Future Radar Technologies and Applications

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IDTechEx

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Agenda for Today's Presentation

1. Radar and its use within different industries
2. Performance requirements for radar in automotive
3. Next generation radar performance and trends
    A. Increased resolution
    B. 4-dimensional detection
    C. High-dynamic range
    D. Cost
    E. Size
    F. Power consumption
4. How radar data can be used for classification

Automotive Radar 2024-2044: Forecasts, Technologies, Applications

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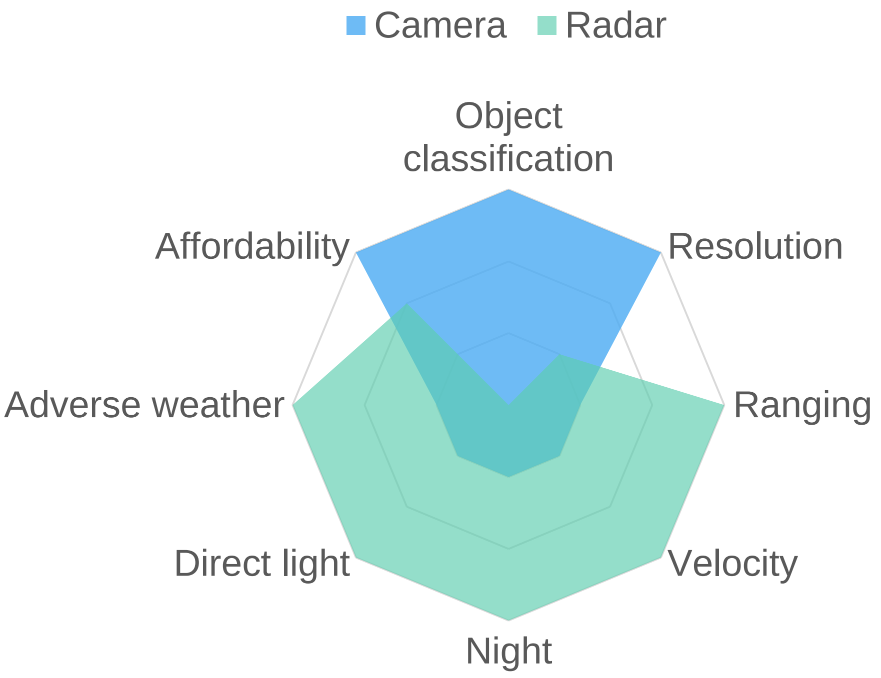
Radar and its Use Within Different Industries

Performance Attributes of Radars

Radar and cameras have very different capabilities.

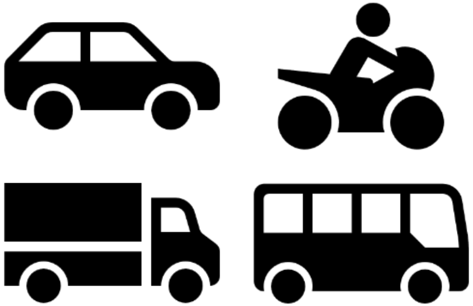
Radar

- Provides range and relative velocity information
- Very robust to poor lighting/poor visibility
- Low resolution



Applications in Different Industries

On-road

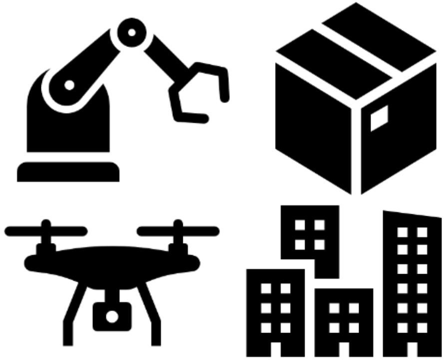


- ADAS features - adaptive cruise control
- Safety features – blind spot detection, automatic emergency braking
- Autonomous driving
- In-cabin applications

Off-road

- Collision avoidance/blind spot detection
- Autonomous operation

Robotics and Other



- Autonomous robotics
- Presence detection and people counting
- Fill level monitoring
- Traffic monitoring
- Surveillance and security
- Health care and vital sign monitoring

Performance Requirements for Radar in Automotive

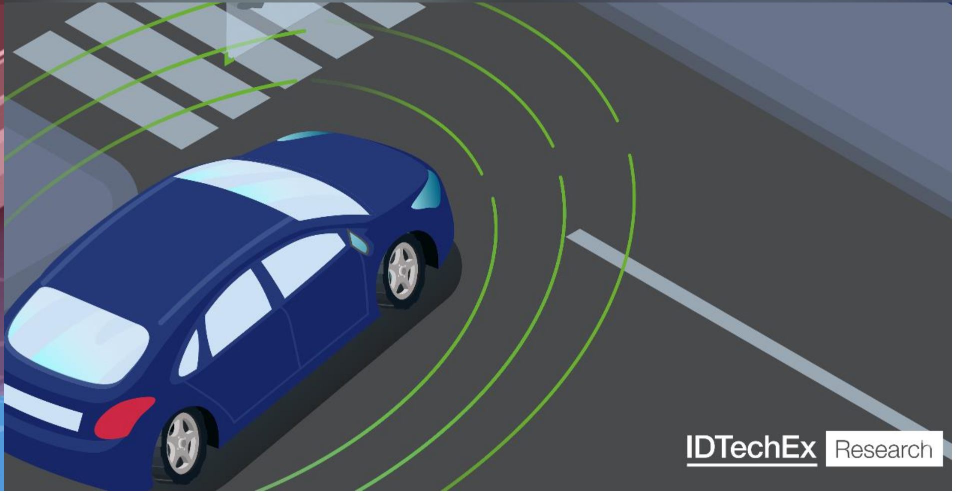
Typical Applications for Automotive Radar

Front monitoring

- Automatic emergency braking
- Adaptive cruise control

Side monitoring

- Blind spot detection
- Junction automatic emergency braking



Typical Applications for Automotive Radar

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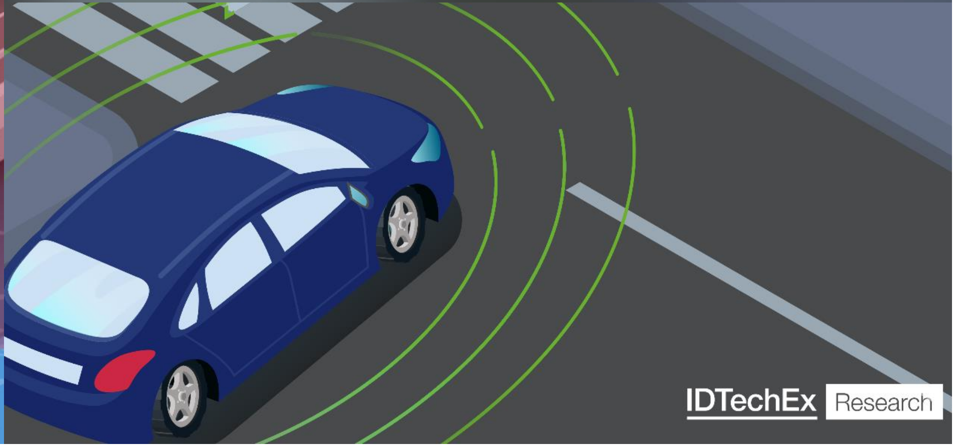
Front monitoring – performance priorities

