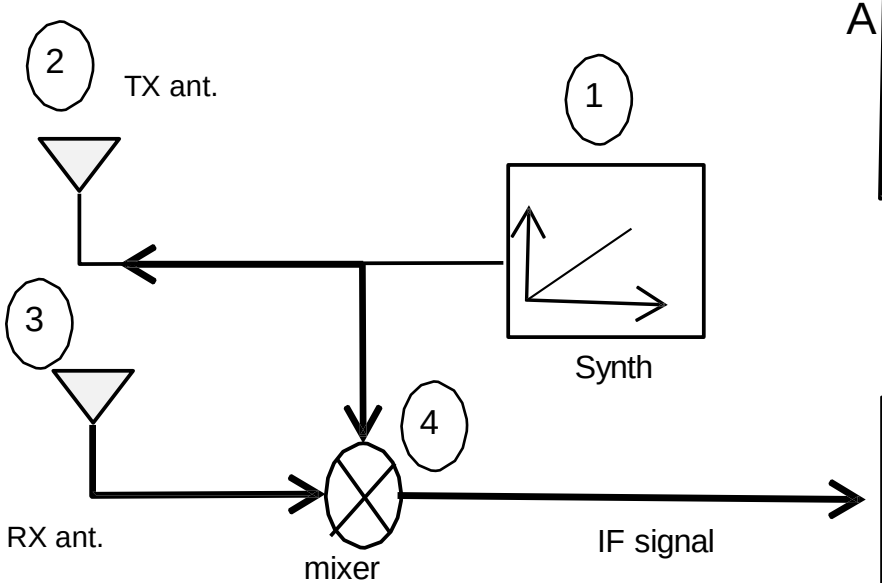
毫米波雷達感測器於車用自動化之創新應用

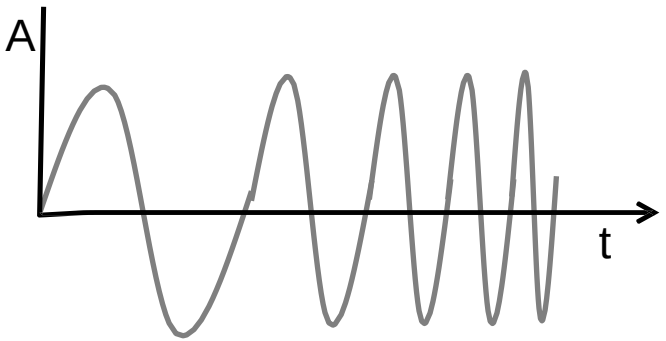
- 毫米波雷達的原理與特性
- TI 毫米波雷達單晶片技術解析與挑戰
- 毫米波雷達感測器輔助汽車駕駛之應用

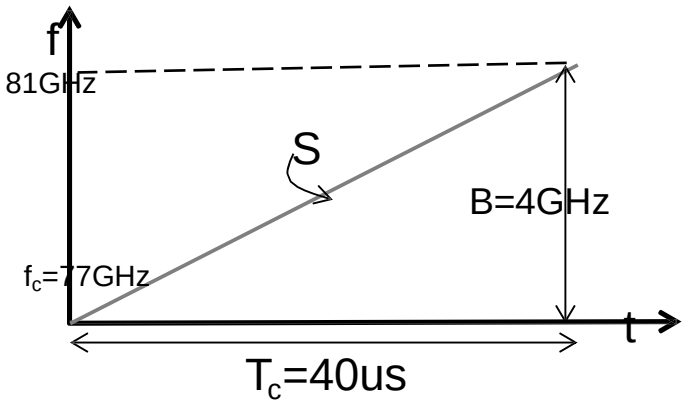
TI Jesse Wang
jessewang@ti.com, 2019/04/24

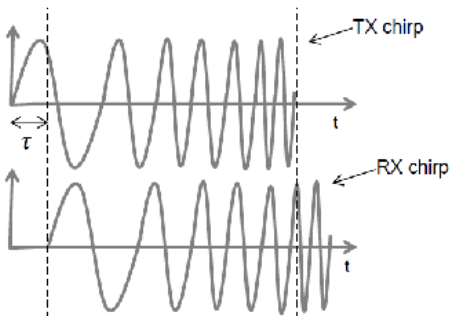
- 毫米波雷達的原理與特性

Basics of FMCW (Frequency Modulation Continue Wave)









1. A synthesizer (synth) generates a "**chirp**"
2. The chirp is transmitted by the TX antenna
3. The chirp is reflected off an object and the reflected chirp is received at the RX antenna.
4. The RX signal and TX signal are 'mixed' and the resulting signal is called an 'IF signal'.

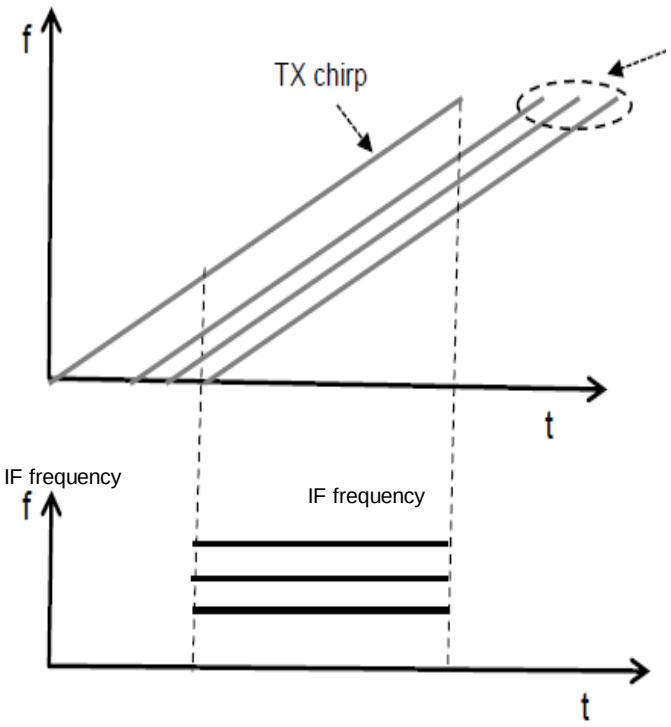
$$\mathrm{Tx} = \sin[w_1 t + \phi_1)\,]$$

$$\mathrm{Rx} = \sin[w_2 t + \phi_2)]$$

$$\mathrm{IF} = \sin\ [(w_1 - w_2)\,t + (\phi_1 - \phi_2)]$$

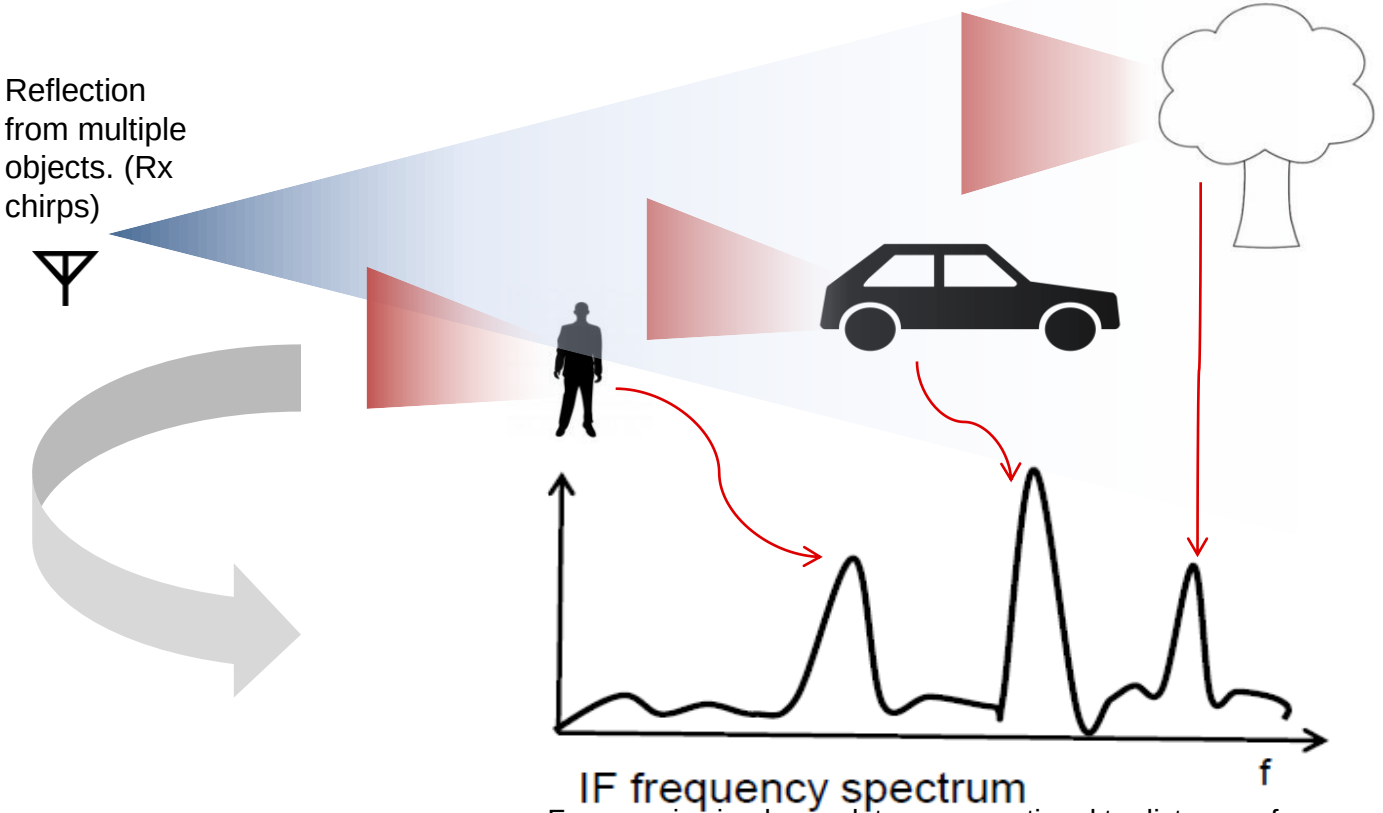
The fundamentals of millimeter wave sensors, http://www.ti.com/lit/wp/spyy005/spyy005.pdf

Basics of FMCW (Distance Measurement)



IF frequency = Tx frequency – Rx frequency

Reflection from multiple objects. (Rx chirps)

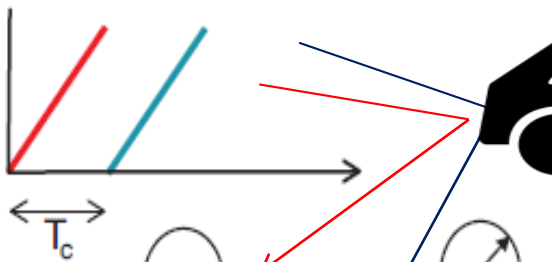


Frequencies in above plot are proportional to distance of objects.
For objects far away the frequency of IF signal is higher.

