

## Special Report on European Microwave Week, Paris Sept. 2024

In response to new active safety regulations and the deployment of AD L3/L4 systems, substantial efforts are being made across all facets of the radar ecosystem. Innovations in antennas structures, internal processing architectures, and the integration of artificial intelligence aim to achieve improved resolution and range performances. Additionally, physical modifications related to various types of coatings are essential for the seamless incorporation of standard or imaging radars. During the recent European Microwave Week, 14 companies showcased their advancements toward enhanced Automotive Imaging Radars during a dedicated Automotive Forum:

### OEMs requirements:



### MERCEDES-BENZ: “Navigating challenges in radar deployment for automated driving and future trajectories”

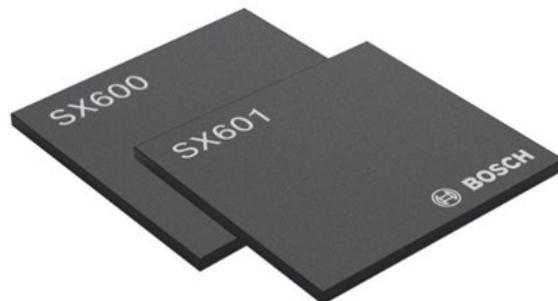
For Mercedes-Benz, Radar performance requirements driven by ADAS situations, include: a better detection/mitigation of false positives/negatives, a 360° cocoon philosophy to determine the type and location of sensors.

Managing sensor integration while balancing cost and performance, is also important. For future L4 systems and L3 and L4 urban systems, **specific requirements** include **elevation Separability**, high sensitivity, wide dynamic range, elevation measurement, **detection of very small objects** at long distances and **azimuth separability**. In addition, ultra-high performance is required at the front of the vehicle, with improved 360° detection performance given by corners radars and image-like radar coverage to enable pattern recognition and the use of AI.

### Radars suppliers:



### BOSCH: “Exploring Design Considerations for a Radar SoC Family in Driver Assistance Systems”



Bosch outlines design considerations for a family of radar SoCs in driver assistance systems. He highlights the failures of cameras for safety, especially in difficult conditions such as fog and reflections from the sun. Bosch radars offer features such as adaptive cruise control, automatic emergency braking, blind spot detection, and automated lane change, helping to reduce collisions and provide a more comfortable ride. Bosch's radar SoC platform uses 22nm FD-SOI technology, providing millimetre capabilities and advanced digital integration. This technology allows for low power consumption and high performance. The presentation also detailed the I/Q concept which enhances **detection**

**robustness and interference mitigation**, which are essential for the proper operation of radars in complex environments. In summary, Bosch develops high-performance and reliable radars, integrating I/Q receivers and powerful digital signal processors to improve the safety and comfort of driver assistance systems.

**With the new SX600 and the SX601**, Bosch offers radar system-on-chip (SoC) solutions operating in the 77 GHz band. While the SX600 has been optimized as a cost-effective radar solution, the SX601 offers increased computing power and memory. Both chips are manufactured using advanced **22nm RFCMOS technology**, contain a complete millimetre-wave sensing frontend as well as a powerful digital signal processor for conventional or AI-based data processing and enable sensor ranges of around 30 percent above the current market standard. CAN XL and Ethernet interfaces provide flexible connections to the vehicle system.

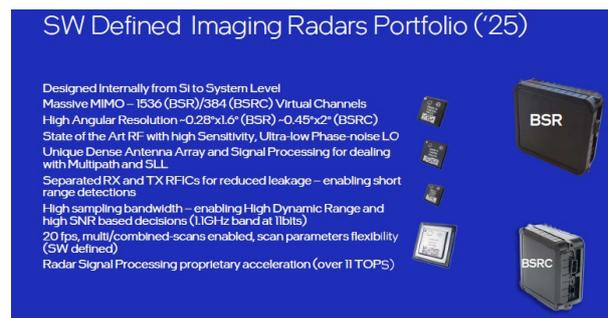
### MAGNA: “Mutual Interference between PMCW and FMCW: An Experimental Approach”



Challenges of interference testing include: The difficulty of characterizing the effect of the interference itself, as the stochastic processes, signal-to-interference ratio (SIR), noise-to-interference ratio (NIR), and power spectral density (PSD) do not provide complete information. Other sensor characteristics, such as equivalent isotropic radiated power (EIRP), presence time, duty cycle,

and bandwidth, have a stronger effect on interference than modulation. The characteristics of the interference scenario itself, such as the distance between the victim and the aggressor, the angle of departure of the aggressor, and timing, have a major impact on the effect of the interference on the victim sensor.

