DESCRIPTION

Title of Invention: WINDOW STRUCTURE

Technical Field

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

Background Art

[0002] Patent Literature 1 describes a window structure. The window of this window structure includes a support frame fixed to a wall and glass surrounded by a window frame. A part of the surface of the glass is covered by a film that shields radio waves. A portion of the surface of the glass from which a part of the film that shields radio waves has been removed is formed as a window portion. The window portion transmits specific radio waves and blocks radio waves other than the specific radio waves.

[0003] Non-Patent Literature 1 describes a transmissive metasurface. The transmissive metasurface has a film shape. The transmissive metasurface, in a state of being attached to a window from the indoor side of a building, bends indoor millimeter-wave radio waves to create a coverage area at the base of the building outdoors.

Citation List

Patent Literature

[0004] [Patent Literature 1] Japanese Unexamined Patent Application Publication No. 2006-87055

Non Patent Literature

[0005] [Non-Patent Literature 1] NTT DOCOMO, Inc., “World’s First Successful Demonstration of Delivering Indoor Radio Waves to the Base

of an Outdoor Building Using a Transmissive Metasurface," Internet <https://www.docomo.ne.jp/binary/pdf/info/news_release/topics_230130_04.pdf>

Summary of Invention

Technical Problem

[0006] Incidentally, there are cases where it is required for a building provided with a window structure to make it difficult for radio waves to be blocked. For example, radio waves for 5G and radio waves for 6G have characteristics of being more easily blocked in a building and more easily attenuated by a building or distance compared to radio waves for 4G. Therefore, it may occur that the communication environment inside a building becomes unstable and radio waves cannot be received.

[0007] One of the objects of the present disclosure is to provide a window structure 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 includes a window having a first surface and a second surface opposite to the first surface, and a sheet attached to at least one of the first surface and the second surface of the window and containing a matrix resin and an inorganic filler. At least one of a reflection intensity of radio waves in a predetermined band that pass through the window and reach the sheet and a reflection intensity of radio waves in the predetermined band that pass through the sheet and reach the window is lower than a reflection intensity of radio waves in the predetermined band that pass through the window when either one of the first surface and the second

surface, or both the first surface and the second surface, are in contact with air.

[0009] In this window structure, at least one of the reflection intensity of radio waves in a predetermined band that pass through the window and reach the sheet and the reflection intensity of radio waves in the predetermined band that pass through the sheet and reach the window is lower than the reflection intensity of radio waves in the predetermined band that pass through the window when the first surface or the second surface of the window, or both, are in contact with air. In this way, because the reflection intensity of radio waves in the predetermined band is low, the intensity of the radio waves passing through the window and the sheet can be increased based on the law of conservation of energy relating 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 the above (1), the dielectric constant of the sheet may be 2 to 70, and the thickness of the sheet may be 10 to 5000 μm.

[0011] (3) In the above (1) or (2), the dielectric constant of the sheet may be 3 to 60, and the thickness of the sheet may be 20 to 3000 μm.

[0012] (4) In any one of the above (1) to (3), the dielectric constant of the sheet may be 4 to 50, and the thickness of the sheet may be 40 to 2500 μm.

[0013] (5) In any one of the above (1) to (4), the sheet may be attached to a part of at least one of the first surface and the second surface.

[0014] (6) In any one of the above (1) to (5), the sheet may be attached

to both the first surface and the second surface.

[0015] (7) In any one of the above (1) to (6), the window may be a window provided in a building, and the second surface may be a surface on the indoor side of the building.

[0016] (8) In any one of the above (1) to (7), the predetermined band of the radio waves may be 27.0 (GHz) to 29.5 (GHz).

Advantageous Effects of Invention

[0017] According to the present disclosure, blocking and attenuation of radio waves by a building can be suppressed.

Brief Description of Drawings

[0018] [FIG. 1] FIG. 1 is a diagram schematically showing a window structure according to an embodiment.

[FIG. 2] FIG. 2 is a cross-sectional view schematically showing the window structure according to the embodiment.

