

mmWave Radar – IWR1642 People Counting Demonstration

Presenters

Abdulraheem Killedar
Wesley He
Gondalia Akash

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mmWave Sensors:

<http://www.ti.com/sensing-products/mmwave/overview.html>

<http://www.ti.com/sensing-products/mmwave/iwr/overview.html>

<http://www.ti.com/sensing-products/mmwave/awr/overview.html>

Agenda

- Demonstration Introduction
- Implementation
 - Signal Processing Chain
 - Tracking Module
- Demo and Run
 - Demo Setup
 - Live Demo Show
- Q&A

People Counting Demonstration using IWR1642

Platform

- IWR1642 – TI's FMCW mmWave (76-81GHz) **Single chip Radar** with 2Tx/4Rx RF front End, ADC, DSP(C674x) and MCU(Cortex-R4F)

Features

- Single chip solution.
- Device outputs point cloud and object tracking information
- Demonstration is locating and tracking moving objects

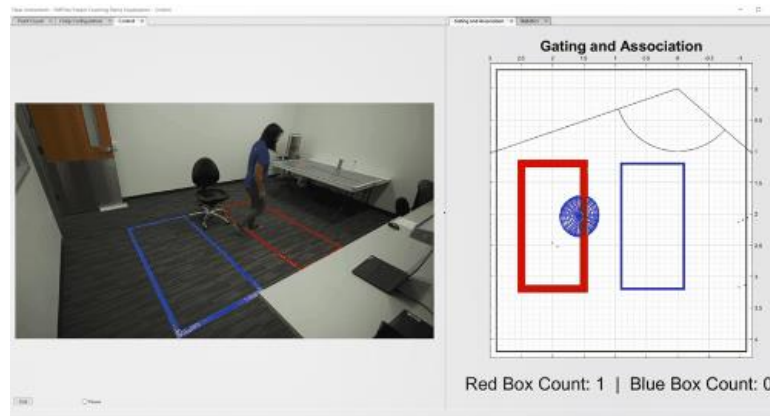
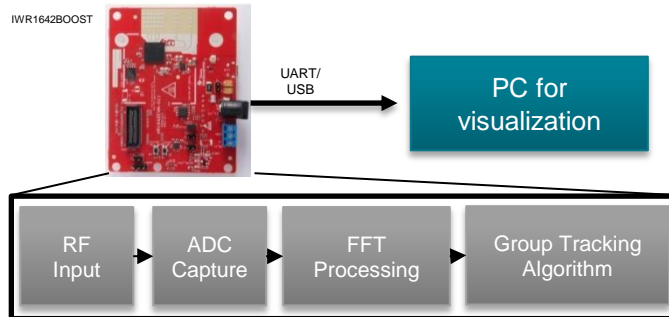
Benefits

- Count and track the people with mmWave Radar, especially in privacy-conscious applications or in challenging environments such as nighttime, fog, smoke

Applications

- | | |
|---------------------|--------------------------|
| • People Counting | • Lighting Sensors |
| • Motion Detector | • HVAC Control |
| • IPNC Video Camera | • Factory Safety Sensors |

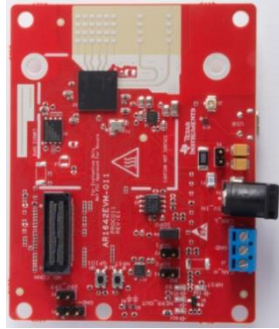
Demonstration using IWR1642 EVM



Implementation

Hardware

- IWR1642
 - 4 RX, 2TX



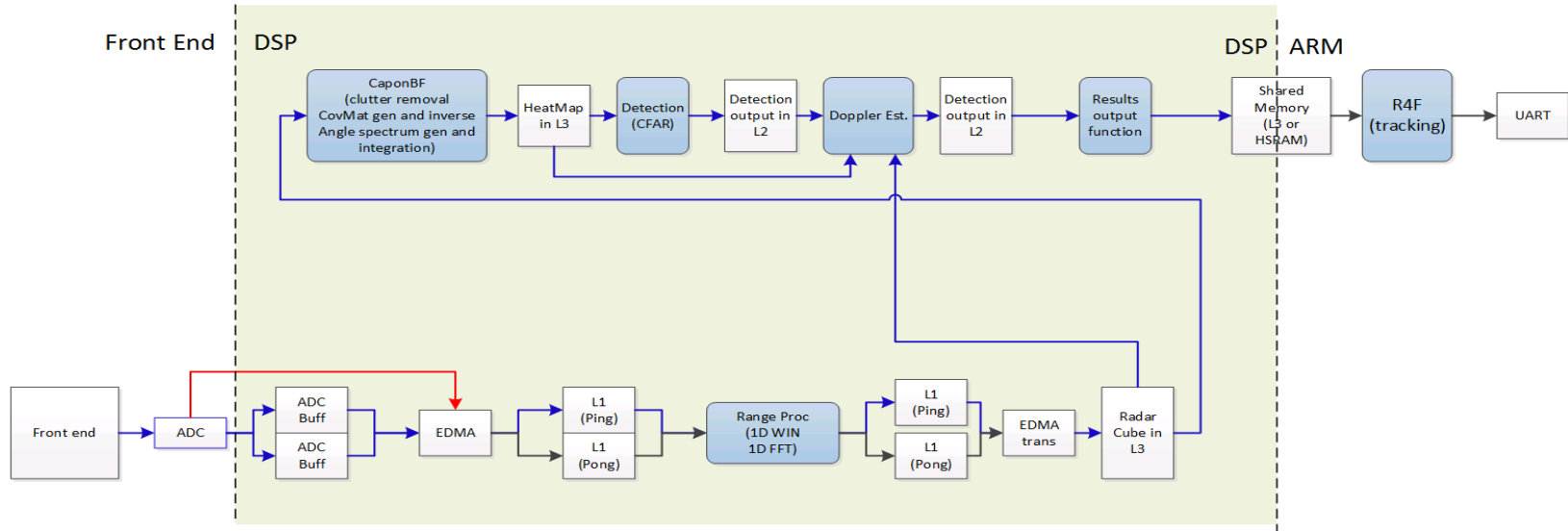
Software

- mmwave_industrial_toolbox_2_1_2
- Check the latest version in TI-REX
 - <http://dev.ti.com/tirex/#/>
 - TI-Design coming soon.