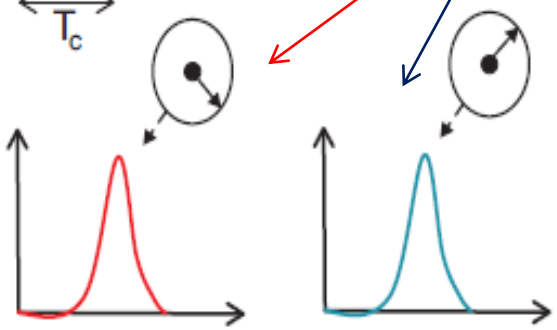
Distance of object is proportional to frequency of IF signal

Basics of FMCW (Velocity and Angle Measurement)

Multiple Transmission chirps separated in time



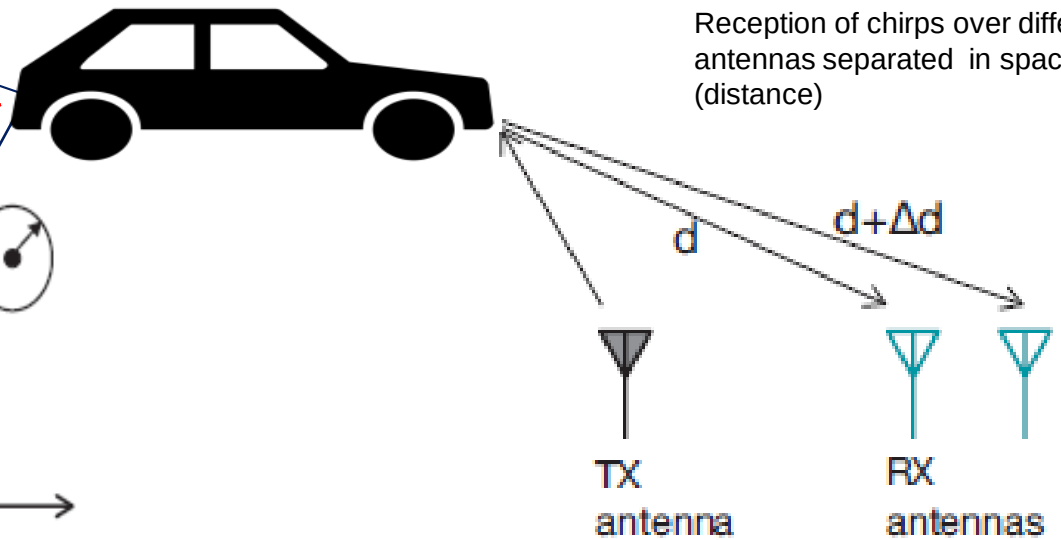
Multiple received chirps. Reflected Signal from moving object has different phase for two reflected chirps. (Intermediate frequency)



Multiple chirps for velocity detection

IF frequency = Tx frequency – Rx frequency

Reception of chirps over different antennas separated in space (distance)



Multiple antennas for angle detection

Velocity and Angle of object reflects in phase difference of IF signal.

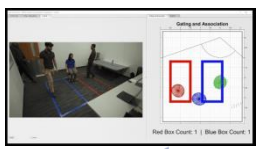
mmWave Sensors – Technology Overview

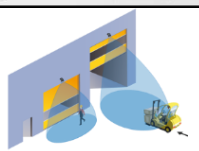
What is mmWave sensing

- mmWave is the band of spectrum between 30GHz and 300GHz
- Electromagnetic waves used for sensing, imaging and communications
- mmWave sensors measure with high accuracy **range**, **velocity** and **angle** of remote objects

When to use mmWave sensing?

- **Immunity to environmental and lighting conditions** : mmWave is impervious to harsh industrial environmental conditions such as water, dust and poor lighting.
- **High precision detection of people up to 50m** sent over UART interface to a PC for visualization using mmWave SDK
  - High range resolution enables to identify two people as close as 4.7cm
- **Accurate 3D sense and detect** to create a safety zone with 160º field of view using a single sensor
  - Enables creating a danger, warning, or safe zones separately
- **Increased Productivity** by tracking velocity of objects approaching the machine to determine when machine should work accordingly

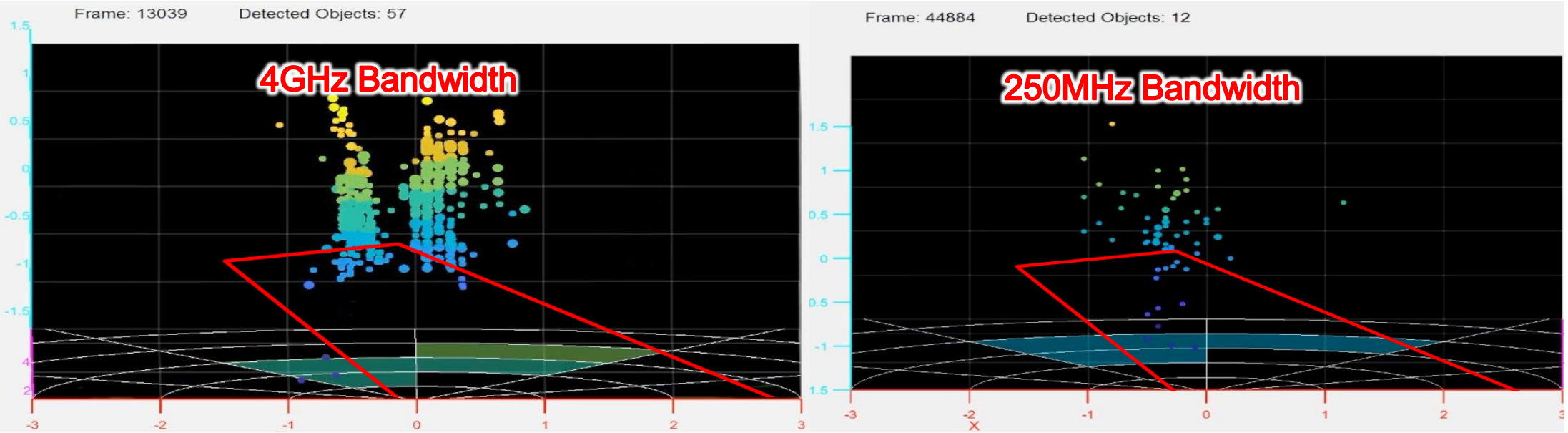






Why Now?

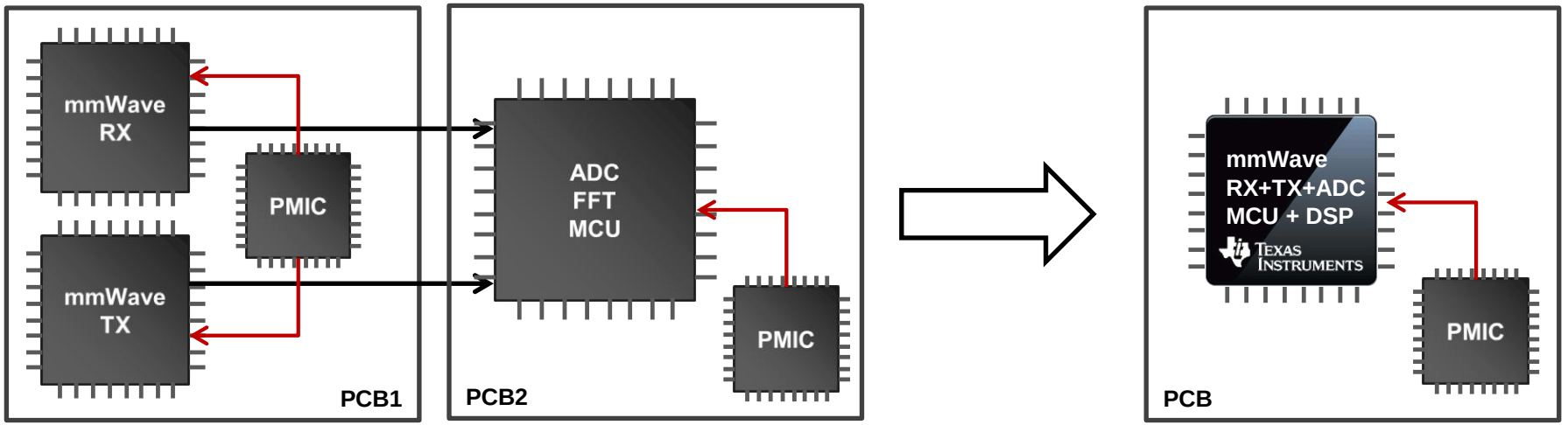
- **Detect very fine motions**, RF technology for **penetration** through materials like plastic, fabric, and drywall. Use in **privacy** conscious applications
- RFCMOS technology enables analog/digital integration in a low-power, small, **single-chip** solution

