Technical Description

-Adaptive Cruise Control-

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0. Structure

1. Definition and function

What is an Adaptive Cruise Control?

The Adaptive Cruise Control (ACC) is a modern cars system to keep the right distance to the preceding car automatically constant. It’s a significant function extension to the conventional cruise control and a huge relief for the driver, because gas- and brake pedal operations are strongly reduced. Also speed limits and safety distances are safely maintained.

On which principles is the ACC based on?

The basic operation of the adaptive cruise control is to ensure variable safety distance to a preceding vehicle. This distance is selectable by the driver.

Radar (**r**adio **d**etecting **a**nd **r**anging) sensors send out radar waves to detect the situation in front of the car. By receiving the reflected signals the system is able to calculate distance and direction of cars driving ahead. As a result, adaptive cruise control is able to accelerate or decelerate the vehicle. For reasons of comfort the brake force, on which the ACC has access, is reduced to 25% of the maximum brake force of the vehicle.

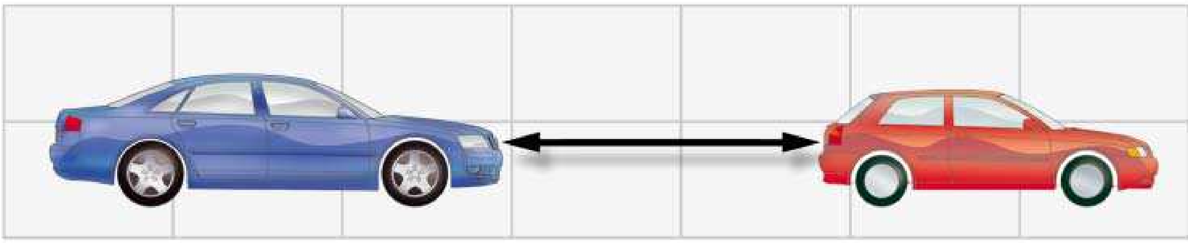
Limitations of the system:

- The ACC does not react on standing objects
- The operation of the radar technology is worsened by rain, spume and slush
- The adaptive cruise control regulates in a speed range of 30-200 km/h
- Adaptive cruise control is a driver assistance system and no security system
- It is not possible to use the system as an “autopilot”
- Tight bends may cause functional restrictions due to the limited visual range of the radar

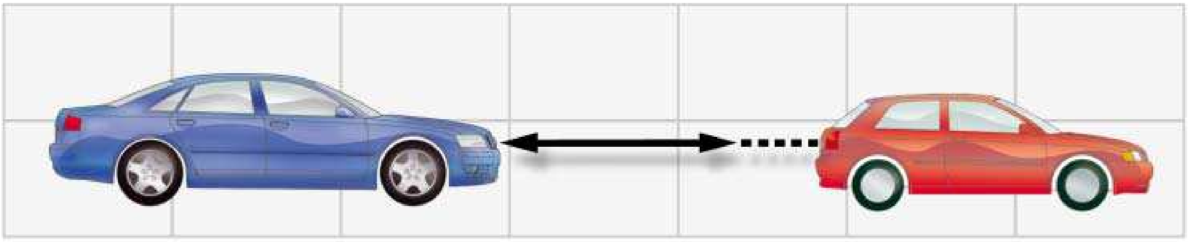
2. Requirements for Adaptive Cruise Control regulation

The following information is relevant for the system to work properly:

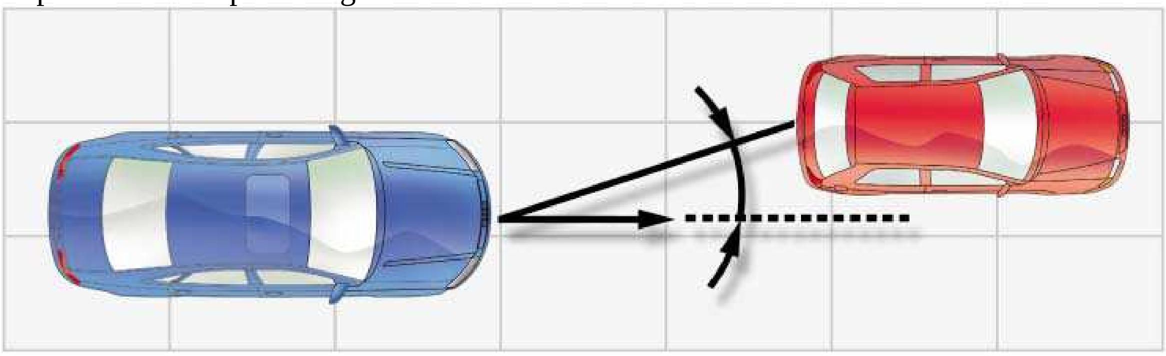
The distance to the preceding vehicle:



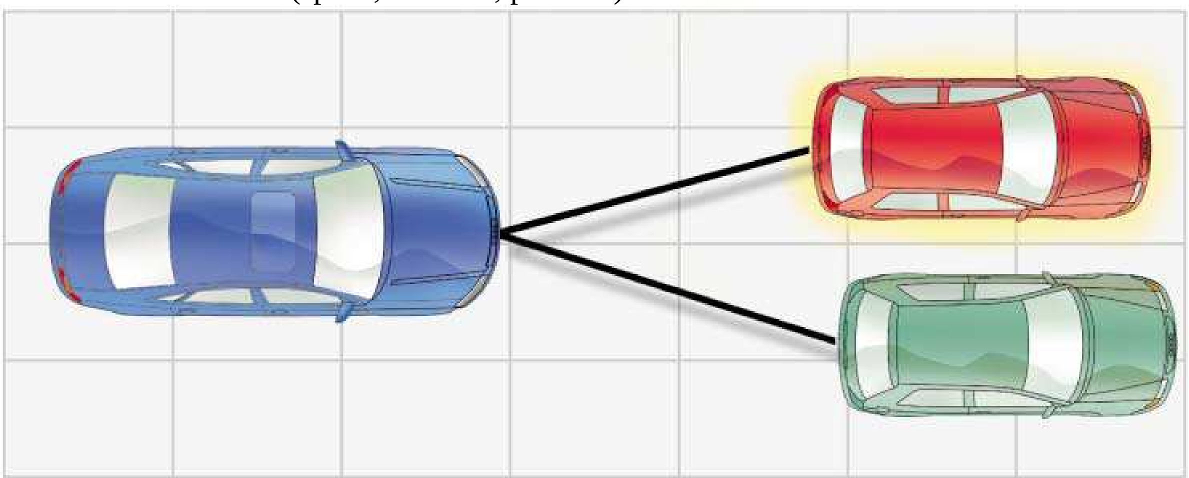
The speed of the preceding vehicle:



The position of the preceding vehicle:



If several vehicles occur in the radars field of view at the same time, the system uses the mentioned information (speed, distance, position) to select one of them:

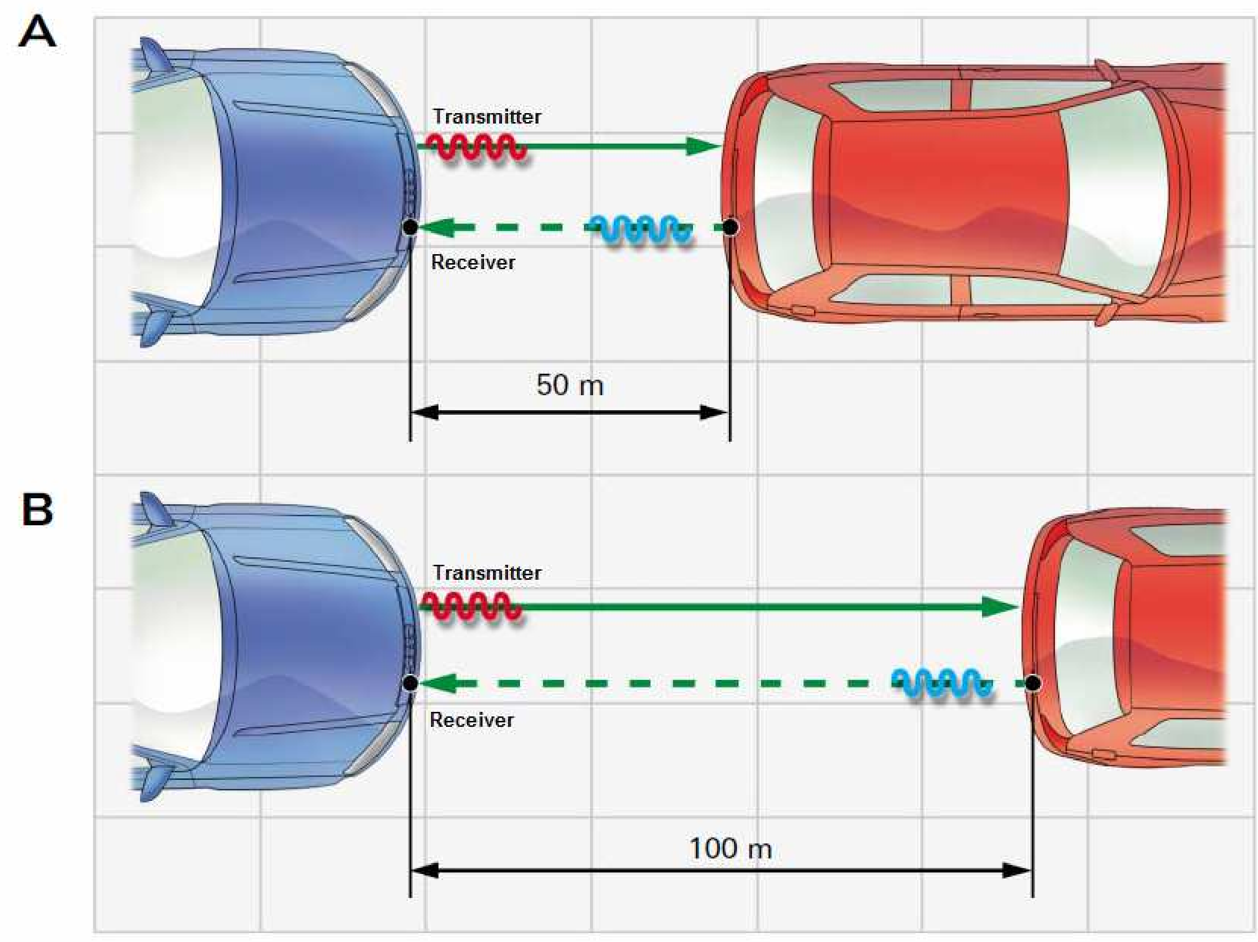


3. Physical principles of the ACC/measurement methods

As mentioned in the definition the radar technology is an important cornerstone of the adaptive cruise control. It's an electronic method for determining the position or the speed of objects. Electromagnetic waves with a specific frequency are sent out by a transmitter. These waves are reflected by the surfaces of objects. The reflected radiation components are recognized as an "echo".

a) Distance measurement

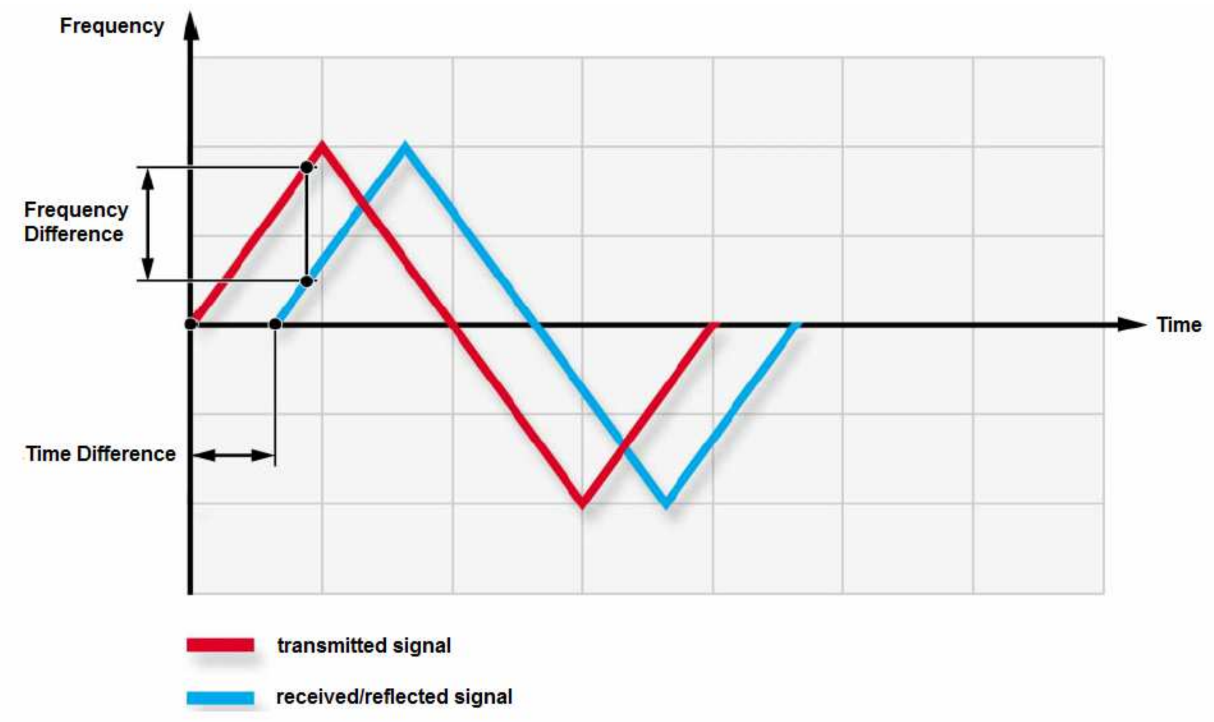
The time between transmitting the signal and receiving the reflected signal components depends on the distance of the object.



For example: The distance in picture B is twice as large as in picture A. The period of time until the reflected signal reaches the receiver in picture B is also twice as large as in picture A.

The ACC uses an indirect time measurement to calculate the distance, which is called FMCW (**F**requency **M**odulated **C**ontinuous **W**ave)-method. The high-frequency oscillations sent out by the transmitter are variable over time and the change of frequency (modulation) is 200 MHz within a millisecond. So the transmitted frequency differs from the received frequency. As "Mode of Transport" a carrier signal having a frequency of 76.5 GHz is used.

The difference between the frequencies of the transmitted and received (reflected) signal is directly dependent on the distance of the object. The greater the distance, the longer the "run time" until the reflected signal is received again. The difference of the frequencies is increasing too.