- High resolution
- Long detection range
- Ranging & velocity measuring
- Robust to all weather/lighting

Side monitoring – performance priorities

- Wide field of view
- Range measuring
- Cheap

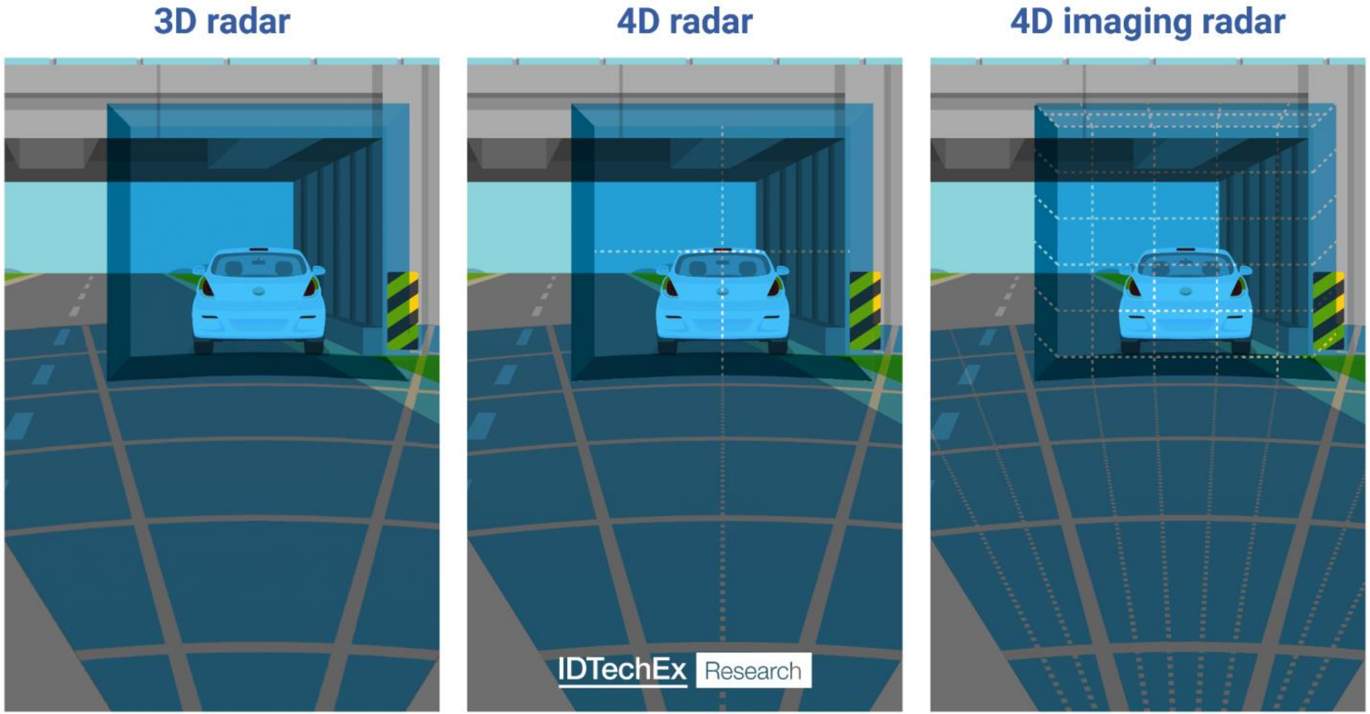


The Need for 4D Imaging Radar

4D imaging radars will be critical for enabling higher levels of autonomy.

A primary example of this need is the car parked under an overpass scenario.

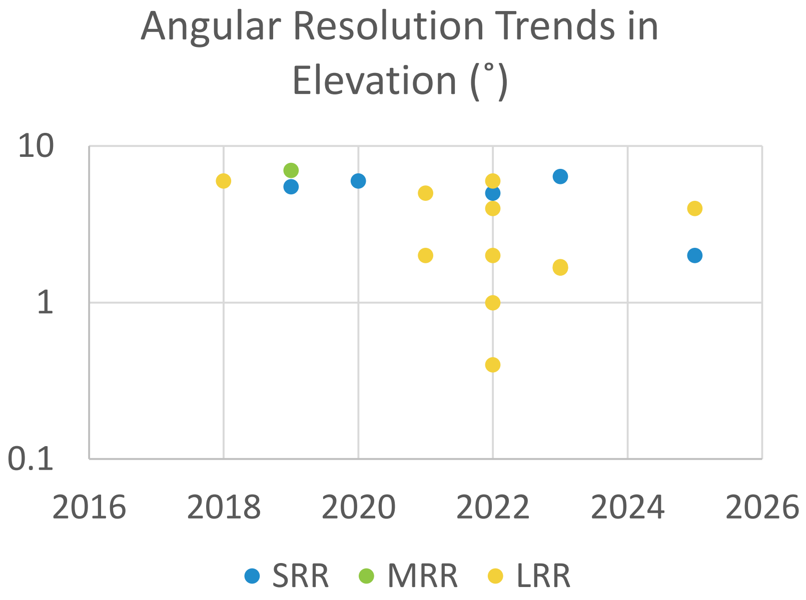
A human can monitor this situation and override a false negative from an ADAS system.

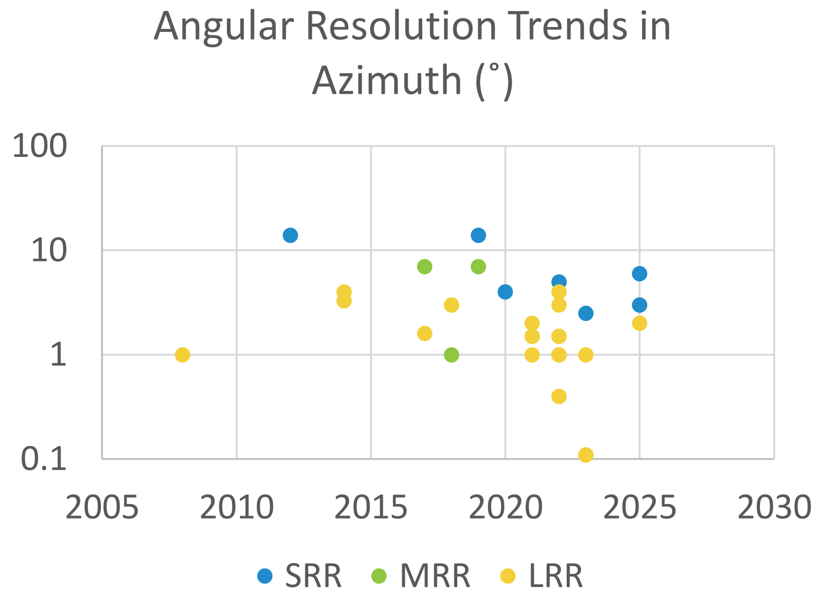


Next Generation Radar Performance and Trends

Radar Trends: Angular Resolution (Lower is Better)

Angular resolution has been improving over the past decades. This is thanks to the introduction of 77 GHz and more channels in the radar. Perhaps more importantly, the resolution of radars in the elevation has been improving.