[FIG. 3] FIG. 3 is a cross-sectional view showing a window and a sheet of the window structure according to the embodiment.

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

[FIG. 5] 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) of FIG. 6 is a cross-sectional view showing a window structure according to a first modification. (b) of FIG. 6 is a cross-sectional view showing a window structure according to a second modification.

[FIG. 7] (a) of FIG. 7 is a cross-sectional view showing a window structure according to a third modification. (b) of FIG. 7 is a cross-

sectional view showing a window structure according to a fourth modification.

[FIG. 8] (a) of FIG. 8 is a cross-sectional view showing a window structure according to a fifth modification. (b) of FIG. 8 is a cross-sectional view showing a window structure according to a sixth modification.

[FIG. 9] FIG. 9 is a diagram for explaining a radio wave intensity measurement test.

[FIG. 10] FIG. 10 is a graph showing results of the radio wave intensity measurement test.

Description of Embodiments

[0019] In the following, embodiments of the window structure 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 denoted by the same reference numerals, and duplicate descriptions are omitted as appropriate. The drawings may partially show simplified or exaggerated depictions for ease of understanding, and dimensional ratios and the like are not limited to those shown in the drawings.

[0020] 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 includes 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 made of, for example, glass. However, the material of the window 10 is not particularly limited.

[0021] FIG. 2 is a cross-sectional view of the window structure 1 when cut 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.

[0022] The sheet 20 is attached to, for example, a part of at least one of the first surface 11 and the second surface 12. In this case, the area of the sheet 20 to be attached is smaller than the area of the window 10. Note that 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 sheet 20 to be attached is approximately the same as the area of the window 10.

[0023] 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 that is in close contact with the second surface 12 of the window 10, and a sheet second surface 22 opposite to 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.

[0024] 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 22 may have irregularities. For example, the sheet 20 may be embossed.

[0025] 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 phenol resin, a melamine resin, a polyurethane resin, or the like. The thermosetting resin contained in the sheet 20 may be, for example, a silicone resin.

[0026] For example, the inorganic filler contained in the sheet 20 is a high-dielectric filler. The relative permittivity 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 permittivity is high, it is easy to adjust the relative permittivity of the sheet 20 with a small filling amount. The relative permittivity of the high-dielectric filler may be 10 or less, and may be 5 or less.

[0027] Examples of the inorganic filler include a titanium-based filler, a zirconium-based filler, an aluminum-based filler, or the like. Examples of the titanium-based filler include barium titanate, calcium titanate, strontium titanate, zirconium oxide, aluminum oxide, or the like. The inorganic filler may be at least one selected from the group consisting of barium titanate, calcium titanate, strontium titanate, and a titanium-

strontium-zirconia-based material.

[0028] 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.

[0029] For example, the sheet 20 contains 1 to 90 volume% of the inorganic filler. The sheet 20 may contain 10 volume% or more, 20 volume% or more, 30 volume% or more, or 40 volume% or more of the inorganic filler. The sheet 20 may contain 80 volume% or less, 70 volume% or less, 60 volume% or less, or 50 volume% or less of the inorganic filler. The relative permittivity of the sheet 20 can be adjusted by the content of the inorganic filler. The content of the inorganic filler may be appropriately adjusted according to the relative permittivity required for the sheet 20.

[0030] 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.

[0031] For example, the thickness of the sheet 20 (the distance from the sheet first surface 21 to the sheet second surface 22) is 10 to 5000 μm. The thickness of the sheet 20 may be 20 to 3000 μm, or may be 40 to 2500 μm. As one example, the thickness of the sheet 20 is 100 to 200 μm. The relative permittivity of the sheet 20 can be adjusted by the thickness of the sheet 20. The thickness of the sheet 20 may be appropriately adjusted according to the relative permittivity required for the sheet 20.

[0032] The dielectric constant of the sheet 20 is, for example, 2 to 70. The dielectric constant of the sheet 20 may be 3 to 60, or may be 4 to 50. As one example, the dielectric constant of the sheet 20 is 20 to 34.