Bandwidth 4GHz vs 0.25GHz – Sensor View



- TI 毫米波雷達單晶片技術解析與挑戰

Single Chip Integration Enabled by CMOS



Discrete Multi-Chip mmWave Sensor

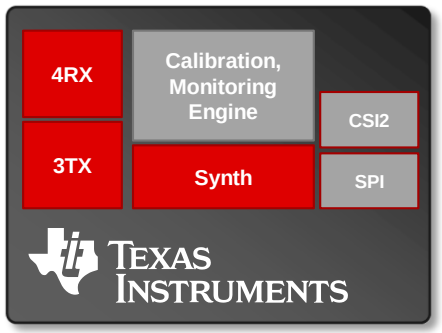
- Discrete solution – expensive
- Complex and critical signal routes
- Unconventional packaging
- Prone to noise
- Lack of system level observability
- Crude implementation of RF and Baseband safety

TI Single-Chip mmWave Sensor

- Smaller in size
- Simpler design
- Built in monitoring and calibration (ASIL)
- High Resolution, less false positives
- Programmable core
- Lower Power

76 – 81 GHz mmWave Sensors

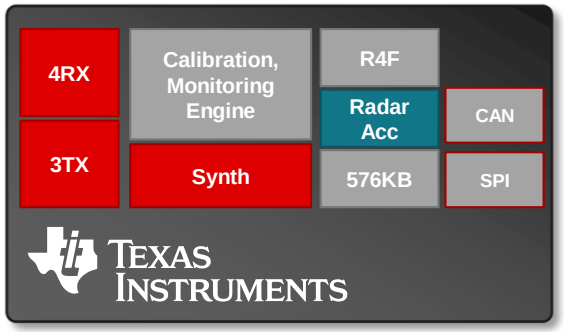
AWR12433



Radar Front-End

- **Use Cases**
  - Imaging Radar Sensor
    - 2x or 4x AWR12 + External DSP
  - MRR and LRR
- **ASIL-B capable**
- **In Production**

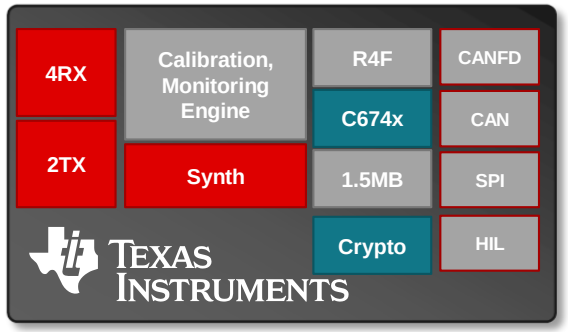
AWR1443



Single Chip Radar

- **Use Cases**
  - Proximity Sensor
  - Obstacle detection sensor
  - Occupant detection
  - Driver monitoring
- **In Production**

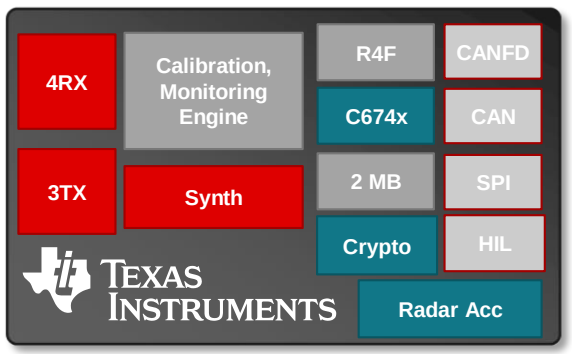
AWR1642



Single Chip Radar

- **Use Cases**
  - USRR Single Chip Radar
    - 160 Degree, 40m
  - SRR Single chip Radar
    - 120m Cross traffic Alert
- **ASIL-B capable**
- **In Production**

AWR1843

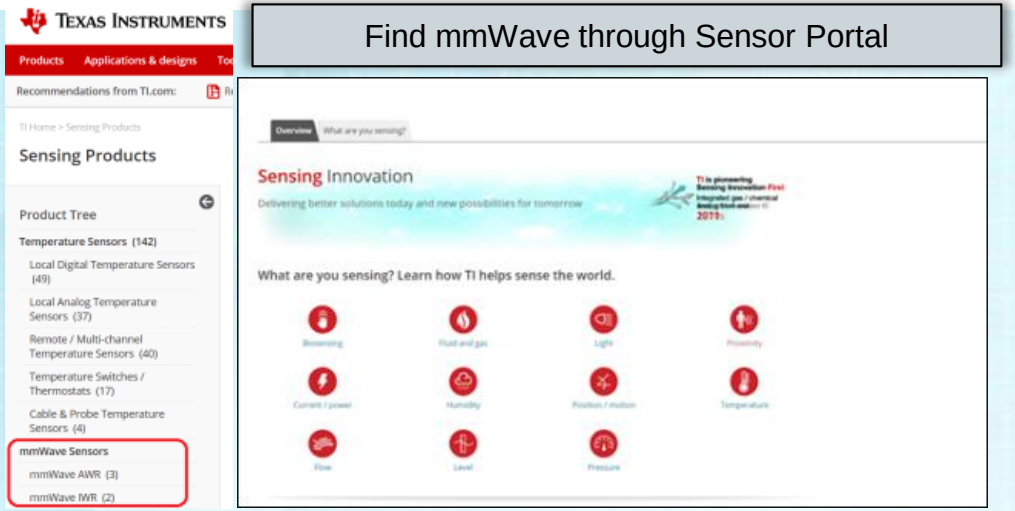


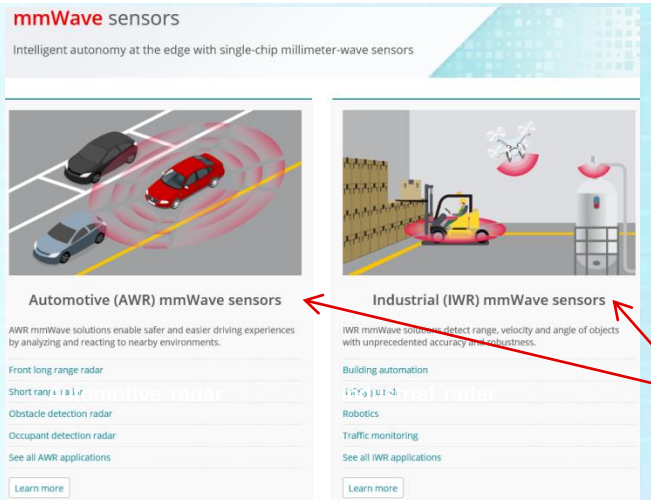
Single Chip Radar

- **Use Cases**
  - Parking w/ height measurement
  - MRR single chip radar
- **ASIL-B capable**
- **Sampling Now**
- **PPAP/RTM: 3Q19**

mmWave Sensors – Presence on ti.com

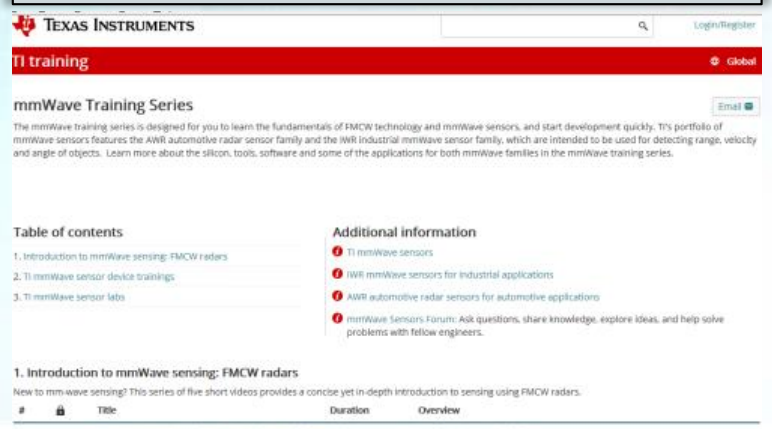
Find mmWave through Sensor Portal



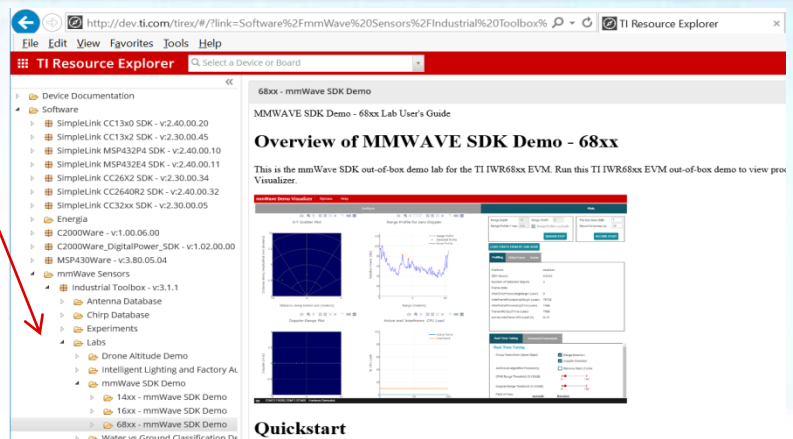


mmWave Portal:
Each title will drive to unique landing pages for Auto and Industrial