SRR, MRR, LRR = short range, medium range, long range

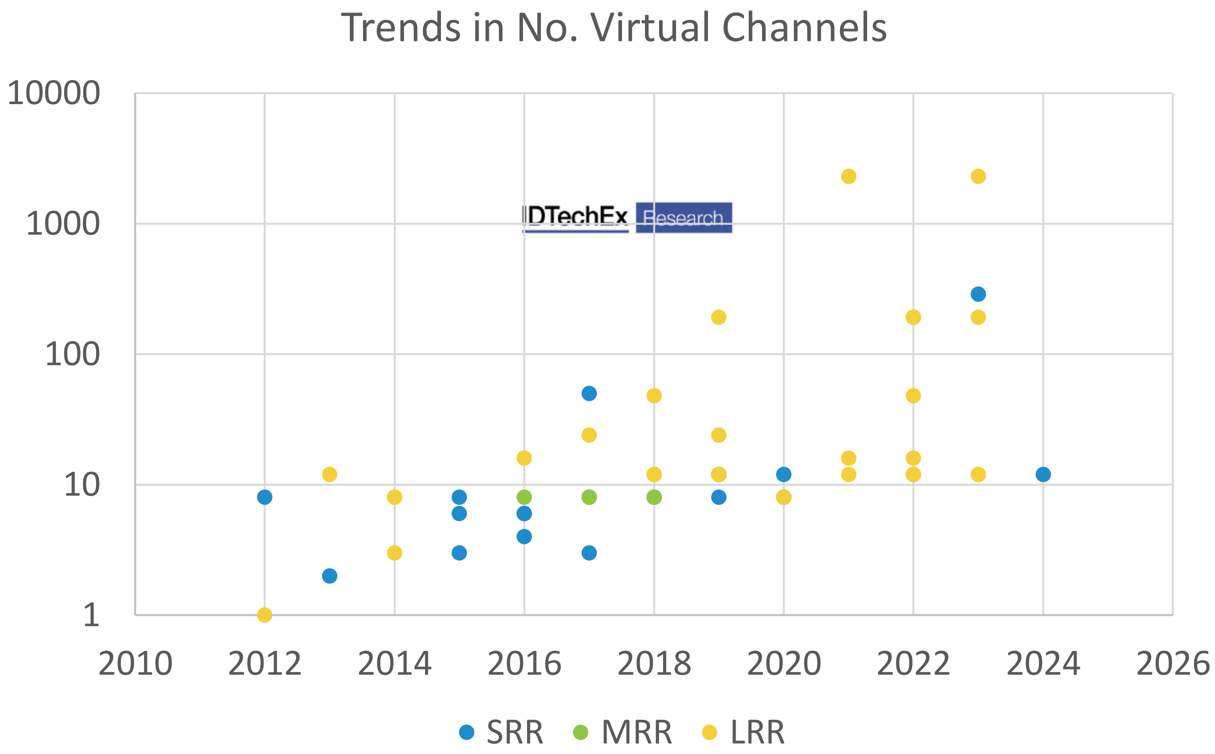
Source: IDTechEx Research

Radar Trends: Virtual Channel Count

One of the enablers of better resolution has been increasing the number of transmitting and receiving channels on the radar.

Virtual channels = No. transmitting channels X No. receiving channels.

Virtual channels are like pixels on a camera – more is better, but that isn't the full story.



SRR, MRR, LRR = short range, medium range, long range

Source: IDTechEx Research

Trading FOV with Range

Improving resolution over the entire field of view.

Here the radar range is 70m with an FOV of 80˚

or

250m with an FOV of 8˚.

Its angular resolution is also dependent on where in the FOV the object is.

