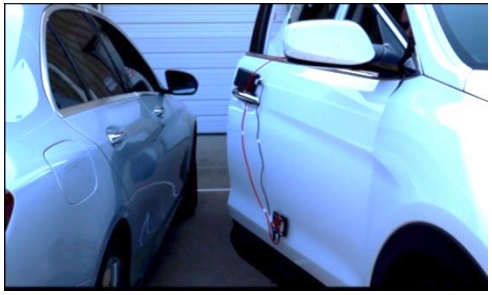
AWR1642- ODS EVM

85 x 65mm

- Available to order on ti.com in April 2018
  www.ti.com/product/AWR1642

- Newly designed antenna
  - Wide field of view
    - $\pm 80^{o}$.
  - Elevation measurement.
  - Detection range of 15m,
- Otherwise similar to AWR1642BOOST EVM.

Obstacle Detection Sensor (4/4) – Evaluation



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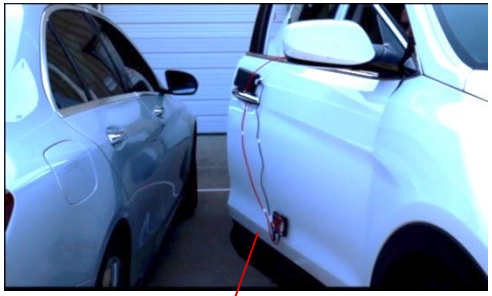
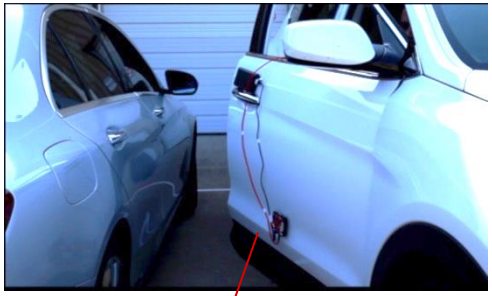


Sensor 50cm from ground

Obstacle Detection Sensor (4/4) – Evaluation



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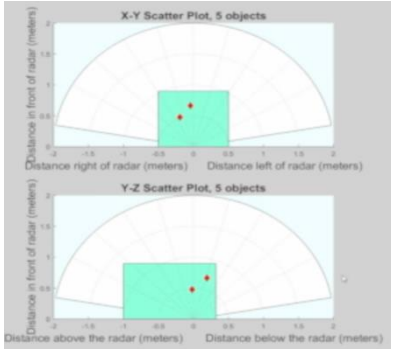

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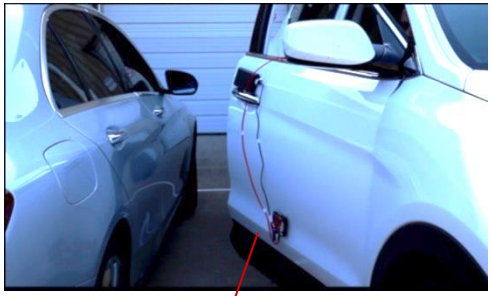
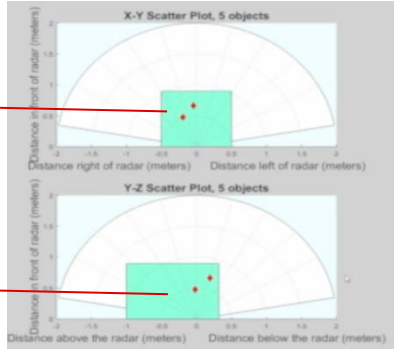


Sensor 50cm from ground

Car door detection in horizontal plane

Car door detection in vertical plane



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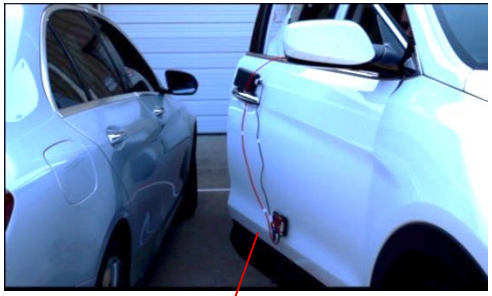

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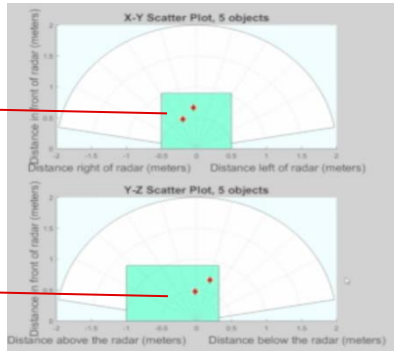
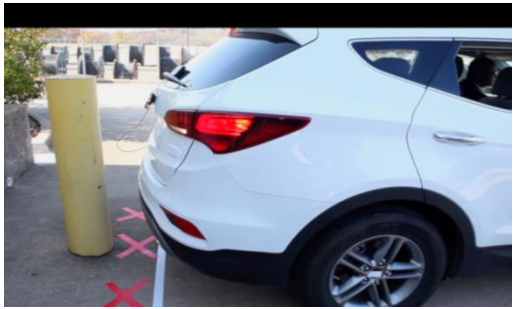
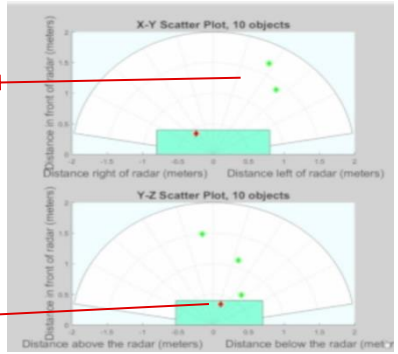




Objects detected not as obstacles

Pole detected as obstacle



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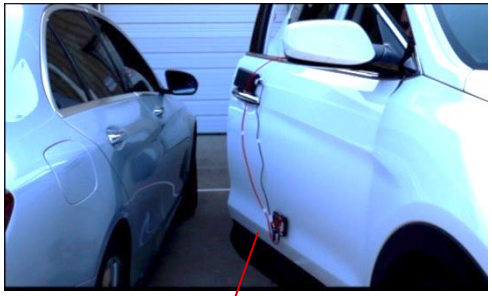

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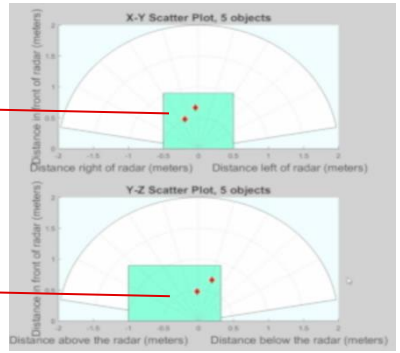
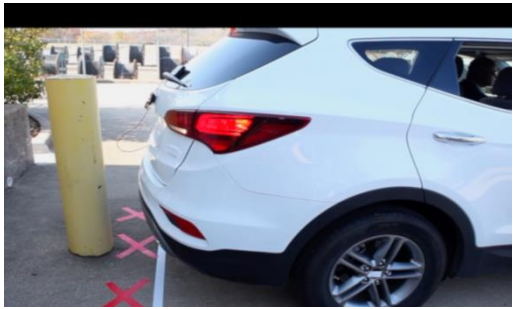
Car door detection in vertical plane