Key Performance Specifications

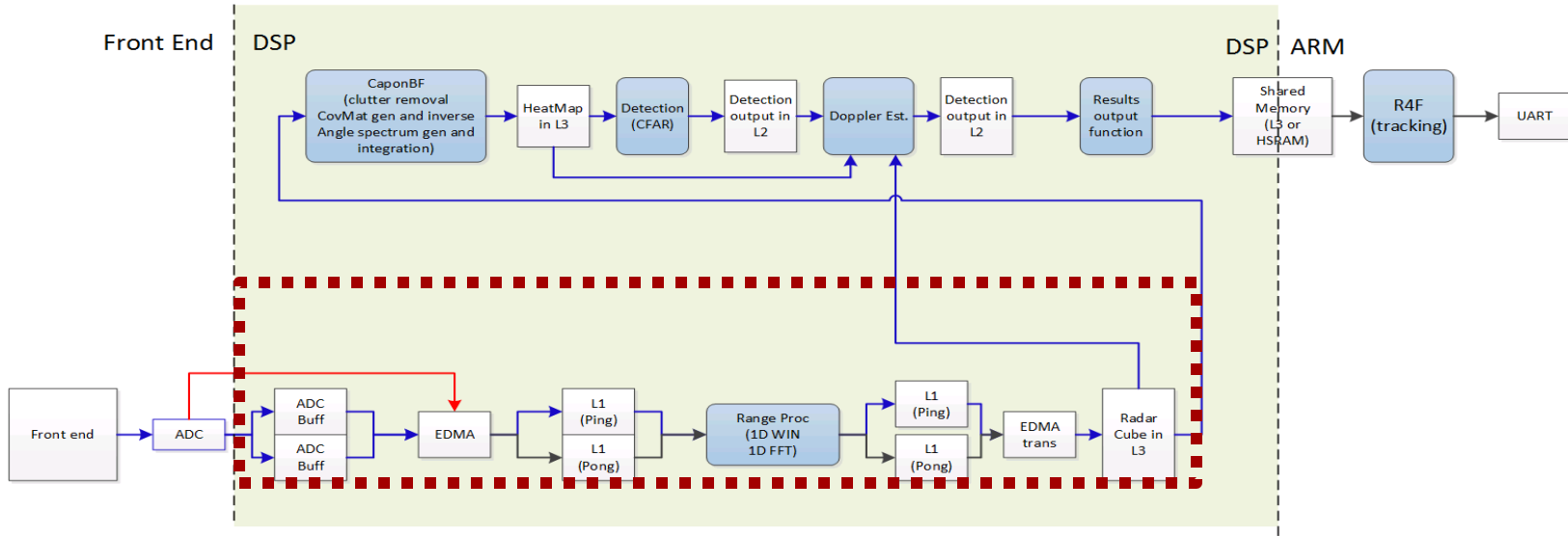
Parameter	Short Range	Long Range
Max range	5 m	12m
Max velocity	18.64 Km/h	18.9 Km/h
Range resolution	4.9 cm	12 cm
Velocity resolution	0.297 Km/h	0.297 Km/h
Field of View	120° horizontal 30° vertical	120° horizontal 30° vertical
Power Consumption	2 watt	2 watt

