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(71) Applicant: **Swisscom AG**
3050 Bern (CH)

(72) Inventor: **Schumacher, Adrian**
3510 Konolfingen (CH)

(74) Representative: **P&TS SA (AG, Ltd.)**
Avenue J.-J. Rousseau 4
P.O. Box 2848
2001 Neuchâtel (CH)

(54) **MULTI-PANE GLAZING UNIT**

(57) Glazing unit (10) comprising at least two glass panes (1, 2), wherein the at least two glass panes (1, 2) comprise a first glass pane (1) and a second glass pane (2), wherein the first glass pane (1) and the second glass pane (2) is configured such that the gap width between the first glass pane (1) and the second glass pane (2) varies between a minimum gap width (4) and a maximum gap width (5).

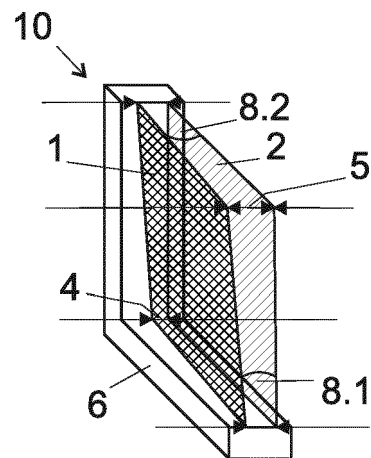


Fig. 8

Description

Field of the invention

[0001] The present invention concerns a multi-pane glazing unit.

Description of related art

[0002] Current double or multi-pane glazing (windows) show a radio frequency (RF) dependent signal attenuation of the radio signal. While lower frequencies experience a low attenuation, higher frequencies (already above approximately 1 GHz) can show significant signal attenuations. This signal attenuation can cause a disturbance for the use of cellular phones or other radio devices working in the attenuated frequency ranges, for example inside of buildings, vehicles etc. This signal attenuation depends for example on the air gap between the at least two glass panes. For higher frequencies, the wavelength gets smaller and the air gap between the two or more glass panes becomes relevant to cause a phase-shift that can destructively add and cause the high signal attenuations. This can be avoided by the use of single pane glazing losing then all the advantages of multi-pane glazing such as improved thermal insulation.

Brief summary of the invention

[0003] The object of the invention is to solve or reduce the problem of the radio frequency dependent signal attenuation of multi-pane glazing units.

[0004] The object is solved by the glazing unit according to the claims.

[0005] The use of a glazing unit with a gap width between a first glass pane and a second glass pane which varies between a minimum gap width and a maximum gap width allows to create a glazing unit with a plurality of gap widths. The varying gap width allows to reduce the signal attenuation for certain frequency bands significantly. This could be further used to design the glazing unit such as to have a certain desired radio frequency transmission function. For example, in some applications, it could be desirable to rather attenuate a first frequency band with respect to a radio signal in a second frequency band.

[0006] The dependent claims refer to further advantageous embodiments.

Brief Description of the Drawings

[0007] The invention will be better understood with the aid of the description of an embodiment given by way of example and illustrated by the figures, in which:

Fig. 1 shows a schematic first example of an embodiment of the glazing unit according to the invention.

Fig. 2 shows a schematic second example of an embodiment of the glazing unit according to the invention.

Fig. 3 shows a schematic third example of an embodiment of the glazing unit according to the invention.

Fig. 4 shows a schematic fourth example of an embodiment of the glazing unit according to the invention.

Fig. 5 shows a schematic fifth example of an embodiment of the glazing unit according to the invention.

Fig. 6 shows a schematic sixth example of an embodiment of the glazing unit according to the invention.

Fig. 7 shows a schematic seventh example of an embodiment of the glazing unit according to the invention.

Fig. 8 shows a schematic eighth example of an embodiment of the glazing unit according to the invention.

Fig. 9 shows the exemplary signal transmission in dependence of the radio frequency between 1 and 6 GHz for double-pane glazing units with different single fixed gap widths between the glass panes and a double-pane glazing unit combining those gap widths, for a signal incidence angle normal to the window surface.

Fig. 10 shows the exemplary signal transmission for the double-pane glazing units shown in Fig. 2 in dependence of the radio frequency between 1 and 40 GHz, for a signal incidence angle normal to the window surface.

Fig. 11 shows the exemplary signal transmission in dependence of the radio frequency between 1 and 40 GHz for triple-pane glazing units with different single fixed gap widths between the glass panes and a triple-pane glazing unit combining those gap widths, for a signal incidence angle normal to the window surface.

Detailed Description of possible embodiments of the Invention

[0008] The invention refers to a multi-pane glazing unit. Multi-pane glazing units are also called insulating glass or insulating glass unit.

[0009] The multi-glazing unit can comprise a direction for mounting the multi-glazing unit in the sense that the multi-glazing unit has an external side and/or an internal

side. The multi-glazing unit could comprise an external side which is configured to be arranged to point to the external side of a space and an internal side which is configured to be arranged to point to the inside of a space. The space is for example, a building space, like a room, a hall, etc.. The space can however also be a vehicle, like a car, truck, airplane, train, etc.. The space can be any other space. The space is preferably closed or closable to the outside. The space can however also be semi-closed or even open. The external side could be defined e.g., by a functional coating which acts different compared to the internal side, e.g., a sun protection or a sil-vering. If there is no difference between a first side and a second side of the glazing unit, the external side shall be the first side and the internal side the second side without any limitation of the invention.

