

## **System and method for teleoperated control of a ground-based passenger motor vehicle**

The invention relates to a system for teleoperated control of a ground-based passenger motor vehicle having the features of the preamble of claim 1, 6 or 9 and a method for teleoperated control of a ground-based passenger motor vehicle having the features of the preamble of claim 12, 17 or 19.

Such systems for teleoperated control of a ground-based passenger motor vehicle comprise, in addition to the ground-based passenger motor vehicle, a control unit arranged spatially separately from the passenger motor vehicle. The passenger motor vehicle is also referred to herein as a vehicle or car. The passenger motor vehicle can be controlled by an operator by means of control signals generated by the operator and transmitted from the control unit to the passenger motor vehicle. In teleoperated control, the operator is physically removed from the vehicle. The driving tasks to be completed are achieved from a distance. The passenger motor vehicle comprises at least one camera. The control unit comprises a display device. Image data determined by means of the camera can be transmitted to the control unit and can be displayed by means of the display device for the operator to control the passenger motor vehicle. The operator can thus recognise obstacles, road conditions or traffic signs, and control the passenger motor vehicle accordingly. The control signals and the image data can be wirelessly transmitted between a vehicle antenna system of the passenger motor vehicle and a transmission antenna system. The control signals and the image data can be transmitted between the transmission antenna system and the control unit wirelessly and/or by wire.

In particular, such a system can be used to carry out a method for teleoperated control of a ground-based passenger motor vehicle, in which the passenger motor vehicle is controlled by an operator by means of control signals generated by the operator and transmitted to the passenger motor vehicle by a control unit arranged spatially separately from the passenger motor vehicle. Image data determined by means of at least one camera of the passenger motor vehicle is transmitted to the control unit and displayed to the operator by means of a display device of the control unit for controlling the passenger motor vehicle. The control signals and the image data are wirelessly transmitted between a vehicle antenna system of the passenger motor vehicle and a transmission antenna system. The wireless transmission between the vehicle antenna system and the transmission antenna takes place via a communication network provided by a provider. Such a communication network comprises a specific network coverage. The wireless transmission between the vehicle antenna system and the transmission antenna enables free

movement of the passenger motor vehicle. The control signals and the image data are transmitted between the transmission antenna system and the control unit wirelessly and/or by wire. This wired transmission preferably takes place via the Internet, in particular via fibre optic cables.

- 5 If the control signals are not transmitted or are transmitted in a disrupted manner due to an interruption or interference in the transmission of the control signals, uncontrolled driving conditions of the passenger motor vehicle may occur. If no image data or distorted image data is displayed for the operator due to an interruption or interference in the transmission of the image data, safe control of the passenger motor vehicle is at least made more difficult for the operator.
- 10 The system and the method for teleoperated control of the ground-based passenger motor vehicle are then used only in areas of interruption-free or interference-free data transmission, wherein these areas are correspondingly restricted due to the existing network coverage. The system and method for teleoperated control of the ground-based passenger motor vehicle thus comprise only limited availability due to the existing network coverage.

- 15 The object of the invention is therefore to design and/or develop the system and the method for teleoperated control of a ground-based passenger motor vehicle in such a way that an interruption-free or interference-free transmission of control signals and image data between the passenger motor vehicle and the control unit is ensured. Furthermore, the areas of interruption-
- 20 free or interference-free data transmission are to be enlarged with constant network coverage and thus the availability of the system and the method for teleoperated control of a ground-based passenger motor vehicle is to be increased.

- This object of the invention is now firstly achieved by a system for teleoperated control of a ground-based passenger motor vehicle having the features of claim 1.

- One aspect of the invention essentially lies first of all in the fact that the vehicle antenna system comprises a directional antenna with an adjustable viewing direction. A directional antenna is an antenna with a pronounced directional effect, i.e. electromagnetic waves are emitted by the antenna into a specific region, or electromagnetic waves coming from this region can be received particularly well by the antenna. The viewing direction represents an imaginary straight line leading away from the directional antenna, which lies centrally in the specific region. As a transmitting antenna, the directional antenna concentrates the energy of the transmitted electromagnetic waves in the viewing direction and thereby generates directional radiation. As a receiving antenna, the maximum sensitivity of the directional antenna lies in the viewing direction.
- 30 An antenna diagram of the directional antenna comprises a pronounced main lobe in which the

viewing direction lies. By adjusting the viewing direction, a transmission bandwidth between the directional antenna and a specific transmission antenna of the transmission antenna system can be optimised, wherein the transmission of the control signals and the image data takes place between this specific transmission antenna and the directional antenna. For this purpose, the viewing direction is preferably aligned with this specific transmission antenna. In particular, the viewing direction can be tracked, so that the directional antenna is always aligned with this specific transmission antenna, regardless of the position/orientation of the passenger motor vehicle in relation to this specific transmission antenna. This ensures an interruption-free or interference-free transmission of the control signals and image data between the passenger motor vehicle and the control unit. The risk of transmission disruptions is minimised. Furthermore, the areas of interruption-free or interference-free data transmission are enlarged with constant network coverage by the directional antenna with adjustable viewing direction and the associated improved data transmission. Thus, the availability of the system and the method for teleoperated control of the ground-based passenger motor vehicle is then increased.

Preferably, the viewing direction can be adjusted by means of a plurality of individual antennas of the directional antenna designed as a group antenna by a phase shift of the individual individual antennas relative to one another that can be generated by means of an antenna control unit of the directional antenna. The individual antennas are preferably arranged next to one another, one behind the other, in an array and/or in a circle. The individual antennas are preferably arranged at a specific distance from one another. The viewing direction can be adjusted, in particular also pivoted, by a targeted adjustment of the phase on each individual antenna. Advantageously, the viewing direction can thus be adjusted without the directional antenna having to be moved mechanically, so that the adjustment of the viewing direction is made possible with little outlay in terms of device technology. Furthermore, a particularly fast movement of the viewing direction is made possible.

More preferably, the viewing direction of the directional antenna can be pivoted in a single plane by means of the antenna control unit. This is possible with little effort in terms of control technology. In this case, vector modulations are preferably used to adjust the phases.