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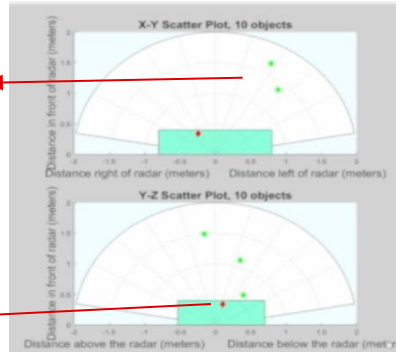


Chirp configuration

Parameter	Value
Chirp bandwidth	4GHz
Chirp periodicity	100µs
Number of chirps per frame	32 (interleaved between TX1 and TX2)
Maximum velocity	17kmph
Range resolution	~4cm
Maximum range	4m
Velocity resolution	1kmph
Memory requirement	~100KB

Reference :

- EVM and TI Design - end of April
- Early evaluation code and EVM schematics available now at mySecureSW

Driver Vital Sign Monitoring

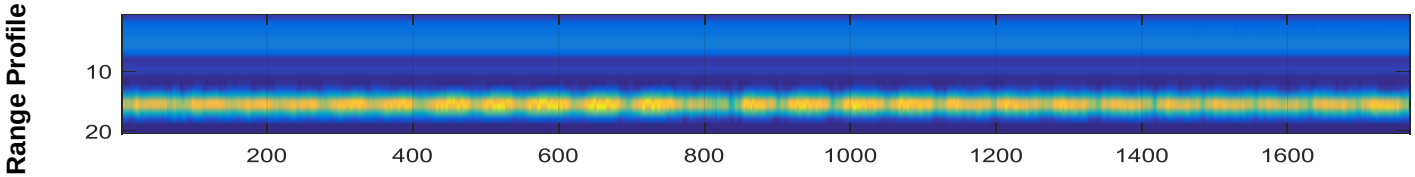
Driver Vital-Signs Monitoring (1/4) - Application

- **Targeted application :** Monitoring of heart and breathing rate of driver.
  - If he/she is falling asleep, the heart/breathing rate would slowly decrease.
- How does Radar measure heart-rate ?
  - 77Ghz radar doesn't penetrate the skin.
  - Radar can measure body surface movements due to breathing/heartrate.
  - Uses the sensitivity of 77Ghz radar to small movements (1mm => 180 degrees phase shift).

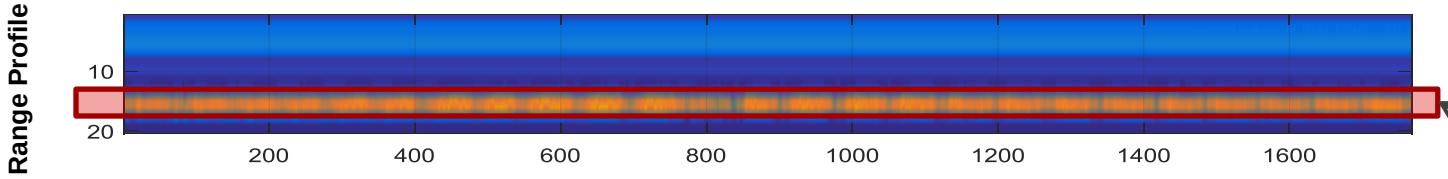
Typical vital sign parameters

		From Front	From Back
Vital Signs	**Frequency**	**Amplitude**	**Amplitude**
Breathing Rate (Adults)	0.1 – 0.5 Hz	~ 1- 12 mm	~ 0.1 – 0.5 mm
Heart Rate (Adults)	0.8 – 2.0 Hz	~ 0.1 – 0.5 mm	~ 0.01 – 0.2 mm