Get the training / E2E support



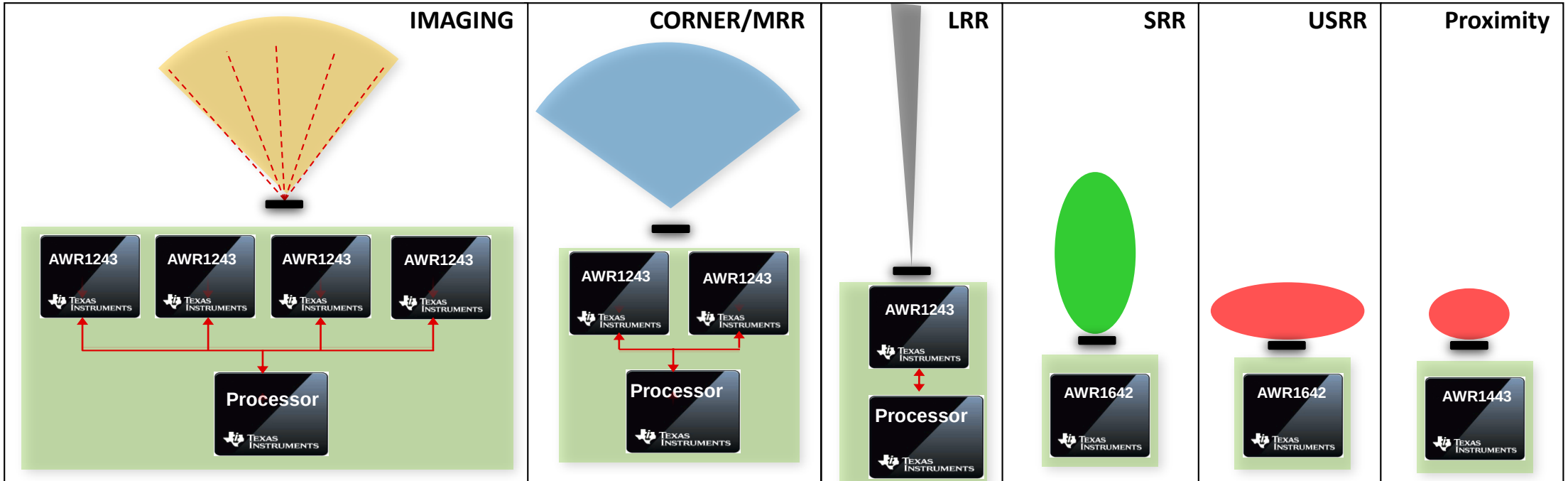
Plenty of example codes with applications in “TI Resource Explorer”

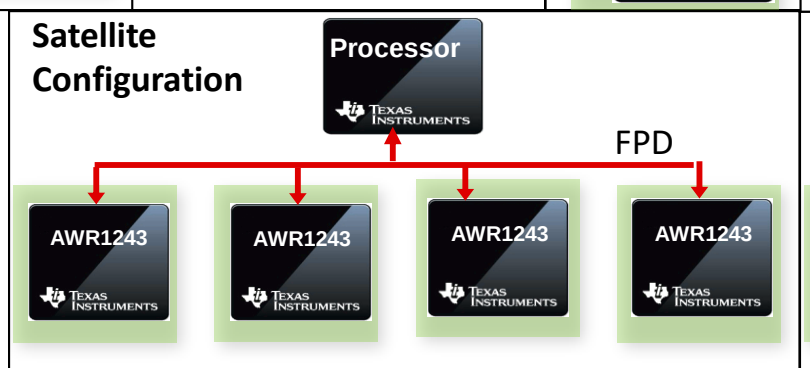


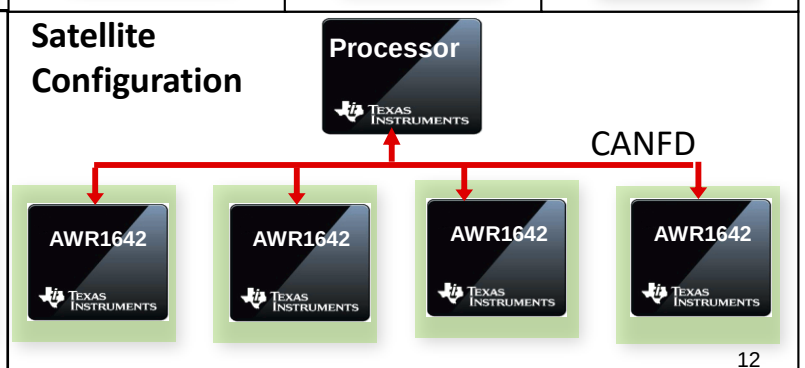
Training material, https://training.ti.com/mmwave-training-series
Sensor E2E forum, https://e2e.ti.com/support/sensors/f/1023

TI Resource Explorer, http://dev.ti.com/tirex/#/

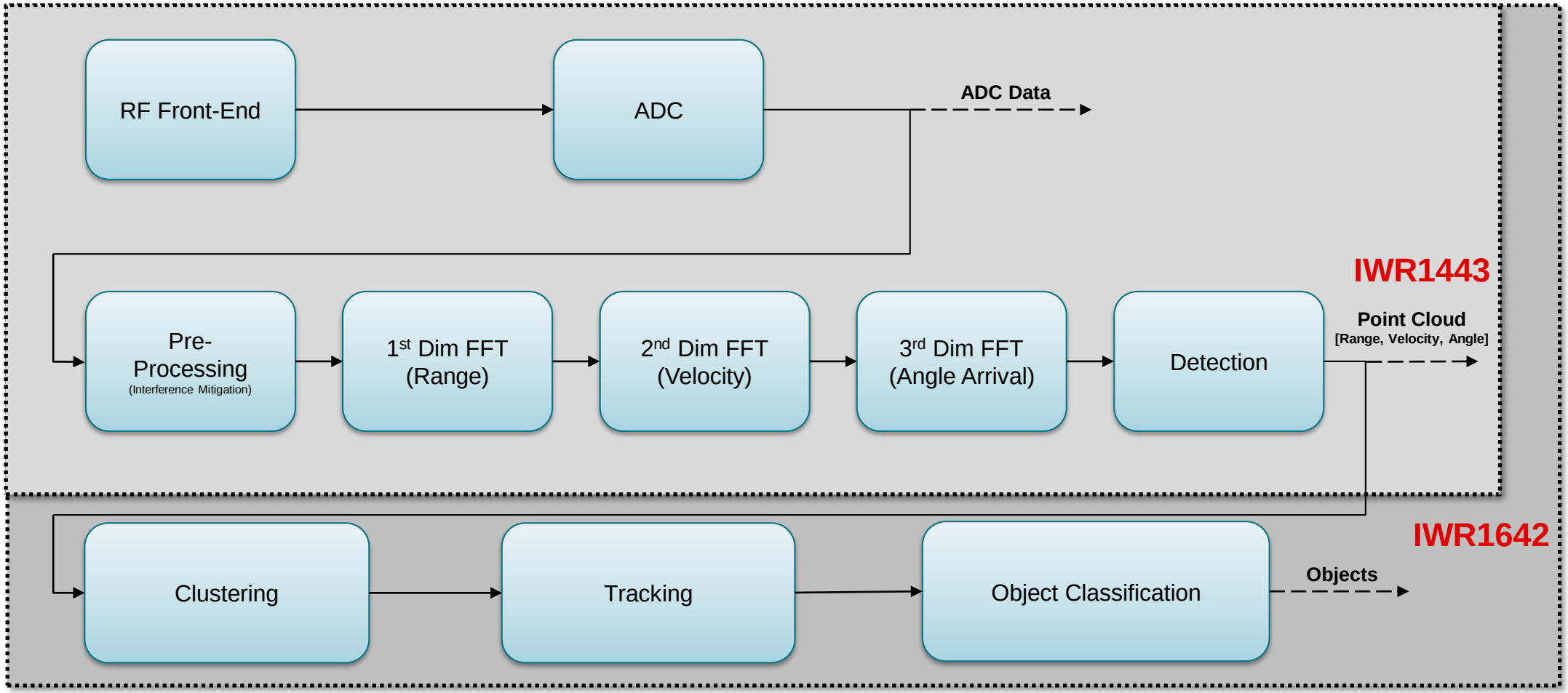
Sensor configuration with TI mmWave solutions







IWR1xxx mmWave Signal Processing

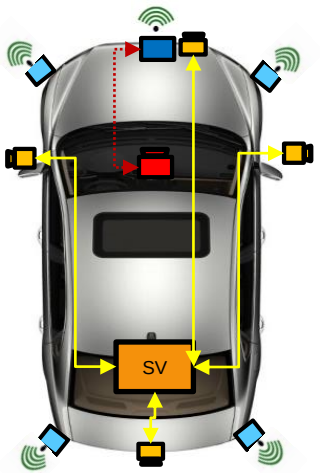


- 毫米波雷達感測器輔助汽車駕駛之應用

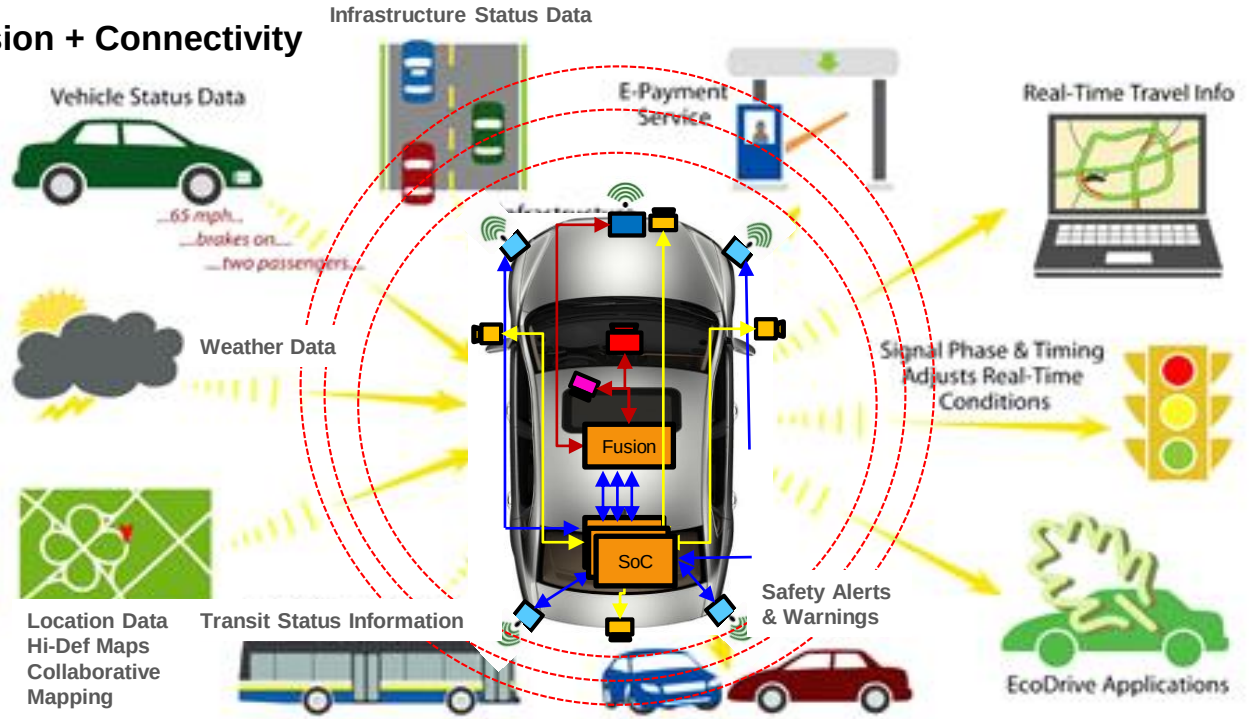
ADAS to Autonomous

Few sensors

More sensors



Fusion + Connectivity



ADAS – Driver Assist to Limited Driver Substitution

- Discrete signal processing with 1-4 sensors per SoC and limited fusion on big ARM SoCs
- Traditional Detection and Classification moving to Deep Learning
- Isolated compute provides security

