DESCRIPTION

TITLE OF INVENTION:

WINDOW STRUCTURE AND SHEET

TECHNICAL FIELD

[0001] The present disclosure relates to a window structure and a sheet.

BACKGROUND

[0002] Patent Document 1 discloses a window structure. The window of this window structure is composed of a support frame fixed to a wall and glass surrounded by a window frame. Part of the surface of the glass is covered with a film that shields against radio waves. On the surface of the glass, a portion where part of the film that shields against radio waves has been removed is formed as a window portion. The window portion allows specific radio waves to pass through and blocks radio waves other than the specific radio waves.

[0003] Non-Patent Document 1 discloses a transmissive metasurface. The transmissive metasurface has a film-like shape. The transmissive metasurface, while being attached to a window on the indoor side of a building, bends indoor millimeter-wave radio waves to form a coverage area at the base of the building outdoors.

CITATION LIST

PATENT LITERATURE

[0004] Patent Document 1: JP 2006-87055 A

NON-PATENT LITERATURE

[0005] Non-Patent Document 1: NTT DOCOMO, INC., “World’s First Successful Demonstration of Delivering Indoor Radio Waves to Outdoor Base of Building with Transmissive Metasurface”. Internet: https://www.docomo.ne.jp/binary/pdf/info/news_release/topics_230130_04.pdf.

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0006] There are cases where it is required to make radio waves less likely to be blocked by a building provided with a window structure. For example, radio waves for 5G and radio waves for 6G have characteristics such that, compared with radio waves for 4G, they are more likely to be blocked in buildings and more likely to be attenuated by buildings or distance. Accordingly, the communication environment inside a building may become unstable, and radio waves may not be received.

[0007] One of the objects of the present disclosure is to provide a window structure and a sheet capable of suppressing blocking and attenuation of radio waves by a building.

SOLUTION TO PROBLEM

[0008] (1) A window structure according to the present disclosure is provided with a window having a first surface and a second surface opposite the first surface, and a sheet attached to at least one of the first surface and the second surface of the window, the sheet containing a matrix resin and an inorganic filler. At least one of the reflection intensity of radio waves in a predetermined band transmitted through the window and reaching the sheet, and the reflection intensity of radio waves in the predetermined band transmitted through the sheet and reaching the window, is lower than the reflection intensity of radio waves in the predetermined band transmitted through the window when either the first surface or the second surface, or both the first surface and the second surface, are in contact with air. The matrix resin is a thermoplastic resin or a thermosetting resin.

[0009] In this window structure, at least one of the reflection intensity of radio waves in a predetermined band transmitted through the window and reaching the sheet and the reflection intensity of radio waves in the predetermined band transmitted through the sheet and reaching the window is lower than the reflection intensity of radio waves in the predetermined band transmitted through the window when either the first surface or the second surface of the window, or both surfaces, are in contact with air. Thus, because the reflection intensity of the radio waves in the predetermined band is low, the intensity of the radio waves transmitted through the window and the sheet can be increased according to the law of conservation of energy in relation to reflection and transmission of radio waves. By suppressing blocking and attenuation of radio waves and increasing the transmission intensity of radio waves, the communication environment inside a building can be stabilized.

[0010] (2) In (1) above, the matrix resin may contain at least one of polystyrene and polyethylene.

[0011] (3) In (1) or (2) above, the sheet may contain 1 to 90% by volume of the inorganic filler.

[0012] (4) In any one of (1) to (3) above, the inorganic filler may be at least one selected from the group consisting of barium titanate, calcium titanate, strontium titanate, and titanium-strontium-zirconia-based materials.

[0013] (5) In any one of (1) to (4) above, the inorganic filler may have a particle size of 0.001 to 100 μm.

[0014] (6) In any one of (1) to (5) above, the window structure may be provided with a double window having two of the windows and the sheet attached to at least one of the first surface and the second surface of the two windows.

[0015] (7) In (6) above, the double window may be provided with a laminated glass interlayer.

[0016] (8) In (6) above, the double window may be provided with a heat-shielding layer.

[0017] (9) In any one of (1) to (8) above, the periphery of the sheet may be fixed to the window by a tape, and the sheet may be in close contact with the window.

[0018] (10) In any one of (1) to (9) above, the sheet may contain at least one of a pressure-sensitive adhesive layer and an adhesive layer.

[0019] (11) In any one of (1) to (10) above, the sheet may be embossed.