[0010] The glazing unit 10 comprises preferably a glazing plane (or glazing unit plane). The glazing plane comprises preferably a first glazing direction and a second glazing direction, both perpendicular to each other and/or both parallel to the glazing plane.

[0011] Fig. 1 to 8 show eight exemplary embodiments for a multi-pane glazing unit 10. The multi-pane glazing unit 10 comprises at least two glass panes. The at least two glass panes comprise (at least) a first glass pane 1 and a second glass pane 2. The glazing unit 10 can comprise (just) two glass panes forming a double-pane glazing unit, often also called double-pane or double-glazing (see embodiments in Fig. 1, 2, 3, 5, 6, 7 and 8). The glazing unit 10 can comprise three glass panes forming a triple-pane glazing unit, also called triple-pane or triple-glazing (see embodiment in Fig. 4). In this case, the at least two glass panes comprise a first glass pane 1, a second glass pane 2 and a third glass pane 3. The multi-pane glazing unit could comprise also more than three glass panes. In this case, the at least two glass panes comprise a first glass pane 1, a second glass pane 2, a third glass pane 3 and at least a fourth glass pane.

[0012] The first glass pane 1 and the second glass pane 2 are preferably neighbouring glass panes in the at least two glass panes. However, the first and the second glass pane 1, 2 can also be arranged such that the multi-pane glazing unit 10 comprises a third glass pane 3 or more glass panes between the first and the second glass pane 1, 2. The first glass pane 1 is preferably the most external glass pane 1, i.e. arranged at the external side of the glazing unit 10. However, the first glass pane 1 can also be arranged at the most internal glass pane, i.e. arranged at the internal side of the glazing unit 10, or can be arranged in between the most external glass pane and the most internal glass pane. The second glass pane 2 is the glass pane neighbouring the first glass pane 1 in direction towards the internal side. In the case of a double pane glazing unit, the second glass pane 2 is thus the most internal glass pane. In the case of a triple pane glazing unit, the second glass pane 2 is thus a central or intermediate glass pane, i.e. arranged between the most external and the most internal glass pane. However, the

second glass pane 2 can also be the most external glass pane or any other glass pane.

[0013] Preferably, the first glass pane 1 has a constant thickness (over the pane plane). However, it is also possible that the thickness of the first glass pane 1 varies over the pane plane. Preferably, the second glass pane 2 has a constant thickness (over the pane plane). However, it is also possible that the thickness of the second glass pane 2 varies over the pane plane. Preferably, each of the at least two glass panes 1, 2 has preferably a constant thickness (over the pane plane). In all shown embodiments in Fig. 1 to 8 the glass panes 1, 2, 3 have a constant thickness over the pane plane. Preferably, the first glass pane 1 and the second glass pane 2 (or all of the at least two glass panes) have the same (constant) thickness. However, it is also possible that the first glass pane 1 has a first (constant) thickness and the second glass pane 2 has a second (constant) thickness which is different from/smaller than/larger than the first thickness. However, it is also possible that the thickness of each of the at least two glass panes 1, 2 varies over the pane plane. Preferably, the first glass pane 1 and the second glass pane 2 (two or more of the at least two glass panes) have a constant thickness. However, it is also possible that the first glass pane 1 and the second glass pane 2 (two or more of the at least two glass panes) have a variable thickness, or that one of the first glass pane 1 and the second glass pane 2 (or of the at least two glass panes) has a variable thickness and another one of the first glass pane 1 and the second glass pane 2 (or of the at least two glass panes) has a constant thickness. The thickness is preferably the size in the direction from the external or first side of the glazing unit to the internal or second side of the glazing unit or of the respective glass pane or in the direction perpendicular to the glazing plane or the respective pane plane or surface.

[0014] The first glass pane 1 has preferably a first surface and a second surface opposed to the first surface. The first glass pane 1 comprises preferably at least one lateral side. The at least one lateral side is substantially perpendicular, preferably perpendicular to the first and second surface of the first glass pane 1. The first glass pane 1 has preferably a rectangular form with four lateral sides. The four lateral sides comprise preferably two first lateral sides parallel to the first glazing direction and two second lateral sides parallel to the second glazing direction. However, other forms of the first glass pane 1 are possible. The first surface is preferably parallel to the pane plane of the first glass pane 1 and/or to the second surface. In Fig. 1 to 8, the first surface is parallel to the second surface. The first surface is preferably flat, i.e. the first surface defines a plane surface (without any curvature). The second surface is preferably parallel to the pane plane of the first glass pane 1. The second surface is preferably flat, i.e. the second surface defines a plane surface (without any curvature). In the embodiments shown in Fig. 1, 3, 4 and 8, the first and second surface of the first glass pane 1 have plane surfaces. However,

it is also possible that the first surface and/or the second surface comprises a non-plane surface such as a surface with a curvature, e.g. a convex or concave surface, or a step. In Fig. 5, the first surface has a convex shape and the second surface has a concave shape. In Fig. 6, the first surface has a concave shape, and the second surface has a convex shape. In Fig. 7, the first surface has a curved shape, similar to a sinus or waveform. In Fig. 2, the first surface comprises steps. All first surfaces and second surfaces and at least one lateral side mentioned in this paragraph refer to the first surface of the first glass pane 1 and the second surface of the first glass pane 1 and the at least one lateral side of the first glass pane 1, respectively.