Low Level Signal Processing Chain: Block Diagram



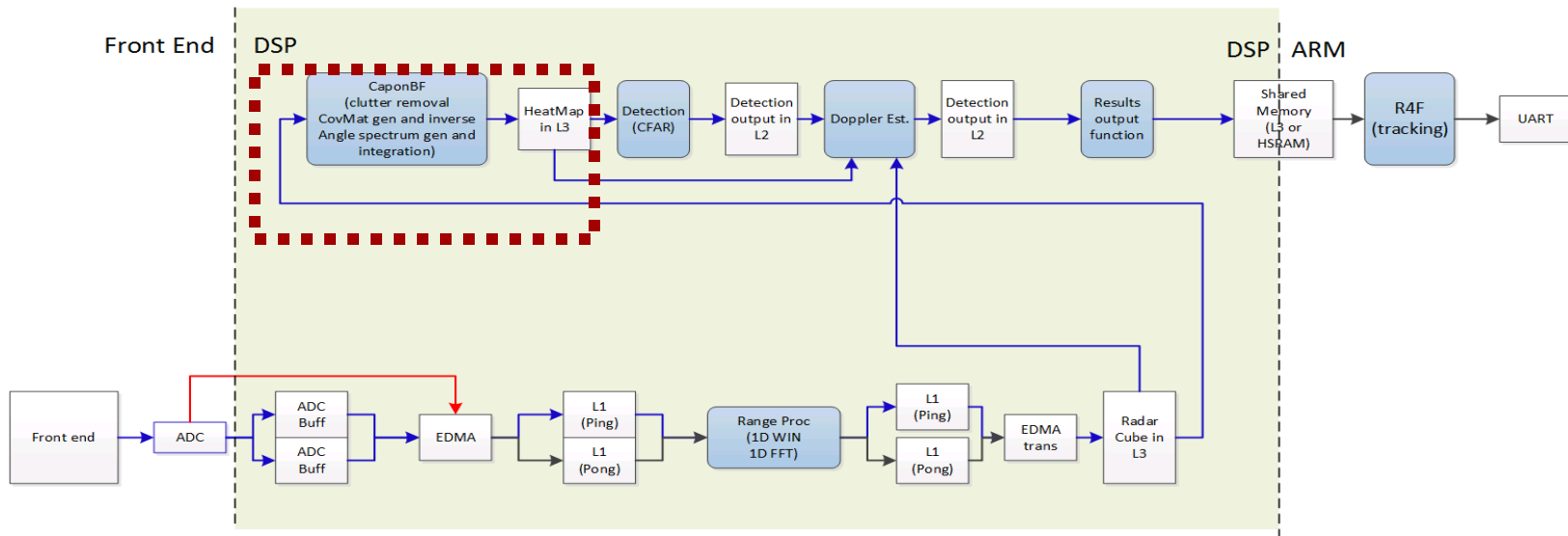
- Low level signal processing chain is implemented on DSP (C674x) of IWR16xx
- Low level signal processing chain outputs detected point cloud with information of range, Doppler, angle, and detection SNR.
- Output point cloud information are shared with R4/tracker in L3 memory for the current implementation.

Front End and Range Processing



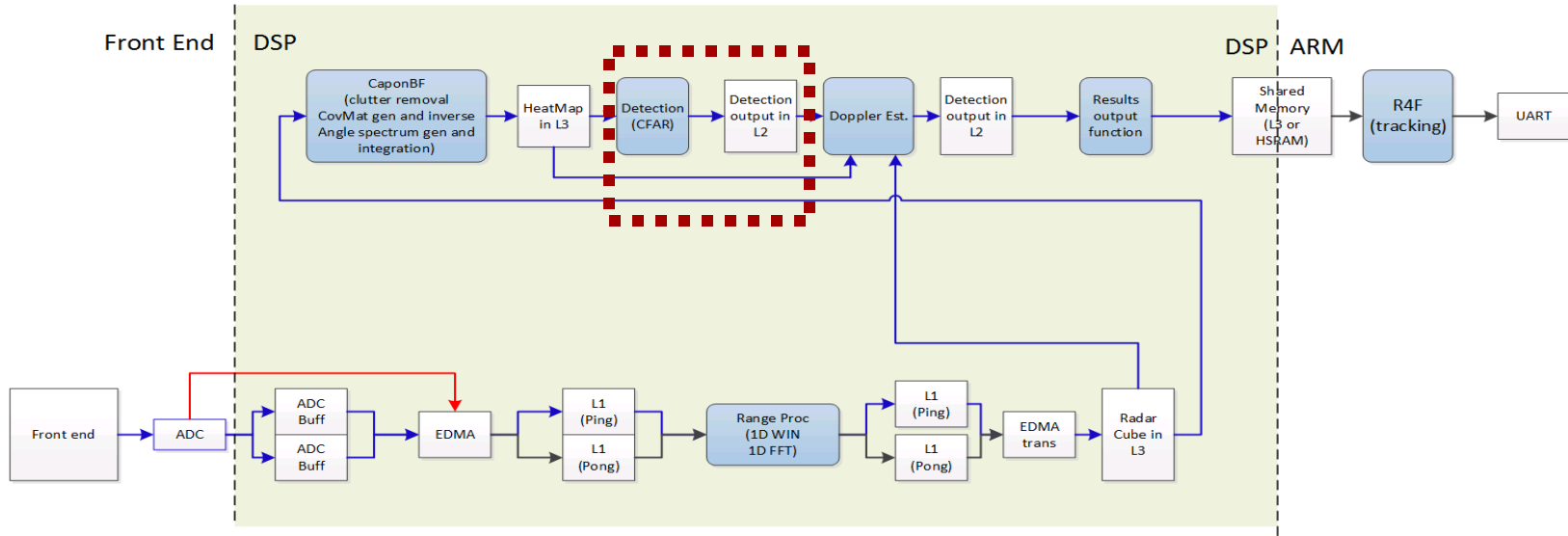
- ADC samples are EDMAed into local scratch buffers in PING-PONG fashion.
- Range processing performs FFT per antenna per chirp.
- Range processing results in local scratch buffers are EDMAed to L3 with transpose.