According to a further embodiment of the system, the viewing direction of the directional antenna can be pivoted in two planes by means of the antenna control unit. In this case, array modulations are preferably used to adjust the phases. This allows the directional antenna to be oriented particularly precisely with the specific transmission antenna.

Advantageously, the viewing direction of the directional antenna can be mechanically adjusted by a movement, preferably a rotation, of the directional antenna. A combination of the above-described electrical adjustment of the viewing direction with the mechanical adjustment by moving the directional antenna is also conceivable.

5 The object of the invention is also achieved by a system for teleoperated control of a ground-based passenger motor vehicle having the features of claim 6.

One aspect of the invention is then essentially that the vehicle antenna system comprises at least  
10 three, preferably four, directional antennas, the viewing directions of which are oriented in such a way that sectors essentially delimited from one another can be covered by means of the directional antennas. The viewing directions are each formed centrally in the respective sectors. Sectors essentially delimited from one another means that a small overlap of the sectors, in particular an overlap at 3 dB, is conceivable in order to avoid a reception/transmission gap  
15 between two directional antennas. The directional antennas are preferably arranged on a circle, wherein the viewing directions are oriented substantially perpendicular to this circle and away from the centre of the circle.

According to a preferred embodiment of the system, the vehicle antenna system comprises  
20 exactly three directional antennas, each of which is positioned at an angle of substantially  $120^\circ$  to one another. Thus, with only three directional antennas, the entire environment of the vehicle can be covered within an angular range of  $360^\circ$ . By means of each of the three directional antennas, a sector of substantially  $120^\circ$  can then advantageously be covered in a horizontal plane. The control signals and image data can then be exchanged between one of the directional  
25 antennas and a transmission antenna arranged in any direction relative to the passenger motor vehicle without having to adjust the viewing direction of one of the antennas. The selection of one of the directional antennas for data transmission is then sufficient.

According to a particularly preferred embodiment of the system, the vehicle antenna system  
30 comprises exactly four directional antennas, each of which is positioned at an angle of substantially  $90^\circ$  to one another. Thus, with only four directional antennas, the entire environment of the vehicle can be covered in an angular range of  $360^\circ$  in a horizontal plane. By means of each of the four directional antennas, a sector of substantially  $90^\circ$  can then advantageously be covered. In contrast to the case with the three directional antennas with a respective transmitting/receiving  
35 sector of essentially  $120^\circ$ , directional antennas of a simpler design in terms of device technology

can then be used. However, it would also be conceivable to use a higher number than four directional antennas to make use of even smaller sectors.

5 The object of the invention is also achieved by a system for teleoperated control of a ground-based passenger motor vehicle having the features of claim 9.

One aspect of the invention is then essentially that the vehicle antenna system comprises at least two directional antennas, wherein a separate transmission path can be formed between each directional antenna and a specific transmission antenna of the transmission antenna system. In  
10 this case, the two transmission paths can be formed, for example, between the two directional antennas and the same transmission antenna. However, it is also conceivable to form the two transmission paths between the two directional antennas and two different transmission antennas. Thus, the system comprises a redundancy with respect to the transmission paths, so that the reliability of achieving the interruption-free or interference-free transmission of the control signals  
15 and image data between the passenger motor vehicle and the control unit is further increased. The risk of transmission disruptions is further reduced.

Advantageously, a mobile communication system, in particular according to the 4G or 5G standard, can be configured by means of the transmission antenna system. The image data and  
20 control signals can preferably be transmitted in real time by means of the mobile communication system, which is ensured in particular by the 4G or 5G standard.

A satellite communication system can more preferably be configured by means of the transmission antenna system. In particular, at least one transmission antenna is configured as a  
25 satellite or is connected to a satellite. One of the directional antennas is then preferably configured for data transmission with such a satellite. If both the mobile communication system and the satellite communication system can be formed by means of the transmission antenna system, further redundancy is achieved at this system level. If the mobile communication system should fail, the satellite communication system will still be available, and vice versa. This further  
30 redundancy leads to a further increase in the security of achieving the interruption-free or interference-free transmission of the control signals and image data between the passenger motor vehicle and the control unit. The risk of transmission disruptions is also further reduced. In particular, the two systems can also be used simultaneously, e.g. in that a transmission path can be or is formed by means of the mobile communication system and a further transmission path  
35 can be or is formed by means of the satellite communication system.

The object of the invention is also achieved by a method for teleoperated control of a ground-based passenger motor vehicle having the features of claim 12.

One aspect of the invention is then essentially that a viewing direction of a directional antenna of the vehicle antenna system is adjusted. By adjusting the viewing direction, the transmission bandwidth between the directional antenna and a specific transmission antenna of the transmission antenna system used for transmitting the control signals and the image data is optimised by orienting the viewing direction as precisely as possible with this transmission antenna. In particular, the viewing direction is tracked, so that the directional antenna is always aligned with this specific transmission antenna, regardless of the position/orientation of the passenger motor vehicle in relation to this specific transmission antenna. This ensures an interruption-free or interference-free transmission of the control signals and image data between the passenger motor vehicle and the control unit and the risk of transmission disruptions is minimised.

Preferably, a specific transmission antenna of the transmission antenna system is selected by adjusting the viewing direction of the directional antenna by means of the antenna control unit and/or with an overall control unit coupled to the control unit in such a way that a maximum possible, but at least a sufficiently high transmission bandwidth is achieved between the specific transmission antenna and the directional antenna. Instead of transmission bandwidth, it is also referred to as a data throughput or a data transmission rate. Preferably, the specific transmission antenna of the transmission antenna system is selected by adjusting the viewing direction of the directional antenna by means of the antenna control unit and/or by means of the overall control unit in such a way that a maximum possible, but at least a sufficiently high data transmission rate or a sufficiently high data throughput between the specific transmission antenna and the directional antenna is achieved. In particular, a low latency is also achieved in the data transmission between the specific transmission antenna and the directional antenna. The latency is so low that it is referred to as data transmission in real time. A specific transmission antenna of the transmission antenna system is specifically selected for data transmission by adjusting the viewing direction of the directional antenna. In addition to measuring the transmission bandwidth, the data transmission rate and/or the data throughput, the criteria described below can help to achieve the maximum possible, but at least the sufficiently high, transmission bandwidth, data transmission rate or the sufficiently high data throughput between the specific transmission antenna and the directional antenna.