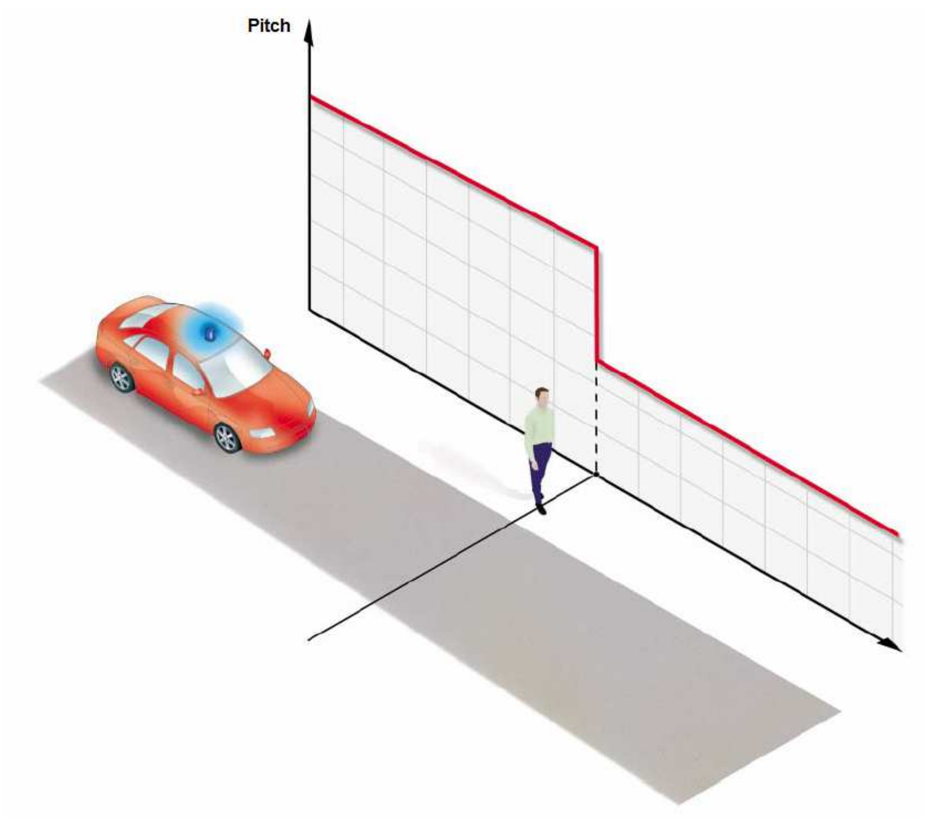


b) Speed measurement

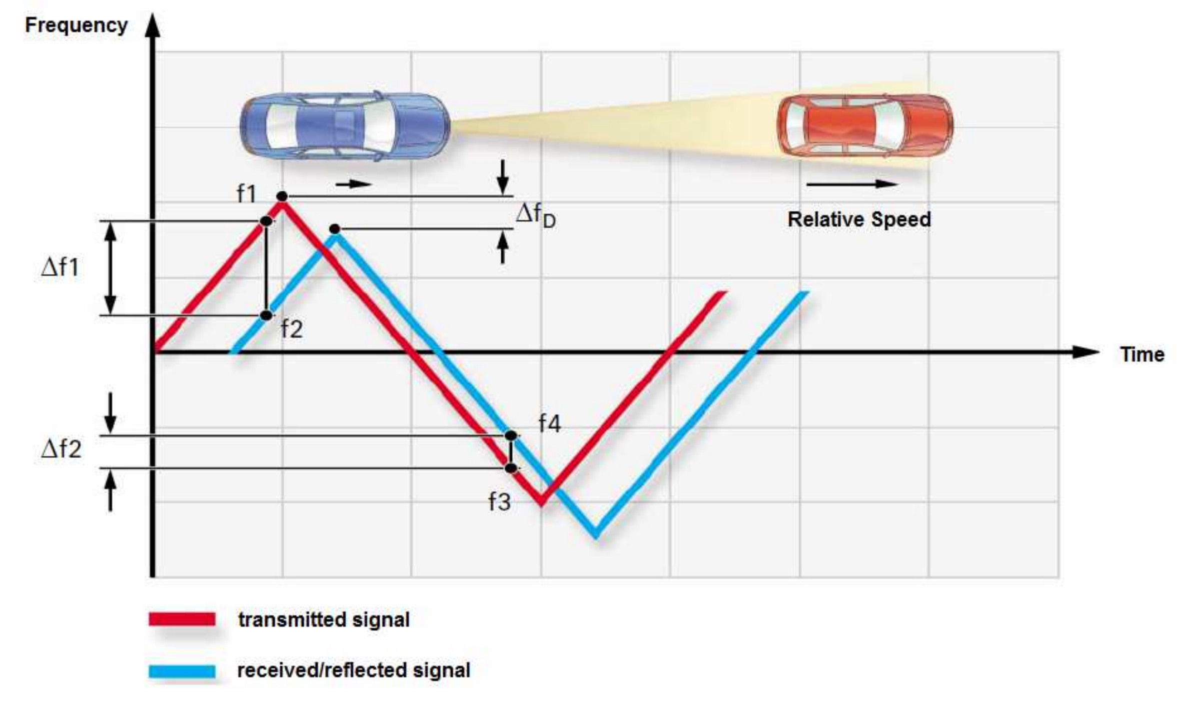
To determine the speed of the preceding vehicle, a physical effect is used, the so-called "Doppler" effect. There is a general difference between moving objects (reflecting the transmitted waves) and objects at rest. Shortens the distance between the transmitter and the object, the frequency of the reflected radiation is increasing, conversely (the distance is getting greater) the frequency decreases. This frequency shift is evaluated by the electronic system and delivers the value of the speed of the preceding vehicle.