[0033] FIG. 3 is a cross-sectional view schematically showing the window 10, the sheet 20, and radio waves W that are 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. Incidentally, radio waves for 5G communication and radio waves for 6G communication have characteristics of being more easily blocked or attenuated in a building compared to radio waves for 4G communication. In FIG. 3, the incident wave W and transmitted waves W4 and W7 are shown by solid lines, reflected waves W1, W5, and W6 are shown by dashed lines, and reflected waves W2 and W3 whose phases have been adjusted by the sheet 20 are shown by thick dashed lines. The reflected waves W2 and W3 are reflected waves whose phases can be adjusted by the sheet 20.

[0034] The sheet 20 according to the present embodiment has a function of controlling radio waves W. The sheet 20 is attached to the window 10 in order to increase the transmittance of radio waves W passing through the window 10. Radio waves W reaching 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 that passes through the first surface 11 and is reflected at the second surface 12, and a transmitted wave W7 that passes through the second surface 12. Radio waves W reaching 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 that passes through the first surface 11 and is reflected at the sheet first surface 21, a reflected wave W3 that passes through the sheet first surface 21 and is reflected at the sheet second surface 22, and a transmitted wave W4 that passes 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 a higher transmittance of radio waves W compared to 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 radio waves W to the indoors is increased.

[0035] FIG. 4 is a diagram schematically showing reflected waves and transmitted waves of radio waves W with respect to the window 10. FIG. 5 is a diagram schematically showing reflected waves and transmitted waves of radio waves W with respect to the window 10 and the sheet 20. The reflection coefficient at the first surface 11 of 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. Since the thickness of the window 10 cannot be adjusted, it is not possible to cancel out the reflected waves W5 and W6 and enhance the transmitted wave W7.

[0036] The reflection coefficient at the first surface 11 of 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. Although the thickness of the window 10 cannot be adjusted, 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.

[0037] Assuming that the relative permittivity of a dielectric is ε_r and the wavelength in vacuum is λ_0, the wavelength λ of radio waves in the dielectric is obtained by the following formula (1). As shown in formula (1), the larger the relative permittivity of the dielectric, the smaller the wavelength λ of radio waves in the dielectric.

[Math. 1]

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

[0038] 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 radio waves passing through the window 10 is shorter than the wavelength of radio waves in air, and the wavelength of radio waves passing through the sheet 20 is shorter than the wavelength of radio waves passing through the window 10. The reflection intensity of radio waves W in a predetermined band that pass through the window 10 and reach the sheet 20 is lower than the reflection intensity of radio waves W in the predetermined band that pass through the window 10 when either one of the first surface 11 and 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 radio waves in a predetermined band that pass through the sheet 20 and reach the window 10 is lower than the reflection intensity of radio waves in the predetermined band that pass through the window 10 when either one of the first surface 11 and the

second surface 12, or both the first surface 11 and the second surface 12, are in contact with air.

[0039] The above-described predetermined band is, for example, a radio wave band of 5G (for example, a millimeter wave band) or a radio wave band of 6G (for example, a sub-terahertz wave band). As one example, the above-described predetermined band is 27.0 (GHz) to 29.5 (GHz). In the present embodiment, the intensity of reflected waves that pass through the window 10, are reflected at the sheet 20 (the sheet first surface 21 or the sheet second surface 22), and travel from the window 10 toward the side opposite to the sheet 20 is lower than the intensity of radio waves that pass through the window 10 and the sheet 20.

[0040] In the present embodiment, the sheet 20 suppresses attenuation of transmitted waves by canceling the phases of reflected waves to attenuate the reflected waves. For example, 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 cancel each other out, whereby the intensity of reflected waves traveling from the window 10 toward the side opposite to the sheet 20 is reduced.

