

Technical White Paper

The Evolution of Automotive Radar: Why Automotive Ethernet and PoDL are Redefining Sensing Architectures



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Abstract

Modern autonomous vehicles require high-bandwidth radar data, necessitating a move toward automotive Ethernet. To prevent the resulting increase in wiring weight and complexity, this paper proposes the adoption of power over data line (PoDL). PoDL integrates power and data into a single cable, minimizing harness mass and potentially reducing sensor costs, optimizing thermal management for next-generation sensing architectures.

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1 Introduction

As the automotive industry transitions from Advanced Driver Assistance Systems (ADAS) Level 2+ to fully autonomous Level 3 and 4, the demand for high-resolution imaging radar is required. This evolution necessitates a move away from legacy communication protocols toward automotive Ethernet. However, the shift to high-bandwidth data creates secondary challenges: an increase in the number of radars used in a car and an increase in the power demand per radar, and the resulting physical power loss of wiring.

This article explores how power over data line (PoDL) serves as the critical enabler for the Ethernet to radar transition. By converging power and high-speed data onto a single twisted pair, PoDL addresses the core constraints of modern vehicle design: weight, cost constraints, thermal management, and architectural scalability.

2 Problem Statement on Current Legacy Parts Communication Topology and Ethernet Advantage

Traditionally, radar sensors relied on low-bandwidth protocols such as CAN, LIN, and so forth. While sufficient for simple object detection, these protocols fail to meet the requirements of modern radar system for several reasons:

- **Bandwidth Bottlenecks:** High-resolution imaging radar generates massive raw data streams that overwhelm legacy buses. The standards of ADAS level 2+ and 3+ require higher antenna counts, wider bandwidth, and raw data output in the radar application.
- **Localized Computing:** Since CAN and LIN cannot support the necessary throughput, most radar processing must be performed in a dedicated radar ECU rather than in a central compute or IVI system. Consequently, less raw data is available to the ADAS stack, which reduces measurement accuracy and overall system performance.
- **Latency and Jitter:** Real-time autonomous decision-making requires deterministic data delivery. Legacy protocols lack the robust time-sensitive networking (TSN) capabilities required to synchronize radar data with a different sensor.
- **Complex Topologies:** Legacy automotive systems are a combination of multiple interfaces: A CAN interface for radar and an Ethernet for backbone communication. This combination introduces complex system hardware and software development.

Legacy systems require separate wiring harnesses for power and data, increasing the complexity of the electrical architecture of the vehicle.

3 The Ethernet Advantage

Automotive Ethernet (10BASE-T1S, 100BASE-T1, and 1000BASE-T1) offers a unified backbone that scales from potentially lower-cost corner radars to high-performance long-range sensors while providing the deterministic performance (TSN) required for safety-critical sensor fusion. Major original equipment manufacturers (OEMs) and Tier-1 suppliers now specify Ethernet for next-generation radar platforms.

The industry is also moving toward raw data processing in a central compute unit to improve ADAS and autonomous driving capabilities. Transferring raw radar data from the radar ECU to the central ADAS processor demands higher speed links—typically 100Mbps, 1Gbps, or even faster. Consequently, the transition from CAN or LIN to Ethernet is becoming a critical enabler for modern automatic drive architectures.

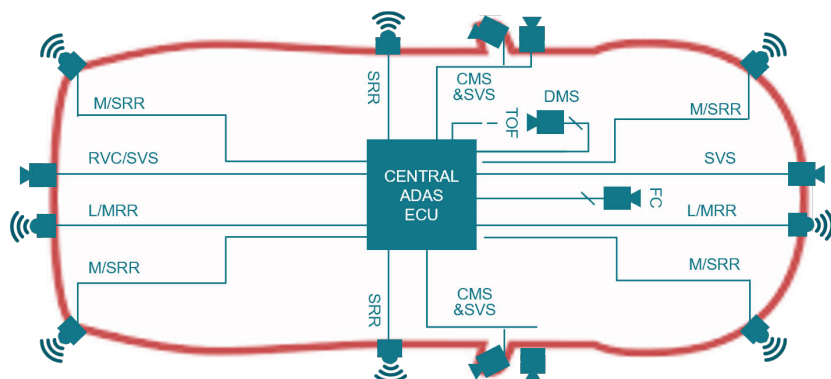


Figure 3-1. Radar in Automotive Vehicle

4 The Critical Hurdle: Power Delivery in the Ethernet Shift

While migrating to Ethernet solves the data-bandwidth problem, the migration creates a significant physical-layer overhead when power delivery is not considered. In a conventional Ethernet implementation that does not use power-over-data-line (PoDL), each sensor requires two separate cable pairs: one for data and one for power.

At the same time, the industry is moving from the traditional three-radar architecture (front, rear, and side) to configurations that employ five or even eight radars per vehicle. Each additional radar adds another power feed, so the number of power cable harnesses grows proportionally.

Therefore, power-over-data-line becomes crucial by allowing the same twisted-pair that carries Ethernet data to also deliver the required supply voltage, eliminating the extra power-only wiring and reducing the overall harness weight, cost, and complexity.