What is the "Doppler" effect?

While the fire truck is approaching, the pedestrian hears the horn signal with a constant high pitch (high frequency). While the fire truck is driving away, the pedestrian hears a lower pitch (lower frequency).



The use of the effect in the ACC

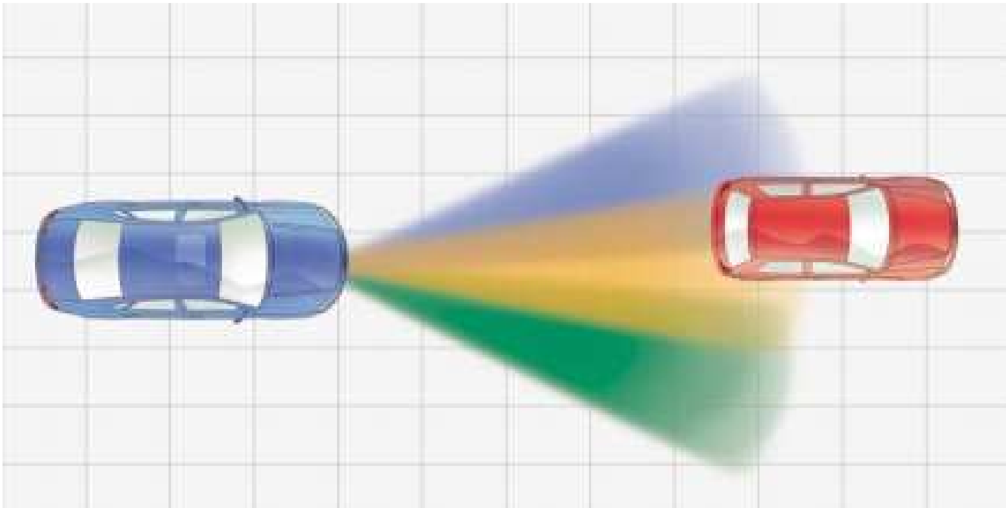


In the diagram the preceding vehicle moves faster, the distance becomes larger. Due to the Doppler-effect, the frequency of the received (reflected) signal is decreasing (ΔfD). This leads to different fequency-differences between rising (Δf1) and falling ramp (Δf2). This shift is evaluated by the control device for distance control.

Δf: Difference of frequency f1/3 of the transmitted signal and f2/4 of the received signal.

