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Technical Brief

Advances in Automotive E Band Antenna Design

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Vehicles increasingly use sensor data for driver alerts and semi-autonomous functions, driven by improvements in data speed and image resolution. Automotive E band frequencies (Long Range Radar: 76-77GHz and Short Range Radar: 77-81GHz) quickly gather relevant data about a vehicle's surroundings. The higher frequencies provide better bandwidth, sweep, and resolution than the traditional 24GHz band. E band frequencies also allow for reduced antenna sizes, which offer flexibility in mounting.

Making E band Work

However, designing and fabricating systems at E band frequencies presents several challenges that adversely affect performance if not adequately addressed. Critical factors to consider when designing for E band frequencies include:

- Dielectric loss
- Moisture Absorption
- Copper insertion loss and surface roughness
- Fabrication tolerances for thin dielectric materials

Selecting the right substrate and fabrication technology is key to addressing these factors when designing antennas for E band frequencies.

Low Dielectric Loss Materials

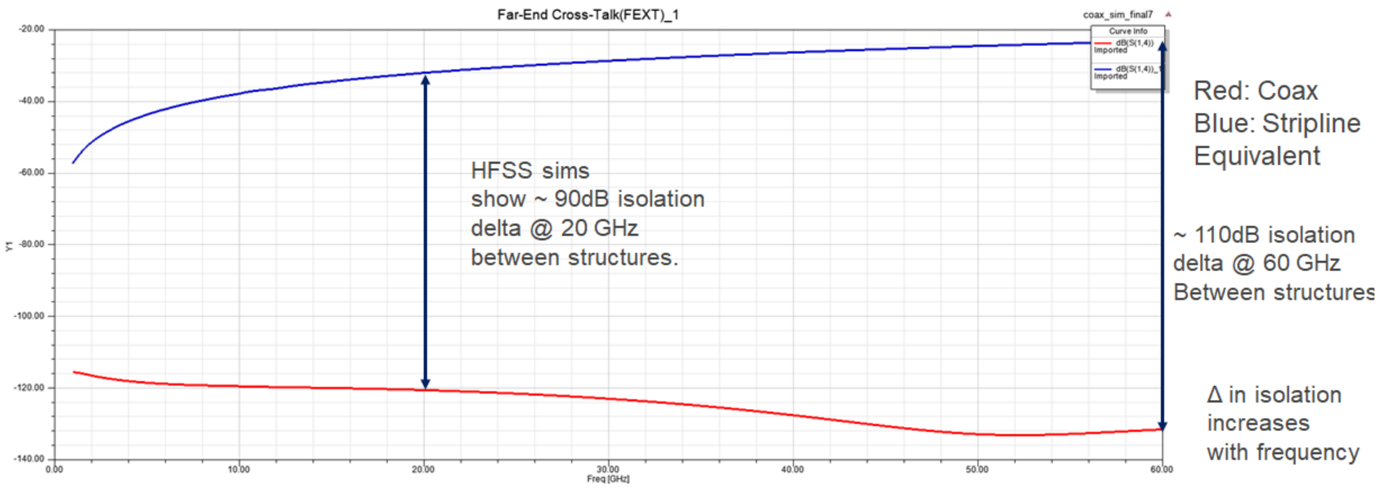
Dielectric loss quantifies a material's inherent dissipation of electromagnetic energy. Minimizing dielectric loss becomes crucial as frequencies increase, especially in waveguide structures. At E band frequencies, waveguide antenna structures such as substrate integrated waveguide (SIW) and gap waveguide antennas are becoming increasingly popular. These structures offer low conductor loss when compared to the classical stripline or microstrip structures. For SIW antenna structures, since the conductor is very wide (i.e., the two parallel plates of a rectangular waveguide), the principal source of loss is dielectric related, so choosing a material that limits this loss is essential to overall performance. While several electronic substrates are generally suitable for antennas, Liquid Crystal Polymer (LCP) has a dissipation factor (governs dielectric loss) of 0.0016. This low loss is conducive to supporting SIW structures, making it an excellent choice for E band antennas.