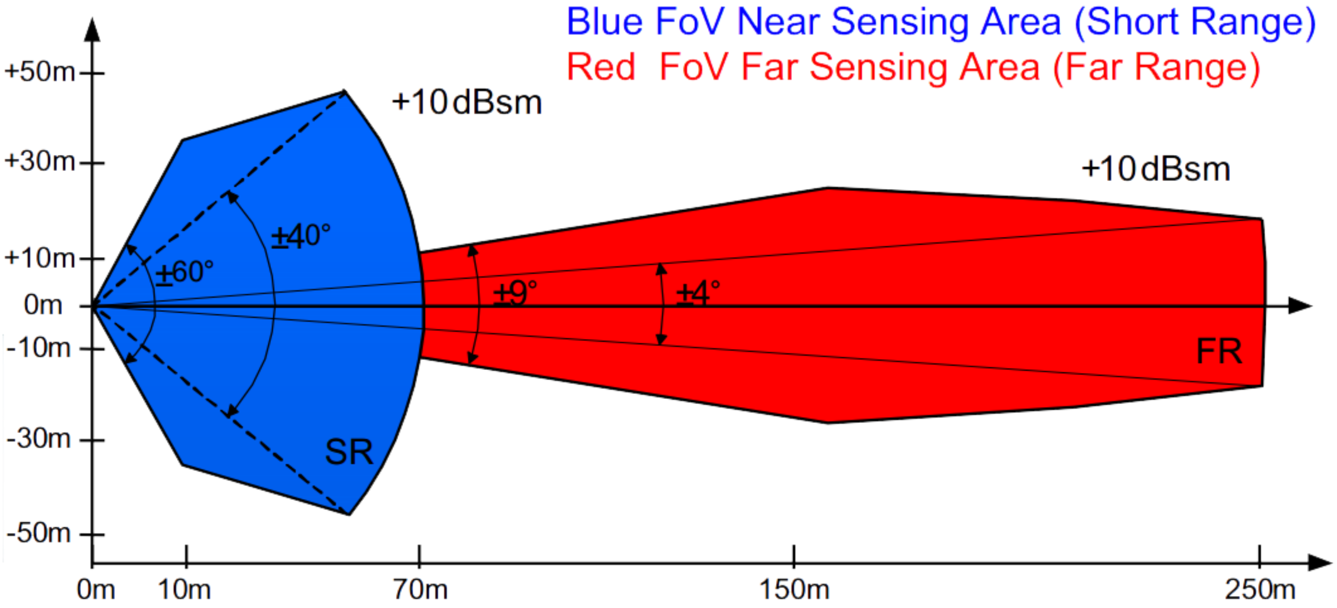


Image source: Nanoradar

Radar Trends: Volume and Footprint

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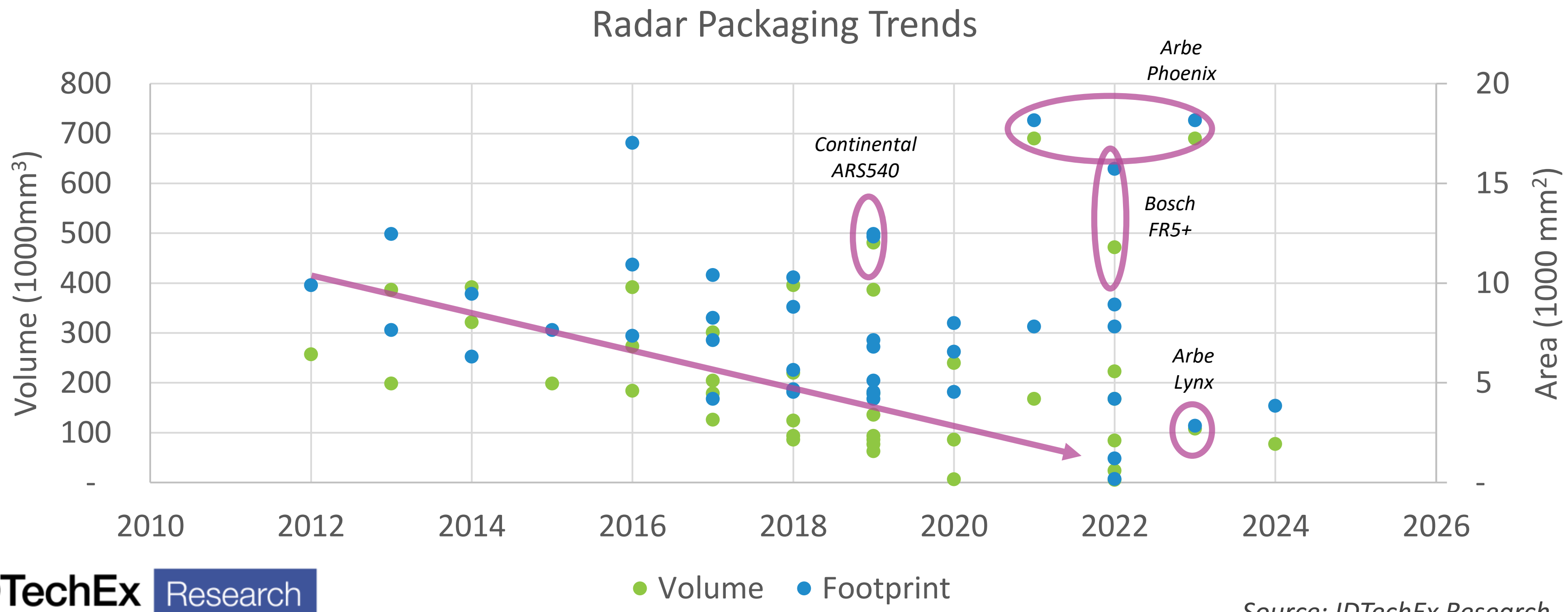
77 GHz radar and improved semiconductor technologies have led to a general reduction in the size of radar.

High performance radars need larger antenna arrays, creating large footprints.

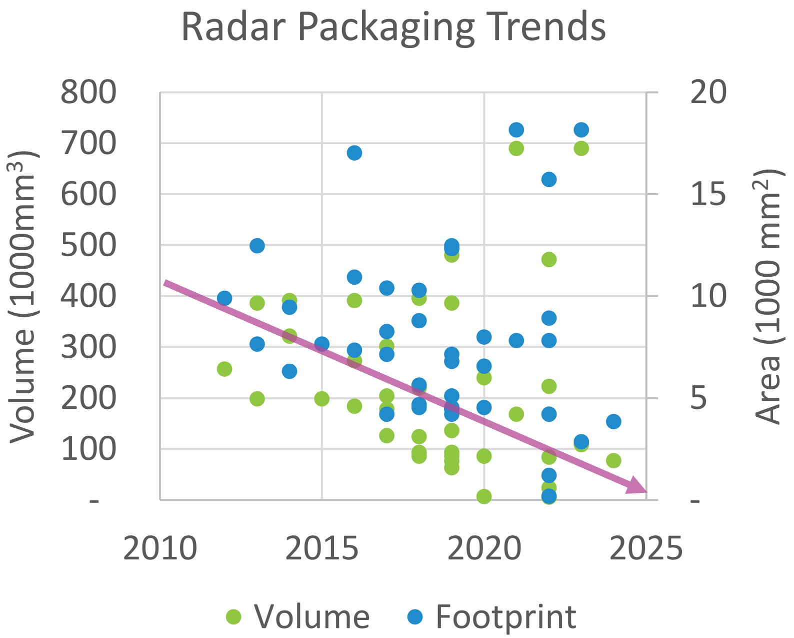


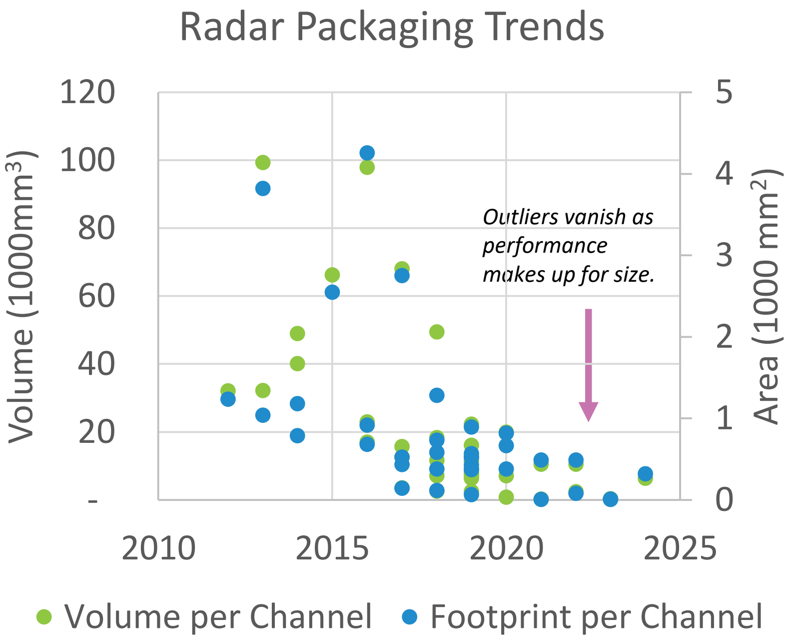
IDTechEx Research

Source: IDTechEx Research

Radar Trends: Packaging and Performance

Larger volumes and footprints can be justified by the increase in performance they allow.





IDTechEx Research

Source: IDTechEx Research

Diverging Radar Types

IDTechEx expects to see further divergence in sizing between high-performance radar and short-range radar.

