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(71) Applicant: **JAGUAR LAND ROVER LIMITED** [GB/G-B]; Abbey Road, Whitley, Coventry Warwickshire CV3 4LF (GB).

(72) Inventor: **STOCKBRIDGE, Peter**; c/o Jaguar Land Rover, Patents Department W/1/073, Abbey Road, Whitley, Coventry Warwickshire CV3 4LF (GB).

(74) Agent: **JAGUAR LAND ROVER PATENTS DEPARTMENT**; c/o Jaguar Land Rover, Patents Department W/1/073, Abbey Road, Whitley, Coventry Warwickshire CV3 4LF (GB).

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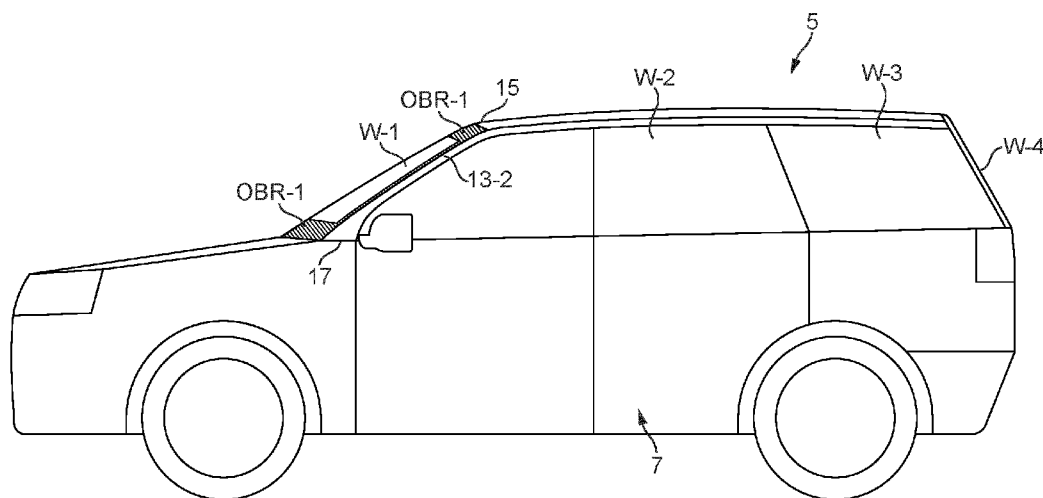


FIG. 1

(57) Abstract: Aspects of the present invention relate to method and apparatus for defining an obscuration region (OBR-n) of a window screen (W-n) of a vehicle (5). The present invention relates to a computer-implemented method configured to define the obscuration region (OBR-n) at least partially to obscure an interior panel (19-n) of the vehicle (5). The method includes generating a model (VM1) of the window screen (W-n) and the interior panel (19-n). A first viewpoint (VP-n) is defined within the model (VM1). A light path (PT-1) is generated within the model (VM1). The light path (PT-1) extends through the window screen (W-n) from the first viewpoint (VP-n) to an inner visible edge (IVE-n) of the interior panel (19-n). An intersection point (INP1) is identified where the light path (PT-1) intersects the window screen (W-n). A boundary (OBB-n) of the obscuration region (OBR-n) is defined in dependence on the identified intersection point (INP1). Aspects of the present invention also relate to a method of manufacturing a window screen for a vehicle; a vehicle; a non-transitory computer-readable medium; and an obscuration region identification system.

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METHOD AND APPARATUS FOR DEFINING AN OBSCURATION REGION

TECHNICAL FIELD

The present disclosure relates to a method and apparatus for defining an obscuration region. The method and apparatus have particular application in defining an obscuration region of a window screen of a vehicle, such as a front or rear windscreen or a side window screen of the vehicle. Aspects of the invention relate to a computer-implemented method of defining an obscuration region of a window screen; a method of manufacturing a window screen for a vehicle; a vehicle; a non-transitory computer-readable medium; and an obscuration region identification system.

BACKGROUND

A window screen of vehicle, such as an automobile, typically comprises an obscuration region. The obscuration region may, for example, comprise or consist of a band extending at least partially around a perimeter of the window screen. The obscuration region is provided to hide or obscure features of the vehicle, particularly when viewed from outside the vehicle. A typical function of the obscuration region is to hide from view a gap formed between an interior trim panel and the window screen or an adjacent body section of the vehicle. The interior trim panel may, for example, be disposed on a pillar or a header of the vehicle body. The obscuration region is positioned and so that vehicle body (body-in-white) cannot easily be seen through the gap. Often, the position and extent of the obscuration region is decided entirely based on the geometry of the trim and windscreen. However, when a physical vehicle is available, for example as a pre-production or a mock-up vehicle, it may be determined that the definition of the obscuration region is not appropriate to perform the desired function. This may result in late tooling changes and/or scrapage to refine the definition of the obscuration region.

It is an aim of the present invention to address one or more of the disadvantages associated with the prior art.

SUMMARY OF THE INVENTION

Aspects and embodiments of the invention provide a computer-implemented method of defining an obscuration region of a window screen; a method of manufacturing a window screen for a vehicle; a vehicle; a non-transitory computer-readable medium; and an obscuration region identification system as claimed in the appended claims.

According to an aspect of the present invention there is provided a computer-implemented method of defining an obscuration region for a window screen of a vehicle to at least partially obscure an interior panel of the vehicle, wherein the method comprises: generating a model of the window screen and the interior panel; defining a first viewpoint within the model; generating a viewpoint reference surface within the model, the viewpoint reference surface extending through the window screen from a first viewpoint to an inner visible edge of the interior panel; modelling a light path through the window screen in dependence on a segment of the viewpoint reference surface extending from the inner visible edge of the interior panel to an inner surface of the window screen; identifying an intersection point where the light path intersects the window screen; and defining a boundary of the obscuration region in dependence on the identified intersection point. The method enables determination of the boundary of the obscuration region to be defined at least partially to obscure from view the interior panel. The defined boundary represents an edge of an obscuration region of the window screen. The method enables determination of an extent of the obscuration region. The boundary of the obscuration region is used to define the obscuration region of the window screen. At least in certain embodiments, the computer-implemented method allows the obscuration region to be defined more accurately, removing or reducing late changes.

A plurality of the light paths may be generated, for example to represent a range of different heights and/or positions from different viewpoints. Refraction due to the glass may be estimated and a required edge for the obscuration to cover the gap with interior trim may be determined for each viewing position assessed.

The light path may be modelled so as to be coincident with (or aligned with) the segment of the viewpoint reference surface extending from the inner visible edge of the interior panel to the inner surface of the window screen. The segment may define a section of the first light path extending from the inner visible edge to the first viewpoint.

The viewpoint reference surface may be generated as a tangent to the inner visible edge of the interior panel. The viewpoint reference surface may extend from the or each viewpoint to the inner visible edge of the interior panel. The inner visible edge may be the innermost edge of the first trim panel that is visible from the or each viewpoint. At least in certain embodiments the viewpoint reference surface is defined as an un-refracted surface (i.e., a surface which is not refracted by the window screen).

As described herein, the light path may be calculated to allow for refraction of light travelling from the or each viewpoint to the inner visible edge. The inner visible edge may be defined as the edge of the interior panel which is disposed closest to the inner surface of the window screen.

The model may define a refractive index of the window screen. The light path may be generated in dependence on the refractive index of the window screen. The light path may be generated to account for refraction on entering into and exiting from the window screen. The refractive index of air may also be modelled.

The window screen may be modelled as consisting of a single layer or more than one layer. The or each layer may be modelled as a layer of glass. The or each layer may be modelled as a layer of a transparent plastic. Alternatively, the window screen may be modelled as comprising a plurality of laminations. The window screen may be modelled as comprising one or more reinforcing layers. The or each reinforcing layer may be composed of a plastic material, such as poly-vinyl butyral (PVB). The or each reinforcing layer may be disposed between two adjacent laminations. Alternatively, or in addition, the reinforcing layer may be disposed on an inside or an outside of the window screen. The model of the window screen may model each lamination and optionally also the or each reinforcing layer.

The light path may be generated to represent refraction at one or more surfaces of the window screen. The refraction may occur at an inner surface of the window screen; and/or at an outer surface of the window screen. Alternatively, or in addition, the light path may be generated to represent refraction at one or more internal surfaces of the window screen. The or each internal surface may, for example, be a surface of a lamination of the window screen.

The window screen comprises an outer surface and an inner surface. The outer surface may be an A-surface. The inner surface may be a B-surface. The intersection point may be the point where the light path intersects the inner surface of the window screen. The intersection point of the light path may correspond to the point where the viewpoint reference surface intersects the inner surface of the window screen. The light path may be generated to represent refraction at the outer surface and/or at the inner surface of the window screen.

The method may comprise determining an angle of incidence of the light path at the inner surface of the window screen. The method may comprise determining an angle of refraction of the light path at the inner surface of the window screen. The method may comprise determining a refracted light path which represents the refracted path of the light through the window screen.

The light path may be generated to represent refraction at one or more internal surfaces disposed between the outer surface and the inner surface of the window screen.

The layer forming the obscuration region may be partially or completely opaque. In certain embodiments, the layer forming the obscuration region may be completely opaque in a first region, for example proximal an outer edge of the window screen; and may be partially opaque in a second region, for example inset from the outer edge of the window screen. The layer forming

the opaque obscuration region may be substantially continuous. The layer forming the partially opaque obscuration region may be interrupted or discontinuous. For example, the layer may comprise apertures to create localised openings in the obscuration region. This may be used to form a dot-fade pattern, for example.

5 The obscuration region of the window screen may comprise or consist of a layer which is applied to a surface of the window screen. The layer may, for example, be applied to an inner or an outer surface of the window screen. Alternatively, or in addition, the layer may be applied to an internal surface of the window screen. For example, the layer may be applied to a surface of a lamination of the window screen. The layer may, for example, be applied by a printing process. Other techniques may be used to form the obscuration region.

10 The intersection point may correspond to the point where the light path intersects a surface of the window screen on which the obscuration region will be formed. The intersection point may correspond to the point where the light path intersects a surface of the window screen on which the obscuration region is disposed.

The obscuration region may be formed on an inner surface of the window screen. The intersection point may correspond to the point where the light path intersects the inner surface of the window screen. This approach may, for example, be applied to define the boundary of an obscuration region which is formed on the inner surface of the window screen.

15 The intersection point may correspond to the point where the light path intersects an internal surface of the window screen, for example a surface of a lamination. This approach may, for example, be applied to define the boundary of an obscuration region which is formed on the internal surface of the window screen. The internal surface may correspond to the surface of a lamination on which the obscuration region will be formed. The light path may be generated to model refraction at the or each surface of one or more lamination. The intersection point may be the intersection of the refracted light path within the window screen and the internal surface of the window screen.

20 The light path may be modelled along a length of the inner visible edge of the interior panel to define the boundary of the obscuration region.

25 The method described herein may be performed at a plurality of locations around the perimeter of the window screen. The boundary may be defined by determining a curve extending through each of the plurality of locations. At least in certain embodiments, the method may be repeated around a perimeter of the window screen to define the boundary of the obscuration region.

