Chassis Systems Control

Mid-range radar sensor (MRR) for front and rear applications

BOSCH
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Customer benefits

- Digital beam forming (DBF) for flexible antenna use and high accuracy throughout the angular range
- Independent mode for height measurement using an elevation antenna, enabling the system to reliably classify objects and brake safely, even when the object is stationary
- Cost-effective design means that the system can be installed as standard across all vehicle segments
- Tailored solutions thanks to flexible design principle
- Self-calibration function reduces fitting costs
- Small size for easy integration into the vehicle
- Can be concealed behind the bumper
- No moving parts, ensuring a high degree of robustness against vibrations
- Sensor data fusion in MRR possible without additional hardware (optional)
- High-speed CAN and FlexRay interfaces enable easy integration into the vehicle
- Uses universally accepted frequency of 76 – 77 GHz – bringing a range of benefits to the user

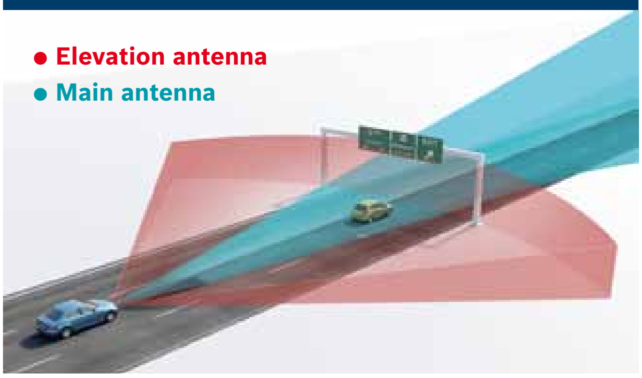
Bosch is expanding its portfolio in the radar sensor sector to include the mid-range radar sensor (MRR). This sensor allows vehicle manufacturers to implement a range of driver assistance functions in their vehicles in order to fulfill the ever-increasing safety standards set by legislators and consumer 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, with automatic emergency braking systems high on the list of priorities. The United States and Japan are also discussing whether to include similar criteria in their own national NCAP rules.

The basis for each MRR variant is the expertise and experience gained by Bosch from developing and manufacturing three previous radar generations. The MRR features a cost-effective and scalable design, which makes it possible for Bosch to offer tailored solutions so that the radar sensor can be installed as standard across all vehicle segments. The MRR forms the basis for a range of safety and comfort driver assistance functions that can increasingly be offered in medium-sized and compact classes at competitive prices.

Features and mechanical design

The MRR is a bi-static multimodal radar with four independent receive channels and digital beam forming (DBF). These technologies allow the MRR to be configured with independent antennae for different directions, which improves the angular measurement accuracy and means that the radar's field of view can be adjusted depending on the situation.

Technical features	MRR	MRR *rear*
Frequency range	76 ... 77 GHz	76 ... 77 GHz
Detection range	0.36 ... 160 m	0.36 ... 80 m
Field of view (horizontal) Main antenna	 ±6° (160 m) ±9° (100 m) ±10° (60 m)	 ±5° (70 m, main beam direction) ±75° (close range)
Elevation antenna	±25° (36 m) ±42° (12 m)	
Measuring accuracy Distance Speed Angle	 0.12 m 0.11 m/s ±0,3°	 0.12 m 0.14 m/s ±0,8°
Object separation capability Distance Speed Angle	 0.72 m 0.66 m/s 7°	 0.72 m 1.4 m/s 7°
Cycle time	~60 ms	~60 ms
Modulation	Frequency modulation (FMCW)	Frequency modulation (FMCW)
Max. number of detected objects	32	32
Dimensions (W x H x D) in mm	70 x 60 x 30 (without connectors) 70 x 82 x 30 (with connectors)	70 x 60 x 30 (without connectors) 70 x 82 x 30 (with connectors)
Weight	~190 g	~190 g
Power consumption	4.5 W	4.5 W



By focusing the main antenna on a narrow main lobe with an opening angle of ±6 degrees, the system is capable of reacting to vehicles in front at long range (up to 160 meters) and performing exceptionally well at higher speeds while also minimizing interference from vehicles in adjacent lanes. Thanks to the elevation antenna, the system achieves an opening angle of ±42 degrees at close range – so a pedestrian stepping out into the road from behind a parked car, for example, is detected at an early stage.

