

Automotive Radar, ADAS, and Fused Silica-based 3DHI



Intro

Automotive radar is the backbone of many of today's advanced driver assistance systems (ADAS). It uses radio waves to detect objects in a vehicle's environment, measuring their distance, speed, and direction. This technology is crucial for enhancing safety through features such as adaptive cruise control, collision avoidance, and blind-spot detection.

ADAS, on the other hand, integrates radar with other sensors like cameras and LiDAR to create an intelligent network that can help drivers avoid accidents, assist in parking, and maintain lane control. The importance of radar in modern vehicles cannot be overstated, as it is the foundation of not only current safety features but also the future of fully autonomous driving systems. This combination of radar and ADAS represents the growing reliance on technology to keep drivers safe and reduce human error, helping to prevent accidents and save lives.



Fused silica, a highly pure form of silicon dioxide (SiO_2), plays a critical role in high-frequency RF (radio frequency) applications due to its low dielectric constant, minimal loss tangent, and excellent thermal stability. These properties make it an ideal material for minimizing signal attenuation and maintaining performance in demanding environments, such as telecommunications and aerospace.

3DHI (Three-Dimensional Heterogeneous Integration) technology further enhances these applications by integrating multiple types of materials and components into compact, high-performance RF modules. Combining the benefits of fused silica with 3DHI allows for the development of advanced RF systems with improved signal integrity, reduced parasitics, and enhanced power efficiency, enabling reliable performance at high frequencies and in complex environments.

Fused silica offers several advantages for applications operating above 24 GHz, particularly in automotive radar, telecommunications, and high-frequency sensor technologies. These benefits are essential as systems increasingly rely on higher frequencies for greater accuracy and resolution.

Early Development of Automotive Radar

Radar technology, which originated in military applications during World War II, has since become a cornerstone of automotive safety. Its ability to detect objects using radio waves was first used to locate enemy aircraft and ships. However, by the 1970s, engineers began adapting radar for automotive use, developing systems that could detect nearby objects and avoid collisions.

The first automotive radars were used primarily for collision avoidance and basic adaptive cruise control. These early applications marked the beginning of integrating radar into vehicle systems and laid the groundwork for the development of ADAS. Without this pioneering work, the advanced safety features we now take for granted would not exist.

Evolution of Radar Sensors in ADAS

The evolution of radar technology in automotive systems has progressed from basic single-function systems to high-resolution, multi-tasking radars that are crucial for ADAS. In its earliest form, automotive radar was mostly used for adaptive cruise control, utilizing low-frequency bands and limited to detecting vehicles ahead.

As technology advanced, radar sensors became more sophisticated, now capable of detecting objects at greater distances, distinguishing between different types of objects, and integrating with other vehicle systems. These advancements enable features like lane-keeping assistance and emergency braking, making driving safer and more intuitive.

A major trend in the evolution of radar is sensor fusion, where radar data is combined with inputs from other sensors like LiDAR and cameras. This creates a more comprehensive understanding of the vehicle's surroundings, leading to more reliable ADAS functionalities and setting the stage for fully autonomous driving.

Key Components of Radar and ADAS

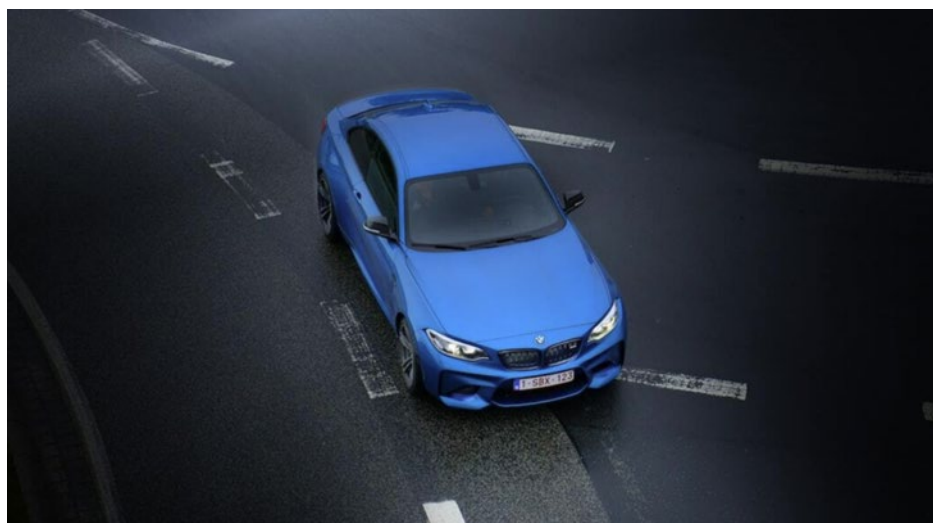
Modern automotive radar systems consist of several key components that work together to detect and measure the distance, speed, and movement of objects around a vehicle. The transmitter sends out radio waves, which bounce off objects and return to the radar's receiver. These signals are then

processed to determine how far away the object is and whether it's moving. The signal processor is critical in turning these raw signals into actionable data, allowing the car's computer systems to understand what's around the vehicle.