Driver Vital-Signs Monitoring (2/4) – Processing

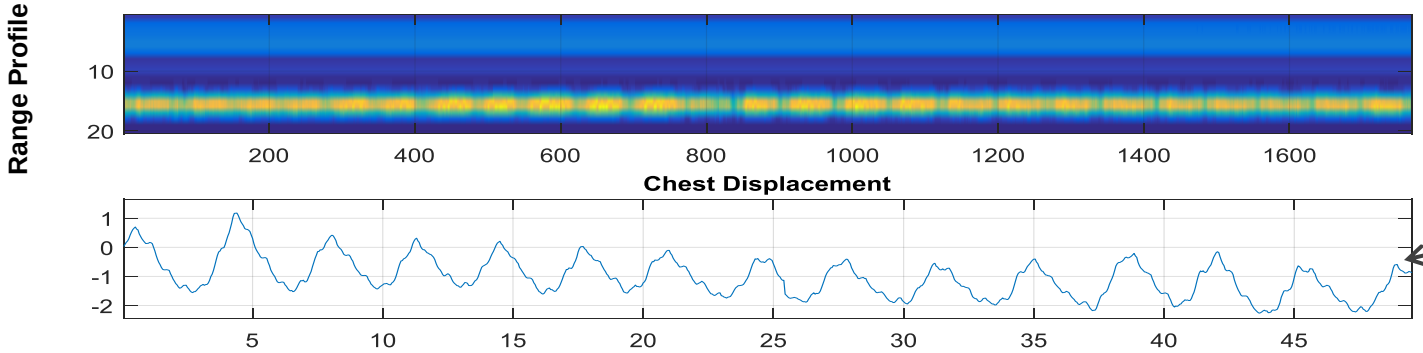


Driver Vital-Signs Monitoring (2/4) – Processing

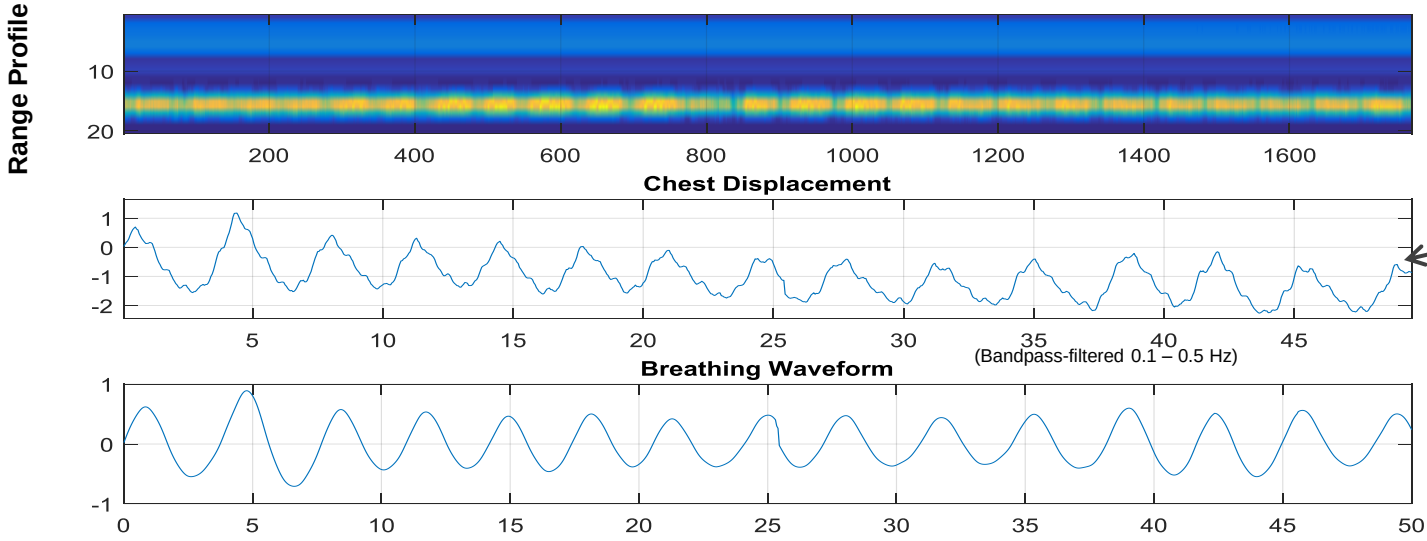


Range
of interest.

Driver Vital-Signs Monitoring (2/4) – Processing



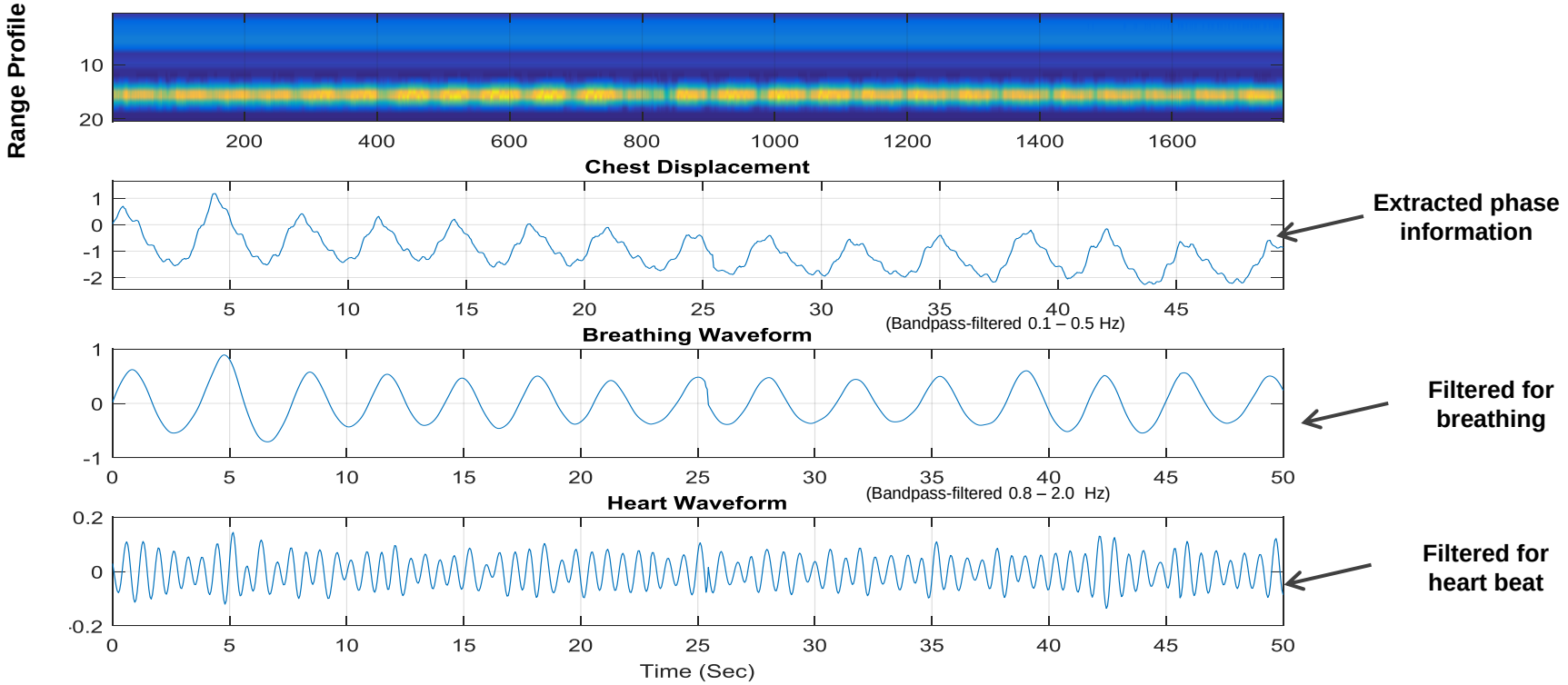
Driver Vital-Signs Monitoring (2/4) – Processing