Impact of Separate Power and Data Lines:

A legacy radar interface implementation requires separation on both the power cable and data cable. This separation introduces the following disadvantages shown in Table 4-1.

Table 4-1. The Disadvantages of a Legacy Radar Interface Implementation

	CAN + Power	Ethernet + Power	Ethernet + PoDL
Cable weight per sensor	0.07kg	0.08kg	0.03kg
Cable cost per sensor	\$0.45 U.S. Dollars	\$0.90 U.S. Dollars	\$0.30 U.S. Dollars
Number of cable bundles and connector	2	2	1
Number of connectors (unchanged)	2	2	1

- **Weight and Cost:** More buses and nodes are required for a radar design based on a CAN due to the bandwidth limitation and indeterministic latency.
- **Harness Complexity and Installation Risk:** When each radar sensor is supplied with a dedicated power harness and a separate high-speed data cable, the wiring bundle quickly becomes bulky and unwieldy. In tight space locations—such as the front-end bumper, rear-corner impact zones, or the under-floor rail—large diameter bundles are difficult to route without bending beyond the minimum radius of the bundle, which can crack the insulation. Every additional wire or connector introduces a new failure point. The penalty compounds when a vehicle adopts a surround-view radar architecture. Adding just two more modules can double the number of power wires, double the number of Ethernet jacks, and increase the total copper mass by several hundred grams. That extra copper not only adds weight and cost but also raises the I^2R loss in the distribution network, meaning more of the battery energy is wasted as heat before the energy even reaches the sensor.
- **Thermal Management:** Power wires generate localized heat. In high-density harnesses, this complicates cooling and contributes to voltage drops over long distances in power connections. Localizing the heat dissipation not only reduces the heat introduced from the power bundle to the radar location but also reduces the heat dissipation in the automotive power cables.

5 The Answer: Power Over Data Line (PoDL)

PoDL (based on the IEEE 802.3bu standard) enables the delivery of DC power over the same single twisted pair used for 100Base-T1 and 1000Base-T1 data. Using a power sourcing equipment (PSE) at the ECU or gateway and a powered device (PD) at the radar, the system can deliver up to 50W—well above the typical <10W requirement for most radar modules.

By converging power and high-speed data into a single twisted pair, PoDL effectively eliminates the inefficiencies inherent in separate line architectures. This consolidation offers a direct weight and potential cost advantage by reducing both the copper mass and the number of required connectors. The resulting slimmer harness significantly simplifies routing, allowing cables to be easily integrated into the tight-space constraints of bumpers and grilles where bulky, separate bundles are prone to damage and bending fatigue.

Furthermore, the transition to PoDL drastically reduces installation risks by minimizing the number of termination points and potential failure modes, such as chafing or connector misalignment. Beyond assembly, architecture improves thermal and electrical efficiency. With a localized power connection around the radar, this reduces the heat dissipation generated by the central power bundle. A localized power connection also reduces the cable reach and I^2R loss which improves the power delivered efficiently. PoDL also makes radar designs more scalable, enabling the deployment of high antenna-count imaging radars that demand both increased data bandwidth and higher power loads without the disproportionate weight and complexity penalties of traditional wiring.

6 Implementation Challenges and Mitigation

Injecting DC power onto a high-speed data line introduces risks of signal integrity. The addition of a differential mode inductor (DMI) network reduces the differential impedance on the line, which leads to return loss degradation. Imbalances between the two conductors generate common-mode currents, causing mode conversion and elevated electromagnetic emissions. Adding series inductance decreases the differential impedance at the lower frequency end and results in voltage droop performance degradation.

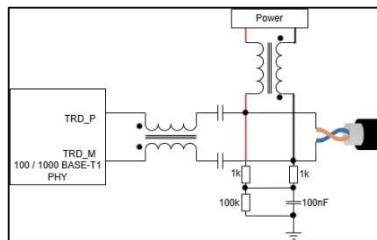


Figure 6-1. PoDL Network Example

Mitigation Strategies

- **Magnetics Selection:** Use specialized high-isolation magnetics designed for a PoDL DMI network. The differential impedance and coupling factors of a DMI network have a significant role in PoDL performance.

Increasing the inductor value of a DMI network helps with return loss and voltage droop. A DMI network typically adds extra differential impedance at the lower frequency end. Increasing the inductor value shifts the differential impedance degradation to the lower frequency range and prevents any effect at the operating frequency range.

A coupling inductor DMI network selection reduces the mode conversion factor when compared to a two isolate inductor DMI network. A coupling DMI network filters out any common mode noise on the line to help with mode conversion. Furthermore, a two isolated inductor DMI network typically has some tolerance difference between the two. Having a higher coupling factor further reduces the differential noise and provides a better mode conversion measurement. Another advantage of coupling a DMI network also has by adding mutual factors which increases the differential inductance or impedance on the line.