The passenger motor vehicle preferably comprises a position determination sensor, in particular a GPS sensor. Based on the position of the passenger motor vehicle determined by means of the position determination sensor, a specific transmission antenna of the transmission antenna system is selected for transmitting the control signals and the image data to this transmission antenna by means of the antenna control unit and/or with the overall control unit. In this context, the antenna control unit and/or the main control unit knows at which locations which of the transmission antennas are optimal for stable communication in terms of a sufficiently high data transmission rate and/or the lowest possible latency. In particular, the antenna control unit and/or the main control unit can also carry out a learning process, which is fed with currently measured values, e.g. the data transmission rate and the associated location, and by means of which optimisation for the future is then carried out autonomously.

More preferably, by means of the overall control unit, a specific transmission antenna of the transmission antenna system is selected by means of the overall control unit on the basis of a specific time in order to transmit the control signals and the image data by means of the antenna control unit and/or the overall control unit in order to achieve a maximum possible transmission bandwidth, but at least a sufficiently high transmission bandwidth. In this context, the antenna control unit and/or the main control unit knows at which times which of the transmission antennas are optimal for stable communication in terms of a sufficiently high data transmission rate and/or the lowest possible latency. In particular, the antenna control unit and/or the main control unit can also carry out a learning process, which is fed with currently measured values, e.g. the data transmission rate and the associated time, and by means of which optimisation for the future is then carried out autonomously.

According to a particularly preferred embodiment of the method, a specific transmission antenna of the transmission antenna system for transmitting the control signals and the image data by means of the respective antenna control unit and/or the overall control unit is selected in each case on the basis of positions of a plurality of passenger motor vehicles determined with the aid of position determination sensors in order to achieve a maximum possible transmission bandwidth, but at least a sufficiently high transmission bandwidth in each case, for each passenger motor vehicle. In particular, the overall control unit is connected to a plurality of control units of a plurality of passenger motor vehicles via data technology. More preferably, the antenna control units of a plurality of passenger motor vehicles are connected to one another via data technology. This enables the transmission bandwidths of a plurality of vehicles to be tuned to the transmission antenna system. Overall, a capacity of the transmission antenna system can be better utilised by this tuning. Forward planning is also conceivable. For example, the transmission antenna of one

of the vehicles used for data transmission could be changed, even if this is not accompanied by an improvement in the data transmission for this vehicle, in order to relieve this transmission antenna for possibly future data transmission with other vehicles.

- 5 The object of the invention is also achieved by a method for teleoperated control of a ground-based passenger motor vehicle having the features of claim 17.

One aspect of the invention is then essentially that the vehicle antenna system comprises at least three, preferably four, directional antennas, the viewing directions of which are oriented in such a way that sectors essentially delimited from one another are covered by means of the directional  
10 antennas. The control signals and image data are exchanged between one of the directional antennas and a transmission antenna arranged in any direction relative to the passenger motor vehicle by selecting one of the directional antennas for data transmission without having to adjust the viewing direction of one of the antennas.

15 Preferably, a specific transmission antenna of the transmission antenna system is selected by means of the antenna control unit and/or with an overall control unit coupled to the control unit by selecting one of the directional antennas in such a way that a maximum possible, but at least a sufficiently high transmission bandwidth is achieved between the specific transmission antenna  
20 and the selected directional antenna. Preferably, one of the directional antennas is selected on the basis of the position of the passenger motor vehicle determined by means of the position determination sensor and/or on the basis of a specific time. The selection of one of the directional antennas could also be made on the basis of transmission rates measured by means of the directional antennas, with possibly different transmission antennas.

25 The object of the invention is also achieved by a method for teleoperated control of a ground-based passenger motor vehicle having the features of claim 19.

One aspect of the invention is then essentially that the vehicle antenna system comprises at least  
30 two directional antennas, wherein a separate transmission path is formed between each directional antenna and a specific transmission antenna of the transmission antenna system. By means of the redundancy generated in this way with respect to the transmission paths, the reliability of achieving the interruption-free or interference-free transmission of the control signals and the image data between the passenger motor vehicle and the control unit is maximised, or at  
35 least increased, and the risk of transmission interference is minimised, or at least reduced.

Advantageously, the control signals and the image data are transmitted via one of the two transmission paths, which is selected in particular by means of an antenna control unit of the vehicle antenna system and/or an overall control unit coupled to the control unit. The other transmission path is then preferably available for other tasks or as a safety reserve.

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According to a further embodiment of the method, the control signals and the image data are transmitted on both transmission paths, in particular in parallel, in particular by first having divided the control signals and the image data into corresponding data packets and subsequently combining the data packets by means of the antenna control unit and/or the overall control unit.

10 The associated data transmission rate can be further increased by the parallel data transmission to two different transmission antennas. The two transmission paths can be assigned to one or two network operators at the same time, wherein the system does not have to be limited to two network operators in total. By means of the two transmission paths, the change of the data transmission to different adjacent transmission antennas is improved in the sense that a stable  
15 data transmission is achieved with high reliability even during the change. This is particularly important when the vehicle is moved from one radio cell of the mobile radio network into an adjacent radio cell. In particular, a smooth transition takes place between the two transmission paths, wherein the data transmission rate of one transmission path decreases, and the data transmission rate of the other transmission path increases until the complete data transmission  
20 takes place via this transmission path. However, it should be noted at this point that the data does not always have to be transmitted to the nearest transmission antenna, but that a more remote transmission antenna can also be used for data transmission.

According to a particularly preferred embodiment of the method, with the help of one of the  
25 directional antennas, the environment of the passenger motor vehicle is searched for transmission antennas of the transmission antenna system that are not currently being used for transmitting the control signals and/or the image data. One of the directional antennas is thus used to scan the "neighbourhood" in order to allow the data transmission to take place partially or completely with an adjacent transmission antenna with increasing utilisation of the currently used  
30 transmission antenna. This leads to a further increase in the security of achieving an interruption-free or interference-free transmission of the control signals and image data between the passenger motor vehicle and the control unit.