[0041] When the energy of reflected waves traveling from the window 10 toward the side opposite to the sheet 20 is R and the energy of transmitted waves passing through the window 10 and the sheet 20 is T, $R + T = 1$ holds from the law of conservation of energy. As described above, when the intensity of reflected waves traveling from the window 10 toward the side opposite to the sheet 20 is reduced, the intensity of transmitted waves W4 passing through the window 10 and the sheet 20

is increased. By attaching the sheet 20 containing a dielectric to the window 10, the intensity of transmitted waves W4 passing through the window 10 and the sheet 20 can be increased.

[0042] When the thickness of the window 10 is d_g, the dielectric constant of the window 10 (for example, glass) is ε_g, the thickness of the sheet 20 is d_a, and the dielectric constant of the sheet 20 is ε_a, by adjusting the values of d_a and ε_a, it becomes possible to shift the phase and intensity of the reflected waves W2 and W3, and phase adjustment by optical path difference of the reflected waves W1 to W3 becomes possible. The values of d_a and ε_a may be adjusted in consideration of multiple reflections.

[0043] In the window structure 1 according to the present embodiment, at least one of the reflection intensity of radio waves W in a predetermined band that pass through the window 10 and reach the sheet 20 and the reflection intensity of radio waves in the predetermined band that pass through the sheet 20 and reach the window 10 is lower than the reflection intensity of radio waves in the predetermined band that pass through the window 10 when the first surface 11 or the second surface 12 of the window 10, or both, are in contact with air. Because the reflection intensity of radio waves in the predetermined band is low, the intensity of radio waves (for example, transmitted waves W4) passing through the window 10 and the sheet 20 can be increased based on the law of conservation of energy relating 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.

[0044] Various modifications of the window structure according to the present disclosure will be described. (a) of FIG. 6 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 sheet 20A differs from the above-described sheet 20 in that the sheet 20A has an adhesive layer 23. The sheet 20A can be used in place 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.

[0045] For example, before being attached to the window 10, the sheet 20A has a release paper adhered to the adhesive layer 23, and the adhesive layer 23 from which the release paper has been peeled off is attached to the window 10. In this case, the above-described tape 30 can be made unnecessary. The sheet 20A may have a bonding agent layer made of a bonding agent instead of the adhesive layer 23. In the window structure 1A, because the sheet 20A is attached to both the first surface 11 and the second surface 12 of the window 10, the transmittance of radio waves can be increased compared to a case where the sheet 20A is not attached to the window 10.

[0046] (b) of FIG. 6 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 radio waves can be increased compared to a case where the sheet 20A is not attached to the window 10. Note that the sheet 20A may be attached to the second surface 12.

[0047] (a) of FIG. 7 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 includes a double window 40 having the two windows 10 and a sheet 20 attached to at least one of the first surfaces 11 and the second surfaces 12 of the two windows 10. For example, an air layer is formed between the two windows 10. (a) of FIG. 7 is a schematic diagram of a case where the sheet 20 is attached to the outer side of the window 10 (for example, the side exposed to the outside air).

[0048] (b) of FIG. 7 is a cross-sectional view showing a window structure 1D according to a fourth modification. In the window structure 1D, the sheet 20 is attached to the inner side of the window 10 (for example, the side in contact with the intermediate layer). In the window structure 1C and the window structure 1D, as with the above-described window structure 1 and the like, because the sheet 20 is attached to the second surface 12 of the window 10, the transmittance of radio waves can be increased compared to a case where the sheet 20 is not attached to the second surface 12. In the above-described window structure 1C and window structure 1D, the sheet 20 may be attached to the first surface 11 of the window 10. The location where the sheet 20 is attached

and the number of sheets 20 to be attached can be changed as appropriate.

[0049] (a) of FIG. 8 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 film 45. In the window structure 1E, the double window 40 includes the laminated glass interlayer film 45. The laminated glass interlayer film 45 is in close contact with each of the two windows 10 between the two windows 10. In this way, the sheet 20 can also be applied to laminated glass.

[0050] (b) of FIG. 8 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 ray shielding layer 46. In the window structure 1F, the double window 40 includes the heat ray shielding layer 46. The heat ray shielding layer 46 is provided to suppress transmission of heat through the double window 40.