[0020] (12) A sheet according to the present disclosure is a sheet attached to at least one of a first surface and a second surface opposite the first surface of a window. The sheet contains a matrix resin and an inorganic filler. At least one of the reflection intensity of radio waves in a predetermined band transmitted through the window and reaching the sheet, and the reflection intensity of radio waves in the predetermined band transmitted through the sheet and reaching the window, is lower than the reflection intensity of radio waves in the predetermined band transmitted through the window when either the first surface or the second surface, or both the first surface and the second surface, are in contact with air. The same effects as those of the window structure mentioned above can be obtained from this sheet.

EFFECTS OF INVENTION

[0021] According to the present disclosure, it is possible to suppress blocking and attenuation of radio waves by a building.

BRIEF DESCRIPTION OF DRAWINGS

[0022] Fig. 1 is a diagram schematically showing a window structure according to an embodiment.

Fig. 2 is a cross-sectional view schematically showing a window structure according to an embodiment.

Fig. 3 is a cross-sectional view showing a window and a sheet in a window structure according to an embodiment.

Fig. 4 is a diagram for explaining reflection and transmission of radio waves with respect to the window of Fig. 3.

Fig. 5 is a diagram for explaining reflection and transmission of radio waves with respect to the window and the sheet of Fig. 3.

Fig. 6(a) is a cross-sectional view showing a window structure according to a first modification. Fig. 6(b) is a cross-sectional view showing a window structure according to a second modification.

Fig. 7(a) is a cross-sectional view showing a window structure according to a third modification. Fig. 7(b) is a cross-sectional view showing a window structure according to a fourth modification.

Fig. 8(a) is a cross-sectional view showing a window structure according to a fifth modification. Fig. 8(b) is a cross-sectional view showing a window structure according to a sixth modification.

Fig. 9 is a diagram for explaining a radio wave intensity measurement test.

Fig. 10 is a graph showing results of the radio wave intensity measurement test.

DESCRIPTION OF EMBODIMENTS

[0023] Hereinafter, embodiments of the window structure and sheet according to the present disclosure will be described with reference to the drawings. In the description of the drawings, the same or corresponding elements are assigned the same reference signs, and redundant descriptions are omitted where appropriate. The drawings may be partially simplified or exaggerated for ease of understanding, and dimensional ratios and the like are not limited to those shown in the drawings.

[0024] Fig. 1 is a diagram schematically showing a window structure 1 according to an embodiment. The window structure 1 is provided in a building S. As one example, the window structure 1 is provided with a frame 2 fixed to the building S, a sash 3 located inside the frame 2, and a window 10 located inside the sash 3. The window 10 is, for example, made of glass. However, the material of the window 10 is not particularly limited.

[0025] Fig. 2 is a cross-sectional view of the window structure 1 taken along a plane extending in the extending direction of the window 10 and in the thickness direction of the window 10. As shown in Fig. 2, the window 10 has a first surface 11 facing the outdoor side of the building S, and a second surface 12 facing the indoor side of the building S. The window structure 1 has a sheet 20 attached to at least one of the first surface 11 and the second surface 12.

[0026] The sheet 20 is, for example, attached to part of at least one of the first surface 11 and the second surface 12. In this case, the area of the attached sheet 20 is smaller than the area of the window 10. The sheet 20 may be attached to the entirety of at least one of the first surface 11 and the second surface 12. In this case, the area of the attached sheet 20 is substantially equal to the area of the window 10.

[0027] Fig. 2 shows an example in which the sheet 20 is attached to the second surface 12. For example, the sheet 20 is in close contact with the window 10. For example, the window structure 1 has a tape 30 for attaching the sheet 20 to the window 10. The periphery of the sheet 20 is fixed to the window 10 by the tape 30. The sheet 20 has, for example, a sheet first surface 21 in close contact with the second surface 12 of the window 10, and a sheet second surface 22 opposite the sheet first surface 21. In the present embodiment, the sheet first surface 21 is a surface facing the outdoor side of the building S, and the sheet second surface 22 is a surface facing the indoor side of the building S.

[0028] For example, the sheet first surface 21 and the sheet second surface 22 are flat surfaces. However, at least one of the sheet first surface 21 and the sheet

second surface may have irregularities. For example, the sheet 20 may be embossed.

[0029] The sheet 20 contains a matrix resin and an inorganic filler. The matrix resin is, for example, a thermoplastic resin or a thermosetting resin. The thermoplastic resin contained in the sheet 20 may be, for example, polystyrene, polyethylene, polypropylene, acrylonitrile butadiene styrene (ABS), acrylic, or polyamide, and the like. The thermoplastic resin contained in the sheet 20 may be at least one selected from the group consisting of polystyrene and polyethylene. The thermosetting resin contained in the sheet 20 may be, for example, a silicone resin, an epoxy resin, a phenolic resin, a melamine resin, or a polyurethane resin, and the like. The thermosetting resin contained in the sheet 20 may be, for example, a silicone resin.