### MOBILEYE: “Imaging Radar: Requirements driven chipset architecture”



Mobileye's Imaging radar offers improved azimuth and vertical resolution, very high dynamic range, and low level of secondary lobes, allowing for accurate detection of targets, including motorcycles over 200m away and objects with low SCR. For that it was necessary to respect the following requirements along the design of a new imaging radar:

- **Architecture Optimization:** Use of massive MIMO and software-defined radar architecture to maximize performance and flexibility, while ensuring optimal compactness and integration.
- **Key Architecture Features:** Separation of RF chipsets for transmit and receive, reduced transmit leakage, and design scalability at chip and antenna array levels.

- **Digital Processing and Range Profile:** Ability to generate digital waveforms, calibration of large antenna arrays, interference management and mitigation, and radar signal processing with proprietary acceleration.

### UHNDER: “4D Long Range Imaging Radars: Opportunities & Challenges for ADAS”



#### Interference

- **Increasing Radar Density**
  - More radars per vehicle
  - Growth of radar-equipped vehicles
- **Challenges with traditional FMCW**
  - FMCW radars have limited interference mitigation and may struggle as radar density increases.
- **Enhanced Interference Mitigation with DCM**
  - DCM supports traditional FMCW interference mitigation techniques
  - DCM signals are encoded, meaning only receivers with the correct code can correlate the transmissions
  - See also Magna presentation at 15:00: "Mutual Interference between FMCW and FMCW: An Experimental Approach"
- **Standardized Interference Testing required**
  - Interference results are difficult to compare due to lack of standardized testing methods and high cost of conducting interference tests.

	FMCW	DCM
Interferer	✓	✓
Receiver	✓	✓✓

The diagram shows a car with radar beams and an 'Interferer' arrow pointing towards it. A table compares FMCW and DCM performance for Interferer and Receiver. DCM shows superior performance for the Receiver (two checkmarks) compared to FMCW (one checkmark).

For Uhnder, the benefits of digital radar technology include better accuracy and resolution thanks to advanced algorithms, an ability to update and customize features via software, a designing smaller, more efficient systems through digital integration, reduced overall radar sensor costs and production costs, enabling immediate processing and interpretation of radar data and ease of adaptation to meet various application needs. Additionally, UHNDER’s 4D radars manage interference and signal distortion using advanced interference mitigation techniques, including Direct Code Modulation (DCM). DCM signals are encoded, which means that only receivers with the correct code can correlate transmissions, reducing interference.

### ZENDAR: “Coherent Multi-Radar Fusion in a Distributed Aperture Radar System”



#### ZENDAR

### Distributed Aperture Radar Breaks The Performance Ceiling

In software, signal from multiple distributed sensors is fused into a coherent virtual array, enhancing radar resolution and accuracy tenfold.

DAR software fuses multiple radars in standard zonal or central processors.

Small, Low Cost Sensor Modules work together enabling 10x greater resolution.

The slide shows a car with multiple radar sensors and their fused signals, illustrating the concept of a distributed aperture radar system.

Zendar’s presentation talked about the coherent fusion of multiple radars into a distributed aperture radar system to improve radar resolution and accuracy.

For Zendar the minimum requirements must allow to **classify road debris at more than 110m, separate person and a car at more than 150m and identify a car stopped under a bridge at more than 150m. This means 0.25° of azimuth separation and 0.85° of elevation separation, so monobloc radars must be more than 45cm apart.**

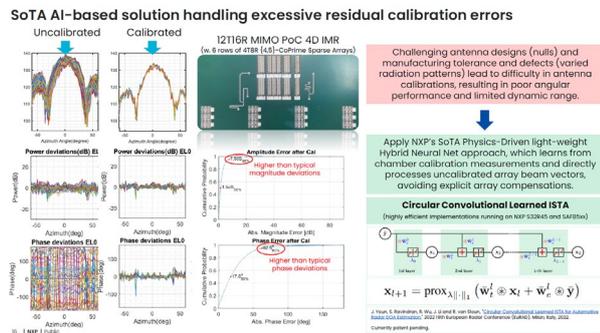


For a good coherent detection given by different monobloc radars it was necessary to evaluate the performance of clock retrieval from an Ethernet link between these radars. The phase noise of the clock obtained through Ethernet was compared to that of a cable-shared reference clock, and it was concluded that the requirements were achievable. These tests revealed a good separation between two targets placed at the same distance, but

laterally separated by 2 meters.

