The fourth generation long-range radar sensor (LRR4) builds upon all of the expertise and experience gathered during the development and manufacturing of the previous three radar generations. Together with mid-range radar sensors, MRR and MRR rear, Bosch offers tailored solutions designed to enable standard use of radar sensors across all vehicle segments.

The LRR4 allows vehicle manufacturers to implement a range of safety and driver assistance functions in their vehicles in order to fulfill the ever-increasing safety standards set by legislators and consumer protection organizations. From 2014, manufacturers striving to obtain the highest rating (five stars) under the Euro NCAP assessment scheme (European New Car Assessment Program) must equip their new models with at least one driver assistance system, and automatic emergency braking systems are high on the list of priorities.

**Features and mechanical design**

The LRR4 is a monostatic multimodal radar that has six fixed radar antennae. The central four antennae feature optimum properties for recording the vehicle’s surroundings at higher speeds. They create a focused beam pattern with an opening angle of ±6 degrees, providing excellent long range detection with minimal interference from traffic in adjacent lanes. In the near range, the LRR4’s outer two antennae expand the field of view to ±20 degrees at a distance of up to five meters, making it possible to quickly detect vehicles entering or leaving the vehicle’s lane.

**Customer benefits**

- Independent mode for height measurement using an elevation antenna, enabling the system to reliably classify obstacles and brake safely, even when the object is stationary
- Can be used in high-speed environments
- Self-calibration function (horizontally) for ease of installation
- Compact size for easy integration into the vehicle
- Scalable system performance with multiple sensor configurations including sensor data fusion (optional)
- Sensor performance unaffected by harsh weather conditions (snow and ice) due to optional lens and radome heating
- Can be concealed behind the bumper/radome
- No moving parts, ensuring a high degree of robustness against vibrations
- High-speed CAN and FlexRay interfaces enable easy integration into the vehicle
The LRR4 is very compact thanks to the high degree of electronic component integration. The compact design allows open integration in the front grill area or concealed installation behind the front fascia or radome with minimal impact on the design of the vehicle. In addition, the LRR4 enables more packaging flexibility compared to the previous generation by offering a horizontal mounting tolerance of ±2 degrees.

The LRR4 is equipped with a horizontal self-calibration function. Once the sensor has been mounted in the vehicle, it automatically searches for reference points during the first journey, and then uses these reference points to calculate the misalignment from the vehicle drive axis. The system software then compensates for this misalignment. While the system is „learning“ this reference information, certain functions may be deactivated or restricted. In order to achieve maximum performance on delivery, the system must be calibrated during the final stages of series production using a defined reference point. Time-consuming and expensive mechanical sensor calibration processes are not required.

The electrical interface, the pin configuration of the vehicle connector and the location of the optional mirror for optical sensor alignment can all be adapted to meet customer-specific requirements. Thanks to the robust sensor design with no moving parts, the LRR4 can be used across all vehicle segments.

Optionally, two LRR4 sensors can be designed into the vehicle. An optional heated lens or radome ensures full sensor availability, even in poor weather conditions, such as snow and ice.

### Operating principle
The radar sensor’s main task is to detect objects and measure their speed and position relative to the movement of the vehicle in which it is mounted. To do this, the LRR4 sends frequency-modulated radar waves in a frequency range of 76 to 77 GHz via its transmitting antenna. These waves are reflected by objects in front of the vehicle. The relative speed and distance between the vehicle and other objects are determined on the basis of the Doppler effect and the delay. Both generate frequency shifts between the sent and received signal. By comparing the amplitudes and phases of the radar signals measured at the receiving antennae, it is possible to determine the position of the object.