Antennas help direct the waves and ensure that radar can focus on the most relevant areas, like the road ahead or nearby vehicles. Together, these components form the backbone of radar-based ADAS, contributing to the effectiveness of features like collision detection, adaptive cruise control, and lane-keeping assistance.

Applications of Radar in ADAS

Radar technology plays a pivotal role in several critical ADAS features that enhance vehicle safety and driving comfort. Adaptive cruise control is one of the most prominent applications, allowing vehicles to automatically adjust speed based on traffic conditions. This feature ensures a safe distance between vehicles, making highway driving easier and reducing the chances of rear-end collisions.



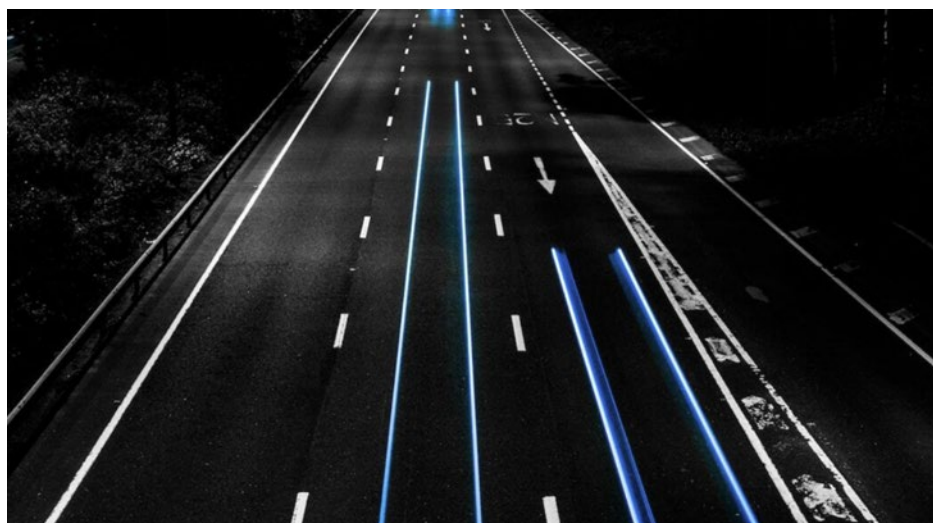
Blind spot monitoring is another vital use of radar, where sensors continuously scan areas that are not visible to the driver, alerting them to nearby vehicles and helping prevent lane-change accidents.

Emergency braking systems rely on radar to detect obstacles in the vehicle's path and apply brakes autonomously to avoid or minimize the impact of collisions. These applications showcase the versatility of radar technology, making it an indispensable component of modern ADAS systems, aimed at improving both safety and convenience for drivers.

Future Trends

Looking ahead, the future of automotive radar is intertwined with advancements in material science, artificial intelligence, 5G connectivity, and sensor fusion.

AI plays a pivotal role in enhancing radar’s ability to interpret complex driving environments, providing faster, more accurate decisions in real-time situations. As cars move towards full autonomy, radar systems must be able to process vast amounts of data, and AI makes this possible.



5G connectivity will also revolutionize radar-based ADAS by enabling vehicle-to-everything (V2X) communications. This means cars will be able to communicate not just with other vehicles, but also with infrastructure, pedestrians, and even the cloud, further improving safety and responsiveness.

Finally, sensor fusion is a key trend where radar works in tandem with LiDAR, cameras, and other sensors to create a more comprehensive view of the vehicle’s surroundings. This multi-sensor approach is essential for making autonomous driving a reality, as no single sensor type can provide the full picture on its own. These trends mark the future of radar and ADAS as we move towards a safer and more connected driving ecosystem.

Current and Future Automotive and ADAS Frequencies

Automotive radar systems use specific radio frequency (RF) bands to detect objects, measure their distance, speed, and trajectory, and facilitate ADAS functionalities like adaptive cruise control, lane-keeping assistance, and emergency braking. Here's a breakdown of the radio frequencies currently in use and the ones expected to dominate in the future:

