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Performance Limits Analysis of Collision Detection System Based on Automotive Radar in Ramp

Hong Cho[1], Byeongwoo Kim[2,*]

[1] Graduate School of Electrical Engineering, University of Ulsan, 93 Daehak-ro, Ulsan, Republic of Korea
hong9life@gmail.com
[2] School of Electrical Engineering, University of Ulsan, 93 Daehak-ro, Ulsan, Republic of Korea
bywokim@ulsan.ac.kr

Abstract. A collision detection system with a radar sensor might not be able to detect a forward vehicle when the host vehicle is on a ramp road. In this study, we researched the performance limits of radar under various ramp road conditions. The degree of risk between the host and forward vehicles was determined using the time-to-collision value. The simulation results show that the collision risk index rapidly changes in accordance with the road gradient. In addition, the area of radar sensors' performance limits was quantitatively analyzed.

Keywords: Automotive Radar, Inclined Road, Collision Detection System, PreScan

1 Introduction

Recently, vehicle safety regulations for automobiles have been strengthened, mainly in advanced countries. In accordance with these reinforced legal regulations, automobile manufacturers have been actively conducting studies on an advanced driver assistance system (ADAS), which supports a driver using cutting-edge technologies for driving processes. An ADAS includes systems for blind-spot detection, lane departure detection and prevention, and automatic emergency braking [1, 2]. To implement these ADAS technologies, sensors are important to identify the surrounding environment. The typical vehicle-mounted sensors for identifying the surrounding environment include ultrasonic waves, radio detection and ranging (radar), light detection and ranging (lidar), and camera sensors. In particular, radar has been widely applied to ADASs because of its excellent vehicle identification performance under various weather environments [3].

Previous studies on radar have only considered its propagation loss characteristics and performance in distance measurement per frequency range on a road without ramps [4, 5]. Thus, it is necessary to analyze the performance of an automotive radar

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* Corresponding Author

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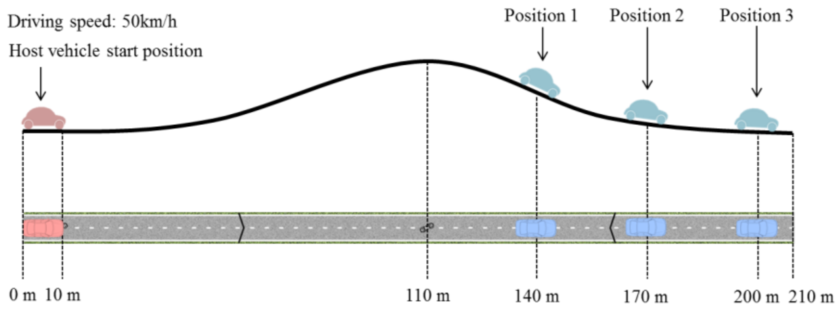

Fig. 1. Simulation scenario for performance limits analysis of automotive radar

sensor on a ramp.

Hence, this study analyzed the performance limits of a collision detection system based on an automotive radar sensor under various ramp conditions.

2 Performance limits analysis

2.1 Simulation configuration

In the scenario used to analyze the performance limits of the automotive radar sensor (Fig. 1), the host vehicle equipped with the radar sensor is driven from a start position (0 m) at a speed of 50 km/h. The target vehicle is in a stationary state (0 km/h) at positions 1, 2, and 3 on the ramp. For the simulation, ramps were modeled with inclines ranging from 1–12%, the maximum incline of normal roads.

Simulations were performed with the target vehicle at positions 1, 2, and 3 for each ramp modeled. In this study, the collision risk between the host and target vehicles was determined using the time to collision (TTC), which was calculated using the ratio of the relative velocity to relative distance with respect to the target vehicle. A smaller TTC value showed a greater risk.

2.2 Simulation results

Fig. 2 illustrates the simulation results at the established positions on each ramp.
The simulation result of Fig. 2(a), for which the incline is 1%, indicates that the radar sensor of the host vehicle could detect the target vehicle in front of it at all positions because of the significantly low gradient, thereby determining the collision risk with the front vehicle in all zones.

