Characterizing the Polarimetric Radar Backscatter Response of Road Surfaces at 230 GHz in Support of Next Generation Sensors for Autonomous Vehicles

Abdulrahman Alaqeel[1,2]*, Amr A. Ibrahim[1], Adib Y. Nashashibi[1], Hussein Shaman[2], and Kamal Sarabandi[1]
(1) The University of Michigan, Ann Arbor, MI 48109, USA
(2) King Abdulaziz City for Science and Technology, Riyadh, 12371, Saudi Arabia

Automotive radars are expected to play a major role in the future autonomous vehicles. Radars' ability to accurately measure the distance to a target and its velocity under all-weather conditions is the main advantage of radars compared to other vehicle's navigation sensors. Due to the need for fine resolution, many suppliers have developed automotive radars operating at Millimeter Wave (MMW) frequencies, especially at 77 GHz. These radars have been used successfully in many driving assistive applications such as adaptive cruise control, lane-change assistance, and collision warning systems, but to push the ability of these radars toward more safety-critical applications like collision mitigation and road condition detection, finer angular resolution is needed. An imaging radar system with a fraction degree angular resolution is needed to resolve vehicles and objects at ranges beyond 100m. Due to limited space for sensors on vehicles, finer angular resolution can only be obtained when operating radar at higher MMW frequencies. We have proposed automotive radars operating at 230 GHz that can improve the angular resolution to 1/3 what can be accomplished with the current 77GHz radar systems. The technology is fast progressing and it is expected that within the next few years the standard SiGe technology be mature enough for fabrication of active components in this desired band. In preparation for emergence of these sensors phenomenology of radar signal interaction with different objects in typical traffic scenes should be understood. Our team has developed bench-top 230 GHz wideband and fast data acquisition and been collecting data from various objects and surfaces.

For autonomous vehicles' sensors, other vehicles are considered the most important target to detect and located. A complete phenomenological study has been conducted in order to characterize the response of different vehicles at this frequency band (Alaqeel, A., A. Ibrahim, A. Nashashibi, H. Shaman, and K. Sarabandi, "The Phenomenology of Radar Backscattering Response of Vehicles at 222 GHz," Proceeding of the IEEE International Geoscience and Remote Sensing Symposium, Fort Worth, Texas, July 23-28, 2017). It is also of high importance to track the road edges and its different lanes. Using high resolution radars and by looking down to the ground, that can be achieved if the radar returns from the road surface (asphalt/concrete) and its sides (grass or sidewalks) can be distinguished. The road condition identification also becomes possible if the rain or snow covered asphalt responses are different than dry/uncovered asphalt, which initial result shows to be the case.

In this work, the backscatter response from different road surfaces under different conditions is studied. In order to characterize the fully polarimetric response of these targets, a set of carful measurements are carried out for each surface at different incidence angles and polarization combinations. The focus is on incidence angles ranging between 80 and 90^{o}. Due to the fading behavior of scattering from individual elements of the illuminated surface, many measurements should be taken and the mean power is calculated. It is well known that the backscatter from such surfaces follows exponential probability density function (PDF), therefore, it is sufficient to know the mean value to characterize the statistics of backscatter power. The measurements go through couple of post-processing steps that include time-gating, calibration to a target of known RCS, and polarimetric calibration. The details of the experiments setup, surfaces measured, data processing as well as the results will be presented in the conference.