Autonomous driving through connected/collaborative technology

- Shift towards centralized signal processing
- Multi-Modal Sensor Fusion provides Robustness and Redundancy
- Heavy use of Deep Learning
- Connected compute needs active security

ADAS → **Autonomous Driving**

Automotive mmWave Sensors

TI's AWR portfolio of 76-81 GHz mmWave sensors scales from high performance front-end to single chip solutions that integrate a DSP and MCU

Mid and long range radar
Adaptive cruise control, emergency braking, highly automated highway driving

Ultra short and short range radar
Blind spot, rear collision avoidance / warning, lane change assist, pedestrian/bicyclist detection, collision avoidance, cross traffic alert, 360 degree view, park assist

Proximity sensing
Occupant detection, body sensor, in cabin gesture recognition, driver monitoring

AWR mmWave Sensors

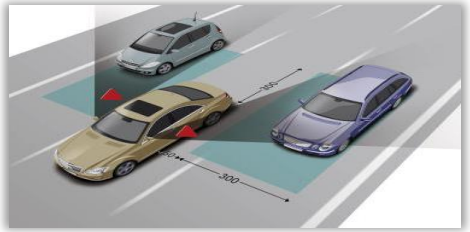
TI's mmWave technology enables highly precise sensing applications across ADAS, body and chassis and infotainment systems by analyzing and reacting to dynamic operating conditions