Angle (Azimuth & No elevation) Processing



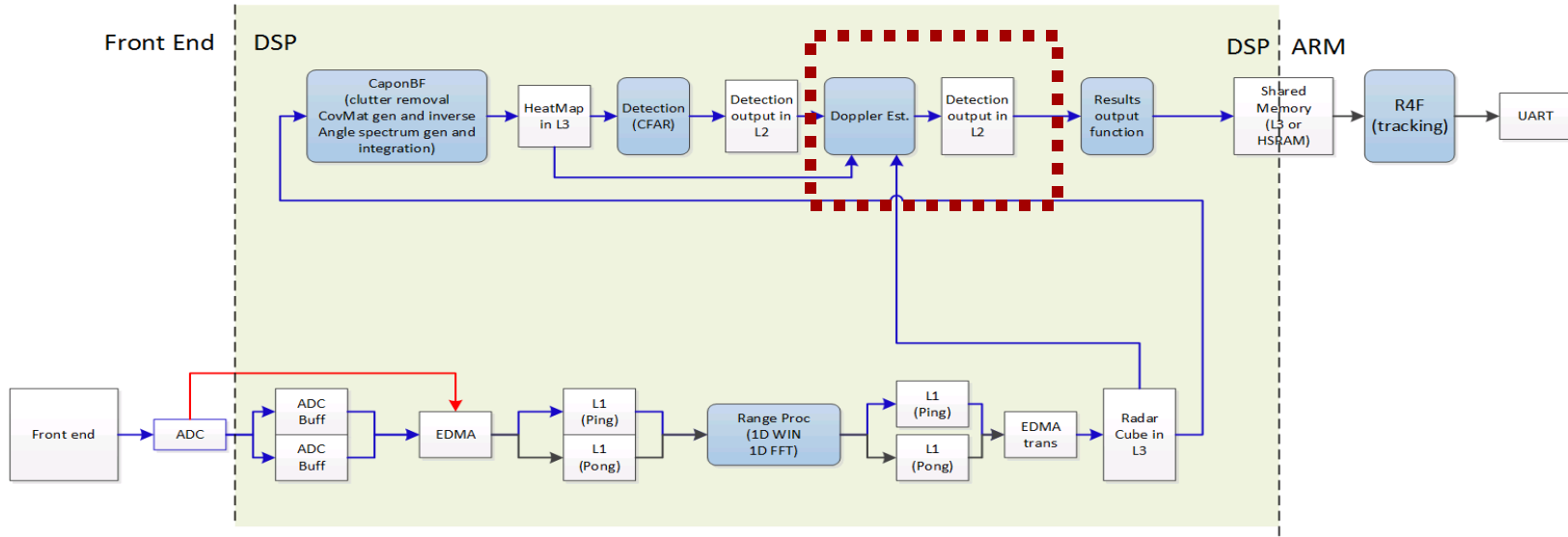
- **Static clutter removal** is performed removing DC components per range bin.
- Per range bin, calculate the Capon BF solution and store the angle spectrum in memory to construct the range-azimuth heatmap.

Object Detection



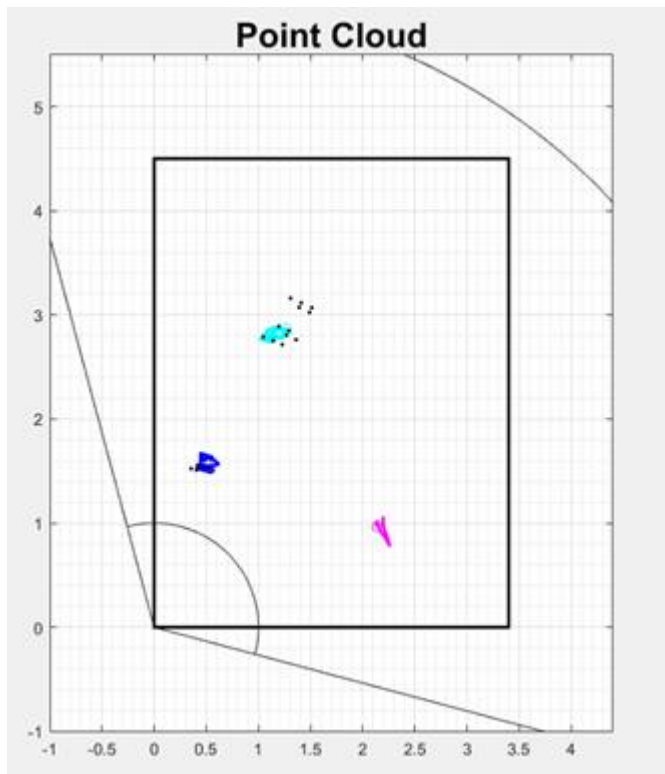
- 2-pass CFAR is performed on the range-azimuth heatmap.
- First pass is cell averaging smallest of (CFAR-CASO) in the range domain.
- Second pass is cell averaging smallest of (CFAR-CASO) in angle domain.

Doppler Estimation

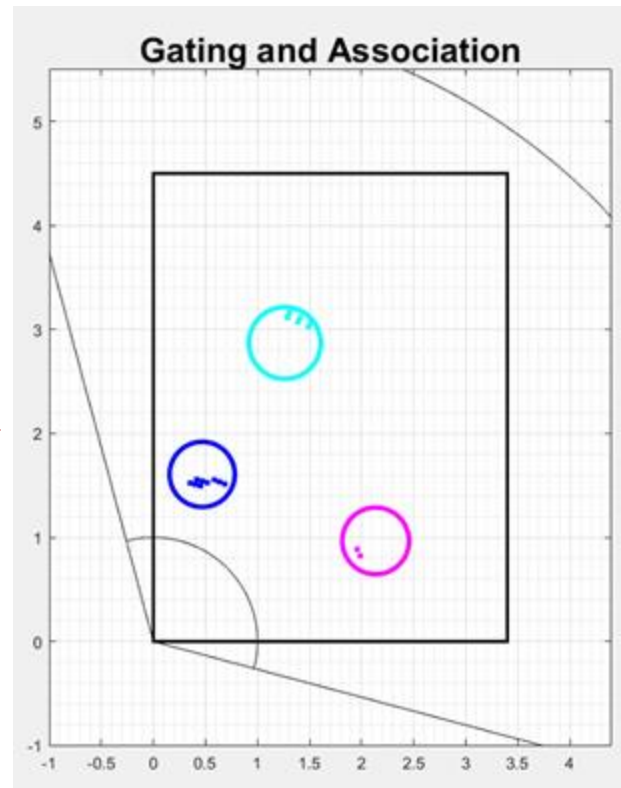


- After detection, per detected point, estimate Doppler by filtering the range bin using Capon beamweights and then FFT with peak searching.