Extracted phase information

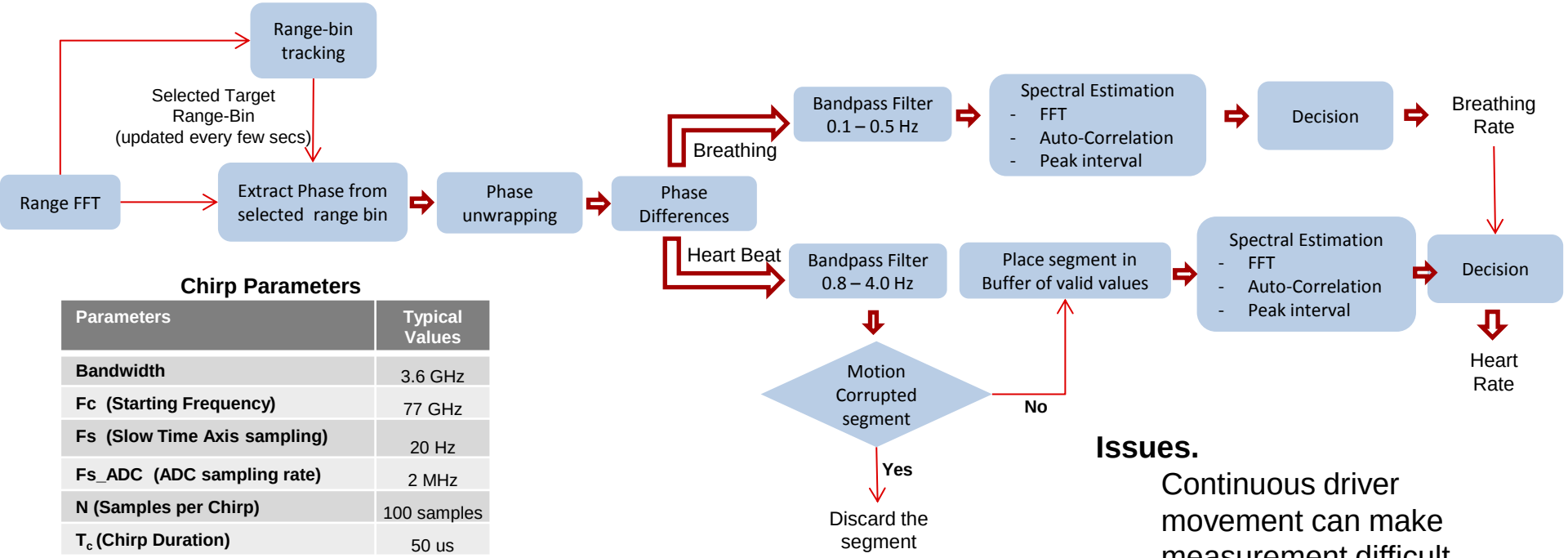
Filtered for breathing

Driver Vital-Signs Monitoring (2/4) – Processing



Driver Vital-Signs Monitoring (3/4) – Processing

- Real-time implementation (20 fps) on the C674x DSP Processing Core
- Processing done over a running window of *T* ~ 16 seconds. New estimates are updated every 1 second
- Memory Requirements ~ 16 kB, CPU Processing time for a single estimate ~ 4 ms



Chirp Parameters

Parameters	Typical Values
Bandwidth	3.6 GHz
Fc (Starting Frequency)	77 GHz
Fs (Slow Time Axis sampling)	20 Hz
Fs_ADC (ADC sampling rate)	2 MHz
N (Samples per Chirp)	100 samples
T_c (Chirp Duration)	50 us

Issues.

Continuous driver movement can make measurement difficult.

Driver Vital-Signs Monitoring (4/4) – Evaluation

- AWR1642 BOOST sensor is used for testing
- The sensor is embedded into the seat, behind the driver.

Driver Vital-Signs Monitoring (4/4) – Evaluation

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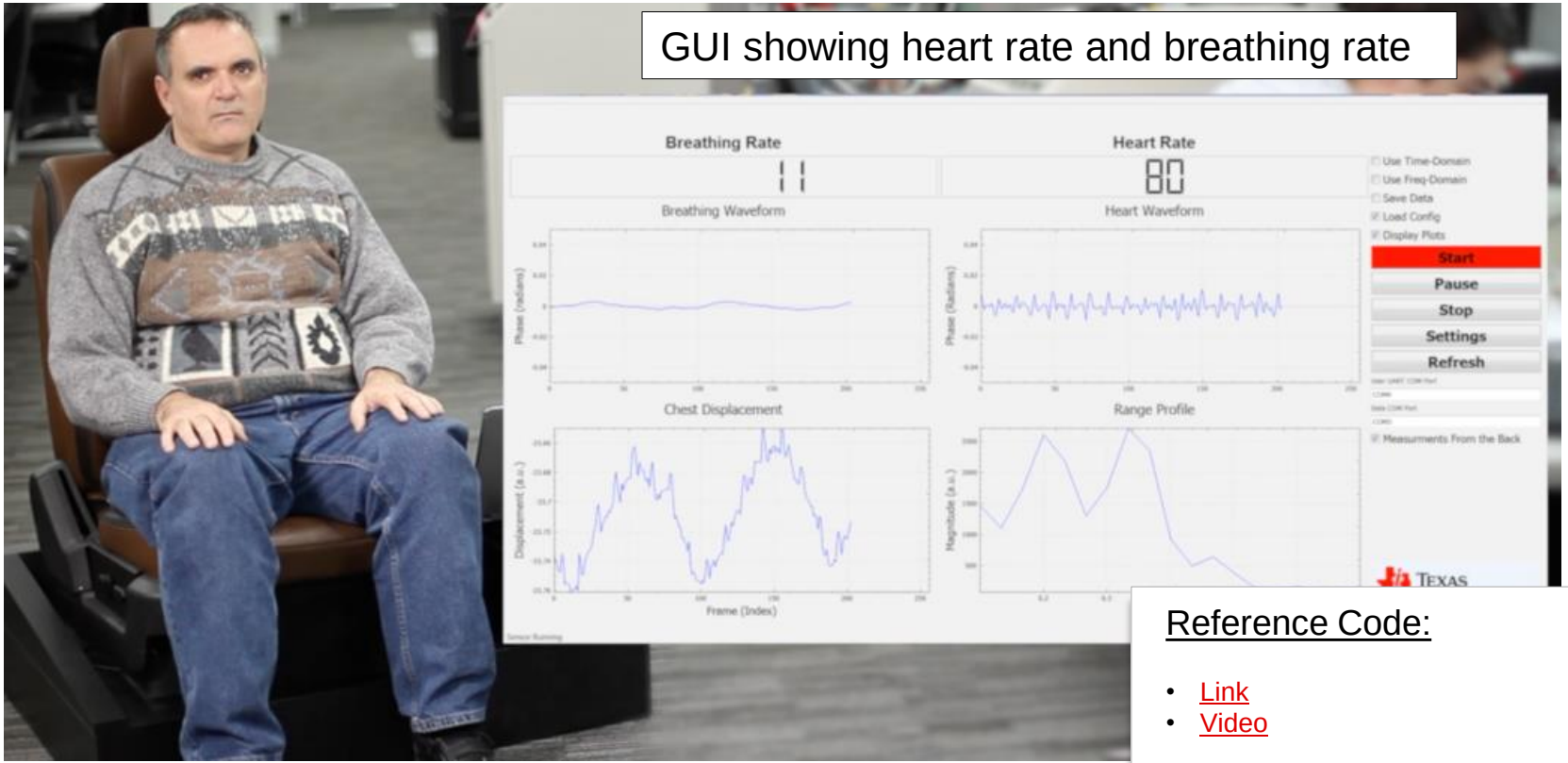
Driver Vital-Signs Monitoring (4/4) – Evaluation



Reference Code:

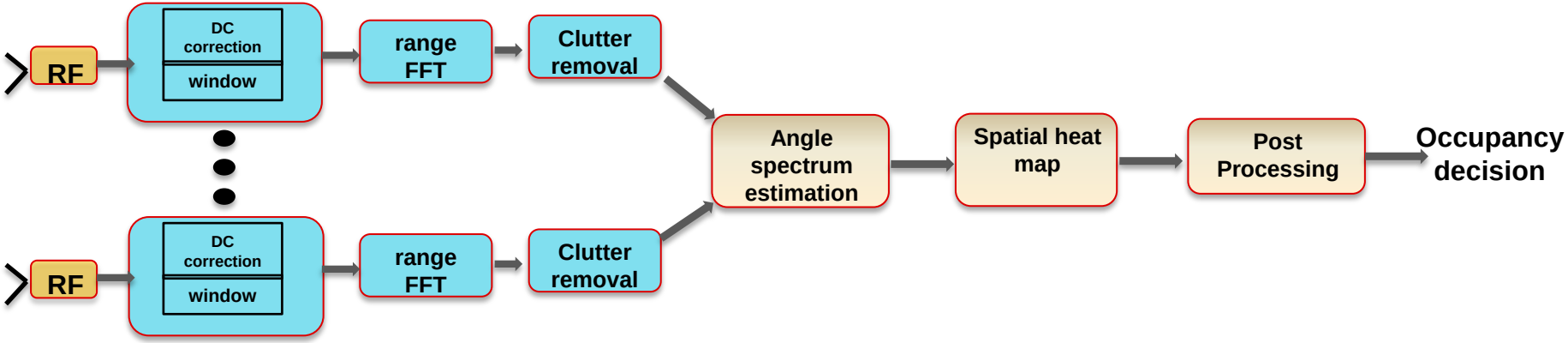
- Link
- Video

Vehicle Occupant Detection

Vehicle Occupant Detection (1/3) - Applications.