30 The boundary of the obscuration region may be defined as corresponding to the identified intersection point. Alternatively, the boundary of the obscuration region may be defined as an offset from the identified intersection point. The offset may be predefined, for example as a positive variable (+ve) or a negative variable (-ve). The offset may be applied in a direction substantially perpendicular to a local edge of the window screen, or in a radial direction. Alternatively, the offset may be determined dynamically, for example based on analysis for a second viewpoint.

The method may be repeated in respect of a second viewpoint. The first and second viewpoints may be offset from each other, for example in a vertical (Z) direction and/or in a horizontal (XY) plane.

35 The window screen and the interior panel may be modelled in a three-dimensional space comprising a ground plane. The first viewpoint may be defined in the three-dimensional space.

The model may optionally define at least a part of a body of the vehicle (the so-called body-in-white). For example, the model may define one or more of the following: a body pillar (such as an A-pillar, a B-pillar or a C-pillar); an upper roof header; a lower transverse member; and a lower side member. The vehicle body or part thereof may be defined with reference to a ground plane.

According to a further aspect of the present invention there is provided a method of manufacturing a window screen for a vehicle. The method may comprise defining the boundary of the obscuration region using the method described herein. The method may comprise forming an obscuration region at least substantially matching the boundary of the obscuration region.

According to a further aspect of the present invention there is provided a window screen for a vehicle manufactured using the method(s) described herein.

According to a further aspect of the present invention there is provided a vehicle comprising a window screen as described herein. The window screen may comprise an obscuration region defined using the method(s) described herein.

According to a further aspect of the present invention there is provided a non-transitory computer-readable medium having a set of instructions stored therein which, when executed, cause a processor to perform the method described herein.

According to a further aspect of the present invention there is provided an obscuration region identification system comprising a controller having at least one processor and a system memory, the at least one processor being configured to implement the method described herein. The obscuration region identification system may be a dedicated computational device. Alternatively, the obscuration region identification system may be a general purpose computational device executing computational instructions to perform the method(s) described herein.

Any control unit or controller described herein may suitably comprise a computational device having one or more electronic processors. The system may comprise a single control unit or electronic controller or alternatively different functions of the controller may be embodied in, or hosted in, different control units or controllers. As used herein the term "controller" or "control unit" will be understood to include both a single control unit or controller and a plurality of control units or controllers collectively operating to provide any stated control functionality. To configure a controller or control unit, a suitable set of instructions may be provided which, when executed, cause said control unit or computational device to implement the control techniques specified herein. The set of instructions may suitably be embedded in said one or more electronic processors. Alternatively, the set of instructions may be provided as software saved on one or more memory associated with said controller to be executed on said computational device. The control unit or controller may be implemented in software run on one or more processors. One or more other control unit or controller may be implemented in software run on one or more processors, optionally the same one or more processors as the first controller. Other suitable arrangements may also be used.

Within the scope of this application it is expressly intended that the various aspects, embodiments, examples and alternatives set out in the preceding paragraphs, in the claims and/or in the following description and drawings, and in particular the individual features thereof, may be taken independently or in any combination. That is, all embodiments and/or features of any embodiment can be combined in any way and/or combination, unless such features are incompatible. The applicant reserves the right to change any originally filed claim or file any new claim accordingly, including the right to amend any originally filed claim to depend from and/or incorporate any feature of any other claim although not originally claimed in that manner.

BRIEF DESCRIPTION OF THE DRAWINGS

One or more embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 shows a schematic representation of a vehicle having an obscuration region associated with a window screen;

Figure 2 shows a perspective view of a virtual model representing a portion of the vehicle shown in Figure 1;

Figure 3 shows a plurality of viewpoints defined relative to the virtual model shown in Figure 2;

Figure 4 shows an inner visible edge of a first trim panel in the virtual model shown in Figure 2;

Figure 5 shows an enlarged view of the first trim panel and the inner visible edge shown in Figure 4;

Figure 6 shows a schematic representation of an obscuration region identification system for determining an obscuration of a window screen in accordance with an embodiment of the present invention;

5 Figure 7 shows a sectional view of a first window screen and a refracted light path from the inner visible edge of trim panel'

Figures 8A and 8B show a schematic representation of the procedure to construct a curve based on the angle of incidence of an incident light surface representing a light path projected towards a viewpoint;

Figures 9A, 9B and 9C show a schematic representation of the procedure to model a trisection of the curve where the incident light intersects the glass surface and the curve based on an angle of incidence on the inner surface of the window screen;

10 Figure 10 illustrates a geometric representation of the trisection shown in Figures 9A, 9B and 9C;

Figure 11A and 11B show a schematic representation of the determination of the refracted light path through the first window screen;

Figure 12A shows a schematic representation of the refracted light path through the first window screen; and

15 Figure 12B shows a schematic representation of the determination of the obscuration boundary at an intersection of the determined refracted light path and an internal surface where the obscuration region is formed.

DETAILED DESCRIPTION

A system 1 and a method for defining an obscuration region OBR-n of a window screen W-n of a vehicle 5 in accordance with an embodiment of the present invention will now be described with reference to the accompanying figures. The system 1 is referred to herein as an obscuration region identification system 1. The method of defining the obscuration region OBR-n is a
20 computer-implemented method. The suffix -n, used with different indices, such as W, OBR, 13 etc, refers to any integer used in the drawings and description, where each of OBR-1, OBR-2, OBR-3 etc are all the same basic entity, where the same considerations apply, but which may be separate regions or different components.

The vehicle 5 in the present embodiment is a road vehicle, such as an automobile, a sports utility vehicle or a utility vehicle. The vehicle 5 comprises a body 7 having a plurality of window apertures 9-n and an occupant cabin 11. Each window aperture
25 9-n is configured to receive one of the window screens W-n. The window screens W-n each comprise or consist of a transparent screen. The transparent screen may be mounted to the body 7. The window screens W-n in the present embodiment comprise a multi-layered laminated glass. By way of example, the window screens W-n may comprise a central layer of poly-vinyl butyral (PVB) sandwiched between inner and outer layers of clear tempered glass to form a laminate. The window screens W-n may have different configurations, for example consisting of a single layer or comprising a plurality of
30 laminations with or without a plastic layer.

The window screens W-n may be fixedly or movably mounted to the body. For example, the window screen W-n may be movably mounted to the body 7 to enable opening and closing of the window screen W-n. As illustrated in Figure 1, the vehicle 7 in the present embodiment comprises a first window screen (front windshield) W-1, a plurality of side window screens W-2, a rear quarter window screen W-3 and a rear window screen (rear windshield) W-4. The obscuration region identification
35 system 1 and method are described herein with reference to defining the first obscuration region OBR-1 of the first window screen W-1 of the vehicle 7. It will be understood that the system and method(s) described herein may be used to define the obscuration region OBR-n of one or more of the other window screens W-n in the vehicle 5. The window screens W-n may be curved in two- or three-dimensions. In certain applications, the window screens W-n may be planar.

The first window screen W-1 is provided in a first window aperture 9-1 formed in the body 7. The first window aperture 9-1 is bounded by a first front pillar (A-pillars) 13-1, a second front pillar (A-pillar) 13-2, an upper roof (header) member 15 and a lower transverse member 17. Trim panels 19-n are provided inside the cabin 11 to hide the body 7 from view, primarily from occupants of the vehicle. A plurality of the trim panels 19-n are provided around the first window aperture 9-1 to hide the body 7. A first trim panel 19-1 is provided over the first front pillar 13-1; a second trim panel 19-2 is provided over the second front pillar 13-2; a header trim panel 19-3 is provided over the upper roof member 15; and a dashboard trim panel 19-4 is provided over the lower transverse member 17. As shown in Figure 5, an edge section 21-n of each trim panel 19-n is disposed proximal to the associated window screen W-n. The edge section 21-n may comprise a panel edge or a flange disposed adjacent to the associated window screen W-n. The window screen W-n may comprise a sunroof or a panoramic window screen disposed in a roof of the vehicle. The obscuration region identification system 1 may define the extent of the obscuration region OBR-n in the sunroof or the panoramic window screen.

The obscuration region OBR-n is provided on the window screens W-n to hide from view at least a portion of the associated interior panel(s) 19-n. More particularly, the obscuration region OBR-n is provided around at least a portion of a periphery of the window screens W-n to hide from view the edge section 21-n of the associated interior panel(s) 19-n disposed adjacent to the associated window screen W-n. Without the obscuration region OBR-n, the edge section 21-n of the interior panel(s) 19-n may be visible through the window screen W-n. The obscuration region OBR-n has a lower optical transmissivity than the remainder of the window screen W-n. In the present embodiment, the obscuration region OBR-n is at least substantially opaque. The obscuration region OBR-n is in the form of an opaque layer disposed on the window screen W-n. The obscuration region OBR-n may be formed by applying a coating to a surface of a lamination of the window screen W-n or an inner/outer surface of the window screen W-n. The obscuration region OBR-n in the present embodiment comprises an opaque coating applied to an inner surface of an outer laminate (referred to as surface 2) of the window screen W-n. Other arrangements of the obscuration region OBR-n are contemplated. For example, the obscuration region OBR-n may be applied to an innermost surface of the window screen W-n. The obscuration region OBR-n in the present embodiment comprises a band or a strip extending at least partway around a perimeter of the window screen W-n. The band or strip may, for example, be substantially continuous and extend inwardly from an outer edge of the window screen W-n. The obscuration region OBR-n may optionally comprise or consist of a transition region, for example comprising an interrupted (discontinuous) pattern or a partially transparent region. The transition region may, for example, comprise a dot-fade pattern. The configuration of a first obscuration region OBR-1 disposed on the first window screen W-1 will now be described in more detail.

The first window screen W-1 in the present embodiment comprises an outer surface 25A (i.e. the A-surface), an inner surface 25B and an internal surface 25C. The internal surface 25C is disposed within the first window screen W-1 between the outer surface 25A and the inner surface 25B. The internal surface 25C may, for example, be formed at the interface between first and second laminates of the first window screen W-1. The internal surface 25C in the present embodiment is defined by an inner surface of an outer laminate of the first window screen W-1. The obscuration region OBR-n is an opaque coating which is applied to the internal surface 25C. The obscuration region OBR-1 may be formed on other internal surfaces, for example on a surface of another laminate of the first window W-1. Alternatively, the obscuration region OBR-1 may be formed on the outer surface 25A or the inner surface 25B of the first window W-1.

The first obscuration region OBR-1 is profiled at least partially to hide from view the interior trim panels 19-n provided around the first window aperture 9-1. More particularly, the first obscuration region OBR-1 is profiled to hide from view the edge sections 21-n of the interior trim panels 19-n provided around the first window aperture 9-1. The first obscuration region OBR-1 comprises a first vertical section 23-1, a second vertical section 23-2, an upper transverse section 23-3 and a lower

transverse section 23-5. The first and second vertical sections 23-1, 23-2 are disposed on the left and right sides respectively of the first window screen W-1. In use, the first and second vertical sections 23-1, 23-2 hide at least a portion of the first and second trim panels 19-1, 19-2 respectively. The upper transverse section 23-3 of the first obscuration region OBR-1 extends at least partway across a top of the first window screen W-1 to hide the at least a portion of the header trim panel 19-3. The lower transverse section 23-4 of the first obscuration region OBR-1 extends at least partway across a bottom of the first window screen W-1 to hide at least a portion of the header trim panel 19-3. The first obscuration region OBR-1 may comprise one or more apertures (not shown). The one or more apertures may, for example, be provided to enable a vehicle identification number to be viewed through the window screen W-n, to mount a rear-view mirror to the first window screen W-1, or to provide a viewing aperture for a sensor, such as an optical camera.