[0030] For example, the inorganic filler contained in the sheet 20 is a high-dielectric filler. The relative dielectric constant of the high-dielectric filler may be, for example, 10 or more, and may be 100 or more, 1000 or more, or 5000 or more. When the relative dielectric constant is high, it is easy to adjust the relative dielectric constant of the sheet 20 with a small amount of filler. The relative dielectric constant of the high-dielectric filler may be 10 or less, and may be 5 or less.

[0031] Examples of the inorganic filler include a titanium-based filler, a zirconium-based filler, and an aluminum-based filler. Examples of the titanium-based filler include barium titanate, calcium titanate, strontium titanate, zirconium oxide, and aluminum oxide. The inorganic filler may be at least one selected from the group consisting of barium titanate, calcium titanate, strontium titanate, and titanium-strontium-zirconia-based materials.

[0032] For example, the particle size of the inorganic filler contained in the sheet 20 is 0.001 to 100 μm. The particle size of the inorganic filler may be 0.01 μm or more, 0.05 μm or more, 0.1 μm or more, 0.5 μm or more, 1 μm or more, or 5 μm or more. The particle size of the inorganic filler may be 50 μm or less, 20 μm or less, or 10 μm or less.

[0033] For example, the sheet 20 contains 1 to 90% by volume of the inorganic filler. The sheet 20 may contain the inorganic filler in an amount of 10% by volume or more, 20% by volume or more, 30% by volume or more, or 40% by volume or more. The sheet 20 may contain the inorganic filler in an amount of 80% by volume or less, 70% by volume or less, 60% by volume or less, or 50% by volume or less. The relative dielectric constant of the sheet 20 can be adjusted by the content of the inorganic filler. The content of the inorganic filler may be appropriately adjusted in accordance with the relative dielectric constant required for the sheet 20.

[0034] The sheet 20 may contain an epoxy resin and a barium titanate filler. In addition, the sheet 20 may contain a polystyrene resin and a barium titanate filler.

[0035] For example, the thickness of the sheet 20 (the distance from the sheet first surface 21 to the sheet second surface 22) is 100 to 200 μm. The relative dielectric constant of the sheet 20 can be adjusted by the thickness of the sheet 20. The thickness of the sheet 20 may be appropriately adjusted in accordance with the

relative dielectric constant required for the sheet 20. As one example, the dielectric constant of the sheet 20 is 29 to 34.

[0036] Fig. 3 is a cross-sectional view schematically showing the window 10, the sheet 20, and radio waves W transmitted through or reflected by the window 10 and the sheet 20. The radio waves W are, for example, radio waves for 5G communication or radio waves for 6G communication. Radio waves for 5G communication and radio waves for 6G communication have characteristics such that, compared with radio waves for 4G communication, they are more likely to be blocked or attenuated in buildings. In Fig. 3, the incident waves W and the transmitted waves W4 and W7 are indicated by solid lines, the reflected waves W1, W5, and W6 are indicated by dashed lines, and the reflected waves W2 and W3 whose phases are adjusted by the sheet 20 are indicated by thick dashed lines. The reflected waves W2 and W3 are reflected waves whose phases can be adjusted by the sheet 20.

[0037] The sheet 20 according to the present embodiment has a function of controlling the radio waves W. The sheet 20 is attached to the window 10 to increase the transmittance of the radio waves W transmitted through the window 10. The radio waves W that reach the window 10 to which the sheet 20 is not attached are separated into a reflected wave W5 reflected at the first surface 11, a reflected wave W6 transmitted through the first surface 11 and reflected at the second surface 12, and a transmitted wave W7 transmitted through the second surface 12. The radio waves W that reach the window 10 to which the sheet 20 is attached are separated into a reflected wave W1 reflected at the first surface 11, a reflected wave W2 transmitted through the first surface 11 and reflected at the sheet first surface 21, a reflected wave W3 transmitted through the sheet first surface 21 and reflected at the sheet second surface 22, and a transmitted wave W4 transmitted through the sheet second surface 22. The intensity of the transmitted wave W4 is greater than the intensity of the transmitted wave W7. The window 10 to which the sheet 20 is attached has higher transmittance for the radio waves W than the window 10 to which the sheet 20 is not attached. For example, when the sheet 20 is attached to the second surface 12 of the window 10, the transmittance of the radio waves W into the interior is increased.

