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# A blind spot detection and warning system based on millimeter wave radar for driver assistance

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ABSTRACT

This paper proposed a blind spot detection and warning system named BSDW for driver assistance under daytime and nighttime conditions. The proposed BSDW system includes system architecture platform, radar hardware system structure, intermediate frequency signal processing, radar target detection algorithms, blind spot area calibration method, system control strategy and system integration. Line frequency modulated continuous wave millimeter-wave radar was used to detect moving targets which come into the rear blind spot alarm area, including left, right and behind area of the subject vehicle. Based on Rayleigh clutter distribution model, a cell greatest, smallest and averaging constant false-alarm rate target detection algorithm named CGSA-CFAR was proposed to maintain higher detection rate and lower false-alarm rate by adjusting power detection threshold in time based on the noise power level, which was estimated according to the proposed target detection algorithm. The proposed system was implemented on embedded hardware platform and verified on the Chery Arrizo7 vehicle. Under urban daytime and nighttime conditions, the early warning rates of the proposed system were up to 98.20% and 98.21% respectively. The results show that the proposed system can detect the targets which come into the rear warning area of the subject vehicle and give early alarm to driver effectively in various urban road environments.



## 1. Introduction

With the rapid development of vehicle electronic technology and more attention to driving safety, Vehicle advanced driver assistance system has become more popular. With the traffic accidents occur frequently in recent years, safe driving assistance systems have become one of the most hot and critical technologies. It can improve road transportation efficiency and decrease driving pleasure [1].

In future, safe driving assistance system will play a significant role in protecting driver and passenger safety and prevent traffic accident occurrence. Because of vehicles spot area, especial rear spot area and driver weak vision, traffic collision accident easily occur when driver change lanes. In order to resolve the problem, many scholars and scientists have used vision and radar technology to detection the targets which come into rear blind spot areas of the subject vehicle [2–5]. This study presents a vehicle blind spot detection and warning system named BSDWS which was a typical radar detection

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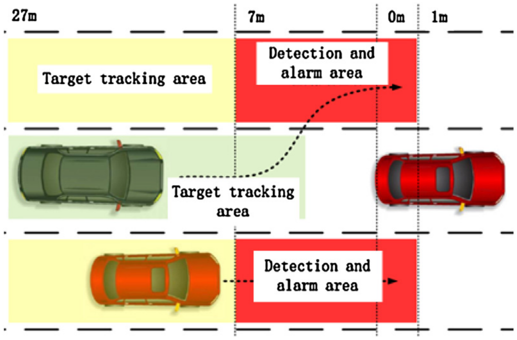


**Fig. 1.** View of the blind spot and target vehicle tracking area.

system. The propose BSDWS includes two radars which were installed left and right inside of rear bumper. The radar system can detect the targets which come into rear blind spot area and obtain target relativity distance, azimuth and speed [6]. The system control algorithm determines whether there are any collision risks in the rear blind spot area. The blind spot area was the viewing angle area on the left and right sides behind the vehicle. It was not covered by the external and internal mirrors, as shown in Fig. 1.The horizontal viewing angle of radar was 130° and vertical viewing angle was 18°. The detection area covered 30–50 m behind the vehicle and 3-3.5 m width on both sides, including behind 3 m and 3 m width blind spot warning area in both side. The left side blind spot area is smaller than right side blind spot area. Besides, the target vehicle tracking will improve system safety and give driver enough reaction time to avoid collision accidents [7]. The blind spot and target vehicle tracking areas are shown in Fig. 1.

The BSDW system required a longitudinal detection distance with a maximum range of 5.5–32.5m. The lane change assistant system named LCAS was the expansion system of the BSDW system. LCA system could reduce 15% to 40% side traffic collision accident [8].

The intermediate frequency analog signal that was returned by radar front end were filtered by analog band-pass filter, and then translated into digital signals which was filtered by digital filter and sent to the radar target detection algorithms. In order decide target position, the radar coordinate was firstly established and then translated into system coordinate which was based on installation angle and vehicle coordinate. When the radar system calibration is completed, targets information data can be efficiently obtained. Second, the boundary coordinate value of rear blind spot area will be calibrated. This study presented a solution which can eliminate target position in system coordinate and decide whether the target is in rear blind spot area or not? Then, based on the longitudinal distance between the subject and target vehicle, the system can estimate weather giving driver an early warning to avoid collision traffic collision accidents. System was implemented on an embedded hardware and software platform, including radar and control subsystems. The system was calibrated and tested on the Chery Arrizo7 car. Under urban daytime and nighttime conditions, the early warning rates were up to 98.38% and 98.34% respectively. The results show that the proposed BSDWS is feasible under daytime and nighttime urban conditions.

The contributions of the study are as follows: The proposed BSDWS is a radar-based system by using advanced millimeter wave radar technology; This study proposes a CFAR target detection algorithm which can improve detection rate in non-Gaussian clutter background environment; Additionally, the proposed BSDWS is implemented on an embedded platform for low cost. The proposed BSDW system has two radars, including master radar and slave radar which are mounted left and right insides of the rear bumper. The system are experienced and recognized by many users.

The paper is organized as follows. Section 2 presents related works in the field of blind spot detection and warning and lane change assistant technology. Section 3 presents system platform architecture. Section 4 presents signal processing and radar target detection algorithms. The system test and verification results are shown in Section 5. Finally, Section 6 offers the conclusions.

## 2. Related works

According to W. Scott Pyle, each year more than 926, 500 vehicles in entire world are involved in lane change traffic accidents because the driver is unaware of the vehicle which comes into the rear blind spot. In order to prevent the accidents, the BSDW system will be necessary.

Numerous experts and scholars have proposed many methods to solve this problem especially under the day and night urban condition. BSDW system has been developed and mainly use active sensor, include visual camera [9,10], millimeter wave radar and Lidar. The most system was implemented based on vision camera. It uses two cameras which are mounted both side under the wing mirror to capture images of the targets in either rear side of the vehicle [11]. Bingfei Wu [1], Lin and Xu [20] presented a vision-based method to implement BSDW system. Wong used six ultrasonic sensors to acquire the speed and position of the vehicle in the rear blind spot area. These images are analyzed by the visual system to determine whether there is a target present or not. Under nighttime environment, the camera can detect headlights to determine the presence of a vehicle target [1,2]. If a vehicle is detected, the system will give the driver early warning. Combined analysis of