The obscuration region identification system 1 is configured to determine a profile of the first obscuration region OBR-1 of the first window screen W-1. In particular, the obscuration region identification system 1 is configured to determine a profile of an inner edge of the first obscuration region OBR-1. The method is implemented on a computational device. For example, the method may be implemented on a general-purpose computer configured to execute a set of instructions. As represented schematically in Figure 6, the obscuration region identification system 1 comprises a controller 31 having at least one electronic processor 33 and a system memory 35. The at least one electronic processor 33 has at least one electrical input 37 and at least one electrical output 39. A set of computational instructions 41 is stored on the system memory 35. When executed the computational instructions 41 cause the controller 31 to implement the method(s) described herein.

The at least one electronic processor 33 is configured to receive user inputs and vehicle data representing a virtual model VM1 of the vehicle 5. The obscuration region identification system 1 is configured to define a virtual model VM1 comprising a virtual representation of at least a portion of the vehicle 5 and the first window screen W-1. The virtual representation of the vehicle 5 in the virtual model VM1 may, for example, be based on Computer Aided Design (CAD) data of the vehicle 5. The virtual representation of the vehicle 5 (or a portion thereof) is defined in a three-dimensional space within the virtual model VM1. In the present embodiment, the virtual model VM1 comprises a virtual representation of a portion of the body 7 of the vehicle 5 which forms the first window aperture 9-1. The first trim panel 19-1, the second trim panel 19-2, the header trim panel 19-3 and the dashboard trim panel (not shown) are defined in the virtual model VM1. A perspective view of the virtual model VM1 is shown in Figure 2. The virtual model VM1 comprises a plurality of viewpoints VP-n defined within the three-dimensional space, as shown in Figure 3. In the present embodiment, the viewpoints VP-n are at predefined fixed locations in the three-dimensional space. The viewpoints VP-n are defined outside an external perimeter of the vehicle 5 in the virtual model M1. At least in certain embodiments, the positioning of the viewpoints VP-n may provide a more accurate representation of a real-world viewing position of a person outside the vehicle 5. The vertical position of the viewpoints VP-n in the three-dimensional space (for example, relative to a virtual ground plane GP1) correspond to a predetermined height of a man or a woman. In the present embodiment, the vertical positions of the viewpoints VP-n are defined corresponding to an eye height of a 95th percentile male and a 5th percentile female. The viewpoints VP-n may be defined at other vertical positions. The vertical position of the or each viewpoint VP-n may be predefined. Alternatively, or in addition, the vertical position of the or each viewpoint VP-n may be adjustable, for example to enable user customisation. This may be appropriate to enable determination of the obscuration region OBR-n for particular physical characteristics, for example in dependence on a height of a specific viewer. Alternatively, or in addition, the height and/or position of the or each viewpoint VP-n may be adjusted to see past an existing obscuration.

The operation of the obscuration region identification system 1 is described herein with reference to the determination of the profile of the first vertical section 23-1 of the first obscuration region OBR-1. As shown in Figures 3 and 4, the first vertical

section 23-1 of the first obscuration region OBR-1 is configured at least partially to hide from view at least a portion of the first trim panel 19-1 disposed on the first front pillar 13-1. The method is described herein with reference to a first viewpoint VP-1. It will be understood that the method may be performed in respect of more than one viewpoint VP-n.

The obscuration region identification system 1 generates a light path PT-n within the virtual model VM1. The light path PT-n extends from the first viewpoint VP-1, through the first window screen W-1 to an inner visible edge IVE-n of the first trim panel 19-1. The inner visible edge IVE-n is the innermost part of the first trim panel 19-1 that is visible from the or each viewpoint VP-n. It will be understood that the inner visible edge IVE-n may vary for different viewpoints VP-n. The light path PT-n is generated as a tangent to the inner visible edge IVE-1 of the first trim panel 19-1. The inner visible edge IVE-n corresponds to the innermost edge of the first trim panel 19-1 that is visible from the first viewpoint VP-1. The light path PT-n comprises a line-of-sight vector extending from the first viewpoint VP-1 to the inner visible edge IVE.

The light path PT-n can be modelled as a linear path extending between the first viewpoint VP-1 and the innermost edge of the first trim panel 19-1. However, it has been recognised that the light traversing the first window screen W-1 is refracted resulting in a non-linear light path PT-n. At least in certain embodiments, the refraction of the light path PT-n is modelled. In the present embodiment, the obscuration region identification system 1 implements a light path model configured to simulate the refraction of the light path PT-n traversing the first window screen W-1. The light path model defines a refractive index of the first window screen W-1. The refraction of light as it passes through the first window screen W-1 in the present embodiment is approximated by modelling the first window screen W-1 as a homogenous screen having a uniform refractive index. The light path model models refraction at an outer surface 25A (i.e. the A-surface) of the first window screen W-1 and at an inner surface 25B of the first window screen W-1. In a variant, the light path model may define the refractive index of each layer of the multi-layered laminate forming the first window screen W-1. The light path model may model refraction at the outer surface 25A, the inner surface 25B and also at the interface between the layers forming the first window screen W-1.

The profile of the first window screen W-1 is defined in the virtual model VM1 to enable more accurate determination of the light path PT-n. The first window screen W-1 is modelled to define the curvature of the first window screen W-1. The first window screen W-1 in the present embodiment is curved in three-dimensions. The light path model is configured to model the light path PT-n from the first viewpoint VP-1 taking account of the curvature of the first window screen W-1.

The light path model is configured to determine the light path PT-n through the first window screen W-1. An intersection point INP1 is identified where the light path PT-n intersects a surface of the first window screen W-1. The intersection point INP1 corresponds to the point where the light path PT-n intersects the surface of the first window screen W-1 on which the obscuration region OBR-1 is formed. In the present embodiment, the obscuration region OBR-1 is formed on the internal surface 25C of the first window screen W-1. The intersection point INP1 corresponds to the point where the light path PT-n intersects the internal surface 25C of the first window screen W-1. Thus, the intersection point INP1 represents the location where the light path PT-n intersects the surface on which the obscuration region OBR-1 is formed. A first boundary OBB-1 of the obscuration region OBR-1 is defined in dependence on the identified intersection point INP1. The first boundary OBB-1 may be defined as corresponding to the identified intersection point INP1. Alternatively, the first boundary OBB-1 may be offset from the identified intersection point INP1 by a predetermined distance. A boundary offset may be defined to increase the width of the obscuration region OBR-1. A boundary offset may be uniform around the periphery of the first window screen W-1. Alternatively, the boundary offset may vary for different regions. For example, a first boundary offset may be defined for the first and second trim panels 19-1, 19-2 and a second boundary offset may be defined for the third trim panel 19-3 and/or the fourth trim panel 19-4. In a variant, the intersection point INP1 corresponds to the point where the light path PT-n intersects the outer surface 25A or the inner surface 25B of the first window screen W-1.

The light path PT-1 is modelled along a length of the inner visible edge IVE-n of the first trim panel 19-1. The first boundary OBB-1 of the obscuration region OBR-1 may be defined along the length of the first trim panel 19-1. The process may be performed around a perimeter of the first window screen W-1 to define the first boundary OBB-1 of the obscuration region OBR-1.

5 The obscuration region identification system 1 determines the first boundary OBB-1 with reference to a first viewpoint VP-1. The obscuration region identification system 1 may optionally repeat the process with reference to a second viewpoint VP-2. The first and second viewpoints VP-1, VP-2 are offset from each other. A second boundary OBB-2 may be determined in respect of the second viewpoint VP-2. The determined first and second boundaries OBB-1, OBB-2 are typically spaced apart from each other. In the present embodiment, the first viewpoint VP-1 is disposed at a first height in the three-dimensional space; and the second viewpoint VP-2 is disposed at a second height in the three-dimensional space. The first height is lower than the second height in an example, but it may also be the same height, but at a different lateral location, as shown in Figure 3). The obscuration region OBR-1 may be defined in dependence on the first and second boundaries OBB-1, OBB-2, for example a mid-point between the first and second boundaries OBB-1, OBB-2, or a maximum obscuration region defined by first and second boundaries OBB-1, OBB-2.

15 The obscuration region identification system 1 to determine the first boundary OBB-1 will now be described with reference to Figures 7 to 11. The operation of the obscuration region identification system 1 is described with reference to the first window screen W-1, but it will be understood that the same process may be applied in respect of each window screen W-n. As outlined above, the obscuration region identification system 1 implements a light path model to model refraction of light traversing the glass forming the first window screen W-1. The refraction of the light path PT-n is evident at the first and second front pillars 13-1, 13-2 of the first window screen W-n. The result is particularly evident when viewing from the opposite side of the vehicle 5, due to the shallow angle of incidence. The determination of the first boundary OBB-1 of the obscuration region OBR-1 associated with the first front pillar 13-1 will now be described by way of example.

25 A first trim panel 19-1 is provided over the first front pillar 13-1. A viewpoint reference surface VRS-1 is defined from the first viewpoint VP-1 to the inner visible edge IVE-1 of the first trim panel 19-1. The viewpoint reference surface VRS-1 comprises a surface coincident with the outermost visible edge of the first trim panel 19-1. The viewpoint reference surface VRS-1 represents the light path PT-1 from the first viewpoint VP-1 to the inner visible edge IVE-1 of the first trim panel 19-1 without refraction.

30 As described herein, the refraction of the light path PT-1 at the inner surface 25B (i.e., the B-surface) of the first window screen W-1 is modelled. The refractive index of the first window screen W-1 is defined as 1.5; and the refractive index of air is defined as 1. The refractive index of the first window screen W-1 may be modified, for example to approximate a refractive index of a laminated window screen.

The application of Snell's law is as follows:

$$n_1 \sin(\theta_i) = n_2 \sin(\theta_r)$$

$$\sin(\theta_r) = \frac{n_1 \sin(\theta_i)}{n_2}$$

35 Where

n_1 = Refractive index of air

n_2 = Refractive index of windscreen

θ_i = Angle of incidence

θ_r = Angle of refraction

Substituting values for n_1 and n_2 gives

$$\sin(\theta_r) = \frac{1 \sin(\theta_i)}{1.5}$$

$$\sin(\theta_r) = \frac{2}{3} \sin(\theta_i)$$

5 The light path model determines the angle of incidence θ_i and the angle of refraction θ_r .

The modelling of the first light path PT-1 through the first window screen W-1 will now be described. The modelling of the first light path PT-1 is illustrated in two-dimensions in the sectional views of the first window screen W-1 shown in Figures 7 to 11. The first light path PT-1 is described in two dimensions with reference to localised points, for example intersection points and points of incidence. It will be understood that the light path models the first light path PT-1 in three dimensions to represent the profile of the inner visible edge IVE-1. The localised points are calculated or extrapolated along the inner visible edge IVE-1 and form curves extending in three dimensions (out of the plane of the page in Figures 7 to 11). The angle of incidence θ_i and the angle of refraction θ_r may vary along the inner visible edge IVE-1, for example in dependence on changes in the profile of the first trim panel 19-1.