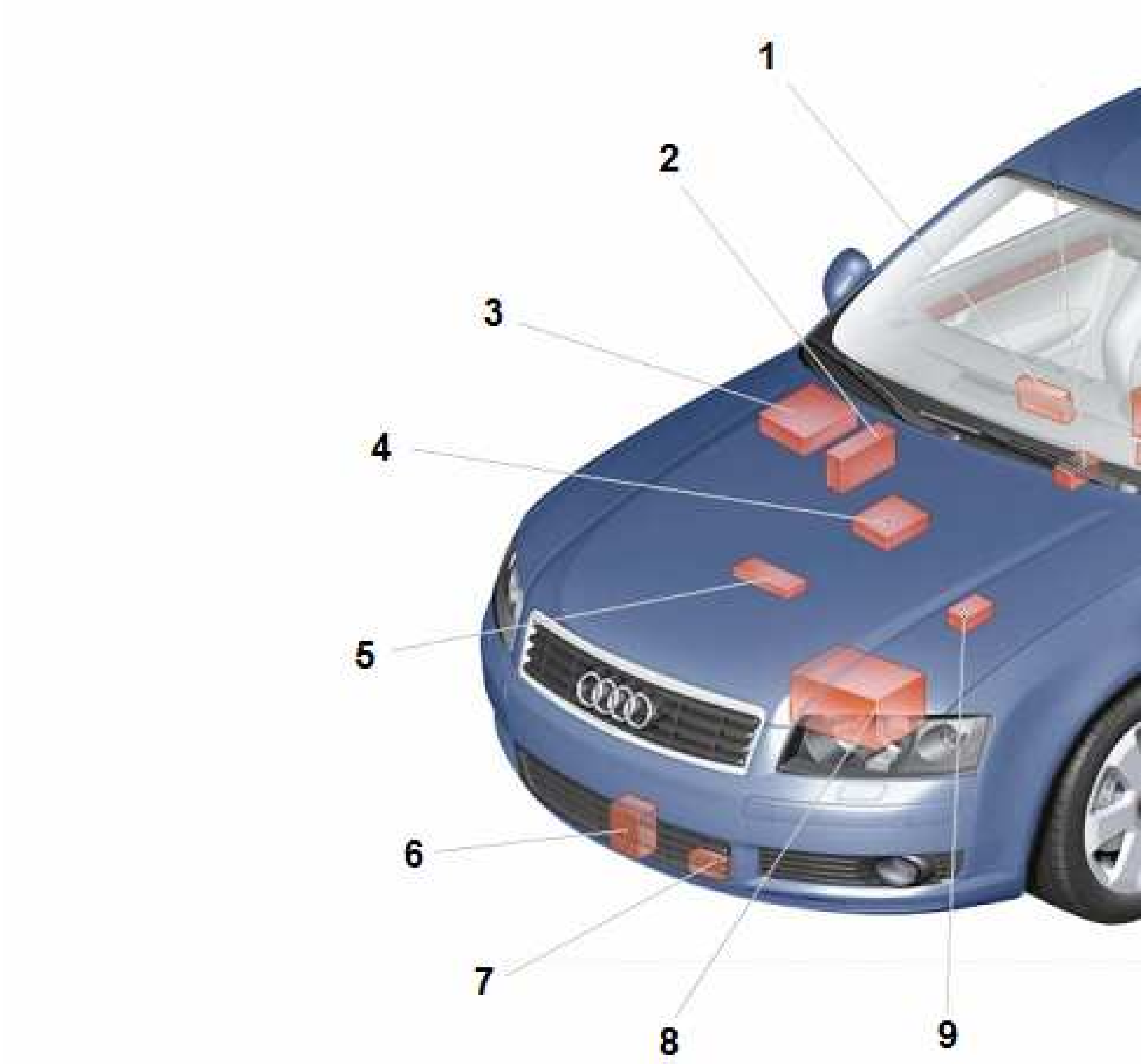
c) *Position measurement*

For the position measurement the system needs the angle in which the other car is driving. For this, a triple-radar is used.



The amplitude ratio delivers the information about the exact position of the red car.

4. Components of the system

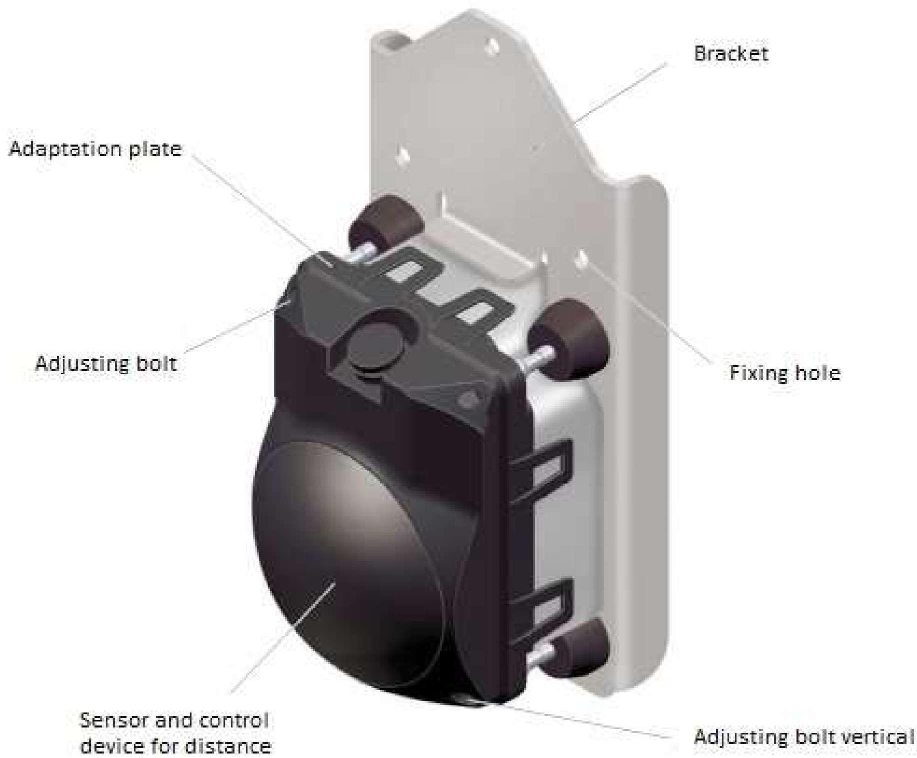


1 – Control device for display and information
2 – Control device gearbox
3 – Control device Motronic
4 – Control interface for gateway
5 – Control device for access and start
6 – Sensor and control device for distance
7 – Temperature detector
8 – Hydraulic system for ABS and ESP
9 – Speed sensor

The devices shown in the picture are relevant for the ACC system to work properly. In the following, these parts and their function will be explained in detail.