[0038] Fig. 4 is a diagram schematically showing reflected and transmitted waves of the radio waves W with respect to the window 10. Fig. 5 is a diagram schematically showing reflected and transmitted waves of the radio waves W with respect to the window 10 and the sheet 20. The reflection coefficient at the first surface 11 of the radio waves W incident on the window 10 to which the sheet 20 is not attached is negative, and the reflection coefficient at the second surface 12 is positive. Because the thickness of the window 10 cannot be adjusted, it is not possible to strengthen the transmitted wave W7 by canceling the reflected waves W5 and W6.

[0039] The reflection coefficient at the first surface 11 of the radio waves W incident on the window 10 to which the sheet 20 is attached is negative, the reflection coefficient at the second surface 12 (sheet first surface 21) is negative, and the reflection coefficient at the sheet second surface 22 is positive. The thickness of the window 10 cannot be adjusted, but by adjusting the dielectric constant and thickness of the sheet 20, it is possible to adjust the intensity and phase of the reflected waves

W2 and W3, thereby suppressing the reflected waves W2 and W3 and strengthening the transmitted wave W4.

[0040] When ε_r is the relative dielectric constant of a dielectric and λ_0 is the wavelength in vacuum, the wavelength λ of the radio waves in the dielectric is determined by the following equation (1). As shown in equation (1), as the relative dielectric constant of the dielectric increases, the wavelength λ of the radio waves in the dielectric decreases.

[Equation 1]

$$\lambda = \lambda_0 \frac{1}{\sqrt{\varepsilon_r}} \qquad \cdots (1)$$

[0041] The dielectric constant of the window 10 (for example, glass) is greater than the dielectric constant of air, and the dielectric constant of the sheet 20 is greater than the dielectric constant of the window 10. The wavelength of the radio waves passing through the window 10 is shorter than the wavelength of the radio waves in air, and the wavelength of the radio waves passing through the sheet 20 is shorter than the wavelength of the radio waves passing through the window 10. The reflection intensity of the radio waves W in a predetermined band transmitted through the window 10 and reaching the sheet 20 is lower than the reflection intensity of the radio waves W in the predetermined band transmitted through the window 10 when either the first surface 11 or the second surface 12, or both the first surface 11 and the second surface 12, are in contact with air. For example, the reflection intensity of the radio waves in a predetermined band transmitted through the sheet 20 and reaching the window 10 is lower than the reflection intensity of the radio waves in the predetermined band transmitted through the window 10 when either the first surface 11 or the second surface 12, or both the first surface 11 and the second surface 12, are in contact with air.

[0042] The predetermined band described above is, for example, a 5G radio wave band (for example, a millimeter-wave band) or a 6G radio wave band (for example, a sub-terahertz-wave band). In the present embodiment, the intensity of the reflected waves that are transmitted through the window 10, reflected at the sheet 20 (sheet first surface 21 or sheet second surface 22), and travel from the window 10 toward the side opposite the sheet 20 is lower than the intensity of the radio waves transmitted through the window 10 and the sheet 20.

[0043] In the present embodiment, the sheet 20 suppresses attenuation of a transmitted wave by canceling the phases of reflected waves and attenuating the reflected waves. For example, the intensity of the reflected waves traveling from the window 10 toward the side opposite the sheet 20 becomes smaller due to the phase of the reflected wave W1 reflected at the first surface 11, the phase of the reflected wave W2 reflected at the sheet first surface 21, and the phase of the reflected wave W3 reflected at the sheet second surface 22 canceling one another.

[0044] When R is the energy of the reflected wave traveling from the window 10 toward the side opposite the sheet 20 and T is the energy of the transmitted wave transmitted through the window 10 and the sheet 20, then R + T = 1 according to the

law of conservation of energy. As mentioned above, when the intensity of the reflected wave traveling from the window 10 toward the side opposite the sheet 20 becomes smaller, the intensity of the transmitted wave W4 transmitted through the window 10 and the sheet 20 becomes larger. By attaching the sheet 20 containing a dielectric to the window 10, the intensity of the transmitted wave W4 transmitted through the window 10 and the sheet 20 can be increased.

[0045] When d_g is the thickness of the window 10, ε_g is the dielectric constant of the window 10 (such as glass), d_a is the thickness of the sheet 20, and ε_a is the dielectric constant of the sheet 20, the phase and intensity of the reflected waves W2 and W3 can be shifted by adjusting the values of d_a and ε_a, thereby enabling phase adjustment of the reflected waves W1 to W3 based on optical path differences. The values of d_a and ε_a may be adjusted taking multiple reflections into account.

