ScuDo

Scuola di Dottorato ~ Doctoral School

WHAT YOU ARE, TAKES YOU FAR

XXXVI Cycle

77 GHz automotive radar integration into a car rear lamp

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Research context and motivation

- **Automotive radars** are usually installed on cars as external black box devices to be connected to vehicle CAN (Controlled Area Network) bus. The standard placing for automotive radar sensors is in tight spots behind bumpers or emblems. While this offers protection to the antenna and does not affect the visual design of the vehicle, it introduces different points of concern for the car maker. For example, long cables need to be laid in the chassis, ad hoc spots need to be created in the car body, radome and painting effects must be evaluated and mitigated.

- The incorrect spacing between the bumper (usually a multy-layer structure) and the antenna can cause multiple reflections, especially when metallic paints are used. These reflections affect range and velocity estimation, worsen direction of arrival estimation and degrade the field of view.

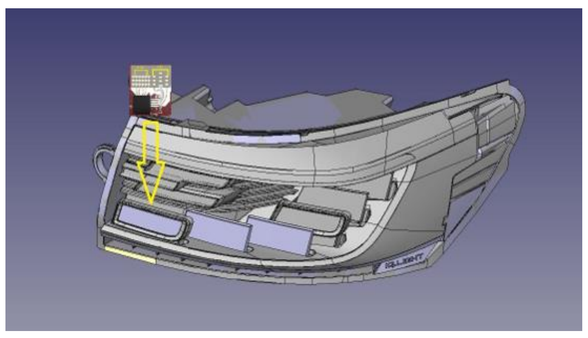
- A part of the vehicle which has been in the discussion for the placing of radar sensor is the **lamp**. Usually car lamps materials are thinner, adjustable, and without painting bringing consistent advantages to the above-mentioned problems. Lamp housing offers higher protection from external disturbances, better protection in case of small accidents and no need for extra-cables.

Addressed research questions/problems

- Integration, design and prototyping of a 77 GHz FMCW (frequency modulated continuous wave) MIMO (multiple input multiple output) **automotive medium range corner radar** into a rear lamp without affecting its external look and its lighting functions.

- Radar must fit behind a 26 mm x 59 mm rectangular part of the target lamp called “petal”.

- Evaluate results of the tests with other corner radar solutions.



Novel contributions

- The integrated design aims to obtain the advantages of placing the radar into the lamp while also optimizing the radar performances by means of tuning PCB electronics, material thicknesses, position of the antennas, upgrading the software and improving thermal dissipation.

Submitted and published works

- Mattia Caffa, Stefano Bottigliero, Federico Ramonda, Luca Gioanola, and Riccardo Maggiora “*Integrated Design and Prototyping of a 77 GHz Automotive Medium Range Radar into Car Rear Lamp* ”, submitted to IEEE Transaction on Vehicular Technology on 28/07/22.

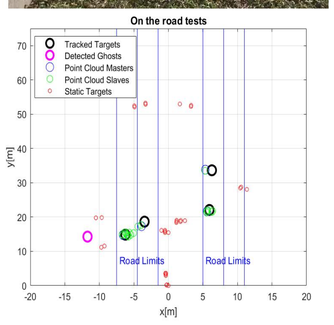
Adopted methodologies

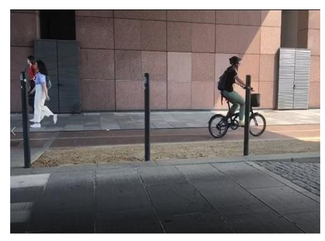
- Two boards have been designed and manufactured to fit in the lamp. The radar PCB, which host an AWR1843 radar chip and the antennas (3 Tx, 4 Rx), has been placed behind the petal. The radar PCB is connected to a second dedicated board for power supply.

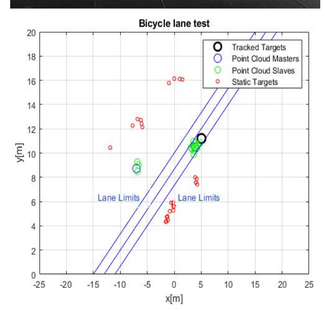
- The thicknesses of the lamp material have been optimized to reduce reflections and to improve SNR (Signal to Noise Ratio) of the received signals.

- State of the art radar firmware for an **automotive medium range corner radar** has been developed on the DSP and ARM available in the radar chip.

- Performance tests at zero ego velocity and with the radar inside the lamp have been carried out in an open field and on the road and optimal results for the detection and tracking of vehicles and bicycles have been obtained up to 75 m range.







Future work

- Hardware improvement with better power supply filtering to reduce noise floor and improve the detection of targets.

- Minimum Redundancy MIMO antenna configuration to improve angular resolution

- Firmware tuning to improve performances of tracking algorithm.

- On the road testing with radar mounted on a car.

List of attended classes

- 01NVSOQ – Advanced antenna engineering (22/2/2021, 6 CFU, 30 h)
- 02SFURV – Programmazione scientifica avanzata in Matalab (25/5/2021, 6 CFU, 30 h)
- 01MMRRV – Tecniche numeriche avanzate per l’analisi ed il progetto di antenne (9/6/2021, 4 CFU, 20 h)
- 01DPJRV – Lens antennas: Fundamentals and present applications (7/12/2021, 2 CFU, 10 h)
- 01DTPRV – Connected Vehicles (23/6/2022, 4 CFU, 20 h)
- 01QRPRV – Satellite Navigation Signal exploitation for atmospheric and environmental monitoring (30/6/2022, 3 CFU, 15 h)
- 02LWHRV – Communication (1/2/2022), 1 CFU, 5 h)
- 01SHMRV – Entrepreneurial Finance (31/5/2022), 1 CFU, 5 h)
- 01UNYRV – Personal branding (11/2/2021), 1 CFU, 1 h)
- 08IXTRV – Project management (8/4/2022), 1 CFU, 5 h)
- 01RISRV – Public speaking (18/2/2022), 1 CFU, 5 h)
- 01SYBRV – Research Integrity (8/2/2022), 1 CFU, 5 h)
- 02RHORV – The new Internet Society (31/5/2022, 1 CFU, 1h)
- 01UNXRV – Thinking out of the box (31/1/2022, 1 CFU, 1h)
- 02RHORV – Time management (31/1/2022, 1 CFU, 2h)
- 01SWQRV – Responsible research and innovation (8/2/2022, 1 CFU, 5h)

Politecnico di Torino

PhD program in

Electrical, Electronics and Communications Engineering