[0015] The second glass pane 2 has preferably a first surface and a second surface opposed to the first surface. The second glass pane 2 comprises preferably at least one lateral side. The at least one lateral side is substantially perpendicular, preferably perpendicular to the first and second surface of the second glass pane 2. The second glass pane 2 has preferably a rectangular form with four lateral sides. The four lateral sides comprise preferably two first lateral sides parallel to the first glazing direction and two second lateral sides parallel to the second glazing direction. However, other forms of the second glass pane 2 are possible. The first surface is preferably parallel to the pane plane of the second glass pane 2 and/or the second surface. In Fig. 1 to 8, the first surface is parallel to the second surface. The second surface is preferably parallel to the pane plane of the second glass pane 2. The first surface is preferably flat, i.e. the first surface defines a plane surface (without any curvature). The second surface is preferably flat, i.e. the second surface defines a plane surface (without any curvature). In the embodiments shown in Fig. 1 to 8, the first and second surfaces have plane surfaces. However, it is also possible that the first surface and/or the second surface comprises a non-plane surface such as a surface with a curvature, e.g. a convex or concave surface. All first surfaces and second surfaces mentioned in this paragraph refer to the first surface of the second glass pane 2 and the second surface of the second glass pane 2 and the at least one lateral side of the second glass pane 2, respectively, if not mentioned otherwise. The first glass pane 1 and the second glass pane 2 are preferably arranged such that the first surface of the first glass pane 1 faces the first surface of the second glass pane 2. In one embodiment, the second surface of the first glass pane 1 is an external side of the glazing unit 10. In one embodiment, the second surface of the second glass pane 2 is an internal side of the glazing unit 10.

[0016] According to the invention, the glazing unit 10 is configured/designed such that the first glass pane 1 and the second glass pane 2 (or at least two of the at least two glass panes 1, 2) have a gap width between each other which varies (in the glazing plane) between a minimum gap width 4 and a maximum gap width 5.

[0017] The difference between the maximum gap

width 5 and the minimum gap width 4 is preferably larger 1 millimetre (mm), preferably larger than 2 mm, preferably larger than 3 mm, preferably larger than 4 mm, preferably larger than 5 mm, preferably larger than 6 mm, preferably larger than 7 mm, preferably larger than 8 mm, preferably larger than 9 mm, preferably larger than 10 mm, preferably larger than 11 mm, preferably larger than 12 mm, preferably larger than 13 mm, preferably larger than 14 mm, preferably larger than 15 mm, preferably larger than 16 mm, preferably larger than 17 mm, preferably larger than 18 mm, preferably larger than 19 mm, preferably larger than 20 mm. The difference between the maximum gap width 5 and the minimum gap width 4 is preferably smaller 50 mm, preferably smaller than 40 mm, preferably smaller than 35 mm, preferably smaller than 30 mm, preferably smaller than 25 mm, preferably smaller than 20 mm, preferably smaller than 15 mm, preferably smaller than 10 mm. The minimum gap width 4 is preferably larger than 0 mm (in this case the first and second glass pane 1, 2 touch each other), preferably larger than 1 mm, preferably larger than 2 mm, preferably larger than 3 mm, preferably larger than 4 mm, preferably larger than 5 mm, preferably larger than 6 mm, preferably larger than 7 mm, preferably larger than 8 mm, preferably larger than 9 mm, preferably larger than 10 mm. The minimum gap width 4 is preferably smaller than 10 mm, preferably than 8 mm, preferably than 6 mm, preferably than 5 mm, preferably than 4 mm, preferably than 3 mm, preferably than 2 mm, preferably than 1.

[0018] The gap width between the first glass pane 1 and the second glass pane 2 (with the transition from the minimum gap width 4 and the maximum gap width 5) varies preferably continuously, i.e. mathematically speaking the gap width (as a function over e.g. the glazing plane) is monotonic and/or continuous and/or the spectrum of all gap widths between the minimum gap width 4 and the maximum gap width 5 are realized between the first and second glass pane 1, 2. Preferably, the gap width between the first glass pane 1 and the second glass pane 2 (with the transition from the minimum gap width 4 and the maximum gap width 5) varies without an edge, i.e. mathematically speaking the gap width (as a function over e.g. the glazing plane) is continuously differentiable. In the embodiments of Fig. 1 and 3 to 8, the gap width between the first glass pane 1 and the second glass pane 2 varies preferably continuously and/or without an edge. Preferably, the gap width between the first glass pane 1 and the second glass pane 2 (with the transition from the minimum gap width 4 and the maximum gap width 5) over the glazing plane, the pane plane of the first or second glass pane 1, 2 (in the following shortly gap width function) is a linear function (see Fig. 1, 3, 4, 8). However, it is also possible the gap width function is a non-linear function (see Fig. 2, 5, 6, 7). The gap width function is preferably continuous, even more preferably continuously differentiable (see Fig. 1, 3 to 8). The gap width function could provide a convex (Fig. 6) or concave (Fig. 5) gap between the first glass pane 1 and the second glass pane