It should be noted at this point that the systems and methods described above can be combined  
35 with one another as desired in order to achieve the most efficient overall system or overall method possible.

The respective unit, for example the antenna control unit or the overall control unit, can be implemented using hardware and/or software. In a hardware implementation, the respective unit can be designed as a device or as part of a device, for example as a computer or as a microprocessor or FPGA. In a software implementation, the respective unit can be designed as a computer program product, as a function, as a routine, as part of a program code or as an executable object.

There are now a large number of possibilities for configuring and further developing the system according to the invention and the method according to the invention in an advantageous manner. Reference may first be made here to the claims subordinate to claim 1, 6, 9, 12, 17 and 19. In the following, preferred embodiments of the system according to the invention and the method according to the invention are explained or described in more detail with reference to the drawing and the associated description. In the drawing:

Fig. 1 schematically shows a first embodiment of a system for teleoperated control of the ground-based passenger motor vehicle in combination with a schematic signal flow diagram of an associated method for teleoperated control of the ground-based passenger motor vehicle;

Fig. 2 schematically shows a second embodiment of a system for teleoperated control of the ground-based passenger motor vehicle in combination with a schematic signal flow diagram of an associated method for teleoperated control of the ground-based passenger motor vehicle; and

Fig. 3 is a highly schematic illustration of a further embodiment of a vehicle antenna system of the system for teleoperated control of the ground-based passenger motor vehicle.

Fig. 1 and Fig. 2 each show an embodiment of a system for teleoperated control of a ground-based passenger motor vehicle 1 with the ground-based passenger motor vehicle 1 and with a control unit 2 arranged spatially separate from the passenger motor vehicle 1, including a schematic signal flow diagram for the associated method for teleoperated control of the ground-based passenger motor vehicle 1. The passenger motor vehicle 1 can be controlled by an operator by means of control signals generated by the operator and transmitted from the control unit 2 to the passenger motor vehicle 1. The passenger motor vehicle 1 comprises at least one camera 3. The control unit 2 comprises a display device 4. Image data determined by means of

the camera 3 can be transmitted to the control unit 2 and can be displayed by means of the display device 4 for the operator to control the passenger motor vehicle 1. The control signals and the image data can be wirelessly transmitted between a vehicle antenna system AFS of the passenger motor vehicle 1 and a transmission antenna system AUS. The control signals and the image data can be transmitted between the transmission antenna system AUS and the control unit 2 wirelessly and/or by wire. To achieve the lowest possible latency, transmission by wire is preferably used.

The passenger motor vehicle 1 is, in particular, a road vehicle. In the case of the passenger motor vehicle 1, all vehicle functions can be controlled via a built-in drive-by-wire system DbW. The vehicle functions can thus be controlled electrically. The vehicle functions are controlled via a central vehicle computing unit F and with the aid of CAN bus data connections. The drive-by-wire system DbW comprises servo motors and/or actuators with which, for example, braking and acceleration pulses as well as steering movements can be implemented. The control signals transmitted by the control unit 2 to the passenger motor vehicle 1 by means of the transmission antenna system AUS are converted, whilst the vehicle is in motion, into actuating signals for the servo motors and/or actuators in the vehicle computing unit F.

The image data and control signals can be transmitted by wire between the transmission antenna system AUS and a data interface DE of the control unit 2. This wired transmission takes place, for example, via a wired Internet connection GL, in particular via a fibre-optic cable, which is shown in Figs. 1 and 2, in each case by way of example, between one of the transmission antennas AU of the transmission antenna system AUS and the data interface DE. It is also conceivable to use a line logically decoupled from the Internet for wired transmission in order to be able to transmit data with lower latency, although access to the Internet for the passenger motor vehicle 1 and the control unit 2 is nevertheless conceivable in principle. In particular, at least large parts of the wired transmission are achieved via a fibre-optic cable.

The image data and control signals can be transmitted between the transmission antenna system AUS and the data interface DE, but also wirelessly by means of a control unit antenna AK of the control unit 2, wherein the control unit antenna AK and the adjacent double arrow are therefore shown as optional by dashed lines. The control unit antenna AK is then part of the data interface DE of the control unit 2.

The passenger motor vehicle 1 comprises at least three cameras 3, preferably three to twelve cameras 3, particularly preferably four to nine cameras 3, in particular five cameras 3. The display

device 4 preferably comprises one screen per camera 3. On each screen, preferably only the image data determined by means of one of the cameras 3 is displayed. This preferably results in a 1:1 allocation between the screens and the cameras 3. The number of cameras 3 depends, in particular, on the type of passenger motor vehicle 1. For example, in the case of a truck, for example, more than the twelve cameras 3 mentioned may be used due to blind spots, etc. It is important that a 360°-view is achieved around the passenger motor vehicle 1. Secondary views, which can be reached as seen from a driver's seat by means of side/rear-view mirrors and/or views of the blind spots, can be embedded by means of the display device 4 in an X° primary view of the path to be travelled in front of the passenger motor vehicle 1. In particular, display devices 4 with three or five screens are used, wherein it is also possible to deviate from the 1:1 assignment between the screens and the cameras 3.

The vehicle antenna system AFS comprises a directional antenna AF with an adjustable viewing direction, which is symbolised in Fig. 1 by the curved double arrow. The viewing direction is symbolised by means of the electromagnetic waves represented by curved lines adjacent to the directional antenna AF. By adjusting the viewing direction, a data transmission of the control signals and the image data between the directional antenna AF and a specific transmission antenna AU of the transmission antenna system can be achieved. This specific transmission antenna AU may be the one closest to the passenger motor vehicle 1 or may be a transmission antenna AU located further away. The directional antenna AF is an antenna with a pronounced directional effect, i.e. electromagnetic waves are emitted by the directional antenna AF into a specific region, or electromagnetic waves coming from this region can be received particularly well by the directional antenna AF. The viewing direction represents an imaginary straight line leading away from the directional antenna, which lies centrally in the specific region. As a transmitting antenna, the directional antenna AF concentrates the energy of the transmitted electromagnetic waves in the viewing direction and thereby generates directional radiation. As a receiving antenna, the maximum sensitivity of the directional antenna AF lies in the viewing direction. By adjusting the viewing direction, this viewing direction can be oriented towards the specific transmission antenna AU, so that data transmission is made possible with a high data transmission rate and low latency.