Moisture Absorption & Stable Dielectric Constant

Water molecules undergo a dielectric relaxation effect at 10-100 GHz; the relative permittivity, or dielectric constant (Dk), of water changes with frequency. If water molecules are trapped inside the dielectric, the substrate Dk will subsequently change, which means that materials set with high water absorption rates increase losses in the antennas, and the water absorption affects antenna gain directly.

Automotive applications must be able to accommodate environmental factors as vehicles are exposed to diverse weather conditions. Changes in the dielectric constant (Dk) over frequency alter the resonant frequency of antennas at the E band range, making the antenna performance unreliable. Choosing a material that will absorb as little water as possible will improve performance. LCP is one potential dielectric option; the near-hermetic properties of LCP eliminate the effect of moisture absorption issues at E band frequencies and keep the dielectric constant stable at around 2.95.

Figure 1: Isolation comparison between embedded coax with continuous solid wall and the stripline equivalent with stitched vias.



Copper Insertion Loss and Surface Roughness

In addition to dielectric loss, leakage is an important consideration when enabling SIW technology on printed circuit boards (PCB), that requires attention to various circuit design elements and ensuring precision in fabrication. Vias should be minimally spaced to mitigate leakage, thus preventing unwanted radiation and coupling. Fabrication processes that enable as small as 3 mil (limit) edge-to-edge spacing of vias reduce the leakage to negligible amounts (5 mil is recommended for extremely high via counts to produce high yields). Benchmark Lark Technology's semi-additive circuit fabrication process includes via wall technology (solid wall instead of via stitching) that extends the feasibly manufacturable frequency range of SIW technology by removing radiation and coupling due to leakage altogether (see Figure 1 for an isolation comparison between a via wall-based embedded coax structure and the traditional via stitched stripline). This fabrication process is dielectric material set agnostic, giving the benefits of 1 mil lines and traces and solid via walls regardless of the material selected to optimize for other factors.

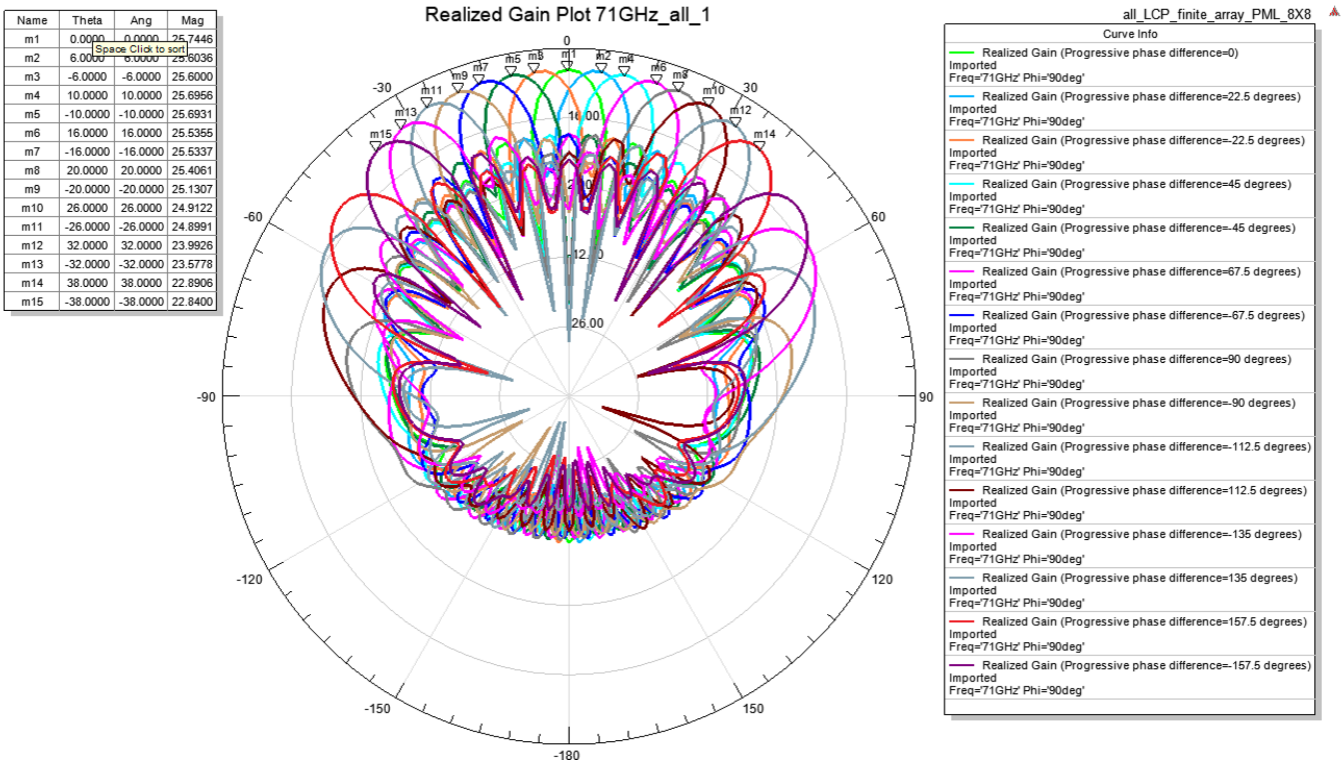
Fabrication Tolerances for Thin Dielectric Materials

