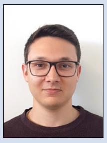

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3D-Printed Antenna for Automotive Radar Applications

Evaluation of Modern Additive Manufacturing Techniques for 77-GHz FMCW MIMO Radar

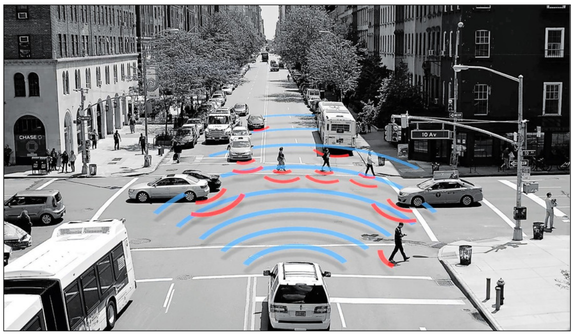
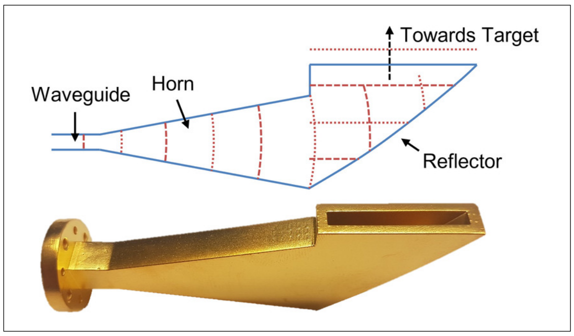
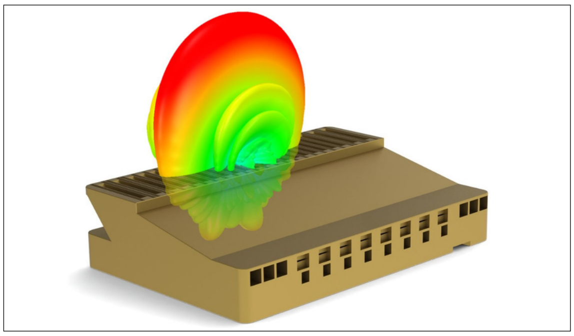


Illustration of a typical environment for automotive radar sensors



Top: Geometry of the horn-reflector antenna
Bottom: 3D-printed and metallized horn-reflector antenna prototype



The final 22-element radar antenna array and a typical resulting radiation pattern

Introduction: Radar sensors constitute an important part of most modern cars, enabling common features such as adaptive cruise control and emergency breaking. These small, cost effective and inherently robust sensors measure the distance, velocity and direction of a target – even under harsh environmental conditions. Beyond that, emerging self-driving vehicles are placing ever-increasing demands on range as well as spatial and angular resolution of these sensors. These requirements are met by using multiple transmit and receive antennas (MIMO) as well as higher frequencies and wider bandwidths. However, current bandwidth and gain limitations of conventional planar patch antennas used in these sensors pose stringent restrictions on the possibilities. Additionally, losses in the microstrip transmission lines used to feed these patch antennas are significant, particularly in the widely used 77-GHz frequency band.

Objective: The increased precision in 3D-printing in combination with the enhanced possibilities to metallize plastic parts creates a range of promising opportunities for designing novel antennas. In the case of automotive radar applications, they open the way to adopt waveguide-based structures, which are far less lossy than their microstrip-based counterparts at 77 GHz. Furthermore, classical waveguide-fed antennas, such as horn antennas, are well-known to provide excellent wideband performance and to achieve the required gain figures. In this project, an antenna geometry is developed, which is compatible with current 3D printing and metallization constraints, is mechanically suitable for use in a MIMO radar antenna array, and provides the electrical characteristics required for automotive radar applications. In a second step, a number of these antennas are combined with a waveguide feeding network to build an entire MIMO radar array system.

Result: An optimized horn-reflector antenna was developed, which not only satisfies all the manufacturing constraints and provides the required radar performance, but also features a small overall form-factor, thereby constituting an ideal building component for MIMO radar arrays. The manufactured prototype achieves an outstanding gain of 17 dBi. The very narrow vertical half-power beamwidth of only 10° helps focusing the radar beam onto other vehicles, while reducing static clutter caused by the road, bridges or curb stones. Furthermore, the antenna produces a wide horizontal -10 dB beamwidth of 115°, allowing a wide field of view of the final radar sensor. Lastly, with a return loss above 13 dB over the entire frequency band of 76-81 GHz, this horn-reflector antenna also proves to be suitable for wideband applications. Based on this antenna geometry, an antenna array consisting of 16 receive and 6 transmit antennas was developed, which is compatible to a preexisting FMCW MIMO radar system. Compared to conventional PCB patch antennas, the considerably lower losses in the feed lines and the higher gain of the 3D printed antenna array extend the range of the entire radar system by a factor of three. Beyond that, the increased number of virtual antennas leads to a doubling of the angular resolution. These performance figures prove that modern manufacturing techniques provide the key-ingredients for novel antenna array solutions, particularly for, but not restricted to, automotive radar applications.