The viewing direction can be adjusted by means of a plurality of individual antennas of the directional antenna AF designed as a group antenna by a phase shift of the individual individual antennas relative to one another that can be generated by means of an antenna control unit 5 of the directional antenna AF. The individual antennas are arranged vertically one above the other, for example, and do not themselves have a pronounced directional effect. The individual antennas

can also be arranged horizontally next to one another, horizontally in the form of an array or horizontally in a circular manner. A plurality of vertically stacked layers of such arrangements can be used for an increased directional effect. As a result of the phase shift of the individual individual antennas with respect to one another, bundling and thus the pronounced directional effect can then be achieved by interference. The energy of the electromagnetic waves is amplified in the desired direction, while the undesired directions are cancelled out by destructive interference. However, in addition to the use of a group antenna comprising a plurality of individual antennas as a directional antenna AF, the use of different directional antennas with a pronounced directional effect would also be conceivable.

The viewing direction of the directional antenna AF can be pivoted in a single plane, for example by means of the antenna control unit 5. In this case, all individual antennas of the directional antenna AF can preferably be driven via a separate phase shifter. A group phase shifter, by means of which a plurality of phase shifters can be controlled simultaneously, is conceivable and preferable.

However, it is also conceivable that the viewing direction of the directional antenna AF can be pivoted in two planes by means of the antenna control unit 5. In this case, each individual antenna is preferably also assigned a separate phase shifter for adjusting the respective phase shift. Here, too, a group phase shifter, by means of which a plurality of phase shifters can then be controlled, is conceivable and preferable.

The viewing direction of the directional antenna AF could also be mechanically adjusted by a movement, preferably a rotation, of the directional antenna AF. Furthermore, combinations of this mechanical and the above-described electronic adjustment of the viewing direction are conceivable. In the mechanical variant, the directional antenna AF is, for example, rotatably connected to the passenger motor vehicle 1 and can be rotated about its axis of rotation by means of a drive such as a servomotor. However, other movement mechanisms for the mechanical variant are also conceivable.

According to Fig. 2, the vehicle antenna system AFS comprises at least three, preferably four, directional antennas AF, the viewing directions of which are oriented in such a way that sectors essentially delimited from one another can be covered by means of the directional antennas AF. The individual sectors overlap at 3 dB so as not to create receiving or transmission gaps between the sectors. Preferably, all directional antennas AF are penetrated by a horizontally oriented plane.

According to Fig. 2, the vehicle antenna system AFS comprises exactly three directional antennas AF, each of which is positioned at an angle of substantially  $120^\circ$  to one another. These angles form, in particular, in a horizontal plane. Usually, a viewing direction of the transmission antennas AU is inclined slightly downward since the transmission antennas AU are arranged higher than the directional antennas AF. Consequently, the viewing directions of the directional antennas AF are correspondingly inclined slightly upwards in order to achieve optimal data transmission.

It would also be conceivable for the vehicle antenna system AFS to comprise exactly four directional antennas AF, each of which is positioned at an angle of essentially  $90^\circ$  to one another. These angles also form, in particular, in a horizontal plane.

According to Fig. 3, the vehicle antenna system AFS comprises a plurality of directional antennas AF, which are arranged in a plurality of, preferably two, planes, each along a common circular path. According to Fig. 3, in each case eight directional antennas AF are arranged along a common circular path at the same distance from one another. In particular, the common circular paths are also formed in a horizontal plane.

Preferably, all sectors of the at least three directional antennas AF together enclose the vehicle antenna system AFS in the azimuth range. Thus, a coverage of the environment of the vehicle antenna system AFS of  $360^\circ$  in the azimuth range is achieved.

According to Fig. 2, the vehicle antenna system AFS comprises at least two directional antennas AF. A separate transmission path can be formed between each directional antenna AF and a specific transmission antenna AU of the transmission antenna system AUS. The separate transmission paths can be formed for the same or for two different transmission antennas AU. If the separate transmission paths are formed to two different transmission antennas AU, different technologies can be used for each transmission path.

A mobile communication system 5G, in particular according to the 4G or 5G standard, can be configured by means of the transmission antenna system AUS. The transmission paths can thus be formed in particular by means of the mobile network. The 5G standard is preferably used to ensure data transmission in real time. Corresponding technologies are then selected for the directional antennas AF.

A satellite communication system S can also be formed by means of the transmission antenna system AUS. In particular, at least one transmission antenna AU is then formed as a satellite 6 or

is connected to a satellite 6. The transmission paths can then be formed, in particular, by means of the satellite communication system. Corresponding technologies are then also selected for the directional antennas AF. In particular, a modem designed as a satellite modem is then also used in combination with the directional antenna AF for communication with the satellite 6. In particular, a viewing direction of a directional antenna AF for satellite communication is inclined upwards to a much greater extent than the viewing direction of a directional antenna AF for mobile communication. It is also conceivable to design one of the transmission paths with the mobile communication system 5G and one of the transmission paths with the satellite communication system S in parallel, i.e. at the same time. Usually, the mobile communication system 5G is preferably used, wherein the satellite communication system S is used if there are problems on the part of the mobile communication system 5G.

In the method for teleoperated control of the ground-based passenger motor vehicle 1, the passenger motor vehicle 1 is controlled by the operator by means of control signals generated by the operator and transmitted to the passenger motor vehicle 1 by a control unit 2 arranged spatially separately from the passenger motor vehicle 1. Image data is determined by means of at least one camera 3 of the passenger motor vehicle 1, transmitted to the control unit 2, and displayed to the operator by means of a display device 4 of the control unit 2 for controlling the passenger motor vehicle 1. The control signals and the image data are wirelessly transmitted between a vehicle antenna system AFS of the passenger motor vehicle 1 and a transmission antenna system AUS. The control signals and the image data are transmitted between the transmission antenna system AUS and the control unit 2 wirelessly and/or by wire. The viewing direction of the directional antenna AF of the vehicle antenna system AFS is adjusted.

