

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)

'Change the channel'
Infotainment control using gesture

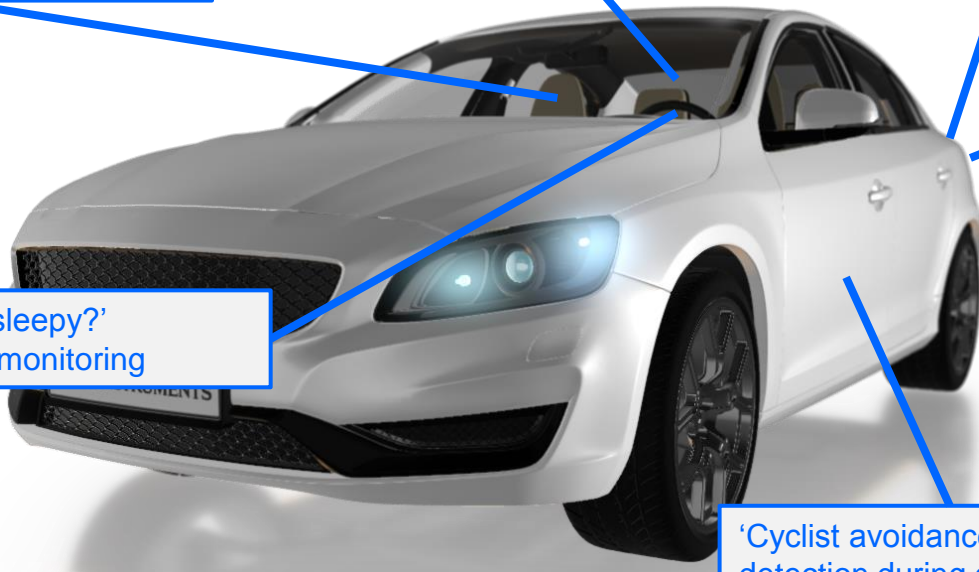
'No child left behind'
Occupancy detection

'Avoid the garage door'
Obstacle detection during trunk opening

'kick to open'
Gesture based trunk opening

'Are you getting sleepy?'
Driver Vital Sign monitoring

'Cyclist avoidance' - Obstacle
detection during door opening



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/spr315/spr315.pdf>

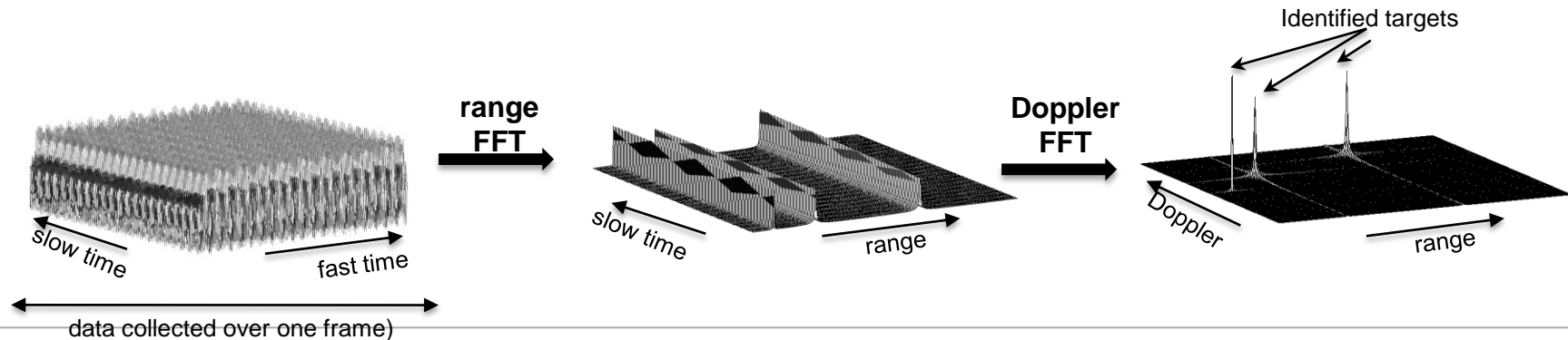
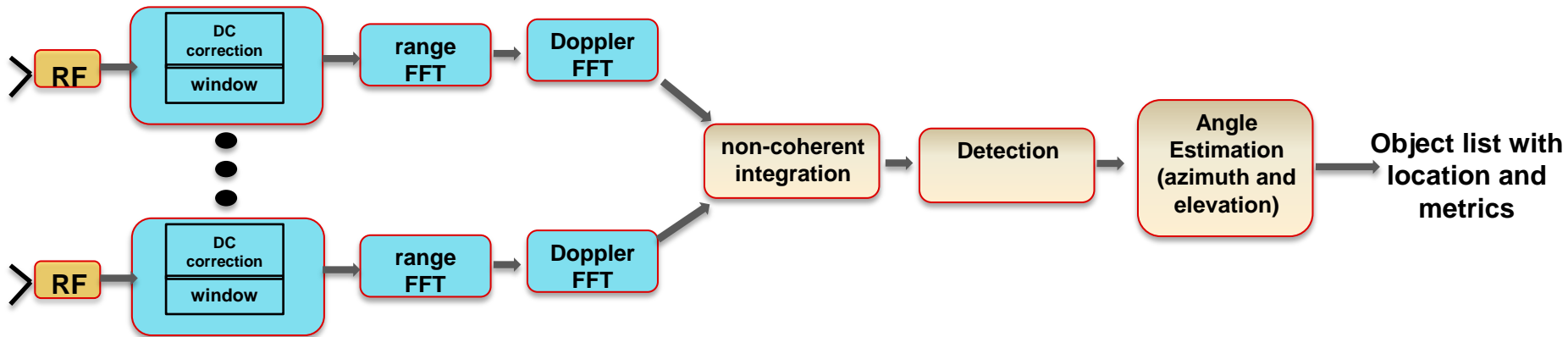
Obstacle Detection Sensor

Obstacle Detection Sensor (1/4) – Applications

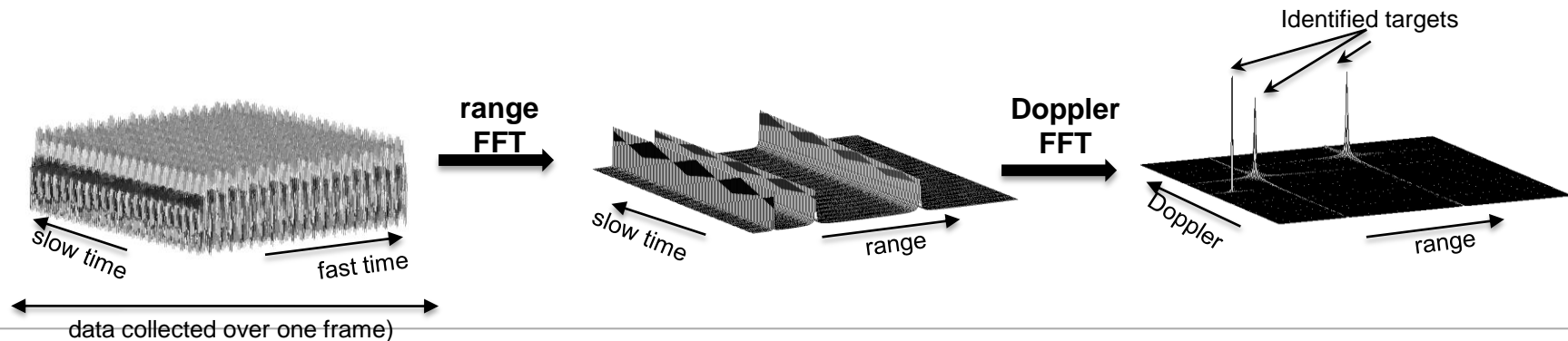
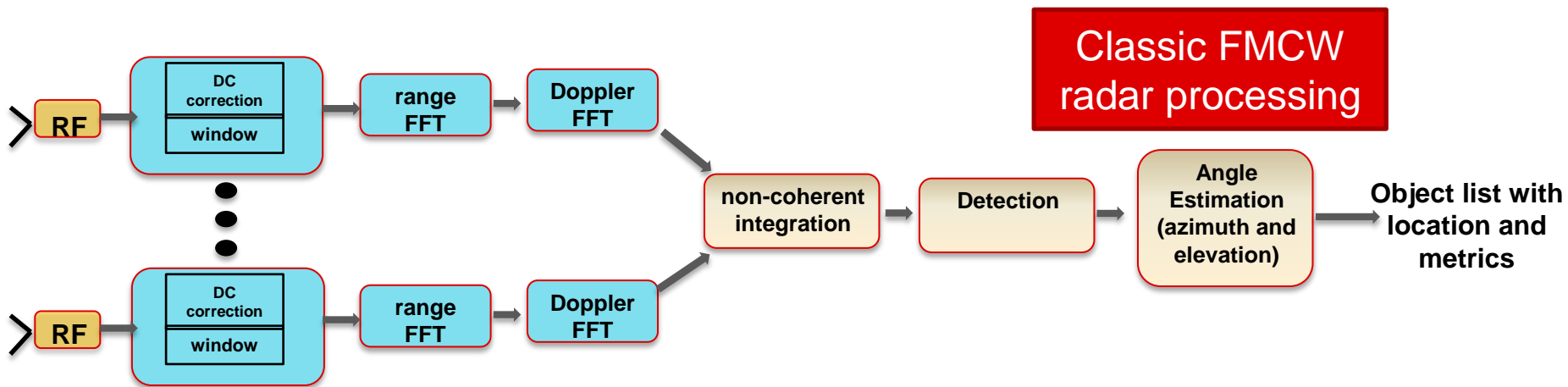
- **Car Door Opening**
 - Detect obstacles around car door and lock movement to avoid damage
- **Trunk Opening**
 - Detect obstacles around trunk to avoid damage while opening
- **Parking assistance**
 - Detect objects like plastic, metal cones, curb, tree, mesh, other cars, motorcycle, pedestrian while 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



