



Automotive Radar – A Signal Processing Perspective on Current Technology and Future Systems

Markus Gardill

Radar systems are a key technology of modern vehicle safety & comfort systems. Without doubt it will only be the symbiosis of Radar, Lidar and camera-based sensor systems which can enable advanced autonomous driving functions soon. Several next generation car models are such announced to have more than 10 radar sensors per vehicle, allowing for the generation of a radar-based 360° surround view necessary for advanced driver assistance as well as semi-autonomous operation. Hence the demand from the automotive industry for high-precision, multi-functional radar systems is higher than ever before, and the increased requirements on functionality and sensor capabilities lead to research and development activities in the field of automotive radar systems in both industry and academic worlds.

Current automotive radar technology is almost exclusively based on the principle of frequency-modulated continuous-wave (FMCW) radar, which has been well known for several decades. However, together with an increase of hardware capabilities such as higher carrier frequencies, modulation bandwidths and ramp slopes, as well as a scaling up of simultaneously utilized transmit and receive channels with independent modulation features, new degrees of freedom have been added to traditional FMCW radar system design and signal processing. The anticipated presentation will accordingly introduce the topic with a review on the fundamentals of radar and FMCW radar. After introducing the system architecture of traditional and modern automotive FMCW radar sensors, with e.g. insights into the concepts of distributed or centralized processing and sensor data fusion, the presentation will dive into the details of fast-chirp FMCW processing – the modulation mode which is used by the vast majority of current automotive FMCW radar systems. Starting with the fundamentals of target range and velocity estimation based on the radar data matrix, the spatial dimension available using modern single-input multiple-output (SIMO) and multiple-input multiple-output (MIMO) radar systems will be introduced and radar processing based on the radar data cube or higher-dimension radar-data tensors is discussed. Of interest is the topic of angular resolution – one of the key drawbacks which e.g. render Lidar systems superior to radar in some situations. Consequently, traditional and modern methods for direction of arrival estimation in FMCW radar systems are presented, starting from traditional monopulse-like algorithms to modern sparse reconstruction techniques. Besides other topics such as blindness, rain & snow and near-field detection the presentation will then introduce the great challenge of FMCW radar system interference. While FMCW radar interference is a challenge which can be handled using adaptive signal processing in today's systems, it will become a severe problem with the increasing number of radar-sensors equipped vehicles in dense traffic situations in the near future and a solution to the expected increase in interference is still an open question.

It is this problem of interference, together with some added functionality, which motivated the proposal of alternative radar waveforms such as pseudo-random or orthogonal-frequency division multiplexing (OFDM) radar for automotive radar



systems. Although not yet of great interest from an industrial perspective, the fundamentals and capabilities of both technologies will be introduced in the remainder of the anticipated presentation.

Biography:

Markus Gardill (S'11-M'15) was born in Bamberg, Germany in 1985. He received the Dipl.-Ing. and Dr.-Ing. degree in systems of information and multimedia technology/electrical engineering from the Friedrich-Alexander-University Erlangen-Nürnberg, Germany, in 2010 and 2015, respectively.

In 2010, he joined the Institute for Electronics Engineering at the Friedrich-Alexander-University Erlangen-Nürnberg as a research assistant and teaching fellow. From 2014 to 2015 he was head of the team Radio Communication Technology. In late 2015 he joined the Robert Bosch GmbH as an R&D engineer for optical and imaging metrology systems and leading the cluster of non-destructive testing for the international production network. In 2016 he joined InnoSenT GmbH as Senior Software Developer for automotive radar signal processing algorithms.

During his affiliation with the Institute for Electronics Engineering he taught Circuits & Systems for Communication, Digital Electronic Systems, Programmable Electronic Systems, and Wireless Automotive Electronics. He currently is lecturer for Wireless Automotive Electronics at the Friedrich-Alexander University Erlangen-Nürnberg.

His main research interest include radar and communication systems, antenna (array) design, and signal processing algorithms. His particular interest is spatio-temporal processing such as e.g. beamforming and direction-of-arrival estimation with a focus on combining the worlds of signal processing and microwave/electromagnetics.

Dr. Gardill is a member of the IEEE Microwave Theory and Techniques Society (IEEE MTT-S) and serves as a member of the IEEE MTT-S Technical Coordinating Committee Digital Signal Processing (MTT-9). He regularly acts as reviewer and TPRC member for several journals and conferences. He is selected as Distinguished Microwave Lecturer (DML) for the DML term 2018-2020 with a presentation focussing automotive radar systems.