2. However, the gap width function can also be a step-function (Fig. 2). The step function could comprise for example one step with the minimum gap width 4 in a first region and the maximum gap width 5 in a second region. The step-function could have two or more steps with one or more intermediate regions with one or more intermediate gap widths (being smaller than the maximum gap width 5 and larger than the minimum gap width 4) as shown in Fig. 2.

[0019] Preferably, the glazing unit 10 comprises further a frame 6. Preferably, the frame 6 is a spacer normally used in the production of insulated glazing units. The frame 6 or spacer holds the at least two glass panes 1, 2 in a fixed position to each other (the position will be described in more detail below) and/or seals hermetically a space between the at least two glass panes 1, 2, preferably between the first surface of the first glass pane 1 and the first surface of the second glass pane 2. The hermetically sealed space between the at least two glass panes 1, 2 and the frame 6 is preferably a vacuum or filled with a certain gas, preferably a monoatomic gas, preferably argon, krypton, xenon, etc.. The glazing unit 10 with the at least two glass panes 1, 2 and the frame 6 can then be mounted in a window frame or any other frame which should hold the glazing unit 10. It is however also possible that the frame 6 of the glazing unit 10 is directly realized by the final frame where the glazing unit 10 is mounted, e.g. the window frame. The frame 6, in particular the space has preferably a rectangular shape with four lateral sides. The four lateral sides comprise preferably two first lateral sides and two second lateral sides. The two first lateral sides are preferably parallel to the first glazing direction. The two second lateral sides are preferably parallel to the second glazing direction. The first lateral sides are arranged preferably at an 90° angle with respect to the second lateral sides. Two opposing lateral sides (two first lateral sides or two second lateral sides) are preferably arranged parallel to each other. Each of the four lateral sides holds one of the lateral sides of the at least two glass panes, i.e. holds at least one of the four lateral sides of the first glass pane 1 and one of the four lateral sides of the second glass pane 2. The first lateral sides of the frame 6 comprise preferably an outer first lateral surface. The second lateral sides of the frame 6 comprise preferably an outer second lateral surface. The first outer lateral surface is preferably perpendicular to the second outer lateral surface. The glazing plane is preferably defined as being perpendicular to the first outer lateral surface of the frame 6 and to the second outer lateral surface of the frame 6.

[0020] There are many realisations for obtaining the described gap width function between the first glass pane 1 and the second glass pane 2.

[0021] In a preferred embodiment, the first and the second glass pane 1, 2 are arranged such that the first surface and/or the pane plane of the first glass pane 1 is arranged at an angle 8 relative to the first surface and/or the pane plane of the second glass pane 2 as shown in

Fig. 1, 3, 4 and 8. Thus, the first surface and/or the pane plane of the first glass pane 1 is not parallel to the first surface and/or the pane plane of the second glass pane 2. Preferably, the first and second glass pane 1, 2 have each a constant thickness and/or have flat first and second surfaces such that classic glass panes can be used without the necessity to change the production and/or form of the glass panes 1, 2. However, the invention works equally for curved multi-glazing panes with curved or non-flat first and second glass panes 1, 2, e.g. for train windows. The angle 8 between the (flat) first side of the first glass pane 1 and the (flat) first side of the second glass pane 2 creates a gap width between the first side of the first glass pane 1 and the first side of the second glass pane 2 which linearly increases from the minimum gap width 4 (at a first lateral side) to the maximum gap width 5 (at a second lateral side opposed to the first lateral side). The angle 8 is preferably larger than 1°, preferably than 2°, preferably than 3°, preferably 4°, preferably than 5°, preferably 6°, preferably than 7°, preferably than 8°, preferably than 9°, preferably than 10°. This could be achieved by arranging one of the first and second glass pane 1, 2 parallel to the glazing unit plane and the other one of the first and second glass pane 1, 2 at an angle 8 to the glazing unit plane as shown in Fig. 1, 4 and 8 where the second glass pane 2 (and in Fig. 4 the third glass pane 3) is arranged parallel to the glazing plane and/or perpendicular to the first outer lateral surface of the frame 6 and/or perpendicular to the second outer lateral surface of the frame 6. This could also be achieved by arranging the first and the second glass pane 1, 2 at half the angle 8 with respect to the glazing unit plane such that the first surface of the first glass pane 1 and the first surface of the second glass pane 2 yield the angle 8 as shown in Fig. 3. This could be achieved by arranging the first glass pane 1 at first portion of the angle 8 with respect to the glazing unit plane and the second glass pane 2 at second portion of the angle 8 with respect to the glazing unit plane such that the first surface of the first glass pane 1 and the first surface of the second glass pane 2 yield the angle 8. The frame 6 is preferably configured to hold the first and the second glass pane 1, 2 in such a position to obtain the described angle 8. The angle 8 can be such that the gap width between (the first surface of) the first glass pane 1 and (the first surface of) the second glass pane 2 varies in the first glazing direction and remains constant in the second glazing direction. Thus, the glazing unit shows at one (second) lateral side the minimum gap width 4 (constant over the whole second lateral side) and at the opposed (second) lateral side the maximum gap width 5 (constant over the whole second lateral side). This has the advantage that the at least one glass pane of the at least two glass panes arranged at an angle to the glazing plane can be mounted more easily in the frame 6. In another embodiment, the angle 8 can be such that the gap width between (the first surface of) the first glass pane 1 and (the first surface of) the second glass pane 2 varies in the first glazing direction