[0046] In the window structure 1 according to the present embodiment, at least one of the reflection intensity of the radio waves W in a predetermined band transmitted through the window 10 and reaching the sheet 20 and the reflection intensity of the radio waves in the predetermined band transmitted through the sheet 20 and reaching the window 10 is lower than the reflection intensity of the radio waves in the predetermined band transmitted through the window 10 when either the first surface 11 or the second surface 12, or both, are in contact with air. Because the reflection intensity of radio waves in a predetermined band is low, the intensity of radio waves (such as transmitted wave W4) transmitted through the window 10 and the sheet 20 can be increased according to the law of conservation of energy in relation to reflection and transmission of radio waves. By suppressing blocking and attenuation of radio waves and increasing the transmission intensity of radio waves, the communication environment inside the building S can be stabilized.

[0047] Various modifications of the window structure according to the present disclosure will be described. Fig. 6(a) is a cross-sectional view schematically showing a window structure 1A according to a first modification. The window structure 1A has a pair of sheets 20A attached to both the first surface 11 and the second surface 12 of the window 10. The sheets 20A differ from the sheet 20 mentioned above in that each sheet has a pressure-sensitive adhesive layer 23. The sheets 20A can be used instead of the sheet 20. The sheet 20A attached to the first surface 11 is, for example, the same as the sheet 20A attached to the second surface 12. However, the sheet 20A attached to the first surface 11 may be different from the sheet 20A attached to the second surface 12. At least one of the thickness and the dielectric constant of the sheet 20A attached to the first surface 11 may be different from at least one of the thickness and the dielectric constant of the sheet 20A attached to the second surface 12.

[0048] For example, before being attached to the window 10, the sheet 20A has a release paper adhered to the pressure-sensitive adhesive layer 23, and the pressure-sensitive adhesive layer 23 from which the release paper has been peeled off is attached to the window 10. In this case, the tape 30 mentioned above may be omitted. The sheet 20A may have an adhesive layer composed of an adhesive instead of the pressure-sensitive adhesive layer 23. In the window structure 1A, because the sheets 20A are attached to both the first surface 11 and the second

surface 12 of the window 10, the transmittance of the radio waves can be increased compared with a case in which the sheets 20A are not attached to the window 10.

[0049] Fig. 6(b) is a cross-sectional view schematically showing a window structure 1B according to a second modification. The window structure 1B has a sheet 20A attached to the first surface 11 of the window 10. In the window structure 1B, because the sheet 20A is attached to the first surface 11 of the window 10, the transmittance of the radio waves can be increased compared with a case in which the sheet 20A is not attached to the window 10. The sheet 20A may also be attached to the second surface 12.

[0050] Fig. 7(a) is a cross-sectional view schematically showing a window structure 1C according to a third modification. The window structure 1C has two windows 10. The window structure 1C is provided with a double window 40 having two windows 10 and a sheet 20 attached to at least one of the first surface 11 and the second surface 12 of the two windows 10. For example, an air layer is formed between the two windows 10. Fig. 7(a) is a schematic diagram of a case in which the sheet 20 is attached to an outer side of the window 10 (for example, a side exposed to the outside air).

[0051] Fig. 7(b) is a cross-sectional view showing a window structure 1D according to a fourth modification. In the window structure 1D, a sheet 20 is attached to an inner side of the window 10 (for example, a side in contact with an intermediate layer). In the window structure 1C and window structure 1D, as with the aforementioned window structure 1 and the like, because the sheet 20 is attached to the second surface 12 of the window 10, the transmittance of the radio waves can be increased compared with a case in which the sheet 20 is not attached to the second surface 12. In the window structure 1C and window structure 1D described above, a sheet 20 may also be attached to the first surface 11 of the window 10. The location at which a sheet 20 is attached and the number of sheets 20 to be attached can be appropriately modified.

[0052] Fig. 8(a) is a cross-sectional view showing a window structure 1E according to a fifth modification. The window structure 1E has two windows 10, a sheet 20, and a laminated glass interlayer 45. In the window structure 1E, the double window 40 is provided with the laminated glass interlayer 45. The laminated glass interlayer 45 is in close contact with each of the two windows 10 between the two windows 10. Thus, the sheet 20 can also be applied to laminated glass.

[0053] Fig. 8(b) is a cross-sectional view showing a window structure 1F according to a sixth modification. The window structure 1F has two windows 10, a sheet 20, and a heat-shielding layer 46. In the window structure 1F, the double window 40 is provided with the heat-shielding layer 46. The heat-shielding layer 46 is provided to suppress transmission of heat to the double window 40.