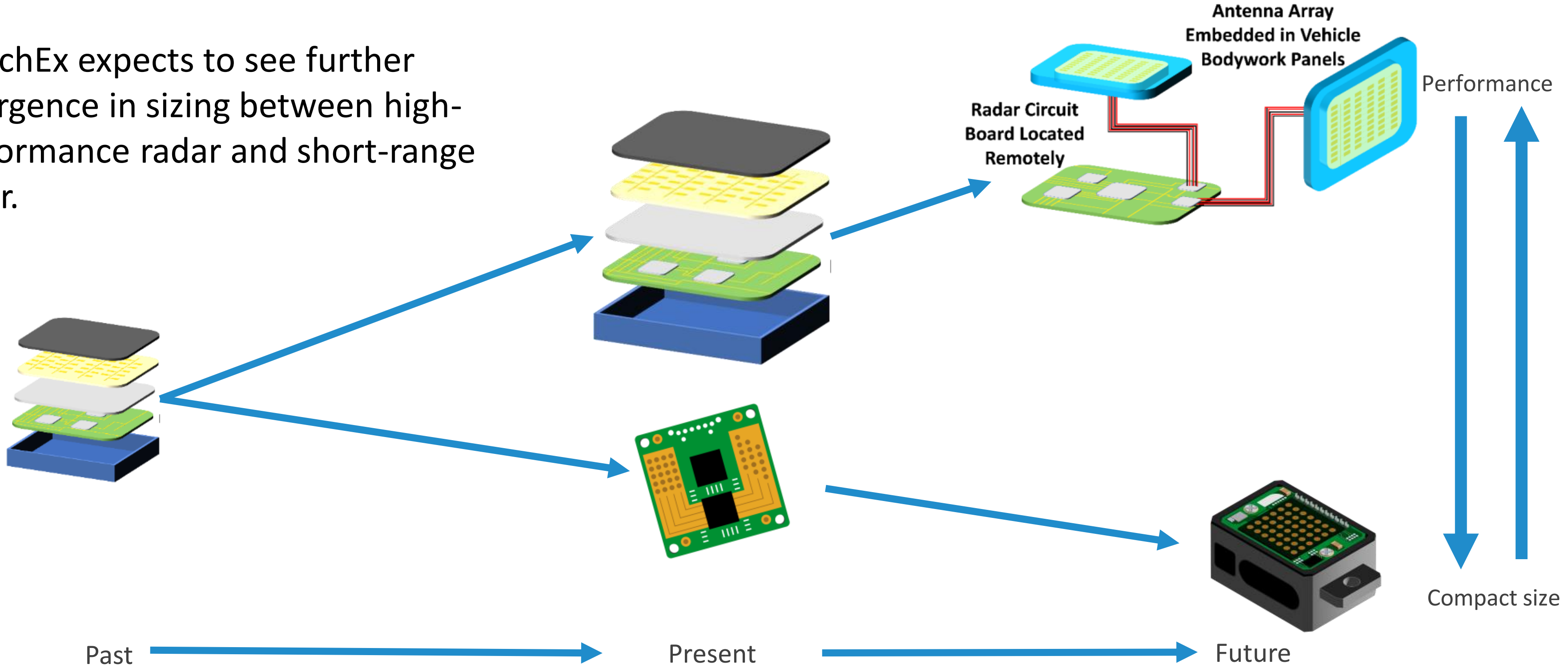


Image Sources: IDTechEx

Radar Power Consumption

Power consumption correlates with performance.

Most radars consume around 5 W, but high-performance radars are in the region of 20-25 W.

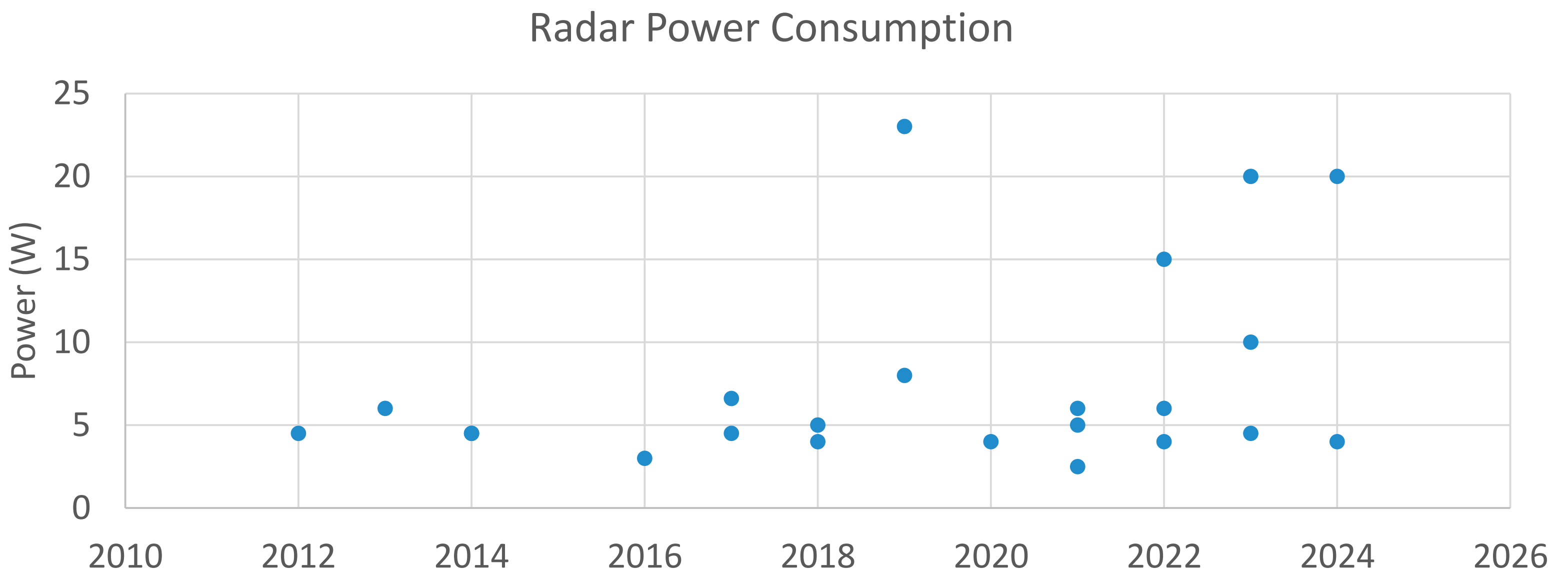
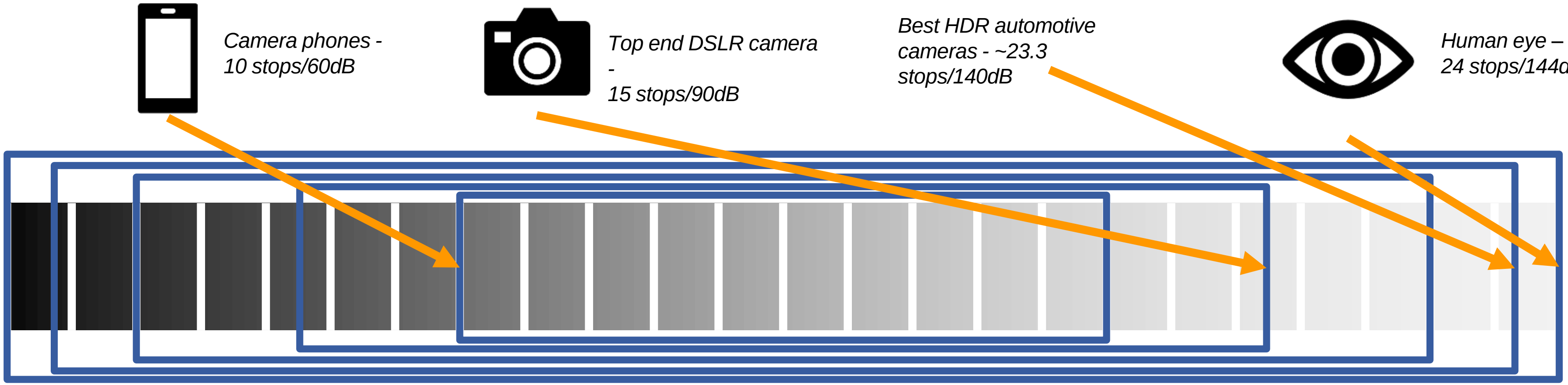