[0051] The heat ray shielding layer 46 is attached to, for example, the second surface 12 of the outdoor-side window 10. However, the heat ray shielding layer 46 may be attached to the first surface 11 of the indoor-side window 10, and the position where the heat ray shielding layer 46 is attached is not particularly limited. In the window structure 1F including the heat ray shielding layer 46, the transmittance of radio waves in the building S can be increased, and heat passing through the double window 40 is suppressed by the heat ray shielding layer 46. Therefore, heat and cold in the building S can be suppressed.

[0052] The embodiment and various modifications of the window

structure according to the present disclosure have been described. However, the present disclosure is not limited to the above-described embodiment or various modifications, and may be further modified within the scope of the gist described in the claims. The structure, shape, size, material, number, and arrangement of each part of the window structure according to the present disclosure can be appropriately changed within the scope of the above-described gist.

[Examples]

[0053] Next, examples of the window structure according to the present disclosure will be described. The window structure according to the present disclosure is not limited to the contents of the following examples. As shown in FIG. 9, radio wave intensity measurement tests were conducted for Examples 1 to 3 and Comparative Examples 1 and 2 described below. The measurement apparatus used in the radio wave intensity measurement tests 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 radio waves from the radio wave irradiator, and a measuring instrument that measures the intensity of radio waves received by the radio wave receiver. Examples 1 to 3 and Comparative Examples 1 and 2 are as follows.

[0054] (Example 1)

Radio waves from the radio wave irradiator were transmitted through the window structure 1, in which the sheet 20 was attached to the window 10, from the window 10 side, and the intensity of 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 each approximately 100 cm.

As shown in Table 1, Samples 1 to 3 were sheet-shaped specimens formed by molding a uniform compound of 55.7 volume% of polystyrene (manufactured by Toyo Styrene Co., Ltd., product name "Toyo Styrol GP G100C") and 44.3 volume% of barium titanate (manufactured by Kyoritsu Material Co., Ltd., product name "BT-SA") to a thickness of approximately 200 μm.

[Table 1]

	Dielectric Constant	Average Thickness (μm)	Resin	Resin Content (vol%)	Inorganic Filler	Inorganic Filler Content (vol%)
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 through the window structure 1, in which the sheet 20 was attached to the window 10, from the window 10 side, and the intensity of 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 each approximately 100 cm.

As shown in Table 2, Samples 4 to 6 were sheet-shaped specimens formed by molding a uniform compound of 53.9 volume% of polystyrene (manufactured by Toyo Styrene Co., Ltd., product name "Toyo Styrol GP G100C") and 46.1 volume% of barium titanate (manufactured by Kyoritsu Material Co., Ltd., product name "BT-SA") to a thickness of approximately 200 μm.

[Table 2]

	Dielectric Constant	Average Thickness (μm)	Resin	Resin Content (vol%)	Inorganic Filler	Inorganic Filler Content (vol%)
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 through the window structure 1, in which the sheet 20 was attached to the window 10, from the window 10 side, and the intensity of 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 sheet-shaped specimens formed by molding a uniform compound of 46.0 volume% of

polystyrene (manufactured by Toyo Styrene Co., Ltd., product name "Toyo Styrol GP G100C") and 54.0 volume% of barium titanate (manufactured by Kyoritsu Material Co., Ltd., product name "BT-SA") to a thickness of approximately 200 μm.

[Table 3]

	Dielectric Constant	Average Thickness (μm)	Resin	Resin Content (vol%)	Inorganic Filler	Inorganic Filler Content (vol%)
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)

Radio waves that passed through the air from the radio wave irradiator were received by the radio wave receiver with nothing placed on the turntable, 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 approximately 200 cm.

(Comparative Example 2)

With only the window 10 placed on the turntable, radio waves transmitted through the window 10 were received by the radio wave receiver, 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 each approximately 100 cm.

[0055] FIG. 10 is a graph showing the results of the radio wave intensity measurement tests 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 transmitted radio waves was increased compared to that of Comparative Example 2 in which only the window 10 was used, and it was found that, depending on the frequency band of the radio waves, the intensity of transmitted radio waves was increased compared to that of Comparative Example 1 in which only air was used.