[0054] The heat-shielding layer 46 is, for example, attached to the second surface 12 of the window 10 on the outdoor side. However, the heat-shielding layer 46 may be attached to the first surface 11 of the window 10 on the indoor side, and the position to which the heat-shielding layer 46 is attached is not particularly limited. In the window structure 1F provided with the heat-shielding layer 46, the transmittance

of the radio waves in the building S can be increased, and heat transmitted through the double window 40 is suppressed by the heat-shielding layer 46. Accordingly, heat and cold in the building S can be suppressed.

[0055] Embodiments and various modifications of the window structure and sheet according to the present disclosure have been described. However, the present disclosure is not limited to the embodiments or various modifications mentioned above, and may be further modified within the scope of the gist set forth in the claims. The structure, shape, size, material, number, and arrangement of the respective parts of the window structure and sheet according to the present disclosure can be appropriately modified within the scope of the gist described above.

EXAMPLES

[0056] Next, examples of the window structure and sheet according to the present disclosure will be described. The window structure and sheet according to the present disclosure are not limited to the contents of the following examples. As shown in Fig. 9, a radio wave intensity measurement test was performed for Examples 1 to 3 and Comparative Examples 1 and 2 described below. The measurement device used in the radio wave intensity measurement test has a turntable on which the window 10 is placed, a radio wave irradiator that irradiates the window 10 with radio waves, a radio wave receiver that receives the radio waves from the radio wave irradiator, and a measuring instrument that measures the intensity of the radio waves received by the radio wave receiver. Examples 1 to 3 and Comparative Examples 1 and 2 are as follows.

[0057] (Example 1)

Radio waves from the radio wave irradiator were transmitted from the window 10 side through the window structure 1, in which the sheet 20 was attached to the window 10, and the intensity of the radio waves transmitted through the window structure 1 was measured by the measuring instrument. As the sheet 20, the following Sample 1, Sample 2, and Sample 3 were prepared and radio wave measurements were performed for each of Samples 1 to 3. The distance from the radio wave irradiator to the window structure 1 and the distance from the window structure 1 to the radio wave receiver were set to about 100 cm.

As shown in Table 1, Samples 1 to 3 were prepared as sheet-like specimens obtained by molding a uniform compound containing 55.7% by volume of polystyrene (product name “Toyo Styrol GP G100C” manufactured by Toyo Styrene Co., Ltd.) and 44.3% by volume of barium titanate (product name “BT-SA” manufactured by KCM Corporation) to a thickness of approximately 200 μm.

[Table 1]

	Dielectric Constant	Average Thickness (μm)	Resin	Resin Content (% by volume)	Inorganic Filler	Inorganic Filler Content (% by volume)
Sample 1	23.2	181.0	Toyo Styrol GP G100C	55.7	BT-SA	44.3
Sample 2	23.0	180.8	Toyo Styrol GP G100C	55.7	BT-SA	44.3
Sample 3	23.0	182.0	Toyo Styrol GP G100C	55.7	BT-SA	44.3

(Example 2)

Radio waves from the radio wave irradiator were transmitted from the window 10 side through the window structure 1, in which the sheet 20 was attached to the window 10, and the intensity of the radio waves transmitted through the window structure 1 was measured by the measuring instrument. As the sheet 20, the following Sample 4, Sample 5, and Sample 6 were prepared and radio wave measurements were performed for each of Samples 4 to 6. The distance from the radio wave irradiator to the window structure 1 and the distance from the window structure 1 to the radio wave receiver were set to about 100 cm.

As shown in Table 2, Samples 4 to 6 were prepared as sheet-like specimens obtained by molding a uniform compound containing 53.9% by volume of polystyrene (product name “Toyo Styrol GP G100C” manufactured by Toyo Styrene Co., Ltd.) and 46.1% by volume of barium titanate (product name “BT-SA” manufactured by KCM Corporation) to a thickness of approximately 200 μm.

[Table 2]

	Dielectric Constant	Average Thickness (μm)	Resin	Resin Content (% by volume)	Inorganic Filler	Inorganic Filler Content (% by volume)
Sample 4	23.3	183.0	Toyo Styrol GP G100C	53.9	BT-SA	46.1
Sample 5	23.5	187.2	Toyo Styrol GP G100C	53.9	BT-SA	46.1
Sample 6	23.3	186.4	Toyo Styrol GP G100C	53.9	BT-SA	46.1

(Example 3)

Radio waves from the radio wave irradiator were transmitted from the window 10 side through the window structure 1, in which the sheet 20 was attached to the window 10, and the intensity of the radio waves transmitted through the window structure 1 was measured by the measuring instrument. As the sheet 20, the following Sample 7, Sample 8, and Sample 9 were prepared and radio wave measurements were performed for each of Samples 7 to 9.