Image Sources: IDTechEx

Dynamic Range – An Emerging Priority

This is how we visualize dynamic range in cameras.

Radars also have dynamic range, referring to the weakest and strongest reflections detectable.



Radars With High Dynamic Range - Mobileye

At CES 2024, Mobileye showed the performance from its upcoming radar product.

One key factor that it had been working on from the outset was dynamic range.

The image here shows Mobileye's radar picking up a pallet at over 230m, near a highly reflective guard rail.

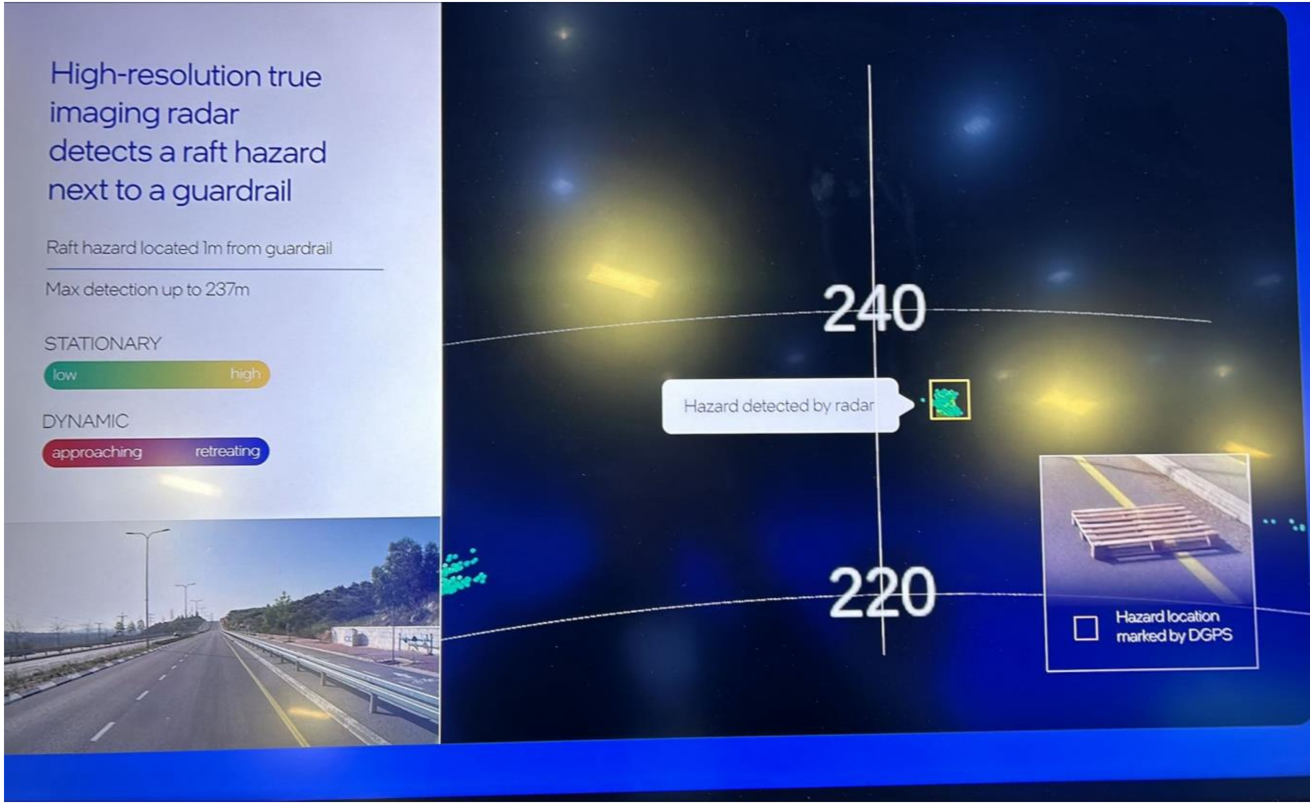


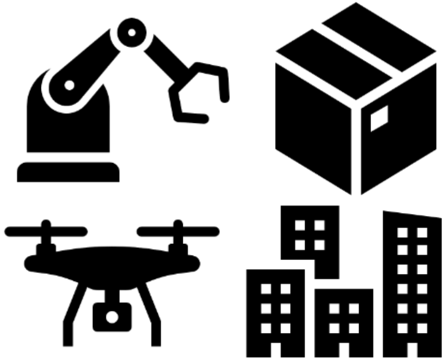
Image Sources: Mobileye at CES, photo taken by IDTechEx analyst.

Radar Price Ranges

On-road

Off-road

Robotics and other



High volume, low performance. Automotive SRR

High volume, high performance. Automotive LRR

High volume, emerging tech from start-up

Medium volume emerging tech.

Low volume emerging tech

Very low volume emerging tech.

$0 $10 $50 $100 $200 $500 $1,000 $5,000

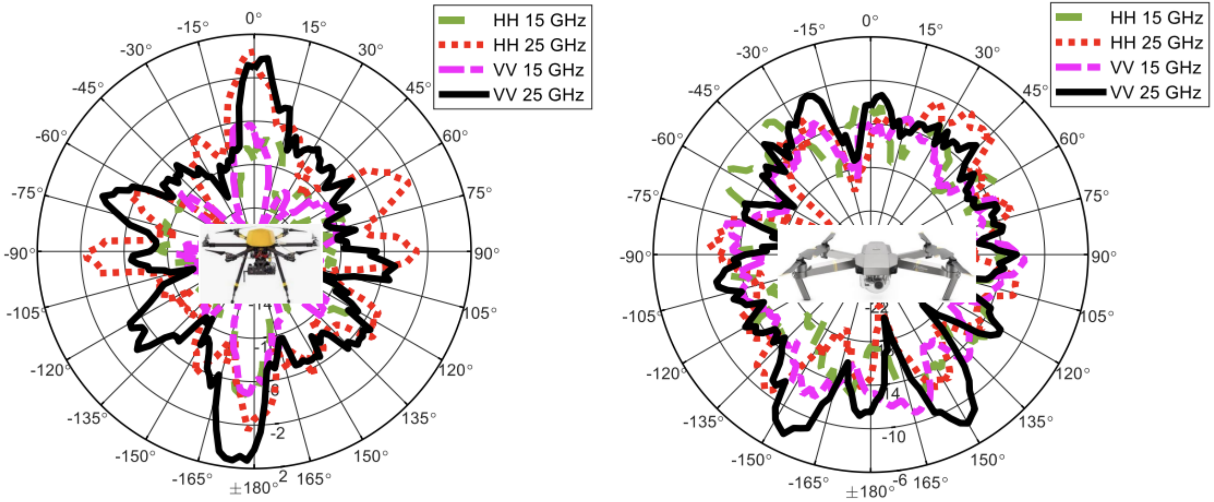
4D imaging radar for automotive

How Radar Data Can Be Used for Classification

Classification With RCS

There is research in the area of using the RCS signature of different objects for classification. This started out for drone identification but also applies to traffic situations.