10 The viewpoint reference surface VRS-1 is defined from the first viewpoint VP-1 to the inner visible edge IVE-1 of the first trim panel 19-1, as shown in Figure 7. The viewpoint reference surface VRS-1 consists of a plane and does not model the refraction of light passing through the first window screen W-1. A first segment SG-1 of the viewpoint reference surface VRS-1 is defined from the inner visible edge IVE-1 to the inner surface 25B of the first window screen W-1. The first segment SG-1 is incident on the inner surface 25B and defines the first light path PT-1 along the inner visible edge IVE-1 to the first viewpoint VP-1. As shown in Figures 8A, the angle between the first segment SG-1 and a surface perpendicular to the inner surface 25B represents a localised angle of incidence θ_i of the first light path PT-1. The refraction of the first light path PT-1 is modelled at the interface defined by the inner surface 25B to determine a refracted light path RPT-1 within the first window screen W-1. The refracted light path RPT-1 is calculated around the perimeter of the inner visible edge IVE-1 to generate an internal refracted surface INS-1 which represents the refracted light path RPT-n.

20 The obscuration region OBR-1 is formed on a predefined surface of the first window screen W-1. In the present embodiment, the obscuration region OBR-1 is formed on the second surface 25C corresponding to the inner surface of the outer laminate of the first window screen W-1. The second surface 25C is modelled in three-dimensions in the light path model to enable determination of the first boundary OBB-1 of the obscuration region OBR-1. The first boundary OBB-1 consists of a curve defined by the intersection of the internal refracted surface INS-1 and the second surface 25C of the first window screen W-1. The first boundary OBB-1 is output to define the extent of the obscuration region OBR-1.

30 The modelling of the first light path PT-1 will now be described in more detail with reference to Figures 8 to 12. As outlined above, the relationship between the angle of incidence θ_i and the angle of refraction θ_r is based on the refractive index of 1.5 for the first window screen W-1. The construction of a curve proportional to the sine of the angle of incidence $\sin(\theta_i)$ is illustrated in Figures 8A and 8B.

35 As shown in Figure 8A, the first segment SG-1 represents a portion of the viewpoint reference surface VRS-1 representing the first light path PT-1 from the inner visible edge IVE-1 to the inner surface 25B of the first window screen W-1. The light path PR-1 is incident with the inner surface 25B (i.e., the B-surface) of the first window screen W-1 at a point of incidence ICP1. The point of incidence ICP1 is determined along the inner visible edge IVE-1 of the first trim panel 19-1 with respect to

the first viewpoint VP-1 to generate a curve of incidence CIP1 on the inner surface 25B of the first window screen W-1. First and second normal surfaces N-1, N-2 are defined perpendicular to the inner surface 25B of the first window screen W-1. The light path PT-1 is inclined relative to the first and second normal surfaces N-1, N-2 at the angle of incidence θ_i .

A reference curve RFC-1 is defined on the inner surface 25B of the first window screen W-1. The first normal surface N-1 intersects the first segment SG-1 along a first reference curve LPP-1 which intersects the first segment SG-1 at a predetermined first offset $\Delta 1$ from the point of incidence ICP1. In the present embodiment, the first offset $\Delta 1$ is 0.1mm. The first offset $\Delta 1$ may be less than or greater than 0.1mm. The first normal surface N-1 intersects the inner surface 25B of the first window screen W-1 along an offset curve OFP-1. As shown in Figure 8B, the offset curve OFP-1 is displaced from the point of incidence ICP1 by a distance $0.1\sin(\theta_i)$ on the inner surface 25B. The curve of incidence CIP1 of the light path PT-1 is determined along the inner visible edge IVE-1 of the first trim panel 19-1 with respect to the first viewpoint VP-1 to generate the reference curve RFC-1 on the inner surface 25B of the first window screen W-1.

An intermediate reference curve INC-1 is generated on the inner surface 25B between the curve of incidence CIP1 and the reference curve RFC-1. The intermediate reference curve INC-1 is located two thirds (2/3) of the distance from the curve of incidence CIP1 to the reference curve RFC-1. The intermediate reference curve INC-1 is generated by determining the location of an intermediate point ITP-1 between the curve of incidence CIP1 and the offset curve OFP-1. The generation of the intermediate reference curve INC-1 is illustrated in Figures 9A-9C. The intermediate point ITP-1 is located two thirds (2/3) of the distance from the curve of incidence CIP1 to the offset curve OFP-1. An offset reference line RL-1 is defined extending parallel to the first segment SG-1 and passing through the offset curve OFP-1. The first reference curve LPP-1 is defined on the first segment SG-1. A second reference point RPP-1 is defined on the offset reference line RL-1 at a predetermined second offset $\Delta 2$ from the inner surface 25B. The second offset $\Delta 2$ is half (0.5) of the first offset $\Delta 1$ (i.e., $\Delta 2 = 0.5 * \Delta 1$). In the present embodiment, the second offset $\Delta 2$ is 0.05mm. The second reference point RPP-1 is defined on the opposite side of the inner surface 25B to the first reference curve LPP-1. As shown in Figure 9C, an intersecting surface INSF-1 is defined to join the first reference curve LPP-1 and the second reference point RPP-1. The intersecting surface INSF-1 intersects the inner surface 25B of the first window screen W-1 at the intermediate point ITP-1, thereby defining the intermediate reference curve INC-1. The intermediate reference curve INC-1 is defined on the inner surface 25B at a distance which is two thirds (2/3) of the offset between the curve of incidence CIP1 and the offset curve OFP-1.

A proof of the location of the intermediate reference curve INC-1 in relation to the curve of incidence CIP1 and the offset curve OFP-1 is shown in Figure 10.

The trisection is explained with reference to a first triangle ABC and a second triangle CDE in Figure 10. The first triangle ABC is formed by the offset reference line RL-1, the inner surface 25B and the intersecting surface INSF-1; and the second triangle CDE is formed by the light path PT-1, the inner surface 25B and the intersecting surface INSF-1 are labelled A to E in Figure 10. The first and second triangles ABC, CDE are similar since they share parallel sides. The angles can be shown to be equal using the alternate interior angles theorem. As the ratio between the sides are constant, $\frac{BC}{CD} = \frac{AB}{DE}$. This shows that the ratio between the parallel lines determines the ratio between the distances from the final intersection and the two curves created therefrom. The angles BAC and CED are equal due to alternate interior angle theorem. Similarly, the angles ABC and CDE are equal due to alternate interior angle theorem. The angles BCA and DCE are equal due to opposite angle theorem. The distance C to D is two thirds (2/3) of the distance B to D. Since the angles of the triangles ABC and CDE are the same and the longest side of the triangle CDE is twice that of the triangle ABC, all of the sides of the triangle CDE are twice as long as

those of the triangle ABC. Therefore, the intermediate reference curve INC-1 is located on the inner surface 25B at a distance which is twice as far from the curve of incidence CIP1 as it is from the offset curve OFP-1.

The determination of the angle of refracted light path RPT-1 through the first window W-1 is illustrated in Figure 11A and 11B. A cylindrical surface CRC-1 is defined having a radius equal to the first offset $\Delta 1$ and having a centre coincident with the curve of incidence CIP1 on the inner surface 25B. The cylindrical surface CRC-1 defines a surface at a constant distance from the point of incidence ICP-1. A first normal surface N' is defined perpendicular to the inner surface 25B along the intermediate reference curve INC-1. The first normal surface N' is projected (downwards) in a direction perpendicular to the inner surface 25B and intersects the cylindrical surface CRC-1 to form a projected edge PJE. The included angle between the first normal surface N1' and the refracted light path RPT-1 is equal to the angle of refraction θ_r . An internal refracted surface INS-1 is defined extending through the projected edge PJE and the curve of incidence CIP1 where the light path PT-1 is incident on the inner surface 25B. The internal refracted surface INS-1 represents the refracted light path RPT-n within the first window screen W-1.

As described herein, the obscuration region OBR-1 is formed on the internal surface 25C of the first window screen W-1. The intersection of the internal refracted surface INS-1 and the internal surface 25C defines the first boundary OBB-1 of the obscuration region OBR-1. The first boundary OBB-1 consists of a curve formed by the intersection of the internal refracted surface INS-1 and the internal surface 25C of the first window screen W-1. The resulting curve corresponds to the first boundary OBB-1 which is appropriate to hide from view (i.e., to obfuscate) the interior trim 19-1.

As shown in Figure 7, when the light passes through the outer surface 25A of the first window screen W-1, the light path PT-n is refracted back to the same direction it came in (assuming the inner and outer surfaces of the first window screen W-1 are parallel to each other). It will be appreciated that the method(s) described herein results in a shift away from the first viewpoint VP-1. However, this offset is small and, since the viewing angle is the same, the variation in the first boundary OBB-1 is negligible.

In a variant, the first boundary OBB-1 may be defined at an intersection of the refracted light path RPT-1 and the outer surface 25A or the inner surface 25B of the first window screen W-1. This may be appropriate, for example, if the obscuration region OBR-1 is formed on the outer surface 25A or the inner surface 25B.

The application of the path of refraction through the first window screen W-1 to determine the first boundary OBB-1 is illustrated in Figures 12A and 12B. The light path PT-1 between the inner visible edge IVE-1 of the first trim panel 19-1 and the inner surface 25B of the first window screen W-1 are shown in Figure 11A. The refracted light path RPT-1 representing the refracted path of the light within the first window screen W-1 is shown in Figure 12A. The internal refracted surface INS-1 represents the path of the refracted light inside the glass forming the first window screen W-1, as illustrated in Figure 12B. The first boundary OBB-1 is defined by the intersection of the internal refracted surface INS-1 and the internal surface 25C of the first window W-1 where the obscuration region OBR-1 is formed. The first boundary OBB-1 represents the extent of the obscuration region OBR-1 required to hide from view the first trim panel 19-1 when viewed from the first viewpoint VP-1. The region between the first boundary OBB-1 and the associated edge of the first window screen W-1 corresponds to the obscuration region OBR-1.

The obscuration region identification system 1 has been described herein with reference to defining the obscuration region OBR-1 to hide from view a trim panel 19-n. It will be understood that the obscuration region identification system 1 may be used to define the obscuration region OBR-1 to hide from view other features. The obscuration region identification system 1 may define the obscuration region OBR-1 in dependence on a housing of a rear-view mirror. The extent of the obscuration

region OBR-1 may be defined in dependence on an inner visible edge of the housing. Alternatively, or in addition, the obscuration region identification system 1 may define the obscuration region OBR-1 in dependence on one or more ventilation duct, for example provided at the bottom of the first window screen W-1. The extent of the obscuration region OBR-1 may be defined in dependence on an inner visible edge of the ventilation duct.

- 5 It will be appreciated that various changes and modifications can be made to the present invention without departing from the scope of the present application.