A specific transmission antenna AU of the transmission antenna system AUS is selected by adjusting the viewing direction of the directional antenna AF by means of the antenna control unit 5 and/or with an overall control unit 7 coupled to the control unit 2 in such a way that a maximum possible, but at least a sufficiently high transmission bandwidth is achieved between the specific transmission antenna AU and the directional antenna AF. Instead of transmission bandwidth, it is also referred to as a data throughput or a data transmission rate. Furthermore, the viewing direction of the directional antenna AF is oriented exactly towards the specific transmission antenna AU in order to maximise the possible data transmission rate. In particular, the viewing direction of the directional antenna AF is tracked in line with the movement of the passenger motor vehicle 1.

The passenger motor vehicle 1 comprises a position determination sensor 8, in particular a GPS sensor. Based on the position of the passenger motor vehicle 1 determined by means of the position determination sensor 8, a specific transmission antenna AU of the transmission antenna system AFS is selected for transmitting the control signals and the image data to this transmission antenna AU by means of the antenna control unit 7 and/or with the overall control unit 5. If it is known by the position determination sensor 8 where the passenger motor vehicle 1 is located and if it is also known, e.g. from corresponding map material, where the transmission antennas AU are located, then the nearest transmission antenna AU, for example, can be selected on the basis of this information. However, a more distant transmission antenna AU can also be selected if, for example, it is known from information from the past that a better transmission rate can be achieved with this transmission antenna AU.

Time in particular also plays a role in the selection of the transmission antenna AU on the basis of information from the past. A specific transmission antenna AU of the transmission antenna system AUS is selected by means of the overall control unit 7 on the basis of a specific time in order to transmit the control signals and the image data by means of the antenna control unit 5 and/or the overall control unit 7 in order to achieve a maximum possible transmission bandwidth, but at least a sufficiently high transmission bandwidth. In particular, the specific transmission antenna AU is selected on the basis of both the specific time and the specific position of the passenger motor vehicle 1.

A specific transmission antenna AU of the transmission antenna system AUS for transmitting the control signals and the image data by means of the respective antenna control unit 5 and/or the overall control unit 7 is selected in each case on the basis of positions of a plurality of passenger motor vehicles 1 determined with the aid of position determination sensors 8 in order to achieve a maximum possible transmission bandwidth, but at least a sufficiently high transmission bandwidth in each case, for each passenger motor vehicle 1. In particular, the overall control unit 7 is connected to a plurality of control units 2 of a plurality of passenger motor vehicles 1 via data technology. It would also be conceivable for the antenna control units 5 of a plurality of passenger motor vehicles 1 to be connected to one another via data technology. In both cases, this makes it possible to tune the transmission bandwidths of a plurality of passenger motor vehicles 1 to one another. By tuning the transmission bandwidths, overloading of individual transmission antennas AU is avoided. Without this tuning, a transmission antenna AU could be overloaded at least for a short time if data transmission of a plurality of directional antennas AF is carried out simultaneously with this transmission antenna AU, in particular started simultaneously. It is also conceivable for a route optimisation of a plurality of passenger motor vehicles 1 to be carried out

by the overall control unit 7 in order to avoid overloading the transmission antennas AU. The overall control unit 7 can be connected to the Internet, so that, for example, such tasks can be performed more easily.

- 5 According to Fig. 2 the vehicle antenna system AFS comprises at least three, preferably four, directional antennas AF, the viewing directions of which are oriented in such a way that sectors essentially delimited from one another are covered by means of the directional antennas AF.

10 A specific transmission antenna AU of the transmission antenna system AUS is selected by means of the antenna control unit 5 and/or with an overall control unit 7 coupled to the control unit 2 by selecting one of the directional antennas AF in such a way that a maximum possible, but at least a sufficiently high transmission bandwidth is achieved between the specific transmission antenna AU and the selected directional antenna AF. Adjusting the viewing direction of the individual directional antennas AF is then not absolutely necessary, but can be advantageous  
15 when it comes to achieving the maximum possible data transmission rate. In particular, the directional antenna AF is selected whose viewing direction comprises the smallest deviation from the specific transmission antenna AU.

20 According to Fig. 2 the vehicle antenna system AFS comprises at least two directional antennas AF. A separate transmission path is formed between each directional antenna AF and a specific transmission antenna AU of the transmission antenna system AUS. The transmission paths are implemented with associated protocols. The exact nature of the protocols also depends in particular on the technology of the communication network.

25 The control signals and the image data are transmitted via one of the two transmission paths, which is selected in particular by means of an antenna control unit 5 of the vehicle antenna system AFS and/or an overall control unit 7 coupled to the control unit 2. The data transmission then takes place via this one transmission path, in particular bidirectionally, since the directions of the transmission of the control signals and the image data are opposite to one another.

30 The control signals and the image data are alternatively transmitted on both transmission paths, in particular in parallel, in particular by first having divided the control signals and the image data into corresponding data packets and subsequently combining the data packets by means of the antenna control unit 5 and/or the overall control unit 7. Here, parallel means at the same time. For  
35 example, part of the image data is transmitted on one of the transmission paths and the other part of the image data is simultaneously transmitted on the other of the transmission paths, wherein

the image data is displayed in its entirety in real time on the display device 4. The antenna control unit 5 comprises, in particular, a router and/or a modem. The control unit 2 also comprises, in particular, a router and/or a modem. The data packets are preferably combined by means of such a respective router of the antenna control unit 5 or the control unit 2.

5

With the help of one of the directional antennas AF, the environment of the passenger motor vehicle 1 is searched for transmission antennas AU of the transmission antenna system that are not currently being used for transmitting the control signals and/or the image data. For example, the electromagnetic waves received by this directional antenna AF are evaluated. In this case, the electromagnetic waves emitted by the transmission antennas AU are detected. With a correspondingly good possible data transmission rate, the transmission antenna AU can then be changed for the transmission of the control signals and/or the image data. The viewing direction of the directional antenna AF is preferably changed during the search.