5. Principle parts in detail

a) Sensor and control device for distance



This is one of the systems most important parts, the sensor and control device for distance. It sends out radar signals and receives the reflected signals.

The control device processes the data and calculates the speed, distance and position of the preceding vehicle. Using the CAN data bus, it sends the particular relevant information to other control devices (control devices for Motronic, gearbox, ABS/ESP).

The control interface for gateway translates the signals – this is necessary due to different bus speeds.

The coverage of the device is heatable to avoid system faults caused by snow or ice.

Important: This device needs to be adjusted absolute correctly by using a special tool for adjustment to work properly. Otherwise car speeds, positions and distance will not be calculated, the system falls out.

b) Control device for Motronic

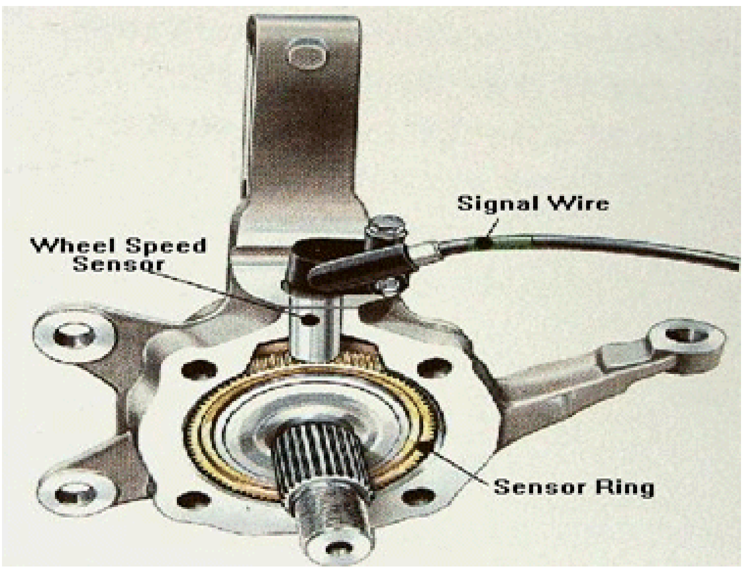
The control device for Motronic is responsible for relevant Engine functions like fuel injection, ignition point, drive regulation etc.

For working properly, it needs a lot of information from sensors all around and in the car, for example the wheel speed and the outdoor temperature to calculate the amount of induction air (different density at different temperatures).

So in the process of distance regulation its task is to slow down the car when the distance to the preceding car reduces and to accelerate when the distance is rising.

The Motronic system works close together with the control device for the gearbox, which chooses the correct gear for the needed vehicle speed/acceleration.

c) Speed sensor

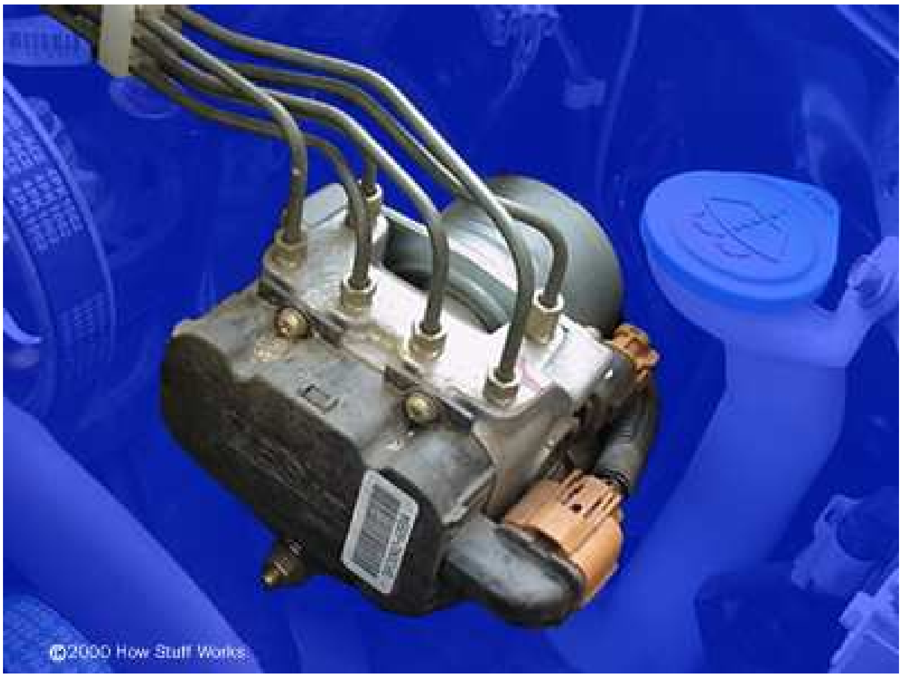


The speed sensor system consists of the wheel speed sensor itself, a sensor ring and the signal wire. The sensor ring rotates as fast as the cars wheel. By the principle of induction, the sensor is able to measure the actual cars speed. The information is sent to the other devices. In the system of distance regulation this signal is absolutely relevant to set the right parameters in acceleration/braking.