CLAIMS

1. A computer-implemented method of defining an obscuration region for a window screen of a vehicle to at least partially obscure an interior panel of the vehicle, wherein the method comprises:
 - generating a model of the window screen and the interior panel;
 - 5 defining a first viewpoint within the model;
 - generating a viewpoint reference surface within the model, the viewpoint reference surface extending through the window screen from the first viewpoint to an inner visible edge of the interior panel;
 - modelling a light path through the window screen in dependence on a segment of the viewpoint reference surface extending from the inner visible edge of the interior panel to an inner surface of the window screen;
 - 10 identifying an intersection point where the light path intersects the window screen; and
 - defining a boundary of the obscuration region in dependence on the identified intersection point.
2. A computer-implemented method as claimed in claim 1, wherein the viewpoint reference surface is generated as a tangent to the inner visible edge of the interior panel.
3. A computer-implemented method as claimed in claim 1 or claim 2, wherein the model defines a refractive index of

15 the window screen; and the light path is generated in dependence on the refractive index of the window screen.
4. A computer-implemented method as claimed in claim 3, wherein the light path is generated to represent refraction at one or more surfaces of the window screen.
5. A computer-implemented method as claimed in any one of the preceding claims, wherein the intersection point corresponds to the point where the light path intersects a surface of the window screen on which the obscuration region is

20 disposed.
6. A computer-implemented method as claimed in any one of the preceding claims, wherein the light path is modelled along a length of the inner visible edge of the interior panel to define the boundary of the obscuration region.
7. A computer-implemented method as claimed in any one of the preceding claims, wherein the method is repeated around a perimeter of the window screen to define the boundary of the obscuration region.
8. A computer-implemented method as claimed in any one of the preceding claims, wherein the boundary of the obscuration region is defined as an offset from the identified intersection point.
9. A computer-implemented method as claimed in any one of the preceding claims, wherein the method is repeated in respect of a second viewpoint, the first and second viewpoints being offset from each other.
10. A computer-implemented method as claimed in any one of the preceding claims, wherein the window screen and

30 the interior panel are modelled in a three-dimensional space comprising a ground plane, the first viewpoint being defined in the three-dimensional space.
11. A method of manufacturing a window screen for a vehicle, the method comprising identifying the boundary of the obscuration region using the method claimed in any one of the preceding claims; and forming an obscuration region at least substantially matching the boundary of the obscuration region.
12. A window screen for a vehicle manufactured using the method claimed in claim 11.
13. A vehicle comprising a window screen as claimed in claim 12.

14. A non-transitory computer-readable medium having a set of instructions stored therein which, when executed, cause a processor to perform the method claimed in any one of claims 1 to 10.
15. An obscuration region identification system 1 comprising a controller having at least one processor and a system memory, the at least one processor being configured to implement the method claimed in any one of claims 1 to 10.