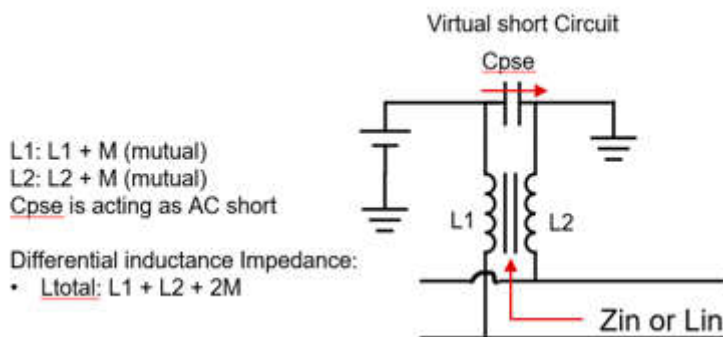


Figure 6-2. Impedance Calculation for PoDL Network

However, a higher inductor value typically has lower current support on a DMI network. If customers want better signal performance with high current support applications, increasing the size of the DMI network is the tradeoff for the DMI network:

- **Power Loss Optimization:** In the high-voltage system of a radar application, there is always a concern about the extra power consumption across the CMT network. For example, in the 48V system, there is always an extra power consumption V^2/R across both the PSE and PD board. However, the following PoDL designs in [Figure 6-3](#) and potentially help with this power loss scenario.

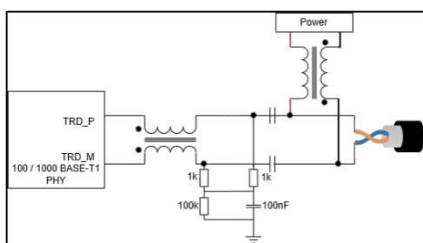


Figure 6-3.

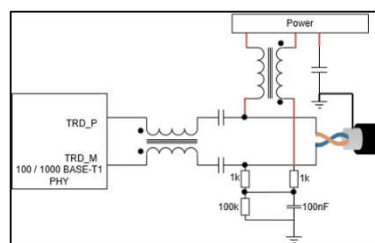


Figure 6-4. Design 1 and Design 2 of a PoDL Network to Resolve Power Loss

- **Design 1 (left figure):** Moves the common-mode termination before the AC coupling capacitors. This design eliminates the power loss at the common-mode termination, removing the loss across that termination entirely.
- **Design 2 (right figure):** Connects both wires to the positive power supply and uses the cable shield as the ground reference. This design also eliminates the power loss across the common-mode termination and is the approach typically used with shielded cables.
- **PCB layout optimization:** For a rigorous decoupling network optimization and controlled impedance routing, follow the layout instruction to further improve signal integrity performance:
 - Place the DMI (differential mode inductor) network with the same layer as the MDI line.
 - Connect vias directly on the DMI footprint and route the vias with the MDI line on the top layer.
 - Minimize the stubs between the DMI and MDI lines.
 - Prevent the vias from being too close to the DMI to prevent any impedance drop and mode conversion.
 - Connect the power and ground polygon pour place in the bottom layer with the DMI network.
 - Void under the DMI and CMC network.
 - TI recommends placing a common mode termination on the bottom layer.
 - Keep the MDI lines and DMI network symmetrical.

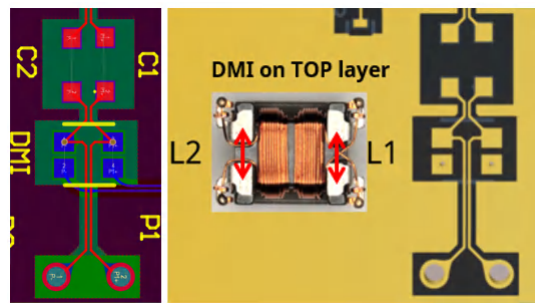


Figure 6-5. PoDL Layout Recommendation

- **Additional Implementation Concerns for a PoDL Network:**

- **Cable Selection:** Cables must be rated for both the differential impedance (100Ω) required by Ethernet and the current carrying capacity required by the PoDL load.
- **Safety and Reliability:** The implementation must adhere to stringent automotive safety standards (ISO 26262) to prevent a power fault from compromising the data integrity of the safety-critical sensing stream. Implement the use of a PSE source device to stop power transfers when there is an overcurrent or undercurrent flow, an unexpected classification, reverse voltage, or current protection.

7 Conclusion

Switching radar sensors from the old CAN or LIN buses to an automotive Ethernet provides the necessary bandwidth and timing for driver-assist and autonomous systems. The problem is that Ethernet alone still requires separate power wiring, which adds weight, cost, and complexity—especially as cars move from three radars to five or eight radars.

Power-over-data-line (PoDL) solves this problem by sending power and high-speed data over the same twisted pair. PoDL cuts the number of cables, reduces harness weight, and potentially reduces costs; making routing easier, while still supporting the high-speed links required for raw-data processing.

In short, PoDL is an option that lets Ethernet fully replace legacy protocols for automotive radars; enabling lighter, potentially cheaper, and scalable sensor networks for the autonomous vehicles of today and tomorrow.

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