Comparative Analysis of Radar Cross Section Based UAV Classification Techniques - Ezuma et al. – 2021



(c) (d)

Other Radar Classification Techniques

4D imaging radar offer a range of benefits for classification.

- RCS – likely material of object, metal vs organic
- Resolution and range – physical sizing of object
- Velocity – speed of object

Source: Arbe

Other Radar Classification Techniques

4D imaging radar offer a range of benefits for classification.

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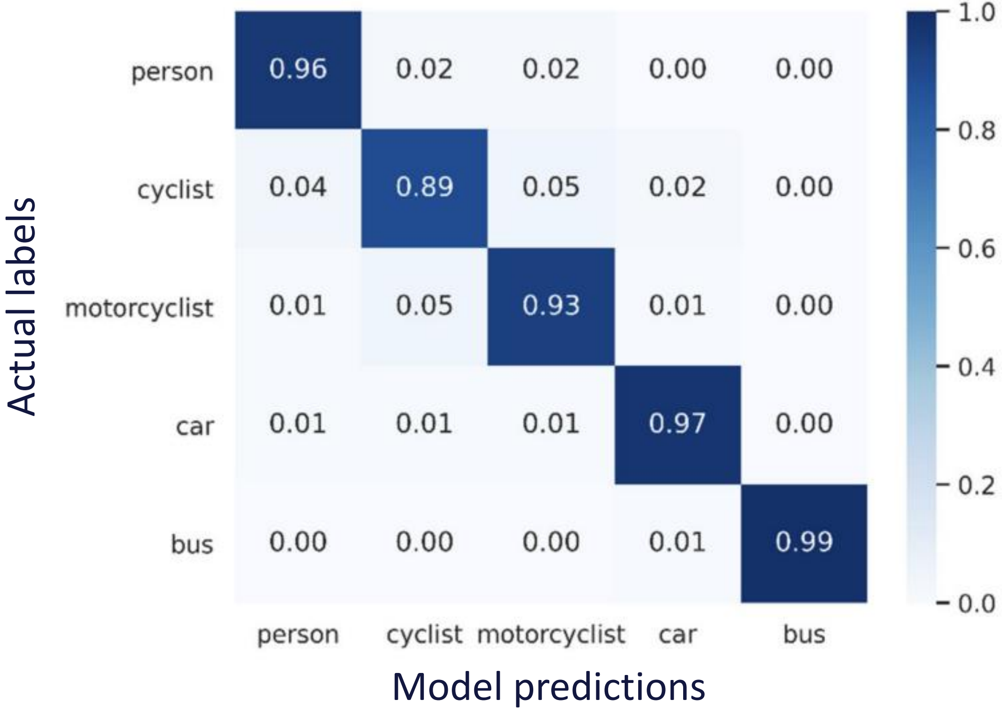
Confusion matrix – radar-based classification



Source: Radar Transformer: An Object Classification Network Based on 4D MMW Imaging Radar, Bai et al. - 2021

Conclusions

- Radar has a variety of applications, but automotive is the largest and most challenging.
- Radar performance and technology has accelerated to meet the demands of autonomous driving.
- 4D imaging radar provide rich data that can be combined with AI to enable accurate classification.

Automotive Radar 2024-2044: Forecasts, Technologies, Applications

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Resources

Key Radar Semiconductor Start-ups

Uhnder
https://www.uhnder.com/

Arbe
https://arberobotics.com/

IDTechEx Market Research

IDTechEx Automotive Radar 2024 – 2044: Forecasts, Technologies, Applications
https://www.idtechex.com/radar

Academic Research on Radar Classification

Radar Object Classification Research, Bai *et al., 2021*
https://www.mdpi.com/1424-8220/21/11/3854

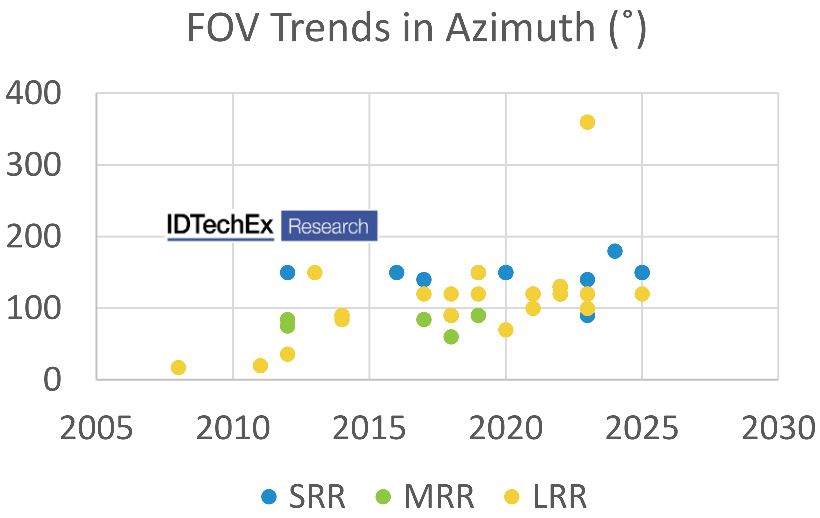
Comparative Analysis of Radar Cross Section Based UAV Classification Techniques, Ezuma et al., 2021
https://arxiv.org/abs/2112.09774

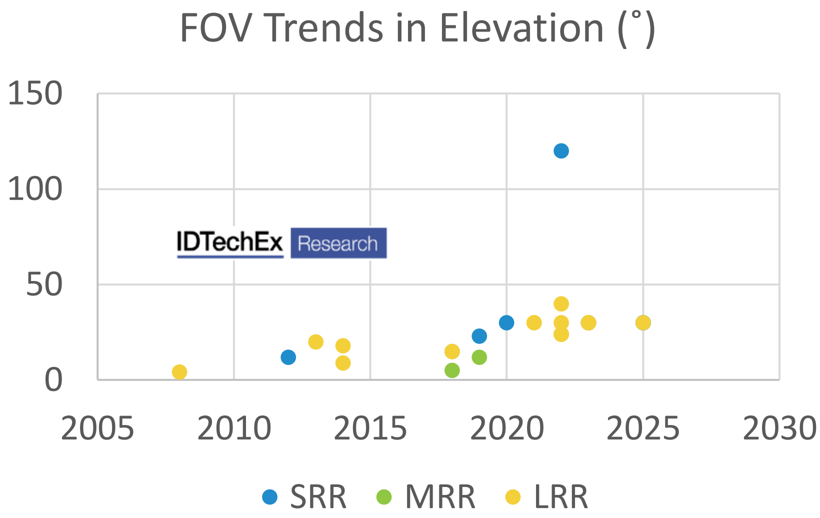
Appendix

Radar Trends: Field of View

Radar field of view has been improving, particularly in elevation, as required by 4D radars.