Current Automotive and ADAS Frequencies Compared

Item	24 GHz (Short Range Radar)	77–79 GHz (Long Range and High-Resolution Radar)	79 GHz (Ultra High-Resolution Radar)
Range (m) (typical)	15–30	Up to 250	100–300
Use Case	Mostly used for short-range applications like parking assistance, blind-spot monitoring, and cross-traffic alerts.	Used for long-range applications like adaptive cruise control, lane-keeping assistance, and collision avoidance. It provides high accuracy and resolution for	Known for providing the highest resolution, this band is critical for applications like object recognition, detailed environmental mapping, and

		detecting vehicles and obstacles at greater distances.	future autonomous driving technologies.
Advantages	Low cost and simpler systems.	Higher resolution and better performance in distinguishing between smaller and closer objects. This band is increasingly favored for both long-range and high-resolution radar systems.	Higher frequency allows for more detailed environmental sensing, improved object classification, and smaller sensor size.
Disadvantages (typical)	Lower resolution compared to higher frequency radars. The 24 GHz band is being phased out in certain regions due to interference issues with other technologies.		
Regulation		The 77–81 GHz band is globally harmonized, making it the leading frequency for future automotive radars.	

Future Trends in Automotive and ADAS Frequencies

79 GHz Band as the Standard

The 79 GHz frequency band is expected to become the global standard for automotive radar due to its combination of long-range detection, high resolution, and interference mitigation.

Higher Resolution: The 79 GHz band provides shorter wavelengths compared to lower-frequency bands, such as 24 GHz or 60 GHz, enabling finer spatial resolution. This allows radar systems to detect smaller objects and distinguish between closely spaced objects more accurately, which is crucial for tasks like pedestrian detection and collision avoidance.

Improved Object Detection: The higher frequency enables better object detection performance, particularly in challenging scenarios like detecting objects at greater distances or at higher speeds. This is vital for high-speed driving and for enhancing the safety and performance of ADAS features like adaptive cruise control and lane-keeping assistance.

Smaller Antennas: The shorter wavelength of 79 GHz signals allows for the design of smaller antennas. This reduces the overall size of the radar modules, making them easier to integrate into the limited space of modern vehicles. Smaller radar systems can be placed at multiple locations around the car, providing better coverage and more comprehensive sensing.

Less Interference: The 79 GHz band is less crowded compared to lower-frequency bands (like the 24 GHz band), leading to reduced interference from other devices or radar systems in nearby vehicles. This helps ensure more reliable performance, especially in urban environments with high traffic density where multiple vehicles may be equipped with radar systems.

Higher Bandwidth: The 79 GHz band allows for a wider bandwidth (typically up to 4 GHz) compared to the 24 GHz band, which supports only a 200 MHz bandwidth. The increased bandwidth enables higher data rates and enhanced accuracy in velocity measurements, making it easier to detect and track fast-moving objects with greater precision.

Compliance with Global Standards: Many regions, including Europe and parts of Asia, are phasing out the 24 GHz band in favor of the 79 GHz band for automotive radar due to the benefits of higher performance and to reduce spectrum congestion. This global alignment simplifies the design and deployment of radar systems across multiple markets.

High-Frequency 140 GHz (Under Research)

Future research is exploring the use of even higher frequencies (140 GHz) for automotive radar, which could provide even greater resolution and the ability to detect smaller objects like pedestrians and bicycles in complex environments.

As cars move towards full autonomy, ultra-high-frequency radar may be needed to provide centimeter-level precision and complement LiDAR and camera systems.

Sensor Fusion with Multiple Frequencies

Future systems are expected to leverage multiple frequencies to cover a wide range of applications (e.g., combining 79 GHz for high resolution with lower frequencies for more extended range).

Enhanced ADAS systems and autonomous driving require a fusion of data from various sensors working across multiple frequency bands to provide a comprehensive and accurate real-time understanding of the driving environment.

Regulatory and Global Harmonization Trends:

Global Adoption of 77–79 GHz: Regulatory bodies are pushing towards the universal adoption of the 77–81 GHz band for automotive radar, especially in the EU, US, and Japan.

Phasing Out of 24 GHz: The 24 GHz band is gradually being phased out in some regions because of limitations in bandwidth and potential interference with other communication systems, though it's still widely used in older vehicles.

Fused-Silica-Based 3D Heterogeneous Integrated (3DHI) Modules for Automotive RF Applications

Fused silica-based 3DHI modules offer several advantages in the automotive and ADAS product categories. These advantages are rooted in the unique properties of fused silica, combined with the 3D integration techniques that enhance the performance, miniaturization, and durability of electronic components.

High Thermal Stability and Durability



Fused silica has excellent thermal stability, meaning it can withstand extreme temperatures often experienced in automotive environments, especially in high-performance ADAS systems that involve radar, cameras, and LiDAR. This ensures long-term reliability and operational consistency,

even in the challenging thermal conditions of vehicle electronics, reducing failure rates in critical safety systems. ADAS components, especially radar and sensor modules, are less prone to thermal degradation, ensuring sustained performance in real-world driving conditions.