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**Technical features**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency range</td>
<td>76...77 GHz</td>
</tr>
<tr>
<td>Detection range</td>
<td>0.36...250 m</td>
</tr>
<tr>
<td>Field of view</td>
<td></td>
</tr>
<tr>
<td>Antenna (single beam)</td>
<td></td>
</tr>
<tr>
<td>Horizontal (typ.)</td>
<td>±6° (200 m) ±10° (100 m) ±15° (30 m) ±20° (5 m) ±4.5° (200 m)</td>
</tr>
<tr>
<td>Vertical (typ.)</td>
<td></td>
</tr>
<tr>
<td>Measuring accuracy</td>
<td></td>
</tr>
<tr>
<td>Distance</td>
<td>±0.12 m</td>
</tr>
<tr>
<td>Speed</td>
<td>0.11 m/s</td>
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<tr>
<td>Angle</td>
<td>±0.1...±0.3°</td>
</tr>
<tr>
<td>Object separation capability</td>
<td></td>
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<tr>
<td>Distance</td>
<td>0.72 m</td>
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<tr>
<td>Speed</td>
<td>0.4 m/s</td>
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<tr>
<td>Angle</td>
<td>4°</td>
</tr>
<tr>
<td>Max. number of detected objects</td>
<td>24</td>
</tr>
<tr>
<td>Cycle time</td>
<td>60 ms</td>
</tr>
<tr>
<td>Modulation</td>
<td>Frequency modulation (FMCW)</td>
</tr>
<tr>
<td>Dimensions (W x H x D) in mm</td>
<td>78 x 81 x 62 (without connectors) 78 x 101 x 62 (with connectors)</td>
</tr>
<tr>
<td>Weight</td>
<td>~240 g</td>
</tr>
<tr>
<td>Power consumption</td>
<td>Typ. 4.5 W</td>
</tr>
</tbody>
</table>

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**Elevation antenna for height measurement**

- **Elevation antenna**
- **Main antenna**

In order to intervene early on and reduce higher speeds in critical, dynamic situations, such as if the vehicle ahead brakes sharply and unexpectedly, the LRR4 features an additional upward elevation beam. This beam enables the LRR4 to measure the height of all objects in order to reliably classify relevant objects and determine whether the vehicle can drive under or over them. In conjunction with its innovative signal processing algorithms, this feature enables the system to cope with complex traffic situations and brake reliably, even in the case of stationary objects.
Areas of application
The LRR4 is the foundation on which a range of safety and driver assistance functions can be implemented. The LRR4 can be used for the following functions:

Predictive emergency braking system
With the LRR4, vehicle manufacturers can meet the requirements for the automatic emergency braking systems „AEB City“ and „AEB Inter-Urban“ as outlined in the Euro NCAP assessment scheme. With its predictive emergency braking system, Bosch is helping to prevent rear-end collisions and reduce the severity of crashes. The system becomes active as soon as the vehicle is started, and supports the driver at all speeds — both day and night.

If the predictive emergency braking system detects that the distance to the preceding vehicle is becoming critically short at a vehicle speed above 30 km/h (18 mph), it prepares the braking system for potential emergency braking. If the driver does not react to the hazardous situation, the system warns the driver via an audible and/or visual signal, followed by a short but noticeable brake jerk.

The system then initiates partial braking to reduce the speed and give the driver valuable time to react. As soon as the driver presses the brake pedal, the system provides braking support. To do this, the system continuously calculates the degree of vehicle deceleration required to avoid the collision. If the system detects that the driver has failed to apply sufficient brake force, it increases the braking pressure to the required level so that the driver can attempt to bring the vehicle to a standstill before a collision occurs.

If the driver fails to react to the immediate risk of collision, and the predictive emergency braking system determines that a rear-end collision is unavoidable, it can — working in conjunction with a video camera — automatically initiate full braking. As a result, the vehicle is traveling at a significantly reduced speed when the collision occurs, reducing the severity of the crash for the passengers of both vehicles.

If the predictive emergency braking system detects that the distance to a moving or stationary vehicle in front is becoming critically short at a vehicle speed below 30 km/h (18 mph), it prepares the braking system for potential emergency braking. If the driver fails to react to the critical situation, the system can automatically initiate full braking in an attempt to prevent the collision. If the rear-end collision is unavoidable, this action can at least minimize the severity of the collision, reducing the risk of injury to the passengers of both vehicles.

Adaptive cruise control (ACC)
With a range of up to 250 meters and a variable field of view, the LRR4 makes it possible to detect vehicles in front and vehicles merging at an early stage — making it the ideal basis for ACC systems. At speeds of up to 200 km/h (124 mph) and a maximum relative speed of up to 100 km/h (62 mph), the system automatically maintains a set distance from the vehicle ahead by automatically reducing the power to the engine, braking or accelerating. The ACC stop & go variant can also automatically apply the brakes until the vehicle comes to a standstill and will resume when instructed by the driver.