For automotive applications there is little benefit of going above 30-40° FOV in elevation. For other industries it could be useful.





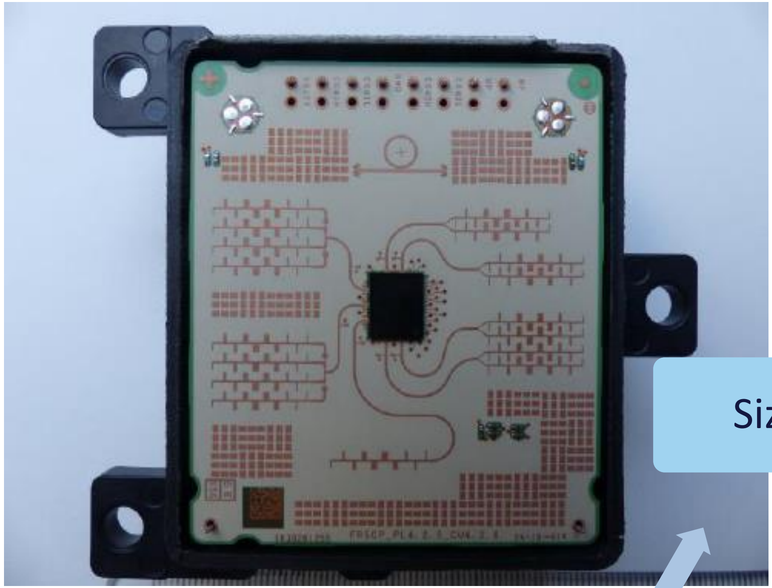
SRR, MRR, LRR = short range, medium range, long range
Source: IDTechEx Research

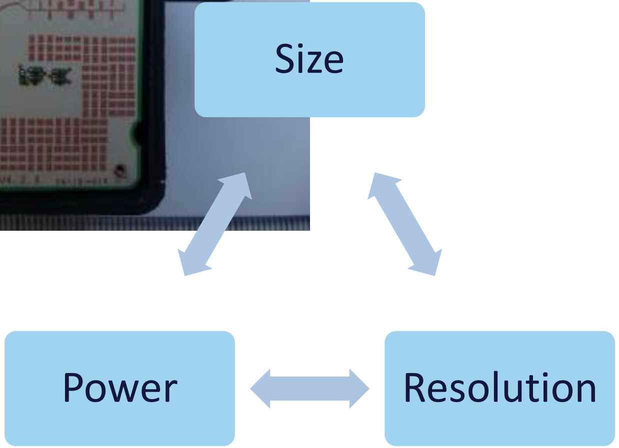
Radar Trilemma

Reducing Size – Antenna elements need to be close together which increases coupling - need to reduce emission power or fewer channels

Increasing Power – High power increases coupling – need a larger antenna board or fewer channels

Improving resolution – More channels means more antenna elements, which increases the radar’s footprint.





Radars With High Dynamic Range - Uhnder

Uhnder is also working on HDR radars.

Mobileye concentrates on minimizing noise, hence being able to distinguish very low reflectivity objects from noise.

Uhnder uses a novel emission encoding technique to improve dynamic range – Digital Code Modulation (DCM).

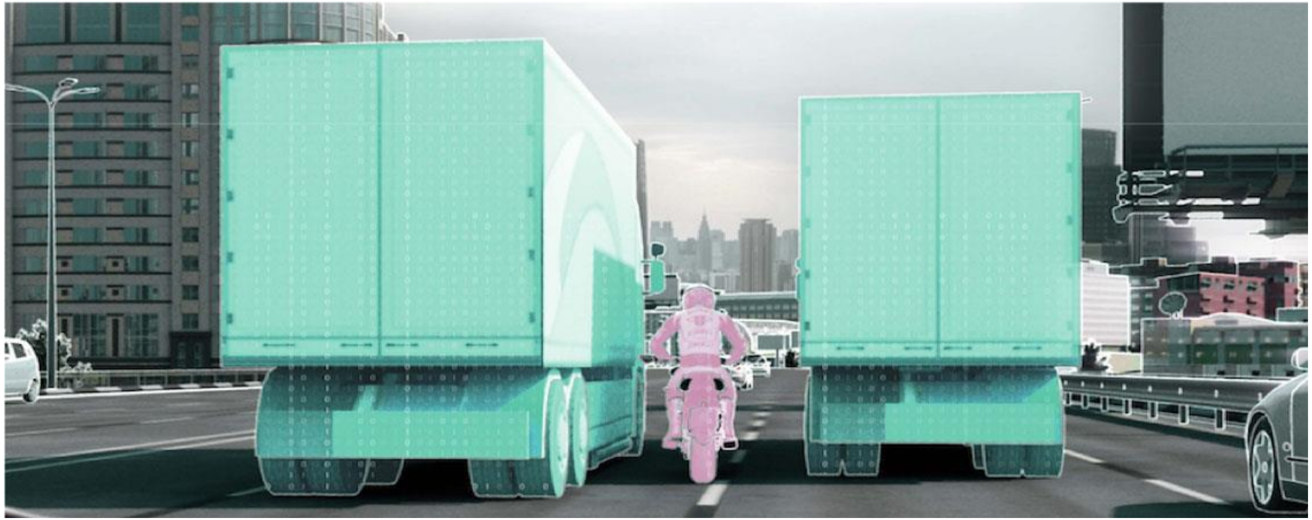


Image Sources: Uhnder

How Much Dynamic Range is Needed?

The formula for this is

$$D = \frac{\sigma_{max}}{\sigma_{min}} \frac{R_{max}^4}{R_{min}^4}$$

Where σ is the radar cross section (RCS) and R is the range.

Cars have an RCS of $100m^2$

Humans have an RCS of $0.1\text{-}1m^2$

If you have a car next to a human D = 1000 = 30dB.

If you have a car at 10m and a human at 100m, D = 10^7 = 70dB.

If you have a pickup (RCS=200) at 10m and a human at 200m, D = 3.2×10^8 = 85dB

Other Radar Classification Techniques

4D imaging radar offer a range of benefits for classification.

- RCS – likely material of object, metal vs organic
- Resolution and range – physical sizing of object
- Velocity – speed of object

Source: Steradian Semiconductor