Enhanced Signal Integrity and Low Loss



Fused silica's low dielectric constant and low-loss properties allow for minimal signal interference and high-frequency signal transmission. In ADAS systems that rely on fast, accurate data transmission (such as high-frequency radar and LiDAR systems operating in the GHz range), these properties ensure higher precision in object detection, classification, and avoidance. This leads to enhanced accuracy and performance in radar and communication systems, key for adaptive cruise control, blind-spot monitoring, and emergency braking systems.

Miniaturization and Integration of Components



3DHI technology enables the stacking and vertical integration of different components on a single platform, significantly reducing the size and footprint of electronic modules. Automotive and ADAS systems benefit from the compactness of 3DHI modules, allowing the integration of multiple sensors (radar, cameras, ultrasonic sensors) in smaller, more efficient packages. This miniaturization is crucial for modern vehicle designs where space is limited, enabling manufacturers to incorporate more advanced functionalities without increasing the size or weight of the system.

Superior Mechanical Properties



Fused silica offers superior hardness and resistance to mechanical stresses, such as vibration and shock, which are common in the automotive environment. The mechanical robustness of fused silica ensures that 3DHI modules can withstand the physical demands of automotive applications, reducing the likelihood of damage and extending the product lifecycle. ADAS components, which are frequently subjected to harsh driving conditions (e.g., off-road or high-speed), are less prone to mechanical failures, enhancing system reliability.

Improved Optical Performance for Sensor Integration



Fused silica is known for its excellent optical properties, such as high transparency in the visible and near-infrared regions, which makes it ideal for optical sensor applications. For ADAS systems that integrate optical sensors (cameras, LiDAR), fused silica enhances optical clarity and signal fidelity, improving the accuracy of object detection and environment mapping. This leads to more accurate data from LiDAR and optical cameras, which is crucial for functions like lane-keeping assistance, pedestrian detection, and fully autonomous driving.

Electromagnetic Shielding



Fused silica, combined with 3DHI technologies, offers effective shielding against electromagnetic interference (EMI), which can disrupt sensitive electronic components in automotive systems. EMI shielding ensures that high-frequency ADAS sensors (like radar and LiDAR) function without signal degradation, even in environments with heavy electromagnetic noise (e.g., urban settings or crowded highways). Improved signal clarity and reduced risk of interference improve the reliability of ADAS features, such as collision avoidance and traffic sign recognition.

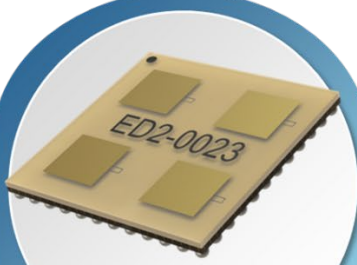
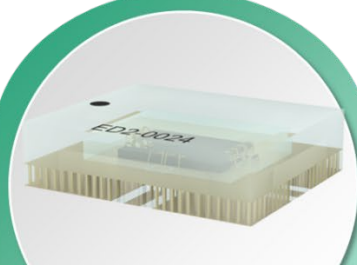
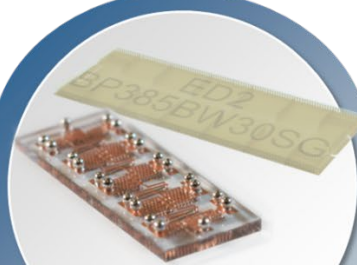
Cost-Effectiveness in Mass Production



3DHI allows for the integration of different materials and components onto a single platform using advanced manufacturing techniques, which can reduce production costs. The cost savings associated with fused silica-based 3DHI modules make it more feasible to mass-produce complex ADAS systems at a lower cost, contributing to the wider adoption of advanced safety features in mid-range and economy vehicles. This drives the democratization of ADAS technologies, making advanced safety features available in more affordable vehicle categories, enhancing road safety across all vehicle segments.

ED2 and Fused-Silica-based 3DHI

Tucson-based Electronic Design and Development Corporation (ED2) was founded in 2018, by a leadership team with deep experience in the fabrication and assembly of fused-silica components and modules. Since that time, the company has been working diligently to design and produce a variety of off-the-shelf (OTS) and custom components, in three (primary) categories: 3DHI; Advanced Packaging; and, Passive Components.

 <p>3D Heterogeneous Modules</p> <ul style="list-style-type: none"> • Integrated 3D Tile + Sensors • Photonics • Processing and Memory Applications • RF and Wireless 	 <p>Packaging</p> <ul style="list-style-type: none"> • Interposers • Fanouts for high-density I/O • Custom Semiconductor • RF and Wireless • Digital Electronics • Optoelectronics 	 <p>Passive</p> <ul style="list-style-type: none"> • Filters (lumped, distributed, waveguide) • Capacitors & Inductors • Resonators • Transformers • Diplexer, Duplexer • EMI, chokes
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