Traffic jam assist
Traffic jam assist helps drivers to reach their destinations as comfortable as possible, even when traffic is congested. In combination with a video camera, the partially-automated driver comfort function controls the longitudinal and lateral movements of the vehicle. If the driver assistance system detects congested or slow-moving traffic at speeds below 60 km/h (37 mph), the driver can activate the function at the push of a button. The vehicle then automatically follows the vehicle in front, and takes over starting, accelerating, braking and steering in its own lane. The system detects the way in which the vehicle in front is driving and adapts accordingly. If it is necessary to change lanes or if irregular obstacles are detected in the lane, the system returns control to the driver.

The driving corridor in which the traffic jam assist controls the vehicle permits a certain offset to the vehicle ahead. The radar sensors detect not only the vehicle ahead but also surrounding vehicles, enabling the system to calculate a driving corridor, even in the absence of lane markings. The driver retains full responsibility for controlling the vehicle and must monitor the system in order to take over control of the vehicle at any time.

In the future, this assistance system will cover higher speeds and more complex driving situations, including automatic lane changes.
Left turn assist
This assistance system continuously monitors the traffic situation ahead of the vehicle. If the vehicle is at a standstill in anticipation of a left turn, and the system detects the risk of a collision with oncoming traffic, the driver is automatically prevented from pulling out until the vehicle posing the risk has passed. If the vehicle is already moving, a warning is issued to the driver at the point at which the system detects the dangerous turning situation.

Integrated cruise assist
This partially-automated function supports the driver in highway driving situations by combining ACC-based longitudinal guidance with the lateral guidance provided by the video-based lane keeping support. Integrated cruise assist can be supplemented with an automatic lane change function, which requires the driver only to indicate a desire to change lanes using the turn signal. Then the system performs the maneuver as soon as it is safe to move into the adjacent lane. This technology requires additional radar sensors to monitor the traffic to the rear and side of the vehicle. Integrated cruise assist provides the driver with extended, partially-automated system support, even at higher speeds, allowing the driver to perform secondary activities that are unrelated to actual driving. However, the driver retains full responsibility for the vehicle and must be able to take over control of the vehicle at any time.

Evasive steering support
Emergency braking is not always sufficient, or may not be the best option to prevent a collision. For example, the laws of physics dictate that rear-end collisions at high approach speeds can only be prevented through evasive maneuvers once the vehicles have passed a certain distance threshold. In this case, the system provides information about a suitable evasion path, and, if necessary, automatically initiates an evasive maneuver. In urban traffic, the evasive steering support can automatically initiate an evasive maneuver, for example, if a car door opens suddenly in the path of the vehicle or if a pedestrian steps out into the road from behind an obstacle. The vehicle does not move beyond the boundaries of its own lane to perform the evasive maneuver. In later stages of development, evasive steering support will be combined with a stereo video sensor in the front of the vehicle to detect fast-moving oncoming traffic, as well as radar sensors in the rear of the vehicle to detect approaching or passing vehicles, thereby allowing the system to steer the vehicle into the opposite lane to prevent an impending rear-end collision.

Sensor data fusion
Sensor data fusion in the LRR4 is possible without the need for additional hardware. When compared to its predecessor, the LRR4 features higher computing power for sensor data fusion involving multiple sensors.

Sensor data fusion combines the benefits of different sensors and measuring principles in the most effective way possible, thus providing data that individual sensors working independently are unable to generate. Data fusion of multiple sensors increases the measurement reliability, range and accuracy.

Video sensors, such as the multi purpose camera or the stereo video camera from Bosch, are the ideal supplement to radar technology. Using sophisticated software algorithms, the fusion of sensor data generates an extremely detailed “image,” which forms the basis for a powerful interpretation of the vehicle’s surroundings.

Sensor data fusion enables the implementation of additional assistance and safety functions, such as pedestrian protection (“AEB Pedestrian”). The function for predictive pedestrian protection meets the safety requirements as specified by Euro NCAP. It continually monitors, in combination with a video camera, the area in front of the vehicle in order to detect impending collisions with pedestrians who are in the path of the vehicle or moving toward it in a way that is likely to present a risk. If the function detects that pedestrians are at risk, it can actively trigger application of the brakes in order to considerably reduce the risk and the consequences of the collision, or to prevent the accident altogether.

Sensor data fusion can also be used to significantly improve the performance of comfort functions. Thanks to the high degree of lateral measuring accuracy of a video camera, the ACC function is able, for example, to detect vehicles merging at an earlier stage, and, therefore, respond in a more dynamic manner. The system also ensures that vehicles in front are assigned to the correct lanes, which further enhances ACC functionality, especially when cornering.