Point cloud, tracking and grouping

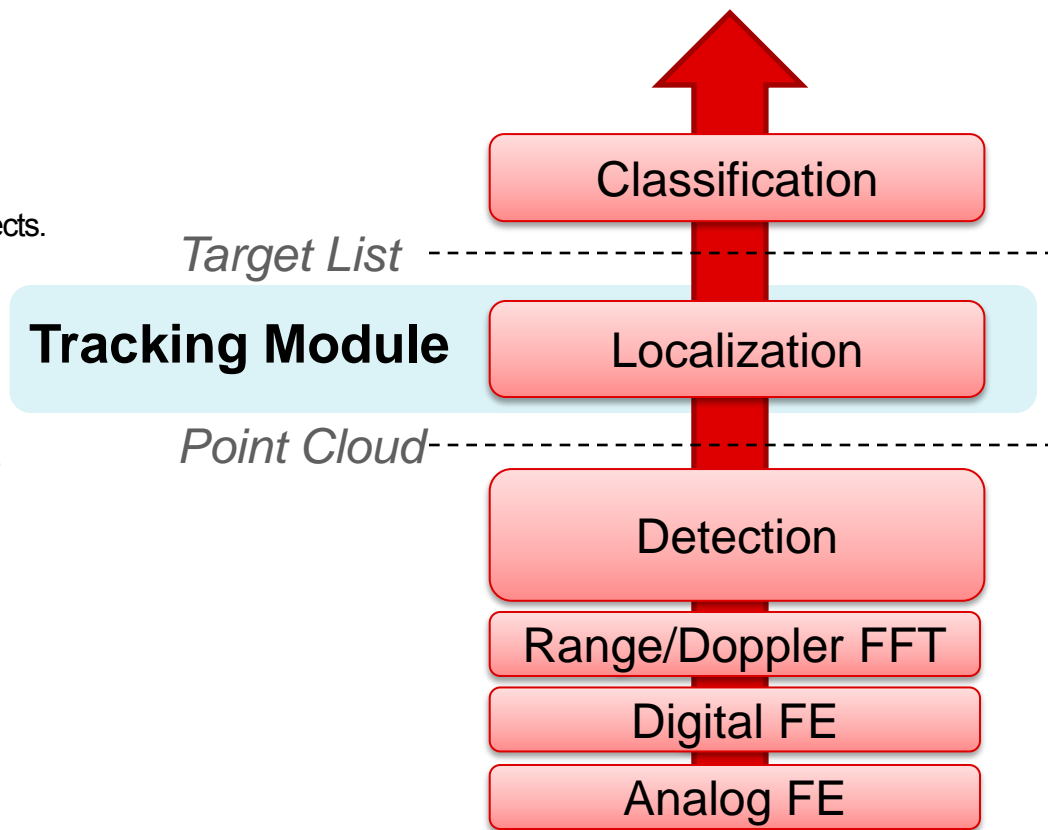


**Tracking
and
Grouping**

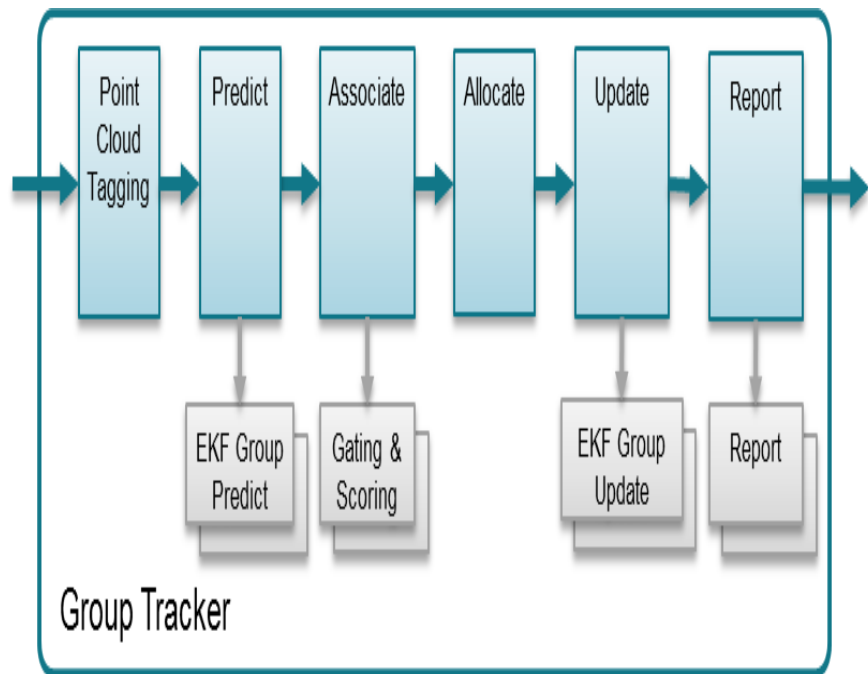


Tracking Module

- Implements **Object Localization**
 - Example: “I am consistently observing an array of objects. Each object has a set of following properties”
 - Uses Detection Layer Data
 - Is a State-full Layer
 - Does not Classify at object
- Input: **Point Cloud**
 - ~1000s of measurements (detection points)/frame
 - Each point has range/angle/radial velocity with associated variances
- Output: **Target List**
 - ~100s of targets/frame
 - Each target properties may include
 - Cartesian position
 - Cartesian velocity
 - Additional Features
 - » Number of points/reflections
 - » Dispersion/Sizes/Density
 - » Timing/History
 - » Velocity spread