Automotive Radar Sensing Applications

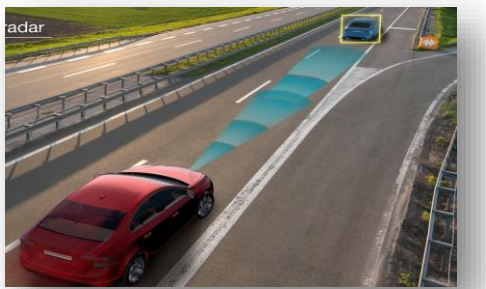
Adaptive Cruise Control

Automatic Emergency Brake

Lane Change Assist



Blind Spot Detection



Imaging Radar

Automatic Parking

In-Cabin Sensing, Near-Field Sensing

In-Cabin and Near-Field Sensing Applications

3D Obstacle Detection

Vehicle Occupant Detection

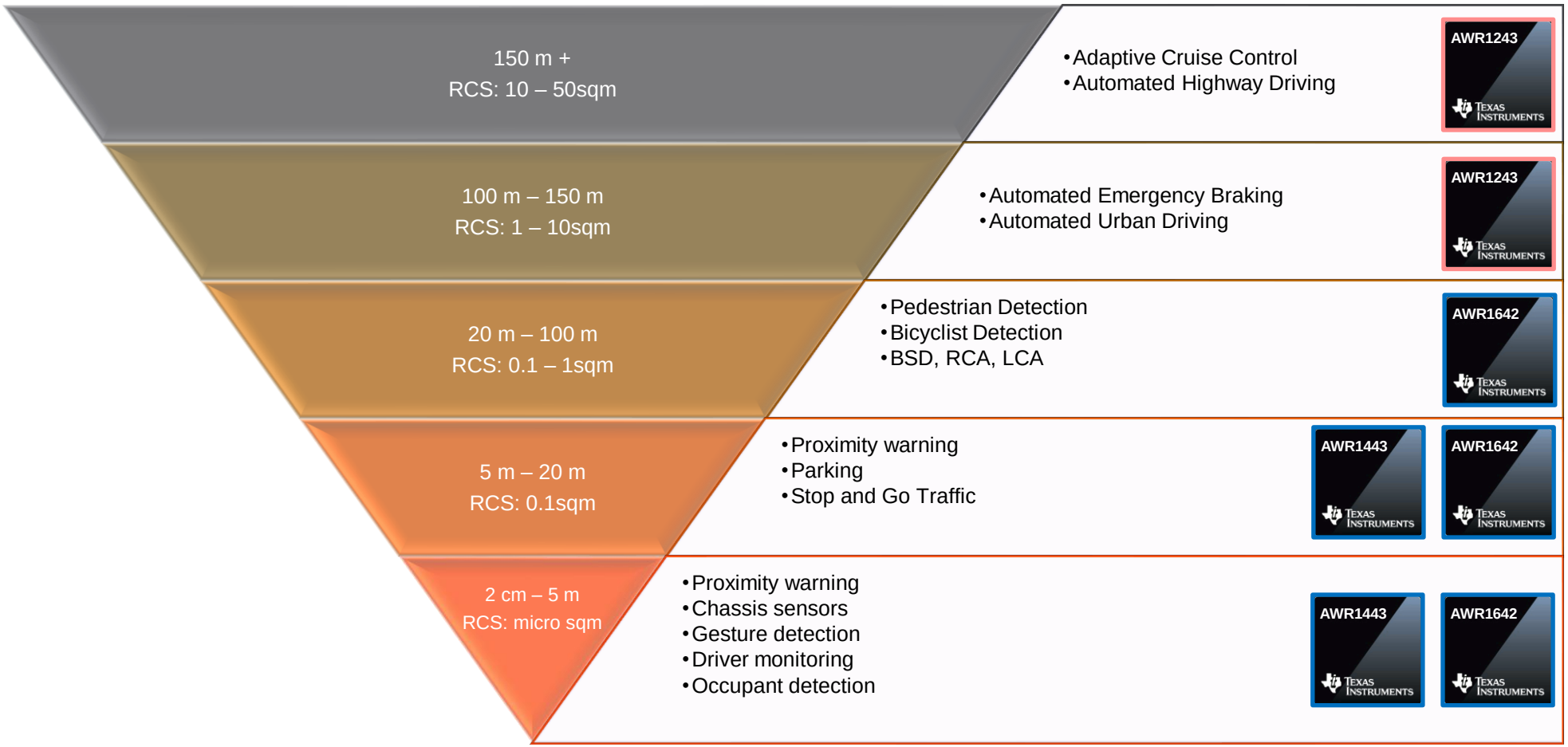
Driver Vital Sign Monitoring

Gesture Recognition

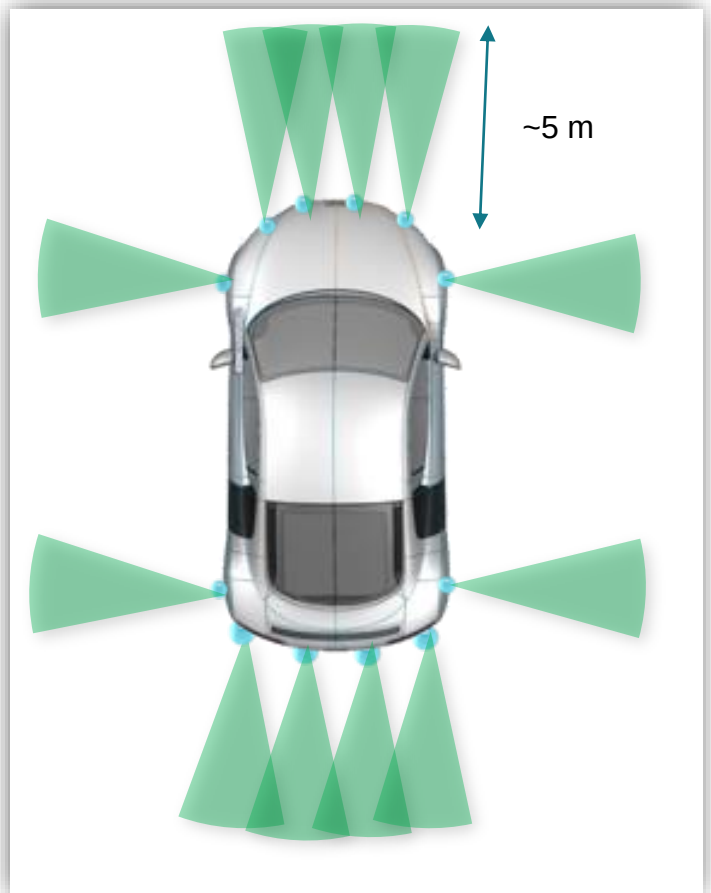
Applications by Range

Single chip solution

Works with external MCU/DSP



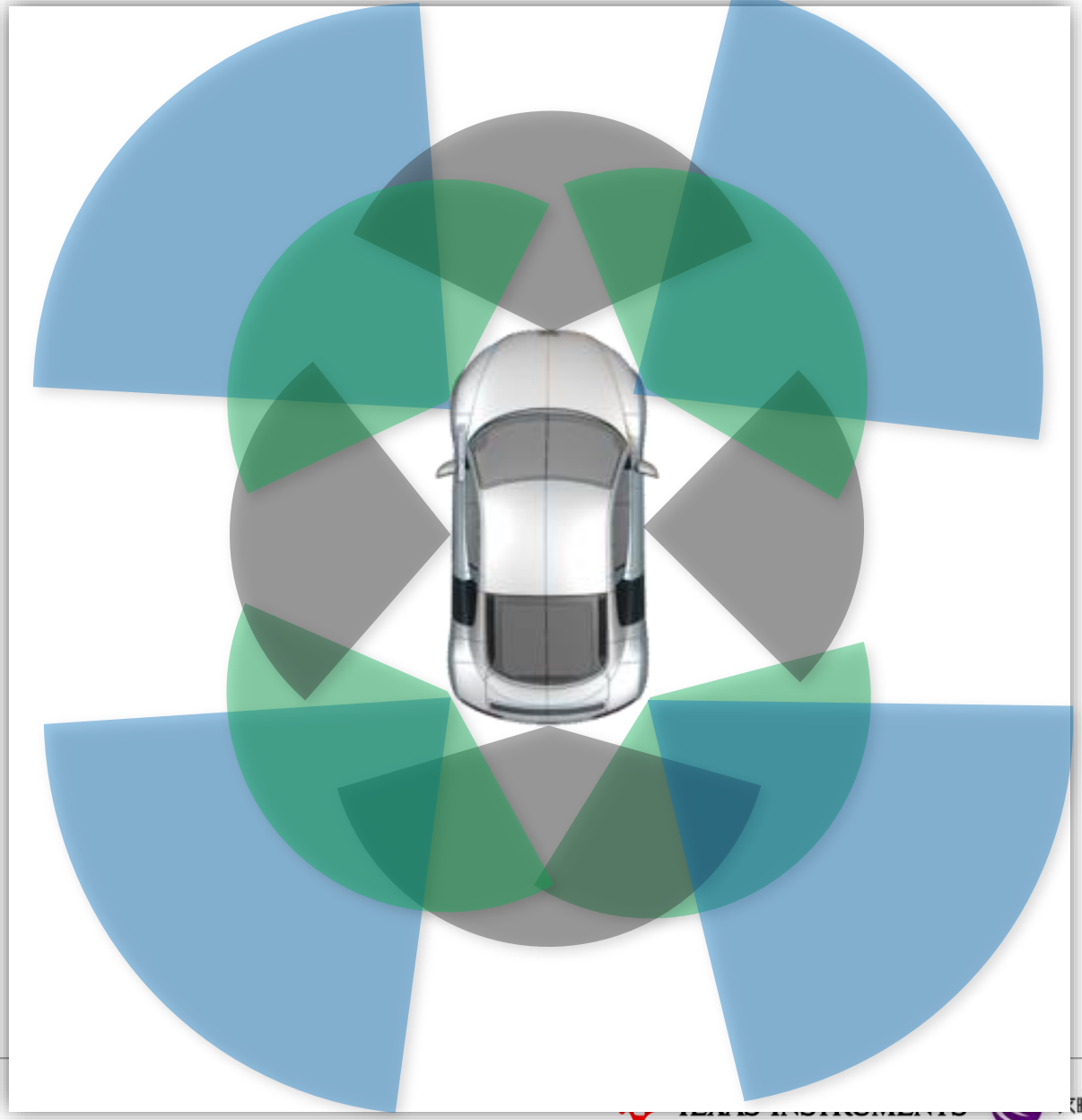
Parking Sensor today



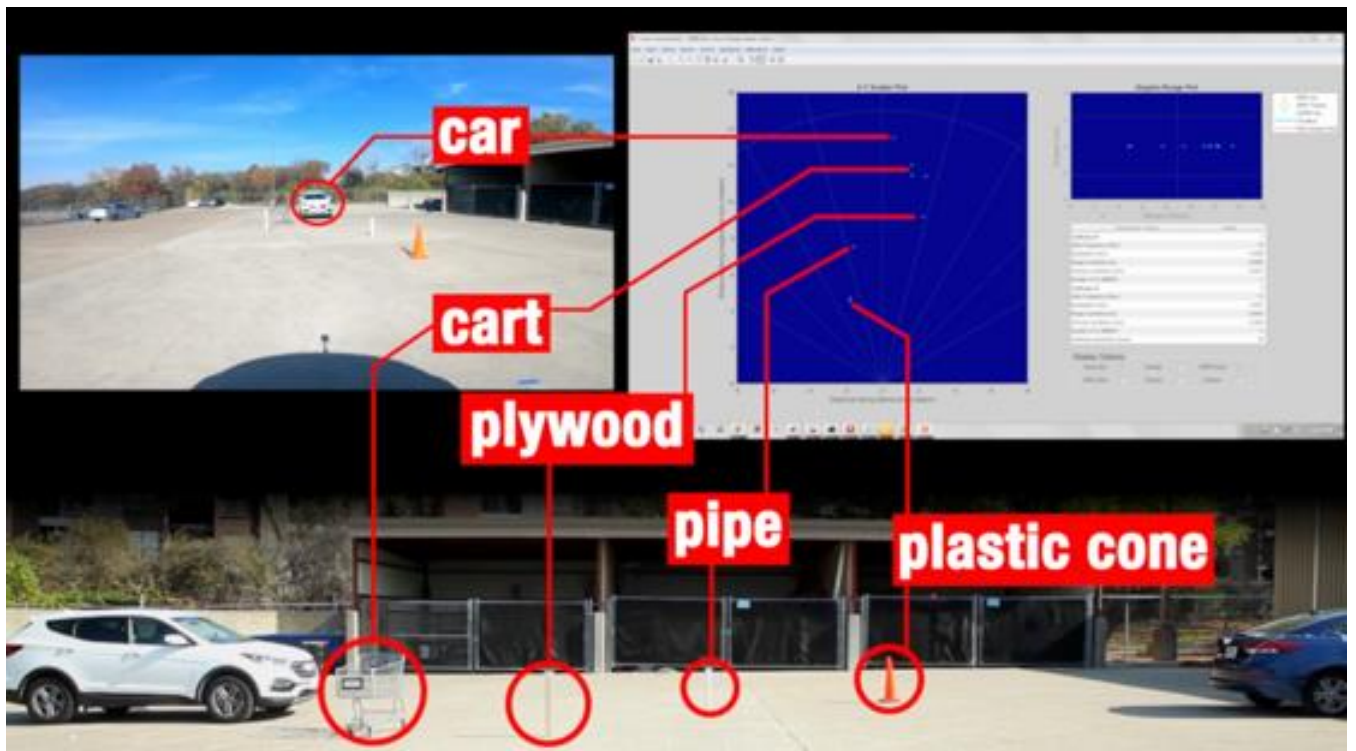
- 12 Ultrasonic sensors
- No 360 deg coverage
- Doesn’t work when covered with mud, snow
- Limited range (15 cm to 5 m)
- Holes in bumper
- Color needs to match

Why Radar Sensors

- Reduced number of sensors
- Extended range ~ 40m
- Wide field of view
- Must for Automated Parking



mmWave for Parking

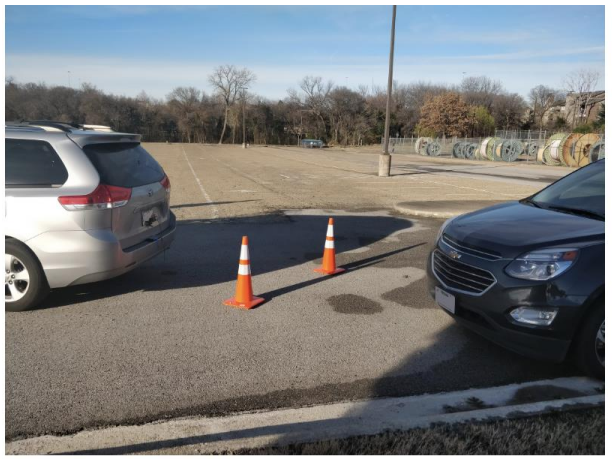


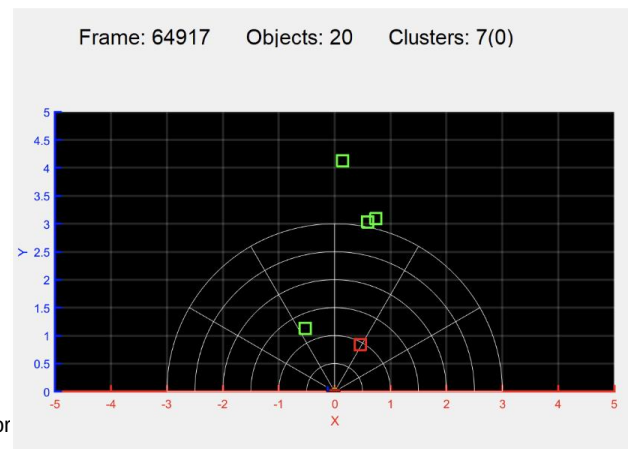
LTCC based
AWR1642 module.
On car bumper

- Wide FOV
- 20+ m Range
- Multi object detection
- Smallest form factor
- Multi modal/functional

https://training.ti.com/parking-object-detection-using-tis-single-chip-mmwave-sensor