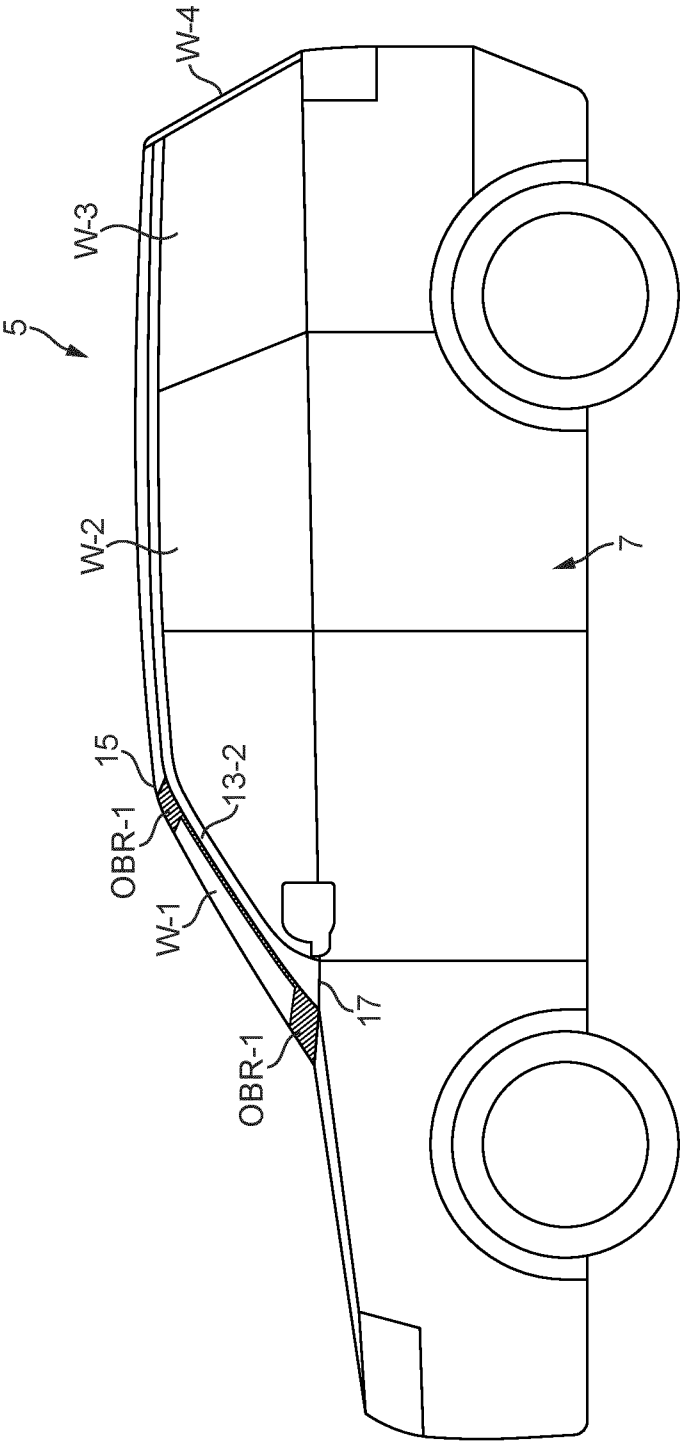


FIG. 1

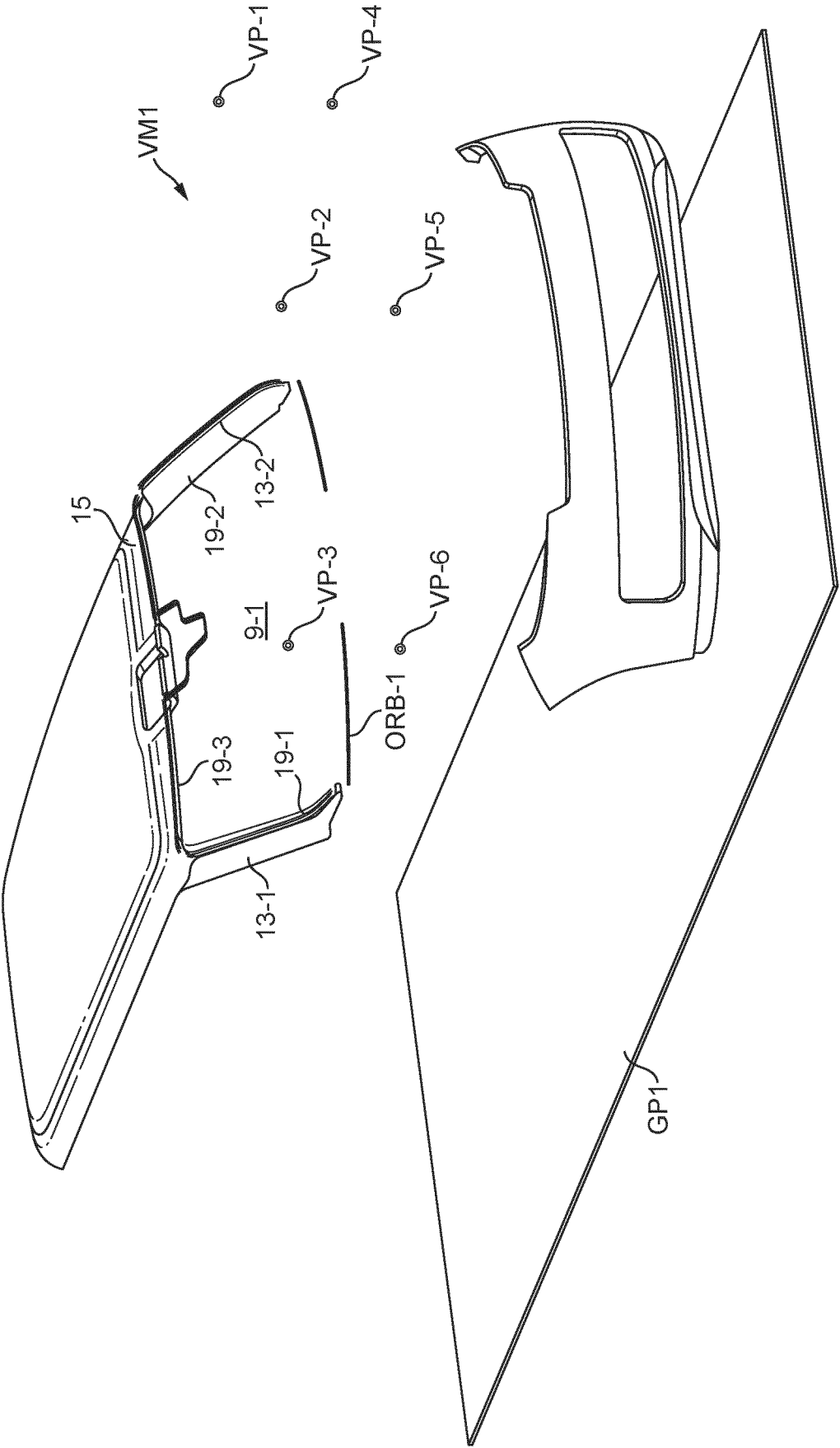


FIG. 2

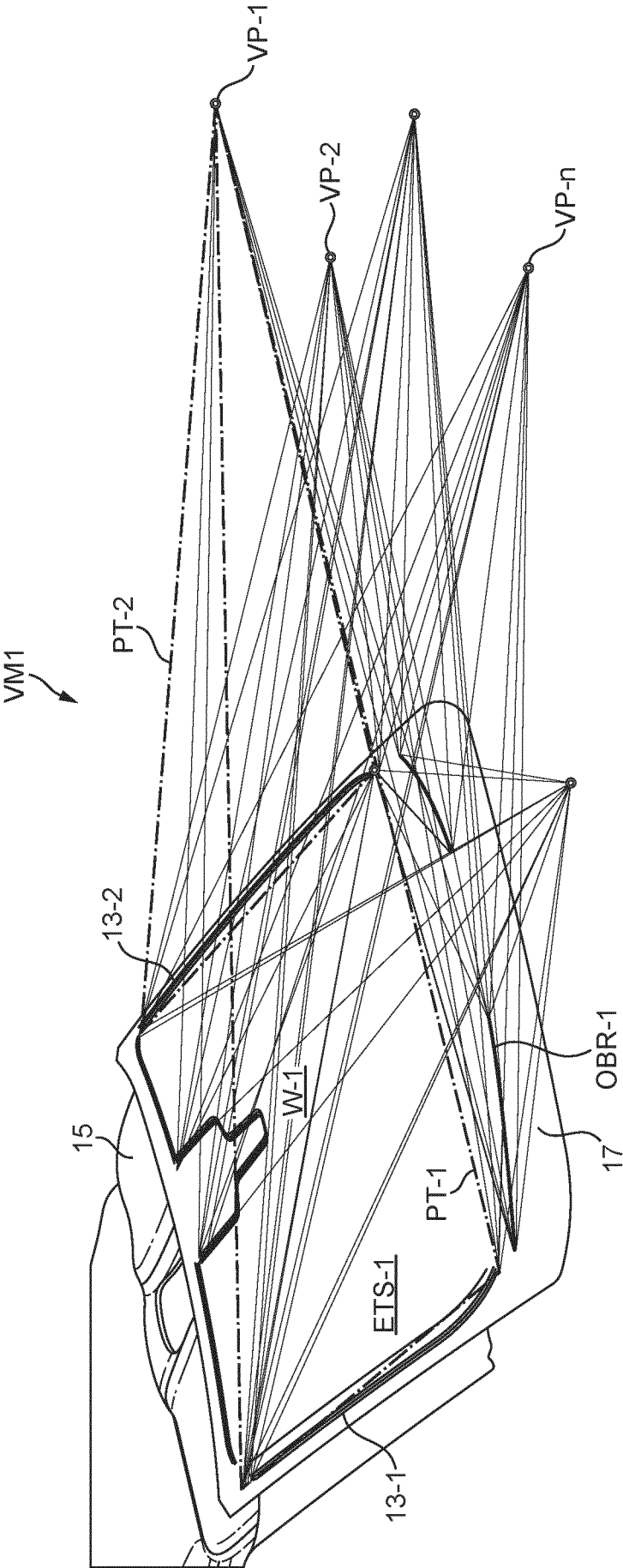


FIG. 3

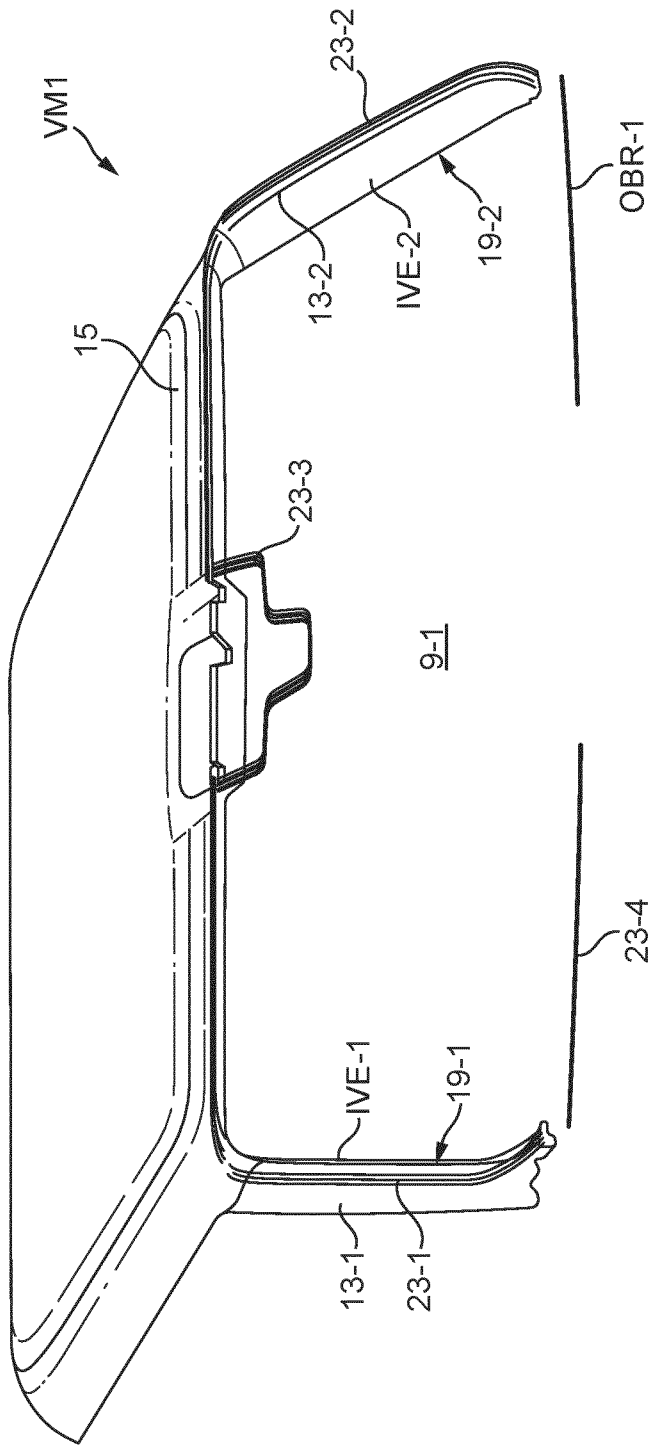


FIG. 4

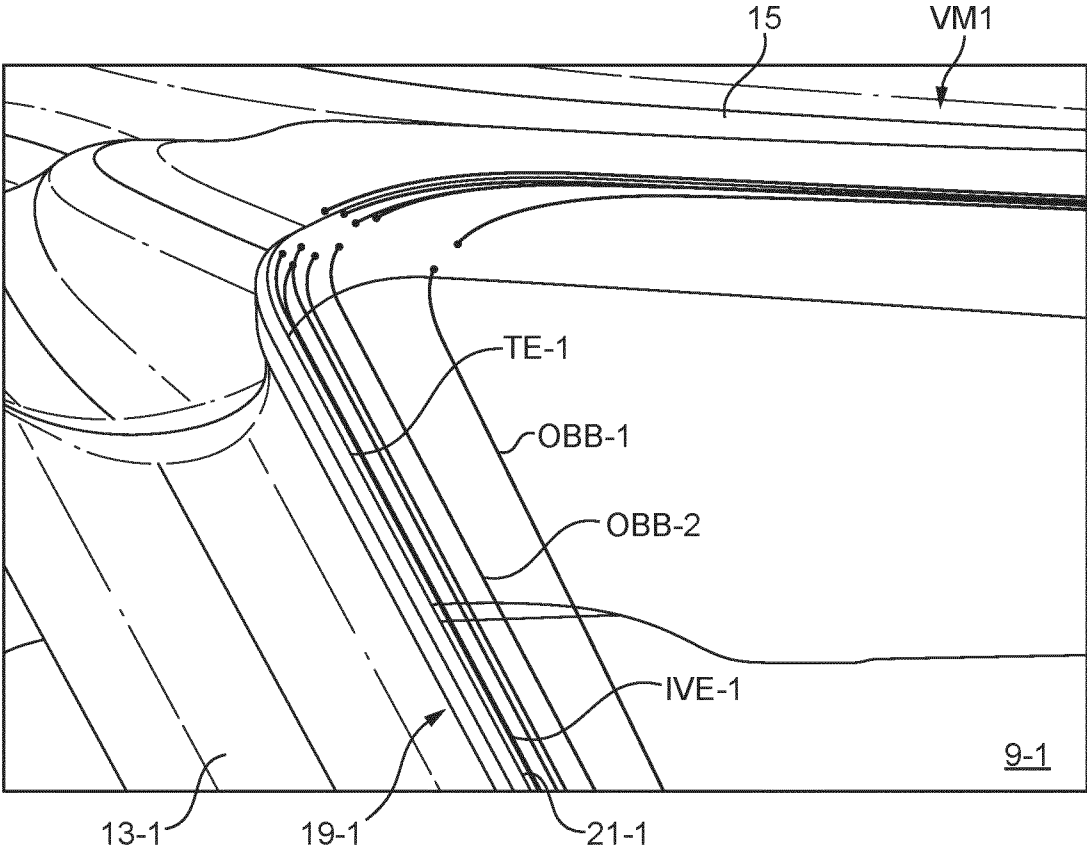


FIG. 5

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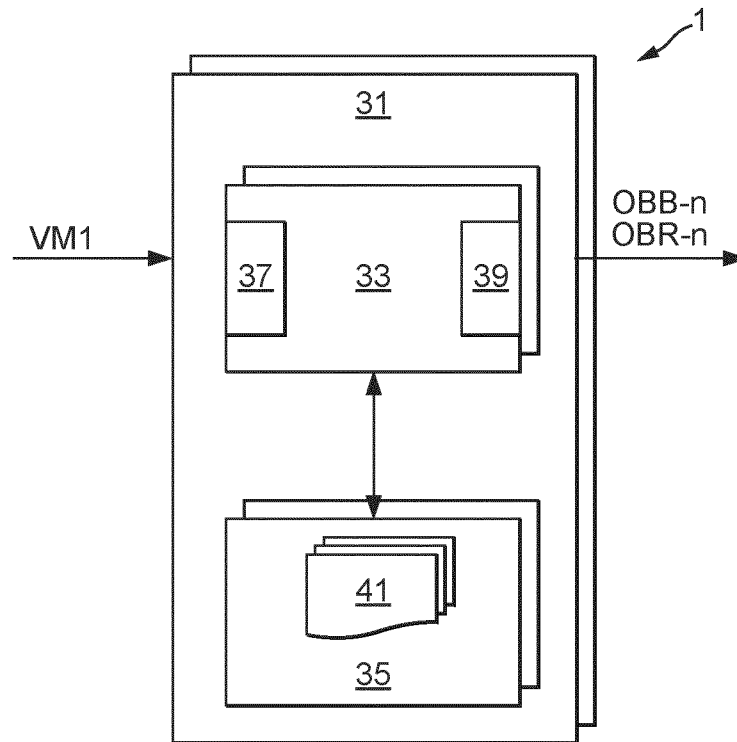