Obstacle Detection Sensor (3/4) –Hardware Platform

AWR1642- ODS EVM



85 x 65mm

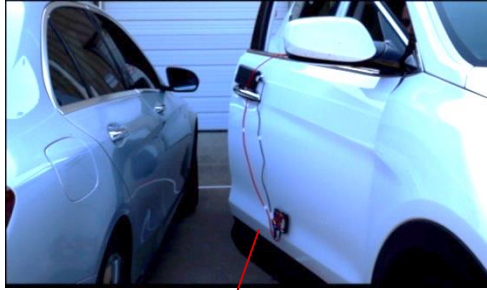
- Available to order on ti.com in April 2018
www.ti.com/product/AWR1642

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

Obstacle Detection Sensor (4/4) – Evaluation



Obstacle Detection Sensor (4/4) – Evaluation

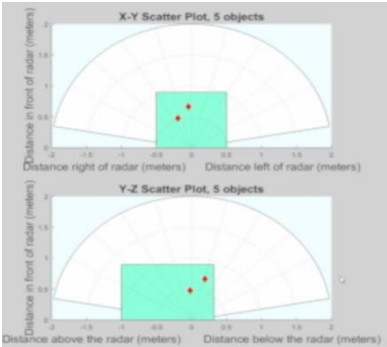


Sensor 50cm from ground

Obstacle Detection Sensor (4/4) – Evaluation



Sensor 50cm from ground



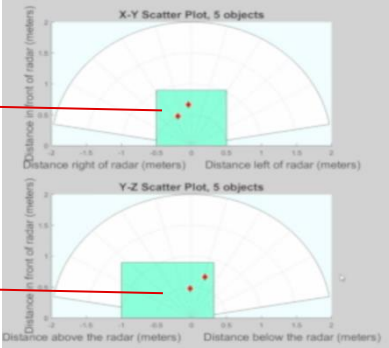
Obstacle Detection Sensor (4/4) – Evaluation



Sensor 50cm from ground

Car door detection in horizontal plane

Car door detection in vertical plane

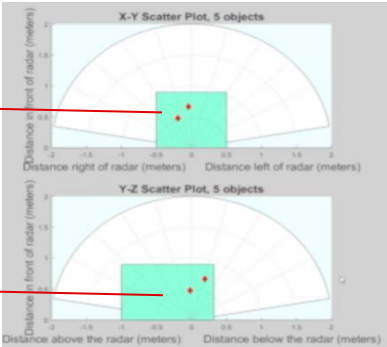


Obstacle Detection Sensor (4/4) – Evaluation



Sensor 50cm from ground

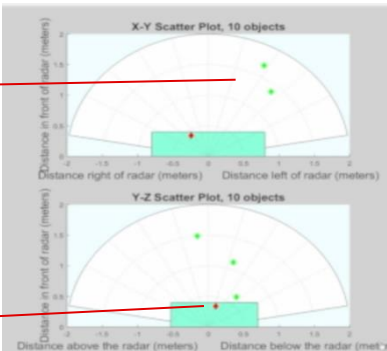
Car door detection in horizontal plane



Car door detection in vertical plane



Objects detected not as obstacles



Pole detected as obstacle

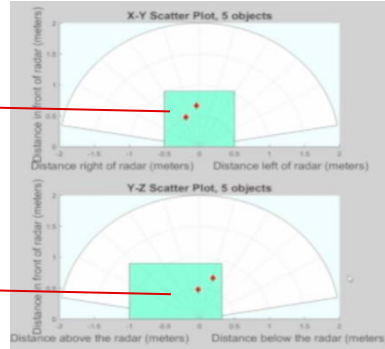
Obstacle Detection Sensor (4/4) – Evaluation



Car door
detection in
horizontal plane

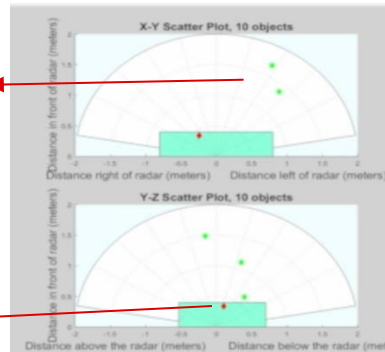
Car door
detection in
vertical plane

Sensor 50cm from ground



Objects detected
not as obstacles

Pole detected
as obstacle



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](https://mySecureSW.com)

Driver Vital Sign Monitoring

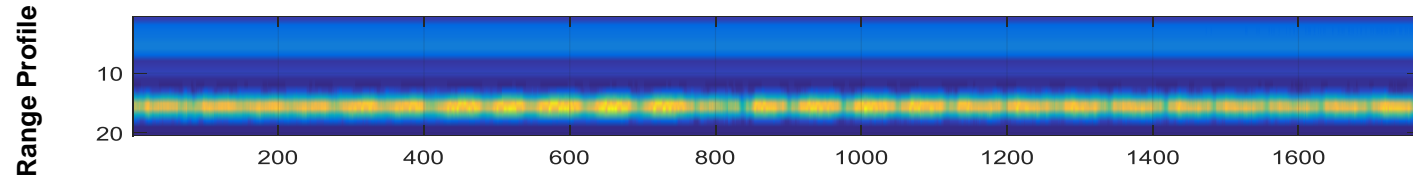
Driver Vital-Signs Monitoring (1/4) - Application

- **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/heart rate.
 - Uses the sensitivity of 77Ghz radar to small movements (1mm => 180 degrees phase shift).