As shown in Table 3, Samples 7 to 9 were prepared as sheet-like specimens obtained by molding a uniform compound containing 46.0% by volume of polystyrene (product name “Toyo Styrol GP G100C” manufactured by Toyo Styrene Co., Ltd.)

and 54.0% by volume of barium titanate (product name “BT-SA” manufactured by KCM Corporation) to a thickness of approximately 200 μm.

[Table 3]

	Dielectric Constant	Average Thickness (μm)	Resin	Resin Content (% by volume)	Inorganic Filler	Inorganic Filler Content (% by volume)
Sample 7	30.1	98.0	Toyo Styrol GP G100C	46.0	BT-SA	54.0
Sample 8	30.2	100.1	Toyo Styrol GP G100C	46.0	BT-SA	54.0
Sample 9	30.0	100.1	Toyo Styrol GP G100C	46.0	BT-SA	54.0

(Comparative Example 1)

With nothing placed on the turntable, the radio wave receiver received radio waves that passed through air from the radio wave irradiator, and the intensity of the radio waves received by the radio wave receiver was measured by the measuring instrument. The distance from the radio wave irradiator to the radio wave receiver was set to about 200 cm.

(Comparative Example 2)

With only the window 10 placed on the turntable, the radio wave receiver received radio waves transmitted through the window 10, and the intensity of the radio waves received by the radio wave receiver was measured by the measuring instrument. The distance from the radio wave irradiator to the window 10 and the distance from the window 10 to the radio wave receiver were set to about 100 cm.

[0058] Fig. 10 is a graph showing results of the radio wave intensity measurement test for Examples 1 to 3 and Comparative Examples 1 and 2. As shown in Fig. 10, in Examples 1 to 3 in which the sheet 20 was attached to the window 10, the intensity of the transmitted radio waves was higher than in Comparative Example 2, which included only the window 10, and it was found that, depending on the radio wave frequency band, the intensity of the transmitted radio waves was higher than in Comparative Example 1, which included only air.

[0059] When the radio-wave band was 27.5 (GHz), the radio wave intensity in Comparative Example 1 was -31.2 (dB), and the radio wave intensity in Comparative Example 2 was -36.8 (dB). In contrast, the radio wave intensity was -32.7 (dB) in Example 1, -32.6 (dB) in Example 2, and -34.0 (dB) in Example 3, and it was found that the intensity of the transmitted radio waves was higher than that in Comparative Example 2.

[0060] When the radio-wave band was 28.0 (GHz), the radio wave intensity in Comparative Example 1 was -31.5 (dB), and the radio wave intensity in Comparative Example 2 was -36.8 (dB). In contrast, the radio wave intensity was -32.0 (dB) in Example 1, -31.4 (dB) in Example 2, and -33.4 (dB) in Example 3, and it was found

that the intensity of the transmitted radio waves was higher than that in Comparative Example 2.

[0061] A radio wave intensity measurement test was performed for Examples 4 to 6 and Comparative Examples 3 and 4 in which the intensity of radio waves in a predetermined band transmitted through the sheet 20 and reaching the window 10 was measured. The measurement device used in Examples 4 to 6 and Comparative Examples 3 and 4 was the same as that mentioned above. Examples 4 to 6 and Comparative Examples 3 and 4 are as follows.

[0062] (Example 4)

Radio waves from the radio wave irradiator were transmitted from the sheet 20 side through the window structure 1, in which the sheet 20 was attached to the window 10, and the intensity of the radio waves transmitted through the window structure 1 was measured by the measuring instrument. Except that the radio waves were transmitted from the sheet 20 side, the procedure was the same as that in Example 1.

(Example 5)

Radio waves from the radio wave irradiator were transmitted from the sheet 20 side through the window structure 1, in which the sheet 20 was attached to the window 10, and the intensity of the radio waves transmitted through the window structure 1 was measured by the measuring instrument. Except that the radio waves were transmitted from the sheet 20 side, the procedure was the same as that in Example 2.

(Example 6)

Radio waves from the radio wave irradiator were transmitted from the sheet 20 side through the window structure 1, in which the sheet 20 was attached to the window 10, and the intensity of the radio waves transmitted through the window structure 1 was measured by the measuring instrument. Except that the radio waves were transmitted from the sheet 20 side, the procedure was the same as that in Example 3.