and the second glazing direction as shown in Fig. 8. Thus, the glazing unit shows at one corner the minimum gap width 4 and at the opposed corner the maximum gap width 5. Consequently, the angle is composed of the first sub-angle 8.1 in the first glazing direction and the second sub-angle 8.2 in the second glazing direction.

[0022] Fig. 9 shows the transmission function of a radio signal in dependence of the radio frequency between 1 GHz and 6 GHz for different embodiments of state-of-the-art-double-pane glazing units each with a different fixed gap width between 6 mm and 24 mm (thin lines). For each of the embodiments, each of the first and the second glass pane 1, 2 has a constant thickness of 4 mm. The transmission coefficient drops to -8 at around 4.5 GHz (for 24mm constant gap width) or to -11 dB at 7 GHz (for 12 mm constant gap width). As can be seen in Fig. 10 which shows the same transmission functions for the same embodiments as shown in Fig. 10 in dependence of the radio frequency between 1 GHz and 40 GHz. Further drops appear at higher frequencies. By an embodiment of a glazing unit with at least two glass panes 1, 2 which include at least two gap widths between a minimum gap width 4 and a maximum gap width 5 allow to significantly reduce said transmission drops. The thick black transmission line drawn in Fig. 10 and 9 would be the theoretical minimum transmission line for an embodiment as shown in Fig. 1 with the gap width varying between the minimum gap width 4 of 6 mm and the maximum gap width 5 of 24 mm. It can be clearly seen that the transmission drop at around 5 GHz can be reduced to -5 dB and the transmission drops at higher frequencies can be removed completely.

[0023] In the embodiment described in Fig. 1, the second surface of the first and/or second glass pane 1, 2 shows also an angle 8 with respect to the glazing unit plane, if the first and/or second glass pane 1, 2 has a constant thickness. To avoid this, the first and/or second glass pane 1, 2 could have a variable thickness such that the second surface of the first and/or second glass pane 1, 2 is parallel to the glazing unit plane.

[0024] In another embodiment, the thickness of the first and/or the second glass pane 1, 2 and/or the form of the first and/or second glass pane 1, 2 is such that the different gap widths between the minimum gap width 4 and the maximum gap width 5 is achieved over the glazing unit plane. For example, the second surfaces of the first and second glass pane 1, 2 can be parallel to each other, while the first surfaces of the first and second glass pane 1, 2 are formed such to form the desired gap width function of the glazing unit plane. The thickness can be formed prismatic such that a linear gap width function is achieved or the thickness of the first and/or second glass pane 1, 2 can be formed convex (or concave) such that a concave (or convex) space between the first and second glass pane 1, 2 is achieved.

[0025] In the previously described embodiment, the varying gap width was achieved by the arrangement (inclination) of at least one of the glass panes 1, 2. In another

embodiment, the thickness of the first and/or the second glass pane 1, 2 and/or the form of the first and/or second glass pane 1, 2 is such that the different gap widths between the minimum gap width 4 and the maximum gap width 5 is achieved over the glazing unit plane. For example, the second surfaces of the first and second glass pane 1, 2 can be parallel to each other, while the first surfaces of the first and second glass pane 1, 2 are formed such to form the desired gap width function of the glazing unit plane. The thickness can be formed prismatic such that a linear gap width function is achieved or the thickness of the first and/or second glass pane 1, 2 can be formed convex (or concave) such that a concave (or convex) space between the first and second glass pane 1, 2 is achieved. Fig. 2, 5, 6 and 7 show embodiments in which at least one of the at least two glass panes has non-plane form to obtain the varying gap width. The form of the glass pane (with respect to the gap) can be a step function (fig. 2), a convex form (Fig. 5), a concave form (Fig. 6), a wave form (Fig. 7) or any other form. In one embodiment, the first glass pane 1 has the non-plane form, while the second glass pane 2 has a plane form (parallel to the glazing plane). The first glass pane 1 (and the second glass pane 2) has preferably a constant thickness. However, it would also be possible to combine the varying thickness and the non-plane shapes of the at least one glass pane to obtain the varying gap widths. The embodiments with glass panes with varying thicknesses and with non-plane forms have however the disadvantage that they require the production of special glass panes. In addition, the change in the thickness of the glass pane increases the weight (for larger thicknesses) or reduces the insulation effects (for smaller thicknesses).