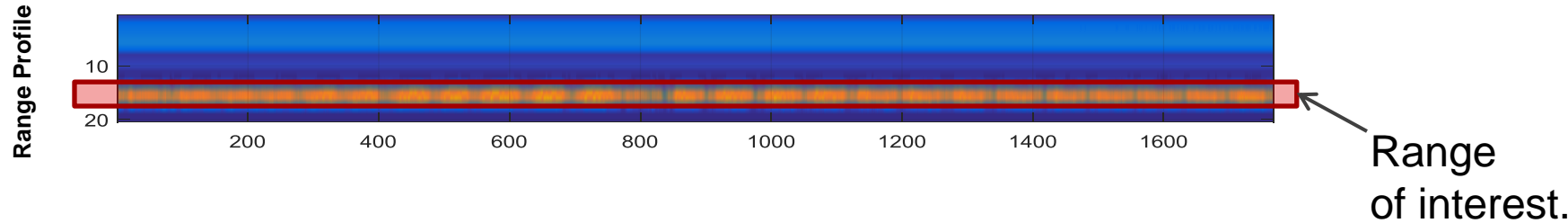
Typical vital sign parameters

		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

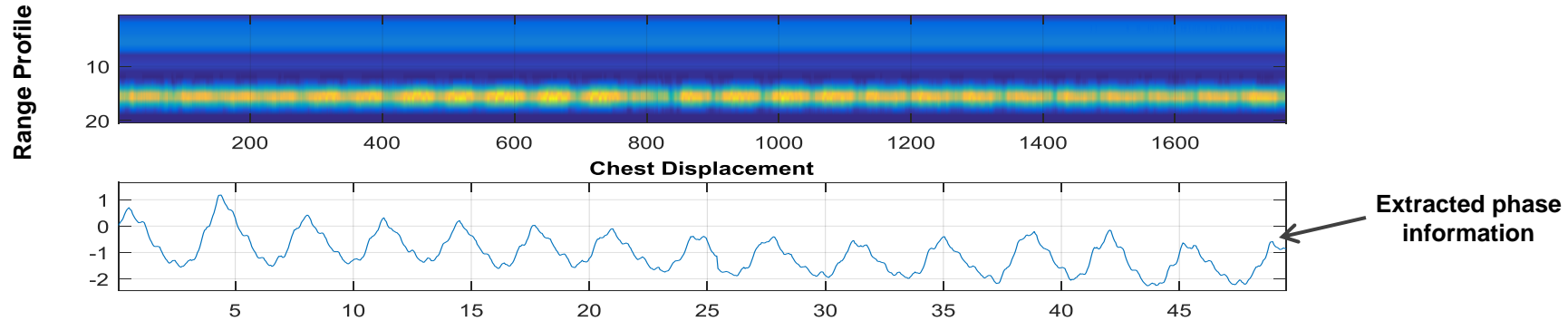
Driver Vital-Signs Monitoring (2/4) – Processing



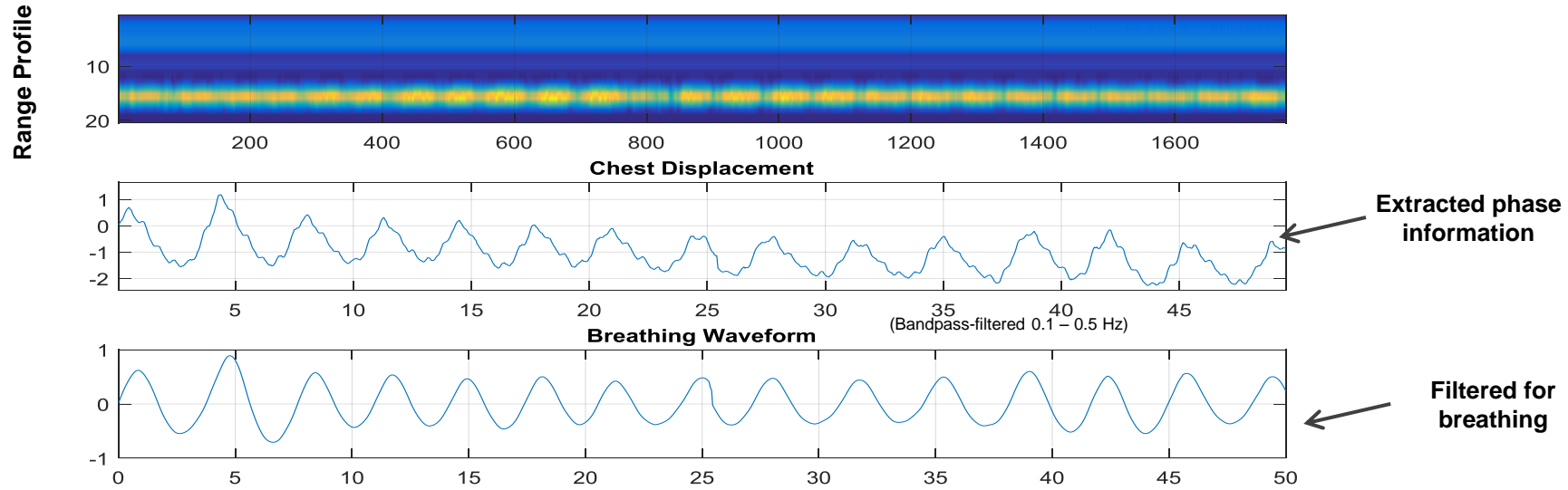
Driver Vital-Signs Monitoring (2/4) – Processing



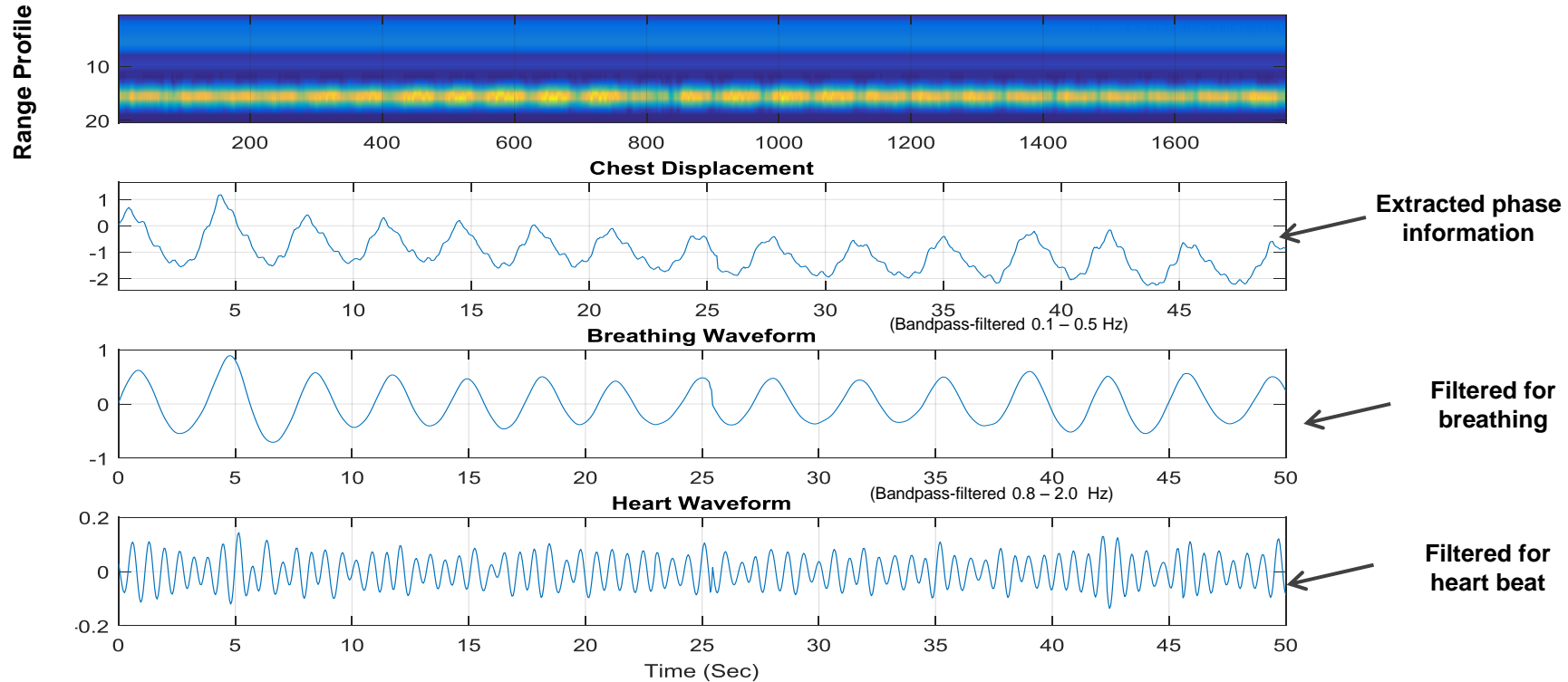
Driver Vital-Signs Monitoring (2/4) – Processing