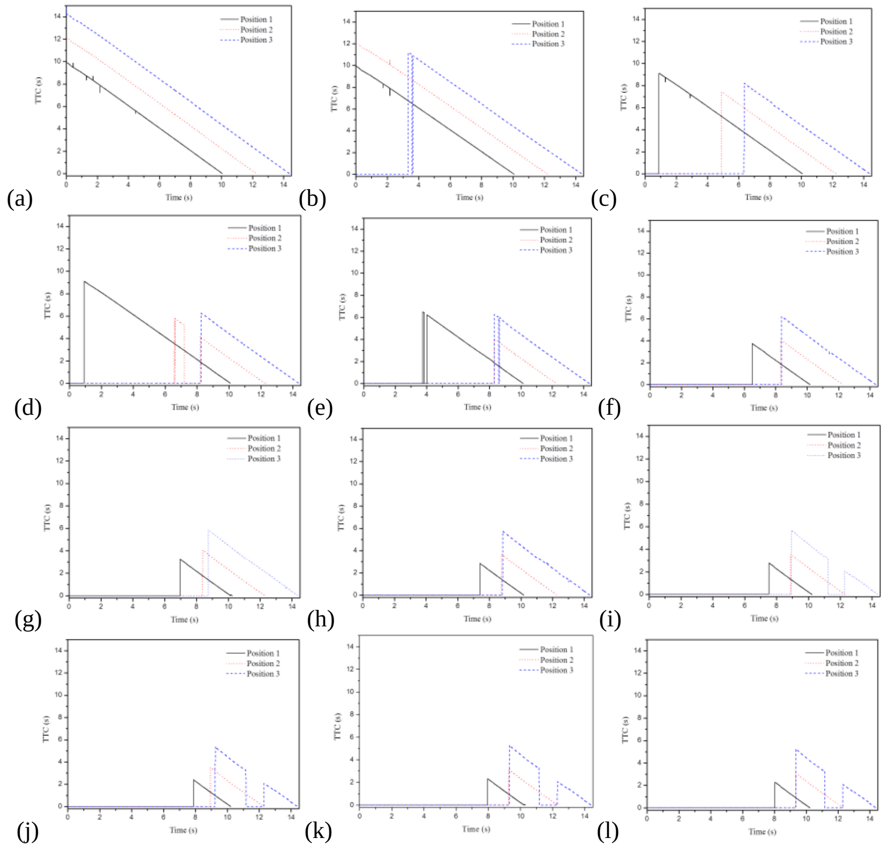

Fig. 2. TTC changes in each ramp: (a)1%, (b)2%, (c)3%, (d)4%, (e)5%, (f)6%, (g)7%, (h)8%, (i)9%, (j)10%, (k)11%, (l)12%

However, Fig. 2(b), for which the incline is 2%, demonstrates that the radar sensor of the host vehicle could not detect the front target vehicle at position 3 due to the gradient of the road. Thus, it failed to determine the collision risk in certain zones. The simulation results of Fig. 2 confirm that a greater gradient results in a greater number of zones in which the radar sensor of the host vehicle cannot detect the front vehicle. Moreover, at position 1 with an incline of 10% or more, the front vehicle was only detected when the TTC was approximately 2 s or less. Because the TTC is the relative velocity to relative distance ratio, if the relative velocity is greater than the established simulation value (50 km/h), the TTC value calculated by the radar sensor will decrease further. A smaller TTC value signifies a more risky situation, in which the two vehicles are about to collide with each other. Thus, it is considered that an ADAS for collision avoidance will not normally be effective in preventing collisions when sudden TTC changes occur.

3 Conclusion

In this study, a performance limit analysis of an automotive radar sensor was conducted using ramps. Target vehicle simulations were performed at different positions and inclines up to the maximum incline of normal roads. The results verified that as the gradient increased, the number of zones in which the radar sensor of the vehicle could detect the front vehicle decreased. It was also confirmed that the TTC value calculated by the radar sensor was detected only when a collision with the front vehicle was about to occur for an incline of 10% or more. This result indicates that even if a host vehicle is equipped with a TTC-based ADAS to prevent collisions, collision avoidance control cannot be perfectly performed because of sudden TTC changes. Further studies on a collision detection system applying inter-vehicular communication will be conducted to overcome the limitations of vehicle-mounted sensors such as an automotive radar sensor on a ramp.

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