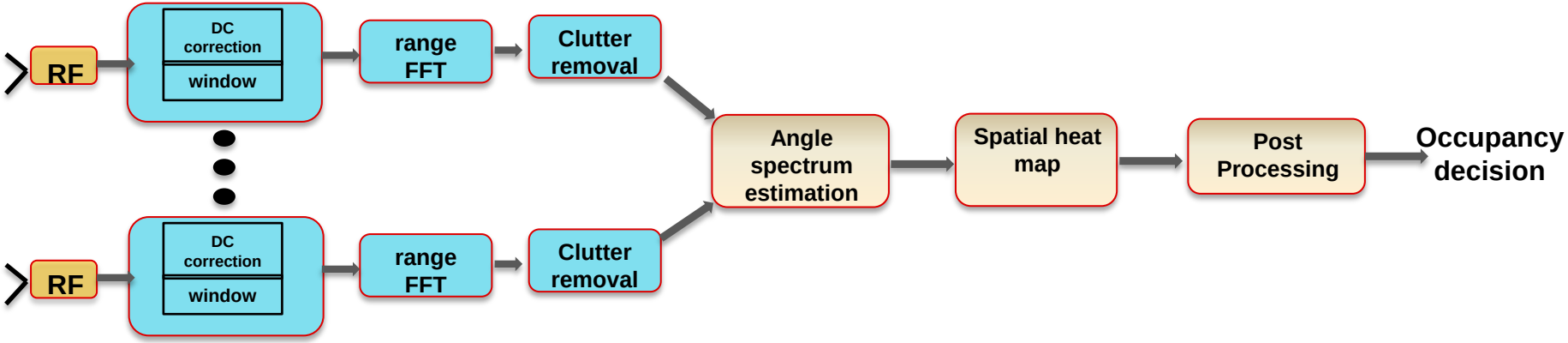
- **Child left behind in car detection**
  - Detect the presence of a child in car when a caregiver locks the car door forgetting to take the child outside
- **Occupancy detection**
  - Detection of a lifeform in any seat to determine the force of airbag deployment in case of crashes
- **Intruder detection**
  - Detection of a intruder breaking into a car

Vehicle Occupant Detection (2/3) - Processing chain.



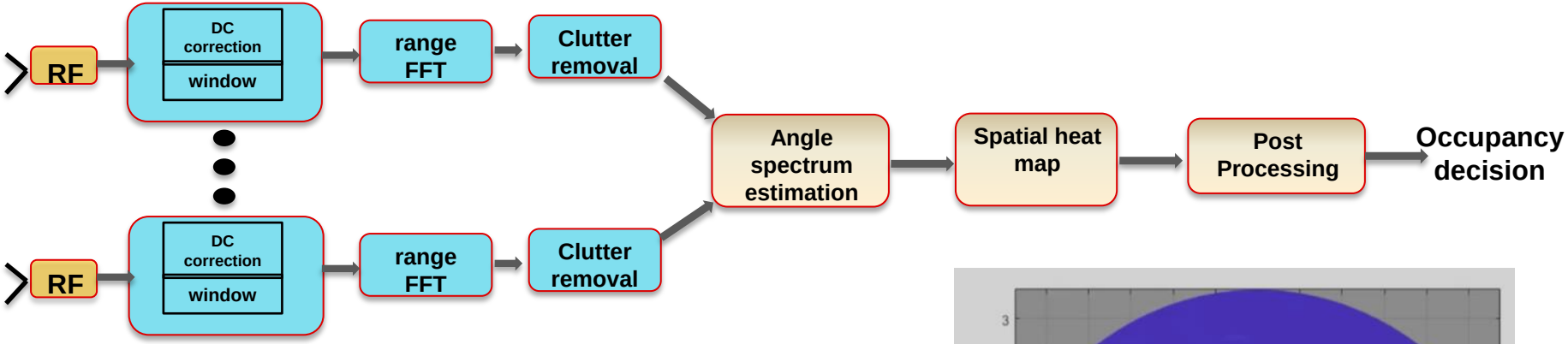
32

Vehicle Occupant Detection (2/3) - Processing chain.



- Main difference with OOB is that
  - No doppler processing is performed.
  - Angle estimation is performed using MVDR.
    - Provides better angular resolution assuming targets are slowly moving.

Vehicle Occupant Detection (2/3) - Processing chain.



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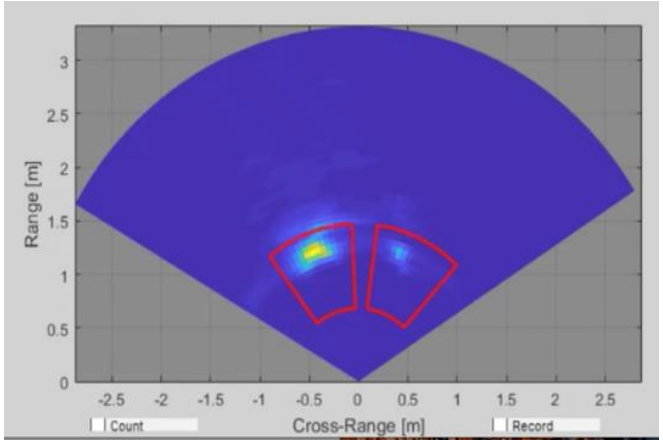

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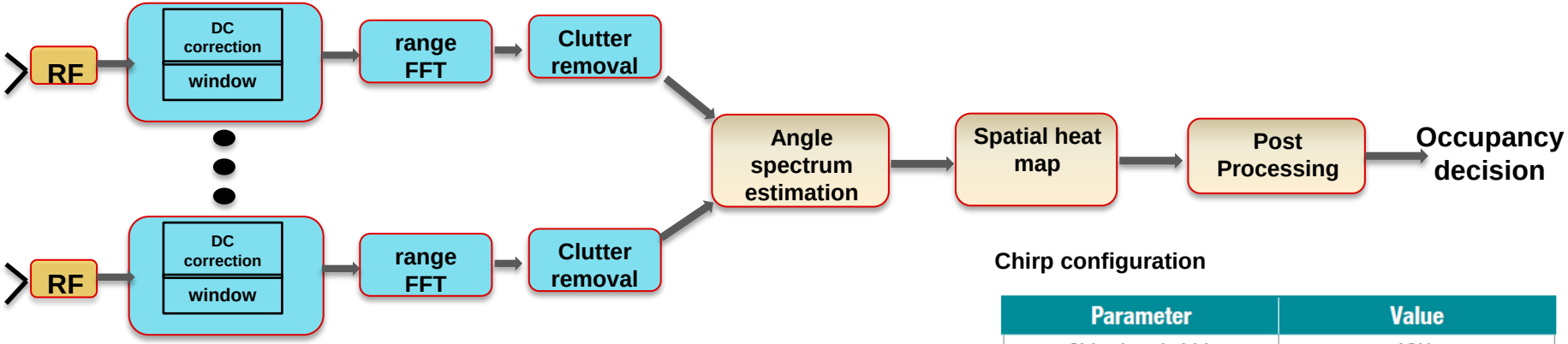

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  - No doppler processing is performed.
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    - Provides better angular resolution assuming targets are slowly moving.