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

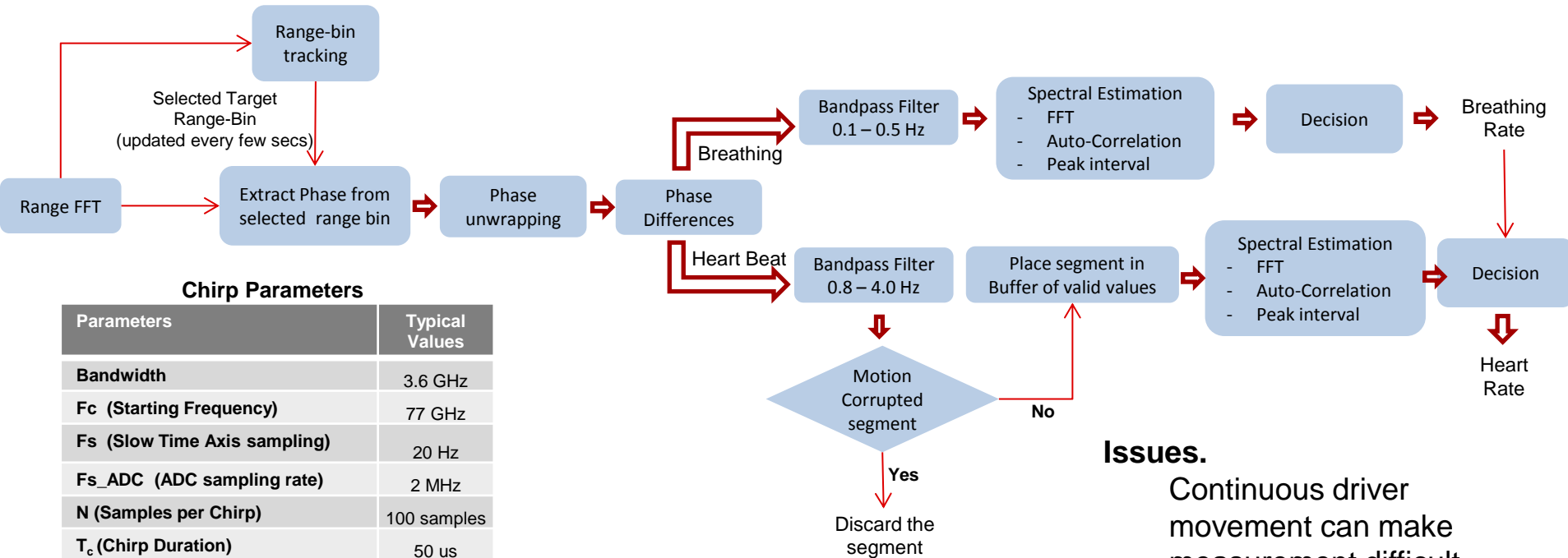


Driver Vital-Signs Monitoring (2/4) – Processing



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 $T \sim 16$ seconds. New estimates are updated every 1 second
- Memory Requirements ~ 16 kB, CPU Processing time for a single estimate ~ 4 ms



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



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

GUI showing heart rate and breathing rate

The GUI displays the following data:

- Breathing Rate:** Breathing Rate: 11. Breathing Waveform plot showing Phase (radians) vs. Frame (Index).
- Heart Rate:** Heart Rate: 80. Heart Waveform plot showing Phase (radians) vs. Frame (Index).
- Chest Displacement:** Chest Displacement plot showing Displacement (a.u.) vs. Frame (Index).
- Range Profile:** Range Profile plot showing Magnitude (a.u.) vs. Range (m).

Control buttons: Start, Pause, Stop, Settings, Refresh.

Settings: Use Time-Domain, Use Freq-Domain, Save Data, Load Config, Display Plots.

Additional options: Measurements From the Back.

Source: Research

TEXAS INSTRUMENTS

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



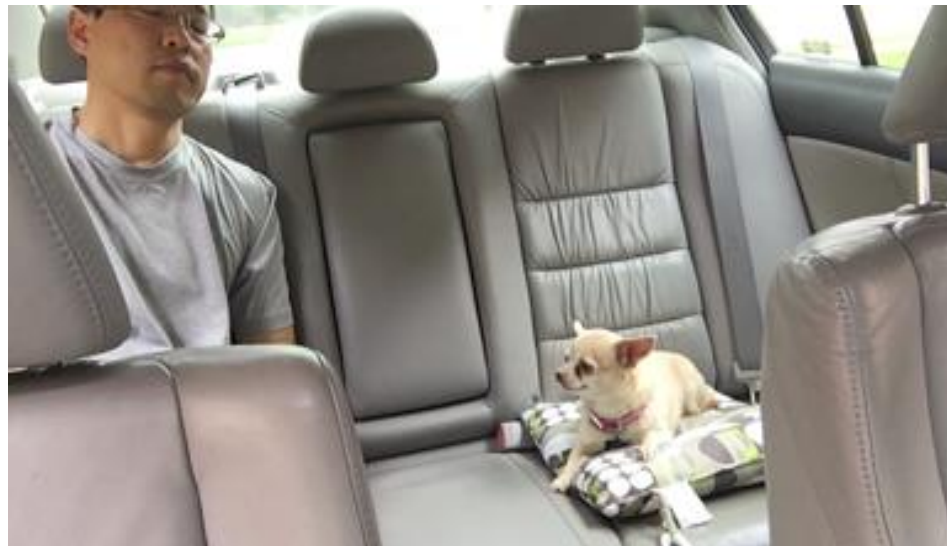
Reference Code:

- [Link](#)
- [Video](#)

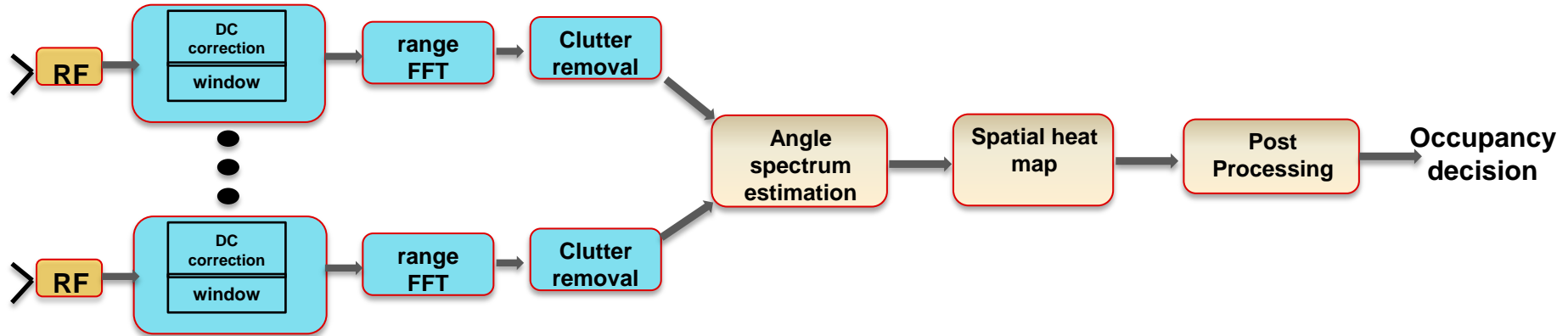
Vehicle Occupant Detection

Vehicle Occupant Detection (1/3) - Applications.

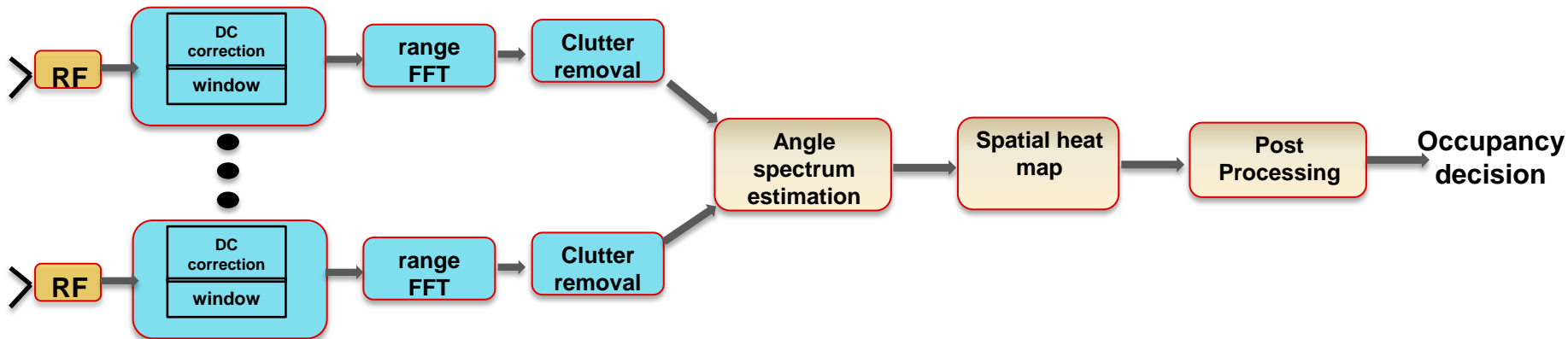
- **Child left behind in car detection**
 - Detect the presence of a child in car when a caregiver locks the car door forgetting to take the child outside
- **Occupancy detection**
 - Detection of a lifeform in any seat to determine the force of airbag deployment in case of crashes
- **Intruder detection**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