FIG. 6

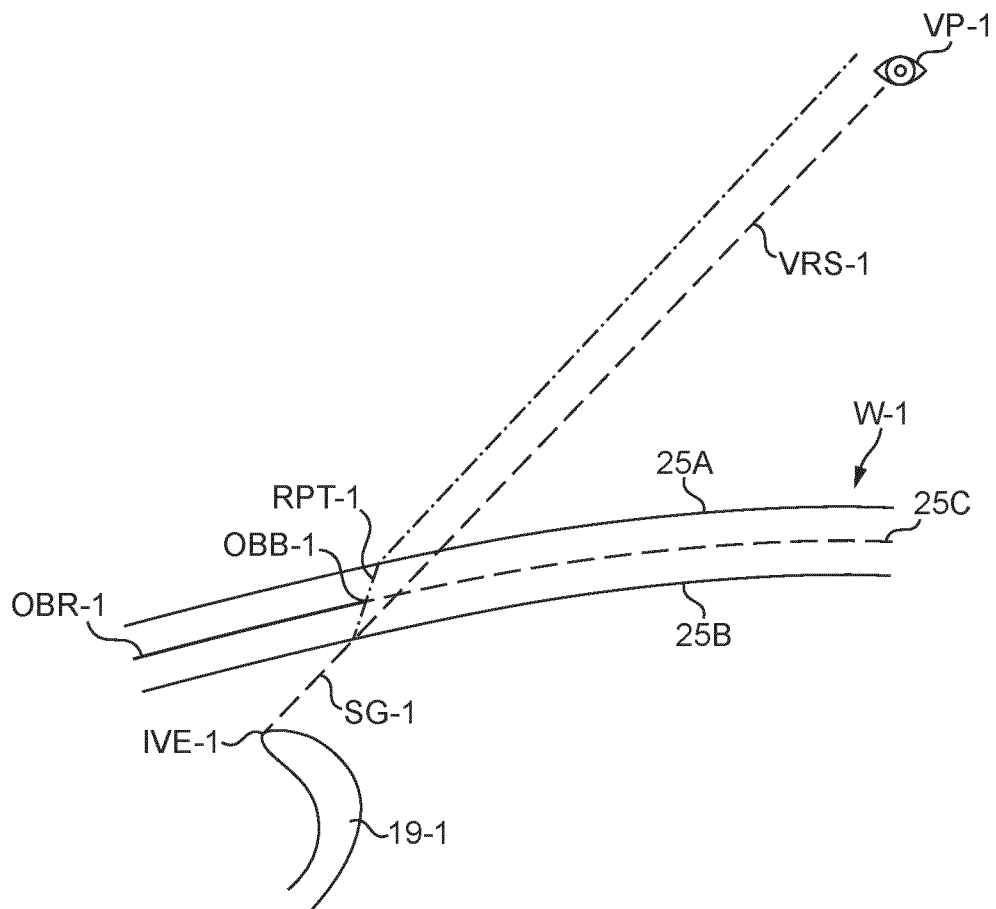


FIG. 7

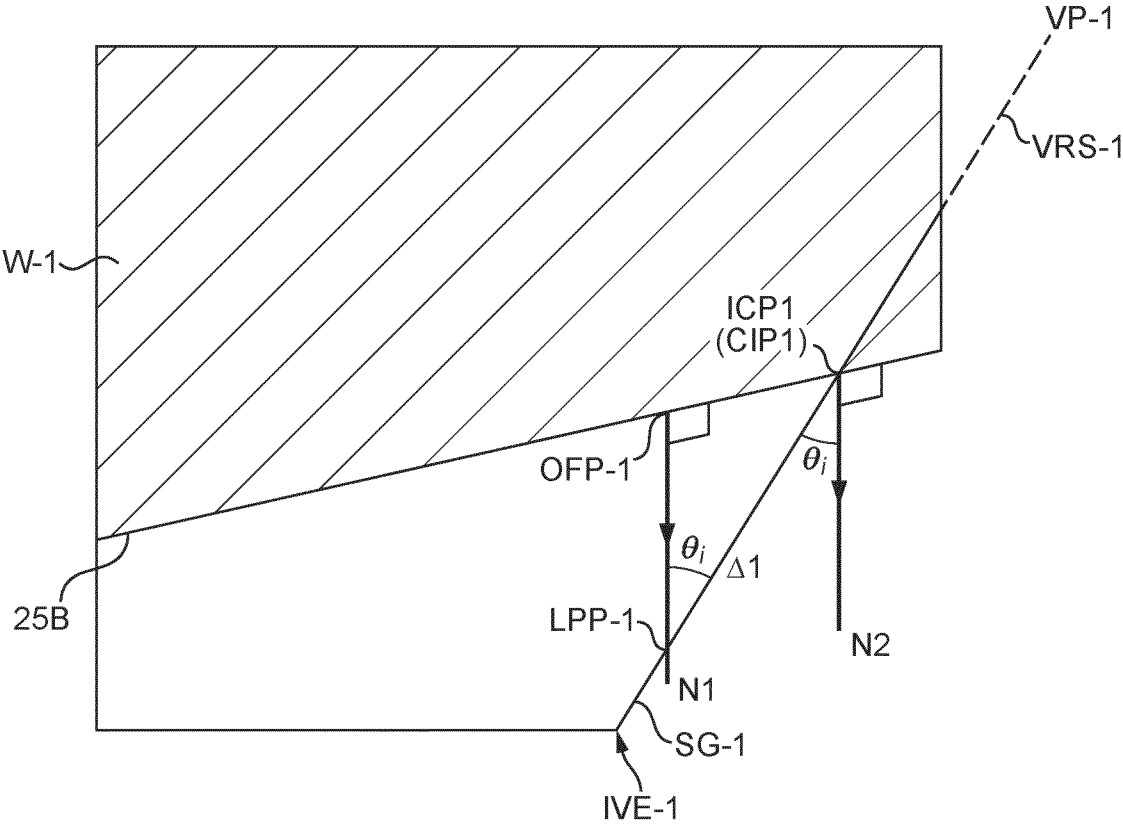


FIG. 8A

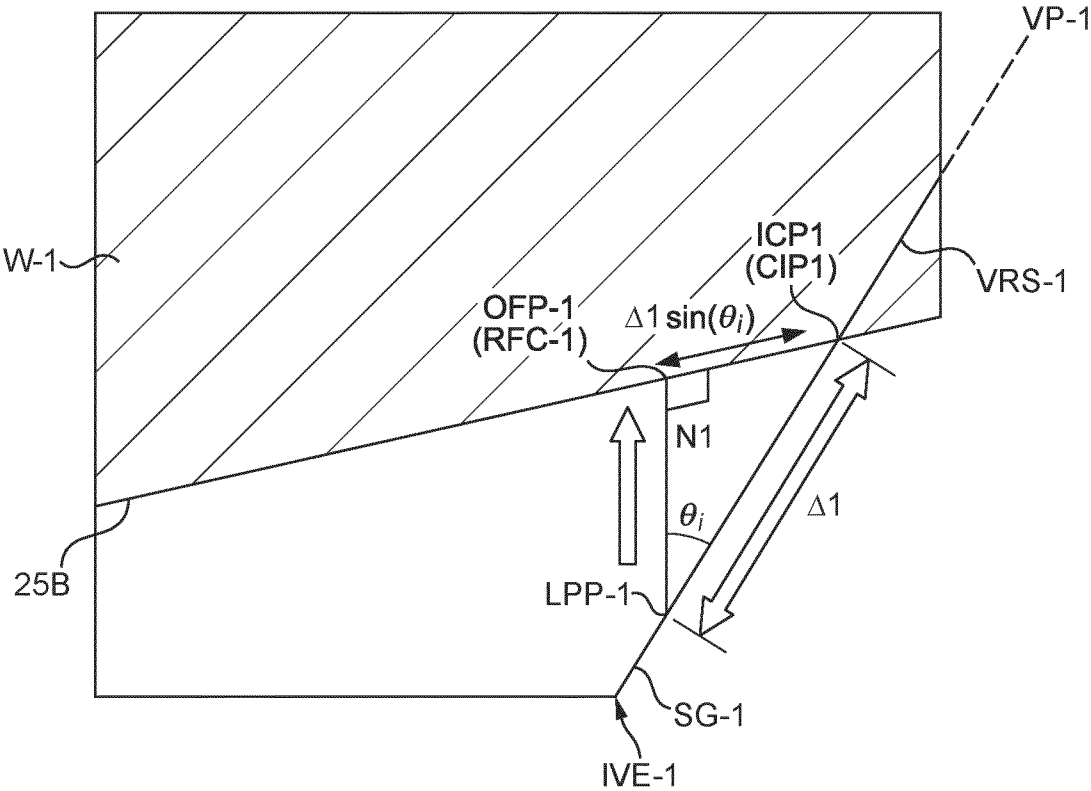


FIG. 8B

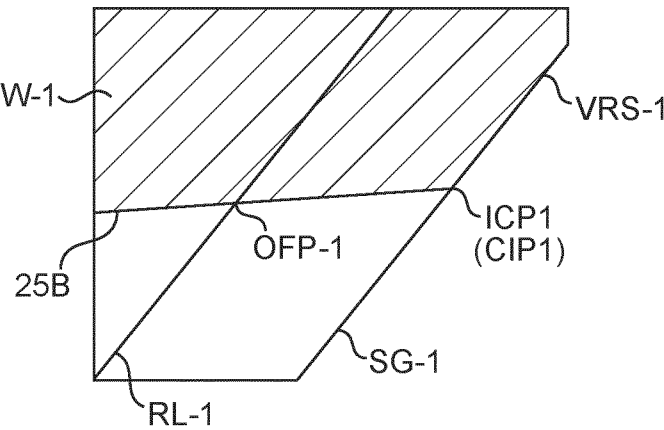


FIG. 9A

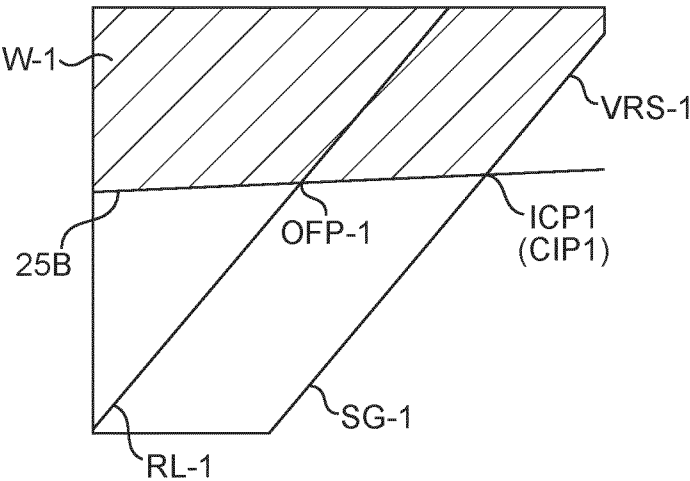


FIG. 9B

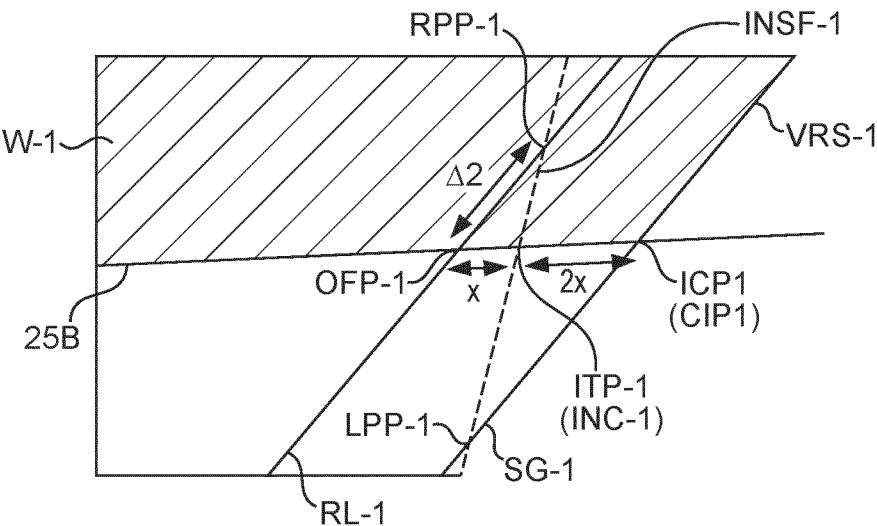


FIG. 9C

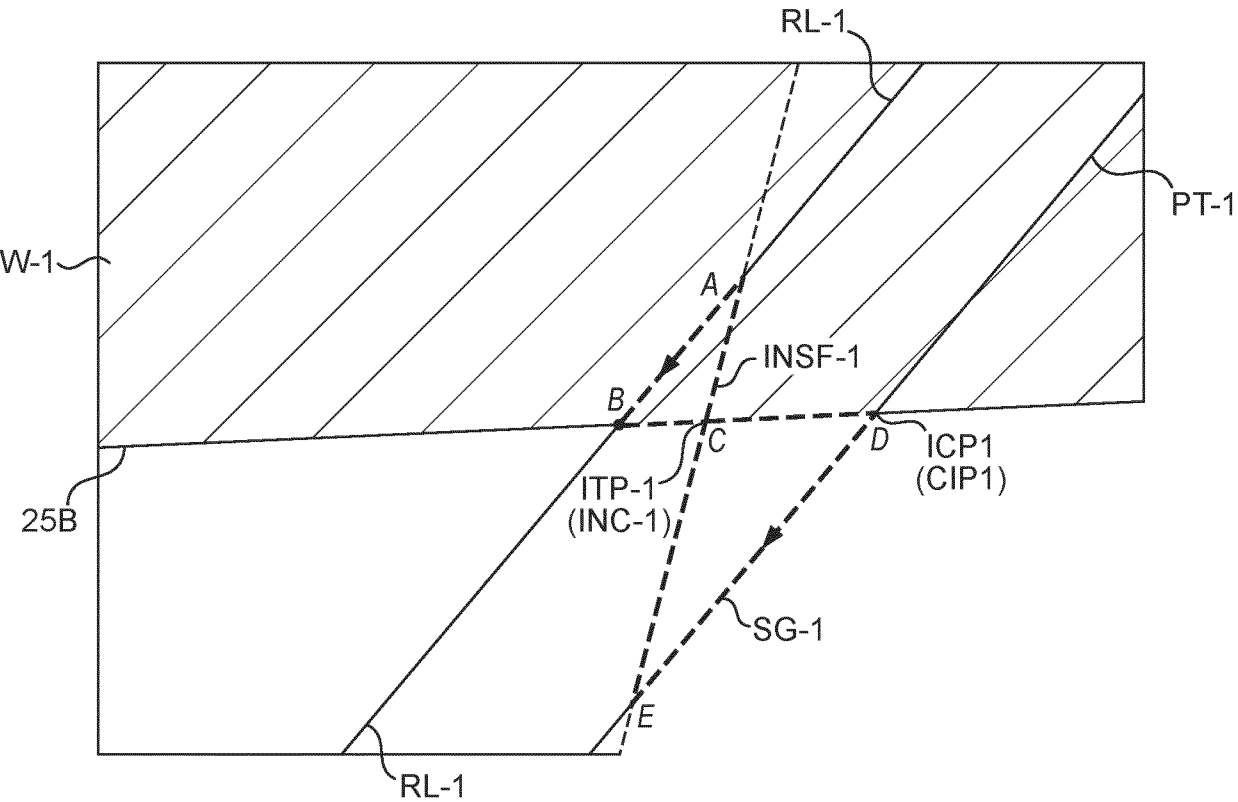


FIG. 10

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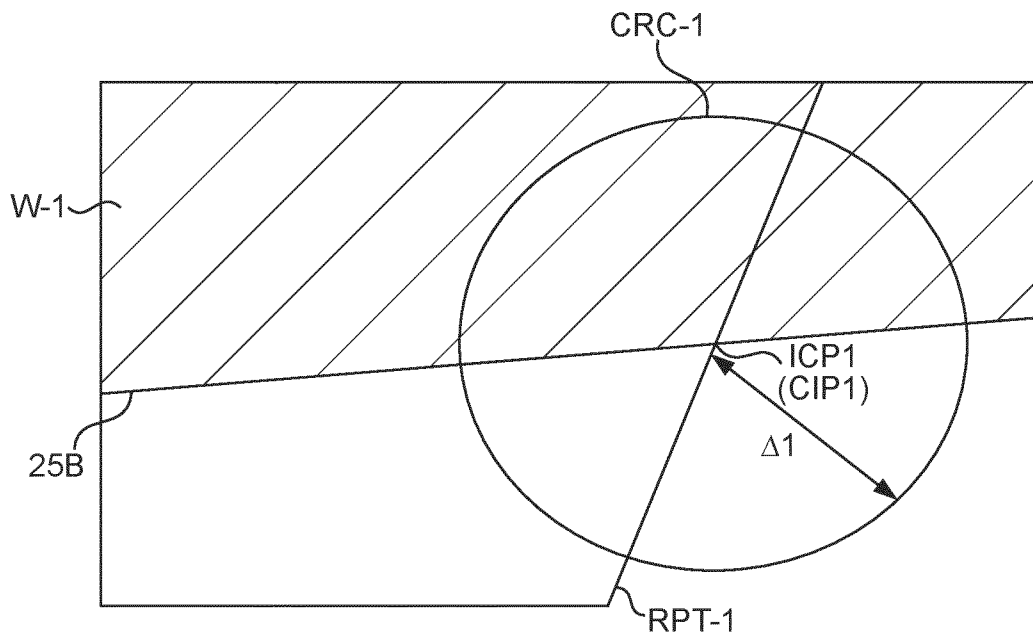


FIG. 11A

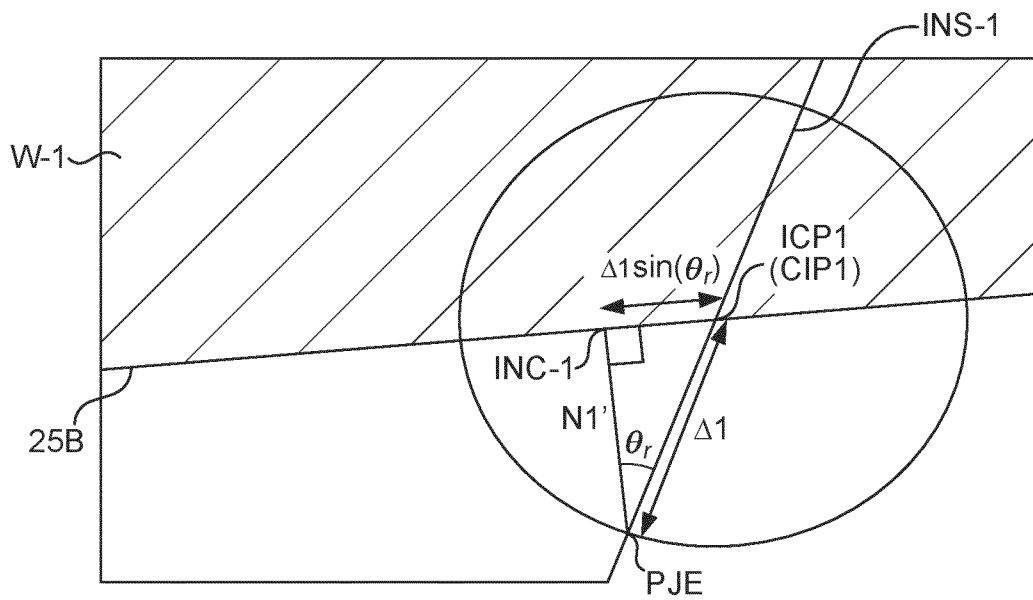


FIG. 11B

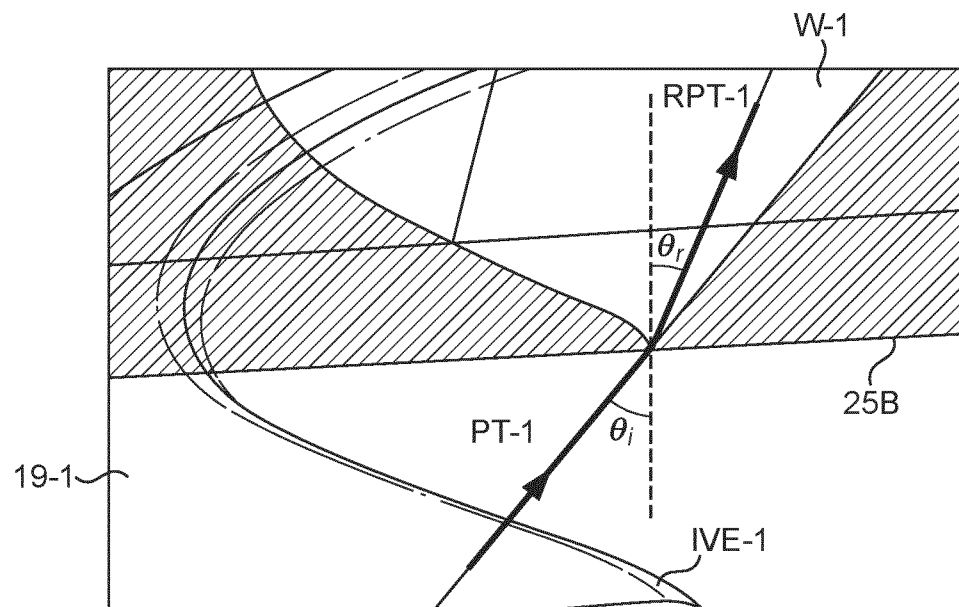


FIG. 12A

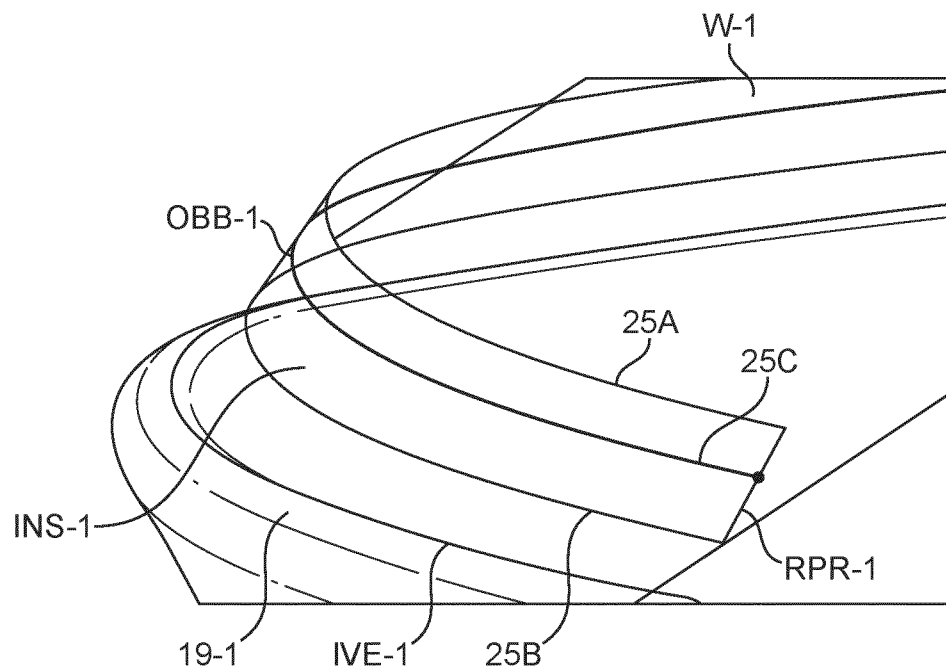


FIG. 12B

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2024/058588

A. CLASSIFICATION OF SUBJECT MATTER INV. B32B17/10 B60R13/00 G06F30/20 ADD.		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) B32B B60R G06F Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2017/232713 A1 (MANNHEIM ASTETE ARTURO [PE] ET AL) 17 August 2017 (2017-08-17) figure 6 paragraph [0054] - paragraph [0055]; figures 8A, 8B paragraph [0029] - paragraph [0030]; figure 1 -----	1 - 15
A	DE 11 2005 003280 T5 (PILKINGTON GROUP LTD [GB]) 15 November 2007 (2007-11-15) abstract paragraph [0002] figures 1, 2 -----	1 - 15
☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 17 June 2024		Date of mailing of the international search report 09/07/2024
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Ross, Christopher

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
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