Tracking Algorithm Blocks



- **Point cloud** input is first tagged based on scene boundaries. Points outside the boundary are ignored
- **Predict function** estimates tracking group centroid for time n based on state and process covariance matrices estimated at time $n-1$. a-priori state and error covariance estimations for each trackable object are computed. At this step we also compute measurement vector estimations.
- **Association** function allows each tracking unit to indicate whether each measurement point is “close enough” (gating), and if it is, to provide the bidding value (scoring). Point is assigned to a highest bidder.
- **Allocation:** Points not assigned, are going through an Allocate function. During the Allocation process, points are first joined into a sets based on their proximity in measurement coordinates. Each set becomes a candidate for allocation decision. It has to pass multiple tests to become a new track. Once passed, the new tracking unit is allocated.
- **Update:** During Update step, tracks are updated based on the set of associated points.
- The **Report function** queries each tracking unit and produces the algorithm output.

Implementation Details – Tracking Config

Parameter	Default Value	Description
maxNumPoints	250	Max # of detection points per frame
maxNumTracks	20	Max # of targets to track at any given time
initialRadialVelocity	0 m/s	Expected target radial velocity at moment of detection
maxURadialVelocity	20 m/s	Max unambiguous radial velocity; sets valid rates from –max to +max
maxAcceleration	5 m/s ²	Max target acceleration; used to compute processing noise matrix
deltaT	50 ms	Frame Rate

TI Resource Explorer(TIREX)

Locate the Demo and Run

Demo Customization

Demo Setup and Customization

There are 3 major steps involved to get to a desired People counting Demo.

Chirp configuration design

For the area of interest like the conference room, hallway etc where the demo is being setup, working with the 5m/12m chirp configuration examples, chirp configuration needs to be designed with max range, range resolution, Max velocity and Velocity resolution in mind.

EVM installation

The EVM needs to be installed at a proper height and with a Elevation tilt to maximize the energy reflection from the objects and hence to get to a rich point cloud. This means directing the majority of transmitted energy towards the area of interest for better reflected energy reception.

GUI and Tracking Parameter Customization

Demo customization is done in **GUI matlab** code for setting up the Demo visualization

The Group tracker needs to be configured for various parameters in `task_app.c` file under the project `pplcount_16xx_mss`, to work on the input point cloud data for localization and tracking via. These parameters include