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

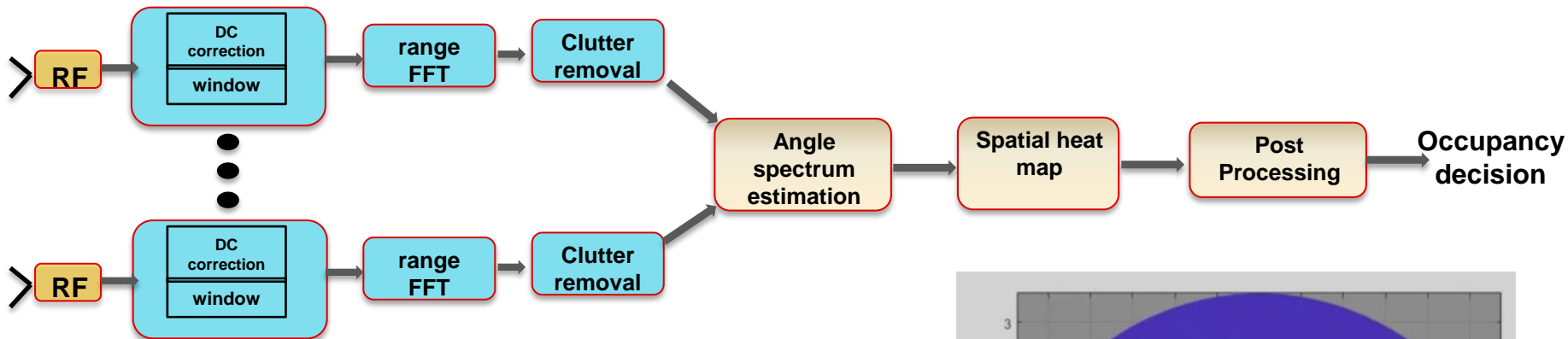


Vehicle Occupant Detection (2/3) - Processing chain.

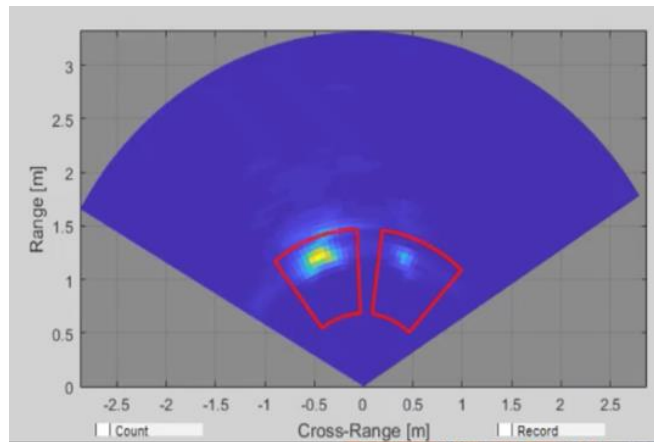


- Main difference with OOB is that
 - No doppler processing is performed.
 - Angle estimation is performed using MVDR.
 - Provides better angular resolution assuming targets are slowly moving.

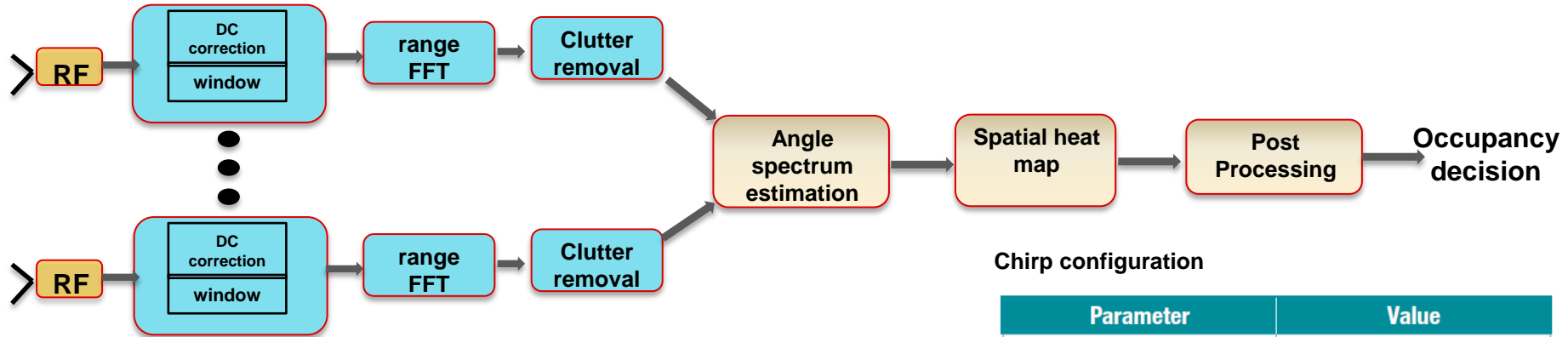
Vehicle Occupant Detection (2/3) - Processing chain.



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



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Chirp configuration

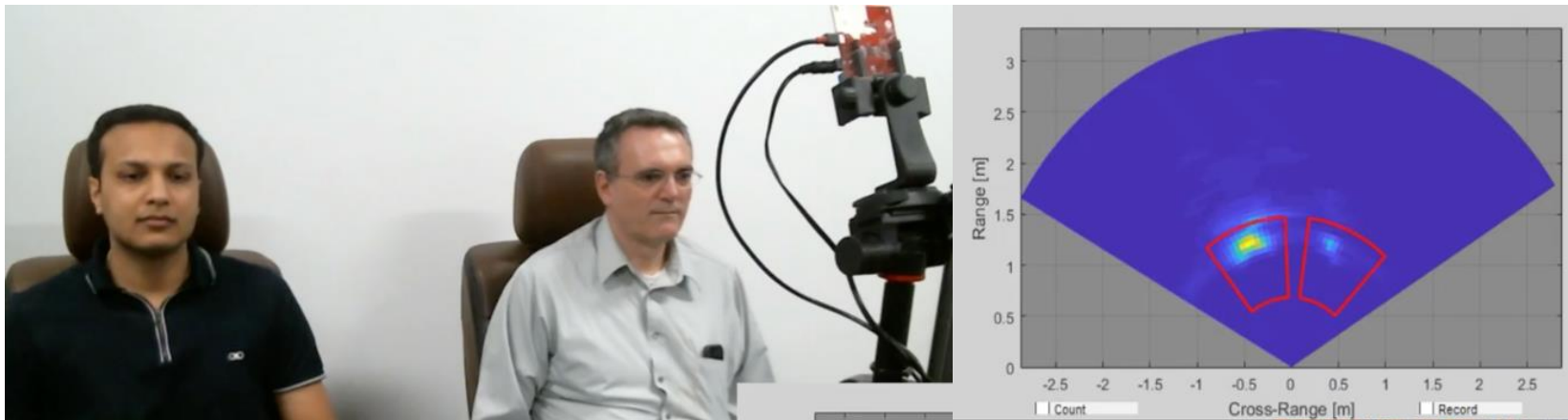
Parameter	Value
Chirp bandwidth	4GHz
Chirp periodicity	340 μ s
Number of chirps	512 (256 each of TX1 and TX2)
Range resolution	~4cm
Maximum range	3m
Maximum velocity	2.28m per second (10kmph)
Velocity resolution	0.02m per second (0.08kmph)
Memory requirement	600KB

Vehicle Occupant Detection (3/3) - Evaluation.



