On Comparing Radar Performance and Conducting Their Assessment Tests

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Abstract. The present article deals with the initial stage of integration of the automatic emergency braking system to the vehicle. The analysis of directives and regulations demands is carried out. The methodology of comparative testing of automobile radars as a part of a vehicle is clearly shown. Basing on the test results, the authors tried to estimate the influence of environmental elements of an automotive radar installed in a car on basic radar characteristics for detecting targets. Further actions are suggested to evaluate the performance of car radars necessary for rational selection of the model itself and the manufacturer of this sensor, which would be important for subsequent development and integration of automatic braking systems and adaptive cruise control.

Key words: ADAS, Automatic Emergency Braking, automotive radar, object detecting, testing, comparison.

Many active driver assistance systems (ADAS), which control speed and direction of the vehicle in automatic mode, are becoming a typical option in a modern car. Taking into consideration positive influence on improving road safety, many ADAS systems are included in the list of vehicle systems required to obtain vehicle type approval and, after the transition period is over, their presence is necessary for vehicle registration. At present, in the countries of the European Union (EU), for registration of vehicles of categories N2, M2 (class B), N3, M3 (class III), it is required to have AEB (Automatic Emergency Braking) [1] and LDWS (Lane Departure Warning System - warning about an unintentional exit from a lane) [2]. The LDWS function does not imply control of the speed and direction of movement of the vehicle and only performs a driver warning. The AEB function must control the deceleration of the car and, accordingly, interact with the braking system, as well as interrupt the fuel supply to the internal combustion engine (ICE) for more effective braking. For cars with automatic transmission, it is also possible to interrupt the transmission of the torque to the wheels of the car by performing control signals from the AEB function. Thus, in the event of misfiring or malfunction resulting in incorrect control signals, the AEB function is potentially more dangerous than LDWS, due to its control interaction with the main vehicle systems. For this reason, all design decisions related to the integration of the AEB function in the vehicle should be carefully checked, including through functional and road tests.

Choosing an AEB detection sensor or a combination of sensors is the first fundamental step in implementing a system. The more justified is the choice of the type and model of a detection sensor at the stage of developing a system concept, the less likely are changes in the system and its environment during development, which in turn entails significant time and material costs. According to the data from open sources and basing on the functional features of various sensors [3-5], the main sensor for detecting the AEB function on foreign cars is a radar located in the elements of the front of the car [6-9]. For this reason, the present work is devoted to solving the problem of rational choice of the radar model, taking into account its...
functioning in the vehicle, as well as the minimum functional assessment of the elements of the environment of the radar in a car.

The main performance characteristics of automobile radars are [5]: a distance range and angle range (azimuth and elevation), distance (angle and velocity) measuring resolution, accuracy of measuring, velocity range. The current regulatory document that regulates the functional requirements for the function of the AEB for the Russian Federation is UN Regulation No. 131 [10]. Therefore, the provisions of the Rules were taken into account when developing a test procedure for checking the above characteristics of automobile radars.

Functional tests were carried out at a specialized training ground. Functional races for a vehicle equipped with a radar are shown in Fig. 1. Before the start of the functional phase of the tests, the vehicle was accelerated to a speed of 80 km / h. The functional stage of the tests ended when the indicated distance was reduced to the minimum value at which the vehicle can be dodged or braked to avoid a collision with the target. To check the detection distance $\mathbf{R}$ and the viewing angle in azimuth $\varphi$, the target in different races should be located differently in the places marked with numbers in Figure 1. Verification of the vertical viewing angle is possible when changing the radar setting on the car - turning it 90 °. Functional rides are performed separately for stationary purposes (car, pedestrian) and separately for moving targets (car speed of 12 km / h, pedestrian - 5 km / h).

![Figure 1. Scheme of functional races when testing automobile radars as part of a vehicle](image)

Verification of the minimum detection distance by radar is performed by approaching the vehicle with the target (in accordance with Figure 1) at the lowest possible steady speed. After the target disappears from the radar's field of view, the functional vehicle slows down to a complete stop.

Two radars participated in the tests examined: Continental ARS 408 and MARS –2A1 / 10 (manufactured by Milander). A CAN adapter was used to communicate with the Continental ARS 408 radar. The MARS –2A1 / 10 radar was connected to a laptop computer via an Ethernet connection. A multifunctional speed meter Racelogic VBOX 3i RTK was used to measure the dynamics of a functional vehicle. The change in the relative position between the functional vehicle and the target was recorded using two telemetry kits and a Racelogic DGNSS RTK base station. The listed equipment and radars were checked sequentially in the design of the GAZelle Next and GAZon Next automobiles. Fragments of testing and installing measuring equipment on prototypes are shown in Fig. 2-3.
According to the results of processing data from radars, after testing, estimates of the trajectories of the objects (car, pedestrian) in the Cartesian coordinate system with the center at the location of the radar were obtained. From the presented results of detection and trajectory tracking of objects, it can be seen that the car is easily detected by radars at distances of 250 m or more (Fig. 3), and the pedestrian - at distances of up to 100 m (Fig. 4).

**Figure 2.** Fragments of functional tests of radars in GAZelle Next: a,b – Installation measuring equipment; c – General view of the prototype with an automotive radar installed in the front
Figure 3. The target of the detection is a car. Results of the trajectory tracking of the car with frontal radars:
   a) ARS 408, b) MARS –2A1/10

Figure 4. Results of the trajectory tracking of the pedestrian with frontal radars:
   a) ARS 408, b) MARS –2A1/10

The results obtained from the tests led to the conclusion that the estimated characteristics of the radars are fully consistent with the information specified by the manufacturer. The environment elements of radars installed on cars do not reduce the performance of these components.

The next step in assessing the performance of car radars is to test them as part of a car on public roads. In this case, the car must be equipped with a video camera. Video recording must be synchronized in time with the transmission of data from the radar. This test setup allows you to estimate the number of false targets captured by the radar, as well as the detection of targets that present a danger of collision in more difficult road conditions, compared with the polygon tests.

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