Chirp configuration

Parameter	Value
Chirp bandwidth	4GHz
Chirp periodicity	340µs
Number of chirps	512 (256 each of TX1 and TX2)
Range resolution	~4cm
Maximum range	3m
Maximum velocity	2.28m per second (10kmph)
Velocity resolution	0.02m per second (0.08kmph)
Memory requirement	600KB

Vehicle Occupant Detection (3/3) - Evaluation.

- Demo can perform zone-based detection.
  - Is a seat occupied?

Vehicle Occupant Detection (3/3) - Evaluation.

- Demo can perform zone-based detection.
  - Is a seat occupied?

Vehicle Occupant Detection (3/3) - Evaluation.

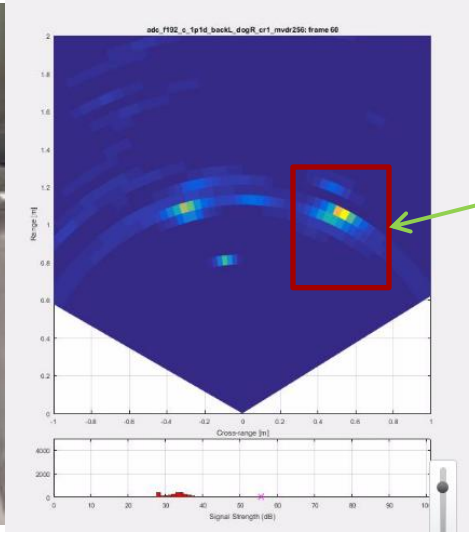
User defined zone.

- Demo can perform zone-based detection.
  - Is a seat occupied?

Vehicle Occupant Detection (3/3) - Evaluation.

- In-car test, demonstrating the detection of pets.
  - Pets have very small RCS

Vehicle Occupant Detection (3/3) - Evaluation.



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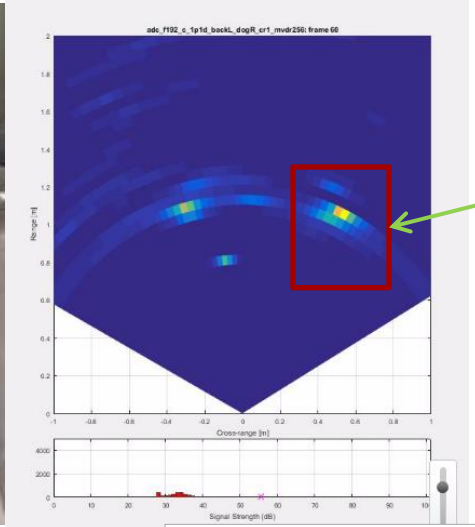
Vehicle Occupant Detection (3/3) - Evaluation.



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  - Pets have very small RCS

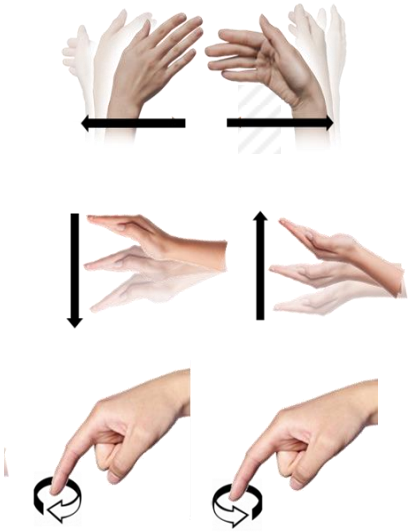
Collateral :

- Source code : link
- white paper : link
- Evaluation module : AWR1642BOOST

Gesture Inference

Gesture Inference (1/4) – Applications

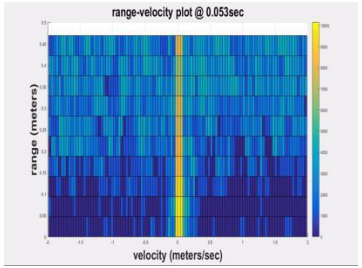
- ‘Kick to open’
  - Detect the kick “gesture” to open the trunk of a car – hands-free.
- In-cabin gestures
  - Swipe up and down to open and close the sun roof.
  - Swipe left and right to change radio channels.
  - Rotate finger to control radio volume.



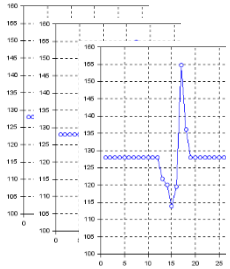
Gesture Inference (2/4) – Processing

Input:
ADC samples

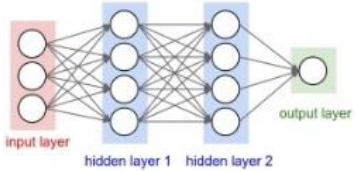
Intermediate O/P:
Range Doppler Image (RDI)



Intermediate O/P:
Per frame Feature Vector

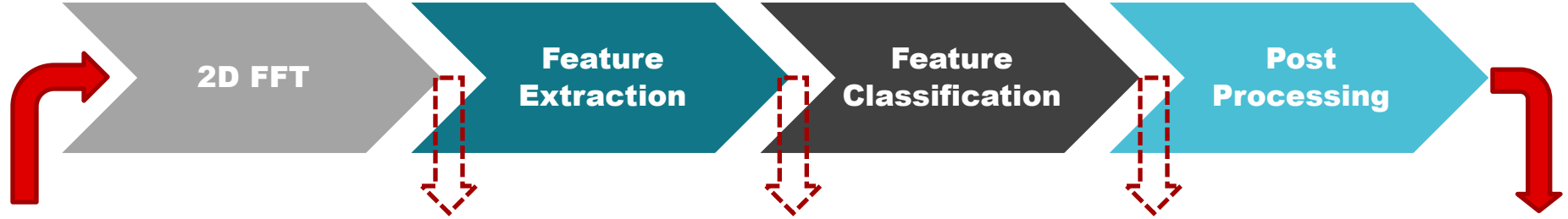


Intermediate O/P:
Classified Gesture



Output:
Filtered Gesture

Gesture Inference (2/4) – Processing



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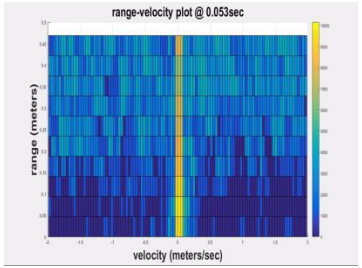

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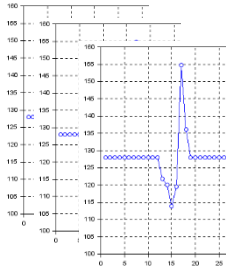

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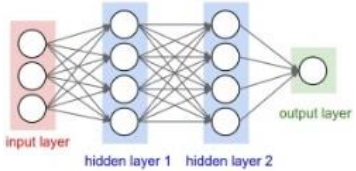
Classified Gesture



Output:
Filtered Gesture

- Radar advantages over camera
  - Fine velocity estimation.
    - Enables detection of fine motion
  - Unaffected by light..

