

Angular Measurements in Azimuth and Elevation using 77 GHz Radar Sensors

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Abstract— The availability of highly integrated cost-effective 77 GHz SiGe-MMICs creates new possibilities for different applications of radar sensors in the automotive area. The ability to measure angles in azimuth and elevation will be a relevant feature for the upcoming radar generations. We present a beamforming solution for angular measurements in both directions with one single sensor, using a combination of series fed arrays and a cylindrical dielectric lens. With this solution amplitude and phase information are split up and independently used to get the azimuth respectively the elevation angle.

I. MOTIVATION

Due to the development of a SiGe technology with transit frequencies exceeding 200 GHz [1] highly integrated and cost effective 77 GHz Si-based radar sensors can be realized and are the basis for a higher market penetration of radar in the automotive area. A four beam single chip SiGe transceiver integrating a VCO, MPA, 4 mixers and onchip test circuitry was developed [5] and introduced into a commercial radar sensor in 2009 [2].

Automotive radar sensors operating at 77 GHz are mainly used for comfort functions in ACC-systems (Adaptive Cruise Control) nowadays. Common sensors in such LRR (Long Range Radar) applications only measure the angle of objects in the azimuth direction. With the focus moving on to safety functions such as PSS (Predictive Safety Systems), objects in a distance of only a few meters in front of a car have to be identified and requirements for a fast and precise detection of the angle in azimuth and also elevation become very important factors for the performance of the radar system.

The development of a novel beamforming concept with angular measurement capabilities in elevation and azimuth direction, using a combination of series fed arrays and a dielectric cylindrical lens, will be discussed in this paper.

II. CONCEPT

A. Functional Principle

Two parameters can be identified as well suited for angular measurements with FMCW-radar sensors using at least two receiving antennas: Amplitude ratio and phase information. Normally only one of these parameters is used to detect the angle of an object, sometimes the second parameter is used additionally as a redundant information source. Especially in systems using dielectric lenses, angular measurements based on evaluation of phase difference are not studied well up to now.

The concept presented in this paper is based on using both information separately; DOA (direction of arrival) estimation using phase difference in azimuth and amplitude ratio for the elevation angle. Therefore both parameters have to be decoupled from each other to get unambiguous results regarding the position of the target. Fig. 1 shows a sketch of our concept to fulfil this demand, using two antennas which are displaced in the z- and y-direction against each other and feed a dielectric planoconvex cylindrical lens with two refracting surfaces. The azimuth angle is declared as α and the elevation angle as β in the following sections.

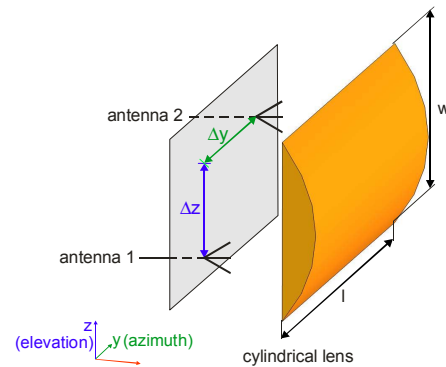


Fig. 1 Functional principle with two antennas and dielectric cylindrical lens

The displacement in the z-direction Δz results in a beam squint due to the optical behaviour of the lens. Because of the small outer dimensions of the lens compared to the wavelength, Fresnel numbers are low and diffraction effects lead to the possibility to use the amplitude ratio of the received signals in the region of beam overlap to measure the elevation angle. The offset in the y-direction Δy permits DOA estimations, since no optical beamforming is done by the lens in this direction; it only acts as a kind of dielectric cover (Fig. 2). A basic requirement to evaluate the phase difference for angular detection in azimuth is that no phase difference in the elevation direction occurs. The phase difference in elevation is strongly influenced by the spacing Δx between lens and antenna. A distance where no phase difference in the region of overlapping beams occurs, irrespective of the angle of incidence, is expected to be located in a minor offset behind the calculated focus distance, due to the curvature shape of the phase in relation to the incidence angle. A detailed discussion on this effect is described in [7].