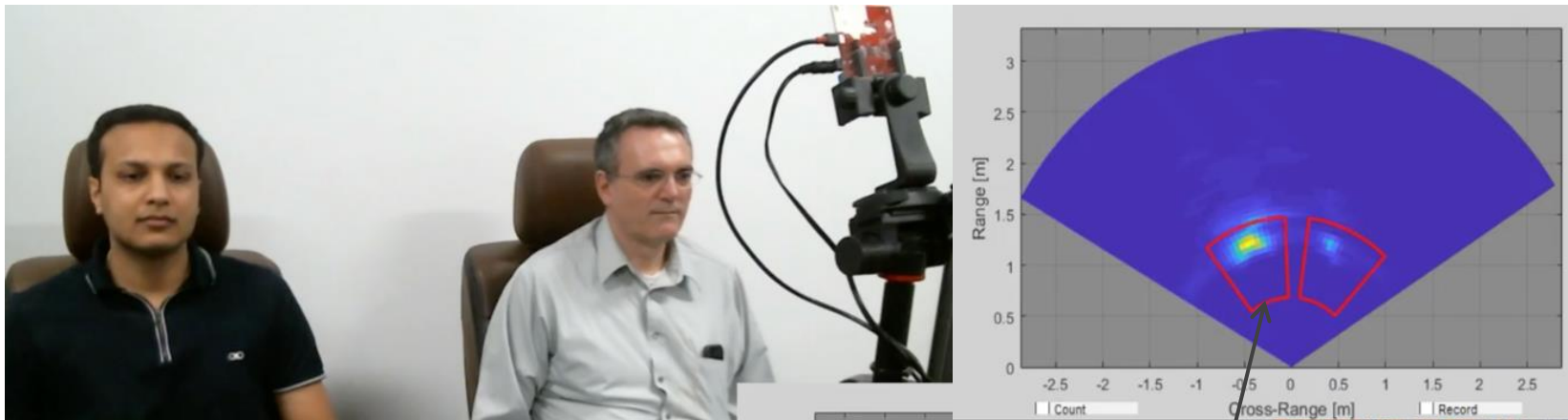
- Demo can perform zone-based detection.
 - Is a seat occupied?

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.

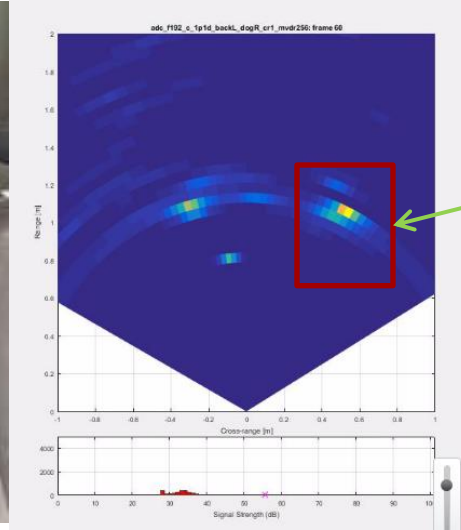
- Demo can perform zone-based detection.
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Vehicle Occupant Detection (3/3) - Evaluation.



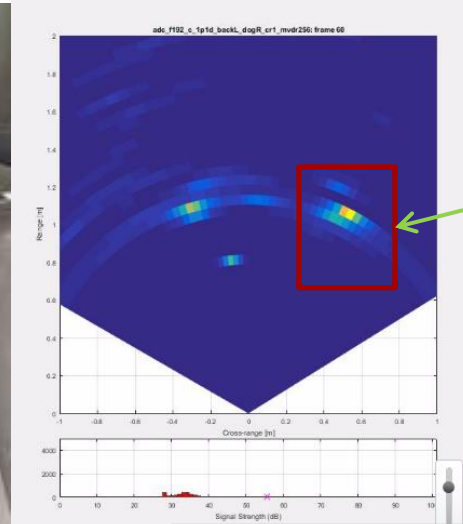
- In-car test, demonstrating the detection of pets.
 - Pets have very small RCS

Vehicle Occupant Detection (3/3) - Evaluation.



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

Vehicle Occupant Detection (3/3) - Evaluation.



Dog

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

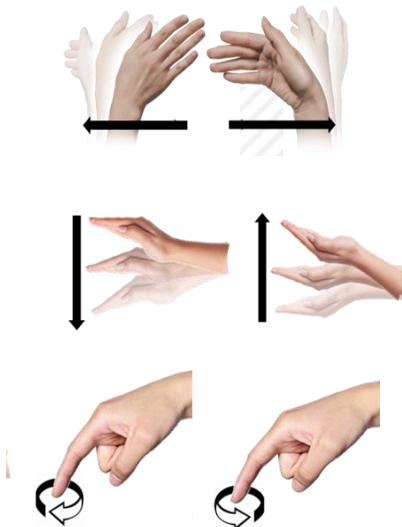
Collateral :

- Source code : [link](#)
- white paper : [link](#)
- Evaluation module : [AWR1642BOOST](#)