All millimeter wave (mmWave) circuits require very stringent fabrication tolerances. At E band frequencies specifically, fabrication yield tolerances become pronounced. To reduce radiation losses in the overall signal feed network, the substrate should be thin, which necessitates narrow traces. Advanced circuit manufacturing technologies such as modified semi-additive processes (MSAP) support very tight tolerances with impedance controlled 1 mil lines and spacing essential for mmWave boards.

Respecting these parameters improves antenna performance and reliability and enhances system performance by reducing power consumption and the size of the overall sensor module. An example of the SIW based 8x8 phased arrays designed around the above considerations by Lark is shown in Figure 2.

Lark specializes in advanced mmWave circuits and antenna design and fabrication. Advanced manufacturing technologies that leverage high-frequency performance material sets like LCP paired with our in-house design expertise, give an edge in E band and other mmWave antenna designs.

Figure 2: Realized gain of 25.5dBi for an 8x8 phased array w.r.t scan angles at 71GHz.



Advanced Design Capabilities: Lark's design capabilities have resulted in successful antenna designs from ultra-high frequency (UHF) and ultra wide-band (UWB) ranges [1] to mmWave. We have several state-of-the-art antenna reference designs from fat monopoles to broadband stacked patches and SIW antennas. We leverage the expanded manufacturing feasibility range enabled by our in-house manufacturing capabilities for next-generation mmWave communication systems. The combination of design and manufacturing capabilities gives our designs a competitive edge in addressing size, weight, and performance challenges common in mmWave systems.

About Benchmark Lark Technology

Benchmark provides solutions across the entire product lifecycle, from innovative technology to world-class engineering, design, manufacturing, and supply chain services. Benchmark Lark Technology works alongside customers to solve technology challenges and develop advanced RF, photonics, and high-speed electronic systems. Leveraging extensive engineering expertise and advanced manufacturing technology for high-density interconnect circuits and precision microelectronics, Lark is a one-partner solution for high-reliability electronics in aerospace & defense, telecommunications, computing, and industrial applications. By vertically-integrating our RF and High-Speed Design Center of Innovation with circuit fabrication, microelectronics, SMT assembly, and functional test, Lark achieves unmatched reductions of size and weight of electronics and exceptional performance at high frequencies.

References

[1] Chang, A. (2020). *U.S. Patent Application No. 16/576,593.*

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