(Comparative Example 3)

In Comparative Example 3, the intensity of the radio waves was measured under the same conditions as in Comparative Example 1.

(Comparative Example 4)

In Comparative Example 4, the intensity of the radio waves was measured under the same conditions as in Comparative Example 2.

[0063] Regarding the results of Examples 4 to 6 and Comparative Examples 4 and 5, when the radio-wave band was 27.5 (GHz), the radio wave intensity in Comparative Example 3 was -31.3 (dB), and the radio wave intensity in Comparative Example 4 was -36.0 (dB). In contrast, the radio wave intensity was -32.7 (dB) in

Example 4, -32.7 (dB) in Example 5, and -34.2 (dB) in Example 6, and it was found that the intensity of the transmitted radio waves was higher than that in Comparative Example 4.

[0064] When the radio-wave band was 28.0 (GHz), the radio wave intensity in Comparative Example 3 was -31.4 (dB), and the radio wave intensity in Comparative Example 4 was -36.7 (dB). In contrast, the radio wave intensity was -31.8 (dB) in Example 4, -31.6 (dB) in Example 5, and -33.3 (dB) in Example 6, and it was found that the intensity of the transmitted radio waves was higher than that in Comparative Example 4.

[0065] As described above, it was found that, in Examples 4 to 6 in which radio waves were incident from the sheet 20 side, as with Examples 1 to 3 in which radio waves were incident from the window 10 side, the intensity of radio waves transmitted through the window structure could be increased.

REFERENCE SIGNS LIST

[0066]

1, 1A, 1B, 1C, 1D, 1E, 1F: Window structure
2: Frame
3: Sash
10: Window
11: First surface
12: Second surface
20, 20A: Sheet
21: Sheet first surface
22: Sheet second surface
23: Pressure-sensitive adhesive layer
30: Tape
40: Double window
45: Glass interlayer
46: Heat-shielding layer
S: Building
W: Radio wave
W1, W2, W3: Reflected wave
W4: Transmitted wave

CLAIMS

[Claim 1]

A window structure comprising:

a window having a first surface and a second surface opposite the first surface; and

a sheet attached to at least one of the first surface and the second surface of the window, the sheet comprising a matrix resin and an inorganic filler,

wherein at least one of the reflection intensity of radio waves in a predetermined band transmitted through the window and reaching the sheet, and the reflection intensity of radio waves in the predetermined band transmitted through the sheet and reaching the window, is lower than the reflection intensity of radio waves in the predetermined band transmitted through the window when either the first surface or the second surface, or both the first surface and the second surface, are in contact with air, and

the matrix resin is a thermoplastic resin or a thermosetting resin.

[Claim 2]

The window structure according to claim 1, wherein:

the matrix resin comprises at least one of polystyrene and polyethylene.

[Claim 3]

The window structure according to claim 1 or 2, wherein:

the sheet comprises 1 to 90% by volume of the inorganic filler.

[Claim 4]

The window structure according to any one of claims 1 to 3, wherein:

the inorganic filler is at least one selected from the group consisting of barium titanate, calcium titanate, strontium titanate, and a titanium-strontium-zirconia-based material.

[Claim 5]

The window structure according to any one of claims 1 to 4, wherein:

the inorganic filler has a particle size of 0.001 to 100 μm.

[Claim 6]

The window structure according to any one of claims 1 to 5, comprising:

a double window having two of the windows, and the sheet attached to at least one of the first surface and the second surface of the two windows.

[Claim 7]

The window structure according to claim 6, wherein:

the double window comprises a laminated glass interlayer.

[Claim 8]

The window structure according to claim 6, wherein:
the double window comprises a heat-shielding layer.

[Claim 9]

The window structure according to any one of claims 1 to 8, wherein:
the periphery of the sheet is fixed to the window by a tape; and
the sheet is in close contact with the window.

[Claim 10]

The window structure according to any one of claims 1 to 9, wherein:
the sheet comprises at least one of a pressure-sensitive adhesive layer and an adhesive layer.

[Claim 11]

The window structure according to any one of claims 1 to 10, wherein:
the sheet is embossed.

[Claim 12]

A sheet attached to at least one of a first surface and a second surface opposite the first surface of a window, wherein:
the sheet comprises a matrix resin and an inorganic filler; and
at least one of the reflection intensity of radio waves in a predetermined band transmitted through the window and reaching the sheet, and the reflection intensity of radio waves in the predetermined band transmitted through the sheet and reaching the window, is lower than the reflection intensity of radio waves in the predetermined band transmitted through the window when either the first surface or the second surface, or both the first surface and the second surface, are in contact with air.