10

### List of reference numerals

|    |     |                                               |
|----|-----|-----------------------------------------------|
|    | 1   | Passenger motor vehicle                       |
|    | 2   | Control unit                                  |
| 5  | 3   | Camera                                        |
|    | 4   | Display device                                |
|    | 5   | Antenna control unit                          |
|    | 6   | Satellite                                     |
|    | 7   | Overall control unit                          |
| 10 | 8   | Position determination sensor                 |
|    |     |                                               |
|    | AFS | Vehicle antenna system                        |
|    | AF  | Directional antenna                           |
|    | F   | Vehicle computing unit                        |
| 15 | DbW | Drive-by-wire system                          |
|    | AUS | Transmission antenna system                   |
|    | AU  | Transmission antenna                          |
|    | AK  | Control unit antenna                          |
|    | DE  | Data interface of the control unit 2          |
| 20 | 5G  | (5G) mobile communication system              |
|    | S   | Satellite communication system                |
|    | GL  | Wired Internet connection (fibre optic cable) |

## Claims

1. System for teleoperated control of a ground-based passenger motor vehicle (1),  
5 comprising the ground-based passenger motor vehicle (1) and a control unit (2) that is spatially  
separate from the passenger motor vehicle (1), wherein: the passenger motor vehicle (1) can be  
controlled by an operator by means of control signals that are generated by the operator and  
transmitted by the control unit (2) to the passenger motor vehicle (1); the passenger motor vehicle  
10 (1) comprises at least one camera (3); the control unit (2) comprises a display device (4); image  
data acquired by means of the camera (3) can be transmitted to the control unit (2) and can be  
displayed to the operator by means of the display device (4) for the purpose of controlling the  
passenger motor vehicle (1); the control signals and the image data can be transmitted between  
a vehicle antenna system (AFS) of the passenger motor vehicle (1) and a transmission antenna  
15 system (AUS) wirelessly; and the control signals and the image data can be transmitted between  
the transmission antenna system (AUS) and the control unit (2) wirelessly or by wire,  
**characterised in that** the vehicle antenna system (AFS) comprises a directional antenna (AF)  
with an adjustable viewing direction.
2. System according to claim 1, **characterised in that** the viewing direction can be adjusted  
20 by means of a plurality of individual antennas of the directional antenna (AF) designed as a group  
antenna by a phase shift of the individual individual antennas relative to one another that can be  
generated by means of an antenna control unit (5) of the directional antenna (AF).
3. System according to claim 1 or 2, **characterised in that** the viewing direction of the  
25 directional antenna (AF) can be pivoted in a single plane by means of the antenna control unit (5).
4. System according to claim 1 or 2, **characterised in that** the viewing direction of the  
directional antenna (AF) can be pivoted in two planes by means of the antenna control unit (5).
- 30 5. System according to any one of the preceding claims, **characterised in that** the viewing  
direction of the directional antenna (AF) can be mechanically adjusted by a movement, preferably  
a rotation, of the directional antenna (AF).
6. System for teleoperated control of a ground-based passenger motor vehicle (1), in  
35 particular according to any one of the preceding claims, comprising the ground-based passenger  
motor vehicle (1) and a control unit (2) that is spatially separate from the passenger motor vehicle

(1), wherein: the passenger motor vehicle (1) can be controlled by an operator by means of control signals that are generated by the operator and transmitted by the control unit (2) to the passenger motor vehicle (1); the passenger motor vehicle (1) comprises at least one camera (3); the control unit (2) comprises a display device (4); image data acquired by means of the camera (3) can be transmitted to the control unit (2) and can be displayed to the operator by means of the display device (4) for the purpose of controlling the passenger motor vehicle (1); the control signals and the image data can be transmitted between a vehicle antenna system (AFS) of the passenger motor vehicle (1) and a transmission antenna system (AUS) wirelessly; and the control signals and the image data can be transmitted between the transmission antenna system (AUS) and the control unit (2) wirelessly or by wire, **characterised in that** the vehicle antenna system (AFS) comprises at least three, preferably four, directional antennas (AF), the viewing directions of which are oriented such that the directional antennas (AF) can cover sectors that are essentially distinct from one another.

7. System according to the preceding claim, **characterised in that** the vehicle antenna system (AFS) comprises exactly three directional antennas (AF), each of which is positioned at an angle of substantially 120° to one another.

8. System according to claim 6, **characterised in that** the vehicle antenna system (AFS) comprises exactly four directional antennas (AF), each of which is positioned at an angle of substantially 90° to one another.

9. System for teleoperated control of a ground-based passenger motor vehicle (1), in particular according to any one of the preceding claims, comprising the ground-based passenger motor vehicle (1) and a control unit (2) that is spatially separate from the passenger motor vehicle (1), wherein: the passenger motor vehicle (1) can be controlled by an operator by means of control signals that are generated by the operator and transmitted by the control unit (2) to the passenger motor vehicle (1); the passenger motor vehicle (1) comprises at least one camera (3); the control unit (2) comprises a display device (4); image data acquired by means of the camera (3) can be transmitted to the control unit (2) and can be displayed to the operator by means of the display device (4) for the purpose of controlling the passenger motor vehicle (1); the control signals and the image data can be transmitted between a vehicle antenna system (AFS) of the passenger motor vehicle (1) and a transmission antenna system (AUS) wirelessly; and the control signals and the image data can be transmitted between the transmission antenna system (AUS) and the control unit (2) wirelessly or by wire, **characterised in that** the vehicle antenna system (AFS) comprises at least two directional antennas (AF), wherein a separate transmission path can be

established between each directional antenna (AF) and a specific transmission antenna (AU) of the transmission antenna system (AUS).

10. System according to claim 9, **characterised in that** a mobile communication system (5G),  
5 in particular according to the 4G or 5G standard, can be configured by means of the transmission antenna system (AUS).

11. System according to claim 9 or 10, **characterised in that** a satellite communication  
10 system (S) can be configured by means of the transmission antenna system (AUS), in particular wherein at least one transmission antenna (AU) is configured as a satellite (6) or is connected to a satellite (6).