Gesture Inference (2/4) – Processing

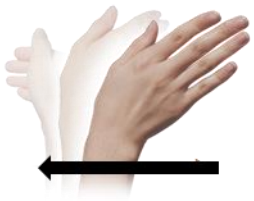
Input:
ADC samples

Output:
Filtered Gesture

Chirp Parameters

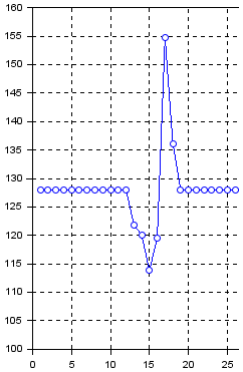
Specifications	Gesture Recognition
Max. Range (m)	3.35 m (ROI limited to 80 cm)
Range Resolution (m)	0.05 m
Absolute Velocity (m/s)	2.5 m/s
Velocity Resolution (m/s)	0.039 m/s
Range Dimension	64
Doppler Dimension	256
Frames/sec	19.6

Gesture Inference (3/4) – Signatures

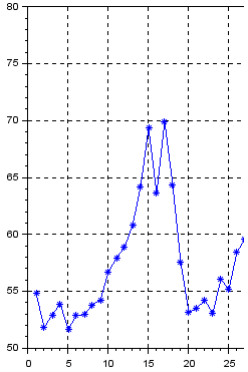


1. Right2Left Swipe

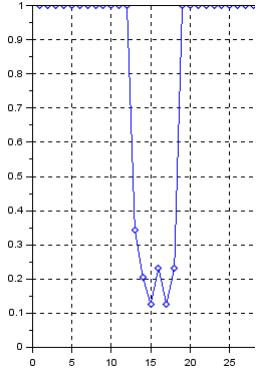
Weighted Doppler



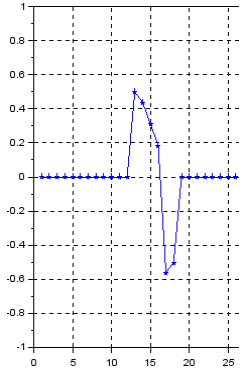
Instantaneous Energy



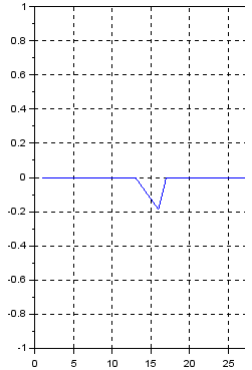
Weighted Range



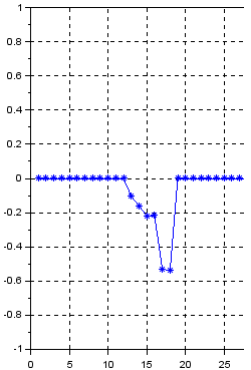
Azimuth Angle



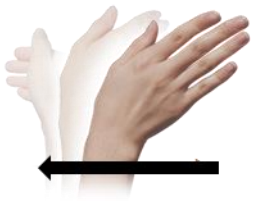
Elevation Angle



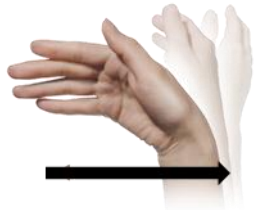
Azimuth-Doppler Correlation



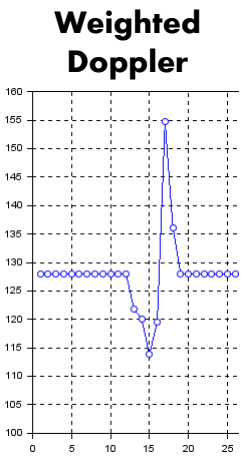
Gesture Inference (3/4) – Signatures

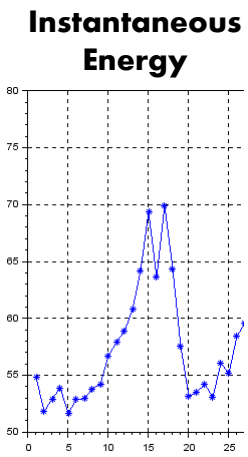


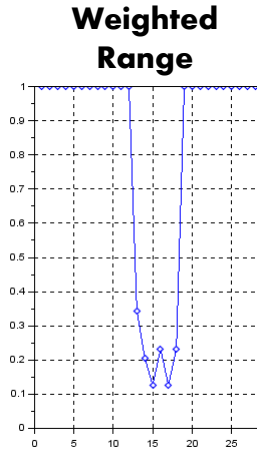
1. Right2Left Swipe

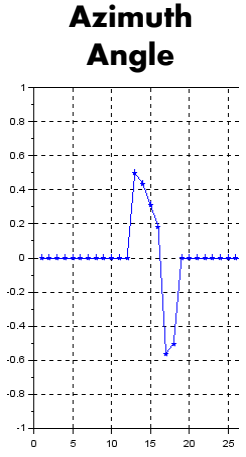


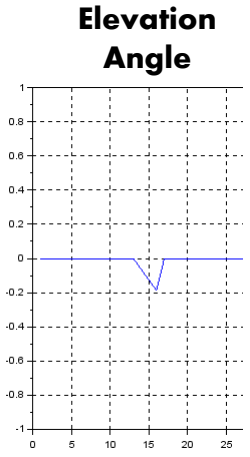
2. Left2Right Swipe

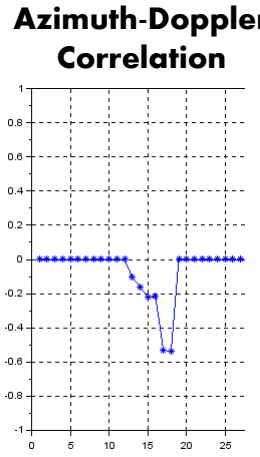


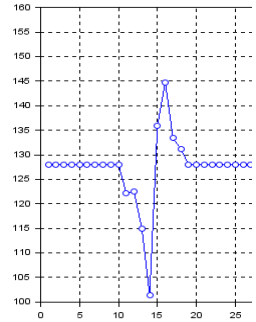


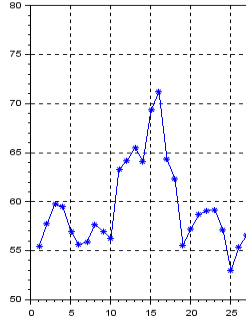


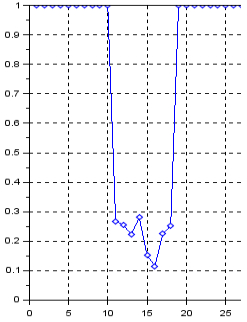


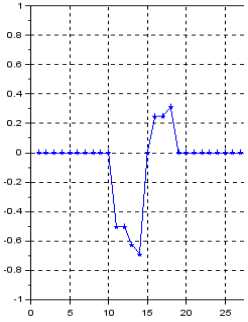


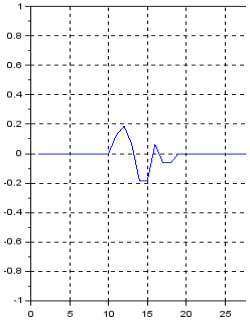


