

Design and Evaluation of Multi-Antenna Systems for Flat Antenna Connectivity Module Under Automotive Roofs

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The advancement of connected and automated driving technologies alongside communications beyond 5G is significantly escalating the demand for vehicular antennas. Internally housed automotive antennas, serving as alternatives to traditional shark-fin designs, are gaining traction due to their stealth capabilities and improved installation flexibility. Among these innovative solutions, the development of roof-mountable Telematics Control Units (TCUs) equipped with integrated multiple antennas has been a focal point of research over several years. The roof-mounted flat antennas connectivity module offers not only hidden integration within the vehicle but also provide broader antenna installation areas compared to conventional designs. Notably, the inclusion of dedicated antenna spaces in these designs helps mitigate interference between antennas, enhancing overall system performance and reliability.

The TCU now necessitates a suite of multiple antennas to support advanced functionalities such as 4×4 Multiple-Input Multiple-Output (MIMO) cellular systems, Bluetooth, Wireless Local Area Network (WLAN), Vehicle-to-Everything (V2X) communication, Global Navigation Satellite System (GNSS), Satellite Digital Audio Radio (SDARS), and satellite communication. However, conventional TCU designs often face significant challenges due to limited internal space. With over ten antenna elements, there is considerable coupling between antennas and shadowing effects that interfere with each other's radiation patterns. This study focuses on automotive antennas integrated within flat antennas connectivity module systems, which demonstrate improved performance compared to traditional TCU designs. By optimizing antenna placement and minimizing interference through spatial diversity, these integrated systems aim to enhance overall communication efficiency and reliability, addressing the limitations posed by constrained internal spaces.

A selection of basic antennas has been implemented, and their performance will be shown, focusing on isolation and radiation patterns. The presentation will also include ray-tracing based simulation results to compare how these antennas perform when mounted in various positions on a vehicle. Specifically, the flat antenna will be evaluated at two distinct locations: the front roof and the rear roof. Simulation outcomes for each position will be compared to analyze the impact of different mounting locations on antenna performance. This comprehensive analysis aims to provide insights into optimal antenna placement for enhanced communication efficiency and signal integrity within vehicular environments.

In summary, this presentation will explore the design, implementation, and benefits of these integrated multi-antenna systems within the context of modern vehicle telematics, focusing on their role in advancing vehicular connectivity and reducing coupling between antennas. The innovative approach of embedding multiple antennas within a roof-mounted flat antennas connectivity module offers a promising solution to mitigate the issues associated with conventional designs, thereby achieving superior performance in complex vehicular communication environments.