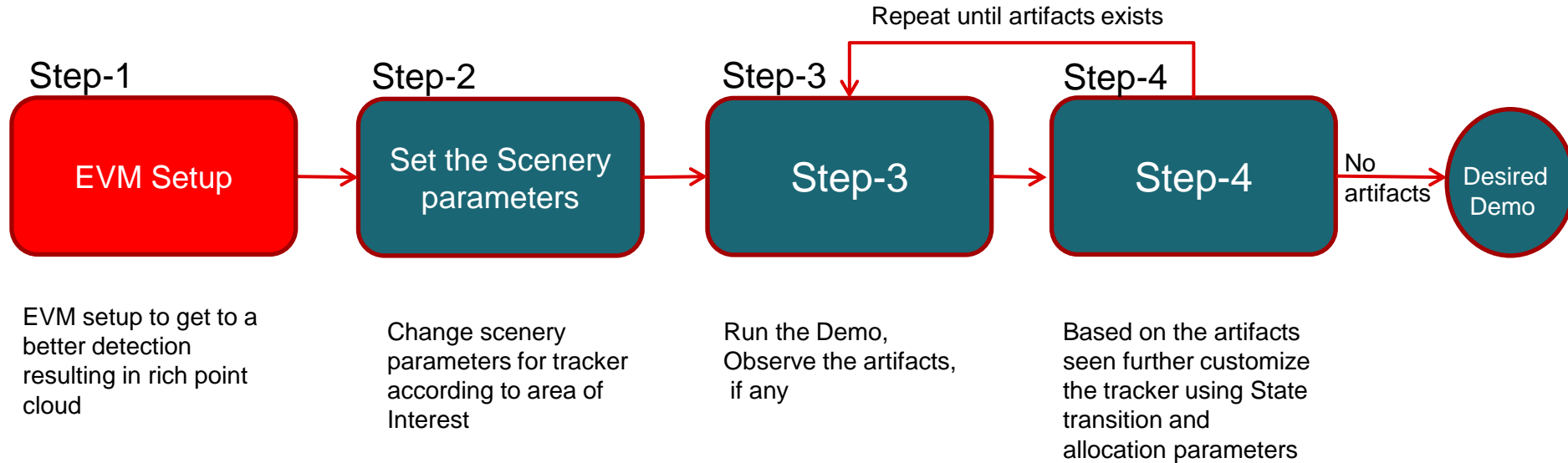
Scenery Parameters

Allocation Parameters

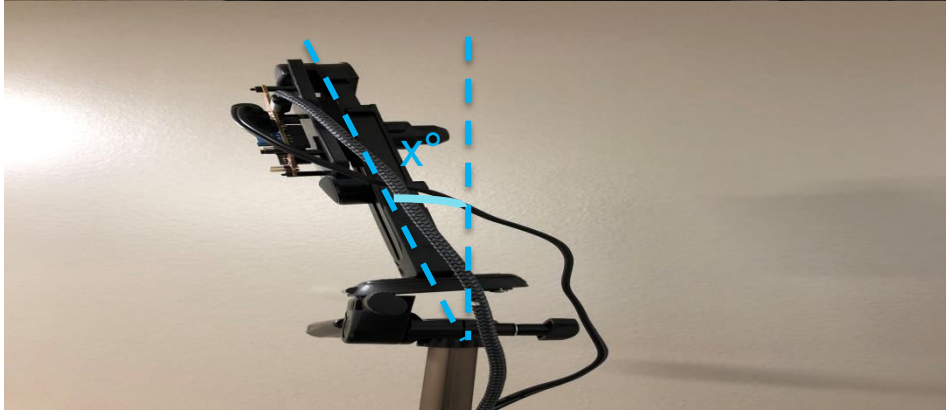
State Transition Parameters

and the Demo needs to be recompiled & built after any change to the above said tracking parameters

Steps for Demo setup



EVM installation

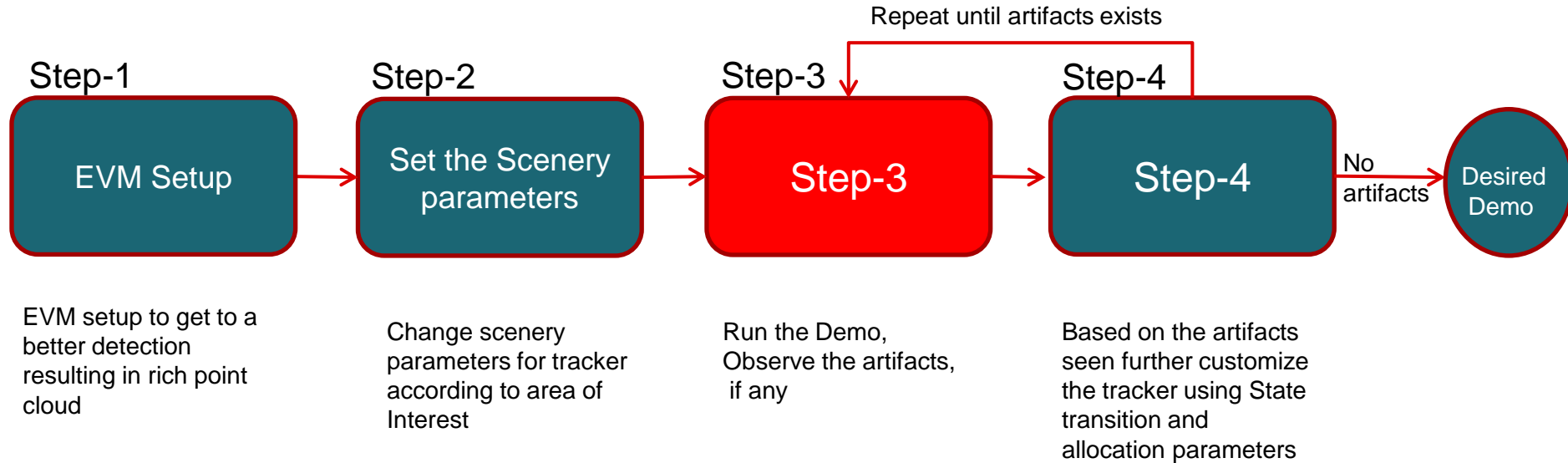


- **Height:**
EVM needs to be installed at least 2-2.5mtrs above ground
- **Tilt in Elevation**
EVM needs to be tilted as shown in the picture with a angle x deg where $10 < x < 45$ deg.

X=10 deg works better for conference/meeting rooms

The elevation tilt helps focus the transmitted energy towards the area of interest and achieve better reflection which results in a good detection thus a rich point cloud.

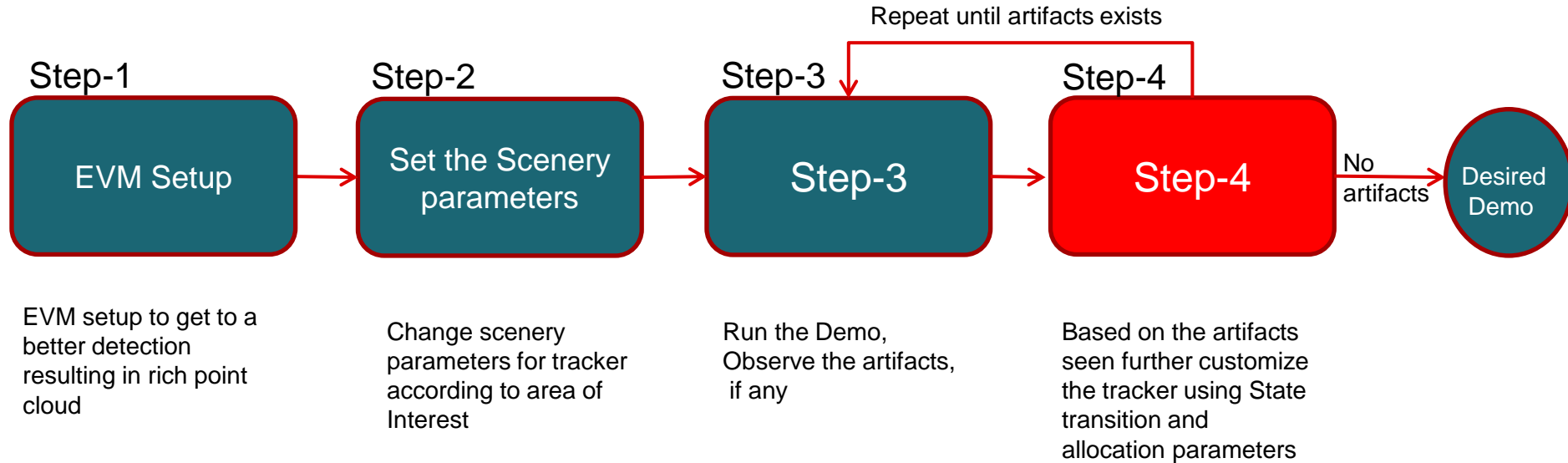
Steps for Demo setup



Tracking Parameter Customization

Run the demo once with the test scenarios in the area of Interest
Observe the performance and note down the artifacts seen.

