In-Conversation

3D Waveguide Antennas Power Next-Gen ADAS Radar Evolution



Francesco Merli
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In an interview with Francesco Merli, VP Wireless Connectivity at HUBER+SUHNER, AutoEV Times explores how next-generation antenna technologies are shaping the future of ADAS and autonomous driving. Francesco highlights the growing limitations of conventional PCB-based designs and explains how 3D waveguide antennas deliver superior performance in high-frequency radar systems. He also shares insights on system-level integration, beamforming precision, and the path toward scalable, reliable Level 4 and Level 5 autonomy.

Read the full interview here:

AutoEV Times: As ADAS evolves toward higher autonomy levels, what specific limitations in current antenna technologies are becoming bottlenecks for next-generation radar systems?

Francesco: ADAS is entering a phase where innovation must coexist with strict automotive realities such as high-volume manufacturability, cost control, and a resilient global supply chain. At the core is the need to fully exploit the 76–81 GHz band with highly stable, repeatable RF performance, something that becomes increasingly difficult under material variability, thermal effects, and tight production tolerances. Delivering this performance without cost escalation puts clear limits on conventional manufacturing approaches.

Crucially, antenna performance cannot be viewed in isolation. Once integrated behind radomes, bumpers, and fascia, real-world vehicle environments impose detuning, loss, and pattern instability that directly impact system reliability. What matters is predictable, stable behavior at vehicle level. Technologies that combine wide bandwidth, low loss, and integration-friendly design are therefore essential to unlocking the next generation of ADAS and automated driving systems.

AutoEV Times: High-resolution imaging radar and 360° coverage demand operation at very high frequencies. What makes 3D waveguide antennas better suited for these requirements compared to traditional PCB-based antenna designs?

Francesco: At very high frequencies, traditional PCB-based antennas increasingly face fundamental challenges, including dielectric and conductor losses, limited bandwidth scalability, and constraints on achievable aperture size and coupling efficiency with radar MMICs. These factors directly affect range, angular accuracy, and beam stability.

3D waveguide antennas avoid many of these limitations. Their metallic, air-filled structures offer extremely low RF loss, enabling larger apertures, broader bandwidths, and greater freedom in array architecture. This translates directly into higher resolution and more accurate beam shaping, both essential for imaging radar and full 360° sensing.

In addition, waveguide antennas are particularly well suited for advanced radar front-ends such as launch-on-package MMIC concepts, providing benefits in transmit power, receiver sensitivity, electromagnetic compatibility, and thermal handling. While especially valuable for automotive ADAS, these characteristics also make them attractive for other demanding sensing applications, including UAVs and industrial systems.

AutoEV Times: In real-world driving conditions — heavy rain, fog, dust, urban interference — how do waveguide antennas improve signal integrity and detection reliability?

Francesco: Radar as a sensing modality is inherently robust against adverse weather and limited visibility, which is one of the key reasons it plays such a central role in ADAS.
High-performance antenna design further enhances this fundamental strength.

3D waveguide antennas preserve signal integrity through very low RF loss and stable electromagnetic behaviour. By minimising attenuation and maintaining predictable beam patterns, they allow radar systems to extract maximum information from weak or partially scattered reflections, which is an important advantage in long-range sensing and cluttered urban environments.

Their construction and broadband behaviour also ensures performance stability across temperature extremes and environmental exposure, avoiding the detuning effects typically seen in dielectric-based solutions. In practice, this enables radar systems to maintain reliable object detection and situational awareness regardless of weather, visibility, or contamination, supporting higher safety margins in real driving conditions.

AutoEV Times: Multi-target adaptive beam steering is increasingly critical for autonomous navigation. How do 3D waveguide structures enable more precise and dynamic beam control?

Francesco: The advantage of 3D waveguide antennas in adaptive beam steering comes from two complementary aspects.

At the single radiating element level, their low loss and wide RF bandwidth ensure high signal quality with excellent amplitude and phase stability, both essential prerequisites for accurate digital beamforming. Then, waveguide technology enables the implementation of larger effective apertures, more sophisticated array geometries, and a higher number of well-controlled channels. These factors directly determine how finely beams can be shaped, steered, and separated in space.

Together, these capabilities support sharper beams, faster steering, and clear discrimination of multiple targets simultaneously. This makes 3D waveguide antennas particularly well suited for the complex, dynamic sensing environments required by advanced ADAS and emerging autonomous driving functions.

AutoEV Times: As radar, LiDAR, and camera systems are deployed across different areas of the vehicle, how important is antenna car body integration at the system level?

Francesco: Antenna design integration is absolutely critical because antenna performance ultimately defines the physical limits of radar capability. Aperture size directly determines azimuth resolution, RF bandwidth sets range resolution, and antenna losses translate directly into usable detection range.

For this reason, antennas cannot be designed independently of their installation environment. Radomes, bumpers, emblems, and fascia all interact electromagnetically with the radar system and must be considered from the earliest design stages as part of a system-level approach.

At HUBER+SUHNER, our engineering teams design antennas with this system-level integration firmly in mind. Over the years, we have demonstrated robust bumper-integration techniques and radar cross-section reduction features across frequency ranges from 76 to 81 GHz. This approach ensures that radar performance is preserved not only on the test bench, but in the fully integrated vehicle, across platforms and production volumes.

AutoEV Times: Looking ahead, what antenna innovations will be necessary to support Level 4 and Level 5 autonomy — and how close are we to that reality?

Francesco: Level 4 and Level 5 autonomy will not be enabled by a single breakthrough in frequency or raw RF performance alone. The real shift is toward system-level robustness: multiple sensing modalities operating together with redundancy, predictable behavior, and consistent performance across a wide range of real-world conditions.

From an antenna perspective, the most important innovations will center on modularity and integration. Future vehicles will likely use multiple radar sensors distributed around the car, often with overlapping fields of view, and antenna solutions must support this architecture efficiently. That means scalable, production-ready antenna modules that are easy to package, integrate behind bumpers or fascia, and reproduce consistently across platforms without expensive redesign cycles.

Equally critical is coexistence and overall system integrity. As sensor counts rise, antennas must help manage mutual interference, maintain stable beam patterns in their installed environment, and support robust calibration for sensor fusion with cameras and LiDAR. In other words, antennas must be designed not just as individual components, but as key elements of a tightly integrated sensing system.

Technically, many of the required building blocks already exist today. The key challenge lies in industrialisation: delivering these capabilities at automotive scale, with the required cost efficiency, reliability, and supply-chain stability. Sensor counts are continuing to rise, with antenna technology now a firmly established cornerstone of safe autonomy. As part of the pledge to connect – today and beyond from HUBER+SUHNER, we remain at the forefront of developing and consolidating innovative antenna capabilities.