[0056] When the radio wave band was 27.5 (GHz), the radio wave intensity of Comparative Example 1 was −31.2 (dB) and the radio wave intensity of Comparative Example 2 was −36.8 (dB). In contrast, the radio wave intensity of Example 1 was −32.7 (dB), the radio wave intensity of Example 2 was −32.6 (dB), and the radio wave intensity of Example 3 was −34.0 (dB), and it was found that the intensity of transmitted radio waves was higher than that of Comparative Example 2.

[0057] When the radio wave band was 28.0 (GHz), the radio wave intensity of Comparative Example 1 was −31.5 (dB) and the radio wave intensity of Comparative Example 2 was −36.8 (dB). In contrast, the radio wave intensity of Example 1 was −32.0 (dB), the radio wave intensity of Example 2 was −31.4 (dB), and the radio wave intensity of Example 3 was −33.4 (dB), and it was found that the intensity of transmitted radio waves was higher than that of Comparative Example 2.

[0058] Radio wave intensity measurement tests were conducted for

Examples 4 to 6 and Comparative Examples 3 and 4 to measure the intensity of radio waves in a predetermined band that pass through the sheet 20 and reach the window 10. The measurement apparatus used in Examples 4 to 6 and Comparative Examples 3 and 4 is the same as the above-described measurement apparatus. Examples 4 to 6 and Comparative Examples 3 and 4 are as follows.

[0059] (Example 4)

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

(Example 5)

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

(Example 6)

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

waves were transmitted from the sheet 20 side.

(Comparative Example 3)

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

(Comparative Example 4)

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

[0060] 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 of Comparative Example 3 was −31.3 (dB) and the radio wave intensity of Comparative Example 4 was −36.0 (dB). In contrast, the radio wave intensity of Example 4 was −32.7 (dB), the radio wave intensity of Example 5 was −32.7 (dB), and the radio wave intensity of Example 6 was −34.2 (dB), and it was found that the intensity of transmitted radio waves was higher than that of Comparative Example 4.

[0061] When the radio wave band was 28.0 (GHz), the radio wave intensity of Comparative Example 3 was −31.4 (dB) and the radio wave intensity of Comparative Example 4 was −36.7 (dB). In contrast, the radio wave intensity of Example 4 was −31.8 (dB), the radio wave intensity of Example 5 was −31.6 (dB), and the radio wave intensity of Example 6 was −33.3 (dB), and it was found that the intensity of transmitted radio waves was higher than that of Comparative Example 4.

[0062] As described above, it was found that in Examples 4 to 6, in which radio waves were incident from the sheet 20 side, the intensity of

radio waves passing through the window structure was increased, as in Examples 1 to 3, in which radio waves were incident from the window 10 side.

Reference Signs List

[0063] 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: adhesive layer; 30: tape; 40: double window; 45: laminated glass interlayer film; 46: heat ray 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 to the first surface; and

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

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

[Claim 2]

The window structure according to claim 1,

wherein a dielectric constant of the sheet is 2 to 70, and

a thickness of the sheet is 10 to 5000 μm.

[Claim 3]

The window structure according to claim 1 or claim 2,

wherein a dielectric constant of the sheet is 3 to 60, and

a thickness of the sheet is 20 to 3000 μm.

[Claim 4]

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

wherein a dielectric constant of the sheet is 4 to 50, and

a thickness of the sheet is 40 to 2500 μm.

[Claim 5]

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

wherein the sheet is attached to a part of at least one of the first surface and the second surface.

[Claim 6]

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

wherein the sheet is attached to both the first surface and the second surface.

[Claim 7]

The window structure according to any one of claims 1 to 6,

wherein the window is a window provided in a building, and

the second surface is a surface on the indoor side of the building.

[Claim 8] The window structure according to any one of claims 1 to 7,

wherein the predetermined band of the radio waves is 27.0 (GHz) to 29.5 (GHz).