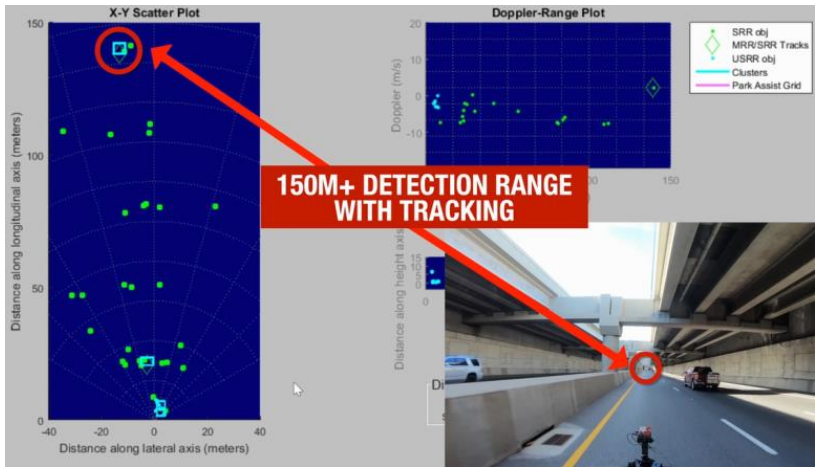
Automated Parking using AWR1843

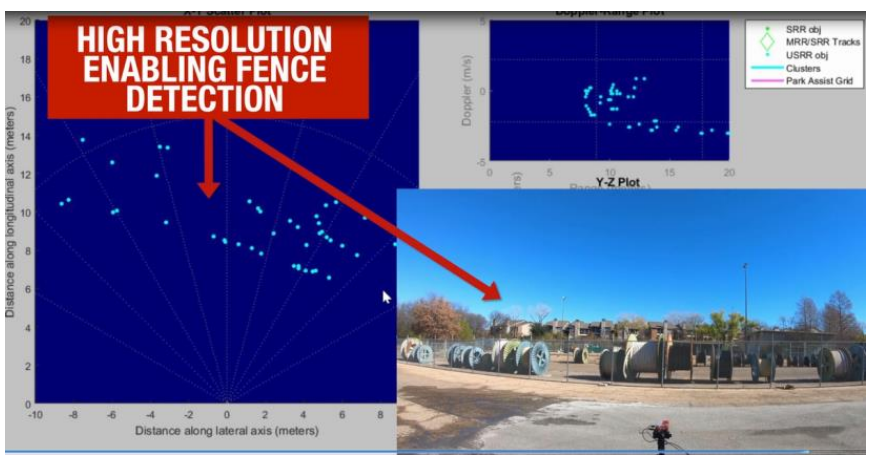




- Reference Code on DSP
- AWR1843BOOST EVM
- Visualization GUI
- 3rd Tx for elevation information
- Dedicated accelerator for FFT processing
- 2MB of on-chip memory

Corner Radar Using Single Chip Radar Sensor





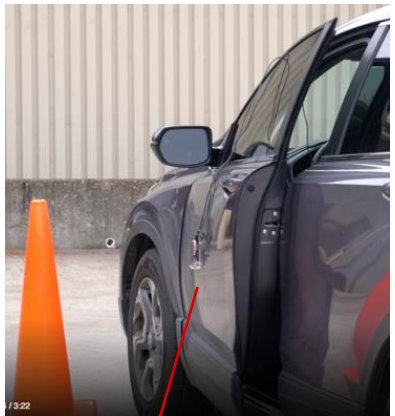
Key Features

- **Single chip drives smallest form factor & lowest cost sensor**
  - World's first RFCMOS single chip sensor already in production, enabling processing at the edge
- **High precision and accurate detection up to 150m**
  - Ultra-wide bandwidth enables separation of objects as close as 4cm
  - Detection of 200+ objects with multi-mode
- **mmWave-SDK, reference designs and system level learnings enable faster TTM**
  - Safety monitoring, device calibration, optimized power architecture, reference algorithms

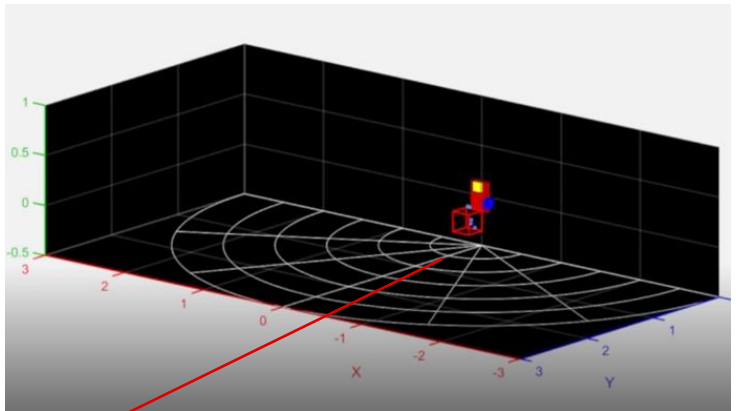
Get Started w/ TI Single Chip Sensors for Corner Radars

- Short range radar reference design
- Medium range radar demonstration reference source code
- Automotive reference design with optimized power architecture
- SRR demonstration video using AWR1642
- MRR demonstration video using AWR1843

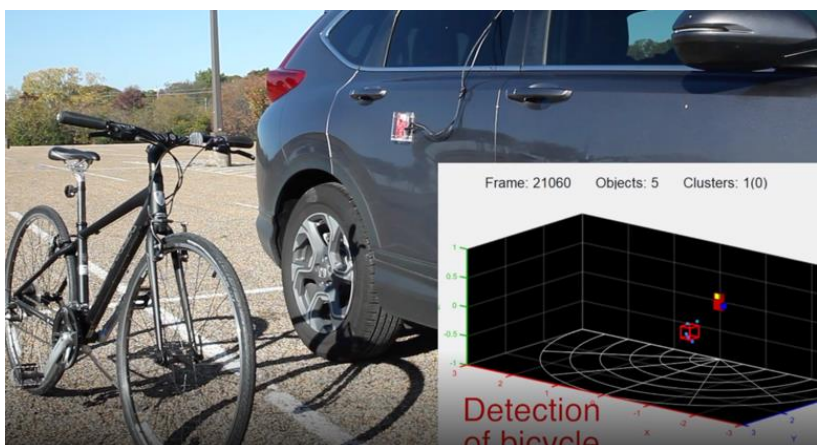
Obstacle Detection Sensor



Sensor 50cm from ground



Traffic cone detected



AWR1642

- 4cm to 15m detection range
- +/- 70 Horizontal FOV
- +/- 40 Vertical FOV
- Extended range and detection in 3d space in any environmental conditions

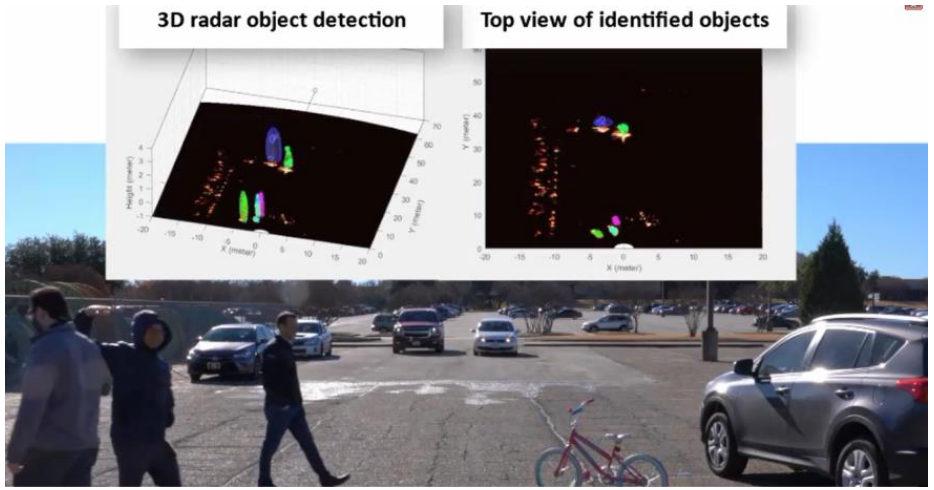
Applications:

- Automatic car door opener
- Parking assistance
- Kick to open trunk

Reference :

- Evaluation Kit: www.ti.com/tool/awr1642boost-ods
- Evaluation code available
- Reference Design: http://www.ti.com/tool/TIDEP-0104

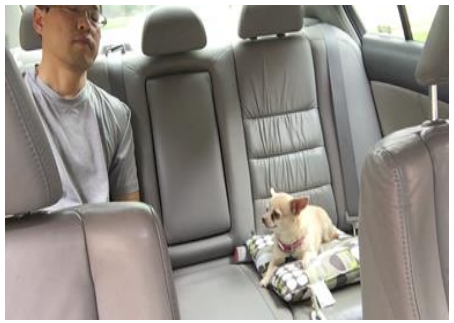
Imaging Radar Using Cascaded High-Performance Front-End

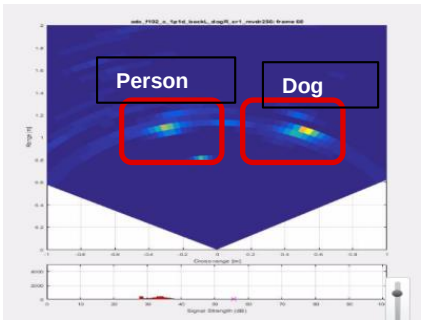


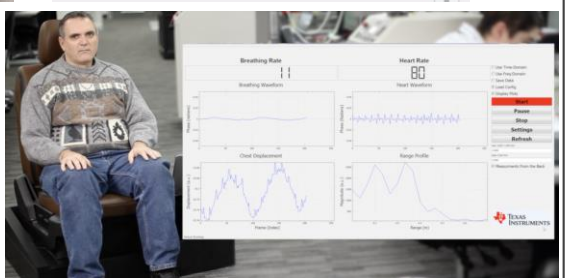
Key Features

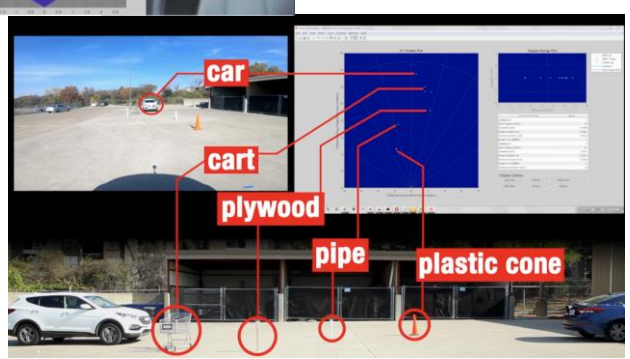
- **High performance and low power imaging radar with lowest BOM**
  - Lidar-like imaging performance, <1° angular resolution
  - 350m+ range for cars and 150m+ for pedestrians
  - Accurate beam steering for longer range object tracking
- **Simplified design with built-in cascade circuitry**
  - 2+ years of systems work to develop algorithms and design guides
  - Multi-channel antenna calibration for MIMO and beamforming
- Imaging radar demonstration video
- Multi-chip cascading application note