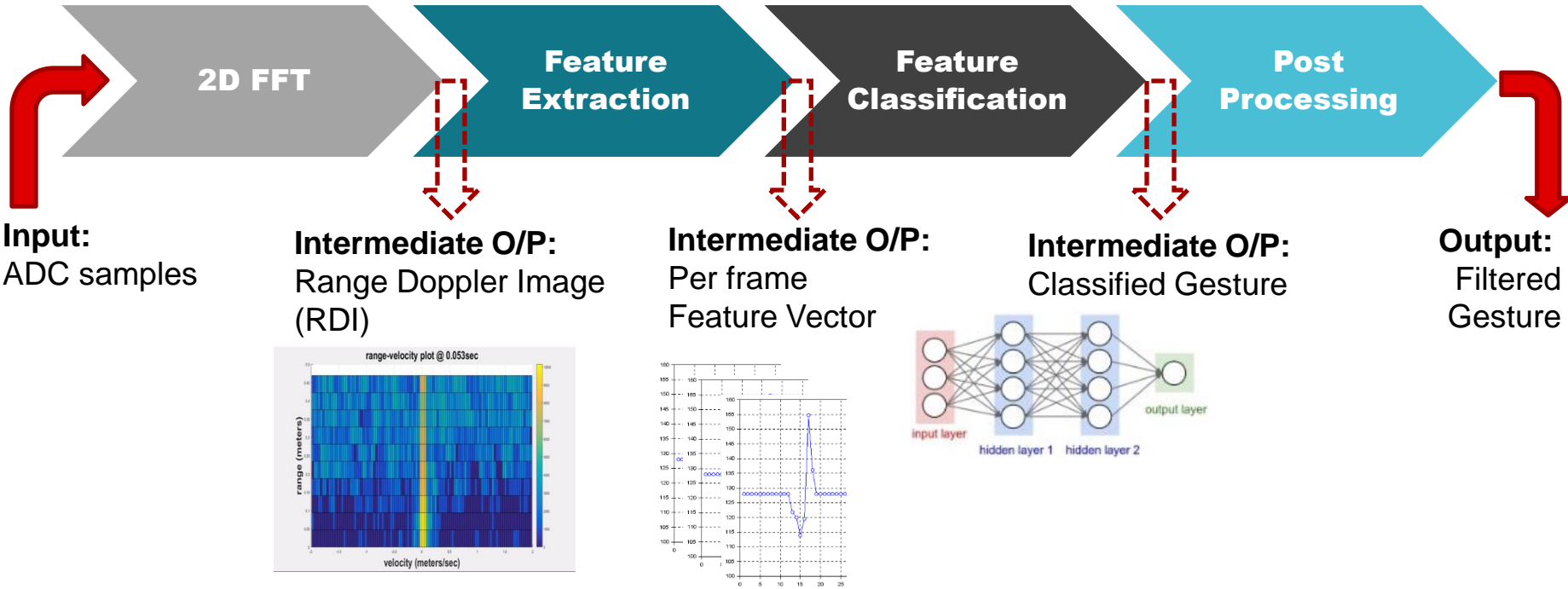
Gesture Inference

Gesture Inference (1/4) – Applications

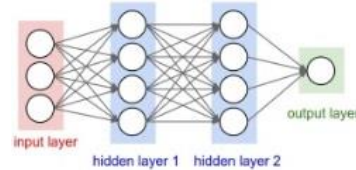
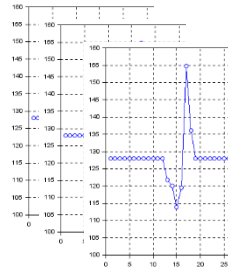
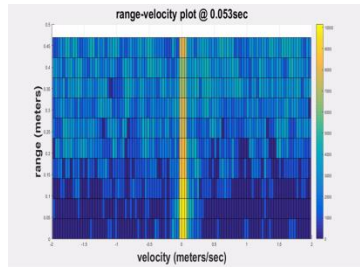
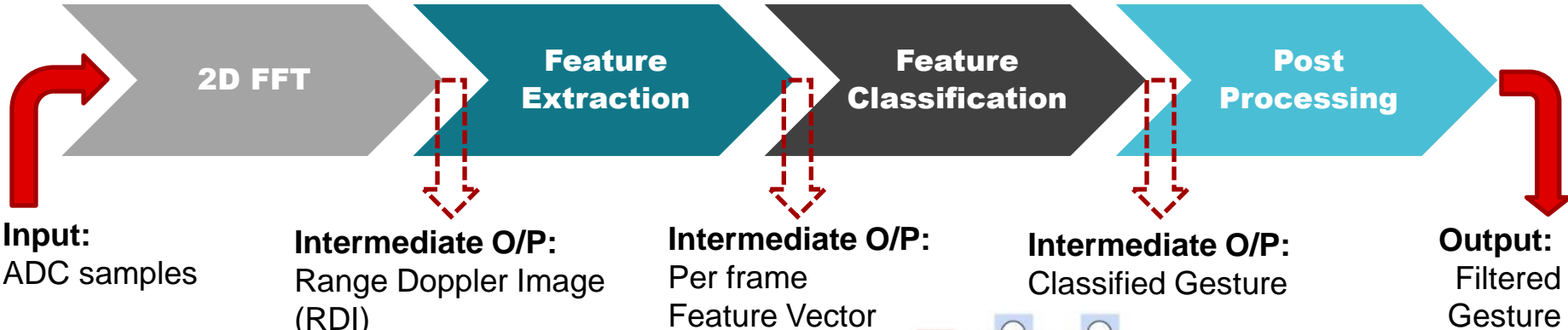
- ‘Kick to open’
 - Detect the kick “gesture” to open the trunk of a car – hands-free.
- In-cabin gestures
 - Swipe up and down to open and close the sun roof.
 - Swipe left and right to change radio channels.
 - Rotate finger to control radio volume.



Gesture Inference (2/4) – Processing

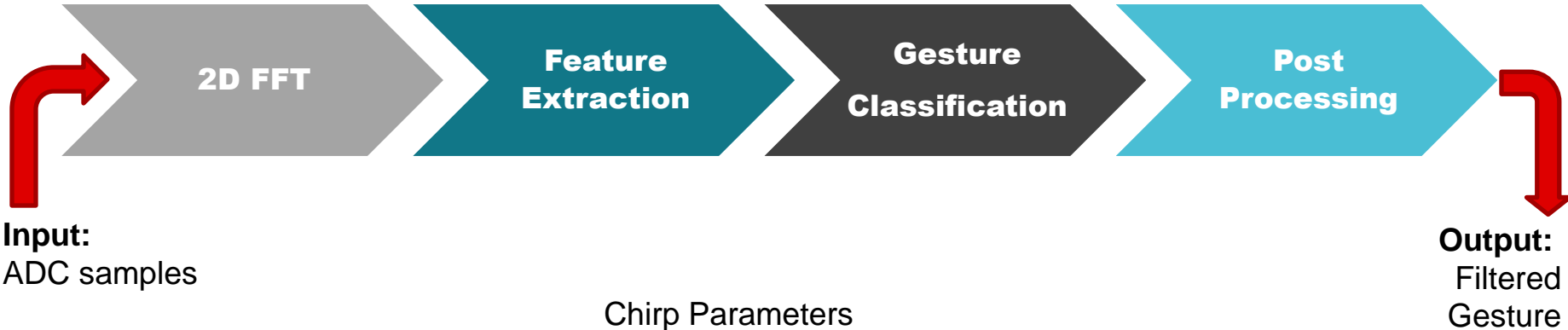


Gesture Inference (2/4) – Processing



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

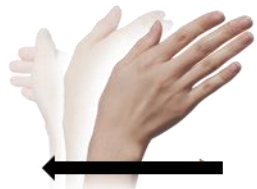
Gesture Inference (2/4) – Processing



Chirp Parameters

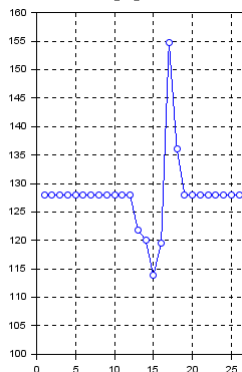
Specifications	Gesture Recognition
Max. Range (m)	3.35 m (ROI limited to 80 cm)
Range Resolution (m)	0.05 m
Absolute Velocity (m/s)	2.5 m/s
Velocity Resolution (m/s)	0.039 m/s
Range Dimension	64
Doppler Dimension	256
Frames/sec	19.6