The high level of integration of the sensor and control unit functionalities, along with the compact design and space-saving planar antennae, mean that the system can be easily integrated into vehicles. The MRR can be concealed in the bumper or fitted in the radiator grill of the vehicle, with minimal impact on the design or cooling air flow.

The MRR variants are equipped with a function for self-calibration. Once the sensor has been fitted in the vehicle, it automatically searches for reference points during the first journey, and then uses these reference points to calculate the sensor axis deviation from the dynamic driving axis. The system software then compensates for this deviation. 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.

Thanks to the robust sensor design, which does not have any mechanical moving parts and features a high tolerance for vibration, the MRR can be used across all vehicle segments. Radome heating is available as an option for the front MRR variant – guaranteeing high sensor availability, even in poor weather conditions, such as snow and ice. On request, a mirror is available for optical sensor orientation.

The MRR uses the frequency band of 76–77 GHz, which is universally accepted for radar applications throughout the automotive sector. Thanks to its triple carrier frequency, a 77 GHz sensor requires only a third of the antenna surface of an existing 24 GHz model in order to cover the same field of view at the same resolution. This means that the sensor is significantly smaller, making it well suited to installation in compact vehicles. The triple frequency also supports the system when measuring speed based on the Doppler effect, producing results that are three times more accurate than measurements from a 24-GHz version. This high level of accuracy means that the 77 GHz sensor is able to intervene at an earlier stage and reduce higher speeds in critical, dynamic situations, for example, if the vehicle in front brakes sharply and unexpectedly.

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 fitted. To do this, the MRR sends frequency-modulated radar waves in a frequency range of 76 to 77 GHz via the transmitting antenna. These waves are reflected by objects in front of or behind the vehicle. The relative speed and distance between the vehicle and other objects is 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 by the four antennae, it is possible to infer the position of the object.

Mid-range radar sensor variants

Bosch is developing front and rear versions of the MRR. These sensors form the basis for a wide range of safety and driver assistance functions.

MRR

The MRR uses an elevation antenna to generate an additional upward elevation beam. This additional beam enables the MRR to measure the height of all detected objects in order to reliably classify relevant objects and determine whether the vehicle can drive under or over them. In conjunction with the 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.

The MRR can be used for the following functions:

- **Predictive emergency braking system**

  With the MRR, 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 accidents. 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 determines 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 detects 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 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 a potential emergency braking procedure. 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 160 meters and variable field of view, the MRR 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 150 km/h (93 mph) and a maximum relative speed of up to 80 km/h (50 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 automatically when instructed by the driver.

- **Heading distance indicator**

  This function measures the distance from the vehicle ahead and, depending on the speed at which the vehicle is traveling, warns the driver when the safe distance from the vehicle in front is not being maintained. The function does not intervene independently, but instead informs the driver of the distance from the vehicle in front via a visual and/or audible signal.

MRR *rear*

The MRR *rear* version monitors the area next to and around the rear of the vehicle, reliably detecting vehicles in the driver's blind spot as well as traffic approaching from behind. Two sensors, one to the left and one to the right, are concealed in the rear bumper of the vehicle. The sensors are angled outward at approximately 45 degrees and can detect objects at a distance of up to 80 meters.

The MRR *rear* can be used for the following functions:

- **Lane change assist**
  Lane change assist can prevent critical situations that occur when changing lane, reducing the risk of accidents. The feature meets ISO standard 17387:2008, type III "lane change warning", type C. When the system detects vehicles in the driver's blind spot or vehicles approaching quickly from behind, it gives drivers a warning, for example, by displaying an illuminated symbol around the side mirror. If the driver indicates before changing lanes, the system can also emit an audible and/or haptic warning to make the driver aware of potential hazards.

- **Rear cross traffic alert**
  Rear cross traffic alert supports the driver when reversing out of transverse parking spaces, even if the driver's view is obstructed by obstacles. If vehicles are detected crossing to the left or right within 50 meters, the function issues an audible and/or visual warning to alert the driver to the impending risk of collision.

Sensor data fusion

The MRR can utilize sensor data fusion without the need for additional hardware. Sensor data fusion combines the benefits of different sensors and measuring principles in the most effective way possible, providing data that individual sensors working in isolation are unable to generate. Fusion of multiple sensors increases the measurement range, reliability 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 powerful 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 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.

Robert Bosch GmbH
Chassis Systems Control

Robert-Bosch-Allee 1
74232 Abstatt
Germany

www.bosch-mobility-solutions.com

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