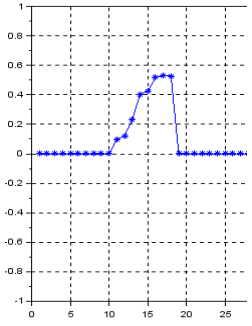




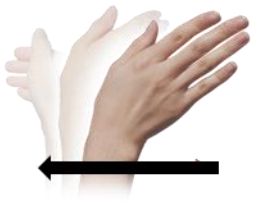




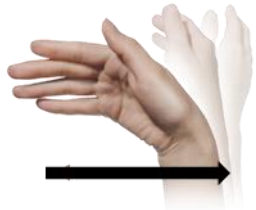




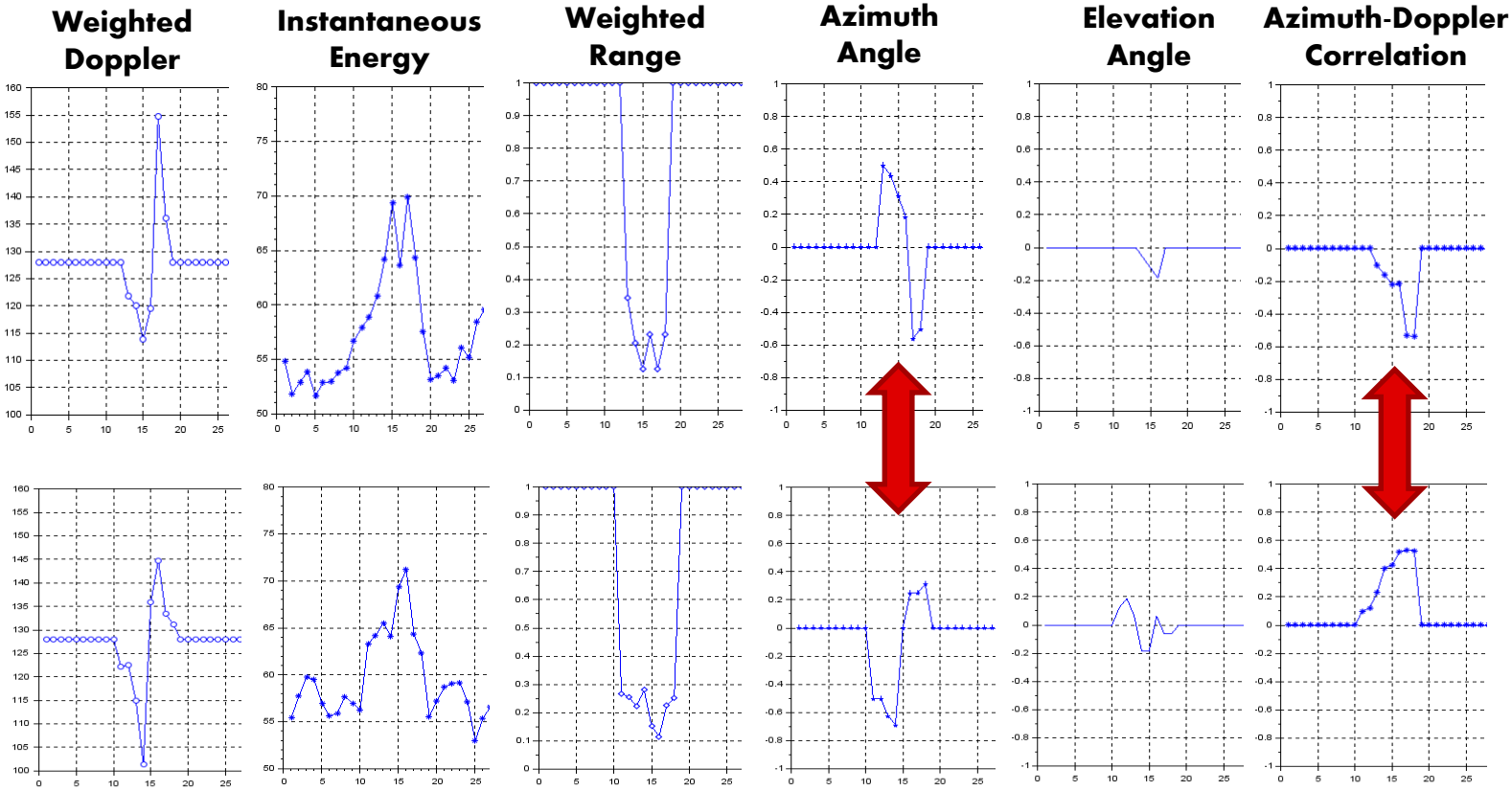
Gesture Inference (3/4) – Signatures



1. Right2Left Swipe



2. Left2Right Swipe



Gesture Inference (4/4) – Evaluation

- AWR1642 ODS sensor is used for testing.
- Neural network runs on the chip.
- Current Status
  - Upto 6 gestures can be detected.
  - Reference processing chain and training feature set
    - Available in May 2018

Summary

- We described a number of adjacent automotive applications using radar including
  - Obstacle detection.
  - Driver vital sign monitoring.
  - Occupancy detection.
  - Gesture recognition.

References – Literature.

Title	Link
AWR1642 Single-Chip 77- and 79-GHz FMCW Radar Sensor datasheet	http://www.ti.com/lit/gpn/awr1642
AWR1443/AWR1642 Technical Reference Manual (Rev. A)	http://www.ti.com/lit/pdf/swru520
Programming Chirp Parameters in TI Radar Devices	http://www.ti.com/lit/pdf/swra553
AWR1642: 77GHz Radar-on-Chip for Short-Range Radar Applications	http://www.ti.com/lit/pdf/spyy006
Automotive 77GHz Radar Module Reference Design with Object Data Output	http://www.ti.com/tool/TIDA-01570
AWR1642 Checklist for Schematic Review, Layout Review, Bringup/Wakeup	http://www.ti.com/lit/zip/swrr154
Automotive body and chassis applications – white paper	http://www.ti.com/lit/wp/spry315/spry315.pdf

References – TIREX.