Gesture Inference (3/4) – Signatures

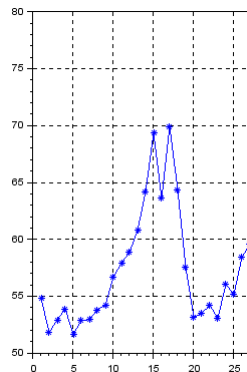


I. Right2Left
Swipe

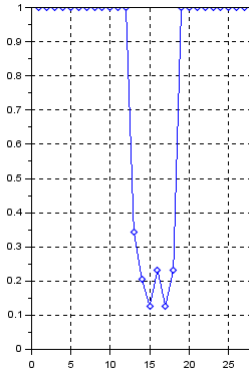
Weighted
Doppler



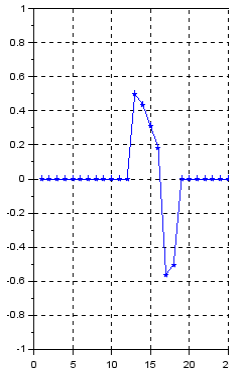
Instantaneous
Energy



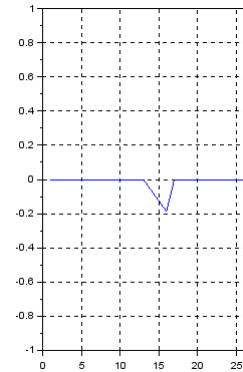
Weighted
Range



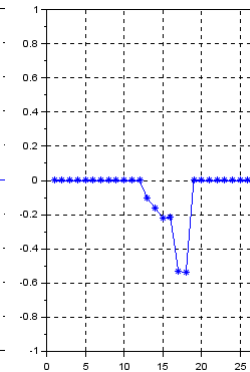
Azimuth
Angle



Elevation
Angle

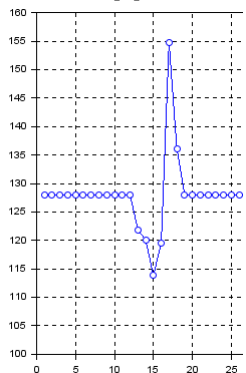


Azimuth-Doppler
Correlation

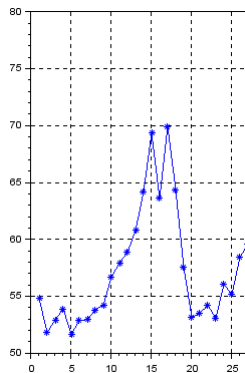


Gesture Inference (3/4) – Signatures

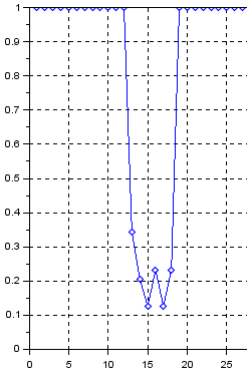
Weighted Doppler



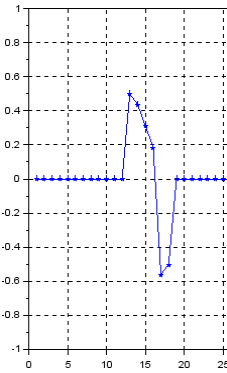
Instantaneous Energy



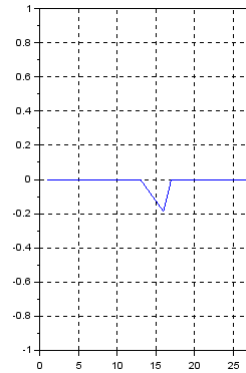
Weighted Range



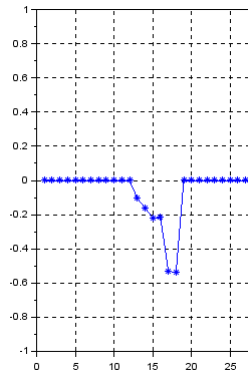
Azimuth Angle



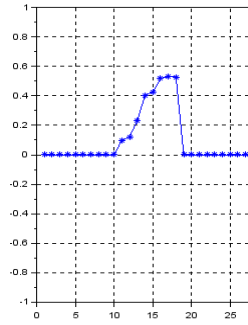
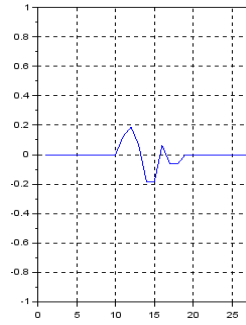
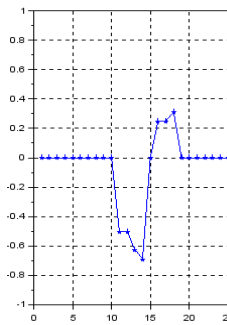
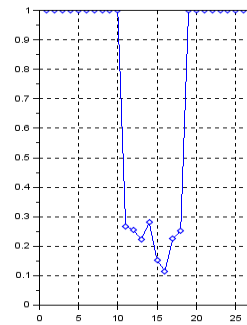
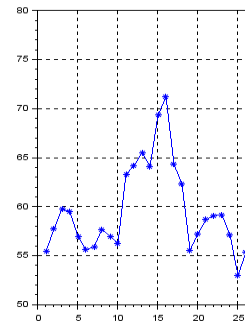
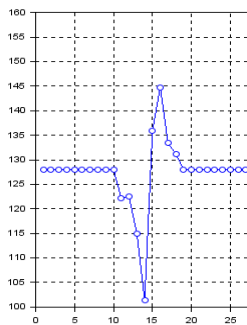
Elevation Angle



Azimuth-Doppler Correlation



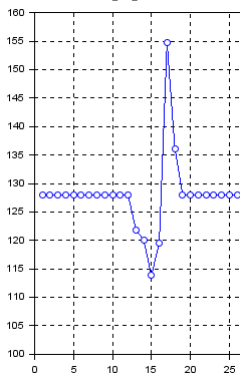
**1. Right2Left
Swipe**



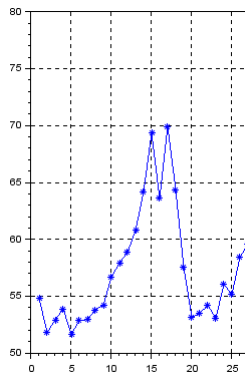
**2. Left2Right
Swipe**

Gesture Inference (3/4) – Signatures

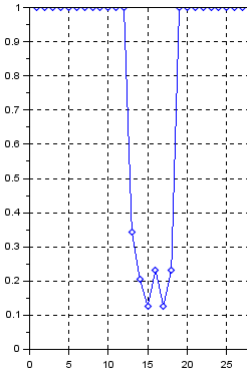
Weighted Doppler



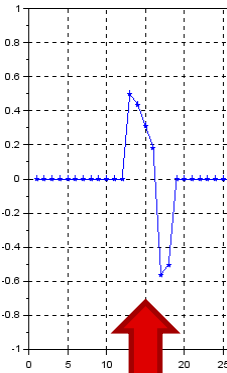
Instantaneous Energy



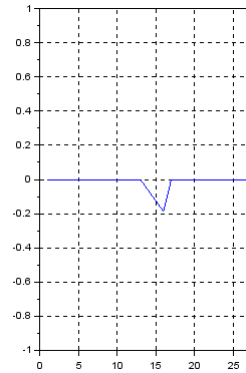
Weighted Range



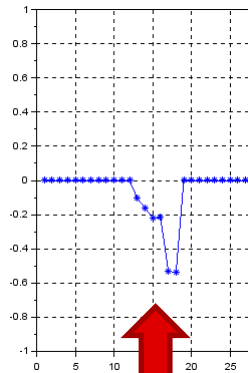
Azimuth Angle



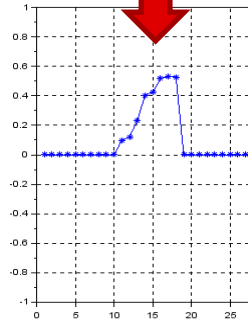
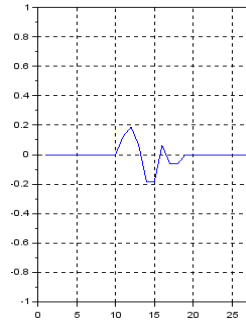
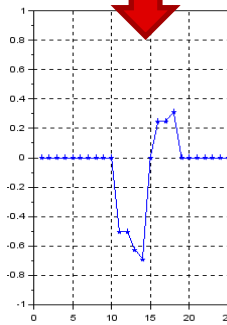
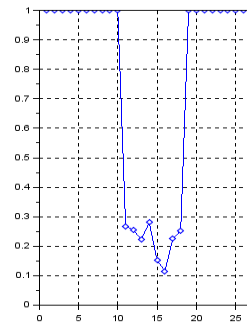
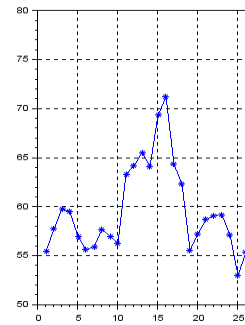
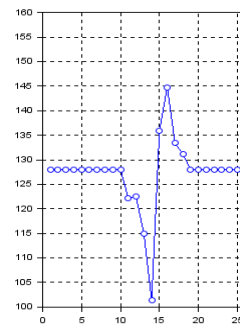
Elevation Angle



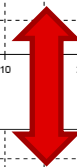
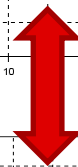
Azimuth-Doppler Correlation



**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.

The screenshot shows a web browser window with the URL `dev.ti.com/tirex/#/`. The browser's address bar contains the URL and search, star, and refresh icons. Below the address bar, there are several tabs: "Schedule a Conferenc", "Suggested Sites", "TI VPN", "TI webex", and "Concur". The main content area is titled "TI Resource Explorer" and features a search bar with the text "Select a Device or Board". To the right of the search bar are icons for full screen, home, eye, and a menu. The left sidebar displays a tree view of resources, including "MSP430Ware - v:3.80.03.07", "TM4C ARM Cortex-M4F MCU - v:2.1.3.156", "Sitara - v:1.02.00.00", "TI-RTOS for MSP430 - v:2.20.00.06", "TI-RTOS for CC2650 - v:2.21.00.06", "TI-RTOS for TivaC - v:2.16.00.08", and "mmWave Sensors". Under "mmWave Sensors", there are sub-items for "Industrial Toolbox - v:2.2.0", "Automotive Toolbox - v:1.2.0", and "Labs". The "Labs" folder is expanded, showing "Driver Vital Signs", "Short Range Radar", and "Vehicle Occupant Detection". The "Driver Vital Signs" lab is selected and highlighted. The main content area displays the title "Driver Vital Signs" and a detailed description: "This lab demonstrates the usage of TI mmWave sensors to detect miniscule motions, such as displacement of the chest when the heart beats or the person breathes. The fundamental principle being demonstrated is the ability of TI's mmWave sensors to detect extremely fine movement of the target using phase measurement. The lab provides full source code and a CCS project and runs on the TI mmWave sensor xWR16xx EVM." Below the description, there are three sections: "Driver Vital Signs" with a refresh and download icon, "PC GUI" with a download icon, and "Getting Started Guide" and "Developer's Guide" with document icons.