[0026] In the case of a glazing unit with three or more glass panes, the second glass pane 2 could be arranged between the first glass pane 1 and the third glass pane and (only) (the first side, the second side and/or the pane plane of) the second glass pane 2 could be arranged at said angle 8 (while the third glass pane 3 is parallel to the second glass pane 2). In one embodiment, the gap width 7 between the second glass pane 2 and the third glass pane 3 is constant. Such an embodiment is shown in Fig. 4. In another embodiment, the first and third glass pane 1, 3 are parallel to the glazing plane, while the second glass pane 2 is arranged at an angle 8 to the glazing plane, the first glass pane 1 or the third glass pane 3. Consequently, the second side of the first glass pane 1 and a second side of the third glass pane would be parallel to the glazing unit plane. This might be easier as the further processing of the glazing unit (e.g. in a window) can be handled as in state-of-the-art-glazing units. Obviously, other arrangements are also possible. In one embodiment, the gap width function between the first glass pane 1 and the second glass pane 2 is the same as the gap width function between the second glass pane 2 and the third glass pane. This can be achieved by a glazing unit 10 with a second glass pane 2 parallel to the glazing

unit 10 and first and third glass pane 1 inclined with respect to the glazing unit plane.

[0027] Fig. 11 shows the transmission function of a radio signal in dependence of the radio frequency between 1 GHz and 40 GHz for different embodiments of state-of-the-art triple-pane glazing units each with a different fixed gap width between 6 mm and 24 mm (thin lines). The fixed gap width in each embodiment shown is the same for the gap width between the first and second glass pane 1, 2 and for the gap width between the second and third glass pane 2, 3. For each of the embodiments, each of the first glass pane 1 (which is arranged at the most external side of the glazing unit) has a constant thickness of 6 mm, while the second glass pane 2 and the third glass pane has a constant thickness of 4 mm. The transmission coefficient drops to -15 dB at around 4 GHz (for 24 mm constant gap width) or to -18 dB at 6 GHz (for 6 mm constant gap width). Further drops appear at higher frequencies. An embodiment of a triple-pane glazing unit with a gap width varying over glazing unit plane between a minimum gap width 4 and a maximum gap width 5 allows to significantly reduce said transmission drops. The thick black transmission line drawn in Fig. 11 would be the theoretical minimum transmission line for an embodiment as shown in Fig. 1 with the gap width varying between the minimum gap width 4 of 6 mm and the maximum gap width 5 of 24 mm. It can be clearly seen that the transmission drop at around 5 GHz can be reduced to less than -4dB and the transmission drops at higher frequencies can be removed.

[0028] One or more or all of the at least two glass panes may have a special coating e.g., for an increased thermal insulation. Preferably, such a coating is not covering the whole pane surface but divided into (small) areas in order to allow radio signals to go through.

[0029] In the embodiment described before, the gap width between first glass pane 1 and the second glass pane 2 varies. In a less preferred embodiment, it is further possible to achieve a high transmission coefficient over a large radio frequency spectrum (with a constant gap width between the first glass pane 1 and the second glass pane 2), but with a thickness of the first glass pane varying between a minimum first glass thickness and a maximum first glass thickness and/or with a thickness of the second glass pane varying between a minimum second glass thickness and a maximum second glass thickness. Examples for such glass panes 1, 2 with varying thickness where described before and could analogously be combined with a constant gap width between the first glass pane 1 and the second glass pane 2.

Claims

1. Glazing unit comprising at least two glass panes (1, 2), wherein the at least two glass panes (1, 2) comprise a first glass pane (1) and a second glass pane (2),

characterized in that

the first glass pane (1) and the second glass pane (2) are configured such that the gap width between the first glass pane (1) and the second glass pane (2) varies between a minimum gap width (4) and a maximum gap width (5); and/or
a thickness of the first glass pane varies between a minimum first glass thickness and a maximum first glass thickness; and/or
a thickness of the second glass pane varies between a minimum second glass thickness and a maximum second glass thickness.

2. Glazing unit according to the previous claim, wherein the first glass pane (1) and the second glass pane (2) is configured such that the gap width between the first glass pane (1) and the second glass pane (2) varies between a minimum gap width (4) and a maximum gap width (5)
3. Glazing unit according to the previous claim, wherein the transition from the minimum gap width (4) and the maximum gap width (5) is continuous.
4. Glazing unit according to the previous claim, wherein the transition from the minimum gap width (4) and the maximum gap width (5) is without an edge.
5. Glazing unit according to one of the previous claims, wherein the first glass pane (1) has a constant thickness and/or the second glass pane (2) has a constant thickness.
6. Glazing unit according to the previous claims, wherein the first glass pane (1) has a different thickness than the second glass pane (2).
7. Glazing unit according to one of claims 1 to 5, wherein the first glass pane (1) has the same thickness as the second glass pane (2).
8. Glazing unit according to one of the previous claims, wherein the first glass pane (1) has a first surface facing towards the second glass pane (2), wherein the first surface of the first glass pane (1) is flat, wherein the second glass pane (2) has a first surface facing towards the first glass pane (1), wherein the first surface of the second glass pane (2) is flat, wherein the first surface of first glass pane (1) is arranged at an angle (8) with respect to the first surface of the second glass pane (2)
9. Glazing unit according to one of claims 1 to 7, wherein the first glass pane (1) has a first surface facing towards the second glass pane (2), wherein the second glass pane (2) has a first surface facing towards the first glass pane (1), wherein the first surface of the first glass pane (1) and/or the first surface of the

second glass pane (2) is convex or concave.