### Components suppliers:

### NXP: “Achieving Angular High-Dynamic Range Performance with Sparse Arrays”



For NXP, to preserve radar’s antennas compacity and efficiency, sparse networks provide significant cost savings. The key to achieving high dynamic range is to use advanced super-resolution algorithms and **maintain very low antenna calibration errors, especially for MIMO networks**. Many advanced algorithms exist to achieve high dynamics with super resolution.

Robust AI-based approaches, such as NXP’s CC-LISTA angle estimator, achieve high dynamics with super resolution, even when the antenna’s array measurements contain large errors.

### GAPWAVEGUIDE: “Waveguide Imaging Radars”

Gapwaveguide highlighted their patented technology, which offers unique non-contact solutions, with cost and performance advantages for millimetre antennas. **Waveguide antennas provide excellent electrical and thermal performance, with losses and bandwidth up to 10 times better than substrate-based options.**

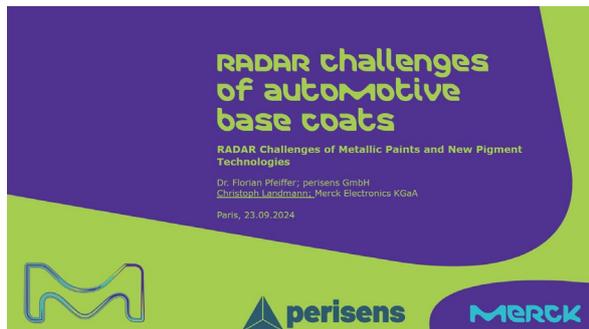


The presentation also introduced the **Sensrad’s Hugin D1 radar**. This automotive radar has waveguided antennas and the highest channel count on the market, using a **48 TX x 48 RX MIMO** configuration and offering high resolution and detection range.

SENSRAD HUGIN D1	Performances
Frequency Range	76 – 81 GHz
Bandwidth	Up to 2 GHz
Range	Up to 300 m
Azimuth	-50 to +50 degrees
Elevation	-15 to +15 degrees
Doppler	-70 to +140 m/s
Range resolution	9.5 cm@36 m, 60cm@300 m
Azimuth resolution	1.25 degree
Elevation resolution	1.5 degree
Doppler resolution	0.1 m/s
Point cloud data size per frame	250 K
Tracked objects	450
Update rate	30 FPS
Modulation and MIMO scheme	FMCW TD-MIMO
Dimensions (W, H, D)	15.3 cm, 12.7 cm, 3.8 cm

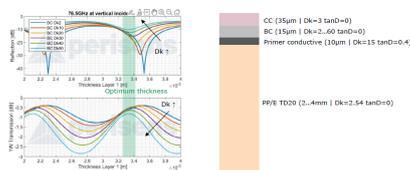
## Bumper's Coating

### MERCK & PERISENS: “RADAR challenges of automotive base coats”



The presentation discussed the challenges of RADAR related to automotive base coats and new pigment technologies. Permittivity affects the reflection of electromagnetic waves by increasing the difference in permittivity between materials, which increases reflection at the material boundary. This can lead to interference and attenuation of waves, thus affecting the performance of RADAR sensors.

RADAR Challenges of Automotive Base Coats  
 Simulation of reflection/transmission vs substrate thickness



Paints with relative permittivity of > 20 have a significant impact on radar transparency

Permittivity increases with metallic content. Metallic pigments, being good conductors with free electrons, increase permittivity when present in the paint. This is due to the oscillation of free electrons under the influence of electromagnetic waves, which enhances surface polarization and, consequently, the material's permittivity. The performance of radar systems can significantly vary depending on the different colours, thicknesses and types of paints used on vehicles. It is crucial to characterise each material to find a compromise and minimise disparities between equipped cars. Perisens and Merck propose a development chain for this purpose.

## Radar's tests

### High Fidelity Radar Object Emulation



Targets in the Radar Scene Emulator (RSE) are modelled using several discrete points, called scattering points. Each scattering point is described by its position, a normalized radar cross-section (RCS per unit area) and a unique ToF + Doppler frequency offset. This modelling makes it possible to represent the spatial extent of objects and micro-Doppler effects. In addition, with a controlled output phase for each scattering point, self-

interference due to multipaths can also be emulated.

## Radar's Market

### YOLE: "Mapping out the latest trends in automotive radar"



The automotive radar market is evolving significantly from 2023 to 2029. Automotive radar revenue grows from \$8.2 billion in 2023 to \$13.1 billion in 2029, with a compound annual growth rate (CAGR) of 8%. **4D radars and imaging radars are the fastest growing, with CAGRs of 24% and 36%** respectively. OMS (Occupant Monitoring System) radars are growing even faster with a CAGR of 57%. On the other hand, traditional radars

(Legacy) see a decrease in their market share with a CAGR of -12%.