Body & Chassis Applications Using Single Chip Radar







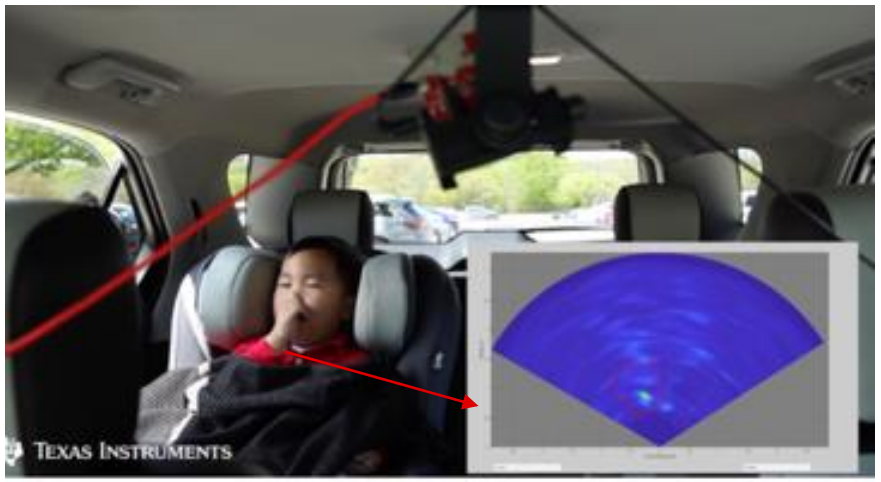


Key Features

- **Single chip drives smallest form factor and lowest cost sensor**
  - Precise, multi-object detection in 3-D space
  - 4cm – 40m detection range
- **Enabling wide range of body & chassis and in-cabin applications**
  - NCAP roadmap driving OEM SOPs
- **Obstacle detection Sensor for automatic car door/trunk opener, vehicle exist warning and automated parking**
  - Reference design with wide FoV antenna
  - Parking demonstration video and Reference Code
- **Vehicle occupant detection for child/pet left-behind warning, intruder detection**
  - Reference design with demonstration
- **Driver vital signs monitoring**
  - Reference algorithms with demonstration
- **Gesture control, Kick-to-open**
  - Gesture recognition demonstration video

Vehicle Occupant detection

Child left behind in car detection



Multi Zone Occupant Detection

AWR1642 sensor

- High accuracy occupant detection inside a car using a single chip
- Detection of life form like baby and even pets
- Robust to sunlight, darkness, can be hidden under fascia

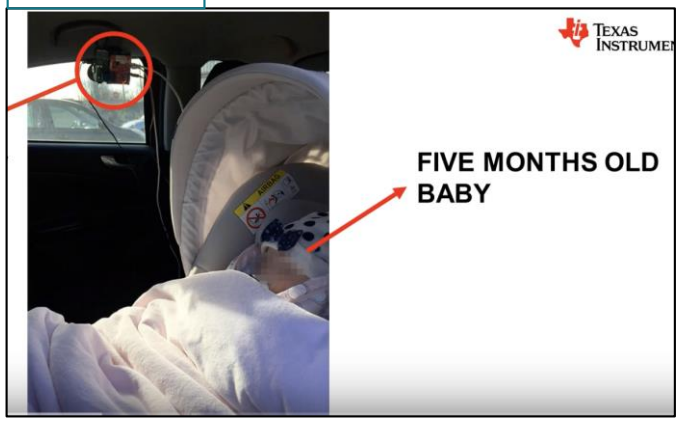
Applications:

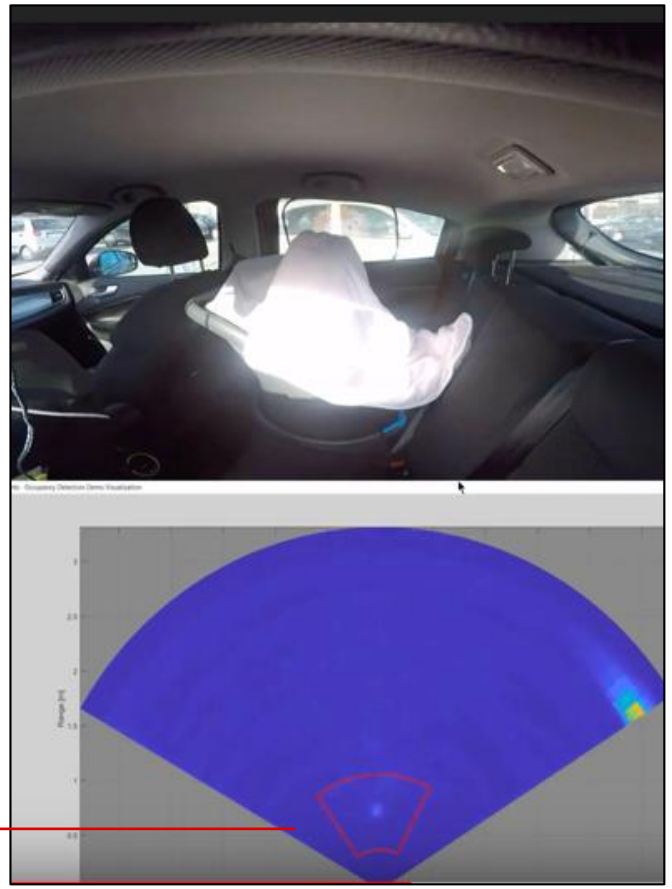
- Child left behind detection in car
- Occupant and intruder detection

- Reference code available LINK
- www.ti.com/tool/TIDEP-01001

Detection of child in a car

AWR sensor





Baby detected

- 5 months old baby in a rear facing child seat covered completely by a blanket/clothing
- Orientation of the seat changed during tests with people moving around the car and no false detections

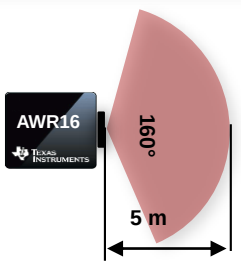
mmWave sensors for occupancy detection

Feature Needs

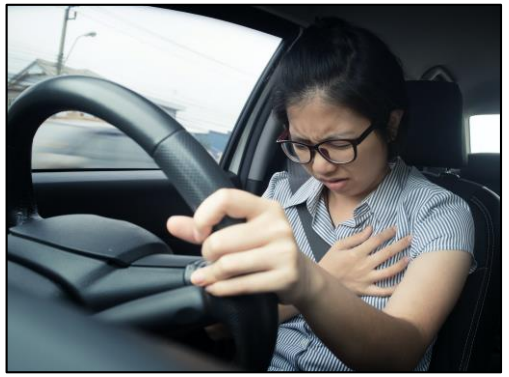
- Unattended child detection
- Position of occupants for personalization
- Air bag deployment
- Euro NCAP 2025 roadmap

Why 77 GHz radar ?

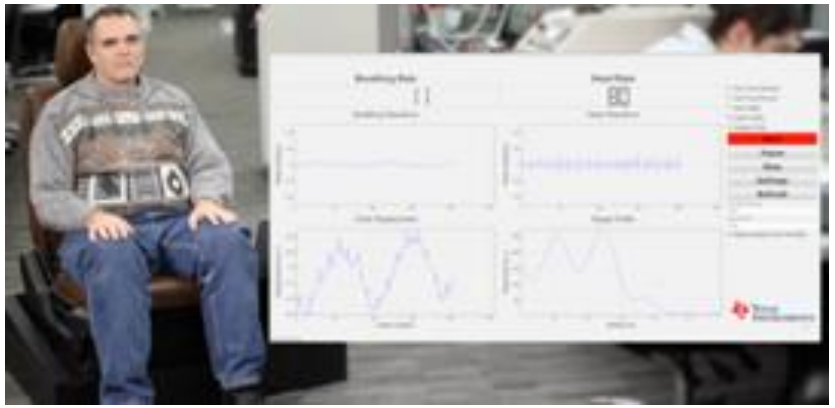
- Less processing and single chip solution
- Contactless and non intrusive
- Robust against any environmental conditions



Driver Vital Sign Detection



Need for Vital sign monitoring



Sensor inside the seat

AWR1642 Sensor

- Contactless and non intrusive sensing
- Robust to any environmental conditions

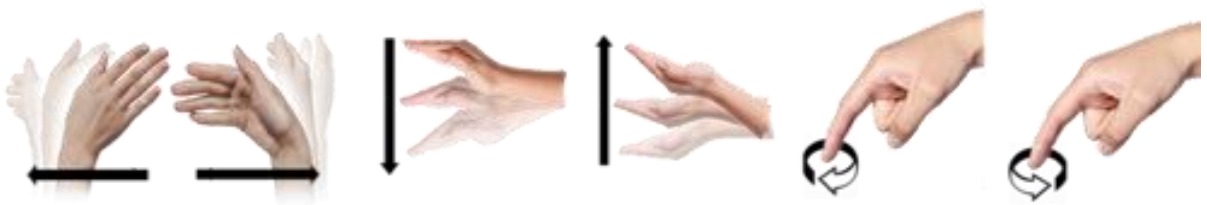
Applications:

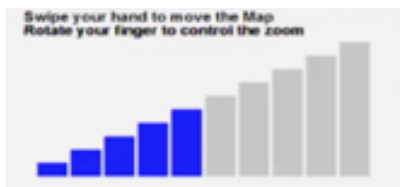
- Driver Heart Rate & Breathing rate detection
- Find driver fatigue/sleepy state
- Alert in case of health conditions

Reference Code:

- Code available on TI Resource Explorer
- Partner Video for detection in moving car

Gesture recognition





Infotainment gesture Sensor

Multi modal Kick Sensor

Why TI mmWave sensor

- Multi class gesture detection on single chip sensor
- Enables detection of fine motions with high accuracy
- Not affected by bright light or dark conditions
- Small form factor, can be placed behind plastic

Thank You