10. Glazing unit according to one of the previous claims,
wherein the at least two glass panes (1, 2) comprise
a third glass pane (3). 5
11. Glazing unit according to the previous claim, wherein
the second glass pane (2) is arranged between the
first glass pane (1) and the third glass pane (3),
wherein the first glass pane (1) and the third glass 10
pane (3) are arranged parallel to each other.
12. Glazing unit according to one of the previous claims
comprising a frame (6) for holding the at least two
glass panes (1, 2). 15
13. Glazing unit according to the previous claim, wherein
the frame (6) has a rectangular shape with two first
lateral sides extending in a first glazing direction and
two second lateral sides extending in a second glaz- 20
ing direction, wherein the two first lateral sides are
opposed to each other, wherein the two second lat-
eral sides are opposed to each other.
14. Glazing unit according to claim 8 and 13, wherein 25
the first glass pane (1) and the second glass pane
(2) are arranged such at the angle (8) that the gap
width between the first surface of the first glass pane
(1) and the first surface of the second glass pane (2)
vary in the first glazing direction and the second glaz- 30
ing direction.
15. Window comprising a glazing unit (10) according to
one of the previous claims. 35

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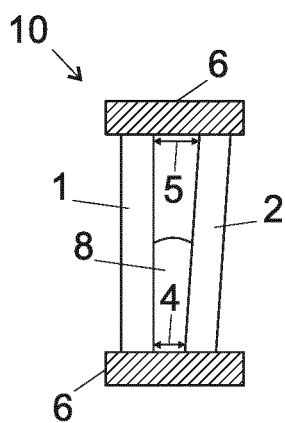