12. Method for teleoperated control of a ground-based passenger motor vehicle (1), in  
particular by means of a system according to any one of claims 1 to 11, wherein the passenger  
15 motor vehicle (1) is controlled by an operator by means of control signals generated by the operator and transmitted to the passenger motor vehicle (1) by a control unit (2) arranged spatially separately from the passenger motor vehicle (1); image data is determined by means of at least one camera (3) of the passenger motor vehicle (1), transmitted to the control unit (2) and displayed to the operator by means of a display device (4) of the control unit (2) for controlling the passenger  
20 motor vehicle (1); the control signals and the image data are transmitted wirelessly between a vehicle antenna system (AFS) of the passenger motor vehicle (1) and a transmission antenna system (AUS); and the control signals and the image data are transmitted between the transmission antenna system (AUS) and the control unit (2) wirelessly and/or by wire, **characterised in that** a viewing direction of a directional antenna (AF) of the vehicle antenna  
25 system (AFS) is adjusted.

13. Method according to the preceding claim, **characterised in that** a specific transmission  
antenna (AU) of the transmission antenna system (AUS) is selected by adjusting the viewing  
direction of the directional antenna (AF) by means of the antenna control unit (5) and/or with an  
30 overall control unit (7) coupled to the control unit (2) in such a way that a maximum possible, but at least a sufficiently high transmission bandwidth is achieved between the specific transmission antenna (AU) and the directional antenna (AF).

14. Method according to claim 12 or 13, **characterised in that** the passenger motor vehicle  
35 (1) comprises a position determination sensor (8), in particular a GPS sensor, wherein a specific transmission antenna (AU) of the transmission antenna system (AFS) for transmitting the control

signals and the image data to this transmission antenna (AU) is selected by means of the antenna control unit (5) and/or with the overall control unit (7) on the basis of the position of the passenger motor vehicle (1) determined by means of the position determination sensor (8).

5 15. Method according to the preceding claim, **characterised in that** a specific transmission antenna (AU) of the transmission antenna system (AUS) is selected by means of the overall control unit (7) on the basis of a specific time in order to transmit the control signals and the image data by means of the antenna control unit (5) and/or the overall control unit (7) in order to achieve a maximum possible transmission bandwidth, but at least a sufficiently high transmission  
10 bandwidth.

16. Method according to claim 14 or 15, **characterised in that** a specific transmission antenna (AU) of the transmission antenna system (AUS) for transmitting the control signals and the image data by means of the respective antenna control unit (5) and/or the overall control unit (7) is  
15 selected in each case on the basis of positions of a plurality of passenger motor vehicles (1) determined with the aid of position determination sensors (8) in order to achieve a maximum possible transmission bandwidth, but at least a sufficiently high transmission bandwidth in each case, for each passenger motor vehicle (1).

20 17. Method for teleoperated control of a ground-based passenger motor vehicle (1), in particular according to any one of claims 12 to 16, in particular by means of a system according to any one of claims 1 to 11, wherein: the passenger motor vehicle (1) is controlled by an operator by means of control signals generated by the operator and transmitted to the passenger motor vehicle (1) by a control unit (2) arranged spatially separately from the passenger motor vehicle  
25 (1); image data is determined by means of at least one camera (3) of the passenger motor vehicle (1), transmitted to the control unit (2) and displayed to the operator by means of a display device (6) of the control unit (2) for controlling the passenger motor vehicle (1); the control signals and the image data are transmitted wirelessly between a vehicle antenna system (AFS) of the passenger motor vehicle (1) and a transmission antenna system (AUS); and the control signals  
30 and the image data are transmitted between the transmission antenna system (AUS) and the control unit (2) wirelessly and/or by wire, **characterised in that** the vehicle antenna system (AFS) comprises at least three, preferably four, directional antennas (AF), the viewing directions of which are aligned such that the directional antennas (AF) cover sectors that are essentially distinct from one another.

18. Method according to the preceding claim, **characterised in that** a specific transmission antenna (AU) of the transmission antenna system (AUS) is selected by means of the antenna control unit (5) and/or with an overall control unit (7) coupled to the control unit (2) by selecting one of the directional antennas (AF) in such a way that a maximum possible, but at least a sufficiently high transmission bandwidth is achieved between the specific transmission antenna (AU) and the selected directional antenna (AF).

19. Method for teleoperated control of a ground-based passenger motor vehicle (1), in particular according to any one of claims 12 to 18, in particular by means of a system according to any one of claims 1 to 11, wherein: the passenger motor vehicle (1) is controlled by an operator by means of control signals generated by the operator and transmitted to the passenger motor vehicle (1) by a control unit (2) arranged spatially separately from the passenger motor vehicle (1); image data is determined by means of at least one camera (3) of the passenger motor vehicle (1), transmitted to the control unit (2) and displayed to the operator by means of a display device (6) of the control unit (2) for controlling the passenger motor vehicle (1); the control signals and the image data are transmitted wirelessly between a vehicle antenna system (AFS) of the passenger motor vehicle (1) and a transmission antenna system (AUS); and the control signals and the image data are transmitted between the transmission antenna system (AUS) and the control unit (2) wirelessly and/or by wire, **characterised in that** the vehicle antenna system (AFS) comprises at least two directional antennas (AF), wherein a separate transmission path is established between each directional antenna (AF) and a specific transmission antenna (AU) of the transmission antenna system (AUS).

20. Method according to the preceding claim, **characterised in that** the control signals and the image data are transmitted via one of the two transmission paths, which is selected in particular by means of an antenna control unit (5) of the vehicle antenna system (AFS) and/or an overall control unit (7) coupled to the control unit (2).

21. Method according to claim 19, **characterised in that** the control signals and the image data are transmitted on both transmission paths, in particular in parallel, in particular by first having divided the control signals and the image data into corresponding data packets and subsequently combining the data packets by means of the antenna control unit (5) and/or the overall control unit (7).

22. Method according to any of claims 19 to 21, **characterised in that**, with the aid of one of the directional antennas (AF), the environment of the passenger motor vehicle (1) is searched for

transmission antennas (AU) of the transmission antenna system (AUS) that are not currently being used for transmitting the control signals and/or the image data.