Steps for Demo setup



Tracking Parameter Customization

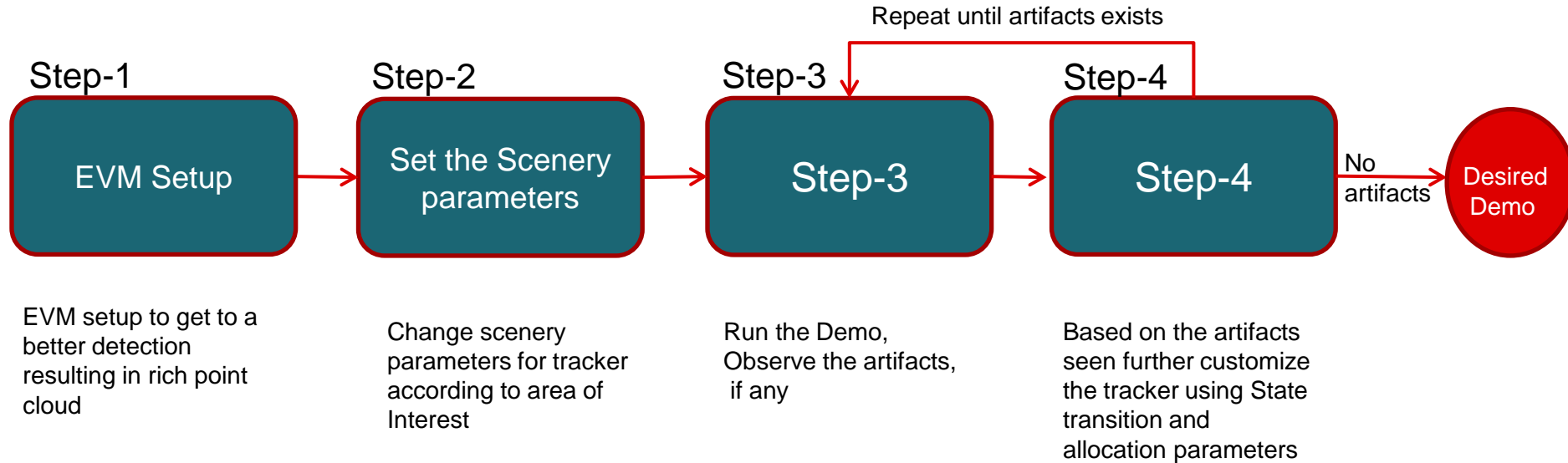
Allocation Parameters

The reflection points reported in point cloud are associated with existing tracking instances. Points that don't get associated are subjects for the allocation decision. Each candidate point is clustered into an allocation set. To join the set, each point needs to be within `maxDistance` and `maxVelThre` from the set's centroid. Once the set is formed, it has to have more than `setPointsThre` members, and pass the minimal velocity and SNR thresholds to start tracking.

`appAllocationParamTable[2]={SNRThreshold,VelocityThreshold,Pointsthreshold,MaxDistanceThre,MaxVelThre}`

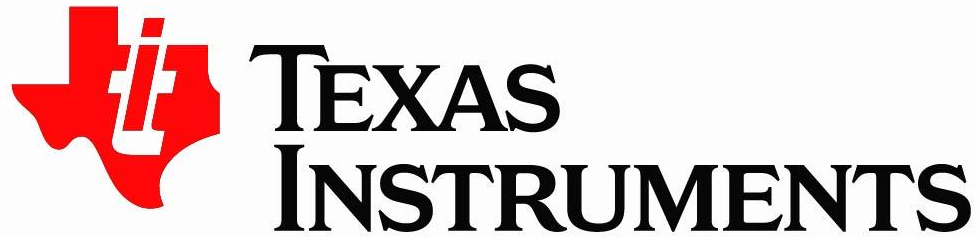
Parameter	Default		Description
SNR Threshold	250	-	Minimum total SNR for the allocation set, linear sum of power ratios
Velocity Threshold	0.1	m/s	Minimum radial velocity of the allocation set centroid
Points Threshold	5	-	Minimum number of points in the allocation set
<code>maxDistanceThre</code>	1	m ²	Maximum squared distance between candidate and centroid to be part of the allocation set
<code>maxVelThre</code>	2	m/s	Maximum velocity difference between candidate and centroid to be part of the allocation set

Steps for Demo setup



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- Ask question on TI's E2E forum @ <http://e2e.ti.com>
- Device product pages
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 - IWR1642: <http://www.ti.com/product/IWR1642>
 - AWR1443: <http://www.ti.com/product/AWR1443>
 - AWR1642: <http://www.ti.com/product/AWR1642>
- Evaluation Modules
 - IWR1443 EVM: <http://www.ti.com/tool/IWR1443BOOST>
 - IWR1642 EVM: <http://www.ti.com/tool/IWR1642BOOST>
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