d) Control device for access and start

The control device for access and start is necessary to check the authority to start the car. This is realized by receiving signals from a chip included in the key.

e) Hydraulic system for ABS/ESP



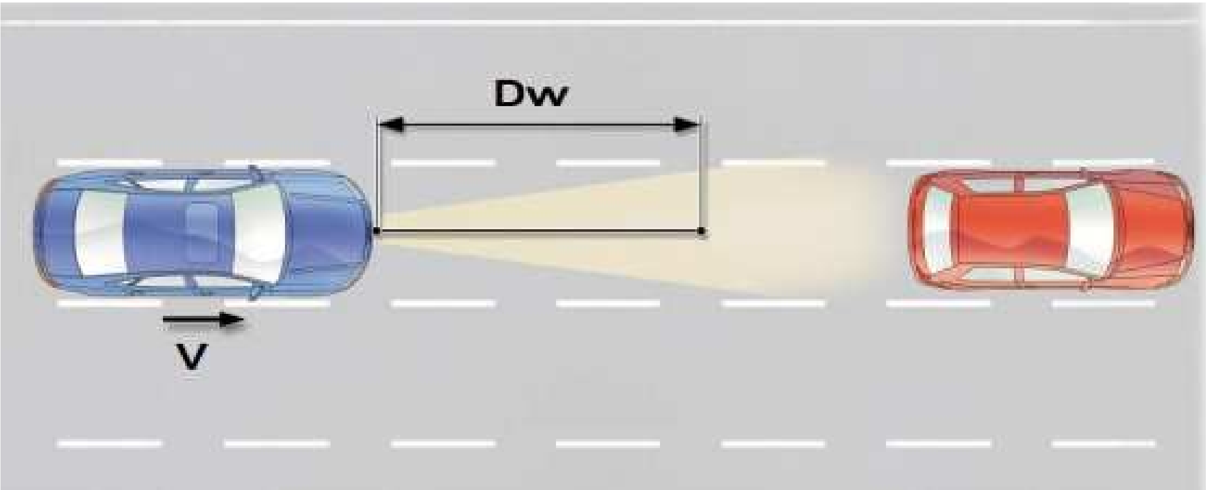
The hydraulic system for ABS/ESP can actively work in the process of braking the car due to reducing distance. It is directly connected by hydraulic oil lines with the brake actuator and is able to regulate the brake pressure. It receives the information from the control devices for Motronic and for distance and acts accordingly.

d) Control device for display and information

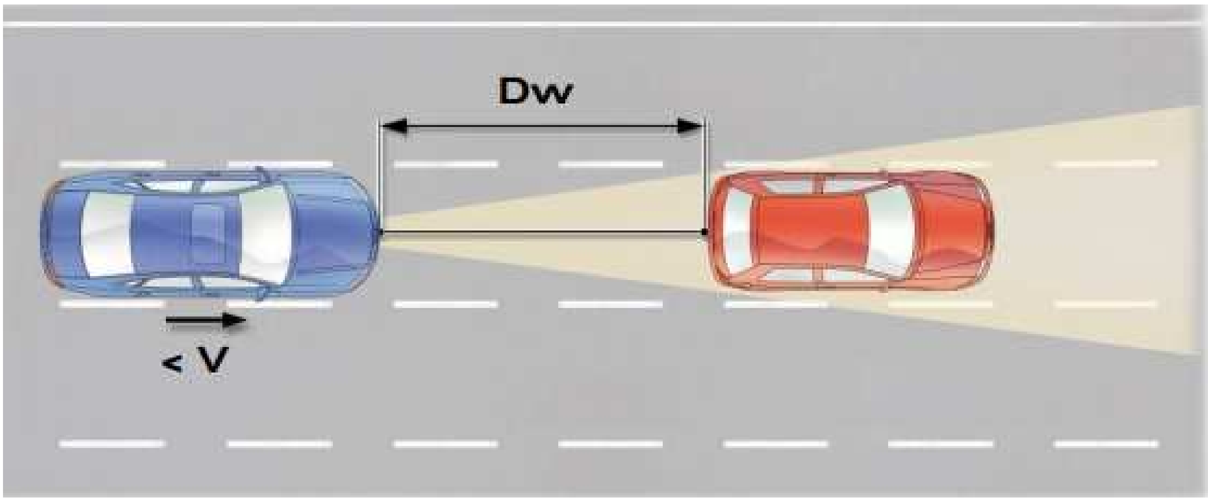
The control device for display and information shows the actual operational state of the whole system to the driver.

6. <u>Description of a working cycle</u>

The systems working cycle starts off with the activation by the driver, who sets the wanted speed (v) and the wanted distance (dw).



The car accelerates until the set speed is reached.



When the sensor and control device for distance detects another car in the same driving lane, the speed will be reduced by release of acceleration or a brake intervention takes place.

When the preceding car leaves the lane, the car will speed up again to the set speed.