Fig. 1

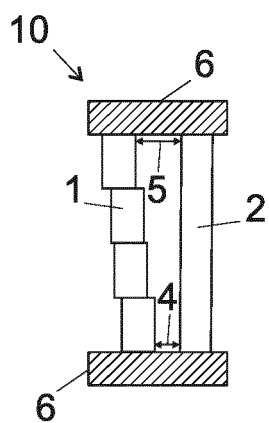


Fig. 2

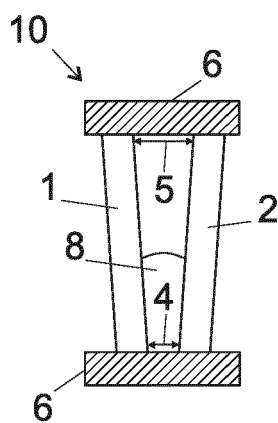


Fig. 3

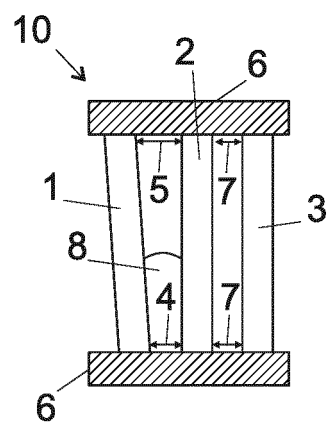


Fig. 4

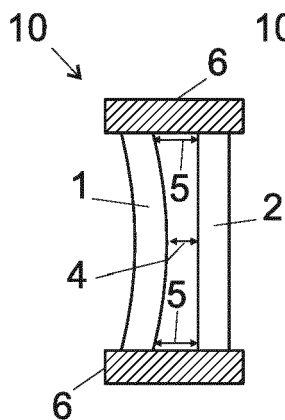


Fig. 5

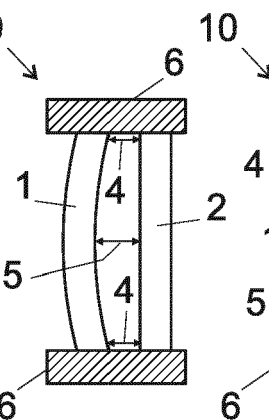


Fig. 6

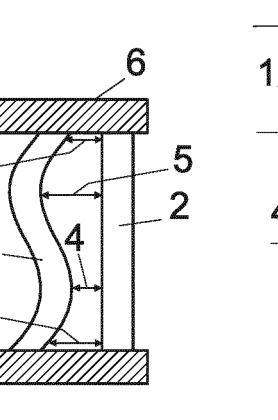


Fig. 7

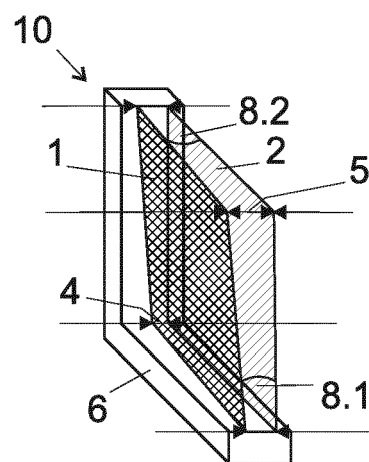


Fig. 8

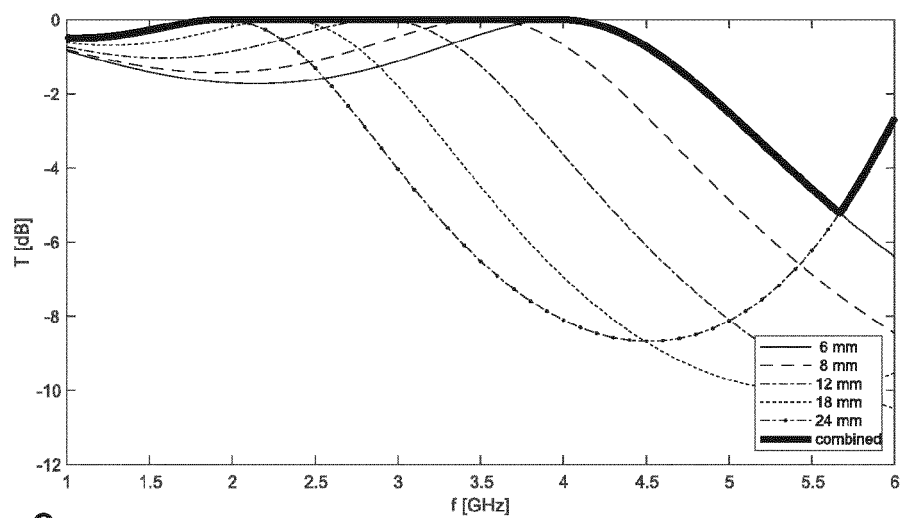


Fig. 9

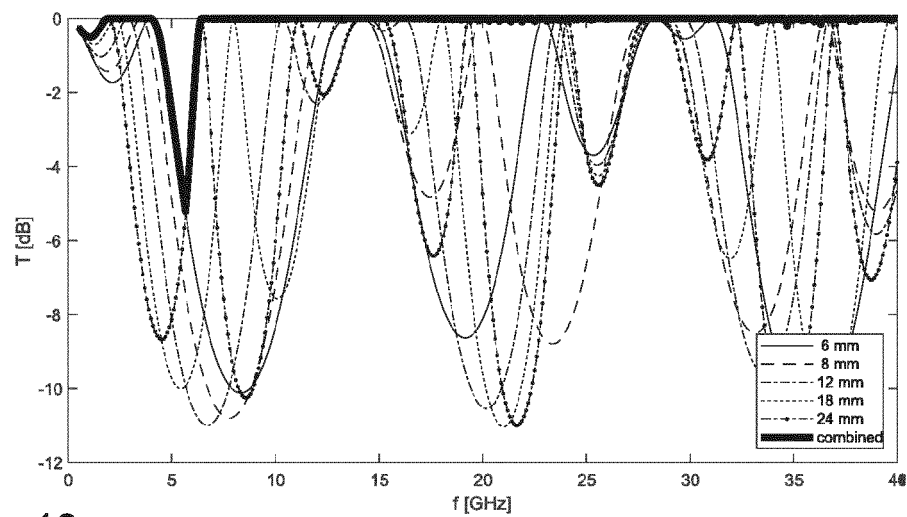


Fig. 10

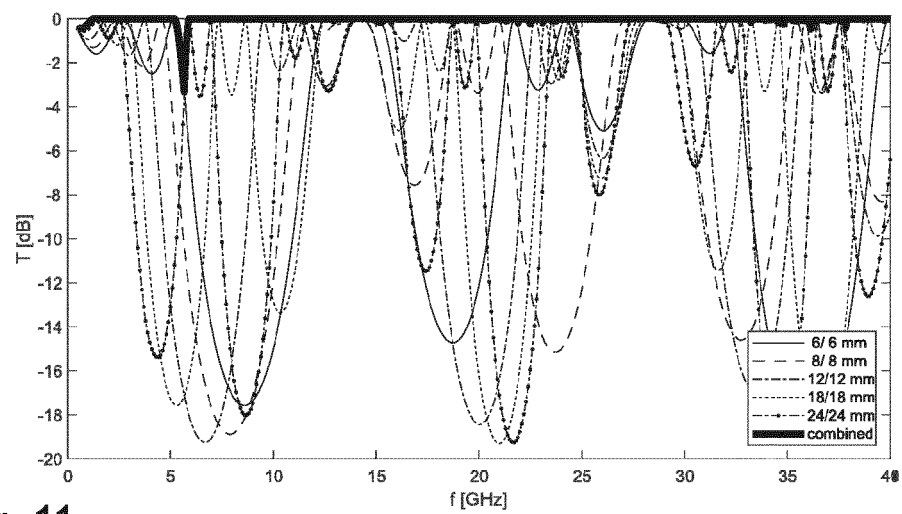


Fig. 11



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Place of search The Hague		Date of completion of the search 20 December 2019	Examiner Jülich, Saskia
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